AC 2007-2047: INNOVATIVE TECHNOLOGY IN THE CLASSROOM

Jimmy Linn, East Carolina University

Jimmy Linn is a Teaching Instructor at East Carolina University. He received his B.Sc. in Electrical Engineering and Mathematics from Rose Hulman Institute of Technology and M.Sc. in Electrical Engineering from Purdue University. He completed a 23 year career with the U.S. Navy as an Electrical Engineer, 11 of which were in research engineering, before getting into academia as an Instructor.

Innovative Technology in the Classroom

The purpose of this paper is to discuss the advantages, disadvantages, and applications of some innovative technologies in the classroom. I have chosen to concentrate on one such technology in this paper. This technology is the use of computer based laboratory experiments in lieu of or to supplement hands-on laboratory experiments. I will focus on computer based lab experiments. The driving force behind this technology is to speed up student progress on laboratory experiments and make the learning experience in the lab more efficient. I choose the electrical field to concentrate my discussion because my background is in electronics and I have significant experience teaching electrical courses with accompanying labs.

I will first give some background information to you so that you may better understand the motivation behind searching for an improved method of conducting electronics laboratory classes. In what I call the beginning, before computer based learning and other computer based tools in the classroom, lab experiments were performed as hands-on experiments with actual parts. These parts were hand wired usually using a proto-board or some similar type of hand wiring device. This method was sound and gave students good first hand practical knowledge of how to wire circuits, and how different electronic circuits worked. The value of hands-on knowledge can not be underestimated. However, this method does have its drawbacks. Students often make wiring mistakes which result in time consuming correction efforts and the replacement of burned out components. In my experience, this can add up to 50% more time to the completion time of the lab experiment. In addition, an inventory of replacement parts must be maintained to assure lab progress continues. The purpose of a lab experiment is to reinforce concepts discussed in the lecture part of the course as well as give the student hands-on experience. These delays tend to throw the labs out of synchronization with the lectures they are to support. As a result, lecture concepts do not always get the practical reinforcement they need for students to fully understand theoretical concepts discussed in those lectures. An alternative approach is to use computer based lab assignments that simulate real live electronic circuits to complement real live parts labs so that concepts may be more efficiently reinforced as well as giving the student the necessary hands-on experience.

Some advantages are that computer based labs greatly reduce wiring error correction time, and totally eliminate burned out components. Simulated wiring is easy, and virtually any standard electronic component is available in the circuit simulation software. Another advantage of computer simulated lab experiments is that large part inventories are not necessary. In addition, since most students now have PCs and/or laptops, simulated lab homework assignments may be made to better prepare the student before his or her lab experience. This too will make the labs more effective as well as efficient. These are some of the advantages of computer simulated laboratory experiments. Figures 2 and 3 are examples of Computer simulated laboratory experiments from two different lab manuals. Figure 2 is an experiment from **Computer Simulated Experiments for Electric Circuits Using Electronics Workbench Multisim®,** by Richard H. Berube. Figure 3 is an experiment from **Computer Simulated Experiments for Electronic Devices Using Electronics Workbench Multisim®**, by Richard H. Berube.

Name________________________________

Date________________________________

EXPERIMENT

6

Series-Parallel Circuits

Objectives:

1. Measure the equivalent resistance of a series-parallel circuit and compare your measured value with the calculated value.
2. Measure the current in each resistor in a series-parallel circuit and compare your measured values with the calculated values.
3. Measure the voltage across each resistor in a series-parallel circuit and compare your measured values with the calculated values.
4. Determine the equivalent resistance of a series-parallel circuit based on the circuit current and voltage.

Materials:

One 0–20 V dc voltage supply
One multimeter
Three 0–10 V dc voltmeters
Three 0–5 mA dc milliammeters
Resistors—2 kΩ and 4 kΩ

Theory:

A series-parallel circuit can be defined as one in which some portions of the circuit consist of circuit elements in series and other portions of the circuit consist of circuit elements in parallel. When two or more circuit elements are in series, all of the characteristics of a series circuit apply. When two or more circuit elements are in parallel, all of the characteristics of a parallel circuit apply. Therefore, to find the equivalent resistance of a series-parallel circuit, you must combine all of the series circuit elements to obtain the equivalent of the series portion of the circuit and combine all of the parallel circuit elements to obtain the equivalent of the parallel portion of the circuit until there is only one equivalent resistance left. **To learn how to combine series and parallel resistances, you must complete Experiments 4 and 5 before attempting this experiment.**

Figure 2-A - Experiment from Computer Simulated Experiments for Electric Circuits Using Electronics Workbench Multisim, Richard H. Berube, Third Edition, Prentice Hall

The equivalent resistance of the circuit in Figure 6-1 can be found from

$$R_{34} = R_3 + R_4$$

$$\frac{1}{R_{234}} = \frac{1}{R_2} + \frac{1}{R_{34}}$$

$$R_{eq} = R_1 + R_{234}$$

The equivalent resistance of the circuit in Figure 6-2 can be found from

$$R_{56} = R_5 + R_6$$

$$\frac{1}{R_{456}} = \frac{1}{R_4} + \frac{1}{R_{56}}$$

$$R_{3456} = R_3 + R_{456}$$

$$\frac{1}{R_{23456}} = \frac{1}{R_2} + \frac{1}{R_{3456}}$$

$$R_{eq} = R_1 + R_{23456}$$

To calculate the currents and voltages in all of the circuit elements in a series-parallel circuit, you must understand Ohm's law and Kirchhoff's current and voltage laws. These laws were studied in Experiments 2, 4, and 5. The circuits in Figures 6-3 and 6-4 are identical to the circuits in Figures 6-1 and 6-2 respectively, except that ammeters and voltmeters are connected for making current and voltage measurements and a voltage source is connected across terminals a-b in place of the multimeter.

