

5.0.0 MEDIA (CABLE AND CONNECTOR) SELECTION

5.0.1 General Comments

When choosing cables and connectors for LVDS it is important to remember:

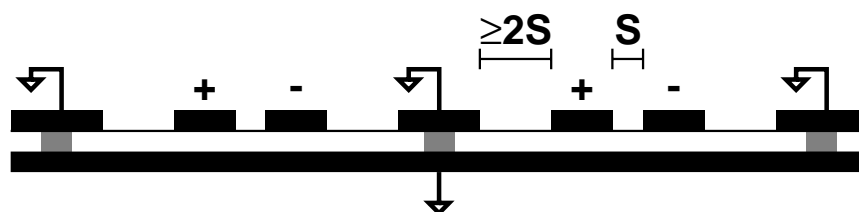
- 1) Use controlled impedance media. The cables and connectors you use should have a matched differential impedance of about 100Ω . They should not introduce major impedance discontinuities.
- 2) Balanced cables (e.g. twisted pair) are usually better than unbalanced cables (ribbon cable, simple coax) for noise reduction and signal quality. Balanced cables tend to generate less EMI due to field canceling effects and also tend to pick up electromagnetic radiation as common mode (not differential mode) noise which is rejected by the receiver.
- 3) For cable distances $<0.5\text{m}$, most cables can be made to work effectively. For distances $0.5\text{m} \leq d \leq 10\text{m}$, CAT 3 (category 3) twisted pair cable works well and is readily available and relatively inexpensive. For distances $>10\text{m}$, and high data rates CAT 5 twisted pair is recommended.

5.2.0 CABLING SUGGESTIONS

As described above, try to use balanced cables (twisted pair, twinax, or flex circuit with closely coupled differential traces). Whatever cable you do choose, following the suggestions below will help you achieve optimal results.

5.2.1 Flex Circuit

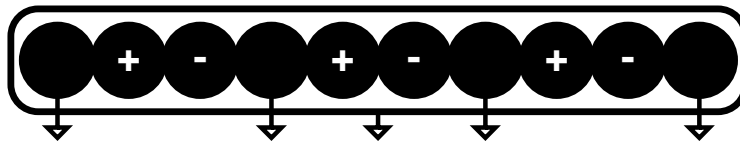
Flex circuit is a good choice for short runs, but it is difficult to shield.



- a) Closely couple the members of differential pairs ($S < W$). Do not run signal pairs near the edges of the cable.
- b) Use a ground plane.
- c) Use ground shield traces between the pairs if there is room. Connect these ground traces to the ground plane through vias at frequent intervals.

5.2.2 Ribbon Cable

Ribbon cable is cheap and is easy to use and shield. Ribbon cable is not well-suited for high speed differential signaling (good coupling is difficult to achieve), but it is OK for short runs.

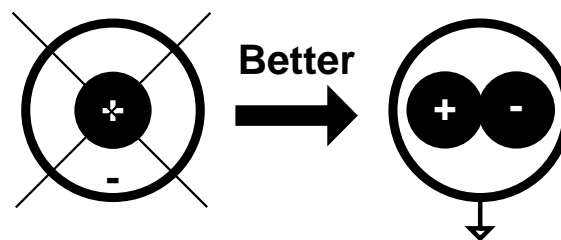


a) If ribbon cable must be used, separate the pairs with ground wires. Do not run signal pairs at the edges of the ribbon cable.

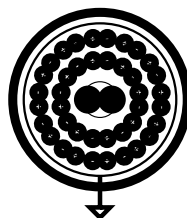
b) Use shielded cable if possible.

5.2.3 Twinax and Coax

Coax is not balanced, so twinax is much better for LVDS.



5.2.4 Twisted Pair

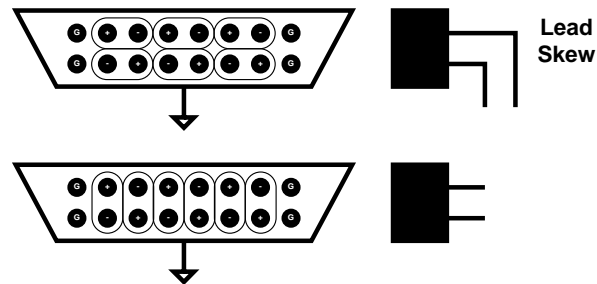


a) Twisted pair is a good choice for LVDS. Category 3 (CAT3) cable is good for runs up to about 10m, while CAT5 is better for longer runs.

b) For lowest skew, group skew-dependent pairs together (towards the center or towards the outside of the cable).

c) Ground and/or terminate unused conductors.

