EXPERIMENT 6: *THE ZENER DIODE AND REGULATION*

Equipment List

- 4x 1N4004 Diodes.
- 10 μF Electrolytic capacitor
- 1μF ceramic capacitor
- 1N4738A zener diode (1 Watt 8.2V)
- LM317 voltage regulator
- Cenco 89 Ω, 2.2 A Rheostat
- 5kΩ Pot or Leeds & Northrup #4754 AC-DC Decade Resistor
- Center Tap Transformer Box
- OS BK 2120B Dual Channel Oscilloscope

Introduction

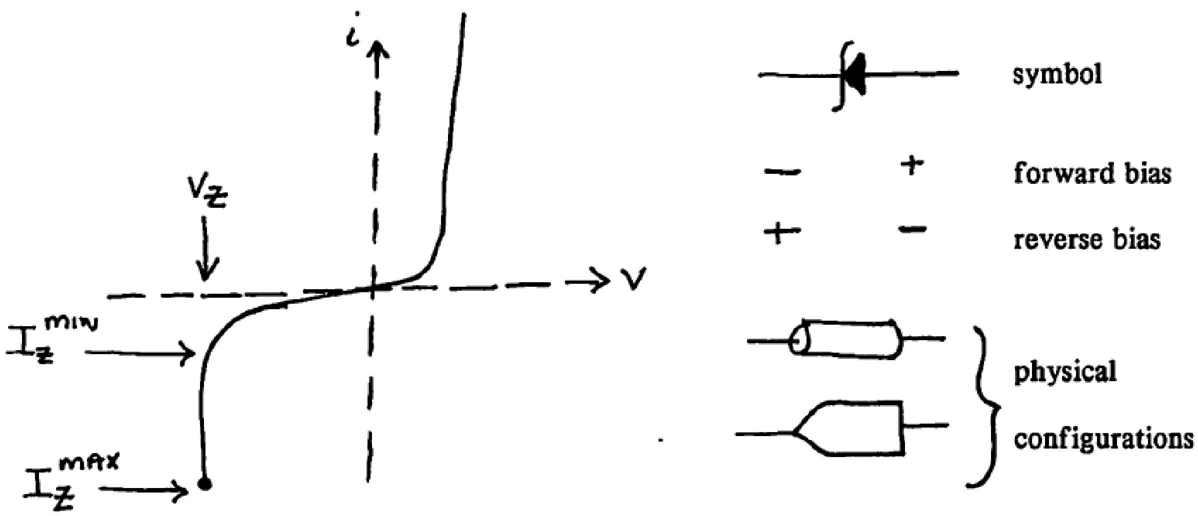

Figure 6.1 Zener Characteristic and Symbol

The forward characteristic of a zener diode is like that of a normal diode. In the reverse direction the characteristic is again normal; i.e., near zero current for any applied reverse bias, until a negative voltage limit, $-V_2$, is reached. At this point something new happens, the diode breaks down and passes as much current as is presented to the zener diode at a near constant voltage. The breakdown is non-destructive so long as a specified maximum power loss, $P_z = V_z \ I_z^{max}$, is not exceeded.

Note that zener diodes come in a variety of packages, some zeners look like bullets while others look just like ordinary diodes. You can reliably identify the diode in hand use the part number on the side.

In the Diode Lab we used a capacitor across the load to filter out much of the AC component from a full wave rectified signal. For long time constants $(R_{load}C \gg 0.02s)$ this method for producing a DC source is quite effective; however, the capacitive filter does a poor job of smoothing the rectifier output for varying loads; i.e., the DC voltage output shifts when R_{load} becomes small. Instead of smoothing the wiggles in the output we could chop the wiggles off with a zener diode (an good voltage regulator within certain current limits). Even better, we could use a voltage regulator like the LM317. In which case we can adjust the chopping voltage with a resistor according to Eq. 1.

$$V_{out} = 1.25V(1 + \tfrac{R_2}{R_1}) \tag{1}$$

Part I: Zener Characteristics

a) Construct the circuit in Fig. 6.2.A. Then attach meters to measure the current through and voltage across the zener diode.

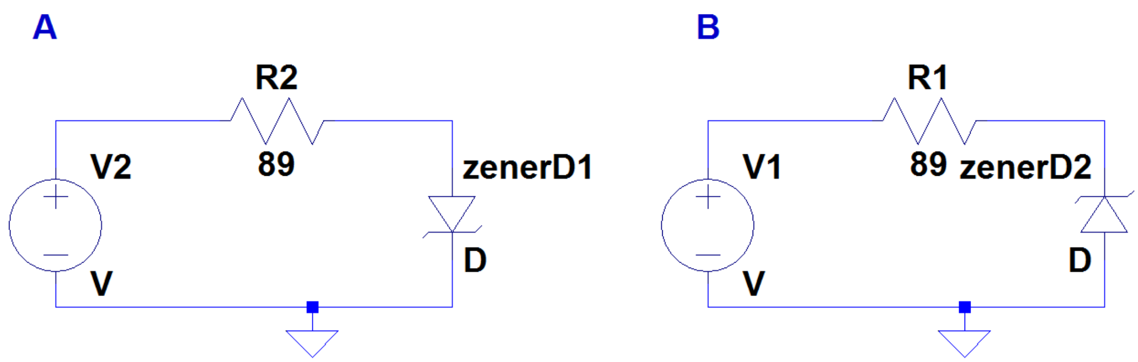

Figure 6.2 Zener Characteristics Circuits with the diode A: forward biased and B: reverse biased.

b) Take several readings of voltage versus current to determine the forward characteristic voltage V_d. Do not exceed 100 mA.

c) Reverse the diode as shown in Fig. 6.2.B and determine the reverse characteristic, V_z, using the same meters and observing the same precautions.

d) Plot your results.

e) Estimate V_z from the plot.

f) These zeners are rated for 1 Watt. What is the maximum current you can pass through the diode, I_z^{max}?

g) Adjust the current to this value. Note the current slowly drops. Why? Well, when a device is rated at a certain power, this means it will operate without destroying itself at this power level. Where does the power go? It heats the device up, until there is equilibrium between heat generated in the device and heat lost by conduction through the leads and convection through the air. Since solid state devices are generally temperature dependent, we expect the characteristic to change slightly as it heats up.

h) Dump the heat from the zener. Use your fingers as a heat "sink" by squeezing the zener diode between two fingers (don't touch the leads, just the case). This should arrest the drift and perhaps reverse the trend.

Part II: Regulated DC power supply using LM317 voltage regulator

You will now build a regulated DC power supply in three stages.

1. Stage one is a repeat of last weeks lab, a transformer feeding power from the electrical grid to a full bridge rectifier (See Fig. 6.3)
2. Stage two is the regulator it can be made either from
    a. A resistor paired with a reverse biased zener diode.
    b. A LM317 circuit (See Fig. 6.4)
3. The load, in this case a 10Ω, 10W resistor.

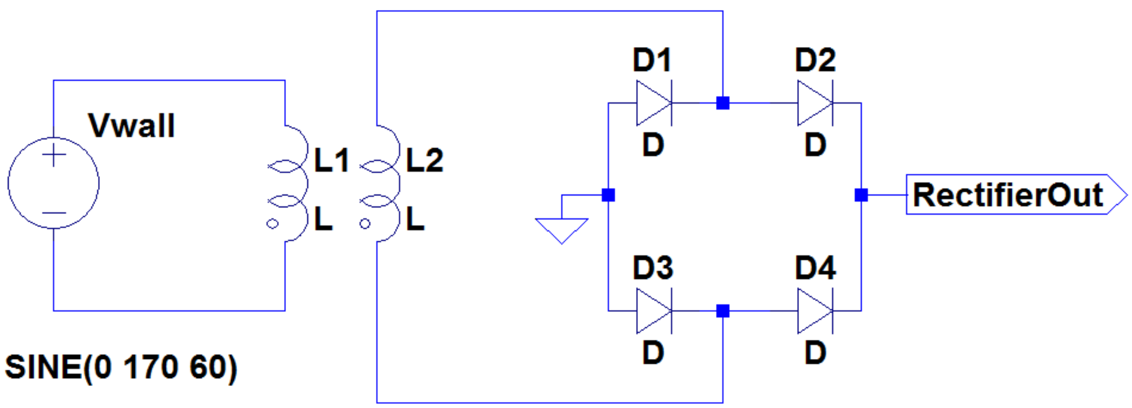

Figure 6.3: The full bridge rectifier, you will place the voltage regulator circuit between the bridge and the 1kΩ load.

Using a LM317 voltage regulator gives more flexibility in selecting the output voltage than a zener diode so we will use this approach.

Constructing the pieces:

- Construct the rectifier portion of circuit in Fig. 6.3 on the left side of your bread board.
- Construct the LM317 regulator circuit (all ofFig. 6.4) in middle of your breadboard. **For R_2 use either**
    - **a decade box set to $1k\Omega$ or**
    - **a $5k\Omega$ potentiometer (Pot) set to $1k\Omega$.**

  Question: based on Eq. 1 what should Vout be at the end of the construction phase?

- Place the load in the right side of your breadboard.

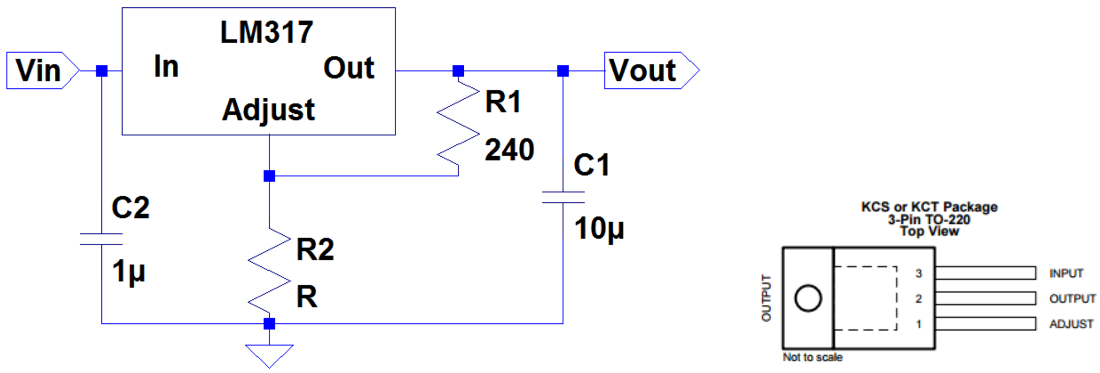

Figure 6.4: A typical LM317 Circuit. The caps are to smooth out fluctuations at the input and the output. Pinout from Texas Instruments data sheet.

Testing the pieces:

- Rectifier: plug the transformer into the wall and measure the voltage between Rectifier Out and ground on the oscilloscope. Does the voltage look the way it should? When it does, make a sketch of RectifierOut wrt ground.
- LM317 regulator: connect the input of the regulator to a DC power supply set to $10V_{DC}$. Measure the voltage between Vout and ground using the oscilloscope. Does the voltage look the way it should? Is it the proper value? Does it respond to changes in R_2 correctly? When it does, make a sketch of Vout wrt ground with R_2=1kΩ.

Stringing the pieces together:

Unplug the transformer from the wall, remove the DC power supply, and the oscilloscope.

- Use Rectifier Out and ground from the circuit on the left side of your breadboard (See Fig. 6.3) to power the circuit in the middle of your bread board (Vin and ground of Fig. 6.4)
- Use Vout and ground from the circuit in the middle of your breadboard to power your load.

Your regulated DC power supply is now completed and connected to a load.

Testing your regulated DC power supply

a) Calculate the predicted load voltage for 5 R_2 values between 200Ω to 2000Ω using Eq. 1.
b) Measure the load voltage for the same 5 R_2 values using the oscilloscope.
c) Calculate the predicted load voltage for R_2 =5kΩ.
d) Measure the load voltage for R_2 =5kΩ using the oscilloscope.

Comment on the size of the difference between the predicted and observed voltages and explain why significant differences exist for some resistor values.

Name:_______________________________________

Part I:

V_d (forward bias characteristic voltage)

V_z (reverse bias characteristic voltage)

I_z^{max}

Staple your part 1 graph to this sheet.

PartII:

Question: based on Eq. 1 what should Vout be at the end of the construction phase?

Sketch from rectifier test phase:

Sketch from regulator test phase:

Resistance	Calculated Vload	Measured Vload
200 Ohm		
2000 Ohm		
5000 Ohm		

Comments on where there is disagreement and why: