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MotionMaster 2000

Advanced Motion Controller

User's Manual

REVISION 3.2

NEWPORT CORPORATION

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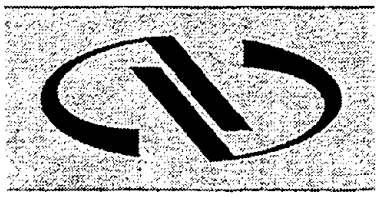
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MOTIONMASTER 2000

ADVANCED MOTION CONTROLLER

USER'S MANUAL

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GENERAL INFORMATION

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1.1 INTRODUCTION

The MotionMaster 2000 is an advanced motion controller which plugs directly into any IBM PC/XT/AT and compatible computers. This includes computers with 8088, 80286, 80386, and 80486 microprocessors, and which are not PS/2 model types. The MotionMaster 2000 can also operate as a stand-alone unit in a separate enclosure. In addition to the PC-bus interface, the unit includes a full duplex RS-232-C serial interface and supports an optional IEEE-488 interface. Using "piggy-back" plug-in modules, one(1) MotionMaster 2000 main-board supports up to four(4) axes of motion consisting of any combination of stepping, and brushless or brush DC servo motors.

The hardware which comprises the MotionMaster 2000 system is:

1. a motherboard that plugs into an expansion slot of an IBM PC/XT/AT and compatible computers.

2. a stepping motor module that plugs onto the motherboard and/or...

3. a DC motor module that plugs onto the motherboard.

1.2 FEATURES

- Four(4) axes control of stepping, DC brushless, or DC brush type motors
- Velocity rates from 0.06 to 1,000,000 counts/second (DC Motor)
- Pulse rates from .02 (1 pulse every 50 seconds) to 1,500,000 pulses per second, 4 axis simultaneous (Stepping Motor)
- powerful and extensive motion control command set
- Absolute and relative positioning
- circular and linear interpolation (DC Motor)

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- time interval command execution and position and velocity updates "on the fly" facilitate contouring
- multi-axis simultaneous (within 10 microseconds) motion initiation
- sample time motion trace capability
- high speed position retrieval (750 microseconds)
- Open-collector positive direction pulse and negative direction pulse or pulse and direction outputs (Stepping Motor)
- Linear (±10V) control signal output (DC Motor)
- On-board 24V, 1 Amp brush DC motor amplifier per module
- Programmable digital PID filters with 16-bit coefficients
- 256 microsecond sampling interval (DC Motor)
- 512 byte command input buffer
- 25,000-bytes of non-volatile program memory
- convenient IF/THEN and WHILE/WEND program constructs based on external trigger signals
- Eight(8) user defined bi-directional I/O bits
- Eight(8) 10-bit Analog-to-Digital converters (optional)
- Four(4) 8-bit Digital-to-Analog converters (optional)
- Four(4) axis joystick motion control
- RS-232-C full duplex interface
- IEEE-488 interface (optional)
- Precision "homing" capability
- System watchdog timer

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1.3 DESCRIPTION

The MotionMaster 2000 is "state-of-the-art" technology with two 16-bit microcontrollers and sophisticated internal software to achieve high-speed intelligent positioning. Its capabilities range from simple point to point positioning to elaborate tasks which require multiaxis coordination and velocity and position change 'on the fly'. The MotionMaster 2000 is accompanied with a software support program which is designed to get the user "up-and-running" within minutes after having received it.

The MotionMaster 2000 is command driven. With a host computer, the user sends commands which direct it to carry out typical operations in a motion control system. For example, included in its command set, there are commands which tell the MotionMaster 2000 the distance, the direction, the speed, and the acceleration of the next move, and which direct it to send system status information, typically the position as the move progresses, whether the move is complete or in progress, and whether an error has occurred. Section 2 describes the complete command set of the MotionMaster 2000.

The MotionMaster 2000 can be set up to interrupt your host computer when a move is complete or any error or unexpected event occurs. This will greatly improve your execution speeds and processing power because your host computer is free to execute other tasks during a typical move and still know exactly when the move is complete ... so that the next one can be initiated, for example. Included with your MotionMaster 2000 are sample programs in both Microsoft and Borland programming languages which show you how to set up and receive interrupts from the MotionMaster 2000.

The MotionMaster 2000 provides 25,000 bytes of non-volatile memory for program / parameter storage. Sophisticated motion control programs with "IF...THEN" and "WHILE...WEND" statements, which test the logical levels of 8 I/O bits, can be created. Also system configurations and options such as velocity, acceleration, software limits, and PID compensation parameters are retained during power off and automatically reloaded at power on.

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The MotionMaster 2000 features encoder counting circuitry and commands which enable the user to read the position of the system at any instant of time. The encoder required is an incremental encoder with TTL compatible quadrature outputs.

The MotionMaster 2000 can be directed to find a home position defined by either the location of a switch or the position where its internal position counter is zero. It also monitors plus and minus direction limits inputs to protect your system from damage.

The MotionMaster 2000 features an elaborate command interpreter and system monitor. Every command received is analyzed for the correct format. If the command format is incorrect, the MotionMaster 2000 will not execute the command and will store a descriptive error message in its output buffer. See Section 6 for a complete listing of messages which the MotionMaster 2000 is capable of reporting.

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1.4 SOFTWARE SUPPORT

The MotionMaster 2000 is accompanied by software support diskette(s). One diskette contains a utility program, MM2000.EXE and associated help files (*.HLP) and the communication interface routines for BASICA/GWBASIC, QuickBASIC 4.5, Microsoft C, Turbo C and Turbo Pascal. The MM2000.EXE program will:

1. Enable you to immediately test and use the MotionMaster 2000 once you hook up your motors and motor drives.

2. Teach you the MotionMaster 2000 commands

3. Generate fully functional sample programs which show you:

    a. the commands to send to the MotionMaster 2000 to create moves, to obtain position data, etc. and

    b. how to send these commands to the MotionMaster 2000 in your programming language (ex. BASIC, QuickBASIC, C, PASCAL) which you will use to develop your application

The MotionMaster 2000 bypasses the slow executing I/O statements found in high level programming languages and instead, implements high speed data transfer with assembly language communication interface routines. These routines are used to transfer commands from your application program to the MotionMaster 2000. These routines are linked with your high level programming language. For a more detailed explanation see Section 2.2, Programming.

You will find the program PROFILE.EXE and associated support files. This program helps you tune the motion of a DC motor system by plotting on your computer screen, the desired and actual positions as a function of time. It may also be used with the stepping motor control module, Step1.5M, to observe the motion profile of step pulses versus encoder counts. See Section 3.

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PROGRAMMING AND COMMANDS

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2.1 INTRODUCTION

The MotionMaster 2000 is a command driven system. The command set, a series of two letter ASCII mnemonic characters directs the motion of each axis, sets operating parameters, obtains real time system status, and provides a macro and stored program capability. The stored program capability provides IF/THEN and WHILE/WEND constructs which test the condition of 8 I/O bits. The macro facility provides the ability to store a series of commands for later execution by a single command.

The MotionMaster 2000 system can be equipped with up to four axes of motor controls. Each motor has a corresponding module mounted on the MotionMaster 2000 motherboard. A typical command will normally be preceded by an axis number to direct the command to that axis. The number-to-module association (1 through 4) is a function of the module's physical position on the MotionMaster 2000 motherboard. If either motor type module (DC or stepper) is plugged into location 1, for example, then that module is recognized, and referred to, as axis 1. See Appendix B for the MotionMaster 2000 module location to axis assignment diagram.

The MotionMaster 2000 implements a two(2) buffer scheme for instruction execution; 1) the command buffer and 2) the program buffer. In addition, the MotionMaster 2000 permits independent, yet simultaneous buffer execution. In other words, the MotionMaster 2000 can execute stored programs and, at the same time, interpret and execute new, real-time commands.

The MotionMaster 2000 provides non-volatile program memory, which is used to execute hundreds of stored instructions. In addition, the unit provides a real-time 512-byte command buffer. Many commands may be transmitted, at anytime, for immediate execution.

This chapter describes all of the MotionMaster 200 commands. The best way to become familiar with the MotionMaster 2000 is simply to use the MotionMaster 2000 start up program MM2000.EXE, type commands at the Terminal menu item, Keyboard option screen and see what happens. The MotionMaster 2000 will execute the commands as expected or, with an error message, tell you why it can't.

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A thorough understanding of the following sections is extremely important. Effective motor controller programming requires a) command set and b) programming mode familiarity. The programmer/user is encouraged to read these sections carefully and refer back to them when necessary.

2.2 PROGRAMMING

If your application is very simple you may use the MM2000.EXE utility program to generate the motions you require. With this program you can:

1. use the pull-down menus to set move parameters, initiate moves and obtain status

2. use the terminal emulation mode to send commands directly from the keyboard, and

3. build a file of commands and download the commands to the MotionMaster 2000. You may choose to execute these commands immediately or store them in the program buffer for later execution.

If your application is more elaborate and will involve other computer controlled equipment, you will have to write your own programs.

As mentioned above, the MotionMaster 2000 is a command driven system. To make it perform a desired function, you must use a host computer to send it a command which is part of its command set. The MotionMaster 2000 must receive the command in its proper form and then it will execute the command. In order for this to happen, there must exist a consistent and orderly protocol for transferring the command. The protocol is implemented by an interface which consists of hardware and associated software.

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The MotionMaster 2000 supports three types of interfaces:

Interface: PC BUS

This interface is used when the MotionMaster 2000 is installed in the PC. The MotionMaster 2000 has on-board hardware to implement the hardware portion of the interface. The software support diskette contains the software portion of the interface. The software is programming language specific, thus we provide you with interface software for BASICA/GWBASIC, QuickBASIC 4.5, Microsoft C, Turbo C, and Turbo Pascal.

For the compiled languages (i.e. all except BASICA/GWBASIC), the interface software is invoked by a common function name:

mmsend(command, address)

Used to send a command to the MotionMaster 2000. Its two parameters are the command and the MotionMaster 2000 PC bus address

mmread(response, address)

Used to receive a response from the MotionMaster 2000. Its two parameters are the memory allocation to store the response and the MotionMaster 2000 PC bus address. This function is used immediately after the mmsend(command,address) function if the command sent is of type which will send back a response.

The sample programs generated by the MM2000.EXE utility program show the use of these function calls. See Section 2.2.1 Sample Programs.

binread(position, address)

Used to receive the response to the 'TP' (tell position) command when the response mode is set to binary with the 'FO' command. See 'TP' command description and sample programs in Appendix F.

For BASICA/GWBASIC the procedure is slightly different. Before entering the BASICA/GWBASIC environment, you must execute the program, BASINSTL.EXE. This program installs the functions 'mmsend' and 'mmread' into memory. Then study the sample programs generated by the MM2000.EXE utility program to see how the functions 'mmsend' and 'mmread' are called upon to perform their functions. The program, BASINSTL.EXE, is located on the software support diskette, in the BASIC directory.

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Interface: IEEE-488

The manufacturer of the interface will provide you with the hardware and associated software. The software will include function calls of the type:

write(command)
read(response)

Use these like the functions mmsend(command,address) and mmread(response,address) are explained above.

NOTE: The IEEE-488 interface may be used when the MotionMaster 2000 is installed in the PC. In this case, the PC is used solely to provide the necessary power supply voltages. You may wish to do this to synchronize all your instruments over a common interface.

NOTE: The following note applies to PC Bus and IEEE-488 Interfaces:

When the MotionMaster 2000 receives a command which directs it to send a response, (ex. 'TP', 'DV' commands, etc.), it will assemble the response and wait 0.5 seconds to receive the interface command to read the response. You must execute the function mmread(command, address) or the equivalent for IEEE-488 within 0.5 seconds of executing the function mmsend(command, address) or equivalent for IEEE-488. If you do not follow this procedure, the MotionMaster 2000 will timeout and will not send the response. Executing the read function after the timeout will 'hang' your computer.

During normal program operation, this will not be a problem. However, it may become a problem when developing your program. During the debugging phase, you will probably 'single step' through your program. You must not 'single step' through the 'mmsend' and mmread' functions. Execute those two functions in sequence and in real computer time.

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Interface: RS-232-C

The software for the interface is an integral part of your programming language. It will have the following generic functions:

output(command)
input(response)

Use these like the functions mmsend(command,address) and mmread(response,address) are explained above.

For example, in BASIC and QuickBASIC, the output command is PRINT#1,CMD$ and the input command is INPUT#1,RESP$.

NOTE: The RS-232-C interface may be used when the MotionMaster 2000 is installed in the PC. In this case, the PC is used solely to provide the necessary power supply voltages. You may wish to do this to synchronize all your instruments over a common interface.

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2.2.1 SAMPLE PROGRAMS

While you were using the MM2000.EXE utility program, you may have noticed, and actually made use of the <Generate Code> option. This option appears on the Move Axis screens, the Move Sequence screen, and all of the Status screens. When selected, this option creates a fully functional sample program using the MotionMaster 2000 commands which appear on the screen. The sample program is stored on the default directory and under the name which you type in at the File Name: prompt. The default directory is your floppy diskette, if you are running off the floppy. If you have copied the Software Support diskette to your hard disk, then the default directory is your hard drive. Note that it is possible to type in the directory where you wish the file to be stored. For example, you may enter "C:\QB45\JOHN" at the file name prompt.

The sample programs are ASCII text files. They can be viewed with the DOS 'type' command or more conveniently, with any text editor.

At the beginning of every sample program, you will see instructions to create an actual executable program. The basic requirement for compiled languages like QuickBASIC, C, and Pascal, is that you must link the communication interface software, mmsend(command,address) and mmread(command,address), with the sample program. These functions are provided to you as object files (*.OBJ).

For interpreter languages like BASICA and GWBASIC, you must execute the program BASINSTL.EXE before entering the BASICA or GWBASIC environment.

The sample programs are general purpose type. You can use them as is or study them for the required technique and optimize them for your program.

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Command Mode:

When command characters arrive from the host computer they are placed into the command buffer. Then, when a carriage-return (ASCII 13 decimal) terminator is received, the command is interpreted. If the command is valid and its parameter is within the specified range, it will be executed. If the command has an error, it will not be executed and a corresponding error message will be stored in the output buffer. This mode of operation is called command mode.

NOTE: The MotionMaster 2000 power up state is command mode.

The MotionMaster 2000 provides a 512-byte character command input buffer. Your application may download a series of commands and then move on to other tasks while the MotionMaster 2000 processes your commands.

An example of a typical command sequence is shown below:

Example 1:

```
"1PA+2000"
"1WS"
"2PR-1000"
```

Assuming for a moment that motor modules 1 and 2 exist, example 1 instructs the MotionMaster 2000 to move axis 1 motor to absolute position +2000, wait for it to stop, and then move axis 2 motor to -1000 counts relative to its present position.

Notice that a command prefix (1 through 4) identifies the target module and motor. A command received without a axis prefix defaults to last prefix issued. And if a command is referenced to a non-existing motor module an error is generated.

Also notice the necessity to explicitly instruct the MotionMaster 2000 to "wait" for axis 1 motion to stop with the "WS" (Wait for Stop) command. This is because the MotionMaster 2000 executes commands contiguously as long as there are commands in the buffer or a command is encountered which instructs it to wait. Executing a move does not automatically suspend command execution until the move is complete.

If, in example 1, the "WS" command is not issued the controller will start the second move immediately after the first move begins and would appear as simultaneous move of axis 1 and axis 2.

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NOTE: Unless told otherwise, the MotionMaster 2000 executes the commands it receives when it receives them and in the order they were received.

Once again, MotionMaster 2000 commands must be terminated by a carriage-return (ASCII 13 decimal). Until a terminator is received, characters are simply kept in contiguous memory and are not evaluated. Note that for added convenience the command interpreter ignores spaces and accepts upper or lower case characters.

Example 2:

"1PA+2000;1WS;2PR-1000"

Example #1 and #2 perform similar operations. In example #2, however, semicolons are used in place of carriage-returns as command delimiters. They serve to keep the MotionMaster 2000 from interpreting any commands on that line until the carriage-return terminator is received at the very end of the string.

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Program Execution Mode:

The MotionMaster 2000 also implements an internal program execution mode of operation to off-load the host computer from the burden of sequencing pre-known target coordinates, for example. And because the MotionMaster 2000 maintains an open communications channel, even while running an internal program, the host computer can continue to direct the MotionMaster 2000 to report any desired status, and even execute other motion commands.

Example 3:

"EP"	(invoke program entry mode)
"1PA+2000"	
"1WS"	
"2PA-1000"	
"%"	(exit program entry mode)
"CP"	(compile stored program)
COMPILATION COMPLETED	(response from MM2000)
END	(response from MM2000)
"EX"	(execute compiled program)

To illustrate the point, we incorporated example #1 into a MotionMaster 2000 program. The first objective is to get the known sequence of commands into the program memory without inadvertently executing them. To facilitate this, the system provides the "EP" (Enter Program) command. Characters received thereafter are redirected to the program buffer. Command syntax and parameters are not evaluate (even after the carriage-return). They are treated as simply a series of characters to be stored in contiguous memory.

The MotionMaster 2000 continues in this mode until it receives the '%' character. This instructs it to exit program entry mode and return to command mode.

Next, the 'CP' command causes the MotionMaster 2000 to evaluate the stored program (source code) for incorrect syntax and parameters usage. If the downloaded program contained an error, the compiler would respond with the message "COMPILATION ABORTED" plus the listing off all the lines which contained an error. The last transmission is the word 'END' to signal the end of data.

Assuming there is no error, we issue the 'EX' (execute program) command to run the program. Note that while the program is running we can still transmit and execute commands like '2TP' (tell position), '1VA5000' (absolute velocity), or '3PR1000' (position relative).

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Example 4:

```
"EP"                  (invoke program entry mode)
"DL A"                (define label 'A')
"1PA-1000;1WS50"      (move axis 1 and wait for stop)
"2PA+2000;2WS50"      (move axis 2 and wait for stop)
"1PA0;2PA0;2WS50"     (move both & wait for axis 2 to stop
"JL A 10"             (jump to label 'A': perform 10 loops
"%"                   (exit program entry mode)
```

In example #4, we introduce label ('DL') and jump ('JL') commands which are only allowed in stored programs. These commands facilitate program flow re-direction backward and forward.

Note that move ('PA') and wait-for-stop ('WS') commands in example #4 have been combined onto a single line for increased program readability.

Example 5:

```
"EP"                  (invoke program entry mode)
"BI1,8"               (configure I/O bits as inputs)
"WHILE 1L,8H"         (while bit-1 low and bit-8 high...)
"1PA-1000;1WS50"      (move axis 1 and wait for stop)
"2PA+2000;2WS50"      (move axis 2 and wait for stop)
"1PA0;2PA0;2WS50"     (move both & wait for axis 2 to stop
"WEND"                (re-evaluate while condition)
"%"                   (exit program entry mode)
```

Example #5 implements a WHILE/WEND loop as a function of I/O bit status. The WHILE command evaluates the user-defined bit condition. In this case, for as long as bit-1 is a logical low and bit-8 is high the move commands get processed. Note that the 'BI' command is necessary to define those bits as inputs first.

Example 6:

```
"EP"                  (invoke program entry mode)
"BI1,8"               (configure I/O bits as inputs)
"DL A"                (define label 'A')
"IF 1H,8L THEN B      (exit 'IF' bit condition true)
"1PA-1000;1WS50"      (move axis 1 and wait for stop)
"2PA+2000;2WS50"      (move axis 2 and wait for stop)
"1PA0;2PA0;2WS50"     (move both & wait for axis 2 to stop
"JL A"                (jump to label 'A' indefinitely)
"DL B"                (define label 'B')
"%"                   (exit program entry mode)
```

The program in example #6 implements a convenient IF...THEN statement. This command is useful in coordinating internal program flow with external events.

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SUMMARY:

Command Mode

1) Commands received are executed immediately!

2) A carriage-return (ASCII 13 decimal) terminates a command and causes the MotionMaster 2000 to begin processing.

3) Multiple commands may exist on a single line if delimited by a semicolons. i.e., "1PR+1000;1WS50;2PR-1000;2WS50"

4) Commands missing target module references default to the last reference. i.e., "1PA+1000;WS50" (the "WS" command defaults to axis 1)

5) The 'WS' command causes the MotionMaster 2000 to "wait" until the target position is reached before processing the next command.

Program Execution Mode

1) The 'EP' command invokes program entry mode which transfers incoming characters to program memory.

2) The '%' command causes the system to exit program entry mode.

3) A stored program must be successfully compiled with the 'CP' command before it can be executed.

4) New commands are accepted and executed even while running a program.

5) The 'WS' command causes the MotionMaster 2000 to "wait" until the target position is reached before processing the next command.

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MOTION

COMMAND	EXAMPLE	ACTION
AB	"AB"	Abort motion
AC	"AC20000"	Set acceleration
MF	"MF"	Turn motor power off
MO	"MO"	Turn motor power on
ML	"ML+"	Move to travel limit
MV	"MV+"	Move indefinitely until stopped
MZ	"MZ-"	Move to top zero (marker) pulse
OA	"OA20000"	Set origin search acceleration
OH	"OH11000"	Set origin search high velocity
OL	"OL900"	Set origin search low velocity
OR	"OR1"	Perform origin search
PA	"PA-10000"	Position absolute
PR	"PR+40000"	Position relative
SD	"SD1"	Speed divide
ST	"ST"	Stop motion
VA	"VA5000"	Set velocity value
VB	"VB"	Set base velocity: start/stop velocity
VR	"VR5000"	Velocity relative: increment/decrement present velocity
VS	"VS2237"	Sample-time velocity mode

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MOTION RELATED

COMMAND	EXAMPLE	ACTION
BA	"BA100"	Enable backlash compensation
CL	"CL 50, 1, 0"	Closed-loop stepper
DH	"DH"	Define home
DS	"DS0"	Derivative sampling interval
FE	"FE500"	Set following error threshold
IL	"IL500"	Set integration limit
JY	"JY1"	Enable joystick control
KI	"KI100"	Set PID Integration constant
KD	"KD100"	Set PID Derivative constant
KP	"KP75"	Set PID Proportional constant
OV	"OV500"	Set overshoot value for floating origin search
SE	"SE1,2"	Simultaneous command execution
SL	"SL+1000"	Set soft (travel) limits
SY	"SY1,2"	Set axes for simultaneous execution
TY	"TY 850B"	Set motor/positioner type
UF	"UF"	Update PID filters

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COMMAND	EXAMPLE	ACTION
CM	"CM2"	Create macro definition
CP	"CP"	Compile program
EM	"EM2"	Execute macro definition
EP	"EP"	Enter program mode
EX	"EX"	Execute program
IE	"IE10"	Initialize time interval execution mode
LM	"LM"	List all macro definitions
LP	"LP"	List stored program lines
PE	"PE"	Store a string of commands for power-on execution
RM	"RM"	Reset all macro definitions
RQ	"RQ7"	Generate an interupt signal to the host computer
QP	"QP"	Quit program execution mode
SV	"SVV0=10"	Set value for up to ten variables
%	"%"	Quit program entry mode
'	" ' "	Program line comments

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REPORTING

COMMAND	EXAMPLE	ACTION
DA	"DA"	Tell desired acceleration
DP	"DP"	Tell desired position
DV	"DV"	Tell desired velocity
MS	"MS"	Tell motor status
RA	"RA2"	Read analog channel 1-8, 10-bit resolution
RB	"RB"	Read I/O bits
RC	"RC"	Report module configuration
TB	"TB"	Tell error message buffer contents
TE	"TE"	Tell error number
TF	"TF"	Tell filters
TL	"TL"	Tell soft limits setting and following error
TM	"TM"	Tell memory
TP	"TP"	Tell (real) position
TR	"TR10,10"	Initialize motion tracing mode
TS	"TS"	Tell status
TT	"TT"	Tell motion trace data
TV	"TV"	Tell (real) velocity
VE	"VE"	Tell software version

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SEQUENCE

COMMAND	EXAMPLE	ACTION
DL	"DL A"	Define jump to label
IF/THEN	"IF 2H THEN A"	IF bit(s) high/low THEN (goto label)
JL	"JL A 250"	Jump to label
RP	"PR100;RP10"	Repeat command
WB	"WB1H"	Wait for bit level, then execute next command
WT	"WT100"	Wait time, then execute next command
WHILE/WEND	"WHILE 3H,6L"	WHILE bit(s) high/low ... WEND
WP	"WP+3000"	Wait for position, then execute next command
WS	"WS100"	Wait for stop plus additional time, then execute next command

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MISCELLANEOUS

COMMAND	EXAMPLE	ACTION
BI	"BI2,7,1"	Define input bits
BO	"BO5,8,4"	Define output bits
CB	"CB2,7,1"	Clear bits
ER	"ER1:10"	Set encoder ratio
FI	"FI1B"	Format interrupt
FM	"FM00"	Format motor
FO	"FO02"	Format output
SB	"SB1,5"	Set bits high
SR	"SR3"	Select baud rate
TG	"TG2,5"	Toggle bits
WD	"WD3,16"	Write value to D/A channel
RS	"RS"	Reset system
XX	"XX"	Purge memory
#	"#"	Emergency stop

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INTERPOLATION

COMMAND	EXAMPLE	ACTION
AV	"AV100"	Set vector acceleration for interpolation
CA	"CA4,3"	Set circular interpolation axes
CR	"CR10,0,0"	Initiate circular interpolation arc pattern
LA	"LA1,2"	Set linear interpolation axes
LN	"LN100,100"	Initiate linear interpolation line pattern
VV	"VV100"	Set vector speed for interpolation

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2.4 DETAILED DESCRIPTION OF COMMANDS

The majority of the MotionMaster 2000 commands are applicable to stepping motors and DC motors. However, a few commands exist which are motor type specific. If a command is motor type specific, then it is labelled as such at the beginning of the command description.

AB

FUNCTION: Abort motion

COMMENTS: This command stops a motion immediately and abruptly with infinite deceleration.

The 'ST' command stops a motion with the programmed deceleration.

If the MotionMaster 2000 is executing a wait command, for example, 'WS' (wait stop), 'WP' (wait position), or 'WT' (wait time), when this command is issued, it will be queued and only executed when all the previous commands are done.

Use the '#' command to stop motion immediately at any time.

EXAMPLE: "2AB" (abort axis 2 motion)

AC n

FUNCTION: Set motor acceleration/deceleration

RANGE:

250 to 1,000,000,000 counts/sec^2	(DC Motor)
150 to 8,000,000 steps/sec^2	(Stepping Motor: Step70K)
15,000 to 450,000,000 steps/sec^2	(Stepping Motor: Step1.5M)

COMMENTS: This command sets motor acceleration and deceleration for subsequent motor rotations. The acceleration and deceleration value remains in effect until changed to another value. Note that this command may not be changed during motion. For stepping motors, the 'AC' parameter may be further modified with the 'SD' command. See the 'SD' command description for a complete explanation.

EXAMPLE: "4AC50000" (set axis 4 acceleration/deceleration)

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FUNCTION: Set vector acceleration for interpolation move

RANGE: 100 to 1,000,000,000 counts/sec^2

COMMENTS: This command sets the vector acceleration for linear and circular interpolation moves. The acceleration on each axis will be calculated automatically to achieve the desired vector acceleration.

This setting will only affect interpolation moves.

EXAMPLE: "AV1000000" (set interpolation vector acceleration to 1000000 counts/sec^2)

BA n

FUNCTION: Enable backlash compensation

RANGE: 1 to 9999

COMMENTS: This command invokes the automatic backlash compensation function. In this mode the MotionMaster 2000 will modify the positioning command by adding n counts (or steps) along the direction whenever there is a motion reversal. The parameter n defines the distance it will compensate, and it should equal the backlash of the system. This function is useful in those systems without direct position feedback.

To get correct compensation, a positive direction move with a distance greater than the backlash should be executed before issuing the BA command. In addition, DC motors must have their PID parameters adjusted to eliminate any overshoot.

This mode is disabled by issuing the BA command without any parameters.

EXAMPLE:

```
"PR100"     (ensure there is no backlash in positive
"BA10"       direction then enable compensation)
```


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BI

FUNCTION: Define I/O bits as inputs

RANGE: 1 to 8

COMMENTS: This command is used to define the specified I/O bits as inputs. Before a bit can be used as an input, it must be defined as an input bit. Note that the unspecified bits remain unaffected and all I/O bits are automatically configured as inputs after a reset. See also the 'RB' command (read I/O bits).

The input bits are accessed at the General Purpose I/O connector on the MotionMaster 2000 motherboard. See Appendix A for pinouts and electrical requirements.

EXAMPLE: "BI1,2,3,4" (define I/O bits 1 through 4 as inputs)

BO n,n

FUNCTION: Define I/O bits as outputs

RANGE: 1 to 8

COMMENTS: This command is used to define the specified I/O bits as outputs. Before a bit can be used as an output, it must be defined as an output bit. Note that the unspecified bits remain unaffected and all I/O bits are automatically configured as inputs after system reset. See also the 'SB' (set bit) and 'CB' (clear bit) commands.

The output bits are accessed at the General Purpose I/O connector on the MotionMaster 2000 motherboard. See Appendix A pinouts and electrical requirements.

EXAMPLE: "BO5,6,7,8" (define I/O bits 5 through 8 as outputs)

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FUNCTION: Circular interpolation coordinate assignment

RANGE: 1 to 4

COMMENTS: This command assigns two axes to X-Y coordinates in which a circular interpolation will be defined and executed by the CR command. Parameter n1 is the axis number assigned to the X axis, and n2 is the axis number assigned to the Y axis. The circular interpolation coordinates are independent from the linear interpolation coordinates.

The default setting is CA 1,2.

EXAMPLE: "CA4,3" (axis 4 and axis 3 will be X axis and Y axis respectively in the CR command)

CB n,n

FUNCTION: Clear bit: set programmable I/O bit(s) low

RANGE: 1 to 8

COMMENTS: Assuming previously defined as outputs with the 'BO' command, this command sets the programmable bit(s) low. This command is useful in synchronizing external devices to internal events (for example, outputting a pulse when a motion is complete).

EXAMPLE:
"BO1,3,8" (set I/O bits 1, 3, and 8 as outputs)
"CB1,3,8" (clear bits 1, 3, and 8)

CL n1,n2,n3 Stepper

FUNCTION: Set parameters, enable/disable, or report status for stepper motor closed-loop.

RANGE:
n1: 1 to 65,535 (maximum error threshold)
n2: 0 to 65,535 (error deadband)
n3: 0 to 255 (sampling interval = (n3+1)*(0.1sec))

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COMMENTS: The Closed-Loop (CL) command is used to set parameters associated with stepper motor closed-loop operation. It's also used to turn the closed-loop positioning feature **ON** and **OFF** (i.e., "2 CL ON" or "2 CL OFF"). To get the MotionMaster to report the current parameter settings and ON/OFF status append a question mark (?) to the CL command (i.e., "1 CL ?").

When the closed-loop positioning mode is turned-ON the MotionMaster monitors the stage/motor encoder feedback so as to automatically correct for deviation from target position.

Following error threshold (n1) is the maximum positioning error permitted before the MotionMaster will automatically (1) abort motion on the offending axis, (2) revert to default open-loop mode, (3) record the error, and (4) alert the host computer via interrupt (see FI command). Position error is defined as follows:

Error = (Step Output) - (Step/Encoder ratio)*(Encoder Feedback)

This parameter permits motor/stage stalled-condition, driver failure, mis-wiring, and encoder failure detection.

Deadband (n2) is the maximum allowable error which will NOT trigger a position error correction. This parameter is necessary because of real world electro-mechanical imprecision (i.e., stage backlash, microstepping inaccuracy) which may result in motor oscillation.

Sampling interval (n3) is the time between position error corrections. Programmable sampling time intervals are in multiples of 0.1 sec (i.e., n3=0 (0.1s), n3=1 (0.2s), etc..) and can be as long as 25.6 seconds (max).

Note that invoking any of the following commands will automatically turn **OFF** closed-loop operation:

AB, ST, OR, MV, ML, MZ, JY

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Axis-2	COMMAND	REMARKS
EXAMPLE:	"2 ER 1:1"	;2000ppr shaft-mounted encoder & mini-step MD4
	"2 FM 0"	;Set to encoder positioning units
	"2 VB 4000"	;Set stepper start/stop speed to 4000 mini-steps/sec
	"2 CL 50,1,0"	;50 max error, 1 count deadband, 0.1sec. sampling rate
	"2 CL ?"	;Report stored settings and feature ON/OFF status
	CL 50, 1, 0	*** Closed-loop ON! *** ;Controller response
	"2 VA 300000"	;Velocity too high for typical mini-stepped motor!
	"2 PA +80000"	;Move axis-2 to target, or desired, position
	E09 AXIS 2 MOTOR FOLLOWING ERROR	;Error message
	"2 CL ?"	;Report stored settings and feature ON/OFF status
	CL 50,1,0 *** Closed-loop OFF ***	;Controller response
	"2FM 1; 2TP	;Report internal step pulse count
	+6523 STEPS	;# of step pulses transmitted to driver before stopped
	"2FM 0; 2TP	;Report internal encoder feedback count
	+4542 COUNTS	;# of encoder counts up until stalled-condition
	"2 DH"	;clear encoder and step pulse counter
	"2 CL on	;Turn axis-2 closed-loop feature ON
	"2 VA 20000"	;Reasonable velocity setting for mini-stepped motor
	"2 PA -15000"	;Move axis-2 to desired position
	"2 CL ?"	;Report stored settings and ON/OFF status
	CL 50,1,0	*** Closed-loop ON! ;Controller response
	"2 CL off"	;Turn stepper closed-loop feature OFF
	"2 CL ?"	;Report stored settings and ON/OFF status
	CL 50,1,0 *** Closed-loop OFF	

HINTS: (1) Use known working encoder to step ratio (see ER command) setting
(2) Check for working encoder feedback (see TP command)
(3) Enable ("CL on") closed-loop stepper when motor is stopped

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CM n

FUNCTION: Create macro definition

RANGE: 1 to 127

COMMENTS: This command permits the user to create a new macro definition. Macro definitions combine multiple MotionMaster 2000 instructions into a single command. 5K-bytes of non-volatile memory are allocated for macro definitions. Macros are executed from either program or real-time command buffers (see 'EM' command). Note that any duplication of definitions will result in an "E12 MACRO ALREADY EXISTS" error.

EXAMPLE:

"CM1;2PR-1000;2WS200;3PR+500;3WS200"	(create macro 1)
"CM5;2PR+1000;2WS200;3PR-500;3WS200"	(create macro 5)
"EM1;EM5"	execute macros)

CP

FUNCTION: Compile stored program

COMMENTS: This command compiles all instructions downloaded into the MotionMaster 2000 program buffer. Commands, jumps, labels and parameters stored in memory are evaluated at this time. If one or more errors are detected, the MotionMaster 2000 is ready to send all error messages. If no errors are encountered, then the MotionMaster 2000 is ready to send the compilation complete message. Therefore, immediately after you issue a 'CP' command, execute the MotionMaster 2000 read function, and repeat the read function until the response is "END".

EXAMPLE 1:

"CP"	(compile stored program)
LINE 0002 E01 BAD COMMAND	(response: program has an error)
COMPILATION ABORTED	
END	

EXAMPLE 2:

"CP"	(compile stored program)
COMPILATION COMPLETED	(response: program has no errors)
END	

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FUNCTION: Perform circular interpolation move

RANGE:
n1: 10 to 1,000,000,000
n2: 0.0 to 360.0
n3: -360.0 to 360.0

COMMENTS: This command initiates an arc pattern move in the X-Y coordinates defined by the CA command, where n1 is the radius; n2 is the start angle; n3 is the sweep angle. Angle parameters are represented in degrees and have 10 post-decimal digits. The sign of the sweep angle defines the direction of the arc move.

To generate the desired path, it is very important to use the correct positions of the center and the start points when the parameters are calculated.

The vector move speed and acceleration are defined by the AV and VV commands.

EXAMPLE: "CR25000,0,-360" (generate a full circle with a radius of 25000 counts, which starts from X axis in CW direction)

DA

FUNCTION: Report desired acceleration/deceleration

COMMENTS: This command reports the desired acceleration and deceleration previously entered with the 'AC' command. Note that, regardless of the 'FM' command position counting configuration, DC motor modules will always respond with units in terms of counts/sec^2 while stepping motor modules respond in steps/sec^2. The response for stepping motor modules includes the divide factor set by the SD command.

EXAMPLE:

"3DA"	(axis 3 desired acceleration)
300000 COUNTS/SEC^2	(DC module typical response)
"2DA"	(axis 2 desired acceleration)
50000/10 STEPS/SEC^2	(stepper module typical response .. the effective acceleration is 5000 steps/sec^2)

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DH

FUNCTION: Define home; reset position counter.

COMMENTS: This command sets the position counter to zero. This zero position becomes the zero reference for subsequent absolute positioning commands. It also defines this location as the floating origin point. The command 'OR0' (go to floating origin) will return the motor to this location.

EXAMPLE:

"2DH"	(reset axis 2 position count)

DL n

FUNCTION: Define a label

RANGE: Alphabet characters A,B,C, ... Z

COMMENTS: The 'DL' command defines a label to be used as a target for 'JL' and 'IF' commands in a downloaded program.

EXAMPLE:

"EP"	
"DL A"	(define label 'A')
"2PR+100"	
"2WS100"	
"JL A 4"	(jump to label 'A'; perform 4 loops)
"2PA0"	
"%"	

DP

FUNCTION: Report last desired target position

COMMENTS: This command reports the last desired position requested with either 'PR' or 'PA' commands. For stepping motor modules the response units will be either encoder counts or steps, depending on the corresponding 'FM' command configuration (see 'FM' command). DC motor module response units are always encoder counts.

EXAMPLE:

"2DP"	(report axis 2 target position)
+1000 COUNTS	(response)
"1DP"	(report axis 1 target position)
+1000 STEPS	(response)

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FUNCTION: Set the PID derivative sampling interval

RANGE: 0 to 255

COMMENTS: This command sets the derivative sampling rate. The derivative signal is multiplied by the coefficient Kd (see 'KD' command) each derivative sampling interval. This product contributes to the motor control output every sample interval (256us), independent of the user-chosen derivative sampling period.

BIT								Selected Derivative
7	6	5	4	3	2	1	0	Sampling Interval
0	0	0	0	0	0	0	0	256us
0	0	0	0	0	0	0	1	512us
0	0	0	0	0	0	1	0	1024us
0	0	0	0	0	0	1	1	2048us
1	1	1	1	1	1	1	1	65536us

EXAMPLE: "3DS0" (set axis 3 derivative sampling to 256us)

DV

FUNCTION: Report last desired target velocity

COMMENTS: This command reports the last desired velocity requested with the 'VA' or 'VR' commands. Note that, regardless of the 'FM' command position counting configuration, DC motor modules will always respond with units in terms of counts/sec while stepping motor modules respond in steps/sec. The response for stepping motor modules also includes the base velocity set with the 'VB' command and the speed divide factor set by the 'SD' command.

EXAMPLE:

"1DV"	report axis 1 desired velocity)
5000 COUNTS/SEC	(DC module typical response)
"2DV"	report axis 2 desired velocity)
500_10000/10 STEPS/SEC	(stepping motor typical response .. the effective velocity is 50 to 1000 steps/sec)

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EM n

FUNCTION: Execute stored macro definition

RANGE: 1 to 127

COMMENT: This command executes stored macro definitions previously created with the 'CM' command. Macros may be called and executed at anytime. They can be executed from within a program or in real-time. Note that commands stored in macro definitions are not evaluated until the macro is executed. Therefore, syntax errors, parameters errors, etc. entered during 'CM' command processing will appear. See also the 'RM' and 'LM' commands.

EXAMPLE:

"CM2;2PA1000;WS;PA0;WS"	(create macro definition #2)
"EP"	(activate program entry mode)
"DL A"	(define label 'A')
"EM2"	(execute macro definition #2)
"JL A 10"	(execute "EM2" 10 times)
"%"	(exit program entry mode)
"CP"	(compile program)
E18 PROGRAM COMPILED	(response to 'CP' command)
END	(response to 'CP' command)
"EX"	(execute program)

EP

FUNCTION: Invoke program entry mode

COMMENTS: This command places the MotionMaster 2000 into the program entry (i.e. command storage) mode. All commands received after an 'EP' command are saved in non-volatile memory. While in this mode, the command input channel is redirected from the normal verification and execution. Commands are simply saved without evaluation.

The %' command exits program entry mode and returns the MotionMaster 2000 to command mode.

EXAMPLE:

"EP"	(invoke program entry mode)
"2PA500"	
"WS100"	
"PA-500"	
"%"	(exit program entry mode)

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FUNCTION: Define encoder ratio

RANGE: n: 1 to 10000
m: 1 to 10000

COMMENTS: This command tells the MotionMaster 2000 the relationship between the number of step pulses it outputs and the number of encoder counts which occur. The two numbers must be integers.

The units for the position parameter of commands 'PA' and 'PR' are either encoder counts or step pulses. The choice is made with the 'FM' command. If you have an encoder, you may (... but do not have to ...) select the encoder count as your units for the 'PA' and 'PR' commands. In this case you must specify the encoder ratio to the MotionMaster 2000, otherwise you will have errors in positioning.

Refer to the MotionMaster 2000 Quick Installation Guide for directions to determine the encoder ratio.

EXAMPLE:

"2ER1:10"	(1 encoder count per 10 pulses on axis 2)
"1ER10:128"	(10 encoder counts per 128 pulses on axis 1)

EX

FUNCTION: Execute stored program

COMMENTS: A successfully compiled program (see 'CP' command) stored in the MotionMaster 2000 memory is executed with this command. While in program execution mode, it is possible to transmit real-time commands to the MotionMaster 2000 for execution. Any command errors or motion errors (i.e. hitting a travel limit) detected during this mode will abort the program and cause the MotionMaster 2000 re-enter command mode.

EXAMPLE:

"EX"	(execute downloaded program)

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FUNCTION: Set maximum motor following error

RANGE: 1 to 32767 encoder counts

COMMENTS: This command is used to set the maximum position error which can be tolerated. Position error is defined as the difference between where the motor should be and where it actually is at every sample time. If the set following error is reached, the motor is stopped and an error message is generated.

EXAMPLE: "2FE5000" (set axis 2 maximum following error to 5000 counts)

FInn

FUNCTION: Select interrupt event

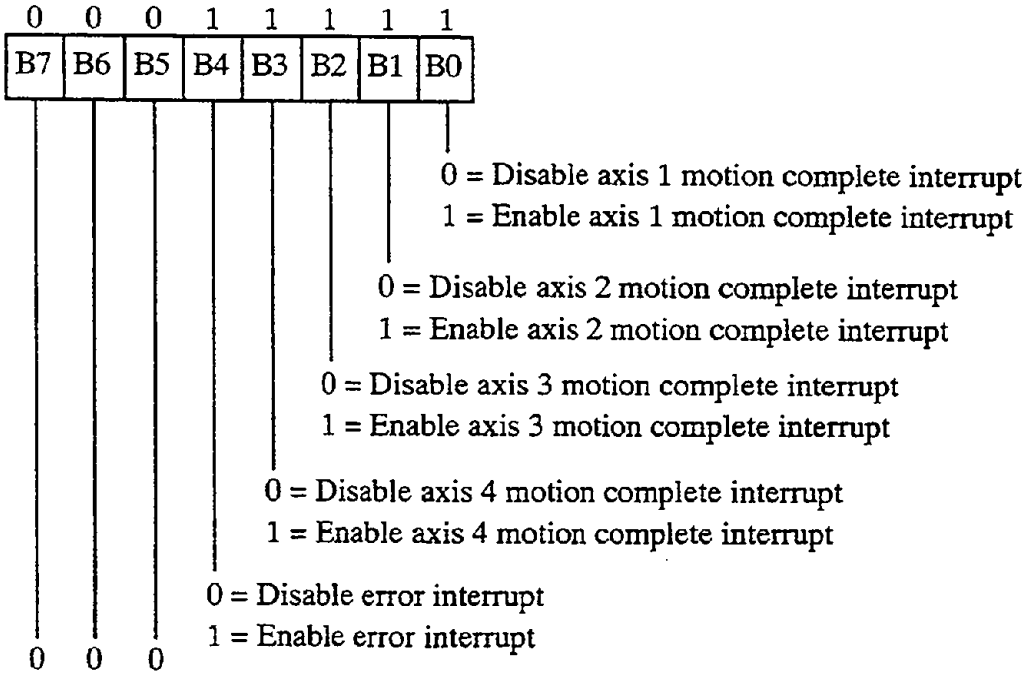
RANGE: 00 to 1F

COMMENTS: This command allows the user to enable or disable MotionMaster 2000 interrupts on selected events. The MotionMaster 2000 may be configured to generate an interrupt on "motion complete" or on the occurrence of an error. Note that the 'TS' (tell status) command reports the board's interrupt status (i.e. whether or not it generated the interrupt) and the 'TE' (tell error) command reports the error code.

Refer to the MotionMaster 2000 Quick Installation Guide for the description of PC Interrupts and Appendix E in this User's Manual for sample programs which show the servicing of MotionMaster 2000 interrupts.

The parameter for the command is the hexadecimal representation of the bit pattern of the byte below.

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EXAMPLE: "FI1B" (generate interrupt on axis 1, 2, and 4 motion complete and error)

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FUNCTION: Format motor options

RANGE: 00 to FF

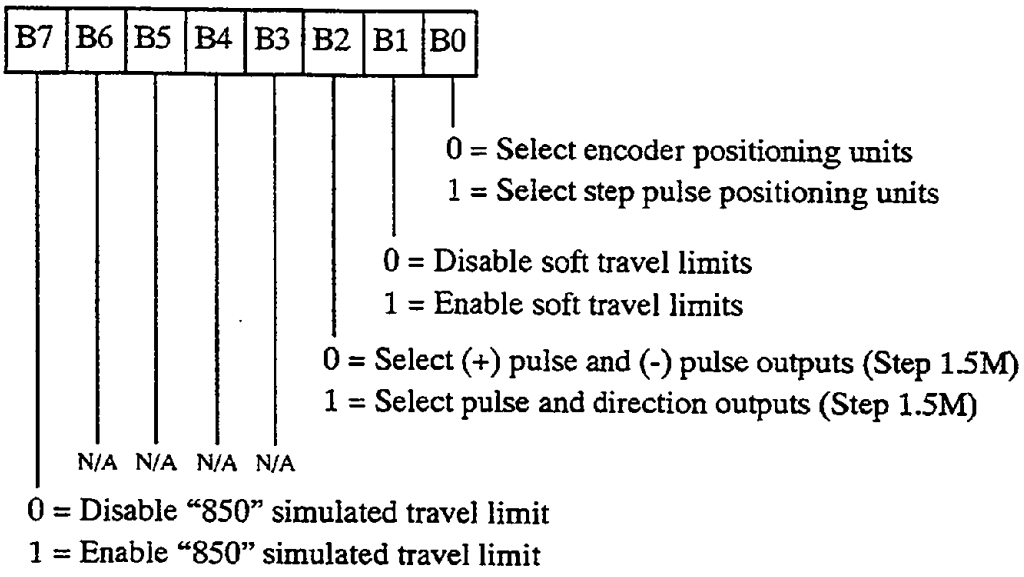
COMMENTS: For stepping motors only, this command sets the units for the positioning commands (i.e. 'PA' and 'PR') numerical parameter and the units for the response to the 'TP' (tell position) command.

For both DC and stepping motors, it enables and disables soft travel limits. See 'SL' command for explanation and use of soft travel limits.

For Stepping Motor, Step1.5M, it selects the motor control outputs to be positive direction pulse and negative direction pulse or pulse and direction.

For DC motors, the positioning parameter unit and the position counting unit is always encoder counts. These cannot be modified with this command.

The parameter for the command is the hexadecimal representation of the bit pattern of the byte below.



EXAMPLE: See next page.

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EXAMPLE: "1FM02" (select encoder units, enable soft limits and select (+)pulse and (-)pulse outputs for Step1.5M)

This command has the following effects:
For "ER1:1" (encoder ratio is 1 encoder count per step)

```
PR1000      ;move 1000 encoder counts from present position
            ;MotionMaster 2000 will output 1000 step pulses
TP          ;response is +1000 COUNTS (i.e. encoder counts)
```

For "ER1:10" (encoder ratio is 1 encoder count per 10 steps)

```
PR1000      ;move 1000 encoder counts from present position
            ;MotionMaster 2000 will output 10000 step pulses
TP          ;response is +1000 COUNTS (i.e. encoder counts)
```

EXAMPLE: "1FM03" (select step pulse units, enable soft limits and select (+)pulse and (-)pulse outputs for Ste1.5M)

This command has the following effects:
For "ER1:1" (encoder ratio is 1 encoder count per step)

```
PR1000      ;move 1000 steps from present position
            ;MotionMaster 2000 will output 1000 step pulses
TP          ;response is +1000 STEPS (i.e motor steps)
```

For "ER1:10" (encoder ratio is 1 encoder count per 10 steps)

```
PR1000      ;move 1000 steps from present position
            ;MotionMaster 2000 will output 1000 step pulses
TP          ;response is +1000 STEPS (i.e. motor steps)
```

NOTE: **When you select step pulse units, the encoder ratio setting has no effect on positioning.**

EXAMPLE: "2FM04" (select encoder units, disable soft limits, and select pulse and direction outputs for Step1.5M)

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FUNCTION: Format response output

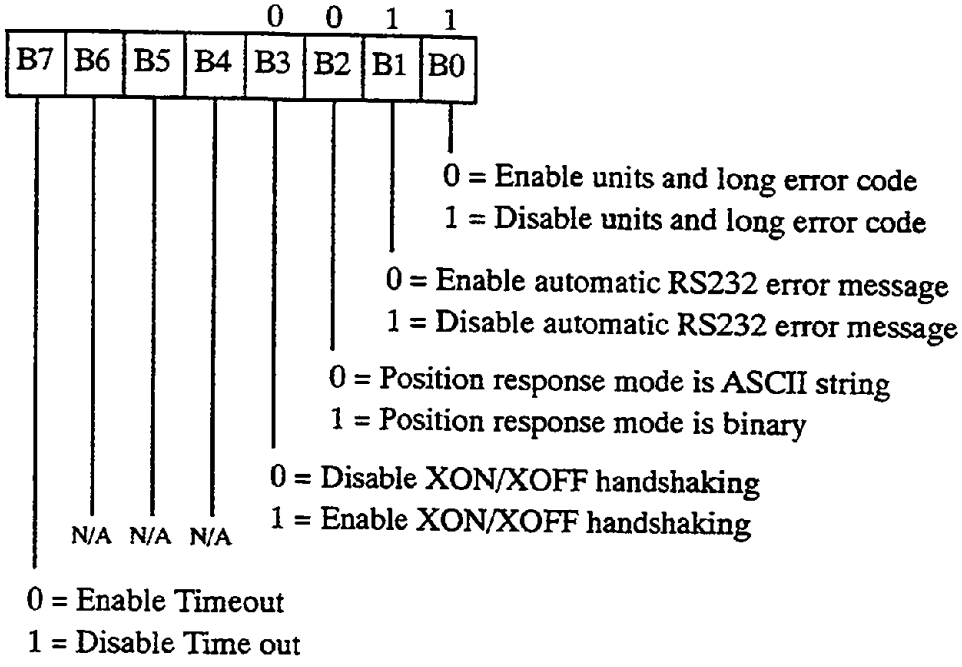
RANGE: 00 to FF

COMMENTS: This command is used to enable or disable units information in response messages (ex. COUNTS/SEC in response to 'TV' [tell velocity] command), to enable or disable automatic error message outputs on RS232, and to select the mode of the response to the 'TP' (tell position) command as either ASCII string or binary. The factory set default mode is ASCII string.

The ASCII string mode returns the numerical position as string characters terminated by a carriage return/line feed combination. The response time is typically 1.5 milliseconds. Use the function mmread(response,address) to obtain the response.

The binary mode returns the numerical position as a 32 bit integer. The response time is typically 750 microseconds. Use the function binread(position,address) to obtain the response. The advantage of using the binary mode is the speed of the response and host computer processing, i.e. the MotionMaster 2000 does not have to convert an integer into a string and then your host computer does not have to convert the string into an integer.

The parameter for this command is the hexadecimal representation of the bit pattern of the byte below.



EXAMPLE: FO03" (Disable units and RS232 error messages, position response mode is ASCII string)

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FUNCTION: Initialize interval execution mode

RANGE: 0 to 10000 milliseconds

COMMENTS: This command sets up the time interval execution mode. A delay interval equal to the command parameter n milliseconds will be inserted between every line of MotionMaster 2000 commands.

This command may be used to perform contouring with DC and stepping motors. For DC motor control, the MotionMaster 2000 can be commanded to change position 'on the fly'. To traverse a contour, define the contour as position versus discrete time. Program the time interval with this command and then send the calculated positions.

For stepping motor control, the MotionMaster 2000 can be commanded to change the velocity 'on the fly'. To traverse a contour, define the contour as velocity versus discrete time. Program the time interval with this command, initiate the motion, and then send the calculated velocities.

The MotionMaster 2000 has a circular interpolation command for DC motor control only. However, with this command, you can perform circular interpolation with stepping motors by programming the velocities as sine and cosine values versus discrete time. Consult Newport/Klinger engineers.

Issuing this command without a parameter or with a 0 will disable the mode.

EXAMPLE:

"IE10"	(set intermittent interval to 10 ms)
"VA1000"	(each speed command in the series will
"VA1050"	be executed at intervals of 10 ms)
"VA1100"	

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IF n,...n THEN label

FUNCTION: Branch to program label if bit condition true

RANGE: 1 to 8

COMMENTS: This command uses the label as a "jump to" target if the specified bit condition is true. Each time this instruction is encountered the bit condition is tested. If the bit condition is false, however, program execution continues with the instruction immediately following the 'IF' command. (See also the 'BI' command).

EXAMPLE:

"EP"	(invoke program entry mode)
"BI 2,7"	(configure bits as inputs)
"DL A"	(define label 'A')
"3PR+1000"	
"3WS"	
"IF 3H,7L THEN A"	(branch to label 'A' if bit-3 high & 7 low)
"3PA0"	
"%"	(exit program entry mode)

IL n

DC Motor

FUNCTION: Set the PID integrator limit constant

RANGE: 0 to 32767

COMMENT: This command is used to set the value for the filter integration limit coefficient 'IL'. The integral term of the filter equation is not allowed to exceed this value. The limiting process is useful for preventing integral wind-up. Like all PID filter parameters, the value is not changed until the 'UF' (update filter) command is issued.

See Section 3 in this User's Manual for an explanation on the use of DC motor filter parameters.

EXAMPLE:

"3IL100"	(set axis 3 integration limit)
"UF"	(update filter)

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JL n,m

FUNCTION: Jump to label during internal program execution

RANGE: n: A,B,C, .. Z
m: 1 to 65535

COMMENT: This command uses the label as a "jump to" target and the second argument as the repetition count. Each time this instruction is encountered the count is decremented by one. If the count is a non-zero after the decrement, program execution will "jump" to the specified label. When the count reaches zero, program execution continues with the instruction immediately following the "JL" command.

If the repetition argument is zero or not specified the program will loop indefinitely!

EXAMPLE:

"EP"	
"DL A"	(define label 'A')
"PR100"	
"WS50"	
"JL A 10"	(jump to label 'A'; perform 10 loops)
"%"	

JY n

FUNCTION: Initialize joystick control mode

RANGE: -4 to +4

COMMENTS: This command sets the corresponding axis to joystick mode. A joystick from Newport/ Klinger is connected to the GPIO connector on the MotionMaster 2000 and controls the speed and the direction of up to 4 motors. The absolute value of parameter defines the A/D channel used for the axis, and the sign determines the relation between the direction of motor movement and the direction of joystick movement.

Issuing this command with a parameter equal to zero, disables joystick control.

See Section 8 in this manual for a more detailed explanation of joystick control.

EXAMPLE:

"1JY4"	(axis 1 assigned to joystick axis 4 through a/d channel 4)
"1JY0"	(disable joystick control of axis 1)

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KD n — DC Motor

FUNCTION: Set the PID derivative constant value

RANGE: 0 to 32767

COMMENTS: This command is used to set the value for the filter derivative (high-pass) coefficient KD. Like all other PID filter parameters, the value is not changed until the 'UF' (Update Filter) command is issued. (See also 'DS' command)

See Section 3 in this User's Manual for an explanation on the use of DC motor filter parameters.

EXAMPLE:

"1KD500"	(set derivative constant for axis 1)
"UF"	(update filter)

KI n — DC Motor

FUNCTION: Set the PID integrator constant value

RANGE: 0 to 32767

COMMENTS: This command is used to set the value for the filter integral (low-pass) coefficient KI. Like all other PID filter parameters, the value is not changed until the 'UF' (Update Filter) command is issued.

See Section 3 in this User's Manual for an explanation on the use of DC motor filter parameters.

EXAMPLE:

"4KI100"	(set integrator constant for axis 4)
"UF"	(update filter)

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FUNCTION: Set the PID proportional constant value

RANGE: 0 to 32767

COMMENTS: This command is used to set the value for the filter proportional (gain) coefficient KP. Like all other PID filter parameters, the value is not changed until the 'UF' (Update Filter) command is issued.

See Section 3 in this User's Manual for an explanation on the use of DC motor filter parameters.

EXAMPLE:

"3KP100"	(set proportional constant for axis 3)
"UF"	(update filter)

FUNCTION: Assign linear interpolation coordinates

RANGE: 1 to 4

COMMENTS: This system assigns two, three or four axes to X-Y, X-Y-Z or X-Y-Z-T coordinates in which a linear interpolation can be defined and executed by the LN command. Parameters n1, n2, n3 and n4 are the numbers of the axes assigned to X, Y, Z and T axes in the linear interpolation coordinates, respectively. The linear interpolation coordinates are independent from the circular interpolation coordinates.

The number of parameters can be less than four.

Default setting is LA 1,2.

EXAMPLE:

"LA2,4,1"	(linear interpolation will be performed in 3-D coordinates where the X axis is axis 2, the Y axis is axis 4, and the Z axis is axis 1)

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LP n, n

FUNCTION: List program lines

RANGE: 1 to 9999

COMMENTS: This command directs the MotionMaster 2000 to output a listing of the currently stored program. To obtain the listing, create your application program such that it repeatedly issues the MotionMaster 2000 read function until the MotionMaster 2000 sends the word "END".

See 'EP' and '%' commands.

EXAMPLE:

"LP"	(list program lines)
0001 PA1000	(response)
0002 WS100	(response)
0003 END	(response)
"LP2,10"	(list program from line 2 to 10)
"LP10"	(list program from line 10 to the end)
"LP,10	(list program from line 1 to 10)

LM

FUNCTION: List all existing macro definitions

COMMENT: This command directs the MotionMaster 2000 to output a list all of the stored macro definitions previously created with the 'CM' (create macro) command. The macro definitions are listed in the order they were saved. This command is useful in determining whether or not a macro already exist and what commands it uses. To obtain the listing, create your application program such that it repeatedly issues the MotionMaster 2000 read function until the MotionMaster 2000 sends the word "END".

See 'EM' and 'RM' commands.

EXAMPLE:

"CM6;2PR-1000;2WS200"	(create macro definition #6)
"CM5;2PR+1000;2WS200"	(create macro definition #5)
"LM"	(list all macros)
MACRO 6: 2PR-1000;2WS200	(response)
MACRO 5: 2PR+1000;2WS200	(response)
END	(response)

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FUNCTION: Perform linear interpolation move

RANGE: -1,000,000,000 to +1,000,000,000

COMMENTS: This command initiates a line pattern move in an X-Y, X-Y-Z, or X-Y-Z-T coordinates defined by the LA command. Parameters n1, n2, n3 and n4 are the relative move distance along the X, Y, Z and T axes.

The number of parameters can be less than four and must be the same as that in the LA command. The coordinate system should be defined correctly before issuing the LA command.

The vector move speed and acceleration are defined by the AV and VV commands.

EXAMPLE: "LN 10000,10000,10000" (generate a diagonal line in a cube of 10000 counts)

MF

FUNCTION: Disable motor power

COMMENTS: For DC motors, this command stops the motor with zero volts for the motor command signal. This produces braking proportional to velocity (caused by motor back-emf). No holding torque is provided after the motor has stopped. Note that the motor is turned-on again with the 'MO', 'PA', 'PR', or 'MV' commands.

For stepping motors, this command sets the inhibit pin low on the 15 pin motor output connector. Refer to the MotionMaster 2000 Quick Installation Guide. The effect of this command is to disable current through the motor windings. Note that the motor is turned-on again with the 'MO', 'PA', 'PR', or 'MV' commands

EXAMPLE: "1MF" (turn motor-off on axis 1)

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ML+ / ML-

FUNCTION: Move to positive travel limit sensor
Move to negative travel limit sensor

COMMENTS: This command directs the MotionMaster 2000 to move until it senses the travel limit sensor. The parameter plus(+) or minus (-) sets the direction of motion. The velocity used is the last "VA" or "VR" entered.

Normally, when a travel limit switch is reached during a motion, the MotionMaster 2000 will stop all motions and generate an error message. However, with this command, reaching the travel limit is the desired function so other motions will not be stopped and an error message will not be generated.

EXAMPLE: "1ML+" (move to plus limit on axis 1)

WARNING

Moving into a positioner travel limit at high speeds may cause damage to the positioner.

MO

FUNCTION: Enable motor power

COMMENTS: This command restores power to the motor and provides holding torque if required. This command is the inverse of the 'MF' command.

For stepping motors, this command sets the inhibit pin high on the 15 pin motor output connector. Refer to the MM2000 Quick Installation Guide.

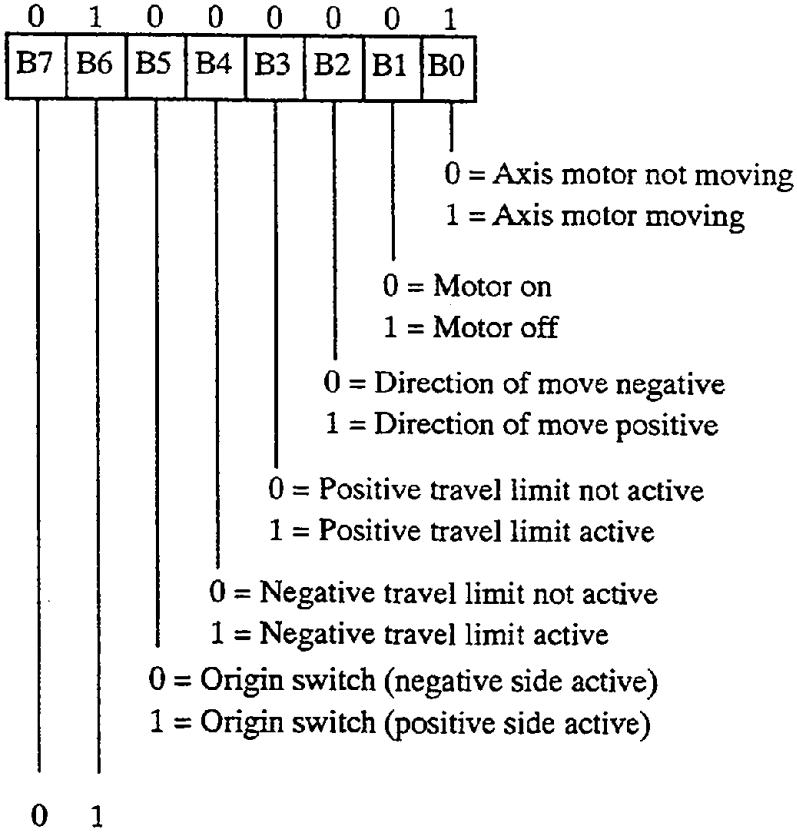
EXAMPLE: "4MO" (restore motor power to axis 4)

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FUNCTION: Report motor status

COMMENTS: This command causes the MotionMaster 2000 to respond with the system information listed below. Each bit in the response byte represents a certain system condition.

The response to this command is the hexadecimal representation of the bit pattern of the byte below.



EXAMPLE:

"2MS"	request axis 2 motor status)
A	(response: on axis 2 no limits, motor on & moving in negative direction)

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MV+ / MV-

FUNCTION: Rotate motor indefinitely in the specified direction

RANGE: + or - direction

COMMENTS: This command rotates a motor indefinitely in the direction specified. The rotation may be stopped by the 'AB', 'ST', and "#" commands, or by a hardware reset signal. The rotation will stop automatically if a travel limit is reached. The velocity used is the last velocity command ('VA' or 'VR') entered. Note that the velocity may be changed "on-the-fly".

EXAMPLE: "3MV+" (move axis 3 indefinitely in the plus direction)

MZ+ / MZ-

FUNCTION: Move to top zero (marker) pulse

COMMENTS: This command directs the MotionMaster 2000 to move until it senses the occurrence of a top zero (marker) pulse.

A top zero pulse is derived from a slot on an encoder disk. The encoder is mounted on the motor shaft. There is one top zero pulse per revolution. The MotionMaster 2000 will rotate the motor until it senses a low to high transition on the top zero pulse.

EXAMPLE: "2MZ-" (move to top zero in the minus direction)

OA n

FUNCTION: Set origin (home) search acceleration/deceleration

RANGE:

250 to 1,000,000,000 counts/sec^2	(DC Motor)
150 to 8,000,000 steps/sec^2	(Stepping Motor: Step70K)
15,000 to 450,000,000 steps/sec^2	(Stepping Motor: Step1.5M)

COMMENTS: This command sets the motor acceleration and deceleration portion of the velocity profile generator for origin search positioning.

For stepping motors, the 'OA' parameter may be further modified with the 'SD' command. See the 'SD'command section for a complete explanation.

EXAMPLE: "2OA50000" (set origin search accel/decel for axis 2)

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OH n

FUNCTION: Set origin (home) search high velocity

RANGE:

0 to 1,000,000 counts/second	(DC Motor)
500 to 70,000 steps/second	(Stepping Motor: Step70K)
100 to 1,500,000 steps/second	(Stepping Motor: Step1.5M)

COMMENTS: This command sets the desired value for absolute velocity used during origin search positioning. The origin search algorithm loads the 'OH' parameter first to quickly find the switch or floating origin then loads the 'OL' parameter to move in slowly.

For stepping motors, the 'OH' parameter may be further modified with the 'SD' command. See the 'SD' command section for a complete explanation

EXAMPLE: "1OH5000" (set axis 1 origin search high velocity)

OL n

FUNCTION: Set origin (home) search low velocity

RANGE:

0 to 1,000,000 counts/second	(DC Motors)
500 to 70,000 steps/second	(Stepping Motor:Step70K)
100 to 1,500,000 steps/second	(Stepping Motor:Step1.5M)

COMMENTS: This command sets the desired value for absolute velocity used during origin search positioning. The origin search algorithm loads the 'OH' parameter first to quickly find the switch or floating origin then loads the 'OL' parameter to move in slowly.

For stepping motors, the 'OL' parameter may be further modified with the 'SD' command. See the 'SD' command section for a complete explanation.

EXAMPLE: "2OH500" (set axis 2 origin search low velocity)

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FUNCTION: Perform origin (home) search

RANGE: n = 0,1, or 2

COMMENTS: This command invokes the MotionMaster 2000 origin search algorithm which automatically seeks a predetermined "home", or origin.

The command 'OR0' directs the MotionMaster 2000 to return the positioning device to the location where the position counter is zero. This is referred to as the floating origin. The floating origin point is defined when the 'DH' command is executed. The 'DH' command sets the position counter to zero.

The command 'OR1' directs the MotionMaster 2000 to return the positioning device to the location of a origin, or home, switch and the next occurrence of a top zero, or marker, pulse. The MotionMaster 2000 origin search algorithm will make one or two passes through the origin switch. Then it will perform the final approach at low speed. Once it reaches the switch, it will then look for a top zero pulse. When it senses the occurrence of the top zero, it will stop the positioning device.

On the DC motor module and stepping motor module, Step70K, you must enable or disable the top zero with a jumper block on the motor module. Refer to the MotionMaster 2000 Quick Installation Guide for more information.

The command 'OR2' is used only for the stepping motor module, Step1.5M. It directs the MotionMaster 2000 to return the positioning device to the location of an origin switch only (i.e. do not look for top zero). Module Step1.5M does not have a hardware top zero enable / disable facility. This command is used to effectively disable top zero.

In either a floating or switch origin search, the positioning device will travel with the speed and acceleration set with the 'OA', 'OH', and 'OL' commands. The origin search algorithm is designed to reach the target position quickly and reduce mechanical backlash.

EXAMPLE: "2OR1" (invoke axis 2 switch origin search)

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OV n

FUNCTION: Set overshoot value for floating origin search

RANGE: 0 to 32,000

COMMENTS: This command determines overshoot which will occur in floating origin search procedure for eliminating the effect of mechanical backlash at the home position.

The units are encoder counts for DC motors, and encoder counts or steps for stepping motors, as set with the 'FM' command.

The default value is 100.

EXAMPLE: "OV500" (set overshoot distance to 500)

PA ± n

FUNCTION: Move motor to absolute position

RANGE:

0 to ±1,000,000,000 counts	(DC Motor)
0 to ±2,147,483,648 steps	(Stepping Motor: Step70K)
0 to ±2,147,483,648 steps	(Stepping Motor: Step1.5M)

COMMENTS: This command directs the MotionMaster 2000 to initiate a move to the specified absolute position. The numerical parameter is treated as the target position relative to position zero. The 'DH' (Define Home) command is used to define the zero position.

For DC Motors, the displacement (number of encoder counts) and the direction of the move is calculated in terms of encoder counts as follows:

ENCODER COUNTS = TARGET POSITION - PRESENT POSITION

The maximum displacement allowed is 1,000,000,000 encoder counts. If this number is exceeded, the MotionMaster 2000 will not initiate the move and will generate an error.

For stepping motors, the displacement (number of steps) and the direction of the move is calculated in terms of steps pulses as follows:

NUMBER OF STEPS = ENCODER RATIO x [TARGET POSITION -PRESENT POSITION]

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The encoder ratio is set with the 'ER' command. If the stepping motor axis was programmed for step pulse positioning units with the 'FM' command, then the 'ER' command specification is ignored and the encoder ratio automatically equals 1.

For Stepping Motor: Step70K, the maximum displacement allowed is 2,147,483,648 motor steps. If this number is exceeded, the MotionMaster 2000 will not initiate the move and will generate an error.

For Stepping Motor: Step1.5M, the maximum displacement allowed is 8,388,608 motor steps. If this number is exceeded, the MotionMaster 2000 will not initiate the move and will generate an error.

Stepping motor modules cannot change position "on the fly", i.e. a 'PA' command may not be issued to an axis while that axis is executing a previous move command. If this does occur, the MotionMaster 2000 will discard the command and generate an "E29 SYSTEM IS BUSY" error message which it will store in its output buffer.

Before issuing a 'PA' command to a stepping motor in motion, send the 'WS' command followed by the 'PA' command, or wait for motion complete by polling status with the 'TS' command or by programming the MotionMaster 2000 to generate an interrupt. See 'FI' command and Appendix E for sample interrupt service programs.

Note that it is possible to issue 'PA' commands to any axis which is not moving,at any time, regardless of whether or not any other axis is moving.

DC motor module can change position "on the fly" i.e. a new target position can be entered before the last one was reached. The module will evaluate its state and proceed towards the last target position entered.

For overall system synchronization, use the 'TS' command or interrupts to determine when a motion is complete and another one may be initiated. See 'FI' command and Appendix E for sample interrupt service programs.

The MotionMaster 2000 will not permit a motor to move to an absolute position beyond the soft travel limits, if soft limits are enabled. See 'SL' and 'FM' commands.

EXAMPLE:

"1PA4000;2PA1000"	(move axis 1 and axis 2 simultaneous)
"1PA1000;WS;PA0"	(move axis 1, wait for stop, then move to zero)
"3PA1000;WP400;4PA50"	(move axis 3, wait for absolute position 400, then move to axis 4)
"4PA1000;WT2000;2PA100	(move axis 4, wait 2 seconds, then move axis 2)

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FUNCTION: Store a string of command(s) for power-on execution

RANGE: Valid commands consisting of a maximum of 20 characters

COMMENTS: This command stores one or several commands for automatic power-on execution.

A null string will disable the function.

EXAMPLE:

"PE EM1;EX"	(MotionMaster 2000 will execute macro 1 and run the stored program when turned on)
or	
"PE 1JY1;2JY2"	(Enable joystick on power-up)
or	
"PE 10R1;20R1"	(Move to origin on power-up)

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FUNCTION: Move motor n encoder counts/steps relative to present position

RANGE:

0 to ±1,000,000,000 counts	(DC Motor)
0 to ±2,147,483,648 steps	(Stepping Motor: Step70K)
0 to ±8,388,607 steps	(Stepping Motor: Step1.5M)

COMMENTS: This command directs the MotionMaster 2000 to make a move equal to the specified number of encoder counts or steps. The numerical parameter is treated as the number of counts, or steps, to be taken from the present position in the specified direction.

For DC motors, the numerical parameter represents the displacement in terms of encoder counts.

For stepping motors, the displacement (number of steps) is calculated as follows:

NUMBER OF STEPS = (ENCODER RATIO) x (PR parameter)

The encoder ratio is set with the 'ER' command. If the stepping motor axis was programmed for step pulse positioning units with the 'FM' command, then the 'ER' command specification is ignored and the encoder ratio automatically equals 1.

Stepping motor modules cannot change position "on the fly", i.e. a "PR" command may not be issued to an axis while that axis is executing a previous move command. If this does occur, the MotionMaster 2000 will discard the command and generate an "E29 SYSTEM IS BUSY" error message which it will store in its output buffer.

Before issuing a 'PR' command to a stepping motor in motion, send the 'WS' command followed by the 'PR' command, or wait for motion complete by polling status with the 'TS' command or by programming the MotionMaster 2000 to generate an interrupt. See 'FI' command and Appendix E for sample interrupt service programs.

Note that it is possible to issue 'PR' commands to any axis which is not moving,at any time, regardless of whether or not any other axis is moving.

DC motor modules can change position "on the fly" i.e. a new relative position can be entered before the last one was reached. The module will evaluate its state and move relative to its position at the instant it received a new 'PR' parameter.

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For overall system synchronization, use the 'TS' command or interrupts to determine when a motion is complete and another one may be initiated. See 'FI' command and Appendix E for sample interrupt service programs.

