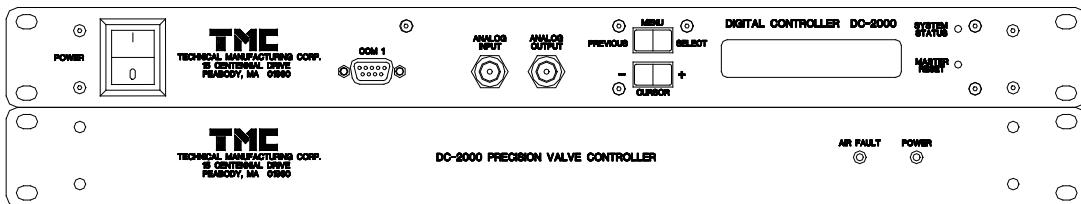


# Electro-Damp<sup>®</sup> PLS System Setup & Operation Manual



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## **1) Principle of operation**

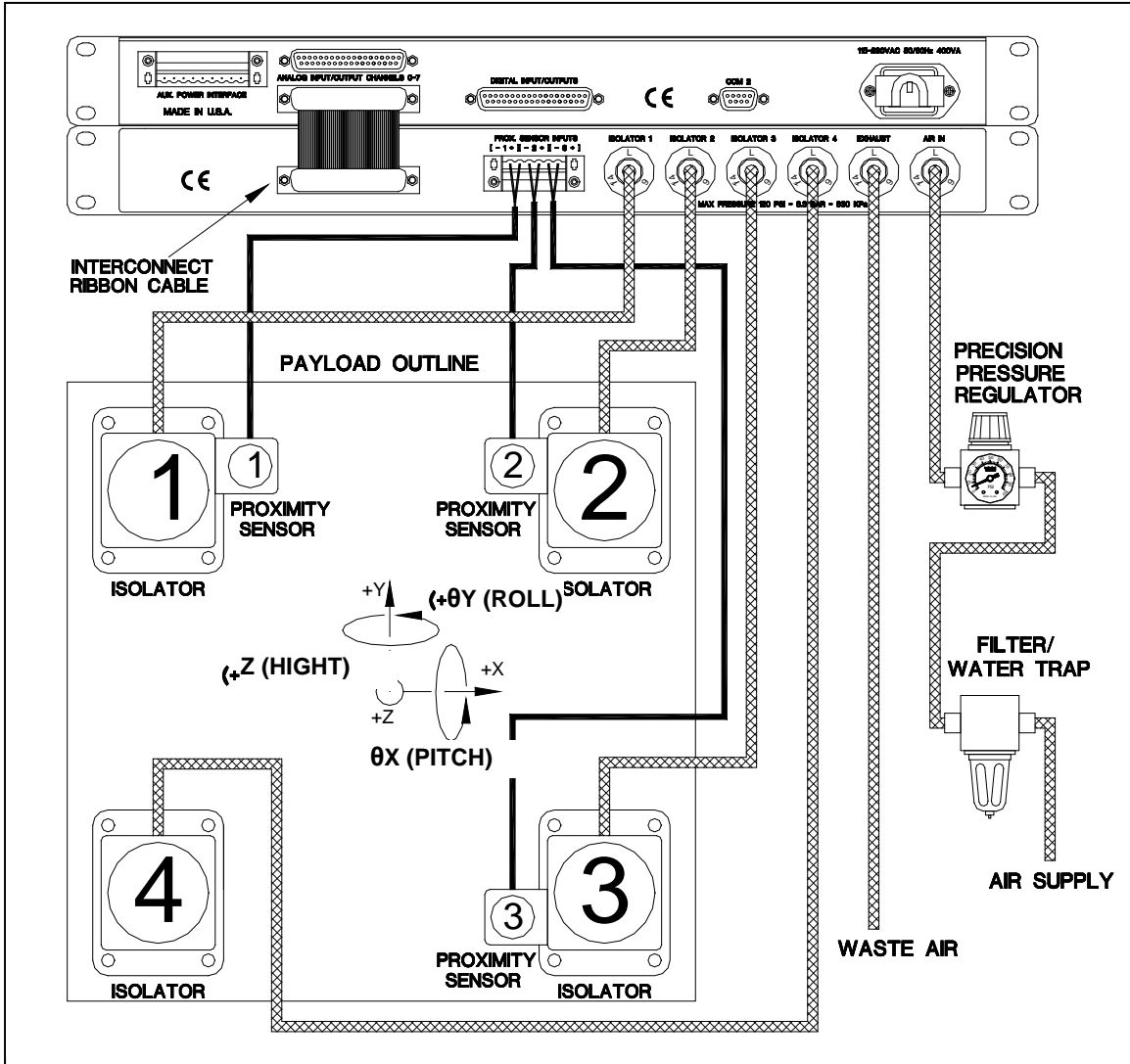
The Electro-Damp<sup>®</sup> PLS valving system is an electronic valving system designed to replace the traditional mechanical valves on a pneumatic isolation system. Electronic valving systems provide much greater precision in the height and tilt control of a payload for applications where it must interface with an external object (docking). It also provides a means for actively steering a payload (lowering, raising, or tilting it), obtaining position status, and remotely changing the servo's characteristics. The DC-2000 digital controller can also receive position information from a moving stage on the payload, and use that information to reduce payload tilting (a technique known as 'feedforward').

The DC-2000 valving system is based on a digital controller and a separate servovalve chassis (called the 'valve box'). The valve box connects to the digital controller through a short ribbon cable, which provides for both power and signal exchange. A set of three eddy-current proximity sensors connected to the valve box measure the payload's height, pitch, and roll. These signals are sent to the digital controller where an algorithm calculates the appropriate signal for the four servovalves. These signals are passed to the valve box where a set of power amplifiers applies the signals to the valves.

The valving system is based on a pure 'Class-A' servoamplifier design (see *Appendix A* for more information on valving techniques).

## 2) Quick Setup

This Section gives quick setup instructions for the DC-2000 valving system as it is used in most applications. Section 3 gives detailed instructions for each of the enumerated steps below. If you encounter difficulties with the installation, please consult the detailed instructions.



**Figure 1: The standard setup. Note that the sign convention for Height, Pitch, and Roll are shown.**

- 1) Determine the permanent location for the controller. Connect the isolators to the valve box using the supplied tubing. Do not use old tubing, as it might contain flow restriction orifices. The connection is detailed in Figure 1 above. Unlike mechanical valving systems, the DC-2000 does not have 'master' and 'slave' legs. This makes

system stability independent of the choice for 'leg 1' position.

- 2) The installation kit includes a 15 foot section of hose tied with cable ties. Connecting this hose to the vent bulkhead on the controller will dramatically reduce the acoustic noise from venting waste air. The coil can be untied if you would like to route the waste air further from the controller.
- 3) Connect the input line from the controller to the output of the precision pressure regulator (the elbow fitting), and connect the input of the regulator to the air filter. Connect the filter to your air supply and turn it on. Set the pressure regulator so its 15psi above the highest expected leg pressure. Calculate the leg pressures by taking the weight burden of each leg (in lb.), and dividing by the isolators' area. TMC has three common isolator sizes (capacities): 350lb (4.0in<sup>2</sup> area), 1,000lb (12.2in<sup>2</sup> area), and 2,500lb (30.7in<sup>2</sup> area). Changing the supply pressure later may require a readjustment of the controller's gains.
- 4) Connect the proximity sensors to the table at the locations shown in Figure 1. The angle between the sensors (with sensor 2 at the vertex) should be close to 90°. The sensors fit into TMC's standard valve bracket. If your payload is non-metallic (granite), you must put metal targets above each sensor. These should be at least 2" square, and centered on the axis of the sensor. Ferrous targets (steel) will give higher float heights than non-ferrous (Al or Cu) targets. Tighten the sensors so they are within 1/8" of the bottom of the payload.
- 5) Connect the proximity sensors to the precision valve box. Take care to connect the brown wire to the (+) inputs, and the blue wire to the (-) inputs. Cross-connecting them can damage the sensor. Make sure that proximity sensor (1) is next to leg (1), sensor (2) is next to leg (2), and sensor (3) is next to leg (3). Connect the DC-2000 controller to the precision valve box with the supplied ribbon cable.
- 6) Make sure the power switch is in the off (0) position. Connect the controller to the wall power with the power cord supplied. The DC-2000 uses 'universal' power supplies, and will run on line voltages from 115-230VAC, 50-60Hz.
- 7) Turn on the DC-2000 power and confirm that the DC-2000's LCD display and the green lamp on the precision valve box both lights up.
- 8) The valving system was shipped with all critical operating parameters set to 'normal' levels. Despite this, three of the parameters (Height, Pitch, and Roll Gains) may require some adjustment after the system is installed. Refer to the subsection *Using the Menu Keys* for help on making gain adjustments.
- 9) Allow the system to float. This can take up to a few minutes, but is usually around 30 seconds. Its possible the system will go into oscillation once floating. If this is mild (tolerable for your payload), then proceed with the steps below. If its too violent, then disconnect the air supply, but leave the controller on. Use the menu keys to adjust the height, pitch, and roll gains down by 6dB (six switch clicks). Turn the air supply back on and see if the oscillation is gone. If so, go to the steps below for fine tuning. If not, recheck the plumbing. If the isolators are not located correctly with respect to the proximity sensors (see Figure 1), then an oscillation may occur.

