

**Lab 1:**

The purpose of this lab is to simulate a simple transmission line (T-line) in ADS and vary the source and sink impedance to investigate reflections.

The transmission line was set as a 50-ohm line with 2 nsec time delay. The rising edge has a 1 nsec 10-90 rise time and follows an erf curve. Three source impedances were tested: 3Ω, 950Ω, and 50Ω. Two sink (or “load”) impedances were tested: 1MΩ and 50Ω. The source voltage pulse is 1V.

Test points were added at the step source and at the node between the end of the transmission line and the load.

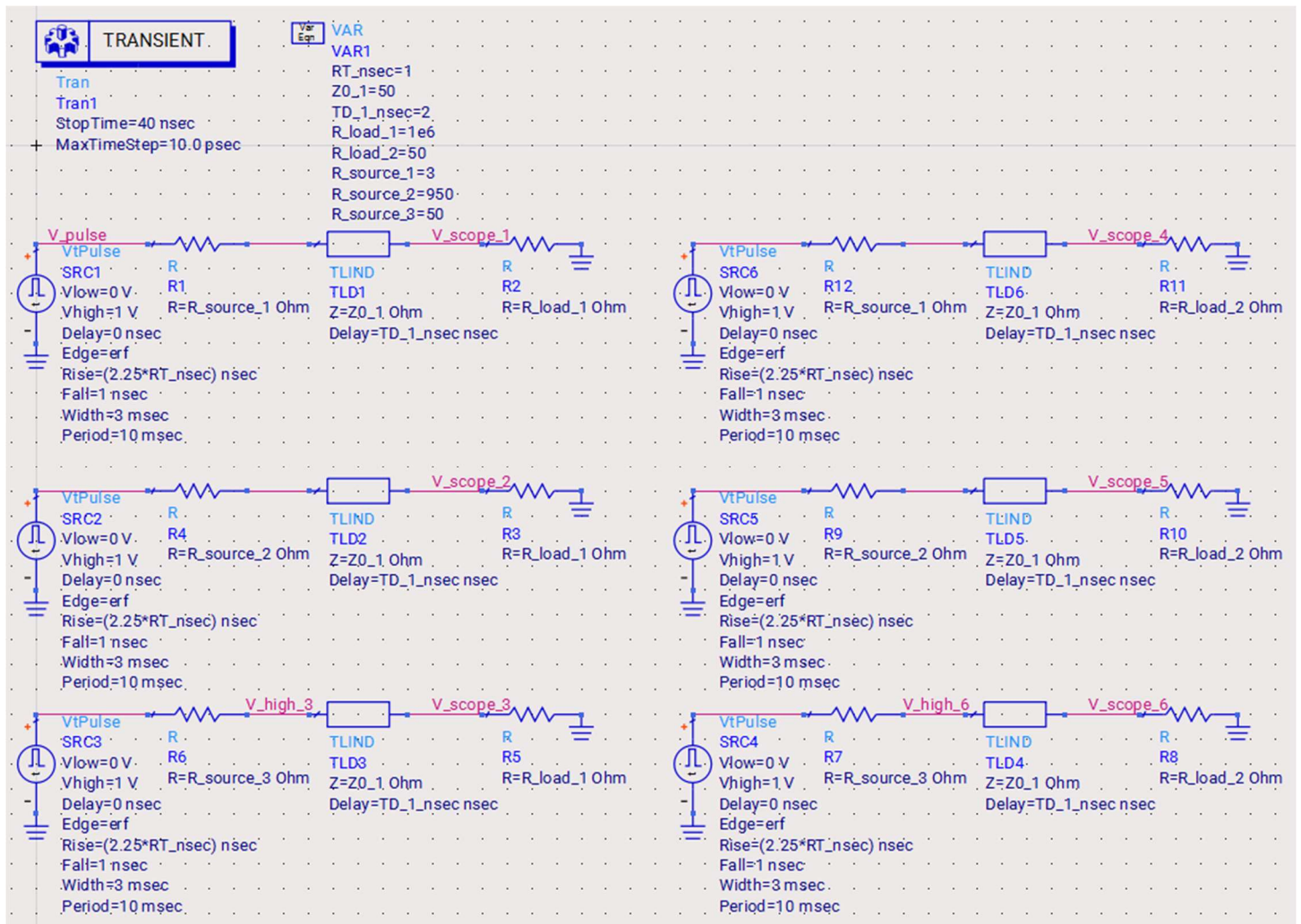


Figure 1: ADS Schematic for the simulation. Transmission line characteristics are unchanged, and the source and sink impedance is varied.

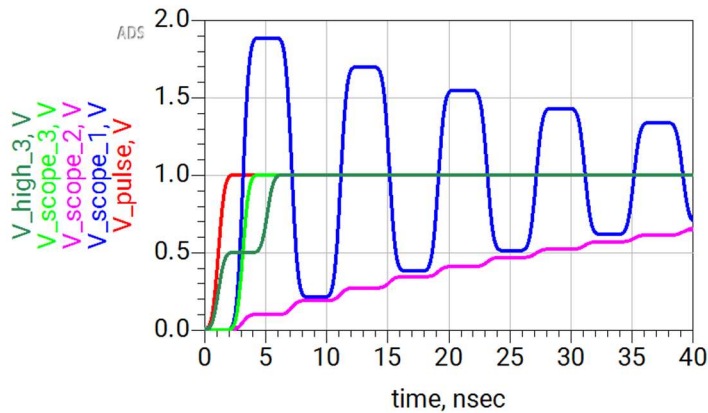


Figure 2: Simulation results with a load impedance of  $1M\Omega$  to simulate an open. (Red:  $V_{pulse}$ ; Blue:  $3\Omega$  source impedance; Purple:  $950\Omega$  source impedance; Lime:  $50\Omega$  source impedance; Mud green: high-side of T-line with  $50\Omega$  source impedance)

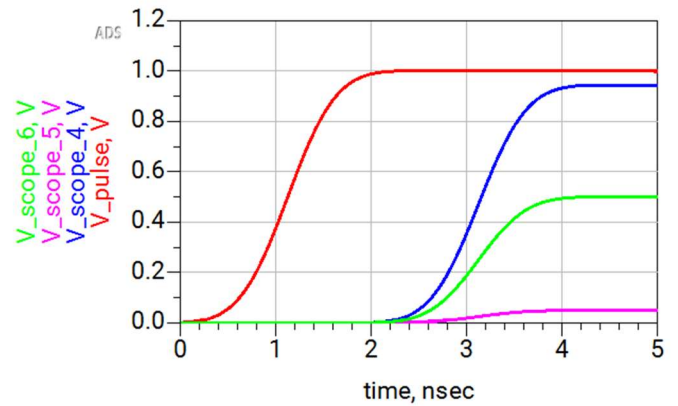


Figure 3: Simulation results with a load impedance of  $50\Omega$  to minimize reflections. (Red:  $V_{pulse}$ ; Blue:  $3\Omega$  source impedance; Purple:  $950\Omega$  source impedance; Lime:  $50\Omega$  source impedance)

In all simulations, the first sight of the signal at the load side occurs 2 nsec after the signal is launched. This is due to the time delay of the T-line. Rise times are unaffected by the T-line.

In the simulations with a  $50\Omega$  load impedance, there were no reflections seen. This is due to the load impedance having the same impedance as the transmission line. While there is an impedance change at the high side of the T-line, there is no time delay between the source and that node, so any reflections are immediately compensated for by the source voltage. In the real world, we would see some reflections in the  $3\Omega$  and  $950\Omega$  source impedance cases due to the transient characteristics of the source. Notably, the higher the source impedance, the lower the voltage at the sink.

In the simulations with a  $1M\Omega$  load impedance, there were reflections. This is due to the load impedance being different from the T-line impedance. The reflections look different for each source impedance. In the case with a low ( $3\Omega$ ) source impedance, there is ringing since a voltage of almost 1V is launched into the T-line which bounces off of the high impedance sink and is reflected back as nearly 2V. When the 2V signal sees the low impedance of the source, the voltage drops to  $\sim 0.2V$  and the voltage source provides an additional 0.8V-worth of current into the line, creating the conditions for ringing. In the case where the source impedance is high ( $950\Omega$ ), there is a “stepping” characteristic to the pulse at the receiver. This is due to the drop in impedance between the source and the T-line causing only 0.05V to be launched down the T-line initially. When the pulse bounces back from the open and “locks in” the higher voltage on the line, the source can supply more current into the T-line, increasing the voltage. This process repeats and the voltage at the sink approaches the source voltage. In the  $50\Omega$  case, the source puts 0.5V into the T-line, and the open doubles the voltage, and reflects back 1V to the source.

So what:

The most important takeaway for me is that matching the impedance of a point-to-point T-line with either the source or the sink impedance will cut down on reflections at the load. If the load impedance is matched, then there will be a measured voltage drop. If the source impedance is matched, there will be a single reflection if the sink impedance is an open, there will be ringing if the source impedance is low, and there will be stepping if the source impedance is high.

Another takeaway is that an ideal T-line has no impact on rise time.