The MotionMaster 2000 will not permit a motor to move to an position beyond the soft travel limits set, if soft limits are enabled. See 'SL' and 'FM' commands.

EXAMPLE:

"1PR1000;2PR2000"	(move axis 1 and axis 2 simultaneously)
"1PR500;WS;PR250"	(move axis 1, wait for stop, then move axis 1 again)
"3PR500;WT1000;4PR50"	(move axis 3, wait for 1 sec., then move axis 4)

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QP

FUNCTION: Quit program execution

COMMENTS: This command causes the MotionMaster 2000 to exit program execution mode and re-enter command mode. This command may be issued at anytime to effect to a real-time program break.

The MotionMaster 2000 will quit the program when the command in progress is complete. For example, if a motion is in progress, it will not be stopped immediately. Instead, it will be carried to completion.

To stop motion immediately while in program execution mode, use the 'ST', 'AB', or '#' command.

EXAMPLE:

"QP"	(terminate program execution)

RA n

FUNCTION: Read 10-bit A/D converter channel

RANGE: 1 to 8

COMMENTS: This command reads any of eight(8) 10-bit analog-to-digital converters available at the General Purpose I/O connector. See Appendix B for pinouts. Depending on, both the reference voltage and input voltage to be converted, the command returns a decimal value ranging from 0 to 1023. See Section 7 in this User's Manual for detailed description of the analog to digital converter.

The numerical value returned is determined by the following formula:

digital output = (Vin/Vref)*1024

This feature is available only if you ordered your MotionMaster 2000 with the optional analog to digital converter.

EXAMPLE:

"RA3"	(read A/D channel 3)
1023	(response = full scale reading)

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RB

FUNCTION: Read I/O bits

COMMENTS: This command reads the logic levels of the 8 input/output bits available at the General Purpose I/O connector. See Appendix B for pinouts and electrical requirements. Before any bits are used as inputs, they should be defined as inputs with the 'BI' command. The logic levels (1=high, 0=low) of the bits is reported as the decimal equivalent of the hexadecimal byte in ASCII coding.

Note that bits configured for output return their present output state when read.

EXAMPLE:

"BI1,2,3,4,5,6,7,8"	(configure all I/O bits as inputs)
"RB"	(read I/O port)
129	(response: bits 1 and 8 are high)

RC

FUNCTION: Report axis configuration

COMMENTS: This command reports the type of motor module present at axis 1 through 4 on the MotionMaster 2000 motherboard.

EXAMPLE:

"RC"
1=stepper70K 2=dc 3=stepper70K 4=unused (response)
"RC"
1=dc 2=stepper1.5M 3=stepper1.5M 4=unused (response)

RM

FUNCTION: Reset all existing macro definitions

COMMENT: This command erases all previously stored macro definitions. See 'CM', 'EM', and 'LM' commands.

EXAMPLE: "RM" (reset all macro definitions)

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RP n

FUNCTION: Repeat command execution

RANGE: 1 to 255

COMMENTS: This command is used to repeat the execution of a command or a series of commands entered in command mode. The 'RP' command is not permitted in stored programs — use 'DL' and 'JL' commands instead.

EXAMPLE: "1PA+100;1WS10;1PA0;1WS10;RP99" (move back and forth 100 times)

RQ n

FUNCTION: Generate an interrupt signal to the host computer

RANGE: 0 to 31

COMMENTS: This command generates an interrupt request signal to the host computer. The parameter 'n' is used to identify the RQ command which generated the interrupt. Upon receiving the interrupt, the host computer interrupt service routine should send the 'TS' command and read the response. If the interrupt was as a result of the 'RQ'command, then bit 7 of the response is 1 and the lower five bits equal the parameter 'n'.

This command can be used to notify the host computer of the progress or flow of command execution in the MotionMaster 2000.

See 'TS' command.

EXAMPLE: "2PR200;WS;2PR300;WS;RQ" (interupt host computer when second motion of axis 2 is complete)

RS

FUNCTION: Reset system

COMMENTS: This command will cause the MotionMaster 2000 to simulate a hardware reset.

EXAMPLE: "RS" (simulate a hardware reset)

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SB n,...n

FUNCTION: Set programmable I/O bit(s) high

RANGE: 1 to 8

COMMENTS: Assuming previously defined as output with the 'BO' command, this command sets the programmable bit(s) high. See Appendix B for pinouts and electrical requirements. This command is useful in synchronizing external devices to internal events (i.e., outputting a pulse when a motion is complete).

EXAMPLE:

"BO1,3,8"	(configure bits 1, 3, & 8 as outputs)
"SB1,3,8"	(set bits 1, 3, and 8 high)

SD n — Stepping Motor: Step70K

FUNCTION: Divide the velocities set with the 'VB' command, the 'VA' and/or 'VR' commands by the 'SD' parameter to obtain a lower effective stepping rate for subsequent moves.

Divide the acceleration set with the 'AC' command and the 'OA' command by the 'SD' parameter to obtain a slower effective acceleration for subsequent moves.

RANGE: n = 0,1,2,3,4

COMMENTS: The normal operating velocity range of the stepping motor module, Step70K, is 500 to 70,000 steps per second. The 'SD' parameter is used to divide this velocity so that you can obtain lower operating velocities.

The possible divisors are 1,10,100,1000, and 10,000. The parameter n specifies the divisor as 10^n.

The effective stepping rate ranges are:

n=0:	500 - 70,000	steps/sec.
n=1:	50 - 7000	steps/sec.
n=2:	5 - 700	steps/sec.
n=3:	0.5 - 70	steps/sec.
n=4:	0.05 - 7	steps/sec.

A stepping rate of 0.05 steps/sec. is 1 step every 20 seconds.

The acceleration rate is similarly divided.

EXAMPLE:

"1VA30000"	(set velocity equals 30,000 steps/sec.)
"SD1"	(effective velocity equals 3000 steps/sec)
"SD4"	effective velocity equals 3 steps/sec)

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FUNCTION: Divide the velocities set with the 'VB', 'VA', 'OH', 'OL' and/or 'VR' commands by the 'SD' parameter to obtain a lower effective stepping rate for subsequent moves.

Divide the acceleration set with the 'AC' command and the 'OA' command by the 'SD' parameter to obtain a slower effective acceleration for subsequent moves.

RANGE: 1 to 5000

COMMENTS: The normal operating velocity range of the stepping motor module, Step1.5M, is 100 to 1,500,000 steps per second. The 'SD' parameter is used to divide this velocity so that you can obtain lower operating velocities.

This command also sets the speed resolution by the formula:

Speed Resolution = 100 / 'SD' parameter

EXAMPLES:

"SD1"	;speed range is 100 - 1,500,000 steps/sec with a speed resolution of 100 steps/sec. The achievable speeds are (in ascending order): 100, 200, 300, 400, ... 1,500,000 steps/sec.
"SD5000"	;speed range is 0.02 - 300 steps/sec average speed. This is one step pulse every 50 seconds. The achievable speeds are: 0.02, 0.04, 0.06, ... 300 steps/sec.

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SE

FUNCTION: Simultaneous command execution

COMMENTS: This command executes all motion commands loaded previously for simultaneous execution.

The time delay between command executions is typically 10 microseconds. The normal command execution time is typically 1 millisecond.

This command, along with the 'SY' command, is used most frequently to start two or more axes of motion simultaneously.

See 'SY' command.

EXAMPLE:

"SY 1,2"	
"1PA1000;2PA2500"	(no motion occurs after this command)
"SE"	(start motion on two axes now)

SL n

FUNCTION: Set ± soft travel limits

RANGE:

±1 to ±1,000,000,000 counts	(DC Motor)
±1 to ±2,147,483,648 counts or steps	(Stepping Motor)

COMMENTS: This command sets the soft travel limits as absolute positions relative to position zero. If subsequently position zero is redefined with the 'DH' command, the soft limits adjust such that they retain their previous absolute positions. An example will best illustrate this point: the commands "DH", "SL+10000", "SL-10000", issued in this order establish soft limits at absolute positions +10000 and -10000. Next, if the commands "PR2000" and "DH" are issued in this order, then the new soft limits become +8000 and -12000.

If the MotionMaster 2000 is directed to make move to a position beyond the soft limits, and the soft limits are enabled, the MotionMaster 2000 will not initiate the move and it will place an error message in its output buffer.

The 'FM' command is used to enable/disable soft limits.

EXAMPLE:

"2SL+50000"	(set axis 2 positive travel limit)
"2SL-50000"	(" " 2 negative " ")

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SR n

FUNCTION: Set RS-232-C communication baud rate.

RANGE: 0 to 4

COMMENTS: This command sets the baud rate for the MotionMaster 2000 RS-232-C interface. However, the other parameters are fixed at 8 data bits, 1 stop bit, and no parity. Note that any changes in baud rate will take affect immediately.

BAUD RATE	PARAMETER
1200	0
2400	1
4800	2
9600	3 (default)
19200	4

EXAMPLE: "SR1" (set RS232 interface to 2400 baud)

ST

FUNCTION: Stop motion with programmed deceleration

COMMENTS: This command halts the positioner/motor using programmed deceleration (see 'AC' command). The 'AB' command performs a hard stop with infinite deceleration.

If the MotionMaster 2000 is executing a wait command, for example, 'WS' (wait stop), 'WP' (wait position), or 'WT' (wait time), when this command is issued, it will be queued and only executed when all the previous commands are done.

Use the '#' command to stop motion immediately at any time.

EXAMPLE: "2ST" (stop axis 2 motor with deceleration)

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SV Vn = expression

FUNCTION: Set variable value for motion command

RANGE: Variable: V0 to V9
Value: -1,000,000,000 to +1,000,000,000

COMMENTS: This command sets a value for the one of ten variables which can be used as parameters in all motion commands. The expression can be a constant or a simple two-operant operation.

Some valid expressions are:

SV V0=1000
SV V1=V0+1000
SV V1=V1*V0
SV V2=V1/V0

All variables are initialized to 0.

EXAMPLE:

```
"EP"
"SVV0=0"                (generate an S curve acceleration
"SVV1=0"                to a speed of 250,000 counts/sec
"MV+"
"DLA;VAV1;WT10;SVV1=V1+V0;SVV0=V0+100;JLA50"
"DLB;VAV1;WT10;SVV1=V1+V0;SVV0=V0-100;JLB50"
"%"
```


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FUNCTION: Set axes for simultaneous execution

RANGE: 1 to 4

COMMENTS: This command is used in conjunction with the 'SE' command to perform simultaneous (within 10 microseconds) command execution.

Typical simultaneous command execution may be updating velocities of two or more axes, starting the motion of two or more axes, etc.

This command assigns the axes which will participate in the next simultaneous execution operation.

The time delay between command executions is typically 10 microseconds.

An 'SY' command without parameters will desynchronize all axes.

See 'SE' command.

EXAMPLE:

"SY 1,2"	(set axis 1 and 2 into synchronization)
"1PR100;2PR200	(prepare, but do not execute)
"SE"	(execute now, simultaneously)

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FUNCTION: Send contents of error message buffer

COMMENTS: This command reports the ASCII contents of the MotionMaster 2000 error message buffer. Whenever a command syntax or parameter error is detected or a motor error is encountered, the MotionMaster 2000 generates a PC-bus interrupt if enabled (see 'FI' command) and transmits the corresponding message to the error buffer. The error buffer can then be read with the 'TB' command.

Note that the 'FO' command may be used to shorten the response length by suppressing error description characters.

For faster responses use the 'TE' command which outputs the error code in a single byte.

The 'TB' command clears the error flag in the 'TS' command response byte.

EXAMPLE:

"TB"	report buffer contents)
E35 AXIS 1 NEGATIVE HARD LIMIT	(response)

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TE

FUNCTION: Report error code

COMMENTS: This command reports the error code generated by the last error encountered. This instruction outputs a single byte where bits 0 through 5 represent the binary value of the code. Bits 7 and 6 are fixed at "0" and "1" respectively in the response. See Section 6 for all possible MotionMaster 2000 message numbers and corresponding messages.

The 'TE' command clears the error flag in the 'TS' command response byte.

BIT									
7	6	5	4	3	2	1	0	Use	
0	.	.	.	.	.	.	.		
.	1	.	.	.	.	.	.	2^6	
.	.	X	.	.	.	.	.	2^5	(error code)
.	.	.	X	.	.	.	.	2^4	
.	.	.	.	X	.	.	.	2^3	
.	.	.	.	.	X	.	.	2^2	
.	.	.	.	.	.	X	.	2^1	
.	.	.	.	.	.	.	X	2^0	(error code)

EXAMPLE:

"TE"	(report error code)
B	(response: HEX 42 - Error code 02 - illegal parameter)
"TE"	(report error code)
@	(response: HEX 40 - Error code 00 - no error)

TF

DC Motor

FUNCTION: Report PID filter parameters

COMMENTS: This command reports the last PID filter parameters received. If any new PID parameters have been issued with either the 'KP', 'KD', 'KI', 'IL' or 'DS', but the 'UF' command has not yet been received then the "filters not updated" message will appear along side the parameters reported. This means that the parameters displayed have not yet been loaded into working PID registers.

EXAMPLE:

"2TF"	(report axis 2 PID filter parameters)
KP=75 KD=100 KI=100 IL=100 DS=0	(response)

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TG n,...n

FUNCTION: Toggle output bit(s)

RANGE: 1 to 8

COMMENT: This command creates a pulse output at the specified I/O bit. Any and all of the 8 MotionMaster 2000 I/O bits may be used. Prior to using a bit for toggle output, it must be defined as an output with the 'BO' command. The pulse polarity depends on the logic level of the output bit just before the 'TG' command is issued. The 'TG' command changes the logic level of the toggle bit twice to create the pulse. The pulse width is typically less than 5 micro-seconds making it suitable for external edge triggering.

See Appendix A for pinouts and electrical requirements.

EXAMPLE:

"BO1,3,7,8"	configure bits as outputs)
"SB1,3,7,8"	(set bits high)
"TG1,3,7,8"	(toggle I/O bits low and back to high)

TL

FUNCTION: Report the soft travel limit positions and following error parameters

COMMENTS: This command reports the current soft travel limit parameters in use for the specified axis. In addition, for DC motor modules only, this command also reports the current DC motor following error threshold previously set with the 'FE' command.

The soft travel limit feature is enabled and disabled with the 'FM' command.

EXAMPLE:

"1TL"	(report software limits and following error)
SL=+1000 SL=-5000 FE=500	(response)

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FUNCTION: Report program memory usage

COMMENTS: This command reports the non-volatile program storage memory (buffer) usage. When a program (source code) is downloaded to the MotionMaster 2000, it goes to the non-volatile program storage area and consumes n number of bytes. When this program is compiled the total bytes consumed = source code + object code. If the overall program requires more bytes than are available, the MotionMaster 2000 will not execute the program.

EXAMPLE:

"TM"	(report memory usage)
100 BYTES USED 24000 BYTES FREE	(response)

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FUNCTION: Tell Position

COMMENTS: This command directs the MotionMaster 2000 to report the current position of the axis specified.

The position data may be obtained as ASCII string characters or as a 32 bit binary integer. The selection is made with the 'FO' command.

The ASCII string mode returns a variable length character string terminated by a carriage return/line feed combination. Use the function mmread(response,address) to obtain the response.

The binary mode returns a 32 bit integer value. Use the function binread(position,address). The response variable must be defined as an integer.

For stepping motors, the units of the response will be either encoder counts ("COUNTS") or motor steps ("STEPS"). The choice is made with the 'FM' command.

For DC motors, the units of the response is always encoder counts ("COUNTS")

The advantage of using the binary mode is the speed of the response and host computer processing, i.e. the MotionMaster 2000 does not have to convert an integer into a string and then your host computer does not have to convert the string into an integer.

With a position read program written in C and the MotionMaster 2000 set to binary mode, it is possible to obtain the position information in 750 microseconds. Alternately, with the MotionMaster 2000 set to ASCII mode, the position information is obtained in 1.5 milliseconds.

See Appendix F for sample binary read programs.

EXAMPLE:

"1TP"	(report axis 1 position)
1000 COUNTS	(response - ASCII)
"2TP"	(report axis 2 position)
2500 STEPS	(response - ASCII)
"FO02"	(select binary mode)
"1TP"	
1000	(response - integer)

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TPE

Stepping Motor: Step1.5M

FUNCTION: Tell position in units of encoder counts

COMMENTS: This command directs the MotionMaster 2000 to report the current position is units of encoder counts, regardless of the positioning units set with the 'FM' command.

The normal 'TP' command reports position in terms of encoder counts or steps. The selection is done with the 'FM' command when the positioning units are programmed.

This command enables you to obtain encoder position data when the position units are set to steps.

EXAMPLE: "TPE" (tell present encoder position)

TPI

Stepping Motor: Step1.5M

FUNCTION: Tell position in units of motor steps

COMMENTS: This command directs the MotionMaster 2000 to report the current position is units of motor steps, regardless of the positioning units set with the 'FM' command.

The normal 'TP' command reports position in terms of encoder counts or steps. The selection is done with the 'FM' command when the positioning units are programmed.

This command enables you to obtain motor steps position data when the position units are set to encoder counts.

EXAMPLE: "TPI" (tell present motor steps position)

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FUNCTION: Initialize motion tracing mode

RANGE: n1: 1 to 10000
n2: 1 to 1000

COMMENTS: This command sets the motion tracing mode for the specified axis. Upon each subsequent motion command execution the MotionMaster 2000 will sample the motion (desired position and actual position) and store it into a trace buffer. Parameter n1 is the time interval (in 100 microsecond units) between samples, and n2 is total number of samples.

The 'TT' command is used to retrieve the data in trace buffer.

Entering the 'TR' command without parameters will turn off the tracing mode

EXAMPLE: "1TR10,1000" The motion of axis 1 will be recorded at 1 ms sampling intervals for a total of 1000 samples)

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FUNCTION: Tell status; report move and interrupt status

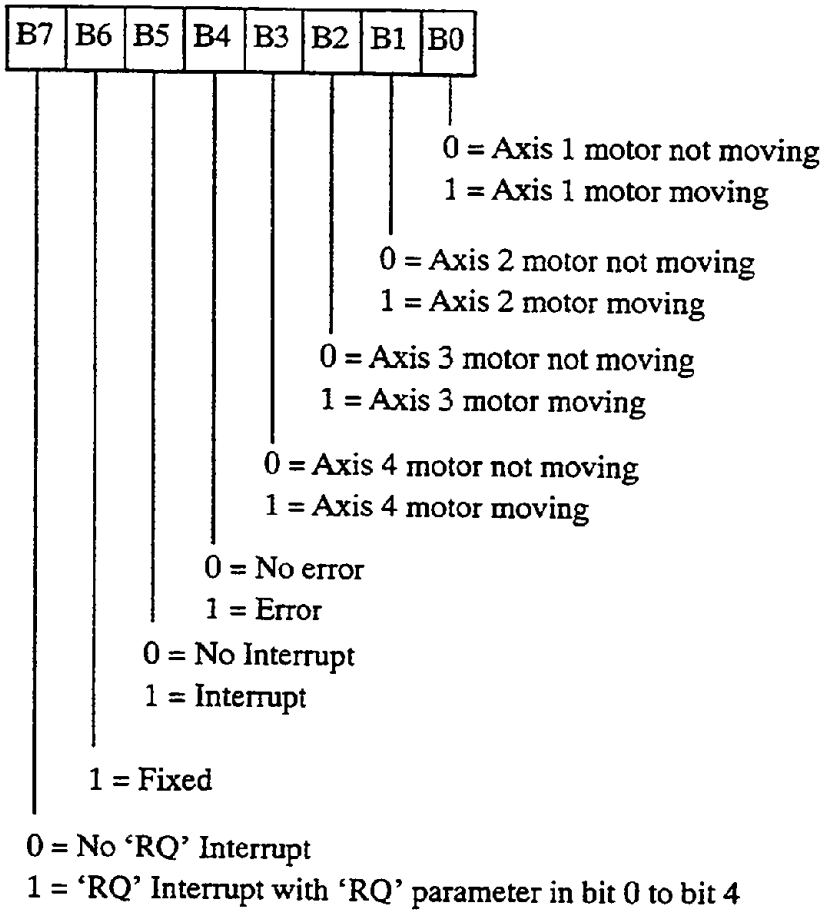
COMMENTS: This command directs the MotionMaster 2000 to report the motion status of all axes and the present state of the interrupt output. This command returns a compact single byte response. The status information is coded in binary and should be parsed accordingly.

The interrupt bit in the response byte is automatically reset after a 'TS' command is executed.

Bit 6 is fixed at "1".

Bit 7 is normally fixed at "0" unless an 'RQ' command was executed previously. The 'RQ' command will set bit 7 to "1". The "RQ' bit is automatically reset after a 'TS' command is executed.

See 'RQ' command.



EXAMPLE:

"TS"	(report move and interrupt status)
A	(response: HEX 41. Axis 1 moving, axis 2, 3, and 4 stationary, no error, and no interrupt)

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TT

FUNCTION: Read motion trace data

COMMENTS: This command directs the MotionMaster 2000 to output the data in the trace buffer. If tracing mode has been enabled, the response to the command will include both actual positions and desired positions which have been sampled and stored during the last move.

Every 2(i)th data is actual position and every 2(i+1)th is desired at (i)th sample time. Like all other multi-line responses from the MotionMaster 2000, the output will be terminated by the string "END".

See 'TR' command.

EXAMPLE:

```
"1TR10,1000"
"1PR2000;WS10"
"TT"
+0          (actual position at 0 ms, 1st sample)
+0          (desired position at 0 ms, 1st sample)
+1          (actual position at 1 ms, 2nd sample)
+2          (desired position at 1 ms, 2nd sample)
.....
.....
+1001       (actual position at 999 ms, 1000th sample)
+1000       (desired position at 999 ms, 1000th sample)
END
```

TV

FUNCTION: Report real-time velocity

COMMENTS: This command directs the MotionMaster 2000 to report the velocity of a motor at the instant it is issued.

For stepping motors, the units of the response is either encoder counts/second or steps/second. The choice is made with the 'FM' command.

For DC motors, the units of the response is encoder counts/ second.

EXAMPLE:

```
"3TV"              (report axis 3 velocity)
3212 COUNTS/SEC    (response)
"4TV"              (report axis 4 velocity)
1000 STEPS/SEC     (response)
```


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FUNCTION: Configures DC servo axis for selected positioner/motor TYpe.

DEVICE: DEFAULT, BMCC, 850B, UE30CC, UE32CC, UE42CC, UE72CC, MT160HD, ?

COMMENTS: This command automatically sets DC servo PID, velocity, acceleration, and following error threshold parameters stored in non-volatile memory to known "working" values for the selected positioner/motor (device).

The 'TY' (or 'TYPE') command will "restrict" velocity (VA), acceleration (AC), and following error (FE) threshold parameter ranges to minimum and maximum values determined appropriate for that device. For example, a UE30CC axis will automatically generate an "E24 PARAMETER OUT OF RANGE" error when commanded to move at an unsuitable speed for that particular device.

However, if the DEFAULT option is selected (i.e., "2 TYPE DEFAULT") the PID, velocity, acceleration, and following error threshold parameters stored in non-volatile memory are set as follows:

"kp100;kd500;ki100;il100;va5000;ac50000;oh5000;ol500;oa50000;fe500"

Furthermore, while in DEFAULT mode parameters are no longer restricted according to device type and thus are limited only to their documented ranges.

To get the MotionMaster 2000 to report the current axis device type configuration in use simply append a "?" to the command. (i.e., "1 TYPE ?")

EXAMPLE:

"2 TY UE30CC"	(configure axis 2 for UE30CC motor driven positioner)
"2 PA +100"	(move axis 2 +100 encoder counts)
"2 VA 15000"	(Set UE30CC positioner velocity to 15,000 counts/sec)
E24 PARAMETER OUT OF RANGE	(Target UE30CC velocity too high)
"2 TY ?"	(report axis 2 configuration type)
UE30CC	(MotionMaster 2000 response)
"1 TYPE DEFAULT"	(set axis 1 to "default" configuration)
"1 VA 100000"	(Set positioner velocity to 100,000 counts/ sec)
"1 TYPE ?"	(report axis 1 configuration type)
DEFAULT	(MotionMaster 2000 response)

NOTE: Hopefully, this command will simplify system configuration by providing a starting point for common Newport/Klinger DC servo positioner configurations. However, it may be necessary to modify some parameters to satisfy application requirements.

UE32CC, UE42CC, UE72CC motors incorporated into positioners with non-standard glass scale (i.e., Heidenhain) feedback may need to optimize PID and motion parameters via MotionMaster 2000's motion profiling (PROFILE.EXE) program.

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FUNCTION: Load PID compensation parameters into working registers and set DAC resoluuon mode.

RANGE:

0 or None	loads filter parameters only
8	loads filter and sets 8-bit DC module to 8-bit DAC resolution mode
12	loads filter and sets 12-bit DC module to 12-bit DAC resolution mode
?	Reports current DC servo module DAC resolution mode setting

COMMENTS: This command transfers new filter parameters (ëKPí, ëKDí, ëKIí, ëILí, and ëDSî) from the input registers, thereby effecting the change in loop compensation filter tuning.

