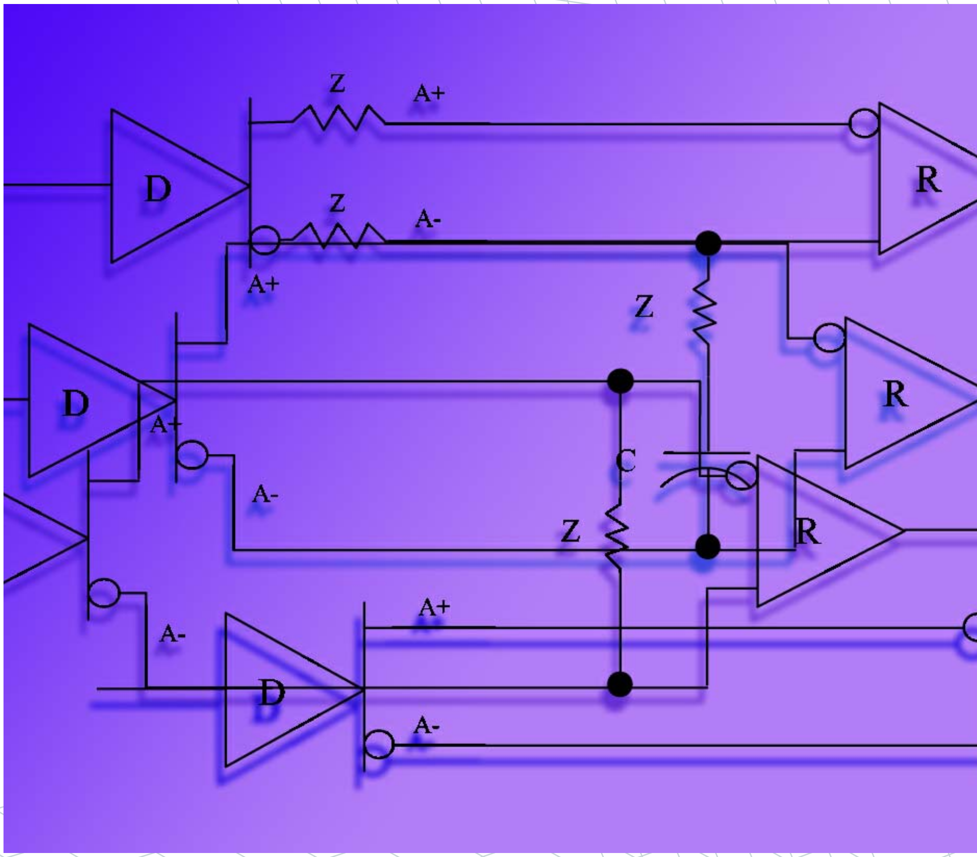
Proper Signal Termination of 422 Data transmission Signals



MicroE Systems
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Introduction

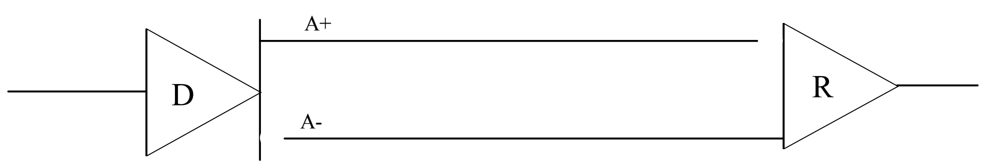
The 422 data transmission standard (ANSI TIA/EIA-422, formally) is a balanced scheme for transmitting digital data over long distances with very good noise immunity. In this scheme, the driver D takes a single signal and generates two complementary or differential signals. These are then sent out over a twisted pair transmission line and received by the receiver R where they are recombined back into the original signal. This arrangement does an excellent job of eliminating common mode noise. Since this noise component will be identical in magnitude and sign on both signals, the difference between these signals will remain unchanged. The 485 standard is similar in almost all respects with the exception that 485 supports multiple drivers while 422 supports only one. For the purposes of this report, we will limit discussion to 422.

In general, 422 driver outputs (A+ and A-) should not exceed ±6V with respect to ground. The differential voltage between them should be greater than ±2V but not exceeding ±10V. By the time the signal pair reaches the receiver, the differential voltage must be greater in magnitude than 200mV (input sensitivity) to get valid state changes.

The role of cable termination in any data transmission scheme is to eliminate or at least minimize signal reflections. Signal reflections are a result of impedance mismatching. When a signal, traveling down a line with a certain characteristic impedance (typically around 100Ω) meets a different impedance at the far end, it will be reflected back to the source. This reflection then encounters another impedance mismatch back at the source, generating additional reflections and so on. Four different termination techniques will be discussed in this report: No Termination, Series Termination, Parallel Termination and AC Termination.

No Termination

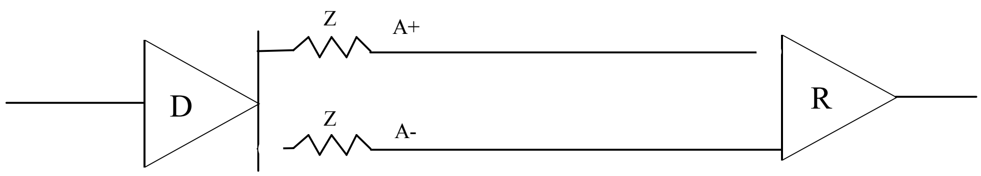
As a rule-of-thumb, no termination is required if your system does not behave like a transmission line. This condition is defined as a data rate of less than 200 kbps or a signal rise/fall time of more than four times the propagation delay induced by the cable. The input resistance of the receiver, as defined by the 422 standard, will be around 4 kΩ. Under these conditions, there will be some signal reflection at the receiver end but it should not be large enough to produce invalid data.



The advantage of this unterminated technique is that it minimizes the amount of current needed to produce a signal at the receiver - therefore minimizing the power consumption by the driver. This is by far the simplest and least expensive solution assuming data rates will be low and cable lengths will be short.

Series Termination

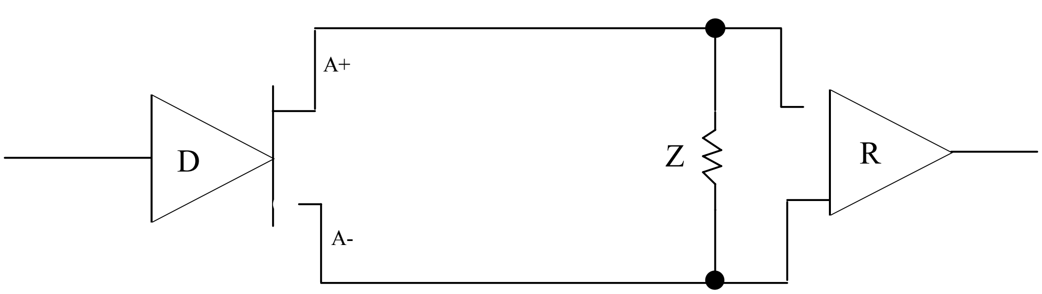
In and effort to reduce reflections while still keeping power dissipation low, another available option is the series or source termination technique. In this arrangement, series resistors Z are positioned at the driver output.



The resistors are chosen such that their value, plus the driver's output impedance matches the transmission line's characteristic impedance. Like the no termination example, a reflection will still be generated at the receiver end but will encounter proper termination once it gets back to the driver eliminating any additional reflections. As a result, data rates will still need to stay low. In addition to signal reflection, another major disadvantage is that series termination is only appropriate for point-to-point applications.

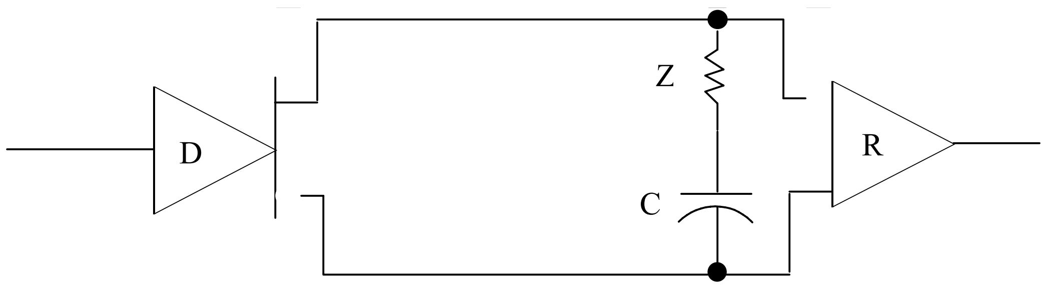
Parallel Termination

By far the most widely used termination method, parallel termination consists of a single resistor connected across the differential inputs at the receiver. The resistor value "Z" is chosen to match the characteristic impedance of the cable as best as possible (±20%). This will, in effect, make the cable appear purely resistive eliminating signal reflections. This technique supports higher data rates and longer cable runs but will increase the driver's power draw due to the current now passing through this resistor.



AC Termination

If both power consumption and signal quality are major concerns, AC Termination offers a compromise between the parallel, series and unterminated schemes. By adding a capacitor in series to the termination resistor the DC current draw is significantly reduced while still keeping signal reflections low.



During a state change, the capacitor acts like a short making the termination appear to be like the parallel example. During steady state, the capacitor charges up and acts like an open making the line appear unterminated. The main disadvantage of this technique is the reduction of data transmission rates due to the resulting RC time constant. The capacitance "C" should be chosen so that the resulting RC time constant is low with respect to the unit interval. Consider the following example:

Suppose we use a multiple twisted pair cable (Belden 9831) with a characteristic impedance of 100Ω and a nominal propagation delay of 1.6 ns/ft. To choose the appropriate value for C, use the following equation:

$$C \leq \text{round trip cable delay/characteristic impedance}$$

For a cable 100 ft long we get (100 ft x 2 x 1.6 ns/ft)/ 100Ω or ≤ 3,200 pF. For a cable only 20 ft long, the same equation yields a value of C ≤ 640 pF. In addition to this, use the following rule-of-thumb for choosing a maximum data rate:

$$\text{RC time constant} \leq 10\% \text{ of unit interval}$$

Working the 100 ft example backwards yields a switching rate that should not exceed 312.5 kHz.

Conclusion

Clearly there is no single termination technique that will be ideal for all situations. As so often is the case, design options are dictated by the particular application. Factors like cable length, desired data rate, power constraints and component cost will play a significant role in the scheme you choose. Other methods such as Power, Alternate-Failsafe, and Bi-Directional termination were not discussed for the sake of brevity and because they don't really apply to encoder applications. The table below offers a quick, at-a-glance comparison of the techniques discussed in this applications note.

Termination	Signal Quality	Data Speed	Power Dissipation
No Termination	Poor	Low	Low
Series	Good	Low	Low
Parallel	Excellent	High	High
AC	Good	Mid-range	Mid-range

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