# Voltage Regulator

## Zener Diode Shunt Voltage Regulator

When an ideal diode is reverse biased, it conducts no current. The depletion layer at the reverse biased pn junction acts like an insulator. Like any real insulator, it can suffer breakdown when the applied potential is sufficiently high. A Zener diode has been specially built so that its depletion layer breaks down (safely) at low voltages. At breakdown, the diode presents very little incremental resistance to current flow, and so it can act like a good voltage reference.

### Simple Zener Regulator Circuit

The circuit in Figure below maintains ~$V_Z$ on its output by reverse biasing the Zener diode with ~$I_Z$ current.

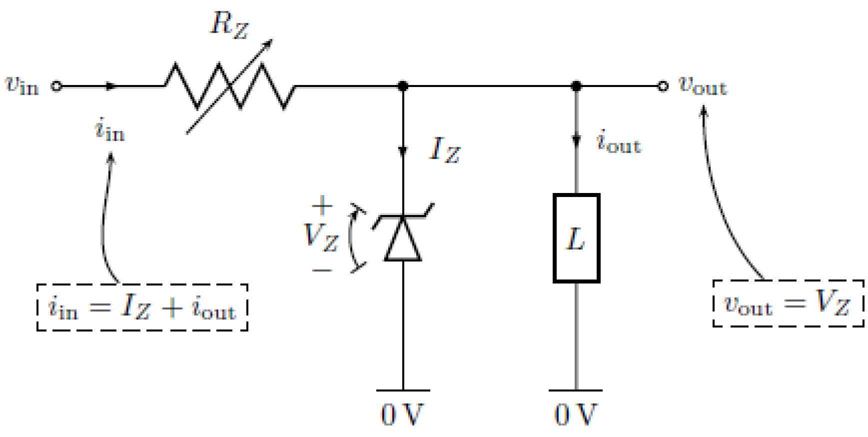


Figure 1: Zener diode shunt voltage regulator with load L.

Typical $V_Z$, $I_Z$, and "on" resistance $R_{on}$ for Zener diodes can be noted from datasheet.

The resistor $R_Z$ both biases the Zener diode and limits the output current $i_{out}$. That is,

$$\boldsymbol{v_{out} = v_{in} - (Iz + i_{out})Rz = v_{in} - \left(I_Z + \frac{V_Z}{L}\right) Rz}, \quad \text{.....(1)}$$

and so, for $v_{out} = V_Z$, $R_Z$ must be chosen so that

$$\boldsymbol{R_Z = \frac{v_{in}-V_Z}{I_Z+i_{out}} = \frac{v_{in}-V_Z}{I_Z+\frac{V_{out}}{L}} = \frac{v_{in}-V_Z}{I_Z+\frac{V_Z}{L}}} \quad \text{.....(2)}$$

where L is the typical load (e.g., ~10 k) and $v_{out}$ is the desired output. As the load L moves off the typical load, the current through the Zener diode will change. A very small L will rob the Zener of so much current that it will move out of its Zener operation range. At that point, the output $v_{out}$ will drop far below $V_Z$ as the circuit reduces to a $R_Z$–L voltage divider.

## Zener Regulator Laboratory Procedure:

1. Design (i.e., choose components for desired output) and build the regulator.
    - Lookup your Zener diode's $I_Z$ and $V_Z$ in the datasheet
        - Using a 4.3V Zener diode will simplify later calculations.
        - Make sure you have the right Zener diode.

    ∗ Diode part numbers (e.g., 1N5229) are written in very small text that is "word-wrapped" around the outside of the glass diode package. Rotate diode to read the text.
    - Use input vin = 15V.
    - Use output vout = $V_Z$.
    - Using equation 2, calculate the $R_Z$ needed to properly bias your Zener diode.
        - Use IZ from datasheet
        - Assume a typical load of 10 k.
2. Verify proper regulator output, but DO NOT TUNE the regulator.
    - Use a 10 k load.
    - Use your digital multimeter to measure the output.
        - If output is far from expected $V_Z$, make sure you calculated biasing resistor $R_Z$ correctly.
    - For your report, refer to equation 1 and discuss how $R_Z$ should be changed to tune the output (e.g., increase it or decrease it).
3. With no load (i.e., L = ∞, an open circuit), record the $i_{in}$ current measured by the power supply as the no-load quiescent current, which is the additional current required to operate the regulator with no load.

| L(Load)Ω | $v_{out}(V)$ | $i_{in}$ $(mA)$ |
|---|---|---|
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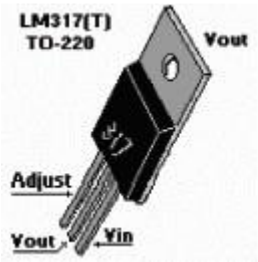
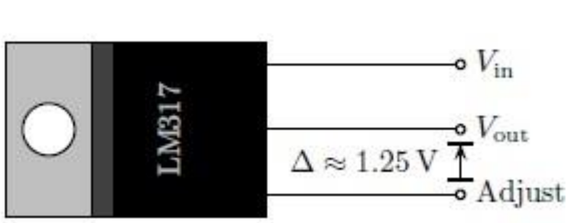
# LM317 Adjustable Positive Series Voltage Regulator

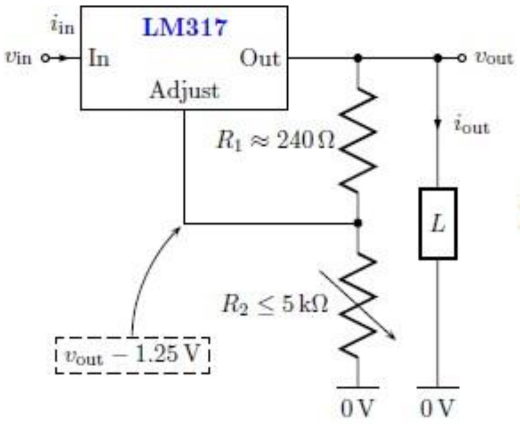



The LM317 maintains 1.25V potential difference between its “Out” and “Adjust” pins, and the voltage divider acts as a lever propping Vout above the ground reference.

