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# Introduction

The MAC 5000 system is the fifth generation automation controller from LEP. System configuration is more simplified and flexible than previously possible with the earlier versions of LEP controllers. By eliminating the limitations imposed by a fixed chassis design, the MAC 5000 controller can easily be configured with different combinations of modules to suit various application requirements. Up to twenty interlocking “stackable” MAC 5000 modules can be used with only a small sacrifice in workspace due to the MAC5000’s compact footprint. The modular nature of the system facilitates troubleshooting and minimizes down time since a malfunctioning module may be easily swapped with a replacement module by the user.

## MAC 5000 System

### Architecture



Figure 1

Each MAC 5000 controller incorporates the main power supply base module and a combination RS-232/USB interface module (see Figure 1). Additional MAC 5000 modules are “stacked” above this base unit interlocking both electrically and mechanically to the prior module. This unique architecture allows for greater system flexibility and provides a simple user serviceable upgrade path as application requirements vary.

## ***System Power Supply***

The system power supply, P/N: 73005001, provides the power to the MAC 5000 bus. The MAC 5000 system uses +5v, +8v, ±15v and +24v for various functions. The following table is a reference for which supplies are most commonly used internally and for what function:

<b><u>Voltage</u></b>	<b><u>Where used</u></b>
+5v	Microprocessors, TTL logic
+8v	Stepper motor standby (at rest) power
±15v	Analog electronics
+24v	Motor drive power, base supply from which other voltages are derived

The front panel of this module has green indicating LED's to show the status of the 24v line and the 5v line. These LED's provide an important trouble-shooting aid as there is no normal condition where any of the LED's should not be lit.

## ***Fuses***

The MAC 5000 has a single fuse integrated into the switching power supply within the base module. This is not a user servicable component; in the unlikely event of a switching power supply failure, the base module would need to be serviced by LEP.

## ***Power Requirement and Ratings***

The MAC 5000 controller automatically switches to accommodate any of the international supply voltages. Simply connect the proper line cord to the rear-panel receptacle and switch it on.

## ***Listings and Conformance Data***

The MAC 5000 system is listed with ETL and tested to UL 3101-1. The system is also CE compliant and has been tested extensively for compliance with international standards for mechanical and electrical safety as well as emission and susceptibility to EMI (electro-magnetic interference). To maintain compliance with these standards use only LEP supplied components.



## Rear Panel Connectors

All connections to the MAC 5000 are made at the rear of each module. Each connector is clearly labeled as to its designated function. Cable connections should be completed prior to power-up of the controller. To ensure proper connections, always tighten screw lock connectors and slide the slide-lock connectors into the locked position.

## Installing/Removing a Module

A module can be installed or removed from the stack of modules using either a 2mm hex wrench or a 1/8" flat blade screw driver. First, loosen the module interlocking screws located at the rear corners of the module with a #1 phillips screw driver. To remove, insert either a 2mm hex wrench or flat blade screw driver into the access hole and gently pry the modules apart. To install a module, angle the front of the module downward slightly and align it with the module below. Lowering the rear of the module should engage the vertical interconnector - a small downward force is all that is required to mechanically and electrically connect the modules. Finally, tighten the module interlocking screws.

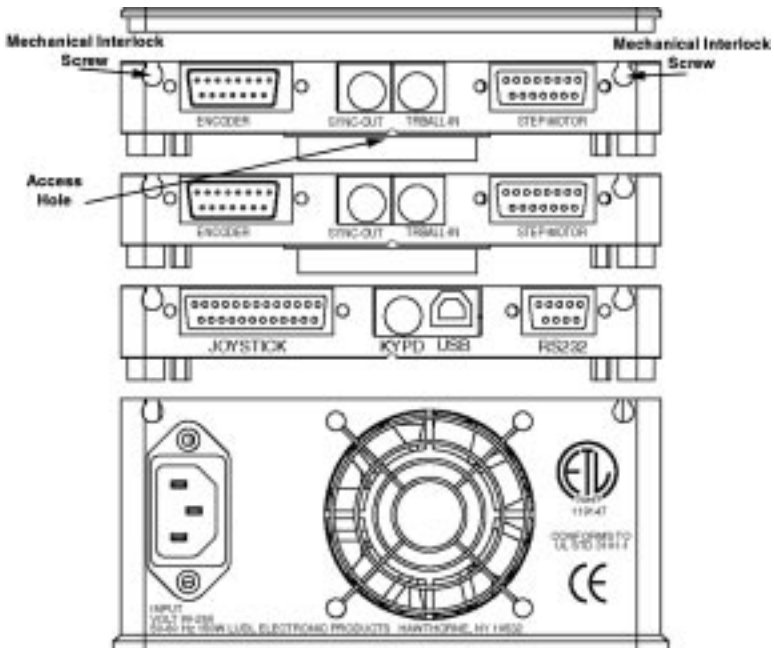


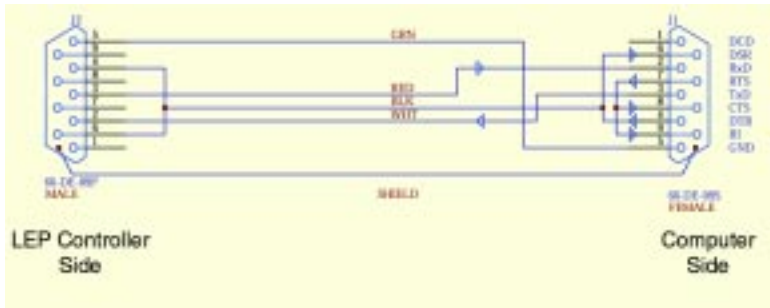
Figure 3

## Line Cord

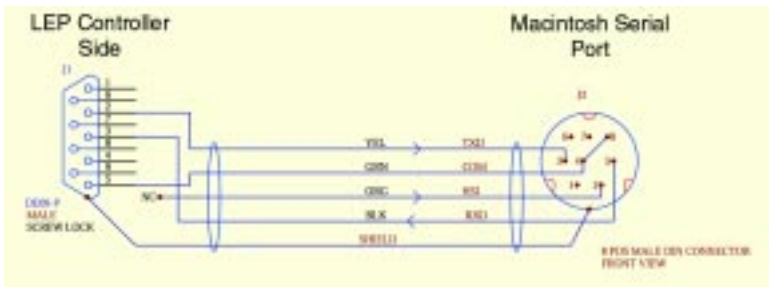
The line cord connection is a standard IEC receptacle. The MAC 5000 switches automatically to accommodate any standard international line voltage and frequency.

## Host Computer Interface Cables

Every MAC 5000 system is supplied with two standard RS232 interface cables which interconnect the rear panel of the controller (9-pin female connector labeled RS232) and an available serial port of the host computer. No hardware handshaking is provided. For IBM compatible computers, a 9-pin male to 9-pin female cable is used. For compatibility with the Apple Macintosh computers, a 9-pin female to 8-pin mini-DIN cable is supplied.



PC Interface Cable  
P/N: 73A00031



Macintosh Interface Cable  
P/N: 73A00043

## **MAC5000 Joysticks**

The joystick provides manual control of a motor for either an XY stage or focus control. The standard LEP joystick, p/n 73000362, features an XY analog joystick with a rotary ‘digipot’ on the side for digital control of a third axis. There are several other joysticks that may be installed with your system. The following table describes the joysticks available for the MAC 5000 system.

<b><u>Part Number</u></b>	<b><u>Description</u></b>
73000360	Simple XY joystick
73000361	XYZ joystick
73000362	XY with integrated digipot
73000365	Digipot only
73000366	XYZ joystick with integrated digipot
73000367	XY joystick with 4 user configurable buttons
73000369	XYZ joystick with 4 user configurable buttons

Upon power-up , the MAC 5000 system performs an automatic ‘calibration’ of the joystick. First the system checks for the presence of the joystick. If a joystick is connected, it reads the current position and assigns it the ‘zero’ position, any deflection from this angle will cause an axis to move. A common problem is that the joystick is slightly deflected on power-up and then released. This makes the stage drift slowly on its own and may cause asymmetrical speed response based on equal deflection of the joystick. Use Figure 4 for reference.

### **XY Deflection Stick**

Pushing the XY joystick will cause the stage to move in the desired direction. The stage movement velocity is exponential with deflection angle of the joystick. This gives very fine accurate control with small deflections, but also provides for higher speeds during larger movements. The actual direction of movement is configured on the motor controller module. The default speeds for the joystick are set to be usable in all configurations of resolution, however, the joystick speed can be changed by host software if desired.

### **High Speed Slew Button**

The button located on the top of the joystick itself is the high speed slew button. Pressing this button will change the maximum speed of the stage with respect to the joystick deflection.