5.2.5 Connectors

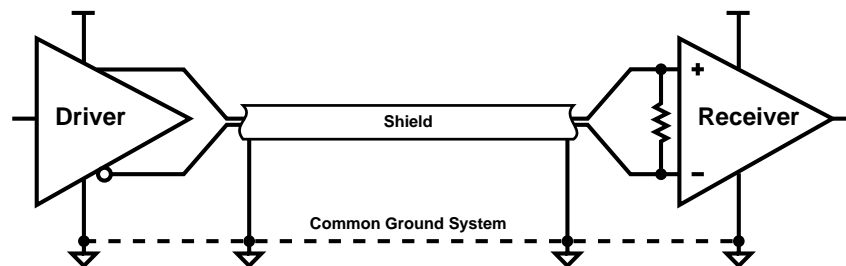


- a) Choose low skew, impedance matching connectors if possible.
- b) Group members of each pair together. **Be sure that the pin assignment you choose on the connector matches the orientation of the pairs. In other words, a pair may be pins 1 and 26 not pins 1 and 2.**
- c) Some connectors have different length leads for different pins. Group pairs on same length leads. Consult the connector manufacturer for the orientation of pins which yield the lowest skew and crosstalk for your particular connector.
- d) Place ground pins between pairs where possible and convenient.
- e) Ground end pins. Do not use end pins for high speed signals.
- f) Ground and/or terminate unused pins.

5.3.0 CABLE GROUND AND SHIELD CONNECTIONS

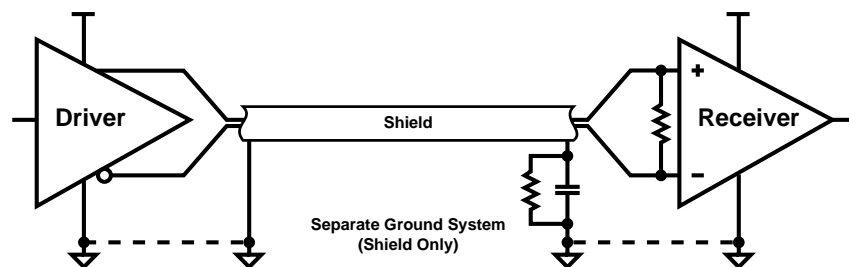
In many systems, cable shielding is required for EMC compliance. Although LVDS provides low EMI benefits when used properly, shielding is still usually a good idea. Together, cable shielding and ground return wires help reduce EMI. The shielding contains the EMI and the ground return wire (the shield in some cables) provides a small loop area AC return path for common mode currents. **Note: it is beyond the scope of this book to effectively deal with cabling systems in detail. Please consult other texts on this subject and be sure to follow applicable safety and legal requirements for cabling, shielding and grounding.**

5.3.1 Common Ground Systems

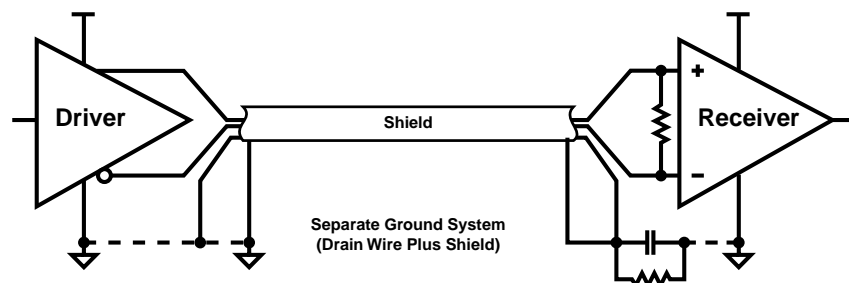


In applications where the grounding system will be common to both the receiver and the driver, the cable shield is connected at both ends (DC connection) to the common ground. Avoid "pig-tail" ground wiring from the cable. In the case where connectors are involved that penetrate the system's enclosure, the cable shield must have a circumferential contact to the connector's conductive backshell.

