Making Light Work Lighter

General Photonics Corporation

PCD – M02/MPD – 001

Miniature Multi-Channel Piezoelectric Actuator Driver Card
With or without Integrated PolaRITE™ III Polarization Controller

Operation Manual

Version 1.4

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IMPORTANT SAFETY NOTE

The MPD-001 board can produce hazardous voltages and currents. The DC voltage on the board can reach 150 V. Use extreme caution when operating the MPD-001. Never touch any part of the board or cable connectors when electrical power is on. Make sure that the power is turned off when connecting or disconnecting cables.

CAUTION

The maximum peak current to each channel of the MPD-001 is 60 mA; however, the maximum current available to each channel will depend on operating conditions. Because the on board DC/DC converter output current rating is 80 mA, the sum of the currents to the four channels cannot exceed 80 mA. If each channel is operated sequentially, the current limit per channel is 60 mA. However, if all 4 channels are in operation simultaneously, the maximum continuous operation current rating for the board is 20 mA per channel. A severely distorted output waveform indicates that the unit is being operated at a current that exceeds the current rating. If a sinusoidal waveform is used as a driving source, the user should check Section 4 in this manual to make sure that the output voltage and driving frequency are within the designed safe operation range.

The driving limitations mentioned above depend on environmental conditions such as ambient temperature and ventilation. It is recommended that the board be mounted in a well-ventilated area for high frequency operation. High temperature operation will significantly decrease the current limit of the driver card. If high temperature operation is required, please contact General Photonics for details.

Section 1. Specifications:

Optical (for PCD-M02)[1]:

Operating Wavelength	1260-1650nm or 980-1310nm standard Others available
Insertion Loss[2]	< 0.05 dB (without connectors) < 0.6 dB (with connectors)
Return Loss	>65 dB
Activation Loss	0.01 dB (P grade), 0.05 dB (A grade)
Polarization Mode Dispersion (PMD)	0.05 ps
Polarization Dependent Loss (PDL)	0.05 dB
Optical Power Handling	1000 mW
Polarization Control Range	0-4π each channel (Optical head V_π per channel ≤35V)
Number of channels	3 or 4

Electrical:

Power Supply:	
Standard	+ 12V DC / 1.2A (continuous) − 12 V DC / 0.1A
With External High Voltage Supply (not generally recommended)	+ 12V DC / 1.2A (continuous) − 12 V DC / 0.1A +160V/100 mA (continuous)
Analog Input (Control Voltage):	
Analog Input Voltage Range	0 to 5V
Input Impedance (Analog Input)	≥20 kΩ
External Input Gain	30 V/V ± 1%
Digital Input:	
Digital input	TTL, 12-bit data, 4-bit control
Output Voltage:	
Output Voltage Range	0-140V DC
Output Impedance	50 Ω
Max. Output Current	20 mA/channel all channels (continuous) 60 mA/channel single channel (continuous) 60 mA per channel (peak current limit)
140V Output Response Time (Rise/fall time)	<30 µs without load (MPD-001) < 400 µs with PolaRite III (PCD-M02)
15V Output Response Time (Rise/fall time)	10 µs, without load (MPD-001) 65 µs with PolaRite III (PCD-M02)
Noise[3]	< 40 mV (RMS)
−3dB Bandwith[4]	16 kHz

Physical and Environmental:

Operating Temperature	0 to 40º C
Storage Temperature	−20 to 60º C
Dimensions	3.94" (L) × 3.94"(W) × 0.69" (H)
External Analog Input Connector	10-pin AMP type with 0.1” pitch
External Digital Input Connector	20-pin AMP type with 0.1” pitch
Power Supply Connector (±12VDC)	3-pin with 0.1” pitch

Notes:

1. Unless otherwise specified, optical specifications in table are referenced without connectors.
2. For SMF-28 compatible fiber. Other fibers may have higher loss, especially with connectors.
3. The noise is measured with the output set to 140V and an output capacitance of 0.18μF (capacitance of piezoelectric actuator used in PolaRITE II/III). It may decrease with higher output capacitance and increase with no output capacitance.
4. The bandwidth is measured at 140V output with no load. Any piezoelectric element added to the output may decrease the bandwidth. The –3 dB bandwidth is defined by the frequency at which the output peak-to-peak voltage drops from 140 V to 100 V (~ 0.707 × 140 V).

Section 2. Overview:

The MPD-001 is a precision, low noise, low drift, high voltage, multiple channel driver board for piezoelectric actuators. The board can drive up to four (4) piezoelectric actuators.

The output driving voltages are controlled by external analog or digital signals. The recommended procedure is to connect only one control input at any one time. If it is necessary to have both inputs connected simultaneously, then when the analog input is in use, the jumper JP1000 should be jumpered; when the digital input is in use, the jumper should be removed and all analog input pins should be set to zero volts.

The MPD-001 is specially designed to drive General Photonics' polarization controllers (PolaRITE III) and commercial piezoelectric actuators with 0-150V drive voltage ranges. A PolaRITE III polarization controller can be mounted directly on the MPD-001 board to create an integrated polarization controller module (General Photonics model PCD-M02). An 8-pin parallel connector is provided for driving other piezoelectric components. Figure 1 shows a top view of the PCD-M02.

