

TMC 188/40 Rev 4.1
Motion Control Module

960912

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Contents

OVERVIEW	7
HARDWARE SPECIFICATIONS	8
GETTING STARTED AND TUNING THE AXIS	9
STEP 1 - CONFIGURING THE TMC MODULE	9
STEP 2 - CONFIGURING THE P/C BASE	9
STEP 3 - INITIALIZING THE WY REGISTERS	9
STEP 4 - SELECTING THE APPROACH	10
STEP 5 - SETTING UP THE INITIALIZATION PARAMETERS	10
STEP 6 - MOVING THE AXIS USING DCSSMON	12
STEP 7 - JOGGING THE AXIS	13
STEP 8 - TUNING THE AXIS	14
P/C PROGRAMMING PRECAUTIONS	15
P/C ERROR HANDLING	15
KEY THINGS TO REMEMBER.....	15
WY REGISTER AND V MEMORY IMAGE DESCRIPTIONS	16
WY REGISTERS	16
AXIS INITIALIZATION PROCESS	17
VINIT AXIS INITIALIZATION PARAMETERS	18
VREAD - AXIS POSITION AND STATUS PARAMETERS.....	19
VWRITE - AXIS DYNAMIC CONTROL PARAMETERS.....	20
V MEMORY EXAMPLE	21
MOTION CONTROL PARAMETERS	23
READ ONLY PARAMETERS (VREAD)	23
INITIALIZATION PARAMETERS (VINIT)	27
DYNAMIC CONTROL COMMANDS (VWRITE).....	33
HOW IT WORKS	43
INITIALIZATION.....	43
PARAMETER USE	43
POSITION SENSING	43
DRIVE OUTPUT	43
CLOSING THE LOOP.....	44
PROPORTIONAL GAINS	44
INTEGRAL AND DIFFERENTIAL GAINS	44
FEED FORWARD.....	45
CONTROL AT REST.....	45
MODULE HARDWARE.....	46
FRONT PANEL INDICATORS	46
MODULE JUMPERS AND EXTERNAL WIRING	47
FAIL-SAFE TIMERS	50
SYSTEM RESET.....	51
CABLE & CONNECTOR INFORMATION.....	51
COMMON PROBLEMS AND SOLUTIONS	53
LADDER PROGRAM CANNOT ACCESS PARAMETERS OR OPERATE MODULE.....	53
DURING A MOVE, THE ACTUAL POSITION IS ERRATIC	53
TRANSDUCER COUNTS FIELD NOT INDICATING TRANSDUCER LOCATION.....	53
TRANSDUCER COUNTS FIELD CHANGES BUT OUTPUT DRIVE DOES NOT WORK.....	53

AXIS INDICATOR IS CONSTANT RED.....	54
DURING A MOVE, THE AXIS COMES TO A HALT FOR NO APPARENT REASON.....	54
HYDRAULIC SYSTEM PROBLEMS.....	55
NONLINEAR VALVES.....	55
SLOW-RESPONSE VALVES	55
HOSES.....	55
PUMPS AND ACCUMULATORS	56
IDENTIFICATION AND CORRECTION.....	56
REPAIRS AND RETURNS.....	59
FIELD REPAIR OF A MODULE	59
DELTA BULLETIN BOARD SYSTEM.....	59
MODULE RETURNS	59
GLOSSARY	60
APPENDIX A: MAPS, TIPS, AND COMMANDS.....	61
STATUS WORD BIT MAP.....	61
MODE WORD BIT MAP	62
EXAMPLE V MEMORY MAP	63
QUICK-START GUIDE	64
AXIS TUNING TIPS	69
DCSMON COMMAND SUMMARY.....	71
CONTROL EQUATIONS.....	73
ASCII CODE CHART	74
APPENDIX B: ASBX/40 ANALOG MODULE.....	75
DESCRIPTION	75
INSTALLATION.....	75
SPECIFICATIONS.....	75
VREAD V MEMORY	75
NEW VREAD PARAMETER DEFINITIONS	77
VINIT V MEMORY.....	77
NEW VINIT PARAMETER DEFINITIONS	78
MODE AND STATUS WORD CHANGES.....	79
PRESSURE-SPECIFIC COMMANDS.....	79
ASBX/40 SETUP	80
SETTING THE PRESSURE SCALE AND PRESSURE OFFSET	81
USING THE TMC 188/40-TA.....	81
PRESSURE PLOTS	82
CONNECTOR	82
APPENDIX C: QSBX/40 QUADRATURE MODULE	83
INTRODUCTION	83
QSBX/40 SPECIFICATIONS	83
QSBX/40 BLOCK DIAGRAM.....	84
IMPORTANT CONSIDERATIONS WHEN USING QUADRATURE ENCODERS.....	84
QUADRATURE ENCODER POSITION MEASUREMENT.....	86
QUADRATURE ENCODER-SPECIFIC COMMANDS	87
TMC 188/40-(T)Q PARAMETER CHANGES	89
READBACK PARAMETERS.....	91
LIMIT AND HOME DIGITAL INPUTS.....	92
QSBX/40 BOARD JUMPERS.....	94
QUADRATURE ENCODER INTERFACE EXAMPLES.....	95

FRONT PANEL INDICATORS	96
FRONT PANEL DB 37 FEMALE CONNECTOR	97
SAMPLE LIMIT AND HOME CONFIGURATION.....	98
APPENDIX D: APPLICATION NOTES.....	99
USING THE OFFSET AND DIRECTION FIELDS.....	99
ACCELERATION AND DECELERATION MODES	101
EVEN ENDING	102
EXAMPLE USING 20MA SERVO VALVES WITH 100MA OUTPUT.....	103
APPENDIX E: SAMPLE LADDER LOGIC	104
TMC 188/40 WIRING DIAGRAMS.....	108
INDEX.....	109

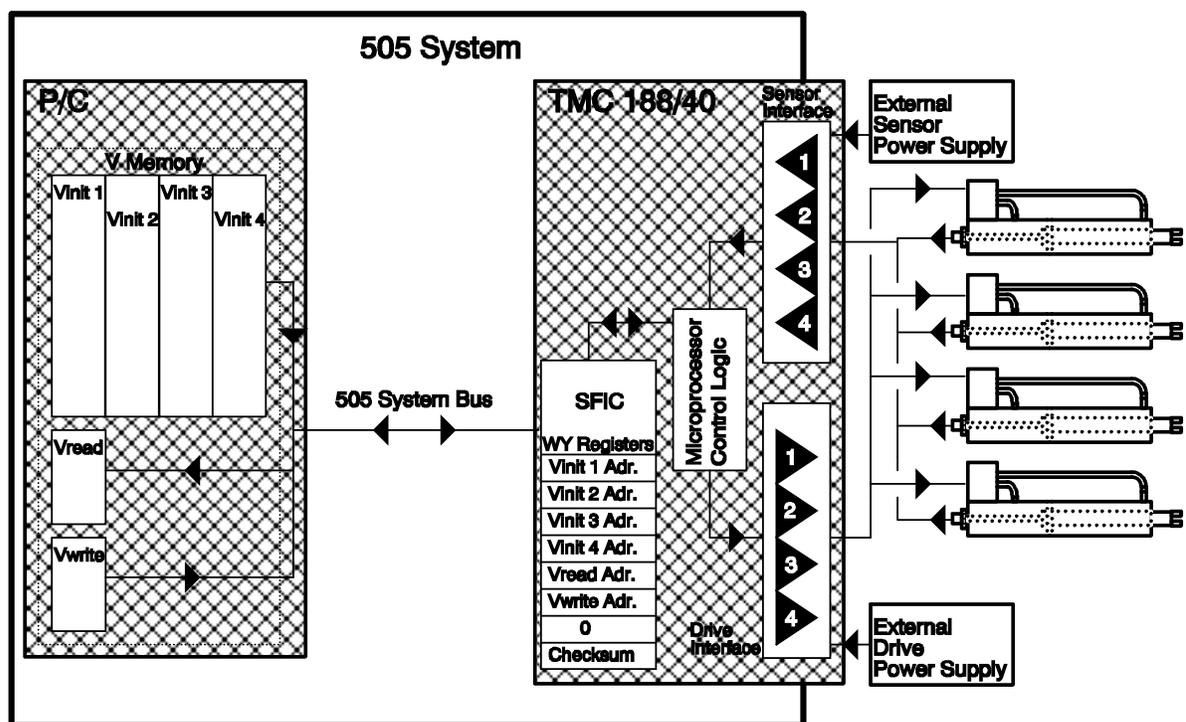
Overview

The TMC 188/40 family of Motion Control Modules provides a complete four-axis position control subsystem for the Siemens SIMATIC TI505 system. The module controls the axes by providing a complete PID loop plus many additional functions, such as on-the-fly coordinated moves and position changes. In its standard configuration the module provides four optically isolated magnetostriuctive interfaces and four optically isolated outputs, each individually configurable for voltage or current mode. A variety of output configurations work with electric servo motors and hydraulic valves. With the Quadrature and Analog options installed, you can control position using either quadrature encoders, analog slide potentiometers, or pressure.

The TMC 188/40 Motion Control Module (MCM) occupies one slot of the SIMATIC TI505 rack (two slots if the Analog or Quadrature options are installed). A Special Function Interface Chip (SFIC) communicates between the SIMATIC TI505 programmable controller (P/C) and the TMC 188/40. The TMC 188/40 is programmed using V Memory and eight SFIC WY registers. The on-board 80C188 processor relieves the P/C of the overhead usually associated with servo control. The MCM updates the actual position and drive output every two milliseconds, assuring accurate positioning even at high speed.

If you need more than four axes of control you can install additional TMC 188/40 modules.

TMC 188/40 System Block Diagram



NOTE: Increase in P/C scan times (per module installed) when using the TMC 188/40 are:

525 10 ms per module (not including P/C or remote overhead)

535 1.6 ms

545 0.8 ms

If the TMC 188/40 is used on a remote base, the P/C scan time will degrade considerably.

Hardware Specifications

TMC 188/40

One slot of SIMATIC TI505 chassis (two slots when ASBX or QSBX options are installed)
 13.875MHz 80188 processor
 SFIC Interface
 2 millisecond control loop time.
 Linear resolution to 0.001 inches
 Maximum velocity - 60,000 position units per second
 Maximum position counts - 65535
 Three hardware fail-safe timers

Standard Position Inputs

Four optically isolated magnetostrictive transducer interfaces
 Field-replaceable transducer protection resistors for Temposonics® I and
 Temposonics® II neuter transducers
 1.5V return pulse sensitivity
 27.75MHz counters
 1, 2, or 4 recirculations
 Positive or negative interrogation pulse
 Maximum update rate - 2 milliseconds

Drive

Four optically isolated, individually configurable servo drive outputs
 Current mode: $\pm 100\text{mA}$, $\pm 50\text{mA}$, or $\pm 25\text{mA}$
 Voltage mode: ± 10 volts, ± 5 volts, or ± 2.5 volts
 12 bit digital to analog converters

Power Requirements

5V	@ 1.0 amps	TI System Bus	
5V	@ 0.5 amps	External Sensor	
15V	@ 0.5 amps	External Sensor	If transducers are connected to the module; 0.1A for module only.
-15V	@ 0.5 amps	External Sensor	
15V	@ 0.5 amps	External Drive	0.1A for module + max current for axes used. Voltage mode uses zero added current per axis.
-15V	@ 0.5 amps	External Drive	

All power supply voltages must be within 5% of the specified voltage.
 Sensor power supplies should be independent of drive power supplies.

Getting Started and Tuning the Axis

CAUTION: When starting the Motion Control Module for the first time, great care must be taken to avoid accidents. The most common accident is a runaway. This is where the MCM tries to move the axis to a position beyond its physical limits.

**MAKE SURE THE POWER TO THE DRIVE IS TURNED OFF
BEFORE STARTING THIS PROCEDURE!**

Step 1 - Configuring The TMC Module

To configure the TMC module so it will work with your system, the following five steps must be taken. See **Module Jumpers and External Wiring** (on page 47) and **TMC Wiring Diagrams** (on page 107) for details about these steps.

1. Select voltage or current mode for the drive output of each axis (Default: current mode).
2. Select the drive level for each axis (Default: 50mA; range: 25, 50, 100mA or 2.5, 5, 10 volts)
3. Individually select each transducer interrogation pulse polarity (Default: Positive; Negative is for short Temposonics® I rods only).
4. Individually select the number of recirculations used on each axis (Default: 4; Range: 1, 2, 4).
5. Wire the transducer and drive cables to your system.

Step 2 - Configuring the P/C Base

To configure the P/C so it will communicate with the TMC 188/40, the appropriate slot in the Base must be initialized. To configure the P/C Base:

1. Run **TISOFT** software.
2. Put it in the **ONLINE** mode.
3. Enter the **CONFIO** menu.
4. Verify the appropriate slot is configured for eight **WY** registers with **SPECIAL FUNCTION** capability. This can be done manually or by doing a **READBS**.
5. Set the I/O address so it will not conflict with other I/O in the system. (The programs supplied with DCSSMON use WY201 through WY208. DCSSMON is a monitor program included with each Motion Control Module. See the DCSSMON manual for more information.)
6. Update the information in the P/C by doing a **WRITPC**.
7. Initialize the **WY** registers as described in the next section.

Step 3 - Initializing the WY Registers

The eight WY registers must be initialized before the TMC 188/40 will begin normal operation. The WY registers define the P/C's V Memory locations where the TMC 188/40 reads and writes information. The initialization can be done either with the CHART utility of TISOFT or with a ladder logic routine (see *filelist.txt* on the DCSSMON disk for example ladder programs).

The following example shows you how to initialize the WY registers. The values are the same as those in the demo program.

WY Register	Value (V Memory Address)	Definition
WY201	201	VINIT Axis 1
WY202	251	VINIT Axis 2
WY203	301	VINIT Axis 3
WY204	351	VINIT Axis 4
WY205	401	VREAD
WY206	451	VWRITE
WY207	0	Reserved
WY208	1956	Checksum (201+251+301+...)

To set up the WY registers:

1. Run **TISOFT**.
2. Put it in the **ON-LINE** mode.
3. Select **CHART**; select **BLDCHT**.
4. Enter **WY201 - WY208** (or whatever WY registers you are going to use).
5. Select **CHGVAL** to set the values for the eight WY registers. The values you enter are the addresses of the V Memory locations which the TMC 188/40 talks to (201, 251, etc. in the demo program).
6. When you have entered all eight values (including the checksum), verify the P/C LED on the TMC 188/40 panel is green.

NOTE: Once the TMC 188/40 finds a correct set of WY registers (including a valid checksum), it will not read them again unless reset. Changes in the WY registers will not take effect until the TMC 188/40 is reset or the power is cycled.

Step 4 - Selecting the Approach

Once the WY registers are initialized, there are two methods to get the TMC 188/40 running. The first is to use DELTA's PC-based program called DCSSMON. DCSSMON provides a simple way for you to get on-line without using a P/C ladder logic program. DCSSMON talks directly to the TMC 188/40 by using the P/C's store and forward commands. Please refer to the DCSSMON manual for help using it.

The second method is for you to follow the steps outlined below. To help you start, an example program is provided with DCSSMON. The latest versions of this demo program are listed in *filelist.txt* on the DCSSMON disk. You can use it with the 525, 535, 545, and 555 controllers after the controller type is specified using TISOFT.

TIP: Use Delta's DCSSMON to help determine initialization parameters and operation. Also, Delta's SSS/10 Servo System Simulator provides a simple way to test your program before connecting the Motion Control Module to your system.

Step 5 - Setting Up the Initialization Parameters

When the TMC 188/40 Motion Control Module is first turned on, default values are used for the initialization parameters. These values are there only to give the MCM so the present position can be maintained. The parameters need to be changed to work optimally in your system. The P/C is

responsible for initializing the parameters when the TMC 188/40 is powered up. It must place the correct values in the Special Function Interface Chip (SFIC) WY registers, write the parameter values to V Memory, and issue a 'P' command to the MCM. The following procedure will help you determine the optimal values for the initialization parameters.

First, disconnect the drive output from the TMC 188/40 (15 pin connector), and find a way to move the axis by hand. Build a chart in TISOFT (or use the chart on the DCSSMON disk) to monitor the appropriate V Memory locations (see the sample V Memory map on pages 21 and 22). Make sure the transducers are connected and powered.

If you want to begin quickly, you can proceed to Step 6 - Moving The Axis. Continue with this section now or return to it later to set the DIRECTION, SCALE, and OFFSET parameter values.

DIRECTION Parameter

Decide whether the ACTUAL POSITION will increase or decrease as the axis extends. (Remember - extending is the direction that returns increasing TRANSDUCER COUNTS.) The DIRECTION parameter should be 0 if the ACTUAL POSITION increases as the axis extends, and it **must** be zero for Quadrature applications (see Appendix C). This is the default value. The DIRECTION parameter should be set to -1 (0FFFFH) **only** if the ACTUAL POSITION decreases when the axis extends. Next, have the P/C issue 'P' command (80D, 50H) in the VWRITE COMMAND field

SCALE Parameter

The SCALE parameter is used to convert the transducer or encoder counts to position units. For magnetostrictive transducers (MDT), compute the SCALE as follows (see pages 30-31 for examples):

$$\text{SCALE} = \frac{32768 \times \text{Position Units per inch}}{\text{MDT Cal Number (in microseconds per inch)} \times 27.75\text{MHz} \times \text{Number of Recirculations}}$$

TIP: Delta's DCSSMON provides an easy way to work with SCALE. Use DCSSMON's commands P0 and P1 to help calculate SCALE, OFFSET, DIRECTION, and EXTEND and RETRACT LIMITS.

For Analog and Quadrature options, see the respective appendix for SCALE information.

OFFSET Parameter

Next, the axis OFFSET must be set. The axis OFFSET is added to the position of the axis before it is stored in the ACTUAL POSITION of V Memory. When you change the OFFSET, make sure to change the EXTEND LIMIT and RETRACT LIMIT by the same amount. Use the following equation to adjust the current ACTUAL POSITION:

$$\text{OFFSET} = \text{Old OFFSET} + \text{Desired Position} - \text{ACTUAL POSITION}$$

If the OFFSET is greater than 32767, subtract 65536 from the OFFSET. If the OFFSET is less than -32768, add 65536 to the OFFSET. When the OFFSET is changed, both the EXTEND and RETRACT limits must be adjusted accordingly. Send an Alt-P to initialize the new values. Check by moving the axis to the extend and retract limits and make any adjustments necessary.

NOTE: 1) Do not use the OFFSET parameter to compensate for severe mechanical misalignment. The physical system must be aligned before the OFFSET parameter is adjusted.
2) After adjusting the DIRECTION, SCALE and OFFSET, be sure to adjust the EXTEND and RETRACT LIMITS as described below. See Appendix D for more information.

Step 6 - Moving the Axis Using DCSSMON

With the axis drive output still disconnected and the transducers on, manually move the axis close to the physical extend limit; be sure to leave some space for error. (Remember: Extending is the direction that returns increasing TRANSDUCER COUNTS.) If you are using DCSSMON, be sure you are in Write mode rather than Read mode (a 'W' rather than an 'R' in the lower right corner of the DCSSMON main screen; press Ctrl-T to toggle the mode). In Read mode the parameters will not be written to V Memory and will be lost on power-down. Enter the ACTUAL POSITION reading as the value for the EXTEND LIMIT parameter. Now move the axis close to the physical retract limit and set the RETRACT LIMIT parameter. Issue a 'P' command.

If you cannot move the axis manually, the following procedure uses DCSSMON and the open loop mode to slowly move the axis.

CAUTION - OPEN LOOP OPERATION IGNORES ALL LIMITS! BE PREPARED TO REMOVE DRIVE POWER!

- A. Connect the TMC drive output to the valves.
- B. In DCSSMON, with the cursor on the axis you want to adjust, enter Alt-R to restore the null. Put 0 (zero) in the REQUESTED POSITION field, enter Alt-Shift-O, and verify that DRIVE = 2048.
- C. Turn on the hydraulics (the axis will drift due to valve null errors).
- D. Put 100 in the REQUESTED POSITION field and enter Alt-Shift-O, then put 0 (zero) in the REQUESTED POSITION field. Verify that DRIVE = 2148. The axis should extend. If the axis retracts, check the drive wiring polarity, hydraulic plumbing, and the value null. Correct any problems before continuing.
- E. When the axis gets to the extend limit, enter Alt-Shift-O, then Alt-P to stop the axis. Enter the ACTUAL POS. value in the EXTEND LIMIT parameter.
- F. Put -100 in the REQUESTED POSITION field and enter Alt-Shift-O, then put 0 (zero) in the REQUESTED POSITION field. Verify that DRIVE = 1948. The axis should retract.
- G. When the axis gets to the retract limit, enter Alt-Shift-O, then Alt-P to stop the axis. Enter the ACTUAL POS. value in the RETRACT LIMIT parameter.
- H. Repeat Steps B through G for each axis in use.

For each axis you'll be using, set the following parameter and profile terms to the indicated values, then press Alt-P on each axis. This will initialize the axis with any changes. (A HALT MASK of 0EFFF hides all errors except OVERDRIVE.)

Parameter terms:

HALT MASK	0EFFF
FEED FWD ADV	0
NULL UPDATE	0
DITHER	0
HYSTERESIS	0
PRO STAT GAIN	5
PRO EXT GAIN	5
PRO RET GAIN	5
INTEGRAL GAIN	0
DIFFER GAIN	0
EXT. FEED FWD.	100
RET. FEED FWD.	100

Profile terms:

MODE	00001
ACCEL	1% of SPEED
DECEL	1% of SPEED
SPEED	20% of maximum system speed (1000 = 1 in/sec)

NOTE: Do not use the INTEGRAL or DIFFERENTIAL GAINS or FEED FORWARD ADVANCE until you have finished with steps 1 to 10 in **Tuning the Axis**. Leave them at their defaults.

Turn off the power to the TMC 188/40 and connect the drive output (if you haven't already done so). Turn the power back on and issue a 'P' command to each axis you are using. Make several short slow moves by entering the REQUESTED POSITION and issuing a GO ('G') command.

TIP: DCSSMON is very useful. We recommend using it to troubleshoot and tune the system. It provides dynamic move information in graphic form.

Increase the speed and accelerations gradually while making longer moves. After a move press INSERT to make a graph of that move, then look for LEAD, LAG, overshoot, or oscillation. Eventually you will reach a speed or acceleration which will cause an error on the axis.

There are three errors to be concerned with at this time. If an overdrive error occurs (green line going to the top or bottom of the screen and axis halted), there is not enough drive capacity to drive the axis at the requested speed. If this occurs, reduce the SPEED. If a LAG error occurs (press Ctrl-B to display the status bits), the appropriate feed forward must be increased. If a LEAD error occurs, the appropriate feed forward must be decreased. In either case, you can enter an 'Alt-F' from DCSSMON or an 'F' command from the P/C ladder program to automatically adjust the feed forward terms. If this does not solve the problem, the acceleration and deceleration ramps are too steep for the response of the system; the ramp distance should be increased.

After the problem causing the error has been corrected, continue to increase the speed and move the axis until you reach the desired speed. Should the system seem a little sloppy, try decreasing the MAXIMUM POSITION ERROR and adjusting one of the system gains (STATIC, EXTEND and RETRACT) until the axis can be moved without getting an error. Remember, the parameters are not updated in the TMC 188/40 until the 'P' command is issued on each axis.

Step 7 - Jogging the Axis

You can jog the axis by setting the REQUESTED POSITION to the EXTEND LIMIT or RETRACT LIMIT, then using the 'G' and 'H' commands repeatedly. This causes the MCM to GO then HALT.

Step 8 - Tuning the Axis

Use Delta's DCSMON program so you can change parameters and graph the moves during the tuning process. At this point you should be able to make slow moves without errors (no red axis LEDs on the TMC front panel).

It will probably be necessary to mask off several bits in the HALT MASK while tuning the system to avoid stopping every time an error occurs (see page 27 for HALT MASK information).

- 1) If the axis oscillates when it shouldn't be moving, reduce the STATIC GAIN.
- 2) If the axis oscillates when it is extending, reduce the EXTEND GAIN.
- 3) If the axis oscillates when it is retracting, reduce the RETRACT GAIN.
- 4) Gains should be increased until the axis starts to oscillate, then follow tips 1 through 3.
- 5) If the axis gets a LEAD error and no LAG error while extending, reduce the EXTEND FEED FORWARD.
- 6) If the axis gets a LAG error and no LEAD error while extending, increase the EXTEND FEED FORWARD.
- 7) If the axis gets a LEAD error and no LAG error while retracting, reduce the RETRACT FEED FORWARD.
- 8) If the axis gets a LAG error and no LEAD error while retracting, increase the RETRACT FEED FORWARD.
- 9) If the axis gets both a LAG error and a LEAD error, check for oscillations (tips 2 & 3). If it is not oscillating, increase the MAX ERROR until you get only one error (tips 5 - 8). Also check the FEED FORWARD ADVANCE (tip 14).
- 10) Once the axis moves smoothly, use the 'F' command (automatic tuning).
- 11) If the axis hunts around the set point, increase the HYSTERESIS gradually until the hunting stops or the axis starts to oscillate. If oscillations occur, reduce the HYSTERESIS.
- 12) The NULL UPDATE should not be used until the HYSTERESIS is adjusted. Try to keep the NULL UPDATE interval value higher than 1000. Systems with fast response times require larger NULL UPDATE intervals.
- 13) If the axis gets no LAG or LEAD errors, reduce the MAX ERROR until errors start to occur then either tune the axis some more (tips 5 - 8), or increase the MAX ERROR a little.
- 14) The FEED FORWARD ADVANCE must be the same for all synchronized axis. Increasing the FEED FORWARD ADVANCE will decrease the chance of getting a LAG error when ramping up or getting a LEAD error while ramping down. If the FEED FORWARD ADVANCE is too high, the axis will LEAD when ramping up and LAG when ramping down.
- 15) The INTEGRAL GAIN is useful only when the feed forward terms cannot correct a problem. This may occur if the upper limit of the feed forward is reached or the axis has a nonlinear response to drive output. If the axis requires a different feed forward to move 10 inches a second than when moving 20 inches a second, the axis is nonlinear and the integrator can help compensate. In these cases a little integral gain will do the job.
- 16) Another problem occurs on moves of a long duration and when the feed forward cannot be adjusted high enough. This usually happens only on systems that move less than 2 inches or 50 mm per second. If the integrator must be used, increase by units of 50. Sometimes the integral gain will get to 500 or more.
- 17) The DIFFERENTIAL GAIN is most useful on systems with slow response times that oscillate at 5 Hz or less. It adds a small boost while accelerating and helps stop while decelerating. Increase this number by ones. The DIFFERENTIAL GAIN should not get over 10; high values will cause oscillation. DIFFERENTIAL GAIN is of little use on systems that respond quickly.

P/C Programming Precautions

The P/C is responsible for:

- Storing the VINIT parameters used by the TMC 188/40.
- Properly initializing the Motion Control Module using the VINIT V Memory locations.
- Loading the MCM's WY registers with the correct V Memory locations.
- Turning off drive power when the TMC reports an error.
- Having a watchdog timer that will shut off drive power if a time-out occurs.
- Issuing an 'H' or HALT command when drive power is turned off and restoring the null when power is turned back on.
- Issuing a 'P' or 'G' command to return an axis to closed loop control after a transducer error clears.

P/C Error Handling

The TMC 188/40 reports errors within two milliseconds after they are detected. It does this by setting a bit in the axis STATUS WORD and flashing the appropriate Front Panel LED. The P/C is responsible for checking errors using the STATUS BITS (see page 26). It is up to the P/C to determine what to do if an error is detected.

You can also use ESTOP and HALT to detect errors by clearing the bits in the HALT and ESTOP masks corresponding to the error bits in the STATUS WORD. See the STATUS WORD bit definitions starting on page 23.

The system must be able to shut down the axes drive power by deenergizing a normally open (held closed) contact. This contact should be in series with an operator emergency off button. If power to the rack is lost, the contact will be deactivated and the axes will stop. If an error occurs on the TMC 188/40, the contact can be deactivated, thus stopping the axes. Usually the P/C will not take so drastic a step until it has determined all control is lost. An 'H' or HALT command for the axis with an error can take care of most error situations.

When two or more axes are in a coordinated move and one axis starts moving slower than it should, it is best to issue a HALT command to all the axes and stop operation until the problem with the faulty axis has been solved.

Key Things to Remember

- Retracting is always toward the transmitter end of the magnetostrictive transducer. (TRANSDUCER COUNTS decrease while retracting.)
- The last 6 inches of the transducer are usually not usable.
- When the DIRECTION is 0, all positions are added to the OFFSET value. When the DIRECTION is -1, all positions are subtracted from the OFFSET.
- When the DIRECTION is 0, all positions from the zero position to the transmitter should be thought of as negative numbers. When the DIRECTION is -1, all positions from the transmitter to the end of the rod should be considered negative numbers.
- Transducer nonlinearity may be an issue when opposing axes are used.

WY Register and V Memory Image Descriptions

The TMC 188/40 communicates with the P/C through a Special Function Interface Chip (SFIC) and V Memory. The SFIC has been configured to appear as eight WY registers in the P/C's I/O area. The WY registers are used to tell the TMC 188/40 where the control parameters are located in V Memory (pointers to V Memory). Once the WY registers are initialized all communication between the P/C and the TMC 188/40 is done through V Memory.

Six of the eight WY registers are used as pointers to V Memory locations, one is reserved as a pointer to the start of the Event Steps Table, and the last is used to pass a checksum of the first seven registers. V Memory is used to pass parameters, receive data, and direct the module to specific action. During a P/C scan, the I/O operations are executed first, followed by the ladder logic, and then SFIC functions. The ladder logic program must contain the steps necessary to initialize the WY registers as well as set up the required control parameters in V Memory.

WY Registers

For the TMC 188/40 to work, you must set up eight consecutive WY registers as shown in the following table. Each WY register contains the V Memory address of the first location of a continuous list of parameters. After the WY registers are set up, all communication between the P/C and the TMC 188/40 passes through V Memory. The following pages list the VINIT, VREAD and VWRITE parameters used by the TMC 188/40. If the analog option is installed (indicated by an 'A' suffix: TMC 188/40TA), the VINIT V Memory is expanded (see Appendix B for details).

WY Register	Type of Parameters	Description
1	VINIT	Axis 1 V Memory address of initialization parameters
2	VINIT	Axis 2 V Memory address of initialization parameters
3	VINIT	Axis 3 V Memory address of initialization parameters
4	VINIT	Axis 4 V Memory address of initialization parameters
5	VREAD	Axis 1-4 V Memory address of position and status data
6	VWRITE	Axis 1-4 V Memory address of dynamic control parameters
7	Reserved	Zero, unless using Event Control Firmware
8	CHECKSUM	WY1+WY2+WY3+WY4+WY5+WY6+WY7 (16 bit, no carry)

NOTE: The TMC 188/40 will not operate if the CHECKSUM is incorrect.

NOTE: The WY registers can be any block of eight consecutive registers in the P/C's I/O area (they don't have to start with WY1). If there is more than one TMC 188/40 in a system, each one must have its own set of eight WY registers. The first four WY registers must contain the address of the V Memory where the initialization parameters for their respective axis are stored. You must enter the sum of the numbers in the first seven registers into the eighth register; this is the checksum used by the controller to verify the register data is valid.

VINIT points to the location containing the axis initialization parameters.

VREAD points to the location the P/C monitors for position and status information.

VWRITE points to the location where the P/C writes the dynamic control parameters.

CHECKSUM is the sum of all the values in the first seven WY registers. It is used to verify the validity of the WY registers. If this value is incorrect, the TMC 188/40 will not operate and the P/C LED on the front panel will flash red and green at a constant rate.

Axis Initialization Process

VINIT values are moved to the TMC 188/40 only when the 'P' command is issued by the P/C to the VWRITE location (see COMMAND parameters on pages 38 - 42). Once issued, it takes two P/C scan cycles to complete the TMC 188/40 axis initialization process. Do not issue a new command until the 'P' (ASCII 80) has been cleared from the COMMAND location in V Memory by the TMC 188/40.

NOTE: If a new command is issued during the initialization scans, it will cause the initialization process to abort.

TMC 188/40TA modules with the pressure mode enabled have more VINIT locations (see Appendix B for details).

TMC 188/40 initialization process:

P/C Scan n -

Change initialization parameter(s) in V Memory

Set the VWRITE V Memory command location to decimal 80 (P)

P/C Scan n+1 -

TMC 188/40 reads initialization parameters from V Memory

TMC 188/40 processes the initialization parameters

NOTE: Once the TMC 188/40 is initialized, changes in the WY registers will not take effect until the power is cycled or the module is reset.

VINIT - Axis Initialization Parameters

WY Registers 1-4 are the V Memory addresses where the following parameters are stored:

V Memory Location	Parameter Name	Default Value	Initialization Parameters Descriptions
1	NEW NULL	2048	Zero offset for drive
2	ESTOP Mask	0FFFF	Disable emergency stop on error condition
3	HALT Mask	00000	Disable halt on error condition
4	Reserved	0FFFF	Not used at this time
5	FEED FORWARD ADVANCE	0	Feed forward advance (in milliseconds)
6	NULL UPDATE	500	Time interval in at which null drive is calculated (in milliseconds)
7	Reserved	0FFFF	Not used at this time
8	DITHER	0	Static friction drive
9	HYSTERESIS	0	Deadband compensation
10	STATIC GAIN	50	Proportional gain at rest
11	EXTEND GAIN	50	Proportional gain when extending
12	RETRACT GAIN	50	Proportional gain when retracting
13	INTEGRAL GAIN	50	Integral gain when in motion
14	DIFFERENTIAL GAIN	0	Differential gain when in motion
15	EXTEND FEED FORWARD	100	Feed-forward drive when extending
16	RETRACT FEED FORWARD	100	Feed forward drive when retracting
17	SCALE	32768	Converts TRANSDUCER COUNTS to position units
18	POSITION OFFSET	0	Offset between position zero and transducer count zero
19	DIRECTION	0	Direction relative to TRANSDUCER COUNTS (0=+, -1= -)
20	MAX ERROR	250	Position error limit
21	AT COMMAND POSITION	50	Maximum position error size for a 'true' status bit indication
22	NEAR COMMAND POSITION	0	Maximum position error size for a 'true' status bit indication
23	EXTEND LIMIT	Position at power-up	Maximum position in position units
24	RETRACT LIMIT	Position at power-up	Minimum position in position units

VREAD - Axis Position and Status Parameters

WY Register 5 is the V Memory address where the following parameters are stored:

V Memory Location	Parameter Name	Axis 1-4 Position and Status Data Descriptions
1	Axis 1 Command Position	Command position (within set limits)
2	Axis 1 Target Position	Calculated instantaneous position (scaled)
3	Axis 1 Actual Position	Measured axis position (scaled)
4	Axis 1 Transducer Counts	Transducer location in raw counts
5	Axis 1 Status	Error and status bits
6	Axis 1 Drive	Drive output in raw D/A counts
7	Axis 1 Target Speed	Calculated axis speed (scaled)
8	Axis 2 Command Position	Command position (within set limits)
9	Axis 2 Target Position	Calculated instantaneous position (scaled)
10	Axis 2 Actual Position	Measured axis position (scaled)
11	Axis 2 Transducer Counts	Transducer location in raw counts
12	Axis 2 Status	Error and status bits
13	Axis 2 Drive	Drive output in raw D/A counts
14	Axis 2 Target Speed	Calculated axis speed (scaled)
15	Axis 3 Command Position	Command position (within set limits)
16	Axis 3 Target Position	Calculated instantaneous position (scaled)
17	Axis 3 Actual Position	Measured axis position (scaled)
18	Axis 3 Transducer Counts	Transducer location in raw counts
19	Axis 3 Status	Error and status bits
20	Axis 3 Drive	Drive output in raw D/A counts
21	Axis 3 Target Speed	Calculated axis speed (scaled)
22	Axis 4 Command Position	Command position (within set limits)
23	Axis 4 Target Position	Calculated instantaneous position (scaled)
24	Axis 4 Actual Position	Measured axis position (scaled)
25	Axis 4 Transducer Counts	Transducer location in raw counts
26	Axis 4 Status	Error and status bits
27	Axis 4 Drive	Drive output in raw D/A counts
28	Axis 4 Target Speed	Calculated axis speed (scaled)

VWRITE - Axis Dynamic Control Parameters

WY Register 6 is the V Memory address where the following parameters are stored:

V Memory Location	Parameter Name	Axis 1- 4 Dynamic Control Parameters Descriptions
1	Mode	Axis 1 mode select bits
2	Acceleration	Axis 1 rate or distance
3	Deceleration	Axis 1 rate or distance
4	Speed	Axis 1 requested speed during motion profile
5	Requested Position	Axis 1 destination position in position units
6	Command	Axis 1 command to be executed
7	Mode	Axis 2 mode select bits
8	Acceleration	Axis 2 rate or distance
9	Deceleration	Axis 2 rate or distance
10	Speed	Axis 2 requested speed during motion profile
11	Requested Position	Axis 2 destination position in position units
12	Command	Axis 2 command to be executed
13	Mode	Axis 3 mode select bits
14	Acceleration	Axis 3 rate or distance
15	Deceleration	Axis 3 rate or distance
16	Speed	Axis 3 requested speed during motion profile
17	Requested Position	Axis 3 destination position in position units
18	Command	Axis 3 command to be executed
19	Mode	Axis 4 mode select bits
20	Acceleration	Axis 4 rate or distance
21	Deceleration	Axis 4 rate or distance
22	Speed	Axis 4 requested speed during motion profile
23	Requested Position	Axis 4 destination position in position units
24	Command	Axis 4 command to be executed

V Memory Example

You can see a complete "picture" of V Memory on the next page. Specific V Memory addresses are used in this example, but the addresses you use in a given application will depend on your P/C ladder program.

VINIT refers to initialization parameters that you write to V Memory using the P/C. **VWRITE** refers to dynamic control parameters that you write to V Memory using the P/C. **VREAD** refers to status information written to V Memory by the TMC 188/40 and monitored by the P/C. One exception to these conventions is the **COMMAND** parameter in **VWRITE**. This location is bidirectional between the TMC 188/40 and P/C. It is written to and monitored by both the P/C and TMC 188/40. Please refer to pages 38 through 42 for more information on the **COMMAND** parameters.

During every scan of the P/C the **VREAD** and **VWRITE** parameters are transferred to and from the TMC 188/40. The **VINIT** parameters are moved from V Memory to the TMC 188/40 **only** when a 'P' command is issued using the **COMMAND** location of the **VWRITE** parameters. To inform the P/C the 'P' command was completed, the TMC 188/40 sets the **COMMAND** **VWRITE** V Memory location to 0. The P/C ladder program must monitor the **COMMAND** location after each command is issued to ensure it was completed.

Motion Control Parameters

The motion control parameters let you control an axis. You need a complete understanding of the parameters and status bits to fully utilize the TMC 188/40's features.

Read Only Parameters (VREAD)

COMMAND POSITION

The COMMAND POSITION is the REQUESTED POSITION with limit checking applied. That is, if the REQUESTED POSITION is outside the RETRACT or EXTEND LIMIT, the COMMAND POSITION will be set to the value of the limit, and the axis will go to the limit. The COMMAND POSITION is updated using the COMMAND parameter when a 'G' (Go) or 'P' (Initialize) command is issued.

TARGET POSITION

The TARGET POSITION is the calculated instantaneous position of the axis. When the axis is moving the TARGET POSITION is updated every two milliseconds as it moves toward the COMMAND POSITION. When an axis is stopped the TARGET POSITION will be the same as the COMMAND POSITION unless an error has occurred.

TRANSDUCER COUNTS

TRANSDUCER COUNTS is the axis position read directly from the transducer counters with no scaling.

ACTUAL POSITION

The ACTUAL POSITION is the measured position of the axis, updated every two milliseconds. The ACTUAL POSITION is calculated from the TRANSDUCER COUNTS with the following formula:

$$\text{ACTUAL POSITION} = \frac{\text{TRANSDUCER COUNTS} \times \text{SCALE}}{32768} \text{ XOR DIRECTION} + \text{OFFSET}$$

If the quadrature encoder (Q option) is installed, the ACTUAL POSITION is calculated using a different formula. Please refer Appendix C for more information.

AXIS STATUS WORD

The axis STATUS word contains 16 bits of information about the status of the axis. You can use six error bits (2, 3, 4, 7, 8, and 10) to trigger a halt or emergency stop of the axis when in Position or Speed modes. In Pressure or Home modes, the errors can only trigger an emergency stop.

BIT DESCRIPTIONS (See map on page 26)

Bits 2 through 5, 8, 10, and 14 through 16 are cleared whenever a 'G' command is given.

NOTE: Bit 1 is the Most Significant Bit, Bit 16 is the Least Significant Bit.

Bit 16 - AT COMMAND POSITION

This bit will be set when the difference between the ACTUAL POSITION and COMMAND POSITION is less than the value in the AT COMMAND POSITION field and the TARGET POSITION equals the COMMAND POSITION. This bit is latched and only cleared by a 'G' command.

NOTE: This bit will not be set if the axis halts outside the AT COMMAND POSITION window.

Bit 15 - NEAR COMMAND POSITION

This bit is similar to the AT COMMAND POSITION except it is set before or at the same time as the AT COMMAND POSITION bit - never later (that is, it has a larger window). The NEAR COMMAND POSITION bit is not latched. This bit can be used to increase throughput where the P/C can check the bit and start another process when it is set.

Bit 14 - HALTED

This bit is set when the axis has been given a HALT (H or 72D) command and the axis has stopped, or an error has caused a halt and the TARGET POSITION has stopped changing. While the axis is halted the NULL UPDATE timer will not run. The HALTED bit is cleared when a new command is issued to the axis.

NOTE: If the axis was halted because of an error and the move was started with a 'G' command, giving it another 'G' command will not clear the HALTED bit because the command has not changed. See Parameter Use on page 43 for more information.

NOTE: If the TMC 188/40 power is on while the axis power is off, or the drive output is disconnected, a HALT command should be issued to keep the null value from changing.

Bit 13 - ACCELERATING

This bit is set while the axis is accelerating.

Bit 12 - AT REQUESTED SPEED

This bit is set while the axis is moving at the speed specified by the SPEED parameter.

Bit 11 - DECELERATING

This bit is set while the axis is decelerating.

Bit 10 - STOPPED

This bit is set when the average speed of the axis is less than 500 position units per second and cleared when the speed is greater than 1000. This bit is used as an axis obstruction indicator.

Bit 9 - ACTIVE

This bit will toggle while the Motion Control Module is running. This bit is only present on axis one. The toggle rate is based on clock field 2. It is used for module testing purposes only.

Bit 8 - PARAMETER ERROR

This bit is set when an initialization parameter or control parameter is out of bounds. In some cases one parameter's limit will depend on the value of another parameter, so firm limits may not always be available. However, the MCM tries to replace the out of bounds value with one that is within range. By comparing the parameter values before and after the error bit was set, the errant parameter can be determined. This bit is cleared when any new command is issued.

Bit 7 - POSITION OVERFLOW / LIMIT SWITCH

This bit is set when the 16-bit ACTUAL POSITION goes beyond 65500 counts. With the Q option installed this bit is set when the external limit switch is open. The POSITION OVERFLOW bit is latched, and is cleared when any new command is issued.

Bit 6 - TRANSDUCER NOT RESPONDING

This bit indicates the transducer is not responding with valid data at least once every 10 milliseconds. The transducer data received is compared with previous data. If the two readings differ by more than 500 counts (1600 if the Q is option used), the new reading is assumed to be an error. When an error is detected the MCM makes an emergency stop, putting the axis in open loop and setting the drive output to the null value for that axis. It also makes the corresponding front panel axis LED (light emitting diode) glow red. Since the axis is in open loop mode, it will drift due to changes in the valves null value.

NOTE: The TRANSDUCER NOT RESPONDING bit (bit 6 of the STATUS word) is NOT latched. Transducer errors will always cause emergency stops, but with intermittent errors bit 6 may be cleared before the P/C detects it. In this case the HALTED bit will be set, but the axis will drift because of null changes in the valve.

Bit 5 - VALVE OUT OF NULL

Normally, when the drive output is zero volts or zero mA, the axis will not move. In hydraulic applications valves sometimes get dirty and the axis will move even when the drive output is zero. The Motion Control Module compensates for this problem, but if more than 10 percent of maximum drive output (± 205 counts) is required to hold a static position this error bit is set.

Bit 4 - OVERDRIVE

This bit is set when the calculated drive output exceeds the output range. Usually this error means the system does not have enough power to drive the axis at the requested speed. During the error the TMC 188/40 sets the drive output to maximum. The OVERDRIVE bit is latched and is cleared when a new command is issued.

Bit 3 - LEAD ERROR

LEAD is the condition where the ACTUAL POSITION gets ahead of the TARGET POSITION. This bit is set when the ACTUAL POSITION leads the TARGET POSITION by more than the amount specified by the MAXIMUM ERROR parameter. Lead errors can occur if the FEED FORWARD is too high or the axis response is too slow to respond to the output while ramping down. In the first case, the FEED FORWARD should be decreased. In the second case, the FEED FORWARD ADVANCE should be increased, or the DECELERATION RAMP should be lengthened. The LEAD ERROR bit is latched and is cleared when any new command is issued.

Bit 2 - LAG ERROR

LAG is the condition where the ACTUAL POSITION falls behind the TARGET POSITION. This bit will be set when the ACTUAL POSITION lags the TARGET POSITION by more than the amount specified by the MAXIMUM ERROR parameter. Lag errors can occur if the FEED FORWARD is too low or the FEED FORWARD ADVANCE is set too high. In the first case, the FEED FORWARD should be increased. In the second case, the FEED FORWARD ADVANCE should be decreased. The LAG ERROR bit is latched and is cleared when a new command is issued.

Bit 1 - PARAMETERS INITIALIZED

This bit is set after a parameter or 'P' command is sent to the TMC 188/40. Until this bit is set the axis will not respond to any GO or 'G' commands. This bit is reset whenever the module is reset.

STATUS Word Bit Map

The axis STATUS word contains 16 bits of information about the status of the axis. This table provides an easy method to convert hexadecimal numbers to bit patterns.

	F	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1
	E	1 1 1 0	1 1 1 0	1 1 1 0	1 1 1 0
Hexadecimal To	D	1 1 0 1	1 1 0 1	1 1 0 1	1 1 0 1
Binary Conversion	C	1 1 0 0	1 1 0 0	1 1 0 0	1 1 0 0
Table	B	1 0 1 1	1 0 1 1	1 0 1 1	1 0 1 1
	A	1 0 1 0	1 0 1 0	1 0 1 0	1 0 1 0
	9	1 0 0 1	1 0 0 1	1 0 0 1	1 0 0 1
	8	1 0 0 0	1 0 0 0	1 0 0 0	1 0 0 0
	7	0 1 1 1	0 1 1 1	0 1 1 1	0 1 1 1
	6	0 1 1 0	0 1 1 0	0 1 1 0	0 1 1 0
	5	0 1 0 1	0 1 0 1	0 1 0 1	0 1 0 1
	4	0 1 0 0	0 1 0 0	0 1 0 0	0 1 0 0
	3	0 0 1 1	0 0 1 1	0 0 1 1	0 0 1 1
	2	0 0 1 0	0 0 1 0	0 0 1 0	0 0 1 0
	1	0 0 0 1	0 0 0 1	0 0 0 1	0 0 0 1
	0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0

		* * *	* * *	*	
		| | | |	| * | | |	| | 1 | 1 | 1 |	| 1 | 1 | 1 | 1 |
		| 1 | 2 | 3 | 4 |	| 5 | 6 | 7 | 8 |	| 9 | 0 | 1 | 2 |	| 3 | 4 | 5 | 6 |
Bit Definition		| _ | _ | _ | _ |	| _ | _ | _ | _ |	| _ | _ | _ | _ |	| _ | _ | _ | _ |
-----		/ / / /	/ / / /	/ / / /	/ / / /
Parameters Initialized	--- 01	- / / / /	/ / / / /	/ / / / /	/ / / / /
*Lag Error	----- 02	-- / / /	/ / / / /	/ / / / /	/ / / / /
*Lead Error	----- 03	--- / /	/ / / / /	/ / / / /	/ / / / /
*Overdrive	----- 04	---- /	/ / / / /	/ / / / /	/ / / / /
			/ / / / /	/ / / / /	/ / / / /
Valve Out Of Null	----- 05	----- /	/ / / / /	/ / / / /	/ / / / /
**Transducer Not Responding	06	----- /	/ / / / /	/ / / / /	/ / / / /
*Position Overflow	07	----- /	/ / / / /	/ / / / /	/ / / / /
*Parameter Error	08	----- /	/ / / / /	/ / / / /	/ / / / /
			/ / / / /	/ / / / /	/ / / / /
Active (axis 1 only)	----- 09	----- /	/ / / / /	/ / / / /	/ / / / /
*Stopped	----- 10	----- /	/ / / / /	/ / / / /	/ / / / /
Decelerating	----- 11	----- /	/ / / / /	/ / / / /	/ / / / /
At Requested Speed	----- 12	----- /	/ / / / /	/ / / / /	/ / / / /
			/ / / / /	/ / / / /	/ / / / /
Accelerating	----- 13	----- /	/ / / / /	/ / / / /	/ / / / /
Halted	----- 14	----- /	/ / / / /	/ / / / /	/ / / / /
Near Command Position	---- 15	----- /	/ / / / /	/ / / / /	/ / / / /
At Command Position	----- 16	----- /	/ / / / /	/ / / / /	/ / / / /

* In Position or Speed modes, can cause a halt or emergency stop if the corresponding bits are clear in the appropriate mask register. In Pressure or Home modes, can cause only an emergency stop if the corresponding bits are cleared.

** WILL cause an emergency stop no matter how the mask register is set.

DRIVE

Drive is the output to the actuator. The 12 bit digital value output (0 to 4095, full negative drive to full positive drive) will generate up to a ± 10 volt or ± 100 mA output, depending on module configuration. NULL DRIVE should be about 2048. If it is below 1844 or above 2252, the VALVE OUT OF NULL bit will be set.

NOTE: There are no pots on the TMC 188/40 to adjust valve null. All this is done in software (see NEW NULL below and NULL UPDATE on page 28).

TARGET SPEED

Target Speed is the calculated speed at which the axis should be moving at any point in time.

Initialization Parameters (VINIT)

NEW NULL (Default: 0 (use previous null) Range: 1844 to 2252)

Sometimes you may want to set the internal null value of an axis. The Motion Control Module will set the initial null to 2048 on startup, which should be neutral drive. In reality, the true value for null may be slightly different and therefore cause a small bump in the position of the axis. If the real value for null is between 1844 and 2252, the value can be entered on startup using the RESTORE NULL command so the bump in position will not occur. See NULL UPDATE parameter description. If a value outside the range is entered it will be ignored and the current null value will be used.

ESTOP MASK (Default: FFFFH; Emergency stop disabled)

The bits in the ESTOP MASK field have a one-to-one correspondence with the bits in the STATUS word. The bits in this field are used to mask the emergency stop which occurs when an error bit (2, 3, 4, 7, 8, or 10) are set in the STATUS word. To enable an emergency stop on an error condition, the appropriate bit must be cleared in both the HALT MASK and the ESTOP MASK. During an emergency stop the drive output is immediately set to the current null value and left there until a new command is issued.

NOTE: During an EMERGENCY STOP or a HALT, the axis will drift due to changes in the valve nulls. The P/C should turn off drive power when the MCM reports an EMERGENCY STOP or HALT.

HALT MASK (Default: 0000H; HALT enabled)

Like the ESTOP MASK, the bits in the HALT MASK field have a one-to-one correspondence with the bits in the STATUS word. The bits in this field are used to mask out the automatic halt that occurs when an error bit (2, 3, 4, 7, 8, or 10) is set in the STATUS word. The default for this field is all zeros (00000), so any error will cause a halt. For simple applications and to learn how to use the TMC 188/40, this field should be left at zero. For applications where two or more axes are moving together, the P/C should mask the automatic halts and take responsibility for handling any errors. See P/C Error Handling on page 15.

FEED FORWARD ADVANCE (Default: 0)

An axis will not respond to a change in the drive output until some time has passed. This causes the error between the actual and target positions to be larger for axes that are moving large masses or have slow valves. The MCM can advance the feed forward portion of its drive output by the number of milliseconds specified by the FEED FORWARD ADVANCE.

FEED FORWARD ADVANCE is implemented by delaying the TARGET POSITION and TARGET SPEED of the axis with respect to the feed forward portion of the drive output by the FEED FORWARD ADVANCE time. This can compensate for an axis with a slow response time so the

target and actual positions track more closely. Always use the minimum amount to get the desired results. Both TARGET POSITION and TARGET SPEED will appear to be delayed by the FEED FORWARD ADVANCE time relative to the drive output. You could also call this a target delay time.

NOTE: If the motion on two or more axes is being coordinated, FEED FORWARD ADVANCE should be set the same on all coordinated axes.

NULL UPDATE (Default: 500; Range: 10 - 65535, 0 = disabled)

NULL UPDATE is the time in milliseconds between null drive value updates. Null drive on an ideal system should be zero volts (or 0 mA) or 2048 output counts to the digital to analog converter (see DRIVE on page 27). In a real system, a zero volt output may cause the axis to drift slowly so the real value of null drive is something other than 2048.

When the axis is AT COMMAND POSITION and not halted, the ACTUAL POSITION is compared with the TARGET POSITION at the interval specified by the NULL UPDATE. If the ACTUAL POSITION is greater than the TARGET POSITION, the value of null drive is decreased by one. If the ACTUAL POSITION is less than the TARGET POSITION, the value of null drive is increased by one. This minimum value depends on the response of the system. For slow valves, use a larger value in the range of 500-1000.

NOTE: The system will oscillate if the NULL UPDATE time is too short, so decrease this number with caution. This value is only meant to correct for the imperfections in the axis' null, not to aid the position error gain in quickly getting the ACTUAL POSITION to AT COMMAND POSITION.

DITHER (Default: 0)

The DITHER value is the amplitude, in percent of full drive, of a 250 Hz square wave that is superimposed on the normal drive output. A value of 10 will cause a square wave of 10% of the drive to be applied on top of the normal output. This keeps the valve free and improves valve response. Leave this parameter at zero unless the valve manufacturer recommends dither be used. DITHER is applied only when the axis is not moving.

HYSTERESIS (Default: 0; Range: 0 to 615)

HYSTERESIS compensates for drive deadband. Some valves and drives will not react to small changes in output around the null drive value. The HYSTERESIS value is added or subtracted from the drive output, depending on the direction of travel. The drive output should then be outside the deadband.

To find the correct HYSTERESIS value, record the NULL UPDATE value then set it to 100. Send a 'P' command, then note the variation in DRIVE value. The correct HYSTERESIS value is half the DRIVE variation. For example, if the DRIVE varies from 2030 to 2060, the variation is 30. Half of 30 is 15, so put 15 in the HYSTERESIS field. When you finish, set the NULL UPDATE to its original value.

CAUTION: The drive will oscillate if the HYSTERESIS value is too large.
--

STATIC GAIN (Default: 50)

STATIC GAIN specifies the amount of drive added to the drive output for a given amount of position error while the axis is at rest (the AT COMMAND POSITION bit set). STATIC GAIN is given in number of counts of drive per 100 units of error. The STATIC GAIN should be set as high as possible without causing the axis to oscillate. See MAX ERROR parameter on page 32.

CAUTION: Increase the STATIC GAIN gradually. Excessive gain can cause oscillations which could cause damage and injury.

EXTEND GAIN (Default: 50)

EXTEND GAIN is similar to the STATIC GAIN, except it applies when the axis is extending. The gain while moving can usually be a little higher than at rest. This will allow tighter control of the axis while moving. (Extending is the direction that returns increasing TRANSDUCER COUNTS.)

RETRACT GAIN (Default: 50)

The RETRACT GAIN is similar to the EXTEND GAIN except it is used only when the axis is retracting.

INTEGRAL GAIN (Default: 50)

The INTEGRAL GAIN is used to adjust the drive developed by the integrator while the axis is moving. The INTEGRAL GAIN field should be adjusted after the feed forwards have been set to optimal values. Using the integrator before the feed forwards have been set properly will cause the system to overshoot the command position.

When a 'G' command is issued, the integrator adds the position error (ACTUAL POSITION - TARGET POSITION) to an accumulator every 2 milliseconds. As long as the error is not approaching zero or has not changed sign, it is added to the accumulator. When the axis starts ramping down, the accumulator is decremented at a rate calculated to bring the value to zero when the axis stops. The drive provided by the integrator is given by:

$$\text{Integral Drive} = \frac{\text{INTEGRAL GAIN} \times \text{Accumulated error}}{10,000}$$

DIFFERENTIAL GAIN (Default: 0)

The DIFFERENTIAL GAIN field is used to control the differentiator. The differentiator can be used on systems that have slow response.

$$\text{Differentiator Drive} = \frac{(\text{TARGET SPEED} - \text{ACTUAL SPEED}) \times \text{DIFFERENTIATOR GAIN}}{100}$$

CAUTION: To avoid oscillation during initial tuning, start with low values such as 1.

EXTEND FEED FORWARD (Default: 100)

NOTE: Use the 'F' command to automatically set the feed forward value. See page 38.

Feed forward is an open loop drive that is proportional to the TARGET SPEED of the axis. This value is expressed in terms of counts of drive per 10,000 position units per second.

EXTEND FEED FORWARD drive is added to the drive output only when the axis is extending. The drive provided by the EXTEND FEED FORWARD is determined as follows:

$$\text{Feed Forward Drive} = \frac{\text{EXTEND FEED FORWARD} \times \text{SPEED}}{10,000}$$

You can find the appropriate value for EXTEND FEED FORWARD by making a move with the axis using a SPEED of 10,000. The amount of output drive required to maintain this speed should be used as the EXTEND FEED FORWARD parameter. If, after the parameter has been set, lag errors occur, the feed forward is too small or the system response is too slow. If lead errors occur, the feed forward is too large or the system response is too slow. If the 'F' command is sent after a valid move (one without overdrive or a null error), the MCM will automatically adjust the EXTEND FEED FORWARD parameter.

RETRACT FEED FORWARD (Default: 100)

See EXTEND FEED FORWARD. Used only when retracting.

