PSI 0204
ANALOG MODULATOR BIAS CONTROLLER

OPERATOR'S INSTRUCTION MANUAL

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Warranty

Photonic Systems, Inc. warrants the PSI 0204 Analog Modulator Bias Controller (hereafter called "the unit") to be free of defects in materials and workmanship for 1 year from the date of delivery. The unit must be returned to the manufacturer for service and/or repair at the buyer's expense.

The warranty is void if the unit has been subjected to abuse and/or attempts to alter and/or repair it without the prior written approval of Photonic Systems, Inc., or if the "Input" optical connector or the "Output" optical connector are damaged while the unit is in the buyer's possession.

Following the warranty period, charges for parts and labor will be as required to repair the unit. Prices for modifications, revisions and non-warranty parts and service, together with labor necessary, will be quoted upon request.

Except as expressly provided above, there is no warranty or guarantee of merchantability or fitness for a particular purpose or of any other kind, express or implied, with respect to the unit or parts furnished or the services performed by the manufacturer. In no event shall the manufacturer be liable for any consequential damages.

Document Scope

This document describes basic installation and operation of the Photonic Systems PSI-0204 Modulator Bias Controller (MBC). The intent is to give the user enough information to place the bias controller into service using common electronic and photonic laboratory tools, instruments and practices. We encourage you to contact PSI with questions on the product's capabilities or performance beyond the scope of this document.

Product Description

The PSI-0204 is a modulator bias controller (MBC) laboratory instrument to control the bias on an external optical modulator for small signal bias applications. When operated with lithium niobate ($LiNbO_3$) modulators, the PSI-0204 provides automatic or manual bias control. Users may select automatic tracking of Quad +, Quad -, Minimum or Maximum bias points as shown in Figure 1. Operation at an externally set manual bias point may also be selected.

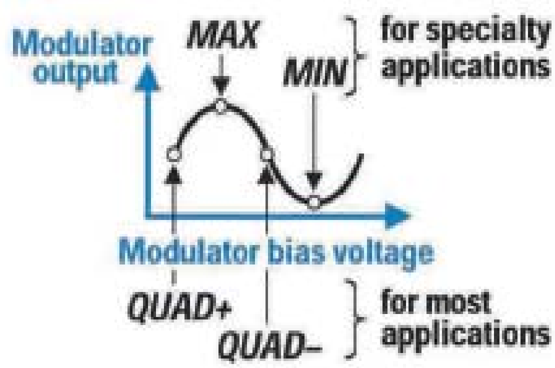


Figure 1. Modulator Transfer Function

Using a dither tone, the PSI-0204 tracks a user selected operating point to within +/- 1° dither of Vπ when operating at quadrature. Dither frequency is set at 1 kHz and dither amplitude is user defined between 20 and 200 mVpp. Bias point accuracy is maintained over a wide operating temperature range of 0° to +50°C. The bias point accuracy is easily maintained over a 20 dB range of optical power.

Designed to simplified use with the user's optical system, these controllers maintain constant bias point operation by compensating for drift in a modulator's transfer function. The controller is typically used by applying a dither tone to the modulator bias voltage and sampled at the modulator optical output. User settings determine bias point and amplitude.

Beyond standard specifications, PSI can modify the PSI-0204 to meet the exact requirements of your application, such as specific dither frequency or very large optical input range.

Front Panel Controls, Connectors and Indicators

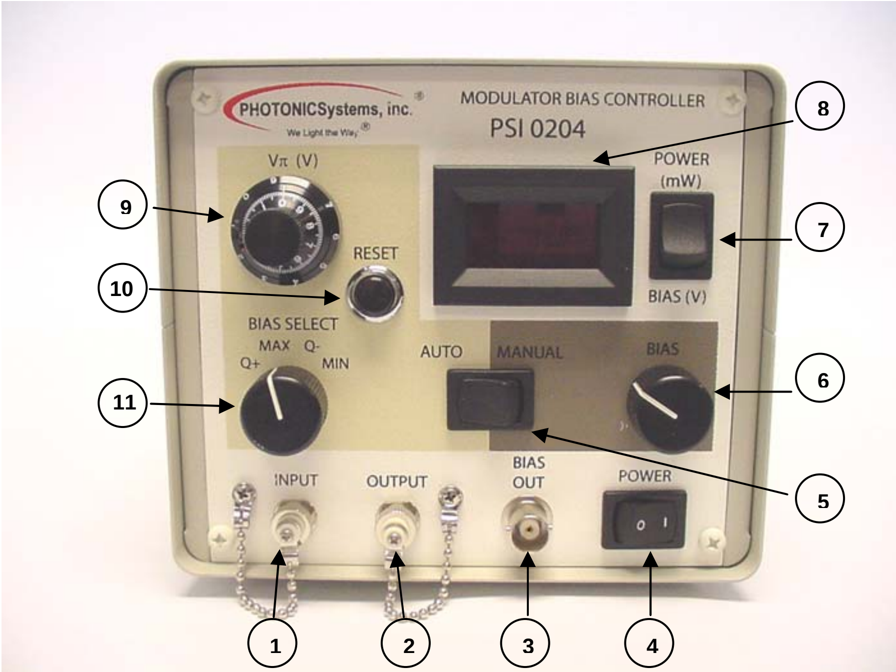


Figure 2. Photograph of the PSI-0204 Modulator Bias Controller with the connections labeled.

1) **Input Optical** This is the optical input to the instrument. The connector is an FC/APC. Follow the optical cleaning procedure shown in Appendix 1 of this document.

2) **Output Optical** This is the optical output from the instrument. The connector is an FC/APC. Follow the optical cleaning procedure shown in Appendix 1 of this document.

3) **Bias Connector** This is a BNC connector that has both the DC bias and dither signal to the modulator. The bias output can drive a maximum output current of 15ma and a maximum capacitance of .2uF. This means that the unit is not to be terminated with a 50 ohm termination and not to drive a bias tee that has a large capacitance on the dc input terminal. Total capacitance loading including the modulator, is not to exceed .2 μF.

4) **Power Switch** This switch controls power to the instrument. Power is off when “0” is depressed, and on when “I” is depressed.

5) **Auto/Manual Switch** This switch connects either the control circuitry to the output BNC or a manually adjusted bias voltage.

6) **Bias Adj. Pot** This control adjusts the output voltage at the output BNC when switched to the manual mode.

7) **Power** (Volt)/ **Bias** (mW) **Switch** This switch determines what is displayed on the front panel meter, either output bias volts or optical power in, displayed in milliwatts.

8) **Display Meter** This meter displays either output bias volts or optical power in, displayed in milliwatts.

9) **V_π (V) Adj Pot** This pot sets the 1 kHz dither amplitude and response time of the instrument. The pot should be set to equal the approximate value of the modulators V_π. When the pot is set to the maximum CW rotation (9.99), the dither voltage is +/- 99.9 mVolts and the maximum output voltage of the instrument will be +/- 15 volts. Example the V_π pot set to 5.00, the dither voltage out will be 1KHz out with an amplitude of +/- 50 mVolts, the maximum voltage out will be +/- 7.5 volts DC out.

10) **Reset Switch** This pushbutton resets the bias voltage to zero volts, in the auto mode. The reset pushbutton forces the output of the instrument to zero volts out, for as long as it is depressed. Approximately 2 seconds after release the instrument will seek the bias point that is set on the quadrature switch.

11) **Bias Select Switch** This 4 position switch selects one of the four operating points, Q+, Max, Q-, Min.

