ML4039D & ML4079D
BERT User Guide

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ML4039D
ML4079D

4-Lane 21-30 Gbaud
Bit Error Ratio Tester 200G
4 x 30G NRZ or 4 x 56G PAM4 Channels

User Manual Revision 1.0
Windows GUI Version v.4.1. r6890 onwards
API Version 2.7
Firmware Version 2.6

MultiLane, S.A.L., Houmal Technology Park, Houmal, Mount Lebanon.

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General Safety Precautions

Review the following safety precautions to avoid injury and prevent damage to this product or any products connected to it. To avoid potential hazards, use this product only as specified.

Only qualified personnel should perform service procedures.

While using this product, you may need to access other parts of the system. Read the General Safety Summary in other system manuals for warnings and cautions related to operating the system.

To Avoid Fire or Personal Injury
Use Proper Power Cord. Only use the power cord specified for this product and certified for the country of use.

Observe All Terminal Ratings. To avoid fire or shock hazard, observe all ratings and markings on the product. Consult the product manual for further ratings information before making connections to the product.
Do not apply a potential to any terminal, including the common terminal that exceeds the maximum rating of that terminal.

Do Not Operate Without Covers.
Do not operate this product with covers or panels removed.

Avoid Exposed Circuitry. Do not touch exposed connections and components when power is present.

Do Not Operate with Suspected Failures.
If you suspect there is damage to this product, have it inspected by qualified service personnel.

Do Not Operate in Wet/Damp Conditions.
Do Not Operate in an Explosive Atmosphere.
Keep Product Surfaces Clean and Dry.

Symbols and Terms in this manual. These terms may appear in this manual:

⚠ **CAUTION:** *Caution statements identify conditions or practices that could result in damage to this product or other property.*

⚠ **CAUTION: Provide adequate cooling.** *Provide adequate cooling to the board to avoid damaging any part of it specifically for the ATE version of the board. Refer to the power section to know the power dissipation values*

Preface

This is the user operation manual for the **ML4039D/ML4079D**. It covers the following information:

- Describes the capabilities of the instrument: how to install it and its software
- Explains how to operate the instrument for: Pattern Generation, Error Detection; how to control the clocking system, inputs/outputs and all the available measurements
- Lists the specifications

Contact MultiLane SAL

MultiLaneSAL is an engineering services company and an OEM supplier of specialty test and communication equipment for the semiconductor and optical transport industries. Multilane delivers ultra-compact test instruments of the highest value and performance for high speed communication and signal integrity applications. The Company has a large engineering team and a fully equipped lab with state of the art equipment, having recently moved to a 6000sq foot facility in ***Houmal Technology Park (HTP).***

Multilane SAL customers can leverage great flexibility and capability in product customization thanks to our team in depth expertise in high speed I/O, Signal Integrity, and access advanced development and test tools. MultiLane has the resources and know-how to meet customer's product development and design requirements. Our R&D has a proven track record in delivering leading edge products and development tool kits to the Automated Test market while applying the production processes to deliver high quality products on schedule and within budget.

Multilane's team is composed of experienced and disciplined engineers offering products and turnkey solutions of modules and systems for high speed IO, Signal Integrity, SOC development and optical communication from verbal requirements (Architecture, PRD, HW/FW/SW design implementation and characterization).

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Product Description

This chapter describes your instrument, operating under Windows.

- *Installation* shows you how to configure and install the instrument, as well as how to install the system software included with the product.
- *Incoming Inspection* provides a procedure for verifying basic operation and functionality
- *Accessories and Options* lists the instrument options available and the standard and optional accessories for this product.

Model and Package Content

This manual supports the instrument **ML4039D/ML4079D**, both Benchtop and ATE.

Hardware Packages
ML4039D: 4 x 28G NRZ or 4 x 56G PAM4 Channels BERT, reference clock output, external reference clock input (Optional)

User Guide Manual
Manual containing user operation guide, software installation and start up procedure.

Software package and documentations:
- Main **ML4039D/ML4079D** GUI.
- USB driver. The Ethernet interface is controlled through the API version 2.0 that includes the Ethernet package.

Overview

ML4039D is a low cost, simple to use, fully integrated, ultra-compact, USB/Fast Ethernet controlled instrument that combines the functions and features of a signal generator, bit error-rate tester and data analysis system with Post Emphasis and Pre Emphasis capabilities.

Key Features

- Data Rates in NRZ mode 22 – 29 Gbps
- Ability to tune the bit rate in steps of 100 kbps and find the RX PLL locking margin
- Data Rates in PAM4 mode 44 - 58 Gbps
- Low intrinsic Jitter < 120 fs rms
- Low power consumption < 22 W
- Automated J2/J9 measurements
- API libraries
- LabView driver and Python wrapper available
- Eye Contour measurements
- Bathtub measurements
- 6 dB pre-emphasis

BER and measurement suite

- Low cost simple to use 4 channel BERT (8 channel in case of ML4079D)
- Supports all basic BERT functions
- Complete BERT measurement capability (histogram and SNR)

