

## ***M-LVDS Signaling Rate Versus Distance***

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*High-Performance Linear/Interface Products*

### **ABSTRACT**

Multipoint LVDS (M-LVDS) devices provide a new class of high-speed, low-power, and standardized interface solutions. This report gives a brief review of TIA/EIA-899 (M-LVDS) and discusses the characteristics that affect the maximum signaling rate and distance. Maximum signaling rates are measured over 3-m, 10-m, 20-m, and 40-m lengths of CAT5 unshielded twisted pair (UTP) cable using the SN65MLVD201 and SN65MLVD207 M-LVDS transceiver.

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### **Introduction**

TIA/EIA-899 (M-LVDS) provides a general-purpose high-speed balanced interface standard. M-LVDS general-purpose applications include multipoint LVDS operation, high-speed signaling where balanced transmission is required, signaling rates, or power requirements beyond the capabilities of TIA/EIA-485, and applications where low electromagnetic radiation and interference with other devices is required.

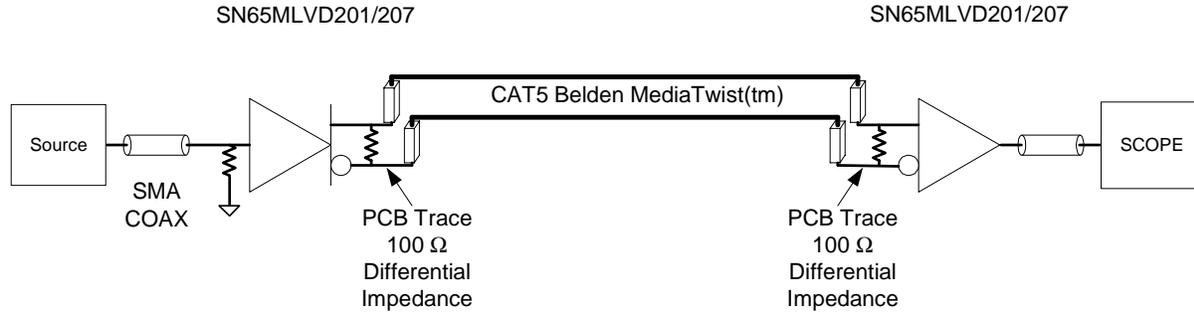
The M-LVDS standard defines a maximum signaling rate of 500 Mbps, it does not specify a maximum distance of balanced media for applications. Instead of a distance, the standard provides a recommended loss between the driver and receiver. The standard recommends a loss of 6 dB or less through the interconnect media (PCB traces, vias, connectors, cables, etc), in order to maintain noise margin. By specifying in terms of signal loss, the transmission distance is then estimated solely by the bandwidth of the interconnect and is not bound to any specific copper media.

For specific uses, the quality of a data transmission circuit is most often characterized by the eye pattern. The eye pattern takes into account data pattern dependent distortion (ISI), differential noise, attenuation, and the line circuits. It is also easy to create. By establishing a minimum eye opening at the receiver output, the maximum distance or signaling rate can be determined for a given interconnection circuit.

This report uses both the 6 dB recommendation found in the standard, and the minimum eye opening at the receiver to plot signaling rate versus distance for the SN65MLVD201 and SN65MLVD207 transceivers. The maximum distance that provides 6 dB of attenuation is calculated from the sinusoidal attenuation of the CAT-5 cable. The eye opening is used to determine the maximum signaling rate for distances less than this calculated maximum.

### **Signaling Rate versus Distance Measurements**

Figure 1 illustrates the test setup used to typify distance versus signaling rate. The SN65MLVD201 is used as the line driver and receiver and the test instruments are listed in the appendix.



