PSI-0204-11
CHIP-SCALE MODULATOR BIAS CONTROLLER

PSI-0204-99
MODULATOR BIAS CONTROLLER EVALUATION BOARD

USER'S GUIDE

Rev I

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1 DOCUMENT SCOPE:

This document describes basic set-up and operation of the Photonic Systems, Inc. PSI-0204-11 chip-scale modulator bias controller (MBC) board and PSI-0204-99 MBC Evaluation Kit. This manual is intended to give the user enough information to place the PSI-0204-11 MBC into service using common electronic laboratory tools, instruments and practices. This MBC product is intended for use in OEM applications where precise optical modulator control is required over time and temperature.

1.1 Document Objectives

Setup- This document describes PSI-0204-11 settings for all user defined functions including:

- Auto or manual mode
- Manual bias points
- Modulator V_{π} range
- Dither amplitude

Operation- This manual also describes basic modulator bias controller theory and operation. This background is provided to offer the user sufficient information to match the controller's capabilities with your application.

2 PSI-0204-11 CHIP-SCALE MODULATOR BIAS CONTROLLER

2.1 *PSI-0204-11 Features*

- Dither based bias control
- Compatible with most optical modulators
- Adjustable dither amplitude: 20 to 330mVpp
- Compatible with wide power supply range: +/-12 to +/- 18V
- Low operating current: <15mA typical
- Wide operating temperature range: 0° to +50° C
- Small Size: 2.5” x 0.7”, 24 pin, 0.6” width DIP

2.2 *Overview of the chip-scale bias controller*

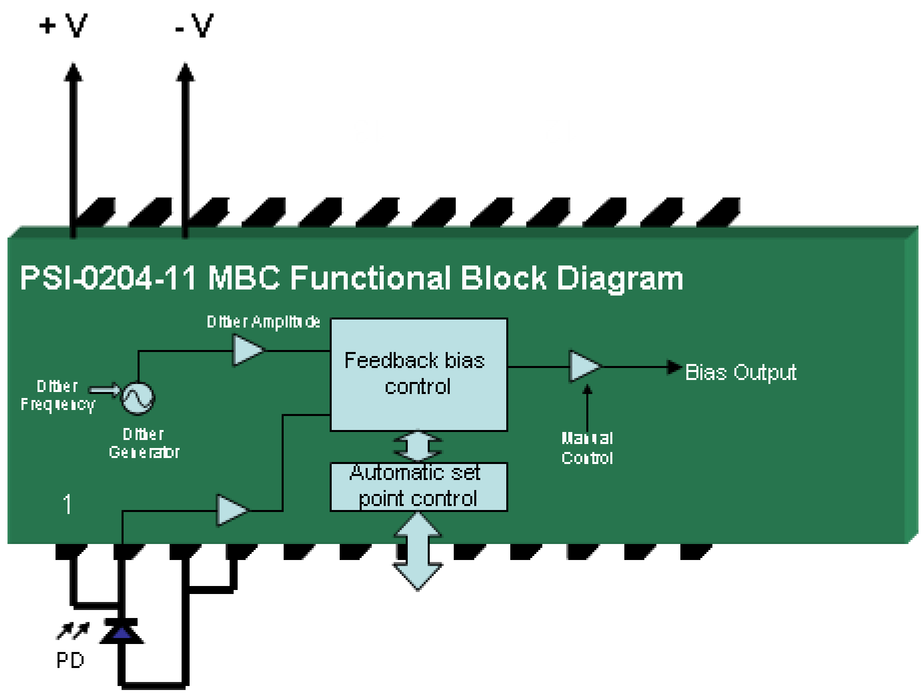
The PSI-0204-11 chip scale modulator bias controller (MBC) offers a drop-in solution for precise control of Lithium Niobate (LiNbO3), polymer, silicon or electro-absorption fiber optic modulators. This controller accurately prevents bias point drift from any of four preset modulator transfer function points.

Control of your modulator is simplified through use of the PSI-0204-11 in your system. This device is based on Photonic Systems experience in design of fiber optic systems and components. Intended for use in OEM optical links or customized experiments with optical modulators, the MBC offers users drop-in modulator bias control, speeding development time and allowing for greater concentration on other design issues.

The controller’s internal dither generator is user adjustable for amplitude. When used in conjunction with an outboard optical photodetector, lock is automatically established on the desired bias point. Automatic control modes allow for selection of Quad+, MAX, Quad- or MIN bias points.

The PSI-0204-11 chip scale modulator bias controller provides precise control of optical modulators with an error of less than 1° at 1% dither of modulator V operating at quadrature and less than 0.1° typically when operating at MIN or MAX points. Operating from dual power supplies between +/-12 to +/-18VDC, the device draws less than 15mA minimizing power consumption within the optical transmitter. The device measures only 2.5 x 0.7 inches, and configured in a 0.6” wide, 24 pin dual in line package.

2.2.1 Block diagram and functional description



The PSI-0204-11 MBC operates by adding a very small amplitude dither signal to the DC bias applied to an optical modulator. This dither signal is later detected as a portion of the light output from the modulator under control through an optical coupler and photodetector. The MBC maintains a constant modulator bias point by continuously adjusting the bias voltage to a predetermined set point. This point may be the modulator's quadrature (Quad +), inverted quadrature (Quad -), minimum (Min), or maximum (Max) points. Also, the controller may be set to operate at a manual voltage.

The dither generator amplitude may be adjusted to meet specific application requirements. Dither amplitude may be adjusted between 20 and 330mVpp through a resistor applied between pins 14 and 15. For information on setting custom dither amplitude, refer to section 2.3.2, *"Setting Custom Dither Amplitude".*

The MBC is designed to automatically hold one of four preset points along a modulator's transfer function: Quad +, Quad -, Max and Min. This point is set for the MBC through ground connections made to pins 16 and 17. Also, the MBC is set into manual or automatic mode by shorting pin 21 to ground. For specific settings, refer section 2.2.4, "*PSI-0204-11 Device Pins and Descriptions*". In the manual mode, a specific bias voltage is selected by applying a voltage to pin 12 between the negative and positive DC supply rails (-V to +V). For more information on setting automatic and manual modes, refer to section 2.3.4, *"Setting the bias control mode"*.

An external photo detector is required to complete the feedback path with the modulator under control. This photo detector is connected to the controller with the cathode at pin 2. Optionally, an on-board photodetector bias source is available at pin 1. Normally, pins 1 and 2 are connected together to the photodetector cathode providing an electrical bias current for the detector. This current is proportional to the modulator light output including the MBC dither tone.

The PSI-0204-11 is contained on a 2.5” x 0.7”, 24 pin, 0.6” wide dual in line package (DIP). This package supports all electrical functionality of the controller.

2.2.2 PSI-0204-11 Specifications

Parameter	**Typical Value**	**Units**
Modulating Signal	Analog small or large signal or DPSK	—
Modulators Supported	$LiNbO_3$	—
Output DC Bias Voltage	0.3 less than supply voltage	volts
Output load capacitance	0.2 Max	μF
Dither Frequency	1	KHz
Maximum Output Current	15	mA
Dither Amplitude, peak to peak	20 to 330; user defined	mVpp
Bias Point Error @ Quad + or Quad – point, 5 to 50 μA photodetector current [1]	1° @1% dither of V_{π} [2]	degrees
Bias Point Error @ Max or Min point, 10 to 100 μA photodetector current [1]	<0.1	degrees
DC Power Supply [3]	+/- 12 to +/-18	volts
DC Operating Current	<15	mA
Operating Temperature Range	0 to +50	degrees C
MBC Board Dimensions	2.5 x 0.7 (6.4 x 1.7cm) ; 24 pin dual in-line package, 0.6” width	in

