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DMC-600

Series User Manual

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How to Use This Manual

The DMC-630 Family User Manual is divided into three parts: System Operation, Instruction Set and Appendices.

The System Operation section provides detailed information about the operation of the DMC-630. This section includes IBM PC communication, programming, system control and a description of system features such as error handling and initialization.

The first part of this section tells the user "how to get started". The Getting Started portion of the manual gives the user a step-by-step guide for operating the DMC-630 in a motion control system. This section takes the user from hooking up the hardware elements to executing motion commands to move three motors.

Section II of the DMC-630 user manual gives decriptions of each of the DMC-630 instructions. This section provides a useful reference when programming the DMC-630 family.

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Note to Users of the DMC-610, -620, -615, -625, -611, -621, -631

The DMC-610 is one-axis, the DMC-620 is two-axis and the DMC-630 is a three-axis card. All commands in this manual refer to the DMC-630. The DMC-610 and DMC-620 have the same commands except the DMC-610 permits the X parameter only and the DMC-620 permits X and Y parameters only.

The CR, VP, VS, VA and CS commands are not valid in the DMC-610.

The DMC-615 and DMC-625 are master/slave versions of the DMC-600 Series. Users of these products should use this manual in addition to the master/slave manual.

The DMC-611, DMC-621 and DMC-631 are enhanced versions of the DMC-600 Series. The enhancement consists of both firmware and hardware modifications. Encoder frequencies up to 2,000,000 counts/sec can be input and the DAC resolution is increased from 8-bits to 12-bits. In addition, several new commands have been added, including:

LA	Arm high-speed latch
RL	Report latch
SE	Specify encoder type
TD	Tell dual encoder position
DD	Define dual encoder position
GA	Specify master axis for electronic gearing
A[i]=n	Define array element
GR	Specify gear ratio
TA	Set up trapezoidal acceleration
RM	Specify acceleration ramp
VR	Specify acceleration for coordinated move
TV	Set up trapezoidal acceleration for coordinated move
TC1	Report explanation of error
DR	Set DAC resolution
FL	Set forward software limit
BL	Set reverse software limit
FI	Searches for encoder index

These commands are denoted by an asterisk (*) in the user manual.

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1. GETTING STARTED

1.1. System Elements

Before you start, you must get all the necessary elements. These include:

1. DMC-610, DMC-620 or DMC-630 controller with 60-pin cable
2. DC Motors with optical encoders (1-3, one per axis)
3. Motor drivers (1-3, one per axis)
4. Power Supplies for drivers
5. IBM PC/XT/AT or compatible

Helpful but not necessary

6. ICB-960 Interconnect board
7. Communication Disk
8. Servo Design Software (SDK) - Strongly Recommended!!

Motor

The motors may be brush type or brushless. They should be properly sized to move the load at the required speed and acceleration.

Driver

The drivers should be suitable for the motor and may be linear or pulse-width-modulated. A driver may have current feedback or voltage feedback. The drivers should accept an analog signal in the þ10V range as a command. The amplifier gain should be set so that a +/-10V command will generate the maximum required current. For example, if the motor peak current is 10A, the amplifier gain should be 1 A/V.

Encoder

The encoders must have two channels in quadrature. They may have an index channel for synchronization. It is easier when a rotary encoder is mounted directly on the motor shaft, however, other forms of coupling are possible. The limitation on the encoder line density is that if the encoder has N cycles per revolution, the maximum frequency of the encoder must be limited to 125 KHz. For example, if N=1000 pulses/rev, the maximum motor velocity is 125 rev/s or 7500 rpm. The DMC-611, -621 and -631 enhanced controllers allow frequencies up to 500 KHz.

The interface between the DMC-630 and the motor/encoder is simplified greatly if the ICB-960 interconnect board is used, especially when the amplifier and the motor are purchased from Galil.

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Servo Design Software

SDK-600 software is available for step-by-step system assembly, design and analysis. It provides automatic tuning for the controller filter. The SDK-600 also has a scope program for displaying X, Y and Z position and velocity.

Now that you have all these parts ready, you can proceed to the first step.

1.2. Connecting the Elements

Step 1 - Installing the DMC-630

The DMC-630 may be installed directly into the IBM expansion bus. The procedure is outlined below.

1. Make sure the IBM PC is in the power-off condition. Unplug power cord from IBM PC.

2. Remove the five screws that hold the IBM System Unit cover in place. These screws are located in the back of the system unit.

3. Slide the system unit cover forward.

4. Remove the metal plate covering the expansion bus slot where the DMC-630 is to be inserted.

5. Insert DMC-630 card in the expansion bus and secure with screw. Make sure the DMC-630 is configured with appropriate options before inserting in IBM Bus (See Appendix E).

6. Re-secure system unit cover and tighten screws.

7. Insert the ribbon cable to JI0 connector. (Ends of cable should be terminated appropriately to system components).

8. Power-up IBM PC.

Step 2 - Establishing Communication

After you have installed the DMC-630 controller and powered-up the IBM PC, you should establish communication between the controller and PC. The easiest way to do this is to use the communication disk available from Galil. (If you do not have the disk, refer to Chapter 4).

To use this disk, first boot-up your computer, then insert the disk in drive A.

Type, TALK_600

to run the DMC-600 interactive communication program.

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Once you have established communication, the terminal display should show a colon, : . If you do not receive a colon, check the addressing. Please consult the factory if you need help.

Step 3 - Encoder Interface

If you are using the ICB-960 interface card, simply connect the JI0 ribbon from the controller to the JI0 connector on the ICB-960. Be sure that the connector edge with the arrow corresponds to pin 1. If you also purchased a motor/encoder from Galil, simply connect the encoder to the keyed connector on the ICB-960 card. With other encoders, connect the encoder signals to the pins marked PHA and PHB. The encoder index, or marker, should be connected to the pin marked IDX. The ICB-960 also provides 5V supply and GND to power the encoder. These signals are available on the appropriately marked pins.

If you are not using the ICB-960 interconnect board, connect the encoder signals to the JI0 connector as follows:

Pin #	Signal
2	+5V
1	GND

X	Y	Z	
33	19	13	Channel A
31	17	11	Channel B
29	15	9	Index

Once the encoder is connected, rotate the motor shaft manually and interrogate the position with the instruction

```
TP (CR)
```

The controller response should vary as the motor is turned.

Repeat the same process of connecting the encoders of the Y and Z axes.

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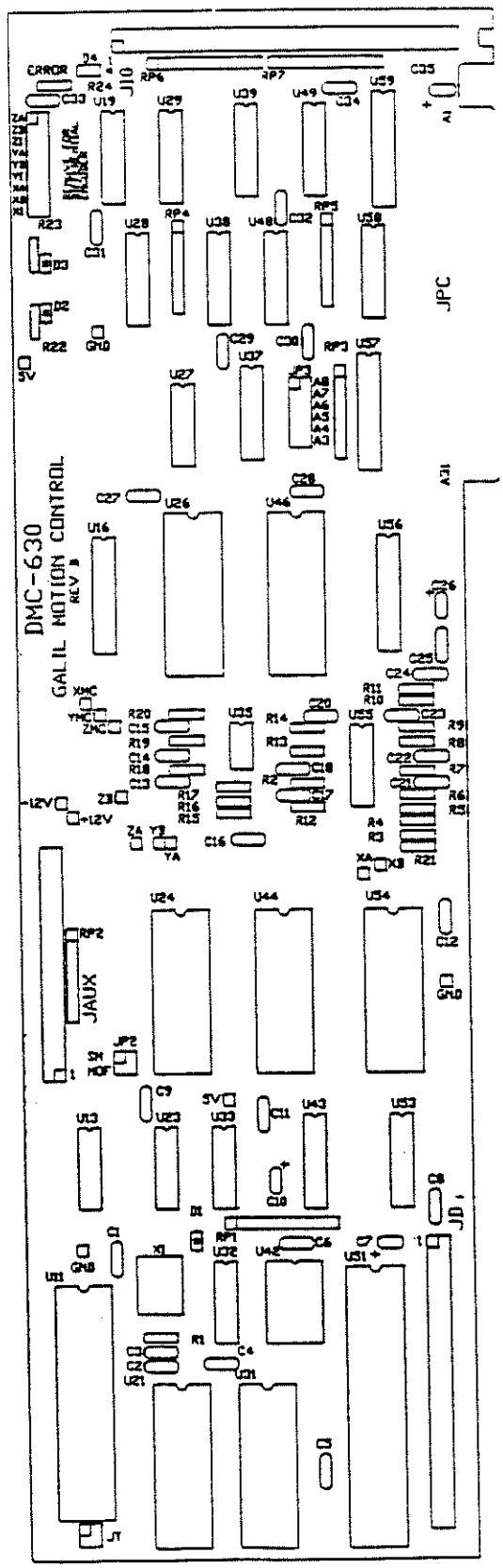


Fig. 1.1 - DMC-630 Layout

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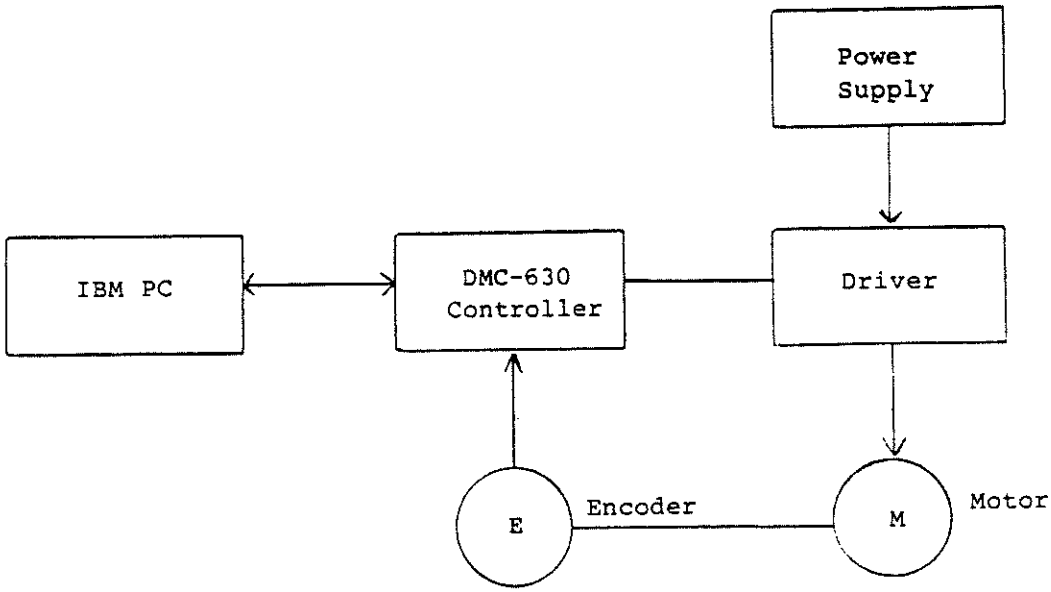


Fig. 1.2 - Elements of Control System

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Step 4 - Connecting the Motors and the Amplifiers

For best results, the amplifier should operate as a current source with no additional compensation. The gain of the amplifier should be such that a 10V input command results in the maximum required current.

The first step is to connect the motor to the amplifier and to adjust the offset signal so that with no input command, the motor stops.

When using the ESA amplifier from Galil Motion Control, connect the motor to pins 1 and 4. The supply voltage and ground are connected to pins 3 and 2 respectively. Adjust the offset trimmer T5 until the motor stops.

Before closing the loop, input the command

```
OE  1,1,1 (CR)
```

This instruction shuts off the motor command when the position error exceeds the error limit (2048 on default).

Also command the instruction

```
GN  1,1,1 (CR)
```

This reduces the gain of the three axes control systems to the minimum value.

Now you can close the loop by applying the motor command signal from the controller to the amplifier.

When the ICB-960 is used with the ESA amplifier, connect the pin of the J4 connector marked MCMD to pin 6 of the amplifier. The GND should be connected to pin 9 of the amplifier only if the amplifier supply is floating in reference to the controller supply. With other amplifiers, apply the motor command signal to the amplifier in a similar manner.

When the loop is closed, there is a 50% probability that the feedback polarity is wrong. When that is the case, the motor runs away causing the controller to shut off, and lighting the red LED. If that occurs, simply reverse the feedback polarity by reversing either the motor wires or the encoder channels. Once the correct feedback polarity is established, repeat Step 4 by first typing SH (Servo Here). The motor should remain at the initial position. The position of the motor may be interrogated with the instruction

```
TP (CR)
```

In response to that, the controller reports the position of the three axes. Under normal conditions, the position should be near zero.

After closing the X-loop, proceed with the same process with the Y and Z axes.

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Step 5 - Compensation

Once the loop has been closed, it is necessary to adjust the filter parameters (GN,ZR,KI) for best response.

A simple procedure is to gradually increase the gain (GN) until the system oscillates. This can be done, for example, with the instruction

```
GN  6
```

which increases the gain of the X axis to 6. The resulting system accuracy may be interrogated with the instruction

```
TEX (CR)
```

which responds with the position error.

As the gain is increased, the position error decreases proportionately. If the system oscillates, lower the gain.

To change the values of the gain of the Y and Z axis, use the instructions

```
GN  ,6 (CR)
```

or

```
GN  ,,6 (CR)
```

respectively. Similarly, the instructions TEY and TEZ return the position errors of Y and Z respectively. More effective compensation can be performed with the SDK software. The procedure is outlined in Chapter 2.

Once the gain parameter is increased to its maximum value, the next step is to add an integrator for improved accuracy. This can be done with the instruction

```
KI  1 (CR)
```

which sets the integrator gain of the X axis at the minimum value of 1. Increasing the value of KI improves the speed of the response but may cause instability. Not all systems may operate with integrators. Their ability depends on the motor and the amplifier. If the integrator function causes system oscillations, it should be avoided.

The compensation process may be repeated for the Y and the Z axes.

Note: The SDK-600 software automatically selects the filter parameters.

1.3. Design Examples

The following examples illustrate the use of the DMC-630 controller.

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Example 1 - Single Axis

Objective: Rotate the X motor a distance of 400 counts and stop.

Instruction	Interpretation
PR 400	Required distance
BGX	Start motion

Example 2 - Profiled Move

Objective: Rotate the X axis a distance of 10,000 counts at a slew speed of 20,000 counts/sec and an acceleration rate of 100,000 count/s^2.

Instruction	Interpretation
PR 10000	Distance
SP 20000	Speed
AC 100000	Acceleration
BGX	Start motion

In response, the motor turns and stops.

Example 3 - Multiple Axes

Objective: To move the three axes independently.

Instruction	Intrepretation
PR 500,1000,600	Distances of X,Y,Z
SP 10000,12000,20000	Slew speeds of X,Y,Z
AC 100000,60000,20000	Acceleration of X,Y,Z
BGXZ	Start X and Z motion
BGY	Start Y motion

The motion parameters may be specified independently as illustrated below.

Example 4 - Independent Moves

Instruction	Interpretation
PR ,300,-600	Distances of Y and Z
SP ,2000	Slew speed of Y
AC ,100000	Acceleration of Y
SP ,,40000	Slew speed of Z
AC ,,200000	Acceleration of Z
BGZ	Start Z motion
BGY	Start Y motion

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Example 5 - Position Interrogation

The position of the three axes may be interrogated with the instruction

```
TP
```

which returns the three positions of the motors.

Individual axis may be interrogated with the instructions

```
TPX
TPY
TPZ
```

The position error, which is the difference between the commanded position and the actual position can be interrogated by the instructions:

```
TE
TEX
TEY
TEZ
```

Example 6 - Absolute Position

Objective: Command motion by specifying the absolute position.

Instruction	Interpretation
DP 0,2000	Define the current positions of X,Y as 0 and 2000
PA 7000,4000	Set the desired absolute positions
BGX	Start X motion
BGY	Start Y motion

After both motions are completed, command:

PA 0,0	Move to 0,0
BGXY	Start both motions

Example 7 - Velocity Control

Objective: Drive the X and the Y motors at specified speeds.

Instruction	Interpretation
JG 10000,-20000	Set speeds
AC 100000,40000	Set accelerations
BGXY	Start motions

after a few seconds, command:

JG -40000	New X speed

and then

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```
JG  ,20000          New Y speed
```

These cause velocity changes including direction reversal. The motion can be stopped with the instruction

```
ST                  Stop
```

Example 8 - Operation Under Torque Limit

The magnitude of the motor command may be limited independently by the instruction TL. The following program illustrates that effect.

```
Instruction         Interpretation
TL  1               Set output limit of X axis to 1 unit
JG  10000           Set X speed
BGX                 Start X motion
```

The X motor will probably not move as the output signal is not sufficient to overcome the friction. If the motion starts, it can be stopped easily by a touch of a finger.

Increase the torque level gradually by instructions such as

```
TL  4               Increase torque to 4 units
```

The maximum level of 127 units provides the full output torque.

Example 9 - Interrogation

The values of the parameters may be interrogated. For example, the instruction

```
GN  ?
```

returns the value of the gain of the X axis. Similarly, the instruction

```
GN  ,,?
```

returns the value of the Z axis gain.

```
GN  ?,?,?
```

returns the gain values for the three axes.

The same procedure applies to other parameters such as KI, ZR, FA, etc.

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Example 10 - Operation in the Buffer Mode

The instructions may be buffered before execution as shown below.

```
Instruction          Interpretation
WT  20000            Wait 20000 milliseconds before reading the
                      next instruction
PR  600000           Distance
SP  10000            Speed
BGX                  Start X motion
JG  ,2000            Set Y speed
AD  400000           Wait until X moved 400,000 counts
BGY                  Start Y motion
AMX                  After X motion is complete
TPX                  Tell position of X
STY                  Stop Y motion
```

Example 11 - Motion Programs

Motion programs may be edited and stored in the memory. They may be executed at a later time.

The instruction

```
ED                   Editor
```

moves the operation to the editor mode where the program may be written and edited. The editor provides the line number. For example, in response to the first ED command, the first line is zero.

```
000  #A              Define label
001  PR 700          Distance
002  SP 2000         Speed
003  BGX             Start X motion
004  EN              End program
```

To exit the editor mode, input <cntrl>Q.

Now the program may be executed with the command

```
XQ  #A
```

Example 12 - Motion Programs with Loops

Motion programs may include conditional jumps as shown below:

```
Instruction          Interpretation
000  #A              Label
001  V1=1000         Set initial value of V1
002  PR V1           Move X motor V1 counts
003  BGX             Start X motion
004  AMX             After X motion is complete
005  WT 500          Wait 500 ms
```

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```
006  TPX                  Tell position X
007  V1=V1+1000           Increase the value of V1
008  JP 2, V1<10000       Repeat if V1<10000
009  EN                   End
```

To start the motion, command:

```
XQ  #A
```

Example 13 - Motion Programs with Trip Points

The motion programs may include trip points as shown below:

```
Instruction              Interpretation
000  #B                  Label
001  DP 0,0              Define initial positions
002  PR 30000,60000      Set targets
003  SP 5000,5000        Set speeds
004  BGX                 Start X motion
005  AD 4000             Wait until X moved 4000
006  BGY                 Start Y motion
007  AP 6000             Wait until position X=6000
008  SP 2000,50000       Change speeds
009  AP ,50000           Wait until position Y=50000
010  SP 10000            Change speed of X
011  EN                  End program
```

Example 14 - Control Variables

Objective: To show how control variables may be utilized.

```
Instruction              Interpretation
000  #A                  Label
001  PR 4000             Initial position
002  SP 2000             Set speed
003  BGX                 Move X
004  AMX                 Wait until move is complete
005  WT 50               Wait 50 ms
006  V1= -PX             Determine distance to zero
007  PR V1/2-0.5         Command X move
008  BGX                 Start X motion
009  AMX                 After X moved
010  WT 50               Wait 50 ms
011  TPX                 Tell X position
012  JP 14, PX=0         Exit if position=0
013  JP 6                Repeat otherwise
014  EN                  End
```

To start the program, command

```
XQ  #A
```

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This program moves X to an initial position of 1000 and returns it to zero in increments of half the distance.

Example 15 - Control Variables and Offset

Objective: Illustrate the use of variables in iterative loops and use of multiple instructions on one line.

```
Instruction                          Interpretation
000  #A;KI0; DP0; V1=-80             Set initial values
001  #B; OF V1; WT 200               Set offset value
002  V2=PEX; MG OFFSET=; V1=         Report offset
003  MG POS ER=; V2=                 Report error
004  JP #C, V2<2;                    Exit if error small
005  V1=V1+1; JP #B                  Decrease offset
006  #C; EN
```

This program starts with a large offset and gradually decreases its value, resulting in decreasing errors.

Example 16 - Coordinated Motion

Objective: Move X and Y on a straight line.

```
Instruction              Interpretation
VP  50000,20000          X and Y distances
VS  10000                Vector velocity
VA  20000                Vector acceleration
BGS                      Start sequence
```

This program coordinates the motion of X and Y. They start and stop simultaneously.

Example 17 - Coordinated Circular Motion

Objective: Illustrate the generation of coordinated motion including circular arcs.

```
Instruction              Interpretation
VP  0,10000              Linear segment
CR  10000,180,-90        Circular segment
VP  30000,20000          Linear segment
VS  10000                Vector speed
VA  5000                 Vector acceleration
BGS                      Start sequence
```

The resulting coordinated motion is represented by Fig. 1.3.

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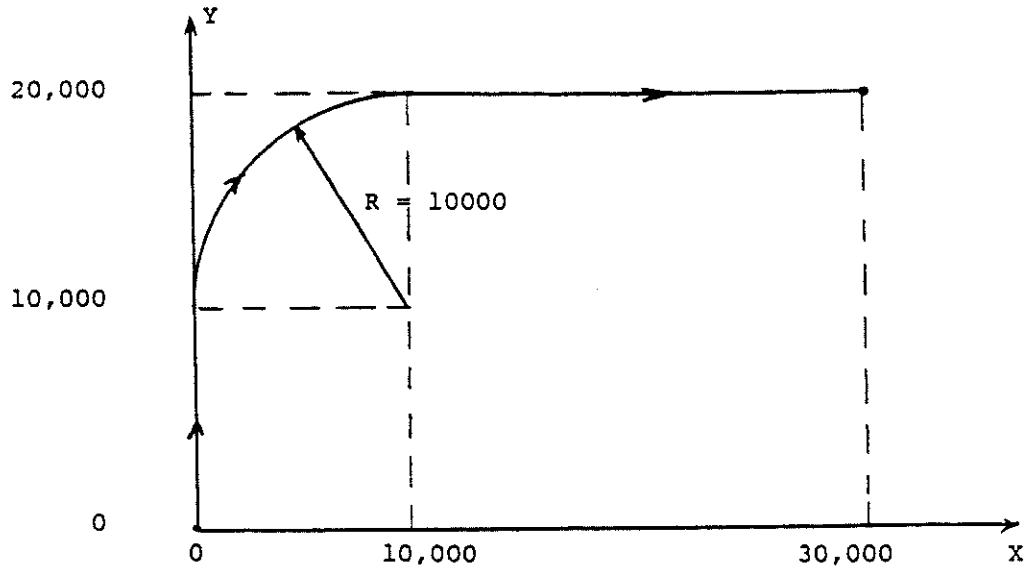


Fig. 1.3 - X-Y Path of Example 17

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2. SYSTEM COMPENSATION

The DMC-630 provides digital compensation with programmable coefficients. These coefficients, GN, ZR, KI, can be adjusted by the user to provide optimum system performance using the experimental procedure described below. A complete mathematical analysis is given in Appendix F. The SDK-600 software provides an automatic tuning procedure as well as the complete mathematical analysis.

2.1. Selecting Filter Parameters

The digital filter includes two functions: Lead and Integrator. The lead function stabilizes the system while the integrator adds to the accuracy. The compensation procedure is done in two steps: First, the lead filter is determined by the parameters GN, ZR; later, the integrator gain, KI, is selected.

The simplest procedure for the selection of the filter parameters is the following: The ZR parameter has a default value of 232, which is near optimal for most motors up to 1HP. For systems with faster response, the value of ZR may be decreased to as low as 220, whereas larger motors may operate more effectively with ZR values as high as 245.

The gain parameter, GN, depends on the amplifier, the motor and the load. The selection procedure starts with the minimum value of GN 1 and increases it gradually. As the gain increases, the system response follows the input more closely and there is less overshoot. However, beyond a certain gain, the system becomes less stable and may become oscillatory. If that occurs, lower the gain to the stable range.

Another method for selecting the ZR and GN parameters is by observing the step response. The motor is commanded to step back and forth, and its response is monitored and displayed on the PC screen using the SDK-600 software from Galil.

The system may be commanded to step back and forth with the following program.

```
000  #A;SP 120000;AC 200000;V1=40     Set parameters
001  V1=-V1;IPV1;AMX;WT 50;JP 1;EN    Step back and forth
```

When using the step response test, it is a good idea to command a small step such as 40 counts to prevent saturation of the elements. The resulting step response of the motor may be observed on the PC screen using the SDK software which displays position versus time.

The step response may be of one of the forms shown in Fig. 2.1. Curve (a) represents a slow underdamped response that can be improved by larger values of GN and ZR. Response b is the ideal one and response c is underdamped and requires reduced gain.

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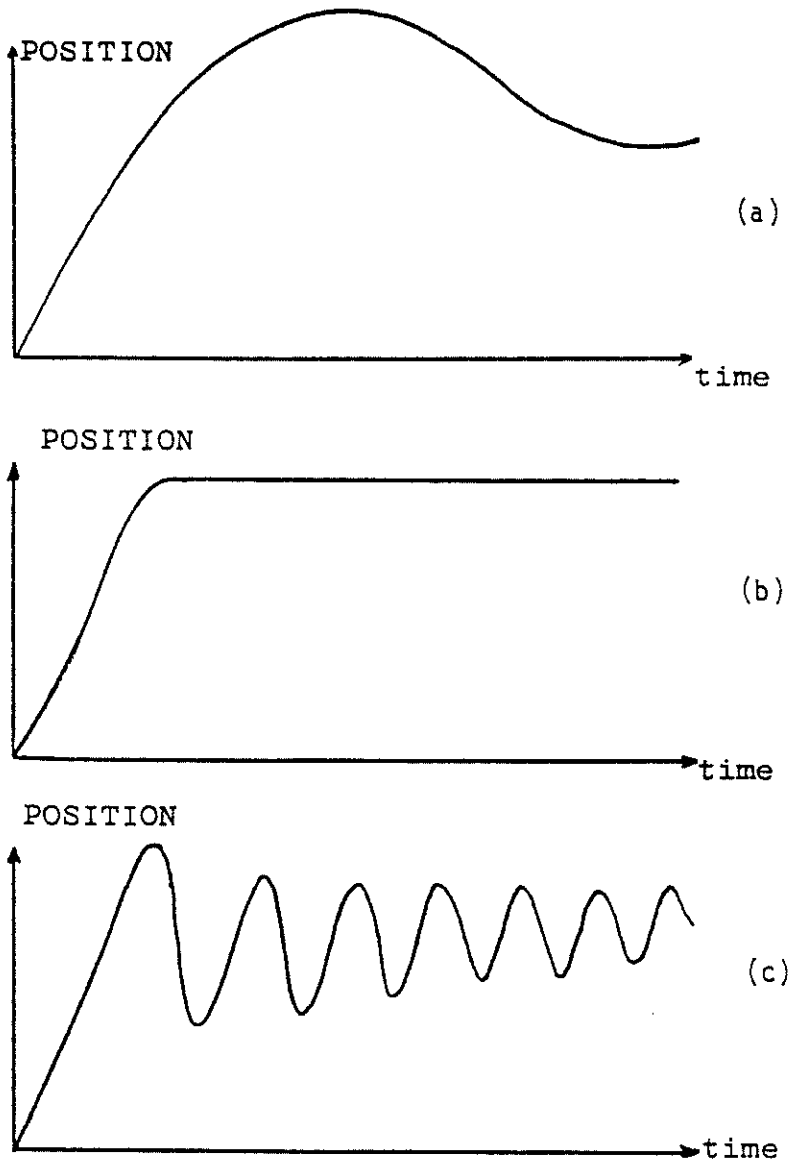


Fig. 2.1 - Typical Step Responses

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Once the lead compensation is selected, KI may be added starting with KI 1, and gradually increasing it until the position error observed when the motor is at rest is eliminated. Monitor the position error by commanding TE. If the system becomes oscillatory, reduce the integrator KI.

2.2. Other Compensation Features

The DMC-630 controller has other features that can help with the system design. These are

FA - Acceleration Feedforward
TL - Torque Limit
TM - Sampling Time

The effect of these features is described below:

Acceleration Feedforward

The FA instruction adds a feedforward term to the motor command. This added term is proportional to both FA and the commanded acceleration. The gain of FA is such that when the acceleration equals 262144 and FA 127, the feedforward signal equals 10V. The acceleration feedforward will reduce the following error and will speed up the motion time.

Torque Limit

The torque limit (TL) instruction will limit the magnitude of the motor command. The normal range of the motor command is between -10V and +10V. The range can be limited between -a and +a volts. Suppose that we command

TL n

This limits the magnitude to a volts where

$$a = \frac{10n}{128} \text{ Volts}$$

The limit on the motor command limits the motor torque. TL can also be viewed as a software adjustable current limit, if the amplifier is a current amplifier. The default value of TL if 127.

Note: For the DMC-6X1 Series, the torque limit default value is 2047 for a 12-bit DAC.

The mathematical model of FA and TL is shown in the diagram of Fig. 2.2.

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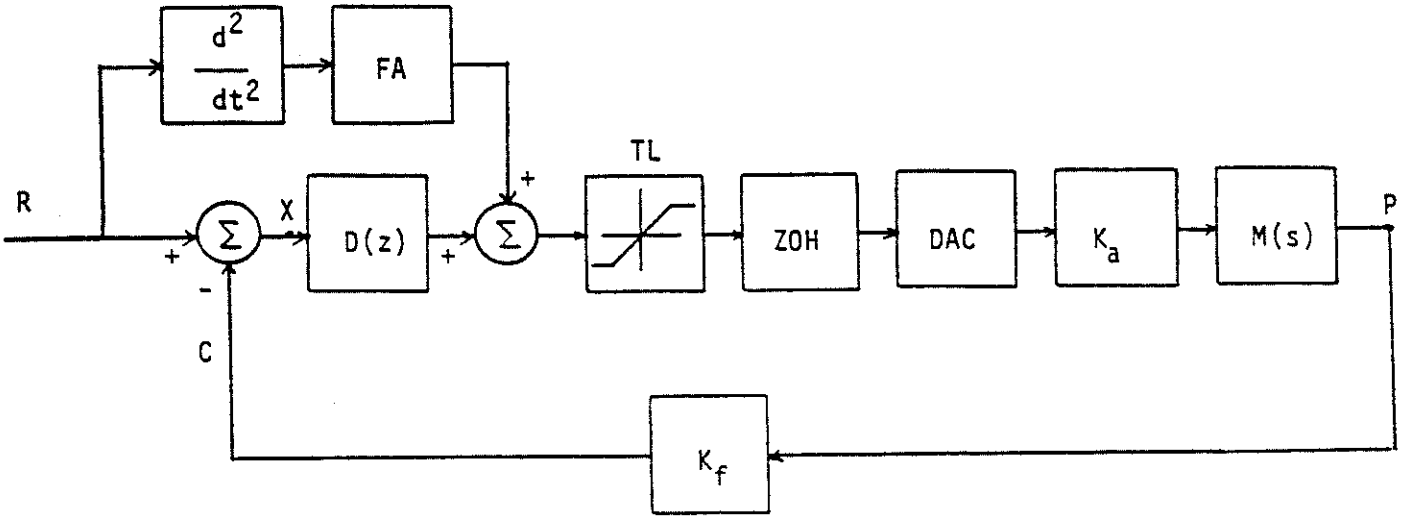


Fig. 2.2 - Mathematical model of FA and TL.

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Sampling Time

The sampling time can be changed with the instruction TM. The command

TM n

will increase the sampling time from 1000 μs to n μs (n>1000). The change in sampling time has several effects on the system. First, it lowers the motor speed by a factor of n/1000. It also lowers the motor acceleration by the ratio $(n/1000)^2$.

A secondary effect is on the digital filter. It introduces longer delay that will normally result in less stable systems. After a change in TM, the filter parameters have to be re-adjusted for best performance.

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3. COMMUNICATION

3.1. Overview

The DMC-630 receives commands from an IBM PC/XT/AT or compatible computer. The controller is configured as a standard IBM PC Bus card that is mapped into the I/O space. Communication between the DMC-630 and IBM PC is in the form of ASCII characters, where data is sent and received via READ and WRITE Registers on the DMC-630. A handshake is required for sending and receiving data.

The DMC-630 contains a 256 character write FIFO buffer, which permits sending commands at high speeds ahead of their actual execution. It also contains a 256 character read buffer.

