Use Equalization To View Closed-Eye Signals With A Digital Oscilloscope

by Dennis Weller, Agilent Technologies

Serial signaling such as PCI Express and Serial ATA are becoming commonplace in new designs. A serial signal consists of a transmitter sending a differential signal over a medium, such as backplane or cable, to a receiver. As signal rates increase, the medium attenuates the signal at the receiver, resulting in a *closed* signal eye (see Fig. 1). The receiver is unable to extract the clock or data from this closed eye.

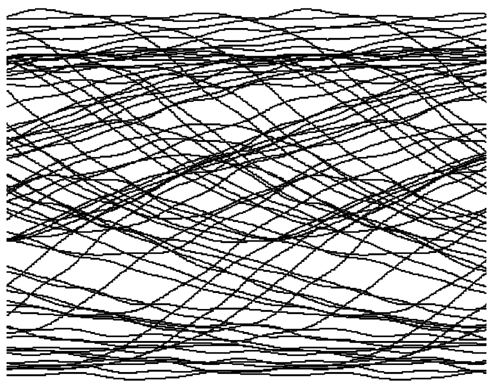

Fig. 1: Closed Eye Signal At Receiver Input

De-emphasis is a common method to compensate for signal loss over the medium to *open* the eye at the receiver. De-emphasis is performed in the transmitter by boosting the amplitude of transition bits, as shown in Fig. 2.

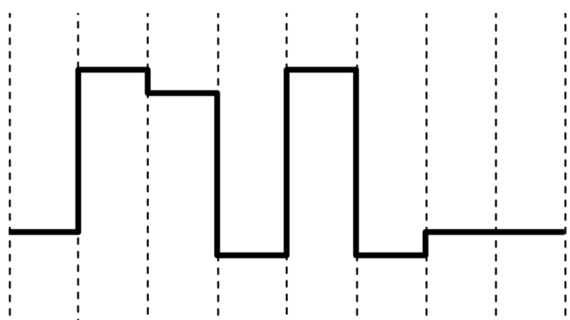

Fig. 2: Transmitter De-Emphasis

At faster data rates and longer medium lengths, de-emphasis alone is not sufficient keep the eye open at the receiver. In this case a method called equalization is used in the receiver to boost the higher frequency components of the signal. This effectively opens the eye inside the receiver (see Fig. 3) enabling the receiver to extract the clock and data. However, the eye is still closed at the receiver’s input pins.

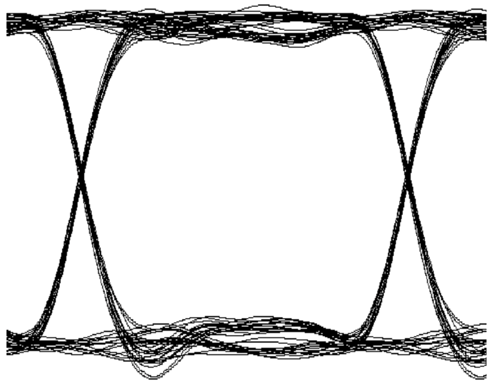

Fig. 3: Equalized Eye Signal Inside Receiver

Often, an oscilloscope is used to observe the signal at the receiver's input pins. Even more desirable would be to determine what the signal looks like inside the receiver after equalization. Or perhaps an engineer would like to determine the optimal equalization for the medium. In all these cases, it is necessary for the oscilloscope to equalize the signal. A digital oscilloscope can do this.

Oscilloscope Configuration

Modern digital oscilloscopes include the capability to process the waveforms with math functions. Using these the response of the oscilloscope can be peaked at higher frequencies to emulate the equalization found in receivers. To demonstrate this, the math functions in an Agilent DSO80000 series oscilloscope are used to equalize a 2.5 Gbit/s serial signal, as shown in Fig. 4.

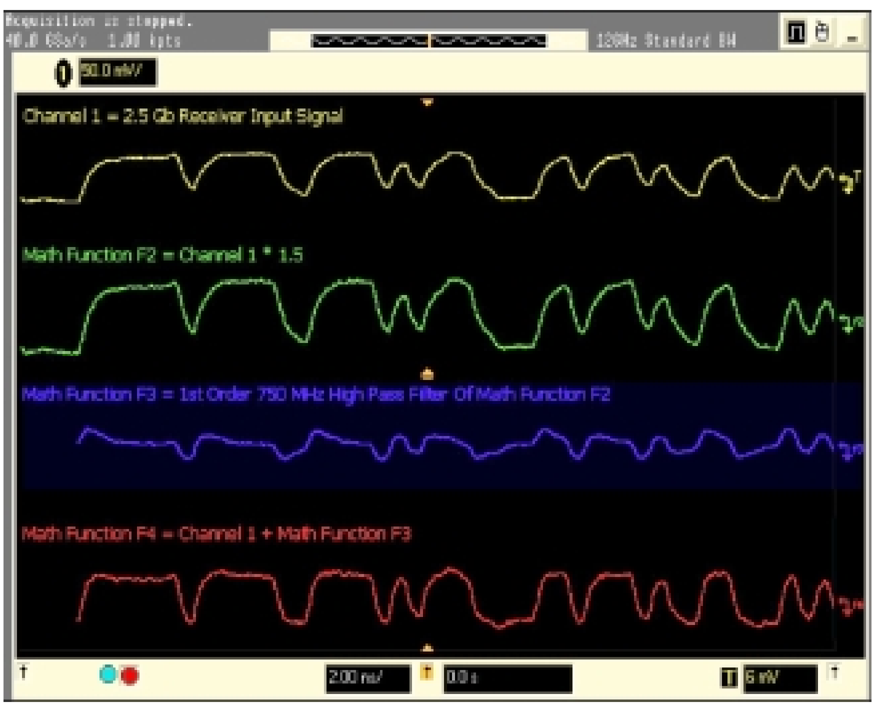

Fig. 4: Math Function Configuration For Equalization

The top (yellow) trace is the receiver's input signal fed into Channel 1 of the oscilloscope. Notice the signal loss due to the medium.

The second trace (green) is math function F2 configured as Channel 1 multiplied by a user adjustable multiplier. In this case, the multiplier is set to 1.5.

The third trace (blue) is math function F3 configured as a 1st order high pass filter of math function F2. The -3dB frequency for F3 is user adjustable, and set to 750 MHz in this example.

The forth trace (red) is math function F4, configured as Channel 1 added to math function F3. Math function F4 represents the equalized signal. The amount of peaking is controlled by the multiplier used for math function F2. The frequency where the peaking takes effect is controlled with math function F3. More specifically, the equalization transfer function H(s) will be:

$$H(s) = 1 + M\left[\frac{s}{s + 2\pi f}\right]$$

Where: $\boldsymbol{M}$ = Math Function F2 multiplier
$\boldsymbol{f}$ = Math Function F3 filter bandwidth

Using the above equation, the math functions can be adjusted to determine the best equalization for a given medium. Or, the math functions can be set to emulate the receiver's equalization to deduce what the eye signal looks like inside the receiver.

In the case of differential signals, often the positive and negative signals are applied to two separate channels of the oscilloscope, and math function F1 is used to create the differential signal. In this case, math function F2 would be configured to multiply math function F1 instead of Channel 1, and math function F4 would add math functions F1 and F3.

Eye Diagrams

Now that the signal has been equalized, the improvement of the eye signal can be observed in Fig. 5, using the oscilloscope's eye mode. The top trace (yellow) is the un-equalized closed eye signal on Channel 1 of the oscilloscope. The bottom trace (red) is the equalized open eye signal on math function F4. Measurements of interest, such as jitter and BER estimation, can now be performed on the equalized signal.

Fig. 5: Eye Diagram View

Conclusion

As data rates increase, eye signals are closing at receiver inputs. A method has been presented to use the math functions of a digital oscilloscope to view these otherwise closed eye signals, emulating the equalizer in the receiver.

About The Author

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