SCALE (Default: 32768; Range 0 to 65535)

TIP: Delta's DCSMON provides an easy way to work with SCALE. Use DCSMON's commands P0 and P1 to help calculate SCALE, OFFSET and DIRECTION.

NOTE: SCALE is used differently when either the quadrature or analog options are used. If these options are installed, see Appendix B or C for more information.

In linear position applications, SCALE can be used for two purposes: transducer compensation or distance translation. Differences in magnetostrictive transducers are compensated by using the SCALE parameter. Each transducer will indicate a different physical distance for a given interrogation cycle. Usually, only a small change from the default value is necessary to compensate the transducer.

A second and more useful feature of SCALE is its ability to translate a fixed physical distance to usable position units (position units from thousandths to hundreds or vice versa). The translation is done using a combination of SCALE and recirculation selection (see page 49 for more information on recirculation).

SCALE can be viewed as the number of position units for every 32768 TRANSDUCER COUNTS. The SCALE parameter is used to convert TRANSDUCER COUNTS to position units (thousandths of an inch, tenth of a millimeter, etc.). It is defined as:

$$\text{SCALE} = \frac{\Delta\text{Position Units}}{\Delta\text{Transducer Count}} \times 32768$$

Linear transducers have a calibration number (typically 9.1 μs per inch) and the TMC 188/40 has a 27.75 MHz oscillator for transducer position measurement counters. To determine length per transducer count for a linear transducer use the following formula:

$$\text{Length/transducer count} = \frac{\text{Position Units per inch}}{\text{Cal Number} \times 27.75 \times \text{Number of Recirculations}}$$

The SCALE parameter can also be adjusted or fine tuned by using position readings from the TMC 188/40 and actual physical measurements in the following formula:

$$\text{SCALE} = \text{Old SCALE} \times \frac{\text{Measured Position 1} - \text{Measured Position 2}}{\text{Position Reading 1} - \text{Position Reading 2}}$$

Where:

OLD SCALE is the default SCALE or a previously calculated SCALE.

Measured position is in position units (thousandth of an inch, etc.) based on a physical measurement of the system. Position readings are taken using the ACTUAL POSITION parameter.

NOTE: If you get a negative value for SCALE, use the absolute value and change the DIRECTION parameter from 0 to -1 (or vice versa).

SCALE Calculation Examples

Example 1

For a system using a magnetostrictive transducer with a calibration number of 9.0110 μs per inch, a position unit of 0.001 inch, and four recirculations, the SCALE will be:

$$\frac{\text{Position Units}}{\text{TRANSDUCER COUNTS}} = \frac{1000(\text{Position Units Per Inch})}{9.0110 \times 27.75 \times 4} = 0.99978$$

$$\text{SCALE} = 0.99978 \times 32768 = 32761$$

Example 2

For a system using a magnetostrictive transducer with a calibration number of 9.0110, a position unit of 0.1 millimeter, and one recirculation, the SCALE will be:

$$\frac{\text{Position Units}}{\text{TRANSDUCER COUNTS}} = \frac{254(\text{Position Units Per Inch})}{9.0110 \times 27.75 \times 1} = 1.0158$$

$$\text{SCALE} = 1.0158 \times 32768 = 33285$$

Fine Tuning for Example 2

Measured Position 1 = 1 meter = 10,000 position units

Position Reading 1 = 10873

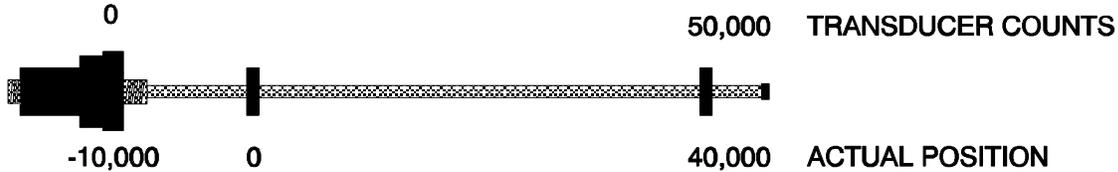
Measured Position 2 = 2 meters = 20,000 position units

Position Reading 2 = 20805

$$\text{SCALE} = 33285(\text{Old SCALE}) \times \frac{10000 - 20000}{10873 - 20805} = \frac{-10000}{-9932} \times 33285 = 33513$$

OFFSET (Default: 0)

OFFSET is used to offset the ACTUAL POSITION with respect to the transducer zero. The OFFSET is specified in position units and is equal to the ACTUAL POSITION at zero TRANSDUCER COUNTS.



CAUTION: If the SCALE is incorrect, an OFFSET value will have the correct effect at only a single point on the axis. Before adjusting the OFFSET, confirm that the SCALE is correct.

When using OFFSET, you must be familiar with the limitations of 16 bit math. See Appendix D.

DIRECTION (Default: 0) Possible options: 0 and -1

The DIRECTION parameter determines whether the ACTUAL POSITION increases or decreases as the TRANSDUCER COUNTS increase. A zero produces a direct relation between ACTUAL COUNTS and TRANSDUCER COUNTS, while a -1 (65535 or 0FFFFH) results in an inverse relationship between the two counts. The ACTUAL POSITION is determined as follows:

$$\text{ACTUAL POSITION} = \frac{\text{TRANSDUCER COUNTS} \times \text{SCALE}}{32768} \text{ XOR DIRECTION} - \text{OFFSET}$$

XOR has the effect of multiplying by -1 when DIRECTION = -1 and multiplying by 1 when DIRECTION = 0.

NOTE: When the DIRECTION parameter is changed, the sign of the EXTEND LIMIT, RETRACT LIMIT and OFFSET must also be changed. Extending is always the direction which increases TRANSDUCER COUNTS.

CAUTION: When using the DIRECTION parameter, you must be familiar with the limitations of 16 bit math.

MAX ERROR (Default: 250)

The MAX ERROR determines how large the difference between the TARGET POSITION and ACTUAL POSITION can get before the LAG ERROR or LEAD ERROR bits are set in the STATUS word. The MAX ERROR also limits the proportional term of the drive output due to a position error to:

$$\text{Maximum Proportional Drive} = \frac{\text{Proportional Gain} \times \text{MAX ERROR}}{100}$$

Proportional Gain is the EXTEND or RETRACT GAIN parameters.

AT COMMAND POSITION (Default: 50)

AT COMMAND POSITION specifies the size of a window around COMMAND POSITION. When the ACTUAL POSITION gets within this window, and the TARGET POSITION equals the COMMAND POSITION, the STATUS word's AT COMMAND POSITION bit is set.

NEAR COMMAND POSITION (Default: 0)

The NEAR COMMAND POSITION is similar to the AT COMMAND POSITION. The NEAR COMMAND POSITION window should be wider than the AT COMMAND POSITION window (unless you want to ignore it, when you would set it to 0). This parameter is useful in letting the P/C know the axis is out of the way of some other equipment.

EXTEND LIMIT (Defaults to ACTUAL POSITION on power-up)

The EXTEND LIMIT specifies the maximum value the TMC 188/40 will allow as a COMMAND POSITION. (When DIRECTION = -1, this is the minimum value.) REQUESTED POSITIONS that exceed this value will be restricted to it. The EXTEND LIMIT is given in position units.

NOTE: The EXTEND LIMIT must be changed when the DIRECTION, SCALE or OFFSET parameters are changed. Also, on power-up the EXTEND LIMIT defaults to the current position of the axis. New EXTEND and RETRACT LIMITS must be issued with a 'P' command before moving the axis.

RETRACT LIMIT (Defaults to ACTUAL POSITION on power-up)

The RETRACT LIMIT specifies the minimum value the TMC 188/40 will allow as a COMMAND POSITION. (When DIRECTION = -1, this is the maximum value.) REQUESTED POSITIONS below this value will be restricted to it. The RETRACT LIMIT is given in position units. The RETRACT LIMIT must be changed when the SCALE, OFFSET or DIRECTION parameters are changed.

Dynamic Control Commands (VWRITE)

You can change the motion control command words MODE, ACCELERATION, DECELERATION, SPEED, REQUESTED POSITION and COMMAND while the axis is in motion.

MODE (Default: 0) (See page 36 for Mode Word bit map)

Nine bits in the MODE word are used to control the way the Motion Control Module responds to control commands and parameters. The modes are selected by setting (to a '1' or high state) the bits in the MODE word. Bit 16 is the least significant bit and bit 1 is the most significant.

BITS 15 AND 16 - ACCELERATION AND DECELERATION MODE SELECT

These two bits of the MODE word select among four acceleration/deceleration (A/D) modes:

		Bit #	
		15	16
A/D Mode 0	(Distance to/from 0 speed)	0	0
A/D Mode 1	(Ramp rate)	0	1
A/D Mode 2	(Distance to specified speed)	1	0
A/D Mode 3	(Time to specified speed)	1	1

In Mode 0, the acceleration and deceleration parameters define the ramp distance in position units to or from zero speed. For example, if the position units are thousandths of an inch and the deceleration parameter is 1000, the axis will ramp to zero speed in 1 inch. The acceleration or deceleration rate is defined as:

$$\text{Rate} = \frac{\text{SPEED}^2}{2000 \times \text{Distance}} \quad \text{for SPEED} > 0$$

Where SPEED is the requested speed and Distance is the acceleration or deceleration parameter.

In Mode 1, the parameters define the ramp rate (that is, distance/second/second or acceleration/ deceleration distance. Distance is defined as:

$$\text{Distance} = \frac{\text{SPEED}^2}{2000 \times \text{Rate}} \quad \text{for SPEED} > 0$$

Where Rate is the acceleration or deceleration parameter.

NOTE: In both Mode 0 and Mode 1, the actual acceleration and deceleration distances are defined as:

$$\text{Actual Distance} = \text{Decel} \times \frac{(\text{Present SPEED})^2}{(\text{REQUESTED SPEED})^2}$$

Where Decel is the acceleration or deceleration distance, Present Speed is the current speed of the axis, REQUESTED SPEED is the new speed, and both SPEED terms are greater than 0.

If the REQUESTED SPEED is larger than the Present SPEED, the Actual Distance will be shorter than the specified Decel distance. If the REQUESTED SPEED is smaller than the Present SPEED, the Actual Distance will be longer than the Decel distance.

If you want to accelerate from one speed to another, use Mode 2.

In Mode 2, the parameters define the distance to the specified SPEED. For moves to and from 0 speed, Mode 2 is equivalent to Mode 0.

In Mode 3, the parameters define the time to the specified speed.

BIT 14 - RESERVED

This bit must be set to 0 for compatibility with previous versions of firmware.

BIT 13 - SIMULATION MODE

When this bit is set, the drive output is set to null and the transducer inputs are ignored. Internally the TARGET POSITION is used as the ACTUAL POSITION. This mode is used for debugging.

BIT 12 - SYNCA (SYNCHRONIZATION BIT A)

When this bit is set, it causes the axis to move in synchronization with other axes on the module which also have this bit set. The axes are synchronized as follows:

- A) The axis with the longest move will move at 100% of the SPEED parameter.
- B) The slave axes follow a profile determined by the length of their moves relative to the master axis, with their speeds equal to the ratio of their move length to the longest move length. All axes will accelerate together, move at their respective speeds together, and decelerate together, arriving at their different COMMAND POSITIONS at the same time.
- C) If any axis is halted by an error condition, all axes will halt together.

BIT 11 - SYNCB (SYNCHRONIZATION BIT B)

This bit has the same effect as bit 12 above. It is used when a second pair of axes must be synchronized on the same module.

BIT 10 - PRESSURE MODE (ANALOG OPTION ONLY)

When this bit is set the axis operates in pressure mode using analog feedback. See the TMC 188/40A information in Appendix B for more information about the pressure mode.

BIT 7 - SPEED CONTROL (QUADRATURE OPTION ONLY)

When this bit is set the axis is placed in Speed Control mode; that is, the Motion Control Module will maintain a specified speed rather than a specified position. This mode can be used only if the quadrature option (QSBX) is installed in the Motion Control Module.

Acceleration/Deceleration modes 0 and 2 are not allowed; use only modes 1 or 3. Therefore valid Speed Control mode words are n2n1 or n2n3, where 'n' can be any mode defined by bits 1 through 4 and 9 through 12, the '2' selects Speed Control mode, and the '1' or '3' select modes 1 or 3. The Acceleration and Deceleration fields are entered in units of inches per second per second.

The meaning of REQUESTED POSITION changes when in Speed Control mode. It defines the direction of rotation, and can only be set to 0 (zero) or -1. '0' makes the axis rotate so the counts increase, while '-1' makes the axis rotate so the counts decrease.

The SPEED and REQUESTED POSITION (direction) can be changed while the axis is moving. Stop the axis by putting a 0 (zero) in the SPEED field.

NOTE: When in Speed Control mode the axis does not maintain position information. To return to Position mode you **must** first enter a 'Z' command, then clear bit 7. See the Z command in Appendix C for more information.

The 'H' command is a Position mode command; while in Speed Control mode an 'H' command is translated into a 'G' command with a requested speed of 0.

The Speed Control mode also has a pressure or torque limit capability. To use it, the Motion Control Module must have the ASBX module installed (see Appendix B). Before commanding a move, the PRESS GAIN, PRESS SCALE, PRESS OFFSET, and PRESS CMD must be entered and sent to the module with a 'P' (Parameter) command. Pressure or torque limiting is entered when the PRESS ACTUAL is greater than or equal to the PRESS CMD. LEAVE THE PRESSURE VALUES AT THE DEFAULT VALUES IF YOU ARE NOT USING PRESSURE OR TORQUE LIMITING.

For best performance the axis should be tuned in Position mode. The critical parameters are the FEED FORWARD and the DIFFERENTIAL terms. The PID routine uses only speed terms for computing output to the drive. This avoids windup due to accumulated position errors. The drive output is computed as follows:

$$\begin{aligned} \text{DRIVE OUTPUT} = & \frac{\text{TARGET SPEED} \times \text{FEED FORWARD}}{10000} + \\ & \frac{(\text{TARGET SPEED} - \text{ACTUAL SPEED}) \times \text{DIFFERENTIAL GAIN}}{100} + \\ & \frac{(\text{Sum of TARGET SPEED} - \text{ACTUAL SPEED}) \times \text{PROPORTIONAL GAIN}}{50000} \end{aligned}$$

BIT 1 - Graph Disable

When this bit is set the controller will not log graph data during a move. This is useful for troubleshooting long sequences of moves.

Mode Word Bit Map

The axis Mode word contains 16 bits of information. This hexadecimal table provides an easy way to convert hexadecimal numbers to bit patterns.

Hexadecimal To Binary Conversion Table	F	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1
	E	1 1 1 0	1 1 1 0	1 1 1 0	1 1 1 0
	D	1 1 0 1	1 1 0 1	1 1 0 1	1 1 0 1
	C	1 1 0 0	1 1 0 0	1 1 0 0	1 1 0 0
	B	1 0 1 1	1 0 1 1	1 0 1 1	1 0 1 1
	A	1 0 1 0	1 0 1 0	1 0 1 0	1 0 1 0
	9	1 0 0 1	1 0 0 1	1 0 0 1	1 0 0 1
	8	1 0 0 0	1 0 0 0	1 0 0 0	1 0 0 0
	7	0 1 1 1	0 1 1 1	0 1 1 1	0 1 1 1
	6	0 1 1 0	0 1 1 0	0 1 1 0	0 1 1 0
	5	0 1 0 1	0 1 0 1	0 1 0 1	0 1 0 1
	4	0 1 0 0	0 1 0 0	0 1 0 0	0 1 0 0
	3	0 0 1 1	0 0 1 1	0 0 1 1	0 0 1 1
	2	0 0 1 0	0 0 1 0	0 0 1 0	0 0 1 0
	1	0 0 0 1	0 0 0 1	0 0 0 1	0 0 0 1
	0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0

		|1|2|3|4|	|5|6|7|8|	|9|0|1|2|	|3|4|5|6|
Bit Definition		| | | |	| | | |	| | | |	| | | |
-----		/ / / /	/ / / /	/ / / /	/ / / /
Graph Disable	01	- / / / /	/ / / /	/ / / /	/ / / /
Reserved	02	-- / / /	/ / / /	/ / / /	/ / / /
Reserved	03	--- / /	/ / / /	/ / / /	/ / / /
Reserved	04	---- /	/ / / /	/ / / /	/ / / /
			/ / / /	/ / / /	/ / / /
Reserved	05	----- /	/ / / /	/ / / /	/ / / /
Reserved	06	----- /	/ / /	/ / / /	/ / / /
Speed Control	07	----- /	/ / / /	/ / / /	/ / / /
Reserved	08	----- /	/ / / /	/ / / /	/ / / /
			/ / / /	/ / / /	/ / / /
Reserved	09	----- /	/ / / /	/ / / /	/ / / /
Pressure Mode	10	----- /	/ / /	/ / / /	/ / / /
Synchronization Bit B	11	----- /	/ /	/ / / /	/ / / /
Synchronization Bit A	12	----- /	/ / / /	/ / / /	/ / / /
			/ / / /	/ / / /	/ / / /
Simulation Mode	13	----- /	/ / / /	/ / / /	/ / / /
Reserved	14	----- /	/ / /	/ / / /	/ / / /
Accel and Decel Mode	15	----- /	/ /	/ / / /	/ / / /
Accel and Decel Mode	16	----- /	/ / / /	/ / / /	/ / / /

ACCELERATION (Default: 1000)

This field determines the acceleration of the axis. The field works in two ways depending on the setting of bits 15 and 16 in the MODE word. If the bits are clear (Acceleration/Deceleration Mode 0), the value in these fields is a distance expressed in position units. If the SCALE is set so one position unit equaled 0.001 inch, then a value of 5000 represents a ramp of 5.000 inches.

If bit 15 is clear and bit 16 is set (A/D Mode 1), this field is an acceleration or deceleration rate and is expressed in 1000 position units/sec/sec. If the SCALE is set so one position unit equals 0.001 inch, then a value of 200 represents an acceleration rate of 200 inches/sec/sec.

Ramping distance (expressed in position units) is simpler to use for applications where the SPEED does not change. The relationship between the ramping distance, acceleration and speed is:

$$\text{Ramp Distance} = \frac{\text{Speed}^2}{\text{Acceleration Rate} \times 2000}$$

$$\text{Acceleration Rate} = \frac{\text{Speed}^2}{\text{Ramp Distance} \times 2000}$$

See pages 33 to 36 for more information about the MODE word.

DECELERATION (Default: 1000)

This field is similar to the ACCELERATION field except it specifies the deceleration ramp or deceleration rate.

SPEED (Default: 1000)

The SPEED parameter sets the constant speed to be achieved after acceleration. The SPEED is expressed in position units/second. If the SCALE is set so one position unit equals 0.001 inch, a speed of 25 inches per second is expressed as 25000.

NOTE: Changing the SPEED without changing the ACCELERATION and DECELERATION distances (expressed in position units) will change the acceleration and deceleration rates. See the control equations on page 72. If you set the SPEED to zero, the axis will do the same as a halt. Use the HALT command rather than set the SPEED to zero.

REQUESTED POSITION

The REQUESTED POSITION is the position the axis is to move to. This value is bounds-checked by the TMC 188/40 using the EXTEND LIMIT and RETRACT LIMIT and is then used as the COMMAND POSITION value. It is also used as a parameter for other commands (E, O, and C).

COMMAND

The following commands are accepted by the TMC 188/40. If you are using DCSSMON, the monitor program supplied with the Motion Control Module (MCM), hold down the Alt key and press:

'C' - Clear Events (43H, 67D) - Event Control Firmware Only

This command clears the specified bits in the Event Register. All bits set to zero in the Parameter Field will be cleared in the Event Register, allowing all new event sequences to be triggered.

For example, if the requested position field is 0FFBF and an Alt-C is sent to the MCM, then bit 10 in the Event Register will be cleared:

```
xx4xH = xxxx xxxx 0100 xxxxB
FFBFH = 1111 1111 1011 1111B
          ---^---
          Bit 10
```

Note: The Event Ready bit should be set on all axes that have bit 10 unmasked.

'E' - Trigger Events (45H, 69D) - Event Control Firmware Only

This command sets bits in the Event Register, causing event sequences to be triggered.

'F' - Adjust Feed Forward (46H, 70D)

The 'F' command is used to automatically adjust the feed forward values. After a move is made where the axis reaches constant speed and the overdrive bit is not set, an 'F' command will set the feed forward for the direction of the last move. This command is quick and easy, and it will allow the system to adjust for changes in system dynamics. It also makes initial tuning easier.

CAUTION: The 'F' command will produce erroneous results if the axis oscillates or doesn't reach constant speed during the move. In this case you can use the Sum of Errors Squared term to adjust the system. See the DCSSMON manual for information about this term.

'G' - Go to REQUESTED POSITION (47H, 71D)

The P/C must make sure all VWRITE parameter words are valid when the 'G' or GO command is given. Normally, once the MODE, ACCELERATION, DECELERATION and SPEED are set, only the REQUESTED POSITION need be changed. Once set, a 'G' put in the COMMAND word will move the axis.

NOTE: The 'G' command can be given while the axis is in motion. If you do this, the Motion Control Module will ramp to the new speed at the rate specified by the ACCELERATION and DECELERATION parameters.

If you have issued a Shift-@ command (quadrature HOME command), do not issue a 'G' until the axis arrives at the HOME position (status bit 16 = 1).

'H' - Halt (48H, 72D)

The HALT command is used for emergency stops, jogging the axis, and preventing the integrator from winding up when the drive power is off. If the axis is moving and an 'H' is issued, the axis will ramp down until it stops, and null updates will be disabled. The STATUS word can be used to determine the difference between a halted (caused by a control error) or AT COMMAND POSITION (caused by the 'H' command). You can jog an axis by alternating GO and HALT commands. To prevent the integrator from winding up, use the 'H' command to stop the axis when drive power is off.

'J' - Jump (relative move) (4AH, 74D)

This command moves the axis the distance specified in the REQUESTED POSITION field. For example, if the REQUESTED POSITION field is 1000, a 'J' command will extend the axis 1000 position units from its target position. A -1000 will retract it 1000 position units.

'K' - Disable Drive Output (4BH, 75D)

This command immediately sets the drive output to the current null value. This is equivalent to an emergency stop. The output will remain at null until a new command is issued.

NOTE: The K command, an Emergency Stop, and the Transducer Not Responding error all put the axis in Open Loop Mode. When in Open Loop Mode, the axis will drift due to valve null errors. The axis remains in Open Loop mode until a 'G' or 'P' command is issued.

'M' - Mask Events (4DH, 77D)) - Event Control Firmware Only

This command is used to mask or unmask events. The parameter field contains a pattern of bits designating which events in the Event Register are disabled. Bits set to 1 in the mask are disabled in the Event Register.

'N' - No-op (4EH, 78D)

This command is used when giving manual commands to an axis. The 'N' is entered first, the data for the axis is modified, then the 'N' is changed to another valid command. This is necessary because it is impossible to manually modify both the command and the data for an axis before the first one is sent to the MCM.

'Shift O' - Open Loop (4FH, 79D)

CAUTION: Use the Open Loop command with care. When operating open loop all safety features of the TMC 188/40 are disabled.

The Open Loop command allows the Programmable Controller to directly specify values for the analog output. The output has a range of -2048 to +2047, where -2048 is full retract and 2047 is full extend drive.

The 'O' command uses the following parameters from the last open loop profile specified:

ACCELERATION and DECELERATION control the rate at which the drive output ramps to the requested value. ACCEL and DECEL are in units of drive per 2 millisecond time interval.

SPEED is used as the limiting value for the drive output.

REQUESTED POSITION specifies the amount of drive to be added to (or subtracted from) the current null value.

To command the TMC 188/40 to output 10% negative drive, you would enter -205 in the REQUESTED POSITION field and 79 (O) in the COMMAND field. A 5 in the

ACCELERATION field would cause the module to ramp the output at 5 units every 2 milliseconds, or 82 milliseconds to ramp to -205.

'P' - Initialize Parameters (50H, 80D)

This command should be the first command given after startup. All initialization parameters are updated when a 'P' command is given. When a 'P' command is given, the TMC 188/40 will wait a few milliseconds to get the ACTUAL POSITION of the axis. This position is then copied into the TARGET POSITION and COMMAND POSITION. This keeps the axis from moving until a 'G' command is issued.

Once the 'P' command is issued, three P/C scans are required before another command can be issued.

'Q' - Quit Events (51H, 81D) - Event Control Firmware only

This command aborts the chain of steps started by an event.

'R' - Restore Null (52H, 82D)

The RESTORE command restores the last SAVED value of null. This value will be 2048 if no previous SAVE or NEW NULL (see page 27) was done.

'S' - Save Null (53H, 83D)

The SAVE command saves the current value of the null so it may be recalled later by a RESTORE command.

'Y' - Yank graph data to VMEM (59H, 89D)

The diagnostic plots stored in the MCM can be loaded into VMEMORY using the 'Y' command. The destination V Memory address is specified in the REQUESTED POSITION field.

'y' - Start graph data collection (79H, 121D)

This command starts graph data collection.

'Z' - Zero the quadrature counts (5AH, 90D) - Quadrature option only

When the axis is stopped, the 'Z' command sets the axis ACTUAL POSITION, TARGET POSITION, and COMMAND POSITION to the values specified in the REQUESTED POSITION field, and the hardware counters on the QSBX/40 are set to the count which represents the REQUESTED POSITION.

When the axis is moving, the 'Z' command sets the ACTUAL POSITION to the REQUESTED POSITION, does not change the COMMAND POSITION, and updates the TARGET POSITION as follows:

$$\text{new TARGET} = \text{old TARGET} - (\text{ACTUAL POSITION} - \text{REQUESTED POSITION})$$

NOTE: You must use an OFFSET that is smaller than the value in the REQUESTED POSITION field. The REQUESTED POSITION value must be between the EXTEND and RETRACT limits. This gives a margin around the HOME position where the axis can be without exceeding the limits of the ACTUAL POSITION range.

'=' - Copy Event Program (3DH, 61D) - Event Control Firmware only

This command copies the Event Control Firmware program from VMEMORY to the Motion Control Module.

'^' - Set Pressure Command (5EH, 94D) - Analog option only (In Event Step Table)

This command sets the PRESS CMD parameter. The target pressure will ramp to the PRESS CMD value at the rate specified by PRESS RAMP.

'\` - Pressure Ramp Rate (5CH, 92D) - Analog option only (In Event Step Table)

This command sets the rate at which the pressure target ramps to a new command pressure. The units are 0.01 pressure units per 2 milliseconds. A value of 200 in the PRESS RAMP field will ramp the pressure target by 1,000 units in 1 second.

'_ ' - Set Pressure Low (5FH, 95D) - Analog option only (In Event Step Table)

This command sets the pressure below which the Motion Control Module changes from Pressure Control to Position Control.

In DCSMON, **do not** press Alt for the following command:

'Shift @' - Quadrature Home (40H, 64D) - Quadrature option only

This command automatically moves the axis, attempting to find the HOME position on a quadrature axis. The AT COMMAND POSITION bit must be set and the axis initialized (with a 'P' command) before the MCM will accept the '@' command. When the HOME input is true, the ACTUAL POSITION is set to the value in the REQUESTED POSITION field.

NOTE: The FEED FORWARD, SPEED, MODE, ACCEL, and DECEL parameters must be set to desired values when the '@' command is issued. During the '@' routine the axis moves open loop and the drive value is calculated as FEED FORWARD x SPEED / 10000.

The '@' command works as follows:

- 1) The AT COMMAND POSITION bit is cleared and the axis retracts until one of the following conditions is met:
 - A) The HOME input is true
 - B) The LIMIT input is false, or
 - C) The axis is obstructed
- 2) The axis then extends until the condition clears, reduces speed by half, then repeats Step 1.
- 3) Steps 1 and 2 repeat until the axis stops exactly on the HOME position.

- 4) When the HOME position is located, the axis extends 100 encoder counts from HOME and the AT COMMAND POSITION bit is set.

If a limit or obstruction is found, the axis reverses direction.

If the axis is between a limit and an obstruction (i.e., caught between the limit switch and the physical limit of the system) the axis is moved beyond the limit away from the obstruction.

If SPEED is set to 0 and an '@' command is issued, only the hardware counters are changed; they are loaded with the preset value defined by:

$$\text{Preset Value} = \frac{(\text{REQUESTED POSITION} - \text{OFFSET}) \times \text{SCALE}}{1000}$$

rather than the default value of 100.

The '@' routine can be terminated at any time with the 'Z' command.

NOTE: When an '@' command is given, the ladder logic program should use a timer to make sure the HOME position is found within a reasonable amount of time. If HOME is not found within the programmed time, stop the axis with a 'Z' command.

The external HOME input causes the counters to be loaded with the preset value determined from the last '@' command. If a new SCALE or OFFSET is issued with a 'P' command, an '@' command must be issued to update the preset value of the external HOME.

How It Works

Initialization

When the Motion Control Module is powered up, the SCALE and OFFSET parameters are set to the default values. The ACTUAL POSITION is then calculated based on the default values. The REQUESTED POSITION, COMMAND POSITION and TARGET POSITION are set to the calculated position. The EXTEND LIMIT and RETRACT LIMIT are set to the ACTUAL POSITION. These values keep a 'G' command from moving the axis until the axis parameters are initialized. This makes the P/C responsible for setting the EXTEND and RETRACT limits using the 'P' command to change the VINIT parameters.