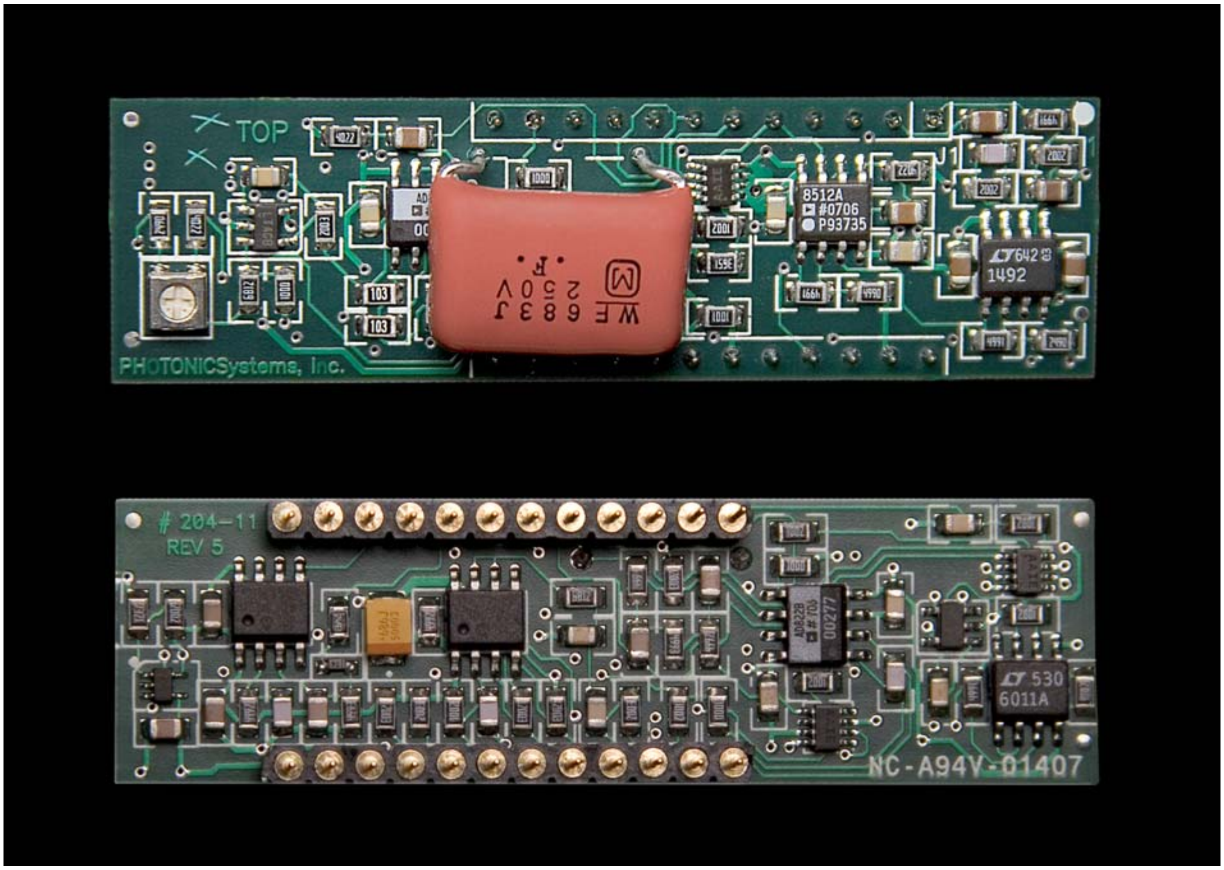
2.2.2.1 Mechanical Specifications

The photograph and drawing below show top view, bottom view and dimensions for the PSI-0204-11 chip scale modulator bias controller. All dimensions are in inches. Tolerances are +/- 0.005 unless otherwise noted.

[1] Equivalent to -23 to -13 dBm of optical power (at quadrature) applied to Fermionics FD-300 or equivalent photo detector. Wider dynamic range controllers available at additional cost; contact PSI for details.

[2] 1% dither corresponds to a peak dither voltage of 0.01x V_{π}.

[3] The MBC will operate at DC power supply voltages as low as +/- 4.75volts. PSI tests and specifies all parameters based on operation at +/- 15 volts.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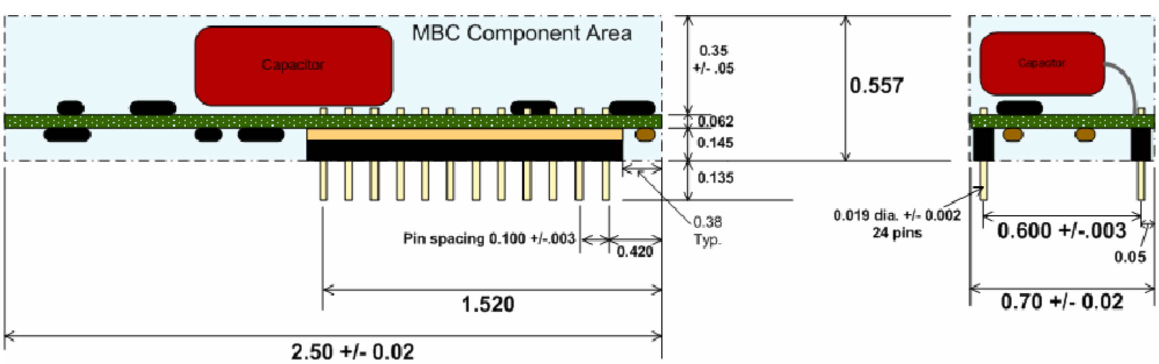
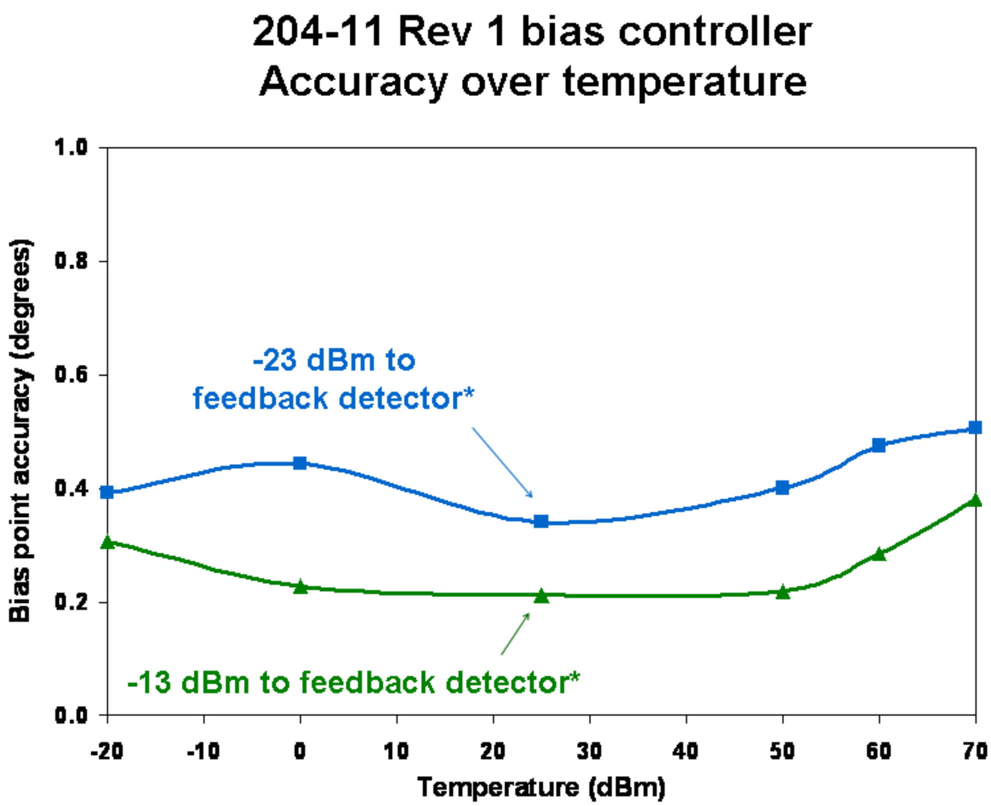
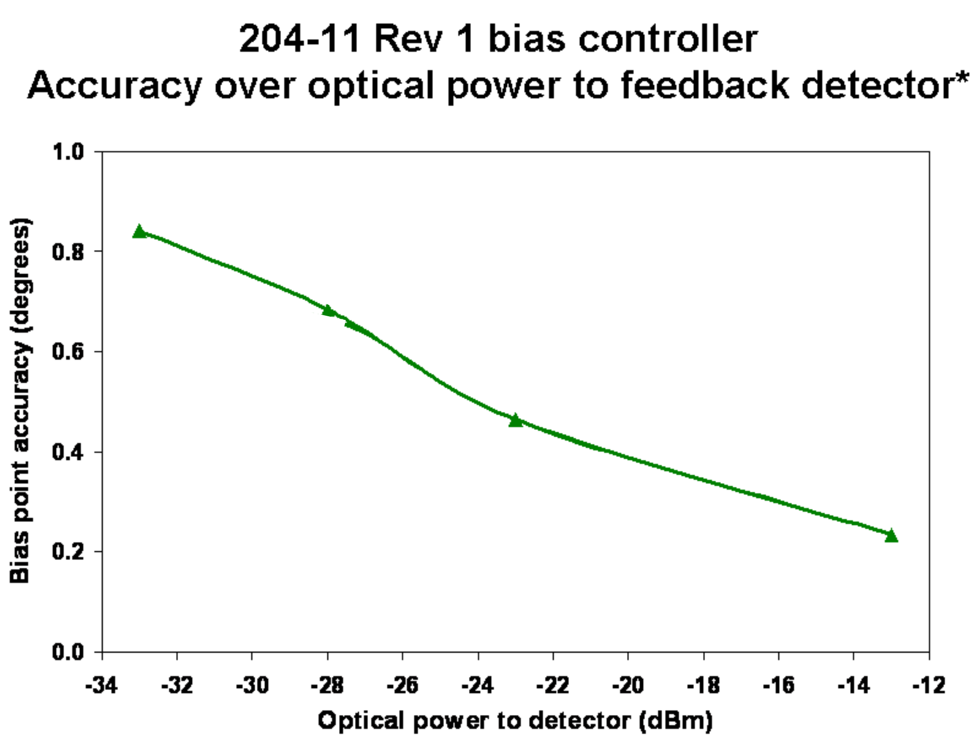

MBC Component Area
Capacitor
0.35
+/- .05
0.557
0.062
0.145
0.135
0.38
Typ.
Pin spacing 0.100 +/-.003
0.420
1.520
2.50 +/- 0.02
Capacitor
0.019 dia. +/- 0.002
24 pins
0.600 +/-.003
0.05
0.70 +/- 0.02

2.2.3 PSI-0204-11 Typical Performance: Temperature and Optical Power





*Assuming detector responsivity ≥ 0.8 A/W

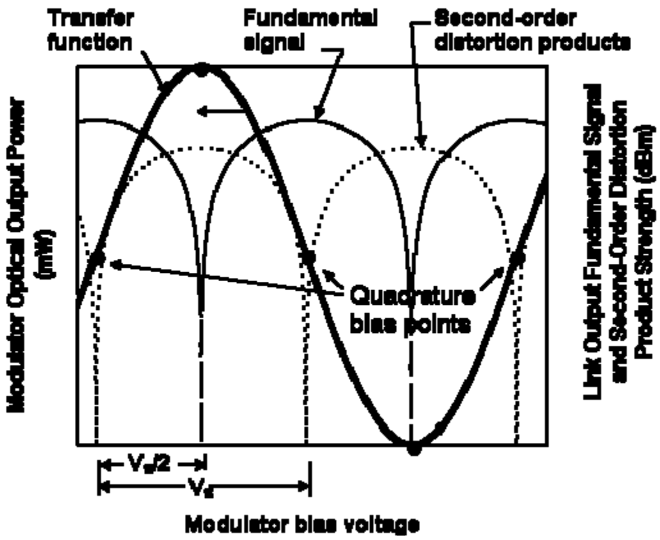
2.2.4 PSI-0204-11 Device Pins and Descriptions

Pin	Function	Description
1	PD Bias	Provides internally generated bias voltage for photodetector. Normally connected together with Pin 2 to the Photodetector cathode.
2	PD Cathode	Photodetector cathode connection. Normally connected to Pin 1 for PD bias.
3	PD Anode	Photo diode anode (analog ground)
4	PD Anode	Photo diode anode (analog ground)
5	Master	Output of PD preamplifier. Normally connected to pin 6. May be used for control of slaved bias controllers.
6	Slave	Input to dither detection circuitry. Normally connected to pin 5. May be used for control from a master bias controller.
7	Ground	Device Ground
8	Intg. In	Control loop integrator input. Normally unused, this input allows for modification of the bias control response time.
9	-Intg. –B	Control loop integrator output. Normally connected to pin 10, this output allows for modification of the bias control response time.
10	+Intg. +B	Control loop integrator output. Normally connected to pin 9, this output allows for modification of the bias control response time.
11	Bias Out	Controller output
12	Manual Bias In	Input for control of bias in manual mode. Input voltage ranges from –V to + V for control of bias voltage.
13	Dither Out– Lo Adj	Low dither voltage output. May be used for fine adjustment of dither amplitude. Normally not used.
14	Dither In	Dither input. Normally connected to pin 15 through a user selectable resistance to set dither amplitude. May be used to implement adjustable dither in conjunction with pin 15.
15	Dither Out Adj	Dither generator output. Normally connected to pin 14 through a user selectable resistance to set dither amplitude. May be used to implement adjustable dither in conjunction with pin 14.
16	Auto Bias Select 2	Input to set auto bias point in conjunction with pin 17. See section 2.3.4 for proper ground or open setting. Device employs internal 200k pull up resistor.
17	Auto Bias Select 1	Input to set auto bias point in conjunction with pin 16. See section 2.3.4 for proper ground or open setting. Device employs internal 200k pull up resistor.
18	Freq. Adj	Dither frequency control. Normally unconnected for 1Khz dither tone. Connection to pin 19 (Vlog) through a resistor varies frequency from 1 to 2 KHz. (future release)
19	+Vlog Out	4.5 volt reference output. Normally not used.
20	Reset	Control loop reset input. Ground for normal operation, allow high for reset; device employs 200k pull up resistor.
21	Auto/Manual Select	Selects Automatic or manual bias point control. Connect to ground for automatic control; open for manual control. Device employs internal 200k pull up resistor.
22	-V	Negative power supply connection. Acceptable range from –4.75 to –18 volts; specifications valid when operated between -12 to -18 volts.
23	Ground	Device Ground
24	+V	Positive power supply connection. Acceptable range from +4.75 to +18 volts; specifications valid when operated between +12 to +18 volts.

2.3 *Using the Chip-scale Modulator Bias Controller*

2.3.1 Application Examples

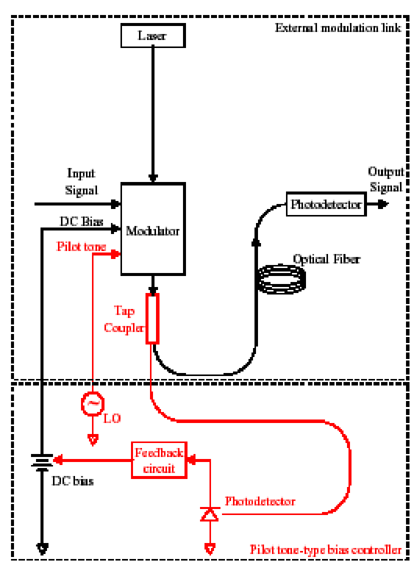
The PSI-0204-11 Modulator bias controller may be used in a number of configurations to match different applications. Common to all applications is the use of a dither tone added to the bias voltage applied to the modulator under control. This dither tone is detected at the modulator's output through an optical coupler and photodetector.



Specific applications may require the controller to hold bias at different points along the modulator's transfer function curve. The figure below shows a modulator's optical output plotted against an applied bias voltage. The change in applied voltage that results in a change from maximum to minimum power or between quadrature points is defined as $V\pi$. Common terminology defines maximum and minimum optical output power as Max and Min points. The median point between Max and Min (quadrature bias points) are defined as Quad + or Quad –, on the positive or negative slope of the transfer function respectively. The PSI-0204-11 modulator bias controller's dither tone is designed to operate at 1% of a typical LiNbO3 modulator's $V\pi$. However, this dither amplitude (and frequency) may be changed depending on application requirements.

2.3.1.1 Small Signal Transmission

The majority of small signal transmission applications will operate at either Quad + or Quad – bias points. This allows for greatest signal transmission integrity because second order distortion products of an applied fundamental are minimized at quadrature. For these applications, the PSI-0204-11 bias controller is set to operate in either Quad + or Quad – mode through pins 16 and 17 as defined in section 2.3.5, below.
A typical small signal transmission application is shown here with the PSI-0204-11 modulator bias controller. Note that the chip-scale MBC does not include a feedback photodetector or tap coupler. For the majority of applications, a photodetector such as Fermionics model FD-300 or equivalent is suggested. The tap coupler should be selected based on the optical power present at the output of the modulator under control. Photodetector current should nominally be set to $100\mu a$ at the maximum optical signal level.



These components must be selected by the user based on application requirements. PSI can provide recommendations for these components as needed, please contact us for assistance.

2.3.2 Selecting a feedback photodetector

The PSI-0204-11 MBC requires an external photodetector to close the feedback loop around the modulator under control. This photodetector receives optical power presented at the output of the modulator through an optical tap coupler. This detector should provide an electrical current in the range of 35-100 micro amps for a detected optical power of approximately 10dBm. Detectors such as the FD-300 from Fermionics provide this capability in an SC connectorized package. The tap coupler and photodetector are also available in an integrated package such as the Eigenlight Integrated Power Monitor or similar devices.

