Technical Note

Using the Eye Pattern to Troubleshoot Signal Impairments

MP2100A

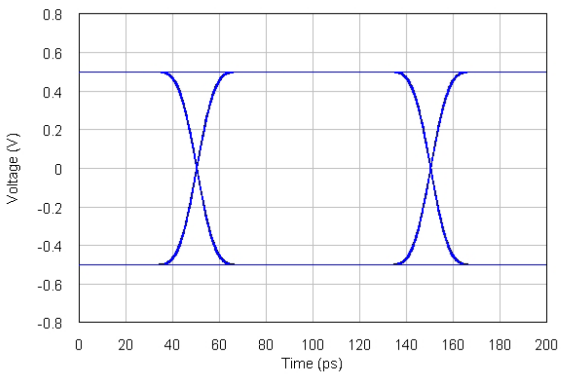
BERTWave Series

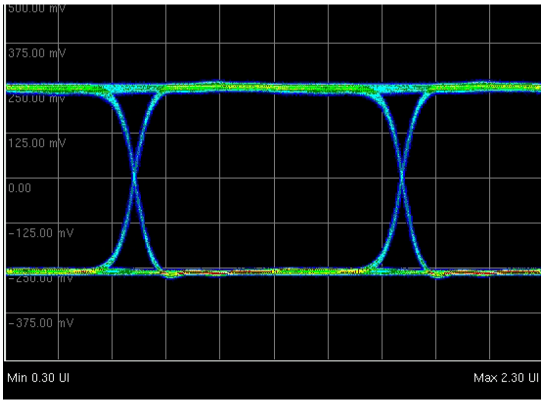
The eye pattern is a useful tool for assessing the integrity of digital signals. The ones and zeroes of a data stream are superimposed to form an eye pattern, providing a good representation of how the data has been affected by a transmission link. Statistical measurements such as extinction ratio and Q-factor are often performed on the eye pattern for compliance testing of devices and transmission paths. These provide good pass/fail criteria, but lend little information as to what may be degrading the signal path.

Undistorted Eye Diagram

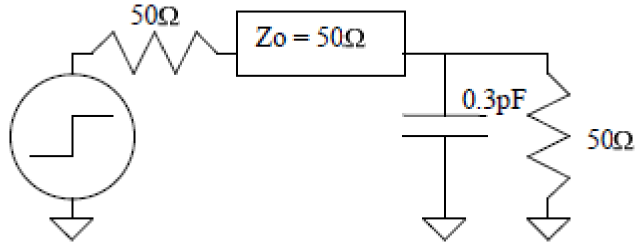
Let’s examine the impact of real-world impairments on the eye pattern. For discussion purposes, assume the data source is an ideal 50 Ω signal generator.

An undistorted eye pattern is shown below. The NRZ signal has no distortion at the one and zero levels and no significant jitter at the crossing points. The picture on left side is simulated

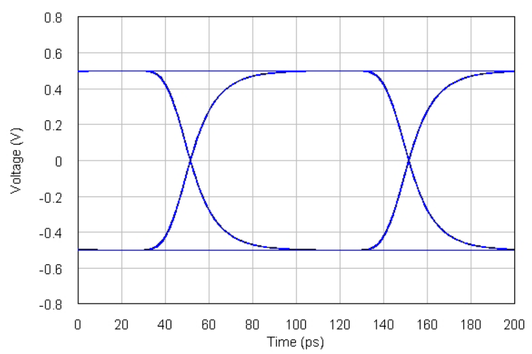


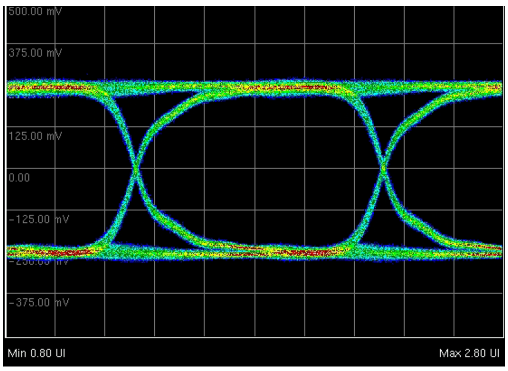


Lumped Element Discontinuity



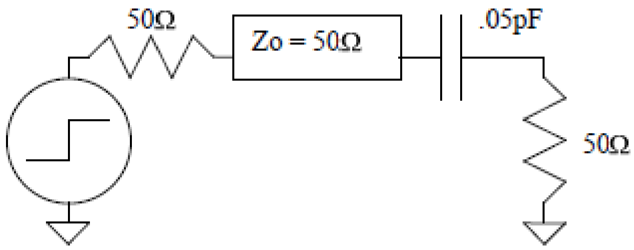
Shunt capacitance or series inductance can cause a distortion of the eye diagram as shown below.



