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Gemini GV6K and Gemini GT6K Programmer's Guide

Effective: October 1, 2001



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IMPORTANT

User Information

WARNING

Gem6K Series products are used to control electrical and mechanical components of motion control systems. You should test your motion system for safety under all potential conditions. Failure to do so can result in damage to equipment and/or serious injury to personnel.

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Technical Assistance ⇨ *Contact your local automation technology center (ATC) or distributor,* ***or ...***

North America and Asia:
Compumotor Division of Parker Hannifin
5500 Business Park Drive
Rohnert Park, CA 94928
Telephone: (800) 358-9070 or (707) 584-7558
Fax: (707) 584-3793
FaxBack: (800) 936-6939 or (707) 586-8586
e-mail: tech_help@cmotor.com
Internet: http://www.compumotor.com

Europe *(non-German speaking)*:
Parker Digiplan
21 Balena Close
Poole, Dorset
England BH17 7DX
Telephone: +44 (0)1202 69 9000
Fax: +44 (0)1202 69 5750

Germany, A ustria, Switzerland:
HAUSER Elektronik GmbH
Postfach: 77607-1720
Robert-Bosch-Str. 22
D-77656 Offenburg
Telephone: +49 (0)781 509-0
Fax: +49 (0)781 509-176

Parker
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Tech nical Su pport
E-mail: Tech_Help@cmotor.com

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OVERVIEW

About This Manual

This manual is designed to help you implement the Gem6K Series Product's features in your application. Detailed feature descriptions are provided, including application scenarios and programming examples. For details on each Gem6K command, refer to the *Gem6K Series Command Reference*.

Organization of This Manual

Chapter	Information
Chapter 1. *Programming Fundamentals*	Discussion of essential programming guidelines and standard programming features such as branching, variables, interrupts, error handling, etc.
Chapter 2. *Communication*	Communication considerations, such as using Motion Planner, alert event handling, communication server and fast status control, RS-232 daisy-chains and RS-485 multi-drops, etc.
Chapter 3. *Basic Operation Setup*	General operation setup conditions, such as number of axes, scaling factors, feedback device setup, programmable input and output functions, end-of-travel limits, homing, etc.
Chapter 4. *Product Control Options*	Considerations for implementing various product control methods, such as programmable I/O, a joystick, an RP240, custom GUI, etc.
Chapter 5. *Custom Profiling*	Descriptions of custom profiling features such as S-Curves, timed data streaming, compiled profiles, on-the-fly motion profiling, registration, and synchronized motion.
Chapter 6. *Following*	Feature descriptions and application examples for using Following features.
Chapter 7. *Multi-Tasking*	Feature descriptions and application examples for using multi-tasking in your application.
Chapter 8. *Troubleshooting*	Methods for isolating and resolving hardware and software problems.

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Programming Examples

Programming examples are provided in this document to demonstrate how the Gem6K product's features may be implemented. These examples are somewhat generalized, due to the diverse nature of the family of Gem6K Series products and their application; consequently, some attributes, such as the I/O bit pattern referenced, may differ from those available with your particular Gem6K product.

Reference Documentation

This document is intended to accompany the printed and online documents listed below, as part of the Gem6K product user documentation set.

INTERNET ACCESS:

These documents are also available to view and print from our web site (www.compumotor.com).

Reference Document	Description
Gem6K Series Hardware Installation Guide	Hardware-related information specific to the Gem6K Series product: • Product hardware specifications • Installation instructions • Troubleshooting procedures • Servo tuning instructions
Gem6K Series Command Reference	Detailed descriptions of all Gem6K Series Programming Language commands. Quick-reference tables are also provided.
EVM32 Installation Guide	Specifications and installation instructions for the EVM32 expansion I/O.
COM6SRVR Communications	The COM6SRVR is a 32-bit OLE automation server for adding Gem6K communication capability to your custom applications created with programming languages such as Visual Basic or Visual C++. This companion document includes descriptions of all methods and properties, and programming examples.
Motion Planner Online Help	Online instructional aids such as: • Tutorials • Introduction and tutorial for programming with Wizards • Context-sensitive help for Wizard-based programming • Documentation of programmer's guide • Step-by-step programming coaches • Conceptual overviews • Advanced programming details • Sample programs • Documentation of the Gem6K Series command language, including all command descriptions and the contents of the manual you are currently reading • Documentation of the Communications Server OLE automation server (facilitates communications between Gem6K and your custom Windows software)

Assumptions of Technical Experience

To effectively use the information in this manual, you should have a fundamental understanding of the following:

- Electronics concepts, such as voltage, switches, current, etc.
- Motion control concepts such as motion profiles, torque, velocity, distance, force, etc.
- Programming skills in a high-level language such as C, C++, or BASIC is helpful
- Ethernet communication protocol (if using the Ethernet port)
- **If you are new to the Gem6K Series Programming Language, we encourage you to use the Motion Planner Wizards Editor (version 4.2 or later for Gem6K support).**

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Before You Begin

Before you begin to implement the Gem6K controller's features in your application you should complete all the installation and test procedures provided in your *Gem6K Series Hardware Installation Guide*.

Install and Use Motion Planner

Motion Planner is a Windows-based graphical interface that assists you with programming and tuning your Gem6K Series controller, as well as setting up your Compumotor drives. The Motion Planner CD-ROM is provided in your ship kit. The Motion Planner interface allows you to:

- Create, edit, download, and upload programs.
- Tune your servo system.
- Test & debug programs and controller operation.

Additional details are provided on page 2 and in the Motion Planner Help System.

Technical Support

For solutions to your questions about implementing Gem6K product software features, first look in this manual. Other aspects of the product (command descriptions, hardware specs, I/O connections, graphical user interfaces, etc.) are discussed in the respective manuals or Online Help systems listed above in *Reference Documentation* (see page ii).

If you cannot find the answer in this documentation, contact your local Automation Technology Center (ATC) or distributor for assistance.

If you need to talk to our in-house application engineers, please contact us at the numbers listed on the inside cover of this manual. (The phone numbers are also provided when you issue the HELP command to the Gem6K controller.) **NOTE**: The BBS contains the latest software upgrades and late-breaking product documentation.
FAX number for technical support;
bulletin board service,#see BBS;
software, update from BBS;
BBS;

Email support: tech_help@cmotor.com

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CHAPTER ONE

1 Programming Fundamentals

IN THIS CHAPTER

This chapter is a guide to general Gem6K programming tasks. It is divided into these main topics:

- Motion Planner programming environment 2
- Command syntax 4
- Creating programs 10
- Storing programs 10
- Executing programs 13
- Creating and executing a set-up program 13
- Program Security 14
- Controlling execution – programs & command buffer 14
- Restricted commands during motion 17
- Using Variables 18
- Program flow control 23
- Program interrupts 29
- Error handling 30
- Non-volatile memory 35
- System performance considerations 35

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Motion Planner Programming Environment

Every Gem6K Series controller is shipped with Motion Planner, a free Windows-based programming tool designed to simplify your programming efforts. The Motion Planner CD-ROM is provided in your ship kit. Updates may be downloaded, free of charge, from the compumotor.com web site.

Motion Planner supports two programming paradigms: Wizard-based programming, and Native Code programming (working directly with the Gem6K programming language).

Wizard-Based Programming

Motion Planner includes the Wizard Editor, which is intended to be your primary program development environment for the Gem6K. (version 4.2 or later)

The Wizard Editor makes programming easy, eliminates the need to learn the programming language and frees you from concerning yourself with syntax errors.

- A Start Wizard guides you through creating your program structure and configuring your Gem6K (drives, feedback, I/O, servo tuning, etc.).
- Additional wizards guide you through all other programming tasks, such as creating motion profiles, I/O handling, error handling, program logic and branching, adding sub-programs, etc.
  NOTE: All programming features that can be implemented with native code (in a text-based Program Editor) can also be accomplished in the Wizard Editor.
- The Tag Name Dictionary allows you to label variables, axes, and I/O so that you can program in terms that are relevant to your machine.
- If you have existing programs in an Editor, you can easily include them into the Wizard editor (using the Native Code wizard), so you don't have to rewrite your code.
- The Wizard Editor also includes interactive debug tools (break points, trace mode) and a status window to help you test and debug your application.
- Context-sensitive help is always available – just click the Help button or press the F1 key.

How to get started:

1. Install Motion Planner.
2. Launch Motion Planner and select your Gem6K product. Motion Planner opens a new Wizard Editor file.
3. When prompted to see an introduction and tutorial, click **Yes**. This will help you understand the basic features of the Wizard Editor and the programming process.

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Native Code Programming

As an alternative to using the Wizard Editor, you may program directly with the Gem6K Command Language ("Native Code"). Motion Planner has several tools to help you:

ACCESSING THE TOOLS: These tools are exposed when you first launch Motion Planner.

- Program Editor: This is your primary interface for programming with the Gem6K Command Language.
- Terminal Emulator: This is your primary communications interface to send commands directly to the Gem6K.
- Servo Tuner: This graphical tuning utility helps you visually tune your servo axes. Then you can copy the resulting gains into your program in the Program Editor. NOTE: Before attempting motion, be sure to tune your axes. Tuning guidelines are provide on page
- Motion Panel: This feature allows definition of quick command buttons and other useful debugging and functional tools to assist in programming your Gem6K.
- Online Help: While you are programming in Motion Planner's Editor, Terminal or Servo Tuner, you have immediate access to all command descriptions (the contents of the *Gem6K Series Command Reference*, as well as the contents to this *Programmer's Guide*). To access the command descriptions, click on the Help menu and select Contents; from there you can browse the "Gem6K Command Language" or you can search for the command or a topic in the Index tab.

The rest of the contents in this manual are directed toward the native code programmer. If you are new to the Gem6K Series Programming Language, be sure to read Chapter 1 (*Programming Fundamentals*) thoroughly. Then proceed to the relevant chapters for the features you need for your programs.

NOTE: If you later decide to use the Wizards Editor, you can copy code from the Program Editor and paste it into Native Code objects in the Wizard program tree.

TIP: For complex programming tasks, like setup programming, error programming, Following profile development, etc., you can use the relevant wizard in the Wizards Editor, then copy the generated code from the Code Viewer and paste it into a Program Editor file.

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Command Syntax

Introduction

The Gem6K programming language accommodates a wide range of needs by providing basic motion control building blocks, as well as sophisticated motion and program flow constructs.

The language comprises simple ASCII mnemonic commands, with each command separated by a command delimiter (carriage return, colon, or line feed). The command delimiter signals the Gem6K product that a command is ready for processing.

Upon receiving a command followed by a command delimiter, the Gem6K controller places the command in its internal command buffer, or queue. Here the command is executed in the order in which it is received. To make the command execute immediately, place an exclamation point (`!`) in front of it (e.g., The `TAS` command will be executed after all commands ahead of it in the command buffer are executed; but `!TAS` will execute before any other commands in the command buffer).

Spaces and tabs within a command are processed as neutral characters. Comments can be specified with the semicolon (`;`) character — all characters following the semicolon and before the command delimiter are considered program comments.

Some commands contain one or more data fields in which you enter numeric or binary values or text:

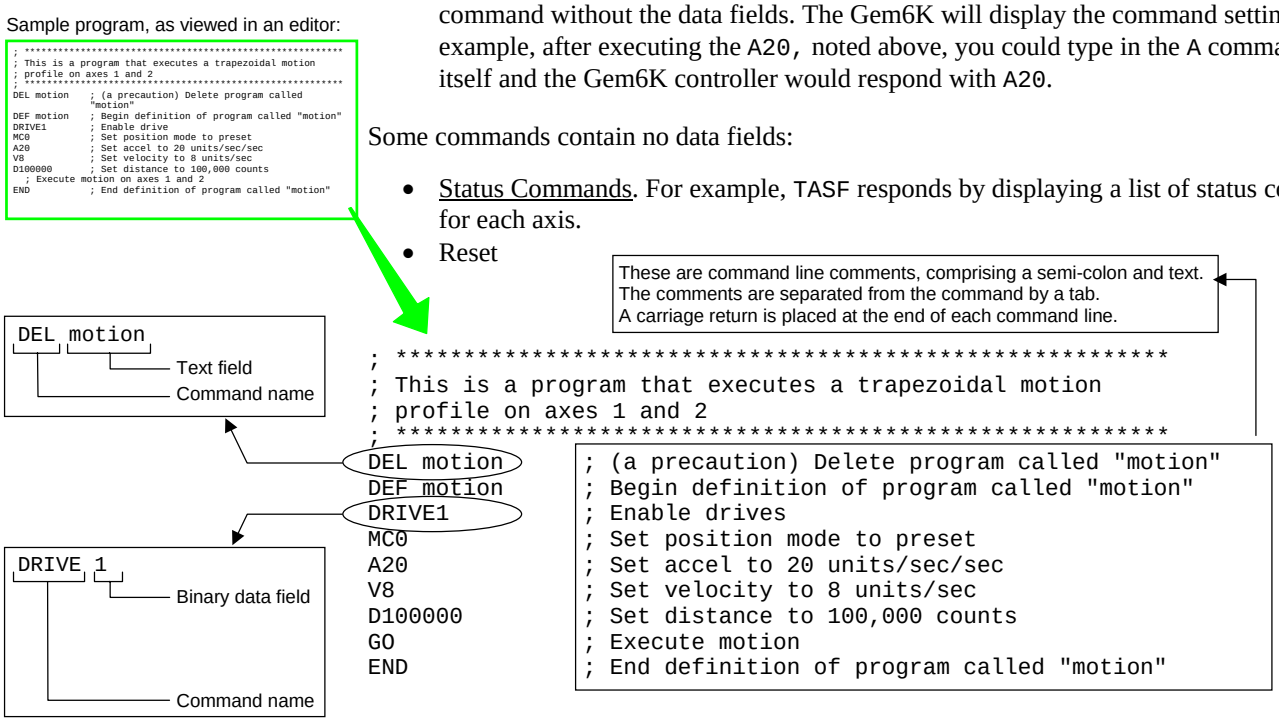
- Numeric data fields. For example, `A20,10` is an acceleration (`A`) command that sets the acceleration to 20 units/sec^2.
- Binary fields. For example, `DRIVE1` is a drive enable (`DRIVE`) command that enables the drive.
- Text fields. For example, `STARTPpowrup` is a startup program assignment (`STARTP`) command that assigns the program called "powrup" as the startup program to be executed automatically when the Gem6K product is power up or reset.
- To check what the data field settings are for a particular command, simply type in the command without the data fields. The Gem6K will display the command settings. For example, after executing the `A20,` noted above, you could type in the `A` command by itself and the Gem6K controller would respond with `A20`.

Some commands contain no data fields:

- Status Commands. For example, `TASF` responds by displaying a list of status conditions for each axis.
- Reset

Sample program, as viewed in an editor:

```
; ********************************************************
; This is a program that executes a trapezoidal motion
; profile on axes 1 and 2
; ********************************************************
DEL motion    ; (a precaution) Delete program called
              "motion"
DEF motion    ; Begin definition of program called "motion"
DRIVE1        ; Enable drive
MC0           ; Set position mode to preset
A20           ; Set accel to 20 units/sec/sec
V8            ; Set velocity to 8 units/sec
D100000       ; Set distance to 100,000 counts
  ; Execute motion on axes 1 and 2
END           ; End definition of program called "motion"
```



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Description of Syntax Letters and Symbols

The command descriptions provided within the *Gem6K Series Command Reference* use alphabetic letters and ASCII symbols within the **Syntax** description to represent different parameter requirements (see INEN example below).

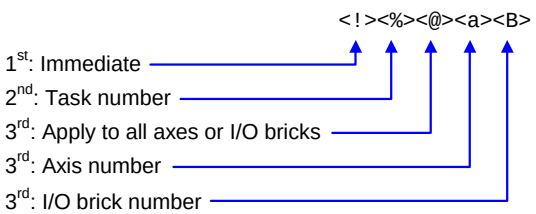
INEN — Input Enable

		Product	Rev
Type	Inputs; Program Debug Tools		
Syntax	<!><B>INEN<d><d><d>...<d>	Gem6K	5.0
Units	d = Ø, 1, E, or X		
Range	Ø = off, 1 = on, E = enable, X = don't change		
Default	E		
Response	INEN: *INENEEEE_EEEE_EEEE_EEEE_E		
See Also	[IN], INFNC, INLVL, INPLC, INSTW, TIN, TIO		

Letter/Symbol	Description
a	Represents an axis specifier.
B	Represents the number of the product's I/O brick. External I/O bricks are represented by numbers 1 through n (to connect external I/O bricks, refer to your product's *Installation Guide*). On-board I/O are address at brick location zero (Ø). If the brick identifier is omitted from the command, the controller assumes the command is supposed to affect the onboard I/O.
b *	Represents the values 1, 0, X or x; does not require field separator between values.
c	Represents a character (A to Z, or a to z)
d	Represents the values 1, 0, X or x, E or e ; does not require field separator between values. E or e enables a specific command field. X or x leaves the specific command field unchanged or ignored. In the ANIEN command, the "d" symbol may also represent a real numeric value.
i	Represents a numeric value that cannot contain a decimal point (integer values only). The numeric range varies by command. Field separator required.
r	Represents a numeric value that may contain a decimal point, but is not required to have a decimal point. The numeric range varies by command. Field separator required.
t	Represents a string of alpha numeric characters from 1 to 6 characters in length. The string must start with a alpha character.
!	Represents an immediate command. Changes a buffered command to an immediate command. Immediate commands are processed immediately, even before previously entered buffered commands.
%	(Multitasking Only) Represents a task identifier. To address the command to a specific task, prefix the command with "i%", where "i" is the task number. For example, the 4%CUT command uses task #4 to execute the program called "CUT".
,	(comma) Represents a field separator. Commands with the symbol r or i in their Syntax description require field separators. Commands with the symbol b or d in their Syntax description **do not** require field separators (but they may be included). See *General Guidelines* table below.
@	Represents a global specifier, where only one field need be entered. Applicable to all commands with multiple command fields.
< >	Indicates that the item contained within the < > is optional, not required by that command. NOTE: Do not confuse with <cr>, <sp>, and <lf>, which refer to the ASCII characters corresponding to a carriage return, space, and line feed, respectively.
[ ]	Indicates that the command between the [ ] must be used in conjunction with another command, and cannot be used by itself.

* The ASCII character b can also be used within a command to precede a binary number. When the b is used in this context, it is not to be replaced with a 0, 1, X, or x. Examples are assignments such as VARB1=b10001, and comparisons such as IF(3IN=b1001X1).

Order of Precedence for Command Prefix Characters (from left to right):



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General Guidelines for Syntax

Guideline Topic	Guideline	Examples

Neutral Characters
• Space (<sp>)
• Tab (<tab>)
	Using neutral characters anywhere within a command will not affect the command.
	(In the examples on the right, a space is represented by <*sp*>, a tab is <*tab*>), and a carriage return is <*cr*>)
		Set velocity to 10 rps:
		`V<sp>10 <cr>`
		Add a comment to the command:
		`V 10 <tab> ;set velocity <cr>`

Command Delimiters:
• Carriage rtn (<cr>)
• Line feed (<lf>)
• Colon (:)
	All commands must be separated by a command delimiter. A carriage return is the most commonly used delimiter. To use a line in a live terminal emulator session, press ctrl/J. The colon (:) delimiter allows you to place multiple commands on one line of code, but only if you add it in the program editor (not during a live terminal emulator session).	Set acceleration to 10 rev/sec/sec:
		`A 10<cr>`
		`A 10<lf>`
		`A 10: V 25: D 25000: GO<cr>`

Case Sensitivity	There is no case sensitivity. Use upper or lower case letters within commands.	Initiate motion
		`GO`
		`go`

Comment Delimiter (;)	All text between a comment delimiter and a command delimiter is considered *program comments*.	Add a comment to the command: `V10<tab> ;set velocity`
Field Separator (,)	Commands with the symbol `r` or `i` in their Syntax description require field separators.	INSGLP EXAMPLE
Global Command Identifier (@)	When you wish to set the command value equal on all axes, add the @ symbol at the beginning of the command (enter only the value for one command field).	Check the status of all digital outputs (onboard, and on external I/O bricks): `@OUT`

Bit Select Operator (.)	The bit select operator allows you to affect one or more binary bits without having to enter all the preceding bits in the command.
	Syntax for setup commands:
	`[command name].[bit #]-[binary value]`
	Syntax for conditional expressions:
	`[command name].[bit #]=[binary value]`
		Enable error-checking bit #9:
		`ERROR.9-1`
		Enable error-check bits #9-12:
		`ERROR.9-1,1,1,1`
		`IF` statement based on value of axis status bit #12:
		`IF(AS.12=b1)`

Left-to-right Math	All mathematical operations assume left-to-right precedence.	`VAR1=5+3*2` Result: Variable 1 is assigned the value of 16 (8*2), not 11 (5+6).
Binary and hexadecimal values	When making assignments with or comparisons against binary or hexadecimal values, you must precede the binary value with the letter “b” or “B”, and the hex value with “h” or “H”. In the binary syntax, an “x” simply means the status of that bit is ignored.	Binary: `IF(IN=b1x01)` Hexadecimal: `IF(IN=h7F)`

Multi-tasking Task Identifier (%)	Use the % command prefix to identify the command with a specific task.	Launch the “`move1`” program in Task 1:
		`1%move1`
		Check the error status for Task 3:
		`3%TER`
		Check the system status for Task 3:
		`3%TSS`

NOTE: The command line is limited to 100 characters (excluding spaces).

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Command Value Substitutions

Many commands can substitute one or more of its command field values with one of these substitution items (demonstrated in the programming example below):

VAR.....Places current value of the numeric variable in the corresponding command field.

VARB .....Uses the value of the binary variable to establish all the command fields.

VARI .....Places current value of the integer variable in the corresponding command field.

READ .....Information is requested at the time the command is executed.

DREAD.....Reads the RP240's numeric keypad into the corresponding command field.

DREADF...Reads the RP240's function keypad into the corresponding command field.

TW.....Places the current value set on the thumbwheels in the corresponding command field.

DAT.....Places the current value of the data program (DATP) in the corresponding command field.

Programming Example: (NOTE: The substitution item must be enclosed in parentheses.)

```
VAR1=15           ; Set variable 1 to 15
A5,(VAR1),4,4     ; Set acceleration to 5,15,4,4 for axes 1-4, respectively
VARB1=b1101XX1    ; Set binary variable 1 to 1101XX1 (bits 5 & 6 not affected)
GO(VARB1)         ; Initiate motion on axes 1, 2 & 4 (value of binary
                  ; variable 1 makes it equivalent to the GO1101 command)
OUT(VARB1)        ; Turn on outputs 1, 2, 4, and 7
VARS1="Enter Velocity" ; Set string variable 1 to the message "Enter Velocity"
V2,(READ1)        ; Set the velocity to 2 on axis 1. Read in the velocity for
                  ; axis 2, output variable string 1 as the prompting message
                  ;   1. Operator sees "ENTER VELOCITY" displayed on the screen.
                  ;   2. Operator enters velocity prefixed by !' (e.g., !'20).
HOMV2,1,(TW1)     ; Set homing velocity to 2 and 1 on axes 1 and 2, respectively.
                  ; Read in the home velocity for axis 3 from thumbwheel set 1
HOMV2,1,(DAT1)    ; Set homing velocity to 2 and 1 on axes 1 and 2, respectively.
                  ; Read home velocity for axis 3 from data program 1.
VARI1=2*3         ; Set integer variable 1 to 6 (2 multiplied by 3)
D(VARI2),,(VARI3) ; Set the distance of axis 1 equal to the value of
                  ; integer variable 2, and the distance of axis 3 equal to
                  ; the value of integer variable 3.
```

RULE OF THUMB

Not all of the commands allow command field substitutions. In general, commands with a binary command field (<b> in the command syntax) will accept the VARB substitution. Commands with a real or integer command field (<r> or <i> in the command syntax) will accept VAR, VARI, READ, DREAD, DREADF, TW or DAT.

Assignment and Comparison Operators

Comparison and assignment operators are used in command arguments for various functions such as variable assignments, conditional branches, wait statements, conditional GOs, etc. Some examples are listed below:

- Assign to numeric variable #6 the value of the encoder position on axis #3 (uses the PE operator): `VAR6=3PE`
- Wait until onboard inputs #3 & #6 become active (uses the IN operator): `WAIT(IN=bxx1xx1)`
- Continue until the value of numeric variable #2 is less than 36: `UNTIL(VAR2<36)`
- IF condition based on if a target zone timeout occurs on axis 2 (uses the AS axis status operator, where status bit #25 is set if a target zone timeout occurs): `IF(2AS.25=b1)`

The available comparison and assignment operators are listed below. For full descriptions, refer to their respective descriptions in the *Gem6K Series Command Reference* (be sure to refer only to the commands in brackets—e.g., A is the acceleration setup command, but [A] is the acceleration assignment/comparison operator).

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* denotes operators that have a correlated status display command.
(e.g., To see a full-text description of each axis status bit accessed with the AS operator, send the TASF command to the Gem6K controller.)
See page 222.

A ..... Acceleration
AD ..... Deceleration
ANI ..... Voltage at the analog inputs on an expansion I/O brick (see page 91 for bit patterns) *
ANO ..... Voltage at the analog outputs on an expansion I/O brick (see page 91 for bit patterns) *
AS ..... Axis status *
ASX ..... Extended axis status (additional axis status items) *
D ..... Distance
DAC ..... Digital-to-analog converter (output voltage) value *
DAT ..... Data program number
DKEY ..... Value of RP240 Key
DPTR ..... Data pointer location *
DREAD ..... Data from the numeric keypad on the RP240
DREADF ..... Data from the function keypad on the RP240
ER ..... Error status *
FB ..... Position of current selected feedback sources *
FS ..... Following status *
IN ..... Input status (input bit patterns provided on page 91) *
INO ..... "Other" input status (ENABLE input reported with bit #6) *
LIM ..... Limit status (end-of-travel limits and home limits) *
MOV ..... Axis moving status
NMCY ..... Current master cycle number *
OUT ..... Output status (output bit patterns provided on page 91) *
PANI ..... Position of analog input, at 205 counts/volts unless otherwise scaled (servo axes) *
PC ..... Commanded position *
PCC ..... Captured commanded position *
PCE ..... Captured encoder position *
PCME ..... Captured master encoder position *
PCMS ..... Captured master cycle position *
PER ..... Position error (servo axes only) *
PME ..... Current master encoder position *
PMAS ..... Current master cycle position *
PE ..... Position of encoder *
PSHF ..... Net position shift since constant Following ratio *
PSLV ..... Current commanded position of the slave axis *
READ ..... Read a numeric value to a numeric variable (VAR)
SC ..... Controller status *
SCAN ..... Runtime of the last scanned PLC program *
SEG ..... Number of segments available in Compiled Profile memory *
SS ..... System status *
SWAP ..... Current active status of tasks *
TASK ..... Number of the controlling task *
TIM ..... Timer value *
TRIG ..... Trigger interrupt status *
TW ..... Thumbwheel data read
US ..... User status *
V ..... Velocity (programmed)
VAR ..... Numeric variable substitution
VARI ..... Integer variable substitution
VARB ..... Binary variable substitution
VEL ..... Velocity (commanded by the controller) *
VELA ..... Velocity (actual, as measured by a position feedback device) *
VMAS ..... Current velocity of the master axis *

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Bit Select Operator

The bit select operator (`.`) makes it easier to base a command argument on the condition of one specific status bit. For example, if you wish to base an `IF` statement on the condition that a user fault input is activated (error status bit #7 is a binary status bit that is "`1`" if a user fault occurred and "`Ø`" if it has not occurred), you could use this command: `IF(ER=bxxxxxx1)`. Using a bit select operator, you could instead use this command: `IF(ER.7=b1)`.

Side Note: You can use a bit select operator to set a particular status bit (e.g., to turn on onboard programmable output #5, you would type the `OUT.5-1` command; to enable error-checking bit #4 to check for drive faults, you would type the `ERROR.4-1` command). . You can also check specific status bits (e.g., to check axis 2's axis status bit #25 to see if a target zone timeout occurred, type the `2TAS.25` command and observe the response).

Binary and Hex Values

When making assignments with or comparisons against binary or hexadecimal values, you must precede the binary value with the letter "`b`" or "`B`", and the hex value with "`h`" or "`H`". Examples: `IF(IN=b1xØ1)` and `IF(IN=h7F)`. In the binary syntax, an "x" simply means the status of that bit is ignored. Refer also to *Using Binary Variables* (page 19).

Related Operator Symbols

Command arguments include special operator symbols (e.g., `+`, `/`, `&`, `'`, `>=`, etc.) to perform bitwise, mathematical, relational, logical, and other special functions. These operators are described in detail, along with programming examples, at the beginning of the *Command Descriptions* section of the *Gem6K Series Command Reference*.

Programmable Inputs and Outputs Bit Patterns

I/O pin outs, specifications, and circuit drawings are provided in each Gem6K Series Hardware Installation Guide.

The Gem6K product has programmable inputs and outputs. The total number of onboard inputs and outputs (trigger inputs, limit inputs, digital outputs) depends on the product. The total number of expansion inputs and outputs (analog inputs, digital inputs and digital outputs) depends on your configuration of expansion I/O bricks connected to the "EXPANSION I/O" connector.

These programmable I/O are represented by binary bit patterns, and it is the bit pattern that you reference when programming and checking the status of specific inputs and outputs. The bit pattern is referenced in commands like `WAIT(IN.4=b1)`, which means wait until onboard programmable input #4 (TRG-2B) becomes active. To ascertain your product's I/O offering and bit patterns, refer to Chapter 3 (page 91).

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Creating Programs

Reminder:

The Motion Planner Wizards interface makes programming easy, eliminates the need to learn the programming language and frees you from concerning yourself with syntax errors. A Start Wizard guides you through creating your program structure and configuring your Gem6K (drives, feedback, I/O, servo tuning, etc.). Additional wizards guide you through all other programming tasks, such as creating motion profiles, I/O handling, error handling, program logic and branching, etc. The Tag Name Dictionary allows you to label variables, axes, I/O so that you can program in terms that are relevant to your machine. If you have existing programs in an Editor, you can easily include them into the Wizard editor, so you don't have to rewrite your code. For additional details about the Wizards programming interface, refer to page 2.

A *program* is a series of commands. These commands are executed in the order in which they are programmed. Immediate commands (commands that begin with an exclamation point [!]) cannot be stored in a program. Only buffered commands may be used in a program. Refer to the program example below.

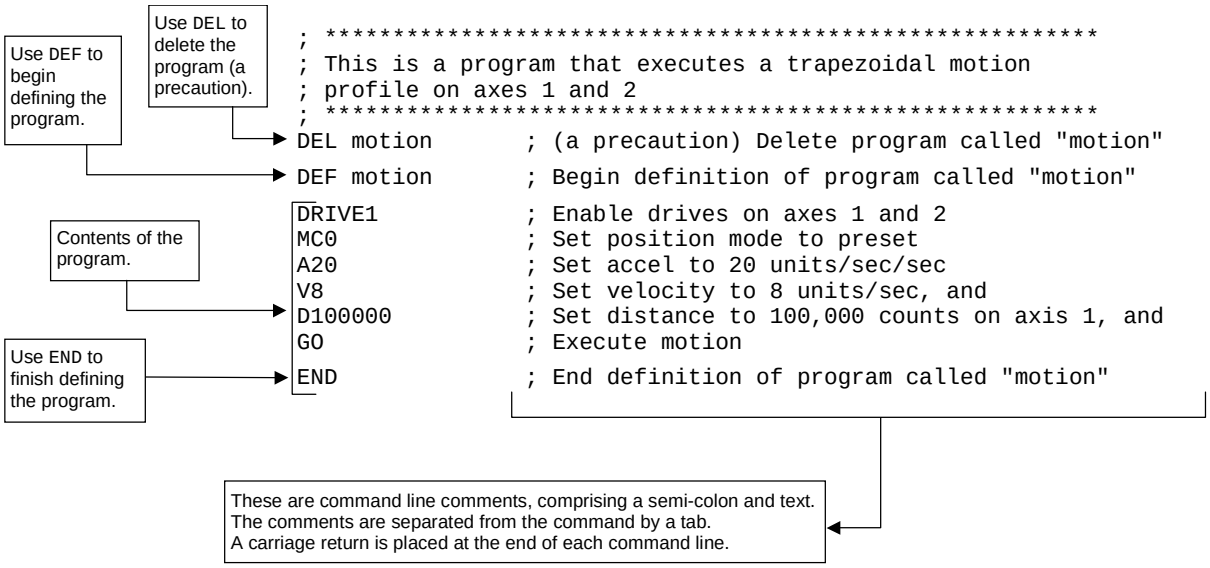
A *subroutine* is defined the same as a program, but it is executed with an unconditional branch command, such as GOSUB, GOTO, or JUMP, from another program (see page 23 for details about unconditional branching). Subroutines can be nested up to 16 levels deep. NOTE: The Gem6K family does not support recursive calling of subroutines.

Debugging Programs: Refer to page 221 for methods to isolate and resolve programming problems.

Compiled profiles & PLC programs are defined like programs, using the DEF and END commands, but are compiled with the PCOMP command and executed with the PRUN command (PLC programs are usually launched in PLC Scan Mode with the SCANP command). Compiled profiles and PLC programs also affect a different part of the product's memory, called *compiled memory*. A compiled *profile* is an individual axis profile (a series of GOBUF commands). A compiled *PLC program* is a pre-compiled program that mimics PLC functionality by scanning through the I/O faster than in normal program execution. For information on compiled profiles, refer to page 139; and for information on PLC programs, refer to page 120.

Program Example

The illustration below identifies the elements that comprise the general structure of a program.



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Storing Programs

After a program or compiled program/profile is defined (DEF) or downloaded to the Gem6K controller, it is automatically stored in non-volatile memory (battery-backed RAM). Information on controlling memory allocation is provided below (see *Memory Allocation*).

Memory Allocation

Your controller's memory has two partitions: one for storing *programs* and one for storing *compiled profiles & PLC programs*. The allocation of memory to these two areas is controlled with the MEMORY command.

"Programs" vs. "Compiled Profiles & PLC Programs"

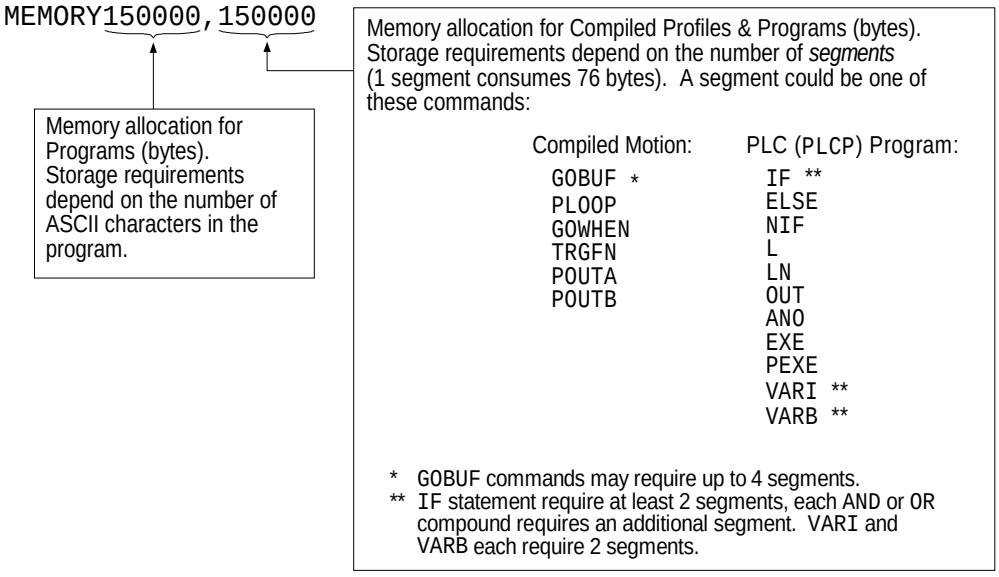
Programs are defined with the DEF and END commands, as demonstrated in the *Program Example* on page 10.

Compiled Profiles & PLC Programs are defined like programs, using the DEF and END commands, but are compiled with the PCOMP command and executed with the PRUN command (PLC programs are usually executed in PLC Scan Mode with the SCANP). A compiled profile (a series of GOBUF commands). A PLC program is a pre-compiled program that mimics PLC functionality by scanning through the I/O faster than in normal program execution.

Programs intended to be compiled are stored in program memory. After they are compiled with the PCOMP command, they remain in program memory and the *segments* (see diagram below) from the compiled program are stored in compiled memory. The TDIR report indicates which programs are compiled as compiled profiles ("COMPILED AS A PATH") and which programs are compiled as PLC programs ("COMPILED AS A PLC PROGRAM") .

For information on compiled profiles, refer to *Compiled Motion Profiling* on page 139; and for information on PLC programs, refer to page 120.

MEMORY command syntax (example)



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The table below identifies memory allocation defaults and limits for all Gem6K Series products. When specifying the memory allocation, use only even numbers. The minimum storage capacity for one partition area (program or compiled) is 1,000 bytes.

Feature	All Other Products
Total memory (bytes)	300,000
Default allocation (program,compiled)	150000,150000
Maximum allocation for programs	299000,1000
Maximum allocation for compiled profiles & PLC programs	1000,299000
Max. # of programs	400
Max. # of labels	600
Max. # of compiled profiles & PLC programs	300
Max. # of compiled profile segments	2069
Max. # of numeric variables (VAR)	225
Max. # of integer variables (VARI)	225
Max. # of binary variables (VARB)	125
Max. # of string variables (VARS)	25

When teaching variable data to a data program (DATP), be aware that the memory required for each data statement of four data points (43 bytes) is taken from the memory allocation for program storage (see *Variable Arrays* in Chapter 3, page 110, for details).

CAUTION

Using a memory allocation command (e.g., `MEMORY200000,100000`) will erase all existing programs and compiled profile segments & PLC programs. However, issuing the `MEMORY` command without parameters (i.e., type `MEMORY` <*cr*> to request the status of how the memory is allocated) will not affect existing programs or compiled segments/programs.

Checking Memory Status

To find out what programs reside in your controller's memory, and how much of the available memory is allocated for programs and compiled profile segments, issue the `TDIR` command (see example response below). Entering the `TMEM` command or the `MEMORY` command (without parameters) will also report the available memory for programs and compiled profile segments.

Sample response to `TDIR` command

```
*1 - SETUP USES 345 BYTES
*2 - PIKPRT USES 333 BYTES
*149322 OF 150000 BYTES (98%) PROGRAM MEMORY REMAINING
*1973 OF 1973 SEGMENTS (100%) COMPILED MEMORY REMAINING
```

Two system status bits (reported with the TSS and SS commands) are available to check when compiled profile segment storage is 75% full or 100% full. System status bit #29 is set when segment storage reaches 75% of capacity; bit #30 indicates when segment storage is 100% full.

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Executing Programs (options)

Following is a list of the primary options for executing programs stored in your controller:

Method	Description	See Also
Execute from a terminal emulator	Type in the name of the program and press enter; or write a program to prompt the operator to select a program from the terminal.	-------
Execute as a subroutine from a "main" program	Use a branch (GOTO, GOSUB, or JUMP) from the main program to execute another stored program.	Page 23
Execute automatically when the controller is powered up	Assign a specific program as a startup program with the STARTP command. When you RESET or cycle power to the controller, the startup program is automatically executed.	Page 13
Execute from a PLC program	Write a PLC program that executes a program (using EXE or PEXE) based on a specific condition (e.g., input state). Use the SCANP command to launch the PLC program in the PLC Scan Mode.	Page 120
Execute a specific program with BCD weighted inputs	Define programmable inputs to function as BCD select inputs, each with a BCD weight. A specific program (identified by its number) is executed based on the combination of active BCD inputs. Related commands: INSELP and INFNCi-B or LIMFNCi-B.	Page 97
Execute a specific program with a dedicated input	Define a programmable input to execute a specific program (by number). Related commands: INSELP and INFNCi-iP or LIMFNCi-P.	Page 103
"Call" from a high-level program	Using a programming language such as BASIC or C, write a program that enables the computer to monitor processes and orchestrate motion and I/O by executing stored programs (or individual commands) in the controller.	Page 133
Execute from an RP240 (remote operator interface)	Execute a stored program from the RUN menu in the RP240's standard menu system.	Page 127
Execute from your own custom Windows program	Use a programming language (e.g., Visual Basic, Visual C++, etc.) and the Gem6K Communications Server (provided on the Motion Planner CD) to create your own windows application to control the Gem6K product. Also included with Motion Planner is PanelMaker, a Visual Basic scripting tool for developing your own customer user interfaces.	---------

Creating and Executing a Set-up Program

Wizards Can Help:

The Motion Planner **Start** Wizard helps you with these setup programming tasks:

- Create a Setup program that configures drives, feedback devices, scaling, limits (end of travel and home), and servo tuning.
- Create a Main program, establish it as the power-up (STARTP) program, and include a GOSUB to the Setup program.

The intent of the Setup program is to place the Gem6K controller in a ready state for subsequent motion control. The setup program must be called from the "main" program for your application; or you can designate (with STARTP) the setup program as the program to be automatically executed when the Gem6K product is powered up or when the RESET command is executed. The setup program typically contains elements such as feedback device configuration, tuning gain selections, programmable I/O definitions, scaling, homing configuration, variable initialization, etc. (more detail on these "basic" features is provided in Chapter 3, *Basic Operation Setup*).

The basic process of creating a setup program is:

1. Create a program to be used as the setup program.
2. Save the program and download it to the Gem6K product.
3. Execute the STARTP command to assign your new program as the "start-up" program (e.g., STARTP setup assigns the program called "setup" as the start-up program). The next time the controller is powered up or reset, the assigned STARTP program will be executed.

   Or call the setup program from the main program for your application.

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Program Security

Issuing the INFNCi-Q or LIMFNCi-Q command enables the *Program Security* feature and assigns the *Program Access* function to the specified programmable input. The "i" represents the number of the programmable input to which you wish to assign the function (see page 91 programmable input bit patterns for your product).

The program security feature denies you access to the DEF, DEL, ERASE, MEMORY, INFNC, and LIMFNC commands until you activate the program access input. Being denied access to these commands effectively restricts altering the user memory allocation. If you try to use these commands when program security is active (program access input is not activated), you will receive the error message *ACCESS DENIED.

For example, once you issue the INFNC5-Q command, onboard input #5 is assigned the program access function and access to the DEF, DEL, ERASE, MEMORY, INFNC, and LIMFNC commands will be denied until you activate onboard input #5.

NOTE: To regain access to these commands without the use of the program access input, you must issue the INEN command to disable the program security input, make the required user memory changes, and then issue the INEN command to re-enable the input. For example, if input 3 on I/O brick 2 is assigned as the Program Security input, use 2INEN.3=1 to disable the input and leave it activated, make the necessary user memory changes, and then use 2INEN.3=E to re-enable the input.

Controlling Execution of Programs and the Command Buffer

The Gem6K controller command buffer is capable of storing 2000 characters waiting to be processed. (*This is separate from the memory allocated for program storage – see* Memory Allocation, *page 11*.) COMEXC affects command execution. Three additional commands, COMEXL, COMEXR and COMEXS, affect the execution of programs and the command buffer.

COMEXC (Continuous Command Execution)

The COMEXC1 command enables the Continuous Command Execution Mode (default is COMEXC0). This mode allows the program to continue to the next command before motion is complete. This is useful for:

- Monitoring other processes while motion is occurring
- Performing calculations in advance of motion completion
- Pre-emptive GOs — executing a new profile with new attributes (distance, accel/decel, velocity, positioning mode, and Following ratio) before motion is complete: The motion profile underway is pre-empted with a new profile when a new GO is issued. The new GO both constructs and launches the pre-empting profile. Pre-emptive GOs are appropriate when the desired motion parameters are not known until motion is already underway. For a detailed description, refer to *On-The-Fly Motion* on page 155.
- Pre-process the next move while the current move is in progress (see CAUTION note). This reduces the processing time for the subsequent move to only a few microseconds.

CAUTION: Avoid executing moves prematurely

With continuous command execution enabled (COMEXC1), if you wish motion to stop before executing the subsequent move, place a WAIT(AS.1=bØ) statement before the subsequent GO command. If you wish to ensure the load settles adequately before the next move, use the WAIT(AS.24=b1) command instead (this requires you to define end-of-move settling criteria — see *Target Zone Mode* on page 84 for details).

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In the programming example below, by enabling the continuous command execution mode (COMEXC1), the controller is able to turn on output #3 after the encoder moves 4000 units of its 125000-unit move. Normally, with COMEXC disabled (COMEXCØ), command processing would be temporarily stopped at the GO1 command until motion is complete.

Programming Example (portion of program only)

```
COMEXC1           ;Enable continuous command execution mode
D125000           ;Set distance
V2                ;Set velocity
A10               ;Set acceleration
GO1               ;Initiate motion on axis 1
WAIT(1PE>4000)    ;Wait for the encoder position to exceed 4000
OUTXX1            ;Turn on onboard programmable output #3
WAIT(AS.1=b0)     ;Wait for motion to complete on axis 1 (AS bit #1 = zero)
OUTXX0            ;Turn off onboard programmable output #3
```

COMEXL (Save Command Buffer on Limit)

The COMEXL command enables saving the command buffer and maintaining program execution when a hardware or software end-of-travel limit is encountered. COMEXL is axis specific (e.g., COMEXL1xx1xxx1 enables saving the buffer for axes 1, 4, and 8).

For more information on end-of-travel limits, refer to page 74.

- COMEXL0: (This is the default setting.) When a limit is hit, every command in the command buffer will be discarded and program execution will be terminated.
- COMEXL1: When a limit is hit, all remaining commands in the command buffer will remain in the command buffer (excluding the command being executed at the time the limit is hit).

COMEXR (Effect of Pause/Continue Input)

The COMEXR command affects whether a "Pause" input (i.e., an input configured as a pause/continue input with the INFNCi-E command or the LIMFNCi-E command) will pause only program execution or both program execution and motion.

COMEXRØ: (This is the default setting.) Upon receiving a pause input, only program execution will be paused; any motion in progress will continue to its predetermined destination. Releasing the pause input or issuing a !C command will resume program execution.

COMEXR1: Upon receiving a pause input, both motion and program execution will be paused; the motion stop function is used to halt motion. *After motion has come to a stop (not during deceleration)*, you can release the pause input or issue a !C command to resume motion and program execution.

Other Ways to Pause

- Issue the PS command before entering a series of buffered commands (to cause motion, activate outputs, etc.), then issue the !C command to execute the commands.
- While program execution is in progress, issuing the !PS command stops program execution, but any move currently in progress will be completed. Resume program execution with the !C command.

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COMEXS (Save Command Buffer on Stop)

The COMEXS command determines the impact on motion, program execution, and the command buffer when the Gem6K receives a Stop command (S, !S, S1, or !S1) or an external Stop input (an input assigned a stop function with INFNCi-D or LIMFNCi-D).

COMEXS0: Under factory default conditions (COMEXS0), when the Gem6K receives a stop command (S, !S, S1, or !S1) or a stop input (INFNCi-D or LIMFNCi-D), the following will happen:

- Motion decelerates to a stop, using the present AD and ADA deceleration values. The motion profile cannot be resumed.
- If S, !S or Stop input:
  - All commands in the Gem6K's command buffer are discarded.
  - Program execution is terminated and cannot be resumed.
- If S1, or !S1 (an axis number is included in the command):
  - All commands in the Gem6K's command buffer are retained.
  - Program execution continues.

COMEXS1: Using the COMEXS1 mode, the Gem6K allows more flexibility in responding to stop conditions, depending on the stop method (see table below).

Stop Method	What Stops? Motion	What Stops? Program	**Resume Motion Profile**. (Allow resume with a !C command or a resume input *)	**Resume Program**. (Allow resume with a !C command or a resume input *)	**Save Command Buffer**. (Save the commands that were in the command buffer when the stop was commanded)
!S or S	Yes	Yes	Yes	Yes	Yes
!S1 or S1	Yes	No	No	No	Yes
Stop input	Yes	Yes	No	Yes	Yes
Pause input * (if COMEXR1)	Yes	Yes	Yes	Yes	Yes
Pause input * (if COMEXR0)	No	Yes	No	Yes	Yes

* A *Pause* input is an input configured with the INFNCi-E command or the LIMFNCi-E command. This is also the *Resume* input that can be used to resume motion and program execution after motion is stopped.

COMEXS2: Using the COMEXS2 mode, the Gem6K responds as it does in the COMEXS0 mode, with the exception that you can still use the program-select inputs to select programs (INSELP value is retained). The program-select input functions are: BCD select (INFNCi-B or LIMFNCi-B) – see page 97, and one-to-one select (INFNCi-P or LIMFNCi-P) – see page 103.

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Restricted Commands During Motion

When motion is in progress on a given axis (or task), some commands cannot have their parameters changed until motion is complete (see table below).

For the commands identified in the table, if the continuous command execution mode is enabled (COMEXC1) and you try to enter new command parameters, you will receive the error response MOTION IN PROGRESS. If the continuous command execution mode in disabled (COMEXCØ), which is the default setting, you will receive the response MOTION IN PROGRESS only if you precede the command with the immediate (!) modifier (e.g., !V2Ø); if you enter a command without the immediate modifier (e.g., V2Ø), you will not receive an error response and the new parameter will be ignored and the old parameter will remain in effect.

Multi-Tasking

If you are using multi-tasking, the restriction on commands is applicable only for the task to which the command is direct. For example, suppose axes 1 and 2 are associated with Task 1 (TSKAX1,2) and axes 3 and 4 are associate with Task 2 (TSKAX3,4). If motion is in progress on axes 1 and 2, Task 1 is considered "in motion" and Task 1 cannot execute a command from the list below. However, while motion is in progress in Task 1 and not Task 2, Task 2 may execute these commands without encountering an error.

All of the commands in the table below, except for SCALE, are axis-dependent. That is, if one axis is moving you can change the parameters on the other axes, provided they are not in motion.

Command	Description
CMDDIR	Commanded Direction Polarity
DRES	Drive Resolution
DRIVE	Drive Shutdown
ENCPOL	Encoder Polarity
ERES	Encoder Resolution
FOLEN	Following Mode Enable
HOM	Go Home
HOMA	Home Acceleration
HOMAA	Average Home Acceleration
HOMAD	Home Deceleration
HOMADA	Average Home Deceleration
HOMV	Home Velocity
HOMVF	Home Final Velocity
JOG	Jog Mode Enable
JOGA	Jog Acceleration
JOGAA	Average Jog Acceleration
JOGAD	Jog Deceleration
JOGADA	Average Jog Deceleration
JOGVH	Jog Velocity High
JOGVL	Jog Velocity Low

Command	Description
JOY	Joystick Mode Enable
JOYA	Joystick Acceleration
JOYAA	Average Joystick Acceleration
JOYAD	Joystick Deceleration
JOYADA	Average Joystick Deceleration
JOYVH	Joystick Velocity High
JOYVL	Joystick Velocity Low
LHAD	Hard Limit Deceleration
LHADA	Average Hard Limit Deceleration
LSAD	Soft Limit Deceleration
LSADA	Average Soft Limit Deceleration
PSET	Establish Absolute Position
SCALE	Enable/Disable Scale Factors *
SCLA	Acceleration Scale Factor
SCLD	Distance Scale Factor
SCLV	Velocity Scale Factor

* If any axis is in motion, you will cause an error if you attempt to change this command's parameters.

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Variables

Gem6K Series controllers have four types of variables, each designated with a different command. All four types are automatically stored in non-volatile memory.

Type	Command	Quantity	Function
Numeric (real)	VAR	225	Store real numeric data (range is ±999,999,999.99999999). Can be used to perform mathematical (=, +, -, *, /, SQRT), trigonometric (ATAN, COS, PI, SIN, TAN), and Boolean (&, |, ^, ~) operations. Can also be used to store ("teach") variable data in variable arrays (called *data programs*) and later use the stored data as a source for motion program parameters (see *Variable Arrays* on page 110 for details).
Integer	VARI	225	Store integer numeric data (range is ±2,147,483,647). Can be used to perform mathematical (=, +, -, *, /) and Boolean (&, |, ^, ~) operations.
Binary	VARB	125	Store 32-bit binary or hexadecimal values. Can also store the binary status bits from status registers. Frequently used registers are: inputs (IN), outputs (OUT), limits (LIM), system (SS), Following (FS), axis (AS & ASX), and error (ER). For example, the VARB2=IN.3 command assigns the binary state of input 12 to binary variable 2. Also use to perform bitwise operations (&, |, ^, ~, >>, <<).
String	VARS	25	Store message strings of 50 characters or less. These message strings can be predefined error messages, user messages, etc. The programming example in the *Command Value Substitutions* (page 7) demonstrates the use of a string variable. Enhancements as of OS revision 5.1.0: • Copy one VARS variable to another VARS variable. VARSn=VARSm may be used, as well as variable substitutions for "n" and "m". • VARS message string was increased from 20 to 50 characters.

NOTE: Variables do not share the same memory (e.g., VAR1, VARI1, VARB1, and VARS1 can all exist at the same time and operate separately).

Converting Between Binary and Numeric Variables

Using the Variable Type Conversion (VCVT) operator, you can convert numeric (VAR or VARI) values to binary (VARB) values, and vice versa. The operation is a signed operation as the binary value is interpreted as a two's complement number. Any *don't care*s (X) in a binary value is interpreted as a zero (Ø).

If the mathematical statement's result is a numeric value, then VCVT converts binary values to numeric values. If the statement's result is a binary value, then VCVT converts numeric values to binary values.

Numeric to Binary

```
Example                 Description/Response
VAR1=-5                 Set numeric variable value = -5
VARB1=VCVT(VAR1)        Convert the numeric value to a binary value
VARB1                   *VARB1=1101_1111_1111_1111_1111_1111_1111_1111
```

Binary to Numeric

```
Example                 Description/Response
VARB1=b0010_0110_0000_0000_0000_0000_0000_0000
                        Set binary variable = +100.0
VAR1=VCVT(VARB1)        Convert binary value to numeric
VAR1                    *VAR1=+100.0
```


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Using Numeric (VAR and VARI) Variables

NOTES

- The examples below show the use of real numeric variables (VAR). Integer variables may be used in the same operations with these exceptions:
  - Values are truncated to nearest integer value
  - Operations using square root (SQRT) and trigonometric (ATAN, COS, PI, SIN, TAN) operators are not allowed
- Some numeric variable operations reduce precision. The following operations reduce the precision of the return value: Division and Trigonometric functions yield 5 decimal places; Square Root yields 3 decimal places; and Inverse Trigonometric functions yield 2 decimal places.

Mathematical Operations

The following examples demonstrate how to perform math operations with numeric variables. Operator precedence occurs from left to right (e.g., VAR1=1+1+1*3 sets VAR1 to 9, not 5).

Addition (+)

Example	Response
VAR1=5+5+5+5+5+5+5	
VAR1	*VAR1=35.0
VAR23=1000.565	
VAR11=VAR1+VAR23	
VAR11	*VAR11=+1035.565
VAR1=VAR1+5	
VAR1	*VAR1=+40.0

Subtraction (-)

Example	Response
VAR3=20-10	
VAR20=15.5	
VAR3=VAR3-VAR20	
VAR3	*VAR3=-5.5

Multiplication (*)

Example	Response
VAR3=10	
VAR3=VAR3*20	
VAR3	*VAR3=+200.0

Division (/)

Example	Response
VAR3=10	
VAR20=15.5	
VAR20	*+15.5
VAR3=VAR3/VAR20	
VAR3	*+0.64516
VAR30=75	
VAR30	*+75.0
VAR19=VAR30/VAR3	
VAR19	*+116.25023

Square Root (SQRT)

Example	Response
VAR3=75	
VAR20=25	
VAR3=SQRT(VAR3)	
VAR3	*+8.660
VAR20=SQRT(VAR20)+SQRT(9)	
VAR20	*+8.0

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Trigonometric Operations

The examples below demonstrate how to perform trigonometric operations with numeric variables.

Sine

Example	Response
RADIAN0	
VAR1=SIN(0)	
VAR1	*VAR1=+0.0
VAR1=SIN(30)	
VAR1	*VAR1=+0.5
VAR1=SIN(45)	
VAR1	*VAR1=+0.70711
VAR1=SIN(60)	
VAR1	*VAR1=+0.86603
VAR1=SIN(90)	
VAR1	*VAR1=+1.0
RADIAN1	
VAR1=SIN(0)	
VAR1	*VAR1=+0.0
VAR1=SIN(PI/6)	
VAR1	*VAR1=+0.5
VAR1=SIN(PI/4)	
VAR1	*VAR1=+0.70711
VAR1=SIN(PI/3)	
VAR1	*VAR1=+0.86603
VAR1=SIN(PI/2)	
VAR1	*VAR1=+1.0

Cosine

Example	Response
RADIAN0	
VAR1=COS(0)	
VAR1	*VAR1=+1.0
VAR1=COS(30)	
VAR1	*VAR1=+0.86603
VAR1=COS(45)	
VAR1	*VAR1=+0.70711
VAR1=COS(60)	
VAR1	*VAR1=+0.5
VAR1=COS(90)	
VAR1	*VAR1=+0.0
RADIAN1	
VAR1=COS(0)	
VAR1	*VAR1=+1.0
VAR1=COS(PI/6)	
VAR1	*VAR1=+0.86603
VAR1=COS(PI/4)	
VAR1	*VAR1=+0.70711
VAR1=COS(PI/3)	
VAR1	*VAR1=+0.5
VAR1=COS(PI/2)	
VAR1	*VAR1=+0.0

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Tangent

Example	Response
RADIAN0	
VAR1=TAN(0)	
VAR1	*VAR1=+0.0
VAR1=TAN(30)	
VAR1	*VAR1=+0.57735
VAR1=TAN(45)	
VAR1	*VAR1=+1.0
VAR1=TAN(60)	
VAR1	*VAR1=+1.73205
RADIAN1	
VAR1=TAN(0)	
VAR1	*VAR1=+0.0
VAR1=TAN(PI/6)	
VAR1	*VAR1=+0.57735
VAR1=TAN(PI/4)	
VAR1	*VAR1=+1.0
VAR1=TAN(PI/3)	
VAR1	*VAR1=+1.73205

Inverse Tangent (Arc Tangent)

Example	Response
RADIAN0	
VAR1=SQRT(2)	
VAR1=ATAN(VAR1/2)	
VAR1	*VAR1=+35.26
VAR1=ATAN(.57735)	
VAR1	*VAR1=+30.0

Boolean Operations

Gem6K Series products have the ability to perform Boolean operations with numeric variables. The following examples illustrate this capability. Refer to the *Gem6K Series Command Reference* for more information on each operator (&, |, ^, and ~).

Boolean And (&)

Example	Response
VAR1=5	
VAR2=-1	
VAR3=VAR1 & VAR2	
VAR3	*VAR3=+0.0

Boolean Or (|)

Example	Response
VAR1=5	
VAR2=-1	
VAR3=VAR1 | VAR2	
VAR3	*VAR3=+1.0

Boolean Exclusive Or (^)

Example	Response
VAR1=5	
VAR2=-1	
VAR3=VAR1 ^ VAR2	
VAR3	*VAR3=+1.0

Boolean Not (~)

Example	Response
VAR1=5	
VAR3=~(VAR1)	
VAR3	*VAR3=+0.0
VAR1=-1	
VAR3=~(VAR1)	
VAR3	*VAR3=+1.0

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Using Binary Variables

The following examples illustrate the Gem6K Series product's ability to perform bitwise functions with binary variables.

Storing binary values. The Gem6K Series Language allows you to store binary numbers in the binary variables (VARB) command. The binary variables start at the left with the least significant bit, and increase to the right. For example, to set bit 1, 5, and 7 you would issue the command `VARB1=b1xxx1x1`. Notice that the letter `b` is required. When assigning a binary variable, any bit set to "x" remains "x" until set to "1" or "0". Any bit that is unspecified is set to "x". To change, or check, one bit without affecting the others, use the bit-select operator (e.g., use `VARB1.3-1` to set only bit #3 of VARB1).

```
Example                 Response
VARB1=b1101XX1          *VARB1=1101_XX1X_XXXX_XXXX_XXXX_XXXX_XXXX_XXXX
```

Storing hexadecimal values. Hexadecimal values can also be stored in binary variables (VARB). The hexadecimal value must be specified the same as the binary value—left is least significant byte, right is most significant. For example, to set bit 1, 5, and 7 you would issue the command `VARB1=h15`. Notice that the letter `h` is required. **NOTE**: When assigning a hexadecimal value to a binary variable, all unspecified bits are set to zero.

```
Example                 Response
VARB1=h7FAD
VARB1                   *VARB1=1110_1111_0101_1011_0000_0000_0000_0000
```

Bitwise And (&)

```
Example                 Response
VARB1=b1101
VARB1                   *VARB1=1101_XXXX_XXXX_XXXX_XXXX_XXXX_XXXX_XXXX
VARB1=VARB1 & bXXX1 1101
VARB1                   *VARB1=XX01_XX0X_XXXX_XXXX_XXXX_XXXX_XXXX_XXXX
VARB1=h0032 FDA1 & h1234 43E9
VARB1                   *VARB1=0000_0000_1100_0000_0010_1000_0101_1000
```

Bitwise Or (|)

```
Example                 Response
VARB1=h32FD
VARB1                   *VARB1=1100_0100_1111_1011_0000_0000_0000_0000
VARB1=VARB1 | bXXX1 1101
VARB1                   *VARB1=11X1_1101_1111_1X11_XXXX_XXXX_XXXX_XXXX
VARB1=h0032 FDA1 | h1234 43E9
VARB1                   *VARB1=1000_0100_1100_0110_1111_1111_0111_1001
```

Bitwise Exclusive Or (^)

```
Example                 Response
VARB1=h32FD ^ bXXX1 1101
VARB1                   *VARB1=XXX1_1001_XXXX_XXXX_XXXX_XXXX_XXXX_XXXX
VARB1=h0032 FDA1 ^ h1234 43E9
VARB1                   *VARB1=1000_0100_0000_0110_1101_0111_0010_0001
```

Bitwise Not (~)

```
Example                 Response
VARB1=~(h32FD)
VARB1                   *VARB1=0011_1011_0000_0100_1111_1111_1111_1111
VARB1=~(b1010 XX11 0101)
VARB1                   *VARB1=0101_XX00_1010_XXXX_XXXX_XXXX_XXXX_XXXX
```

Shift Left to Right (>>)

```
Example                 Response
VARB1=h32FD >> h4
VARB1                   *VARB1=0000_1100_0100_1111_1011_0000_0000_0000
VARB1=b1010 XX11 0101 >> b11
VARB1                   *VARB1=0001_010X_X110_101X_XXXX_XXXX_XXXX_XXXX
```

Shift Right to Left (<<)

```
Example                 Response
VARB1=h32FD << h4
VARB1                   *VARB1=0100_1111_1011_0000_0000_0000_0000_0000
VARB1=b1010 XX11 0101 << b11
VARB1                   *VARB1=0XX1_1010_1XXX_XXXX_XXXX_XXXX_XXXX_X000
```


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Program flow refers to the order in which commands will be executed, and when or whether they will be executed at all. In general, commands are executed in the order in which they are received. However, certain commands can redirect the order in which commands will be processed.

You can affect program flow with:

- Unconditional Loops and Branches
- Conditional Loops and Branches

Unconditional Looping and Branching

Unconditional Looping

The Loop (L) command is an unconditional looping command. You may use this command to repeat the execution of a group of commands for a predetermined number of iterations. You can nest Loop commands up to 16 levels deep. The code sample (portion of a program) below demonstrates a loop of 5 iterations.

```
MA0       ; Sets unit to Incremental mode
A50       ; Sets acceleration to 50
V5        ; Sets velocity to 5
L5        ; Loops 5 times
D2000     ; Sets distance to 2,000
GO1       ; Executes the move (Go)
T2        ; Delays 2 seconds after the move
LN        ; Ends loop
```

Unconditional Branching

When an unconditional branch is processed, the flow of program execution ("control") passes to the program or label specified in the branch command. Depending on the branch command used, processing may or may not return to the original program (the "calling" program). There are three ways to branch unconditionally:

GOSUB: The GOSUB command branches to the program name or label stated in the GOSUB command. After the called program or label is executed, processing returns to the calling program at the next command line after the GOSUB branch command.

GOTO: The GOTO command branches to the program name or label stated in the GOTO command. After the called program or label is executed, processing **does not** return to the calling program—instead, the program will end. This holds true unless the subroutine in which the GOTO resides was called with a GOSUB by another program; in this case, the END in the GOTO program will initiate a return to the calling program. For example, if processing flows from a GOSUB in program A to program B, and then a GOTO from program B to program C, when the END command is processed in program C, processing returns to program A at the command line after the GOSUB.

JUMP: The JUMP command branches to the program name or label stated in the JUMP command. All nested IFs, WHILEs, and REPEATs, loops (L), and subroutines are cleared; thus, the program or label that the JUMP initiates **will not** return control to the calling program; instead, the called program will end.

If an invalid program or label name is entered, the branch command will be ignored and processing will continue with the next line in the program.

Gem6K Series products do not support recursive calling of subroutines.

Using labels: Labels, defined with the $ command, provide a method of branching to specific locations within the same program. Labels can only be defined within a program and executed with a GOTO, GOSUB, or JUMP command from within the same program (*see Example B below*).

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NOTE

Be careful about performing a GOTO within a loop or branch statement area (i.e., between L&LN, between IF & NIF, between REPEAT & UNTIL, or between WHILE & NWHILE). Branching to a different location within the same program will cause the next L, IF, REPEAT, or WHILE statement encountered to be nested within the previous L, IF, REPEAT, or WHILE statement area, unless an LN, NIF, UNTIL, or NWHILE command has already been encountered.

** To avoid this nesting situation, use the JUMP command instead of the GOTO command.

Example A

DESCRIPTION: The program cut1 is executed until it gets to the command GOSUB prompt. From there it branches unconditionally to the subroutine (actually a program) called prompt. The subroutine prompt queries the operator for the number of parts to process. After the part number is entered (e.g., operator enters the !'12 command to process 12 parts), the rest of the prompt subroutine is executed and control goes back to the cut1 program and resumes program execution with the next command after the GOSUB, which is MAØØ.

```
DEL cut1                ; Delete a program before defining it
DEF cut1                ; Begin definition of program cut1
HOM11                   ; Send axes 1 and 2 to the home position
WAIT(1AS=b0XXX1 AND 2AS=b0XXX1)   ; Wait for axes 1 and 2 to come
                        ; to a halt at home
GOSUB prompt            ; Go to subroutine program called prompt
MA00                    ; Place axes 1 and 2 in the incremental mode
A10,30                  ; Set acceleration: axis 1 = 10, axis 2 = 30
AD5,12                  ; Set deceleration: axis 1 = 5, axis 2 = 12
V5,8                    ; Set velocity: axis 1 = 5, axis 2 = 8
D16000,100000           ; Set distance: axis 1 = 16,000; axis 2 = 100,000
OUT.3-1                 ; Turn on onboard output number 3
T5                      ; Wait for 5 seconds
L(VAR2)                 ; Begin loop (number of loops = value of VAR2)
  GO11                  ; Initiate moves on axes 1 and 2
  T3                    ; Wait for 3 seconds
LN                      ; End loop
OUT.3-0                 ; Turn off onboard output number 3
END                     ; End definition of program cut1

DEF prompt              ; Begin definition of program prompt
VARS1="Enter part count >"  ; Place message in string variable #1
VAR2=READ1              ; Prompt operator with string variable #1,
                        ; and read data into numeric variable #2
                        ; NOTE:  Type !' before the part count number.
END                     ; End definition of program prompt
```

Example B

DESCRIPTION: This example demonstrates the use of labels ($).

```
DEL pick                ; Delete a program before defining it
DEF pick                ; Begin definition of program pick
GO1100                  ; Initiate motion and axes 1 and 2
IF(VAR1=5)              ; If variable 1 = 5, then execute commands
                        ; between IF and ELSE. Otherwise, execute
                        ; commands between ELSE and NIF
    GOTO pick1          ; Goto label pick1
  ELSE                  ; Else part of IF statement
    GOTO pick2          ; Goto label pick2
NIF                     ; End of IF statement
$ pick1                 ; Define label for pick1
  GO0011                ; Initiate motion on axes 3 and 4
  BREAK                 ; Break out of current subroutine or program
$ pick2                 ; Define label for pick2
  GO1001                ; Initiate motion on axes 1 and 4
END                     ; End definition of program pick
```


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Conditional Looping and Branching

Conditional looping (REPEAT/UNTIL and WHILE/NWHILE) entails repeating a set of commands until or while a certain condition exists. In *conditional branching* (IF/ELSE/NIF), a specific set of commands is executed based on a certain condition. Both rely on the fulfillment of a conditional *expression*, a condition specified in the UNTIL, WHILE, or IF commands.

A WAIT command pauses command execution until a specific condition exists.

Flow Control Expression Examples

This section provides examples of expressions that can be used in conditional branching and looping commands (UNTIL, WHILE, and IF) and the WAIT command. These expressions can be constructed, in conjunction with relational and logical operators, with the following operands:

- Numeric variables and binary variables
- Inputs and outputs
- Current motion parameters and status
- Current commanded and actual position
- Error, axis, and system status
- Timer value
- Data read from the serial port
- Data read from the RP240
- Following conditions
- Multi-tasking conditions

Numeric and Binary Variables

A numeric variable (VAR or VARI) can be used within an expression if it is compared against another numeric variable, a value, or one of the comparison commands (see list on page 7). When comparing a variable against another value, variable, or comparison command, the relational operators (=, >, >=, <, <=, <>) and logical operators (AND, OR, NOT) are used.

Expression	Description
(VAR1<VAR2)	True expression if variable 1 is less than variable 2
(VAR1>=2500)	True expression if variable 1 is greater than or equal to 2500
(VAR1=1AD)	True expression if variable 1 is equal to the decel of axis 1
(VAR1<VAR2 AND VAR4>1PE)	True expression if variable 1 is less than variable 2 and variable 4 is greater than the value of encoder 1

A binary variable (VARB) can be used within an expression, if the variable is compared against another binary variable, or a value. When comparing a variable against another value or variable, the relational operators (=, >, >=, <, <=, <>) and logical operators (AND, OR, NOT) are used.

Expression	Description
(VARB1<>VARB2)	True expression if binary variable 1 is not equal to binary variable 2
(VARB1=b1101 X111)	True expression if binary variable 1 is equal to 1101 X111
(VARB1<VARB2 AND VARB4>hF)	True expression if binary variable 1 is less than binary variable 2 and binary variable 4 is greater than the hexadecimal value of F

Inputs and Outputs

An input or output operand (ANI, IN, INO, LIM, OUT, TRIG) can be used within an expression, if the operand is compared against a binary variable or a binary or hexadecimal value. When making the comparison, the relational operators (=, >, >=, <, <=, <>) and logical operators (AND, OR, NOT) are used.

Expression	Description
(IN.3=b1)	True expression if onboard input 3 is equal to 1
(LIM>h3)	True expression if limit status is greater than hexadecimal 3

Current Motion Parameters and Status

Motion parameters consist of A, AD, D, V, VEL, status MOV. The motion parameters can be used within an expression, if the operand is compared against a numeric variable or value. The motion status operand must be compared against a binary variable or a binary or hexadecimal value. When making the comparison, the relational operators (=, >, >=, <, <=, <>) and logical operators (AND, OR, NOT) are used. (Following conditions are addressed below.)

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Expression	Description
(VAR1<1VEL)	True expression if the value of variable 1 is less than the commanded velocity of axis 1
(1AD=25000)	True expression if axis 1 deceleration equals 25000
(MOV=b00)	True expression if moving status equals ØØ (axes 1 & 2 are not moving)

Current Commanded & Actual Position

The current commanded and actual positions (ANI, DAC, FB, PANI, PC, PCC, PCE, PCME, PCMS, PE, PER, PE, PMAS, PME, PSHF, PSLV) can be used within an expression, if the operand is compared against a numeric variable or value. When making the comparison, the relational operators (=, >, >=, <, <=, <>) and logical operators (AND, OR, NOT) are used.

Expression	Description
(VAR1<1FB)	True expression if the value of variable 1 is less than the actual position (position of the assigned feedback device) of axis 1
(2PC=4000)	True expression if axis 2 commanded position equals 4000
(VAR1<1PME)	True expression if VAR1 is < master encoder position of axis 1
(2PE=25000)	True expression if axis 2 encoder position equals 25000

Error, Axis, and System Status

The error status, axis status, and system status operands (ER, AS, ASX, SS) can be used within an expression, if the operand is compared against a binary variable or a binary or hexadecimal value. When making the comparison, the relational operators (=, >, >=, <, <=, <>) and logical operators (AND, OR, NOT) are used. Refer to page 222 for a list of status bit functions.

Expression	Description
(ER.12=b1)	True expression if error status bit 12 is equal to 1
(AS=h3FFD)	True expression if axis status is equal to hexadecimal 3FFD

Timer Value

The current timer value (TIM) can be used within an expression, if the operand is compared against a numeric variable or value. When making the comparison, the relational operators (=, >, >=, <, <=, <>) and logical operators (AND, OR, NOT) are used.

Expression	Description
(VAR1<TIM)	True expression if the value of variable 1 is less than the timer value

Data Read from the Communications Port

The READ command can be used to input data from a serial port or the Ethernet port into a numeric variable. After the data has been read into a numeric variable, that variable may be used in an expression.

Example	Description
VARS8="ENTER DATA"	Define message (string variable 8)
VAR2=READ8	Send message (string variable 8) and then wait for immediate data to be read (into numeric variable 2)
!'88.3	Immediate data input (must type !' before the numeric value)
IF (VAR2<=100)	Evaluate expression to see if data read is < or equal to 100
. . . . .	
NIF	End of IF

Data Read from the RP240

The DREAD and DREADF commands can be used to input data from the RP240 into a numeric variable. DREAD reads a number from the RP240's numeric keypad. DREADF reads a number representing a RP240 function key. After the data has been read into a numeric variable, that variable may be used in an expression. The DKEY operator allows you to read the current state of the RP240 keypad (each key has a unique numeric value).

```
DCLEAR0             ; Clear RP240 display
DWRITE"HIT F4"      ; Send message to RP240 display
VAR3=DREADF         ; Read data from a RP240 function key into
                    ; numeric variable 3
IF (DKEY=24)        ; Evaluate expression to see if function key F4 was hit
DCLEAR2             ; Clear RP240 display line 2
DWRITE"TRY AGAIN"   ; Send message to RP240 display
NIF                 ; End of IF
```


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RP240 Data Read Immediate Mode

The DREADI1 command allows continual numeric or function key data entry from the RP240 (when used in conjunction with the DREAD and/or DREADF commands). In this immediate mode, program execution is not paused (waiting for data entry) when a DREAD or DREADF command is encountered. Refer to the DREAD and DREADF command descriptions for programming examples.

NOTES

- While in the Data Read Immediate Mode, data is read into numeric variables only (VAR).
- This feature is not designed to be used in conjunction with the RP240's standard menus; the **RUN**, **JOG**, and **DJOG** menus will disable the DREADI mode.
- Do not assign the same variable to read numeric data and function key data—pick only one.

Following Conditions

These Following conditions are available for conditional expressions: Axis status bit #26 (AS.26), Error status bit #14 (ER.14), Following status (FS), NMCY, PCME, PCMS, PMAS, PME, PSHF, PSLV, and VMAS.

Expression	Description
(2AS.26=b1)	True if a new motion profile on axis 2 is waiting for the GOWHEN condition to be true or a TRGFNc1xxxxxxx trigger.
(1ER.14=b1)	True if the GOWHEN condition on axis 1 is already true when the subsequent GO, GOL, FSHFC, or FSHFD command is executed.
(3FS.7=b0)	True if the master for follower axis 3 is in motion.
(2NMCY>200)	True if the master for axis 2 has moved through 200 cycles.
(1PMAS>12)	True if the master for axis 1 has traveled more than 12 units.
(1PSHF>1.5)	True if follower axis 1 has shifted more than 1.5 units.
(3PSLV>24)	True if follower axis 3's commanded position is more than 24 units.
(1VMAS<2)	True if the velocity of the master for axis 1 is less than 2 units/sec.

Multi-Tasking Conditions

These Multi-tasking conditions are available for conditional expressions: Status of which tasks are current active (SWAP), identity of the task in which the command is executed (TASK).

Expression	Description
(SWAP.3=b1)	True if Task 3 is active.
(TASK=3)	True if the task executing the conditional expression is Task 3.

Conditional Looping

The Gem6K controller supports two conditional looping structures—REPEAT/UNTIL and WHILE/NWHILE.

All commands between REPEAT and UNTIL are repeated until the expression contained within the parenthesis of the UNTIL command is true. The example below illustrates how a typical REPEAT/UNTIL conditional loop works. In this example, the REPEAT loop will execute 1 time, at which point the expression stated within the UNTIL command will be evaluated. If the expression is true, command processing will continue with the first command following the UNTIL command. If the expression is false, the REPEAT loop will be repeated.

```
VAR5=0           ; Initializes variable 5 to 0
DEL prog10       ; Delete a program before defining it
DEF prog10       ; Defines program prog10
INFNC1-A         ; Assign onboard input 1 as g.p. input for use with IN
INFNC2-A         ; Assign onboard input 2 as g.p. input for use with IN
INFNC3-A         ; Assign onboard input 3 as g.p. input for use with IN
INFNC4-A         ; Assign onboard input 4 as g.p. input for use with IN
OUTFNC1-A        ; Assign onboard output 1 is a general-purpose output
A50              ; Acceleration is 50
AD50             ; Deceleration is 50
V5               ; Sets velocity to 5
D25000           ; Distance is 25,000
REPEAT           ; Begins the REPEAT loop
  GO1            ; Executes the move (Go)
  VAR5=VAR5+1    ; Variable 5 counts up from 0
```


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```
UNTIL(IN=b1110 OR VAR5>10) ; When inputs 1-4 are 1110, respectively, or
                ; VAR5 is greater than 10, the loop will stop.
OUT1            ; Turn on output 1 when finished with REPEAT loop
END             ; End program definition
RUN prog10      ; Initiate program prog10
```

All commands between WHILE and NWHILE are repeated as long as the WHILE condition is true. The following example illustrates how a typical WHILE/NWHILE conditional loop works. In this example, the WHILE loop will execute if the expression is true. If the expression is false, the WHILE loop will not execute.

```
VAR5=0          ; Initializes variable 5 to 0
DEL prog10      ; Delete a program before defining it
DEF prog10      ; Defines program prog10
INFNC1-A        ; Assign onboard input 1 as g.p. input for use with IN
INFNC2-A        ; Assign onboard input 2 as g.p. input for use with IN
INFNC3-A        ; Assign onboard input 3 as g.p. input for use with IN
INFNC4-A        ; Assign onboard input 4 as g.p. input for use with IN
OUTFNC1-A       ; Assign onboard output 1 is a general-purpose output
A50             ; Acceleration is 50
AD50            ; Deceleration is 50
V5              ; Sets velocity to 5
D25000          ; Distance is 25,000
WHILE(IN=b1110 OR VAR5>10)  ; While the inputs 1-4 are 1110, respectively
                ; or VAR5 is greater than 10, the loop will continue.
  GO1           ; Executes the move (Go)
  VAR5=VAR5+1   ; Variable 5 counts up from 0
NWHILE          ; End WHILE command
OUT1            ; Turn on output 1 when finished with WHILE loop
END             ; End program definition

; ***************************************************
; * To run prog10, execute the "RUN prog10" command     *
; ***************************************************
```

Conditional Branching

You can use the IF command for conditional branching. All commands between IF and ELSE are executed if the expression contained within the parentheses of the IF command is true. If the expression is false, the commands between ELSE and NIF are executed. If the ELSE is not needed, it may be omitted. The commands between IF and NIF are executed if the expression is true. Examples of these commands are as follows.

```
DEL prog10      ; Delete a program before defining it
DEF prog10      ; Defines program prog10
INFNC1-A        ; Assign onboard input 1 as g.p. input for use with IN
INFNC2-A        ; Assign onboard input 2 as g.p. input for use with IN
INFNC3-A        ; Assign onboard input 3 as g.p. input for use with IN
INFNC4-A        ; Assign onboard input 4 as g.p. input for use with IN
A50             ; Acceleration is 50
AD50            ; Deceleration is 50
V5              ; Sets velocity to 5
IF(VAR1>0)      ; IF variable 1 is greater than zero
   D25000       ; Distance is 25,000
   ELSE         ; Else
   D50000       ; Distance is 50,000
NIF             ; End if command
IF(IN=b1110)    ; If onboard inputs 1-4 are 1110, initiate axis 1 move
   GO1          ; Executes the move (Go)
NIF             ; End IF command
END             ; End program definition

; ***************************************************
; * To run prog10, execute the "RUN prog10" command     *
; ***************************************************
```


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Program Interrupts *(ON Conditions)*

Multi-Tasking
Each task has its own ONP program and its own set of ON conditions.

While executing a program, the Gem6K controller can interrupt the program based on several possible *ON conditions*: programmable input(s) status, user status, or the value of numeric variables #1 or #2. These ON conditions are enabled with the ONCOND command, and are defined with the commands listed below. After the ON conditions are enabled (with the ONCOND command), an ON condition interrupt can occur at any point in program execution. When an ON condition occurs, the controller performs a GOSUB to the program assigned as the ON program and then passes control back to the original program and resumes command execution at the command line from which the interruption occurred.

Within the ON program, the programmer is responsible for checking which ON condition caused the branch (if multiple ON conditions are enabled with the ONCOND command). Once a branch to the ON program occurs, the ON program will not be called again until after it has finished executing. After returning from the ON program, the condition that caused the branch must evaluate false before another branch to the ON program will be allowed.

SETUP FOR PROGRAM INTERRUPT (see programming example below)

1. Define a program to be used as the ON program to which the controller will GOSUB when an ON condition evaluates true.
2. Use the ONP command to assign the program as the ON program.
3. Use the ONCOND command to enable the ON conditions that you are using. The syntax for the ONCOND command is ONCOND<b><b><b><b>, where the first <b> is for the ONIN condition, the second for ONUS, the third for ONVARA, and the fourth for ONVARB.

ON conditions:

ONIN	Specify an input bit pattern that will cause a GOSUB to the program assigned as the ON program (see programming example below).
ONUS	Specify an user status bit pattern that will cause a GOSUB to the ON program. The user status bits are defined with the INDUST command.
ONVARA	Specify the range of numeric variable #1 (VAR1) that will cause a GOSUB to the ON program. For example, ONVARAØ,2Ø establishes the condition that if the value of VAR1 is ≤0 or ≥20, the ON program will be called.
ONVARB	This is the same function as ONVARA, but for numeric variable #2 (VAR2)

Programming Example: Configures the controller to increment variable #1 when input #1 goes active. If input #1 does go active, control will be passed (GOSUB) to the ON program (onjump), the commands within the ON program will be executed, and control will then be passed back to the original program.

```
DEF onjump      ; Begin definition of program onjump
VAR1=VAR1+1     ; Increment variable 1
END             ; End definition of program onjump

VAR1=0          ; Initialize variable 1
ONIN1           ; When input 1 becomes active, branch to the ON program
ONP onjump      ; Assign the onjump program as the ON program
ONCOND1000      ; Enable only the ONIN function. Disable the ONUS,
                ; ONVARA, and ONVARB functions, respectively
```

Situations in which ON conditions WILL NOT interrupt immediately

These are situations in which an ON condition does not immediately interrupt the program in progress. However, the fact that the ON condition evaluated true is retained, and when the condition listed below is no longer preventing the interrupt, the interrupt will occur.

- While motion is in progress due to GO, GOL, GOWHEN, HOM, JOY, JOG, or PRUN and the continuous command execution mode is disabled (COMEXCØ).
- While a WAIT statement is in progress
- While a time delay (T) is in progress
- While a program is being defined (DEF)
- While a pause (PS) is in progress
- While a data read (DREAD, DREADI, DREADF, or READ) is in progress

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Error Handling

Wizards can help:
Motion Planner's Wizard Editor provides an Error Program wizard that creates an Error program, provides safeguards for preventing unwanted calls to the Error program, and includes conditional code to handle the errors you wish to check.

DEBUG TOOLS
For information on program debug tools, refer to page 221.

The Gem6K Series products have the ability to detect and recover the following error conditions:

Error bit 1* ..... Stall Detected: Functions when stall detection has been enabled (ESTALL or DSTALL) and ESK1 is set.
Error bit 2 ..... Hard Limit Hit: Functions when hard limits are enabled (LH).
Error bit 3 ..... Soft Limit Hit: Functions when soft limits are enabled (LS).
Error bit 4 ..... Drive Fault: Detected only if the drive is enabled (DRIVE1).
Error bit 5 ..... Command Kill or Commanded Stop: K, !K,<ctrl>K, S, or !S command sent.
Error bit 6 ..... Kill Input: When an input is defined as a Kill input (INFNCi-C) and that input becomes active.
Error bit 7 ..... User Fault Input: When an input is defined as a User fault input (INFNCi-F) and that input becomes active.
Error bit 8 ..... Stop Input: When an input is defined as a Stop input (INFNCi-D) and that input becomes active.
Error bit 9 ..... Enable Input is activated (not grounded).
Error bit 10 ..... Pre-emptive (on-the-fly) GO or a registration move not possible
Error bit 11** .... Target zone settling timeout period (set with the STRGTT command) is exceeded.
Error bit 12** .... Maximum position error (set with the SMPER command) is exceeded.
Error bit 13 ..... RESERVED.
Error bit 14 ..... GOWHEN condition already true when GO, FSHFC, or FSHFD was executed
Error bit 15 ..... RESERVED.
Error bit 16 ..... Bad command detected (bit is cleared with TCMDER command).
Error bit 17 ..... RESERVED.
Error bit 18 ..... Cable to expansion I/O brick is disconnected or power to the I/O brick is lost; error is cleared by reconnecting to I/O brick and issuing the ERROR.18-0 command and then the ERROR.18-1 command. (Multi-tasking: this condition also kills all tasks.)
Error bits 19-22 . RESERVED.
Error bit 23 ..... Error bit 20 RESERVED.
Error bit 23 ..... Ethernet Client connection error.
Error bit 24 ..... Error bit 24 Ethernet Client polling error.
Error bit 25-32 ... RESERVED.

* Steppers only
** Servos only

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Enabling Error Checking

To detect and respond to the error conditions noted above, the corresponding error-checking bit(s) must be enabled with the ERROR command (refer to the *ERROR Bit #* column in the table below). If an error condition occurs and the associated error-checking bit has been enabled with the ERROR command, the Gem6K controller will branch to the error program.

For example, if you wish the Gem6K controller to branch to the error program when a hardware end-of-travel limit is encountered (error bit #2) or when a drive fault occurs (error bit #4), you would issue the ERROR01Ø1 command to enable error-checking bits #2 and #4.

MULTI-TASKING

If you are operating multiple tasks, be aware that you must enable error conditions (ERROR) and specify an error program (ERRORP) for each task (e.g., 2%ERROR.2-1 and 2%ERRORP FIX for Task 2). Each task has its own error status register (reported with ER, TER, and TERF). Regarding axis-related error conditions (e.g., drive fault, end-of-travel limit, etc.), only errors on the task's associated (TSKAX) axes will cause a branch to the task's ERROR P program.

☞ Helpful Hint: Within the structure of your error program, you can use the IF and ER commands to check which error caused the call to the ERRORP program and respond accordingly.

Defining the Error Program

The purpose of the error program is to provide a programmed response to certain error conditions (see list above) that may occur during the operation of your system. Programmed responses typically include actions such as shutting down the drive(s), activating or de-activating outputs, etc. Refer to the error program set-up example below.

Using the ERRORP command, you can assign any previously defined program as the error program. For example, to assign a previously defined program named CRASH as the error program, enter the ERRORP CRASH command. To un-assign a program from being the error program, issue the ERRORP CLR command (e.g., as in this example, it does not delete the CRASH program, but merely unlinks it from its assignment as the error program).

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Canceling the Branch to the Error Program

NOTE: In addition to canceling the branch to the error program, you must also remedy the cause of the error; otherwise, the error program will be called again when you resume operation. Refer to the *How to Remedy the Error* column in the table below for details.

If an error condition occurs and the associated error-checking bit has been enabled with the ERROR command, the Gem6K controller will branch to the error program. The error program will be continuously called/repeated until you cancel the branch to the error program. (This is true for all cases except error condition #9, **ENABLE** input activated, in which case the error program is called only once.)

There are three options for canceling the branch to the error program:

- Disable the error-checking bit with the ERROR.n-Ø command, where "n" is the number of the error-checking bit you wish to disable. For example, to disable error checking for the kill input activation (bit #6), issue the ERROR.6-Ø command. To re-enable the error-checking bit, issue the ERROR.n-1 command.
- Delete the program assigned as the ERRORP program (DEL <name of program>).
- Satisfy the *How to Remedy the Error* requirement identified in the table below.

ERROR Bit #	Cause of the Error	Branch Type to Error Program	How to Remedy the Error
1	**Steppers only**: Stall detected (Stall Detection and Kill On Stall must be enabled first—see ESTALL and ESK, respectively).	Gosub	Issue a GO command.
2	Hard Limit Hit. (hard limits must be enabled first—see LH)	If COMEXLØ, then Goto; If COMEXL1, then Gosub	Change direction & issue GO command on the axis that hit the limit; or issue LHØ.
3	Soft Limit Hit. (soft limits must be enabled first—see LS)	If COMEXLØ, then Goto; If COMEXL1, then Gosub	Change direction & issue GO command on the axis that hit the limit; or issue LSØ.
4	Drive Fault (Detected only if you enable drive, DRIVE1, and drive fault input, DRFEN.)	Goto	Clear the fault condition at the drive, & issue a DRIVE1 command for the faulted axis.
5	Commanded Stop or Kill (whenever a K, !K, <ctrl>K, K, or !S command is sent). See note below entitled "Commanded Kill or Stop".	If !K, then Goto; If !S & COMEXSØ, then Goto; If !S & COMEXS1, then Gosub, but need !C	No fault condition is present—there is no error to clear. If you want the program to stop, you must issue the !HALT command.
6	Kill Input Activated (see INFNCi-C or LIMFNCi-C)	Goto	Deactivate the kill input.
7	User Fault Input Activated (see INFNCi-F or LIMFNCi-F).	Goto	Deactivate the user fault input, or disable it by assigning it a different function (INFNC or LIMFNC).
8	Stop input activated (see INFNCi-D or LIMFNCi-C).	Goto	Deactivate the stop input, or disable it by assigning it a different function.
9	ENABLE input not grounded. (see "ESTOP" below)	Goto	Re-ground ENABLE input, and issue @DRIVE1.
10	Profile for pre-emptive GO or registration move not possible at the time of attempted execution.	Gosub	Issue another GO command.
11	**Servos only**: Target Zone Timeout (STRGTT value has been exceeded).	Gosub	Issue these commands in this order: STRGTEØ, DØ, GO, STRGTE1

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12	**Servos only**: Exceeded Max. Allowable Position Error (set with the SMPER command).	Gosub	Issue a DRIVE1 command to the axis that exceeded the allowable position error. Verify that feedback device is working properly.
14	GOWHEN condition was already true when the subsequent GO, GOL, FGADV, FSHFC, or FSHFD command was executed.	Goto	Issue another GOWHEN command; or issue a !K command and check the program logic (use the TRACE and STEP features if necessary).
16	Bad command was detected.	Gosub	Issue the TCMDER command to I.D. the command.
17	Encoder failure detected (EFAIL1 must be enabled before this error can be detected).	Gosub	Reconnect the encoder while the axis is in the EFAIL1 mode.
18	Cable to an expansion I/O brick is disconnected, or power to the I/O brick is lost.	Goto	Reconnect I/O brick cable. Issue the ERROR.18-0 command and then the ERROR.18-1 command.
23	Ethernet Client connection error. See the Ethernet Client section for additional details.	Gosub	
24	Ethernet Client polling error. See the Ethernet Client section for additional details.	Gosub	

Reserved Bits: Bits 13, 15, 19-22 and 25-32.

Branching Types: If the error condition calls for a GOSUB, then after the ERRORP program is executed, program control returns to the point at which the error occurred. To prevent a return to the point at which the error occurred, use the HALT command to end program execution or use the GOTO command to go to a different program. If the error condition calls for a GOTO, there is no way to return to the point at which the error occurred.

Commanded Kill or Stop: When ERROR bit 5 is enabled (ERROR.5-1), a Stop (S or !S) or a Kill (K, !K or <ctrl>K) command will cause the controller to branch to the error program. Note, however, that this error condition does not set an error bit (ER), because there is no way to clear the error condition upon leaving the error program. Therefore, you should use the IF(ER=b00000000000000000000000000000000) statement in your error program to determine if the cause of the error was a commanded kill or stop (i.e., if no error bits are set).

If ESTOP (ENABLE input) also cuts power to drives: This note is for systems in which power to the drives (not the Gem6K) is cut if the ENABLE input is opened. If you enable ERROR bit #9: When the ENABLE input is opened (and power is cut to the drives), the ERRORP program is called. Because the drives have lost power, the Gem6K will detect drive faults, which in turn kills the ERRORP program. If the ENABLE input is still ungrounded, the ERRORP program will again be called and then killed because of the drive fault condition (causing an endless loop). The resolution is to place the @DRFEN0 command in the ERRORP program so that it can disable checking the drive fault input and thereby circumvent the endless loop of calling the ERRORP program. Be sure to later re-enable drive fault checking with @DRFEN1 after the ENABLE input is re-grounded.

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Error Program Set-up Example

The following is an example of how to set up an error program. This particular example is for handling the occurrence of a user fault.

Step 1 Create a program file (in Motion Planner's Editor module) to set up the error program:

```
; *********************************************************************
; * Assign the user fault input function to onboard trigger input 1. *
; * The purpose of the user fault input is to detect the occurrence  *
; * of a fault external to the Gem6K controller and the motor/drive. *
; * This input will generate an error condition.                     *
; *********************************************************************

INFNC1-F      ; Define onboard trigger input #1 as a user fault input

; *********************************************************************
; * Define a program to respond to the user fault (call the program  *
; * fault), and then assign that program as the error program. The   *
; * purpose of the fault program is to display a message to inform   *
; * the operator that the user fault input has been activated.       *
; *********************************************************************

DEL fault     ; Delete a program before defining it (a precaution)
DEF fault     ; Begin definition of program fault
IF(ER.7=b1)   ; Check if error bit 7 equals 1
              ; (which means the user fault input has been activated)
WRITE"FAULT INPUT\10\13"   ; Send the message FAULT INPUT
T3            ; Wait 3 seconds
NIF           ; End IF command
END           ; End definition of program fault
ERRORP fault  ; Assign the program called fault as the error program

; *********************************************************************
; * Enable the user fault error-checking bit by putting a "1" in     *
; * the seventh bit of the ERROR command.  After enabling this       *
; * error-checking bit, the controller will branch to the error      *
; * program whenever the user fault input is activated.              *
; *********************************************************************
ERROR0000001  ; Branch to error program upon user fault input (As an
              ; alternative to the ERROR0000001 command, you could also
              ; enable bit #7 by issuing the ERROR.7-1 command.)
```

Step 2 Save the program file in the Editor module. Then, using the Terminal module, download the program file to the Gem6K controller.

Step 3 Test the error handling:

1. While in the terminal emulator, enter these four commands:

```
L                     ; Loop command
WRITE"IN LOOP\10\13"  ; Display the message "IN LOOP"
T2                    ; Wait 2 seconds
LN                    ; End the loop ("IN LOOP" will be displayed
                      ; once every 2 seconds)
```

2. While the loop (`IN LOOP`) is executing in the terminal emulator, enter the `!INEN1` command. The `!INEN1` command disables input #1 and forces it on for testing purposes. This simulates the physical activation of input #1. (Since the error program is called continuously until the branch to the error program is canceled, the message `FAULT INPUT` will be repeatedly displayed once every 3 seconds.)

3. While the `FAULT INPUT` loop is executing in the terminal emulator, enter the `!INENE` command. The `!INENE` command re-enables input #1. The message `IN LOOP` will not be displayed again, because the user fault input error is a GOTO branch (not a GOSUB branch) to the error program.

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Non-Volatile Memory

The items listed below are automatically stored in the Gem6K product's non-volatile memory (battery-backed RAM). Cycling power or issuing a RESET command will not affect these settings.

- Power-up program (STARTP)
- Programs (defined with DEF & END)
- Compiled profiles and PLC programs (PCOMP). Compiled profiles and PLC programs are always saved in the Compiled portion of battery-backed RAM. However, compiled individual axis profiles (GOBUF profiles) are removed from Compiled memory if you run them with the PRUN command and later cycle power or reset the controller (you will have to re-compile them with the PCOMP command).
- Memory allocation (MEMORY)
- Axis type definition (AXSDEF)
- Variables: VAR, VARI, VARB, and VARS
- Scaling: SCALE, SCLA, SCLD, SCLV, SCLMAS
- Commanded direction polarity (CMDDIR)
- Encoder polarity (ENCPOL)
- Device address for RS-232 or RS-485 serial communication (ADDR)
- Baud rate for RS-232 or RS-485 serial communication (BAUD)
- Ethernet IP address (NTADDR
- Ethernet network mask (NTMASK)
- RP240 check and serial port functionality (DRPCHK)
- RP240 password (DPASS)
- Servo gain sets (SGSET)

A checksum is calculated for the non-volatile memory area each time you power up or reset your Gem6K controller. A bad checksum indicates that the user memory has been corrupted (possibly due to electrical noise) or has been cleared (due to a spent battery). The controller will clear all user memory when a bad checksum is calculated on power up or reset, and bit 22 will be set in the TSS command response.

System Performance

Several commands (listed below), when enabled, will slow command processing. This degradation in performance will not be noticeable for most applications. But for some, it may be necessary to disable one or all of these commands.

- SCALE (enable/disable scaling)
- INDUSE (enable/disable user status updates)
- INFNC (trigger and extended input functions; excluding functions "A" and "H")
- LIMFNC (limit input functions; excluding functions "A", "R", "S", and "T")
- OUTFNC (digital output functions; excluding function "A")
- ONCOND (enable/disable ON conditions)

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CHAPTER TWO

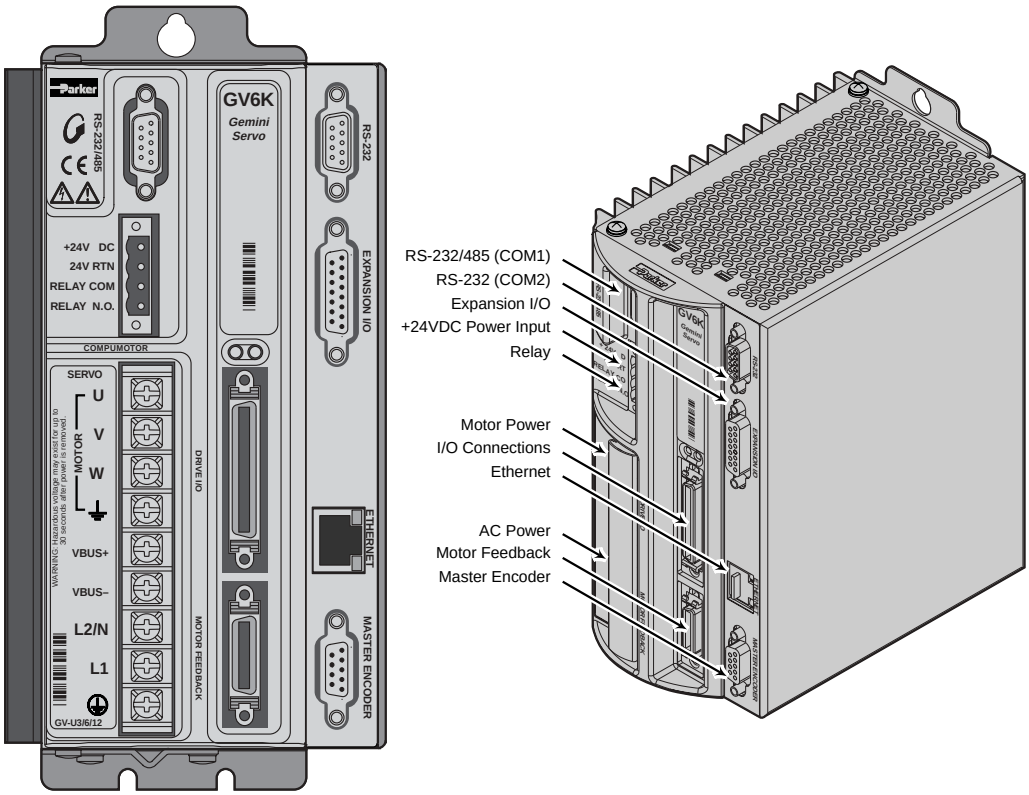
2 Communication

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Communication Options



COM1 Port (RS-232/485)	Set up for use as the primary RS-232 or RS-485 port. Configurable for the RP240 (requires external +5VDC supply)
COM2 Port (RS-232)	Set up for use as an additional RS-232 port. Configurable for the RP240. Operating system upgrades via this port only.
Ethernet Port	Refer to the configuration procedures that follow.
Using multiple ports	You can communicate to either the Ethernet port or COM1 at any given time. Enabling the Ethernet port (NTFEN1) will disable COM1. COM2 is always enabled for use as RS232 or with an RP240.

Motion Planner Communication Features

Motion Planner provides easy direct communication links to the product:

- Communicate directly from any Motion Planner utility (Wizard Editor, Program Editor, Terminal Emulator, and Panels).
- Communication setup parameters (Ethernet and serial communication).
- Download the Gem6K product's soft operating system. The operating system is loaded at the factory, but may use this feature to download upgrades.
- Download motion programs to the controller, and upload motion programs from the controller.

Communications Server: Also available on the Motion Planner CD is a 32-bit OLE automation server for adding Gem6K communication capability to your custom applications created with programming languages such as Visual Basic or Visual C++. For details, refer to the COM6SRVR Programmer's Guide or to the Motion Planner Help System.

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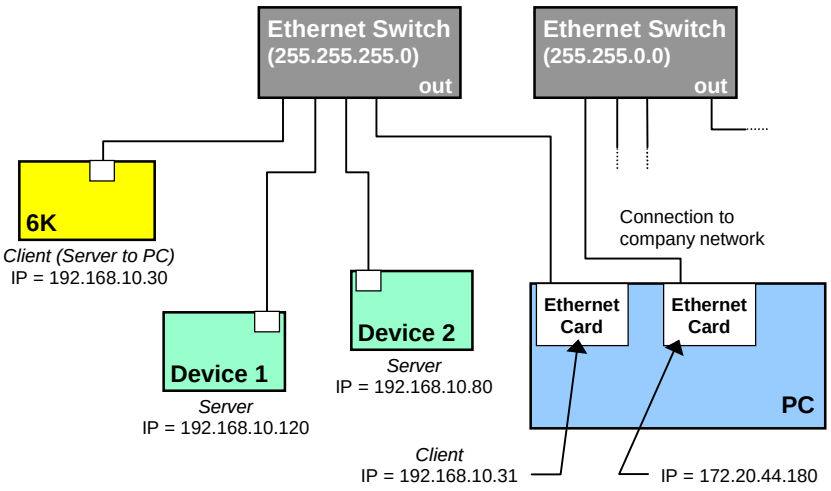
Overview

The Gem6K is equipped for Ethernet communication. It includes 10Base-T (10Mbps twisted pair); TCP/IP protocol. RJ-45 connector. Default IP address is 192.168.10.30. You have these options for networking the Gem6K over Ethernet:

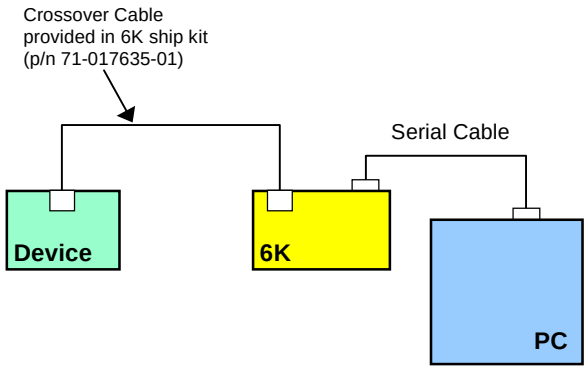
Setup Wizard Available
The Motion Planner Wizard Editor provides a setup wizard, called "Network", to help you establish 6K Client/Server communication (up to six servers).

- **Gem6K as a client**. You can connect the Gem6K via Ethernet to multiple devices, creating a client/server network. The Gem6K is the *client*, and has the ability to open or close a connection with another device (*server*) and request information from that device. The Gem6K supports up to 6 simultaneous server connections. Devices (servers) that may be connected to the Gem6K include:
  - Allen Bradley SLC5-05 PLC (see page 51 for setup procedures)
  - OPTO22 SNAP I/O, using Modbus/TCP protocol (see page 48 for setup procedures)
  - DVT vision system cameras (see page 50 for setup procedures)

EXAMPLE — Closed Network:



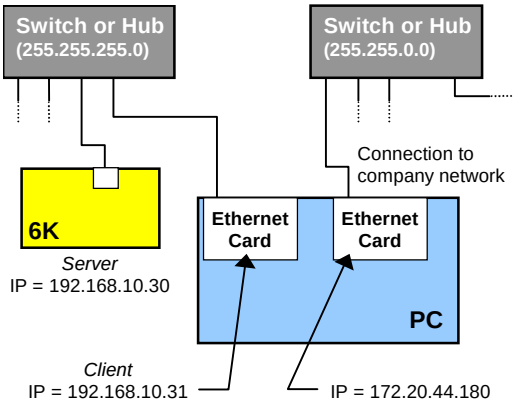
EXAMPLE — Direct Connect to One Server:



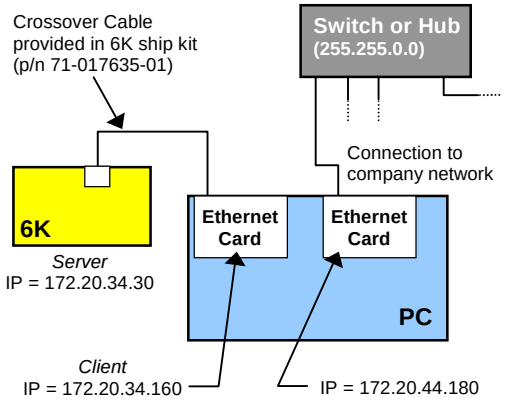
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- **Gem6K as a server**. The Gem6K waits for a PC to establish a connection with it and then provides information on a continual or requested basis. The PC communicates with the Gem6K through the use of the COM6SRVR Communications Server, which is what Motion Planner uses to communicate with the Gem6K (for details, refer to the *COM6SRVR Communications Server Programmer's Reference*—see www.compumotor.com for this document). The Gem6K does not support simultaneous connections with multiple clients (PCs).

  EXAMPLE — Closed Network:

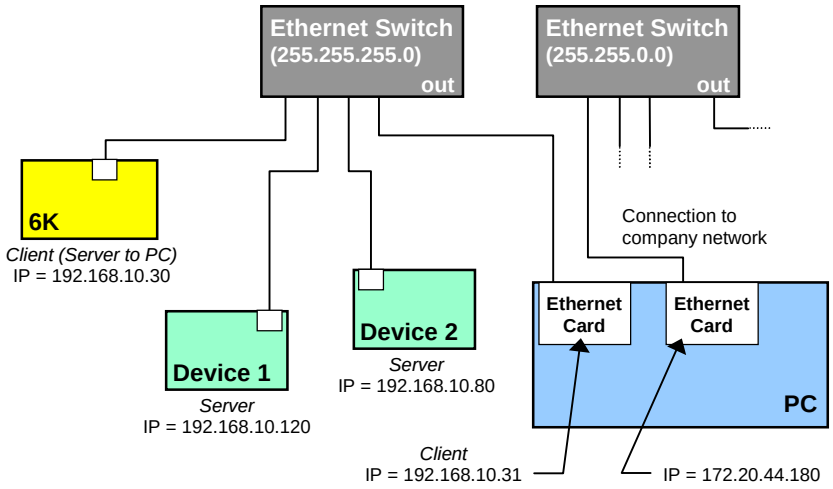


  EXAMPLE — Direct Connect to PC:



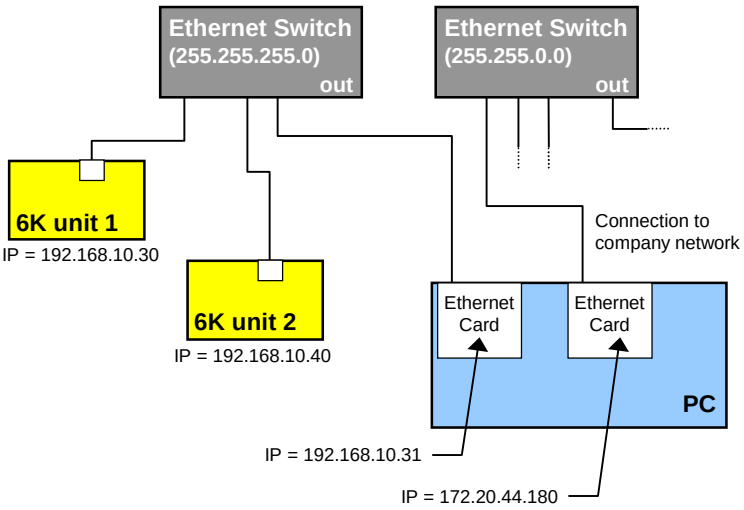
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- **Combination of server and client**. For example, the Gem6K could be the client for an OPTO22 (server) and an Allen-Bradley PLC (server). At the same time, a software program running on a PC could be using the Gem6K as a server.



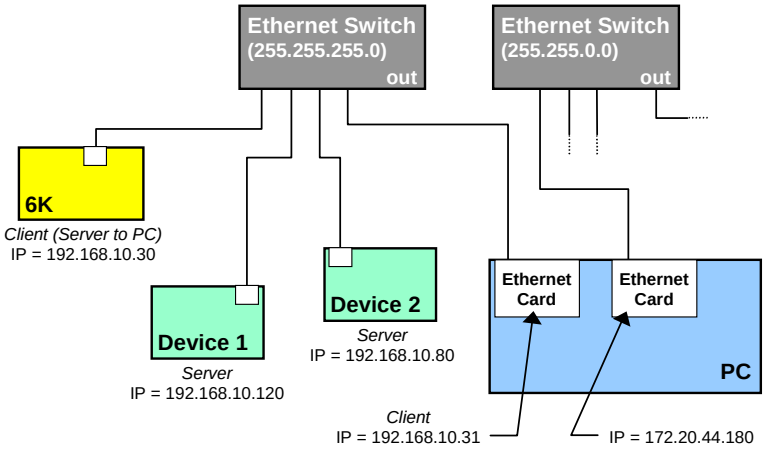
- **Peer-to-peer network with other 6K or Gem6K units**. The 6K may be connected to other 6K devices (6K Controllers or Gem6K drive/controllers) via Ethernet. Up to eight 6K devices may be networked in this manner. This type of connection uses *UDP broadcasting* and is not a client/server relationship. (see page 46 for setup procedures)

Setup Wizard Available
The Motion Planner Wizard Editor provides a setup wizard, called "Network", to help you establish 6K peer-to-peer communication.

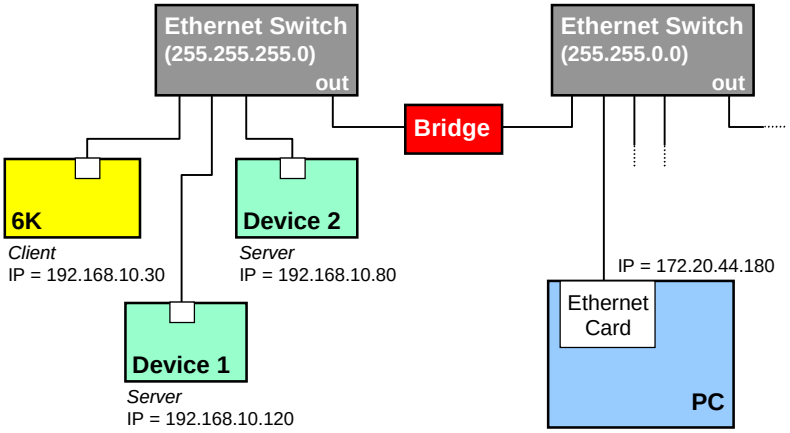


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- **Use a closed network.** Because of network broadcasts, it is best to put the Gem6K, along with any associated server devices, on a closed network with its own subnet. If you have a PC connected to the Ethernet Client/Server network and the PC is also connect to your company's network, use one Ethernet card for the Ethernet Client/Server network and another Ethernet card for the company network (refer to the example below) .



- If the Gem6K is placed on an open network, put the Gem6K and any associated server devices on one side of a Ethernet network switch with its own subnet and install a bridge to filter traffic, such that broadcast traffic does not pass in either direction (see diagram below). This will prevent the Gem6K from broadcasting to the entire network.

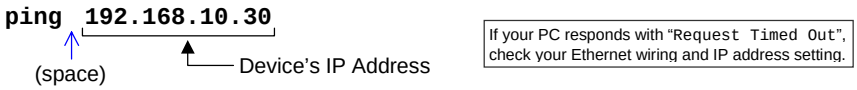


- A switch (recommended) or hub must be used if you are making more than one Ethernet connection with the Gem6K.
- The Gem6K client must have the same subnet address as all of the server devices it will connect to (PLC, OPTO22, DVT, etc.). For example, if the subnet mask (`NTMASK`) is 255.255.255.0, and the subnet address is 192.168.10.*, then all devices (including the Gem6K) must have an address starting with 192.168.10.*, where the * number is unique to the device.
- Fieldbus (DeviceNet or Profibus) versions of the Gem6K (part numbers Gem6Kn-DN or Gem6Kn-PB) cannot also communicate as an Ethernet Client at the same time. If you have a Fieldbus unit and need to use Ethernet instead, execute the `OPTENØ`

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command, then the RESET command (this disables the Fieldbus features), and then the NTFEN1 or NTFEN2 command. To re-enable Fieldbus communication, execute the NTFENØ command, then the RESET command (this disables Ethernet communication), and then the OPTEN1 command.

- You cannot communicate to the Gem6K with simultaneous transmissions over both the "ETHERNET" and "RS-232" (PORT1) connections.
- Follow the manufacturer's setup procedure for each Allen-Bradley PLC, DVT camera and OPTO22 Ethernet I/O rack.
- You should be able to ping every Gem6K, DVT camera, PLC and OPTO22 I/O rack from the PC. Use the **ping** command at the DOS prompt:



- The following Ethernet setup commands need only be sent once to the Gem6K, because they are saved in non-volatile memory and are remembered on power-up and RESET: NTID, NTIO, NTIP, NTMPRB, NTMPRI, NTMPWB, and NTMPWI.
- If a PC is connected to the Gem6K/Device Ethernet network, then the PC should include all devices in a static mapping table. The static mapping procedure, for the Gem6K's address, is found on page 44.
- If the Gem6K is in a peer-to-peer network, enable Ethernet communication with the NTFEN1 command (NTFEN2 mode is not compatible with peer-to-peer communication).

Configuring the Gem6K for Ethernet Communication

PC-to-Gem6K Communication over RS-232 Only

If your PC will be communicating to the Gem6K over RS-232 (not Ethernet), follow this procedure:

1. Connect the Gem6K controller to your network (refer to *Networking Guidelines* on page 42).
2. Establish an RS-232 communication link between the Gem6K and your computer (connect to the Gem6K's "RS-232" connector according to the instructions in the *Gem6K Installation Guide*).
3. Install Motion Planner on your computer, and launch Motion Planner. Click on the Terminal tab to view the terminal emulator.
4. In the Terminal window, click on the  button to view the Communications Settings dialog. Select the Port tab and select the COM port that is connected to the Gem6K's "RS-232" connector (see Step 2 above). Click OK.
5. In the Terminal window, enable Ethernet communication with the appropriate NTFEN command:
   a. If you are using the Gem6K as a server or client, type the NTFEN2 command and press ENTER, then type the RESET command and press ENTER.
   b. If you are using the 6K in a peer-to-peer connection with another 6K or Gem6K, type the NTFEN1 command and press ENTER, then type the RESET command and press ENTER.

PC-to-Gem6K Communication over Ethernet

If your PC will be communicating to the Gem6K over Ethernet, follow this procedure:

1. Connect the Gem6K controller to your network (refer to *Networking Guidelines* on page 42).

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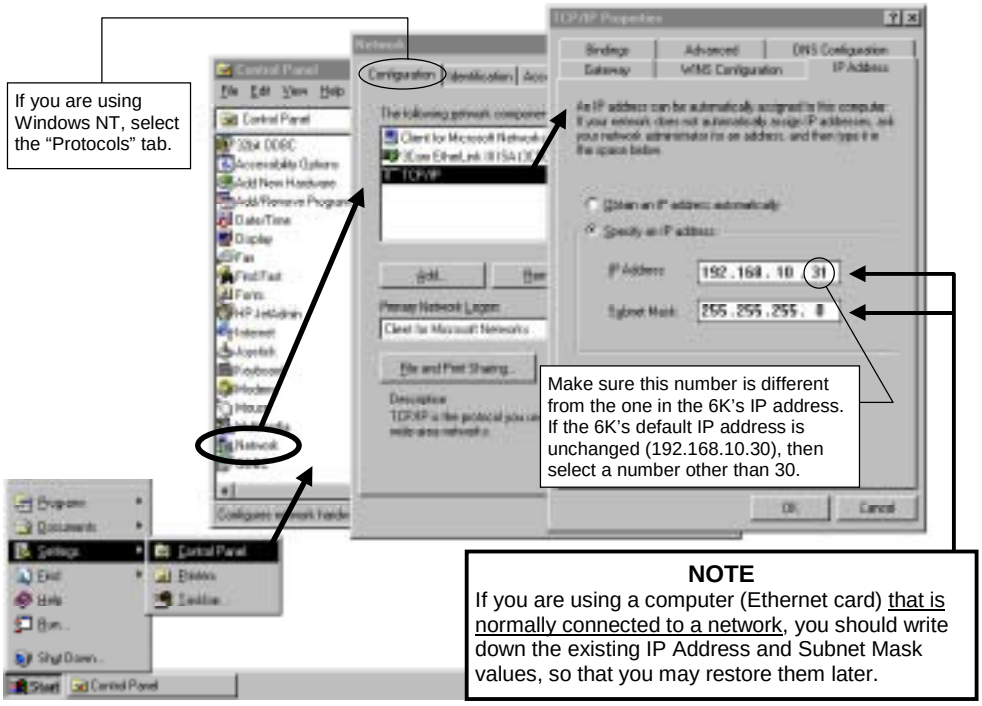
Changing the Gem6K's IP Address or Subnet Mask

The factory default Gem6K IP address is 192.168.10.30; the default mask is 255.255.255.0.

If the default address and mask are not compatible with your network, you may change them with the NTADDR and NTMASK commands, respectively (see *Gem6K Series Command Reference* for details on the NTADDR and NTMASK commands). To ascertain the Gem6K's Mac address, use the TNTMAC command. The NTADDR, NTMASK and TNTMAC commands may be sent to the 6K controller over an RS-232 interface (see Steps 4-6). **NOTE**: If you change the 6K's IP address or mask, the changes will not take affect until you cycle power or issue a RESET command.

2. Install your Ethernet card and configure it for TCP/IP protocol. Refer to your Ethernet card's user documentation for instructions. (If you need to change the 6K's IP address or subnet mask, refer to the note on the left.)

3. (**see illustration below**) Configure your Ethernet card's TCP/IP properties so that your computer can communicate with the 6K controller.
   a. Access the Control Panels directory.
   b. Open the Network control panel.
   c. In the Network control dialog, select the Configuration tab (95/98) or the Protocols tab (NT) and double-click the TCP/IP network item to view the TCP/IP Properties dialog.
   d. In the TCP/IP Properties dialog, select the IP Address tab, select "Specify an IP Address", type in 192.168.10.31 in the "IP Address" field, and type in 255.255.255.0 in the "Subnet Mask" field.
   e. Click the OK buttons in both dialogs to finish setting up your computer's IP address.



3. Establish an RS-232 communication link between the Gem6K and your computer (connect to the Gem6K's "RS-232" connector according to the instructions in the *Gem6K Installation Guide*).

4. Install Motion Planner on your computer, and launch Motion Planner. Click on the Terminal tab to view the terminal emulator.

5. In the Terminal window, click on the button to view the Communications Settings dialog. Select the Port tab and select the COM port that is connected to the Gem6K's "RS-232" connector (see Step 4 above). Click OK.

6. In the Terminal window, enable Ethernet communication with the appropriate NTFEN command:
   a. If you are using the Gem6K as a server or client, type the NTFEN2 command and press ENTER, then type the RESET command and press ENTER.
   b. If you are using the 6K in a peer-to-peer connection with another 6K or Gem6K, type the NTFEN1 command and press ENTER, then type the RESET command and press ENTER.

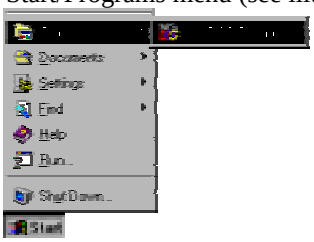
7. Use the following sub-procedure to statically map the Gem6K's Ethernet MAC address to IP address of the Ethernet card in your PC. Static mapping eliminates the need for the PC

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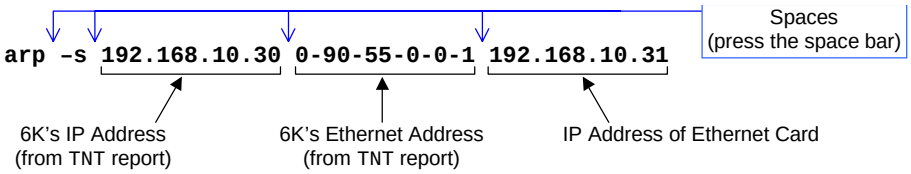
to ARP the Gem6K controller, thereby reducing communication overhead.

a. In Motion Planner's Terminal window, type `TNT` and press ENTER. The response includes the Gem6K IP address, and the Gem6K Ethernet address value in hex (this is also known as the "MAC" address). Write down the IP address and the Ethernet address (hex value) for later use in the procedure below.

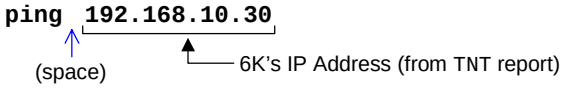
b. Start a DOS window. The typical method to start a DOS window is to select MS-DOS Prompt from the Start/Programs menu (see illustration below).



c. At the DOS prompt, type the **`arp -s`** command (see example below) and press ENTER.



d. To verify the mapped addresses, type the **`arp -a`** command and press ENTER.

> If you receive the response "`No ARP Entries Found`":
>
> 1) Switch to the Motion Planner Terminal window, type `NTFEN2` (or `NTFEN1` if using a peer-to-peer network) and press ENTER, then type `RESET` and press ENTER.
>
> 2) Switch to the DOS window, type the **`ping`** command and press ENTER:
>
> 
>
>
> If your PC responds with "`Request Timed Out`", check your Ethernet wiring and IP address setting.
>
> 3) Repeat the **`arp -s`** command as instructed above. Use **`arp -a`** to verify.
>
> 4) Switch to the Motion Planner Terminal window, type `NTFEN2` (or `NTFEN1` if using a peer-to-peer network) and press ENTER, then type `RESET` and press ENTER.

e. (OPTIONAL) Automate the **`arp -s`** static mapping command. *This allows your PC to automatically perform the static mapping when it is booted; otherwise, you will have to manually perform static mapping every time you boot your PC.*

- Windows 95/98: Add the **`arp -s`** command to the Autoexec.bat file.
- Windows NT: Create a batch file that contains the **`arp -s`** command. Save the file (name the file "GEM6KARP.BAT") to the root directory on the C drive. Using Windows Explorer, locate the Gem6KARP.BAT file, create a shortcut, then cut and paste the shortcut into the StartUp directory. Windows NT has several StartUp directories to accommodate various user configurations. We recommend using the Administrators or All Users locations. For example, you can paste the shortcut into the WinNt\Profiles\AllUsers\StartMenu\Programs\StartUp directory, allowing all users to statically map the IP and Mac addresses whenever the PC is booted.

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Ethernet Connection Status LEDs (located on the RJ-45 "ETHERNET" connector):
- Green LED turns on to indicate the Ethernet physical connection is OK.
- Yellow LED flashes to indicate the Gem6K is transmitting over the Ethernet interface.

f. Connect the Gem6K Controller to your computer using a cross-over 10Base-T cable (5-foot cable provided in ship kit).

g. In Motion Planner's Terminal window, click on the  button to view the Communications Settings dialog. Select the Port tab, select "Network" and type the IP address (192.168.10.30) in the text field. Click OK.

h. You may now communicate to the Gem6K controller over the Ethernet interface. Reminder: You cannot communicate to the Gem6K with simultaneous transmissions over both the "ETHERNET" and "RS-232" (PORT1) connections.

8. Connect the Gem6K Controller to your computer using a cross-over 10Base-T cable (5-foot cable provided in ship kit).

9. In Motion Planner's Terminal window, click on the  button to view the Communications Settings dialog. Select the Port tab, select "Network" and type the IP address (192.168.10.30) in the text field. Click OK.

10. You may now communicate to the Gem6K controller over the Ethernet interface. Reminder: You cannot communicate to the Gem6K with simultaneous transmissions over both the "ETHERNET" and "RS-232" (PORT1) connections.

Ethernet Connection Status LEDs (located on the RJ-45 "ETHERNET" connector):
- Green LED turns on to indicate the Ethernet physical connection is OK.
- Yellow LED flashes to indicate the Gem6K is transmitting over the Ethernet interface.

Networking with Other 6K or Gem6K Products (Peer-to-Peer)

This feature is used to communicate information between 6Ks and Gem6Ks over Ethernet. This is not a client or server; this feature uses UDP broadcasting over the subnet to transfer data, so no client/server connection is needed.

There can be up to 8 different 6K or Gem6K devices sharing information, with each device having access to each shared data from the 7 other device. Each device can broadcast 8 pieces of information by way of "shared output" variables (VARSHO1 through VARSHO8). These variables can share with other devices the values of its motion attributes, controller status, variables, etc. (see list below).

A.....Acceleration
AD.....Deceleration
ANI .....Analog input voltage
ANO .....Analog output voltage
AS.....Axis status
ASX .....Extended axis status
D.....Distance
DAC .....DAC output value
DKEY ...RP240 keypad value
ER.....Error status
FB.....Feedback device pos.
FS.....Following status
IN.....Input status
INO .....Enable input status
LIM .....Limit input status
MOV .....Axis moving status
NMCY... Master cycle number
OUT..... Output status
PANI... Analog input position
PC..... Commanded position
PCC..... Captured command pos.
PCE..... Captured encoder pos.
PCME... Captured master enc. pos.
PE..... Encoder position
PER..... Position error
PMAS... Position of Master
PME..... Master encoder pos.
PSHF... Net position shift
PSLV... Follower pos. command
SC..... Controller status
SCAN... PLC scan time
SEG..... Free segment buffers
SS.....System status
SWAP.....Task swap assignment
TASK.....Task number
TIM.....Timer value
TRIG.....Trigger interrupt status
US.....User-defined status
V.....Velocity
VARI.....Integer variable
VARB.....Binary variable
VEL.....Commanded velocity
VELA.....Actual velocity
VMAS.....Velocity of the master
VARSHI .Shared input variable

The type of data can be either binary, as in the AS (axis status) operand, or a 32-bit unscaled integer, as in PE (encoder position) operand. The data stored in the VARSHO is not scaled.

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Each unit will re-broadcast its updated VARSHO data at a rate set with the NTRATE command. RECOMMENDATION: Set all devices to broadcast at the same NTRATE rate of 50 milliseconds.

Setup

For 6K or Gem6K sending and/or receiving information via the Peer to Peer feature:

1. Connect the 6K/Gem6K products to the network and configure each 6K/Gem6K for Ethernet communication according to the procedures on page 43.
2. Set the broadcasting rate with NTRATE command, preferably the same for each unit.
3. If the unit is to receive data only (not send) you are finished with the setup for that unit. If the unit is to send also, complete steps 4 and 5.
4. Assign a unique unit number (1-8) with the NTID command.
5. Assign data to the eight broadcast variables with the VARSHO command.
6. Repeat steps 2-5 for each unit in the peer-to-peer network.

Example

First 6K or Gem6K:

```
NTID1           ; Assign this unit a peer-to-peer unit number of 1
VARSHO1 = 1A    ; Shared variable #1 contains axis 1's acceleration
VARSHO2 = 1PE   ; Shared variable #2 contains axis 1's encoder
                ;position
; ***************************************************************
; * Use this space to define shared output variables VARSHO3 – ;VARSHO7. *
; ***************************************************************
VARSHO8 = VARI1  ; Shared variable #8 contains the value of VARI1
NTRATE50         ; Set the broadcasting rate to 50 milliseconds
```

Second 6K or Gem6K:

```
NTID2           ; Assign this unit an ID of 2
VARSHO1 = 1D    ; Shared variable #1 contains axis 1's programmed
                ;distance
VARSHO2 = 3PE   ; Shared variable #2 contains axis 3's encoder
                position
; ***************************************************************
; * Use this space to define shared output variables VARSHO3 – VARSHO7. *
; ***************************************************************
VARSHO8 = 1ANI.1  ; Shared variable #8 contains the voltage value at
                ;analog
                ; input 1 on I/O brick 1
NTRATE50        ; Set the broadcasting rate to 50 milliseconds
```

Third 6K or Gem6K:

```
NTRATE50        ; Set the broadcasting rate to 50 milliseconds
; This third unit will receive data only. Therefore, it does not
;require
; a unit ID number or VARSHO data assignment
```


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Program Interaction

Each Unit can read the broadcast variables of each other unit with the nVARSHIi command. The "n" specifies the ID number (NTID) of the unit you want to read from, the "i" is the VARSHO number of that unit to be read. For example, if you want unit 1 to read unit 2's VARSHO8 data, then use 2VARSHI8.

Using the VARSHI command, you can process data from the VARSHO variable of another peer-to-peer unit in these ways:

- Assign the VARSHO data to a VAR (numeric), VARI (integer), or VARB (binary) variable. For example, the command VARI1=2VARSHI8 assigns the value of VARSHO8 on unit 2 to the VARI1 integer variable.
- Assign the VARSHO data to a virtual input (IN). For example, 3IN=2VARSHI3 assigns the binary value of VARSHO3 from unit 2 to virtual input brick 3.
- Use the VARSHO data in a conditional expression for an IF, WAIT, WHILE, or UNTIL statement. For example, if VARSHO5 on unit 2 is assigned is assigned the status of onboard trigger input 3 (VARSHO5=IN.3), then you could use this command to make unit 1 wait until trigger input 3 on unit 2 was on: WAIT(2VARSHI5=b1).

Example

First 6K or Gem6K (unit 1):

```
VARI1 = 2VARSHI8; Assign Unit 2's VARSHO8 (which is the voltage
             ; value at analog input 1 on I/O brick 1) to VARI1.
```

Second 6K or Gem6K (unit 2):

```
VARI100 = 1VARSHI2; Assign Unit 1's VARSHO2 (which is the encoder
             ;position of axis 1) to VARI100.
```

Third 6K or Gem6K (reading data only):

```
VARI90 = 1VARSHI1; Assign Unit 1's VARSHO1 (which is the
             ;acceleration of axis 1) to VARI90.
```

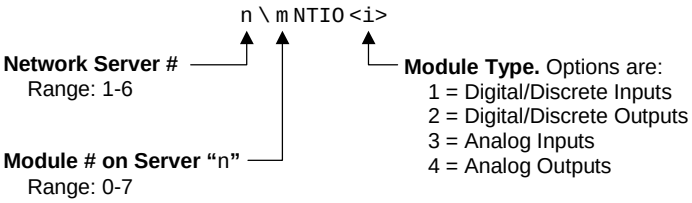
Networking with OPTO22 SNAP I/O

The Gem6K client can communicate with the OPTO22 SNAP I/O server to read digital and analog inputs and outputs, and write digital and analog outputs. The Gem6K supports up to eight modules per OPTO22.

Setup

1. Follow the manufacturer's setup procedure for the OPTO22 Ethernet I/O rack.
2. Connect the Gem6K and OPTO22 products in a network and configure the Gem6K for Ethernet communication according to the procedures on page 43.
3. Choose a Server Connection Number for this device. The Gem6K can support up to 6 simultaneous server connections. Pick a number (1-6) that has not been used already for another connection. This will be used to reference the OPTO22 unit from now on.
4. Enter the IP address of the OPTO22 and specify a 2 for connection type with the NTIP command. For example, if the OPTO22 is Server #3 and its IP address is 172.20.34.170, then the command would be 3NTIP2,172,20,34,170.
5. Attempt a connection to the device with NTCONN. For example, if the server number is 3, the command would be 3NTCONN1. If the connection is successful, Network Status bit #1 is set (see NTS, TNTS, TNTSF). If the connection is unsuccessful, Error Status bit #23 is set (see ER, TER, TERF).
6. Inform the Gem6K of the configuration of the OPTO22. For each module position, use the NTIO command to specify the type of module in that position.

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For example, if there is a digital input module in slot 0, then the command would be `3\0NTIO1`. If there is an Analog Input module in slot 7, then the command would be `3\7NTIO3`.

7. Set the polling rate with the `NTPOLL` command. 50 milliseconds is recommended. For example, to set the polling rate to 50 ms on server #3, use the `3NTPOLL50` command. If there is an error during polling, then Error Status bit #24 will be set.

Example

```
NTADDR172,34,54,123 ; Set the IP address of the Gem6K
OPTEN0              ; Disable the option card (for Fieldbus units only)
RESET
NTFEN2              ; Enable network function on Gem6K
RESET

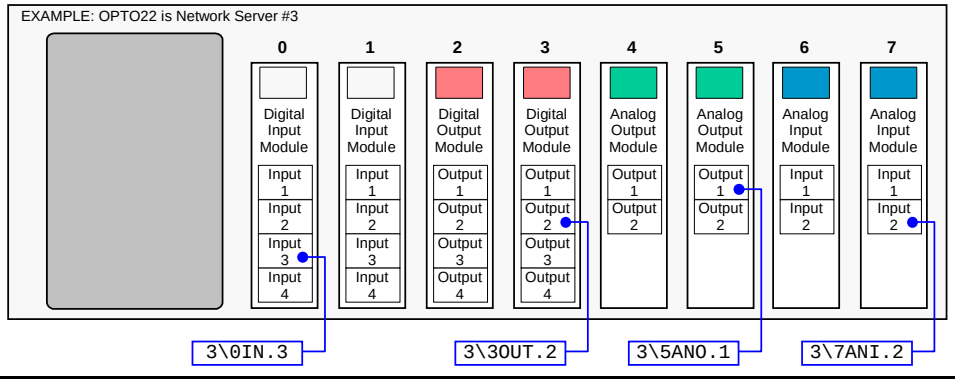
DEL OPTOSU
DEF OPTOSU
2NTIP2,172,34,54,124; Identify an OPTO22 device as Server #2, which is
                    ; located at IP address 172.34.54.124
2NTCONN1            ; Attempt connection to Server #2 (OPTO22)
2\1NTIO2            ; Configure OPTO22 module 1 as digital output
2\2NTIO2            ; Configure OPTO22 module 2 as digital output
2\3NTIO1            ; Configure OPTO22 module 3 as digital input
2\4NTIO3            ; Configure OPTO22 module 4 as analog input
2NTPOLL50           ; Begin polling, set polling interval to 50 ms
END
```

Program Interaction

Once the OPTO22 is configured and a connection is made, you can then set outputs and check inputs.

How the Gem6K addresses OPTO22 I/O locations:

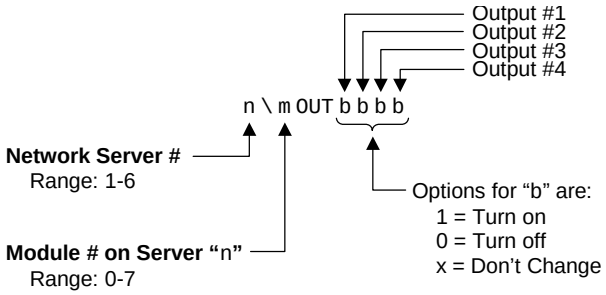
The Gem6K addresses each I/O bit by its location on a specific module. (NOTE: I/O points are not addressed by an absolute 32-bit location on the OPTO22.) Digital input and output modules have four I/O points, or channels, and are numbered 1-4. Analog input and output modules have two I/O points, or channels, and are numbered 1-2.



- To verify the I/O configuration (as per `NTIO`) and to check the status of each module's inputs and outputs, type `n\TIO`, where "`n`" is the server number.
- To set a digital output, type `n\mOUT.i-b`, where "`n`" is the server number, "`m`" is the

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module number, "i" is the point number on that module and "b" is the state (1 = on, 0 = off). To set multiple digital outputs on the same module, type n\mOUTbbbb:



For example (Server #3), to turn on outputs #1 and #4 and leave outputs #2 and #3 unchanged on module #2, type 3\2OUT1XX1. To turn off only output #4, type 3\2OUT.4-0.

- To set an analog output voltage, type n\mANO.i-r, where "n" is the server number, "m" is the module number, "i" is the output number on that module and "r" is the voltage. For example, to set analog output #1 on module #5 of Server #3 to 6.4V, type 3\5ANO.1=6.4.
- To read a digital input or output module, use the assignment/comparison operands (n\mIN or n\mOUT) or the transfer commands (n\mTIN or n\mTOUT). Examples are:
  - IF(3\0IN=b1100) is an IF condition that reads all four digital inputs on module #0.
    IF(3\0IN.2=b1) is an IF condition that reads only digital input #2 on module #0.
  - IF(3\2OUT=b1100) is an IF condition that reads all four outputs on module #2.
    IF(3\2OUT.3=b1) is an IF condition that reads only digital output #3 on module #2.
  - 3\0TIN transfers the binary status of all four digital inputs on module #0.
    3\0TIN.2 transfers the binary status of only digital input #2 on module #0.
  - 3\2TOUT transfers the binary status of all four digital outputs on module #2.
    3\2TOUT.3 transfers the binary status of only digital output #3 on module #2.
- To read an analog input or output module, use the assignment/comparison operands (n\mANI or n\mANO) or the transfer commands (n\mTANI or n\mTANO). Examples are:
  - WAIT(3\7ANI.2<2.4) is an WAIT condition that reads analog input #2 on module #7.
  - IF(3\5ANO.1>=1.0) is an IF condition that reads analog output #1 on module #5.
  - 3\6TANI transfers the voltage status of both analog inputs on module #6.
    3\6TANI.2 transfers the voltage status of only analog input #2 on module #6.
  - 3\4TANO transfers the voltage status of both analog outputs on module #4.
    3\4TANO.1 transfers the voltage status of only analog output #1 on module #4.

Networking with a DVT Vision System

The DVT client can send trigger commands to the camera. The camera should send back ASCII strings of the form VARn = 123.456, VARm = 234.567. The strings will be VAR assignments delineated by commas. These values will then be written to the Gem6K's VARs. This data can represent anything, such as an x-y coordinate.

Setup

1. Follow the manufacturer's setup procedure for the DVT camera.
2. Connect the Gem6K and DVT camera in a network and configure the Gem6K for Ethernet communication according to the procedures on page 43.
3. Choose a Server Connection Number for this device. The Gem6K can support up to 6 simultaneous client connections. Pick a number (1-6) that has not been used already for another server connection. This will be used to reference the device from now on.
4. Enter the IP address of the camera and specify a 3 for connection type with the NTIP command. For example, if the DVT camera is Server #6 and its IP address is

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172.20.34.150, then the command would be `6NTIP3,172,20,34,150`.

5. Attempt a connection to the device with `NTCONN`. For example, if the server number is 6, the command would be `6NTCONN1`. If the connection is successful, Network Status bit #1 is set (see `NTS`, `TNTS`, `TNTSF`). If the connection is unsuccessful, Error Status bit #23 is set (see `ER`, `TER`, `TERF`).

Example

```
6NTIP3,172,34,54,150  ; Identify a DVT camera as Server #6, located at
                      ; IP address 172.34.54.150.
6NTCONN1              ; Attempt the connection to Server #6
```

Program Interaction

Once a connection has been established, you can write trigger commands to the camera using the `NTWRIT` command.

Example

```
DEL DVT
DEF DVT
6NTCONN1              ; Attempt connection to DVT camera
6NTWRIT"DVT commands" ; Write the text "DVT commands" to camera
END
```

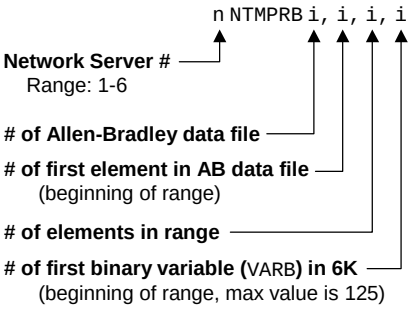
Networking with an Allen-Bradley SLC 5/05 PLC

The Allen-Bradley SLC 5/05 exchanges integer and binary data with the Gem6K. The data exchange is accomplished by mapping integer variables (`VARI`) and binary variables (`VARB`) in the Gem6K with data elements in the PLC's integer and binary data files. The Gem6K limits the amount of variable mapping to 100 binary variables (50 write, 50 read) and 100 integer variables (50 write, 50 read).

Setup

1. Follow the manufacturer's setup procedure for each Allen-Bradley PLC, DVT camera and OPTO22 Ethernet I/O rack.
2. Connect the Gem6K and Allen-Bradley PLC in a network and configure the Gem6K for Ethernet communication according to the procedures on page 43.
3. Choose a connection number for this device. The Gem6K can support up to 6 simultaneous client connections. Pick a number (1-6) that has not been used already for another client connection. This will be used to reference the device from now on.
4. Enter the IP address of the PLC and specify a 1 for connection type with the `NTIP` command. For example, if the PLC is Server #5 and its IP address is 172.20.34.124, then the command would be `3NTIP1,172,20,34,124`.
5. Attempt a connection to the device with `NTCONN`. For example, if the server number is 5, the command would be `5NTCONN1`. If the connection is successful, Network Status bit #1 is set (see `NTS`, `TNTS`, `TNTSF`). If the connection is unsuccessful, Error Status bit #23 is set (see `ER`, `TER`, `TERF`).
6. Map the required integer and binary variables between the Gem6K and the data files in the Allen-Bradley PLC. There are four mappings possible (a programming example is provided below).
   - Use the `NTMPRB` command to read up to 50 binary elements from a PLC's binary file and write them to `VARB` variables in the Gem6K.

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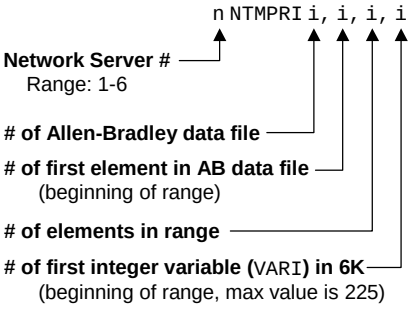
EXAMPLE:

IF:

- Allen-Bradley PLC is server #5
- The PLC's binary data file 3 has 30 elements. Use data elements 15-29 (15 elements total) for binary data that is to be shared with the 6K.
- Use the 6K's binary variables 35-49 (15 variables total) to store the data from the PLC.

The required mapping command is:
`5NTMPRB3,15,15,35`

- Use the `NTMPRI` command to read up to 50 integers elements from a PLC's Integer file and write them to `VARI` variables in the Gem6K.



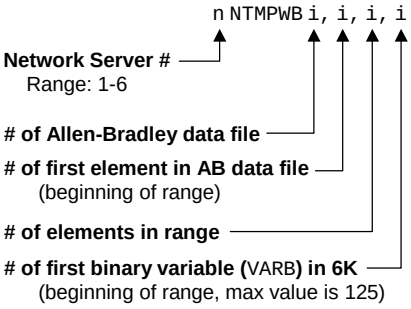
EXAMPLE:

IF:

- Allen-Bradley PLC is server #5
- The PLC's integer data file 9 has 30 elements. Use data elements 15-29 (15 elements total) for integer data that is to be shared with the 6K.
- Use the 6K's integer variables 35-49 (15 variables total) to store the data from the PLC.

The required mapping command is:
`5NTMPRI9,15,15,35`

- Use the `NTMPWB` command to write up to 50 binary values from `VARB` variables in the Gem6K to binary elements in a PLC's binary file.



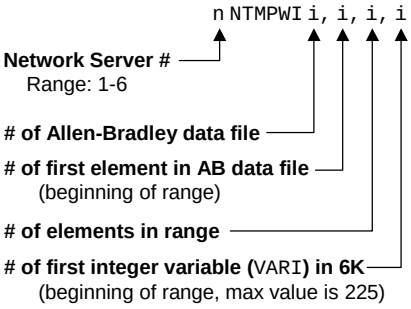
EXAMPLE:

IF:

- Allen-Bradley PLC is server #5
- In the PLC's binary data file 3, use data elements 0-14 (15 elements total) for binary data that is to be transmitted from the 6K.
- Use the 6K's binary variables 20-34 (15 variables total) to store the data to be transmitted to the PLC.

The required mapping command is:
`5NTMPWB3,0,15,20`

- Use the `NTMPWI` command to write up to 50 integers values from `VARI` variables in the Gem6K to a integer elements in a PLC's integer file.



EXAMPLE:

IF:

- Allen-Bradley PLC is server #5
- The PLC's integer data file 9 has 30 elements. Use data elements 0-14 (15 elements total) for integer data to be transmitted from the 6K.
- Use the 6K's integer variables 20-34 (15 variables total) to store the data to be transmitted to the PLC.

The required mapping command is:
`5NTMPWI9,0,15,20`

7. Set the polling rate with the `NTPOLL` command. 50 milliseconds is recommended. For example, to set the polling rate to 50 ms on Server #5, use the `5NTPOLL50` command. If there is an error during polling, Error Status bit #24 will be set (see `ER`, `TER` or `TERF`).

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Example

```
NTADDR172,34,54,123  ; Set the IP address of the Gem6K
OPTEN0               ; Disable the option card (for Fieldbus units
                       only)
RESET
NTFEN2               ; Enable network function on Gem6K
RESET
5NTIP1,172,34,54,124 ; Identify network server #5 as an Allen Bradley
                       PLC
                     ; at IP address 172.34.54.124
5NTCONN1             ; Connect to network server #5
5NTMPRB11,7,1,106    ; File 11, element 7 in the AB PLC is mapped to
                       the Gem6K's
                     ; binary variable VARB106
5NTMPRI20,5,2,128    ; File 20, elements 5-6 in the AB PLC are mapped
                       to
                     ; the Gem6K's integer variables VARI128-VARI129,
                       respectively
5NTMPWB11,3,4,100    ; File 11, elements 3-6, in the AB PLC are
                       mapped to
                     ; the Gem6K's binary variables VARB100-VARB103
5NTMPWI20,3,2,120    ; File 20, elements 3-4, in the AB PLC are
                       mapped to
                     ; the Gem6K's integer variables VARI120-VARB121
5NTPOLL50            ; Start polling network server #5, set interval
                       to 50 ms.
   ;
                       ****************************************
                       ***********************
   ; The Gem6K's VARB106 will read from the PLC's File 11, element 7.
   ; The Gem6K's VARI128-VARI129 will read from the PLC's File 20,
                       elements 5-6.
   ; The PLC's File 11, elements 3-6 will read from the Gem6K's
                       VARB100-VARB103.
   ; The PLC's File 20, elements 3-4 will read from the Gem6K's
                       VARI120-VARB121.
   ;
                       ****************************************
                       ***********************
```

Program Interaction

After the connection is established, mapping has been set up, and polling enabled, the Gem6K starts exchanging data automatically with the PLC. Here is how to:

- Write a binary variable to the PLC: Simply write a value to one of the `VARB` variables in the `NTMPWB` mapping. The new data will be written to the binary file during the next poll.
- Write an integer variable to the PLC: Simply write a value to one of the `VARI` variables in the `NTMPWI` mapping. The new data will be written to the integer file during the next poll.
- Read a binary variable from the PLC: The `VARB` variables in the `NTMPRB` mapping correspond to the values in the binary file in the PLC.
- Read an integer variable from the PLC: The `VARI` variables in the `NTMPRI` mapping correspond to the values in the integer file in the PLC.

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Example

```
VARB100 = HAB79          ; Element 3 in file 10 of the AB PLC will be
                         equal to VARB100
if(VARB106 = B1111111111111111)    ; VARB106 will be equal to
                         variable 7 in
                                   ; file 10 of the AB PLC
if(VARI129 = 17)         ; Element 6 in file 20 of the AB PLC will be
                         equal to VARI129
VARI121 = 17             ; Element 4 in file 20 of the AB PLC will be
                         equal to VARI121
```

Error Conditions

Error Messages

The 6K will transmit error message to alert you of certain error conditions. Below is a list of the error messages related to Ethernet networking.

Error Response	Possible Cause
CONNECTION COULD NOT BE CLOSED OR ALREADY CLOSED	Tried to close the network server connection (nNTCONNØ) when the connection was already closed.
CONNECTION COULD NOT BE OPENED	Tried NTCONN1 and failed. Problem could be invalid IP address or it refused a connection.
CONNECTION ERROR, CONNECTION IS NOW BEING CLOSED	Connection error or timeout with server. When polling and get timeout or message aborted. This condition also sets Error Status bit #23 (see ER, TER, TERF).
CONNECTION IS NOT OPEN	Tried a NTWRIT when connection is not open; or tried a \TANI or \TANO or \TIN or \TOUT or \TIO when connection is not open.
CONNECTION IS OPEN - MUST CLOSE FIRST	Tried to open a network server connection (nNTCONN1) when the connection was already open.
ERROR, INVALID FILE TYPE, NUMBER OR SIZE. SETTING NTMP COMMANDS TO 0 ELEMENTS. CHECK MAPPING.	Tried to read the wrong Allen-Bradley PLC file type, there are not enough elements in the file, or the file doesn't exist. The 6K automatically stop polling all mapped binary and integer variables (equivalent to executing the NTMPRBi,i,0,i, NTMPWBi,i,0,i, NTMPRIi,i,0,i, and NTMPWIi,i,0,i, commands).
ERROR, INVALID STRING	The DVT camera sent an invalid string response.
ETHERNET CAN NOT BE USED WITH OPTION CARD - SEE OPTEN	Tried to enable Ethernet communication (NTFEN) on a Fieldbus version of the 6K (part number is 6Kn-PB for PROFIBUS units, 6Kn-DN for DeviceNet units). You must disable the internal option card with OPTENØ before enabling Ethernet communication. The 6K cannot communicate over a Fieldbus connection and Ethernet connection simultaneously.
ETHERNET COMMUNICATION MUST BE ENABLED BEFORE MAKING CONNECTION - SEE NTFEN	Tried to connect to an Ethernet server (nNTCONN1) before you enabled Ethernet communication in the 6K with the NTFEN command.
INVALID CONNECTION NUMBER	Tried to make an NTS assignment or comparison using an invalid server number (e.g., VARB1 = 7NTS).Tried to address an Ethernet command to a server connection number outside of the range 1-6. What's the difference between this and the "INVALID SERVER TYPE" error?
INVALID I/O POINT	Tried to read or write an OPTO22 I/O point that is not configured according to the NTIO command.
INVALID POINT TYPE OR NUMBER,	Tried to set or read an I/O point (with an \IN, \OUT, \ANI,

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Error Response	Possible Cause
SEE NTIO	\ANO, \TANI, \TANO, \TIN, or \TOUT command), but that I/O point was configured with the NTIO command to be different I/O type.
INVALID SERVER TYPE	Tried an OPTO22-related command (\TANI, \TANO, \TIN, \TOUT, \TIO, \IN, \OUT, \ANI, \ANO, etc.) for a non-OPTO22 connection.
NETWORK INPUTS AND OUTPUTS CANNOT BE ASSIGNED TO A VARSHO	Tried to assign the status of OPTO22 I/O to a VARSHO variable.
NETWORK IP ADDRESS CANNOT BE CHANGED WHILE CONNECTION IS OPEN, SEE NTCONN	Tried to execute an NTIP command while the connection is open.
NO NETWORK IP ADDRESS SPECIFIED FOR CONNECTION, SEE NTIP	Tried to connect (nNTCONN1) to a server # that has not yet been established with the NTIP command, or tried to connect to a server in an incompatible subnet.
NTFEN MUST BE 1 TO USE THIS COMMAND	(Peer-to-peer connection only) Tried to execute an NTRATE command while NTFEN is set to a value other than NTFEN1.
NTRATE MUST BE 0 TO CHANGE NTFEN	(Peer-to-peer connection only) Tried to execute an NTFEN command while NTRATE is set to a non-zero value.
NTSELP ALREADY ENABLED ON THIS TASK	NTSELP, which enables program selection via OPTO22 inputs, has already been enabled (if multitasking, it has been enabled for this specific Task).
OPTION CARD CAN NOT BE USED WITH ETHERNET - SEE NTFEN	Tried to enable the internal Fieldbus Option card for PROFIBUS or DeviceNet communication (6Kn-PB and 6Kn-DN products only) with the OPTEN1 command. You must disable Ethernet communications with the NTFENØ command before enabling the Option card. The 6K cannot communicate over a Fieldbus connection and Ethernet connection simultaneously.
VARB USED BY OPTION CARD	Tried to map a binary variable to read from or write to an Allen-Bradley data file, but the variable is already used for Fieldbus (PROFIBUS or DeviceNet) data transfer functions.
VARIABLE MAPPING CONFLICT, SEE NTMPRB, NTMPRI, NTMPWI, NTMPWB MAPPINGS	Tried to map the same 6K VARB or VARI variables for read and write functions. Or tried to map the same 6K VARB or VARI variables to another PLC.

Error Handling

The 6K has a Error Status register for logging certain error conditions. If you enable checking for an error condition (see ERROR command), the 6K will branch to the designated error program (see ERRORP command) when it detects the error condition. The Ethernet networking related Error Status register bits are noted below.

ERROR Bit #	Cause of the Error	Branch Type to ERRORP	How to Remedy the Error
23	Ethernet Client Connection Error. (Can't connect.)	Gosub	Clear the error bit (ERROR.23-0), re-establish the Ethernet connection (nNTCONN1), and then issue ERROR.23-1.
24	Ethernet Client Polling Error. (After connect and polling device for data, polling timeout occurred. Cause could be disconnect, client lost power, etc.)	Gosub	Clear the error bit (ERROR.24-0), re-establish the Ethernet connection (nNTCONN1), and then issue ERROR.24-1.

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In this section:

- Controlling Multiple Serial Ports
- RS-232 Daisy Chaining
- RS-485 Multi-Drop

Controlling Multiple Serial Ports

Every Gem6K Series product has two serial ports. The "**RS-232**" connector is referenced as the "COM2" serial port, and the "**RS-232/485**" connector is referenced as the "COM1" serial port.

XON/XOFF

The XONOFF command was created to enable or disable XON/XOFF ASCII handshaking. (XONOFF1 enables XON/XOFF, XONOFFØ disables XON/XOFF) Defaults: XONOFF1 for the COM1 port, XONOFF1 for the COM2 port.

Controllers on a multi-drop do not support XON/XOFF; to ensure that XON/XOFF is disabled for COM1, send the PORT1 command followed by the XONOFFØ command.

Configuring the COM Port

To control the applicable port for setting up serial communication and transmitting ASCII text strings, use the PORT command. PORT1 selects COM1 and PORT2 selects COM2.

- Serial communication setup commands (see list below) affect the COM port selected with the last PORT command. For example, to configure the COM1 port for Gem6K language commands only (e.g., to communicate to the Gem6K product over an RS-485 interface), execute the PORT1 command, then execute the DRPCHKØ command. (refer to the ***Gem6K Series Command Reference*** to details on each command)
  - DRPCHK..... RP240 Check
  - E..... Enable Serial Communication
  - ECHO..... Enable Communication Echo
  - BOT..... Beginning of Transmission Characters
  - BAUD..... Serial Communication Baud Rate
  - EOT..... End of Transmission Characters
  - EOL..... End of Line Terminating Characters
  - ERRBAD..... Error Prompt
  - ERRDEF..... Program Definition Prompt
  - ERRLVL..... Error Detection Level
  - ERRORK..... Good Prompt
  - XONOFF..... Enable or disable XON/XOFF

- The PORT command also selects the COM port through which the WRITE and READ commands transmit ASCII text strings. If an RP240 is connected, the DWRITE command (and all other RP240 commands) will affect the RP240 regardless of the PORT command setting. If no RP240 is detected, the commands are sent to the COM2 port. DWRITE text strings are always terminated with a carriage return.

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Setup for Gem6K Language or RP240

To configure the COM ports for use with Gem6K language commands or an RP240, use the DRPCHK command. The DRPCHK command affects the COM port selected with the last PORT command. The default for COM1 is DRPCHKØ; the default for COM2 is DRPCHKØ. The DRPCHK setting is automatically saved in non-volatile memory. NOTE: Only one COM port may be set to DRPCHK2 or DRPCHK3 at any given time.

DRPCHKØ..... Use the COM port for Gem6K language commands only. This is the default setting for COM1 and COM2, and if using RS-485 half duplex on COM1. Power-up messages appear on all ports set to DRPCHKØ.

DRPCHK1..... Check for the presence of an RP240 at power-up/reset. If an RP240 is present, initialize the RP240. If an RP240 is not present, use the port only for Gem6K language commands. NOTE: RP240 commands will be sent at power-up and reset.

DRPCHK2..... Check for the presence of an RP240 every 5-6 seconds. If an RP240 is plugged in, initialize the RP240.

DRPCHK3..... Check for the presence of an RP240 at power-up/reset. If an RP240 is present, the initialize the RP240. If an RP240 is not present, use the COM port for DWRITE commands only, and ignore received characters.

Selecting a Destination Port for Transmitting from the Controller

To define the port (COM port) through which the Gem6K product sends its responses, you have 3 options:

- Do nothing different. The response will be sent to the COM port through which the request was made. If the command is in a stored program, the report will be sent to the COM port selected by the most recent PORT command.
- Prefix the command with [. This causes the response to be sent to both COM ports. (e.g., the [TFS command response will be sent through both COM ports)
- Prefix the command with]. This causes the response to be sent to the alternative COM port. For example, if a report back (e.g.,]TAS) is requested from COM1, the response is sent through COM2. If the command is in a stored program, the report will be sent out the alternate port from the one selected by the most recent PORT command.

RS-232C Daisy-Chaining

Up to ninety-nine stand-alone Gem6K Series products may be daisy-chained. There are two methods of daisy-chaining: one uses a computer or terminal as the controller in the chain; the other uses one Gem6K product as the master controller. Refer to you product's *Installation Guide* for daisy-chain connections.

Follow these steps to implement daisy-chaining:

Step 1

To enable and disable communications on a particular controller unit in the chain, you must use the Daisy-Chain Address (ADDR) command to establish a unique device address for each the unit. The ADDR command automatically configures unit addresses for daisy chaining. This command allows up to 99 units on a daisy chain to be uniquely addressed.

Sending ADDRi to the first unit in the daisy chain sets its address to be (i). The first unit in turn transmits ADDR(i + 1) to the next unit to set its address to (i + 1). This continues down the daisy chain until the last unit of (n) daisy-chained units has its address set to (i + n).

Note that a controller with the default device address of zero (0) will send an initial power-up start message similar to the following:

