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

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ABSTRACT

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

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 takeoff 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, TIA/EIA-232 (a.k.a RS-232), and TIA/EIA-422 (a.k.a. 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. The EMI generated from LVDS is lower than most 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. EMI test results illustrate the LVDS advantage over existing data transmission standards, including TIA/EIA-232, TIA/EIA-422, and the standard TTL.

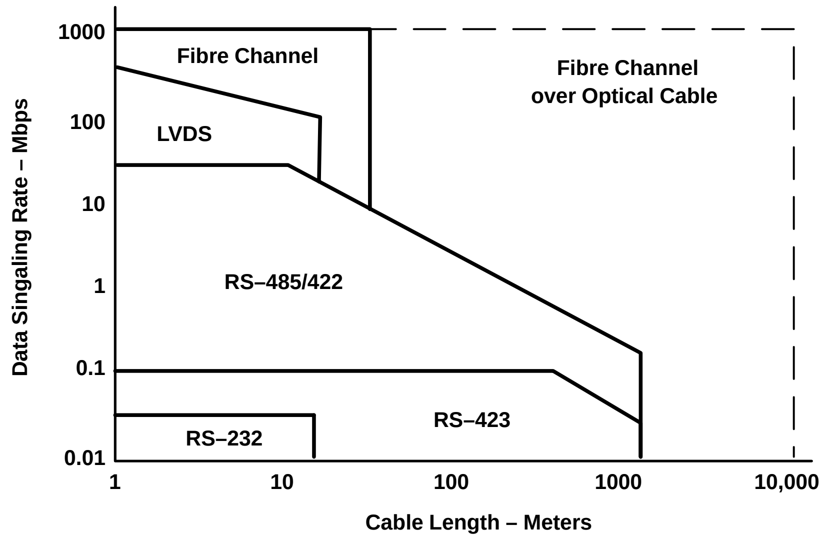

Figure 1. Data Signaling Rate vs Cable Length

EMI Denial

When data transmission standards such as TIA/EIA-232 and TIA/EIA-422 were developed, EMI was hardly the concern that it is today. TIA/EIA-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. TIA/EIA-232 addressed this concern by limiting the signal slew rate to 30 V/µsec.

As the computer market evolved, the need arose for higher speeds and new data transmission technologies. TIA/EIA-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 TIA/EIA-232. But, by today's standards TIA/EIA-422 is power hungry. It is basically a 5-V technology and TIA/EIA-422 line drivers usually operate with 60 mW of power dissipated in the load. Also, the 5-V rail has thermal implications that designers have to address.

Higher Speeds, Lower Voltage

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

LVDS has a maximum data rate of 1923 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. The power dissipated by the load is 2 mW. By comparison, the 60-mW load in a typical TIA/EIA-422 implementation is 30 times more than LVDS. The signal levels of some of these data transmission standards are shown in Figure 2.

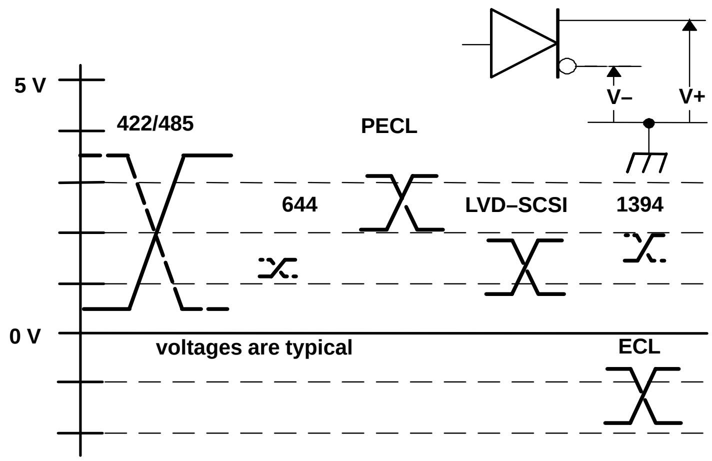

Figure 2. Signal Levels of Common Data Transmission Standards

Current changes in a conductor radiates electromagnetic energy. It increases with the rate and the amplitude of that change. Therefore, if the signal change is very small and slow, little energy is radiated from the conductor. But LVDS manages to lower radiation 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 450 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 do not have as far to go to change states. A small voltage swing lowers the power in the transmission medium and at the load. The signal transitions are smaller and much faster than TIA/EIA-422, so the radiation that results is not only reduced, but is pushed up in the frequency spectrum.

Field Cancellation

The LVDS interfaces use differential low-power signaling. One of the advantages of both TIA/EIA-422 and LVDS is that they are differential. In single-ended topologies, such as single-ended PECL, BTL, and TIA/EIA-232, 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 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 reduce these levels. The cost, weight, connector pins, etc., associated with use of shielded cable is the price paid as a result of lessons learned of what can happen when shielded cable is not used. Differential signaling and the use of shielded twisted-pair cable has become the implementation of choice in noise sensitive environments (Figure 3).

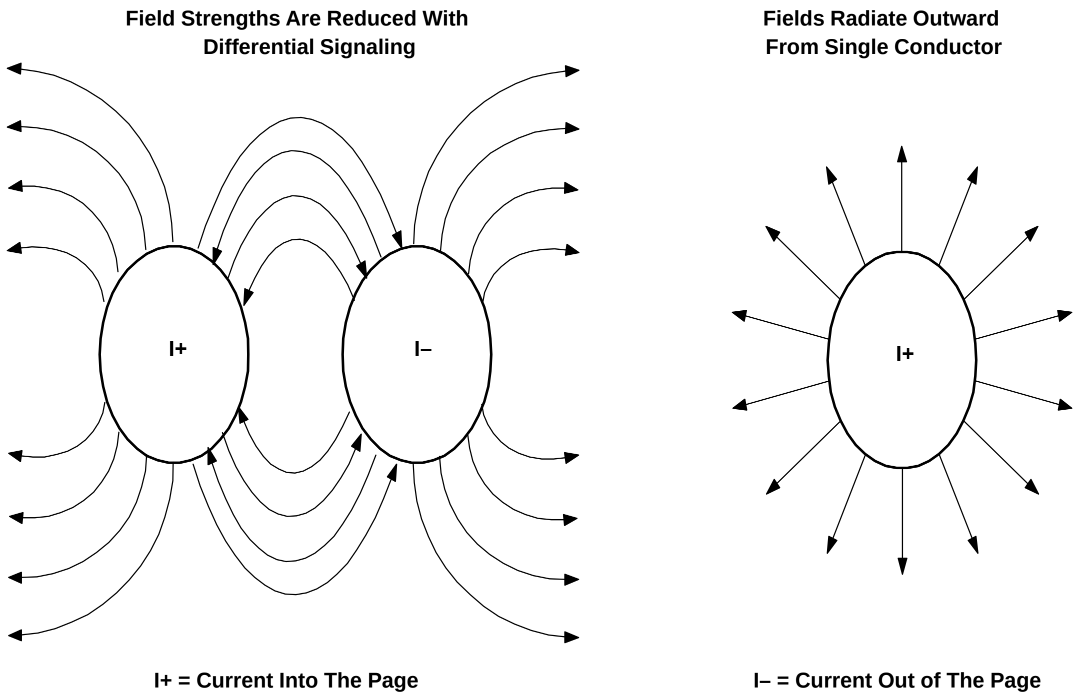

Figure 3. Fields Partially Cancel Out in Differential Topologies

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.

Test Results

Results were tabulated using the DSI-2000 EMI Measurement and Analysis software. The TIA/EIA-422 devices tested were an AM26LS31, SN75ALS192, and an AM26LV31, which is a 3.3-V driver. The AHC08 TTL driver and Sn75188 TIA/EIA-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 TIA/EIA-422 devices, to 60 MHz for the AHC08 TTl, and to 10 kHz for the TIA/EIA-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 SN65LVDS31 was installed and measured, See Table 1 for test examples.

Table 1. Field Strength of Various Signaling Standards vs LVDS

FREQUENCY RANGE	TIA/EIA-422	TIA/EIA-422	TIA/EIA-422	TTL	TIA/EIA-232
	AM26LS31 vs SN65LVDS31	SN74ALS192 vs SN65LVDS31	AM26LS31 vs SN65LVDS31	SN74AHC08 vs SN65LVDS31	SN75188 vs SN65LVDS31
10 kHz–100 kHz	3 dB	0 dB	3 dB	3 dB	26 dB
100 kHz–1 MHz	6 dB	3 dB	3 dB	6 dB	36 dB
1 MHz–10 MHz	6 dB	6 dB	6 dB	9 dB	26
10 MHz–100 Mhz	9 dB	12 dB	12 dB	12 dB	20 dB
100 MHz–200 MHz	12 dB	15 dB	9 dB	20 dB	12 dB
200 MHz–500 MHz	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 TIA/EIA-232 single conductor schemes exhibit extremely high radiated emission levels compared to LVDS. 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 TIA/EIA-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.

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 reduce power and cost, and a 400 MBPS data rate, make sure you add reduced emissions to the list of benefits associated with an LVDS interface. So, the next time you are designing an interface, and you are 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.

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