BIRZEIT UNIVERSITY

Faculty Of Engineering and Technology

Electrical and Computer Engineering Department

CIRCUITS AND ELECTRONICS LABORATORY

ENEE 2103

Experiment #: 11

Zener Diodes and Voltage Regulators

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1.Abstract

The aim of this experiment is to construct the I.V characteristic of Zener diode, and to demonstrate the use of Zener diode as voltage regulator, also to examine the operation of voltage regulator. There are many tools used in this experiment and these tools are resistors, Zener diodes, dc input voltage, BJT transistors, operational amplifiers, Digital multi meter(DMM), three terminal fixed voltage regulator(7805), and the LM317 adjustable voltage regulator.

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2.Theory

2.1. Zener Diode

Zener diodes are silicone-based discrete semiconductor devices which allow current to flow bidirectionally - either reverse or forward. Diodes are comprised of a heavily-doped P-N silicone junction.

Zener diodes have a set reverse breakdown voltage. When this is reached, they start to conduct current and continue to operate unceasingly in the reverse bias direction without incurring damage. One of the main benefits of Zener diodes is that a varying range of voltages will still maintain a constant voltage drop across the diode. As a result, Zener diodes can be used for voltage regulation applications.[1]

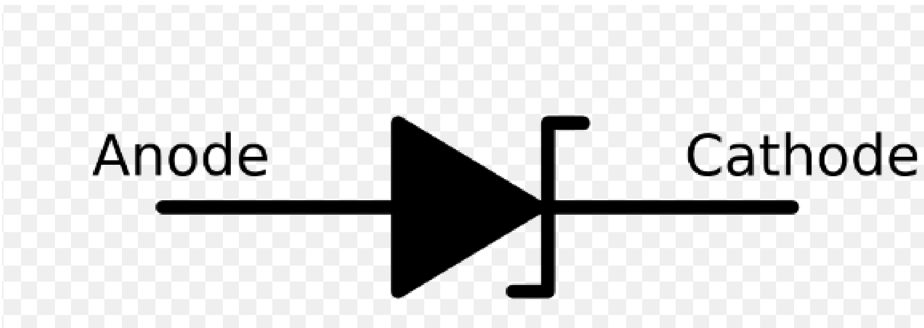


Figure 2.1: Zener diode symbol

2.2. Zener Diode Applications

Zener diodes are used for a range of applications, including:

1)Voltage regulation.

2)Voltage reference.

3)Surge suppression.

4)Switching applications.

5)Clipper circuits. [1]

2.3. How Does a Voltage Regulator Work

A voltage regulator is a circuit that creates and maintains a fixed output voltage, irrespective of changes to the input voltage or load conditions.

Voltage regulators (VRs) keep the voltages from a power supply within a range that is compatible with the other electrical components. While voltage regulators are most commonly used for DC/DC power conversion, some can perform AC/AC or AC/DC power conversion as well. This article will focus on DC/DC voltage regulators.[2]

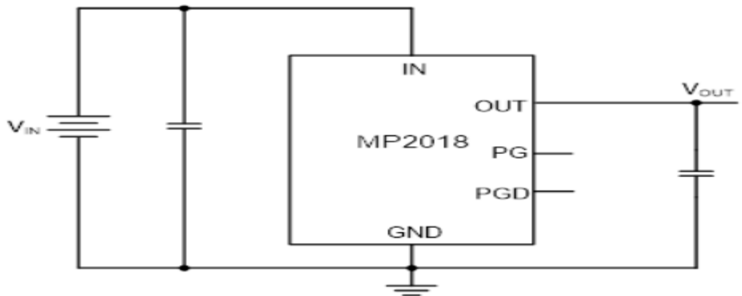


Figure 2.2: linear regulator

2.4. A Regulated Power Supply

Regulated power supplies have voltage regulators on their output. This means that the regulator ensures the output voltage will always stay at the rated value of the power supply, regardless of the current that the device is consuming. Any change in the input voltage will not affect the output voltage because of the regulators.