This photodetector is normally connected to the MBC with the cathode to pins 1 and 2 and the anode to pins 3 and 4. Pin 1 provides a bias supply through an RC filtering network. Pin 2 is a capacitively coupled input to a trans-impedance amplifier that coverts the detected dither current to a voltage. This voltage then is processed through an auto-ranging amplifier that provides an extended dynamic range. Pins 3 and 4 provide a ground signal return for the photodetector anode. When using the PSI-0204-99 Evaluation Board, these pins are used to create an optical power monitor voltage through the detector's anode.

2.3.3 Setting a custom dither amplitude

The PSI-0204-11 MBC has the ability to operate over a wide range of dither amplitude. Although designed for highest accuracy at a dither amplitude of 1% of the modulator's $V\pi$, the controller may be set to operate with a dither amplitude between 20 and 330mVpp. The precise amplitude is set through a resistance applied between pins 14 and 15 of the MBC. When used in conjunction with the PSI-0204-99 Evaluation Board, the dither amplitude is factory set to 100mVpp. This corresponds to a 1% dither for a modulator with $V\pi$ of 5 volts.

2.3.4 Setting the bias point control mode

MBC Pin Bias Point	Pin 17	Pin 16
Q+	Open	Open
Q-	Ground	Open
Max	Open	Ground
Min	Ground	Ground

Table 1: Auto bias control point settings.

As discussed in section 2.3.1, different applications will require operation of the modulator bias controller in one of four modes. The PSI-0204-11 will operate in Max, Min, Quad + or Quad – modes as the particular application dictates. The operating mode is set through applying a ground to pins 16 and 17 as shown in Table 1. Note that most applications will operate in Quad +, with both pins 16 and 17 open. External pull-up resistors are not needed.

2.3.5 Setting custom loop response time

The chip-scale modulator bias controller tracks changes in dither amplitude to provide a stable modulator bias. This circuitry integrates dither fluctuations over time to avoid excessive bias point movement. In future releases of the controller, the user will be able to set a specific response time to match the nature of an application. In this release of the controller, the user is advised to use the factory set response time by connecting together controller pins 9 and 10. Pin 8 must also be unconnected for factory set integrator performance. Contact PSI for assistance in setting a custom loop response time.

On the PSI-0204-99 Evaluation Board, placing a jumper on pins 1&2 of J14 sets a fast integration time constant. With pins 3&4 of J14 shorted, the time constant is slowed by a factor of approximately three.

2.3.6 Using master-slave controllers

The PSI-0204-11 MBC may be used in applications where one or more controllers are slaved from a master controller source. In these applications, the slave controllers obtain their optical feedback signal from the master controller. This is accomplished by applying the master detector output (pin 5) to the slave dither detector inputs (pin 6).

2.3.7 Initiating controller reset

In certain situations, it may be desirable to reset the modulator bias point. The controller may be reset to zero volts by removal of ground to pin 20. This pin is held at a low state for normal operation; an external pull-up resistor is not required.

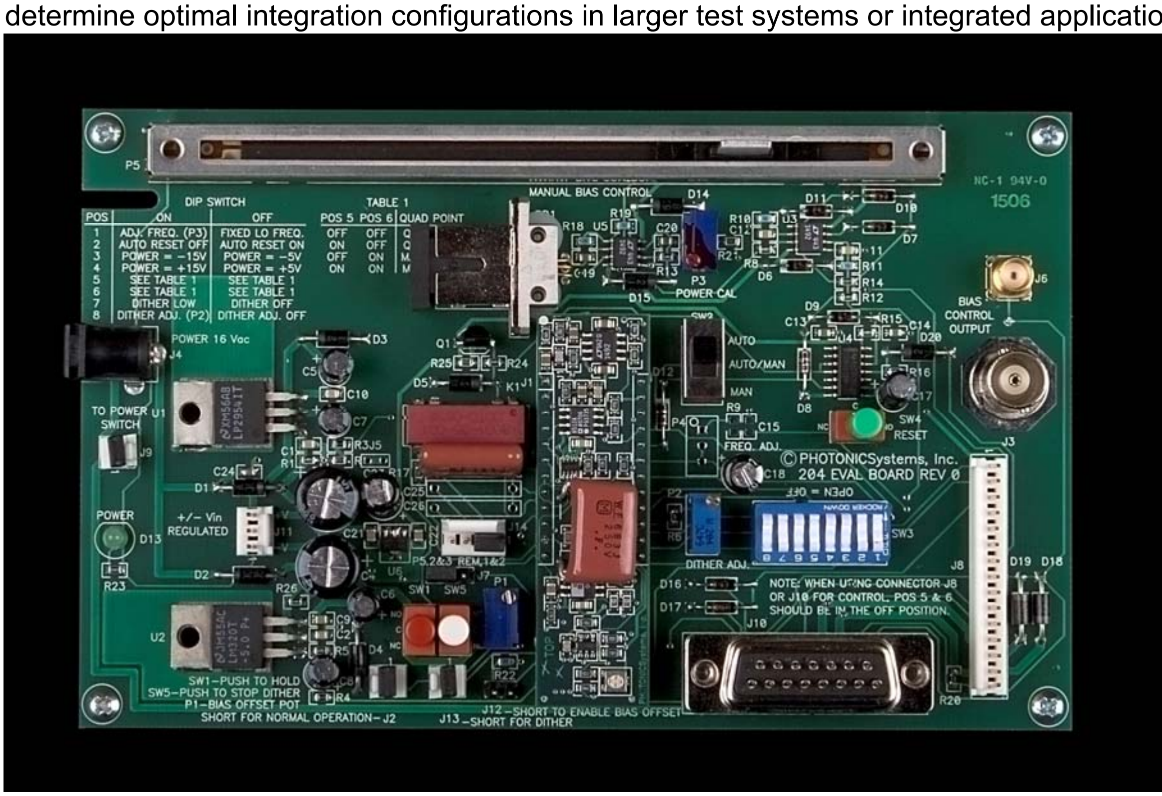
3 PSI-0204-99 MODULATOR BIAS CONTROLLER EVALUATION BOARD

3.1 PSI-0204-99 Features

- Evaluation platform for PSI-0204-11chip-scale modulator bias controller
- Integral photodetector or optional tap monitor photodiode (contact PSI)
- DIP Switches to control bias point operation, power supply selection and dither amplitude adjustability
- Control to set dither amplitude
- Auto bias point offset adjustment
- Large slider control for precise adjustment of manual bias set point
- Bias monitor port
- Dither disable pushbutton
- Operates from AC or DC power sources
- Includes all components to test MBC in laboratory applications
- Includes a PSI-0204-11chip-scale MBC andAC power supply

3.2 Overview of the chip-scale controller evaluation board

The PSI-0204-99 Modulator Bias Controller Evaluation Board is a single PC board designed to allow for simple testing and evaluation of PSI-0204-11 chip scale modulator bias controllers. This board allows for drop-in testing of all functions of any of PSI's chip-scale bias controllers. The board also offers OEM users an easy way to test the controller's performance and determine optimal integration configurations in larger test systems or integrated applications.



The evaluation board is capable of exercising all functions of the chip scale bias controller including Automatic bias control at MIN, MAX, QUAD+ or QUAD- points as well as a user set manual bias point. A large slider control allows for precise setting of a manual bias point. DIP switches set the automatic bias operating point as well as other control functions. The board may be operated from +/-15 or +/-5 VDC or 16VAC through a wall mounted power supply included with the evaluation kit. Dither amplitude, and optical power monitoring calibration are set by on-board potentiometers. Pushbuttons provide for temporary disable or hold of the dither generator. A reset function is also provided through a pushbutton. Bias output is provided through an SMA and BNC connector. An on-board photodetector and DC connectors allow users to complete a neat, integrated testing solution.

3.3 Operating the Modulator Bias Controller Evaluation Board

The PSI-0204-99 Modulator Bias Controller evaluation board was designed to allow for rapid set-up and testing of the chip-scale modulator controller device. We have made the evaluation board extremely flexible in its ability to match a range of physical, electrical and optical application requirements. The board requires no external electrical components and is shipped ready to connect to a user supplied tap coupler monitoring the modulator under control. There are several settings and controls that allow the user to fully exercise the modulator and controller under test.

3.3.1 Basic Switch Settings

Most functions of the PSI-0204-99 Modulator Bias Controller evaluation board are set up through an 8 position DIP switch bank (SW3) located at the lower right of the board. These switches enable the dither generator with a fixed frequency and amplitude, enable automatic reset, set the automatic bias control point and determine +/-5 or +/-15 volt supply operation.

