

**PROTECTION PRODUCTS**

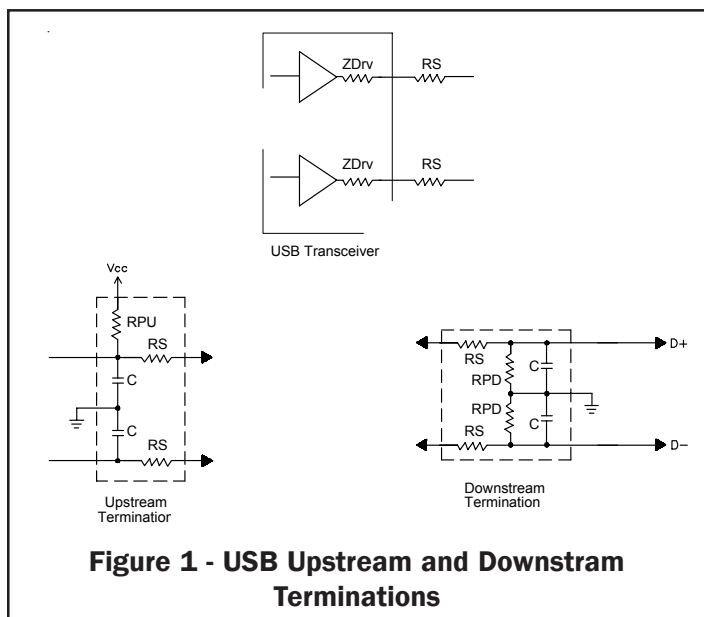
**USB Line Termination**

The Universal Serial Bus (USB) line termination is specified in the USB 1.1 specification to insure proper terminations so that signal integrity is maintained. The termination requirement varies depending on what driver chipset is used, whether the port is upstream or downstream, and if the transceiver operates in full or low speed. The following will help dissect the USB line termination specification.

The USB has two types of configurations, upstream and downstream. If your port hooks to the host either directly or through a hub you are upstream. If you are the host or your port provides access to the host then you are downstream. In some cases, a device or circuit may have upstream and downstream ports. For example, a printer may have both upstream and downstream ports. The printer port that hooks up to the central processing unit (CPU) on the computer motherboard is an upstream. If it has an extra USB port so that another device can hook up to the CPU through the printer then it is a downstream port.

The USB uses a differential output driver to drive the USB data signal onto the USB cable. D+ and D- identify these lines. The USB uses pull up or pull down resistors on these lines to determine if the line is an upstream or downstream line. A 15kΩ pull down resistor on each of the D+ and D- lines identifies a downstream port. A 1.5kΩ pull up resistor on either the D+ or D- line identifies an upstream port. If the pull up resistor is on the D+ line, the port is identified as operating in full-speed (12Mb/s). If pull up resistor is on the D- line, the port is identified as operating in low-speed (1.5Mb/s). Figure 1 illustrates the terminations for an upstream and downstream USB port.

The USB differential driver line needs to match the cable impedance in order to preserve signal integrity and reduce signal reflections. The USB twisted pair cable has an impedance of 90Ω +/- 15%. The impedance of the CMOS drivers is significantly smaller. To achieve matching impedance, a series resistor is needed on both the D+ and D- USB differential driver lines. The series resistor required varies in value as the impedance of the driver varies. When the USB 1.1 specification was written, a series resistor between the range of 28Ω to 44Ω was required. Most USB drivers



**Figure 1 - USB Upstream and Downstream Terminations**

will require a termination resistor of 16 - 33Ω.

The rise and fall time, measured from 10% to 90%, is specified in the USB 1.1 specification to minimize RFI emissions and signal skew. This in turn specifies the capacitance necessary to achieve the required rise and fall time. In the case of full speed USB 1.1 upstream or downstream, the rise and fall time must be between 4ns and 20ns, and the edges must match to within +/- 10%. This means that the loading capacitance must be no more than 75pF between the line and ground on each line of the transceiver. The recommended value is 50pF. In the case of low speed, the rise and fall time must be between 75ns to 300ns, and the edges must match to within +/- 20%. The USB 1.1 spec recommends 200pF to 600pF for downstream and 50 to 150 pF for upstream.

Semtech's STF201, STF202, and STF203 provide termination, filtering and ESD protection by combining an EMI filter and line termination device with integrated TVS diodes. The STF201 and STF202 are in SOT-23 6L packages and are designed for downstream and upstream ports respectively in peripherals and computers. The STF203 is in a small SC-70 package and is designed for upstream ports in portable electronics such as cell phones, digital cameras, and PDAs. All three devices contain a 47pF capacitor, series termination resistors (22Ω or 30Ω), and pull-up or pull down resistors for port identification. ESD protection is included for both signal lines and the power line.