This works as long as the device is not drawing more than the rated output current of the power supply. In fancy electrical terms, a regulated power supply provides a constant output voltage, independent of the output current. A regulated power supply with multiple regulators can offer multiple output voltages for operating different devices. Regulated power supplies maintain the voltage at the desired level and are ideal for almost all types of electronic devices because of the steady supply of voltage they offer.[3]

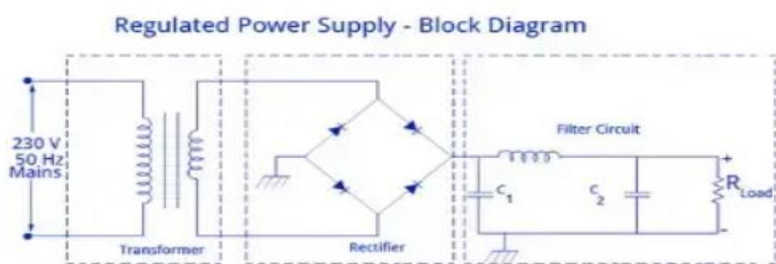


Figure 2.3: regulated power supply

2.5. 7805 Voltage Regulator

7805 is a three terminal linear voltage regulator IC with a fixed output voltage of 5V which is useful in a wide range of applications. Currently, the 7805 Voltage Regulator IC is manufactured by Texas Instruments, ON Semiconductor, Diodes incorporated, Infineon Technologies.

Some of the important features of the 7805 IC are as follows:

- It can deliver up to 1.5 A of current (with heat sink).
- Has both internal current limiting and thermal shutdown features.
- Requires very minimum external components to fully function.[4]

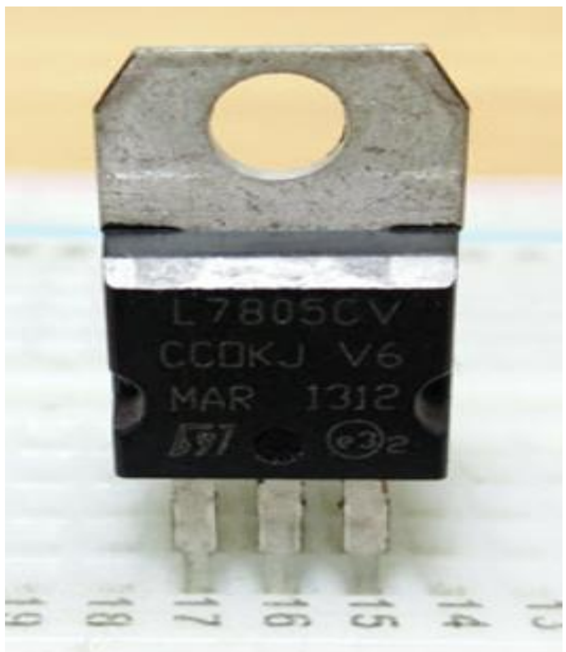


Figure 2.4: 7805 voltage regulator

2.6. the LM317 adjustable voltage regulator

The three terminals are input pin, output pin, and adjustment pin. The LM317 circuit is capable to provide variable DC power supply with an output of 1A and can be adjusted up to 30V. The circuit consists of a low-side resistor and high-side resistor connected in series forming a resistive voltage divider which is a passive linear circuit used to produce an output voltage.

Decoupling capacitors are used for decoupling or to prevent undesired coupling of one part of an electrical circuit from another part. To avoid the effect of noise caused by some circuit elements over the remaining elements of the circuit, the decoupling capacitors in the circuit are used for addressing the input noise and output transients. A heat sink is used with the circuit to avoid the components getting overheated due to more power dissipation.[5]

There are some special features of the LM317 regulator and a few are as follows:

1) It is capable of providing an excess current of 1.5A, hence it is conceptually considered as an operational amplifier with an output voltage ranging from 1.2V to 37V.

2) The LM317 voltage regulator circuit internally consists of thermal overload protection and short circuit current limiting constant with temperature.