Prior to applying power to the evaluation board, ensure that the switches are set according to your application and Table 2, below.

POS	ON	OFF (OPEN)
1	Adjustable Dither Frequency (future use)	Fixed Frequency (1KHz)
2	Auto Reset Off	Auto Reset On
3	Power= -15V	Power= -5V
4	Power=+15V	Power=+5V
5	Bias Mode, see section 3.3.1.1	Bias Mode, see section 3.3.1.1
6	Bias Mode, see section 3.3.1.1	Bias Mode, see section 3.3.1.1
7	Dither Low	Dither Off
8	Dither High Adj. (P2)	Dither Adj. Off

Table 2: SW3 functions and settings

3.3.1.1 Setting the auto bias point

MBC Pin / Bias Point	Position 5	Position 6
Q+	Open	Open
Q-	Ground	Open
Max	Open	Ground
Min	Ground	Ground

Table 1: Auto bias control point settings.

As discussed in section 2.3.1, different applications will require operation of the modulator bias controller in one of four modes. The PSI-0204-11 MBC will operate in Max, Min, Quad + or Quad – modes as the particular application dictates. The operating mode is set through applying a ground to pins 16 and 17 of the MBC through SW3 of the PSI-0204-99 Evaluation Board as shown in Table 1. Note that most applications will operate in Quad +, with positions 5 and 6 open.

3.3.2 Control Settings

There are three potentiometers on the evaluation board which set specific operating points for the modulator controller under evaluation. The following sections describe these control settings.

3.3.2.1 Dither Amplitude Adjustment

P2 sets the dither amplitude added to the bias signal present at J3, output to the modulator under control. Adjusting this potentiometer will set the dither between 20 and 300mVpp. This control is factory set for 130mvpp. The actual dither amplitude may be quickly changed through positions 7 and 8 of the DIP switch bank SW3. Refer to the table below for use of these switches:

SW 3, Position 7	SW 3, Position 8	Preset Dither Value
ON	OFF	130mVpp
OFF	ON	20mVpp

3.3.2.2 Frequency Adjustment- future revision

In a future revision, P4 will define the frequency of the dither tone added to the bias output at J3. Adjusting this control will change the dither frequency. This potentiometer is not populated at this time.

3.3.2.3 Bias Offset Adjustment- future revision

In a future revision, P1 sets a bias offset to the bias output presented at the controller output. This offset is enabled through jumper J12.

3.3.2.4 Response Time Adjustment

The PSI-0204-11 MBC tracks changes in dither amplitude to provide a stable modulator bias. This circuitry integrates dither fluctuations over time to avoid excessive bias point movement. The user may select either a fast or slow response time. On the PSI-0204-99 evaluation board, placing a jumper on pins 1&2 of J14 sets the fast integration time constant. With pins 3&4 of J14 shorted, the time constant is slowed by a factor of approximately three.

3.3.2.5 Power Calibration Adjustment

The PSI-0204-99 Evaluation Board includes a buffered relative power output indicator test point. This allows the user to monitor optical power received at the photodetector, PD1.

J8 or J10 pin	*Label*	*Description*
1	Q+/-	Auto bias point select- equivalent to pin 17 of PSI-0204-11. See table 1 on page 12 for settings. Line employs internal 200K pull-up resistor.
2	Min/Max	Auto bias point select- equivalent to pin 16 of PSI-0204-11. See table 1 on page 12 for settings. Line employs internal 200K pull-up resistor.
3	Min	Not used
4	+5 volts	+5 volt power supply rail output
5	Power Switch 1	Use with pin 6 for external power switch. Remove jumper from J9.
6	Power Switch 2	Use with pin 5 for external power switch. Remove jumper from J9.
7	Reset Input	Ground momentarily to initiate controller reset.
8	Bias Output	Bias output to modulator. Parallel connection with BNC and SMA connectors
9	Power Meter	Optical power input monitor- provides buffered monitor voltage. Factory set at 1 Volt for 100 micro watts at PD1.
10	Auto/manual Select	Input for selection of Auto/Manual select. SW2 must be in manual position to enable external control. Line employs internal 200K pull-up resistor.
11	Ground	Evaluation board ground connection
12	Bias Wiper (Manual Control)	Input for manual bias control operation
13	V-	Connection to -V power supply rail
14	V+	Connection to +V power supply rail
15	Power LED	Connection for power status LED

Access to this circuit is at pin 9 of J8 and pin 9 of J10 (D-Sub connector). Adjustment of P3 allows the user to set a defined voltage for a known power level at the detector. For example, if a 10% tap coupler is in use with 1mW at its input (hence, 0.9mW at the output and 100 μW at PD1), P3 may be adjusted to 1 volt, allowing direct observation of optical power changes from this nominal point. P3 is factory set to 1 volt for 100 μW detected at PD1.

3.3.3 Electrical Connections

Most electrical connections are made to the PSI-0204-99 Evaluation Board through one of two parallel connectors located at the lower right board corner. J10 provides a D-type 15 pin connector. J8 is a single in line 15 pin Molex connector. Note that positions 5 and 6 of SW3 on the evaluation board must be in the open position to allow external bias point control. Logical inputs, pins 1, 2, 7 and 10 employ internal 200K ohm pull-up resistors to +5V and may be driven from appropriate external logic sources. Connector functions are assigned as shown in the table above.

3.3.4 Optical Connections

The PSI-0204-99 Evaluation Board provides an integral monitor photodetector to complete the feedback loop needed for control of a MZM modulator. The input to this photodetector is fed from a tap optical coupler monitoring the output from the modulator under control. This tap coupler is not supplied in the evaluation kit.

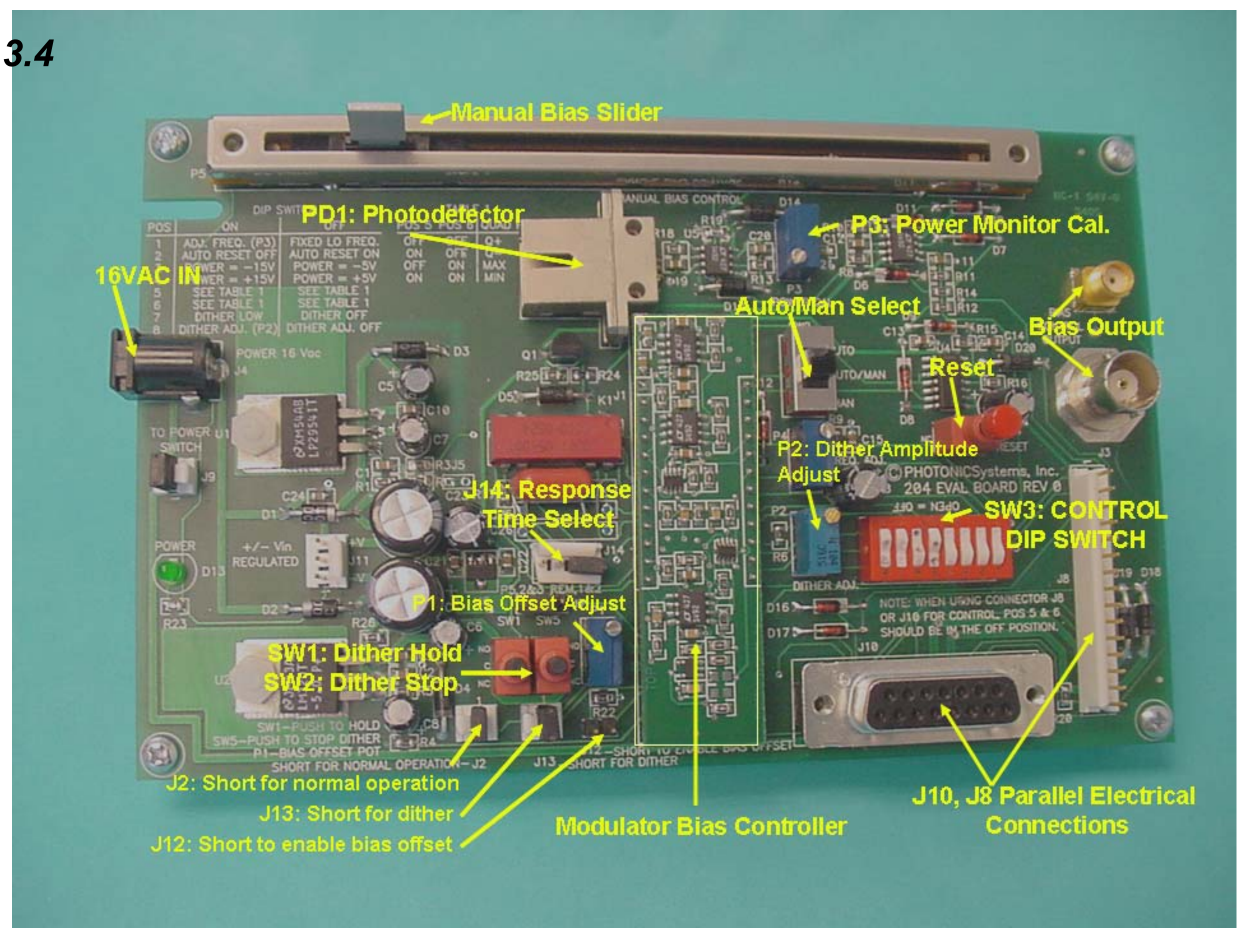
The integral photodetector is an SC type optical connector and is located at the top center of the evaluation board. The optical fiber should be routed as flat as possible to the board during operation to avoid fiber microbends. Also, be sure to follow cleaning procedures for optical connectors as defined in Appendix 1 of this document.