**NOTE: The controller will not save your gain settings on power-down unless you go to the menu item *save parameters* and hit *select* twice.**

To adjust the gains, you need to monitor the motion of the payload. This can be done by eye, but the best method is to use an oscilloscope connected to the DC-2000's BNC output jack. Adjust one degree of freedom at a time, starting with pitch, then roll and lastly height. Use the menu keys to set the BNC output to *Pitch*. Disturb the payload in pitch by pushing the payload sideways by a few mm. You can also use a signal generator to disturb the payload (see *Detailed Setup* for more details). Observe the signal on the scope. You will notice two things. There is a damped oscillation around 1.5-2Hz in frequency, and superimposed on this is a slow exponential curve which eventually comes back to zero volts. The first is called the isolator's ***settling time***, and the second is the isolator's ***leveling time***. Both are affected by the gain setting.

Use the menu keys to get to the *Adjust Gains* menu, and hit *select*. Hit (+) to get to *pitch gain*, and hit *select*. Increase the gain as you bump the payload. As you increase the gain, the leveling time should decrease. At some point, you will observe the settling time start to degrade. At this point you should back the gain off by a click or two. Repeat the process with roll and height (remember to reset the BNC output each time).

- 10) Fine adjustment of the payload's height and tilt can be done by moving slowly the proximity sensors up or down in their brackets. **NOTE:** use care moving the sensors up from their initial position, since this can cause the payload to rest on the sensors when the system is turned off. This can permanently damage the sensors and/or the mounting brackets. Extra fine adjustments of the float height can be done through the *Height Offset Adjustment* menu item described below.
- 11) Horizontal proximity Sensors position, in relations to their target, is used to provide the payload horizontal "zero point" reference. Sensors performance is optimum at the certain distance from their target. Since number of factors effect sensors operation, position adjustment/check is recommended. The adjustment should take place only after payload is floating, stable and leveled. The goal is to monitor "row" signal from each horizontal proximity sensors, and one by one mechanically move them to/from the target in order to minimize sensor's output signal (monitored on the oscilloscope). As signal become smaller (less then +/- 1V), mechanical fine adjustment is difficult. At that point the sensors position has to be fixed, and "residual bias signal will be corrected by controller's s/w at the next system power up, or with menu command "Re-Center Horiz. Win".

The Quick Setup is now complete.

There are several options which can be accessed through the menu keys to fine tune the behavior of the leveling system. They are all volatile until saved using the *Save Parameters* menu option. These are:

**Valve Dither:** is a small AC signal which is applied to the servovalves to improve their linearity and sensitivity. The valve dither option allows you to set both the amplitude and frequency of this dithering.

**Height Offset Adjustment:** The software height adjustment allows you to fine-tune payloads level by making small changes to the operating heights of each Isolator. Normally, the float height of the payload should be adjusted by physically moving the proximity sensors in their brackets, as discussed above. Making *small* adjustments in this manner is awkward. The Height Offset allows you to move each corner of the payload up or down by very small amounts (~ 0.2mm). It should be used only as a final fine tuning.

**Go/NoGo Window:** is a bi-polar window centered about the nominal operating height for each proximity sensor. If the payload moves outside of this window for any one of the sensors, the front panel LED turns YELLOW, and other warning flags may be set (a bit on the DI/O, or a bit in a status word which can be requested over the serial port). This menu option allows you to adjust the size of this window in ADC counts.

### **3) Detailed Setup**

The following Section contains an item-by-item detailed discussion of the previous Section's steps. This should not be required unless you encounter trouble setting up your system, or you have an application which requires an unusual configuration.

- 1) The location and orientation of the DC-2000 and the precision valve box is not critical. They should not be placed where they could be exposed to water or excessive heat. The system requires four isolators, and these should be in a rectangular pattern. **It is important** that the legs (and their proximity sensors) are numbered in a clockwise or counterclockwise manner (with corners 2 and 4 adjacent to corner 1). Failure to do so will cause the system to misbehave.
- 2) The system will work best if the length of the air lines from the valve box to the isolators is minimized. The vent air line can be very long, but should be free from anything which might impede air flow (such as pinches or kinks in the tubing, or a muffler at its far end).
- 3) Many air compressors cause water to accumulate in the air lines. This water can cause the servovalves in the precision valve box to malfunction. The supplied filter has a plastic trap which will collect this water if kept upright. If you have a lot of water, you may need to periodically empty this trap by pressing the valve at the bottom of the trap. The input air line can be of any length, but like the vent line should be protected from pinches or kinks. If your system has more than 15psi pressure difference between isolators, the system may not work well. If this is the case, then the pressure may have to be decreased to 5-15psi above the highest expected leg pressure. If the system still does not function well, you may need to move the isolators to redistribute the load, add additional isolators to the system, or return to mechanical height control valves. Consult a TMC sales engineer for assistance.
- 4) The proximity sensors can also sense metal placed near their sides. For this reason, all metal components (such as fixed brackets or the frame holding the isolators) should be a minimum of 2" away from the sensors. Metal within this distance will

cause the float height of the system to decrease, and can change the positioning gain of the sensors (possibly affecting the system's performance). Its also important that the target area for the sensors be symmetric about their axes. For example, placing the sensor near the edge of a payload will cause the sensor to sense horizontal payload motions. This will cause a cross-coupling between the different motions of the table and can degrade system performance.

- 5) There are no additional comments for this step.
- 6) There are no additional comments for this step.
- 7) The green lamp on the precision valve box simply indicates that power is being supplied to the valves. If this lamp fails to light, check that the interconnecting ribbon cable is properly seated.
- 8) There are no additional comments for this step.
- 9) The DC-2000 allows you to add signals to the height, pitch, and roll signals measured by the proximity sensors. Doing this forces the payload to track the added signal. This was designed to help TMC service personnel measure the servo *loop transfer functions*, but can also be used to 'bump' the payload for gain adjustments. This is the preferred procedure, since it provides a uniform test disturbance, and can be done when physical access to the payload is difficult. Go to the *Setup BNC I/O* menu and hit *select*. Hit (+) to get to the *Setup BNC Input* and hit *select*. Scroll to the DOF you are adjusting (height, pitch, or roll), and hit *select*, then *previous* twice. Setup a low-frequency signal generator for a square-wave output at around 0.1 to 0.3 Hz, and around 0.2 Volt amplitude. With a scope on the BNC output, you can now monitor the system's step responses.
- 10) There are no additional comments for this step.
- 11) To adjust horizontal proximity sensors position setting, use external oscilloscope, connected to the Controller's BNC connector "ANALOG OUPUT". From the menu option, select "Monitor Signal on BNC"/"1X\_row". That will set signal from horizontal proximity sensor on the Isolator #1 to the BNC output. Monitor that signal on the oscilloscope and move the proximity sensor to the position, where signal is close to "zero" (  $-200\text{mV} < 1X\_row \text{ signal} < +200\text{mV}$ ). Lock sensor in that position. Repeat the same procedure for sensors "2Y\_row" and "3X\_row".

## **4) Using the Digital Controller**

### **System Status LED:**

The System Status LED on the controller is green in normal operation. It changes to yellow if the payload moves outside of the go/nogo window set in the menu system.



Immediately after power up, the LED will turn red, then flash green for ~5 seconds. The period, when the LED flashes green, is when new software can be downloaded into the controller using the 'manual' download option.

The function of the LED can be customized for different applications.

## **The Menu Tree:**

### **Using the Menu Keys:**

The figure below shows an example of how to navigate the menu tree. The top level (active on power-up) shows the product name, and the firmware revision number. Pressing any key puts you on the *main options* menu level. From here, you can select any of the controller's primary functions. The primary functions can vary from application to application, but usually include gain adjustments, configuring the analog front panel BNC terminals, LCD display options, restoring default parameters, and saving parameters to non-volatile memory. The above example shows how to display the payload's roll position on the LCD display. In general, pressing *Select* moves you one level down the tree ('selecting' the currently displayed option), and *Previous* one level up. The (+) and (-) keys are used to select between the different options at a given menu level, or to change a parameter's value (such as adjusting a gain up or down). Moving down the tree always brings you to the first option at each new level. Moving up the tree puts you back to the menu option you started from.