3) Stocking many fixed voltages can be eliminated.[5]

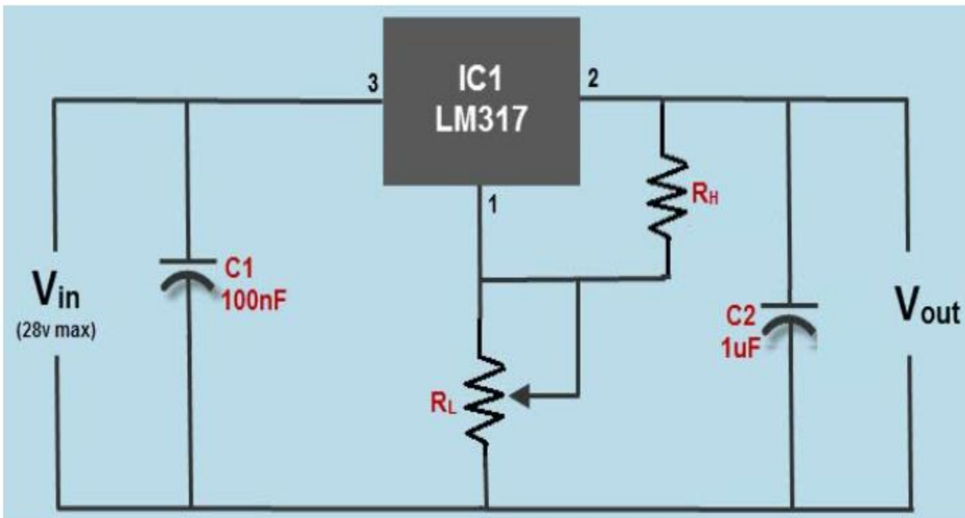


Figure 2.5 : LM317 Voltage Regulator Circuit

3.Procedure & Discussion

3.1. ZENER DIODE

In this part, the circuit was connected as shown in Figure 3.1.1 below, the applied voltage E was set to (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 2, 3, 4, 5, 6)V, then the voltage across the Zener diode was measured as shown in Table1 below.

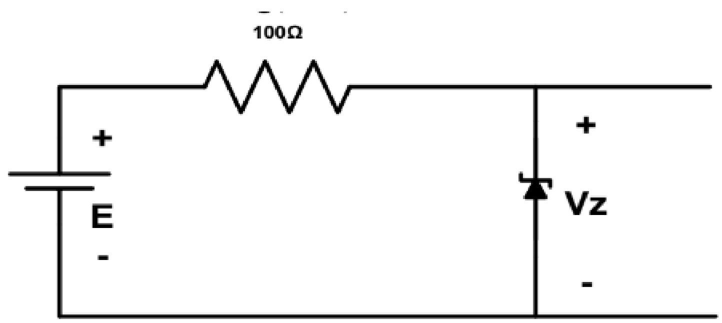
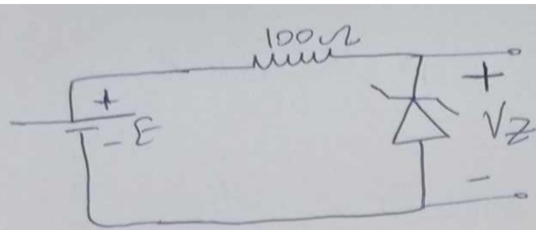


Figure 3.1.1: Zener diode circuit

Set	Measure	Calculate	
E(V)	VZ(V)	VR(V)	I(mA)
0.1	0.1	0	0
0.2	0.2	0	0
0.3	0.27	0.03	0.3
0.4	0.43	0.03	0.3
0.5	0.45	0.05	0.5
0.6	0.57	0.03	0.3
0.7	0.66	0.04	0.4
0.8	0.74	0.06	0.6
0.9	0.89	0.01	0.1
1	0.98	0.02	0.2
2	1.78	0.22	2.2
3	2.48	0.52	5.2
4	2.85	1.15	11.5
5	3.06	1.94	19.4
6	3.19	2.8	28

Table1: values of VZ and VR and I

Calculation:



$-E + V_R + V_Z = 0$

1) when $E = 0,1$ V

$-0,1 + V_R + 0,1 = 0$

$\boxed{V_R = 0} \rightarrow I_R = 0$

2) when $E = 0,2$ V

$-0,2 + V_R + 0,2 = 0 \rightarrow V_R = 0 \rightarrow I = 0$ mA

3) when $E = 0,3$ V

$-0,3 + V_R + 0,27 = 0 \rightarrow V_R = 0,03$ V $\rightarrow I = \frac{0,03}{100} = 0,3$ mA

4) when $E = 0,4$ V

$-0,4 + V_R + 0,43 = 0 \rightarrow V_R = 0,03$ V $\rightarrow I = \frac{0,03}{100} = 0,3$ mA

5) when $E = 0,5$ V

$-0,5 + V_R + 0,45 = 0 \rightarrow V_R = 0,05$ V $\rightarrow I = \frac{0,05}{100} = 0,5$ mA

6) when $E = 0,6$ V

$-0,6 + V_R + 0,57 = 0 \rightarrow V_R = 0,03$ V $\rightarrow I = \frac{0,03}{100} = 03$ mA

7) when $E = 0,7$ V

$-0,7 + V_R + 0,66 = 0 \rightarrow V_R = 0,04$ V $\rightarrow I = \frac{0,04}{100} = 0,4$ mA

8) when $E = 0,8$ V

$-0,8 + V_R + 0,74 = 0 \rightarrow V_R = 0,06$ V $\rightarrow I = 0,6$ mA

9 when $E = 0{,}9\,V$

$-0{,}9 + V_R + 0{,}89 = 0 \rightarrow V_R = 0{,}01\,V \rightarrow I = 0{,}1\,mA$

10 when $E = 1\,V$

$-1 + V_R + 0{,}98 = 0 \rightarrow V_R = 0{,}02\,V \rightarrow I = 0{,}2\,mA$

11 when $E = 2\,V$

$-2 + V_R + 1{,}78 = 0 \rightarrow V_R = 0{,}22\,V \rightarrow I = 2{,}2\,mA$

12 when $E = 3\,V$

$-3 + V_R + 2{,}48 = 0 \rightarrow V_R = 0{,}52\,V \rightarrow I = 5{,}2\,mA$

13 when $E = 4\,V$

$-4 + V_R + 2{,}85 = 0 \rightarrow V_R = 1{,}15\,V \rightarrow I = \frac{1{,}15}{100} = 11{,}5\,mA$

