MX100E Series
Reference Transmitters
with Linear RF Amplifiers

User Guide

Table of Contents

Chapter 1 Introduction

1.1 Intended Use

This product is intended to be used as a linear reference transmitter for characterization of optical detectors with bandwidths up to 100 GHz. This product is intended to be used in a laboratory environment with controlled temperature and humidity.

This product may only be used in accordance with the instructions described in this manual. Any other use will invalidate the warranty.

1.2 Explanation of Safety Warnings

WARNING Warning indicates a hazard with a medium level of risk that, if not avoided, could result in death or serious injury.

NOTICE Indicates information considered important, but not hazard-related, such as possible damage to the product.

Danger, Warning, or Caution

Laser Radiation Warning

Shock Warning

ESD Component Caution

The CE markings on the product are the manufacturer's declaration that the product complies with the essential requirements of the relevant European health, safety, and environmental protection legislation.

The wheelie bin symbol on the product, the accessories or packaging indicates that this device must not be treated as unsorted municipal waste but must be collected separately.

1.3 Description

Thorlabs' MX100E Series of Linear Reference Transmitters are designed for high-speed fiber optic test and measurement applications. Each transmitter incorporates a telecommunication-grade lithium niobate ($LiNbO_3$) modulator that is stabilized by a fully automatic bias controller and driven by a high-fidelity linear RF amplifier. The MX100E is optimized for linear applications. Select an internal tunable laser source, fixed-wavelength laser source, or couple an external laser, operating from 1525 nm to 1575 nm for the MX100E and 1260 nm to 1360 nm for the MX100E-1310, to the PM FC/PC fiber optic connector on the input panel. The instrument is fully driven using the intuitive graphical user interface (GUI) touchscreen, and the RS-232 connection on the back panel enables remote control of many instrument functions. Please contact Thorlabs Technical Support for up-to-date information on the firmware revisions and control functions available.

This instrument can be controlled in two ways. The simplest method is directly via the built-in graphical user interface (GUI) and touchscreen. The instrument can also be operated remotely via the RS-232 or USB ports on the back panel. Remote control is enabled using simple SCPI-type serial commands from a PC. See the remote-control user guide (RCUG), which can be downloaded from **https://www.thorlabs.com/manuals.cfm**.

The most recent firmware and remote-control software tool can be downloaded by visiting **https://www.thorlabs.com/software_pages/viewsoftwarepage.cfm?code=MX**. Thorlabs' technical support can provide up-to-date information on available firmware revisions and control functions.

1.4 Technical Data

1.4.1 Block Diagram

Each linear transmitter is fully integrated and contains the laser source, linear amplifier, lithium niobate ($LiNbO_3$) Mach-Zehnder intensity modulator (MZM), and automatic bias controller; the only required external input is the signal source to the Amplifier RF In port.

The MX100E transmitter includes a C-band tunable laser, and the MX100E-1310 transmitter includes a 1310 nm fixed-wavelength laser. The C-band laser sources are tunable on the ITU 50 GHz grid and include a dither feature for wavelength stabilization.

Optical power is monitored in three places (Mon-1,-2,-3) for the purpose of enabling bias and power control. These power values are also available at the I/O port. Mon-1 is at the Laser Input, Mon-2 is at the MZM Output, and Mon-3 is at the final Optical Output.

An external laser source, operating from 1525 nm to 1575 nm for the MX100E or 1260 nm to 1360 nm for the MX100E-1310, can also be used to provide the optical input. Either the internal laser or an external laser source may be coupled to the Laser In port, which uses PM fiber with light linearly polarized along the slow axis, as shown on the front panel. The maximum input power to the Laser In port is 17 dBm (50 mW).

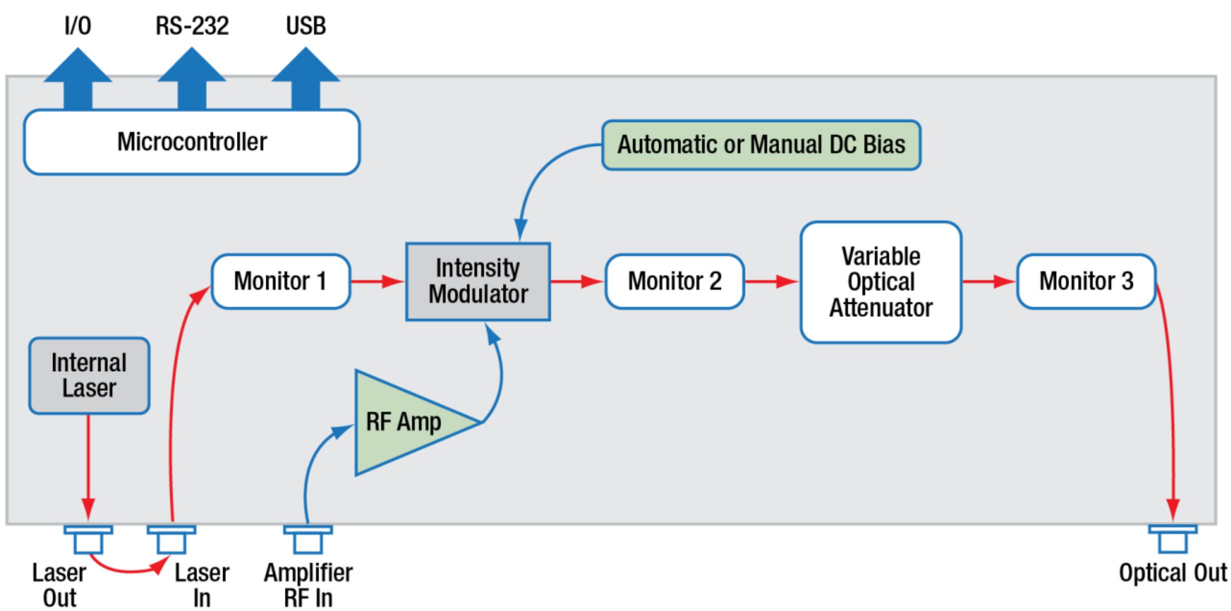


Figure 1 Key Components of MX100E Series Linear Transmitters

1.4.2 General System Specifications

All Specifications are at nominal instrument wavelength (1550 nm for MX100E, 1310 nm for MX100E-1310) and 25 °C ambient temperature, unless otherwise noted.

Parameter		Typical Values	Additional Information
Laser Output Power		17 dBm	From Internal Laser
Optical Input Power		17 dBm Max	From External Laser, 20 dBm Absolute Max
Optical Output Power[a,b]		6 dBm	Biased for Peak Optical Output
Internal Laser Wavelength Range	**MX100E**	C-Band	External Cavity Laser Tunable, See Laser Specifications
	MX100E-1310	1310 nm	Distributed Feedback (DFB) Laser
External Laser Wavelength Range[c]	**MX100E**	1525 nm - 1575 nm	
	MX100E-1310	1260 nm - 1360 nm	
DC Optical Extinction Ratio	**MX100E**	20 dB	
	MX100E-1310	13 dB	
Input RF Connector Type		1.0 mm (W) Connector	
Baud Rate (Max)		115 Gbaud/s	
Small Signal Bandwidth (-6 dB)		100 GHz	Linear, Analog Response
Low Frequency Cutoff (Max)		100 kHz	
System Linearity		<3.5% THD[d] for <500 mVpp Input	At 1 GHz
		<3.5% THD[d] for <600 mVpp Input	At 10 GHz
Amplifier RF Input		0.5 V_{pp}	1 V_{pp} Absolute Max RF
Amplifier Gain		11 dB	Small Signal
Amplifier DC Input (Max)		±5 V	Input is AC Coupled
Modulator RF V_π	**MX100E**	3.3 V_{pp}	At 1 MHz
		3.7 V_{pp}	At 2 GHz
	MX100E-1310	2.5 V_{pp}	At 1 MHz
		2.8 V_{pp}	At 2 GHz
Optical Insertion Loss[e]		11 dB	From LASER IN to OPTICAL OUT
Fiber Type		PM1300-XP (Loopback Fiber) SMF-28 (OPTICAL OUT)	

a. When using internal laser and supplied loopback cable, the output power can be reduced by using the internal VOA.
b. Output power is typically 3 dB lower when bias is set at quadrature point.
c. Using the modulator at another wavelength (e.g. visible light) may cause an increase in insertion loss and will void the warranty.
d. Total Harmonic Distortion
e. At Peak Bias

1.4.3 Power and Environmental Specifications

Parameter	Min	Max
Main AC Voltage	100 VAC	250 VAC
Power Consumption	-	60 VA
Line Frequency	50 Hz	60 Hz
Operating Temperature	10 °C	40 °C
Storage Temperature	0 °C	50 °C
Relative Humidity[f]	5%	85%

1.4.4 Internal Control Specifications

Parameter	Typical	Notes
Power Monitor Calibration Wavelength	1550 nm	MX100E
	1310 nm	MX100E-1310
Power Monitor Accuracy	±0.5 dBm	Each Monitor, At Calibrated Wavelength
Power Monitor Resolution	0.01 dBm	Each Monitor
Power Monitor Insertion Loss	0.1 dB	Per Monitor
VOA Attenuation Range	1 dB to 20 dB	-
VOA Response Time	1 s	-

f. Non-Condensing Environment

1.4.5 Tunable Laser Specifications

Tunable laser specifications for MX100E.

Parameter	Unit	Min	Typ.	Max
Optical Output Power	dBm	-	17	-
Frequency Range	THz	191.50	-	196.25
Wavelength Range	nm	1527.6	-	1565.5
Frequency Accuracy	GHz	-1.5	-	1.5
Tuning Resolution	GHz	-	50	-
Tuning Speed (Between Wavelengths)	s	-	10	-
Fine Tuning Resolution	MHz	-	1	-
Fine Tuning Speed	GHz/s	-	1	-
Fine Tuning Range	GHz	-30	-	30
Side Mode Suppression Ratio (SMSR)	dB	40	55	-
Optical Signal to Noise Ratio (OSNR)	dB	40	60	-
Intrinsic Linewidth	kHz	-	10	15
Relative Intensity Noise (RIN)	dB/Hz	-	-	-145
Back Reflection	dB	-	-	-14
Polarization Extinction Ratio (PER)	dB	18	-	-

1.4.6 Fixed-Wavelength Laser Specifications

Fixed-wavelength laser specifications for MX100E-1310.

Parameter	Unit	Min	Typ.	Max
Optical Output Power	dBm	-	17	-
Wavelength	nm	-	1310	-
SMSR	dB	-	45	-
Intrinsic Line Width	MHz	-	-	10
PER	dB	-	20	-

1.4.7 Graphs

A typical frequency response for each transmitter is plotted below in Figure 2. The phase response is not shown.

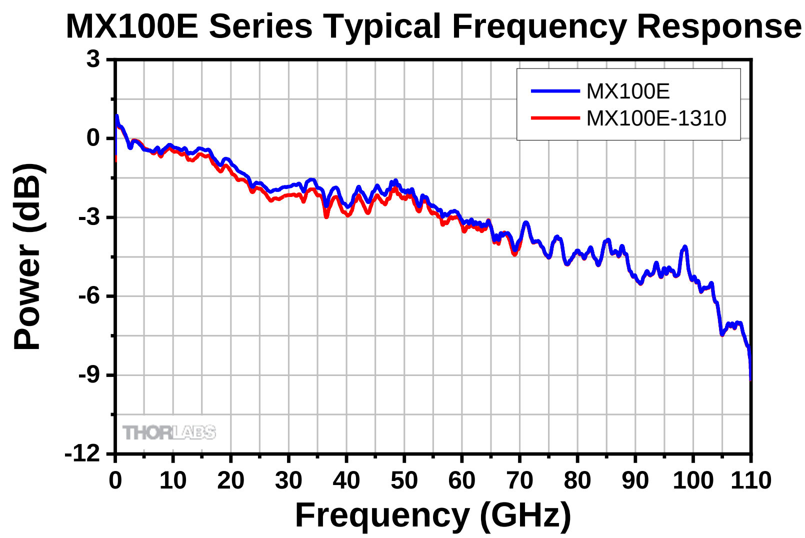


Figure 2 MX100E Series Typical Frequency Response

Figure 3 shows laser frequency noise as a function of optical frequency when the laser is operated with and without dither enabled. The red trace shows low noise operation when dither is turned off. Wavelength stability is improved by operating with dither, but the blue trace shows that this comes at the expense of added noise.

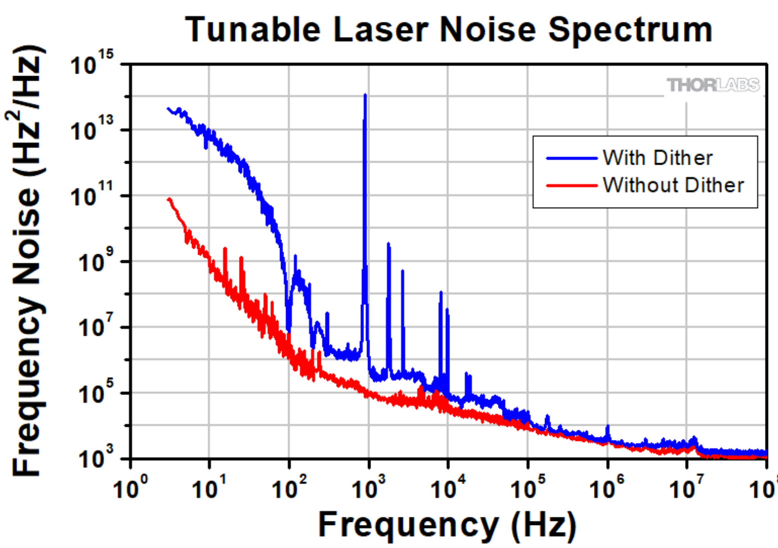


Figure 3 FM Noise Spectrum of the laser with and without dither. Wavelength stability is improved with dither but at the expense of adding noise (blue line). The red line shows Low Noise operation with dither turned off.

