ELECENG 2EI4: Electronic Devices and Circuits 1

Design Project 1

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Summary

Project Statement

Create a dc power supply that can run at 120V (rms) at 1 kHz and deliver 10 mA at 3V +/- 0.1V.

The design consists of a full-wave rectifier that uses a center-tapped transformer in order to convert from AC to DC. It consists of a resistor, a rectifier, two diodes, and two independent voltage sources for each diode. The two independent voltage sources take an input voltage and AC is converted to DC using the transformer to give a final output of 10mA with a 3 +- 0.1 V.

Design

(i) Transformer: The input voltage that is used in the simulation of this circuit was 3.9 V as it is considered an ideal diode model. However, since the diodes were ON in the real life so that will be considered a constant drop model. Therefore the input voltage value of the real-life model will be more than 3.9 V. the calculation is shown below:

$$V_f = 0.7\,V \text{ [constant diode model]}$$

$$V_o = V_{pi} - V_f$$

$$3 = V_{pi} - 2(0.7)$$

$$\boxed{V_{pi} = 4.4\,V}$$

(ii) Rectifier: The rectifier topology that was used in this project is a Full-wave center-tapped transformer. A full-wave rectifier circuit takes the two separate voltage waveforms generated by the full-wave center-tapped transformer and rectifies them, or converts them from AC to DC, by only allowing current to flow in one direction (Shaik). The reason I used this topology is that it is very efficient and converts AC to DC by providing a smoother graph of the output. It also uses less number of diodes (two) than a full-wave rectifier (four) which also means that the output will be finer and smoother. Speaking about the diode, I used two forward-voltage (Vf) diodes to identify the voltage drop when conducting in the forward direction. These diodes have their independent voltage sources which provide them the input voltage of 3.9V that is calculated above. The diode I used in this project was 1N4148.

(iii) Filter: A 100μF capacitor was used as a filter in this topology. The significance of using a capacitor in a full-wave center-tapped transformer is that it smoothens out any possible fluctuations in the output, thus producing a steady DC voltage at the output. A capacitor also reduces the ripple voltage, which is a type of AC circuit present in a DC waveform. The following picture shows the calculation of the component value:

$$V_{ripp} = \frac{IT}{C}$$

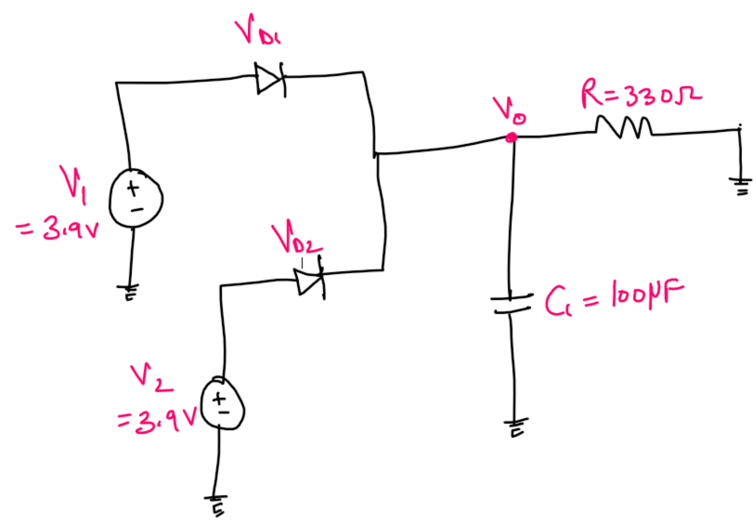
Calculated from difference between maximum and minimum ripple voltage

$$0.1 = \frac{(0.01)(0.001)}{C}$$

$$C = \frac{(0.01)(0.001)}{0.1} = 100 \times 10^{-6}$$

$$\therefore \boxed{C = 100\mu F}$$

(v) Circuit schematic



(vi) Calculations for the component values of different elements:

Resistance:

$V = 3V$ [required] $\quad I = 10mA$ [required]

$$R = \frac{V}{I} = \frac{3V}{10mA} = 0.3 \times 10^3 \Omega = 300\Omega$$

However, since we have a R of 330Ω in my kit, I will be using it.

