ECE 2274 Lab 2 (Network Theorems)

Forward (DO NOT TURN IN)

You are expected to use engineering exponents for all answers (p,n,μ,m, N/A, k, M, G) and to give each with a precision between one and three leading digits and zero to one decimal place.

EX: 20.1 mA, 10.1 MHz, 1.0 V, 220 μF

Your calculator will have a setting that will automatically generate the correct format.

The lab uses 10% resistor values at 5% tolerance. Use only 10% resistor values with multipliers between 10 Ω and 1 MΩ for any calculation. These are the values available in the lab:

10	12	15	18	22	27	33	39	47	56	68	82

Lab 2 Summary

The purpose of this lab procedure is to demonstrate the parasitic (unwanted) effects of our lab equipment. We will investigate the extra capacitance and resistance introduced into various circuits by our instruments and the cables, breadboard, and wires we are using to connect them. By the end of this lab procedure you should be able to:

1. Measure the unit length capacitance of cables
2. Understand and explain the practical differences between loose wires, twisted pairs, and coaxial cables.
3. Observe the negative effects of mismatched cable impedances
4. Measure the input impedance of an oscilloscope and the parasitic capacitance it presents to a circuit
5. Understand how a resistance measurement and capacitance measurement are performed by the DMM
6. Measure the parasitic capacitance of a 10X probe
7. Observe the effects of parasitic capacitance on sensitive circuits
8. Accurately measure the low resistance value of a cable connected to an alligator clip and breadboard using both 4 wire techniques and a Wheatstone bridge circuit.

We will perform a series of simple experiments to show the various parasitics we must be aware of in our measurements and ways to compensate for them.

- We will begin by measuring the capacitance of a BNC to banana plug adapter and a length of a coaxial BNC cable, as well as a twisted pair of red and black cables.
- We will then observe the effect of loose wires, twisted pair cables, and coaxial cables on a generated signal transmitted from our function generator to our oscilloscope.
- We will measure the input impedance of the oscilloscope on its three settings, and observe how the resistance measurement is performed by the multi meter

- We will then measure the capacitance of the scope's input when the scope is set for both DC and AC coupling.
- We will observe the effect of a 10X probe on the measured capacitance of the scope's input.
- We will construct an RC filter circuit and then investigate the effects of parasitic loading on circuit performance
- We will construct a Wheatstone bridge and use it to perform accurate resistance measurements of a length of cable

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Pre Lab (TURN IN 1 PER PERSON AT BEGINNING OF LAB)

Name: _____   Day and Time: _____

CRN: _____

Please complete the following short answer questions. Use whatever resources you feel are required to locate the information needed to answer the questions. Use basic schematics / diagrams or simple equations.

1. Look up the value of capacitance per meter for RG58 coaxial cable (5 pts):

2. Calculate the resistance for a 1-meter length of 18 AWG wire (5 pts):

3. Look up the maximum power transfer theorem. Also look up some standard cable and output impedances. Why do you think an oscilloscope has multiple possible input impedances? (5 pts):

4. Derive the equation for the output voltage of a RC low pass filter (HINT: Use a voltage divider) (5 pts):

5. Solve the output equation to locate the 3-dB cutoff frequency of a Low Pass RC filter as a function of R and C *(Look up 3 dB bandwidth and understand what this means!)*: (5 pts):

6. Calculate the cutoff point for a low pass RC filter with a series resistor valued at 1 M Ω and a shunt capacitor valued at 220 pF: (5 pts):

7. Describe how capacitance adds in parallel with other capacitance (5 pts):

8. In your own words, describe how a Wheatstone bridge can be used to measure a small resistance. (HINT, look up Wheatstone Bridge) (10 pts):

9. Derive an equation to solve for the small resistance in a bridge circuit using the known values. (10 pts):

10. Draw a simple diagram of the cross section of a coaxial cable. (5 pts):

11. Research twisted pair cables and coaxial cables. Write an advantage of each over loose wires. Which type of cables has the best high frequency performance? (5 pts):

12. Why is ground called ground? What is the meaning of bond ground? (15 pts):

13. On a BNC to male banana plug adapter, which plug is the "black" cable? Where is the "black" cable inside the BNC cable? (15 pts):

14. Look up Impedance mismatch and briefly describe what it means (5 pts):

Lab Procedure (DO NOT TURN IN)

Required Equipment

To conduct the experiments in this lab procedure you will need to acquire:

- A 10x Probe
- 7 banana plug terminated cables
- Two BNC cables
- A BNC to male banana plug adapter
- Two BNC to female banana plug adapters
- Two BNC to clip lead adapters
- A 10 Ω and 1 MΩ resistor
- A 220 pF capacitor
- A breadboard
- Alligator clips

Setup

Begin by powering up your equipment. Today we will need the lower left and lower right multi meters, the oscilloscope, a power supply, and the function generator.

Cable Capacitance

Connect your BNC to Banana plug adapter to the capacitance measurement ports of one of your DMMs. Record the capacitance of the adapter.

Now connect a BNC cable to the adapter and leave the other end unconnected. Record the capacitance of the cable and adapter and determine the capacitance of the cable. Does the value you determined roughly agree with the value you looked up in the pre lab?

Demonstration of Cable Limitations

Now connect your female banana plug to BNC adapters to the output of the function generator and the channel 1 input oscilloscope. Connect them using a single banana plug cable from red to red. Set the generator to a 5 V$_{pp}$ square wave at 1 kHz. Observe the amplitude on the oscilloscope. Increase the frequency of the wave until you see the signal's amplitude change significantly.

Use your best judgement to determine when the signal becomes altered too much to determine a maximum usable frequency for the loose cable. Set the generator to that frequency and disable the output. Record this frequency.

Connect the black cable, enable the output, and observe the difference between the maximum usable frequency of the single cable and the pair. Play with the cables and observe the signal change at high frequencies.

Set the frequency on the function generator to a 10 MHz square wave with an amplitude of 5 V_{pp}. Observe the waveform. Now press the channel 1 button to bring up the channel settings. Change the input impedance of the channel from 1 MΩ to 50 Ω. What effect does this have on the square wave? Record your observation.

(For extra credit: draw a block diagram of the system you created with the characteristic impedances of each block labeled. Explain how this block diagram explains the effect you just observed. Put this by your explanation of the effect changing the scope impedance has on the signal)

Change the channel impedance back to 1 MΩ before continuing!

Now remove the cables from the oscilloscope's adapter. Twist the cables together into a moderately tight winding, then reconnect them to the oscilloscope. Enable the output and observe the difference in the signal. Once again, determine the maximum frequency you would be comfortable using this cable to transmit.

Replace the banana plug cable with a BNC cable. Determine the maximum frequency you would use this cable to transmit.

What is a general rule about the cables you have observed? What are some advantages and disadvantages of each?

Scope Parameter Measurements

Connect the BNC cable to the DMM. Connect the other end of the BNC cable to the channel 1 input on the scope. Set the DMM to measure resistance. Now press the channel 1 button to bring up the channel settings. Observe and record the resistance of the scope input at the 3 settings: 1 MΩ 75 Ω and 50Ω with DC coupling. Record these resistances. Using the display on the oscilloscope determine the current that the DMM produces to measure resistance.

Change the coupling to AC, what is the DC resistance?

Now change the coupling back to DC and change the DMM to measure capacitance. What is the capacitance of the input at the 1 MΩ setting? Observe and describe the waveform the DMM generates on the scope. How can the DMM measure capacitance from this waveform?

Change the coupling back to AC and measure the capacitance.

Now disconnect the cable from the scope and adapter. Connect your 10x probe to the scope.

Connect the ground clip of the 10x probe to the negative plug of the adapter by clipping it into the open banana plug hole. Gently remove the clip from the front of the probe and touch the probe to the inside of the banana plug jack for the positive terminal of the capacitance measurement. Record this capacitance measurement. Note the difference between the AC coupled capacitance with the cable and the 10x Probe.

Parasitic Loading

Construct the simple low pass RC filter shown below:
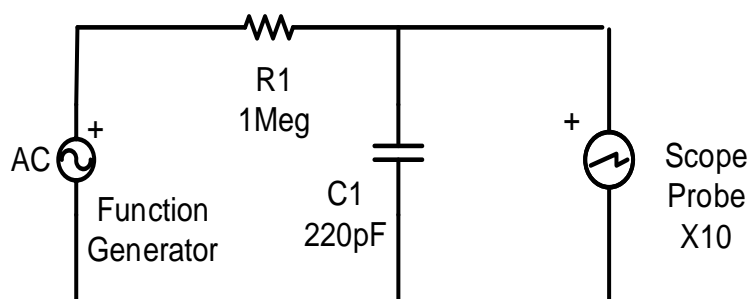
Connect your function generator across the filter and then use the 10x probe and AC coupling to measure the output (middle node) of the filter. Set the function generator to a 5 V_{pp} 350 Hz sine wave. Observe the amplitude of the output on the oscilloscope.

Now connect a BNC cable to channel 2 of the oscilloscope and set the coupling to AC. Select a BNC to clip lead adapter and connect the negative clip to the circuit ground. Now connect the positive clip next to the 10x probe. Observe the voltage measurement on the 10X probe. How did it change? Disconnect and reconnect the positive clip to observe the effect of this change. Explain what is causing this change and why the 10x probe does not have a similar issue.

Wheatstone Bridge

Using a 4-wire measurement, measure the resistance of your 10 Ω and 1 MΩ resistors as accurately as possible. *(NOTE: Using two banana to BNC adaptors, two BNC cables, and two BNC to clip lead adapters makes this much easier to manage!)* Then construct the circuit shown below: The unknown resistance is banana plug wire with two alligator clips on the ends.

Now perform a 4 wire resistance measurement of the unknown resistor (banana wire with two alligator clips). Record this resistance of the wire. Install the unknown resistor in the bridge clipped to the bottom of the R2 the 10Ω resistor to the bottom of the bridge

Cable 1

Channel 2 1Vdc

Decade Box   R1 1MEG

V

DMM

+

Cable 2

R2 10   Cable and Clip
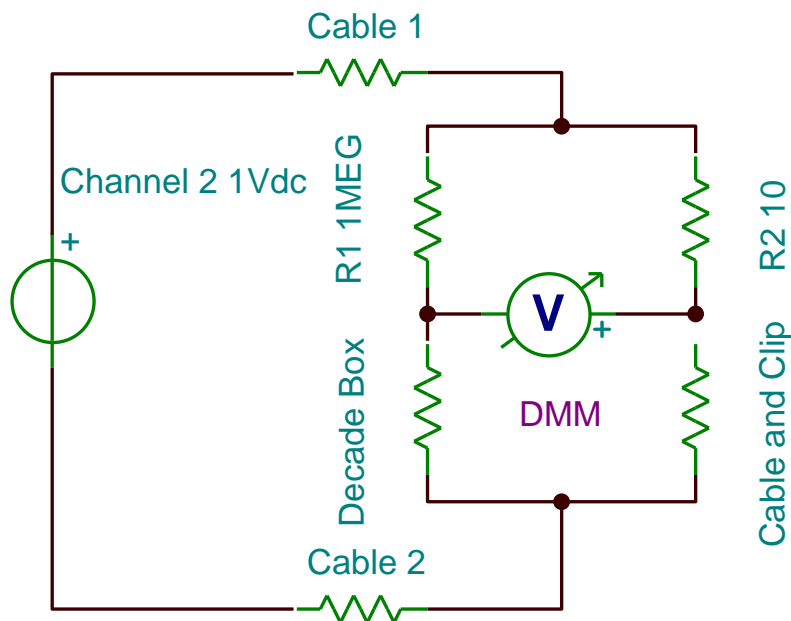
Use 3 adjacent breadboard holes on the power rail for the top of the bridge, and carefully connect banana plug alligator clips to the midpoints of the bridge. Connect the mid points of the bridge using short segments of wire to two banana plug terminals on the bread board. Connect a DMM set to measure a DC voltage (auto range) across these two banana plugs. Connect power to the third banana plug. Set **(BUT DO NOT TURN ON)** the voltage on your supply to 1.00 volts. Set the decade box to an initial value of 100 kΩ. **Always set the decade box resistance to 100k OΩ when changing the value to ensure you do not blow the fuse!**

Power up the supply and set the decade box to a value of 1 kΩ. Observe the Voltage across the central with the DMM. Adjust the value of the decade box until the Voltage is as close to 0 as possible.

Record the value of the decade box when this occurs, measure the resistance using a DMM to confirm. Using the formula you derived (HINT: it is a simple ratio) calculate the resistance of the cable under test. How does this compare to your calculated value? What could be some causes of any variation from your calculated value?

Lab Data Sheet (TURN IN 1 PER GROUP)

Name: _____   TA: _____

Name: _____   Day and Time: _____

CRN: _____   Bench: _____

Cable Capacitance (15 pts)

	Adapter	Coaxial BNC Cable	Difference from prelab value?
Measured Capacitance			

Cable Limitations

Maximum Frequency for single cable (5 pts):

How is current flowing in a closed circuit without a "black" cable? (15 pts)

Maximum Frequency of loose cable (5 pts):

Explain in words what happens when you change the scope's input impedance to 50 Ω? (Extra Credit diagram here) (5 + 10 pts):

Maximum Frequency of Twisted Pai (5 pts):

Maximum Frequency of coaxial cable (5 pts):

Describe a general rule for choosing cables based on your observation (5 pts):

Oscilloscope Measurements

Input Impedance	1 MΩ	75 Ω	50Ω
Measured Resistance			
DMM Current Produced			

DC resistance of AC coupled scope (5 pts):

Scope Setup	DC Coupled	AC Coupled	AC Coupled + 10X probe
Measured Capacitance			

Describe the waveform, how can this be used to measure capacitance (5 pts)? *(HINT: use google)*

Parasitic Loading

Probes Used	10x Probe	10x Probe and 1x probe
Amplitude Observed		

Explain the effect you just observed? Why did the 10X probe not cause the same effect (20 pts)?

Wheatstone Bridge

Resistor Nominal Value	10 Ω	1 MΩ
4-Wire Measured Value		

Measurement Banana wire	4 Wire Measurement	Minimum Voltage	Decade Box Measured Value	Banana wire measured from bride calculation.
Value				

Using the equation you derived in the prelab, calculate the unknown resistance of the cable (10 pts):