1.4.8 Mechanical Drawing

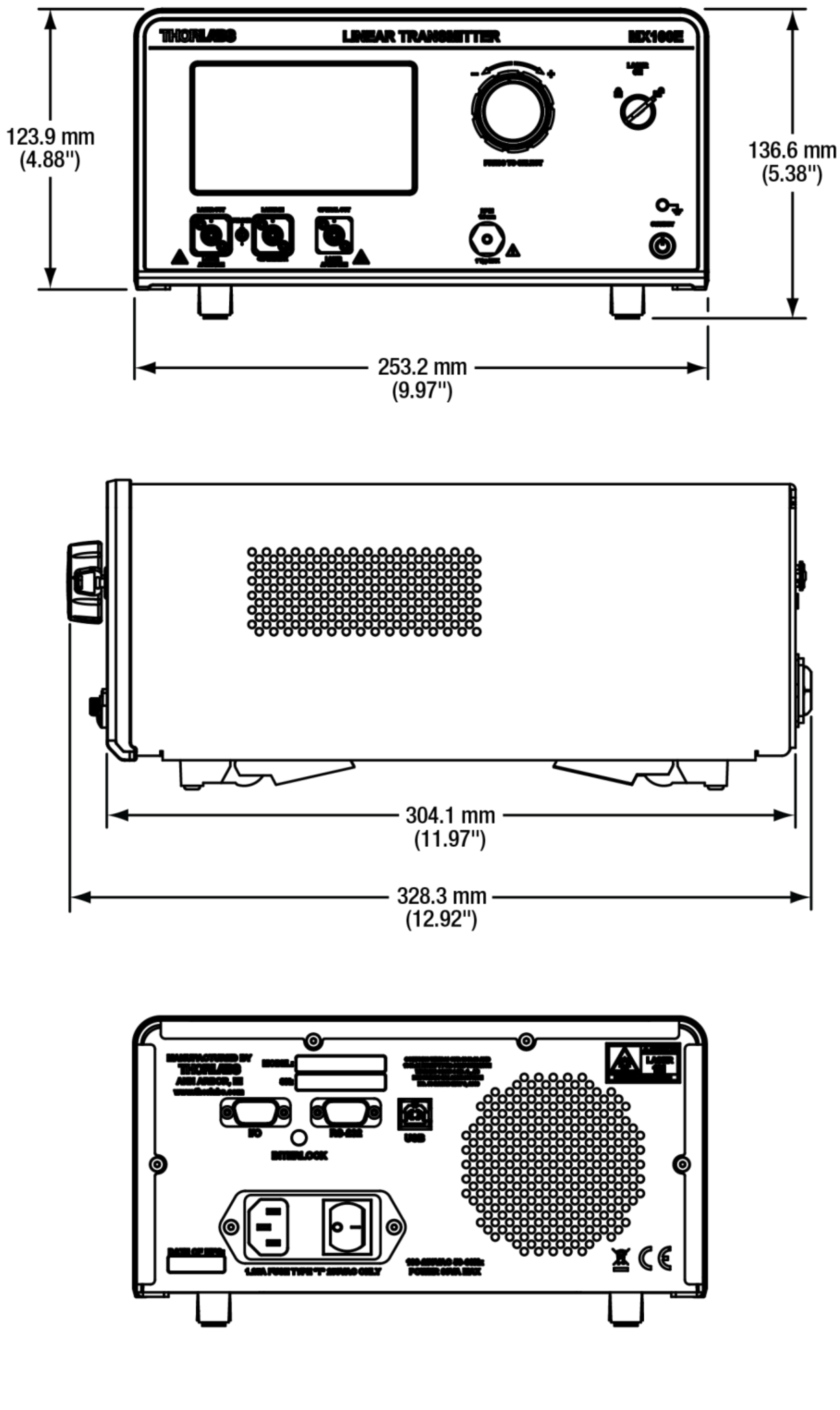


Figure 4 Linear Transmitter Mechanical Drawing

1.5 Components

1.5.1 Front and Back Panel Overview

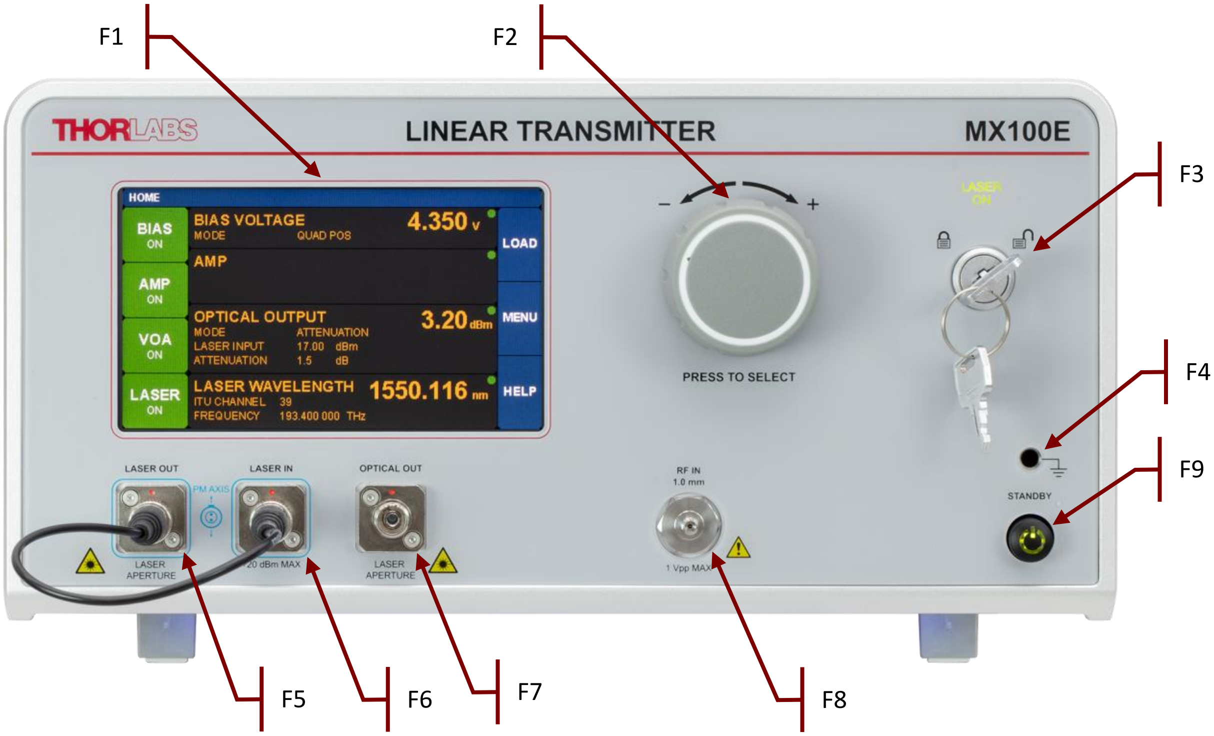


Figure 5 Front Panel

Callout	Description
F1	Touchscreen Display
F2	Adjustment Knob
F3	Key Switch and Indicator 🔒 Lasing Disabled; 🔓 Lasing Enabled
F4	Grounding Jack (Banana Connector) ⏚ Earth Ground
F5[a]	Laser Output (PM FC/PC Connector)
F6[a]	Laser Input (PM FC/PC Connector)
F7[b]	Optical Output (FC/PC Connector)
F8	Amplifier RF Input (1.0 mm Connector)
F9	Standby Button

a. Uses PANDA Fiber for Internal Connection
b. Uses SMF-28-Compatible Fiber for Internal Connection

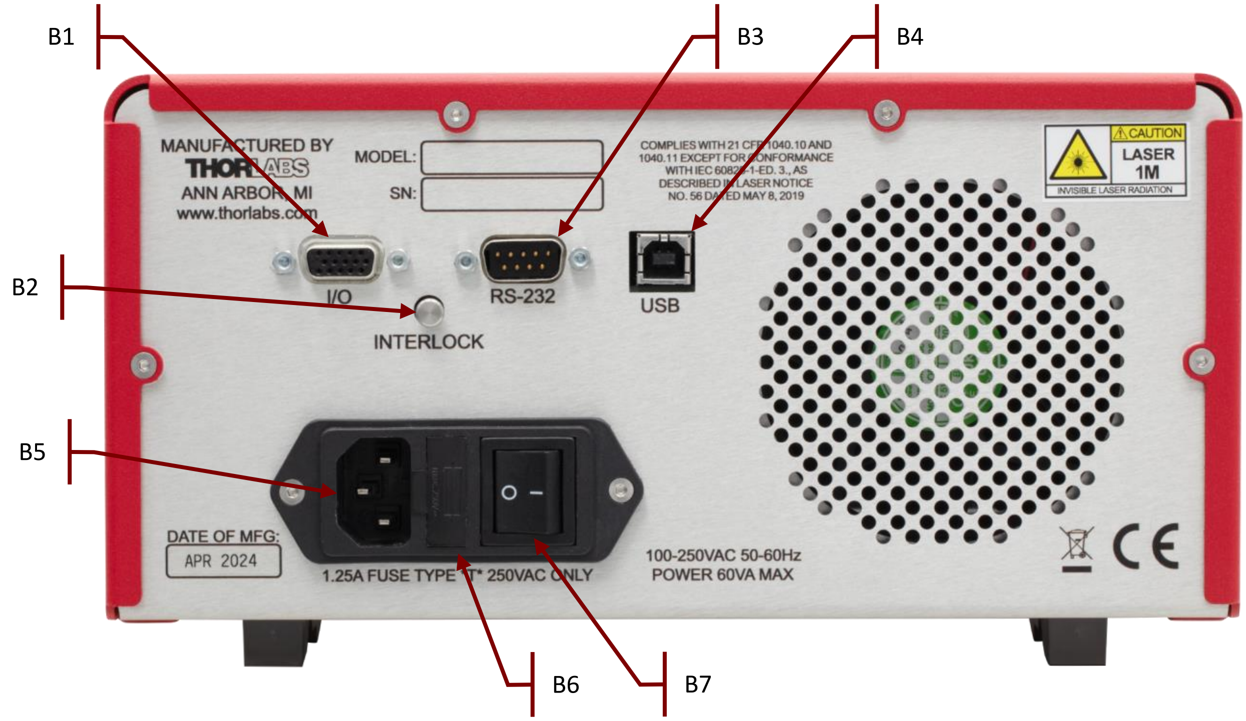


Figure 6 Back Panel

Callout	Description
B1	I/O Port (HD-DB15 Connector, Female)
B2	Laser Interlock (2.5 mm Mono Phono Jack)
B3	RS232 Port (DB9 Connector, Male)
B4	USB Port (USB Type B Connector)
B5	Power Connector
B6	Fuse Tray
B7	Power Switch **I** Supply On; **O** Supply Off

1.6 Simplified Declaration of Conformity

The full text of the EU declaration of conformity is available at the following internet address:

https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=13436

1.7 FCC Designation

The following statement applies to the products covered in this manual, unless otherwise specified herein. The statement for other products will appear in the accompanying documentation.

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not

installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
—Reorient or relocate the receiving antenna.
—Increase the separation between the equipment and receiver.
—Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
—Consult the dealer or an experienced radio/TV technician for help.

This product has been tested and found to comply with the limits according to IEC 61326-1 for using connection cables shorter than 3 meters (9.8 feet).

Thorlabs is not responsible for any radio television interference caused by modifications of this equipment or the substitution or attachment of connecting cables and equipment other than those specified by Thorlabs. The correction of interference caused by such unauthorized modification, substitution or attachment will be the responsibility of the user. The use of shielded I/O cables is required when connecting this equipment to any and all optional peripheral or host devices. Failure to do so may violate FCC and ICES rules.

Chapter 2 Safety

All statements regarding safety of operation and technical data in this instruction manual will only apply when the unit is operated correctly. If equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired. Only with written consent from Thorlabs may changes to single components be carried out or components not supplied by Thorlabs be used.

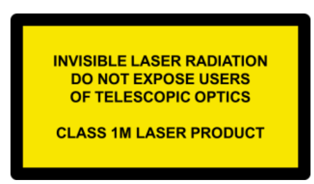
⚠WARNING

Risk of Electrical Shock
Before applying power to the instrument, make sure that the protective conductor of the 3 conductor mains power cord is correctly connected to the protective earth contact of the socket outlet. Improper grounding can cause electric shock with damage to your health or even death. Only use mains cable with sufficient current and voltage ratings for this instrument. The local supply voltage must be in the range specified on the rear panel, and the correct fuse must be installed in the fuse holder. If not, please replace the main fuse (see Chapter 5). Do not position equipment in a way that makes it difficult for the user to operate the disconnecting device. Do not remove covers. Refer servicing to qualified personnel.

Risk of Explosion
The instrument must not be operated in explosion endangered environments.

Laser Radiation
Avoid Exposure - Radiation emitted from apertures. Do not look into the laser aperture while the laser is on. Injury to the eye may result. Laser should not be turned on unless there is an optical fiber connected to the laser output port.

Caution - Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.



NOTICE

ESD Sensitive Component
The components inside this instrument are ESD sensitive. Take all appropriate precautions to discharge personnel and equipment before making any connections to the unit. A front panel grounding jack is provided for connection to a wrist strap.

Components not Water Resistant
This instrument should be kept clear of environments where liquid spills or condensing moisture are likely. It is not water resistant. To avoid damage to the instrument, do not expose it to spray, liquids, or solvents.

Follow Intended Usage Guidelines
Inputs and outputs must only be connected with shielded connection cables.

Do not obstruct air ventilation slots in housing.

Mobile telephones, cellular phones, or other radio transmitters are not to be used within the range of three meters of this unit since the electromagnetic field intensity may then exceed the maximum allowed disturbance values according to IEC 61326-1.

Chapter 3 Installation

3.1 Warranty Information

This precision device is only serviceable if returned and properly packed into the complete original packaging including the complete shipment plus the cardboard insert that holds the enclosed devices. If necessary, ask for replacement packaging. Refer servicing to qualified personnel.

3.2 Packing List

Inspect the shipping container for damage. If the shipping container seems to be damaged, retain it until all contents have been inspected and the unit has been mechanically and electrically tested. Verify receipt of the following items:

- Linear Transmitter Main Unit
- Power Cord According to Local Power Supply
- PM Loopback Fiber Optical Cable
- Interlock Keys
- 2.5 mm Interlock Pin (in Back Panel)
- 1.25 A 250 VAC Fuse (Spare)
- USB Type A to Type B Cable, 6' Long
- 1.0 mm Non-Shorting Dust Cap (For RF Connector)

3.3 Unpacking Instructions

Exercise caution when unpacking the instrument as it contains sensitive electronic and optical components. A simple shipping inventory should be performed when unpacking to ensure all parts mentioned in Section 3.2 are present and accounted for before beginning the installation process.

3.4 Installation Instructions

MX100E series instruments require roughly 9.8" x 12.7" (24.9 cm x 32.3 cm) of table space, not including clearance for mating optical or electrical cables. In addition, the instrument has air intakes on the bottom, left, and right sides of the enclosure, which are perforated to permit air flow. An outlet fan is located at the rear of the enclosure. Allow at least an additional 3" (7.6 cm) on each side of the instrument for proper air circulation.

3.4.1 Hardware Set Up

1. For first use, plug the main power cable into the back panel connector, and then plug the other end into an AC wall receptacle.
2. Flip the power switch on the back panel to the ON (I) position. The unit will now be in the "Standby" mode, and the front panel standby button should glow amber.

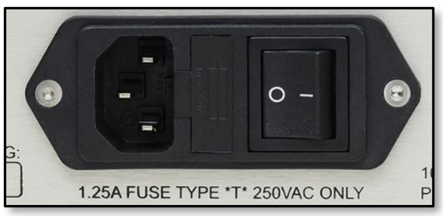


Figure 7 Power Cable Port, Fuse, and Power Switch

Figure 8 Indicator Glows Amber When Instrument is in Standby

3. Attach the PM loop-back fiber optic cable between the LASER OUT and LASER IN FC connectors on the front panel. Be sure to clean both ends of the fiber as described in the Maintenance Section of this manual.