AC source Voltage peak-to-peak:

$$V_{peak} = (\sqrt{2})\,V_{rms}$$

$$= (\sqrt{2})(120)$$

$$V_{peak} = 169.706\ V$$

$$\approx \boxed{170\,V}$$

Number of turns ratio:

$N_1 = 170\,V \qquad N_2 = 5\,V$

$$\frac{N_1}{N_2} = \left(\frac{L_1}{L_2}\right)^2$$

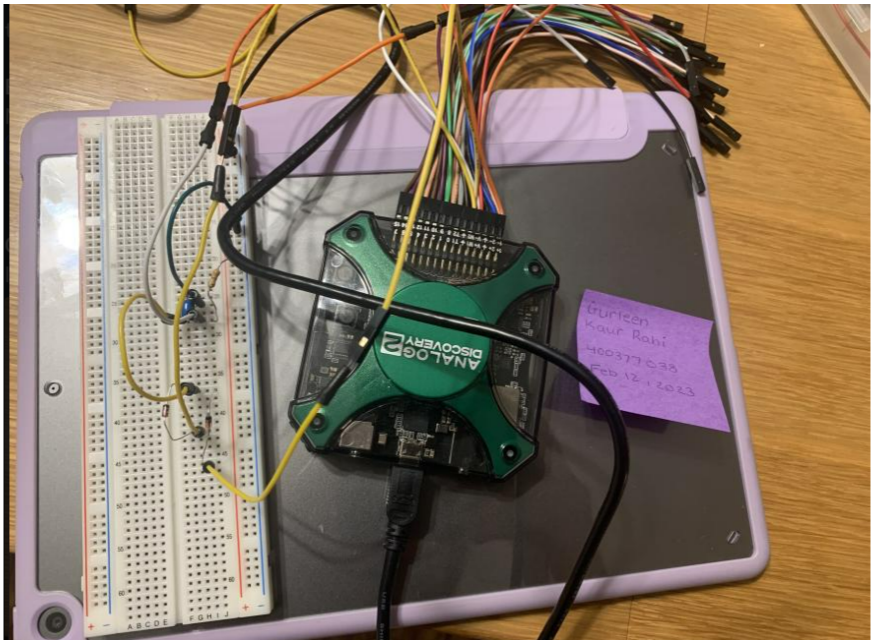
$$\frac{170}{5} = \left(\frac{L_1}{L_2}\right)^2 = 36.559$$

$$\boxed{\begin{array}{l} L_1 \approx 1.33225\,H \\ L_2 = 1mA \end{array}}$$

(vii) According to my design calculations, the performance of my design should be very efficient due to the type of topology chosen. This means ignoring any possible errors that could possibly happen, to get the output voltage of 3V, 4.4V of input voltage is needed for each diode to operate and provide the desired output result. Using the components with the above component values, the circuit is expected to transform from AC to DC to give a smoother output voltage of 3+-0.1 V along with a current of 10mA.

(viii) Safety is a really important aspect to consider when making a circuit design. In the design, an aspect of safety that I considered is that I made sure all components are grounded. If components are not grounded, then it might be a problem for the circuit overall which could result in the burning of the non-grounded element. Secondly, I used a resistor as a design margin to make sure the current is not overloaded in the circuit. Overloading of current can also burn one or two wires in the circuit.

Measurement and Analysis

(i) 

(ii) W1 wire of the AD2 is connected to V1 of the first diode and the W2 wire of the AD2 is connected to V2 of the second diode. Then a 100µF capacitor is connected in parallel with a 330-ohm resistor as a filter of this Full-wave center-tapped transformer. All the components are connected with a ground wire. Also, the +1 channel of AD2 is connected to the node voltage of the capacitor so as to measure Vo, the voltage at the node where the capacitor is connected. The performance of this design is measured using the Waveform software. Oscilloscope will plot the voltage Vo, once the circuit is all set to conduct current. Wavegen will determine the type of the graph (sine wave) and will take the input of the amplitude and frequency of the independent voltage devices of the diodes. If the oscilloscope graphs a straight line at 3V and 10mA of current passes at 3V that means our circuit design is correct as we obtained the required result.

(iii) The pictures below show the oscilloscope output of this circuit design. The first picture shows that Vo = 3.012V when both Wavegen and Osciloscope are running. The second picture gives the value of the current when the value of Vo is 3.012V. We can see that when the voltage (yellow line) is equal to 3V, the value of the current (red line) is equal to 10mA. This is the result that we expected before the circuit was running as the current is obtained by dividing the voltage (3V) by the value of the resistor (330 ohms) in the Math function for the red graph.