3.3.5 Other Electrical Controls

As a full featured evaluation tool, the PSI-0204-99 Evaluation Board provides a convenient means to test all functions of the chip scale modulator bias controller. In addition to the functions described above, the evaluation board supports control of the functions listed below. Refer to the labeled picture for locations of switches, controls and jumpers.

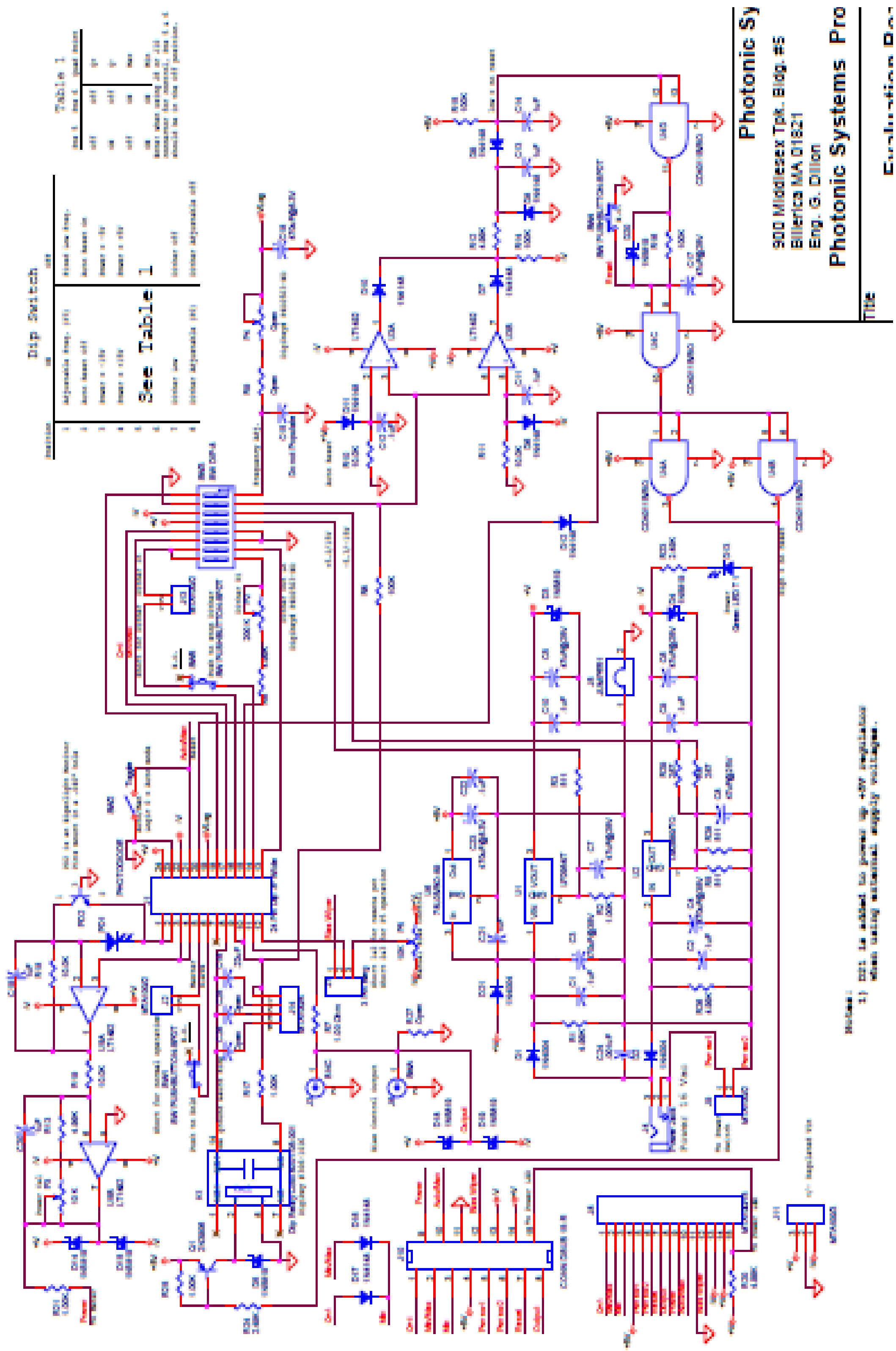
Optical Input: SC connectorized photo detector PD1
Manual Bias Control Slider: Sets precise bias point in manual mode
16VAC Input: Power connection from 16VAC line adapter.
Power Monitor Calibrate, P3: Calibrates optical power monitor voltage test point. (normally 1v=100μw.)
Auto/Man Select: Sets automatic or manual bias control.
Reset: Pushbutton that resets automatic bias point control, if needed.
Control DIP Switch: Multi-function control of bias point and other operations. See section 3.3.1.
Dither Amplitude Adjust, P2: Sets dither voltage amplitude.
Bias Output Connectors: BNC and SMA connectors provided for connection to modulator and monitoring oscilloscope, if desired.
Response Time Select, J14: presets integration time constant to fast or slow values.
Bias Offset Adjust, P1& J12: Adds DC offset to bias point when J12 is shorted
Dither Hold, SW1: Holds dither when pressed
Dither Stop, SW2: Momentarily removes dither when pressed.
Dither Enable, J13: Short to apply dither on bias signal

3.4



3.4 Evaluation Board Schematic

The following schematic is provided both to assist in use of the evaluation board and aide in design of circuitry in support of the PSI-0204-11 chip-scale modulator bias controller. Contact PSI to receive a higher resolution schematic pdf file.



4 CONTROLLER SET-UP

Figure 4-1 Modulator Bias Controller System shows how the PSI 0204-11Chip-Scale Modulator Bias Controller and PSI-0204-99 evaluation board operate together in a typical optical modulator control application. The user must supply all intermediate electrical and optical cables to complete the loop with the external modulator and laser under control. In the case where a PSI-0204-99 Evaluation Board is in use, the user supplies a tap coupler with an appropriate coupling ratio to achieve a nominal optical power level of -13 to -28 dBm at the PSI-0204-99 integral photo detector.

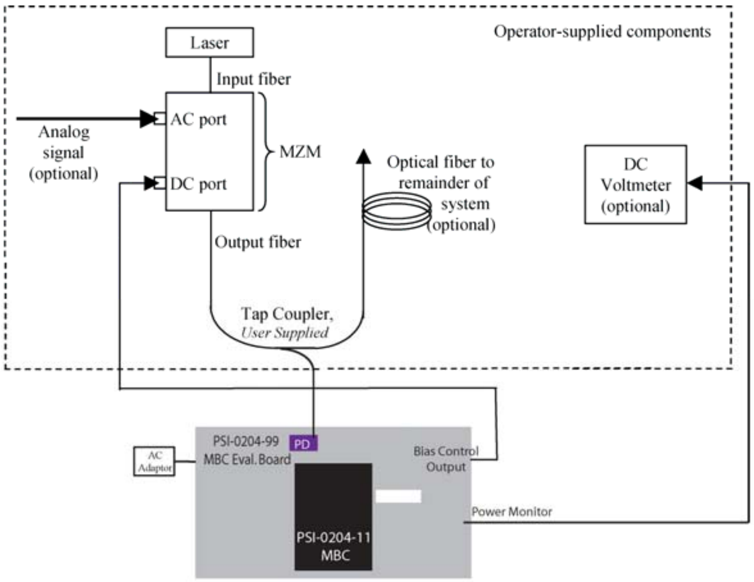


Figure 4-1 Modulator Bias Controller System

If the optical modulator has only one electrical input port, check to be certain that this port will accept a DC bias voltage. Some manufacturers do not intend the modulator electrodes to receive a DC bias, and therefore may have capacitively coupled the electrodes to the input port; a DC voltage at a capacitively coupled input port will not affect the optical output from the device. (The PSI 0204-11 Chip-Scale Modulator Bias Controller can be used to determine if this is the case—see step 7 below.) If the single electrical input port will accept a DC bias voltage, then the modulator control is achieved by connecting the link components as shown in Figure 4. Note that this configuration requires a bias tee if the modulator is also to receive an AC input signal.