Try it out. Remember that you cannot hurt the controller, or permanently change parameter values until you go to the *Save Parameters* menu option, which also requests a confirmation. Even if you do save the parameters, the controller can be returned to 'factory default' settings using the *Restore Defaults* menu item (not shown in the figure above).

**It is important to note that no settings are automatically saved!** After you have configured the system to your liking, you *must go to the 'save all settings'* menu item to permanently store your configuration.

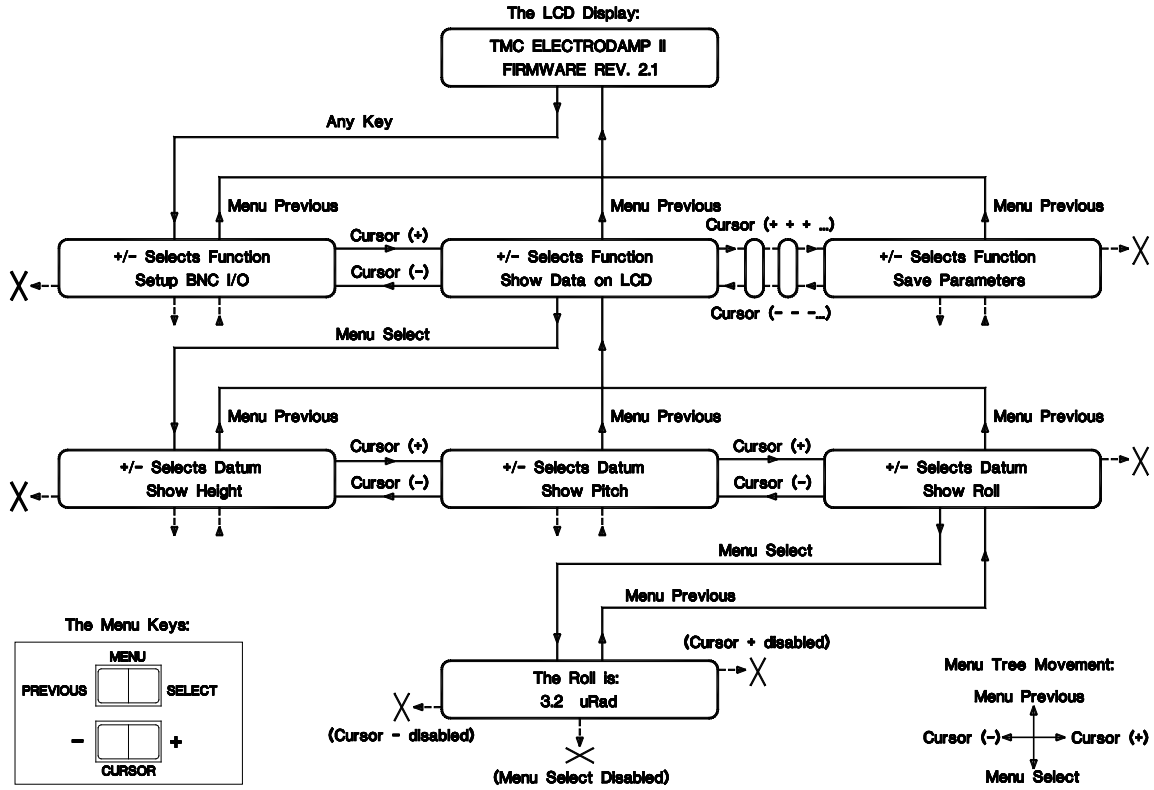


Figure 2: An example of how to use the menu keys to display the payload 'roll' on the LCD display.

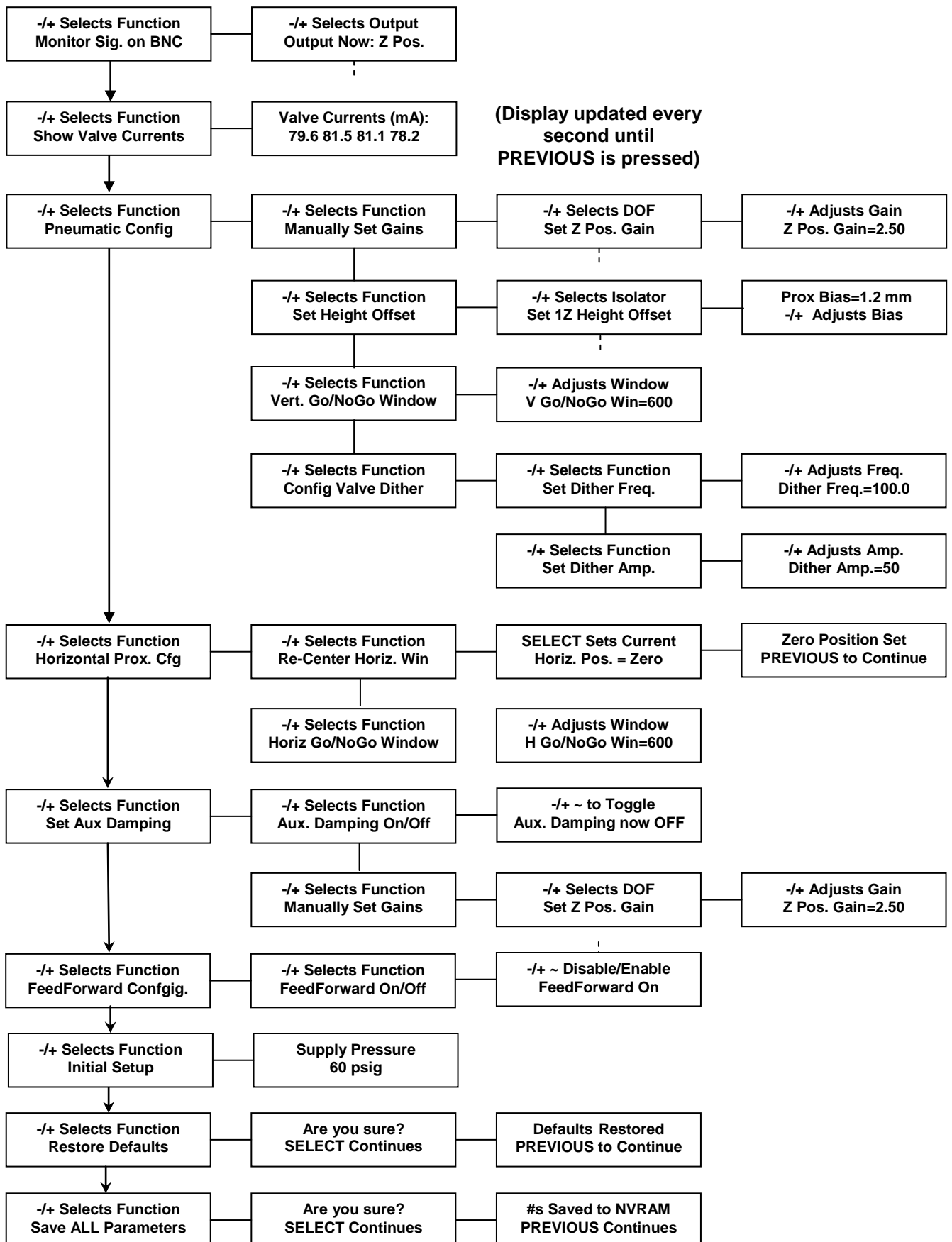


Figure 3: Detailed menu tree

## Detailed Explanation of Menu Functions:

**“Monitor Sig. of BNC”** allows you to select any one of position 6 measured DOFs on the payload, or individual proximity sensors on the front panel BNC Output connector. Pressing SELECT will display the current output parameter. Pressing the (+) or (-) keys will change the output. The output is immediate. The BNC monitor signal is NOT stored in NVRAM. The default output is the Z position (measured with proximity sensors).

**“Show Valve Currents”** allows you to display on the LCD the servo valves driving currents. The display will update every second. PREVIOUS quits. Function is used for troubleshooting.

**“Pneumatic Config”** is the top-level menu item which is selected to configure all functions of the system concerned with the pneumatic height control and leveling system. The functions which can be selected are:

**“Manually Set Gains”** allows you to set the gains for the Z Position, Theta-X position, and Theta-Y position DOFs. The **BNC Output** is automatically set to the DOF which is being adjusted.

**“Set Height Offset”** adds a bias to the Z Position of the selected Isolator. The main use of that function is to do the payload “fine” leveling, by control the fine height positioning of each Isolator.

**“Vert. Go/NoGo Window”** is a window which can be used to provide a go/nogo signal to the user for wafer loading, etc. The go/nogo status is reported on the front panel by the System Status LED turning from green to yellow. In addition, the serial port and/or digital IO ports may be programmed to report the current go/nogo status.

Calibrating the go/nogo window requires an external dial gauge be mounted between the frame and the floating payload. With the gauge in place, dial in a large height offset. Make note of the change in the height of the payload as measured by the dial gauge. Dividing the height offset by the reading gives you a calibration in (DSP counts / micron) – or whatever units your gauge reads in. This is the gain of the proximity sensors. This is required because the gain changes with the proximity sensor target material, thickness and size. If the height calibration (above) gave a result of 3 counts / micron, and your wafer loading spec was +/-100 microns in the Z position of the payload, then the window should be set to 300.

**“Config Valve Dither”** To obtain high precision in the pneumatic leveling system, the air flow to the isolators must be controlled to an extremely precise level. To do this, a ‘dither’ is used in the control signal to the valves to help overcome small amounts of mechanical friction in the valve’s moving parts. This dither can be fully configured. Once configured, the parameters of the dither must be saved by going to the *“Save ALL Settings”* menu option on the top level menu. The controller may be programmed to turn the dither on or off with a command over the serial and/or digital I/O ports.

**“Set Dither Freq.”** Use this to select the dither frequency for the valves. The default value is 100Hz. This can be moved up or down to avoid any structural resonances your system may have, or other sensitive frequencies (harmonics of video scans, etc.).

**“Set Dither Amp.”** selects the amplitude of the dither signal in DSP counts. It is adjustable in 10 count steps. Smaller settings will minimize noise on the payload at the dither frequency, but may decrease the system height stability. A higher setting improves leveling precision, but increases noise on the payload.

**“Horizontal Prox. Cfg”** is used to setup Horizontal Proximity Sensors measurement. Horizontal position measured against the preset go/nogo window triggers go/nogo flags to the customers control system. Control is always on.

**“Re-Center Horiz. Win”** if selected, reset the initial horizontal proximity sensors bias to set outputs of the horizontal proximity sensors to zero at current payload position.

**“Horiz Go/NoGo Window”** is a window which used to provide a go/nogo signal to the user for wafer loading, etc. The “go” status is reported on the front panel by the green System Status LED. The “nogo” status is reported by turning from green to yellow. In addition, the serial ports are programmed to report the current go/nogo status.

***Calibrating the go/nogo window*** requires external space filler with the width equal to specified go/nogo window limit (for example 100 $\mu$ m). To start calibration, first, give the system enough time to stabilize its position, and then set horizontal proximity sensors to zero (use menu option “Re-Center Horiz. Win”). Dial in a small value of horizontal go/nogo window (use menu option “Horizontal Prox. Cfg”/”-/+ Adjusts Window”) to make LED on the controller’s front panel color green. Place the filler between the frame and the floating payload to “move” the payload to the go/nogo window limit. LED will change its color to amber. With the filler in place, reduce value of horizontal go/nogo window, until the LED will change its color from amber to green. Remove filler and give system enough time to stabilize its position. LED should still be green color. Save the parameters in flash memory (use menu option: “Save All Parameters”).

**“FeedForward Config.”** Feedforward works by taking the feedforward input, multiplying it by a *coupling constant*, and applying the result to the valves that control the DOF you wish to improve.

**“FeedForward On/Off”** Turns the feedforward On and Off. This state is saved in the “*Save all Settings*” menu option.

**“Calibrate X – FF”** is used to automatically calibrate the coupling parameters

**“Set Aux Damping”** allows you to display on the LCD the auxiliary damping servo loop current status, switch it on/off and adjust related gains. Auxiliary damping is used to significantly increase damping in pneumatic feedback loops. That helps reduce settling

time for moving stages. In some applications Auxiliary damping could increase high frequency noise.

*Caution: auxiliary damping required quick change in isolator's pressure. That could be limited due to the length of air lines between valve box and isolators, and valves type, used in the valve box.*

**“Aux. Damping On/Off”** When selected, this will prompt you with either “Aux. Damping now OFF”, or “Aux. Damping now ON”. Hitting select will switch the status of Auxiliary damping function to opposite. For example, if the status was Off, it will be set to Auxiliary Damping On.

**“Manually Set Gains”** allows you to set the gains for the Z Position, Theta-X position, and Theta-Y position DOFs. The **BNC Output** is automatically set to the DOF which is being adjusted.

**“Restore Defaults”** restores the system to the factory settings and gains. The feedforward coupling constants are set to zero, the LM control loops are open (off).

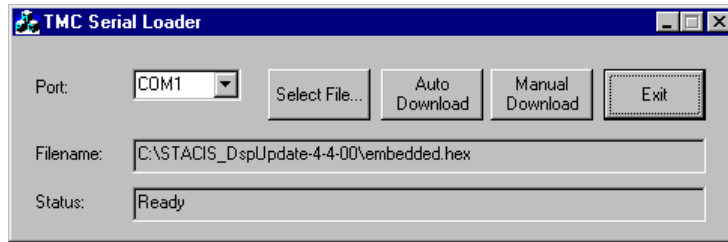
**“Initial Setup”** used to help operator to set devices, outside of the ED PLS, to the values optimized for system proper functioning.

**“Supply Pressure”** displays recommended air pressure to be set on the precision pressure regulator to supply air to ED PLS.

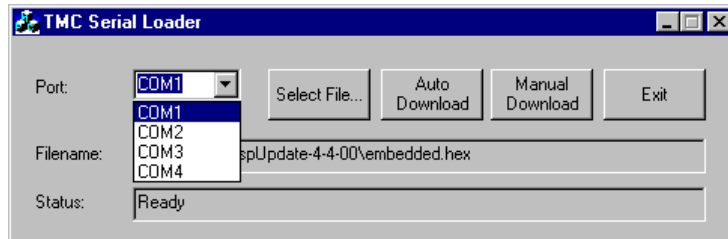
**“Save ALL Settings”** saves the following parameters to NVRAM. They will be restored when the system is powered off and back on again. All gains (9) are stored. The height offset, go/nogo window, valve dither frequency & amplitudes are stored. The open/closed (on/off) status of the LM controls is stored. All feedforward coupling constants and feedforward status (on/off) are stored. **Use care with this function.** All settings currently in NVRAM will be lost, and cannot be restored. Only the factory default settings may be restored after this operation.

## **Downloading New Software:**

From time to time you may need to upgrade your software. Your software diskette includes a program called **SerialLoader.exe** (for MS Windows 95/98) which can be used to download new application software to the controller through any one of the serial ports (COM1 or COM2). A special section in the controller's non-volatile memory (called the 'boot sector') cannot be upgraded in this way, and requires a special software application available from TMC. When you first run SerialLoader, you get the following dialog box:

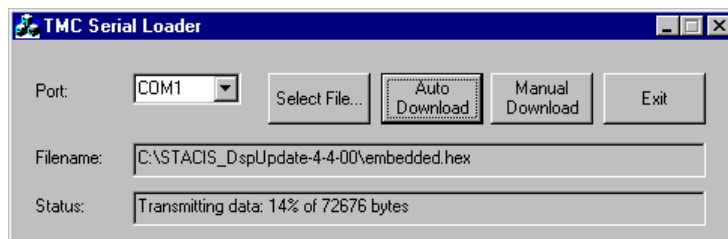


The first step is to select which serial port **on your computer** that you will use to download the new software:

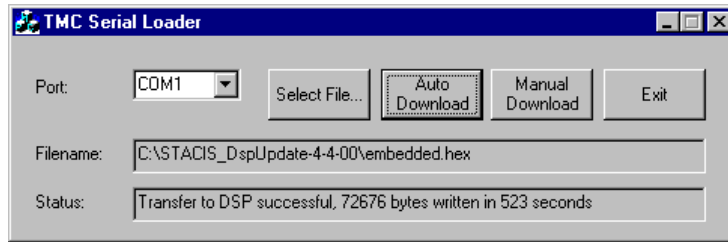


Next, press *Select File*. This brings up a standard Windows file dialog box, from which you can locate the new System Profile *.hex* file to load into the controller. Once the file is located, it will be displayed in the *Filename* field, and the *Auto Download* and *Manual Download* buttons will turn from gray to solid.