Rear Panel Connectors

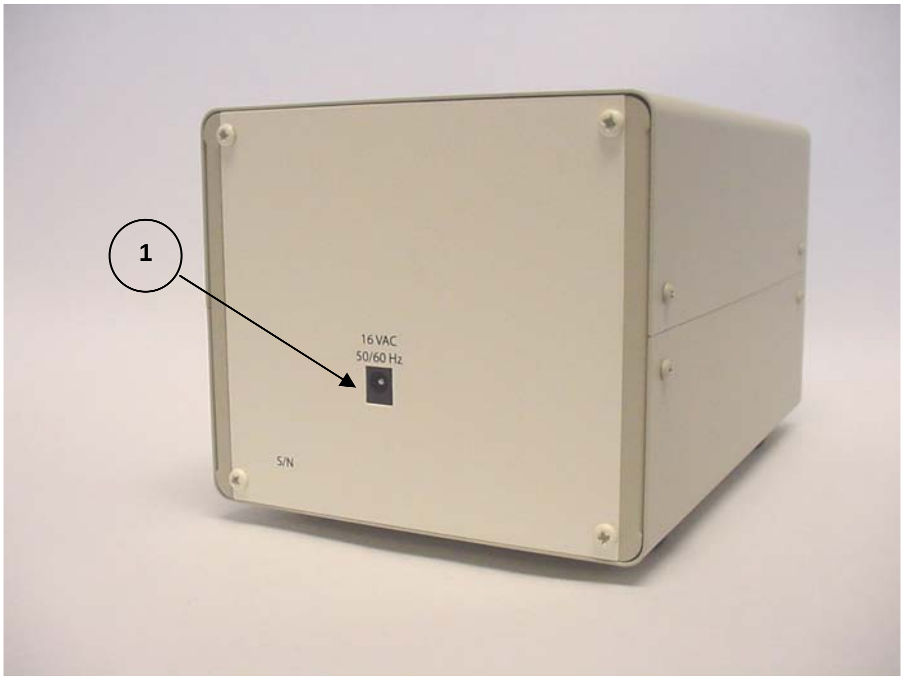


Figure 3. Photograph of the rear panel of the PSI-0204 Modulator Bias Controller with the connection labeled.

1) **16 VAC Input** Receptacle
2) **Not Shown (Optional)** BNC, optical power monitor (mW).

Details of Control Operation

The capture rate of the instrument is determined by three main variables. The variables are:

1) Quadrature Mode (Q+,Q-) and Min/Max. Min/Max is faster responding than Q+/-.
2) Dither amplitude is expressed in percent of V_π. For example, if a 5 volt V_π modulator has a 1% dither (V_π Pot @5.00) it will have the same response time as a 10 volt V_π modulator with the dither pot set to 9.99.
3) The response time of the instrument is directly related to the optical signal strength, if the optical signal is attenuated by a factor of 10, then the response time of the instrument will be 10 times longer.

The instrument comes with the internal auto reset enabled. This reset will act like the front panel reset pushbutton has been depressed, when the **Output Bias** port is within 10% of the maximum voltage it can achieve, based on the V_π **pot** setting.

Set-up

Figure 4 shows how the PSI 0204 Analog Modulator Bias Controller should be connected to the components in an external modulation link that uses a Mach-Zehnder interferometric modulator (MZM) having separate DC and AC input electrical ports. For best results, make the necessary connections in the order specified in the numbered list on the following page.

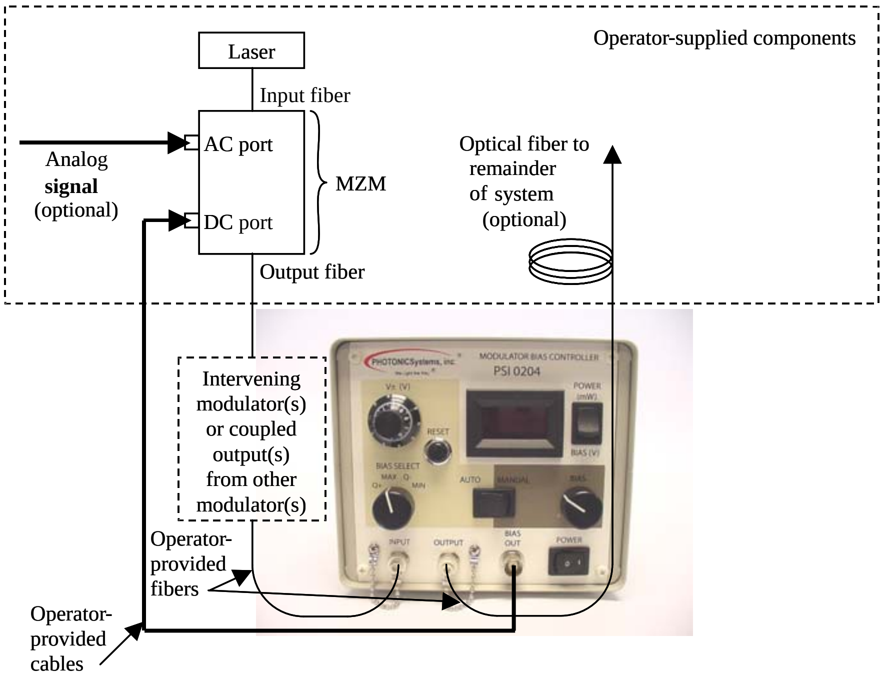


Figure 4. **Required connections for bias control of an MZM with separate AC and DC input ports.**

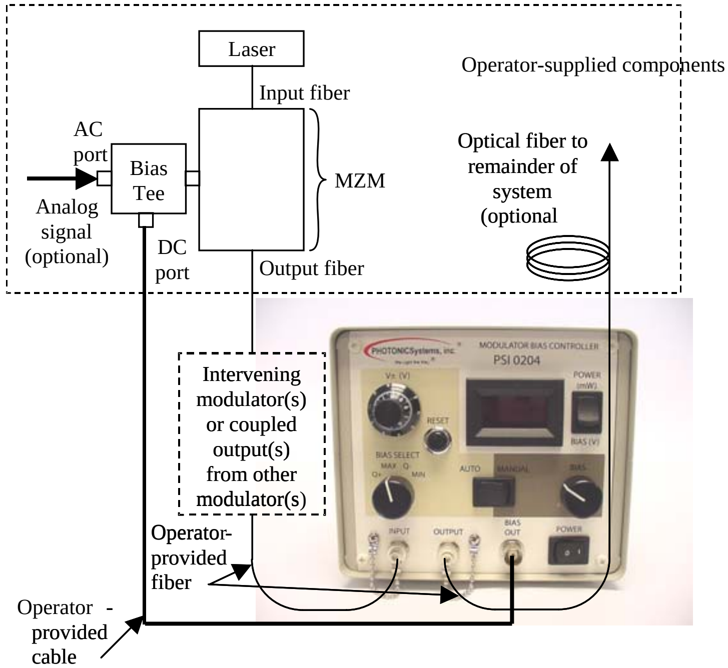


Figure 5. Required connections for bias control of an MZM with a single electrical input port.

If the MZM has only one electrical input port and it will accept a DC bias voltage, then modulator control is achieved by connecting the link components as shown in

Figure 5. This configuration requires a bias tee if the modulator is also to receive an AC input signal.

For best results, make component connections in the following order:

1. With the laser off, connect the AC adaptor (provided) to the **16 VAC Input** receptacle on the rear. Plug the adaptor into a standard electrical outlet. On the front panel, press the **Power** Switch into the on position (denoted "|").

2. Set the **Auto / Manual** Mode Select Switch *on the Controller* to the "Manual" position.

3. Set the **Input Power (mW) / Bias (V)** Readout Select Switch *on the Controller* to the "Bias (V)" position.

4. Turn the **Manual Bias** Control Knob until the **Readout** displays approximately 0 Volts, and then connect one end of a BNC cable to the **Bias** BNC and the other end to the DC port on the modulator or bias tee (depending on the modulator design).

5. Check that the type of connector on your modulator's output fiber pigtail is compatible with the Controller's **Input** Optical Connector. IMPORTANT: BE SURE TO FOLLOW THE OPTICAL CLEANING PROCEDURE SHOWN IN APPENDIX 1 OF THIS DOCUMENT! Remove the dust cover on the **Input** Optical Connector and insert the cleaned fiber.

6. Check that the type of connector on fiber you plan to use for the output for compatibility with the Controller's **Output** Optical Connector. IMPORTANT: BE SURE TO FOLLOW THE OPTICAL CLEANING PROCEDURE SHOWN IN APPENDIX 1 OF THIS DOCUMENT! Remove the dust cover on the **Output** Optical Connector and insert the cleaned fiber.

7. Turn the laser on.

8. Set the **Input Power (mW) / Bias (V)** Readout Select Switch on the unit to the "Input Power (mW)" position and, using the **Manual Bias** Control Knob, slowly vary the bias and verify that the **Readout** displays optical power that changes with bias. (If this does not happen check that, first, the laser is emitting light, and second, there is optical continuity from the laser through the modulator(s) to this modulator's output fiber pigtail.

Operating Instructions

Before beginning to operate the PSI 0204 Analog Modulator Bias Controller, follow the instructions in "Set-Up" (preceding two pages of this manual). Observe the following precautions:

- Before inserting a fiber into the **Input** or the **Output** optical connector to the unit, check that the type of connector on the fiber is compatible with the unit's optical connectors, and thoroughly clean the connector on the fiber. IMPORTANT: BE SURE TO FOLLOW THE OPTICAL CLEANING PROCEDURE SHOWN IN APPENDIX 1 OF THIS DOCUMENT. It is important that this be done each time a fiber is inserted into one of these connectors.
- After removing a fiber from either the **Input** or the **Output** optical connector, replace the dust cover that was provided for the connector.

For each modulator in your system, initiate automatic bias control by adjusting the knobs and switches on the controller that you have connected to it (using the preceding "Set-Up" instructions) as follows:

1. Set the **Auto / Manual** Mode Select Switch to the "Manual" position.

2. Turn the **Manual Bias** Control Knob until the **Readout** displays approximately 0 Volts.

3. Select the desired modulator bias point using the **Auto Bias Point Select** knob. From left to right, these points are described as follows:
   - *QUAD+* (the "quadrature" bias point on a positive slope of the modulator transfer function curve)
   - *MAX* (a bias point where the optical output of the modulator is at a local maximum)
   - *QUAD–* (the "quadrature" bias point on a negative slope of the modulator transfer function curve)
   - *MIN* (a bias point where the optical output of the modulator is at a local minimum)

4. Set the **Auto / Manual** Mode Select Switch *on the controller* to the "Auto" position and press the **Reset** Button. When a unit has found the correct bias point, the DC bias voltage displayed on its **Readout** will stop varying dramatically.

5. While a controller is holding a bias point in Auto mode, it is possible to change to a different bias point by simply turning its **Auto Bias Point Select** knob to the appropriate setting.

Measurement Example: V_π of a Mach-Zehnder Modulator

The PSI 0204 Analog Modulator Bias Controller can measure V_π of the Mach-Zehnder modulator.

Measurement of V_π—The V_π of a Mach-Zehnder modulator (MZM) is the difference between the bias voltage at the *MAX* point on the transfer function curve and the nearest two *MIN* points on the curve. Therefore, after steps 1-6 of the procedure outlined in the "Set-Up" section of the manual has been completed, V_π can be determined as follows:

1. Set the **Input Power (mW) / Bias (V)** Readout Select Switch to the "Bias (V)" position.
2. Turn the **Manual Bias** Control Knob until the **Readout** displays approximately 0 Volts.
3. Turn the **Auto Bias Point Select** Knob to the *MAX* position.
4. Set the **Auto / Manual** Mode Select Switch to the "Auto" position, and press the **Reset** Button. Wait, when the unit has found the correct bias point, the voltage displayed on the **Readout** will stop varying dramatically. Record this voltage.
5. Turn the **Auto Bias Point Select** Knob to the *MIN* position.
6. When the voltage displayed on the **Readout** has stopped varying dramatically, record this voltage. Calculate V_π by subtracting the smaller of these two voltages (where either the *MAX* or the *MIN* point occurs) from the larger.

Model 0204 Analog Modulator Bias Controller Specifications

PARAMETER	VALUE	UNITS
Modulating Signal	Analog small	
Wavelength	1250-1600	nm
Polarization Maintaining Input & Output	Optional	
Acceptable input optical power (standard)	0.2 - 10	mW
Output DC bias voltage Vpi Pot @ 9.99	–15 to +15	V
DC output impedance Bias Port (front panel) Bias Monitor Port (rear panel) optional	 100 1.0	 Ω kΩ
Modulator/Bias-T Load Capacitance	<0.2	µF
Dither frequency *	1.0	kHz
Dither peak voltage Vpi Pot @ 9.99 (max)	+/- 100	mV
Bias point error at *QUAD* +/- point at *MAX* or *MIN* point	 1.0 0.2	 degree degree
Time to acquire selected Auto Bias Point	10 (full optical power)	sec.
Power	16 VAC @ 0.2 Amp	Volts
Optical Connectors	FC/APC	
Case dimensions Width Height Depth	 5.75 5.25 8.75	 in. in. in.
Weight Case AC Adaptor	 3.5 0.5	 lb. lb.

* The dither is present in both the “Auto” and “Manual” modes of operation.

Appendix 1: Optical Connector Inspection and Cleaning Precautions

Optical fiber connectors and bulkheads require care. Please cap all connections when not in use. PSI has provided an automatic connector cleaner (CLETOP) and connector inspection microscope for cleaning use with this product. It is very important that the following procedures be observed when inserting optical fiber ends into the optical connectors. Please note: Damage to the optical connector caused by failure to follow these instructions is not covered by the warranty.

Caution: Fiber handling warnings and reminders

- Grasp only the connector housing when plugging or unplugging connectors
- Install dust caps on unplugged connectors
- Store unused dust caps in a re-sealable container to prevent dust on the caps from being transferred to the fiber end
- Do not re-use swabs or cleaning tissues. Dispose of properly.
- Do not use alcohol or other wet cleaner without a way to ensure that all residues are removed.
- Do not clean bulkhead receptacles without a means of inspection following the cleaning. The attempted cleaning could easily make the condition worse.
- Do not touch the end face of the fiber connector.
- Do not use isopropyl alcohol around open flames or sparks.

Warning: Make sure that light source is off before proceeding!!

Inspection and Cleaning Procedure

The following are general steps that should be performed for cleaning fiber ends. DetaLS/RX on Cletop and wet cleaning methods as well as recommended inspection tools will be discussed in the next sections.

1. Inspect the fiber end with the provided fiberscope with 400x magnification.

2. If the fiber end is contaminated, clean using the Cletop cleaning method described below.

3. Inspect the connector again using the fiberscope. Only if the entire connector surface is as pristine as the properly cleaned fiber in Figure 6 can it be installed into a fiber bulkhead receptacle.

4. If the fiber end is still contaminated, attempt the Cletop cleaning method again.

5. Inspect the connector again using the fiberscope.

6. If the connector is still contaminated, clean using a wet cleaning method described below immediately followed by the Cletop cleaning method to remove all residues.

7. Inspect the connector again using the fiberscope.

8. Repeat this process until the end face is clean.

9. If the fiber end cleaning is unsuccessful, the contamination may be due to scratching, improper polishing, or other damage. Use of a dirty or damaged connector in these high-power optical connections may result in permanent, catastrophic damage to both halves of the connector and to nearby fibers, rendering the channel inoperable.

Cletop Cleaning Method

1. Move the thumb lever to expose the cleaning cloth. Each time the lever is pressed, a clean section of cloth is exposed.

2. Holding the fiber end at a slight angle to allow full contact of the angle fiber with the Cletop cleaning cloth, twist 90 degrees and then drag down across the exposed cleaning cloth applying a small amount of pressure.

3. Do not re-use the same section of cleaning cloth once a fiber end has been cleaned. To expose a new section of cleaning cloth, release the thumb lever, then actuate the lever again.

4. Inspect with fiberscope.

Wet Cleaning Method

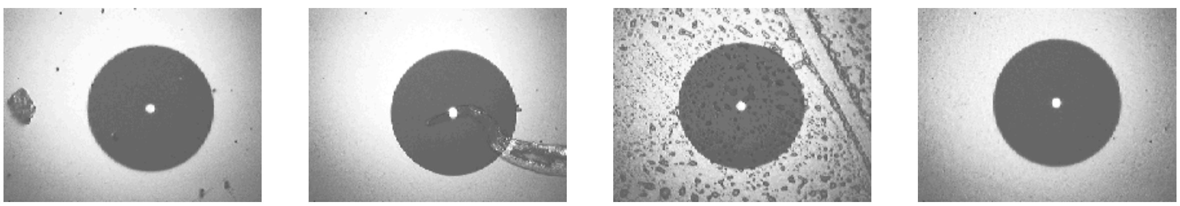
Only if the Cletop cleaning method does not adequately clean the connector, use an optical quality cleaning cloth and fluid. Optical grade isopropyl alcohol is frequently used as the cleaning fluid, but alcohol is not very quick drying and leaves residue.

