# Transmission of High-Speed Serial Signals over Common Cable Media

March 2004 Technical Note TN1066

## Introduction

Designers are often faced with moving serial data from one location to another, over moderate distances, and in the most efficient manner. Transmitting large blocks of parallel data originally required large banks of parallel line drivers and receivers. With the introduction of serializer/deserializer (SERDES) devices, designers can convert wide parallel data buses into a serial data stream. This permits smaller, less expensive cables and connectors to be used, and reduces the interference and EMI generated in large cable bundles. Today, Lattice Semiconductor offers SERDES devices that can transfer serial data at several gigabits per second (Gbps) over backplane and cable mediums.

Lattice's 3.125 Gbps SERDES (which is included in Lattice's ORT/ORSO82G5, ORT/ORSO42G5 and ORSPI4 devices) complies with many industry interface standards. Each industry standard specifies the requirements for an electrical layer of a differential (balanced) interface. Although the standards define a theoretical maximum signaling rate specified across a short trace length on a printed circuit board, as the transmission distance increases, the effects of connectors and cabling reduce this rate. Cable effects can become the primary factor limiting system performance once lengths of tens of meters have been reached.

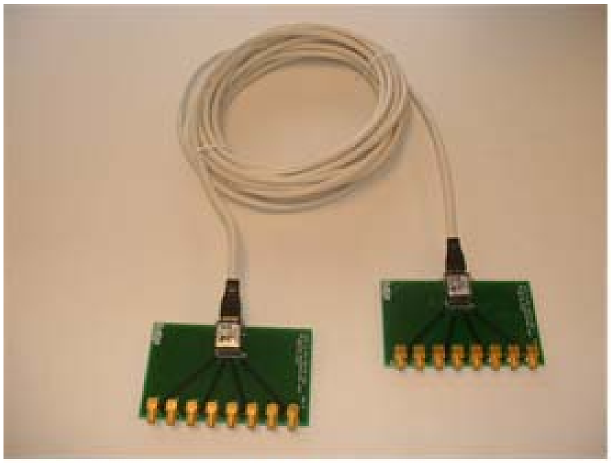
For some time, electrical connections of very great length over lossy interconnect have been problematic and often times thought not possible for many applications. As transmission rates have increased, higher performance twisted pair cabling has become a necessity. Use of twisted pair cabling for backbone interfaces has pushed the performance passed its original specifications. This use of common copper cabling has driven the industry to introduce many new products. This technical note will report the results of the performance of traditional twisted pair cables as well as compare the use of higher performance cabling recently introduced by Tyco Electronics.

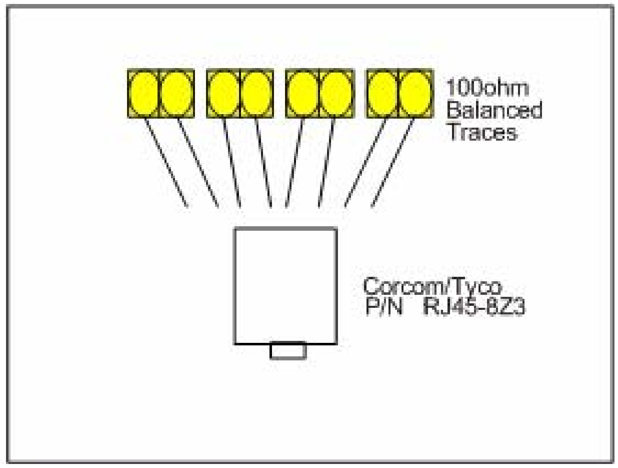
## Category 5, 5E, and 6

One standard, TIA/EIA–568A Commercial Building Telecommunications Cabling Standard, defines the transmission requirements for commercial building telecommunication wiring. It classifies cabling into different categories based upon attenuation and crosstalk losses over frequency. Twisted-pair is classified in different categories. Most differential signaling applications requiring cabling utilize CAT5 and CAT5E cable. The allowable attenuation vs. frequency for CAT5 cable is specified in TIA/EIA–568A.

This report illustrates the performance of differential CML serializer/deserializer devices using different clock-rate and different lengths of standard CAT5-unshielded twisted pair (UTP), CAT5E-Standard-shielded pair (SSP) and CAT6 cable between the serializer/transmitter and receiver/deserializer. The setup used an evaluation board equipped with SMA connectors. These connectors were cabled to an interposer module (Figure 1) which translates the SMA connections to an RJ-45 connection.

*Figure 1. : SMA to RJ-45 Interposer*

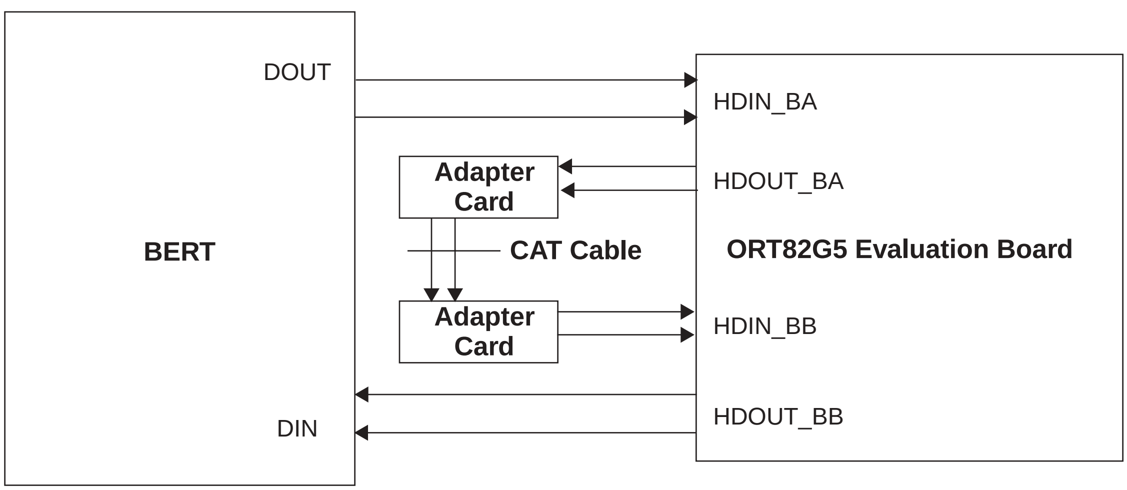





Results are presented as cable length vs. data rate. The test was performed using a single channel serial Bit Error Rate Tester (BERT) capable of running up to 3.5 Gbps. Tests were performed by transmitting both pseudo-random binary sequence (PRBS) data from the BERT to the ORT82G5 deserializer and serializer and back again. This means that data and clock had to be properly recovered to avoid errors.

The basic test setup is shown in Figure 2. Eye-pattern measurements from a Agilent DCA oscilloscope were also taken of the high-speed serialized (CML signals), as well as the deserializer output. The eye patterns on the output of the serializer were analyzed for signal integrity and low jitter. The experiment was conducted using one transmit and receive channel (as shown in diagram) as well as two channels operating independently. No errors were detected when both channels were running in parallel eliminating any crosstalk concerns.

*Figure 2. Test Set-Up*




The results show how increased cable lengths affect bit error rate, while varying the cable connections between the serializer and deserializer. When the cable length is increased, performance will degrade to a point where the link between serializer and deserializer is not longer usable. Data was also taken using different transmit pre-emphasis settings of the ORT82G5 device. From this data a designer can determine the maximum data transfer rate for different lengths of cable and see the effects of pre-emphasis on the cable channels.

The BERT equipment can provide outputs in different formats. The results were determined by go/no-go testing using standard error ratio format. This ratio is simply the number of wrong data bits detected (bit errors) divided by the total number of data bits received. As the different test parameters were changed the test to fail point was recorded. The results are summarized in Table 1 and Table 2. In our evaluation the data collection was limited to a maximum cable length, but performance beyond that length can be assumed.

***Table 1. CAT5 and CAT6 Cable Test Single-Pair with PRBS $2^5$***

| Cable Length | Gen Frequency (MHz) | Data Rate (Gbps) | P.E. |
|---|---|---|---|
| CAT5 7 ft. | 145 | 2.90 | 0% |
| | 154 | 3.08 | 12.5% |
| | 161 | 3.22 | 25.0% |
| CAT5 15 ft. | 112 | 2.24 | 0% |
| | 124 | 2.48 | 12.5% |
| | 130 | 2.60 | 25.0% |
| CAT5E 25 ft. double shield | 104 | 2.08 | 0% |
| | 122 | 2.44 | 12.50% |
| | 135 | 2.70 | 25% |
| CAT6 14 ft. | 146 | 2.92 | 0% |
| | 150 | 3.00 | 12.5% |
| | 160 | 3.20 | 25% |

***Table 2. CAT5 and CAT6 Cable Test Single-Pair with PRBS $2^{31}$***

| Cable Length | Gen Frequency (MHz) | Data Rate (Gbps) | P.E. |
|---|---|---|---|
| CAT5 7 ft. | 75 | 1.50 | 0% |
| | 88 | 1.76 | 12.5% |
| | 107 | 2.14 | 25.0% |
| CAT5 15 ft. | 51 | 1.02 | 0% |
| | 68 | 1.36 | 12.5% |
| | 91 | 1.82 | 25.0% |
| CAT5E 25 ft. double shield | 52 | 1.04 | 0% |
| | 69 | 1.38 | 12.50% |
| | 86 | 1.72 | 25% |
| CAT6 14 ft. | 65 | 1.30 | 0% |
| | 85 | 1.70 | 12.5% |
| | 92 | 1.84 | 25% |

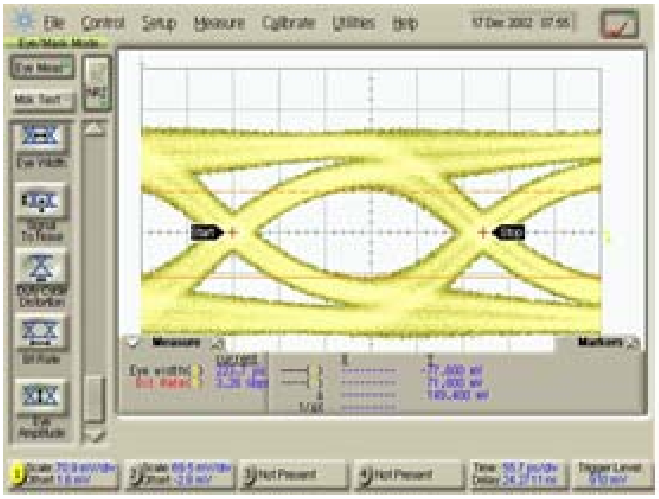
The results show that the ORT82G5 will perform well using CAT5, CAT5E, and CAT6 cable, as well as the limitations of data rate as cable length is increased. The use of pre-emphasis to compensate for the cable environment, also demonstrated its usefulness and flexibility. The tables show the improved performance as pre-emphasis is adjusted.

Signal pre-emphasis is a means of compensating for the increased line loss that occurs at higher frequencies. A simple algorithm can be employed in the line driver to increase transmitted signal amplitude, whenever the data patterns have transitions (and therefore higher frequency content). This function is provided by the ORT82G5 SERDES CML drivers.

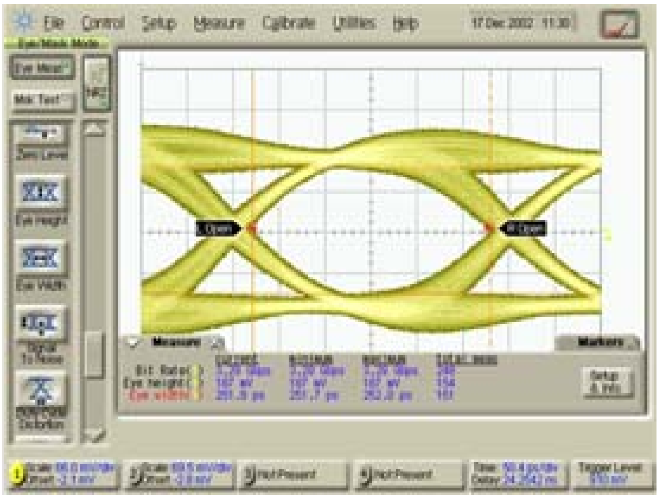
For longer cable lengths, a significant increase in eye opening often results. Noticeable differences between the use of pre-emphasis can be compared in diagrams shown in Figure 3. The use of the pre-emphasis can extend the maximum usable cable length. A more detailed description of the pre-emphasis feature may be found in ORCA ORT/ORSO82G5 and ORT/ORSO42G5 Data Sheets.

***Figure 3. $2^{-31}$ PRBS Examples Using 12 Foot Cable***

**No Pre-Emphasis**



**25% Pre-Emphasis**



## Tyco Electronics' 1mm Giga I/O Cable Performance

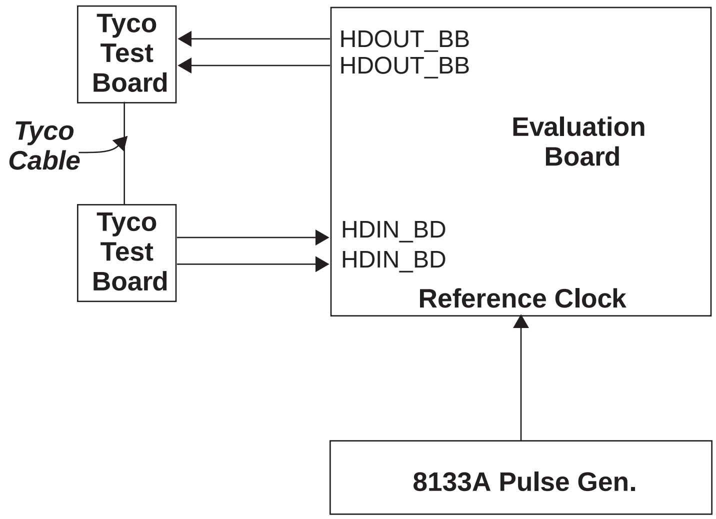
Tyco Electronics has introduced a hybrid cable assembly that utilizes passive equalization in a very small form factor connector. Utilization of this cable assembly and the on-chip pre-emphasis lengthens the reach of SPP cable mediums. The 1mm Giga I/O Cable has proven higher data rates can be achieved across longer lengths of cable.

***Figure 4. Tyco's 1mm Giga I/O Assembly***

Experimentation utilized an ORT82G5 evaluation board and clock source. The data was looped outside of the ORT82G5 device through the 1mm Giga I/O cable and SMA interposer board as shown in Figure 5. The ORT82G5 was programmed with an internal $2^{-7}$ PRBS generator/checker. Data was transmitted from the device and looped back to the receiver. The pass/fail condition was based on the success of data and clock being properly recovered without errors detected by the checker

The SERDES reference clock was swept to failure. Test results showed that the 26 ft (8 m) cable with passive equalization and ORT82G5 provisioned to 25% pre-emphasis could run up to 3.44 Gbps and 4.1Gbps across 4ft (1.3m) of cable.

*Figure 5. 1mm Giga I/O Test Setup*




The transmit signal eye was captured on an Agilent DCA oscilloscope after passing through the 1mm Giga I/O cable. The results of the cable were compared to standard 50 ohm matched impedance coax cable with the ORT82G5 device set to 25% pre-emphasis. These diagrams are shown in Figure 6 - Figure 8. The data highlights the benefits of the passive equalization when compared to the effects of pre-emphasis alone. The eye opening meets the expectations of many standards. Consequently, pre-emphasis and equalization must be optimized for the data rate and cable length to achieve quality low BER.

*Figure 6. : 4 Foot Giga I/O @ 4.1 Gbps*

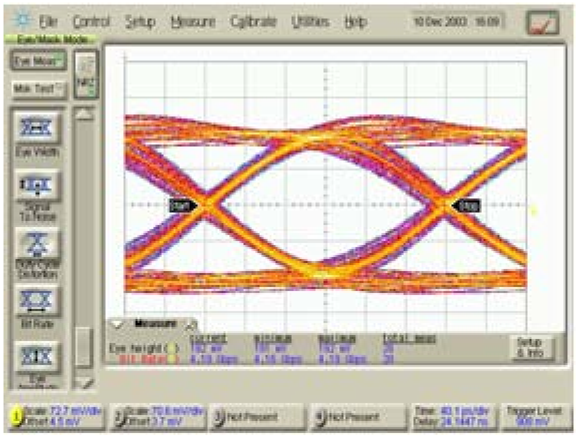


***Figure 7. 26 Foot Giga I/O @ 3.4 Gbps***

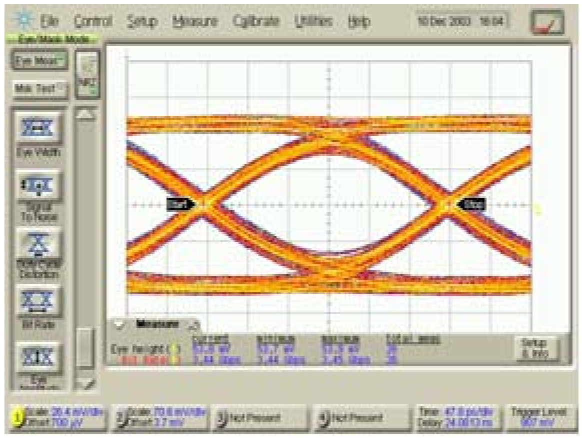
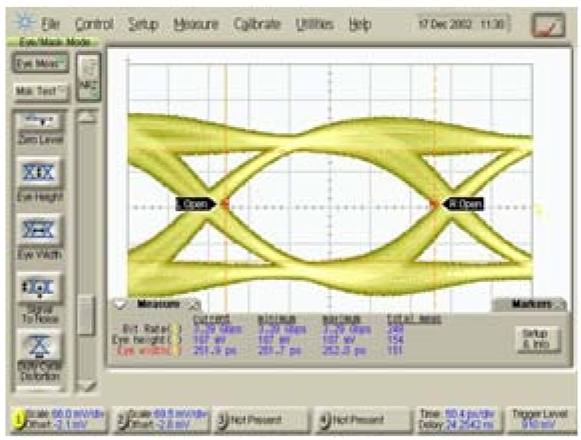



***Figure 8. 10 Foot Coax @ 3.2 Gbps***




## Conclusion

The use of twisted pair cabling is possible for high-speed serial data rates. Lattice SERDES devices allow easy system design migration into wired back-bone configurations. The use of SSP and UTP cables for patch-cord and cross connect jumpers is possible when the designer understands the attenuation trade-offs. To ensure overall system integrity for data rate over 1 Gbps, cables need to be terminated with high quality connecting hardware.

For longer cable applications, the use of hybrid cable assemblies plays a vital role. Serial data rates greater than 3 Gbps can be achieved across moderate distances of cable. This is possible because of the rapid advances in the SERDES I/O and copper interconnect design that can accommodate or even compensate for frequency dependent parameters. With careful system design, designers, who optimize the passive cable equalization and the active pre-emphasis of the Lattice SERDES, will achieve reliable high-speed systems.

## References

1.) ORCA ORT82G5 and ORT42G5 Data Sheet

2.) ORCA ORSO82G5 and ORSO42G5 Data Sheet

3.) Tyco Electronics - 1mm GIGA I/O Cable Assembly Customer Evaluation kit User's Guide

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