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AN072

Driving Teradyne FR4 and GETEK Backplanes with the Hotlink II™ Transceivers

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Associated Project: No

Associated Part Family: HotLink II™

Software Version: NA

Related Application Notes: AN1025, AN17006

This application note gives an overview of HOTLink II™ serial transmission lines and the causes and types of jitter. This document also explains how the HOTLink II transceiver can transmit and receive error-free, high-speed serial data over industry-standard Teradyne backplanes.

Contents

Introduction

The HOTLink II family of data communications products consists of point-to-point or point-to-multipoint communication building blocks, providing encoding, serialization, deserialization, and decoding at high speed. This family of devices is compatible with many communications standards. A HOTLink II device is a frequency-agile transceiver with the ability to transport serial data at a rate from 0.195 to 1.5 Gigabits per second (Gbps) per channel.

HOTLink II transceivers are ideal for a variety of applications in which parallel interfaces can be replaced with high-speed, point-to-point serial links. Some applications include interconnecting backplanes on switches, routers, servers, and video transmission systems.

The HOTLink II family of devices is designed to support serial communication over both optical and copper interfaces. When driving high-speed signals over copper, one of the key concerns is the effect jitter has on signal integrity. Specifically, many of the standards with which the HOTLink II family is compliant specify how much jitter the physical layer device may generate and must tolerate.

For other documents related to the topics discussed in this application note, see References on page 9.

Primary Topics

The primary topics covered in this application note are:

- Printed circuit board transmission lines
    - Transverse electromagnetic (TEM) transmission line characteristics
    - Balanced and unbalanced TEM transmission lines
    - TEM transmission line geometries
    - PCB substrate effects on transmission properties
    - Jitter in serial transmission lines
- HOTLink II transceiver driving Teradyne FR4 and GETEK backplane boards
    - Jitter performance
    - Crosstalk robustness

The first topic provides a background discussion of serial transmissions in printed circuit boards. The second demonstrates the actual behavior of HOTLink II devices while driving Teradyne FR4 and GETEK backplane boards.

Printed Circuit Board Transmission Lines

Serial digital data, such as that produced by the HOTLink II device, are transmitted using electromagnetic energy.

Copper, whether in circuit board traces or in cables, is one medium used to transport electromagnetic energy. With slow signal-switching speeds and short interconnect distances, a signal placed on one end of a trace eventually shows up at the other end. Systems of this type are used when the signalling rate is very low or when the primary concern is delivering energy to a load, such as in a light switch.

In high-speed communications systems, many other concerns exist. Not only must energy be delivered to the communications link receiver, but the signal delivered must arrive with minimal distortion. Delivery of electromagnetic energy with minimal (or controlled) distortion requires the proper use of transmission lines. However, even with properly designed boards, jitter and attenuation can plague systems that operate in the Gbps range.

Teradyne FR4 and GETEK Backplane Boards as Transmission Lines

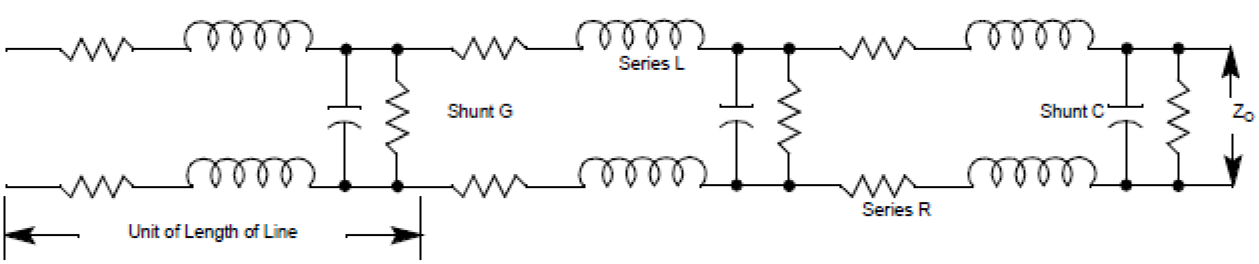
FR4 and GETEK are two of the most common dielectric substrates used in the fabrication of copper circuit boards. Companies such as Teradyne manufacture backplane boards using these and other substrates. This application note examines the HOTLink II device's performance driving Gbps signals across Teradyne backplane boards, but it first gives an overview of transmission line characteristics and geometries, as well as the effects that substrate and jitter have on serial transmissions.

Copper traces in Teradyne backplane boards act as TEM transmission lines. Basically, this implies that a signal's energy is located in the electric and magnetic fields between two conductors, or between a conductor and one or more ground planes; these fields are orthogonal to the direction of signal propagation (see Reference 1 for a more in-depth overview).

TEM Transmission Line Characteristics

The transmission line has numerous distributed parameters that determine its operation and characteristics. These distributed parameters include the series inductance (L) of the conductors in the transmission line, the shunt capacitance (C) between the conductors, the series resistance (R) of the conductors, and the shunt conductance (G) between the conductors.

Figure 1. Equivalent Circuit of a Differential Transmission Line



Because these properties remain constant per unit length of transmission line, they are referred to as distributed properties. These parameters are functions of the diameter and spacing of the conductors and the dielectric constant of the spacer used between them. A schematic equivalent of these elements in a balanced (two-wire) transmission line is shown in Figure 1.

Transmission lines are usually characterized by two parameters: characteristic impedance (Z_0) and velocity of propagation (V_P). The determination of these values is imperative for correct operation of the transmission line.

Characteristic Impedance

The characteristic impedance identifies the impedance seen by a source when driving a transmission line terminated at the load-end with a pure-resistance equal to the characteristic impedance. While this could appear to be a circular definition, it is valid. If the load end of the transmission line is terminated in an impedance other than the characteristic impedance of the line, the source end of the line sees an impedance different than either that of the load or the characteristic impedance of the line. A transmission line terminated in its characteristic impedance has the same load characteristic of a fixed resistor because this characteristic impedance is generally unaffected by frequency.

In most transmission lines, the series-R and shunt-C values are usually very small and have minimal effect on the impedance of the line. This means that the characteristic impedance is determined almost entirely by the series-L and shunt-C shown in Figure 1. This relationship is shown in Equation 1.

$$Z_0 = \sqrt{\frac{L}{C}}$$

Equation 1

Typical Z0 values for copper traces in circuit boards are 50 Ω and 75 Ω. These values are determined by the geometry of the conductors and the properties of the dielectric between the conductors.

The three parameters that are most relevant to impedance are trace width, trace height above ground plane, and dielectric constant of the board substrate.

Velocity of Propagation

In free space, an electromagnetic wave travels at nearly 300,000,000 meters per second (speed of light, abbreviated by the symbol “c”). The wave propagates at or near this same rate as it moves through a transmission line with a vacuum dielectric separator between the conductors.

Real transmission lines are seldom found with a vacuum dielectric. Instead, various non-conductive materials are used to maintain the spacing between the two conductors of the transmission line. These separators all have different dielectric constants and all of them slow down the propagation of the signal. The rate the signal propagates, relative to the speed of light, is known as the velocity of propagation (VP) and is sometimes expressed as a percentage of the speed of light or as a propagation delay in time per unit distance. This velocity difference may be calculated using Equation 2, where ε_r is the relative dielectric constant of the transmission line.

$$V_P = \frac{c}{\sqrt{\varepsilon_r}}$$

Equation 2

For this calculation to work, the entire electromagnetic field must propagate within the dielectric. Many transmission lines are structured such that some of the field propagates in the dielectric, while other parts propagate in the surrounding air. For transmission lines of this type the equation must be modified to account for the mixed dielectrics.

For example, a typical approximation for the dielectric constant of FR4 is 4.3. Using Equation 2, we get

$$\frac{3.0\times10^8 \text{m/s}}{\sqrt{4.3}} = 1.44\times10^8 \text{m/s} = 69.1 \text{ps/cm.}$$

Equation 3

This is a delay of about 175 ps per inch, but 150 ps per inch is a typical approximation.

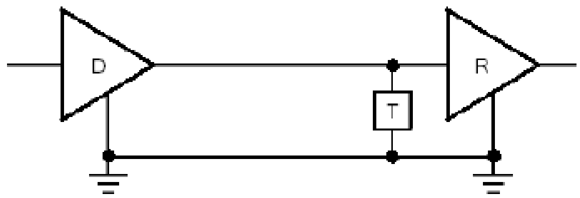
Balanced and Unbalanced TEM Transmission Lines

TEM transmission lines may be grouped in any number of different ways: by length, by construction, by dielectric, by usage, and so on. For operation with the HOTLink II device, they are generally split into two categories: unbalanced and balanced transmission lines. This application note focuses on differential signalling using a pair of unbalanced traces, since that is the most common method used for high-speed serial transmissions in backplane material. Some discussion of balanced signals has been included for completeness.

Unbalanced Transmission Line

Figure 2 shows a driver/receiver combination used in an unbalanced transmission line. In this configuration, a single driver sources and sinks current into the transmission line with the return path provided by a common ground.

Figure 2. Unbalanced Transmission Line



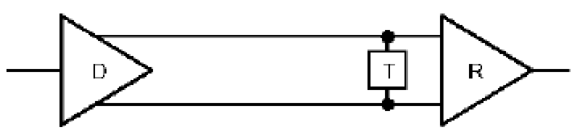
In this configuration, other communications paths can share the common ground. This allows for fewer wires in a cable, and fewer contacts in a connector. The main problems suffered by this type of transmission line are susceptibility to external noise, crosstalk, ground potential differences, and limited noise margin.