3.2. Communication Registers - Description

Register	Description	Address	READ/WRITE
READ	for receiving data	N	Read only
WRITE	for transmitting data	N	Write only
STATUS	for handshaking	N + 1	Read only
CLEAR BUFFER	for clearing write FIFO buffer	N + 1	Write only

Status Bits	7	6	5	4	3	2	1	0
					Error	Buffer	Write	Read

Status Bit	Name	Logic State	Meaning
0	Read	0	Data to be read*
		1	No data to be read, must not read
1	Write	0	Buffer full, not ready to write
		1	Buffer not full, ok to send characters
2	Write Buffer empty	0	Buffer empty
		1	Buffer not empty
3	Error	0	Excessive position error on any axis
		1	No error

*If read buffer gets full, controller holds execution of communication.

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3.3. Registers - Address Selection

The READ and WRITE registers occupy the same address, N, in the I/O space. The STATUS and CLEAR BUFFER registers occupy the next address, N+1.

The selection of the address (N) is done by placing the appropriate jumpers on the jumpers labeled A2 through A8 on the DMC-630.

Since the allowable address of the DMC-630 starts at 512, A2 through A8 denote 2^2 through 2^8 bits of an address after 512 has been subtracted from it.

For example, to select an address (N), first make sure it is divisible by four. Then subtract 512 from N. Next, use jumpers A2 through A8 to represent the binary result. A jumper across A represents a binary zero. An open across A represents binary one.

Example:

Select address (N) of the DMC-630 as 1000.

Step 1 - Check if N is divisible by 4.

$$\frac{1000}{4} = 250$$

Step 2 - Subtract 512 from N.

1000 - 512 = 488

Step 3 - Convert (N - 512) into binary

488 Decimal = 1 1 1 1 0 1 0 0 0

$2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0$

Step 4 - Let A^2 through A^8 denote bits 2^2 through 2^8 of (N - 512).

Then, jumper bits represented by zero. Bits represented by one, leave open.

JUMPER CONFIGURATION

A8	A7	A6	A5	A4	A3	A2
0	0	0	0	X	0	X

X = Jumpered

0 = Open

NOTE: The default address of the DMC-630 is 1000 (A4 and A2 jumpered).

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3.4. Handshake

READ - To receive data from the DMC-630, bit 0 of the status register must be checked. If bit 0 is zero, the DMC-630 has at least one data-byte in the READ register to be read. Bit 0 must be checked for the appropriate state for every character read.

WRITE - To transmit data to the DMC-630, bit 1 of the status register is checked. If bit 1 is one, the DMC-630 FIFO buffer is not full, and up to 256 characters may be written to the data register. If bit 1 is zero, the buffer is full and no additional data can be sent. The buffer may be cleared by writing to the CLEAR BUFFER Register however, previous data sent will be lost.

NOTE: Failure to ever read the data in the read register will ultimately cause the DMC-630 to hang up once the Read FIFO is full.

3.5. Controller Response to Data

Most DMC-630 instructions are represented by two characters followed by the appropriate parameters. Each instruction must be terminated by a carriage return or semicolon.

Instructions are sent in ASCII, and the DMC-630 decodes each ASCII character (one byte) one at a time. It takes approximately 100 Ìsec for the controller to decode each character. However, the PC can send data to the controller at a much faster rate because of the FIFO buffer. The decoding of the carriage return or ; is equivalent in length to five bytes of data.

After the instruction is decoded, the DMC-630 returns a colon (:) if the instruction was valid or a question mark (?) if the instruction was not valid or was not recognized.

For instructions requiring data, such as Tell Position (TP), the DMC-630 will return the data followed by a carriage return, line feed and
: .

It is good practice to check for : after each command is sent to prevent errors. An echo function is provided to enable associating the DMC-630 response with the data sent. The echo is enabled by sending the command EO 1 to the controller.

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4. PROGRAMMING

4.1. Instruction Set Format

The DMC-630 provides an extensive instruction set for programming a variety of motion applications. Most instructions in the DMC-630 instruction set are represented by two characters followed by an applicable parameter. These instructions are sent one character at a time in ASCII. A semicolon or carriage return terminates the instruction. There are a few special instructions which are non-ASCII. These will be discussed later.

Example:

```
PR  4000;
```

PR is the 2 character instruction code (Position Relative). 4000 is the parameter which represents the required position value. The ; terminates the instruction.

A complete listing of instructions is given in Section II of this user manual. The instructions are listed alphabetically.

Where applicable, instruction parameters may be specified for the X,Y,Z axis. Here, the axis data is separated by commas. Even if there is no data for one axis, the commas must be used to assure correct axis assignment.

The format is x,y,z.

Example:

PR 2000	Specify X data only
PR 2000,4000	Specify X and Y data
PR 2000,4000,8000	Specify X,Y,Z data
PR ,4000	Specify Y only
PR ,4000,8000	Specify Y and Z
PR ,,8000	Specify Z only
PR 2000,,8000	Specify X and Z

Instructions which require X,Y,Z data are followed by x,y,z in the instruction listing. x,y and z are replaced with the appropriate data.

Other instructions require action to be taken on the X,Y or Z axis. These instructions are followed by uppercase XYZ in the instruction set. To cause action on the desired axis or axes, the instruction must be followed by X,Y or Z. If no axes follows the instruction, action will take place on all three axes. S is used to specify a coordinated X,Y sequence.

Example:

BG X	Begin X axis motion only
BG XY	Begin X and Y axes
BG XYZ	Begin X,Y,Z axes
BG Y	Begin Y only
BG YZ	Begin Y and Z axis

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```
BG Z                        Begin Z
BG XZ                       Begin X and Z
BG                          Begin X,Y,Z axis
BG S                        Begin coordinated sequence
BG SZ                       Begin coordinated sequence and Z axis
```

The DMC-630 also provides interrogation instructions. These instructions return data.

Example: The position of the X axis is 0, Y is -1, and Z =1

```
:TP X                       Tell position of X axis
0000000                     Position Data
:TP XY                      Tell position of X,Y axes
0000000,-0000001            Position Data
:TP                         Tell position of X,Y,Z axes
0000000,-0000001,0000001    Position Data
```

The data is entered and reported back in hexadecimal or decimal depending on if the DMC-630 is configured for the HX or DC mode. In HX, the data is returned in two's complement hexadecimal.

For example, if the X axis is at position -1, the response of the controller is

```
TP X                        Request position of X
FFFFFF                      Returns position in Hex;two's complement
```

4.2. Writing Motion Programs

Instructions can be sent from the PC for immediate execution or they may be downloaded into the DMC-630 memory. The DMC-630 memory stores up to 500 lines of 32 characters per line. Multiple commands may be stored on a line. A semicolon separates each command on a line. Programs and subroutines are distinguished by labels (#). Programs are entered into memory using the editor.

Example:

```
:ED                                 Enter Editor
000 #A                              Label #A, Begin Program A
001 PR 1000;SP 20000;AC 100000      Define position, speed and acceleration
002 BG X                            Begin motion
003 AMX; SB1                        After Motion Complete, Set Bit 1
004 EN                              End Program
<control> Q                         Quit Editor
:XQ #A                              Execute Program #A
```

In the example above, the command ED is used to put the DMC-630 in the edit mode. The edit mode is entered at the first available line number where a command doesn't already exist, or the ED command can be followed by a line number or label specification.

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In the edit mode, the memory line numbers are displayed from 000 to 200 decimal. 000 is the first line in memory, 001 is the next line and so on. Each line can contain up to 32 characters.

The first line number in the example contains the program label, #A. All programs and subroutines must start with a label and end with an EN command.

Line number 001 contains the instructions for specifying the position, speed and acceleration. Each instruction is separated by a semicolon since they are on the same line. The next line begins the motion on the X-axis. Line number 003 is the after motion complete command. The DMC-630 sequencer waits at this instruction until the motion is complete. When the motion is complete, the next instruction, SB1, is given. Line number 004 is the end command.

The program starting at label #A and ending at the EN statement is now entered. To execute the program, you must exit the edit mode. Type <control>Q to quit the editor. Type XQ #A to execute program #A.

Instructions which are useful in writing programs are listed below and are described in the following sections.

AD	x,y,z	Continue program after distance moved
AI	n	Continue program after input
AM	XYZS	Continue program after motion complete
AP	x,y,z	Continue program after position reached
EN		End Program
JP	destination,condition	Jump to destination on condition
JS	destination,condition	Jump to subroutine on condition
MG	XXXX	Print a message
NO	XXXX	No operation (comment)
RE	n	Return from Error Routine
WT	n	Continue program after n msec have elapsed
XQ	n	Execute program at label or line number
Vn=		Define a variable
#n		Define a label

Labels

Programs and subroutines must begin with a label. Labels are defined using the # followed by one lower case or upper case letter. There are also three special labels, ^, [and], which are used to define input interrupt subroutines, limit switch subroutines and error handling subroutines, respectively.

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Examples of labels are:

```
VALID Labels
     #A
     #a
     #Z
     #[
```

To execute a program that begins with a label, enter XQ #n, where n is the label.

Conditional Commands

Conditional commands control the execution order and timing of statements in a program. For example, the wait command (WT) causes the program to hold execution at the current instruction until the specified time has elapsed. The After Motion (AM) instruction holds execution of the next command until the motion is complete on the specified axis. The AD instruction waits until the specified relative distance has elapsed.

The AI command waits for the specified input. AP waits until the specified absolute position is detected. AS waits until the motion profile has reached the specified speed.

Example:

```
#A                          Label #A
PA 1000,2000,3000;BG        Begin X,Y,Z
AMX; CB 1                   After X done, clear bit 1
AMY; SB 2                   After Y done, set bit 2
AMZ; CB 2                   After Z done, clear bit 2
AI 5                        After input 5 is set
PA 0,0,0;BG                 Begin motion to origin
EN                          End Program
```

The other conditional instructions are the JP and JS instructions which cause a branch to another program label, line number or subroutine if a logical condition is satisfied. The JP and JS instruction have the format:

```
JS destination, logical condition
JP destination, logical condition
```

The destination is a program line number or label. The condition is the status of motion, motor off, error, an input or output line, time, variable or limit switch. The use of logical operators =, <, > is permitted in specifying a condition. Mathematical operations are also permitted. Arithmetic operations are performed from left to right.

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Jump Conditions

Condition	Meaning
LX=0 (=1)	X latch armed (disarmed) *
LY=0 (=1)	Y latch armed (disarmed) *
LZ=0 (=1)	Z latch armed (disarmed) *
LFX=0 (=1)	X Forward limit switch is low (is high)
LFY=0 (=1)	Y Forward limit switch is low (is high)
LFZ=0 (=1)	Z Forward limit switch is low (is high)
LRX=0 (=1)	X reverse limit switch is low (is high)
LRY=0 (=1)	Y reverse limit switch is low (is high)
LRZ=0 (=1)	Z reverse limit switch is low (is high)
MX=0 (=1)	X-axis not in motion (in motion)
MY=0 (=1)	Y-axis not in motion (in motion)
MZ=0 (=1)	Z-axis not in motion (in motion)
OX=0 (=1)	X-axis motor is on (motor-off)
OY=0 (=1)	Y-axis motor is on (motor-off)
OZ=0 (=1)	Z-axis motor is on (motor-off)
PX={specify number}	X-axis position
PY={specify number}	Y-axis position
PZ={specify number}	Z-axis position
PDX={specify number}	X-axis dual encoder position *
PDY={specify number}	Y-axis dual encoder position *
PDZ={specify number}	Z-axis dual encoder position *
PCX={specify number}	X-axis captured position *
PCY={specify number}	Y-axis captured position *
PCZ={specify number}	Z-axis captured position *
PEX={specify number}	X-axis position error
PEY={specify number}	Y-axis position error
PEZ={specify number}	Z-axis position error
T= {specify number}	Time

*Available for DMC-6X1 Series only.

Mathematical Operations, Jumps if equation satisfied

Example: V1+V2<V3 V2*V4/2=0

O0=0 (=1)	Output 0 is low (is high)
O1=0 (=1)	Output 1 is low (is high)
O2=0 (=1)	Output 2 is low (is high)
O3=0 (=1)	Output 3 is low (is high)
O4=0 (=1)	Output 4 is low (is high)
O5=0 (=1)	Output 5 is low (is high)
O6=0 (=1)	Output 6 is low (is high)
O7=0 (=1)	Output 7 is low (is high)
I1=0 (=1)	Input 1 is low (is high)
I2=0 (=1)	Input 2 is low (is high)
I3=0 (=1)	Input 3 is low (is high)
I4=0 (=1)	Input 4 is low (is high)
I5=0 (=1)	Input 5 is low (is high)
I6=0 (=1)	Input 6 is low (is high)
I7=0 (=1)	Input 7 is low (is high)
I8=0 (=1)	Input 8 is low (is high)

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Example:

```
JP  #A, I1=1              Jump to label A if input 1 is high
JP  #B, V1+V2<V3          Jump to label B if V3 is greater than or
                            equal to the sum of V1 and V2
JP  2, PEX=0              Jump to line 2 if position error of X
                            axis equals zero
JP  #A, MX=1              Jump to label A if X-axis is in motion

JP  #B, MY=0              Jump to label B if Y-axis motion
                            complete
JP  #C, 0X=1              Jump to label C if X-axis motor is off
JP  #A, LFX=0             Jump to label A if forward limit switch
                            X is low
JP  #B, LRY=1             Jump to label B if reverse limit switch
                            Y is high
JS  #C, V1*V6=4           Jump to subroutine C if the product of
                            V1 and V6 is equal to 4
JP  #D, PY=PX/2           Jump to D if the position of Y equals
                            the position of X divided by 2.
JP  #e                    Jump to e
```

Variables

The DMC-630 allows for the use of variables which provide programming flexibility. Variables may be defined, manipulated and assigned to system parameters.

The DMC-630 provides 64 user definable variables which are specified by the commands V0 through V63. The LT (Let) command defines the variable, however, if Vn= is given, the LT is assumed. Variables can be defined as real numbers, or be defined as the actual motor position (PX,PY,PZ), dual encoder position (PDX,PDY,PDZ) - for DMC-6X1 Series only, position error (PEX,PEY,PEZ), motion status (MX, MY, MZ), motor off (0X, 0Y, 0Z), as the state of input and output lines and as Time (T). Variables are real numbers between the range of +/- 8388607.000. The fractional part has a resolution of 1/256th.

Example:

```
LT  V1=6                  Define V1 as the value 6
V2 = 10.125               Define V2 as the value 10.125
V3 = PEX                  Define V3 as the position error of X
LT  V7=PY                 Define V7 as the Y position
V8 = I2                   Define V8 as the state of input line 2
V6 = I0                   Define V6 as the binary number formed by
                            the four input lines I4-I1
V1 =                      Return value of V1
```

Variables can be manipulated using the mathematical operations of add, subtract, multiply and divide. These operations are executed from left to right.

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Example:

```
V1 = V2+V3*2          Define V1 as the sum of V2 and V3 then
                        multiplied by 2
V63 = PEX/2           Define V63 as the position error of X
                        divided by 2
V10 = PX-PY           Define V10 as the position of X minus
                        the position of Y
V11 = 2*V7            Define V11 as the product of 2 times V7
V2 = PDX              Define V2 as dual encoder position of X
```

Variables can be defined and manipulated within a motion program. They can also be assigned by the host computer during program execution. Variables can also be tested using the logical operations in the conditional jump statement.

Example:

```
JP  #A, V1<V2         Jump to A if V1 is less than or equal to
                        V2
JP  #B, PEX=0         Jump to B if position error of X
                        equals zero
JP  #C, I1=1          Jump to C if input 1 is high
```

Once variables are defined and manipulated, they can be assigned as the value of a motion parameter. For example, the position error of one axis can be defined as the new position of another axis.

Example:

```
PR  PEX,PEY           Define X and Y travel as X and Y
                        position error
SP  V1/2              Set the speed as V1 divided by 2
AC  V1*V2             Set the acceleration as V1
                        multiplied by V2
```

Inputting Data

The command, IN, is used to prompt the user to enter a value. The entered value is assigned to the specified variable.

Example:

```
IN ENTER SPEED,V1     Prompts user to "Enter Speed".
                      The entered value is assigned to
                      variable V1.
```

Print Statement

The MG command can be used to print a statement during program execution. Up to 29 characters can follow the MG command. The final (CR)(LF) may be inhibited by ending the command with a ; . For example, variable values can be returned using ;Vn= following the MG statement.

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Example:

```
Statement                  Function
MG Hello There             Prints "Hello There"
MG Position of X=;V1=      Prints "Position of X = 0000000.000"
```

The OP code, NO, can be used as a comment statement. During execution, the command has no operation. Up to 29 characters can follow the NO command.
Subroutines

Subroutines may be used in sequences. Subroutines begin with a specified line number or label and end with an END (EN) statement. Subroutines are called from the main program with the jump subroutine instruction JS, followed by a label or line number operand. Up to 5 subroutines can be nested.

An example of a subroutine to draw a square 500 counts per side is given below. The square is drawn at vector position 1000,1000.

Example:

```
#S;NO Square Subroutine  Begin sequence subroutine
V1=500;JS #L             Define length of side
V1=-V1;JS #L             Switch direction
EN                       End subroutine
#L;PR V1,V1;BGX          Define X,Y; Begin X
AMX;BGY;AMY              After motion on X, Begin Y
EN                       End subroutine
#M;NO Main Program       Begin Main Program
CB0                      Clear output bit 0 (pick up pen)
VP 1000,1000;BGS         Define vector position; move pen
SB0                      Set output bit 0 (put down pen)
JS #S;CB0                Jump to square subroutine
EN                       End Main Program
```

4.3. Editing Motion Programs

DMC-630 programs may be entered, modified or deleted using the DMC-630 editor. The editor instructions are listed below and described in detail.

EDITOR INSTRUCTIONS

Instruction	Function
ED #A or n	Edit line
<RETURN>	Save line
<cntrl>P	Previous line
<cntrl>I	Insert line
<cntrl>D	Delete line
<cntrl>Q	Quit editor
LS #A or n, #A or n	List (not used in Edit mode)

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ED

The ED command puts the DMC-630 in the edit mode. If no operand follows the command, the editor will default to the last line of the program. The user can edit a specific line number or label using the operand n or #A. When ED0 is typed, the terminal displays:

```
:ED0
000
```

The cursor will now be following the line number.

If a line number is given that has not previously been edited, the DMC-630 will begin editing at the last line edited.

The maximum number of lines in a program is 500. Line numbers will appear as 000, 001, 002 and so on.

Example:

Instruction	Function
:ED	Puts editor at end of program
:ED 5	Puts editor at line 5
:ED #C	Puts editor at label #C

<RETURN>

Typing the return key causes the current line to be saved. The editor will automatically advance to the next line. Thus, hitting a series of <RETURN> will cause the editor to advance a series of lines.

<cntrl>P

The <cntrl>P command moves the editor to the previous line.

<cntrl>I

The <cntrl>I command inserts a line above the current line. For example, if the editor is at line number 2 and <cntrl>I is applied, a new line will be inserted between lines 1 and 2. This new line will be labeled line 2. The old line number 2 is renumbered as line 3.

<cntrl>D

The <cntrl>D command deletes the line currently being edited. For example, if the editor is at line number 2 and <cntrl>D is applied, line 2 will be deleted. The previous line number 3 is now renumbered as line number 2.

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<cntrl>Q

The <cntrl>Q quits the editor mode. In response, the DMC-630 will return a colon.

LS

The LS command lists the program. If no operand follows the LS command, the entire program will be listed. The user can start listing at a specific line or label using the operand n or #A. A command and new line number or label following the start listing operand specifies the location at which listing is to stop. The LS command cannot be given when the DMC-630 is in the edit mode.

Example:

Instruction	Function
: LS	List entire program
: LS 5	Begin listing at line 5
: LS 5,9	List lines 5 thru 9
: LS #A,9	List line label #A thru line 9

4.4. Executing a Program

A program can be executed using the XQ command. The XQ command must always be followed by a label which defines the beginning of a program to be executed. For example, XQ#A means execute the sequence starting at label #A. Remember to Quit the edit mode before executing a program.

4.5. Debugging Programs

The DMC-630 provides trace and error code commands which are used in debugging programs. The trace command may be activated using the command, TR1. This command causes each line in a program to be sent out to the communications port immediately prior to execution. The TR1 command is useful for debugging programs. TR0 disables the trace function. The TR command may also be included as part of a program.

If there is a program error, the DMC-630 will halt program execution at the line number at which an error occurs. This line will be displayed. The user can obtain information about the type of error condition that occurred by using the command, TC. This command reports back a number between 1 and 255. These numbers correspond to the following error conditions. For the enhanced DMC-6X1 Series, the TC1 command will also report the text error condition.

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Error Codes:

1	Unrecognized command
2	Command only from program
3	Command not valid in program
4	Operand error
5	Command too long
6	Number out of range
7	Command not valid while running
8	Command not valid when not running
9	Bad variable number
10	Empty sequence line or label
11	Invalid label or line number
12	Subroutine more than 8 deep
13	JG only valid when running in jog mode
14	Checksum error
16	IP incorrect sign during position move or IP given during forced deceleration
17	Edit & DL not valid when program running
18	Command not valid when contouring
20	Begin not valid with motor off
21	Begin not valid while running
22	Begin cannot be executed because of limit switch
24	Begin not valid because no VP,CR sequence defined
25	Variable not given in IN command
26	AM must not have more than one parameter
29	Not valid during coordinated move
30	Sequence segment too short
31	Total move distance in a sequence > 8 million
32	More than 255 segments in a sequence
33	Download Error (line too long or too many lines)
40	Contouring record format error
41	Contouring record range error
42	Contour record data being sent too slowly
45	Array index or syntax error
46	Gear axis both master and follower
50	MP only valid in Master/Slave Mode
51	No sequence in Master/Slave

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5. MODES OF MOTION

The DMC-630 controller can operate in various modes of motion including profiled positioning of each axis, incremental positioning, jogging and coordinated motion of two axis. In all of these modes, the DMC-630 must be in Servo operation.

5.1. Profiled Positioning (Independent)

In this mode, the acceleration rate (AC), slew speed (SP) and end position (PA) or (PR) for each axis are specified. On Begin (BG), the DMC-630 generates a trapezoidal or triangular velocity profile and position trajectory. A new command position along the profile is generated every 1 msec. Motion is complete when the last position command or target position is generated by the DMC-630. The actual motor motion may not be complete at this point.

The Begin command can be issued for all axes either simultaneously or independently. A new Begin command for motion on an axis may not be given until motion is complete on that axis.

The speed can be changed at any time during motion. The acceleration cannot be changed during positioning. A stop command can be issued at any time to decelerate the motor to a stop before it reaches its final position.

The IP n command may be used while the motor is moving to specify a new position target. The new end position is equal to the old end position plus the increment, n. Upon receiving the IP command, a revised profile will be generated for motion towards the new end position. The position increment, n, must be in the same direction of motion. The IP command does not require a begin. Note: If the motor is not moving, the IP n command is equivalent to the PR and BG command combination.

Example:

Required Motion Profiles

X-Axis	500	counts	Position
	10000	count/sec	Speed
	500000	counts/sec^2	Acceleration
Y-Axis	1000	counts	Position
	15000	count/sec	Speed
	500000	counts/sec^2	Acceleration
Z-Axis	100	counts	Position
	5000	counts/sec	Speed
	500000	counts/sec^2	Acceleration

Start X and Y motion at same time. After 20 msec, start Z motion. If input 1 is high, stop Y motion.

```
000 #A                          BEGIN PROGRAM
001 PR 500,1000,100             Specify position
```

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```
002 SP 10000,15000,5000          Specify speed
003 AC 500000,500000,500000      Specify acceleration
004 BG XY                        Begin X and Y
005 WT 20;BG Z                   Wait 20 msec and begin Z
006 JP #B,I1=0                   Jump if input 1 is low
007 STY                          Stop Y
008 #B;END                       END PROGRAM
```

Figure 5.1 shows the velocity profiles for the X,Y and Z axis.

5.2. Jog Mode

In this mode, an end position is not specified and the motor slews at the specified speed until a stop (ST) command is issued. The acceleration and jog speed are specified using the AC and JG command, respectively. The direction of motion is specified by the sign of the JG parameter. Motion begins on the Begin command.

The jog speed, acceleration, and direction of motion may be changed at any time during motion. The IP n command can also be used to instantly change the motor position. Upon receiving this command, the motor will instantly try to servo to a position which is equal to the increment, n, plus the current position. This command is useful when trying to synchronize the position of two motors while they are moving.

It should be noted that the DMC-630 operates as a position controller even while in the jog mode. The DMC-630 converts the speed and acceleration profile into a position trajectory. A new position target is specified every 1 msec. This method of control results in very precise speed regulation with phase lock accuracy.

Example:

Required Motion Profile

1) Jog X motor at 500000 counts/sec
   Direction is forward

2) Start Y motor after 1000 msec
   Jog Y at 20000 counts/sec
   Direction is reverse

3) After 2000 msec
   Change X speed to 100000 counts/sec and change direction of X motion

4) Stop X and Y after Input 1 is high

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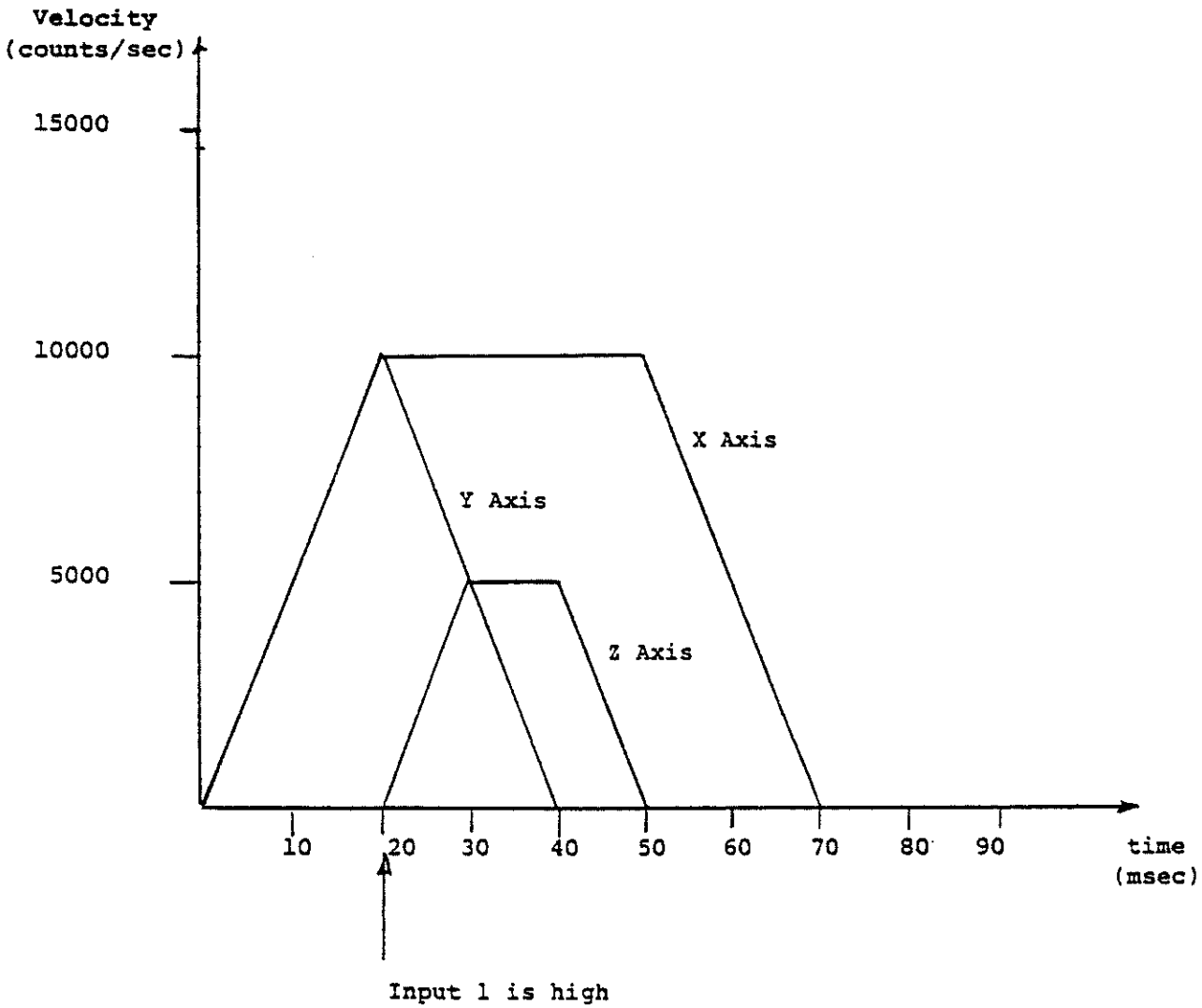


Fig. 5.1 - Velocity Profiles of X,Y,Z

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```
000 #A                          BEGIN PROGRAM
001 JG 500000,-20000            Set X,Y jog speeds and direction
002 AC 500000,500000            Set X,Y acceleration
003 BG X                        Begin jogging X
004 WT 1000;BGY                 After 1000 msec, begin jogging Y
005 WT 1000;JG -100000          After 2000 msec from Begin X, change
                                 speed and direction
006 AI 1;STXY                   After input 1 is high, stop X,Y
                                 motion
007 EN                          END PROGRAM
```

5.3. Coordinated Motion Sequences

Operation in this mode allows motion along the X and Y axis to be coordinated. The Z-axis is independent. In this mode, the vector position, vector speed (feedrate) and acceleration are specified. Both linear and circular arc segments can be specified. The coordinated motion mode provides continuous motion along the path.

Up to 255 straight line and arc segments can be given ahead of execution to specify a motion path or sequence. Upon the begin sequence (BGS) command, continuous motion along the segments is generated at the vector speed and acceleration.

The terms of coordinated motion are best explained in terms of the vector motion. The vector velocity, Vs, which is also known as the feed rate, is the vector sum of the velocities along the X and Y axes, Vx and Vy.

$$V_s = \sqrt{Vx^2 + Vy^2}$$

The vector distance is the integral of Vs, or the total distance traveled along the path. To illustrate this further, suppose that a string was placed along the path in the X-Y plane. The length of that string, represents the distance traveled by the vector motion.

The path consists of straight line segments and circular arcs. Up to 255 segments may be added to define a motion sequence. Larger numbers of segments must be broken into several sequences. The motor must stop at the end of each sequence.

The vector velocity is specified independently of the path to allow continuous motion. The path is specified as a collection of segments. For the purpose of specifying the path, define a special X-Y coordinate system whose origin is the starting point of the sequence. Each linear segment is specified by the X-Y coordinate of the final point expressed in units of resolution and each circular arc is defined by the arc radius, the starting angle and the angular width of the arc. The zero angle corresponds to the positive direction of the X-axis and the CCW direction of rotation is positive. Angles are expressed in degrees and the resolution is 1/256th of a degree. For example, the path shown in Fig. 5.2 is specified by the instructions:

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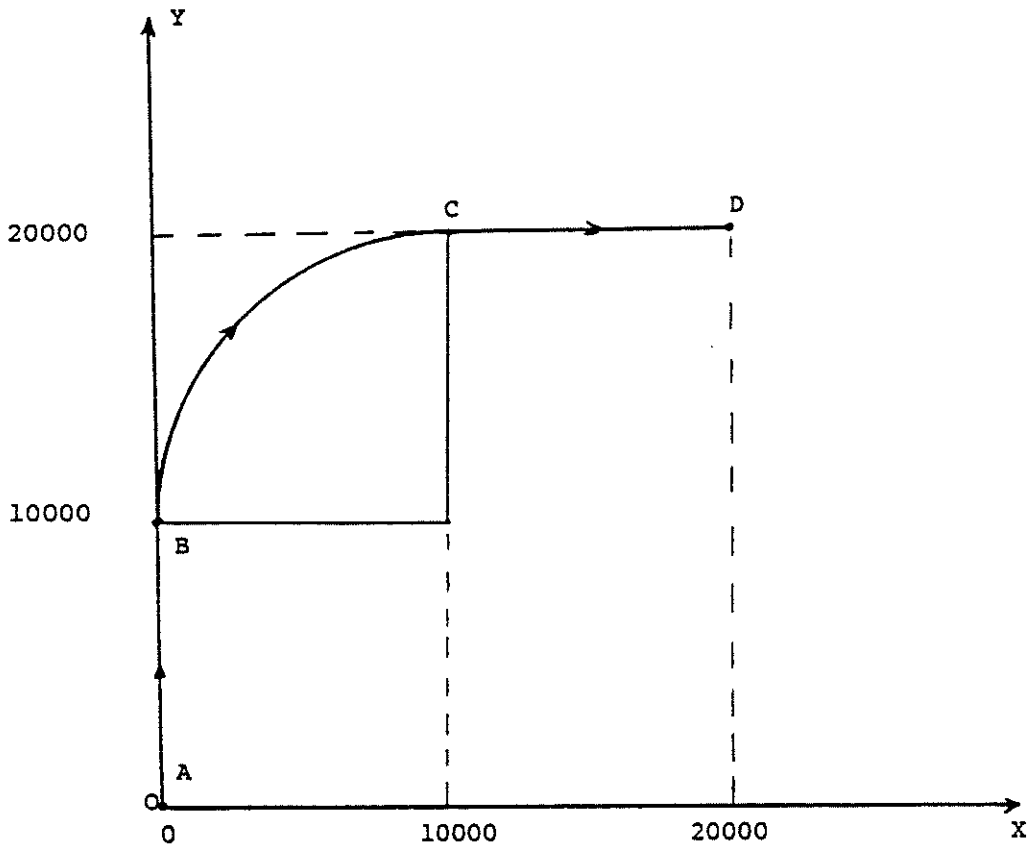


Fig. 5.2 - X-Y Motion Path

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```
VP  0, 10000
CR  10000, 180, -90
VP  20000, 20000
```

The first line describes the straight line vector segment between points A and B. The next segment is a circular arc, which starts at an angle of 180½ and traverses -90½. Finally, the third line describes the linear segment between points C and D. Note that the total length of the motion consists of the segments:

A-B	Linear	10000 units
B-C	Circular	$R\lvert\Delta\theta\rvert 2\pi = 15708$
		360
C-D	Linear	10000
	Total	35708 counts

In general, the length of each linear segment is

$$L_k = \sqrt{Xk^2 + Yk^2}$$

Where X_k and Y_k are the changes in X and Y positions along the linear segment. The length of the circular arc is

$$L_k = R_k \lvert\Delta\theta_k\rvert 2\pi/360$$

The total travel distance is given by

$$D = \sum_{k=1}^{n} L_k$$

This total distance must not exceed 8,388607. The velocity profile may be specified independently in terms of the vector velocity and acceleration.

