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VMC 186/40

Motion Controller Module

931104

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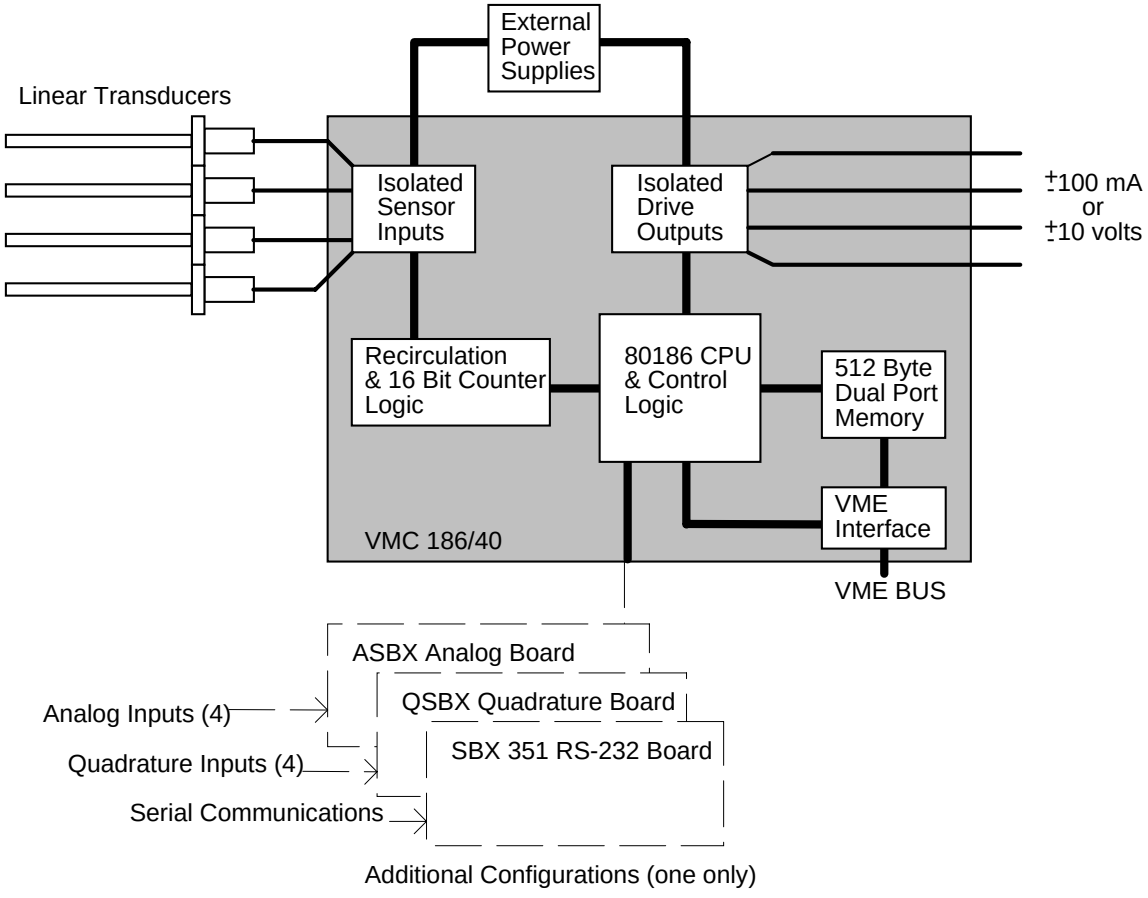
Overview

The VMC 186/40 motion controller module was designed to provide a complete four axis position control sub-system for the VME bus. Each axis is controlled by an on-board processor that provides a complete PID loop in addition to numerous special functions. Coordinated moves and position changes can be made on-the-fly. With various options, it is possible to control position using either quadrature encoders, analog slide potentiometers or magnetostrictive transducers. In its standard configuration, the module provides four optically isolated magnetostrictive interfaces and four optically isolated ±100 mA (±10 volts with resistors installed) outputs which can be used to drive electric servo motors and hydraulic servo valves.

The VMC 186/40 occupies one slot (two slots if options installed) of the VME rack. Programming of the VMC 186/40 is done using memory reads and writes. The on-board 80186 processor relieves the VME Controller of the overhead usually associated with servo control. The motion controller module updates the actual position and drive output every millisecond, assuring accurate positioning even at high speeds.

If more than four axis of control are required, additional VMC 186/40 modules can be installed.

VMC 186/40 Block Diagram



Hardware Specifications

VMC 186/40

12 MHz 80C186 processor
Addressable 512 byte dual port RAM
Bus interrupt for motion control errors or time interval
iSBX connector for options (Serial I/F, Analog or Quadrature Options)
One millisecond control loop time.
Linear resolution to ±0.0005 inches
Maximum velocity up to 120 inches per second using ±0.002 resolution
65535 position counts
Three hardware fail-safe timers
6U VME

Standard Position Inputs

Four optically isolated magnetostrictive transducer interfaces
1.5V return pulse sensitivity
55.5 MHz counters
1, 2 or 4 recirculations (2 default)
Positive or negative interrogating pulse

Drive

Four optically isolated servo drives
Servo Drive - ±100 milliamps (±10 volts with 100 ohm resistors installed in sockets)
12 bit digital to analog converters

Power Requirements

5V	@ 2.0 amps	VME Bus
5V	@ 0.5 amps	External Sensor
15V	@ 0.5 amps	External Sensor
-15V	@ 0.5 amps	External Sensor
15V	@ 0.5 amps	External Drive
-15V	@ 0.5 amps	External Drive

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

VME Memory Map

Memory Map Using Default Address

Axis 1	0D0000H-0D007FH
Axis 2	0D0080H-0D00FFH
Axis 3	0D0100H-0D017FH
Axis 4	0D0180H-0D01FFH

Individual Axis Memory Map

Hex Offset	Parameter Name	Default Value	Descriptions
00H	Command Position	Read Only	Requested Position with limits checked
02H	Target Position	Read Only	Calculated position of axis
04H	Actual Position	Read Only	Scaled position measurement
06H	Transducer Counts	Read Only	Raw transducer counts
08H	Status Word	Read Only	Axis error and status
0AH	Drive	Read Only	Output drive in raw A/D counts (12 bit)
0CH	Target Speed	Read Only	Calculated speed
0EH	Null Drive	Read Only	Current value for null drive
10H-39H	24 Reserved words		
40H	Axis 1 Free Running Clock	Read Only	Free running 16 bit counter using millisecond clock
	Axis 2 Active Bit Interval	256	Active Bit toggle interval in milliseconds (*Status Word* axis 1)
	Axis 3 Graph Interval	2	Data capture interval (two millisecond increments)
	Axis 4 Reserved		
42H	VME Status_ID	0	VME status code for interrupt
44H	New Null	2048 (Write Only)	Entry for preset drive offset
46H	Estop Mask	FFFFH	Enables emergency stop on errors (Bit = 0 = Enabled)
48H	Halt Mask	0000H	Enables ramped stop on errors (Bit = 0 = Enabled)
4AH	Interrupt Mask	FFFFH	Enables VME interrupt based on *Status Word* (Bit = 0 = Enabled)
4CH	Feed Forward Advance	0	Time shift in milliseconds for Feed Forward term
4EH	Null Update	500	Null calculation interval in milliseconds
50H	Minimum Update Time (Axis one only)	1000	Minimum time in microseconds between sensor readings
52H	Dither	0	Static friction drive in percent of full drive
54H	Hysteresis	0	Deadband compensation
56H	Static Gain	50	Proportional gain at rest
58H	Extend Gain	50	Proportional gain when extending
5AH	Retract Gain	50	Proportional gain when retracting
5CH	Integral Gain	0	Integral gain while in motion
5EH	Differential Gain	0	Differential gain
60H	Extend Feed Forward	100	Feed-forward drive when extending
62H	Retract Feed Forward	100	Feed forward drive when retracting
64H	Scale	32768	Measured position conversation number
66H	Position Offset	0	Fixed position offset
68H	Direction	0	Sign of position units with respect to Transducer Counts
6AH	Maximum Position Error	250	Set point for position error indication
6CH	At Command Position	50	Window around requested position for status bit
6EH	Near Command Position	0	Window around requested position for status bit
70H	Extend Limit	Position on power-up	Maximum length allowed
72H	Retract Limit	Position on power-up	Minimum length allowed
74H	Mode	0	Function selection bits
76H	Acceleration	1000	Acceleration rate or distance
78H	Deceleration	1000	Deceleration rate or distance
7AH	Requested Speed	1000	Maximum speed during a move
7CH	Requested Position	N/A	Destination position in position units
7EH	Command	N/A	Command to be executed (F, G, H, P,O, R, S)

Motion Control Parameters

The motion control parameters are the means of axis control. A complete understanding of the parameters and *Status Word* bits are necessary in order to fully utilize the motion controller's features.

Read Only Parameters

Command Position

The *Command Position* is the *Requested Position* with bounds checking applied. If the *Requested Position* was outside the *Retract* or *Extend Limit*, the *Command Position* will be truncated to the value of the limit, and the axis will go only to the limit. The *Command Position* is updated when a 'G' or GO command is issued using the *Command* parameter.

Note: If the requested position is outside the limits, the *Parameter Error* bit in the *Status Word* will be set. If the *Halt* or *Estop* masks are enabled for a parameter error, the axis will not move.

Target Position

The *Target Position* is the calculated position where the axis should be at any moment. When the axis is moving, the *Target Position* is updated every millisecond as it moves toward the *Command Position.* When an axis is stopped, the *Target Position* should be the same as the *Command Position* unless an error has occurred.

Actual Position

The *Actual Position* is the measured position of the axis at any moment. This position is updated every millisecond. The *Actual Position* is obtained from the *Transducer Counts* with the following formula:

$$\textit{Actual Position} = \frac{\textit{Transducer Counts} * \textit{Scale}}{32768} \text{ XOR } \textit{Direction} + \textit{Offset}$$

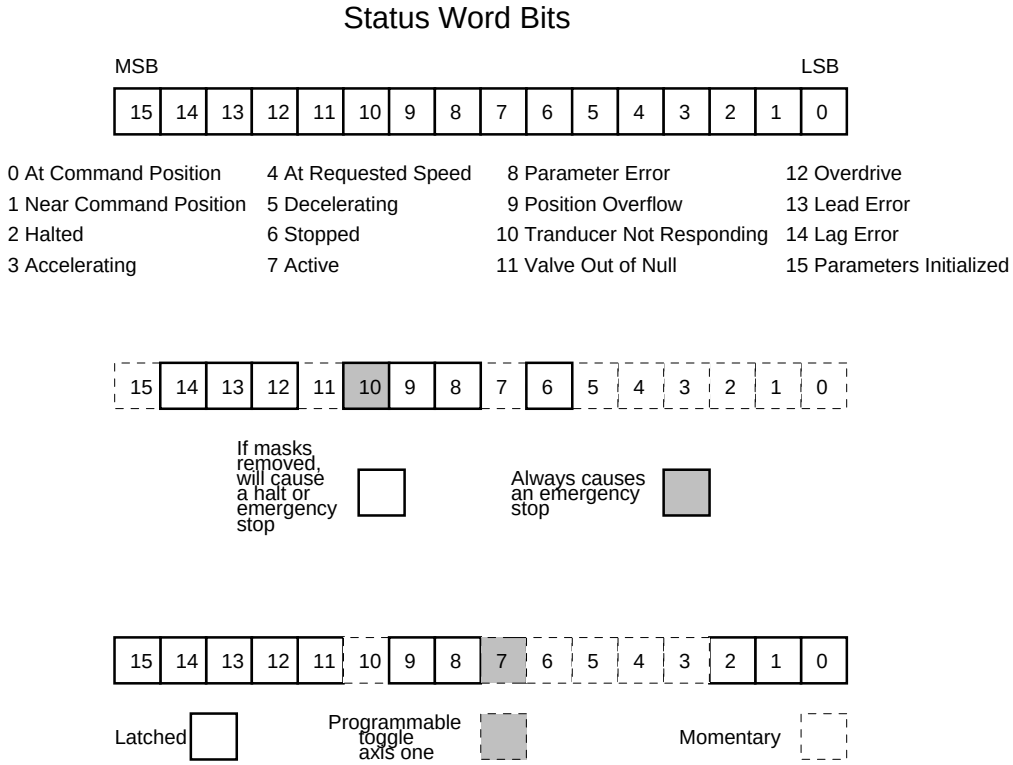
If the quadrature encoder (Q option) is installed, the *Actual Position* is calculated using a different formula. Please refer to the quadrature addendum for more information.

Transducer Counts

Transducer Counts is the axis position read directly from the transducer without scaling.

Status Word

The *Status Word* contains 16 bits of information about the axis. Five bits represent some type of motion error *(Lag, Lead, Overdrive, Position Overflow*, and *Parameter Error*) and can be used to trigger a halt or emergency stop. Seven bits indicate something about the motion profile (*At Command Position, Near Command Position, Halted, Accelerating, At Requested Speed, Decelerating* and *Stopped*) and can be used by the VME Controlled to monitor the motion profile. Two bits can be used to monitor transducer and drive performance (Transducer Not Responding, Value Out of Null). One bit (Parameters Initialized) can be used to make sure the VMC 186/40 has accepted control parameters, and another bit (Active) can be used to generate a periodic VME interrupt.



Bit Descriptions

The *Status Word* bits 0, 1, 2, 6, 8, 9 and 11-14 are cleared whenever a 'G' command is given.

Bit 0 = ***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. This bit is latched and is only cleared by a 'G' command**.**

Note: This bit will not be set if the axis is halted outside the *At Command Position* window.

Bit 1 = ***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 (i.e., it has a larger window). The *Near Command Position* bit is latched and is only cleared by a 'G' command.

Bit 2 = ***Halted***

This bit is set when the axis has been given a Halt ('H') command or an error has caused a halt and the axis has come to a stop. 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 VMC 186/40 is left 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 drifting.

Bit 3 = ***Accelerating***

This bit equals one (TRUE) while the axis target is accelerating. It is not latched.

Bit 4 = ***At Maximum Speed***

This bit equals one (TRUE) while the axis target is moving at the speed specified by the *Requested Speed* parameter. It is not latched.

Bit 5 = ***Decelerating***

This bit equals one (TRUE) while the axis target is decelerating. It is not latched.

Bit 6 = ***Stopped***

This bit equals one (TRUE) when the average speed of the axis is less than 2000 *Transducer Counts* per second. This bit is intended for use as an axis obstruction indication. It is not latched.

Bit 7 = ***Active***

This bit will toggle while the motion controller module is running (axis one only). The interval the bit toggles is programmable using axis's two *Clock Word*. The *Active* bit can be used for a module watchdog or provide a programmable VME interrupt.

Bit 8 = ***Parameter Error***

This bit will be 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 hard and fast limits may not always be available. However, the motion controller does try to replace the offending value with another that is within range. By comparing the values written with the values after the error bit was set, the offending parameter can be determined. This bit is cleared when a new command is issued.

Bit 9 = ***Position Overflow***

This bit is set when the 16 bit *Actual Position* is about to overflow. This occurs when the *Actual Position* tries to go beyond 65500. The *Position Overflow* bit is latched and is cleared when a new command is issued.

Bit 10 = ***Transducer Not Responding***

This bit will indicate when the transducer does not respond 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, the new reading is assumed to be an error. When an error is detected an emergency stop is made and the corresponding front panel axis indicator will glow red

CAUTION: The *Transducer Not Responding* bit is not latched. Transducer errors will always cause emergency stops, but with intermittent errors, the bit may be cleared before the VME Controller sees it. In this case, the axis will remain stopped with the *Halted* bit set. It is possible to consistently detect this error by enabling the *Interrupt Mask* and responding to a VME interrupt.

Bit 11 = ***Valve Out Of Null***

Normally, when the drive output is zero volts or milliamps, the axis will not move. In hydraulic applications valves sometimes get dirty and the axis will tend to move even when the drive output is zero. The motion controller module will try to compensate for this problem, but if more than 10 percent of minimum or maximum drive output is required to hold a static position this error bit will be set. It will be cleared when a 'G' Go command is used.

Bit 12 = ***Overdrive***

This bit is set when the calculated drive output would exceed the 12 bit range of the A/D converter. Usually this error is an indication the system does not have enough power to drive the axis at the requested speed. The computer will truncate the drive to 12 bits. The *Overdrive* bit is latched and is cleared when a new command is issued.

Bit 13 = ***Lead Error***

Lead is a condition where the actual position gets ahead of the target position. This bit will be 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 a new command is issued.

Bit 14 = ***Lag Error***

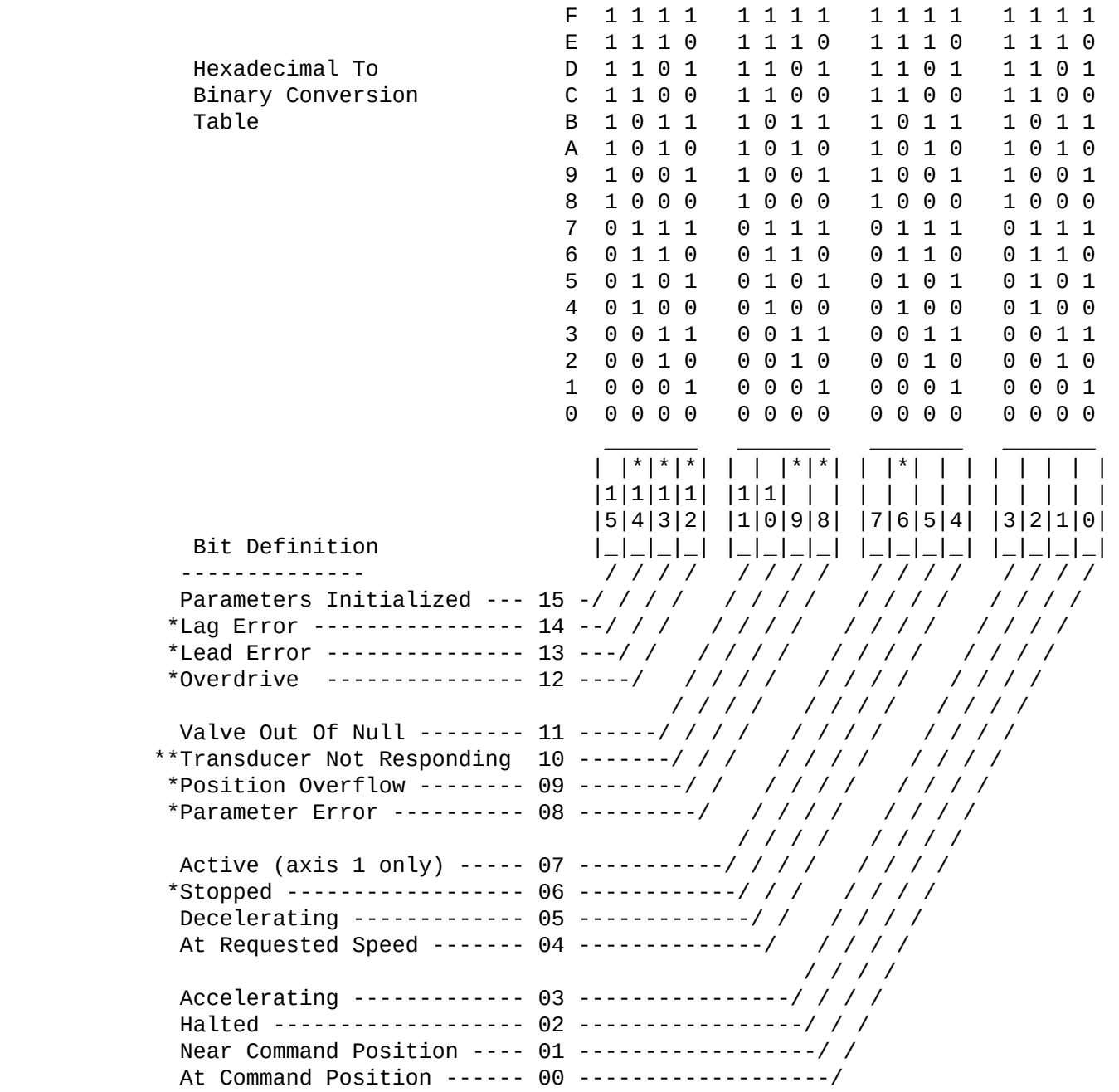
Lag is a condition where the actual position falls behind the target position. This bit will be set when the actual position lags the target position by more than the amount specified by the *Maximum Error* parameter. Lag errors can occur if the *Feed Forward* is too low or the *Feed Forward Advance* 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 15 = ***Parameters Initialized***

This bit is set after a parameter or 'P' command. Until this bit is set, the axis will not respond to any go 'G' commands. This bit is reset whenever the module is reset.

Industrial Bus Status Word Bit Map

The axis *Status Word* contains 16 bits of information about the status of the axis. The hexadecimal table provides an easy method to convert bit patterns to hexadecimal numbers.



* Can cause a halt or emergency stop if the corresponding bits are clear in the appropriate mask register.

** Will cause an emergency stop no matter what the *Estop* mask register is set to.

Drive

Drive is the output to the actuator. The 12 bit digital value output (0 - full negative drive to 4095 - full positive drive) will cause a ±100 milliamp drive current). Null drive should be about 2048.

Note: Null adjustments are done in software using *New Null* and *Null Update* (see page 14). When using valves with an amplifier card, it may be possible to adjust the null using its adjustments.

Target Speed

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

Null Drive

Null Drive is the current value of the null drive. The value can be read by the VME controller and saved for later use. The *Null Drive* value is updated at intervals specified by the *Null Update* parameter.

Reserved Words

When the VMC 186/40 has the analog option installed, these memory location are used for additional parameters. Also, custom application programs may use these locations.

Axis Setup Parameters

Clock (Default: N/A,256,2,N/A)

The *Clock* parameter is used for four separate functions. On axis one this field provides access to a one millisecond free running 16 bit counter. On axis two, the toggle interval for the *Status Word*'s *Active* bit. is programmed. The toggle interval can be programmed from 0 to 65535. If programmed with a 0, a one millisecond interval will be assumed. On axis three the interval at which the graph information is saved is programmed. The graph interval can be programmed in two millisecond increments. Axis four is not used.

VME Status_ID (Default: 0)

During the VME interrupt cycle the lower byte of the *VME Status_ID* value is put on the VME bus. If the value reflects the axis number, the interrupt handler can easily determined which axis created the interrupt.

Note: If more than one axis creates an interrupt, the *VME Status_ID* will reflect the last axis to cause an interrupt.

New Null (Default: 2048) Range: 1844 to 2252

Sometimes it is desirable to set the internal null value of an axis. The motion controller will set the initial null to 2048 on start-up 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 here on start-up so the bump in position will not occur.

See *Null Update* parameter description on page 14. If a value outside the range is used, it will be ignored (set to 0).

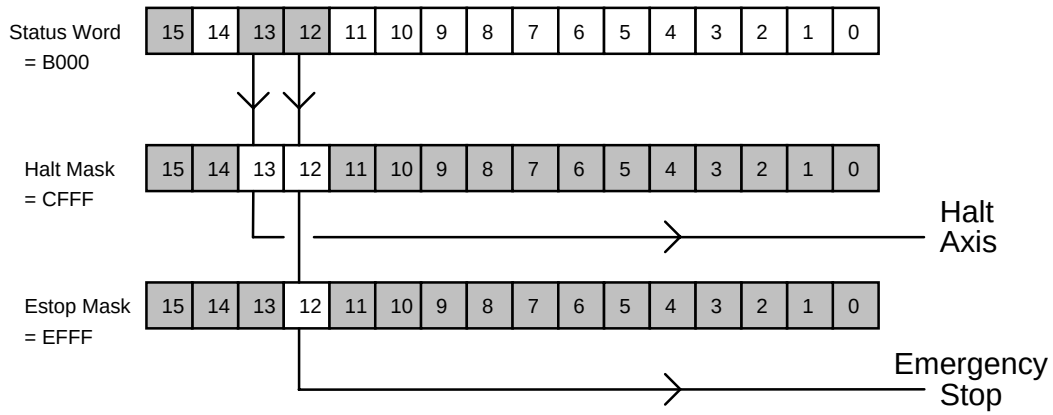
Estop Mask (Default: FFFFH Emergency stop disabled)

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 out the emergency stop that occurs when an error bit is set in the *Status Word*. During an emergency stop, the drive output is immediately set to null and held there until a new command is issued. To enable an emergency stop on an error condition, the appropriate bit must be **cleared** in both the *Halt Mask* and the *Estop Mask*.

Halt Mask (Default: 0000H HALT enabled)

Like the *Estop Mask*, *t*he 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 is set in the *Status Word*. On start-up, this field is zero and any error will cause a halt. For applications where two or more axes are moving together, the VME controller should mask out the automatic halts and take responsibility for handling any errors. See the error handling section on page 30.

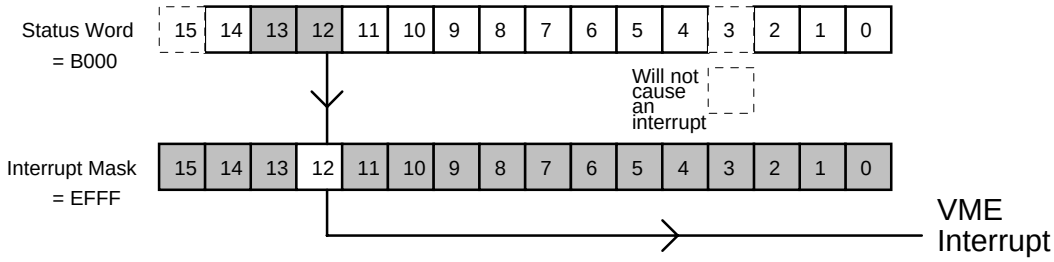
Status Word, Halt and Estop Masks



Lead error causes a Halt and Overdrive causes an emergency stop

Interrupt Mask (Default: FFFFH Interrupts disabled)

The bits in the *Interrupt Mask* are used to selectively enable interrupts. By clearing bit 12 of the mask, the VMC 186/40 can generate a overdrive error interrupt when an overdrive condition is detected. This word only needs to be used if the VME controller is configured to accept a bus interrupt. On start-up, this word is FFFFH. Therefore, all of the interrupts are disabled.



Overdrive error causes a VME interrupt

Feed Forward Advance (Default: 0)

If an axis will not respond to a change in the drive output until some time has passed, a large position error will be generated. This can happen in applications that are moving large masses or have slow valves. By using *Feed Forward Advance*, the motion controller can time shift the feed forward portion of its drive output by the number of milliseconds specified.

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 the target position and target speed will appear to be delayed with respect to the drive output by the *Feed Forward Advance* time. One 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.

Null Update (Default: 500) Range: 10 - 65535, 0 = disabled

Null Update is the time in milliseconds that the drive null is checked and the value for *Null Drive* is updated. *Null Drive* on an ideal system should be zero milliamps (0 volts) or 2048 output to the digital to analog converter. In a real system, a zero milliamp 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 the requested position, (had not been halted), the actual position is compared with the target position at the interval specified by *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 start to oscillate if the interval is too small, 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 to quickly get the actual position to the command position. **Fast response systems may work better with *Null Update* set to 0 (disabled).**

Minimum Update Time (Default: 1000)

Minimum Update Time is used to specify the minimum interval between position updates for the transducer. It is possible for the transducer to generate position update interrupts in less then a hundred microseconds. The default value allows each axis to be read every millisecond. The range of acceptable values is 0 to 2000

If the value is 0, the transducer position update interrupts will occur synchronously with the PID loop calculations every millisecond. Using synchronous readings provides a means to determine exactly when the position data is read. This reduces the variance between the measured position and actual position. Any variance may create control errors when the VMC 186/40 is used with a high speed target.

If a value other than 0 is used, its range should be between 250 to 2000. The transducer position measurement will not be synchronized to the system clock, but will be free running. This means the transducer position is updated as often as possible. When the rod is retracted (position at a minimum), the updates can be so frequent that all of the processing time of the VMC 186/40 can be used.

Minimum Update Time is specified using axis one. There is only one setting for all four axes. The other axes parameters are unused.

Dither (Default: 0)

The *Dither* value is the amplitude, in percent of full drive, of a 500 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 that dither be used. *Dither* is applied only when the axis is at rest.

Hysteresis (Default: 0)

Hysteresis is used to compensate for drive dead band. 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 of the dead band.

CAUTION: Do not make this value too big or the drive will oscillate.

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. *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 *Maximum Position Error* parameter on page 19.

CAUTION: Increase the *Static Gain* slowly. Excessive gain can cause oscillations that could damage both man and machine.

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 for retracting only.

Integral Gain (Default: 0)

The *Integral Gain* is used to adjust the drive provided 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 forward's have been set properly will cause the system to overshoot at the set point.

When a 'G' command is issued, the integrator starts adding the position error (actual position - target position) to an accumulator every millisecond. 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:

$$\text{Integral Drive} = \frac{\textit{Integral Gain} * \text{Accumulator}}{20{,}000}$$

Differential Gain (Default: 0)

The *Differential Gain* field is used to control the differentiator. The differentiator may be used on systems that have slow response. The differentiator looks at the change in error between the target and actual positions over the last 20 milliseconds. The change in error is multiplied by the *Differential Gain* value to get the differential drive.

```
Differentiator Drive = (Error(t) - Error(t-20)) * Differential Gain
```

CAUTION: During initial tuning, start with low values such as 10 to avoid oscillations.

Extend Feed Forward (Default: 100)

Tip: Use the 'F' command to automatically set feed forward values (see page 22).

