The George Washington University
School of Engineering and Applied Science
Department of Electrical and Computer Engineering
ECE 20 - LAB

Experiment # 2
Solid State Diodes
Applications I

Components:

Kit Part #	***Spice Part Name***	***Part Description***	***Symbol Name*** ***(used in schematics throughout this lab manual)***
1N4002	D1N4002	Series Silicon Diode	D1 – D4
166K18	*XFRM_NONLIN*	$115V_{RMS}$ – $18V_{RMS}$ Center Tapped Transformer	TX1
Resistor	R	16k Ω Resistor	R1
Resistor	R	Value determined in prelab	RL
Capacitor	C	Value determined in prelab	C1-C2

Table 1.1

Objectives:

- To measure the output characteristics of your transformer
- To build and safely test a half wave rectifier
- To build and safely test a full wave rectifier
- To build and safely test a bridge rectifier
- To design, build and test a voltage doubler

Prelab: ***(Submit electronically prior to lab meeting,*** *also have a printed copy for yourself during lab)*

(note: the Orcad lite edition of SPICE that comes with your textbook, may not be able to simulate all of the circuits in your prelab. Allot sufficient time to come to Tompkins Hall Lab to perform the simulations on the lab computer's edition of SPICE).

1. Read through lab, generate an equipment list.
2. Read "Tutorial #2 - *Simulating Transformers in SPICE*" on lab website.
3. Download and **Print** the specification sheet for the transformer in your kit: Hammond vendor #166K18 *(see the lab website for links to spec sheet downloads, ensure this part # matches your ECE 20 kit parts list)*

    a) From the spec sheet, for the transformer with your model #, populate the following table for each characteristic of the transformer:
    Note: C.T. on the spec sheet means: Center Tap

Characteristic	**Value + unit**	**Convert any RMS values to V_P, then V_{PP}**
Primary Voltage		V_P = V_{PP}=
Frequency		
Secondary Voltage		V_P = V_{PP}=
Secondary Current Limit		
*Calculate Power Limit (secondary V*I limit)*		
Calculate turn ratio (N_P/N_S)		

Table 1.2 – Spec Sheet Values

4. Using the tutorial + values from table 1.2, construct a center-tapped transformer with a turn ratio that matches the transformer in your kit, use a transient simulation in spice to plot 10 cycles of the primary and secondary voltage (remember SPICE uses V_P, not V_{RMS})

5. Use the transformer you have built in step 4 to construct the three different rectifying circuits in Figures 1.1, 1.2, & 1.3. For the circuits that use a '*non*-center tapped' transformer, simply use the top-half of the secondary coil of your center-tapped transformer. Include the plots of the voltage across R1 in your prelab writeup. If you are unfamiliar with what each rectifier does, read sections 3.5 – 3.5.3 (in Sedra) to understand them further.