In Figure 2, the (temperature-independent) output is given by

$v_{out} = (1.25) * (1 + \frac{R_2}{R_1})$……………………………………………………………………………(3)



(a) Using variable-resistor divider.

Figure 2: LM317 adjustable series voltage regulator with load L. Use 40V > (vin − vout) > 3V.

## LM317 IC Regulator Laboratory Procedure:

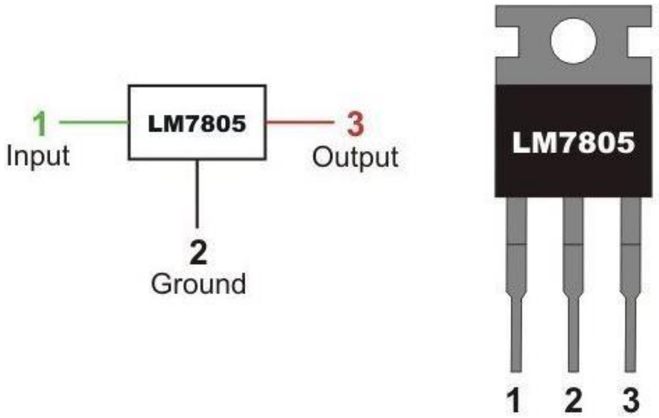
1. Design (i.e., choose components for desired output) and build the regulator in Figure 2(a).
   - RESISTOR VALUES SHOWN in schematics reflect nominal potentiometer sizes.
   - Again, use input vin = 15V.
   - Use equation 3 to calculate the proper R2/R1 ratio.
   - From Figure 2(a), set $R_1 \approx 240$ and calculate $R_2$. Implement $R_2$ with a variable resistor made from adjacent legs of a 2 k or 5 k potentiometer.

2. Tune regulator output by adjusting the $R_1$–$R_2$ divider (or potentiometer) until measured $v_{out} \approx 10V$.
   - Use a 10k load.
   - Use your digital multimeter (DMM) to measure the output voltage.

3. Use your DMM to measure (and RECORD) the potential between the Output and Adjust pins. What is expected?
4. Vary the load resistance and note the output voltage values.
5. With no load (i.e., L = ∞, an open circuit), record the $i_{in}$ current measured by the power supply as the no-load quiescent current, which is the additional current required to operate the regulator with no load.

| L(Load)Ω | $v_{out}(V)$ |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |

## LM7805 Voltage Regulator




## Line Regulation:

Line regulation refers to the ability of a circuit to maintain constant (regulated) output voltage with change in the input voltage.

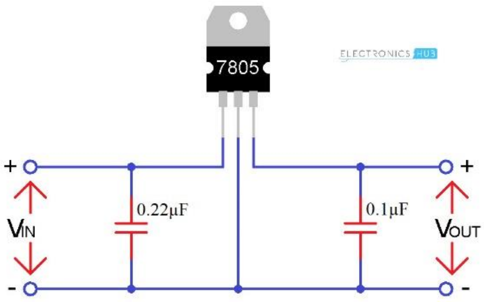



*Figure 3: LM7805 voltage regulator*

1. Design and build the circuit given in fig 3.
2. Apply a DC input voltage ranging from 0 volts to 15 volts in steps (at least 5) and measure the output voltage using your DMM.
3. Note the results and present them as a table.

| $V_{in}$ (v) | $V_{out}$ (v) |
|---|---|
| … | … |
| … | … |
| | |

## Load Regulation:

Load regulation refers to the ability of a circuit to maintain constant (regulated) output voltage with change in the load resistance.

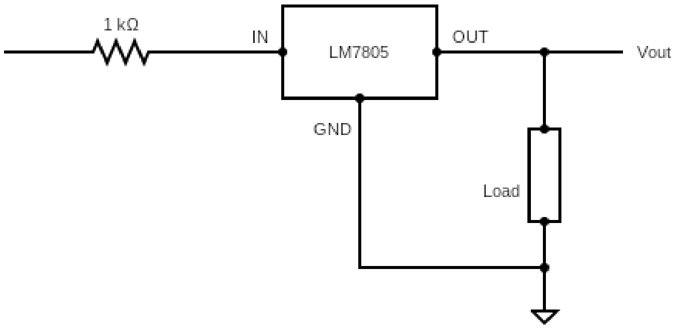



*Figure 4: LM7805 voltage regulator*

1. Design and build the circuit given in fig 4.
2. Apply a DC input of 15 volts and vary the load resistance in steps (at least 5) and measure the output voltage using your DMM.
3. Note the results and present them as a table.

| $V_{in}$ (v) | $V_{out}$ (v) |
|---|---|
| … | … |
| … | … |
| | |