Santa Clara University	ELEN 115 Fall 2023	Dr. Shoba Krishnan
Laboratory #5: Rectifiers		

I. Objectives

- To study rectifiers and analyze their performance.
- To calculate the average voltage obtained from each rectifier circuit
- To understand harmonic distortion and filtering requirements for various topologies

II. Laboratory Procedure

Preparation for lab:
Defining a transformer:
You will be making a transformer by using two inductors that are coupled.
See Figure 1.

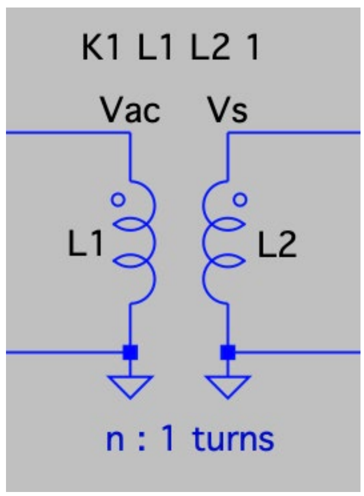

Figure 1. Transformer model

Place an inductor and label it L1. Place another inductor adjacent and label it L2.
Add a spice directive

```
K L1 L2 1
```

This states that L1 and L2 are coupled with a 100% efficiency.

Question: If the coupling coefficient is 0.99 what do you think that implies?
You pick vales for L1 and L2 to get the turns ratio n:1. If you want a transfer with a **10:1** ratio, then you put a value for L1 **100** times that of L2.

Defining an ideal diode:
For the diode model use the below script and add that to any schematic where you will be using an ideal diode.

```
.model MyidealDiode D(Ron=1m Roff=100Meg Vfwd=0)
```

Question: What does this ideal model state about the behavior of the diode?

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Part 1: Half Wave Rectifier with resistive load

In this part you will be studying the performance of the half wave rectifier
Draw the schematic shown in Figure 2.

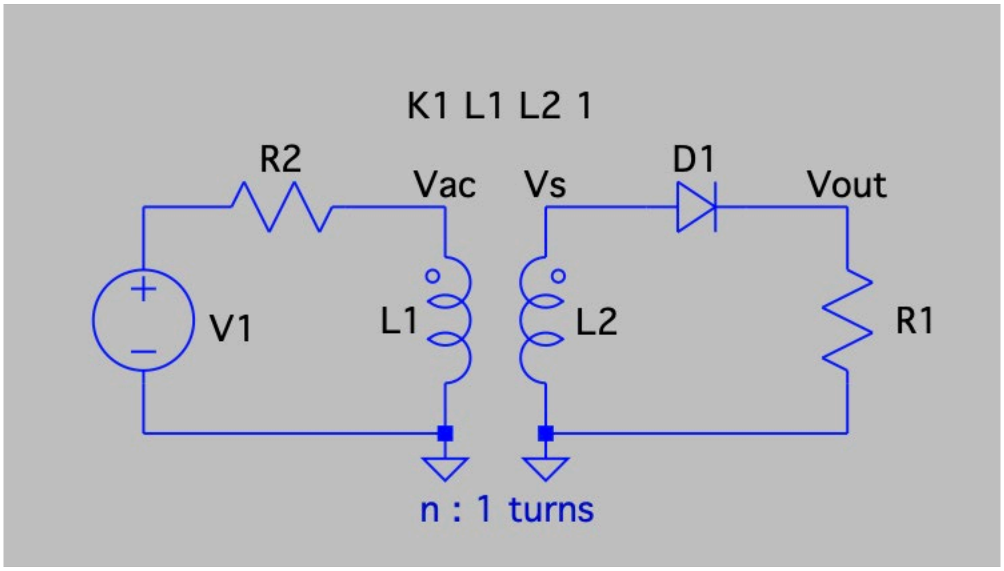

Figure 2. Half-Wave Rectifier

Simulations:

(1) Make the voltage source V1 a sinusoidal source with 170V amplitude and 60Hz frequency. You will need to add a small resistor R2 in series for the simulation to run. Set it to 1mΩ.

(2) For the diode, select it and enter **`MyidealDiode`** for its model. Include the directive for the ideal diode model as shown earlier.

(3) Pick the values of L1 and L2 of the transformer to be 144mH and 1mH respectively. Pick the value of the load R1 = 50ohms.

Question: What do the L1, L2 values provide in turns ratio?

(4) Label the input and output voltages as shown in Figure 2.

(5) Setup a Transient Analysis for 300ms, using 1us time step. But display the data after 150ms when the system has reached steady state. The statement that helps do this is

.tran 1us 300ms 150ms

(6) Using the measure statement below, find the average output voltage

.meas Vavg AVG V(Vout)

(7) Run the simulation.

Observations and Calculations:

In this section you will be analyze the output of the rectifier to understand its performance

1. From your transient plot, complete the entries in Table 1 for the
   a. output voltage
   b. load current
   c. source voltage
   d. source current

2. Run a FFT/Fourier analysis on the output to observe the frequency components of the output. Record your results in the table.
   To view an FFT of the transient simulation, right click on the waveform viewer and select *View>FFT*. In the window that pops up, select the waveforms of interest and ***select 4096 for Number of data point samples in time***. Make sure to include this plot in your final report. Enter the *.op* commands (Spice directive) **.OPTIONS plotwinsize=0** and **.OPTIONS numdgt=7** to give your simulation more resolution.

   Note: To get a log file showing the harmonic distortions via a Fourier transform, enter the *.op* commands **.FOUR 60hz 12 I(Rload)** and **.FOUR 60hz 12 V(Vo)**. For these commands, the arguments represent the fundamental frequency, the number of harmonics to be measured, and the voltage to be used, respectively. After the simulation is run, the harmonic distortion log file can be found in the same directory as the circuit file and it can be view it as a .log. Use WordPad to view it.
3. Complete the FFT part in Table 1.

Table 1. Sample table

	Average	RMS	Peak	FFT DC Value	FFT n = 1	FFT n=2	FFT n=4	FFT n=6	FFT n = 8	FFT n=10	FFT n=12
Output Voltage											
Load Current				-	-	-	-	-	-	-	-
Source Voltage				-	-	-	-	-	-	-	-

4. **Observations to be noted for the report:**

   - What do you notice with the waveforms? Describe what is happening when the AC signal is positive and when the signal is negative.
   - What are important parameters to consider when picking a diode?
   - What is average output voltage possible for this rectifier. What average was obtained. Are these the same. Explain why or why not?
   - Draw a graph showing the frequency content of the output showing the harmonics.
   - Take screen shot of your circuit and all waveforms that you think are necessary to support your claims above.

Part 2: Half Wave Rectifier with resistive-capacitive load

1. Modify the previous circuit from Part 1 to add a capacitor load in parallel with the resistor as shown in Figure 3. The diodes will be ideal. Set the value of C1 to be 250uF.

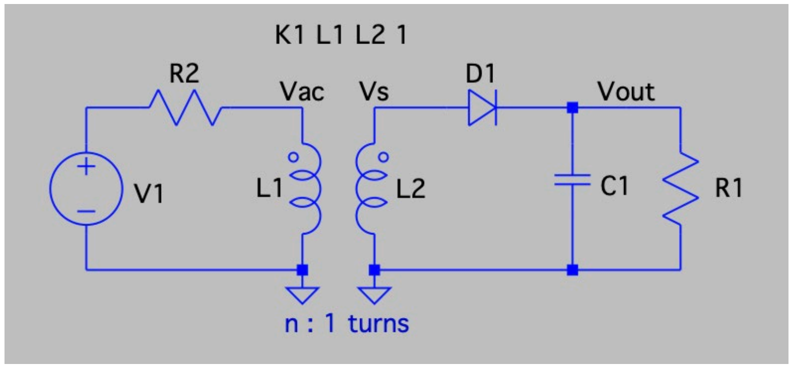

Figure 3. Half-Wave Rectifier with a RC Load

2. Using the same options as before, run a transient analysis. Zoom in on two to three cycles of the output ***after*** it has reached steady-state.
3. Rerun simulations for C1 to be 2.5mF.

Observations

1. Plot the secondary voltage and the output voltage superimposed on each other.
2. Plot this for both capacitor values

From your transient plot, find the following values and fill the table:

	Average	RMS	Peak	Voltage Ripple
Output Voltage				

What do you notice with the waveform?
Describe how the addition of the capacitor effects the output signal.
What happens to the output signal if the capacitor were to increase?
What if the resistor were to decrease?
What is the ripple voltage seen at the output?
Take screen shot of your circuit and all waveforms that you think are necessary to support your claims above.

Part 3: Full-Wave Rectifier

(1) Draw the schematic for the full wave rectifier in Figure 5 using ideal diodes and resistive load R1 = 50 ohms. Label the source voltage Vs_Top and Vs_Bot so as to measure the voltages across the two secondary coils. Pick the values of L1 of the transformer to be 144mH and use 1mH for L2 and L3.

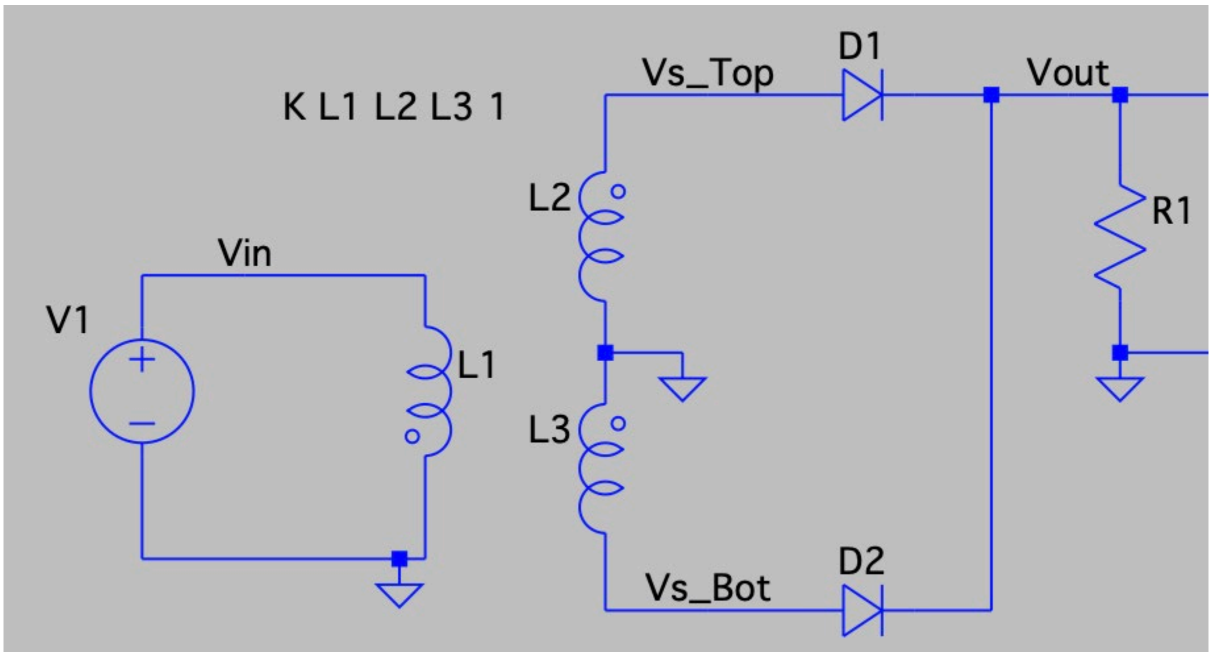

Figure 5. Full wave rectifier

Repeat the simulations and observations from Part 1.
Fill the table for this section also.

Further observations to be noted for the report:

- How does the average output voltage compare to the half wave rectifier?
- What do you observe about the harmonics?
- If a capacitor is added in parallel with the resistive load R1, draw the expected waveform.

Part 4: Bridge Rectifier

Draw the schematic for the bridge rectifier in Figure 6 using ideal diodes and resistive load RL = 50 ohms. Label the source voltage Vsp and Vsn so as to measure across the secondary.

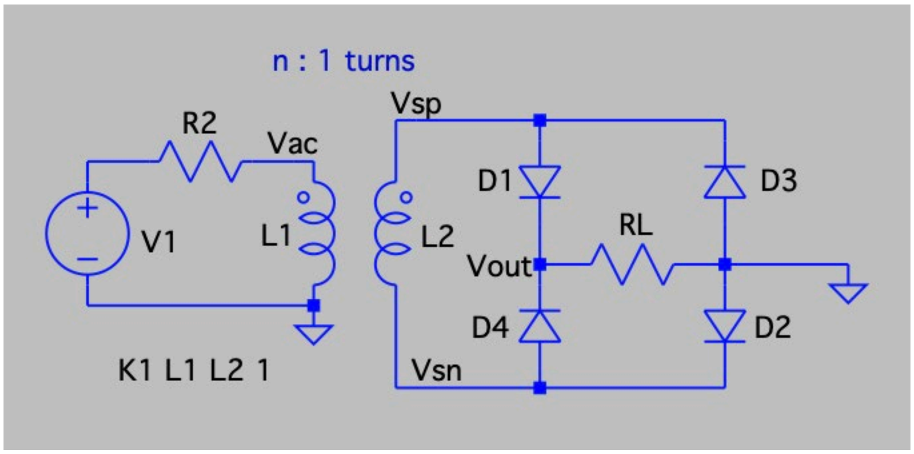

Figure 6. Single phase rectifier

Repeat the simulations and Observations from Part 1.
Fill the table for this section also.
Measure the value of the peak current in the diodes.
Measure the maximum reverse voltage for the diodes.

Further observations to be noted for the report:

- How does the average output voltage compare to the half wave rectifier?
- What do you observe about the harmonics?
- What are the advantages of this bridge rectifier perform compared to the full-wave rectifier of Part3.

III. Report

Describe the objective and procedures of this lab with your own words. The lab report should contain schematics, simulation waveforms and/or measurement results, and answers to questions in the laboratory procedure.

Further questions to be noted for the report:

- Which rectifier has the least stringent requirements for an output filter. Explain your answer.