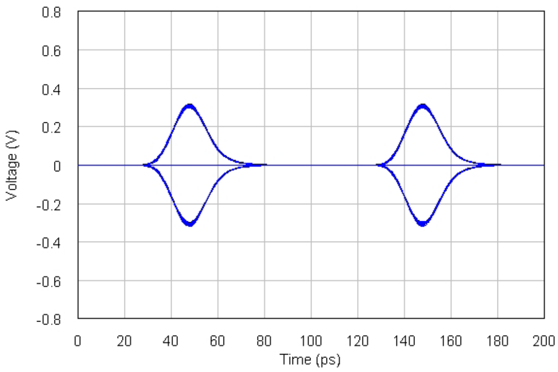


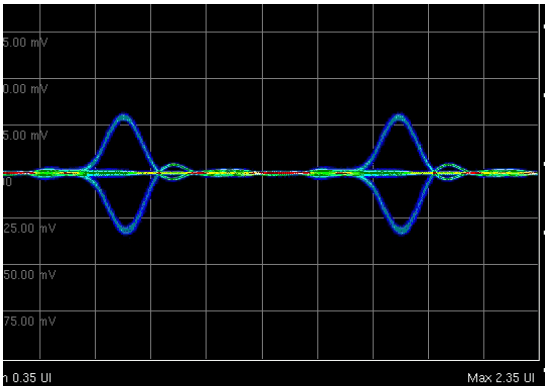
The shunt capacitance opposes fast voltage transitions and will slow down the rising and falling edges of a data pattern. The degradation will have an exponential response with time constant τ=RC. A 50 Ω load and 0.3 pF parasitic capacitance will produce a 15 psec time constant. Series inductance will have a similar effect as it opposes fast current transitions. In this case, the time constant is L/R. A 50 Ω load and 0.75 nH parasitic inductance will also produce a 15psec time constant.

Open Circuit or Short Circuit Discontinuity



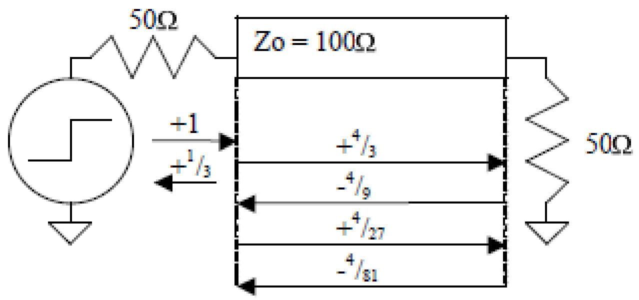
This is a serious impairment that can be modeled as a very small series capacitance or shunt inductance. Only the high frequency content of the data pattern will pass through the impairment, producing pulses where the crossing point of the eye diagram used to be. The center of the eye pattern is completely closed. Damaged connectors and cables can often cause this effect.





Series Transmission Line Discontinuity

Undershoot in an eye pattern can be caused by both high impedance and low impedance transmission line sections. In the simulated example below, a 100 Ω, λ/4 line is inserted in the transmission path. Multiple reflections occur at the 50 Ω - 100 Ω boundaries. The reflection coefficient is equal to (ZL-Z0)/(ZL+Z0). If the initial pulse from the 50 Ω source is 1 volt amplitude, a positive voltage reflection increases it to 1+(100-50)/(100+50) = 4/3 in the 100 Ω line.



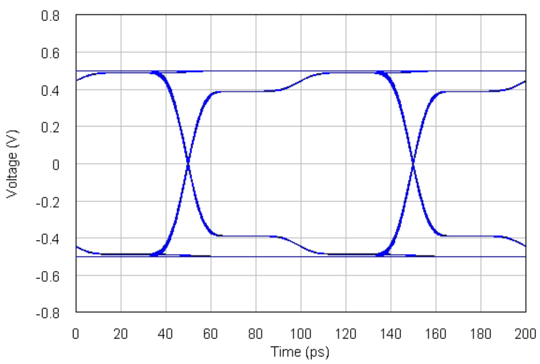
Because of the reflection at the 100Ω transmission line and 50Ω load interface, only