For example, the velocity profile corresponding to the path of Fig. 5.2 may be specified in terms of the vector speed and acceleration.

```
VS  100000
VA  2000000
```

The resulting vector velocity is shown in Fig. 5.3.

The acceleration time, T_a, is given by

$$T_a = \frac{VS}{VA} = \frac{100000}{2000000} = 0.05s$$

The slew time, T_s, is given by

$$T_s = \frac{D}{VS} - T_a = \frac{35708}{100000} = -0.05 = 0.307\ s$$

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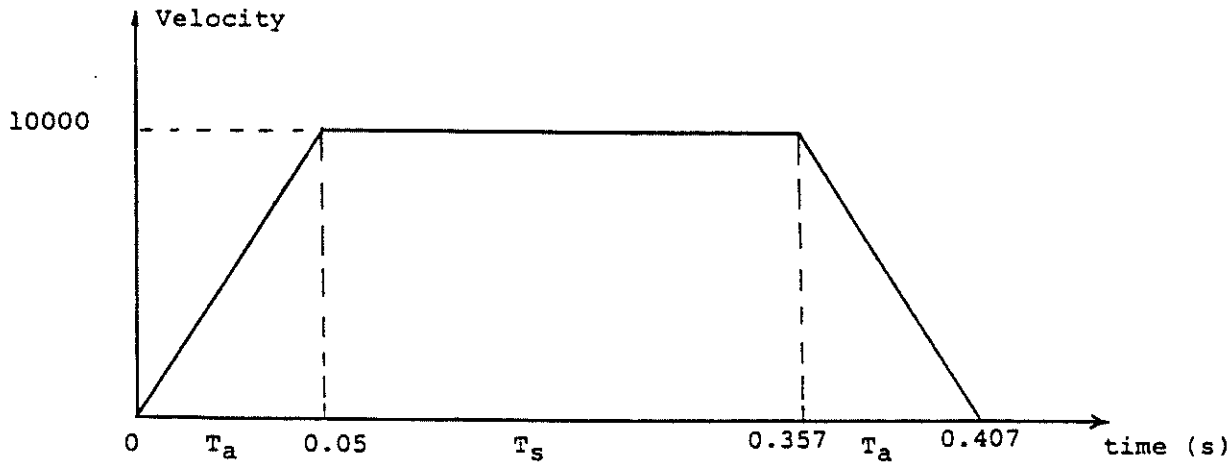


Fig. 5.3 - Vector Velocity Profile

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The total motion time, Tt, is given by

$$T_t = \frac{D}{VS} + T_a = 0.407s$$

The velocities along the X and Y axes are such that the direction of motion follows the specified path, yet the vector velocity fits the vector speed and acceleration requirements.

For example, the velocities along the X and Y axes for the path shown in Fig. 5.2 are given in Fig. 5.4.

Fig. 5.4a. shows the vector velocity. It also indicates the position point along the path starting at A and ending at D. Between the points A and B, the motion is along the Y axis. Therefore,

$$V_y = Vs$$

and

$$V_x = 0$$

Between the points B and C, the velocities vary gradually and finally, between the points C and D, the motion is in the X direction.

The following examples illustrate the generation of coordinated motion.

Example 5.1. - Linear Interpolation

Move the X-Y system along a straight line as shown in Fig. 5.5. with a vector velocity of 20,000 count/s and a vector acceleration of 100,000 count/s^2. The vector velocity is shown in Fig. 5.6.

The program consists of the following instructions:

```
VP  20000, 10000     Vector position
VS  20000            Vector velocity
VA  100000           Vector acceleration
BGS                  Start sequence
```

The first instruction, VP, defines the path to the final point. VS and VA define the vector velocity and acceleration respectively and BGS starts the motion sequence.

Example 5.2.

Generate a motion sequence corresponding to Fig. 5.7. The vector velocity is 4000 count/s and the vector acceleration is 100,000 count/s^2.

Determine the motion time and show the vector velocity vs the X and Y velocities.

The motion consists of three segments:

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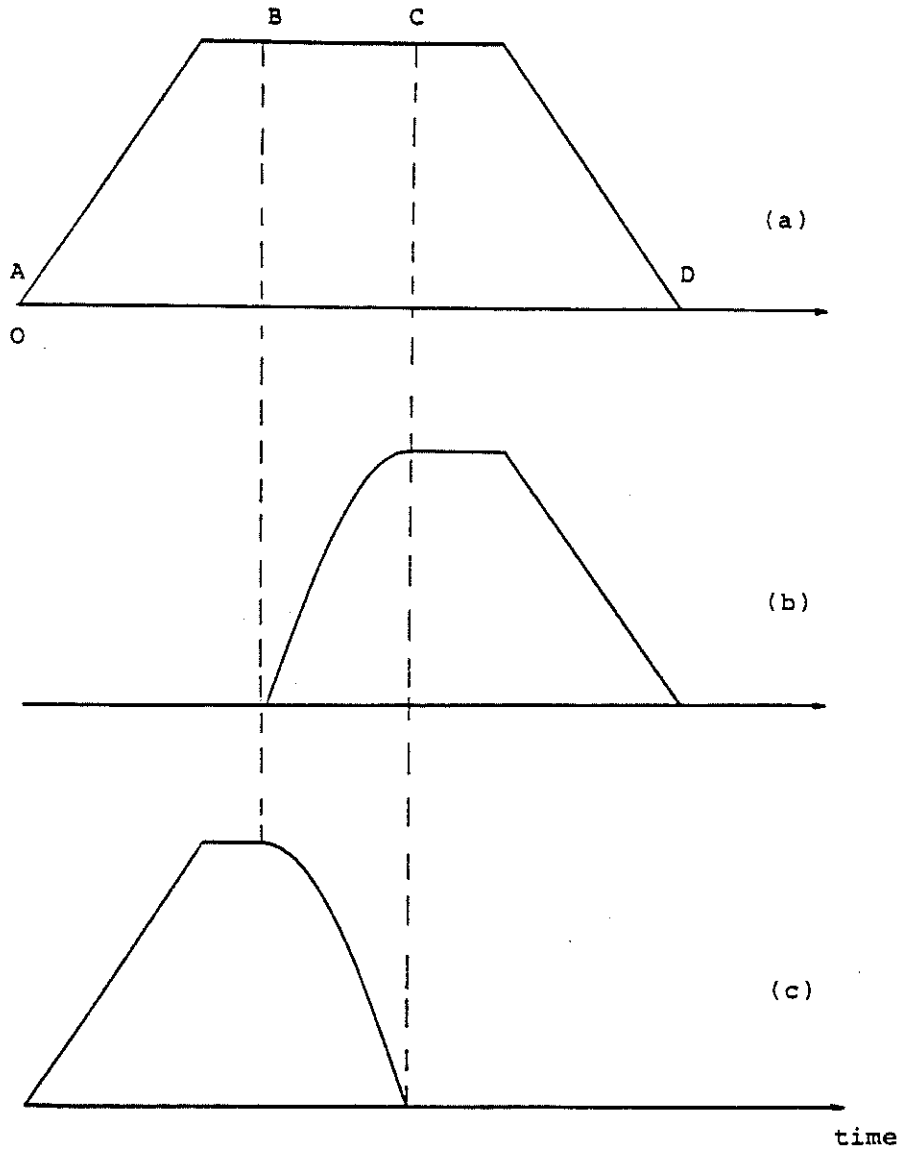


Fig. 5.4 - Vector and Axes Velocities

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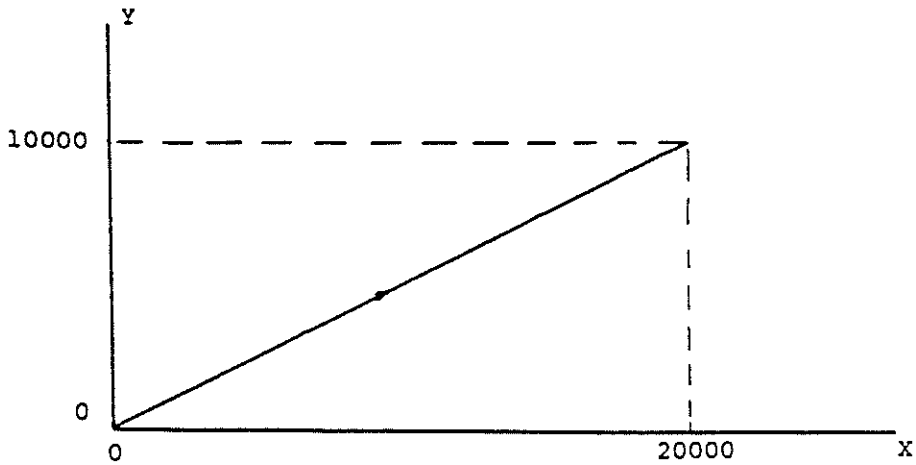


Fig. 5.5 - Motion Path of Example 5.1

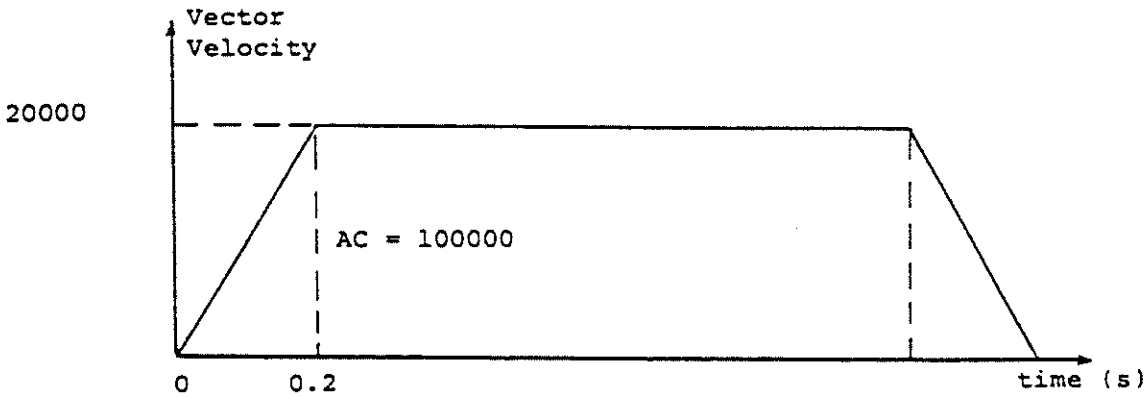


Fig. 5.6 - Vector Velocity of Example 5.1

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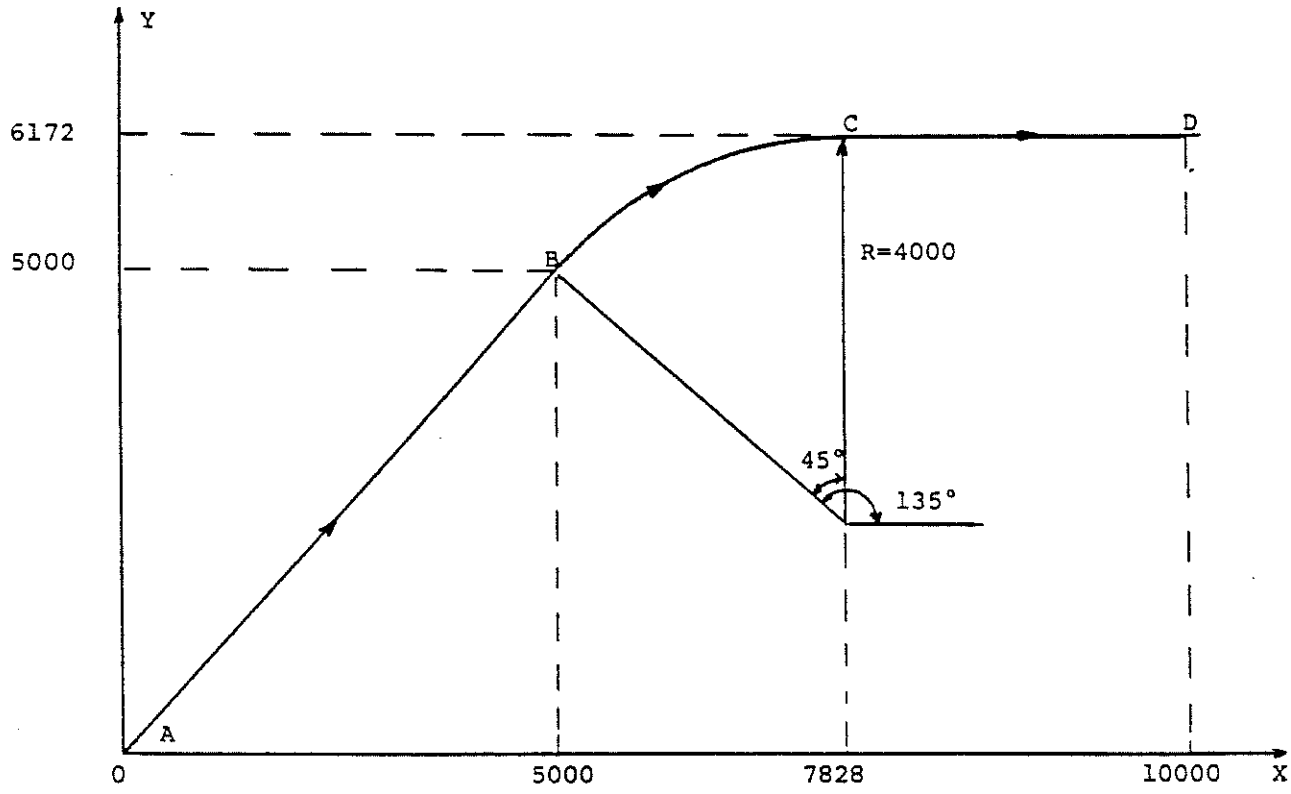


Fig. 5.7 - Motion Path of Example 5.2

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1. Linear, ending at point (5000, 5000)
2. Arc with radius R=4000 starting at 135° and width -45°
3. Linear, ending at (10000, 6172)

The motion can be generated with the program

```
VP  5000, 5000          Initial segment
CR  4000, 135, -45      Circular segment
VP  10000, 6172         Third segment
VS  4000                Vector speed
VA  100000              Vector acceleration
BGS                     Start the sequence
```

The lengths of the segments are

A-B Linear $L_1 = \sqrt{X^2 + Y^2} = 7071$
B-C Circular $L_2 = R|\Delta\Theta|2\pi/360 = 3141$
C-D Linear $L_2 = \Delta X = 2172$
Total $D = L_1 + L_2 + L_3 = 12384$ counts

The acceleration time is:

$$T_a = \frac{VS}{VA} = \frac{4000}{100000} = 0.04s$$

$$T_s = \frac{D}{Vs} - T_a = \frac{12384}{100000} - 0.04 = 0.084$$

Total time is:

$$T_t = 2\ T_a + T_s = 0.164s$$

The velocities are shown in Fig. 5.8.

Each sequence is limited to 255 segments. If a larger number of segments are required, they can be combined into several sequences. However, the system will come to a stop at the end of each sequence.

The axes velocities Vx and Vy, are continuous only if the connecting motion segments have the same tangent. Other angular connections result in velocity discontinuities as shown below.

Example 5.3.

Generate a motion along the path shown in Fig. 5.9.

The motion can be programmed as a single sequence with the following program.

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```
VP  4000, 3000
VP  7000, 7000
VS  20000
VA  200000
BGS
```

This results in velocities as shown in Fig. 5.10.

Note that the commanded velocities have discontinuities at the transition point at t=0.3. This results in a velocity error causing a deviation from the required path.

The deviation can be eliminated by generating the motion as two separate sequences, as shown by the following program.

```
VP  4000, 3000
VA  100000
VS  20000
BGS
AMS
VP  3000, 4000
VA  100000
VS  2000
BGS
```

The coordinated mode permits the use of the trip points WT and AD. AP is not allowed. WT causes a time delay and operates the same manner as in the independent mode.

The AD n holds the instruction until the motion has reached a total vector distance of n counts from the start of the sequence. This is illustrated below.

Example 5.4.

Consider the path shown in Fig. 5.11. The objective is to move along the circular arc and the first half of the linear segment at a constant vector speed. Starting at the point X=15,000, the vector velocity has to drop to one half of its original value and proceed with the motion to the end point.

The circular arc has a radius of 10000 counts and a width of 90½, therefore, its length is

$$L1 = R|\Delta\theta|2\pi/360 = 10000*90*2*/360 = 15708$$

The change in velocity should take place at point C, which is 5000 counts beyond point B, a total distance of 20708 from the start.

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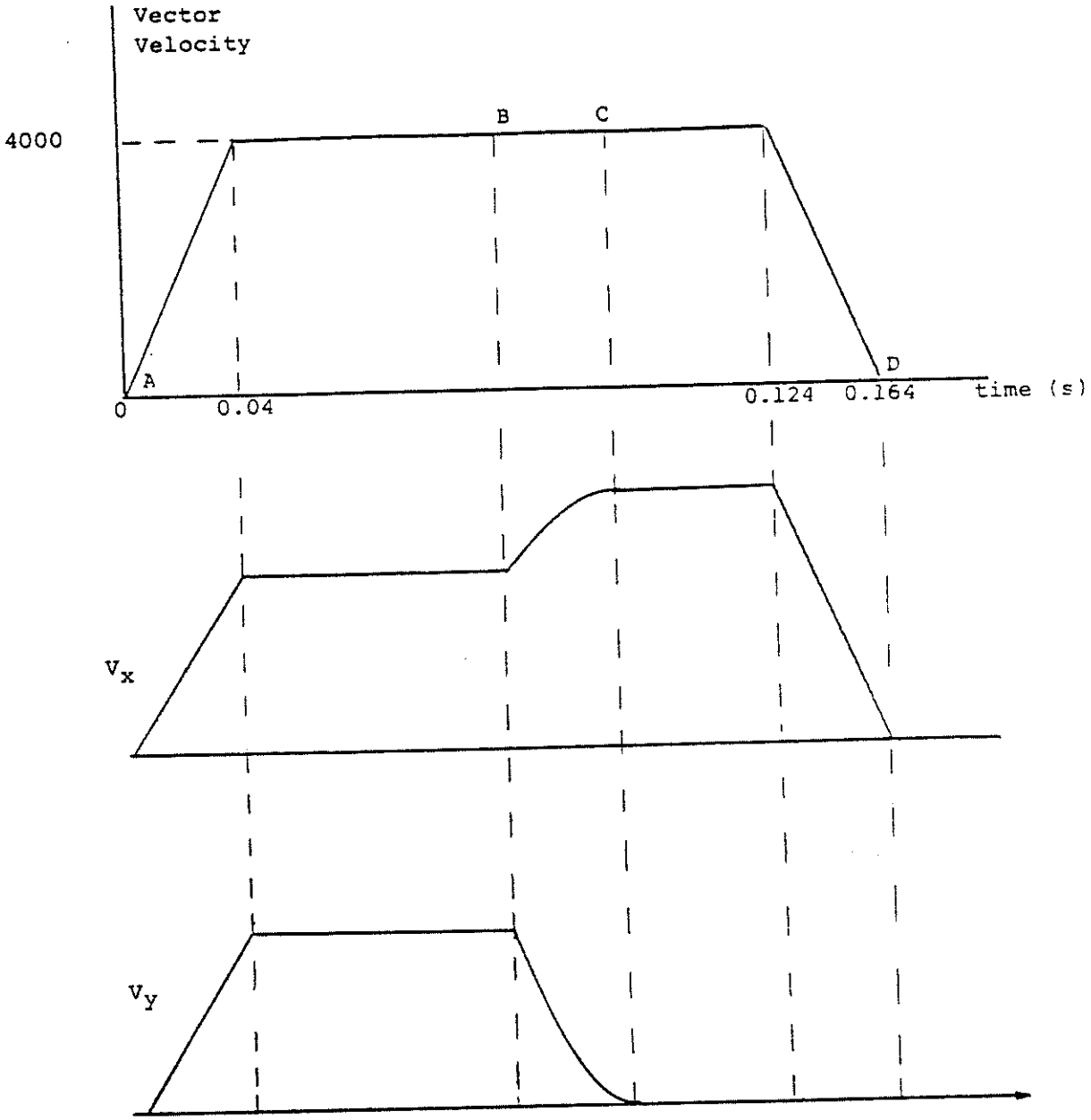


Fig. 5.8 - Vector and Axes Velocities of Example 5.2

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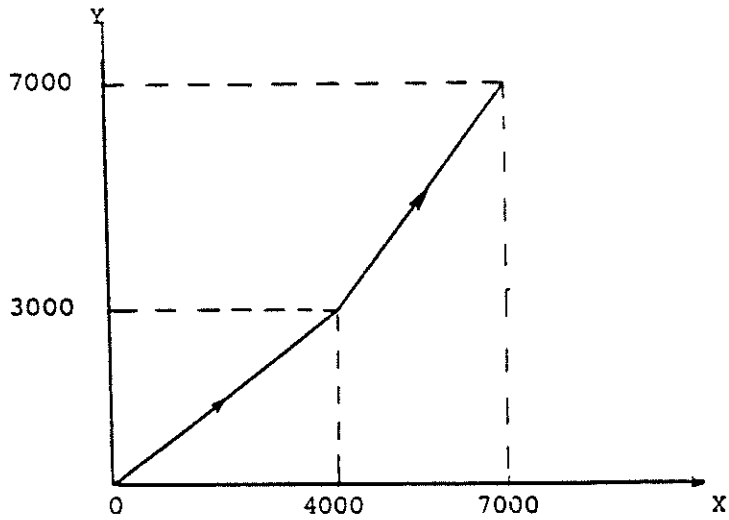


Fig. 5.9 - Motion Path of Example 5.3

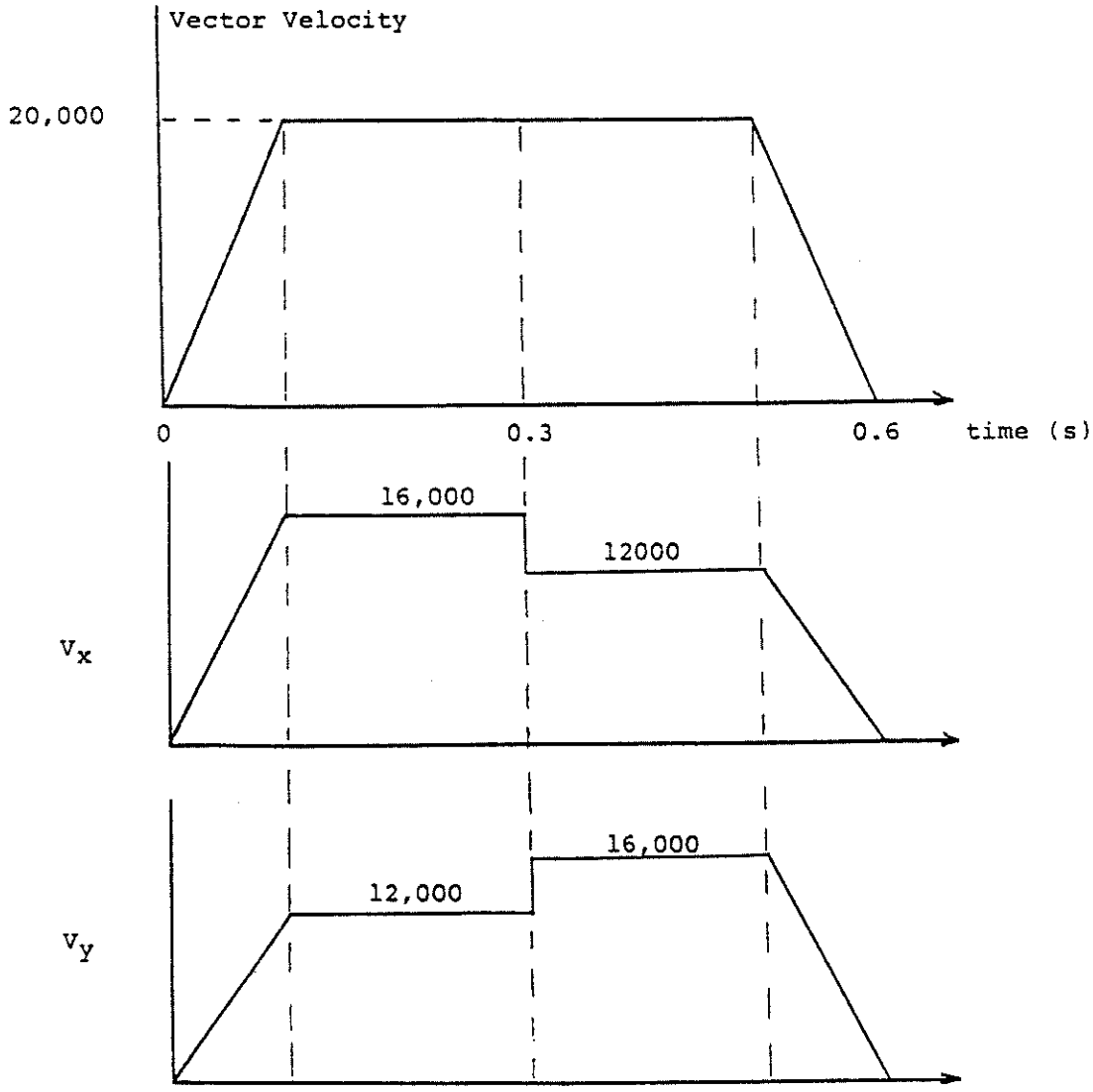


Fig. 5.10- Velocities of Example 5.3

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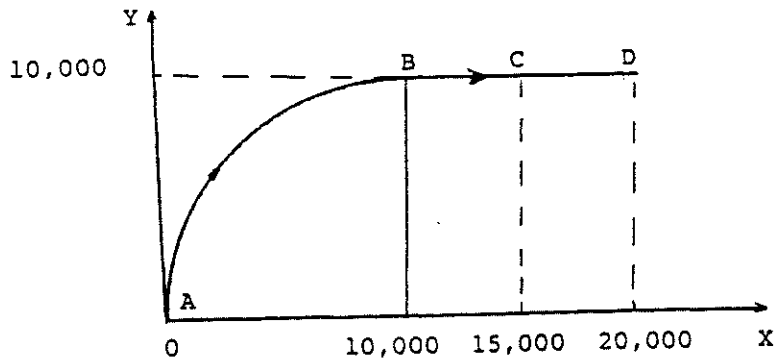


Fig. 5.11 - Motion Path of Example 5.4

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The required motion is generated by the program

```
CR  10000, 180, -90
VP  20000, 10000
VS  40000
VA  500000
BGS
AD  20708
VS  20000
```

The resulting velocities are shown in Fig. 5.12.

The motion of the Z axis may be synchronized with the coordinated X-Y motion by the WT and AD trippoint as shown below.

Example 5.5.

A required 3-dimensional motion path is shown in Fig. 5.13. The motion in the X-Y plane must be continuous. At some specified position, the Z axis performs a move as described. Note that the distance between points A and B is

$$\sqrt{12000^2 + 16000^2} = 20000$$

and the distance to point C is

$$\sqrt{30,000^2 + 40000^2} = 50000$$

Accordingly, the Z motion should take place after distances of 20000 and 50000.

The motion may be generated by the following program:

```
VP  60000, 45000        Vector path
VS  5000                Vector speed
VA  200000              Vector acceleration
BGS                     Start sequence motion
SP  ,, 100000           Speed of Z axis
AC  ,, 2000000          Acceleration of Z axis
AD  30000               Hold sequence until a distance of 20000
                          was reached
PR  ,, 3000             Distance Z
BGZ                     Start Z motion up
AMZ                     After Z moved
WT  20                  Wait 20 ms
PR  ,, -3000            Distance Z
BGZ                     Start Z motion down
AD  50000
PR  ,, 3000
BGZ                     Repeat second move of Z
AMZ
WT  20
PR  ,, -3000
BGZ
```

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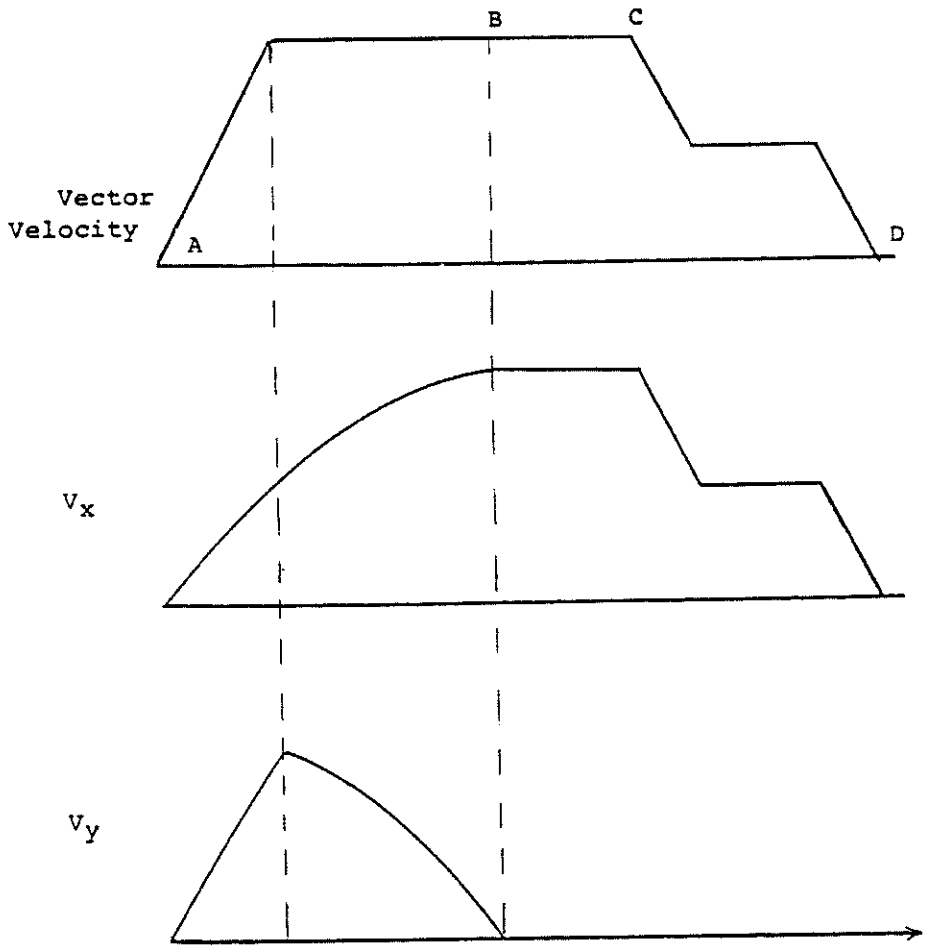


Fig. 5.12 - Velocities of Example 5.4

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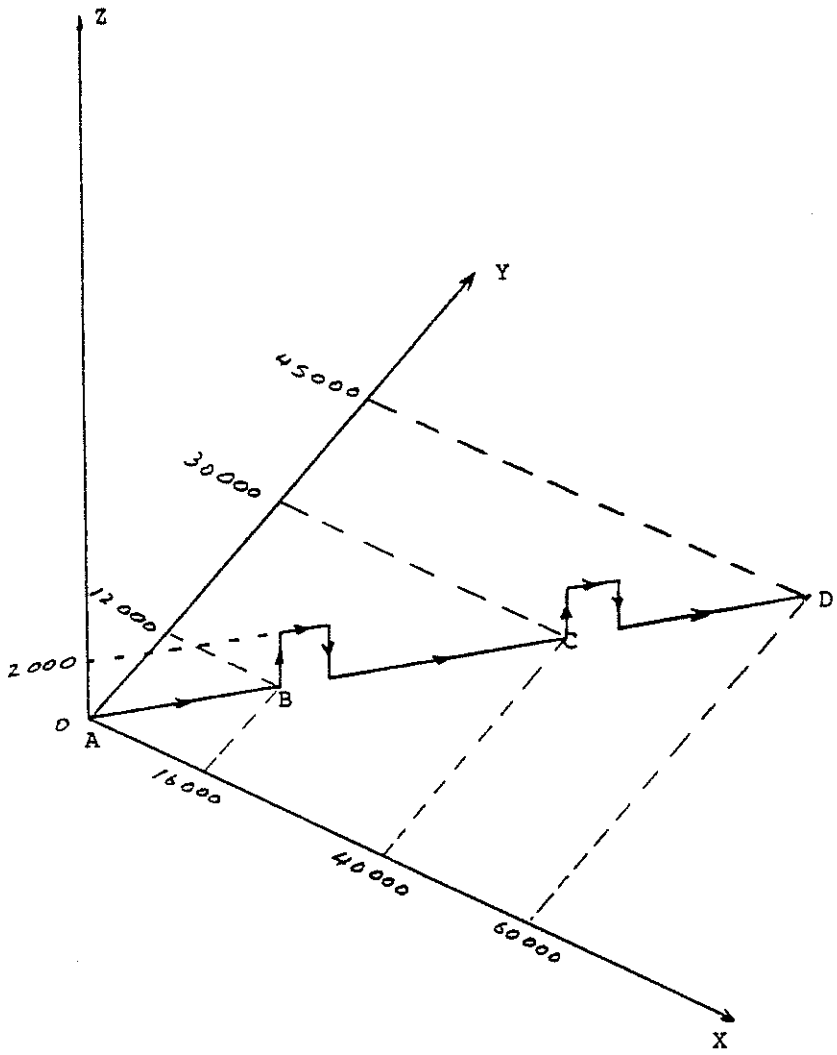


Fig. 5.13 - Motion Path for Example 5.5

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Summary of Instructions - Coordinated Mode

VP m,n - Vector Position

Defines the end point of a segment in a motion sequence as an X-Y coordinate in reference to the starting point of the sequence. m and n may be numbers in the range of $+/-8 \cdot 10^6$, provided that the total distance traveled by one sequence must be limited to $8 \cdot 10^6$.

CR R, Θ, $\Delta\Theta$ - Circle

Generates circular arcs. R, expressed in units of encoder counts, is limited to 8 10^6. Θ and $\Delta\Theta$ are expressed in degrees. Θ is limited to the range 0.000-360.000 and $\Delta\Theta$ is limited to +/-65000.000.

VS n - Vector Speed

Defines the vector speed of the motion in units of count/sec. VS is related to the axes velocities, V_x and V_y, by

$$VS = \sqrt{V_x^2 + V_y^2}$$

The speed range, n, is limited to the range 2-500,000 count/s, with a resolution of 2.

VA n - Vector Acceleration

Defines the acceleration rate along the path in units of count/s^2. The range of n is between 1024 and $8 \cdot 10^6$ count/s^2.

AD n - After Distance

The instruction AD n will hold the execution of the following command until the distance traversed by the vector motion reached n counts. n is a positive number in the range $0-8 \cdot 10^6$.

AMS - After Move-Sequence

The instruction AMS holds execution of the following command until the motion sequence is completed.

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5.4. Motion Contouring Mode

The motion contouring mode allows the generation of an arbitrary motion trajectory with any of the axes. The learn mode allows learn-and-playback of the motion trajectories.

In the contouring mode, the user specifies the motion increments, DX, DY and DZ as well as the corresponding time increment, DT. The controller performs linear interpolation between the specified increments. One point for each millisecond.

Consider, for example, the trajectory shown on Fig. 5.14. The position X may be described by the points:

```
Point 1     X=0    at   T=0 ms
Point 2     X=48   at   T=4 ms
Point 3     X=138  at   T=12 ms
Point 4     X=302  at   T=28 ms
```

The same trajectory may be represented by the increments

```
Increment 1     DX = 48   DT = 4
Increment 2     DX = 90   DT = 8
Increment 3     DX = 164  DT = 16
```

When the controller receives the command to generate a trajectory along these points, it interpolates linearly between the points. The resulting interpolated points include the position 12 at 1 ms, position 24 at 2 ms, etc.

Communication Format - Contouring

The contouring mode is initiated by the instruction

```
CM XYZ
```

The parameters X,Y,Z select the axis for this mode. Any combinations of one, two or three axes may be selected. Axes which are not selected for contouring may operate independently in other modes. Once the contouring axes are selected, they cannot be changed on-the-fly. The user must exit the contouring mode before the selected axes may be changed.

The mode initiation command is followed by data records, which are terminated by an end record, as shown in Fig. 5.15.

The format of the data record is shown in Fig. 5.16. A data record consists of 8 bytes which include a header, a time increment byte, and two bytes each for DX, DY and DZ.

The header byte is 80H. The time increment byte is a number between 81H and 88H. The difference between that number and 80H defines the number n. n must be limited to

$$1 < n < 8$$

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The time interval, DT, is related to n by

$$DT = 2^n$$

as a consequence, DT may be in the range

$$2 < DT < 256 \text{ ms.}$$

Following are the increments DX, DY and DZ. Each increment is described by two bytes. Although the value of the increments for non-contouring axes are ignored, the format of 8 bytes per data record must be kept.

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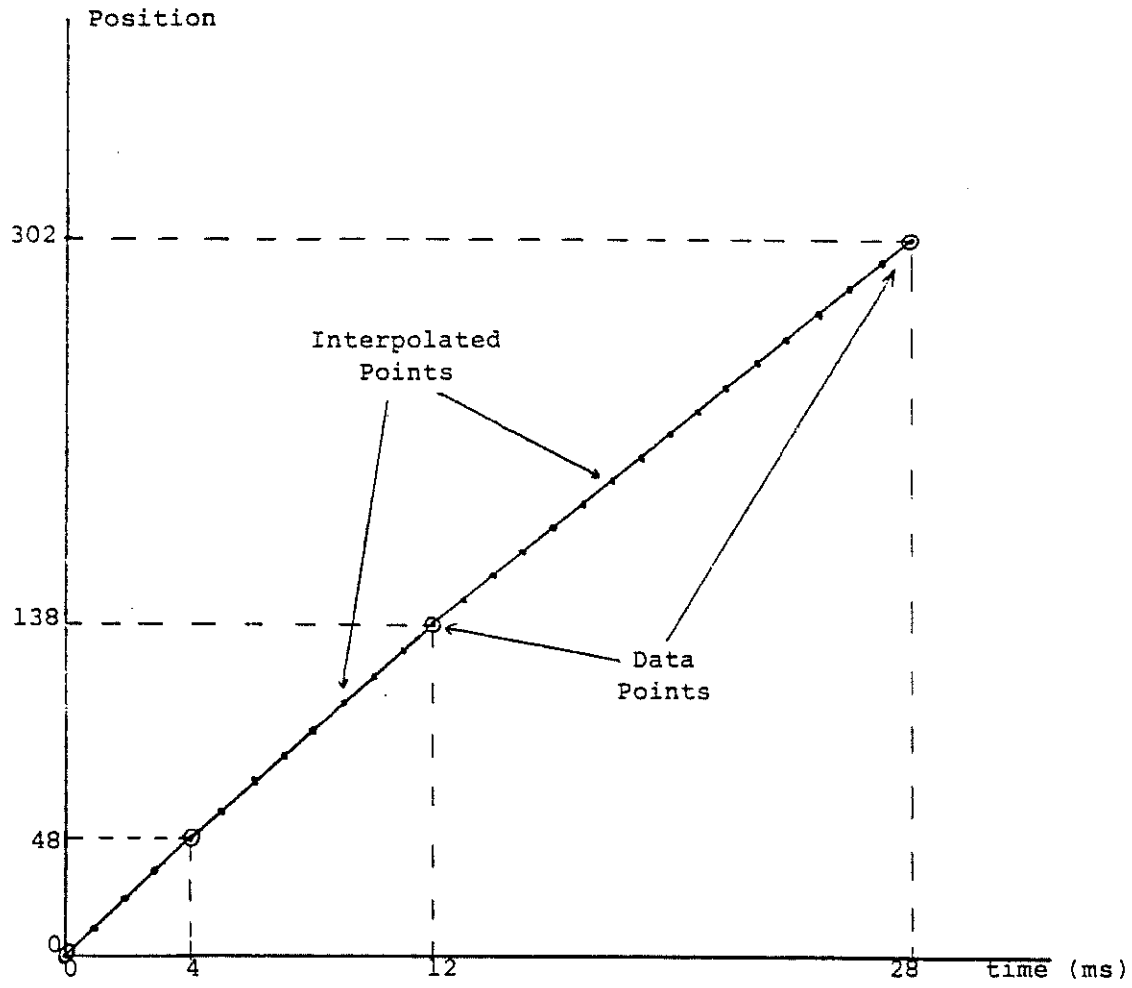


Fig. 5.14 - Required Trajectory

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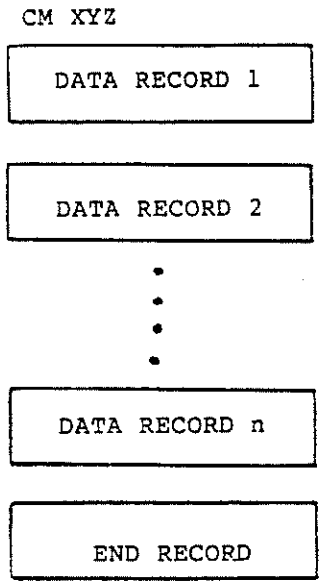


Fig. 5.15 - Structure of Information Flow

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80H	Header
81H - 88H	DT
MX	DX
NX	
MY	DY
NY	
MZ	DZ
NZ	

Fig. 5.16 - Data Record

80H
80H

Fig. 5.17 - End Record

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The contouring mode must be terminated with an end record, including the byte 80H twice, as shown in Fig. 5.17.

Operation - Contouring

1. Any combination of axes may be controlled in the contouring mode. Axes non-contouring may be operated in other modes.

2. While data records are transmitted to the controller, other commands may be sent too. However, it is advisable to operate with relatively large time intervals (n equals more than 4) to allow for sufficient communication time between records of data.

3. The time interval, DT, is defined by the number n by the equation

   DT = 2n (DT in milliseconds)

   The permitted range of n is between 1 and 8 resulting in a time intervals between 2 and 256 milliseconds.

4. The increments DX, DY and DZ are defined by two bytes. The upper byte is limited to +/-125, resulting in increments in the range of +/-32,000. Position increments must be specified for all the three axes. However, the value of the increments for non-contouring axes are ignored.

5. When a data record is received, it is processed immediately. The controller does not seek new data records until the end of the specified time interval (DT). This implies that the execution of other commands in the FIFO is delayed by the corresponding time intervals.

6. When bad data is received, the controller responds with a ?. The cause of the error may be diagnosed with the TC (Tell Code) instruction. The response to TC may include the codes

   40 - Format Error
   41 - Range Error

   Format error will occur if the header byte is not 80H or if the most significant bit of the second byte is zero.

   Range error includes a value of n outside the range 1-8 and the most significant byte of the position increment not being within +/-125.

7. If no new data record is found, the controller waits for new data. No new motion commands are generated while waiting.

8. When the off-on-error mode is activated, OE 1, and a large position error is developed for any one of the contouring axes, all the contouring axes will be shut off.

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9. End Record - The contouring mode is terminated by an end record consisting of the byte 80H twice.

Learn Mode - LN

The learn mode enables collecting position data in a form compatible with the contouring mode. This allows recording the position data by the host computer and playing it back to duplicate a specific motion.

The learn mode is activated with the instruction

LN n

The parameter n defines the time interval. The value of n must be between 1 and 8 and it sets the time interval to

$DT = 2^n$

In response to the LN n instruction, the controller transmits data records in the format discussed above. These records may be sent back to the controller for "replay" of the motion trajectory.

The time interval may be changed with another LN n instruction. The change takes place after the completion of the current time intervals.

When the time interval is long (typically above 64 ms), the position increments may exceed the range of +/-32,000. In that case, the controller reports an increment of 32,256 or 7EH at the most significant byte.

The learn mode is terminated with the instruction

LN or LN0

which causes the controller to transmit an end record.

Data records are stored in the read buffer. If the read buffer gets full, data records will be lost. If that occurs, bit 4 of the second byte of the data record will be set.

5.5. Electronic Gearing (For DMC-621 and DMC-631 only)

Electronic gearing allows 1 or 2 axes to be electronically geared to one master axis. The master may rotate in both directions and the geared axes will follow at the specified gear ratio. The gear ratio may be different for each axis and changed during motion.

The command GAX, GAY or GAZ specifies the master axis. There may only be one master. GR x,y,z specifies the gear ratios for the slaves where the ratio may be a number between +/-127.994. GR 0,0,0 turns off electronic gearing for any set of axes. A limit switch will also disable electronic gearing for that axis. GR causes the specified axes to be geared to the actual position of the

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master. The master axis may be commanded with motion commands such as PR, PA or JG.

Command Summary - Electronic Gearing

GA n	Specify master axis for gearing where n=X,Y or Z for X,Y or Z-axis master n=XC,YC,ZC for commanded position as master
GR x,y,z	Sets gear ratio for slave axes. 0 disables electronic gearing for specified axis.

Example:

Master axis moves 10000 counts at slew speed of 100000 counts/sec. Y is defined as the master. X,Z are geared to master at ratios of 5,-.5 respectively.

GAY	Specify master axis as Y
GR 5,,-.5	Set gear ratios
PR ,10000	Specify Y position
SP ,100000	Specify Y speed
BGY	Begin motion

Example - Electronic Gearing

Run two geared motors at speeds of 1.132 and -0.045 times the speed of an external master. The master motor turns at speeds between 0 and 1800 RPM (2000 counts/rev encoder).

Solution: Use a DMC-631 controller where the Z-axis is the master and X and Y are the geared axes.

MO Z	Turn Z off, for external master
GA Z	Specify master axis
GR 1.132,-.045	Specify gear ratios

Now suppose the gear ratio of the X-axis is to change on-the-fly to 2. This can be achieved by commanding:

```
GR 2
```

When the master motor is driven by an external controller, the master encoder may be applied to the auxiliary encoder of the slave motor.

For example, to synchronize the motor X with an external encoder with a gear ratio 1, apply the external encoder to the Y-axis of a DMC-621 controller and use the instructions:

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```
GAY                     Define master as Y
GR1                     Set gear ratio as 1:1
```

In several applications where both the master and the follower are controlled by the DMC-600 controller, it may be desired to synchronize the follower with the commanded position of the master, rather than the actual position. This eliminates the coupling between the axes which may lead to oscillations.

For example, assume that a gantry is driven by two axes, X,Y, on both sides. The X-axis is the master and the Y-axis is the follower. To synchronize Y with the commanded position of X, use the instructions:

```
GAXC                    Specify master as commanded position of X
GR,1                    Set gear ratio for Y as 1:1
PR 3000                 Command X motion
BGX                     Start motion
```

You may also perform profiled position corrections in the electronic gearing mode. Suppose, for example, that you need to advance the slave 10 counts. Simply command

```
IP 10
```

which is equivalent to PR 10; BG.

Often the correction is quite large. Such requirements are common in synchronizing cutting knives or conveyor belts.

Example - Synchronize two conveyor belts with trapezoidal velocity correction.

```
GAX                     Define master axis as X
GR,2                    Set gear ratio 2:1 for Y
PR,300                  Specify correction distance
SP,5000                 Specify correction speed
AC,100000               Specify correction acceleration
BGY                     Start correction
```

5.6. Dual Loop-Auxiliary Encoder (DMC-6X1 Series only)

The DMC-6X1 Series provides additional inputs for a 2-channel encoder on each axis. These inputs can be used for dual-loop applications where encoders are placed on both the motor and on the load, or when a train of pulses needs to be counted.

The auxiliary encoder accepts encoders with two channels in quadrature. It can also accept encoders with a single channel or two up/down pulse trains, called INC/DEC.

The auxiliary encoder or INC/DEC signals are connected to the auxiliary 40-pin connector at the following input lines.

```
Pin 13  CHA Z or INC Z          Pin 19  CHB Y or DEC Y
Pin 15  CHB Z or DEC Z          Pin 21  CHA X or INC X
```

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Pin 17 CHA Y or INC Y Pin 23 CHB X or DEC X

To enable and configure the auxiliary encoder counters, use the SE x,y,z command, where

x,y,z may be 0,1,-1

where

0 -- Disable auxiliary encoders
1 -- Enables dual encoders of quandrature types
-1 -- Enables auxiliary input for INC or DEC. Inactive input must be low.

The DD x,y,z command can be used to define the position of the auxiliary encoders. For example,

DD 0,500,-30

sets their initial values.

The positions of the auxiliary encoders may be interrogated with TD. For example,

TD XYZ

returns the value of the X,Y and Z auxiliary encoders.

The auxiliary encoder position may be assigned to variables with instructions

V1=PDX or V1=PDY or V1=PDZ

Example - Backlash Compensation

Run a linear slide by a rotary motor via a lead screw. As the lead screw has a backlash, it is necessary to use a linear encoder to monitor the position of the slide. In addition, for stability reasons, it is best to use a rotary encoder on the motor.

Implementation

Connect the rotary encoder to the X-axis and connect the linear encoder to the auxiliary encoder of X. The design approach is to drive the motor a distance, which corresponds to 40,000 rotary counts. Once the motion is complete, the controller monitors the position of the linear encoder and performs position corrections.

This is done by the following program.

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Instruction	Interpretation
#D	Label
SE1	Set mode
DD0	Set initial value
PR 40000	Main move
BGX	Start motion
#C1	Correction loop
AMX;WT 20	Wait for motion completion
IP 40000-PDX	Correct linear encoder error
EN	End program

5.7. S-Curve Profiling (DMC-6X1 only*)

The DMC-6X1 Series allows S-curve profiling where the acceleration is a trapezoid or triangular. This results in reduced vibration in the system, especially in systems with flexible mechanical structures.

To set the trapezoidal acceleration mode in the independent or coordinated moves, use the instructions:

TA x,y,z	Set trapezoidal acceleration for independent move
TV n	Set trapezoidal acceleration for coordinated move

where

x,y,z, n=1	Trapezoidal acceleration
x,y,z, n=0	Standard (square) acceleration

The additional parameter of the acceleration ramp (Acceleration derivatives) is set by the instructions:

RM x,y,z	Specify acceleration ramp for independent move
VR n	Specify acceleration ramp in coordinated move

The units of the acceleration ramp are in (count/sec^2)/2 ms. For example, if the peak acceleration rate is 100,000 count/s^2 and the peak acceleration must be reached in 20 ms, the time interval equals 10 x 2 ms and therefore, the acceleration ramp equals

$$\text{Ramp} = \frac{100{,}000}{10} = 10{,}000 \text{ (count/s}^2\text{)/2 ms}$$

Note: It is not possible to change the velocity or acceleration of an S-curve move once it has begun.

The general velocity profile with trapezoidal acceleration is shown in Fig.5.1. Define the time intervals:

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TR - Time interval for acceleration ramp
TA - Time interval where the acceleration is constant
Ts - Time interval where the speed is constant

The motion paremeters are given by:

D - Distance [counts]
S - Speed [count/s]
A - Acceleration [count/s^2]
R - Acceleration Ramp [(count/s^2)/2 ms]

The relationship between the time interval, in seconds, and the motion paremeters are:

A = R*TR*500
S = A*(TR+TA)
D = S*(2TR + TA + TS)

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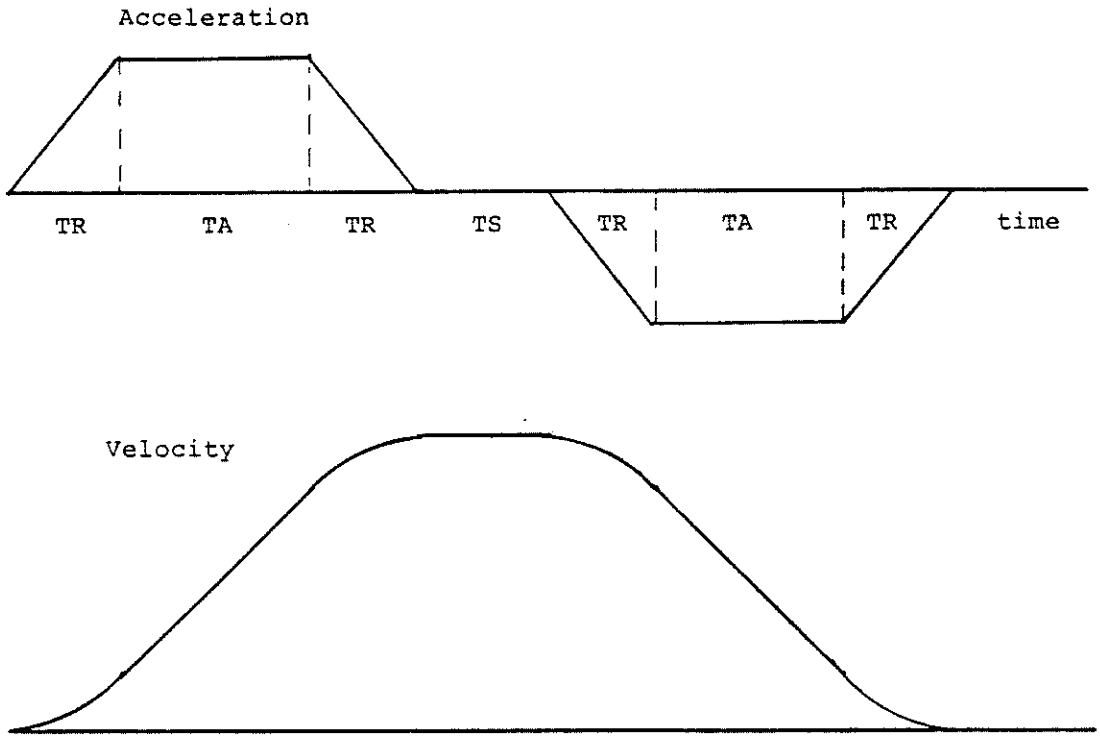


Fig. 5.1 - Trapezoidal Velocity (S-Curve) Profile,

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Example - Consider an independent move with the parameters:

D = 55,000 counts
TR = .2
TA = .3
TS = .4

From the above equations we can compute the rest of the parameters:

S = 50,000 count/s
A = 100,000 count/s^2
R = 1000 (count/s^2)/2 ms

The move can be generated by the program:

```
TA 1                Set S-curve mode
PR 55000           Specify distance
SP 50000            Specify slew speed
AC 100000           Specify peak acceleration
RM 1000             Specify acceleration ramp
BGX                 Start motion
```

In order to produce a smooth velocity profile, the speed and the distance must be selected so that the slew speed can be reached. This requires the following condition:

D>S*(2*TR+TA)

For example, for the paremeters:

TR = 0.2s
TA = 0.3s
S = 80000 count/s

The distance, D, must be at least 56,000 counts to produce a smooth S curve.

5.8. High Speed Position Capture (DMC-6X1 only*)

Often it is desirable to capture the position precisely. The DMC-6X1 provides a position latch feature. This feature allows the position of X,Y or Z to be captured within 200 nanoseconds of an external signal. The external signal is input at the 40-pin connector through the following inputs and is active low.

Pin 29 Z-axis latch
Pin 33 Y-axis latch
Pin 37 X-axis latch

The DMC-600 software commands, LA and RL, are used to arm the latch and report the latched position. The variables LX,LY, and LZ return the latch status. A one means the latch is armed. A zero implies the latch is disarmed or has occurred. The steps to use the latch are as follows:

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1. Give the LA XYZ command to arm the latch for the specified axis or axes.

2. Test to see if latch occurred for LX=0, LY=0 or LZ=0

3. After the latch has occurred, read the captured position with the RL XYZ command or V1=PCX or PCY or PCZ command.

Note 1: The latch must be re-armed after each latching event.

Note 2: If the latch signal is already low when the latch is armed, the latch will occur immediately.

Example:

```
#L                  Latch program
JG,5000             Jog Y
BGY                 Begin Y
LAY                 Arm Latch
#W                  Loop for Latch=1
JP #W,LY=1          Test for latch occurring
V1=PCY              Report position
EN                  End
```

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6. USING VARIABLES

Control variables allow the controller to perform high-level supervisory functions. Operations with variables include three functions:

Variable definition
Mathematical operations
Assignment

A variable Vk with k being an integer between 0 and 63, may be defined by equating its value to a constant. The variable may be defined as a real number in the range of +/-8388607.000. The fractional part has a resolution of 1/256.

For example:

```
V1 = 3
V2 = -2.500
```

The variables may also be defined by equating them to the position or the position error of the three axes. For example:

```
V3 = PX          Define V3 as position of X
```

or

```
V4 = PEY         Define V4 as position error of Y
```

An alternative method is to equate the variable to any of the 8 input lines. For example,

```
V5 = I7          Define V5 as input line 7
```

It is also possible to equate a variable to the binary value defined by the input lines I4-I1 with the instruction

```
V5 = I0
```

The resulting value of V5 ranges between 0 and 15.

Variables can be manipulated using mathematical operations. The four mathematical operations of add, subtract, multiply and divide are permitted with the order of operations progressing from the left to the right. For example, the instruction

```
V5 = 2*V4 + 5/V2
```

defines V5 as two times V4 plus 5, then the total sum is divided by V2.

The mathematical operation may be combined with the definition, as illustrated by the following instruction:

```
V6 = 2*PEX + 3
```

The variables may be assigned as the value of system parameters such as the gain

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```
GN  V1, V2, 3
```

or it may define a motion variable as the distance, speed or acceleration. For example,

```
PR  V1
```

commands the X axis to move a distance of V1 counts.

The relationship between the control variables and the motion command loop are illustrated by the diagram of Fig. 6.1.

The operation with variables may be performed without an explicit use of the variables. For example, the instruction

```
PR  PEY + 2
```

performs the functions of variable definition, manipulation and assignment.

To illustrate the effect of the control variables, consider the following examples:

Example 6.1. - Variable - Length Motion

The controller is required to perform a move of variable length. The velocity and the acceleration are proportional to the distance. This results in a constant motion time, regardless of the length. The velocity profile is shown in Fig. 6.2.

The motion program is as follows:

```
000  #A
001  PR V1; SP 2*V1; AC 20*V1
002  BGX; EN
```

To execute the motion, command:

```
V1 = 7000
XQ #A
```

Example 6.2 - Balancing Gravitational Forces

When a gravitational force is applied to the load, the system tends to develop a proportional position error. This position error may be eliminated by the use of the integrator. The integrator, however, may result in conditional stability in some systems and its use may be prohibited. In those cases, the error may be eliminated by applying an offset signal. The proposed method is to increase the offset value

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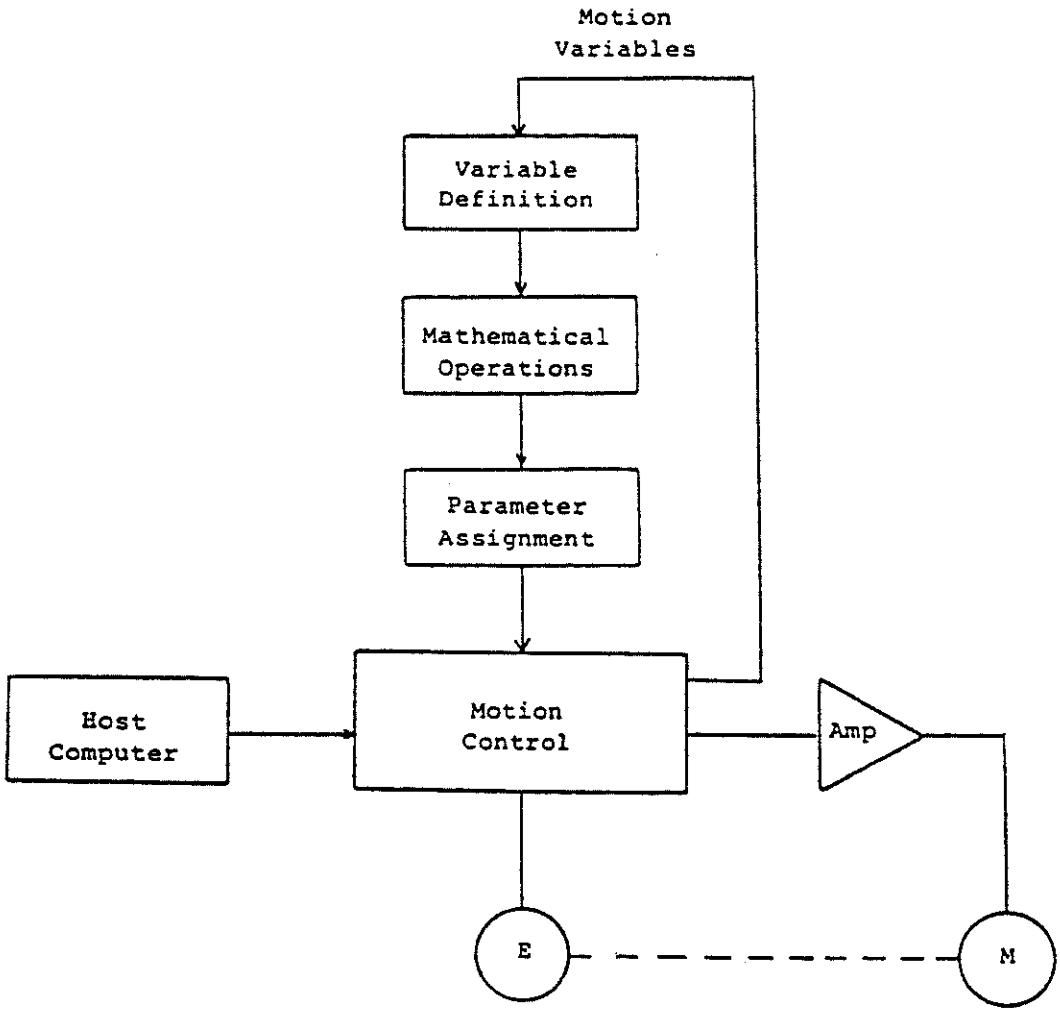


Fig. 6.1 - Functional Block Diagram of the Motion Control System and the Control Variables

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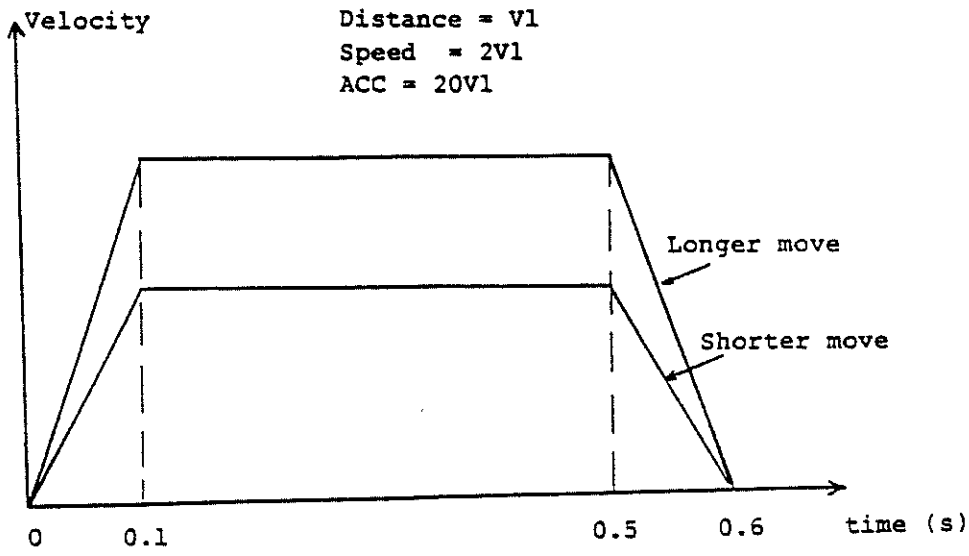


Fig. 6.2 - Velocity Profile of Example 6.1

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gradually until the position error falls within an acceptable range (eg. þ2 counts). This is performed by the following program.

```
000  #A              Label
001  V3 = 0.1        Algorithm gain
002  V1 = 0          Initial offset value
003  OF V1           Apply offset
004  WT 10           Wait for system to settle
005  V2 = PEX        Measure error
006  V1 = V2*V3+V1   Modify offset
007  JP 3, V1>2      Repeat if error large
008  JP 3, V1<-2     Repeat if error large
009  EN              End
```

The constant V3 determines the convergence rate of the algorithm. Values that are too small cause slow convergence whereas large values cause the process to diverge.

6.1. Arrays (Available for DMC-6X1 only*)

The DMC-6X1 Series provides a one dimensional 1024 element array for storing parameters. The array element is defined by

```
A[i] = n
```

where

A specifies the array
i is the array element i=0 thru 1023
and n is the numerical value

Example:

```
A[2]=1000          Define the third array element as the number 1000
V3=7               V3 equals 7
A[V3]=PEX          The eighth array element is set to the position
                    error of the X-axis
```

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7. UNCOMMITTED I/O

Output Port

The DMC-630 has an 8-bit uncommitted output port for controlling external events. Each bit on the output port may be set and cleared with the software instructions SB (Set Bit) and CB (Clear Bit), respectively.

For example:

Instruction	Function
SB6	Sets bit 6 of output port
CB4	Clears bit 4 of output port

The output port may also be written to as an 8-bit word using the instruction OP (output port). This instruction allows a single command to define the state of the entire 8-bit output port.

For example:

Instruction	Function
OP6	Sets bit 1 and 2 of output port to high. All other bits are 0.
OP0	Sets all bits of output port to zero.
OP 255	Sets all bits of output port to one.

The output port is useful for firing relays or controlling external switches and events during a motion sequence.

Input Port

The DMC-630 has eight uncommitted inputs for controlling motion by local switches. For example, a jump on condition instruction can be used to execute a sequence if a high condition is noted on an input bit. The After Input (AI) instruction waits until the specified input has occurred.

Example:

```
JP #A,I1=0          Jump to A if input 1 is low
JP #B,I2=1          Jump to B if input 2 is high
AI 7                Wait until input 7 is high
AI -6               Wait until input 6 is low
```

The command IO defines the state of inputs 1,2,3 and 4. This command is useful for interfacing to thumbwheels (Appendix H).

```
JP #C,I0=6          Jump to C if I1=0,I2=1,I3=1,I4=0
JP #A,I0=0          Jump to A if I1,I2,I3,I4 are all low
```

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Example:

Motor X must turn at 4000 counts/sec when the user flips a panel switch to on. When panel switch is turned to off position, motor X must stop turning.

Solution: Connect panel switch to input 1 on DMC-630. High on input bit 1 means switch is in on position.

Instruction	Function
#S;JG 4000	Set speed
AI 1;BGX	Begin after input 1 goes high
AI -1;STX	Stop after input 1 goes low
AMX;JP #S	After motion, repeat
EN;	

Input Interrupts

The DMC-630 provides an input interrupt function which causes the program to automatically execute the instructions following the #^ label. This function is enabled using the II m,n command. m,n specifies the range if inputs effected. A low input on any of the specified inputs will cause automatic execution of the #^ subroutine. RI is used to return from this subroutine.

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8. ERROR HANDLING

The DMC-630 provides several features to check for error conditions and to inhibit the motor on error. These features help protect the various system components from damage.

8.1. Hardware Protection

The DMC-630 includes hardware input and output protection lines for various error and mechanical limit conditions. These include:

Output Protection Lines

Error*	This signal goes low when the position error on any axis exceeds the value specified by the error limit command, ER.

Input Protection Lines

Abort*	A low input stops motion instantly without a controlled deceleration. Also aborts motion program.
Forward Limit Switch*	Low input inhibits motion in forward direction. Also causes execution of limit switch subroutine, #[.
Reverse Limit Switch*	Low input inhibits motion in reverse direction. Also causes execution of limit switch subroutine, #[.

8.2. Programmable Error Limit

The DMC-630 provides a programmable error limit. The error limit can set for any number between 1 and 2047 by using the ER n command.

Example:

ER 200,300,400	Set X-axis error limit for 200, Y-axis error limit to 300, Z-axis error limit to 400 counts.
ER ,1	Set Y-axis error limit to 1 count.

The units of the error limit are quadrature counts. The error is the difference between the command position and actual encoder position. If the absolute value of the error exceeds the value specified by ER, the DMC-630 will generate several signals to warn the host system of the error condition. These signals include:

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Signal or Function	State if Error Occurs
Status Register-Bit 3	Goes low
#[Label	Jumps to automatic limit subroutine
#] Label	Jumps to automatic error subroutine
Error Output Line	Goes low
OE Function	Shuts motor off

The jump on condition statement is useful for branching on a given error within a program. The position error of X,Y, and Z can be monitored during execution.

Example:

```
JP #A,PEX>5          Jump to A if position error on X is
                     greater than 5.

JP #B,PEY=0          Jump to B if position error on Y
                     equals 0.
```

8.3. Off-On-Error

The software command, off-on-error (OE1) turns the motor off when the position error exceeds the limit set by the ER command. The program being executed is also aborted. To re-enable the system, use the reset (RS), servo (SV) or servo here (SH) command. To activate the OE function for each axis, specify 1 for X,Y and Z axis. 0 disables off-on-error.

Example:

```
OE  1,1,1        Enable off-on-error for X,Y and Z
OE  0,1,0        Enable off-on-error for Y axis only.
                 Disable X and Z off-on-error.
```

8.4. Automatic Error Routine

The] label causes the statements following to be automatically executed if error on any axis exceeds the specified error limit. The error routine must be closed with the RE command. The RE command returns from the error subroutine to the main program. NOTE: The error subroutine will be entered again unless the error condition is gone.

Example:

```
#]               Start error routine on error
MG error         Send message
SB1              Fire relay
```

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```
STX                     Stop motor
AMX                     After stopped
SHX                     Servo motor here to clear error
RE                      Return to main program
```

8.5. Limit Switch

The DMC-630 provides forward and reverse limit switches which inhibit motion in the respective direction. There is also a special label for automatic execution of a limit switch subroutine. The #[label specifies the start of the limit switch subroutine. This label causes the statements following to be automatically executed if any limit switch is activated. The RE command ends the subroutine.

The state of the forward and reverse limit switches may also be tested during the Jump on Condition statement. The condition LR specifies the reverse limit and LF specifies the forward limit. XYZ following LR or LF specify the axis.

Examples:

```
JP #A, LRX=0            Jump to A if Reverse limit on X is low
JP #B, LFY=1            Jump to B if Forward limit on Y is high
```

8.6. Software Position Limit* (DMC-6X1 only)

The DMC-6X1 Series provides forward and reverse software limits for each axis. The limits are specified by the command FL x,y,z and BL x,y,z, where the limit switch subroutines and deceleration occurs at position x+1, y+1, z+1 for the forward limit and at x-1, y-1, z-1 for the reverse limit. To disable the software limit, set the value to 8838607 for the forward limit and -8838607 for the negative limit. If the software limit is exceeded during motion, motion on that axis will decelerate to stop and further motion in the respective limit direction will be inhibited. The software limits will also trigger the #[label subroutine.

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9. INITIALIZATION

9.1. Default Settings

The Default configuration of the DMC-630 as shipped from the factory is:

Default Parameters

Parameter	Default Value
AC	262144
DB	0
DP	0
FA	0
GN	16
KI	0
OF	0
OP	0
PA	0
PL	0
PR	0
RC	0
SA	0
SP	8192
TL	127 (2047 for 12-bit)
TM	1000
ZR	232
ER	2047 (32767 for 12-bit)

The default numbering system is configured for decimal. The off-on-error is disabled on default. Unless the MOF (Motor Off) jumper is jumpered, the DMC-630 wakes up in the servo mode.

9.2. Homing Motors to a Reference

The Find Edge (FE) and Home (HM) instructions may be used to home the motor to a mechanical reference. This reference is connected to the Home input line. The HM command initializes the motor to the encoder index pulse in addition to the Home input.

Find Edge

The find edge instruction (FE) is useful for initializing the motor to a home switch. The home switch is connected to the HOMING input. When the find edge command and begin is issued, the motor will accelerate up to the slew speed and slew until a transition is detected on the HOMING line. The motor will then decelerate to a stop. A high acceleration value must be input before the find edge command is issued of the motor is to decelerate rapidly after sensing the home switch. The velocity profile generated is shown in Figure 9.1.

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Home Command

The Home Command can be used to position the motor on the index pulse after the home switch is detected. This allows for finer positioning on initialization.

The Home Command (HM) causes the following sequence of events to occur.

1. Upon begin, motor accelerates to the slew speed. The direction of its motion is determined by the state of the homing input. A zero (GND) will cause the motor to start in the forward direction; a one (+5V) will cause it to start in the reverse direction.

2. Upon detecting the home switch changing state, the motor begins decelerating to a stop.

3. The motor then slews very slowly back until the home switch toggles again.

4. The motor then slews forward until the encoder index pulse is detected.

5. The DMC-630 defines the Home position (Ø) as the position at which the index was detected.

The Homing sequence generates the profile in Figure 9.2.

Find Index

The Find Index command (FI) is used to search for the encoder index only. Upon FI and BG, the motor accelerates to the slew speed given by the JG command and searches for a transition from low to high on the encoder index. When the transition is detected, motion stops and the position is defined as zero. To improve accuracy, the slew speed during the search should be specified as 500 counts/s or less. The direction of motion is specified by the sign of the JG command.

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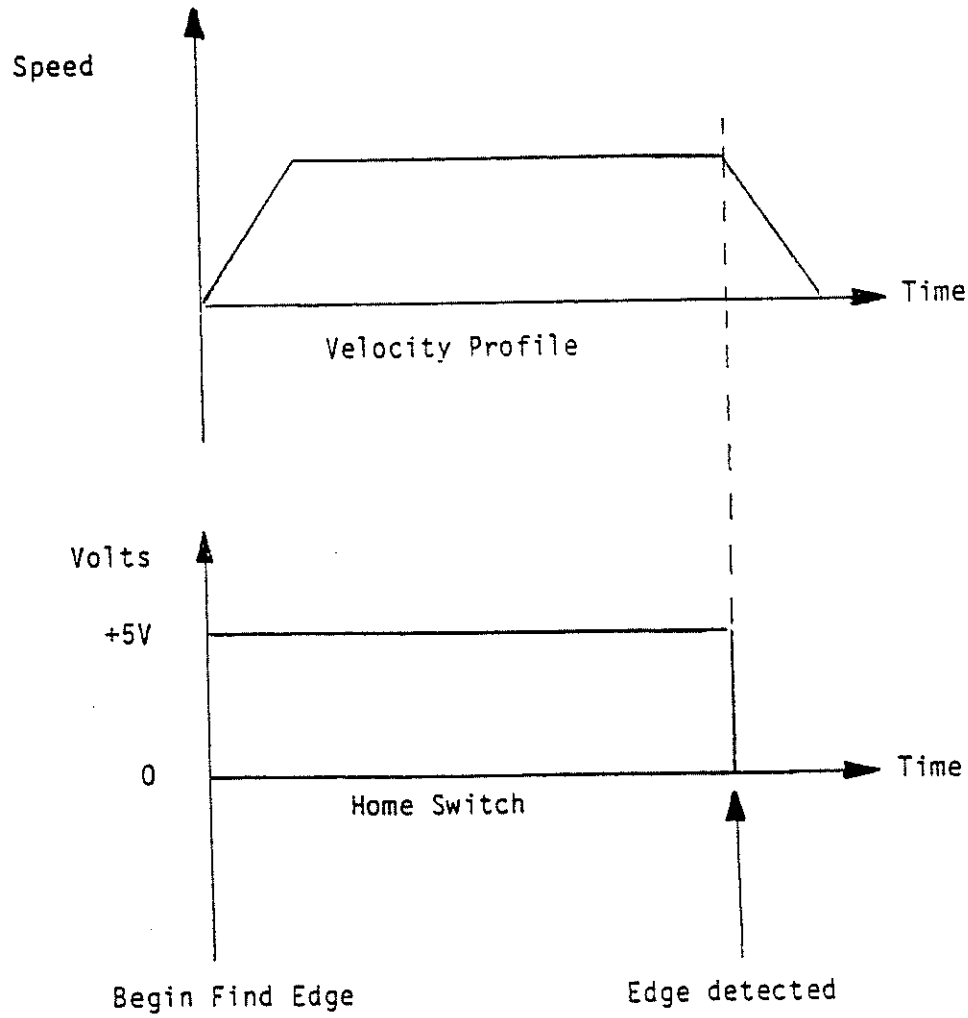
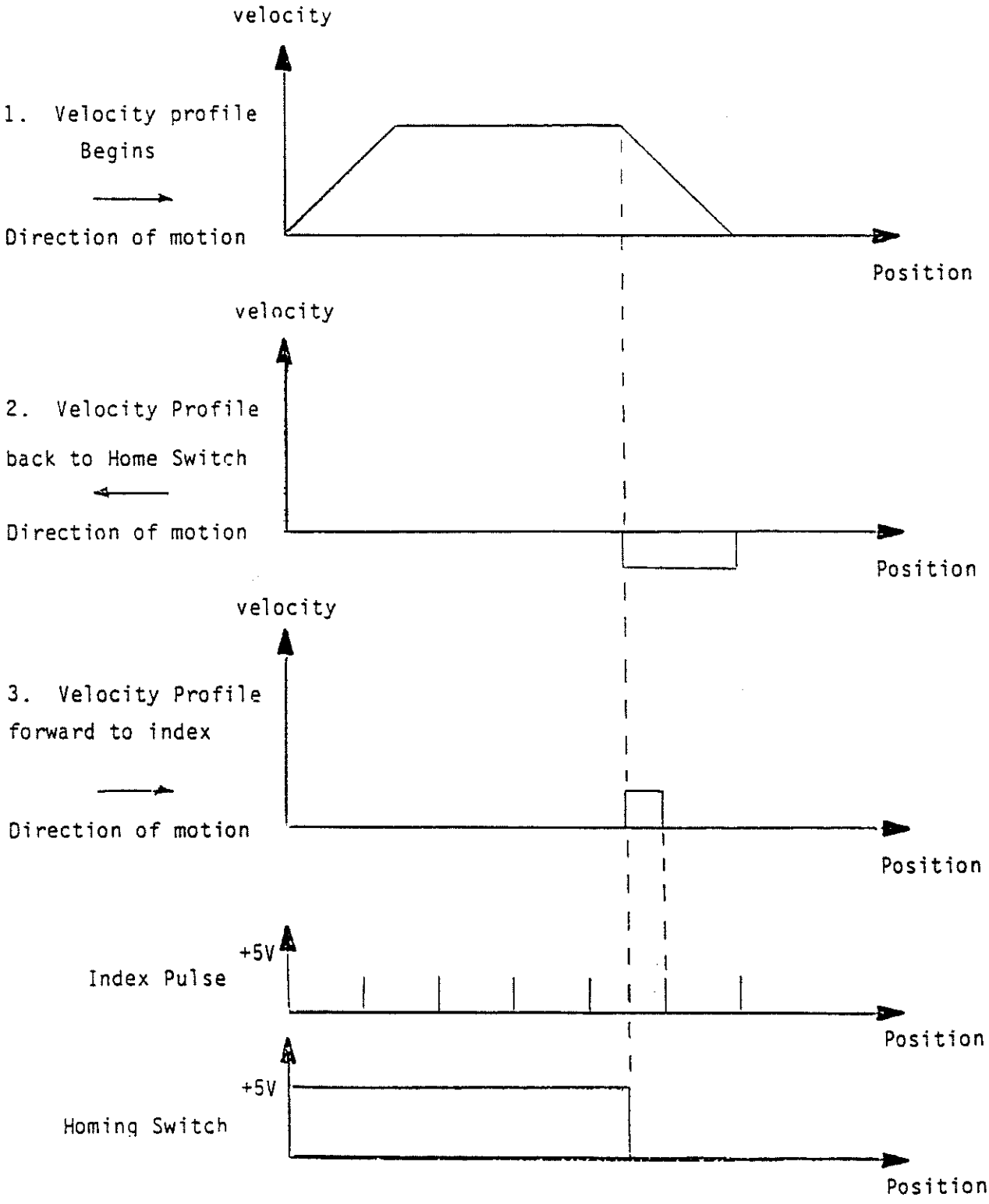


Fig. 9.1 - Using the Find Edge Command

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Fig. 9.2 - Homing Command Sequence



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9.3. Manual Positioning

The motor may be positioned manually by using the Motor Off Command (MO) and the Servo Here Command (SH). The motor off command turns off the servo. The motor can then be positioned manually, for initial alignment for example. When the motor is positioned at the desired position, the servo here command can be issued. This command causes the DMC-630 to generate a new command position based on the current position. This command differs from the Servo (SV) command which will drive the motor to the old programmed command position.

The define position command (DP) can be issued to define the current position as any new position. For example the command DP 5,100 defines the X position as 5 and Y position as 100. This command is useful following initialization or during manual positioning.

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II. INSTRUCTION SET

Each executable instruction is listed in the following section in alphabetical order.

The two-letter Opcode for each instruction is placed in the upper right and upper left corners. Directly below them is the syntax format. Some commands require actual values to be specified following the instruction. These commands are followed by lower case x,y,z. Values may be specified for any axis separately or any combination of axes. Axis values are separated by commas. Valid x,y,z syntax is listed below:

Valid x,y,z syntax

AC x	Specify x only
AC x,y	Specify x and y only
AC x,,z	Specify x and z only
AC x,y,z	Specify x,y,z
AC ,y	Specify y only
AC ,y,z	Specify y and z
AC ,,z	Specify z

Where x,y, and z are replaced by actual values.

A ? returns the specified value for that axis. For example, AC ?,?,?, returns the acceleration of the X,Y and Z axis. The syntax format is the same as x,y,z except ? replaces the values.

Other commands require action on the X,Y, or Z axis to be specified. These commands are followed by uppercase X,Y, or Z. Action for a particular axis or any combination is specified by writing X,Y, or Z. No commas are needed. Valid XYZ syntax is listed below:

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Valid XYZ syntax

```
SH X            Servo Here, X only
SH XY           Servo Here, X and Y axes
SH XZ           Servo Here, X and Z axes
SH XYZ          Servo Here, X,Y, and Z axes
SH Y            Servo Here, Y only
SH YZ           Servo Here, Y and Z axes
SH Z            Servo Here, Z only
SH              Servo Here, X,Y, and Z axes
```

Where X,Y and Z specify axis.

Below the syntax formats are any range restrictions on the numeric fields in the decimal numbering system.

In the upper right, the restrictions on allowable execution are enumerated. "While moving" states whether or not the command is valid while the controller is performing a previously defined motion. "In a program" states whether the command may be used as part of a user-defined program. "Not in a program" states whether the command may be used other than in a user-defined program. Finally, "Default Value" defines the values the instruction's parameters will have after a Master Reset.

Toward the center of the page, a description of the performance of the command is given. Also in this section the units of the parameters, if any, will be given. Lastly, a series of examples is given to show how the instruction might be used.

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A[i]=n	While Moving	YES
	In a Program	YES
	Not in a Program	YES
	Default Value	--

Where i is an integer between 0 and 1023
and n is a numerical value or variable

DESCRIPTION: A[i]=n defines the ith element of the array, A. The array may have up to 1024 elements from i=0 to i=1023. i may also be a variable for an integer 0 to 1023.

EXAMPLE:

```
A[2]=16          The third array element is 16
V6=5
A[V6]=10.9       The 6th array element is 10.9
```

*For DMC-6X1 Series only.

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AB ABORT AB

AB n	While Moving	YES
	In a program	YES*
	Not in a program	YES
	Default Value	

Where n = 0 or 1
0 stops program and motion
1 aborts motion only

DESCRIPTION: Abort stops a motion instantly without a controlled deceleration. If there is an application program operating, an abort command also aborts the program unless AB1 was used. If the command off on error (OE1) has been activated, an abort command will shut off the motor commands.

EXAMPLES:

AB	Stops motion
OE1,1,1	Enable off-on-error
AB	Shuts off Motor Command and stops motion
AB1	Stops motion but leaves the program operating

* If an abort is part of a sequence it still aborts the sequence.

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AC x,y,z	While Moving	YES*
AC ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	262144

x,y,z are unsigned numbers in the range
1024 to 8,308,807 decimal

DESCRIPTION: This command sets the acceleration rate of the motors for independent moves, or it will return a previously set value as seven or eight decimal digits. The parameters input will be rounded down to the nearest factor of 1024. The units of the parameters are counts per second squared.

EXAMPLES:

AC 150000,200000,300000	Set X-axis acceleration to 150000, Y-axis to 200000 counts/sec^2, and the Z-axis to 300000 counts/sec^2
AC ?,?,? 0149504,0199680,0299008	Return Acceleration

* The acceleration command may be changed during a motion only if it is not a position (PA or PR) move.

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AD x	While Moving	YES
AD ,y	In a program	YES
AD ,,z	Not in a program	YES
	Default Value	---

x,y,z are unsigned integers in the range
0 to 8388607 decimal

DESCRIPTION: The After Distance command is a trippoint used to control the timing of events. This command will hold up the execution of the following command until the position command has reached the specified relative distance from the start of the move. The units of the command are quadrature counts. Only one axis may be specified at a time.

EXAMPLES:

```
#A                      BEGIN PROGRAM
PR 10000,20000,30000    Specify positions
BG                      Begin motion
AD 5000                 After X reaches 5000
MG Halfway to X         Send message
AD ,10000               After Y reaches 10000
MG Halfway to Y         Send message
AD ,,15000              After z reaches 15000
MG Halfway to Z         Send message
EN                      END PROGRAM
```

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AI n	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	

n is a signed integer in the range
1 to 8 decimal

DESCRIPTION: The AI command is used in motion programs to wait until after the specified input has occurred. If n is positive, it waits for the input to go high. If n is negative, it waits for n to go low.

EXAMPLES:

```
#A                  BEGIN PROGRAM
AI 8                Wait until input 8 is high
SP 10000            Speed is 10000 counts/sec
AC 20000            Acceleration is 20000 counts/sec»
PR 400              Specify position
BG X                Begin motion
EN                  END PROGRAM
```

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AM X	While Moving	YES
AM Y	In a program	YES
AM Z	Not in a program	YES
AM S	Default Value	---
AM		

X,Y,Z,S specifies X,Y,Z axis or sequence

DESCRIPTION: The After Move command is a trippoint used to control the timing of events. This command will hold up execution of the following commands until the current move is completed. If specifying an axis, only one axis may be specified at a time except for a coordinated sequence. AM with no parameter specifies that motion on all axes is complete.

EXAMPLES:

```
#D                      PROGRAM D
PR 5000,5000,5000       Position Relative Moves
BG X                    Start the X-axis
AM X                    After the move is complete on X,
BG Y                    Start the Y-axis
AM Y                    After the move is complete on Y,
BG Z                    Start the Z-axis
AM Z                    After the move is complete on Z,
EN                      END OF PROGRAM

#F                      PROGRAM F
PR 5000,6000,7000       Position Relative Moves
BG                      Start X,Y and Z axes
AM                      After motion complete
MG DONE                 Print message
EN                      END OF PROGRAM
```

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AP x	While Moving	YES
AP ,y	In a program	YES
AP ,,z	Not in a program	YES
	Default Value	---

x,y,z are signed integers in the range
-8388608 to 8388608 decimal

DESCRIPTION: The After Position command is a trippoint used to control the timing of events. This command will hold up the execution of the following command until the absolute actual position of the motor crosses the position specified. The units of the command are in quadrature counts. Only one axis may be specified at a time. This trippoint will also be cleared by the completion of a move.

EXAMPLES: Assume that the motor is being used to apply a constant force of 10% maximum. We want to terminate the activity when it has reached ten revolutions. Assume the encoder has 500 slits (2000 quadrature counts).

```
#B                  PROGRAM B
TL 13               Limit torque to 10%
JG 100              Jog mode (speed of 100 counts/sec)
BG X                Begin move
AP 200000           After 10 revolutions
ST                  Stop
EN                  END OF PROGRAM
```

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AS XYZ	While Moving	YES
AS S	In a program	YES
AS SZ	Not in a program	YES
	Default Value	---

DESCRIPTION: The At Speed command is a trippoint that occurs when the generated motion profile has reached the specified speed. This command will hold up execution of the following commands until the speed is reached. The AS command will operate after either accelerating or decelerating.

EXAMPLES:

```
#A                  PROGRAM A
PR 100000           Specify position
SP 10000            Specify speed
BG X                Begin X
AS X                After speed is reached
SB 1                Set Bit 1
EN                  END PROGRAM
```

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BG XYZ	While Moving	NO
BG S	In a program	YES
BG SZ	Not in a program	YES
	Default Value	---

DESCRIPTION: The BEGIN Command starts a motion on the specified axis or sequence.

EXAMPLES:

PR 2000,3000	Set up for a relative move
BG XY	Start the X and Y motors moving
HM	Set up for the homing
BGX	Start only the X-axis moving
JG 1000,4000	Set up for jog
BGY	Start only the Y-axis moving
VP 1000,2000	Specify vector position
VS 20000	Specify vector velocity
BGS	Begin coordinated sequence
VP 4000,-1000	Specify vector position
PR ,,8000	Specify z position
BGSZ	Begin sequence and z

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BL x,y,z	While Moving	YES
	In a Program	YES
	Not in a Program	YES
	Default Value	-8388607

x,y,z are signed numbers in the range
-8388607 to 8388607 decimal

DESCRIPTION: The Reverse Limit command sets the reverse software position limit. If this limit is exceeded during motion, motion on that axis will decelerate to a stop. Reverse motion beyond this limit is not permitted. The reverse limit is activated at x-1, y-1 and z-1. To disable the reverse limit, set x,y,z to -8388607.

*For DMC-6X1 Series only.

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CB CLEAR BIT CB

CB n	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	---

n is an integer in the range
0 to 7 decimal

DESCRIPTION: The Clear Bit command clears one of eight bits on the output port. The Clear Bit (CB) and Set Bit (SB) instructions can be used to control the state of output lines.

EXAMPLES:

```
:CB  0                Clear output bit 0
```

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CM XYZ	While Moving	NO
	In a program	NO
	Not in a program	YES
	Defaule Value	---

DESCRIPTION: The Contouring Mode is initiated by the instruction CM XYZ. This mode allows the generation of an arbitrary motion trajectory with any of the axes. In this mode, the user specifies the motion increments, DX, DY and DZ and the time increment DT. The format for the increments is non-ASCII. Refer to Section 5.4 for details.

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CR r,θ,Δθ

While Moving	NO
In a program	YES
Not in a program	YES
Default Value	---

r is an unsigned real number in the range
10 to 1000000 decimal

θ is an unsigned real number in the range
0 to +/-65000.000 decimal

Δθ is a signed real number in the range
.008 to +/-65000.000 decimal

The units of θ and Δθ are degrees and the resolution is 1/128th of a degree.

The units of r are quadrature counts.

DESCRIPTION: The Circle command specifies an x,y arc segment of radius, r, starting at angle, θ, and traversing over angle Δθ. A positive Δθ denotes counterclockwise traverse, negative Δθ denotes clockwise. Motion begins after the command, Begin Sequence, BG S. All parameters, r, θ, Δθ, must be specified.

NOTE: This command is not valid in the DMC-610.

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CS	While Moving	NO
	In a program	---
	Not in a program	YES
	Default Value	---

DESCRIPTION: The Clear Sequence command will remove VP and CR commands stored in a motion sequence. Note, after a sequence has been run, the CS command is not necessary to put in a new sequence. This command is useful when you have incorrectly specified VP or CR commands.

NOTE: This command is not valid for the DMC-610.

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DB x,y,z	While Moving	YES
DB ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	0

x,y,z are unsigned numbers in the range
0 to 127 decimal

DESCRIPTION: The Deadband command provides for a section of zero motor command output. The width of the deadband section will be twice the number input. The units of this command are quadrature counts.

EXAMPLES:

DB 3,4,5	Set X-axis deadband to 3 Y-axis deadband to 4 Z-axis deadband to 5
DB 2	Set X-axis deadband to 2 Leave Y-axis deadband unchanged
DB ,1	Set Y-axis deadband to 1 Leave X-axis deadband unchanged
DB ?,?,? 002,001,004	Return both values
DB ? 002	Return X-axis deadband
DB ,? 001	Return Y-axis deadband

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DC	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	Decimal

DESCRIPTION: The Decimal command sets the controller to interpret all future numbers as decimal numbers.

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DD* DEFINE DUAL ENCODER DD

DD x,y,z	While Moving	NO
	In a Program	YES
	Not in a Program	YES
	Default Value	0,0,0

x,y,z are signed integers in the range
-8388607 to 8388607 decimal

DESCRIPTION: The DD x,y,z command defines the starting positions of the auxiliary encoders. The auxiliary encoders may be used for dual-loop applications and are input through the 40-pin auxiliary connector. TD returns the position of the auxiliary encoders; SE enables the dual encoders.

EXAMPLE:

SE 1,1,1	Enable auxiliary encoders
DD 0,100,200	Set the current auxiliary encoder position to 0 for the X-axis, 100 for the Y-axis, and 200 for the Z-axis.

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While Moving	YES*
In a program	NO
Not in a program	YES
Default Value	---

DESCRIPTION: The Download command transfers a data file from the host computer to the DMC-630. Instructions in the file will be accepted as a datastream without line numbers. The file is terminated using <control> Z, <control> Q, <control> D, or \ .

Downloading a data file will clear any programs in the DMC-630 RAM. The data is entered beginning at line 0. If there are too many lines or too many characters per line, the DMC-630 will return a ? .

For the DMC-6X1 Series, the DL #n command may be used, where n defines the label for beginning the download. The program is appended at this label.

EXAMPLES:

DL;	Begin download
#A;PR 4000,BGX	Data
AMX;MG DONE	Data
EN	Data
<control> Z	End download

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DP DEFINE POSITION DP

DP x,y,z	While Moving	NO
DP ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	0,0

x,y,z are signed integers in the range
-8388607 to 8388607 decimal

DESCRIPTION: The Define Position command sets the current motor position and current command positions to a user specified value. If a ? is used, it returns the current position of the motor. The units are in quadrature counts.

EXAMPLES:

:DP 0,100,200	Sets the current position of X-axis to 0, the Y-axis to 100, Z-axis to 200.
:DP ,-50000	Sets the current position of Y-axis to -50000 (FF3CB0 hex). The X-axis remains unchanged.
:DP ?,?,? 0000000,-0050000,0000200	Returns both motor positions
:DP ? 0000000	Returns the X-axis motor position

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DR* DAC RESOLUTION DR

DR x,y,z	While Moving	YES
DR ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	12,12,12

x,y,z are 10 or 12

DESCRIPTION: The DR command specifies a 10 or 12-bit resolution for the controller motor command output.

EXAMPLES:

DR 12,12,10	Specifies X and Y-axis as 12-bits and Z-axis as 10-bits

*For DMC-6X1 Series only.

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ED	While Moving	YES
ED n	In a program	NO
ED #L	Not in a program	YES
	Default Value	Last line

n is an unsigned integer in the range
0 to 500 decimal

DESCRIPTION: The Edit command puts the controller into the Edit subsystem (See Section I.6). In the Edit subsystem, programs can be created, changed, or destroyed. The commands in the Edit subsystem are

<cntrl>D	Deletes a line
<cntrl>I	Inserts a line before the current one
<cntrl>P	Displays the previous line
<cntrl>Q	Exits the Edit subsystem
<return>	Saves a line

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EN	While Moving	YES
	In a program	YES
	Not in a program	NO
	Default Value	---

DESCRIPTION: The END command is used to designate the end of a program or subroutine. If a subroutine has been called by the JS instruction, the EN command will return execution to the instruction after the JS command. If there is no subroutine being executed, the program terminates.

EXAMPLES:

```
#A              PROGRAM A
PR 500          Relative Position move
BGX             Begin the move
AMX             After the move is complete
PR 1000         Set another Position Relative move
BGX             Begin the move
EN              END OF PROGRAM
```

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EO	ECHO	EO
EO 0	While Moving	YES
EO 1	In a program	YES
	Not in a program	YES
	Default Value	E00

DESCRIPTION: The Echo command turns the echo on if EO1. If the echo is off, characters input over the bus will not be echoed back.

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ER x,y,z	While Moving	YES
ER ?,?,?	In a program	YES
	Not in a program	YES
	Default	2047

x,y,z are unsigned numbers in the range
1 to 2047 decimal
(1 to 32767 decimal for DMC-6X1)

DESCRIPTION: The Error Limit Command sets the magnitude of the position errors that will trigger an error condition. When the limit is exceeded, the Error output will go low (true). If the OFF ON ERROR (OE1) command is active, the motors will be disabled. The units of this are quadrature counts.

EXAMPLES:

ER 200,300,400	Set the X-axis error limit to 200, the Y-axis error limit to 300, and the Z-axis error limit to 400.
ER ,1000	Set the Y-axis error limit to 1000, leave the X-axis error limit unchanged
ER ?,?, 00200,00100,00400	Return X, Y, and Z values
ER ? 00200	Return X value

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FA — ACCELERATION FEEDFORWARD — FA

FA x,y,z	While Moving	YES*
FA ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	0

x,y,z are unsigned numbers in the range
0 to 255 decimal

DESCRIPTION: The FA command sets the acceleration feedforward coefficient, or returns the previously set value. This coefficient, when scaled by the acceleration, adds a torque bias during the acceleration phase and subtracts the bias during the deceleration phase of a motion.

ACCELERATION FEEDFORWARD BIAS = FA * AC/262144

The FEEDFORWARD BIAS product is limited to 127. See Section I.2 for further analysis. FA will only be operational during independent moves.

EXAMPLES:

```
AC 500000,1000000       Set feedforward coefficient to 10 for
FA 10,15                  the X-axis and 15 for the Y-axis.
                          The effective bias will be 19 units
                          (1.5V) for X and 57 units (4.4V) for Y.

FA ?,?                  Return X and Y values
010,015
```

* If the feedforward coefficient is changed during a move, then the change will not take effect until the next move.

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FE XYZ	While Moving	NO
	In a program	YES
	Not in a program	YES
	Default Value	---

DESCRIPTION: The Find Edge command moves a motor until a transition is seen on the homing input for that axis. The direction of motion depends on the initial state of the homin input (0 for forward, 1 for reverse). Once the transition is detected, the motor decelerates to a stop.

This command is useful for creating your own homing sequences. See Section I.9.

EXAMPLES:

```
FE          Set find edge mode
BG          Begin all axes

FEX         Only find edge on X
BGX

FEY         Only find edge on Y
BGY

FEZ         Only find edge on Z
BGZ
```

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FI* FIND INDEX FI

FI XYZ

While Moving	NO
In a Program	YES
Not in a Program	YES
Default Value	0

DESCRIPTION: The FI and BG commands move the motor until an encoder index pulse is detected. The controller looks for a transition from low to high. When the transition is detected, motion stops and the position is defined as zero. To improve accuracy, the speed during the search should be specified as 500 counts/s or less. The FI command is useful in custom homing sequences. The direction for motion is specified by the sign of the JG command.

EXAMPLE:

```
#H                  Home Routine
JG 500              Set speed and forward direction
FIX                 Find index
BGX                 Begin motion
AMX                 After motion
MG FOUND INDEX
```

*For DMC-6X1 Series only.

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FL* SET FORWARD LIMIT FL

FL x,y,z	While Moving	YES
	In a Program	YES
	Not in a Program	YES
	Default Value	8388607

x,y,z are signed numbers in the range -8388607 to 8388607 decimal

DESCRIPTION: The Forward Limit command sets the forward limit software position limit. If this limit is exceeded during motion, motion on that axis will decelerate to a stop. Forward motion beyond this limit is not permitted. The forward limit is activated at x+1, y+1, z+1. The forward limit is disabled at 8388607.

EXAMPLE:

FL 150000 Set forward limit to 150000 counts on the X-axis

*For DMC-6X1 Series only.

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GA* SPECIFY MASTER GEARING AXIS GA

GA n

While Moving	YES
In a Program	YES
Not in a Program	YES
Default Value	0

n=X or Y or Z for main encoder as axis master
n=XC or YC or ZC for command position as master axis

DESCRIPTION: The GA command specifies the master axis for electronic gearing. Only one axis may be defined as the master, however, the master may be specified for the main encoder input, the auxiliary encoder input or as the command position for an axis. The ratios for the slave axes are specified with the GR command

EXAMPLE:

```
#G                  Gear Program
GAX                 Specify X-axis as master
GR,.5,-2.5          Specify Y and Z ratios
JG 5000             Specify master jog speed
BGX                 Begin motion
WT 100              Wait 100 msec
STX                 Stop
```

*For DMC-6X1 Series only.

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GN x,y,z	While Moving	YES
GN ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	16

x,y,z are unsigned numbers in the range
0 to 255 decimal

DESCRIPTION: The Gain command (GN) sets the gain of the control loop or returns the previously set value. It fits in the control equation as follows:

$$D(z) = \frac{GN\ (z-ZR/256)}{4\ (z-PL/256)}$$

See Section I.2 for in-depth analysis.

EXAMPLES:

GN 12,14,15	Set X-axis gain to 12 Set Y-axis gain to 14 Set Z-axis gain to 15
GN 6	Set X-axis gain to 6 Leave Y-axis gain unchanged
GN ,8	Set Y-axis gain to 8 Leave X-axis gain unchanged
GN ?,? 006,008,015	Returns X,Y,Z gains
GN ? 006	Returns X gain
GN ,? 008	Returns Y gain

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GR* SPECIFY GEAR RATIO GR

GR x,y,z	While Moving	YES
	In a Program	YES
	Not in a Program	YES
	Default Value	0

x,y,z are signed numbers in the range +/-127
decimal with a fractional resolution of .004
0 disables gearing

DESCRIPTION: GR specifies the gear ratios for the geared axes in the elecronic gearing mode. The master axis is defined by the GAX or GAY or GAZ command when the main encoder is used.

The gear ratio may be different for each geared axis and range between +/-127.996. The slave axis will be geared to the actual position of the master. The master can move in both directions. GR 0,0,0 disables gearing for each axis. A limit switch also disables gearing.

EXAMPLE:

```
#G                  Gear Program
MOY                 Turn off servo to Y motor
GAY                 Specify master axis as Y
GR .25,,-5          Specify X and Z gear ratios
EN                  End
```

When the Y motor is rotated by hand, the X motor will rotate at 1/4 the speed; the Z motor will rotate 5 times the speed in the opposite direction.

*For DMC-6X1 Series only.

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HM XYZ	While Moving	NO
	In a program	YES
	Not in a program	YES
	Default Value	---

DESCRIPTION: The Home Command performs a three-stage homing sequence. The first stage consists of the motor moving at the user programmed speed until it sees a transition on the homing input for that axis. The direction for this first stage is determined by the initial state of the HOMING INPUT (0 for forward, 1 for reverse). Once the homing input changes state, the motor decelerates to a stop.

The second state consists of the motor changing directions and slowly approaching the transition again. When it detects the transition, it stops.

The third stage consists of the motor slowly moving forward until it detects an index pulse from the encoder. It stops at this point and defines it as position 0.

See Section I.9.

EXAMPLES:

:HM	Set Homing Mode for all axes
:BG	Home all axes
:BGX	Home only the X-axis
:BGY	Home only the Y-axis
:BGZ	Home only the Z-axis

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HX	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	Decimal

DESCRIPTION: The Hex command sets the controller to interpret all future numbers as hexadecimal (base 16) numbers. Negative numbers should be input as signal hex numbers.

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II INPUT INTERRUPT II

II m,n,o	While Moving	YES
	In a program	YES
	Not in a program	NO
	Default Value	---

m is an integer in the range
0 to 8 decimal

n is an integer in the range
1 to 8 decimal

o is an intger in the range
0 to 255 decimal

DESCRIPTION: The Input Interrupt enables the interrupt function for the specified inputs. m specifies the beginning input and n specifies the final input in the range. For example, II 2,4 specifies interrupts occurring for Input 2, Input 3 and Input 4. m equals 0 disables the Input Interrupts. If only the m parameter is given, only that input will generate an interrupt.

The parameter o is an interrupt mask. If m and n are unused, o contains a number with the mask. A 1 designates that input to be enabled for an interrupt.

Example: II,,5 enables inputs 1 and 3.

If any of the specified inputs go low during program execution, the program will jump to the subroutine with label #^. Any trippoints set by the program will be cleared. The RI command is used to return from the #^ routine. The RI command also re-enables input interrupts. To avoid returning to the main program on an interrupt, use the command ZS to zero the subroutine stack.

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EXAMPLES:

```
#A                      PROGRAM A
II 1                    Specify interrupt on input 1
JG 5000                 Specify jog speed
BGX                     Begin motion
WT 10000;ST X           Wait 10000 msec
EN                      END PROGRAM
#^                      Interrupt subroutine
STX                     Stop X
RI                      Return to main program
```

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IP x,y,z	While Moving	YES
IP ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	---

x,y,z are signed numbers in the range
-8388607 to 8388607 decimal for cases 1,2
-32767 to 32767 for case 3

DESCRIPTION: The Increment Position command allows for a change in the command position while the motor is moving. This command does not require a BG. The command has three effects depending on the motion being executed.

Case 1: Motor is standing still
An IP x,y,z command is equivalent to a PR x,y,z and BG command. The motor will move to the specified position at the requested slew speed and acceleration.

Case 2: Motor is moving towards specified position
An IP x,y,z command will cause the motor to move to a new position target, which is the old target plus x,y,z. x,y,z must be in the same direction as the existing motion.

Case 3: Motor is in the Jog Mode
An IP x,y,z command will cause the motor to instantly try to servo to a position x,y,z from the present instantaneous position. The SP and AC parameters have no effect. This command is useful when synchronizing 2 axis in which one of the axis' speed is indeterminant due to a variable diameter pulley.

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JG x,y,z	While Moving	YES*
JG ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	40000

x,y,z are signed numbers in the range
0 to 500000 decimal

DESCRIPTION: The JOG command sets the jog mode. The parameters following the JG, set the slew speed of the axes. Use of the question mark is the same as in the SP command.

EXAMPLES:

JG 100,500,2000	Set for jog mode with a slew speed of 100 counts/sec for the X-axis, 500 counts/sec for the Y-axis, and 2000 counts/sec for the Z-axis
JG ,,-2000	Change the Z axis to slew in the negative direction at -2000 counts/sec.

* The JOG (JG) command may be executed during a motion if the controller is already in JOG mode.

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JP #L	While Moving	YES
JP n	In a program	YES
JP #L,condition	Not in a program	NO
JP n,condition	Default Value	---

n is an integer in the range
0 to 200 decimal

L is A to Z, a to z, or [

DESCRIPTION: The Jump on Condition command causes the program to jump to a line number, n, or label, #L, on the occurrance of the specified condition. The condition may be the status of inputs, outputs, motor or variable state. The use of logical operators and mathematical operations is permitted in condition statements. A jump without a condition is also permitted.

Valid Mathematical Operations

+	Add
*	Multiply
/	Divide
-	Subtract

Valid Logical Operators

> greater than
< less than or equal to
= equal to

Valid Condition Parameters

Vn	Variables
PEX	Position Error X
PEY	Position Error Y
PEZ	Position Error Z
PX	Position X
PY	Position Y
PZ	Position Z
In	Input lines
On	Output lines
n	numbers, including fractions
LF	Forward Limit Switch
LR	Reverse Limit Switch
MX	Motion on X (MX=1 if in motion)

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MY	Motion on Y (MY=1 if in motion)
MZ	Motion on Z (MZ=1 if in motion)
0X	Motor off X (0X=1 if motor off)
0Y	Motor off Y (0Y=1 if motor off)
0Z	Motor off Z (0Z=1 if motor off)

EXAMPLES:

Statement	Function
JP #A	Jump to label A
JP #B,V1=0	Jump to label B if V1 is equal to zero
JP #C,V1<V2	Jump to loabel C if V1 is less than or equal to V2
JP #D,V1+V2=V3*V4	Jump to label D if the sum of V1 and V2 is equal to the product of V3 and V4
JP #E,PEX=0	Jump to label E if the position error on X is zero
JP #F,PY=PZ	Jump to label F if the Y and Z position are equal
JP 5,PEX<V3/2	Jump to line number 5 if the position error on X is less than or equal to V3 divided by 2
JP 17,I1=1	Jump to line number 17 if input 1 is high
JP #G,LFX=0	Jump to label G if Forward limit switch on X is 0

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JS #L	While Moving	YES
JS n	In a program	YES
JS #L,condition	Not in a program	NO
JS n,condition	Default Value	---

n is an integer in the range
0 to 200 decimal

L is A to Z, a to z, or [,]

DESCRIPTION: The Jump to Subroutine on condition command will change the sequential order of execution of command in a program. If the jump is taken, program execution will continue at the line specified by the first parameter, which can be either a line number or label. The line number of the JS command is saved and after the next EN command is encountered (END of subroutine), program execution will continue with the instruction JS command. There can be a JS command within a subroutine. These can be nested 5 deep.

Please refer to the JP command for a description of valid conditions.

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KI x,y,z	While Moving	YES
KI ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	0

x,y,z are integers in the range
0 to 255 decimal

DESCRIPTION: The KI command sets the integral gain of the control loop. It fits in the control equation as follows:

$$D(z) = \frac{GN\ (Z-ZR/256)}{4\ \ (Z-PL/256)} + \frac{KI}{256\ (Z-1)}$$

The integrator term will reduce the position error at rest to zero.

EXAMPLES:

KI 12,14,16	Specify X,Y,Z-axis integral
KI 7	Specify X-axis only
KI ,,8	Specify Z-axis only
KI ?,?,?	Return X,Y,Z KI
007,014,008	

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L* LATCH STATUS L

LX	While Moving	YES
LY	In a Program	YES
LZ	Not in a Program	YES
	Default Value	0

DESCRIPTION: The L command returns the high speed latch status as a variable. A one implies the latch is armed. A zero means the high speed latch has occurred and is disarmed. Note this command can only be used in equating to the variables or testing conditions.

EXAMPLE:

```
V1=LX              Sets V1 equal to latch X status
JP #B,LY=0         Jumps to #B if latch Y is disarmed
```

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LA XYZ	While Moving	YES
	In a Program	YES
	Not in a Program	YES
	Default Value	0

X,Y,Z specify the X,Y and Z axes

DESCRIPTION: The LA command enables the high speed position latching function of the controller where the position is captured within 200 nanoseconds of a low input on pin 29-latch Z, pin 33-latch Y, pin 37-Latch X. (40-pin connector)

EXAMPLE:

```
LA X            Arm the latch for X-axis
#L              Label
JP #L,LX=1      Loop until latch occurs
V1=PCX          Assign latch value to V1
RL X            Report latch value
```

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LN n	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	---

n is an integer in the range 0 to 8

DESCRIPTION: The Learn Mode enables collecting position data in a form compatible with the contouring mode (CM). This allows recording the position data by the host computer and playing it back to duplicate a specific motion. The Learn Mode is activated with the instruction LN n, where the parameter n defines the time interval. The value of n must be between 1 and 8 where the time interval is equal to 2n. In response, the controller transmits data records corresponding to motor position. Refer to Section 5.4 for details. n=0 terminates the Learn Mode.

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LS	LS n,m	While Moving	YES
LS n	LS n,#K	In a program	NO
LS ,m	LS #L,m	Not in a program	YES
LS #L	LS #L,#K	Default Value	0, Last line
LS ,#K			

n,m are integers in the range
0 to 200 decimal

L,K are A to Z, a to z or [,]

DESCRIPTION: The List command sends a listing of the programs in memory out IBM PC port. The listing will start with the line pointed to by the first parameter, which can be either a line number or a label. If no parameter is specified it will start with line 0. The listing will end with the line pointed to by the second parameter--again either a line number or label. If no parameter is specified, the listing will go to the last line of the program.

EXAMPLE:

```
:LS #A,6              List program starting at #A through line 6

002 #A
003 PR 500
004 BGX
005 AM
006 WT 200
```

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LT Vn=m	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	---

n is in the range 0 to 63 decimal
m is a real number, PEX, PEY, PEZ
PX, PY, PZ, I0 through I9, or O0 through O9

DESCRIPTION: The LET command defines a variable as a number, as the value of an input or output line, or as the position or position error of an axis. A variable may also be defined without the LT command by specifying Vn= .

EXAMPLES:

LT V1=7	Define V1 as number 7
LT V2=PEX	Define V2 as position error of X
LT V3=PY+PZ	Define V3 as position of Y plus Z
LT V4=9.125	Define V4 as number 9.125

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MG ccccccccccccccc	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	---

c is any letter, number, symbol, or <cntrl>G

DESCRIPTION: The Message command sends up to 29 ASCII characters out the IBM PC Bus port. This can be used to alert an operator, send instructions, or return a variable value. The <cntrl>G or "Bell" character will sound a buzzer on most computers or terminals. A semicolon at the end of the message inhibits the carriage return line feed.

EXAMPLES:

```
#R                      PROGRAM R
MG Begin Program        Message
MG V1=;V1=              Message-Print V1 value
DP 0                    Define position as 0
PR 100                  Position X is 100
BGX                     Begin X
AMX                     After Motion X
MG Position=;TPX        Print Message-return X position
EN                      End Program

:XQ #R                  Begin Program
V1=0000000.000
Position = 0000100,,
```

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MO XYZ	While Moving	NO
	In a program	YES
	Not in a program	YES
	Default Value	---

DESCRIPTION: The Motor Off command shuts off the control algorithm. The controller will continue to monitor the motor position. To turn the motor back on use the Servo or Servo Here commands (SV) or (SH). The controller can be configured to wake-up in the motor-off mode if MOF is jumpered.

EXAMPLES:

MO	Turn off all motors
MOX	Turn off the X motor Leave the Z,Y motors unchanged
MOY	Turn off the Y motor Leave the X,Z motors unchanged
MOZX	Turn off the Z and X motors Leave the Y motor unchanged
SH	Turn all motors on

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NO	While Moving	YES
NO ccccccccccccccc	In a program	YES
	Not in a program	YES
	Default Value	---

c is any letter, number, symbol or <cntrl>G

DESCRIPTION: The No Operation command performs no action in a sequence, but can be used as a place holder. After the NO, up to 29 characters can be given to form a program comment. This helps to document a program.

EXAMPLES:

```
#A                    PROGRAM A
NO                    No Operation
NO This Program       No Operation
NO Does Absolutely    No Operation
NO Nothing            No Operation
EN                    END OF PROGRAM
```

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OE x,y,z	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default value	0,0,0

x,y,z are 0 or 1. 0 disables function.
1 enables off-on-error.

DESCRIPTION: The Off on Error command sets the DMC-630 to shut off the motor command if a position error in excess of the limit specified by the ER command occurs. The OE1 command enables this function, while the OE0 command disables it. When the OE command is enabled, an Abort either from the Abort input or the Abort command will shut off the motor.

EXAMPLES:

OE 1,1,1	Enable OE on all axes
OE 0	Disable OE on X-axis Y and Z remain unchanged
OE ,,1	Enable OE on Z axis X and Y remain unchanged
OE 1,0,1	Enable OE on X and Z axis Y remains unchanged

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OF x,y,z	While Moving	YES
OF ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	0

x,y,z are signed numbers in the range
-127 to 127 decimal
(-2047 to 2047 decimal for 12-bit DAC in DMC-6X1)

DESCRIPTION: The offset command sets a bias in the motor command output or returns a previously set value. This can be used to counteract gravity or an offset in an amplifier.

EXAMPLES:

OF 1,-2,3	Set X-axis offset to 1, the Y-axis offset to -2, the Z-axis to 3
OF -3	Set X-axis offset to -3 Leave Y-axis offset unchanged
OF ,0	Set Y-axis offset to 0 Leave X-axis offset unchanged
OF ?,?,? -003,000,003	Return offsets
OF ? -003	Return X offset
OF ,? 000	Return Y offset

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OP m,n	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	0

m is an integer in the range
0 to 256 decimal
n is an integer in the range
1 to 8 decimal

DESCRIPTION: The Output Port command sends 8 bits of data to the output port of the controller. It is convenient to specify the HX mode before setting OP. You can use the output port to control external switches and relays. The n parameter is used to specify the number of bits effected starting with the LSB. The other bits are masked. For example, if n=2, only output bit 0 and 1 will be changed by OF m. If the n parameter is not specified, all bits will be changed.

EXAMPLES:

HX	Set Hex mode
OP 0	Clear Output port
OP 85	Set bits 7,2 and 0; clear the others
OP 85,2	Set bit 0. Clear bit 1. Others unchanged.

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PX	While Moving	YES
PY	In a Program	YES
PZ	Not in a Program	YES
	Default Value	---

DESCRIPTION: The Position command will respond with the position of that axis. This function allows the program to utilize the current position of the specified axis. The position can also be saved in a variable, which can later be used in a mathematical expression.

NOTE: This command can only be used in equating to the variables or in setting conditions.

EXAMPLES:

V1=PX	Sets V1 as current position of X-axis
JP #B,PY<10000	Jumps to label B if position of Y exceeds 10000
V2=PX*3-10000	Sets V2 as 3 times the position of X-axis minus 10000

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PA x,y,z	While Moving	NO
PA ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	

x,y,z are signed integers in the range
-8388607 to 8388607 decimal

DESCRIPTION: The Position Absolute command will set the final destination of the next move. If a ? is used, then the current destination (current command position if not moving, destination if in a move) is returned. The largest position move possible is 8388607. A commanded move greater than this number will create a move in the other direction (numeric rollover). Units are in quadrature counts.

EXAMPLES:

:PA 400,-600,500	X-axis will go to 400 counts, Y-axis will go to -600 counts, Z-axis will go to 500 counts on the next BG command
:PA ?,?,? 0000000,0000000,0000000	Returns the current commanded position
:BG	Start the move
:PA ? -0000600	Returns the X-axis destination
:PA 700	X-axis will go to 700 on the next move, while the Y-axis and Z-axis will travel the previously set relative distance if the preceding move was a PR move, or will not move if the preceding move was a PA move.

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PC*	CAPTURED POSITION	PC
PCX	While Moving	YES
PCY	In a Program	YES
PCZ	Not in a Program	YES
	Default Value	0

DESCRIPTION: The PC command returns the value of the captured position from the high speed latch. This command can only be used when equating to variables or testing conditions.

EXAMPLE:

```
V1=PCX              Sets V1 equal to captured position
JP #B,PCY>1000      Jump to #B if captured Y position is more
                      than 1000
```

*For DMC-6X1 Series only.

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PD* DUAL ENCODER POSITION PD

PDX	While Moving	YES
PDY	In a Program	YES
PDZ	Not in a Program	YES
	Default Value	0

DESCRIPTION: The PD command returns the dual encoder position as a variable. This command can only be used in equating to variables or when testing conditions.

EXAMPLE:

V1=PDX	Sets V1 equal to auxiliary X encoder position
JP #B,PDX>10000	Jump to #B if auxiliary encoder position is greater than 10000

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PEX	While Moving	YES
PEY	In a Program	YES
PEZ	Not in a Program	YES
	Default Value	---

DESCRIPTION: The Position Error command will respond with the position error of that axis. This function allows the program to utilize the current position error of the specified axis. The position error can also be saved in a variable, which can then be utilized in a mathematical expression.

NOTE: This command can only be used in equating to the variables or in setting conditions.

EXAMPLES:

V1=PEX	Sets V1 equal to position error of X-axis
V2=PEY	Sets V2 equal to position error of Y-axis
JP #P,PEX*PEX>100	Jump to label P if the square of the position error is greater than 100 or if the error is out of +/-10 counts range.

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PL x,y,z	While Moving	YES
PL ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	0

x,y,z are unsigned numbers in the range
0 to 255 decimal

DESCRIPTION: The Pole command sets the compensating pole in the control loop or returns the previously set value. It fits in the control equation as follows:

$$D(z) = \frac{GN \quad (z-ZR/256)}{4 \quad (z-PL/256)}$$

See Section I.2 for further analysis.

EXAMPLES:

PL 20,30,40	Set X-axis pole to 20 Y-axis pole to 30 Z-axis pole to 40
PL 15	Set X-axis pole to 15 Leave Y,Z poles unchanged
PL ,50	Set Y-axis pole to 50 Leave X,Z axis poles unchanged
PL ?,?,? 015,050,040	Return X,Y,Z poles
PL ? 015	Return X-axis pole
PL ,? 050	Return Y-axis pole

Note: The Pole is not used in the DMC-6X1 Series.

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PR x,y,z	While Moving	NO
PR ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	0

x,y,z are signed integers in the range
-8388607 to 8388607 decimal

DESCRIPTION: The Position Relative command sets the incremental distance and direction of the next move. If a ? is used, then the current incremental distance is returned (even if it was set by a PA command). Units are in quadrature counts.

EXAMPLES:

:PR 100,200,300	On the next move the X-axis will go 100 counts, the Y-axis will go 200 counts forward, Z-axis will go 300 counts
:PR 500	The X-axis will go 500 counts on the next move while the Y-axis will go its previously set relative distance
:PR ?,?,?	Return relative distances
0000100,0000200,0000300	
:PR ,?	Return the Y-axis relative distance
0000200	

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RC x,y,z	While Moving	YES
RC ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	0,0,0

x,y,z are 0 or 1
0 disables function
1 enables Report-when-complete

DESCRIPTION: The Report When Complete command will return an X,Y, or Z to the host computer upon completion of the X,Y, or Z motion, respectively. This function may be enabled or disabled by setting 1 or 0 for each axis.

EXAMPLES:

RC 0,0,0	Disable report when complete on X,Y,Z axis
RC ,,1	Enable report when complete on Z axis only. X and Y unchanged.
RC 1,0,1	Enable report when complete on X and Z axis. Disable Y axis.

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RE n

While Moving	NO
In a program	YES
Not in a program	NO
Default Value	---

n = 0 or 1
0 clears interrupted trippoint
1 restores state of trippoint

DESCRIPTION: The return from error routine is used to end an error handling subroutine or limit switch handling subroutine. The error handling subroutine begins with the #] label. The limit switch handling subroutine begins with the #[. An RE at the end of these routines causes a return to the main program. Care should be taken to be sure the error or limit switch conditions no longer occur to avoid re-entering the subroutines. If the program sequencer was waiting for a trippoint to occur, prior to the error interrupt, the trippoint condition is preserved on the return to the program if RE1 is used. RE0 clears the trippoint. To avoid returning to the main program on an interrupt, use the ZS command to zero the subroutine stack.

EXAMPLES:

```
000 #[              Begin Error Handling Subroutine
001 MG ERROR        Print message
002 SB1             Set output bit 1
003 RE              Return to main program and
                     clear trippoint
```

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RI	While Moving	NO
	In a program	YES
	Not in a program	NO
	Default Value	---

n = 0 or 1
0 clears interrupt trippoint
1 restores trippoint

DESCRIPTION: The Return From Interrupt Routine is used to end the interrupt subroutine beginning with the label #^. An RI at the end of this routine causes a routine to the main program. The RI command also re-enables input interrupts. If the program sequencer was interrupted while waiting for a trippoint, such as WT, RI1 restores the trippoint on the return to the program. RI0 clears the trippoint. To avoid returning to the main program on an interrupt, use the command ZS to zero the subroutine stack. This turns the jump subroutine into a jump only.

EXAMPLES:

```
#^                      Begin interrupt subroutine
MG INPUT INTERRUPT      Print Message
SB 1                    Set output line 1
RI 1                    Return to the main program and
                         restore trippoint
```

or

```
#^                      Begin interrupt subroutine
MG INTERRUPT            Print Message
ZS                      Zero subroutine stack
JP #A                   Jump to #A
```

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RL* — REPORT POSITION LATCH — RL

RL XYZ	While Moving	YES
	In a Program	YES
	Not in a Program	YES
	Default Value	0

X,Y,Z are X,Y and Z-axis

DESCRIPTION: The RL command returns the last position captured by the high speed position latch. The latch must first be armed by the LA command and then a low signal must occur on the appropriate input on the 40-pin connector. Pin 27 latch Z, Pin 31 Latch Y, Pin 35 Latch X. The latch status can be tested with the LX,LY or LZ command.

EXAMPLE:

```
JG ,5000            Jog Y-axis
BGY                 Begin jogging
LAY                 Arm latch
#B                  Loop until latch occurs
JP #B,LY=1          Test for latch still armed
RL                  Report latch
```

To assign the latched position value to variables, use the instruction V1=PCX, PCY or PCZ.

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RM* SPECIFY ACCELERATION RAMP RM

RM x,y,z	While Moving	NO
	In a Program	YES
	Not in a Program	YES
	Default Value	1024

x,y,z are numbers in the range 1024 to 8,308,807
The units are (counts/sec^2)/2 msec

DESCRIPTION: RM x,y,z specifies the acceleration ramp (jerk rate) during independent moves (PR,PA,JG). The command TA 1,1,1 must be used to enable the trapezoidal or "S-curve" mode. During this mode, the controller will generate commands to ramp the acceleration up to the peak acceleration value, AC. The rate of acceleration change is given by RM.

EXAMPLE:

TA 1	Set "S-curve" mode
PR 50000	Distance
SP 60000	Slew speed
AC 180000	Peak acceleration
RM 2160	Acceleration rate
BGX	Begin motion

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RS	While Moving	YES
	In a program	NO
	Not in a program	YES
	Default Value	---

DESCRIPTION: The Reset command resets the state of the processor to its power-on condition. The previously saved state of the controller, along with parameter values, and saved sequences are restored.

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SB n	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	

n is an integer in the range
0 to 7 decimal

DESCRIPTION: The Set Bit command sets one of eight bits on the output port.

EXAMPLES:

SB 5	Set output bit 5
SB 0	Set output bit 0

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SC	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	---

DESCRIPTION: The instruction Stop Code allows the user to determine why a motor stops. The controller responds with the stop code as follows:

CODE	MEANING
0	Motors are running, independent mode
1	Motors stopped at commanded independent position
2	Decelerating or stopped by FWD limit switches
3	Decelerating or stopped by REV limit switches
4	Decelerating or stopped by Stop Command (ST)
6	Stopped by Abort input
7	Stopped by Abort command (AB)
8	Decelerating or stopped by Off-on-Error (OE1)
9	Stopped after Finding Edge (FE)
10	Stopped after Homing (HM)
100	Motors are running, vector sequence
101	Motors stopped at commanded vector
102	Contouring Stop

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SE* — SPECIFY ENCODER TYPE — SE

SE x,y,z

While Moving	NO
In a Program	YES
Not in a Program	YES
Default Value	0

x,y,z may be 0,1,-1
where 0 disables auxiliary encoders
1 enables dual encoders of quadrature type
-1 enables auxiliary input for INC & DEC

DESCRIPTION: SE specifies the encoder type for the dual encoder mode. The type may be quadrature encoders (CHA and CHB) or incremental and decrement pulses (INC and DEC).

EXAMPLE:

```
SE 1,0,-1
```

*For DMC-6X1 Series only.

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SH XYZ	While Moving	NO
	In a program	YES
	Not in a program	YES
	Default Value	---

DESCRIPTION: The Servo Here command tells the controller to use the current motor position as the command position and to start controlling.

This command can be useful when the position of a motor has been manually adjusted following a motor off (MO) command.

EXAMPLES:

SH	Servo X,Y,Z motors
SHX	Only servo the X motor, the Y and Z motors remain in its previous state
SHY	Servo the Y motor; leave the X and Z motors unchanged
SHZ	Servo the Z motor; leave the X and Y motors unchanged

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SP x,y,z	While Moving	YES
SP ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	8192

x,y,z are unsigned numbers in the range
2 to 500000 decimal

DESCRIPTION: This command sets the slew speed of any or all axes for independent moves, or it will return the previously set value. The parameters input will be rounded down to the nearest factor of 2. The units of the parameter are in counts per second.

EXAMPLES:

PR 2000,3000,4000	Specify x,y,z position
SP 5000,6000,7000	Specify x,y,z speeds
BG XYZ	Begin motion of all axes
AM Z	After Z motion is complete
VS 40000	Specify vector speed
VP 10000,10000	Specify X,Y vector position
BG S	Begin vector motion

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ST XYZ	While Moving	YES
ST	In a program	YES
ST S	Not in a program	YES
ST SZ	Default Value	---

DESCRIPTION: The Stop Command stops motion on the specified axis.

Motors will come to a decelerated stop. If ST is given without an axis specification, program execution will stop in addition to XYZ. XYZ specification will not halt program execution.

EXAMPLES:

ST X	Stop X axis motion
ST S	Stop coordinated XY sequence
ST XYZ	Stop X,Y,Z motion
ST	Stop program and XYZ motion
ST SZ	Stop coordinated XY sequence and Z motion

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SV XYZ	While Moving	NO
	In a program	YES
	Not in a program	YES
	Default Value	---

DESCRIPTION: The Servo command enables the control law and amplifier.

The motor will servo to its previously set command position.

EXAMPLES:

SV	Servo X,Y,Z axes
SVX	Servo the X-axis, leave the Y-axis, Z-axis unchanged
SVY	Servo the Y-axis, leave the X-axis, Z-axis unchanged
SVXY	Servo X and Y axes

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T	TIME	T
=T	While Moving	YES
	In a Program	YES
	Not in a Program	YES
	Default Value	---

DESCRIPTION: The Time command allows the program to access time as variable. The range for T is between +/-8388607.

NOTE: This command can only valid when used during setting the variables with current time.

