This schematic displays the maximum voltage that went through the circuit.
This graph shows the relationship between the voltage and the current that entered the diode. The orange line is a line of fit for part of the data.

\[ R_f = 328\Omega \]

\[ V_f = 1.73V \]

Why are three 1kΩ resistors used in parallel when a standard value 330Ω resistor is available?

**Answer:**

They are in parallel because **1kΩ resistors are a lot less fat than a 330Ω resistor**. The 1kΩ resistors are also more abundant and are probably less expensive than the 330Ω one. Additionally, you have greater power handling with the 1kΩ resistors because less current is travelling through them rather than having only one current run through the 330Ω resistor.
Section I : Data

<table>
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<th>Resistor</th>
<th>Nominal Value</th>
<th>Units</th>
<th>Tolerance</th>
<th>Upper Bound</th>
<th>Units</th>
<th>Lower Bound</th>
<th>Units</th>
<th>Measured</th>
<th>Units</th>
<th>In Tolerance?</th>
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<tr>
<td>1</td>
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<td>kΩ</td>
<td>+/- 5%</td>
<td>1.575</td>
<td>kΩ</td>
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<td>Ω</td>
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<td>Ω</td>
<td>1.045</td>
<td>Ω</td>
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<tr>
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<tr>
<td>10</td>
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<td>MΩ</td>
<td>+/- 5%</td>
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<td>MΩ</td>
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<td>MΩ</td>
<td>4.34</td>
<td>MΩ</td>
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</tr>
</tbody>
</table>

Comments:
Couldn’t seem to get the k to be lower case in kΩ.
The boarders really help with readability.

Section II : Total Circuit Resistance

<table>
<thead>
<tr>
<th>Calculated</th>
<th>Measured</th>
<th>Percent Error</th>
</tr>
</thead>
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<td>Value</td>
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<td>Ω</td>
<td>856</td>
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</table>

Comments:
Well, I'm pleased with that error after a semester of Physics classes and 20% error on every lab.
My data does not suck as bad as it could be is not a good validation.

Section III : Voltages

Comments:
That second one is pretty big.

<table>
<thead>
<tr>
<th>Calculated</th>
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<th>Percent Error</th>
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</thead>
<tbody>
<tr>
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<td>Value</td>
</tr>
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</tr>
<tr>
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<td>3.84</td>
<td>3.835</td>
</tr>
<tr>
<td>V3</td>
<td>4.09</td>
<td>4.1</td>
</tr>
<tr>
<td>V4</td>
<td>0.87</td>
<td>1.042</td>
</tr>
<tr>
<td>V5</td>
<td>3.06</td>
<td>3.067</td>
</tr>
</tbody>
</table>
2. (10 Points) Use superposition to determine $V_W$ in the circuit below.
The total cost of all my components was under the specified two dollar limit.

The time that I spent working on this project is shown in the table below.

| TABLE II |
| Time spent on project |
| --- | --- |
| Part of project worked on | Hours spent working on part |
| Pre-lab | 2 |
| Working in lab | 2 |
| Writing Report | 2 |
| Total Time | 6 |

VI. CONCLUSION

In conclusion I designed a BJT amplifier that met all of the specifications given. I captured a voltage gain of 37.3 dB. This gain measurement was approximately the same as all the specified frequencies, 1 kHz to 100 kHz. I measured a voltage swing of 2 V peak to peak without clipping the output. The current that I obtained was 11.4 mA. I obtained all the measurements with little complication.

VI. References

Lab Data

From: Paul Buschkopf <buschkopfp@uwplatt.edu>

Subject: Lab Data

To: John Goomey <goomeyj@uwplatt.edu>

Professor Goomey,

I took my lab data home over the weekend to work on my lab. Until now I thought that my lab data had been safe although my dog had gotten into my back pack and chewed up part of my physics notebook. I know it sounds ridiculous, but looking through my backpack I realized that he must have gotten the sheet that had been signed, seeing as it was right next to that notebook. I will turn in my data that I had approved, however it is not the sheet that has the initials on it. I thought I would give you a heads up and hopefully can still get some credit for it.

In 15 years of teaching, this is my first 'my dog ate my homework' excuse.
4. (10 Points) Determine $V_o$ in the circuit below.

\[ V_o = \frac{3V - V_A}{6\Omega} \]

hmm... maybe if I could identify the type of elephant this would be credible. The facts would indicate African, however the ears indicate Indian. The rounded head could also be an African trait. The trunk seems to indicate Indian, however again decided to cover up my work but can assure you that I got the right answer (and credit)!!
The following are true/false questions taken from the National Society of Professional Engineers website (http://www.nspe.org/Ethics/EthicsResources/EthicsExam/index.html). At the end of each question, I have supplied the portion of the NSPE Code of Ethics that explains the answers. (The NSPE code of ethics can be found at http://www.nspe.org/Ethics/CodeofEthics/index.html).

For each of the questions below, refer to the NSPE Code of Ethics to explain, in a sentence or two, why the answer is true or false. Do not just write the code as your answer, but point out the wording from the code that specifically makes the statement true or false.

1. Engineers in the fulfillment of their professional duties must carefully consider the safety, health and welfare of the public. (NSPE Code I.1)
   - Protecting the public, true

2. Engineers may issue subjective and partial statements if such statements are in writing and consistent with the best interests of their employer, client or the public. (NSPE Code I.3)
   - They must follow regulations and instructions if it's safe, true

3. Engineers shall not be required to engage in truthful acts when required to protect the public health, safety and welfare. (NSPE Code of Ethics I.5)
   - Don't half ass anything false

4. Engineers may not be required to follow the provisions of state or federal law when such actions could endanger or compromise their employer or their client's interests. (NSPE Code of Ethics I.6)
   - Must do a good and truthful job, false

5. Engineers shall undertake assignments only when qualified by education or experience in the specific technical fields involved. (NSPE Code II.2.a.)
   - True only take what you are qualified to do

6. Engineers shall not affix their signatures to plans or documents dealing with subject matter in which they lack competence, but may affix their signatures to plans or documents not prepared under their direction and control where the engineer has a good faith belief that such plans or documents were competently prepared by another designated party. (NSPE II.2.b.)
   - All documents must be prepared in front of the engineer, false
Abstract—The purpose of this project is to observe the input and output waveforms of a resistor-inductor circuit and a resistor-capacitor circuit. I did this to multiple combinations of resistor-inductor and resistor-capacitor circuits using an oscilloscope. From the oscilloscope I observed each circuit over multiple frequencies, increasing each measuring frequency by a factor of 10. At the end of the lab I concluded that inductors and capacitor have similar like properties at very large frequencies, and that inductors and capacitors are affected inversely by the changing frequency.

Index Terms—Capacitor, Frequency, Function Generator, Inductor, Oscilloscope, Resistor

I. INTRODUCTION

For this project there were three different parts that needed to be completed. The first part was constructing an resistor-capacitor circuit, using a 10kΩ resistor and a 1µF capacitor. The second part was using a 10Ω resistor and an 820µH inductor. The third part was creating my own circuit and seeing what its response was. Each circuit was measured across a range of frequencies that were varied by a factor of 10.

II. PROCEDURE

A. Part I

To start the project I constructed the first circuit using a 10kΩ resistor and a 1µF capacitor, as shown by the schematic in Fig. 1. Then I turned on the oscilloscope and the function generator. I set the function generator to 2V peak-to-peak and the starting frequency to 600Hz square wave. I took a range of measurements across frequencies that varied from 600Hz by a factor of 10, and I downloaded the images shown in the results section.

Fig.1: General schematic used for part I and part III of this project.

B. Part II

For part II I set up a circuit consisting of a 10Ω resistor and an 820µH inductor. The schematic in Fig. 2 shows the general form of the circuit used. I left the voltage at 2V peak-to-peak and set the starting frequency to 70kHz square wave. I took a range of measurements across the circuit starting with the initial starting frequency then decreasing the frequency by a factor of 10 until I reached 7Hz.

Fig. 2: General circuit schematic used for part II and part III.

C. Part III

For part III I created three different circuits and took a range of measurements across varying frequencies. The first circuit I constructed used a 10kΩ resistor and an 820µH inductor. The frequencies that were used ranged from 60Hz to 600kHz. The general for of the schematic used for this circuit is shown by Fig. 2. The second circuit I created used a 10kΩ resistor and a 10mH inductor. Measured frequency ranges were taken between 6Hz and 6MHz. The third circuit consisted of a 10kΩ resistor and a 75pF capacitor, with frequencies ranging from 6Hz to 76MHz. The general form of the schematic is shown by Fig. 1.

III. RESULTS

A. Part I

For the first part I started by taking results at at 600Hz as instructed. I downloaded the image collected at the starting frequency from the oscilloscope, which is shown by Fig. 3. At 600Hz the graph shows a clear square waveform as expected.

Fig. 3: Graph of square waveform from circuit used in part I at 600Hz.
As I increased the frequency by a factor of 10 from 600Hz to 6kHz and 60kHz the graph appeared to square off more but there was no significant change. The graphs of the 6kHz and 60kHz is shown by Fig. 4.

When I decreased the starting frequency by a factor of 10 the graphs started to change. At 60Hz the input and output waveforms started to deform. The right sides of the squares dipped toward their origins. At 6Hz the graph does not resemble a square wave at all. The right side of the squares has dipped closer to the center and has a decay before they drop off. The graphs of the two recorded frequencies is shown by Fig. 5.

For part II I used 70kHz as the starting frequency for the circuit used in part II, which consisted of a 10Ω resistor and an 820µH inductor. The waveform of the input slightly resembles a square wave but the output does not. The output wave appears to be more of a triangle waveform than a square. The graph of the waveform of the 70kHz is shown by Fig. 6.

After I decreased the frequency from 70kHz to 7kHz there was no resemblance of a square in the waveform. The input appears to have decay in it like the graph of the 6Hz from Fig. 5. The output is closer to a sin function than a square function. The graph of the 7kHz collected by the oscilloscope is shown by Fig. 7.

When I decreased the frequency down to 700Hz the output began to take a more square like form but the input appears to be getting thinner with a very steep drop off toward the origin. After decreasing the frequency further down to 7Hz the output had a rectangular form. The input has become vertical lines. The graphs of the 700Hz and 7Hz is shown by Fig. 8.
C. Part III

For part III I collected data on three different circuits consisting of either resistor and inductor or a resistor and capacitor. The first circuit I used consisted of a 10kΩ resistor and 820mH inductor. I started collecting data at 600Hz and increased and decreased the frequency by a factor of 10. At 600Hz the waveforms of the input and output both resemble square waves with the output having a line on the left side of each of the waves. The collected graph is shown by Fig. 9.

![Graph of square waveform from the first circuit used in part III at 600Hz.](image1)

When I reduced the frequency down to 60Hz the circuit did not appear as expected. I expected similar results as part II when the only difference between the circuits was that the circuit in part II used a 10Ω resistor instead of the 10kΩ. The input of the waveform resembles more a resistor-capacitor circuit. When I decreased the frequency down to 6Hz the input still resembles more of a resistor-capacitor circuit than the expected circuit. The output for both the 6Hz and 60Hz doesn't appear to change. The graphs of the collected data from the oscilloscope is shown by Fig. 10.

![Graphs of the 60Hz (top) and the 6Hz (bottom) of the waveforms collected from the first circuit used in part III.](image2)

After I increased the frequency to 60kHz and 600kHz is where things became interesting. The inputs of both frequencies were as predicted, having a square waveform. The outputs did something very strange and unexpected. The 60kHz had mini waves across the supposed to be horizontal parts of the waves. The 600kHz turned into a sin wave. The graphs of the waveforms is shown by Fig. 11.

![Graphs of the 60kHz (top) and the 600kHz (bottom) of the waveforms collected from the first circuit used in part III.](image3)

For the second circuit that I created I connected a 10mH inductor with a 10kΩ resistor. I started collecting data at 600Hz. The graph is similar to the circuit with the 10kΩ resistor and the 820mH inductor. The graph of the second circuit used for part III is shown by Fig. 12.

![Graph of square waveform from the second circuit used in part III at 600Hz.](image4)

When I reduced the frequency down to 6Hz the graph appeared the same as the first circuit used but when I increased the frequency to 6MHz the graph changed to something different. The output appears to be a sin function and the input looks like a deformed sin function. The graphs of the 6Hz and the 6MHz is shown by Fig. 13.

![Graphs of the 6Hz (top) and the 6MHz (bottom) of the waveforms collected from the second circuit used in part III.](image5)
For the third circuit I created I connected a 10kΩ resistor with a 75pF capacitor. The starting frequency I used was 600kHz and the graph of the collected waveform from the oscilloscope is shown by Fig. 14. The waveforms of the input and output both resemble a square wave function. This was expected based on the previous results.

![Fig. 14: Graph of square waveform from the third circuit used in part III at 600kHz.](image)

When I set the frequency to 600Hz the input stayed the same as the 600kHz but the output had only vertical lines. The upper graph shown in Fig. 15 shows the input and output values of the third circuit used at 600Hz. The bottom graph of Fig. 15 shows the same circuit at 75 MHz. When collecting data the input and output lines were constantly moving and I had to pause the screen to see the wave functions shown. The output has a small resemblance of a sin function but it is close to the center of the wave.

![Fig. 15: Graphs of the 600Hz (top) and the 75MHz(bottom) of the waveforms collected from the third circuit used in part III.](image)

### IV. DISCUSSION

From the results that I have collected I have found that at very high frequencies, which vary depending on the components, both capacitors and inductors have similar properties. When a circuit with either a capacitor or inductor has a frequency that is in the megahertz, they both go from being square wave functions to sin wave functions. At the lower frequencies, such as frequencies in the single digits, inductors and capacitors are different. Capacitors have a slower decay toward the origin for the inputs. With the outputs the capacitor’s output acts like the input while the inductors output takes on a more rectangular shape showing the square wave function. Both inductors and capacitors have similar properties at the higher frequencies but they are very different at lower frequencies, with the only similarity being that they both do not look like square wave functions.

### V. CONCLUSION

This project helped me to understand how capacitors and inductors respond to certain frequencies. It was interesting to see some similarities between a capacitor and inductor at the high frequencies and how the square wave functions turned into sin wave form.

### REFERENCES

Abstract—The purpose of this project is to observe the impedance of multiple capacitors, inductors, and resistors. I also tested to see if the impedance was affected by the difference between using two wires or by using multiple wires to the same inputs. I collected the data by attaching the individual components to a NI ELVIS and then using the impedance analyzer on the connected computer. By doing this I was able to see how the frequency affected each of the individual components. At the end of the lab I concluded that larger resistors are affected by impedance and to try and use as little wire as possible when constructing a circuit.

Index Terms—Capacitor, Frequency, Impedance, Inductor, NI ELVIS, Phase Angle, Phase Shift, Resistor

I. INTRODUCTION

For this project I had two parts that need to be completed. First I had to measure the impedance of multiple capacitors, inductors, and resistors. The second thing I had to do was take two resistors and compare the differences in impedance between connecting two wires between the inputs and using multiple wires. I measured the impedances by using an impedance analyzer on the computer which was connected to an NI ELVIS. The impedances were measured across a range of frequencies specified in the project guidelines.

II. PROCEDURE

A. Part I

To start the project I first turned on the NI ELVIS and opened the impedance analyzer on the computer. I then sorted each of the components into groups consisting of capacitors, inductors, and resistors. After they were sorted into their corresponding groups I began to take measurements starting with capacitors, then inductors, and finally resistors. The components had to be put into the HI current and LO current inputs at the bottom left of the NI ELVIS station as specified in the project guidelines.

Each of the components had the magnitude and phase angle recorded across a range of frequencies consisting of 100 Hz, 500Hz, 1000Hz, 3000Hz, 5000Hz, 10000Hz, and 20000Hz.

B. Part II

For part II I had to take the 100Ω and 100kΩ resistors and see if the impedance changed if I used two longer pieces of wire and if I used multiple little wires to connect the two inputs. I started with the two long wires and connected them to the 100Ω resistor and collected data across the same range of frequencies as part I. Then I switched the 100Ω resistor with the 100kΩ resistor and collected data same as the 100Ω resistor. After I was finished with the two long wires I connected eight little wires to the two inputs and the resistor. I first collected data for the 100kΩ resistor then when I was done I switched out it out for the 100Ω resistor.

III. RESULTS

A. Part I

The resistors had unexpected results when I was taking data. As shown by the higher graph of Fig. 1 the 100Ω resistor had minor changes in it, which is a little unexpected because the frequency theoretically shouldn’t have any effect on the resistor. One thing I found really unusual was that the 100kΩ resistor was affected greatly by the frequency as shown by the lower graph of Fig. 1.

Fig 1: Scatter plots fo the magnitude vs. frequency of the 100Ω resistor (top) and the 100kΩ resistor (bottom).
The effect of the frequency on the resistors can also be observed by the phase angle. Fig. 2 shows a graph of the two resistors phase angles. The 100Ω resistor behaves almost as expected but the 100kΩ has a large change in the phase angle ranging from -0.55 degrees to -43.51 degrees. Theoretically the phase angle should be zero.

The capacitors behaved as expected with the higher the frequency the lower the magnitude. The graphs of the 220mF and 22mF capacitors are shown by Fig. 3 and the 122pF capacitor is shown by Fig. 4. One thing can be observed by the graph is that the resistors behave very similarly with each having a sharp drop in magnitude after 100Hz.

The inductors behaved very differently from one another. The 33µH had a very small change of magnitude while the 33mH had a very large magnitude change. The collected data shows that the larger the inductor the more the frequency affects it. Fig. 6 shows the two graphs show how the frequency affects the magnitudes of the two inductors.
For the 100Ω resistor the series wires behaved like the resistor without any wire, with the magnitude staying around 100. The parallel jumping wires did not behave like the resistor, instead its graph has a regression in it as the frequency is increased. The phase angle shows the same results, with the series wires having almost no change while the parallel jumpers have a decent change in the phase angle. The results of the collected data are shown by Fig. 8.

The 100kΩ resistor showed a different result for the series and parallel jumpers than the 100Ω resistor. As shown by the graphs, there is not a large difference between the series and parallel jumpers. Both the phase angle and the magnitude have the same correlations. Fig. 9 and Fig. 10 show the magnitude and phase angle over a changing frequency.

For the 33µH inductor the series wires behaved like the inductor without any wire, with the phase angle staying more similar between the two inductors than the magnitudes, as shown by Fig. 7. The graph shows that the phase angle of 33mH tends to level out quicker than the 33µH.

The phase angles of the two inductors show more similarities between the two inductors than the magnitudes, as shown by Fig. 7. The graph shows that the phase angle of 33mH tends to level out quicker than the 33µH.

B. Part II

While taking data for part II I found that how the inputs are connected makes a difference. Using the two resistors I found that if only two longer pieces of wire are used the resistors behave more like they would if they were plugged directly into the inputs. When I used eight pieces of wire to connect the inductors to the inputs I found that there were some minor changes in the magnitude and phase angles.
Fig. 10: Scatter plot of the phase angle vs. frequency of the series and parallel jumper wires for the 100Ω resistor.

IV. DISCUSSION

From the results I have collected during this lab I can conclude that the previous labs involving frequencies are more clearly explained. The data in the previous labs did not behave exactly as expected and now knowing that the frequency affects each component in a different way makes me more comfortable with the abnormality of the previous data.

To conclude my results of each of the components I found that some of results were very surprising. The 100Ω resistor wasn’t affected by the frequencies much, which was to be expected but the 100kΩ resistor was surprising in how much it was affected by the frequency change. The 220µF, 47µF, and 122pF capacitors behaved as expected the only thing that seemed out of place was that the phase angle of the 220µF was most affected compared to the other two and for the size of the capacitors it would seem like the 122pF capacitor should have been most affected. The 33mH and 33µH inductors seemed to follow the trend that the smaller the inductor the less it is affected by frequencies.

Part II of this project has helped me understand how important it is to use as little wire as possible when wiring circuits to avoid adding extra resistance and to minimize the effect of frequencies on the wires.

A lot of this project was spent writing up the report of the collected data. Table 1 shows the time spent on the project and the time spent on the write up.

<table>
<thead>
<tr>
<th>Process</th>
<th>Time (hours)</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>Testing</td>
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<tr>
<td>Report</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Table II shows the cost of each part, with the prices provided by Digikey. Some of the prices on the parts are a little surprising.

<table>
<thead>
<tr>
<th>Parts</th>
<th>Part #’s</th>
<th>Price ($)</th>
</tr>
</thead>
<tbody>
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<td>100Ω resistor</td>
<td>CF18JT100R</td>
<td>0.00589</td>
</tr>
<tr>
<td>100kΩ resistor</td>
<td>CF18JT100K</td>
<td>0.00589</td>
</tr>
<tr>
<td>33mH inductor</td>
<td>RL187-3335-RC</td>
<td>0.34075</td>
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<tr>
<td>33µH inductor</td>
<td>RL622-330K-RC</td>
<td>0.75000</td>
</tr>
<tr>
<td>220µF capacitor</td>
<td>B0510-2R5224-R</td>
<td>1.72000</td>
</tr>
<tr>
<td>22mF capacitor</td>
<td>NP222M100</td>
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</tr>
<tr>
<td>122pF capacitor</td>
<td>K12U100J005</td>
<td>0.41000</td>
</tr>
</tbody>
</table>

V. CONCLUSION

This project was important for the understanding of how components in a circuit are affected by different frequencies. It is important to know that larger resistors are affected more by frequencies. Capacitors tend to follow the same basic trend and inductors depend on how large they are as to how they will react to certain frequencies. As far as part II it is important to understand that more little wires will result in faulty data.

REFERENCES


Closed book. One hand-generated standard sheet of notes allowed (put your name on the sheet and turn it in with your exam).

All work must be done in a neat and orderly fashion to be graded. Any work that is not to be graded must be erased or clearly crossed out. Final answers must be underlined or circled in order to receive credit.

1. (10 Points) Determine the energy stored in the capacitor and inductor in the circuit below.
2. (10 Points) Determine the Thevenin equivalent circuit of the circuit shown below.

\[ \frac{6 - V_B}{6k\Omega} + \frac{0 - V_B}{3k\Omega} + \frac{V_A - V_B}{4k\Omega} = 0 \]

What the Hell is Thevenin?
3. (10 Points) Use superposition to determine the voltage $V_o$ in the circuit below.

There is no case where a $3k\Omega + 12k\Omega$ resistor are in parallel.

$$\frac{1}{3k\Omega} + \frac{1}{12k\Omega} = \frac{1}{R_{eq}} = 0.4\Omega$$

Without a reference node to do this,

$$\frac{V_o - V_{A}}{4k\Omega} = 0$$

$$V_o = 4.5V$$
4. (10 Points) Let $v_{in}(t) = 2\cos(50,000t) \text{V}$. Determine $v_o(t)$ in the circuit below.

![Circuit Diagram]

$v_{in}(t) = 2\cos(50,000t) \text{V}$
All work must be done in a neat and orderly fashion to be graded. Any work that is not to be graded must be erased or clearly crossed out. Final answers must be underlined or boxed in order to receive credit.

1. (10 Points) Assume the bipolar junction transistor in the circuit below has a common-emitter current gain of 100. Determine the emitter current and the emitter-collector voltage.

\[ I_E + V_{EC} = V_{EC} + V_{EB} \]

\[ I_E = 10 \mu A \]
\[ I_c = \beta I_E \]
\[ I_c = 100(10 \mu A) \]
\[ I_c = 1 mA \]

\[ I_E = I_c + I_B \]
\[ I_E = 1 mA + 10 \mu A = 1.01 mA \]
\[ I_E = 1.01 mA \text{ answer} \]

\[ V_{EC} = 0.99 V \leq 0.2 \text{ Saturation} \]
\[ V_{EC} = 0.2 V \text{ backward} \]

\[ I_E = \frac{2 - 0.2}{1 k\Omega} = 1.8 mA \text{ } \]

\[ \boxed{V_{EC} = 0.2 V} \]
2. Assume the bipolar junction transistor in the circuit below has a common-emitter current gain of 100 and an infinite Early voltage. Determine diffusion resistance and the small signal transconductance of the bipolar junction transistor.

\[ r_m = \frac{R}{10} \]
\[ B = 100 \]

\[ V_{CC} = 10 \text{ V} \]
\[ V_{BE} = 1 \text{ V} \]

\[ I_e = 8I_b \]

\[ 10 - I_e(5.28\text{ k}) - V_{CE(on)} - I_e(5.28\text{ k}) = 1.2 = 0 \]
\[ 10 - 100I_e(5.28\text{ k}) - 0.7 = I_e(5.28\text{ k}) - 1.2 = 0 \]
\[ I_e = 500 \text{ mA} - 5.28\text{ k} = 8.1 \]
\[ I_e = 16.4 \mu\text{A} \]
\[ I_c = 18I_e \]

\[ g_m = \frac{I_e}{I_c} = \frac{16.4 \mu\text{A}}{1.64 \text{ mA}} = 9.98 \text{ A/V} \]
\[ r_m = \frac{6.28 \text{ k}}{16.4 \mu\text{A}} = 369.1 \text{ k} \]

\[ A_v = \frac{V_o}{V_i} = -g_m \frac{r_m}{r_{beq}} \]
\[ A_v = -12.1 \frac{V}{V} \]
Dear Mrs. [Redacted]

April 20th, 1994

You may already know this, but in case Alex has neglected to tell you, I am assigning him to detention for one hour this Friday, April 22nd. The reason is as follows:

Alex consistently defied me. During class he contradicted me numerous times when I insisted that the length of one kilometer was greater than that of one mile. Every other student in class accepted my lesson without argument, but your son refused to believe what I told him, offering such rebuttals as, “You’re lying to the class,” and commanding other students to challenge my curriculum.

Although he was correct, Alex’s actions show a blatant disregard for authority, and a complete lack of respect for his school. In the future, Alex would be better off simply accepting my teachings without resistance.

Please see to it that your son understands this.

Regards,

[Redacted]
Abstract—The goal of this design project was to create a circuit which would produce a rectified current within a range of 8 to 14 volts peak, at a minimum of one amp. A transformer, bridge rectifier, capacitor, shunt resistor, and a series of load resistors were used to achieve this goal. I successfully created a circuit which produced a voltage of 8.12 \text{V}_{\text{peak}}. The ripple voltage I measured was only 0.776 \text{V}_{\text{peak}}. I measured these voltages across a 50Ω and two 10Ω resistors in series. I also measured the current through these resistors to be 1.10 amps. I measured the unloaded voltage of my circuit to be 13.2 volts.

Index Terms—Bridge circuits, Full-Wave Rectifier, Power Transformers, Rectifier

I. INTRODUCTION

In this design project I designed an electrical circuit which when powered by 120 V_{\text{RMS}} at 60 Hz from a wall outlet would produce an 8-12 volts of rectified current. I used a transformer connected to wall voltage on the primary side; on the secondary side the transformer was specified to be 8 V_{\text{RMS}} at 1.6 amps. I then connected the transformer to a bridge rectifier which was specified to have a 1 volt drop across it. The AC output of this was then connected to a 5600 µF capacitor which leveled out the oscillating voltage more. I connected my 510 Ω shunt resistor in parallel with my capacitor. The purpose of the shunt resistor is to draw current from the transformer when there is no load attached. Finally, I connected a detachable series of load resistors. The total resistance of my load resistors was 8 Ω.

II. PROCEDURE

For this design project I began by figuring out what size components I would need, by using a few different equations. First I used Equation 1 to determine that a good voltage rating for the secondary coils of the transformer would be 8 V_{\text{RMS}}.

\begin{equation}
V_{\text{RMS}} = \frac{V_{\text{peak}}}{\sqrt{2}}
\end{equation}

The resulting peak voltage from the transformer was calculated to be 11.3 \text{V}_{\text{peak}}. Using this peak voltage and a rectifier voltage drop of one volt I used Equation 2 to calculate the best load resistor, shunt resistor and capacitor values to be 8 Ω, 510 Ω and 5600 µF so that the ripple voltage remained less than 20% of the peak voltage.

\begin{equation}
V_{\text{ripple}} = V_{\text{peak}} \times \frac{R_{\text{load}}}{R_{\text{load}} + R_{\text{shunt}} + R_{\text{capacitor}}}
\end{equation}

Using the values I calculated for the ripple voltage in the circuit, the resistance of the circuit, and the peak voltage I calculated the peak and average current through the bridge rectifier to be 14.7 A_{\text{peak}} and 2.87 A_{\text{peak}}, respectively. I made these calculations using Equation 3 and Equation 4.

\begin{equation}
I_{\text{average}} = \frac{V_{\text{peak}}}{R_{\text{load}} + R_{\text{shunt}} + R_{\text{capacitor}}}
\end{equation}

\begin{equation}
I_{\text{peak}} = \sqrt{2} \times \frac{V_{\text{peak}}}{R_{\text{load}} + R_{\text{shunt}} + R_{\text{capacitor}}}
\end{equation}

I used the average and peak current values which I calculated to choose a bridge rectifier that would be able to handle those currents. All of these calculations fit within the specification provided for the design project.

Using all of the calculated and tested component values, I created a schematic of my circuit using PSpice. I have attached the schematic diagram as Figure 1 below.

Figure 1: This is the schematic I created in PSpice which illustrates the circuit which I actually used in the laboratory to take my measurements.

The units on the four resistors in the schematic are ohms; the unit on the capacitor is µF. The AC voltage source on the left side of the schematic represents the wall outlet voltage.

After I had designed my circuit for this design project I soldered all the components onto protoboard. I was sure to keep the load resistor detachable so I could measure unloaded voltage.

III. PARTS LIST

This project used a minimal number of parts which I did not...
Summary

In lab 2, 10 resistors were obtained. Once obtained, their nominal resistance from their color code was recorded. Also the lower and upper tolerance limits were calculated for each resistor. After that was completed a DMM was used to measure each of the resistors and verification was confirmed that each resistor fell within their specified range calculated previously. A circuit was constructed and connected to a 10V power supply. Voltages were taken from AE, BE, CE, DE.

Design

\[ \text{Voltage (AB)} = \frac{180}{940} \times 10 = 1.91V \]
\[ \text{Measured Voltage (AE)} = 10.19\Omega \]

\[ \text{Voltage (BC)} = \frac{330}{940} \times 10 = 3.51V \]
\[ \text{Measured Voltage (BE)} = 8.09\Omega \]

\[ \text{Voltage (CE)} = \frac{430}{940} \times 10 = 4.57V \]
\[ \text{Measured Voltage (CE)} = 4.16\Omega \]

\[ \text{Voltage (CD)} = \frac{510}{2010} \times 4.57 = 1.16V \]
\[ \text{Measured Voltage (DE)} = 3.1\Omega \]
Voltage (DE) = \(\frac{1500}{2010} \times 4.57 = 3.41V\)

Resistance (AC) = 180 + 330 = 510\(\Omega\)

Resistance (CDE) = \(\left(\frac{645000}{1930}\right) + 510 = 844.2\Omega\) \(\leftarrow \text{NO!}\)

Resistance equivalent = 510 + 844.2 = 1.35k\(\Omega\)

Measure Total Resistance = 851\(\Omega\)

The calculated values and the measure values of the voltage across the resistors were pretty close. There was a 9% error in the calculations and measured, with that error considered into each calculation that would make up for the different answers. In general, the calculation and measurement were pretty close to one another without the percent error number ignored. In contrast, the measurement and calculation of the total resistance in the circuit was the farthest off with a 37% error. This percent is significantly high due to the fact that all the calculation and measurement of the circuit were off by greater than 5% and if you accumulate that over all the resistor, the total would have a greater percent error than the individual resistor.

Figure 1. m.
Directions: Read all problems carefully. The point value for each problem is given after the problem statement. Think. Write your responses neatly. Underline and label the final answer(s) of numerical problems.

1. (Engineering Programs)
   List all of the engineering degrees you could earn at UWP. (7 pts)
   - Civil
   - Electrical
   - Mechanical
   - Industrial
   - Software
   - Computer Science
   - Environmental

2. (Engineering Careers)
   Identify the type of engineer (or engineers) that would perform the following task, and briefly explain your answer. (6 pts)
   a. Analyze causes of worker injury at a John Deere factory.
      Mechanical/Industrial: They would be able to make machines and environments safer.
   b. Design a power plant.
      Civil: They deal with structural
   c. Designing the optical system for a laser sighting device.
      Mechanical/Electrical: Mechanical could come up with a design, Electrical would make it work.
      As usual.
8. **(Engineering Problem Solving)**  
List and explain two reasons why engineering calculations should be well formatted, organized, and neat. One of the reasons should relate to your academic career and the other should relate to your future professional career. (4 pts)  
- Professors need to see if you understood the information and see where you went wrong. If your work is well organized, it’s easier for the teacher to read and understand. Most likely a better grade will be received.
- In your profession, every calculation needs to be well organized and neat because people need to check for errors easily. If an error is made and isn’t fixed the safety and health of the public could be harmed.

9. **(Significant Figures / Unit Conversions)**  
The flow rate through a pipe was measured at 68 m³/day. What is this in gal/min? There are 264.17 gallons in 1 m³. Show all work, and express your answer with the appropriate number of significant digits. (6 pts)  
\[
\frac{68 \text{ m}^3}{1 \text{ day}} \times \frac{264.17 \text{ gallons}}{1 \text{ m}^3} \times \frac{24 \text{ hours}}{1 \text{ day}} \times \frac{1 \text{ min}}{60 \text{ hours}} = 45,000 \text{ gallons/minute}
\]

10. **(Simultaneous Equations)**  
Solve the following set of equations: (6 pts)  
\[
\begin{align*}
2a + 3b + 4c &= 0 \\
6b - 4c - 12 &= 0 \\
7a + 6d &= 10 \\
2a - 6c + 12b + 8d &= 14
\end{align*}
\]

\[
\begin{bmatrix}
0 & 3 & 4 & 0 \\
6 & -4 & 0 & -12 \\
7 & 0 & 6 & -10 \\
12 & -6 & 8 & -14
\end{bmatrix} \begin{bmatrix}
a \\
b \\
c \\
d
\end{bmatrix} = \begin{bmatrix}
0 \\
0 \\
0 \\
0
\end{bmatrix}
\]

Plug into calc. and use ref.
8. (Engineering Problem Solving)
List and explain two reasons why engineering calculations should be well formatted, organized, and neat. One of the reasons should relate to your academic career and the other should relate to your future professional career. (4 pts)

Engineering calculations should be well formatted, organized, and neat so that your work looks professional, so you or your professor doesn't miss read your work, and so that your work is of top quality.

9. (Significant Figures / Unit Conversions)
The flowrate through a pipe was measured at 68 m³/day. What is this in gal/min? There are 264.17 gallons in 1 m³. Show all work, and express your answer with the appropriate number of significant digits. (6 pts)

\[
\frac{68 \text{ m}^3}{\text{day}} \times \frac{1 \text{ day}}{24 \text{ hr}} \times \frac{1 \text{ hr}}{1440 \text{ min}} \times \frac{264.17 \text{ gal}}{1 \text{ m}^3} = 5.2 \times 10^4 \text{ gal/min}
\]

Long hours in your universe? - 2

10. (Simultaneous Equations)
Solve the following set of equations: (6 pts)

\[
\begin{align*}
2a + 3b + 4c &= 0 \\
6b - 4c - 12 &= 0 \\
7a + 6d &= 10 \\
2a - 6c + 12b + 8d &= 14
\end{align*}
\]
8. **(Engineering Problem Solving)**
List and explain two reasons why engineering calculations should be well formatted, organized, and neat. One of the reasons should relate to your academic career and the other should relate to your future professional career. (4 pts)

Calculations should be neat in school because this allows you to get some credit if you got the wrong answer due to an arithmetic mistake. Also, your teacher will know you understand the concept and what you are doing, you just made a stupid mistake.

In your professional career it is important so people can see how you got to the solution and check every step to make sure there are no mistakes that could become dangerous.

9. **(Significant Figures / Unit Conversions)**
The flow rate through a pipe was measured at 68 m$^3$/day. What is this in gal/min? There are 264.17 gallons in 1 m$^3$. Show all work, and express your answer with the appropriate number of significant digits. (6 pts)

\[
\frac{68 \text{ m}^3}{1 \text{ day}} \times \frac{264.17 \text{ gal}}{1 \text{ m}^3} = 17963.56 \text{ gal/day}
\]

\[
\frac{17963.56 \text{ gal/day}}{60 \text{ h/day}} = 249.39 \text{ gal/h}
\]

60 hours in a day?

\[
\frac{249.39 \text{ gal/h}}{60 \text{ min/h}} = 4.16 \text{ gal/min}
\]

10. **(Simultaneous Equations)**
Solve the following set of equations: (6 pts)

\[
\begin{align*}
2a + 3b + 4c &= 0 \\
6b - 4c &= -12 \\
7a + 6d &= 10 \\
2a - 6c + 12b + 8d &= 14 \\
2a + 3b + 4c + 6d &= 0 \\
6b - 4c + 10 &= 12 \\
7a + 6d - 4c + 10 &= 10 \\
2a + 12b - 6c + 8d &= 14
\end{align*}
\]

\[
\begin{align*}
a &= 2.67 \\
b &= -0.74 \\
c &= -1.89 \\
d &= -1.44
\end{align*}
\]
GE 2930

From: [Redacted]

Subject: GE 2930

To: John Goomey <goomeyj@uwplatt.edu>

Hi John,

I've been looking things over for class here, and I'm rather worried. It seems as if it may be absolutely impossible at this point to pass your course. Reason I believe that to be true is because of the weight that the exams carry. I guess I can't say it is impossible, but with the exams being 55% of the course, and me have earned only half of those points thus far, as well as some of my assignments that have gotten points docked off of them, I suppose that I would have to earn every possible point from here on out just to get a C. All the courses I've been through and am in thus far, there has been practice exams available with solutions to those problems, or some sort of study guide. Is there anything at all that you could do that could better prepare me for the final exams?? I really, really want to pass this course. I've been trying so hard!

Please let me know,

Thank you,
Objective Summary

I went to a duo trumpet recital. There were two trumpet players and a pianist. The first section was trumpet occupied by piano. The next was just a trumpet, the fourth was trumpet and piano again, and the last was the two trumpets.

What I Learned

I learned that if you practice an instrument a lot you can have your own recital. I also learned that if you talk too much during it you can get kicked out. The trumpet players used mutes and other devices on their trumpets to make different sounds. I have never heard those sounds come out of a trumpet before, and I used to play it.

My impression

I think that the presentation very good. They played very well. The only thing is I didn’t know when to clap. So there were awkward silences between songs. Some of those sounds they made sounded awesome and I wish I still played. I have no idea on how to improve that recital.
The objective of the IIE meeting was to inform those that are thinking of joining or are part of the society, on what the plans are for the year. They went over how they raise money for the club, information on the engineer conference, and volunteer work. The meeting also offered a social environment that allowed people to meet new people. This was carried out by using a sheet of toilet paper. You had to say one interesting fact about yourself for every piece that you had.

Some things that I learned from the meeting include new names, ways that I can volunteer to help raise money for IIE, and information on the engineering conference. I learned some new people’s names, and some uninteresting facts about themselves. I learned that IIE raises its money by selling pop, renting out lockers, and performing other volunteer work. Some things that I could volunteer for include: picking up trash off the side of a road, working at IIE stands to help sell things, and working at the barbeque.

I thought that the meeting didn’t inform me on anything that had to do with industrial engineering. It only explained ways that you could help out and what the agenda was going to be for the year. I think that they should describe things that are going on in the job market for industrial engineers and maybe some news headlines. I also think that games or activities that have to do with industrial engineering could have been put in to the meeting. Maybe a speaker that is in the field could come in and speak. I thought that the meeting was boring and lacked any real information about the field of Industrial Engineering.
Section 08
SAE club meeting
9-30-10
Engineering Hall Rm. 115
9-30-10

Objective Summary
At this club meeting, we discussed what exactly would be happening. We also were told that the shop days are on Fridays starting at 3 o’clock.

What I Learned
What I learned at this meeting is that we need to be trained to use the machines. Also, I learned that they actually separate people into smaller groups to work on the Baja vehicle. This was surprising to me because I thought that everyone worked on the car together and that they actually assigned jobs to people on the work days.

My Opinion
In my opinion, I thought the meeting was actually shorter than expected. I really would not have made any changes to the meeting. The reason for this is because I actually learned a lot from the meeting than I would if I changed it if I did.
Sept. 17, 20, Platteville, was picked up on two outstanding warrants out of Grant County. According to a Platteville police report, an officer was in the area responding to a noise complaint when he heard loud voices at a residence. After discovering the warrants, the officer was taken into custody and brought to the police department and posted bond and was released.
The SAE racing team is broken up into separate categories: the Formula team (that's what I am on), the Baja team, and the snowmobile team. The SAE Formula Team meetings are usually pretty fun because you get a little update with what's going on in all aspects of the car. We go over Chassis, brakes, engine, electronics, suspension, body (my subdivision), controls, and finally the drive train of the formula car. Each sub-divisions team leaders let us as a whole group know where they're at on their project and what they're looking at to get done in the near future. Then towards the end of the meeting we go over any up and coming events like for instance at this meeting Austin Scott (the head honcho) let the group know that we were going to be having a lab certification coming up so that all of us would be able to start working in car. He also informed us about the team picture and that we had to dress up for it. Then we usually split up into our subdivisions and have our own meeting but our team leader (Kyle Shisler) wasn't there that night so the body team didn't get together after this meeting.

I have learned a lot about the aerodynamics of a car and how much time, money, and man power really goes into a project like this. Building a race car in general seems like it would be hard but doable. Because it's just wheels, engine, brakes, and steering and you slap them together, but there is so much more engineering and thought that goes into these things. A single race car can have subdivisions broken into subdivisions divided into subdivisions.

I think the whole process is pretty cool. I have been really enjoying all of the meetings and all the stuff I have been learning from everyone. I love the idea that a bunch of students have gotten together and built a formula race car literally from the ground up. I am ecstatic about being a part of this team.
Problem solving

1) \(4\)

2) \(3\)

3) \(2\)

4) \(2\)

5) \(2\) days really? - \(\frac{1}{12}\)

6) \(6013\) gallons

7) \(25.1\) tons

8) \(8.75\)

9) \(16\text{ km} \times \frac{1\text{ h}}{70\text{ km}} = 46\text{ h}\)

10) \(46\text{ h} \times \frac{60\text{ min}}{1\text{ h}} = 27\text{ minutes}\)

11) \(28\text{ minutes}\)

12) \(44\text{ MPH}\)

13) \(-\frac{1}{4}\)

14) \(6\) mini-vans

15) \(393.\) X

16) \(60\) recruits

17) \(3.493 \times 10^8\)

18) \(2.780 \times 10^6\) mm

19) \(1.0545 \times 10^3\) mm

20) \(-\frac{1}{4}\)

A) Yes, the speed limit was 44 MPH

B) \(52\text{ km} \times \frac{1\text{ h}}{70\text{ km}} = 46\text{ h}\)

C) \(46\text{ h} \times \frac{60\text{ min}}{1\text{ h}} = 27\text{ minutes}\)

D) \(28\text{ minutes}\)

E) \(-\frac{1}{4}\)

\text{Use a leading zero when the number is less than 1.}
Design Project #1: Rectifiers (Sep. 2010)

Abstract—The objective of this design lab was to teach me how to design rectifiers and basic DC power supplies. I was given specifications for a rectifier design which I had to meet or exceed its limits. With these specifications, I found which electrical components to utilize and designed a bridged rectifier. With this design project I found that the bridge rectifier is one of the better rectifier designs. Throughout this report I have explained how I designed my circuit, what measurements I obtained from the circuit, what I had concluded about the experiment, and how much the circuit had cost.

Index Terms—AC-DC Power Conversion, Diodes, and Rectifiers

I. INTRODUCTION

The design lab was designed to teach me how to meet design specifications and to create a rectifier. Throughout this report I will explain my process of choosing my electrical elements and my process of choosing the correct rectifier build.

First, I will explain my process in which I concluded a bridge rectifier was best suited for the specifications given:

- Must be a full-wave rectifier
- Peak output voltage must be \( V_p \leq 16V \)
- No load voltage must be \( V_p \leq 18V \)
- Load \( \geq 0.5A \) peak
- Peak to peak ripple voltage \( \leq 20\% \) of \( V_p \)
- Maximum total component cost \( \$20 \)

Since I needed a full-wave rectifier I had the choice between a center-tapped (transformer) rectifier or bridge rectifier. These rectifiers are classified as full-wave rectifiers since they make full use of the input waveform, whereas, a half-wave rectifier only conducts half of the waveform. Half-wave rectifiers can only conduct in one direction, meaning that on the negative portion of the waveform the diode blocks the signal. Full-wave rectifiers can conduct both in the positive and negative portions of the waveform. Using the full waveform is more efficient and does not waste the negative half-cycle.

With that understanding I had to choose between the two full-wave rectifiers, so I researched their properties. The center-tapped transformer as shown below: (Figure 1)

![Figure 1: Center-tapped rectifier basic design.](image)

My design then had to be changed to a bridge rectifier circuit. As shown below: (Figure 2).

![Figure 2: Bridge rectifier basic design.](image)

More diodes are used in the bridge rectifier design, but the circuit gave me the ability to utilize both the windings in the center-tapped transformer as one, meaning the peak to peak voltage was doubled. This design fixed my voltage deficiency. With this final design choice made I continued to do the necessary procedures to find what components were needed to meet the specifications.

II. PROCEDURE FOR PAPER SUBMISSION

A. Initial Measurements

The first step of the design lab was to choose a transformer and find its peak voltage of the secondary winding. To do this I had to connect my line cord to the appropriate primary winding wires and plug the line cord into the wall socket (While keeping the wall socket turned off). Then I connected high-impedance probes to one of the secondary windings positive terminals and the ground respectively. When the probes were secured I turned on the wall socket and made preparations to measure the peak to peak output voltage of my transformer without current being drawn. Once the oscilloscope was ready I turned on the wall socket and made the quick measurement of the transformer. Once I had a good measurement I stopped the oscilloscope to save the data and immediately turned the wall socket off (This technique for measuring my design will be used for all peak to peak measurements).
From this peak to peak measurement I found that my transformer can meet the specifications. With this found I then continued to calculate what components were suitable for my transformer and specifications.

B. Selection of Components

All components and final data will be in the EQUIPMENT section. This part of the procedure will provide the information behind my calculations and explain what methods I used. The first important decision I had to make was what max voltage I would use (within the specifications). Once I had made that decision I used had to find a diode drop that was best suited for the design. With that diode drop I could calculate the max voltage from my secondary winding voltage.

$$V_M = V_S - \alpha V_f$$

EQ 1: $V_M$ = Voltage Max, $V_S$ = Secondary Winding Voltage, $\alpha$ = Number of Diodes in Series, $V_f$ = Forward Diode Voltage Drop.

Since $V_M$ is dependent on how many diodes I had in series with the secondary winding voltage I was able to control my max voltage. Then I had to calculate also with the secondary winding voltage and the forward voltage drop what was my peak inverse voltage needed for the diodes.

$$PIV = V_S - V_f$$

EQ 2: PIV = Peak Inverse Voltage

After I calculated PIV, I had to choose what amperage I was looking to output from the design. Once I had made that decision I had to use Ohm’s Law (V=RI) to calculate what resistance was needed and what power rating the load resistor had to have. With that I could calculate my ripple voltage that is less than twenty percent of my max voltage. So I found what twenty percent of my max voltage was and then compared that number with the equation:

$$V_f = \frac{V_M}{2fRC}$$

EQ 3: $V_f$ = Ripple Voltage, $f$ = frequency (60Hz), $R$ = Resistance of Load Resistor (Ω), $C$ = Capacitor (F)

With the PIV and ripple voltage found I had to continue to find the diodes average current and the diodes max current in the design.

$$I_{Dpeak} = \frac{V_M}{R} \left(1 + \pi \sqrt{\frac{2V_M}{V_f}} \right)$$

$$I_{DAverage} = \frac{1}{\pi} \sqrt{\frac{V_M}{V_f}} R \left(1 + \pi \sqrt{\frac{2V_M}{V_f}} \right)$$

EQ 4 & 5: $I_{Dpeak}$ = Peak Current Through Diode, $I_{DAverage}$ = Average Current

Through Diode

With all these calculations I was able to find the general values needed for my load resistor, capacitor, and diodes.

C. Design

The design for the bridge rectifier was ready, but I had an issue with my no load voltage remaining too high. So I had to integrate a shunt resistor into my design. The shunt resistor should allow the diodes to continue to pull voltage through them without a load so the diodes continue to pull voltage from the source. This then keeps my voltage under the given specifications of having less than 18 V.

I then found another flaw in my design. I wasn’t getting enough voltage drop from my diodes to keep the design within the specifications. So I added a second diode in series with one diode for each cycle. This then was my final adjustment for my design.

D. Construction

Following my schematic the design came together well. Although I had forgotten that we had to demonstrate our design with a load and without a load. Therefore, I had to create a way to disconnect my load resistor easily. I chose to run two wires between the load and the rectifier so I was able to disconnect the load resistor easily.

E. Final Measurements

Once I had constructed my final circuit I ran similar test as I had previously stated in part A of the procedure. I connected two high-impedance probes to my load resistor and took the peak to peak voltage and the ripple voltage. Then after those measurements I disconnected the load resistor from the rectifier and measured the peak to peak voltage across my shunt resistor. All measurements came within the specifications. See the RESULTS section of the lab report.
III. SCHEMATIC

Figure 3: Final Bridge Rectifier Design, consisting of six diodes, a shunt resistor (100 Ω), a load resistor (15 Ω), and a capacitor (6800 μF).

My final schematic was a bridge rectifier which had three diodes in each half-cycle. The shunt resistor was used to bring my no load voltage down and my 6800 μF capacitor was used to reduce my ripple voltage. Finally, my load resistor was 15 Ω with a 25 W power rating. The low ohm rating allowed me to draw a large amount of current and the power rating was high in order to be stable with the rectifiers power output.

IV. EQUIPMENT

<table>
<thead>
<tr>
<th>Part</th>
<th>Part #</th>
<th>Cost</th>
<th>Quantity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diode</td>
<td>UF2004</td>
<td>$0.48</td>
<td>6</td>
<td>$2.88</td>
</tr>
<tr>
<td>Capacitor</td>
<td>565-1069-ND</td>
<td>$2.16</td>
<td>1</td>
<td>$2.16</td>
</tr>
<tr>
<td>Resistor Load</td>
<td>615-15R0-FBW</td>
<td>$1.25</td>
<td>1</td>
<td>$1.25</td>
</tr>
<tr>
<td>Resistor Shunt</td>
<td>RFP-5-100AX</td>
<td>$1.35</td>
<td>1</td>
<td>$1.35</td>
</tr>
<tr>
<td>Line Cord</td>
<td>--</td>
<td>$0.99</td>
<td>1</td>
<td>$0.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total $18.62</td>
</tr>
</tbody>
</table>

Table 1: Parts used in the bridge rectifier, prices found via online or from store where it was purchased.

Figure 4 shows that I found the peak to peak output load voltage to be 15V, which is within the specification that it must be between 11V and 16V.

V. RESULTS

Figure 5: Peak to peak ripple voltage with load (1.4V)

Figure 5 shows that I found the peak to peak ripple voltage with load to be 1.4V, which is less than twenty percent of my output voltage.
VI. DISCUSSION

My design output a peak to peak output load voltage of 15V. Then I divide the 15V with my load resistor value of 15Ω, I found my load current to be 1A. In actual lab I measure my output current to be 0.89A. I have successfully met all the specifications of the lab. The most difficult part of this design lab was doing the calculations to find what components to use. It was frustrating because if I would have screwed up I wouldn't have had enough time to order different parts. Luckily the lab group was very helpful and lent me a part or two. Also it was helpful when I had to think things out and discuss with someone about my design.

VII. CONCLUSION

The lab finished well. I had constructed a circuit which could output 0.89A and fit all specifications. I had put in many hours into these areas of the design lab:

- Part Finalization and ordering- 2 hours
- Construction- 3 hours
- Measurements- ½ hour
- Report writing- 4 hours

The design lab was very time consuming and I plan to be more prepared for the next lab.
designer fails to understand why or how they work. There was
a solution that involved some sharing of gates. I found it using
software modeling, but even after spending hours tracing the
functions, the algebra was too cumbersome for me to follow.
Furthermore, the implementation used one extra NAND gate
(and one less inversion) so it was a wash at best. Obviously
"optimization" is subjective, based on what target(s) we are
optimizing for. While adding more levels may or may not
be optimal, given some criteria, it does reduce all the gates
to simple two input NAND gates (and inverters). While my
implementation was not the prettiest, either on paper or on
a breadboard, it should be the least expensive to build in
hardware (in theory, of course).

The simulation part of the lab was confusing at best. After
several missteps, I managed to compile the project with zero
errors. The whole thing felt a bit like driving a tank to the
grocery store, except the tank was built by aliens with an
unspecified number of limbs, using an unknown language.
While the aliens are chasing you. With guns. Probably guns,
although they might just want to say hi. The point is I had
no idea what the software was designed to do, let alone figure
out how to do it. It was grossly overpowered for the project,
and I was unsure what it was supposed to look like even if I
was doing things right. I can generally guess what to put into
a program, so long as I have a general idea what to expect to
come out of the program. I knew neither. I'm sure, however,
that it is a wonderful piece of software that will be immensely
useful. Probably. Or, I'll crash it into a tree. Either way, I'll
wind up with one hell of a headache.

I also learned that you can dismount a fingernail under
the end of a chip and "pop" it off a breadboard and expect
to be able to reuse the chip. I wrecked three chips before I
noticed that I had either broken off a leg or broken the internal
connection to the pin.

VII. CONCLUSION

The design, optimization and implementation of a circuit so
simple that it seems almost trivial on paper, can be surprisingly
Byzantine, as this project proves. Considering the fact that,
even at this level, the tools at hand are fairly high-level (there
are hidden complexities inside a simple NAND gate or inverter
that are well beyond the scope of this project), I have a
newfound admiration for the intricate and labyrinthine designs
of even the most mundane of modern appliances and electronic
devices.
Objective:
The purpose of the lab is to familiarize ourselves with an LED and use Kirchoff's laws. In this lab we will make a circuit containing an LED and gather data over a range of voltages applied to the circuit, in order to develop a quantitative model for the LED circuit. And show how the voltage changes as we increase it in the lab and measure it across the different nodes.

Schematic:
This is the schematic of the circuit that we had to construct during lab.

![Schematic Diagram]

Figure 1

The figure above is the circuit that we used in the lab to find the voltage that we would use to make the graph of the LED. Also, the way that we measured the voltage was we used the DMM and the red probe was placed right after all of the 1kΩ resistors and the black probe was placed right after the LED which is the symbol that looks like a triangle with a line at the point.

Data:
The data were obtained from us measuring the different voltages of the circuit and also calculated after class.

\[
\frac{1}{R_{eq}} = \frac{1}{1002} + \frac{1}{999} + \frac{1}{1001}
\]

\[
R_{eq} = 333\Omega
\]

This was the equivalent resistance that we calculated during the lab from the three different resistors that were given to us.
This graph shows the way that the current changes as the voltage increased and also a linear fit line from 2 different points on the graph and from it we found the equation that can help us find 

\[ y = 0.1053x - 0.2046 \]
The following are true/false questions taken from the National Society of Professional Engineers website (http://www.nspe.org/Ethics/EthicsResources/EthicsExam/index.html). At the end of each question, I have supplied the portion of the NSPE Code of Ethics that explains the answers. (The NSPE code of ethics can be found at http://www.nspe.org/Ethics/CodeofEthics/index.html).

For each of the questions below, refer to the NSPE Code of Ethics to explain, in a sentence or two, why the answer is true or false. Do not just write the code as your answer, but point out the wording from the code that specifically makes the statement true or false.

1. Engineers in the fulfillment of their professional duties must carefully consider the safety, health and welfare of the public. (NSPE Code 1.1)
   - True, Engineers are held responsible for considering all of these.

2. Engineers may issue subjective and partial statements if such statements are in writing and consistent with the best interests of their employer, client or the public. (NSPE Code 1.3)
   - True, it states they are allowed to issue objective public statements, which means it would have to be to the best interest of the employer.

3. Engineers shall not be required to engage in truthful acts when required to protect the public health safety and welfare. (NSPE Code of Ethics 1.5)
   - False, it states that the engineer shall avoid deceptive acts, and when they are allowed to stay away from engaging in truthful acts is very deceptive.

4. Engineers may not be required to follow the provisions of state or federal law when such actions could endanger or compromise their employer or their client's interests. (NSPE Code of Ethics 1.6)
   - False, the engineer shall conduct themselves lawfully, meaning they do have to follow the provisions of state or federal law.

5. Engineers shall undertake assignments only when qualified by education or experience in the specific technical fields involved. (NSPE Code II.2.a.)
   - True, every engineer has a certain specialty they focus on in their particular field and they should not take over an assignment with little to no knowledge.

6. Engineers shall not affix their signatures to plans or documents dealing with subject matter in which they lack competence, but may affix their signatures to plans or documents not prepared under their direction and control where the engineer has a good faith belief that such plans or documents were competently prepared by another designated party. (NSPE II.2.b.)
   - False, an engineer may not affix their signature to anything.

Really? So does that mean I can't sign my driver's licence?
Discussion:

During this lab we had to use the DMM to gather different voltages from different parts of the circuit. I started by setting $V_{in}$ to 0V and then raising the voltage by intervals of 0.5V up to 16V. During this time we measured the voltage across the LED to make the graph. After we got the data from the experiment then we used the equation $\text{Current} = (V_{in} - V_{on LED})/R_{eq}$ to find the current which was $I_D$. From this data we got the graph which has a linear line of best fit because when the voltage is small the LED does not turn on for the first voltages because they were small. From the linear equation we can then find $V_f$ is 1.94V and then $R_f$ is 9.524Ω. During the experiment we had to use three 1kΩ resistors. But we could have just used a 330Ω resistor which would save time and materials. I had to use the three resistors because if we were to use a 330Ω resistor then the actual resistance could be different from what it’s supposed to be and then the calculations could be wrong. So using the three 1kΩ resistors instead of the 330Ω equivalent resistor was helpful because the tolerance of each 1kΩ resistors in parallel is better than just the one resistor by itself. Also the 1kΩ resistors are standard values of resistors that one can get in a store and the 330Ω is not a standard value resistor.
B. Measurements

The only data that was necessary to collect was the output signal. This indicates the gain of the amplifier. The current \( I_0 \) was read at 7.5 mA. This is displayed via importing a Wintek picture of the output versus the input. Figure 2 shows that my circuit in Figure 1 yields a gain of approximately 10.19 V/V which is well within the specifications of a gain less than 11 V/V and greater than or equal to 10 V/V.

![Figure 2: A Wintek picture of the output (Channel 2) versus the input (Channel 1) of the circuit in figure 1.](image)

C. Conclusion

Although all specifications were met, not everything occurred as planned from the pre-laboratory analysis. As stated earlier, the output resistance was calculated incorrectly. The working model on PSpice is included in this report on page 2 along with the PSpice simulation representing the gain of the circuit that shows a gain of 10.19 V/V.

This laboratory was not too strenuous as it did not take as long as other laboratories in the past. The pre-laboratory analysis took approximately 5 hours, the wiring and debugging took 1.5 hours, and the written report took 1.5 hours for a total of 8 hours to complete this laboratory.

After taking 8 hours, I'm surprised you finished the project.
Figure 1 is the saturation region design of the amplifier with important currents and voltages listed. All resistances are measured in ohms.

Figure II is the triode region design of the amplifier with important voltages and currents listed. All resistances are measured in ohms.

II. MEASUREMENTS

A. First Measurements

After building a circuit for each region I tested the drain to source voltage and the drain current to verify that I was near the simulation values. For the saturation region, the expected value for $V_{DS}$ was 3.333V. The measured value was only 3.084V. The drain current then went up to 17.4mA when it should have been 16.3mA. I had to go back to the paper and look at what I could do to decrease the error. For the triode region, $V_{DS}$ was at 0.394V and should have been 0.3V. $I_D$ was 11.47mA and should have been 11.3mA. The triode region was much closer than the saturation region.

B. Re-Design

The drain to source voltage was too high so I thought that my solution was to increase that value while meeting the specifications. I thought to check the drain and source resistances to see how far off they were from the ideal calculated value for them. I calculated them to each be exactly 204Ω and used 200Ω resistors for both. They actually measured to about 196Ω. So I realized why the measured $V_{DS}$ and $I_P$ values were so different than expected. I knew that increasing the resistance would solve the problem. I tried to find 200Ω resistors that were closer to 204Ω and found none. So I started to measure the next standard resistor value of 220Ω and most of them were about 216Ω. If I changed them out then I would go from a low $V_{DS}$ and high $I_D$ to a high $V_{DS}$ and a low $I_D$. Then I contemplated changing just the $R_S$ value to 220Ω and leave $R_P$ the same. So I did, knowing that it would have a very small effect on the rest of the circuit and would allow my circuit to meet specifications. Figure 3 is the new schematic for the saturation region.

C. Final Measurements

After swapping $R_S$ I tested the circuit again. This time $V_{DS}$ was 3.394V and $I_D$ was 16.24mA. This was much closer to the specified value so I kept it. Since I rounded down from 204Ω to 200Ω to find a standard $R_S$ and $R_P$ value, and the actual resistor values were even lower, there was too much error. Once I sorted out the saturation region I could apply the appropriate signal for each region and make sure the output matched the transient simulation. The two outputs measured on the oscilloscope are figures IV and V.

Figure IV is the oscilloscope reading of the input and output voltage for saturation. The input is channel 1 and the output is channel 2.
I have a few questions for the word assignment.
1. Are we supposed to complete the Excel document insert, with the ratio of cost?
2. Should I save and drop the file in Word 03 format, or can it stay in Word 07?

Thanks
Objective:

The purpose of this laboratory project is to become further acquainted with the use of an oscilloscope. Also, to observe the behavior of resistor and resistor-capacitor circuits.

Schematic:

Below are the two schematics of the circuits that we had to build in lab for finding the different waive forms and how they reacted different when we changed the amount of frequency that we used.

\[ V_1 \quad 1k\Omega \quad V_2 \]
\[ V_3 \quad 1k\Omega \quad V_4 \]

(a) Resistive circuit

(b) RC circuit

Date:

This table has the data from the circuit with a capacitor.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Actual</th>
<th>$\Delta T$</th>
<th>Amp</th>
<th>Phase Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Hz</td>
<td>99Hz</td>
<td>120ms</td>
<td>4.8V</td>
<td>4320</td>
</tr>
<tr>
<td>1kHz</td>
<td>991.1Hz</td>
<td>10ms</td>
<td>4.8V</td>
<td>3600</td>
</tr>
<tr>
<td>10kHz</td>
<td>10.0kHz</td>
<td>14$\mu$s</td>
<td>3.24V</td>
<td>540</td>
</tr>
<tr>
<td>100kHz</td>
<td>100.3kHz</td>
<td>2.4$\mu$s</td>
<td>0.50V</td>
<td>864</td>
</tr>
<tr>
<td>1MHz</td>
<td>1.044MHz</td>
<td>220ns</td>
<td>0.052V</td>
<td>792</td>
</tr>
</tbody>
</table>

This table has the data from the two resistor circuit.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Actual</th>
<th>$\Delta T$</th>
<th>Amp</th>
<th>Phase Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Hz</td>
<td>99.01Hz</td>
<td>0</td>
<td>2.32V</td>
<td>0</td>
</tr>
<tr>
<td>1kHz</td>
<td>998.1Hz</td>
<td>0</td>
<td>2.32V</td>
<td>0</td>
</tr>
<tr>
<td>10kHz</td>
<td>10.0kHz</td>
<td>0</td>
<td>2.50V</td>
<td>0</td>
</tr>
<tr>
<td>100kHz</td>
<td>100.4kHz</td>
<td>0</td>
<td>2.40V</td>
<td>0</td>
</tr>
<tr>
<td>1MHz</td>
<td>1.055MHz</td>
<td>60ns</td>
<td>2.20V</td>
<td>2160</td>
</tr>
</tbody>
</table>

The Phase shift equation that was used in this lab was $\text{Phase Shift} = F \times \Delta T \times 360$. And this was used for both of the different phase shifts for both tables.
Discussion:

During this lab we had to use a simple circuit which had three elements. During the pre-lab we simulated what would happen to the circuits if we were to send different values of frequency and how they would react to this. The first circuit had a power source that had five volts and two 1k\(\Omega\) resistors. The graphs for this circuit were the same because for the simulation we got a straight horizontal line and during the lab the values of the phase shift were 0 for most of the time and that means that the graph was a straight line like what we got during the simulation. For the circuit that had a 15\(\mu\)F capacitor instead of a 1k\(\Omega\) resistor the graph during the pre-lab simulation had a curve that as frequency increased the voltage decreased. The graphs that we got during lab were very similar to the one of the pre-lab as they all had similar behavior. As frequency increased the voltage decreased like what we got in the pre-lab. The capacitor circuit would have a curve to it because the capacitor would change the phase shift as frequency was applied to it. In the end both of the graphs that we got during the pre-lab were similar to the graphs that we observed during this lab.
Open book, closed notes.
- Show all work, neatly, and circle or underline the final answer for credit.
- Any work that is not to be graded must either be clearly crossed out or completely erased.
- State AND validate any assumptions made.
- Assume T=300K unless otherwise stated.
- Hints may be purchased for points.

1. A Schottky diode is formed with tungsten on n-type silicon with \( N_d = 1 \times 10^{16} \text{ cm}^{-3} \). The diode has a cross-sectional area of \( 2 \times 10^{-4} \text{ cm}^2 \). Determine the current if a forward voltage of 0.3V is applied.

\[
J_{ST} = \frac{A^* T^2 e^{-\frac{\phi_B n}{kT}}}{kT} \text{ Area is given } \quad \text{ and find } I\text{,} -3 \\
A^* = \frac{4\pi e m^* k^2}{h^2} \phi_B n = \frac{1}{e} (E_g - e\phi_0) \phi_0 = \sqrt{\frac{eE}{4\pi \varepsilon_0}} \phi_B n = 0.54 \text{ V} \text{ mass of an electron } \quad -2
\]

\[
A^* = \frac{4\pi (1.6 \times 10^{-19}) (1.08) (8.62 \times 10^{-5})}{(4.135 \times 10^{-15})} \quad \phi_B n = 0.54 \text{ V} \text{ mass of an electron } \quad -2
\]

\[
A^* = 2.282 \times 10^{17} \quad \text{ unreasonable}
\]

\[
J_{ST} = (2.282 \times 10^{17}) (300)^2 e = 2.05 \times 10^{22}
\]

\[
J = (2.05 \times 10^{22}) \left[ e^{\frac{1.16 \times 10^{-9} (6.3)}{0.0269}} - 1 \right] = (2.054 \times 10^{22}) \left( \frac{1}{100 \text{ cm}} \right)^2
\]

\[
\phi_m = 4.55 \text{ V} \phi_B n = 4.55 - 4.101 = 0.44 \text{ V}
\]

\[
\theta = 2.054 \times 10^{18} \text{ cm}^{-2} \quad \text{ units are off}
\]

\[
10^{18} \text{? !? cm}^{-2} \text{?}
\]

Do you have an idea of how much current that is?
Data:

The following data were obtained through measuring the voltage across the diode. Also a graph of the data calculated and measured will be on the following page.

<table>
<thead>
<tr>
<th>Voltage Supplied</th>
<th>Voltage across diode</th>
<th>Calculated Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.5</td>
<td>0.5</td>
<td>4.968091591</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2.41035E+15</td>
</tr>
<tr>
<td>1.5</td>
<td>1.5</td>
<td>1.16942E+24</td>
</tr>
<tr>
<td>2</td>
<td>1.77</td>
<td>5.73257E+28</td>
</tr>
<tr>
<td>2.5</td>
<td>1.83</td>
<td>6.31911E+29</td>
</tr>
<tr>
<td>3</td>
<td>1.86</td>
<td>2.09802E+30</td>
</tr>
<tr>
<td>3.5</td>
<td>1.89</td>
<td>6.96567E+30</td>
</tr>
<tr>
<td>4</td>
<td>1.91</td>
<td>1.55024E+31</td>
</tr>
<tr>
<td>4.5</td>
<td>1.92</td>
<td>2.31268E+31</td>
</tr>
<tr>
<td>5</td>
<td>1.94</td>
<td>5.14697E+31</td>
</tr>
<tr>
<td>5.5</td>
<td>1.96</td>
<td>1.14548E+32</td>
</tr>
<tr>
<td>6</td>
<td>1.97</td>
<td>1.70885E+32</td>
</tr>
<tr>
<td>6.5</td>
<td>1.97</td>
<td>1.70885E+32</td>
</tr>
<tr>
<td>7</td>
<td>1.98</td>
<td>2.54931E+32</td>
</tr>
<tr>
<td>7.5</td>
<td>2.01</td>
<td>8.46401E+32</td>
</tr>
<tr>
<td>8</td>
<td>2.02</td>
<td>1.26268E+33</td>
</tr>
<tr>
<td>8.5</td>
<td>2.03</td>
<td>1.8837E+33</td>
</tr>
<tr>
<td>9</td>
<td>2.05</td>
<td>4.19225E+33</td>
</tr>
<tr>
<td>9.5</td>
<td>2.06</td>
<td>6.25411E+33</td>
</tr>
<tr>
<td>10</td>
<td>2.07</td>
<td>9.33003E+33</td>
</tr>
<tr>
<td>10.5</td>
<td>2.08</td>
<td>1.39188E+34</td>
</tr>
<tr>
<td>11</td>
<td>2.09</td>
<td>2.07644E+34</td>
</tr>
<tr>
<td>11.5</td>
<td>2.1</td>
<td>3.09768E+34</td>
</tr>
<tr>
<td>12</td>
<td>2.11</td>
<td>4.62119E+34</td>
</tr>
</tbody>
</table>

Figure 2 Data collected in the lab. Voltage supplied, voltage across the diode and calculated voltage.

1. Table is not needed
2. Way too many sig. figs.
3. If currents were anywhere near what you calculated this wouldn't exist anymore. What is equivalent to a neon generator bulb?
Laboratory Projects #3: LED’s and Kirchhoff’s Laws

EE1210
Lab Date: February 24th

Discussion

This lab displayed that not all electrical components obey Ohm’s law, one of these being the LED. Because of the circuit’s structure including a resistor of a known value which does obey Ohm’s law in series with the LED; we are able to calculate a current vs. voltage relationship for the LED using Kirchhoff’s current and voltage laws. The current voltage relationship can be seen in the graph and expressed as the modified line equation seen above in the data section.

One reason for the use of three 1kΩ resistor is to add complication to the math, adding room for computation errors, thereby amusing the professor. Or to give the students practice using mathematical techniques learned in the classroom on an application. It also could be due to the added mass of the component containers allowing for more force to be applied when hitting a student with a container, in a symbolic teacher student hazing ritual. An additional reason may be to increase the maximum wattage rating of that particular section of the circuit. There is also a possibly that in the process of moving from one academic building to another, all the 330Ω resistors might have been misplaced. Yet another reason could be to justify asking why as a question for the report.
## Data

<table>
<thead>
<tr>
<th>Resistors</th>
<th>Color Order</th>
<th>Calculated Resistance</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Orange White Red Gold</td>
<td>3900Ω</td>
<td>5%</td>
</tr>
<tr>
<td>2</td>
<td>Green Brown Brown Gold</td>
<td>510Ω</td>
<td>5%</td>
</tr>
<tr>
<td>3</td>
<td>Orange Orange Brown Gold</td>
<td>330Ω</td>
<td>5%</td>
</tr>
<tr>
<td>4</td>
<td>Orange Blue Brown Gold</td>
<td>310Ω</td>
<td>5%</td>
</tr>
<tr>
<td>5</td>
<td>Yellow Orange Brown Gold</td>
<td>430Ω</td>
<td>5%</td>
</tr>
<tr>
<td>6</td>
<td>Brown Red Gold Gold</td>
<td>1.2Ω</td>
<td>5%</td>
</tr>
<tr>
<td>7</td>
<td>Brown Gray Brown Gold</td>
<td>180Ω</td>
<td>5%</td>
</tr>
<tr>
<td>8</td>
<td>Brown Green Red Gold</td>
<td>1500Ω</td>
<td>5%</td>
</tr>
<tr>
<td>9</td>
<td>Red Yellow Black Gold</td>
<td>24Ω</td>
<td>5%</td>
</tr>
<tr>
<td>10</td>
<td>Orange Black Brown Gold</td>
<td>300Ω</td>
<td>5%</td>
</tr>
<tr>
<td>11</td>
<td>Red Red Orange Gold</td>
<td>22000Ω</td>
<td>5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resistors</th>
<th>Resistance Range</th>
<th>Resistors</th>
<th>Measured Resistance</th>
<th>Resistance Between AE= 864Ω</th>
<th>Voltage Between AE= 10V</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4095Ω - 3705Ω</td>
<td>1</td>
<td>3860Ω</td>
<td>Voltage Between AE= 10V</td>
<td>Voltage Between AE= 10V</td>
</tr>
<tr>
<td>2</td>
<td>533.5Ω - 484.5Ω</td>
<td>2</td>
<td>510Ω</td>
<td>Voltage Between AE= 10V</td>
<td>Voltage Between AE= 10V</td>
</tr>
<tr>
<td>3</td>
<td>346.5Ω - 313.5Ω</td>
<td>3</td>
<td>328Ω</td>
<td>Voltage Between AE= 10V</td>
<td>Voltage Between AE= 10V</td>
</tr>
<tr>
<td>4</td>
<td>378Ω - 342Ω</td>
<td>4</td>
<td>358Ω</td>
<td>Voltage Between AE= 10V</td>
<td>Voltage Between AE= 10V</td>
</tr>
<tr>
<td>5</td>
<td>451.5Ω - 408.5Ω</td>
<td>5</td>
<td>430Ω</td>
<td>Voltage Between AE= 10V</td>
<td>Voltage Between AE= 10V</td>
</tr>
<tr>
<td>6</td>
<td>1.26Ω - 1.14Ω</td>
<td>6</td>
<td>1Ω</td>
<td>Voltage Between AE= 10V</td>
<td>Voltage Between AE= 10V</td>
</tr>
<tr>
<td>7</td>
<td>189Ω - 171Ω</td>
<td>7</td>
<td>177Ω</td>
<td>Voltage Between AE= 10V</td>
<td>Voltage Between AE= 10V</td>
</tr>
<tr>
<td>8</td>
<td>1575Ω - 1425Ω</td>
<td>8</td>
<td>1490Ω</td>
<td>Voltage Between AE= 10V</td>
<td>Voltage Between AE= 10V</td>
</tr>
<tr>
<td>9</td>
<td>25.2Ω - 22.8Ω</td>
<td>9</td>
<td>20Ω</td>
<td>Voltage Between AE= 10V</td>
<td>Voltage Between AE= 10V</td>
</tr>
<tr>
<td>10</td>
<td>315Ω - 285Ω</td>
<td>10</td>
<td>297Ω</td>
<td>Voltage Between AE= 10V</td>
<td>Voltage Between AE= 10V</td>
</tr>
<tr>
<td>11</td>
<td>23100Ω - 20900Ω</td>
<td>11</td>
<td>21800Ω</td>
<td>Voltage Between AE= 10V</td>
<td>Voltage Between AE= 10V</td>
</tr>
</tbody>
</table>

**Table 1:** Measurements obtained during the lab. Calculated measurements were read off of the resistors themselves. The measured data was found using a DMN.
Figure 2.03

<table>
<thead>
<tr>
<th>From Node</th>
<th>To Node</th>
<th>Calculated Voltage</th>
<th>Measured Voltage</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>10.00</td>
<td>10.03</td>
<td>Volts</td>
</tr>
<tr>
<td>B</td>
<td>E</td>
<td>7.91</td>
<td>7.94</td>
<td>Volts</td>
</tr>
<tr>
<td>C</td>
<td>E</td>
<td>4.10</td>
<td>4.11</td>
<td>Volts</td>
</tr>
<tr>
<td>D</td>
<td>E</td>
<td>3.05</td>
<td>3.08</td>
<td>Volts</td>
</tr>
</tbody>
</table>

Voltage Across Circuit - data table

Figure 2.04

<table>
<thead>
<tr>
<th>Calculated Resistance</th>
<th>Measured Resistance</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>864</td>
<td>854</td>
<td>Ohms</td>
</tr>
</tbody>
</table>

Resistance of Circuit - data table

Discussion

The first part of the lab was to measure and identify the ten resistors that we were given. This information is recorded in Figure 2.01. From this data we observed that all but one of the resistors were within there tolerance range. The only one that was not within it was a one ohm resistor. The reason for this is that our DMM had an error of plus or minus 0.4 ohms.

The second part of the lab was to build the circuit represented in Figure 2.02. After we had constructed this circuit we measured the voltages across various parts of the Circuit. Our data was recorded in Figure 2.03. From this data and the previous evidence that our DMM is not perfect we conclude that all parts of the circuit are within there tolerance. The calculated and measured resistance for the circuit are given in figure 2.04.

Conclusion

From this information we can conclude that in all laboratory settings there is going to be discrepancies from the calculated data. This can be accounted for using the tolerance of the instruments that you are using.
3. A silicon n-channel JFET has a channel thickness of 0.5μm, a channel doping of $N_s=10^{16}$cm$^{-3}$ and a gate doping of $N_d=10^{18}$cm$^{-3}$.
   a. Determine the gate voltage at which the channel pinches off.

   
   $$V_{th} = V_L m \left( \frac{N_d}{N_i} \right) = (25.9 \text{ m}) \left( \frac{10^{18}}{1.5 \times 10^{16}} \right) = 0.8139 \text{ V}$$

   $$V_{po} = \frac{e a^2 N_X}{2 \varepsilon_s} = \frac{(1.6 \times 10^{-19})(3.2457 \times 10^6)^2}{2(8.85 \times 10^{-14})} \approx 8.139 \text{ V}$$

   $$V_G = -7.33 \text{ V}$$

4. In a MOSFET, why is the parasitic BJT off under normal operation? In snapback breakdown, how does the parasitic BJT turn on?

   I don't remember. Please refer to my notes because I remember you talking about it.

   -10
8. List three reasons you might visit a faculty member during his/her office hours. (6 pts)
   - Help on homework
   - Get to know your teachers
   - Review your grades

9. Write the spreadsheet equation as you would enter it in cell C7 in order to calculate
   \[ y = \frac{a \cdot x}{b} - c \]. The equation should be written such that it can easily be copied down to
   cells C8:C12. (8 pts)

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   \[ y = \left( \frac{55 \cdot 8_+}{81} \right) - 3 \]

   If you wanted to change the values of \( a, b, c \) and \( c \), you could enter them in the
   cell #s for them instead of values.

10. Solve the following set of equations: (8 pts)

\[
\begin{align*}
4a + b + c + 2d &= 1 \\
5a + 2b + 3c + 5d - 10 &= 0 \\
7a + 5b + 8c + 7d + 8 &= 10 \\
12a + 13b + 15c + 12d &= 14
\end{align*}
\]

\[ A = 1.5571 \]
\[ B = 6.9714 \]
\[ C = -2.4571 \]
\[ D = -4.8714 \]
8. List three reasons you might visit a faculty member during his/her office hours. (6 pts)

- Get help on homework
- Just to talk because they get lonely
- Help study for a test

9. Write the spreadsheet equation as you would enter it in cell C7 in order to calculate

\[ y = \frac{a \cdot x}{b} - c \]. The equation should be written such that it can easily be copied down to cells C8:C12. (8 pts)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>a =</td>
<td>55</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>b =</td>
<td>81</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>c =</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td>x</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td>y</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

\[ \frac{55 - B}{81} - 32 - 3 \]

10. Solve the following set of equations: (8 pts)

\[
\begin{align*}
4a + b + c + 2d &= 1 \\
5a + 2b + 3c + 5d - 10 &= 0 \\
7a + 5b + 8c + 7d + 8 &= 10 \\
12a + 13b + 15c + 12d &= 14
\end{align*}
\]

\[
\begin{bmatrix}
4 & 1 & 2 & 17 \\
5 & 2 & 6 & 10 \\
7 & 5 & 7 & 2 \\
12 & 12 & 15 & 14
\end{bmatrix}
\]

\[
\begin{align*}
a &= -2.4 \\
b &= 3.9 \\
c &= 2.4 \\
d &= 6.1
\end{align*}
\]
Show all work, neatly, and circle or underline the final answer for credit. Any work that is not to be graded must either be crossed out or erased. State AND validate any assumptions made. Assume $T=300K$

1. Explain how (and why) a bipolar junction transistor produces gain when in forward active mode.

A bipolar junction transistor produces gain when in the forward active mode because the hobbits in the collector region and the hobbits in the emitter region are natural enemies. The base of a bipolar junction transistor acts as the battleground on which the hobbits engage war to determine the hobbit champion, similar to trench warfare in World War I. However, since the emitter hobbits are doped more heavily (meaning they have a tank), they clearly have the upper hand. Once the emitter hobbits defeat the collector hobbits, they excitedly storm the collector region, bringing with them the signal they found in the base region, once they arrive at the collector, they are so excited that they amplify their signal, similar to the way a country would raise its flag after winning a war.

This is how a bipolar junction transistor operates—signal gain in forward-active mode.
Objective

For this function I went to the writing center to get a freshman English essay looked at. I had to make an appointment for this function, which made for 11:30 in the morning on the function date. My objective was to get my essay looked at and get some feedback and some proofreading help.

What I Learned

By going to the writing center and getting my paper looked at I found out that there were adjustments that I needed to make. I also got explained on putting more citations in my paper. The thing they didn’t really help me on was proofreading.

Opinion

I did like taking my paper to the writing center. I liked the feedback that was given to me and the environment of the center. The thing that I wish would improve would be that the person going over your paper proofread it more and help find grammar errors, because me personally is terrible at proofreading and would like the help on that.
State at least four differences in operation between pn junction and Schottky diodes. Clearly explain each term/ mechanism.

1) The pn junction diode is named "pn junction diode" while the Schottky diode is named "Schottky diode." It is quicker and easier to say "Schottky" than "pn junction" since "Schottky" has only two syllables and "pn junction" is four.
Worn out? Reverse Saturation got you down? Then step into a SCHOTTKYS!

SCHOTTKY
High Energy Drink!
Has REAL bits of Metal and Semiconductors so you'll go long!

Poor grammar
Description of Circuit Design

The first step in my design process was to acquire a BJT that met the laboratory specifications. I purchased a 2N2222 BJT from another student. The next step in my procedure was to measure the characteristics of my BJT using the curve tracer. With the curve tracer I found Ic, Vce and β. Using the information from the curve trace I calculated what the values for my base resistors and my emitter resistor should be for the bias point. Then I used a small signal model to find what my Vbe would be with my current choices of resistors. After which I calculated the minimum size that my capacitors would need to be to meet the spec for cutoff. Next I simulated the design using PSpice which caused me some problems because it would show my output signal being cutoff no matter what I did. To solve this problem I ignored it and assembled my design on the breadboard and found that it worked correctly.

Graphs and Data

The following is a screen capture of the operation of my circuit. Channel 1 is the input and channel 2 is the output.
1) a. 4
   b. 3
   c. 2
   d. 2
   e. 2
   f. infinite or? x

2) a. 84
   b. 3.142
   c. 0.00517
   d. 64.16
   e. 2.71
   f. 999 x

3) a. 65.175 x
   b. 3.493x10^3
   c. 2 cm x
   d. 105.5 cm
   e. 71% results
   f. 3.14

4) 7 trips
   6 vans

5) a) V=9ft^2 h
   V=9ft*8.4
   V=800ft^3
   800ft^3 x 7.48=5984 gal
   5984gal

b) 800ft^3, 162.4 ft x 1 ton=249.6 tons
   2 tons

   c) Z = 50gal/20trips: 200gal/ton
      6000/200 = 30
      30 days

6) 60 mi x 1.609=90.45
   (80 kph yes)

b) 35 km/h 100 min / 60 min = 1.50 km
   150 km
   70 km/h = 43.306
   40m/min
Objective

The purpose of this lab was to come to understand the resistor color-codes and understand the use of a common ground.

Schematic

Below is the schematic of that circuit we measured in the lab, shamelessly copy-pasted from the lab instructions.

![Schematic Diagram]

Figure 1: A circuit that was used in lab 2. It most likely holds little purpose outside of educational value.

Data

Below is a bunch of boxes with numbers in them. You could most likely guess what they mean, but being evil, I will spoil it for you. The data is resistor data from Part 1 of the lab, and Rosebud is a sled.

<table>
<thead>
<tr>
<th>Resister</th>
<th>Calculated(Ωs)</th>
<th>Measured(Ωs)</th>
<th>Percent Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>430</td>
<td>427</td>
<td>0.6%</td>
</tr>
<tr>
<td>2</td>
<td>120000</td>
<td>119300</td>
<td>0.58%</td>
</tr>
<tr>
<td>3</td>
<td>1800000</td>
<td>1766000</td>
<td>1.89%</td>
</tr>
<tr>
<td>4</td>
<td>330</td>
<td>326</td>
<td>1.2%</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>15.3</td>
<td>2%</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1.7</td>
<td>70%</td>
</tr>
<tr>
<td>7</td>
<td>330</td>
<td>314</td>
<td>4.8%</td>
</tr>
<tr>
<td>8</td>
<td>1500</td>
<td>1456</td>
<td>2.9%</td>
</tr>
<tr>
<td>9</td>
<td>510</td>
<td>495</td>
<td>2.9%</td>
</tr>
<tr>
<td>10</td>
<td>200</td>
<td>190.3</td>
<td>4.85%</td>
</tr>
</tbody>
</table>

Table 1: Resistors in values both read by color-code and measured with a DMM.
Below is another beautiful system of rectangles and symbols that attempt to portray voltages between nodes and a common ground.

<table>
<thead>
<tr>
<th></th>
<th>Calculated (Vs)</th>
<th>Measured (Vs)</th>
<th>Percent Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{AE}$</td>
<td>10</td>
<td>9.98</td>
<td>0.2%</td>
</tr>
<tr>
<td>$V_{BE}$</td>
<td>7.915</td>
<td>7.92</td>
<td>0.1%</td>
</tr>
<tr>
<td>$V_{CE}$</td>
<td>4.097</td>
<td>4.10</td>
<td>0.1%</td>
</tr>
<tr>
<td>$V_{DE}$</td>
<td>3.059</td>
<td>3.06</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

Table 2: Calculated voltages between nodes and a common (e), along with measured values.

**Discussion**

The lab and the data the lab provided mostly showed two things. First of all, when the gold band says "+/- 5%", it actually means that. Measured resistances were very often off by one or two percent at least. One exception to this was the measurement of the 1 ohm resistor, which had a 70% difference from the calculated value. This is mostly because of imperfections in the measurement devise—the probes of the DMM alone had a resistance that is important when dealing with such small values.

The circuit voltages were more enlightening, allowing the mental imagery of a circuit being a terrain map with nodes at various voltage heights relative to each other to help simplify everything. Also, the percent error was amazingly low; indeed, they seem to greatly increase one’s confidence in the powers of science.
After every number add Ω

Yellow: 430  yellow orange brown
Red: yellow 120000 brown red yellow
Brown: 180000 brown grey green
Orange: 330 orange orange brown
Brown green black

Brown black add 1
Orange orange brown 330
Brown green red 1500
Green brown brown 510
Red black brown 200

<table>
<thead>
<tr>
<th>Color</th>
<th>Range</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>430</td>
<td>427</td>
</tr>
<tr>
<td>2</td>
<td>120000</td>
<td>119300</td>
</tr>
<tr>
<td>3</td>
<td>1800000</td>
<td>1766000</td>
</tr>
<tr>
<td>4</td>
<td>330</td>
<td>326</td>
</tr>
<tr>
<td>5</td>
<td>125</td>
<td>120</td>
</tr>
<tr>
<td>6</td>
<td>1625</td>
<td>1546</td>
</tr>
<tr>
<td>7</td>
<td>1900</td>
<td>1456</td>
</tr>
<tr>
<td>8</td>
<td>510</td>
<td>495</td>
</tr>
<tr>
<td>9</td>
<td>200</td>
<td>190.3</td>
</tr>
</tbody>
</table>

A-E 860Ω

\[
\begin{align*}
V_{ac} &= 9.98\, \text{V} \\
V_{dc} &= 2.92\, \text{V} \\
\overline{V_{dc}} &= 4.10\, \text{V} \\
\overline{V_{dc}} &= 5.86\, \text{V}
\end{align*}
\]