Target Applications

- Production testing of transceivers
- Functional and SI testing

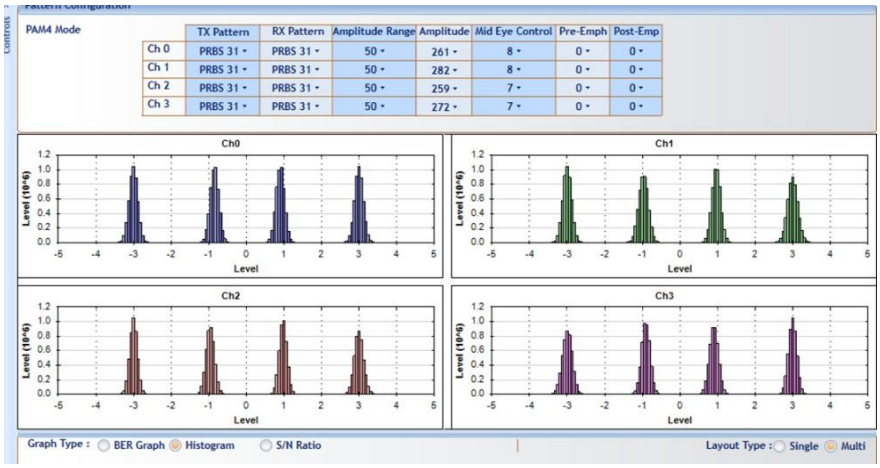


Figure 1: Histogram PAM4

Product Software

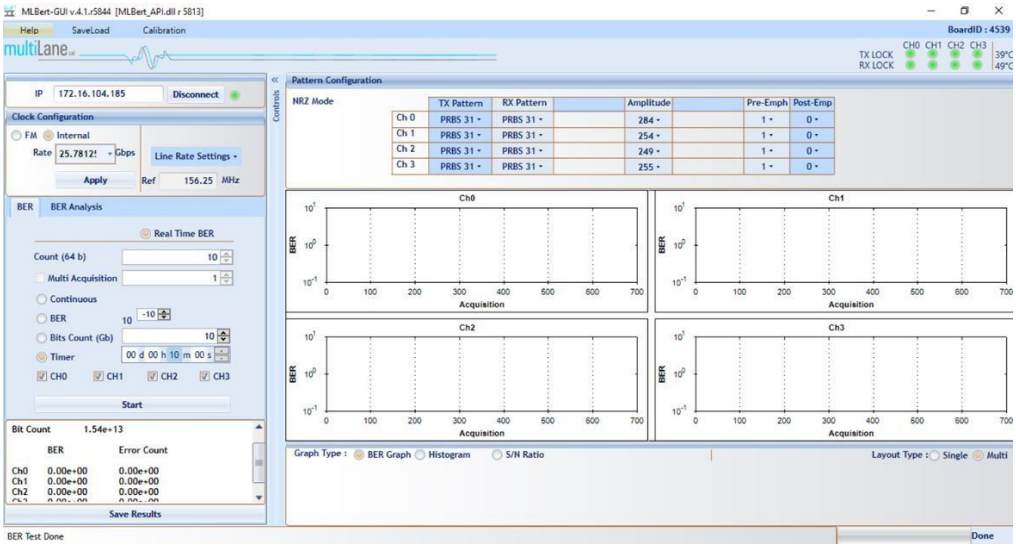


Figure 2: ML4039D BERT GUI

The instrument includes the following software:

- **ML4039D GUI.**
- **MultiLane ML4039D USB driver.**
- **ML4039D ETHernet Configuration Software.**

Instrument GUI runs on Windows XP (32/64 bit), Windows 7,8 and 10.

NOTE. *These applications require the Microsoft .NET Framework 3.5.*
If the Microsoft.NET Framework 3.5 is needed, it can be downloaded through this link: http://download.microsoft.com/download/2/0/e/20e90413-712f-438c-988e-fdaa79a8ac3d/dotnetfx35.exe.

For more products updates, check the following webpage:
www.multilaneinc.com/products.html

Minimum PC Requirements

The Windows PC properties for the **ML4039D GUI** application must meet the following specifications:

- Windows 7 or greater
- Minimum 1 GB RAM
- 1 Ethernet card to establish connection with the device
- USB Connector
- Pentium 4 processor 2.0 GHz or greater
- .NET Framework 3.5 sp1

NOTE. *It is recommended to connect the BERT via Ethernet to one PC only to prevent conflict from multiple user commands.*

Installation

This chapter covers installation of the instrument, addressing the following topics:

- System Start-up
- How to connect to the instrument

Note: For windows vista, 7, 8 and 10 users should always run the GUI as administrator.

First Steps

- When you first receive the instrument, it has a pre-configured IP address from the factory. This IP address is printed on a label on the instrument's backplate. You may choose to keep this IP or to change it. If you need to change the IP, there are two ways to do it: either through the USB interface, or through the Ethernet interface. If you do choose USB, then you first have to install the USB driver of this instrument from the ML website, then use the application named ETHconfig. If however you choose the LAN interface to change the IP, then you need to download the application IPChanger from the ML website then temporarily change your PC's IP to be in the same domain as the instrument, i.e. 172.16.xx.xx. once you've successfully changed the instrument's IP, you can change back your PC's IP.
- Please make sure you print a label with the newly assigned IP address and stick it on the instrument. If for some reason you cannot remember what IP address your instrument has, you will have to use the USB interface together with the ETHconfig software to "read" the IP.

Connect through Ethernet:

Connect the PC to the front panel via the RJ45 connector located on the front panel through an Ethernet cable to be able to control it.
In order to connect via Ethernet, the IP address of the board is required.
To learn more options on how to connect the Ethernet cable go to the section Connect through an Ethernet Cable.

- Note that no drivers are required; you simply should know the current board IP address, you need to enter it in the text box next to the **IP** label shown in the below picture, then click on the **connect** button.

Figure 3: Connect Via Ethernet

- You are now connected.
- Once connected, the **Connect** button turns into **Disconnect**.
- To make sure that you are connected, you can also ping your device.
- To change the IP address of the board, you need to install the USB drivers (refer to section USB Driver Installation).

- Install the Ethernet configuration software that allows you to read, write the **IP** address, **Mask** and **Gateway** of the instrument.

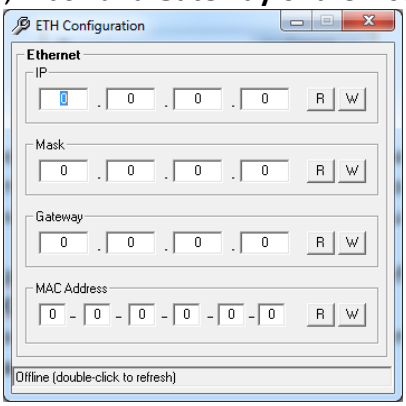


Figure 4: Ethernet Configuration

The instrument is now powered up and connected through the right IP address. Next, you need to configure the signal generated.

GUI Overview

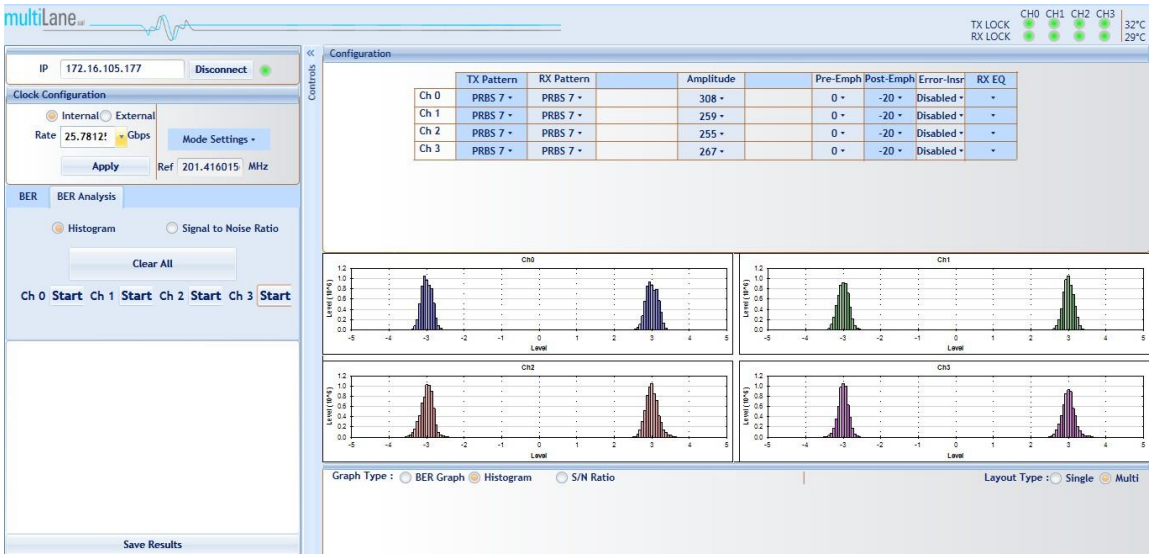
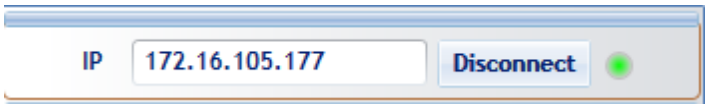


Figure 5: ML4039D GUI

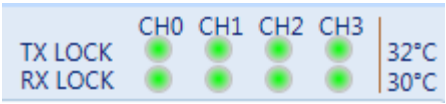
In your instrument's GUI, there are several control fields that are each explained below.

Instrument Connect Field



The first thing you want to do is to make sure you are connected to the instrument. If you are, the connect button will read Disconnect and the green LED lights up.

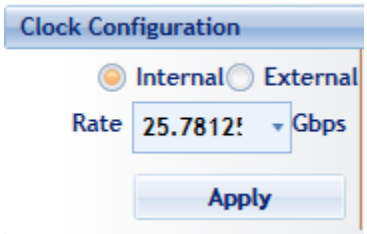
Lock and Temperature Status Field



Keep an eye on the LEDs and temperature readings on this field. TX Lock means that the PLL of the PPG is locked. RX lock goes green only if a signal of correct polarity and PRBS kind is detected on the error-detector.

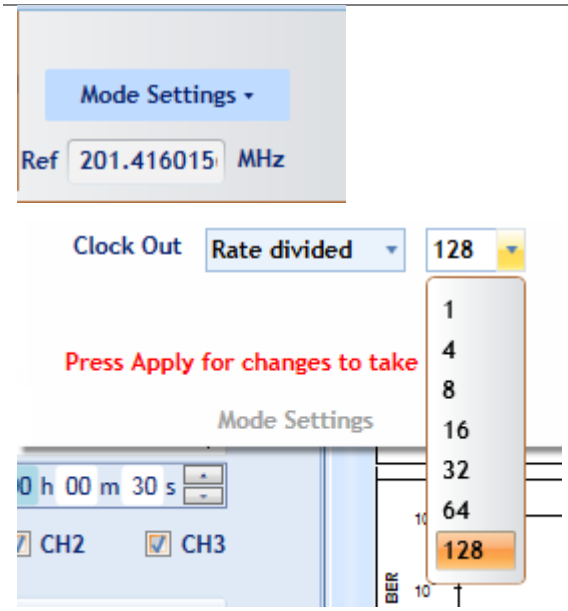
If the temperature reaches 65C, the electronics will auto shut off.

Line Rate Configuration (Applies to all channels at once)



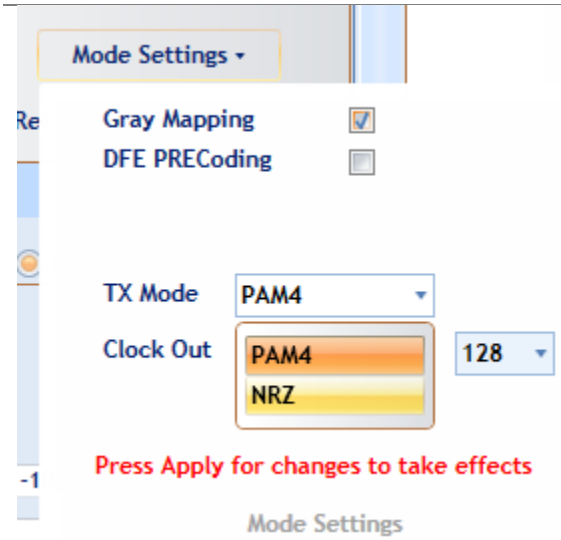
This is where you set the bitrate for all 4/8 channels. You can also select the clock input. The clock is internal by default. You should only change to external clock feed in when you need to synchronize two or more ML4039Ds to each other in a slave-master fashion; In that case you connect the clocks in daisy chain. After changing from internal to external clock and vice versa, you have to click apply for changes to take effect (this takes a few seconds).

Mode & Clock Out Settings (Apply to all channels at once)



The "Ref" denotes the frequency of the clock output. This is a function of the bitrate and will vary according to your clock-out settings under the "Mode" menu. Knowing the clock frequency being output by the BERT is helpful when you are trying to trigger an oscilloscope.

Some oscilloscopes require a clock frequency above 2 GHz. To get the ML4039D/79D to output that, go under mode settings and select the Clock out to be "Rate Divided". Choose the denominator so that the result is within the scope range.



To switch between NRZ and PAM-4 coding, use the TX Mode setting, then click Apply.

The options Gray Mapping and DFE pre-coding are only available in PAM4 mode.

DFE Pre-coding sends a pre-amble for a DFE receiver to sync to before the actual PRBS pattern is transmitted, to avoid DFE error propagation. The decoder implements a 1+D scheme in response to an $x = \frac{1}{1+D}$ encoding.

The ML4039D/79D receiver does not use DFE for equalization (it uses adaptive FFE), therefore this setting is only important when using a 3rd party error-detector.

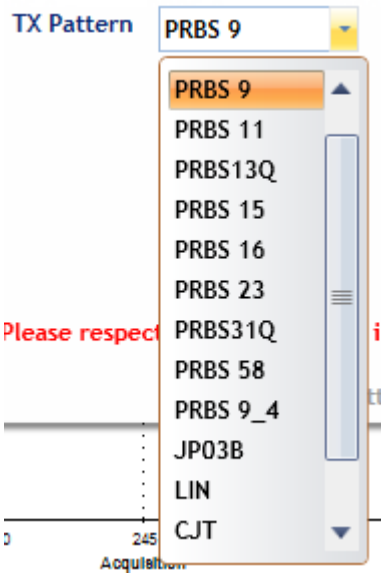
Gray Mapping enables use of PRBSxxQ defined in IEEE802.3bs. When Gray mapping is enabled, the PRBS13 and PRBS31 under the pattern select menu turn into PRBS13Q and PRBS31Q respectively. Gray mapping basically re-

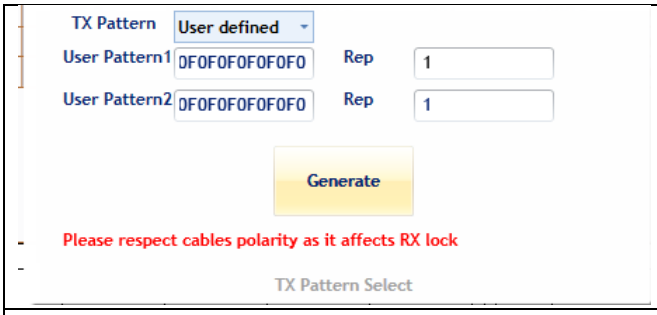
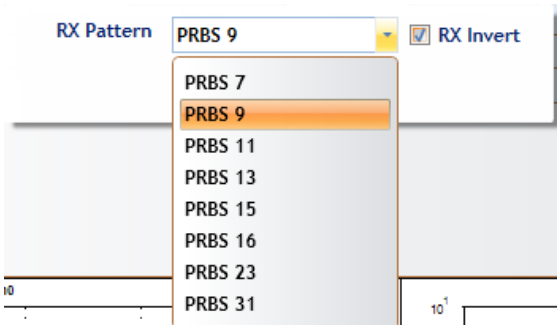
	arranges the symbol mapping to the following: 00 → 0 01 → 1 11 → 2 10 → 3