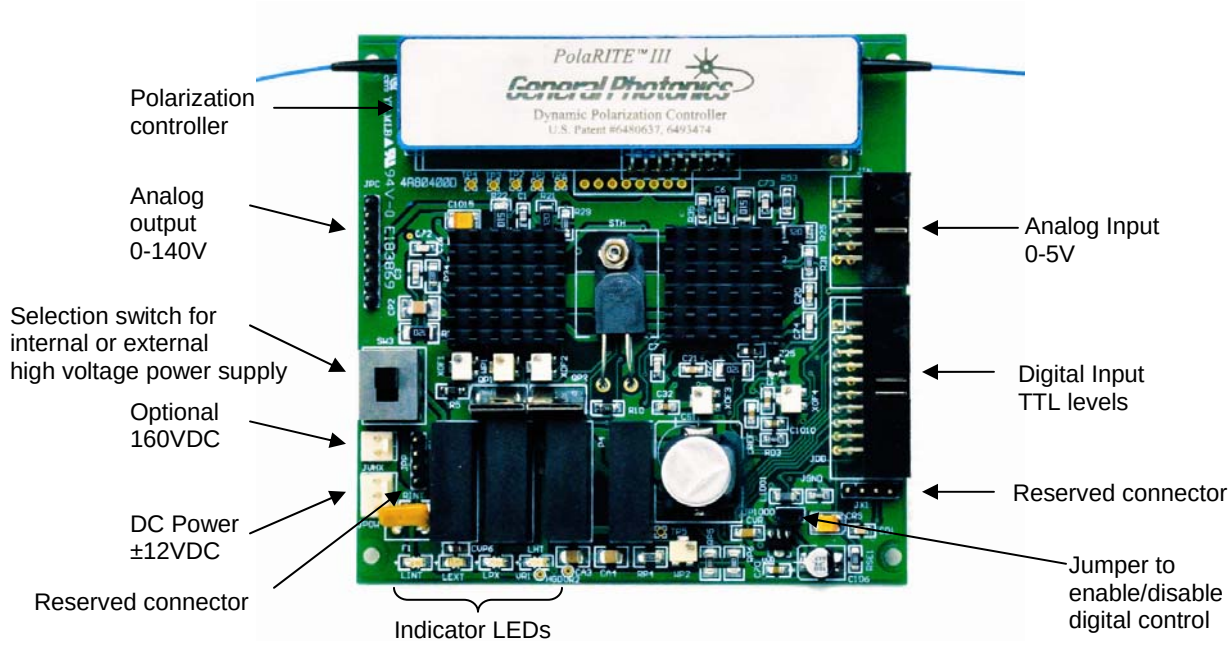


Figure 1 Top view of PCD-M02 (MPD-001 board with integrated PolaRITE III polarization controller) with principal electrical connectors labeled.

The MPD-001/PCD-M02 accepts both analog and digital control signals. It has a closed loop gain of 30V/V, so analog input voltages of 0-5V are sufficient to cover the 0-140V output voltage range. The external analog control voltage can be supplied by any stable voltage source including function generators, DAC output, or DC supplies. For digital control applications, the MPD-001/PCD-M02 can be controlled by a 17-bit parallel TTL digital signal from any logic circuit. The digital signal controls each channel individually.

One attractive feature of the MPD-001/PCD-M02 is that the standard board operates at ± 12V, which can easily be provided by commonly available laboratory or industrial power supplies. These power supplies are not included with the product.