5.3.2 Separate Ground Systems



Where AC and/or DC voltage potentials exist between the driver and receiver sub-systems or where these do not share a common ground system, the cable shield should be connected to the receiver's ground system via a capacitor of suitable value and voltage rating to handle the average DC and peak AC voltages that may be present. A "bleeder resistor" should be connected across the capacitor. The value of this resistor (and capacitor) may be governed by safety requirements (UL, CSA, VDE, BS, or other) or other statutory requirements. Care should be taken when selecting the resistor value so as not to allow potentially lethal voltages to be developed across it.



When the cable has an integral drain wire and a woven braid shield, both are connected together at the driver and receiver ends and treated as a common shield conductor. For non-metallic shield materials (like aluminized mylar) with a drain wire, treat the drain wire as the shield connection as in the cases described for metallic shields.

5.4.0 LVDS SIGNAL QUALITY: JITTER MEASUREMENTS USING EYE PATTERNS

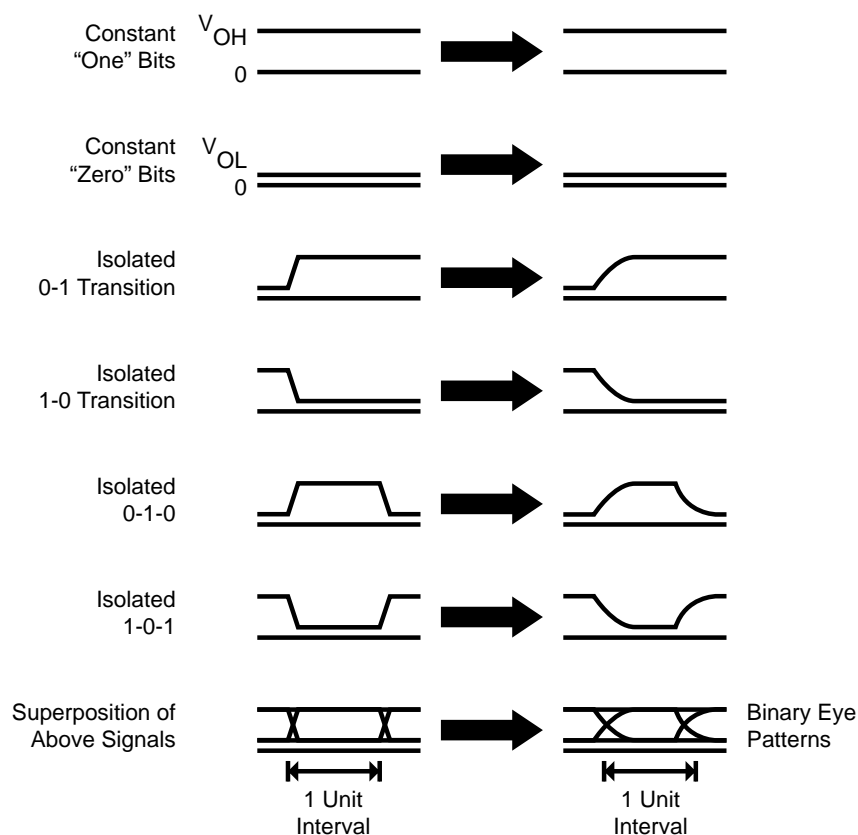
5.4.1 LVDS Signal Quality

This report provides data rate versus cable length recommendations for LVDS drivers and receivers in a typical application for a particular twisted pair cable. The questions of: "How Far?" and "How Fast?" seem simple to answer at first, but after detailed study their answers become quite complex. This is not a simple device parameter specification. But rather, a system level question where a number of other parameters besides the switching characteristics of the drivers and receivers must be known. This includes the measurement criteria for signal quality that has been selected, and also the pulse coding that will be used (NRZ for example). Additionally, other system level components should be known too. This includes details about cables, connectors, and printed circuit board (PCB). Since the purpose is to measure signal quality, it should be done in a test fixture that closely matches the end environment — or even better — in the actual application. Eye pattern measurements are useful in measuring the amount of jitter versus the unit interval to establish the data rate versus cable length curves and therefore are a very accurate way to measure the expected signal quality in the end application.

5.4.2 Why Eye Patterns?

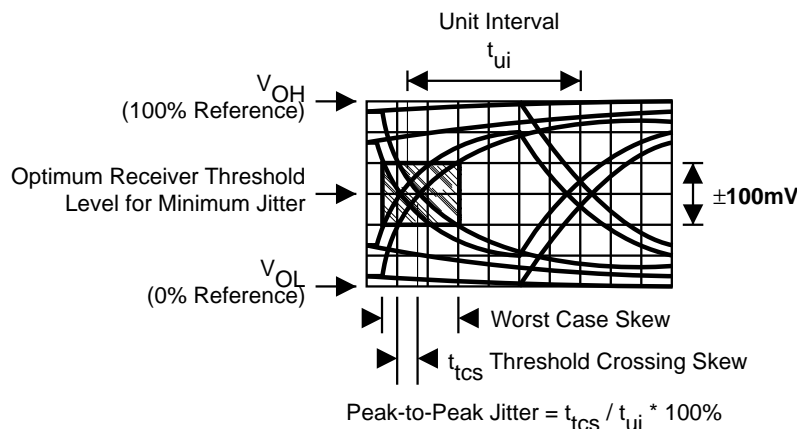
The eye pattern is used to measure the effects of inter symbol interference on random data being transmitted through a particular medium. The transition time of the signal is effected by the prior data bits. This is especially true for NRZ data which does not guarantee transitions on the line. For example in NRZ coding, a transition high after a long series of lows has a slower rise time than the rise time of a periodic (010101) waveform. This is due to the low pass filter effects that the cable causes. The figure below illustrates the superposition of six different data patterns. Overlaid they form the eye pattern that is the input to the cable. The right hand side of this figure illustrates the same pattern at the end of the cable. Note the rounding of the formerly sharp transitions. The width of the crossing point is now wider, and the opening of the eye is also now smaller (see application note AN-808 for an extensive discussion on eye patterns).

When line drivers (generators) are supplying symmetrical signals to clock leads, the period of the clock, rather than the unit interval of the clock waveform, should be used to determine the maximum cable lengths (e.g., though the clock rate is twice the data rate, the same maximum cable length limits apply). This is due to the fact that a periodic waveform is not prone to distortion from inter symbol distortion as is a data line.



Formation of an Eye Pattern by Superposition.

The figure below describes the measurement locations for minimum jitter. Peak-to-Peak Jitter is the width of the signal crossing the optimal receiver thresholds. For a differential receiver, that would correspond to 0V (differential). However, the receiver is specified to switch between -100mV and $+100\text{mV}$. Therefore for a worst case jitter measurement, a box should be drawn between $\pm 100\text{mV}$ and jitter measured between the first and last crossing at $\pm 100\text{mV}$. If the vertical axis units in the figure were 100mV/division , the worst case jitter is at $\pm 100\text{mV}$ levels.



NRZ Data Eye Pattern.

5.4.3 Eye Pattern Test Circuit

LVDS drivers and receivers are intended to be primarily used in an uncomplicated point-to-point configuration as shown in the figure below. This figure details the test circuit that was used to acquire the Eye pattern measurements. It includes the following components:

PCB#1: DS90C031 LVDS Quad Driver soldered to the PCB with matched PCB traces between the device (located near the edge of the PCB) to the connector. The connector is a AMP amplit 50 series connector.

Cable: Cable used for this testing was Berk-Tek part number 271211. This is a 105 Ω (Differential Mode) 128 AWG stranded twisted pair cable (25 Pair with overall shield) commonly used on SCSI applications. This cable represents a common data interface cable. For this test report the following cable lengths were tested: 1, 2, 3, 5, and 10 meter(s). Cables longer than 10 meters were not tested, but may be employed at lower data rates.

PCB#2: DS90C032 LVDS Quad Receiver soldered to the PCB with matched PCB traces between the device (located near the edge of the PCB) to the connector. The connector is a AMP amplit 50 series connector. A 100 Ω surface mount resistor was used to terminate the cable at the receiver input pins.

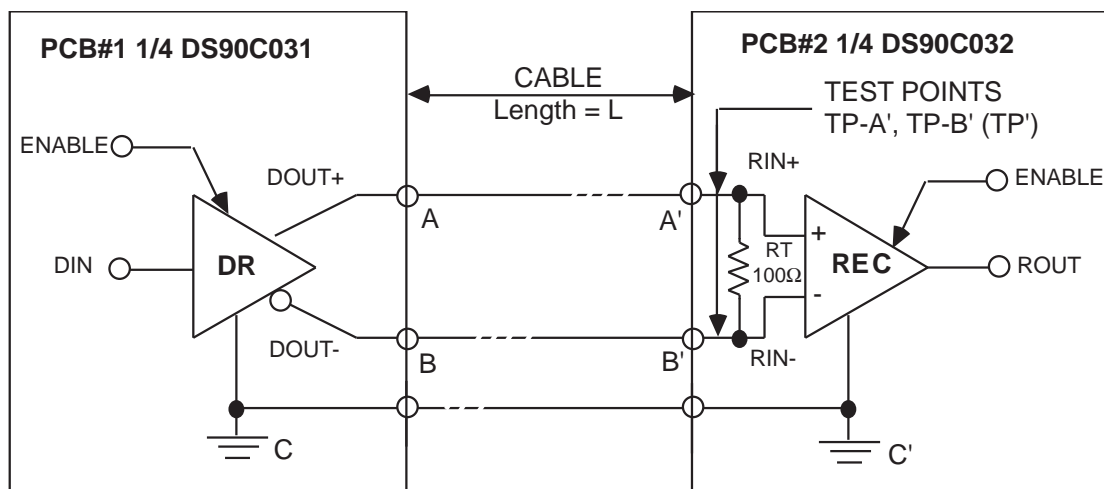


Figure 3. LVDS Signal Quality Test Circuit

5.4.4 Test Procedure

A pseudo-random (PRBS) generator was connected to the driver input, and the resulting eye pattern (measured differentially at TP') was observed on the oscilloscope. Different cable lengths (L) were tested, and the frequency of the input signal was increased until the measured jitter equaled 20% with respect to the unit interval for the particular cable length. The coding scheme used was NRZ. Jitter was measured twice at two different voltage points. First, jitter was measured at the 0V differential voltage (optimal receiver threshold point) for minimum jitter, and second at the maximum receiver threshold points ($\pm 100\text{mV}$) to obtain the worst case or maximum jitter at the receiver thresholds. Occasionally jitter is measured at the crossing point alone, this will result in a much lower jitter point, but ignores the fact that the receivers may not switch at that very point. For this reason this signal quality test report measured jitter at both points.

5.4.5 Results and Data Points

20% Jitter Table @ 0V Differential (Minimum Jitter)

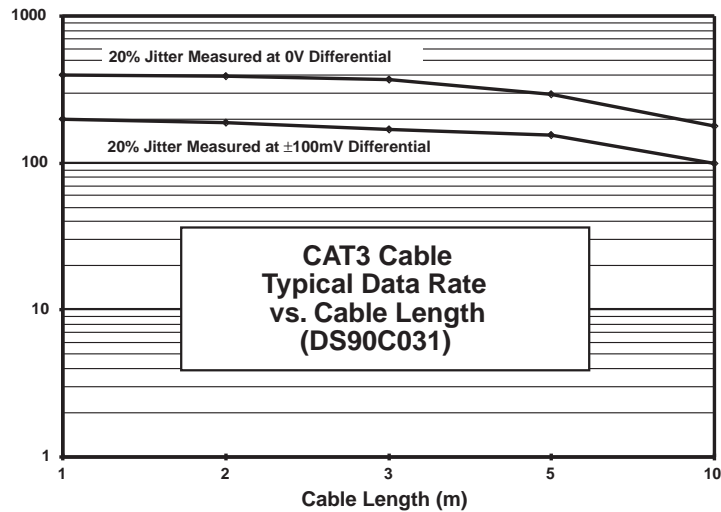
Cable Length (m)	Data Rate (Mbps)	Unit Interval (ns)	Jitter (ns)
1	400	2.500	0.490
2	391	2.555	0.520
3	370	2.703	0.524
5	295	3.390	0.680
10	180	5.550	1.160

As described above, Jitter was measured at the 0V differential point. For the case with the 1 meter cable, 490ps of jitter at 400Mbps was measured, and 1.160ns of jitter at 180Mbps and with the 10 meter cable.

