In this lab we are examining loading behavior of cabling by engaging with a brain teaser: can you figure out the contents of the mystery box? The learning goals are listed below.

1. Deal with Thevenin models in a pracitcal context.
2. Be convinced of the virtue of oscilloscope probes by observing loading effects of different cables.
3. Refamiliarize yourself with the oscilloscope by making a Bode Plot.

# 1 Comparing the 10X Scope Probe to a BNC Cable

*Text Reference: Horowitz and Hill pp1045 to1049, Lab Manual Ref: Hays and Horowitz PP 62, 63*

Capacitive loading is always a consideration when measuring high frequency circuits. Here is an exercise to give you a feel for the loading that an oscilloscope can cause.

1. Make a series of measurements to characterize the impedance of different types of oscilloscope probes.
   (a) Use the RLC meter to measure the capacitance between the signal terminal and the shield of a BNC (coaxial) cable which is terminated with a pair of hooks or gator clips. We will refer to this cable (with its termination) as your "BNC Probe." Double check that the resistance between the shield and signal is infinite: sometimes cable dielectrics are leaky.
   (b) Measure the resistance and capacitance along the length of a 10x oscilloscope probe cable; i.e.: the resistance between the probe hook and the center conductor that connects to the oscilloscope. The settings of the RLC meter matter when taking this measurement (they basically didn't for the simpler BNC cable); do you want a high or low probe frequency when measuring resistance? How about capacitance?
   (c) Look at the face of the oscilloscope to determine the input resistance and capacitance of each channel.
   (d) Draw a model of an oscilloscope probe connected to an oscilloscope and find the input resistance and capacitance of the probe. When finding the input resistance and capacitance you may calculate resistance in a low frequency limit and capacitance in a high frequency limit. What is the DC gain of a 10x oscilloscope probe?
2. Make another series of measurements to examine the loading of the two types of probes when the source impedance is increased. Start by adding a 10 k$\Omega$ resistor in series with the output of your function generator.
   (a) Determine the output impedance of the function generator before you add the 10k$\Omega$ resistor to it.
   (b) Calculate the corner frequency of the two Bode plots representing each probe type connected to a function generator with a 10 k$\Omega$ source impedance.
   (c) Verify the -3 dB corner of each probe type on the oscilloscope by making a Bode plot for each. Explain any differences from your estimated value.

# 2 Figure Out the Thevenin Impedances of the Mystery Box

You will now use the probes you have characterized to load a mystery box and determine its secrets. The mystery box should be modeled as a single function generator connected to two outputs, $A$ and $B$, by output impedances $Z_A$ and $Z_B$. This model is pictured in Figure 1 (reverse). You may assume $Z_A$ is either purely resistive or purely reactive. You may assume the same for $Z_B$. Note that $Z_A$ being reactive doesn't imply $Z_B$ is reactive and vice-versa.

In general, Thevenin models may have an arbitrary impedance $Z_{th} = R + jX$, but we're working with the simpler, purely real and purely imaginary cases in this lab.

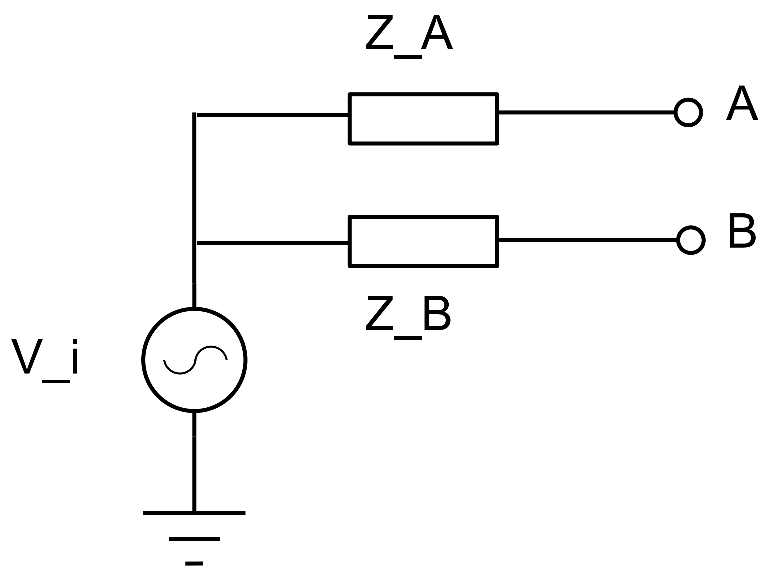


Figure 1: A schematic model of the mystery box.

1. Observe the outputs of a mystery box with the 10x and BNC probes. We only have six mystery boxes, so we need to share them. Plan your measurements carefully and execute them quickly to minimize the amount of time you need with a mystery box. Do all of your measurements on the same mystery box.

2. Determine the Thevinin equivalent circuit of the function generator for outputs $A$ and $B$ using the information obtained from your two probes. Show your calculations. Simplifying your circuit before analyzing it may make your life easier. For instance, if a component is in parallel with something that has a much lower impedance, then you might consider removing it from your schematic before doing analysis. Document all such assumptions.

3. Sketch the wave generated by the mystery box's function generator before it is loaded. Include axis labels.