In an unbalanced transmission line, the electromagnetic field necessary for signal propagation exists between the driven line and the ground path. The receiver operates by comparing the amplitude of the received signal relative to ground.

Balanced Transmission Line

Figure 3 shows a driver and receiver configured for use with a balanced transmission line. In this configuration, two drivers source and sink complementary signals into the two wires of the transmission line. These signals need to be matched in amplitude, and must be 180 degrees out of phase with each other for the receiver to work properly.

Figure 3. Balanced Transmission Line



In this configuration, a common ground is not always necessary. Since there is no ground requirement, the sensitivity to ground potential differences is greatly reduced. All that is required is that the signals remain within the input (common-mode) range of the receiver.

Susceptibility to crosstalk is also greatly reduced. The construction of a balanced transmission line requires that the two conductors be in close proximity to each other (without an intervening ground or power plane). This means that any transients induced in one conductor of a balanced transmission line will have the same (or nearly the same) transient (with the same magnitude and phase) induced in the other conductor. This crosstalk is, in effect, a form of common mode noise that (within limits) is rejected by the differential receiver.

In a balanced transmission line, the electric and magnetic fields exist between the two driven lines — there is no dynamic current flow in any present ground path. The receiver is implemented as a differential amplifier that operates by comparing the amplitude difference between the two received signals.

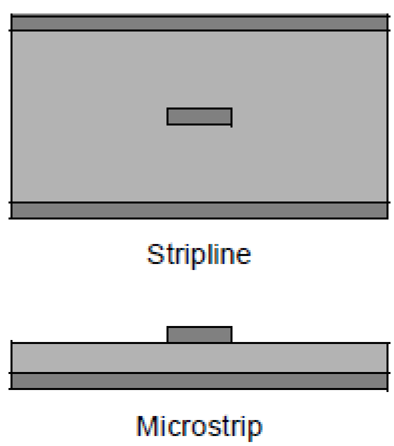
Since the HOTLink II transceiver produces differential signals, the use of balanced transmission lines is recommended. Unfortunately, this is not practical for most boards; therefore, a closely-spaced pair of unbalanced traces is usually sufficient.

TEM Transmission Line Geometries

Figure 4 shows the cross-sectional construction of the two primary types of circuit-board-based transmission lines. While other configurations are possible, the stripline and microstrip constructions follow standard circuit board manufacturing flows, and thus see the largest industry usage.

These types of transmission lines are used to route high-speed signals from a few centimeters to approximately a meter of circuit board. They are often routed through connectors as well as backplanes. Because of the relatively short distances used with these types of transmission lines, they are usually considered no losses. However, in longer transmission lines, such as the backplanes used later in this paper, there can be measurable losses.

Figure 4. Circuit Board Transmission Lines



Microstrip Transmission Lines

Microstrip transmission lines are characterized by having a single strip-conductor spaced above a ground plane by a dielectric. This dielectric is usually the same material used for the remainder of the circuit board.

In a transmission line of this type, some of the electromagnetic field propagates in the air above the strip conductor, while the remainder propagates through the circuit board dielectric. Because of this mixed medium, the Vp calculation for a microstrip transmission line is different from that in Equation 2. See Reference 1 for a more in-depth discussion of the calculation of Vp and Z_0 in microstrip transmission lines.

Stripline

Stripline transmission lines are characterized by having a single-strip conductor spaced between two ground planes by a dielectric. This dielectric is usually the same material used for the remainder of the circuit board.

Unlike a microstrip transmission line, where part of the electromagnetic field propagates in air, the field in a stripline transmission line is bounded by the ground planes and must remain within the circuit board dielectric. This means that the VP for a stripline transmission line is determined only by the dielectric constant and thus follows the calculation in Equation 2. See Reference 1 for a more in-depth discussion of the calculation of Z_0 in stripline transmission lines.

PCB Substrate Effects on Transmission Properties

As discussed in the previous section, one way to change the characteristic impedance of a backplane trace is to vary the dielectric constant of the substrate. It is possible to control the transmission properties of a PCB trace (such as attenuation) without changing the characteristic impedance; this is done by varying both the dielectric constant of the substrate and the geometry of the copper trace. Reference 5 discusses this in more detail.

For instance, even though the value of er in FR4 material is often approximated at 4.3, this value can range from 4 to 6 depending on the manufacturer. Similarly, ε_r in different GETEK boards can take on values ranging from 3.6 to 4.5, depending on the manufacturer. Therefore, we can get different transmission properties by varying the transmission line construction using a single type of dielectric material or by changing dielectric materials entirely.

Table 1 lists the typical values of the relative dielectric constants for a number of common circuit board substrates. This dielectric constant alone determines the Vp (and the propagation delay) for the transmission line.

Table 1. Properties of Circuit Board Substrates

Material	Dielectric Constant	Stripline Prop Delay (ps/cm)
FR4	4.7	72.3
GETEK	3.8	65.0
Mylar®	5	74.5
Alumina	9.9	105
Teflon®	2.1	48.3

As mentioned above, signal attenuation varies between dielectric materials. Because the electromagnetic energy transported in a TEM transmission line is located in the EM fields (which are in the dielectric), the dielectric itself causes signal loss. The magnitude of the attenuation is dependent on the dielectric. Reference 3 discusses dielectric and other losses in high-speed serial transmissions in circuit boards.

At low frequencies, the relative dielectric constant of the substrate is roughly independent of frequency. However, as the frequency increases, the dielectric constant changes.

Table 2. Variation in Dielectric Constant and Loss Tangent as a Function of Frequency (Reference 4)

	Dielectric Constant		Loss Tangent	
	GETEK	FR4	GETEK	FR4
500 MHz	4.3	4.38	0.004	0.0105
1.0 GHz	4.1	4.40	0.006	0.0101
1.8 GHz	4.5	4.94	0.006	0.0122
4.0 GHz	4.3	4.7	0.006	0.0125

The dielectric loss is roughly proportional to the product of the system's operating frequency and the loss tangent. GETEK is often chosen for higher signalling rates because its dielectric loss is much lower at those operating frequencies, as shown in Table 2.

In the same way that the dielectric affects propagation delay and attenuation, the total amount of jitter in a serial digital transmission is a function of the dielectric material of the circuit board substrate.

Jitter in Serial Transmission Lines

Simplistically, jitter is the deviation between an event's expected and actual locations in the time domain. The magnitude of jitter is the amount the period of a signal deviates from its ideal value. Various standards bodies define jitter in different ways, but the basic meaning is always the same. For the purposes of this discussion, we will adopt the very common definition found in the Fibre Channel "Methodology for Jitter Specification" document (Reference 6): "The deviation from the ideal timing of an event. The reference event is the differential zero crossing for electrical signals and the nominal receiver threshold power level for optical systems. Jitter is composed of both deterministic and Gaussian (random) content."

Jitter is an important consideration in serial transmissions because it can limit the ability of a receiver to recover both the clock and the data.

Random Jitter

Random jitter "is characterized by a Gaussian distribution. Random jitter is defined to be the peak-to-peak value which is given to be 14 times the standard deviation of the Gaussian distribution for a BER of 10-12." Because random jitter is Gaussian in nature, it is unbounded and continues to increase with time.

Random jitter can come from a number of sources. For instance, variations in temperature change the mobility of charge carriers in semiconductor crystals, which causes random variations in current flow. Other sources can include thermal vibrations in conductors, process anomalies, and background radiation.

Deterministic Jitter

Apart from attenuation, one of the largest contributors to signal degradation in high-speed serial links is deterministic jitter, which is "jitter with [a] non-Gaussian probability density function. Deterministic jitter (DJ) is always bounded in amplitude and has specific causes. Four kinds of deterministic jitter are identified: duty cycle distortion, data dependent, sinusoidal, and uncorrelated (to the data) bounded. DJ is characterized by its bounded, peak-to-peak value."

Duty Cycle Distortion

Duty cycle distortion (DCD) is the "difference in the mean pulse width of a "1" pulse compared to the mean pulse width of a "0" pulse in a clock-like (repeating 0, 1, 0, 1, ...) bit sequence. DCD is part of the DJ distribution and is measured at the ideal receiver threshold point."

Typically, DCD is caused when a signal's pull-up is of a different strength than its pull-down (causing the slew rate for rising and falling edges to be different), or when the decision threshold for the signal is offset from its ideal level.

Data Dependent Jitter and Inter-Symbol Interference

Fibre Channel defines data dependent jitter as "jitter which is added when the transmission pattern is changed from a clock to a non-clock like pattern. Includes Inter-Symbol Interference." This DDJ is the jitter that depends on the history of the data pattern. The primary source of DDJ is the bandwidth limitations of the system. Higher frequency signals (clock-like patterns) have less time to settle than lower frequency ones. This leads to variations in the initial conditions for transitions from bit to bit. These variations in initial conditions result in variation of times at which the voltage crosses the zero level.