Feed forward is an open loop drive which 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:

$$\text{Feed Forward Drive} = \frac{\textit{Extend Feed Forward} * \text{Target Speed}}{10{,}000}$$

The appropriate value for *Extend Feed Forward* can be found by making a move with the axis using a *Requested Speed* of 10,000. The amount of output drive required to maintain the 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 big or the system response is too slow. The 'F' command used after an extend move on the axis will automatically adjust the *Extend Feed Forward* parameter.

Retract Feed Forward (Default: 100)

Same as *Extend Feed Forward* and used 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 installed, see separate addendum for more information.

The *Scale* parameter is a multiplier used to convert transducer counts to a physical position. For example: if each transducer count equals 0.001 inches of physical travel and the desired position resolution is 0.001 inches, then the multiplier would be 1. However, if one transducer count equals .0012 inches of physical travel, then a multiplier of 1.2 would be used. Since the VMC 186/40 only understands 16 bit unsigned integer numbers, 0 is used for a multiplier of 0, 32768 for a multiplier of 1 and 65535 for a multiplier of 1.999.

By using the *Scale* parameter, transducer counts can be expressed in any standard measurement increment (inches, mm, etc.). A number of the VMC 186/40 parameters are expressed in position units to make it easier to visualize the effect of the parameter. Position units can be 0.001", 0.1 mm, etc. However, the primary use for the *Scale* parameter is to compensate for variations in magnetostrictive transducers.

The value used for the *Scale* parameter is affected by the number or recirculations selected (hardware jumper). Recirculation selection is based on the transducer length and desired position resolution. When using four recirculations, the most common position resolution is 0.0005". With two recirculations, the position resolution is usually 0.001" and with one recirculation it is 0.002" or 0.05 mm. For more information on recirculation see page 33.

Linear transducers have a calibration number (typically 9.1 μs per inch) and the VMC 186/40 has a 55.5 MHz oscillator for transducer position measurement counters. To determine the *Scale* for a magnetostrictive transducer use the following formula:

$$Scale = \frac{32768}{\text{Position Unit} * \text{Cal Number} * 55.5 * \text{Number of Recirculations}}$$

The calibration number must be specified in the same base units as the position units (inches, mm, etc.). If the calibration number is expressed in inches then position units would be expressed in inches (i.e. 9.1392 microseconds per inch for a calibration number and .001 inch resolution is desired)

The *Scale* parameter can also be adjusted or fine tuned by using position readings from the VMC 186/40 and actual physical measurements in the following formula:

$$Scale = \text{Old Scale} * \frac{\text{Position Reading 1} - \text{Position Reading 2}}{\text{Measured Position 1} - \text{Measured Position 2}}$$

Where Old Scale is the default *Scale* or a previously calculated *Scale,* and measured position is in position units (thousandth of an inch, etc.) from a physical measurement of the system. Position readings are taken using the *Actual Position* parameter.

Note: If a negative value is obtained for *Scale*, the absolute value must be used and the *Direction* parameter changed from 0 to -1 or vice versa. Also, when the *Scale* parameter is changed, the *Extend Limit, Retract Limit* and *Offset* must also be changed.

Scale Calculation Examples

Example 1

For a system using a magnetostrictive transducer with a calibration number of 9.1392, a position unit equal to one thousandths of an inch, and two recirculations, the *Scale* will be found as follows:

$$Scale = \frac{32768}{.001 * 9.1392 * 55.5 * 2} = 32301$$

Example 2

For a system using a magnetostrictive transducer with a calibration number of 9.0110, a position unit equal to one tenth of a millimeter, and one recirculation, the *Scale* will be found as follows:

$$Scale = \frac{32768}{.003937"(.1mm) * 9.0110 * 55.5 * 1} = 16642$$

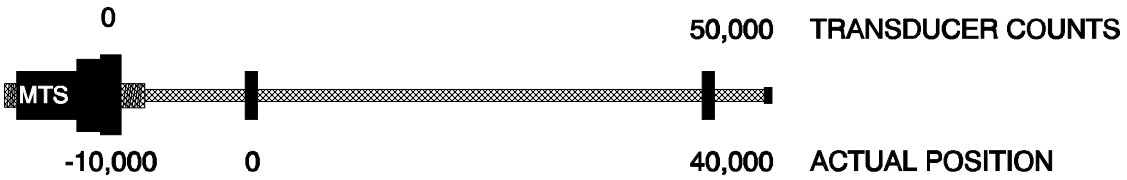
Fine tuning for example 2

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

$$Scale = 16642(Old\ Scale) * \frac{10873 - 20805}{10000 - 20000} = \frac{-9932}{-10000} * 16642 = 16529$$

Position 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: When using the *Offset* parameter, you must be familiar with the limitations of 16 bit math.

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:

$$\textit{Actual Position} = \frac{\textit{Transducer Counts} * \textit{Scale}}{32768} \text{ XOR } \textit{Direction} + \textit{Offset}$$

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.

Maximum Position Error (Default: 250)

The *Maximum Position 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 *Maximum Position Error* also limits the proportional term of the drive output due to a position error to:

$$\text{Maximum Proportional Drive} = \frac{\text{Proportional Gain} * \textit{Maximum Position Error}}{100}$$

Proportional Gain represents the *Extend* or *Retract Gain* parameters.

At Command Position (Default: 50)

At Command Position specifies the size of a window around the *Command Position*. When the actual position gets within this window, the *At Command Position* bit is set in the *Status Word*. The size of the window is expressed in position units.

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 the *Near Command Position* is to be ignored, in which case it should be set to 0. This parameter is useful in letting the VME controller know the axis is out of the way of some other equipment. The size of the window is expressed in position units.

Extend Limit (Defaults to actual position on reset)

The *Extend Limit* specifies the maximum value that the VMC 186/40 will allow as a *Command Position*. (When *Direction* = -1 (65535), this is a minimum value.) Requested positions that exceed this value will be truncated. 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 start-up the *Extend Limit* defaults to the current position of the axis. New *Extend* and *Retract Limits* must be issued using a 'P' command before the axis will move.

Retract Limit (Defaults to actual position on reset)

The *Retract Limit* specifies the minimum value the VMC 186/40 will allow as a command position. (When *Direction* = -1, this is a maximum value.) Requested positions below this value will be truncated. 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 Parameters

The motion control parameters *Mode, Acceleration, Deceleration , Requested Speed, Requested Position* and *Command* can be changed while the axis is in motion. Changing these parameters while the axis is in motion permits complex motion profiles to be executed as well as complete open loop control.

Mode (Default: 0000H)

The Mode parameter is used to select special features. Each bit represents a separate feature or option.

Bit 0 = **Acceleration and Deceleration**

This bit selects the acceleration and deceleration mode. It determines how the values in the *Deceleration* and *Acceleration* fields are to be interpreted. If this bit is cleared, the values are interpreted as a ramp distance in position units. If set, the value is interpreted as an acceleration or deceleration rate.

BIT 1 = **Reserved**

Always have bit cleared.

BIT 2 = **Unipolar Drive**

When this bit is set, the drive is always positive (0 to 100 mA). In some applications extending and retracting are determined by external hardware and negative drive would not be used. This mode only affects the drive, the VMC 186/40 still expects to see the transducer counts decrease when retracting (even through the drive will be positive when retracting).

BIT 3 = **Simulator**

When set, this bit enables the axis simulator mode. In the simulator mode, the VMC 186/40 ignores the sensor inputs and sets the drive at null. When a 'G' command is given, the VMC 186/40 automatically copies the calculated target position into the actual position. This means the controller will execute a "perfect" move. The simulator mode permits testing of the VME controller routines without affecting or being affected by external hardware.

BIT 4 = **Synchronize A**

When set, the axis will synchronize its moves with all other axes having the same synchronize bit set. Not only will the moves be started at the same time, but they will finish at the same time. Acceleration, speed and deceleration for all axes are keyed to the axis with the furthest to travel. This axis's requested speed is used to calculate the other axes acceleration, speed and deceleration. A 'G' command is issued to the axis with the furthest to travel and then all the axes will begin their move.

If a condition causes a synchronized axis to halt or stop, all synchronized axes will respond the same. However, enabling the *Halt* or *Estop* masks on one synchronized axis does not enable the masks on the other synchronized axes.

BIT 5 = **Synchronize B**

If more than one group of axes need to be synchronized, this bit is set in the second group.

BIT 6 = **Enable Pressure Mode**

If set, the pressure mode for the A (analog) option is used. See the VMC 186/40A addendum for more information.

BIT 7 = **Reserved**

Always have bit cleared.

BIT 8 = **Reserved**
Always have bit cleared.
BIT 9 = **Reserved**
Always have bit cleared.
BIT 10 = **Reserved**
Always have bit cleared.
BIT 11 = **Reserved**
Always have bit cleared.
BIT 12 = **Reserved**
Always have bit cleared.
BIT 13 = **Reserved**
Always have bit cleared.
BIT 14 = **Reserved**
Always have bit cleared.
BIT 15 = **Graph Inhibit**
If set, previous graph data will be saved and new data will be inhibited. By setting and clearing this bit, data from a specific move (extend or retract) can be saved for later review while normal production continues.

Acceleration (Default: 1000)

This field determines the rate at which the axis will accelerate. The field can be interpreted in two ways depending on bit 0 of the *Mode* parameter. If the bit is cleared, the value in these fields is a distance expressed in position units. If the *Scale* were set so one position unit equaled 0.001", then a value of 5000 would represent a ramp of 5.000".

If the *Mode* bit 0 is set, this field is interpreted as acceleration or deceleration rate and is expressed in 1000 position units/sec/sec. If *Scale* were set so one position unit equaled 0.001", then a value of 200 would represent an acceleration rate of 200 inches/sec/sec.

Using ramping distance (expressed in position units) is simpler for applications where the *Requested Speed* does not change. The relationship between the ramping distance, acceleration and requested speed is:

$$\text{Ramp Distance} = \frac{\textit{Requested Speed} * \textit{Requested Speed}}{\text{Acceleration Rate} * 2000}$$

$$\text{Acceleration Rate} = \frac{\textit{Requested Speed} * \textit{Requested Speed}}{\text{Ramp Distance} * 2000}$$

Deceleration (Default: 1000)

This field is similar to the *Acceleration* parameter except it specifies the deceleration ramp or deceleration rate.

