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Reducing Electromagnetic Interference (EMI) With Low Voltage Differential Signaling (LVDS)

Application Report

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Reducing Electromagnetic Interference (EMI) With Low Voltage Differential Signaling (LVDS)

ABSTRACT

This document discusses alternatives associated with the electromagnetic interference (EMI) using low voltage differential signaling (LVDS) interface.

1 Electromagnetic Interference (EMI)

Electromagnetic interference (EMI) is sometimes a mere inconvenience, as when it interferes with commercial television and radio broadcast signals. In other situations however, it can be dangerous, even life threatening. For example, some restaurant patrons need to know if microwave ovens are in use, and airline passengers cannot use their phones or laptop computers during take off or landing.

EMI problems have been increasing with the proliferation of mobile electronic systems, wireless communication systems, and computer networks. The electromagnetic spectrum is becoming increasingly crowded.

EMI can be a problem, whether sending data across town or across the room. This application report examines what can be done to reduce the EMI levels that are created when sending data from point A to point B. The only way to effectively attack the problem is to determine all of the sources of EMI, and either develop alternative technologies, which radiate less interference, or design more effective techniques for existing technologies. Engineers who have worked on the latter are familiar with the use of EMI gaskets, shielded twisted-pair (STP) cable, and steel wool. Traditional data transmissions standards, such as BTL, GTL, RS-232, and RS-422 are used widely, as the availability of parts makes the designers' job easier. However, the EMI generated by using these standards can make the system engineers' job more difficult.

A relatively new signaling method, known as low-voltage differential signaling (LVDS), could solve some of these problems. Recent LVDS advertisements highlight the fast data rates, low power dissipation, and low cost, but low EMI emissions is another advantage. The EMI generated from LVDS is lower than the common data transmission standards. There are some limitations to using LVDS, such as its limited interface (cable length) distance (Figure 1) and relatively low noise thresholds. A series of tests illustrates the LVDS advantage over existing data transmission standards concerning EMI includes RS-232, RS-422, and the standard TTL.

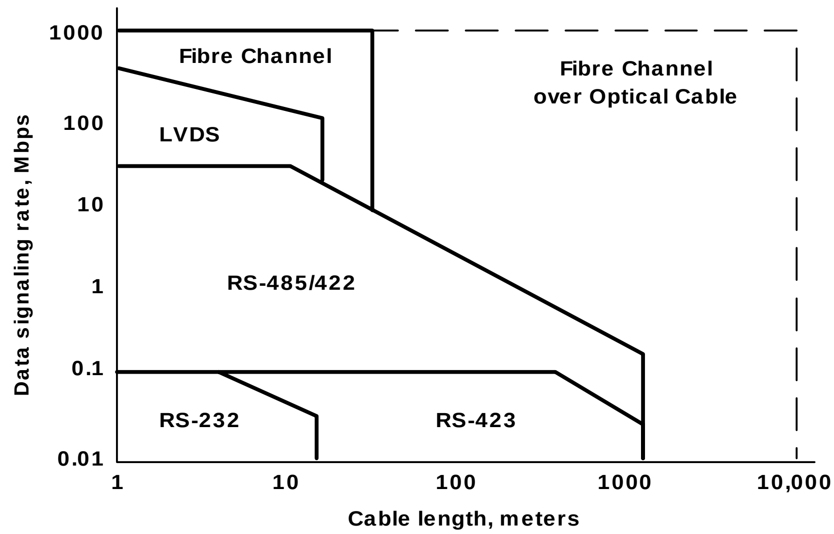

Figure 1. Data Rate vs Cable Length

1.1 EMI Denial

When data transmission standards such as RS-232 and RS-422 were developed, EMI was hardly the concern that it is today. RS-232, the oldest of the physical interfaces, was first used in Teletype machines. It eventually migrated to computers, where it still is used as a means of communicating data from a motherboard to peripheral devices like printers or keyboards. EMI was a concern, but not necessarily a problem. RS-232 addressed this concern by limiting the signal slew rate to 30V/µsec.