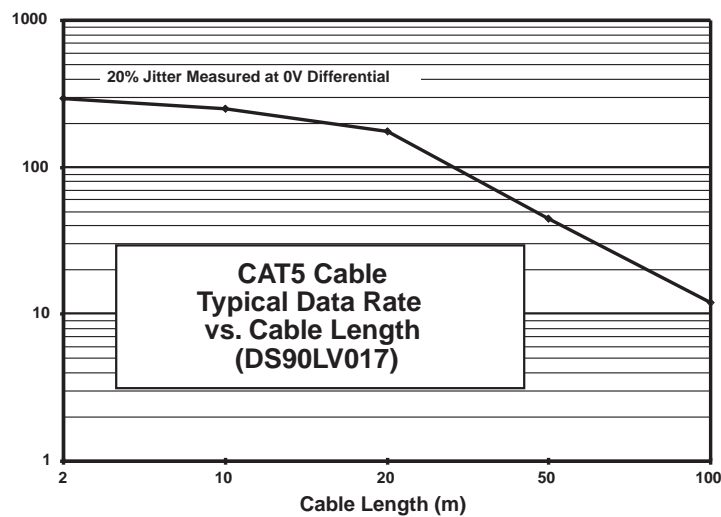
20% Jitter Table @ $\pm 100\text{ mV}$ (Maximum Jitter)

Cable Length (m)	Data Rate (Mbps)	Unit Interval (ns)	Jitter (ns)
1	200	5.000	1.000
2	190	5.263	1.053
3	170	5.882	1.176
5	155.5	6.431	1.286
10	100	10.000	2.000

The second case measured jitter between $\pm 100\text{mV}$ levels. For the 1 meter cable, 1ns of jitter was measured at 200Mbps, and for the 10 meter cable, 2ns of jitter occurred at 100Mbps.



Typical Data Rate vs. Cable Length for 0-10m CAT3 Cable.



Typical Data Rate taken just prior to printing this document for 2-100m CAT5 Cable

The figures above are a graphical representation of the relationship between data rate and cable length for the application under test. Both curves assume a maximum allotment of 20% jitter with respect to the unit interval. Basically, data rates between 200-400 Mbps are possible on the shorter lengths, and rates of 100-200Mbps are possible at 10 meters. Note that employing a different coding scheme, cable, wire gauge (AWG), etc. will create a different relationship between maximum data rate versus cable length. Designers are greatly encouraged to experiment on their own.

5.4.6 Conclusions

Eye patterns provide a useful tool to analyze jitter and the resulting signal quality as it captures the effects of a random data pattern. They provide a method to determine the maximum cable length for a given data rate or vice versa. Different systems, however, can tolerate different levels of jitter. Commonly 5%, 10%, or 20% is acceptable with 20% jitter usually being an upper practical limit. More than 20% jitter tends to close down the eye opening, making error-free recovery of NRZ data more difficult. This report illustrates data rate versus distance for a common, inexpensive type of cable.

5.5.0 BIT ERROR RATE (BER) TESTING

5.5.1 LVDS Cable Driving Performance

The questions of: “How Far?” and “How Fast?” seem simple to answer at first, but after detailed study their answers become quite complex. This is not a simple device parameter specification. But rather, a system level question, and to be answered correctly a number of other parameters besides the switching characteristics of the drivers and receivers must be known. This includes the measurement criteria for signal quality that has been selected, and the pulse coding that will be used (Non-Return to Zero (NRZ) for example — see application note AN-808 for more information about coding). Additionally, other system level components should be known too. This includes details about the cable, connector, and information about the printed circuit board (PCB). Since the purpose is to measure signal quality/performance, it should be done in a test fixture that matches the end environment precisely if possible. The actual application would be best if possible. There are numerous methods to measure signal quality, including eye pattern (jitter) measurements and Bit Error Rate tests (BER).

This report provides the results of a series of Bit Error Rate tests performed on the DS90C031/2 LVDS Quad Line Driver/Receiver devices. The results can be generalized to other National LVDS products. Four drivers were used to drive 1 to 5 meters of standard twisted pair cables at selected data rates. Four receivers were used to recover the data at the load end of the cable.