1. Dampen the cleaning cloth, such as the Kimwipes provided with the cleaning fluid. Do not saturate the cloth.

2. Holding the fiber end at a slight angle to allow full contact of the angle fiber with to the cloth, twist and wipe the end face in the damp area of the cloth several times.

3. Repeat the twist and clean on a clean, dry area of the cleaning cloth.

4. Inspect the end face.



Dust **Dirt** **Fingerprint** **Properly Cleaned Fiber**

Figure 6: Examples of fiber connector faces as viewed from the connector inspection microscope. (From: http://www.cletop.com/user/Cleaning_Paper.htm)

By always following the above inspection and cleaning procedures, you are guaranteeing that the optical connectors remain in pristine condition. Therefore, it should never be necessary to attempt to clean the bulkhead connectors on the front panel of the LS/RX or on the side of the TX module. Do not insert anything into these bulkhead connectors, except for optical connectors that have been cleaned as outlined in procedure.

Appendix 2: Theory of Operation

In an external modulation fiber-optic link that uses a Mach-Zehnder interferometric modulator (MZM), the link performance depends strongly on the modulator's DC bias point. The bold curve in Figure 7 shows the transfer function of an MZM and how the half-wave voltage V_{π} is defined. The transfer function shape dictates how an external modulation link's output analog signal power and second-order distortion products vary with modulator bias.

In a system that uses a fiber-optic link to convey a small analog signal without converting it to a new frequency, the output fundamental signal strength is maximum when the modulator is biased at any voltage that is half-way between a maximum and a minimum transmission point on the transfer function curve—a so-called "quadrature" bias point (see Figure 7). Maintaining the MZM bias at quadrature is very important in systems with bandwidths wider than one octave, because only at quadrature are second-order distortion products minimized. Note that the curves in Figure 7 are periodic, and that quadrature bias points occur on both the positive and negative slopes of the transfer function curve. Biasing the MZM at quadrature on a negative slope vs. a positive slope changes the phase of the link output signal by 180º.

In some MZM applications it is desirable to bias the modulator at either the maximum or the minimum transmission point on the transfer function curve rather than at quadrature bias.