2.1 Electrical Features

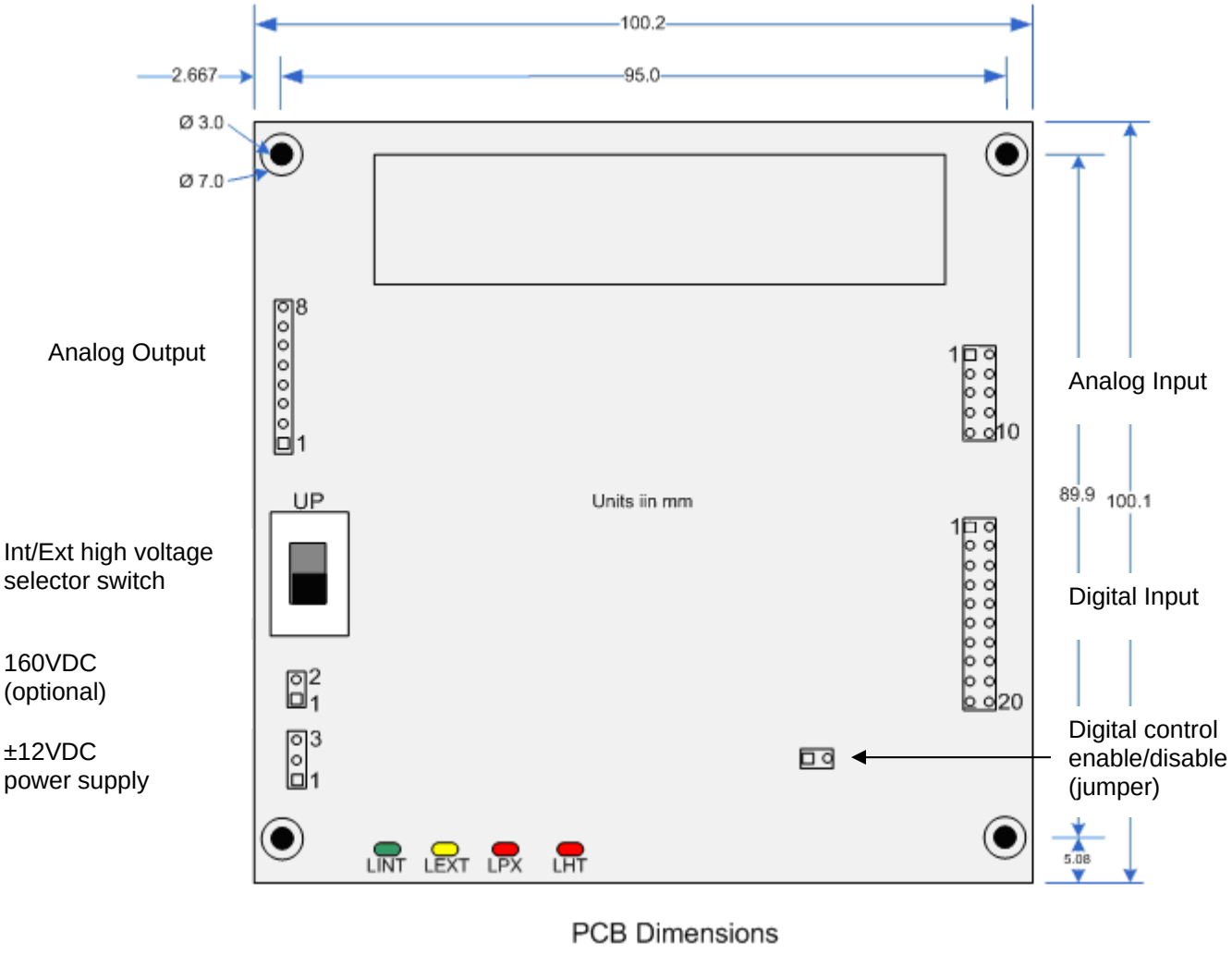


Figure 2 Board schematic with principal connector pinouts labeled.

Principal electrical features are as follows, going clockwise around the board from the top right.

Analog Input

The analog input connector accepts up to four 0-5V analog control voltages to control the four channels of the board.

The digital input should be disabled (jumper JP1000 in place) before using analog control.

Table 1 Analog input connector (JIN) pinout

Pin number	Assignment	Function
1	V_1	Channel 1 input
2	V_3	Channel 3 input
3	AGND	Analog ground
4	AGND	Analog ground
5	V_2	Channel 2 input
6	V_4	Channel 4 input
7	AGND	Analog ground
8	AGND	Analog ground
9	AGND	Analog ground
10	AGND	Analog ground

Digital Input

The digital input connector accepts TTL levels for the 12 data bits, 2 channel control bits, read/write, chip select, and reset.

Digital input must be enabled (jumper JP1000 removed) to use digital control. If the analog input is left connected during digital control, all analog input pins should be set to zero volts.

Table 2 Digital input connector (JDD) pinout

Pin number	Assignment	Function
1	RW	Read/Write
2	/CS	Chip select, negative active
3	/RESET	Asynchronous Reset Input, set DAC and input registers zero-scale (000H)
4	A0	Channel control bit 1
5	A1	Channel control bit 2
6	DB0	Digital signal least significant bit (LSB)
7	DB1	Digital signal bit 2
8	DB2	Digital signal bit 3
9	DB3	Digital signal bit 4
10	DB4	Digital signal bit 5
11	DB5	Digital signal bit 6
12	DB6	Digital signal bit 7
13	DB7	Digital signal bit 8
14	DB8	Digital signal bit 9
15	DB9	Digital signal bit 10
16	DB10	Digital signal bit 11
17	DB11	Digital signal most significant bit (MSB)
18	DGND	Digital ground
19	DGND	Digital ground
20	NC	NC

The analog and digital input connectors are 10-pin and 20-pin AMP type connectors, respectively. All connectors on the MPD-001/PCD-M02 have a standard 0.10 inch (2.54 mm) pin separation.

Figure 3 shows the pin diagram for both input connectors. The analog input connector uses 5 independent connections, and the digital input connector has 18 independent connections.

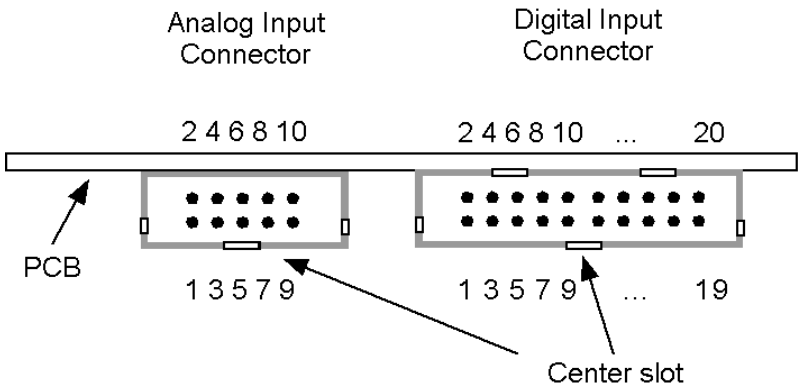


Figure 3 Analog and digital input connector configurations.