There are two modes for downloading software: Automatic and Manual. Automatic downloads can be run at any time during normal controller function. When selected, the controller will reboot and the downloading will start in the middle of boot process. *Manual Download* can be used if the controller is not responding at all. In this case, turn off the power to the controller, and turn it back on. Watch the *system status* LED on the front panel. Hit the *Manual Download* button at any time while the green *status* LED is flashing, and the download will proceed. The dialog window will indicate the progress of the download in the *Status* window (in %):



After the download is complete, the *Status* window will indicate the total bytes transmitted, and the time required in seconds. 'Successful' means the downloaded *.HEX* file passed a checksum test, and was written to flash (non-volatile) memory:



After the download, the controller will automatically reboot, and the new software will run.

### **Failed Downloads:**

A download can fail for many reasons. If the download fails the checksum, the new software is NOT written to flash. If the controller does not reboot automatically, you should manually shut the power off and then back on to reboot the old version of the application software. From there, repeat the downloading process described above.

### **Electronically Interfacing with the Controller:**

The DC-2000 offers many ways to interface with other computers or machines. It has a 16x16 DI/O interface and three COM ports (COM1 on the front panel, COM2 on the rear panel, and a telephone modem interface for remote access). **There is no 'standard set' of commands** for the controller. TMC customizes the instruction set for each OEM application. These can be commands to alter gains, or to return status words. The controller can also set bits on the DI/O port, the relay status, or even send strings on the COM ports on user-defined 'alarm' conditions. Contact TMC for more information.

## **Serial Port Commands & the Status Byte**

### **The Serial Port Commands:**

The Electro-Damp<sup>®</sup> PLS system can be controlled remotely using the serial ports. Although detailed setup must be done through the front panel menu system, most operational 'modes' can be controlled through the ports. Likewise, the current status of the system can be monitored with the **status byte**. The status byte is an eight bit word that indicates the current operational state of the system.

***The serial ports are 9600 baud, 8 data bits, 1 stop bit, no parity, no handshaking.***

There are two serial ports on the controller. Commands can be issued to either serial port, but the response of each port is different. The rear serial port is meant to be connected to a host computer. When a command is issued to the rear serial port, the controller only echoes back the status byte, terminated by a **<CR>**. The front serial port



will echo back replies like “**System now docking: 28 <CR>**”, indicating what command was typed, and what the current status byte is. If an unknown command is issued to the front port, the controller echoes back “Unknown Command”. Thus the front port can be used to control basic modes. It can also be used to download new application software to the controller.

All of the commands are one character long, terminated by **a <CR>** (no <LF>). The controller executes the command, and returns the system status byte (x00-xFF<CR>). The **s <CR>** command stands for ‘status’, and is a null command: It returns the status byte without changing any of the systems current operating parameters.

The table below summarizes the controller’s serial port command set:

**Table 1: Summary of Serial Port Commands**

<b>s &lt;CR&gt;</b>	<b>“Read Status”</b> . Return Status Byte, no change to system operating parameters.
<b>c &lt;CR&gt;</b>	<b>“Control Mode”</b> – Controls status of pneumatic system: valves dither on, height control integrators active. This mode is for the highest degree of payload positioning control. Returns new status byte to reflect mode.
<b>h &lt;CR&gt;</b>	<b>“Hold Mode”</b> – Controls status of pneumatic system: valve dither off, integrators on hold. Proportional feedback to valves only. Sacrifices some positioning stability for better noise performance. Returns new status byte to reflect mode.
<b>d &lt;CR&gt;</b>	<b>“Dock”</b> the system. Lowers the air pressure in the isolators so the payload lowers itself onto the isolators’ lower mechanical stops. Returns new status byte to reflect mode.
<b>f &lt;CR&gt;</b>	<b>“Float”</b> the system. Opposite of “Dock”. Returns the system to normal (Control Mode) operation after a “d” command docking. Returns new status byte to reflect mode.
<b>e &lt;CR&gt;</b>	<b>“Enable Feed Forward”</b> . This command turns on both X and Y axis Feed Forward. Returns the status byte.
<b>k &lt;CR&gt;</b>	<b>“Disable Feed Forward”</b> . This command turns off both X and Y axis Feed Forward. Returns the status byte.
<b>p &lt;CR&gt;</b>	<b>“Part Number”</b> . This command sends the TMC part number and revision for the system software to the front panel LCD. It also echoes the PN to the front serial port if that port is used.
<b>a &lt;CR&gt;</b>	<b>“Acquire Data”</b> . Collects reading from all 6 Position Sensors and 4 FF signals for 10 sec. at 100Hz rate (see format below)
<b>g &lt;CR&gt;</b>	<b>“Get Data”</b> . Transfer 1000 strings of collected data to PC.
<b>b &lt;CR&gt;</b>	<b>“Acquire Data Sample”</b> . Sends to PC the string of current values of all 6 Position Sensors and 4 FF signals (the same format as above).
<b>r &lt;CR&gt;</b>	<b>“Reset”</b> . System Reset. Restores parameters to values saved in NVRAM, initiates startup sequence. Returns status byte showing current mode.

## The Status Byte:

The Status Byte is reported over the serial port as a combined 8 bit value of two ASCII format bytes, followed by the <CR>. The table below shows the meaning of each bit in the status byte. The normal status byte reports the operating condition of the machine. It indicates if the linear motor feedback is on or off, the system is docked, within a go/nogo window, etc. A system operating normally (with feedback and feedforward on) would report x00.

**Table 2: Status Byte:**

Bit on Status Byte:	Bit 0 = 0 (system OK)
0	system OK = 0
1	Outside Go/NoGo=1, OK=0
2	Not Floating=1, OK=0
3	Linear Motors Off=1, ON=0
4	Hold Mode=1, Control=0
5	Docked=1, Undocked=0
6	Test in Progress=1, Done=0
7	FeedForward Off=1, On=0

### Status Byte Details:

The bits on the status byte do not have a one-to-one correspondence with the commands. Several of the commands can affect one or more bits on the status byte. In particular:

#### **Bit 0:**

This bit is set when the system did not pass the self Diagnostic Test.

#### **Bit 1:**

This bit is only controlled by the user-set go-nogo window option in the LCD menu system. If the payload goes outside of the go-nogo window, the bit is set to 1. Otherwise it is 0.

#### **Bit 2:**

This bit is set to 1 (see Note below) if the system is not floating within a larger (few mm) go-nogo window. If outside this window, there has either been an unusual disturbance to the payload, or the valving system has had a malfunction. At that moment all LM will be disabled and Bit 3 set to 1. The bit is not cleared (set to 0) until the system has been inside this window for more than 30 seconds.

#### **Note:**

- **This bit is used if LM (linear motors) are part of the system, otherwise Bit 2 always set to 0.**
- **When the “Not Floating” condition detected, all stage motions have to STOP immediately!**

### **Bit 3:**

This indicates if the Linear Motors are enabled (see Note below). When the motors are off, neither the feedback or feedforward systems function. **Many conditions can set this bit to 1 (motors off)**. The bit is set to 1 (motors off) when whenever **Bit 2** is set (see above), if the system fails (see **Bit 0** above). The **x <CR>** command turns off the linear motors and sets the bit. Conversely, the bit is 0 only when the floating OK (Bit 2 = 0), and the motors are enabled with the 'o' command or using the menu system to toggle the linear motors on. If the system has been configured with the motors to be enabled on power up, a reset command will also reset the bit.

**Note: This bit is used if LM (linear motors) are part of the system, otherwise Bit 3 always set to 0.**

### **Bit 4:**

Bit set to "1" by the 'h' command on either serial port. It is reset to 0 (valve dithering on and the integrators enabled) by issuing the **c <CR>** command, or by a system reset.

### **Bit 5:**

This bit is only set by a docking command issued to either serial port ('d'). It is reset to 0 with the floating command (**f <CR>**), or by a system reset.

### **Bit 6:**

This bit is set to 1 if the controller is performing **any** test or collecting measurement data. It can be assumed that while set, the system is not running in an operational mode (unless the test bit has been triggered by "command **a <CR>** - "ACQUIRE"). The tests which set this bit are: any function under the "System Diagnostic." menu branch including Auto Gain calibration, testing actuators, and testing sensors. The bit is set to zero when the test has been completed (in the case of System Diagnostic), or when the measurement data collection is completed.

### **Bit 7:**

This bit is set to 0 if the feedforward system is enabled. This controlled through the LCD menu system or by the **e <CR>** and **k <CR>** serial port commands. Note that a status of "0" does not ensure that feedforward is running. If the linear motor system has been disabled (see the notes for Bit 3), or the feedforward parameters have not been adapted (the coupling constants are zero), then feedforward will not function.

