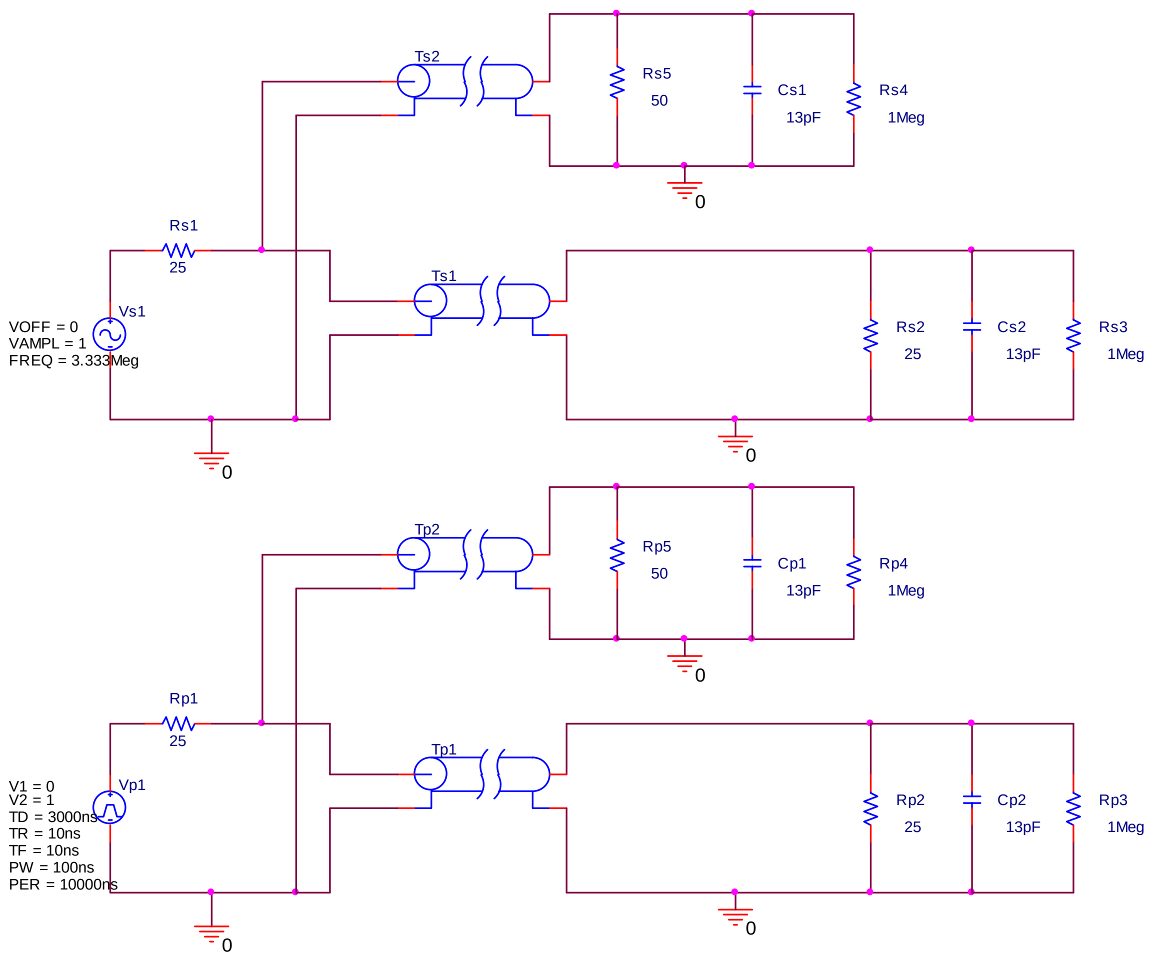
Homework 2

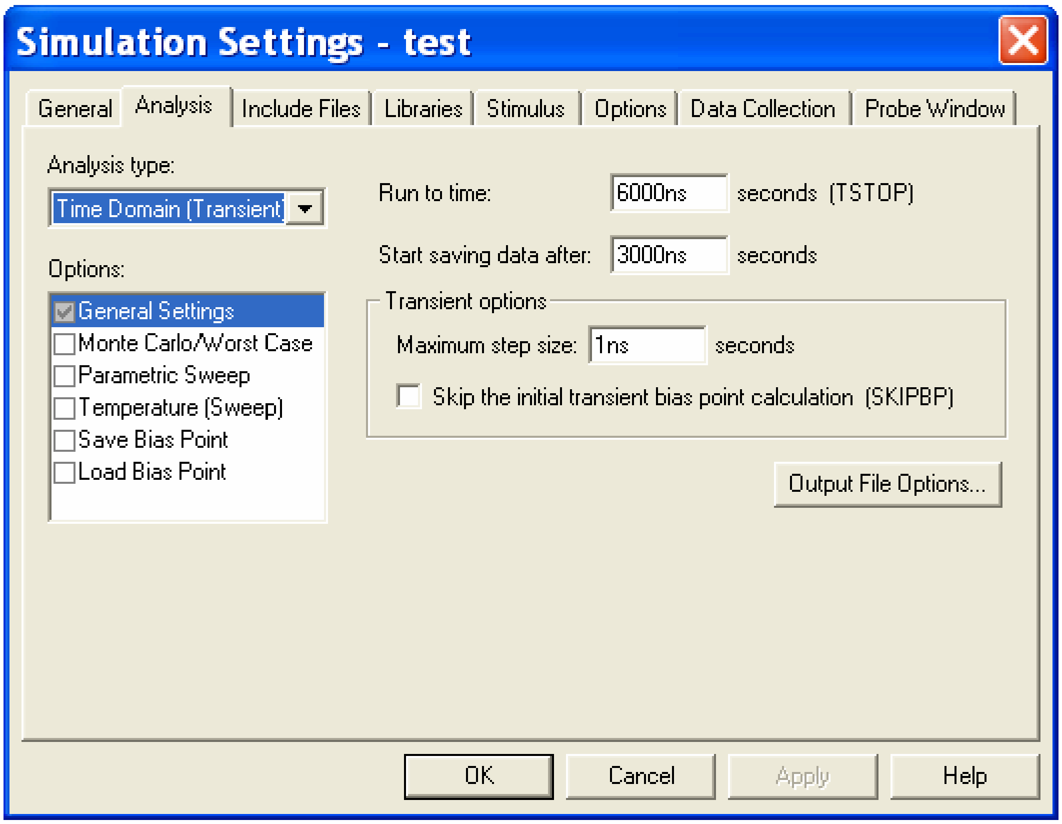
Due 1 February 2005

1. PSpice Simulation of Transmission Line

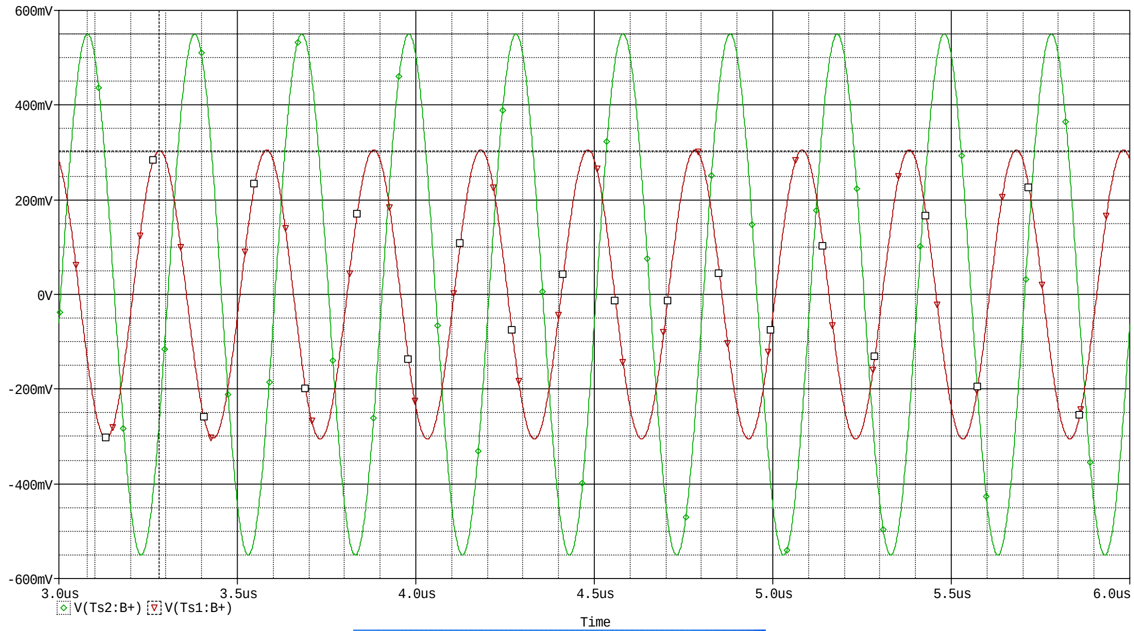
We want to consider the same lossless transmission line used in two different applications. All lines have a characteristic impedance of 50 Ohms. The top cable T2 connects the function generator to a scope channel. This cable is quite short. Assume that it is an RG58/U cable of length 2 meters. The bottom cable T1 has a length of 100 meters. When setting up these circuits in PSpice, you will need to specify the characteristic impedance and the delay time for each line. This configuration is meant to be realistic so the input resistance and capacitance of the scope is shown in each case. The short cables are terminated properly with 50 Ohms. (We did not do this in the studio experiment, but should have to get the best possible results.) The longer cable is improperly terminated with 25 Ohms and the function generator also has an internal impedance of 25 Ohms. Can you recall how to make a 25 Ohm resistor if we only have 50 and 93 Ohm terminators?



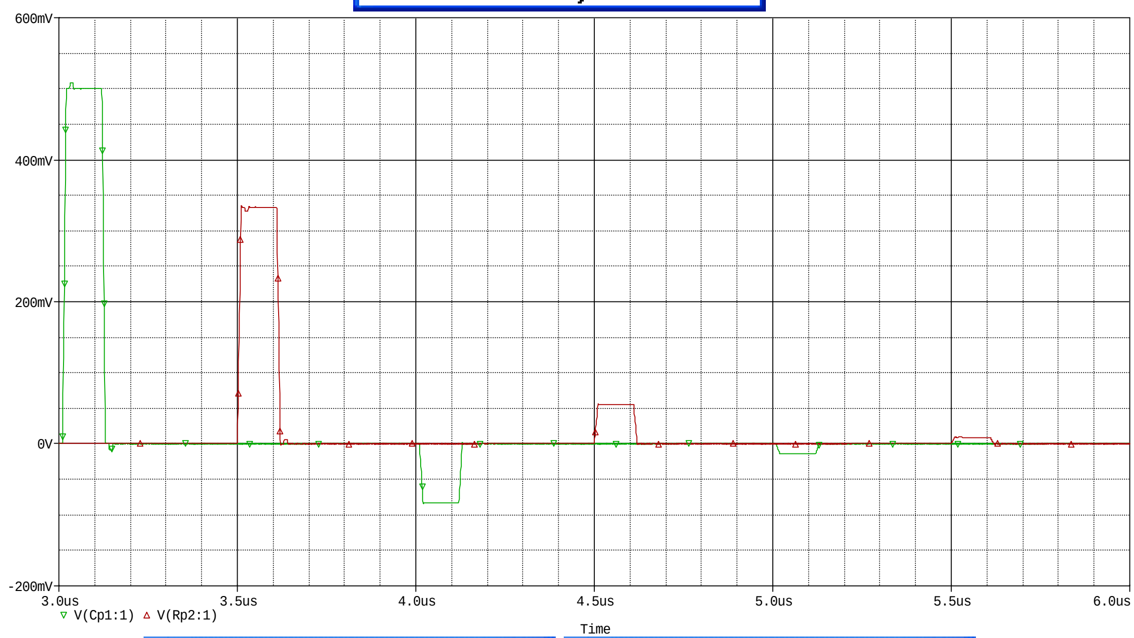
The two applications involve different voltage sources: a sinusoidal input voltage (VSIN) and a pulsed voltage (VPULSE). The sinusoidal source has a magnitude of 1 V with a frequency of 3.333 MHz. The pulsed source produces a single pulse of 1 V with a width of 100ns. We have put a delay of 3000ns on this pulse so that we can analyze the circuits starting after 3000ns. We have also specified a period of 10000ns, so we will see only one pulse from the source. We do this so that the circuit can reach steady state conditions. Otherwise we will see a lot of transients even in the sinusoidal case. We set up the simulation to begin storing data after 3000ns, by making the following choices.



The small maximum step size gives smooth plots and we look only at 3000ns of time starting at 3000ns. Set up these circuits as shown and these simulation settings. Generate separate plots of (1) the voltages observed on the scope channels for the sinusoidal case and (2) the voltages observed on the scope channels for the pulsed case. This gives us the input and output voltages observed on the long transmission line. After doing the next two problems, you will return to these plots and explain why they are correct.



Probe Cursor		
A1 =	3.0767u,	548.557m
A2 =	3.2822u,	303.628m
dif=	-205.438n,	244.929m



Probe Cursor		
A1 =	3.0767u,	499.989m
A2 =	3.5671u,	333.328m
dif=	-490.383n,	166.661m

Probe Cursor		
A1 =	4.0641u,	-83.337m
A2 =	4.5535u,	55.458m
dif=	-489.358n,	-138.794m

2. Input Impedance of a Line

This question relates to the sinusoidal voltage.

a. Determine the input impedance of both lines.

b. From the input impedance, determine the input power to each line.
c. From the input power to each line, determine the power delivered to each load.
d. From the power delivered to each load, determine the voltage observed at each scope channel. This should allow you to explain the magnitude of the observed voltages.
e. Explain why the phase difference between the two voltages observed in your plots also makes sense.

$Z_{in} = Z(-d) = Z_o \dfrac{Z_L + jZ_o \tan\beta d}{Z_o + jZ_L \tan\beta d}$ = 50 for the short line.

$$Z_{in} = Z_o \frac{Z_L + jZ_o \tan\beta d}{Z_o + jZ_L \tan\beta d} = 50\frac{25 + j50(1.73)}{50 + j25(1.73)} = 57.1 + j37.1$$

The parallel combination of these two input impedances is 29.2+j7.2. Therefore, the voltage across the input will be given by $1\dfrac{29.2 + j7.2}{25 + 29.2 + j7.2} = .55 + j.061$

The magnitude of this voltage is .55 which agrees with the input voltage determined using PSpice. The input power to each line is, for the long line

$P_{in} = \dfrac{1}{2}\mathrm{Re}\left(\dfrac{V_{in}^{\,2}}{Z_{in}^{\,*}}\right) = 2mW$ *and for the short line* $P_{in} = \dfrac{1}{2}\mathrm{Re}\left(\dfrac{V_{in}^{\,2}}{Z_{in}^{\,*}}\right) = 3mW$. The output power and voltage are the same as the input power and voltage for the short line since it is matched. The output power will yield a different output voltage for the long line.

$P_{out} = \dfrac{1}{2}\mathrm{Re}\left(\dfrac{V_{out}^{\,2}}{25}\right) = 2mW$ *thus* $V_{out} = \sqrt{50(.002)} = .316$ *which also agrees reasonably with the PSpice output. The phase difference observed should be about 200ns. The time delay on the line is 500ns and the period of the wave is 300ns. Thus, a 500ns delay will appear as a 200ns delay since the signals repeat every 300ns. The detailed reading of the output from PSpice uses the cursors. The window generated by the cursors is included above.*

3. Pulses on a Transmission Line

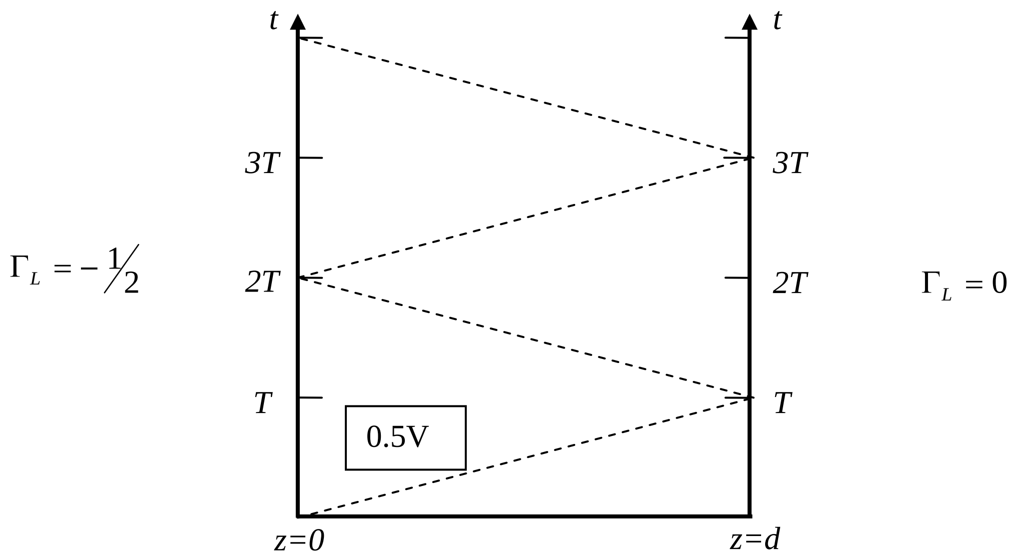
This question relates to the pulsed voltage.

a. Determine the voltage input to the lines from the voltage divider relationship that characterizes the initial line voltages.
b. Determine the reflection coefficients at the load and source end for both lines.
c. Generate the bounce diagram for both lines, showing the voltages observed until the level reaches less than 5% of the initial pulse height.
d. Sketch the voltages observed at the input and output ends of the line.

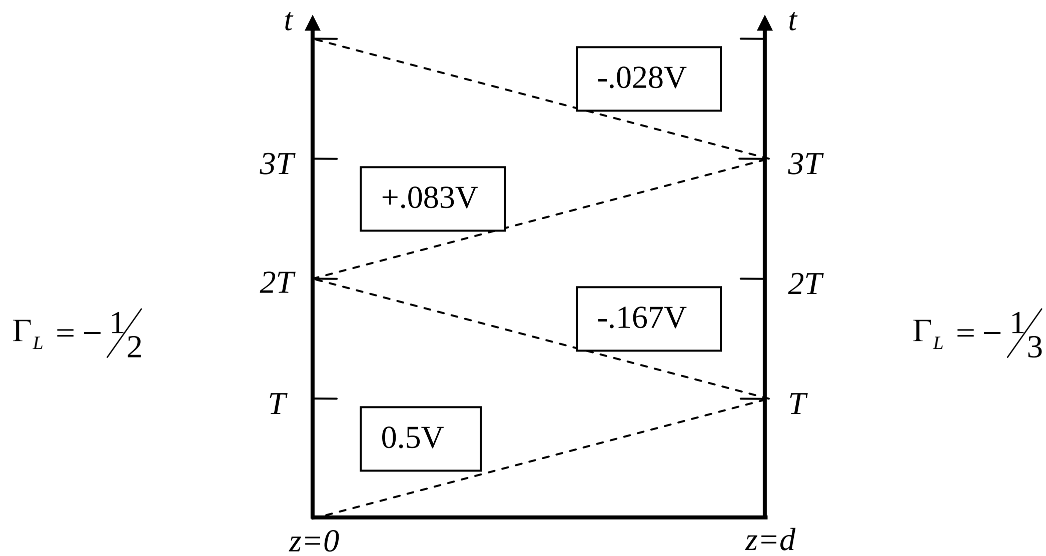
The voltage input to the lines again involves the voltage divider action with the parallel combination of the lines. For transients/pulses, the initial input impedance is the characteristic impedance. Thus, the parallel combo of two 50 Ohm resistances is 25 Ohms and half of the source voltage will appear across each of the lines. This voltage will appear unchanged at the load on the short line because it is matched, with a very short delay of 10ns. The first voltage observed on the end of the short line is indeed 0.5 V, *as this predicts. The reflection coefficient at the load for the short line is zero since the line is matched. The reflection coefficient at the load for the long line is (25-50)/(25+50) or -1/3. The reflection coefficient at the source end is a bit more complicated to determine. For each line the load seen at the source end is the parallel combo of 25 and 50 ohms, since the other line is connected in parallel. Thus the load resistance will be 16.67 Ohms. The reflection coefficient in this case is (16.67-50)/(16.67+50)=-1/2.*

Bounce Diagrams:

Short Line



Long Line



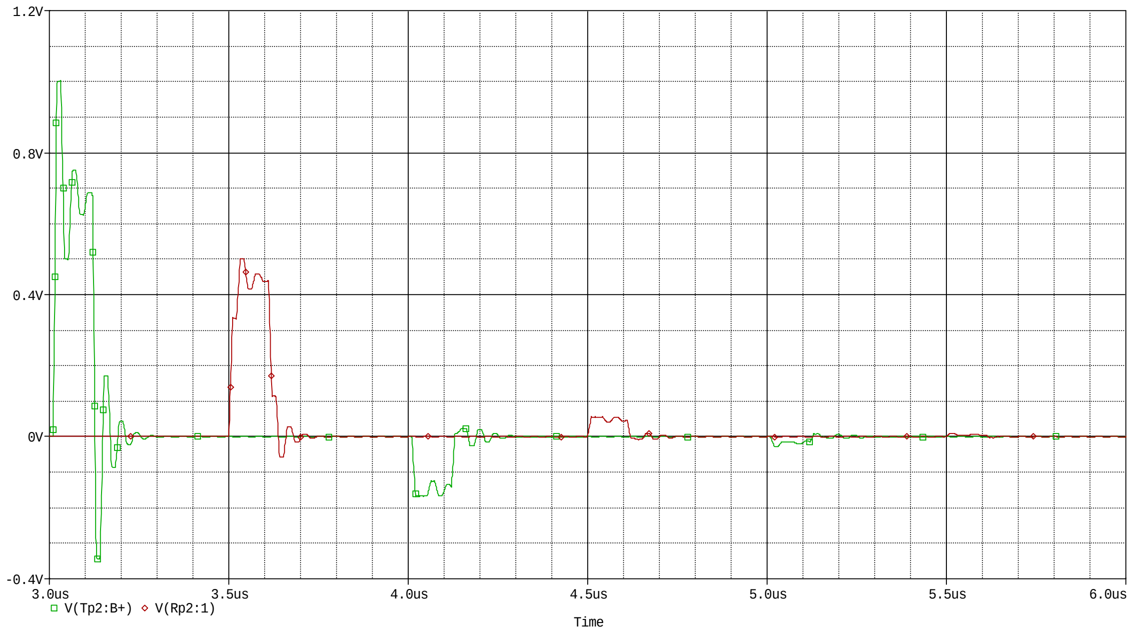
On the short line, the voltage starts out at 0.5V and arrives at the load the same way since there is no reflection. For the long line, at the first reflection, the voltage amplitude will be 0.5-.167=.333. For the second reflection (at the source) the total amplitude will be -.167+.083= .083. For the third reflection (at the load) the total amplitude will be 0.083-.028=0.055 and all other reflections will be smaller. The delay between each pulse will be 500ns. Thus, the output from PSpice is completely consistent with the bounce diagram. The small difference at the input end is due to the 10ns delay getting to the scope end of the short line.

4. Comparison Between Modeling and Theory

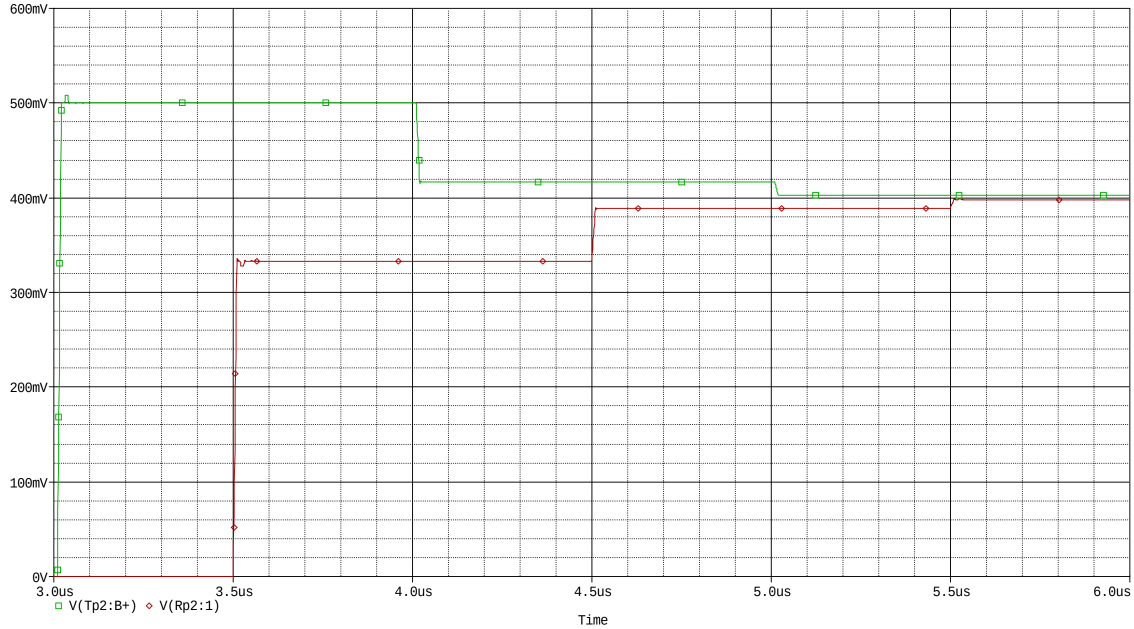
a. Use your results for problem 2 to explain the voltages observed for the sinusoidal source.
b. User your results for problem 3 to explain the voltages observed for the pulsed source.

This is done above. The probe cursor outputs confirm the values calculated by the bounce diagram.

Extra: Try removing the 50 Ohm terminating resistor from the short line. You will see that the pulses become very messy. This effect gets reduced somewhat with loss, but is still there.



Also, with the terminating resistors in place, make the pulse very long (greater than 3microseconds. Run PSpice and then explain the results you observe.


600mV
500mV
400mV
300mV
200mV
100mV
0V
3.0us
3.5us
4.0us
4.5us
5.0us
5.5us
6.0us
V(Tp2:B+)
V(Rp2:1)
Time