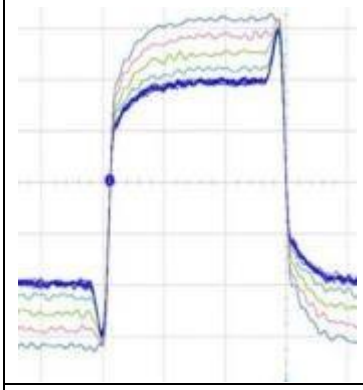
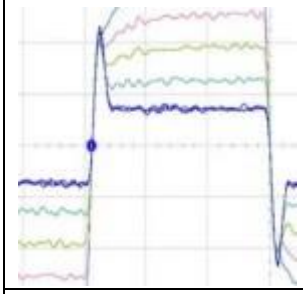
Per-Channel Settings

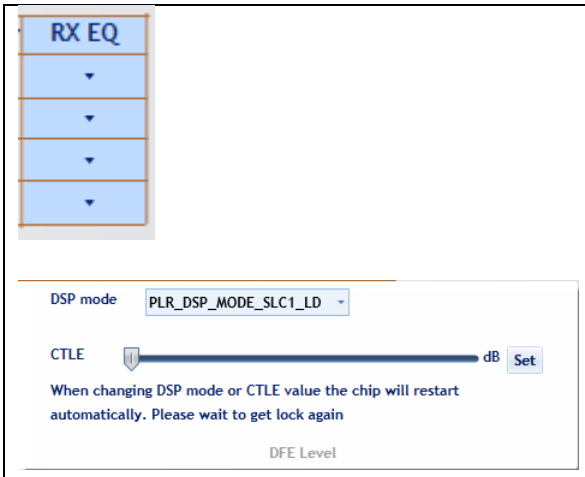
	TX Pattern	RX Pattern	Outter Eye	Amplitude	Inner Eye	Pre-Emph	Post-Emph	Error-Insr	RX EQ
Ch 0	PRBS 9	PRBS 9	2000	213	1000	0	0	Disabled	0
Ch 1	PRBS 9	PRBS 9	2000	220	1000	0	0	Disabled	0
Ch 2	PRBS 9	PRBS 9	2000	210	1000	0	0	Disabled	0
Ch 3	PRBS 9	PRBS 9	2000	222	1000	0	0	Disabled	0

You can adjust these settings on a per channel basis. These are:

	The ML4039D/79D can output a wide range of pre-defined patterns. In addition to the PRBS patterns, there are linearity and jitter test patterns. Also, on top of the pre-defined patterns the user has the possibility of defining his/her own pattern – more on this further below. Note: error detection only works on the PRBS patterns existing in the RX pattern drop down list. It isn't possible to do error detection on custom defined patterns.
User-defined Pattern	The custom pattern is made up of 2 fields with 16 hexadecimal characters each. One must fill out both fields with all 32 hex characters. Every hex character is 4 bits wide, making up 2 PAM4 symbols; example 0xF is 1111 so in Gray-

	coded PAM domain this results in 22, assuming the PAM levels are denoted 0, 1, 2 and 3 Example 2: to transmit a stair signal 0123, fill out the fields with repetitions of 1E
	In the RX Pattern menu, one can browse all the patterns with which error detection is possible. Note that TX and RX pattern must be the same to acquire RX lock and consequently be able to do measurements. Also the pattern polarity is very important and makes all the difference between having RX PLL lock or no lock at all. You can ensure correct polarity by connecting the TX-P side of the cable to the RX-P and the TX-N to the RX-N. if you do not respect this rule, you can still invert polarity from the GUI on the RX side only.
	Inner and Outer eye level controls trim the high and low values of the <u>middle</u> PAM eye. Possible control values range from 500 to 1500 for the inner eye control and from 1500 to 2000 for the outer eye. Optimal values are typically in the middle of the range. Example of tweaking the Outer eye settings is shown below
<u>Amplitude Settings:</u> 	Think of the amplitude as a digital equalizer with main tap, pre-cursor (pre-emphasis) and post-cursor (post-emphasis). In the regular case, pre- and post-cursors are set to zero; the amplitude is controlled using the main tap. This is also the case during factory calibration. The main, pre- and post-taps use digital values ranging between -1000 and +1000. Increasing and decreasing

	the pre and post cursors will also affect the amplitude; therefore, you should enable constant Vpeak if you wish to maintain the swing level while changing pre- or post-emphasis. Note that the amplitude reading in mV will only be accurate if the pre- and post-cursors are zero. Do not confuse the amplitude in mV with the digital value of the Main Tap slider labeled "digit". The "digit" changes between -1000 and +1000 while the amplitude in mV can only be positive <u>Scaling:</u> changes the scale of the entire signal in steps of 10% while maintaining the pulse shape.
	Pre-cursor effect on a pulse
	Post-cursor effect on a pulse
<u>RX Equalization</u>	There are 2 different equalizers in the error detectors: an FFE-based adaptive equalizer, and a manual CTLE. While the CTLE is optional and straight forward, the FFE is

	mandatory and self-adjusting. There are different FFE equalizer settings for different channel characteristics: ▪ SLC1 and SLC2 are slicer blocks that compare the FFE output to their decision thresholds. These threshold are adaptive. SLC1 is the default equalizer ▪ LDEQ is a Level Dependent Equalizer, used to equalize the 2 inner-levels of the PAM4 eye. Optional ▪ RC is a Reflection Canceller to compensate for group delay distortion.
Error Insertion	Error insertion is carried out on a block by block basis. Each block is 64 bits, divided into 32 MSBs and 32 LSBs.

Example Inner and Outer setting Effect:

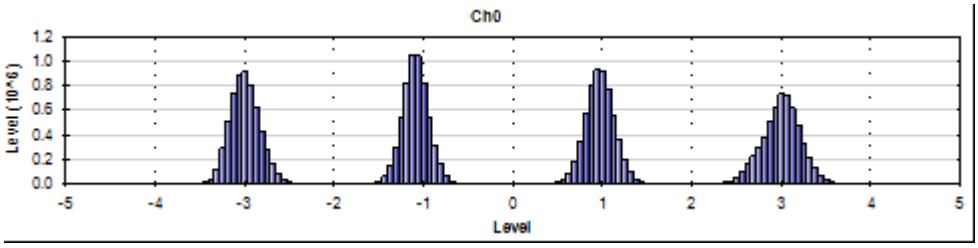


Figure 6: Default Inner and Outer settings of 1000 and 2000

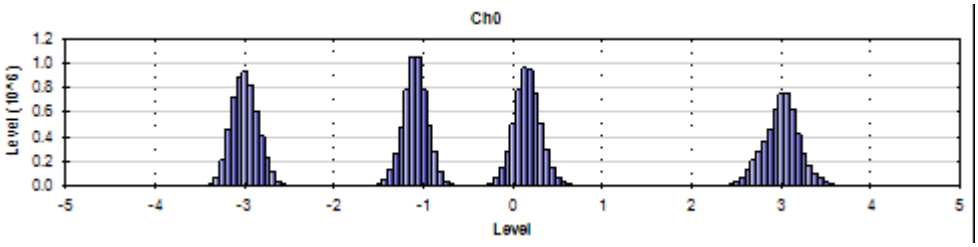


Figure 7: Outer Eye is set 1600; Inner eye kept at 2000

Taking Measurements

Bit Error Ratio Reading

To be able to start BER measurements, the instrument ports should be in the loopback mode, which means TX port should be connected to the RX port and the PPG and ED patterns should match. One does not necessarily need to supply a PRBS from the same physical instrument – the source can be a different instrument and the error-detector of the ML4039D can derive its own clock from the received data (no need for a separate clock link). However, if Gray coding is used in the source, one should tell the receiver to expect Gray coding as well. If there is a match in pattern, polarity and coding but still no lock, there could be an MSB/LSB swap on one side.

BER Control

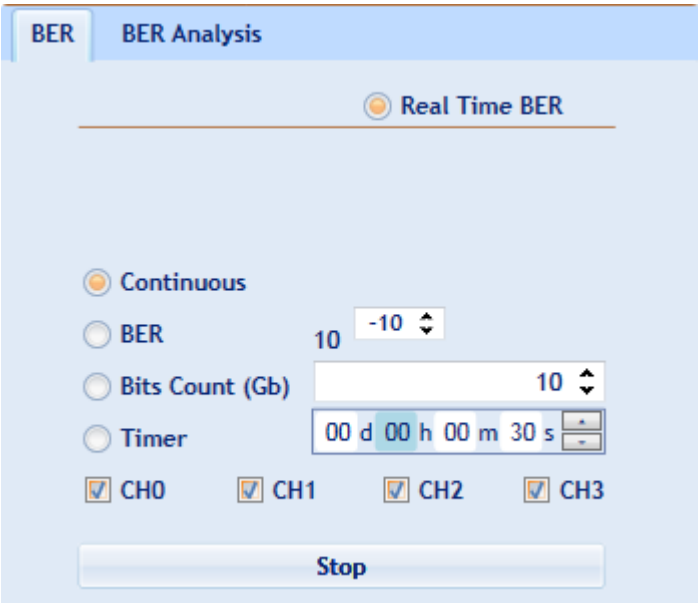
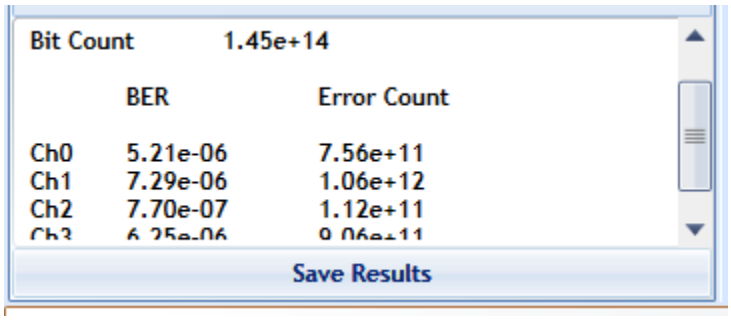


Figure 8: BER Control panel

A BER measurement can run in continuous mode, and will not stop until the user intervenes and clicks the stop button. BER can also be set to run unit a target value is reached or until a certain number of bits has been transmitted (units of 10 gigabits). The Timer lets the user set a time for the BER to stop.

BER Tabe of Results

The summary of BER measurements is shown in the following pane:



BER Graph

Plots BER values collected on the graph

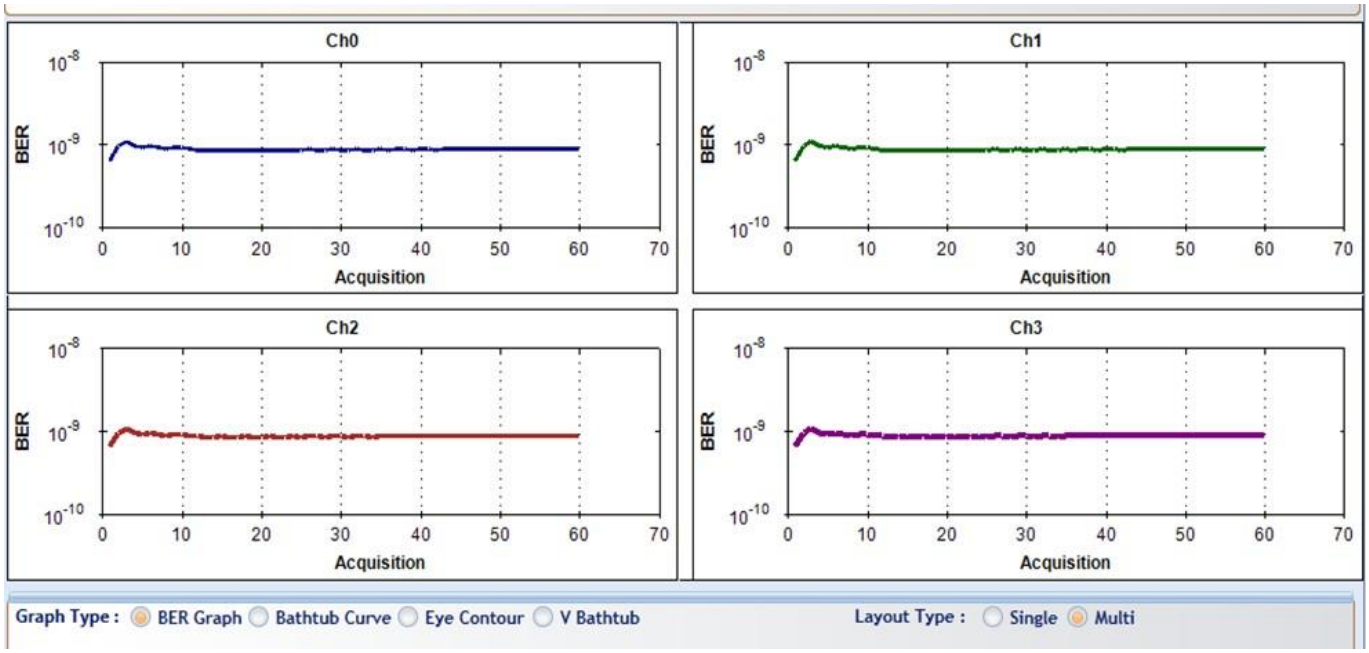


Figure 9: BER Graphs

Histogram Analysis

The histogram is the tool of choice to troubleshoot the link. You can think of it as a scope built into the receiver and it works even if you do not have pattern lock. For both NRZ and PAM signals, the histogram graph is shown as follows:

