Voltage Regulator Design on Breadboard

Circuit Overview

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

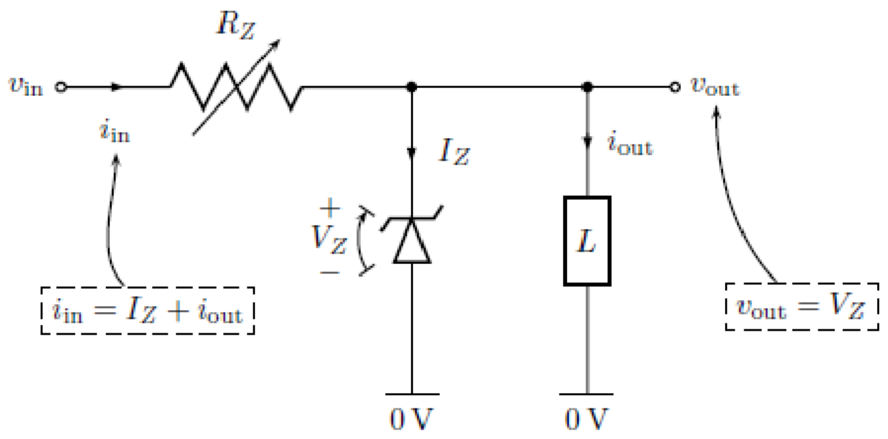

Figure 1: Zener diode shunt voltage regulator with load L.

The circuit in Figure 1. maintains $\sim V_Z$ on its output by reverse biasing the Zener diode with $\sim I_Z$ current. 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, where L is the typical load (e.g., $\sim 10\,\text{k}$) 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.

The following equations can be easily verified using KCL and KVL:

$$v_{out} = v_{in} - (I_Z + i_{out})R_Z = v_{in} - \left(I_Z + \frac{V_Z}{L}\right) R_Z \tag{1}$$

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

$$R_Z = \frac{v_{in} - V_Z}{I_Z + i_{out}} = \frac{v_{in} - V_Z}{I_Z + \frac{V_{out}}{L}} = \frac{v_{in} - V_Z}{I_Z + \frac{V_Z}{L}} \tag{2}$$

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 4.7V or 5.6V 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 $v_{in} = 15V$.
- Use output $v_{out} = V_Z$.
- 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., $L = \infty$, 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	$V_{out}(V)$	$i_{in}(mA)$

LM7805 Fixed Voltage Regulator

The LM7805 is a fixed 5 V regulator. Since the output voltage is fixed, no external resistors are needed for setting the voltage.

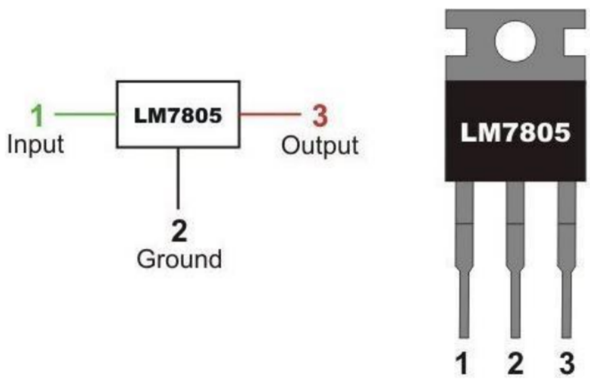

Figure 2: LM7805 voltage regulator

Line Regulation

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

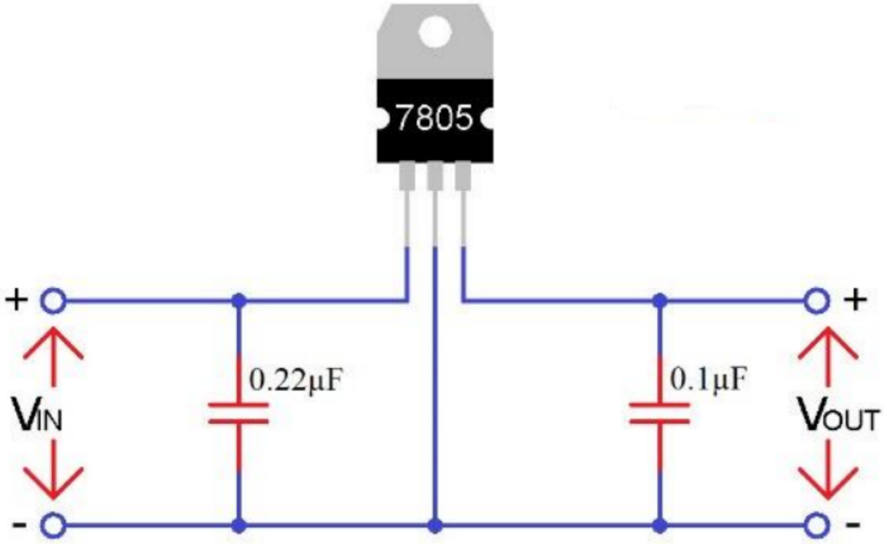

Figure 3: LM7805 Line Regulation

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.

$V_{\mathbf{in}}(v)$	$V_{\mathbf{out}}(v)$
...	...
...	...
...	...

Load Regulation

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

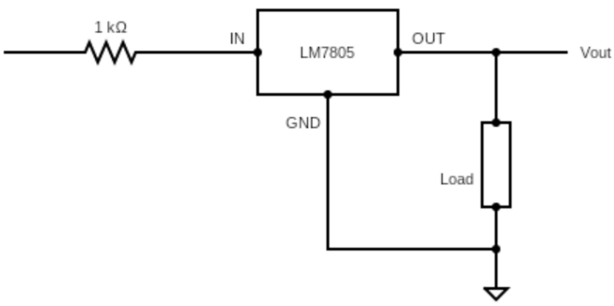

Figure 4: LM7805 Load Regulation

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.

$V_{\text{in}}(v)$	$V_{\text{out}}(v)$
...	...
...	...
...	...

LM317 Adjustable Voltage Regulator

The LM317 is a three-terminal adjustable positive series voltage regulator. It maintains a constant 1.25 V potential difference between its 'OUT' and 'ADJUST' pins. An external resistor divider (R_1 and R_2) uses this internal reference to set a desired output voltage. LM317 adjustable series voltage

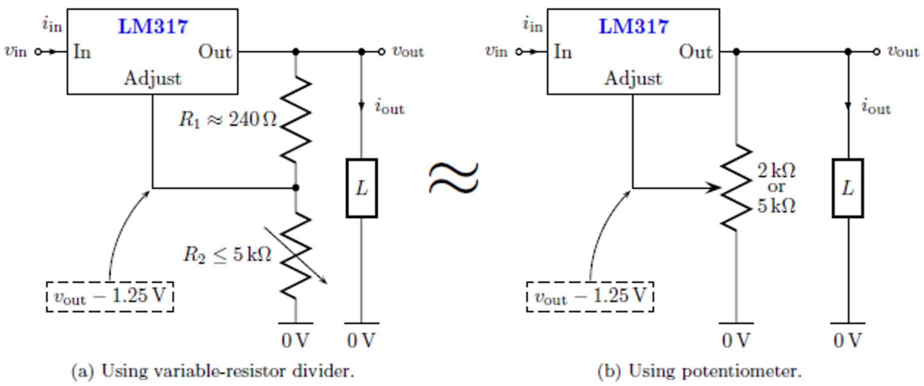

Figure 5: Using variable resistor divider

regulator with load L. Use 40V > (vin − vout) > 3V. The output voltage is determined by the formula:

$$v_{out} = 1.25V \times \left(1 + \frac{R_2}{R_1}\right) \tag{1}$$

LM317 IC Regulator Laboratory Procedure:

1. Design (i.e., choose components for desired output) and build the regulator in Figure 2(a) or (b).
   - Resistor values shown in schematics reflect nominal potentiometer sizes.
   - Again, use input $v_{in} = 15$V and output $v_{out} = 10$V.
   - Use equation (1) to calculate the proper $R_1/(R_1 + R_2)$ ratio.
   - You have two implementation options.
     (i) From Figure 5(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.
     (ii) From Figure 5(b), adjust a 2 k or 5 k potentiometer for the right $R_1/(R_1 + R_2)$ ratio.

   While you should perform all calculations for your report, it may be easiest to skip calculations for now and tune 2 k or 5 k potentiometer until output reaches desired 10V.

   A brief about Potentiometer: There are two types of resistors: fixed resistors and variable resistors based on the resistance value. Potentiometers are a type of adjustable resistor that has three pins. Now, the potentiometer is filled with resistive material and turning the knob changes the amount of this material and so the resistance of the material. Try exploring more stuff about potentiometer as it is an important equipment in lab experiments.

2. Tune regulator output by adjusting the R_1–R_2 divider (or potentiometer) until measured $V_{out} \approx$ 10V.
   - Use a 10 k load.
   - Use your digital multi meter (DMM) to measure the output.
3. Use your DMM to measure (and RECORD) the potential between the Output and Adjust pins. What is expected?
4. With no load (i.e., $L = \infty$, 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. Try finding out a potential disadvantage of this kind of

L(Load)Ω	$V_{out}(V)$	$i_{in}(mA)$