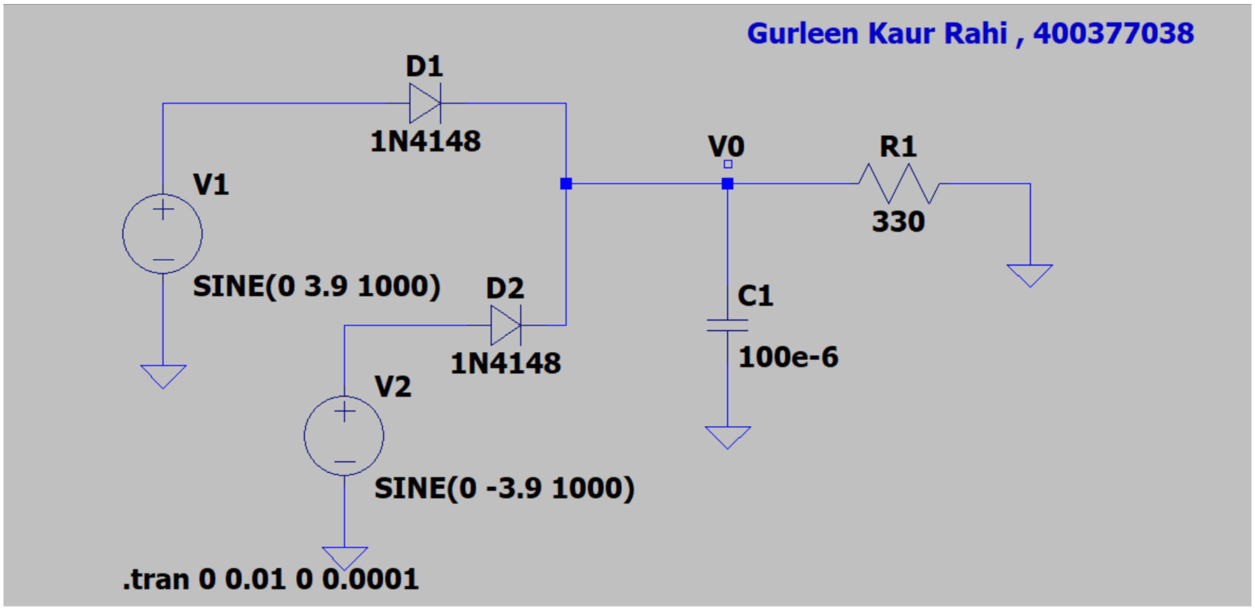
(iv)


WaveForms (new workspace)
Workspace Control Settings Window Help
Welcome Help Wavegen 1 Scope 1
File Control View Window
Export Rec. +XY +XYZ 3D +Zoom FFT Spectrogram Spectrogram 3D Histogram Persistence Data Measurements Logging Audio X Cursors Y Cursors Notes Digital Measurements
Single Stop
Mode: Repeated Auto Source: Channel 1 Condition: Rising Level: 0 V Hyst.: Auto
Buffer: 10 Auto Set Type: Edge LCondition: Less Length: 100 ns HoldOff: 100 ns
C1 V C2 V Auto C1 C2 8192 samples at 100 MHz | 2023-02-11 23:30:17.316
X: -20.2646 us
C1: 3.012 V
C2: -3.26 mV
-26.6 us -22.68 us -18.76 us -14.84 us -10.92 us -7 us -3.08 us 0.84 us 4.76 us 8.68 us 12.6 us
Time Position: -7 us Base: 3.92 us/div
Options
Add Channel
Channel 1 (1±) Offset: -1 V Range: 500 mV/div
Channel 2 (2±) Offset: -1 V Range: 500 mV/div
Manual Trigger Discovery2 C SN:210321B3D72B USB WF3.18.1 Status: OK