After the 'P' command is sent, two additional P/C scans are needed to process the parameters. A new ACTUAL POSITION is computed and the REQUESTED POSITION, COMMAND POSITION, and TARGET POSITION are updated with the new ACTUAL POSITION.

Once the VINIT parameters are set, you can move an axis by setting the ACCELERATION and DECELERATION distance or rate, SPEED, and REQUESTED POSITION to the desired values, then writing a 'G' in the VWRITE COMMAND field. The TMC 188/40 will move the axis to the new position using the most recently programmed parameters.

Parameter Use

The VWRITE parameters (MODE, ACCEL, DECEL, SPEED, REQUESTED POSITION, and COMMAND) can be changed while the axis is moving, and any change will take effect on the next scan. For each new move, usually only new REQUESTED POSITION and COMMAND parameters are written.

If an axis halts because of an error, the condition can be cleared by sending a new COMMAND. Since the last command is stored in the command register, the new command must be different for the MCM to detect the change. For example, if a move is started with a 'G' command and the move halts on an error, another 'G' command will not clear the error since it is the same as the command stored in the COMMAND register. However, if the first 'G' command is followed by an 'N' command (No-Op), then another 'G' command would clear a HALTED condition, since the MCM would detect the change from 'N' to 'G'.

Position Sensing

Position sensing is done by sending a TTL-level interrogation pulse to the axis transducer, then measuring the time between the start and stop pulses returned by the transducer. The polarity of the interrogation pulse can be set with jumpers P4-P7. The return pulse must be a positive pulse of at least 1.5 volts. The time resolution is determined by the frequency of the counter crystal (27.75 MHz. in the TMC 188/40). The actual resolution is determined by the number of interrogation pulses used for a single position measurement. Each pulse is called a recirculation.

In the TMC 88/40 the number of recirculations can be selected with jumpers P8-P11. Usually four recirculations are used, giving the best resolution. See page 49 for more information about recirculation (For Quadrature or Analog options, see the appropriate appendix).

Drive Output

The drive calculated by the TMC 188/40 is sent to a 12-bit digital-to-analog converter (DAC). The output of the DAC can be configured for either voltage or current mode. Jumpers P12, P13, P14, and P15 select the mode. Jumpers P16, P17, P18 and P19 select the full scale range (± 10 volts, ± 5 volts, ± 2.5 volts or ± 100 mA, ± 50 mA, ± 25 mA). For best resolution use as much of the output's range

as possible. Servo valves usually need a current output so the output drive will not be affected by changes in coil resistance.

NOTE: Some servo valves have two 40 milliamp coils which will draw a total of 80 milliamps when wired in parallel (MCM configured for $\pm 100\text{mA}$ current mode). This means the valves will be fully open at only 80% of the drive. If so, the OVERDRIVE status bit will not be set since the output drive never exceeds 100%, which can interfere with the automatic feed forward adjust command. See Appendix D for an application note showing how to scale the output current to avoid this problem.

Closing the Loop

The TMC 188/40 uses the information from the position sensor to correct for differences between the ACTUAL POSITION and the TARGET POSITION. A positioner will tend to drift away from the TARGET POSITION and the change in location is sensed by the position transducer. The Motion Control Module finds the difference between where it is (ACTUAL POSITION) and where it should be (TARGET POSITION). It then changes the drive output so the ACTUAL POSITION will move back to where it should be. This is called "closing the loop."

When an axis is moving, the MCM's target generator changes the TARGET POSITION so it follows the move profile defined by REQUESTED POSITION, SPEED, ACCEL, DECEL, and MODE. If the ACTUAL POSITION is behind (lagging) the TARGET POSITION, the MCM will increase the drive to help the ACTUAL POSITION catch up with the TARGET POSITION. If the ACTUAL POSITION is ahead of the TARGET POSITION (leading), the computer will reduce the drive output to slow the axis down. The amount of drive change for a given position error is determined by three different error gains: PROPORTIONAL STATIC GAIN, PROPORTIONAL EXTEND GAIN and PROPORTIONAL RETRACT GAIN.

Proportional Gains

The ability to independently adjust STATIC, EXTEND, and RETRACT GAINS lets you compensate for differences in system dynamics such as the difference in force and velocity constants of a hydraulic cylinder when extending and retracting. Thus the difference between the ACTUAL POSITION and TARGET POSITION can be reduced by increasing one of the three error gains.

However, if a little bit of error gain is good, a lot is not always better. The point where an axis will oscillate depends on the response time of the system. The slower the response time, the lower the error gains required to cause the system to oscillate. Generally, use the largest error gain that doesn't cause oscillations.

Integral and Differential Gains

In addition to the three proportional error gains (STATIC, EXTEND and RETRACT GAINS), there are two others: INTEGRAL and DIFFERENTIAL GAIN. The majority of applications do not require the use of either the integrator or differentiator. If you need to use them, start with a value of 2 for the DIFFERENTIAL GAIN and 50 for the INTEGRAL GAIN.

The integrator is only active when the axis is in motion. When a 'G' command is issued, the integrator starts adding the position error (ACTUAL POSITION - TARGET POSITION) to an accumulator every 2 milliseconds. As long as the error is not approaching zero or has not changed sign, it is added to the accumulator. When the axis starts ramping down, the accumulator is decremented at a rate calculated to bring the value to zero when the axis stops. The drive provided by the integrator is given by:

$$\text{Integral Drive} = \frac{\text{INTEGRAL GAIN} \times \text{Accumulator}}{10,000}$$

The differentiator looks at the difference between the target and actual speeds. The difference is multiplied by the DIFFERENTIAL GAIN and divided by 100 to get the differentiator drive:

$$\text{Differentiator Drive} = \frac{(\text{TARGET SPEED} - \text{ACTUAL SPEED}) \times \text{DIFFERENTIAL GAIN}}{100}$$

Feed Forward

When the axis is moving, the difference between the TARGET POSITION and the ACTUAL POSITION may become large, even when the error gain is as high as it can be without causing oscillation. There are three tuning parameters called EXTEND FEED FORWARD, RETRACT FEED FORWARD, and FEED FORWARD ADVANCE that help reduce the difference between the ACTUAL POSITION and TARGET POSITION.

The first two feed forward parameters compensate for the system's physical differences between extending and retracting. Feed forward is an open loop drive output that is proportional to the TARGET SPEED of the axis. The ACTUAL SPEED of the axis should be proportional to the drive output. The difference between the TARGET SPEED and the ACTUAL SPEED should be small if the feed forward is adjusted correctly.

Therefore, the difference between the TARGET POSITION and ACTUAL POSITION should be small while the axis is moving. If the feed forward is too low, the ACTUAL POSITION will LAG the TARGET POSITION. If it is too high, the ACTUAL POSITION will LEAD the TARGET POSITION and the axis will overshoot the COMMAND POSITION.

If the axis response is very slow, the axis will overshoot even if the feed forwards are adjusted correctly. This happens because the axis does not decelerate when the Motion Control Module commands it. The TMC 188/40 can advance the feed forward component of the drive output so the axis will decelerate at the proper time. The amount of advance is determined by the FEED FORWARD ADVANCE parameter.

Control at Rest

When the TMC is controlling the position of an axis at rest, it uses three parameters: PROPORTIONAL STATIC GAIN, NULL UPDATE and DIFFERENTIAL GAIN. The PROPORTIONAL STATIC GAIN provides a drive output proportional to the error between the ACTUAL POSITION and TARGET POSITION.

The NULL UPDATE compensates for the null offset inherent in many hydraulic valves. Every NULL UPDATE period (see NULL UPDATE on page 28), one count of drive is added or subtracted to the null drive value when there is a position error at set point. As long as there is an error, a count will be added until it is corrected.

If the DIFFERENTIAL GAIN is set to a value greater than zero, the differentiator will influence the drive when the axis is at rest. See page 29 for more information about the differentiator.

NOTE: Axes will oscillate if the error gains are too high.

Module Hardware

Front Panel Indicators

There are six multicolored light emitting diodes on the front panel of the TMC 188/40. These LEDs provide status information about the module and each of the four axes.

The LED labeled Run is the run indicator of the TMC 188/40's microprocessor. When the Run indicator is green, the drive outputs are enabled. If the Run indicator is red, the drive outputs are disabled and the axis will not move (unless the axis is out of null). The RUN indicator is controlled by an 80 microsecond fail-safe timer that is reset by activity on the processor bus.

The LED labeled P/C indicates the status of communication with the P/C.

The LEDs labeled 1 through 4 indicate whether the input magnetostrictive transducers are working. The Motion Control Module checks the status of the transducers every 10 milliseconds. Should a control error other than a transducer error occur on an axis, the LED for the axis in error will flash red repeatedly until a new command is issued.

NOTE: If a magnetostrictive transducer fails to respond, the output of the corresponding axis will be set to the current drive null value and its LED will turn red. If the axis transducer then comes 'on-line', it will respond to commands and its LED will turn green. The P/C will see a change in the V Memory STATUS bits when either event occurs.

TMC 188/40 Front Panel Indicators

Run indicator constant red	On-board processor halted, output drives disabled
Run indicator constant green	On-board processor running
P/C indicator constant red	505 I/O bus is disabled
P/C flashing green to red	WY registers NOT initialized
P/C indicator green	WY registers initialized, P/C scanning
P/C indicator clear or OFF	Initialized, P/C NOT scanning
1,2,3,4 indicator constant red	Transducer consistently not responding on the axis
1,2,3,4 indicator flashing red-green (extending) to yellow-green (retracting)	Program has detected a control error on the axis (color varies with transducer distance)
1,2,3,4 indicator green	Axis magnetostrictive transducer working. The intensity is directly proportional to the transducer measured distance.
1,2,3,4 indicator off	Simulation mode on (mode bit 13 set) (also see NOTE below)

NOTE: If either the quadrature or analog position options are used, the axis indicators (1,2,3,4) will be off unless an axis error occurs. If an axis error condition occurs, they will flash red.

Module Jumpers and External Wiring

The TMC 188/40 can be placed in any TI505 slot. It appears to the P/C as a Special Function Interface Chip (SFIC) device. External power supplies must be provided for both the transducer inputs and drive outputs. The power supplies must supply +5 volts and ± 15 volts with at least 500 mA. Do not connect the power supplies to any other loads, if possible. This precaution will separate the P/C system from any noise or electrical faults on the wires going to the transducers or drives.

When wiring the system it is important the axes extend when a positive voltage or current is sent to the drive. The extend direction is defined as the direction which causes the transducer or other type of sensor to return increasing counts. The extend direction on a magnetostrictive transducer is away from the transmitting end.

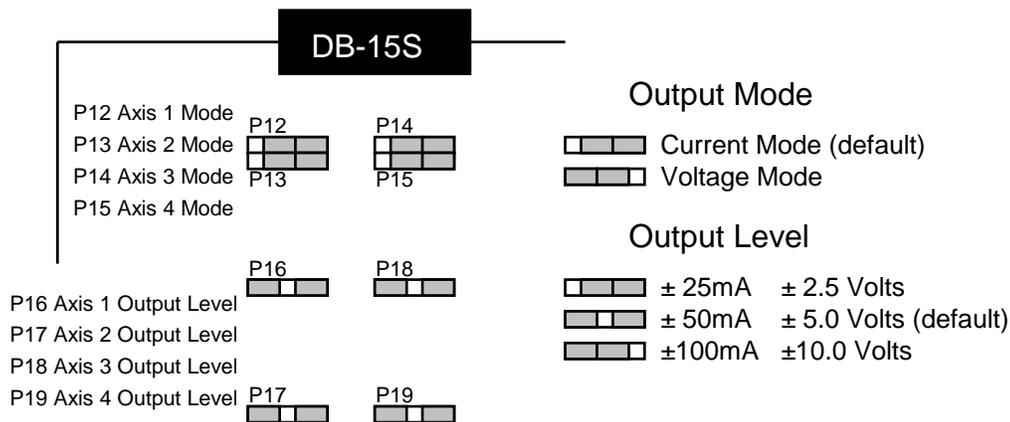
The wiring information later in this manual has wire color code data for the Temposonics® brand of magnetostrictive transducers and cables supplied by Delta Computer Systems, Inc.

NOTE: Noise problems with magnetostrictive transducers may be reduced by connecting a 220 Ohm resistor between the interrogation pulse and common. Locate the resistor as close to the transducer as possible.

CAUTION: Do not connect the drive outputs to the drives until the extend and retract limits have been computed and the P/C has properly initialized the TMC 188/40 with these limits.

Drive Selection

The default drive configuration is current mode with a range of ± 50 milliamps. To change the output configuration change the jumper as follows:



Magnetostrictive Transducer Interrogation Pulse Polarity

Temposonics® I Only (Default - positive polarity)

Jumpers P4-P7 are used to select the polarity of the magnetostrictive transducer interrogation pulse. The MCM is shipped with all four axes configured for positive interrogation pulses. Transducers can be ordered with either positive or negative interrogation pulses. Usually, the 1 foot transducers or shorter come with negative interrogation pulses. We recommend ordering only positive interrogation pulse for system consistency.

NOTE: If the TMC 188/40 is configured for positive interrogation pulses and is connected to a negative interrogation pulse transducer, current limiting resistors on the TMC 188/40 will burn out. These current limiting resistors protect the transducer rod; they are field replaceable.

Jumpers P4-P7

P4 1-2	axis 1 positive pulse	P6 1-2	axis 3 positive pulse
P4 2-3	axis 1 negative pulse	P6 2-3	axis 3 negative pulse
P5 1-2	axis 2 positive pulse	P7 1-2	axis 4 positive pulse
P5 2-3	axis 2 negative pulse	P7 2-3	axis 4 negative pulse



Note: Temposonics® II and other vendor’s transducers are all positive polarity.

Transducer Protection Resistors

Current limit resistors R62 - R65 (4.7 Ohm, 1/4W, 5%) and R53 - R56 (15 Ohm, 1/4W, 5%) help to protect some types of transducers from damage caused by miswiring or overvoltage. For Temposonics® I and Temposonics® II neuter types, connect the transducer power leads to the TMC 188/40 to take advantage of these resistors. For all other types of magnetostrictive transducers connect the power leads directly to the power supplies.

Number of Recirculations

Recirculation is a term used with magnetostrictive transducers. It indicates how many times the transducer is interrogated for a single distance measurement. If recirculation is set to one, only one interrogation pulse is issued. If set to four, then four interrogation pulses are issued.

There is a relationship between speed, resolution, and distance; the greater the number of recirculations, the greater the resolution and the slower the speed and shorter the maximum transducer length. The lower the number of recirculations, the lower the resolution, the faster the speed, and the greater the transducer length. See the tables below.

$$\text{Counts Per Inch} = \frac{\text{Transducer Cal Number (9.1us/inch typical)}}{36\text{ns per clock (27.75MHz clock)}} \times \text{Recirculations}$$

$$\text{Maximum Linear Transducer Length} = \frac{65535}{\text{Counts per Inch}}$$

$$\text{Longest Measurement Time} = \text{Transducer Length(in.)} \times \text{Cal Number} \times \text{Recirculations}$$

$$\text{Maximum Resolution} = \frac{\text{Inch}}{\text{Counts per Inch}}$$

Number of Recirculations	Maximum Linear Transducer Length	Measurement Time @ 60"	Maximum Usable Transducer Resolution
1	260"	546us	.004"
2	130"	1092us	.002"
4	65"	2184us	.001"

$$\text{Counts per mm} = \frac{\text{Transducer Cal Number (358.27ns/mm typical)}}{36\text{ns per clock (27.75MHz clock)}} \times \text{Recirculations}$$

$$\text{Maximum Linear Transducer Length} = \frac{65535}{\text{Counts per mm}}$$

$$\text{Longest Measurement Time} = \text{Transducer Length(mm)} \times \text{Cal Number} \times \text{Recirculations}$$

$$\text{Maximum Resolution} = \frac{1 \text{ mm}}{\text{Counts per mm}}$$

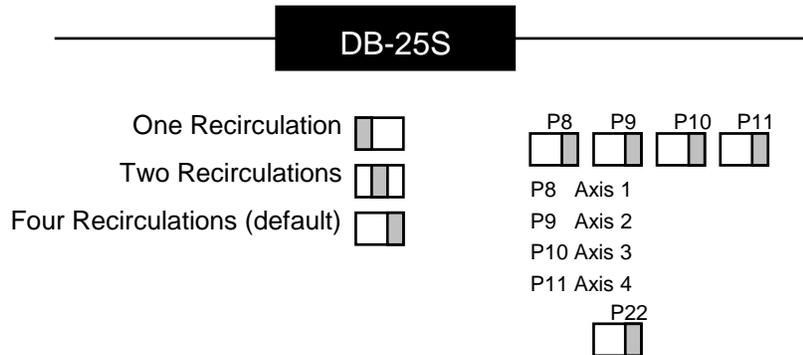
Number of Recirculations	Maximum Linear Transducer Length	Measurement Time @ 1.5M	Maximum Usable Transducer Resolution
1	6586mm	537us	.100mm
2	3293mm	1075us	.0502mm
4	1647mm	2150us	.0251mm

CAUTION: The longest measurement time should never exceed 2 milliseconds. The data used by the TMC 188/40 must be available within its two millisecond control loop. If more than 2 milliseconds are required to obtain a position measurement, the controller will slow down to a four millisecond control loop.

JUMPER P8-P11
(Default - four recirculations)

Jumper P8 for axis 1	Jumper P9 for axis 2
Jumper P11 for axis 3	Jumper P10 for axis 4

Jumper Pins	Recirculation Selected
1-2	1
3-4	2
5-6	4



Fail-Safe Timers

The TMC 188/40 has three fail-safe timers: a 15 microsecond drive output shutoff, a 15 millisecond software reset, and a 50 millisecond hardware restart.

Drive Output Shutoff - 15 microsecond

The fastest fail-safe timer on the TMC 188/40 is set for 15 microseconds and is retriggered every time there is activity on the module's internal bus. If the timer fails to be retriggered within 15 microseconds, the drive outputs are disabled. When internal bus activity resumes, the drive outputs are re-enabled.

Software Restart - 15 millisecond

A 15 millisecond fail-safe timer is connected to the non-maskable interrupt. Normally, the fail-safe timer is retriggered every two milliseconds. If something should happen where the fail-safe timer is not reset, a non-maskable interrupt will occur. This will force the processor to jump back to the beginning of the code in the PROM unless the non-maskable interrupt vector is corrupted.

Hardware Restart - 50 millisecond

A 50 millisecond fail-safe timer is connected to the module reset. Normally the fail-safe timer is retriggered every two milliseconds by the on-board processor. If the processor fails to retrigger the fail-safe timer, and if the non-maskable interrupt vector is not corrupted, a software restart will occur after 15 milliseconds. If the software restart fails, a hardware restart will occur which has the same effect on the TMC 188/40 as executing a system reset.

System Reset

The TI505 system reset is connected to the TMC 188/40 microprocessor reset. This allows the P/C to reset the TMC 188/40. When system reset is active and P22 is installed, the TMC 188/40 processor is held in the reset state. When the TMC 188/40 is held in the reset state the 15 microsecond timer will disable the drive circuits.

Cable & Connector Information

Delta Computer Systems' wire color codes (PART # MCCBS-02, DB25 to transducer).

Pin	Function	Color
1	+15 input	RED
2	Power supply common	BLACK
3	-15 input	WHITE
4	+5 input	GREEN
5	+12 output	ORANGE
6	Common	GRAY
7	Interrogation pulse 1	BROWN
8	+15v axis 1	PINK
9	Return pulse 1	YELLOW
10	-15v axis 1	VIOLET
11	Common	TAN
12	Interrogation pulse 2	BLUE
13	+15v axis 2	RED/BLACK
14	Return pulse 2	RED/YELLOW
15	-15v axis 2	RED/GREEN
16	Common	WHITE/BLACK
17	Interrogation pulse 3	WHITE/BLUE
18	+15v axis 3	WHITE/RED
19	Return pulse 3	WHITE/YELLOW
20	-15v axis 3	WHITE/GREEN
21	Common	WHITE/GRAY
22	Interrogation pulse 4	WHITE/BROWN
23	+15v axis 4	WHITE/ORANGE
24	Return pulse 4	WHITE/BLACK/RED
25	-15v axis 4	WHITE/VIOLET

NOTE: It may be necessary to add a 220 ohm resistor between the interrogation pulse and common (pins E and B for Temposonics® I) at the transducer. This reduces the amount of electrical noise in the system.

For Temposonics® I and neuter Temposonics® II rods only:

Whenever possible, connect the transducer's ± 15 volts directly to the TMC 188/40. The MCM includes current limiting resistors that protect the transducers.

PART # MCCBS-01, DB15 to valves or motor amplifier.

PIN	Function	Wire Color
1	+15 input	RED
2	Power Supply Common	BLACK
3	-15 input	WHITE
4	Common	GREEN
5	Drive Out 1	ORANGE
6	Common	BLUE
7	Common	BROWN
8	Drive Out 2	YELLOW
9	Common	RED/BLACK
10	Drive Out 4	RED/YELLOW
11	Common	RED/GREEN
12	Common	TAN
13	Drive Out 3	PINK
14	Common	GRAY
15	Common	VIOLET

NOTE: Output polarity must be set so linear position increases when the voltage or current increases.

Common Problems and Solutions

Ladder program cannot access parameters or operate module

- A) Usually this means the WY registers are not initialized or the slot is not configured properly (P/C front panel indicator is flashing red-green). Before the TMC 188/40 will begin normal operation, the eight WY registers must be initialized. The WY registers define the P/C's V Memory locations where the TMC 188/40 reads and writes information. The initialization can be done either with the CHART utility of TISOFT or with a ladder logic routine (see Appendix E starting on page 103). To set up the WY registers using TISOFT:
- 1) Run **TISOFT**.
 - 2) Put it in the **ON-LINE** mode.
 - 3) Select **CHART**.
 - 4) Select **BLDCHT**.
 - 5) Enter **WY201 - WY208** (or whatever WY registers you are going to use).
 - 6) Select **CHGVAL** to set the values for the eight WY registers. The values entered are the addresses of the V Memory locations where the TMC 188/40 talks to (201, 251, etc. in the demo program).
 - 7) When you have entered all eight values (including the checksum), verify the P/C LED on the TMC 188/40 panel is green.

More information about the WY registers starts on page 9.

NOTE: Once the TMC 188/40 finds a correct set of WY registers (including a valid checksum), it will not read them again. Changes in the WY registers will not take effect until the TMC 188/40 is reset or the power is cycled.

- B) Verify the P/C is accessing the correct V Memory locations for the TMC 188/40 parameters.

During a move, the ACTUAL POSITION is erratic

Electrical noise or a defective transducer can cause this problem. Monitor STATUS word bit 6 to determine if the module is detecting a transducer error. To reduce electrical noise do the following:

- A) Make sure the transducer wiring is separated from all other wiring (AC power, drive cables, PWM servo valves, etc.)
- B) Add a termination resistor as close to the transducer as possible (220 ohm for Temposonics®).
- C) Terminate the shield at module end, the transducer end, or both.
- D) Install a pair of Delta Computer Systems' AMP/10 RS-422 converter cards. If a Temposonics® II transducer is used, use the RPM option and one Delta AMP/10 card. See TMC Wiring Diagrams starting on page 107.

TRANSDUCER COUNTS field not indicating transducer location

See "Axis indicator is constant red" below.

TRANSDUCER COUNTS field changes but output drive does not work

See "... axis comes to a halt for no apparent reason" below.

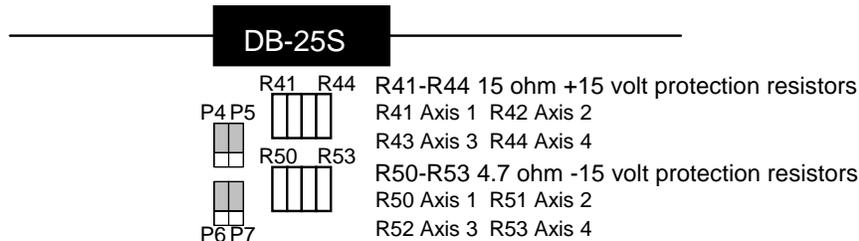
Axis indicator is constant red

This indicates the transducer is not responding to the module. Every two milliseconds the module interrogates the transducer's position. If a return response is not seen, the indicator will be a constant red. Check the following:

- A) Polarity of the interrogation pulse (see page 48).
- B) External transducer power supply to make sure ± 15 volts is present
- C) Transducer power from the module to make sure ± 15 volts is present
- D) External transducer power supply to make sure +5 volts is present

If the +12 volt output is used, check its voltage also. If not present, make sure a +15 volt supply is connected.

If the transducer power provided by the module has failed, check the 4.7 ohm and 15 ohm resistors on the module (see below). These resistors act as fuses and may be open if there is a problem with the transducer or external wiring. Change the 4.7 ohm 5% resistor(s) if there is a problem with the -15 volt supply. Change the 15 ohm 5% resistors if there is a problem with the +15 volt supply.



During a move, the axis comes to a halt for no apparent reason

When the module detects a transducer error an emergency stop is made. See "ACTUAL POSITION is erratic" above for more information. Other reasons for halting are the P/C commanded a Halt or one of the following errors happened:

- | | |
|-------------------|-----------------|
| Lag error | Lead error |
| Overdrive error | Stopped |
| Position overflow | Parameter error |

These errors will cause the axis to stop if the HALT MASK does not have the error bits masked (see STATUS WORD bit descriptions starting on page 23 for more information).

NOTE: The TRANSDUCER NOT RESPONDING bit (bit 6 of the STATUS word) is NOT latched.

Transducer errors will always cause emergency stops, but with intermittent errors, bit 6 may be cleared before the P/C sees it. In this case, the axis will remain stopped with the HALTED bit (bit 14) set. The axis will be in open loop and will drift if the valve null is off.

Hydraulic System Problems

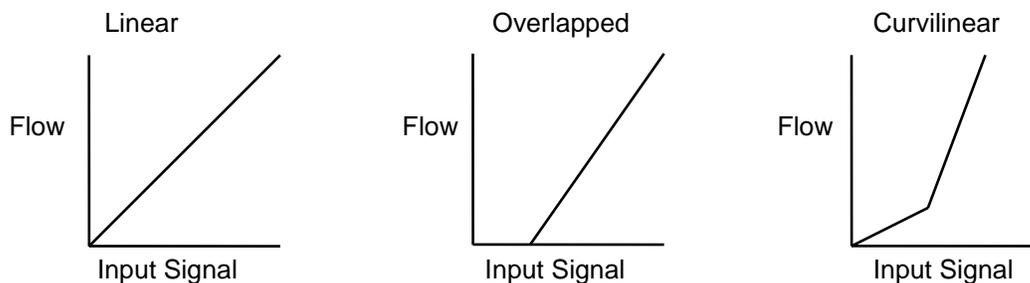
These hydraulic system problems can make system tuning difficult or impossible.

Nonlinear Valves

A valve is linear when the flow through it is directly proportional to the input signal over the entire range of the input signal. It is nonlinear when the output is not directly proportional to the input. You may find two types of valve nonlinearity:

Overlapped valves - Oil does not start to flow through these valves until the spool has moved some distance. This causes a deadband in the system, where small amounts of drive do not produce motion. Overlapped valves are designed for manual and on/off type control and are not suited for servo control. These valves should be replaced with non-overlapped valves.

Curvilinear valves - The flow through these valves increases slowly as the input signal increases for the first 20% of range. Beyond 20% the flow increases rapidly as the input increases. This is equivalent to having two different gains for different signal levels. The low gain at low flow causes poor response at slow speeds, and the high gain at high speed can cause instability. These problems are more pronounced when heavy loads are moved by relatively small cylinders.



Slow-Response Valves

Valves with slow response cause the MCM to overcompensate for disturbances in the motion of the system. Since the system does not respond immediately to the control signal, the MCM continues to increase the drive signal. By the time the system begins to respond to the error, the control signal has become too large and the system overshoots. The MCM then attempts to control in the opposite direction, but again it overshoots. These valves can cause the system to oscillate around the set point as the MCM overshoots first in one direction, then the other.

Hoses

Long hoses between the valves and cylinder act as accumulators and make the system respond as if it has a spring in it (imagine trying to control the position of one end of a Slinky™ by moving the other end!). The lines between the valves and cylinders must be as short and rigid as possible.

Pumps and Accumulators

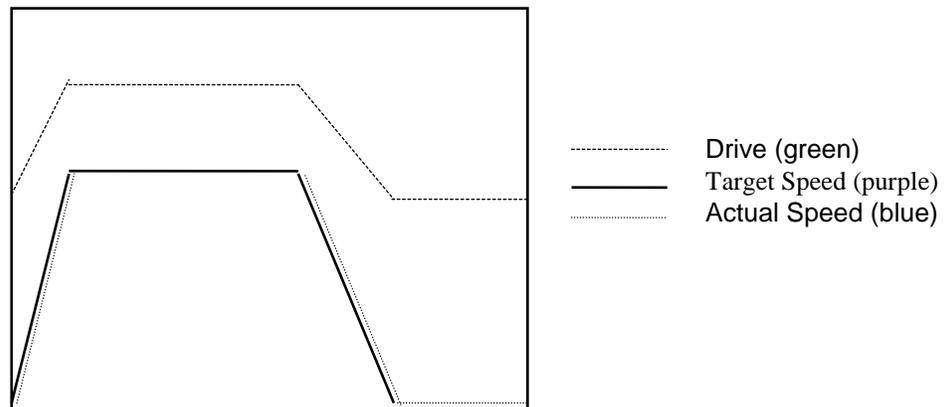
Insufficient pump and/or accumulator capacity will cause the system response to degrade during a move because the effective pressure drops.