## **How Commands Change the Status:**

To help understand how the different menu and serial port commands can change the status of the system, the following table can be helpful. It assumes the system is running in the 'normal' condition (status = 00) before the command is issued. The resulting status byte (far right column) is the result of the command *after* it is executed. For example, the **d <CR>** command will echo back status byte "22" or "20" when the command is issued. This indicates that the system is in "docking" mode, and payload position, at that moment, is outside or inside of the defined horizontal and vertical go-nogo window. Horizontal LM, if it needed, will start to move the payload to the "0" position. As the payload goes inside of the go-nogo window, the respond to the **s <CR>** command, issued after the **d <CR>** command, will switch from "22" to "20".

**Table 3: Status Byte due to System Commands**

	Bit 7 FeedForward off	Bit 6 Test in Progress	Bit 5 Docked	Bit 4 Hold Mode	Bit 3 Linear Motors off	Bit 2 Not Floating	Bit 1 Outside Go/NoGo	Bit 0 Error	Status Byte Result
<b>S</b>	0	0	0	0	0	0	0	0	<b>00</b> <b>(Normal Status)</b>
<b>C</b>	0	0	0	0	0	0	0	0	<b>00</b>
<b>H</b>	0	0	0	<b>1</b>	0	0	0	0	<b>10</b>
<b>D</b>	0	0	<b>1</b>	0	<b>1</b>	<b>1</b>	<b>1</b>	0	<b>2e</b>
<b>F</b>	0	0	0	0	0	0	0	0	<b>00</b>
<b>E &amp; Menu Equivalent</b>	0	0	0	0	0	0	0	0	<b>00</b>
<b>K &amp; Menu Equivalent</b>	<b>1</b>	0	0	0	0	0	0	0	<b>80</b>
<b>P</b>	0	0	0	0	0	0	0	0	<b>00</b>
<b>G</b>	0	0	0	0	0	0	0	0	<b>00</b>
<b>A</b>	0	<b>1</b>	0	0	0	0	0	0	<b>40</b>
<b>B</b>	0	0	0	0	0	0	0	0	<b>00</b>
<b>R</b>	0	0	0	0	0	0	0	<b>Reset to 0</b>	<b>00</b>

## Payload Motion Recording:

"**ACQUIRE DATA**" (format "a"),

After command is received, status byte **Bit 6** ("test in the progress") will switch to "1", and status byte will be echoed back to Com. Port. In the same time, the internal buffers, with previously collected data, will be cleared. For the next 10 seconds, current values samples from all 6 Position Sensors and 4 FF signals will be saved, as a separate strings of data, every 100ms (at 100Hz rate).

After 1000 strings with data samples will be collected (10 seconds), status byte **Bit 6** ("test in the progress") will be switched to "0", as an indication, that data is ready to be transmitted to Host computer.

"**GET DATA**" (format "g"),

*Caution, the command has to be sent only after confirmation, that status byte Bit 6 ("test in the progress") is equal "0".*

Strings of collected data will be transferred to PC over serial port (front or back, depends were command "g" has been received) in the following format:

```
nnnn , sAAAAA,sAAAAA,sAAAAA,sAAAAA,AAAAA,sAAAAA,sAAAAA,sAAAAA,sAAAAA,sAAAAA.\r
```

were:

- *nnnn* - scan number (it could be up to 5000 scans over period of data collection)
- *sAAAAA* – measured channel signal value in counts. 's' is a sign (minus is "-", space, treated as "+");
- position of *sAAAAA* represents channel:
- channel 0 = V1 (vertical proximity sensor on Isolator#1)
- channel 1 = V2 (vertical proximity sensor on Isolator#2)
- channel 2 = V3 (vertical proximity sensor on Isolator#3)
- channel 3 = H1 (horizontal proximity sensor on Isolator#1)
- channel 4 = H2 (horizontal proximity sensor on Isolator#2)
- channel 5 = H3 (horizontal proximity sensor on Isolator#3)
- channel 6 = ffXP (feedforward X position as TMC controller receives it from the stage controller)
- channel 7 = ffYP (feedforward Y position as TMC controller receives it from the stage controller)
- channel 8 = ffXA (feedforward X acceleration as TMC controller receives it from the stage controller)
- channel 9 = ffYA (feedforward Y acceleration as TMC controller receives it from the stage controller)
- ".\r" end-of-line token (dot = "0x2E"; CR = "0x0D")

*Example, below shows data received from the TMC controller through front COM1 port, by using Hyper terminal on Host Computer:*

```
index,  V1,    V2,    V3,    H1,    H2,    H3,    ffXP,  ffYP,  ffXA,  ffYA.
0000 , 19304, 35087, 24176, 33354, 45331, 27864, 30547,-40255, 00002,-00045.
0001 , 19298, 35082, 24170, 33359, 45309, 27854, 30533,-40258, 00006,-00041.
0002 , 19289, 35099, 24162, 33358, 45286, 27838, 30516,-40246, 00020,-00048.
0003 , 19245, 35104, 24155, 33384, 45255, 27816, 30501,-40244, 00036,-00043.
.....
0999 , 18934, 35611, 24158, 33143, 44762, 27388, 10427,-40261, 00002,-00038.
1000 , 18923, 35604, 24155, 33154, 44755, 27376, 10432,-40265, 00006,-00033.
```

"**ACQUIRE DATA SAMPLE**" (format "b"),

Current values of all 6 Position Sensors and 4 FF signals are saved in the string (the same format as above). That string is transferred to PC over serial port (front or back, depends were command "b" has been received).

*Example, below shows data received from the TMC controller through front COM1 port:*  
*0000 , 19304, 35087, 24176, 33354, 45331, 27864, 30547,-40255, 00002,-00045.*

## The DI/O Interface:

The DC-2000 offers 16 digital inputs and 16 digital outputs. Both inputs and outputs are isolated with optical couplers. Figure 3 below shows a schematic diagram of the controller's internal wiring. The connections to the outside world are shown on the right. The (+5Volts) and (GND) on the DB-37 connector are configured with jumpers on the 'Power Board' internal to the controller:

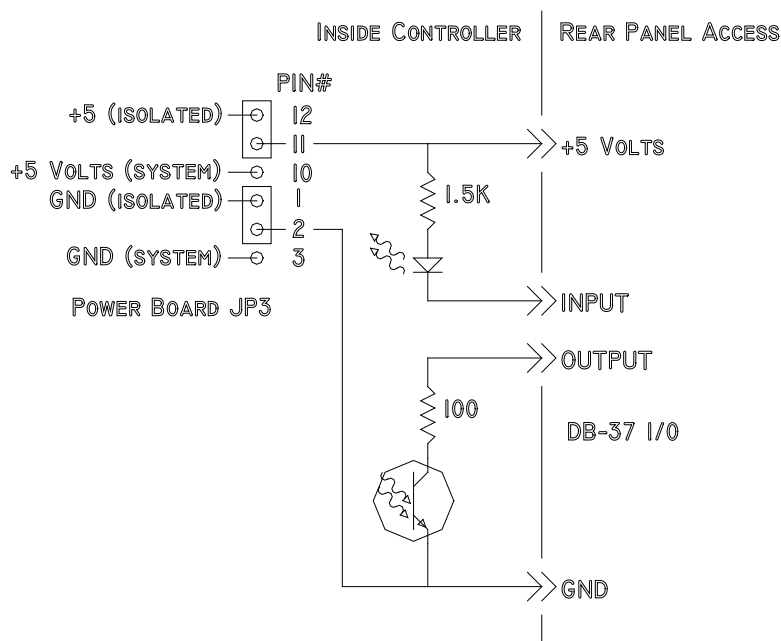


Figure 4: A schematic of the digital inputs and outputs

- The (+5Volts) and (GND) on the DB-37 connector are configured with jumpers and are connected to an isolated power supply (300mA, 1.5W), internal to the controller.
- The jumpers are set as shown above by default, but can be changed before shipping upon request. **The jumpers are internal to the controller and must be changed at the factory, or by authorized TMC personnel only**
- All of the LED (+) terminals are connected to a common +5 volt bus through 1.5 KOhm resistors.
- All of the open collector emitters are connected to a common ground bus.
- Current-limiting 100 Ohm resistors are used to protect the output transistors.
- Both +5V and GND are available on the DB-37 connector.

See the following section for the exact pinout of the DB-37 connector.