```
*PARKER Gem6K MOTION CONTROLLER
*NO REMOTE PANEL
```

NOTE: For daisy chaining , you can use either PORT1 (COM1 RS232/484 connector), or PORT2 (COM1 RS 232 connector).

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Step 2

Connect the daisy-chain with a terminal as the master (see diagram in the product's *Installation Guide*).

It is necessary to have the error level set to 1 for all units on the daisy-chain (ERRLVL1). When the error level is not set to 1, the controller sends ERROK or ERRBAD prompts after each command, which makes daisy-chaining impossible. Send the ERRLVL1 command to each unit in the chain. (NOTE: To send a the ERRLVL1 command to one specific unit on the chain, prefix the command with the appropriate unit's device address and an underline.)

Commands PORT1 (or PORT2 if that port is being used):

```
0_ERRLVL1      ; set error level to Ø for unit #Ø
1_ERRLVL1      ; Set error level to 1 for unit #1
2_ERRLVL1      ; Set error level to 1 for unit #2
3_ERRLVL1      ; Set error level to 1 for unit #3
```

After this has been accomplished, a carriage return sent from the terminal will not cause any controller to send a prompt. Verify this. Instructions below (step 3) show how to set the error level to 1 automatically on power-up by using the controller's power-up start program (highly recommended).

After the error level for all units has been set to ERRLVL1, send a Gem6K series command to all units on the daisy-chain by entering that command from the master terminal.

Commands:

```
OUT1111        ; Turn on onboard outputs 1-4 on all units
A50            ; Set accel to 50 (all units)
```

To send a Gem6K series command to one particular unit on the chain, prefix the command with the appropriate unit's device address and an underline:

Commands:

```
2_OUT0         ; Turn off onboard output 1 on unit #2
4_OUT0         ; Turn off onboard output 1 on unit #4
```

To receive data from a particular controller on the chain, you **must** prefix the command with the appropriate unit's device address and an underline:

Commands:

```
1_A            ; Request acceleration information from unit #1
*A50           ; Response from unit #1
```

Use the E command to enable/disable RS-232C communications for an individual unit. If all Gem6K controller units on the daisy chain are enabled, commands without a device address identifier will be executed by all units. Because of the daisy-chain's serial nature, the commands will be executed approximately 1 ms per character later on each successive unit in the chain (assuming 9600 baud).

Units with the RS-232C disabled (EØ) will not respond to any commands, except E1; however, characters are still echoed to the next device in the daisy chain.

Commands:

```
3_E0           ; Disable RS-232C on unit #3
VAR1=1         ; Set variable #1 to 1 on all other units
3_E1           ; Enable RS-232C on unit #3
3_VAR1=5       ; Set variable #1 to 5 on unit #3
```

Verify communication to all units by using the techniques described above.

Step 3

Now that communication is established, programming of the units can begin (alternatively, units can be programmed individually by connecting the master terminal to one unit at a time). To allow daisy-chaining between multiple controllers, the ERRLVL1 command must be used to prevent units from sending error messages and command prompts. In every daisy-chained

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unit, the ERRLVL1 command should be placed in the program that is defined as the STARTP program:

```
Program:
DEF chain      ; Begin definition of program chain
ERRLVL1        ; Set error level to 1
GOTO main      ; Go to program main
END            ; End definition of program chain
STARTP chain   ; Designates program chain as the power-up program
```

To define program `main` for unit #0:

```
Program:
0_DEF main     ; Begin definition of program main on unit #0
0_GO           ; Start motion
0_END          ; End definition of program main on unit #0
```

Step 4

After all programming is completed, program execution may be controlled by either a master terminal, or by a Gem6K Series controller used as a master.

Daisy-Chaining from a Computer or Terminal

Controlling the daisy-chain from a master computer or terminal follows the examples above:

```
Commands:
0_RUN main     ; Run program main on unit #0
1_RUN main     ; Run program main on unit #1
2_GO1          ; Start motion on unit #2
3_A            ; Get A command response from unit #3
```

Daisy-Chaining from a Master Gem6K Controller

Controlling the daisy-chain from a master Gem6K controller (the first unit on the daisy-chain) requires the programs stored in the master controller to control program and command execution on the slave controllers. The example below demonstrates the use of the WRITE command to send commands to other units on the daisy chain.

NOTE

The last unit on the daisy-chain must have RS-232C echo disabled (ECHOØ command).

Master controller's `main` program:

```
Program:
DEF main                ; Program main
L                       ; Indefinite loop
 WHILE (IN.1 = b0)      ; Wait for input #1 to go active
 NWHILE
 GO                     ; Initiate move
 WHILE (IN.1 = b1)      ; Wait for input #1 to go inactive
 NWHILE
 WRITE"2_D2000"         ; Send message "2_D2000" down daisy chain
 WRITE"2_ACK"           ; Send message "2_ACK" down the daisy chain
LN                      ; End of loop
END                     ; End of program main
```

Controller unit #2 `ack` program:

```
Program:
DEF ack                 ; Program ack
GO1                     ; Start motion
END                     ; End of program ack
```


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Daisy-Chaining and RP240s

RP240s cannot be placed in the drive/controller daisy chain; RP240s can only be connected to the designated RP240 port on a drive/controller. It is possible to use only one RP240 with a drive/controller daisy-chain to input data for multiple units on the chain. The example below (for the drive/controller master with an RP240 connected) reads data from the RP240 into variables #1 (*data1*) & #2 (*data2*), then sends the messages `3_Ddata1,data2`<CR> and `3_GO`<CR>.

Sample portion of code:

```
L                       ; Indefinite loop
 VAR1=DREAD             ; Read RP240 data into variable #1
 VAR2=DREAD             ; Read RP240 data into variable #2
 EOT0,0,0,0             ; Turn off <CR>
 WRITE"3_D"             ; Send message "3_D" down the daisy chain
 WRVAR1                 ; Send variable #1 data down the daisy chain
 WRITE","               ; Send message "," down the daisy chain
 EOT13,0,0,0            ; Turn on <CR>
 WRVAR2                 ; Send variable #2 data down the daisy chain
 WRITE"3_GO"            ; Send message "3_GO" down the daisy chain
LN                      ; End of loop
```

RS-485 Multi-Drop

Up to 99 Gem6K Series products may be multi-dropped. Refer to your product's ***Installation Guide*** for multi-drop connections.

To establish device addresses, using the `ADDR` command:

The `ADDR` command allows you to establish up to 99 unique addresses. To use the `ADDR` command, you must address each unit individually before it is connected on the multi drop. For example, given that each product is shipped configured with address zero, you could set up a 4-unit multi-drop with the commands below, and then connect them in a multi drop:

1. Connect the unit that is to be unit #1 and transmit the `Ø_ADDR1` command to it.
2. Connect the unit that is to be unit #2 and transmit the `Ø_ADDR2` command to it.
3. Connect the unit that is to be unit #3 and transmit the `Ø_ADDR3` command to it.
4. Connect the unit that is to be unit #4 and transmit the `Ø_ADDR4` command to it.

If you need to replace a unit in the multi drop, send the `Ø_ADDRi` command to it, where "`i`" is the address you wish the new unit to have.

To send a Gem6K command from the master to a specific unit in the multi-drop, prefix the command with the unit address and an underscore (e.g., `3_OUTØ` turns off output #1 on unit #3). The master unit (if it is not a Gem6K product) may receive data from a multi-drop unit.

The `ECHO` command was enhanced with options 2 and 3. The purpose is to accommodate an RS-485 multi-drop configuration in which a host computer communicates to the “master” Gem6K controller over RS-232 (COM2 port) and the master Gem6K controller communicates over RS-485 (COM1 port) to the rest of the units on the multi-drop. For this configuration, the echo setup should be configured by sending to the master the following commands executed in the order shown. In this example, it is assumed that the master's device address is set to 1. Hence, each command is prefixed with “`1_`” to address only the master unit.

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1_PORT2..... Subsequent command affects COM1, the RS-485 port
1_ECHO2..... Echo characters back through the other port, COM2
1_PORT1..... Subsequent command affects COM2, the RS-232 port
1_ECHO3..... Echo characters back through both ports, COM1 and COM2

NOTES

Controllers on a multi-drop do not support XON/XOFF. To ensure that XON/XOFF is disabled for COM1, send the PORT1 command followed by the XONOFFØ command.

Only ECHOØ or ECHO2 can be used.

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CHAPTER THREE

3 Basic Operation Setup

IN THIS CHAPTER

This chapter will enable you to understand and implement these basic operation features:

- Before You Begin (setup programs, Motion Planner, resetting, etc.) 64
- Memory Allocation **(CAUTION:** Do not place in "setup" program**)** 65
- Drive Setup (fault level, resolution, disable drive on kill) 66
- Scaling 67
- Positioning Modes 71
- End-of-Travel Limits 74
- Homing 79
- Encoder-Based Stepper Operation (stepper axes only) 84
- Tuning Procedures (servos only) 85
- Target Zone Mode (servo axes only) 84
- Programmable Inputs and Outputs (incl. triggers and auxiliary outputs) 90
- Variable Arrays (*teaching variable data*) 110

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WARNING

The Gem6K Product is used to control your system's electrical and mechanical components. Therefore, you should test your system for safety under all potential conditions. Failure to do so can result in damage to equipment and/or serious injury to personnel.

Setup Parameters Discussed in this Chapter

Below is a list of the setup parameters discussed in this chapter. You can check the status of each parameter setting by entering the respective setup command without any command fields (e.g., typing LIMFNC <*cr*> displays the current function and state of each limit input). Some setup parameters are also reported with the TSTAT and TASF status commands (these and other status commands are described on page 222).

Setup Parameter	Command	See Pg.
Memory (status with TDIR & TMEM)	MEMORY	11 & 65
Drive Setup		66
Drive resolution (stepper only)	DRES	
Drive disable on kill	KDRIVE	
Drive stall detection	DSTALL	
Scaling		67
Enable scaling factor	SCALE	
Acceleration scaling factor	SCLA	
Distance scaling factor	SCLD	
Velocity scaling factor	SCLV	
Positioning Mode		71
Continuous or preset	MC	
Preset: absolute or incremental	MA	
Encoder Based Stepper Operation (stepper only)		84
Encoder resolution	ERES	
Encoder capture/counting enable	ENCCNT	
Use encoder as counter	ENCSND ((keep?))	
Stall detection	ESTALL	
Kill when stall is detected	ESK	
Stall deadband	ESDB	
Tuning Procedures (servos only)		85
Current loop bandwidth	DIBW	
Torque/force limit	DMTLIM	
Velocity limit	DMVLIM	
Notch filter A depth	DNOTAD	
Notch filter A frequency	DNOTAF	
Notch filter A quality factor	DNOTAQ	
Notch filter B depth	DNOTBF	
Notch filter B quality factor	DNOTBQ	
Notch filter B frequency	DNOTBF	
Notch lead filter break frequency	DNOTLD	
Notch lag filter break frequency	DNOTLG	
Position loop bandwidth	DPBW	
Velocity loop bandwidth	DVBW	
Load damping	LDAMP	
Load-to-rotor inertia ratio or load-to-force mass ratio	LJRAT	
Acceleration feed forward gain	DNOTBF	
Servo control signal offset	SGAF	
Integrator enable	SGINTE	
Current damping ratio	SGIRAT	

Setup Parameter	Command	See Pg.
Target Zone end-of-move settling criteria (servo axes)		84
Target zone mode enable	STRGTE	
Target distance zone	STRGTD	
Target velocity zone	STRGTV	
Target settling timeout period	STRGTT	
Programmable Input Functions		90
Define input functions	INFNC & LIMFNC	
Input active level	INLVL & LIMLVL	
Input debounce	INDEB	
Trigger interrupt - special functions	TRGFN	
Trigger interrupt - lockout time	TRGLOT	
Virtual Inputs	IN	
Programmable Output Functions		90
Define output functions	OUTFNC	
Output active level	OUTLVL	
End-of-travel limits		74
Limit function assignments	LIMFNC & INFNC	
Hardware – enabled	LH	
Hardware – deceleration	LHAD	
Hardware – s-curve decel	LHADA	
Hardware – active level of input	LIMLVL	
Software – enabled	LS	
Software – deceleration	LSAD	
Software – s-curve decel	LSADA	
Software – negative direction limit	LSNEG	
Software – positive direction limit	LSPOS	
Homing		79
Limit function assignments	LIMFNC & INFNC	
Acceleration	HOMA	
S-curve acceleration	HOMAA	
Deceleration	HOMAD	
S-curve deceleration	HOMADA	
Backup to home	HOMBAC	
Final approach direction	HOMDF	
Stopping edge of switch	HOMEDG	
Home switch active level	LIMLVL	
Velocity	HOMV	
Velocity of final approach	HOMVF	
Home to Z channel input	HOMZ	
Variable Arrays (*teaching* variable data)		110
Initialize numeric variable for data	VAR or VARI	
Define data program and program size	DATSIZ	
Set data pointer & establish increment	DATPTR	
Reset data pointer to specific location	DATRST	

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Position loop ratio .....SGPRAT	
Velocity/position bandwidth ratio .....SGPSIG	
Velocity feed forward gain .....SGVP	
Velocity damping ratio .....SGVRAT	

Using a Setup Program

The features described in this chapter are configured with certain Gem6K Series commands, commonly referred to as "setup commands." We recommend placing these commands (except MEMORY) into a special "setup program" that is executed to prepare the Gem6K Series product for subsequent controller operations. Further details about setup programming are provided in the *Creating and Executing a Setup Program* section, page 13.

USE THE START WIZARD IN MOTION PLANNER

The easiest way to get started with your setup program is to use the Start Wizard in Motion Planner's Wizard Editor. After the Start wizard is finished, you can include additional setup code according to your programming needs. The Start wizard also defines which program is your start-up (STARTP) program. If you do not wish to program you entire application with the Wizards, you can use the Start wizard to get the basic setup accomplished, and then copy the generated code into the Program Editor. **(Wizard version 4.2 or later required)**

Resetting the Controller

There are two primary ways to reset the Gem6K controller (listed below).

- Cycle power.
- Execute the RESET command.

When the controller is reset, most of the previously entered command parameters are returned to their original factory default values. All programs and variables, as well as certain command values, are retained in non-volatile memory (see page 35). If a start-up program is assigned with the STARTP command, resetting the controller will automatically execute that program. If you are using an RP240, the RESET function is available if you use the default menu system (see page 130).

Memory Allocation

For details about memory allocation, refer to *Storing Programs* on page 11.

CAUTION

Issuing a new MEMORY command (e.g., MEMORY200000,100000) will erase all existing programs and compiled profiles residing in the Gem6K product's memory. To determine the status of memory allocation, use the TMEM command.

Do not place the MEMORY command in the program assigned as the startup (STARTP) program. Doing so would erase all programs and segments upon cycling power or issuing the RESET command.

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Drive Stall Detection (stepper only)

The DSTALL command determines if the encoderless stall feature will be checked as Drive Stall indicator.

The state of the encoderless stall feature can be monitored at all times with Extended Axis Status bit #17 (reported with TASX, TASF, and the ASX assignment/comparison operand).

When a Drive Stall is detected, the Gem6K responds as follows: (this response is the same as that for Encoder Stall Detection, which is enabled with the ESTALL command)

- The stall is reported with Axis Status bit #12 (reported with TAS, TASF, and AS).
- If ERROR error-checking bit #1 is enabled (ERROR.1-1):
  - The stall is reported with Error Status bit #1 (reported with TER, TERF, and ER).
  - The Gem6K branches to the assigned ERRORP program.
- If the Kill-on-Stall feature is enabled (ESK1), the Gem6K immediately kills motion.

Drive Resolution (stepper only)

The drive resolution controls the number of steps the Gem6K controller considers as a full revolution for the motor drive. The drive's resolution is set with the DRES command (default is 25,000 steps/rev).

Disable Drive On Kill (servo only)

Normally, when you issue a Kill command (K, !K, or <ctrl>K) or activate an input configured as a kill input (see INFNCi-C or LIMFNCi-C command), motion is stopped at the hard limit (LHAD/LHADA) deceleration setting and the drives are left in the enabled state (DRIVE1).

However, your application may require you to *disable* (*shut down* or *de-energize*) the drives in a Kill situation to, for example, prevent damage to the motors or other system mechanical components. If so, set the controller to the *Disable Drive on Kill* mode with the KDRIVE1 command. In this mode, a kill command or kill input will shut down the drives immediately, letting the motors *free wheel* (without control from the drives) to a stop.

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Scaling

Units of Measure without Scaling

Scaling is disabled (SCALEØ) as the factory default condition:

- Steppers: When scaling is disabled, all distance values entered are in commanded counts (sometimes referred to as *motor steps*), and all acceleration, deceleration and velocity values entered are internally multiplied by the DRES command value.
- Servos:

Motion Attribute	Units of Measure (per feedback source) Encoder	Resolver
Accel/Decel	Revs/sec/sec *	revs/sec/sec
Velocity	Revs/sec *	revs/sec
Distance	Counts (*steps*) **	Counts (*steps*) **

* All accel/decel & velocity values are internally multiplied by the ERES value.
** Distance is measured in the counts received from the feedback device.

What is Scaling?

Scaling allows you to program acceleration, deceleration, velocity, and position values in units of measure that are appropriate for your application. The SCALE command is used to enable or disable scaling (SCALE1 to enable, SCALEØ to disable). The motion type(s) you are using in your application determines which scale factor commands you need to configure:

Type of Motion	Accel/Decel Scaling	Velocity Scaling	Distance Scaling
Standard Point-to-Point Motion	SCLA	SCLV	SCLD
Following	SCLA	SCLV	SCLD for follower distances SCLMAS for master distances

* A separate description of implementing scaling for Following is provided on page 70.

When Should I Define Scaling Factors?

Scaling calculations are performed when a program is defined or downloaded. Consequently, you must enable scaling (SCALE1) and define the scaling factors (SCLD, SCLA, SCLV, SCLMAS) *prior* to defining (DEF), uploading (TPROG), or running (RUN) the program.

NOTE
All scaling parameters are saved in battery-backed RAM

RECOMMENDATION: Place the scaling commands at the beginning of your program file, *before* the location of any defined programs. This ensures that the motion parameters in subsequent programs in your program file are scaled correctly. When you use Motion Planner's Setup Generator wizard, the scaling commands are automatically placed in the appropriate location in your program file.

ALTERNATIVE: Scaling factors could be defined via a terminal emulator ***just before*** defining or downloading a program. Because scaling command values are saved in battery-backed RAM (remembered after you cycle power or issue a RESET command), all subsequent program definitions and downloads will be scaled correctly.

NOTES

- Scaling commands are not allowed in a program. If there are scaling commands in a program, the controller will report an error message ("COMMAND NOT ALLOWED IN PROGRAM") when the program is downloaded.
- If you intend to upload a program with scaled motion parameters, be sure to use Motion Planner. Motion Planner automatically uploads the scaling parameters and places them at the beginning of the program file containing the uploaded program from the controller. This ensures correct scaling when the program file is later downloaded.

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Acceleration & Deceleration Scaling (SCLA)

Steppers: If scaling is enabled (SCALE1), all accel/decel values entered are internally multiplied by the acceleration scaling factor to convert user units/sec/sec to commanded counts/sec/sec. The scaled values are always in reference in commanded counts, regardless of the existence of an encoder.

Servos: If scaling is enabled (SCALE1), all accel/decel values entered are internally multiplied by the acceleration scaling factor to convert user units/sec/sec to encoder or analog input counts/sec/sec.

All accel/decel commands for point-to-point motion (e.g., A, AA, AD, HOMA, HOMAD, JOGA, etc.) are multiplied by the SCLA command value.

As the accel/decel scaling factor (SCLA) changes, the resolution of the accel and decel values and the number of positions to the right of the decimal point also change (see table at right). An accel/decel value with greater resolution than allowed will be truncated (e.g., if scaling is set to SCLA10, the A9.9999 command would be truncated to A9.9).

SCLA value **(steps/unit²)**	**Decimal Places**
1 - 9	0
10 - 99	1
100 - 999	2
1000 - 9999	3
10000 - 99999	4
100000 - 999999	5

Use the following equations to determine the range of acceleration and deceleration values for your product.

Axis Type	**Min. Accel or Decel (resolution)**	**Max. Accel or Decel**
Stepper	$\frac{0.001 * \text{DRES}}{\text{SCLA}}$	$\frac{999.9999 * \text{DRES}}{\text{SCLA}}$
Servo	Encoder feedback: $\frac{0.001 * \text{ERES}}{\text{SCLA}}$ Resolver	Encoder feedback: $\frac{999.9999 * \text{ERES}}{\text{SCLA}}$ Resolver

Velocity Scaling (SCLV)

Steppers: If scaling is enabled (SCALE1), all velocity values entered are internally multiplied by the velocity scaling factor to convert user units/sec to commanded counts/sec. The scaled values are always in reference to commanded counts (sometimes referred to as “motor steps”).

Servos: If scaling is enabled (SCALE1), all velocity values entered are internally multiplied by the velocity scaling factor to convert user units/sec to encoder or analog input counts/sec.

All velocity commands for point-to-point motion (e.g., V, HOMV, HOMVF, JOGVH, JOGVL, etc.) are multiplied by the SCLV command value.

As the velocity scaling factor (SCLV) changes, the velocity command's range and its decimal places also change (see table below). A velocity value with greater resolution than allowed will be truncated. For example, if scaling is set to SCLV10, the V9.9999 command would be truncated to V9.9.

SCLV Value **(counts/unit)**	**Velocity Resolution (units/sec)**	**Decimal Places**
1 - 9	1	0
10 - 99	0.1	1
100 - 999	0.01	2
1000 - 9999	0.001	3
10000 - 99999	0.0001	4
100000 - 999999	0.00001	5

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Use the following equations to determine the maximum velocity range for your product type.

Max. Velocity for Steppers	**Max. Velocity for Servos** (determined by feedback source selected for axis #1)
$\frac{6{,}5000{,}000}{SCLV}$ *n* = maximum velocity as set by the PULSE command.	Encoder Feedback: $\frac{6{,}5000{,}000}{SCLV}$ Resolver

Distance Scaling (SCLD and SCLMAS)

Steppers: If scaling is enabled (SCALE1), all distance values entered are internally multiplied by the distance scaling factor to convert user units to commanded counts ("motor steps"). ←

Servos: If scaling is enabled (SCALE1), all distance values entered are internally multiplied by the distance scaling factor to convert user units to encoder or analog input counts.

All distance commands for point-to-point motion (e.g., D, PSET, REG, SMPER) are multiplied by the SCLD command value.

Scaling for Following Motion: The SCLD command defines the follower's distance scale factor, and the SCLMAS command defines the master's distance scale factor. The Following-related commands that are affected by SCLD and SCLMAS are listed in the table below.

Commands Affected by Master Scaling (SCLMAS)	**Commands Affected by Follower Scaling (SCLD)**
FMCLEN: *Master Cycle Length*	FOLRN: *Follower-to-Master Ratio (Numerator)*
FMCP: *Master Cycle Position Offset*	FSHFD: *Preset Phase Shift*
FOLMD: *Master Distance*	GOWHEN: *Conditional GO* (left-hand variable ≠ PMAS)
FOLRD: *Follower-to-Master Ratio (Denominator)*	TPSHF & [PSHF]: *Net Position Shift of Follower*
GOWHEN: *Conditional GO* (left-hand variable is PMAS)	TPSLV & [PSLV]: *Position of Follower Axis*
TPMAS & [PMAS]: *Position of Master Axis*	
TVMAS & [VMAS]: *Velocity of Master Axis*	

Fractional Step Truncation

If you are operating in the incremental mode (MAØ), or specifying master distance values with FOLMD, when the distance scaling factor (SCLD or SCLMAS) and the distance value are multiplied, a fraction of one step may be left over. This fraction is truncated when the distance value is used in the move algorithm. This truncation error can accumulate over a period of time, when performing incremental moves continuously in the same direction. To eliminate this truncation problem, set SCLD or SCLMAS to 1, or a multiple of 10.

As the SCLD or SCLMAS scaling factor changes, the distance command's range and its decimal places also change (see table below). A distance value with greater resolution than allowed will be truncated. For example, if scaling is set to SCLD400, the D105.2776 command would be truncated to D105.277.

SCLD or SCLMAS **Value (counts/unit)**	**Distance Resolution (units)**	**Distance Range (units)**	**Decimal Places**
1 - 9	1.0	0 - ±999999999	0
10 - 99	0.10	0.0 - ±99999999.9	1
100 - 999	0.010	0.00 - ±9999999.99	2
1000 - 9999	0.0010	0.000 - ±999999.999	3
10000 - 99999	0.00010	0.0000 - ±99999.9999	4
100000 - 999999	0.00001	0.00000 - ±9999.99999	5

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Scaling Example — Steppers

User has a 25,000 step/rev motor/drive attached to 5-pitch leadscrew. The user wants to program motion parameters in inches; therefore the scale factor calculation is: 25,000 steps/rev x 5 revs/inch = 125,000 steps/inch. For instance, with a scale factor of 125,000, the operator could enter a move distance value of 2.000 and the controller would send out 250,000 pulses, corresponding to two inches of travel.

```
SCALE1            ; Enable scaling
DRES25000         ; Set drive resolution to 25,000 steps/rev
SCLD125000        ; Allow entering distance in inches
SCLV125000        ; Allow entering velocity in inches/sec
SCLA125000        ; Allow entering accel/decel in inches/sec/sec
```

Scaling Example — Servos

User has a 4,000 count/rev servo motor/drive system (using a 1000-line encoder) attached to a 5-pitch leadscrew. The user wants to position in inches; therefore, the scale factor calculation is 4,000 counts/rev x 5 revs/inch = 20,000 counts/inch.

```
ERES4000          ; Set encoder resolution to 4000 steps/rev (post quadrature)
SCALE1            ; Enable scaling
SCLD20000         ; Allow entering distance values in inches
SCLV20000         ; Allow entering velocity values in inches/sec
SCLA20000         ; Allow entering accel/decel values in inches/sec/sec
                  ; Select ANI feedback for axis #1
                  ; Enable scaling
                  ; Allow entering distance values in volts
                  ; Allow entering velocity values in volts/sec
                  ; Allow entering accel/decel values in volts/sec/sec
                  ; Select encoder feedback for both axes (prepare for motion)
```

Scaling Example — Following

Typically, the master and follower scale factors are programmed so that master and follower units are the same, but this is not required. Consider the scenario below as an example.

The master is a 1000-line encoder (4000 counts/rev post-quadrature) mounted to a 50 teeth/rev pulley attached to a 10 teeth/inch conveyor belt, resulting in 80 counts/tooth (4000 counts/50 teeth = 80 counts/tooth). To program in inches, you would set up the master scaling factor with the `SCLMAS800` command (80 counts/tooth * 10 teeth/inch = 800 counts/inch).

The follower axis is a servo motor with position feedback from a 1000-line encoder (4000 counts/rev). The motor is mounted to a 4-pitch (4 revs/inch) leadscrew. Thus, to program in inches, you would set up the follower scaling factor with the `SCLD16000` command (4000 counts/rev * 4 revs/inch = 16000 counts/inch).

```
SCALE1            ; Enable scaling
SCLMAS800         ; Master scaling:
                  ; (80 counts/tooth * 10 teeth/inch = 800 counts/inch)
SCLD16000         ; Follower scaling:
                  ; (4000 counts/rev * 4 revs/inch = 16000 counts/inch)
```


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Positioning Modes

The Gem6K controller can be programmed to position in either the preset (incremental or absolute) mode or the continuous mode. You should select the mode that will be most convenient for your application. For example, a repetitive cut-to-length application requires incremental positioning. X-Y positioning, on the other hand, is better served in the absolute mode. Continuous mode is useful for applications that require constant movement of the load based on internal conditions or inputs, not distance.

Refer also to the Scaling *section on page 67.*

Positioning modes require acceleration, deceleration, velocity, and distance commands (*continuous mode does not require distance*). The table below identifies these commands and their units of measure, and which scaling command affects them.

Parameter	Units (Unscaled), Stepper	Units (Unscaled), Servo	Unit Scaling Command *
Acceleration	revs/sec^2	encoder/resolver: revs/sec^2	SCLA
Deceleration	revs/sec^2	encoder/resolver: revs/sec^2	SCLA
Velocity	revs/sec	encoder/resolver: revs/sec	SCLV
Distance	steps	counts	SCLD ***

* Scaling must first be enabled with the SCALE1 command. For details on scaling, refer to page 67.
*** An axis assigned as a master (for Following) is scaled by the SCLMAS command.

On-The-Fly (Pre-emptive Go) Motion Profiling

While motion is in progress (regardless of the positioning mode), you can change these motion parameters to affect a new profile:

- Acceleration (A) — s-curve acceleration not allowed during on-the-fly changes
- Deceleration (AD) — s-curve deceleration not allowed during on-the-fly changes
- Velocity (V)
- Distance (D)
- Preset or Continuous Positioning Mode Selection (MC)
- Incremental or Absolute Positioning Mode Selection (MA)
- Following Ratio Numerator and Denominator (FOLRN and FOLRD, respectively)

The motion parameters can be changed by sending the respective command (e.g., A, V, D, MC, etc.) followed by the GO command. If the continuous command execution mode is enabled (COMEXC1), you can execute buffered commands; otherwise, you must prefix each command with an immediate command identifier (e.g., !A, !V, !D, !MC, etc., followed by !GO). The new GO command pre-empts the motion profile in progress with a new profile based on the new motion parameter(s).

For more information, see *On-The-Fly Motion Profiling* on page 155.

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Preset Positioning Mode

A *preset* move is a point-to-point move of a specified distance. You can select preset moves by putting the Gem6K controller into preset mode (canceling continuous mode) using the MCØ command. Preset moves allow you to position the motor/load in relation to the previous stopped position (*incremental mode*—enabled with the MAØ command) or in relation to a defined zero reference position (*absolute mode*—enabled with the MA1 command).

Incremental Mode Moves

The incremental mode is the controller's default power-up mode. When using the Incremental Mode (MAØ), a preset move moves the motor/load the specified distance from its starting position. For example, if you start at position *N*, executing the D6ØØØ command in the MAØ mode will move the motor/load 6,000 units from the *N* position. Executing the D6ØØØ command again will move the motor/load an additional 6,000 units, ending the move 12,000 units from position *N*.

You can specify the direction of the move by using the optional sign + or - (e.g., D+6ØØØ or D-6ØØØ). Whenever you do not specify the direction (e.g., D6ØØØ), the unit defaults to the positive (+) direction.

Example

```
SCALE0  ; Disable scaling
MA0     ; Set to Incremental Position Mode
A2      ; Set acceleration to 2 units/sec/sec
V5      ; Set velocity to 5 units/sec
D4000   ; Set distance to 4,000 positive units
GO      ; Initiate motion on (move 4,000 positive units)
GO      ; Repeat the move
D-8000  ; Set distance to 8,000 negative units
        ; (return to original position)
GO      ; Initiate motion on (move 8,000 units in the negative
        ; direction and end at its original starting position)
```

Absolute Mode Moves

A preset move in the Absolute Mode (MA1) moves the motor/load the distance that you specify from the *absolute zero position*.

Establishing a *Zero Position*

One way to establish the zero position is to issue the PSET command when the load is at the location you would like to reference as absolute position zero (e.g., PSETØ defines the current position as absolute position zero). Steppers with encoder feedback can use the PESET command set the absolute encoder position in ENCCNT1 mode.

The zero position is also established when the Go Home (HOM) command is issued, the absolute position register is automatically set to zero after reaching the home position, thus designating the home position as position zero.

The direction of an absolute preset move depends upon the motor's/load's position at the beginning of the move and the position you command it to move to. For example, if the motor/load is at absolute position +12,500, and you instruct it to move to position +5,000 (e.g., with the D5ØØØ command), it will move in the negative direction a distance of 7,500 steps to reach the absolute position of +5,000.

The Gem6K controller retains the absolute position, even while the unit is in the incremental mode. To ascertain the absolute position, use the TPC and PC commands.

Example

```
SCALE0  ; Disable scaling
MA1     ; Set the controller to the absolute positioning mode
PSET0   ; Set current absolute position to zero
A5      ; Set acceleration to 5 units/sec/sec
V3      ; Set velocity to 3 units/sec
D4000   ; Set move to absolute position 4,000 units
GO      ; Initiate move (move to absolute position +4,000)
D8000   ; Set move to absolute position +8,000
GO      ; Initiate move (starting from position +4,000, move 4,000
        ; additional units in the positive direction to position +8,000)
D0      ; Set move to absolute position zero
GO      ; Initiate move (starting at absolute position +8,000,
        ; move 8,000 units in the negative direction to position zero)
```


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Continuous Positioning Mode

The Continuous Mode (MC1) is useful in these situations:

- Applications that require constant movement of the load
- Synchronize the motor to external events such as trigger input signals
- Changing the motion profile after a specified distance or after a specified time period (T command) has elapsed

You can manipulate the motor movement with either buffered or immediate commands. After you issue the GO command, buffered commands are not executed unless the continuous command execution mode (COMEXC1 command) is enabled. Once COMEXC1 is enabled, buffered commands are executed in the order in which they were programmed. More information on the COMEXC mode is provided on page 14.

The command can be specified as *immediate* by placing an exclamation mark (!) in front of the command. When a command is specified as immediate, it is placed at the front of the command queue and is executed immediately.

Example A

```
COMEXC1          ; Enable continuous command processing mode
COMEXS1          ; Allow command execution to continue after stop
MC1              ; Sets mode to continuous
A10              ; Sets acceleration to 10
V1               ; Sets velocity to 1
GO               ; Initiates move (Go)
WAIT(VEL=1)      ; Wait to reach continuous velocity
T5               ; Time delay of 5 seconds
S1               ; Initiate stop
WAIT(MOV=b0)     ; Wait for motion to completely stop
COMEXC0          ; Disable continuous command processing mode
; When the move is executed, the load will accelerate to 1 unit/sec,
; continue at that rate for 5 seconds, and then decelerate to a stop.
```

Example B

```
DEF prog1        ; Begin definition of program prog1
COMEXC1          ; Enable continuous command processing mode
COMEXS1          ; Allow command execution to continue after stop
MC1              ; Set to continuous positioning mode
A10              ; Set acceleration to 10
V1               ; Set velocity to 1
GO               ; Initiate move (Go)
WAIT(VEL=1)      ; Wait for motor to reach continuous velocity
T3               ; Time delay of 3 seconds
A50              ; Set acceleration to 50
V10              ; Set velocity to 10
GO               ; Initiate acceleration and velocity changes
T5               ; Time delay of 5 seconds
S1               ; Initiate stop
WAIT(MOV=b0)     ; Wait for motion to completely stop
COMEXC0          ; Disable continuous command processing mode
END              ; End definition of program prog1
```

While in continuous mode, motion can be stopped if:

- You issue an immediate Stop (!S) or Kill (!K or ctrl/K) command.
- The load trips an end-of-travel limit switch or encounters a software end-of-travel limit.
- The load trips a registration input (a trigger input configured with the INFNCi-H command to function as a registration input).
- The load trips an input configured as a kill input (INFNCi-C or LIMFNCi-C) or a stop input (INFNCi-D or LIMFNCi-D).

NOTE

While the axis is moving, you cannot change the parameters of some commands (such as DRIVE and HOM). This rule applies during the COMEXC1 mode and even if you prefix the command with an immediate command identifier (!). For more information, refer to *Restricted Commands During Motion* on page 17.

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Linear Motion

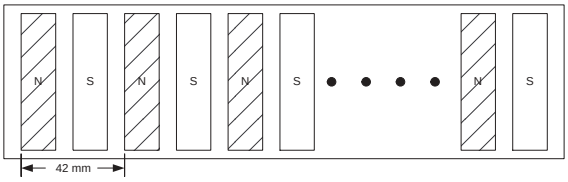
All Gemini drives operate internally in rotary units. If you use a linear motor, you must convert some of the motion parameters to their rotary equivalents:

- `A` ..... Acceleration
- `AA` ..... Acceleration (S-Curve)
- `AD` ..... Deceleration
- `ADA` ..... Deceleration (S-Curve)
- `D` ..... Distance/Position
- `HOMA` ..... Home Acceleration
- `HOMV` ..... Home Velocity
- `HOMVF` ..... Home Final Velocity
- `LHAD` ..... Hardware EOT Limit Decel
- `LHADA` ..... Hardware EOT Limit Decel (S-Curve)
- `LSAD` ..... Software EOT Limit Decel
- `LSADA` ..... Software EOT Limit Decel (S-Curve)
- `PSET` ..... Absolute Position Reference
- `REG` ..... Registration Distance
- `REGLOD` ..... Registration Lockout Distance
- `STRGTD` ..... Target Zone Distance
- `STRGTV` ..... Target Zone Velocity
- `V` ..... Velocity

> **NOTE**: Motor setup is handled differently. If you use the Motion Planner setup wizard, you may enter the motor data in linear units and the software converts them to rotary units before they are downloaded to the drive.

To make the conversion from linear to rotary and vice versa, the motor electrical pitch, or `DMEPIT`, must be known. The electrical pitch relates the linear distance required for the equivalent of one rotary motor revolution. Mechanically, the definition of the electrical pitch is the linear distance between two magnets comprising a full magnetic cycle. The illustration (below) shows an example of an electrical pitch of 42mm (`DMEPIT42`). NOTE: Parker linear motors have an electrical pitch of 42mm.

Linear motor track



Definition of DMEPIT (Electrical Pitch)

The feedback resolution (`ERES`) value must be set to the number of counts for the electrical pitch (1 rev).

$$ERES = \underbrace{\frac{\#\,counts}{1\,m}}_{\text{from encoder}} \times \underbrace{\frac{1\,m}{1000\,mm}}_{\text{conversion}} \times \underbrace{\frac{DMEPIT(mm)}{1\,(rev)}}_{\text{from motor}} = \frac{\#\,counts}{1\,(rev)}$$

Most linear encoders are metric, and most of those are 1 micron (1 μm):

$$1\ micron\ encoder = \frac{1\ count}{1\ \mu m} = \frac{1{,}000{,}000\ counts}{m}$$

Use the following formulas to convert from linear to rotary units. An sample conversion for position, acceleration, and velocity is provided on page 76.

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Linear Position

- D (distance)
- PSET (absolute position reference)
- REG (registration distance)
- REGLOD (registration lockout distance)
- STRGTD (target zone distance)

Metric:

$$Position_{rotary}(counts) = \underbrace{\frac{\#counts}{1(m)}}_{\text{from encoder}} \times Position_{linear}(m)$$

English:

$$Position_{rotary}(counts) = \underbrace{\frac{\#counts}{1(m)}}_{\text{from encoder}} \times \frac{.0254(m)}{1(in)} \times Position_{linear}(in)$$

$$Position_{rotary}(counts) = \underbrace{\frac{\#counts}{1(m)}}_{\text{from encoder}} \times \frac{.0254(m)}{1(in)} \times \frac{12(in)}{1(ft)} \times Position_{linear}(ft)$$

Linear Velocity

- V (velocity)
- HOMV (home velocity)
- HOMVF (home final velocity)
- STRGTV (target velocity)

Metric:

$$Velocity_{rotary}(rps) = \frac{1}{DMEPIT(mm)} \times \frac{1000(mm)}{1(m)} \times Velocity_{linear}(m/s)$$

English:

$$Velocity_{rotary}(rps) = \frac{1}{DMEPIT(mm)} \times \frac{25.4(mm)}{1(in)} \times Velocity_{linear}(in/s)$$

$$Velocity_{rotary}(rps) = \frac{1}{DMEPIT(mm)} \times \frac{25.4(mm)}{1(in)} \times \frac{12(in)}{1(ft)} \times Velocity_{linear}(ft/s)$$

Linear Acceleration

- A (acceleration)
- AA (s-curve accel)
- AD (deceleration)
- AD (s-curve decel)
- HOMA (home accel)
- LHAD (hard limit decel)
- LHADA (hard limit s-curve decel)
- LSAD (soft limit decel)
- LSADA (soft limit s-curve decel)

Metric:

$$Accel_{rotary}(rpss) = \frac{1}{DMEPIT(mm)} \times \frac{1000(mm)}{1(m)} \times Accel_{linear}(m/s^2)$$

English:

$$Accel_{rotary}(rpss) = \frac{1}{DMEPIT(mm)} \times \frac{25.4(mm)}{1(in)} \times Accel_{linear}(in/s^2)$$

$$Accel_{rotary}(rpss) = \frac{1}{DMEPIT(mm)} \times \frac{25.4(mm)}{1(in)} \times \frac{12(in)}{1(ft)} \times Accel_{linear}(ft/s^2)$$

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Conversion Example

Using a Parker 406-LXR-M-D15-E2 linear motor, the electrical pitch is 42mm (`DMEPIT42`) and the encoder is 1 micron. Here, we will convert an acceleration of 10 inches/sec^2, a velocity of 5 inches/sec, and a distance of 20 inches:

1. Calculate `ERES` in counts/rev (result is `ERES42000`):

$$ERES = \underbrace{\frac{1\,000\,000\ counts}{1\,(m)}}_{\text{from encoder}} \times \underbrace{\frac{1\,(m)}{1000\,(mm)}}_{\text{conversion}} \times \underbrace{\frac{42\,(mm)}{1\,(rev)}}_{\text{from motor}} = \frac{42\,000\ counts}{1\,(rev)}$$

2. Convert an acceleration of 10 inches/sec^2 to its rotary equivalent in revs/sec^2:

$$Accel_{rotary}(rpss) = \frac{1}{42\,(mm)} \times \frac{25.4\,(mm)}{1\,(in)} \times 10\,(in/s^2) = 6.0476\ rpss$$

3. Convert a velocity of 5 inches/sec to its rotary equivalent in revs/sec:

$$Velocity_{rotary}(rps) = \frac{1}{42\,(mm)} \times \frac{25.4\,(mm)}{1\,(in)} \times 5\,(in/s) = 3.0238\ rps$$

4. Convert a distance of 20 inches to its rotary equivalent in counts:

$$Position_{rotary}(counts) = \underbrace{\frac{1000\,000\ counts}{1\,(m)}}_{\text{from encoder}} \times \frac{.0254\,(m)}{1\,(in)} \times 20.0\,(in) = 508\,000$$

The program values resulting from these conversions are:

```
ERES42000     ; Set encoder resolution to 42000 counts/rev
A6.0476       ; Set acceleration to 6.0476 revs/sec/sec
              ; (10 inches/sec/sec)
V3.0238       ; Set velocity to 3.0238 revs/sec (5 inches/sec)
D508000       ; Set distance to 508,000 counts (20 inches)
```


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End-of-Travel Limits

Related Commands:

LH .....Hard limit enable
LHAD .....Hard limit decel
LHADA.....Hard limit decel (s)
LIMLVL.....Limit switch polarity
LS .....Soft limit enable
LSAD .....Soft limit decel
LSADA.....Soft limit decel (s)
LSNEG.....Soft limit (negative)
LSPOS.....Soft limit (positive)
TLIM .....Hard limit status
TASF .....Bits 15-18 indicate if hard or soft limit was encountered
TERF .....Bit 2: hard limit hit
Bit 3: soft limit hit
(must enable ERROR checking bits 2 & 3)
ERROR.....Bit 2 or 3 is enabled, the Gem6K will branch to the ERRORP program if a hard or soft limit is encountered

The Gem6K controller can respond to both hardware and software end-of-travel limits. The purpose of hardware and software end-of-travel limits is to prevent the motor's load from traveling past defined limits. Software and hardware limits are typically positioned in such a way that when the software limit is reached, the motor/load will start to decelerate toward the hardware limit, thus allowing for a much smoother stop at the hardware limit. Software limits can be used regardless of incremental or absolute positioning. When a hardware or software end-of-travel limit is reached, the Gem6K controller stops that axis using the respective hardware deceleration rate (set with LHAD & LHADA) or software limit deceleration rate (set with LSAD & LSADA).

How to set up hardware end-of-travel limits (for each axis)**:**

1. Connect the end-of-travel limit inputs according to the instructions in your Gem6K product's *Installation Guide*. To help assure safety, connect normally-closed switches and leave the active level at default "active low" setting (set with the LIMLVL command).
2. (Optional) Define the inputs to be used as end-of-travel inputs for the respective axes. **NOTE**: When the Gem6K product is shipped from the factory, the inputs on the "LIMITS/HOME" connectors are factory-configured with the LIMFNC command to function as end-of-travel and home limits for their respective axes. If you intend to use digital inputs on an external I/O brick as limit inputs:
   a. Assign the limit function to the external input with the INFNC command. For example, 1INFNC9-1R assigns the "axis 1 positive end-of-travel limit" function to the 1st input on SIM2 (I/O point 9) of I/O brick 1.
   b. Reassign the respective "LIMITS/HOME" input to a non-limit function with the LIMFNC command. For example, LIMFNC1-A assigns the "general-purpose input" function to limit input 1 (normally assigned the "axis 1 positive end-of-travel limit" function).
3. Set the hard limit deceleration rate (LHAD & LHADA) to be used when the limit switch is activated. The LHADA command allows you to define an s-curve deceleration. Steppers: If your system is moving heavy loads or operating at high velocities, you may need to decrease the LHAD command value (deceleration rate) to prevent the motor from stalling.

NOTES ON HARDWARE LIMITS

- Gem6K controllers are shipped from the factory with the hardware end-of-travel limits enabled, but not connected. Therefore, **motion will not be allowed until you do one of the following**:
  - Install limit switches or jumper the end-of-travel limit terminals to the GND terminal (*refer to your product's Installation Guide for wiring instructions*).
  - Disable the limits with the LH command (recommended only if the load is not coupled).
  - Reverse the active level of the limits by executing the LIMLVL0 command for the respective axis.

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How to set up software end-of-travel limits (for each axis)**:**

1. Use the LS command to enable the software end-of-travel limits/
2. Define the positive-direction limit with the LSPOS command, and define the negative-direction limit with the LSNEG command. If you have scaling enabled (SCALE1), these limit values are scaled by the SCLD command. Both software limits may be defined with positive values.

NOTES ON SOFTWARE LIMITS

- The software limits (LSPOS & LSNEG) are referenced from a position of absolute zero. or negative values. *Care must be taken when performing incremental moves because the software limits are always defined in absolute terms.* They must be large enough to accommodate the moves, or a new zero reference position must be defined (using the PSET command) before each move.
- To ensure proper motion when using soft end-of-travel limits, be sure to set the LSPOS value to an absolute value greater than the LSNEG value.

Programming Example

In this sample of code (not a complete program), the hardware and software limits are enabled. The distance scaling command (SCLD) is used to define software limit locations in revolutions from the absolute zero position (assumes a 4000 step/rev resolution). Deceleration rates are specified for both software and hardware limits. If a limit is encountered, the motor will decelerate to a stop.

```
; *******************************************************
; These scaling setup commands are downloaded before the
; limit setup commands are executed:
SCALE1       ; Enable scaling
SCLD4000     ; Program soft limit distance in revs
SCLA4000     ; Program soft limit accel/decel in revs/sec/sec
ERES4000     ; Set encoder resolution to 4000 steps/rev
; *******************************************************
LH3          ; Enable limits 1 and 2, disable limits 3 and 4
LHAD10       ; Set hard limit deceleration
LSAD5        ; Set soft limit deceleration
LSNEG0       ; Set negative direction soft limit
             ; (0 revs)
LSPOS10      ; Establish positive soft limit
             ; (10 revs)
LS3          ; Enable soft limits
```


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Homing *(Using the Home Inputs)*

Refer to the product's *Installation Guide* for instructions to wire a hardware home limit switch.

The *homing operation* is a sequence of moves that position an axis using the Home Limit input and/or the Z Channel input of an incremental encoder. The goal of the homing operation is to return the load to a repeatable initial starting location.

Zero Reference After Homing: As soon as the homing operation is successfully completed, the absolute position register is reset to zero, thus establishing a zero reference position.

The homing operation has several potential homing functions you can customize to suit the needs of your application (illustrations of the effects of these commands are presented below):

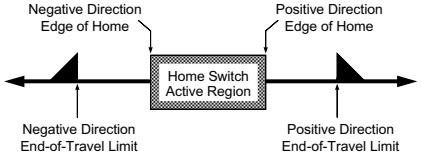
Command	Homing Function (see respective command descriptions for further details)	Default
HOM	Initiate the homing move. To start the homing move in the positive direction, use HOMØ; to home in the negative direction, use HOM1.	HOMx (do not home)
HOMA	Acceleration while homing.	HOMA1Ø (10 units/sec^2)
HOMAA	S-curve acceleration while homing.	HOMAA10 (10 units/sec^2)
HOMAD	Deceleration while homing.	HOMAD10 (10 units/sec^2)
HOMADA	S-curve deceleration while homing.	HOMADA10 (10 units/sec^2)
HOMBAC	Back up to home. The load will decelerate to a stop after encountering the active edge of the home region, and then will move in the opposite direction at the HOMVF velocity until the active edge of the home region is encountered. Allows the use of HOMEDG and HOMDF.	HOMBAC0 (function disabled)
HOMDF	Final approach direction —during backup to home (HOMBAC) or during homing to the Z channel input of an incremental encoder (HOMZ).	HOMDF0 (positive direction)
HOMEDG	Specify the side of the home switch on which to stop (either the positive-travel side or the negative-travel side).	HOMEGD0 (positive-travel side of switch)
LIMLVL	Define the home limit input active level (i.e., the state, high or low, which is to be considered an activation of the input). To use a normally-open switch, select active low (LIMLVL0); to use a normally-closed switch, select active high (LIMLVL1).	LIMLVL0 (active-low, use a normally-open switch)
HOMV	Velocity while seeking the home position (see also HOMVF).	HOMV1 (1 unit/sec)
HOMVF	Velocity while in final approach to home position—during backup to home (HOMBAC) or during homing to the Z channel input of an incremental encoder (HOMZ).	HOMVF.1 (0.1 unit/sec)
HOMZ	Home to the Z channel input from an incremental encoder. NOTE: The home limit input must be active prior to homing to the Z channel.	HOMZ0 (function disabled)

Homing Status:

Status of homing moves is stored in bit #5 of the axis status register (indicates whether or not the home operation was successful). To display the status, use the TASF command or the TAS command. To use the status in a conditional expression (e.g., for an IF statement), use the AS assignment/comparison operator.

NOTES ABOUT HOMING

- Avoid using pause and resume functions during the homing operation. A pause command (PS or !PS) or pause/resume input (input configured with the INFNCi-E or LIMFNCi-E command) will pause the homing motion. However, when the subsequent resume command (C or !C) or pause/resume input occurs, motion will resume at the beginning of the homing motion sequence.
- Relevance of positive and negative direction:

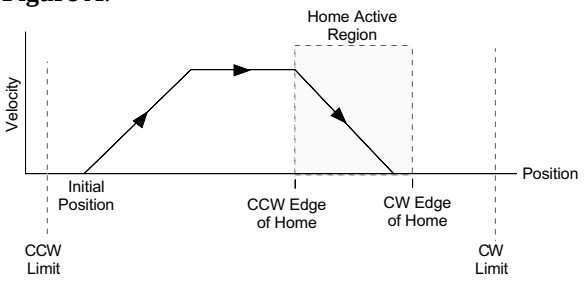


- If an end-of-travel limit is encountered during the homing operation, the motion will be reversed and the home switch will be sought in the opposite direction. If a second limit is encountered, the homing operation will be terminated, stopping motion at the second limit.

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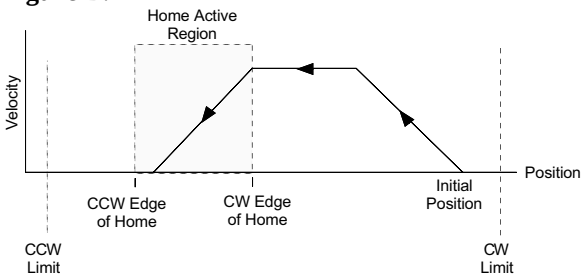
Figures A and B show the homing operation when HOMBAC is not enabled. *"CW" refers to the positive direction and "CCW" refers to the negative direction.*

Figure A:



Home Profile Attributes (commands):
- Start home move in positive direction (HOM0)
- Backup To Home disabled (HOMBAC0)

Figure B:



Home Profile Attributes (commands):
- Start home move in negative direction (HOM1)
- Backup To Home disabled (HOMBAC0)

Positive Homing, Backup to Home Enabled

The seven steps below describe a sample homing operation when HOMBAC is enabled (see Figure C). The final approach direction (HOMDF) is CW and the home edge (HOMEDG) is the CW edge. *"CW" refers to the positive direction and "CCW" refers to the negative direction.*

NOTE

To better illustrate the direction changes in the backup-to-home operation, the illustrations in the remainder of this section show the backup-to-home movements with varied velocities. In reality, the backup-to-home movements are performed at the same velocity (HOMVF value).

Step 1 A CW home move is started with the HOMØ command at the HOMA and HOMAA accelerations. Default HOMA is 10 revs (or inches) per sec^2.

Step 2 The HOMV velocity is reached (move continues at that velocity until home input goes active).

Step 3 The CCW edge of the home input is detected, this means the home input is active. At this time the move is decelerated at the HOMAD and HOMADA command values. It does not matter if the home input becomes inactive during this deceleration.

Step 4 After stopping, the direction is reversed and a second move with a peak velocity specified by the HOMVF value is started.

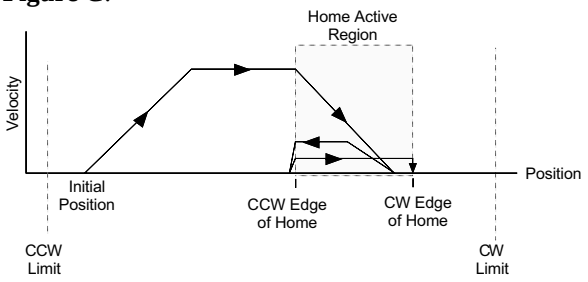
Step 5 This move continues until the CCW edge of the home input is reached.

Step 6 Upon reaching the CCW edge, the move is decelerated at the HOMAD and HOMADA command values, the direction is reversed, and another move is started in the CW direction at the HOMVF velocity.

Step 7 As soon as the home input CW edge is reached, this last move is immediately terminated. The load is at home and the absolute position register is reset to zero.

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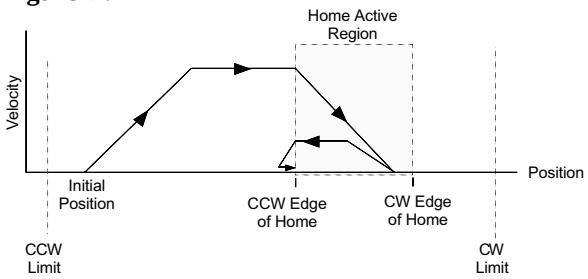
Figure C:



Home Profile Attributes (commands):
- Start home move in positive direction (HOM0)
- Backup To Home enabled (HOMBAC1)
- Final approach direction is positive (HOMDF0)
- Stop on the positive-travel side of the home switch active region (HOMEDG0)

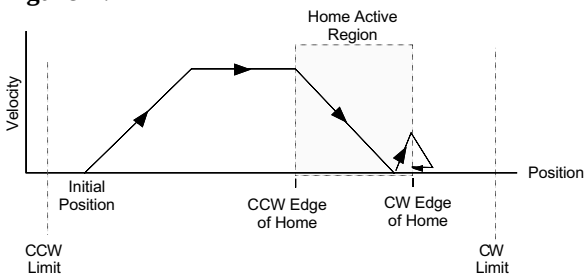
Figures D through F show the homing operation for different values of HOMDF and HOMEDG, when HOMBAC is enabled. *"CW" refers to the positive direction and "CCW" refers to the negative direction.*

Figure D:



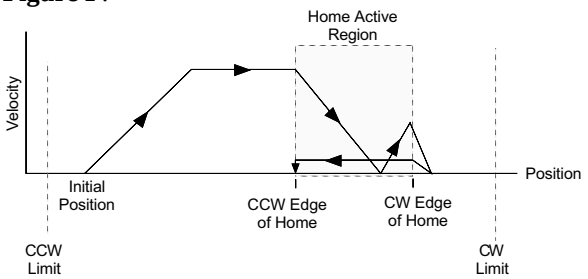
Home Profile Attributes (commands):
- Start home move in positive direction (HOM0)
- Backup To Home enabled (HOMBAC1)
- Final approach direction is positive (HOMDF0)
- Stop on the negative-travel side of the home switch active region (HOMEDG1)

Figure E:



Home Profile Attributes (commands):
- Start home move in positive direction (HOM0)
- Backup To Home enabled (HOMBAC1)
- Final approach direction is negative (HOMDF1)
- Stop on the positive-travel side of the home switch active region (HOMEDG0)

Figure F:



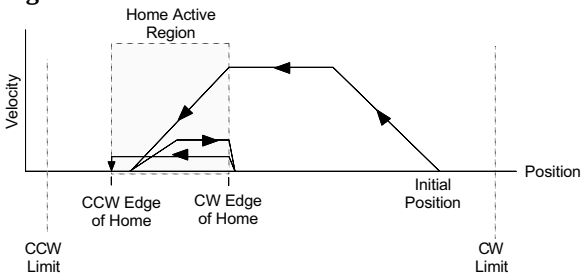
Home Profile Attributes (commands):
- Start home move in positive direction (HOM0)
- Backup To Home enabled (HOMBAC1)
- Final approach direction is negative (HOMDF1)
- Stop on the negative-travel side of the home switch active region (HOMEDG1)

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Negative Homing, Backup to Home Enabled

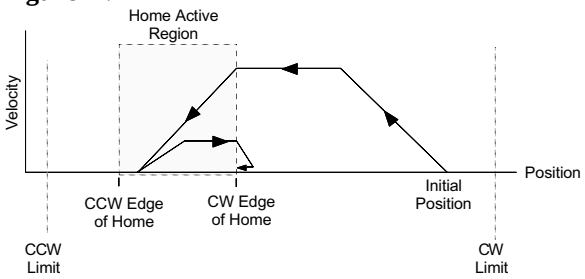
Figures G through J show the homing operation for different values of HOMDF and HOMEDG, when HOMBAC is enabled. *"CW" refers to the positive direction and "CCW" refers to the negative direction.*

Figure G:



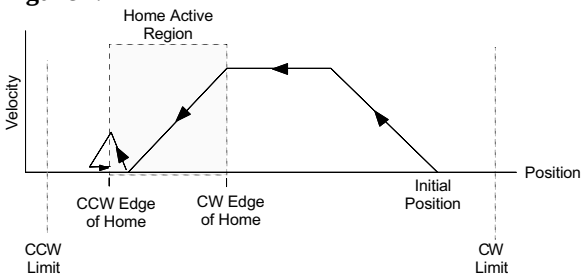
Home Profile Attributes (commands):
- Start home move in negative direction (HOM1)
- Backup To Home enabled (HOMBAC1)
- Final approach direction is negative (HOMDF1)
- Stop on the negative-travel side of the home switch active region (HOMEDG1)

Figure H:



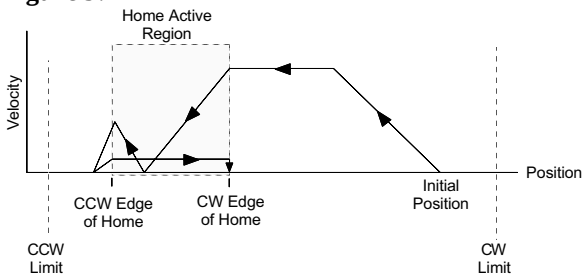
Home Profile Attributes (commands):
- Start home move in negative direction (HOM1)
- Backup To Home enabled (HOMBAC1)
- Final approach direction is negative (HOMDF1)
- Stop on the positive-travel side of the home switch active region (HOMEDG0)

Figure I:



Home Profile Attributes (commands):
- Start home move in negative direction (HOM1)
- Backup To Home enabled (HOMBAC1)
- Final approach direction is positive (HOMDF0)
- Stop on the negative-travel side of the home switch active region (HOMEDG1)

Figure J:



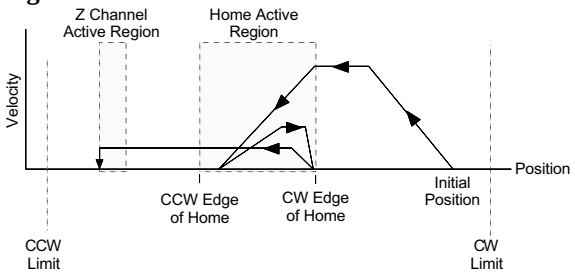
Home Profile Attributes (commands):
- Start home move in negative direction (HOM1)
- Backup To Home enabled (HOMBAC1)
- Final approach direction is positive (HOMDF0)
- Stop on the positive-travel side of the home switch active region (HOMEDG0)

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Homing Using The Z-Channel

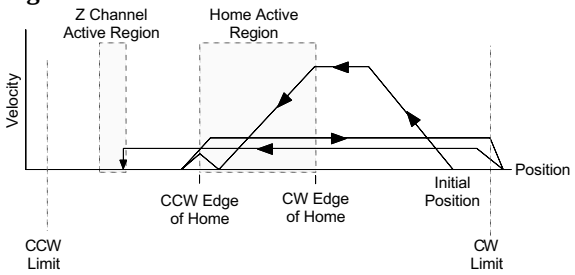
Figures K through O show the homing operation when homing to an encoder index pulse, or Z channel, is enabled (HOMZ1). The Z-channel will only be recognized after the home input is activated. It is desirable to position the Z channel within the home active region; this reduces the time required to search for the Z channel. *"CW" refers to the positive direction and "CCW" refers to the negative direction.*

Figure K:



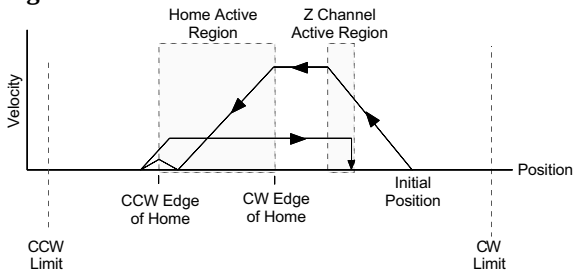
Home Profile Attributes (commands):
- Z-Channel homing enabled (HOMZ1)
- Start home move in negative direction (HOM1)
- Backup To Home enabled (HOMBAC1)
- Final approach direction is negative (HOMDF1)
- Stop on the negative-travel side of the z-channel active region (HOMEDG1)

Figure L:



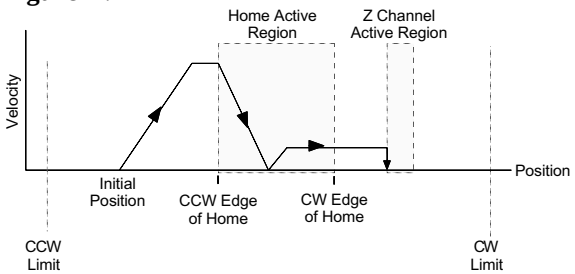
Home Profile Attributes (commands):
- Z-Channel homing enabled (HOMZ1)
- Start home move in negative direction (HOM1)
- Backup To Home enabled (HOMBAC1)
- Final approach direction is positive (HOMDF0)
- Stop on the positive-travel side of the z-channel active region (HOMEDG0)

Figure M:



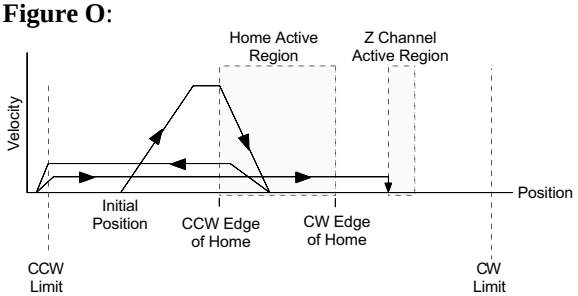
Home Profile Attributes (commands):
- Z-Channel homing enabled (HOMZ1)
- Start home move in negative direction (HOM1)
- Backup To Home enabled (HOMBAC1)
- Final approach direction is positive (HOMDF0)
- Stop on the positive-travel side of the z-channel active region (HOMEDG0)

Figure N:



Home Profile Attributes (commands):
- Z-Channel homing enabled (HOMZ1)
- Start home move in positive direction (HOM0)
- Backup To Home disabled (HOMBAC0)
- Final approach direction is positive (HOMDF0)
- Stop on the positive-travel side of the z-channel active region (HOMEDG0)

Figure O:



Home Profile Attributes (commands):
- Z-Channel homing enabled (HOMZ1)
- Start home move in positive direction (HOM0)
- Backup To Home enabled (HOMBAC1)
- Final approach direction is positive (HOMDF0)
- Stop on the positive-travel side of the z-channel active region (HOMEDG0)

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Encoder-Based Stepper Operation (stepper only)

When using an encoder in a stepper application, you may configure the following:

- Encoder resolution
- Stall Detection & Kill-on-Stall, Stall Deadband
- Encoder-based position reference and position capture

Encoder Resolution

You must specify the encoder resolution with the ERES command.

Stall Detection & Kill-on-Stall

To detect stalls without an encoder, refer to *Drive Stall Detection* on page 66.

The ESTALL1 command enables the drive to detect encoder-based stall conditions. **NOTE**: Encoder count reference must be enabled (ENCCNT1) before stall detect (ESTALL) can be used.

If used with *Kill-on-Stall* enabled (ESK1 command), the move in progress will be aborted upon detecting a stall. If queried with the ER or the AS commands, the user may branch to any other section of program when a stall is detected. Refer to the ER, and AS command descriptions in the *Gem6K Series Command Reference* for more information.

Kill-on-Stall functions only if the stall detection is enabled (ESTALL1).

⚠ WARNING ⚠

Disabling the Kill-on-Stall function with the ESKØ command will allow the controller to finish the move regardless of a stall detection, even if the load is jammed. **This can potentially damage user equipment and injure personnel.**

Stall Deadband

Another encoder set-up parameter is the Stall Backlash Deadband (ESDB) command. This command sets the number of commanded counts of error allowed, after a change in direction, before a stall will be detected. This is useful for situations in which backlash in a system can cause false stall situations.

Encoder Set Up Example

The example below illustrates the features discussed in the previous paragraphs. The DRES statement defines the motor resolutions. The ERES statement defines the number of encoder steps per encoder revolution. A standard 1000-line encoder is used that produces 4000 quadrature steps/rev. Encoder counting (ENCCNT), stall detect (ESTALL) and kill-on-stall (ESK1) are enabled. If a stall is detected (more than 10 steps out without an encoder step back), the motor's movement is killed. The ESDB statement defines the stall deadband.

Examples for 4 Axes (command line samples)

```
DRES25000                    ; Set drive resolution
ERES4000                     ; Set encoder resolution
ESK1                         ; Enable kill motion on stall
ENCCNT1                      ; Enable encoder counting (this is
                             ; required for ESTALL to work)
ESTALL1                      ; Enable stall detection
ESDB0                        ; Set stall deadband
```


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Encoder Count/Capture Referencing

Use ENCCNT to configure steppers to reference either the encoder position or the commanded position when capturing the position (see INFNCi-H) and checking the encoder position (PE and TPE). When checking the actual velocity (VELA and TVELA), ENCCNT determines whether the velocity, in units of revs/sec, is derived with the encoder resolution (ERES) or the drive resolution (DRES). The default setting (ENCCNT0) references the commanded position.

Example

```
INFNC1-H    ; Configure trigger 1A as position capture input
ENCCNT10    ; Capture encoder position when trigger 1A is activated
```

Tuning Procedures (servos only)

During the *Express Setup* procedure shown in the *Hardware Installation Guide, Chapter 2 Installation*, the drive uses default values for tuning parameters, based upon the motor information you entered. That procedure assumes that the motor is ***unloaded***. In the following tuning procedures, you will enter in system information that will characterize the load on the motor. **Before you continue with the tuning procedures you must have first configured your drive for the motor being used. See the *Express Setup* section in the *Hardware Installation Guide, Chapter 2: Installation.***

Entering Load Settings

The main load setting you will adjust is LJRAT, which is the load-to-rotor inertia value for your system. The more accurately you know this value, the closer your tuning bandwidth settings will correspond to the actual dynamic performance of your system. If you only know this value approximately, you can adjust this value until you achieve the system performance you desire. The total system inertia is given by the following formula:

$$\textit{Total system inertia} = \textit{motor rotor inertia} * (1 + \textit{LJRAT})$$

If your system has significant mechanical damping, you will also want to adjust the LDAMP setting which specifies system damping provided by the load. If you know that you have significant damping in your system from your load but do not know its exact value, you can adjust this value until you achieve the system performance that you desire.

Both the LJRAT and the LDAMP values can be set in the *Full Setup* section of the GV6K wizard in Motion Planner. These values can also be set in the terminal mode of Motion Planner. During the tuning process you may want to use the terminal emulator to establish appropriate values for these parameters and then upload and save the drive's full configuration settings for use with other units.

Position Mode Tuning

For most applications, the default tuning parameters for position mode are set to provide good, stiff motor shaft performance for a given load setting. With the default tuning parameters set in the Express Setup procedure, you need only set the system load-to-rotor inertia ratio and your system will be tuned. If your system has significant mechanical damping, you may need to set the system damping as well. Should you wish to modify the default values and fine tune your system for position mode, use the following procedures:

WARNING

This procedure causes the motor shaft to move. Make sure that shaft motion will not damage equipment or injure personnel.

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Position Mode Tuning Procedure

Primary Tuning Procedure

1. Disable the drive.
2. Configure the drive for *position tuning mode* (DMODE17). In this mode, the drive commands an alternating 1/4 revolution step change in position at a one second repetition rate.
3. Enable the drive and observe your system's response. (If necessary, you can connect an oscilloscope as described in *Advanced Tuning* below.)
   Ringing or an oscillating response indicates that the position loop bandwidth is too high. To eliminate oscillations:
   - decrease bandwidth using the DPBW command.

   A sluggish response indicates that position loop bandwidth is too low. To improve the response:
   - increase bandwidth by using the DPBW command.

   NOTE: Ringing, oscillations, or a sluggish response can also indicate inaccurate drive settings for LJRAT or LDAMP.
4. After you achieve a satisfactory system response, reconfigure the drive for position mode (DMODE12). This completes the primary tuning procedure.
   If you are unable to achieve a satisfactory response, proceed to the advanced tuning procedure below.

Advanced Tuning Procedure

1. Disable the drive.
2. Configure the drive for *position tuning mode* (DMODE17). In this mode, the drive commands an alternating 1/4 revolution step change in position at a one second repetition rate.
   (In some applications a different move profile may give better results. Choose a move similar to that required by your application, but using fast acceleration and deceleration rates. Be sure the maximum velocity of your move is well below the rated speed of your drive/motor combination.
3. Configure ANALOG MONITOR A to show position error (DMONAV3).
4. Connect one channel of your oscilloscope to the drive's ANALOG MONITOR A (pin 21). Connect your oscilloscope's ground to the drive's ANALOG GROUND (pin 25).
5. Adjust your oscilloscope to display position error. (The analog monitor can be scaled, in percent, with the DMONAS command.)
6. Enable the drive and observe your system's response. Position error will increase during acceleration, but should decay smoothly to near zero without significant ringing or instability.
   Ringing or an oscillating response indicates that the position loop bandwidth is too high, or the position loop damping is too low. To eliminate ringing or oscillations:
   - decrease bandwidth using the DPBW command; then, if necessary:
   - adjust damping by using the SGPRAT command. Use the value that gives the best performance.
   - in applications with backlash or high static friction, disabling the velocity integrator (SGINTE0) can help improve stability.
   - NOTE: In position mode, the velocity loop bandwidth tracks changes in position loop bandwidth by a ratio set by the SGPSIG command.

   A sluggish response indicates that position loop bandwidth is too low, or position loop damping is too high. To improve the response:
   - increase bandwidth by using the DPBW command; then, if necessary:
   - adjust damping by using the SGPRAT command. Use the value that gives the best performance.

   NOTE: Ringing or a sluggish response can also indicate inaccurate drive settings for LJRAT or LDAMP.
7. After you achieve a satisfactory system response, reconfigure the drive for position mode (DMODE12). This completes the advanced tuning procedure.

If ringing or oscillations persist, and do not seem to be affected by the above adjustments, you may need to use notch filters or lead/lag filters. See the *Filter Adjustments* procedure below.

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Filter Adjustments

If the previous tuning procedures did not eliminate ringing or oscillations, then mechanical resonances may be causing problems with your system's response.

Before trying the procedure below, we recommend that you check your mechanical system, especially the mechanical stiffness and mounting rigidity of your system. Use bellows or disk style couplers, not helical couplers. Once you have optimized your mechanical system, filters may allow increased performance, without causing system instability.

Filters can improve response by reducing system gain over the same frequencies that contain resonances. You can then increase the gain for frequencies outside this range, without exciting the resonance and causing instability.

The first procedure below describes how to set the drive's two notch filters, to reduce resonance and improve your system's response. The second and third procedures describe how to set the drive's lead and lag filters.

WARNING

These procedures cause the motor shaft to move. Make sure that shaft motion will not damage equipment or injure personnel.

Notch Filter Adjustment Procedure

1. Configure the analog monitor to show q-axis current (DMONAV19).
2. Configure the drive for position tuning mode (DMODE17).
3. Configure DMTLIM to approximately 1/3 of the default value for your Compumotor motor.
4. Connect one channel of your oscilloscope to the drive's ANALOG MONITOR A (pin 21). Connect your oscilloscope's ground to the drive's ANALOG GROUND (pin 25).
5. From the oscilloscope display, observe the system's response to the tuning mode's step input. Note the frequency of the oscillatory current waveform that is superimposed on the 1 Hz step command signal.
6. Using the DNOTAF command, set the notch filter to the frequency noted in Step 5.
7. Using the DNOTAD command, slowly increase the depth of the notch filter from 0.0 to 1.0 until the ringing decreases.
8. Continue to observe the response to step command signal. Ringing should be reduced or eliminated.
9. Adjust the Q of the filter (DNOTAQ command). Use the following guidelines:
   - Set Q as low as possible. Resonances change with load; therefore, your system will be more robust with a lower Q value. (Default = 1)
   - If Q is too low, system stiffness will be reduced outside the resonant range.
   - If Q is too high, the response peak may shift in frequency.
10. After reducing the resonance, you may notice a second resonance. Use the second notch filter (DNOTBF, DNOTBD and DNOTBQ) to reduce the second resonance. Follow the same procedure as outlined in steps 1 – 9 above.
11. If you are done adjusting filters, reconfigure DMTLIM to its default value. Otherwise, proceed to the *Lag Filter Adjustment* procedure below.

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Lag Filter Adjustment Procedure

The lag filter can act as a low pass filter, and reduce the effects of electrical noise on the commanded torque. (It can also reduce the effects of resonance at low frequencies—below 60 Hz—where the notch filters are not effective.)

1. As described in Steps 2 – 3 in the *Notch Filter Adjustment* procedure above, reduce DMTLIM and connect an oscilloscope.
2. Verify that the lead filter is turned off (DNOTLDØ).
3. Configure the drive for position tuning mode. Observe the system's response to the tuning mode's step input.
4. Choose a value for the lag filter (DNOTLG) that reduces low frequency resonance and provides satisfactory system performance.
5. If you are done adjusting filters, reconfigure DMTLIM to its default value. Otherwise, proceed to the *Lead /Lag Filter Adjustment* procedure below.

Lead/Lag Filter Adjustment Procedure

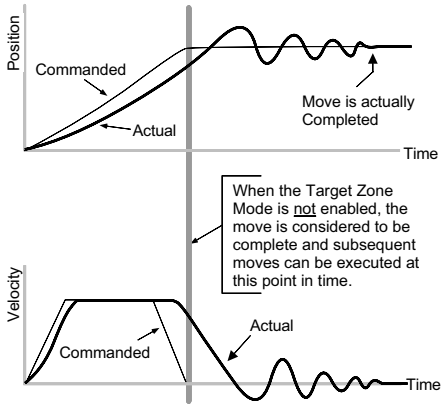
The lead filter can counteract the effects of the lag filter at higher frequencies. Do not use the lead filter by itself—if you use the lead filter, you must also use the lag filter.

1. As described in Steps 2 – 3 in the *Notch Filter Adjustment* procedure above, reduce DMTLIM and connect an oscilloscope.
2. Set the lag filter (DNOTLG) as described above.
3. Configure the drive for position tuning mode. Observe the system's response to the tuning mode's step input.
4. Choose a value for the lead filter (DNOTLD) that improves system performance. This value will typically be higher in frequency than the lag filter setting.
5. You must choose a value for the lead filter that is *higher* in frequency than the lag filter value. However, do not set the lead filter higher than four times the lag filter frequency, or a drive configuration warning will result, and the drive will use the previous filter settings.
6. If you are done adjusting filters, reconfigure DMTLIM to its default value.

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Target Zone Mode *(move completion criteria for servos only)*

Under default operation (Target Zone Mode not enabled), the Gem6K product's move completion criteria is simply derived from the move trajectory. The Gem6K product considers the current preset move to be complete when the commanded trajectory has reached the desired target position; after that, subsequent commands/moves can be executed. Consequently, the next move or external operation can begin before the actual position has settled to the commanded position (see diagram).



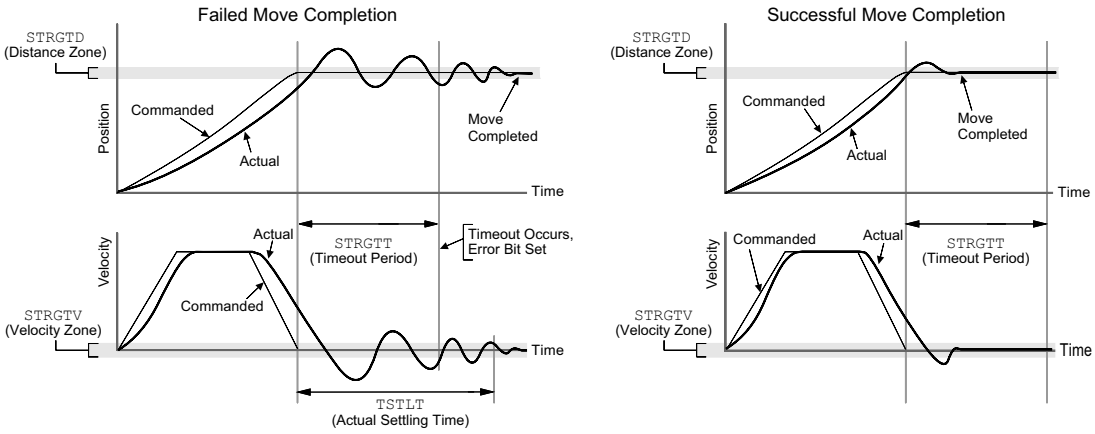
To prevent premature command execution before the actual position settles into the commanded position, use the *Target Zone Mode*. In this mode, enabled with the STRGTE command, the move cannot be considered complete until the actual position and actual velocity are within the *target zone* (that is, within the distance zone defined by STRGTD and less than or equal to the velocity defined by STRGTV). If the load does not settle into the target zone before the timeout period set with the STRGTT command, the Gem6K product detects a *timeout error* (see illustration below).

If the timeout error occurs, you can prevent subsequent command/move execution only if you enable the ERROR command to continually check for this error condition, and when it occurs to branch to a programmed response you can define in the ERRORP program. (Refer to the *Error Handling* section, page 30, for error program examples.)

As an example, setting the distance zone to ±5 counts (STRGTD5), the velocity zone to ≤0.5 revs/sec (STRGTV0.5), and the timeout period to 1/2 second (STRGTT500), a move with a distance of 8,000 counts (D8000) must end up between position 7,995 and 8,005 and settle down to ≤0.5 rps within 500 ms (1/2 second) after the commanded profile is complete.

Damping is critical

To ensure that a move settles within the distance zone, it must be damped to the point that it will not move out of the zone in an oscillatory manner. This helps ensure the actual velocity falls within the target velocity zone set with the STRGTV command (see illustration below).



Checking the Settling Time

Checking the Actual Settling Time: Using the TSTLT command, you can display the actual time it took the last move to settle into the target zone (that is, within the distance zone defined by STRGTD and less than or equal to the velocity defined by STRGTV). The reported value represents milliseconds. The TSTLT command is usable whether or not the Target Zone Settling Mode is enabled with the STRGTE command.

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Programmable Inputs and Outputs *(onboard and external inputs & outputs)*

Programmable inputs and outputs allow the controller to detect and respond to the state of switches, thumbwheels, electronic sensors, and outputs of other equipment such as drives and PLCs. The I/O that may be used as programmable inputs and outputs are:

- Onboard I/O:
  - Limit inputs on the Drive I/O connector (pins 28, 29, and 31)
  - Trigger inputs on the Drive I/O connector (pins 37 and 38). A "master trigger" is also available on the Drive I/O connector (pin 35). These are general purpose on board digital inputs but can be redefined as trigger inputs.
  - Digital outputs on the Drive I/O connector (pins 41, 43, 45, 46, 48, and 49)
  - Relay output on the +24VDC power input connector (screw terminals)
- Expansion I/O located on I/O bricks connected to the Gem6K controller's "EXPANSION I/O" connector. Each I/O brick can hold from 1 to 4 of these I/O SIM modules in any combination (each SIM module provides 8 inputs or outputs, for a total of 32 I/O points per I/O brick):
  - Digital inputs
  - Digital outputs
  - Analog inputs
  - Analog outputs

USING THE STATE OF I/O TO CONTROL PROGRAMMED EVENTS: Based on the binary state of the inputs and outputs (binary status can be used in assignment/comparison operations using the `LIM`, `IN` and `OUT` operators), the controller can make program flow decisions and assign values to binary variables for subsequent mathematical operations. These operations and the associated program flow, branching, and variable commands are listed below.

Operation based on I/O State	Associated Commands	See Also*
I/O state assigned to a binary variable	`LIM`, `[IN]`, `[OUT]`, `VARB`	*Variables* (page 18)
I/O state used as a basis for comparison in conditional branching & looping statements	`LIM`, `[IN]`, `[OUT]`, `IF`, `ELSE`, `NIF`, `REPEAT`, `UNTIL`, `WAIT`, `WHILE`, `NWHILE`	*Program Flow Control* (page 23)
Input state used as a basis for a conditional `GO`	`[IN]`, `GOWHEN`, `LIM`	*Synchronizing Motion* (page 163)
I/O state used as a basis for a program interrupt (GOSUB) conditional statement	`ONIN`	*Program Interrupts* (page 29)
Mimic PLC functionality by scanning I/O states with a compiled program	`PLCP`, `SCANP`	*PLC Scan Mode* (page 120)

* Refer also to the respective command descriptions in the *Gem6K Series Command Reference*.

I/O UPDATE RATE: The programmable inputs and outputs are sampled at the "system update rate," which is every 2 ms.

EXPANSION I/O BRICKS: If the I/O brick is disconnected or if it loses power, the controller will perform a kill (all tasks) and set error bit #18 (see `ERROR`). (If you disable the "Kill on I/O Disconnect" mode with `KIOENØ`, the Gem6K will not perform the kill.) The controller will remember the brick configuration (volatile memory) in effect at the time the disconnection occurred. When you reconnect the I/O brick, the controller checks to see if anything changed (SIM by SIM) from the state when it was disconnected. If an existing SIM slot is changed (different SIM, vacant SIM slot, or jumper setting), the controller will set the SIM to factory default `INEN` and `OUTLVL` settings. If a new SIM is installed where there was none before, the new SIM is auto-configured to factory defaults.

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Programmable I/O Bit Patterns

The Gem6K has programmable inputs and outputs. The total number of onboard inputs and outputs (analog inputs, digital inputs, and digital outputs) is fixed. The total number of expansion inputs and outputs (analog inputs, analog outputs, digital inputs and digital outputs) depends on your configuration of expansion I/O bricks.

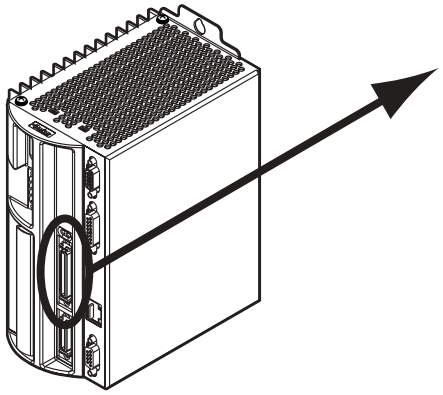
These programmable I/O are represented by binary bit patterns, and it is the bit pattern that you reference when programming and checking the status of specific inputs and outputs. The bit pattern is referenced 1 to *n*, from left to right.

- Onboard I/O. For example, the status command to check all onboard digital inputs is `TIN`.
  An example response is: `*TIN0100_0`.
  Bit 1 — Bit 5
- Expansion I/O. For example, the status command to check all digital inputs on I/O brick 2 is `2TIN`.
  An example response is: `*2TIN0010_0110_1100_0000_XXXX_XXXX_XXXX_XXXX`.
  I/O Brick 2 — Bit 1 — Bit 32

Onboard Programmable I/O

I/O	Location	Programming	Status Report, Assignment
Limit Inputs	"DRIVE I/O" connector	`LIMFNC`, `LIMEN`, `LIMLVL`	`TLIM`, `LIM`
Digital Inputs	"DRIVE I/O" connector	`INFNC`, `INLVL`, `INEN`, `ONIN`, `INPLC`, `INSTW`	`TIN`, `IN`
Outputs (digital)	"DRIVE I/O" connector	`OUT`, `OUTFNC`, `OUTLVL`, `OUTEN`, `OUTALL`, `OUTPLC`, `OUTTW`, `POUT`	`TOUT`, `[OUT]`
Analog Input	"DRIVE I/O" connector	`JOYAXH`, `JOYCDB`, `JOYCTR`, `JOYEDB`, `ANIRNG`, `ANIMAS`	`TANI`, `[ANI]`

Limit Inputs ("DRIVE I/O" connector)



Input bit pattern for `LIM`, `TLIM`, `LIMEN`, `LIMFNC`, and `LIMLVL`:

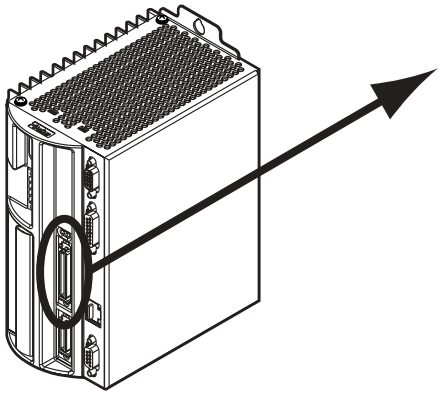
Bit #	Pin #	Function *
1	28	Positive end-of-travel limit
2	29	Negative end-of-travel limit
3	31	Home limit

* The functions listed are the factory default functions; other functions may be assigned with the `LIMFNC` command.

Sample response to `TLIM` (limit inputs status) command:
`*TLIM110`

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Digital Inputs (“DRIVE I/O” connector)



Input bit pattern for `TIN`, `IN`, `INFNC`, `INLVL`, `INEN`, `INPLC`, `INSTW`, `ONIN`:

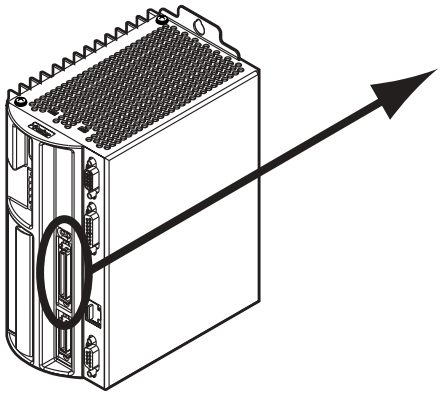
Bit #	Pin #	Function *
1	37	Input 1 (if assigned, TRIG-A)
2	38	Input 2 (if assigned, TRIG-B)
3	39	Input 3
4	34	Input 4
5	35	Input 5 (if assigned, TRIG-M)

* If the input is assigned the “trigger interrupt” function with the `INFNCi-H` command:
TRIG-A must be on Input 1
TRIG-B must be on Input 2
TRIG-M must be on input 5

Sample response to `TIN` (input status) command:

```
*TIN0010_1
```

Digital Outputs (“DRIVE I/O” connector)



Output bit pattern for `TOUT`, `[OUT]`, `OUT`, `OUTFNC`, `OUTLVL`, `OUTEN`, `OUTALL`, `OUTPLC`, `OUTTW`, `POUT`:

Bit #	Pin #	Function
1	41	Output 1.
2	43	Output 2.
3	45	Output 3.
4	46	Output 4.
5	48	Output 5.
6	49	Output 6.
7	Relay	Output 7.

Sample response to `TOUT`
(onboard outputs status) command:

```
*TOUT0000_000
```


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Expansion I/O Bricks

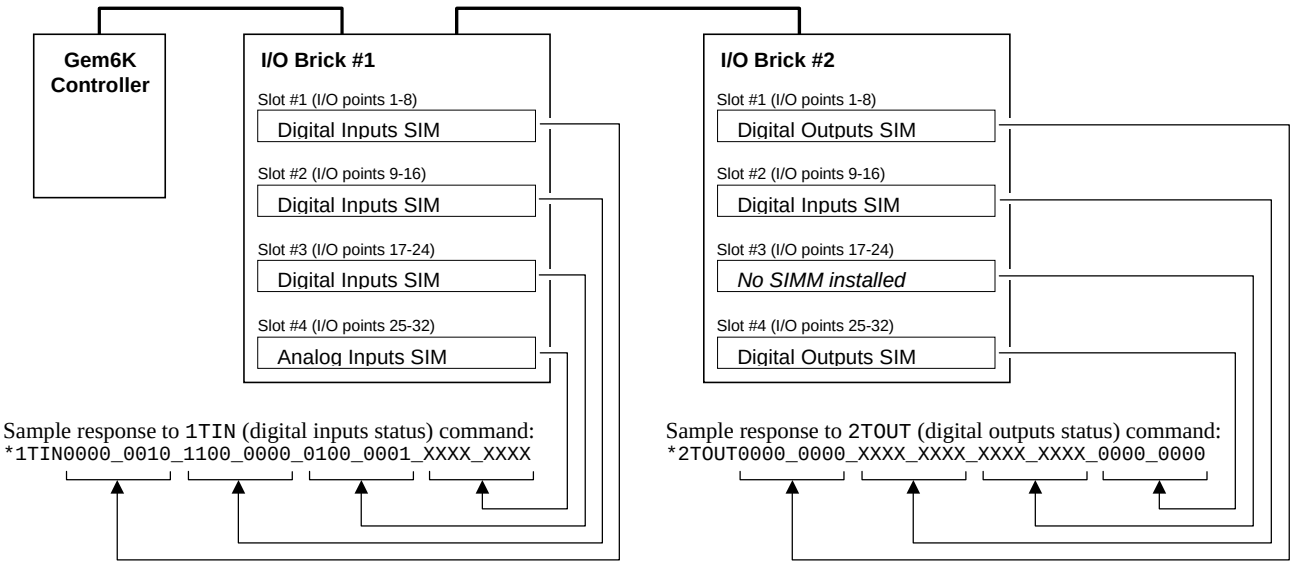
The Gem6K product allows you to expand your system I/O by connecting up to 8 I/O bricks (see *Installation Guide* for connections). Expansion I/O bricks may be ordered separately (referred to as the "EVM32"). Each I/O brick can hold from 1 to 4 of these I/O SIM modules in any combination:

SIM Type	Programming	Status Report, Assignment
Digital Inputs SIM (8 inputs)	INFNC, INLVL, INEN, ONIN, INPLC, INSTW	TIN, IN, TIO
Digital Outputs SIM (8 outputs)	OUT, OUTFNC, OUTLVL, OUTEN, OUTALL, OUTPLC, OUTTW, POUT	TOUT, [OUT], TIO
Analog Inputs SIM (8 inputs)	• Enable/Disable: ANIEN. • Voltage range: ANIRNG. • Joystick setup: JOYAXH, JOYAXL, JOYCDB, JOYCTR, JOYEDB, JOYZ. • Following master source: ANIMAS, FOLMAS	• Voltage: TANI, ANI, TIO • Servo position: TPANI, PANI, FB, TFB
Analog Outputs SIM (8 outputs)	ANO	TANO, [ANO], TIO

Each I/O brick has a unique "brick address", denoted with the "<B>" symbol in the command syntax. The I/O bricks are connected in series to the "EXPANSION I/O" connector on the Gem6K. The 1st I/O brick has address #1, the next brick has address #2, and so on. (**NOTE**: If you leave out the brick address in the command, the Gem6K product assumes you are addressing the command to the onboard I/O.) Each I/O brick has 32 I/O addresses, referenced as absolute I/O point locations:

- SIM slot 1 = I/O points 1-8
- SIM slot 2 = I/O points 9-16
- SIM slot 3 = I/O points 17-24
- SIM slot 4 = I/O points 25-32

Example:



The TIO command identifies the connected I/O bricks (and installed SIMs), including the status of each I/O point:

```
*BRICK 1:  SIM Type         Status      Function
      1-8: DIGITAL INPUTS   0000_0000   AAAA_AAAA
     9-16: DIGITAL INPUTS   0000_0000   AAAA_AAAA
    17-24: DIGITAL INPUTS   0000_0000   AAAA_AAAA
    25-32: ANALOG INPUTS    0.000,0.000,0.000,0.000,0.000,0.000,0.000,0.000

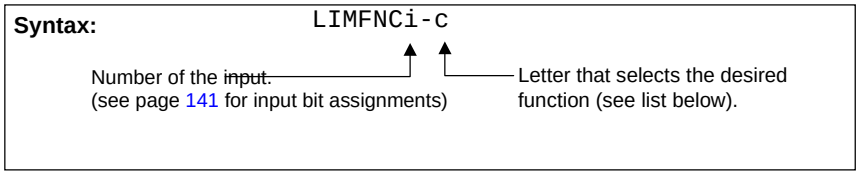
*BRICK 2:  SIM Type         Status      Function
      1-8: DIGITAL OUTPUTS  0000_0000   AAAA_AAAA  -- SINKING
     9-16: DIGITAL INPUTS   0000_0000   AAAA_AAAA
    17-24: NO SIM PRESENT
    25-32: DIGITAL OUTPUTS  0000_0000   AAAA_AAAA  -- SOURCING
```


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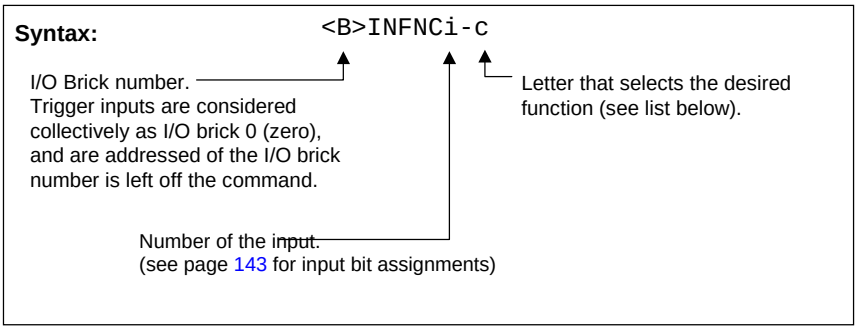
Input Functions

Programmable input functions may be assigned to the digital inputs on the Gem6K, as well as to digital inputs on an expansion I/O brick connected to the Gem6K product. The appropriate input function command (`LIMFNC` or `INFNC`) depends on which input you are configuring:

- Onboard limit inputs — use `LIMFNC`:



- Onboard digital inputs and digital inputs installed on an expansion I/O brick — use `INFNC`:



Virtual Inputs

Virtual Inputs provide programming input functionality for data or external events that are not ordinarily represented by inputs. The Virtual Input Override (`IN`) command allows you to substitute almost any 32-bit data operand as a virtual input brick of 32 inputs (integer values are converted to binary). Page 8 provides a list of the data operands; the only data operands that are not allowed are: `SIN`, `COS`, `TAN`, `ATAN`, `VCVT`, `SQRT`, `VAR`, `TW`, `READ`, `DREAD`, `DREADF`, `DAT`, `DPTR`, and `PI`.

The virtual inputs behave similar to real inputs in that they are affected by `INEN` and `INLVL`, and they affect `INFNC`, `INPLC`, `INSTW`, `INDUST`, `ONIN`, and `GOWHEN(<B>IN=b<bbbb>)` commands. Unlike real inputs, virtual inputs are not affected by the `INDEB` debounce setting.

NOTE: A virtual input can only be defined for expansion I/O bricks that are not connected on the serial I/O network (remember that up to 8 I/O bricks are allowed). For example, if your Gem6K unit has two I/O bricks, you can designate I/O bricks 3-8 as virtual I/O bricks.

EXAMPLE: Suppose a PLC is sending binary data via the `VARB1` command to the Gem6K. If the binary state of `VARB1` is assigned to input brick 2 `(2IN=VARB1)`, the Gem6K can respond based on programmable input functions set up with the `INFNC` command.

```
2TIN            ; Brick 2 is not connected; therefore, the Gem6K will
                ; respond with an error message: "*INCORRECT I/O BRICK"
2IN=VARB1       ; Map the binary state of VARB1 to be the input state
                ; of "virtual" input brick 2 (2IN)
VARB1=b10100000 ; Change "virtual" input brick 2IN to a new VARB1 value
2TIN            ; Check the input status. The response will be:
                ; "*2IN1010_0000_0000_0000_0000_0000_0000_0000"
```


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Letter Designator	Function
A	General-purpose input (**default function for onboard and expansion digital inputs on I/O bricks**)
B	BCD program select
C	Kill
D	Stop
E	Pause/Continue
F	User fault
G	<RESERVED>
H	Trigger Interrupt for position capture or registration (trigger inputs only). Special trigger functions can be assigned with the TRGFN command (see page 166).
I	Cause an "Alarm Event" over the Ethernet interface
J	Jog in the positive-counting direction
K	Jog in the negative-counting direction
L	Jog velocity select
M	Joystick release
O	Joystick velocity select
P	One-to-one program select
Q	Program security
R	End-of-travel limit for positive-counting direction *
S	End-of-travel limit for negative-counting direction *
T	Home limit *

* Limit inputs are factory-set to their respective end-of-travel or home limit function (see page 74).

NOTES

- **Multi-tasking:** If the LIMFNC or INFNC command does not include the task identifier (%) prefix, the function affects the task that executes the LIMFNC or INFNC command. The only functions that may be directed to a task with % are: C, D, E, F, and P (e.g., 2%INFNC3-F assigns onboard input 3 as a user fault input for task 2). Multiple tasks may share the same input, but the input may only be assigned one function.

Input Status

Below is a list of the status commands you may use to ascertain the current state and/or defined function of the limit inputs (LIMFNC) and trigger and I/O brick inputs (INFNC).

* The purpose of the IN and LIM operators is to use the state of the inputs as a basis for conditional statements (IF, REPEAT, WHILE, GOWHEN, etc.) or for binary variable assignments (VARB). For examples, refer to the *Conditional Looping and Branching* section on page 25.

Limit inputs (LIMFNC):

- Status display commands:
  - LIMFNC..... Active state and programmed function of all limit inputs
  - LIMFNCi..... Same as LIMFNC display, but only for the input number ("i")
  - TLIM..... Hardware state of all limit inputs (binary report); use TLIM.i to check the state of only one input ("i")
- Status assignment/comparison operator: *
  - LIM..... Hardware state (binary) of all limit inputs; use LIM.i to check the state of only one input ("i")

Trigger inputs and digital inputs on expansion I/O bricks (INFNC):

- Status display commands:
  - TIO..... I/O brick configuration (which SIMs are present)
  - INFNC ..... Active state and programmed function of all trigger inputs
  - INFNCi..... Same as INFNC display, but only for the trigger input number ("i")
  - <B>INFNC ..... Active state and programmed function of all inputs on I/O brick B
  - <B>INFNCi..... Same as INFNC display, but only for the input number ("i") on brick B
  - TIN..... Hardware state of all onboard trigger inputs (binary report); use TIN.i to check the state of only one input ("i")
  - <B>TIN..... Hardware state of all digital inputs on I/O brick B (binary report) ; use <B>TIN.i to check the state of only one input ("i") on brick B
- Status assignment/comparison operator: *
  - <B>IN ..... Hardware state (binary) of triggers and expansion digital inputs; use <B>IN.i to check the state of only one input ("i") on brick B

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Input Active Levels

Many people refer to a voltage level when referencing the state of programmable inputs and outputs. Using LIMLVL (for limit inputs) and INLVL (for triggers and I/O brick inputs), you can define the logic levels of the programmable inputs as positive or negative. The Gem6K product defaults to an input level of zero volts as its active level (referred to as "active low"); thus, a "1" will appear in a status command (TLIM & LIM, or TIN & IN) referencing an input state when the voltage level is zero volts.

Active Level Setting	State	LIM/TLIM or IN/TIN Report
Active Low, *the default setting* • LIMLVL0 for limits • INLVL0 for triggers/I/O bricks	Grounded — sinking current (device drive the input is on)	1 (active)
	Not Grounded — not sinking current (device drive the input is off)	0 (inactive)
Active High • LIMLVL1 for limits • INLVL1 for triggers/I/O bricks	Grounded — sinking current (device drive the input is on)	0 (inactive)
	Not Grounded — not sinking current (device drive the input is off)	1 (active)

Input Debounce Time

Using the INDEB command, you can change the input debounce time for programmable inputs. The debounce is the period of time that the input must be held in a certain state before the controller recognizes it. This directly affects the rate at which the inputs can change state and be recognized. The default setting is 4 ms. For example, to set the debounce for all digital inputs on I/O brick 2 to 5 ms, use the 2INDEB6 command.

Exception for Trigger Inputs: For trigger inputs that are assigned the "Trigger Interrupt" function (INFNCi-H), the debounce is instead governed by the TRGLOT setting. The TRGLOT setting applies to all trigger inputs defined as "Trigger Interrupt" inputs. The TRGLOT debounce time is the time required between a trigger's initial active transition and its secondary active transition. This allows rapid recognition of a trigger, but prevents subsequent bouncing of the input from causing a false position capture. The default TRGLOT setting is 24 ms.

Limit Inputs. The limit inputs found on the connectors are not normally debounced; however, if a limit is assigned a different function with the LIMFNC command (other than LIMFNCi-R, LIMFNCi-S, or LIMFNCi-T), the input is debounced using the INDEB setting for the on-board trigger inputs (I/O brick 0). If a I/O brick input or an onboard trigger input is assigned a limit input function (INFNCi-R, INFNCi-S, or INFNCi-T), the input will not be debounced.

"General Purpose"

- LIMFNCi-A
- INFNCi-A

This is the default function for INFNC inputs (onboard digital inputs and I/O brick inputs). When an input is defined as a *General Purpose* input, the input is used as a standard input. You can then use this input to synchronize or trigger program events, through the use of the LIM or IN operator.

Example

```
DEL prog1       ; Precaution: Delete a program before defining it
DEF prog1       ; Begin definition of program prog1
INFNC1-A        ; No function (general purpose) for input 1
INFNC2-A        ; No function (general purpose) for input 2
INFNC3-D        ; Input 3 is a stop input
A10             ; Set acceleration
V10             ; Set velocity
D5              ; Set distance
WAIT(IN=b1XX)   ; Wait for onboard input 1
GO              ; Initiate motion
IF(IN=bX1)      ; If onboard input 2
TFB             ; Transfer feedback device position
NIF             ; End IF statement
END             ; End definition of program prog1
```


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BCD Program Select

- `LIMFNCi-B`
- `INFNCi-B`

The *BCD program select* function allows you to execute defined programs by activating the program select inputs.

BCD program select inputs are assigned BCD weights, with the least weight on the smallest numbered input. The next BCD weight is assigned to the next input defined as a BCD input. For example, the table to the right shows the BCD weights if inputs 1-8 are configured as program select inputs.

Input #	BCD Weight
Input 1	1
Input 2	2
Input 3	4
Input 4	8
Input 5	10
Input 6	20
Input 7	40
Input 8	80

To execute a particular program, you activate the combination of inputs to achieve the BCD weight that corresponds to the *number of the program* (see note below). For example, if inputs 1-8 are defined as BCD inputs (as in the example above), activating inputs 4 and 6 would execute program #28, activating inputs 1 and 4 would execute program #9, and so on.

Program Numbers

A program's number is determined by the order in which the program was downloaded to the controller. The number of each program stored in the controller's memory can be obtained through the `TDIR` command — refer to the number reported in front of each program name. When selecting programs with BCD Program Select inputs, a program is executed when the total BCD weight of the active BCD inputs equals the program's number.

Before you can execute programs using the BCD program select inputs, you must first enable scanning with the `INSELP1` command. Once enabled, the controller will continuously scan the BCD inputs and execute the program (by number) according to the weight of the currently active BCD inputs. After executing and completing the selected program, the controller will scan the inputs again. NOTE: To disable scanning, enter `!INSELPØ` or place `INSELPØ` in a program that can be selected.

The `INSELP` command also determines how long the BCD program select input level must be maintained before the controller executes the program. This delay is referred to as debounce time (but is not affected by the `INDEB` setting).

Example

```
RESET       ; Return controller to power-up conditions
ERASE       ; Erase all programs
DEF PROG1   ; Begin definition of program PROG1
TPE         ; Transfer position of encoder
END         ; End program
DEF PROG2   ; Begin definition of program PROG2
TREV        ; Transfer software revision
END         ; End program
DEF PROG3   ; Begin definition of program PROG3
TSTAT       ; Transfer statistics
END         ; End program
INFNC1-B    ; Assign onboard input 1 as a BCD program select input
INFNC2-B    ; Assign onboard input 2 as a BCD program select input
INSELP1,50  ; Enable scanning inputs, levels must be maintained for 50ms
TDIR        ; Display number and name of programs stored in memory
; response from TDIR should be similar to following:
;          *1 - PROG1 USES 6 BYTES
;          *2 - PROG2 USES 18 BYTES
;          *3 - PROG3 USES 99 BYTES
;          *32877 OF 33000 BYTES (98%) PROGRAM MEMORY REMAINING
;          *500 OF 500 SEGMENTS (100%) COMPILED MEMORY REMAINING
```

☞ *The number in front of each program name is the BCD weight required to execute the program.*

You can now execute the programs by activating the correct combination of inputs:

- Activate digital input 1 (BCD weight of 1) to execute program #1 (`PROG1`)
- Activate digital input 2 (BCD weight of 2) to execute program #2 (`PROG2`)
- Activate digital inputs 1 & 2 (BCD weight of 3) to execute program #3 (`PROG3`)

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Kill

- LIMFNCi-C
- INFNCi-C

When an input defined as a *Kill* input goes active:

- Motion stops (using the LHAD and LHADA decel rate).
- Program currently in progress is terminated.
- Commands currently in the command buffer are eliminated.
- Drive is left in the enabled state (@DRIVE1), unless the "disable drive on kill" function is enabled with the KDRIVE command (see description on page 66).
- If error-checking bit 6 is enabled (e.g., ERROR.6-1), the error status is reported by bit 6 of the TERF, TER and ER commands and the error program (assigned with the ERRORP command) will be executed to respond to the error condition.

NOTE: Kill is not intended as a means to temporarily inhibit motion; use the *Pause/Continue* input function instead (LIMFNCi-E or INFNCi-E).

Stop

- LIMFNCi-D
- INFNCi-D

An input defined as a *Stop* input will stop motion (see examples below). Deceleration is controlled by the programmed AD/ADA deceleration ramp. If error-checking bit 8 is enabled (e.g., ERROR.8-1), the error status is reported by bit 8 of the TERF, TER and ER commands and the error program (assigned with the ERRORP command) will be executed to respond to the error condition.

After the Stop input is received, further program execution is dependent upon the COMEXS command setting:

COMEXSØ: (default setting) Upon receiving a stop input, motion will stop, program execution will be terminated and cannot be resumed, and every command in the buffer will be discarded.

COMEXS1: Upon receiving a stop input, motion will stop, program execution will pause, and all commands following the command currently being executed will remain in the command buffer (*but the move in progress will not be saved*).

You can resume program execution (but not the move in progress) by issuing an immediate Continue (!C) command or by activating a pause/resume input (i.e., a general-purpose input configured as a pause/continue input with the INFNCi-E command—see below). *You cannot resume program execution while the move in progress is decelerating.*

COMEXS2: Upon receiving a stop input, the Gem6K responds as it does in the COMEXS0 mode, with the exception that you can still use the program-select inputs to select programs (INSELP value is retained). The program-select input functions are: BCD select (INFNCi-B or LIMFNCi-B; see page 97), and one-to-one select (INFNCi-P or LIMFNCi-P; see page 103). For further details on program selection with inputs, refer to INFNC (or LIMFNC) and INSELP.

Example: The 3INFNC2-D command assigns the "stop" function to the 2nd input on SIM1 of I/O brick #3. When this input is activated, motion will stop.

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Pause/Continue

- LIMFNCi-E
- INFNCi-E

An input defined as a *Pause/Continue* input will affect motion and program execution depending on the COMEXR command setting, as described below. In both cases, when the input is activated, the current command being processed will be allowed to finish executing before the program is paused.

COMEXRØ: Upon receiving a pause input, only program execution will be paused; any motion in progress will continue to its predetermined destination. Releasing the pause input or issuing a !C command will resume program execution.

COMEXR1: Upon receiving a pause input, both motion and program execution will be paused; the motion stop function is used to halt motion. Releasing the pause input or issuing a !C command will resume motion and program execution. *You cannot resume program execution while the move in progress is decelerating.*

User Fault

- LIMFNCi-F
- INFNCi-F

An input defined as a *User Fault* input acts as an immediate Kill (!K) command, stopping motion and terminating program execution. Motion is stopped at the rate set with the hard limit (LHAD & LHADA) commands.

If error-checking bit #7 is enabled (e.g., ERROR.7-1), then a user fault input will cause a branch to the ERRORP error program (for more information, see *Error Handling* on page 30) and the occurrence of a user fault input will be reported by error bit #7 (see TERF, TER and ER commands).

Trigger Interrupt (INFNCi-H)

This function is available only for onboard trigger inputs. Any trigger input may be defined as a Trigger Interrupt input and can be used for these functions:

- Position Capture (see below)
- Special trigger functions assigned with the TRGFN command (see below)
- Registration (see discussion on page 159)

Notes About Trigger Interrupt Inputs

- The trigger interrupt input is debounced for 24 ms (default) before another input on the same trigger is recognized. If your application requires a different debounce time, you can change it with the TRGLOT command (refer to *Input Debounce Time* on page 96).
- When configured as Trigger Interrupts, the triggers cannot be affected by the input enable (INEN) command.
- Status: Use the TTRIG and TRIG commands to ascertain if a trigger interrupt input has been activated. TTRIG displays the status as a binary report, and TRIG is an assignment/comparison operator for using the status information in a conditional expression (e.g., in an IF statement). Each TTRIG/TRIG bit is cleared when the respective captured position value is read with the PCC, PCE, PCME, PCMS, TPCC, TPCE, TPCME, or TPCMS commands, but the position information is still available from the respective register until it is overwritten by a subsequent position capture by the same trigger input.

Position Capture

The Gem6K has two dedicated trigger inputs, referred to as "TRIG-A" and "TRIG-B." These trigger inputs are located on the DRIVE/10 connector. When either trigger input (TRIG-A or TRIG-B) is assigned the Trigger Interrupt function, activating the input performs a *hardware capture* of the position. If the Gem6K is used as a follower in Following, activating the trigger also performs an *interpolated capture* of the associated master axis position.

An additional trigger, labeled "TRIG-M", may be used to perform a hardware capture of the Master Encoder (the encoder connected to the "MASTER ENCODER" connector), as well as the motor position (encoder position on servo axes; commanded or encoder position for steppers, depending on the ENCCNT setting). To assign TRIG-M as a trigger interrupt input, use the

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INFNC17-H command.

When a Trigger Interrupt input is activated, the controller captures the relevant positions and stores them in registers that are available at the next system update (2 ms) through the use of these transfer and assignment/comparison commands:

Captured Information	Transfer	Assignment/Comparison	Offset *	Scale Factor **
Commanded position	TPCC	PCC	PSET	SCLD
Encoder position	TPCE	PCE	PSET	SCLD
Master encoder position	TPCME	PCME	PMESET	SCLMAS
Master cycle position	TPCMS	PCMS	PSET	SCLMAS

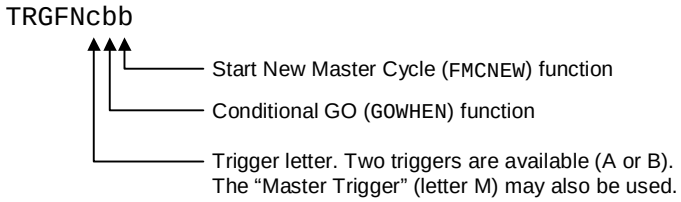
* Captured values are offset by any existing PSET or PMESET offset.
** If scaling is enabled, the captured position is scaled by SCLD or SCLMAS.

Notes About Position Capture

- Hardware Capture: The encoder position is captured within ± 1 encoder count. The commanded position capture accuracy is ± 1 count.
- Interpolated Capture: There is a time delay of up to 50 µs between activating the trigger interrupt input and capturing the position; therefore, the accuracy of the captured position is equal to 50 µs multiplied by the velocity at the time the input was activated.
- Servo vs. Stepper. The nature of the position captured with a Trigger Interrupt input may be different, depending on whether the drive is a servo or stepper. For servos, both the commanded and encoder positions are captured. Analog input feedback cannot be captured. For steppers, if the ENCCNT command is set to ENCCNT0 (default condition), only the commanded position is captured. If ENCCNT1 mode is enabled, only the encoder position is captured.

Trigger Functions

The Trigger Functions command (TRGFN) allows you to assign additional functions to trigger inputs that have been defined as trigger interrupt inputs with the INFNCi-H command. These trigger functions are cleared once the function is triggered. Command syntax is:



- "Conditional GO" Function (TRGFNc1x): Suspend execution of the next start-motion command until the specified trigger input goes active. Start-motion commands are:
  - GO (standard command to begin motion)
  - FSHFC (begin continuous shift – for Following motion)
  - FSHFD (begin preset shift – for Following motion)

  Axis status bit #26 (reported with TASF, TAS, or AS) is set to one (1) when there is a pending "Conditional GO" condition initiated by a TRGFN command; this bit is cleared when the trigger is activated or when a stop command or a kill command is issued. If you need execution to be triggered by other factors (e.g., input state, master position, encoder position, etc.) use the GOWHEN command; refer to GOWHEN command or page 163 for details.

- "New Master Cycle" Function (TRGFNcx1): This is equivalent to executing the FMCNEW command. When the specified trigger input goes active, the controller begins a new Following master cycle. Refer to the FMCNEW command or to page 183 for more on master cycles.

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Code Examples

```
INFNC1-H        ; Assign trigger A (onboard input 1) to function as
                ; a trigger interrupt input.
INFNC2-H        ; Assign trigger B (onboard input 2) to function as
                ; a trigger interrupt input.
TRGFNAx1        ; When trigger A goes active, begin a new master cycle
TRGFNB1         ; When trigger B goes active, execute the move commanded
                ; with the GO command.
GO              ; The move is commanded, but will not execute until
                ; trigger B becomes active.
```

Registration

If registration is enabled (with the RE command), activating a trigger interrupt input will initiate a registration move defined with the REG command. Refer to page 159 for details on the Registration feature.

Alarm Event

- LIMFNCi-I
- INFNCi-I

An input specified as an *Alarm Event* input will cause the Gem6K controller to set an Alarm Event in the Communications Server over the Ethernet interface. You must first enable the Alarm checking bit for this input-driven alarm (INTHW.23-1). For details on using alarms and other Communications Server features, refer to the *COM6SRVR Programmer's Guide* or to the Motion Planner help system.

Jogging the Motor

- LIMFNCi-J
- LIMFNCi-K
- LIMFNCi-L
- INFNCi-J
- INFNCi-K
- INFNCi-L

In some applications, you may want to manually move (*jog*) the load. You can configure these jog-related input functions:

"J" ....Jog in the positive counting direction when the input is active, stop when the input is inactive.

"K" ....Jog in the negative counting direction when the input is active, stop when the input is inactive.

"L" ....Select the high (JOGVH) or low (JOGVL) velocity setting for jog motion. Activating the input selects high velocity, deactivating the input selects low velocity.

The jog profile is defined with these commands listed below. **NOTE**: If scaling is enabled (SCALE1) the velocity is scaled by SCLV and accel/decel is scaled by SCLA.

JOGVH..... High velocity range for jogging. The high velocity is used when the jogging speed-select input (configured with INFNCi-L) is active.
JOGVL..... Low velocity range for jogging. The low velocity is used when the jogging speed-select input (configured with INFNCi-L) is inactive.
JOGA..... Jog acceleration
JOGAA..... Jog acceleration (s-curve profile)
JOGAD..... Jog deceleration
JOGADA .... Jog deceleration (s-curve profile)

Once you set up the jog functions and move profile, you can attach a switch to the designated jog inputs and perform jogging. (Jog motion will not occur unless Jog Mode is enabled with the JOG command.) The example below shows you how to define a program to set up jogging.

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Example

Step 1 Define program for jog setup:

```
DEF prog1     ; Begin definition of program prog1
JOGA25        ; Jog acceleration to 25 units/sec/sec
JOGAD25       ; Jog deceleration to 25 units/sec/sec
JOGVL.5       ; Low-speed jog velocity to 0.5 units/sec
JOGVH5        ; High-speed jog velocity to 5 units/sec
INFNC1-J      ; Trigger input 1 is a positive-direction jog input, axis 1
INFNC2-K      ; Trigger input 2 is a negative-direction jog input, axis 1
INFNC3-L      ; Trigger input 3 is a speed-select input, axis 1
JOG1          ; Enable Jog function for axis 1
END           ; End program definition
```

Step 2 Download and run the `prog1` program.

Step 3 Activate input 1 to move the load in the positive direction at a velocity of 0.5 units/sec (until trigger input 1 is released). Deactivate the input to stop the axis.

Step 4 Activate input 2 to move the load in the negative direction at a velocity of 0.5 units/sec (until input 2 is released). Deactivate the input to stop the axis.

Step 5 Activate input 3 to switch to high-speed jogging.

Step 6 Repeat steps 3 and 4 to perform high-speed jogging at the `JOGVH` value (5 rps).

Joystick Functions

- `LIMFNCi-M`
- `LIMFNCi-N`
- `LIMFNCi-O`
- `INFNCi-M`
- `INFNCi-N`
- `INFNCi-O`

As part of the joystick setup process, you can configure programmable inputs to serve the joystick input functions listed below. Full details on joystick setup and operation are provided on page 130.

"`M`" ....The *Joystick Release* input signals the controller to end joystick operation and resume program execution with the next statement in your program. When the input is open (high, sinking current), the joystick mode is disabled (joystick mode can be enabled only if the input is closed, and only with the `JOY` command). When the input is closed (low, not sinking current), joystick mode can be enabled with the `JOY` command. The general process of using Joystick mode is:

1. Assign the "Joystick Release" input function to a programmable input.
2. At the appropriate place in the program, enable joystick control of motion (with the `JOY` command). (Joystick mode cannot be enabled unless the "Joystick Release" input is closed.) When the `JOY` command enables joystick mode, program execution stops (assuming the Continuous Command Execution Mode is disabled with the `COMEXCØ` command).
3. Use the joystick to move as required.
4. When you are finished using the joystick, open the "Joystick Release" input to disable the joystick mode. This allows program execution to resume with the next statement after the initial `JOY` command that started the joystick mode.

"`O`" ...The *Joystick Velocity Select* input allows you to select the velocity for joystick motion. The `JOYVH` and `JOYVL` commands establish the high-speed velocity and the low-speed velocity, respectively. Opening the Velocity Select input (input is high, sinking current) selects the `JOYVH` configuration. Closing the Velocity Select input (input is low, not sinking current) selects the `JOYVL` configuration. The high range could be used to quickly move to a location, the low range could be used for accurate positioning. NOTE: When this input is not connected, joystick motion always uses the `JOYVL` velocity setting.

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One-to-One Program Select

- `LIMFNCi-iP`
- `INFNCi-iP`

An input defined as a *One-to-One Program Select* input is assigned to execute one specific program. The targeted program is reference by its *number* (see note).

Program Numbers

A program's number is determined by the order in which the program was downloaded to the controller. The number of each program stored in the controller's memory can be obtained through the `TDIR` command — refer to the number reported in front of each program name. When selecting programs with One-to-One Program Select inputs, the program number is assigned to one specific input and is executed when the input is activated (see example below).

Before you can execute programs using the One-to-One program select inputs, you must first enable scanning with the `INSELP2` command. Once enabled, the controller will continuously scan the inputs and execute the program (by number) according to the program number assigned to the input. After executing and completing the selected program, the controller will scan the inputs again. NOTE: To disable scanning, enter `!INSELPØ` or place `INSELPØ` in a program that can be selected.

The `INSELP` command also determines how long the program select input level must be maintained before the controller executes the program. This delay is referred to as debounce time (but is not affected by the `INDEB` setting).

Example

```
RESET       ; Return controller to power-up default conditions
DEF proga   ; Begin definition of program proga
TFB         ; Transfer position of feedback devices
END         ; End program
DEF progb   ; Begin definition of program progb
TREV        ; Transfer software revision
END         ; End program
DEF progc   ; Begin definition of program progc
TSTAT       ; Transfer statistics
END         ; End program
TDIR        ; Response should show:   *1 - PROGA USES 36 BYTES
            ;                         *2 - PROGB USES 70 BYTES
            ;                         *3 - PROGC USES 133 BYTES
INFNC4-1P   ; input 4 will select proga
INFNC5-2P   ; input 5 will select progb
INFNC6-3P   ; input 6 will select progc
INSELP2,50  ; Enable scanning of inputs with a strobe time of 50 ms
```

You can now execute programs by making a contact closure from an input to ground to activate the input:

- Activate input #4 to execute program #1 (`proga`)
- Activate input #5 to execute program #2 (`progb`)
- Activate input #6 to execute program #3 (`progc`)

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Program Security

- LIMFNCi-Q
- INFNCi-Q

Once an input is assigned the *Program Security* function, the Program Security feature is enabled. The program security feature denies you access to the DEF, DEL, ERASE, MEMORY, LIMFNC and INFNC commands until you activate the Program Security input. Being denied access to these commands effectively restricts altering the user memory allocation. If you try to use these commands when program security is active (program security input is not activated), you will receive the error message *ACCESS DENIED.

For example, once you issue the 2INFNC7-Q command, input #7 on I/O brick #2 (2IN.7) is assigned the program security function and access to the DEF, DEL, ERASE, MEMORY, LIMFNC and INFNC commands will be denied until you activate 2IN.7.

To regain access to the DEF, DEL, ERASE, MEMORY, LIMFNC or INFNC commands without the use of the program security input, you must issue the INEN command to disable the program security input, make the required user memory changes, and then issue the INEN command to re-enable the input. For example, if input 3 on brick 2 is assigned as the Program Security input, use 2INEN.3=1 to disable the input and leave it activated, make the necessary user memory changes, and then use 2INEN.3=E to re-enable the input.

NOTE: If you wish the Program Security feature to be enabled on power-up, place the INFNCi-Q or LIMFNCi-Q command in the start-up program (STARTP).

Limit Functions

- LIMFNCi-aR
- LIMFNCi-aS
- LIMFNCi-aT
- INFNCi-aR
- INFNCi-aS
- INFNCi-aT

Input numbers are factory-configured with the LIMFNC command to function as end-of-travel and home limits (see illustration on page 91). The limit functions are:

"R" .... *Positive-Direction End-of-Travel Limit* input, axis specific.

"S" .... *Negative-Direction End-of-Travel Limit* input, axis specific.

"T" .... *Home Limit* input, axis specific.

If you intend to use digital inputs on an external I/O brick as limit inputs:

1. Assign the limit function to the external input with the INFNC command. For example, 1INFNC9-1R assigns the "axis 1 positive end-of-travel limit" function to the 1st input on SIM2 (I/O point 9) of I/O brick 1.
2. Reassign the respective "LIMITS" input to a non-limit function with the LIMFNC command. For example, LIMFNC1-A assigns the "general-purpose input" function to limit input 1 (normally assigned the "axis 1 positive end-of-travel limit" function).

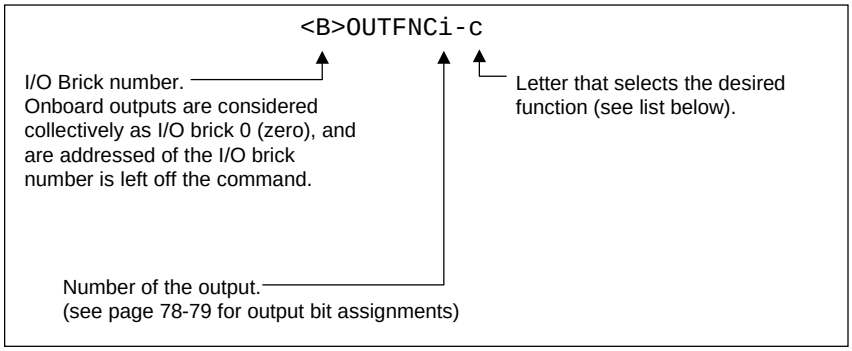
NOTE: Once an input or I/O brick input is assigned a limit function, it is no longer debounced (INDEB has no effect), and it must be enabled/disabled with the LH command instead of the INEN command.

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Output Functions

The Gem6K product provides programmable digital outputs, found on the drive I/O connect. Additional digital outputs may be installed on expansion I/O bricks (see example on page 93).

You can turn the controller's programmable outputs on and off with the Output (OUT, POUT or OUTALL) commands, or you can use the Output Function (OUTFNC) command to configure them to activate based on seven different situations. The OUTFNC syntax is as follows:



Letter Designator	Function
A	General-purpose output (**default function**)
<a>B	Moving/not moving
C	Program in progress
<a>D	Hardware or software end-of-travel limit encountered
<a>E	Stall indicator — stepper only
F	Fault indicator (indicates drive fault input or user fault input is active)
G	Position error exceeds max. limit set with SMPER — servo only
H	Output on position

NOTES

- **Multi-tasking:** If the OUTFNC command does not include the task identifier (%) prefix, the function affects the task that executes the OUTFNC command. “Program in progress” (function C) is only function that may be directed to a specific task with %. Multiple tasks may share the same output, but the output may only be assigned one function.
- **Limit of 32 output functions:** You may assign a maximum of 32 OUTFNC functions. This excludes function A (“general-purpose”).

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Output Status

Below is a list of the status commands you may use to ascertain the current state and/or defined function of the outputs.

- Status display commands:
  - `TIO`.....I/O brick configuration (which SIMs are present, including sinking/sourcing)
  - `OUTFNC`.....Active state and programmed function of all onboard outputs
  - `OUTFNCi` .....Same as `OUTFNC` display, but only for the output number ("`i`")
  - `<B>OUTFNC`.....Active state and programmed function of all outputs on I/O brick `B`
  - `<B>OUTFNCi` .....Same as `OUTFNC` display, but only for the output number ("`i`") on I/O brick `B`
  - `TOUT` .....Hardware state of all onboard outputs (binary report); use `TOUT.i` to check the state of only one output ("`i`")
  - `<B>TOUT` .....Hardware state of all outputs (binary report) on I/O brick `B`; use `<B>TOUT.i` to check the state of only one output ("`i`") on brick `B`
- Status assignment/comparison operator: *
  - `OUT`.....Hardware state (binary) of all onboard outputs; use `OUT.i` to check the state of only one output ("`i`")
  - `<B>OUT`.....Hardware state (binary) of all outputs on I/O brick `B`; use `<B>OUT.i` to check the state of only one output ("`i`") on I/O brick `B`

  * The purpose of the `OUT` operator is to use the state of the outputs as a basis for conditional statements (`IF`, `REPEAT`, `WHILE`, `GOWHEN`, etc.) or for binary variable assignments (`VARB`).

Output Active Levels

Using `OUTLVL`, you can define the logic levels of the programmable outputs as positive or negative. `OUTLVL0` selects active low (default setting); `OUTLVL1` selects active high.

Onboard Digital Outputs

`OUTLVL` **Setting**	`OUT` **State ***	**Current**	`TOUT` **Status**
`OUTLVL0` (default)	`OUT1`	Sinking current	`1`
`OUTLVL0` (default)	`OUT0`	No current flow	`0`
`OUTLVL1`	`OUT1`	No current flow	`1`
`OUTLVL1`	`OUT0`	Sinking current	`0`

* The output is "active" when it is commanded by the `OUT`, `OUTPA`, or `POUTA` commands (for example, `OUTxx1` activates output #3).

Outputs on Expansion I/O Bricks:

- Sinking vs. Sourcing Outputs. On power up, the Gem6K controller auto-detects the type of output SIM installed on each external I/O brick, and automatically changes the `OUTLVL` setting accordingly. If sinking (NPN) outputs are detected, `OUTLVL` is set to active low (`OUTLVL0`); if sourcing (PNP) outputs are detected, `OUTLVL` is set to active high (`OUTLVL1`).
- Disconnect I/O Brick. If the I/O brick is disconnected (or if it loses power), the controller will perform a kill (all tasks) and set error bit #18. (If you disable the "Kill on I/O Disconnect" mode with `KIOENØ`, the Gem6K will not perform the kill.) The controller will remember the brick configuration (volatile memory) in effect at the time the disconnection occurred. When you reconnect the I/O brick, the controller checks to see if anything changed (SIM by SIM) from the state when it was disconnected. If an existing SIM slot is changed (different SIM, vacant SIM slot, or jumper setting), the controller will set the SIM to factory default `INEN` and `OUTLVL` settings. If a new SIM is installed where there was none before, the new SIM is auto-configured to factory defaults.

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- Relationships:

Output Type	OUTLVL Setting	OUT State *	Current	OUT/TOUT status	LED
NPN (sinking)	OUTLVL0 (default)	OUT1	Sinking current	1	ON
NPN	OUTLVL0 (default)	OUT0	No current flow	0	OFF
NPN	OUTLVL1	OUT1	No current flow	1	OFF
NPN	OUTLVL1	OUT0	Sinking current	0	ON
PNP (sourcing)	OUTLVL0	OUT1	No current flow	1	OFF
PNP	OUTLVL0	OUT0	Sourcing current	0	ON
PNP	OUTLVL1 (default)	OUT1	Sourcing current	1	ON
PNP	OUTLVL1 (default)	OUT0	No current flow	0	OFF

* The output is "active" when it is commanded by the OUT, OUTP, or POUT command (for example, OUTxx1 activates output #3).

"General Purpose" (OUTFNCi-A)

The default function for the outputs is *General Purpose*. As such, the output is used as a standard output, turning it on or off with the OUT, OUTP or OUTALL commands to affect processes external to the controller. To view the state of the outputs, use the TOUT command. To use the state of the outputs as a basis for conditional branching or looping statements (IF, REPEAT, WHILE, etc.), use the [OUT] command.

Moving/Not Moving (In Position) (OUTFNCi-B)

When assigned the *Moving/Not Moving* function, the output will activate when motion is commanded. As soon as the move is completed, the output will change to the opposite state.

Servos: If the target zone mode is enabled (STRGTE1), the output will not change state until the move completion criteria set with the STRGTD and STRGTV commands has been met. (For more information, refer to the *Target Zone* section on page 84.) In this manner, the Moving/Not Moving output functions as an *In Position* output.

Example

The code example below defines onboard outputs 1 and 2 as *General Purpose* outputs and output 3 as a *Moving/Not Moving* output. Before the motor moves 4,000 steps, output 1 turns on and output 2 turns off. These outputs remain in this state until the move is completed, then output 1 turns off and output 2 turns on. While the motor/load is moving, output 3 remains on.

```
SCALE0          ; Disable scaling
MC0             ; Set axis 1 to preset positioning mode
MA0             ; Select incremental positioning mode
A10             ; Set axis 1 acceleration to 10
V5              ; Set axis 1 velocity to 5
D4000           ; Set axis 1 distance to 4,000 counts
OUTFNC1-A       ; Set onboard output 1 as a general purpose output
OUTFNC2-A       ; Set onboard output 2 as a general purpose output
OUTFNC3-B       ; Set onboard output 3 as axis 1 Moving/Not Moving output
OUT10           ; Turn onboard output 1 on and output 2 off
GO              ; Initiates axis 1 move
OUT01           ; Turn onboard output 1 off and output 2 on
```

Program in Progress (OUTFNCi-C)

When assigned the *Program in Progress* function, the output will activate when a program is being executed. After the program is finished, the output's state is reversed. The action of executing a program is also reported with system status bit 3 (see TSSF, TSS and SS commands).

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Limit Encountered (OUTFNCi-D)

When assigned the *Limit Encountered* function, the output will activate when a hard or soft end-of-travel limit has been encountered.

If a hard or soft limit is encountered, you will not be able to move the motor/load in that same direction until you clear the limit by changing direction (D) and issuing a GO command. (An alternative is to disable the limits with the LHØ command, but this is recommended only if the motor is not coupled to the load.) The event of encountering an end-of-travel limit is also reported with axis status bits 15-18 (see TASF, TAS and AS commands, summary on page 222).

Stall Indicator (OUTFNCi-E)

Stepper Axis Only

When assigned the *Stall Indicator* function, the output will activate when a stall is detected. To detect a stall, you must first connect an encoder and enable stall detection with the ESTALL1 command. Refer to *Encoder-Based Stepper Operation* on page 84 for further discussion on stall detection.

Fault Output (OUTFNCi-F)

When assigned the *Fault Output* function, the output will activate when either the user fault input or the drive fault input becomes active. The user fault input is a general-purpose input defined as a user fault input with the LIMFNCi-F or INFNCi-F command (see page 99).

Maximum Position Error Exceeded (OUTFNCi-G)

Servos Only

When assigned the *Max. Position Error Exceeded* function, the output will activate when the maximum allowable position error, as defined with the SMPER command, is exceeded.

The position error (TPER) is defined as the difference between the commanded position (TPC) and the actual position as measured by the feedback device (TFB). When the maximum position error is exceeded (usually due to lagging load, instability, or loss of position feedback), the controller shuts down the drive and sets error status bit #12 (reported by the TERF, TER and ER commands if bit #12 of the ERROR command is enabled).

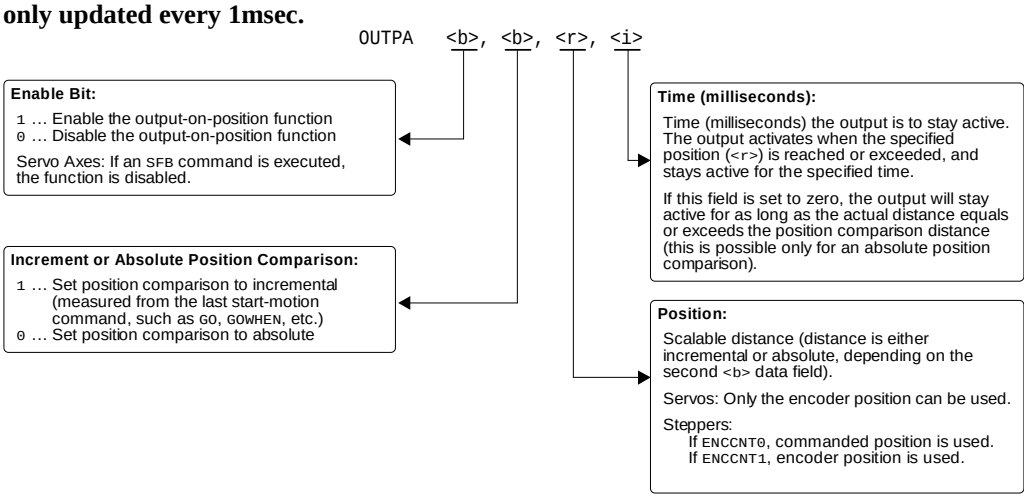
NOTE

If the SMPER command is set to zero (SMPERØ — the default value), the position error will not be monitored; thus, the *Maximum Position Error Exceeded* function will not be usable.

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Output on Position (OUTFNCi-H)

The *Output on Position* feature activates the designated output when the motor or load has reached a specified position. To use this feature, you must first assign the Output on Position function to output #1, and define the Output on Position characteristics with the OUTP command. **Note: this is a firmware feature (not hardware) and the output on position is only updated every 1msec.**



Sample Code for Setup

In this example, the user wants to turn on output when the motor (servo) reaches encoder position 50,000. The output must remain on for 50 milliseconds.

```
                    ; Define axis 1 as servo, axis 2 as stepper
                    ; Select encoder feedback for axis 1
OUTFNC1-H           ; Define onboard output #1 as an "output on
                    ; position" output
                    ; Define onboard output #2 as an "output on
                    ; position" output
OUTP1,0,+50000,50   ; Turn on onboard output #1 for 50 ms when the
                    ; encoder position is > or =
                    ; absolute position +50,000
```

Notes about Output On Position

- On servos, this feature can be used only with encoder feedback and is not operational with ANI (analog input) feedback.
  On steppers, this feature can be based on commanded position or encoder position, depending on the ENCCNT setting (default is ENCCNT0, which uses the commanded position).
- The output activates only during motion; thus, issuing a PSET command to set the absolute position counter to activate the output on position will not turn on the output until the next motion occurs.

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Variable Arrays (*teaching* variable data)

More on variables: see page 18.

Variable data arrays provide a method of storing (*teaching*) variable data and later using the stored data as a source for motion program parameters. The variable data can be any value that can be stored in a numeric (VAR or VARI) variable (e.g., position, acceleration, velocity, etc.). The variable data is stored into a *data program*, which is an array of *data elements* that have a specific address from which to write and read the variable data. Data programs do not contain Gem6K Series commands.

The information below describes the principles of using the data program in a teach-type application. Following that is an application example in which the joystick is used to teach position data to be used in a motion program.

Basics of Teach-Data Applications

The basic process of using a data program for data teaching applications is as follows:

1. Initialize a data program.
2. Teach (store/write) variable data into the data program.
3. Read the data elements from the data program into a motion program.

1. Initialize a Data Program

This is accomplished with the DATSIZ command. The DATSIZ command syntax is DATSIZi<,i>. The first integer (i) represents the number of the data program (1 - 50). You can create up to 50 separate data programs. The data program is automatically given a specific program name (DATPi). The second integer represents the total number of data elements (up to 6,500) you want in the data program. Upon issuing the DATSIZ command, the data program is created with all the data elements initialized with a value of zero.

The data program has a tabular structure, where the data elements are stored 4 to a line. Each line of data elements is called a *data statement*. Each element is numbered in sequential order from left to right (1 - 4) and top to bottom (1 - 4, 5 - 8, 9 - 12, etc.). You can use the TPROG DATPi command ("i" represents the number of the data program) to display all the data elements of the data program.

For example, if you issue the DATSIZ1,13 command, data program #1 (called DATP1) is created with 13 data elements initialized to zero. The response to the TPROG DATP1 command is depicted below. Each line (*data statement*) begins with DATA=, and each data element is separated with a comma.

```
*DATA=+0.0,+0.0,+0.0,+0.0
*DATA=+0.0,+0.0,+0.0,+0.0
*DATA=+0.0,+0.0,+0.0,+0.0
*DATA=+0.0
```

Each data statement, comprising four data elements, uses 43 bytes of memory. The memory for each data statement is subtracted from the memory allocated for user programs (see MEMORY command).

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2. Teach the Data to the Data Program

The data that you wish to write to the data elements in the data program must first be placed into numeric variables (VAR). Once the data is stored into numeric variables, the data elements in the data program can be edited by using the Data Pointer (DATPTR) command to move the data pointer to that element, and then using the Data Teach (DATTCH) command to write the datum from the numeric variable into the element.

When the DATSIZ command is issued, the internal data pointer is automatically positioned to data element #1. Using the default settings for the DATPTR command, the numberic variable data is written to the data elements in sequential order, incrementing one by one. When the last data element in the data program is written, the data pointer is automatically set to data element #1 and a warning message (*WARNING: POINTER HAS WRAPPED AROUND TO DATA POINT 1) is displayed. The warning message does not interrupt program execution.

The DATPTR command syntax is DATPTRi,i,i. The first integer (i) represents the data program number (1 through 50). The second integer represents the number of the data element to point to (1 through 6500). The third integer represents the number of data elements by which the pointer will increment after writing each data element from the DATTCH command, or after recalling a data element with the DAT command.

The DATTCH command syntax is DATTCHi<,i,i,i>. Each integer (i) represents the number of a numeric variable. The value of the numeric variable will be stored into the data element(s) of the currently active data program (i.e., the program last specified with the last DATSIZ or DATPTR command). As indicated by the number of integers in the syntax, the maximum number of variable values that can be stored in the data program per DATTCH command is 4. Each successive value from the DATTCH command is stored to the data program according to the pattern established by the third integer of the DATPTR command.

As an example, suppose data program #1 is configured to hold 13 data elements (DATSIZ1,13), the data pointer is configured to start at data element #1 and increment 1 data element after every value stored from the DATTCH command (DATPTR1,1,1), and the values of numeric variables #1 through #3 are already assigned (VAR1=2, VAR2=4, VAR3=8). If you then enter the DATTCH1,2,3 command, the values of VAR1 through VAR3 will be assigned respectively to the first three data elements in the data program, leaving the pointer pointing to data element #4. The response to the TPROG DATP1 command would be as follows (the text is highlighted to illustrate the final location of the data pointer after the DATTCH1,2,3 command is executed):

```
*DATA=+2.Ø,+4.Ø,+8.Ø,+Ø.Ø
*DATA=+Ø.Ø,+Ø.Ø,+Ø.Ø,+Ø.Ø
*DATA=+Ø.Ø,+Ø.Ø,+Ø.Ø,+Ø.Ø
*DATA=+Ø.Ø
```

If you had set the DATPTR command to increment 2 data elements after every value from the DATTCH command (DATPTR1,1,2), the data program would be filled differently and the data pointer would end up pointing to data element #7:

```
*DATA=+2.Ø,+Ø.Ø,+4.Ø,+Ø.Ø
*DATA=+8.Ø,+Ø.Ø,+Ø.Ø,+Ø.Ø
*DATA=+Ø.Ø,+Ø.Ø,+Ø.Ø,+Ø.Ø
*DATA=+Ø.Ø
```

3. Recall the Data from the Data Program

After storing (*teaching*) your variables to the data program, you can use the DATPTR command to point to the data elements and the DATi ("i" = data program number) data assignment command to read the stored variables to your motion program. *You cannot recall more than one data element at a time; therefore, if you want to recall the data in a one-by-one sequence, the third integer of the DATPTR command must be a 1 (this is the default setting).*

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Summary of Related Gem6K Series Commands

DATSIZ..... Establishes the number of data elements a specific data program is to contain. A new DATPi program name is automatically generated according to the number of the data program (i = 1 through 50). The memory required for the data program is subtracted from the memory allocated for user programs (see MEMORY command).

DATPTR..... Moves the data pointer to a specific data element in any data program. This command also establishes the number of data elements by which the pointer increments after writing each data element from the DATTCH command and after recalling each data element with the DAT command.

DATTCH..... Stores the variable data into the data program specified with the last DATSIZ or DATPTR command. After the data is stored, the data pointer is incremented the number of times entered in the third integer of the DATPTR command. *The data must first be assigned to a numeric variable before it can be taught to the data program.*

TDPTR..... Responds with a 3-integer status report (i,i,i): First integer is the number of the active data program (the program # specified with the last DATSIZ or DATPTR command); Second integer is the location number of the data element to which the data pointer is currently pointing; Third integer is the increment set with the last DATPTR command.

[DPTR] ... From the currently active data program, uses the number of the data pointer's location in a numeric variable assignment operation or a conditional statement operation.

[DATPi] . The name of the data program created after issuing the DATSIZ command. The integer (i) represents the number of the data program. Data programs can be deleted just like any other user program (e.g., DEL DATP1).

[DATi] ... From the data program specified with i, assigns the numeric value of the data element (currently pointed to by the data pointer) to a specified variable parameter in a Gem6K series command (e.g., D(DAT3),(DAT3)).

Teach-Data Application Example

For the sake of brevity, this example is limited to teaching 10 position data points; however, in a typical application, many more points would be taught. Also, it is assumed that end-of-travel and home limits are wired and a homing move has been programmed.

What follows is a suggested method of programming the controller to teach I/O data points. To accomplish the teach application, a program called MAIN is created, comprising three subroutines: SETUP (to set up for teaching data to the data program), TEACH (to teach the positions), and DOPATH (to implement a motion program based on the positions taught).

The joystick operation in this example is based on using an analog inputs (ANI) SIM on an expansion I/O brick. The ANI SIM is in slot 2 of I/O brick 1 and inputs 1 and 2 are used to control axes 1 and 2, respectively. A digital input SIM is installed in slot 1 of I/O brick 1, and input 1 on that SIM is assigned the Joystick Release function to trigger the position teach operation.

Step 1 **Initialize a Data Program.**

```
DEL DATP1       ; Delete data program #1 (DATP1) in preparation for
                ; creating a new data program #1
DATSIZ1,1Ø      ; Create data program #1 (named DATP1) with an
                ; allocation of 10 data elements. Each element is
                ; initialized to zero.
```


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Step 2 **Define the SETUP Subroutine.** The SETUP subroutine need only run once.

```
DEF SETUP       ; Begin definition of the subroutine called SETUP
1INFNC1-M       ; Assign digital input 1 on SIM 2 (I/O point #1) of
                ; I/O brick 1 to function as a "Joystick Release" input.
JOYVH3          ; Set the maximum velocity (3 units/sec)
                ; achievable when the joystick is at full
                ; deflection
JOYAXH1-9       ; Assign ANI input 1 on SIM 2 (I/O point #9) of I/O
                ; brick 1
VAR1=Ø          ; Initialize variable #1 equal to zero
VAR2=Ø          ; Initialize variable #2 equal to zero
DRIVE1          ; Enable the drive
MA1             ; Enable the absolute positioning mode
END             ; End definition of the subroutine called SETUP
```

Step 3 **Define the TEACH Subroutine.**

```
DEF TEACH       ; Begin definition of the subroutine called TEACH
HOM1            ; Home the axis (absolute position counter is set to
                ; zero after the homing move)
DATPTR1,1,1     ; Select data program #1 (DATP1) as the current active
                ; data program, and move the data pointer to the first
                ; data element. After each DATTCH value is stored to
                ; DATP1, increment the data pointer by 1 data element.
REPEAT          ; Set up a repeat/until loop
JOY1            ; Enable joystick mode. At this point,
                ; you can start moving into position with the
                ; joystick. WHILE USING THE JOYSTICK, COMMAND PROCESSING
                ; IS STOPPED HERE UNTIL YOU ACTIVATE THE JOYSTICK
                ; RELEASE INPUT. Activating the joystick release input
                ; disables the joystick mode and allows the subsequent
                ; commands to be executed (assign the current positions
                ; to the variables and then store the positions in the
                ; data program).
VAR1=1PM        ; Set variable #1 equal to the position of motor 1
DATTCH1         ; Store variable #1. (The first time through the
                ; repeat/until loop, variable #1 is stored into data ;
                ;element #1. The data pointer is automatically
                ; incremented once after each data element and ends up
                ;pointing to the third data element in anticipation of
                ;the next DATTCH command.)
WAIT(1IN.1=b1)  ; Wait for the joystick release input to be de-activated
UNTIL(DPTR=1)   ; Repeat the loop until the data pointer wraps around
                ; to data element #1 (data program full)
END             ; End definition of the subroutine called TEACH
```


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Step 4 **Define the DOPATH Subroutine.**

```
DEF DOPATH      ; Begin definition of the subroutine called DOPATH
HOM1            ; Move to the home position
                ; (absolute counters set to zero)
A5Ø             ; Set up the acceleration
V3              ; Set up the velocity
DATPTR1,1,1     ; Select data program #1 (DATP1) as the current active
                ; data program, and set the data pointer to the first
                ; data element. Increment the data pointer one element
                ; after every data assignment with the DAT command.
REPEAT          ; Set up a repeat/until loop
D(DAT1)         ; The position is recalled into
                ; the distance command
GO              ; Move to the position
T.5             ; Wait for 0.5 seconds
UNTIL(DPTR=1)   ; Repeat the loop until the data pointer wraps around
                ; to data element #1 (all data elements have been read)
HOM1            ; Move back to the home position
END             ; End definition of the subroutine called DOPATH
```

Step 5 **Define the MAIN Program (Include SETUP, TEACH, and DOPATH).**

```
DEF MAIN        ; Begin definition of the program called MAIN
SETUP           ; Execute the subroutine called SETUP
TEACH           ; Execute the subroutine called TEACH
DOPATH          ; Execute the subroutine called DOPATH
END             ; End definition of the program called MAIN
```

Step 6 **Run the MAIN Program and Teach the Positions with the Joystick.**

1. Enter the MAIN command to execute the teach application program.
2. 2. Use the joystick to move to the position to be taught.
3. Once in position, activate the *joystick release* input to teach the positions.
4. Repeat steps 2 and 3 for the remaining nine teach locations. After triggering the joystick release input the tenth time, the controller will home the motor, repeat the path that was taught, and then return to the home position.

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CHAPTER FOUR

4 Product Control Options

IN THIS CHAPTER

This chapter explains various options for controlling your Gem6K product:

- Safety features 116
- Overview of product control options 116
- Programmable I/O *(switches, thumbwheels, PLCs, PLC Scan Mode, etc.)* 118
- RP240 remote operator panel 123
- Joystick and analog input interface *(requires ANI SIM on expansion I/O brick)* 130
- Host computer interface 133

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Safety Features

WARNING

The Gem6K Product is used to control your system's electrical and mechanical components. Therefore, you should test your system for safety under all potential conditions. Failure to do so can result in damage to equipment and/or serious injury to personnel.

To help ensure a safe operating environment, you should take advantage of the safety features listed below. These features must not be construed as the only methods of ensuring safety. *See Also* refers you to where you can find more in-depth information about the feature (system connections and/or programming instructions)

Feature	Description	See Also
Enable Input	The ENABLE input, found on the product's drive I/O connector, is provided as an emergency stop input to the controller. If the ENABLE input is opened (disconnected from GND), output to the motors is inhibited.	Product's hardware *Installation Guide*
End-of-travel Limit Inputs	End-of-travel limits prevent the load from crashing through mechanical stops, an incident that can damage equipment and injure personnel. Use hardware or software limits, as your application requires.	*End-of-Travel Limits* (page 74)
User Fault Input	Using the `INFNCi-F` command or the `LIMFNCi-F` command, you can assign the *user fault* function to any of the programmable inputs. You can then wire the input to activate when an external event, considered a *fault* by the user, occurs.	*Input Functions* (page 99)
Maximum Allowable Position Error (**servos only**)	A *position error* (`TPER`) is defined as the difference between the commanded position (`TPC`) and the actual position as measured by the feedback device (`TFB`). The maximum allowable position error is set with the `SMPER` command. When the maximum allowable position error is exceeded (usually due to instability or loss of position feedback), the controller shuts down the drive and sets error status bit #12 (reported by the `TER` command). If `SMPER` is set to zero (`SMPERØ`), position error will not be monitored.	*Servo Setup* (page 85)

Programmed Error-Handling Responses

When any of the safety features listed above are exercised (e.g., **DFT** input is activated, etc.), the controller considers it an error condition. With the exception of the shutdown output activation, you can enable the ERROR command to check for the error condition, and when it occurs to branch to an assigned ERRORP program. Refer to *Error Handling* (page 30) for further information.

Options Overview

Stand-Alone Interface Options

After defining and storing controller programs, the controller can operate in a stand-alone fashion. A program stored in the controller may interactively prompt the user for input as part of the program (input via I/O switches, thumbwheels, RP240, joystick). A joystick can be use for situations requiring manual manipulation of the load.

Option	Application Example

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RP240 (see page 123)	**Grinding**: Program the RP240 function keys to select certain part types, and program one function key as a GO button. Select the part you want to grind, then put the part in the grinding machine and press the GO function key. The controller will then move the machine according to the predefined program assigned to the function key selected.
Joystick (see page 130)	**X-Y scanning/calibration**: Enter the joystick mode and use the 2-axis joystick to position an X-Y table under a microscope to arbitrarily scan different parts of the work piece (e.g., semi-conductor wafer). You can record certain locations to be used later in a motion process (e.g., for drilling, cutting, or photographing the work piece). Refer to page 112 an example using the joystick to teach positions.
ANI Analog Inputs (see page **Error! Bookmark not defined.**)	**Injection Molding**: Use for feedback from a pressure sensor to maintain constant, programmable force. (Note: ANI control requires that you install an analog input SIM on an expansion I/O brick.)
Programmable inputs scanned in PLC Scan Mode (see page 120)	The PLC Scan feature allows you to create a pre-compiled program that mimics PLC functionality by scanning through the I/O faster than in a normal program run. Because the functions of PLC programs are pre-compiled, delays associated with command processing are eliminated during profile execution, allowing more rapid sequencing of actions than would be possible with programs which are not compiled. Command processing is then free to monitor other activities.

Programmable Logic Controller

The controller's programmable I/O may be connected to most PLCs. After defining and storing controller programs, the PLC typically executes programs, loads data, and manipulates inputs to the controller. The PLC instructs the controller to perform the motion segment of a total machine process.

EXAMPLE (X-Y point-to-point): A PLC controls several tools to stack and bore several steel plates at once. The controller is programmed to move an X-Y table in a pre-programmed sequence. The controller moves the load when the inputs are properly configured, signals the PLC when the load is in position, and waits for the signal to continue to the next position.

Host Computer Interface

A computer may be used to control a motion or machine process. A PC can monitor processes and orchestrate motion by sending motion commands to the controller or by executing motion programs already stored in the controller. This control might come from a BASIC or C program. A BASIC program example is provided on page 117.

Custom Graphical User Interfaces (GUIs)

Compumotor offers tools you can use to create your own custom graphical user interfaces (GUIs). More detailed descriptions are provided on page 144.

- ActiveX Control: A Gem6K product communication control for custom 32-bit applications (e.g., developed with VisualBasic). Provided with Motion Planner.
- PanelMaker: A VBScript-based operator interface tool. This is an add-on to Motion Planner, sold separately.

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Programmable I/O Functions

Programmable inputs and outputs are provided to allow the controller to detect and respond to the state of switches, thumbwheels, electronic sensors, and outputs of other equipment such as drives and PLCs. Listed below are the programmable functions that may be assigned to the programmable I/O.

Programmable I/O offering differs by product. The total number of onboard inputs and outputs (trigger inputs, limit inputs, digital outputs) depends on the product. The total number of expansion inputs and outputs (analog inputs, digital inputs and digital outputs) depends on your configuration of expansion I/O bricks. To ascertain your product's I/O bit patterns, refer to page 91.

NOTE

Refer to page 90 for instructions on establishing programmable input and output functions. Instructions for connecting to I/O devices are provided in your product's *Installation Guide*.

Input Functions

Input functions may be assigned to two basic groups of programmable inputs. `LIMFNC` assigns functions to the limit inputs found on the "LIMITS/HOME" connector. `INFNC` assigns functions to the trigger inputs (on the "TRIGGERS/OUTPUTS" connector) and to the digital inputs installed on expansion I/O bricks. The syntax, `LIMFNCi-c` or `INFNCi-c`, requires a letter designator ("`c`") that corresponds to an input function; options for the input functions are listed in the table below.

Virtual Inputs can be established to provide programmable input functionality for data or external events that are not ordinarily represented by inputs. See page 94 for details.

Letter Designator	Function
`A`	General-purpose input (**default function for triggers & inputs on I/O bricks**)
`B`	BCD program select
`C`	Kill
`D`	Stop
`E`	Pause/Continue
`F`	User fault
`G`	<RESERVED>
`H`	Trigger Interrupt for position capture or registration (trigger inputs only). Special trigger functions can be assigned with the `TRGFN` command (see page 166).
`I`	Cause alarm event (requires Ethernet interface) in Communications Server
`J`	Jog in the positive-counting direction
`K`	Jog in the negative-counting direction
`L`	Jog velocity select
`M`	Joystick release
`N`	Joystick axis select
`O`	Joystick velocity select
`P`	One-to-one program select
`Q`	Program security
`R`	End-of-travel limit for positive-counting direction *
`S`	End-of-travel limit for negative-counting direction *
`T`	Home limit *

* The limit inputs are factory-set to their respective end-of-travel or home limit function (see page 91).

Output Functions

Command	Function
`OUTFNCi-A`	General-purpose output (**default function**)
`OUTFNCi-B`	Moving/not moving
`OUTFNCi-C`	Program in progress
`OUTFNCi-D`	Hardware or software end-of-travel limit encountered
`OUTFNCi-E`	Stall indicator — stepper axes only
`OUTFNCi-F`	Fault indicator (indicates drive fault input or user fault input is active)
`OUTFNCi-G`	Position error exceeds max. limit set with `SMPER` — servo axes only
`OUTFNCi-H`	Output on position

* The "`i`" in the command syntax represents the number of the programmable input (e.g., `OUTFNC3-H` assigns onboard output #3 as an "output on position" function).

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Thumbwheels

You can connect the controller's programmable I/O to a bank of thumbwheel switches to allow operator selection of motion or machine control parameters.

The commands that allow for thumbwheel data entry are:

`INSTW`..... Establish thumbwheel data inputs
`OUTTW`..... Establish thumbwheel data outputs
`TW`..... Read thumbwheels or PLC inputs
`INPLC`..... Establish PLC data inputs
`OUTPLC`..... Establish PLC data outputs

Thumbwheel Setup

The controller's programming language allows direct input of BCD thumbwheel data via the programmable inputs. Use the steps below to set up and read the thumbwheel interface. Refer to the *Gem6K Series Command Reference* for descriptions of the commands used below.

Step 1 Wire your thumbwheels to the Gem6K. Refer to your product's *Installation Guide* for I/O specifications.

Step 2 Set up the inputs and outputs for operation with thumbwheels. The data valid input will be an input which the operator holds active to let the controller read the thumbwheels. This input is not necessary; however, it is often used when interfacing with PLCs.

```
OUTPLC1,1-4,0,12    ; Configure PLC output set 1:
                    ;   onboard outputs 1-4 are strobe outputs,
                    ;   no output enable bit,
                    ;   12 ms strobe time per digit read.
INPLC1,1-8,9        ; Configure PLC input set 1:
                    ;   onboard inputs 1-8 are data inputs,
                    ;   onboard input 9 is a sign input,
                    ;   no data valid input.
INLVL000000000      ; Onboard inputs 1-9 configured active low
```

Step 3 The thumbwheels are read sequentially by outputs 1-4, which strobe two digits at a time. The sign bit is optional. Set the thumbwheels to **+12345678** and type in the following commands:

```
VAR1=TW5            ; Assign data from all 8 thumbwheel digits to VAR1
VAR1                ; Displays the variable (*VAR1=+0.12345678).
                    ; If you do not receive this response, return to
                    ; step 1 and retry.
```

PLCs

The controller's programmable I/O may be connected to most PLCs. After defining and storing controller programs, the PLC typically executes programs, loads data, and manipulates inputs to the controller. The PLC instructs the controller to perform the motion segment of a total machine process.

Refer to your product's *Installation Guide* for instructions on connecting to I/O devices. For higher current or voltages above 24VDC, use external signal conditioning such as OPTO-22 compatible I/O signal conditioning racks. Contact your local distributor or automation technology center for information on these products.

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PLC Scan Mode

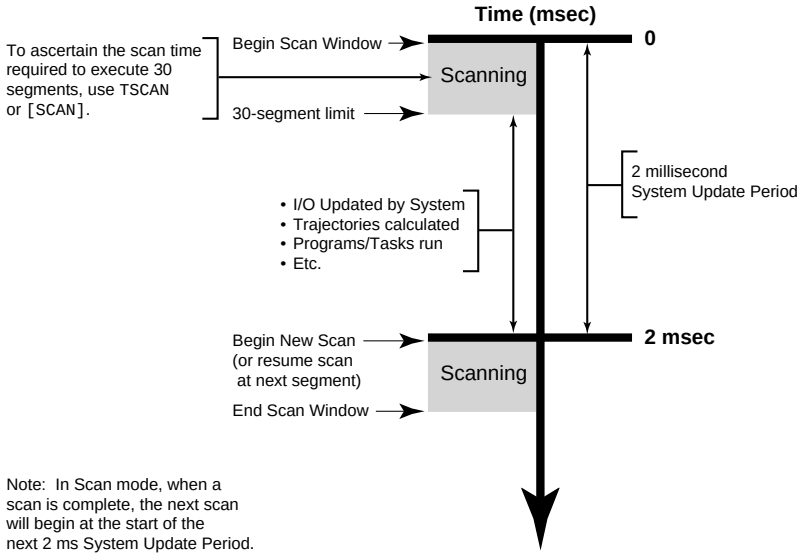
The PLC feature allows you to create a pre-compiled program that mimics PLC functionality by scanning through the I/O faster than in a normal program run. Because the functions of PLC programs are pre-compiled, delays associated with command processing are eliminated during profile execution, allowing more rapid sequencing of actions than would be possible with programs which are not compiled. Command processing is then free to monitor other activities.

Scan Time

To check how much time (in 2 ms increments) the last scan took to complete, issue the TSCAN command or use the SCAN operand for variable assignments and IF conditions.

For example, if the last PLC program took 3 system updates (2 ms each) to scan, then TSCAN would report *TSCAN6, indicating that it took 6 ms to complete the scan. Each pass, if taking the same path through the conditional branches (IF statements), will always report the same TSCAN value.

The PLC program is scanned/ executed at the beginning of the 2-ms update period. The scan will stop after 30 segments have been executed and resume at the next 2-ms update. PLCP programs, when compiled, comprise a linked list of PLC segments. During a scan, each segment is counted until the total number of segments executed exceeds 30.



If the 30-segment limit occurs while executing a multi-segment statement, then that statement will finish no matter how many segments it executes. For example, if 29 segments have executed, then the next segment will cause the scan to pause until the next 2-ms update. If that next statement is VARI1=1PE, which executes 2 segments, then VARI1=1PE will complete its operations before pausing the scan.

To Implement a PLC Program …

1. Define the PLC program (DEF PLCPi statement, followed by commands from the list below, followed by END). Up to 99 PLC programs may be defined, identified as PLCP1, PLCP2, PLCP3, and so on. Only these commands are allowed in a PLC program:

   - IF, ELSE, and NIF (conditional branching) —The PLC program uses the non-scaled integer ("raw") operand values (e.g., PE value is not scaled by SCLD or ERES; PANI value is ADC counts, not volts). The only operands that are not allowed are: SIN, COS, TAN, ATAN, VCVT, SQRT, VAR, TW, READ, DREAD, DREADF, DAT, DPTR, and PI.
   - L and LN (loops)
   - HALT —
     - If the PLC program is executed with SCANP, HALT will terminate the current PLC program and kill the SCANP mode
     - If the PLC program is executed with PRUN, HALT will stop the PLC program (and the program that executed the PRUN statement) running in that task.
   - BREAK —
     - If the PLC program is executed with SCANP, BREAK will end only the current scan loop. At the next 2-millsecond update, the scan will restart at the first line of the PLC program.
     - If the PLC program is executed with PRUN, BREAK will stop the PLC program and execution will continue in the program from which the PRUN was executed (resuming at the command immediately following the PRUN command).
   - TIMST and TIMSTP (start and stop the timer) —
   - OUT (turn on a digital output)

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- ANO (set an analog output voltage – requires an extended I/O brick with on an analog output SIM) —
- EXE (execute a program in a specific task — e.g., 2%EXE MOVE)
- PEXE (execute a compiled program in a specific task — e.g., 3%PEXE PLCP4)
- VARI (integer variables). A VARI assignment expression is limited to one math function — either addition (+) or subtraction (-). The operands can be any of the monitored integer assignment operators (e.g., PE, PC, etc.).
  NOTE: The PLC program uses the non-scaled ("raw") operand values.
- VARB (binary variables). Bitwise operations are limited to Boolean And (&), Boolean Inclusive Or (|), and Boolean Exclusive Or (^). The operands can be any of the monitored binary assignment operators (e.g., IN, LIM, AS, VARB, etc.).

2. Compile the PLC program (PCOMP PLCPi). A compiled program runs much faster than a standard program. After the PLCP program is compiled, it is placed in the Gem6K controller's "compiled" memory partition (see MEMORY command). To verify which PLC programs are compiled, type in the TDIR command; compiled PLC programs are identified as "COMPILED AS A PLC PROGRAM".

3. Execute the PLC program (SCANP PLCPi). When the PLC program is launched with the SCANP command, it is executed in the "PLC Scan Mode". The advantage of the PLC Scan Mode is that the PLC program is executed within a dedicated 0.5 ms time slot during every 2 ms system update period. This gives the PLCP program faster throughput for monitoring and manipulating I/O.

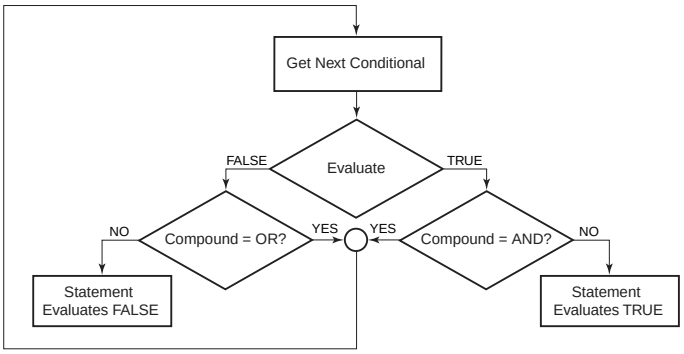
   An alternative execution method is to use the PRUN command (PRUN PLCPi). This method is similar to the SCANP PLCPi method, but will only run through the PLCP program once.

Technical Notes About PLC Programs

- **Controller Status** bit #3 is set when a PLCP program is being executed in Scan Mode. To check the controller status, use SC, TSC, or TSCF.
- **Launching programs external to the scan**: Using the EXE command or the PEXE command, a scan program can launch another program in a specified task. EXE launches a standard, non-compiled program; PEXE launches a compiled program.
- **Stopping the scan**: The scan program can be stopped in either of two ways: using the !K command, or clearing the scan program by issuing a SCANP CLR command.
- **Timing the PLC program outputs**: It is not possible to control where the PLC program will pause if the scan takes more than the allowed time. This means that there can be a time lag of several update periods before the outputs, analog outputs, and/or variables affected by the PLC program are updated. The order in which the scan takes place should be considered when creating PLC programs to minimize the effects of such a lag. One way to avoid the lag is to create a binary variable as a temporary holding place for the desired output states. The last commands before the END statement of the PLC program can set the outputs according to the final status of the variable, such that all output states are written at the same time, just as the scan completes. This method is demonstrated in the example program below.
- **Memory Requirements**: Most commands allowed in a PLC program consume one segment of compiled memory after the program is compiled with PCOMP; the exceptions are VARI and VARB (each consume 2 segments) and IF statements. Each IF conditional evaluation compounded with either an AND or an OR operator consumes an additional segment (e.g., IF(IN.1=b1 AND 1AS.1=b0) consumes three segments of compiled memory). The number of compounds is limited only by the memory available.
- **Order of Evaluation for Conditional Expressions**:
  Because only one level of parenthesis is allowed, the order of evaluation of IF

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conditionals is from left to right. Refer to the flowchart below for the evaluation logic.

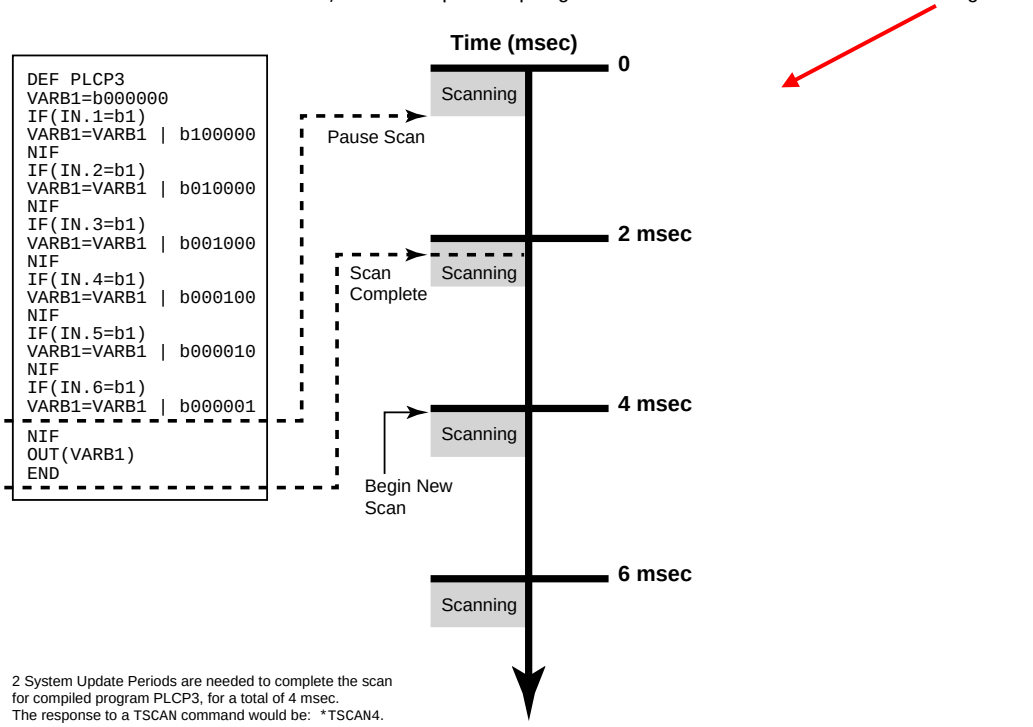


Programming Example

```
DEF PLCP3
; Binary states of outputs 1-6 represented by VARB1 bits 1-6.
; Outputs 1-6 set at the end of program.
VARB1=b000000             ; Initialize binary variable 1
IF(IN.1=b1)               ; If onboard input 1 is ON, turn output 1 ON
  VARB1=VARB1 | b100000   ; Set binary bit for output 1 only to ON
  NIF
IF(IN.2=b1)               ; If onboard input 2 is ON, turn output 2 ON
  VARB1=VARB1 | b010000   ; Set binary bit for output 2 only to ON
  NIF
IF(IN.3=b1)               ; If onboard input 3 is ON, turn output 3 ON
  VARB1=VARB1 | b001000   ; Set binary bit for output 3 only to ON
  NIF
IF(IN.4=b1)               ; If onboard input 4 is ON, turn output 4 ON
  VARB1=VARB1 | b000100   ; Set binary bit for output 4 only to ON
  NIF
IF(IN.5=b1)               ; If onboard input 5 is ON, turn output 5 ON
  VARB1=VARB1 | b000010   ; Set binary bit for output 5 only to ON
  NIF
IF(IN.6=b1)               ; If onboard input 6 is ON, turn output 6 ON
  VARB1=VARB1 | b000001   ; Set binary bit for output 6 only to ON
  NIF
OUT(VARB1)                ; Turn on appropriate onboard outputs
END

PCOMP PLCP3               ; Compile program PLCP3

SCANP PLCP3               ; Run compiled program PLCP3 in Scan mode. See diagram.
```

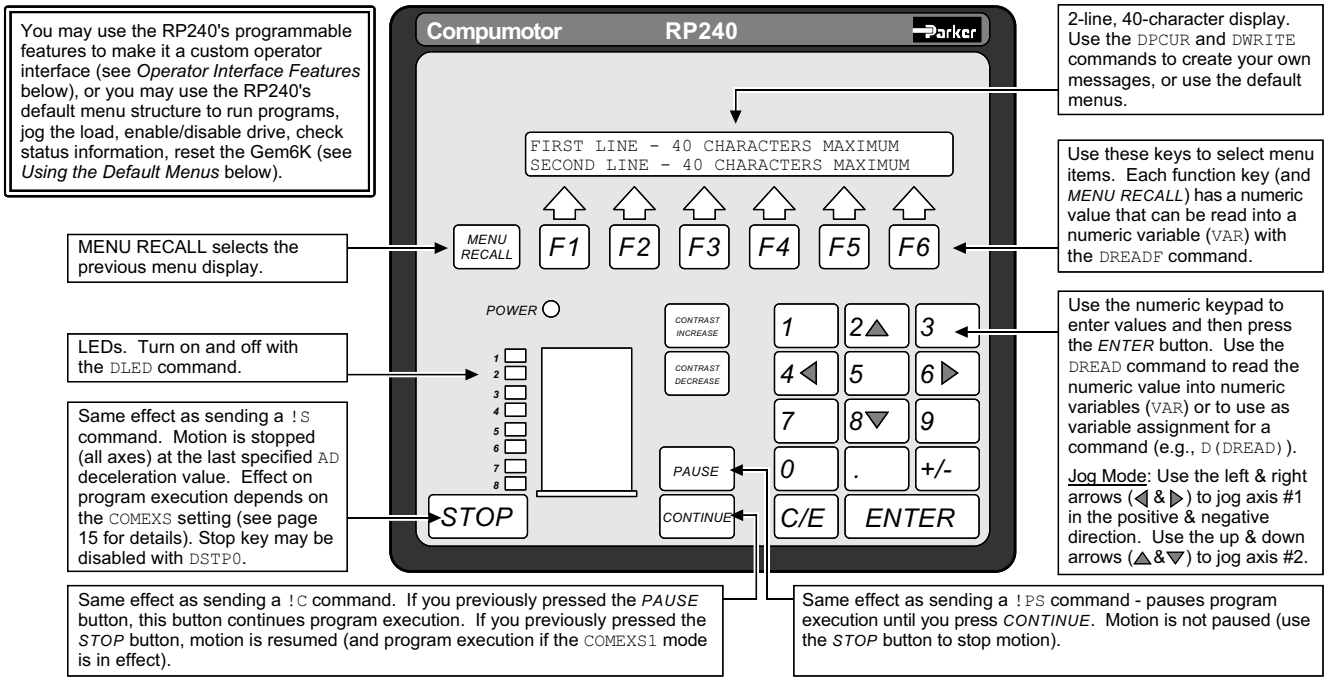


2 System Update Periods are needed to complete the scan for compiled program PLCP3, for a total of 4 msec.
The response to a TSCAN command would be: *TSCAN4.

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RP240 Remote Operator Panel

Gem6K Series products are directly compatible with the Compumotor RP240 Remote Operator Panel. This section describes how to use your Gem6K product with the RP240. Instructions for connecting the RP240 are provided in the *Gem6K Hardware Installation Guide*. Refer to the *Model RP240 User Guide* (p/n 88-012156-01) for information on RP240 hardware specifications, mounting guidelines, environmental considerations, and troubleshooting.



Configuration

NOTE

As shipped from the factory, your Gem6K product is configured to operate an RP240 from the **RS-232** connector (referred to as the "COM 2" port). This should be appropriate for the majority of applications requiring RP240 interface.

For more information on controlling your product's multiple serial ports, refer to page 56.

Every Gem6K Series product has two serial ports. The **RS-232/485** connector is referenced as the "COM1" serial port, and the **RS-232** connector is referenced as the "COM2" serial port.

To configure the Gem6K product's serial ports for use with the RP240 and/or Gem6K language commands, use the DRPCHK command. Be sure to select the affected serial port (**COM 1** or **COM 2**) with the PORT command before you execute the DRPCHK command. Once you issue the DRPCHK command, it is automatically saved in non-volatile memory. The configuration options are:

DRPCHKØ .....Use the serial port for Gem6K commands only (default for **COM 1**)

DRPCHK1 .....Check for RP240 on power up or reset. If detected, initialize RP240. If no RP240, use serial port for Gem6K commands.

DRPCHK2 .....Check for RP240 every 5-6 seconds. If detected, initialize RP240. Do not use

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port for Gem6K commands.

`DRPCHK3` ..... Check for RP240 on power up or reset. If detected, initialize RP240. If no RP240, use serial port for `DWRITE` command only. The `DWRITE` command can be used to transmit text strings to remote RS-232C devices. (default setting for **COM 2**)

Example **COM 2** is to be used for RS-232; **COM 1** is to be used for RP240, but the RP240 will be plugged in on an as-needed basis. The set-up commands for such an application should be executed in the following order:

```
PORT1      ; Select COM1 serial port for setup
DRPCHK2    ; Configure COM1 for RP240, periodic check
PORT2      ; Select COM2 serial port for setup
DRPCHKØ    ; Configure COM2 for Gem6K commands only
```

Operator Interface Features

The RP240 may be used as your product's *operator interface*, not a program entry terminal. As an operator interface, the RP240 offers the following features:

- Displays text and variables
- 8 LEDs can be used as programmable status lights
- Operator data entry of variables: read data from RP240 into variables and command value substitutions (see *Command Value Substitutions* on page 7).

Typically the user creates a program in the Gem6K controller to control the RP240 display and RP240 LEDs. The program can read data and make variable assignments via the RP240's keypad and function keys.

The Gem6K Series software commands for the RP240 are listed below. Detailed descriptions are provided in the *Gem6K Series Command Reference*. The example below demonstrates the majority of these Gem6K Series commands for the RP240.

`DCLEAR`.....Clear The RP240 Display
`DJOG`.....Enter RP240 Jog Mode
`[DKEY]`.....Numeric value of RP240 Key
`DLED`.....Turn RP240 LEDs On/Off
`DPASS`.....Change RP240 Password
`DPCUR`.....Position The Cursor On The RP240 Display
`[DREAD]` .....Read RP240 Data
`[DREADF]` .....Read RP240 Function Key
`DREADI`.....RP240 Data Read Immediate Mode
`DRPCHK`.....Check for RP240
`DSTP`.....Enable/Disable the RP240 Stop Key
`DVAR`.....Display Variable On RP240
`DWRITE`.....Display Text On The RP240 Display

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Programming Example

```
DEF panel1                        ; Define program panel1
REPEAT                            ; Start of repeat loop
 DCLEAR0                          ; Clear display
 DWRITE"SELECT A FUNCTION KEY"    ; Display text "SELECT A FUNCTION KEY"
 DPCUR2,2                         ; Move cursor to line 2 column 2
 DWRITE"DIST"                     ; Display text "DIST"
 DPCUR2,9                         ; Move cursor to line 2 column 9
 DWRITE"GO"                       ; Display text "GO"
 DPCUR2,35                        ; Move cursor to line 2 column 35
 DWRITE"EXIT"                     ; Display text "EXIT"
 VAR1 = DREADF                    ; Input a function key
 IF (VAR1=1)                      ; If function key #1 hit
   GOSUB panel2                   ; GOSUB program panel2
  ELSE                            ; Else
  IF (VAR1=2)                     ; If function key #2 hit
   DLED1                          ; Turn on LED #1
   GO1                            ; Start motion on axis #1
   DLED0                          ; Turn off LED #1
  NIF                             ; End of IF (VAR1=2)
 NIF                              ; End of IF (VAR1=1)
UNTIL (VAR1=6)                    ; Repeat until VAR1=6 (function key 6)
DCLEAR0                           ; Clear display
DWRITE"LAST FUNCTION KEY = F"     ; Display text "LAST FUNCTION KEY = F"
DVAR1,1,0,0                       ; Display variable 1
END                               ; End of panel1

DEF panel2                        ; Define prog panel2
DCLEAR0                           ; Clear display
DWRITE"ENTER DISTANCE"            ; Display text "ENTER DISTANCE"
D(DREAD)                          ; Enter distance number from RP240
END                               ; End of panel2
```

Using the Default Menus

On power-up, the Gem6K product will automatically default to a mode in which it controls the RP240 with the menu-driven functions listed below.

The flow chart below illustrates the RP240's menu structure in the default operating mode (when no Gem6K product user program is controlling the RP240). Press the ***Menu Recall*** key to back up to the previous screen. The menu functions are described in detail below.

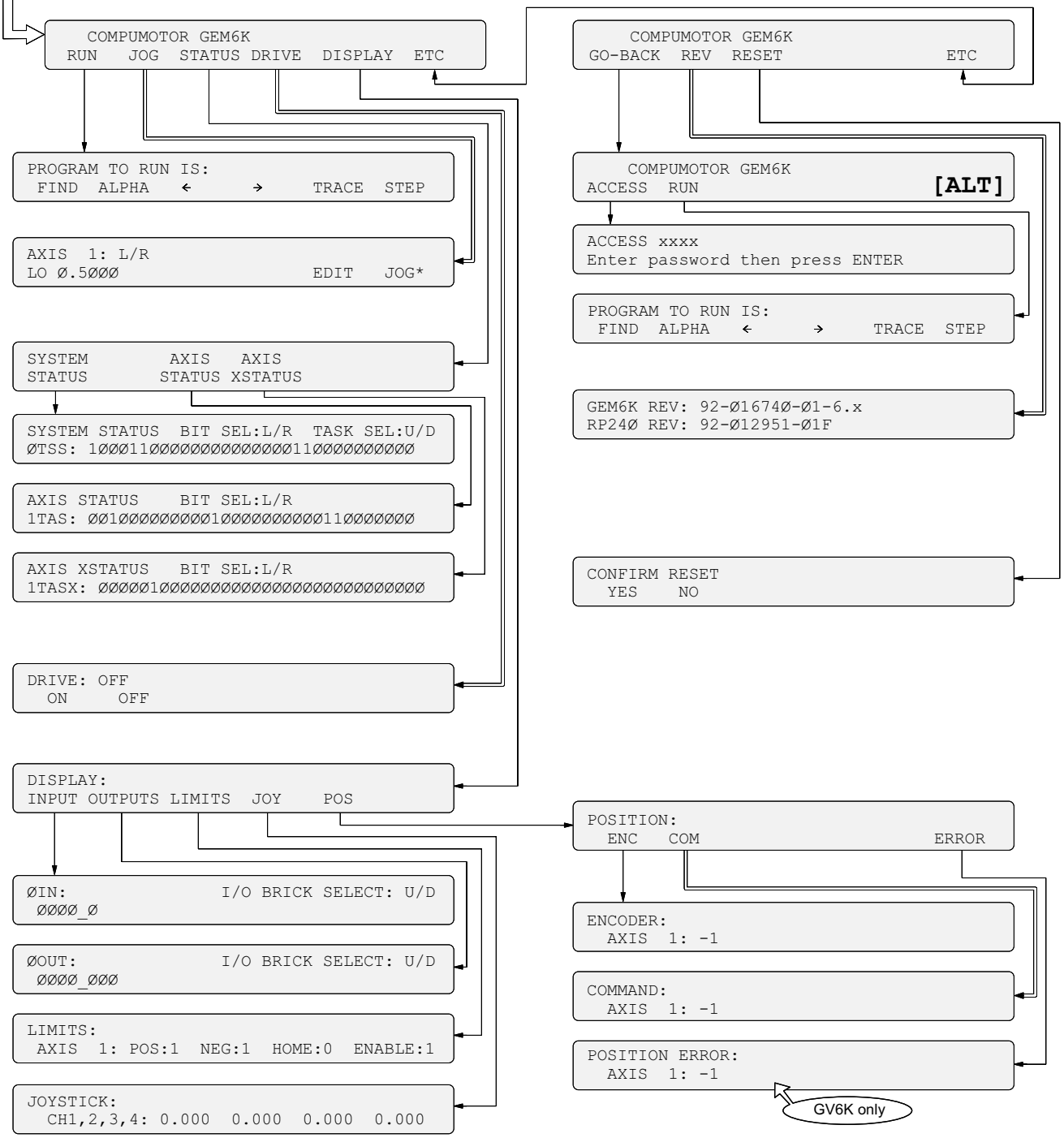
- Run a stored program (RUN, STOP, PAUSE and CONTINUE functions)
- Jog the load
- Display the status of:
  - System (TSS), for each task
  - Axis (TAS)
  - Extended Axis (TASX)
  - I/O (TIN and TOUT)
  - Limits (TLIM) and ENABLE input (TINO bit #6)
  - Position: Commanded (TPC), Encoder (TPE)
  - Firmware revision levels for the Gem6K product (TREV) and the RP240
- Enable or disable the internal drive (DRIVE)
- Access RP240 menu functions with a security password (set with DPASS)
- Reset the Gem6K product (equivalent to the RESET command)

NOTE: To disable these menus, the start-up program (the program assigned with the STARTP command) must contain the DCLEARØ command.

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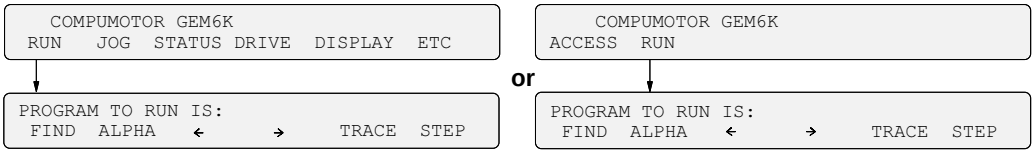
Default Power-up Menu

- If you change the password with the DPASS command, the menu marked with **[ALT]** becomes the power-up menu. The default password is “6800” for the Gem6K controller.
- Arrows indicate the menu path when you press the corresponding function key below the menu item.
- To back up to the previous menu item, press the *MENU RECALL* button.



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Running a Stored Program



After accessing the RUN menu, press ***F1*** to "find" the names of the programs stored in the Gem6K product's memory; pressing ***F1*** repeatedly displays subsequent programs in the order in which they were stored in BBRAM. To execute the program, press the ***ENTER*** key.

To type in a program name at the location of the cursor, first select alpha or numeric characters with the ***F2*** function key (characters will be alpha if an asterisk appears to the right of ALPHA, or numeric if no asterisk appears). If alpha, press the up (2) or down (8) keys to move through the alphabet, if numeric, press the desired number key. Press ***F3*** to move the cursor to the left, or ***F4*** to move the cursor to the right.

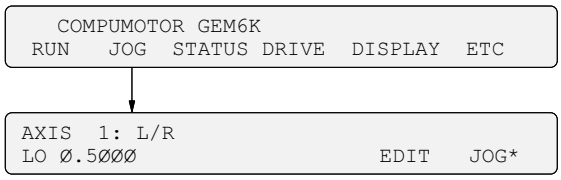
Only user programs defined with DEF and END may be executed from this menu. Compiled profiles (GOBUF profiles) cannot be executed from this menu; they must be executed from the terminal emulator with the PRUN command, or you can place the PRUN (name of path) command in a user program and then execute that program from this menu.

HINT: If you wish to display each command as it is executed, select STEP and TRACE and press the ENTER key to step through the program.

When a program is RUN and TRACE is selected (TRACE*), the RP240 display will trace all program commands as they are executed. This is different from the TRACE command in that the trace output goes to the RP240 display, not to a terminal via the serial port.

When a program is RUN and STEP is selected, step mode has been entered. This is similar to the STEP command, but when selected from the RUN menu the step mode allows single stepping by pressing the ***ENTER*** key. Both RP240 trace mode and step mode are exited when program execution is terminated.

Jogging



You can jog the axis by pressing the arrow keys on the RP240's numeric keypad. The left and right arrow keys are for jogging the axis in the negative and positive direction, respectively. Pressing an arrow key starts motion and releasing the arrow key stops motion.

The HI and LO values in the jog menu represent the velocity in units of revs/sec. If scaling is enabled, the value is multiplied by the programmed SCLV value.

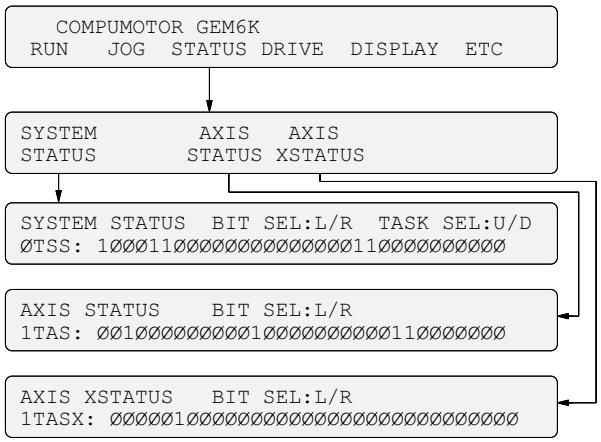
To edit the jog velocity* values:

1. Press the ***F5*** function key under EDIT (edit mode indicated with an asterisk).
2. Press the ***F1*** function key to select the HI and LO values (cursor appears under the first digit of the value selected).
3. Using the numeric keyboard, enter the value desired.
4. Repeat steps 2 and 3 for all values to be changed.
5. Press ***ENTER*** when finished editing.
6. To jog with the new velocity values, first press the ***F6*** function key (under JOG) to enable the arrow keys again.

Jog accel and decel values are specified by the JOGA and JOGAD commands, respectively.

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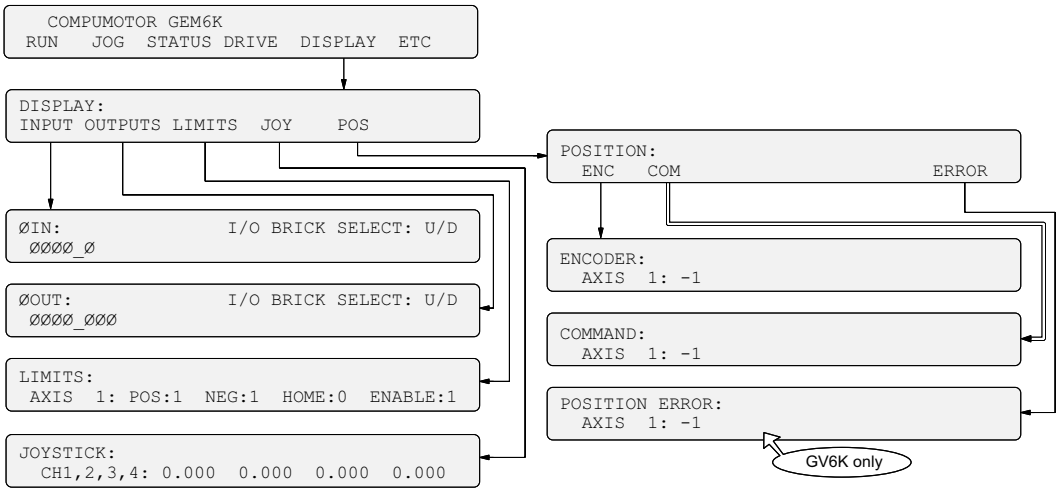
Status Reports:
System & Axis



After accessing the desired status menu, you can ascertain the function and status of each system (TSS, for each task) or axis (TAS and TASX) status bit by pressing the arrow keys on the numeric keypad.

To view a more descriptive explanation of each status bit (includes a text description), press the left or right arrow keys on the numeric keypad.

Status Reports:
I/O, Limits, Position



INPUTS Menu: This menu displays the TIN bit patterns for programmable inputs (onboard triggers and digital inputs on expansion I/O bricks). Remember that I/O bit patterns vary by product (see page 91 to find the bit patterns for your product). The initial menu show the trigger inputs status; use the up and down arrows to select the status of inputs on expansion I/O bricks.

OUTPUTS Menu: This menu displays the TOUT bit patterns for programmable outputs (onboard outputs and digital outputs on expansion I/O bricks). Remember that I/O bit patterns vary by product (see page 91 to find the bit patterns for your product). The initial menu show the onboard outputs; use the up and down arrows to select the status of outputs on expansion I/O bricks.

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LIMITS Menu:

- The POS, NEG and HOME status items represent the hardware states of the limit inputs on the "LIMITS/HOME" connector, regardless of their LIMFNC input function assignments; they do not represent INFNC limit functions assigned to onboard trigger inputs or digital inputs on expansion I/O bricks.
- "POS" refers to the hardware end-of-travel limit imposed when counting in the positive direction. "NEG" refers to the limit imposed when counting in the negative direction.
- A "1" indicates that the input is grounded, "0" indicates not grounded.

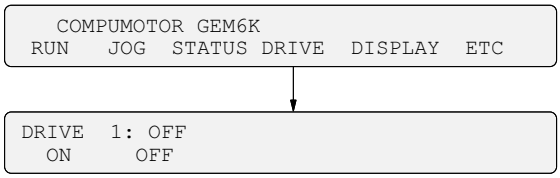
  The end-of-travel limits (POS and NEG) must be grounded to allow motion (this is reversed if the active level is reversed with the LIMLVL command).

  The Enable input (ENABLE input terminal) must also be grounded before motion is allowed. When not grounded, the output to the motor is cut off and the shutdown outputs are activated.

POS Menu:

- The position values (encoder, commanded, and position error) shown are continually updated.
- The position error ("ERROR") report is applicable only to servo axes.
- Position values are subject to the SCLD scaling factor (if scaling is enabled—SCALE1), PSET offset value, encoder polarity (ENCPOL), and commanded direction polarity (CMDDIR).

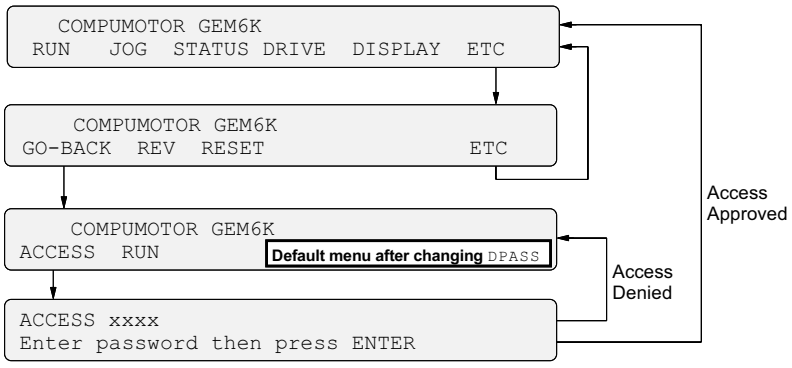
Enabling and Disabling the Drive(s)



In the DRIVE menu, the current status of the drive(s) is displayed. To enable or disable the drive, press ***F1*** or ***F2***, respectively This menu offers the same functionality as the DRIVE command.

WARNING
Shutting down a rotary drive system allows the load to freewheel if there is no brake installed.

Access Security

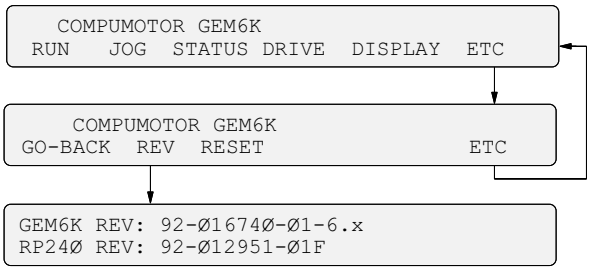


If the RP240 password is modified with the DPASS command to be other than the default (see *Changing the Password* below) the ACCESS menu then becomes the new default menu after power-up or executing a RESET. After that, the new password must then be entered to access the original default menu (see "Access Approved" path in illustration). If the operator does not know the new password, all he or she can do is run programs stored in the Gem6K product (RUN).

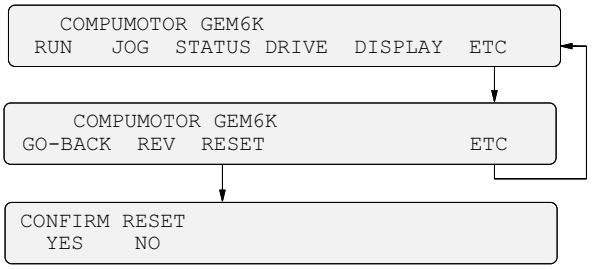
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Changing the Password: The default password for Gem6K products is “6000”. A new password (numeric value of up to 4 characters) can be established with the DPASS command. For example, the DPASS2001 command sets the password to 2001.

Revision Levels



Resetting the Gem6K Product



After accessing the RESET menu, press the ***F1*** key to execute a reset (or press ***F2*** to cancel and exit the menu). The reset is identical to issuing a RESET command or cycling power to the Gem6K product. If a start-up program has been assigned with the STARTP command, that program will be executed.

CAUTION

Executing a reset will restore most command values (exclusions: see page 65) to their factory default setting.

Joystick Control, Analog Inputs

Refer to your **Installation Guide** *for connection procedures.*

The Gem6K allows you to add analog input (ANI) SIMs to the expansion I/O bricks (sold separately). Each ANI SIM provides 8 analog inputs. The default voltage range for these input is -10VDC to +10VDC, but other ranges are selectable with the ANIRNG command. ANI inputs may be used in a variety of ways:

- Control an axis with a joystick (see *Joystick Control*)
- Use the voltage value to control other events. The voltage value on the ANI inputs can be read using the ANI or TANI commands.

Joystick Control

The controller supports joystick operation with digital inputs and analog inputs. The digital inputs include the onboard limit inputs and trigger inputs, as well as digital input SIMs on an external I/O brick. The 12-bit analog inputs are available on board (single analog input) or if you install an analog input SIM on an external I/O brick (default voltage range is -10V to +10V, selectable with ANIRNG).

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To Set Up Joystick Operation

(refer also to the example code below)

1. Select the required digital inputs and analog inputs required for joystick operation. Connect the joystick as instructed in your controller's *Installation Guide*.
2. Assign the appropriate input functions to the digital inputs used for joystick's operation:
   - Release Input: `INFNCi-M` for triggers & I/O brick inputs, or `LIMFNCi-M` for limit inputs.
   - Velocity Select Input: `INFNCi-O` for triggers & external inputs, or `LIMFNCi-O` for limit inputs.
3. (optional) Use the `ANIRNG` command to select the voltage range for the analog inputs you will use. The default range is -10VDC to +10VDC (other options are 0 to +5V, -5 to +5V, and 0 to +10V).
4. Use the `JOYAXH` command to assign the analog input that will control the axis.
5. Define the joystick motion parameters:
   - Max. Velocity when Velocity Select input switch is open/high (`JOYVH` command). If the Velocity Select input is not used, joystick motion always uses the `JOYVH` velocity.
   - Max. Velocity when Velocity Select input switch is closed/low (`JOYVL` command).
   - Accel (`JOYA` command).
   - Accel for s-curve profiling (`JOYAA` command).
   - Decel (`JOYAD` command).
   - Decel for s-curve profiling (`JOYADA` command).
6. Define the usable voltage zone for your joystick:
   (make sure you have first assigned the analog inputs – see step 3 above)
   - End Deadband (`JOYEDB`): Defines the voltage offset (from the -10V & +10V endpoints) at which max. velocity occurs. Default is 0.1V, maxing voltage at -9.9V and +9.9V.
   - Center Voltage (`JOYCTR` or `JOYZ`): Defines the voltage when the joystick is at rest to be the zero-velocity center. Default `JOYCTR` setting is 0V.
   - Center Deadband (`JOYCDB`): Defines the zero-velocity range on either side of the Center Voltage. Default is 0.1V, setting the zero-velocity range at -0.1V to +0.1V.
7. To jog the axis:
   a. In your program, enable Joystick Operation with the `JOY` command (Joystick Release input must be closed in order to enable joystick mode). When the `JOY` command enables joystick mode, program execution stops (assuming the Continuous Command Execution Mode is disabled with the `COMEXCØ` command).
   b. Move the load with the joystick.
   c. When you are finished, open the Joystick Release input to disable joystick mode. This allows program execution to resume with the next statement after the initial `JOY` command that started the joystick mode.

Joystick Programming Example

(refer also to the illustration below)

Application Requirements: This example represents a typical two-axis joystick application in which a high-velocity range is required to move to a region, then a low-velocity range is required for a fine search. After the search is completed it is necessary to record the load positions, then move to the next region. A digital input can be used to indicate that the position should be read. The Joystick Release input is used to exit the joystick mode and continue with the motion program.

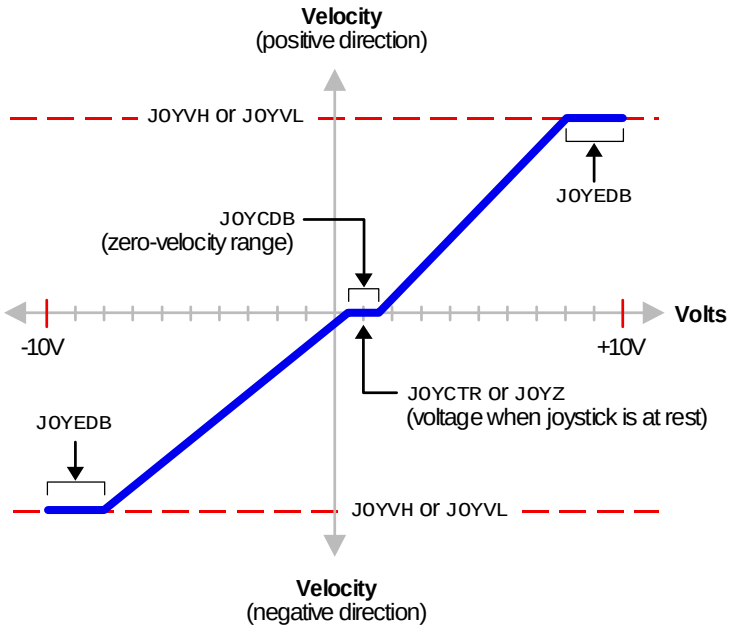
Hardware Configuration:

- An analog input SIM is installed in the 3rd slot of I/O brick 1. The eight analog inputs (1-8) are addressed as input numbers 17-24 on the I/O brick. Analog input 17 will control the motion.
- A digital input SIM is installed in the 1st slot of I/O brick 1. The eight digital inputs (1-8) are addressed as input numbers 1-8 on the I/O brick. Digital input 6 will be used for the Joystick Release function, and input 7 will be used for the Joystick Velocity Select input. Input 8 will be used to indicate that the position should be read.

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Setup Code (the drawing below shows the usable voltage configuration):

```
1INFNC7-M         ; Assign Joystick Release f(n) to brick 1, input 7
1INFNC8-O         ; Assign Joystick Velocity Select f(n) to brick 1, input 8
JOYAXH1-17        ; Assign analog input 17 to control the motion,
JOYVH1            ; Max. velocity is 10 units/sec when the
                  ; Velocity Select input (1IN.7) is open (high)
JOYVL10           ; Max. velocity is 1 unit/sec when the
                  ; Velocity Select input (1IN.7) is closed (low)
JOYA100           ; Set joystick accel to 100 units/sec/sec
JOYAD100          ; Set joystick decel to 100 units/sec/sec
;**** COMMANDS TO SET UP USABLE VOLTAGE: **********
1JOYCTR.17=+1.0   ; Set center voltage for analog input 17
                  ; to+1.0V. The +1.0V value was
                  ; ascertained by checking the voltage of the both
                  ; inputs (with the 1TANI.17)
                  ; when the joystick was at rest.
1JOYCDB.17=0.5    ; Set center deadband to compensate for the fact that
                  ; when the joystick is at rest, the voltage received on
                  ; the analog input may fluctuate +/- 0.5V on either
                  ; side of the +1.0V center.
1JOYEDB.17=2.0    ; Set end deadband to compensate for the fact that the
                  ; joystick can produce only -8.0V to +8.0V.
;*********************************************
JOY1              ; Enable joystick mode
```



Analog Input Interface

Refer to your product's **Installation Guide** *for ANI connection information.*

Using analog (ANI) inputs on expansion I/O bricks, your controller can use analog voltage as a means to control the program based on external conditions.

Each ANI SIM on an expansion I/O brick provides eight analog inputs. The 12-bit analog inputs have a default voltage range of -10VDC to +10VDC. Other ranges are selectable with the `ANIRNG` command (0 to +5VDC, 0 to +10VDC, and -5 to +5VDC). The voltage value of the ANI inputs can be transferred to the terminal with the `TANI` command, or used in an assignment or comparison operation with the `ANI` operator (e.g., `IF(1ANI<2.4)`).

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Another choice for product control is to use a host computer and execute a motion program using the serial interface (RS-232 or RS-485). A host computer may be used to run a motion program interactively from a BASIC or C program (high-level program controls the Gem6K product and acts as a user interface). A BASIC program example is provided below.

```
10  '       Gem6K Series Serial Communication BASIC Routine
12  '                        Gem6K.BAS
14  '
16  ' ************************************************************
18  '
20  ' This program will set the communications parameters for the
22  ' serial port on a PC to communicate with a Gem6K series
24  ' stand-alone product.
26  '
28  ' ************************************************************
30  '
100 '*** open com port 1 at 9600 baud, no parity, 8 data bits, 1 stop bit
110 '*** activate Request to Send (RS), suppress Clear to Send (CS), suppress
120 '*** DATA set ready (DS), and suppress Carrier Detect (CD) ***
130 OPEN "COM1:9600,N,8,1,RS,CS,DS,CD" FOR RANDOM AS #1
140 '
150 '*** initialize variables ***
160 MOVE$ = ""        ' *** commands to be sent to the product ***
170 RESPONSE$ = ""    ' *** response from the product ***
180 POSITION$ = ""    ' *** feedback position reported ***
190 SETUP$ = ""       ' *** setup commands ***
200 '
210 '*** format the screen and wait for the user to start the program ***
220 CLS : LOCATE 12, 20
230 PRINT "Press any key to start the program"
240 '
250 '*** wait for the user to press a key ***
260 PRESS$ = INKEY$
270 IF PRESS$ = "" THEN 260
280 CLS
290 '
300 '*** set a pre-defined move to make ***
310 SETUP$ = "ECHO1:ERRLVL0:LH0:"
320 MOVE$ = "A100:V2:D50000:GO1:TFB:"
330 '
340 '
400 '*** send the commands to the product ***
410 PRINT #1, SETUP$
420 PRINT #1, MOVE$
430 '
500 '   *** read the response from the TFB command ***
510 '   *** the controller will send a leading "+" or "-" in response to the TFB command to
520 '   *** indicate which direction travel has occurred. ***
530 WHILE (RESPONSE$ <> "+" AND RESPONSE$ <> "-") ' *** this loop waits for the "+"
540   RESPONSE$ = INPUT$(1, #1)                   ' *** or "-" characters to be returned
550 WEND                                          ' *** before reading the position ***
560 '
570 WHILE (RESPONSE$ <> CHR$(13))        ' *** this loop reads one character at a time
580   POSITION$ = POSITION$ + RESPONSE$  ' *** from the serial buffer until a carriage
590   RESPONSE$ = INPUT$(1, #1)          ' *** return is encountered ***
600 WEND
610 '
620 '*** print the response to the screen ***
630 LOCATE 12, 20: PRINT "Position is " + POSITION$
640 '
650 'END
```


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TO ORDER

To order Motion OCX Toolkit™, DDE6000™, or Motion Toolbox®, contact your local Automation Technology Center (ATC) or distributor.

ActiveX Control

Provided with Motion Planner is the Gem6K ActiveX control, a 32-bit control which can be used as an interface tool between your custom Windows application and the Gem6K product. For example, you might use the ActiveX control with a third-part factory automation software and operator interface, such as Wonderware's In-Touch™.

PanelMaker

Sold separately as an add-on utility to Motion Planner, PanelMaker is a custom GUI creation tool based on the VisualBasic Scripting language. Using PanelMaker, you can create custom interfaces for operator input and diagnostics. The PanelMaker custom controls include:

- Communication between the application and the Gem6K product•

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CHAPTER FIVE

5 Custom Profiling

IN THIS CHAPTER

This chapter explains how to use these custom profiling features:

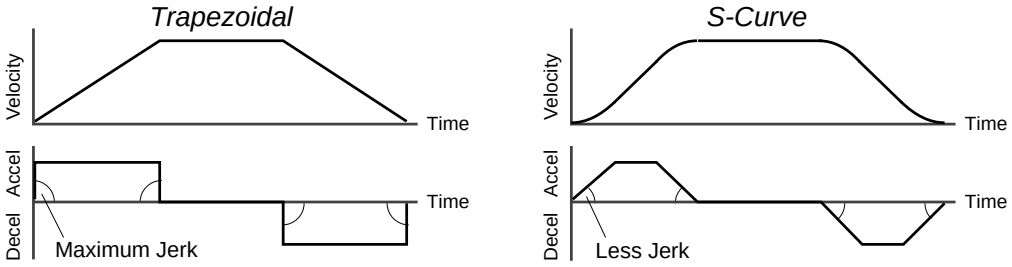
- S-Curve Profiling 136
- Compiled Motion Profiling 139
- On-the-Fly Motion (pre-emptive GOs) 155
- Registration 159
- Synchronizing Motion 163

For basic motion (accel/velocity/distance), see page 71
For homing profiles, see page 79
For Following profiles, see page 168

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S-Curve Profiling

Controllers allow you to perform *S-curve* move profiles, in addition to the usual trapezoidal profiles. S-curve profiling provides smoother motion control by reducing the *jerk* (rate of change) in acceleration and deceleration portions of the move profile (see drawing below). Because S-curve profiling reduces jerk, it improves position tracking performance.



S-Curve Programming Requirements

To program an S-curve profile, you must use the *average accel/decel* commands provided in the Gem6K Series programming language. For every maximum accel/decel command (e.g., A, AD, HOMA, HOMAD, JOGA, JOGAD, etc.) there is an *average* command for S-curve profiling (see table below).

Maximum Accel/Decel Commands:		Average ("S-Curve") Accel/Decel Commands:	
Command	**Function**	**Command**	**Function**
A	Acceleration	AA	Average Acceleration
AD	Deceleration	ADA	Average Deceleration
HOMA	Home Acceleration	HOMAA	Average Home Acceleration
HOMAD	Home Deceleration	HOMADA	Average Home Deceleration
JOGA	Jog Acceleration	JOGAA	Average Jog Acceleration
JOGAD	Jog Deceleration	JOGADA	Average Jog Deceleration
JOYA	Joystick Acceleration	JOYAA	Average Joystick Acceleration
JOYAD	Joystick Deceleration	JOYADA	Average Joystick Deceleration
LHAD	Hard Limit Deceleration	LHADA	Average Hard Limit Deceleration
LSAD	Soft Limit Deceleration	LSADA	Average Soft Limit Deceleration
PA	Path Acceleration	PAA	Average Path Acceleration
PAD	Path Deceleration	PADA	Average Path Deceleration

Determining the S-Curve Characteristics

The command values for average accel/decel (AA, ADA, etc.) and maximum accel/decel (A, AD, etc.) determine the characteristics of the S-curve. To smooth the accel/decel ramps, you must enter average accel/decel command values that satisfy the equation $\frac{1}{2} A \leq AA < A$, where A represents maximum accel/decel and AA represents average accel/decel. Given this requirement, the following conditions are possible:

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Acceleration Setting	Profiling Condition
AA > ½ A, but AA < A	S-curve profile with a variable period of constant acceleration. Increasing the AA value above the pure S-curve level (AA > ½ A), the time required to reach the target velocity and the target distance is decreased. However, increasing AA also increases jerk.
AA = ½ A	*Pure S-curve* (no period of constant acceleration—smoothest motion).
AA = A	Trapezoidal profile (but can be changed to an S-curve by specifying a new AA value less than A).
AA < ½ A; or AA > A	When you issue the `GO` command, the move will not be executed and an error message, `*INVALID CONDITIONS FOR S_CURVE ACCELERATION–FIELD` *n*, will be displayed.
AA = zero	S-curve profiling is disabled. Trapezoidal profiling is enabled. AA tracks A. (*Track* means the command's value will match the other command's value and will continue to match whatever the other command's value is set to.) However, if you enter an average decel command (e.g., `ADA`, `HOMADA`, etc.) equal to zero, you will receive the "`INVALID DATA-FIELD` n" error.
AA ≠ zero and AA ≠ A	S-curve profiling is enabled **only for standard moves** (e.g., not for compiled motion, or on-the-fly motion changes). All subsequent standard moves for that axis must comply with this equation: ½ A ≤ AA < A.
AA > ½ A	Average accel/decel is raised above the pure S-curve level; this decreases the time required to reach the target velocity and distance. However, increasing AA also increases jerk. After increasing AA, you can reduce jerk by increasing A, but be aware that increasing A requires a greater torque to achieve the commanded velocity at the mid-point of the acceleration profile.
No AA value ever entered	Profile will default to trapezoidal. AA tracks A.

If you never change the A or AA deceleration commands, AA deceleration will track AA acceleration. However, once you change A deceleration, AA deceleration will no longer track changes in AA acceleration. For example, if you never change the `AD` or `ADA` command values, `ADA` will track the `AA` command value. But once you change `AD`, the `ADA` command value will no longer track the changes in the `AA` command value.

The calculation for determining S-curve average accel and decel move times is as follows (*calculation method identical for S-curve and trapezoidal moves*):

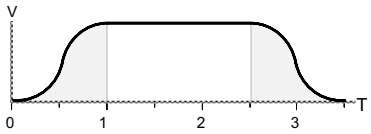
$$\text{Time} = \frac{\text{Velocity}}{A_{avg}} \quad \text{or} \quad \text{Time} = \sqrt{\frac{2 * \text{Distance}}{A_{avg}}}$$

Scaling affects the AA average acceleration (`AA`, `ADA`, etc.) the same as it does for the A maximum acceleration (`A`, `AD`, etc.). See page 67 for details on scaling.

NOTE: Equations for calculating jerk are provided on page 138.

Programming Example

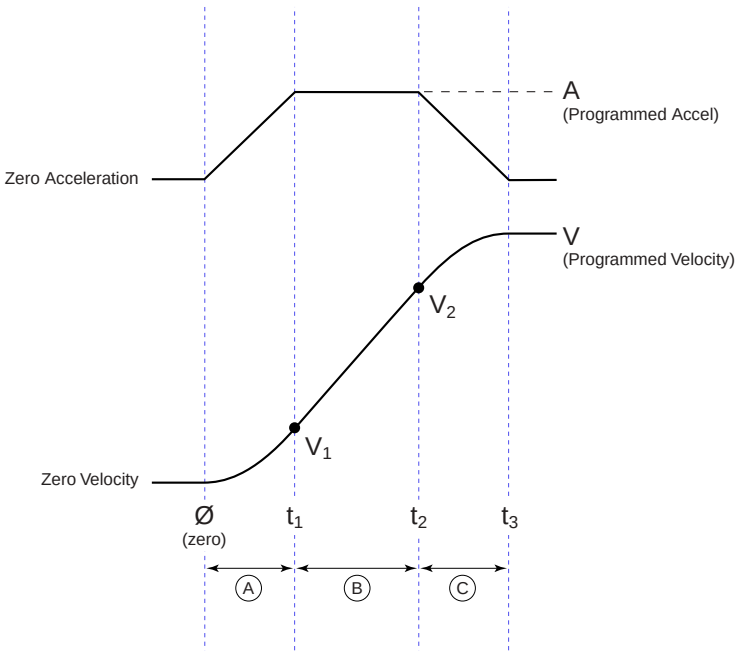
```
; In this example, axis 1 executes a pure S-curve and takes 1 second
; to reach a velocity of 5 rps.
SCALE0     ; Disable scaling
DEF SCURV  ; Begin definition of program SCURV
MA0        ; Select incremental positioning mode
D40000     ; Set distances to 40,000 positive-
           ; direction steps
A10        ; Set max. accel to 10 rev/sec/sec
AA5        ; Set avg. accel to 5 rev/sec/sec on
AD10       ; Set max. decel to 10 rev/sec/sec
ADA5       ; Set avg. decel to 5 rev/sec/sec on
V5         ; Set velocity to 5 rps
GO1        ; Execute motion
END        ; End definition of program
```



Move profile

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Calculating Jerk



Rules of Motion:

$$\text{Jerk} = \frac{da}{dt}$$

$$a = \frac{dv}{dt}$$

$$v = \frac{dx}{dt} \quad (x = \text{distance})$$

Assuming the accel profile starts when the load is at zero velocity and the ramp to the programmed velocity is not compromised:

$$\textbf{Jerk} = J_A = \frac{A^2 * AA}{V\ (A\text{-}AA)}$$

A = programmed acceleration (A, AD, HOMAD, etc.)
AA = average acceleration (AA, ADA, HOMAA, etc.)
V = programmed velocity (V, HOMV, etc.)

$$t_1 = \frac{A}{J_A}$$

$$t_2 = \frac{V}{AA} - \frac{A}{J_A}$$

$$t_3 = \frac{V}{AA}$$

NOTE: $t_3 - t_2 = t_1$

$$V_1 = \frac{J_A * t_1^2}{2} = \frac{A^2}{2 * J_A}$$

$$V_2 = V - \frac{A^2}{2 * J_A}$$

Ⓐ $t_1 \geq t \geq Ø$

$$a(t) = J_A * t$$

$$v(t) = \frac{J_A * t^2}{2}$$

$$d(t) = \frac{J_A * t^3}{6}$$

Ⓑ $t_2 \geq t > t_1$

$$a(t) = A$$

$$v(t) = \frac{A^2}{2J_A} + A * (t - t_1)$$

$$d(t) = \frac{J_A * t_1^3}{6} + \left(\frac{A * (t - t_1)^2}{2}\right) + \left(V_1 * (t - t_1)\right)$$

Ⓒ $t_3 \geq t > t_2$

$$a(t) = A - (J_A * (t - t_2))$$

$$v(t) = V - \left(\frac{J_A * (t_3 - t)^2}{2}\right)$$

$$d(t) = \frac{V^2}{2AA} + \left(\frac{J_A\ (t_3 - t)^3}{6}\right) - \left(V * (t_3 - t)\right)$$

a (t) = acceleration at time t
v (t) = velocity at time t
d (t) = distance at time t

Starting at a Non-Zero Velocity: If starting the acceleration profile with a non-zero initial velocity, the move comprises two components: a constant velocity component, and an s-curve component. Typically, the change of velocity should be used in the S-curve calculations. Thus, in the calculations above, you would substitute "$(V_F - V_O)$" for "V" (V_F = final velocity, V_O = initial velocity). For example, the jerk equation would be:

$$\textbf{Jerk} = J_A = \frac{A^2 * AA}{(V_F - V_O)\ (A\text{-}AA)}$$

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Compiled Motion Profiling

Gem6K Series products allow you to construct complex individual axis motion profiles which are compiled and saved. You can define separate and independent profiles for each individual axis. The profiles may contain:

- Sequences of motion
- Loops
- Programmable output changes
- Embedded dwells
- Direction changes
- Trigger functions

Related Commands:

Brief descriptions of related commands are found on page 139. For detailed descriptions, refer to the *Gem6K Series Command Reference*.

☞ *PLCP programs are stored in compiled memory (see page 11).*

Compiled motion profiles are defined like programs (using the DEF and END commands); the commands used to construct the motion profile segments are stored in a program (stored in *Program* memory). This program is then compiled (using the PCOMP command) and the compiled profile *segments* (GOBUF, PLOOP, GOWHEN, TRGFN, and POUTA statements) from the program are stored in *Compiled* memory. (**TIP**: The TDIR command reports which programs are compiled as a compiled profile.) You can then execute the compiled profile with the PRUN command.

The amount of RAM allocated for storing compiled profile segments is determined by the MEMORY command setting. The list below identifies memory allocation defaults and limits for Gem6K Series products. Further details on re-allocating memory are provided on page 11.

Total memory (bytes) 300,000
Default allocation (program,compiled)..... MEMORY150000,150000
Maximum allocation for compiled profiles MEMORY1000,299000
Maximum # of compiled profiles 300
Maximum # of compiled profile segments 2069

CAUTIONS

- Issuing a memory allocation command (e.g., MEMORY70000,230000) will erase all existing programs and compiled path segments. However, issuing the MEMORY command by itself (i.e., MEMORY—to request the status of how the memory is allocated) will not affect existing programs or segments.
- After compiling (PCOMP) and running (PRUN) a compiled profile. The profile segments will be deleted from *compiled* memory if you cycle power or issue a RESET command.

After compiling (PCOMP), you can execute the profiles with the PRUN command, and all of the motion and functions compiled into the profile are executed without any further commands during profile execution.

Because the motion and functions are *pre-compiled*, delays associated with command processing are eliminated during profile execution, allowing more rapid sequencing of actions than would be possible with programs which are not compiled. Command processing is then free to monitor other activities, such as I/O and communications.

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NOTES

- During compilation (PCOMP), most commands are executed the same as if no profile were being defined, even those which are not relevant to the construction of a profile. This is also true of non-compiled motion commands embedded in a compiled motion program during PCOMP. For this reason, it's good to limit commands between DEF and END to those which actually assist in the construction of the profile. Even for those that do actually assist in the construction of the profile, such as A, V, and D, it is important to remember that the command is executed and data actually changes, and it is not restored after compilation is completed.
- If your compiled motion program contains variables, the variables are evaluation only at compile time.

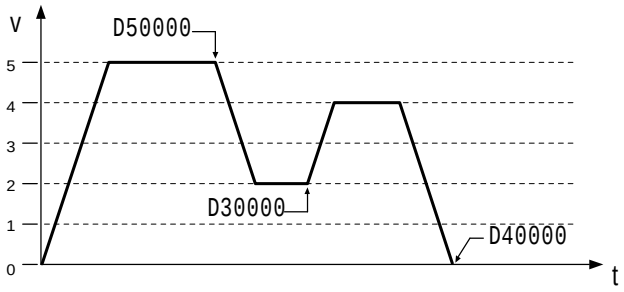
Each motion segment in a compiled motion profile may have its own distance, velocity, acceleration, and deceleration, as shown in the program example below:

Programming Example

```
DEF simple        ; Begin definition of program simple
MC0               ; Preset positioning mode (disable continuous mode)
D50000            ; Distance is 50000
A10               ; Acceleration is 10
AD10              ; Deceleration is 10
V5                ; Velocity is 5
GOBUF1            ; Store the first motion segment for axis 1.
                  ; Profile attributes are: MC0, A10, AD10, V5, D50000
D30000            ; Distance is 30000
V2                ; Velocity is 2
GOBUF1            ; Store the second motion segment for axis 1
                  ; Profile attributes are: MC0, A10, AD10, V2, D30000
D40000            ; Distance is 40000
V4                ; Velocity is 4
GOBUF1            ; Store the third motion segment for axis 1
                  ; Profile attributes are: MC0, A10, AD10, V4, D40000
                  ; Because this is the last segment in a preset profile,
                  ; the velocity will automatically end at zero.
END               ; End program definition

PCOMP simple      ; Compile simple
PRUN simple       ; Run simple
```

The resulting profile from the above program:



STATUS COMMANDS: Use these commands to check the status of compiled profiles.

System Status (TSSF, TSS, & SS):

- Bit #29 is set if compiled memory is 75% full.
- Bit #30 is set if compiled memory is 100% full.
- Bit #31 is set if a compile (PCOMP) failed; this bit is cleared on power-up, reset, or after a successful compile. Possible causes include:
  - Errors in profile design (e.g., change direction while at non-zero velocity, distance & velocity equate to <1 count/system update, preset move profile ends in non-zero velocity).
  - Profile will cause a Following error (see TFS, TFSF & FS status).
  - Out of memory (see system status bit #30)
  - Axis already in motion at the time of the PCOMP command
  - Loop programming errors (e.g., no matching PLOOP or PLN, more than 4 embedded PLOOP/END loops)

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Axis Status (TASF, TAS, & AS): Bit #31 is set while compiled a GOBUF profile is executing.

TSEG & SEG: Reports the number of available segments in compiled memory.

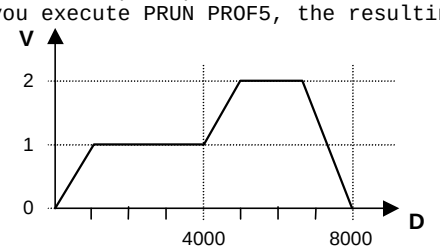
TDIR: Identifies programs that are "compiled as a path" (compiled with the PCOMP command) and reports the percentage of remaining compiled memory.

Rules for Using Velocity in Preset Compiled Motion

When defining preset mode (MC0) compiled profiles there are several rules that govern the velocity.

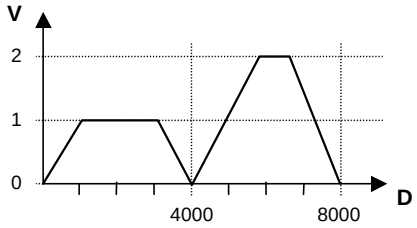
Rule #1: The last segment in the compiled profile will automatically end at zero velocity (only if not in a PLOOP/PLN loop).

```
DEF PROF5   ; Begin definition of profile #5
MC0         ; Select preset positioning
V1          ; Set velocity to 1 rev/sec
D4000       ; Set distance to 4000
GOBUF1      ; First motion segment (V1, D4000)
V2          ; Set velocity to 2 (second segment)
GOBUF1      ; Second motion segment (V2, D4000)
END         ; End definition of profile #5
PCOMP       ; Compile profile #5
; When you execute PRUN PROF5, the resulting profile is:
```



Rule #2: If you wish intermediate segments to end in zero velocity, use the VF0 command in the respective GOBUF segment.

```
DEF PROF6   ; Begin definition of profile #6
MC0         ; Select preset positioning
V1          ; Set velocity to 1 rev/sec
VF0         ; End this segment at zero velocity
D4000       ; Set distance to 4000
GOBUF1      ; First motion segment (V1, D4000, VF0)
V2          ; Set velocity to 2 (second segment)
VF0         ; End this segment at zero velocity
GOBUF1      ; Second motion segment (V2, D4000, VF0)
END         ; End definition of profile #6
PCOMP       ; Compile profile #6
; When you execute PRUN PROF6, the resulting profile is:
```



Rule #3: **CAUTION**: With compiled loops (PLOOP and PLN), the last segment within the loop must end at zero velocity or there must be a final segment placed outside the loop. Otherwise, when the profile is compiled with PCOMP you'll receive the "ERROR: MOTION ENDS IN NON-ZERO VELOCITY–AXIS n" error message and system status bit #31 will be set. after the final segment is completed, the motor will continue moving at the last segment's velocity.

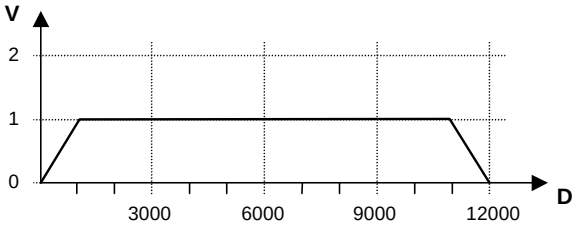
```
DEF PROF7   ; Begin definition of profile #7
MC0         ; Select preset positioning
D3000       ; Set distance to 3000
PLOOP4      ; Loop (between PLOOP & PLN) 4 times
V1          ; Set velocity to 1 rev/sec
GOBUF1      ; First motion segment
PLN1        ; End loop
END         ; End definition of profile #7
```


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```
PCOMP       ; Compile profile #7, but instead of compile, you receive
            ; an error message
```

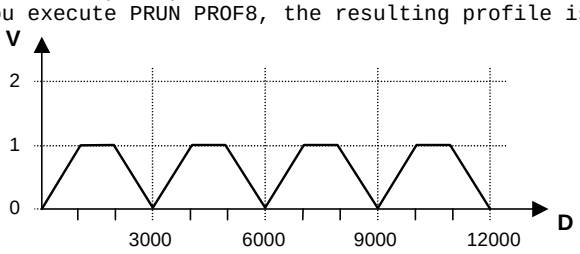
To fix the profile, reduce the PLOOP count by one and add a GOBUF statement after the PLN command:

```
DEF PROF7   ; Begin definition of profile #7
MC0         ; Select preset positioning
D3000       ; Set distance to 3000
PLOOP3      ; Loop (between PLOOP & PLN) 3 times
V1          ; Set velocity to 1 rev/sec
GOBUF1      ; Looped motion segment
PLN1        ; End loop
GOBUF1      ; Last motion segment (end at zero velocity)
END         ; End definition of profile #7
PCOMP       ; Compile profile #7
; When you execute PRUN PROF7, the resulting profile is:
```



Rule #4: With compiled loops (PLOOP and PLN), if you wish the velocity at the end of each loop to end at zero, use a VF0 command.

```
DEF PROF8   ; Begin definition of profile #8
MC0         ; Select preset positioning
D3000       ; Set distance to 3000
PLOOP4      ; Loop (between PLOOP & PLN) 4 times
V1          ; Set velocity to 1 rev/sec
VF0         ; End each segment at zero velocity
GOBUF1      ; Looped motion segment
PLN1        ; End loop
END         ; End definition of profile #8
PCOMP       ; Compile profile #8
; When you execute PRUN PROF8, the resulting profile is:
```



Compiled Following Profiles

More details on Following are found in Chapter 6 (page 168).

The new FOLRNF command designates that the motor will move the load the distance designated in a preset GOBUF segment, completing the move at the specified final ratio. The only allowable value for FOLRNF is zero (0). FOLRNF is allowed for a segment only if the starting ratio is also zero, i.e., it must be the first segment, or the previous segment must have ended in zero ratio. FOLRNF is only useful with compiled preset Following moves because the starting and final ratios are already zero for motion initiated with GO.

Compiled motion profiles may be constructed with any combination of preset or continuous motion segments. A continuous (MC1) Following segment will start with the final ratio of the previous segment, and end with the ratio given by FOLRN and FOLRD. The motion segment will consist of one ramp from the starting ratio to the final ratio. Just as with continuous Following ramps outside of a compiled profile, the master travel over which the ramp takes place is specified with FOLMD. The slave travel over which the ramp takes place is simply the

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product of master travel and average ratio. Because the slave travel is not specified explicitly, it is possible for arithmetic round-off errors to cause actual slave travel during a ramp to differ from theoretical calculations. For applications in which slave distance is important, preset segments should be used.

A preset (MCØ) Following segment will also start with the final ratio of the previous segment, but may end in one of two ways. FOLRNF specifies the final ratio of a preset Following segment. The only valid value for FOLRNF is zero (0). If FOLRNFØ is given before the GOBUF, the resulting motion segment will be constructed exactly as preset Following moves are outside of compiled profiles. In this case, the starting ratio must be zero, the final ratio will be zero, and the maximum intermediate ratio will be given by FOLRN and FOLRD. The relationships between ratio, master distance, and slave distance for this case are given on page 192 under the heading *Master and Follower Distance Calculations*. The FOLRNF command affects only the immediately subsequent preset Following segment, and must be given explicitly for each preset segment which is to end in zero ratio.

If FOLRNFØ is not given before the GOBUF, the segment will end with the ratio given by FOLRN and FOLRD, and need not start with zero ratio. This type of motion segment is constrained, however, to intermediate ratios which fall between the starting and final ratios.

Compiled profiles are built from motion segments created with the GOBUF command. That is, the motion segments may be all Following or all non-Following, but not a mixture of Following and non-Following.

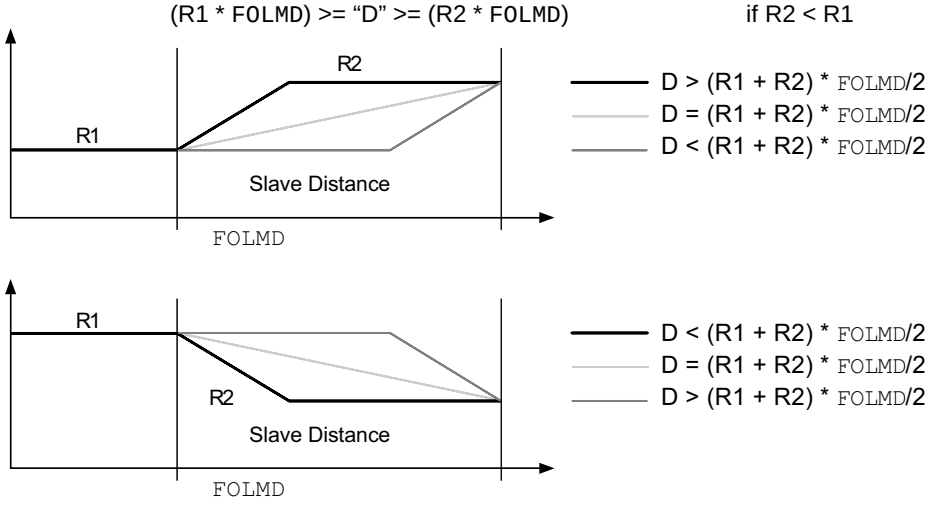
The GOBUF command builds the appropriate type of motion segment based on the values of FOLMAS and FOLEN during compilation. These parameters may not be changed inside a compiled program after a GOBUF. The choice of zero or non-zero FOLMAS must be the same during PRUN as during PCOMP (if non-zero, the value can be changed, but still must be non-zero). If a non-zero FOLMAS is given, the value of FOLEN must be the same during PRUN as during PCOMP.

Distance Calculations For Compiled Following Moves

The graph below shows 6 possibilities of ratio change profiles for preset segments, with legal FOLMD and "D" values constrained by the requirement that the average ratio (given by "D"/FOLMD) is between R1 and R2. If the distance is outside these ranges, in the profile used to get from R1 to R2 over FOLMD (covering "D" slave distance), an error message will be generated during the PCOMP command. For the graphs shown, the constraints are expressed by:

(R1 * FOLMD) <= "D" <= (R2 * FOLMD) if R2 > R1

(R1 * FOLMD) >= "D" >= (R2 * FOLMD) if R2 < R1



The two graphs above show the cases of R1<R2 or R1>R2, but the distance calculations of the ramp and constant ratio portions are the same for the two cases. For each graph, the heavy lined profile (first case) of these mimics the shape of the corresponding preset velocity change

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(FOLENØ) segments in that the ramp takes place before the constant ratio portion. The second case occurs only if the distance specified exactly matches the start and end ratios and FOLMD1. In the third case, the ramp takes place after the constant ratio portion. In the first and third cases, only two segments are built, and the slave and master distances traveled in each segment are easily calculated with the simple formulas shown below. These formulas are based on positive ratios and master and slave distances. In the construction of Following profiles, ratios and master distances are always positive, with direction implied by the sign of the slave distance. For calculations with negative slave distances, simply use the magnitude of "D" in the formulas below, and invert the sign of the resulting slave distances.

Case 1 (Ramp first)	MD1 = [D-(R2*FOLMD)]/((R1-R2)/2)	where MD1 = master distance during ramp
	MD2 = FOLMD - MD1	where MD2 = master distance during flat
	D1 = .5*(R1+R2)*MD1	where D1 = slave distance during ramp
	D2 = D - D1	where D2 = slave distance during flat
Case 2 (Ramp only)	MD1 = FOLMD	where MD1 = master distance during ramp
	D1 = D	where D1 = slave distance during ramp
Case 3 (Ramp last)	MD1 = [D-(R1*FOLMD)]/((R2-R1)/2)	where MD1 = master distance during ramp
	MD2 = FOLMD - MD1	where MD2 = master distance during flat
	D1 = .5*(R1+R2)*MD1	where D1 = slave distance during ramp
	D2 = D - D1	where D2 = slave distance during flat

Dwells and Direction Changes

Compiled profiles may incorporate changes in direction only if the preceding motion segment has come to rest. This may be achieved for non-Following segments either by creating a continuous segment with a goal velocity of zero, or by preceding a preset segment with VFØ. It may be achieved for Following segments either by creating a continuous or preset segment with a goal ratio of zero, or by preceding a preset segment with FOLRNFØ. In all cases, motion within the profile comes to rest, although the profile is not yet complete. Even though the motor is not moving, the axis status bit 1 (AS.1) will remain set, indicating a profile is still underway. Only then can you change direction (using the D+ or D- command, D~ is not allowed) within a profile. An attempt to incorporate changes in direction if the preceding motion segment has not come to rest will result in a compilation error.

In many applications, it may be useful to create a time delay between moves. For example, a machine cycle may require a move out, dwell for 2 seconds, and move back. To create this dwell, a compiled GOWHEN may be used between the two moves. The code within a compiled program may look like:

```
MC0             ; Preset incremental positioning used
D(VAR1)         ; Target position is in VAR1
VF0             ; Motion comes to rest at end of move (or use FOLRNFØ)
GOBUF1          ; Create move out segment
GOWHEN(T=2000)  ; Profile delays for 2 seconds
D-              ; Return position is home (direction reversed)
VF0             ; Motion comes to rest at end of move (or use FOLRNFØ)
GOBUF1          ; Create move back home segment
```

In Following applications, it may be more useful to create a master travel delay between moves. For example, a machine cycle replacing a cam may require a move out, dwell for 2000 master counts, and move back. To create this dwell, a compiled GOBUF of zero slave distance may be used between the two moves. The code within a compiled program may look

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like:

```
MC0             ; Preset incremental positioning used
D(VAR1)         ; Target position is in VAR1
FOLMD4000       ; Move takes place over 4000 master counts
FOLRNF0         ; Motion comes to rest at end of move
GOBUF1          ; Create move out segment
D0              ; No change in target position
FOLMD2000       ; Dwell takes place over 2000 master counts
FOLRNF0         ; Motion comes to rest at end of  “move” (dwell)
GOBUF1          ; Create dwell segment
D(VAR1)         ; Return position is home (direction change implied)
D-              ; Return position is home (direction reversed)
FOLMD4000       ; Move takes place over 4000 master counts
FOLRNF0         ; Motion comes to rest at end of move
GOBUF1          ; Create move back home segment
```

Compiled Motion Versus On-The-Fly Motion

The two basic ways of creating a complex profile are with compiled motion or with on-the-fly pre-emptive GO commands. With compiled motion, portions of a profile are built piece by piece, and stored for later execution. Compiled motion is appropriate for profiles with motion segments of pre-determined velocity, acceleration and distance. Compiled motion profiles allow for shorter motion segments, which results in faster cycle times because there is no command processing and execution delay. The axes may perform their own motion control and coordination, freeing program flow for other tasks, such as I/O, machine control, and host requests. The disadvantages to pre-defined compiled motion profiles are the amount of memory use and limited run-time decision making and I/O processing.

With pre-emptive GO moves, the motion profile underway is pre-empted with a new profile when a new GO command is issued. The new GO command constructs and launches the pre-empting profile. Pre-emptive GOs are appropriate when the desired motion parameters are not known until motion is already underway.

The table below summarizes the differences between the use of compiled motion and on-the-fly motion.

