University of California, Berkeley *Fall 2017*
EECS 142/242A *Prof. A. Niknejad*

Problem Set 2

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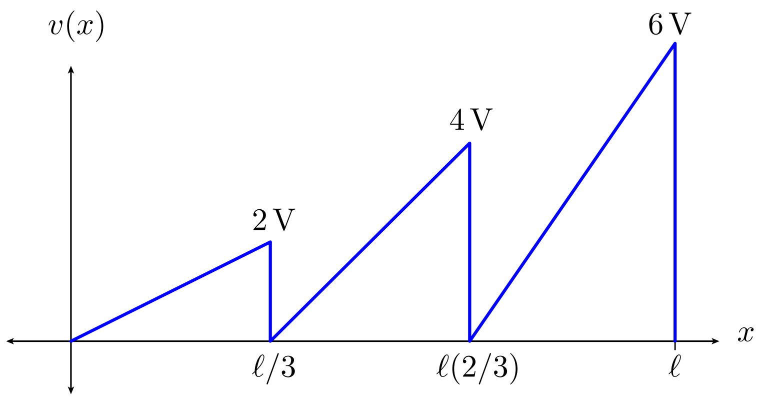
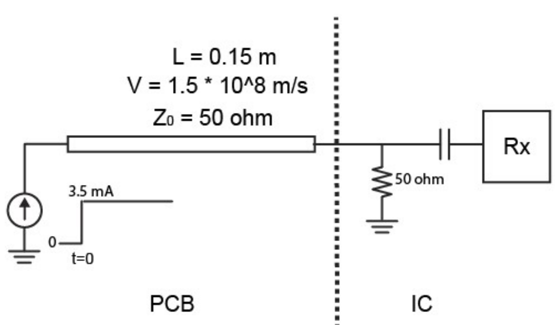
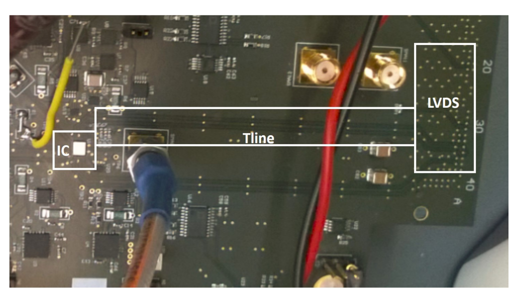
1. Suppose you would like the following waveform $v(x)$ to scroll across a transmission line and appear as shown. The line is 2.5 meters in length and has a characteristic impedance of 75Ω and 138pF/m of capacitance. (a) What voltage waveform is needed at the source vs. time to make this happen? Clearly label the time axis. (b) At what time does the entire message appear on the line? (c) How much energy is stored on the line at this point? (d) Now make the message slow down by a factor of 3. Redraw the time-domain waveform and specify Z_L.



2. The figure below shows the single-ended version of a LVDS driver, where the 50Ω load termination is realized on IC and the transmission line is realized on printed circuit board (PCB) to connect the current source 15 cm away. The Rx block has a very high input impedance. A photo of a real-world example of using a PCB transmission line is also shown.





(a) Plot the time-domain voltage waveform at the 50Ω termination. Assume the line has been discharged before $t = 0$s.

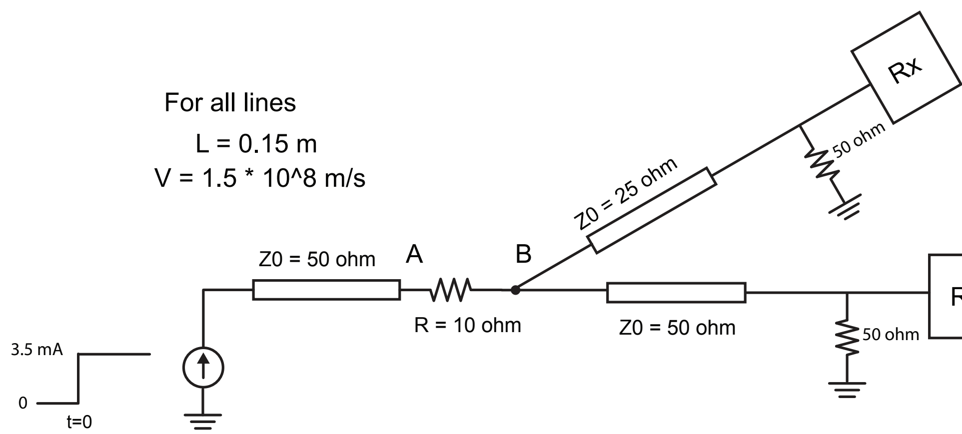
(b) With $Z_0 = 60\Omega$, calculate the voltage at the 50Ω termination at $t = \infty$.

(c) Assume the Rx input bias voltage is 1 V and has a very high input impedance. If the maximum tolerable Rx input is 1.2V, what is the maximum Z_0 deviation from the nominal value of 50Ω?

(d) (*242, 142 optional*) Using the simulation tools, find the two transmission-line widths that correspond to Z_0 of 50Ω and 60Ω (at 1 GHz). The transmission line is a micro-strip line with an infinite ground plane and the PCB substrate thickness is 1.6 mm with substrate dielectric constant of 4.0. The metal is copper and the metal thickness is 0.017 mm.

(e) (*242, 142 optional*) Is it possible for my PCB line to be designed with $Z_0 = 50\Omega$, but deviates to $Z_0 = 60\Omega$ after fabrication by a PCB foundry. Survey on the website of any PCB foundry and comment on this possibility.

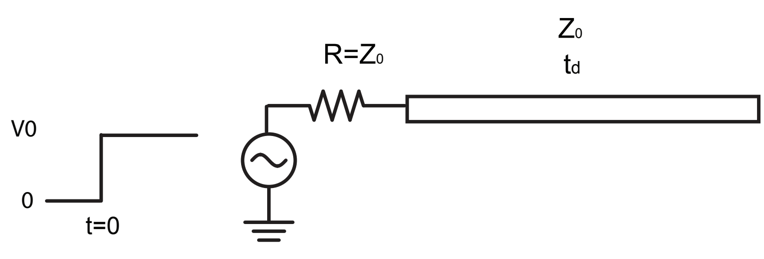
3. In this problem, consider two transmission lines combined in parallel as shown below.



(a) What are the magnitudes of the forward traveling voltage wave (V^+) and the backward traveling wave (V^-) at A and B, at $t = 1.5$ns.

(b) Repeat part (a) but at time $t = 3.5$ns.

(c) Repeat part (a) but at time $t = \infty$s (steady state). Is there a way to bypass the tedious sum of infinite geometric series?



4. A step voltage source is connected to a transmission line, as shown above.

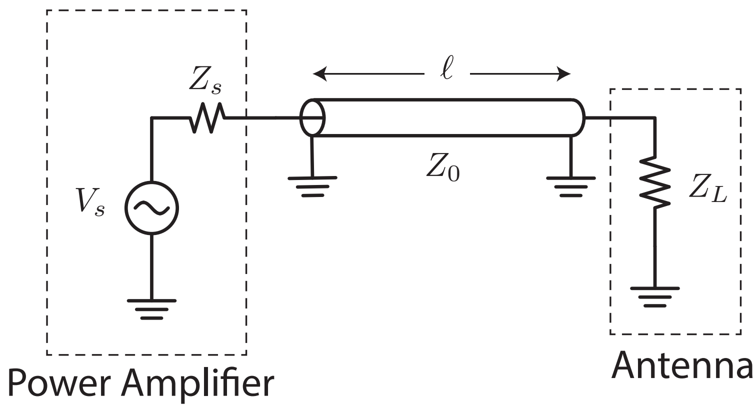
(a) Draw the time-domain response of the current flowing through the voltage source.

(b) Using the time-domain response to calculate the total energy delivered by the voltage source and the total energy consumed on the resistor. What is the energy stored on the transmission line at $t = \infty$s?

(c) Express the total capacitance of the transmission line by the line parameters Z_0 and t_d.

(d) Repeat parts (a)-(b) but with the source resistance changed to $2Z_0$.

(e) Calculate the energy stored on the transmission line at $t = \infty$s. Is there a way to bypass the tedious sum of infinite geometric series?



5. Consider a power amplifier (modeled by an equivalent source) is driving and antenna load through a section of transmission line $Z_0 = 50\Omega$ ($\epsilon_r = 4$) of length 21.875cm. The antenna is designed nominally to match to 50Ω but due to its placement on a metallic surface, the actual impedance is unknown. Fortunately, as a former student of 142/242, you have the right tools to solve this problem. Unfortunately you are alone in the lab and the network analyzer and oscilliscope are locked up. To meet a difficult deadline, you decide to work with the tools at hand.

   Suppose that we use a capacitive probe and scan it along the transmission line. We find that as we move away from the load, the magnitude of the voltage on the line drops and hits a minimum at a distance of 4.75mm from the load. Also, if we move to a distance of 36mm from the load, the voltage is maximum with a $SWR = 3$.

   (a) What is the operating frequency of the power amplifier?

   (b) What is the load (antenna) impedance at the frequency?

   (c) In sinusoidal steady state, what are the boundary conditions at the load?

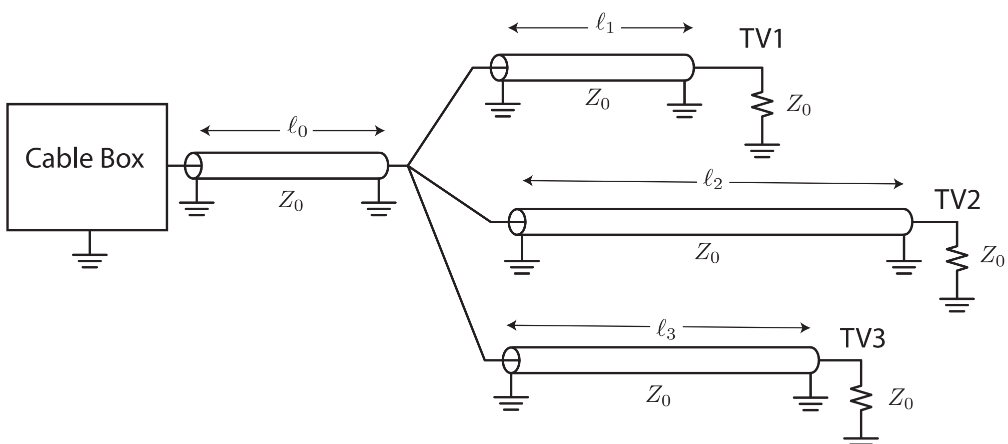
   (d) Similarly, what are the boundary conditions at the source? Assume $Z_s = 5\Omega$ but keep your answer in symbolic form.

   (e) Using the above boundary conditions, find the voltage waveform along the transmission line and plot its magnitude. Verify the results of the probe experiment you did in part (a). Use Mathematica or a similar package to do the calculation and plots.

(f) Suppose that the voltage source (amplifier) has a swing of 10V. How much power is delivered by the source and how much power reaches the load (antenna)? What is the efficiency? How much better/worse is this than an antenna matched to 50Ω?

(g) Suppose the transmission line is low loss so that all of your above calculations are approximately valid, except your power calculation. If the line loss is .1 dB per centimeter, redo the power calculation. You can use Mathematica or a similar tool.

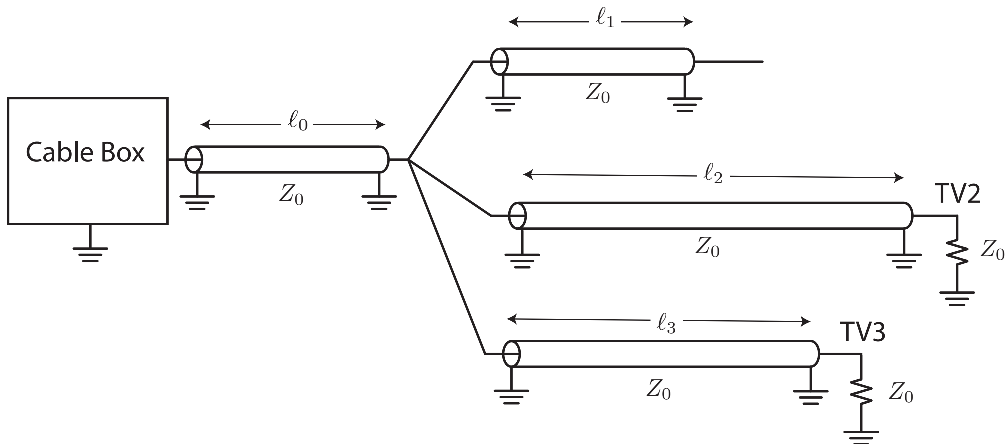
6. Given that you are now a 142/242A studenmt, the world sees you with a different eye. All of your friends, particularly the engineers, look at you with a sense of adoration and reverie. The down side is that everyone is asking you to solve their difficult problems. One of your friends tells you about a problem he's having, which is distribution of a cable TV signal to three television sets, as shown below. The goal is to split the signal in three and have the three TV's operating with the same performance as a single TV, but the problem is that the signal quality has degraded.



(a) Suppose $\ell_0 = 1.22$m, $\ell_1 = 2.59$m, $\ell_2 = 11.23$m, and $\ell_3 = 33.85$m. All cables are 75Ω and have a velocity of propagation of 1×10^8m/s. If the TV is tuned to channel 14, approximately at 473 MHz, what is the impedance seen by the cable box?

(b) Assume the Cable Box puts out a signal at -30 dBm. How much power reaches each television set?

(c) It is discovered that the system performance gets much worse when the first TV is unplugged, as shown. Explain what is happening. How much power reaches TV2 and TV3?



(d) After explaining the concept of impedance matching, your friends come up with the following solution. Does it work? What is the impedance seen by the Cable Box? How much power reaches each TV set?