Pressure transients due to insufficient accumulator volume cause jerky motion, particularly during starts and stops. Note: Even systems with 'fast' pumps usually require at least a small accumulator near the cylinder to get smooth motion.

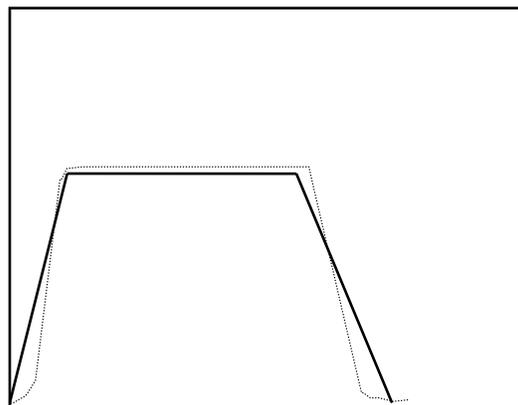
Insufficient pump capacity can result in inadequate control when moving many axes simultaneously or when making long moves. In these cases pressure can drop so much a fully open valve cannot maintain the requested speed.

Identification and Correction

To identify and correct these problems, make a move with very low (or zero) gains except the feed forwards. Graph the move with DCSMON. The graph (ignoring the Position terms) should show:

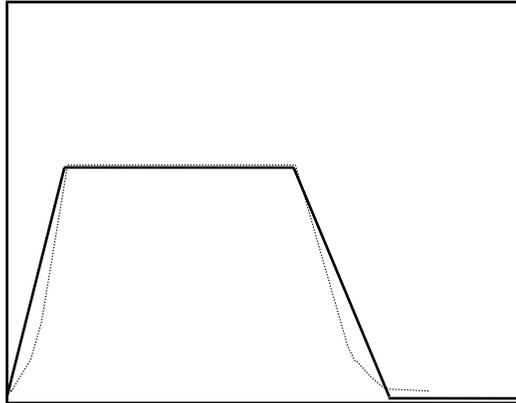


If the actual speed and target speed show:



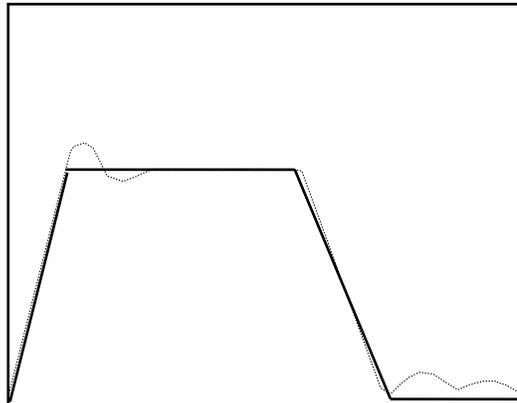
Your valve probably has overlap. Replace the valve with a linear one or try increasing the HYSTERESIS.

If the speeds show:



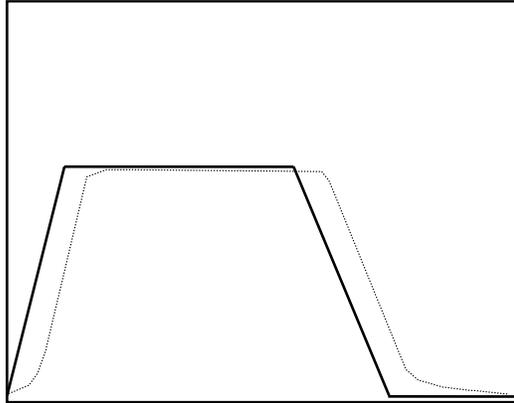
Your valve is probably curvilinear. Replace the valve with a linear one or increase the static gain and tune the system for high-speed stability; expect poor control at low speed and when stopped.

If the speeds show:



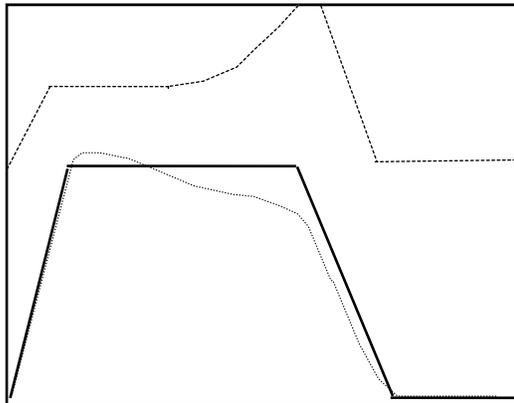
You may have too much hose between the valve and the cylinder. Reduce the amount of hose or add differential gain (usually less than 5).

If the speeds show:



Your valve may have slow response. Add feed forward advance equal to the time between the two speed lines.

With normal gain values, if the graph shows:



Your pump and/or accumulator may be inadequate (you are running out of oil). Reduce speed, increase pump pressure, add accumulator volume, or get a bigger pump.

Repairs and Returns

Field Repair of a Module

The following list of common problems and solutions is for those interested in repairing their module. Any repairs other than replacing the transducer protection resistors or pulse drivers will void the warranty.

- 1) If the transducer count is not being updated, check 4.7 ohm 5% resistor(s) (R62-R65) if problem exists with the -15 volts. Check the 15 ohm 5% resistors (R53-R56) if problem exists with the +15 volts.

NOTE: These protection resistors can be used only with Temposonics® I and Temposonics® II neuter transducers. All other types must be connected directly to the power supplies.

- 2) If an interrogation pulse is missing, change pulse drivers U18 and U19 (SN75158P).
- 3) See Appendix D for servo valve wiring to confirm that the proper output drive is being used.

Delta Bulletin Board System

Delta maintains a BBS system and an Internet site you can use to download the latest product information and application notes, ask questions, and report problems. Our BBS telephone number is:

503/283-5646 300 to 14,400 bps, 8 bits, no parity, 1 stop bit

and our Internet address is:

Web: <http://www.deltacompsys.com>

Email: email@deltacompsys.com

Module Returns

If you return a TMC 188/40 for repair, please contact Delta prior to shipment for an RMA number. Returned modules must be packaged in static protection material and the RMA number clearly marked on the outside of package. A list of symptoms must be included with returned modules. Send the module to:

Delta Computer Systems, Inc.
11719 NE 95th St. , Suite D
Vancouver WA 98682-2444

Phone: 360/254-8688
Fax: 360/254-5435
Pager: 360/699-7784 (24 hr)

Warranty Repairs

Motion control products warranty period is 15 months from date of shipment from Delta Computer Systems or its distributors. Repairs required because of obvious installation failures (burned resistors, traces, etc.) are not covered and will be billed at standard repair rates. An RMA number must be issued before items can be returned for repair.

Returns

Returned items (in new condition and less than 120 days after shipment from Delta) must be approved by Delta and are subject to a 25% restocking fee. An RMA number must be issued before items can be returned for restocking.

Glossary

ACTUAL POSITION - The measured (real) physical distance expressed in position units.

Cleared - A FALSE or logical '0' value.

COMMAND - An ASCII character needed to start a particular action on the Motion Control Module.

Counts - Raw number of digital counts for a given physical distance. The number has NOT been scaled to represent the actual physical distance.

Dither - A small square wave added to the output drive.

Encoder - A mechanical device which converts rotary positions to digital signals.

Extending - Moving or turning the axis so the transducer counts increase.

Feed Forward - A term used to express the amount of output drive needed to reach a desired speed, or the open loop gain of a control system.

PID - Control industry term used to indicate Proportional, Integral and Differential error compensation.

Position Unit - Basic unit of distance measurement for a specific application (i.e., thousandths of an inch, tenths of millimeters, thousandths of revolutions, etc.). Position units are calculated by using SCALE and COUNTS.

Recirculation - The number of times a magnetostrictive transducer is interrogated during a measurement. More recirculations provide higher resolution at a cost of increased measurement time and reduced maximum sensor length (Limited to 65,536 counts in the TMC 188/40).

Retracting - Moving or turning the axis so the transducer counts decrease.

SBX - System bus expansion; a generic name for a type of circuit board with specific electrical and physical specifications which conform to the Intel standard. Two SBX connectors are provided on the TMC 188/40 module.

SCALE - A multiplier used to translate transducer counts to position units. It can be used to compensate for differences in magnetostrictive transducers.

Set - A TRUE or logical '1' value.

Target - A calculated or preset value used to determine the amount of position or speed error.

Transducer - A general term that refers to a device which converts a physical parameter to an electrical signal.

Transducer Counts - See Counts.

Appendix A: Maps, Tips, and Commands

STATUS Word Bit Map

The axis Status word contains 16 bits of information about the status of the axis. This hexadecimal table provides an easy way to convert hexadecimal numbers to bit patterns.

	F	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1
	E	1 1 1 0	1 1 1 0	1 1 1 0	1 1 1 0
Hexadecimal To	D	1 1 0 1	1 1 0 1	1 1 0 1	1 1 0 1
Binary Conversion	C	1 1 0 0	1 1 0 0	1 1 0 0	1 1 0 0
Table	B	1 0 1 1	1 0 1 1	1 0 1 1	1 0 1 1
	A	1 0 1 0	1 0 1 0	1 0 1 0	1 0 1 0
	9	1 0 0 1	1 0 0 1	1 0 0 1	1 0 0 1
	8	1 0 0 0	1 0 0 0	1 0 0 0	1 0 0 0
	7	0 1 1 1	0 1 1 1	0 1 1 1	0 1 1 1
	6	0 1 1 0	0 1 1 0	0 1 1 0	0 1 1 0
	5	0 1 0 1	0 1 0 1	0 1 0 1	0 1 0 1
	4	0 1 0 0	0 1 0 0	0 1 0 0	0 1 0 0
	3	0 0 1 1	0 0 1 1	0 0 1 1	0 0 1 1
	2	0 0 1 0	0 0 1 0	0 0 1 0	0 0 1 0
	1	0 0 0 1	0 0 0 1	0 0 0 1	0 0 0 1
	0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0

		* * *	* * *	*	
		| | | |	| * | | |	| 1 | 1 | 1 |	| 1 | 1 | 1 | 1 |
		| 1 | 2 | 3 | 4 |	| 5 | 6 | 7 | 8 |	| 9 | 0 | 1 | 2 |	| 3 | 4 | 5 | 6 |
Bit Definition		| _ | _ | _ |	| _ | _ | _ |	| _ | _ | _ |	| _ | _ | _ |
-----		/ / / /	/ / / /	/ / / /	/ / / /
Parameters Initialized ---	01	- / / / /	/ / / / /	/ / / / /	/ / / / /
*Lag Error -----	02	-- / / /	/ / / / /	/ / / / /	/ / / / /
*Lead Error -----	03	--- / /	/ / / / /	/ / / / /	/ / / / /
*Overdrive -----	04	---- /	/ / / / /	/ / / / /	/ / / / /
			/ / / / /	/ / / / /	/ / / / /
Valve Out Of Null -----	05	----- /	/ / / / /	/ / / / /	/ / / / /
**Transducer Not Responding	06	----- /	/ / / / /	/ / / / /	/ / / / /
*Position Overflow -----	07	----- /	/ / / / /	/ / / / /	/ / / / /
*Parameter Error -----	08	----- /	/ / / / /	/ / / / /	/ / / / /
			/ / / / /	/ / / / /	/ / / / /
Active (Axis 1 only) -----	09	----- /	/ / / / /	/ / / / /	/ / / / /
*Stopped -----	10	----- /	/ / / / /	/ / / / /	/ / / / /
Decelerating -----	11	----- /	/ / / / /	/ / / / /	/ / / / /
At Requested Speed -----	12	----- /	/ / / / /	/ / / / /	/ / / / /
			/ / / / /	/ / / / /	/ / / / /
Accelerating -----	13	----- /	/ / / / /	/ / / / /	/ / / / /
Halted -----	14	----- /	/ / / / /	/ / / / /	/ / / / /
Near Command Position ----	15	----- /	/ / / / /	/ / / / /	/ / / / /
At Command Position -----	16	----- /	/ / / / /	/ / / / /	/ / / / /

* In Position or Speed modes, can cause a halt or emergency stop if the corresponding bits are clear in the appropriate mask register. In Pressure or Home modes, can cause only an emergency stop if the corresponding bits are cleared.

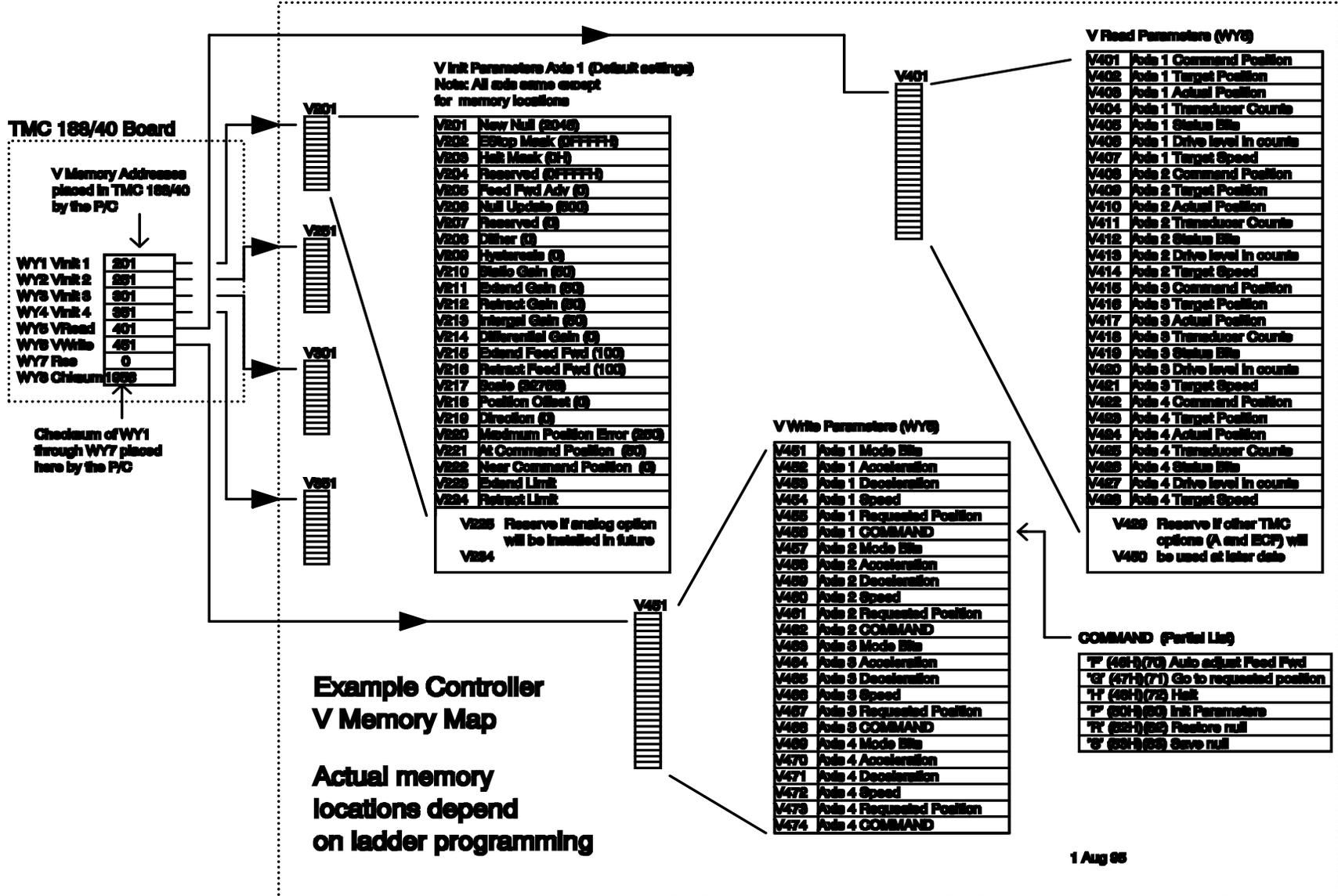
** WILL cause an emergency stop no matter how the mask register is set.

MODE Word Bit Map

The axis Mode word contains 16 bits of information. This hexadecimal table provides an easy way to convert hexadecimal numbers to bit patterns.

	F	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1
	E	1 1 1 0	1 1 1 0	1 1 1 0	1 1 1 0
	D	1 1 0 1	1 1 0 1	1 1 0 1	1 1 0 1
Hexadecimal To	C	1 1 0 0	1 1 0 0	1 1 0 0	1 1 0 0
Binary Conversion	B	1 0 1 1	1 0 1 1	1 0 1 1	1 0 1 1
Table	A	1 0 1 0	1 0 1 0	1 0 1 0	1 0 1 0
	9	1 0 0 1	1 0 0 1	1 0 0 1	1 0 0 1
	8	1 0 0 0	1 0 0 0	1 0 0 0	1 0 0 0
	7	0 1 1 1	0 1 1 1	0 1 1 1	0 1 1 1
	6	0 1 1 0	0 1 1 0	0 1 1 0	0 1 1 0
	5	0 1 0 1	0 1 0 1	0 1 0 1	0 1 0 1
	4	0 1 0 0	0 1 0 0	0 1 0 0	0 1 0 0
	3	0 0 1 1	0 0 1 1	0 0 1 1	0 0 1 1
	2	0 0 1 0	0 0 1 0	0 0 1 0	0 0 1 0
	1	0 0 0 1	0 0 0 1	0 0 0 1	0 0 0 1
	0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0

		| | | |	| | | |	| 1 | 1 | 1 |	| 1 | 1 | 1 | 1 |
		| 1 | 2 | 3 | 4 |	| 5 | 6 | 7 | 8 |	| 9 | 0 | 1 | 2 |	| 3 | 4 | 5 | 6 |
Bit Definition		| | | |	| | | |	| | | |	| | | |
-----		/ / / /	/ / / /	/ / / /	/ / / /
Reserved -----	01	- / / / /	/ / / / /	/ / / / /	/ / / / /
Reserved -----	02	-- / / /	/ / / / /	/ / / / /	/ / / / /
Reserved -----	03	--- / /	/ / / / /	/ / / / /	/ / / / /
Reserved -----	04	---- /	/ / / / /	/ / / / /	/ / / / /
			/ / / / /	/ / / / /	/ / / / /
Reserved -----	05	----- /	/ / / / /	/ / / / /	/ / / / /
Reserved -----	06	----- /	/ / / / /	/ / / / /	/ / / / /
Speed Control -----	07	----- /	/ / / / /	/ / / / /	/ / / / /
Reserved -----	08	----- /	/ / / / /	/ / / / /	/ / / / /
			/ / / / /	/ / / / /	/ / / / /
Reserved -----	09	----- /	/ / / / /	/ / / / /	/ / / / /
Pressure Mode -----	10	----- /	/ / / / /	/ / / / /	/ / / / /
Synchronization Bit B ----	11	----- /	/ / / / /	/ / / / /	/ / / / /
Synchronization Bit A ----	12	----- /	/ / / / /	/ / / / /	/ / / / /
			/ / / / /	/ / / / /	/ / / / /
Simulation Mode -----	13	----- /	/ / / / /	/ / / / /	/ / / / /
Reserved -----	14	----- /	/ / / / /	/ / / / /	/ / / / /
Accel and Decel Mode -----	15	----- /	/ / / / /	/ / / / /	/ / / / /
Accel and Decel Mode -----	16	----- /	/ / / / /	/ / / / /	/ / / / /



Example V Memory Map

Quick-Start Guide

This quick-start guide is an aid to setting up the Delta Computer Systems family of TMC 188/40 (TMC) Motion Control Modules using magnetostrictive transducers. These instructions are not comprehensive; we assume you are familiar with programming and operating your Siemens SIMATIC TI505 P/C. If you need more information about a topic please see the noted section of this manual.

CAUTION: When starting a motion control system for the first time, great care must be taken to avoid accidents. The most common accident is a 'runaway', when the motion controller tries to move an axis beyond its physical limits.

MAKE SURE THE DRIVE POWER IS OFF BEFORE STARTING THIS PROCEDURE!

A) Configure The TMC Module

(See **Module Jumpers and External Wiring** on page 47)

- 1) Individually select either voltage or current mode for each drive output (Default: current mode).
- 2) Individually select each drive level (Default: 50mA; range: 25, 50, 100mA or 2.5, 5, 10 volts)
- 3) Individually select each transducer interrogation pulse polarity (Default: Positive; Negative is for short Temposonics I rods only).
- 4) Individually select the number of recirculations used on each axis (Default: 4).
- 5) Wire the transducer and drive cables to your system, using the **Module Jumpers and External Wiring** and **TMC Wiring Diagrams** sections of this manual for detailed information.

B) Configure The P/C Base

(See **Getting Started, Step 1** on page 9)

To configure your Programmable Controller to communicate with the TMC, you must initialize the proper slot in the Base:

- 1) Run **TISOFT** and put it in the **ONLINE** mode.
- 2) Enter the **CONFIO** menu and verify the correct slot is configured for 8 WY registers with **SPECIAL FUNCTION** capability. Do this manually or by using **READBS**.
- 3) Set the I/O address so it won't conflict with other I/O in the system (Delta's demo programs use WY201 through WY208; see *filelist.txt* on the DCSMON disk for the latest demo programs).
- 4) Update the P/C by doing a **WRITPC**.

C) Initialize The WY Registers

(See **Getting Started, Step 2** on page 9)

The WY registers define the locations in the P/C's V Memory the TMC uses for talking with the P/C. Initialization can be done either with TISOFT's CHART utility or with a ladder logic routine.

Example WY Register Values

WY Register	V Mem Address	Definition
WY201	201	VINIT Axis 1
WY202	251	VINIT Axis 2
WY203	301	VINIT Axis 2
WY204	351	VINIT Axis 2
WY205	401	VREAD
WY206	451	VWRITE
WY207	0	Reserved for ECF
WY208	1956	Checksum (201 + 251 + ... = 1956)

To set up the WY registers:

- 1) Run **TISOFT** and put it in the **ONLINE** mode
- 2) Select **CHART**; select **BLDCHT**
- 3) Enter **WY201 - WY208** (or whatever WY registers you are using)
- 4) Select **CHGVAL** to set the values for the 8 - WY registers. The values you enter are the addresses of the V Memory locations and the checksum the TMC uses. The values in the table above are those used in Delta's demo programs.
- 5) When you have entered all 8 values, verify the P/C LED on the TMC front panel is green.

Once the TMC finds a valid set of WY registers (including a correct checksum) it will not read them again. Changes in the WY registers will not take effect until the TMC is reset or the power is cycled.

D) Start DCSSMON

(See **Getting Started, Step 3** on page 9)

Exit TISOFT and run INSTALL on the DCSSMON disk to install DCSSMON, then run 'DCSSMON /F'. If you prefer using TISOFT to configure your TMC, see **GETTING STARTED AND MOVING THE AXIS, Steps 3 and 4** on pages 9 and 10.

E) Move The Axis

(See **Getting Started, Step 5** on page 10)

CAUTION: SAFETY IS YOUR RESPONSIBILITY! This procedure will work for most simple hydraulic systems; if you are unsure of the characteristics of your system, we recommend you consult a hydraulics specialist.

- 1) With the drive output disconnected and the transducers connected, manually move the axis close to the physical extend limit, being sure to leave some space for error. (Remember: Extending is the direction that returns increasing COUNTS.)

Confirm DCSSMON is in 'write' rather than 'read back' mode (a 'W' rather than an 'R' in the lower right corner of the screen; press Ctrl-T to toggle the mode). Enter the ACTUAL POS. reading as the value of the EXTEND LIMIT parameter.

- 2) Now move the axis close to the physical retract limit and set the RETRACT LIMIT parameter equal to the ACTUAL POS.

If you cannot move the axis manually, the following procedure explains how to use the open loop mode to slowly move the axis.

CAUTION: OPEN LOOP OPERATION IGNORES ALL LIMITS!

- A) Connect the TMC drive output to the valves.
 - B) In DCSMON, with the cursor on the axis you want to adjust, enter Alt-R to restore the null. Put 0 in the REQUESTED POSITION field, enter Alt-Shift-O, and verify that DRIVE = 2048.
 - C) Turn on the hydraulics (the axis will drift due to valve null errors).
 - D) Put 100 in the REQUESTED POSITION field and enter Alt-Shift-O, then put 0 in the REQUESTED POSITION field. Verify that DRIVE = 2148. The axis should extend. If the axis retracts, check the drive wiring polarity, hydraulic plumbing, and the valve null. Correct any problems before continuing.
 - E) When the axis gets to the extend limit, enter Alt-Shift-O then Alt-P to stop the axis. Enter the ACTUAL POS. value in the EXTEND LIMIT parameter.
 - F) Put -100 in the REQUESTED POSITION field and enter Alt-Shift-O, then put 0 in the REQUESTED POSITION field. Verify that DRIVE = 1948. The axis should retract.
 - G) When the axis gets to the retract limit, enter Alt-Shift-O then Alt-P to stop the axis. Enter the ACTUAL POS. value in the RETRACT LIMIT parameter.
 - H) Repeat Steps B through G for each axis in use.
- 3) For each axis you will be using, set the following parameter and profile terms to the indicated values, then press Alt-P. This will initialize the axis with any changes.

Parameter terms:

HALT MASK	0EFFF
FEED FWD ADV	0
NULL UPDATE	0
DITHER	0
HYSTERESIS	0
PRO STAT GAIN	5
PRO EXT GAIN	5
PRO RET GAIN	5
INTEGRAL GAIN	0
DIFFER GAIN	0
EXT. FEED FWD.	100
RET. FEED FWD.	100

Profile terms:

MODE	00001
ACCEL	1% of SPEED
DECEL	1% of SPEED
SPEED	20% of maximum system speed (1000 = 1 in/sec)

- 4) Turn off the power to the TMC and connect the drive output. Confirm that positive drive output causes oil to enter the 'A' port and causes the axis to extend.
Make sure you have a manual drive shutoff available, then turn the power back on and enter Alt-P on each axis you will move.
Turn on the drive power. If the axis 'runs away' try reversing the A and B valve ports or the drive output leads to correct it.
- 5) Make a long move by entering a requested position which is at the other end of the axis from the actual position, then issuing a Alt-G (GO command).
- 6) Press the Insert key to plot the data to the screen.
Confirm you didn't get an overdrive condition (green line going to the top or bottom of the screen and axis halted). If you did, reduce the SPEED and try again.
Next, confirm the axis attained the requested speed (the purple SPEED line is trapezoidal, not triangular). If the axis did not get to speed, increase the acceleration and deceleration parameters.
- 7) When you have a good move (one which reaches the requested speed and doesn't overdrive) enter an Alt-F command (automatic feed forward adjust) at the DCSSMON main screen. The feed forward value for the direction of the last move will change.
- 8) Repeat Steps 5 - 7 for the opposite direction.
- 9) Double the PRO EXT GAIN, PRO RET GAIN, and PRO STAT GAIN values, then enter Alt-P. Make moves in both directions and look at the plots.
If there are signs of oscillation in the move (drive, speed, or position showing wavy lines on the DCSSMON plot), reduce the gains by 25% and make more moves. Keep reducing the gains until the oscillation stop.
If the oscillation doesn't stop, consult **Common Problems and Solutions** on page 53.
- 10) As long as the axis does not oscillate, repeat Step 9.
- 11) Readjust the feed forward values after moves in each direction using the Alt-F command, as in Steps 5 - 8.

NOTE: Use the Sum of Errors Squared term (Σe^2) on the top line of the DCSSMON plot screen to help you tune the axis; the smaller the number the better-tuned the system. Repeat Steps 5-9 using the same profile terms until you get the lowest number.

Repeat these steps for each axis you are using on the TMC. If you can't make the axis move properly, consult the **Hydraulic System Problems** section in the manual.

Consult the **Motion Control Parameters** section of the manual for more information about the parameters you set to 0 in Step 3.

F) Save The Parameters

After your TMC is tuned, save the parameters by entering:

S <CR> (saves to the current .bdn file)
or:
S <filename><CR> (saves to filename.bdn)

where *n* is the number of the TMC module in your system. If you have more than one module in the system, DCSSMON knows which one you are tuning so it inserts the proper number in the .bdn file extension.

P/C Programming Notes

The Programmable Controller is responsible for:

- Storing the VINIT parameters used by the TMC.
- Properly initializing the TMC using the VINIT V Memory locations.
- Loading the TMC's WY registers with the correct V Memory locations.
- Issuing an 'H' (HALT) command when drive power is off, or restoring the null when power is restored.
- Turning off drive power when the TMC reports an error.
- Having a watchdog timer that shuts off drive power if a time-out occurs.

Transducer Notes

- Retracting is always toward the transmitter end of the transducer (COUNTS decrease while retracting).
- The last 6 inches of a magnetostrictive transducer are usually not usable.
- Transducer non-linearity may be an issue when opposing axes are used.
- When the DIRECTION is 0, all positions are added to the OFFSET value. When the DIRECTION is -1, all positions are subtracted from the OFFSET.
- When the DIRECTION is 0 and the REQUESTED POSITION is more negative than the OFFSET, the axis will extend (increasing transducer counts). When the DIRECTION is -1 and the REQUESTED POSITION is more positive than the OFFSET, the axis will extend.