Requested Speed (Default: 10000)

The *Requested Speed* parameter sets the constant speed to be achieved after acceleration. The *Requested Speed* is expressed in position units/second. If the *Scale* is set so one position unit equals 0.001", a maximum speed of 25 inches per second is expressed as 25000.

Note: Changing the *Requested Speed* without changing the acceleration and deceleration distances (expressed in position units) will change the acceleration and deceleration rates. See control equations on page 26. Should the *Requested Speed* be set to zero, the axis will do the same as a halt. Use the Halt command rather than set the *Requested Speed* to zero.

Requested Position

The *Requested Position* is the position the axis is to move to. This value is bounds checked by the VMC 186/40 using the *Extend Limit* and *Retract Limit* and then used as the *Command Position*.

Command

Note: The *Command* parameter is set to zero by the VMC 186/40 after the command is accepted.

The following commands are accepted by the VMC 186/40:

'P' - Set parameters (50H)(80) This command should be given as the first command after startup and only when all of the axes are stopped. All initialization parameters are updated when a 'P' command is given. The minimum requirement of this command is to set the *Extend* and *Retract Limits* to their proper values (see Getting Started on page 27). When a 'P' command is given, the VMC 186/40 will wait for a few milliseconds to get the actual position of the axis. This position is then copied into the *Target* and *Command Position*. This keeps the axis from moving until a 'G' command is issued.

'**G' - Go to Requested Position (47H)(71)** The VME controller is responsible for making sure all parameters are valid when the 'G' or GO command is given. Normally, once the *Mode, Acceleration, Deceleration* and *Requested Speed* are set, only the *Requested Position* needs to be changed. Once set, a 'G' put in the *Command* parameter is used to get the axis to move.

Note: The 'G' command can be given while the axis is in motion. If given while the axis is in motion, the motion controller module will ramp to the new speed at the rate specified by the *Acceleration* and *Deceleration* parameters and go to the *Requested Position*.

'H' - Halt (48H)(72) The Halt command is used for emergency stops, jogging the axis, or when the drive power is off. If the axis is moving and an 'H' is used, the axis will ramp down until it stops and the null update will be disabled. The *Status Word* can be used to determine the difference between a halted axis (caused by a control error) or *At Command Position* (caused by the 'H' command). Jogging an axis is accomplished by alternating Go and Halt commands.

'F' - Set Feed Forward (46H)(70) The 'F' command is used to automatically set the feed forward values. After a move is made where the axis is allowed to reach constant velocity and both the *Overdrive* and *Valve Out of Null Status Word* bits were not set, an 'F' command will set the feed forward for the direction last moved. This command is quick and easy, and it will allow the system to adjust for changes in system dynamics. This will also make setup easier.

CAUTION: If the axis oscillates or doesn't reach steady state during the move, the 'F' command will produce erroneous results.

"**O' - Override (4FH)(79)** This command allows the user to control the drive independently of closed loop control. The command is used in connection with *Requested Speed*, and *Requested Position* parameters to change the drive output. The parameter definitions for the override command are as follows:

Requested Speed	Maximum drive offset limit (both ±)
Requested Position	Drive offset (Range 0 - ±2047)

The value placed in the *Requested Speed* parameter is the maximum offset from null that is permitted. The value placed in the *Requested Position* parameter will be added to the present null drive value. The default null drive value is 2048 which produces 0.0 mA/0.0 V output. When an Override command is given, the null update will be disabled.

For example; if the operator wanted to produce 10% of full extend drive:
(assumes current *Null Drive* value of 2048)

Requested Speed 2047 (maximum valve drive)
Requested Position 204 (10% of full positive drive)
Command 79 ('O')
Results in a *Drive* value of 2252 (null + 204)

Another example; to retract at 50% of full drive (assumes current *Null Drive* value of 2048)
Requested Speed 2047 (maximum valve drive)
Requested Position -1024 (50% of full negative drive, 64511 decimal)
Command 79 ('O')
Results in a drive value of 1024 (null + (-1024))

Prior to August of 1992, the Override command would put the axis into a mode in which only counts and servo drive would be updated. After this date, *Actual Position* will update, providing scaled position information.

CAUTION: - Use of this command provides no safety limitation, or conditions.

S' - Save Null (53H)(83) The Save command saves the current value of the null so that it may be recalled later by a Restore command.

'R' - Restore Null (52H)(82) The Restore command restores the last saved value of null. This value will be 2048 if no previous Save or *New Null* (see page 12) was executed.

How It Works

Initialization

As the motion controller starts up, the *Scale* and *Position Offset* will be 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 also set to the actual position. These values keep a 'G' command from moving the axis until the axis parameters are initialized. This puts the responsibility of opening up the limits on the VME Controller by using the 'P' command to change the parameters. After a 'P' command is issued, a new actual position is computed and the *Target Position, Actual Position, Requested Position* and *Command Position* and are updated with the new actual position.

Once the initialization parameters are set, moving an axis can be accomplished by setting the *Acceleration* and *Deceleration* distance or rate, *Requested Speed*, and *Requested Position* to the desired values and writing a 'G' in the *Command* parameter. The VMC 186/40 will move the axis to the new position using the most recently programmed parameters. These same parameters can be changed while the axis is moving, but only if a new *Requested Position* and *Command* are issued for each new move.

Position Sensing

The position sensing of the VMC 186/40 is done by sending an interrogation pulse to the axis transducer and measuring the time between the interrogation pulse and returned pulse by the transducer. The polarity of the interrogation pulse can be set by the proper selection of jumpers P4-P7 (see page 32). 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 which is 55.5 MHz. The actual resolution is determined by the number of interrogation pulses used for a single position measurement. Each pulse is called a recirculation. On the VMC 186/40, the number of recirculations can be selected in hardware by the proper selection of jumpers P8-P11. Normally, two recirculations are used. See page 33 for more information on recirculations.

Drive Output

The drive output is ±100 mA at full drive. Motor drives and some proportional valves require voltage outputs. If a voltage is needed, use a voltage divider across the output to develop the appropriate voltage range (install 100 ohm resistors in sockets R1-R4 if ±10 volts is needed). Use as much of the full swing in the output as possible for best results. Servo valves usually use a current source since the output drive will not be affected by changes in coil resistance. Some servo valves have two 40 milliamp coils which will draw a total of 80 milliamps when wired in parallel. This means that full drive will occur at only 80% of the drive. **If so, the *Overdrive* status bit will not be set since the output drive never exceeds 100%**.

Closing the Loop

The VMC 186/40 CPU uses the information from the position sensing to correct for differences between the actual position and target position. A positioner will tend to drift away from the target position and the change in location is detected by the position transducer. The VMC 186/40 finds the difference between where it is and where it should be. It then changes the drive output so the actual position will move back to where it should be. This is called "closing the loop." The same thing occurs when an axis is moving, except the target position is also moving. If the actual position is lagging behind the target position, the VMC 186/40 will increase the drive to help the actual position catch up to the target position. If the actual position is ahead of the target position or leading, the VMC 186/40 will reduce the drive output to slow the axis down. The amount of drive for a given error in position is determined by three different proportional error gains: *Static Gain*, *Extend Gain* and *Retract Gain*.

The ability to independently adjust static, extend and retract gains provides a means to 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 and target positions 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 at which the 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. In general, use the largest error gain possible that doesn't cause oscillations.

Note: The axis will oscillate if the proportional gain is too high.

Integral and Differential Gains

In addition to the three proportional error gains, there are two other gains: integral and differential. The majority of applications do not require the use of either the integrator or differentiator. If used, 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 millisecond. 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:

$$\text{Integral Drive} = \frac{\textit{Integral Gain} * \text{Accumulator}}{20{,}000}$$

The differentiator looks at the change in error between the target and actual positions over the last 20 milliseconds. The change in error is multiplied by the *Differential Gain* value to get the differential drive.

$$\text{Differentiator Drive} = (\text{Error}(t) - \text{Error}(t-20)) * \textit{Differential Gain}$$

Feed Forward

When the axis is moving, the difference between the target and the actual position may become large, even when the error gain is as high as it can be without causing oscillations. There are two more parameters called *Extend Feed Forward* and *Retract Feed Forward* to help reduce the difference between the actual and target position. The two feed forwards 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 will be small if the feed forward is adjusted correctly. Therefore, the difference between the target 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 desired position.

Feed Forward Advance

If the axis response is very slow, the axis will overshoot even when the feed forwards are adjusted correctly. This happens because the axis does not decelerate when the motion controller module tells it to. The VMC 186/40 can advance or "time shift" the feed forward component of the drive output so the axis will decelerate at the proper time. The time shift is programmed in milliseconds using the *Feed Forward Advance* parameter.

Control at Rest

When the VMC 186/40 is controlling the position of an axis at rest, it uses three parameters: *Static Gain*, *Null Update* and *Differential Gain*. *Static Gain* provides a drive output proportional to the error between the actual and target position. The *Null Update* value compensates for the null offset inherent in many hydraulic valves. Every *Null Update* period (see page 14), 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 then zero, the differentiator will affect the drive when the axis is at rest. See page 25 for more information on the differentiator.

Control Equations

The control software uses the two following equations to do most of the calculations for the target position (following equations assume position units are thousandths of an inch):

$$\text{Ramp Time} = \frac{2000 * \text{Distance}}{\textit{Requested Speed}}$$

$$A = \frac{\textit{Requested Speed} * \textit{Requested Speed}}{2000 * \text{Distance}}$$

Ramp Time in milliseconds
Requested Speed in thousandths of inches per second
Distance is acceleration or deceleration distance in thousandths of inches
A is acceleration or deceleration rate in inches per second per second

Actual Position = (((*Transducer Counts* * *Scale*) / 32768) XOR *Direction*) + *Offset*

Ramp Distance = (*Requested Speed* * *Requested Speed*) / (Acceleration Rate * 2000)

Drive Output = Proportional Drive + Feed Forward Drive + Integral Drive + Differential Drive

Proportional Drive = (*Target Position* - *Actual Position*) * Proportional Gain / 100
Feed Forward Drive = (*Target Speed* * *Feed Forward*) / 10000
Integral Drive = Error Accumulator * *Integral Gain* / 20000
Differentiator Drive = (Error(t) - Error(t-20)) * *Differential Gain*

Getting Started and Tuning the Axis

CAUTION: Great care must be taken to avoid accidents when starting the motion controller module for the first time. The most common accident is a runaway. This is where the motion controller tries to go to a position beyond the physical limits of the axis. **Make sure the power to the drive is turned off before starting this procedure.**

TIP: If the VMC 186/40 serial interface option is installed, use Delta's DCSMON setup program 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 module to a real system.

Step 1 - Setting Up the Initialization Parameters

When the VMC 186/40 motion controller module is first turned on, default values are used for the initialization parameters. These values are there only to give the motion controller something to work with so the present position can be maintained. The parameters need to be changed to work optimally in your system. The VME Controller is responsible for initializing the parameters by placing the correct values in the correct memory locations and issuing a 'P' command. The following procedure will help in finding the optimal values for the initialization parameters.

First, disconnect the drive output from the VMC 186/40 (15 pin connector), and establish a means of moving the axis under manual control. Using some type of memory monitor (DCSMON), monitor the appropriate memory locations. Make sure the transducers are connected and powered up. Observe the *Transducer Counts* field. The counts should change as the sensing point on the transducer is moved.

TIP: Use the simulation mode of VMC 186/40 to test the VME Controller program (see page 20).

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* will increase as the axis extends. This is the default value. The *Direction* parameter should be set to -1 (0FFFFH) if the *Actual Position* decreases when the axis extends. The VME Controller must now issue a parameter 'P' command in *Command* field. Manually retract the axis until it is near the *Retract Limit*. Set the *Retract Limit* to the *Actual Position.*

Scale Parameter

The next step is to compute the *Scale* factor that converts *Transducer Counts* to position units. For magnetostrictive transducers, the *Scale* is computed by:

$$Scale = \frac{32768000}{\text{Magnetostrictive Transducer Cal Number} \times 55.5 \times \text{Number of Recirculations}}$$

For Analog and Quadrature options see the respective addendum for *Scale* usage.

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 (*see separate DCSMON manual*)*.

Position 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*. When the *Offset* is changed, make sure to change the *Extend Limit* and *Retract Limit* by the same amount. Use the following equation to adjust the current *Actual Position* to be something else:

```
Offset = Old Offset + Desired Position - Actual Position
```

Note: After adjusting the *Direction*, *Scale* and *Offset*, be sure to adjust the *Extend* and *Retract Limits* as described below.

Step 2 - Moving the Axis

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 safety. (Remember: extending is the direction that returns increasing *Transducer Counts*.) 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.

Make sure the *Drive* parameter is at or near 2048 (null) and connect the drive output. Make several short slow moves by setting *Acceleration, Deceleration* and *Requested Speed*, entering the *Requested Position*, and issuing a Go, 'G' command.

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

At this point the *Halt Mask* should still be set to zero and any errors on the axis will cause it to stop. If the axis indicator light flashes red after a 'G' command, check the *Status Word* error bits to determine what caused the error.

Increase the speed and accelerations slowly while making longer moves. Use DCSMON to make plots of the moves, and look for lead, lag, overshoot or oscillations. Eventually the moves will cause an error on the axis.

There are three errors to be concerned with at this time. If an overdrive error occurs, there is not enough drive capacity to drive the axis at the requested speed. Should this occur, reduce the *Requested Speed*. If a lag error occurs, the appropriate feed forward must be increased. If a lead error occurs, the appropriate feed forward must be decreased. If the lag or lead error cannot be eliminated, try increasing the *Feed Forward Advance* parameter. In case it still doesn't solve the problem, the acceleration and deceleration ramps are too steep for the response of the system, and the ramp distance should be made longer. After the problem causing the error has been fixed, keep moving the axis back and forth 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 position can be moved without getting an error. Remember, the parameters are not updated in the VMC 186/40 until the 'P' command is issued.

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.

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.

Step 3 - Jogging the Axis

Jogging the axis can be accomplished by setting the *Requested Position* to the *Extend* or *Retract Limit* and using the 'G' and 'H' commands repeatedly. This causes the motion controller to Go and Halt.

Step 4 - Tuning the Axis

It is best to use Delta's DCSMON program so moves can be plotted during the tuning process.

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 13 for *Halt Mask* information).

Note: Do not use the *Integral* or *Differential Gains* or *Feed Forward Advance* until you have finished with tips 1 to 10. Leave them at zero.

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 *Maximum Position 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* slowly 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 *Maximum Position Error* until errors start to occur then either tune the axis some more (tips 5 - 8), or increase the *Maximum Position Error* a little.
14 The *Feed Forward Advance* must be the same for all synchronized axes. 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 can't 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 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. The better the feed forwards are adjusted, the lower the integral gain needs to be.
16 Another problem occurs on moves of a long duration and when the feed forward can't 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 integrator gain will get to 500 or more.
17 The *Differential Gain* is of little use on systems that 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 oscillations.

VME Controller Programming Precautions

The VME Controller is responsible for:

- Storing the parameters used by the VMC 186/40.
- Making sure the motion controller is properly initialized.

CAUTION: The VME Controller is also responsible for issuing an 'H' or Halt command when drive power is off. Also, to set the *New Null* when power is turned back on.

The motion controller provides a *Status Word* for each axis. Should an error bit be set in the *Status Word*, the VME Controller is responsible for shutting down the axis drive power. The VME Controller should have a watch dog timer that will shut down the drives if a time-out should occur.

VME Controller Error Handling

The VMC 186/40 reports errors within a millisecond. This is done by setting a bit in the axis *Status Word* and flashing the appropriate Front Panel LED. The VME Controller is responsible for checking errors using the *Status Word*. It is up to the VME Controller to determine what should be done if an error is detected.

The system must have the capability to shut down the axis drive power using a normally open output which is activated to close when the system is running. 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 VMC 186/40, the contact can be deactivated, thus stopping the axes. Usually the VME Controller will not take so drastic a step until it has determined that 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 moving in a coordinated manner and one axis starts moving slower than it should, it is probably best to issue a Halt command to all the axes and stop operation until the problem with the faulty axis has been solved.

It is also possible to use Estop and Halt on error detection by clearing the appropriate bits in the *Halt Mask* and the *Estop Mask* corresponding to the error bits in the *Status Word*.

Key Items 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.
- Always know the position of the transducer transmitter because all positions between the transmitter and the retract position will cause the axis to retract. Other positions outside the extend and retract limits will cause the axis to extend.
- When the direction is 0, all positions from the transmitter to the zero position 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.
- Linear transducer non-linearity may be a concern in applications where opposing axis are used.

Front Panel Indicators

There are five multicolored light emitting diodes (LED) on the front panel of the VMC 186/40. The LED's provide status information about each axis.

The LED labeled Run is the run indicator of the VMC 186/40 microprocessor. When the Run indicator is green, the drive outputs are enabled. If the Run indicator is red (processor dead), 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's labeled 1 through 4 indicate whether the input transducers are working and provide a crude indication of measured position. The motion controller module checks the status of the transducer every 10 milliseconds. Should a control error occur on an axis other than a transducer error, the LED for the axis in error will flash red repetitively until a new command is used.

Note: If a transducer fails to respond, the output to the corresponding axis will be set to the current drive null and its LED will be red. If the axis magnetostrictive transducer comes on line, it will respond to commands and its LED will turn green. The VME Controller will see a change in the *Status Word* when either event occurs.

VMC 186/40 Front Panel Indicators

Run indicator constant red	On-board processor halted, output drives disabled
Run indicator constant green	On-board processor running
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.

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.

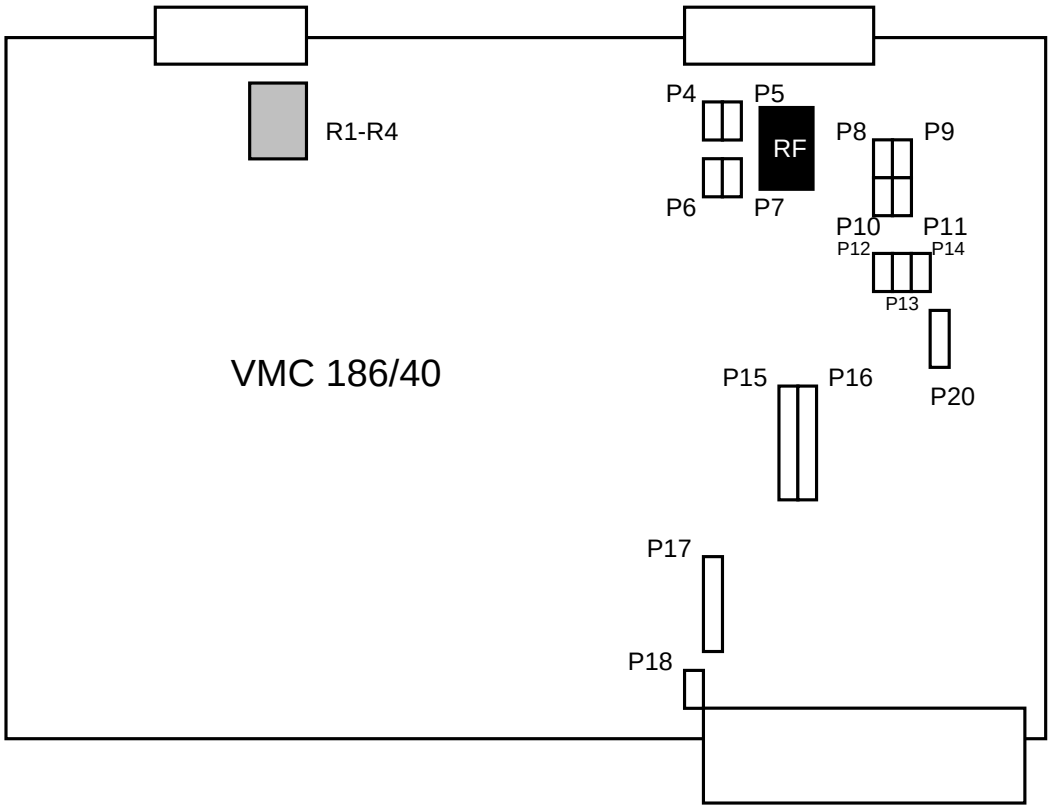
Hardware Configuration Information

Supported VME Bus Address Modifiers

The following address modifiers are supported:

29H	Short non-privileged access (16 bit) (check with Delta before using)
2DH	Short supervisory (check with Delta before using)
39H (GE 90-70)	Standard non-privileged data access (24 bit)
3D	Standard supervisory access

Note: If these address modifiers are not used or a long word accesses is requested, a bus error will be generated.