Command/Issue	Compiled Motion	On-The-Fly Motion
GOBUF	Constructs motion segment and appends to previously constructed segment	N/A
PRUN	Used to launch previously compiled motion	N/A
GO	GO causes move during PCOMP	GO Constructs & launches profile, even if moving
Direction changes	Only if previous motion segment comes to rest (MCØ & VFØ or MC1 & VØ), else compile error	Not allowed during motion, else AS.3Ø, ER.1Ø
Insufficient room for AD (decel) value	Same as on-the-fly	Decel is modified (steppers); Motion is killed, AS.3Ø (servos)

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Related Commands

GOBUF

Store a Motion Segment in Compiled Memory:

The GOBUF command creates a motion segment as part of a profile and places it in a segment of compiled memory, to be executed after all previous GOBUF motion segments have been executed. An individual axis profile is constructed by sequentially appending motion segments using GOBUF commands. Each motion segment may have its own distance to travel, velocity, acceleration, and deceleration.

The end of a GOBUF motion segment in preset mode is determined by the distance or position specified. The end of a GOBUF motion segment in continuous mode is determined by the goal velocity specified. In both cases, the final velocity and position achieved by a segment will be the starting velocity and position for the next segment. If either type of segment is followed by a GOWHEN command, the segment's final velocity will be maintained until the GOWHEN condition becomes true.

PLOOP & PLN

Loop Start & Loop End (Compiled Motion only):

The PLOOP and PLN commands specify the beginning and end of an axis-specific profile loop, respectively. All segments defined between the PLOOP and PLN commands are included within that loop.

VF & FOLRNF

Final Velocity & Numerator of Slave-to-Master Final Ratio:

The VF and FOLRNF commands are used to designate that the motor will move the load the distance designated in a preset GOBUF motion segment, completing the move at a final speed of zero. The VF command is used when the Following mode is disabled (FOLENØ). The FOLRNF command is used when the Following mode is enabled (FOLEN1).

GOWHEN

Conditional GO:

When GOWHEN is compiled in a profile, the GOWHEN condition is stored as part of that profile instead of being executed immediately. When progress through the profile reaches the compiled GOWHEN, AS.26 is set, and the next segment's execution will be suspended until the GOWHEN condition becomes true. This allows subsequent GOWHEN and GOBUF combinations to be issued and stored, instead of overriding each other.

TRGFN

Trigger Functions:

When TRGFN is compiled in a profile, the TRGFN condition is stored as part of that profile instead of being executed immediately. When progress through the profile reaches the compiled TRGFN, the embedded trigger functions are assigned to that trigger. AS.26 is set if the GOWHEN function has been assigned to the trigger, and the next segment's execution will be suspended until the specified trigger input goes active. This allows subsequent TRGFN, GOWHEN, and GOBUF combinations to be issued and stored, instead of overriding each other.

PCOMP, PRUN & PUCOMP

Compile a Program, Run a Compiled Program, & Un-Compile a Compiled Program:

The PCOMP, PRUN, and PUCOMP commands allow you to incorporate individual axis profiles within compiled motion profiles. Compiled motion for the Gem6K series allows you to construct complex motion programs using individual profiles (a series of GOBUF commands).

PEXE

Execute Compiled GOBUF Profile from PLC Program:

You can place a PEXE command inside a compiled PLCP program. When the PLCP program is scanned in the PLC Scan Mode (SCANP), the PEXE command launches the specified compiled profile in another task. For details on the PLC Scan Mode, see page 120.

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POUTA

Output During Compiled Motion Profile:

The POUTA command turns the programmable output bits on and off.

TSEG & SEG

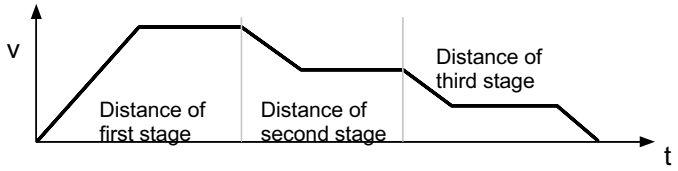
*Transfer/Display (*TSEG*) or Assign (*SEG*) the Number of Free Segment Buffers*:

The TSEG command returns the number of free segment buffers in compiled memory. The SEG command is used to assign the number of free segment buffers in compiled memory to a variable or to make a comparison against another value.

Compiled Motion — Sample Application 1

A manufacturer has an application where wire is being wrapped onto a spindle. There is a motor controlling the rotational speed of the spindle. Every application of the spindle requires that the motor runs at a fast speed with a slow acceleration for the first few revolutions, a medium speed for the next couple of revolutions, and a slower speed as the spindle gets fuller to maintain somewhat of a constant velocity off the feed wire. The technician would like to use an RP240 to enter the velocity and number of revolutions for each stage of winding. Programmable outputs 1, 2 and 3 are wired to status LEDs, and should go on for the respective stages of winding (output 1 for stage 1, etc.).

Profile



Program

```
DEF PROFIL            ; Define motion profile program
VAR10 = 4000 * VAR4   ; Get distance of first stage
                      ; (assuming 4000 steps/revolution)
D(VAR10)              ; Set distance
V(VAR1)               ; Set velocity of first stage
POUTA.1-1             ; Turn output 1 on
GOBUF1                ; Build motion
VAR10 = 4000 * VAR5   ; Get distance of second stage
D(VAR10)              ; Set distance
V(VAR2)               ; Set velocity of second stage
POUTA01               ; Turn output 1 off and output 2 on
GOBUF1                ; Build motion
VAR10 = 4000 * VAR6   ; Get distance of third stage
D(VAR10)              ; Set distance
V(VAR3)               ; Set velocity of third stage
POUTAx01              ; Turn output 2 off and output 3 on
GOBUF1                ; Build motion
POUTA.3-0             ; Turn off output 3
END                   ; End motion profile program


DEF EXMPL1            ; Define program example 1
L                     ; Continual loop of program execution
DCLEAR0               ; Clear all lines on RP240 display
DPCUR1,1              ; Position cursor at line 1, column 1
DWRITE"ENTER VELOCITY STAGE 1"      ; Prompt user
VAR1 = DREAD          ; Get 1st velocity from RP240 entry
DCLEAR1               ; Clear line 1 on RP240 display
DPCUR1,1              ; Position cursor at line 1, column 1
DWRITE"ENTER VELOCITY STAGE 2"      ; Prompt user
VAR2 = DREAD          ; Get 2nd velocity from RP240 entry
DCLEAR1               ; Clear line 1 on RP240 display
DPCUR1,1              ; Position cursor at line 1, column 1
DWRITE"ENTER VELOCITY STAGE 3"      ; Prompt user
VAR3 = DREAD          ; Get 3rd velocity from RP240 entry
DCLEAR1               ; Clear line 1 on RP240 display
DPCUR1,1              ; Position cursor at line 1, column 1
DWRITE"ENTER REVOLUTIONS STAGE 1"   ; Prompt user
```

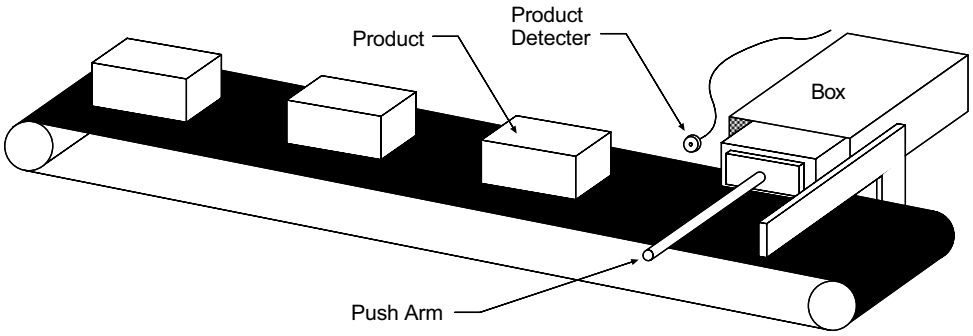

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```
VAR4 = DREAD          ; Get # of windings 1st stage from RP240 entry
DCLEAR1               ; Clear line 1 on RP240 display
DPCUR1,1              ; Position cursor at line 1, column 1
DWRITE"ENTER REVOLUTIONS STAGE 2"   ; Prompt user
VAR5 = DREAD          ; Get # of windings 2nd stage from RP240 entry
DCLEAR1               ; Clear line 1 on RP240 display
DPCUR1,1              ; Position cursor at line 1, column 1
DWRITE"ENTER REVOLUTIONS STAGE 3"   ; Prompt user
VAR6 = DREAD          ; Get # of windings 3rd stage from RP240 entry
PCOMP PROFIL          ; Re-compile profile with new vel/dist info
$AGAIN                ; Label for repeating same profile
PRUN PROFIL           ; Execute profile
DCLEAR1               ; Clear line 1 on RP240 display
DPCUR1,1              ; Position cursor at line 1, column 1
DWRITE"SAME DATA (1=YES,2=NO)"
                      ; Prompt user if perform again with old data
VAR7 = DREAD          ; Get response
IF(VAR7=1)            ; If user wants to perform same profile
  GOTO AGAIN          ; perform again
NIF                   ; End conditional
LN                    ; End command execution loop
END                   ; End definition program example 1

; ***************************************
; * To begin, execute the EXMPL1 program   *
; ***************************************
```

Compiled Motion — Sample Application 2

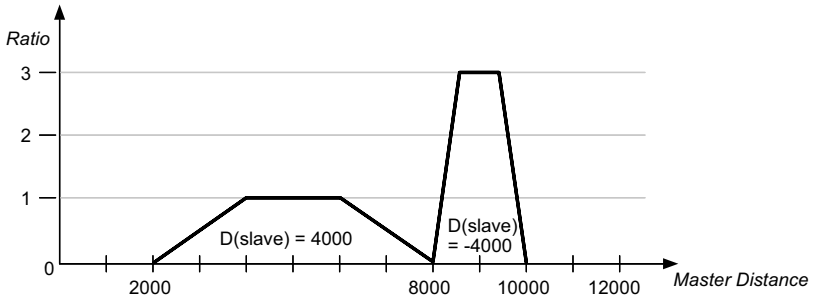
Here's an example of replacing a mechanical cam using a compiled Following profile. There is evenly spaced product coming in on a feeder belt. The feeder belt may vary in speed. The cam that you are replacing controls a push arm that will push the product into a box for shipping. You would also like the arm to retract at a faster rate than it extends. In other words, you would like to have a smooth push to load and a fast retract to set up for the next product. Since this is a cam, this profile must repeat continuously for each product or master cycle but won't start until the first product is detected.



The feeder belt is the master and the master cycle length (space from the front of one product to the front of the next) is 12000 master (encoder) counts on the feeder belt. The push of the product will start 2000 counts into the master cycle. The push will take place over Gem6K master counts, and the retract over 2000 master counts. The distance the push arm (slave) must travel is 4000 counts. Assume the detector is wired to trigger 1A (onboard trigger input 1). Below is a graph of this Following profile.

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Profile



Program

```
; Setup code
FOLMAS1           ; Master is coming in on the master encoder input
FOLEN1            ; Enable Following
INFNC1-H          ; Assign onboard input 1 (TRG-1A) as trigger interrupt

; Motion program
DEL EXPL2         ; Delete program (in case it already exists in memory)
DEF EXPL2         ; Begin definition of program example 2
1TRGFNA1          ; Launch axis 1 profile upon receiving TRG-1A
                  ; (1st product detected)
PLOOP0            ; Loop continuously to mimic a mechanical cam

; Program first move - dwell
FOLRN1            ; Set up ratios - numerator
FOLRD1            ; and denominator
FOLMD2000         ; Over a distance of 2000 master steps
D0                ; slave will not move
FOLRNF0           ; and end at zero ratio
GOBUF1            ; Build motion


; Program second move - positive slave move
FOLMD6000         ; Over a distance of 6000 master steps
D4000             ; slave will move 4000 steps
FOLRNF0           ; and end at zero ratio
GOBUF1            ; Build motion

; Program third move - negative slave move
FOLRN3            ; New ratio to accommodate larger distance of slave travel
FOLMD2000         ; Over a distance of 2000 master steps
D-4000            ; slave will move -4000 steps
FOLRNF0           ; and end at zero ratio
GOBUF1            ; Build motion

; Program last move - dwell
FOLMD2000         ; Over a distance of 2000 master steps
D0                ; slave will not move
FOLRNF0           ; and end at zero ratio
GOBUF1            ; Build motion
PLN1              ; Close cam loop
END               ; End program example 2

PCOMP EXPL2       ; Compile program EXPL2

; **  To execute the program, enter the PRUN EXPL2 command  **
```


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Program Modification

Let's now modify the constraints of the system. Let's say that the product will be spaced roughly 12000 master counts apart. It may or may not be exactly 12000, but it will never be less than 10000 (just to make sure the retraction finishes before the next product is detected). We can then modify the program to wait for the product to be detected each cycle. We can also take the extra "dwell" or zero distance move out of the end of the profile. See program below:

```
; Setup code
FOLMAS1           ; Master is coming in on the master encoder
FOLEN1            ; Enable Following mode
INFNC1-H          ; Assign onboard input 1 (TRG-1A) as trigger interrupt

; Motion program
DEL EXPL2B        ; Delete program (in case it already exists in memory)
DEF EXPL2B        ; Begin definition of program example 2b
PLOOP0            ; Loop continuously to mimic a mechanical cam
1TRGFNA1          ; Pause axis 1 profile until TRG-1A is activated
                  ; (detect next product)

; Program first move - dwell
FOLRN1            ; Set up ratios - numerator
FOLRD1            ; and denominator
FOLMD2000         ; Over a distance of 2000 master steps
D0                ; slave will not move
FOLRNF0           ; and end at zero ratio
GOBUF1            ; Build motion

; Program second move - positive slave move
FOLMD6000         ; Over a distance of 6000 master steps
D4000             ; slave will move 4000 steps
FOLRNF0           ; and end at zero ratio
GOBUF1            ; Build motion

; Program third move - negative slave move
FOLRN3            ; New ratio to accommodate larger distance of slave travel
FOLMD2000         ; Over a distance of 2000 master steps
D-4000            ; slave will move -4000 steps
FOLRNF0           ; and end at zero ratio
GOBUF1            ; Build motion
PLN1              ; Close cam loop
END               ; End program example 2b

PCOMP EXPL2B      ; Compile program EXPL2B

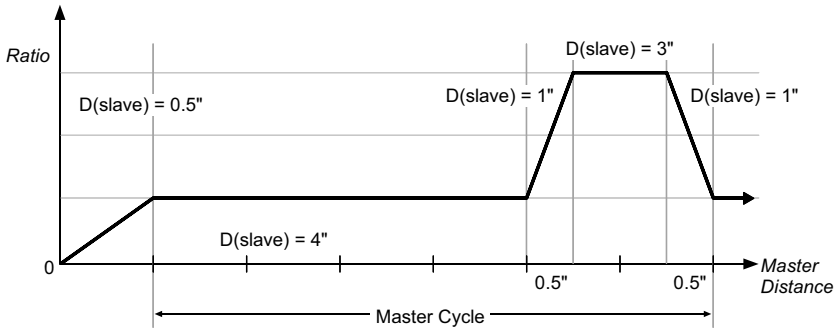
; ********************************************************
; * To execute the program, enter the PRUN EXPL2B command  *
; ********************************************************
```


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Compiled Motion — Sample Application 3

In this application, there is a wheel that stamps a logo onto the product. The product is assumed to be entering at a constant and fixed spacing, each product is 4 inches in length with 2 inches separating each unit. The stamp wheel has a circumference of 9 inches, and must be traveling at a 1 to 1 ratio with the product at the time of stamping. The stamp wheel must then travel five inches in just 2 inches of master travel. There is a sensor wired to trigger A of the Gem6K controller to detect the first product and start the cycling. At the time of the trigger the product is 1 inch away from contact with the stamp wheel. Assume that the home position of the slave is 0.5 inches away from a stamp. The mechanics of the system give 3000 steps of master travel per inch and 1500 steps of slave travel per inch.

Profile



As you can see above, we have a multi-tiered Following profile. By multi-tiered we mean that ratio is changing from a non-zero value to another non-zero value. To program this profile effectively, we will break the profile into pieces as shown with the dotted lines in the above illustration:

Program

```
FOLMAS1         ; Define the master as the master encoder input
FOLEN1          ; Enable Following
INFNC1-H        ; Assign onboard input 1 (TRG-1A) as trigger interrupt
SCLMAS3000      ; Set scaling of master steps per inch
SCLD1500        ; Set scaling of slave steps per inch
SCALE1          ; Enable scaling

DEF EXMPL3      ; Start definition of example program 3
1TRGFNA1        ; Launch axis 1 profile when TRG-1A is activated

; Program first ramp from ratio 0 to ratio 1
FOLRD1          ; Set Following ratio - denominator
FOLRN1          ; Set the Following ratio at 1 to 1
FOLMD1          ; Over a master distance of 1"
D0.5            ; Slave will travel 0.5"
GOBUF1          ; Build motion

PLOOP0          ; Start the continuous loop

; Program constant ratio
FOLRN1          ; At a 1 to 1 ratio
FOLMD4          ; Over a master distance of 4"
D4              ; Slave will travel 4"
GOBUF1          ; Build motion

; Program ramp to new ratio
FOLRN3          ; Go to a 3 to 1 ratio
FOLMD0.5        ; Over a master distance of 0.5"
D1              ; Slave will travel 1"
GOBUF1          ; Build motion
```


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```
; Program second constant ratio
FOLRN3          ; At a 3 to 1 ratio
FOLMD1          ; Over a master distance of 1"
D3              ; Slave will travel 3"
GOBUF1          ; Build motion

; Program ramp to lower ratio
FOLRN1          ; Go to a 1 to 1 ratio
FOLMD0.5        ; Over a master distance of 0.5"
D1              ; Slave will travel 1"
GOBUF1          ; Build motion
PLN1            ; Close motion loop

; Define the exit motion
FOLRN0          ; Stop slave at zero ratio (and zero velocity)
FOLMD1          ; Over a master distance of 1"
D0.5            ; And a slave distance of 0.5"
GOBUF1          ; Build motion
END             ; End definition of example program 3

PCOMP EXMPL3    ; Compile example program 3

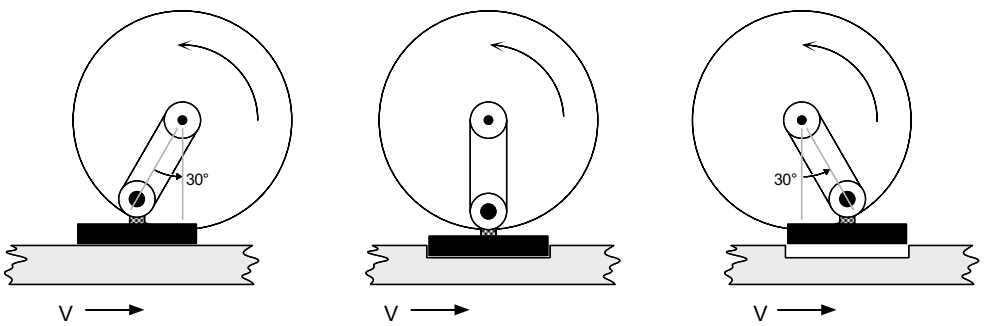
; ********************************************************
; * To execute the program, enter the PRUN EXMPL3 command  *
; ********************************************************
```

NOTE: The `GOBUF` command has been added to the "`Define the exit motion`" portion of the program despite the fact that an infinite loop has been programmed earlier in the program. This is to avoid an error message when the program is compiled.

Compiled Motion — Sample Application 4

A manufacturer of stamped molds needs to make a machine which will stamp molds into a continuous flow of extruded plastic material. The stamp must be lowered 0.5 inches into the plastic to leave the correct impression. Because the flow is continuous, the stamp must also move in synchronization with plastic in the direction of flow as it is lowered and raised. The initial design approach to the machine required two axes of motion. One was needed to lower and raise the stamp, the other to allow the stamp to follow the plastic. With the availability of complex Following cam profiles the job can done with a single axis.

In the drawing below, the stamp is attached to a rotating arm in such a way that the stamp remains level as the arm rotates. The length of the arm at the stamp fixture, or radius of rotation, is exactly one inch. The arm is mounted above the plastic so that at the bottom of its rotation (270 degrees), the stamp will be 0.5 inches into the plastic. Using trigonometry, the horizontal and vertical positions and speeds may be calculated at other arm angles. Because the stamp must follow the flow of the plastic, we must adjust the ratio of rotational speed to plastic speed so that the horizontal velocity component of the arm stays at 1:1 with the plastic while the stamp is in the plastic.



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The table below shows these relationships. The arm is directly driven with a servo motor having 4096 steps per revolution. The table shows increments of 30 degrees, which is about 341 servo motor steps, or about 0.524 slave inches measured around the circumference described by rotation of the arm. The plastic flow is measured with an encoder giving 1000 steps per inch of flow. To maintain ratios in terms of inches, FOLRD will always be 1000. The required FOLRN value is simply the inverse of the arm's horizontal velocity component multiplied by the number of slave steps per inch. The corresponding ratio in terms of surface speeds is given in parentheses. The required FOLMD is the number of master steps corresponding to the horizontal component of slave rotation.

Arm angle, degrees	Horizontal component (in.) = cos(deg)	FOLMD = 1000 * delta cos(deg)	Horizontal vel component = -sin(deg)	Required FOLRN = -651.9/sin(deg)
210	-0.866	n/a	0.500	1304 (2:1)
240	-0.500	366	0.866	753 (1.155:1)
270	0.000	500	1.000	652 (1:1)
300	0.500	500	0.866	753 (1.155:1)
330	0.866	366	0.500	1304 (2:1)

The profile that we construct from these number is meant to approximate the inverse sine function in the last column, but of course, will actually be a series of ramps and constant ratio segments. Let's review the Compiled Following Move Distance Calculations to determines the exact shape and error in the first motion segment(from 210 to 240 degrees). First, we need to determine if the ramp or constant ratio is first for that segment. Using ratios and distances in inches, we have:

R1 = 2 ..... Starting ratio
R2 = 1.155 ..... Final ratio
D = (2*pi)/12 = 0.524 ..... Distance at stamp hinge
FOLMD=.366 ..... Travel along plastic

We find (R1+R2) * FOLMD/2 = 0.577, which is greater than D, so the "Ramp First" equations apply to this segment. Let's examine the error at the junction between the ramp and constant ratio portion of this segment.

MD1 = [D - (R2 * FOLMD)] / ((R1 - R2) / 2) = 0.239 master inches
D1 = 0.5 * (R1 + R2) * MD1 = 0.377 slave inches at circumference = 21.6 degrees
cos(210+21.6) - cos(210) = -0.621 - (-0.866) = 0.245 inches slave horizontal travel
error = horizontal slave travel - master travel = 0.245 - 0.239 = 0.006 inches

A similar calculation may be done for the "elbow" of the next of the next segment, and symmetry indicates these errors will be the same between 270 and 330 degrees. The error along intermediate points may be found with linear interpolation of ratio and master distance. In this case, the errors fall within manufacturing tolerance. If the errors were too large, the travel could be broken into more segments, each with exactly correct positions and ratios at their boundaries.

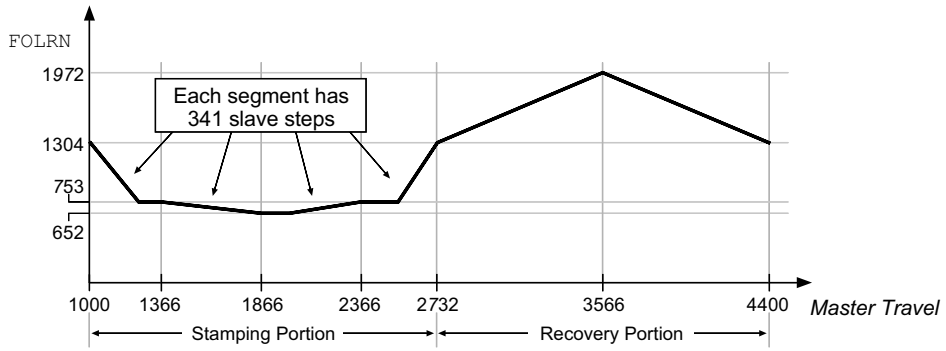
So far, we have only discussed the portion of the profile which lowers and raises the stamp. During the remainder of the profile, the arm must continue its rotation to bring the stamp to its starting position in time for the next mold. The mold is 3 inches long, and .4 inches are needed between molds for strength at the edges. This makes the total master cycle 3.4 inches long. The total slave cycle must be 4096 steps, so the segments required to bring the arm around must complete the portions of master and slave cycles not already accounted for. We will create two segments, which divide the remaining master and slave travels in two, and are mirror images of each other. The average ratio of these two segments must simply be slave travel divided by master travel, i.e., (D / FOLMD). As previously determined, the FOLRN value for the boundaries of the stamping portion of the profile is 638. From this value and the average ratio, we can calculate the peak FOLRN value.

D = 0.5 * remaining slave = 0.5 * (4096 - 4 * 341) = 1366
FOLMD = 0.5 * remaining master = 0.5 * [1000 * (3.4 - 2 * 0.866)] = 834
peak ratio = FOLRN/1000
0.5 * (FOLRN/1000 + 1304/1000) = average ratio = D / FOLMD = 1366 / 834 = 1.638
FOLRN = 1972 (solved from above)

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Finally, we need to design a segment used to create a smooth entry into the repetitive portion of the profile. We'll assume that the home position of the arm is at 180 degrees, so it needs to achieve the FOLRN ratio of 1304 in 30 degrees (341 slave steps). Using the same averaging arithmetic as above, the required master distance for the entry segment is 523 steps. A sensor is positioned with this entry segment in mind, and wired to **TRG-1A**. A function to start motion when the sensor is triggered will be imbedded inside the profile. The motion segments for the stamping portion and recovery portions of the profile must be enclosed in a loop, and may be programmed by picking the numbers from the table and equations above. Because the ratio denominators are the same for all segments, and the slave distances are the same for the entry and each of the stamping segments, these are commanded only when the values change.

Repetitive Portion of Profile



Program

```
FOLMAS1          ; Follow master encoder
FOLEN1           ; Enable Following mode
INFNC1-H         ; Enable trigger 1 (TRG-1A) for interrupt function
SCALE0           ; Parameters are in steps
DEF STAMP        ; Start program definition
TRGFNA1          ; Motion profile starts upon trigger 1 (TRG-1A)
FOLRD1000        ; Ratio denominator, 1000 steps per inch
;define the entry segment
D341             ; Distance of 341 steps is about 30 degrees
FOLRN1304        ; Goal ratio for start segment
FOLMD523         ; Master distance during ramp
GOBUF1           ; Build start segment
PLOOP0           ; Start the continuous loop
;this profile section starts 2-to-1 ratio, or a starting FOLRN1304
FOLRN753         ; Goal ratio for segment
FOLMD366         ; Master travel in steps for segment
GOBUF1           ; Build motion segment
;the 2nd section of profile starts with the final ratio of the 1st section
FOLRN652         ; Goal ratio for segment
FOLMD500         ; Master travel in steps for segment
GOBUF1           ; Build motion segment
;the next two sections are mirror images of the first two
FOLRN753         ; Goal ratio for third segment
FOLMD500         ; Master travel in steps for 3rd segment
GOBUF1           ; Build motion segment
FOLRN1304        ; Goal ratio for 4th segment
FOLMD366         ; Master travel in steps for 4th segment
GOBUF1           ; Build motion segment
;the next two sections complete the loop and are mirror images of each other
D1366            ; Slave travel in recovery segments
FOLMD834         ; Master travel in steps for recovery segments
FOLRN1972        ; Goal ratio for ramp up segment
GOBUF1           ; Build ramp up motion segment
FOLRN523         ; Goal ratio for ramp down segment
GOBUF1           ; Build ramp down motion segment
PLN1             ; End of loop cycle
;finally, a segment to end motion
D341             ; Distance of 341 steps is about 30 degrees
FOLRN0           ; Goal ratio for end segment
FOLMD1000        ; Master distance during ramp
GOBUF1           ; Build end segment
END              ; End of STAMP program definition

PCOMP STAMP      ; Compile the program

; ********************************************************
; * To execute the program, enter the PRUN STAMP command   *
; ********************************************************
```


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On-the-Fly Motion (pre-emptive GOs)

While motion is in progress, you can change these motion parameters to affect a new profile:

- Acceleration (A) — s-curve acceleration is not allowed
- Deceleration (AD) — s-curve deceleration is not allowed
- Velocity (V)
- Distance (D)
- Preset or Continuous Positioning Mode Selection (MC)
- Incremental or Absolute Positioning Mode Selection (MA)
- Following Ratio Numerator and Denominator (FOLRN and FOLRD, respectively)

The motion parameters can be changed by sending the respective command (e.g., A, V, D, MC) followed by the GO command. If the continuous command execution mode is enabled (COMEXC1), you can execute buffered commands; otherwise (COMEXCØ), you must prefix each command with an immediate command identifier (e.g., !A, !V, !D, !MC, followed by !GO).

The new GO command pre-empts the motion profile in progress with a new profile based on the new motion parameter(s). On-the-fly motion changes are applicable only for motion started with the GO command, and not for motion started with other commands such as HOM, JOG, JOY, or PRUN.

On-the-fly motion changes are most likely to be used to change the velocity and/or goal position of a preset move already underway. In the event that the goal position is completely unknown before motion starts, a move may be started in continuous mode (MC1), with a switch to preset mode (MCØ), a distance command (D), and a GO given later. In absolute positioning mode (MA1) the new goal position given with a pre-emptive GO is explicit in the D command. In incremental positioning (MAØ) the distance given with a new pre-emptive GO is always measured from the at-rest position before the original GO. If a move is stopped (with the S command), and then resumed (with the C command), this resumed motion is considered to be part of the original GO. A subsequent distance given with a new pre-emptive GO is measured from the at rest position before the original GO, not the intermediate stopped position.

Programming Example: *This program creates a 2-tiered profile (single-axis) that changes velocity and deceleration at specific motor positions.*

```
SCALE0           ; Disable scaling
DEL OTF          ; Delete program (in case program is already in memory)
DEF OTF          ; Begin definition of program
PSET0            ; Set position to zero
COMEXC1          ; Enable continuous command processing mode
MC0              ; Select preset positioning
MA0              ; Select incremental positioning
A20              ; Set accel to 20 revs/sec/sec
AD20             ; Set decel to 20 revs/sec/sec
V9               ; Set velocity to 9 revs/sec
D500000          ; Set distance to 20 revs
GO1              ; Initiate motion
WAIT(PC>100000)  ; Wait until commanded position > 100000 steps (4 revs)
V4               ; Slow down for machine operation
GO1              ; Initiate new profile with new velocity
WAIT(PC>450000)  ; Wait until the motor position > 450000 steps (18 revs)
AD5              ; Set decel for gentle stop
V1               ; Slow down for gentle stop
GO1              ; Initiate new profile with new velocity
END              ; End program definition
```


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The table below summarizes the restrictions on pre-emptive GOs.

Condition	Possible?
Execute GO during MC1 & FOLENØ	Yes
Execute GO during MC1 & FOLEN1	Yes
Execute GO during MCØ & FOLENØ	Yes
Execute GO during MCØ & FOLEN1	No
Change MC setting during motion	Yes (but cannot change MC1 to MCØ during FOLEN1)
Change ENC setting during motion	No
Change FOLENØ to FOLEN1 during motion	No
Change FOLEN1 to FOLENØ during motion	Only while MC1, constant ratio, and not shifting

OTF Error Conditions

The ability to change the goal position on the fly raises the possibility of several error conditions:

Further instructions about handling error conditions are provided on page 30.

Error Conditions	Gem6K Response		
	Set axis status bit #30	Set error status bit #10	Kill motion (decelerate at the LHAD value)
The new position goal of an on-the-fly GO cannot be reached with the current direction, velocity, and decel.	**YES**	**YES**	NO
The direction of the new goal position is opposite that of current travel	**YES**	**YES**	**YES**
There has not yet been an overshoot, but it is not possible to decelerate to the new distance from the current velocity using the specified AD value.	**YES**	**YES**	**YES**

RELATED STATUS COMMANDS

Axis Status — Bit #30: (this status bit is cleared with the next GO command)

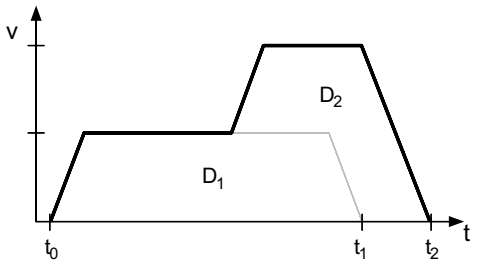
AS.30 ....Assignment & comparison operator — use in a conditional expression (see pg. 25).
TASF .....Full text description of each status bit. (see "Preset Move Overshot" line item)
TAS .....Binary report of each status bit (bits 1-32 from left to right). See bit #30.

Error Status — Bit #10: The error status is monitored and reported only if you enable error-checking bit #10 with the ERROR command (e.g., ERROR.1Ø-1). NOTE: When the error occurs, the controller with branch to the error program (assigned with the ERRORP command). (this status bit is cleared with the next GO command)

ER.10 ....Assignment & comparison operator — use in a conditional expression (see pg. 25).
TERF .....Full text description of each status bit. (see "Preset Move Overshot" line item)
TER .....Binary report of each status bit (bits 1-32 from left to right). See bit #10.

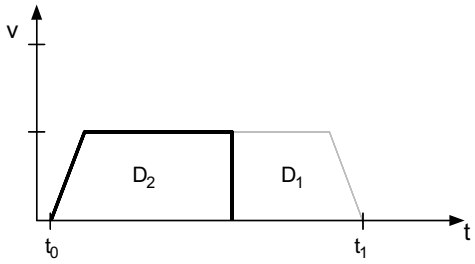
Scenarios

Scenario #1: OTF change of velocity and distance, where new commanded distance (D_2) is greater than the original distance (D_1) that was pre-empted [$D_2 > D_1$]. The distances are the areas under the profiles, starting at t_0 for both. If the original move had continued, D_1 would have been reached at time t_1. D_2 is reached at time t_2.

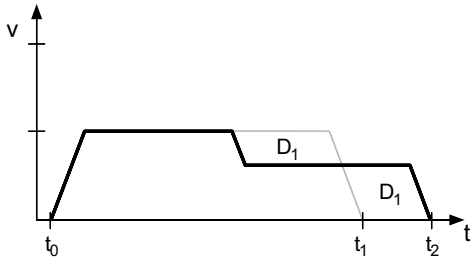


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Scenario #2: OTF change of distance, where new commanded distance (D_2) is less than the original distance (D_1) that was pre-empted [$D_2 < D_1$]. In this example, the position where the OTF change was entered is already beyond D_2 (or D_2 can not be reached with the commanded deceleration). The result is an error and motion is killed (decel at the LHAD value) and TAS bit #30 and TER bit #10 are set.



Scenario #3: OTF change of velocity. Note that motion must continue for a longer time at the reduced velocity to reach the original commanded distance than if it had continued at the original velocity ($t_2 > t_1$).

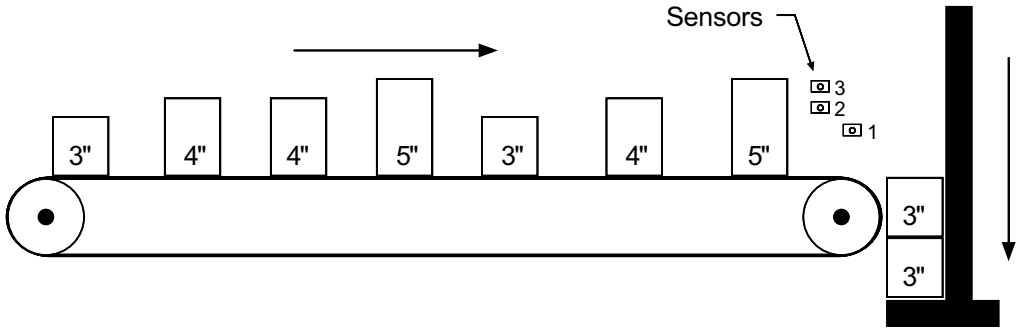


On-The-Fly Motion — Sample Application

A manufacturer of three products wishes to produce a “sampler-pak” package which will contain a few of each of his products. The products all have the same width and length, but are 3, 4, and 5 inches high respectively. The 3 products are fed from individual lines into a common conveyor, and arrive at a stacking and wrapping station. At this station, a tray accepts a product and must have moved down by that product’s height by the time the next product arrives. This means that each time a new product arrives, the velocity of the tray must be changed to match the height of that product. Although product spacing will be regular, the ordering of product type on the common conveyor will be random, due to variations in the input lines. Also, a finished sampler-pak should contain 5 products or be at least 18 inches high, whichever occurs first. This means that the total move distance of the tray will be unknown until the last product arrives. When the last product is stacked, an output is asserted which will pause the conveyor and start the wrapping process. When wrapping is complete, the sampler-pak is removed from the tray, and the tray returns to the starting position.

The basic problems in this application are that the move distance is not known until near the end, and the velocity must change on the fly. As the products approach the tray, they are detected with a near vertical arrangement of three sensors. Products of heights 3, 4, and 5 inches are detected by 1, 2, or all 3 sensors respectively. Input 1 always detects a product, and switches last, so that the others will be stable. When each product is identified, the motion profile is modified accordingly.

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Program (portion only)

```
VAR1=0                        ; Initialize product count
VAR2=0                        ; Initialize move distance variable
VAR3=0                        ; Initialize velocity
A10                           ; Moderate acceleration
MC0                           ; Start with preset move
WHILE(VAR1<5 AND VAR2<18)     ; Loop until cycle complete
WAIT(IN.1=B1)                 ; Wait for start of next product
                              ; (onboard input 1 is activated)
VAR1=VAR1+1                   ; Update product count
IF(IN.2=B1)                   ; If not a 3" product
  IF(IN.3=B1)                 ; If it is a 5" product
    VAR3=5                    ; Set velocity
    VAR2=VAR2+5               ; Update distance
  ELSE                        ; If not 5", must be 4"
    VAR3=4                    ; Set velocity
    VAR2=VAR2+4               ; Update distance
  NIF                         ; End of 5" case check
ELSE                          ; 3" inch case
  VAR3=3                      ; Set velocity
  VAR2=VAR2+3                 ; Update distance
NIF                           ; End of 3" case check
V(VAR3)                       ; New velocity
D(VAR2)                       ; New distance
WAIT(IN.1=B0)                 ; Wait for end of this product
GO1                           ; Implement new distance and velocity
NWHILE                        ; Sampler-pak completed product detection
WAIT(AS.1=B0)                 ; Wait for move to complete
OUT1                          ; Output to indicate stacking complete
```


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Registration

A "registration input" is a trigger input assigned the "trigger interrupt" function with the INFNCi-H *command.*

When a *registration input* is activated, the motion profile currently being executed is replaced by the registration profile with its own distance (REG), acceleration (A & AA), deceleration (AD & ADA), and velocity (V) values. The registration move may interrupt any preset, continuous, or registration move in progress.

The registration move does not alter the rest of the program being executed when registration occurs, nor does it affect commands being executed in the background if the controller is operating in the continuous command execution mode (COMEXC1).

Registration moves will not be executed while the motor is not performing a move, while in the joystick mode (JOY1), or while decelerating due to a stop, kill, soft limit, or hard limit.

How to Set up a Registration Move

Before you can initiate a registration move, you must program these elements (refer also to the programming examples below):

1. Configure one of the trigger inputs (TRG-nA [#1] or TRG-nB [#2]) to function as a trigger interrupt input; this is done with the INFNCi-H command, where "i" is the input bit number representing the targeted trigger input. **Note** that the "Master Trigger" input may not be used for registration.
2. Specify the distance of the registration move with the REG command. For servo axes, the distance refers to the encoder position. For stepper axes, the distance refers to commanded position if ENCCNT0 (default setting) or encoder position if ENCCNT1.
3. Enable the registration function with the RE command. Registration is performed only when the registration function is enabled, and with a non-zero distance specified in the respective axis-designation field of the REG command.
   NOTE: The registration move is executed using the A, AA, AD, ADA, and V values that were in effect when the REG command was entered.



ENCCNT*: Encoder capture options for stepper axes are discussed on page 85.*

Registration Move Accuracy (see also *Registration Move Status* below)

The accuracy of the registration move distance specified with the REG command is ±1 count (servo axes: encoder count; stepper axes: commanded count if ENCCNT0 or encoder count if ENCCNT1).

RULE OF THUMB: To prevent position overshoot, make sure the REG distance is greater than 4 ms multiplied by the incoming velocity.

The lapse between activating the registration input and commencing the registration move (this does not affect the move accuracy) is less than one position sample period (2 ms).

The REG distance will be scaled by the distance scale factor (SCLD value) if scaling is enabled (SCALE1). See page 67 for details on scaling.

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Preventing Unwanted Registration Moves (*methods*)

- Registration Input Debounce: Registration Input Debounce: By default, the registration inputs are debounced for 2 ms before another input on the same trigger is recognized. (The debounce time is the time required between a trigger's initial active transition and its secondary active transition.) Therefore, the maximum rate that a registration input can initiate registration moves is 500 times per second. If your application requires a shorter debounce time, you can change it with the TRGLOT command.
- Registration Single-Shot: The REGSS command allows you to program the Gem6K controller to ignore any registration commands after the first registration move has been initiated. Refer to the REGSS command description for further details and an application example.
- Registration Lockout Distance: The REGLOD command specifies what distance an axis must travel before any trigger assigned as a registration input will be recognized. Refer to the *Sample Application 3* below.

Registration Move Status & Error Handling

Axis Status — Bit #28: This status bit is set when a registration move has been initiated by any registration input (trigger). This status bit is cleared with the next GO command.

AS.28 .....Assignment & comparison operator — use in a conditional expression (see pg. 26).
TASF.....Full text description of each status bit. (see "Reg Move Commanded" line item)
TAS.....Binary report of each status bit (bits 1-32 from left to right). See bit #28.

Axis Status — Bit #30: If, when the registration input is activated, the registration move profile cannot be performed with the specified motion parameters, the Gem6K controller will kill the move in progress and set axis status bit #30. This status bit is cleared with the next GO command.

AS.3Ø .....Assignment & comparison operator — use in a conditional expression (see pg. 26).
TASF.....Full text description of each status bit. (see "Preset Move Overshot" line item)
TAS.....Binary report of each status bit (bits 1-32 from left to right). See bit #30.

Further instructions about handling error conditions are provided on page 30.

Error Status — Bit #10: This status bit may be set if axis status bit #30 is set. The error status is monitored and reported only if you enable error-checking bit #10 with the ERROR command (e.g., ERROR.1Ø-1). NOTE: When the error occurs, the controller will branch to the error program (assigned with the ERRORP command). This status bit is cleared with the next GO command.

ER.1Ø .....Assignment & comparison operator — use in a conditional expression (see pg. 26).
TERF.....Full text description of each status bit. (see "Preset Move Overshot" line item)
TER.....Binary report of each status bit (bits 1-32 from left to right). See bit #10.

Trigger Status — Bits #1-17: Trigger status bits are set when a registration move has been initiated by trigger inputs A or B, or with the TRIG-M (master trigger) input. This also indicates that the position has been captured. As soon as the captured information is transferred or assigned/compared (see page 99), the respective trigger status bit is cleared (set to Ø).

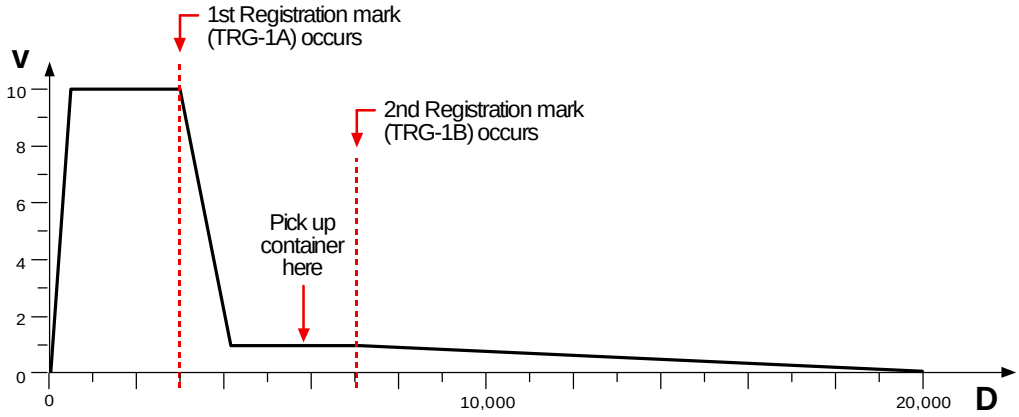
TRIG.....Assignment & comparison operator — use in a conditional expression.(see pg. 26).
TTRIG .....Binary report of each status bit (bits 1-17 from left to right). From left to right the bits represent trigger A and B, the 17th bit is master trigger M (the "MASTER TRIG" input terminal) — see page 91.

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Registration — Sample Application 1

In this example, two-tiered registration is achieved (see illustration below). While the motor is executing it's 50,000-unit move, trigger input 1 (TRG-1A) is activated and executes registration move A to slow the load's movement. An open container of volatile liquid is then placed on the conveyor belts. After picking up the liquid and while registration move A is still in progress, trigger input 2 (TRG-1B) is activated and executes registration move B to slow the load to gentle stop.

```
DEL REGI1     ; Delete program (in case program already resides in memory)
DEF REGI1     ; Begin program definition
INFNC1-H      ; Define trigger input 1 (TRG-1A) as trigger interrupt input
INFNC2-H      ; Define trigger input 2 (TRG-1B) as trigger interrupt input
A20           ; Set acceleration on axis 1 to 20 units/sec2
AD40          ; Set deceleration on axis 1 to 40 units/sec2
V1            ; Set velocity on axis 1 to 1 unit/sec
1REGA4000     ; Set TRG-1A's registration distance on axis 1 to 4000 units
              ; (registration A move will use the A, AD, & V values above)
A5            ; Set acceleration on axis 1 to 5 units/sec/sec
AD2           ; Set deceleration on axis 1 to 2 units/sec/sec
V.5           ; Set velocity on axis 1 to 0.5 units/sec
1REGB13000    ; Set TRG-1B's registration distance on axis 1 to 13,000 units
              ; (registration B move will use the A, AD, & V values above)
RE10          ; Enable registration on axis 1 only
A50           ; Set acceleration to 50 units/sec/sec on axis 1
AD50          ; Set deceleration to 50 units/sec/sec on axis 1
V10           ; Set velocity to 10 unit/sec on axis 1
D50000        ; Set distance to 50000 units on axis 1
GO10          ; Initiate motion on axis 1
END           ; End program definition
```

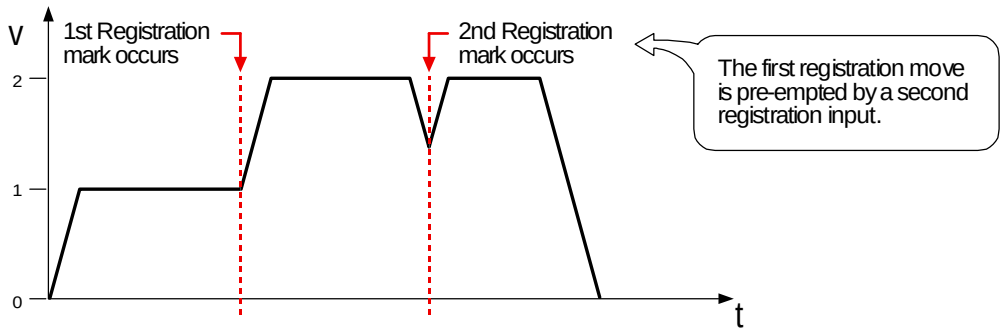


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Registration — Sample Application 2

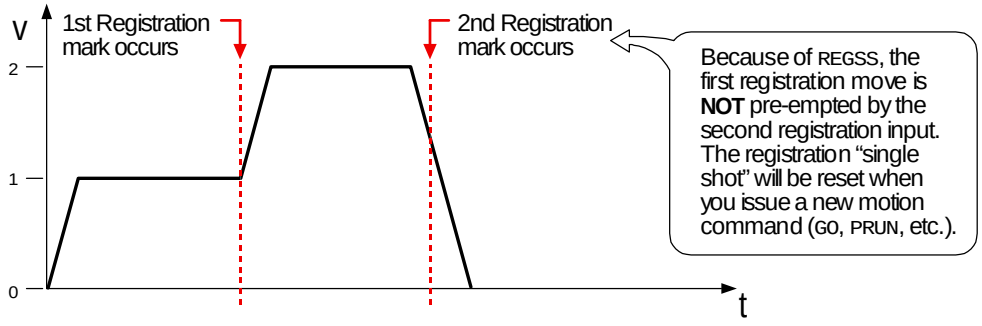
A user has a line of material with randomly spaced registration marks. It is known that the first mark must initiate a registration move, and that each registration move cannot be interrupted or the end product will be destroyed. Since the distance between marks is random, it is impossible to predict if a second registration mark will occur before the first registration move has finished.

```
DEL REGI2     ; Delete program (in case program already resides in memory)
DEF REGI2     ; Begin program definition
INFNC1-H      ; Trigger capture mode for trigger 1 (TRG-A)
RE1           ; Enable registration
V2            ; Set registration move to a velocity of 2 rps
REGA20000     ; and a distance of 20000 steps
MC1           ; Start a mode continuous
V1            ; move at a velocity of 1 rps
GO1           ; Initiate motion
END           ; End program definition
```



In order to stop the second registration from occurring, REGSS can be used:

```
DEL REGI2b    ; Delete program (in case program already resides in memory)
DEF REGI2b    ; Begin program definition
INFNC1-H      ; Trigger capture mode for trigger 1 (TRG-A)
RE1           ; Enable registration
V2            ; Set registration move to a velocity of 2 rps
REGA20000     ; and a distance of 20000 steps
REGSS1        ; Enable registration single shot mode
MC1           ; Start a mode continuous
V1            ; move at a velocity of 1 rps
GO1           ; Initiate motion
END           ; End program definition
```

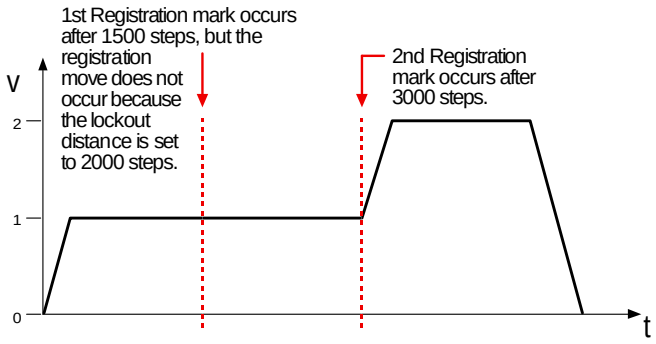


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Registration — Sample Application 3

A print wheel uses registration to initiate each print cycle. From the beginning of motion, the controller should ignore all registration marks before traveling 2000 steps. This is to ensure that the unit is up to speed and that the registration mark is a valid one.

```
DEL REGI3     ; Delete program (in case program already resides in memory)
DEF REGI3     ; Begin program definition
INFNC1-H      ; Trigger capture mode for trigger 1 (TRG-A)
RE1           ; Enable registration
V2            ; Set registration move to a velocity of 2 rps
REGA2500      ; and a distance of 2500 steps
REGLOD2000    ; Set registration lockout distance to 2000 steps
MC1           ; Start a mode continuous
V1            ; move at a velocity of 1 rps
GO1           ; Initiate motion
END           ; End program definition
```



Synchronizing Motion (GOWHEN and TRGFN operations)

GOWHEN and TRGFN allow you to synchronize the execution of motion and other events:

- GOWHEN — synchronize execution of the subsequent start-motion command (GO, GOL, FGADV, FSHFC, or FSHFD) to:
  - Position (commanded, feedback device, motor, master, slave, Following shift)
  - Master cycle number
  - Input status
  - Time delay (dwell)
- TRGFN:
  - Suspend execution of the next start-motion command (GO, GOL, FGADV, FSHFC, or FSHFD) until the specified trigger input goes active.
  - Suspend beginning a new Following master cycle until the specified trigger input goes active.

Conditional “GO”s (GOWHEN)

The GOWHEN command is used to synchronize a motion profile with a specified position count, input status, dwell (time delay), or master cycle number. Command processing does not wait for the GOWHEN conditions (relational expressions) to become true during the GOWHEN command. Rather, the motion from the subsequent start-motion command (GO, GOL, FGADV, FSHFC, and FSHFD) will be suspended until the condition becomes true.

Start-motion type commands that **cannot** be synchronized using the GOWHEN command are: HOM, JOG, JOY, and PRUN. A preset GO command that is already in motion can start a new profile using the GOWHEN and GO sequence of commands. Continuous moves (MC1) already in progress can change to a new velocity based upon the GOWHEN and GO sequence. Both preset and continuous moves can be started from rest with the GOWHEN and GO sequence.

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GOWHEN Syntax

```
GOWHEN(expression,expression,expression,...)
```

Relational Expression Syntax:
`(<left operand> <relational operator> <right operand>)`

Possible Operators:

- `FB`..... Feedback device position
- `LIM`..... Limit input state
- `NMCY`... Master cycle number
- `PC`..... Commanded position
- `PE`..... Encoder position
- `PMAS`... Master position
- `PSLC`... Slave position
- `PSHF`... Following shift
- `IN`..... Input state
- `T`..... Dwell (in milliseconds)

Possible Operators:

`>=`
`<=`
`=`
`>`
`<`

Possible Operators:

- Numeric variables (`VAR` or `VARI`)
- Decimal constant
- Binary value (`b___`) for the `IN` and `LIM` operators only

EXAMPLES

```
GOWHEN(PE>4ØØØØ)    ; suspend next GO until encoder position > 4ØØØØ
GOWHEN(IN.6=b1)     ; suspend next GO until onboard input #6 is activated (b1)
GOWHEN(PMAS>255)    ; suspend next GO until the master has traveled 255
                    ; master distance units
```

Using the numeric variable operand: VAR will be sampled only once, at the moment the GOWHEN command is executed. To use other right-hand side data sources, precede the GOWHEN command with a command that loads a variable with the data source desired and then use that variable in the GOWHEN expression.

SCALING

If scaling is enabled (SCALE1), the right-hand operand is multiplied by SCLD if the left-hand operand is FB, PC, PE, PSLV, or PSHF. The right-hand operand is multiplied by the SCLMAS value if the left-hand operand is PMAS. (The SCLD or SCLMAS values used correlate to the axis specified with the variable–e.g., a GOWHEN expression with PE scales the encoder position by the SCLD value.)

GOWHEN Status

Axis Status — Bit #26: Bit #26 is set when motion has been commanded by a GO, GOL, FGADV, FSHFC, or FSHFD command, but is suspended due to a pending GOWHEN condition. This status bit is cleared when the GOWHEN condition is true or when a stop (!S) or kill (!K or ^K) command is executed. The GOWHEN command can be cleared using S or K command (e.g., !S11XØ or !KØXX1).

`AS.26` .....Assignment & comparison operator — use in a conditional expression (see page 26).
`TASF`.....Full text description of each status bit. (see "`Gowhen is Pending`" line item)
`TAS`.....Binary report of each status bit (bits 1-32 from left to right). See bit #26.

Axis Status — Bit #29: Bit #29 is set when the input state of position relationship specificed in the GOWHEN expression was already true when the subsequent GO, GOL, FGADV, FSHFC or FSHFD command was executed.

`AS.29` .....Assignment & comparison operator — use in a conditional expression (see page 26).
`TASF`.....Full text description of each status bit. (see "`Gowhen Error`" line item)
`TAS`.....Binary report of each status bit (bits 1-32 from left to right). See bit #29.

Further instructions about handling error conditions are provided on page 30.

Error Status — Bit #14: Bit #14 is set if the input state or position relationship specified in the GOWHEN expression was already true when the subsequent GO, GOL, FGADV, FSHFC, or FSHFD command is issued. The error status is monitored and reported only if you enable error-checking bit #14 with the ERROR command (e.g., ERROR.14-1). NOTE: When the error occurs, the controller with branch to the error program (assigned with the ERRORP command).

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ER.14 .....Assignment & comparison operator — use in a conditional expression (see page 26).
TERF.....Full text description of each status bit. (see "GOWHEN condition true" line item)
TER.....Binary report of each status bit (bits 1-32 from left to right). See bit #14.

GOWHEN ... On A Trigger Input

If you wish motion to be triggered with a trigger input, use the TRGFNc1 command. The TRGFNc1 command executes in the same manner as the GOWHEN command, except that motion is executed when the specified trigger input "c" is activated.. For more information, refer to *Trigger Functions* below.

GOWHEN vs WAIT

A WAIT will cause the controller program to halt program flow (except for execution of immediate commands) until the condition specified is satisfied. Common uses for this function include delaying subsequent I/O activation until the master has achieved a required position or an object has been sensed.

By contrast, a GOWHEN will suspend the motion profile until the specified condition is met. It does **not** affect program flow. If you wish motion to be triggered with a trigger input, use the TRGFNc1 command. The TRGFNc1 command executes in the same manner as the GOWHEN command, except that motion is executed when the specified trigger input (c) is activated (see *Trigger Functions* below for details). In addition, GOWHEN expressions are limited to the operands listed above; WAIT can use additional operands such as FS (Following status) and VMAS (velocity of master).

Factors Affecting GOWHEN Execution

If a second GOWHEN command is executed **before** a start-motion command (GO, GOL, FSHFC, or FSHFD), then the first GOWHEN is over-written by the second GOWHEN command. (GOWHEN commands are not nested.) An error is not generated when a GOWHEN command is over-written by another GOWHEN.

While waiting for a GOWHEN condition to be met **and** a start-motion command **has** been issued, if a second GOWHEN command is encountered, then the first sequence is disabled and another start-motion command is needed to re-arm the second GOWHEN sequence.

A new GOWHEN command must be issued for each start-motion command (GO, GOL, FGADV, FSHFC, or FSHFD). That is, once a GOWHEN condition is met and the motion command is executed, subsequent motion commands will not be affected by the same GOWHEN command.

If the GOWHEN and start-motion commands are issued, the motion profile is delayed until the GOWHEN condition is met. If a second start-motion command is encountered, the second start-motion command will override the GOWHEN command and start motion. If this override situation is not desired, it can be avoided by using a WAIT condition between the first start-motion command and the second start-motion command.

It is probable that the GOWHEN command, the GO command, and the GOWHEN condition becoming true may be separated in time, and by other commands. Situations may arise, or commands may be given which make the GOWHEN invalid or inappropriate. In these cases, the GOWHEN condition is cleared, and any motion pending the GOWHEN condition becoming true is canceled. These situations include execution of the JOG, JOY, HOM, PRUN, and DRIVEØ commands, as well motion being stopped due to hard or soft limits, a drive fault, an immediate stop (!S), or an immediate kill (!K or ^K).

☞ GOWHEN in Compiled Motion *(Compiled Motion is discussed on page 139)*

When used in a compiled program, a GOWHEN will pause the profile in progress (motion continues at constant velocity) until the GOWHEN condition evaluates true. When executing a compiled Following profile, the GOWHEN is ignored on the reverse Following path (i.e., when the master is moving in the opposite direction of that which is specified in the FOLMAS command). A compiled GOWHEN may require up to 4 segments of compiled memory storage.

Sample Gem6K Code

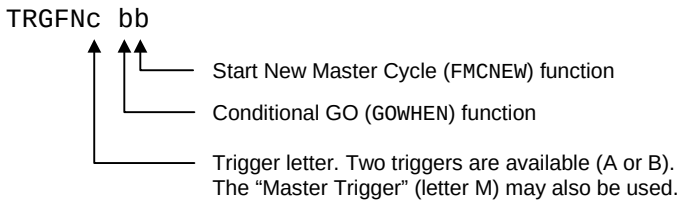
In the example below, the motor must start motion when input #2 signals a safe condition. While waiting, the program must be monitoring inputs and serving other system requirements, so a WAIT statement cannot be used; instead, a GOWHEN and GO sequence will delay the move profile of axis 2.

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```
MC0             ; Set to preset move mode
D20             ; Set distance end-point
COMEXC1         ; Enable continuous command execution mode
V1              ; Set velocity
A100            ; Set acceleration
GOWHEN(IN.2=b1) ; Delay profile. When expression is true (input #2 is
                ; low) start motion.
GO              ; Command to move. Motor will not start until
                ; conditions in the GOWHEN statement are true.
                ; Command processing does not wait, so other system
                ; functions may be performed.
```

Trigger Functions (TRGFN)

The Trigger Functions command (TRGFN) allows you to assign additional functions to trigger inputs that have been defined as "trigger interrupt" inputs (INFNCi-H):



- "**Conditional GO**" Function (TRGFNc1x): Suspend execution of the next start-motion command until specified trigger input "c" goes active. Start-motion commands are listed below. Refer to page 163 or to the GOWHEN command description for additional details.
  - GO (standard command to begin motion)
  - FGADV (begin geared advance – for Following motion)
  - FSHFC (begin continuous shift – for Following motion)
  - FSHFD (begin preset shift – for Following motion)

  Axis status bit #26 (reported with TASF, TAS, or AS) is set to one (1) when there is a pending "Conditional GO" condition initiated by a TRGFN command; this bit is cleared when the trigger is activated or when a stop command (S) or a kill command (K) is issued. If you need execution to be triggered by other factors (e.g., input state, master position, encoder position, etc.) use the GOWHEN command.

- "**New Master Cycle**" Function (TRGFNcx1): This is equivalent to executing the FMCNEW command. When specified trigger input "c" goes active, the controller begins a new Following master cycle. For more information on master cycles, refer to page 182 or to the FMCNEW command description.

These trigger functions are cleared once the function is complete (trigger input is activated). To use the trigger to perform a GOWHEN function again, the TRGFN command must be given again.

Sample Gem6K Code

```
INFNC1-H    ; Define input #1 (TRG-A) as a trigger interrupt input
INFNC2-H    ; Define input #2 (TRG-B) as a trigger interrupt input
TRGFNBx1    ; When TRG-1B goes active, motor will begin a new
            ; master cycle
TRGFNB1x    ; When TRG-2B goes active, motor will execute the move
            ; commanded with the GO command.
GO1         ; The move is commanded, but will not execute
            ; until trigger 2B goes active.
```


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CHAPTER SIX

6 Following

IN THIS CHAPTER

This chapter will help you understand Ratio Following:

- Introduction to Ratio Following 168
- Implementing Ratio Following 170
- Master Cycle Concept 182
- Technical Considerations for Following 186
- Troubleshooting for Following 196
- Following Commands (list) 198

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Ratio Following – *Introduction*

As part of its standard features, the Gem6K Series Drive/Controller family allows you to solve applications requiring *Ratio Following*.

Compiled Profiles

You can pre-compile Following profiles (saves processing time). See page 142 for details.

Ratio Following is, essentially, controlled motion based on the measurement of external motion. This includes concepts such as an electronic gearbox, trackball, follower axis feed-to-length, as well as complex changes of ratio as a function of master position. Ratio Following can include continuous, preset, and registration-like moves in which the velocity is replaced with a ratio.

The follower axis may follow in either direction and change ratio while moving, with phase shifts allowed during motion at otherwise constant ratio. Ratio changes or new moves may be dependent on master position or based on receipt of a trigger input. Also, a follower axis may perform Following moves or normal time-based moves in the same application because Following can be enabled and disabled at will. *Product cycles* (operations which repeat with periodic master travel) can be easily specified with the master cycle concept (see page 182).

In Ratio Following, acceleration ramps between ratios will take place over a user-specified master distance. Product cycles can be easily specified with the master cycle concept.

This chapter highlights the capabilities of the Gem6K Following features and provides application examples. If you need more details on the operation or syntax of a particular command, please refer to the *Gem6K Series Command Reference*.

Before delving into the specifics of Ratio Following, read on to gain a basic understanding of how the Gem6K *follows*.

What can be a master?

The Gem6K can be made to "follow" any of the master input ("master") sources listed in the table below.

- Incremental encoder. The encoder can be the axis-related "ENCODER" port on a stepper, or it can be the "MASTER ENCODER" port.
- Analog input (servo axes only). This requires an ANI SIM be installed on an expansion I/O brick (see your product's *Installation Guide* for instructions). ANI SIMs and expansion I/O bricks are sold separately.
- Internal count source (a "virtual master" option)
- Internal sine wave source (a "virtual master" option)
- Integer variable (VARI)

A servo axis may not follow its own feedback device input (encoder or analog input).
A stepper axis may follow its own encoder input, as long as that axis does not use the Encoder Stall Detect feature (ESTALL1 mode).

For instructions on assigning a master for a particular follower axis, refer to *Define the Master and Follower* (page 170), or refer to the FOLMAS command description in the Gem6K *Series Command Reference*.

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Following Status (TFSF, TFS & FS Commands)

Many of the Following features described in this document have associated status bits that can be displayed (with the TFSF and TFS commands) or used in assignment or comparison operations (with the FS operator). The portions of this document which describe those features also summarize the related status bits.

FS **Bit**	**Function** (YES = 1; NO = Ø)	
1	Follower in Ratio Move	A Following move is in progress.
2	Ratio is Negative	The current ratio is negative (i.e., follower counts counting in the opposite direction from master).
3	Follower Ratio Changing	The follower is ramping from one ratio to another (including a ramp to or from zero ratio).
4	Follower At Ratio	The follower is at constant non-zero ratio.

Bits 1-4 indicate the status of the follower axis in Following motion.

* 5	FOLMAS Active	A master is specified with the FOLMAS command.
* 6	FOLEN Active	Following has been enabled with the FOLEN command.
* 7	Master is Moving	The specified master is currently in motion.
8	Master Dir Neg	The current master direction is negative. (Bit must be cleared to allow Following move in preset mode—MCØ).

Bits 5-8 indicate the status required for Following motion (i.e., a master must be assigned, Following must be enabled, the master must be moving, and for many features, the master direction must be positive).

Unless the master is a commanded position of another axis, minor vibration of the master will likely cause bits 7-8 to toggle on and off, even if the master is nominally “at rest”. These bits are meant primarily as a quick diagnosis for the absence of master motion, or master motion in the wrong direction. Many features require positive master counting to work properly.

9	OK to Shift	Conditions are valid to issue shift commands (FSHFD or FSHFC).
10	Shifting now	A shift move is in progress.
11	Shift is Continuous	An FSHFC-based shift move is in progress.
12	Shift Dir is Neg	The direction of the shift move in progress is negative.

Bits 9-12 indicate the shift status of the follower. Shifting is super-imposed motion, but if viewed alone, can have its own status. In other words, bits 10-12 describe only the shifting portion of motion.

13	Master Cyc Trig Pend	A master cycle restart is pending the occurrence of the specified trigger.
14	Mas Cyc Len Given	A non-zero master cycle length has been specified with the FMCLEN command.
15	Master Cyc Pos Neg	The current master cycle position (PMAS) is negative. This could be by caused by a negative initial master cycle position (FMCP), or if the master is moving in the negative direction.
16	Master Cyc Num > 0	The master position (PMAS) has exceeded the master cycle length (FMCLEN) at least once, causing the master cycle number (NMCY) to increment.

Bits 13-16 indicate the status of master cycle counting. If a Following application is taking advantage of master cycle counting, these bits provide a quick summary of some important master cycle information.

17	Mas Pos Prediction On	Master position prediction has been enabled (FPPEN).
18	Mas Filtering On	A non-zero value for master position filtering (FFILT) is in effect.
19	<RESERVED>	
20	<RESERVED>	

Bit 17 and 18 indicate the status of master position measurement features.

21	<RESERVED>	
22	<RESERVED>	
23	OK to do FGADV move	OK to do Geared Advance move (master assigned with FOLMAS, Following enabled with FOLEN, and follower axis is either not moving, or moving at constant ratio in continuous mode).
24	FGADV move underway	Geared Advance move profile is in progress.

Bits 23 and 24 indicate the status of a Geared Advance move.

25	<RESERVED>	
26	FMAXA/FMAXV limited	The present Following move profile is being limited by FMAXA or FMAXV.
27	<RESERVED>	
28	<RESERVED>	

Bits 23 and 24 indicate the status of a Geared Advance move.

* All these conditions must be true before Following motion will occur.

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Implementing Ratio Following

This section covers the basic elements of implementing Ratio Following:

- Applying Following setup parameters
- Move profiles
- Performing phase shifts (FSHFC and FSHFD)
- Geared advanced (FGADV)
- Application scenarios:
  - Electronic gearbox
  - Trackball

Ratio Following Setup Parameters

Prior to executing a Following move, there are several setup parameters that must be specified. These parameters may be established:

Programming examples — see application examples later in this chapter.

- Define the *master* and *follower* (FOLMAS)
- Define master & follower scaling factors (SCLMAS, SCLA, SCLD, and SCLV) – *if required*
- Define the follower-to-master Following ratio (FOLRN and FOLRD)
- Define the master distance (FOLMD) – *define scaling first*
- Enable the Following Mode (FOLEN)

Following Status
(see TFSF, TFS and FS commands)

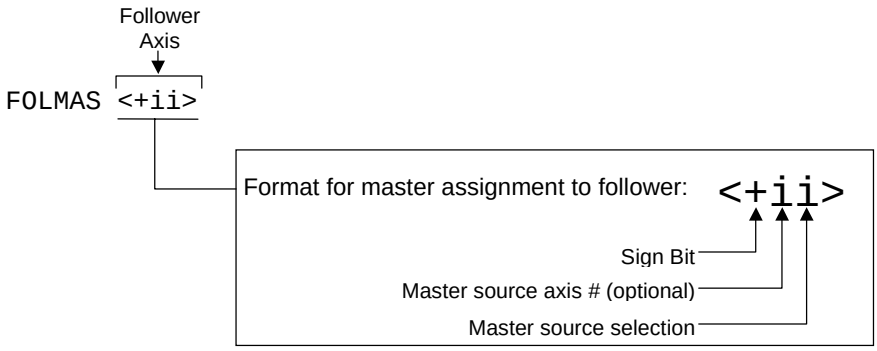
Following Status bits 5-8 (see table below) are meant to indicate the status required for Following motion (i.e., a master must be assigned, Following must be enabled, the master must be moving, and for many features, the master direction must be positive).

Bits 7-8 represent master motion and master direction respectively. Unless the master is a commanded position of another axis, it is likely that minor vibration of the master will cause these bits to toggle on and off, even if the master is nominally "at rest". These bits are meant primarily as a quick diagnosis for the absence of master motion, or master motion in the wrong direction. Many features require positive master counting to work properly.

Bit #	Function (yes = 1; no = Ø)
5	FOLMAS Active .....A master is specified with the FOLMAS command.
6	FOLEN Active .....Following has been enabled with the FOLEN command.
7	Master is Moving.....The specified master is currently in motion.
8	Master Dir Neg.....The current master direction is negative. (bit must be cleared to allow Following move in preset mode–MCØ).

Define the Master and Follower; (FOLMAS)

The FOLMAS command defines the masters and the followers. The command syntax is:



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- Sign bit (±): Specifies the count direction of the master source which will result in positive master travel counts. The sign bit is not meant to be used simply to change the direction of follower motion. That function can be done with the sign of the D command. Rather, the sign bit is used to allow forward motion of the physical master (e.g., conveyor belt, rotating wheel, or the continuous feed of material or product) to result in positive counts. Several features described later in this document require increasing master counts for proper operation. These include Following motion in preset positioning mode (MCØ) , master cycle counting, and executing GOWHEN based on master cycle position.
- Master source axis number (1st i): Selects the axis number of the master source. This number is not required when selecting the Master Encoder as the master source. . If the master source is "8" (VARI), this represents the integer variable (VARI) number.
- Master source selection (2nd i): Selects the master source (according to the master source axis number). The options, selected by their respective number, are:
  - 1.... Incremental encoder connected to one of the axis-related "ENCODER" ports, or the "MASTER ENCODER" port. If the master encoder is selected, the master source input number must be omitted from the syntax.
  - 2.... Analog input (servo axes only). This requires an ANI SIM be installed on an expansion I/O brick (see your product's *Installation Guide* for instructions), and the ANI input must be designated as a master input source with the ANIMAS command. ANI SIMs and expansion I/O bricks are sold separately.
  - 5.... Internal count source (see *Following a Virtual Master* below for details)
  - 6.... Internal sine wave source (see *Following a Virtual Master* below for details)
  - 8.... VARI variable (see *Following an Integer Variable* below for details)

NOTES

- Servo controllers: The follower axis cannot use its own commanded position or its currently selected feedback device (encoder or ANI) as the master input.
- Stepper controllers: A follower axis that is using the Stall Detect mode (ESTALL1) cannot use its own encoder as the master input.
- If scaling is enabled (SCALE1), the measurement of the master is scaled by the SCLMAS value.

As an example, suppose the **Master Encoder** input is to be the master input for follower axis 1, and forward travel of the physical master (e.g., conveyor belt) results in negative counts on the **Master Encoder**. Given these operating constraints, you would use the FOLMAS-1 command.

The default axis follower setting is disabled. If you do not want the axis to be a follower, simply leave it not configured (e.g., FOLMAS+11 command configures axis #1 as a follower to encoder #1;). If an axis is currently configured as a follower, you can disable its follower status by putting a zero (Ø) in the parameter field (e.g., the FOLMASØ command disables axis 1 from being a follower axis).

As soon as the master/follower configuration is specified with the FOLMAS command, a continuously updated relationship is maintained between the follower's position and the master's position. The update period is 2 ms.

FOLMAS Setting Not Saved in Non-Volatile Memory

The FOLMAS configuration is not saved in non-volatile memory. Therefore, you may wish to include it in the power-up program (STARTP).

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Following a Virtual Master

The Gem6K allows two "Virtual Master" options for applications that require the synchronization features of Following, but have no external master to measure.

- Internal count source.
- Internal sine wave.

Internal Count Source

The internal count source is intended to mimic the counts which might be received on an external encoder port. Just as may be encountered with an external encoder, this count source may speed up, slow down, stop, or count backwards. There is one count source with a user definable and variable count frequency. The count frequency, specified in counts per second with FVMFRQ, is a signed value, allowing the master to move forward or backwards. The rate at which the count frequency may change is specified in counts per second per second with the FVMACC command. This allows smooth changes in master velocity and direction. Neither of these commands are scaled or have associated report backs. The accumulated raw count and count rate have no report back, but may be accessed via TPMAS and TVMAS respectively if the internal count source is specified as master.

The associated commands are:

FVMFRQi	Where "i" is the count frequency in counts/sec (range is 0-1,000000)
FVMACCi	Where "i" is the count accel in counts/sec^2 (range is 0-9,999,999)

The count source is always enabled, counting at the signed rate specified with the FVMFRQ command. There are no start or stop commands, no modes, distances, or limit inputs. To stop and start the count source, specify zero or non-zero values respectively for the FVMFRQ command. To add or subtract a "preset" number of counts (i.e., move the master forward or backward a "preset distance"), you must calculate the time required for that distance, (using the frequency and acceleration values), and command the appropriate value of FVMFRQ for that duration.

Internal Sine Wave

The internal sine wave is generated using the internal count source as a frequency input. By designating the internal sine wave as a master (e.g., FOLMAS+16), you may produce a sinusoidally oscillating motion, with control of the phase (angle), amplitude, and center of oscillation. There is one sine wave using the variable count frequency (FVMFRQ) to increase or decrease the angle from which the sine is calculated. Each count of the count frequency changes the angle by one tenth (0.1) of a degree. For example, a FVMFRQ value of 3600 would create an angular frequency of 3600 tenths degrees per second, or 1 cycle per second. When used as a source for the sine wave, the maximum value for FVMFRQ is 144000. This results in a maximum of 40 Hz angular frequency. Higher frequencies are not allowed because they may be subject to aliasing.

The associated commands are:

SINANGi	Where "i" is the new angle (range is 0.0-360.0 degrees)
SINAMPi	Where "i" is the amplitude (range is 0-9,999,999 — maximum peak-to-peak is 16384))
SINGOb	Where "b" is the binary start/stop for the master axis: 1 = restart from zero degrees 0 = stop the sine wave

The SINAMP command is included in the specification in order to allow a change in slave amplitude without changing the center of oscillation. Changing the ratio (with FOLRN) will also change the slave amplitude, but unless the command is given at exactly the master zero crossing, it will also change the center of slave oscillation. The center of oscillation may be changed by a controlled amount by using the FSHFD command. The SINAMP command affects the sine wave immediately, without any built in ramp in amplitude. If a gentle change is desired, a user program should be written which

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repeatedly issues the command with small changes in value, until the desired value is reached.

Using SINGO with a "0" parameter abruptly stops the sine wave, without changing its current magnitude. Using SINGO with a "1" parameter abruptly starts the sine wave, also without changing its current magnitude. To gently pause the slave output, use an FVMFRQ value of zero, with a moderate FVMACC value; to resume, restore the FVMFRQ value.

The SINGO with a "1" parameter always starts at the previous angle, which may not be the desired start of oscillation. The SINANG command will instantly change the angle and corresponding sine of the angle. This represents an abrupt change in master position. If the slave is still following when this occurs, there will be an abrupt change in commanded slave position. To start the slave properly, move the slave to the desired start position first (using MC0, D, GO), then issue SINANG, then MC1, GO1, and finally SINGO. If SINANG is issued without any parameters, the current angle is reported, not the most recent user SINANG command value.

Sinewave Example:

In the example below, the follower will oscillate at 1 Hz centered around zero, with a peak-to-peak amplitude of 2048. Assume both the master axis and the follower axis use the same units. Based on this assumption, we can use a following ratio of 1 to 1 and control the amplitude with the SINAMP command. In order to provide a gentle start the oscillation is started at the bottom of the cycle, where the velocity is zero.

```
D-1024            ; Establish desired bottom of oscillation
MC0               ; Put into preset move mode
GO1               ; Move to desired bottom location
FOLMAS16          ; Set follower to follow internal sine wave
FOLRN1            ; Set following ratio to 1 to 1
FOLRD1
FOLEN1            ; Enable following mode
MC1               ; Enable continuous motion
SINAMP1024        ; Establish center to peak amplitude
FVMFRQ3600        ; Establish 1 Hz frequency
FVMACC999999      ; Reach frequency rapidly
SINANG270         ; Start angle at bottom of cycle
GO1               ; Lock follower to master (not started yet)
SINGO1            ; Start sine wave (and hence follower motion)
```

Following an Integer Variable

Syntax is FOLMASn8. This option allows an axis to follow the integer variable (VARI) specified with "n"; that is, VARIn. The range for "n" is 1-8 (VARI1 – VARI8). For example, FOLMAS48 assigns axis #1 to follow VARI4.

This option is particularly useful in conjunction with the INVARI (Map Inputs to a VARI Variable) feature. INVARI continuously updates a specified VARI variable with the value of a specified group of digital inputs, allowing an axis to follow a binary input pattern. Another useful way to update the value of the VARI variable is to calculate its value in a PLCP program (launched with the SCANP command).

The INVARI and SCANP options for updating VARI are good choices, because both are performed every system update, thus facilitating smooth Following motion. It is also possible to use an extra task (multi-tasking) to calculate VARI values, but the resulting updates will not be as fast (not perfectly periodic); consequently, Follow motion will be less smooth.

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Define the Master and Follower Scaling Factors; (SCLMAS); . . . . *if required*;

If you will be scaling your motion parameters (distance, velocity, acceleration/deceleration), be aware that the only variance from non-Following scaling is that the master source (distance) is scaled by the SCLMAS value. Virtual master sources are not scaled.

> Typically, the master and follower scale factors are programmed so that master and follower units are the same, but this is not required. Consider the scenario below as an example.
>
> The master is a 1000-line encoder (4000 counts/rev post-quadrature) mounted to a 50 teeth/rev pulley attached to a 10 teeth/inch conveyor belt, resulting in 80 counts/tooth (4000 counts/50 teeth = 80 counts/tooth). To program in inches, you would set up the master scaling factor with the SCLMAS800 command (80 counts/tooth * 10 teeth/inch = 800 counts/inch).
>
> The follower axis is a servo motor with position feedback from a 1000-line encoder (4000 counts/rev). The motor is mounted to a 4-pitch (4 revs/inch) leadscrew. Thus, to program in inches, you would set up the follower scaling factor with the SCLD16000 command (4000 counts/rev * 4 revs/inch = 1Gem6K counts/inch).

NOTE: Additional details on scaling and non-scaled units of measure are presented on page 67.

Define the Follower-to-Master Following Ratio (FOLRN & FOLRD)

The FOLRN and FOLRD commands establish the goal ratio between the follower and master travel, just as the V command establishes the goal velocity for a typical non-Following move. The FOLRN command specifies the ratio's numerator (follower travel), and the FOLRD command specifies the ratio's denominator (master travel). If the denominator (FOLRD) is not specified, it is assumed to be 1.

FOLRNF may be used to define a final ratio for compiled Following profiles (see page 142).

FOLRN and FOLRD are specified with two positive numbers, but the resulting ratio applies to moves in both directions; the actual follower direction will depend on the direction commanded with the D command and master direction. Numeric variables (VAR) can be used with these commands for follower and/or master parameters (e.g., FOLRN(VAR1) : FOLRD3). The maximum value of the resulting quotient is 127 to 1.

For a preset Following move (MCØ mode), the FOLRN/FOLRD ratio represents the maximum allowed ratio. For a continuous move (MC1 mode), it represents the final ratio r eached by the follower axis.

Example

As an example, assume the follower-to-master ratio is set to 5-to-3 for an axis (FOLRN5 : FOLRD3). The first parameter (5) is scaled by the SCLD value to give follower steps. The second parameter (3) is scaled by the SCLMAS value to give master steps. If the SCLD setting is 25000 and the SCLMAS setting is 4000, the follower-to-master step ratio would be 5 * 25000 to 3 * 4000, or 125 follower steps for every 12 master steps.

Define the Master Distance; (FOLMD);

The "master distance" for moves in the Following mode (FOLEN1) is analogous to the move time for normal time-based moves with Following disabled (FOLENØ). For time-based moves, the time required to ramp to a new velocity (MC1 mode) or move to a new position (MCØ mode) is determined indirectly by the acceleration (A), deceleration (AD), and velocity (V) command values. For Following mode moves, a ramp to a new ratio (MC1 mode) or a move to a new position (MCØ mode) takes place over a specific master distance, not over a specific time. This distance is defined directly by the user with the FOLMD command.

In other words, the FOLMD command defines the master distance over which a preset follower move will take place, or the master distance over which a continuous follower move will change from its current ratio (including zero) to the commanded ratio (ratio established by FOLRN and FOLRD).

By carefully specifying a master distance (FOLMD), a precise position relationship between master and follower during all phases of the profile is ensured.

☞ **HINT**: If the follower axis is in continuous mode (MC1) and the master is starting from rest, setting FOLMD to Ø will ensure precise tracking of the master's acceleration ramp.

If scaling is enabled (SCALE1), the FOLMD value is scaled by the SCLMAS parameter.

Examples and more information on this topic can be found below in the section titled *Follower vs. Master Move Profiles*.

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Enable the Following Mode; (FOLEN1)

When an axis is configured as a follower with the FOLMAS command, it will continuously monitor the position and motion of its master, even if the follower is at rest. This allows subsequent motion to be related to the motion of the master via ratios (FOLRN/FOLRD) and ramping over master distances (FOLMD). Such moves are done with Following enabled (FOLEN1).

It is also possible, and sometimes desirable, to have the follower axis motion independent of master axis motion, yet still "aware" of master position. For example, a move may need to start at a specified master position, yet finish in a fixed time, independent of the master speed. This move would be performed with Following disabled (FOLENØ).

Following may be enabled or disabled between moves, as needed, without affecting the monitoring of the master.

If a move is performed with Following disabled, its motion profile is determined by the acceleration, deceleration, and velocity specified with the A, AD, and V commands. Its motion is the same as if the axis were not configured as a follower, but the axis does monitor the master.

If a move is performed with Following enabled, its profile is determined by the specified master distance (FOLMD) and Following ratio (FOLRN/FOLRD). The next section describes such profiles.

Follower vs. Master Move Profiles

Before an axis begins moving in the Following Mode (FOLEN1), the program should define how the follower will reach the commanded ratio. This is accomplished with the FOLRN and FOLRD commands. The acceleration and deceleration of the follower can be defined in two ways: a time-based acceleration ramp with the A and AD commands, or acceleration over a certain master distance with the FOLMD command. Specifying an acceleration (A) for the follower means that the acceleration ramp is time-based and there is no position relationship between master and follower until the commanded Following ratio (defined with FOLRN and FOLRD) is reached. Specifying a master distance for the follower's move profile (FOLMD) ensures a precise position relationship between master and follower during all phases of the profile. Thus, whenever the position relationship between master and follower is important, the FOLMD method should be used. Following Status (TFSF, TFS, and FS) bits 1-4 indicate the status of follower in motion. They mimic the meaning and organization of Axis Status (TASF and AS) bits 1-4, except that each bit indicates the current state of the ratio, rather than the current state of the velocity:

Bit #	Function (YES = 1; NO = Ø)
1	Follower in Ratio Move ..... A Following move is in progress
2	Ratio is Negative..... The current ratio is negative (i.e., the follower counts are counting in the opposite direction from the master counts).
3	Follower Ratio Changing .. The follower is ramping from one ratio to another (including a ramp to or from zero ratio).
4	Follower At Ratio ..... The follower is at constant non-zero ratio.

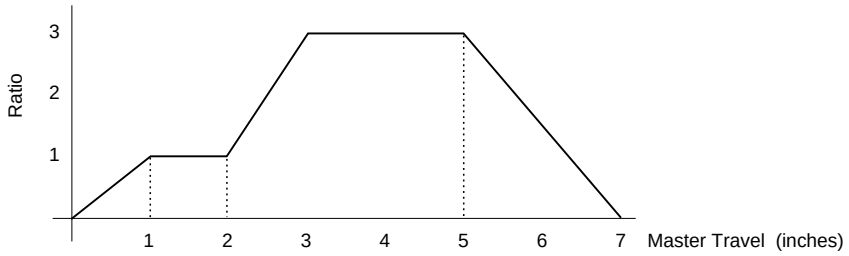
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Continuous Positioning Mode Moves

For Following moves in the continuous positioning mode (MC1), FOLMD specifies the exact master travel distance over which the follower ratio changes. This will be required for any application that uses multiple ratios and continuous moves for the construction of precisely defined multi-segment moves.

☞ **HINT**: If the follower is in continuous mode (MC1) and the master is starting from rest, setting FOLMD to Ø will ensure precise tracking of the master's acceleration ramp.

In the profile below, the first two moves each change ratio over one master inch, and the final ramp to zero takes place over two master inches.



Example

In the sample Gem6K code below, assume the follower has a 1000-line encoder connected to a 2-pitch leadscrew. This gives 8000 follower axis steps per inch. The master is a toothed belt with a pulley connected to the master encoder, such that there are 800 master steps per inch.

```
SCALE1              ; Enable scaling
SCLD8000            ; Set scaling so that follower commands are in inches
SCLMAS800           ; Set scaling so that master commands are in inches
COMEXC1             ; Allow commands during motion
FOLMAS1             ; Define master to be master encoder input
FOLEN1              ; Enable Following (will follow master encoder)
FOLMD1              ; Follower to change ratio over 1 inch of the master travel
FOLRD1              ; Set Following ratio denominator to 1 for subsequent ratios
D+                  ; Set direction positive
MC1                 ; Mode set to continuous clockwise moves
FOLRN1              ; Set Following ratio numerator to 1 (ratio set to 1:1)
FMCNEW1             ; Restart master cycle counting
GO1                 ; Start from rest to reach velocity of master encoder
WAIT(1FS.4=B1)      ; (for steppers) Wait until follower is at ratio
FOLRN3              ; Set Following ratio numerator to 3 (ratio set to 3:1)
GOWHEN (1PMAS>=2)   ; Enable motion pre-processing so that the next ramp
                    ; begins at master position 2
GO1                 ; Follower starts ratio change to 3 to 1 at master position 2
FOLRN0              ; Set Following ratio numerator to zero (ratio is 0 to 1)
FOLMD2              ; Follower changes ratio over 2 inches of master travel
WAIT(1AS.26=b0)     ; Wait until the previous ramp is started
                    ; (GOWHEN bit in axis status register is cleared)
WAIT(1FS.3=b0)      ; Wait until the previous ramp is finished
GOWHEN(1PMAS>=5)    ; Enable motion pre-processing so that follower motion
                    ; begins at master position 5
GO1                 ; Wait for master to reach 5 revolutions before
                    ; follower starts ratio change to 0 (zero)
```


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Preset Positioning Mode Moves

For preset positioning mode (MCØ) moves, the FOLMD parameter is the master distance over which the entire follower move is to take place.

As an example, a follower is to move 20 inches over a master distance of 25 inches with a maximum ratio of 1:1 (ratio set with the FOLRN1 and FOLRD1 commands). The program and a diagram of the move profiles are provided below.

```
FOLMAS1          ; Define master to be master encoder
FOLMD25          ; Define follower to perform the move over 25 inches
                 ; of the master
MC0              ; Set positioning mode to preset
MA0              ; Set preset positioning mode to incremental
D20              ; Set follower distance to 20 inches
FOLRN1           ; Set Following ratio numerator to 1
FOLRD1           ; Set Following ratio denominator to 1 (ratio is 1:1)
GO1              ; Perform the follower move
```



If the master distance specified is too large for the follower distance and ratio (FOLRN and FOLRD) commanded, the follower will never actually reach the commanded ratio, and the move profile will look similar to that below. Here, the FOLMD is 25 inches and the follower is commanded to move 10 inches:



If the master distance is too small for the follower distance and ratio commanded, the Gem6K will not perform the move at all. For example, if the FOLMD is 25, the ratio is 1:1, and the follower is commanded to move 30 inches, the move will not even be attempted. The error message "INVALID DATA" will be displayed (depending on the ERRLVL setting) and program execution will continue.

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Performing Phase Shifts

Following Status (TFSF, TFS and FS) bits 9-12 indicate the shift status of the follower. Shifting is super-imposed motion, but if viewed alone, can have its own status. In other words, bits 10-12 describe only the shifting portion of motion.

Bit #	Function (YES = 1; NO = Ø)
9	OK to Shift.....Conditions are valid to issue shift commands (FSHFD or FSHFC).
10	Shifting now .....A shift move is in progress.
11	Shift is Continuous.....An FSHFC-based shift move is in progress.
12	Shift Dir is Neg.....The direction of the shift move in progress is negative.

When a follower is following a master continuously, it may be necessary to adjust, or *shift*, the Following *phase* (follower's position with respect to the master) independent of motion due to ratio moves. The FSHFC and FSHFD commands allow time-based follower moves to be superimposed upon ratio Following moves. Because phase shifts are time-based, they are independent of master motion; in fact, the master may be at rest and a shift may still be performed.

Use the FSHFD command to perform a preset shift move with a specific change in follower phase. The FSHFD distance value will be scaled by SCLD if scaling is enabled (SCALE1).

Use the FSHFC command to superimpose a continuous shift move in the positive (FSHFC1) or negative (FSHFC2) direction. The FSHFC parameters stop (Ø) and kill (3) can be used to halt a continuous FSHFC move or a preset FSHFD move without affect the ratio motion.

The most recently defined velocity and acceleration (i.e., the V and A values) for the follower will determine the basis for the superimposed shift move profile for both FSHFC and FSHFD moves. The commanded velocity of the FSHFC or FSHFD move will be added to the current velocity at which the follower is performing the Following move . For example, assume a follower is traveling at 1 rps in the positive direction as a result of following a master. If a FSHFC move is commanded in the positive direction at 2 rps, the follower's actual velocity (after acceleration) will be 3 rps.

For servos, shifting may be performed whenever Following is enabled (FOLEN1). For steppers, this may only be done while Following is enabled and the follower is either not in a move, or is in continuous positioning mode (MC1) and moving at constant ratio. For both products, TFS/FS bit 9 indicates when a shift is allowed.

The current follower position (TPSLV value) and the net follower shift accumulated since the most recent FOLEN1 command (TPSHF value) may be read into numeric variables (VAR) using the PSLV and PSHF commands, respectively (e.g., VAR6=1PSLV). They may also be used for subsequent decision making (e.g., IF(1PSHF<6), GOWHEN(1PSLV>VAR2), etc.).

The TPSHF and PSHF values are set to zero each time the Following mode is enabled (FOLEN1), even if the follower is already in Following mode. This provides a way of clearing these values for programming convenience.

Note that the distance traveled during the time-based deceleration due to stop, kill, or limits is included in the PSHF value. By comparing "before and after" values of PSHF, a Gem6K program may calculate how much shift was required to perform visual- or sensor-based alignment of a master/follower phase relationship.

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Phase Shift Examples

An FSHFC or FSHFD move may be needed to adjust the follower position *on the fly* because of a load condition which changes during the continuous Following move. Below are programming examples to demonstrate both shift methods.

FSHFC Example

An operator is visually inspecting the follower's continuous Following motion with respect to the master. If he notices that the master and follower are out of synchronization, it may be desirable to have an interrupt programmed (e.g., activated by pressing a push-button switch) that will allow the operator to move the follower at a superimposed correction speed until the operator chooses to have the follower start tracking the master again (by releasing the push-button). The programming example below illustrates this.

Assume all scale factors and set-up parameters have been entered for the master and follower. In this example, the follower is continually following the master at a 1:1 ratio. If the operator notices some mis-alignment between master and follower, he can press 1 of 2 pushbuttons (connected to onboard trigger inputs #1 and #2) to shift the follower in the positive or negative direction until the button is released. After the adjustment, the program continues on as before.

```
DEL SHIFT       ; Delete program before defining
DEF SHIFT       ; Begin definition of program called SHIFT
COMEXS1         ; Continue command execution after stop
COMEXC1         ; Continue command execution during motion
FOLMAS1         ; Master encoder is the master
FOLRN1          ; Set follower-to-master Following ratio numerator to 1
FOLRD1          ; Set follower-to-master Following ratio denominator to 1
                ; (ratio set to 1:1)
FOLEN1          ; Enable Following mode
A25             ; Set acceleration
AD18            ; Set deceleration
V5              ; Set velocity
D+              ; Set direction to positive
MC1             ; Select continuous positioning mode
GO1             ; Start following master continuously
VARB1=b10       ; Define onboard input pattern #1 and assign to VARB
VARB2=b01       ; Define onboard input pattern #2 and assign to VARB
$TESTIN         ; Define label called TESTIN
IF(IN=VARB1)    ; IF statement (if input #1 is activated, do the jump)
JUMP SHIFTP     ; Jump to shift follower in the positive direction
                ; when pattern 1 active
NIF             ; End of IF statement
IF(IN=VARB2)    ; IF statement (if input #2 is activated, do the jump)
JUMP SHIFTN     ; Jump to shift follower in the negative direction
                ; when pattern 2 active
NIF             ; End of IF statement
JUMP TESTIN     ; Return to main program loop
$SHIFTP         ; Define label called SHIFTP (subroutine to shift in
                ; the positive direction)
FSHFC1          ; Start continuous follower shift in positive direction
WAIT(IN.1=B0)   ; Continue shift until input bit #1 is deactivated
FSHFC0          ; Stop shift move
WAIT(1FS.10=B0) ; (steppers only) Wait until the shift is completed
JUMP TESTIN     ; Return to main program loop
$SHIFTN         ; Define label called SHIFTN (subroutine to shift
                ; in the negative direction)
FSHFC2          ; Start continuous follower shift move in the
                ; negative direction
WAIT(IN.2=B0)   ; Continue shift until bit #2 is deactivated
FSHFC0          ; Stop shift move
WAIT(1FS.10=B0) ; (steppers only) Wait until the shift is completed
JUMP TESTIN     ; Return to main program loop
END             ; End definition of program called SHIFT
```


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FSHFD Example

In this example, the follower follows a master that moves in a continuous cycle. Once each cycle, the master and follower both pick parts. The master's part is detected by a sensor connected to trigger 1B, and the follower's part is detected by a sensor connected to trigger 1A. After both parts are detected, they must be aligned. The sensors are mounted 2 inches apart from each other, so that proper alignment would result in 2 inches of follower travel between detection of the master's part and detection of the follower's part.

The follower position is sampled when each of the sensors activates. The difference between the follower positions is compared to the required 2 inches. If the measured difference is greater than or less than 2 inches, then a shift move to correct the alignment is made. At that point, the follower will then start tracking the master again. The follower is continually following the master at a 1:1 ratio.

```
DEL ALIGN          ; Delete program before defining
DEF ALIGN          ; Begin definition of program called ALIGN
COMEXC1            ; Allow continuous command execution during motion
FOLMAS1            ; The master encoder input is the master
FOLRN1             ; Set follower-to-master ratio numerator to 1
FOLRD1             ; Set follower-to-master ratio denominator to 1
                   ; (ratio set to 1:1)
FOLEN1             ; Enable Following mode
MC1                ; Enable continuous positioning mode
D+                 ; Set direction to positive
GO1                ; Start Following master continually
INFNC1-H           ; Enable trigger input 1A to latch position of follower
                   ; when the follower's part is detected
INFNC2-H           ; Enable trigger input 1B to latch position of follower
                   ; when the master's part is detected
$SYNCLP            ; Main loop where synchronizing moves occur
WAIT(TRIG.1=b1 AND TRIG.2=b1)
                   ; Wait for both follower and master inputs to occur
VAR10=1PCCA        ; Load VAR10 with the follower commanded position due
                   ; to follower input activation
VAR11=1PCCB        ; Load VAR11 with the follower commanded position due
                   ; to master input activation
VAR12=VAR10-VAR11  ; Load VAR12 with the offset distance
VAR13=VAR12-2      ; Calculate the required shift
FSHFD(VAR13)       ; Perform synchronization move of distance in VAR13
JUMP SYNCLP        ; Return (jump) to main program loop
END                ; End of program
```

Geared Advance Following

The FGADV command provides the ability to super-impose an advance or retard on Following motion. This is the same ability provided by the FSHFD command (see *Performing Phase Shifts* above), except that the super-imposed motion is also geared to master motion. The FGADV command has the positive or negative "advance" distance as a parameter, but it initiates motion instead of simply setting up the distance. The shape of the super-imposed profile is determined by the FOLMD, FOLRN, and FOLRD commands (just as a normal preset Following move).

The FGADV command profile may be delayed with the GOWHEN command.

A FGADV move may be performed only while the conditions below exist (Following status bit #23, reported with the FS, TFS, and TFSF commands, indicates that it is "OK to do FGADV move"):

- Master is specified with a FOLMAS command
- Following is enabled with the FOLEN command
- The follower is either not moving, or moving at constant ratio in continuous mode (MC1)

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A FGADV move may not be performed:

- During a preset (MC0) move
- In a compiled profile or program

Following Status (FS, TFS, and TFSF) bit #24 reports if a "FGADV move is underway".

Example

```
COMEXC1         ; All command processing during motion
FOLRN25         ; Set numerator of follower-to-master Following ratio
FOLRD10         ; Set denominator of follower-to-master Following ratio
FOLMD1000       ; Set master distance to 1000 units
MC1             ; Enable continuous positioning mode
D+              ; Set direction to positive
FOLEN1          ; Enable Following
GO              ; Ramp up to a 2.5:1 ratio over 1000 master distance units
FOLMD500        ; Set master distance to 500 units
FOLRN13         ; Superimposed ratio will be 1.3 (added to 2.5 = 3.8 total)
WAIT(FS.23=B1)  ; Wait for OK to do geared advance
                ; (in this case, ramp is complete)
FGAVD400        ; Advance the follower 400 counts over a distance
                ; of 500 master counts
WAIT (FS.23=B1) ; Wait for OK to do geared advance  (in this case,
                ; FGADV400 super-imposed profile is complete)
FGADV-400       ; Retard the follower 400 counts over a distance of
                ; 500 master counts (2.5 - 1.3 = 1.2 net ratio)
```

Summary of Ratio Following Commands

ANIMAS ..... Assigns an analog input to be used as a master in a FOLMAS assignment (requires a ANI SIM located on an expansion I/O brick)

FGADV ..... Defines the geared advance distance

FOLEN ..... Enables or disables Following mode

FOLMAS ..... Defines masters

FOLMD ..... Defines the master distance over which follower acceleration or moves are to take place

FOLRN and FOLRD ..... Establishes the maximum follower-to-master ratio for a preset move or the final ratio for a continuous move (FOLRN for the numerator and FOLRD for the denominator)

FSHFD ..... Initiates preset advance or retard (shift) of follower position during continuous Following moves

FSHFC ..... Initiates continuous advance or retard (shift) of follower position (or kills or stops the shift portion of motion) during continuous Following moves

FVMACC ..... Establishes the rate at which the virtual master count frequency (FVMFRQ) may change.

FVMFRQ ..... Defines the frequency of the virtual master count.

SCLD ..... Sets the follower distance scale factor

SCLMAS ..... Sets the master distance scale factor

SINAMP ..... Defines the amplitude of the internal sine wave

SINANG ..... Defines the phase angle of the internal sine wave

SINGO ..... Initiates the internal sine wave

TPSHF or [PSHF] ..... Transfers or assigns the net position shift since constant ratio

TPSLV or [PSLV] ..... Transfers or assigns the current follower position

TVMAS or [VMAS] ..... Transfers or assigns the velocity of the master

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Master Cycle Concept

Ratio Following can also address applications that require precise programming synchronization between moves and I/O control based on master positions or external conditions. The concept of the master cycle greatly simplifies the required synchronization.

A master cycle is simply an amount of master travel over which one or more related follower axis events take place. The distance traveled by the master in a master cycle is called the *master cycle length*. A *master cycle position* is the master position relative to the start of the current master cycle. The value of master cycle position increases as positive-direction *master cycle counts* are received, until it reaches the value specified for master cycle length. At that point, the master cycle position becomes zero, and the *master cycle number* is incremented by one—this condition is called *rollover*.

The master cycle concept is analogous to minutes and hours on a clock. If the master cycle is considered an hour, then the master cycle length is 60 minutes. The number of minutes past the hour is the master cycle position, and current hour is the master cycle number. In this analogy, the master cycle position decrements from 59 to zero as the hour increases by one.

By specifying a master cycle length, periodic actions may be programmed in a loop or with subroutines which refer to cycle positions, even though the master may be running continuously. To accommodate applications where the feed of the product is random, the start of the master cycle may be defined with trigger inputs. Two types of *waits* are also programmable to allow suspension of program operation or follower moves based on master positions or external conditions.

Master Cycle Commands

Following Status (TFSF, TFS and FS) bits 13-16 indicate the status of master cycle counting. If a following application is taking advantage of master cycle counting, these bits provide a quick summary of some important master cycle information:

Bit #	**Function** (YES = 1; NO = Ø)
13	Master Cyc Trig Pend .....A master cycle restart pending the occurrence of the specified trigger.
14	Mas Cyc Len Given.....A non-zero master cycle length has been specified with FMCLEN.
15	Master Cyc Pos Neg .....The current master cycle position (PMAS) is negative. This could be by caused by a negative initial master cycle position (FMCP), or if the master is moving in the negative direction.
16	Master Cyc Num > 0 .....The master position (PMAS) has exceeded the master cycle length (FMCLEN) at least once, causing the master cycle number (NMCY) to increment.

Master Cycle Length (FMCLEN);

The FMCLEN command is used to define the length of the master cycle. The value entered with this command is scaled by the SCLMAS parameter to allow specification of the master cycle length in user units. This parameter must be defined before those commands which wait for periodically repeating master positions are executed.

The default value of FMCLEN is zero, which means the master cycle length is practically infinite (i.e., 4,294,967,246 steps, after scaling). If a value of zero is chosen, the master cycle position will keep increasing until this very high value is exceeded or a new cycle is defined with the FMCNEW command (or triggered after a TRGFNCx1 command) described below. If a non-zero value for FMCLEN is chosen, the internally maintained master cycle position will keep increasing until it reaches the value of FMCLEN. At this point, it immediately rolls over to zero and continues to count.

The master cycle length may be changed with the FMCLEN command even after a master cycle has been started. The new master cycle length takes affect as soon as it is issued. If the new master cycle length is greater than the current master cycle position, the cycle position will not change, but will rollover when the new master cycle length is reached. If the new master

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cycle length is less than the current master cycle position, the new master cycle position becomes equal to the old cycle position minus one or more multiples of the new cycle length.

Example Code

```
FMCLEN23            ; Set master cycle length:
                    ; (axis 1: 23 units
```

Restart Master Cycle Counting (FMCNEW or TRGFNcx1xxxxxx);

Once the length of the master cycle has been specified with the FMCLEN command, master cycle counting may be restarted immediately with the FMCNEW command, or based on activating a trigger input as specified with the TRGFNcx1 command. The new master cycle count is started at an initial position specified with the FMCP command (see below).

When the TRGFNcx1 command is used, the restart of master cycle counting is pending activation of the specified trigger. If an FMCNEW command is issued while waiting for the specified trigger to activate, counting is restarted immediately with the FMCNEW command, and the TRGFNcx1 command is canceled.

When using TRGFNcx1

- Before the TRGFN command can be used, you must first assign the trigger interrupt function to the specified trigger input with the INFNCi-H command, where "i" is the input number of the trigger input desired for the function (input bit assignments vary by product).
- Because the Gem6K program will not wait for the trigger to occur before continuing on with normal program execution, a WAIT or GOWHEN condition based on PMAS will not evaluate true if the restart of master cycle counting is pending the activation of a trigger. To halt program operation, the WAIT command can be used.

A new master cycle will restart automatically when the total master cycle length (FMCLEN value) is reached. This is useful in continuous feed applications.

Example Code

```
FMCNEW1       ; Restart new master cycle counting
INFNC2-H      ; Assign input #2 (TRG-1B) the trigger interrupt
              ; function (prerequisite to using the TRGFN features)
1TRGFNBx1     ; When trigger input 2 (TRG-1B) goes active,
```

Initial Master Cycle Position (FMCP);

The FMCP command allows you to assign **for the first cycle only**, an initial master cycle position to be a value other than zero. When master cycle counting is restarted with the FMCNEW command or with the trigger specified in the TRGFNcx1 command, the master cycle position takes the initial value previously specified with the FMCP command. The value for FMCP is scaled by SCLMAS if scaling is enabled (SCALE1)

FMCP was designed to accommodate situations in which the trigger that restarts master cycle counting occurs either before the desired cycle start, or somewhere in the middle of what is to be the first cycle. In the former case, the FMCP value must be negative. The master cycle position is initialized with that value, and will increase right through zero until it reaches the master cycle length (FMCLEN). At that point, it will roll over to zero as usual.

The continuous cut-to-length example below illustrates the use of a negative FMCP (a trigger that senses the motion of the master is physically offset from the master position at which some action must take place). If it is desired that the first cycle is defined as already partially complete when master cycle counting is restarted, the FMCP value must be greater than zero, but less than the master cycle length.

To give a value for FMCP which is greater than master cycle length is meaningless since master cycle positions are always less than the master cycle length. The Gem6K responds to this case as soon as a new master cycle counting begins by using zero instead of the initial value specified with FMCP.

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Transfer and Assignment/ Comparison of Master Cycle Position and Number;

The current master cycle position and the current master cycle number may be displayed with the TPMAS and TNMCY commands, respectively. These values may also be read into numeric variables (VAR) at any time using the PMAS and NMCY commands (e.g., VAR6=NMCY). If position capture is used, the master cycle position and be captured, and the value is available with the TPCMS and PCMS commands.

Very often, the master cycle number will be directly related to the quantity of product produced in a manufacturing run, and the master cycle position can be used to determine what portion of a current cycle is complete.

The master cycle number is sampled once per *position sampling period* (see note, left). If the master cycle length (FMCLEN) divided by the master's velocity (VMAS) is less than the position sampling period (2 ms), then the sample (TNMCY or NMCY value) may not be accurate.

Details on using PMAS in conditional expressions is provided below in *Using Conditional Statements with PMAS*.

Using Conditional Statements with Master Cycle Position (PMAS);

The current master cycle position (PMAS) value may be used in comparison expressions, just like other position variables such as PC, PE, and FB. PMAS is a special case, however, because its value rolls over to zero when the master cycle length (FMCLEN) is met or exceeded. This means that PMAS values greater than or equal to the master cycle length will never be reported with the TPMAS command, or with expressions such as (VAR1=1PMAS).

The other fact that makes PMAS special is that master cycle counting may be restarted after the command containing the PMAS expression has been executed. Either the FMCNEW command or the TRGFNCX1 command may be used to restart counting, each with a different effect on the evaluation of PMAS.

The treatment of PMAS in comparison expressions depends on the command using the expression, as described below. WAIT and GOWHEN are treated as special cases.

IF, UNTIL, and WHILE

These commands evaluate the current value of PMAS in the same way that TPMAS does (i.e., PMAS values will never be greater than or equal to the master cycle length). With these commands, avoid comparing PMAS to be greater than or equal to variables or constants which are nearly equal to the master cycle length, because rollover may occur before a PMAS sample is read which makes the comparison true. If such a comparison is necessary, it should be combined (using OR) with a comparison for master cycle number (NMCY) being greater than the current master cycle number.

Also, master cycle counting restart may be pending activation of a trigger, but this will not affect the evaluation of PMAS for IF, WAIT, and WHILE. It is simply evaluated based on counting currently underway.

WAIT and GOWHEN

These commands evaluate the current value of PMAS differently than TPMAS does, in such a way that it is possible to compare PMAS to variables or constants which are greater than or equal to the master cycle length and still have the comparison be reliably detected.

Effectively, PMAS is evaluated as if the master cycle length were suddenly set to its maximum value (2^{32}) at the time the WAIT or GOWHEN command is encountered. It eliminates the need to OR the PMAS comparison with a comparison for master cycle number (NMCY) being greater than the current master cycle number. Such multiple expressions are not allowed in the GOWHEN command, so this alternative evaluation of PMAS offers the required flexibility.

This method of evaluation of PMAS allows commands which sequence follower axis events through a master cycle to be placed in a loop. The WAIT or GOWHEN command at the top of the loop can execute, even though the actual master travel has not finished the previous cycle. If it is desired to WAIT or GOWHEN for a master cycle position of the next master cycle, the variable or constant specified in the command should be calculated by adding one master cycle length to the desired master cycle position.

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Finally, master cycle counting restart may be pending activation of a trigger (TRGFNcx1), and this will suspend the evaluation of PMAS for these commands. PMAS is not sampled, and the comparison evaluates as false. During this time, if the pending status of master cycle counting restart is aborted with FMCNEWØ, the GOWHEN condition is also cleared, and any motion profile of any axis waiting on *that* PMAS comparison will be canceled. Otherwise, when master cycle counting is restarted by a trigger, evaluation takes place as described above. This allows GOWHEN to include waiting on a trigger without explicitly including it in the GOWHEN expression.

Synchronizing Following Moves with Master Positions

A final special case allows perfect synchronization between the start of a Following motion profile of a follower axis and a specified position of its master. If a GOWHEN(1PMAS >= x) expression is used to synchronize a follower with its own master, with the operator specifically ">=", a special synchronization occurs. Although it may be impossible for the Gem6K product to sample the exact master position specified, the Following motion profile is calculated from master travel based on that position. This allows for the construction of profiles in which the synchronization of master and follower positions is well defined and precisely maintained. This feature requires positive travel of the master, which can be achieved with the appropriate sign for the FOLMAS specification.

Summary of Master Cycle and Wait Commands

FMCLEN	Defines the length of the master cycle
FMCNEW	Immediately restart master cycle counting
FMCP	Defines the initial position of a new master cycle
GOWHEN	GOWHEN suspends execution of the next move on the specified axis until the specified conditional statement (based on T, IN, LIM, FB, NMCY, PC, PE, PMAS, PSLV, or PSHF) is true
TNMCY or [NMCY]	Transfers or assigns the current master cycle number
TPCMS or [PCMS]	Transfers or assigns the captured master cycle position
TPMAS or [PMAS]	Transfers or assigns the current master cycle position
TRGFN	aTRGFNc1x initiates a GOWHEN, suspending execution of the next follower move on axis (a) until the specified trigger input (c) goes active. aTRGFNcx1 causes master cycle counting to restart when the specified trigger input (c) goes active.
WAIT	WAIT suspends program execution until the specified conditional statement (based on PMAS, FS, NMCY, PCMS, PSHF, PSLV, or VMAS) is true; WAIT(SS.i=b1) suspends program execution until a trigger input is activated. The "i" is the programmable input bit number corresponding to the trigger input. (Input bit assignments vary by product; refer to the Programmable I/O Bit Patterns table on page 91 to determine the correct bit pattern for your product.)
AS and TAS bit #26	AS and TAS (and TASF) bit #26 is set when there is a profile suspended pending GOWHEN condition, initiated either by a GOWHEN command or a TRGFNc1 command; this bit is cleared when the GOWHEN condition is true or when a stop or kill command is issued.
ER and TER bit #14	ER, TER, and TERF bit #14 is set if the GOWHEN condition is already true when the GO, GOL, FGADV, FSHFC, or FSHFD command is given (ERROR bit #14 must first be enabled to check for this condition)

NOTE

The continuous cut-to-length application example below illustrates the use of the master cycle concept and the commands above.

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Technical Considerations for Following

In the introduction to Following (see page 168), the algorithm for Gem6K Following was briefly discussed. Here we will address some of the more technical aspects of Following:

- Performance
- Master Position Prediction
- Master Position Filtering
- Following error
- Maximum acceleration and velocity (stepper axes only)
- Factors affecting Following accuracy
- Preset vs. Continuous Following moves
- Master and follower axis distance calculations
- Using other features with Following

Keep in mind that in all cases, the follower position is calculated from a sampled master position.

Performance Considerations

When a follower axis is following a master, the Gem6K does not simply measure the master velocity to derive follower axis velocity. Instead, the Gem6K samples the master position (*position sampling period = 2 ms*) and calculates the corresponding follower axis position command. This is true even if the follower axis is in the process of changing ratios. A follower axis is not simply following velocity, but rather position. With this algorithm, the master and follower position or phase relationship is maintained indefinitely, without any drift over time due to velocity measurement errors.

The Gem6K also measures master velocity by measuring the change in master position over a number of sample periods. The present master velocity and position may be used to calculate the next commanded follower position, so the follower has no velocity-dependent phase delay. This concept is known as *Master Position Prediction* and may be enabled or disabled as needed with the `FPPEN` command.

The Gem6K's default Following algorithm should work well for most applications; however, you can change the Following algorithm to meet application-specific needs. For instance, suppose that the speed of the master is very slow, or has some vibration. For a case like this, the Gem6K allows you to filter the master position signal to generate a smooth follower position command. This is known as *Master Position Filtering* and is programmed with the `FFILT` command.

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Master Position Prediction

Master Position Prediction is a technique used to compensate for the fact a follower's position command cannot be calculated and implemented infinitely fast.

The master position prediction mode is enabled by default (FPPEN1) in the Following algorithm, but can be turned off as desired with the FPPENØ command.

The Gem6K measures master position once per *position sampling period* (2 ms), and calculates a corresponding follower position command. This calculation and achieving the subsequent follower commanded position requires 2 sample periods (4 ms).

If master position prediction mode is disabled (FPPENØ), waiting 2 sample periods results in a follower position lag. That is, by the time the follower reaches the position that corresponds to the sampled master position, 2 sample periods have gone by, and the master may be at a new position. Measured in time, the lag is 2 sample periods. Measured in position, the lag is 2 sample periods ∗ current follower velocity.

For example, suppose the follower is traveling at a speed of 25000 counts per second. If master position prediction mode is disabled (FPPENØ), the follower will lag the master by 100 counts (25000 counts/sec ∗ 4 ms = 100 counts).

By measuring the change in master position over sequential sample periods, the master's present velocity is calculated. The present master velocity and position are used to predict future master position. If master position prediction mode is enabled (FPPEN1, the predicted future master position is used to determine the follower's position command. In this case the follower has no velocity-dependent phase delay. The follower's velocity for a given sample will always be the velocity required to move from its current position to the next calculated position command.

If the master motion is fairly smooth and velocity is not very slow, the measurement of its recent velocity will be very accurate, and a good way of predicting future position. But the master motion may be rough, or the measurements may be inaccurate if there is no filtering (see *Master Position Filtering* below). In this case, the predicted master position and the corresponding follower position command will have some error, which may vary in sign and magnitude from one sample to the next. This random variation in follower position command error results in rough motion. The problem is particularly pronounced if there is vibration on the master.

It may be desirable to disable the master position prediction mode (FPPENØ) when maximum follower smoothness is important and minor phase delays can be accommodated.

If master filtering is enabled (FFILT_Ø), then the prediction algorithm would be used on the filtered master position, resulting in a smoother follower position command. However, due to the delay introduced by the filtering, the prediction algorithm would not compensate for the total delay in the follower's tracking command. (See also *Master Position Filtering* below.)

Following Status (TFSF, TFS, and FS) bit 17 indicates the status of where or not the master position prediction mode is enabled.

Master Position Filtering

The follower axis' position command is calculated at each *position sample period* (2 ms). This calculation is a function of the master position and the master velocity estimated from the change in master position over 2 position sample periods.

The *Master Position Filter* feature allows you to apply a low-pass filter to the measurement of master position. Master position filtering is used in these situations:

- Measurement of master position is contaminated by either electrical noise (when analog input is the master) or mechanical vibration.
- Measurement noise is minimal, but the motion that occurs on the master input is oscillatory. In this case, using the filter can prevent the oscillatory signal from propagating into the follower axis (i.e., ensuring smoother motion on the follower axis).

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The bandwidth of the low-pass filter is controlled with the FFILT command:

FFILT Setting	Low pass Filter Bandwidth
Ø	infinite (no filtering) – *default setting*
1	120 Hz
2	80 Hz
3	50 Hz
4	20 Hz

When considering whether or how much master position filtering to use, consider the application requirement itself. The application requirements related to filtering can be categorized into these three types:

Type I: If an application requires smooth motion but also high follower tracking accuracy, then a heavy filtering should **not** be used. It should not be used because it may introduce too much velocity phase lag, although the motion may be smooth. In other words, the master axis in the first place should produce very smooth motion and low sensor measurement noise such that a higher level of master filtering is not needed.

Type II: If follower axis velocity tracking error is not critical but smooth follower axis motion is desired, then you can use a higher level of master filtering to deal with sensor noise or master vibration problems.

Type III: If it is determined that under certain dynamic conditions the master position's oscillatory measurement is purely caused by its vibration motion (noise is insignificant), and it is necessary for the follower to follow such motion, then the filter command should not be used or only use the highest bandwidth (FFILT1).

Following Status (TFSF, TFS, and FS) bit 18 indicates the status of master position filtering.

Following Error

As soon as an axis becomes configured as a follower, the follower's position command is continuously updated and maintained. At each update, the position command is calculated from the current master position and velocity, and the current ratio or velocity of the follower.

Whenever the commanded position is not equal to the actual follower position, a *Following error* exists. This error, if any, may be positive or negative, depending on both the reason for the error and the direction of follower travel. Following error is defined as the difference between the commanded position and the actual position.

```
Following Error = Commanded position - Actual position
```

If the follower is traveling in the positive direction and the actual position lags the commanded position, the error will be positive. If the follower is traveling in the negative direction and the actual position lags the commanded position, the error will be negative. This error is always monitored, and may be read into a numeric variable (VAR) at any time using the PER command. The error value in follower steps is scaled by SCLD for the axis. This value may be used for subsequent decision making, or simply storing the error corresponding to some other event.

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Maximum Velocity and Acceleration (Stepper Axes Only)

The follower's attempt to faithfully follow the master may command velocities and accelerations that the follower axis is physically not able to complete. Therefore, the FMAXV and FMAXA commands are provided to set the maximum velocity and acceleration at which the follower will be allowed to move.

If the follower is commanded to move at rates beyond the defined maximums, the follower will begin falling behind it's commanded position. If this happens, a correction velocity will be applied to correct the position error as soon as the commanded velocity and acceleration fall within the limitation of FMAXV and FMAXA.

The FMAXA and FMAXV commands should be used only to protect against worst case conditions, and should be avoided altogether if they are not needed. If an axis is not able to follow its profile because of limitations imposed by these commands, some correction motion will occur. If the maximum acceleration (FMAXA value) is set very low, some oscillation about the commanded position may occur because the follower is not allowed to decelerate fast enough to prevent overshoot.

Factors Affecting Following Accuracy

There are additional accuracy requirements of Following applications beyond those of standard positioning. The follower axis must maintain positioning accuracy while in motion, not just at the end of moves, because it is trying to stay synchronized with the master.

Assuming parameters such as master and follower scaling and ratios have been specified correctly, the overall positioning accuracy for an application depends on several factors:

- Resolution of the master
- Resolution of the follower axis
- Position sampling accuracy
- Accuracy of the follower axis motor and drive
- Accuracy of load mechanics
- Master position prediction
- Master velocity relative to master position prediction & master position filtering
- Tuning (servo axes only)
- Repeatability of the trigger inputs and sensors

Just as with a mechanical arrangement, the accuracy errors can build up with every link from the beginning to the end. The overall worst case accuracy error will be the sum of all the sources of error listed below. The errors fall into two broad categories, namely, master measurement errors and follower errors. These both ultimately affect follower accuracy, because the commanded follower position is based on the measured master position.

It is important to understand how master measurement errors result in follower position errors. In many applications, master and follower units will be the same (e.g., inches, millimeters, degrees). These applications will require linear speeds or surface speeds to be matched (i.e., a 1:1 ratio). For example, suppose that in a rotary knife application, there were 500 master steps per inch of material, so an error in master measurement of one encoder step would result in 0.002 inches of follower position error.

If the master and follower units are not the same, or the ratio is not 1:1, the master error times the ratio of the application gives the follower error. An example would be a rotary master and a linear follower. For instance, suppose one revolution of a wheel gives 4000 master counts, and results in 10 inches of travel on the follower. The ratio is then 10 inches/revolution. The follower error which results from one step of master measurement error is (1/4000) * 10 inches/revolution = 0.0025 inches.

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Resolution of the Master;

The best case master measurement precision is the inverse of the number of master steps per user's master unit. For example, if there are 100 master steps/inch, then the master measurement precision is 0.01 inches. Even if all other sources of error are eliminated, follower accuracy will only be that which corresponds to 1 step of the master (e.g., 0.01 inches in the previous example).

Resolution of the Follower;

The best case follower axis precision is the inverse of the number of follower steps per user's position unit. For example, if there are 1000 follower steps/inch, then the follower resolution is 0.001 inches. Even if all other sources of error are eliminated, follower positioning accuracy will only be that which corresponds to 1 step of the follower. This must be at least as great as the precision required by the application.

Position Sampling Accuracy;

The position sampling rate for the Gem6K depends on whether it is a servo or a stepper. The sample period for is 2 ms.

The repeatability of the sampling rate, from one sample to the next, may vary by as much as 100 µs. This affect may be eliminated by using non-zero master position filter (FFILT) command values. Otherwise, measurement of master position may be off by as much as (20 to 100 microseconds * master speed). This may appear to be a significant value at high master speeds, but it should be noted that this error changes in value (and usually sign) every sample period. It is effectively like a noise of 200-600 Hz; if the mechanical frequency response of the motor and load is much less than this frequency, the load cannot respond to this error.

Accuracy of the Follower Motor and Drive;

The precision also depends on how accurately the drive follows its commanded position while moving. Even if master measurement were perfect, if the drive accuracy is poor, the precision will be poor.

In the case of stepper drives, this amounts to the specified motor/drive accuracy.

In the case of servo drives, the better the drive is tuned for smoothness and zero Following error, the better the precision of the positioning. Often, this really only matters for a specific portion of the profile, so the drive should be tuned for zero Following error at that portion.

Accuracy of the Load Mechanics

The accuracy (not repeatability) of the load mechanics must be added to the overall build up of accuracy error. This includes backlash for applications which involve motion in both directions.

Master Position Prediction;

The master position prediction mode may be enabled or disabled with the FPPEN command, but each state contributes a different error.

Disabled (FPPENØ): The follower position command is based on a master position that is 2 sample periods (4 ms) old. This means that master measurement error due to disabling the position prediction mode will be (2 sample periods * master speed).

Enabled (FPPEN1): If the position prediction mode is enabled (default setting), its accuracy is also affected by position sampling accuracy, master speed, and master position filtering. The error due to enabling the position prediction mode is about twice that due to sampling accuracy (i.e., 40 to 200 microseconds * master speed). As with the error due to position sampling accuracy, the error due to the position prediction mode being enabled is like a noise on the order of 200-600 Hz, which is not noticed by large loads.

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Master Velocity Relative to Master Position Prediction;

Variation in Master Velocity: Although increasing master position filtering (increasing the FFILT command value) eliminates the error due to sampling accuracy, it increases the error due to variations in master speed when the master position prediction mode is enabled (FPPEN1).

Most applications maintain a constant master speed, or change very slowly, so this effect is minimal. But if the master is changing rapidly, there may be a significant master speed measurement error. Because predicted master positions are in part based on master speed measurement, the can result in an error in master position prediction mode (FPPEN1). This effect will always be smaller than that due to the master position prediction mode being disabled (FPPENØ).

Tuning;
(Servo Axes Only)

A servo system's tuning has a direct impact on how well the follower axis can track the master input. Overshoot, lag, oscillation, etc., can be devastating to Following performance. The best tool to use for tuning the Gem6K series controller is Motion Planner's Gemini Servo Tuner utility.

Repeatability of the Trigger Inputs and Sensors;

Some applications may use the trigger inputs for functions like registration moves, GOWHENs, or new cycles. For these applications, the repeatability of the trigger inputs and sensors add to the overall position error.

Refer to page 99 for accuracy specifications on the trigger input position capture function. Refer to your sensor manufacturer's documentation for the sensor repeatability. In the Gem6K controller, the position capture from the trigger inputs have approximately 100 µs repeatability, and the sensor repeatability (SR) should be determined, too. Velocity * time = distance, so the error due to repeatability is (SR + 0.0001 seconds) * speed = error. If the sensor repeatability is given in terms of distance, that value can be added directly.

Preset vs. Continuous Following Moves

When a follower performs a preset (MCØ) move in Following mode (FOLEN1), the commanded position is either incremental or absolute in nature, but it does have a commanded endpoint. The direction traveled by the follower will be determined by the commanded endpoint position, and the direction the master is counting.

Let's illustrate this with an example. Assume all necessary set-up commands have been previously issued for our follower (axis #1) and master so that distances specified are in revolutions:

```
FOLRN3      ; Set Following follower-to-master ratio numerator to 3
FOLRD4      ; Set Following follower-to-master ratio denominator to 4
            ; (ratio is 3 revs on the follower to 4 revs on the master)
FOLEN1      ; Enable Following on axis #1
FOLMD10     ; Set preset move to take place over 10 master revolutions
MC0         ; Set follower to preset positioning mode
MA1         ; Set follower to absolute positioning mode
PSET0       ; Set current absolute position reference to zero
D5          ; Set move distance to absolute position 5 revolutions
GO1         ; Initiate move to absolute position 5
```

If the master is stationary when the GO1 command is executed, the follower will remain stationary also. If the master begins to move and master pulses are positive in direction, the follower will begin the preset move in the positive direction. If the master pulses stop arriving before 10 master revolutions have been traveled, the follower will also stop moving, but that GO1 command will not be completed. If the master then starts to count in the negative direction, the follower will follow in the negative direction, but only as far as it's starting position. If the master continues to count negative, the follower will remain stationary. The

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GO1 command will not actually be completed until the master has traveled at least 10 revolutions in the positive direction from where it was at the time the GO1 command was executed. If the master oscillates back and forth between it's position at the start of the GO1 command to just under 10 revolutions, the follower will oscillate back and forth as well.

The master must be counting in the positive direction for any preset (MCØ) GO1s commanded on the follower to be completed. If mechanics of the system dictate that the count on the source of the master pulses is negative, a minus (-) sign should be entered in the FOLMAS command so that Gem6K sees the master counts as positive.

Continuous follower moves (MC1) react much differently to master pulse direction. Whereas a preset move will only start the profile if the master counts are counting in the positive direction, a continuous move will begin the ramp to its new ratio following the master in either direction. As long as the master is counting in the positive direction, the direction towards which the follower starts in a continuous move is determined by the argument (sign) of the D command. The follower direction is positive for D+ and negative for D-.

If the master is counting in the negative direction when follower begins a continuous move, the direction towards which the follower moves is opposite to that commanded with the D command. The follower direction is positive for D- and negative for D+.

If the master changes direction during a continuous follower move, the follower will also reverse direction. As with standard continuous moves, the GO1 will continue until terminated by S, K, end-of-travel limits, stall condition, or command to go to zero velocity. As with preset moves, the sign on the FOLMAS command determines the direction of master counting with respect to the direction of actual counting on the master input.

Master and Follower Distance Calculations

The formulas below show the relationship between master move distances and the corresponding follower move distances. These relationships may be used to assist in the design of Following mode moves in which both the position and duration of constant ratio are important.

In such calculations, it is helpful to use SCLMAS and SCLD values which allow the master and follower distances to be expressed in the same units (e.g., inches or millimeters). In this case, many applications will be designed to reach a final ratio of 1:1, and the distances in these figures can be easily calculated.

☞ **HINT**: For a trapezoidal preset follower axis move with a maximum ratio of 1:1, the master and follower distances during the constant ratio portion will be the same. The follower travel during acceleration will be exactly half of the corresponding master travel, and it will also occur during deceleration.

Master Distance (FOLMD)

The FOLMD command determines the master distance over which the acceleration (mode continuous moves – MC1) or the entire move (preset moves – MCØ) takes place. If the follower axis is in continuous positioning mode (MC1), FOLMD is the master distance over which the follower axis is to accel or decel from the current ratio to the new ratio. If the follower axis is in preset positioning mode (MCØ), FOLMD is the master distance over which the follower's entire move will take place.

When the Follower is in Continuous Positioning Mode (MC1)

$$D = \frac{FOLMD * (R_2 + R_1)}{2}$$

where:

- FOLMD = Master distance
- R_2 = New ratio (FOLRN ÷ FOLRD)
- R_1 = Current ratio (FOLRN ÷ FOLRD)
- D = Follower distance traveled during ramp

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When the Follower is in Preset Positioning Mode (MCØ)

Trapezoidal Follower Moves

$D_{max} = (FOLMD * R_{max})$

$D_1 = \frac{(D_{max} - D)}{2}$

$MD_1 = \frac{2 * D_1}{R_{max}}$

$D_2 = D - (2 * D_1)$

$MD_2 = \frac{D_2}{R_{max}}$

$FOLMD = (2 * MD_1) + MD_2$

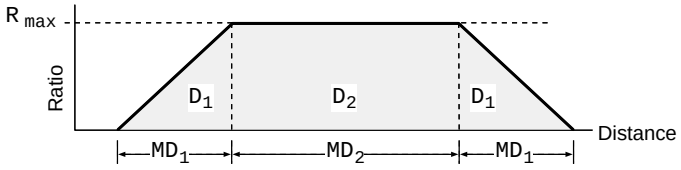
where:

- FOLMD = Master distance
- MD_1 = Master distance during accel & decel ramps
- MD_2 = Master distance during constant ratio
- D = Total follower axis preset distance commanded
- D_1 = Follower travel during accel and decel ramps
- D_2 = Follower travel during constant ratio
- D_{max} = Maximum follower distance possible (assuming no accel or decel)
- R_{max} = Maximum ratio = FOLRN ÷ FOLRD

Trapezoidal profile if:

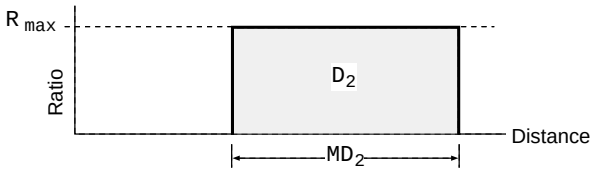
$D = (D_2 + 2 * D_1) < D_{max}$

These Profiles depict ratio vs. distance



Rectangular profile if:

$D_2 = D$
$D_1 = zero$
$MD_2 = FOLMD$
$MD_1 = zero$



Triangular Follower Moves

$D = \frac{R_{peak} * FOLMD}{2}$

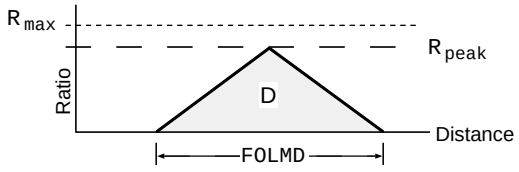
where:

- FOLMD = Master distance
- R_{peak} = Peak ratio reached during move
- D = Total follower distance

Triangular profile if:

$D < 1/2\ D_{max}$

This Profile depicts ratio vs. distance



Distance Calculation Example

In the example below, the desired travel during constant ratio is already contained in numeric variable #1 (VAR1), and may have been read from thumbwheels or a DATA command. The corresponding follower move distance (D) and FOLMD are calculated as shown:

```
VAR2=2              ; Desired follower travel during accel and decel combined
VAR3=2 * VAR2       ; Required master travel during these ramps
VAR4=VAR1 + VAR2    ; Move distance is constant ratio portion plus ramps
VAR5=VAR1 + VAR3    ; Master travel for entire follower move
FOLMD(VAR5)         ; Establish calculated master travel
D(VAR4)             ; Establish calculated follower travel
GO1                 ; Make desired follower move
```

Similar calculations may be done for a series of continuous move ramps to ratios, separated by GOWHEN for master cycle positions. These ramps may be repeated in a loop to create a

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continuous cyclical follower profile..

Beware of Roundoff Error (Scaling only)

Some potential for roundoff error exists if the scaling of a move distance or master distance by SCLD and SCLMAS does not result in an integer number of steps. Some additional care must be taken in the segment by segment construction of profiles using ramps to continuous ratio. The Gem6K maintains a follower position command which is calculated from the commanded constant ratios, the ramps to the new ratios, and the master travel over which these take place. At the end of each ramp or constant ratio portion, this commanded position is calculated to the nearest integer follower step. If the ratios and master travel result in a non-integer follower travel for a segment, the fractional part of that segment's calculated travel will be lost. In a cyclical application, repeated truncations could build up to a significant error. This may be avoided through careful attention to design of the profile.

Using Other Features with Following

The Gem6K has many features that may be used in the same application as its Following features. In some cases, having configured an axis as a follower with the FOLMAS command will affect, or be affected by, the operation of other features, as described below.

Setups used by FOLMAS (Stepper Axes Only)

The FOLMAS command uses the drive resolution (DRES) and the velocity range (PULSE) data to configure an axis as a follower. In order for this data to be used correctly, these commands must be given before FOLMAS. These commands are not allowed after FOLMAS is given. After FOLMAS is executed, the MC command may be used to change from incremental to absolute positioning and back.

S (Stop) & K (Kill) Commands

Stop (S) and Kill (K) commands cause the follower to do a non-Following decel, even if the follower is in Following mode. A stop or a kill, buffered or immediate, will clear a pending GOWHEN condition (clears AS bit #26).

Kill Conditions

Under default operation (FOLK0), certain error conditions (i.e., drive fault input active, or max. position error limit exceeded) will cause the Gem6K to disable the drive and kill the Following profile (follower's commanded position loses synchronization with the master).

If you enable Following Kill (FOLK1), these error conditions will still disable the drive (DRIVE0), but will not kill the Following profile. Because the Following profile is still running, the controller keeps track of what the follower's position should be in the Following trajectory. To resume Following operation, resolve the error condition (drive fault, excessive position error), enable the drive (DRIVE1), and command the controller to impose a shift to compensate for the lapse/shift that occurred while the drive was disabled and the follower was not moving. To impose the shift, assign the negative of the internally monitored shift value (PSHF) to a variable (e.g., VAR1 = -1 * PSHF) and command the shift using a variable substitution in the FSHFD command (e.g., FSHFD(VAR1)).

The FOLK command only preserves Following profiles; normal velocity-based profiles will be killed regardless of the FOLK command.

GO Command

If a follower axis is in Following mode (FOLEN1), moves will ramp to a ratio (set with FOLRN and FOLRD). If it is not in Following mode, moves will ramp to a velocity (V). Switching in and out of Following mode does not change the value for final ratio or final velocity goals, but simply changes which parameter is used as the goal.

Registration Moves

(see page 159)

Registration inputs may be enabled with the INFNCi-H command while an axis is a follower, and registration moves may interrupt either a Following mode move or a time-based move. The registration move itself, however, is always a time based move, and implements the registration velocity with respect to a stationary reference. Any trigger input may be used as a registration input or for any Following feature which uses triggers, even at the same time.

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Enter/Exit Following Mode While Moving

The FOLENØ command may be executed while a follower axis is moving at constant ratio. In this case, the current velocity becomes the constant velocity, and the follower may accelerate or decelerate to other velocities. The FOLEN1 command may not be executed while the follower axis is moving in the non-Following mode. Attempting to do so will result in the error response "MOTION IN PROGRESS".

Pause and Continue

A program may be paused and continued, even if configured as a follower. The program does not lose track of the master input, even though motion is stopped. As usual, if a program finishes normally, or if COMEXS is set to zero (COMEXSØ), the program may not be continued. If a program is resumed, partially completed Following moves will be completed; however, the remainder of the move is completed over the entire original master distance (FOLMD value).

TVEL and TVELA Commands

The TVEL and VEL commands have always reported an unsigned value (i.e. magnitude), consistent with the fact that the V command is always positive, even if the move direction is negative. When Following is enabled (FOLEN1), TVEL and VEL report the net magnitude of commanded velocity due to following and/or shifting. For example, if the follower axis is Following in the positive direction at 1 rps, TVEL reports 1.000. If a shift in the negative direction of 1.5 rps is then commanded, TVEL will report 0.5 – still positive, even though the net direction is negative.

By contrast, TVELA and VELA have always been signed. In the above example, TVELA will report -0.5.

TASF, TAS & AS Axis Status Bits

Axis Status (TASF, TAS and AS) bits 1-4 represent the motion status of an axis. Bits 1 and 2 represent the moving and direction status of the net motion of an axis, including the combination of following and shifting.

Bits 3 and 4 represent acceleration and velocity, respectively. With Following disabled (FOLENØ), the accel and velocity can only be due to a commanded time-based profile. With Following enabled (FOLEN1), the net commanded velocity and accel could be due to following the master and/or a simultaneous shift (time-based profile). Bits 3 and 4 only reflect the acceleration and velocity status of the time-based profile, not the combined command.

For example, if the follower axis is Following in the positive direction at 1 rps, TAS reports 1ØØØ. If a continuous shift (FSHFC2) of 0.8 rps in the negative direction is then commanded, TAS will report 1Ø1Ø, while the shaft is decelerating to 0.2 rps. When the continuous shift velocity is reached, TAS will report 1ØØ1.

Changing Feedback Sources **(Servo Axes only)**

Changing feedback sources (SFB) may result in a follower axis Following its own feedback. For this reason, changing feedback sources is not allowed while a master is specified (FOLMAS).

Following and Other Motion

Following motion is initiated with the GO command, just like normal motion. Other motion, which does not depend on the motion of an external master, may not be used while a follower axis is in Following mode (FOLEN1). These motion types include jog mode, joystick mode, and homing. To use these motion types, Following must be disabled (FOLENØ) — see *Enter/Exit Following Mode While Moving* above for precautions.

Conditional Statements Using PMAS

The master cycle position (PMAS) value may be used in the comparison argument of these commands:

- WAIT & GOWHEN: If it is desired to WAIT or GOWHEN on a master cycle position of the next master cycle, one master cycle length (value of FMCLEN) should be added to the master cycle position specified in the argument. This allows commands that sequence follower axis events through a master cycle to be placed in a loop. The WAIT or GOWHEN command at the top of the loop could execute, even though the actual master

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travel had not finished the previous cycle. This is done to allow a PMAS value which is equal to the master cycle length to be specified and reliably detected.

- IF, UNTIL, & WHILE: These arguments use the instantaneous PMAS value. Be careful to avoid specifying PMAS values that are nearly equal to the master cycle length (FMCLEN), because rollover may occur before a PMAS sample is read.

Compiled Motion

Following profiles may be pre-compiled to save processing time. For details, refer to page 142.

Troubleshooting for Following *(see also Chapter 8)*

Following applications are often more complex than others, because motion of the followers is programmed as a function of the motion of the master. This requires the motion of the master to be well characterized and accurately specified in the program. It often requires an unfamiliar way of thinking about the motion of the desired follower. The table below offers some possible reasons for troubles which may be encountered in achieving the desired follower motion.

Symptom	Possible Causes
Follower does not follow master	• Improper FOLMAS • Poor connection if master is encoder • Master running backward • No encoder power (when the encoder is selected as the master)
Follower motion is	• FFILT command value too low • Unnecessary FPPEN amplifies master roughness
Ratio seems wrong	• FOLRN and FOLRD follower-to-master ratio values are inaccurate, possibly reversed • SCLD or SCLMAS wrong • Following limited by FMAXV or FMAXA (steppers only)
Follower profile wrong, or un-repeatable	• WAIT used where GOWHEN should be • Too little master travel between GOWHEN and GO1, desired PMAS is missed
Master/follower alignment drifts over many cycles	• Roundoff error due to fractional steps resulting from SCLD or SCLMAS and user's parameters • Ratios and master distances specified result in fractional follower steps covered during ramps, constant ratio
Follower lags Following position **(steppers only)**	• Inhibited by FMAXV • FMAXA *clips* acceleration peaks resulting from attempt to follow rough master

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Error Messages

If an illegal programming condition is discovered while programming or executing programs, the Gem6K responds with an error message. If a program execution error is detected, the program is aborted.

The table below lists all the error messages that relate to Following, and indicates the command and cause that may generate them. These error messages are displayed only if the error level is set to level 4 with the ERRLVL4 command (this is the default setting).

Error Message	Cause
FOLMAS NOT SPECIFIED	No FOLMAS for the axis is currently specified. It will occur if FMCNEW, FSHFC, or FSHFD commands are executed and no FOLMAS command was executed, or FOLMASØ was executed.
INCORRECT DATA	Velocity (V), acceleration (A), or deceleration (AD) command is zero. (used by FSHFC & FSHFD)
INVALID CONDITIONS FOR COMMAND	The FOLMD command value is too small to achieve the preset distance and still remain within the FOLRN/FOLRD ratio. A command phase shift cannot be performed: FSHFD.....Error if already shifting or performing other time based move. FSHFC.....Error if currently executing a FSHFD move, or if currently executing another FSHFC move in the opposite direction. The FOLEN1 command was given while a profile was suspended by a GOWHEN.
INVALID DATA	The parameter supplied with the command is invalid. FFILT.....Error if: smooth number is not 0-4 FMCLEN.....Error if: master steps > 999999999 or negative FMCP.....Error if: master steps > 999999999 or <-999999999 FOLMD.....Error if: master steps > 999999999 or negative FOLRD.....Error if: master steps > 999999999 or negative FOLRN.....Error if: follower steps>999999999 or negative FSHFC.....Error if: number is not 0-3 FSHFD.....Error if: follower steps>999999999 or <-999999999 GOWHEN.....Error if: position > 999999999 or <-999999999 WAIT.....Error if: position > 999999999 or <-999999999 Error if a GO command is given in the preset positioning mode (MCØ) and: FOLRN = zero FOLMD = zero, or too small (see *Preset Positioning Mode Moves* on page 177)
INVALID FOLMAS SPECIFIED	An illegal master was specified in FOLMAS. A follower may never use its own commanded position or feedback source as its master.
INVALID RATIO	Error if the FOLRN:FOLRD ratio after scaling is > 127 when a GO is executed.
MASTER SLAVE DISTANCE MISMATCH	Attempting a preset Following move with a FOLMD value that is too small.
MOTION IN PROGRESS	The FOLEN1 command was given while that follower was moving in a non-Following mode.
NOT VALID DURING FOLLOWING MOTION	A GO command was given while moving in the Following mode (FOLEN1) and while in the preset positioning mode (MCØ).
NOT VALID DURING RAMP	A GO command was given while moving in a Following ramp and while in the continuous positioning mode (MC1). Following status (FS) bit #3 will be set to 1.

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Following Commands

Detailed information about these commands is provided in the *Gem6K Series Command Reference*.

ANIMAS ..... Assigns an analog input to be used as a master in a FOLMAS assignment (requires a ANI SIM located on an expansion I/O brick).

ERROR..... Enable bit #14 to check for when a GOWHEN condition is already true when a subsequent GO, GOL, FGADV, FSHFC, or FSHFD command is given.

ERRORP ..... If ERROR bit #14 is enabled, a GOSUB branch to the error program occurs if a GOWHEN condition is already true when a subsequent GO, GOL, FGADV, FSHFC, or FSHFD command is given.

FFILT..... Sets the bandwidth for master position filtering.

FGADV..... Defines the geared advance distance.

FMAXA..... Stepper axes only: Sets the max. acceleration a follower may use while Following.

FMAXV..... Stepper axes only: Sets the max. velocity at which a follower may travel.

FMCLEN ..... Defines the length of the master cycle.

FMCNEW ..... Restarts new master cycle counting immediately. To make this a trigger-based operation instead of issuing the FMCNEW command, use the TRGFNcx1 command.

FMCP..... Defines the initial position of a new master cycle.

FOLEN..... Enables or disables Following mode.

FOLK..... Allows drive fault or maximum position error to disable drive without killing the Following profile.

FOLMAS ..... Defines master for follower.

FOLMD..... Defines the master distance over which ratio changes or moves are to take place.

FOLRD..... Establishes the DENOMINATOR ONLY for the max. follower-to-master ratio for a preset move or the final ratio for a continuous move (use in combination with the FOLRN command).

FOLRN..... Establishes the NUMERATOR ONLY for the max. follower-to-master ratio for a preset move or the final ratio for a continuous move (use in combination with the FOLRD command).

FPPEN..... Allows master position prediction to be enabled or disabled.

FSHFC..... Allows continuous advance or retard (shift) of follower position during continuous Following moves.

FSHFD..... Allows preset advance or retard (shift) of follower position during continuous Following moves.

FVMACC ..... Establishes the rate at which the virtual master count frequency (FVMFRQ) may change for an axis.

FVMFRQ ..... Defines the frequency of the virtual master count.

GOWHEN ..... A GOWHEN command suspends execution of the next follower move until the specified conditional statement (based on T, IN, LIM, PC, PE, PMAS, PSLV, or PSHF) is true. To make this a trigger-based operation instead of issuing the GOWHEN command, use the TRGFNc1x command.

SCLD..... Sets the follower distance scale factor.

SCLMAS ..... Sets the master scale factor.

SINAMP ..... Defines the amplitude of the internal sine wave.

SINANG ..... Defines the phase angle of the internal sine wave.

SINGO..... Initiates the internal sine wave.

TRGFN..... aTRGFNc1x initiates a GOWHEN. Suspends execution of the next follower move on follower axis (a) until the specified trigger input (c) goes active.
aTRGFNcx1 allows master cycle counting to be restarted on axis (a) when the specified trigger input (c) goes active.

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Status and Assignment Commands:

TASF, TAS & [AS].....Bit 26 of each axis status is set (1) if a motion profile suspended by a GOWHEN (including TRGFNc1x) is pending on that axis. The bit is cleared when the GOWHEN is true, or when a stop (S) or kill (K) command is executed.

TERF, TER & [ER].....Bit 14 is set if the GOWHEN condition is already true when a subsequent GO, GOL, FGADV, FSHFC, or FSHFD command is given. (The corresponding error-checking bits must be enabled with the ERROR command before the error will be detectable.)

TFSF, TFS & [FS].....Transfers or assigns/compares the Following status or each axis.

TNMCY and [NMCY] ....Transfers or assigns the current master cycle number.

TPCMS and [PCMS] ....Transfers or assigns the current captured master cycle position.

TPMAS and [PMAS] ....Transfers or assigns the current master cycle position.

TPSHF and [PSHF] ....Transfers or assigns the net position shift since constant ratio.

TPSLV and [PSLV] ....Transfers or assigns the follower's current commanded position.

TVMAS and [VMAS] ....Transfers or assigns the current velocity of the master axis.

WAIT .....A WAIT command suspends program execution until the specified conditional statement (based on PMAS, FS, NMCY, PCMS, PSHF, PSLV, or VMAS) is true;
WAIT(SS.i=b1) suspends program execution until a trigger input is activated ("i" is the input bit number corresponding to the trigger input—refer to the Gem6K *Series Command Reference*).

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CHAPTER SEVEN

7

Multi-Tasking

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- Introduction to Multi-Tasking 202
- Using Gem6K Resources While Multi-Tasking 210
- Multi-Tasking Performance Issues 214
- Multi-Tasking Application Examples 215

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Introduction to Multi-Tasking

What is Multi-Tasking? Multi-tasking is the ability of the Gem6K to run more than one program at the same time. This allows users to manage independent activities, aside from just motion.

Why use Multi-Tasking?

- Multiple independent *tasks* can act on the same process or same axis.
- A supervisory program can control and coordinate multiple processes.

What is a Task? A system task is a program execution environment, not a program. Each task runs independently. Each task can be used to run independent programs. Any task may run any program. Multiple tasks could even be running the same program simultaneously. Each task may either be:

- Running a program
- Monitoring `ON`, `ERROR`, or `INSELP` conditions
- Inactive (**not** running a program or monitoring conditions)

Using Multi-Tasking to Run Programs

Use the Wizard

Motion Planner provides a Multi-Tasking wizard, accessed from the Editor. The wizard leads you, step by step, through the process of setting up for multi-tasking.

Multi-tasking is initiated by the *Task Supervisor*. The supervisor is the Gem6K's main program execution environment — it runs the `STARTP` program and contains the command buffer and parser. If the multi-tasking feature is not being used, the supervisor is the lone program execution environment of the Gem6K, as shown in Figure 1. When multi-tasking is in operation, the supervisor is referred to as "Task 0".

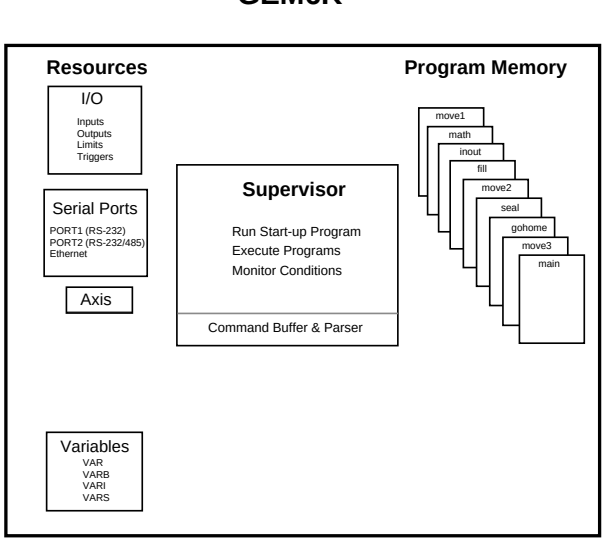


Figure 1: Gem6K Supervisor, with no Multi-Tasking

The Gem6K can have a maximum of 10 tasks, in addition to the Task Supervisor (Task 0). Each task acts as an individual program execution environment. The boxes shown under Resources in Fig. 1, and the following Figures, represent the resources that the supervisor and tasks monitor and manipulate (see list below). These resources can be shared with other tasks.

- I/O.....Inputs and Outputs (onboard I/O and expansion I/O bricks)
- Communication ports ...."`RS-232`", "`RS-232/485`", and "`ETHERNET`"

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- Axis ..... The Gem6K axis can be shared with any tasks
- Variables ..... Real (VAR), binary (VARB), integer (VARI), and string (VARS)

"Program Memory" is the Gem6K's non-volatile memory where programs are stored. Any task may run any program. Multiple tasks could even be running the same program simultaneously. Programs in multi-tasking are defined as they typically are with the Gem6K

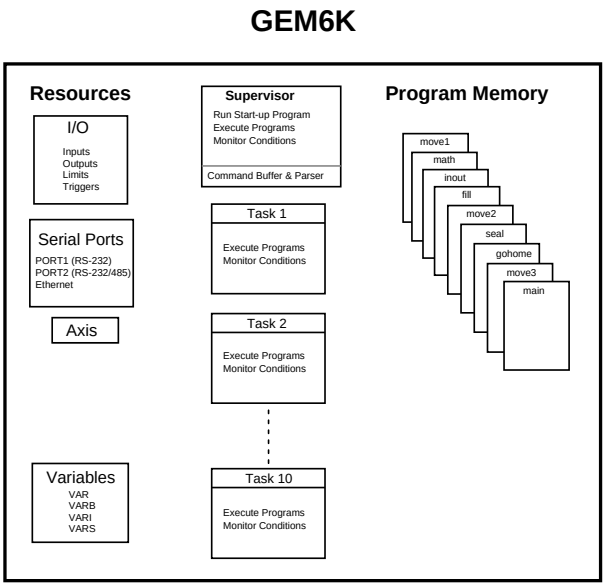


Figure 2: Gem6K8 - Multi-Tasking with 10 tasks.

The Task Identifier (%) prefix is used to specify that the associated command will **affect** the indicated task number. For most simple multi-tasking applications, the % prefix will only be used to start a program running in a specific task. Multi-tasking programs can be started through the communication ports (see Figs. 3a-3c), or from a program (see Figs. 4a-4d). Note that the programs are run in the tasks specified with the % prefix.

Starting Tasks from a Communications Port

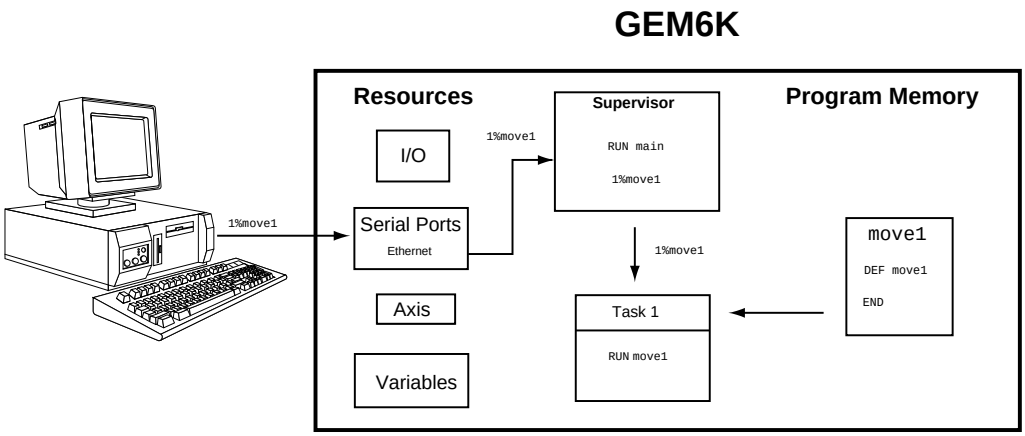


Figure 3a: Multi-Tasking initiated from a computer terminal.

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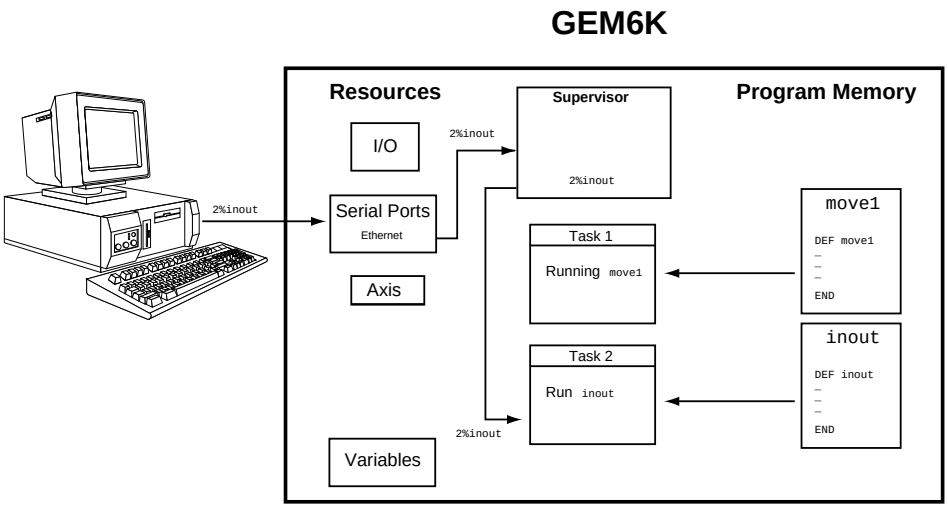


Figure 3b: Multi-Tasking initiated from a computer terminal (cont'd).

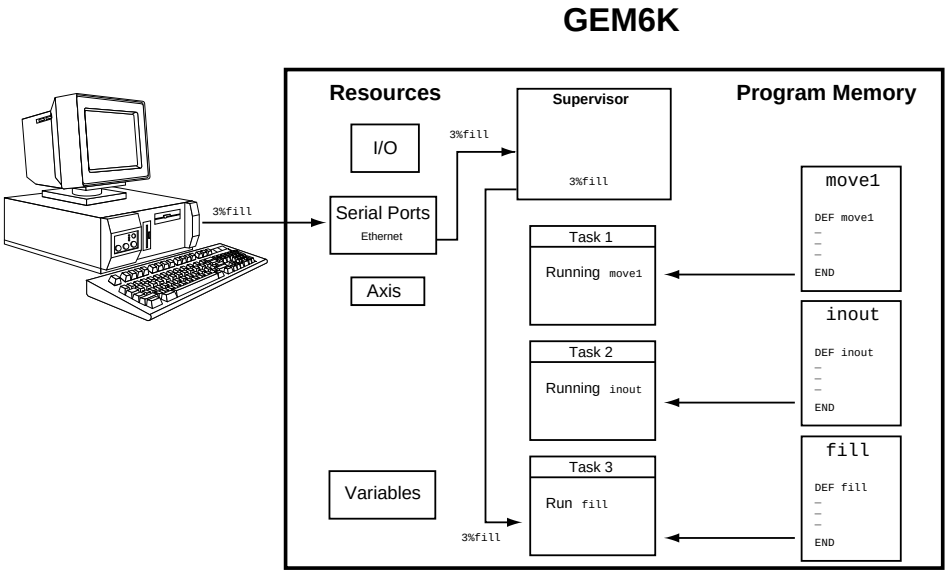


Figure 3c: Multi-Tasking initiated from a computer terminal (cont'd).

Starting Tasks from a Program

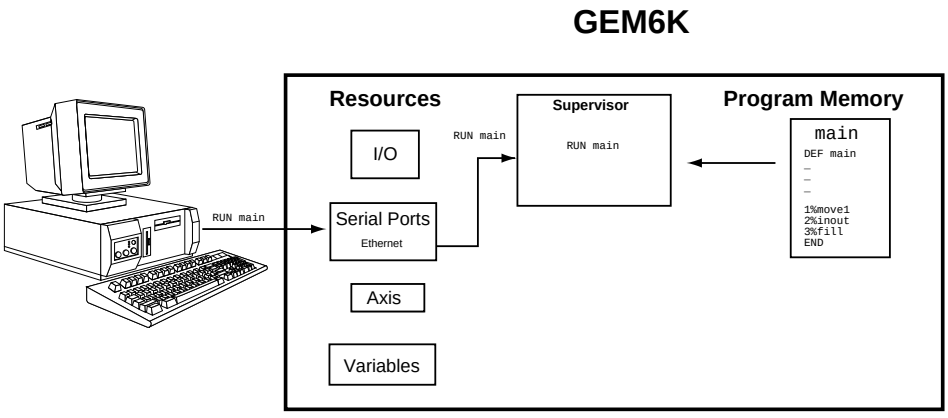


Figure 4a: Multi-Tasking initiated from a program.

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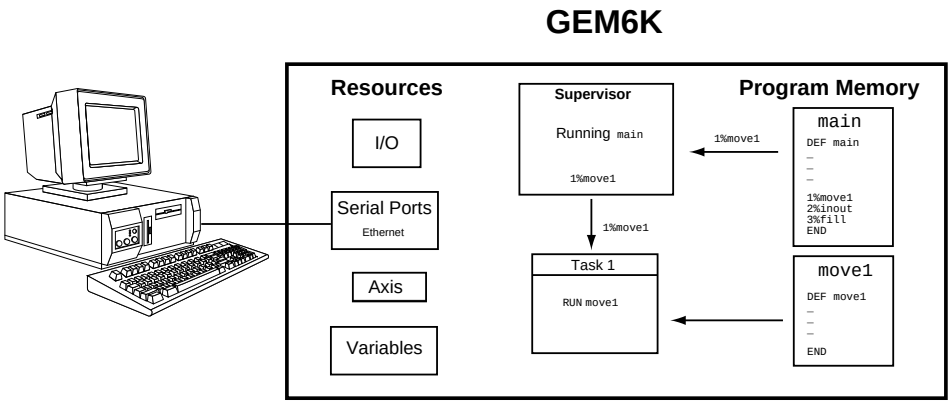


Figure 4b: Multi-Tasking initiated from a program (cont'd).

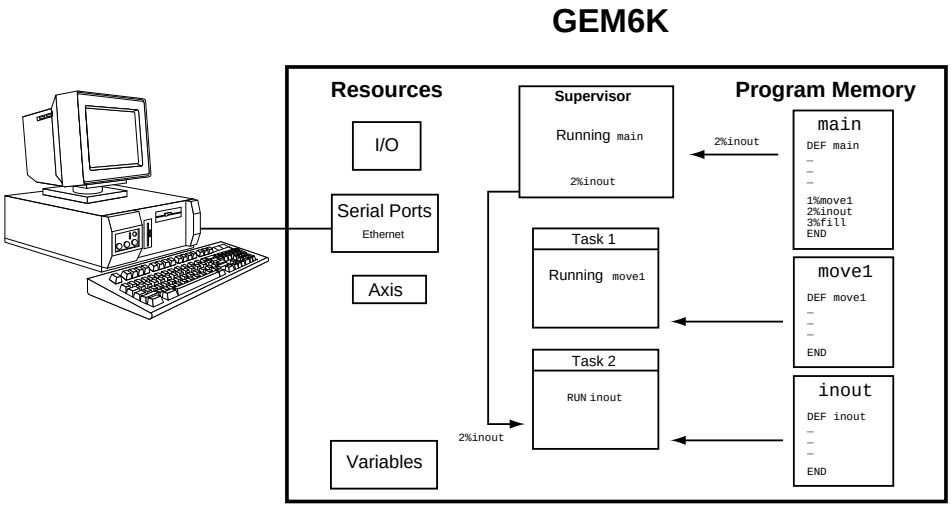


Figure 4c: Multi-Tasking initiated from a program (cont'd).

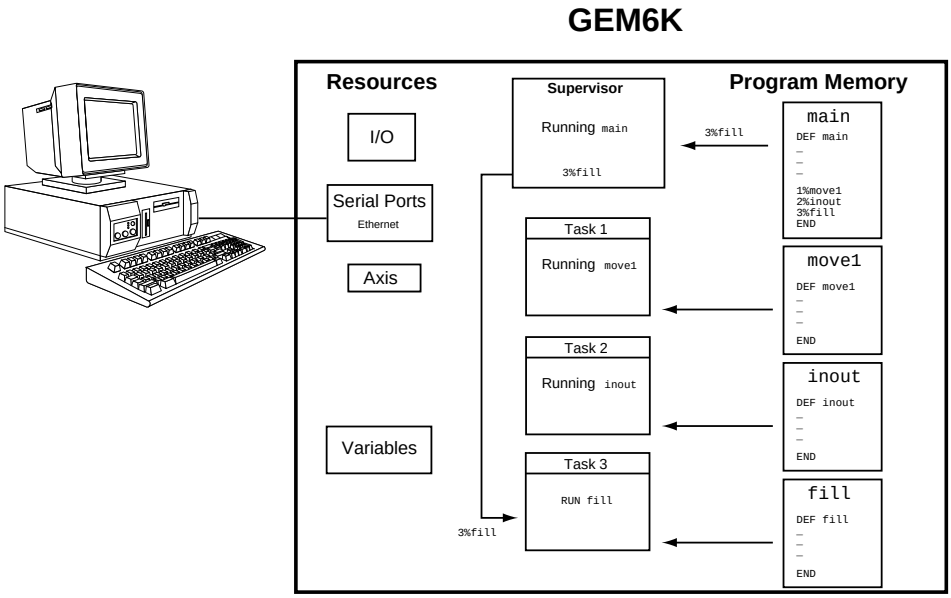


Figure 4d: Multi-Tasking initiated from a program (cont'd).

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A new task is initiated by identifying the task number with the Task Identifier (`%`) prefix, followed by the name of the program to be run in the specified task. Because the `%` prefix specifies the task number that the associated command will **affect**, new tasks can be started from within other tasks. Fig. 5b shows the `move1` program in task 1 being started by the main program in the supervisor. Fig. 5c shows the `fill` program in task 3 being started by the `move1` program in task 1 with the `3%fill` command. Fig. 5d shows the `inout` program in task 2 being started by the `fill` program in task 3 with the `2%inout` command.

Program execution in a task is controlled by commands executed from the program the task is running. In the example shown in Figs 5a-5d, program execution in Task 1 is controlled by commands executed from the `move1` program, program execution in Task 2 is controlled by commands executed from the `inout` program, and program execution in Task 3 is controlled by commands executed from the `fill` program.

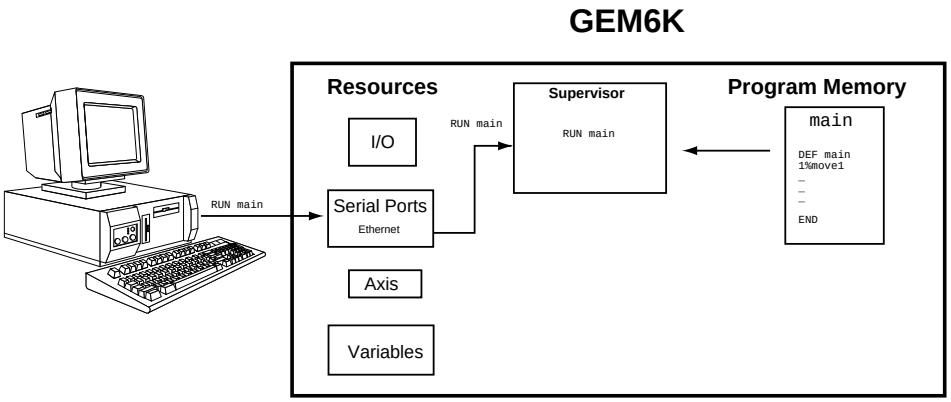


Figure 5a: Initiating multi-tasking.

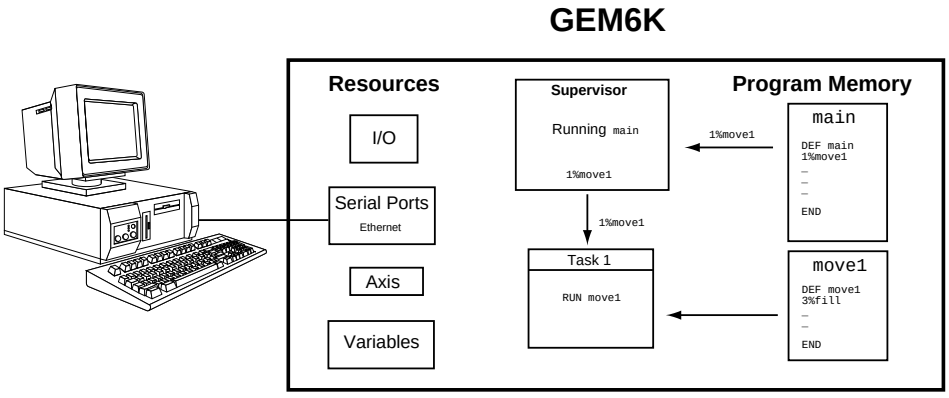


Figure 5b: Task initiated from another task (cont'd).

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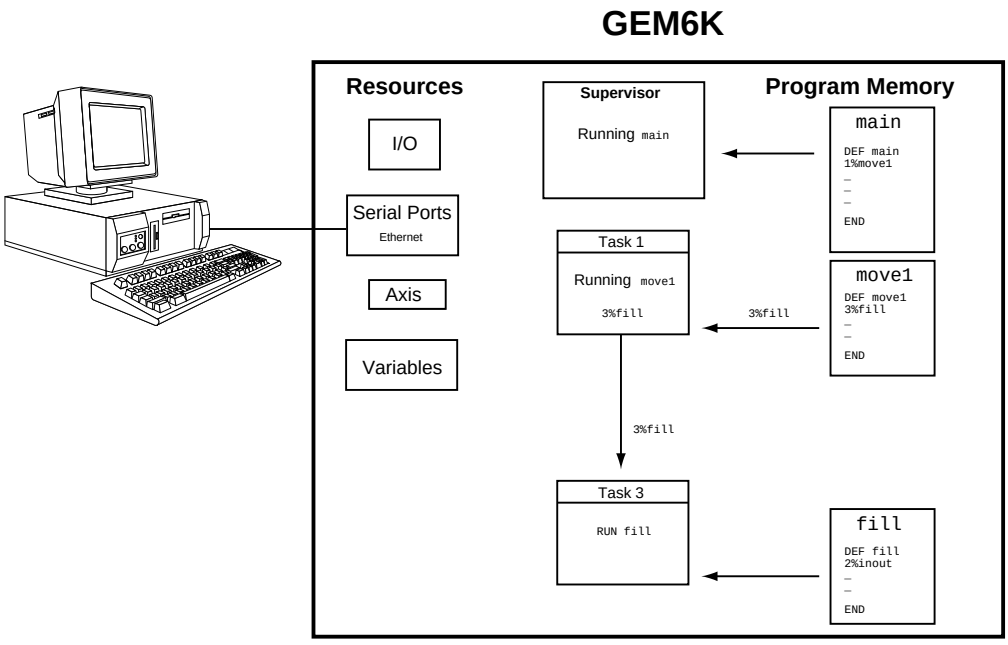


Figure 5c: Task initiated from another task (cont'd).

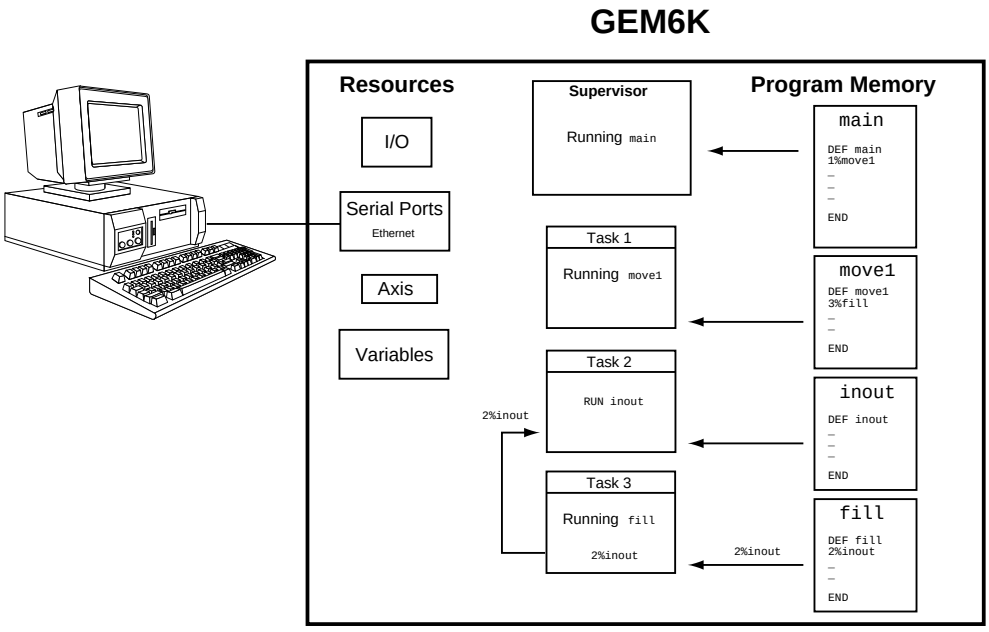


Figure 5d: Task initiated from another task (cont'd).

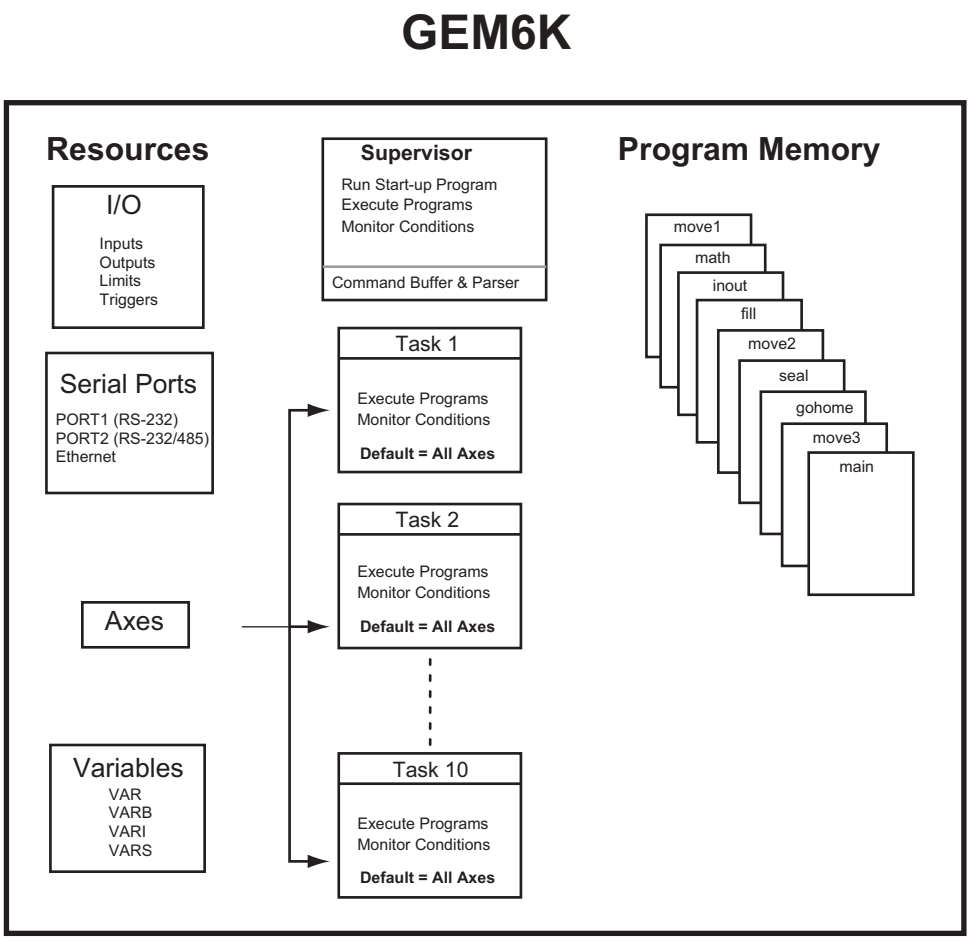
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Tasks

The default condition in multi-tasking is that each task is associated with motion, as shown in Fig. 6a. This means that when a task associated with motion hits an end-of travel limit, program execution will be killed within that task. It may therefore be necessary to unassign motion association for a given task to allow an independent program execution environment. When this is done, the unassigned task cannot control or quary any information about the motor or motion.

Refer to page 210 for more details about associating axes with tasks.

The TSKAX command allows you to unassign the motion from the task. By assigning the task to no motion(TSKAX0), the task can not control or query information on the Gem6K motor or motion..