Axis Tuning Tips

Delta's DCSMON program simplifies tuning since you can graph moves during the tuning process. The following tuning steps assume DCSMON is being used.

While tuning, you will probably need to mask off several bits in the HALT MASK to avoid stopping every time an error occurs (see page 27 for HALT MASK information).

CAUTION: Do not use the INTEGRAL or DIFFERENTIAL GAINS or FEED FORWARD ADVANCE until you have finished with Tips 1 to 10. Leave them set at the defaults.

- 1) If the axis oscillates when it shouldn't be moving, reduce the STATIC GAIN.
- 2) If the axis oscillates when it is extending, reduce the EXTEND GAIN.
- 3) If the axis oscillates when it is retracting, reduce the RETRACT GAIN.
- 4) Gains should be increased until the axis starts to oscillate, then follow tips 1 through 3.
- 5) If the axis gets a LEAD error and no LAG error while extending, reduce the EXTEND FEED FORWARD.
- 6) If the axis gets a LAG error and no LEAD error while extending, increase the EXTEND FEED FORWARD.
- 7) If the axis gets a LEAD error and no LAG error while retracting, reduce the RETRACT FEED FORWARD.
- 8) If the axis gets a LAG error and no LEAD error while retracting, increase the RETRACT FEED FORWARD.
- 9) If the axis gets both a LAG error and a LEAD error, check for oscillations (tips 2 & 3). If it is not oscillating, increase the MAX ERROR until you get only one error (tips 5 - 8). Also check the FEED FORWARD ADVANCE (tip 14).
- 10) Once the axis moves smoothly, use the 'F' command (automatic tuning).
- 11) If the axis hunts around the set point, increase the HYSTERESIS gradually until the hunting stops or the axis starts to oscillate. If oscillations occur, reduce the HYSTERESIS.
- 12) The NULL UPDATE should not be used until the HYSTERESIS is adjusted. Try to keep the NULL UPDATE interval value higher than 1000. Systems with fast response times require larger NULL UPDATE intervals.
- 13) If the axis gets no LAG or LEAD errors, reduce the MAX ERROR until errors start to occur then either repeat tips 5 through 8, or increase the MAX ERROR a little.
- 14) The FEED FORWARD ADVANCE must be the same for all synchronized axis. Increasing the FEED FORWARD ADVANCE will decrease the chance of getting a LAG error when ramping up or getting a LEAD error while ramping down. If the FEED FORWARD ADVANCE is too high, the axis will LEAD when ramping up and LAG when ramping down.
- 15) The INTEGRAL GAIN is useful only when the feed forward terms cannot be adjusted correctly. This may occur if the upper limit of the feed forward is reached or the axis has a nonlinear response to drive output. If the axis requires a different feed forward value to move 10 inches a second than to move 20 inches a second, the axis is nonlinear and the integrator can help compensate. In these cases a little integral gain will do the job. The better the feed forwards are adjusted, the lower the integral gain needed.
- 16) Another problem occurs on moves of a long duration and when the feed forward cannot be adjusted high enough. This usually happens only on systems that move less than 2 inches (50 mm) per second. If the integrator must be used, increase by units of 50. Sometimes the integral gain will get to 500 or more.
- 17) The DIFFERENTIAL GAIN is of little use on systems which respond quickly. It is most useful on systems with slow response times that oscillate at 5 Hz or less. It adds a small boost while accelerating and helps stop while decelerating. Increase this number by ones. The DIFFERENTIAL GAIN should not get over 10; high values will cause oscillation.

DCSMON Command Summary

Main Screen Usage

←↑→↓	Move cursor to selected axis and parameter
Esc	Return to previous screen
Ctrl B	Toggle status words bits
Ctrl D	Switch to DOS
Ctrl H	Context-sensitive help
Ctrl O	Toggle pressure parameters
Ctrl Q	Quit DCSMON
Shift ?	General help file
R <fname>	Read module parameters file from disk
S <fname>	Save module parameters file to disk
Ctrl PgUp	Select next MCM (TMC)
Ctrl PgDn	Select previous MCM (TMC)

DCSMON Commands

Hold down **Ctrl** key and press:

A	Edit Auto mode spreadsheet
B	Toggle Status Bit display
C	Configuration, firmware version screen
D	DOS shell, type EXIT to return
E	Edit current .INI file
F	Edit function key spreadsheet
H	Context-sensitive help
O	Toggle pressure parameters
P	Edit profile spreadsheet
S	Go to steps table (ECF)
T	Toggle Write/Readback
V	View datalog data
W	View VMEM, WY, WX register spreadsheet (TMC)

Help Files

Ctrl H	Context-sensitive help
Shift ?	General help file

Using the Datalog

Insert	Retrieve and display axis datalog in graph form
Home	Cursor full left
End	Cursor full right
Page Up	Coarse cursor left
Page Down	Coarse cursor right
← →	Fine cursor left, right
Ctrl V	View datalog data
Tab	Move data table
RP <fname>	Read plot from disk
SP <fname>	Save plot to disk

Motion Control Commands

Shift @	64D, 40H	Home position (Quadrature option)
[	91D, 5BH	Set outputs (MMC41)
]	93D, 5DH	Clear outputs (MMC41)

Hold down **Alt** key and press:

A	65D, 41H	Initiate auto move mode, cycle between commands in auto spreadsheet
C	67D, 43H	Clear ECF event
E	69D, 45H	Set ECF event
F	70D, 46H	Feedforward adjust
G	71D, 47H	Go
H	72D, 48H	Halt
J	74D, 4AH	Jump (relative move)
K	75D, 4BH	Kill ECF events
M	77D, 4DH	ECF event mask
N	78D, 4EH	Nothing / No-op
Shift O	79D, 4FH	Open loop
P	80D, 50H	Initialize Parameters
Q	81B, 51H	Quit ECF events
R	82D, 52H	Restore null
S	83D, 53H	Save null
U	85D, 55H	Upload parameters to EEPROM (MMC)
Y	89D, 59H	Yank plot data to VMEM
Z	90D, 5AH	Zero quadrature counts
=	61D, 3DH	Copy step program from VMEM to MCM
^	94D, 5EH	Pressure command
\	92D, 5CH	Pressure ramp rate
_	95D, 5FH	Pressure low

Event Control Firmware (ECF)

Alt C	Clear event(s) on module
Alt E	Set event(s) on module
Alt K	Kill events
Alt M	Update event(s) mask register on module
Alt Q	Quit events
Ctrl S	Save events steps to disk

Spreadsheet Edit Keys

End, Home, ←↑→↓	Move cursor
Shift ←↑→↓	Highlight text
Ctrl C	Copy highlighted text
Ctrl X	Cut highlighted text
Ctrl V	Paste buffered text
Ctrl G	Move to next event step
Ctrl R	Read events steps from disk
Ctrl W	Set field width (TMC VMemory editor)
Esc	Exit to main screen
text	Enter text to fill highlighted cells

Special Functions

Ctrl P	Edit motion profiles (MMC)
Ctrl T	Toggle readback mode
Ctrl W	Edit V memory (TMC)
P0, P1	Scale, offset, direction, extend, and retract calculation
Alt F	Auto feedforward adjust

Using the Demo Features

F1-F10	Move using predetermined positions
Alt F1-F10	Move and generate a datalog (RADISYS, SBS, and ZYCOM only)
Alt A	Toggle Auto move - when on, DCSMON cycles through Automove file
Ctrl A	Edit Automove file using Table Editor
Ctrl F	Edit F1-F10 keys using Table Editor
Ctrl F1-F10	Move using predetermined positions and profiles

Viewing Configurations

Ctrl C	View system configuration
Ctrl E	Call editor to configure DCSMON

DOS Command Line Options

Syntax: DCSMON [opt 1] [opt 2]...
... [opt n]<CR>

opt 1	Initialization file; the default is DCSMON.INI. Do not enter the file extension (.INI).
opt 2	Project filename specification; the default is DCSMON.BD1. Enter only if an initialization file has been entered as opt 1, and do not enter the file extension (.BDn).

If DCSMON is started with no options specified, the default files are used.

Other options are:

/D	Created a debug file (debug.txt) with a history of all commands executed from DCSMON
/F	Forces initialization of the module when DCSMON starts
/L	Starts DCSMON in look-only mode
/R	Starts DCSMON in read mode
/W	Starts DCSMON in write mode

The '/' can also be a '-'. These options can all be specified in the .ini file, but when specified on the command line they supersede the .ini file.

Control Equations

These are the main equations that are used for target position calculations:

$$\text{Ramp Time} = \frac{2000 \times \text{Distance}}{\text{Speed}}$$

$$A = \frac{\text{Speed} \times \text{Speed}}{2000 \times \text{Distance}}$$

Ramp Time in milliseconds

Speed in thousandths of an inch per second

Distance is acceleration or deceleration distance in thousandths of inches

A is acceleration or deceleration rate in inches per second per second

$$\text{ACTUAL POSITION} = ((\text{COUNTS} \times \text{SCALE} / 32768) \text{ XOR } \text{DIRECTION}) + \text{OFFSET}$$

$$\text{RAMP DIST} = \text{SPEED} \times \text{SPEED} / (\text{ACCEL RATE} \times 2000)$$

$$\text{DRIVE OUTPUT} = \text{Proportional Drive} + \text{Feed Forward Drive} + \text{Integral Drive} \\ + \text{Differential Drive}$$

Where:

$$\text{Proportional Drive} = \frac{(\text{TARGET POSITION} - \text{ACTUAL POSITION}) \times \text{PROPORTIONAL GAIN}}{100}$$

$$\text{Feed Forward Drive} = \frac{\text{TARGET SPEED} \times \text{FEED FORWARD}}{10000}$$

$$\text{Integral Drive} = \frac{\text{INTEGRAL GAIN} \times \text{Accumulated error}}{10000}$$

$$\text{Differentiator Drive} = \frac{(\text{TARGET SPEED} - \text{ACTUAL SPEED}) \times \text{DIFFERENTIAL GAIN}}{100}$$

ASCII Code Chart

This is a list of all the standard ASCII control characters, listing the keyboard character, hex value, and decimal value of the character.

Key	Hex	Dec	Key	Hex	Dec	Key	Hex	Dec
^@	00	00	+	2B	43	V	56	86
^A	01	01	,	2C	44	W	57	87
^B	02	02	-	2D	45	X	58	88
^C	03	03	.	2E	46	Y	59	89
^D	04	04	/	2F	47	Z	5A	90
^E	05	05	0	30	48	[	5B	91
^F	06	06	1	31	49	\	5C	92
^G	07	07	2	32	50	]	5D	93
^H	08	08	3	33	51	^	5E	94
^I	09	09	4	34	52	_	5F	95
^J	0A	10	5	35	53	`	60	96
^K	0B	11	6	36	54	a	62	97
^L	0C	12	7	37	55	b	62	98
^M	0D	13	8	38	56	c	63	99
^N	0E	14	9	39	57	d	64	100
^O	0F	15	:	3A	58	e	65	101
^P	10	16	;	3B	59	f	66	102
^Q	11	17	<	3C	60	g	67	103
^R	12	18	=	3D	61	h	68	104
^S	13	19	>	3E	62	i	69	105
^T	14	20	?	3F	63	j	6A	106
^U	15	21	@	40	64	k	6B	107
^V	16	22	A	41	65	l	6C	108
^W	17	23	B	42	66	m	6D	109
^X	18	24	C	43	67	n	6E	110
^Y	19	25	D	44	68	o	6F	111
^Z	1A	26	E	45	69	p	70	112
^[	1B	27	F	46	70	q	71	113
^\	1C	28	G	47	71	r	72	114
^]	1D	29	H	48	72	s	73	115
^^	1E	30	I	49	73	t	74	116
^-	1F	31	J	4A	74	u	75	117
space	20	32	K	4B	75	v	76	118
!	21	33	L	4C	76	w	77	119
"	22	34	M	4D	77	x	78	120
#	23	35	N	4E	78	y	79	121
\$	24	36	O	4F	79	z	7A	122
%	25	37	P	50	80	{	7B	123
&	26	38	Q	51	81	|	7C	124
'	27	39	R	52	82	}	7D	125
(	28	40	S	53	83	~	7E	126
)	29	41	T	54	84	rub	7F	127
*	2A	42	U	55	85			

Appendix B: ASBX/40 Analog Module

Description

The ASBX/40 analog input module has four channels of isolated analog inputs. The inputs are multiplexed to a 12-bit analog-to-digital converter. The module communicates with the host TMC 188/40 through the iSBX™ bus. One jumper sets all inputs as either single ended or bipolar; however, the input range of each channel is individually configurable. The inputs are configured and calibrated at the factory prior to shipment.

Installation

You can install the ASBX/40 on either iSBX™ connector of the TMC 188/40 module. Secure it to the module with a 6-32 nylon screw.

The combination of an ASBX/40 and a TMC 188/40 is called a TMC 188/40-TA, as it combines both magnetostrictive transducer interfaces and analog inputs in the same module. The four analog axes are independently configurable for two modes of operation:

Pressure mode - In this mode the standard magnetostrictive transducer feedback is used to control the axis position with the analog feedback used as a pressure override. That is, the axis moves toward the requested position until the pressure reaches a specified value, then the pressure is maintained.

Position mode - In this mode the magnetostrictive transducer is ignored and the analog signal is used as position feedback.

The TMC 188/40-TA occupies two slots in the Siemens SIMATIC TI505 I/O rack.

Specifications

Input Range	+/-5 V +/-10 V 0 - 5 V 0 - 10 V 4 - 20 mA
Resolution	12 bits (4096 counts)
Isolation	750 VDC
Input Impedance	400k Ω differential (voltage input) 249 Ω differential (current input) 200k Ω each input to common (voltage and current input)

Summary of Differences Between The TMC 188/40-TA and the TMC 188/40

- 1) READ parameters are increased from 28 to 40 (from 7 to 10 per axis)
- 2) VINIT parameters are increased from 24 to 34 per axis
- 3) Bit 10 of the MODE word is defined
- 4) Bits 10 through 13 of the STATUS word are redefined

VREAD V Memory

The VREAD V Memory pointed to by WY5 is enlarged to 40 words (10 per axis) when the ASBX/40 card is installed in the TMC 188/40. Here is the enlarged VREAD memory map:

WORD	PARAMETER
0	Axis 1 COMMAND POSITION
1	Axis 1 TARGET POSITION
2	Axis 1 ACTUAL POSITION
3	Axis 1 TRANSDUCER COUNTS
4	Axis 1 STATUS
5	Axis 1 DRIVE
6	Axis 1 TARGET SPEED
7	Axis 1 NULL DRIVE
8	Axis 1 PRESSURE ACTUAL
9	Axis 1 PRESSURE COUNTS
10	Axis 2 COMMAND POSITION
11	Axis 2 TARGET POSITION
12	Axis 2 ACTUAL POSITION
13	Axis 2 TRANSDUCER COUNTS
14	Axis 2 STATUS
15	Axis 2 DRIVE
16	Axis 2 TARGET SPEED
17	Axis 2 NULL DRIVE
18	Axis 2 PRESSURE ACTUAL
19	Axis 2 PRESSURE COUNTS
20	Axis 3 COMMAND POSITION
21	Axis 3 TARGET POSITION
22	Axis 3 ACTUAL POSITION
23	Axis 3 TRANSDUCER COUNTS
24	Axis 3 STATUS
25	Axis 3 DRIVE
26	Axis 3 TARGET SPEED
27	Axis 3 NULL DRIVE
28	Axis 3 PRESSURE ACTUAL
29	Axis 3 PRESSURE COUNTS
30	Axis 4 COMMAND POSITION
31	Axis 4 TARGET POSITION
32	Axis 4 ACTUAL POSITION
33	Axis 4 TRANSDUCER COUNTS
34	Axis 4 STATUS
35	Axis 4 DRIVE
36	Axis 4 TARGET SPEED
37	Axis 4 NULL DRIVE
38	Axis 4 PRESSURE ACTUAL
39	Axis 4 PRESSURE COUNTS

New VREAD Parameter Definitions

NULL DRIVE -

The current values of NULL DRIVE are available to the P/C.

PRESSURE COUNTS -

PRESSURE COUNTS is the reading from the analog-to-digital converter with no scaling or offset. PRESSURE COUNTS is a 12-bit number read every 2 milliseconds.

PRESSURE ACTUAL -

PRESSURE ACTUAL is the value obtained by scaling and offsetting the pressure counts as follows:

$$\text{PRESSURE ACTUAL} = \text{PRESSURE SCALE} \times (\text{PRESSURE COUNTS} + \text{PRESSURE OFFSET})$$

1000

VINIT V Memory

The VINIT initialization parameters in V Memory pointed to by WY1 through WY4 have been expanded from 24 to 34 words. Here is the new parameter list:

WORD	PARAMETER	DEFAULT VALUE
0	PRESSURE DIFFERENTIATOR	0
1	PRESSURE INTEGRATOR	0
2	PRESSURE GAIN	1000
3	PRESSURE SCALE	1000
4	PRESSURE OFFSET	0
5	PRESSURE RAMP	0
6	PRESSURE LOW	32767
7	PRESSURE COMMAND	32767
8	Reserved	0
9	Reserved	0
10	NEW NULL	0
11	ESTOP MASK	0FFFFH
12	HALT MASK	0
13	Reserved	0
14	FEED FORWARD ADVANCE	0
15	NULL UPDATE	500
16	Reserved	0
17	DITHER	0
18	HYSTERESIS	0
19	STATIC GAIN	50
20	EXTEND GAIN	50
21	RETRACT GAIN	50
22	INTEGRAL GAIN	50
23	DIFFERENTIAL GAIN 0	
24	EXTEND FEED FORWARD	100
25	RETRACT FEED FORWARD	100
26	SCALE	32768
27	OFFSET	0
28	DIRECTION	0
29	MAXIMUM POSITION ERROR	250
30	AT COMMAND POSITION	50
31	NEAR COMMAND POSITION	0
32	EXTEND LIMIT	Position on power up

New VINIT Parameter Definitions

PRESSURE DIFFERENTIATOR - Range: 0 to 1000, Default: 0

The PRESSURE DIFFERENTIATOR is the gain of the differential term in the PID loop. It helps the axis track rapid pressure changes. Values that are too large will cause the axis to oscillate.

PRESSURE INTEGRATOR - Range: 0 to 20,000, Default: 0

The PRESSURE INTEGRATOR is the gain of the integral term in the PID loop. It helps the axis track slow pressure changes. Values that are too large will cause the axis to overshoot or oscillate.

PRESSURE GAIN - Range: -5000 to +5000; Default: 1000

PRESSURE GAIN is the gain of the proportional term in the PID loop. It produces an output drive proportional to the error between the target pressure and the PRESSURE ACTUAL. Values that are too high will cause the axis to oscillate. PRESSURE GAIN is specified as the number of drive counts per 1000 counts of error. Negative gain values are used to increase pressure while retracting.

PRESSURE SCALE - Range: -5000 to +5000; Default: 1000

PRESSURE SCALE is used to convert PRESSURE COUNTS (from the A to D converter) to PRESSURE ACTUAL (a meaningful pressure value). PRESSURE ACTUAL is determined as follows:

$$\text{PRESSURE ACTUAL} = \text{PRESSURE SCALE} \times \frac{(\text{PRESSURE COUNTS} + \text{PRESSURE OFFSET})}{1000}$$

Therefore:

$$\Delta \text{ PRESSURE SCALE} = \text{PRESSURE ACTUAL} \times 1000 / \Delta \text{ PRESSURE COUNTS}$$

That is, the PRESSURE SCALE is the number of units of PRESSURE ACTUAL for every 1000 PRESSURE COUNTS.

PRESSURE OFFSET - Range: -4095 to +4095; Default: 0

PRESSURE OFFSET specifies the amount the PRESSURE COUNTS is shifted (or offset) from zero. Note that the offset is applied to the PRESSURE COUNTS rather than the PRESSURE ACTUAL. See page 80 for factory calibration values.

PRESSURE RAMP - Range: 0 to 32767; Default: 0

PRESSURE RAMP specifies the rate of change of the target pressure as it approaches the PRESSURE COMMAND after the latter has been changed. The PRESSURE RAMP is specified in units of PRESSURE ACTUAL per 2 millisecond interval.

PRESSURE RAMP can be changed at any time without a "P" or "G" command.

PRESSURE LOW - Range: -32767 to +32767; Default: - 32767

PRESSURE LOW determines the value of PRESSURE ACTUAL at which the TMC 188/40-TA enters (and exits) pressure mode. Pressure mode is entered when PRESSURE ACTUAL is greater than or equal to PRESSURE LOW. The TMC 188/40-TA exits pressure mode when the PRESSURE ACTUAL drops below PRESSURE LOW.

PRESSURE LOW can be changed at any time without a “P” or “G” command.

PRESSURE COMMAND - Range: PRESSURE LOW to 32767; Default: 32767

PRESSURE COMMAND is the value the target pressure will ramp to and stay at. It is specified by the Programmable Controller. The TMC 188/40-TA attempts to make the PRESSURE ACTUAL match the target pressure whenever it is in pressure mode.

PRESSURE COMMAND can be changed at any time without a “P” or “G” command.

MODE and STATUS WORD Changes

MODE Word Bit 10

Bit 10 of the MODE Word is used to select pressure mode. When bit 10 is true, the pressure mode is turned on. When bit 10 is false, the TMC 188/40-TA is in magnetostrictive transducer mode. A new command must be issued to the TMC 188/40-TA for a change in bit 10 to be detected.

If analog position mode jumpers P4 1 through 4 are present, they override bit 10 for any axis they are installed on. Installing a jumper places the axis in analog position mode regardless of the state of bit 10.

STATUS Word Bits 10 through 13

Bit 10 (Stopped bit) indicates both when the axis is stopped and when it is in pressure mode.

Bit 11 (Decelerating bit) indicates the PRESSURE TARGET is ramping down when in pressure mode.

Bit 12 (At Speed bit) indicates the PRESSURE TARGET is the same as PRESSURE COMMAND.

Bit 13 (Accelerating bit) indicates the PRESSURE TARGET is ramping up when in pressure mode.

Pressure-Specific Commands

The TMC 188/40-TA accepts the following pressure-specific commands:

‘V’ - Set Pressure Ramp (5CH, 92D)

This command sets the rate at which the pressure target ramps to a new command pressure. The units are 0.01 pressure units per 2 milliseconds. A value of 200 will ramp the pressure target by 1,000 pressure units in 1 second.

‘^’ - **Set Requested Pressure** (5EH, 94D)

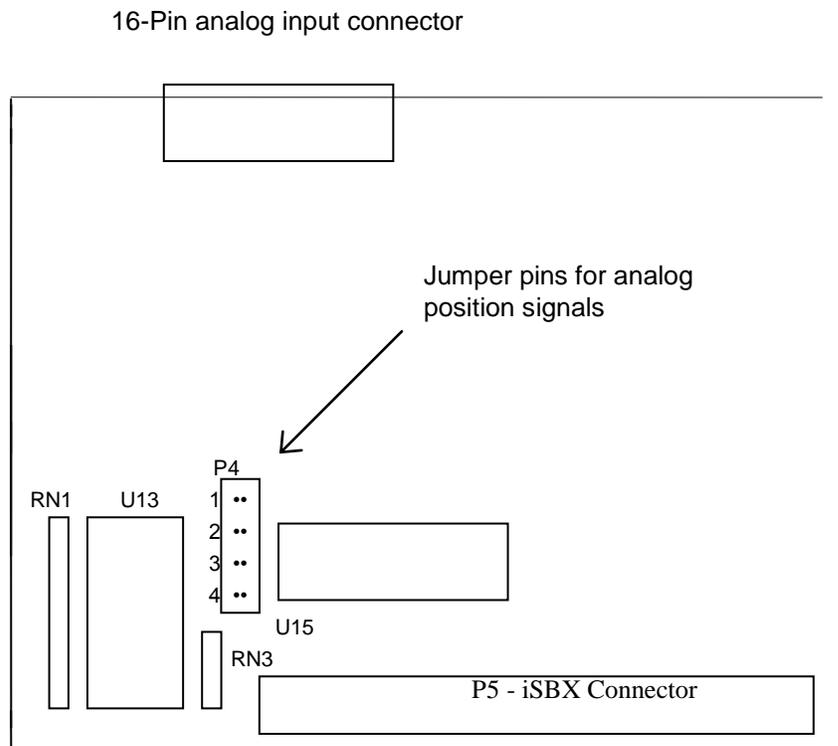
This command changes the requested pressure in the TMC 188/40-TA. The target pressure will ramp up to the requested pressure at the rate specified by PRESSURE RAMP.

‘_’ - **Set Pressure Low** (5FH, 95D)

The pressure low parameter specifies the value at which the module changes from pressure control back to position control.

ASBX/40 SETUP

The analog inputs on the ASBX/40 are configured by the factory to the user's specifications prior to shipment. The only user setup required is the installation of the mode selection jumpers. Each axis has a pair of pins on header P4, which when jumpered together tell the TMC 188/40-TA to operate that axis in position mode (with analog position signals). The jumper is removed to operate an axis in pressure mode. When the jumper is installed the analog counts are shown in the DCSMON COUNTS field and PRESSURE COUNTS are zero. The figure below shows the location of the jumpers:



Setting the PRESSURE SCALE and PRESSURE OFFSET

When the ASBX/40 is shipped it is calibrated to produce 41 PRESSURE COUNTS at the low end of the input range and 4055 PRESSURE COUNTS at the high end of the input range, for a span of 4014 PRESSURE COUNTS. This creates a 1% margin at each end of the scale to allow for drift in the input signal or circuitry.

NOTE: The span in PRESSURE COUNTS and the inherent offset must be considered when setting the PRESSURE SCALE and PRESSURE OFFSET.

Using the TMC 188/40-TA

Each axis can be independently configured for position or pressure mode. When using an axis in analog position mode (with the P4 jumper installed), the axis operates the same as with a magnetostrictive transducer with two exceptions:

- 1) The SCALE parameter is defined as

$$\text{SCALE} = \frac{\Delta \text{ACTUAL POSITION}}{\Delta \text{TRANSDUCER COUNTS}} \times 1000$$

- 2) The TRANSDUCER COUNTS is limited to 4095 because of the 12 bit resolution of the analog to digital converter on the ASBX/40 module.

When using an axis in pressure mode (no jumper at P4), the axis can function as a standard axis by clearing (entering a 0 at) bit 10 of the MODE Word, or an axis can control position and pressure by setting bit 10 (to 1). With bit 10 set, the module will control position using a magnetostrictive transducer until the pressure reaches PRESSURE LOW. At this point the axis starts controlling the pressure. The motion of the axis is controlled so the pressure increases at the PRESSURE RAMP rate until it reaches the PRESSURE COMMAND value. The pressure is then maintained until any of the following conditions are met:

- 1) The PRESSURE COMMAND is changed; the axis then moves to ramp the pressure up or down to the new PRESSURE COMMAND.
- 2) A new command is given instructing the axis to move back (bit 10 is cleared).
- 3) The pressure drops below the PRESSURE LOW value; the axis then switches from pressure mode to magnetostrictive transducer position control, and it moves to the COMMAND POSITION.
- 4) The ACTUAL POSITION is the same as the COMMAND POSITION.

You can change three pressure parameters at any time without issuing a new command: PRESSURE LOW, PRESSURE RAMP, and PRESSURE COMMAND. This allows you to follow pressure profiles that can be dynamically updated.

A PID loop is implemented on the pressure control. The integral and differential terms allow the controller to accurately maintain pressure while following a moving target. This is useful in applications where an object is being simultaneously clamped and moved.

Pressure Plots

A TMC 188/40-TA automatically records pressure readings during a move. This data can be used by DCSSMON to generate screen plots or saved to disk for reference or diagnostic purposes.

Connector

The TMC 188/40-TA is supplied with a cable and 37-pin D-sub connector. The wiring is as follows:

PIN #	Function	Wire Color
1	Axis 1 + input	BLACK pair 1
20	Axis 1 - input	RED pair 1
Shell	Shield	
2	Axis 2 + input	BLACK pair 2
21	Axis 2 - input	WHITE pair 2
Shell	Shield	
3	Axis 3 + input	BLACK pair 3
22	Axis 3 - input	GREEN pair 3
Shell	Shield	
4	Axis 4 + input	BLACK pair 4
23	Axis 4 - input	BLUE pair 4
Shell	Shield	
5	Analog Common	BLACK pair 5
24	N.C.	YELLOW pair 5
6	N.C.	BLACK pair 6
25	Digital Common	BROWN pair 6
7	B1	BLACK pair 7
26	B2	ORANGE pair 7
8	B3	RED pair 8
27	B4	WHITE pair 8
9-19	N.C.	
28-37	N.C.	

Appendix C: QSBX/40 Quadrature Module

Introduction

The QSBX/40 module adds quadrature and digital input capability to the TMC 188/40, making it either a TMC 188/40-TQ (magnetostrictive transducer and quadrature inputs) or a TMC 188/40-Q (quadrature inputs only). The QSBX/40 module mounts on either of the two iSBX™ connectors present on the TMC 188/40.

The module adds 4 channels of quadrature inputs to the existing magnetostrictive transducer inputs; each of the 4 axes can use either type of input. It can also be installed on a TMC 188/40 without magnetostrictive transducer inputs, offering 4 channels of quadrature inputs only.

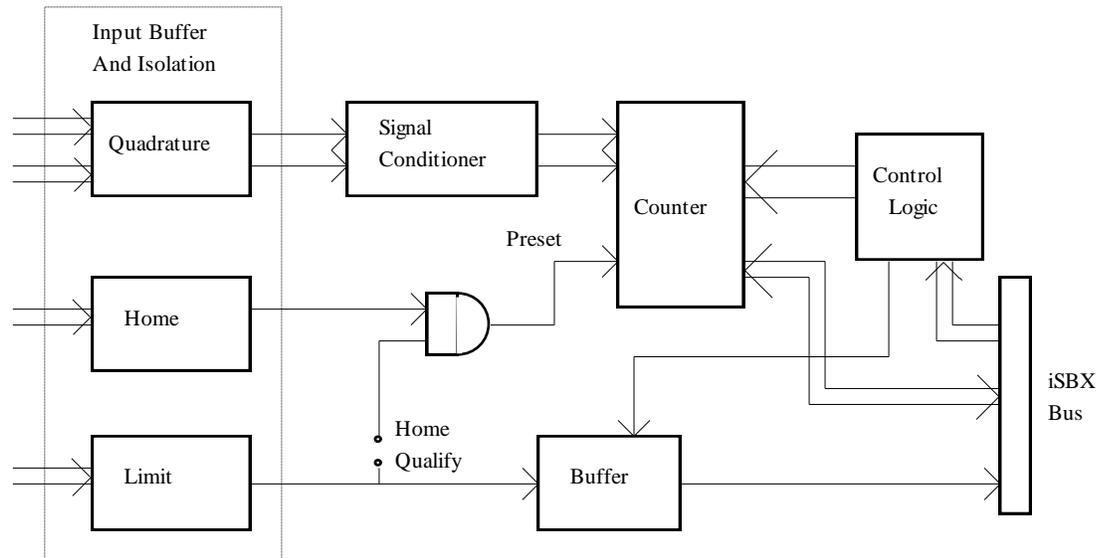
The TMC 188/40-TQ and the TMC 188/40-Q each occupies two slots in the Siemens SIMATIC TI 505 series Programmable Controller rack.

Both versions have 2 digital inputs available per quadrature axis for Home and Limit functions. All inputs and outputs on the TMC 188/40-(T)Q are optically isolated. The TMC 188/40 (T)Q is designed primarily for use as a position controller, although it can be used for some speed control applications.

QSBX/40 Specifications

Quadrature Encoder Interface	Phases Input Isolation Inactive Input Voltage Threshold Active Input Voltage Threshold Active Input Current Threshold Maximum Input Voltage Encoder Compatibility Frequency Response	A and B 2500 VAC (optical) from inputs to controller module and all other inputs. 1.5 VDC maximum 3.25 VDC minimum 5 mA typical., 9.5 mA max. 24 VDC Open collector 5 to 24 VDC, TTL and Differential 200 kHz, (800,000 edges per second) using TTL drive
Digital Inputs	LIMIT Inputs HOME Inputs Input Isolation Inactive Input Voltage Threshold Active Input Voltage Threshold Active Input Current Threshold Maximum Input Voltage	L1, L2, L3 and L4 (one per axis) H1, H2, H3 and H4 (one per axis) 2500 VAC (optical) 1.5 VDC maximum 3.25 VDC minimum 5 mA typical., 9.5 mA max. 24 VDC
Position Resolution	Hardware Counters	24 bit - A scaled 16 bit count is used by the Programmable Controller

QSBX/40 Block Diagram



Important Considerations When Using Quadrature Encoders

DIRECTION Parameter

The DIRECTION parameter must be set to zero. This forces the Transducer Counts to increase when the axis is extending. To reverse the direction, reverse the A and B signals from the quadrature encoder and reverse the drive output leads from the TMC 188/40-(T)Q.

SCALE Parameter

The way the SCALE parameter is used by the TMC 188/40-TQ changes when a quadrature encoder is selected. The method used to calculate position units for a quadrature axis is given below. See pages 88 and 89 for examples of the SCALE parameter.

With quadrature encoders:

$$\text{ACTUAL POSITION} = (\text{Transducer COUNTS} \times 1000 / \text{SCALE}) + \text{OFFSET}$$

With Magnetostrictive Transducers:

$$\text{ACTUAL POSITION} = (\text{Transducer COUNTS} \times \text{SCALE} / 32768) \\ \text{XOR DIRECTION} + \text{OFFSET}$$

Maximum Speed And Quadrature Encoder Counts

The maximum quadrature encoder speed for the QSBX/40 is 200 kHz. The QSBX/40 counts each edge of the quadrature input, so a 1000 pulse per revolution (PPR) quadrature encoder would generate 4000 counts per revolution. For example:

$$200 \text{ kHz} = 800,000 \text{ quadrature encoder counts per second}$$

$$\text{MAX RPM} = (800,000 \text{ counts per second} / 4 \text{ counts per encoder pulse}) / \text{PPR} \times 60 \text{ seconds}$$

$$\text{MAX RPM} = 12,000,000 / \text{PPR}$$

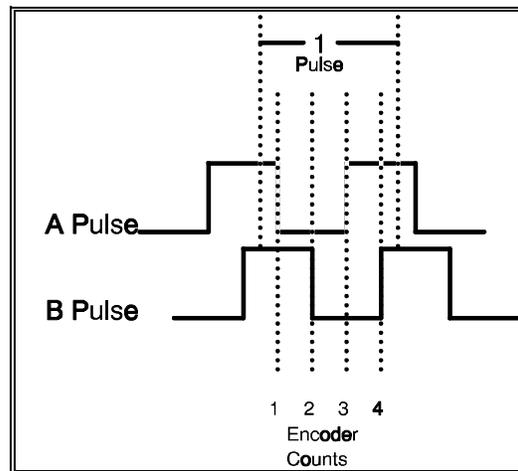
A system with a 250 PPR quadrature encoder would have a maximum speed of 48,000 RPM.

Overdrive Error

An overdrive error during a move could indicate the quadrature encoder signal has been lost. We recommend clearing the overdrive bit (bit 4, 0EFFF) in both the HALT and ESTOP masks so the drive output is disabled immediately when an overdrive error occurs.

Quadrature Encoder Position Measurement

Quadrature encoders produce output pulses on two channels which are 90 degrees out of phase with each other. These two sets of pulses are decoded by the QSBX/40 to produce up-counts or down-counts (depending on direction) with 4 times the resolution of the incoming pulse trains. The counts are recorded on 24-bit hardware counters which are read by the TMC 188/40-(T)Q.



The 24 bit hardware counts are moved to 32 bit software counters by the TMC 188/40-(T)Q. All position calculations are based on these 32 bit software counters using signed integers with a range of $\pm 2,147,483,648$ counts.

NOTE: The highest usable number of quadrature encoder counts is 4,294,836 because of the 16 bit limitation of the SCALE parameter:

$$\frac{65,535 \text{ maximum counts} \times 65,535 \text{ maximum SCALE value}}{1000 \text{ position units}} = 4,294,836$$

Quadrature Encoder-Specific Commands

The TMC 188/40-(T)Q has two commands which are specific to quadrature encoders:

@ Command (40H, 64D)

The @ command automatically moves the axis, attempting to find the Home position. The At Command Position bit must be set and the axis initialized (with a 'P' command) before the TMC 188/40 (T)Q will accept the @ command. When the Home input is active (true), the Actual Position is set to the value in the Requested Position field.

NOTE: The FEED FORWARD, SPEED, MODE , ACCEL and DECEL parameters must be set to desired values when the @ command is issued. During the Home routine the axis moves under open loop control and the drive output is calculated as:

$$\text{FEED FORWARD} \times \text{SPEED} / 10,000$$

The @ command works as follows:

- 1) The AT COMMAND POSITION bit is cleared and the axis retracts until one of the following conditions is met:
 - A) the Home input is true,
 - B) the Limit input is false, or
 - C) the axis is obstructed
- 2) The axis then extends until the condition clears. If the Home was encountered the axis reduces drive by half, then repeats Step 1.
- 3) Steps 1 and 2 repeat until the axis stops exactly on the Home position.
- 4) When the Home is located, the axis extends 100 quadrature encoder counts from the Home position, the AT COMMAND POSITION bit is set, and the ACTUAL POSITION is set to the value in the REQUESTED POSITION field + (100 counts * SCALE).

If a limit or obstruction is encountered, the axis reverses direction.

If the axis is between a limit and an obstruction (i.e. caught between the limit switch and the physical limit of the system) the axis is moved beyond the limit away from the obstruction.

The Home routine can be terminated at any time with the Z command.

When an @ command is given, the ladder logic program should use a timer to make sure the Home is found within a reasonable amount of time. If no Home is found the axis will be stopped and the AT COMMAND POSITION bit will remain cleared.

The Home input causes the counters to be loaded with the Preset Value determined from the last @ command. If a new SCALE or OFFSET is issued with a P command, an @ command must be issued to update the Preset Value of the Home input.

If SPEED is set to 0 (zero) and an @ command is issued, then only the hardware counters are changed; they are loaded with a Preset Value defined by:

$$\text{Preset Value} = (\text{Requested Position} - \text{Offset}) \times \text{SCALE} / 1000$$

rather than the default value of 100. The next time the Home input is active this preset value will be transferred to the transducer counts value.

Z Command (5AH, 90D)

When the axis is stopped, the Z command sets the axis ACTUAL POSITION, TARGET POSITION, and COMMAND POSITION to the value specified in the REQUESTED POSITION field, and the counters on the QSBX/40 are loaded with the value calculated as follows:

$$\text{Counter Value} = (\text{REQUESTED POSITION} - \text{OFFSET}) \times \text{SCALE} / 1000$$

When the axis is moving, the Z command sets the ACTUAL POSITION to the REQUESTED POSITION, does not change the COMMAND POSITION, and updates the TARGET POSITION as follows:

$$\text{new TARGET POSITION} = \text{old TARGET POSITION} - (\text{ACTUAL POSITION} - \text{REQUESTED POSITION})$$

NOTE: When issuing a Z command, the REQUESTED POSITION should be greater than the OFFSET parameter. The REQUESTED POSITION must also fall between the EXTEND and RETRACT limits. See the modified OFFSET parameter definition in this appendix for more information.

TMC 188/40-(T)Q Parameter Changes

The definition and use of several initialization parameters have been changed to work with quadrature encoders. Axes using magnetostrictive transducers are not affected.

DIRECTION (Default: 0)

The DIRECTION parameter must be set to zero (positive direction). **Reverse the A and B quadrature signals and the drive output leads to reverse the direction.**

SCALE (Default: 1000; 512 minimum, 65535 maximum)

When a quadrature input is selected, this field is interpreted as quadrature encoder counts per 1000 position or angle units. A SCALE of 5000 means 5 encoder counts will yield 1 position unit. Since the Programmable Controller is limited to 16 bit numbers (0-65535), SCALE is used to determine the system's usable resolution. (The larger the SCALE parameter, the lower the usable resolution.) The ratio of SCALE to the system's mechanical resolution determines the units of measurement used. The following examples illustrate how the SCALE parameter is used.

Terms:

PPR = Pulses Per Revolution is the number of lines on the quadrature encoder disk.

Mechanical Resolution = Number of quadrature encoder counts per inch (or centimeter, turn, etc.)

Unit of measurement = Result of scaling the quadrature encoder counts - usually 0.001 inch, 0.1 mm, 0.1 degree., etc.

Usable resolution = Number of Units of measurement per inch (or centimeter, turn, etc.)

Example 1

1,000 PPR quadrature encoder (4,000 quadrature encoder counts per 1 revolution)

Lead screw ratio = 1 inch of travel per revolution

Mechanical resolution = 4,000 counts per inch

Total travel = 10 inches

Maximum quadrature encoder counts = 40,000 (10 x 4,000)

Option 1

SCALE = 4,000

Unit of measurement = 0.001 inch

Usable resolution = 1,000 parts per inch

Option 2

SCALE = 1,000

Units of measurement = 0.00025 inches (SCALE / mechanical resolution/1000)

Usable resolution = 4,000 parts per inch

NOTE: A SCALE of 800 could be used, resulting in a unit of measurement of 0.0002 inches and a usable resolution of 5,000 parts per inch. This increased resolution may be helpful conceptually, but the real system resolution is still limited to the 4,000 parts per inch of the mechanical system.

Example 2

1,000 PPR quadrature encoder (4,000 quadrature encoder counts per 1 revolution)
 Lead screw ratio = 1 inch of travel per 5 revolutions
 Mechanical resolution = 20,000 counts per inch
 Total travel = 6 inches
 Maximum quadrature encoder counts = $4,000 \times 5 \times 6 = 120,000$

Option 1

SCALE = 20,000
 Units of measurement = 0.001 inch
 Usable resolution = 1,000 parts per inch

Option 2

SCALE = 2,000
 Units of measurement = 0.0001 inch ((SCALE / 1000)/mechanical resolution)
 Usable resolution = 10,000 parts per inch

Note: A SCALE of 1,000 **cannot** be used because it would mean using a unit of measurement of 1/20,000 (0.00005 inch) and a total travel of 120,000 units (6 inches x 20,000), which is greater than the maximum ACTUAL POSITION count limit of 65535 units.

OFFSET (Default: 0; -32,768 minimum, 0 maximum)

The OFFSET parameter determines the range of numbers accepted by the TMC 188/40-(T)Q as valid REQUESTED POSITION values. OFFSETS are always negative, and the minimum limit of the range is the OFFSET. The maximum limit is the OFFSET value plus 65,535.

Example:	OFFSET	Position Range
	-10,000	-10,000 to 55,535

Readback Parameters

TRANSDUCER COUNTS

This field contains the number of counts read from the quadrature encoder. (Quadrature encoder counts per revolution = 4 x pulses per revolution.) Since the quadrature encoder counts can exceed 65535, this field will roll over (reset to zero) every 65536 counts.

NOTE: If an application uses the Transducer Counts field, it must keep track of the rollovers (the number of times the counts pass 65,535 and rolls over to 0).

STATUS Word

STATUS Word Bit 6 - Transducer Not Responding

When using an quadrature encoder, Status Word bit 6 is set when the count rate exceeds 800,000 quadrature encoder counts per second (200,000 pulses per second). The bit is not latched and will be cleared when the count rate falls below 800,000 quadrature encoder counts per second.

NOTE: An emergency stop will be made when bit 6 is set.

STATUS Word Bit 7 - Out of Limit

Bit 7 equals zero (0) when the Limit input is Active (Within-Limits). It is one (1) when the Limit is inactive (Out-of-Limit). Since the Limit input is designed to be fail-safe, an inactive input is taken as an 'Out-of-Limit' condition.

Limit and Home Digital Inputs

Each quadrature axis can be controlled using the Limit and Home digital inputs. Normally each input is independent of the other. The Limit input lets you halt a move if the axis extends beyond a physical protection point. The Home input lets you preset the position counters to some known value.

The Home input is used to preset the position counters to a specific value. Whenever the Home input is active, the position counter will be preset to the specified value.

The Limit input is designed to be normally Active, permitting fail-safe operation. The type of stop (if any) is determined by bit 7 in the ESTOP and HALT masks. The choice is either an emergency stop (ESTOP) or a ramped stop (Halt). See the table below for details. The Limit input can also be used as a digital input. It can be monitored directly using the Status Word bit 7. Status Word bit 7 is equal to zero when the input is active.

NOTE: If no hardware Limit input is used, bit 7 in the Halt masks must be set to 1.

State of Limit Input	HALT Mask Bit 7	ESTOP Mask Bit 7	Result
*Inactive (No current)	Zero (Enabled)	Zero (Enabled)	The TMC 188/40-(T)Q sets the drive to null (emergency stop). Once stopped, the axis can be moved again by requesting a new position.**
*Inactive (No current)	Zero (Enabled)	One (Disabled)	If the axis is moving, the TMC 188/40-(T)Q decelerates at the rate set by the Deceleration parameter. The TMC 188/40-(T)Q starts its deceleration on detection of a high to low transition on the Limit hardware input. Once stopped, the axis can be moved again by requesting a new position.**
*Inactive (No current)	One (Disabled)	N/A	The TMC 188/40-(T)Q will not stop or decelerate the axis. The Halt mask must be enabled for either type of stop to be made. The Limit input can be monitored by using Status Word bit 7.
Active (Current flowing)	N/A	N/A	Normal mode. TMC 188/40-(T)Q controls axis as directed. The Limit input can be monitored by using Status Word bit 7.

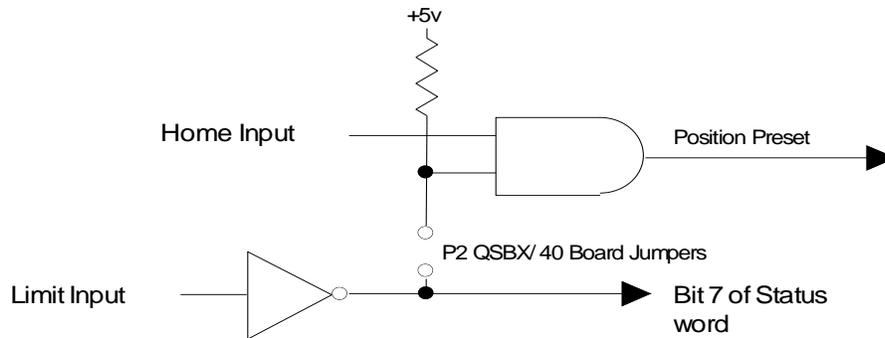
* Results are unpredictable if the LIMIT input is not stable.

** Once the LIMIT Active-to-Inactive edge is detected and the axis is stopped, it is the Programmable Controller's responsibility to make sure the requested positions are within the correct limits before another move is made.

CAUTION: The HALT MASK bit must be enabled (set to zero) to use the ESTOP MASK.
--

Home Qualifying

When board jumper P2 is installed, the Limit input can be used to qualify the Home input.



Limit Input

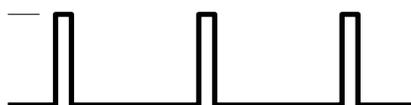
Active Input (>3.25 VDC)



Inactive Input (<1.5VDC)

Home Input

Active Input (>3.25 VDC)



Inactive Input (<1.5VDC)

Qualified Home

Active Input (>3.25 VDC)



Inactive Input (<1.5VDC)

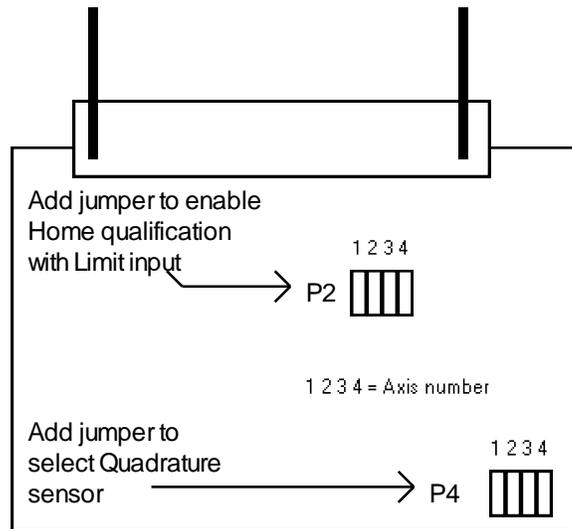
Home Position Preset

Notice in the figure above (with jumper installed) the Home position is only preset if the Limit is Inactive and Home is Active.

While the Home input is active, the counter is held at the preset value even if the axis moves (i.e., it is not edge sensitive).

CAUTION: The hardware Home input must be deactivated when the axis is given a G command; otherwise the drive output could become large.

QSBX/40 Board Jumpers



Quadrature Axes Selection

The axes using quadrature encoder feedback are selected by installing jumpers on the stake pins labeled P4. For example, if jumpers are installed in P4-2 and P4-4, then:

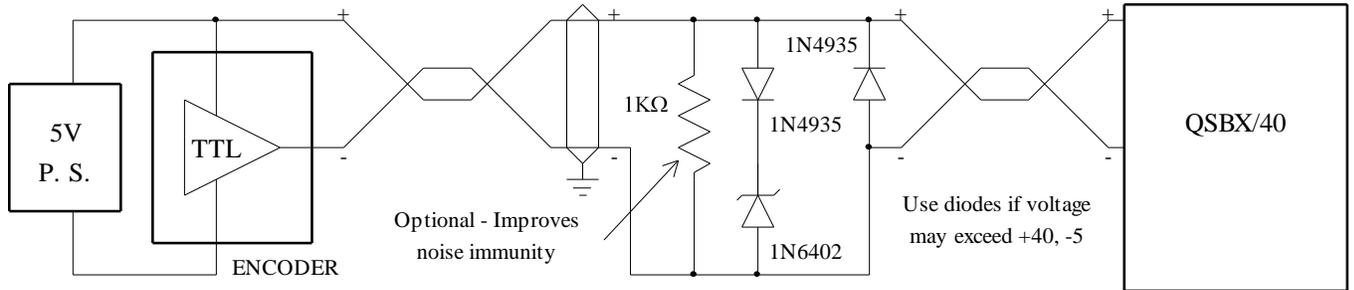
- Axis #1 -- Magnetostrictive
- Axis #2 -- Quadrature
- Axis #3 -- Magnetostrictive
- Axis #4 -- Quadrature

Home Qualify Jumpers

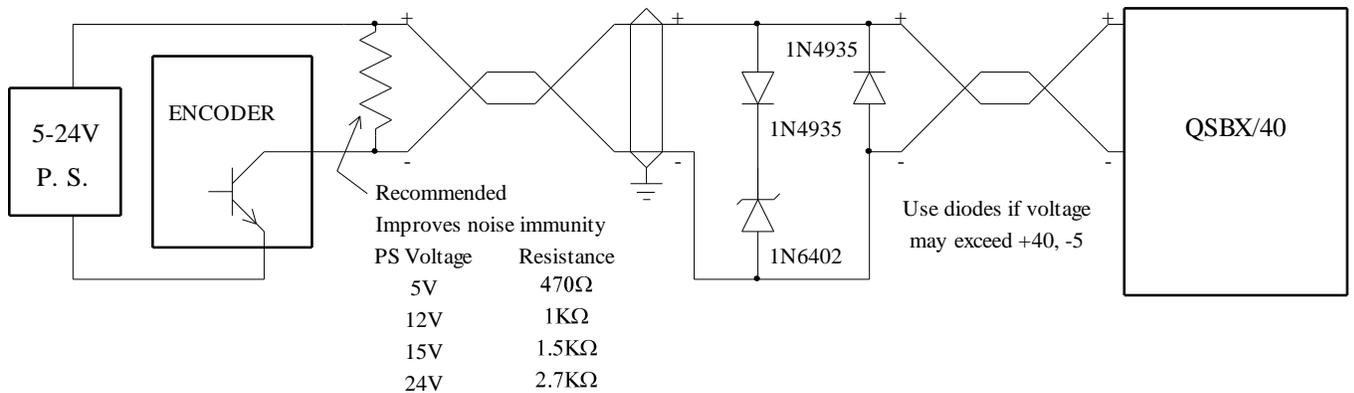
The jumpers used to qualify the Home input are located at P2. Installation of the jumper will inhibit the Home input if the Limit input is Active (normal fail-safe condition). With the jumper removed, only the Home input needs to be Active to preset the TMC 188/40-(T)Q to the home position.

Quadrature Encoder Interface Examples

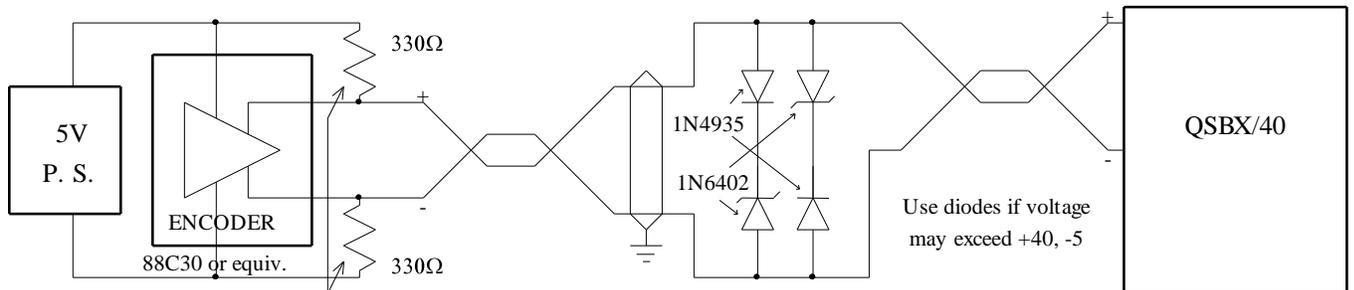
TTL



Open Collector



Differential Line Driver



Resistors recommended if the PS is between 4.75 and 5.0 V or the line resistance is more than 5.5 ohms. If PS = 5.25, the line res. can be 22 ohms without resistors.

NOTE : Practical line lengths may be limited by noise. In demanding environments differential receivers should be used.

Line Res.	28AWG	24AWG
5.5 Ohm	75 ft	175 ft
7.5 Ohm	100 ft	250 ft
22 Ohm	300 ft	700 ft

Front Panel Indicators

The indicator LEDs for the axes (labeled 1, 2, 3, and 4) using quadrature encoders on the TMC 188/40-TQ work as follows:

Red	Jumper P4 not installed on QSBX/40
Flashing Red	Control error detected or no Limit input
Green	Quadrature - OFF; MDT - green when transducer OK

The TMC 188/40 Q (no magnetostrictive transducers) LEDs work as follows:

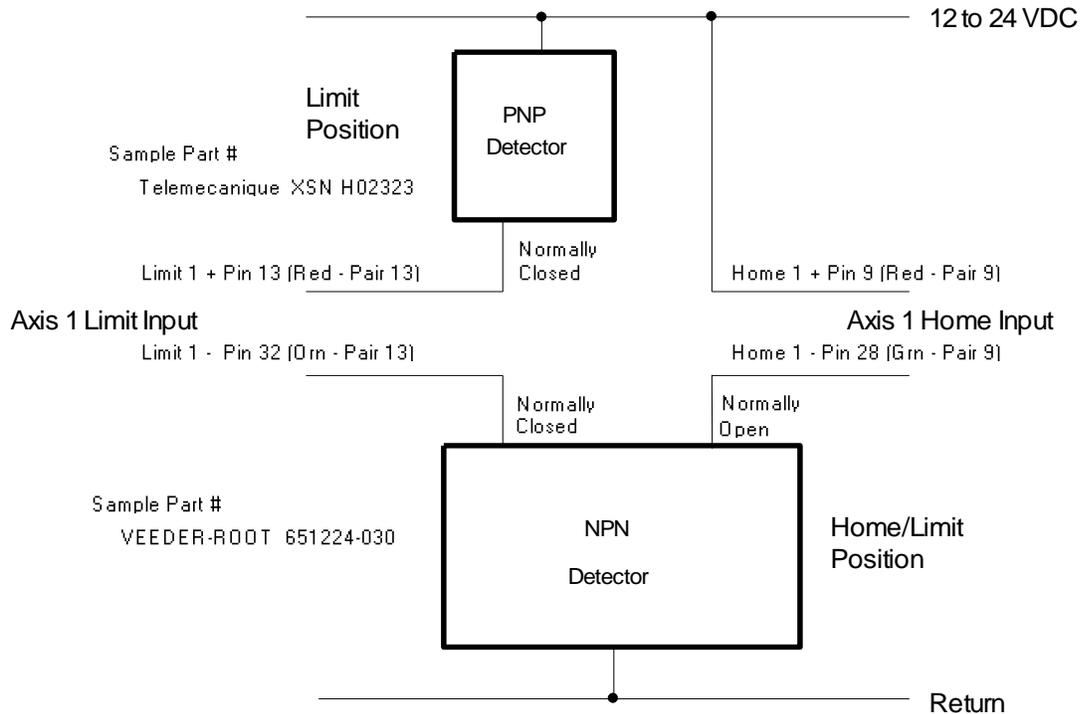
Red	Jumper P4 not installed on QSBX/40
Flashing Red	Control error detected or no Limit input
Green	Quadrature status OK

Front Panel DB 37 Female Connector

DB 37P to pigtail cable (10 feet) for quadrature inputs.