14 when $E = 5\,V$

$-5 + V_R + 3{,}06 = 0 \rightarrow V_R = 1{,}94\,V \rightarrow I = 19{,}4\,mA$

15 when $E = 6\,V$

$-6 + V_R + 3{,}19 = 0 \rightarrow V_R = 2{,}81\,V \rightarrow I = 28\,mA$

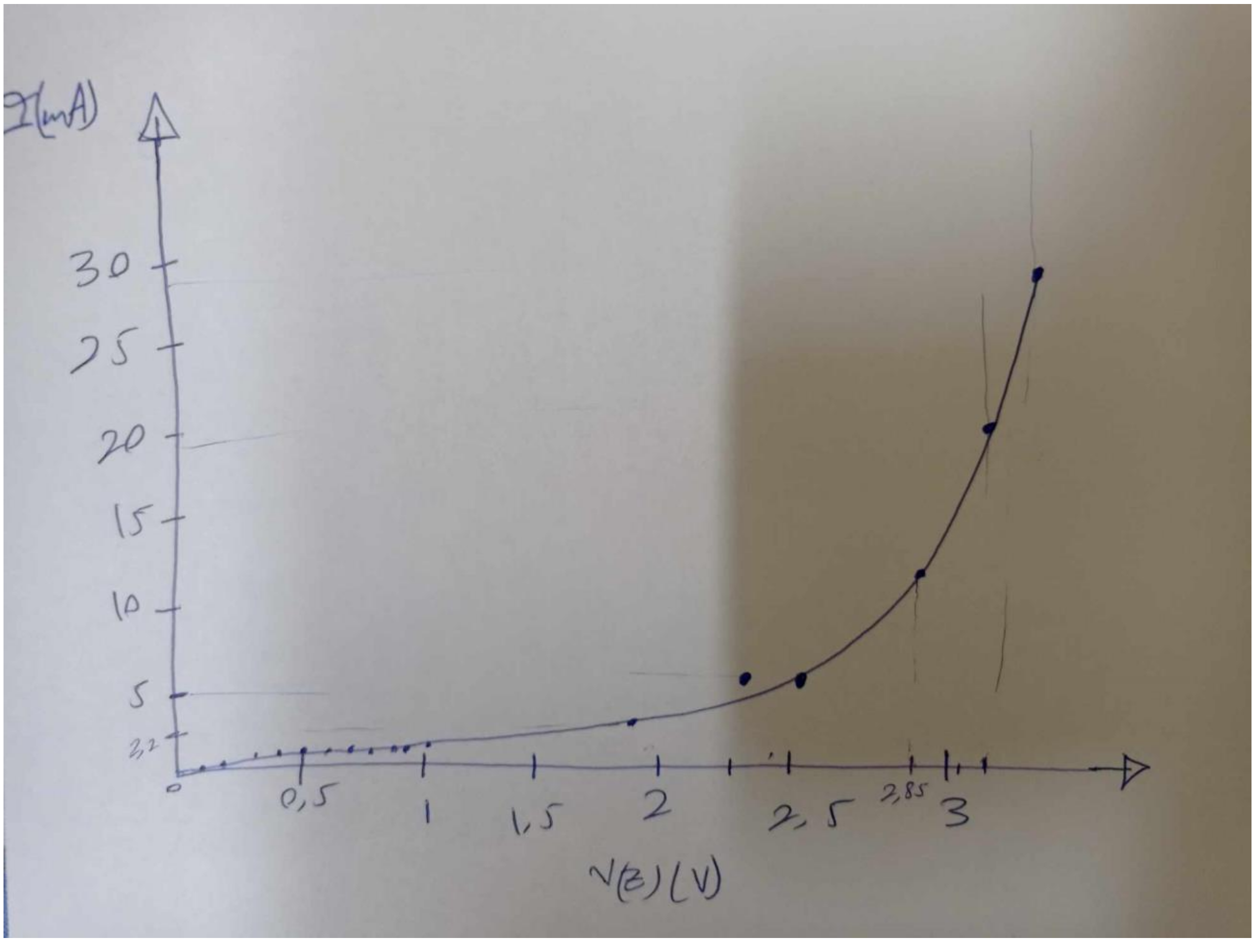


Figure 3.1.2: VZ and I graph

- The current equation I = VE-VZ \ R.

- VR = I * R or VR = VE-VZ.

Note that in forward bias it allows current, and in reverse bias it blocks current.

A Zener diode functions similarly to a regular diode when forward-biased. However, in reverse-biased mode, a small leakage current flows through the diode. As the reverse voltage increases and reaches the breakdown voltage (Vz), current begins to flow through the diode.

This current reaches a maximum level determined by the series resistor, after which it stabilizes and remains constant across a wide range of applied voltages.

After that the circuit was connected as shown in Figure 3.1.3 below by adding RL resistor, and E was set to (10, 11, 12, 13, 14) V, then the load voltage VL was measured as shown in Table2 below.

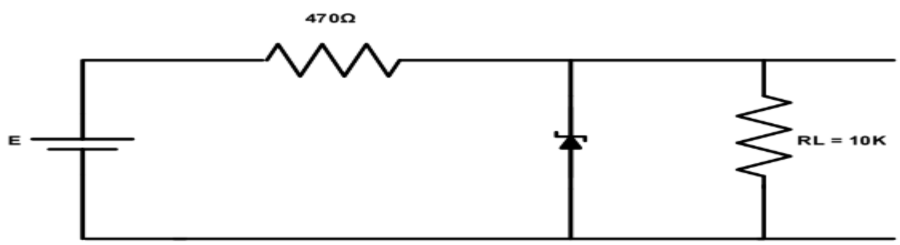


Figure 3.1.3: circuit after adding RL

E	10	11	12	13	14
VL	2.92v	2.97v	3.02v	3.07v	3.11v

Table2: values of VL after adding RL

Note that VL = VZ (both are in parallel).

then E was set to 10v and the load voltage VL was measured for RL= (8.2K,6.8K,4.7K,2.2k), as shown Table3 below.