Inter-Symbol Interference (ISI) is essentially the same as DDJ, but the definition is generalized to include transitions between any bit sequences, not simply from 'clock-like to non clock-like' data. Fibre Channel defines ISI as "data dependent deterministic jitter caused by the time differences required for the signal to arrive at the receiver threshold when starting from different places in bit sequences (symbols). For example when using media that attenuates the peak amplitude of the bit sequence consisting of alternating 0, 1, 0, 1... more than peak amplitude of the bit sequence consisting of 0, 0, 0, 0, 1, 1, 1, 1... the time required to reach the receiver threshold with the 0, 1, 0, 1... is less than required from the 0, 0, 0, 0, 1, 1, 1, 1.... The run length of 4 produces a higher amplitude which takes more time to overcome when changing bit values and therefore produces a time difference compared to the run length of 1 bit sequence. When different run lengths are mixed in the same transmission the different bit sequences (symbols) therefore interfere with each other. ISI is expected whenever any bit sequence has frequency components that are propagated at different rates by the transmission media."

Sinusoidal Jitter

Sinusoidal (or periodic) jitter contributes to deterministic jitter with a magnitude that varies periodically. Sinusoidal jitter is typically caused by external periodic events, such as power supply switching or a strong RF signal. An unstable clock recovery phase-locked loop (PLL) may also cause periodic jitter. (Some sources define sinusoidal jitter as being related to periodicity in the data pattern. Regardless of the definition chosen, sinusoidal jitter contributes a periodic change in the length of a bit period.)

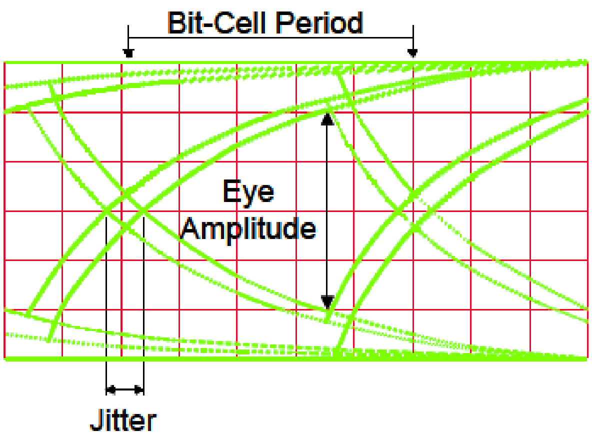
Uncorrelated Jitter

Any other process not related to the data can be a source of uncorrelated jitter. For instance, a noisy power rail could cause jitter that is neither related to the data nor periodic; this would be classified as uncorrelated jitter.

Viewing Jitter in a System

One easy way to view the jitter in a system is to overlay all of the bit transitions onto a single digital signal analyzer trace, using a jitter-free bit clock as a trigger. (A sampling scope will not work.) This is called an eye diagram. A sample eye diagram is shown in Figure 5.

Figure 5. Eye Diagram

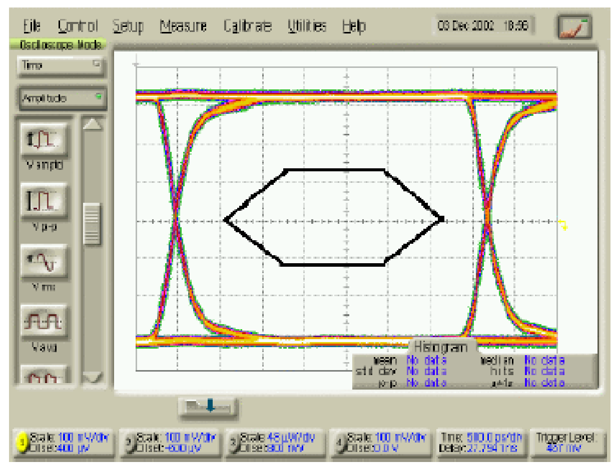


An eye diagram shows a number of important features of the signal. First, we can see the total amount of jitter. The jitter we see on the screen is a combination of deterministic and random jitter, and it represents the range within which essentially all of the jitter lies. Many of the communications standards that the HOTLink II device supports, such as Fibre Channel and ESCON, specify the total amount of jitter that the systems should be allowed to tolerate. The amount of jitter is often specified in Unit Intervals, or UI. A system with 0.5 UI of jitter has an amount of jitter equal to half of a bit period. The jitter shown in Figure 5 is about 0.15 UI, or 15% of the bit period.

The amplitude of the eye is another important consideration. The difference between a high and a low at a sampling point must be large enough to allow the receiver to differentiate between the two. Again, serial digital transport standards specify the amplitudes that the eyes must meet. See References 2 and 6 for more discussion on jitter.

Many of these standards are more rigorous, and also specify an eye mask, or a shape, which must fit inside the eye. This requirement ensures that both the jitter and amplitude of the signal are within a range that the receiver can tolerate. An eye mask for DVB-ASI is shown in Figure 6. That figure shows an actual eye diagram coming from a HOTLink II device mounted on a HOTLink II evaluation board heated to 85 °C. The eye mask's amplitude is scaled to the output's swing. This is not of concern because a cable driver is normally used to amplify the signal. What this eye does show, however, is good jitter margin over the eye mask; this margin passes on through the cable driver in its entirety. The jitter is even better at room temperature.

Figure 6. Eye Mask for DVB-ASI Eye



HOTLink II Transceiver Driving Teradyne FR4 and GETEK Backplane Boards

FR4 and GETEK are two of the most common dielectric substrates used in the fabrication of copper circuit boards. Companies such as Teradyne manufacture backplane boards using these and other substrates. This application note examines the HOTLink II device's performance driving Gbps signals across Teradyne backplane boards, but it first gives an overview of transmission line characteristics and geometries, as well as the effects that substrate and jitter have on serial transmissions.

Copper traces in Teradyne backplane boards act as TEM transmission lines. Basically, this implies that a signal's energy is located in the electric and magnetic fields between two conductors, or between a conductor and one or more ground planes; these fields are orthogonal to the direction of signal propagation (see Reference 1 for a more in-depth overview).

The HOTLink II transceiver's high receive PLL jitter tolerance and high input sensitivity become apparent when signals are driven through long backplane traces. This section presents the behavior of the HOTLink II transceiver while driving and receiving signals over two 30-inch Teradyne backplane boards. These two backplanes were made with FR4 and GETEK substrates, two dielectrics commonly used in backplanes. It also shows how the HOTLink II transceiver is able to consistently recover both clock and data, even in the presence of the large amount of jitter that is typically found in Gbps transmissions over copper.

The backplane boards used in the experiments are both Teradyne backplane boards with 50 Ω stripline traces.

The Teradyne FR4 board, RPD SYST-UM 30, is a 30-inch backplane. The conductors are stripline traces with a 10 mil trace width. The serial I/Os of the HOTLink II CYP(V)15G0401DXB devices were connected to the backplane through a daughter card.

The connection between the backplane board and the daughter card was made with a Teradyne VHDM connector. This interface, unlike many other possible connectors, adds very little jitter because of all the ground connections between signal lines in the connector. The grounded shielding provides a low-inductance current return, reducing crosstalk and therefore crosstalk-induced jitter in the serial signal. The backplane board, VHDM connectors and daughter boards are shown in Figure 8.

The Teradyne GETEK board, RAM-001N, is a 30-inch backplane with 8 mil stripline traces. This board used the same VHDM daughter card connectors as the FR4 board. The connections between the HOTLink II evaluation boards and the daughter cards were made with 50 W coaxial cables with SMA connectors.

Eye diagrams were observed using an Agilent 86100A communications signal analyzer, and the device reference clocks were generated using an Agilent 8133A pulse generator.

Handling Jitter in FR4 and GETEK Backplanes

This experiment focused on examining an eye diagram after the signal is passed through a Teradyne backplane. One HOTLink II evaluation board generated and transmitted K28.5 word sync sequence data onto the backplane, and the signal analyzer received the backplane's single ended output and generated an eye diagram. The Agilent signal analyzer was triggered using a bit clock provided by an Agilent 8133A pulse generator. An Anritsu MP1758A provided a divide-by-ten function, yielding a REFCLK synchronous to the bit trigger. The output of the MP1758A was passed through another Agilent 8133A to ensure that the REFCLK provided to the evaluation board contained very little jitter.

Jitter, eye height, and eye width were measured for 15 minutes, yielding 2500 measurements of each of these parameters. This experiment was repeated across multiple frequencies: the 1.5 Gb/s is the fastest rate at which the HOTLink II transceiver will operate, 1.25 Gb/s is the data rate used in Gigabit Ethernet, 1.0 Gb/s is approximately the rate for 1x Fibre Channel, and 500 Mb/s is a typical low-speed rate.

The setup is shown in Figure 7, and the results are shown in Table 3, Table 4, and Table 5. The resulting eye diagrams are shown in Appendix A — Eye Diagrams.

Figure 7. Set-up for Single-ended Jitter Test

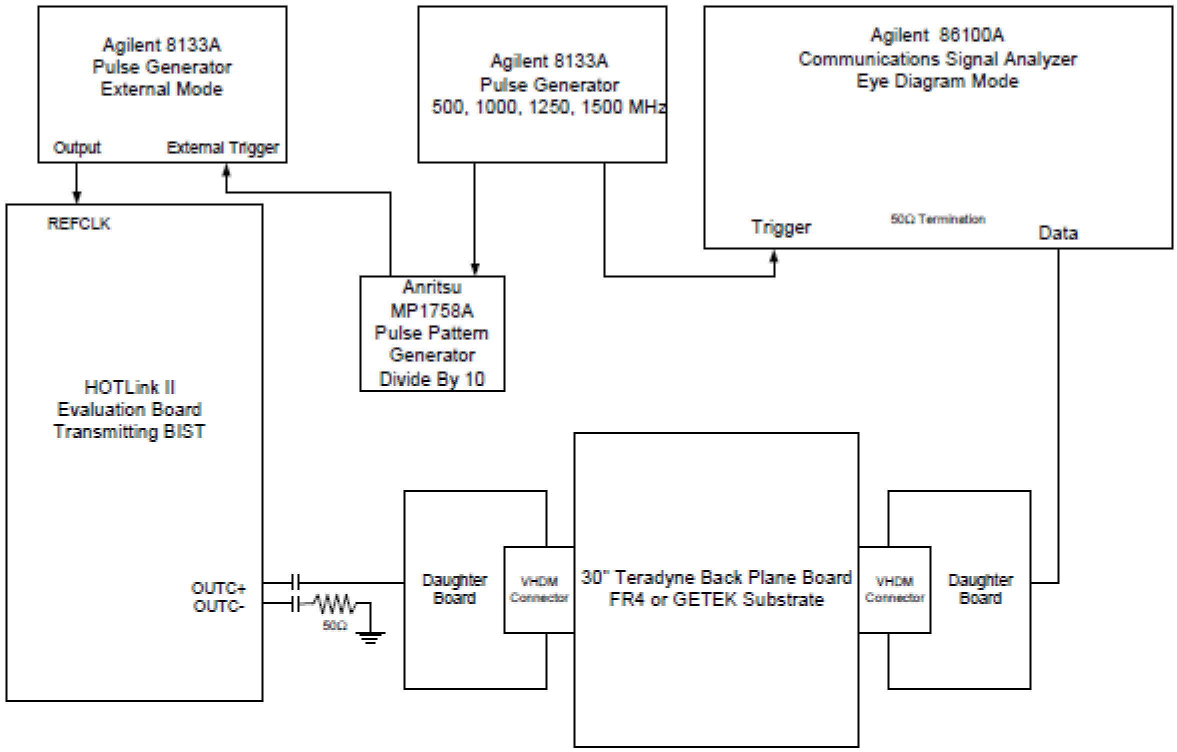


Table 3. HOTLink II Transceiver Connected Directly to Signal Analyzer

Eye Parameter Measured	Data Rate (Gb/s)			
	0.50	1.0	1.25	1.5
Jitter, peak-peak (ps)	74	67	81	81
Jitter, RMS (ps)	10	9	10	11
Eye Width (ps)	1937	941	739	603
Eye Height (mV)	561	534	513	497

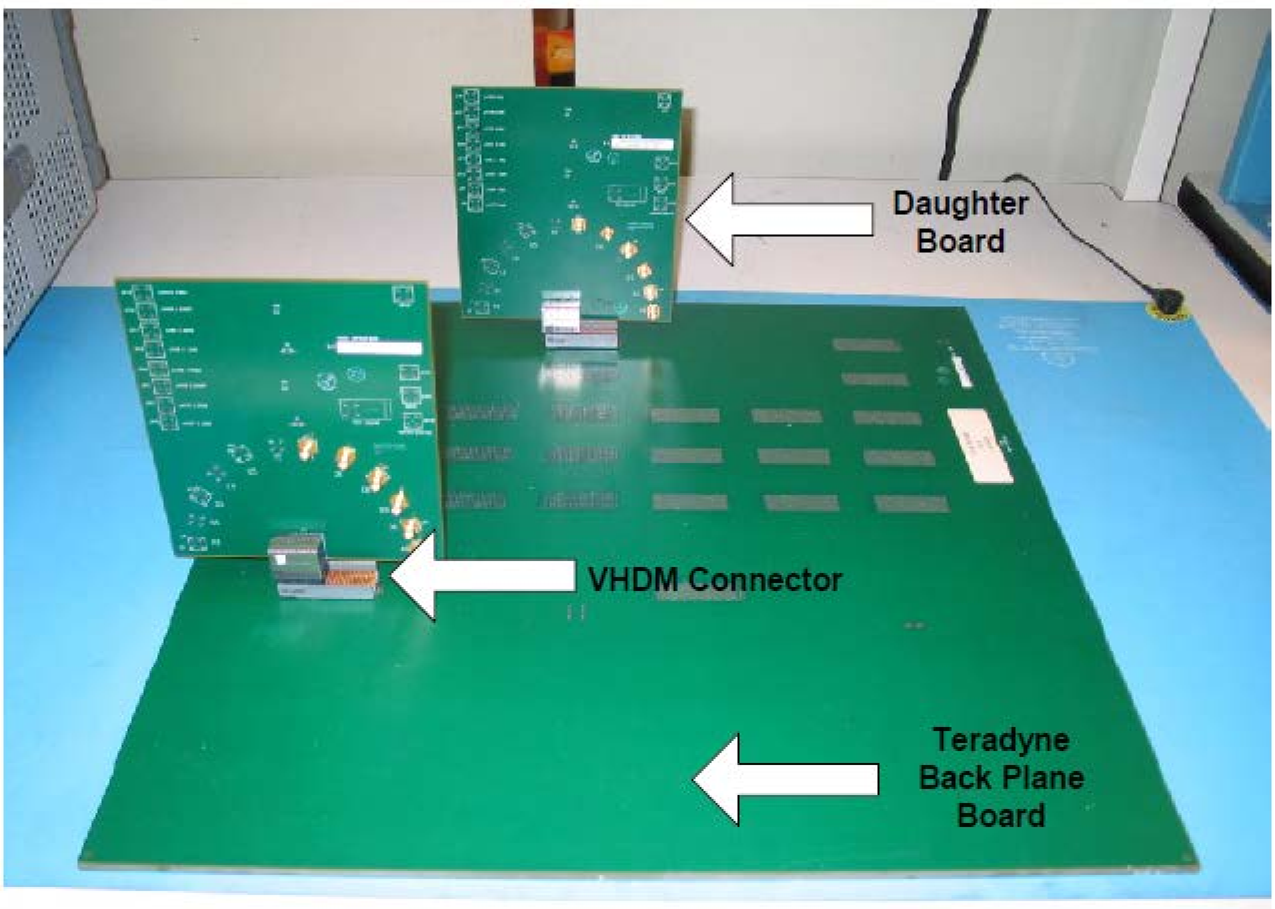
Table 4. HOTLink II Transceiver Driving 30" of GETEK Backplane

Eye Parameter Measured	Data Rate (Gb/s)			
	0.50	1.0	1.25	1.5
Jitter, peak-peak (ps)	104	127	166	170
Jitter, RMS (ps)	18	23	31	30
Eye Width (ps)	1898	861	612	482
Eye Height (mV)	411	288	226	140

Table 5. HOTLink II Transceiver Driving 30” of Teradyne FR4 Backplane

Eye Parameter Measured	Data Rate (Gb/s)			
	0.50	1.0	1.25	1.5
Jitter, peak-peak (ps)	119	164	186	219
Jitter, RMS (ps)	20	30	36	41
Eye Width (ps)	1979	816	585	422
Eye Height (mV)	396	258	185	86

Figure 8. Teradyne Backplane Board with Daughter Cards



HOTLink II Transceiver's Crosstalk Robustness in Teradyne Backplanes

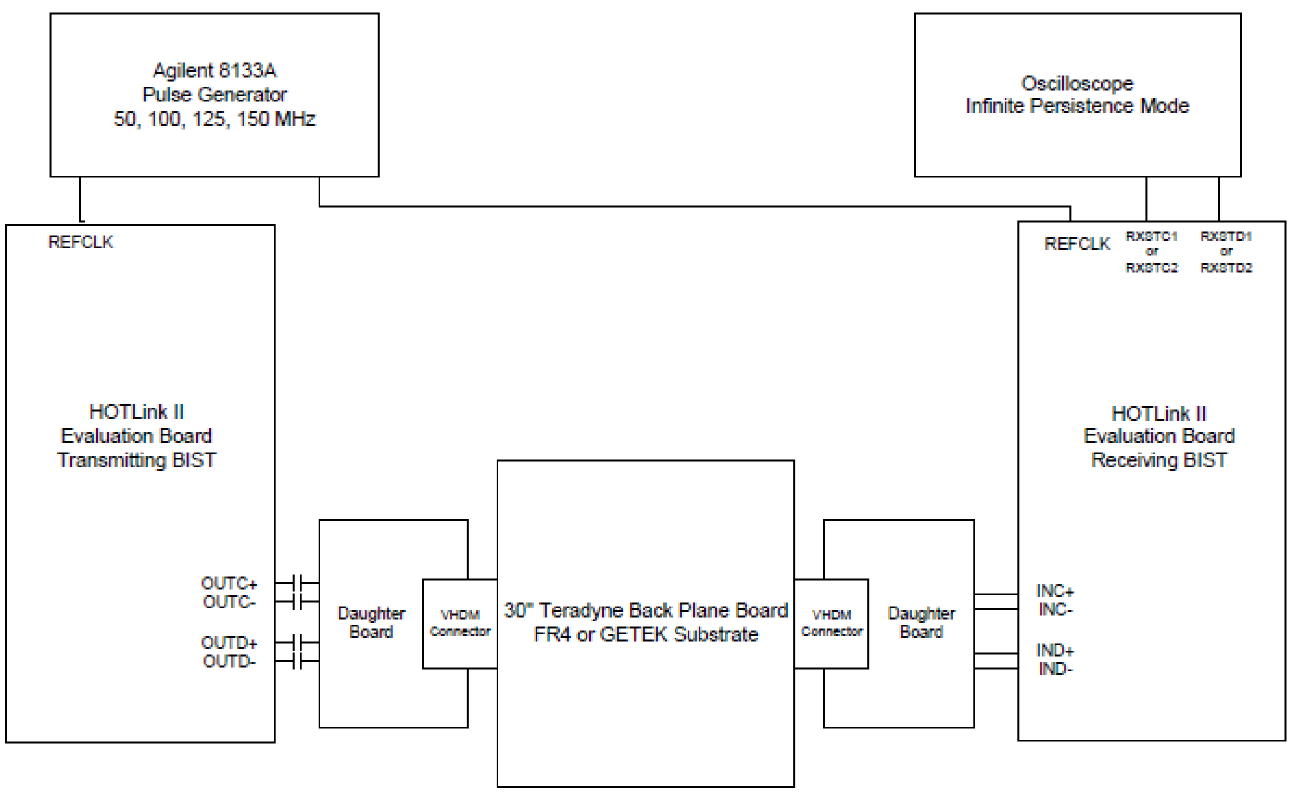
This experiment observed the effect of crosstalk on the HOTLink II transceivers' signal over the 30 inches of Teradyne FR4 and GETEK backplanes. Two HOTLink II evaluation boards were set up and connected by a backplane through the daughter cards with VHDM connectors. BIST data was transmitted from one HOTLink II evaluation board to another. To take into account the effect of crosstalk (and therefore crosstalk-induced jitter) between channels, two channels that are close together on the chip (in this case, channels C and D) were connected to two adjacent traces on the backplanes. The setup is shown in Figure 9, and the results are shown in Table 6.