### **Digipot**

The digipot is a digital input device that is similar to a single axis trackball or mouse. The input is incremental. This means that the movement is directly coupled to the input. For example, if one turn of the knob turns the motor a half



turn, then the motor will always turn in this ratio whenever the knob is turned regardless of the speed at which the knob is turned.

**Digipot Gain**

The digipot gain is set by the three position toggle switch mounted on the back of the joystick housing . This is used for either fine, medium, or coarse type movements of the focus drive.

**User Buttons**

There are two (four on the 73000367 or 73000369) user defined buttons available on the LEP joystick. The buttons have no direct function on the MAC 5000 system other than the fact that host software can read them via the interface port. A typical application would be the host software executing some type of subroutine based on the switch status.

**Centering Spring Control**

The two sliders arranged in line with the X and Y axis of the joystick control the self-centering function of the joystick. Normally these sliders should be left in the engaged position. If they become loose, the stage may creep along slowly and it may appear that there is something wrong.

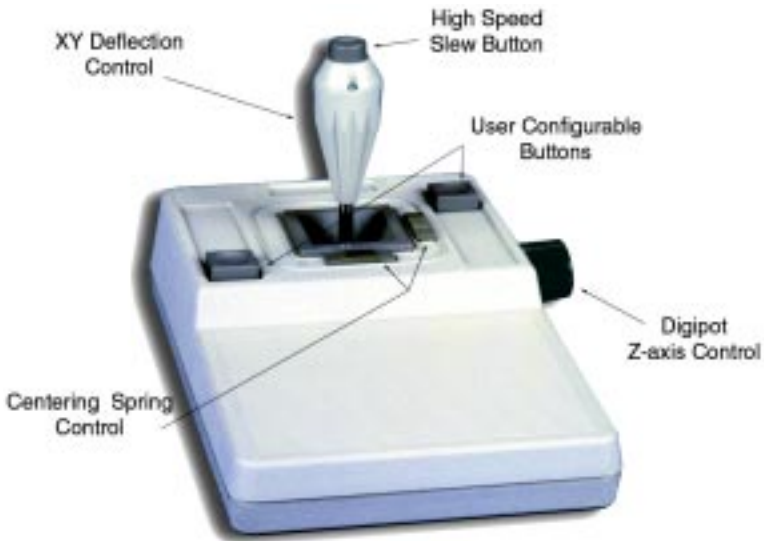


Figure 4

## ***BioPrecision XY Stage***

BioPrecision stages utilize zero-backlash ballscrews and ground crossed-roller bearing ways to meet the demanding requirements of high precision microscopy. The resolution of each stage is dependent on two factors: the pitch of the ballscrew divided by the microstepping resolution or encoder resolution. Unless otherwise specified upright BioPrecision (3"x2" and 4"x4") stages have a default resolution equal to .1 microns/step whereas inverted BioPrecision stages have a default resolution of .2 microns/step.

The X and Y axis on the stage are electrically equivalent which is a valuable troubleshooting aid since the user may swap cables from one axis to the other to discern if a malfunction is specific to the stage axis or the controller. This simple test can point you in the right direction in the event of problems.

The universal design of the BioPrecision stage allows simple integration with most microscopes using interchangeable stage adapters, however, some microscope configurations cause interference with the full travel of the stage.

One of the most critical steps during installation of the stage is adjustment of the stage travel limits.

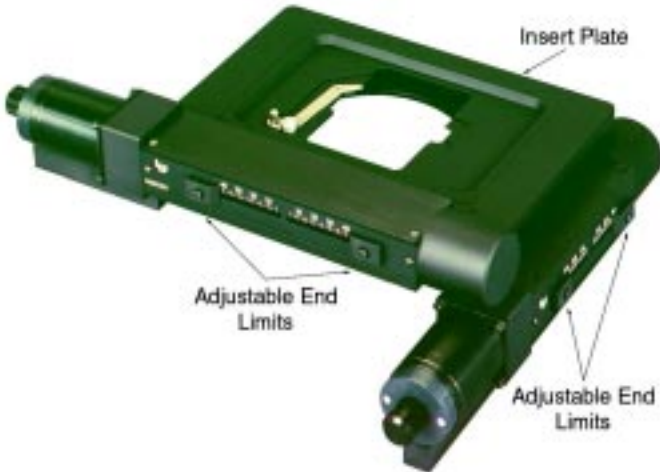


Figure 5

Depending on the microscope model, adjustment of the limits (see Figure 5) is

required to avoid interference from either the microscope stand or expensive optics. The technique to accomplish this is summarized in this simple procedure:

- Mount the specimen to the stage and focus the optics near the center of stage travel.
- Slowly move the stage with the joystick to a point where interference occurs, either with the optics or the microscope stand.
- Adjust the stage limits for the direction of travel.
- Repeat for the other axes and directions of travel.

Once the limits are properly set, the stage insert plate should be leveled to maintain focus over the travel range. The leveling is accomplished using the set screws located at the edge of the insert plate. It is nearly impossible to maintain perfect focus over the entire travel (particularly with high power objectives), however, a good rule of thumb is there should be no need for more adjustment than a quarter turn of the fine focus knob.

### ***BioPoint 2 XY Stage***

All LEP BioPoint 2 motorized XY stages consist of an X and Y axis stepper motor driving a teflon coated leadscrew drive system. The BioPoint 2 stage is controlled with a dual axis drive module and interconnected to the XY stage with a single 15-pin cable.

All stages have electronic and mechanical limits on travel. The limit switches are an electronic protection to prevent the system from encountering the mechanical limits which would cause the stage to stall, lose position and perhaps cause damage to expensive optics. The limit switches can also be used for location of the home position of the stage provided the software does not allow the stage to strike the switches at a high rate of speed.

The universal design of the BioPoint 2 stage allows simple integration with most microscopes using interchangeable adapters, however, some microscope configurations cause interference with the full travel of the stage. Therefore, the Y axis of the BioPoint 2 upright stage is shipped with removable travel limiters. To enable the full 50mm Y axis travel it is necessary to remove the limiters using a #1 Phillips head screwdriver. Figure 6 shows the two locations for the 25mm and 50mm travel limiters. Remove the two travel limiter and relocate them to the two outer locations.

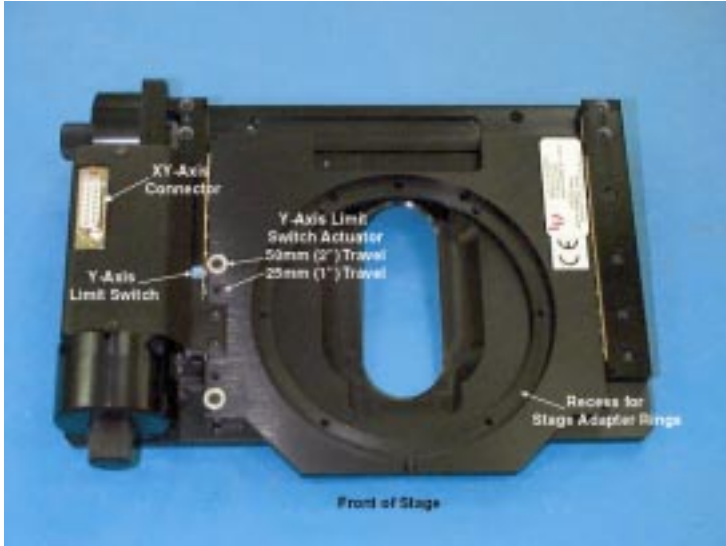


Figure 6

### ***Verification of Operation***

Once all the connections are made, the system is powered up and the operation is verified. A few quick checks can ensure that the connections are properly set and the system is functioning properly.

#### **Stepper Motor Stage**

When power is applied, the motors become energized. In their energized state, the motor is more difficult to rotate by hand. Deflecting the joystick will cause the motor to rotate, thus, the stage will begin to move. At the end of the travel, the stage should contact the limit switch, stop the motor and illuminate the associated LED (i.e. CW or CCW) on the front panel of the MAC 5000 controller.

#### **DC Motor Stage**

A DC motor stage may be verified in the same manner as the stepper motor stage. If the stage is not moving with a smooth fluid movement or if the stage is vibrating, ensure the configuration DIP switch settings for the X and Y axis are set for a DC stage. See page 24.

## **Focus Drive Motor**

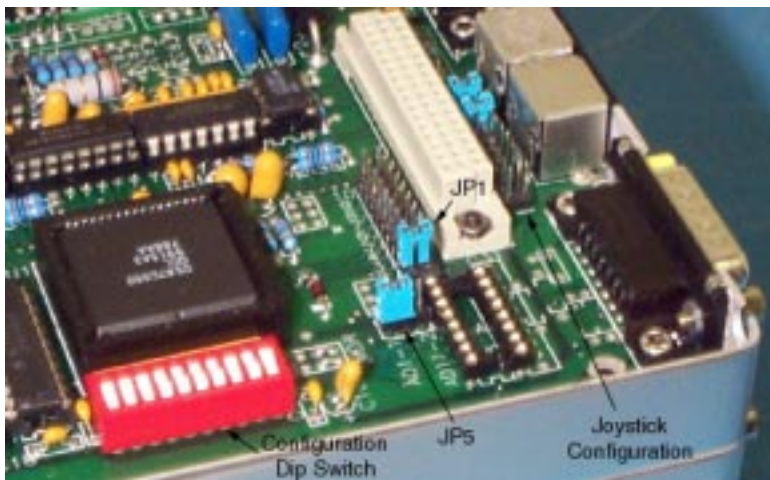
Similar to the stage, the focus motor may be verified by turning the knob (digital potentiometer) on the side of the joystick housing. As the digipot is rotated, the focus motor should move accordingly. Some LEP focus drives do not provide limit switches; consult the focus drive installation manual for further details on your specific drive.

## **MAC 5000 Module Configuration**

Each MAC 5000 module requires a unique address (1-20) and may be configured to meet specific application requirements. This is accomplished using jumpers located near the module's vertical interconnectors and DIP switches on each module. The following sections detail available configuration options.

### ***Setting the Module Address***

The MAC 5000 uses a simple jumper scheme to set the address. A two position jumper selects a range from 1-10 or 11-20, then a ten position jumper selects the actual address. For instance, if the selected range is 1-10, and position 7 on the ten position jumper is selected, the module is set for address 7. Whereas if the selected range is 11-20, the same ten position jumper setting would represent address 17. See Figure 8 for examples. A module can be set to any address in the allowed range. The high level interface functions, however, assume that certain modules of a certain type are set for specific addresses. See chart on page 16.



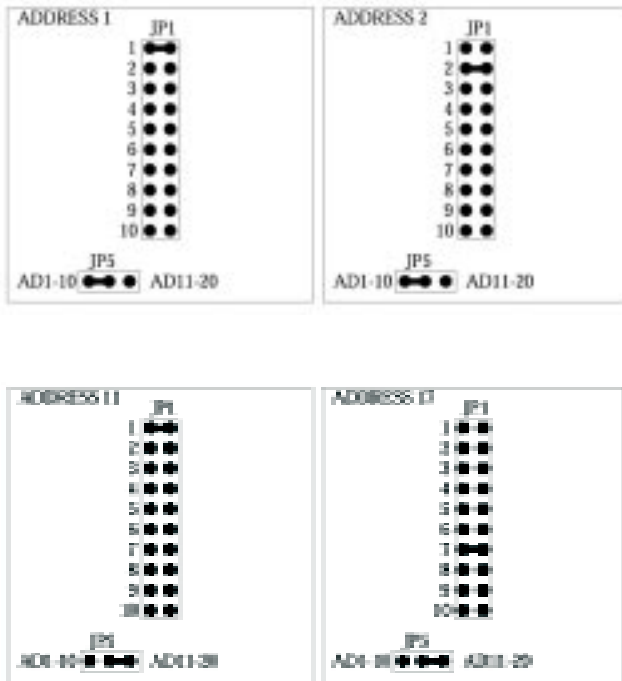
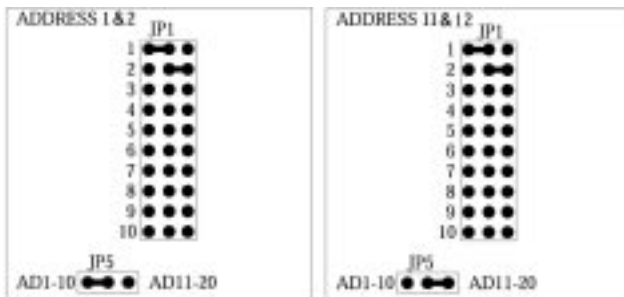


Figure 8

In some cases, a single module can control two axes of motion. To simplify programming, a dual motor controller/driver module will be represented by two unique addresses which are configured using a variation of the addressing scheme described previously. Again a two position jumper selects a range from 1-10 or 11-20, then a ten position jumper (using three pins) selects the addresses. The two pins closest the JP5 set the Motor 1 address, the other set of pins is used for Motor 2. See the following examples:



## Configuring the Joystick/Digipot Input

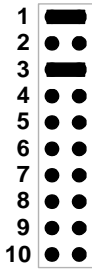
Some modules have the option of using either analog or digital input from a joystick/digipot for manual control of an axis. How these modules respond to a LEP joystick/digipot is configurable using two jumpers located near the 48-pin vertical interconnectors on each module (see Figure on page 15 for reference). Essentially, all joystick/digipot input signals are available through the vertical interconnector on each module. The jumper positions route the desired joystick/digipot input signal from the interconnector bus to the microprocessor on each module.

Typically each axis in the system would respond to specific joystick/digipot motion.

Joystick Motion	Joystick/Trackball Options
Left & Right deflection	Joystick X
Up & Down deflection	Joystick Y
Rotation on top of joystick	Focus Joystick
Rotaton of Digipot	Focus Digipot
Special applications	Digipot X / Digipot Y

### JOYSTICK / TRACKBALL OPTIONS:

#### JOYSTICK X



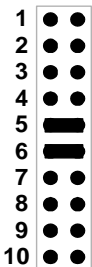
#### JOYSTICK Y



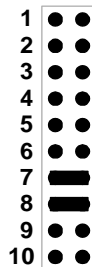
#### FOCUS JOYSTICK



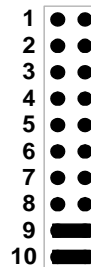
#### DIGIPOT X



#### DIGIPOT Y



#### FOCUS DIGIPOT



**High Level Module ID's:**

<b>Address</b>	<b>Module Type</b>	<b>High Level ID</b>	<b>Description</b>
1	MCSTS/MCDCS	X	Stage X axis
2	MCSTS/MCDCS	Y	Stage X axis
3	MCSTS	B	Microscope Z-axis
4	MCSTS/MCDCS	R	Robot Radius 1 axis
5	MCSTS/MCDCS	C	Robot Radius 2 axis
6	MCSTS/MCDCS	Z	Robot Lift axis
7	MCSTS/MCDCS	T	Robot Theta axis
8/9	DAIO	I/O	Digital I/O ports
10	FLNOF	A	Flat/Notch aligner
11	AFCMS	F	Video autofocus
12		P(1)	Spare
13		P2	Spare
14		P3	Spare
15		P4	Spare
16		P5	Spare
17	FWSHCST/DC	S(1)	Filter wheel 1
18	FWSHCST/DC	S2	Filter wheel 2
19	FWSHCST/DC	S3	Filter wheel 3
20	FWSHCST/DC	S4	Filter wheel 4
21	FWSHCST/DC	S5	Filter wheel 5



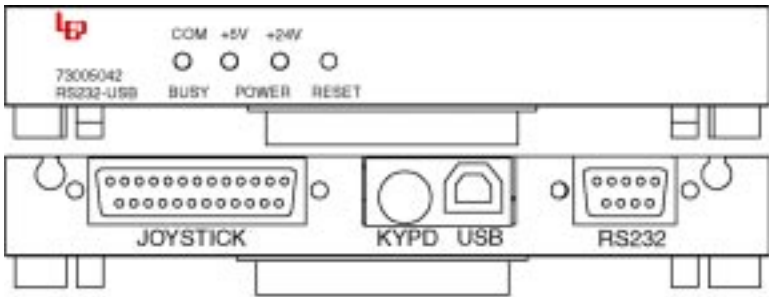
# RS-232 Interface

## General Description

The MAC 5000 host computer interface serves a dual role. First the RS-232+USB interface provides a means for the host computer to communicate with the MAC 5000 controller. Second, the secondary power supply is integrated with this module.

The interface supports two modes of communication: an ASCII mode and a binary mode. The ASCII mode processes recognizable commands such as “MOVE X=1000” . The binary mode provides a lower level of communication providing higher throughput and universal adaptability.

Joystick input is by the DB-25 connector. The input is compatible with any LEP joysticks supporting up to three axes with digipot. It is recommended that the user refrain from use of the joystick or RS-232 serial communication until completion of interface initialization routine which is approximately 5 seconds after power up. The standard RS-232 port supports baud rates up to 115k; the USB interface complies with the USB standard 1.3. A separate mini-din connector is available for RS-232 communication with the optional 73005045 MAC5000 keypad.



## Configuration DIP Switches

There is a single 8 position DIP switch on the RS-232 interface module used to configure the serial communication parameters. The following tables detail the function of the DIP switch:

Baud Rate	Sw1	Sw2	Sw3
19200	open	open	open
9600 (default)	open	open	closed
4800	closed	open	open
2400	closed	open	closed
115200	open	closed	open
57600	open	closed	closed
38400	closed	closed	open
28800	closed	closed	closed

The serial parity bit is also switch selectable; switch number 4 represents parity select and switch number 5 represents parity check.

Parity	Switch 4	Switch 5
Odd	open	open
Even	closed	open
None	n/a	closed

Switches 6 and 7 program a delay between transmission of the serial data. When the both switches are closed there is no delay, when both are open there is a 1.5 ms delay.

Switch 8 sets the power up communication mode:

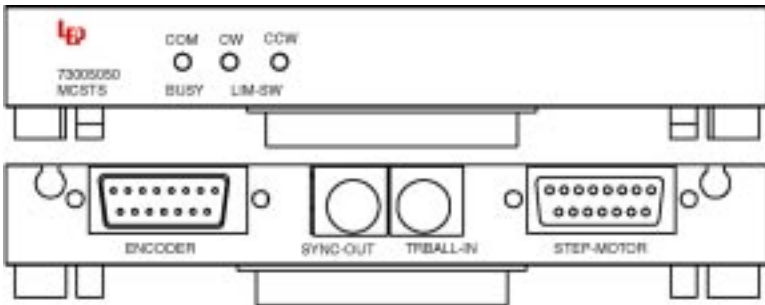
Mode	Sw8
Low Level (default)	open
High Level	Closed

# Microstepping Motor Controller/Driver

## General Description

The MCSTS module, P/N: 73005050 and 73005056, is a self-contained microprocessor motor controller with a high performance regulated linear microstepping driver. The linear driver provides the highest accuracy without excessive motor heating or EMI radiation that can sometimes be a problem with conventional chopper type drives. All functions are built-in to the module: analog joystick control, digital joystick control, limit switches, pre-limit input, open or closed loop stepper motor control, configurable microstepping resolution and motor current selection.

The MCSTS module step-motor connector supports two phase stepper motors with CW and CCW limits, home position signaling, encoder inputs and a single pre-limit. A SYNC-OUT 8 pin mini-din connector has step/direction output as well as inputs for move triggering. Stand-alone trackball control is available via the TRBALL-IN connector. The separate encoder connection is for the use of a second positioning encoder for dual encoder systems. In a dual encoder system the primary encoder input is used for motor servo and the secondary input is the position.



## Configuration DIP Switches

There are two separate DIP switches located on this module. A ten position configuration switch and a four position switch for setting motor current. The ten position configuration DIP switch controls the following functions:

### Microstep Size

The microstep size is selectable from either the configuration DIP switch or from software via the RS-232 interface. Switch positions 1-3 provide this setting according to the table below:

Data	Steps/Rev*	Sw1	Sw2	Sw3
0	40,000	0	0	0
1	20,000	1	0	0
2	10,000	0	1	0
3	5,000	1	1	0
4	2,000	0	0	1
5	1,000	1	0	1
6	400	0	1	1
7	soft select**	1	1	1

0 = close

1 = open

\*The Steps/revolution is valid for a 1.8° stepper motor.

\*\*The default resolution in soft select mode is 10,000 steps/rev.

### Joystick Direction

To ensure that the motion axis responds intuitively with respect to the joystick deflection, the joystick direction is configurable. The default setting is set to operate correctly for an LEP stage that is operated on a microscope without image erecting optics.

Switch 4	Direction
Open	Motor turns CW when joystick is deflected to the right
Closed	Motor turns CCW when joystick is deflected to the left

Although there is a default setting it may be that the user may feel more comfortable with the joystick direction set in the opposite way.

### **Limit Switch Logic**

Standard LEP components, including stages and focus drives use a normally open limit switch arrangement, where the input is pulled low, the limit is active. The default switch setting accommodates LEP products without change. However, the LEP controller offers the flexibility to accommodate other manufacturer's products since the input can be configured to activate the limit condition with an active high signal.

Switch 5	Input Logic
Open	Active high
Closed	Active low (default)

### **Motor Direction**

Similar to joystick direction configuration, the motor direction is also configurable. This configuration essentially changes the sign of the position as it is tracked by the microprocessor.

Switch 6	Direction
Open	Motor turns CW in the positive direction
Closed	Motor turns CCW in the positive direction

### **Motor Boost Control**

In the default configuration, the motor controller microprocessor applies a 24v boost to a motor after passing a specific speed threshold. Below this level, the motor is operating on the base voltage of 8v at the programmed current level. However, in some system configurations with certain types of motors, it is desirable to keep the boost voltage applied at all times.

Switch 7	Direction
Open	Boost is enabled at all speeds
Closed	Boost is enabled at specified speeds (Default)

### **Enable Position Feedback**

This important configuration option defines how the motor position is tracked. The configuration provides for setting the controller to operate the motor in either open or closed loop mode. In the open loop mode, the position is tracked according to how many pulses have been generated to rotate the motor. This mode offers very acceptable performance in most applications. The most notable problem with open loop mode is that the recorded position and the actual position may differ, sometimes greatly, if the motor either stalls, skips or if it is physically disturbed.

Closed loop mode is a much more complicated system where the motor is controlled with reference to an encoder input. Typically on the LEP stages, the encoder is a rotary type mounted on the end of the leadscrew shaft. The closed loop mode performance is improved over the open loop mode by correcting for the possibility of motor mispositioning due to missed steps, stalling or physical disturbance.

Switch 8	Mode
Open	Closed loop (encoder required)
Closed	Open loop

### **Reverse Encoder Phase**

There are instances where a motor and its associated feedback device are not directly coupled. Depending on the system configuration, it is possible that the encoder and the motor are not moving in phase with each other. Therefore, it becomes necessary to reverse the encoder phase.

Switch 9	Mode
Open	Reversed encoder/motor phase relationship
Closed	Default encoder/motor phase relationship

### **AutoFocus Mode**

To use the AutoFocus option the AFC/MTR jumpers have to moved to the AFC position. In the Slave mode, the address and bank jumpers are disabled.

Switch 10	Mode
Open	AFC Slave
Closed	Default Normal Motor Driver Operation

## Motor Current Program

There is a 4 position DIP switch located near the front of the module which is used to set the peak motor current according to the following formula:

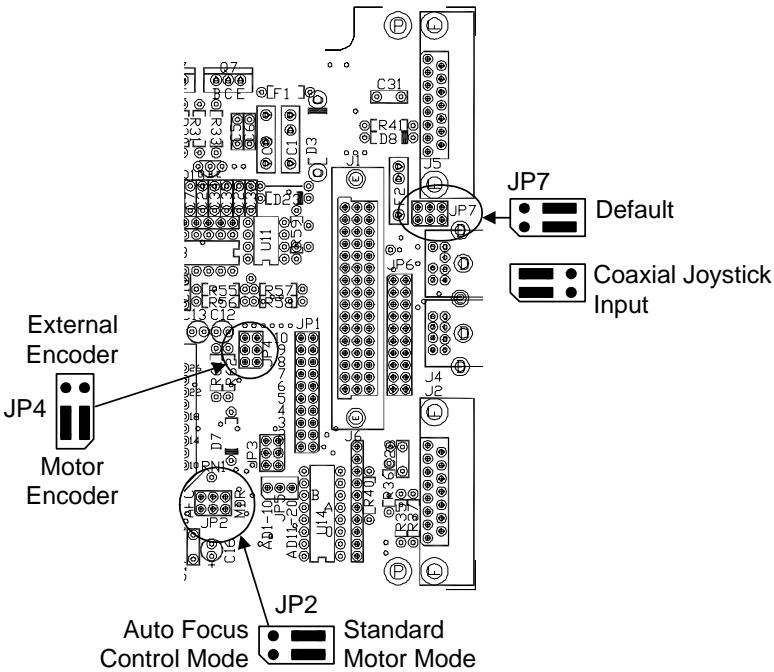
$$\text{Motor current} = .2 + .2(\text{number of closed switches}) \text{ amps}$$

The default setting is .8 a (800ma) which corresponds to three switches closed.

## Optional Jumper Settings

When mating this module with a P/N 73005085 module move JP2 jumpers to the Auto Focus Control Mode position.

To use the external encoder port, on the back of the module, move JP4 jumpers to the External Encoder position.