Pin	Function	Wire Color
1	Axis 1 Phase A+ input	BLACK pair 1
20	Axis 1 Phase A- input	RED pair 1
2	Axis 1 Phase B+ input	BLACK pair 2
21	Axis 1 Phase B- input	WHITE pair 2
3	Axis 2 Phase A+ input	BLACK pair 3
22	Axis 2 Phase A- input	GREEN pair 3
4	Axis 2 Phase B+ input	BLACK pair 4
23	Axis 2 Phase B- input	BLUE pair 4
5	Axis 3 Phase A+ input	BLACK pair 5
24	Axis 3 Phase A- input	YELLOW pair 5
6	Axis 3 Phase B+ input	BLACK pair 6
25	Axis 3 Phase B- input	BROWN pair 6
7	Axis 4 Phase A+ input	BLACK pair 7
26	Axis 4 Phase A- input	ORANGE pair 7
8	Axis 4 Phase B+ input	RED pair 8
27	Axis 4 Phase B- input	WHITE pair 8
9	Axis 1 HOME+ input	RED pair 9
28	Axis 1 HOME- input	GREEN pair 9
10	Axis 2 HOME+ input	RED pair 10
29	Axis 2 HOME- input	BLUE pair 10
11	Axis 3 HOME+ input	RED pair 11
30	Axis 3 HOME - input	YELLOW pair 11
12	Axis 4 HOME+ input	RED pair 12
31	Axis 4 HOME- input	BROWN pair 12
13	Axis 1 LIMIT + input	RED pair 13
32	Axis 1 LIMIT - input	ORANGE pair 13
14	Axis 2 LIMIT + input	GREEN pair 14
33	Axis 2 LIMIT - input	WHITE pair 14
15	Axis 3 LIMIT + input	GREEN pair 15
34	Axis 3 LIMIT - input	BLUE pair 15
16	Axis 4 LIMIT + input	GREEN pair 16
35	Axis 4 LIMIT - input	YELLOW pair 16
17	N.C.	GREEN pair 17
36	N.C.	BROWN pair 17
18	N.C.	GREEN pair 18
37	N.C.	ORANGE pair 18

Sample Limit and Home Configuration



The optically-isolated Home and Limit inputs (one each per axis) can be configured as shown above. This configuration uses a combination Home/Limit detector at one end of the travel and a Limit detector at the other end. The Home/Limit detector has two independent NPN open collector outputs. The normally closed output is used for the Limit function and is connected so either detector will operate the Limit input. The normally open output of the Home/Limit detector generates the Home (reset) signal.

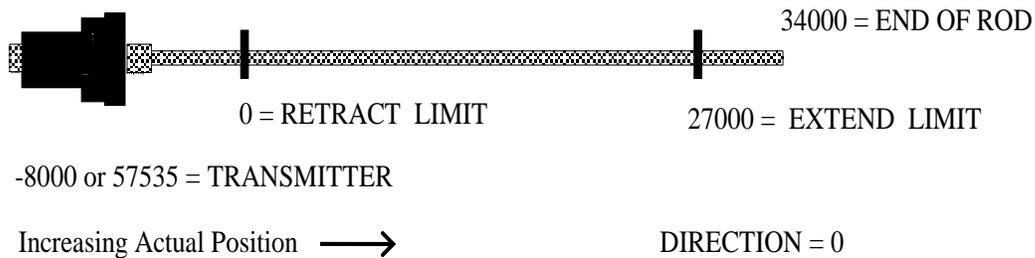
Appendix D: Application Notes

Using the OFFSET and DIRECTION Fields

The TMC 188/40 assumes the zero position is at the transmitting end of the transducer rod and that position increases as the magnet moves away from the transducer transmitter. However, this may not be suitable for all applications. For example, the magnet cannot get to the zero position because it is actually inside the transmitter. Physically it may not be possible to get within eight inches of the zero position. To make this position indicate 0 inches you must subtract 8000 in the OFFSET field (assuming a 0.001" position unit). Subtract the OFFSET from 0 (which equals 65536 in 16 bit math) and use that number as the OFFSET. For this example $65536 - 8000 = 57536$. Remember to subtract 8000 from the EXTEND LIMIT and RETRACT LIMIT.

END OF ROD	42000	- 8000 =	34000
EXTEND LIMIT	35000	- 8000 =	27000
RETRACT LIMIT	8000-	8000 =	0
TRANSMITTER	0 (65536)	- 8000 =	57535
OFFSET	0 (65536)	- 8000 =	57535
DIRECTION	0	=	0

Here is how these parameters look:



-8000 or 57535 = TRANSMITTER

NOTE: In this example, positions between the transmitter at -8 inches (57535 in 16-bit math) and the RETRACT LIMIT at 0 inches will cause the axis to move to the RETRACT LIMIT. Positions between 27000 and 57535 will cause the axis to move to the EXTEND LIMIT.

Once the parameters have been updated in VINIT V Memory, place a 'P' in the COMMAND parameter of VWRITE V Memory to tell the TMC 188/40 to accept the new values. Now, if the axis is told to go to 60 inches, which way will it move? With the 8 inch OFFSET, all numbers between 57535 and 65536 are between the transmitter and the retract limit, so they are negative positions (behind the retract limit). 60 inches is the same as -5.536 inches ($60000 - 65536 = -5536$). Therefore the axis will retract to the RETRACT LIMIT. As you can see, when the OFFSET is set to a value other than zero, you must consider all values to be both signed and unsigned. In this example, all numbers between 57535 and 65536 are really negative numbers.

Next, consider the case where the position at the EXTEND LIMIT is zero and the position at the RETRACT LIMIT is 27 inches. Since we want the position to increase as the axis retracts it is necessary to set the DIRECTION field to -1 or 65535. When the DIRECTION field changes, the other positions must change as follows:

END OF ROD	42000:	65536 - 42000 =	23536
------------	--------	-----------------	-------

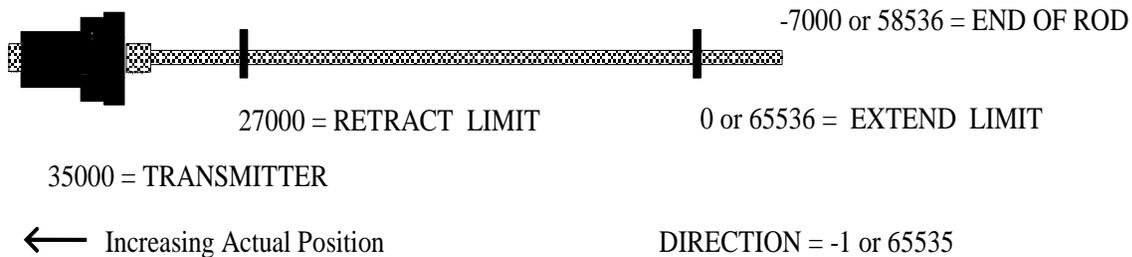
EXTEND LIMIT	35000:	$65536 - 35000 =$	30536
RETRACT LIMIT	8000:	$65536 - 8000 =$	57536
TRANSMITTER	0:	$65536 - 0 =$	$65536 = 0$
OFFSET	0:	0	
DIRECTION	0:	-1 or 65535	

From the position table above, the new position is 65536 minus the old position. Remember to change the extend and retract limits.

The next step is to change the OFFSET so the EXTEND LIMIT is the 0 position. This can be done by subtracting the EXTEND LIMIT position from the OFFSET as follows:

END OF ROD	$23536 - 30536 =$	-7000 , or 58536	$(65536 - 7000 = 58536)$
EXTEND LIMIT	$30536 - 30536 =$	0	
RETRACT LIMIT	$57536 - 30536 =$	27000	
TRANSMITTER	$0 - 30536 =$	-30536 , or 35000	$(65536 - 30536 = 35000)$
OFFSET	$0 - 30536 =$		-30536 , or 35000 $(65536 - 30536 = 35000)$
DIRECTION		-1 or 65535	

Here is how these parameters look:



NOTE: In this example, positions between the transmitter at 35000 and the RETRACT LIMIT at 27000 will cause the axis to move to the RETRACT LIMIT. Positions between 35000 and 65536 will cause the axis to move to the EXTEND LIMIT.

NOTE: DCSSMON stores the parameters in a 32-bit format with a range of -65535 to +65535. It does this to display them with their correct signs. To update DCSSMON's files, you must save the parameters to the module's BDn (board) file. After you have adjusted them so the axes move correctly, enter 'S <CR>' at DCSSMON's main screen to save the parameters in the module's BDn file.

Acceleration and Deceleration Modes

The Motion Control Module defaults to expressing acceleration and deceleration in ramping distance. A value of 2000 in the acceleration field represents a ramp length of 2 inches. By setting bit 16 of the Mode word to 1, acceleration can be expressed in inches/sec². Generally, expressing acceleration as a ramp distance is easier if two or more axes must move together in coordination but not at the same speed or distance. Otherwise, expressing the acceleration in inches/sec² is easier. The drawback to using the distance method is that the acceleration and deceleration distance must change every time the speed changes, if the rate is to be constant. The relationship between the rate and the distance is:

$$\text{Rate} = (\text{Speed} \times \text{Speed}) / (2000 \times \text{Distance})$$

or

$$\text{Distance} = (\text{Speed} \times \text{Speed}) / (2000 \times \text{Rate})$$

These calculations are not difficult, but by expressing the acceleration and deceleration as a rate the Motion Control Module will calculate the ramp distances. The distance mode is for applications such as headrigs or x-y positioning devices, where you want two different axes to move to new positions and arrive at the same time even though they must move different distances. For example, assume an x-y plotter at position 0,0. Now assume you want to move straight to position 4,3. To do this set the x axis' speed, acceleration, and deceleration distance. Now use 3/4 of the x speed for the y speed and do likewise for the y ramps. The parameters might look like this:

	X	Y
	-----	-----
ACCEL	2000	1500
DECEL	2000	1500
SPEED	12000	9000
REQ POS	4000	3000

The two axes will draw a straight line between 0,0 and 4,3.

Even Ending

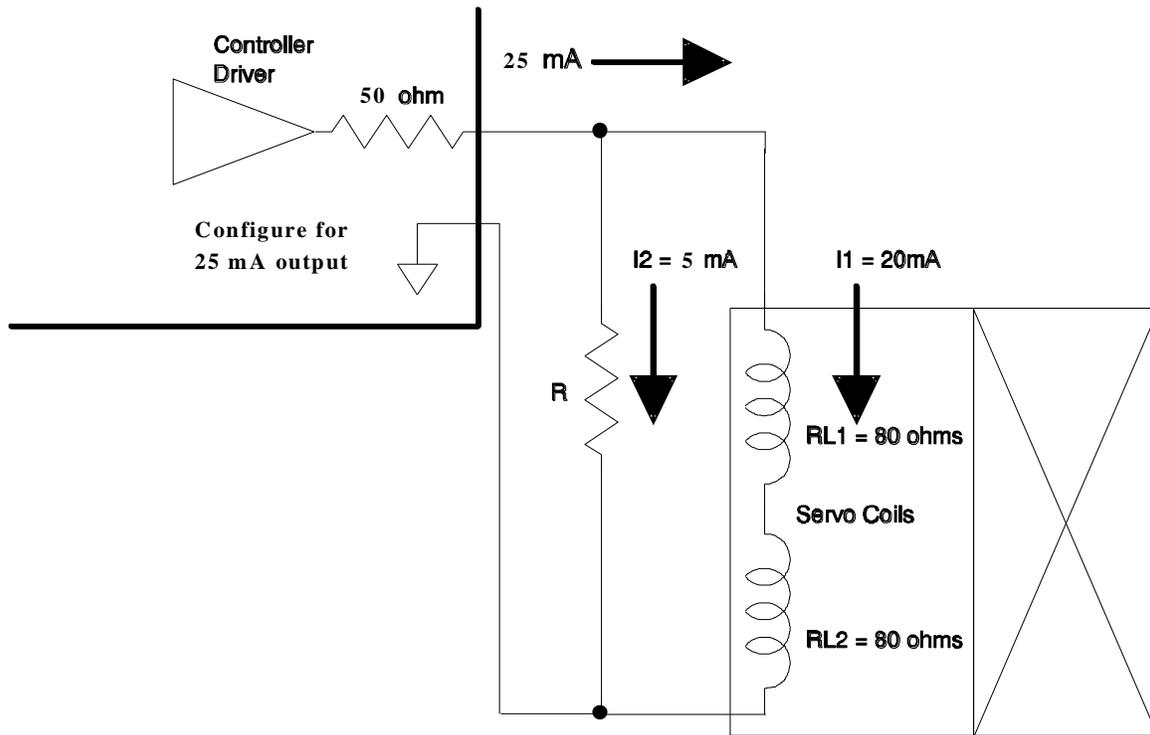
The TMC 188/40 can do even ending. To do this the Motion Control Module monitors the actual position of each axis every two milliseconds and checks it's movement. If the axis is obstructed the STOPPED bit (bit 10) in the status field is set. By setting the masks appropriately, the MCM can halt the axes by ramping or stopping immediately. In even ending applications the STOPPED bit on both axes should set at about the same time. The two positions can then be read and a left or right shift can be done by extending one axis and retracting the other. By moving the extending axis a little faster than the retracting axis, you can avoid dropping the clamped object.

In even ending applications you can generally ignore the lag, lead and overdrive errors because the hydraulic pressure will be reduced to avoid damaging whatever is being even ended. You should also use the 'S' (save null) command before clamping, since clamping can cause the TMC 188/40 null to change. The 'R' (restore null) command will retrieve the saved null value.

There are two limitations to using the STOPPED bit:

- 1) The axis must be moving 1 inch/second or greater
- 2) It takes 10 milliseconds to detect the obstruction.

Example Using 20mA Servo Valves with 25mA Output



$$V_{\text{out}} = 20 \text{ mA} \times (80 \text{ Ohms} + 80 \text{ Ohms}) = 3.2 \text{ volts across coils}$$

$$R = 3.2 \text{ volts} / 5 \text{ mA} = 640 \text{ Ohms}$$

You can use a this technique to scale the output current (100 mA, 50 mA, or 25 mA) to a lower full scale current. This lets you use the maximum output resolution of the TMC 188/40 with valves needing less than one of the full-scale outputs.

To find what wattage of resistor to use, calculate the power dissipation:

$$\text{Power} = I^2 \times R$$

SO:

$$\text{Power} = (5 \text{ mA})^2 \times 640 \text{ Ohms} = 0.016 \text{ Watts}$$

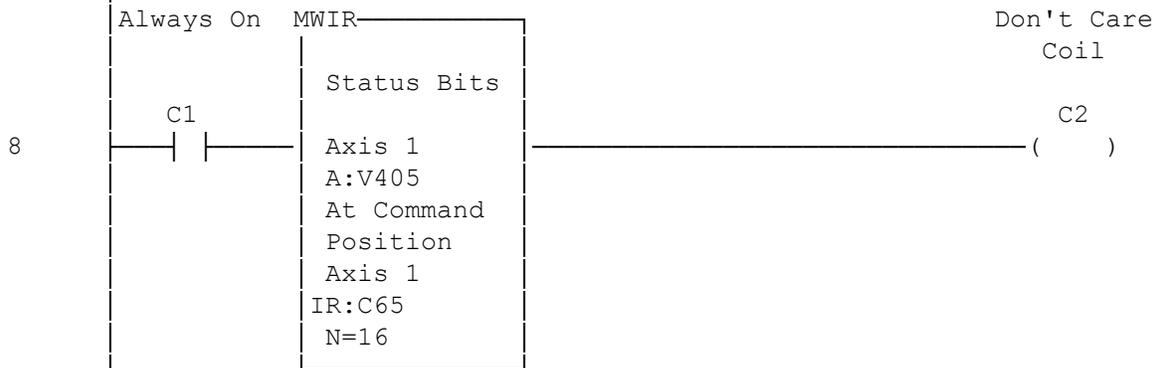
A quarter Watt resistor would be a good choice.

For Model 525 and 535 controllers:

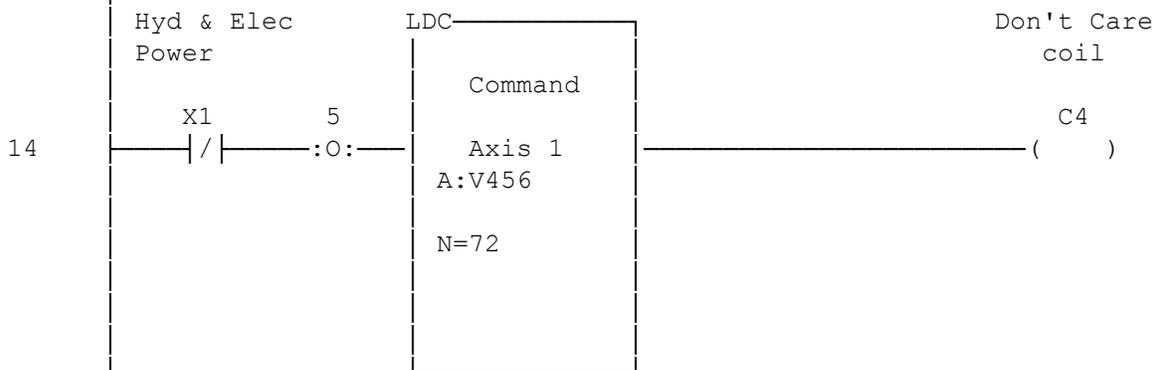
This rung writes the status register to coils. It copies the 16-bit word at V405 (Axis 1 Status Bits) to coils C65 through C80. This lets you use the contacts to monitor the axes' status without using the less-efficient bit picks. The At Command Position bit (Status Bit 16) is written to C65, the first coil.

For Model 545 and 555 controllers:

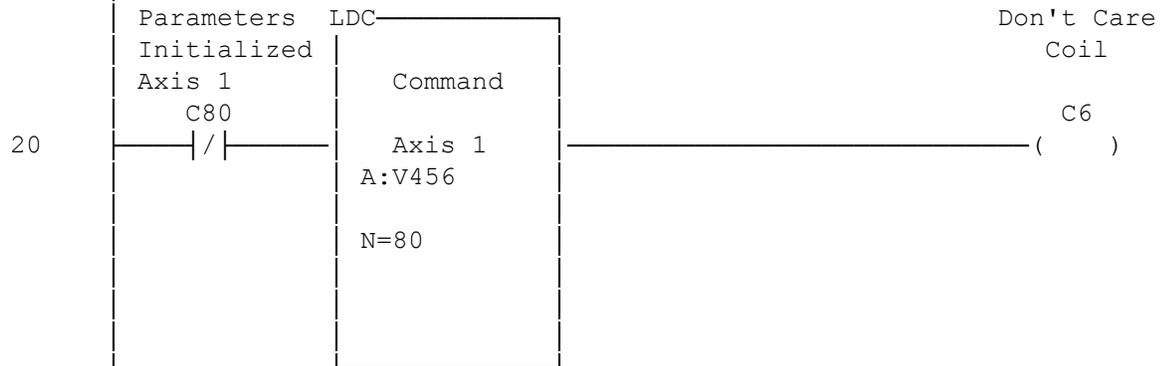
A bit pick routine will work as well.



This rung halts the axis when hydraulic or electric power is turned off. It writes a 72 ('H' or 'HALT' command) to V456, the Axis 1 command register. This prevents the integral term from winding up.



This rung initializes Axis 1 whenever the Parameter Initialized bit is not set in the status field. It writes an 80 ('P' or 'Initialize Parameters' command) to V456 (the Axis 1 command register). It does this every scan until the axis is initialized and coil C80 is energized. See Address 8.



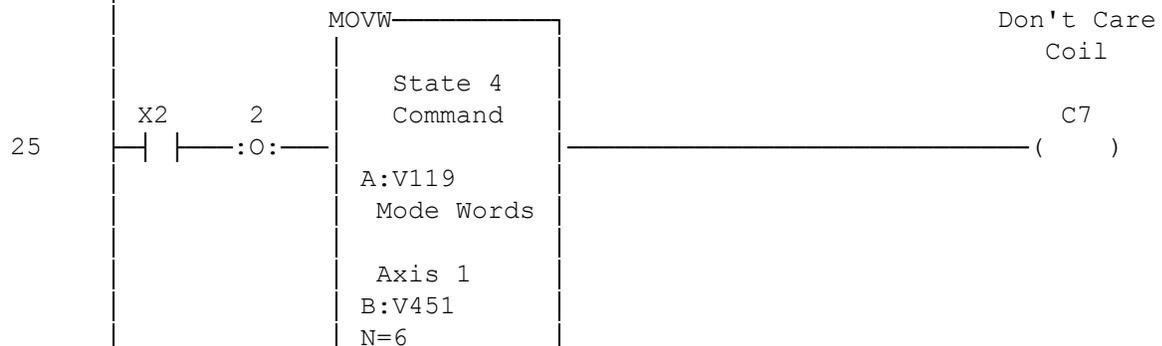
This rung copies 6, 16-bit words (the MODE, ACCEL, DECEL, SPEED, POSITION, and COMMAND words) from V119 through V124 to the V Memory command registers of Axis 1 (V451 through V456). The source of the parameters is a table starting at V101. Using a table, rather than hard coding, makes the

ladder

easier to change. The one shot guarantees the words move only once, on the first scan after X2 is energized.

For example, if the following values are in the table, the axis will move to 10000 with a Speed of 5000 and Accel and Decel terms of 100:

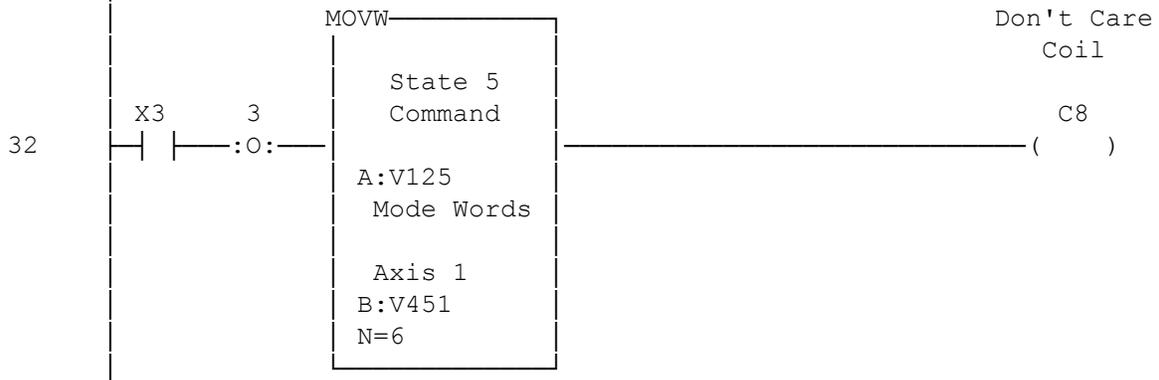
Term	Table	Value	Command Reg.
Mode	V119	1	V451
Accel	V120	100	V452
Decel	V121	100	V453
Speed	V122	5000	V454
Position	V123	10000	V455
Command	V124	71	V456



This rung copies a different 6, 16-bit words from V125 through V130 to the V Memory command registers of Axis 1.

For example, if the following values are in the table, the axis will move to 20000 with a Speed of 15000 and Accel and Decel terms of 200:

Term	Table	Value	Command Reg.
Mode	V125	1	V451
Accel	V126	200	V452
Decel	V127	200	V453
Speed	V128	15000	V454
Position	V129	20000	V455
Command	V130	71	V456



TMC 188/40 Wiring Diagrams

- 1) Motion Control Module Wiring Diagram
- 2) Magnetostrictive Transducer Wiring Diagram
- 3) TMC 188/40 Typical Wiring

Index

A

@ Command • 38, 40 - 42, 70, 86
 ACCELERATING • 24
 ACCELERATION • 37, 38, 39, 43
 ACTIVE • 24
 ACTUAL POSITION • 11, 12, 23, 25, 29, 31, 34, 40,
 41, 43 - 45, 53, 54, 72, 75, 80
 Application Notes • 98
 ASBX/40 • 74
 ASCII • 60, 73
 AT COMMAND POSITION • 23, 24, 32, 33, 41, 42,
 76
 AT REQUESTED SPEED • 24
 AXIS STATUS WORD • 23

C

Cable & Connector Information • 51
 CHART • 9, 10, 53
 Checksum • 10, 16, 53
 Clear Events • 38
 Closing the Loop • 44
 COMMAND • 23, 24, 34, 38, 43, 78
 Common Problems and Solutions • 53
 CONFIO • 9
 Connectors • 51, 52, 81, 96
 Control at Rest • 45

D

DCSMON • 9 - 14, 30, 38, 41, 53, 56, 69 - 71, 79,
 81
 DECELERATING • 24
 DIFFERENTIAL GAIN • 13, 14, 29, 35, 44, 69
 DIRECTION • 11, 30 - 33, 83, 88, 98, 99
 Disable Drive Output • 39
 DITHER • 28
 DRIVE • 27, 72
 Drive Output • 35, 43, 72
 Drive Output Shutoff • 50
 Drive Selection • 47

E

Encoder • 42
 ESTOP MASK • 15, 27
 Even Ending • 101
 EXTEND FEED FORWARD • 14, 29, 45, 69
 EXTEND GAIN • 14, 29, 69
 EXTEND LIMIT • 11 - 13, 33, 43, 98, 99
 External Wiring • 47

F

Feed Forward • 30, 38, 45, 60, 72
 FEED FORWARD ADVANCE • 13, 14, 27, 28, 45,
 69

G

G • 13, 23 - 25, 29, 35, 38, 40, 43, 44, 70, 73, 77,
 78
 GO • 13, 23, 25, 38, 39

H

H see HALT
 HALT • 13 - 15, 24, 27, 39, 54, 69
 HALT MASK • 14, 15, 27, 69, 76
 HALTED • 24, 25, 54
 Hardware Restart • 50
 Home Inputs • 91
 Home Qualify • 92
 HYSTERESIS • 14, 28, 69, 76

I

I/O • 9, 16
 Initialization • 9, 10, 16, 17, 21, 40, 53, 71, 76
 INTEGRAL GAIN • 13, 14, 29, 44, 69, 72, 76
 Interrogation • 43, 47 - 49, 59
 Interrogation Pulse Polarity • 48

L

LAG • 13, 14, 25, 45, 69
 LAG ERROR • 25
 LEAD • 13, 14, 25, 45, 69
 LEAD ERROR • 25
 Limit Inputs • 91

M

Magnetostrictive • 7, 8, 11, 15, 30, 46 - 49, 60, 74,
 78, 80
 Mask Events • 39
 MAX ERROR • 14, 32, 69
 MODE • 33, 36, 38, 41, 62, 74, 78
 Module Hardware • 46
 Module Jumpers • 47

N

NEAR COMMAND POSITION • 24, 33
 NEW NULL • 27

NULL UPDATE • 14, 28, 45, 69

O

OFFSET • 11, 32, 40, 41, 43, 77, 80, 98, 99

Open Loop • 39

OVERDRIVE • 25, 84

P

P (Initialization) • 11 - 13, 17, 25, 33, 35, 40, 43, 70, 71, 77, 78, 98

P/C • 7, 9 - 11, 15 - 17, 21, 25, 27, 33, 40, 43, 46, 47, 51, 53, 54, 76

PARAMETER ERROR • 24

PARAMETERS INITIALIZED • 25

PID • 7, 35, 60, 77, 80

POSITION OVERFLOW • 24

Position • 43, 79, 85

Pressure • 35, 41, 56, 58, 70, 74, 76 - 81

PRESSURE COMMAND • 77, 78, 80

PRESSURE DIFFERENTIATOR • 77

PRESSURE GAIN • 77

PRESSURE INTEGRATOR • 77

PRESSURE LOW • 78, 80

PRESSURE OFFSET • 77, 80

PRESSURE RAMP • 77, 79, 80

PRESSURE SCALE • 77, 80

Programmable Controller • 7, 39, 78

Q

Quadrature • 23, 30, 35, 38, 40, 41, 46, 70, 82 - 97

R

READBS • 9

Recirculation • 11, 31, 49, 50, 60

Repairs and Returns • 59

REQUESTED POSITION • 13, 23, 35, 37, 39 - 41, 43

Restore Null • 40

RETRACT FEED FORWARD • 14, 30, 45, 69

RETRACT GAIN • 14, 29, 32, 44, 69

RETRACT LIMIT • 11 - 13, 33, 43, 98, 99

S

Save Null • 40

SBX • 60

SCALE • 11, 30 - 32, 35, 37, 40, 43, 60, 77, 80, 83, 88

Scan time • 7

Set • 9, 17, 38, 40, 41, 60, 70, 71, 78, 79

Set Feed Forward • 38

Set Parameters • 40

Set Pressure Low • 41, 79

Set Pressure Ramp • 78

Set Requested Pressure • 79

SFIC • 7, 8, 11, 16, 47

Simulation • 34, 36

Software Restart • 50

Special Function Interface Chip • 7, 11, 16, 47

SPEED • 13, 24, 29, 33 - 35, 37, 39, 41 - 43, 45, 72, 100

STATIC GAIN • 14, 29, 45, 69

STATUS Word • 15, 23, 26, 54, 78, 90

STOPPED • 24

Sum of Errors Squared • 38, 67

SyncA • 34

SyncB • 34

System Reset • 51

T

TARGET • 23 - 25, 27, 29, 34, 35, 40, 41, 43 - 45, 72, 78

TI505 • 7, 47, 51, 74

TISOFT • 9, 10, 11, 53

TRANSDUCER COUNTS • 11, 12, 15, 18, 23, 29 - 32, 53, 80, 90

TRANSDUCER NOT RESPONDING • 25, 54

Transducer Protection Resistors • 48

Trigger Events • 38

V

V Memory • 7, 9 - 12, 15 - 22, 46, 53, 63, 75, 76, 98

VALVE OUT OF NULL • 25

VINIT • 10, 15 - 18, 21, 27, 43, 74, 76, 77, 98

VREAD • 10, 16, 17, 19, 21 - 23, 75, 76

VWRITE • 10, 16, 17, 20, 21, 33, 38, 43, 98

W

WRITPC • 9

WY registers • 7, 9 - 11, 15 - 17, 46, 53

Z

Z Command • 87