WaveForms (new workspace)
Workspace Control Settings Window Help
Welcome Help Wavegen 1 Scope 1
File Control View Window
Export Rec. +XY +XYZ 3D +Zoom FFT Spectrogram Spectrogram 3D Histogram Persistence Data Measurements Logging Audio X Cursors Y Cursors Notes Digital Measurements
Single Stop
Mode: Repeated Auto Source: Channel 1 Condition: Rising Level: 0 V Hyst.: Auto
Buffer: 10 Auto Set Type: Edge LCondition: Less Length: 100 ns HoldOff: 100 ns
C1 V C2 V M1 mA Auto C1 C2 M1 8192 samples at 100 MHz | 2023-02-11 23:51:00.211
Time base will be extended!
-10.3 ns -9.3 ns -8.3 ns -7.3 ns -6.3 ns -5.3 ns -4.3 ns -3.3 ns -2.3 ns -1.3 ns -0.3 ns
Time Position: -5.3 ns Base: 1 ns/div
Options
Add Channel
Channel 1 (1±) Offset: -1 V Range: 500 mV/div
Channel 2 (2±) Offset: -1 V Range: 500 mV/div
Math 1 Offset: 0 A Range: 10 mA/div C1/330
Manual Trigger Discovery2 C SN:210321B3D72B USB WF3.18.1 Status: OK

Simulation

(i)

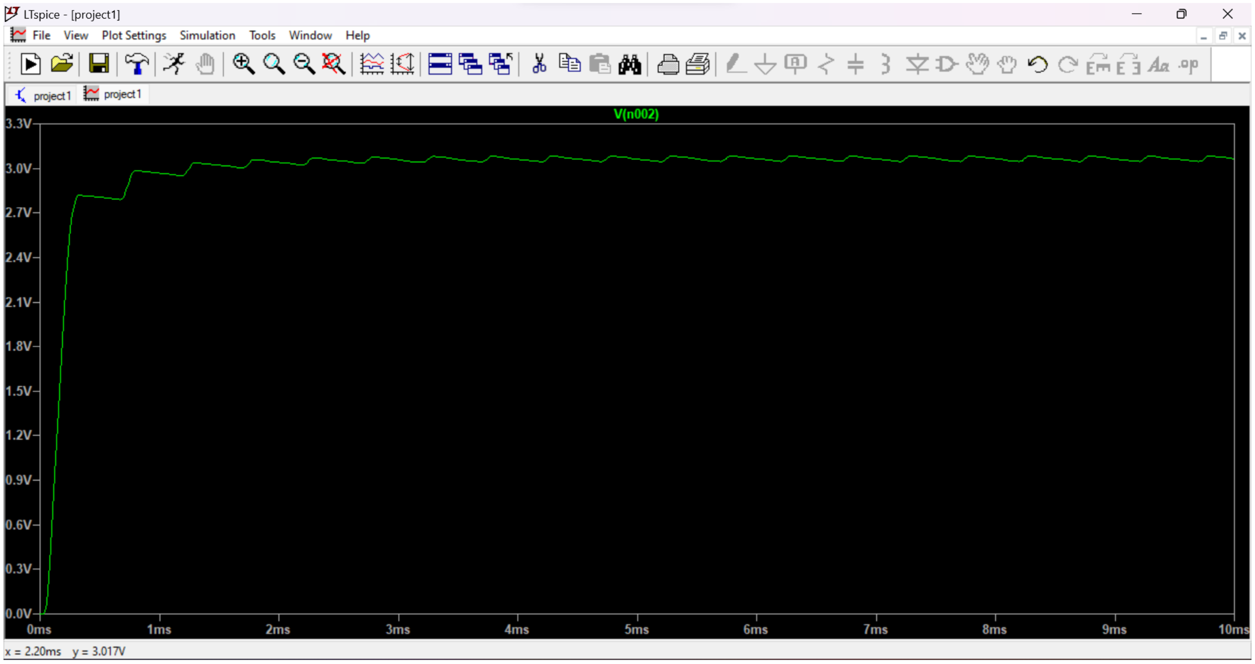


(ii)

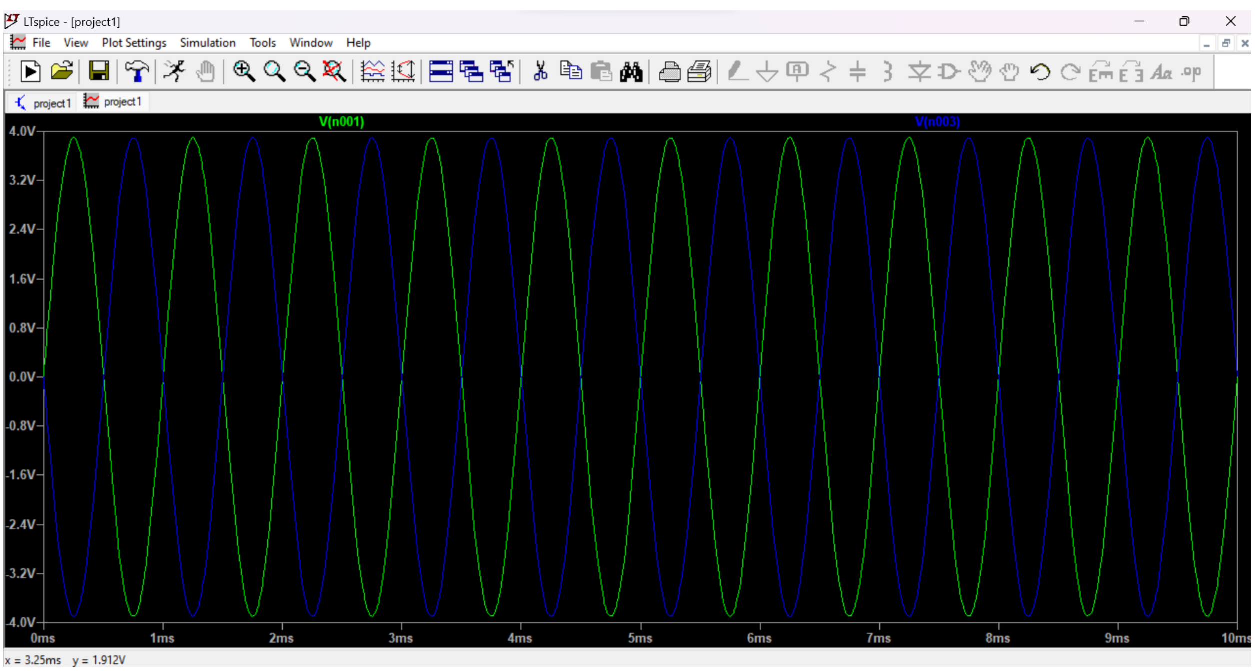
V1 N001 0 SINE(0 3.9 1000)
V2 N003 0 SINE(0 -3.9 1000)
D1 N001 N002 1N4148
D2 N003 N002 1N4148
C1 N002 0 100e-6
R1 0 N002 330
.model D D
.lib C:\Users\gurle\AppData\Local\LTspice\lib\cmp\standard.dio
.tran 0 0.01 0 0.0001
* Gurleen Kaur Rahi , 400377038
.backanno
.end

(iii) Simulation conditions: The type of simulation that we chose for both independent voltage sources is a sinusoidal wave with a frequency of 1kHz. This is so because this circuit is required to convert from AC to DC. Therefore, the input voltage has to be a sine function with an amplitude value (3.9) and frequency (1000Hz). The simulation time for the graph of the output voltage is given in milliseconds and the simulation is a V-t graph.

(iv)



Simulation Input voltage (3.9V)



Discussion

(i) According to the measurements, designs, and simulations, it is seen that the values that are taken for the components give the correct result as expected. However, for the circuit in real life, the input voltage used was 4.6 V instead of 4.4 V which was shown in the calculations. This could be because of any possible error that could be a systematic error or a technical error. It is different from the input voltage of the simulation because that is considered an ideal diode mode where by default Von for a diode is equal to 0. The real-life design is considered a constant drop model so by default Von is equal to 0.7V for each diode. This is why for the simulation, the input voltage is 4.6-0.7=3.9V.

(ii) There were not many discrepancies that were observed in this design. One discrepancy that was observed with AD2 was that initially, it was giving very low voltage at 4.6V even though the circuit was correct. But after running the same simulation multiple times it gave me the correct results. This could be because of the time delay of the voltage being taken from the AD2.

(iii) The limitations of the design helped to decide and choose the best topology for the circuit. One limitation of the circuit was that it has to have components with the same value as the calculations in order to get the required results and also so that there is no overloading of current. The limitations of the measurement were that since we need the output to be 3 +- 0.1 V and the current as 10 mA, we cannot choose any capacitor or resistor values. There is only a specific value of the component that we can choose which we have chosen above.

(iv) There were no problems observed in the measurement calculations.

Sources:

[1] A. Shaik, "Full wave rectifier," *Full wave rectifier - Center tapped full wave rectifier*. [Online]. Available: https://www.physics-and-radio-electronics.com/electronic-devices-and-circuits/rectifier/fullwaverectifier.html#:~:text=The%20center%20tapped%20full%20wave%20rectifier%20uses%20a%20center%20tapped,two%20parts%3A%20positive%20and%20negative. [Accessed: 13-Feb-2023].