Table 6. Results of Crosstalk Test

REFCLK Frequency	Serial Data Rate	Time to Measure 10^{12} bits	Number of Errors	Test Result
150 MHz	1.5 Gb/s	12 min.	0	Pass
125 MHz	1.25 Gb/s	14 min.	0	Pass
100 MHz	1.00 Gb/s	17 min.	0	Pass
50 MHz	500 Mb/s	34 min.	0	Pass

The results from this test show that the link operation is not affected by signals in neighbouring channels or neighbouring backplane traces in nominal operating conditions.

Figure 9. Setup for Crosstalk Tests



Summary

Frequency-agile HOTLink II transceivers interface very well with long backplanes across all of the data rates the device supports. Specifically, the devices can operate error-free under conditions of high jitter and high crosstalk in industry-standard Teradyne 30-inch FR4 and GETEK backplanes.

References

1. High-Speed Board and Interconnect Considerations. Cohen, T. G. Patel. Teradyne, Inc.
2. Design Considerations for Gigabit Backplane Systems. Cohen, T. G. Patel, and K. Rothstein. Teradyne, Inc.
3. Fibre Channel - Methodologies for Jitter Specification. Secretariat National Committee for Information Technology Standardization, June 9, 1999.

About the Author

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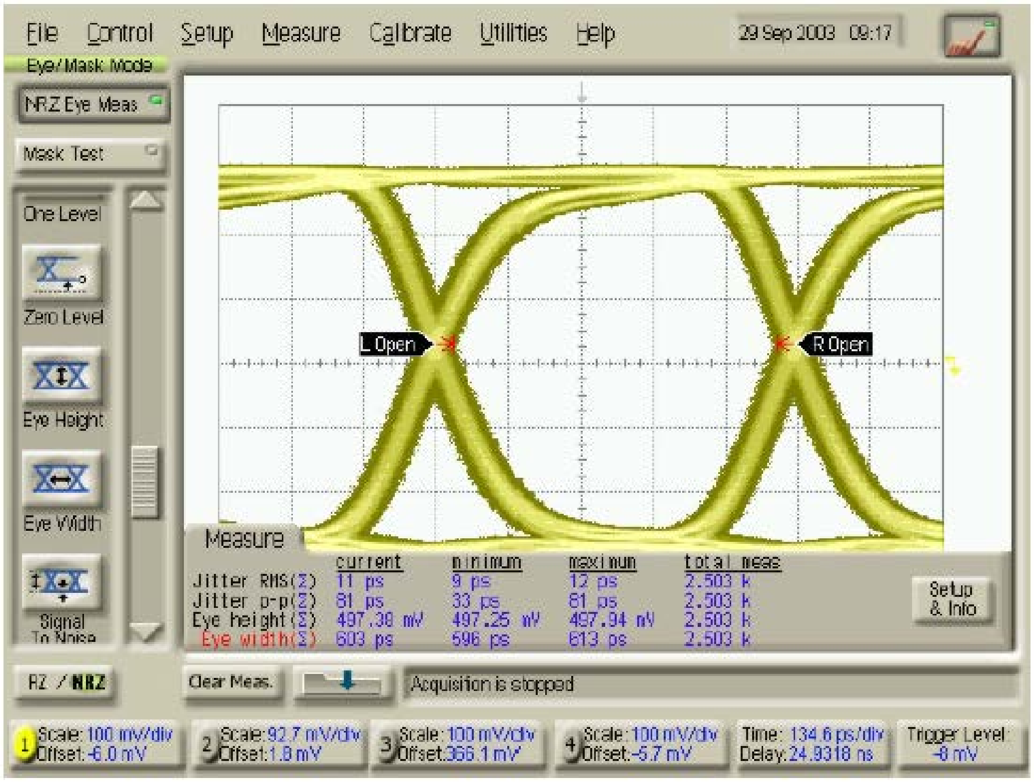
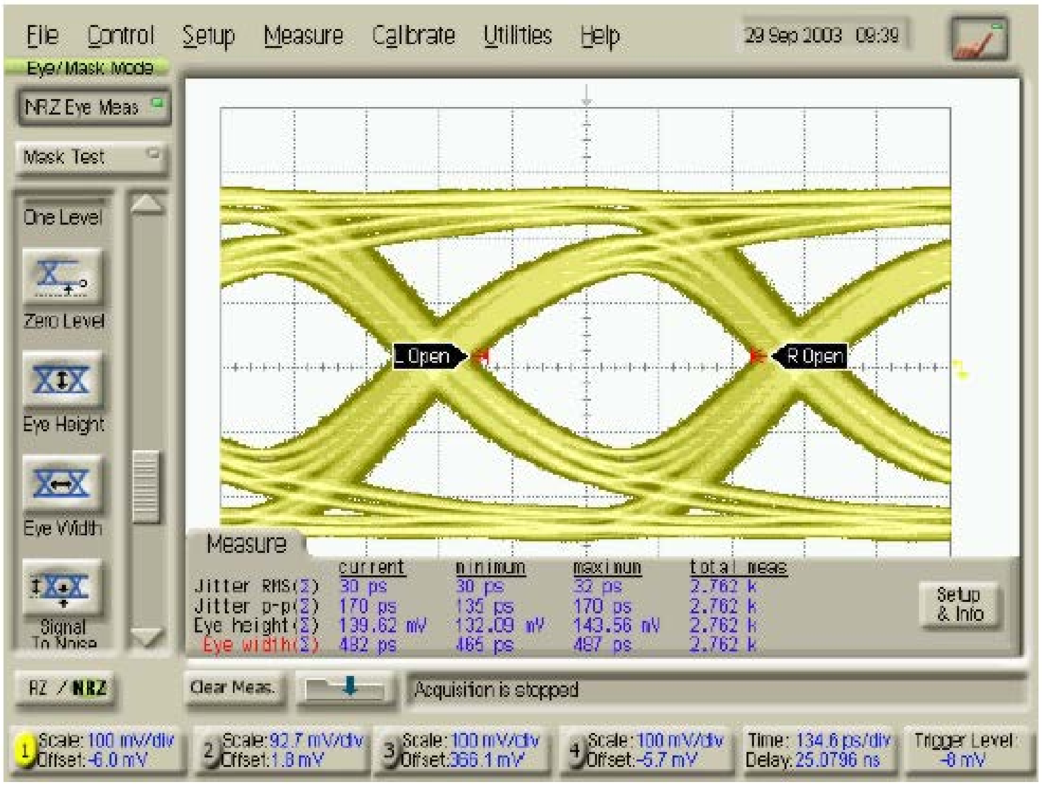
Appendix A — Eye Diagrams

Table 7. Eye Diagrams after Transmission of K28.5 Word Sync Sequence through a Backplane at 1.50 Gb/s

Medium	Eye Diagram
Short Coaxial Cable	

30” GETEK Backplane	

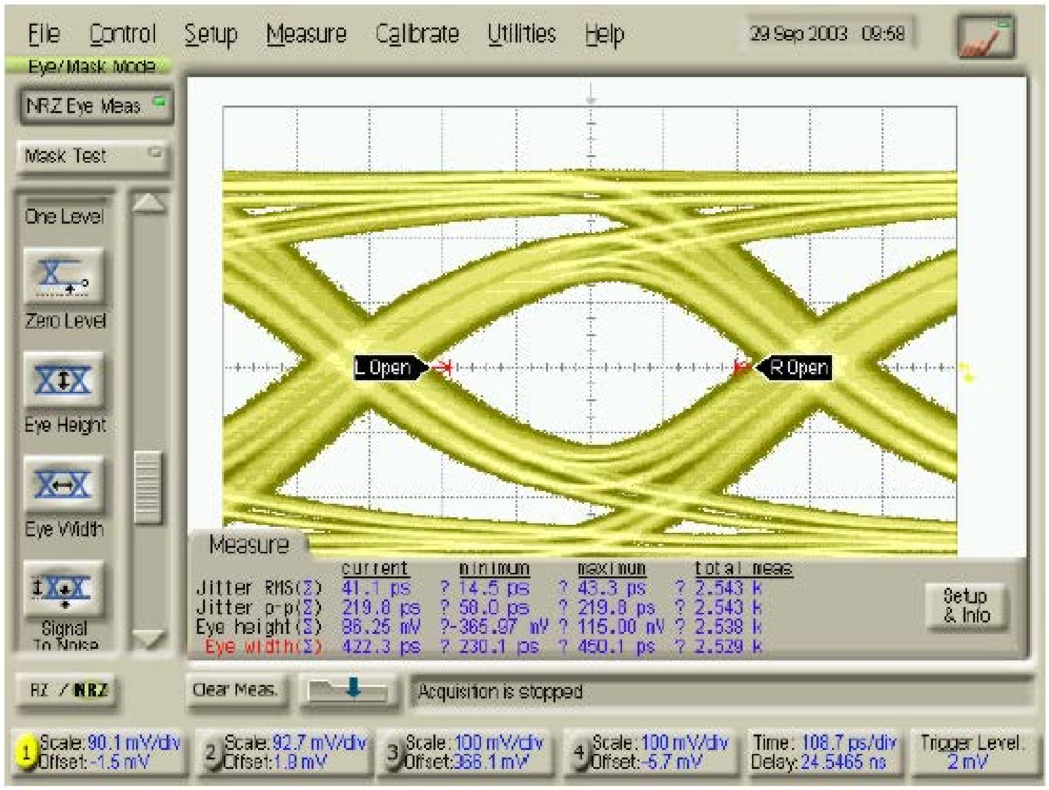
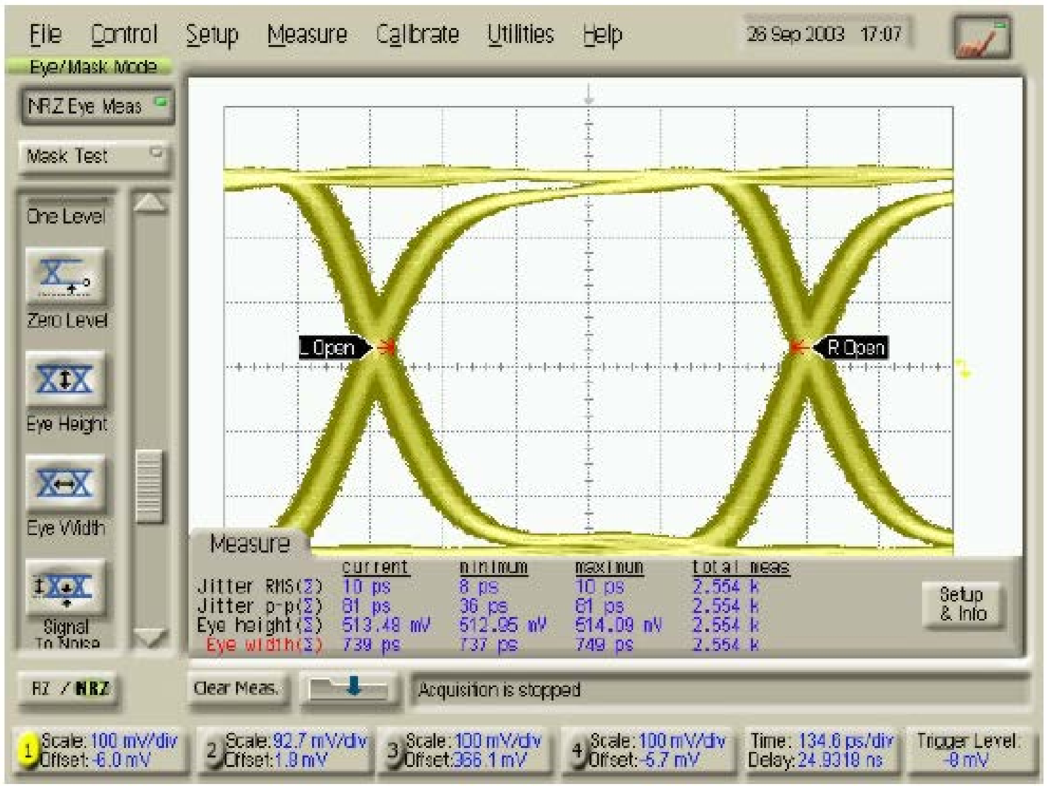
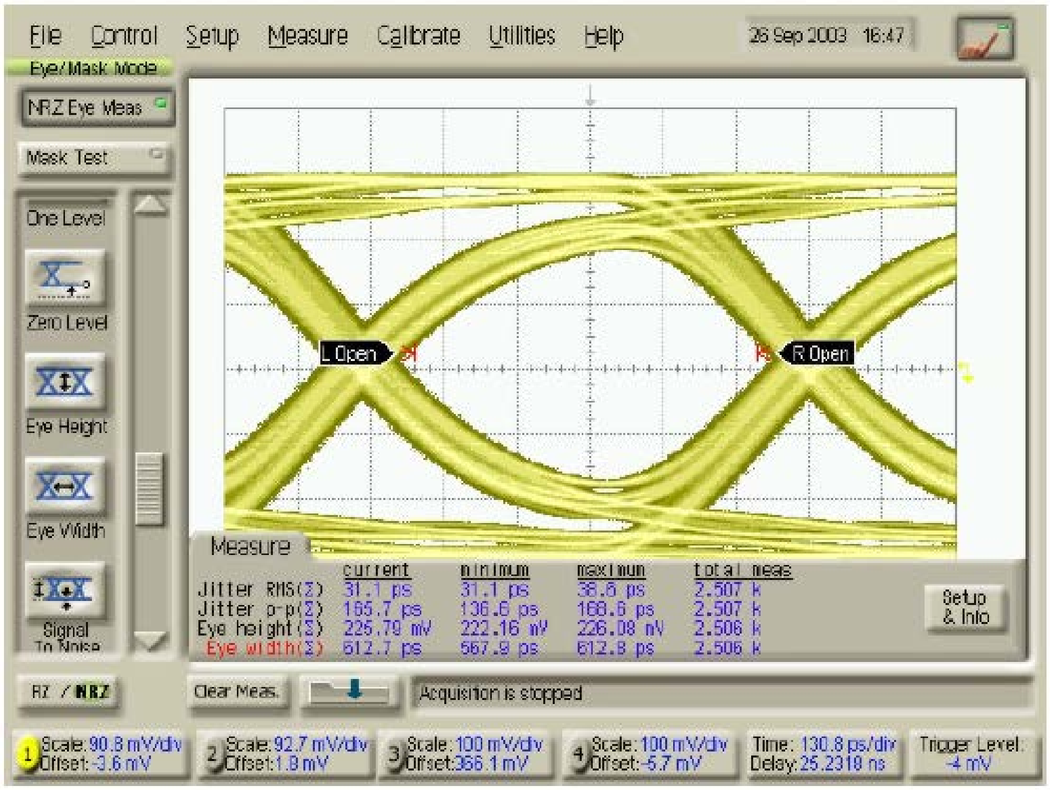
30” FR4 Backplane	

Table 8. Eye Diagrams after Transmission of K28.5 Word Sync Sequence through a Backplane at 1.25 Gb/s