The UF command can also set 8-bit DC servo modules to 8-bit DAC operation mode. This is necessary for proper 8-bit DC servo module operation. And since the MotionMaster firmware can not automatically distinguish between 8-bit and 12-bit DC servo modules, and defaults to 12-bit mode, you must ìmanuallyî configure 8-bit modules (if used) with this command. Also note that once set, the DAC mode is stored in non-volatile memory and is automatically reloaded upon power cycle or board reset.

WARNING

Do Not Set 12-Bit DC Servo Modules to 8-Bit Mode or 8-Bit Modules To 12-Bit Mode. This May Cause A Dangerous Motor ìRun-Awayî Condition!

EXAMPLE:

"1kp100;1kd500;uf"î	(update axis-1 PID compensation filters)
"4 uf 8"	(set axis-4 to 8-bit DAC resolution mode)
"4 uf ?"	(report axis-4 setting)
Axis Set For 8-Bit DC Servo Module	(response)
"2 uf 12"	(set axis-2 to 12-bit DAC resolution mode)
"2 uf ?"	(report axis-2 setting)
Axis Set For 12-Bit DC Servo Module	(response)

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VA n

FUNCTION: Set absolute velocity

RANGE:

0 to 1,000,000 counts/second	(DC Motor)
500 to 70,000 steps/second	(Stepping Motor: Step70K)
100 to 1,500,000 steps/second	(Stepping Motor: Step1.5M)

COMMENTS: This command sets the velocity for the next move and all subsequent moves until changed to a new value ... i.e. if you have a series of moves at the same velocity, it is not necessary to repeatedly issue the 'VA' command.

For stepping motors, the velocity is always in terms of steps/second, irrespective of the 'FM' command setting.

For DC motors, the velocity is in terms of encoder counts/second.

A new velocity value may be sent while a move is in progress. The MotionMaster 2000 will automatically accelerate or decelerate to the new velocity.

For stepping motors, to obtain an operating velocity less than 500 steps/second (Step70K) and 100 steps/second (Step1.5M), use the 'SD' command to divide the programmed velocity.

EXAMPLE: "4VA50000" (set axis 4 absolute velocity)

VB n

Stepping Motor

FUNCTION: Set stepping motor base (start/stop) velocity

RANGE:

500 to velocity set with 'VA' and/or 'VR' commands (Step70K)
100 to velocity set with 'VA' and/or 'VR' commands (Step1.5M)

COMMENTS: This command sets the start/stop velocity for stepping motors only. The allowed start/stop velocity must be less than or equal to the velocity set with the 'VA' and/or 'VR' commands.

To obtain a base velocity less than 500 steps/second and 100 steps/second, use the 'SD' command to divide the programmed velocity.

EXAMPLE: "4VB760" (set axis 4 start/stop velocity)

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VE

FUNCTION: Report MotionMaster 2000 firmware version

COMMENTS: This command reports the revision level of the MotionMaster 2000 firmware.

EXAMPLE: "VE"
Newport Corporation MM2000 Version x.x

VR ± n

FUNCTION: Velocity relative; increment/decrement present velocity

RANGE:
1 to 1,000,000 counts/second (DC Motor)
1 to 70,000 steps/second (Stepping Motor: Step70K)
1 to 1,500,000 steps/second (Stepping Motor: Step1.5M)

COMMENTS: This command is used to increment and decrement the present operating velocity. The new velocity is calculated as:

new velocity = last velocity + 'VR' velocity

The new velocity must remain positive and within the minimum/maximum range for the motor type.

For DC motors:
Minimum Velocity = 1 encoder count/second
Maximum Velocity = 1,000,000,000 encoder counts/second

For Stepping Motor: Step70K:
Minimum Velocity = 500 steps/second
Maximum Velocity = 70,000 steps/second

For Stepping Motor: Step1.5M:
Minimum Velocity = 100 steps/second
Maximum Velocity = 1,500,000 steps/second

For stepping motors, the velocity is always in terms of steps/second, irrespective of the 'FM' command setting.

For DC motors, the velocity is in terms of encoder counts/second.

A new velocity value may be sent while a move is in progress. The MotionMaster 2000 will automatically accelerate or decelerate to the new velocity.

EXAMPLE: "3VR-5000" (decrease axis 3 absolute velocity by 5000)

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VS n — DC Motor

FUNCTION: Set velocity in terms of sample time

RANGE: 1 to 16,777,778

COMMENTS: This command allows the user to input a new value for absolute velocity. The parameter is in terms of counts/65536/256us, not counts/second. The advantages of this command over the 'VA' and 'VR' commands are a) processing speed and b) added velocity resolution. For example, VS1 = 0.06 counts/second.

EXAMPLE: "1VS16778" (set axis 1 to 1000 counts/second)

VV n — DC Motor

FUNCTION: Set vector speed for interpolation move

RANGE: 100 to 1,000,000 counts/sec

COMMENTS: This command sets the vector speed for a linear or circular interpolation move. The speed on each axis will be calculated automatically to get the desired vector acceleration.

This setting only affects the interpolation move.

EXAMPLE: "VV1000000" (set interpolation vector speed to 1000000 counts/sec)

WB n,m

FUNCTION: Wait for the specified bits to attain the specified logical levels

RANGE: n: 1 to 8
m: H(igh)/L(ow)

COMMENTS: This command causes the MotionMaster 2000 to wait for the specified bits to attain the specified logic level (high/low) and then proceed to execute the next command.

This command is used to synchronize command execution with external events.

EXAMPLE:
"BI1,2" (define bits 1 and 2 as inputs)
"WB1L,2H" (wait for bit 1 low and bit 2 high)
"1PR1000" (then move axis 1)

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FUNCTION: Write to 8-bit D/A channel

RANGE: n: 1,2,3,4
m: 0 to 255

COMMENTS: This command is used to create a desired analog output voltage at any of the four MotionMaster 2000 digital to analog converter outputs. See Section 7 in this User's Manual for more information on the use of the digital to analog converters and see Appendix A for pinouts.

The output analog voltage is function of the parameter value and reference voltage.

The equation for the analog voltage output is:
voltage out = 10 * (('WD' parameter)/256)

On power supply systems which output +12V and -12V (like the PC), the maximum voltage out will be 9 volts. You cannot attain the full scale value of 10 volts. To attain the full scale value of 10 volts, you must break the +12 volt connection from the PC and connect a +15 volt power supply to the +12 volt power input pin See Appendix C. Consult Newport/Klinger Corporation before undertaking this task.

EXAMPLE: "WD2,255" (full scale output on D/A channel 2)

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WHILE...WEND

FUNCTION: Execute a series of commands in a loop as long as a given I/O bit condition is true.

RANGE: 1 to 8 H(igh)/(L)ow

COMMENTS: If the bit condition is true, loop commands are executed until the WEND statement is encountered. The MotionMaster 2000 then returns to the WHILE statement and checks the bit condition. If it is still true, the process is repeated. If it is not true, execution resumes with the command following the WEND statement. WHILE/WEND loops may not be nested. An unmatched WHILE statement generates a "WHILE WITHOUT WEND" error, and an unmatched WEND statement generates a "WEND WITHOUT WHILE" error during compilation (see 'CP' command).

EXAMPLE:

"EP"	(invoke program entry mode)
"BI1,3	(configure I/O bits 1 & 3 as inputs)
"WHILE 1H,3L"	(WHILE bit-1 is high & bit-3 is low...)
"2PR1000;WS1000"	
"1PR500"	
"WEND"	(check bits again)
"2PA0;1PA0"	
"%"	(exit program entry mode)

WP n

FUNCTION: Wait Position: wait until motor crosses absolute position

RANGE:

0 to ±1,000,000,000	(DC Motor)
0 to ±2,147,483,648	(Stepping Motor: Step70K)
0 to ±2,147,483,648	(Stepping Motor: Step1.5M)

COMMENTS: This command directs MotionMaster 2000 to wait until the desired absolute position is crossed, or reached, before processing the next command. This command is useful for position synchronization.

For stepping motors, the units of the parameter are either encoder counts or motor steps. The choice is made with the 'FM' command.

For DC motors, the units of the parameter are always encoder counts.

EXAMPLE:

"1PA+5000"	(move axis 1 to absolute position +5000)
"1WP+2000"	(wait until axis 1 crosses position +2000)
"3PA-1000"	(...then move axis 3)

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WS n

FUNCTION: Wait for stop, then process next command

RANGE: n can be omitted or n = 1 to 32767

COMMENTS: This command directs the MotionMaster 2000 to wait for the previous move to be completed on the specified axis before proceeding to execute the next command. In addition, you may specify a time parameter for the MotionMaster 2000 to wait after the command is complete.

The MotionMaster 2000 will normally execute commands as they are received or read out of its program buffer without waiting for previous commands to be completed. Thus it is necessary to explicitly tell the MotionMaster 2000 to wait for the completion of the previous command before processing the next command if that is the result that you desire.

EXAMPLE:

"2PA5000"	(move axis 2 to absolute position +5000)
"2WS500"	(wait 0.5 second after the motor has stopped)
"2TP"	(report position)

WT n

FUNCTION: Time delay

RANGE: 1 to 32767 milliseconds

COMMENTS: This command directs the MotionMaster 2000 to wait the specified time, and then execute the next command.

EXAMPLE:

"2PA+1000"	(initiate axis 2 move to position +1000)
"WT2000"	(wait 2 seconds)
"3PA-1000"	(then move axis 3 motor to position -1000)

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XX

FUNCTION: Purge memory

COMMENTS: This command is used to purge the contents of non-volatile memory. All previously stored program commands, trajectory parameters, and options are erased and replaced with default values.

This command is only used if the MotionMaster 2000 non-volatile memory becomes corrupted and causes faulty operation.

EXAMPLE:

"XX"	(purge MotionMaster 2000 memory)

%

FUNCTION: Exit program entry mode

COMMENTS: The percent character causes the MotionMaster 2000 to exit program entry mode and re-enter command mode.

EXAMPLE:

"EP"	(invoke program entry mode)
"2PA1000"	
"2WS10"	
"1PA-1000"	
"%"	(exit program entry mode)
"CP"	(compile program)
"EX"	(execute program)

'

FUNCTION: Permit program line comments

COMMENTS: Characters received after an apostrophe are not evaluated during compilation and are used as program line comments.

EXAMPLE:

```
"EP"
"2PA+2000 'First Target"
"2PA-1500 'Second Target"
"%"
```


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FUNCTION: Emergency stop

COMMENTS: The pound sign character "#" command is provided for an emergency situation where all moves must be aborted and previously transmitted commands not yet executed in the buffer should be ignored.

This command is not queued in the MotionMaster 2000 command buffer. It has the highest priority. It is executed immediately regardless of the MotionMaster 2000 command execution state.

This command must be used if it is necessary to stop motion immediately while the MotionMaster 2000 is executing a wait command, for example, 'WS' (wait stop), 'WT' (wait time), or 'WP' (wait position).

The pound sign character "#" should be transmitted without a carriage return (ASCII 13) string terminator.

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DC MOTOR SERVO LOOP TUNING

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3. 1 INTRODUCTION

The MotionMaster 2000 controls the rotation and the stop position of DC motor accurately with a position servo loop algorithm. It continuously monitors the actual position versus the desired position of the motor. If a difference exists, henceforth referred to as the position error, it outputs an analog control voltage which will rotate the motor such as to reduce the position error to zero. The MotionMaster 2000 relies on a digital TTL incremental quadrature encoder to provide the actual position information.

Position Error = Desired Position - Actual Position

During motion, the desired position increments according to a trapezoidal velocity profile. The trapezoidal velocity profile generator computes the desired position of the motor as a function of time. The calculated desired positions are compared to the actual positions at fixed time intervals and a corresponding analog control voltage is formed which rotates the motor such that it achieves the desired positions. The position error during motion is referred to as the following error.

During a stop or hold position, the desired position remains constant. Any disturbance to the actual position, due to a load torque or physical rotation of the motor, is quickly countered by a control voltage which rotates the motor back to the original position.

The MotionMaster 2000 acts upon the position error with a mathematical algorithm called the PID. The PID is programmable, enabling you to achieve an accurate and stable DC motor control system.

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In the PID acronym, the P stands for Proportional and is commonly called Gain; the I stands for Integral; the D stands for Derivative and is commonly called Damping.

The MotionMaster 2000 determines the position error every 256 microseconds, processes the error with the PID algorithm, and outputs the results in the form of a motor amplifier control voltage, in the range of -10 volts to +10 volts. The motor control voltage, calculated with the PID algorithm, is the position error multiplied by a constant (called the KP coefficient), plus the sum all previous error multiplied by a constant (called the KI coefficient), plus the difference between the last two errors multiplied by a constant (called the KD coefficient). Additionally, since the summation of all errors can escalate to a large number, a limit is placed on the maximum contribution allowed from the KI coefficient, called the integration limit, IL. The following discrete-time equation shows the PID algorithm:

$$u(n) = kp*e(n) + ki\Sigma e(n) + kd[e(n)-e(n-1)]$$

The process of servo loop tuning is the assigning of values to KP, KD, KI, and IL coefficients and then observing the system response with these values. This process is repeated until a satisfactory system performance is achieved.

The PID algorithm is sometimes referred to as a position loop compensation filter and the KP, KD, KI, and IL values are referred to as the loop filter parameters.

The MotionMaster 2000 has programmable PID filter parameters. In addition, the MotionMaster 2000 software support includes a program called PROFILE.EXE. This program enables you to set PID parameters and then shows you the motor motion with these parameters by sampling the motion and plotting on your computer screen, the desired and the actual positions as a function of time.

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3.3 TUNING NEWPORT/KLINGER DC MOTOR POSITIONING STAGES

Listed below are suggested PID filter parameters for the different Newport/ Klinger positioning stages. If some adjustment is necessary, we suggest that you use the motion profiling program to observe the actual stage performance and adjust the PID parameters to obtain your required stage performance.

Positioner: UTM25CC0.1

PID Parameters: KP400 KD600 KI20 IL20 DS0

Comments: 9 kg load, UE33CC motor

Positioner: UTM50CC0.1

PID Parameters: KP200 KD2000 KI10 IL10 DS0

Comments: UE33CC motor

Positioner: UZS80CC0.1

PID Parameters: KP1000 KD10000 KI5 IL5 DS0

Comments: 3 kg load, UE31CC motor

Positioner: URM100CC

PID Parameters: KP200 KD10000 KI10 IL10 DS0

Comments: 30 kg load, UE31CC motor

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Positioner: 850B

PID Parameters: KP1500 KD5000 KI100 IL100 DS0

Comments: Also see "TY" command

Positioner: 496

PID Parameters: KP1500 KD5000 UI50 IL50 DS0

Comments: 30 kg load

Positioner: UR100

PID Parameters: KP1500 KD10000 KI120 IL120 DS0

Comments: 2000 points/revolution encoder

UE30CC motor

Positioner: UT100

PID Parameters: KP1500 KD10000 KI120 IL120 DS0

Comments: 2000 points/revolution encoder

UE30CC motor

Positioner: BMCC

PID Parameters: KP1000 KD3500 KI50 IL50 DS0

Comments: 2000 points/revolution encoder

UE22CC motor

Positioner: MT160HD

PID Parameters: KP5 KD0 KI100 IL15 DS0

Comments: Linear encoder with tachometer

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3.4 SERVO LOOP TUNING WITH THE MOTION PROFILE PROGRAM

The Motion Profile program was developed to enable you observe the actual motion of your motor as a function of time. This is an excellent tool for adjusting the PID parameters because the motor performance must be observed and judged.

To support the Motion Profile program, the MotionMaster 2000 has two commands which direct it to sample a motion at regular, fixed intervals of time, store the position data in its internal memory, and then output the data to the host computer when the trace is done.

Command: TR n,m

Function: Capture m samples of desired and actual positions at time interval equals n times 100 microseconds.

Example: TR10,500
Capture 500 samples of position data at 1 millisecond time intervals.

Command: TT

Function: Output store position data to host computer

Comments: The MotionMaster 2000 outputs the position data in the following form:

Actual Position 1
Desired Position 1
Actual Position 2
Desired Position 2
.
.
Actual Position m
Desired Position m
END

Example:
"TT"
0 (response)
2
3
6
.
.
100
100
END

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3.4.1 USING THE MOTION PROFILE PROGRAM

The Motion Profile program is menu driven and its structure and use is exactly the same as the MotionMaster 2000 start up program, MM2000.EXE. For faster execution, copy the MotionMaster 2000 Motion Profile diskette to your hard drive.

The program requires a computer with a VGA or EGA monitor. The default monitor type is VGA. For VGA monitors, simply type 'profile' at the computer prompt. For EGA monitors, type 'profile ega' at the computer prompt. Once the program is running, the operating procedure is:

1. Select Controller, PC BUS, Address, and Interrupt Number

2. Select Profile and open the parameter entry screen.

3. Enter the desired values for the parameters shown.

4. Select Execute and observe the plot of the desired and actual positions as a function of time.

5. Press Escape, enter new values for the parameters and go to step 4.

In addition, the Motion Profile program features a Status/Position screen and Terminal mode screens where commands may be entered an executed interactively or a file of commands may be downloaded and executed.

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3.4.2 THE PROFILE PARAMETER ENTRY SCREEN

Item: **Distance and Direction**

Comments: Enter the number of encoder counts you wish the motor to move. Initially, set it between 100 and 1000. Later, you may wish to profile your actual application motions.

Item: **Velocity**

Comments: Set to your application velocity or try the maximum velocity of 1,000,000 encoder counts/second.

Item: **Acceleration**

Comments: Set to your application acceleration or try the maximum acceleration of 9,999,999 encoder counts/second^2.

Note: Setting maximum velocity and acceleration values will show the maximum velocity and accelerations which can be achieved with the corresponding motor/stage.

Item: **Sample Time**

Comments: This number sets the time interval at which the MotionMaster 2000 will capture and store the desired and actual positions of the motor during motion. The parameter unit is 100 microseconds.

Enter a small number for fine resolution and enter a large number for coarse resolution.

Item: **Number of Samples**

Comments: This entry sets the number of positions to be captured at the sample time interval.

Enter a small number to examine the beginning of the motion. Enter a large number to observe the whole motion.

Item: **KP, KD, KI, IL**

Comments: These entries set the filter parameter values for the next motion. See below for selection criterion.

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3.4.3 FILTER PARAMETERS SELECTION CRITERION

The general goal in a DC motor control system is to perform a motion and stop at a position which is stable and accurate. An additional goal of stability is quick settling, typically a few milliseconds. These goals are achievable with the correct set of filter parameters. However, certain undesirable effects must be tolerated. Essentially, the tuning of PID parameters is a compromise between achieving what you must have and accepting the undesirable effects. For example, an accurate and quick settle motion response will have overshoot. The table below shows a collection of desired system performance features, followed by PID filter parameters involved, followed by a list of undesirable side effects.

Feature:	**Accurate Final Position**
PID:	KP and KI
Side Effect:	Overshoot
Feature:	**Quick Settling**
PID:	KP and KD
Side Effect:	Overshoot
Feature:	**No Overshoot**
PID:	KP only, and KD=KI=IL=0
Side Effect:	Long Settle Time, Possibly Inaccurate
Feature:	**Small Following Error**
PID:	High KP
Side Effect:	Overshoot

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3.4.4 PID TUNING GUIDELINES

Set the velocity and acceleration to the required values for your application. Experiment with different distance parameters. Examine different portions of the motion profile by adjusting the sample time and the number of samples. For a fixed set of distance, velocity, acceleration, sample time, and number of samples, experiment with the KP, KD, KI, and IL parameters as follows:

Set KP=10 KD=0 KI=0 IL=0, execute and observe the response.

Set KP=20 KD=0 KI=0 IL=0, execute and observe the response.

Double KP in the this manner several times while all others remain at zero. Note that as the KP is increased, the following error decreases, i.e. the actual position is closer and closer to the desired position. Thus, the KP controls how closely the actual position tracks the desired position.

Increasing KP will eventually lead to overshoot and oscillations. Select the KP value which produces overshoot but settles quickly. Note if the final position is accurate or is off by a few encoder counts.

To improve the accuracy, you will assign values to KI and IL. Start and increase KI and IL with small values.

Set KI=10 IL=10, execute and observe the response.

Increase KI and IL in several steps, observing the effects after each increase. Note that as these are increased, the final position is more accurate, however, the overshoot in increasing. Select the smallest KI and IL values which produce an accurate final position.

Keeping all other values constant, now increase KD to attempt to eliminate the overshoot. Start with a small KD value, for example KD=100, and observe the response. Double KD several times and observe the result. Note that it may not be possible to eliminate the overshoot. You must compromise on some overshoot if the other system requirements are essential.

Study the list of filter parameter selection criterion, and see if you can obtain a better response.

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As a second test of system performance you will now program the MotionMaster 2000 to move the motor back and forth and observe the settle position. Included on your MotionMaster 2000 Motion Profile diskettes are four files which contain MotionMaster 2000 commands to move each axis back and forth 1000 encoder counts. The names of these files are TUNEAX1, TUNEAX2, TUNEAX3, and TUNEAX4.

Escape out of the Profile menu item and move to the Terminal menu item, File option. Assuming you are tuning axis 1, type 'tuneax1' and press Enter.

When done, escape and select Terminal/Keyboard menu item. Type 'lp' and see the list of MotionMaster 2000 commands. Type 'cp' to compile. Type 'ex' to execute.

Escape and select the Status/Position menu item. Select <Continuous Update> and press Enter. When selected, <Continuous Update> will flash and the motor position will be displayed in real time. Note how accurately the stop positions equal 0 and 1000.

Based on the observed position accuracy and overshoot, you may wish to change some PID parameters. Escape and select Terminal/Keyboard menu. Type 'ltf'. The current filter parameters are displayed. Change any filter parameter value in the following manner, for example KP: Type 'kp2000;uf'. You must always enter the 'uf' command in order for the filter values to take effect.

Escape and return to the Status/Position screen. Select <Continuous Update> and observe the response. Repeat any of the above procedures.

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RS-232-C INTERFACE

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4.1 INTRODUCTION

The MotionMaster 2000 system includes a full duplex (able to transmit and receive simultaneously) RS-232-C interface with a 512-byte input buffer. A MotionMaster 2000 command consists of an axis number designator, followed by two(2) letter mnemonic characters, followed optionally by a numerical parameter and terminated by a carriage return. Also, commands may be in either upper or lower case characters, with or without spaces anywhere in the command line. i.e.,"3Pa +100". And, for example, if the command prefix is "3" then module 3 will execute the command. A command sent without an axis number defaults to the last axis addressed. For example, in the command sequence, "2PA+100;WS10;TP" the 'WS' and 'TP' commands default to axis 2.

A command or command sequence to the MotionMaster 2000 is terminate with a carriage return only. However, the response from the MotionMaster 2000 is always terminated by a carriage return / line feed character sequence.

See Section 2 for the MotionMaster 2000 programming techniques and the complete command set.

To use the RS-232-C interface, you may use: 1. The MotionMaster 2000 start up program. MM2000.EXE and select the RS-232-C interface. 2. Newport/Klinger's EZ232 Terminal Emulator program. 3. Any commercially available programs like PROCOMM, XTALK, and 4. Write your own program which writes to and reads from the communication ports.

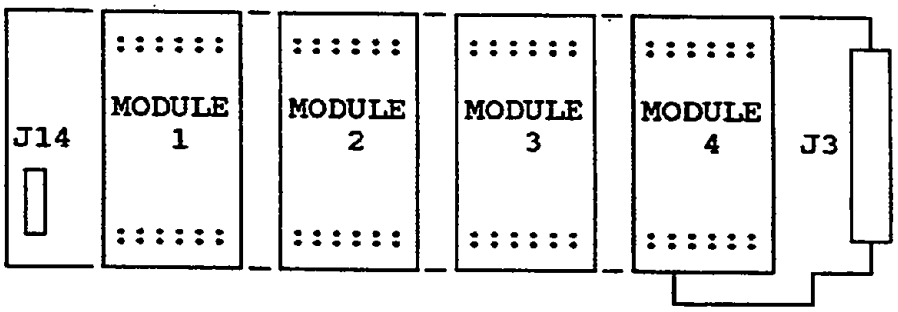


Figure 4-1. MotionMaster 2000

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4.2 WIRING AND CONFIGURATION

The MotionMaster provides a 10-pin header, J14, for RS-232-C interfacing. If the board is installed in a PC then the user will be responsible for bringing-out those signals. Only three(3) signals are required for RS-232-C interfacing:

Pin Number:	Function:
3	MotionMaster 2000 Receive Data
2	MotionMaster 2000 Transmit Data
5	Ground

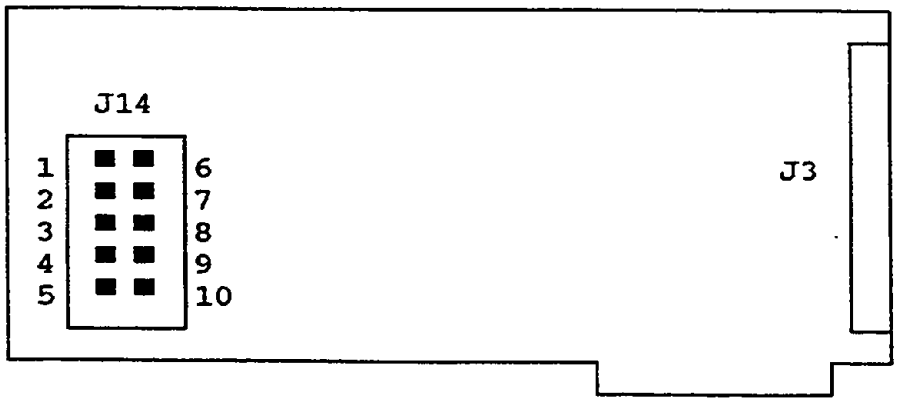


Figure 4-2: J14 Exploded View

The RS-232-C configuration is fixed at 8 data bits, no parity, and 1 stop bit. The baud rate, however, is software selectable (see 'SR' command) and is factory set to 9600 baud. i.e., "SR3"

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The MotionMaster 2000 provides support for daisy-chained RS232 serial communication. Up to 128 axes of motion may be controlled through one RS232 serial port.

