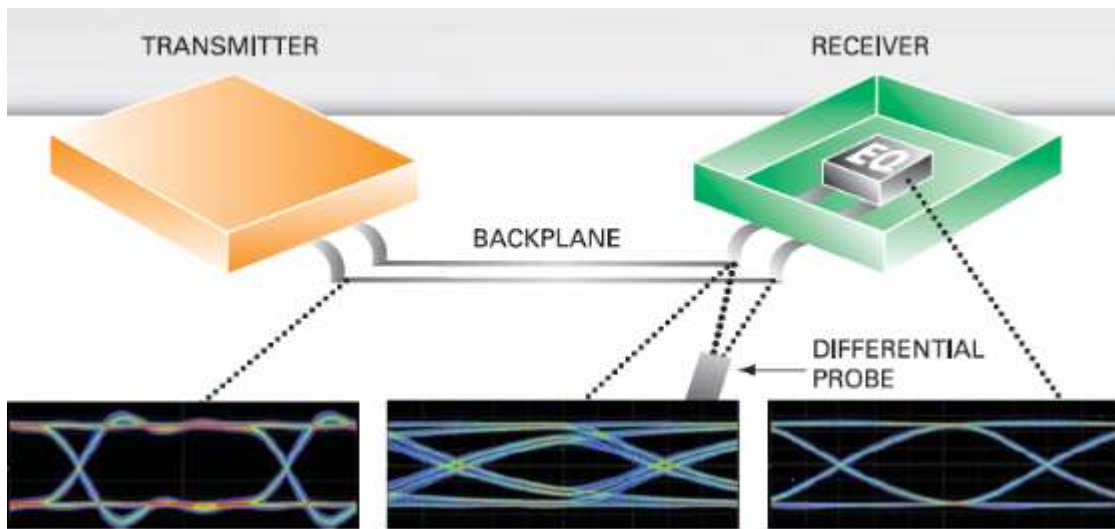




Eye Doctor II



Operator's Manual

February, 2009



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EYEDRII-OM-E RevA

917093 RevA

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Eye Doctor II Overview

Eye Doctor II is a complete set of tools that allows the full-range of de-embedding, emulation and equalization on full record lengths (up to 512 Mpts) with little impact on waveform processing time and with results integrated into the oscilloscope interface for further analysis using LeCroy's complete analysis deep toolbox. Eye Doctor II uses industry-standard S-parameter measurements and Touchstone files that are created with simulators, VNAs, TDRs, LeCroy WaveExpert, etc. and are the universal language of the signal integrity engineer. All basic capability is easily accessible in a streamlined, simple user interface. More advanced capability is accessible in through the Processing Web Editor.

Key Features

- **Transmitter Emphasis Emulation** - Transmitter Emphasis Emulation gives the user the ability to add or remove emphasis from their signal. Using the Auto Add or Auto Remove capability, the user can simply enter the amount of emphasis they would like to add or remove. Custom mode allows the user to specify the specific tap values for the linear tapped delay line filter that creates the emphasis. Both Pre-emphasis and De-emphasis are supported in Eye Doctor II
- **Fixture De-embedding** - Fixture De-embedding gives the user the ability to move the reference for their measurement to a point before their fixture, such as directly to the transmitter output, by removing the effects of the fixture. The user must have a Touchstone Format S-Parameter file that describes their fixture to de-embed.
- **Channel Emulation / De-embedding** - Channel Emulation / De-Embedding gives the user the ability to move the reference for their measurement to a different point in their system. This feature allows the user to either move the reference to a point after a serial data channel by emulating the channel effects, or to a point before a serial data channel by de-embedding the channel (similar to Fixture De-embedding). For both emulation and de-embedding of serial data channels, the user must have a Touchstone Format S-Parameter file that describes their channel.
- **Receiver Equalization Emulation** - Receiver Equalization give the user the ability to emulate the effects that a Continuous Time Linear Equalizer and/or Feed Forward Equalizer would have on a serial data signal. This is critical step for some serial data signals that could have a completely closed eye at the receive input.

Eye Doctor II Setup

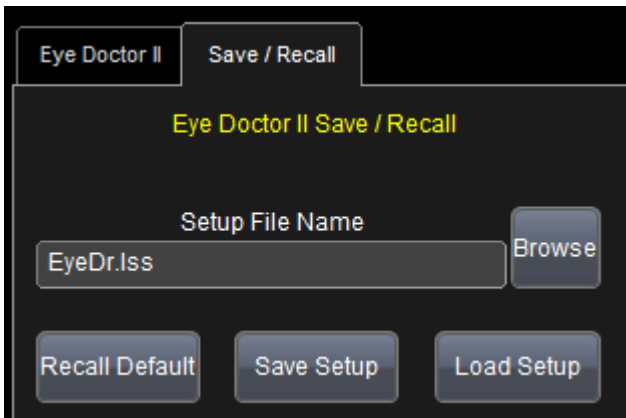
You can access the Eye Doctor II dialog by choosing **Analysis** → **Eye Doctor II**. The **Eye Doctor II** dialog shows the flow of the data from the transmitter to the receiver. Each of the blocks in the flow diagram is a button. When you touch one of these buttons, the corresponding dialog is displayed. For example, touching the Signal Input button displays the Signal Input dialog. Additionally, the checkboxes underneath each button allows you to view the output waveform from that block.



1. Touch **Analysis** → **Eye Doctor II** on the menu bar.
2. On the **Eye Doctor II** Dialog, touch the [Signal Input](#) button to set up your signal input sources and set your nominal bit rate.
3. Touch the [Emphasis](#) button add or remove pre-emphasis or de-emphasis from your serial data signal.
4. Touch the [Emulate / De-embed](#) button to:
 - Emulate Channel / De-embed Fixture
 - De-embed Channel / De-embed Fixture
 - De-embed Fixture Only
5. Touch the [Equalizer](#) button to emulate either a **Continuous Time Linear Equalizer (CTLE)** or a **Feed Forward Equalizer (FFE)**.
6. Touch **Save / Recall** to save your current Eye Doctor II setup or recall a previous Eye Doctor II Setup.
7. Touch **Turn Off Views** to automatically uncheck all 4 of the **Show** output waveforms checkboxes located underneath each button.

Save / Recall

Click the **Save/Recall** button on the **Eye Doctor II** dialog to save your current Eye Doctor II setup or recall a previously saved Eye Doctor II setup.



Saving your current Eye Doctor II Setup

1. Click on the **Setup File Name** dialog to specify the desired name for your setup file that you would like to save. Click **Browse** button to select an existing file to save over or to specify a new location for the saved setup.
2. Click on the **Save Setup** button.

Recalling your previously saved Eye Doctor II Setup

1. Click on the **Browse** button to select the setup file that you would like to recall.
2. Click on the **Load Setup** button.

For more information, see **Eye Doctor II Overview**.

Signal Input

Click on the **Signal Input** button on the **Eye Doctor II** dialog to access the **Signal Input** dialog.



Signal Input Setup

1. Touch **Analysis** → **Eye Doctor II** on the menu bar.
2. On the **Eye Doctor II** dialog, touch the **Signal Input** button.
3. In the **Eye Doctor II Input(s)** section, if you are using a differential probe, touch the **1 Input (or Diff. Probe)** button. Press the **Input1** button and select an input source from the **Select Source** popup window.