Figure 9 PM Loopback Fiber Cable Installed

4. Insert the key into the interlock switch and turn it towards the unlock symbol (🔓). This allows the laser to be turned on, but the LASER ON indicator will not glow green until the laser is turned on by the touchscreen button.
5. Turn on the unit by pressing the amber standby button on the front panel which will then turn green to indicate the unit is fully on. The touchscreen display will come up with a splash screen for about 5 seconds and then go to the home page. The unit will initialize in the factory default state with all functions OFF.

Figure 10 Interlock Key Switch

Figure 11 Indicator Glows Green When Instrument is Fully Enabled

3.4.2 Controls on the Home Page

Full access to all of the transmitter's controls and functions is available using the resistive touchscreen display, which is sensitive to finger pressure or the tap of a plastic stylus. In addition, the knob on the front panel can be used in place of the on-screen arrow buttons for quickly changing set-point values. Pressing (clicking) the knob will confirm a new set-point value.

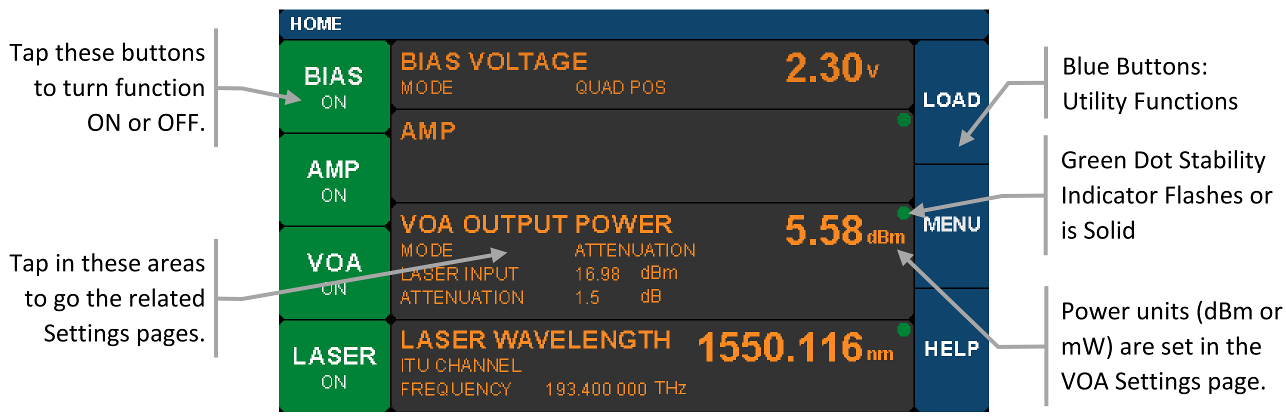


Figure 12 Home Screen Features

The Home screen (or dashboard) is organized into three main sections.

The left side contains the ON/OFF buttons for each of the main instrument functions. Tapping any of these buttons will toggle the function on and off. The same ON/OFF functionality is also available on the individual Settings pages. The function button turns green to indicate the function is ON and turns red to indicate the function is disabled.

The center section on the main dashboard is for reporting operational values of each section. Tapping the screen in this middle area will take the user to the corresponding Settings page for each section. Note that the green dot in each of these sections indicates the function is stable. A blinking green dot indicates the function is still stabilizing.

The right side of the screen provides access to the main utility functions of the box.

The screen shot below shows some of the common warning indicators on the HOME page. Some functions may be disabled when the laser input power is low. In this case, function buttons will be disabled and warnings indicators will appear.

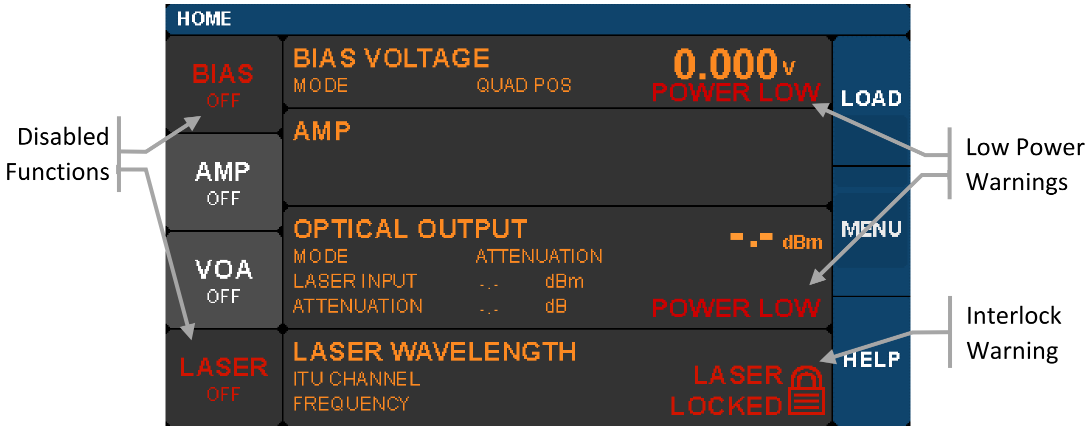


Figure 13 Home Screen Warnings and Indicators

3.4.3 Controls on the Settings Pages

The Settings pages all possess the same general design and functionality as shown in the example screen shot below. The upper section with white letters displays the parameters that can be changed. Simply tap on the parameter of interest. A yellow border highlights the choice and controls for that parameter are presented.

The lower section with amber letters displays selected related values convenient to monitor from the page.

The right-hand column provides the controls for changing the values for the selected parameters. The main control knob on the front panel can also be used to adjust and confirm selected values. The screen shots below show examples of the touchscreen controls.

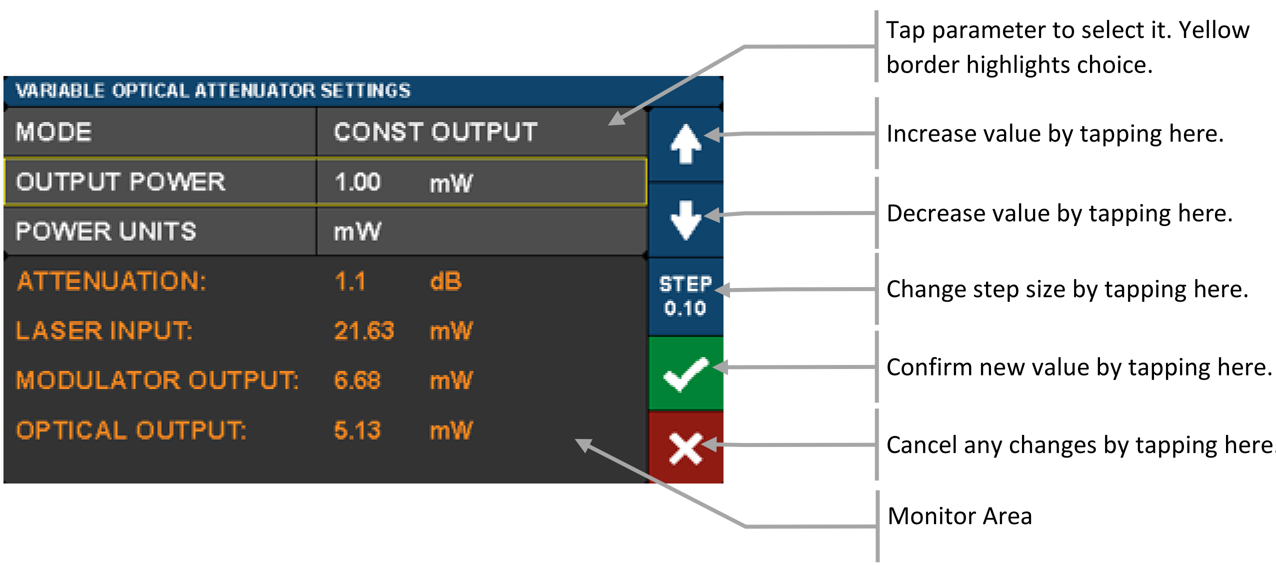


Figure 14 Setting Parameter Values: Design and Functionality of the Settings Pages

Fields that have adjustable values will show a flag if the minimum or maximum values have been reached. These are set by firmware at the factory.

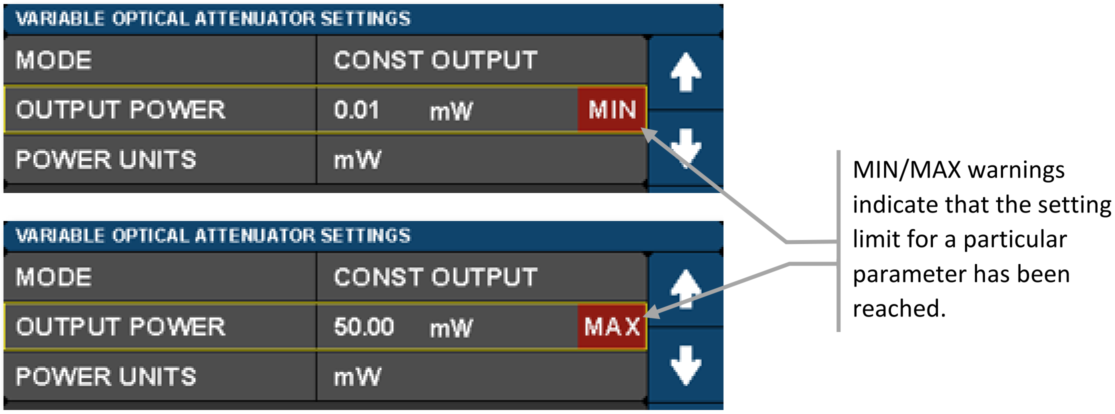


Figure 15 MAX and MIN Warnings Indicate Parameter's Upper or Lower Setting Limit Reached

3.4.4 Quick Start

The following steps summarize the setup procedure required to operate the transmitter in the standard mode. Please refer to previous sections in this chapter and the expanded operating instructions in Chapter 4 for additional information.

1. Turn on power to the transmitter via the power switch on the back panel (Figure 7).
1. Press and hold the standby button on the front panel until the indicator light changes from amber to green (Figure 8 and Figure 11).
2. Turn the key switch to unlock (Figure 10).
3. Turn the laser on by tapping the LASER touchscreen button on the Home page (Figure 12).
    a. LASER touchscreen button changing from grey to green indicates Laser On command has been received.
    b. Front panel LASER ON indicator illuminates green to indicate the laser has power and is on.
    c. Flashing green dot above laser wavelength in Laser section on the Home page indicates the laser is stabilizing (i.e. not yet settled at optical power/frequency setpoint). Solid green dot indicates that the laser is stable.
4. Enable the bias controller by tapping the BIAS touchscreen button on the Home page (Figure 12). Wait for completion of the calibration process. The instrument will enable the default Quadrature mode with positive slope bias point (Section 4.3).
5. Take note of the output power, which is shown in the center right section of the Home page (Figure 12).
6. Turn on the VOA controller to adjust output power, if desired, by tapping the VOA touchscreen button on the Home page (Figure 12 and Section 4.4).
7. Apply the input RF signal to the female 1.0 mm connector on the front panel (Figure 5) noting the specified limits for a linear response (Section 1.4.2).
8. Turn on the amplifier by tapping the AMP touchscreen button on the Home page (Figure 12).

NOTICE **The female 1.0 mm connector on the front panel is a very sensitive input, connected directly to the 100 GHz amplifier. Be very careful with this connector.**

i. Be sure the input cable is discharged before attaching it to the connector.

ii. Do not overtighten the connection. Tighten connections using a standard 4 lb-in torque wrench design for 1.0 mm coaxial connectors.

iii. Make sure the cable is properly supported to avoid any stress on the connector.

iv. Observe the maximum input voltage listed in Section 1.4.2.

Figure 16 The MX100E Linear Transmitter

3.4.5 Safe Shutdown

The following steps summarize the shutdown procedure required to provide a controlled, internal power-down sequence for the electronics, particularly when shutting down from a state when modulator bias is enabled.

1. If modulator bias is off, skip to step 4.
2. Turn modulator bias off by pressing the button on the touchscreen display.
3. A status message and status bar will appear on the screen indicating that the modulator bias voltage is ramping down (Figure 17). **DO NOT** proceed until this message leaves the screen.
4. Press the standby button on the front panel until the indicator light changes from green to amber and the screen turns off.
5. Switch off the main power on the back panel.

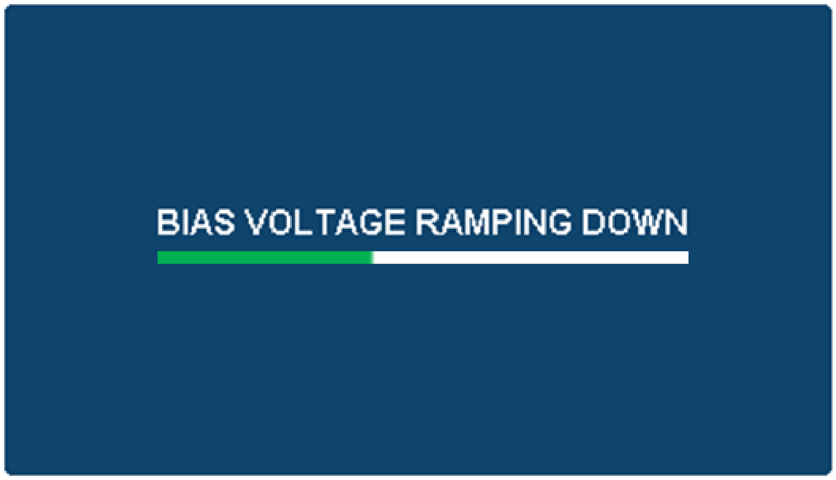


Figure 17 Bias Voltage Ramping Down Status Message

Chapter 4 Operating Instructions

4.1 The Modulator Transmission Function

The Mach-Zehnder modulator (MZM) has a repetitive transmission function with applied voltage as can be seen in the diagram below. For the MZM to work correctly, a DC bias voltage must be applied and maintained at the desired set point. The high-frequency AC signal can then be applied to the modulator to enable the correct optical modulation of the laser beam. The most common operating points are the peak, null, and quadrature points as shown below.

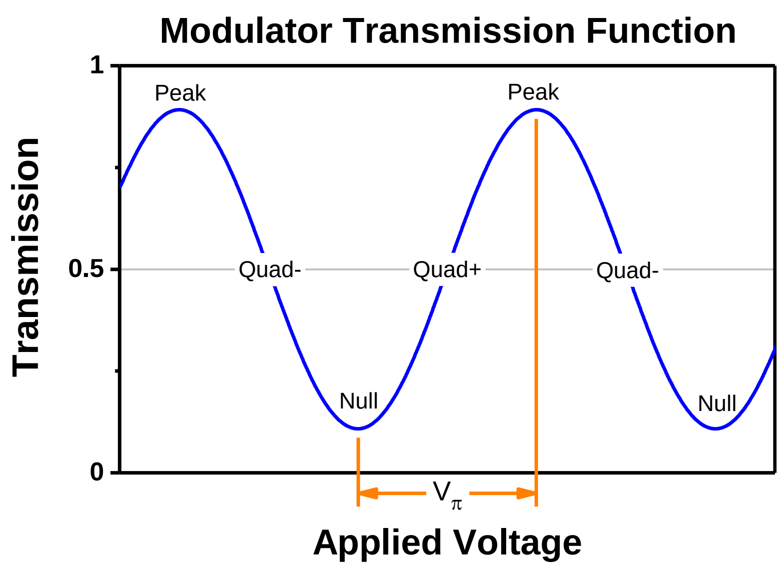


Figure 18 Bias Points on the Modulator Transmission Function

Note that a real transmission function does not go perfectly from 0% to 100%. This is characterized by the Extinction Ratio of the modulator (Peak power / Null power). The efficiency of the modulator is also characterized by V_π, which is defined as the voltage necessary to change the transmission from Null to Peak. The most linear response of the modulator is achieved by biasing it at one of the Quadrature points where the transmission is closest to 50%. Some non-linear, frequency doubling, and phase modulation applications require biasing at the Null or Peak.

The purpose of the Bias settings (Section 4.3) is to hold the modulator at the chosen operation point. Active control of the MZM bias point is essential, as the modulator is temperature sensitive and will drift over time. Without active control, the optimal bias point for a linear response can drift, causing non-linear artifacts and frequency doubling to appear in the optical output.

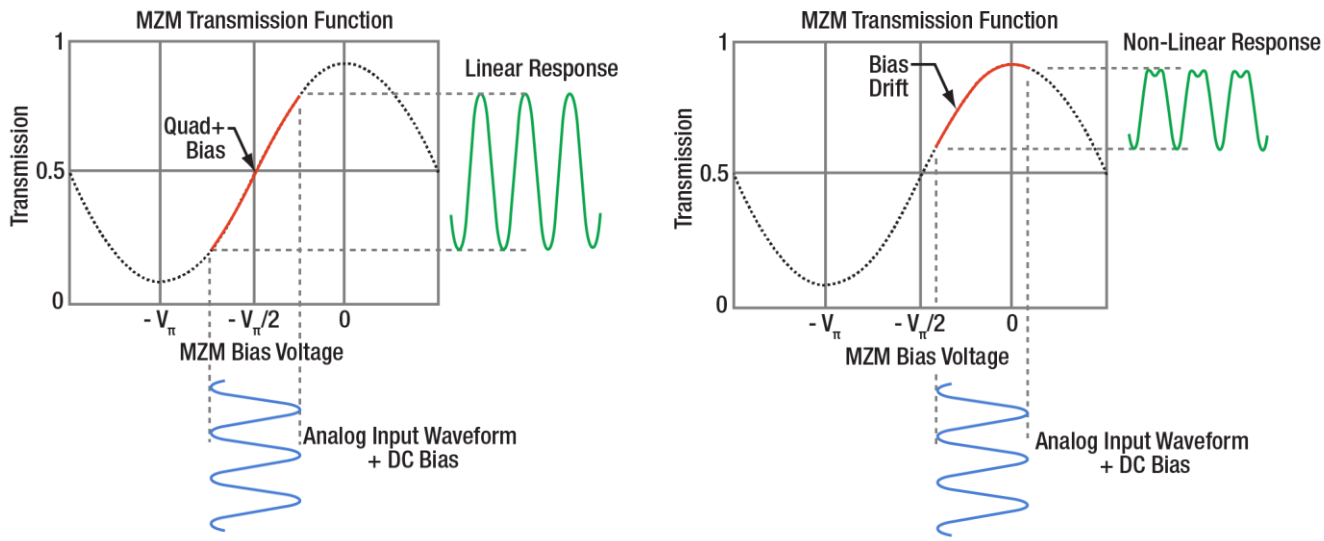


Figure 19 (Left) The linear response observed when MZM is biased at the optimal positive quadrature point. (Right) Without active control, the thermal shift in the MZM transmission function results in a non-linear response.

The Peak and Null modes use a dither tone as part of a lock-in control scheme to keep the MZM bias stable. The dither tone allows the control algorithm to track the drifting but at the cost of decreased signal-to-noise ratio (SNR) due to the injection of a single frequency tone into the MZM bias.

4.2 Control Loop Diagram

The following diagram shows the control loops added to the block diagram. From this diagram, the user can see how the power monitors and VOA are used to provide stability and control to the whole system. It will be helpful to refer to this diagram to gain a better understanding of the functionality of the unit as described in the upcoming sections of the manual.

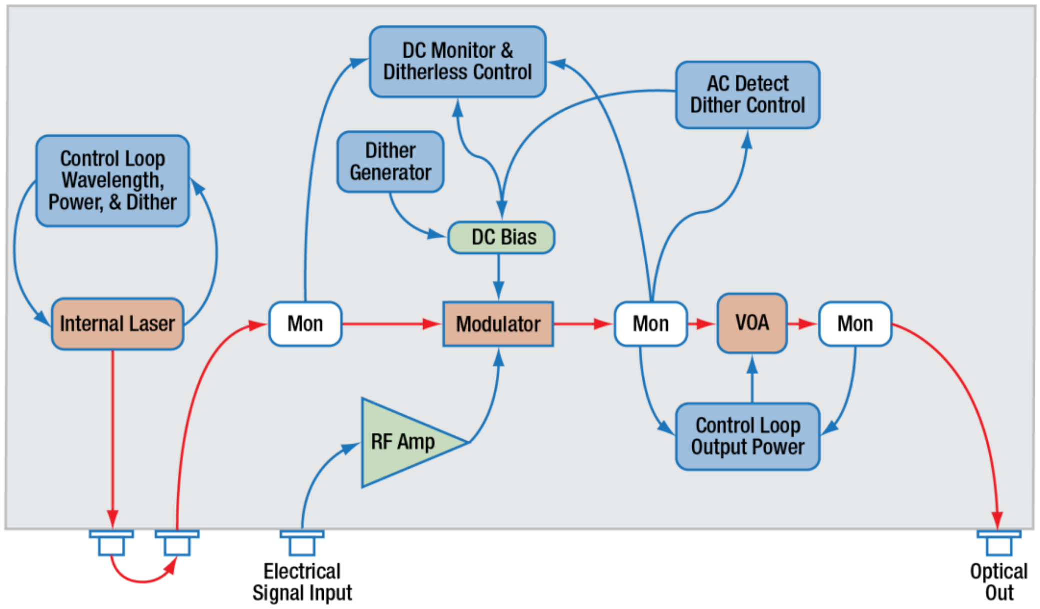


Figure 20   Block Diagram of the MX100E Transmitter Showing Control Loops

4.3 Bias Settings Page

The Bias Settings page is accessed by tapping the center bias monitors pane on the Home page. When the MZM Bias control is first turned on, the MX100E transmitter performs a calibration routine to determine the approximate bias voltages required for the various MZM operating points. This allows the instrument to switch between bias modes quickly and effectively. The user may perform this calibration anytime by pressing the Reset Auto Bias button on the right side of the Bias Settings page. This button is not available if the Bias is off or in Manual mode. Note that during calibration routines, changing bias modes, and briefly after enabling/disabling bias (i.e. any time the bias voltage setpoint is under automatic control), the VOA in the instrument is configured for maximum attenuation to protect a downstream optical component from inadvertent optical overload during the bias transition sweep. 'Attenuation protection measures' are not active when bias is disabled or in Manual Bias mode.

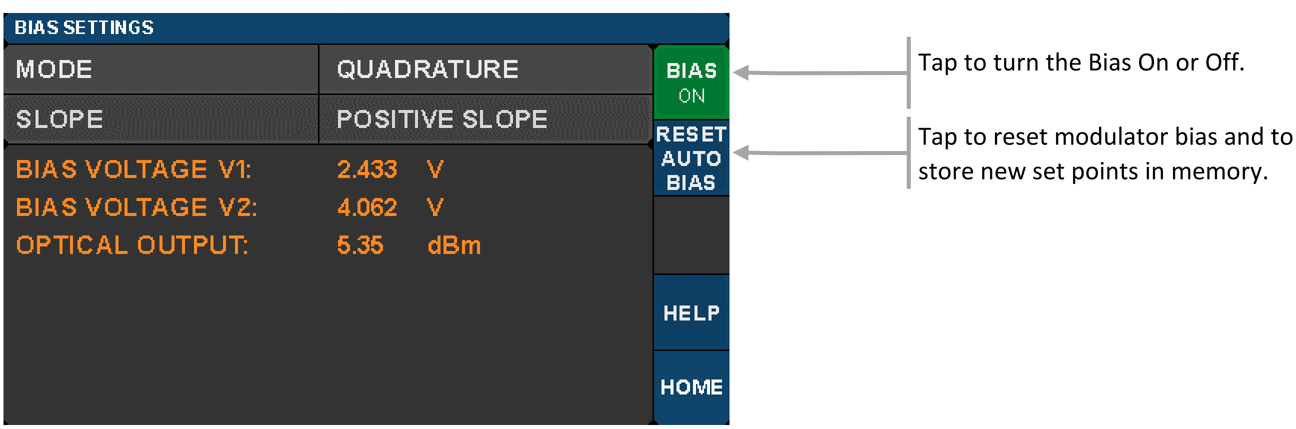


Figure 21   Bias Settings Home Screen

The Bias Settings page contains the settings for controlling the modulator bias and operating modes. There are four modes for MZM bias control: 1) Quadrature, 2) Peak, 3) Null, and 4) Manual. The screen shot in Figure 22 is an example of the information presented and the controls available when the Mode field is selected while the controller is operating in Quadrature mode. The blue buttons enable switching between modes.

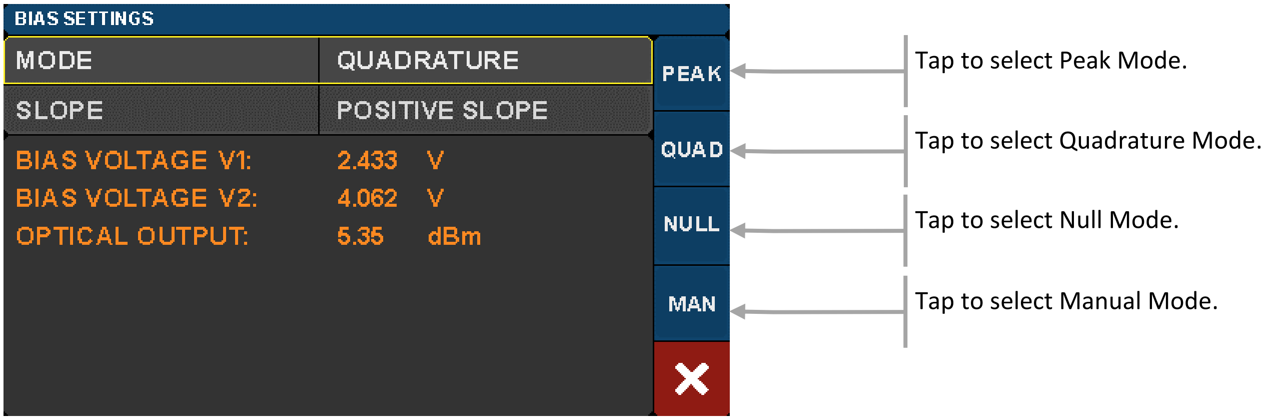


Figure 22 Bias Settings Screen to Select Operating Mode

Note that on MX100E series transmitters, two bias voltages are displayed on the Bias Settings pages: Bias Voltage V1 and Bias Voltage V2. The modulators internal to MX100E instruments have two DC bias ports for controlling a thermo-optic phase shifter in each arm of the MZM. Bias Voltage V1 and Bias Voltage V2 are controlled synchronously to maintain the desired operating point.

4.3.1 Quadrature Mode

Quadrature is the default mode and biases the MZM at the 50% point on the MZM transmission curve shown in Figure 19. Quadrature mode is recommended for digital signals such as On-Off-Keying (OOK) that require a high extinction ratio.

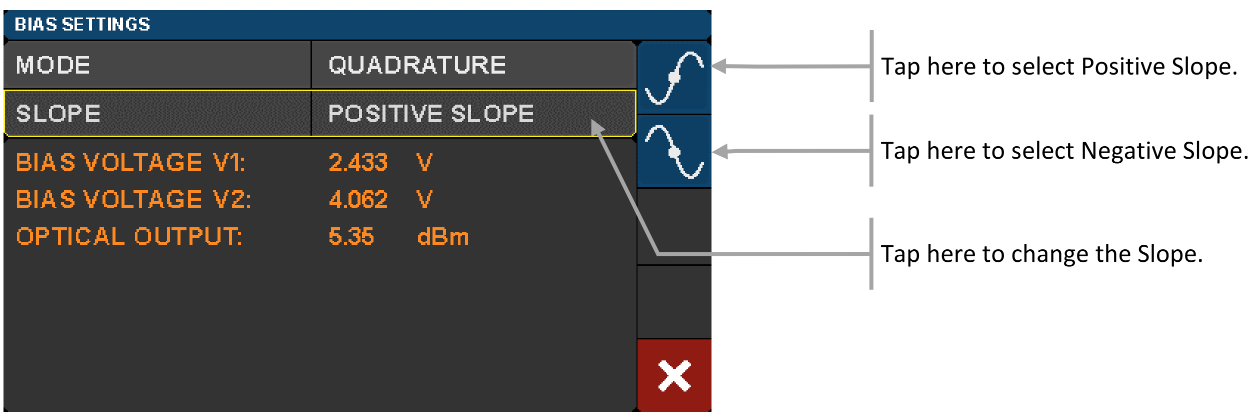


Figure 23 Locate Bias Point on Positive or Negative Slope

Quadrature mode also allows the user to select between two operating points by selecting the Slope field. Positive slope is the non-inverting operating point where increasing voltage on the MZM results in increasing optical output power. Negative slope is the inverting operating point where increasing voltage on the MZM results in decreasing optical output power. This effectively changes the phase of the response function.

On MX100E series transmitters, quadrature mode is achieved by maintaining a modulator input to output ratio that is twice as high as the peak modulator input to output ratio found during the calibration routine. This mode functions exactly as described for Manual Constant Ratio in Section 4.3.4, except the setpoint is calculated during the calibration routine and not user adjustable. Since quadrature mode is input to output ratio driven, if optical power on the Laser In port changes after the initial calibration routine has been run, it is recommended to reset the bias calibration by pressing the "Reset Auto Bias" button (Figure 21) to ensure expected operation.

4.3.2 Peak Mode

The Peak Mode adjusts the DC bias voltage so the transmission is centered at a nearby transmission maximum.

Peak and Null modes are often used to obtain phase modulation and non-linear frequency doubling. The optical phase is 180° shifted on opposite sides of the Null point.

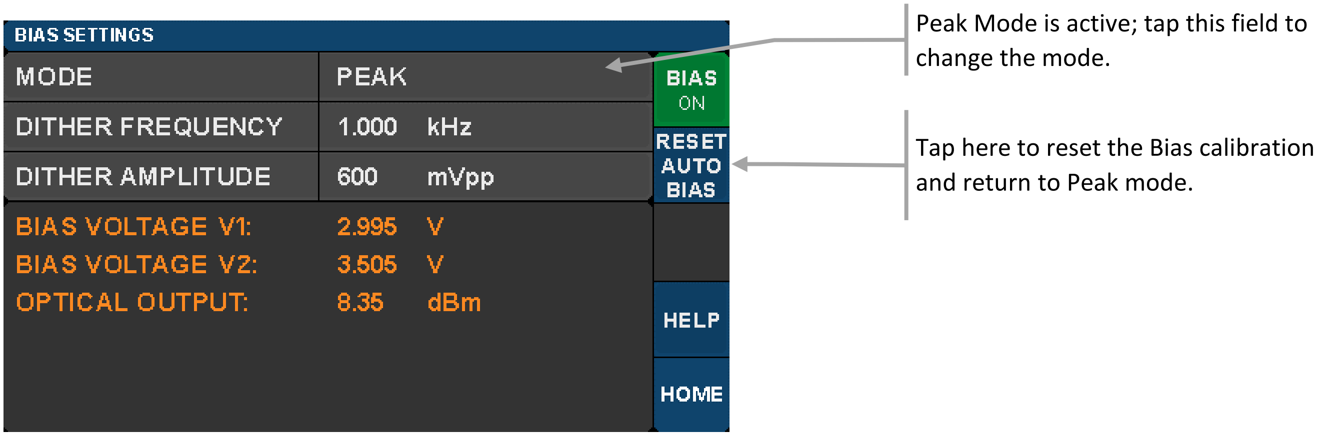


Figure 24 Peak Mode Settings

The bias control circuit uses an AC dither tone to stabilize the bias point of the modulator. A small AC voltage is applied to the DC bias so that the optical output is also slightly modulated. Both the amplitude and the frequency of AC dither tone can be selected by the user. The modulated optical output is detected by a frequency and phase sensitive detector, which can then interpret whether the DC bias is at the correct level for the chosen set-point (Peak or Null). The DC bias voltage is then continuously adjusted to maintain the correct set-point.

The frequency of the dither tone will not exceed 10 kHz. This frequency limit, which is usually well below the low frequency cut-off for the RF signal of interest, is chosen to prevent interference. As described in the following, the dither tone can also be disabled if other methods of bias control are desired (e.g. manual or ratio control).

The dither tone frequency may be changed by tapping the Dither Frequency field, which is highlighted in Figure 25. Standard frequencies are selected using the blue buttons, or a custom frequency may be chosen by pressing User Define. The dither tone frequency usually has very little effect on the accuracy of the bias control, but in some cases a different frequency may work better or be desirable depending on the RF signal applied or on the specific application. The User Define button allows for the selection of an arbitrary frequency between 1 kHz and 10 kHz with 1 Hz resolution.

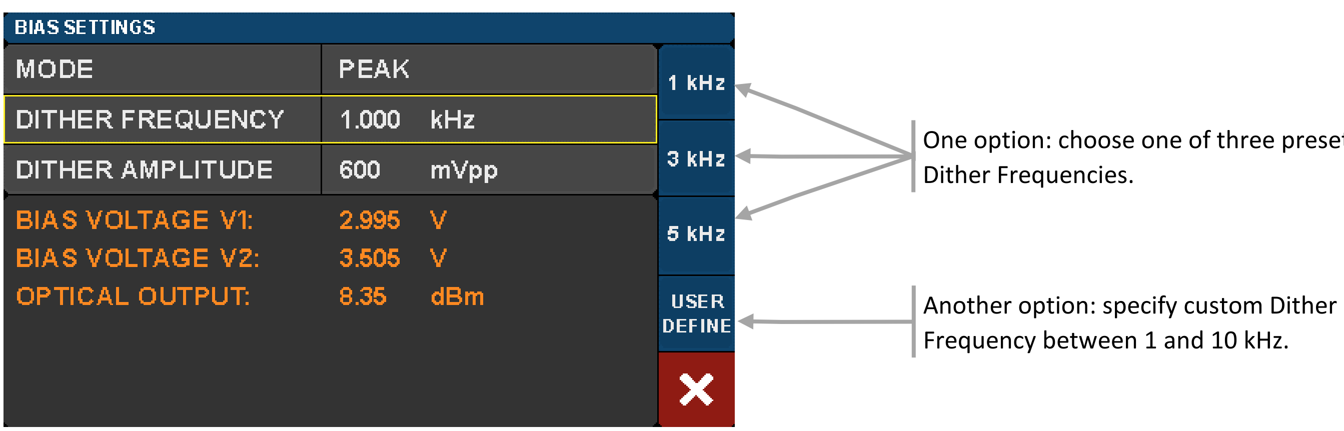


Figure 25 Dither Frequency Selection while Peak Mode Enabled

The dither tone amplitude can also be adjusted to any amplitude between 20 mV and 2 V with 1 mV resolution by tapping the Dither Amplitude field highlighted in Figure 26. Higher amplitudes will typically be more stable in the presence of MZM drift and broadband RF signals, but larger dither tones also decrease SNR. If the amplitude is too low, the MZM bias may not stay locked. Typically, a value from 300 mV to 500 mV is a good starting point.

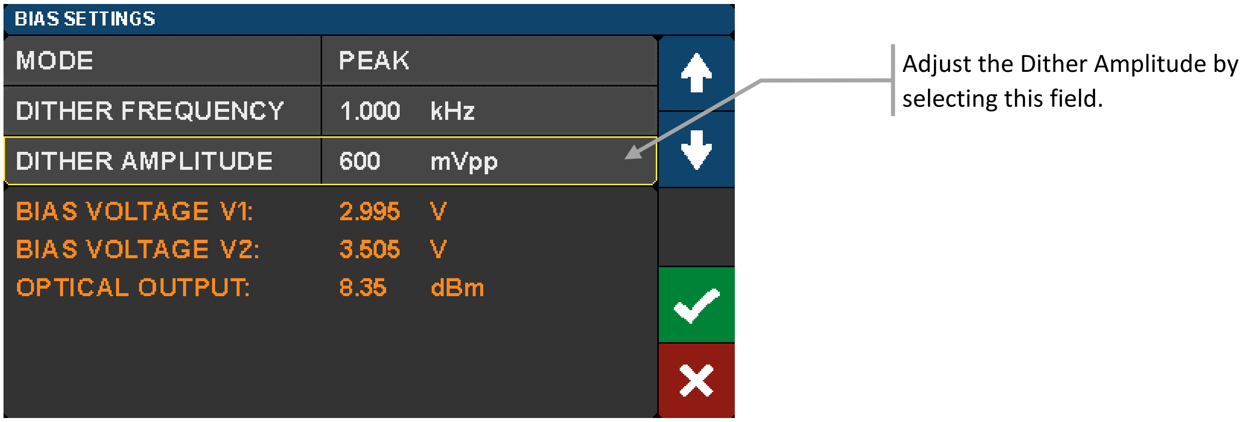


Figure 26 Dither Amplitude Adjustment

4.3.3 Null Mode

The Null Mode adjusts the DC bias voltage so the transmission is centered at a nearby transmission minimum. In the Null mode only dither frequency and amplitude settings are available. These settings are the same as previously described for the Peak mode.

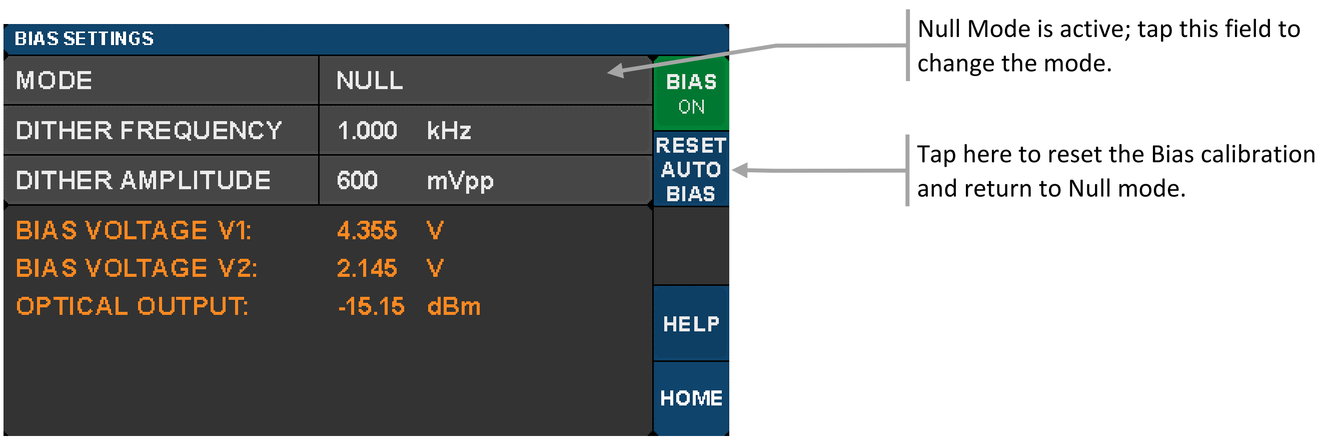


Figure 27 Null Mode Settings

4.3.4 Manual Mode

The Manual mode allows the user to bias the modulator at any desired point of the transmission function. Manual mode offers two operation options: 1) Constant Bias, or 2) Constant Ratio. In both of these options, the dither function is not active, and the controller uses different techniques to hold the bias steady. The desired option is chosen by selecting the HOLD field.

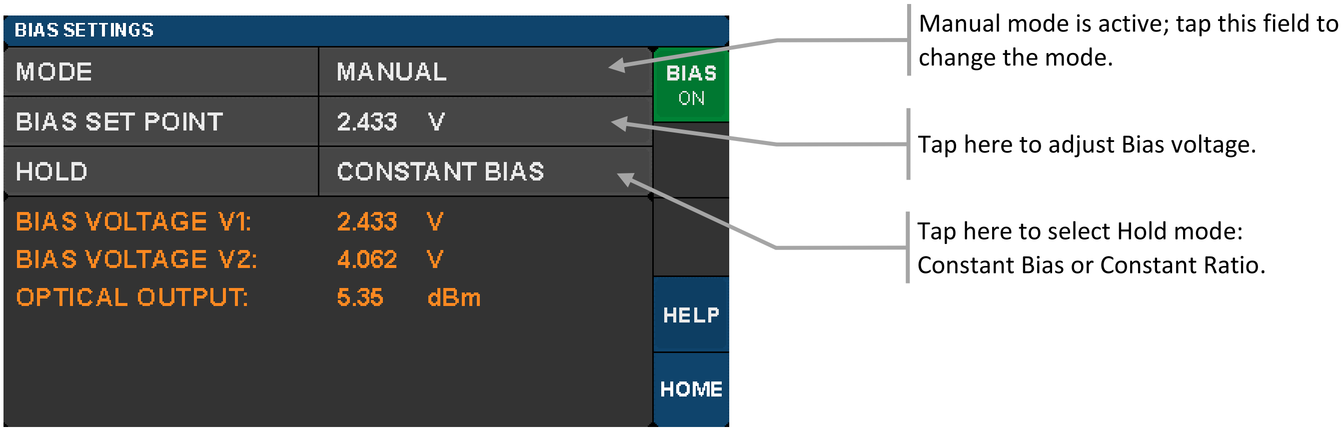


Figure 28 Constant Bias Manual Mode Settings

Constant Bias is the most basic mode of operation and will apply a user selected DC voltage to the MZM bias ports. This can be useful for performing brief measurements that only take a few minutes. During longer duration experiments, the MZM is more likely to drift. In Constant Bias mode, Bias Voltage V1 is the only controllable voltage. Bias Voltage V2 will adjust equally and in the opposite direction to maintain expected operation.

Constant Ratio works by holding the MZM ratio of input light (at Mon-1) to output light (at Mon-2), see Figure 1 for reference, at a constant value (typically at or close to Quadrature). Note that Constant Ratio does NOT take into account the insertion loss (IL) of the MZM. Therefore, the user must have some knowledge of the IL between Mon-1 and Mon-2, which is equivalent to the IL of the modulator. For example, if the modulator has an IL of 3 dB, then the I/O ratio at maximum transmission is already 2:1. To bias the modulator at the 50% point, the ratio must be doubled to 4:1. The MZM insertion loss is listed in the specifications.

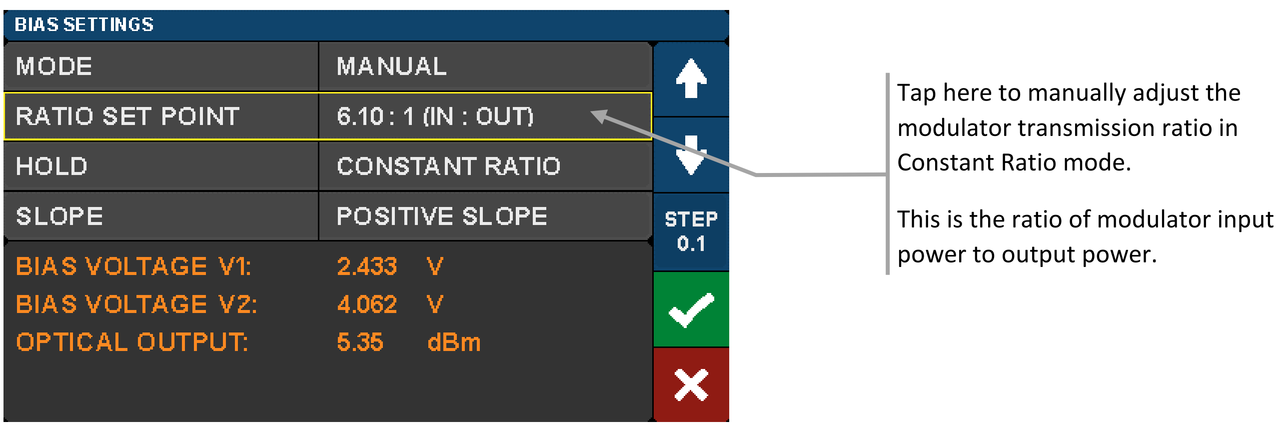


Figure 29 Constant Ratio Manual Modes Settings

In the Constant Ratio mode there is an option to select between the two available operating regions by selecting the Slope field. Positive slope is the non-inverting operating point where increasing voltage on the MZM results in increasing optical output power. Negative slope is the inverting operating point where increasing voltage on the MZM results in decreasing optical output power.

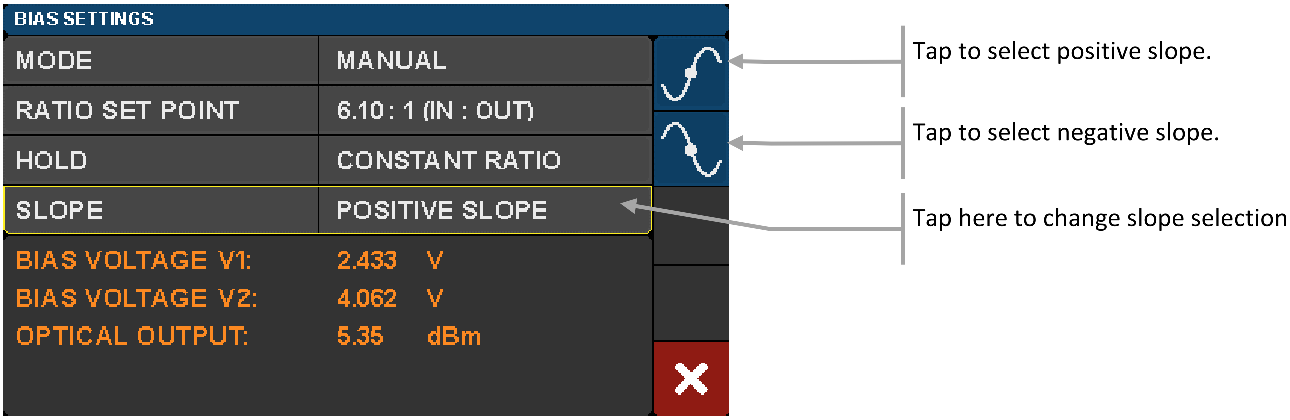


Figure 30 Selecting Operating Point in Constant Ratio Mode

When switching to one of the Manual modes from a different bias mode, the Manual mode set point is automatically calculated to keep the MZM at the same location on the transmission function.

4.4 Amplifier Information

The MX100E series transmitters contain a fixed-gain linear amplifier with approximately 11 dB of gain, which corresponds to a typical voltage gain of 3.55 V/V.

Linear Transmission: To achieve linear transmission, the output swing of the amplifier must be significantly less than the Vπ of the modulator. The amplifier gain curve plotted in Figure 31 shows the relationship between the input and output signals of the amplifier. As the output swing of the amplifier approaches the Vπ of the modulator, nonlinearities will be added by the modulator. Alternatively, pre-compensation can be added to the electrical signal to allow for both a good extinction ratio and a linear response despite the non-linear behavior of the modulator. Please contact Thorlabs technical support for additional information or assistance in implementing this technique.

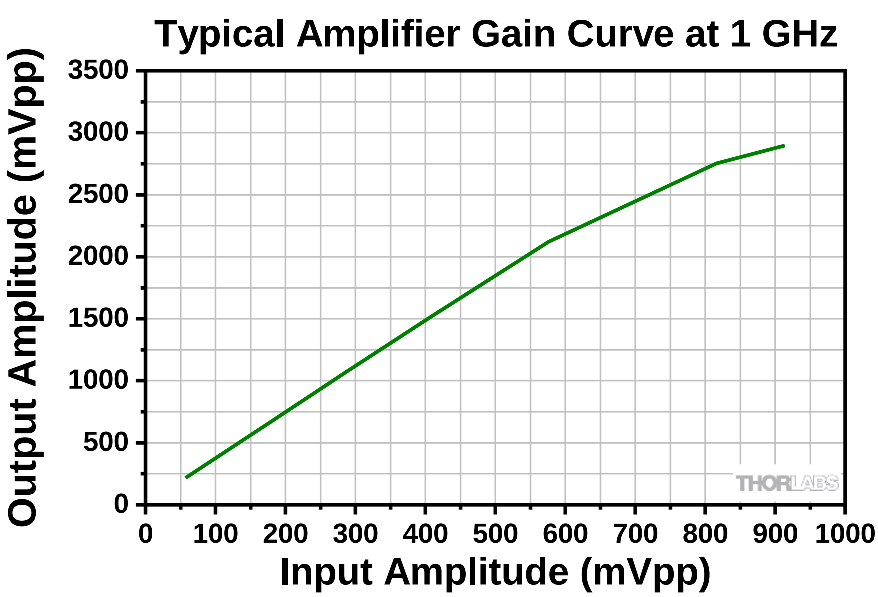


Figure 31 Typical Amplifier Gain Curve at 1 GHz

4.5 Variable Optical Attenuator Settings Page

Tap in the VOA monitors pane on the Home page to access the Variable Optical Attenuator (VOA) Settings page shown below. The VOA provides the means for adjusting and stabilizing the output power after the MZM. The VOA can operate in either of two modes: 1) Constant Attenuation, and 2) Constant Output Power.

Note that units of all power measurements are determined by the Power Units setting this page, see Figure 33.

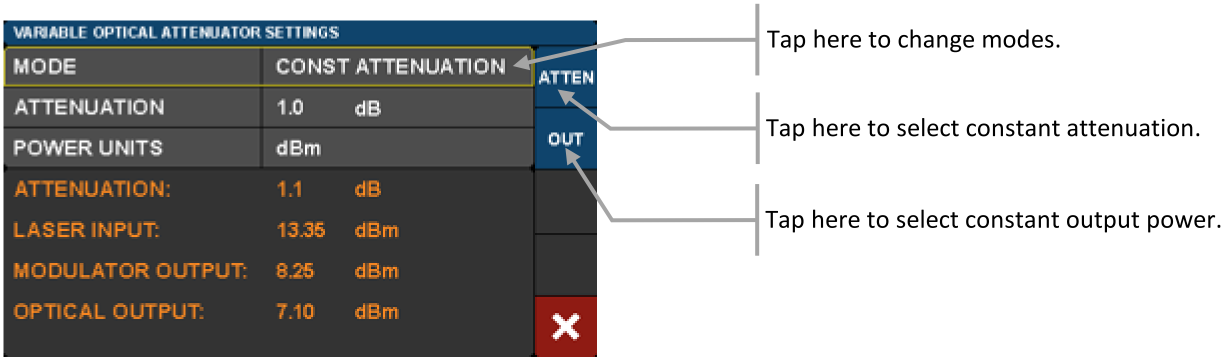


Figure 32 Constant Attenuation Mode of the VOA

Constant Attenuation Mode maintains a fixed attenuation level between the output of the MZM and the output port on the front panel. Any fluctuations at the input are transferred to the output.

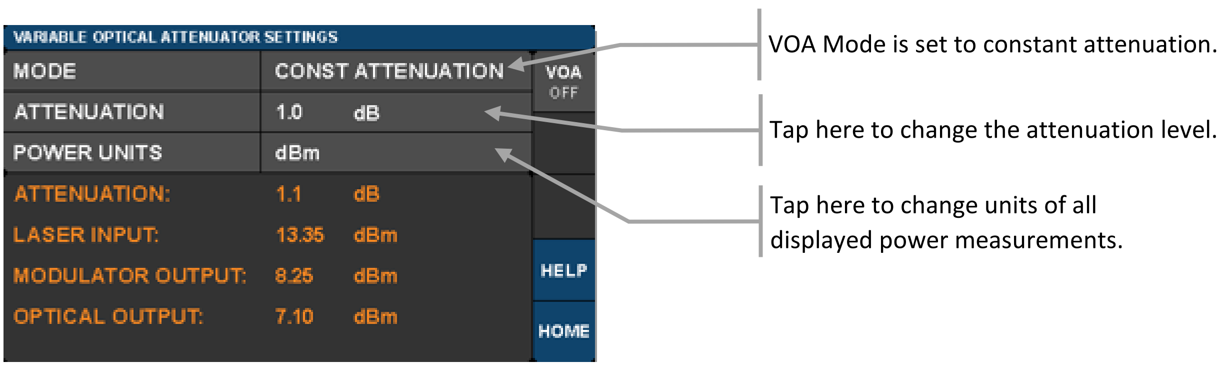


Figure 33 Constant Attenuation Mode Settings

Constant Output Power Mode acts as a stabilizer by holding the final optical power constant independent of input fluctuations (within controllable limits such as input power and attenuation).

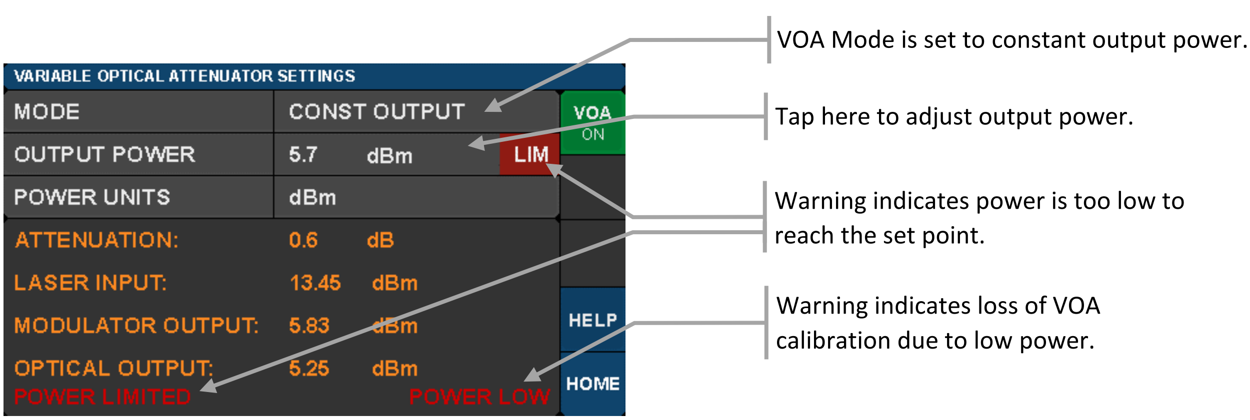


Figure 34 Constant Optical Output Mode of the VOA

4.6 Laser Settings Page (Tunable Laser Only)

To access the Laser Settings page, tap on the Laser monitors pane on the Home page. Here the user can control the laser wavelength and choose whether or not to use the dither feature to stabilize the wavelength. Turning the dither off will result in lower phase and intensity noise, but the wavelength may drift slightly over time. The monitors on this page provide live readings of many parameters.

When the internal laser source is a C-band tunable laser, tap on the Laser Monitors pane on the home page to access the Laser Settings page. This page is not available when the 1310 nm fixed-wavelength source is the internal laser. When the internal laser is not the standard C-band tunable laser, the laser type is denoted in the Options label on the rear panel of the instrument (please see Figure 6 for location of the Options label).

Optical frequency can be set at increments of 50 GHz for C-band tunable internal lasers. C-band lasers also support a fine tuning frequency offset feature, allowing the frequency to be adjusted by an offset from -30.000 GHz to +30.000 GHz. The ITU channel number on these pages is an index number given only for convenience, which is unique to this instrument; actual frequencies and spacings are specified by the ITU standard.

To adjust the ITU channel, tap on the ITU CHANNEL row and use the arrow buttons to increment or decrement the channel. Press the green check mark to accept the new channel, or the red cancel button to abort the change. You may also use the adjustment knob. Note that you are initially editing by channel, as indicated by the STEP CHAN button. Note that the frequency and wavelength value are estimated based on the laser's nominal 50 GHz channel spacing, not measured by the instrument.

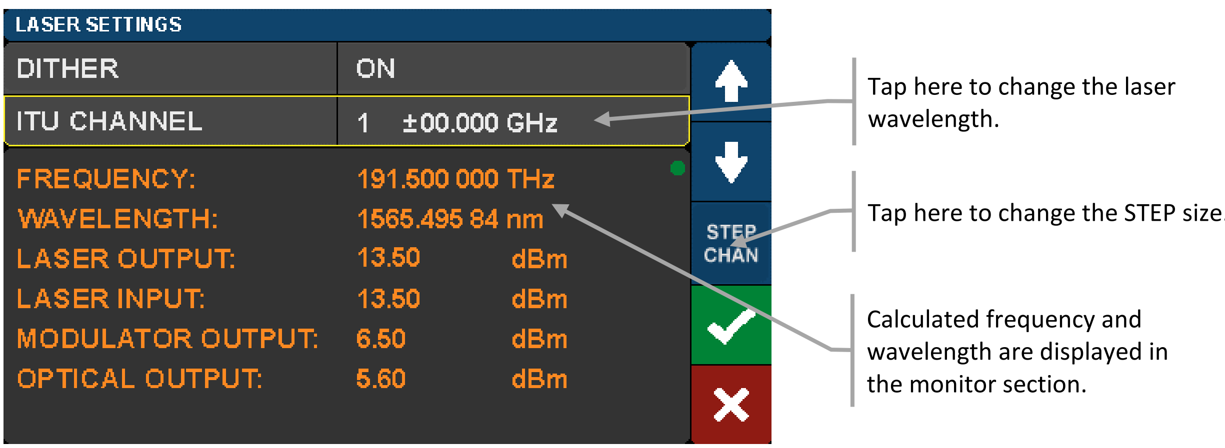


Figure 35 Changing the ITU Channel Number

To apply a fine-tuning frequency offset, tap the STEP CHAN button. The button will cycle to the next mode, STEP 10GHz. In this mode, using the up or down arrows or control knob will adjust the most significant digit of the frequency offset. Tapping the button repeatedly will cycle through the STEP 1GHz, STEP 100MHz, STEP 10MHz, and STEP 1MHz modes, allowing you to edit the offset in finer units of 1GHz, 100MHz, 10MHz, or 1MHz. Tapping the button one more time will cycle back to STEP CHAN mode.

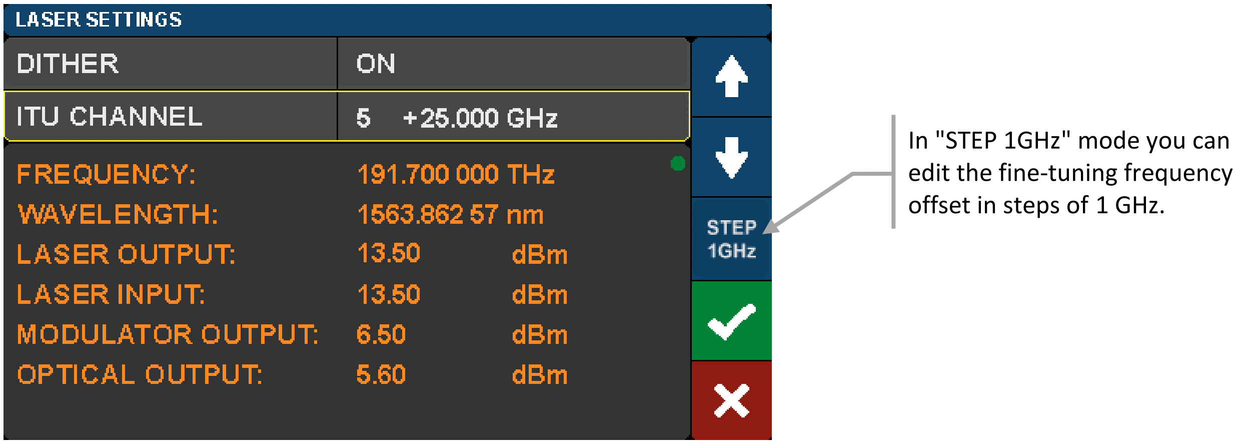


Figure 36 Changing the Fine-Tuning Step Size

Note that while the C-band lasers can have their frequency adjusted by increments as small as 1 MHz, the laser's actual tuning accuracy is not this fine. See Section 1.4.5 for more information.