Module Jumpers and Removable Resistors

RF	Resistor fuses for transducer power (page 41)
R1-R4	Sockets for 100 Ω resistors, when installed, convert current outputs to ±10 volts (page 38)
P4-P7	Select transducer interrogation pulse polarity (page 32)
P8-P11	Select number of transducer recirculations (page 33)
P12	Enable a VMC 186/40 module reset if the module fails to toggle a 60 ms timer (page 36)
P13	Enable on-board interrupt if the module fails to toggle a 13 ms timer (page 36)
P14	Permit a VME bus reset to reset the VMC 186/40 (page 36)
P15	Board VME bus address selection for A09 through A15 (page 35)
P16	Board VME bus address selection for A16 through A23 (page 35)
P17	Selects IRQ interrupt line to use on the VME bus (page 37)
P18	Selects IRQ number to acknowledge from the VME bus (page 37)
P20	Provided for firmware development (page 37)

Magnetostrictive Transducer Interrogation Pulse Polarity

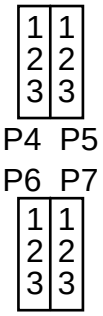
(Default positive polarity)

Jumpers P4-P7 are used to select the polarity of the magnetostrictive transducer interrogation pulse. The motion controller 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 VMC 186/40 is connected to a negative interrogation pulse transducer when it is configured for positive interrogation pulses, current limiting resistors on the VMC 186/40 will burn out. The current limiting resistors protect the transducer rod and 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



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 it is set to four, then four interrogation pulses are issued.

The trade-offs are measurement speed, resolution, and transducer length. The higher the number of recirculations, the higher the resolution, the slower the speed and the shorter the transducer length. The lower the number of recirculations, the lower the resolution, the faster the speed, and the longer the transducer rod. See the following tables.

$$\text{Counts Per Inch} = \frac{\text{Transducer Delay per Inch (9.1us typical)}}{\text{18ns per clock (55.5 Mhz clk)}} * \text{Recirculations}$$

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

$$\text{Longest Measurement Time} = \text{Transducer Length in Inches} * \text{Delay} * \text{Recirculation}$$

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

Number of Recirculations	Maximum Linear Transducer Length	Typical Measurement Time @ 30"	Maximum Usable Transducer Resolution
1	130"	273us	.002"
2	65"	546us	.001"
4	32"	1092us	.0005"

$$\text{Counts per mm} = \frac{\text{Transducer Delay per mm (358.27ns typical)}}{\text{18ns per clock (55.5 Mhz clk)}} * \text{Recirculations}$$

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

Longest Measurement Time = Distance on Transducer in mm * Delay * Recirculation

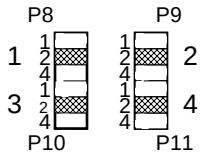
$$\text{Maximum Resolution} = \frac{1\text{ mm}}{\text{Counts per mm}}$$

Number of Recirculations	Maximum Linear Transducer Length	Typical Measurement Time @ 750mm	Maximum Usable Transducer Resolution
1	3293mm	269us	.0502mm
2	1647mm	537us	.0251mm
4	823mm	1075us	.0126mm

CAUTION: The longest measurement time should never exceed 1000 microseconds. The data used by the VMC 186/40 must be available within its millisecond control loop for precise control. If more than 1000 microseconds is required to obtain a position measurement, the controller will slow down to a two millisecond control loop. If a two millisecond control loop is required, a slight bump will occur in the motion of the axis at the transition point.

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

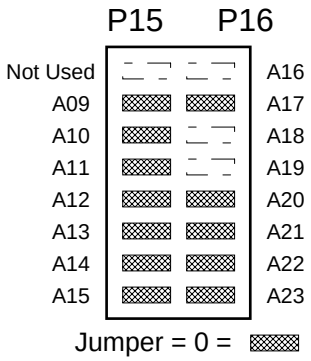


Dual Port Address Selection

Jumpers P15-P16 (Default for 0D0000H)

Jumpers P15-P16 are used to set the VME bus address of the dual port memory of the VMC 186/40. The jumpers allow the dual port memory to be placed anywhere in the 16 megabyte address space. The upper 15 address lines are used to select the dual port RAM which always starts on a 512 byte boundary.

With the jumpers installed below, the dual port address is 0D0000. With no jumpers installed, the dual port address is FFFE00H.



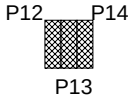
Fail Safe Timer Operation

The VMC 186/40 has three fail safe timers. The fastest acting timer is the 80186 address latch enable fail safe. This fail safe timer uses the rising edge of the address latch to enable it to retrigger a 12 microsecond monostable. The Run/Halt indicator is green and the drive outputs are enabled while the monostable is active. If the monostable should time-out, the Run/Halt indicator will turn red and the drive outputs will be disabled.

During normal operation the program retriggers two monostables every millisecond. The software restart monostable can be jumpered to the non-maskable interrupt by installing jumper P13. The software restart monostable will time-out after 13 milliseconds. The hardware restart monostable can be jumpered to the board reset by installing jumper P12. The hardware restart monostable will time-out in 60 milliseconds.

Action	Time	Implementation	Result
Address latch enable.	12us	Red Run/Halt LED (hardware only)	Drive disable
Software restart	13ms	Hardware and software	Non maskable on board interrupt
Hardware restart	60ms	Hardware and software	Board reset

Fail Safe Timers Jumpers



Jumper P12 (Default for restart)

When jumper P12 is installed, the 60 millisecond fail safe timer is connected to the board reset. Normally, the fail safe timer is reset every millisecond. If the processor fails to reset the fail safe timer, a software restart should occur after 13 milliseconds if the on board processor's non maskable interrupt vector is not corrupted. If the software restart fails, a hardware restart will occur which has the same affect on the VMC 186/40 as pushing the system reset. Both jumpers P12 and P13 should be installed for safe operation.

Jumper P13 (Default for restart)

When jumper P13 is installed, the 13 millisecond fail safe timer is connected to the non maskable interrupt. Normally, the fail safe timer is reset every millisecond. If something should happen where the fail safe timer is not reset, a non-maskable interrupt will occur and the processor will jump back to the beginning of the code in the PROM, if the non-maskable interrupt vector is not corrupted. **This jumper should always be installed.**

On Board Reset Jumper P14 (Default for reset)

When jumper P14 is installed, the VME Sysreset (P1-C12) is connected to the VMC 186/40 processor reset. This allows the VME Controller to reset the VMC 186/40. When Sysreset is active and P14 is installed, the VMC 186/40 processor is held in the reset state. When the VMC 186/40 is held in the reset state, the 12us time-out will disable the drive circuits.

VME Bus Interrupt Selection

Jumper P17 and P18
(Default - IRQ6)

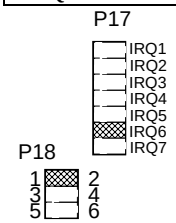
Note: **Both** P17 and P18 must be changed if a different IRQ is used

The VMC 186/40 is an ROAK interrupter (Release On Acknowledge - the interrupt is released on reading the status/ID). When the VMC 186/40 generates an interrupt on the selected IRQ line (jumper P17 selected), it will respond to an 8 bit, 16 bit, or 32 bit interrupt acknowledge cycle by providing an 8 bit status/ID on D00-D07. The returned status/ID code is programmed using the lower eight bits of the dual port parameter *VME Status_Id*. This code should be used to indicate the axis and then to index into an appropriate interrupt processing routine.

Note: The status/ID byte is transferred using odd address low data bus D08(O) VME bus conventions.

During the interrupt acknowledge cycle, the VME Controller will indicate which IRQ line it is responding to by putting the IRQ binary code on address lines A1, A2 and A3. This code MUST match the code programmed with P18. For example: if IRQ 6 (programmed by P17) is used, the binary equivalent must be set by P18 for 06H (P18: 1-2 and P18:3-4). If the code is mismatched, the interrupt handler will time out and the VMC 186/40 will never get an interrupt acknowledged.