EXAMPLE:

V1=T Sets V1 at current time

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TA* SET UP TRAPEZOIDAL ACCELERATION TA

TA x,y,z

While Moving	NO
In a Program	YES
Not in a Program	YES
Default Value	0

x,y,z are 0 or 1
1 enables trapezoidal acceleration mode
0 disables trapezoidal acceleration mode

DESCRIPTION: The command TA1 is required to set the trapezoidal acceleration (S-curve) mode during independent moves (PR, PA, JG). RM n specifies the actual acceleration ramp in (counts/sec^2)/2 msec

EXAMPLE:

```
TA 1,,0              Set "S-curve" mode for x and z
PR 50000,,7000       Distance
SP 60000,,5000       Slew speed
AC 180000,,100000    Peak acceleration
RM 2160,,1000        Acceleration rate
BGXZ                 Begin motion
```

*For DMC-6X1 Series only.

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TB	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	---

n is an integer in the range
0 to 255

DESCRIPTION: These commands give information on the status of the controllers.

Bit 7	Always low
Bit 6	Executing program if high
Bit 5	Contour Mode active if high
Bit 4	Hex Mode if high
Bit 3	Always low
Bit 2	Always low
Bit 1	Trace function enabled if high
Bit 0	Always low

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TC	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	

DESCRIPTION: The Tell Error Code returns a number between 1 and 255. This number is a code that reflects why a command was not accepted by the DMC-630 processing unit. This command is useful when the DMC-630 halts execution of a program at a command or when the response to a command is a question mark. Entering the TC command will provide the user with a code as to the reason. After TC has been read, it is set to zero

*Note: For DMC-6X1 Series, the TC1 command may be used where the 1 designates that the text message for TC is also to be returned.

Error Codes:

1	Unrecognized command
2	Command only from program
3	Command not valid in program
4	Operand error
5	Command too long
6	Number out of range
7	Command not valid while running
8	Command not valid while not running
9	Bad variable number
10	Empty program line or label
11	Invalid label or line number
12	Subroutine more than 8 deep
13	JG only valid when running in jog mode
14	Checksum error
16	IP incorrect sign during position move or IP given during forced deceleration
17	Edit & DL not valid while program running
18	Command not valid when contouring
20	Begin not valid with motor off
21	Begin not valid while running
22	Begin cannot be executed because of Limit Switch
24	Begin not valid because no VP,CR sequence defined
25	Variable not given in IN command
26	AM must not have more than one parameter

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29	Not valid during coordinated move
30	Sequence segment too short
31	Total move distance in a sequence > 8 million
32	More than 255 segments in a sequence
33	Download Error (line too long or too many lines)
40	Contouring record format error
41	Contouring record range error
42	Contour record data being sent too slowly
45	Array index or syntax error
46	Gear axis both master and follower
50	MP only valid in Master/Slave Mode
51	No sequence in Master/Slave

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TD X,Y,Z	While Moving	YES
	In a Program	YES
	Not in a Program	YES
	Default Value	---

where X,Y,Z are the X,Y and Z axes

DESCRIPTION: TD returns the position of the auxiliary encoder inputs. The auxiliary encoders are enabled with the SE command. To assign the dual encoder position to a variable, use the instruction V1=PDX, PDY or PDZ.

EXAMPLE:

```
TDY                Tell the Y auxiliary encoder
```

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TE XYZ	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	---

DESCRIPTION: This command returns the current position error of the motor(s) in a form of a four-digit hex number or five-digit decimal number.

EXAMPLES: Assume that the position errors for the X,Y and Z axis are 5, -2 and 0, respectively.

```
TE                      Return all position errors
00005,-00002,00000

TEX                     Return the X motor position error
00005

TEY                     Return the Y motor position error
-00002

HX                      Change to HX
TP                      Return position error in HX
0005,FFFE,0000
```

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TI	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	---

DESCRIPTION: Returns the state of the general inputs, I1 through I8.

MSB	Bit 7	Input 8
	Bit 6	Input 7
	Bit 5	Input 6
	Bit 4	Input 5
	Bit 3	Input 4
	Bit 2	Input 3
	Bit 1	Input 2
	Bit 0	Input 1

Example:

```
TI
008     Input 4 is high, others low

TI
000     All inputs low
```

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TL — TORQUE LIMIT — TL

TL x,y,z	While Moving	YES
TL ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	127

x,y,z are unsigned numbers in the range
1 to 127 decimal
(1 to 2047 decimal for -12 bit DAC in DMC-6X1 Series)

DESCRIPTION: The Torque Limit command sets the limit on the Output DAC's or PWM signal. 127 will allow for full scale, 64 limits the output to 50% of its range, 96 limits it to 75%, etc.

EXAMPLES:

TL 13,64,127	Limit X-axis to 10% of full scale Y-axis to 50% of full scale Z-axis to 100% of full scale
TL 114	Limit X-axis to 90% of full scale Leave Y,Z unchanged
TL ,96	Limit Y-axis to 90% of full scale
TL ?,?,? 114,96,127	Return limits
TL ? 114	Return X-axis limit
TL ,? 96	Return Y-axis limit

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TM n	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	1000

n is an integer in the range
1000 to 32767 decimal

DESCRIPTION: The TM command sets the sampling period of the control loop. Changing the sampling period will uncalibrate the speed and acceleration parameters (See Section I.2). A negative number turns off the internal clock allowing for an external source to be used as the time base.

EXAMPLES:

TM -1000	Turn off external clock
TM 2000	Set sample rate to 2000 ìsec (This will cut all speeds in half and all acceleration in fourths)
TM 1000	Return to default sample rate

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TP — TELL POSITION — TP

TP XYZ	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	---

DESCRIPTION: This command returns the current position of the motor(s) in the form of a six-digit hex number or seven-digit decimal number.

EXAMPLES: Assume the X-axis is at the position 200 (decimal), the Y-axis is at the position -10 (decimal), and the Z-axis is at position 0.

```
TP                      Return X,Y,Z positions
0000200,-0000010,0000000

TPX                     Return the X motor position
0000200

TPY                     Return the Y motor position
-0000010

HX                      Change to hex

TP                      Return X,Y,Z in hex
0000C8,FFFFF6,000000
```

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TR1	While Moving	YES
TR0	In a program	YES
	Not in a program	YES
	Default Value	TR0

DESCRIPTION: The Trace command causes each instruction in a program to be sent out the communications port prior to execution. TR1 enables this function and TR0 disables it. The trace command is useful in debugging programs.

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TS XYZ	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	---

DESCRIPTION: Returns the state of the Home, Index, Forward Limit and Reverse limits for each axis. Also returns error, motion, and motor status.

X

Bit 7	Home X
Bit 6	Index X
Bit 5	Forward Limit X
Bit 4	Reverse Limit X
Bit 3	Latch X (1=armed)*
Bit 2	X motor off if high
Bit 1	X in motion if high
Bit 0	X error if high

Y

Bit 7	Home Y
Bit 6	Index Y
Bit 5	Forward Limit Y
Bit 4	Reverse Limit Y
Bit 3	Latch Y (1=armed)*
Bit 2	Y motor off if high
Bit 1	Y in motion if high
Bit 0	Y error if high

Z

Bit 7	Home Z
Bit 6	Index Z
Bit 5	Forward Limit Z
Bit 4	Reverse Limit Z
Bit 3	Latch Z (1=armed)*
Bit 2	Z motor off if high
Bit 1	Z in motion if high
Bit 0	Z error if high

*Bit 3 tests for latch in DMC-6X1 Series only, otherwise Bit 3 is always low.

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TT	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	---

DESCRIPTION: The Tell Torque instruction reports the two's complement eight-bit motor command before it has been converted into analog.

The relationship between the value returned by TT and the analog motor command is:

TT(Decimal)	TT(Hex)	Motor Command
-127	81	-10V Most negative
-1	FF	-0.08V
0	0	0
127	7F	10V Most positive

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TV* SET UP TRAPEZOIDAL ACCEL-COORDINATED TV

TV n	While Moving	NO
	In a Program	YES
	Not in a Program	YES
	Default Value	0

n=0 turns off trapezoidal accel mode
n=1 turns on trapezoidal accel mode

DESCRIPTION: The command TV 1 is required to set the trapezoidal acceleration (S-curve) mode during coordinated moves (VP and CR). VR n specifies the actual acceleration ramp in (counts/sec^2)/2 msec. When TV1 is specified, the controller will generate commands to ramp the acceleration up to the peak vector acceleration value, VA. The rate of acceleration is given by VR.

EXAMPLE:

TV 1	Set "S-curve" mode
VP 50000,50000	Vector distance
VS 10000	Vector speed
VA 50000	Peak vector acceleration
VR 2000	Specify acceleration rate
BGS	Begin sequence

*For DMC-6X1 Series only.

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While Moving	YES
In a program	NO
Not in a program	YES
Default Value	---

DESCRIPTION: The Upload command transfers data from the DMC-630 to a host computer. Programs are sent without line numbers. Uploading is terminated with a control Z.

EXAMPLES:

UL;	Begin Upload
#A	Line 0
This is an Example	Line 1
No Program	Line 2
EN	Line 3
<control> Z	Terminator

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Vn= VARIABLE Vn=

Vn=m	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	0

n is an integer in the range
0 to 63 decimal
m is a real number, PEX,PEY,PEZ
PX,PY,PZ,I0 through I8, or O0 through O9
MX, MY, MZ (1 in motion)
OX, OY, OZ (1 is motor off)
T (Time)

DESCRIPTION: The Vn= command is used to define a variable. A variable is specified using the LT command or Vn= command. Variables can be specified as real numbers, constants, position or position error of an axis, the status of I/O lines, motion status, motor status and time. Once specified, a variable can be manipulated using arithmetic operations. Arithmetic operations proceed from left to right. Variables can have values of real numbers between the range of þ8388607.000. The fractional part has a resolution of 1/256th. The Vn= command will only send a carriage return line feed if the command is terminated in a carriage return. If terminated in a ; no carriage return line feed is sent.

EXAMPLES:

V1 = 5	Sets V1 equal to five
V2 = PEX	Sets V2 as position error of X
V3 = V1+5	Sets V3 as V1 plus five
V3 =	Return value of V3
0000010.000	
V4 = 899.99	Set V4
V4 =	Return value of V4
0000899.988	
V5 = T	Sets V5 as the actual time. The response is a constantly running clock in increments of 976 microseconds (i.e. 1024

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```
                          equals 1 second)
V6 = MY                   Sets V6 as motion status of Y.
                          If Y is in motion, value
                          returned is 1.
V7 = I7                   Sets V7 as value of Input 7.
```

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VA n	While Moving	NO
VA ?	In a program	YES
	Not in a program	YES
	Default Value	0

n is an unsigned number in the range
1024 to 33282288 decimal

DESCRIPTION: This command sets the acceleration rate of the vector in a coordinated X,Y motion sequence. The parameter input will be rounded down to the nearest factor of 1024. The units of the parameter is counts per second squared.

EXAMPLES:

VA 1024	Set vector acceleration to 1024 counts/sec^2
VA ? 00001024	Return vector acceleration

NOTE: This command is not valid in the DMC-610.

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VP x,y	While Moving	NO
	In a program	YES
	Not in a program	YES
	Default Value	

x,y are signed integers in the range
-8388607 to 8388607 decimal

DESCRIPTION: The vector position command defines the target coordinates of a straight line segment in a motion sequence. The motion starts with the Begin sequence command. The units are in quadrature counts.

NOTE: Both the X and Y parameters must be specified.

A move of zero length is invalid.

EXAMPLES:

```
#A                  PROGRAM A
VP 1000,2000        Specify vector position X,Y
VS 2000             Specify vector speed
VA 400000           Specify vector acceleration
BGS                 Begin motion sequence
EN                  END PROGRAM
```

NOTE: This command is not valid in the DMC-610.

*IMPORTANT: The first vector in a coordinated motion sequence defines the origin for that sequence. All other vectors in the sequence are defined with respect to the start of the move.

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VR* SPECIFY ACCEL RAMP - COORDINATED VR

VR n	While Moving	NO
	In a Program	YES
	Not in a Program	YES
	Default Value	1024

n is a number in the range 1024 to 8,308,807
the units are (counts/sec^2)/2 msec

DESCRIPTION: VR n specifies the acceleration ramp (jerk rate) during coordinated moves. The units are (counts/sec^2)/2 msec. The command TV 1 must be used to enable the trapezoidal or "S-curve" mode. During this mode, the controller will generate commands to ramp the acceleration up to the peak vector acceleration value, VA. The rate of acceleration is given by VR.

EXAMPLE:

```
TV 1                Set "S-curve" mode
VP 50000,50000      Vector distance
VS 10000            Vector speed
VA 50000            Vector acceleration
VR 2000             Acceleration rate
BGS                 Begin sequence
```

*For DMC-6X1 Series only.

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VS n	While Moving	YES
VS ?	In a program	YES
	Not in a program	YES
	Default Value	

n is an unsigned number in the range
2 to 500000 decimal

DESCRIPTION: The command vector speed specifies the speed of the X,Y vector in a coordinated motion sequence. The parameter input is rounded down to the nearest factor of 2. The units are counts per second.

EXAMPLES:

VS 2000	Define vector speed as 2000 counts/sec
VS ?	Return vector speed
002000	

NOTE: This command is not valid in the DMC-610.

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Wt n	While Moving	YES
	In a program	YES
	Not in a program	YES
	Default Value	---

n is an integer in the range
0 to 65353 decimal

DESCRIPTION: The Wait command is a trippoint used to time events. After this command is executed, the controller will wait for the number of samples specified before executing the next command. If the TM command has not been used to change the sample rate, then the units of the Wait command are milliseconds.

EXAMPLES: Assume that 10 seconds after a move is over a relay must be closed.

```
#A                  PROGRAM A
PR 50000            Position relative move
BGX                 Begin the move
AMX                 After the move is over
WT 10000            Wait 10000 milliseconds
SB 0                Turn on relay
EN                  END PROGRAM
```

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XQ #L	While Moving	NO
	In a program	NO
	Not in a program	YES
	Default Value	---

L is a label A to Z, a to z, or [, or]

DESCRIPTION: The Execute Program command starts a previously entered program operating. Execution will start at the label specified.

EXAMPLES:

:XQ #A	Start execution at label A
:XQ #d	Start execution at label d

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ZR x,y,z	While Moving	YES
ZR ?,?,?	In a program	YES
	Not in a program	YES
	Default Value	232

x,y,z are unsigned numbers in the range
0 to 255 decimal

DESCRIPTION: The Zero command sets the compensating zero in the control loop or returns the previously set value. It fits in the control equation as follows:

$$D(z) = \frac{GN}{4} \frac{(z-ZR/256)}{(z-PL/256)}$$

See Section I.2 for further analysis.

EXAMPLES:

ZR 250,240,220	Set X-axis zero to 250 Y-axis zero to 240 Z-axis zero to 220
ZR 235	Set X-axis zero to 235 Leave Y,Z zero unchanged
ZR ,252	Set Y-axis zero to 252 Leave X,Z zero unchanged
ZR ?,?,? 235,252,220	Return all zeroes
ZR ? 235	Return X zero
ZR ,? 252	Return Y zero

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ZS ZERO SUBROUTINE STACK ZS

ZS n

While Moving	?
In a program	YES
Not in a program	NO
Default Value	---

n = 0 or 1

DESCRIPTION: The ZS command is only valid in an application program and is used to avoid returning from an interrupt (either input or error). ZS alone returns the stack to its original condition. ZS1 adjusts the stack to eliminate one return. This turns the jump to subroutine into a jump. Do not use RI (Return from Interrupt) when using ZS. To re-enable interrupts, you must use II command again.

EXAMPLES:

```
#^                        Interrupt Routine
MG INTERRUPT OCCURRED     Print Message
ZS                        Zero Stack
JP #A                     Jump to #A or other location
```

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LABEL

#L	While Moving	YES
	In a program	YES
	Not in a program	NO
	Default Value	---

L is A to Z, a to z, or [, or]

DESCRIPTION: The Label (#) command names a line in a program. It can be used to name the start of a program, a place to jump to, or the start of a subroutine. Valid labels are single character upper or lower case letters. [,], are special labels. The] label will mark the point where the controller will start execution if the position error exceeds the error limit. The [label marks the point where the controller will start execution if a limit switch occurs. The ^ label marks the beginning of the input interrupt.

EXAMPLES:

```
VALID LABELS
#A
#a

INVALID LABELS
#A1
#aa
#Label
```

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APPENDIX A Decimal to Hex Conversion

The Hexadecimal numbering system (base 16) is used in addition to the decimal system in the DMC-630. To send commands in hex the command (HX) is used, and to convert back to decimal (DC) is used.

DECIMAL	HEX	POWERS OF 16	
		N	16^N
0	0		
1	1		
2	2	0	1
3	3	1	16
4	4	2	256
5	5	3	4096
6	6	4	65536
7	7	5	1048567
8	8	6	16777216
9	9		
10	A		
11	B		
12	C		
13	D		
14	E		
15	F		

HEX number 3FA71B would be

$$(3 \cdot 1048576) + (15 \cdot 65536) + (10 \cdot 4096) + (7 \cdot 256) + (1 \cdot 16) + 11$$

$$= 4171547 \text{ decimal}$$

Note: Negative hex values are represented as 2's complement quantities.

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APPENDIX B Pulse Width Modulation

Besides the analog motor command, the DMC-630 produces two types of pulse width modulated signals which can be used to directly drive an amplifier. The forms are for a "chopper" or an "inverter" amplifier configuration.

In the "inverter" form, the PWM signal will be 50% duty cycle for 0 current, 0% duty cycle for full negative current, and 99.6% duty cycle for full positive current. This method of driving an amplifier has the advantage of being very linear, but it is not very power efficient. The DMC-630 will produce this form of PWM if the "SM" jumper is left unjumpered.

If the "SM" jumper is jumpered, then the form of PWM is the "chopper" form. In this form, the PWM duty cycle represents the magnitude of current, while the sign of the current is contained in the SIGN signal. Zero or low is for positive current, one or high is for negative current. This form of PWM is more power efficient but is nonlinear.

Note that when the "SM" jumper is jumpered, the analog motor command will not be valid.

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APPENDIX C Encoder Types

As configured from the factory, the DMC-630 will interface directly to a 2 channel quadrature encoder, with TTL level outputs. However, other types of encoders can also be used.

Incremental encoders which produce sinusoidal signals may be used if their DC level is 1.4 volts. If the DC level is zero volts, configure for differential encoders and put ground into CHA-, CHB- and Index-.

Differential encoders which output CHA-, CHB- and Index-, in addition to CHA, CHB and Index, may also be used with the DMC-630. To use the differential encoder inputs, remove all nine of the DE jumpers.

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APPENDIX D DMC-630 Pin-Outs

J10 - 60 pin

1	Ground	2	+5V
3	Error Output*	4	Reset Input*
5	Motor Command Output, Z	6	Motor Command Output, Y
7	Motor Command Output, X	8	Ground
9	Index, Z	10	Index-, Z
11	Channel B,Z	12	Channel B-,Z
13	Channel A,Z	14	Channel A-,Z
15	Index, Y	16	Index-, Y
17	Channel B,Y	18	Channel B-,Y
19	Channel A,Y	20	Channel A-,Y
21	Forward Limit Switch,Z*	22	Reverse Limit Switch,Z*
23	Home Input,Z	24	Forward Limit Switch,Y*
25	Reverse Limit Switch,Y*	26	Home Input,Y
27	Abort Input*	28	+5V
29	Index,X	30	Index-,X
31	Channel B,X	32	Channel B-,X
33	Channel A,X	34	Channel A-,X
35	Forward Limit Switch,X*	36	Reverse Limit Switch,X*
37	Home Input,X	38	Ground
39	N.C.	40	Input 8
41	Input 7	42	Input 6
43	Input 5	44	Input 4
45	Input 3	46	Input 2
47	Input 1	48	Ground
49	Output 7	50	Output 6
51	Output 5	52	Output 4
53	Output 3	54	Output 2
55	Output 1	56	Output 0
57	+12V	58	-12V
59	+5V	60	Ground

*Active Low

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J AUX - 40 pin

1	N.C.	2	N.C.
3	N.C.	4	N.C.
5	N.C.	6	N.C.
7	N.C.	8	N.C.
9	Motion Complete,Y*	10	Motion Complete,Z*
11	Motion Complete,X*	12	Ground
13	Increment Input,Z or CHA Z	14	N.C.
15	Decrement Input,Z or CHB Z	16	N.C.
17	Increment Input,Y or CHA Y	18	N.C.
19	Decrement Input,Y or CHB Y	20	N.C.
21	Increment Input,X or CHA X	22	N.C.
23	Decrement Input,X or CHB X	24	N.C.
25	Vcc	26	Ground
27	PWM Output,Z	28	N.C.
29	Sign Output,Z Latch Z*(6X1)	30	N.C.
31	PWM Output,Y	32	N.C.
33	Sign Output,Y Latch Y*(6X1)	34	N.C.
35	PWM Output,X	36	N.C.
37	Sign Output,X Latch X*(6X1)	38	N.C.
39	+12V	40	-12V

*Active Low

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Pin-Out Description

Outputs

Motion Complete* (Auxiliary)	Goes low when DMC-630 processor has completed generating motion profile. Motor may not actually be at position yet.
Analog Motor Command	þ10 Volt range signal for driving amplifier. In servo mode, motor command output is updated at the controller sample rate, every 1 msec. In the motor off mode, this output is held at 0 volts.
PWM (Auxiliary)	Pulse-width-modulated motor command for driving switching transistors directly. Not used if Analog motor command is input to amplifier. The switching frequency is 39.2KHz. The PWM output is available in two formats: Inverter and Sign Magnitude. In the Inverter mode, the PWM signal is 9% duty cycle for full negative voltage, 50% for 0 voltage and 99.6% for full positive voltage. In the Sign Magnitude Mode, (Jumper SM), the PWM signal is 0% for 0 voltage, 99.2% for full voltage, and the sign of the motor command is available at the sign output. (See Appendix B)
Sign (Auxiliary)	Used with the PWM signal to give the sign of the motor command. Not used if analog motor command is input to amplifier. (See Appendix B)
Error*	The signal goes low when the position error exceeds the value specified by the error limit command, ER.
Output 0-Output 7	These 8 outputs are uncommitted and may be designated by the user to toggle relays and trigger external events. The output lines are toggled by Set Bit, SB, and Clear Bit, CB, instructions. The OP instruction is used to define the state of all the bits of the Output port.

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Inputs

Encoder CHA, CHB	Position feedback from incremental encoder with two channels in quadrature, CHA and CHB. The encoder may be analog or TTL (See Appendix C). Any resolution encoder may be used as long as the maximum frequency does not exceed 500,000 quadrature states/sec. The DMC-630 performs quadrature decoding of the encoder signals resulting in a resolution of quadrature counts (4 x encoder cycles).
Encoder Index	Once-Per-Revolution encoder pulse. Used in Homing sequence to define home on an encoder index. (Optional)
Encoder CHA-,CHB-,Index-	Differential inputs from encoder. May be input along with CHA, CHB for noise immunity of encoder signals. The CHA- and CHB- inputs are optional. (Note: Remove jumper if differential input is used).
Abort*	A low input stops motion instantly without a controlled deceleration. Also aborts motion program.
Reset*	A low input resets the state of the processor to its power-on condition. The previously saved state of the controller, along with parameter values, and saved sequences are restored.
Forward Limit Switch*	Low input inhibits motion in forward direction. Also causes execution of limit switch subroutine, #].
Reverse Limit Switch*	Low input inhibits motion in reverse direction. Also causes execution of limit switch subroutine, #].
Home Switch	Input for Homing (HM) and Find Edge (FE) instructions. Upon begin of HM or FE, the motor accelerates to slew speed. A transition on this input will cause the motor to decelerate to a stop. The initial direction of motion is forward if the input starts low, and reverse if the input starts high.
Increment (Auxiliary)	Each rising edge on this input increments the position command counter by one

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	quadrature count. Note: Position counter loses calibration.
Decrement (Auxiliary)	Each rising edge on this input decrements the position command counter by one quadrature count. Note: Position counter loses calibration.
Input 1-Input 8	Uncommitted inputs. May be defined by the user to trigger events. Inputs are checked with the Conditional Jump instruction and After Input instruction. Lowest 4 bits are checked using IO=n statement.

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APPENDIX E Jumpers

Label	Function (If jumpered)
SM	Selects Sign Magnitude mode for PWM output (With SM jumper, the Analog command is not a valid command).
A2-A8	Jumpers for Address Selection
MO	Motor off on power up
DE	Enables differential encoder inputs

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APPENDIX F

F.1. Modeling

In order to understand the operation of the system we start with the description of the system's main elements and their mathematical models. The functional elements of the system are shown in Fig. F.1.

Motor-Amplifier

The mathematical model of the motor and the amplifier depends on the type of the amplifier. When the amplifier is a voltage source with a gain Ka [V/V], the transfer function of the motor is:

$$\frac{P}{E} = \frac{1/K_t}{s(s\,T_m + 1)(s\,T_e + 1)} \text{ [rad/volt]}$$

where

$$T_m = \frac{RJ}{Kt} \text{ [s]}$$

and

$$T_e = \frac{L}{R} \text{ [s]}$$

and the motor parameters and units are

Kt - Torque constant [Nm/A]

R - Armature resistance [Ω]

J - Combined inertia of motor and load [Kg•m^2]

L - Armature inductance [H]

If the motor parameters are given in English units, it is necessary to convert the quantities to MKS units. For example, consider a motor with the parameters:
Kt = 14.16 oz•in/A = 0.1 Nm/A
R = 2 Ω
J = 0.0283 oz•in•s^2 = 2.10-4 kg•m^2
L = 0.004 H

Then the corresponding time constants are

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$$T_m = 0.04 \text{ sec}$$

and

$$T_e = 0.002 \text{ sec}$$

and the motor transfer function is

$$\frac{P}{E} = \frac{10}{s(0.04s + 1)(0.002s + 1)} \text{ [rad/V]}$$

When the amplifier has a current feedback and acts as a current source, the transfer function of the motor is modified to form

$$\frac{P}{E} = \frac{K_t}{Js^2}$$

where Kt and J are as defined previously. For example, the motor described by the previous example will have the transfer function

$$\frac{P}{E} = \frac{500}{s^2} \text{ [rad/A]}$$

If the motor is a DC brushless motor, it is driven by an amplifier that performs the commutation. The combined transfer function of the motor amplifier combination is the same as that of a similar brush motor, as described by the previous equations.

Encoder
The encoder generates N pulses per revolution. It outputs two signals, Channel A and B which are in quadrature. Due to the quadrature relationship between the encoder channels, the position resolution is increased to 4N quadrature counts/rev.

The model of the encoder can be represented by a gain of

$$K_f = \frac{4N}{2\pi} \text{ [counts/rad]}$$

For example, a 1000 lines/rev encoder is modeled as

$$K_f = 638$$

DAC
The DAC or D-to-A convertor converts an 8-bit number to an analog voltage. The input range of the numbers is 256 and the output voltage range is þ10V or 20V. Therefore, the effective gain of the DAC is

$$K_d = \frac{20}{256} = 0.08 \text{ [Volt/count]}$$

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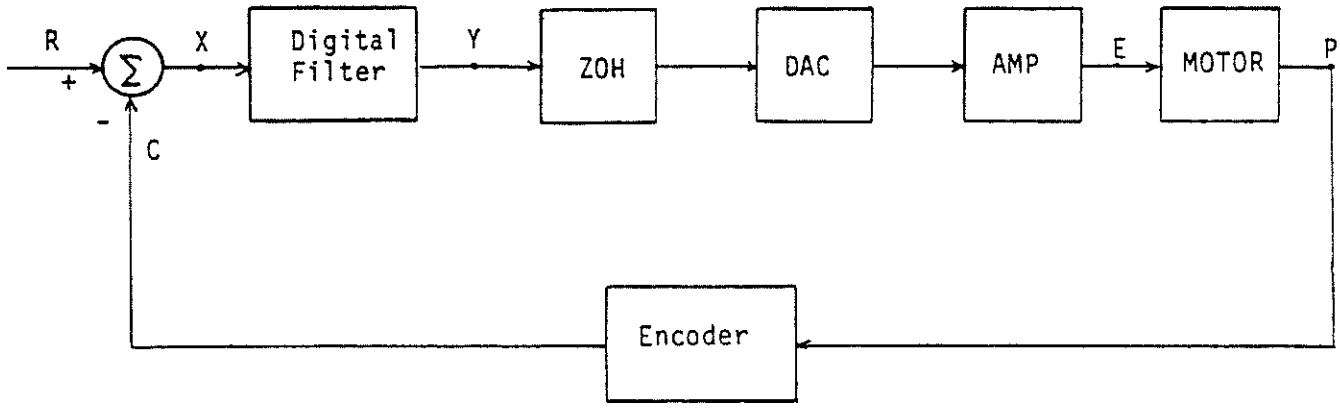


Fig. F.1 - Functional Elements of a Motion Control System.

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Digital Filter

The digital filter has a transfer function of

$$D(z) = K\frac{z-A}{z-B} + \frac{C}{z-1}$$

and a sampling time of T = 1 ms.

The filter parameters, K, A, B and C are selected by the instructions GN, ZR, PL, KI, respectively. The relationship between the filter coefficients and the instructions are:

K = GN/4
A = ZR/256
B = PL/256
C = KI/256

This filter includes a lead compensation and an integrator. It is

equivalent to a continuous filter with a transfer function G(s)

$$G(s) = g\frac{s+a}{s+b} + \frac{f}{s}$$

where

$$a = \frac{2000(1-A)}{(1+A)} = \frac{2000(256-ZR)}{(256+ZR)}$$

$$b = \frac{2000(1-B)}{(1+B)} = \frac{2000(256-PL)}{(256+PL)}$$

$$g = K\frac{1+A}{1+B} = \frac{GN}{4}\frac{(256+ZR)}{(256+PL)}$$

$$f = 1000\ C = 3.9\ KI$$

For example, if the filter parameters are
GN = 32
ZR = 224
PL = 64
KI = 4
T = 0.001 s
the digital filter coefficients are
K = 8
A = 0.875
B = 0.25

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C = 0.0156

and the equivalent continuous filter, G(s), is

$$G(s) = \frac{12(s+133)}{(s+1200)} + \frac{15.6}{s}$$

ZOH

The ZOH, or zero-order-hold, represents the effect of the sampling process, where the motor command is updated once per sampling period. The effect of the ZOH can be modeled by the transfer function:

$$H(s) = \frac{1}{1+sT/2}$$

Since the sampling period is T = 0.001, H(s) becomes

$$H(s) = \frac{2000}{s+2000}$$

This completes the modeling of the system elements. Next, we discuss the system analysis.

F.2. System Analysis

To analyze the system we start with a block diagram model of the system elements. The analysis procedure is illustrated in terms of the following example.

Consider a position control system with the following parameters:

$K_t = 0.1$	Nm/A	Torque constant
$J = 2.10^{-4}$	$kg \cdot m^2$	System moment of inertia
R = 2	Ω	Motor resistance
$K_a = 2$	Amp/Volt	Current amplifier gain
GN = 32		Digital filter gain
ZR = 245		Digital filter zero
PL = 0		Digital filter pole
KI = 0		No integrator
N = 500	Counts/rev	Encoder line density

The transfer function of the system elements are:

Motor

$$M(s) = \frac{P}{I} = \frac{K_t}{Js^2} = \frac{500}{s^2} \quad [Rad/A]$$

Amp

$$K_a = 2 \quad [Amp/V]$$

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DAC

$$K_d = 0.08 \qquad [V/count]$$

Encoder

$$K_f = \frac{4N}{2\pi} = 318 \qquad [count/rad]$$

ZOH

$$H(s) = \frac{2000}{s+2000}$$

Digital Filter

GN = 32, ZR = 243, PL = 0, T = 0.001

Therefore,

$$D(z) = 8\ \frac{z-0.95}{z}$$

or K = 8, A = 0.95, B = 0

Accordingly, the coefficients of the continuous filter are:

$$g = 8 \cdot 1.95 = 15.6$$

$$a = 2000\ \frac{1-0.95}{1+0.95} = 51 \text{ rad/s}$$

$$b = 2000 \text{ rad/s}$$

The complete block diagram is shown in Fig. F.2.

The open loop transfer function, A(s), is the product of all the elements in the loop.

$$A(s) = \frac{7.94 \cdot 10^8\ (s+51)}{s^2\ (s+2000)^2}$$

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To analyze the system stability, determine the crossover frequency, ω_c at which $A(j\omega_c)$ equals one. This can be done by the Bode plot of $A(j\omega)$, as shown in Fig. 2.3.

For the given example, $\omega_c = 200$.

Next we determine the phase of A(s) at the crossover frequency.

$$A(j200) = \frac{7.94 \cdot 10^8 \ (j200+51)}{(j200)^2 (j200+2000)^2}$$

$$\alpha = \arg\,[A(j200)] = \tan^{-1}\frac{200}{51} - 180^\circ - 2\tan^{-1}\frac{200}{2000} =$$

$$76^\circ - 180 - 11^\circ = -115^\circ$$

Finally, the phase margin, PM, equals

$$PM = 180^\circ + \alpha = 65^\circ$$

As long as PM is positive, the system is stable. However, for a well damped system, PM should be between 30½ and 45½.

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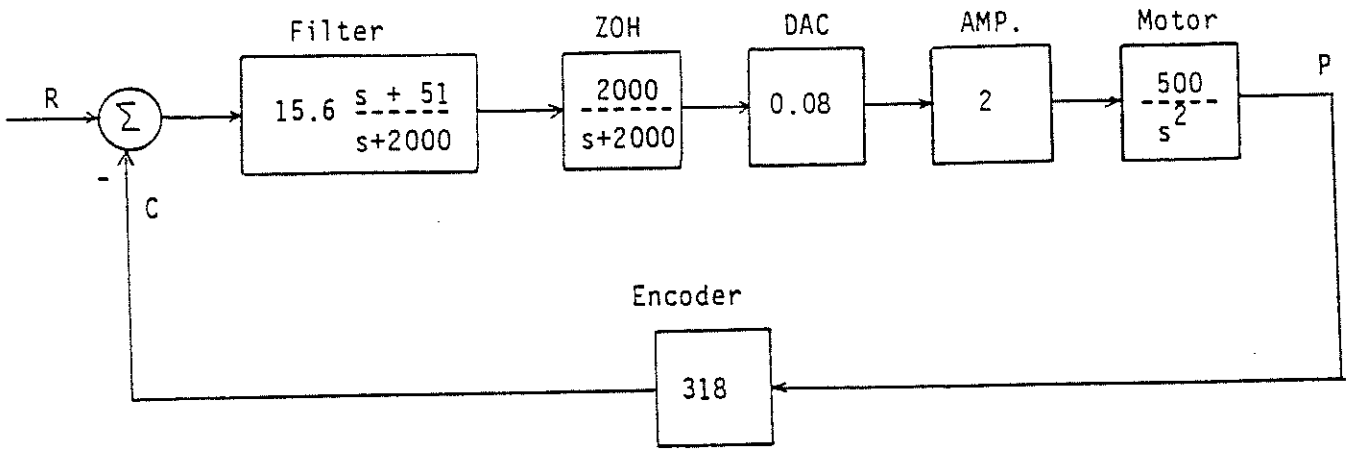


Fig. F.2 - Mathematical model of the control system.

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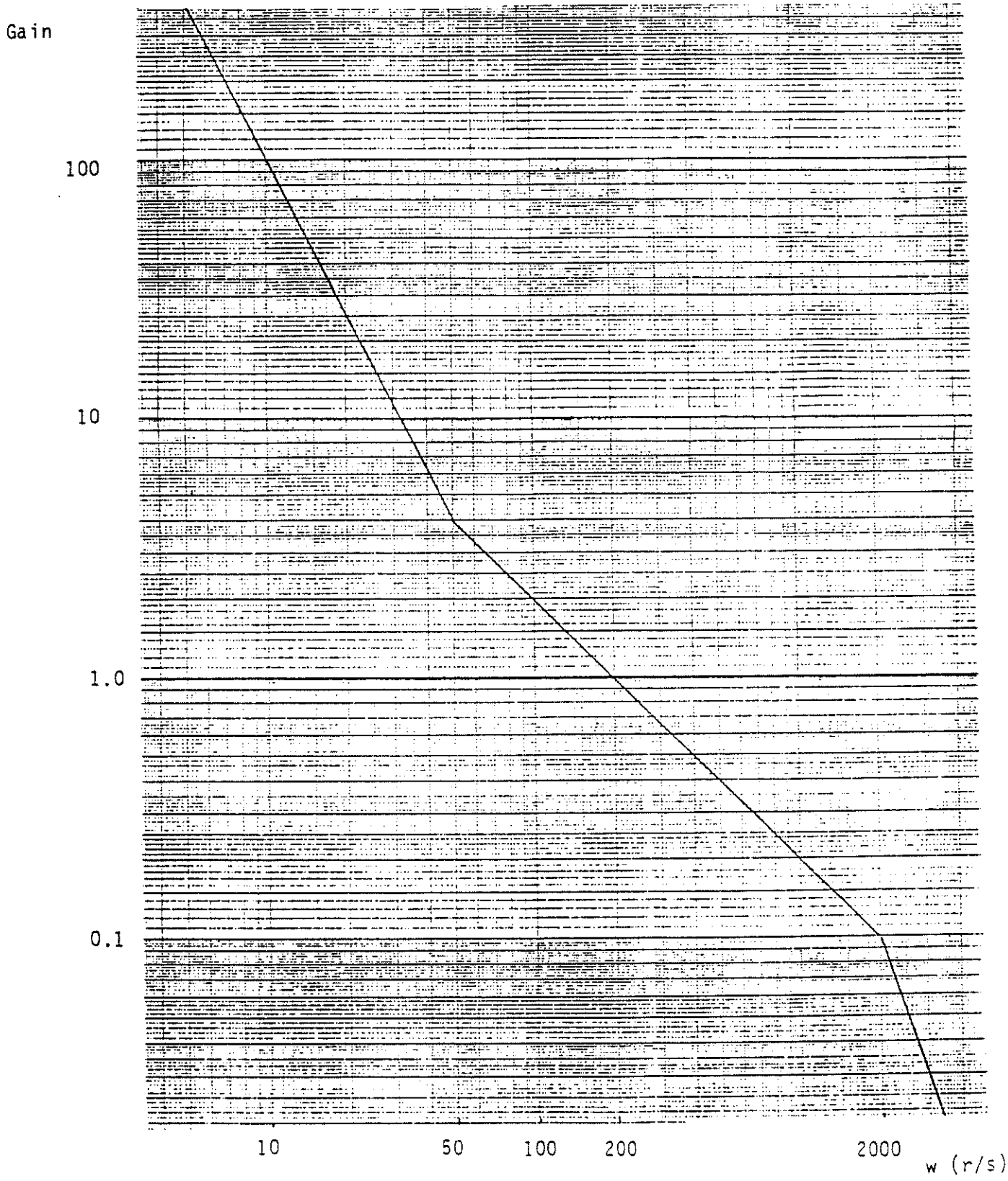


Fig. F.3 - Bode plot of the open loop transfer function.

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Next we can discuss the design of control systems.

F.3. System Design and Compensation

The closed-loop control system can be stabilized by a digital filter which is preprogrammed in the DMC-630 controller. The filter parameters can be selected by the user for the best compensation of the given system. There are two methods for system compensation: Analytical which is described below and Experimental which is described in Chapter 2.

The analytical method requires exact knowledge of the system parameters, whereas the experimental method can be used when the motor and load parameters are unknown.

The Analytical Method

The analytical design method is aimed at closing the loop at a crossover frequency, c, (with a phase margin PM). The system parameters are assumed known. The design procedure is best illustrated by a design example.

Consider a system with the following parameters:

$K_t = 0.01$	Nm/A	Torque constant
$R = 2$		Motor resistance
$J = 10^{-4}$	kg m^2	Moment of inertia of motor and load
$K_a = 0.5$	A/V	Amplifier gain
$N = 1000$	lines/rev	Encoder line density

The DAC of the DMC-630 outputs þ10V, or an 8 bit command of þ128 counts.

The design objective is to select the filter parameters in order to close a position loop with a crossover frequency of wc = 500 rad/s and a phase margin of 45½.

The first step is to develop a mathematical model of the system, as discussed in the previous section.

Motor

$$M(s) = \frac{P}{I} = \frac{K_t}{Js^t} = \frac{1000}{s^2} \quad \text{[Rad/Amp]}$$

Amp

$$K_a = 0.5 \quad \text{[Amp/V]}$$

DAC

$$K_d = \frac{10}{128} = 0.08 \quad \text{[V/count]}$$

Encoder

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$$K_f = \frac{4N}{2\pi} = 636 \qquad \text{[count/rad]}$$

ZOH

$$H(s) = \frac{2000}{s+2000}$$

Compensation Filter

$$G(s) = g\,\frac{s+a}{s+b}$$

The next step is to combine all the system elements, with the exception of G(s), into one function L(s).

$$L(s) = M(s)\,K_a\,K_d\,K_f\,H(s) = \frac{5.1 \cdot 10^7}{s\,(s+2000)}$$

Then the open loop transfer function, A(s), is

$$A(s) = L(s)\,G(s).$$

Now determine the magnitude and phase of L(s) at the frequency w_c=500.

$$L(j500) = \frac{5.1 \cdot 10^7}{(j500)\quad(j500+2000)}$$

This function has a magnitude of

$$\left| L(j500) \right| = 0.1$$

and a phase

$$\arg\,[L(j500)] = -180^\circ - \tan^{-1}\frac{500}{2000} = -194^\circ$$

G(s) is selected so that A(s) has a crossover frequency of 500 rad/s and a phase margin of 45°. This requires that

$$\left| A(j500) \right| = 1$$

$$\arg\,[A(j500)] = -135^\circ$$

However, since

$$A(s) = L(s)\,G(s)$$

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then it follows that G(s) must have a magnitude of

$$\left|G(j500)\right| = \left|\frac{A(j500)}{L(j500)}\right| = 10$$

and a phase

$$\arg\,[G(j500)] = \arg\,[A(j500)] - \arg\,[L(j500)] = -135^{\circ} + 194^{\circ} = 59^{\circ}$$

In other words, we need to select G(s) which satisfies these requirements. To obtain a positive phase shift, we need to select a lead compensation of the form

$$G(s) = g\,\frac{s+a}{s+b}$$

The choice of a and b depends on the required phase lead and crossover frequency.

The following table gives the filter parameters for the required phase lead and crossover frequency.

Table: Pole and Zero Frequencies

Required phase lead	Zero frequency a [rad/s]	Pole frequency b [rad/s]
30°	$0.58\ w_c$	$1.73\ w_c$
40°	$0.47\ w_c$	$2.14\ w_c$
50°	$0.36\ w_c$	$2.75\ w_c$
60°	$0.27\ w_c$	$3.75\ w_c$

For the system requirements we select

$$a = 0.27 \cdot 500 = 135 \text{ rad/s}$$

$$b = 3.75 \cdot 500 = 1875 \text{ rad/s}$$

We also have to choose the gain, g, so that the magnitude of G(j500) equals 10.

$$\left|G(j500)\right| = g\left|\frac{j500 + 135}{j500 + 1875}\right| = 10$$

Then

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$$g = 10\left|\frac{j500 + 1875}{j500 + 135}\right| = 37.5$$

and the required filter is

$$G(s) = 37.5\,\frac{s+135}{s+1875}$$

The compensation is implemented by a digital filter with a sampling period T = 0.001 s.

The programmed filter has three parameters; GN, ZR, PL. These are found by the equations:

$$GN = 4g\,\frac{2+aT}{2+bT}$$

$$ZR = 256\,\frac{2-aT}{2+aT}$$

$$PL = 256\,\frac{2-bT}{2+bT}$$

For the given example, we obtain

$$aT = 0.135$$

$$bT = 1.875$$

$$g = 37.5$$

Therefore,

$$GN = 84$$

$$ZR = 224$$

$$PL = 8$$

these parameters will produce the required design.

The analytical procedure described above leads to the selection of the parameters of the lead filter, namely GN, ZR, and PL.

The selection of the integrator gain, KI, requires an analysis of potential non-linear modes. The resulting analysis is very complex and is not recommended. Instead, the experimental method is suggested for setting the integrator gain.

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APPENDIX G Related Products

PC-Mate	Packaged power amplifier and supply. One, two or three axis available. Connects directly to DMC-600 cable. Screw-type terminals for motor, encoder, and I/O.
SSA Series	High performance pulse-width-modulated power amplifiers. Current mode of operation. Available in range of sizes from 20 volts-80 volts, up to 40 Amps. Requires external supply.
Motor-5-500, Motor-50-1000 Motor-500-1000	DC motor with incremental encoder. 3 sizes, 5 oz-in up to 500 oz-in.
ICB-960	Interconnect board for connecting each axis on the DMC-630 to other system elements such as motor, amplifier and encoder. Breaks out ribbon cable into convenient testpoints, jumpers and switches. Not required with PC-Mate.
SDK-600 Software	Servo Design Software for DMC-600 Series. For design and analysis of servo systems. Displays position and velocity of motor on PC.
COM-Disk	Communication software for DMC-600. Includes Talk-600 menu-driven terminal emulator.
DMC-63010	Special sensor interface which allows input of up to three 16-bit parallel sensors (LVDT's, absolute encoders, resolvers), or up to eight analog sensors. Mounts behind DMC-600.
CAD-to-DMC	Software that converts AUTOCAD or equivalent DXF files into DMC controller files. Includes AUTOSKETCH program, CAD-to-DMC translator and run-time executive.
-12 Upgrade	12-bit DAC upgrade

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APPENDIX H

Rev (1-88)

Application Note #19
Thumbwheel Interface
for DMC-630

Thumbwheels may be interfaced to the DMC-610, DMC-620, or DMC-630 using the suggested circuit shown below.

This circuit shows interface to eight thumbwheel switches. The DMC-630 reads one switch at a time. The DMC-630 configures the three output lines 0, 1 and 2 for the appropriate state, 0 through 7, to select each thumbwheel. All output lines are configured at the same time using the OP instruction.

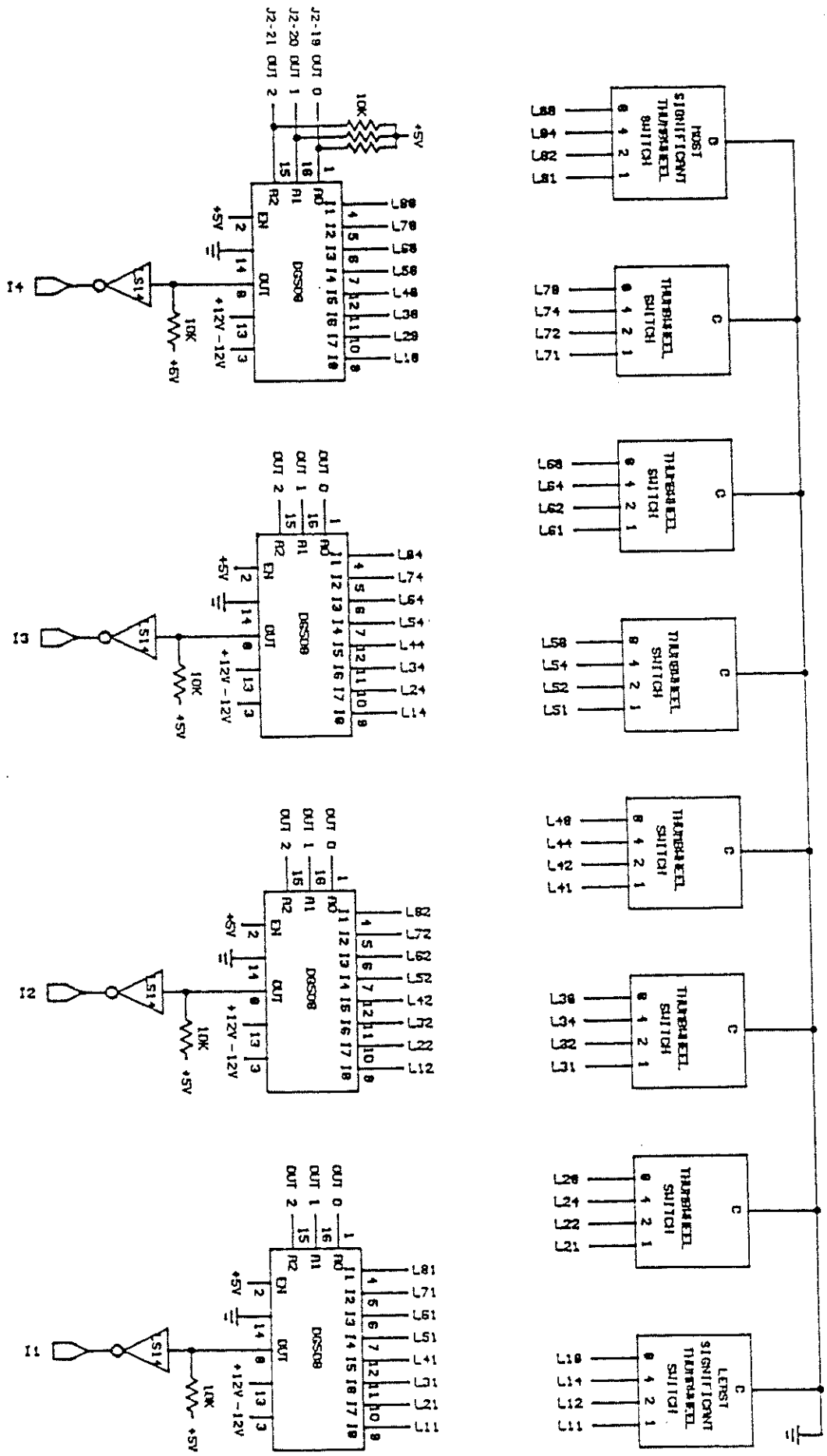
The thumbwheel switch data is read using the IO variable. This variable looks at the state of the 4 input lines, I1, I2, I3 and I4.

An example subroutine to read 8 BCD thumbwheel switches is shown below. The variable V1 indicates the thumbwheel to be read. V1 varies between 0 and 7.

```
Program          Interpretation

#S               Begin Subroutine
V6=0;V1=0        Initialize Variables
#A;OP V1         Select Thumbwheel
V6=10*V6+IO      Read Thumbwheel, convert to base 10
V1=V1+1          Select next Thumbwheel
JP #A,V1<7       Jump to #A to read next Thumbwheel if V1 is
                  less than or equal to seven
```

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APPENDIX I Noise Considerations

Galil controllers are microprocessor-based, where the processor is fetching instructions from memory in a controlled sequence. Electrical disturbances, such as from power supply disturbances, noise on input lines, or ground loops could cause the microprocessor to execute instructions erroneously or "hang-up". Such a condition could cause motor runaway which might result in system damage. It is strongly recommended that the engineer eliminate potential noise sources in the design process.

A few guidelines are provided here:

1. Noise on General and Switch Inputs

You can add ferrite beads and capacitors to minimize noise disturbances on inputs. A better approach is to use opto-isolators near the controller on each input line. See Figure 1 for an example circuit.

2. Ground Loops

A ground loop can occur when a magnetic field passes through the ground path inducing a current. This can be avoided by connecting grounds in a tree structure instead of in a loop (See Figure 2).

If you are shielding components, all shields must be terminated only at one end.

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3. Encoder Noise

Erroneous counting due to encoder noise is prevented from the controller filtering circuitry. However, in extremely noisy environments, extra protection can be achieved by using differential encoders.

4. Catastrophic Failure

To protect your hardware from controller failures, it is a good idea to connect mechanical limits and emergency stop inputs to the amplifier in addition to the controller. To further protect the system against amplifier failures, it is advised to connect the motor to the amplifier by a relay. Whenever the extreme mechanical limits are activated, the relay will disconnect the motor from the amplifier and short its leads.

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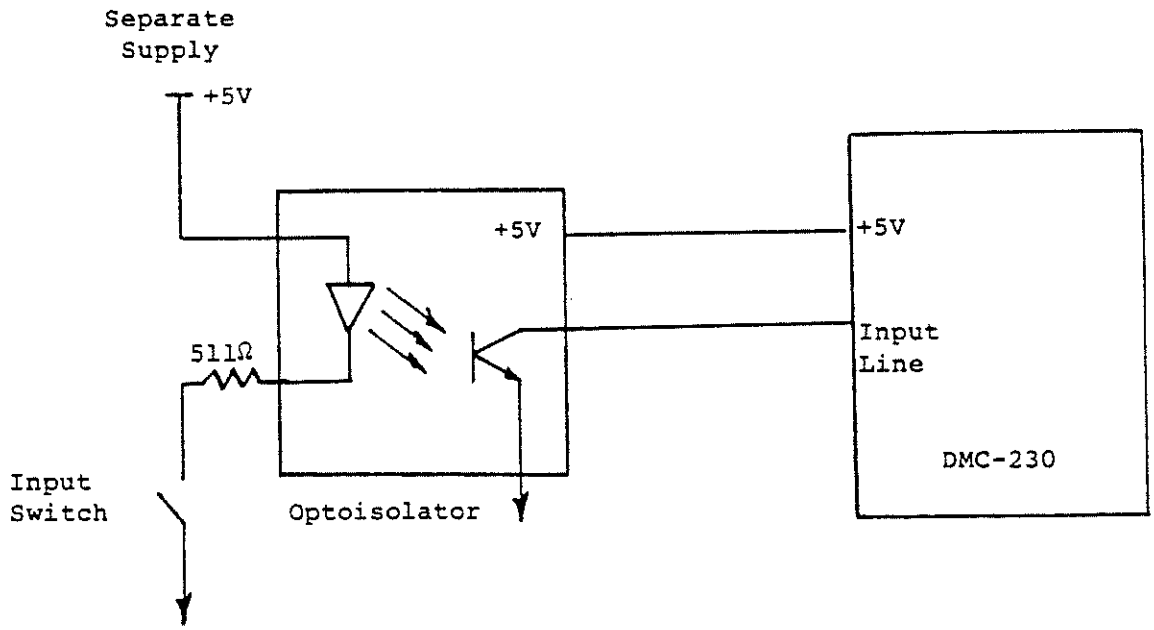


Fig. 1 - Optoisolating Inputs

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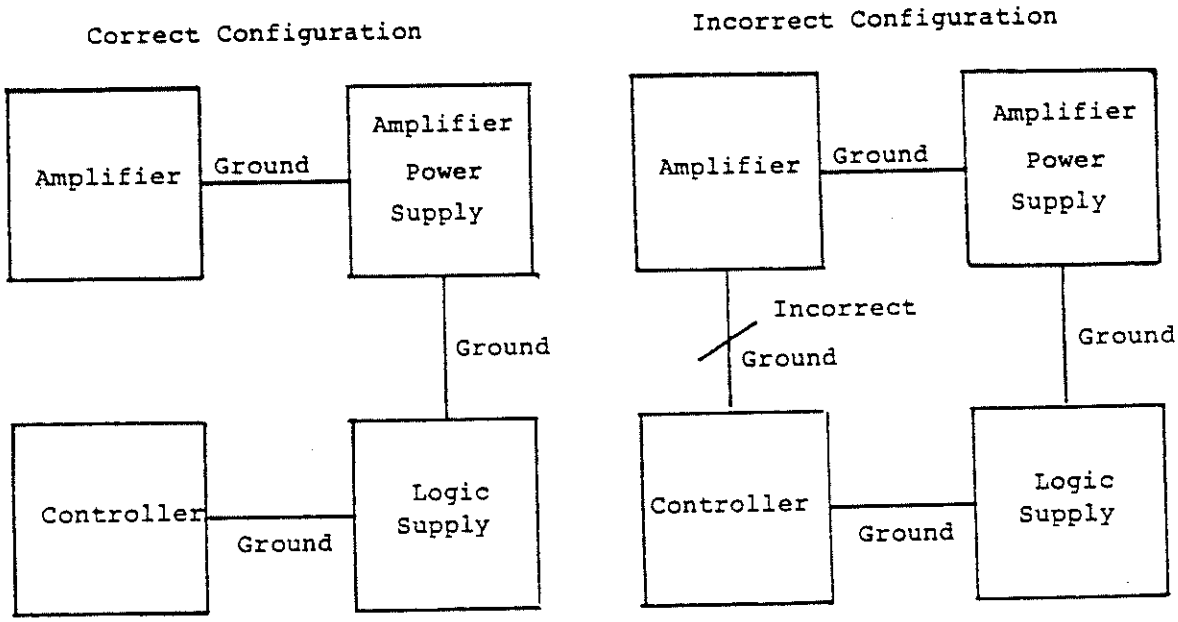
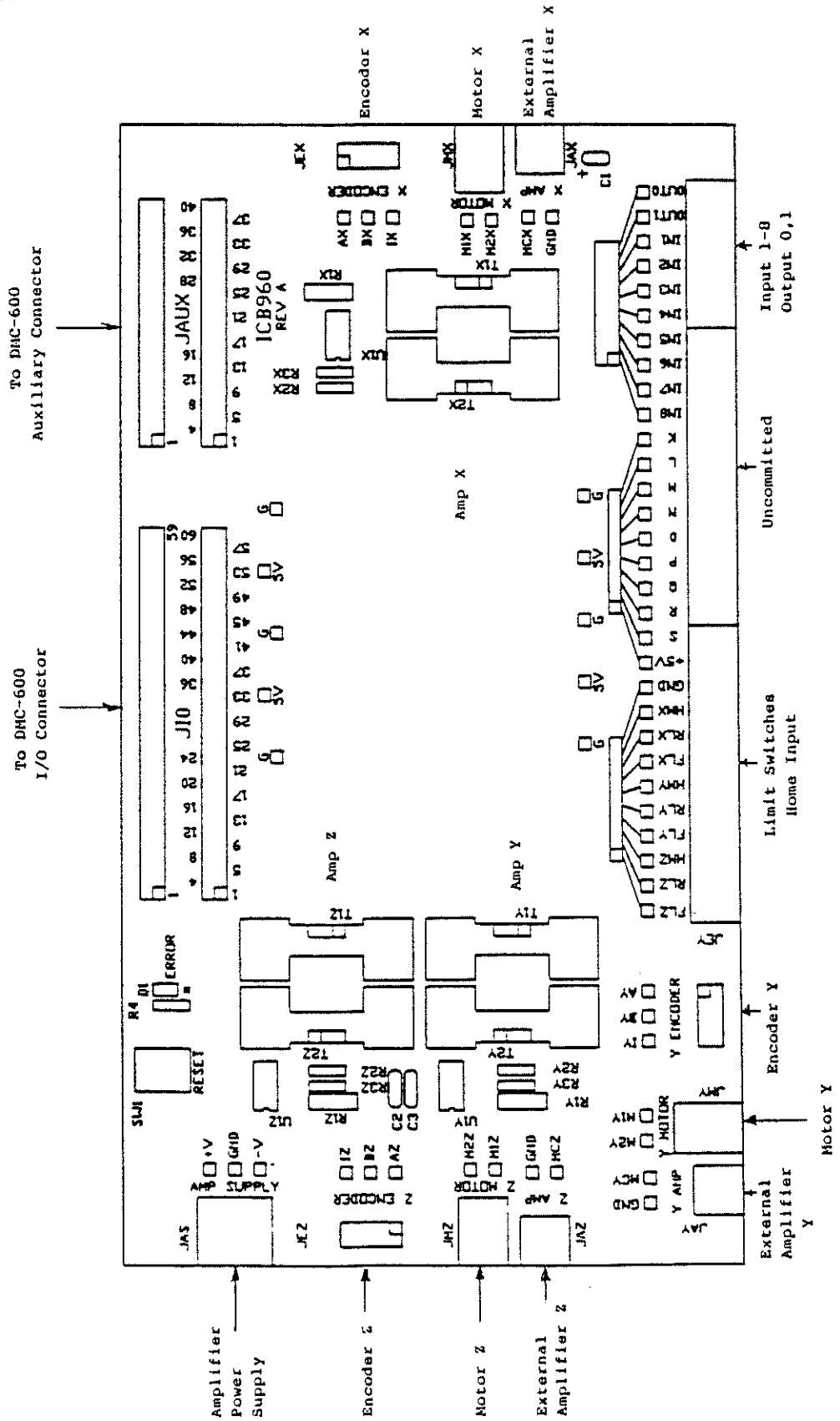


Fig. 2 - Ground Loops

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APPENDIX J ICB-960 Connection



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APPENDIX K - DMC-600 Series Specifications

Board Size:
- Full Size PC Bus
- 13" x 4"

 # Of Axis:
- 1, 2 or 3 per card - multiple card synchronization

Connector:
- 60-pin ribbon

Operating Temperature:
- 0 degrees to 70 degrees

Inputs:
- 8 uncommitted TTL inputs
- Quadrature encoder inputs plus index
- Forward and Reverse limits - TTL
- Home - TTL
- Abort - TTL

Outputs:
- 8 uncommitted TTL outputs
- +/-10 Volt range Analog Motor Command
- Error - TTL
- Pulse-width-modulated motor command

Modes of Motion:
- Independent Positioning of any axis
- Coordinated vector positioning of XY axes
- Linear and circular interpolation of XY axes
- Coordinated Motion Sequences - up to 255 segments
- Jogging of any axis
- Contouring (position vs time trajectory)

Servo Loop Update time:
- 1 msec

Position Range:
- +/-8,000,000 counts per move

Position Accuracy:
- +/-1 quadrature count

Velocity Range:
- 2-500,000 quad counts/sec
- (2-2,000,000 quad counts/sec with upgrade)
- Programmable during motion

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Velocity Accuracy:
Phase-locked, .005% steady-state

Programming Specifications:
I/O mapped
256 character FIFO buffer
ASCII command format
64 user-definable variables
Arithemtic operations; +,-,x,/
Triggers for time, motion complete, inputs, limits

Programming Memory:
500 lines x 32 characters

Stabilizing Filter:
Digital filter with gain, damping and integration
Tachometer not required

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APPENDIX L - DMC-600 Command Summary

Filter Parameters

DB x,y,z	Dead Band (counts)
FA x,y,z	Acceleration Feedforward
GN x,y,z	Gain
KI x,y,z	Integral Gain
OF x,y,z	Offset (counts)
PL x,y,z	Pole
TL x,y,z	Torque Limit (counts)
TM n	Sample Time (sec)
ZR x,y,z	Zero
DR x,y,z*	DAC Resolution

Motion

AC x,y,z	Acceleration (counts/sec)
CR r, ,	Circle (counts,degrees,degrees)
FE XYZ	Find Edge
HM XYZ	Home
IP x,y,z	Increment Position (counts)
JG x,y,z	Jog (counts/sec)
PA x,y,z	Position Absolute (counts)
PR x,y,z	Position Relative (counts)
SP x,y,z	Speed (counts/sec)
VA n	Vector Acceleration (counts/sec)
VP x,y	Vector Position (counts)
VS n	Vector Speed (counts/sec)
CM XYZ	Contour Mode
LN n	Learn Mode
TA n*	Set up trapezoidal acceleration
RM x,y,z*	Specify acceleration ramp - independent
VR n*	Specify acceleration ramp - coordinated
TV n*	Set up trapezoidal acceleration mode

Stop/Start

AB	Abort Motion
BG XYZS	Begin Motion
GR x,y,z*	Specify gear ratio
GA n*	Set master axis for gearing
SG XYZ	Servo Here
ST XYZ	Stop Motion
SV XYZ	Servo
MO XYZ	Motor Off

*For DMC-6X1 Series only

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General

BL x,y,z*	Specify reverse limit
CB n	Clear Output Bit
DC	Decimal
DD x,y,z*	Define Dual Encoder Position
DL	Downlaods Datafile
DP x,y,z	Define Position
EO n	Echo on if n=1
ER x,y,z	Error Limit
FL x,y,z*	Specify Forward Limit
HX	Hexadecimal
LA*	Arm Latch
OE x,y,z	Off-On-Error if 1
OP n,m,o	Write to Output Port
RC x,y,z	Report when done if 1
RL XYZ*	Report Latched Position
RS	Reset
SB n	Set Bit
SE n*	Specify Encoder Type
TD XYZ*	Tell Dual-Encoder Position
UL	Upload Datafile
\	Clear Input Buffer

Editor

ED n	Edit at label or line
<Control>D	Delete Line
<Control>I	Insert Line
<Control>P	Edit Previous Line
<Control>Q	Quit Editor
<Return>	Save Line
LS n	List Program
TR n	Trace Program if n=1

Interrogate

SC	Stop Code
TC	Tell Error Code
TE XYZ	Tell Error (counts)
TI XYZ	Tell Inputs
TP XYZ	Tell Position (counts)
TS	Tell Switches
TT XYZ	Tell Torque (counts)
TB	Tell Bits

continued. . .

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Programming

AD x,y,z	After Distance
AI n	After Input
AM XYZS	After Motion Complete
AP x,y,z	After Position
AS	After Speed Reached
CS	Clear the Motion Sequence
EN	End
JP	Jump on Condition
JS	Jump to Subroutine
MG xxxx	Message
NO xxxx	No Operation
RE	Return from Error Routine
RI	Return from Input Interrupt
II	Interrupt for Inputs
WT n	Wait for n msec
XQ n	Execute Program
VN=	Variable Definition
#n	Label Definition
LTVn=	Let Variable be defined
Inxxx,Vn	Input Variable

Note: x,y,z represents parameters to be replaced by actual value
XYZ represents chosen axis and should be specified by X, Y, or Z combination. S represents coordinated XY sequence.

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