## Connector Pinouts:

The following tables show the pinouts for each of the connectors on the back of the DC-2000:

Digital Input/Output DB-37 Connector Pinout:							
Pin Number	Function	Pin Number	Function	Pin Number	Function	Pin Number	Function
1	D in 0	11	+5 VDC	21	D in 9	31	D out 1
2	D in 1	12	D out 8	22	D in 10	32	D out 2
3	D in 2	13	D out 9	23	D in 11	33	D out 3
4	D in 3	14	D out 10	24	D in 12	34	D out 4
5	D in 4	15	D out 11	25	D in 13	35	D out 5
6	D in 5	16	D out 12	26	D in 14	36	D out 6
7	D in 6	17	D out 13	27	D in 15	37	D out 7
8	D in 7	18	D out 14	28	GND	-	-
9	N. C.	19	D out 15	29	+5 VDC	-	-
10	GND.	20	D in 8	30	D out 0	-	-

**NOTES:** 'N.C.' means 'no connection'. The +5 VDC and GND connections shown in this table are configured as shown in the previous section. By default they are connected to an isolated power supply (300mA, 1.5W).

Analog Input/Output Channels 0-7 DB-37 Connector Pinout:							
Pin Number	Function	Pin Number	Function	Pin Number	Function	Pin Number	Function
1	A Out 0	11	A In 6	21	A Out 3	31	GND
2	A Out 2	12	GND	22	GND	32	+15 VDC
3	GND	13	GND	23	A Out 5	33	-15 VDC
4	A Out 4	14	GND	24	A Out 7	34	GND
5	A Out 6	15	GND	25	GND	35	GND
6	GND	16	+V Aux	26	A In 1	36	GND
7	A In 0	17	+V Aux	27	A In 3	37	GND
8	A In 2	18	+V Aux	28	GND	-	-
9	GND	19	+V Aux	29	A In 5	-	-
10	A In 4	20	A Out 1	30	A in 7	-	-

**NOTES:** For both Analog I/O connectors, the GND connections are chassis ground (non-isolated), and the  $\pm 15$  VDC pins are also non-isolated. The '+V Aux' pins are connected to a dedicated power supply for powering systems external to the digital controller. The typical supply provided with the DC-2000 is a 24VDC, 25W switching power supply. It is non-isolated, and is used for powering the servo valves in the precision valve controller.

### Analog Input/Output Channels 8-15 DB-37 Connector Pinout:

Pin Number	Function	Pin Number	Function	Pin Number	Function	Pin Number	Function
1	A Out 8	11	A In 14	21	A Out 11	31	GND
2	A Out 10	12	GND	22	GND	32	+15 VDC
3	GND	13	GND	23	A Out 13	33	-15 VDC
4	A Out 12	14	GND	24	A Out 15	34	GND
5	A Out 14	15	GND	25	GND	35	GND
6	GND	16	+V Aux	26	A In 9	36	GND
7	A In 8	17	+V Aux	27	A In 11	37	GND
8	A In 10	18	+V Aux	28	GND	-	-
9	GND	19	+V Aux	29	A In 13	-	-
10	A In 12	20	A Out 9	30	A in 15	-	-

**NOTE:** Analog Input 15 is connected to the controller's front-panel BNC input. Likewise, analog output 15 is connected to the controller's front-panel BNC output.

The COM ports on the controller follow the RS-232 standard. The Baud rate is 9600 with 8 data bits, 1 stop bit, no parity, and RTS/CTS (hardware) flow control. The pinouts for the ports are given below:

<b>COM1 and COM2 DB-9 Pinouts:</b>			
<b>COM 1</b>		<b>COM 2</b>	
PIN Number	Function	Pin Number	Function
1	N.C.	1	N.C.
2	TXD2	2	TXD2
3	RXD2	3	RXD2
4	N.C.	4	N.C.
5	GND	5	GND
6	N.C.	6	N.C.
7	CTS2	7	CTS2
8	RTS2	8	RTS2
9	N.C.	9	N.C.

The rear panel also includes an auxiliary power interface which can be used for powering external devices or for alarm signals (such as warning lights). It provides access to a SPDT relay, and power from the dedicated power supply, either switched or unswitched by the relay. The relay is controlled by the application software, which can be customized to switch the relay on virtually any command or condition.



Aux. Power Interface Pheonix 9-Pin Connector:			
Pin Number	Function	Pin Number	Function
1	+24 VDC	6	GND
2	GND	7	Relay +24VDC/NC
3	Relay Common	8	Relay +24VDC/NO
4	Relay NC	9	GND
5	Relay NO	-	-

## Feed Forward System Setup

The stage controller should produce analog signals proportional to the position and acceleration of each axis. The accuracy of D-to-A conversion for analog position and acceleration should not be less than 12 bits. The signals are bi-polar, single-ended ground referenced. The signal update rate must be 1 KHz or more.

The customer should supply the cable between the stage controller and TMC FF interface. The TMC FF input has range of  $\pm 10V$ , interface connector is D-Sub 25 Male, and signal layout is as follow:

**Table 4: Feed Forward DB25 mail connector**

<p><b>Feed forward connector:</b></p> <p><b>D type 25 pin male connector</b></p>	<ul style="list-style-type: none"> <li>● <b>Pin 1 - SHELL</b></li> <li>● <b>Pin 2 - X Acceleration</b></li> <li>● <b>Pin 3 - GND</b></li> <li>● <b>Pin 5 - Y Acceleration</b></li> <li>● <b>Pin 6 - GND</b></li> <li>● <b>Pin 8 - X Position</b></li> <li>● <b>Pin 9 - GND</b></li> <li>● <b>Pin 11 - Y Position</b></li> <li>● <b>Pin 12 – GND</b></li> <li>● <b>The rest of pins are not connected</b></li> </ul>
--	---

The “X Position” and the “Y Position” signals are scaled to  $\pm 8V$  range. These signals should be around 0V at the “Home” position (usually geometrical center of motion for each axis), and **not exceed the limit of +8V or -8V at the outmost positions of each axis.**

The “X Acceleration” and the “Y Acceleration” signals are scaled to  $\pm 8V$  range; these signals must be 0V when the axis does not change speed. The foreseen maximum of acceleration should and **not exceed the limits of +8V or -8V.** For example: if working acceleration is 0.3g and future planned acceleration will be 0.5g, then 0.5g should be represented as 8V, and 0.3g will be 4.8V.

In order to achieve the best performance of stage FF, certain conditions should be met and certain requirements should apply to the stage controller and its software:

- 1) The “X Position” and the “Y Position” signals should be the REAL positions (from encoders). The TARGET position (which stage is approaching during motion) is less desirable because of some position error during motion and DAC update rate, but acceptable if this position error during any motion profile is less than or equal to  $\frac{1}{4}$  of D-to-A LSB. For example: for 14-bit conversion and travel of 444 mm the LSB will be 0.027mm. If position error during any motion profile (fast acceleration, and signal update rate of 1 KHz, for example) is less than 0.0068 mm, then the target position value for stage FF is as good as the real one.
- 2) The “X Acceleration” and “Y Acceleration” signals must be the REAL accelerations (second time derivative of encoder signal). The stage acceleration motion profile should be “S-curve” (when the time derivative of acceleration has a trapezoidal form); the “triangle” acceleration profile (when the time derivative of acceleration is a constant) is less desirable, because the time profile of the applied to the payload force would be also trapezoidal, without instantaneous change. Instantaneous force change with the “triangle acceleration profile” could be visualized as a hammer strike on payload, which causes resonances of stage and payload. In the opposite, trapezoidal force profile with “S-curve” is much gentler and would not cause resonances.