P17	P18 5-6	P18 3-4	P18 1-2
IRQ 1	Jumper	Jumper	
IRQ 2	Jumper		Jumper
IRQ 3	Jumper		
IRQ 4		Jumper	Jumper
IRQ 5		Jumper	
IRQ 6 (Default)			Jumper
IRQ 7			



Firmware Development

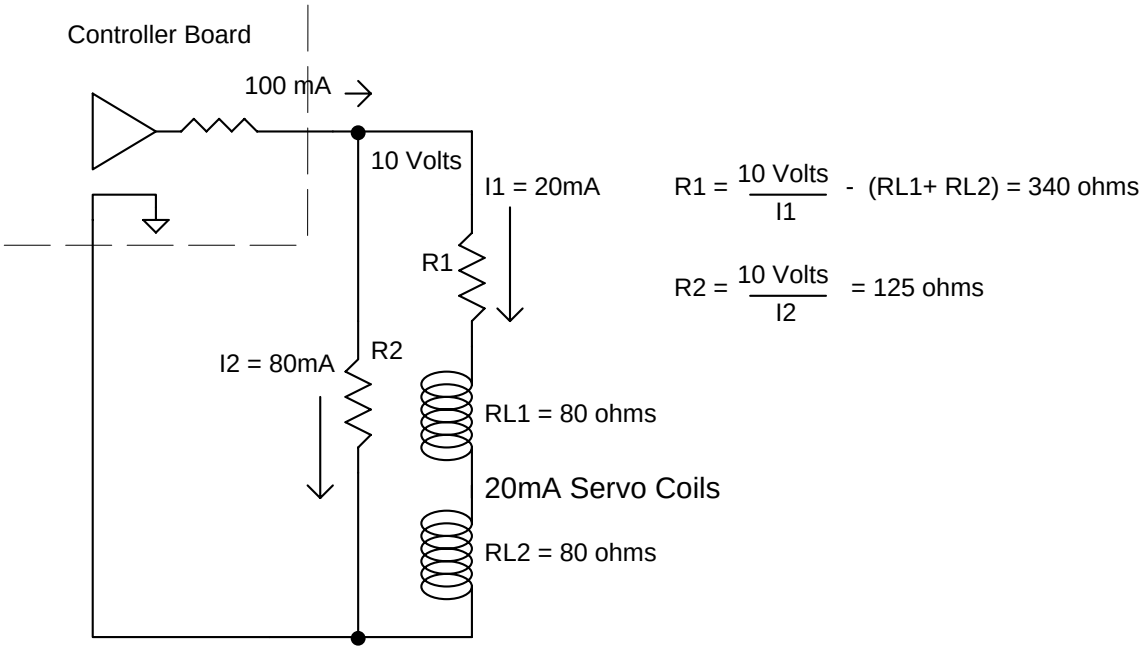
P20 must be jumpered between positions 1 and 2 for normal operation. P20 is provided for Delta's firmware development process.



Drive Selection

The default drive configuration is ±100 milliamps. To change the output drive to ±10 volts, install a 100 ohm 1 watt resistor (supplied) to the board's resistor sockets (upper left corner). R1 is axis one, R2 axis two, R3 axis three and R4 is axis four.

An external resistor network can be used to scale the 100mA output to a lower full scale current. This allows the maximum output resolution of the VMC 186/40 board to be utilized with valves of less than full scale output. Use of the network will also help to prevent damage to the controller board from excessive power dissipation.



Resistor network power dissipation can be calculated by:

$R2 = I^2 * R = (80mA)^2 * 125 = 0.80$ watts
$R1 = I^2 * R = (20mA)^2 * 340 = 0.14$ watts

External Wiring and Site Installation Information

The VMC 186/40 can be placed in any VME chassis slot. External power supplies must be provided for both the transducer inputs and drive outputs. The power supplies should supply +5 volts and ± 15 volts with at least 500 mA. If possible, do not connect the power supplies to any other loads.

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

Note: Electrical noise problems on older style magnetostrictive transducer 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 limits have been computed and VMC 186/40 properly initialized with these limits using the VME controller.

Delta Computer Systems, Inc. supplies two cables with each module. One for the transducers and one for the drives. The cable with the male DB 25 is used to connect the transducers to the DB25 front panel connector. Its wire color is:

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

If possible, always connect the transducer's ±15 volts directly to the VMC 186/40. The module provides current limiting resistors to protect the transducer.

Typical Temposonics Connector

MS310614A-P Connector	Function	Color
A	+12 to +15V	Green
B	DC Common	Black
C	Return Pulse	Orange
D	-13.5 to -15V	Blue
E	Interrogation Pulse	White
F	+11.5 to +12V	Red

The cable provided with module to connect the application's drive inputs to the DB15 front panel connector uses the following color code:

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

Axis indicator is constant red.

This is an indication the transducer is not responding to the module. Every millisecond 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 32).
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 +15 volt supply is connected.

If the transducer power provided by the module has failed, check the 4.7 ohm (R64 axis 1, R65 axis 2, R66 axis 3, R67 axis 4) and 15 ohm (R54 axis 1, R55 axis 2, R56 axis 3, R57 axis 4) resistors on the module. These resistors act as fuses and may be open if a problem with the transducer or external wiring occurred. Change the 4.7 ohm 5% resistor(s) if a problem exists with the -15 volt supply. Change the 15 ohm 5% resistors if a problem exists with the +15 volt supply.

During a move, the *Actual Position* is erratic.

Electrical noise or a defective transducer is usually the cause of this problem. Monitor *Status Word* bit 10 to determine if the module is detecting a transducer error. To reduce electrical noise check the following:

a. Make sure the transducer wiring is separated from all other wiring.
b. Add a termination resistor as close to the transducer as possible (220 ohm for Temposonics).
c. Terminate the shield at module end, or transducer end or both.
d. Install a pair of Delta Computer Systems, Inc. AMP/10 RS-422 converter cards. If a TEMPO II transducer is used, the RPM option along with one AMP/10 card is recommended. See attached wiring diagrams.

During a move, the axis comes to a halt without any 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:

Lag error	Lead error
Overdrive error	Stopped
Position overflow	Parameter error

These errors will cause the axis to stop if the *Halt Mask* doesn't have the error bits masked (see *Status Word* bit descriptions starting on page 8 for more information.).

Note: The *Transducer Not Responding* bit (bit 10 of the *Status Word*) is NOT latched. Transducer errors will always cause emergency stops, but with intermittent errors, bit 10 may be cleared before the VME Controller sees it. In this case, the axis will remain stopped with the *Halted* bit set.

***Transducer Counts* field not indicating transducer location.**

See "AXIS indicator constant red" above.

***Transducer Counts* field changes but output drive does not work**

See "Drive comes to a halt without any apparent reason" above.

Repairs and Returns

Field Module Repair

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

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

2). If interrogation pulse failure, change pulse drivers U10 and U11 (SN75158P)

Module Returns

When returning the VMC 186/40 for repair, please contact Delta prior to shipment for an RMA number. Returned modules should be packaged in static protection material and the RMA number clearly marked on the outside of package. Please include a short note explaining the problem. Send module to:

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

Phone: 360-254-8688
Fax: 360-254-5435

Warranty Repairs

Motion control products warranty period is 15 months from date of shipment from Delta Computer Systems, Inc. Repairs required because of obvious installation failures (burned resistors, traces, etc.) are not covered and will be billed at standard repair rates.

Returns

Returned items (in new condition and less than 120 days from 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 re-stocking.

Glossary

Actual Position
The measured (real) physical distance expressed in position units.

Cleared
Refers to a FALSE or logic zero value.

Command
An ASCII character needed to commence a particular action on the motion controller.

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
Refers to a mechanical device that converts rotary positions to digital signals.

Extending
Moving or turning the axis such that 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 transducer counts.

Recirculation
The number of times a magnetostrictive transducer is interrogated for a measurement. More recirculations provide higher resolution at a cost of increased measurement time and reduced sensor length.

Retracting
Moving or turning the axis such that the transducer counts decrease.

SBX
A generic name for a type of circuit board with specific electrical and physical specifications. One SBX connector is provided on the VMC 186/40 board.

Scale
A multiplier used to translate transducer counts to position units. It can be used as a means of compensation for differences in magnetostrictive transducers.

Set
When referring to *Status Word* bits it refers to a TRUE or logic one value. It also refers to a physical position to which the motion controller was told to move.

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 that converts a given physical distance to an electrical signal.

Transducer Counts
See Counts.

ASCII Code Chart

Code	Mnem	Dec	Hex	Code	Dec	Hex	Code	Dec	Hex	Code	Dec	Hex
	NUL	0	00	SP	32	20	@	64	40	`	96	60
Ctrl A	SOH	1	01	!	33	21	A	65	41	a	97	61
Ctrl B	STX	2	02	"	34	22	B	66	42	b	98	62
Ctrl C	ETX	3	03	#	35	23	C	67	43	c	99	63
Ctrl D	EOT	4	04	$	36	24	D	68	44	d	100	64
Ctrl E	ENQ	5	05	%	37	25	E	69	45	e	101	65
Ctrl F	ACK	6	06	&	38	26	F	70	46	f	102	66
Ctrl G	BEL	7	07	'	39	27	G	71	47	g	103	67
Ctrl H	BS	8	08	(	40	28	H	72	48	h	104	68
Ctrl I	HT	9	09	)	41	29	I	73	49	i	105	69
Ctrl J	LF	10	0A	*	42	2A	J	74	4A	j	106	6A
Ctrl K	VT	11	0B	+	43	2B	K	75	4B	k	107	6B
Ctrl L	FF	12	0C	,	44	2C	L	76	4C	l	108	6C
Ctrl M	CR	13	0D	-	45	2D	M	77	4D	m	109	6D
Ctrl N	SO	14	0E	.	46	2E	N	78	4E	n	110	6E
Ctrl O	SI	15	0F	/	47	2F	O	79	4F	o	111	6F
Ctrl P	DLE	16	10	0	48	30	P	80	50	p	112	70
Ctrl Q	DC1	17	11	1	49	31	Q	81	51	q	113	71
Ctrl R	DC2	18	12	2	50	32	R	82	52	r	114	72
Ctrl S	DC3	19	13	3	51	33	S	83	53	s	115	73
Ctrl T	DC4	20	14	4	52	34	T	84	54	t	116	74
Ctrl U	NAK	21	15	5	53	35	U	85	55	u	117	75
Ctrl V	SYN	22	16	6	54	36	V	86	56	v	118	76
Ctrl W	ETB	23	17	7	55	37	W	87	57	w	119	77
Ctrl X	CAN	24	18	8	56	38	X	88	58	x	120	78
Ctrl Y	EM	25	19	9	57	39	Y	89	59	y	121	79
Ctrl Z	SUB	26	1A	:	58	3A	Z	90	5A	z	122	7A
	ESC	27	1B	;	59	3B	[	91	5B	{	123	7B
	FS	28	1C	<	60	3C	\	92	5C	|	124	7C
	GS	29	1D	=	61	3D	]	93	5D	}	125	7D
	RS	30	1E	>	62	3E	^	94	5E	~	126	7E
	US	31	1F	?	63	3F	_	95	5F	DEL	127	7F

External Wiring Examples

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