National Polytechnic Institute
Superior School of Computer Sciences

Analog Electronics.

Practice 3 - Zener Diode and Voltage Regulators.

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Contents

1 Introduction:

The present practice introduces the operation of power supply circuits built using filters, rectifiers, and then voltage regulators. Starting with an ac voltage, a steady dc voltage is obtained by rectifying the ac voltage, then filtering to a dc level and, finally, regulating to obtain a desired fixed dc voltage. The regulation is usually obtained from an IC voltage regulator unit, which takes a dc voltage and provides a somewhat lower dc voltage, which remains the same even if the input dc voltage varies or the output load connected to the dc voltage changes. A block diagram containing the parts of a typical power supply and the voltage at various points in the unit is shown in Figure 1.0. The ac voltage, typically 120 V rms, is connected to a transformer, which steps that ac voltage down to the level for the desired dc output. A diode rectifier then provides a full-wave rectified voltage that is initially filtered by a simple capacitor filter to produce a dc voltage. This resulting dc voltage usually has some ripple or ac voltage variation. A regulator circuit can use this dc input to provide a dc voltage that not only has much less ripple voltage but also remains the same dc value even if the input dc voltage varies somewhat or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of a number of popular voltage regulator IC units.

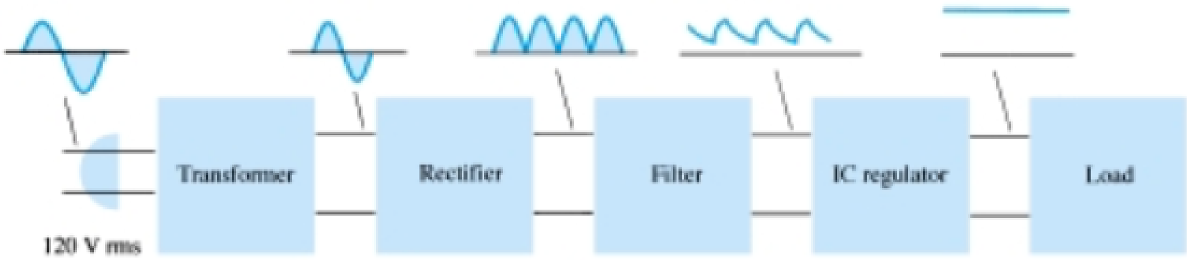

Figure 1.0: Block diagram showing part of a power supply.

1.1 IC Voltage Regulators:

Voltage regulators comprise a class of widely used ICs. Regulator IC units contain the circuitry for reference source, comparator amplifier, control device, and overload protection all in a single IC. The IC units provide regulation of either a fixed positive voltage, a fixed negative voltage, or an adjustably set voltage. A power supply can be built using a transformer connected to the ac supply line to step the ac voltage to a desired amplitude, then rectifying that ac voltage, filtering with a capacitor and RC filter, if desired, and finally regulating the dc voltage using an IC regulator. The regulators can be selected for operation with load currents from hundreds of milliamperes to tens of amperes, corresponding to power ratings from milliwatts to tens of watts.

1.1.1 Three-Terminal Voltage Regulator:

Figure 1.1.1.0 shows the basic connection of a three-terminal voltage regulator IC to a load. The fixed voltage regulator has an unregulated dc input voltage, V_i, applied to one input terminal, a regulated output dc voltage, V_0, from a second terminal, with the third terminal connected to ground. For a selected regulator, IC device specifications list a voltage range over which the input voltage can vary to maintain a regulated output voltage over a range of load current. The specifications also list the amount of output voltage change resulting from a change in load current (load regulation) or in input voltage (line regulation).

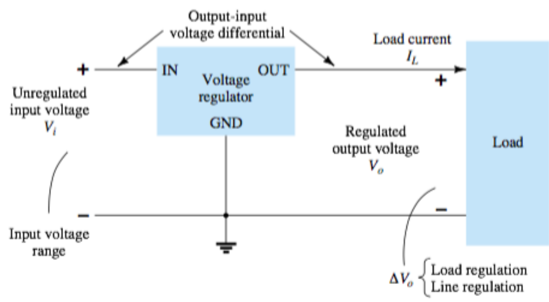

Figure 1.1.1.0: Block representation of three-terminal voltage regulator.

1.1.2 Fixed Positive Voltage Regulators:

The series 78 regulators provide fixed regulated voltages from 5 to 24 V. Figure 1.1.2.0 shows how one such IC, a ***7812***, is connected to provide voltage regulation with output from this unit of +12 V dc. An unregulated input voltage V_i it's filtered by capacitor C_1 and connected to the ICs ***IN*** terminal. The ICs ***OUT*** terminal provides a regulated + 12 V, which it's filtered by capacitor C_2 (mostly for any high-frequency noise).

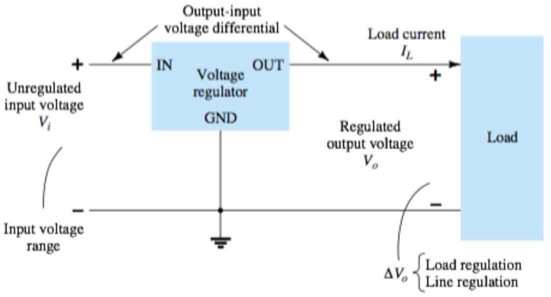

Figure 1.1.2.0: Connection of 7812 voltage regulator.

The third IC terminal is connected to ground ***GND***. While the input voltage may vary over some permissible voltage range and the output load may vary over some acceptable range, the output voltage remains constant within specified voltage variation limits. These limitations are spelled out in the manufacturer's specification sheets. A table of positive voltage regulator ICs is provided in Table 1:

The connection of a 7812 in a complete voltage supply is shown in the connection of Figure 1.1.2.1. The ac line voltage (***120*** V_{rms}) is stepped down to 18 V rms across each half of the center-tapped transformer. A full-wave rectifier and capacitor filter then provides an unregulated dc voltage, shown as a dc voltage of about 22 V, with ac ripple of a few volts as input to the voltage regulator. The 7812 IC then provides an output that is a regulated + 12 V dc.

IC part	Output Voltage [V]	Minimum V_i [V]
7805	+ 5	7.3
7806	+ 6	8.3
7808	+ 8	10.5
7810	+ 10	12.5
7812	+ 12	14.6
7815	+ 15	17.7
7818	+ 18	21.0
7824	+ 24	27.1

Table 1: Positive Voltage Regulators in 78xx Series.

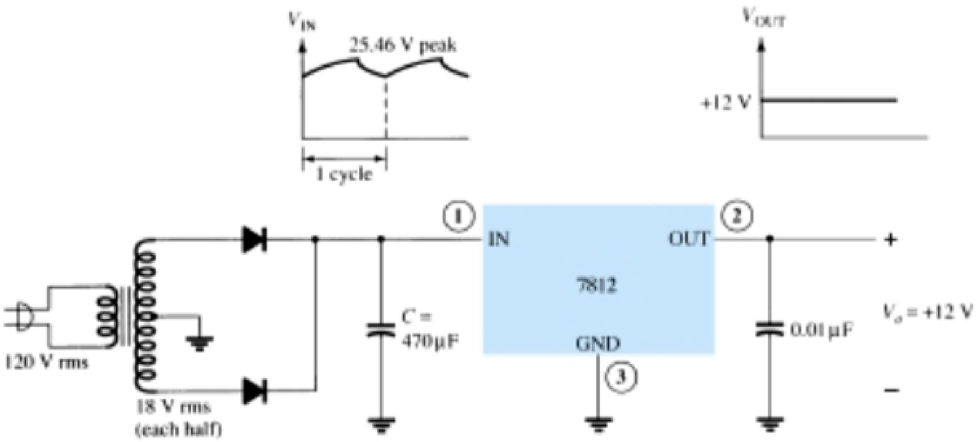

Figure 1.1.2.1: + 12 V power supply.

1.1.3 Fixed Negative Voltage Regulators:

The series 7900 ICs provide negative voltage regulators, similar to those providing positive voltages. A list of negative voltage regulator ICs is provided in Table 2. As shown, IC regulators are available for a range of fixed negative voltages, the selected IC providing the rated output voltage as long as the input voltage is maintained greater than the minimum input value. For example, the 7912 provides an output of -12 V as long as the input to the regulator IC is more negative than -14.6 V.

IC part	Output Voltage [V]	Minimum V_i [V]
7905	-5	-7.3
7906	-6	-8.3
7908	-8	-10.5
7910	-10	-12.5
7912	-12	-14.6
7915	-15	-17.7
7918	-18	-21.0
7924	-24	-27.1

Table 2: Negative Voltage Regulators in 79xx Series.

1.1.4 Adjustable Voltage Regulators:

Voltage regulators are also available in circuit configurations that allow the user to set the output voltage to a desired regulated value. The LM317, for example, can be operated with the output voltage regulated at any setting over the range of voltage from 1.2 to 37 V. In Figure 1.1.4.0 shows how the regulated output voltage of an LM317 can be set.

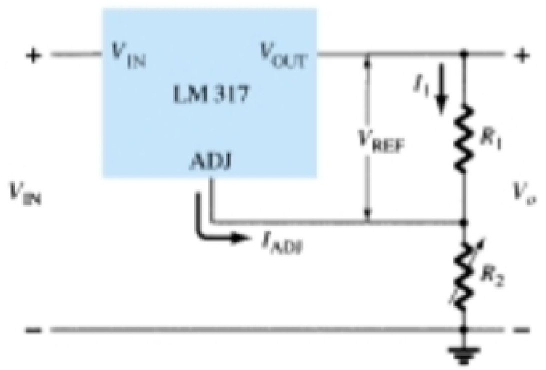

Figure 1.1.4.0: Connection of LM317 adjustable-voltage regulator.

Resistors R_1 and R_2 Set the output to any desired voltage over the adjustment range (1.2 to 37 V). The output voltage desired can be calculated using:

$$V_0 = V_{ref}(1 + \frac{R_1}{R_2}) + I_{adj}R_2 \qquad (1)$$

2 Objective:

- Analyze the breakdown voltage of a Zener Diode.
- Analyze the principal circuits with Zener Diodes.
- Implement and analyze the different IC that works as voltage regulated sources.
- Implement and analyze the different types of sources: Fixed and Adjustable.

3 Development:

We are going to analyze several circuits with different voltage regulators. Also, we are going to use some Zener Diodes, with this, we are going to visualize how this devices can operate as voltage regulators too.

3.1 Zener Diode:

Following the Figure 3.1.0, we assembled 3 similar circuits but using different R_L and R_{lim} resistors as well different Zener diodes. In each circuit we connected a voltage source in V_{in} varying it from 3.0 to 15 V in intervals of 1 V. All the measures for voltage in R_L were registered in the tables below.

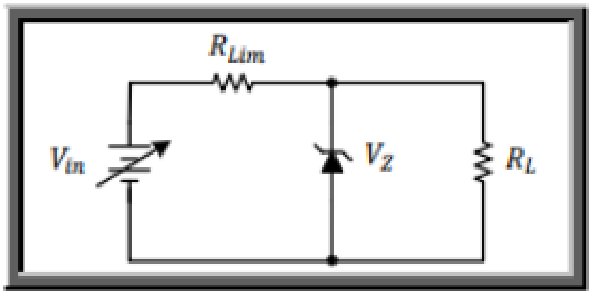

Figure 3.1.0: Zener diode circuit.

Observation: *For measure the voltage in R_L it's necessary to connect a voltmeter in parallel with the resistor.*

(i) ***First circuit:***

1. Zener Diode: 3.3 V
2. R_L resistor: 33 Ω.
3. R_{lim} resistor: 82 Ω.

(ii) ***Second circuit:***

1. Zener Diode: 5.1 V
2. R_L resistor: 49 Ω.
3. R_{lim} resistor: 56 Ω.

(iii) ***Third circuit:***

1. Zener Diode: 9.1 V
2. R_L resistor: 82 Ω.
3. R_{lim} resistor: 27 Ω.

Source Voltage	Voltage in R_L
3.0 V	0.85 V
4.0 V	1.13 V
5.0 V	1.42 V
6.0 V	1.69 V
7.0 V	1.96 V
8.0 V	2.23 V
9.0 V	2.48 V
10.0 V	2.71 V
11.0 V	2.90 V
12.0 V	3.0 V
13.0 V	3.2 V
14.0 V	3.3 V
15.0 V	3.3 V

Source Voltage	Voltage in R_L
3.0 V	1.3 V
4.0 V	1.8 V
5.0 V	2.2 V
6.0 V	2.6 V
7.0 V	3.1 V
8.0 V	3.5 V
9.0 V	4.0 V
10.0 V	4.4 V
11.0 V	4.9 V
12.0 V	5.1 V
13.0 V	5.2 V
14.0 V	5.2 V
15.0 V	5.3 V

Source Voltage	Voltage in R_L
3.0 V	2.2 V
4.0 V	2.9 V
5.0 V	3.7 V
6.0 V	4.5 V
7.0 V	5.3 V
8.0 V	6.0 V
9.0 V	6.7 V
10.0 V	7.4 V
11.0 V	8.1 V
12.0 V	8.7 V
13.0 V	9.0 V
14.0 V	9.2 V
15.0 V	9.3 V

3.2 Fixed Positive Voltage Regulator:

As we mentioned in ***Section 1***, there are ICs that has the purpose of regulate voltage. In this section we analyze two ***Fixed Positive Voltage Regulators***. The IC series that we use were the ***78XX***, specifying, the IC ***7805*** and the ***7812***. Following the Figure 3.2.0, we assembled 2 very similar circuits but switching between this two IC, in each circuit we connected a voltage source in V_{in} varying it from 3.0 to 16 V in intervals of 1 V:

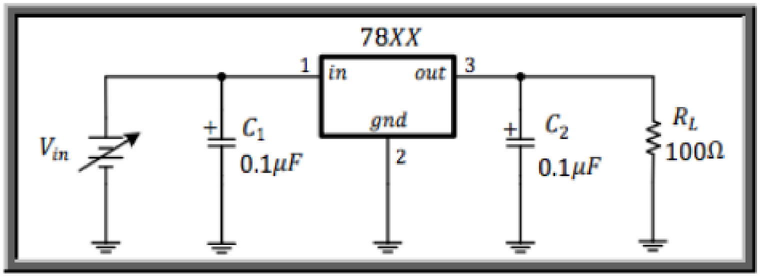

Figure 3.2.0: Fixed positive voltage regulator circuit.

Once the circuit was assembled, we measure the voltage in the resistor R_L, and the results were registered in the tables bellow.

Observation: *For measure the voltage in R_L it's necessary to connect a voltmeter in parallel with the resistor.*

(i) ***First Circuit, IC used: 7805:***

Source Voltage	Voltage in R_L
3.0 V	1.3 V
4.0 V	2.4 V
5.0 V	3.3 V
6.0 V	4.3 V
7.0 V	5.0 V
8.0 V	5.0 V
9.0 V	5.0 V
10.0 V	5.0 V
11.0 V	5.0 V
12.0 V	5.0 V
13.0 V	5.0 V
14.0 V	5.0 V
15.0 V	5.0 V
16.0 V	5.0 V

(ii) ***Second Circuit, IC used: 7812:***

Source Voltage	Voltage in R_L
3.0 V	1.6 V
4.0 V	2.5 V
5.0 V	3.5 V
6.0 V	4.4 V
7.0 V	5.4 V
8.0 V	6.4 V
9.0 V	7.4 V
10.0 V	8.4 V
11.0 V	9.4 V
12.0 V	10.3 V
13.0 V	11.3 V
14.0 V	11.9 V
15.0 V	11.9 V
16.0 V	11.9 V

3.3 Fixed Negative Voltage Regulator:

Following the previous procedure, in this section we analyze two ***Fixed Negative Voltage Regulators***. The IC series that we use were the ***79XX***, specifying, the IC ***7905*** and the ***7912***. Following the Figure 3.3.0, we assembled 2 very similar circuits but switching between this two IC, in each circuit we connected a voltage source in V_{in} varying it from 3.0 to 16 V in intervals of 1 V:

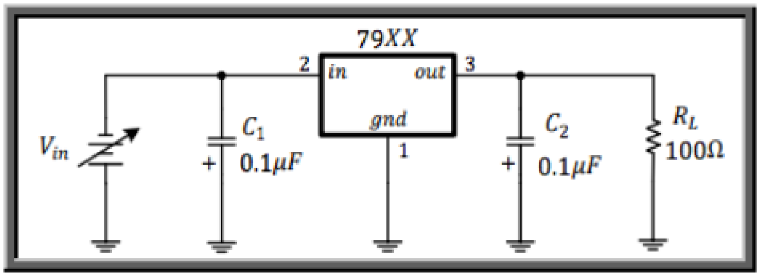

Figure 3.3.0: Fixed negative voltage regulator circuit.

Once the circuit was assembled, we measure the voltage in the resistor R_L, and the results were registered in the tables bellow.

Observation: *For measure the voltage in R_L it's necessary to connect a voltmeter in parallel with the resistor.*

(i) ***First Circuit, IC used: 7905:***

Source Voltage	Voltage in R_L
3.0 V	-0.56 V
4.0 V	-2.3 V
5.0 V	-4.2 V
6.0 V	-4.9 V
7.0 V	-4.9 V
8.0 V	-4.9 V
9.0 V	-4.9 V
10.0 V	-4.9 V
11.0 V	-4.9 V
12.0 V	-4.9 V
13.0 V	-4.9 V
14.0 V	-4.9 V
15.0 V	-4.9 V
16.0 V	-4.9 V

(ii) ***Second Circuit, IC used: 7912:***

Source Voltage	Voltage in R_L
3.0 V	-1.4 V
4.0 V	-3.3 V
5.0 V	-4.2 V
6.0 V	-5.3 V
7.0 V	-6.2 V
8.0 V	-7.2 V
9.0 V	-8.2 V
10.0 V	-9.2 V
11.0 V	-10.2 V
12.0 V	-11.2 V
13.0 V	-11.9 V
14.0 V	-11.9 V
15.0 V	-11.9 V
16.0 V	-11.9 V

3.4 Adjustable Positive Voltage Regulator:

In this section we analyze a ***Adjustable Positive Voltage Regulator***. The IC that we use was the ***LM317***. Following the Figure 3.4.0, we assembled the circuit, and this time, we used a fixed voltage source $V_{in} = 20$ V. What we are going to adjust it's the resistor R_2, this resistor it's a potentiometer of 10kΩ max:

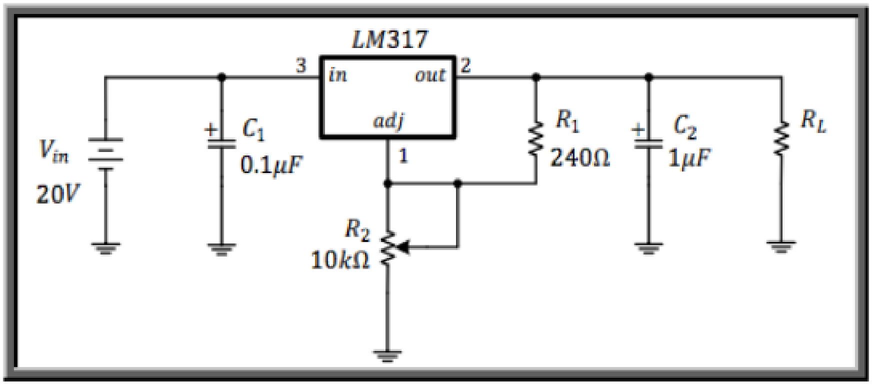

Figure 3.4.0: Adjustable positive voltage regulator circuit.

Once the circuit were assembled, we put the potentiometer in his minimum and maximum resistance, and measure the voltage in the resistor R_L in each case, $V_{0_{min}}$ and $V_{0_{max}}$ respectively:

Observation: *For measure the voltage in R_L it's necessary to connect a voltmeter in parallel with the resistor.*

$$V_{0_{max}} = 18.2V \tag{2}$$
$$V_{0_{min}} = 1.2V \tag{3}$$

3.5 Adjustable Negative Voltage Regulator:

In this section we analyze a ***Adjustable Negative Voltage Regulator***. The IC that we use was the ***LM337***. Following the Figure 3.5.0, we assembled the circuit, and this time, we used a fixed voltage source $V_{in} = 20$ V. What we are going to adjust it's the resistor R_2, this resistor it's a potentiometer of 10kΩ max:

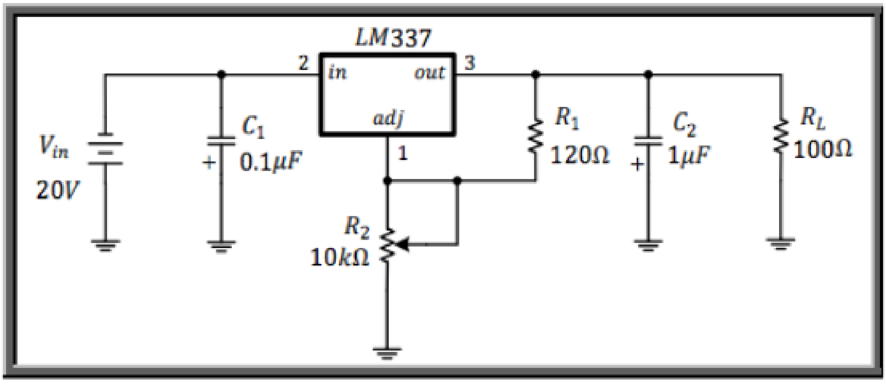

Figure 3.5.0: Adjustable negative voltage regulator circuit.

Once the circuit were assembled, we put the potentiometer in his minimum and maximum resistance, and measure the voltage in the resistor R_L in each case, $V_{0_{min}}$ and $V_{0_{max}}$ respectively:

Observation: *For measure the voltage in R_L it's necessary to connect a voltmeter in parallel with the resistor.*

$$V_{0_{max}} = -18.2V \tag{4}$$
$$V_{0_{min}} = -1.3V \tag{5}$$

4 Simulations:

For each circuit that we have analyze in the section 3, we simulate each one of them, and we proceeded to make a table with all the simulated results. As well, we made a comparative between the simulated values and the previously obtained.

4.1 Zener Diode:

(i) ***First circuit:***

1. Zener Diode: 3.3 V
2. R_L resistor: 33 Ω.
3. R_{lim} resistor: 82 Ω.

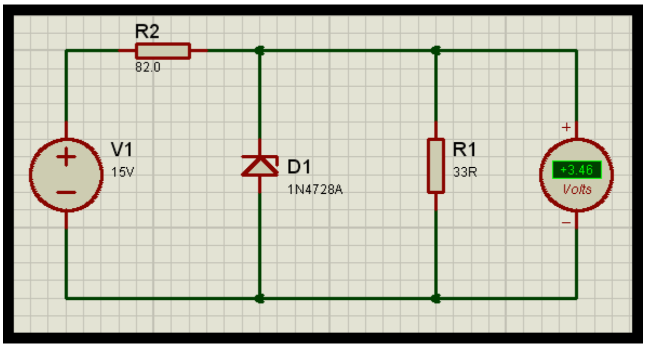

Figure 4.1.0: 3.3 V Zener diode simulation.

Source Voltage	Voltage in R_L
3.0 V	0.86 V
4.0 V	1.15 V
5.0 V	1.43 V
6.0 V	1.72 V
7.0 V	2.01 V
8.0 V	2.30 V
9.0 V	2.58 V
10.0 V	2.87 V
11.0 V	3.15 V
12.0 V	3.27 V
13.0 V	3.34 V
14.0 V	3.40 V
15.0 V	3.46 V

(ii) ***Second circuit:***

1. Zener Diode: 5.1 V
2. R_L resistor: 49 Ω.
3. R_{lim} resistor: 56 Ω.

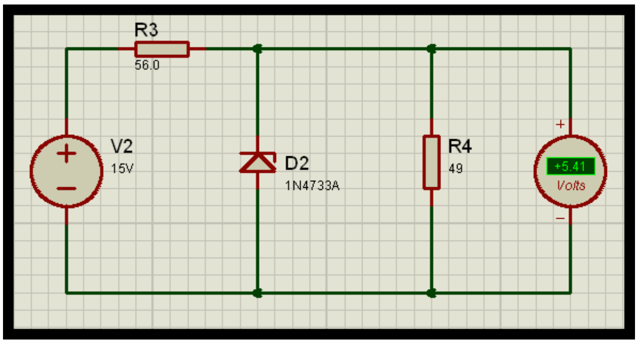

Figure 4.1.1: 5.1 V Zener diode simulation.

Source Voltage	Voltage in R_L
3.0 V	1.40 V
4.0 V	1.87 V
5.0 V	2.33 V
6.0 V	2.80 V
7.0 V	3.27 V
8.0 V	3.73 V
9.0 V	4.20 V
10.0 V	4.63 V
11.0 V	5.03 V
12.0 V	5.16 V
13.0 V	5.25 V
14.0 V	5.33 V
15.0 V	5.41 V

(i) ***Third circuit:***

1. Zener Diode: 9.1 V
2. R_L resistor: 82 Ω.
3. R_{lim} resistor: 27 Ω.

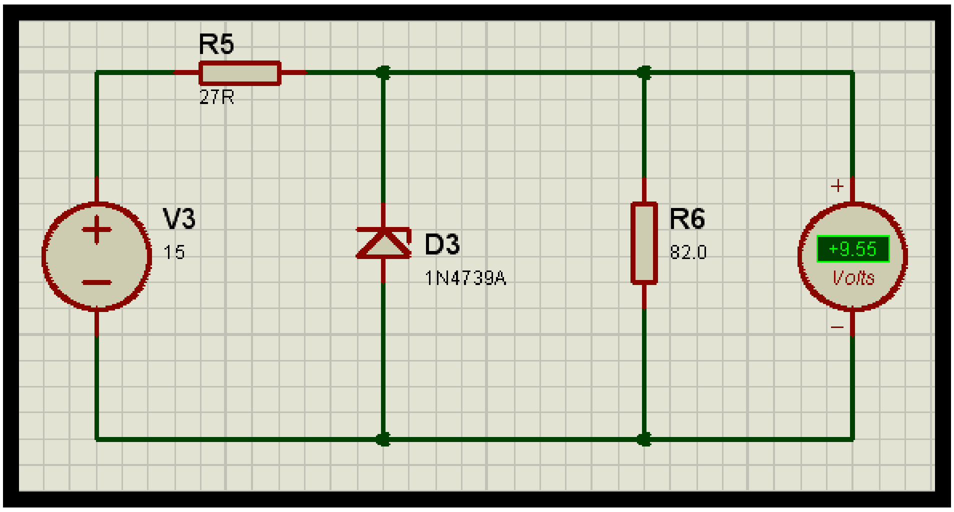

Figure 4.1.2: 9.1 V Zener diode simulation.

Source Voltage	Voltage in R_L
3.0 V	2.26 V
4.0 V	3.01 V
5.0 V	3.76 V
6.0 V	4.51 V
7.0 V	5.27 V
8.0 V	6.02 V
9.0 V	6.77 V
10.0 V	7.52 V
11.0 V	8.28 V
12.0 V	9.01 V
13.0 V	9.23 V
14.0 V	9.40 V
15.0 V	9.55 V

4.2 Fixed Positive Voltage Regulator:

(i) ***First Circuit, IC used: 7805:***

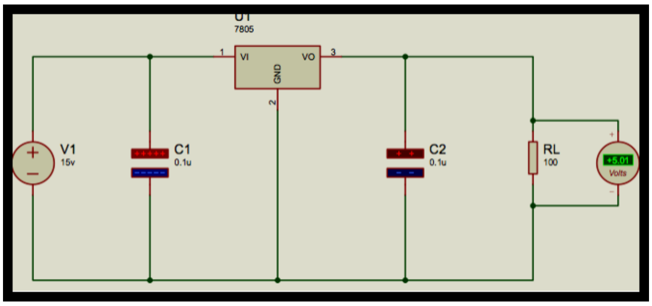

Figure 4.2.0: LM7805 - Fixed Positive voltage regulator circuit.

Source Voltage	Voltage in R_L
3.0 V	1.72 V
4.0 V	2.70 V
5.0 V	3.60 V
6.0 V	4.67 V
7.0 V	5.0 V
8.0 V	5.0 V
9.0 V	5.0 V
10.0 V	5.0 V
11.0 V	5.0 V
12.0 V	5.0 V
13.0 V	5.0 V
14.0 V	5.0 V
15.0 V	5.0 V
16.0 V	5.0 V

(ii) ***Second Circuit, IC used: 7812:***

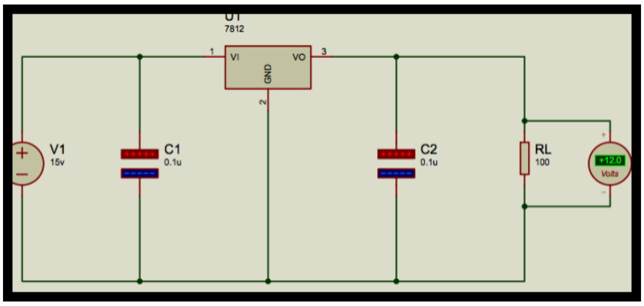

Figure 4.2.1: LM7812 - Fixed Positive voltage regulator circuit.

Source Voltage	Voltage in R_L
3.0 V	1.72 V
4.0 V	2.70 V
5.0 V	3.69 V
6.0 V	4.67 V
7.0 V	5.66 V
8.0 V	6.65 V
9.0 V	7.64 V
10.0 V	8.64 V
11.0 V	9.63 V
12.0 V	10.6 V
13.0 V	11.6 V
14.0 V	12.0 V
15.0 V	12.0 V
16.0 V	12.0 V

4.3 Fixed Negative Voltage Regulator:

(i) ***First Circuit, IC used: 7905:***

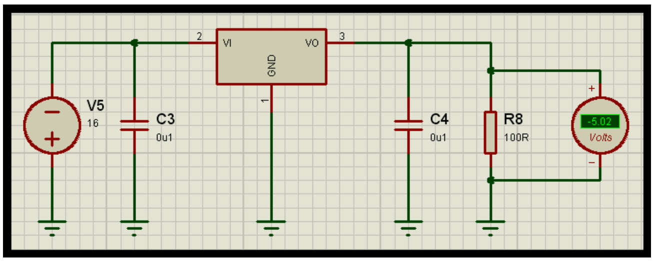

Figure 4.3.0: LM7905 - Fixed negative voltage regulator circuit.

Source Voltage	Voltage in R_L
3.0 V	-2.23 V
4.0 V	-3.21 V
5.0 V	-4.20 V
6.0 V	-5.02 V
7.0 V	-5.02 V
8.0 V	-5.02 V
9.0 V	-5.02 V
10.0 V	-5.02 V
11.0 V	-5.02 V
12.0 V	-5.02 V
13.0 V	-5.02 V
14.0 V	-5.02 V
15.0 V	-5.02 V
16.0 V	-5.02 V

(ii) ***Second Circuit, IC used: 7912:***

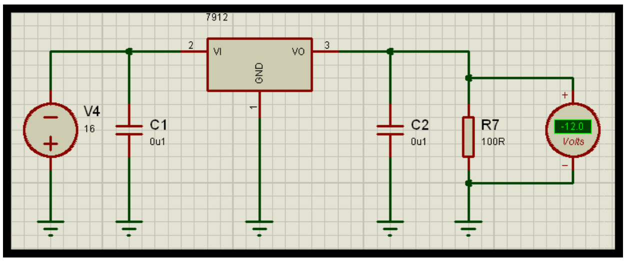

Figure 4.3.1: LM7912 - Fixed negative voltage regulator circuit.

Source Voltage	Voltage in R_L
3.0 V	-2.23 V
4.0 V	-3.21 V
5.0 V	-4.20 V
6.0 V	-5.19 V
7.0 V	-6.17 V
8.0 V	-7.16 V
9.0 V	-8.15 V
10.0 V	-9.14 V
11.0 V	-10.1 V
12.0 V	-11.1 V
13.0 V	-12.0 V
14.0 V	-12.0 V
15.0 V	-12.0 V
16.0 V	-12.0 V

4.4 Adjustable Positive Voltage Regulator:

(i) LM317 circuit with variable resistor in his lower value:

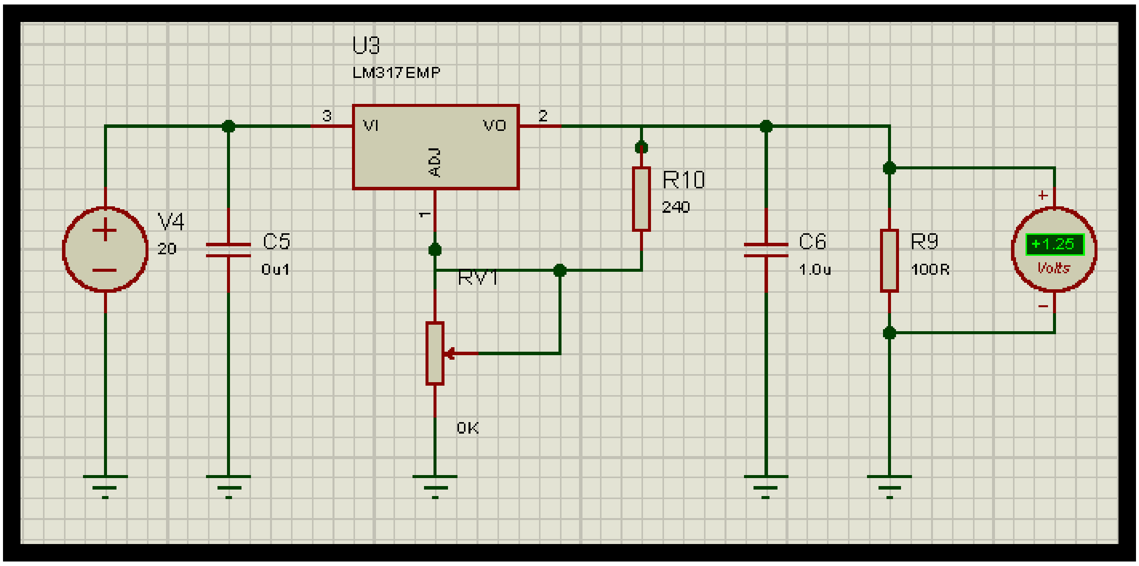

Figure 4.4.0: 0K resistor in adjustable positive voltage regulator circuit.

$$V_{0_{min}} = 1.25V \tag{6}$$

(ii) LM317 circuit with variable resistor in his maximum value:

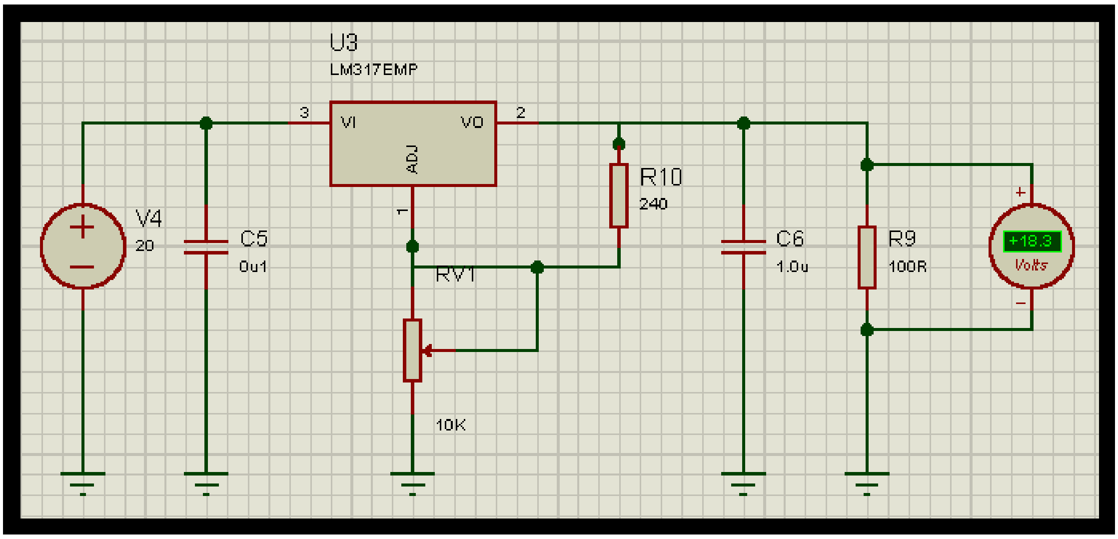

Figure 4.4.1: 10K resistor in adjustable positive voltage regulator circuit.

$$V_{0_{max}} = 18.3V \tag{7}$$

4.5 Adjustable Negative Voltage Regulator:

(i) LM337 circuit with variable resistor in his lower value:

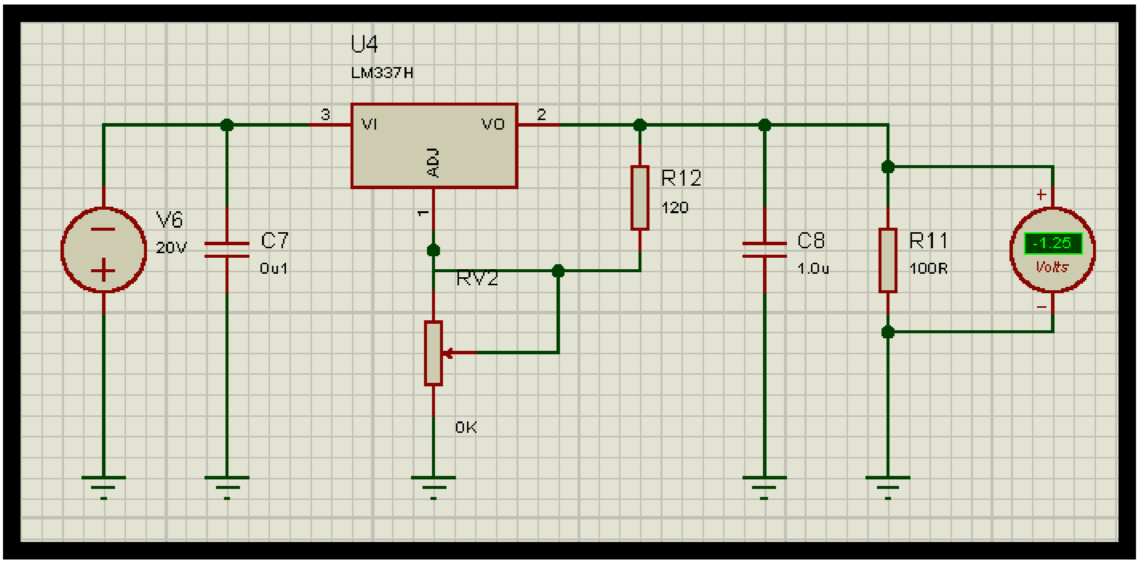

Figure 4.5.0: 0K resistor in adjustable negative voltage regulator circuit.

$$V_{0_{min}} = -1.25V \tag{8}$$

(ii) LM337 circuit with variable resistor in his maximum value:

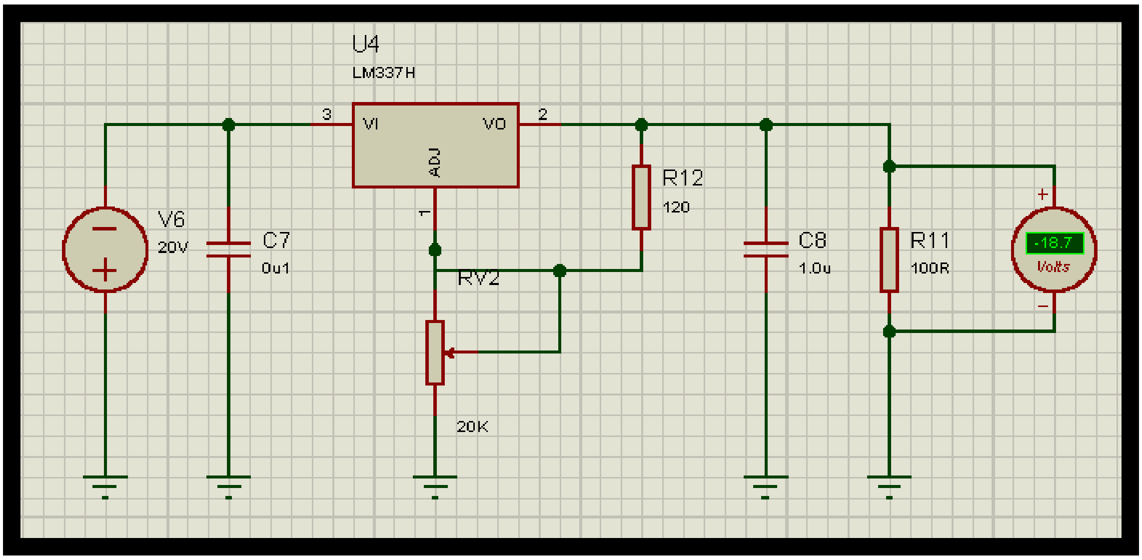

Figure 4.5.1: 10K resistor in adjustable negative voltage regulator circuit.

$$V_{0_{max}} = -18.7V \tag{9}$$

5 Comparisons:

In this section we will compare our simulated results with the ones obtained in the section 3.

5.1 Zener Diode:

(i) ***First circuit:***

1. Zener Diode: 3.3 V
2. R_L resistor: 33 Ω.
3. R_{lim} resistor: 82 Ω.

1. Development values:

Source Voltage	Voltage in R_L
3.0 V	0.85 V
4.0 V	1.13 V
5.0 V	1.42 V
6.0 V	1.69 V
7.0 V	1.96 V
8.0 V	2.23 V
9.0 V	2.48 V
10.0 V	2.71 V
11.0 V	2.90 V
12.0 V	3.0 V
13.0 V	3.2 V
14.0 V	3.3 V
15.0 V	3.3 V

2. Simulated values:

Source Voltage	Voltage in R_L
3.0 V	0.86 V
4.0 V	1.15 V
5.0 V	1.43 V
6.0 V	1.72 V
7.0 V	2.01 V
8.0 V	2.30 V
9.0 V	2.58 V
10.0 V	2.87 V
11.0 V	3.15 V
12.0 V	3.27 V
13.0 V	3.34 V
14.0 V	3.40 V
15.0 V	3.46 V

(ii) ***Second circuit:***

1. Zener Diode: 5.1 V
2. R_L resistor: 49 Ω.
3. R_{lim} resistor: 56 Ω.

1. Development values:

Source Voltage	Voltage in R_L
3.0 V	1.3 V
4.0 V	1.8 V
5.0 V	2.2 V
6.0 V	2.6 V
7.0 V	3.1 V
8.0 V	3.5 V
9.0 V	4.0 V
10.0 V	4.4 V
11.0 V	4.9 V
12.0 V	5.1 V
13.0 V	5.2 V
14.0 V	5.2 V
15.0 V	5.3 V

2. Simulated values:

Source Voltage	Voltage in R_L
3.0 V	1.40 V
4.0 V	1.87 V
5.0 V	2.33 V
6.0 V	2.80 V
7.0 V	3.27 V
8.0 V	3.73 V
9.0 V	4.20 V
10.0 V	4.63 V
11.0 V	5.03 V
12.0 V	5.16 V
13.0 V	5.25 V
14.0 V	5.33 V
15.0 V	5.41 V

(iii) ***Third circuit:***

1. Zener Diode: 9.1 V
2. R_L resistor: 82 Ω.
3. R_{lim} resistor: 27 Ω.

1. Development values:

Source Voltage	Voltage in R_L
3.0 V	2.2 V
4.0 V	2.9 V
5.0 V	3.7 V
6.0 V	4.5 V
7.0 V	5.3 V
8.0 V	6.0 V
9.0 V	6.7 V
10.0 V	7.4 V
11.0 V	8.1 V
12.0 V	8.7 V
13.0 V	9.0 V
14.0 V	9.2 V
15.0 V	9.3 V

2. Simulated values:

Source Voltage	Voltage in R_L
3.0 V	2.26 V
4.0 V	3.01 V
5.0 V	3.76 V
6.0 V	4.51 V
7.0 V	5.27 V
8.0 V	6.02 V
9.0 V	6.77 V
10.0 V	7.52 V
11.0 V	8.28 V
12.0 V	9.01 V
13.0 V	9.23 V
14.0 V	9.40 V
15.0 V	9.55 V

5.2 Fixed Positive Voltage Regulator:

(i) ***IC used: 7805:***

1. Development values:

Source Voltage	Voltage in R_L
3.0 V	1.3 V
4.0 V	2.4 V
5.0 V	3.3 V
6.0 V	4.3 V
7.0 V	5.0 V
8.0 V	5.0 V
9.0 V	5.0 V
10.0 V	5.0 V
11.0 V	5.0 V
12.0 V	5.0 V
13.0 V	5.0 V
14.0 V	5.0 V
15.0 V	5.0 V
16.0 V	5.0 V

2. Simulated values:

Source Voltage	Voltage in R_L
3.0 V	1.72 V
4.0 V	2.70 V
5.0 V	3.60 V
6.0 V	4.67 V
7.0 V	5.0 V
8.0 V	5.0 V
9.0 V	5.0 V
10.0 V	5.0 V
11.0 V	5.0 V
12.0 V	5.0 V
13.0 V	5.0 V
14.0 V	5.0 V
15.0 V	5.0 V
16.0 V	5.0 V

(ii) ***IC used: 7812:***

1. Development values:

Source Voltage	Voltage in R_L
3.0 V	1.6 V
4.0 V	2.5 V
5.0 V	3.5 V
6.0 V	4.4 V
7.0 V	5.4 V
8.0 V	6.4 V
9.0 V	7.4 V
10.0 V	8.4 V
11.0 V	9.4 V
12.0 V	10.3 V
13.0 V	11.3 V
14.0 V	11.9 V
15.0 V	11.9 V
16.0 V	11.9 V

2. Simulated values:

Source Voltage	Voltage in R_L
3.0 V	1.72 V
4.0 V	2.70 V
5.0 V	3.69 V
6.0 V	4.67 V
7.0 V	5.66 V
8.0 V	6.65 V
9.0 V	7.64 V
10.0 V	8.64 V
11.0 V	9.63 V
12.0 V	10.6 V
13.0 V	11.6 V
14.0 V	12.0 V
15.0 V	12.0 V
16.0 V	12.0 V

5.3 Fixed Negative Voltage Regulator:

(i) ***IC used: 7905:***

1. Development values:

Source Voltage	Voltage in R_L
3.0 V	-0.56 V
4.0 V	-2.3 V
5.0 V	-4.2 V
6.0 V	-4.9 V
7.0 V	-4.9 V
8.0 V	-4.9 V
9.0 V	-4.9 V
10.0 V	-4.9 V
11.0 V	-4.9 V
12.0 V	-4.9 V
13.0 V	-4.9 V
14.0 V	-4.9 V
15.0 V	-4.9 V
16.0 V	-4.9 V

2. Simulated values:

Source Voltage	Voltage in R_L
3.0 V	-2.23 V
4.0 V	-3.21 V
5.0 V	-4.20 V
6.0 V	-5.02 V
7.0 V	-5.02 V
8.0 V	-5.02 V
9.0 V	-5.02 V
10.0 V	-5.02 V
11.0 V	-5.02 V
12.0 V	-5.02 V
13.0 V	-5.02 V
14.0 V	-5.02 V
15.0 V	-5.02 V
16.0 V	-5.02 V

(ii) ***IC used: 7912:***

1. Development values:

Source Voltage	Voltage in R_L
3.0 V	-1.4 V
4.0 V	-3.3 V
5.0 V	-4.2 V
6.0 V	-5.3 V
7.0 V	-6.2 V
8.0 V	-7.2 V
9.0 V	-8.2 V
10.0 V	-9.2 V
11.0 V	-10.2 V
12.0 V	-11.2 V
13.0 V	-11.9 V
14.0 V	-11.9 V
15.0 V	-11.9 V
16.0 V	-11.9 V

2. Simulated values:

Source Voltage	Voltage in R_L
3.0 V	-2.23 V
4.0 V	-3.21 V
5.0 V	-4.20 V
6.0 V	-5.19 V
7.0 V	-6.17 V
8.0 V	-7.16 V
9.0 V	-8.15 V
10.0 V	-9.14 V
11.0 V	-10.1 V
12.0 V	-11.1 V
13.0 V	-12.0 V
14.0 V	-12.0 V
15.0 V	-12.0 V
16.0 V	-12.0 V

5.4 Adjustable Positive Voltage Regulator:

(i) Development values:

$$V_{0_{max}} = 18.2V \tag{10}$$
$$V_{0_{min}} = 1.2V \tag{11}$$

(ii) Simulated values:

$$V_{0_{max}} = 18.3V \tag{12}$$
$$V_{0_{min}} = 1.25V \tag{13}$$

5.5 Adjustable Negative Voltage Regulator:

(i) Development values:

$$V_{0_{max}} = -18.2V \tag{14}$$
$$V_{0_{min}} = -1.3V \tag{15}$$

(ii) Simulated values:

$$V_{0_{max}} = -18.7V \tag{16}$$
$$V_{0_{min}} = -1.25V \tag{17}$$

6 Questionnaire:

- ***Mention the principle of operation of the zener diode?***

  Zener diodes are diodes that are designed to maintain a constant voltage at their terminals, called Voltage or Zener Voltage (Vz) when reverse polarized, ie when the cathode is with a positive voltage and the negative anode A zener diode in connection with the reverse polarization always has the same voltage at the ends (zener voltage).

- ***What happens to a zener if the voltage of the source is less than its voltage?***

  The diode does not conduct voltage, we will only have the constant voltage Vz, when connected to a voltage equal to Vz or greater.

- ***What is the purpose of a voltage regulator?***

  A voltage regulator is an electronic device designed to maintain a constant voltage level.

- ***What output voltage do you have on a 5 volt fixed voltage regulator if the input voltage is 5 volts?***

  0 volts.

- ***Why in the variable voltage regulators the minimum is 1.2 V?***

  It is due to the barrier voltages of some internal semiconductor regulators that are between the "output" pin and the "adjust" pin.

7 Conclusions:

The voltage regulators have a multiple functions in the industry as in our daily life, a lot of devices that we use every day, internally could implement one of the methods of regulation that we have analyze in this practice, this, with the purpose of protect our devices. In general, it was a interesting thing to visualize the functionality of the zener diode, because in class it's a bit difficult to figure or imagine whats the zener knee and why the voltage in this region act like it was fixed. As and alternative, if we don't want to use a zener diode, we have a IC series that regulate voltage, in this practice we use the LM7805 and LM7812 for positive fixed regulations, as well the LM7905 and LM7912 as negative fixed regulation.

8 Bibliographic References:

[1] BOYLESTAD, Robert L. "Electronic Devices and Circuit Theory". Edit. Prentice Hall. 2009.