To operate under this mode, every MotionMaster 2000 board will have its own board address which can be assigned by setting the switch bank S2. Switch S2.2 is the most significant bit and S2.6 is the least significant bit of the address. The address is derived as the binary equivalent of the switch settings. If a switch is ON, then its value is 1 times its positional weight. If the switch is OFF (or OPEN) then its value is zero. The table below shows a partial list of possible RS232 addresses:

S2.2	S2.3	S2.4	S2.5	S2.6	ADDRESS
OFF	OFF	OFF	OFF	OFF	0
OFF	OFF	OFF	OFF	ON	1
OFF	OFF	OFF	ON	ON	3
OFF	OFF	ON	OFF	ON	5
OFF	ON	ON	ON	OFF	14
ON	OFF	ON	ON	ON	23

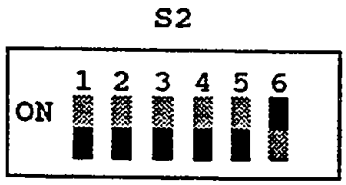


Figure 4-3: Device Address Selection

Switch S2.1 should be ON (or CLOSED), to enable daisy-chained serial communication mode.

The effective axis prefix depends on the position of module and the address of the board:

Axis prefix = position of module + (address of board * 4)

For example, the first module on the board with an address 2 will have an axis prefix of 9.

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When the MotionMaster 2000 receives a character from the host computer in daisy-chained RS232 mode, it always sends that character to next board in the chain. Therefore, the host will receive whatever it just sent out. This echo can be used to ensure the integrity of the chain.

When the MotionMaster 2000 sends a string to the host, a related axis prefix number followed by a arrowhead ">" will be attached to the string as its header. To guarantee only one "talker" in the chain at a time, responses from each MotionMaster 2000 board should be synchronized by disabling RS232 error message transmission through the 'FO' command. For a more detailed explanation of the 'FO' command see Section 2.2, Programming.

4.4 RS232 SOFTWARE HANDSHAKE (XON/XOFF)

The MotionMaster 2000 provides RS232 XON/XOFF capability. This feature is enabled by the command 'FO 8' (set bit 3 of FO byte). The host computer can control the transmission from the MotionMaster 2000 by sending XON/XOFF control characters. The MotionMaster 2000 will wait for a XON (ASCII 17) Decimal before sending anything if the host previously sent a XOFF (ASCII 19 Decimal) to stop transmission. The MotionMaster 2000 has a 0.5 second time-out while waiting for a XON during the output procedure.

The MotionMaster 2000 will also send a XOFF when its 512 byte receive buffer is full, then it will send an XON when the buffer becomes approximately half full.

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IEEE-488 INTERFACE

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5.1 INTRODUCTION

The MotionMaster 2000 system provides an optional IEEE-488 interface with a 512-byte input buffer. The interface is used to transfer commands from the host computer to the MotionMaster 2000 and transfer responses from the Motionmaster 2000 to the host computer. A MotionMaster 2000 command consists of an axis number designator, followed by two(2) letter mnemonic characters, followed optionally by a numerical parameter and terminated by a carriage return. Also, commands may be in either upper or lower case characters, with or without spaces anywhere in the command line. i.e.,"3Pa +100". And, for example, if the command prefix is "3" then module 3 will execute the command. A command sent without an axis number defaults to the last axis addressed. For example, in the command sequence, "2PA+100;WS10;TP" the 'WS' and 'TP' commands default to axis 2. See Section 2 for the description of the MotionMaster 2000 commands.

Responses from the MotionMaster 2000 are always terminated with a carriage return / line feed combination.

One(1) MotionMaster 2000 board supports up to four motor modules to achieve complex multi-axis positioning. But, due to GPIB protocol restrictions, only 14 MotionMaster 2000 boards (56 axes) may occupy the same GPIB bus. Note that as many as 64 boards (256 axes) using GPIB bus expanders may be accessed.

The MotionMaster 2000 IEEE-488 interface is accessed at its J13 connector. See Figure 5.1.

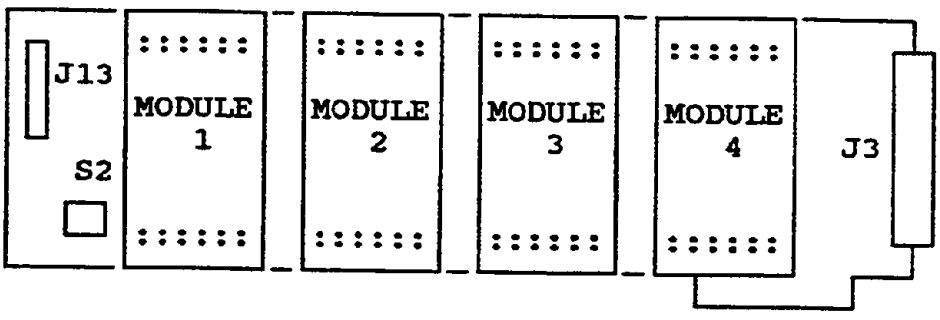


Figure 5-1. MotionMaster 2000

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5.2 ADDRESS SELECTION

The IEEE-488 controller (host computer) may selectively access each board by placing its (the board's) device talk/listen address on the bus. This device address is selectable via dip switch bank S2. Switch S2.2 is the most significant bit and S2.6 is the least significant bit of the address. The address is derived as the binary equivalent of the switch settings. If a switch is ON, then its value is 1 times its positional weight. If the switch is OFF (or OPEN) then its value is zero. The table below shows a partial list of possible IEEE-488 addresses:

S2.2	S2.3	S2.4	S2.5	S2.6	ADDRESS
OFF	OFF	OFF	OFF	ON	1
OFF	OFF	OFF	ON	ON	3
OFF	OFF	ON	OFF	ON	5
OFF	ON	ON	ON	OFF	14
ON	OFF	ON	ON	ON	23

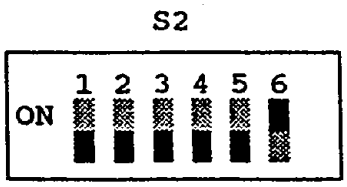


Figure 5-2. Device Address Selection

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The manufacturer of your IEEE-488 interface provided you with the hardware and associated software to implement the IEEE-488 interface. The software consists of commands to output ASCII characters and input ASCII characters from the IEEE-488 compatible devices on the bus. The MotionMaster 2000 has an ASCII command set and also outputs system status in ASCII format.

To send a command to the MotionMaster 2000, for example, positioning command like 'PA1000', 'PR2000', etc., use the IEEE-488 specific command with the general form:

output(ASCII characters)

All MotionMaster 2000 commands must be terminated with a carriage return (ASCII 13 decimal). You must append a carriage return to every command. Also ensure that a line feed is not being sent automatically with the carriage return. The line feed will be interpreted as the next command. This will cause the MotionMaster 2000 to indicate a command error because the line feed in not a valid command.

To receive a response from the MotionMaster 2000, for example, 'TP' (tell position), 'TS' (tell status), etc., use the IEEE-488 specific command with the general form:

input(ASCII characters)

All responses from the MotionMaster 2000 are terminated with a carriage return / line feed combination. This is set and may not be changed. You must configure your IEEE-488 controller to terminate the input (read) function when it sense the carriage return / line feed characters.

All responses from the MotionMaster 2000 must be obtained within 0.5 seconds from the time a response-type command is sent. For example, the following must be executed in sequence and in real computer time:

output('TP')
input(response)

If the procedure is not followed, the MotionMaster 2000 will time out and will not respond later on. This will cause your IEEE-488 interface to hang up until its own timeout period expires.

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Some MotionMaster commands need to output more than one line of information. The list program ("LP") command, for example, may transmit as many as 9999 lines of commands (provided a program that size existed).

First, the application program must distinguish between those commands that will be reporting information from those commands that will not so that you do not inadvertently ask for a response when the MotionMaster 2000 when it does not have one.

Next, the application program should also distinguish single line responses from multi-line response commands. For commands which will return a multi-line response, the application program will have to assert the IEEE-488 input request, read the data, and repeat this process until all lines have been received. See command descriptions and requirements in Section 2.

To assist the user the MotionMaster 2000 automatically outputs an "END" line string indicating end-of-transmission for multi-line response commands. For example, the MotionMaster 2000 response to the 'LP' (list program) command may be:

```
0001 2PA+1000
0002 2WS10
0003 1PA-5000
0004 END
```

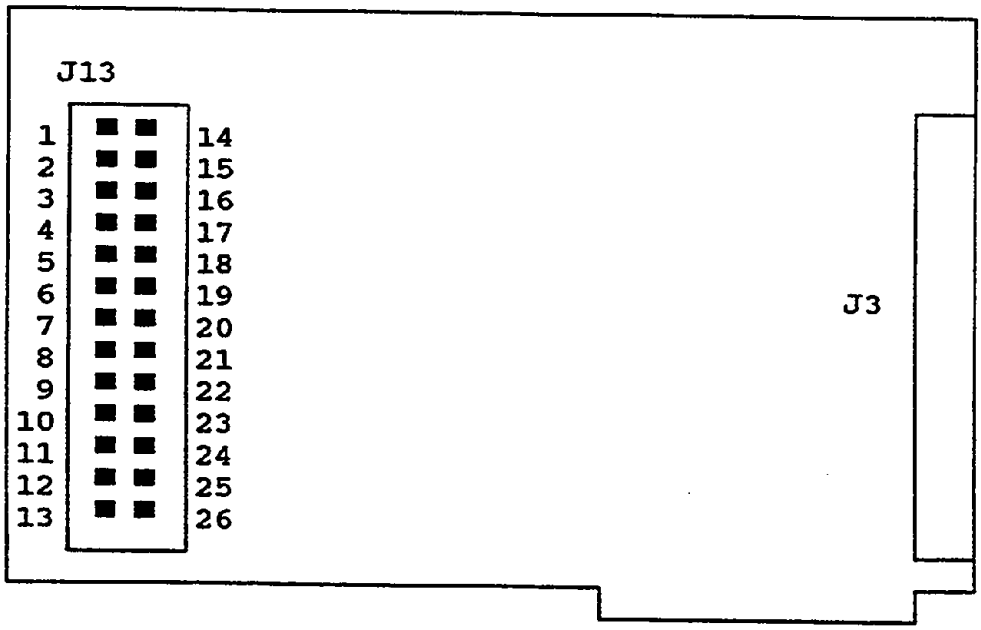
Note the word 'END' as the last line sent by the MotionMaster 2000.

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5.4 IEEE-488 CONNECTOR PINOUTS

The MotionMaster 2000 provides a 26-pin connector, J13, for the IEEE-488 interface.

J13 Pin		J13 Pin	
1)	Data I/O bit-1	14)	Data I/O bit-5
2)	Data I/O bit-2	15)	Data I/O bit-6
3)	Data I/O bit-3	16)	Data I/O bit-7
4)	Data I/O bit-4	17)	Data I/O bit-8
5)	End or Identify (EOI)	18)	Remote Enable
6)	Data Valid (DAV)	19)	Ground
7)	Not Ready For Data (NRFD)	20)	Ground
8)	Not Data Accepted (NDAC)	21)	Ground
9)	Interface Clear (IFC)	22)	Ground
10)	Service Request (SRQ)	23)	Ground
11)	Attention (ATN)	24)	Ground
12)	Chassis Ground	25)	Ground
13)	not used	26)	not used



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ERROR MESSAGES

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6.1 INTRODUCTION

The MotionMaster 2000 has an elaborate command interpreter and system monitor. Every command received is analyzed for syntax and correct format. The result of the analysis is stored in the output buffer in plain English. During moves and while idle, system inputs are monitored and any change is reported to the user via the output buffer. To read the contents of the output buffer, send the command 'TB' (tell buffer) and then execute a MotionMaster 2000 read function.

For faster and more compact error reads, use the 'TE' command. The MotionMaster 2000 response to this command is a one byte, binary coded error number.

Below is a listing of all possible MotionMaster 2000 messages. The message consists of the prefix letter 'E', followed by the message number, followed by the description.

6.2 LIST OF ERROR MESSAGES

E00 NO ERROR
Command received is correct and will be executed.

E01 BAD COMMAND
Command does not exist in the MotionMaster 2000 command set.

E02 ILLEGAL PARAMETER
Parameter field contains non-numeric character or numeric parameter out of range.

E03 COMMUNICATION TIMEOUT
A communication transfer was initiated and never completed.

E04 MODULE NOT PRESENT
Command sent to a module which is not on the MotionMaster 2000 board.

E05 COMMAND/MODULE MISMATCH
A stepping motor specific command sent to a DC motor, or a DC motor specific command sent to a stepping motor.

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E06 RESERVED

E07 RESERVED

E08 AXIS 1 MOTOR FOLLOWING ERROR

The present real position of the DC motor connected to axis 1 is lagging the present desired position by more encoder counts than specified with the 'FE' (following error) command.
See Section 3, DC Motor Servo Loop Tuning

E09 AXIS 2 MOTOR FOLLOWING ERROR

The present real position of the DC motor connected to axis 2 is lagging the present desired position by more encoder counts than specified with the 'FE' (following error) command.
See Section 3, DC Motor Servo Loop Tuning

E10 AXIS 3 MOTOR FOLLOWING ERROR

The present real position of the DC motor connected to axis 3 is lagging the present desired position by more encoder counts than specified with the 'FE' (following error) command.
See Section 3, DC Motor Servo Loop Tuning

E11 AXIS 4 MOTOR FOLLOWING ERROR

The present real position of the DC motor connected to axis 4 is lagging the present desired position by more encoder counts than specified with the 'FE' (following error) command.
See Section 3, DC Motor Servo Loop Tuning

E12 MACRO ALREADY EXIST

You tried to create a macro with the same number of an existing macro. First erase the old macro, then create the new one.

E13 EMERGENCY STOP ACTIVATED

An emergency stop was executed because the MotionMaster 2000 received the '#' character.

E14 INSUFFICIENT MEMORY

The MotionMaster 2000 program memory is full. No more commands can be stored.

E15 MACRO NOT FOUND

The execute macro command ('EM') was sent with a macro number which does not exist.

E16 MISSING PROGRAM

There is no program to execute.

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E17 PROGRAM NOT COMPILED

The execute program command ('EX') was sent without first compiling the program with the 'CP' command.

E18 REPEAT FAILURE

A carriage return was sent to repeat last command. However, no valid command exists for repeat execution.

E19 NOT ALLOWED IN PROGRAM EXECUTION MODE

Command or command sequence not allowed in program mode.

E20 TARGET LABEL NOT IN PROGRAM

A jump to a label in a program reference a undefined label.

E21 REDEFINED LABEL

The same label exists in more than one position in a program.

E22 EXECUTABLE ONLY WITHIN PROGRAM

Command or command sequence can only be executed in the program mode. Cannot be executed in immediate command execute mode.

E23 COMMAND LINE EXCEEDS 80 CHARACTERS

The sequence of commands entered contains more than 80 characters.

E24 PARAMETER OUT OF RANGE

E25 INTERNAL COMMUNICATION ERROR

The communication between the MotionMaster 2000 master and slave processors has an error.

E26 RS232 ERROR

An RS-232-C framing error or overrun error exist. The RS-232-C communication parameters may be incorrect.

E27 RECEIVER BUFFER FULL

The 512 byte command input buffer is full. Commands are being sent too quickly for the MotionMaster 2000 to process.

E28 STORED PROGRAM CORRUPTED

The battery backed RAM has been erased or written over with bad data.

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E29 SYSTEM IS BUSY

For stepping motor: Move or acceleration command sent to an axis which is presently executing a previous move command.
For DC motor: Acceleration command sent to an axis which is presently executing a move command.

E30 NESTED WHILE/WEND NOT PERMITTED

E31 WEND WITHOUT WHILE FOUND

E32 WHILE WITHOUT WEND FOUND

E33 CLEAR FM BIT-0 FOR CLOSED LOOP STEPPER

See CL command.

E34 INTERNAL FAILURE

MotionMaster 2000 master processor did not receive anticipated data from the slave processors.

E35 AXIS 1 NEGATIVE HARD LIMIT

The MotionMaster 2000 has sensed a high level at its negative travel limit input. It will interpreter this as reaching a negative travel limit.

E36 AXIS 2 NEGATIVE HARD LIMIT

E37 AXIS 3 NEGATIVE HARD LIMIT

E38 AXIS 4 NEGATIVE HARD LIMIT

E39 AXIS 1 POSITIVE HARD LIMIT

E40 AXIS 2 POSITIVE HARD LIMIT

E41 AXIS 3 POSITIVE HARD LIMIT

E42 AXIS 4 POSITIVE HARD LIMIT

E43 AXIS 1 NEGATIVE SOFT LIMIT

Command directs the MotionMaster 2000 to move past a previously defined position set as the soft limit with the 'SL' command.

E44 AXIS 2 NEGATIVE SOFT LIMIT

E45 AXIS 3 NEGATIVE SOFT LIMIT

E46 AXIS 4 NEGATIVE SOFT LIMIT

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E47 AXIS 1 POSITIVE SOFT LIMIT

E48 AXIS 2 POSITIVE SOFT LIMIT

E49 AXIS 3 POSITIVE SOFT LIMIT

E50 AXIS 4 POSITIVE SOFT LIMIT

E51 AXIS 1 JOYSTICK SOFT LIMIT

E52 AXIS 2 JOYSTICK SOFT LIMIT

E53 AXIS 3 JOYSTICK SOFT LIMIT

E54 AXIS 4 JOYSTICK SOFT LIMIT

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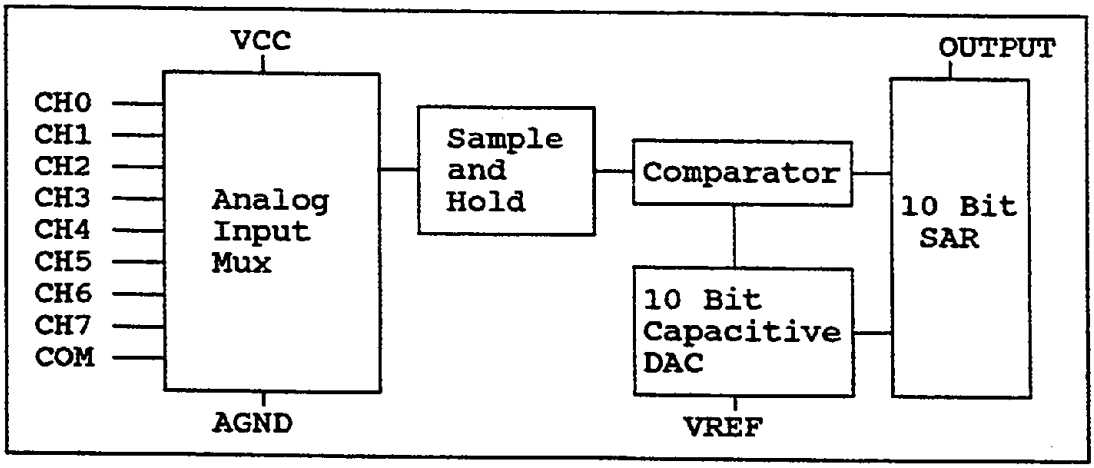
A/D AND D/A CONVERTERS

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7.1 Analog to Digital Converter

The MotionMaster 2000 provides an optional 8 channel 10-bit analog to digital converter. It will convert any analog voltage up to 10 volts into a numerical form. The 'RA' command is used to direct the MotionMaster 2000 to convert the voltage at the specified channel and respond with a numerical equivalent.

A/D Block Diagram



The input pins CH0 - CH7, VCC, AGND, and VREF are accessed on the General Purpose I/O connector. See Appendix B. The output is obtained with the MotionMaster 2000 'RA' (read analog) command.

The conversion formula is:

digital output = (V input/VREF)*1023

One LSB = VREF/1024
Total Error = +/-0.5LSB

When V input equals VREF, the output is full scale, which is 1023.

Conversion Time: 1 millisecond ...

Includes the time for the MotionMaster 2000 to interpret the command, perform the A/D conversion, and send the result to the host.

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7.1.1 Input Voltage Requirements

VCC is the A/D converter supply voltage:
Minimum value = 5V
Maximum value = 10V

VREF:
Minimum value = 0V
Maximum value = 10V
Source Impedance less than 10 ohms ... use low impedance OP-AMP or a power supply

CH0 - CH7 sample voltage inputs:
Minimum value = 0V
Maximum value = 10V
Source Impedance less than 1K ... use low impedance OP-AMP.

VREF and the sample voltage inputs must always be less than or equal to the power supply voltage VCC.

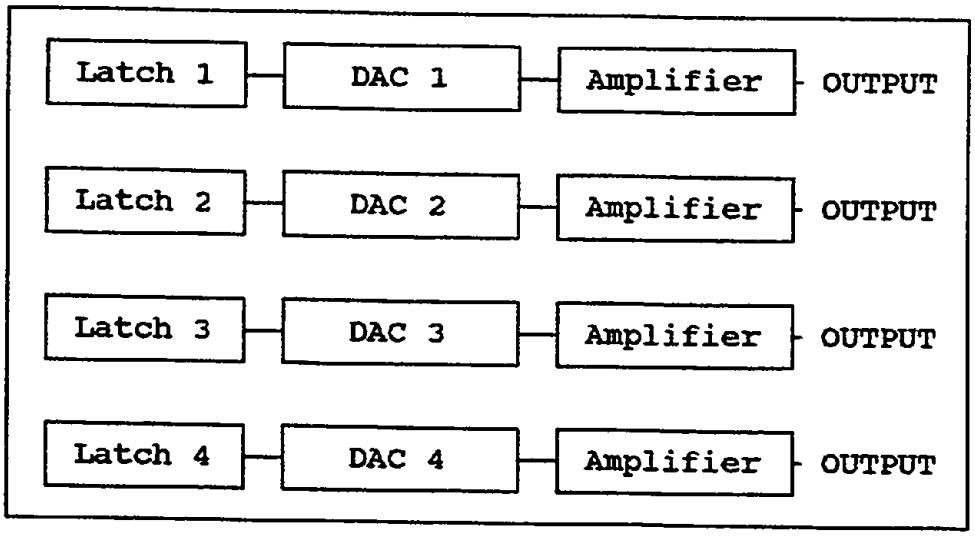
Normally you will supply a VREF voltage equal to the largest sample voltage that will be converted. However, you may supply a VREF smaller than the sample voltage to obtain higher resolution at a selected portion of your sample voltage.

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7.2 Digital to Analog Converter

The MotionMaster 2000 provides an optional 4 channel 8-bit digital to analog converter. It will convert a numerical value to an analog voltage up to 10 volts The 'WD' command is used to direct the MotionMaster 2000 to convert the specified numerical parameter of the command to a corresponding analog voltage.

D/A Block Diagram



The output pins are accessed on the General Purpose I/O connector. See Appendix B. The output is obtained with the 'WD' command. The parameters for the 'WD' command are the output number (1-4) and the digital number to convert.

The conversion formula is:

voltage out = 10 * (("WD" parameter)/256)

One LSB = 10/256
Total Error = +/- 2LSB

The output amplifiers can source and sink 5 milliamps.

On power supply systems which output +12V and -12V (like the PC), the maximum voltage out will be 9 volts. You cannot attain the full scale value of 10 volts. To attain the full scale value of 10 volts, you must break the +12 volt connection from the PC and connect a +15 volt power supply to the +12 volt power input pin. See Appendix D. Consult Newport/Klinger Corp. before undertaking this task.

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JOYSTICK

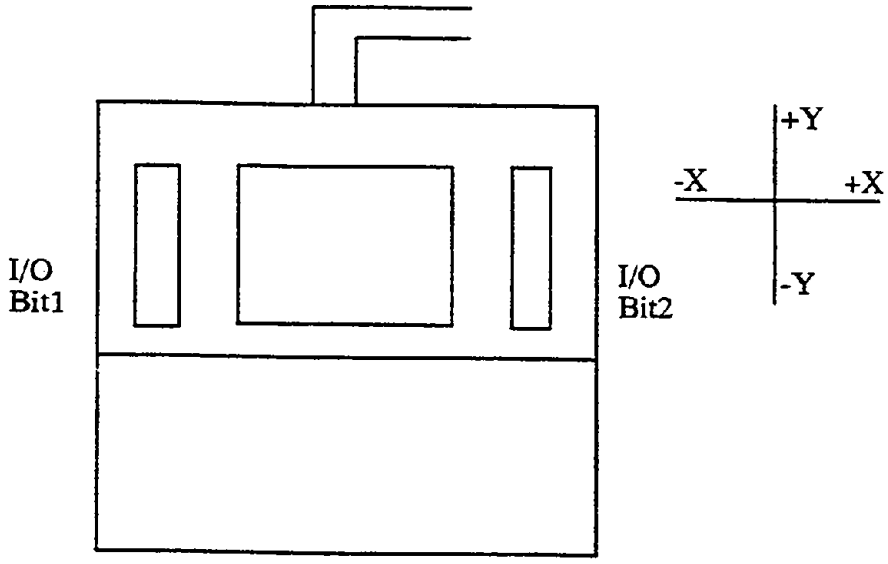
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8.1 INTRODUCTION

The MotionMaster 2000 Joystick enables manual control of four axes of motion. It also features 2 input buttons which may be used in conjunction with the MotionMaster 2000 commands to trigger certain command execution sequences.

8.2 DESCRIPTION

The MotionMaster 2000 Joystick is connected to the MotionMaster 2000 General Purpose Input/Output connector. The joystick outputs four analog signals to the MotionMaster 2000 analog to digital inputs. These analog signals are interpreted as movement and speed control commands every 32 milli-seconds.



The joystick consists of three potentiometers and three switches. Two potentiometers are configured as X-Y control. The output of the X-axis potentiometer is routed to Channel 1 A/D input (pin 1 on the GPIO). The output of the Y-axis potentiometer is routed to Channel 2 A/D input (pin 2 on the GPIO).

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The third potentiometer resides in the bulb of the handle. It is actuated by twisting the bulb clockwise and counterclockwise. The output of this potentiometer is multiplexed to Channel 3 and Channel 4 A/D inputs (pin 3 and 4 on the GPIO, respectively). The multiplexing operation is selected with the switch on top of the handle. On power up, the potentiometer output is routed to Channel 3 A/D input. Pressing the switch once, routes the output to Channel 4 A/D input. Pressing the switch again, routes the output back to Channel 3 A/D input, etc.

On the left and right side of the joystick are two long rectangular switches. The left switch is routed to Programmable I/O Bit 1 (pin 25 on the GPIO). The right switch is routed to Programmable I/O Bit 2 (pin 26 on the GPIO). When a switch is pressed, it outputs a high signal (5V DC). These switches may be used to control the MotionMaster 2000 IF...THEN, WHILE...WEND, and WB (wait bit high/low) command structures. In addition, they may be used with the 'RB' (read bits) command to control the action of your application program. For example, reading a position and storing the data in a file whenever a bit changes its logic level from zero to one.

CAUTION

TURN OFF MM2000 BEFORE CONNECTING OR DISCONNECT JOYSTICK.

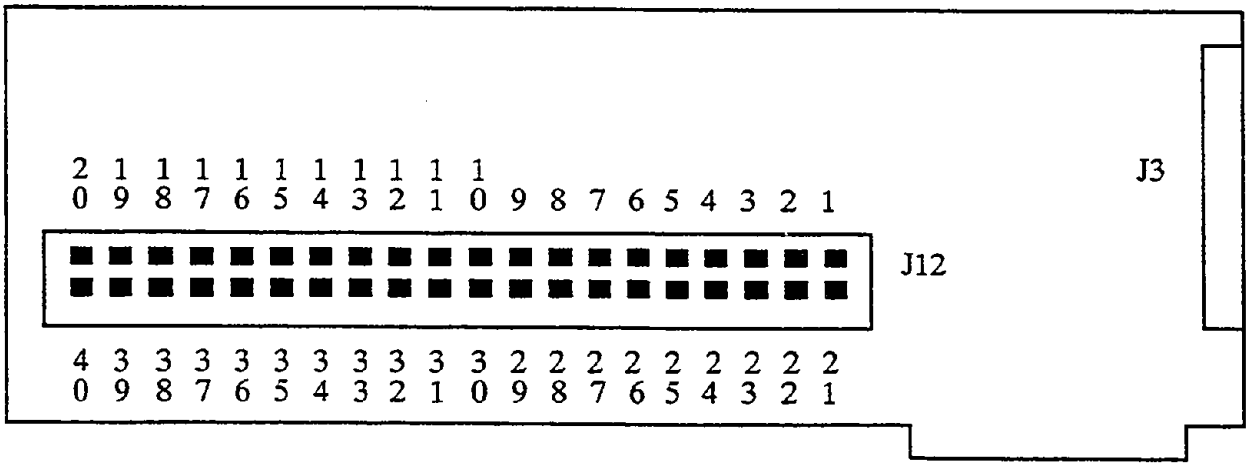
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APPENDIX A
GENERAL PURPOSE I/O SIGNALS

The MotionMaster 2000 provides a 40-pin header, J12, for general purpose I/O signal interfacing. The numbers in brackets (i.e. [xx]) are the pinouts of a 37 pin D connector, if connected to the 40-pin header.

J12 Pin		J12 Pin	
1)[1]	Channel 1 (10-bit) A/D input	21)[20]	Channel 2 (8-bit) D/A output
2)[2]	Channel 2 (10-bit) A/D input	22)[21]	Channel 3 (8-bit) D/A output
3)[3]	Channel 3 (10-bit) A/D input	23)[22]	Channel 4 (8-bit) D/A output
4)[4]	Channel 4 (10-bit) A/D input	24)[23]	D/A ground
5)[5]	Channel 5 (10-bit) A/D input	25)[24]	Programmable TTL I/O bit-1
6)[6]	Channel 6 (10-bit) A/D input	26)[25]	Programmable TTL I/O bit-2
7)[7]	Channel 7 (10-bit) A/D input	27)[26]	Programmable TTL I/O bit-3
8)[8]	Channel 8 (10-bit) A/D input	28)[27]	Programmable TTL I/O bit-4
9)[9]	A/D ground	29)[28]	Programmable TTL I/O bit-5
10)[10]	A/D reference voltage input	30)[29]	Programmable TTL I/O bit-6
11)[11]	A/D VDD input	31)[30]	Programmable TTL I/O bit-7
12)[12]	NC	32)[31]	Programmable TTL I/O bit-8
13)[13]	NC	33)[32]	-12 Volts (100 mA max.)
14)[14]	NC	34)[33]	+12 Volts (100 mA max.)
15)[15]	NC	35)[34]	+5 Volts (100 mA max.)
16)[16]	NC	36)[35]	Ground
17)[17]	NC	37)[36]	System reset (low level) input
18)[18]	Emergency stop (rising edge) input38)	[37]	NC
19)[19]	Channel 1 (8-bit) D/A output	39)	NC
20)	NC	40)	NC

NOTE: Do not connect any voltage to pins which are labelled NC (no connect)



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SIGNAL DESCRIPTIONS

1 - 8 Channel n (10-bit) A/D input

To these pins, connect the analog voltages to be converted, referred to henceforth, as the "sample voltage"

The sample voltage source impedance should be less than 1K. Use a low output impedance OP-AMP.

See Section 7 in this User's Manual for information on the analog to digital converter.

9 A/D Ground

This is the ground reference for the sample voltage inputs. Connect the sample voltage ground to this pin.

10 A/D voltage reference input

This input sets the span of the converter. This voltage determines the full scale output of the converter, i.e. when the sample voltage equals the voltage reference, then the digital output is 1023, which is full scale.

This voltage reference input will normally be equal to the largest sample voltage. However, you may use a smaller voltage reference to obtain higher resolution at a selected portion of your sample voltage.

The source impedance of the voltage drive for this input should be less than 10 ohms. Use a low impedance OP-AMP or a power supply.

11 A/D VDD input

This is the power supply voltage for the analog to digital converter.
Connect an external power supply to this input or use the +5V output at pin 35.

Maximum value = 10V
Minimum value = 5V

Must be greater than or equal to the voltage reference input and the sample voltage inputs.

18 Emergency stop input

Connecting this pin to +5V will stop all motion immediately.

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19, 21 - 23 Channel n (8-bit) D/A output

This pins are the outputs of the 4 digital to analog converters.

Each D/A converter includes an output buffer amplifier capable of sourcing and sinking up to 5 milliamps of output current.

See Section 7 in this User's Manual for information on the digital to analog converter.

24 D/A Ground

This pin is the ground reference point for the analog voltage outputs.

25 - 32 Programmable TTL I/O bit n

These bits are connected directly to the internal processor and thus are bi-directional. Before a bit is used, it must be defined as an input or as an output. Use the MotionMaster 2000 commands, 'BI' and 'BO' for this purpose.

Use the 'RB' (read bits) command to read the input bits and use the 'CB' (clear bit), 'SB' (set bit) and 'TG' (toggle bit) commands to manipulate the output bits.

Note that some bits can be inputs and the others can be outputs at the same time.

There is no internal electrical protection on these bits. You must not connect a voltage greater than +5V and less than zero volts to these bits.

Each bit can sink 2 milliamps and source 1 milliamp. It is best to external buffer these signals. Use a transistor or any TTL chip appropriate for your application (ex. 74LS04, 7406, 7407, 74LS244, etc.)

33 -12 Volts (100 mA max.)

-12 volt supply output from the PC I/O channel. Use only to drive high impedance inputs.

or ...

-12 volt supply output from the power input connector, J2. See appendix C.

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34 +12 Volts (100 mA max.)

+12 volt supply output from the PC I/O channel. Use only to drive high impedance inputs.

or ...

+12 volt supply output from the power input connector, J2. See appendix C.

35 +5 Volts (100 mA max.)

+5 volt supply output from the PC I/O channel. Use only to drive high impedance inputs.

or ...

+5 volt supply output from the power input connector, J2. See appendix C.

36 Ground

Ground output from the PC I/O channel.

or ...

Ground output from the power input connector, J2. See appendix C. output

37 System reset input

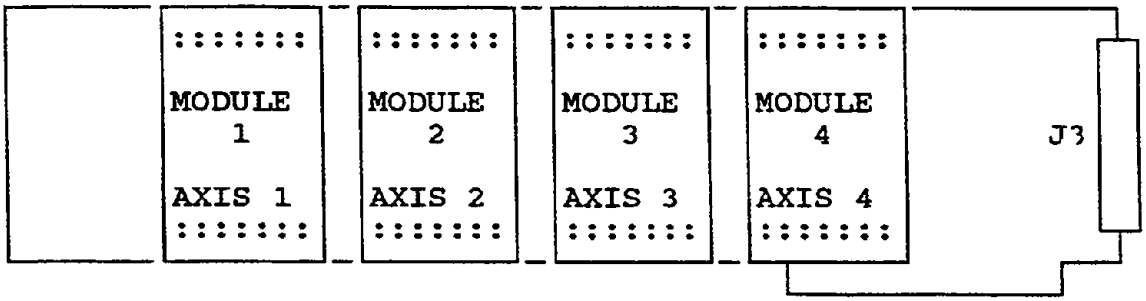
Connecting this pin to ground causes the MotionMaster 2000 to reset and enter its power up state.

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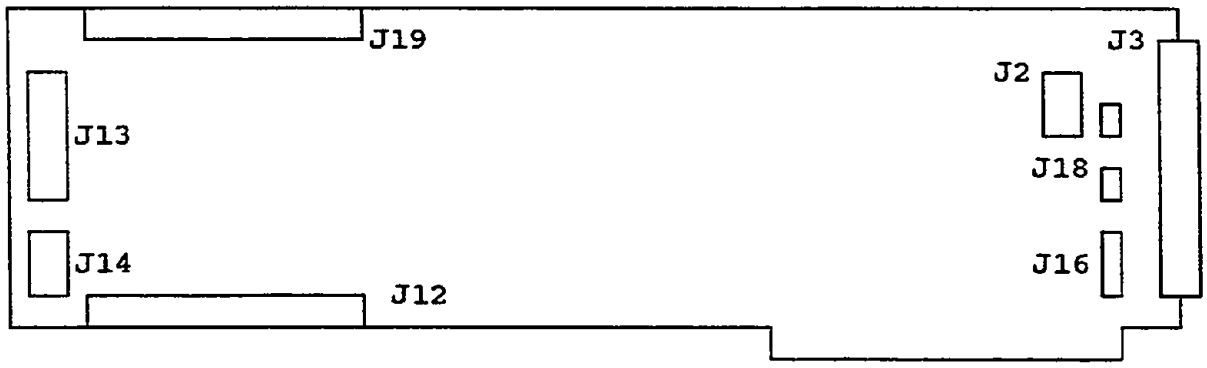
APPENDIX B
MotionMaster 2000 HARDWARE DIAGRAMS

MotionMaster 2000 System

The MotionMaster 2000 system hardware consists of a motherboard and plug in motor modules. A module's location on the motherboard determines its axis reference. Module 1 = axis 1, module 2 = axis 2, etc.



MotionMaster 2000 Motherboard

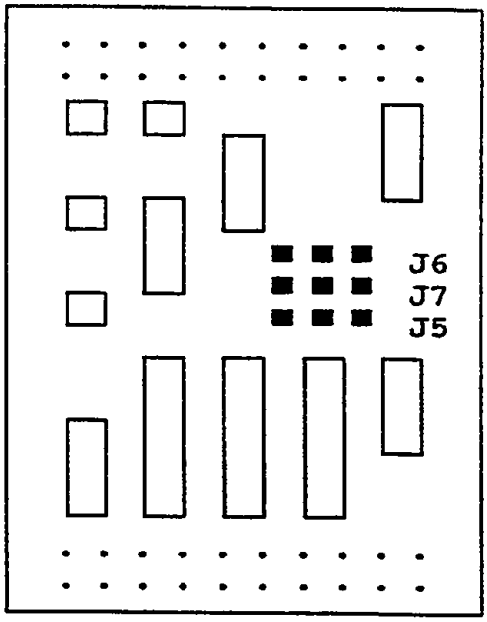


J2 External Power Supply Connector
J3 Motor Driver Output Connector
J12 General Purpose Input/Output Connector
J13 IEEE-488 Connector
J14 RS-232-C Connector
J16 PC Bus Address Selector
J18 Interrupt Number Selector
J19 Expansion Connector

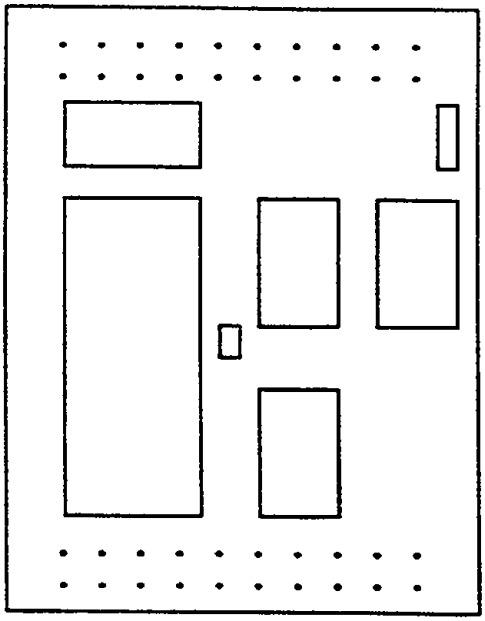
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MotionMaster 2000 Motor Modules

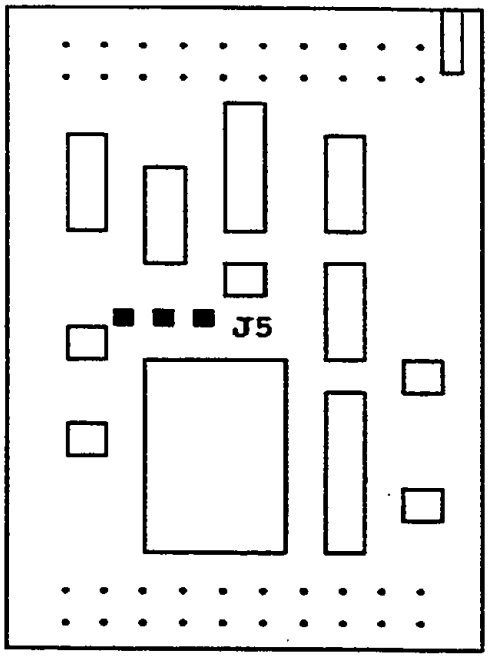
Model Step70K



Model Step1.5M

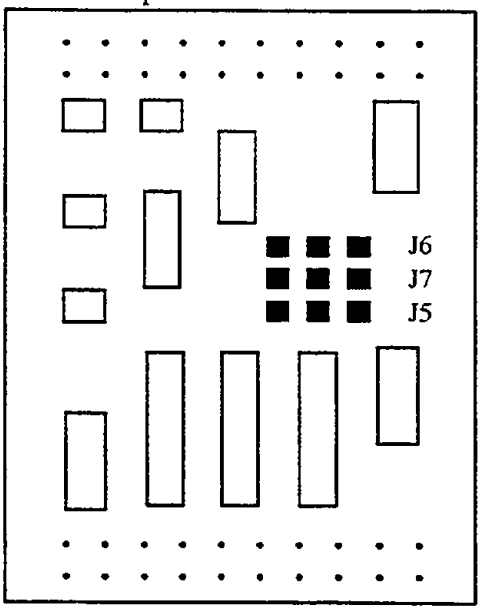


Model DC

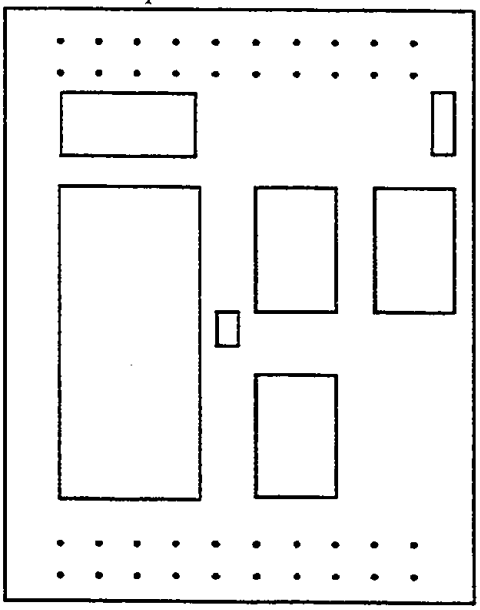


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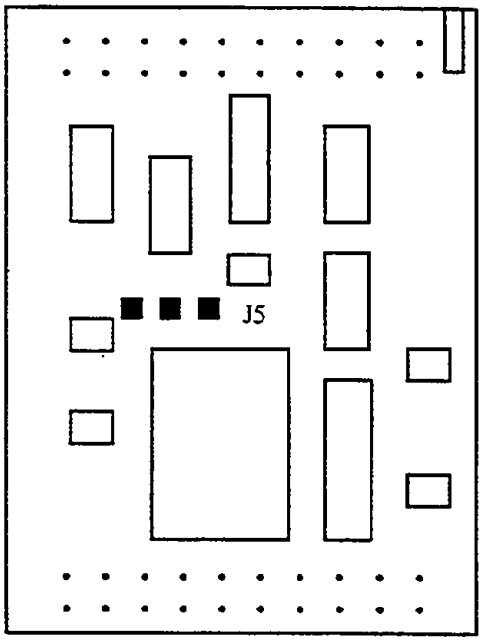
Model Step70K



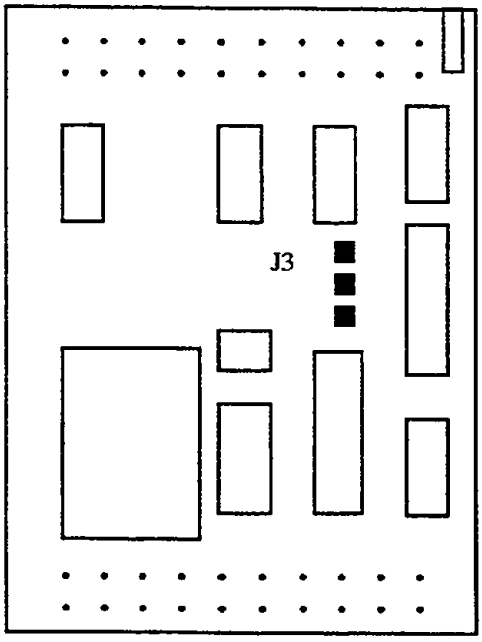
Model Step1.5M



Model DC 8-Bit



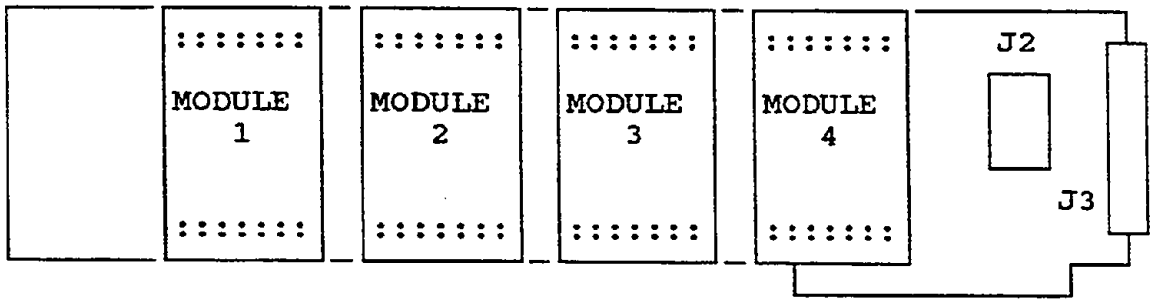
Model DC 12-Bit



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APPENDIX C
EXTERNAL POWER SUPPLY CONNECTOR J2

The MotionMaster 2000 main-board provides a 4-pin header, Amp p/n 350211-1, for external ±12 Volt, +5 Volt, and ground connection.



Using this connector the user can supply the MotionMaster board the necessary power for stand-alone (not in PC-bus) operation. This adapter mates with Amp socket housing p/n 1-480722-0 or p/n 1-480424-0.

J2

Pin		
1	+5Vdc	@ 1.0 A (typical)
2	+12Vdc	@ 0.5 A "
3	-12Vdc	@ 0.5 A "
4	GROUND	

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APPENDIX D
MOTOR I/O CONNECTOR J3

Using "piggy-back" plug-in modules, one(1) MotionMaster 2000 main-board supports as many as four(4) axes of motion consisting of any combination of stepping, and brushless or brush DC servo motors. The motion system related input/output (I/O) signals are available at 68-pin connector, J3. You may tap into the signals here, or you may use the interface box which conveniently divides the signals into 4 axes of motor control.