The evolving computer marketplace required, higher speeds and new data transmission technologies. RS-422 originated in the telecommunications industry as a data transmission technique for short-haul modems and other applications. It featured a balanced differential signaling scheme that enabled faster speeds and longer distances than RS-232. But, by today’s standards RS-422 is power hungry. It is basically a 5-V technology and RS-422 line drivers usually operate with 60 mW of power across the load. Also, the 5-V rail has thermal implications that designers have had to address.

2 Higher Speeds, Lower Voltage

LVDS follows RS-422 and RS-232 as a next-generation general-purpose, high-speed differential interface for serial and parallel data transmission applications over copper (Figure 2). This new signaling scheme offers improvements in higher bandwidth and lower power consumption. LVDS is implemented in two standards: TIA/EIA-644 Electrical Characteristics of Low Voltage Differential Signaling, and in the IEEE's 1596.3-1996, LVDS for the Scalable Coherent Interface.

LVDS has a recommended maximum data rate of 655 megabits per second, and it consumes a tenth of the power of high-speed transmission technologies like ECL and 5-V PECL. The LVDS standards were designed for high data transmission speeds. To achieve this goal, LVDS drivers with their current-mode design can operate from a constant current that results in power consumption much less (data rate) than a voltage-mode line driver as frequency climbs. The power dissipated by the load is 2-mW. By comparison, the 60-mW load in a typical RS-422 implementation is 30 times more than LVDS. The signal levels of some of these data transmission standards are shown in Figure 2.

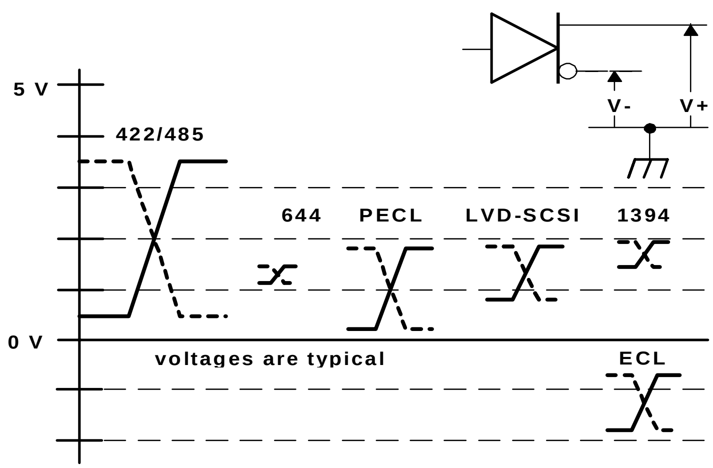

Figure 2. Signal Levels of Common Data Transmission Standards

Current changes in a conductor generate EMI. It increases with the rate and the amplitude of that change. Therefore, if the signal change is very small and slow, little EMI will be radiated from the conductor. But LVDS manages to lower EMI even though data rates have increased.

LVDS interfaces are high speed, and have low power dissipation. An LVDS signal’s low-voltage swing (Figure 2) changes a maximum of 400 mV (a minimum of 250 mV) and is centered at 1.2 V with respect to the driver ground. Digital signals can change logic-states faster when they don’t have as far to go to change states. A small voltage swing at a small constant current lowers the power in the transmission medium and at the load. The signal transitions are smaller and much faster than RS-422, so the EMI that results is not only reduced, but is pushed up in the frequency spectrum. [Note: The FCC is keeping pace by raising the upper frequency limit for compliance.]

3 Differential EMI Canceling

The LVDS interfaces use differential low-power signaling. One of the advantages of both RS-422 and LVDS is that they are differential. In single-ended topologies, such as PECL, BTL, and RS-232, the EMI emissions radiate outward from the single conductor. In contrast, balanced differential lines have two equal but opposite signals. The concentric magnetic fields radiated by each of the two conductors react with one another, bending toward each other and, ultimately, canceling a significant portion of the EMI emissions each of the two lines would generate on their own. The coupling of the two wires allows cancellation of most of the low-frequency fields generated along the conductor. Stray fringe electric fields and, at higher frequencies, the effects of mismatches and small line imbalances become evident. Shielded cables, which use a metal braid or foil to surround the conductors, are used to *knock down* these EMI levels. The cost, weight, connector pins, etc., associated with use of shielded cable is the lesson we have learned of what can happen when shielded cable is not used. Differential signaling and the use of shielded cable has become the de facto implementation of choice, but driven by necessity (Figure 3).