Digital Control Enable/Disable

The jumper at position JP1000 enables/disables digital control.

Note that there is no enable/disable mechanism for the analog control. It is always enabled.

The MPD-001/PCD-M02 is designed to be controlled via either analog or digital inputs. Only one input type should be used at any one time. Simultaneous analog and digital inputs while both analog and digital control are enabled (jumper off) can drive the system to saturation and damage the board.

Analog control:
For analog control, the jumper should be on (default configuration). This disables the digital control. The board will respond only to the analog input voltages, and any input to the digital port will not affect the analog circuit or the output voltages to the piezos.

Digital control:
For digital control, the jumper should be removed. This enables the digital control; however, it does not disable the analog circuit. Any input to the analog control port will also affect the output voltages. To prevent this, analog inputs should be disconnected or set to zero during digital control.

Indicator LEDs

The 4 indicator LEDs along the bottom of the board indicate whether the +12VDC and internal or external high voltage supplies are connected and functioning.

Label	Color	Function
LINT	Green	+12V indicator (INT setting)
LEXT	Yellow	+12V indicator (EXT setting)
LPX	Red	+150VDC indicator (external high voltage source)
LHT	Red	+150VDC indicator (using internal high voltage source)

If the board is set to use its internal high voltage source (default setting), the +12V power supply is connected, and the internal high voltage source is working properly, the LINT and LHT LEDs should be lit.

If the board is set to use an external high voltage source, and the +12V and external high voltage sources are connected, the LEXT and LPX LEDs should be lit.

±12VDC Power Supplies

The MPD-001/PCD-M02 board requires ±12VDC power supplies regardless of whether it is using an internal or external high voltage source.

Table 3 DC power supply connector (JPOW) pinout

Pin number	Assignment
1	+12 V
2	AGND (analog ground)
3	−12 V

160VDC External Source (Optional)

The MPD-001/PCD-M02 can be set to bypass its internal DC/DC converters and use an external high voltage source instead. This function is provided for users with specialized applications that may require higher current than can be supplied by the internal high voltage source. However, using this function requires special precautions and is not generally recommended. Most users and applications will not need this function.

Table 4 Optional 160VDC connector (JVHX) pinout

Pin number	Assignment
1	160V
2	AGND (analog ground)

High Voltage Source Selector Switch

Switch SW3 selects between the board's internal high voltage source and a user's external high voltage source. The board is shipped with the switch in the "internal (DOWN)" position. Most users will not have to change the setting.

Switch Position	High voltage source
DOWN (default)	**Internal (board DC/DC converters)**
UP (optional)	External high voltage source

Analog Output

The analog output connector supplies the 0-140V output voltages when the MPD-001 board is used to drive external piezo devices. On the PCD-M02, this connector is not used to connect the polarization controller to the board, but can be used in testing to verify voltages applied to the polarization controller.

Table 5 Analog output connector (JPC) pinout

Pin number	Assignment	Function
1	AGND	Analog ground
2	AGND	Analog ground
3	AGND	Analog ground
4	V1	Channel 1 analog output, positive
5	V2	Channel 2 analog output, positive
6	V3	Channel 3 analog output, positive
7	V4	Channel 4 analog output, positive
8	AGND	Analog ground

Note: The analog output connection must be carefully checked to ensure that the orientation is correct. A reversed connection using a parallel cable will short the channel 3 and channel 4 outputs to ground, which may cause damage to circuit components if not corrected immediately.

2.2 Mechanical Drawing

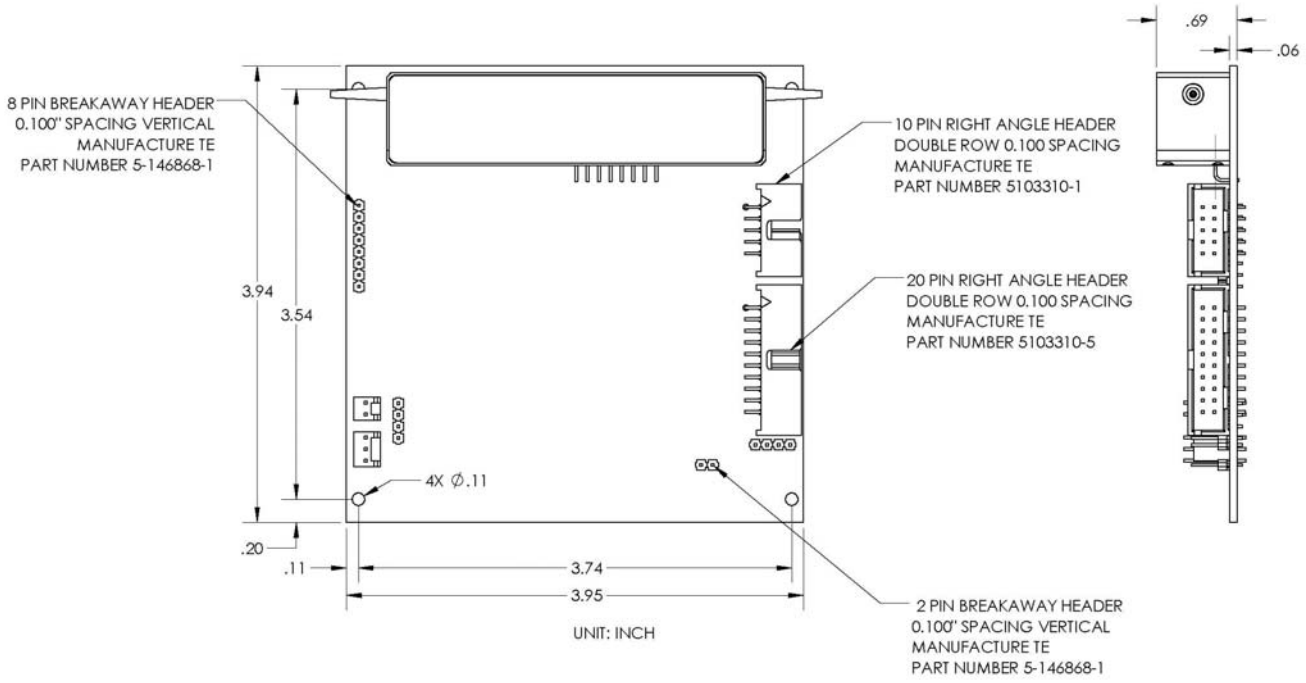


Figure 4 Dimensions of MPD-001/PCD-M02

Figure 4 shows the dimensions of the board, the dimensions and locations of mounting holes, and the model numbers of the principal electrical connectors.

Section 3. Operation Instructions:

Important Safety Notes

The MPD-001/PCD-M02 board can produce hazardous voltages and currents. The DC voltage on the board can reach 150 V. Use extreme caution when operating the MPD-001/PCD-M02. Make sure that the power is turned off when connecting or disconnecting cables.

When using the MPD-001 as a custom piezoelectric actuator driver, users must check the maximum allowed voltage on their actuator to make sure that the output voltage from the MPD-001 does not exceed the limit of their device. The maximum output voltage from the MPD-001 is ~140 V.

The capacitive properties of piezoelectric actuators can cause them to retain large amounts of charge that can cause electric shock to humans. To safely discharge a piezoelectric actuator, the user should set the input control voltage to 0 V.

Note: Do not place a negative voltage on a piezoelectric element. A high negative voltage can reverse the polarity of a piezoelectric element, causing the behavior of the device to change completely. If a negative voltage is applied to a piezoelectric element, the user should check with the supplier regarding the procedure to re-pole the device.

3.1 Getting started

Unpacking

The MPD-001/PCD-M02 module is shipped with a set of cables to facilitate user applications, as listed in Table 6. Check the shipping package to ensure that all accessories are present.

Table 6 MPD-001/PCD-M02 board and accessory list

Item	Part name	GP part number	Quantity	Note
1	MPD-001 board or PCD-M02 module	MPD-001-4X or PCD-M02-3/4X	1	Piezo driver board or Integrated polarization controller module
2	Power cable		1	±12 VDC (3-wire, 1 connector))
3	Analog input cable		1	(10-wire, 1 connector)
4	Digital input cable		1	(20-wire, 1 connector)

Setup

1. Power supply setup:

   Standard power configuration using the board's internal DC/DC converters (default option):
   a. Set the power supply selection switch to the INT side (down position when board is positioned as in Figure 1).
   b. Set a dual output power supply to 12 V. If the power supply has configurable current limits, make sure that they are set to ≥1.2A for +12V and ≥0.1A for the −12V. Turn off the supply and connect the power supply to the board (3-pin connector JPOW, lower left on Figure 1) using the pin assignments specified in Table 3.

   External high voltage power supply (optional; generally not recommended):
   a. To bypass the internal DC/DC converters and use an external high voltage power supply, set the power supply selection switch to the EXT side (up position when board is positioned as in Figure 1).
   b. Connect the ±12V (3-pin connector JPOW, lower left on Figure 1) and 160V (2-pin connector JVHX, lower left on Figure 1) power supplies to the board using the pin assignments listed in Table 3 and Table 4, respectively.
2. Before connecting analog or digital input cables to the MPD-001/PCD-M02 board, connect analog or digital input cable to the appropriate analog or digital control signal source.
3. Analog/digital setup:
   a. To use analog input, put the 2-pin jumper at JP1000 in place.
   b. To use digital input, remove the jumper at JP1000 and make sure that there is no input signal to the analog port (remove analog input connector or set all analog input pins to zero volts).
4. If the MPD-001 board is being used to drive one or more external piezoelectric actuators, connect the analog output (8-pin connector JPC, upper left in Figure 1 and Figure 2, pinout in Table 5) to the external piezoelectric device. For a PCD-M02 unit (integrated with a PolaRITE III polarization controller), skip this step.

3.2 Operation

The MPD-001/PCD-M02 board can be operated under either analog or digital control modes. These two modes cannot be operated at the same time. Typical analog applications include continuous piezoelectric actuation, slow speed polarization scrambling, etc.

3.2.1 Analog Control Mode Operation

To operate the MPD-001/PCD-M02 in analog control mode, a multi-channel (at least 4 channels) DC or AC signal generator is required. Typical signal sources are function generators, DC power supplies, digital-analog-converter output lines, computer controlled analog output boards, etc. Analog signals can be applied to all channels simultaneously.

1. With the board still powered off, set the analog signal source at or near zero or to lowest output level. Connect analog input connector cable to analog input connector JIN (10-pin connector, upper right in Figure 1 and Figure 2, pinout in Table 1).
2. When external piezoelectric elements or a remote PolaRITE III controller are used, check analog output connector and cable to make sure that the connection and polarity are correct (Table 5).
3. Turn on the ±12V DC power supply. If the power supply has current readout, the steady state +12V current should be less than 0.3 A when input analog signals are set at zero.
4. Adjust voltages applied to the analog input connector to the desired levels. Analog input voltage range is 0-5V. Do not apply negative voltages. In general, the +12V current should be less than 1.0 A during continuous driving operation.
5. If a function generator is used, set the amplitude and offset such that the applied voltage does not go below 0 or above 5V. Make sure that the applied signal frequency and amplitude do not overload the circuit. To avoid damage to the amplifier board, periodic analog inputs (such as from a function generator) should meet the following conditions:

    a. For one channel operating alone, or for two channels (channels 1 and 3 or 2 and 4) operating simultaneously, input conditions must satisfy:
    BW = f * V < 2.5 kHz · V.
    For example, if peak-to-peak input voltage V = 2V, input frequency f must be < 1.25 kHz

    b. For three or 4 channels operating simultaneously, or if channels 1 and 2 or 3 and 4 are operating simultaneously, input conditions must satisfy:
    BW = f * V < 1.25 kHz · V.
    For example, if peak-to-peak input voltage V = 2V, input frequency f must be < 0.625 kHz.

6. To minimize noise, it is recommended that any analog input channels that are not being used be grounded.

7. Turn off the power supply to power down the board.

3.2.2 Digital Control Mode Operation

All digital (data, control and addressing) inputs are TTL.

Unlike the analog control mode, the digital control signals operate sequentially. The digital control signal is applied to one channel at a time. Of the 17 digital control signal lines, 3 are used for digital control signals, 12 for data and 2 for addressing, as listed in Table 2. The data lines are used for loading 12-bit parallel voltage level control signals to a selected channel. The other 5 lines are for data traffic control and addressing. Therefore, a parallel output signal source such as a digital input/output (DIO) board or computer parallel port is required to perform digital control.

1. With the board still powered off, connect digital input connector cable to digital input connector (20-pin connector JDD, lower right in Figure 1 and Figure 2, pinout in Table 2).
2. If the MPD-001 board is being used to drive external piezoelectric elements or a remote PolaRITE III controller, check analog output connector and cable to make sure that the connection and polarity are correct (Table 5).
3. Turn on the ±12V DC power supply. If the power supply has current readout, the steady state +12V current should be less than 0.3 A when inputs are set to zero.
4. Input the digital control signals.

Digital control pin descriptions:

a. RW (read/write): 1 = default
0 = load data

b. CS (chip select): 1 = default
0 = chip selected.

This feature is useful when multiple MPD-001/PCD-M02 boards are in use. The user can apply the CS signal to select different boards when sharing data lines.

c. RESET: To reset the board, the reset pin needs to be pulled low for at least 50ns and then released. After reset, the analog output pins are set to 0 Volts.

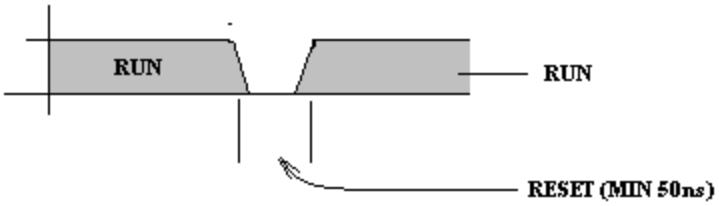


Figure 5 Function of RESET pin

The reset function is only required to initialize the system when first powered on, or if the state of the machine is not known or is questionable; for example, if the digital input cable is reinserted with the power on.

In general, the reset pin does not need to be connected. On power-up, the MPD-001/PCD-M02 does its own reset.

d. A0, A1 (channel select): Select the output channel to be controlled.

Table 7 Output channel selection

Channel	A1	A0	Corresponding Analog output pin
1	0	0	4
2	0	1	5
3	1	0	6
4	1	1	7

e. DB0-DB11: Data bits. Set the voltage to the selected channel.
DB0 = least significant bit.
DB11 = most significant bit.

Timing Diagram:

The timing diagram shown below explains the timing sequence for digital control. TTL levels should be set for the R/W, A0/A1 and data lines, then the /CS line should be pulled low for at least 50 ns. The delay required between setting R/W, A0/A1 and data lines and pulling the /CS low is 0ns (no delay required). Also, after /CS goes high again, no delay is required before the new data, address, or R/W lines are set. If all signals cannot be set simultaneously it is best to set the CS last when initiating the process and first at the end of the process, as shown below.