J3 Pin	Module	Stepping Motor	DC Motor
1	1	CW or pulse output	±10V analog control signal output
2	1	CCW or direction output	- Motor drive output (1 Amp)
3	1	Motor ON/OFF output	+ Motor drive output (1 Amp)
10	1	Top zero (index) input	Top zero (index) input
5	1	Top zero (index) NOT input	Top zero (index) NOT input
8	1	Encoder channel A input	Encoder channel A input
9	1	Encoder channel B input	Encoder channel B input
6	1	Encoder channel A NOT input	Encoder channel A NOT input
7	1	Encoder channel B NOT inupt	Encoder channel B NOT input
11	1	Origin (home) switch input	Origin (home) switch input
14	1	- Travel limit input	- Travel limit input
12	1	+ Travel limit input	+ Travel limit input
37	2	CW or pulse output	±10V analog control signal output
38	2	CCW or direction output	- Motor drive output (1 Amp)
39	2	Motor ON/OFF output	+ Motor drive output (1 Amp)
46	2	Top zero (index) input	Top zero (index) input
41	2	Top zero (index) NOT input	Top zero (index) NOT input
44	2	Encoder channel A input	Encoder channel A input
45	2	Encoder channel B input	Encoder channel B input
42	2	Encoder channel A NOT input	Encoder channel A NOT input
43	2	Encoder channel B NOT inupt	Encoder channel B NOT input
47	2	Origin (home) switch input	Origin (home) switch input
49	2	- Travel limit input	- Travel limit input
48	2	+ Travel limit input	+ Travel limit input

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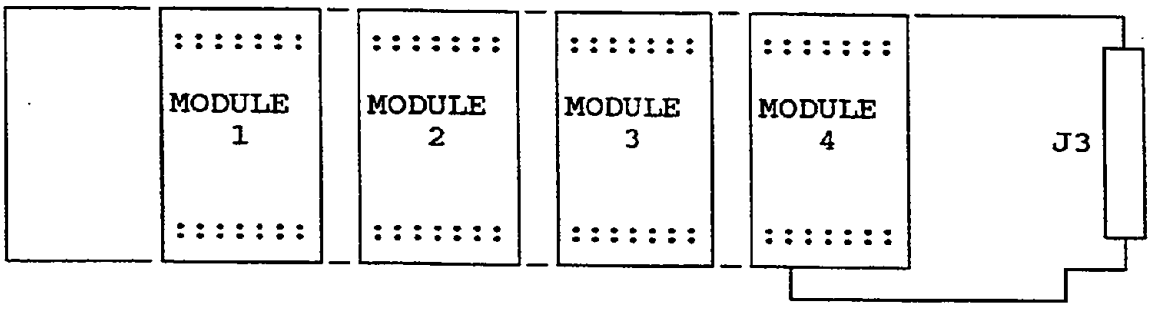
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J3 Pin	Module	Stepping Motor	DC Motor
16	3	CW or pulse output	±10V analog control signal output
17	3	CCW or direction output	- Motor drive output (1 Amp)
18	3	Motor ON/OFF output	+ Motor drive output (1 Amp)
25	3	Top zero (index) input	Top zero (index) input
20	3	Top zero (index) NOT input	Top zero (index) NOT input
23	3	Encoder channel A input	Encoder channel A input
24	3	Encoder channel B input	Encoder channel B input
21	3	Encoder channel A NOT input	Encoder channel A NOT input
22	3	Encoder channel B NOT inupt	Encoder channel B NOT input
26	3	Origin (home) switch input	Origin (home) switch input
30	3	- Travel limit input	- Travel limit input
28	3	+ Travel limit input	+ Travel limit input
50	4	CW or pulse output	±10V analog control signal output
51	4	CCW or direction output	- Motor drive output (1 Amp)
52	4	Motor ON/OFF output	+ Motor drive output (1 Amp)
59	4	Top zero (index) input	Top zero (index) input
54	4	Top zero (index) NOT input	Top zero (index) NOT input
57	4	Encoder channel A input	Encoder channel A input
58	4	Encoder channel B input	Encoder channel B input
55	4	Encoder channel A NOT input	Encoder channel A NOT input
56	4	Encoder channel B NOT inupt	Encoder channel B NOT input
60	4	Origin (home) switch input	Origin (home) switch input
62	4	- Travel limit input	- Travel limit input
61	4	+ Travel limit input	+ Travel limit input

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J3 Pin	Module	Stepping Motor	DC Motor
31	-	I/O bit 1	I/O bit 1
65	-	I/O bit 2	I/O bit 2
32	-	I/O bit 3	I/O bit 3
66	-	I/O bit 4	I/O bit 4
33	-	I/O bit 5	I/O bit 5
67	-	I/O bit 6	I/O bit 6
34	-	I/O bit 7	I/O bit 7
68	-	Reset	Reset
13	-	+5V DC	+5V DC
27	-	+5V DC	+5V DC
35	-	+5V DC	+5V DC
63	-	+12V DC	+12V DC
64	-	-12V DC	-12V DC
15	-	Ground	Ground
29	-	Ground	Ground
36	-	Ground	Ground
4	-	Reserved	Reserved
40	-	Reserved	Reserved
19	-	Reserved	Reserved
53	-	Reserved	Reserved



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APPENDIX E
INTERRUPT SERVICE SAMPLE PROGRAMS

All of the following interrupt service sample programs perform the following:

1. set up the host computer to receive the interrupt
2. direct the MotionMaster 2000 to generate an interrupt when axis 1 motion is complete and/or error occurs
3. initiate the move on axis 1
4. when the interrupt is generated, read the position counter, and initiate a move on axis 2.

NOTE: All of the following sample programs are provided for you on the MotionMaster 2000 software support diskette in the respective directories.

Microsoft QuickBASIC 4.5 Sample Program

```
' QuickBASIC 4.5 Interrupt Service Sample Program
' Program name: INTERUPT.BAS

' To create an executable program, INTERUPT.EXE, using the command line
' compiler and linker, copy INTERUPT.BAS and QB45MM.OBJ to your QB45
' directory and then type:
'               bc /w/v interupt;
'               link interupt qb45mm;

' qb45mm is the communications interface object file
' qb45mm.obj is on your MotionMaster 2000 diskette in directory /QB45

' To execute this sample program within the QB environment, copy qb45mm.qlb
' to your QB45 directory, and enter the QB environment with:

'               qb interupt /l qb45mm.qlb

' qb45mm.qlb is on your MotionMaster 2000 diskette in directory /QB45
```


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```
' Program Beginning

ON UEVENT GOSUB ServiceInt
UEVENT ON
IntNumber% = 3                          'MotionMaster 2000 set for interrupt 3
Intr% = IntNumber% + 8
CALL SetInt(Intr%)

Term$ = CHR$(13)
Cmd% = 1

DIM CmdArray$(6)
CmdArray$(1) = "1FI11"
CmdArray$(2) = "VA1000"
CmdArray$(3) = "AC75000"
CmdArray$(4) = "DH"
CmdArray$(5) = "PR2000"
CmdArray$(6) = "end"
mmadd% = &H340

DO
   Cmd$ = CmdArray$(Cmd%)
   IF Cmd$ = "end" THEN EXIT DO
   Cmd$ = Cmd$ + Term$
   CALL mmsend(Cmd$, mmadd%)        'call interface routine
   Cmd% = Cmd% + 1
LOOP

CLS
IntFlag% = 0
LOCATE 2, 1
PRINT "Performing other tasks during the move:  Incrementing a variable !!!"
DO
   Kount% = Kount% + 1
   LOCATE 3, 1
   PRINT Kount%
LOOP WHILE IntFlag% = 0

Cmd$ = "tp" + Term$
CALL mmsend(Cmd$, mmadd%)           'call interface routine
Resp$ = SPACE$(80)
CALL mmread(Resp$, mmadd%)          'call interface routine
Resp$ = RTRIM$(Resp$)
LOCATE 5, 1
PRINT "Motor Position After First Move = "; Resp$;
```


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```
LOCATE 7, 1
PRINT "Another move initiated ..."

Cmd$ = "fi00" + Term$                   'disable interrupt
CALL mmsend(Cmd$, mmadd%)               'call interface routine

Cmd$ = "pr-2000" + Term$                'send another move command
CALL mmsend(Cmd$, mmadd%)               'call interface routine

CALL ClrInt(Intr%)                      'restore original service routine vector
END

ServiceInt:
   IntFlag% = 1
   RETURN
```


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Microsoft C and Turbo C Sample Program

```
/* Microsoft C and Turbo C Interrupt Service Sample Program
   Program Name: INTERUPT.C

To create an executable program, INTERUPT.EXE, (medium memory model),
with the command line compiler and linker, use the following:

        Microsoft C:    cl /AM interupt.c mcm_mm.obj
        Borland C:      tcc -mm interupt.c tcm_mm.obj

    . mcm_mm.obj is on your MotionMaster 2000 diskette in directory /MC51
    . tcm_mm.obj is on your MotionMaster 2000 diskette in directory /TC20
*/

#include <stdio.h>
#include <string.h>
#include <dos.h>

/* Definition for the 8259 Programmable Interrupt Controller (PIC) */
#define P8259_0  0x20   /* Address of interrupt status register */
#define P8259_1  0x21   /* Address of interrupt mask register */
#define irq_done 0x20   /* Written to PIC at end of interrupt service */

/* MotionMaster 2000 configuration */
#define mm2000_irq  3   /* Assume MM2000 J18 configured for IRQ3 */
#define mm_add  0x340   /* Assume MM2000 J16 configured for address 340h */

void interrupt far new_vector (void);
void (interrupt far *old_vector) (void);
void mm_int_setup(void);
void clean_up (void);

int mm_irq_flag=0, intmask;
int int_disable_mask=0x00, int_number=0, int_enable_mask=0xff ;
int k=0;
char  response[80], *cmd_ptr, cmd_copy[80];
char  *cmd_array[] =
{
"1FI11\r",              /* generate interrupt on axis 1 motion complete or error */
"1VA1000;AC50000\r",    /* set axis 1 velocity and acceleration */
"1DH;PR2000\r",         /* clear position counter and move axis 1 */
NULL
};
```


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```
main ()
{
int cmd_num=0, mm_position;

    mm_int_setup();   /* unmask 8259 Programmable Interrupt Controller */
    old_vector = _dos_getvect (mm2000_irq + 8); /* copy originl vector */
    _dos_setvect (mm2000_irq + 8, new_vector);  /* install user vector */

    while (cmd_array[cmd_num])      /* transmit array */
      {
      strcpy(cmd_copy,cmd_array[cmd_num]);
      mmsend(cmd_copy,mm_add);    /* pass command & board addr. */
      ++cmd_num;                  /* point to next command string */
      }

    printf("\n\rProcessing other tasks during move: Incrementing a variable !!!\n");

    while (mm_irq_flag == 0){       /* wait for MotionMaster interrupt */
        ++k;
        printf("\r%i",k);
        }

    mmsend("1TP\r",mm_add);   /* pass command & board addr.*/
    mmread(response,mm_add);  /* get response from MotionMaster */
    printf("\r\n\nMotor Position After First Move = %s\r",response);

    printf("\n\nAnother move initiated ...\n");
    mmsend("1FI00\r",mm_add);
    mmsend("1PR-2000\r",mm_add);

clean_up ();          /* restore original vector and mask irq */
}


void interrupt far new_vector (void)
{
    mm_irq_flag=1;            /* set MotionMaster interrupt flag and...*/
    outp(P8259_0, irq_done);  /* tell PIC irq service is done */
}
```


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```
void clean_up (void)
{
    _dos_setvect (mm2000_irq + 8,old_vector);  /* restore original vector */

    intmask = inp(P8259_1) | int_disable_mask; /* mask interrupt */
    outp(P8259_1, intmask);
}

void mm_int_setup(void)
{

    if (mm2000_irq == 3) {          /* setup for IRQ3 */
       int_enable_mask = 0xf7;
       int_disable_mask = 0x08;
       int_number = 11;
       }

    if (mm2000_irq == 5) {          /* setup for IRQ5 */
       int_enable_mask = 0xdf;
       int_disable_mask = 0x20;
       int_number = 13;
       }

    if (mm2000_irq == 7) {          /* setup for IRQ7 */
       int_enable_mask = 0x7f;
       int_disable_mask = 0x80;
       int_number = 15;
       }

intmask = inp(P8259_1) & int_enable_mask; /* AND 8259's irq mask register..*/

outp(P8259_1, intmask);                   /*...with int_enable_mask byte */
}
```


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```
{
  Turbo Pascal 5.0, 5.5 Interrupt Service Sample Program
  Program name: INTERUPT.PAS

  To run in the Turbo Pascal program development environment, load file
  INTERUPT.PAS

  To create an executable program, INTERUPT.EXE, use the following command:
  tpc interupt

  mm2000.obj is on your MotionMaster 2000 diskette in directory /TPASCAL
  Copy this file to your Turbo Pascal directory

}

{$F+}          {force far procedure call}
{$L mm2000}    {include MotionMaster 2000 interface software}

USES DOS,CRT;

const
  IntNumber = 3;

var
  command      :string;
  mmadd        :integer;
  response     :string;
  cr           :char;
  cmd          :integer;
  cmdarray     :array[1..5] of string;
  SaveVec      :pointer;
  IntMask      :integer;
  mm_int_flag  :integer;
  kount        :integer;

procedure mmsend(var cmd:string; addr:integer); external;
procedure mmread(var resp:string; addr:integer); external;
procedure binread(var binpos:longint; addr:integer); external;
```


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```
procedure EnableInts;
inline ($FB);                          {enable other interrupts}

procedure ServiceInt;interrupt;
begin
  EnableInts;
  mm_int_flag:=1;
  Port[$20]:=$20;                      {Signal that interrupt was serviced}
end;

procedure SetInt;
begin
  GetIntVec(IntNumber+8,SaveVec);
  SetIntVec(IntNumber+8,@ServiceInt);
  if IntNumber=3 then                      {determine interrupt enable bit}
    begin                                {for interrupt number}
      IntMask:=$08;
    end
  else if IntNumber=5 then
    begin
      IntMask:=$20;
    end
  else if IntNumber=7 then
    begin
      IntMask:=$80;
    end;
  Port[$21]:=Port[$21] AND NOT(IntMask)    {enable interupt}
end;

procedure ClrInt;
begin
  SetIntVec(IntNumber+8,SaveVec);
end;

begin
  mmadd:=$340;
  mm_int_flag:=0;
  cr:=chr(13);
  SetInt;                          {set up new interrupt vector: points
                                   {to MotionMaster 2000 service routine}

  cmdarray[1]:='1FI11';                {enable MotionMaster 2000 interrupt on}
                                   {axis 1 motion complete and/or error}
  cmdarray[2]:='VA1000';               {set velocity}
  cmdarray[3]:='AC75000';              {set acceleration}
  cmdarray[4]:='DH;PR2000';            {initiate move}
  cmdarray[5]:='end';
```


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```
  cmd:=1;
  ClrScr;
  command:=cmdarray[cmd];
  while command<>'end' do
     begin
        command:=command+cr;
        mmsend(command,mmadd);
        cmd:=cmd+1;
        command:=cmdarray[cmd];
     end;

  gotoxy(1,2);
  writeln('Performing other tasks during the move:  Incrementing a variable !!!');
  kount:=0;

  repeat
     {Perform ...}
     {          other ...}
     {                    tasks ...}

     kount:=kount+1;
     gotoxy(1,3);
     writeln(kount);

  until mm_int_flag=1;

  command:='1tp';                    {read axis 1 position}
  command:=command+cr;
  mmsend(command,mmadd);
  mmread(response,mmadd);
  gotoxy(1,5);
  writeln('Motor Position After First Move = ',response);

  command:='1fi00';                  {disable interrupt}
  command:=command+cr;
  mmsend(command,mmadd);

  gotoxy(1,7);
  writeln('Next move initiated ...');
  command:='1pr-2000';                 {initiate next move}
  command:=command+cr;
  mmsend(command,mmadd);

  ClrInt;                          {restore old interrupt vector}
  Port[$21]:=Port[$21] OR IntMask     {disable interupt}

end.
```


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APPENDIX F
BINARY POSITION READ SAMPLE PROGRAMS

All of the following binary read sample programs perform the following:

1. Set mode to ASCII
2. Program velocity, acceleration, and initiate a motion.
3. When motion is complete, change mode to binary and read the position as a 4 byte integer.
4. Change back to ASCII mode and read the desired velocity and acceleration.

NOTE: All of the following sample programs are provided for you on the MotionMaster 2000 software support diskette in the respective directories.

Microsoft QuickBasic 4.5 Sample Program

```
' QuickBASIC 4.5 Binary Position Read Sample Program
' Program Name: BINREAD.BAS

' To create an executable program, BINREAD.EXE, with the command line
' compiler and linker, use the following:

'               bc binread;
'               link binread qb45mm;

' qb45mm is the communications interface object file
' qb45mm.obj is on your MotionMaster 2000 diskette in directory /QB45

' To execute this sample program within the QB environment, enter the
' environment with the following command:

'               qb binread /l qb45mm.qlb

' qb45mm.qlb is on your MotionMaster 2000 diskette in directory /QB45
```


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```
' Program Beginning

CLS
Term$ = CHR$(13)
Cmd% = 1
BinResp& = &H0
DIM CmdArray$(10)
CmdArray$(1) = "1fo00;va1000"                'set mode = ASCII
CmdArray$(2) = "ac75000"
CmdArray$(3) = "dh"
CmdArray$(4) = "pr1000;ws"                   'initiate move and wait for stop
CmdArray$(5) = "fo04"                        'set mode = binary
CmdArray$(6) = "TP"
CmdArray$(7) = "fo00"                        'set mode = ASCII
CmdArray$(8) = "DV"
CmdArray$(9) = "DA"
CmdArray$(10) = "end"
mmadd% = &H340

DO
   Cmd$ = CmdArray$(Cmd%)
   IF Cmd$ = "end" THEN EXIT DO
   CmdTemp$ = Cmd$
   Cmd$ = Cmd$ + Term$
   CALL mmsend(Cmd$, mmadd%)                 'call interface routine
   GOSUB TestIfResponse
   Cmd% = Cmd% + 1
LOOP
END

TestIfResponse:
   Resp$ = SPACE$(80)
   IF INSTR("1234", LEFT$(CmdTemp$, 1)) <> 0 THEN
      CmdTemp$ = MID$(CmdTemp$, 2, 2)
   END IF
   SELECT CASE CmdTemp$
      CASE "TP"
         CALL binread(BinResp&, mmadd%)   'call interface routine
         PRINT "Current Binary Position: "; BinResp&

      CASE "TS"
         CALL mmread(Resp$, mmadd%)       'call interface routine
         Resp$ = RTRIM$(Resp$)
         PRINT "Current Status: (See User's Manual for Interpretation) "; Resp$
```


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```
  CASE "CP"
    CALL mmread(Resp$, mmadd%)        'call interface routine
    Resp$ = RTRIM$(Resp$)
    PRINT "Compile Message: "; Resp$
    Resp$ = SPACE$(80)
    CALL mmread(Resp$, mmadd%)        'call interface routine
    Resp$ = RTRIM$(Resp$)
    PRINT "Compile Message: "; Resp$

  CASE "DV"
    CALL mmread(Resp$, mmadd%)        'call interface routine
    Resp$ = RTRIM$(Resp$)
    PRINT "Current Set Velocity: "; Resp$;

  CASE "DP"
    CALL mmread(Resp$, mmadd%)        'call interface routine
    Resp$ = RTRIM$(Resp$)
    PRINT "Current Desired Position: "; Resp$;

  CASE "DA"
    CALL mmread(Resp$, mmadd%)        'call interface routine
    Resp$ = RTRIM$(Resp$)
    PRINT "Current Set Acceleration: "; Resp$;

  CASE "TF"
    CALL mmread(Resp$, mmadd%)        'call interface routine
    Resp$ = RTRIM$(Resp$)
    PRINT "Current DC Motor Filters: "; Resp$;

END SELECT
RETURN
```


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```
/*  Microsoft C and Turbo C Binary Position Read Sample Program
    Program name: BINREAD.C

    To create an executable program, BINREAD.EXE, (medium memory model),
    with the command line compiler and linker, use the following command:

    Microsoft C:    cl /AM binread.c mcm_mm.obj
    Borland C:      tcc -mm binread.c tcc_mm.obj

    . mcm_mm.obj is on your MotionMaster 2000 diskette in directory /MC51
    . tcm_mm.obj is on your MotionMaster 2000 diskette in directory /TC20
*/
#include <string.h>

char  tp[] = "TP";
char  ts[] = "TS";
char  cp[] = "CP";
char  da[] = "DA";
char  dv[] = "DV";
char  dp[] = "DP";
char  tf[] = "TF";
int   mm_add;
char  cmd_copy1[80];
char  cmd_copy2[80];
char  response[80];
char  *cmd;
char  cr[]={'\r'};
char  *cmd_parse;
int   cmd_num;
long int binpos;
```


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```
char  *cmd_array[15]=
{
"1fo00",                /* set mode=ASCII*/
"va10000",
"ac75000",
"dh;pr+1000;ws",        /*initiate move and wait for stop*/
"fo04",                 /* set mode=binary */
"TP",
"fo00",                 /* set mode=ASCII */
"DV",
"DA",
"end"
};

main()
{
    mm_add=0x340;
    cmd_num = 0;
    while (strcmp(cmd_array[cmd_num],"end") != 0)
    {
      strcpy(cmd_copy1,cmd_array[cmd_num]);  /* make 2 copies of command*/
      strcpy(cmd_copy2,cmd_array[cmd_num]);
      cmd = strcat(cmd_copy1, cr);
      mmsend(cmd,mm_add);            /* pass command pointer & board addr.*/
      test_response();
      ++cmd_num;
    }
}

test_response()
{
    cmd_parse=strstr(cmd_copy2,tp);    /* test if "tp" is last in command*/
    if (strcmp(cmd_parse,tp) == 0)
    {
      binread(&binpos,mm_add);
      printf("\nCurrent Binary Position: %li",binpos);
    }

    cmd_parse=strstr(cmd_copy2,ts);
    if (strcmp(cmd_parse,ts) == 0)
    {
      mmread(response,mm_add);
      printf("\nCurrent Status: (See User's Manual for Interpretation) %s",response);
    }
```


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```
    cmd_parse=strstr(cmd_copy2,cp);
    if (strcmp(cmd_parse,cp) == 0)
    {
       mmread(response,mm_add);
       printf("\nCompile Message: %s",response);
       mmread(response,mm_add);
       printf("\nCompile Message: %s",response);
    }

    cmd_parse=strstr(cmd_copy2,dv);
    if (strcmp(cmd_parse,dv) == 0)
    {
       mmread(response,mm_add);
       printf("\nCurrent Set Velocity: %s",response);
    }

    cmd_parse=strstr(cmd_copy2,da);
    if (strcmp(cmd_parse,da) == 0)
    {
       mmread(response,mm_add);
       printf("\nCurrent Set Acceleration: %s",response);
    }

    cmd_parse=strstr(cmd_copy2,dp);
    if (strcmp(cmd_parse,dp) == 0)
    {
       mmread(response,mm_add);
       printf("\nCurrent Desired Position: %s",response);
    }

    cmd_parse=strstr(cmd_copy2,tf);
    if (strcmp(cmd_parse,tf) == 0)
    {
       mmread(response,mm_add);
       printf("\nCurrent DC Motor Filters: %s",response);
    }
}
```


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```
{
  Turbo Pascal 5.0, 5.5 Binary Read Sample Program

  To run in the Turbo Pascal program development environment, load file
  BINREAD.PAS

  To create an executable program, BINREAD.EXE file, use the following
  command line:

  tpc binread

  mm2000.obj is on your MotionMaster 2000 diskette in directory /TPASCAL
  Copy this file to your Turbo Pascal directory

}

{$F+}          {force far procedure call}
{$L mm2000}    {include MotionMaster 2000 interface software}


var
   command  :string;
   mmadd    :integer;
   response :string;
   binposit :longint;
   cr       :char;
   cmdsave  :string;
   cmdtemp  :string;
   cmd      :integer;
   cmdarray:array[1..15] of string;

procedure mmsend(var cmd:string; addr:integer); external;
procedure mmread(var resp:string; addr:integer); external;
procedure binread(var binpos:longint; addr:integer); external;
procedure TestResponse(cmdsave:string);
begin
   cmdtemp:=cmdsave;
   delete (cmdtemp,2,length(cmdtemp)-1);
   if cmdtemp='1' then
      begin
         delete (cmdsave,1,1);   {delete axis id}
      end
```


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```
else if cmdtemp='2' then
  begin
    delete (cmdsave,1,1);   {delete axis id}
  end
else if cmdtemp='3' then
  begin
    delete (cmdsave,1,1);   {delete axis id}
  end
else if cmdtemp='4' then
  begin
    delete (cmdsave,1,1);   {delete axis id}
  end;

if cmdsave='TP'then
  begin
    binread(binposit,mmadd);
    writeln('Current Position: ',binposit);
  end

else if cmdsave='TS' then
  begin
    mmread(response,mmadd);
    writeln('Current Status [See User Manual for Interpretation]: ',response);
  end

else if cmdsave='CP' then
  begin
    mmread(response,mmadd);
    writeln('Compile Message: ',response);
    mmread(response,mmadd);
    writeln('Compile Message: ',response);
  end

else if cmdsave='DV'then
  begin
    mmread(response,mmadd);
    writeln('Desired Velocity = ',response);
  end

else if cmdsave='DP'then
  begin
    mmread(response,mmadd);
    writeln('Desired Position = ',response);
  end
```


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```
   else if cmdsave='TF'then
      begin
         mmread(response,mmadd);
         writeln('Current DC Filter Parameters = ',response);
      end

   else if cmdsave='DA' then
      begin
         mmread(response,mmadd);
         writeln('Desired Acceleration = ',response);
      end;
end;


begin
   cmdarray[1]:='1fo00';            {set mode = ASCII}
   cmdarray[2]:='va10000';
   cmdarray[3]:='ac75000';
   cmdarray[4]:='dh';
   cmdarray[5]:='pr1000;ws';        {initiate move and wait for stop}
   cmdarray[6]:='fo04';             {set mode = binary}
   cmdarray[7]:='TP';
   cmdarray[8]:='fo00';             {set mode = ASCII}
   cmdarray[9]:='DV';
   cmdarray[10]:='DA';
   cmdarray[11]:='end';

   mmadd:=$340;
   cr:=chr(13);

   cmd:=1;
   command:=cmdarray[cmd];

   while command<>'end' do
      begin
         cmdsave:=command;
         command:=command+cr;
         mmsend(command,mmadd);
         TestResponse(cmdsave);
         cmd:=cmd+1;
         command:=cmdarray[cmd];
      end;
end.
```


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