```
DEF main      ; Begin definition of program called "main"
1%TSKAX1      ; Associate task 1 with motion
2%TSKAX0      ; Do not associate task 2 with motion)
1%move1       ; Execute the "move1" program in Task 1
2%inout       ; Execute the "inout" program in Task 2 (Will not affect any
              ; motion)
END           ; End definition of program called "main"
```


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How a “Kill” Works While Multi-Tasking

The general rule of command execution within a task is that the command affects only the task in which it was executed or to which it was directed via the % prefix. This includes almost all motion commands when tasks have an associated (TSKAX) axis. The exception is the Kill command. A “K” or “!K” without prefix or parameters will kill all controller axes, and programs running in all tasks. This exception is made to allow one short, familiar command to effectively stop all controller processes. As usual, a “K” with parameters (e.g., Kx11) will kill motion only on the specified axis, and will not kill the program. A “K” prefixed with a task specifier but without parameters (e.g., 3%K) will kill the program and motion if the task has an associated axis.

Certain inputs can be used to kill programs and motion. These inputs and their results under multi-tasking are:

- Drive Fault input. Kills program execution and the associated axis for all tasks that are associated with the faulted axis.
- Kill input (INFNCi-C or LIMFNCi-C). If prefixed with the task identifier (e.g., 2%INFNC3-C), it will kill the designated task, its program and the associated axis. If not prefixed with a task identifier, it will kill the controller axis, and all programs running in all tasks. It will also cause a branch to the task’s error program if the task’s error-checking bit 6 is enabled (n%ERROR.6-1).
- User fault input (INFNCi-F or LIMFNCi-F). This input functions the same as the kill input noted above, with the exception that it will also cause a branch to the task’s error program if the task’s error-checking bit 7 is enabled (n%ERROR.7-1).

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Associating Axes with Tasks

The default condition in multi-tasking is that each task is associated with motion. The TSKAX command allows you to unassign the task from the motion, thus constraining task response and control to I/O only. The TSKAX command allows you to specify motion (1) or no motion (0). This association covers all interaction between axes commands, conditions or inputs and task program flow, including the following:

- Motion data commands (e.g., A, V, D). These commands will apply only if the task is associated with motion.
- Stop, pause, and continue commands and inputs. These commands will affect motion only on tasks associated with motion: S (stop) command — without parameters, PS (pause) command, and C (continue) command. Inputs programmed with these functions will affect motion only on tasks associated with motion and specified in the input function assignment (with the n% prefix): Kill input (n%INFNCi-C or n%LIMFNCi-C), stop input (n%INFNCi-D or n%LIMFNCi-D), pause/continue input (n%INFNCi-E or n%LIMFNCi-E), and user fault input (n%INFNCi-F or n%LIMFNCi-F).
- Drive fault and limit inputs. If a drive fault or end-of-travel limit occurs, only tasks assocaited with motion will be killed.
- ON conditions. Axis status bits are only monitored if the task is associated with motion.
- ERROR conditions. Each task has its own error status register (ER, TER, TERF), error-checking bits (ERROR), and error program (ERRORP).
- Command buffer control:
  - COMEXC. Pauses command processing of that task until the associated motion has stopped
  - COMEXL. Allows the specified associated motion to not kill that task's program.

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Sharing Common Resources Between Multiple Tasks

Controller resources other than processing time must also be shared between multiple tasks. All physical inputs and outputs are shared (i.e., each task may read all inputs and write to all outputs). Some of the functions associated with that I/O (defined with LIMFNC, INFNC and OUTFNC commands) are unique for each task. All variables (VAR, VARI, VARB, VARS), DATA programs, and the DATPTR are shared. If one task modifies a variable, a DATA program, or DATPTR, the new value is the same for all tasks. There are no "private" variables. The serial ports are shared (i.e., any task may read from, or write to, any serial port). When a task writes to a serial port, the characters are all sent to the output buffer at once, but execution proceeds to the next command without waiting for those characters to be transmitted.

The data assignment functions READ, DREAD, or DREADF, and TW are also shared between tasks, but in these cases, the task is not allowed to execute the next command until the data has been received and assigned. This requires waiting for human or host input, or thumbwheel strobe time. During this time, that task is "blocked", and that data assignment function (READ, DREAD, or DREADF, or TW) is owned by the blocked task. If another task is active, it will continue to execute commands. If this second task attempts to access a data assignment function which is still owned by the first task, the second task becomes blocked also. This situation persists until the first task receives and assigns its data. At that point, ownership of the data assignment function passes to the second task, until it too receives and assigns its data. All this blocking and ownership is automatic, not requiring coordination by the user.

Locking Resources to a Specific Task

Examples:
LOCK1,1 locks COM1
LOCK1,0 unlocks COM1
LOCK2,1 locks COM2
LOCK2,0 unlocks COM2
LOCK3,1 locks swapping
LOCK3,0 unlocks swapping

The LOCK command may be used by a system task to gain or release exclusive ownership of a resource. This will allow that task to complete a sequence of commands with that resource while preventing another task from using the resource in between commands. Any other task attempting to access or LOCK that resource will become blocked (i.e., become temporarily totally inactive) until the resource is released by the task that owns it. Resources which may be LOCKed are:

- COM1 — the "RS-232" connector or the "ETHERNET" connector
- COM2 — the "RS-232/485" connector
- Task Swapping — When task swapping is locked to a specific task, command statements in all other tasks will not be executed until the task swapping is again unlocked. For more information on task swapping, refer to page 214.

NOTE: A resource may be locked by a task only while that task is executing a program. If program execution is terminated for any reason (e.g., stop, kill, limit, fault, or just reaching the END of a program), all resources locked by that task will become unlocked.

For example, to report the current position of a robotic arm, one might program:

```
VAR10 = 1PM                ; position of axis one
LOCK1,1                    ; lock COM1 ("RS-232" port) resource
WRITE "Arm Position is"    ; write string
WVAR10                     ; write position
WRITE "inches\13"          ; write string and carriage return
LOCK1,0                    ; release COM1 to other tasks
; Between the LOCK commands, other tasks will run unless they
; attempt to access COM1, in which case they become
; temporarily blocked.
```

How Multi-tasking and the % Prefix Affect Commands and Responses

Multi-tasking affects many, but not all, of the Gem6K commands and features. The table below lists the commands that are affected by multi-tasking and the task-identifier (%) prefix. Any command that is not listed may be considered unaffected by multi-tasking. Any

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command which has motion data (e.g., A, V, D) is only affected if the task has been associated with motion via the TSKAX command. Any command listed below as affected by the % prefix may also accept the @ character as a task number; in this case, all tasks will be affected by the command.

The response (if any) sent to the terminal by the command will be prefixed with the task number and % sign if the command had been executed by any task other than Task 0, the Supervisor Task. For commands executed in Task 1, if the command itself had the 1% prefix, then the response will also have the prefix. Otherwise, the response will not be prefixed. Therefore, if no multi-tasking is used, no responses will have task prefixes. If multi-tasking is used, however, you can determine which task originated the response. A response could be the result of a transfer command (e.g., TER), a command with no parameters (e.g. MC), TRACE output, or an error message.

Command(s)	Effect of % Prefix	Effect of Multi-tasking
GOTO, IF, ELSE, NIF, WHILE, NWHILE, REPEAT, UNTIL, L, LN, LX	None (ignored)	These commands direct program flow only on the task from which they are executed.
GOSUB, RUN, <progname>, JUMP, HALT, BP, PS, T, WAIT, C	Effectively inserts command into numbered task's program	These commands initiate, interrupt or continue program flow only on implicitly or explicitly specified task.
COMEXC, COMEXR, COMEXS	Affects mode on numbered task	These commands affect program flow only on implicitly or explicitly specified task.
S, K	Specifies affected task only	These commands affect program flow (depending on parameters given) only on implicitly or explicitly specified task. A "K" with no prefix or parameters kills all tasks.
ERROR, ERRORP, TER, TERF, ER	Affect/report on numbered task	These commands affect/report error conditions and programs only on implicitly or explicitly specified task (each task has its own error status register and error program).
TCMDER, TSS, TSSF, SS, TSTAT	Report on numbered task	These commands report command errors and status only on implicitly or explicitly specified task.
TTIM, TIMINT, TIMST, TIMSTP, TIM	Command refers to timer of numbered task	Each task has an independent timer. Also, TIMST0,# resets the timer to # msec., TIMST1,# restarts the timer with the TIM value of task #.
TRACE, TRACEP, TEX, STEP, #	Command refers to numbered task	Each task has its own trace and step mode. This allows tracing on a single task, or combined tasks commands.
ONCOND, ONIN, ONP, ONUS, ONVARA, ONVARB	Command refers to numbered task	Each task has its own set of ON conditions and its own ONP program.
LIMFNCi-C, LIMFNCi-D, LIMFNCi-E, LIMFNCi-F, LIMFNCi-P, INFNCi-C, INFNCi-D, INFNCi-E, INFNCi-F, INFNCi-P, INSELP, OUTFNCi-C	Command refers to numbered task	These functions are task specific. All others affect the entire controller and cannot be affected by the % prefix.

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Input and Output Functions and Multi-tasking

The Gem6K has inputs and outputs (onboard and on external optional I/O bricks) that may be assigned various I/O functions with these function assignment commands:

`LIMFNC`..... Assigns input functions to the dedicated limit inputs on the "LIMITS/HOME" connectors (factory default functions are the respective `R`, `S`, and `T` limit input functions).

`INFNC`..... Assigns input functions to the onboard digital inputs (trigger input on the "TRIGGERS/OUTPUTS" connectors) and to the digital inputs on external I/O bricks.

`OUTFNC`..... Assigns output functions to the onboard digital outputs (outputs on the "TRIGGERS/OUTPUTS" connectors) and to the digital outputs on external I/O bricks.

The Gem6K's I/O and events involving programmed I/O are related to tasks only if:

- The input or output function assignment is associated with a specific task. For example, because of the `1%` prefix, the `1%INFNC3-F` command assigns the "user fault" function to onboard input 3 and directs its function to be specific to Task 1.
- An input or output is assigned a specific function and the input or output is associated with a specific task. For example, if Task 1 is associated with motion (`1%TSKAX1`) and onboard input 4 is assigned as a "stop" input (`INFNC4-D`), then when onboard input 4 goes active motion is stopped; thus Task 1 is affected by input 4.

Each input or output group (`LIMFNC`, `INFNC`, and `OUTFNC`) is limited to a maximum of 32 function assignments at one time. Exceptions are: function `A`, `LIMFNC` functions `R`, `S`, and `T`, and `INFNC` function `H`. A given input or output may be assigned only one function, although for task-specific functions, this I/O point may perform the same function for multiple tasks (by using the `%` prefix). This only counts as one function against the maximum total of 32, even though it is shared by multiple tasks. A given I/O point may not perform different functions for different tasks. Re-assigning a I/O point's function in any (same or different) task will result in removing the assignment of the previous function in the previous task(s). For example:

```
1%2INFNC4-C     ; module 2's 4th input will kill task 1
2%2INFNC4-C     ; module 2's 4th input now kills tasks 1 & 2
3%2INFNC4-D     ; module 2's 4th input will stop task 3,
                ; it no longer has a kill function for tasks 1 & 2
```


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When is a Task Active?

Tasks are always ready to become active if commanded to do so. No special command is required to allow a task to do something. A task is active if it is:

- Executing a program (SS.3=B1)
- Executing a T or WAIT command (even if not running a program)
- Monitoring drive faults conditions (DRFEN1)
- Monitoring ONCOND conditions (SS.15=B1)
- Waiting in Program Select Mode (INSELP1 and SS.18=B1)
- Monitoring ERROR conditions (ERROR has any non-zero bit)

A task becomes active when it receives a command to perform something from the list above. A task which is not active does not create any overhead (delays) in command processing for tasks which are active. Once a task becomes active, however, it takes its turn in the sequence of swapping (see below), and checks for all of the conditions listed above. This adds a processing burden which will slow the command execution rate of programs running in other tasks.

A task becomes inactive if nothing from the above list is occurring. There is no special command "kill task" to disable all these modes/conditions/activities at once. The standards methods for terminating these (S, INSELP0, ERROR0, etc.) are needed to make a task completely inactive, and therefore not creating command processing overhead. Task 0, the Task Supervisor, will always be active, even if nothing from the above list is occurring, because Task 0 always checks the input command buffer for commands to execute.

The TSWAP command reports a binary bit pattern indicating the tasks that are currently active. Bit 1 represents task 1, bit 2 represents task 2, etc. A "1" indicates that the task is active, and a "0" indicates that the task is inactive. The SWAP assignment operator allows the same information to be assigned to a binary variable, or evaluated in a conditional statement such as IF or WAIT. This is useful for determining which tasks have any activity, whereas the system status (SS) and error status (ER) states reveal exactly what activity a given task has at that time.

Task Swapping

The Gem6K has only one processor responsible for executing programs, therefore, multiple tasks are not actually executing simultaneously. Tasks take turns executing when they are active. A task's "turn" consists of executing one command and checking its input, output, ON, ERROR and INSELP conditions before relinquishing control to the next task. The process of changing from one task to the next is called **task swapping**. The Gem6K determines when to swap tasks. The user is not required (or allowed) to determine how long a task should run, or when to relinquish control to another task.

Although the user does not determine how long a task should run, or when to relinquish control to another task, the number of "turns" a task gets before swapping may be set with the TSKTRN command. The default value is one for all active tasks. Thus, each task has equal weight, swapping after every command. If a task needs a larger share of processing time however, the TSKTRN value for that task can be increased. For example, if task 2 issued a TSKTRN6 command, while the others stayed at 1, programs running in task 2 would execute six commands before relinquishing. The TSKTRN value for a task may be changed at any time, allowing a task to increase its weight for an isolated section of program statements.

The TTASK command reports to the display the task number of the task which executed the

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command. This could be used for diagnostic purposes, as a way to indicate which task is executing a given section of program. The corresponding TASK assignment allows the program itself to determine which task is executing it. The current task number TASK may be assigned to a variable or evaluated in a conditional statement such as IF. This allows a single program to be used as a subroutine called from programs running in all tasks, yet this routine could contain sections of statements which are executed by some tasks and not others.

Task Execution Speed

Two terms describe the execution speed of tasks in multi-tasking environments.

Performance

Performance is a measure of how fast a task executes commands, and could be described in terms of commands per second. Because tasks must take turns executing, performance will decrease when tasks are added. For example, the performance of a task sharing the controller with two other tasks will be just one third of its performance if it were running by itself. Using the TSKTRN command described above, the relative performances of tasks may be altered.

Determinism

Determinism is a measure of how independent the performance of one task is from the commands and conditions involved in another task. If task swapping were done via a periodic interrupt (time slicing), task performance would be completely determinate, i.e., each task would run exactly for its time slice, not more or less. In the Gem6K products, task swapping is not time sliced, rather each task is allowed to execute one command and check its input, output, ON, ERROR and INSELP conditions before relinquishing control to the next task. For this reason, the performance of each task is somewhat determined by the commands and conditions underway in the other tasks. Most commands execute in approximately the same time. The others (some math commands, and line and arc commands) are broken into sections with durations that approximate those of the average command (approximately 2 ms). Swapping also takes place between these sections, allowing all task performance to be reasonably determinate regardless of which commands are being executed by other tasks.

Although time slicing would give completely determined task performance, the task swapping would need to include additional task save and restore functions to completely protect the task from the interrupt. This additional overhead would effectively rob processor time from the time slice, resulting in lower task performance. Task swapping in the Gem6K product does not add this overhead, and is therefore extremely efficient, taking less than 0.5% of task execution time.

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CHAPTER EIGHT

8 Troubleshooting

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Troubleshooting Basics

When your system does not function properly (or as you expect it to operate), the first thing that you must do is identify and isolate the problem. When you have accomplished this, you can effectively begin to resolve the problem.

The first step is to isolate each system component and ensure that each component functions properly when it is run independently. You may have to dismantle your system and put it back together piece by piece to detect the problem. If you have additional units available, you may want to exchange them with existing components in your system to help identify the source of the problem.

Determine if the problem is mechanical, electrical, or software-related. Can you repeat or re-create the problem? Random events may appear to be related, but they are not necessarily contributing factors to your problem. You may be experiencing more than one problem. You must isolate and solve one problem at a time.

Log (document) all testing and problem isolation procedures. Also, if you are having difficulty isolating a problem, be sure to document all occurrences of the problem along with as much specific information as possible. You may need to review and consult these notes later. This will also prevent you from duplicating your testing efforts.

Once you isolate the problem, refer to the problem solutions contained in this chapter. If the problem persists, contact your local technical support resource (see *Technical Support* below).

Electrical Noise

If you suspect that the problems are caused by electrical noise, refer to your Gem6K product's *Installation Guide* for help.

Solutions to Common Problems

NOTES

- Some hardware-related causes are provided because it is sometimes difficult to identify a problem as either hardware or software related.
- Refer to other sections of this manual for more information on controller programming guidelines, system set up, and general feature implementation. You may also need to refer to the command descriptions in the *Gem6K Series Command Reference*. Refer to your product's *Installation Guide* for hardware-related issues.

Problem	Cause	Solution
Communication (Ethernet) errors.	1. Ethernet card not installed correctly.	1. Refer to the user instructions that came with your Ethernet card.
	2. Ethernet IP address conflict.	2. Change IP address with the NTADDR command. (make sure it is matched by the setup in Motion Planner)
	3. Connection to Ethernet port is compromised or miswired.	3. Refer to the connection instructions in the *Installation Guide*.
Communication (serial) not operative, or receive garbled characters.	1. Improper interface connections or communication protocol.	1. See troubleshooting section in your product's *Installation Guide*.
	2. COM port disabled.	2.a. Enable serial communication with the E1 command. 2.b. If using RS-485, make sure the internal jumpers are set accordingly (see *Installation Guide*). Make sure COM 2 port is enabled for sending Gem6K language commands (execute the PORT2 and DRPCHKØ commands).
	3. In daisy chain, unit may not be set to proper address.	3. Verify DIP switch settings (see Installation Guide), verify proper application of the ADDR command.

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Problem	Cause	Solution
Direction is reversed. (stepper axes only)	1. Phase of step motor reversed (motor does not move in the commanded direction).	1. Switch A+ with A- connection from drive to motor.
	2. Phase of encoder reversed (reported TPE direction is reversed).	2. Swap the A+ and A– connection at the ENCODER connector.
Direction is reversed, servo condition is unstable. (servo axes only)	1. Not tuned properly.	1. Refer to tuning instructions in your product's *Installation Guide*.
	2. Phase of encoder reversed.	2. Software remedy for encoder feedback only: For the affected axis, issue ENCPOL1. Hardware remedy: If using encoder feedback, swap the A+ and A- connections to the Gem6K product. If using ANI feedback, change the mounting so that the counting direction is reversed.
Distance, velocity, and accel are incorrect as programmed.	1. Incorrect resolution setting.	1.a. Stepper axes: Set the resolution on the to match the Gem6K product's DRES command setting (default DRES setting is 4,000 steps/rev). 1.b. Match the Gem6K product's ERES command setting (default ERES setting is 4,000 counts/rev) to match the post-quadrature resolution of the encoder. ERES values for Compumotor encoders: Stepper axes: • RE, -RC, -EC, & -E Series Encoders:..... ERES4000 • HJ Series Encoders:..... ERES2048 Servo axes (SM, BE, N or J Series Servo Motors): • SM/N/JxxxxD-xxxx:..... ERES2000 • SM/N/JxxxxE-xxxx:..... ERES4000 • BExxxxJ-xxxx: ERES8000
	2. Wrong scaling values.	3. Check the scaling parameters (SCALE1, SCLA, SCLD, SCLV, SCLMAS) – see also page 67.
Erratic operation.	1. Electrical Noise.	1. Reduce electrical noise or move product away from noise source.
	2. Improper shielding.	2. Refer to the instructions in your product's *Installation Guide*.
	3. Improper wiring.	3. Check wiring for opens, shorts, & mis-wired connections.
Feedback device (encoder or resolver) counts missing.	1. Improper wiring.	1. Check wiring.
	2. Feedback device slipping.	2. Check and tighten feedback device coupling.
	3. Encoder too hot.	3. Reduce encoder temperature with heatsink, thermal insulator, etc.
	4. Electrical noise.	4a. Shield wiring. 4b. Use encoder with differential outputs.
	5. Encoder frequency too high.	5. Peak encoder frequency must be below 8 MHz post-quadrature. Peak frequency must account for velocity ripple.
Following problems —	*See page* 196	

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Diagnostic LEDs:	*All other LED states indicate hardware conditions; refer to your product's Installation Guide for details.*	Note: There are two diagnostic LED's on the Gem6K. The left hand LED shows Green or Red, the right hand LED shows Yellow or Green.
Both LED's are off.	1. No power.	1. Check 120/240VAC power connection and 24VDC power connection and restore power as necessary.
Left LED is Red, Right LED is Green	1. 24VDC power only, no AC applied. 2. Operating system download in progress. 3. Operating system download aborted before successful completion.	1. Check 120/240VAC power connection and restore power as necessary. 2. Wait for download to finish before resetting drive or cycling power. 3. Contact Applications for help on recovering after an aborted operating system download (or see web site FAQ).
Left LED is Red, Right LED is not illuminated.	1. Drive faulted. 2. Operating system download in progress. 3. Operating system download aborted before successful completion.	1. Check status with TASF and TASXF commands to determine cause and correct error condition as necessary. 2. Wait for download to finish before resetting drive or cycling power. 3. Contact Applications for help on recovering after an aborted operating system download (or see web site FAQ).
Left LED is not illuminated, Right LED is Yellow.	1. Initialization in progress. This occurs during power-up and reset.	1. Wait for unit to complete its power up or reset process.
Left LED is Green, Right LED is flashing Yellow/Green	1. Drive is in auto-run mode (DMODE13)	1. Change mode back to position mode (DMODE12).
Motion does not occur.	1. LED's not lit at all (no power) or red LED is illuminated	1. See LED troubleshooting as noted above.
	2. End-of-travel limits are active.	2.a. Move load off of limits or disable limits by sending the `LHØ` command to the affected axis. 2.b. Software limits: Set `LSPOS` to a value greater than `LSNEG`.
	3. Improper wiring.	5. Check enable & limit connections..
	4. ENABLE input is not grounded.	6. Ground the ENABLE input connection.
	5. Load is jammed.	7. Remove power and clear jam.
	6. No torque from motor.	8. See problem: *Torque, loss of*.
	7. Max. position error (`SMPER` value) exceeded. (servo axes only)	9. Check to see if `TAS`/`TASF` bit #23 is set, and issue the `DRIVE1` command to the axis that exceeded the position error limit.
	8. Drive has faulted.	10. Check to see if `TAS`/`TASF` bit #14 is set.
Power-up Program does not execute.	1. ENABLE input is not grounded.	1. Ground the ENABLE input to GND and reset the product.
	2. `STARTP` program is not defined.	2. Check the response to the `STARTP` command. If no program is reported, define the `STARTP` program and reset (see page 13, or refer to the `STARTP` command description).
Program access denied: receive the message `*ACCESS DENIED` when trying to use the `DEF`, `DEL`, `ERASE`, `LIMFNC`, `INFNC`, or `MEMORY` commands.	1. Program security function has been enabled (`INFNCi-Q` or `LIMFNCi-Q`) and the program access input has not been activated	1.a. Activate the assigned program access input, perform your programming changes, then deactivate the program access input. 1.b. Refer to the instructions on page 104, or to the `INFNC` or `LIMFNC` command descriptions.
Program execution: the first time a program is run, the move distances are incorrect. Upon downloading the program the second time, move distances are correct.	1. Scaling parameters were not issued when the program was downloaded; or scaling parameters have been changed since the program was defined.	1. Issue the scaling parameters (`SCALE1`, `SCLA`, `SCLD`, `SCLV`, `SCLMAS`) before saving any programs.
Problem	**Cause**	**Solution**
Torque, loss of.	1. Improper wiring.	1. Check wiring to the drive, as well as other system wiring.
	2. No power to drive.	2. Check power to drive.
	3. Drive failed.	3. Check drive status.
	4. Drive faulted.	4. Check drive status.
	5. Shutdown issued to drive.	5. Re-enable drive by sending the `DRIVE1` command.
Velocity & acceleration is incorrect as programmed.	See *Distance* problem noted above.	

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Program Debug Tools

After creating your programs, you may need to debug the programs to ensure that they perform as expected. The Gem6K provides several debugging tools. Detailed descriptions are provided on the following pages.

- **Status Commands**: Use the "Transfer" commands (e.g., `TAS`, `TSS`, `TIN`) to display various controller status information. Multi-Tasking: System (`TSS`) and Error (`TER`) status information is task specific; to check the status for a specific task, you must prefix the status command with the task identifier (e.g., `2%TSS` to check the system status for task 2).
- **Error Messages**: You can enable the Gem6K to display error messages when it detects certain programming errors as you enter them or as the program is run. When the controller detects an error with a command, you can issue the `TCMDER` command to find out which command caused the error.
- **Trace mode**: Trace a program as it is executing.
- **Single-Step mode**: Step through the program one command at a time.
- **Break Points**: Establish locations in your program, where command processing will halt and a message will be transmitted to the PC.
- **Simulate Programmable I/O Activation**: You can set the desired state of the Gem6K's inputs and outputs via software commands.
- **Simulate Analog Input Activation**: Without an actual voltage present, you can simulate a specific voltage on the Gem6K's analog input channels using the `ANIEN` command.
- **Motion Planner's Panel Gallery**: Motion Planner's Panel Gallery provides an assortment of test panels you can use to verify various system I/O and operating parameters.

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Status Commands

Status commands are provided to assist your diagnostic efforts. These commands display status information such as, axis-specific conditions, general system conditions, error conditions, etc.

Checking Specific Setup Parameters

One way to check the conditions that are established with a specific setup command is to simply type in the command name without parameters. For example, type "ERES" to check the encoder resolution setting; the response would look something like: *ERES4ØØØ.

Refer to page 64 for a list of most setup parameters and their respective commands.

TIP: To send a status command to the Gem6K product during program execution, prefix the command with an "!" (e.g., !TASF).

Below is a list of the status commands that are commonly used for diagnostics. Additional status commands are available for checking other elements of your application (see *List of All Status Commands* below). For more information on each status command, refer to the respective command description in the ***Gem6K Series Command Reference***.

SPECIAL NOTATIONS

* The command has a binary report version (just leave the "F" off when you type it in—e.g., TAS). This is used more by experienced Gem6K programmers. Using the binary report command, you can check the status of one particular bit (e.g., The TAS.1 command reports "1" if motor is moving or "Ø" if it is not moving.). In the binary report the bits are numbered left to right, 1 through *n*. A "1" in the binary report correlates to a "YES" in the full text report, and a "Ø" correlates to a "NO" in the full text report.

† The command has an assignment/comparison operator that uses the bit status for conditional expressions and variable assignments. For example, the WAIT(1AS.1=bØ) command pauses program execution until status bit number 1 (1AS.1) reports a binary zero value (indicates that the motor is not-moving). See page 7 and page 25 for more information on using assignment and comparison operators in conditional expressions and variable assignments.

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TASF	Reports axis-specific conditions.	* (TAS)	† (AS)

1. Axis is in motion (commanded)	17. Positive-direction software limit (LSPOS) encountered
2. Direction is negative	18. Negative-direction software limit (LSNEG) encountered
3. Accelerating (n/a to deceleration)	19. Within Deadband (steppers) Within deadband (EPMDB) — steppers only
4. At velocity	20. RESERVED In position (COMEXP)
5. Home Successful (HOM)	21. RESERVED
6. In absolute positioning mode (MA)	22. RESERVED
7. In continuous positioning mode (MC)	23. Position error limit is exceeded (SMPER) (servos)
8. In Jog Mode (JOG)	24. Load is within Target Zone (STRGTD & STRGTV) (servos)
9. In Joystick Mode (JOY)	25. Target Zone timeout occurred (STRGTT) (servos)
10. RESERVEDIn Encoder Step Mode (ENC) — steppers	26. Motion suspended, pending GOWHEN
11. Position Maintenance Mode (steppers)Position Maintenance on (EPM) — steppers	27. RESERVED
12. Stall detected (ESTALL) (steppers)	28. Registration move occurred since last GO
13. Drive shutdown occurred	29. GOWHEN Error: Input or position true before Go
14. Drive fault occurred	30. Pre-emptive (OTF) GO or Registration profile not possible
15. Positive-direction hardware limit hit	31. Compiled GOBUF profile is executing
16. Negative-direction hardware limit hit	32. RESERVED

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TASXF	Reports extended axis-specific conditions.	* (TASX)	† (ASX)

1. Motor Fault
2. Low voltage Fault
3. Drive over-temperature Fault
4. RESERVED
5. Resolver failure detected (servos)
6.RESERVED
7. Motor configuration error
8. RESERVED
9. Velocity error limit (SMVER) (servos)
10. Bridge fault
11. Bridge temperature fault (servos)
12. Over-voltage (servos)
13-16. RESERVED
17. Stall detected (ESTALL or DSTALL) (steppers)
18. Override mode invoked
19. Bridge in foldback mode (servos)
20. Power dissipation circuit active (not applicable on some servos)
21. Bad Hall state (servos)
22. Unrecognized hardware (consult factory)
23.User fault input active
24. Keep alive active
25. Power dissipation circuit fault (not applicable on some servos)
26. RESERVED
27. RESERVED
28. Motor configuration warning
29. ORES failure
30. Motor thermal model fault (servos)
31. Command torque/force at limit (TTRQ=DMTLIM) (servos)
32. RESERVED

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TSTAT	Reports general system setup and current conditions.

Sample response for the Gem6K:

```
*Gem6K revision: 92-XXXXXX-01-6.0  Gem6K  GV6K-L3E D1.72 F1.3
*Ethernet address: xxxxxxxxxx;  IP address: 192.168.10.30
*Power-up program assignment (STARTP): SETUP
*ENABLE input OK: Yes
*Drive status (DRIVE): 0
*Drive resolution (DRES): 25000
*Encoder resolution (ERES): 4000
*Hard Limit enable: LH3
*Soft Limit enable: LS0
*Current Motion Attributes:
*  Scaling enabled (SCALE1): 0
*  Acceleration scaler (SCLA): 4000
*  Distance scaler (SCLD): 1
*  Velocity scaler (SCLV): 4000
*  Commanded position (TPC): +0
*  A10.0000
*  AA10.0000
*  AD10.0000
*  ADA10.0000
*  V1.0000
*  D+4000
*I/O Status:
*  Onboard limit inputs:
*    Hardware state (TLIM):   000
*  Expansion I/O bricks: See TIO response
*Axis Status (see TASF for full text report):
*  Axis #1 (1TAS): 0010_0000_0000_1000_0000_0001_0000_0000
*System Status (This is task 0 status if using multi-tasking.):
*0 Programs Defined; Scale Enable 0
*    System status (TSSF):   1000_1100_0000_0000_0000_0100_0000_0000
```


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TSSF

Reports current system conditions. * (TSS) † (SS)
Multi-tasking: Each task has its own system status; therefore, to check the system status for a specific task, prefix the TSSF command (e.g., 2%TSSF).

1. System is ready
2. RESERVED
3. Executing a Program
4. Last command was immediate
5. In ASCII Mode
6. In Echo Mode (ECHO)
7. Defining a Program (DEF)
8. In Trace Mode (TRACE, TRACEP)
9. In Step Mode (STEP)
10. FS Translate Mode
11. Command error (check with TCMDER)
12. Break Point Active (BP)
13. Pause Active (PS or pause input)
14. Wait Active (WAIT)
15. Monitoring On Conditions (ONCOND)
16. Waiting for Data (READ)
17. Loading Thumbwheel Data (TW operator)
18. In External Program Select Mode (INSELP)
19. Dwell in Progress (T command)
20. Waiting for RP240 Data (DREAD or DREADF)
21. RP240 Connected
22. Non-volatile Memory Error
23. Gathering servo data (servos)
24. Suspend on Swap (multi-tasking)
25. RESERVED
26. Suspended on COM1 (multi-tasking)
27. Suspended on COM2 (multi-tasking)
28. Program Pending (multi-tasking)
29. Compiled memory partition is 75% full
30. Compiled memory partition is 100% full
31. Compile operation (PCOMP) failed
32. EXE Failed (multi-tasking)

TINOF

Reports the status of the ENABLE input. * (TINO) † (INO)

1-5. RESERVED
6. ENABLE input OK (motion not inhibited
7-8. RESERVED

TFSF

Reports Following Mode conditions (details on page 170). * (TFS) † (FS)

1. Follower in ratio move
2. Current ratio is negative
3. Follower is changing ratio
4. Follower at ratio (constant non-zero ratio)
5. FOLMAS Active
6. Following Mode enabled (FOLEN)
7. Master is moving
8. Master direction is negative
9. OK to Shift
10. Shifting now
11. FSHFC-based shift move is in progress
12. Shift direction is negative
13. Master cycle trigger input is pending
14. Mas cycle length (FMCLEN) given
15. Master cycle position is negative
16. Master cycle number is > 0
17. Master position prediction mode enabled (FPPEN)
18. Master position filtering mode enabled (FFILT)
19. Performing FRC move
20. RESERVED
21. Master window given
22. Inside master window
23. OK to do a geared advance (FGADV) move
24. Geared advance (FGADV) move is underway
25. RESERVED
26. Present Following move is limited by FMAXA or FMAXV.
27. RESERVED
28. RESERVED
29. RESERVED
30. RESERVED
31. RESERVED
32. RESERVED

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TERF	Reports error conditions. ** * (TER) † (ER) Multi-tasking: Each task has its own error status; therefore, to check the error status for a specific task, prefix the TERF command (e.g., 2%TErF).

1. Stall detected. 1st: Enable Stall Detection (ESTALL or DSTALL).
2. Hardware end-of-travel limit encountered. 1st: Enable hard limits (LH).
3. Software end-of-travel limit encountered. 1st: Enable hard limits (LH).
4. Drive Fault is active.

5. RESERVED
6. A programmable input, defined as a “kill” input, is active.
7. A programmable input, defined as a “user fault” input, is active.
8. A programmable input, defined as a “stop” input, is active.

9. ENABLE input not grounded.
10. Pre-emptive (OTF) GO or Registration profile not possible.
11. Target Zone settling timeout period (STRGTT) is exceeded. — servo only
12. Max. position error (SMPER value) is exceeded. — servo only

13. RESERVED
14. GOWHEN condition already true.
15. RESERVED
16. Bad command detected (use TCMDER to identify the bad command).

17. RESERVED
18. Expansion I/O brick is disconnected or has lost power.
19-22. RESERVED

23. Client connect error
24. Client polling error
25-32. RESERVED

** The error condition will not be reported until you enable the respective error-checking bit with the ERROR command (for details, see page 30 or the ERROR command description). NOTE that when the error-checking bit is enabled and the error occurs, the controller will branch to the “error” program that you assigned with the ERRORP command.

Other status commands commonly used for diagnostics:

TDIR..... Identifies the name and number of all programs residing in the Gem6K product's memory. Also reports percent of available memory for programs and compiled path segments.

TCMDER.... Identifies the bad command that caused the error prompt (?). (see page 232 for details)

TEX..... Execution status (and line of code) of the current program in progress. Task specific.

TIN..... Binary report of all programmable and trigger inputs (“1” = active, “Ø“ = inactive). INFNC also reports the state and programmed function of each input. (see page 91 for bit assignments)

TOUT..... Binary report of all programmable and auxiliary outputs (“1” = active, “Ø“ = inactive). OUTFNC also reports the state and programmed function of each output. (see page 91 for bit assignments)

TLIM..... Binary report of all limit inputs (“1” = active, “Ø“ = inactive). LIMFNC also reports the state and programmed function of each limit input. (see page 91 for bit assignments)

TIO..... Reports current contents on all expansion I/O bricks connected to the Gem6K. Includes current state and function of the digital inputs and outputs, as well as voltage of analog inputs.

TPER..... (servo axes) Reports the difference between the commanded position and the actual position as measure by the feedback device.

TPC..... Current commanded position.

TPE..... Current position of the encoder.

TFB..... (servo axes) Current position of the feedback device selected with the last SFB command.

TPMAS..... Current position of the Following master

TPSLV..... Current position of the Following slave

TNMCY..... Current master cycle number.

TNT..... Reports the current Ethernet conditions (Ethernet enabled/disabled, IP address, Ethernet MAC address, Ethernet cable connected/disconnected).

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List of All Status Commands

SPECIAL NOTATIONS

* The command responds with a binary report. This is used more by experienced Gem6K programmers. Using the bit select operator (`.`), you can check the status of one particular bit (e.g., The `TAS.1` command reports "`1`" if the motor is moving or "`Ø`" if it is not moving.). In the binary report, the bits are numbered left to right, 1 through *n*. A "`1`" in the binary report correlates to a "`YES`" in the full text report, and a "`Ø`" correlates to a "`NO`" in the full text report.

Δ The command has a full-text report version (just add an "F" when you type it in—e.g., `TASF`). This makes it easier to check status information without having to look up the purpose of each status bit. (see full-text descriptions, beginning on page 222)

† The command has an assignment/comparison operator that uses the bit status for conditional expressions and variable assignments. For example, the `WAIT(1AS.1=bØ)` pauses progress execution until the status bit number 1 (`1AS.1`) reports a binary zero value (indicates that the axis is not-moving). See page 7 and page 25 for more information on using assignment and comparison operators in conditional expressions and variable assignments.

COMMAND	STATUS SUBJECT
`TANI`	Voltage of ANI analog inputs on EVM32 bricks *(servo products with ANI option)* †
`TANO`	Voltage of ANO analog inputs on EVM32 bricks †
`TAS`	Binary Report of Axis Status * Δ †
`TASX`	Binary Report of Axis Status – extended * Δ †
`TCMDER`	Command Error (view command that caused the error prompt)
`TDIR`	Program Directory and Available Memory
`TDPTR`	Data Pointer Status †
`TER`	Error Status * Δ †
`TEX`	Program Execution Status †
`TFB`	Position of Selected Feedback Devices †
`TFS`	Binary Report of Following Status * Δ †
`TGAIN`	Current Value of Active Servo Gains
`TIN`	Binary Report of Status of Programmable Inputs * †
`TINO`	Status of the ENABLE input (bit #6) * Δ †
`TIO`	Report of all I/O on expansion I/O bricks
`TLABEL`	Defined Labels (names of)
`TLIM`	Binary Report of Hardware Status of All Limit Inputs †
`TMEM`	Memory Usage (partition and available memory)
`TNMCY`	Master Cycle Number †
`TNT`	Current Ethernet Conditions, including the `TNTMAC` report
`TNTMAC`	Ethernet Address
`TOUT`	Binary Report of Status of Programmable Outputs * †
`TPANI`	Position of ANI Inputs †
`TPC`	Commanded Position †
`TPCC`	Captured Commanded Position †
`TPCE`	Captured Encoder Position †
`TPCME`	Captured Master Encoder Position †
`TPCMS`	Captured Master Cycle Position †
`TPE`	Position of Encoder †
`TPER`	Position Error †
`TPMAS`	Position of Master Axis †
`TPME`	Position of Master Encoder †
`TPROG`	Contents of a Program
`TPSHF`	Net Position Shift †
`TPSLV`	Current Commanded Position of the Slave †
`TREV`	Firmware Revision Level
`TSC`	Binary Report of Controller Status * Δ †
`TSCAN`	Scan Time of Last PLC Program
`TSGSET`	Servo Gain Sets
`TSEG`	Number of Free Segment Buffers †
`TSS`	Binary Report of System Status * Δ †
`TSTAT`	Statistics
`TSTLT`	Settling Time
`TSWAP`	Identify Currently Active Tasks (in multi-tasking) * †
`TTASK`	Task Number of the program that executes this command †
`TTIM`	Time Value †
`TTRIG`	Status of "Trigger Interrupt" Activation * †
`TUS`	User Status * †
`TVEL`	Current Commanded Velocity †
`TVELA`	Current Actual Velocity †
`TVMAS`	Current Velocity of the Master Axis †

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Error Messages

Depending on the error level setting (set with the ERRLVL command), when a programming error is created, the Gem6K will respond with an error message and/or an error prompt. A list of all possible error messages is provided in a table below. The default error prompt is a question mark (?), but you can change it with the ERRBAD command if you wish.

At error level 4 (ERRLVL4—the factory default setting) the Gem6K responds with both the error message and the error prompt. At error level 3 (ERRLVL3), the Gem6K responds with only the error prompt.

Error Response	Possible Cause
ACCESS DENIED	Program security feature enabled, but program access input (INFNCi-Q) not activated.
ALREADY DEFINED FOR THUMBWHEELS	Attempting to assign an I/O function to an I/O that is already defined as a thumbwheel I/O.
ALTERNATIVE TASK NOT ALLOWED	Attempting to execute a LOCK command directed to another task.
AXIS NOT READY	Compiled Profile path compilation error.
COMMAND NOT IMPLEMENTED	Command is not applicable to the Gem6K Series product.
COMMAND NOT ALLOWED IN PROGRAM	Command is not allowed inside a program definition (between DEF and END).
COMMAND/DRIVE MISMATCH	The command (or ≥ one field in the command) is not appropriate to the AXSDEF configuration (e.g., attempting to execute a servo tuning command on a stepper axis)
ERROR: MOTION ENDS IN NON-ZERO VELOCITY - AXIS *N*	Compiled Motion: The last GOBUF segment within a PLOOP/PLN loop does not end at zero velocity, or there is no final GOBUF segment placed outside the loop.
FOLMAS NOT SPECIFIED	No FOLMAS for the axis is currently specified. It will occur if FMCNEW, FSHFC, or FSHFD commands are executed and no FOLMASØ command was executed, or FOLMAS0 was executed.
INCORRECT AXIS	Axis specified is incorrect.
INCORRECT BRICK NUMBER	Attempted to execute a command that addresses an I/O brick that is not connected to your Gem6K.
INCORRECT DATA	Incorrect command syntax. Following: Velocity (V), acceleration (A) or deceleration (AD) command is zero (used by FSHFC & FSHFD).
INPUT(S) NOT DEFINED AS JOYSTICK INPUT	Attempted to execute JOYCDB, JOYCTR, JOYEDB, or JOYZ before executing JOYAXH or JOYAXL to assign the analog input to an axis.
INSUFFICIENT MEMORY	Not enough memory for the user program or compiled profile segments. This may be remedied by reallocating memory (see MEMORY command description).
INVALID COMMAND	Command is invalid because of existing conditions

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Programming Error Messages *(continued)*

Error Response	Possible Cause
INVALID CONDITIONS FOR COMMAND	System not ready for command (e.g., LN command issued before the L command). Following (these conditions can cause an error during Following): • The FOLMD value is too small to achieve the preset distance and still remain within the FOLRN/FOLRD ratio. • A phase shift cannot be performed: FSHFD Error if already shifting or performing other time based move. FSHFC .... Error if currently executing a FSHFD move, or if currently executing another FSHFC move in the opposite direction. • The FOLEN1 command was given while a profile was suspended by a GOWHEN.
INVALID CONDITIONS FOR S_CURVE ACCELERATION–FIELD *n*	Average (AA) acceleration or deceleration command (e.g., AA, ADA, HOMAA, HOMADA, etc.) with a range that violates the equation ½A ≤ AA ≤ A (A is the max. accel or decel command—e.g., A, AD, HOMA, HOMAD, etc.)
INVALID DATA	Data for a command is out of range. Following (these conditions can cause an error during Following): • The parameter supplied with the command is valid. FFILT Error if: smooth number is not 0-4 FMCLEN .. Error if: master steps > 999999999 or negative FMCP..... Error if: master steps > 999999999 or < -999999999 FOLMD .... Error if: master steps > 999999999 or negative FOLRD .... Error if: master steps > 999999999 or negative FOLRN .... Error if: follower steps > 999999999 or negative FSHFC .... Error if: number is not 0-3 FSHFD .... Error if: follower steps > 999999999 or < -999999999 GOWHEN .. Error if: position > 999999999 or < -999999999 WAIT..... Error if: position > 999999999 or < -999999999 • Error if a GO command is given in the preset positioning mode (MCØ) and: FOLRN = zero FOLMD = zero, or too small (see Following chapter on page 177)
INVALID FOLMAS SPECIFIED	Following: An illegal master was specified in FOLMAS. A follower may never use its own commanded position or feedback source as its master.
INVALID RATIO	Following: Error if the FOLRN:FOLRD ratio after scaling is > 127 when a GO is executed
INVALID TASK IDENTIFIER	Attempting to launch a PEXE or EXE command into the supervisor task (task 0).
LABEL ALREADY DEFINED	Defining a program or label with an existing program name or label name
MASTER SLAVE DISTANCE MISMATCH	Attempting a preset Following move with a FOLMD value that is too small
MAXIMUM COMMAND LENGTH EXCEEDED	Command exceeds the maximum number of characters
MAXIMUM COUNTS PER SECOND EXCEEDED	Velocity value is greater than 1,600,000 counts/sec
MOTION IN PROGRESS	Attempting to execute a command not allowed during motion (see *Restricted Commands During Motion* on page 17.) Following: The FOLEN1 command was given while that follower was moving in a non-Following mode.

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Programming Error Messages *(continued)*

Error Response	Possible Cause
NEST LEVEL TOO DEEP	IFs, REPEATs, WHILEs, or GOSUBs nested greater than 16 levels (for each type)
NO MOTION IN PROGRESS	Attempting to execute a command that requires motion, but motion is not in progress
NO PATH SEGMENTS DEFINED	Compiled Profile compilation error
NO PROGRAM BEING DEFINED	END command issued before a DEF command
NOT ALLOWED IF SFBØ	Changes to tuning commands and SMPER are not allowed if SFBØ is selected
NOT ALLOWED IN PATH	Compiled Profile path compilation error
NOT DEFINING A PATH	Executing a compiled profile command while not in a path
NOT VALID DURING FOLLOWING MOTION	A GO command was given while moving in the Following mode (FOLEN1) and while in the preset positioning mode (MCØ).
NOT VALID DURING RAMP	A GO command was given while moving in a Following ramp and while in the continuous positioning mode (MC1). Following status (FS) bit #3 will be set to 1. A FOLEN command was given during one of these conditions: • During a shift (FSHFC or FSHFD) • During a change in ratio (FOLRN/FOLRD) • During deceleration to a stop
OUTPUT USED AS OUTFNC	Attempted to change an output that is not a “general purpose” (OUTFNCi-A) output (see page 107)
PATH ALREADY MOVING	Compiled Profile compilation error
PATH NOT COMPILED	Attempting to execute a individual profile that has not been compiled
STRING ALREADY DEFINED	A string (program name or label) with the specified name already exists
STRING IS A COMMAND	Defining a program or label that is a command or a variant of a command
UNDEFINED LABEL	Command issued to product is not a command or program name
WARNING: POINTER HAS WRAPPED AROUND TO DATA POINT 1	During the process of writing data (DATTCH) or recalling data (DAT), the pointer reached the last data element in the program and automatically wrapped around to the first datum in the program
WARNING: ENABLE INPUT INACTIVE	**ENABLE** input is no longer connected to ground (**GND**)
WARNING: DEFINED WITH ANOTHER TW/PLC	Duplicate I/O in multiple thumbwheel definitions

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Identifying Bad Commands

To facilitate program debugging, the Transfer Command Error (TCMDER) command allows you to display the first command that the controller detects as an error. This is especially useful if you receive an error message when running or downloading a program, because it catches and remembers the command that caused the error.

Using Motion Planner:

If you are typing the command in a live terminal emulator session, the controller will detect the bad command and respond with an error message, followed by the ERRBAD error prompt (?). If the bad command was detected on download, the bad command is reported automatically (see example below).

NOTE: If you are not using Motion Planner, you'll have to type in the TCMDER command at the error prompt to display the bad command.

Once a command error has occurred, the command and its fields are stored and system status bit #11 (reported in the TSSF, TSS and SS commands) is set to 1, and error status bit #16 (reported in the TERF, TER and ER commands) is set to 1. The status bit remains set until the TCMDER command is issued.

Example Error Scenario

1. In Motion Planner's program editor, create and save a program with a programming error:

```
DEL badprg    ; Delete a program before defining and downloading
DEF badprg    ; Begin definition of program called badprg
MA1           ; Select the absolute preset positioning mode
A25           ; Set acceleration
AD11          ; Set deceleration
V5            ; Set velocity
VAR1=0        ; Set variable #1 equal to zero
GO1           ; Initiate move on axis
IF(VAR1<)16   ; MISTYPED IF STATEMENT - should be typed as "IF(VAR1<16)"
VAR1=VAR1+1   ; If variable #1 is < 16, increment the counter by 1
NIF           ; End IF statement
END           ; End programming of program called badprg
```

2. Using Motion Planner's terminal emulator, download the program to the Gem6K Series product. Notice that an error response identifies the bad command as an "INCORRECT DATA" item and displays it:

```
> *NO ERRORS
*INCORRECT DATA
> *IF(VAR1<)16
>
```

Trace Mode

You can use the Trace mode to debug a program. The Trace mode allows you to track, command-by-command, the entire program as it runs. The Gem6K will display all of the commands as they are executed. **NOTE**: Program tracing is also available on the RP240 display (see page 127).

The example below demonstrates the Trace mode.

Step 1 Create a program called prog1:

```
DEF prog1           ; Begin definition of program prog1
A10                 ; Acceleration is 10
AD10                ; Deceleration is 10
V5                  ; Velocity is 5
L3                  ; Loop 3 times
GOSUB prog3         ; Gosub to program #3 (prog3)
LN                  ; End the loop
END                 ; End definition of program prog1
```


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Step 2 Create a program `prog3`:

```
DEF prog3           ; Begin definition of program prog3
D50000              ; Sets the distance to 50,000
GO1                 ; Initiates motion
END                 ; End definition of program prog3
```

Step 3 Enable the Trace Mode:

```
TRACE1              ; Enables the Trace mode
```

Step 4 Execute the program `prog1`: (each command in the program is displayed as it is executed)

```
EOT13,10,0          ; Set End-of-Transmission characters to <cr>,<lf>
RUN prog1           ; Run program prog1
```

The response will be:

```
*PROGRAM=PROG1       COMMAND=A10.0000
*PROGRAM=PROG1       COMMAND=AD10.0000
*PROGRAM=PROG1       COMMAND=V5.0000
*PROGRAM=PROG1       COMMAND=L3
*PROGRAM=PROG1       COMMAND=GOSUB PROG3  LOOP COUNT=1
*PROGRAM=PROG3       COMMAND=D50000  LOOP COUNT=1
*PROGRAM=PROG3       COMMAND=GO1  LOOP COUNT=1
*PROGRAM=PROG3       COMMAND=END  LOOP COUNT=1
*PROGRAM=PROG1       COMMAND=LN  LOOP COUNT=1
*PROGRAM=PROG1       COMMAND=GOSUB PROG3  LOOP COUNT=2
*PROGRAM=PROG3       COMMAND=D50000  LOOP COUNT=2
*PROGRAM=PROG3       COMMAND=GO1  LOOP COUNT=2
*PROGRAM=PROG3       COMMAND=END  LOOP COUNT=2
*PROGRAM=PROG1       COMMAND=LN  LOOP COUNT=2
*PROGRAM=PROG1       COMMAND=GOSUB PROG3  LOOP COUNT=3
*PROGRAM=PROG3       COMMAND=D50000  LOOP COUNT=3
*PROGRAM=PROG3       COMMAND=GO1  LOOP COUNT=3
*PROGRAM=PROG3       COMMAND=END  LOOP COUNT=3
*PROGRAM=PROG1       COMMAND=LN  LOOP COUNT=3
*PROGRAM=PROG1       COMMAND=END
```

The format for the Trace mode display is:

```
Program Name  ...  Command  ...  Loop Count    or
Program Name  ...  Command  ...  Repeat Count  or
Program Name  ...  Command  ...  While Count
```

Step 5 Exit the Trace Mode.

```
TRACE0              ; Disables the Trace mode
```

Tracing Program Flow

Using the TRACEP command, you can monitor the entry and exit of programs and their associated nest levels.

For example, let's assume these four programs are defined:

```
DEF PICK1
GOSUB PICK2
GOTO PICK3
END

DEF PICK2
GOSUB PICK4
END

DEF PICK3
END

DEF PICK 4
END
```


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Now we'll enable the TRACEP mode and launch the calling program (PICK1) to start tracing the program flow:

```
>TRACEP1
>PICK1
*INITIATE PROGRAM:    PICK1   NEST=1
*INITIATE PROGRAM:    PICK2   NEST=2
*INITIATE PROGRAM:    PICK4   NEST=3
*END:                 PROGRAM NOW: PICK2   NEST=2
*END:                 PROGRAM NOW: PICK1   NEST=1
*INITIATE PROGRAM:    PICK3   NEST=1
*END:                 PROGRAM EXECUTION TERMINATED
>TRACEP0
```

Single-Step Mode

The Single-Step mode allows you to execute one command at a time. Use the STEP command to enable Single-Step mode. To execute a command, you must use the !# sign. By entering a !# followed by a delimiter, you will execute the next command in the sequence. If you follow the !# sign with a number (*n*) and a delimiter, you will execute the next *n* commands. The Single-Step mode is demonstrated below (using the programs from the Trace mode above).

Step 1 Enable the Single-Step Mode:

```
STEP1       ; Enables Single Step Mode
```

Step 2 Enable the Trace Mode and begin execution of program prog1:

```
TRACE1      ; Enables the Trace mode
RUN prog1   ; Run program called prog1
```

Step 3 Execute one command at a time by using the !# command:

```
!#          ; Executes one command
```

The response will be:

```
        *PROGRAM=PROG1       COMMAND=A10.0000
```

Step 4 To execute more than one command at a time, follow the !# sign with the number of commands you want executed:

```
!#3         ; Executes three commands
```

The response will be:

```
        *PROGRAM=PROG1       COMMAND=AD10.0000
        *PROGRAM=PROG1       COMMAND=V5.0000
        *PROGRAM=PROG1       COMMAND=L3
```

To complete the sequence, use the # sign until all the commands are completed (!#16 would complete the example).

Step 5 To exit Single-Step mode, type:

```
STEP0       ; Disables Single Step Mode
```


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Break Points

The Break Point (BP) command allows you to establish a location in the program where command processing will halt and a message will be transmitted to the PC. There are 32 break points available, BP1 to BP32, all transmitting the message *BREAKPOINT NUMBER n<cr> where n is the break point number.

After halting at a break point, command processing can be resumed by issuing an immediate continue (!C) command.

The break point command is useful for stopping a program at specific locations in order to test status for debugging or other purposes.

Example

```
DEF prog1         ; Begin definition of program named prog1
D50000            ; Set distance: 50000 units on axis 1
MA1               ; Absolute mode for axes 1
GO1               ; Initiate motion on axes 1
IF(1PC>40000)     ; Compare axis 1 commanded position to 40000
BP1               ; If motor position is > 40000 units, set break point #1
NIF               ; End IF statement
D80000            ; Set distance: 80000 units on axis 1
GO1               ; Initiate motion on axes 1
BP2               ; Set break point #2
END               ; End program definition
RUN prog1         ; Execute program prog1
```

In the example above, when the IF statement evaluates true, the controller will transmit the message *BREAKPOINT NUMBER 1. A !C command must be issued before processing will continue. Once processing has continued, the second break point command will be encountered, and the message *BREAKPOINT NUMBER 2 will be transmitted, and processing of commands will pause until a second !C command is received.

Simulating I/O Activation

If your application has inputs and outputs that integrate the Gem6K with other components in your system, you can simulate the activation of these inputs and outputs so that you can run your programs without activating the rest of your system. Thus, you can debug your program independent of the rest of your system.

There are two commands that allow you to simulate the input and output states desired. The INEN command controls the inputs and the OUTEN command controls the outputs.

NOTE

The INEN command has no effect on the trigger inputs when they are configured as *trigger interrupt* (position latch) inputs with the INFNCi-H command.

The OUTEN command has no effect on the onboard outputs when they are configured as *output-on-position* outputs with the OUTFNCi-H command.

You will generally use the INEN command to cause a specific input pattern to occur so that a program can be run or an input condition can become true. Use the OUTEN command to simulate the output patterns that are needed, and to prevent an external portion of your system from being initiated by an output transition. When you execute your program, the OUTEN command overrides the outputs and holds them in a defined state.

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Outputs

The following steps describe the use and function of the OUTEN command

Step 1 Display the state of the outputs with the TOUT command:

```
TOUT          ; Displays the state of the outputs
```

The response will be:

```
*TOUT0000_000
```

Display the function of the outputs with the OUTFNC command:

```
OUTFNC        ; Displays the state of the outputs
```

The response will be:

```
*OUTFNC1-A PROGRAMMABLE OUTPUT - STATUS OFF
*OUTFNC2-A PROGRAMMABLE OUTPUT - STATUS OFF
*OUTFNC3-A PROGRAMMABLE OUTPUT - STATUS OFF
*OUTFNC4-A PROGRAMMABLE OUTPUT - STATUS OFF
*OUTFNC5-A PROGRAMMABLE OUTPUT - STATUS OFF
*OUTFNC6-A PROGRAMMABLE OUTPUT - STATUS OFF
*OUTFNC7-A FAULT OUTPUT - STATUS OFF
```

Step 2 Disable outputs 1 - 4, leave them in the ON state.

```
OUTEN1111     ; Disable outputs 1-4, leave them in ON state
OUTFNC        ; Displays the state of the outputs
```

The response will be:

```
*OUTFNC1-A PROGRAMMABLE OUTPUT - STATUS DISABLED ON
*OUTFNC2-A PROGRAMMABLE OUTPUT - STATUS DISABLED ON
*OUTFNC3-A PROGRAMMABLE OUTPUT - STATUS DISABLED ON
*OUTFNC4-A PROGRAMMABLE OUTPUT - STATUS DISABLED ON
*OUTFNC5-A PROGRAMMABLE OUTPUT - STATUS OFF
*OUTFNC6-A PROGRAMMABLE OUTPUT - STATUS OFF
*OUTFNC7-A FAULT OUTPUT - STATUS OFF
```

Step 3 Change the output state using the OUT command. The status of all outputs, including auxiliary outputs, is displayed. The output bit pattern varies by product. To determine the bit pattern for your product, refer to the OUTEN command description.

```
OUT1010       ; Activates outputs 1 and 3, deactivates outputs 2 and 4
```

Display the state of the outputs with the OUTFNC command.

```
OUTFNC        ; Displays the state of the outputs
```

The response will be:

```
*OUTFNC1-A PROGRAMMABLE OUTPUT - STATUS DISABLED ON
*OUTFNC2-A PROGRAMMABLE OUTPUT - STATUS DISABLED ON
*OUTFNC3-A PROGRAMMABLE OUTPUT - STATUS DISABLED ON
*OUTFNC4-A PROGRAMMABLE OUTPUT - STATUS DISABLED ON
*OUTFNC5-A PROGRAMMABLE OUTPUT - STATUS OFF
*OUTFNC6-A PROGRAMMABLE OUTPUT - STATUS OFF
*OUTFNC7-A FAULT OUTPUT - STATUS OFF
```

Notice that output 2 and output 4 have not changed state because the output (OUT) command has no effect on disabled outputs.

Step 4 To re-enable the outputs, use the OUTEN command.

```
OUTENEEEE     ; Re-enables outputs 1-4
```


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Inputs

The steps below describe the use and function of the INEN command. You can use it to cause an input state to occur. The inputs will not actually be in this state but the Gem6K treats them as if they are in the given state and will use this state to execute its program.

Step 1 This program will wait for an input state to occur and will then make a preset move:

```
INFNC1-A      ; Onboard input #1 is has no function
INFNC2-A      ; Onboard input #2 is has no function
INLVL00       ; Set input #1 and #2 active level to low
DEF prog8     ; Begin definition of program prog8
A100          ; Acceleration is set to 100
AD100         ; Deceleration is 100
V5            ; Velocity is 5
D25000        ; Distance is 25,000
WAIT(IN=b11)  ; Waits for the input state to be 11
GO1           ; Initiate motion
END           ; End definition of program prog8
```

Step 2 Enable the Trace mode so that you can view the program as it is executed:

```
TRACE1        ; Enables the trace mode
```

Step 3 Execute the program:

```
RUN prog8     ; Runs program prog8
```

Step 4 The program will execute until the WAIT(IN=b11) command is encountered. The program will then pause, waiting for the input condition to be satisfied. Simulate the input state using the INEN command. Inputs with an E value are not affected. Note that the input bit pattern varies by product. To determine the bit pattern for your product, refer to the INEN command description.

```
!INEN11       ; Disables inputs 1 and 2, leaving them in the ON state
```

The motor will now move for 25000 steps.

Step 5 Deactivate the input simulation:

```
INENEE        ; Re-enables inputs 1 and 2
```

Simulating Analog Input Channel Voltages

Without actually applying any voltage, you can test any command or function that references the voltage on an analog input (located on an expansion I/O brick). For example, 2ANIEN.1=1.2,1.6,1.8 overrides I/O brick 2's hardware analog input 1 through 3 as follows: 1.2V on input 1, 1.6V on input 2, and 1.8V on input 3.

Another application for the ANIEN command may be to use it in an ERRORP program to override the analog input voltage in response to a fault.

Motion Planner's Panel Gallery

Motion Planner's Panel Gallery provides diagnostic panels for testing your programs and monitor the following:

- I/O (programmable I/O, analog I/O, limits)
- Motion (motor and feedback device position, velocity)
- Status (axis, system, interrupt, user-defined, Following)
- Terminal (direct communication with the product, to check for error messages, etc.)

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Technical Support

For solutions to your questions about implementing Gem6K product software features, first look in this manual. Other aspects of the product (command descriptions, hardware specs, I/O connections, graphical user interfaces, etc.) are discussed in the respective manuals listed in *Reference Documentation* on page ii.

If you cannot find the answer in this documentation, contact your local Automation Technology Center (ATC) or distributor for assistance.

If you need to talk to our in-house application engineers, please contact us at the numbers listed on the inside cover of this manual. (The phone numbers are also provided when you issue the HELP command to the Gem6K.)

Operating System Upgrades

You may obtain an upgraded Gem6K operating system from our web site at http://www.compumotor.com. Instructions for downloading and upgrading the operating system are provided on the web page.

Product Return Procedure

If you must return your Gem6K Series product to affect repairs or upgrades, use this procedure:

Step 1 Get the serial number and the model number of the defective unit, and a purchase order number to cover repair costs in the event the unit is determined by the manufacturers to be out of warranty.

Step 2 Before you return the unit, have someone from your organization with a technical understanding of the Gem6K Series product and its application include answers to the following questions:

- What is the extent of the failure/reason for return?
- How long did it operate?
- Did any other items fail at the same time?
- What was happening when the unit failed (e.g., installing the unit, cycling power, starting other equipment, etc.)?
- How was the product configured (in detail)?
- What, if any, cables were modified and how?
- With what equipment is the unit interfaced?
- What was the application?
- What was the system environment (temperature, enclosure, spacing, unit orientation, contaminants, etc.)?
- What upgrades, if any, are required (hardware, software, user guide)?

Step 3 Call for a return authorization. Refer to the Technical Support phone numbers provided on the inside cover of this manual. The support personnel will also provide shipping guidelines.

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