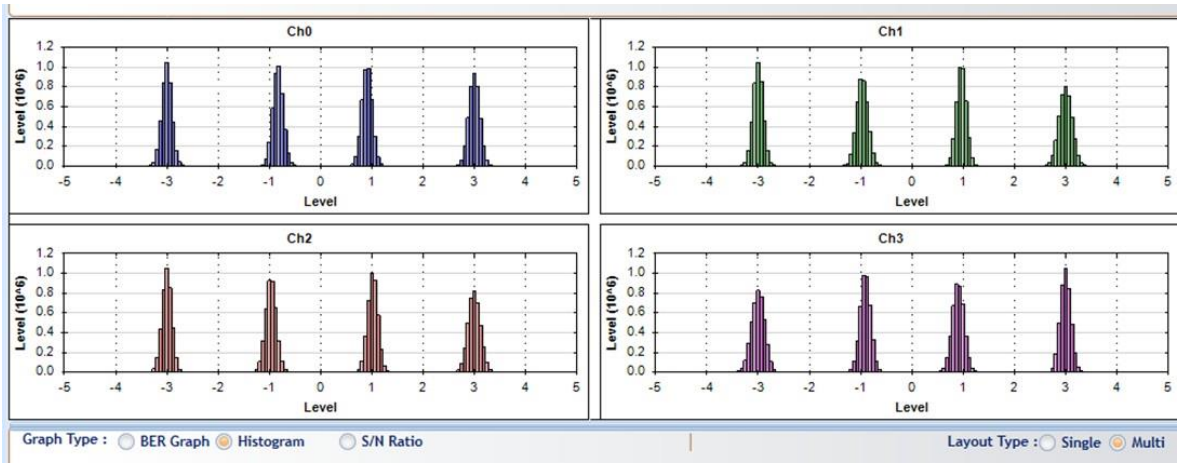


Figure 10: PAM Histogram

- The thinner the peaks the better the performance of the PAM signal and the less the jitter. These peaks can be enhanced using the pre/post-emphasis available.

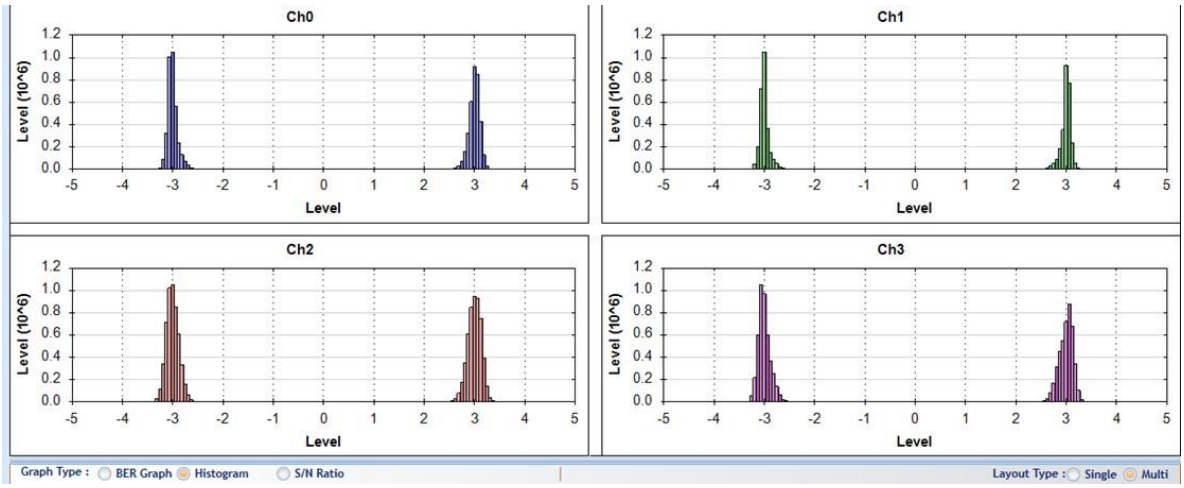


Figure 11: NRZ Histogram

- The same analogy applies as that of the PAM histogram.

Signal to Noise Ratio Analysis

SNR is a quantitative way to measure the strength of the received signal- it is given in dB.

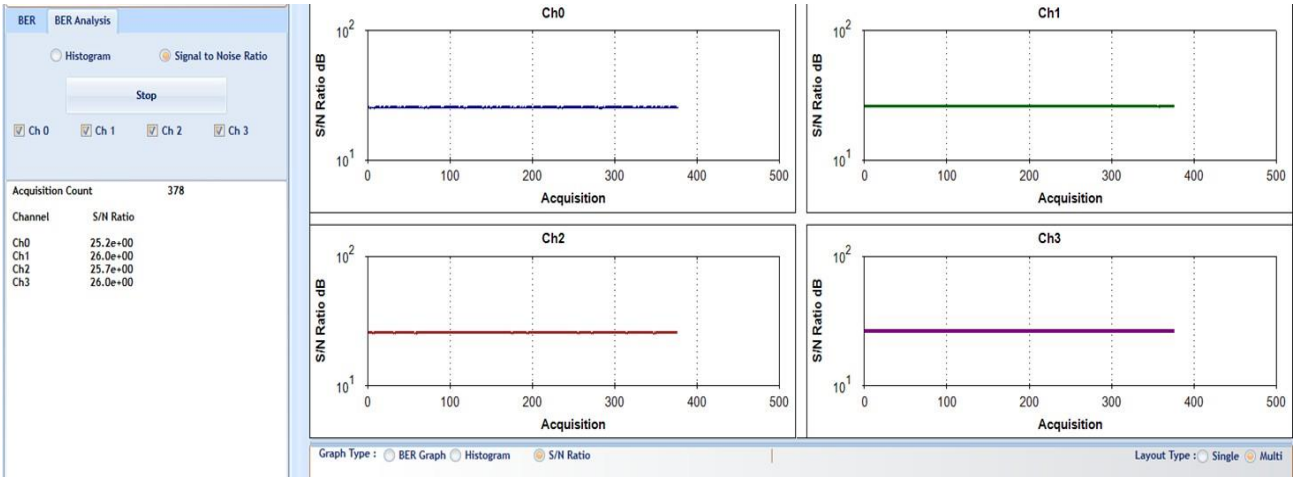


Figure 12: SNR ratio for PAM signal

Log file System

In the **ML4039D** BERT there is a log file system, where every exception handled or unhandled by the GUI will be saved. After the first run, the GUI creates a file in the main directory/exception log, and saves all the existed exceptions. In case the user had a problem with software, he can send the exception file to our team.

Note: the exception file will be deleted automatically after every 1 week of work.

How to Connect to the Instrument

The ML4039D and ML4079D have two PC interfaces: USB and Ethernet. The USB interface is only for changing the IP address of the instrument and for downloading boot loader and firmware. One cannot interface with the GUI through USB.

The Ethernet interface is used to interface with the GUI and APIs running on a Windows or Linux system. Ethernet may also be used to change the IP address and update the firmware as well.

NOTE. *This release supports Ethernet connection for the software applications (note that the IP[1] should be in the same range of the network).*

Connecting Through an Ethernet cable

To establish an Ethernet connection between the **ML4039D** panel and the PC, connect an Ethernet **patch chord** between the panel and the Router or Switch, and make sure you can connect your PC to the router via cable or wireless. Try pinging the instrument to verify that a connection has been established.

Make sure to have the correct IP address

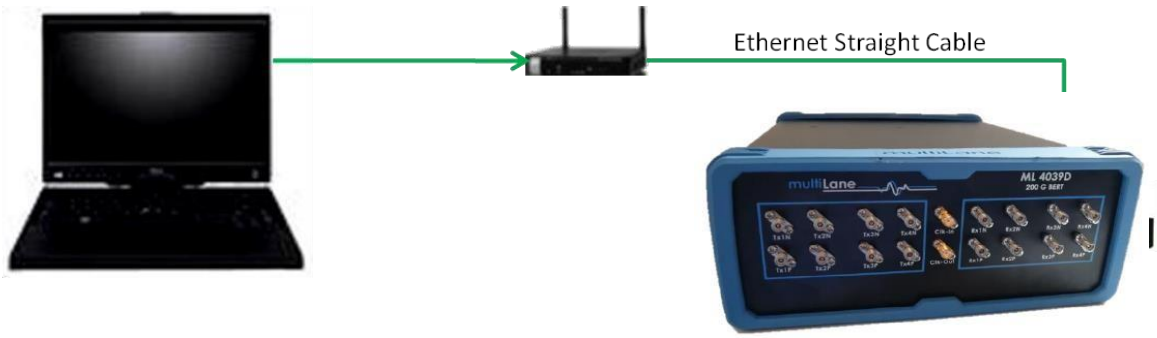


Figure 13: **ML4039D** connected to PC via Ethernet

[1]http:// *en.wikipedia.org/wiki/**IP**_address*

Connecting Through USB cables

Connect a USB cable between the panel and the PC.

USB Driver Installation

The USB driver is available for download on www.multilaneinc.com

The following instructions are applicable for a manual USB driver installation using Windows XP, Windows 7, 8 and 10.

- Power on the instrument.
- Plug-in the USB cable into the PC and connect it to the panel

USB Driver Installation on Windows XP, Windows 7 platforms

- Ignore the messages *new hardware found* or *driver software not successfully installed* by pressing **cancel** or **close**.
- Go to the device manager via a right click on **My Computer:**
  - Click on **Manage**.
  - Click on **Device Manager**.
- Right click on the top-level tab
  (Here multilane-PC) and select "**Scan for hardware changes**".

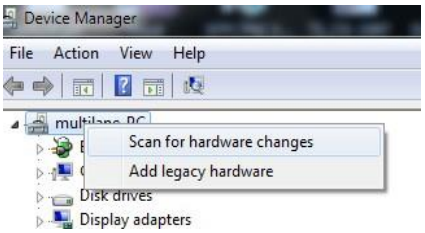


Figure 14: Scan for Hardware Changes

- A message appears stating: "**Scanning Plug and Play compliant hardware**".

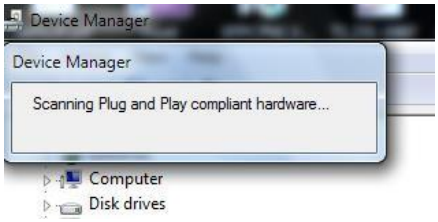


Figure 15: Scanning for Plugs

- In the **Other Devices** tab, the **ML4039 USB Device** description appears.
- In the **Other Devices** tab, right-click on the **ML4039 USB Device** and select "**Update Driver Software**"
- A dialog box appears asking for the method to search for the driver software. Select "**Browse my computer for driver software**".
- A dialog box appears asking for the Driver software path. Enter the path and click "**Next**".
- A security dialog box appears, select "**Install this driver software anyway**".
- The PC commences Driver software installation.
    - A Windows message appears (after some time) saying that you have successfully updated your driver software.
- Press close.
- In the Device Manager, a new tab appears named **MultiLane SAL Devices**. Expanding it reveals "**MultiLane SAL ML4039 USB Device**".
- You are now connected via USB and you can control the instrument.

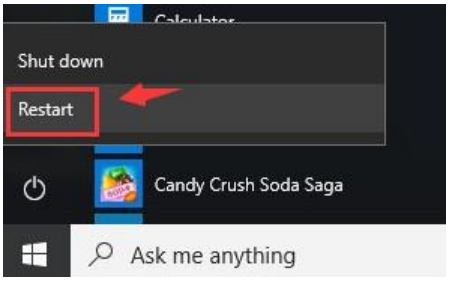
USB Driver Installation on Windows 8 platforms:

- Select "Settings" for the right-side menu, then "Change PC settings" 1.2. Under the "General" tab, scroll down to "Advanced startup" and click on "Restart now"
- Select "Troubleshoot/Advanced options/Startup settings/Restart" 1.4. Press "F7" for the "7) Disable driver signature enforcement"
- Install the MCHPUSB driver manually from MCHPUSB.inf ("Install this driver software anyway")
- Control Panel
  Open "Device manager" from the "Control panel". Right click the unrecognized device and select "Update driver software" .Select "Browse my computer for driver software". Select "Let me pick from a list of device drivers on my computer". Select "Custom USB device". Select the corresponding model (Microchip Custom USB Device)

USB Driver Installation on Windows 10 platforms:

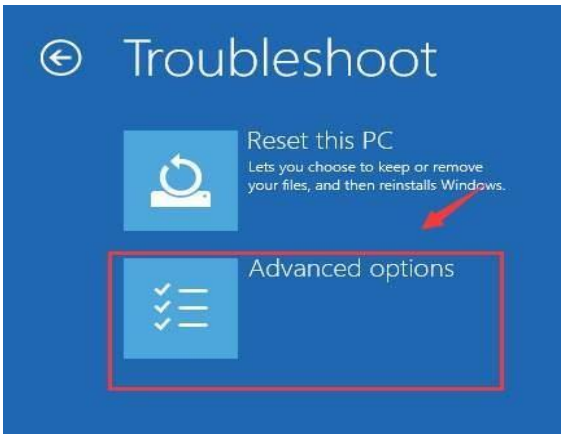
This method allows you to shut off driver signature enforcement feature for once. It is not a permanent change. Restart your computer and this feature is back on again.

1) Press Start button, and then click the icon for Restart and Shut down. Now, press and hold Shift key when you choose Restart.

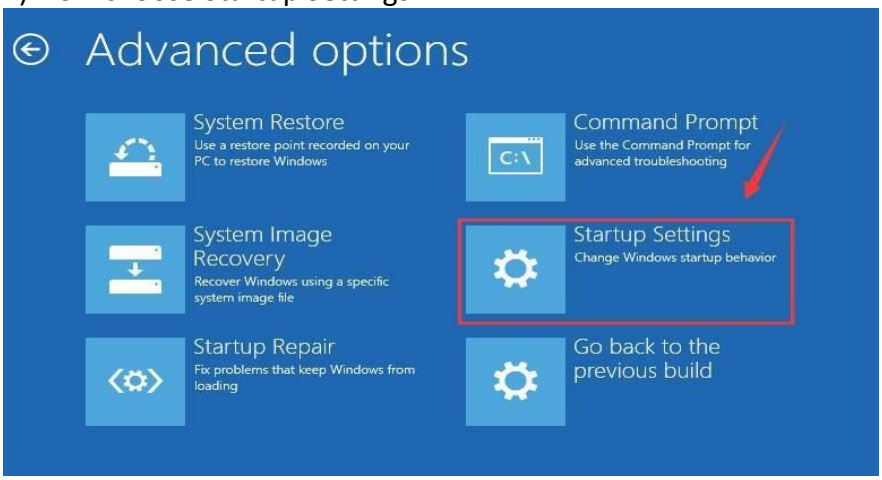


2) Choose Troubleshoot.

3) Choose Advanced options.