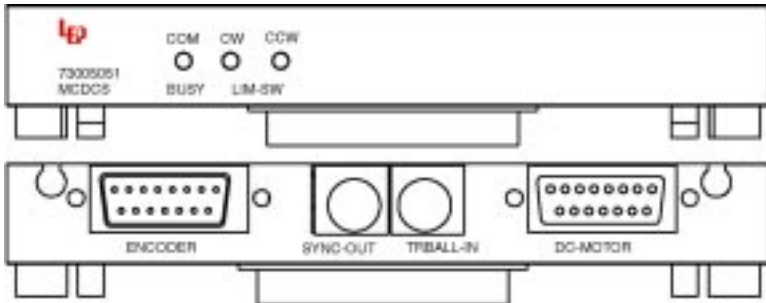


# DC Servo Motor Controller/Driver

## General Description

The MCCDCS module, P/N 73005051 and 73005057 is a complete microprocessor-based motor controller and servo amplifier system in a single MAC 5000 module. The module employs a dedicated DSP processor to provide high performance motion control for DC servo motors. Presets for 7 common applications are embedded to make implementation quick and easy. A full featured command set for “state based” servo parameters is available for no compromise servo tuning.

Motor connections includes motor output and inputs for the servo encoder, limit switches, home position and pre-limits. Special sync inputs and outputs are available on the 8 pin SYNCN-OUT mini-din connector. A unique step/direction output is available to enable data collection “on the fly.” An auxiliary trackball input is also included. Support for a second incremental encoder input is included for systems with separate linear encoders or external positioning feedback devices.



## Configuration DIP Switches

There is a single eight position DIP switch located on this module used for configuration purposes. The following details there functions:

### Joystick Direction

To ensure that the motion axis responds predictably with respect to the joystick deflection direction, the joystick direction is configurable. The default setting is set to operate correctly for an LEP stage that is operated on a microscope without image erecting optics.



Switch 1	Direction
Open	Motor turns CW when joystick is deflected to the right
Closed	Motor turns CCW when joystick is deflected to the left

Although there is a default setting it maybe that even on standard LEP components the user may feel more comfortable with the joystick direction set in the opposite way.

### **Limit Switch Logic**

Standard LEP components, including stages, robots and focus drives use a normally open limit switch arrangement, where the input is pulled low, the limit is active. The default switch setting accommodates the LEP stages without change. The input can be configured to activate the limit condition with an active high signal .

Switch 2	Input Logic
Open	Active high
Closed	Active low (default)

### **Motor Direction**

As with the joystick direction configuration, the motor direction is also configurable. This configuration essentially changes the sign of the position as it is tracked by the microprocessor.

Switch 3	Direction
Open	Motor turns CW in the positive direction
Closed	Motor turns CCW in the positive direction

### **Predefined DSP Parameters**

The 73005051 module has the capability to store up to 8 DSP parameter profiles. These parameter profiles have been optimized for specific LEP DC driven devices. Switch positions 4-6 assign the appropriate DSP parameters according to the following table:

Data	DC Device	Sw4	Sw5	Sw6
0	Last Record Stored	0	0	0
1	Stage 1	1	0	0
2	Stage 2	0	1	0
3	Robot Arm	1	1	0
4	Robot Rotation	0	0	1
5	Robot Lift	1	0	1
6	Focus Drive	0	1	1
7	DC Gearhead Motor	1	1	1

1 = Switch Open                      0 = Switch Closed

The parameter profiles define the DSP control loop parameters such as gain, acceleration, velocity, resolution, etc... Refer to the MAC 5000 programming manual for more detailed information; visit our web site at [www.ludl.com](http://www.ludl.com) for the latest available information.

Note: Stage 1 should be used for smaller stages (i.e. 3x2, 4x4, inverted). Stage 2 should be used for larger stages (i.e. > 6x6). If the wrong parameter profile is used, system performance may be adversely affected.

### **Reverse Encoder Phase**

There are instances where a motor and its associated feedback device are not directly coupled. Depending on the system configuration, it is possible that the encoder and the motor are not moving in phase with each other. Therefore, it becomes necessary to reverse the encoder phase.

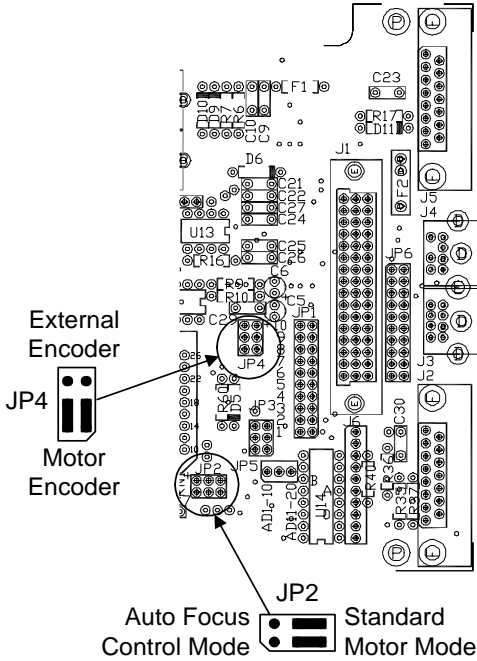
Switch 7	Mode
Open	Reversed encoder/motor phase relationship
Closed	Default encoder/motor phase relationship

Sw8 has no assigned function at this time.

### Optional Jumper Settings

When mating this module with a P/N 73005085 module move JP2 jumpers to the Auto Focus Control Mode position.

To use the external encoder port, on the back of the module, move JP4 jumpers to the External Encoder position.

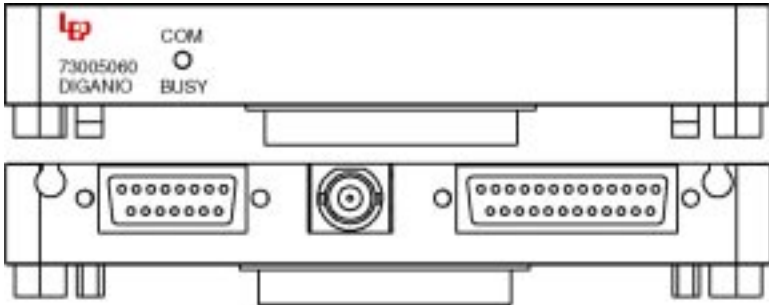


# Digital/Analog I/O

## General Description

The DAIO module is a general purpose I/O module that supports 8 open collector outputs (two of which can be source drive outputs (24v DC), 8 TTL inputs, (4) 8-bit analog (0-5v) inputs and either 2, 3 or 4 analog outputs. The standard 73005060 module is configured for 4 analog outputs, 0-10v 8 bits per channel. For applications which may benefit from a higher resolution analog output, the 73005061 module is available and is configured for (1) 16-bit analog 0-10v output and (2) 8-bit 0-10v analog outputs.

Common applications of the DAIO module would be remote control of an illumination source, detecting the status of an interlock switches, and vacuum control/sense in wafer handling applications. These are just a few applications; contact LEP technical support for details regarding other uses and pin-out information.



## Configuration DIP switches

There is a single 4 position DIP switch on the DAIO module. The default configuration is all 4 switches in the closed position. However, if Sw4 is open the analog output channels will initialize to 1/2 the calibrated output of 10v - namely 5v.

# Stepper Motor Filter/Shutter Controller

## General Description

The stepper motor filter wheel/shutter controller (FWSHCST), p/n: 73005080, is a microprocessor controlled half step motor driver capable of operating up to two six position filter wheels and three high speed shutters.

LEP stepper motor filter wheels are available in two configurations - a single six position wheel or a dual wheel which may accommodate up to twelve filter positions in a single unit. 25 mm and 32 mm filter aperture versions are available for each configuration. The filter wheel is driven by the stepper motor via a timing belt and an integral home position (Hall effect) sensor is utilized for automatic initialization. The maximum speed is 100 ms between adjacent filter positions. Additionally, the operating speed is software programmable and DIP switch configurable. Microscope specific mounting flanges are available which simplify mechanical integration of LEP filter wheels with most microscopes offered by Leica, Olympus, Nikon and Zeiss. Filters can be easily inserted and removed from the filter wheel while the entire assembly is mounted on the microscope due to the hinged construction of the filter wheel.

Up to three high speed shutters may be controlled using the same module. The drive electronics utilize a bi-level drive, supplying an initial high opening voltage for high-speed action (< 5ms to open or close) followed by a lower holding voltage which allows shutters to be held open indefinitely without damage. Manufactured specifically for high temperature applications, these shutters have proven to be extremely durable under heavy usage due to their simple design.

New features have been added to LEP Filter Wheel/Shutter modules which add to their versatility:

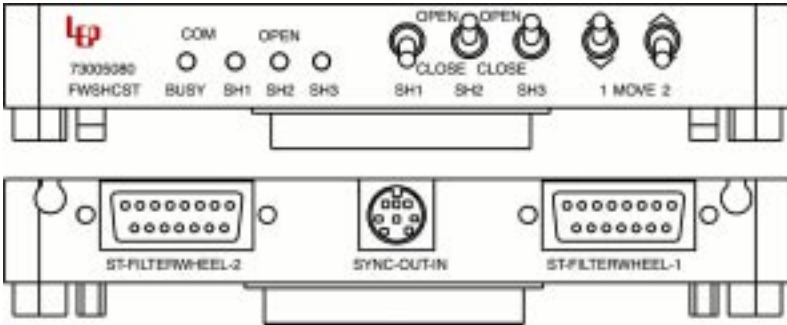
- High speed synch mode where a TTL output signal may trigger an image capture after a filter position change.
- Sequencer macro function to simplify repetitive filter movements.
- External TTL signals may be used for shutter synchronization.

The MAC 5000 programming manual details the specifics of implementing these new functions.

## Connections

Connections are made at the rear panel of the MAC 5000 module via a DB-15 female connector labeled Filter wheel 1 and Filter wheel 2. Each filter wheel/shutter combination requires a separate 15 pin cable. Most MAC 5000 filter

wheels are manufactured with a single internal shutter; auxiliary shutters may be added to the system by connecting to a 4 pin port on the filter wheel housing or, if available, one of the DB-15 filter wheel connectors.



## Front Panel Control Functions

The 73005080 module allows manual control of key filter wheel/shutter functions using five switches located on the front panel. A user may control the state (i.e. open or closed) of two shutters simply by using the toggle switches which are labeled SH1 and SH2. Note that software control overrides the front panel switch setting. Indicator LED's on the front panel illuminate to signify that a shutter is open and darken when the shutter is closed. The filter position of filter wheel 1 and filter wheel 2 may be changed using the toggle switches labeled 1 MOVE 2; the wheel will respond with a sequential movement dependent on the direction which the switch was toggled. Both wheels may be re-initialized to the "HOME" position by depressing the push button switch labeled HOME.

## Configuration DIP Switches

There is a single 6 position configuration DIP switch on this module. The functions of the DIP switches are as follows:

### Filter Wheel Speed

The filter wheel speed is configurable using Sw1 and Sw2.

Filter Wheel Speed	Sw 1	Sw 2
Fastest (Default)	Closed	Closed
Slowest	Open	Open

Due to the higher inertia of the 32 mm filter wheel it is recommended that

Sw1=closed and Sw2=open; this will program a lower start speed and mitigate possibility of stalling the stepper motor.

### **External Shutter Trigger and Sequencer Trigger**

The standard LEP shutter may be triggered using an external TTL signal generated from another device. This can be used to synchronize the exposure time for both devices.

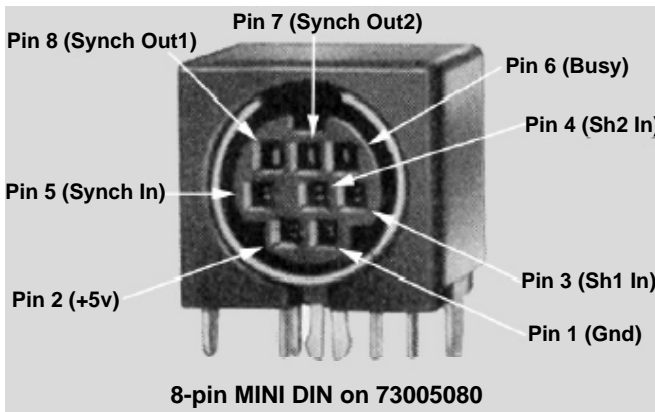
When the sequencer macro function is utilized, the active level of the Synch In trigger signal is also defined by this switch. The active level is configurable using the DIP switch setting or may be superceded by software control:

<b>Input Logic</b>	<b>Sw 3</b>
Active Low (Default)	Closed
Active High	Open

For more detailed information on using the external shutter trigger and synchronization mode, refer to the MAC 5000 programming manual. The following figure shows the pin assignments for the available signals:

### **External Synchronization Trigger**

The LEP filter wheel/shutter control module can also be used to trigger an external device such as a camera or frame grabber. This Synch Out signal follows the status of shutter 1 and shutter 2. The active state as well as the type of output is configured using switches 4 and 5, respectively.



<b>Output Logic</b>	<b>Sw 4</b>
Active Low (Shutter open)	Closed
Active High (Shutter open)	Open

If the Level type output is chosen, the Synch Out line will follow the state of the shutter. For example, if the shutter is open for 300ms, then the line will remain active for the duration of the exposure. If the pulse type output is selected, then a 650 microsecond pulse will be generated to trigger some external device.

<b>Output Signal</b>	<b>Sw5</b>
Level (follows shutter state)	Closed
Pulse (as shutter opens)	Open

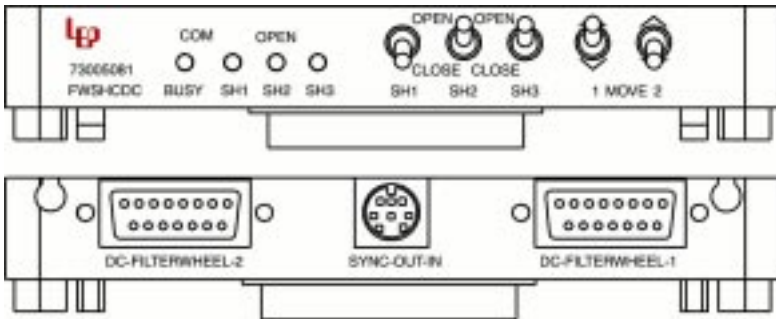


# DC Servo Filter/Shutter Controller

## General Description

The FWSHCDC module, P/N 73005081 is a complete microprocessor motor controller and servo amplifier system in a single MAC 5000 module. The module employs a dedicated DSP processor to provide high performance motion control for the DC servo motors used in LEP high speed filter wheels. Similar to its stepper motor controller counterpart, this module is capable of operating up to two six position filter wheels and three high speed shutters. The major advantage to the DC filter wheel system is speed; 30 ms between adjacent filter positions as opposed to 100 ms with the stepper filter wheel systems. Also, the DC filter wheel system operates as a closed loop system. This means the filter position is controlled with reference to feedback from an encoder input. The closed loop mode performance is improved over the open loop mode used by the stepper filter wheel by correcting for the possibility of misregistration due to missed steps, stalling or physical disturbance.

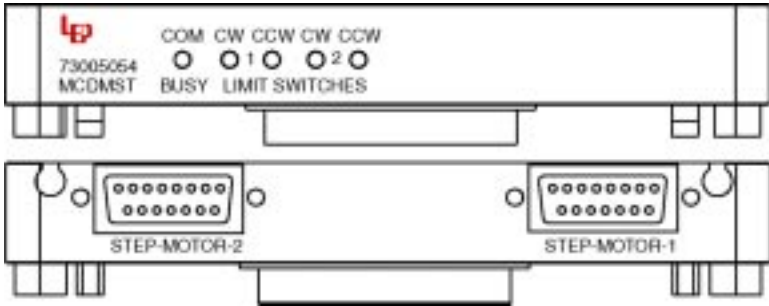
The cable connections, front panel control functions, configuration switch settings, and mini din pin-out are identical for the 73005081 (FWSHCDC) module are identical to that of the 73005080 (FWSHCST) module. Please reference pages 29-32 for details.



# Dual Stepper Motor Controller/Driver

## General Description

The MCDMST module, P/N 73005054, is microprocessor controlled microstepping motor driver which controls up to two individual stepper motors. This module features user configurable end limit inputs and configurable relative motor direction for both the primary and secondary motor. This motor control is limited to slower speeds with no encoder input possibilities. Since this module supports two motion axes it is addressable as two separate modules with independently selectable addresses. Motor resolution is jumper and software configurable. Microstep resolutions of up to 200x are available which yields 40,000 microsteps with a standard 1.8 degree stepper motor. Please contact LEP for information regarding motor compatibility for custom system integrations.



## Configuration DIP switches

### Microstep Size

The microstep size is selectable from either the configuration DIP switch or from software via the RS-232 interface. Switch positions 1-3 provide this setting according to the table below:

Data	Steps/Rev <sup>+</sup>	Sw1	Sw2	Sw3
0	40,000	0	0	0
1	20,000	1	0	0
2	10,000	0	1	0
3	5,000	1	1	0
4	2,000	0	0	1
5	1,000	1	0	1
6	400	0	1	1
7	10,000 <sup>**</sup>	1	1	1

0 = close      1 = open

\*The Steps/revolution is valid for a 1.8° stepper motor.

\*\*The default resolution is 10,000 steps/rev.

### **X Joystick Direction**

To ensure that the motion axis responds intuitively with respect to the joystick deflection, the joystick direction is configurable. The default setting is set to operate correctly for an LEP stage that is operated on a microscope without image erecting optics.

Switch 4	Direction
Open	X-axis motor turns CW in the positive direction
Closed	X-axis motor turns CCW in the positive direction

### **XY Limit Switch Logic**

Standard LEP components, including stages, robots and focus drives use a normally open limit switch arrangement, where the input is pulled low, the limit is active. The default switch setting accommodates LEP products without change. However, the LEP controller offers the flexibility to accommodate other manufacturer's products since the input can be configured to activate the limit condition with an active high signal.

Switch 5	Input Logic
Open	Active high
Closed	Active low (default)

### **X Motor Direction**

Similar to joystick direction configuration, the motor direction is also configurable. This configuration essentially changes the sign of the position as it is tracked by the microprocessor.

<b>Switch 6</b>	<b>Direction</b>
Open	Motor turns CW in the positive direction
Closed	Motor turns CCW in the positive direction

### **Y Joystick Direction**

To ensure that the motion axis responds intuitively with respect to the joystick deflection, the joystick direction is configurable. The default setting is set to operate correctly for an LEP stage that is operated on a microscope without image erecting optics.

<b>Switch 7</b>	<b>Direction</b>
Open	Y-axis motor turns CW in the positive direction
Closed	Y-axis motor turns CCW in the positive direction

### **Enable Position Feedback**

This important configuration option defines how the motor position is tracked. The configuration provides for setting the controller to operate the motor in either open or closed loop mode. In the open loop mode, the position is tracked according to how many pulses have been generated to rotate the motor. This mode offers very acceptable performance in most applications. The most notable problem with open loop mode is that the recorded position and the actual position may differ, sometimes greatly, if the motor either stalls, skips or if it is physically disturbed.

Closed loop mode is a much more complicated system where the motor is controlled with reference to an encoder input. Typically on the LEP stages, the encoder is a rotary type mounted on the end of the leadscrew shaft. The closed

loop mode performance is improved over the open loop mode by correcting for the possibility of motor mispositioning due to missed steps, stalling or physical disturbance.

Switch 8	Mode
Open	Closed loop (encoder required)
Closed	Open loop

### **Y Motor Direction**

Similar to joystick direction configuration, the motor direction is also configurable. This configuration essentially changes the sign of the position as it is tracked by the microprocessor.

Switch 9	Direction
Open	Motor turns CW in the positive direction
Closed	Motor turns CCW in the positive direction

Note: Switch 10 has no function.

### **Motor Current Program**

There is a 4 position DIP switch located near the middle of the module which is used to set the peak motor current according to the following table:

S2	Peak Current
All Closed	200mA
1 Open	400mA
2 Open	600mA
3 Open	800mA
All Open	1A

The default setting is (800ma) which corresponds to three switches open.

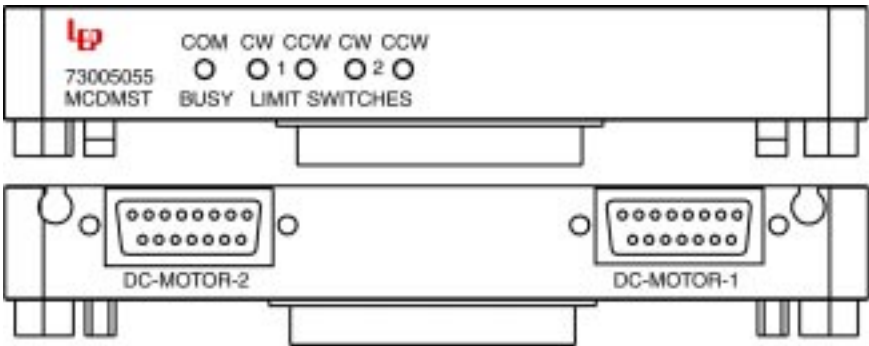
**Note:** Current setting is opposite of the convention used on the 73005050.

# Dual DC Motor Controller/Driver

## General Description

The MCDMDC module, P/N 73005055, is a microprocessor-based motor controller and servo amplifier system, which controls up to two individual DC motors, in a single MAC 5000 module. The module employs two dedicated DSP processors to provide high performance motion control for dual DC servo motors. Presets for 4 common applications are embedded to make implementation quick and easy. A full featured command set for “state based” servo parameters is available for no compromise servo tuning.

Both motor connections includes motor output and inputs for the servo encoder, limit switches, home position and pre-limits. A unique step/direction output is available to enable data collection “on the fly”. Please contact LEP for information regarding motor compatibility for custom system integrations.



## Configuration DIP Switches

There is a single ten position DIP switch located on this module used for configuration purposes. Switches 1-5 are used to configure Axis 1. Switches 6-10 are used to configure Axis 2. The functions of the DIP switches are as follows:

### Joystick Direction

To ensure that the motion axis responds predictably with respect to the joystick deflection direction, the joystick direction is configurable. The default setting is set to operate correctly for an LEP stage that is operated on a microscope without image erecting optics.

Switch 1	Direction
Open	Motor turns CW when joystick is deflected to the right
Closed	Motor turns CW when joystick is deflected to the left (default)

### **Limit Switch Logic**

Standard LEP components, including stages, robots and focus drives use a normally open limit switch arrangement, where the input is pulled low, the limit is active. The default switch setting accommodates LEP products without change. However, the LEP controller offers the flexibility to accommodate other manufacturer's products since the input can be configured to activate the limit condition with an active high signal.

Switch 2	Input Logic
Open	Active high
Closed	Active low (default)

### **Motor Direction**

To ensure that the motion of an axis responds predictably with respect to a software command, the relative motor direction is configurable. This configuration essentially changes the sign of the position as it is tracked by the microprocessor.

Switch 3	Direction
Open	Motor turns CW in the positive direction
Closed	Motor turns CCW in the positive direction

### **Predefined DSP Parameters**

The 73005055 module stores 4 DSP parameter profiles. These parameter profiles have been optimized for LEP DC Stage driven devices. Switch positions 4-5 assign the appropriate DSP parameters according to the following table:

Data	DC Device	Sw4	Sw5
0	Last Record Stored	0	0
1	Stage 1	1	0
2	Stage 2	0	1
3	DC GearHead Motor	1	1

1 = Switch Open                      0 = Switch Closed

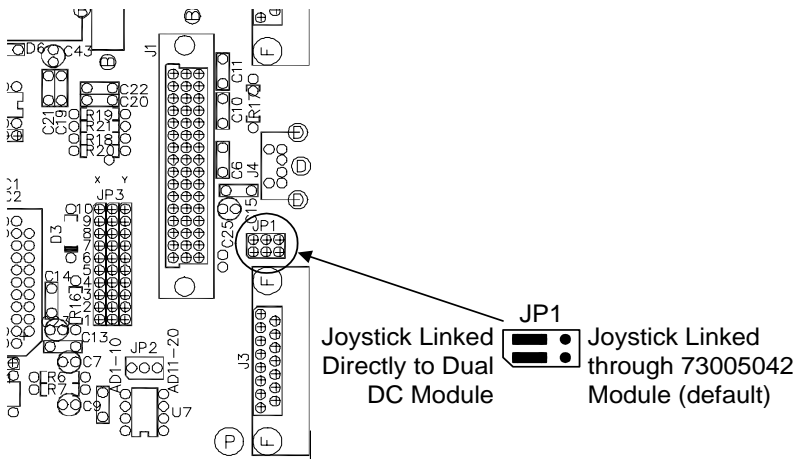
The parameter profiles define the DSP control loop parameters such as gain, acceleration, velocity, resolution, etc... Refer to the MAC 5000 programming manual for more detailed information; visit our web site at [www.ludl.com](http://www.ludl.com) for the latest available information.

Note: Stage 1 should be used for smaller stages (i.e. 3x2, 4x4, inverted). Stage 2 should be used for larger stages (i.e. > 6x6). If the wrong parameter profile is used, system performance may be adversely affected.

Switches 6-10 (Axis 2) have the same function as switches 1-5 (Axis 1).

### Optional Joystick Input

To link a joystick directly to the 73005055 module move JP1 jumpers to following diagram:





# Video Autofocus Processor

## General Description

The AFSC module, P/N: 73005085 is a video image processing module which uses the video signal contrast for focus optimization. The system accepts RS-170, RS-330, NTSC, or PAL video (color or monochrome) and utilizes either a 73005056 stepper module or a 73005057 DC module to drive the focus motor over a programmed range of focus travel. This focus scanning range will ultimately determine focusing speed, anywhere from 1 to 4 seconds, with a resolution up to .01 microns and repeatability better than two times the depth of field.

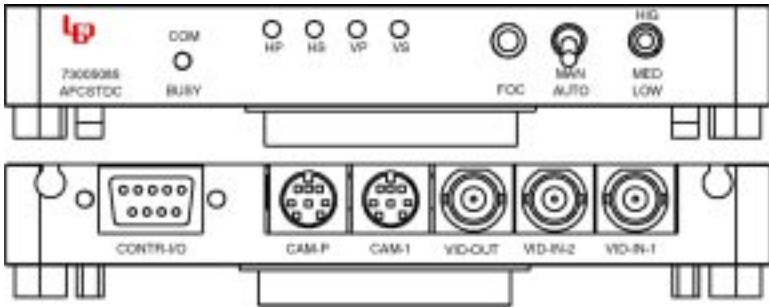
The 73005085 module is located directly above the associated drive module. This configuration allows the modules to utilize a local communication bus in an effort to mitigate any communication delays. An extensive command set is available for setting all focus parameters, i.e. image averaging, search speed, delay between measurements, and scan distance in addition to all control codes of a standard motor drive. The system power up defaults are normally adequate for most focusing functions except the more critical such as those involving low light levels, unstable microscopes, and very low contrast images.

The autofocus module uses only a portion of the video image for contrast measurements. This focus window is superimposed on the video image output of the controller and defined through software commands or from the front panel. The size of the window is very important to ensure repeatable and accurate focusing. A window which is too large with excessive video contrast may overflow measurements resulting in inaccurate focusing, whereas, a window which is too small may provide insufficient signal resulting in poor focusing repeatability.

## Connections

Integration of the autofocus system with existing equipment is relatively straightforward. Refer to your focus drive installation manual for the proper mechanical connection of the focus motor to your microscope.

First, connect the 15-pin focus motor connector to the rear of the Z-axis control module; ensure the slide lock is engaged since loose connections may cause the system to malfunction. Then connect the camera output to the BNC connector labelled VIDEO IN (75 ohm impedance standard) and connect the output to the video monitor to the VIDEO OUT BNC. In the event you are not using the MAC 5000 controller as a pass through for the video signal, the two position video termination jumper located near the edge connector of the 73005085 module should be moved to the outer position.



## ***Front Panel Control Functions***

The AFSC module allows manual control of the focus window, scanning range, and focusing using the front panel controls.

The three position toggle switch labeled High, Med, and Low allows the user to select the default focus scanning range which is appropriate for the objective currently being used.

The push button labeled FOC is used to manually initiate the focusing sequence. By turning the small slotted screws inside the access holes labeled HP and VP, the horizontal position and the vertical position, respectively, of the focus window may be adjusted. Similarly, the horizontal size and vertical size may be adjusted using HS and VS respectively.

## ***Maximizing Performance***

To obtain maximum performance of the autofocus, there are several key issues that should be addressed. The most important factor is the video image itself. The video image should not be too bright to wash out the contrast. Conversely, it should not be too dim so there is noise and/or low contrast. The persistence of the video camera is also important. An ISIT camera, for example, has a very slow

reaction time and will cause the autofocus to improperly focus because it measures very fast. The objective lens used is very important since it contributes to two factors that influence the focus. The depth of focus is determined by the objective and consequently affects the range where there is contrast. The objective also provides contrast based on the optical characteristics of the lens. At very high magnification, a high numerical aperture lens will provide a very shallow depth of focus which, depending upon the sample and optical quality, can produce washed-out low-contrast images. Finally, the image content is a determining factor in the focus performance. The autofocus will have difficulty focusing on a bare specimen with little or no contrast.

The performance of the autofocus with images that have low contrast, high noise, slow response, or low levels can be improved by altering the focusing parameters. The parameters that affect the focus are: focus search range, number of focus measurements within the search range (sampling rate), number of frames to count before taking a measurement, and scan speed.

The search range is programmable for the coarse and fine searches for each high, medium, and low focus range. This is useful if your microscope focus mechanism provides too little or too much focus travel. This indirectly changes the resolution of the autofocus measurement since this range is divided by the number of measurements taken in the scan.

The profile distance defines the resolution of the autofocus. The autofocus will first search the fine range; if a valid focus point is not found it will search the coarse range, and then the fine range again taking 'n' number of measurements for each range. If no valid focus is found during the scan sequence the Z-axis position will be returned to the original position prior to focusing. The total distance travelled during a scan is equal to the product of the profile distance (in steps) and the sampling rate. The range and number of measurements should be set so that the coarse range will travel through the focus plane but not crash the objective lens into the specimen. The fine range should be set so that the resolution is less than the depth of focus for the particular lens.

When focusing, a programmable delay may be added before the actual contrast reading. This may be used to allow time for the mechanical focus system to stabilize and slow video response (e.g. of a SIT or ISIT camera) to catch up. In addition, the focus scan speed is also programmable. The scan speed may be decreased to compensate for unstable mechanical assemblies or fluid samples that must be moved slowly or increased to minimize time delays.

## Configuration DIP Switches

### Focusing Mode

The 730005085 module may use one of two different focusing algorithms. The default mode is selected during power-up, however, the mode may be changed using a software command (see MAC5000 programming manual for details). The continuous profile algorithm may use faster search speeds and larger search ranges resulting in a lower total search time particularly for lower power objectives, however it requires a fast response camera (e.g. CCD camera).

Switch 1	Focusing Mode
Open	Continuous contrast profile while moving at a constant speed
Closed	Discrete contrast profile (identical to MAC2000 algorithm)

### Limit Constrained Focusing

When using the continuous contrast profile algorithm, the low focus range may be defined via software commands or limit switches (if available).

Switch 2	Low Focus Range
Open	Use the end limit switches
Closed	Use the programmed low focus range <b>(Default)</b>

### Video Selection

This switch is used to configure the autofocus module for the specific type of video input used in your system:

Switch 3	Video Input
Open	PAL
Closed	NTSC <b>(Default)</b>

### Contrast Signal Diagnostic

The 73005085 module allows the user to display a bar graph on the video screen which represents the relative contrast signal measurement. This may be used to confirm proper operation of the module by manually scanning a Z distance confirming the peak of the bar graph coincides with a focused image within the focus window.

Switch 4	Diagnostic Mode
Open	Bar graph is displayed
Closed	Bar graph is not displayed <b>(Default)</b>

### Manual Focus Window Control

The front panel 'trim pots' allow manual control of the size and position of the focus window. Once set, it may desirable to limit changes to the focus window settings:

Switch 5	Manual Window Control
Open	Front panel 'trim pots' disabled
Closed	Front panel 'trim pots' enabled <b>(Default)</b>

# Warranty Information

## ***Warranty Time Period and Limitations***

Ludl Electronic Products Ltd., hereafter referred to as **LEP**, warrants its products to be free from malfunctions and defects in both materials and workmanship for a period of one year from the date of original purchase.

Units returned to **LEP** that have been subject to abuse, misuse, damage or accident; have been connected, installed or adjusted contrary to the instructions furnished by **LEP** or repaired by unauthorized persons will not be covered by this warranty.

This warranty becomes null and void if you fail to pack equipment in a manner consistent with the original product packaging and damage occurs during product shipment.

**LEP** reserves the right to discontinue models; change specifications, price or design of this device at any time without notice and without incurring any obligation whatsoever.

The purchaser agrees to assume all liabilities for any damages and/or bodily injury which may result from the use or misuse of this device by the purchaser, his employees or agents.

**LEP** shall not be liable in any way for consequential damages resulting from use of this device.

This warranty is in lieu of all other representations or warranties expressed or implied and no agent or representative of **LEP** is authorized to assume any other obligation in connection with the sale and purchase of this device.

All instruments are delivered with serial tags located on the rear panel or bottom of the unit. These serial numbers are used to track the manufacturing date and the revision level. If this serial number is removed for any reason, the warranty is void.

## ***Warranty Repair Coverage***

**LEP** under this warranty is limited to repairing or replacing the defective device when returned to the factory, shipping charges prepaid, within one (1) year from date of original purchase. Such repair service will include all labor as well as any necessary adjustments and/or replacement parts.

If replacement parts are used in making repairs, these parts may be remanufactured, and/or may contain remanufactured materials. If it is necessary to replace the entire system, it may be replaced with a remanufactured system.

## ***Application Support***

For application specific support, please contact your reseller, systems integrator, software manufacturer, or dealer directly. If additional technical support is required, your service provider should contact **LEP** with a detailed description of the problem, system configuration, and any available troubleshooting information.

## ***How to Obtain Service***

You may visit our web site at <http://www.ludl.com>; simply choose the appropriate contact group and we will promptly respond to your inquiries.

When returning any **LEP** equipment for repair you must first obtain an RMA (Return Merchandise Authorization) number from one of our Customer Service Representatives. The unit should be packed in its original packing materials and a detailed problem report should be enclosed. The accompanying paperwork should reference the RMA# and all items which were shipped to **LEP**.

## ***Disclaimer***

**LEP Ltd.** assumes no responsibility for damage of equipment or loss of information as a result of misuse of the contents in this manual. All information contained within is accurate at the time of printing.