Figure 6-1 Series-Parallel Resistors—Equivalent Resistance

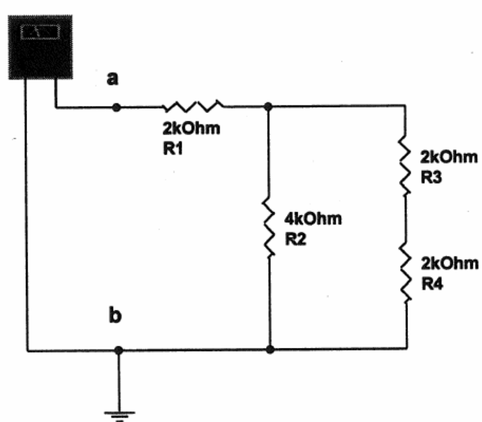


Figure 2-B

Figure 6-2 Series-Parallel Resistors—Equivalent Resistance

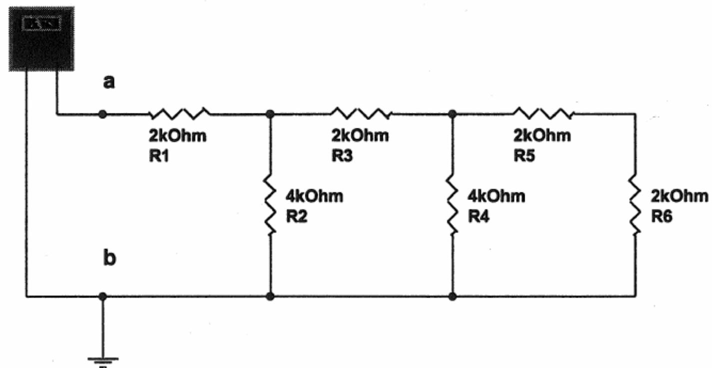


Figure 6-3 Series-Parallel Resistors—Voltage and Current Measurements

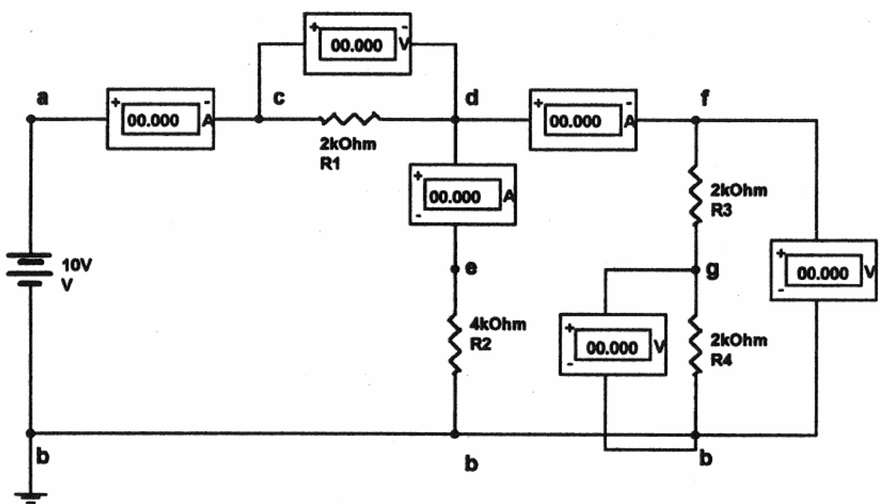


Figure 6-4 Series-Parallel Resistors—Voltage and Current Measurements

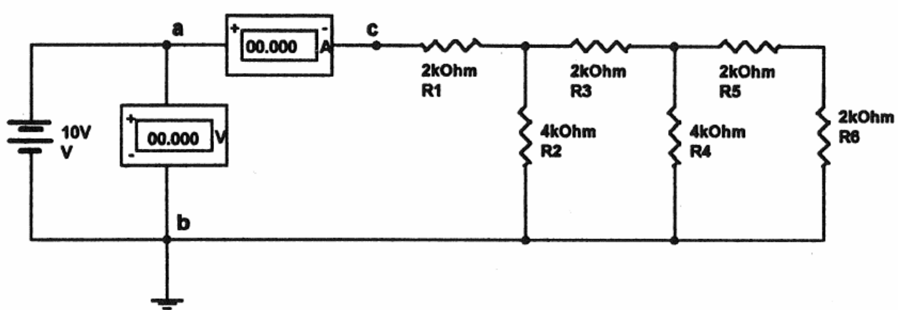


Figure 2-C

The equivalent resistance of the circuit in Figure 6-1 can be found from

$$R_{34} = R_3 + R_4$$

$$\frac{1}{R_{234}} = \frac{1}{R_2} + \frac{1}{R_{34}}$$

$$R_{eq} = R_1 + R_{234}$$

The equivalent resistance of the circuit in Figure 6-2 can be found from

$$R_{56} = R_5 + R_6$$

$$\frac{1}{R_{456}} = \frac{1}{R_4} + \frac{1}{R_{56}}$$

$$R_{3456} = R_3 + R_{456}$$

$$\frac{1}{R_{23456}} = \frac{1}{R_2} + \frac{1}{R_{3456}}$$

$$R_{eq} = R_1 + R_{23456}$$

To calculate the currents and voltages in all of the circuit elements in a series-parallel circuit, you must understand Ohm's law and Kirchhoff's current and voltage laws. These laws were studied in Experiments 2, 4, and 5. The circuits in Figures 6-3 and 6-4 are identical to the circuits in Figures 6-1 and 6-2 respectively, except that ammeters and voltmeters are connected for making current and voltage measurements and a voltage source is connected across terminals a-b in place of the multimeter.

Figure 6-1 Series-Parallel Resistors—Equivalent Resistance

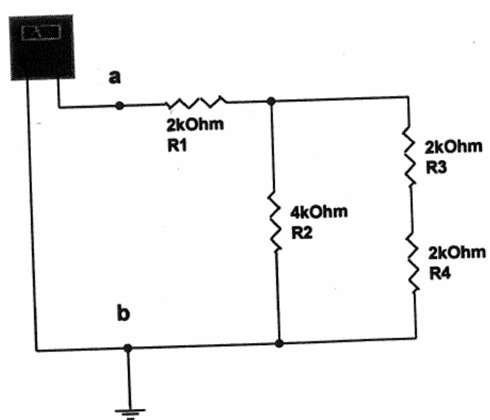


Figure 2-D

Procedure:

Step 1. Pull down the File menu and open FIG6-1. Using the multimeter to measure the equivalent resistance of the series-parallel circuit, click the On-Off switch to run the simulation. Record the equivalent resistance of the series-parallel circuit. Make sure Ω is selected on the multimeter.

R_{eq} = ________

Step 2. Calculate the equivalent resistance of the series-parallel circuit in Figure 6-1.

Question: How did the calculated equivalent resistance in Step 2 compare with the measured equivalent resistance in Step 1?

Step 3. Pull down the File menu and open FIG6-2. Using the multimeter to measure the equivalent resistance of the series-parallel circuit, click the On-Off switch to run the simulation. Record the equivalent resistance of the series-parallel circuit. Make sure Ω is selected on the multimeter.

R_{eq} = ________

Step 4. Calculate the equivalent resistance of the series-parallel circuit in Figure 6-2.

Question: How did the calculated equivalent resistance in Step 4 compare with the measured equivalent resistance in Step 3?

Figure 2-E

Step 5. Pull down the File menu and open FIG6-3. Click the On-Off switch to run the simulation. Record currents I_{ac}, I_{de}, and I_{df}, and voltages V_{cd}, V_{fb}, and V_{gb}.

I_{ac} = __________ I_{de} = __________ I_{df} = __________

V_{cd} = __________ V_{fb} = __________ V_{gb} = __________

Question: What is the relationship between currents I_{ac}, I_{de}, and I_{df}? Does this relationship confirm Kirchhoff's current law?

Step 6. Based on the equivalent resistance (R_{eq}) calculated in Step 2 and the value of voltage source V, calculate the circuit current (I_{ac}).

Question: How did the calculated value for I_{ac} compare with the measured value in Step 5?

Step 7. Based on the value of current I_{ac} calculated in Step 6, calculate voltage V_{cd}.

Question: How did the calculated value for V_{cd} compare with the measured value in Step 5?

Step 8. Based on the value of voltage V_{cd} and source voltage V, use Kirchhoff's voltage law to calculate voltage V_{fb}.

Figure 2-F

Question: How did the calculated value for V_{fb} compare with the measured value in Step 5?

Step 9. Based on the value of voltage V_{fb}, calculate currents I_{de} and I_{df}.

Question: How did the calculated values for currents I_{de} and I_{df} compare with the measured values in Step 5?

Step 10. Based on current I_{df}, calculate voltage V_{gb}.

Question: How did the calculated value for voltage V_{gb} compare with the measured value in Step 5?

Step 11. Based on current I_{df}, calculate voltage V_{fg}.

Question: What is the relationship between voltages V_{fg}, V_{gb}, and V_{fb}?

Step 12. Based on the source voltage V and the measured circuit current I_{ac}, calculate the equivalent resistance (R_{eq}) of the series-parallel circuit in Figure 6-3.

Figure 2-G

Question: How did the calculated value of the equivalent resistance in Step 12 for the circuit in Figure 6-3 compare with the equivalent resistance measured in Step 1?

Step 13. Pull down the File menu and open FIG6-4. Click the On-Off switch to run the simulation. Record voltage V_{ab} and current I_{ac}.

V_{ab} = __________ I_{ac} = __________

Step 14. Based on the voltage and current measured in Step 13, calculate the equivalent resistance of the series-parallel circuit in Figure 6-4.

Question: How did the calculated value of the equivalent resistance in Step 14 for the circuit in Figure 6-4 compare with the equivalent resistance measured in Step 3?

Troubleshooting Problems

1. Pull down the File menu and open FIG6-5. Click the On-Off switch to run the simulation. Based on the current and voltage readings, determine the resistance of R_1, R_2, and R_3.

   R_1 = __________ R_2 = __________ R_3 = __________

2. Pull down the File menu and open FIG6-6. Click the On-Off switch to run the simulation. Based on the current reading, determine the voltage of voltage source V.

   V = __________

Figure 2-H

3. Pull down the File menu and open FIG6-7. Click the On-Off switch to run the simulation. Based on the current and voltage readings, determine the resistance of R_1, R_2, R_3, and R_4.

R_1 = ________ R_2 = ________

R_3 = ________ R_4 = ________

4. Pull down the File menu and open FIG6-8. Click the On-Off switch to run the simulation. Based on the current and voltage readings, determine the defective component and the defect.

Defective component ________ Defect ________

5. Pull down the File menu and open FIG6-9. Click the On-Off switch to run the simulation. Using the multimeter, determine the defective component and the defect.

Defective component ________ Defect ________

6. Pull down the File menu and open FIG6-10. Click the On-Off switch to run the simulation. Using the multimeter, determine the defective component and the defect.

Defective component ________ Defect ________

Figure 2-I

EXPERIMENT

20

Name____________________

Date____________________

Large-Signal Class A Amplifier

Objectives:

1. Determine the dc load line and locate the operating point (Q-point) on the dc load line for a large-signal class A common-emitter amplifier.
2. Determine the ac load line for a large-signal class A common-emitter amplifier.
3. Center the operating point (Q-point) on the ac load line.
4. Determine the maximum ac peak-to-peak output voltage swing before peak clipping occurs and compare the measured value with the expected value.
5. Observe nonlinear distortion of the output waveshape.
6. Measure the large-signal voltage gain of a class A common-emitter amplifier and compare the measured and calculated values.
7. Measure the maximum undistorted output power for a class A amplifier.
8. Determine the amplifier efficiency of a class A amplifier.

Materials:

One 2N3904 bipolar junction transistor
One 20 V dc power supply
Capacitors: two 10 μF, one 470 μF
One digital multimeter
One function generator
One dual-trace oscilloscope
Resistors: one 5 Ω, one 95 Ω, two 100 Ω, one 1 kΩ, one 2.4 kΩ

Theory:

A **power amplifier** is a **large-signal amplifier** that normally provides power to an antenna or speaker in the final stage of a communications transmitter or receiver. When an amplifier is biased so that it operates in the linear region (between saturation and cutoff) of the transistor collector characteristic curve plot for the full 360 degrees of the input sine wave cycle, it is classified as a **class A amplifier**. This means that collector current flows during the full input sine wave cycle, making class A amplifiers the **least efficient** of the different classes of large-signal amplifiers. In a large-signal amplifier, the input signal causes the operating point (Q-point) to move over a much larger portion of the ac load line than in a small-signal amplifier. Therefore, large-signal class A amplifiers require the operating point to be as close as possible to the center of the ac load line to avoid clipping of the output waveform. In a class A amplifier, the output voltage waveform has the same shape as the input voltage waveform, making it the **most linear** of the different classes of large-signal amplifiers. Most small-

Figure 3-A - Experiment from Computer Simulated Experiments for Electronics Devices Using Electronics Workbench Multisim, Richard H. Berube, Third Edition, Prentice Hall

signal amplifiers are class A amplifiers. In this experiment you will study a large-signal class A amplifier.

For the large-signal class A common-emitter amplifier shown in Figures 20-1 and 20-2, the **dc collector-emitter voltage (V_{CE})** can be calculated from

$$V_{CE} = V_C - V_E$$

The **dc collector current (I_C)** can be found by calculating the current in the collector resistor (R_C). Therefore,

$$I_C = \frac{V_{CC} - V_C}{R_C}$$

The **ac collector resistance (R_c)** is equal to the parallel equivalent of the collector resistor (R_C) and the load resistor (R_L). Therefore,

$$R_c = \frac{R_C R_L}{R_C + R_L}$$

The **ac load line** has a slope of $1/(R_c + R_e)$ and crosses the dc load line Q-point. (See Theory in Experiment 18 to locate the dc load line and the Q-point). The ac load line crosses the horizontal axis of the transistor collector characteristic curve plot at V_{CE} equal to $V_{CEQ} + (I_{CQ})(R_c + R_e)$, where V_{CEQ} is the collector-emitter voltage at the Q-point and I_{CQ} is the collector current at the Q-point.

The **amplifier voltage gain** is measured by dividing the ac peak-to-peak output voltage (V_o) by the ac peak-to-peak input voltage (V_{in}). The **expected amplifier voltage gain (A_V)** for a common-emitter amplifier is calculated from

$$A_V = \frac{R_c}{r_e + R_e}$$

where R_c is the ac collector resistance, $r_e \cong 25\ mV/I_E(mA)$, and R_e is the unbypassed emitter resistance.

In order to center the Q-point on the ac load line, you must try different values of R_E until V_{CEQ} is equal to $(I_{CQ})(R_c + R_e)$, where $I_{CQ} \cong I_{EQ} = V_E/(R_E + R_e)$, $V_{CEQ} = V_{CC} - I_{CQ}(R_E + R_e + R_C)$, R_c is equal to the ac collector resistance, and R_C is equal to the dc collector resistance.

The **amplifier output power (P_o)** can be calculated as follows:

$$P_o = \frac{V_{rms}^2}{R_L} = \frac{V_{o(p-p)}^2}{8R_L}$$

where $V_{o(p-p)}$ is the peak-to-peak output voltage and $V_{rms} = V_{o(p-p)}/2\sqrt{2}$.

Figure 3-B

The **efficiency** (η) of a large-signal amplifier is equal to the maximum output power (P_o) divided by the power supplied by the source (P_S) times 100%. Therefore,

$$\eta = \frac{P_o}{P_S}(100\%)$$

where $P_S = (V_{CC})(I_S)$. The current at the source (I_S) is determined from

$$I_S = I_{12} + I_{CQ}$$

where $I_{12} = V_{CC}/(R_1 + R_2)$. *Note*: I_{12} is the current in resistors R_1 and R_2, neglecting the base current.

Figure 20-1 Large-Signal Class A Amplifier, DC Analysis

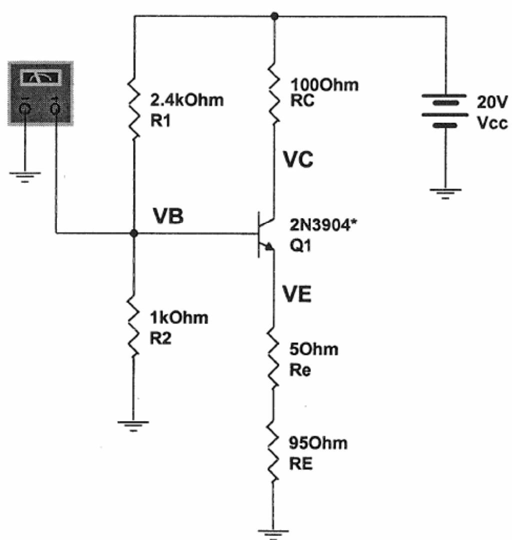
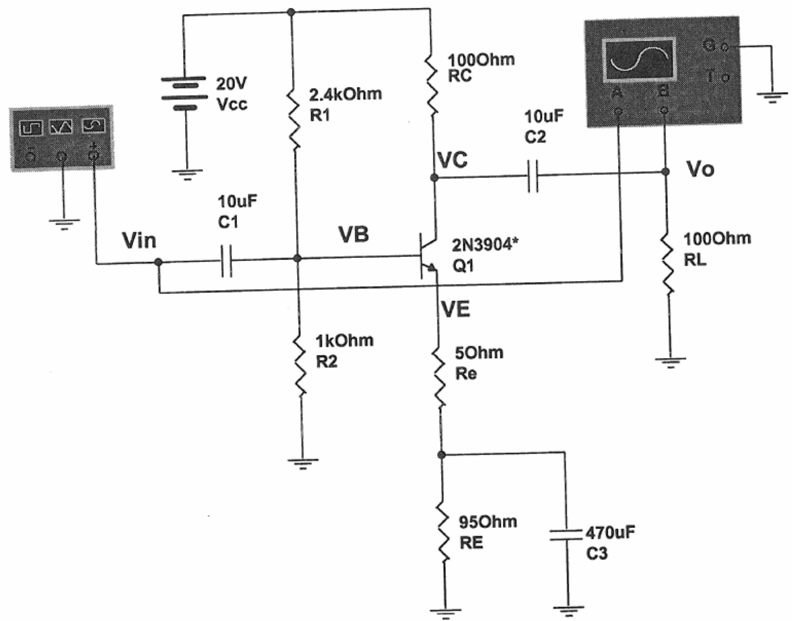


Figure 3-C

Figure 20-2 Large-Signal Class A Amplifier



Procedure:

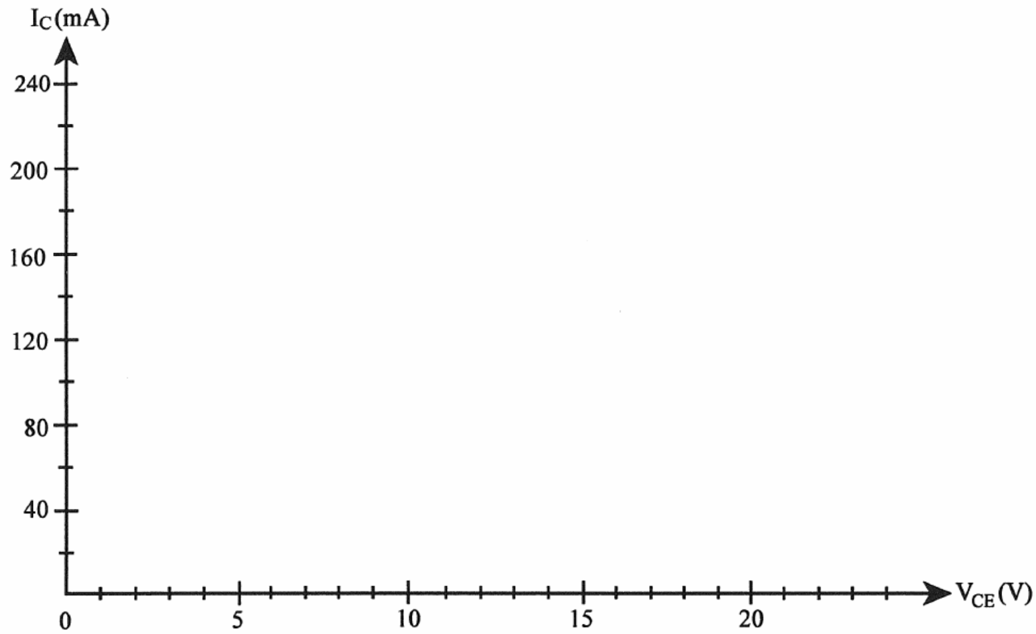
Step 1. Open circuit file FIG20-1. Bring down the multimeter enlargement and make sure that the following settings are selected: V, DC (——). Run the simulation. After steady state has been reached, record the dc base voltage (V_B). Next, move the multimeter positive lead to node V_E, run the simulation, and record the dc emitter voltage (V_E). Then move the multimeter positive lead to node V_C, run the simulation, record the dc collector voltage (V_C), then pause the simulation.

V_B = ________ V_E = ________ V_C = ________

Step 2. Based on the voltages recorded in Step 1, calculate the dc collector-emitter voltage (V_{CE}) and the dc collector current (I_C).

Figure 3-D

Step 3. Draw the dc load line on the graph provided. Based on the calculations in Step 2, locate the operating point (Q-point) on the dc load line.



Step 4. Open circuit file FIG20-2. Bring down the oscilloscope enlargement and make sure that the following settings are selected: Time base (Scale = 100 μs/Div, Xpos = 0, Y/T), Ch A (Scale = 200 mV/Div, Ypos = 0, AC), Ch B (Scale = 2 V/Div, Ypos = 0, AC), Trigger (Pos edge, Level = 0, Nor, A). Bring down the function generator enlargement and make sure that the following settings are selected: *Sine Wave*, Freq = 2 kHz, Ampl = 250 mV, Offset = 0. Based on the value of R_C and R_L, calculate the ac collector resistance (R_c), and then draw the ac load line through the Q-point on the graph in Step 3.

Questions: Is the operating point (Q-point) in the center of the dc load line? In the center of the ac load line?

Figure 3-E

Why is it necessary for the Q-point to be in the center of the ac load line for large-signal inputs?

Step 5. Run the simulation. Keep increasing the input signal voltage on the function generator until output (blue curve plot) peak distortion begins to occur. Then reduce the input signal level until there is no longer any output peak distortion. *Pause* the simulation and record the maximum undistorted ac peak-to-peak output voltage (V_o) and the ac peak-to-peak input voltage (V_{in}).

V_{in} = __________ V_o = __________

Step 6. Based on the voltages measured in Step 5, determine the voltage gain (A_V) of the amplifier.

Step 7. Calculate the expected voltage gain (A_V) based on the value of the ac collector resistance (R_c), the unbypassed emitter resistance (R_e), and the transistor ac emitter resistance (r_e), where $r_e \cong 25mV/I_E(mA)$.

Questions: How did the measured amplifier voltage gain compare with the calculated voltage gain?

What effect does unbypassed emitter resistance have on the amplifier voltage gain? On the voltage gain stability?

Figure 3-F

Step 8. Calculate the value of R_E required to center the Q-point on the ac load line. *Hint*: Try different values of R_E until $V_{CEQ} = (I_{CQ})(R_c + R_e)$ at the new Q-point. See Theory for details.

Question: Did you need to increase or decrease R_E to center the Q-point on the ac load line? **Explain why.**

Step 9. Change R_E to the value calculated in Step 8 and repeat the procedure in Step 5. Record the maximum undistorted ac peak-to-peak output (blue curve plot) voltage (V_o) and the ac peak-to-peak input voltage (V_{in}) for this centered Q-point.

V_{in} = __________ V_o = __________

Question: How did the maximum undistorted peak-to-peak output voltage measured in Step 9, for the centered Q-point, compare with the maximum undistorted peak-to-peak voltage measured in Step 5, for the original Q-point that was not centered?

Step 10. Calculate the new dc values for I_{CQ} and V_{CEQ} for the new value of R_E. Locate the new dc load line and the new Q-point. Draw the new ac load line through the new Q-point.

Figure 3-G

Question: Was the new Q-point near the center of the new ac load line?

Step 11. Based on the new centered Q-point on the new ac load line, estimate what the maximum ac peak-to-peak output voltage (V_o) should be before output clipping occurs.

V_o = __________

Question: How did the maximum undistorted peak-to-peak output voltage measured in Step 9, for the centered Q-point, compare with the expected maximum estimated in Step 11? **Explain any difference.**

Step 12. Based on the maximum undistorted ac peak-to-peak output voltage (V_o) measured in Step 9, calculate the maximum undistorted output power (P_o) to the load (R_L).

Step 13. Based on the supply voltage (V_{CC}), the new collector current at the new operating point (I_{CQ}), and the bias resistor current (I_{12}), calculate the power supplied by the dc voltage source (P_S).

Step 14. Based on the power supplied by the dc voltage source (P_S) and the maximum undistorted output power (P_o) calculated in Step 12, calculate the efficiency (η) of the amplifier.

Question: Is the efficiency of a class A amplifier high or low? **Explain.**

Figure 3-H

Troubleshooting Problems

1. Open circuit file FIG20-3 and run the simulation. Locate the defective component and state the defect (short or open). You can use any instrument available and make any measurement desired.

   Defective component: ____________ Defect: __________

2. Open the circuit file FIG20-4 and run the simulation. Locate the defective component and state the defect (short or open). You can use any instrument available and make any measurement desired.

   Defective component: ____________ Defect: __________

3. Open circuit file FIG20-5 and run the simulation. Locate the defective component and state the defect (short or open). You can use any instrument available and make any measurement desired.

   Defective component: ____________ Defect: __________

4. Open circuit file FIG20-6 and run the simulation. Locate the defective component and state the defect (short or open). You can use any instrument available and make any measurement desired.

   Defective component: ____________ Defect: __________

5. Open circuit file FIG20-7 and run the simulation. Locate the defective component and state the defect (short or open). You can use any instrument available and make any measurement desired.

   Defective component: ____________ Defect: __________

Figure 3-I

Some of the disadvantages are that an initial investment of sufficient computing resources in the lab to provide for student needs is necessary, students must be computer literate, and the hands-on experience gained through traditional labs is lost. But now let's analyze the extent of these disadvantages. First, lets look at the computing resource requirement. In past years, this could have been significant. But recently with the price of computers coming down and with the networking capabilities of these computers, and competitive prices for simulation software such as Labview© and Multisim©, the cost of these resources are no greater than the cost of lab equipment for hands-on experiments. And these costs may be offset either partially or entirely by a reduction of parts inventories and less lab equipment. Now lets look at computer literacy of students. Computers are a required tool in many academic disciplines and computer literacy is expected. In technology fields, employers expect computer literacy. That leaves the loss of hands-on experience. This argument will no doubt continue for years to come. Employers will no doubt want as much hands-on knowledge as a school can give them. Academic institutions will continue to claim that what sets their graduates apart from hands-on craftsmen is the theoretical, conceptual and problem solving knowledge taught them by the academic institution. And that makes them more valuable. It is this argument that causes colleges, universities and other academic institutions to maintain both hands-on and computer based lab tools in their laboratories.

I am not suggesting that all electronics labs be converted to computer based labs. It has been my experience that a range of from 33% to 67% of computer based lab experiments is a good starting point. The learning environment, types of students and other factors will serve to fine tune this percentage. It is very important to remember that the use of new and innovative methods in the classroom is only another tool to be used to facilitate the learning process. To decide if this tool is applicable to a given situation, I recommend following the flow diagram in figure 1. First, course objectives must be evaluated to determine if a computer based lab model is consistent with reinforcing those objectives. If the answer is yes, then a search for applicable off the shelf software must be done to determine if available software will meet training and education requirements. If no such software is available, consideration of custom software may be given. Is it cost effective? As one can see from figure 1, the decision process for deciding if computer based laboratory experiments is the correct choice is not trivial. Each of these decisions must be carefully evaluated.

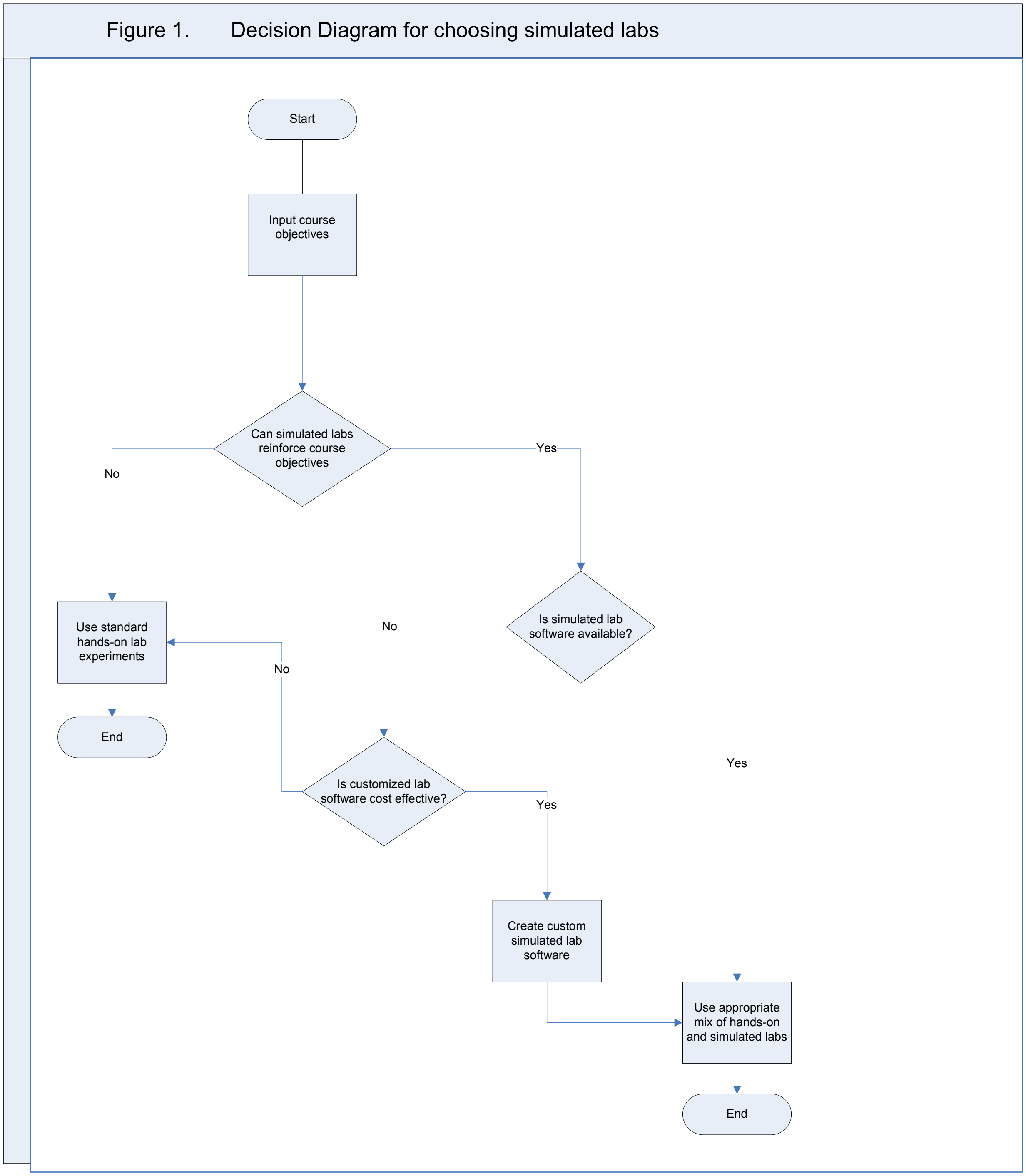


Figure 1. This figure is intended to serve as a guide for making a decision regarding the incorporation of computer based laboratory software into training and education objectives.

In some classes like robotics, student feedback regarding robot simulation software has been overwhelmingly positive. If the robot simulation software is a very close and accurate simulation of the robot students are being trained on, students get a very good feel for the actual robot, and the programming and move training go smoothly. Often, working with robot simulation software may prevent damage either to the robot or surrounding equipment due to inexperienced programming. This and other applications of laboratory simulators such as the use of a laboratory simulator in Electric Power Systems [1] shows the broad range of application for this technology.

The use of animated software has also been proven to be very effective where an ordered sequence of events is being taught to students. An example of this is the training of students to operate or maintain specialized equipment. This type of training is beneficial in community colleges offering apprenticeship training. Often, equipment manufacturers provide such software.

All previous examples I have discussed involve using computer software tools in the classroom. However, probably the most far reaching impact in terms of student education is obtained not by using this technology in the classroom, but by having students use a student version of the software on their own computer and have them work homework assignments utilizing these tools. Student feedback indicates they spend far more time on the computer using the software and learning much more than they would have using the standard approach. Test scores also bear this out. At industry sites such as Alcoa Aluminum and AES Power Plant, exam scores indicate about a full letter grade, (10 percentage points) test score improvement in the test averages. The improvement was even greater (about 14 percentage points)at Ivy Tech State College Electronics Maintenance Program. Other applications of computer assisted learning such as organic chemistry have shown that students spend greater amounts of time on lessons but learn more, especially with students having lower and middle ability ranges [2].

Another application of innovative technology in the classroom is wireless fault insertion. Toyota and other manufacturers use manual instructor induced faults in training equipment. But only the military to my knowledge has used wireless fault insertion to any wide degree. It offers the advantage that an instructor can insert multiple faults in multiple equipment trainers simultaneously from the instructor console. This speeds up diagnostic labs dramatically. As with all technology, it may not be for everyone. But under the right circumstances and in the proper environment, this technology may offer significant advantages over existing training methods.

All of these examples of the use of computer based technology in the classroom have been based on the application in a traditional face-to-face classroom with face-to-face laboratory classes. But, possibly the most far reaching positive results may well be obtained in Distance Education. With Distance Education, face-to-face contact is minimized. Computer based tools are the prime implementers of this form of education, and the use of computer based laboratory tools and the application of this technology in the laboratory is a significant contributor to the success of distance education where it is successful in technology, engineering and engineering technology education. Distance Education is the key to allowing more people to get or advance their education and make life-long learning possible for everybody. The use of computer based tools for lecture and both computer based and multimedia tools in laboratory environments holds the key to a successful distance education course.

In conclusion, examples of the use of innovative technology in the classroom have been put forth. Various methods of assessment have been used to assess the impact of using these methods. Exam scores and student feedback are two very important assessment tools used. In the environments I have stated, these assessment tools have been very positive. It is my sincere hope that the listener may return and use these and other innovative technologies in their classroom with equal or better results.

References

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[2] Education Resources Information Center publication ED084770 – The Use of Modular Computer-Based Lessons in a Modification of the Classical Introductory Course in Organic Chemistry