Medium	Eye Diagram
No Backplane	

30” GETEK Backplane	

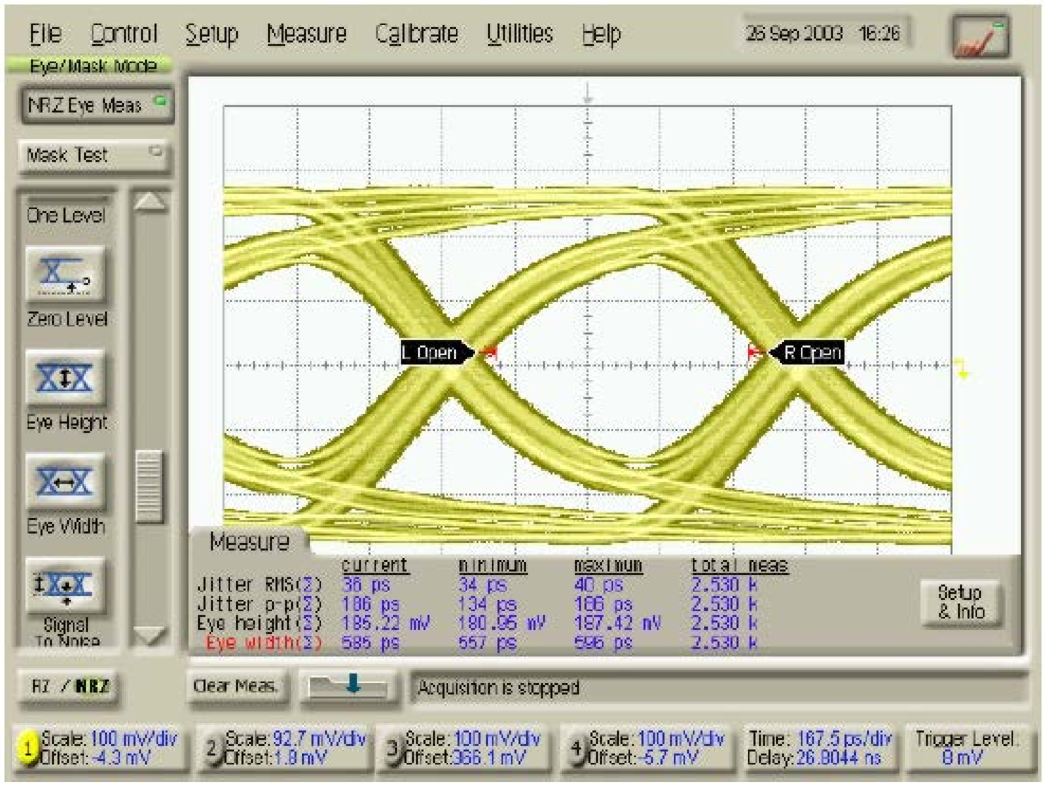
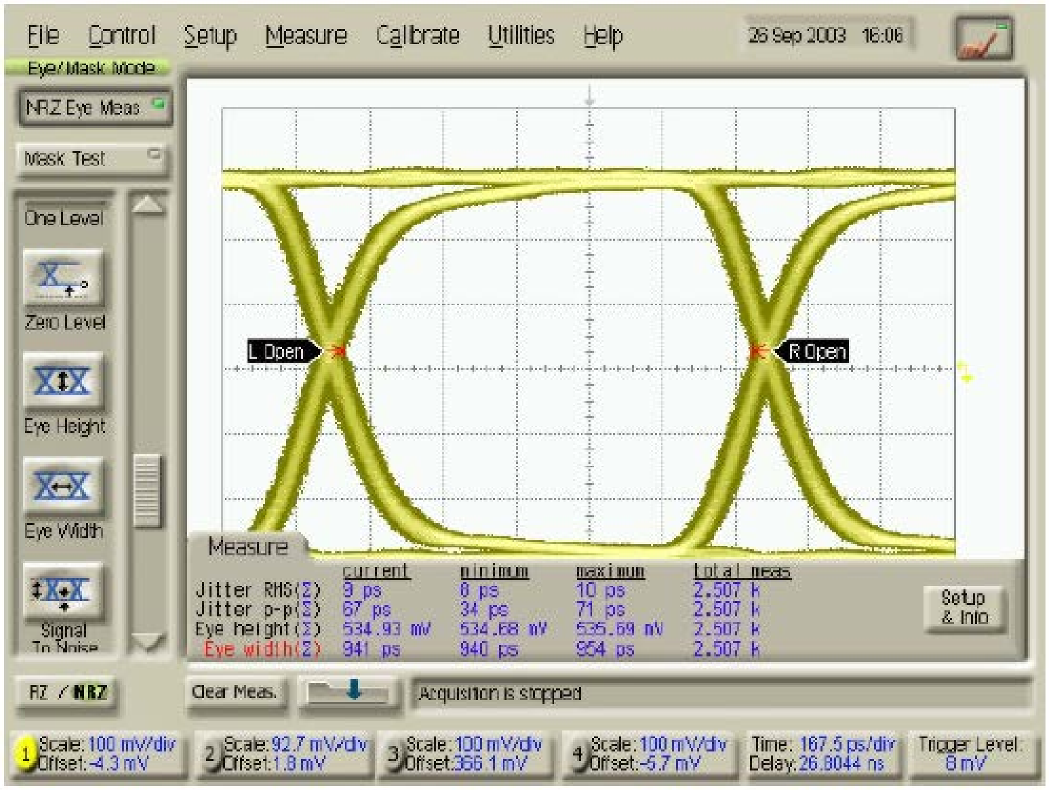
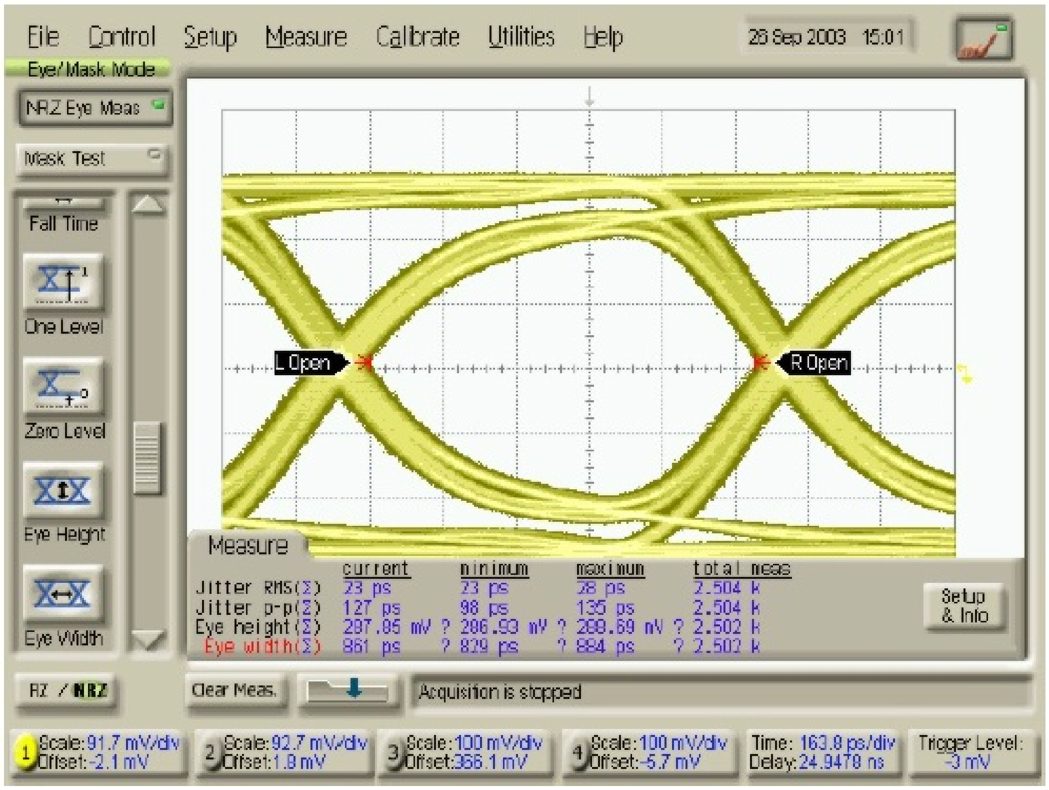
30” FR4 Backplane	

Table 9. Eye Diagrams After Transmission of K28.5 Word Sync Sequence Through a Backplane at 1.0 Gb/s

Medium	Eye Diagram
No Backplane	

30” GETEK Backplane	

30” FR4 Backplane

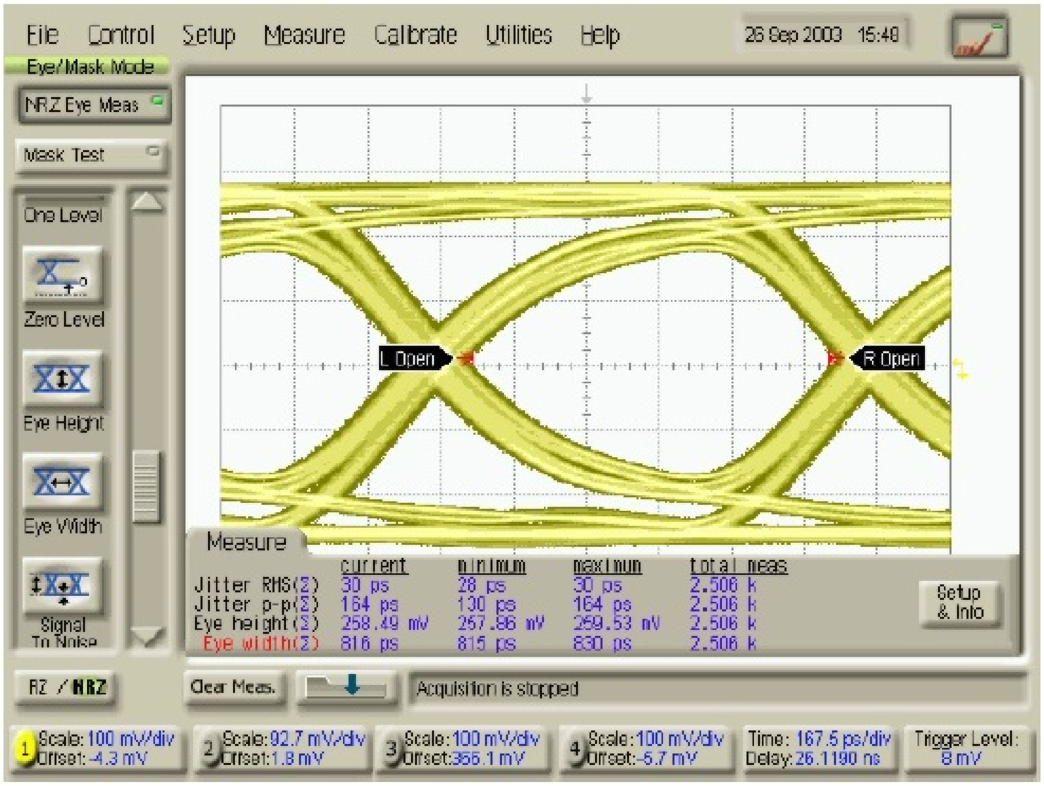
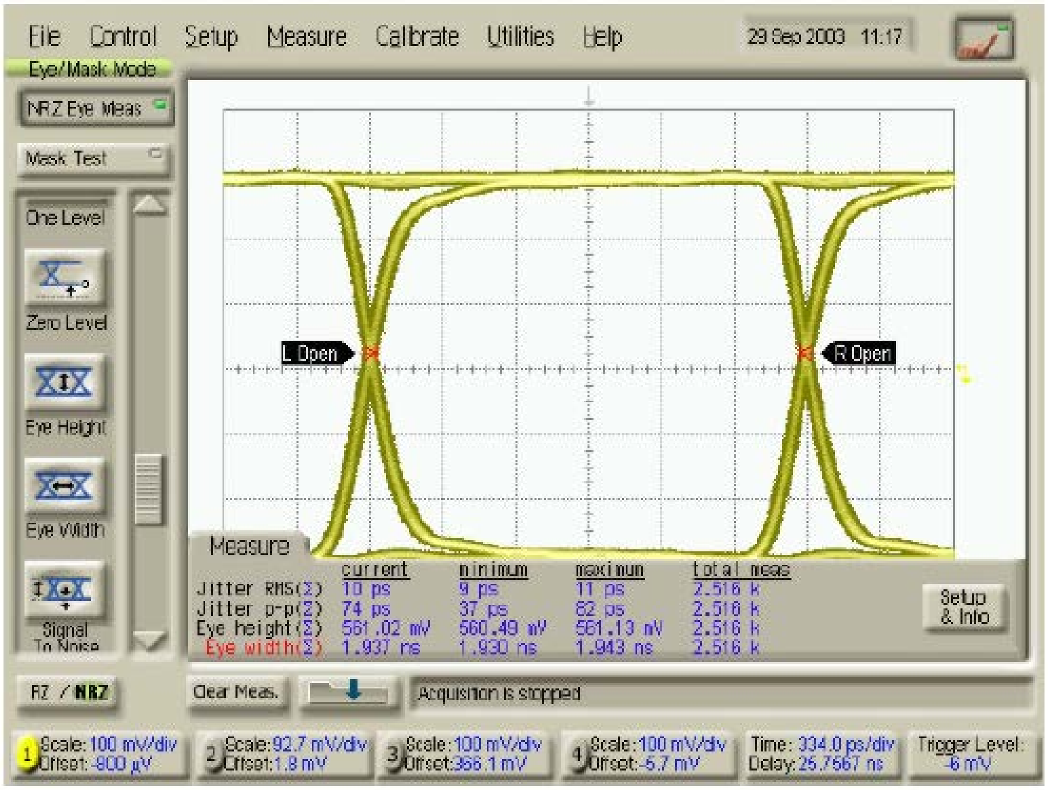
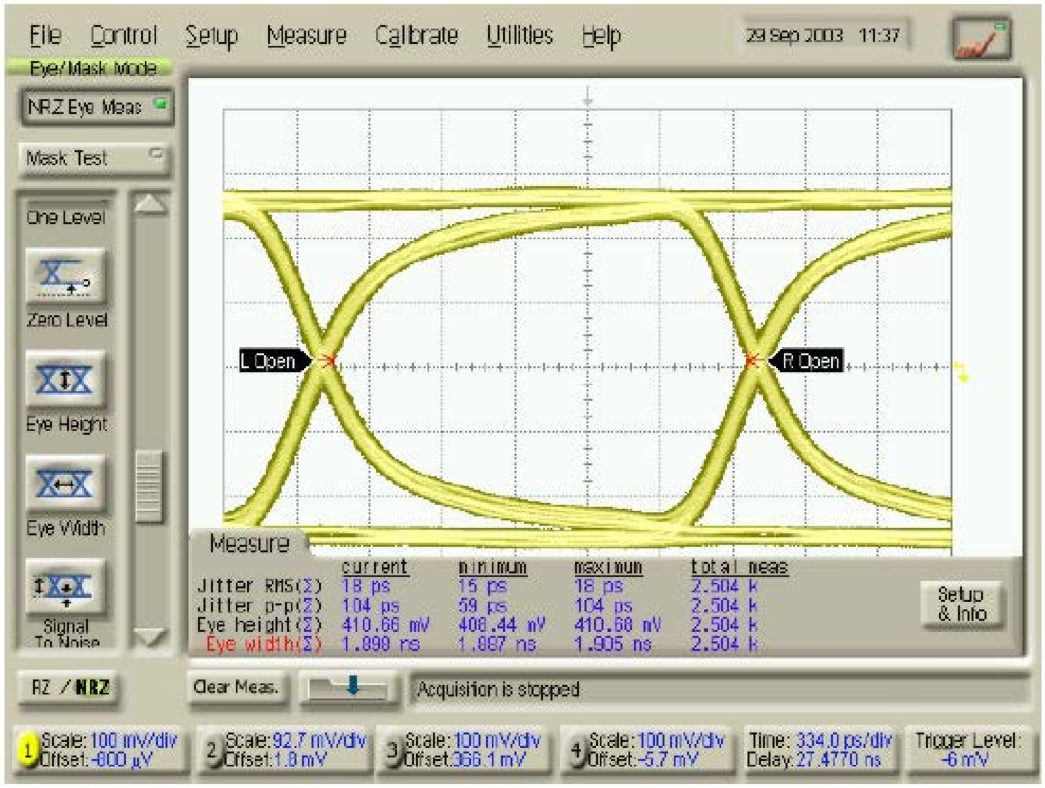
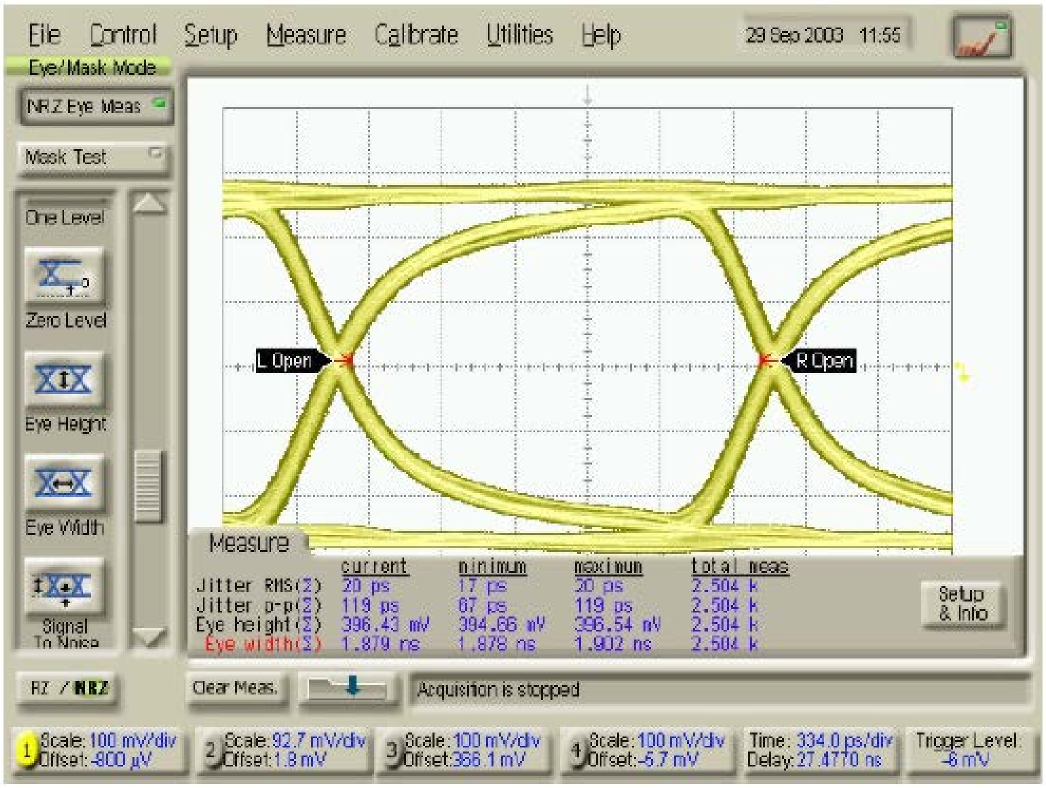


Table 10. Eye Diagrams after Transmission of K28.5 Word Sync Sequence through a Backplane at 500 Mb/s

Medium	Eye Diagram
No Backplane	

30” GETEK Backplane	

30” FR4 Backplane	

Document History

Document Title: Driving Teradyne FR4 and GETEK Backplanes with the HOTLink II™ Transceivers - AN072

Document Number: 001-43099

Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	1770639	CGX	11/26/2007	Old application note: Obtained spec number, applied new template, updated copyright, added source and revision disclaimers. No technical updates made.
*A	3129843	SAAC	01/06/2011	Corrected typo in Primary Topics; updated Equation 3; modified Table 4 heading.
*B	4270193	YLIU	02/05/2014	Updated in new template. Completing Sunset Review.

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