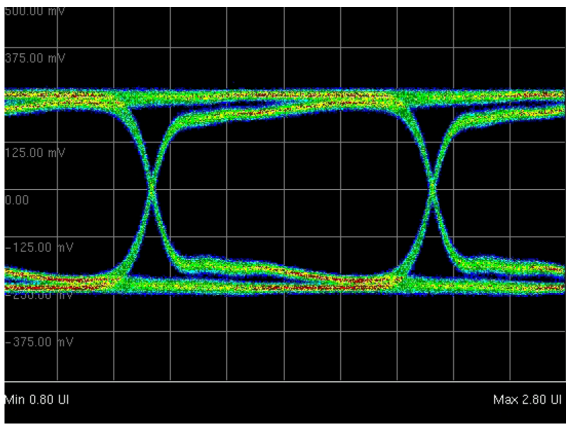
$$4/3 - 4/9 = 8/9$$

of the initial pulse amplitude makes it to the load. This effect is evident in the closure of the left half of the eye. The second reflection brings the signal level up to

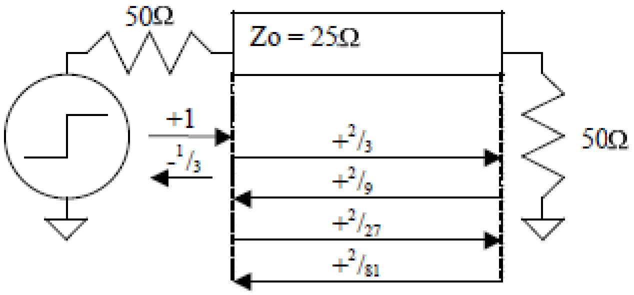
$$4/3 - 4/9 + 4/27 - 4/81 = 80/81$$

of the initial amplitude. This is barely noticeable as a miniscule closure in the right half of the eye. Longer lengths of transmission line will cause a larger horizontal portion of the eye to be closed by the initial reflection, and greater impedance mismatches will cause larger vertical eye closure.





The same exercise can be performed for a low impedance transmission line section.



For the initial reflection:

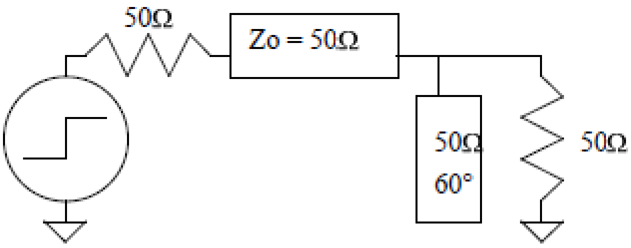
$_2/_3 + {}_2/_9 = {}_8/_9$

For the second reflection:

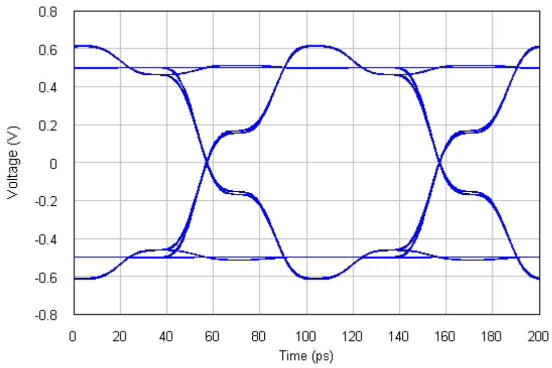
$_2/_3 + {}_2/_9 + {}_2/_{27} + {}_2/_{81} = {}_{80}/_{81}$

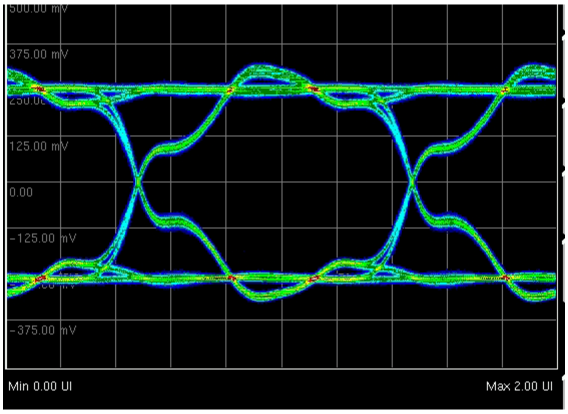
Poor connector interfaces, incorrect trace widths, and series circuit elements that are too wide are all possible causes of this discontinuity.

Shunt Transmission Line Discontinuity



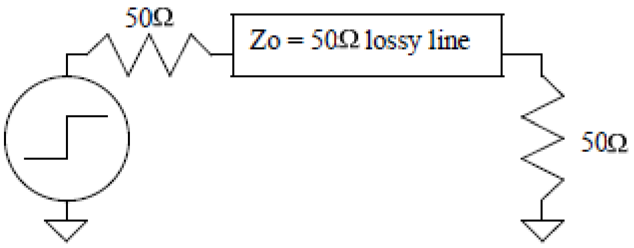
The eye pattern below is caused by a shunt open stub that is 60 degrees long at the bit rate. The stub can cause overshoot, ringing and oddities in the crossing point of the eye. The amount of distortion increases with the length of the stub.



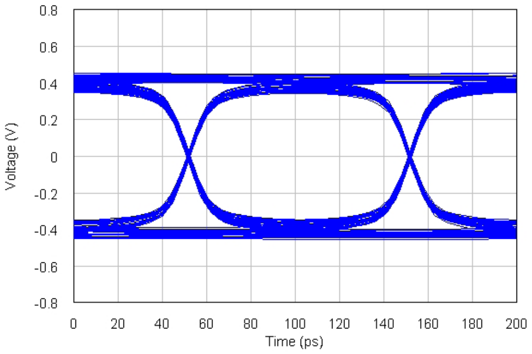


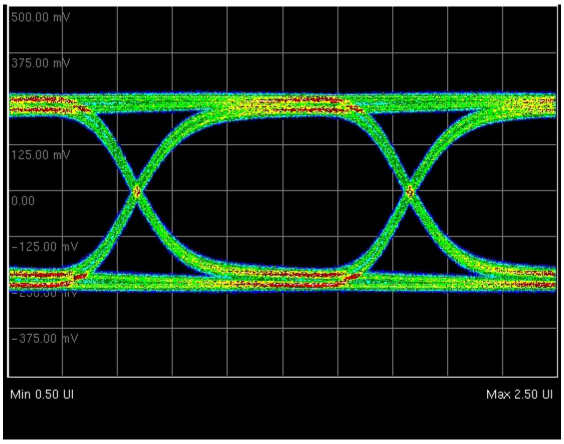
Transmission line stubs can be caused by poorly designed shunt bias circuits. If a shunt bias element such as an inductor is not placed directly on the transmission line, there will be an unwanted stub in the circuit.

Lossy Line

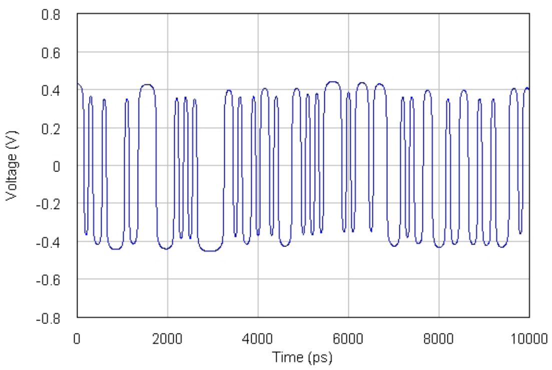


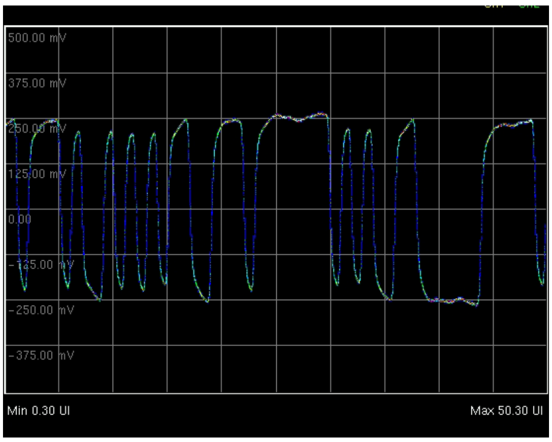
Lossy transmission lines distort the eye pattern because there is more loss at high frequencies than low frequency. Alternating zeroes and ones will be attenuated more than long stretches of consecutive bits. The eye will close up and the zero and one levels will appear thicker and may even split.





It is easy to see this effect looking at the pulse pattern. The peak-to-peak amplitude of 1010 sequences is less than that of a 111000 sequence, because the 1010 pattern has more high frequency content than the 111000 pattern and is therefore attenuated more by the cable.





In conclusion, the eye pattern is a useful tool for troubleshooting signal impairments. Careful inspection of the shape of the eye pattern can reveal the cause of the signal distortion in a transmission line. Removal of the impairments can be an eye opening experience.

Specifications are subject to change without notice.

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