Performance of LVDS with different cables

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Introduction to LVDS

Low-voltage differential signaling (LVDS) runs fast—very fast. One of the most frequently asked questions about data transmission applications is, “How fast and how far?” The answer depends on technology, system circumstances (noise, crosstalk, stubs, etc.) and the connection media.

TI’s family of LVDS line circuits enables signaling rates in excess of 400 Mbps, and using such TIA/EIA-644 standard devices may result in cable performance being the determining factor in the overall system performance. LVDS is a data transmission standard that utilizes a balanced interface and a low voltage swing to solve many of the problems associated with existing signaling technologies. Lower signal amplitudes reduce the power used by the line circuits, and balanced signaling reduces noise coupling to allow higher signaling rates. LVDS, as standardized in TIA/EIA-644, specifies a maximum signaling rate of 655 Mbps. In practice, the maximum signaling rate will be determined by the quality of the transmission media between the line driver and receiver. Since a transmission line’s length and characteristics determine the maximum usable signaling rate, this article looks at some of the dependencies and interactions between these cable characteristics and the signaling rate. See Reference 1 for the detailed version of this article.

Cable selection

Prior to the cable selection, a designer has to evaluate the determining system parameters such as:

- signaling rate,
- cable length,
- single-ended or differential (balanced) signaling,
- point-to-point, multidrop or multipoint configuration,
- noise margin,
- flexibility, and
- costs.

Depending on the specific application and environment, the following decisions need to be made:

- Unshielded or shielded (taped, braided, or combination of both)?
- Round or flat?
- Coaxial, multiconductor or twisted pair (TP) cable?

The need for shielding depends mainly on the noise environment. For long transmission lines, a braided or served shield is recommended to ensure good isolation between the signal lines and the environment. However, this type of shielding is permeable at high frequencies, and double-shielded cables that are both taped and braided typically perform better. Multiconductor cables are cheaper and easier to handle than twisted pair or coaxial cables, especially in terms of termination. While twisted pair is less expensive and more flexible than coaxial, it generally does not provide the noise immunity and bandwidth available with coaxial cables. Nevertheless, differential data transmission requires a balanced pair of conductors. The answer to the round- or flat-cable question is usually determined by the environment. For internal applications with low noise, a flat untwisted cable is usually adequate. However, in noisy environments, shielding is often required, and industry standards call for shielded twisted pair (STP) cable. For balanced (or differential) data transmission, such as LVDS, twisted pair cable is recommended since it provides two identical conductors to transmit the signal and its complement. Ideally, any distortion will affect both conductors equally; therefore, the differential signal will not change.

The cable-standard TIA/EIA-568-A

Since cable quality contributes strongly to signal quality, it should be evaluated in detail. One standard, the TIA/EIA-568-A Commercial Building Telecommunications Cabling Standard, defines the transmission requirements for commercial building telecommunication wiring. Twisted pair is classified herein in different categories, abbreviated by CATX. CAT3 is characterized up to 16 MHz, CAT4 to a maximum of 20 MHz, and CAT5 for 100 MHz and above. CAT6 and CAT7 are in preparation. Parameters such as attenuation, dc resistance, skew, capacitance to GND and between lines, etc., are specified in TIA/EIA-568A.

Measurements

Seven different cables are tested with the LVDS evaluation module (EVM). Each EVM contains one SN65LVDS31 quad line driver and one SN65LVDS32 quad line receiver, and each of the cables listed below is tested as the interconnection media between the LVDS driver and receiver.

- Cable A: CAT 3, no shield, outside conductor diameter ∅ 0.52 mm
- Cable B: CAT 5, no shield, ∅ 0.52 mm
- Cable C: CAT 5, taped over all shield, ∅ 0.52 mm
- Cable D: Exceeding CAT 5, specified up to 300 MHz, braided over all shield plus taped individual shield for any pair, ∅ 0.64 mm
- Cable E: Exceeding CAT 5, specified up to 350 MHz, ∅ 0.64 mm, no shield
- Cable F: Exceeding CAT 5, specified up to 350 MHz, self-shielded, ∅ 0.64 mm
- Cable G: Twin-axial cable, specified up 1 GHz

For each measurement, a pseudo-random binary signal (PRBS) with a non-return to zero (NRZ) format is used. PRBS patterns are applied to the input of the transmitter; then eye patterns are measured at the input of the receiver. Tests are performed on Cables A through F with lengths of

1, 5, and 10 meters (only a 10-meter length is available for the testing of Cable G). Since all cables tested contain four pairs, crosstalk is created by transmitting through two of the pairs in one direction while the remaining two pairs are driven in the opposite direction. All of the data listed is measured with the four transmitters in operation.

Test setup

The LVDS EVM contains one SN65LVDS31 quad line driver and one SN65LVDS32 quad line receiver, as shown in Figure 1. All four channels of the line driver are utilized to simulate crosstalk by transmitting PRBS in opposite directions. The EVM is CE-certified and available via distribution, and detailed information on the EVM is available in Reference 2.

Jitter measurement

The eye pattern is a useful tool to measure the overall signal quality at the end of a transmission line. It includes all of the effects of systemic and random distortion, and shows the time during which the signal may be considered valid. A typical eye pattern is illustrated in Figure 2 with the significant attributes identified.

Several characteristics of the eye pattern indicate the signal quality of the transmission circuit. The height or opening of the eye above or below the receiver threshold level at the sampling instant is the noise margin of the system. The spread of the transitions across the receiver thresholds measures the peak-to-peak jitter of the data signal. The signal rise and fall times can be measured relative to the 0% and 100% levels provided by the long series of low and high levels.

Jitter is the time frame during which the logic state transition of a signal occurs. The jitter may be given either as an absolute number

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Figure 1. Test setup

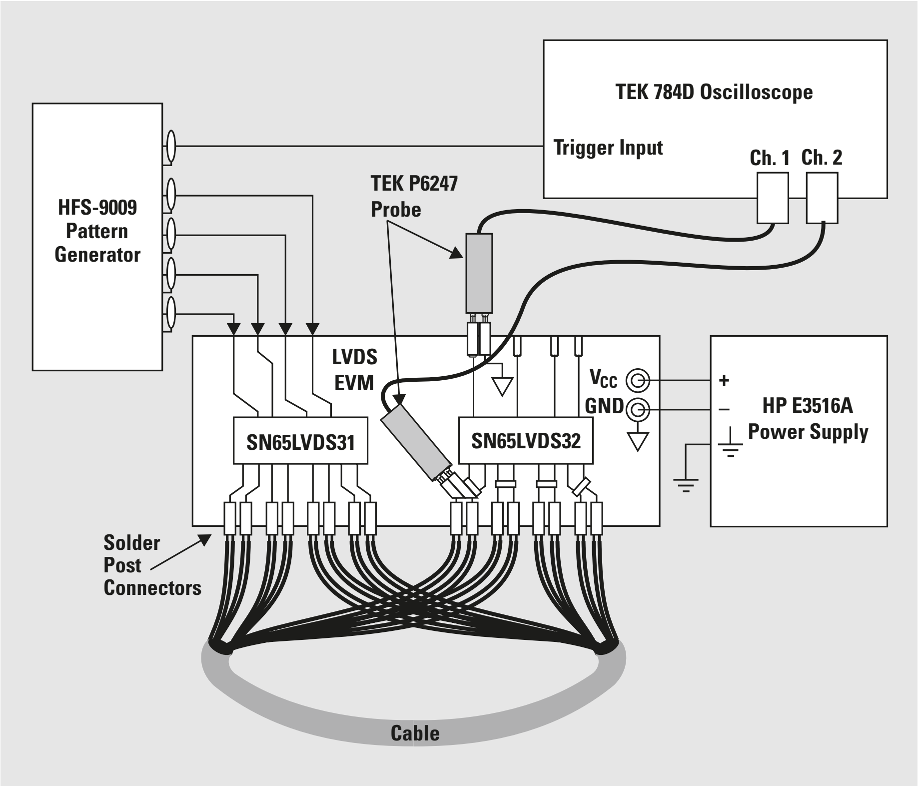
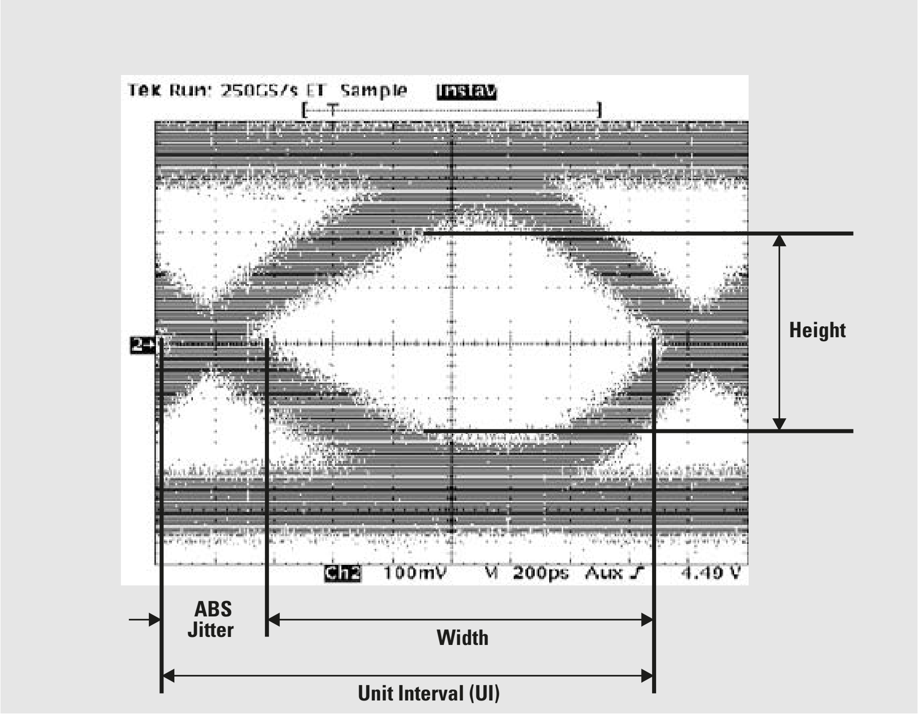


Figure 2. Typical eye pattern



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or as a percentage with reference to the unit interval (UI). This UI or bit length equals the reciprocal value of the signaling rate, and the time during which a logic state is valid is just the UI minus the jitter. Percent jitter (the jitter time divided by the UI times 100) is more commonly used, and it represents the portion of UI during which a logic state should be considered indeterminate.

Table 1. Signaling rates vs. cable length for 5% jitter

CABLE LENGTH (m)	SIGNALING RATES (Mbps)						
	CABLE A	CABLE B	CABLE C	CABLE D	CABLE E	CABLE F	CABLE G
1	240	200	240	270	180	230	N/A
5	205	210	230	250	215	230	N/A
10	180	150	195	200	145	180	195

Results

Jitter at the input of the receiver is measured at the zero voltage differential, then calculated with respect to the duration of the unit interval. The results are expressed as a percentage of jitter. At 400 Mbps the jitter ranges between 17% for the worst twisted pair cable (mostly 12% to 13%) and 10% for the twin-axial cable over 10 meters. For shorter runs the jitter is reduced towards 8% to 13% for 5 m of length and ranges from 7.5% to 12.5% over distances of 1 m. The decrease of jitter with a reduced data rate is a linear function, so half the data rate equals approximately half the amount of jitter. Detailed graphs on these measurements can be found in Reference 1.

The linear increase of the jitter (as a percent of UI) with the signaling rate in all measured cables is a relative measure of the high-frequency characteristics of the cable. The results are summarized in Table 1, which displays the signaling rates that resulted in a jitter of 5% of UI present at the input to the LVDS32 receiver. System tolerance to jitter is highly application-dependent, and maximum allowable jitter tolerances typically range from 5% to 20% depending upon actual system requirements. Note that this data was collected with signals present on the other three twisted wire pairs in the cable.

Test results show that, as expected, slightly better performance was achieved with the shielded Cables E and F than the unshielded Cables C and D. It is difficult to identify the noise coupling source as inter-system or intra-system, but if electromagnetic noise is a concern, shielding should be used. Transmitting data through a single channel and signal pair may reduce the absolute jitter by up to 10%.

Cable length and signaling rate

Equation 1 was developed based on the gathered data. This equation approximates percent output jitter through an LVDS32 receiver, given the cable length (m) and signaling rate (Mbps), and is valid for cable lengths from 5 m to 20 m and signaling rates of 100 Mbps up to 400 Mbps.

$$\text{Output jitter} = \frac{\left\{\left[1+\left(\frac{0.0023(S)}{1+\frac{L-1}{7.63}}\right)\right]\left[(200+15L)S\right]\right\}}{10{,}000}, \qquad \textbf{(1)}$$

where S is the signaling rate in Mbps and L is cable length in meters.

This data is based upon the CAT5 cables tested, and the reader should be advised that a marginal cable that minimally meets the requirements of CAT5 may yield actual performance less desirable than the results predicted here with Equation 1.

Conclusion

Especially at high data rates like with LVDS, the quality and length of the transmission media have a significant impact on the overall system performance. For signaling rates in the range of several hundred megabits, one has to expect a jitter ranging around 10% to 15% on distances up to 10 meters with today's cables. This article helps the designer find an appropriate cable solution based upon actual requirements and the environment.

References

For more information related to this article, you can download an Acrobat Reader file at www-s.ti.com/sc/techlit/*litnumber* and replace *"litnumber"* with the **TI Lit. #** for the materials listed below.

Document Title	**TI Lit. #**
1. "Performance of LVDS with Different Cables," Application Report	slla053
2. "Low Voltage Differential Signaling (LVDS) Evaluation Module (EVM)," User's Guide . .	—

Related Web sites

www.ti.com/sc/docs/products/msp/intrface/index.htm
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