To turn the dither setting on or off, tap on the DITHER row and use the ON or OFF buttons to change the setting, or the red cancel button to abort the change.

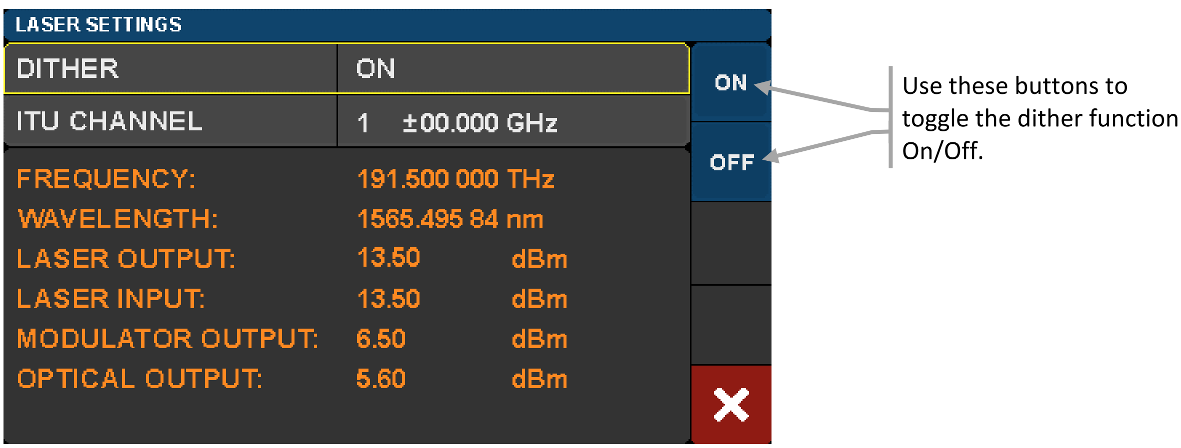


Figure 37 Enabling and Disabling Laser Dither

4.7 Load Page

Access the Load page by tapping the blue Load button on the Home page. The Load page has a factory-defined, standard operating mode stored as a preset. Applying the preset configures the transmitter with the stored instrument settings and is a fast way to put the instrument in a known state.

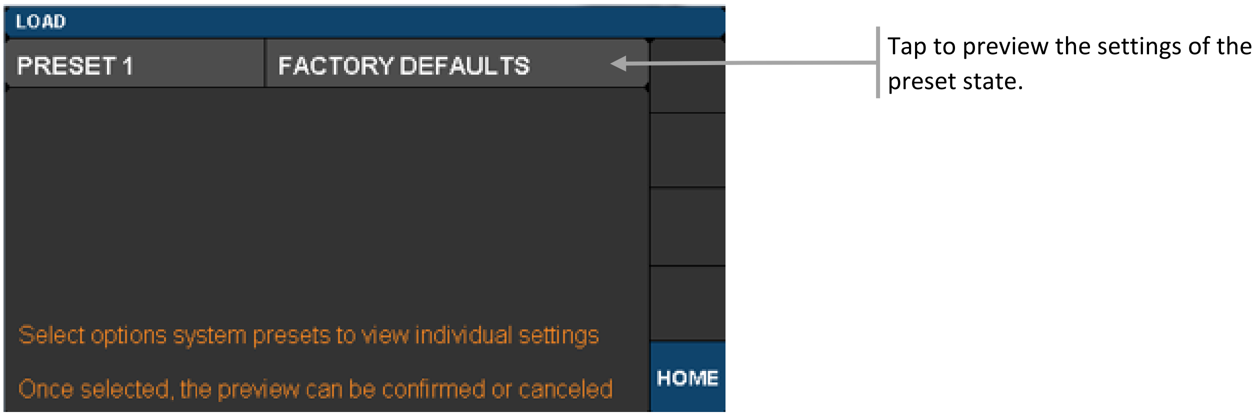


Figure 38 Preset State Options on the Load Page

Tapping on one of the presets will bring up a window that displays all the stored settings. The user can then review the choice before confirming with the green checkmark.

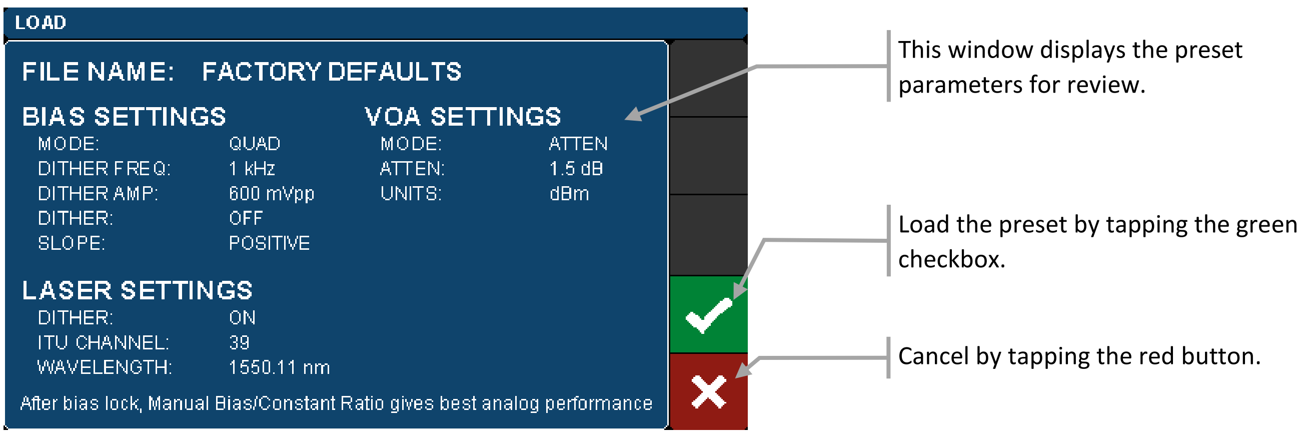


Figure 39 Reviewing the Parameter Values Set by a Preset State

4.8 Menu Page

To get to this page tap the blue Menu button on the Home page. The Menu page has links to several pages that allow the user to control the display, sounds, lights, and get help information. The following sections describe these functions in more detail.

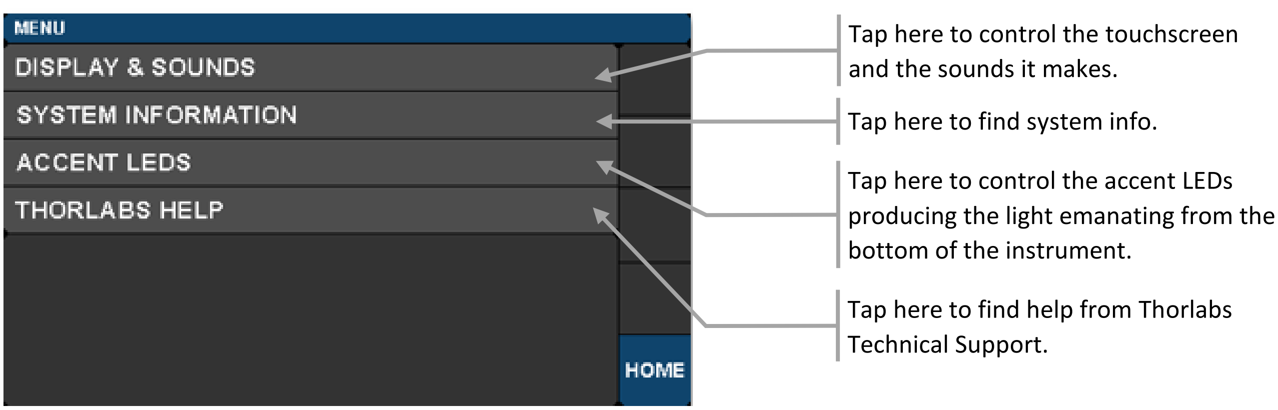


Figure 40 Controls on the Menu Page

4.8.1 Display and Sound Settings Page

To open the screen shown below, tap the DISPLAY AND SOUNDS button on the Menu page.

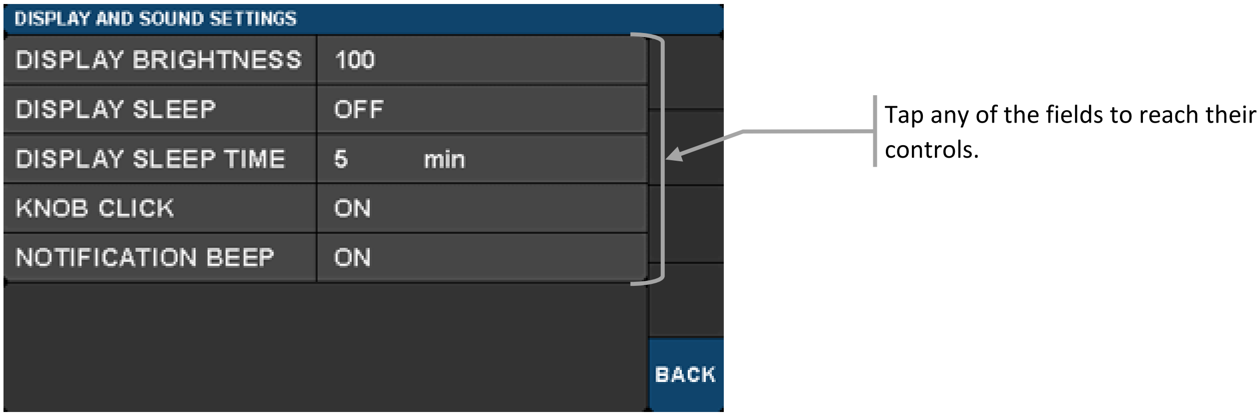


Figure 41 Display and Sound Settings Page

- DISPLAY BRIGHTNESS controls the overall brightness of the touchscreen display. Adjusting the brightness to 0 forces the display to enter Sleep mode. Exit Sleep mode by touching the display or turning/pressing the adjustment knob.
- DISPLAY SLEEP toggles the ability to enter Sleep mode (On/Off). When On, Sleep mode will be entered when the sleep time has expired due to no user interaction with the touchscreen display or adjustment knob. When Sleep mode is entered, the touchscreen display turns off while allowing the unit to continue to function. Exit Sleep mode by touching the display or turning/pressing the adjustment knob.
- DISPLAY SLEEP TIME controls how long the touchscreen display is visible before entering Sleep mode.
- KNOB CLICK toggles the sound produced when turning the adjustment knob (On/Off).
- NOTIFICATION BEEP toggles the sound associated with on-screen notifications (On/Off). Any notification or error that appears on the screen will produce a beep (MIN/MAX adjustment, Power Limited, Power Low, etc.).

4.8.2 System Information Page

To open the screen shown below, tap the SYSTEM INFORMATION button on the Menu pane.

The System Information page displays the installed hardware and software versions. This is useful information to reference when speaking with Thorlabs' tech support or when verifying firmware revisions. The image shown in Figure 42 illustrates the format of the System Information page, but this example is given for informational purposes only and does not show valid configuration information.

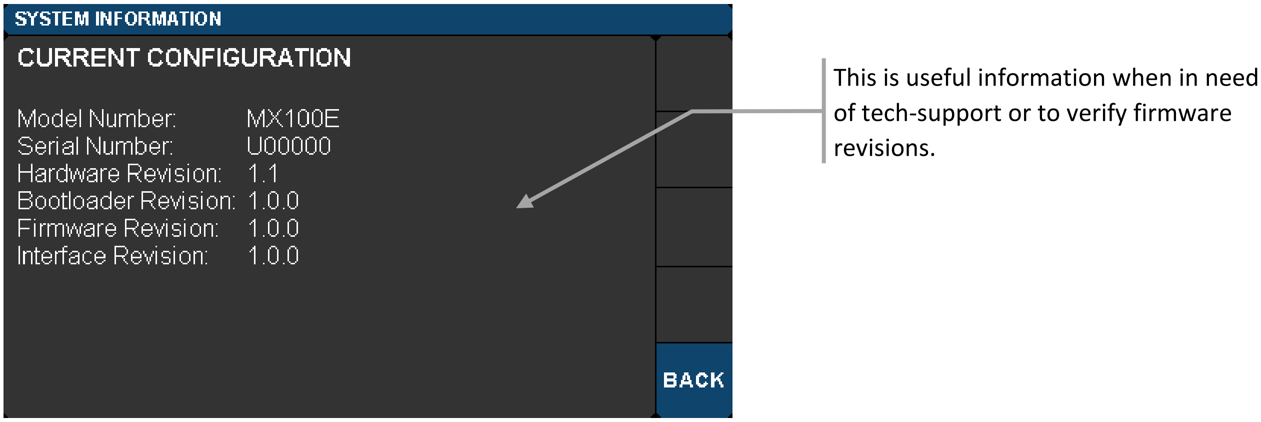


Figure 42 System Information Page

4.8.3 Accent LED Settings Page

To open the screen shown below, tap the ACCENT LEDS button on the Menu pane.

The accent LED settings control the intensity of the color LEDs that emanate from the bottom of the instrument. These are a fun aesthetic feature. You can set them to your favorite color.

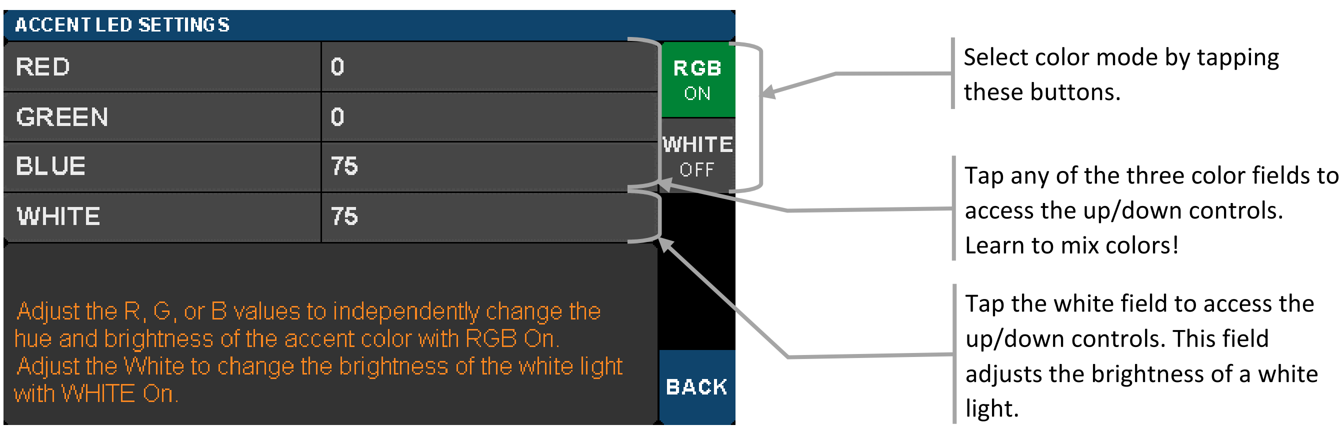


Figure 43 Controls to Adjust the LEDs Providing the Under-Instrument Accent Light

4.8.4 Thorlabs Help Page

To open the screen shown below, tap the THORLABS HELP button on the Menu pane. The Thorlabs Help page displays the Thorlabs Tech Support phone number, Thorlabs web site URL, and the installed hardware and software versions. This information will be useful when speaking with Tech Support. The image shown in Figure 44 illustrates the format of the Thorlabs Help page, but this example is given for informational purposes only and does not show valid configuration information.

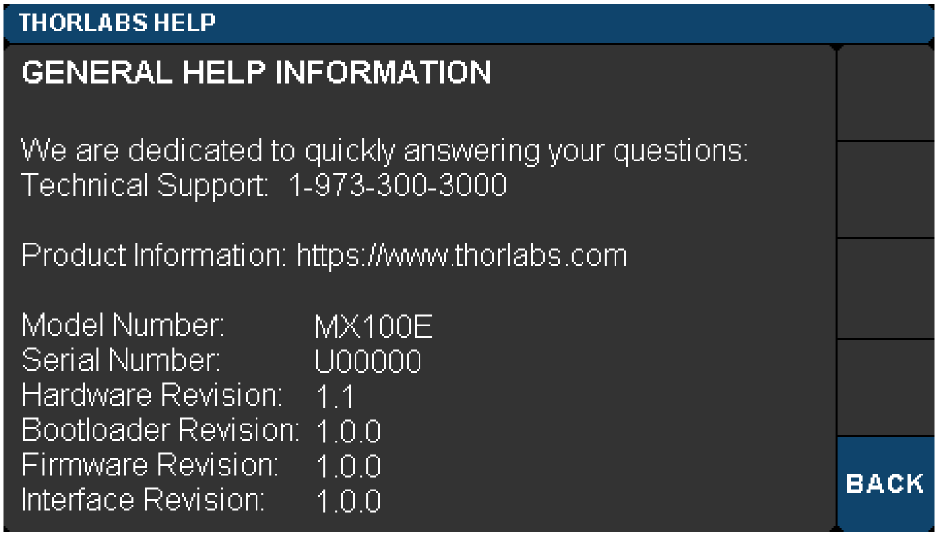


Figure 44 Thorlabs Help Page

4.9 Control and PC Connections

4.9.1 General Purpose I/O, RS-232, and USB Connections

The back panel has connectors for monitor and control functions, as well as for upgrading the firmware. Both the RS-232 and the USB connections can be used for remotely controlling the MX100E transmitter via SCPI type serial commands. Which connector to choose for remote control operation depends on the demands of the application and the user's preference. When using the RS-232 connector, a null modem cable is required to operate with most USB to RS-232 adapters. See the remote control user guide (RCUG), which can be downloaded from **https://www.thorlabs.com/manuals.cfm**, for information about the commands and connecting the unit to a PC.

The most recent firmware and remote control software tools are available from Thorlabs' website at **https://www.thorlabs.com/software_pages/viewsoftwarepage.cfm?code=MX**. The instrument's firmware can be updated by uploading the new version from a PC via the USB port. Thorlabs' technical support can provide up-to-date information on available firmware revisions and control functions.

The 15-pin I/O connector provides outputs from the power monitors in the optical path (see the block diagram in Figure 20). The power monitors provide a voltage that is proportional to the optical power with one of two gain settings. These values are available on the I/O HD-DB15 connector. The gain setting for each monitor is determined by software and reported on the corresponding Gain Indicator pins. 0.0 V indicates Low Gain (40 V/W) and 3.3 V indicates High Gain (4000 V/W).

Maximum output voltage at the monitor pin is less than 12 V (into a high impedance). Power monitor bandwidth is limited to about 150 Hz.

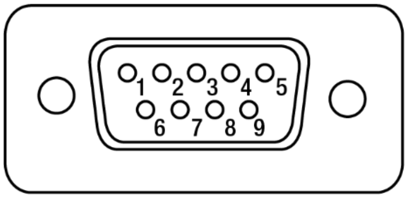


Figure 45 **RS-232 DB9 Connector Pin Configuration**

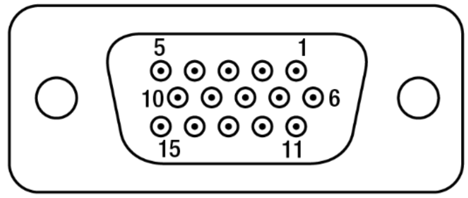


Figure 46 **I/O Connector Pin Configuration**

RS-232 DB9 Connector (Male)	
Pin #	**Description**
1	Not Connected
2	RS-232 Input
3	RS-232 Output
4	Not Connected
5	Digital Ground
6	Not Connected
7	Not Connected
8	Not Connected
9	Not Connected

I/O HD-DB15 Connector (Female)	
Pin #	**Description**
1	Power Monitor 1 (Mon-1)
2	Power Monitor 2 (Mon-2)
3	Power Monitor 3 (Mon-3)
4	Reserved for Future Use
5	Analog Ground
6	Analog Ground
7	Analog Ground
8	Analog Ground
9	Analog Ground
10	Analog Ground
11	Reserved for Future Use
12	Reserved for Future Use
13	Power Monitor 1 (Mon-1) Gain Indicator
14	Power Monitor 2 (Mon-2) Gain Indicator
15	Power Monitor 3 (Mon-3) Gain Indicator

4.10 The Laser Safety Interlock

The instrument is equipped with a remote interlock connector located on the rear panel. In order to enable the laser source, a short circuit must be applied across the terminals of the Remote Interlock connector. In practice this connection is made available to allow the user to connect a remote actuated switch to the connector. The switch (which must be normally open) has to be closed in order for the laser to be enabled. If the switch changes to an open state, the laser source will automatically shut down. If the switch returns to a closed condition the laser source must be turned on again in the touchscreen GUI.

All units shipped from Thorlabs are configured with a shorting device installed in the Interlock connector. If you are not going to use this feature, then leave the shorting device installed. The unit will operate normally as described in the procedures above.

If you wish to make use of the Interlock feature you will need to acquire the appropriate 2.5 mm plug, wire it to the remote interlock switch, and then plug it in to the back-panel interlock jack in place of the shorting plug. This type of plug is readily available at most electronics stores. The electrical specifications for the interlock input are shown in the following table.

Specification	Value
Interlock Switch Requirements	Must be Normally Open Dry Contacts Apply no External Voltages to the Interlock Input
Type of Mating Connector	2.5 mm Mono Phono Jack
Open Circuit Voltage	<5 VDC (Center Pin is at 5 VDC, Ring is Ground)
Short Circuit Current (Typical)	7 mA
Connector Polarity	Tip is Ground, Barrel is at 5 VDC Max

The user's safety circuit must be attached to the phono plug and wired such that the ring and center pin are shorted when it is safe to enable the laser. The laser will be enabled when connection is closed. If it changes to an open state, the laser source will turn off.

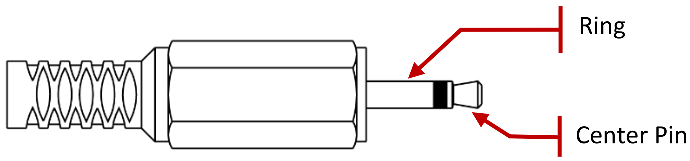


Figure 47 Diagram of a Phono-Type Plug

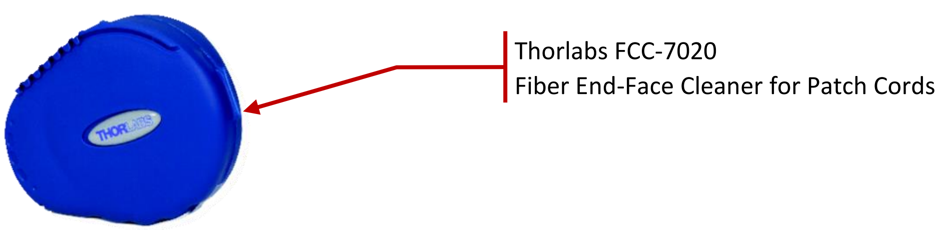
Chapter 5 Maintenance, Repair, and Fuses

5.1 Maintenance and Repair

The instrument should not need regular maintenance by the user. If necessary, the display, housing, and front panel can be cleaned using a soft cloth moistened with normal, mild glass cleaner. Do not use any chemical solvents or harsh cleaners on the display. Do not spray any cleaning solutions directly onto any part of the unit.

The instrument does not contain any modules that can be repaired by the user. If a malfunction occurs, please contact Thorlabs Technical Support and arrangements will be made to investigate the problem. Do not remove the cover. There are no user serviceable components inside.

Optical patch cords used to connect to the front panel of the instrument should have their end faces cleaned every time a new connection is made. The end faces of the internal fiber connectors can easily be damaged by the use of dirty fiber ends. If damage occurs, the instrument will need to be sent back for repair. We suggest using a fiber end-face cleaning product such as the Thorlabs FCC-7020 shown below. Alternatively, a lint-free cloth moistened with isopropyl alcohol or methanol can be used. Never use acetone.



The optical connectors on the front panel may be cleaned using a 2.5 mm bulkhead cleaner such as the Thorlabs FBC250. This allows the user to clean the fiber end-face without removing it from the internal bulkhead adapter.

5.2 Replacement Parts

The following parts can be obtained by contacting Thorlabs Technical Support:

- 1.0 mm Dust Cap (Used for Front Panel RF Connector)
- Laser Interlock Keys for Front Panel Switch
- 2.5 mm Interlock Pin (for Back Panel)
- 1.25 A 250 VAC Fuse for Main Power
- Instrument IEC Main Power Cord
- Instrument Flip Foot

5.3 Replacing the Main Fuse

The system is protected by a main fuse located in the power entry module where the main power cable plugs into the back panel of the instrument. If the instrument does not appear to power-up, especially after a power outage or storm, you can check the condition of the main power fuse without removing the cover of the instrument by following the following steps.

⚠WARNING

Warning: Risk of Electrical Shock

To avoid electrical shock and severe injury, carefully follow all directions below to disconnect the instrument from power.

1. Put the instrument in "Standby" mode by pressing the standby button on the front of the instrument. Wait until the button turns from green to amber.
2. Turn the power off using the switch on the back panel of the instrument.
3. Unplug the main power cable.
4. Carefully remove the fuse holder slide from the power entry module (use a flat screwdriver)

Figure 48 Power Entry Module

Figure 49 Removing the Fuse Holder Slide

5. Investigate the fuse. This can be done with a simple continuity check. If in doubt, replace the fuse. A spare fuse is stored in the fuse holder. Additional replacement fuses can be purchased from Thorlabs. **Always use fuses of the same type as the original**.

Figure 50 Fuse

6. Reinstall the fuse holder slide into the power entry module, taking care that it fully seats until the top is flush with the rest of the power entry module.
7. Plug the main power cable back into the unit and power on as described in the Getting Started section of the manual.

If the fuse blows repeatedly, it is likely that an internal failure has occurred. Do not attempt to bypass the fuse as this can create a dangerous situation that could further damage the instrument or harm personnel. In this case, please contact Technical Support for directions.

Chapter 6 Troubleshooting

Below is some information about status indicators and a few checks to help in troubleshooting general problems. If you have any questions, please contact your local Thorlabs Technical Support office.

- If the unit does not appear to turn on correctly, please check the following items:
- Ensure that the main AC receptacle is powered
- Ensure that main power cable is fully seated at both ends
- Ensure that back power switch is in the "I" position
- Check the main power fuse (see Maintenance and Repair Section)

The color of the Standby Button, which is on the front panel, indicates several status conditions as follows:

Standby Button Color	Condition
Solid Green	Indicates normal ON state.
Solid Amber	Indicates unit is in Standby Mode. Press the button to turn the instrument ON.
Blinking Green	Indicates the main AC power is unstable. When the AC power is restored, the instrument will return to the standby mode (amber).
Blinking Amber	Indicates the instrument is overheated. Make sure the fan is running and none of the vents are blocked. If there are no ventilation issues, then the box should cool itself and return to the standby. Do not operate, or leave the instrument in standby mode, in an environment above 40 °C.
Blinking Amber/Green	Indicates the instrument is both overheated and the main AC power is unstable (see individual troubleshooting for these conditions above).
Fading Amber/Green	Indicates the instrument is in the firmware upgrade mode. If this condition appears after attempting to upgrade the firmware, the update may have failed, or the unit may have been left in the update mode. Try running the firmware update again. This condition may have also been reached by holding down the standby button for a long time while turning on the power. In this case, turn the unit off, wait for a few seconds, and turn it back on. If this condition for any other reason, turn the unit off, wait for a few seconds, and turn it back on. If these attempts to recover continue to fail, the instrument's firmware may have been corrupted. Contact Tech Support for help.

If the optical power at any point of the system is lower than expected, resolving the problem always starts by cleaning the optical fiber ends. Contaminated fiber ends, which attenuates the intensity of the transmitted light, is a very common issue when using single-mode fibers. Follow the suggestions provided in the Maintenance and Repair section of this manual to clean the optical fiber ends.

Chapter 7 Disposal

Thorlabs verifies our compliance with the WEEE (Waste Electrical and Electronic Equipment) directive of the European Community and the corresponding national laws. Accordingly, all end users in the EC may return "end of life" Annex I category electrical and electronic equipment sold after August 13, 2005 to Thorlabs, without incurring disposal charges. Eligible units are marked with the crossed out "wheelie bin" logo (see right), were sold to and are currently owned by a company or institute within the EC and are not dissembled or contaminated. Contact Thorlabs for more information. Waste treatment is your own responsibility. "End of life" units must be returned to Thorlabs or handed to a company specializing in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site. It is the user's responsibility to delete all private data stored on the device prior to disposal.

Chapter 8 Thorlabs Worldwide Contacts

For technical support or sales inquiries, please visit us at www.thorlabs.com/contact for our most up-to-date contact information.

Corporate Headquarters
Thorlabs, Inc.
43 Sparta Ave
Newton, New Jersey 07860
United States

sales@thorlabs.com
techsupport@thorlabs.com

Product Manufacturer
Thorlabs Ultrafast Optoelectronics
110 Parkland Plaza
Ann Arbor, Michigan 48103
United States

sales@thorlabs.com
techsupport@thorlabs.com

EU Importer
Thorlabs GmbH
Münchner Weg 1
D-85232 Bergkirchen
Germany

sales.de@thorlabs.com
europe@thorlabs.com

UK Importer
Thorlabs Ltd.
204 Lancaster Way Business Park
Ely CB6 3NX
United Kingdom

sales.uk@thorlabs.com
techsupport.uk@thorlabs.com