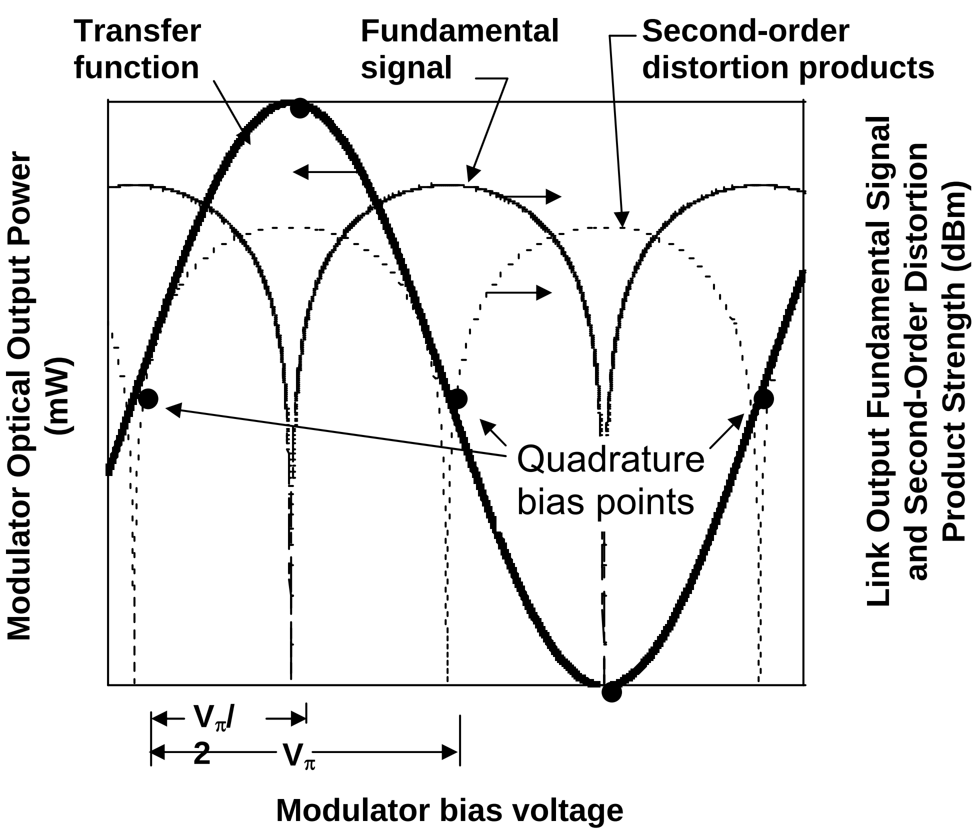


Figure 7. MZM transfer function, and link output power at the fundamental and second-order distortion product frequencies.

Ideally, any one of the points identified in Figure 7 would occur at a specific DC bias voltage that remains constant for all time despite variations in environmental conditions. Pyroelectric, photorefractive and photoconductive effects in the MZM's electro-optic material (often lithium niobate, or a semiconductor like GaAs, or an electro-optic polymer) cause the transfer function to "drift" to the left or to the right, such that a specific DC bias voltage (or even 0 Volts) may, for example, yield a quadrature point on the transfer function curve at one time, but yield a minimum point on the curve at a later time and/or at a different temperature. In many fiber-optic link applications, this tendency of MZMs to drift makes active bias control necessary.

Figure 8 shows the method that the PSI 0204 Analog Modulator Bias Controller uses to maintain an MZM's bias voltage at one of the quadrature points or at a maximum or minimum point on the transfer function curve. The controller consists of a local oscillator that generates a low-frequency dither signal, and a coupler that taps a small percentage of the MZM's optical output power and feeds it to a photodetector. The dither signal is present in both the "Auto" and "Manual" modes of operation.

When the controller is operated in quadrature bias point mode, the photodetected signal is the input to a feedback circuit that continuously adjusts the MZM's DC bias voltage to minimize the detected second harmonic of the dither frequency. Conversely, when the desired bias point is a maximum or a minimum point on the transfer function curve, the photodetected signal is the input to a feedback circuit that continuously adjusts the MZM's DC bias voltage to minimize the signal power detected at the dither frequency itself.

Comparing the phase of the dither signal at the output of the controller to the phases of the detected dither and its second harmonic distinguishes a quadrature bias point on a positive slope of the transfer function from one on a negative slope, and distinguishes a maximum point on the transfer function curve from a minimum point.

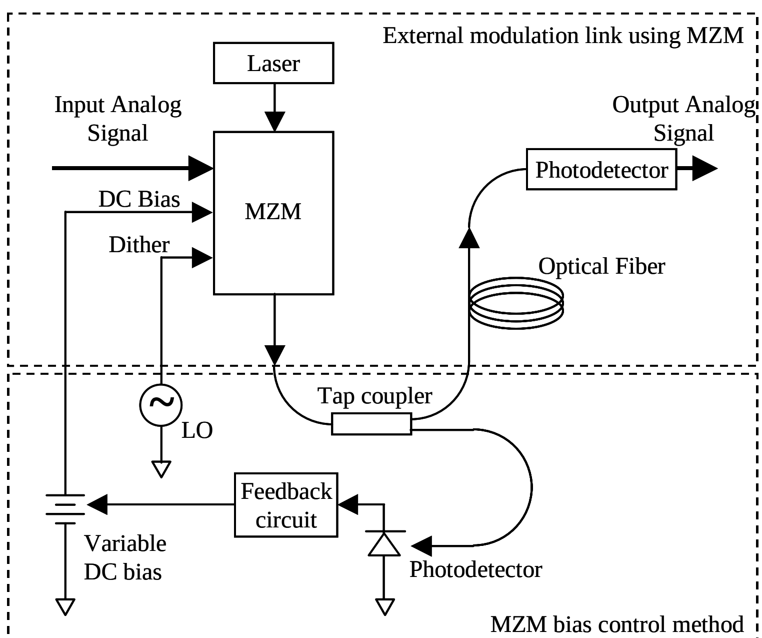


Figure 8. Method of controlling external modulator bias by injecting a dither signal and using feedback correction to maintain a desired bias point.