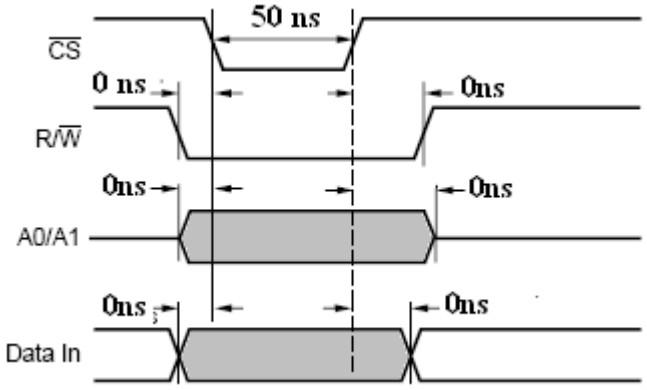


Figure 6 Timing diagram to write data to the MPD-001/PCD-M02

5. Turn off power supply to power down the board.

Section 4. Application Notes:

4.1 Piezoelectric actuator driving current estimate

Step voltage waveform

The MPD-001 is a precision voltage amplifier designed specifically to drive piezo actuators. Since piezoelectric actuators can be modeled as capacitors when not at their resonance frequencies, we can estimate their driving current based on the equation:

$$I(t) = C\, dV/dt \quad (1a)$$

or

$$I = C\, \delta V/\delta T \text{ (for a linear ramp)} \quad (1b)$$

For example, the instantaneous current required to drive a piezoelectric actuator with a capacitance of 0.18μF from 0 to 20V in 100μs is

$$I = 0.18\mu F \times 20V / 100\mu s = 36\ mA$$

Each individual driving channel in the MPD-001 board has a peak current limit set at 60mA; therefore it has sufficient current for this application.

Continuous sinusoidal waveform

When a biased sinusoidal waveform is applied to a specified channel on a MPD-001 board, the maximum output current can be expressed as:

$$I_{max} = \pi \cdot C \cdot V_{pp} \cdot f_{max}, \quad (2)$$

and the continuous operation current as:

$$I_{RMS} \approx 0.707 \cdot \pi \cdot C \cdot V_{pp} \cdot f_{cont}. \quad (3)$$

For I_{max} = 60 mA and C = 0.18 μF, we have:

$$V_{pp} \cdot f_{max} \approx 100\ V\text{-}kHz, \quad (4)$$

and for I_{RMS} = 20 mA, we have

$$V_{pp} \cdot f_{cont} \approx 50\ V\text{-}kHz. \quad (5)$$

Therefore, when the MPD-001 board is employed to drive a PolaRITE III polarization controller, we can use Eq. 4 to estimate the maximum output voltage-frequency product for single actuator operation. When the voltage-frequency product exceeds the limit set in Eq. 4, the output waveform will be severely distorted.

When all four output channels in a MPD-001 board are driven by the same sinusoidal waveform, the power supply limit of 80 mA (20 mA per channel) will require a driving

condition specified by Eq. 5. For clarity, Eq. 4 and Eq. 5 are graphically illustrated in Figure 7.

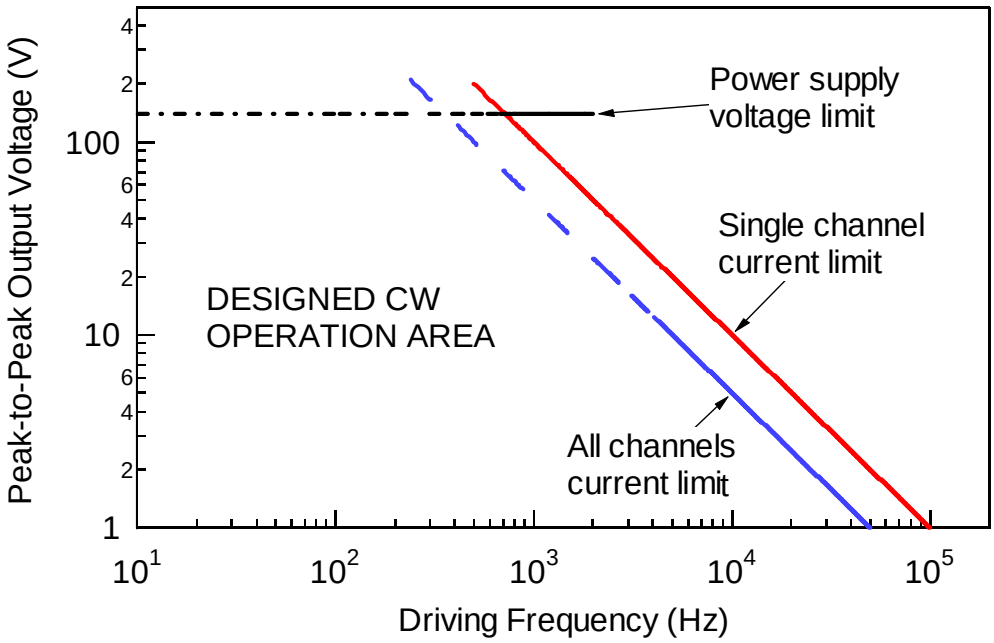


Figure 7 Current limit and power supply constraints on the peak-to-peak output voltage and driving frequency. The black horizontal line is the power supply high voltage limit. The red solid line is the single channel operation current limit. The blue broken line is the total current supply limit when all 4 channels are driven by a single sine frequency.

