EEAP 243
Lab 2

Lab Work:
Questions Due:

MEASUREMENT OF VOLTAGE, CURRENT, AND IMPEDANCE

READING ASSIGNMENT: Horowitz, pgs. 8-20

Abstract:
This lab will demonstrate advanced use of the test instruments and some of their shortcomings. Linear resistances and non-linear resistances such as diodes will be characterized using the test equipment. Simple networks which demonstrate Kirchoff's Laws, Ohm's Law, impedance and superposition will be examined.

You should always review these assignments before coming to the lab and make calculations to predict your experimental data. If you review the lab assignment including the assigned reading you will know what your data should look like, you will be able to catch your mistakes, and you will spend less time in the lab. For this lab, calculate the resistor voltages and currents in part 4 before coming to the lab.

NOTE: This assignment requires the use of two DMM's and will consequently require two lab groups to work together. Each lab group should work with the group immediately across from them so that test leads can be kept short.

Part 1 - DC Measurements

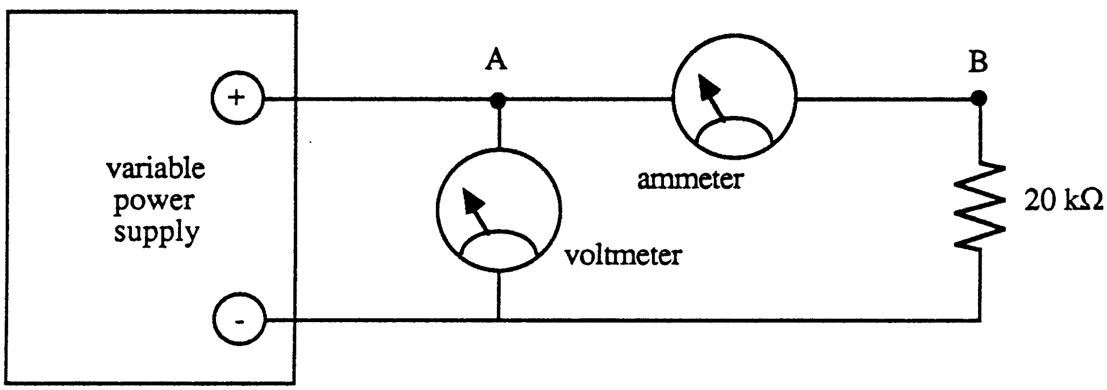


Figure 2.1

Construct the circuit shown above. Measure V and I with two DMM's as mentioned in the note above. Record your results for five different voltages of your choice between 1 and 15 volts.

Remove the voltmeter's positive terminal from point A and reconnect it at point B. Again record V and I for five different values of V.

Construct the circuit shown below using your breadboard. The diode is shown in the forward-biased mode.

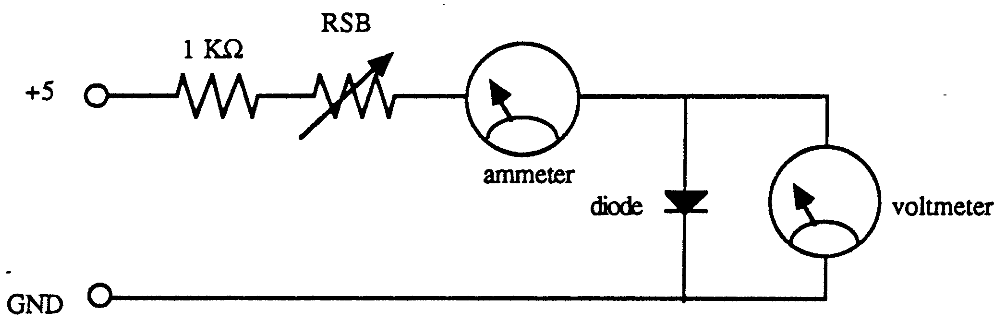


Figure 2.2 (a)

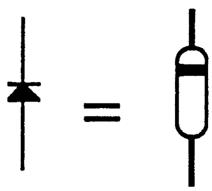


Figure 2.2 (b)

Record the values of I and V in Table 2.3 as you set the resistance of the RSB to 10K, 20K, 30K, 40K and 50K. Then, reverse the diode in your circuit and repeat the measurements. Record your results in Table 2.3.

A zener diode is a special diode used in voltage regulators and voltage protection circuits. Replace the diode you used above with the zener diode in your part kit. Record the values of I and V in Table 2.4 as you set the resistance of the RSB to 10K, 20K, 30K, 40K and 50K. Then, reverse the diode in your circuit and repeat the measurements. Record your results in Table 2.4.

Part 2 - AC Measurements

Your DMM reads AC by first converting the AC signal to a DC voltage and then measuring the DC. It is not capable of making accurate measurements at all frequencies. We will measure the frequency response of the DMM by comparing oscilloscope and DMM readings over a wide range of frequencies.

Connect the DMM input VKS (A-5) to the signal generator output (B-4) and to the oscilloscope's channel 1 input CH1 (C-8). Connect the DMM's common input COM (A-5) to the station ground (D-11). Set the oscilloscope to 0.5 V/cm, bright line off, and AC coupling. Set the output of the signal generator to 4 volts peak-to-peak. Do this by adjusting the generator's amplitude knob so that the entire signal spans eight major divisions on the oscilloscope. This establishes a reference amplitude of 4 volts peak-peak at 1 KHz. Set the DMM to read AC volts on the 2 volt scale.

Complete Table 2.5. Be sure that, for each line on the table, you have made the corresponding signal generator vernier, signal generator range, and oscilloscope sweep speed settings. To read peak-to-peak voltage (Vp-p) on the oscilloscope, set the vertical position so that the bottom of the waveform is on a major division, measure the height of the waveform in major divisions, and multiply by the vertical sensitivity. The DMM reads root-mean-square voltage (V_{rms}) automatically.

Part 3 - RMS Voltage Measurement

Since the oscilloscope displays information graphically, it can display any waveform so long as the signal does not change faster than the oscilloscope can move the electron beam. The DMM does not give wave shape information and cannot directly measure the total RMS voltage of a combined AC and DC signal. However, the total RMS voltage of a combined signal can be calculated using the following equation.

$$\text{Total RMS voltage} = \sqrt{(\text{AC voltage})^2 + (\text{DC voltage})^2} \qquad (2.1)$$

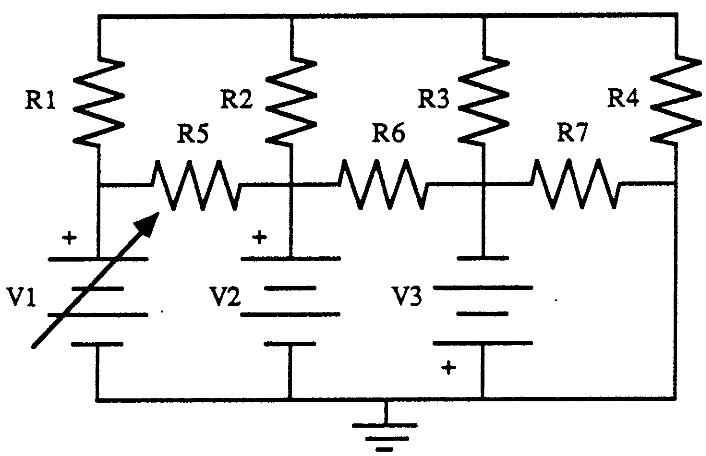
Connect the DMM and oscilloscope directly to the generator's 600 ohm output and set the oscilloscope to DC coupling. Select a 1 KHz sine wave and, using the oscilloscope, set the generator to produce a 4 Vpp signal with +1 V DC offset. Measure both the AC and DC components of the signal using the DMM and the oscilloscope. Repeat the measurements for the triangle and square waves.

Move the test lead to the generator's pulse output. Using the oscilloscope, measure ~~and record the duty cycle (high time vs. low time) of the pulse, its peak-to-peak amplitude, and its vertical position relative to the zero volt reference.~~ its AC and DC components. Measure both the AC and DC components of the pulse using the DMM.

PLEASE CALL A TEACHING ASSISTANT TO CHECK YOUR DATA BEFORE CONTINUING.

Part 4 - Kirchoff's Laws

Build the circuit shown in Fig. 2.3 using your protoboard. Use the RSB for the one resistance which is not a standard value. Use the DMM to measure all of the voltages (including the sources) and all of the currents. Record your measurements in Table 2.7. IF YOU MEASURE ANY CURRENT ABOVE 10 mA YOU ARE DOING SOMETHING WRONG! The meter must be put in series with the resistors (or sources) to measure current. To do this you must disconnect one end of a resistor (or source) from the rest of the circuit and use the meter to bridge the broken connection. Remember to use the "VKS" input for measuring voltage and the "mA" input for measuring current.



R1 - 1.5k R2 - 1.2k ~~R3 - 5.1k~~ 5.6K
~~R4 - 520Ω~~ 560Ω R5 - 12k R6 - 1.2M R7 - 15k
V1 - 10 volts V2 - 5 volts V3 - 15 volts

Figure 2.3 Resistive network

Part 5 - Impedance of the test equipment

Your signal generator has an equivalent circuit such as shown in Figure 2.5 with an internal impedance R_{OUT}.

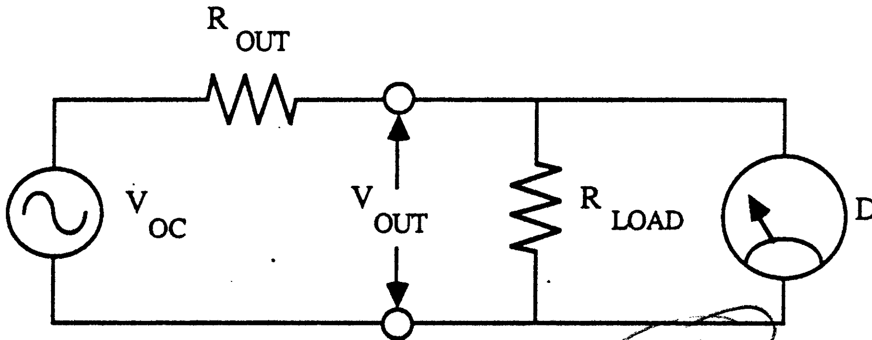


Figure 2.4 at 1kHz — zero volts offset

Set your (ac) signal generator output to 1 volt rms using your DMM. Now connect a 470Ω resistor (R_{LOAD} as shown above) between the output of the signal generator and ground. DO NOT change the signal generator settings. Record the new generator rms output voltage. In Table 2.8.

Construct the circuit shown in Figure 2.5 using 10K resistors for R.

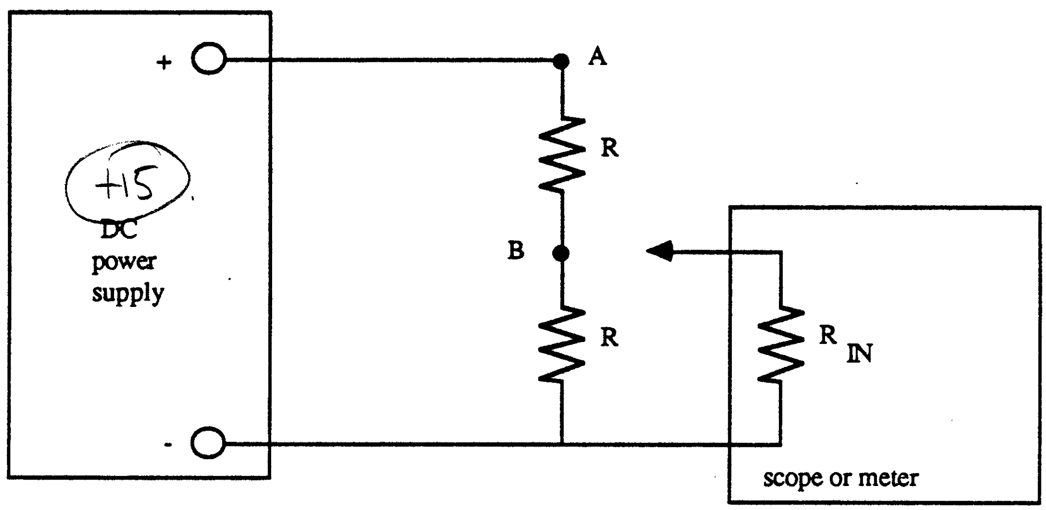


Figure 2.5

Record your results in Table 2.9.

Measure the voltages at points A and B using the DMM. Use the voltage range setting which gives you maximum accuracy. Now repeat your measurements using the oscilloscope. Again use the range setting which allows for maximum accuracy. Do not at any time connect the oscilloscope and DMM inputs together. Repeat your measurements changing R to 100K, 1M and 10M.

PLEASE CALL A TEACHING ASSISTANT TO CHECK YOUR DATA BEFORE LEAVING.

Questions:

1. Plot your results from Table 2.1 and 2.2 on the same graph. What is the significance of the slope of the best fitting line through each set of data? Explain any difference between your results for points A and B in the circuit.
2. Using your data from Tables 2.3 and 2.4 plot V versus $\log_{10} I$ on the same graph for the forward and reverse biased diode and zener diode.
3. Using your results from question 2, what might have happened if you had connected the +5 volt supply directly to the diode you measured? DON'T ACTUALLY TRY IT!
4. (a) Make a graph of your data from Table 2.5 plotting the oscilloscope amplitude on the vertical axis and the log of the frequency on the horizontal axis. Multiply each DMM reading by 2.828 and plot the DMM amplitude on the same graph. frequency response
   (b) Why are the DMM measurements multiplied by 2.828 before plotting?
   (c) Assuming that the oscilloscope measurements are correct, at what frequency does the DMM give a 5% error?
   (d) Should the DMM be trusted when measuring AC signals over 10 KHz?
5. (a) What are the general RMS voltage equations, in terms of the peak voltage times a constant, for the sine, triangle, square and pulse waveforms?
   (b) Calculate the RMS voltages of the four signals using the oscilloscope measurements.
   (c) Calculate the RMS voltages of the four signals using the DMM measurements.
6. (a) Starting from the source voltages and resistance values, calculate the voltage across and current through each resistor in Figure 2.3. Do not use any of your experimental data. Show your work.
   (b) Compare your actual measurements from Table 2.7 to the values you calculated in (a). Why aren't they exactly the same?
   (c) Assuming the voltages and currents you measured were accurate, calculate the actual value of each resistor by using the voltages and currents measured. Were the resistors within their stated tolerances?
7. Using your data from Tables 2.8 and 2.9, calculate R_{OUT} for the signal generator and R_{IN} for the DMM and oscilloscope?

EEAP 243 LAB 2 EVALUATION

NAME (print)_____________________________ CHECKPOINT #1 ___ DATE _____
GRADE _____/_____ CHECKPOINT #2 ___ DATE _____

With respect to the course material, this lab was: (pick one)
___ highly relevant ___ relevant ___ not relevant ___ completely irrelevant

This lab was: (pick one)
___ too long ___ long ___ just right ___ short ___ too short

This lab was: (pick one)
___ too hard ___ hard ___ just right ___ easy ___ too easy

The background material in the lab assignment was: (pick one)
___ too detailed ___ just right ___ sufficient ___ insufficient ___ totally inadequate

The step by step procedures in the lab assignment were: (pick one)
___ too detailed ___ just right ___ sufficient ___ insufficient ___ totally inadequate

Describe any mistakes made in the lab assignment.

Describe anything that just didn't work right.

Describe how this lab could be made better.

QUIZ

NOTE: THE TEACHING ASSISTANT IS TO SELECT BOTH QUESTIONS FROM THE UNDERLINED OPTIONS AT THE SECOND CHECKPOINT

Question #1

sine wave RMS = __________ $\times V_{peak}$

triangle wave RMS = __________ $\times V_{peak}$

square wave RMS = __________ $\times V_{peak}$

Question #2

What will happen to the voltage at point A in Fig.2.1 if we increase/decrease the value of $R_1/R_2/R_3/R_4$?

The voltage will increase / decrease / stay the same.

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NAMES: ____

Lab 2 Data

V	I
________	________
________	________
________	________
________	________
________	________

Table 2.1 V-I characteristics of 20K resistor

V	I
________	________
________	________
________	________
________	________
________	________

Table 2.2 V-I characteristics of 20K resistor

	--- forward biased ---		--- reverse biased ---	
RSB	V	I	V	I
10K	________	________	________	________
20K	________	________	________	________
30K	________	________	________	________
40K	________	________	________	________
50K	________	________	________	________

Table 2.3 V-I characteristics of diode

RSB	--- forward biased --- V	I	--- reverse biased --- V	I
10K				
20K				
30K				
40K				
50K				

Table 2.4 V-I characteristics of zener diode

VERNIER	RANGE	TIME/CM	SCOPE (V_{pp})	DMM (V_{rms})
1	10 Hz	20 mS		
2	10 Hz	10 mS		
5	10 Hz	5 mS		
1	100 Hz	2 mS		
2	100 Hz	1 mS		
5	100 Hz	0.5 mS		
1	1 KHz	0.2 mS		
2	1 KHz	0.1 mS		
5	1 KHz	50 µS		
1	10 KHz	20 µS		
2	10 KHz	10 µS		
5	10 KHz	5 µS		
1	100 KHz	2 µS		
2	100 KHz	1 µS		
5	100 KHz	0.5 µS		
10	100 KHz	0.5 µS		

Table 2.5 - DMM Frequency Response Data

waveform	DMM (DC)	DMM(AC)	Oscilloscope (AC)	Oscilloscope (DC)
sine				
triangle				
square				

Table 2.6 RMS voltages for various waveforms

RESISTOR	VOLTAGE	CURRENT
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Table 2.7 Measured Voltages/Currents in Resistor Mesh Circuit

V_{out}	R_{LOAD}
1.0	∞
	470Ω

Table 2.8 Loaded generator output

R	$V_{A,oscilloscope}$	$V_{B,oscilloscope}$	$V_{A,DMM}$	$V_{B,DMM}$
10K				
100K				
1M				
10M				

Table 2.9 DMM and oscilloscope loading