**Figure 1. Test Setup**

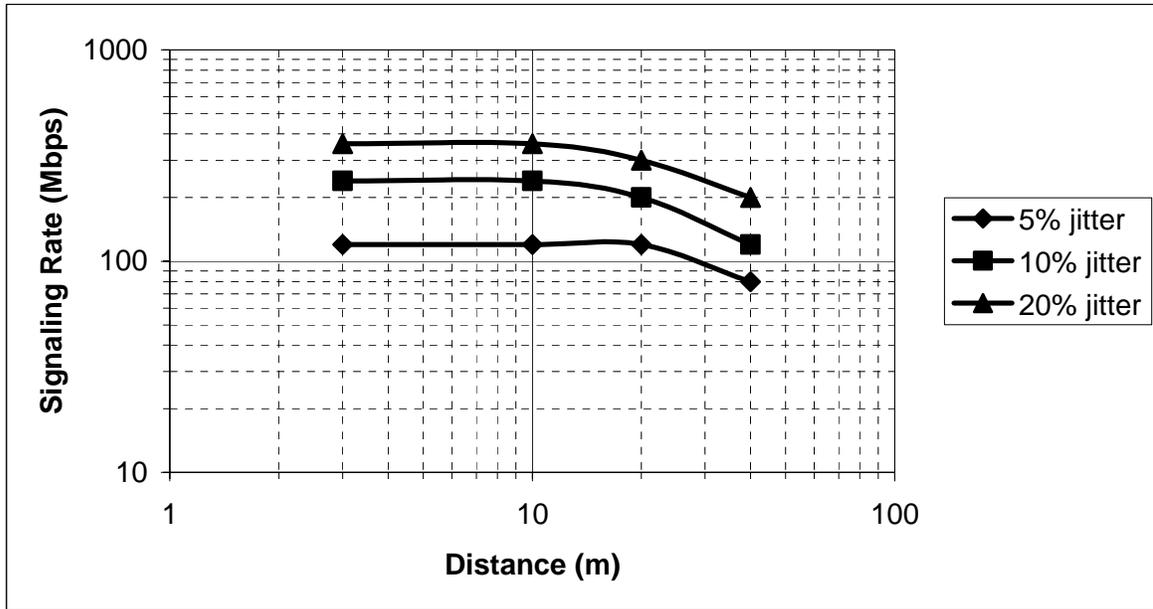
The cable used for this investigation was category-5 Belden MediaTwist™. The cable data sheet provides capacitance, delay, and other properties. The data sheet also describes the cables attenuation per unit length as a function of frequency. The maximum attenuation in decibel per 100 meters is given by the following equation:

$$\text{Attenuation} = 1.808 * \sqrt{F} + 0.017 * F + \frac{0.05}{\sqrt{F}}$$

Where F is the sinusoidal frequency in MHz from 0.772 to 350

The maximum distance boundary for 100 Mbps is estimated from 6 dB of attenuation of a 100-MHz sine wave. Using the attenuation equation, -6 dB occurs at a cable length of 30.3 m, and testing is then limited to a maximum of 40 meters with intermediate data points at 3 m, 10 m, and 20 m. At each cable length, the eye pattern is observed at the output of the receiver and the signaling rate adjusted until the peak-to-peak jitter at the 50%-amplitude crossing comprised 5%, 10%, and 20% of the unit interval. In each case, a pseudo-random bit stream (PRBS) with a pattern run length of  $2^{31} - 1$  is used as the data. The results are plotted in Figure 2.

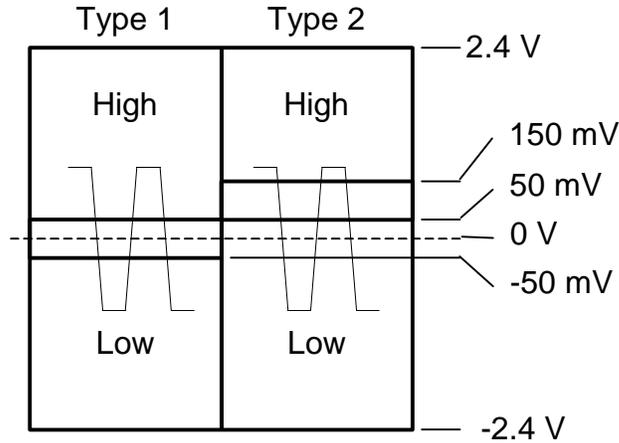
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**Figure 2. SN65MLVD201 Signaling Rate versus Distance**

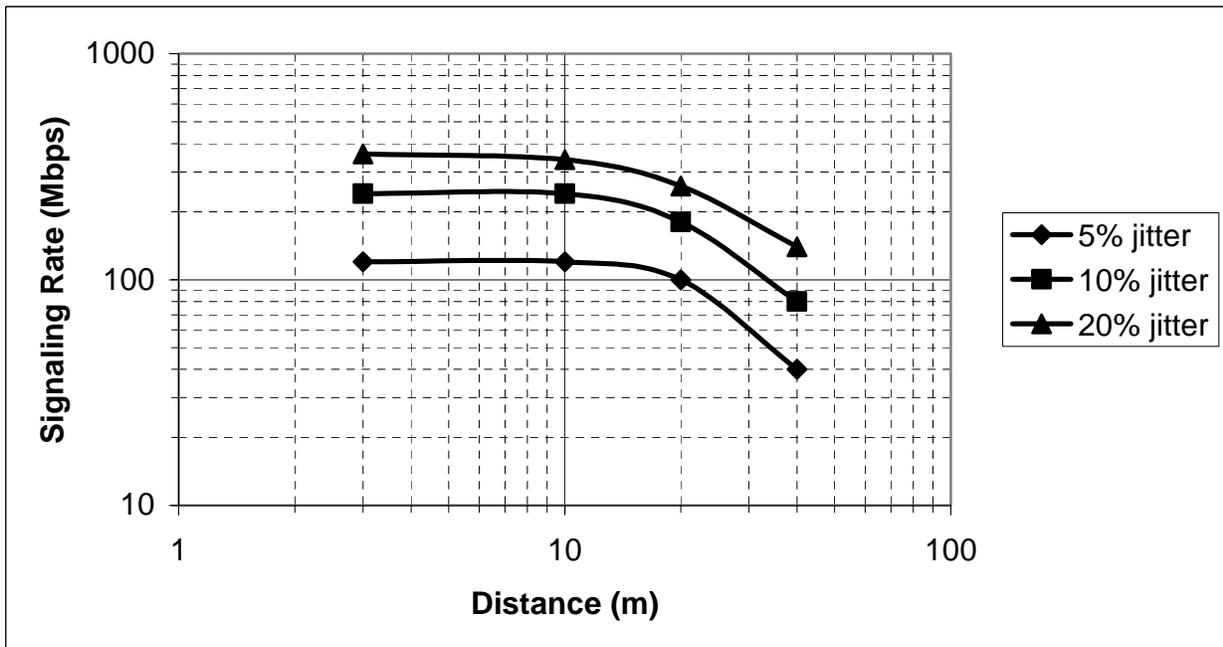
In Figure 2, the two distinct regions are less than 10 m and greater than 10 m. Less than 10 m, the level of percent jitter is constant. After 10 m, the signaling rate is decreased as the cable length is increased in order to maintain a constant eye opening. This indicates that the cable has little impact on the eye-pattern jitter for lengths below 10 m, and jitter from the driver and receiver dominates. It is interesting that the TIA/EIA-899 distance guideline for 100 Mbps closely coincides with the 5% jitter curve at 30 m. This gives some credibility to this guideline and suggests it is a conservative one.

The TIA/EIA-899 standard describes two types of receivers, Type-1 and Type-2. The Type-1 receiver has a differential input voltage threshold centered on 0 V, while the Type-2 receiver has an input threshold centered on 100 mV. This offset input voltage provides a valid bus state with no voltage difference and can be useful during bus faults or idle-line conditions. Figure 3 shows a comparison between the Type-1 and Type-2 threshold regions.



**Figure 3. Thresholds for Type-1 and Type-2 Receivers**

Since the signal at the input of the receiver does not change instantly, the additional time for the input to slew to the offset threshold of the Type-2 receiver is expected to induce more time jitter than a Type-1 receiver. To verify this, the Type-1 SN65MLVD201 receiver is replaced with the Type-2 SN65MLVD207 and the measurements retaken. The results are graphed in Figure 4.



**Figure 4. SN65MLVD207 Signaling Rate versus Distance**

Again, for cable lengths under 10 m, there is little eye-pattern degradation with distance, and the top signaling rates are comparable with the Type-1 case. A steeper decline in signaling rate above 10 m in Figure 4 can be attributed to the offset threshold in the Type-2 receiver and the slower signal transitions with longer cable lengths. TIA/EIA-899 acknowledges this phenomenon by recommending Type-2 receivers for control signals and slower signaling rates than Type-1 receivers.

## Discussion

The answer to *How fast and far?* is not a simple one. As the measurements show, accepting an 80% open eye-pattern can more than double the top signaling rate for a 95% open eye in these examples. A data transmission circuit's tolerance to jitter depends upon the system's timing budget and varies with application. What these measurements can provide is a basis to estimate performance of the SN65MLVD201 and SN65MLVD207 devices if the user understands the system variables and their effect on signaling rate.

The electrical characteristics of the cable or other interconnecting media have an effect on the eye pattern. The results of the signaling rate versus distance are cable dependent, varying with wire size and the quality of the twist within a conductor pair. Adding an overall shield as well as the type of shield gives different results. Ultimately, the designer must know the characteristics of the specific cable and compare them to the CAT-5 cable used here to estimate the cable's impact on signaling rate or distance.

If the interconnection is not a cable but a rigid circuit board, it is hard to conceive of one large or bad enough to limit the signaling rate of these devices due to distance or eye-pattern closing. Typically, other factors limit signaling rates on circuit boards.

This example is an uncomplicated simplex connection with a single driver and receiver connected to the bus. Other modes of operation and physical implementations add discontinuities to the line that affect the eye pattern. Each connector, test point, solder pad, or other connection to the transmission media takes away some of the signal and changes the resultant eye pattern. Whether it is significant can only be determined for a specific bus design. TIA/EIA-899 does give some guidelines and specifications to at least maintain positive noise margin and maximize the signaling rate.

Since the jitter in this investigation is dominated by the line circuits when the distance is less than 10 m, line circuits with different jitter characteristics impact the top signaling rate as well. The SN65MLVD201 and '207 data sheet specifies peak-to-peak jitter. If a device does not specify jitter, pulse skew or pulse-width distortion is the next best proxy. If neither of these is specified, measurement is the only alternative. The effects of temperature, supply voltage, and process variation on the critical characteristics of the line circuits and cables may also have a marginal effect on the ultimate signaling rate or distance.