## 5) Technical Specifications:

**Warning:**  
**No user-serviceable parts inside components.**  
Please return units to TMC for repair or service.

### Physical Dimensions:

DC-2000 Controller.....1.75"(44.5mm)H x 19"(482.6mm)W x 14.5"(368.3mm)D  
(1 Standard RETMA unit w/rack mounting holes)  
Precision Valve Box.....1.75"(44.5mm)H x 19"(482.6mm)W x 14.5"(368.3mm)D  
(1 Standard RETMA unit w/rack mounting holes)  
Combined Height      2 RETMA rack units, or 3.5"(88.9mm) x 14.5"(368.3mm)D

### Weights:

DC-2000 Controller..... 12.75 lb (5.8kg)  
Precision Valve Box..... 10.75 lb (4.9kg)  
Combined ..... 23.5 lb (10.7kg)

### Environmental (refer to EN 61010-1: 1993, EN 61010-1/A2: 1995):

For indoor use only, up to an elevation of 2,000m (6560ft.)  
Maximum allowable temperature range: ..... 5°C to 35°C  
Maximum allowable humidity ..... 80% up to 31°C, decreasing linearly to  
50% relative humidity at 40°C  
Tolerance in mains supply voltage ..... +/-10% of nominal voltage  
Overvoltage category.....2  
Pollution degree (IEC 664).....2  
Ventilation requirements ..... 25mm clearance on sides, 0mm top and bottom

### Power Requirements:

Power Input Voltage Range ..... 115-230 VAC 400VA  
Input Frequency Range .....50-60 Hz

### DC-2000 Performance Specifications:

Analog Inputs..... 16 x16 bit / 96dB Dynamic Range, ±10V full scale  
Analog Input Protection ..... ±15 Volts  
Analog Outputs..... 16 x 14 bit / 84dB Dynamic Range, ±10V full scale  
Analog Output Protection..... indefinite short circuit protection  
Digital Input Current Rating..... 2mA min / 30mA max.  
Digital Output Current Rating..... 30mA max.  
Digital I/O Protection..... full optical isolation (see *The DI/O Interface*)  
DI/O Isolated Supply..... 5VDC, 300mA max. (1.5 Watt)  
COM Ports..... 9600 Baud, 8 data, 1 stop, no parity, RTS/CTS flow control  
DSP Engine ..... TMC320C32 / 60MHz  
Sampling Rate .....5KHz (Max. Transport Delay 0.6ms)

### **Precision Valve Box:**

Long Term Height Stability.....	±50 microns
Long Term Tilt Stability .....	±50 microradians
Servo Valves .....	4 x 2-way variable-orifice proportional servo valves
Valving Technique .....	Pure Class-A (See <b>Appendix A</b> )
Maximum Input Pressure .....	120 PSI or 8.3 Bar or 830 KPa
Nominal Air Consumption .....	60 slpm (2 scfm)
Air Requirements.....	Clean, dry air, filtered to 20 microns or better
Proximity Sensors.....	3 x Eddy current NAMUR
Fail Safe .....	Isolators deflate on power failure or power off
Lamps.....	Green (power OK), Yellow (air pressure lost)
Pneumatic Fittings .....	'One-touch' quick fittings for ¼" O.D. hose

### **Miscellaneous:**

CE Compatibility .....	Equipment is tested to EN/IEC 51010-1
Aux. Power Interface Relay ratings.....	10 A / 250 Vac

### **Normal System Components:**

- (1) DC-2000 Digital Controller
- (1) 3.5" floppy disk with application .HEX file and serial downloader
- (1) Precision Valve Box
- (1) Interconnect ribbon cable
- (3) Turck Bi10-G30-Y0 proximity sensors
- (1) 120vac power cord (or cord appropriate for your country/voltage)
- (30ft.) ¼ O.D. polyurethane tubing
- (1) Exhaust noise silencer (15ft coiled polyurethane tubing).
- (1) Precision air pressure regulator
- (1) air filter.
- (1) Operating Manual (this document)
- (1) Screw terminal connector for proximity sensors

## 6) Troubleshooting

**Problem:** *My system doesn't float.*

**Answer:**

Check that the LCD background and the green power lamp on the valve box both are lit (showing the power is connected). If the system has power, do you hear air flow? If not, make sure the air supply is correctly connected. Make sure the proximity sensors have a proper metal target, and are close enough to the targets. If the targets seem close enough, but it still doesn't float, try placing a metal object (such as a quarter) on top of each sensor. If the isolators are lifting the payload (to its top stops), remove the coins and move the sensors closer to the payload. If the system doesn't float, the supply pressure is probably too low. Remove the coins. Confirm the pressure is at least 15psi above the highest isolator pressure. You might have calculated this wrong - you will not harm the system by simply increasing the pressure to test if this is the problem. Make sure the proximity sensors are facing upwards. They will not work looking down on a payload. You may have an air line which is not correctly connected, or pinched. Check the air line connections by removing the hose at each isolator and checking for free flow. Once the system is floating, proceed to the instructions on how to set the gains in the Quick-Setup portion of this manual.

**Problem:** *Some, but not all of the isolators float.*

**Answer:**

First determine if your system is gravitationally unstable. If it is, the system will sit on one edge for a while (up to several minutes), then suddenly 'flop' over to the opposite edge. It will eventually flop back, and repeat the pattern. See the answer to the next *Problem* if this is the case. If your system just sits with some isolators down, then you have probably connected the air lines or the proximity sensors incorrectly (for example, proximity sensors 1 & 2 switched). Recheck all connections. If the system is plumbed correctly, the supply pressure is probably set too low. Increase it by 10 psi. You may have an air line which is not correctly connected, or pinched. Check the air line connections.

**Problem:** *My system flops back and forth in tilt from travel limit to travel limit (unstable in tilt).*

**Answer:**

Your system is most likely *gravitationally unstable*. Any payload supported under its center-of-mass wants to 'fall over'. Normally, the isolators provide a restoring force which prevents this. It's possible to make a system unstable, however, by placing the center-of-mass too high, or making the distance between isolators too short. The general rule of thumb for stability is:

$$\frac{[\text{Isolator Separation}]^2}{\text{Center of Gravity Height} + 7\text{inches (or 18cm)}} > 60\text{inches or 1.5meters}$$

Note: the height is measured from the top of the isolator's 'load disk'.

Borderline systems tend to behave poorly. Some systems which are stable with mechanical height control valves maybe unstable with electronic valving systems: mechanical valves act like springs which can help stabilize a system (but also degrade the vibration isolation). Solutions to this problem include lowering the center-of-gravity of the system and increasing the separation between the isolators. Its also possible to use *negative piston rings* which increase the isolators' stiffness for large displacements. Contact a TMC sales engineer for more information on this last option.

**Problem:** *My float height isn't 15mm above the sensors*

**Answer:**

15mm is the nominal float height for a ferrous metal target (like steel). Several things can reduce this height: (1) an aluminum target; (2) a small target, or one which has an edge near the sensor; (3) a thin target (such as metal tape); or (4) a fixed piece of metal located near the sensor. The last of these is the least desirable, and should be corrected if possible by moving the sensor and/or the piece of metal. All sensor should have comparable targets.

**Problem:** *I see some low-frequency noise in the positioning of the payload which is above the specification.*

**Answer:**

Most air compressors only control pressure to about 10 psi. This can produce position noise on your payload which is correlated with the compressor's on/off cycling. Your DC-2000 was provided with a precision pressure regulator which should filter out most of this noise. To improve the regulation, you can place an additional regulator between the pressure source and the original regulator. Set its pressure approximately midway between the line pressure and pressure setting on the original regulator. Changes in barometric pressure can also cause noise on a payload, since the sealed chambers of the isolators make them act like barometers. Many environments (such as clean rooms) have very aggressive air handling systems which can generate 'barometric noise'. Likewise, if the system is placed near an air vent, or has some air circulating about it as part of a 'mini-environment', the table can see excess positioning noise (since these air flows are usually turbulent). These sources of noise are not controllable by the valving system and must be addressed at the source. The

specifications for the DC-2000 valving system were determined in a sealed room with no air circulation system running.

**Problem:** *The system takes too long to level after a disturbance (shift in mass distribution).*

**Answer:**

Like mechanical valves, the DC-2000 valving system is a gain-limited servo. The gain is limited by the need to preserve vibration isolation in the system above a few Hertz. For this reason, the DC-2000 will level a payload at about the same speed as a mechanical valving system, depending on the disturbance. Mechanical height control valves are nonlinear in that they have a very large air flow for large payload displacements, but an unproportionally small flow for small displacements. Since the servovalves in the valve box are linear, the electronic system will have an improved leveling response for small displacements, but a slower response for large ones. Check that the pitch and roll gains are as high as they can be without the system oscillating. You may want to consider using stage feedforward (described earlier) to reduce leveling time.

**Problem:** *I can't mount the sensors so there is a right angle between sensors 1&2 and 2&3*

**Answer:**

Do the best you can. The closer the system is to a right triangle, the better it will behave. On some systems, the angle can deviate by 20 degrees or more and still function well. If you must use a large angle, try to make the center-of-mass of the payload lie on the line between sensors 2&3.

**Problem:** *My isolators inflate to full pressure, lifting the payload to its travel limits, independent of the gain, or even if the power is off(!)*

**Answer:**

If the isolators inflate when the power is off, you have probably connected the air supply line to the vent port of the controller. Recheck your plumbing.

## **Technical Help**

If you need additional help with the installation of your DC-2000 system, or would like more information regarding our other active products, call TMC at (800) 542-9725, or contact us via e-mail at [service@techmfg.com](mailto:service@techmfg.com).