OR

If you are using two single-ended probes to calculate the differential signal, touch the **Input1-Input2** button. **Input2** is subtracted from **Input1**. Touch the **Input1** and **Input2** buttons and select a source for each from the **Select Source** pop-up window.

Nominal Bit Rate

The nominal bit rate must be set in order for the [Emphasis](#) and [Equalizer](#) blocks in Eye Doctor II to function properly. In order for these blocks to work correctly, the bit rate does not have to be exact, but it should be within +/-3%.

For more information, see [Eye Doctor II Overview](#).

Emphasis

Emphasis Overview

Click on the **Emphasis** button on the **Eye Doctor II** dialog to access the **Emphasis** dialog.



Emphasis is added to a signal as a way to pre-compensate for expected channel losses. Since high frequency components are attenuated more by serial data fixtures and channels (making the high frequency components higher amplitude than the low frequency components at the far end of the serial data channel) they can be the same amplitude. Checking or unchecking the **Enable** checkbox allows you to quickly enable or disable the **Emphasis** block.

The Emphasis section allows you to:

- **Add Pre-emphasis** - This boosts the high frequency components of your input signal by the amount **Gain** specified. (For more information, see **Auto Add Emphasis**.)
- **Add De-emphasis** - This attenuates the low frequency components of your input signal by the amount **Gain** specified. (For more information, see **Auto Add Emphasis**.)
- **Remove Pre-emphasis** - This attenuates the high frequency components of your input signal by the **Gain** amount specified. (For more information, see **Auto Remove Emphasis**.)
- **Remove De-emphasis** - This boosts the low frequency components of your input signal by the **Gain** amount specified. (For more information, see **Auto Remove Emphasis**.)
- **Custom** - Specify up to 8 tap values for a custom FIR filter response. (For more information, see **Custom Emphasis**.)

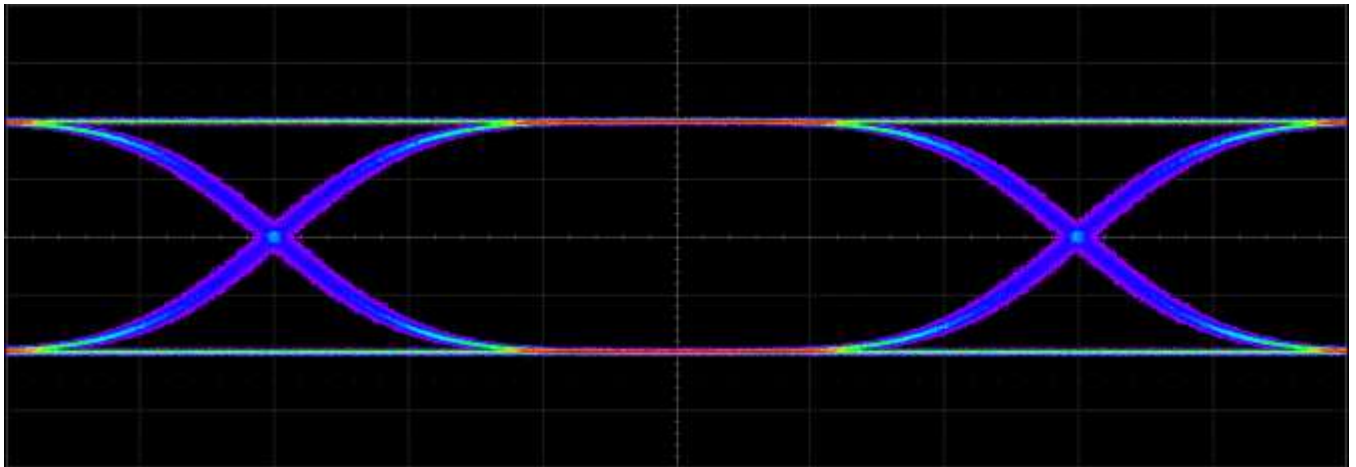
For more information, see **Eye Doctor II Overview**.

Auto Add Emphasis

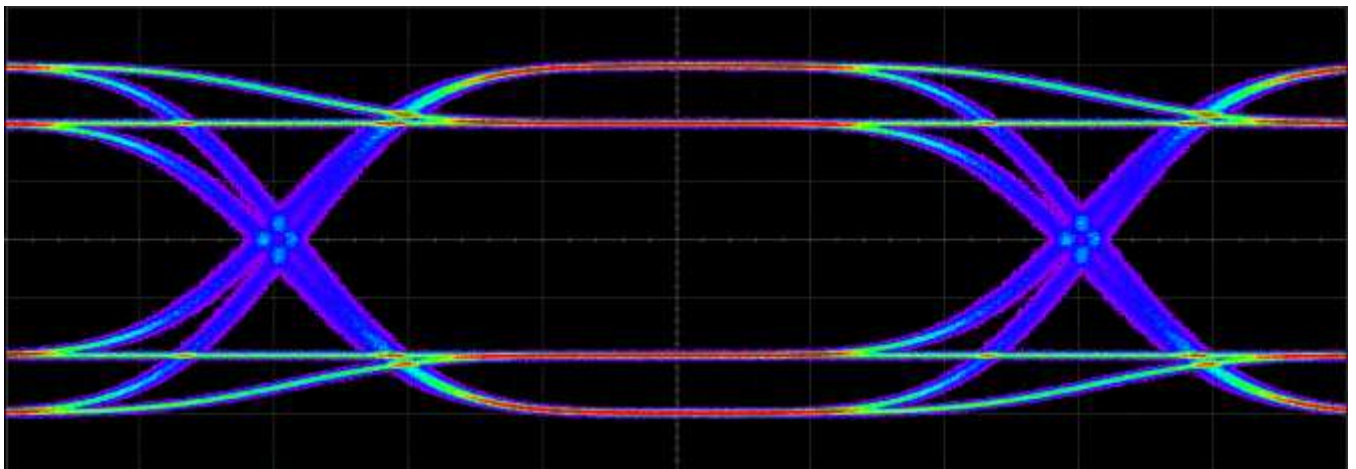
Auto Add Emphasis automatically determines the appropriate tap values for your input signal when you specify the amount of emphasis to add in the **Gain** box. Pre-emphasis and de-emphasis can be automatically added.

Automatically adding pre-emphasis boosts the high frequency components of the input signal by the **Gain** amount specified.