Last, but by no means least, is common-mode noise. Common-mode noise is generally not noticeable in the eye pattern but can play a big role in limiting the transmission distance. Noise coupling to the circuit has many variables and there is no safe distance guideline to give. It is known that noise coupling increases with cable length. Standard compliant M-LVDS devices operate with up to 2 V of common-mode noise, but length allowed can often only be determined at the installation, or by comparison to other known working circuits.

## Conclusion

A simplex M-LVDS circuit can signal at 360 Mbps on a CAT-5 cable up to 10 m, or 200 Mbps on a 40-m cable with an 80% open eye pattern. However, different eye-pattern openings, line circuits, transmission media, bus structures, or operating conditions affect the ultimate signaling rate or distance for a particular installation. A sinusoidal signal loss of 6 dB at the signaling rate in hertz is a good and conservative estimate for the maximum cable length.

Aside from signal quality, common-mode noise coupling to the environment may well be the determining factor for the maximum transmission distance. A 40-m cable length operates successfully in an electronics laboratory environment, but a general guideline for common-mode noise with distance is impossible without specifying many variables. Common-mode noise is best evaluated at the actual installation.

## References

1. TIA/EIA-899 Electrical Characteristics of Multipoint-Low-Voltage Differential Signaling (M-LVDS) Interface Circuits For Multipoint Data Interchange
2. SLLA108, Introduction to M-LVDS (TIA/EIA-899)
3. SLLU039, Multipoint Low Voltage Differential Signaling (M-LVDS) Evaluation Module
4. SLLA053B, Performance of LVDS With Different Cables
5. SLLS463B, SN65MLVD20X High-Speed Differential 50- $\Omega$  Line Driver and Receiver
6. 07/01/02 REV. 17 MEDIATWIST™ - 1872A

## Appendix

### Measured Percent Eye-pattern Jitter versus Signaling Rate

Signaling Rate (Mbps)	CAT-5 Cable Length							
	3 m		10 m		20 m		40 m	
	MLVD201	MLVD207	MLVD201	MLVD207	MLVD201	MLVD207	MLVD201	MLVD207
20	0.4%	0.4%	0.6%	0.5%	0.5%	0.8%	1.0%	2.2%
40	0.7%	0.9%	0.8%	0.9%	0.8%	1.6%	1.8%	4.0%
60	1.2%	1.6%	1.7%	1.4%	1.3%	2.4%	2.6%	5.8%
80	1.8%	2.1%	2.0%	2.3%	2.0%	3.1%	3.4%	8.4%
100	2.0%	2.4%	2.5%	3.5%	2.6%	4.7%	5.6%	11.2%
120	2.9%	3.4%	3.9%	3.8%	3.7%	5.8%	7.9%	15.0%
140	5.5%	5.5%	5.0%	5.2%	5.5%	7.9%	11.3%	18.5%
160	5.5%	5.8%	6.5%	5.6%	7.8%	8.5%	13.6%	21.7%
180	6.4%	5.8%	7.3%	5.9%	7.6%	9.4%	16.0%	24.4%
200	7.3%	7.0%	9.1%	8.2%	9.8%	11.4%	19.1%	28.1%
220	8.8%	9.1%	9.1%	8.7%	12.0%	13.1%	22.9%	
240	9.9%	9.5%	9.4%	9.4%	13.1%	13.9%	25.7%	
260	10.2%	11.7%	11.0%	12.0%	14.0%	16.9%		
280	14.4%	15.2%	12.9%	14.2%	16.0%	20.5%		
300	13.5%	14.8%	15.3%	16.4%	18.8%			
320	19.2%	17.6%	15.5%	16.5%	21.3%			
340	16.2%	17.1%	17.2%	19.8%				
360	18.9%	17.9%	19.8%	21.3%				
380	21.3%	21.3%	24.3%					

## Materials

The M-LVDS devices in this paper are the production released SN65MLVDS201 (Type-1 receiver) and the production release SN65MLVD207 (Type-2 receiver). All of these devices are tested on the SN65MLVD2xx EVM.

The data source which provides the  $2^{31} - 1$  PRBS is an HP 70841B Pattern Generator and HP70311A Clock Source.

The HP 83480A Digital Communications Analyzer (DCA) was used to measure the total jitter (eye pattern measurement). The data transmission medium between the two EVMS is CAT-5 Belden Media Twist™ SMA connectors and 50-Ohm coaxial cables are used to carry signals from the data source to the transmitting EVM and from the receiving EVM to the DCA.

The BER measurements are conducted with the HP70842B Error Detector, HP70841B Pattern Generator, HP70311A Clock Source, and HP70004A Display.

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