ELECENG 2EI4: Electronic Devices and Circuits

Design Project #1

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Contents

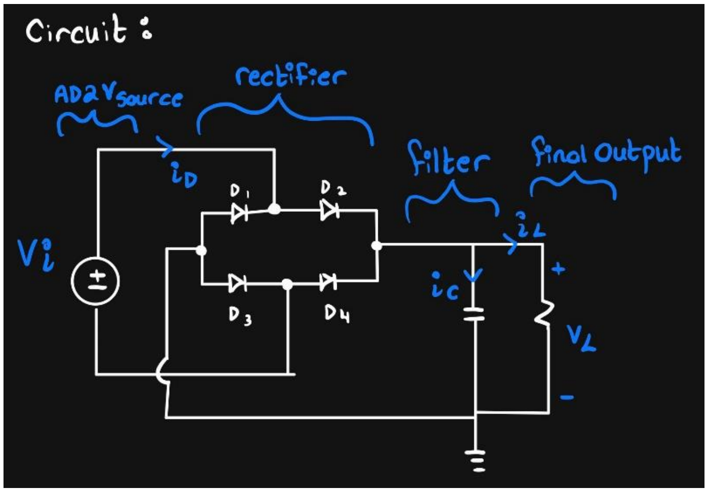
Summary:

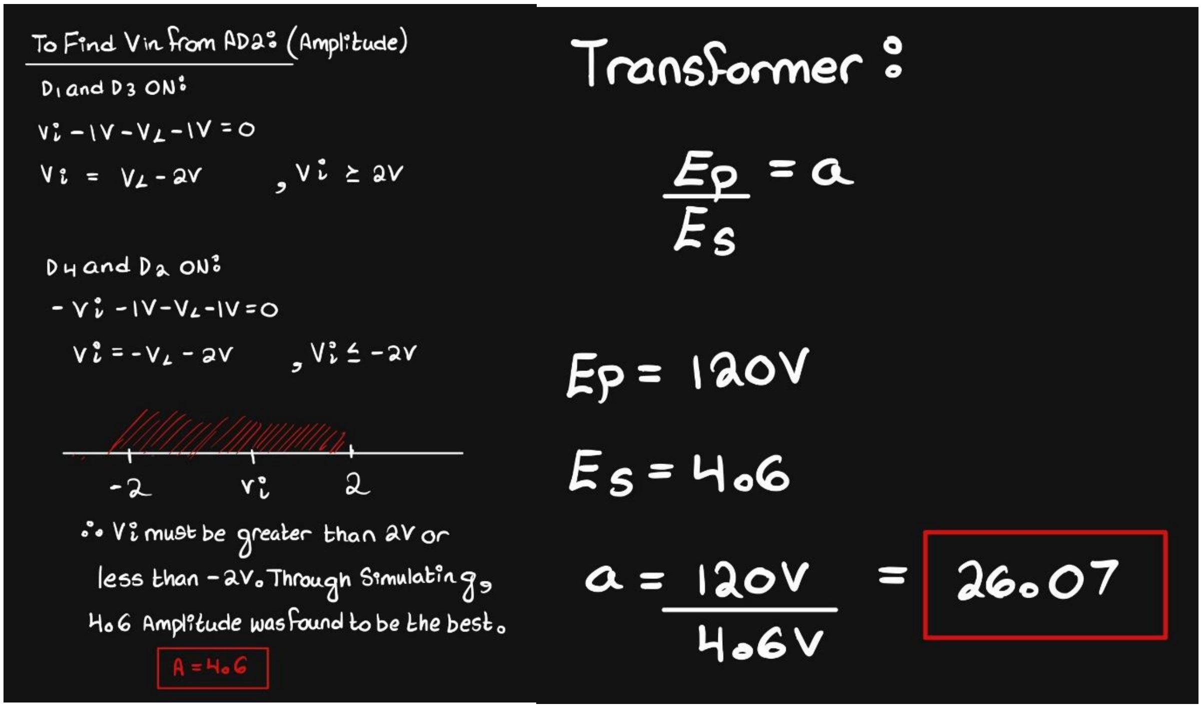
Purpose: The purpose of this lab is to design and build a DC power supply within the specifications of 10mA delivery at 3V± 0.1V from a source that is 120V at a frequency of 1kHz.

Design Description: There are 4 main blocks to designing a DC power supply, this includes a transformer, rectifier, filter, and regulator. For the purpose of this lab, we will be skipping the transformer component which has an output voltage V_i that is then connected as an input voltage to the rectifier. In doing so, we are imagining we had connected a 120V source to a transformer and selecting the output voltage, Vi with the AD2 ourselves. We connect this input voltage to a rectifier of our choice, which will connect to a resistor in which we measure the load voltage and load current. We will also have to use a filter to create a more accurate output, which will involve a capacitor in parallel with the said resistor.

Design:

i. Transformer:





ii. Rectifier: The rectifier topology chosen for this design is a bridge full-wave rectifier. The reason for this design decision was due to the relevant trade-offs between this rectifier and the half-wave rectifier. On one hand, the half-wave is simpler to implement and requires less diodes to implement, but it is also less efficient than the full-wave rectifier [1]. Since cost is not one of our concerns with this project, opting for a more efficient topology would make more sense. This is why I chose the full-wave rectifier as it is mainly used for highly efficient conversion from AC to DC voltage.

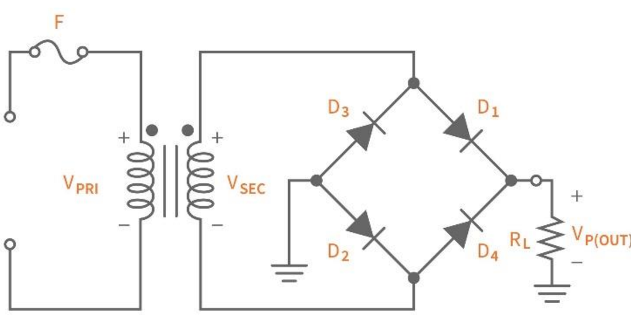


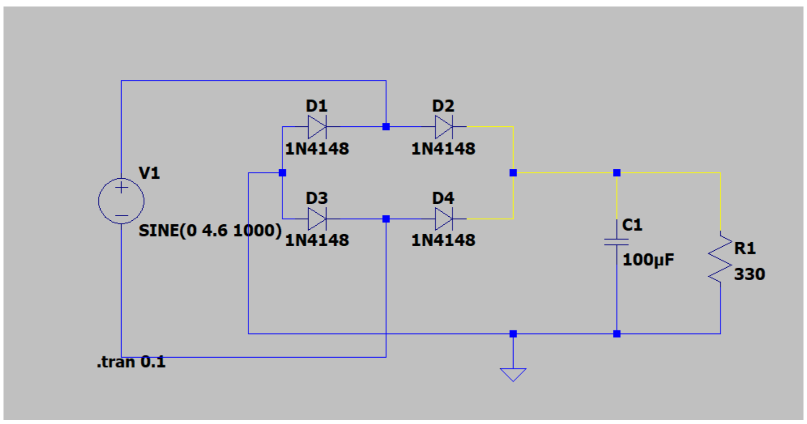
Figure 1 Circuit of a Bridge Full-Wave Rectifier [2]

As seen from the circuit above (and ignoring the transformer), a full-wave rectifier will require the use of 4 diodes connected together in the form a bridge. Typically, a transformer would be connected on one side, but in our case, we will be using the AD2 as input. With this in mind, the relevant diode parameters in our case with the 1N4148 diode is a forward voltage of 1V at a current of 10mA and a constant forward current of 0.3A [3].

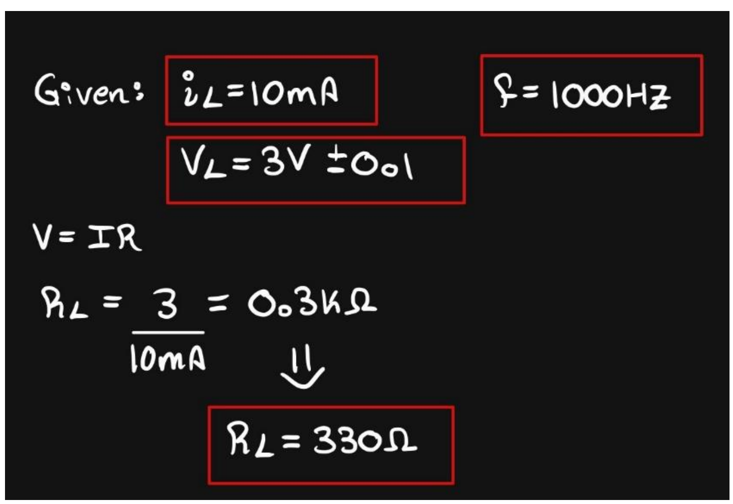
iii. **Filter:** One of the simplest filters that we can implement in our design is known as a RC filter. This is done by placing a capacitor across the load resistor from the rectifier. This will reduce the variation across the load resistor as the nature of capacitors is to resist the change in voltage. The component value used for this design will be a 50µF, however a 100µF will be used instead due to lack of access. This is due to the relation of the V_{ripple} and the capacitor value, we want to keep V_r small to create a voltage output as close to DC as possible, and therefore based on the equation $V_{ripple} = \frac{V_p}{fCR}$, therefore C should be selected with CR>>T in mind.

iv. **Regulator:** Due to the reasonable output voltage produced by the DC power supply, a regulator was not used in this design.

v. **Circuit Schematic:**



vi. **Calculations:**



$$C = \frac{I_{out}}{f \cdot V_{ripple}}$$

$$I_{out} = \frac{V_{peak}}{R} = \frac{3V}{330\Omega} \approx 10mA$$

we want a 3V DC voltage.

Calculated from given

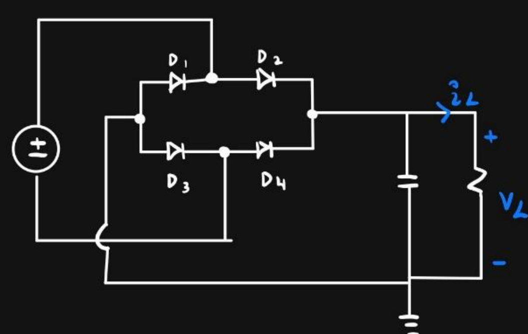
$$C = \frac{10mA}{1KHz \cdot (0.2)}$$

0.1 error threshold for +/-, ∴ 0.2

$$\boxed{C = 50\mu F}$$

vii. **Expected Performance:**

Expected Performance:



$V = IR$

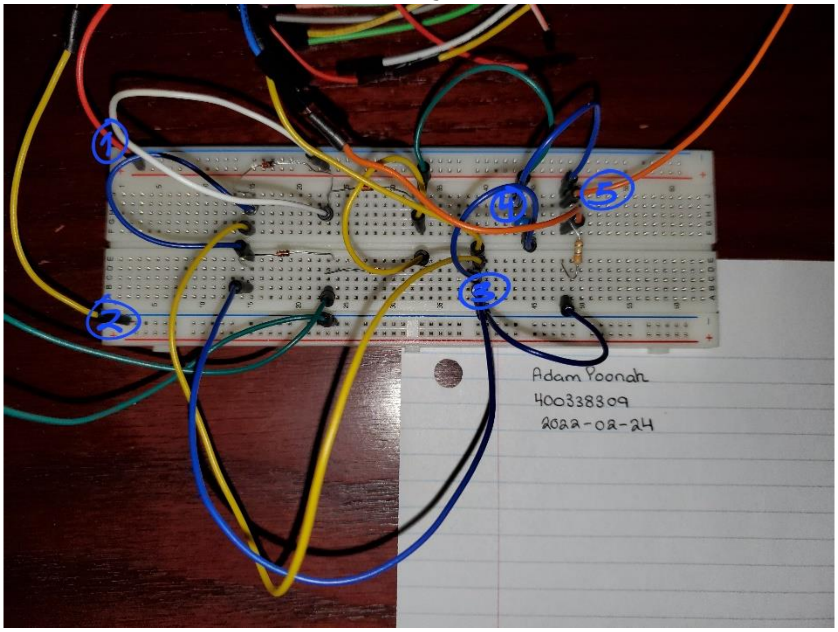
we expect $V_L = \frac{I}{R} = \frac{10mA}{330} \approx 3V$ (I from + → -)

$V_L = \frac{I}{R} = \frac{-10mA}{330} \approx -3V$ (I from - → +)

viii. Design Trade-offs: Some trade-offs within this design is the complexity of the circuit as well as the efficient in performance. For starters, the full-wave bridge rectifier is more efficient than the half-wave rectifier, however it comes at the cost of using more components, such as 4 diodes instead of 1 that would be required for a half wave rectifier. At first it seemed intuitive to use this design as the purpose of this lab was to create a DC power supply within specified requirements, however there is another topology of rectifiers which would have been just as efficient and used less diodes to implement. The center taped full wave rectifier would be more effective in the over all design, with not as many trade-offs.

When it comes to component ratings, they were extremely important for the safety and design margins for this design. In this design, the are many components such as diodes, resistors, and a capacitor had component ratings which impacted the design. For starters, the diodes used in this lab had a forward voltage of 1V as opposed to the typical 0.7 we are used to in class. This would have impacted the input voltage calculations and the current as we would have been restricted to a input voltage greater/lower than 1.4V instead of 2V. The diode also had a maximum repetitive reverse voltage (V_{rrm}) which would have been a safety consideration if we were using a transformer with a voltage of 120V.

Measurement and Analysis:



1. W1
2. Ground
3. Ground
4. 1+
5. 2+

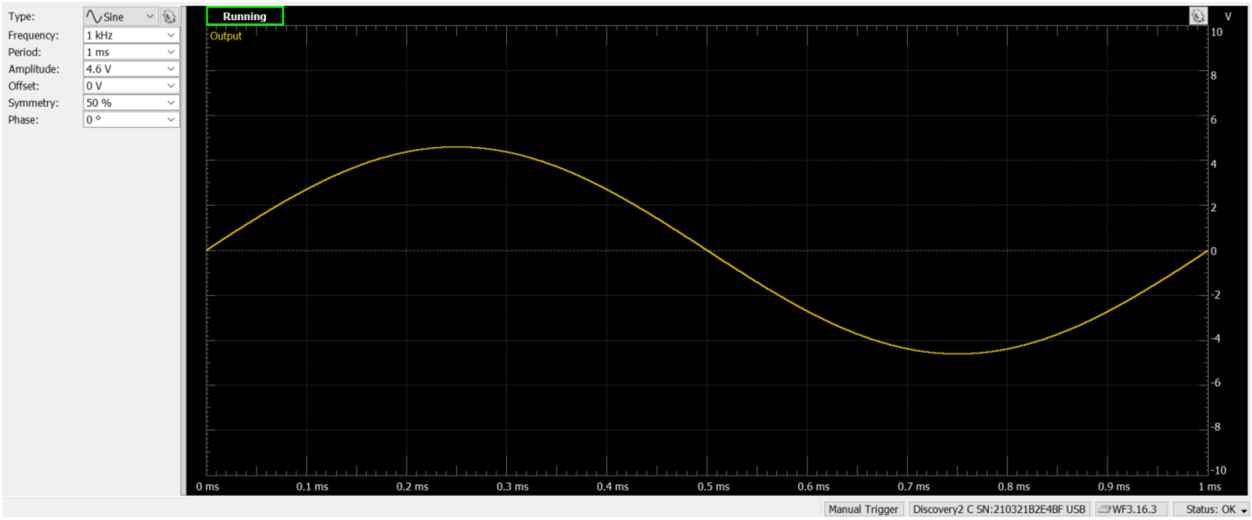
ii. Since we want to find the voltage across the 330Ω resistor, the channel 1 pin is placed at the top of the resistor to measure the voltage across. Similarly, we want to measure the current the load, so once again we place the voltmeter channel 2 pin across this node. However, this time we will not be analyzing this value through the oscilloscope, but instead we use the math function to plot current as I=V/R = C2/330.

iii. Key measurement results:

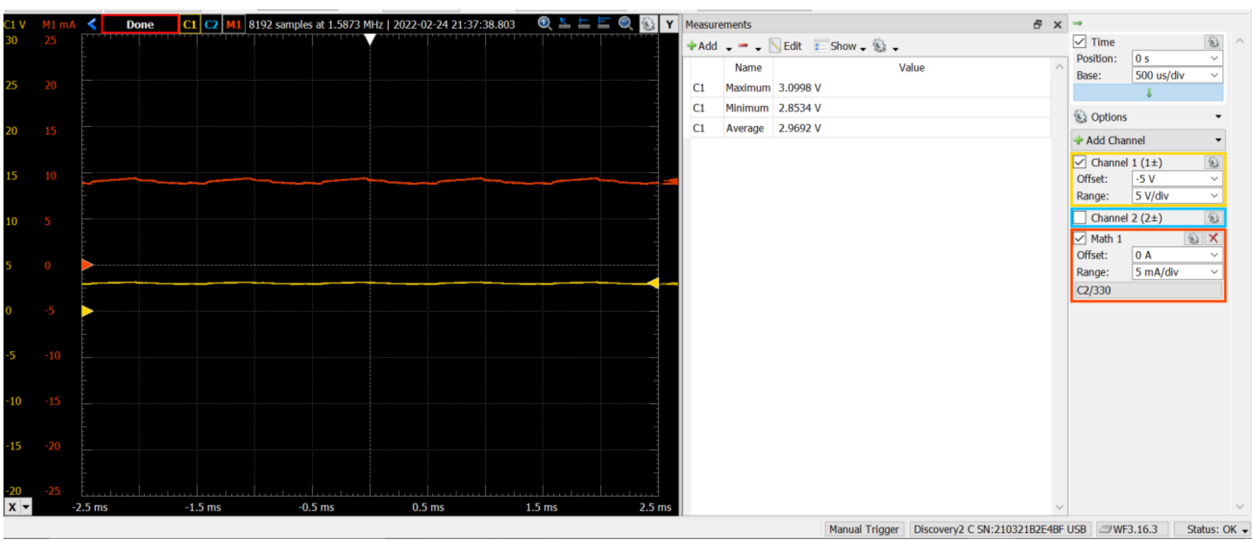
Average Load Voltage	**2.9692V**
Average Load Current	**0.09A**
Peak2Peak Load Voltage	**182mV**
Peak2Peak Load Current	**0.532mA**
Maximum Load Voltage	**3.09V**
Minimum Load Voltage	**2.85V**

iv. Screenshots:

Wavegen used for the input voltage:

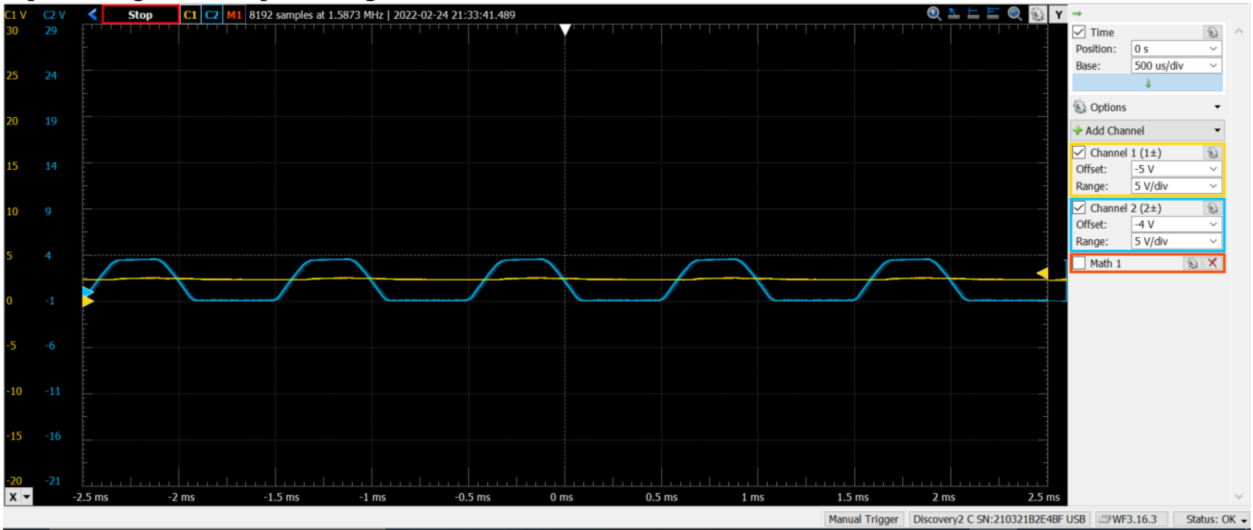


Output voltage alongside output Current:



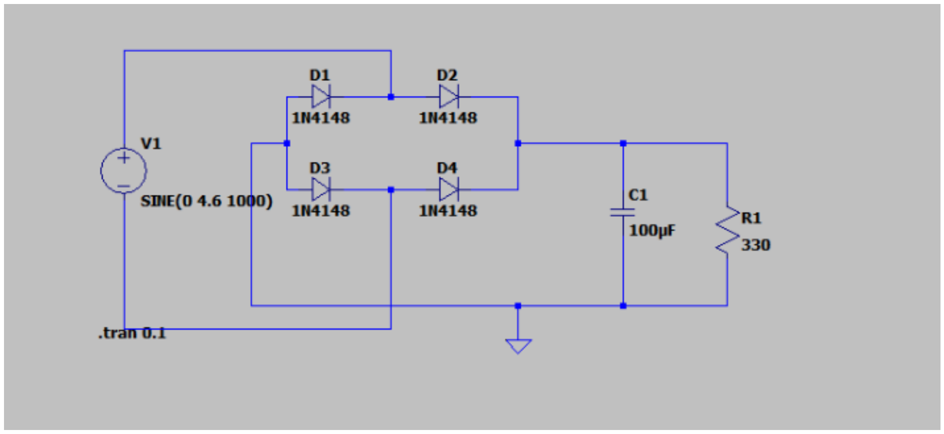
As seen from above, the oscilloscope has the voltage load plotted on channel 1 and the Current load on the math channel. Both of these values obtained hover around the expected results. The average voltage across the 330Ω resistor is approximately 3.09V and a current of about 0.09A which is roughly 10mA. This value of current being slightly off can be attributed to the use of a 100 µF capacitor as opposed to a 50 µF one, or general sources of error. The maximum output voltage also meets the specifications as it has a maximum value of 3.09 and a minimum value of 2.8534V.

Input voltage and Output voltage obtained:

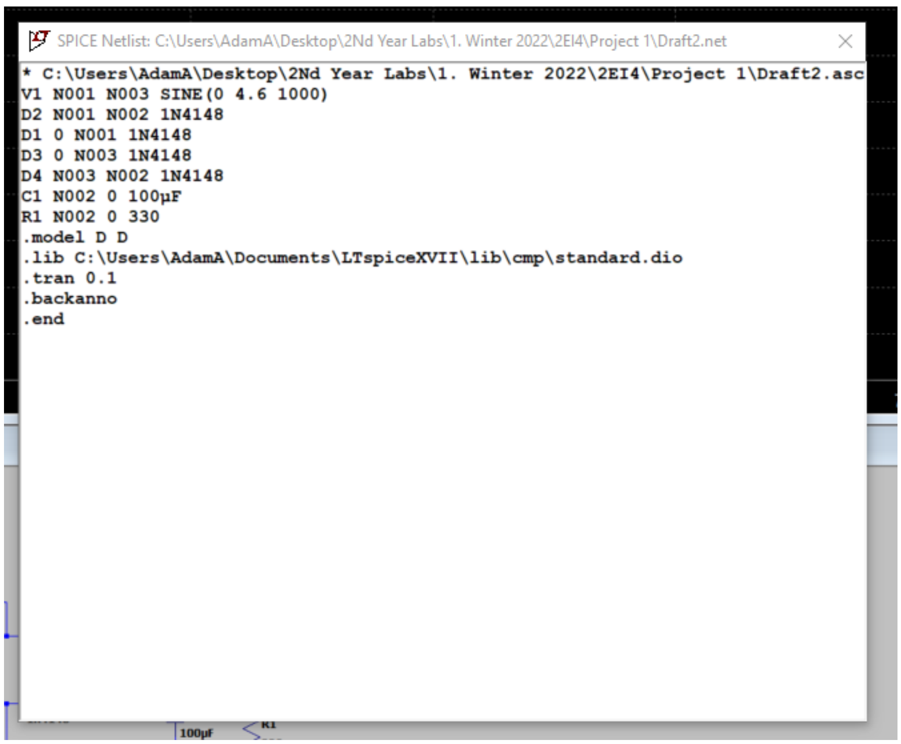


Simulation:

i. Schematic:



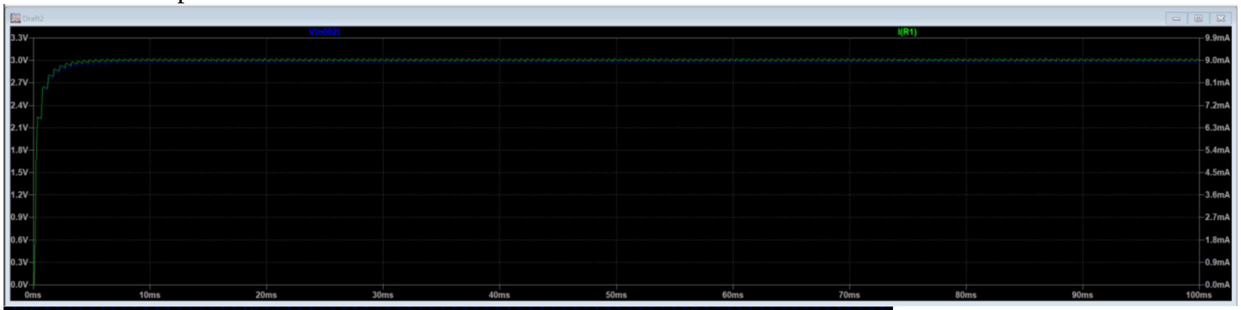
ii. Netlist:

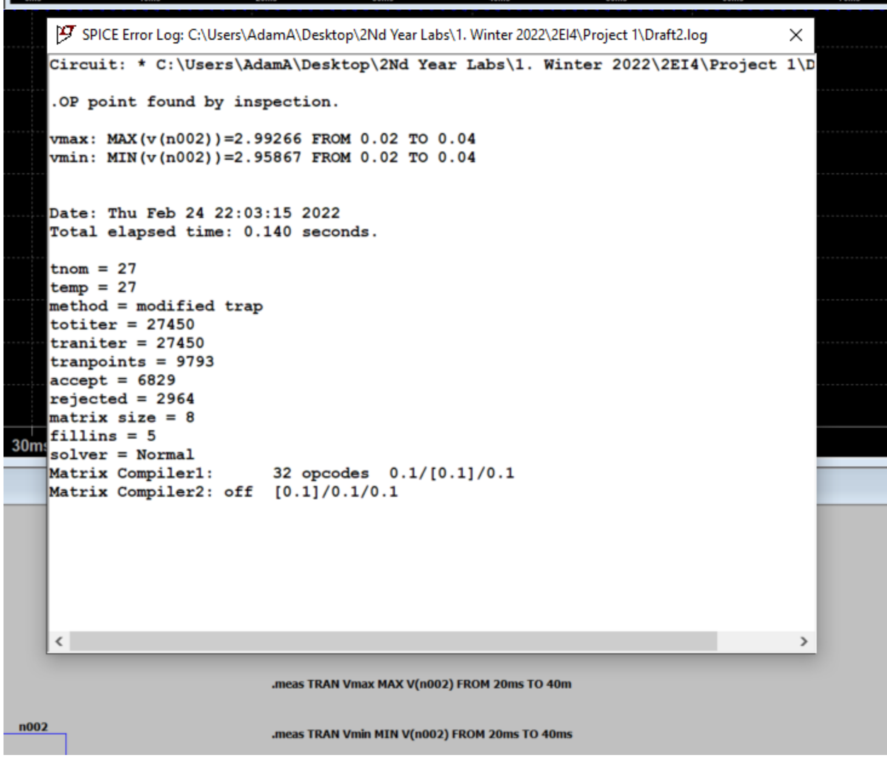

SPICE Netlist: C:\Users\AdamA\Desktop\2Nd Year Labs\1. Winter 2022\2EI4\Project 1\Draft2.net

```
* C:\Users\AdamA\Desktop\2Nd Year Labs\1. Winter 2022\2EI4\Project 1\Draft2.asc
V1 N001 N003 SINE(0 4.6 1000)
D2 N001 N002 1N4148
D1 0 N001 1N4148
D3 0 N003 1N4148
D4 N003 N002 1N4148
C1 N002 0 100µF
R1 N002 0 330
.model D D
.lib C:\Users\AdamA\Documents\LTspiceXVII\lib\cmp\standard.dio
.tran 0.1
.backanno
.end
```

iii. The conditions for this simulation are: AC power supply with an amplitude of 4.6V, a frequency of 1000Hz, a simulation time of 100ms, simulation type of transient 0.1, normal diode models matching our kit (1N4148)

iv. Simulation output:





As seen from the measure function, the max output voltage is 2.99 while the minimum output voltage is 2.95. This fits the design specifications.

Discussion:

i. The design yielded results which match both the simulation and measurement results. However, some error which may have occurred during the measurement process may account for some discrepancies, which are minor and within the performance we expect to see. The expected max voltage from our design was calculated to be 3V, however once a real simulation was done and the maximum output was done with accurate calculations it came out to be 2.99V. A similar occurrence occurred with the minimum being calculated at -3V, but the simulation showed a value of -2.96V instead. Looking at the real measurements, we are close but not exactly at 3V, with a measured peak voltage of 3.09V and a minimum voltage of 2.85V.

ii. Some discrepancies observed occurred between the simulation and measurement results. Although extremely small, these discrepancies can be attributed to several things. Firstly, the nature of real-world circuit design leads to inevitable sources of error which cannot be fixed. Despite the simulation running perfectly, building the exact same circuit will not always lead to the same results. Some factors that can impact this is the use of the AD2 which may not output a voltage at 100% efficiency. Another discrepancy observed was within the current of the load resistor. Despite the voltage output being nearly perfect, for some reason the current was slightly off. I believe this may have occurred due to the use of a 100uF capacitor instead of a 50uF which was calculated.

iii. Some limitations of the design are the input voltage used. Due to the nature of the diodes, doing an analysis of the circuit shows that the input voltage must be a value less than -2Vor greater than 2V. This is because current will flow within a maximum of two diodes at a time (each with a 1V forward voltage). These restrictions can be reduced if a half-wave rectifier was used instead, or a full-wave center-tapped transformer was used which would allow for voltage inputs greater than 1V or less than -1V, since they only pass through one diode. Other limitations include the peripherals used such as the AD2 having a maximum and minimum input voltage of -5V and 5V.

iv. A problem I encountered was during the circuit design process with using an actual breadboard. Often times a schematic done within a program is difficult to visualize in a real-world setting, which is why I found myself struggling to connect the circuit in a proper loop to allow current to flow. I found that using an LED allowed for real-world debugging where I could visually see when a full loop was made and that the current would flow as expected. Another issue I encountered was the occurrence of the voltage being clipped by the AD2, it was difficult to resolve this issue however it seemed to have been an issue that many students faced and may be attributed to an error within the device.

References

[1] “Difference between Half Wave and Full Wave Rectifier (with Comparison Chart) - Electronics Coach.” https://electronicscoach.com/difference-between-half-wave-and-full-wave-rectifier.html#KeyDifferences (accessed Feb. 23, 2022).

[2] “Center-Tapped Full-Wave Rectifier Operation - Tutorials | CircuitBread.” https://www.circuitbread.com/tutorials/center-tapped-full-wave-rectifier-operation (accessed Feb. 23, 2022).

[3] “1N4148 Diode Small Signal Fast Switching 0.3A 100V.” https://abra-electronics.com/ics-semiconductors/diodes-rectifiers/switching-diodes/1n4148-diode-small-signal-fast-switching-03a-100v-1n4148.html (accessed Feb. 23, 2022).