Driver Circuits for RS-485

The designer of a RS-485 physical layer must set a maximum baud rate appropriate for the link. This enables her/him to select a RS-485 driver circuit that is suitable for the required speed. This may be selected that are rated at a speed equal to or greater than the required baud rate. Knowing this, you might wonder if there are any disadvantages in choosing the fastest devices available? The answer is yes!

Although it is true that a fast circuit can be used for both high and low baud rates, there are real drawbacks in using a driver that supports a baud rate higher than needed...

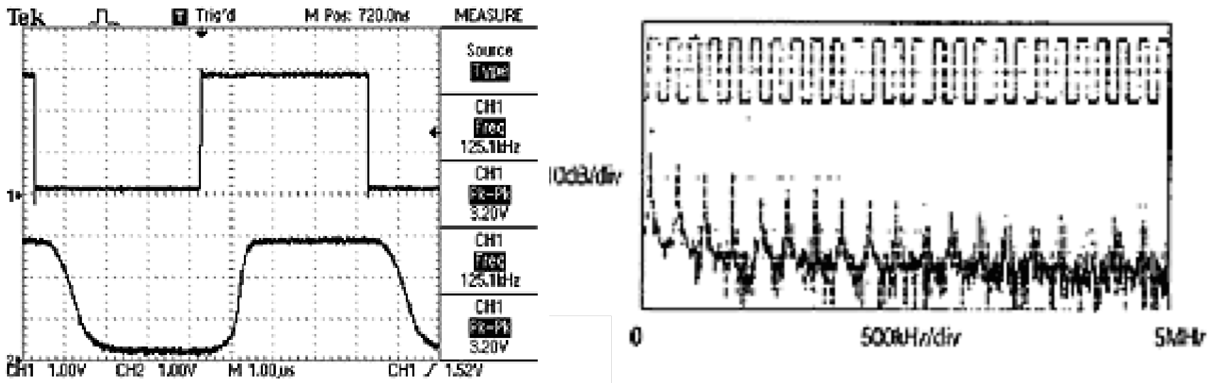

Figure 1: Plots for a 125kHz (250kbaud) test signal, without limiting slew-rate
(a) driver input (TTL) and non-inverted output waveform
(b) driver output waveform and corresponding frequency domain signal

Figure 1 shows the signal (a) and the (b) Fourier transform for a driver specified for *high-speed* operation at many Mbaud. The frequency domain signal (b) shows frequency components in the signal that are much higher than 2Mbps. These high-frequency components result in the square edges in the signal that can be seen. (Note also the propagation delay through the driver circuit visible in (a)).

A driver circuit normally includes both a transmitter and a receiver. First let's focus on the a high baud rate receiver, which accepts a wide bandwidth input signal. This makes the receiver more susceptible to interference at higher frequencies (e.g. >> 250 kHz in this example), picked-up as the signal travels along the cable. The wide-band receiver results in reduced ability to detect the wanted signal, whereas a band-limited signal (e.g. using a low-pass filter) reduces this susceptibility to any unwanted interference/noise outside the filter band. It is therefore wise to use a receiver that filters the signal at frequencies above the baud rate.

So where does interference originate? One source is from other radio frequency equipment. However, interference may also originate from other RS-485 cables. A balanced transmitter generates two equal, but opposite, signals that are sent using the two wires forming a twisted pair. This minimizes radiated emissions because the wires are virtually on top of each other, they will each radiate the exact opposite signal. This has the effect of canceling out any radiated signal, and ideally results in no net radiated emissions.

Twisted-pair cabling tends to work fairly well when the cable is tightly twisted relative to the maximum frequency, but, like everything in engineering, it isn't perfect. Inevitably, some radiated emissions will leak out. As a general rule, the higher the frequency components in the signal and the longer the cable, the worse this becomes. A driver circuit therefore also includes an output filter to control the slew-rate of the signal sent on the wires. This shapes the signal in the frequency domain to match the spectrum of the receiver filter. This has the effect of reducing signal harmonics at frequencies above the baud rate. (There is anyway not much point in sending the frequency components of a signal that the receiver will subsequently filter!)

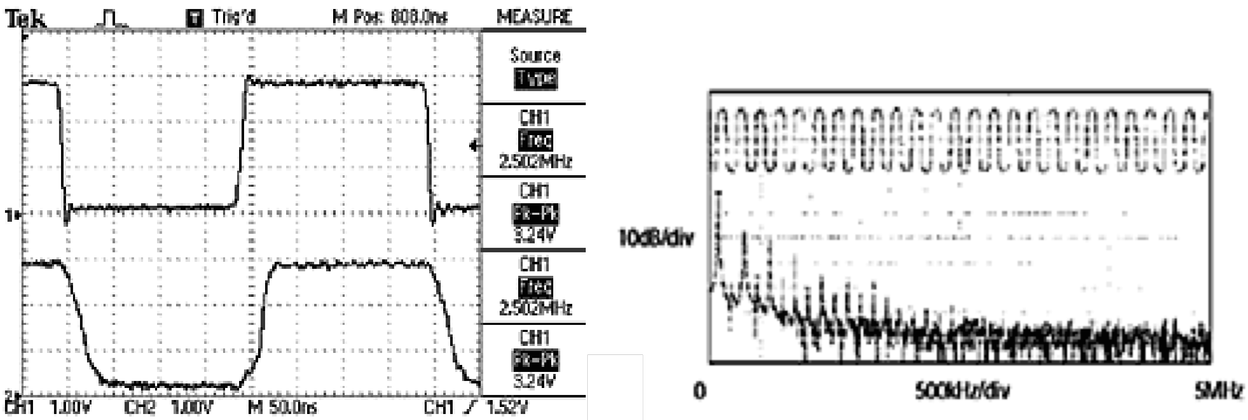

Figure 2: Plots for a 125kHz (250kbaud) test signal, with an appropriate limiting slew-rate.
(a) driver input (TTL) and non-inverted output waveform
(b) driver output waveform and corresponding frequency domain signal

In summary, slew-rate limiting at the transmitter works by slowing the edges of the RS-485 signal down, reducing the signal's high-frequency components. Figure 2 shows the Fourier transform of a slew-rate-limited signal (b) shows that the frequency components above 2MHz are virtually eliminated. An appropriate choice of driver/receiver circuit at the transmitter and receiver hence both reduces radiated emissions and reduces susceptibility to noise and improper termination. This however results in "distortion" of the signal (i.e. the signal on the wire is different to the input bit stream). This is clearly visible in figure 3.

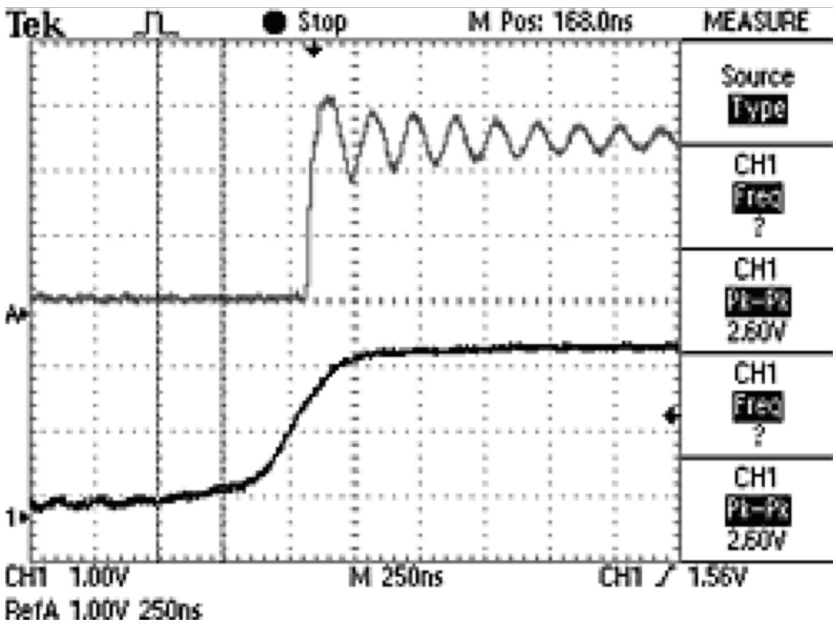

Figure 3: Time domain plots from an oscilloscope showing the start of a pulse sent with slew-rate limiting at 2.5 Mbaud (above) and one shaped to 250 kbaud (below).

Cable terminations are also important. Both ends of the cable should be properly terminated with the characteristic impedance of the cable to prevent reflections. Resistor and cable tolerances, among other things, can result in mismatches between these two impedances. This will result in reflections that increase the noise and can and potential corruption of data. Similar to radiated emissions, the higher the frequency components and the longer the cable, the more likely it is that reflections will affect the performance. Selecting an appropriate driver chip therefore can impact the performance of a serial communications system!

Additional Demonstrator Notes

Most usual problems are:

- Incorrect power connections
- Failure to connect the control pins

Bssic bus connection: