

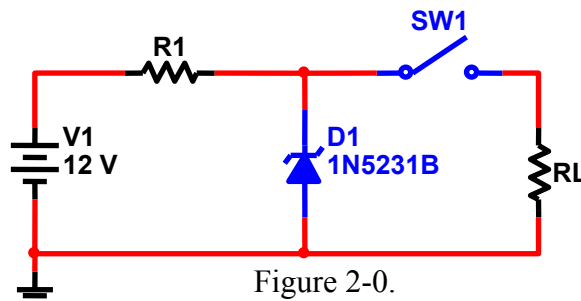
## ECE 2201 – PRELAB 2

### DIODE APPLICATIONS

P1. Review this experiment IN ADVANCE and prepare Circuit Diagrams, Tables, and Graphs in your notebook, prior to coming to lab.

P2. Hand Analysis:

- (1) For the zener diode regulator shown in Fig. 2-0 below, determine a value for the series resistance R1 to maximize the zener current without exceeding the 0.5W power rating of the zener diode. NOTE: Assume a zener voltage of 5.1 Volts when the zener is on. Also assume that the switch is open (no load).



- (2) What is the maximum load current that can be drawn from this regulated supply without the output voltage dropping below the zener voltage?
  - (3) What is the minimum load resistance  $R_L$  that can be applied to the output without the voltage dropping below the zener voltage?
  - (4) If a load resistance of  $75\Omega$  is applied to the output, determine the power dissipation in R1, D1 and  $R_L$ . Specify the minimum power rating requirements for R1 and  $R_L$  if a safety margin of (approximately) 50% is required.
  - (5) If these resistors are to be purchased in standard packages of 0.25W, 0.5W, 1W, 2W and 5W. What packages would you recommend?
- P3. Simulate each of the following circuits within this assignment PRIOR to coming to lab and bring copies of the schematics and output waveforms with you to be checked off in lab.
- Figure 2-2: Half-Wave Rectifier Circuit (no filter cap)
  - Figure 2-3: Half-Wave Rectifier Circuit (with filter cap)
  - Figure 2-4: Full-Wave Rectifier Circuit (no filter cap)
  - Figure 2-5: Full-Wave Rectifier Circuit (with filter cap)
  - Figure 2-6: Full-Wave Rectifier Circuit (with cap and Zener regulator)
  - Figure 2-7: Full-Wave Rectifier Circuit (with cap and LM7805 linear regulator)

## ECE 2201

### LAB 2 – DIODE APPLICATIONS

#### PURPOSE:

The purpose of this laboratory assignment is to investigate the operation of several DC power supply configurations which utilize *Half-Wave and Full-Wave Rectifiers*. Capacitive filtering and voltage regulation are also covered, including the design of a simple *Zener Diode Voltage Regulator*. The performance of a DC Power supply utilizing a voltage regulator IC is also investigated.

Upon completion of this lab investigation you should be able to:

- Recognize various DC power supply topologies utilizing half-wave and full-wave rectifiers.
- Choose a filter capacitor to meet ripple voltage specification.
- Measure the performance of an unregulated DC power supply.
- Design a zener diode voltage regulator to meet given specifications.
- Measure the performance of a regulated DC power supply.

#### MATERIALS:

- ECE Lab Kit
- DVM
- Oscilloscope
- Transformer box

NOTE: This lab requires the use of a transformer box depicted in Fig. 2-1 which will be supplied to you in lab. Be sure to switch off power when making wiring changes!

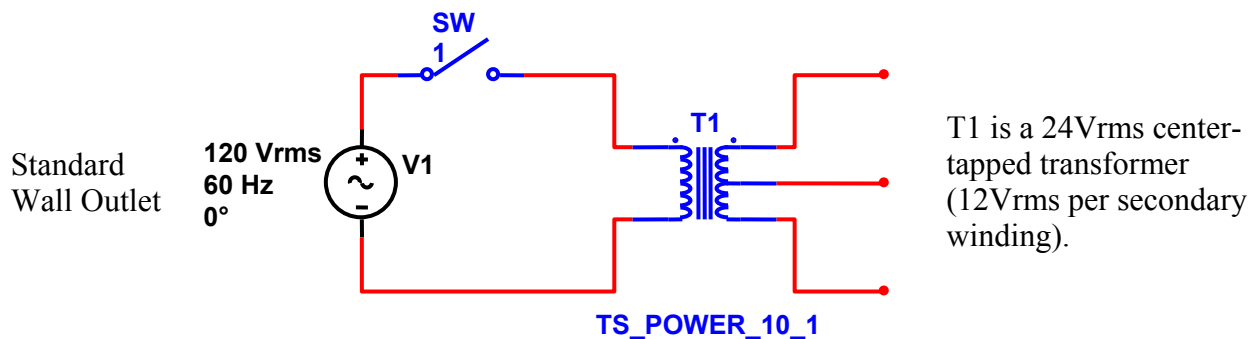


Figure 2-1

## PART I: UNREGULATED DC POWER SUPPLY WITH HALF-WAVE RECTIFIER

### Half Wave Rectifier (no filter capacitor)

- 1.1. Using the transformer box, a 1N4004 diode and a 1k $\Omega$  resistor, build the half-wave rectifier circuit shown in Fig 2-2. The 1k $\Omega$  resistor comprises the electrical load powered by this circuit. NOTE: Only one half of the transformer secondary is connected for this part of the lab.

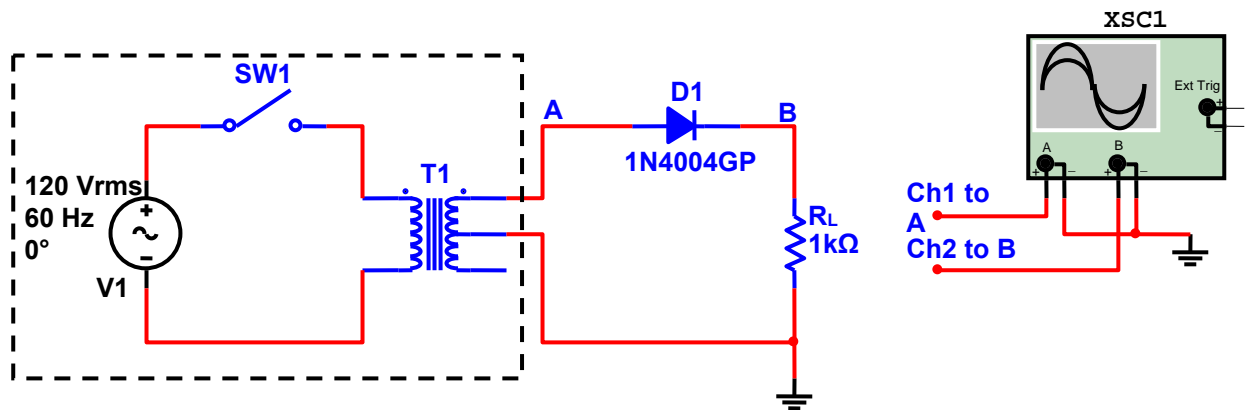


Figure 2-2

### Input and Output Waveforms

- 1.2. Using two channels of the oscilloscope view the output of the transformer on Ch1 (A) and the output voltage after the rectifier on Ch2 (B). Be sure to connect at least one scope ground to the ground reference point. Use the following scope settings:

Vertical Sensitivity:	5V/div (each channel)
Horizontal Time Scale:	5msec/div
Probe Multiplier:	X1 or X10 (MUST be matched to probe menu)
Coupling:	Direct Coupling, (average DC values WILL NOT be blocked)
Triggering:	Either Ch1 or LINE triggering (recommended)

NOTE: Be sure that the vertical positions are initially set to zero so that you do not have any vertical offset. Set the probe coupling to GND if necessary and zero the vertical positions.

- 1.3. If your scope is properly set up, you should see at least two complete cycles of both the input and output voltage waveforms. Accurately sketch these waveforms in your lab notebook and indicate any interesting features of the graphs. Comment on the operation of the circuit. How well does this circuit work as a half-wave rectifier?

### Half Wave Rectifier (with filter capacitor)

1.4. Modify the half wave rectifier circuit by adding a  $10\mu\text{F}$  filter capacitor, as shown in Fig 2-3.

**CAUTION: BE SURE TO OBSERVE THE CORRECT POLARITY OF THE CAPACITOR, OR IT MAY EXPLODE!**

Capacitors of the electrolytic type contain a *dielectric* that is polarized. When connected with the wrong polarity, the dielectric will conduct electricity and dissipate power as heat (rather than act as an insulator). This heat often vaporizes the dielectric, causing excessive pressure and rupturing the package.

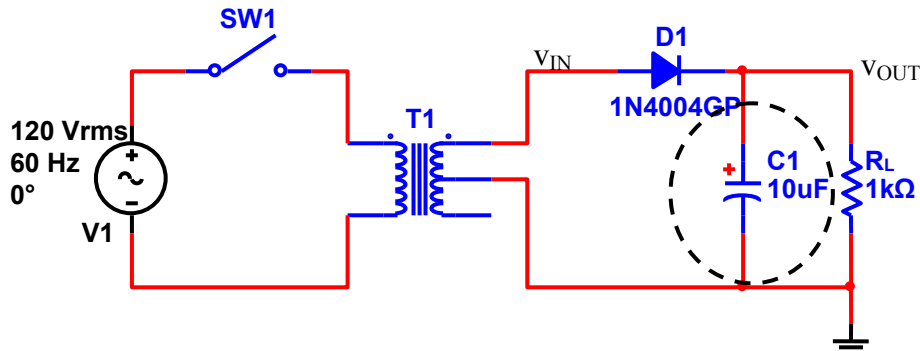


Figure 2-3.

### Input and Output Waveforms

1.5. Measure and sketch the input and output voltage waveforms  $v_{\text{IN}}$  and  $v_{\text{OUT}}$  with the filter capacitor in place. Compare the output voltage to the circuit without the filter capacitor. Does it have the same peak value? Explain. How well does this circuit meet the requirements of producing a smooth DC output voltage? What size is the ripple voltage?

1.6. Change the capacitance value to  $100\mu\text{F}$  and sketch the output waveform. What is the amplitude of the ripple voltage with the larger capacitor?

### Using AC Coupling to Measure Ripple Voltage

1.7. Ripple voltage can be measured more accurately using the *AC Coupling* feature of the oscilloscope. This feature inserts an internal capacitor in series with the probe to block the DC average of the signal, only permitting the changing “AC” portion of the signal to be displayed.

1.8. Set Channel 2 to AC Coupling and increase the sensitivity of the voltage scale to  $0.5\text{V/div}$ . Measure the amplitude of the ripple voltage with the  $100\mu\text{F}$  capacitor in place. Also measure the frequency of the ripple. Why is AC Coupling an invaluable feature when measuring DC power supply ripple?

### Design Challenge

1.9. Determine a capacitance value to reduce the ripple to less than  $1\text{V}_{\text{pk-pk}}$ , and try this value. To obtain larger capacitance values, connect additional capacitors in parallel. **BE SURE TO OBSERVE POLARITY!!**

## PART II: UNREGULATED DC POWER SUPPLY WITH FULL-WAVE RECTIFIER

As seen in the previous half-wave circuit, ripple voltage can be reduced by increasing the size of the filter capacitor. Another approach to reduce the ripple is to recharge the capacitor more often. In this part of the lab, the full-wave rectifier circuit will be used to achieve this result.

- 2.1. Build the full-wave rectifier circuit shown in Fig. 2-4 by adding an additional diode, D2. Note that the filter capacitor has been removed.

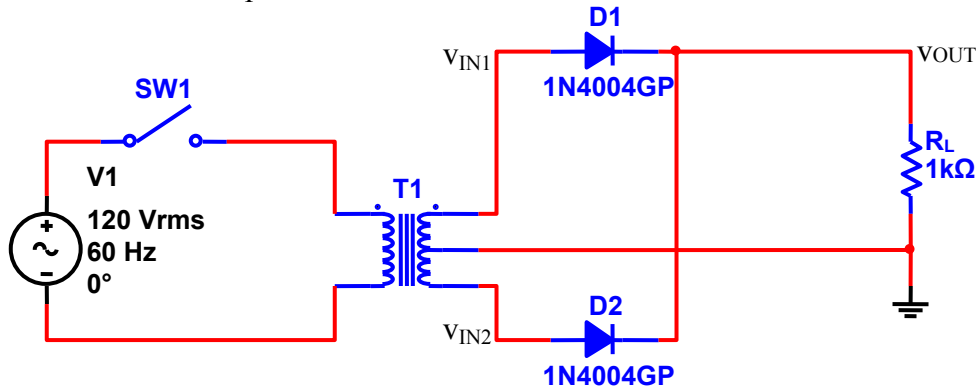


Figure 2-4.

### Center-tapped transformer waveforms

- 2.2. Set up the oscilloscope to view  $v_{IN1}$  on Ch1 and  $v_{IN2}$  on Ch2. Set up the time base of the scope to show at least two full cycles of the sine wave.
- 2.3. Sketch the  $v_{IN1}$  and  $v_{IN2}$  waveforms. How do they compare to one another, in terms of shape, amplitude and phase?

### Full wave rectifier (without filter capacitor)

- 2.4. Use Ch2 (or another channel) on the oscilloscope to observe  $v_{OUT}$  and sketch. How does it compare to the output of the unfiltered half-wave rectifier?

### Full wave rectifier (with filter capacitor)

- 2.5. Modify the full wave rectifier circuit by adding a  $10\mu\text{F}$  filter capacitor, as shown in Fig 2-5. BE SURE TO OBSERVE THE CORRECT ORIENTATION OF THE POLARIZED CAPACITOR!

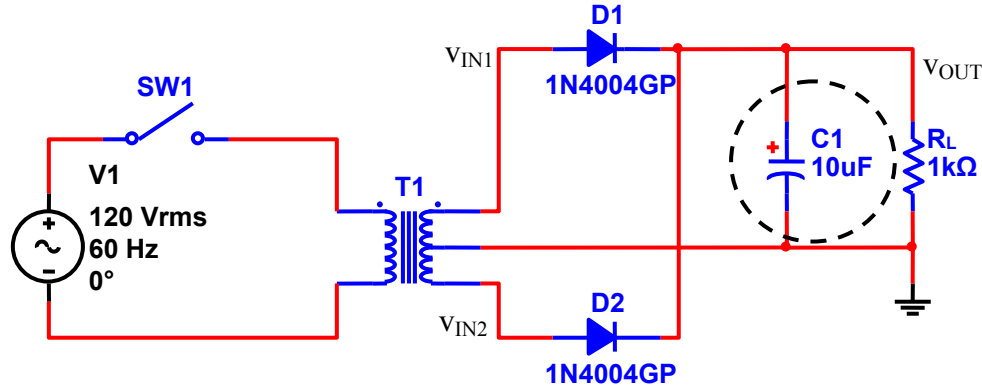


Figure 2-5

### Input, output waveforms

- 2.6. Sketch the output waveform as shown on the oscilloscope. How does this waveform compare to the unfiltered output?

### Ripple waveform

- 2.7. Using the AC coupling feature on the oscilloscope, measure the frequency and peak-to-peak amplitude of the ripple waveform “riding” on the output DC voltage. How does the ripple of the full-wave circuit compare to the half-wave rectifier (for the same size  $10\mu\text{F}$  capacitor)?

### Design Challenge

- 2.8. Determine a capacitance value to reduce the ripple to less than  $1\text{V}_{\text{pk-pk}}$ , and try this value. How does this capacitor value compare to the one you chose for the half-wave circuit (in part 1.9)? AGAIN, BE SURE TO OBSERVE CAPACITOR POLARITY!!

### PART III: DC POWER SUPPLY WITH ZENER DIODE REGULATOR

In the previous part of this lab, you saw how ripple can be reduced by increasing the size of the filter capacitor as well as using both phases of the 60Hz sine wave. To achieve even lower ripple (and a better approximation to the ideal of a constant DC voltage), a zener diode voltage regulator can be used.

#### Full-Wave Rectifier (with filter capacitor and zener regulator)

- 3.1. Modify the full wave rectifier circuit by adding the zener diode regulator subcircuit as shown in Figure 2-6. NOTE: Add SERIES RESISTOR R1 comprised of one  $250\Omega$  ( $1/2W$ ) resistor OR TWO  $510\Omega$  ( $1/4W$ ) resistors in PARALLEL. ALSO note that zener diode D3 is in parallel with the load resistor  $R_L$ .