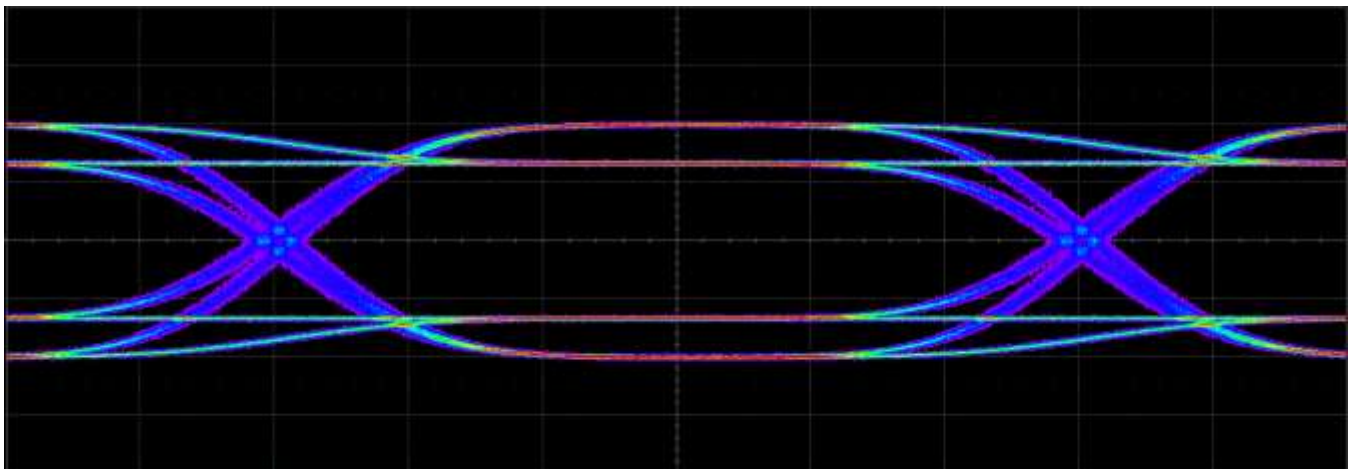
Automatically adding de-emphasis attenuates the low frequency components of the input signal by the **Gain** amount specified.



This image shows a 5 Gb/s Eye Diagram without emphasis added to it



This image shows a 5 Gb/s Eye Diagram with 3.5 dB of pre-emphasis added to it



This image shows a 5 Gb/s Eye Diagram with 3.5 dB of de-emphasis added to it.

For more information, see **Emphasis Overview**.

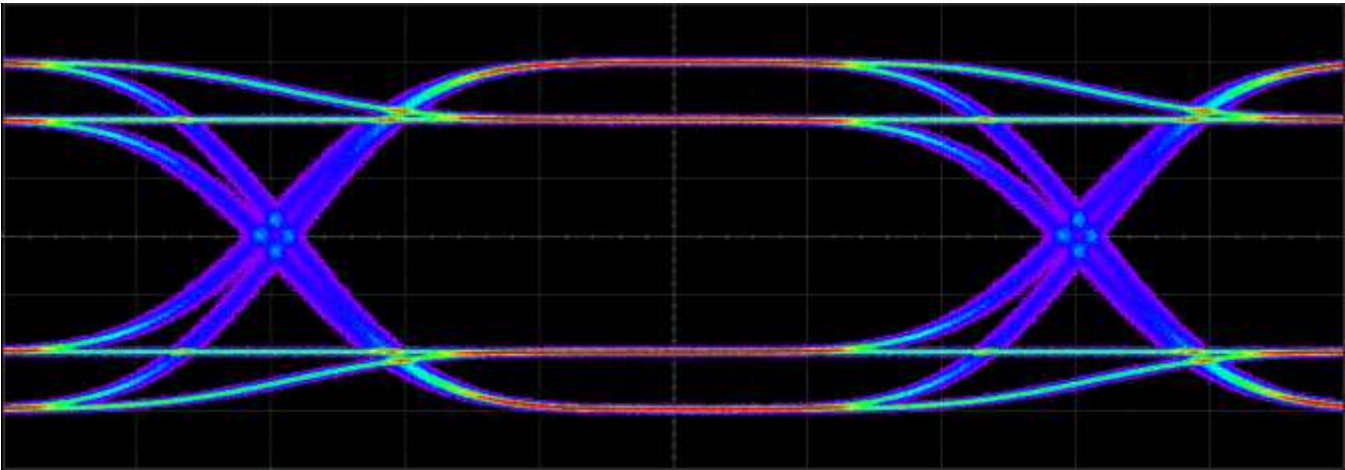
Eye Doctor II

Auto Remove Emphasis

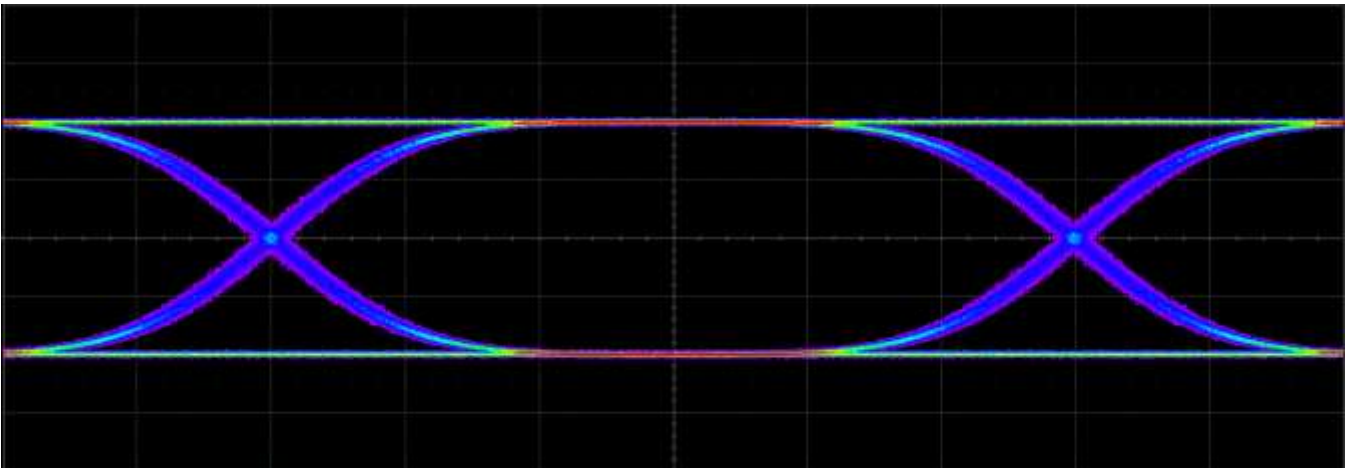
Auto Remove Emphasis automatically determines the appropriate tap values for your input signal when you specify the amount of emphasis to add in the **Gain** box. Pre-emphasis and de-emphasis can be automatically removed.

Automatically removing pre-emphasis attenuates the high frequency components of the input signal by the **Gain** amount specified.

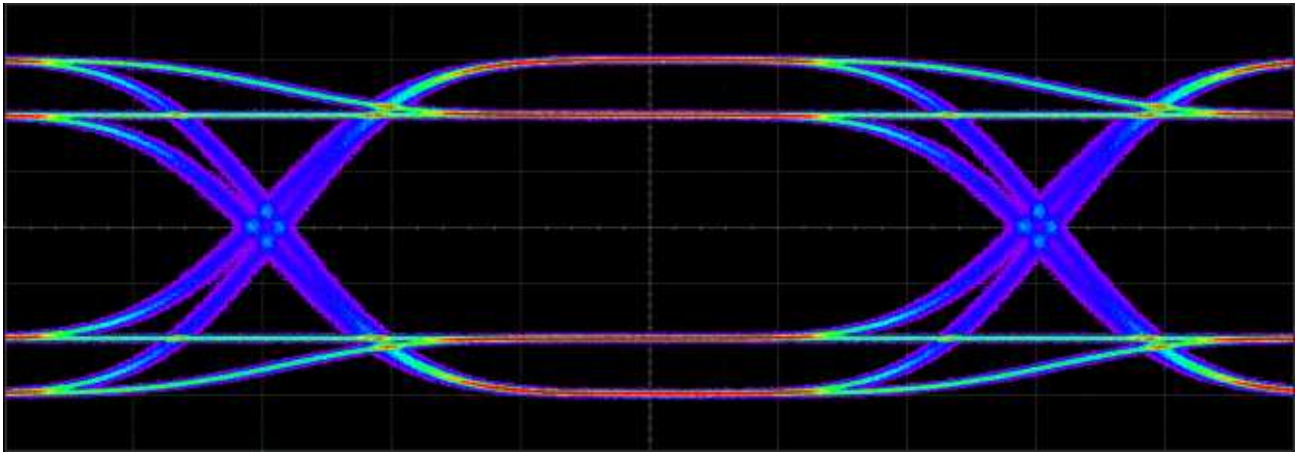
Automatically removing de-emphasis boosts the low frequency components of the input signal by the **Gain** amount specified.



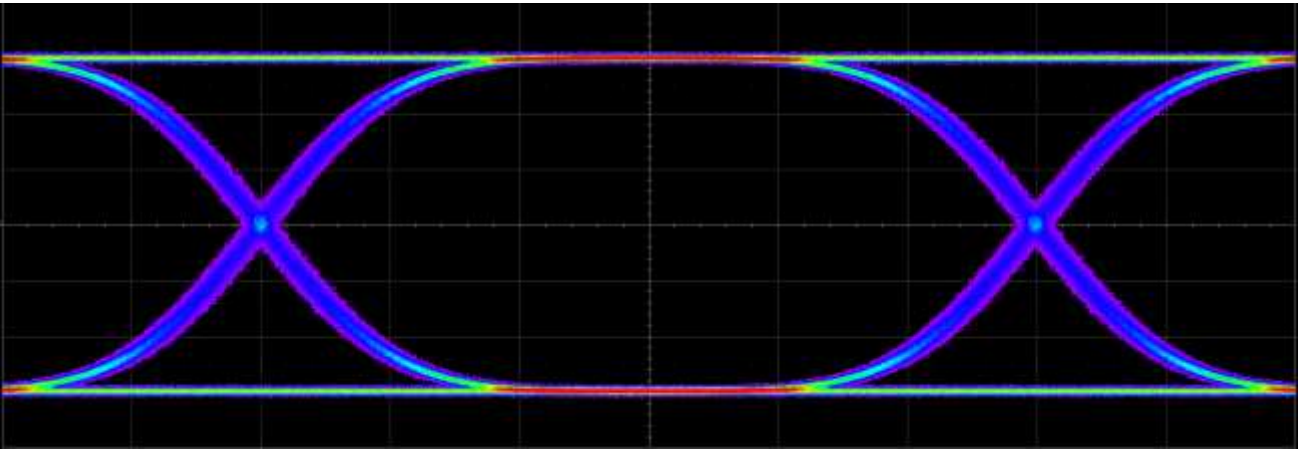
This image is a 5 Gb/s Eye Diagram of a signal that has 3.5 dB of pre-emphasis.



This image is the same 5 Gb/s Eye Diagram with the 3.5 dB of pre-emphasis removed.



This image is a 5 Gb/s Eye Diagram of a signal that has 3.5 dB of de-emphasis.

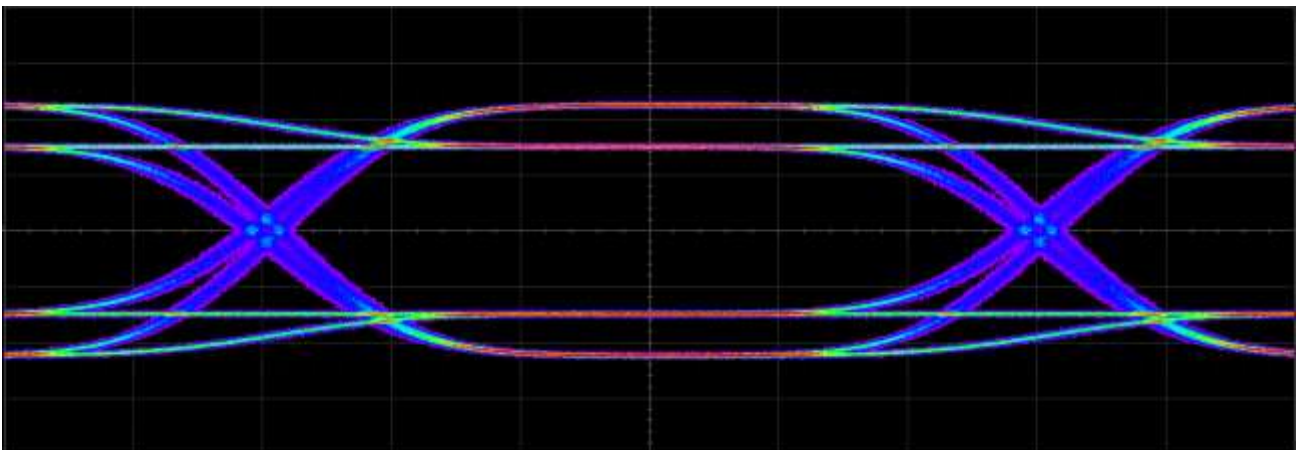


This image is the same 5 Gb/s Eye Diagram with the 3.5 dB of de-emphasis removed.

For more information, see **Emphasis Overview**.

Custom Emphasis

Custom emphasis allows you to enter in up to 8 tap values for a custom FIR filter.



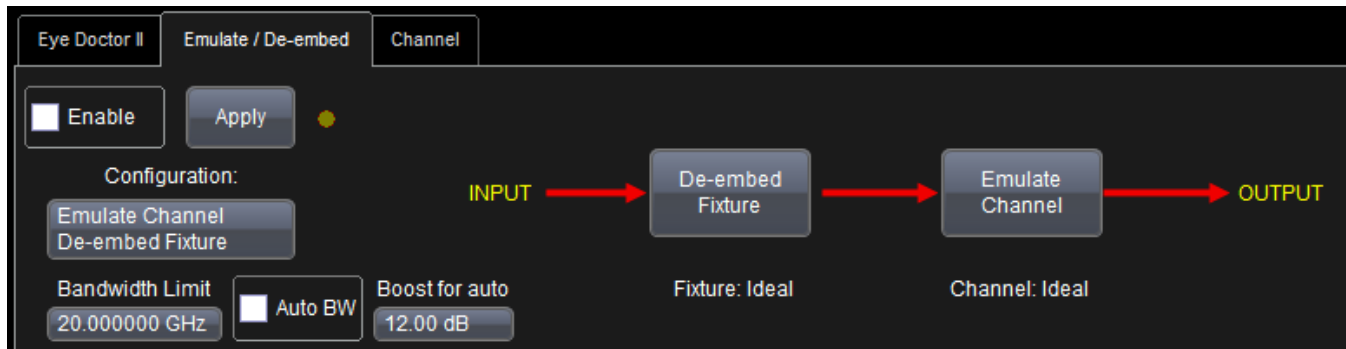
This image shows a 5 Gb/s Eye Diagram with a custom Finite Impulse Response (FIR) filter with Tap 0 = $-250e-3$ and Tap 1 = 1.25

For more information, see **Emphasis Overview**.