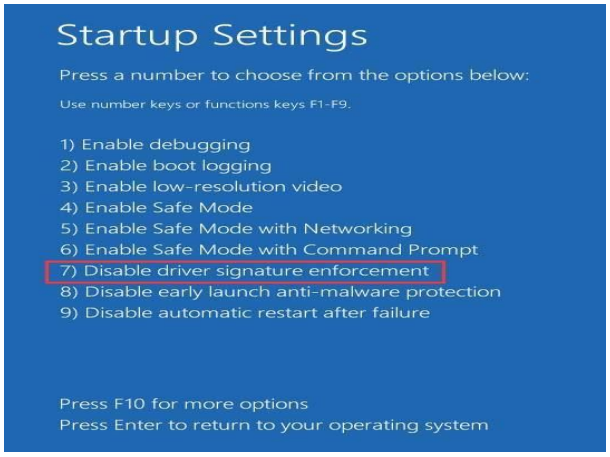


4) Now choose Startup Settings.



5) Click the Restart button here.

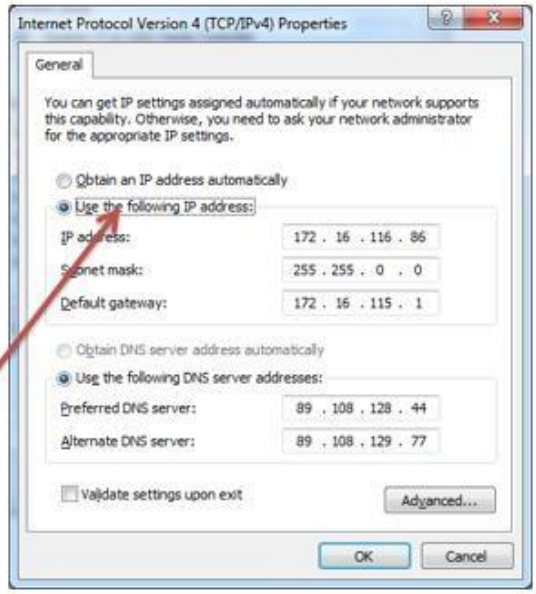
6) Press F7 key on your keyboard to go Disable driver signature enforcement.



7) Your PC will restart now and the driver signature enforcement feature will be disabled. You are free to install unsigned drivers as you want. As mentioned above, this is not a permanent fix and it will be gone the next time you restart your computer.

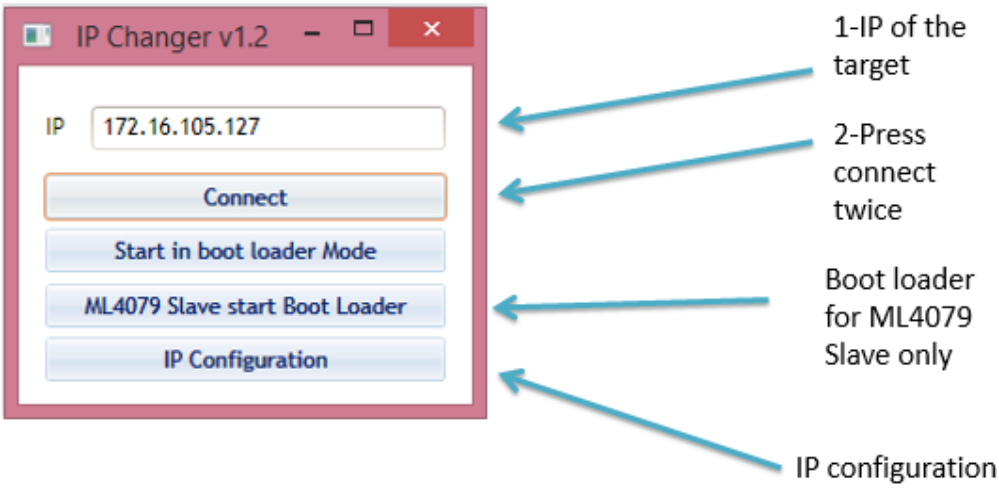
Firmware Upgrade on ML4039D & ML4079D

1- Download the ML IP Changer Application for the ML website
2- Change the static IP of the PC you are using to connect to the instrument



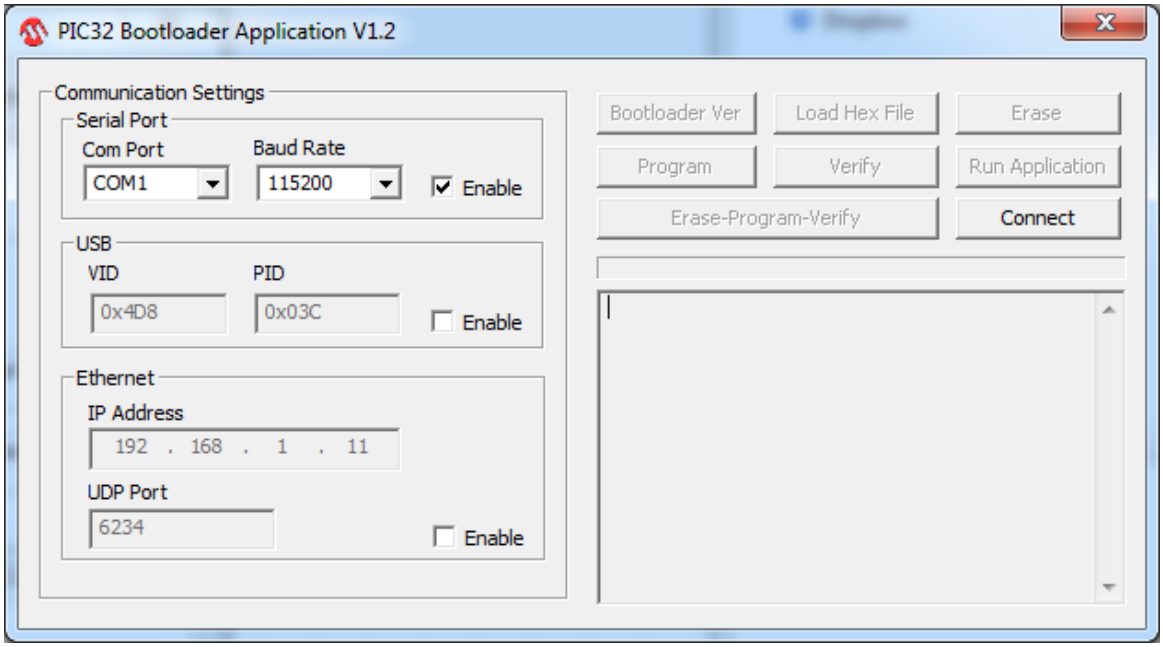
Before choosing to connect via Ethernet go to you network setting s and add a custom IP, in range with the ip on the hardware :
Ex: put 172.16.100.101
Mask : 255.255.0.0

3- Start the IP changer app, you should see the following; follow steps below:



Note that Boot loader is only for ML4079 Slave using USB

4- To update firmware, start in bootloader mode.



5- One can either use USB or Ethernet to update the firmware. If you choose Ethernet, your PC should be in the range of 192.168.1.x
6- Load the .hex file
7- Choose Erase program verify
8- Click: run application
9- Cycle power

Manual Revision History

This section describes the changes that were implemented in this document. The changes are listed by revision, starting with the most current publication.

Revision 1.0: 5/29/18

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