5.5.2 What is a BER Test?

Bit Error Rate testing is one way to measure of the performance of a communications system. The standard equation for an bit error rate measurement is:

$$\text{Bit Error Rate} = (\text{Number of Bit errors}) / (\text{Total Number of Bits})$$

Common measurement points are bit error rates of:

$<1 \times 10^{-12}$ => One or less errors in 1 trillion bits sent

$<1 \times 10^{-14}$ => One or less errors in 100 trillion bits sent

Note that BER testing is time intensive. The time length of the test is determined by the data rate and also the desired performance bench mark. For example if the data rate is 50Mbps, and the bench mark is an error rate of 1×10^{-14} or better, a run time of 2,000,000 seconds is required for a serial channel. 2,000,000 seconds equates to 555.6 hours or 23.15 days!

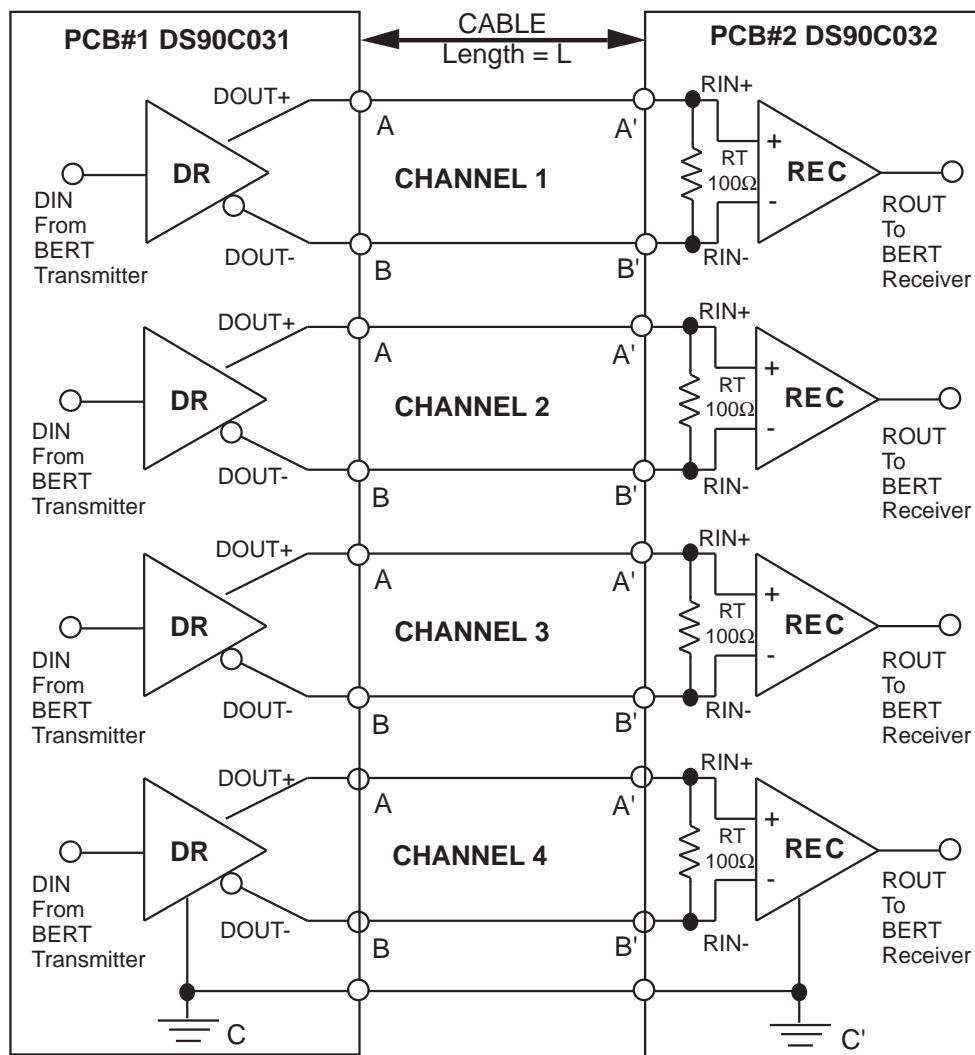
5.5.3 BER Test Circuit

LVDS drivers and receivers are intended to be primary used in an uncomplicated point-to-point configuration as shown in Figure 1. This figure details the test circuit that was used. It includes the following components:

PCB#1: DS90C031 LVDS Quad Driver soldered to the PCB with matched PCB traces between the device (located near the edge of the PCB) to the connector. The connector is an AMP amplit 50 series connector

Cable: Cable used for this testing was Berk-Tek part number 271211. This is a 105Ω (Differential Mode) 28 AWG stranded twisted pair cable (25 Pair with overall shield) commonly used in SCSI applications. This cable represents a common data interface cable. For this test report cable lengths of 1 and 5 meters were tested.

PCB#2: DS90C032 LVDS Quad Receiver soldered to the PCB with matched PCB traces between the device (located near the edge of the PCB) to the connector. The connector is a AMP amplit 50 series connector. A 100Ω surface mount resistor was used to terminate the cable at the receiver input pins.



LVDS BER test circuit.

5.5.4 Test Procedure

A parallel high-speed BER transmitter/receiver set (Tektronix MultiBERT-100) was employed for the tests. The transmitter was connected to the driver inputs, and the receiver outputs were connected to the BERT receiver inputs. Different cable lengths and data rates were tested. The BER tester was configured to provide a PRBS (Pseudo Random Bit Sequence) of $2^{15}-1$ (32,767 bit long sequence). In the first test, the same input signal was applied to all four of the LVDS channels under test. For the other tests, the PRBS was offset by 4 bits, thus providing a random sequence between channels. The coding scheme used was NRZ. Upon system test configuration, the test was allowed to run uninterrupted for a set amount of time. At completion of the time block the results were recorded which included: elapsed seconds, total bits transmitted, and number of bit errors recorded. For the three tests documented below, a power supply voltage of +5.0V was used, and the tests were conducted at room temperature.

5.5.5 Tests and Results

The goal of the tests was to demonstrate errors rates of less than $<1 \times 10^{-12}$ are obtainable.

TEST #1 Conditions:

Data Rate = 50Mbps
Cable Length = 1 meter
PRBS Code = $2^{15}-1$ NRZ

For this test, the PRBS code applied to the four driver inputs was identical. This created a “simultaneous output switching” condition on the device.

TEST #1 Results:

Total Seconds: 87,085 (1 day)
Total Bits: $1,723 \times 10^{13}$
Errors = 0
Error Rate = $< 1 \times 10^{-12}$

TEST #2 Conditions:

Data Rate = 100Mbps
Cable Length = 1 meter
PRBS Code = $2^{15}-1$ NRZ

For this test, the PRBS code applied to the four driver inputs was offset by four bits. This creates a random pattern between channels.

TEST #2 Results:

Total Seconds: 10,717 (~3 hr.)
Total Bits: 4.38×10^{12}
Errors = 0
Error Rate = $< 1 \times 10^{-12}$

TEST #3 Conditions:

Data Rate = 100Mbps
Cable Length = 5 meter
PRBS Code = $2^{15}-1$ NRZ

For this test, the PRBS code applied to the four driver inputs was offset by four bits. This creates a random pattern between channels.

TEST #3 Results:

Total Seconds: 10,050
Total Bits: 4×10^{12}
Errors = 0
Error Rate = $< 1 \times 10^{-12}$

5.5.6 Conclusions

All three of the tests ran error free and demonstrate extremely low bit error rates using LVDS technology. The tests concluded error rates of $< 1 \times 10^{-12}$ can be obtained at 100Mbps operation across 5 meters of twisted pair cable. BER tests only provide a “Go — No Go” data point if zero errors are detected. It is recommended to conduct further tests to determine the point of failure (data errors). This will yield important data that indicates the amount of margin in the system. This was done in the tests conducted by increasing the cable length from 1 meter to 5 meters, and also adjusting the data rate from 50Mbps to 100Mbps. Additionally, bench checks were made while adjusting the power supply voltage from 5.0V to 4.5V and 5.5V, adjusting clock frequency, and by applying heat/cold to the device under test (DUT). No errors were detected during these checks (tests were checks only and were not conducted over time, i.e. 24 hours). BER tests conclude that the PRBS patterns were transmitted error free across the link. This was concluded by applying a pattern to the input and monitoring the receiver output signal.