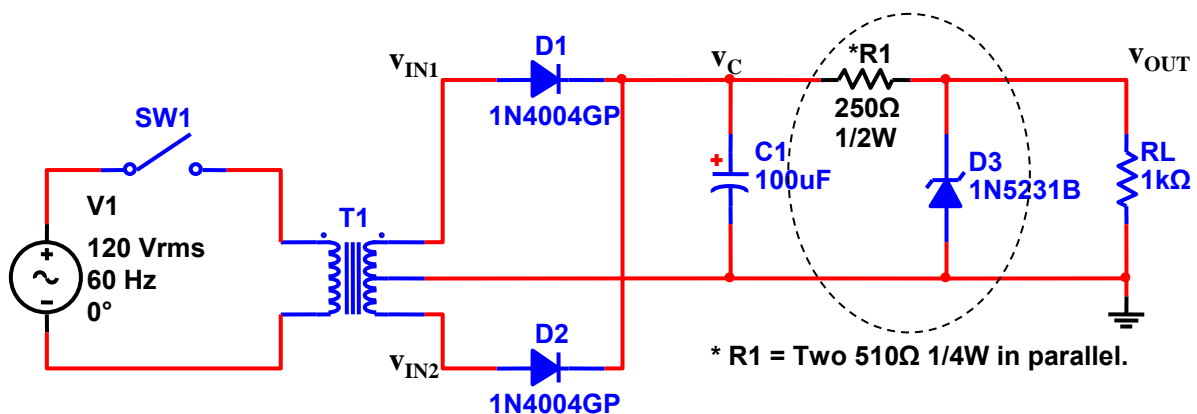


Figure 2-6.

#### Input, output waveforms

- 3.2. Using the scope, record each of the waveforms indicated - the input voltages  $V_{IN1}$  and  $V_{IN2}$ , the capacitor voltage  $V_C$  and the output voltage,  $V_{OUT}$ . How do these waveforms compare? Briefly explain what is happening to the voltage at each stage of this power supply.

#### Ripple waveform

- 3.3. Using the AC coupling feature on the oscilloscope, measure the frequency and peak-to-peak amplitude of the ripple waveform “riding” on the output DC voltage. How does this value compare to the ripple voltage without the zener regulator in part 2.7?

## PART IV: REGULATED DC POWER SUPPLY USING VOLTAGE REGULATOR IC

In practice, DC power supplies utilize a voltage regulator IC whose job it is to maintain a constant output voltage to within tens of millivolts of the specified value. In this way, a regulated DC power supply can be used in place of a battery over a wide range of load variations. In this part of the lab, you will construct a regulated DC power supply using the LM7805 5VDC Regulator IC.

- 4.1. Construct the circuit of Fig. 2-7. It is identical to the previous circuit, except that the zener regulator has been replaced by the LM7805 regulator IC.

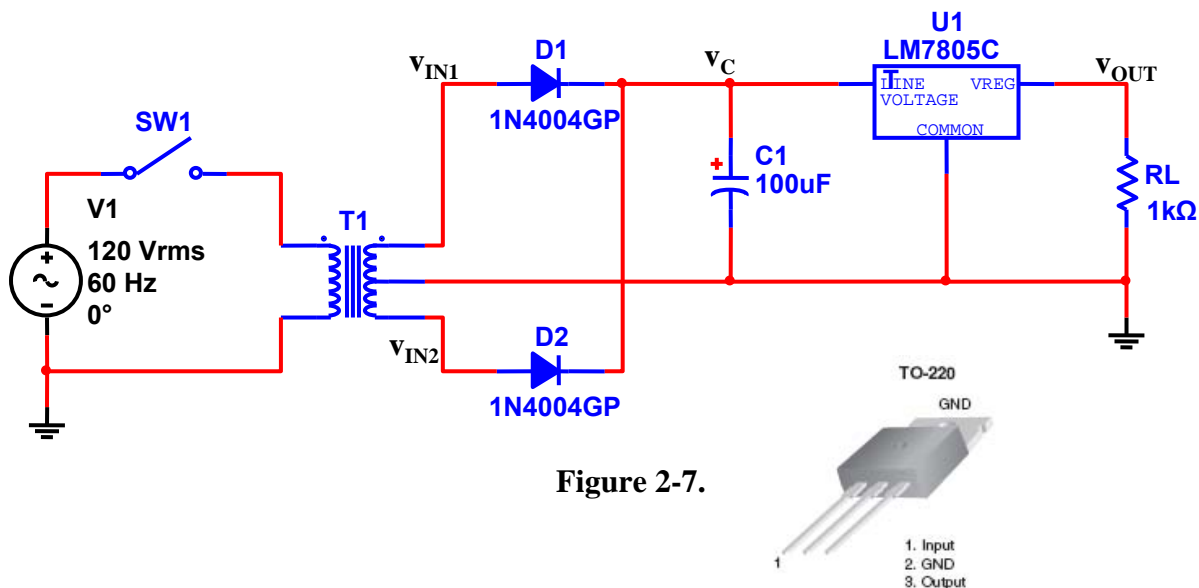


Figure 2-7.

- 4.2. Using the oscilloscope, monitor the capacitor voltage,  $v_C$  and the output voltage,  $v_{OUT}$ . Verify that the output voltage is a regulated 5VDC supply. What is the load current in this circuit?

### Load Variation

- 4.3. Decrease the load resistor to  $100\Omega$  while observing the capacitor voltage,  $v_C$ . What is the load current? What is the size of the ripple voltage across the  $100\mu\text{F}$  capacitor? Is the regulator still able to function within its specification (ie. provide 4.8 to 5.2V)?
- 4.4. Now decrease the load resistor to a  $51\Omega$  ( $1/2\text{W}$ ) OR TWO  $100\Omega$  ( $1/4\text{W}$ ) resistors in parallel and observe  $v_C$ . What is the size of the ripple? Is the regulator able to function within spec?

### Design Challenge

- 4.5. Determine the minimum size capacitance required to allow the regulator to work within specification, with the  $51\Omega$  load connected. Choose the closest value in your kit or combine capacitors in parallel to meet or exceed the required value. Connect this capacitance and verify proper operation of the regulator.



## LAB WRITE-UP

**This lab assignment contains FOUR parts. Each section should include:**

- (1) A brief statement describing the scope of each experiment.
- (2) Detailed schematics with all components labeled, values indicated and equipment used.
- (3) Explanations of each concept with key mathematical derivations that govern the behavior of the system.
- (4) Experimental results including tables, graphs, and oscillograms.
- (5) Pertinent simulations for comparison.
- (6) Overall conclusions and observations.

**Additional details for each part of this lab are given below:**

### **PART I: UNREGULATED DC POWER SUPPLY WITH HALF-WAVE RECTIFIER**

- W1. Include circuits and input and output waveforms for the half-wave rectifier, before and after adding a filter capacitor.
- W2. Explain the relationship between ripple voltage, capacitance value and load resistance and compare calculated theoretical values to measurement and simulation.
- W3. For the design challenge, compare your predictions to what you actually measured and comment on your results.

### **PART II: UNREGULATED DC POWER SUPPLY WITH FULL-WAVE RECTIFIER**

- W4. Include circuits and input and output waveforms for the full-wave rectifier, before and after adding a filter capacitor.
- W5. Explain the relationship between ripple voltage, capacitance value and load resistance and compare calculated theoretical values to measurement and simulation.
- W6. For the design challenge, compare your predictions to what you actually measured and comment on your results.
- W7. Compare the full-wave circuit to the half-wave and comment on any improvements.

### **PART III: DC POWER SUPPLY WITH ZENER DIODE REGULATOR**

- W8. Include circuits and input and output waveforms for the DC power supply utilizing the zener diode regulator.
- W9. Compare calculated values to measurement and simulation.
- W10. Comment on the effectiveness of this regulator design.

**PART IV: REGULATED DC POWER SUPPLY USING VOLTAGE REGULATOR IC**

- W11. Include circuits and input and output waveforms for the DC power supply utilizing the voltage regulator IC.
- W12. Compare calculated values to measurement and simulation.
- W13. Comment on the effectiveness of this regulator design under varying load conditions.
- W14. For the design challenge, explain how you determined the required capacitance value.