For best results, make the necessary connections to the PSI Modulator Bias Controller in the following order:

1. Connect the AC adaptor (provided) to the **16 VAC Input** Receptacle and plug the adaptor into a standard electrical outlet.

2. Set the **Auto / Manual** Mode Select Switch to the “Manual” position.

3. Connect a voltmeter to pin 8 of J8/J10.

4. Adjust the **manual bias slider** until the **Voltmeter** displays approximately 0 Volts.

5. Check that the type of connector on your modulator's output fiber pigtail is compatible with the tap coupler's **Input** Optical Connector. Angled polish connectors (APC) are strongly recommended for best results. <u>Thoroughly</u> clean the connector on the fiber (very important—see Appendix 1: Optical Connector Cleaning Precautions). Remove the dust cover and insert this fiber.

6. Connect one end of a BNC cable to the **Bias** Port, and the other end to the DC port on the modulator or bias tee (depending on the modulator design—see discussion above).

7. Using the **Manual Bias** slider, slowly vary the bias and verify that the Voltmeter 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 to the modulator's output fiber pigtail.) Vary the bias to determine the approximate maximum optical power out of the modulator.

8. Measure the optical power applied at the feedback photodetector on the PSI-0204-99 evaluation board. This power should be between -13 to -28dBm for proper operation.

9. Determine the V_{π} of the modulator. If the modulator's V_{π} is not between 0.3 and 10 V, the bias controller may not work properly.

10. Apply the small signal input to the modulator, and connect any additional link components as shown in either Figure 3 or Figure 4. When connecting a fiber to any optical connector, observe the instructions outlined in step 5 above and in Appendix 1: Optical Connector Cleaning Precautions.

5 PSI-0204-99 OPERATING INSTRUCTIONS

Before beginning to operate the PSI 0204-99 Modulator Bias Controller Evaluation Board, follow the instructions in "Set-Up" (preceding two pages of this manual). Observe the following precautions:

- Before inserting a fiber into the integral photo detector, 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. It is important that this be done each and every time a fiber is inserted into one of these connectors (see Appendix 1).
- After removing a fiber from any optical connector, replace the dust cover that was provided for the connector.

After "Set-Up" has been completed, initiate automatic bias control as follows:

1. Apply power to the PSI-0204-99 evaluation board.
2. Adjust the **Manual Bias** Control slider until the voltmeter displays approximately 0 Volts.
3. Select the desired modulator bias point as discussed in section 3.3.1 of this document. The pre-set bias points available for automatic control are :

   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 to the "Auto" position and press the **Reset** Button. When the unit has found the correct bias point, the DC bias voltage displayed on the voltmeter will stop varying dramatically. However, the tendency of the modulator to "drift" (as discussed in Appendix 2 of this manual) dictates that the bias voltage will not remain constant but instead slowly drift upward or downward.
5. Periodically check the bias voltage displayed on the voltmeter. If this voltage has drifted beyond the limits shown below (and in "Specifications" on page 14), it is likely that the desired bias point has drifted beyond the output voltage range of the bias controller, causing it to lose its lock on the correct bias point. Figure 5 on the following page outlines an example of how this can occur. Press the **Reset** Button, and the unit will re-initiate a search for the correct bias point, beginning at 0 Volts.
6. While the controller is holding one type of bias point in Auto mode, it is possible to change to a different bias point by simply resetting the mode DIP switches to the appropriate position. Depending on the level of the bias voltage before switching to a new position, the controller may stray out of its voltage range when searching for the new bias point. This situation is rectified by pressing the **Reset** Button.
7. If you wish to find another occurrence of the same type of bias point (*i.e., QUAD+, MAX, QUAD–, or MIN*), pressing the **Reset** Button will find the occurrence that is

nearest to 0 Volts. Different instances of one type of bias point occur every 2 × V_π volts from one another. For example, if the modulator bias is currently locked at a *QUAD*+ bias point occurring at a bias of –9.0 Volts, and if V_π=5.0 Volts, then pressing the **Reset** Button will cause the unit to find the instance of the *QUAD*+ bias point that occurs at +1.0 Volts.

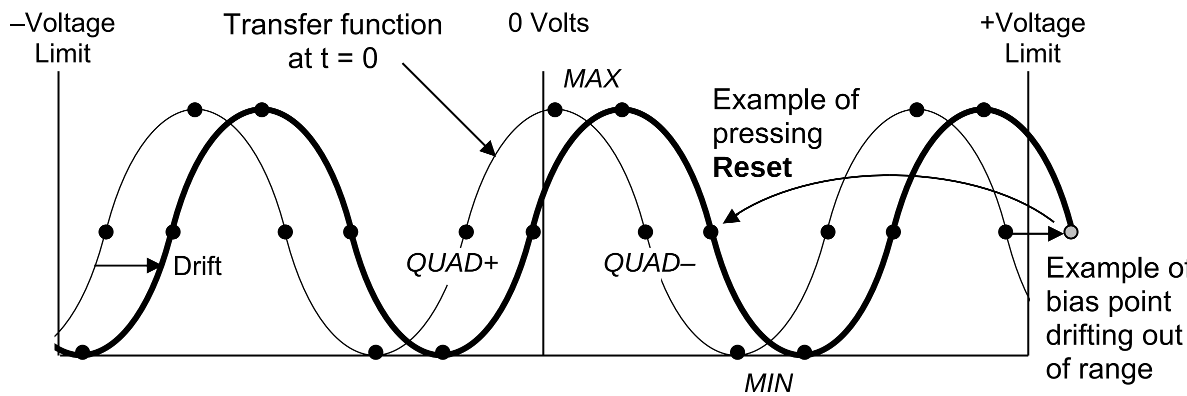


Figure 5. Effect of modulator bias drift. The bold curve shows an example of the transfer function drifting to the right of where it had been at a time t=0. If at t=0 the controller were locked, for example, on the *QUAD*– bias point just to the left of the +Voltage limit, the figure shows how drift of this magnitude and in this direction would cause the controller to lose its lock on this bias point once it has moved beyond the bias voltage limit. In this example, pressing the **Reset** Button would cause the controller to move to the *QUAD*– bias point nearest 0 Volts.

6 Using your modulator bias controller

The PSI 0204-11 Modulator Bias Controller can simplify the characterization of some of a Mach-Zehnder interferometric modulator's performance parameters.

6.1 Measurement of Vπ

The V_π of a Mach-Zehnder modulator (MZM) is the difference between the bias voltage at one of the *MAX* points on the transfer function curve and either of the nearest two *MIN* points on the curve. Therefore, after steps 1-9 of the procedure outlined in the "Set-Up" section of the manual have been completed, V_π can be determined as follows:

1. Turn the **Manual Bias** Control slider until the **Voltmeter** displays approximately 0 Volts.
2. Set the **Auto Bias Point** to the *MAX* position.
3. Set the **Auto / Manual** Mode Select Switch to the "Auto" position, and press the **Reset** Button. When the unit has found the correct bias point, the voltage displayed on the **Voltmeter** will stop varying dramatically. Record this voltage.
4. Set the mode DIP switches for *MIN* operation.
5. When the voltage displayed on the **Voltmeter** 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.

6.2 Quantification of drift rate as a function of DC bias

Figure 6 shows how modulator bias drift is sometimes quantified. The drift mechanisms in most modulator materials make it likely that the rate of drift will increase with the magnitude (absolute value) of the initial bias voltage, as the example shown in Figure 6 illustrates. After the procedure outlined in the "Set-Up" section of the manual has been completed, this type of bias drift characterization can be carried out as follows:

1. Turn the **Manual Bias** Control slider until the **Voltmeter** displays approximately 0 Volts.
2. Set the mode DIP switches to any valid operation point (eg: MIN, MAX, QUAD+, QUAD-).
3. Set the **Auto / Manual** Mode Select Switch to the "Auto" position, and press the **Reset** Button. When the unit has found the correct bias point, the voltage displayed on the **Voltmeter** will stop varying dramatically. Record this voltage.
4. Continue recording the voltage displayed on the **Voltmeter** at predetermined time intervals so that you can generate the type of bias voltage vs. time curve in the example shown in Figure 6.
5. Repeat this process at other initial bias voltages by repeating steps 3-5 using the other three mode settings, or by using the procedures outlined in the "Operating Instructions" section of the manual to arrive at different occurrences of the same type of bias point.