Emulate / De-embed

Emulate / De-embed Overview

Click on the **Emulate / De-embed** button on the **Eye Doctor II** dialog to access the **Emulate / De-embed** dialog.



The **Emulate / De-embed** block allows you to De-embed Fixtures, De-embed Serial Data Channels and Emulate Serial Data Channels

- **Fixture De-embedding** - Use Fixture De-embedding to move the reference for your measurement to a point before the fixture, such as directly to the transmitter output, by removing the effects of the fixture. A Touchstone Format S-Parameter file describing your fixture is required to de-embed.
- **Channel Emulation / De-embedding** - Use Channel Emulation / De-Embedding to move the reference for your measurement to a different point in your system. You can either move the reference to a point after a serial data channel by emulating the channel effects, or to a point before a serial data channel by de-embedding the channel (similar to Fixture De-embedding). For both emulation and de-embedding of serial data channels, a Touchstone Format S-Parameter file describing your channel is required.

Emulate / De-embed Setup

1. Choose a **Configuration**.
2. Click on the **De-Embed Fixture**, **Emulate Channel** and/or **De-embed Channel** buttons to specify the S-parameters for the fixtures and channels. (For more information, please refer to the **Fixture and Channel Dialog** section of this manual.)
3. Specify a **Bandwidth Limit** or check the **Auto BW** checkbox and specify a **Boost for Auto** amount.
4. Click **Apply**. Every time a change is made to anything in the **Emulate / De-embed** dialog, **Apply** must be clicked again in order to update the associated processing. If **Apply** is not clicked, the processing defined from the last time the **Apply** button was clicked is still in use. The expected use case for **Apply** is to make all the necessary changes, and then click **Apply**.

PLEASE NOTE THE FOLLOWING:

- Specifying a **Bandwidth Limit** is only required if the chosen configuration requires de-embedding. For example, if the **Emulate Channel / De-embed Fixture** configuration is chosen, but the de-embed fixture block is left as ideal, the bandwidth limit has no effect on the signal.
- The indicator light next to the **Apply** button turns green if everything is properly setup. If the indicator does not turn green, it means there is something wrong with your selected s-parameter file or port assignment. Use the **View Response** functionality to help debug your issue.
- For more information on the **De-embed Fixture**, **Emulate Channel** or **De-embed Channel** menus please refer to the **Fixture and Channel Dialog** section of this manual.

For more information, see **Eye Doctor II Overview**.

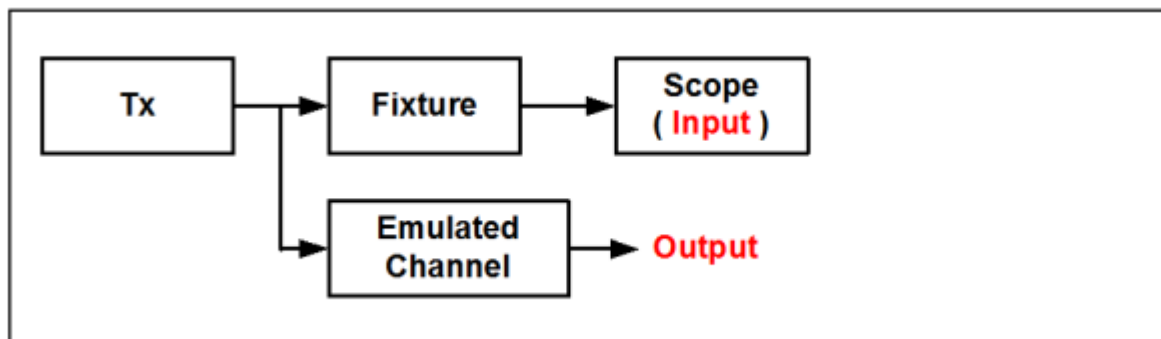
Configuration

The **Configuration** selection box in the **Emulate / De-embed** dialog allows you to choose from 3 configurations:



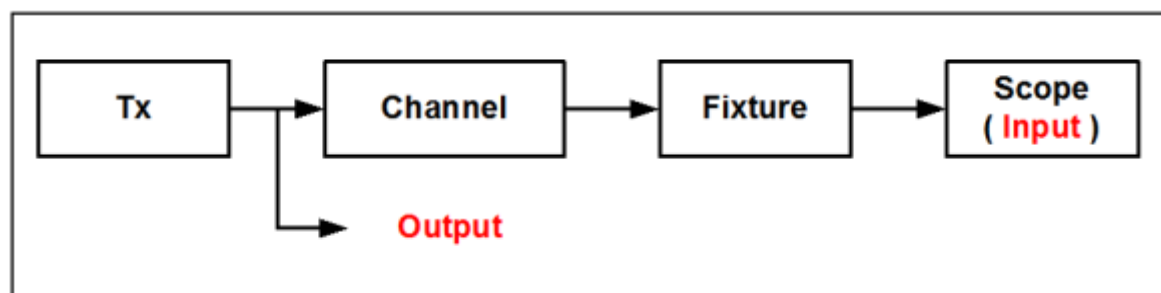
Emulate Channel / De-embed Fixture

The **Emulate Channel / De-embed Fixture** configuration allows you to both de-embed a fixture and emulate a serial data channel at the same time. This is used when you are using a fixture to measure at the transmitter side of the serial data channel. It first moves the measurement reference to the output of the transmitter, and then moves the reference to the far side of a serial data channel. This allows you to emulate the effects the serial data channel has on your signal, with the fixture effects removed.



De-embed Channel / De-embed Fixture

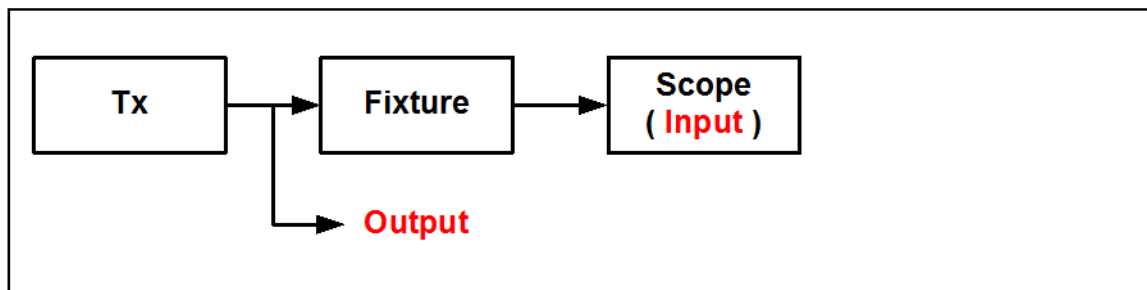
The **De-embed Channel / De-embed Fixture** configuration allows to you both de-embed a fixture and de-embed a serial data channel at the same time. This is used when you are using a fixture to measure at the receiver side of the serial data channel. It moves the measurement reference back to the output of the transmitter. This allows you to see what the serial data signal looked like at the transmitters output with the effects of the channel and fixture removed.



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De-embed Fixture Only

The De-embed Fixture Only configuration allows you to simply remove the fixture effects from your measurements. This allows you to see what the serial data signal looked like at the transmitters output with the effects of the fixture removed.



For more information, see [Emulate / De-embed Overview](#).

Bandwidth Limit

When De-embedding fixture or channels a bandwidth limit is required and must be set.



Bandwidth Limit imposes a reasonably sharp low pass filter in addition to the S-parameter system response. This is useful when de-embedding a lossy channel, to limit the amount of boost applied. When a channel is de-embedded, high frequency response must be boosted to compensate for the high frequency attenuation in the channel. However, if the signal has been attenuated into the noise floor, boosting the signal on the oscilloscope makes it impossible to distinguish between the signal and the noise. The system boosts the noise along with the signal. The **Bandwidth Limit** setting can limit the overall response to the lower frequencies where signal components are detectable above the noise. If this value is set to zero, the default, then no bandwidth limit is applied.

Auto BW and **Boost for Auto** has the same effect as Bandwidth Limit but instead of setting the bandwidth, you set the maximum boost to allow. Eye Doctor II looks at the S-parameter responses and sets up the low pass filter (see **Bandwidth Limit**, previous) at the frequency where one of the outputs has more boost than the specified **Boost for Auto**. **Boost for Auto** can be set between 3 dB and 20 dB. The bandwidth in use is reported back to the user.

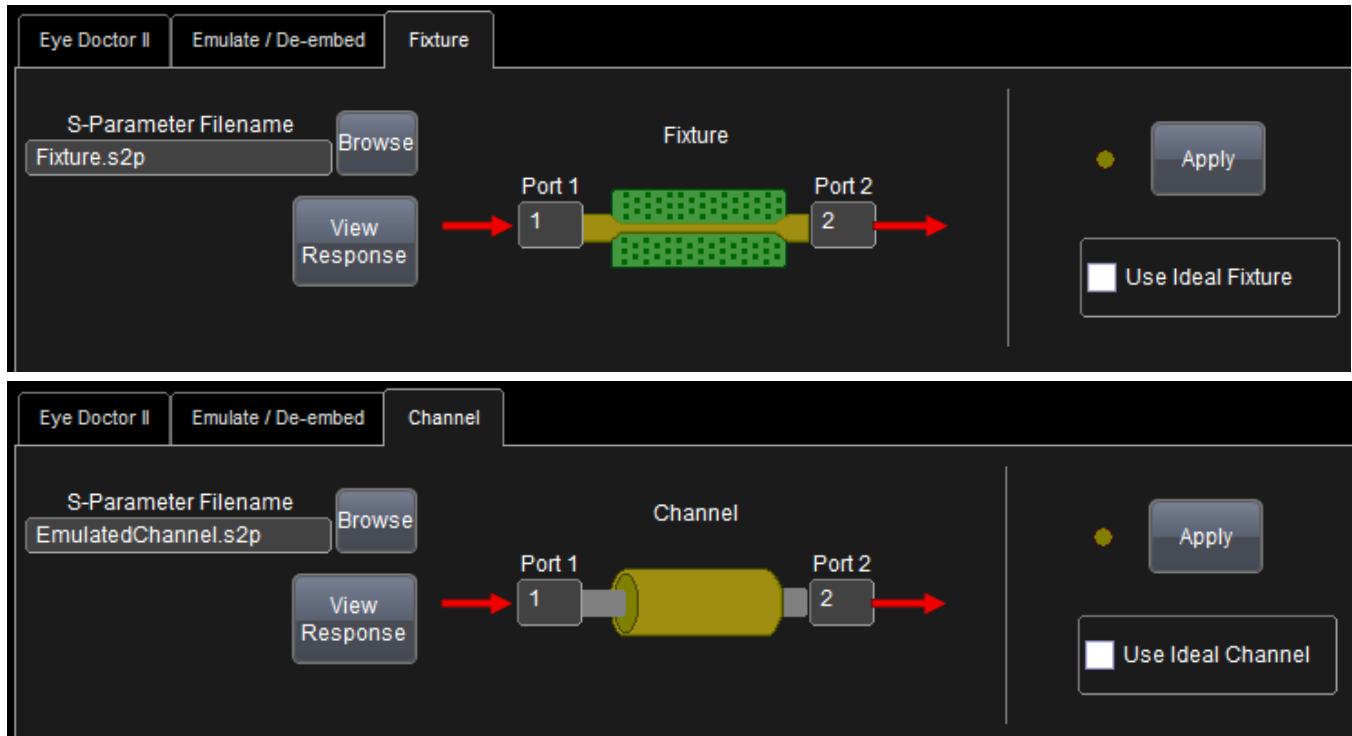
Note: If you are emulating a passive fixture or channel, then the S-parameter system does not have any boost, and the bandwidth in use is the highest bandwidth possible.

For more information, see [Emulate / De-embed Overview](#).

Fixture and Channel Dialog

Click the **De-embed Fixture**, **De-embed Channel** or **Emulate Channel** button from the **Emulate / De-embed** dialog to access the **Fixture** or **Channel** dialog. The Fixture and Channel dialogs have identical functionality. A Single Ended or Differential dialog is shown depending on the selection made on the **Signal Input** dialog. (If **1 Input (or Diff. Probe)** is selected, the Single Ended dialog is shown. If **Input1-Input2** is selected, the Differential dialog is shown.)

Single Ended Fixture and Channel Dialog Functionality

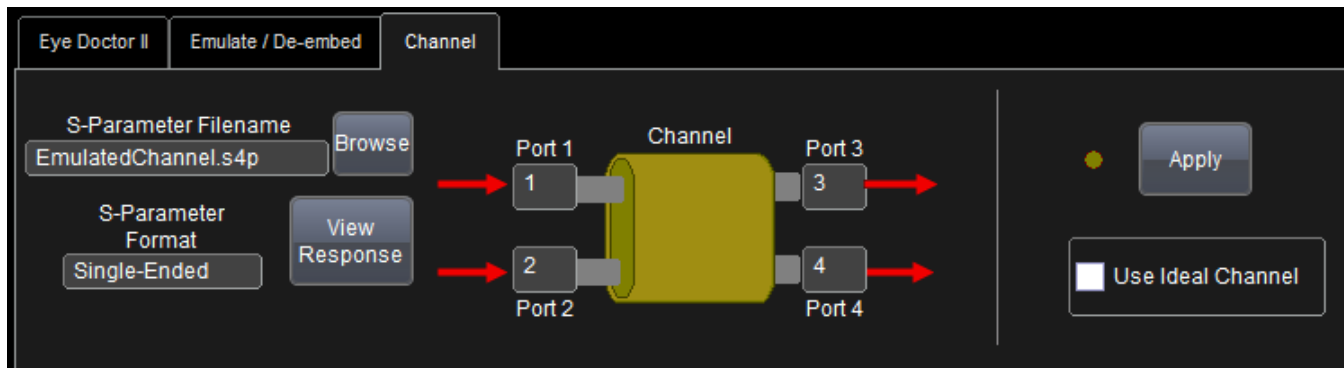


1. Check the **Use Ideal Fixture** or **Use Ideal Channel** checkbox to use a perfect fixture or channel with no loss.
2. Click **Browse** to select the Touchstone format s-parameter file for the fixture or channel that you would like to de-embed or emulate.
3. Specify the port assignments that correspond to you selected s-parameter file. (The number in the port assignment control refers to the column in the Touchstone format s-parameter file. This is useful for re-mapping the ports of your s-parameter file to the default port for Eye Doctor II without having to modify the s-parameter file.)
4. View the response of your selected s-parameter file. (For more information please refer to the **View Response** section of this manual.)
5. Click **Apply** to build the appropriate file for your selected fixture and/or channel settings.

PLEASE NOTE THE FOLLOWING:

- The indicator light next to the **Apply** button turns green if everything is properly setup. If the indicator does not turn green, it means there is something wrong with your selected s-parameter file or port assignment. Use the **View Response** functionality to help debug your issue.
- S-parameter files should cover the frequency range up to (at least) 1/2 the oscilloscope's sample rate. For example, if the s-parameter file only covers up to 10 GHz, then the oscilloscope sample rate should be 20 GS/s. When the fixture or channel is being emulated, there is little effect. However, if the fixture or channel is being de-embedded, then the s-parameter matrix must be inverted. If it does not have data up to half the oscilloscope's sample rate it can cause problems. For this reason, this requirement is particularly important when de-embedding.

Differential Fixture and Channel Dialog Functionality



1. Check the **Use Ideal Fixture** or **Use Ideal Channel** checkbox to use a perfect fixture or channel with no loss.
2. Select the Touchstone format s-parameter file for the fixture or channel that you would like to de-embed or emulate.
3. Specify the port assignments that correspond to you selected s-parameter file. (The number in the port assignment control refers to the column in the Touchstone format s-parameter file. This is useful for re-mapping the ports of your s-parameter file to the default port for Eye Doctor II without having to modify the s-parameter file.)
4. Select **S-Parameter Format** - Either **Single-Ended** or **Mixed Mode**.
5. View the response of your selected s-parameter file. (For more information please refer to the **View Response** section of this manual.)
6. Click **Apply** to build the appropriate file for your selected fixture and/or channel settings.

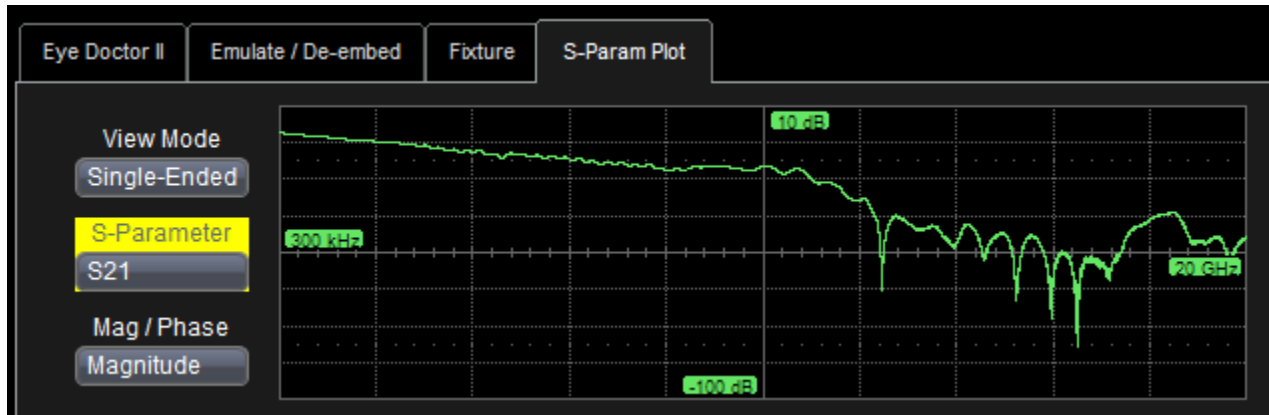
PLEASE NOTE THE FOLLOWING:

- The indicator light next to the **Apply** button turns green if everything is properly setup. If the indicator does not turn green, it means there is something wrong with your selected s-parameter file or port assignment. Use the **View Response** functionality to help debug your issue.
- S-parameter files should cover the frequency range up to (at least) 1/2 the oscilloscope's sample rate. For example, if the s-parameter file only covers up to 10 GHz, then the oscilloscope sample rate should be 20 GS/s. When the fixture or channel is being emulated, there is little effect. However, if the fixture or channel is being de-embedded, then the s-parameter matrix must be inverted. If it does not have data up to half the oscilloscope's sample rate it can cause problems. For this reason, this requirement is particularly important when de-embedding.

For more information, see **Emulate / De-embed Overview**.

View Response

The **View Response** button on the Fixture and Channel Menus allows you to view the magnitude or phase plot for the selected s-parameter file.



Eye Doctor II allows for easy viewing of all the s-parameter plots from your selected Touchstone format S-parameter file.

1. Specify which s-parameter file you would like to view.
2. Specify whether you would like to view the magnitude or phase of the s-parameter.

PLEASE NOTE THE FOLLOWING:

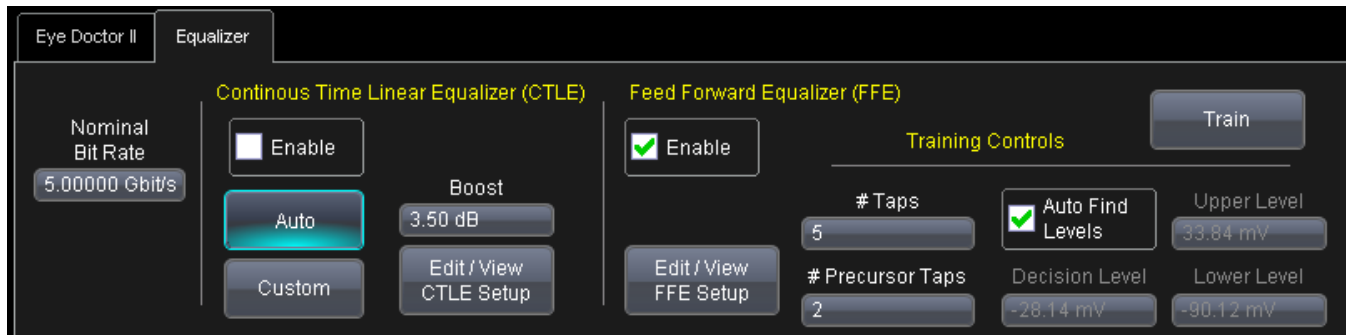
- For 4 port s-parameter files, you have the choice to view the Single-Ended or Mixed Mode s-parameters using the **View Mode** control.
- You can use a Math to zoom the S-parameter plot that was view last. To do this, select EDrResp as the source for the zoom function. This will enable you to view a s-parameter plot on the full grid and use cursors on the trace.

For more information, see **Emulate / De-embed Overview**.

Equalizer

Equalizer Overview

Click on the **Equalizer** button on the **Eye Doctor II** dialog to access the **Equalizer** dialog.



The Equalizer feature allows you to see the waveform after equalization. Both **Continuous Time Linear Equalizer (CTLE)** and **Feed Forward Equalizer (FFE)** are supported. They can be run individually or together.

The **Nominal Bit Rate** shown in this dialog is always the same as what is shown in the **Signal Input** dialog.

Continuous Time Linear Equalizer (CTLE)

To use the CTLE:

1. Check the **Enable** checkbox in the **Continuous Time Linear Equalizer (CTLE)** section.
2. Specify the amount of **Boost** to use for equalization.

Note: For more information on CTLE refer to the **Continuous Time Linear Equalizer (CTLE)** section of this manual.

Feed Forward Equalizer (FFE)

To use the FFE:

1. Check the **Enable** checkbox in the **Feed Forward Equalizer (FFE)** section.
2. Specify the number of taps in the **# Taps** dialog.
3. Specify how many of those taps should be precursor taps in the **# Precursor Taps** dialog.

Note: The number of precursor taps is often around half of the total number of taps.

4. Either check the **Auto Find Levels** check box or manually enter the **Upper Level**, **Lower Level** and **Decision Level**.
5. Click the **Train** button.

Note: For more information on FFE refer to the **Feed Forward Equalizer (FFE)** section of this manual.

For more information, see **Eye Doctor II Overview**.

Continuous Time Linear Equalizer (CTLE)

A first order Continuous Time Linear Equalizer (CTLE) is implemented in the Eye Doctor II software. The reference equalization algorithm for PCI-Express 3.0 and for SuperSpeed USB is a first order CTLE. The default settings for DC Gain and Boost for our implementation are the settings for SuperSpeed USB.

The CTLE is defined by DC Gain and the placement of 2 Poles and 1 Zero.

If you set the **Boost** on our **Equalizer** dialog, the DC Gain is unaffected and the higher frequency pole is placed at the bit rate and the lower frequency pole at a fraction of the bit rate as used in SuperSpeed USB. The Zero to deliver the requested Boost is also moved.

If you press the **Edit / View CTLE Setup** then you can set the DC Gain, and the positions of the 2 Poles and 1 Zero (as follows).

Eye Doctor II
Equalizer
CTLE Parameters

Continuous Time Linear Equalizer Parameter Control

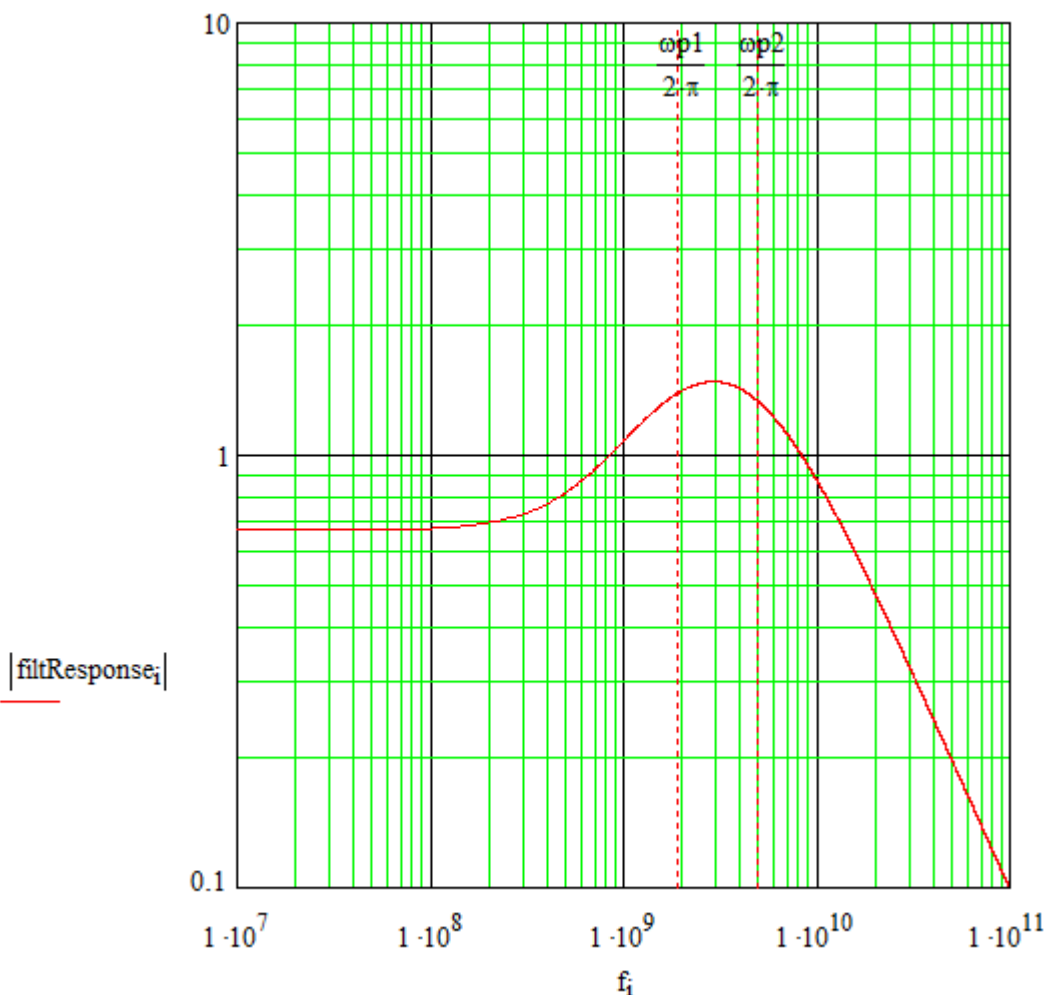
DC Gain:

Zero Frequency:

Pole 1 Frequency:

Pole 2 Frequency:

$$H(s) = \frac{A_{dc} \omega_{p1} \omega_{p2}}{\omega_z} \cdot \frac{s + \omega_z}{(s + \omega_{p1})(s + \omega_{p2})}$$



This graph shows the response of the CTLE response for SuperSpeed USB. Eye Doctor II uses these settings as the default for the CTLE.

For more information, see **Equalizer Overview**.

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Feed Forward Equalizer (FFE)

A Feed Forward Equalizer (FFE) is implemented as a 1 tap per unit interval Finite Impulse Response (FIR) filter. This is a linear tapped delay line equalizer. An FFE can compensate for Inter-Symbol Interference (ISI) due to preceding and following bits. Therefore, it is typical for the number of precursor taps to be at least 1 less than the number of taps used. Using an FFE introduces a delay in your output waveform. This delay is due to the number of precursor taps.

While the best way to use the FFE is to train it, you can also enter the exact taps weights (if known) on the FFE Taps dialog (as follows).

Tap Index	Tap Weight
00:	1.000000
01:	0e-6
02:	0e-6
03:	0e-6
04:	0e-6
05:	0e-6
06:	0e-6
07:	0e-6
08:	0e-6
09:	0e-6
10:	0e-6
11:	0e-6
12:	0e-6
13:	0e-6
14:	0e-6
15:	0e-6
16:	0e-6
17:	0e-6
18:	0e-6
19:	0e-6

For more information, see [Equalizer Overview](#).