Rise time estimate when piezoelectric actuator is used as load

Under a step voltage driving condition, and assuming that the rise time of the driving signal is negligible, the rise time of the output waveform can be estimated from Eq. 1b and the current limit of 60 mA. Using C=0.18 μF, from the PolaRite III, as an example,

$$T_R = C \times \delta V / I_{max} = 3 \times \delta V \ (\mu s) \qquad (6)$$

Eq. 6 depicts a linear relationship between the rise time and the amplitude of the output voltage step under given current limit condition.

Note that the above estimates are for room temperature conditions.

4.2 Typical applications of the MPD-001/PCD-M02

In addition to functioning as a driver for external piezoelectric actuators, the MPD-001 can be used in various polarization control applications with an integrated PolaRITE III polarization controller (as the PCD-M02 integrated polarization controller module).

Dynamic polarization control

The PCD-M02 can be used to transform any arbitrary input polarization state to any arbitrary output polarization state. With the aid of a polarization detection device, the user can electronically control the voltage applied to each channel to adjust the output polarization state.

Polarization scrambling

The PCD-M02 can be used as a low speed polarization scrambler to randomize the input polarization state. The control signal can be 4 random step voltages or 4 sine wave voltages with the following peak-to-peak voltage and frequency relationship:

$$V_{i,\,pp}=1.531V_{\pi,\,i}\text{, i=1-4;} \tag{7}$$

$$nf_i \neq mf_j,\ m,\ n= \pm 1, \pm 2, \ldots \text{, i, j=1-4, and i}\neq\text{j.} \tag{8}$$

As mentioned in Section 4.1, the scrambling frequencies are limited by power supply constraints or circuit current limits. For a PolaRITE III in off-resonance mode, the maximum scrambling frequency is about 1kHz. The extremely low polarization dependent loss (PDL) and polarization scrambling capability make the PolaRITE III polarization controllers very useful in optical component PDL measurement.

For high frequency polarization scrambling, General Photonics offers resonant type scramblers (PCD-003/5 modules or PCD-104 instrument). Contact General Photonics for additional information.

Polarization stabilization

Using the appropriate feedback electronics and control algorithm, the PCD-M02 can be used as part of a polarization stabilization system. The feedback signal can be the maximum (or minimum) optical power output through a polarizer, or the maximum (or minimum) output voltage of a modulation signal. The stabilization speed depends on the algorithm, feedback loop time, detection approaches, system noise level, etc.

General Photonics also offers complete high-speed, reset free polarization stabilization products (POS-202/3/4 instruments or POS-002 module). Contact General Photonics for additional information.

Section 5. Technical Support:

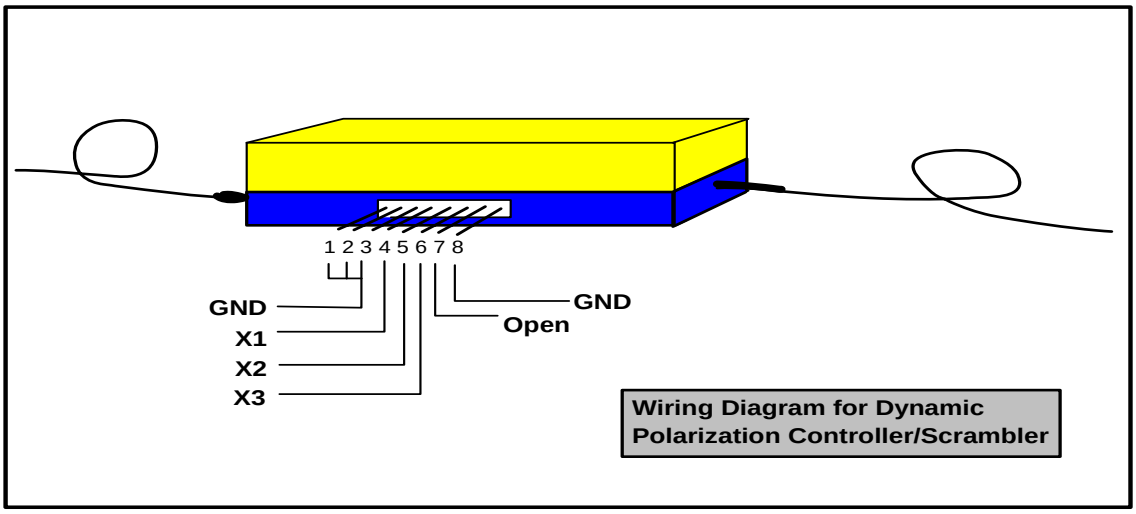
The MPD-001/PCD-M02 has no user serviceable parts. Service should be performed only by manufacturer-authorized personnel.

General Photonics is committed to high quality standards and customer satisfaction. For any questions regarding the quality and the use of the MPD-001/PCD-M02, or future suggestions, please contact General Photonics Corporation at (909)-590-5473 (telephone) or (909)-902-5536 (fax), or by e-mail at support@generalphotonics.com. General Photonics will respond to all customer questions within 24 hours during regular business hours. You can also write to:

General Photonics
14351 Pipeline Avenue
Chino, California 91710
USA

Appendix A: Wiring Diagram of PolaRITE III

3 channel PolaRITE III:



4 channel PolaRITE III: