Introducing Circuit Design in Freshmen Lab

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Abstract

The electrical and computer engineering curriculum at the Klipsch School of Electrical and Computer Engineering at New Mexico State University now requires that students successfully complete a capstone design class (senior design project) before they can graduate. To reach this point, students need guidance and practice in design. If students are exposed to design early in their educations, then the capstone project won't seem like such an insurmountable chore, but more of an interesting challenge. In lab, freshmen are led through the basic principles, and then asked to think about and design circuits. Since this is lab, they can then check their designs by building the circuits and testing them. This then lays the foundation for continued projects that will lead to the capstone class. In this paper, the lab structure and ideas will be presented that encourages students to begin designing circuits.

I. Introduction

Many of the concepts of electrical engineering are based on simple concepts, however, if one has never experienced these concepts before, some of the relationships are difficult to visualize. In the course of re-evaluating the curriculum at the Klipsch School of Electrical and Computer Engineering at New Mexico State University, (NMSU), the faculty decided to add a lab to the introductory circuits class so that the students can experience some part of electrical engineering early in their education at the university. This way, the students begin to feel a part of the department and get to see the basis for all of Electrical Engineering.

Many of the incoming freshmen at NMSU are not ready for calculus, or are just ready to begin first-semester calculus and so are required to fulfill their math obligations before taking Electrical Engineering, (EE), classes. This introductory circuits class is designed to use mostly algebra, and later in the course to use some basic derivatives. This way students can begin taking and experiencing EE before they finish the calculus sequence.

Many incoming freshmen also have not had the opportunity to tinker around with electronic components, and so have no "feel" for the basics that students 15 to 20 years ago seemed to have. Somehow they have missed knowing what a short circuit is and the damage it can cause. Much of this practical experience is no longer present in our incoming freshmen. At the capstone level, it has been noted that students don't really know what they need to do. They lack insight and experience into design and planning a substantial project.

This freshman level circuits class has been designed to give this hands on experience that has been found lacking. Students who complete this class will have had exposure to simple design problems that build the foundation for future design projects. This paper will describe the labs that have been set up and how design has been introduced into the labs to encourage the students to think critically and understand the concepts they are attempting to learn.

II. Lab set up

The first three labs introduce the basic concepts needed in EE. These labs are designed to help the students learn to measure voltage, current and resistance as well as to become familiar with the basic equipment in the lab e.g. power supplies, soldering irons, and meters. As the students become familiar with the circuit elements, the first design is introduced. The students have just completed a lab on equivalent resistance and now they must design a circuit that measures a given resistance across two of the terminals using only certain resistors. They must obtain this design with a certain tolerance. Once the design is complete, they then measure the amount of resistance to confirm that the design is correct. The lab instructor must also witness this measurement and verify that the specifications have been met.

The labs now progress to more advanced concepts. One of the fundamental concepts in EE is voltage division and the concept of maximum power delivered to a load. In this voltage division lab experiment, the students are led through a series of circuits so they can experience and plot their results and see that voltage division does work, and that there is a point where the power to a load is a maximum. Once this concept has been firmly rooted, the students are faced with a dose of reality. A circuit is given that seems so defy the concept they just learned. Students are then encouraged to think about what is happening and to investigate their equipment and the limits of their equipment. Once they have determined the problem, they are asked to think of ways to solve this erroneous reading and get correct results again. Another design is then proposed for them to expand on the concepts learned to design a two stage voltage divider. This particular lab has been included with this paper as an example of how design can be incorporated into the lab.

The following labs allow students to see that the theory learned in class does indeed work. Labs focusing on different types of circuit analysis are then completed. These techniques include Nodal analysis, mesh analysis, superposition, and Thevenin equivalent circuits. The students witness that these techniques are valid. This series of labs is again topped off with a design problem. They need to use concepts from the Thevenin and voltage division labs to design an interface between a source and a load that has a given resistance. Students are also asked to look at the practical side of the Thevenin circuit and figure out how to determine the internal resistance of a battery.

The remaining labs have the students apply their learned circuit analysis techniques to various applications: LED’s, diodes, Op Amps, capacitors, and inductors. They learn to use more equipment like frequency generators, and oscilloscopes. The lab experience is then culminated with a lab project. They must put together a kit (that includes soldering, and intermediate testing). They must get their kit to work, investigate why it does what it does, and report their findings to their lab sections in an oral report.

III. Summary

At the end of the semester, students have gained much needed hands on experience and have become familiar with the equipment they will continue to use in other labs. They have gained self confidence in their circuit abilities and have designed and built several circuits. Each design was checked and verified by the lab instructor. If the design didn't work, the students had to re-do the design until it did work. Each student has indicated[2] that this lab is a positive experience and that they have gained useful information from participation in the labs. The first students through this newly designed curriculum are currently sophomores and have not yet reached the capstone level. When they do reach the capstone class, the capstone faculty will be surveyed to determine if the student's preparation level has increased. A sample of the lab on Volage Division is included in the Appendix to this paper.

Bibliography

1. The Ethics Challenge, produced by Lockheed Martin Corporation, Westlake Village CA, 1998
2. Student course evaluations, Fall 1998, Spring 1999.

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Appendix: Sample Lab

Lab 4
Voltage and Current Division

Objective: The purpose of this lab is to become familiar with voltage division and current division and understand what is happening in the circuit (with respect to current, voltage, and power)

Parts Needed:

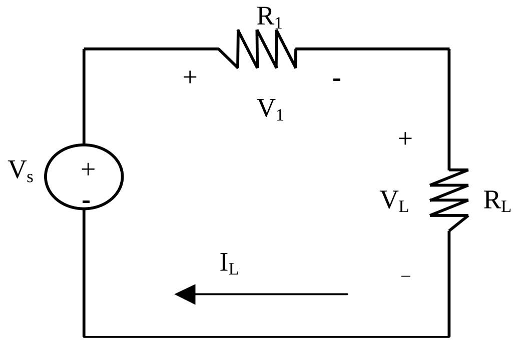
1	1KΩ resistor
1	2KΩ resistor
2	5.1 KΩ resistors
1	10KΩ resistor
2	18KΩ resistors
?	other resistors from your tool box as needed for design
2	10MΩ resistors
1	9 volt battery

Digital Multimeter (DMM)

Part I: Voltage Dividers

You will be building several voltage dividers in this lab. Please record all of your results in the tables provided.

Observe the circuit below. The L subscript refers to Load. Hence V_L is the load voltage, and R_L is the load resistor.



Component	Theoretical Value	Actual measured Value	Calculated from measured Values
V_s	9v		X
R_1	5.1KΩ		X
R_L	10KΩ		P_A=
V_1			
V_L			
I_L			

Procedure:

1. Calculate the expected voltages for each case and place these values in the Theoretical Value column.
2. Measure the resistor values. Place these values in the Actual Measured Value column.
3. Build the circuit in the above diagram and measure the voltages and the current. Place these values in the Actual Measured column.
4. Use the measured values of V_S , R_1, and R_L, to calculate new expected values for the voltages and the current. Place these values in the last column.
5. Calculate the Power Absorbed by the load resistor using the measured voltage and measured resistance values. Recall that $P=vi=v^2/R$.
6. Now, change R_L to 5.1KΩ and repeat steps 1 through 5. Record the results in the table below.
7. Lastly, change R_L to 1KΩ and repeat steps 1 through 5. Record the results in the table below.

Component	Theoretical Value	Actual measured Value	Calculated from measured Values
V_s	9v		X
R_1	5.1KΩ		X
R_L	5.1KΩ		P_A=
V_1			
V_L			
I_L			

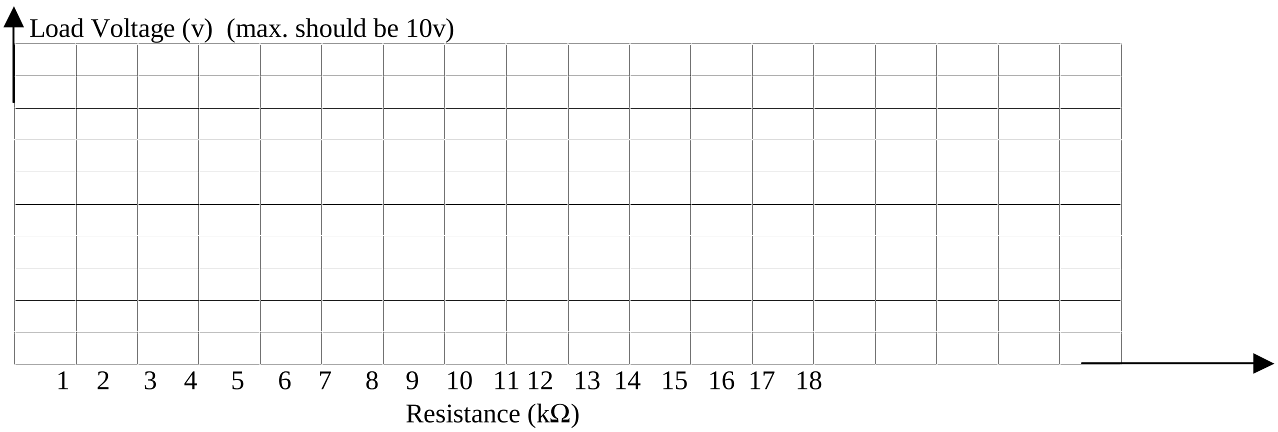
Component	Theoretical Value	Actual measured Value	Calculated from measured Values
V_s	9v		X
R_1	5.1KΩ		X
R_L	1KΩ		P_A=
V_1			
V_L			
I_L			

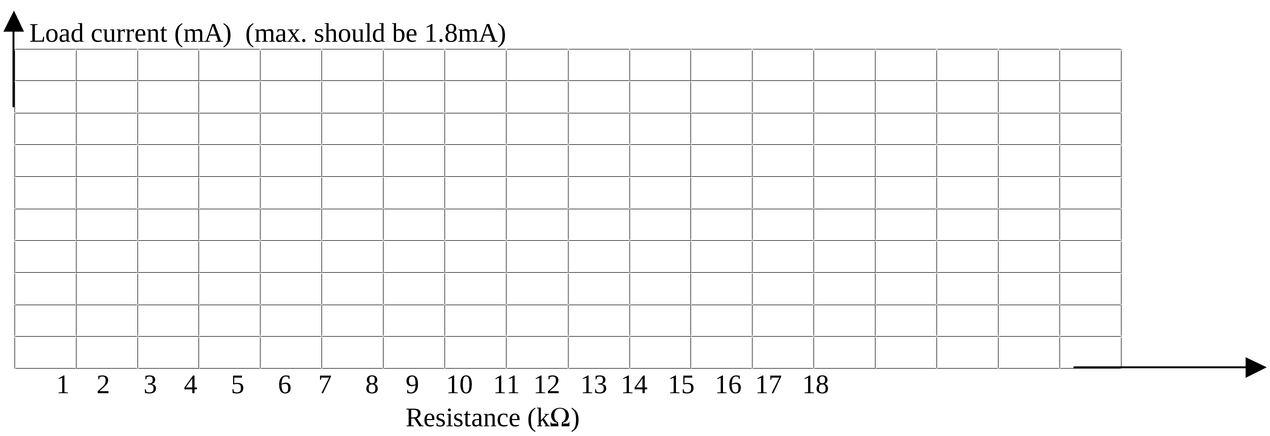
Observations:

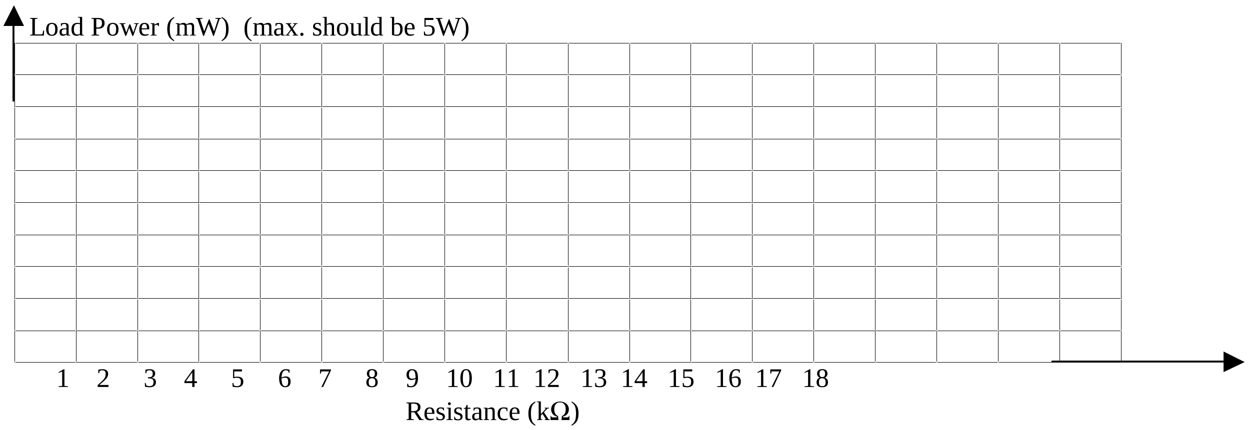
What do you observe from the tables? Do the voltages add up correctly (i.e. is KVL still working)?

Did the voltage "divide" the way you think it should?

Plot the load voltage, load current, and power absorbed by the load on the following plots. Add more points by measuring results for R_L = 2KΩ and 18KΩ or by calculating the results for these values.





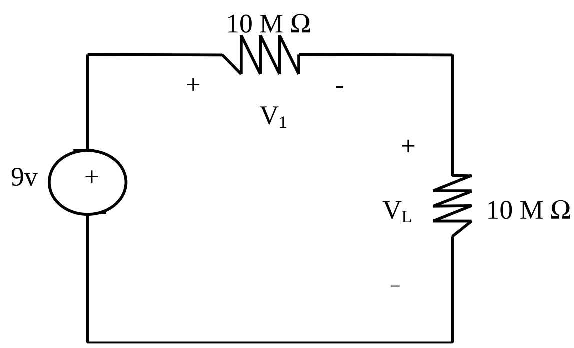


What do you notice about the voltage to the load?

What do you notice about the current to the load?

What do you notice about the power to the load?

Now, build the circuit below and make the voltage calculations and measurements:



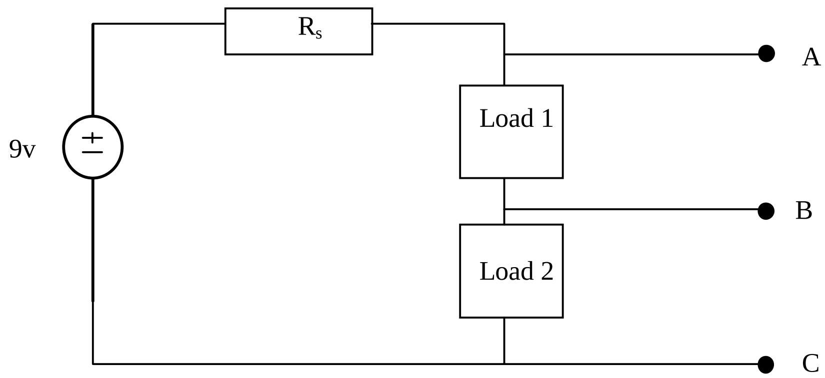
Component	Expected Value	Measured Value
V_1		
V_L		

Did you get the results that you expected? Explain why or why not.

What is the problem with this circuit?

How can we fix the problem?

Design a circuit that will divide the voltage so that we could have 3v and/or 1.5v. You need to design the 2 load portions and the R_s portion so that you can measure 3v across the 1st and 2nd load and 1.5v across just the 2nd load. You need to be within 0.1 volts. Use the diagram below as an aid for your design.



The voltage V_{AC} = 3 v,   and V_{BC} = 1.5 v
Draw your design below. Each of the loads can be thought of as a single resistor. As you work on your design, write down the equations that you need to solve this problem. (Make sure you have enough equations – the number of unknowns should equal the number of equations).
Measure the voltages to ensure you are within the specifications. Show your derivations and results.   Have your lab TA verify that your design works.

Lab TA sign for verification:___________________________________

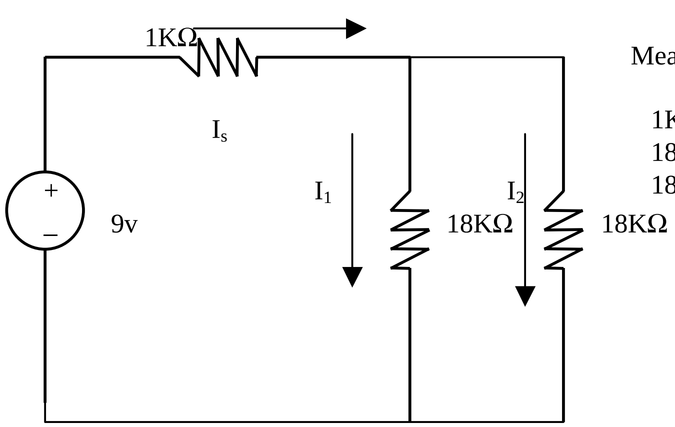
V_{AC} = _______________________

V_{BC} = _______________________

Part II: Current Division

Procedure:

1. Lay out the circuit below:



Measured Resistance

1KΩ → ________
18KΩ→ ________
18KΩ→ ________

2. Calculate what the currents should be (use measured values)
3. Measure the currents.

Components	Calculated Values	Measured Values
I_s		
I_1		
I_2		

Does the current divide as you expected? Comment on any differences you've encountered.

SUMMARY:

Does Voltage Division work as predicted?

What value resistance gives the maximum power to the load?

Generalize the above statement: Given a Thevenin circuit with source voltage V_s and resistance R_s, what value load resistor is needed to deliver the maximum power to the load?

Does current division work as predicted?

What things do you need to be aware of when measuring voltage and current?