

Introduction to Terminations

Basic Transmission Line Theory

Every signal trace on a PCB is a transmission line. This is the medium by which signals are transmitted within the varied electrical systems that utilize PCBs. As the edge rates and clock speeds increase in a system, impedance matching along the signal path is required. As signals travel through transmission lines they encounter discontinuities in impedance. These discontinuities begin at the output of the signal driver and occur at every via, branch etc. along the path until reaching the device input. For each discontinuity, an impedance increase leads to positive reflections, while a decrease in impedance leads to negative reflections.

The challenge facing the circuit designer is to eliminate or minimize these reflections. Designers can achieve this result by ensuring there is proper termination of the transmission lines.

Termination Techniques

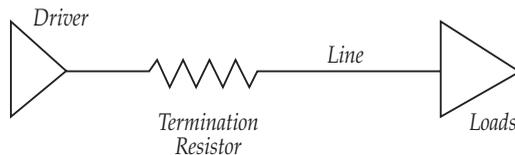
- Series (source) termination
- Resistor network termination
- RC termination
- Diode termination

Series Termination

In a series transmission the resistance and transmission line impedance acts as a voltage divider on the incident wave of the signal, thereby reducing amplitude by a factor of two (assuming). This type of termination does not allow the input device to switch until the signal encounters an unterminated end and reflects back to the source. The correct R value is based on transmission line impedance (Zl) and the lowest output impedance (Zo). The formula is: $R_t = Z_l - Z_o$

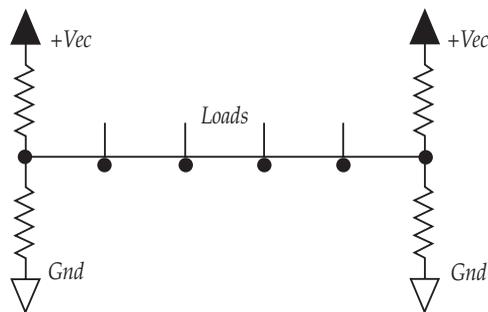
Series termination is ideal for discrete components and suitable for embedded resistors. A typical application is terminating clock nets (first signals are terminated as speed increases). A disadvantage for this termination is all loads within electrical distance of 1/2 signal rise time (e.g. $4\text{ ns} = w/n8''$).

Series Termination



Resistor Network Termination

A resistor network termination addresses an impedance mismatch between Tx and Rx, which results in multiple triggering due to ringing. In this termination there are two or more pull-up/pull-down resistors at the receiving end of the transmission line. The main advantage of these terminations is the ability to place a network at each end of the bus. However, resistor networks have high power consumption (e.g. a $16 \times 33\ \text{ohms}$ network at 5 vdc requires approximately 10 mA at each termination). In addition, one can usually not select resistance values to completely eliminate reflections, only to dampen the effect. Resistor network terminations are ideal for pull-up (to tie inactive signal lines on-board to logic high level) and pull-down (to tie inactive signal lines on-board to logic low level).



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Schottky Diode Networks

RC Termination

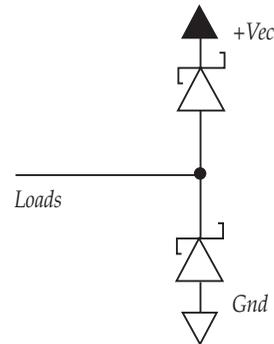
RC terminations are designed for systems where two way propagation delay is greater than the signal rise or fall time, which results in ringing and noise. If there is an increased settling time due to ringing this will reduce system performance. RC terminations clean and terminate the signal, are effective at high frequencies and edge rates, consume essentially no power, and they do not require the load to be lumped, making them effective for long traces. Their biggest drawback is that the capacitance value is dependent on signal rise time, therefore every output device with faster rise times would need a different capacitance value. In addition, the rise and fall times of transmission lines are marginally lengthened.



Schottky Diode Termination

Schottky diodes are used in pairs to clamp signal excursion on transmission lines. These components effectively reduce overshoot, undershoot and signal reflection within +/- 0.5V. Schottky diodes provide a turn-on time faster than signal rise time allowing them to avoid a spike at the leading edge of a reflection. Diodes have no effect on signal rise times or driver load and offer some ESD protection to other components on the line.

Schottky Diode Termination



RCD Termination

The resistor-capacitor-diode termination is intended for use on microstrip lines or lines with controlled impedance. They can be used with any type of distributed load such as DRAM, SRAM, or other data bus application. Ideal systems are those where the amount of undershoot and amount/length of ringing are proportional to electrical line length relative to the fall time of driving signal. An RCD termination will always provide a smaller undershoot. Greater improvement in a system can be achieved several ways - increasing driver speed, increasing loading by adding more components, increasing the distance between chips (longer line), or with a higher impedance line (such as increased spacing to ground plane). These components also offer improved system performance through faster settling time, reduce problems of latch-up caused by undershoot, and elimination of reflections and ringing effects thereby reducing EMI/RFI.