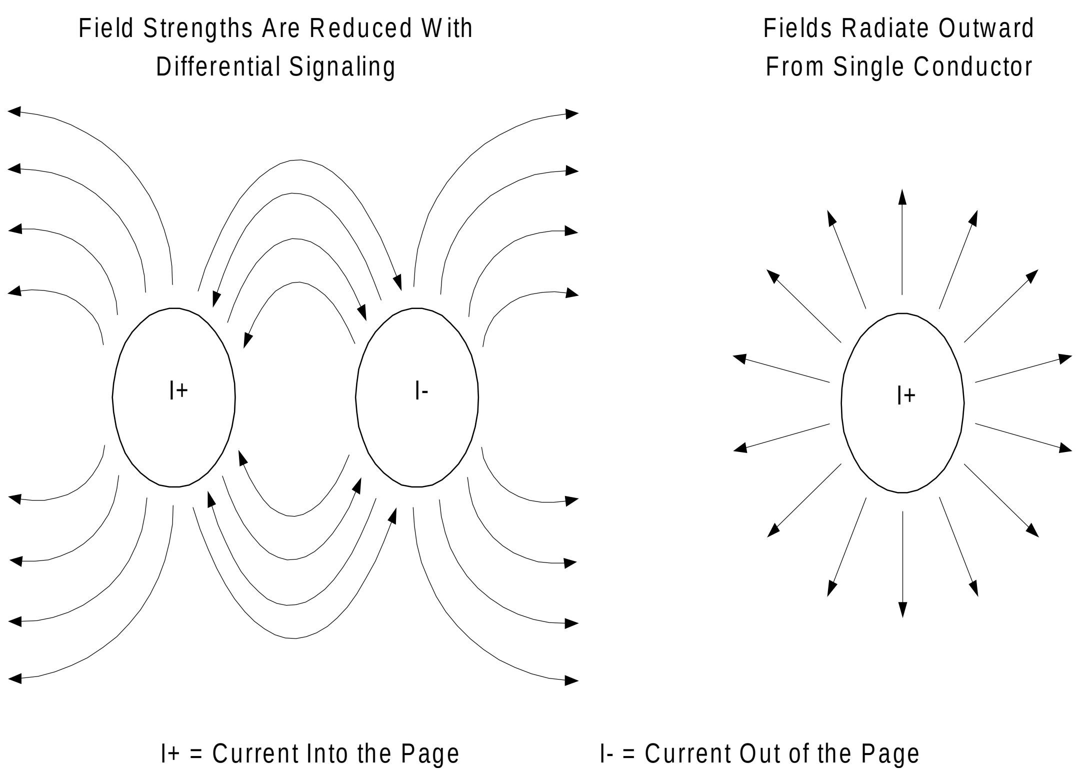

Figure 3. Fields Partially Cancel Out in Differential Topologies

4 Testing for EMI

To demonstrate these effects, several devices were tested in the Electro Magnetic Effects (EME) Laboratory at Raytheon E-Systems in Richardson, Texas. Each device was installed on a test board, and enclosed in a grounded metal chassis located against the outside wall of the Lindren™ anechoic chamber. A 3-meter cable was connected to the test board, with the cable loop pulled into the chamber though the chamber wall. The unshielded twisted pair (UTP) was mounted on a wooden plank raised 5 cm from the ground plane. A series of antennas allowed a sweep from 10 kHz to 1 GHz.

Decoupling capacitance was the same for each device tested, and line filters were installed in the metal chassis to allow VCC and ground into the sealed chassis. Bulkhead feedthroughs allowed the input signals and scope probes into the chassis. A Tektronix HFS9003 pattern was set up with a looping pattern of CA hex (11001010). The VCC and signal levels used were nominal values obtained from the data sheets for each device.

Each antenna was located 1 meter from the test cable and connected to a Dynamic Sciences RSX-200 EMI Test Receiver. Each measurement consisted of two frequency sweeps. The first sweep was taken with the VCC power turned off, and the coupling of the data generator onto the test cable was measured. A second sweep was made with VCC turned on. The results of the first sweep were subtracted from the results of the second sweep and then saved.

4.1 Test Results

Results were tabulated using the DSI-2000™ EMI Measurement and Analysis software. The RS-422 devices tested were an AM26LS31, SN75ALS192, and an AM26LV31, which is a 3.3-V driver. The AHC08 TTL driver and SN75188 RS-232 device were also tested. Although the LVDS is capable of higher data rates than these other devices, the clock rate on the HFS9003 was set to 10 MHz for testing the RS-422 devices, to 60 MHz for the AHC08 TTL, and to 10 kHz for the RS-232 device. The test board for each device had a corresponding receiver device with specified terminations in place. Each device was installed and measured, and then the LVDS31 was installed and measured. See Table 1 for test examples.

Table 1. Test Examples

	RS-422	RS-422	RS-422	TTL	RS-232
	AM26LS 31 vs. LVDS	SN75ALS19 2 vs. LVDS	AM26LV31 vs. LVDS	SN74AHC08 vs. LVDS	SN75188 vs. LVDS
10 kHz - 100 kHz	+3 dB	+0 dB	+3 dB	+3 dB	+26 dB
100 kHz - 1MHz	+6 dB	+3 dB	+3 dB	+6 dB	+36 dB
1 MHz - 10 MHz	+6 dB	+6 dB	+6 dB	+9 dB	+26 dB
10 MHz - 100 MHz	+9 dB	+12 dB	+12 dB	+12 dB	+20 dB
100 MHz - 200MHz	+12 dB	+15 dB	+9 dB	+20 dB	+12 dB
200 MHz - 500MHz	+20 dB	+15 dB	+12 dB	+20 dB	-
500 MHz - 1 GHz	+6 dB	+6 dB	+6 dB	+20 dB	-

Note: The DSI-2000 collects the results in dBu V/m so the results shown in Table 1 are calculated using 20 log and not 10 log.

It is evident from the results in Table 1 that the TTL and RS-232 single conductor schemes do not perform as well as desired. Noticeable improvement can be seen when the differential topology is used, but the LVDS interface shows a significant reduction in EMI can be achieved compared to standard RS-422 interfaces. A slight reduction in EMI from the low voltage AM26LV31 was expected, because the output of the driver does not have to swing as far as the 5-V parts. This difference was more noticeable at the higher frequencies and is shown in Figure 4.

The following colored graphs can only be seen on-line or printed using a color printer.

AM26LV31 (= Red Trace) vs LVDS31 (= Blue Trace)

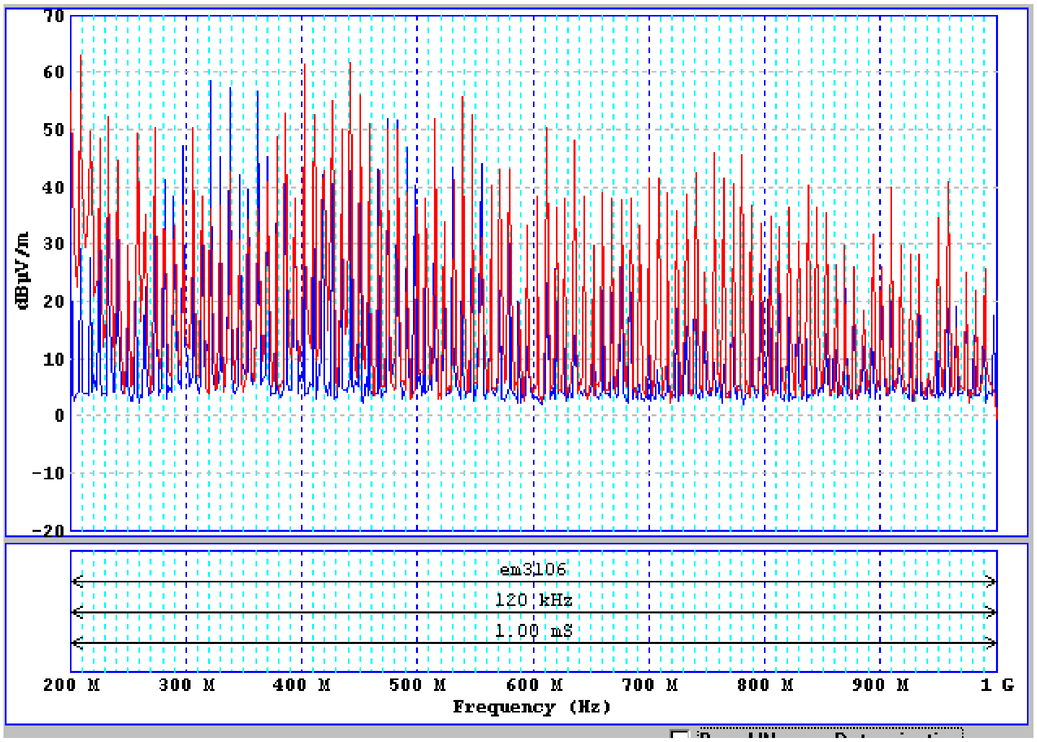

Figure 4. LV31 vs LVDS31 from 200 MHz to 1GHz

As expected, the RS-232 produced the highest levels of EMI, and a comparison to the LVDS31 is shown in Figure 5.

75188 = Red Trace

LVDS31 = Blue Trace

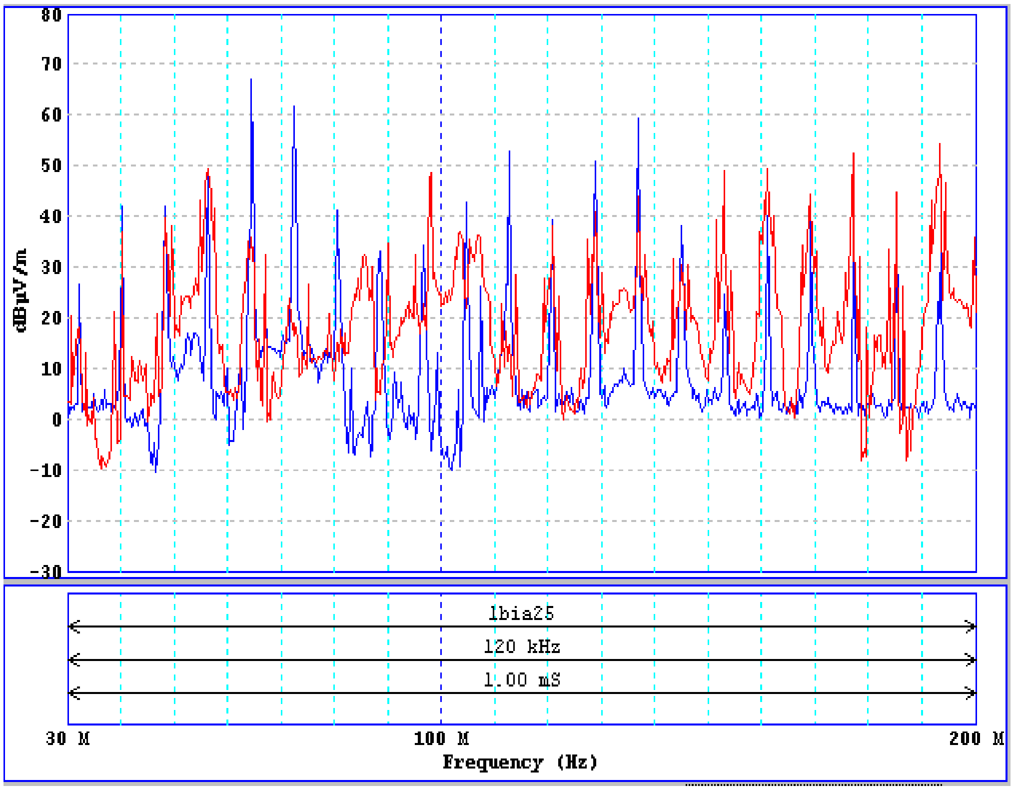

Figure 5. EMI Measured From an RS-232 Interface (Red) and an LVDS Interface (Blue)

Another test compared the LVDS31 with the data rate at 60 MHz and 190 MHz. This test should have been performed at 200 MHz, but that is a crossover frequency at the upper range of the BIA25 antenna and the low end of the 3106 DRG antenna. By using 190 MHz, plotting results at the edge of the graph were avoided.

Closely spaced harmonics should be expected at the lower frequency, but the amplitudes should not be higher at the higher frequencies, and the noise floor should not change. Figure 6 shows the results of this comparison of the LVDS31 at both 60 MHz and 190 MHz with the following color traces.

LVDS31 at 60MHz Clock Rate = Red Trace

LVDS31 at 190 MHz Clock Rate = Blue Trace

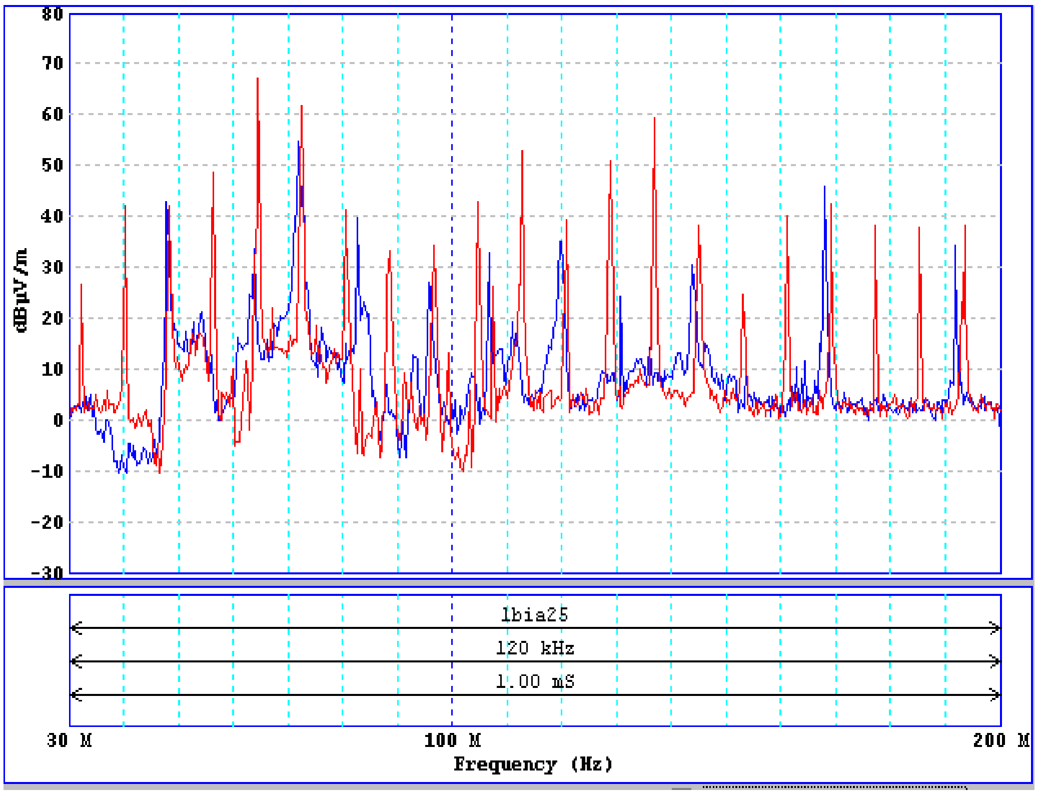

Figure 6. Comparison of LVDS31 at 60 MHz and 190 MHz Clock Rates

5 Conclusion

With the very real dangers posed by EMI, the advantage of LVDS over other data transmission schemes may be useful information for anyone designing data interfaces. In addition to reduced power and cost, and a 400 MB/sec data rate, make sure you add reduced emissions to the list of benefits associated with an LVDS interface. So, the next time you're designing an interface, and you're about to copy and paste the old 422 or 232 port into your new design, you may want to reconsider. You might want to switch over to an LVDS interface. Besides, with the speed, power, and EMI benefits, you may find some system engineer buying your lunch with the money he saved on steel wool and foil.