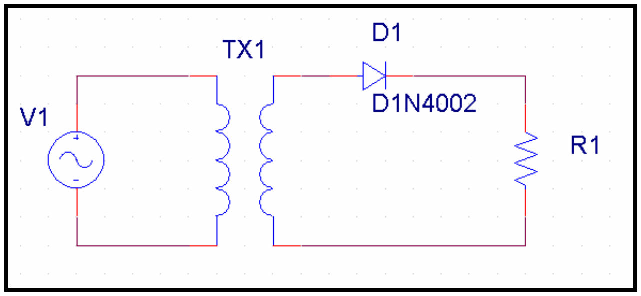


Fig 1.1 -- Half Wave Rectifier

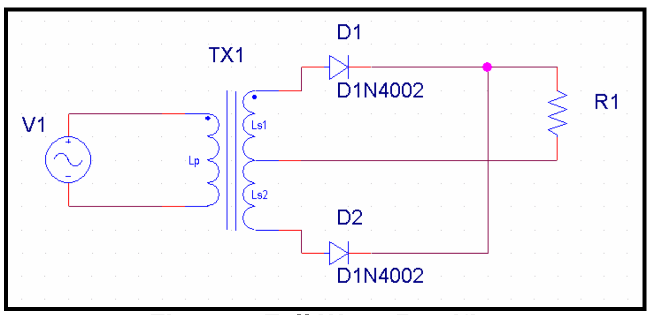


Fig 1.2 – Full Wave Rectifier

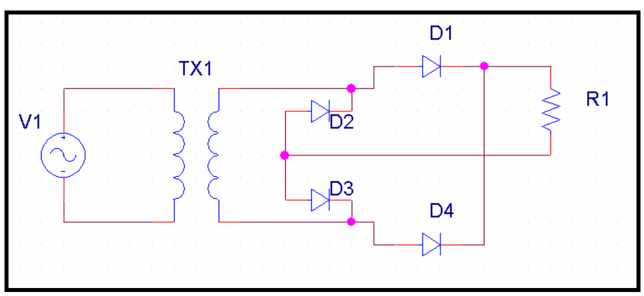


Fig 1.3 -- Bridge Rectifier

6. In the event of a prelab quiz, be prepared to draw the three waveforms that would result from each of the rectifier circuits.

7. Build a Voltage Doubler Circuit that meets the following specifications:

- Input: 12 Vp (output of the top half of your transformer)
- Output: -24 V +/- 5%
- Type of Load: resistor
- Max power dissipated by load resistor: **100 mW**

How to go about the design:
Using SPICE and section 3.6.3 of your textbook (p 189 in 5th edition Sedra), design, build and simulate a 'Voltage Doubler' circuit. For the AC voltage source in the textbook (Vp sin *wt*), you will use the **top half of the secondary coil of the center-tapped transformer** you've been simulating with thus far. Experiment with the various size capacitors available in your ECE 20 kit to reduce the time the circuit requires to reach its 'steady state.'

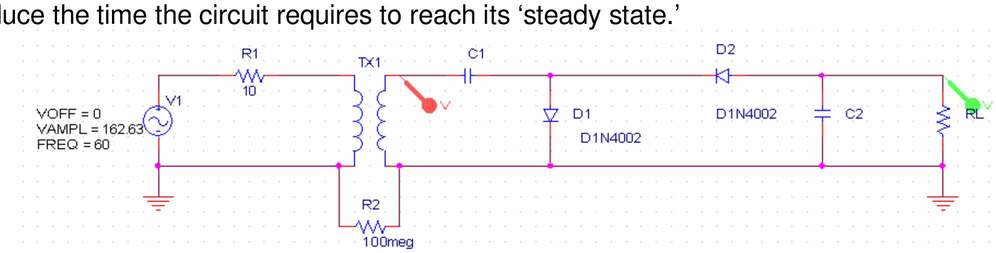


Fig 1.4 – Sample Voltage Doubler Circuit using *non-center* tapped transformer

-Figure 1.5 shows a successful 'doubling' of a V_{source}=9V_{RMS} (12.698 V_P) source. The green trace shows a nearly doubled value of -23.9 Volts, which is nearly $|2V_P|$. Notice 'steady-state' for the circuit isn't reached for roughly 6 cycles. Note: the green trace is nearly a DC signal, that is the purpose of a voltage doubler.

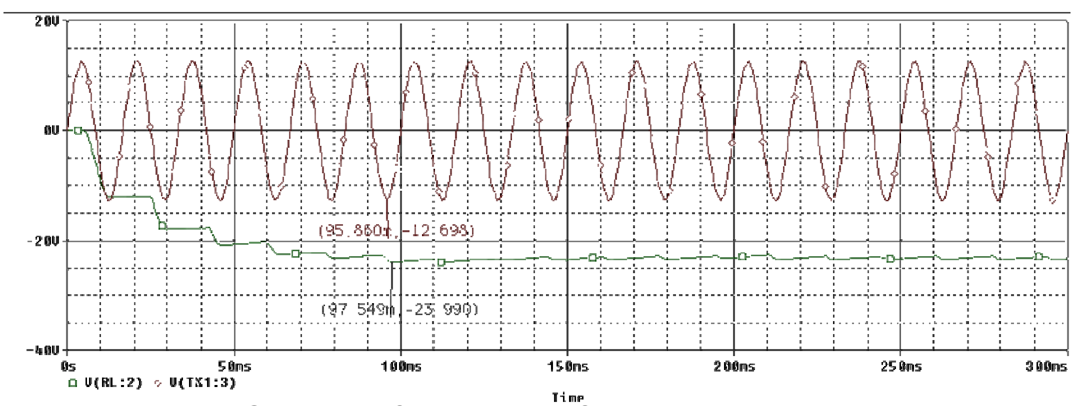


Fig 1.5 – Secondary Coil voltage & Output Voltage across load resistor

-Figure 1.6 shows the power dissipated by the load resistor (using a W probe), is roughly 100mWatts. You must choose an appropriate size load resistor for your voltage doubler, to dissipate no more than 100mW of power. Use P=IV and V=IR to determine the size of your load resistor.

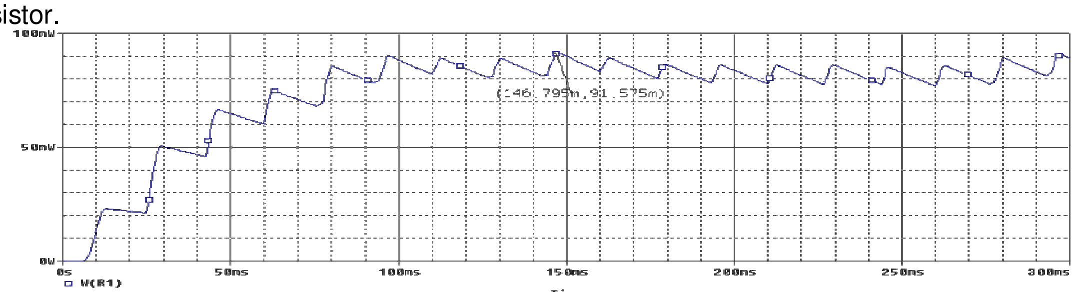


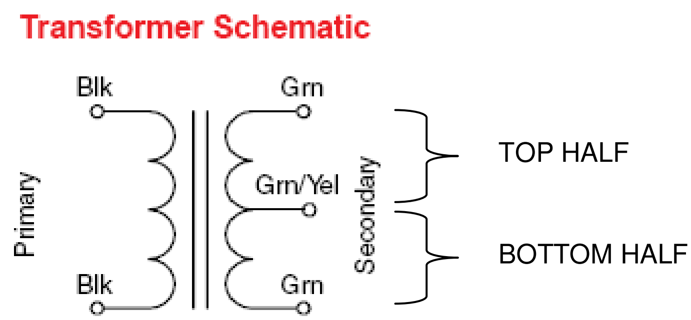
Fig 1.6 – Output Power dissipated by load resistor

Lab:

CAUTION!
BE CAREFUL DURING THIS EXPERIMENT!
HAZARDOUS VOLTAGES WILL
BE PRESENT WHEN YOU PERFORM
YOUR MEASUREMENTS

CAUTION: The transformer in this lab has a primary voltage of roughly 120V_{RMS}, if not handled properly, injury can occur from your transformer.

Part 1 – Determining the Turn Ratio of the Transformer



- Plug all the output wires coming from the secondary coil of the transformer into a breadboard before connecting it to the AC outlet.

- Connect TX1 to an AC outlet located on your bench.

- Your GTA will measure the *primary* coil's voltage and announce it to the lab, record it as $V1_{RMS}$, CALCULATE: $V1_P$ and $V1_{PP}$ for the primary coil in a table.

- Use the **Keithley Model 175** to measure the voltage across the TOP HALF of the *secondary* coil. Record the RMS voltage as $V2_{TOP\ RMS}$, then CALCULATE the V_P and $V_{PP.}$ Record this in a table.

- Use the **Keithley Model 175** to measure the voltage across the BOTTOM HALF of the *secondary* coil. Record the RMS voltage as $V2_{BOTTOM\ RMS}$, then CALCULATE the V_P and $V_{PP.}$ Record this in a table.

- Use the **Keithley Model 175** to measure the voltage across the ENTIRE *secondary* coil (green wire to green wire). Record the RMS voltage as $V2_{RMS}$, then CALCULATE the V_P and $V_{PP.}$ Record this in a table.

- Determine the turns ratio (V1/V2), record in the table.

- Connect the **oscilloscope** only to the secondary. **Never** connect the scope to the primary! The negative lead on the scope probe is ground. If you connect this lead to the primary, you will cause **120 V_{RMS} at 20 Amps** to short through your probe to ground!

    1. Use the scope to measure the voltages across the TOP HALF, BOTTOM HALF, and across the ENTIRE secondary coil. You should have 3 waveforms.
    2. Capture each waveform using a computer OR ***draw*** each waveform in your lab report. Make sure to record the time scale and voltage scale, and calculate the frequency and Vp of each wave you record.

3. Label this plot Figure A - Unloaded Transformer Secondary Waveform. **Disconnect** TX1 from the AC outlet! Hand calculate $V2_{TOP\ RMS}$, $V2_{BOTTOM\ RMS}$, and $V2_{RMS}$ $V2_P$, and $V2_{PP}$, and record in a table.
4. If using the digital scope, the 'AUTOSET' feature will most likely fail. You must set the time scale yourself (determine the period of a 60Hz wave, then multiply by 5 to get ~5 waveforms on the screen). You may also need to adjust the vertical voltage scale to fit the entire wave on screen.

Part II - Testing Positive Rectifiers

WARNING - Hazardous voltages will be present!

- Construct the rectifier circuit shown in Figure 1.1. Test the circuit for a possible short to ground with an ohm meter. Correct any wiring errors and test again. **Connect TX1** to an AC outlet. Measure and record the waveform across R1 using the oscilloscope, ensure to set the trigger level correctly. **Disconnect TX1** from the AC outlet! Plot and label the waveform Figure 1A -- Waveform across R1 in Half Wave Rectifier. Indicate and measure any relevant detail.

WARNING - Hazardous voltages will be present!

- Construct the circuit shown in Figure 1.2. Test the circuit for a possible short to ground with an ohm meter. Correct any wiring errors and test again. **Connect TX1** to an AC outlet. Measure and record the waveform across R1. **Disconnect TX1** from the AC outlet! Plot and label the waveform Figure 2A -- Waveform across R1 in Full Wave Rectifier. Indicate and measure any relevant detail.

WARNING - Hazardous voltages will be present!

- Construct the circuit shown in Figure 1.3. Test the circuit for a possible short to ground with an ohm meter. Correct any wiring errors and test again. **Connect TX1** to an AC outlet. Measure and record the waveform across R1. **Disconnect TX1** from the AC outlet! Plot and label the waveform Figure 3A -- Waveform across R1 in Bridge Rectifier. Indicate and measure any relevant detail.

Part III - Testing Voltage Doubler Design

WARNING - Hazardous voltages will be present!

- Build the voltage doubler designed in the prelab. Use the oscilloscope to measure the voltages found during simulation. *Note: the resistor should NOT be a 16k ohm, it should be the value you calculated to reach the 100mW power dissipation goal of the design.*

Analysis of Results (Lab Writeup)

a. Compare the measure results of the output of your transformer to those obtained using PSPICE. Include your comparison waveforms and details of what you measured.

b. Compare the measured results of each type of positive rectifier to those obtained using PSPICE. Include in your comparison all waveforms and details that you measured.

c. For each rectifier plot, indicate what is occurring in each region. As an example, explain which diodes are on and off in each region.

d. Why would one use a bridge rectifier over a full wave rectifier?

e. Explain the theory behind the voltage doubler you designed. Show all waveforms and explain what each component does.