LVDS to Improve EMC in Motor Drives

With growing demand for higher switching frequencies and more compact packaging in motor drive systems, the risk of noisy signals and Electro Magnetic Interference (EMI) increases dramatically. Noise and EMI management have become a necessity for acceptable and robust functioning of motor drive systems and also for meeting the external agency Electro Magnetic Compatibility (EMC) standards.

There are many sources of noise generation in AC Drives (Variable Frequency Drives), Servo Motor Drives, Computer Network Connected (CNC) and Robotic multi-axis motor drive systems. The noise that is generated can find multiple paths to propagate as the motor sense and control signals move from one stage to another in the motor drive system. If the noise is high enough the power stage of the motor drive system has the risk of getting into false switching states impacting the speed, torque and position of the motor. While the traditional noise and EMI management techniques help with noise reduction, signal integrity and noise reduction are still a challenge.

We still have room to improve the signal integrity further by employing Low Voltage Differential Signaling (LVDS) for signal transfer between the different boards instead of using single ended CMOS/TTL techniques.

Motor Drive System

If we were to simplify the system architecture of a typical motor drive system, it consists of an AC voltage input stage, which is usually a 3 phase input power supply. This is followed by the rectifier stage that converts the AC voltage into DC power rails (DC+ and DC-). This is followed by the inverter stage. DC capacitors provide both DC filtering to the rectifier and switching currents to the Integrated Gate Bipolar Transistor (IGBT) gate drivers in the inverter stage. The isolated gate driver drives the IGBT and implements isolation of the power stage. The power stage is also called the hot side because it handles high voltages. Figure 1 shows the different stages of a motor drive system.

The motor drive is a closed loop feedback system. An encoder located close to the motor along with voltage and current sense circuits provides both position and speed feedback to the control stage. The processor or the FPGA in the control unit receives these feedback signals and provides the input to the Pulse Width Modulator (PWM). PWM drives the isolated IGBT gate drivers.

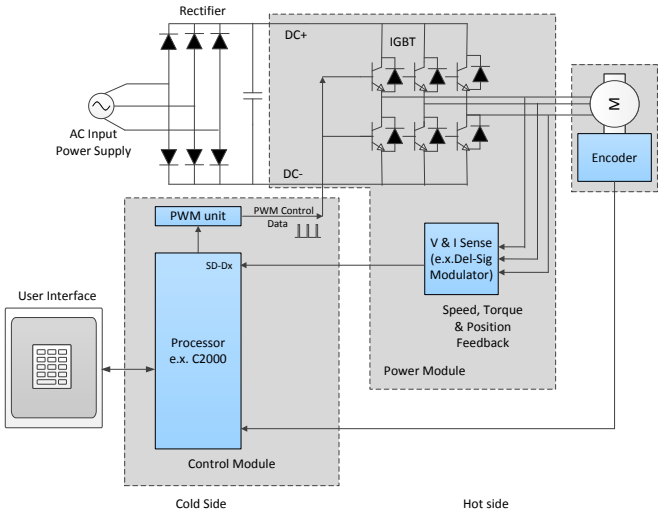

Figure 1. Typical Motor Drive System Block Diagram

There could be an additional communications unit (not shown in Figure 1) with real-time processing capability based on the system architecture. The I/O block which is accessible to humans is the user interface. It could be connected to a Programmable Logic Controller (PLC) or Human Machine Interface (HMI) through standard communication interfaces. The control unit, communications unit, and the I/O unit are also referred to the cold-side of the motor drive system.

It is important that the noise does not get transferred between the different motor drive stages. The standard interfaces used between these boards/modules vary from directly sending single ended TTL/CMOS signals through wires, using SPI interface format, or using differential interfaces like RS-422, RS-485. The next section analyzes the advantages of using differential signals and how LVDS can help with noise reduction.

Single Ended Signals Vs Differential LVDS Signals

LVDS is an industry standard differential signaling interface used for both low and high-speed transmission of digital data over copper. It is a physical layer used for point to point transmission of data, clock and control signals.

The main advantages of using LVDS are:

- Noise Reduction
- Low EMI Emission
- Low Power
- Supports High Data Rates
- Common Mode Noise Immunity

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Sending single ended CMOS/TLL signals through a standard cable allows for external noise to impact the signal integrity. LVDS uses balanced differential but equal and opposite signals. When external noise is present in the environment, both wires will receive nearly equal amount of noise. Because the receiver only considers the voltage potential between the two wires, the external noise will be canceled out and therefore helps with noise reduction. This property enables LVDS to have a very high Signal-to-Noise Ratio (SNR), and is one of the reasons why LVDS technology is so robust.

LVDS interface also generates low EMI compared to single-ended transmission lines where electric field lines are free to radiate away from the conductor. Some of these fields can travel as Transverse Electro Magnetic (TEM) waves which escape the system and cause EMI problems to adjacent circuits. As complementary current runs in the differential pair, both lines will generate magnetic fields but in the opposite direction. In turn, the magnetic field partially cancels each other. Only the stray fringing fields are allowed to escape to the far field. Therefore they have much less field energy available to propagate as TEM waves and affect the adjacent systems.

LVDS standard also consumes about 10 times lower power compared to single ended interfaces and other differential signaling interface standards like RS-422, RS-485 and Ethernet. This is because LVDS only has 350 millivolt voltage swing. LVDS works well in both low and high speeds from few Kbps up to 1350 Mbps. The next section explores where we can use LVDS in the motor drive system and what it buys us.

LVDS Implementation 1: Board to Board Communication

LVDS Transmitters/Drivers and Receivers help with the noise reduction between PCB's both at low and high data rates and also short and long distances. Figure 2 shows the different implementations of LVDS drivers and receivers.

A single ended ribbon cable or a cat 5 cable is used usually to transfer signals physically between the multiple boards in the motor drive system. Adding an LVDS Driver (TX) and Reciever (RX) between the different boards converts the signals to the differential format thus offering the benefits of a differential interface. An LVDS TX/RX can be added between the control board and the communication board (not shown here), between the encoder and the control board, and between the control and I/O user interface board.

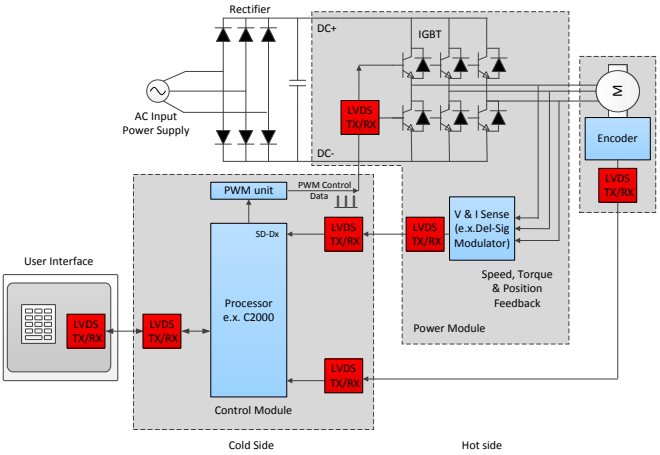

Figure 2. LVDS Implementation 1: Board to Board Communication

LVDS Implementation 2: Between ADC and Processor

Using LVDS TX/RX between the voltage and current sense ADC in the power board and the processor in the control board helps with noise reduction. Instead of using a standard single ended cable to tranfer the signals, using a LVDS TX/RX to send the data and clock signals between the ADC and the processor reduces the noise in the output of the ADC. Figure 3 (A) shows the noise in the output voltage of the delta-sigma modulator at a data rate of 20 Mbps and 20 MHz clock sent along a 20-cm ribbon cable. Figure 3 (B) shows a ~600-mV improvement in noise in the output of delta-sigma modulator AMC1305 after using low cost LVDS TX/RX. This significant noise reduction helps with the overall signal integrity.

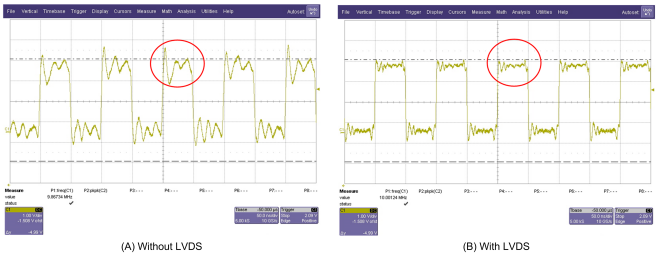

Figure 3. AMC1305 ADC Output Voltage Waveform with and without LVDS

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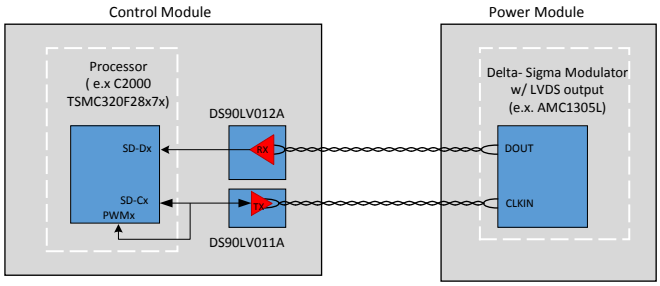

Figure 4. LVDS Implementation Between ADC with LVDS Output and Processor

Figure 4 shows the implementation of an LVDS receiver between AMC1305L and C2000 MCU. Figure 5 shows the implementation of an LVDS transmitter and receiver between the ADC and a C2000 MCU. Two single channel driver (DS90LV011A) and receiver (DS90LV012A) pairs are used to transmit data and clock signals between the boards.

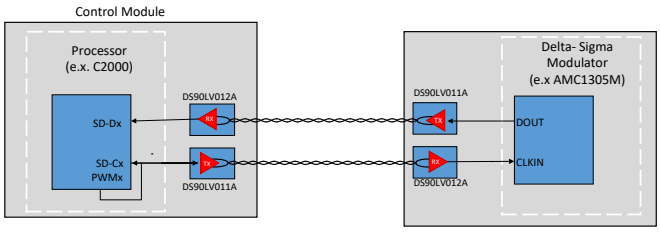

Figure 5. LVDS Implementation Between ADC and Processor

LVDS Implementation 3: SPI over LVDS

SPI ports are still popular for communication on the same PCB or between two PCB's in a noisy motor drive environment. SPI is a single ended signal transmission protocol which is more susceptible to noise. SPI communication involves using four lanes of data/clk communication lines which generates EMI that can affect the other adjacent circuitry. Sending SPI signals over a LVDS driver and receiver helps with the noise reduction. To showcase this advantage of sending SPI signals over LVDS TI has released the TI Design TIDA-060017. Please refer to TIDA-060017 (TIDUED8) to download the detailed implementation of SPI over LVDS and checkout our demo board.

Figure 6 shows a reconstructed sine wave post-processed by the controller after receiving a noisy single-ended SPI signal versus through LVDS Line Driver and Reciever.

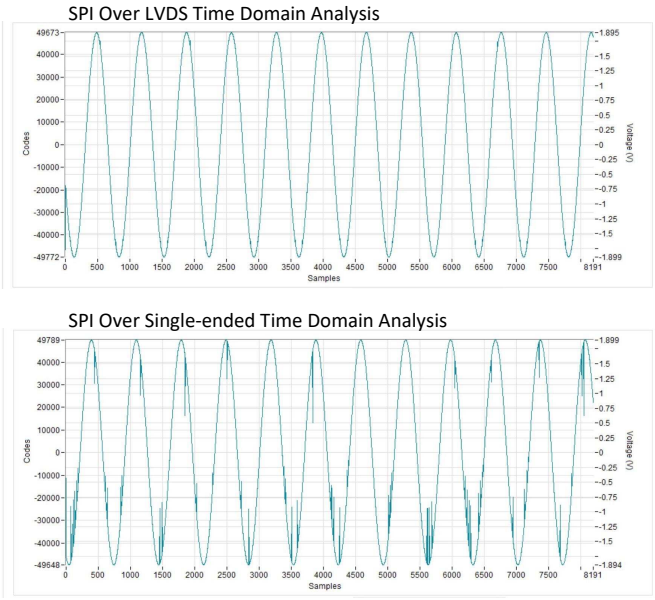

Figure 6. SPI Over LVDS vs SPI Over Single Ended

As noise reduction and signal integrity become more and more critical in motor drive applications, using an external LVDS TX/RX offers noise reduction and several other advantages at a very low cost.

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