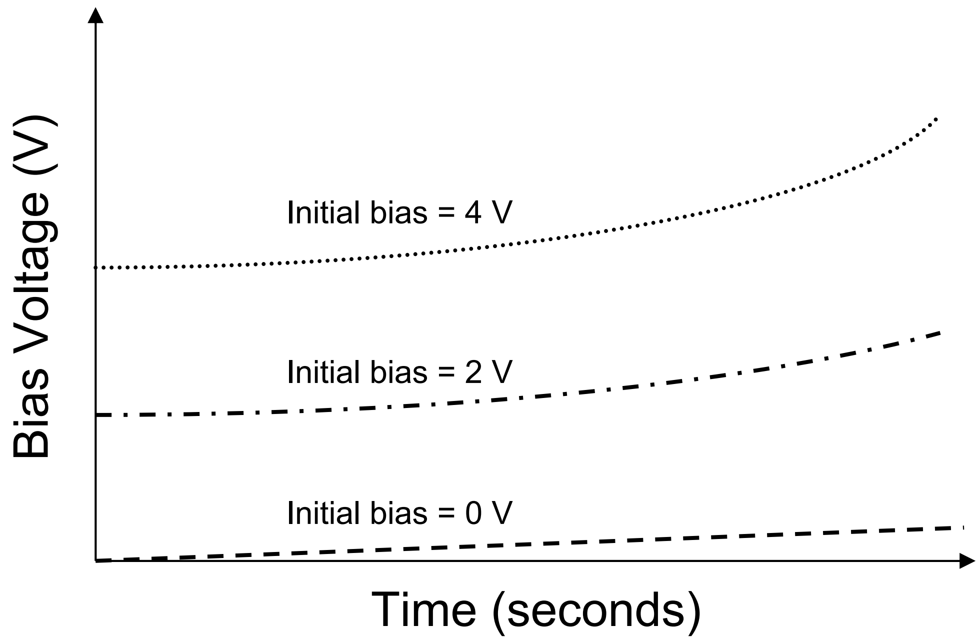


Figure 6. Example of how the bias drift rate of a Mach-Zehnder modulator is typically quantified.

7 APPENDIX 1: OPTICAL CONNECTOR CLEANING PRECAUTIONS

It is very important that the following three procedures be observed when inserting optical fiber ends into the Optical Connectors of the PSI 0204-99 Modulator Bias Controller Evaluation Board. Please note: Damage to the Optical Connector caused by failure to follow these instructions is not covered by the warranty.

1 Before inserting a fiber into the optical connector, clean it using alcohol and a lint-free wipe or with a Connector Cleaner sold expressly for this purpose. Then spray the connector with compressed air. It is vitally important that this be done each and every time you insert a fiber into one of the two optical connectors of the unit.

2 After removing a fiber from either the optical connector, replace the dust cover that was provided for the connector.

3 By always following procedures 1 and 2, you are assuring that the Optical Connectors remain in pristine condition. Therefore, it should never be necessary to attempt to clean the photodiode connector. Do not insert anything into the connector, except for optical connectors that have been cleaned as outlined in procedure 1 above, or the dust covers as mentioned in procedure 2 above.

8 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 8-1: MZM Transfer Function and link output power at fundamental and second-order distortion product **frequencies**) 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 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 4-1 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.

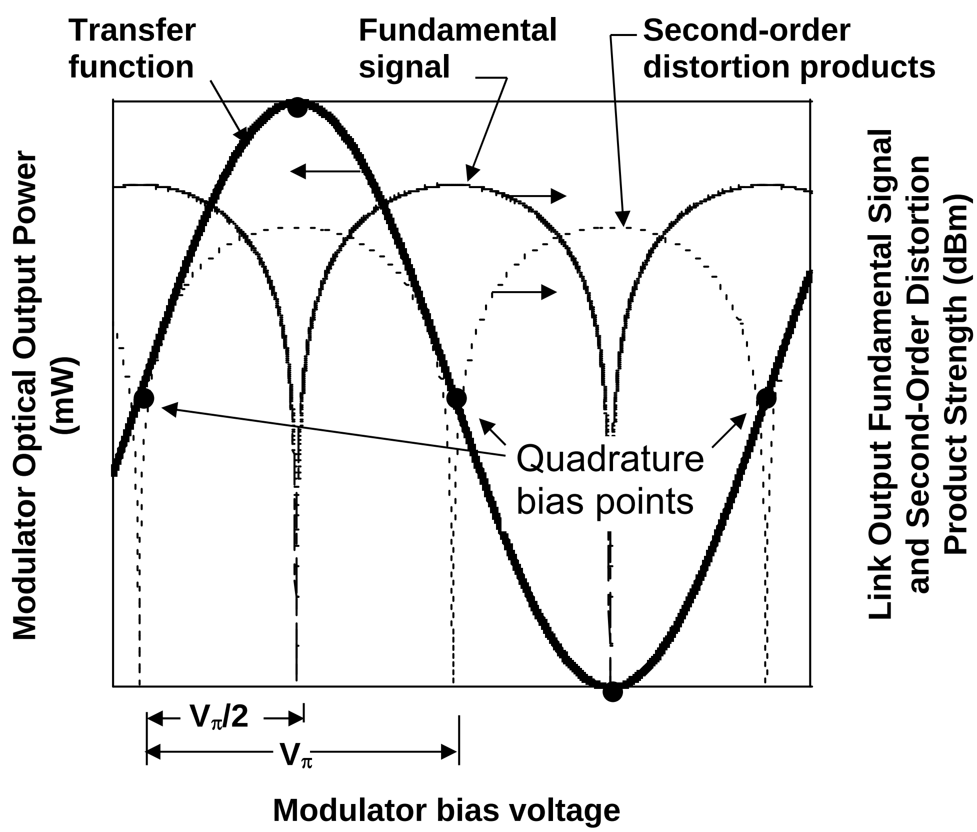


Figure 8-1: MZM Transfer Function and link output power at fundamental and second-order distortion product frequencies

Ideally, any one of the points identified in Figure 8-1 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 8-2 shows the method that the PSI-0204-11 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 operates in conjunction with 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 “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.

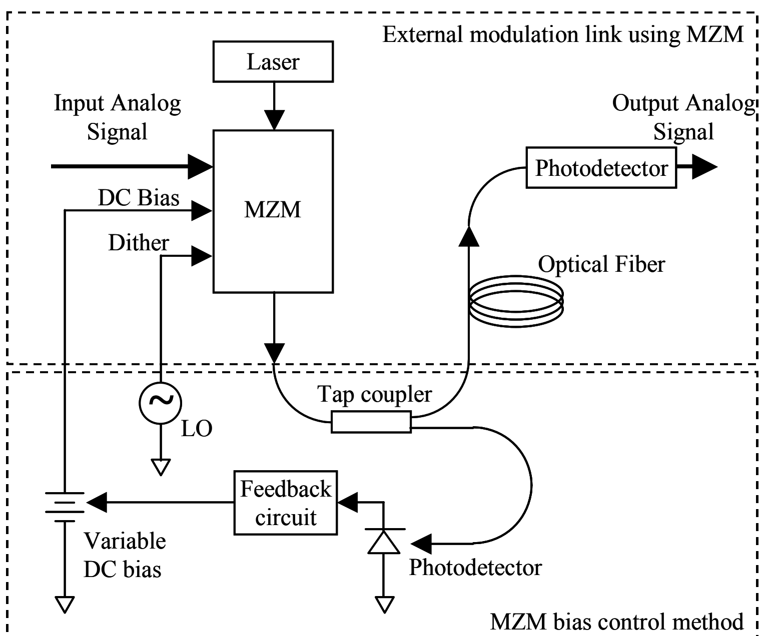


Figure 8-2: Method of Controlling External Modulator Bias with Injected Dither Tone

Warranty

Photonic Systems, Inc. warrants the PSI 0204-11 modulator bias controller and PSI-0204-99 modulator bias controller evaluation platform to be free of defects in materials and workmanship for 1 year from the date of delivery. Products must be returned to the manufacturer for service and/or repair at the buyer's shipping expense. The buyer must contact PSI and receive a valid return material authorization (RMA) number prior to returning any products.

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 unit shows evidence of component tampering 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.