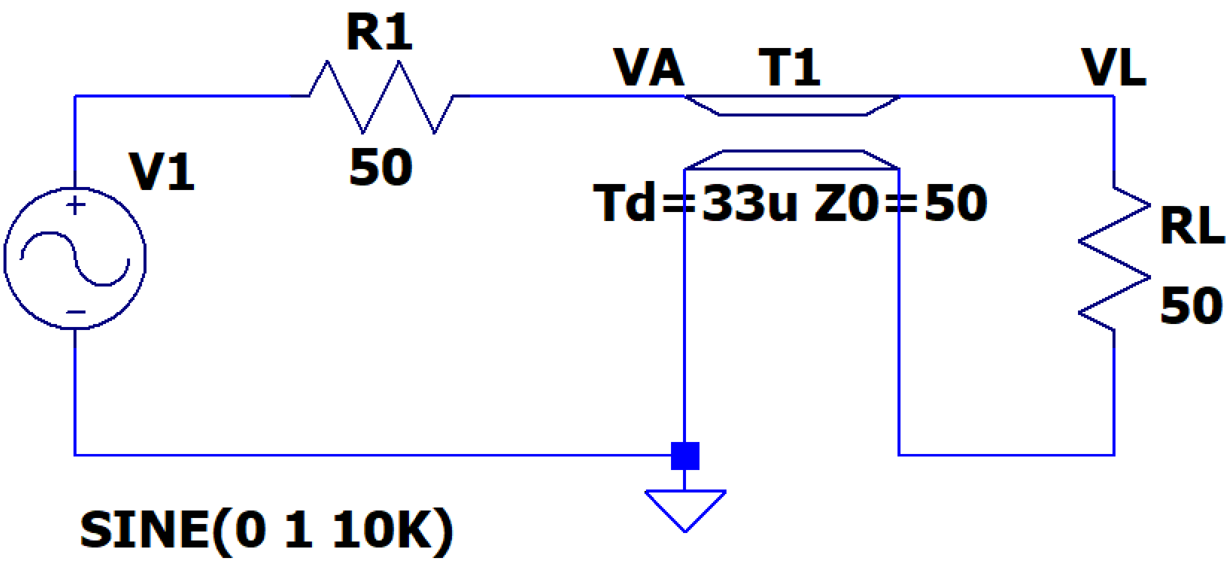
Fields and Waves I
Studio Session 1
January 17th, 2024
Due 11:59pm, January 24th

In this initial lab, we will try to get a better sense for how transmission lines work by exploring with some simulations. When you have completed the lab, submit the answers to the underlined questions on Gradescope. If you wish, you may work with a partner and submit one report for both of you. There is no need for a "formal" lab report.

Part 1: LTSpice Transmission Line Simulation



Creating a Lossless Transmission Line Model in LTSpice

1. Open a new LTSpice schematic.
2. Open the Component Library and select the "tline" component. Add it to your schematic.
3. The transmission line model is defined by two parameters
   a. Td = time delay in seconds
   b. Z0 = characteristic impedance in ohms
4. Add a voltage source (V1 = 10kHz sine wave with 1V amplitude), source resistance (R1 = 50Ω), and load resistance (R2=50Ω) to complete the circuit.
5. Assign the transmission line the following properties:
   a. Td = 33us
   b. Z0 = 50ohms

Transmission Line Simulations
Set up a transient simulation with an end time of 0.5ms (this will be 5 cycles of the input signal). Run the simulation and plot the input voltage to the line (VA) and the output voltage (VL). Verify that the signal delay is consistent with the tline properties you entered. Was the entire voltage at the input of the transmission line transferred to the load?

Now try changing the value of the load impedance. Keeping the Z_0 of the transmission line the same, change the load impedance to something higher than Z_0. Then, change the load impedance to something lower than Z_0.

<u>Question 1</u>: Calculate the reflection coefficient at the load for the case in which your load impedance is **higher** than Z_0. Apply a sinusoidal input voltage and compare the voltage amplitude at the input of the transmission line (after the source resistor) to the voltage amplitude at the output. Can you explain these voltage amplitudes in terms of the reflection coefficient?

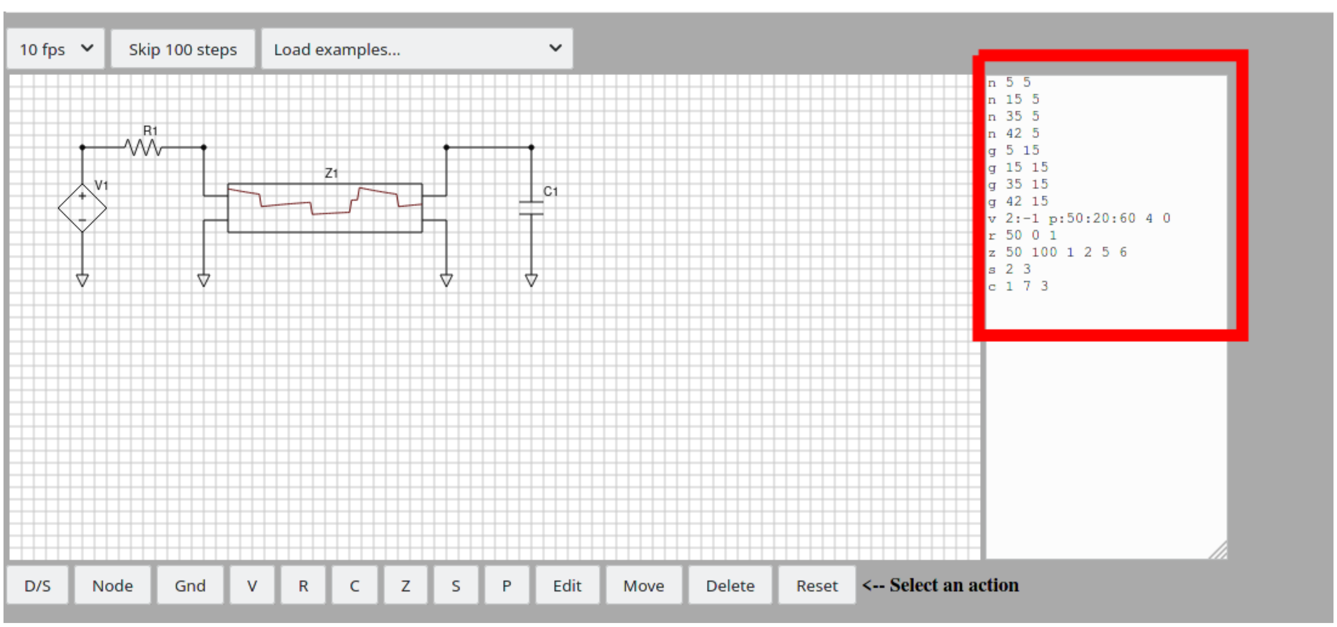
<u>Question 2</u>: Calculate the reflection coefficient at the load for the case in which your load impedance is **lower** than Z_0. Apply a sinusoidal input voltage and compare the voltage amplitude at the input of the transmission line (after the source resistor) to the voltage amplitude at the output. Can you explain these voltage amplitudes in terms of the reflection coefficient?

Part 2: Real-Time Transmission Line Simulation

Now we will try to get a better sense of how transmission lines work by experimenting with an interactive, simulated transmission line. The rectangular area in the region below represents a length of line. You will see that the signal on the line varies both in time and in space (along the x direction).

Open the transmission line simulator at this URL:
https://web.archive.org/web/20200115084836/http://svn.clifford.at/tools/trunk/electrotools/tdtlsim.html

This simulation shows a series of pulses being sent down a transmission line to a terminating resistor (initially shown as a capacitor).



Question 3: The panel to the right of the simulation defines the circuit topography. (See image above, highlighted in red.) The last line reads "c 1 7 3". Change it to "r 50 7 3" and hit "Reset". This will change the terminating capacitor to a 50-ohm terminating resistor. The rectangle labeled Z1 represents the transmission line and shows a graph of the voltage at different parts of the line. What do you observe?

Question 4: The 11th line of code reads "z 50 100 1 2 5 6". This defines the transmission line as having a characteristic impedance of 50 ohms and a delay of 100. Change the "100" to a different value of your choice. What do you observe? Did you make the transmission line "shorter" or "longer"?

Question 5: Since the terminating resistor and the transmission line are both set to 50 ohms, they are said to be "impedance matched". Change the terminating resistor value to something else by changing the last line of code to "r x 7 3", where x is a number of your choice. What do you observe? Do you see any reflection-like behavior from the terminating resistor? What about if you change the "50" in the 11th line of code to something else (i.e. changing the line's characteristic impedance?

Question 6: Change the 9th line of code to the following: " v 2:-1 s:25:0 4 0". The voltage source has now been modified to emit a sinusoidal voltage instead of pulses. Change the terminating resistor (last line of code) back to "r 50 7 3". What do you observe?

Question 7: Change the value of the terminating resistor again. Start at a value that is close to 50 ohms and then observe the effect of either progressively decreasing it to 0 ohms or progressively increasing it to a very large value. What happens?

Question 8: When sending pulses down the transmission line, what impact did you observe from any mismatch between the characteristic impedance of the transmission line and the terminating resistance? Did the magnitude of mismatch matter? Show a screenshot to demonstrate.

Question 9: While experimenting with the transmission line, under what circumstances did you observe forward-moving waves? Under what circumstances did you observe backward-moving waves?

Question 10: Under what circumstances were you able to observe standing waves? (A standing wave does not appear to move either forward or backward.) *Note*: D/S button allows you switch between two different views of the signal on the transmission line: one displaying separate forward- and backward-traveling waves and one displaying the sum of the forward- and backward-moving waves.

Question 11: You should find that you are able to create a standing wave under two different sets of load resistor conditions, but the standing waves are not the same. What's different about the standing waves created under those two different conditions?

Question 12: What can you conclude about the possibility of forming standing waves from traveling waves?