RL	8.2K	6.8K	4.7K	2.2K
VL	2.92v	2.92v	2.91v	2.88v

Table3: values of VL when E=10v

Note that the zener will conduct the increase of current in I, while the load current remains constant. The output voltage remains constant irrespective of the changes in the input voltage.

- When the input voltage is constant but the load resistance RL decreases. This will cause an increase in load current. The extra current cannot come from the source, because drop in R will not change as the zener is within its regulating range.

3.2.THE VOLTAGE REGULATED POWER SUPPLY

In this part the circuit was connected as shown in Figure 3.2.1 below.

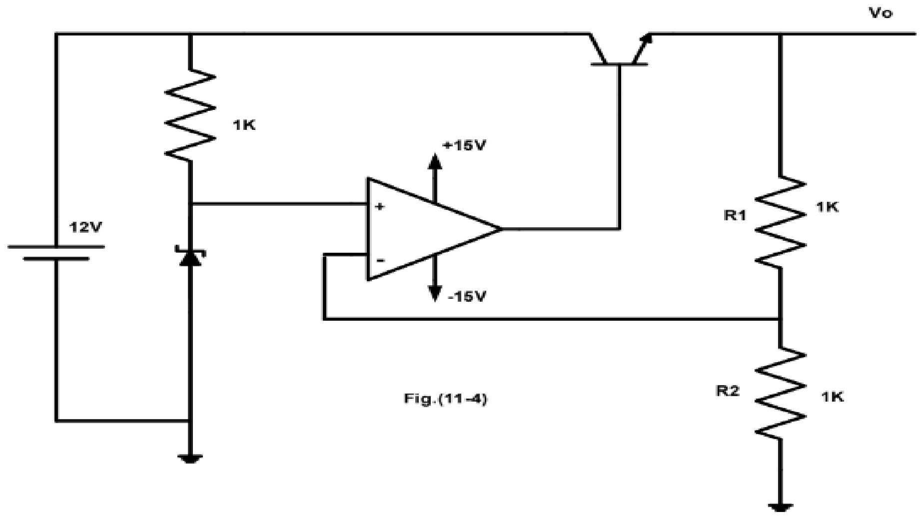


Figure 3.2.1: voltage regulated power supply circuit

Then Vo was measured -> Vo=5.78v

After that a 1K load resistor(RL) was attached to the output, and Io and Vo was measured, then Io and Vo was measured for RL =(680, 470, 220, 100)ohm, as shown in Table4 below.

RL	open	1k	680K	470K	220K	100	50
Vo(v)	5.78	5.79	5.78	5.784	5.7	5.7	5.6
Io(mA)	zero	5.8	8.5	12.3	26.3	57.3	112.6

Table4: values of Vo and Io after adding RL

Note that the main principle of the voltage regulator is a circuit that creates and maintains a fixed output voltage, irrespective of changes to the input voltage or load conditions. As shown in Table4 the voltage remained constant, while the current changes with the change of the resistor RL.

Then RL was set back to 1K, and the value of R2 was changed to 470 ohm then to 2.2K, and the new value of Vo was measured as shown in Table5 below.

RL	R2	Vo
1Kohm	470ohm	8.977v
1Kohm	2.2Kohm	4.19v

Table5: values of Vo when change the value of R2

Note that Vo = Vz * (1 + r1\r2) and R1 is fixed, then changing in R2 effects the output voltage value.

3.3. THREE TERMINAL FIXED VOLTAGE REGULATOR 7805

In this part the circuit was connected as shown in Figure 3.3.1 below.

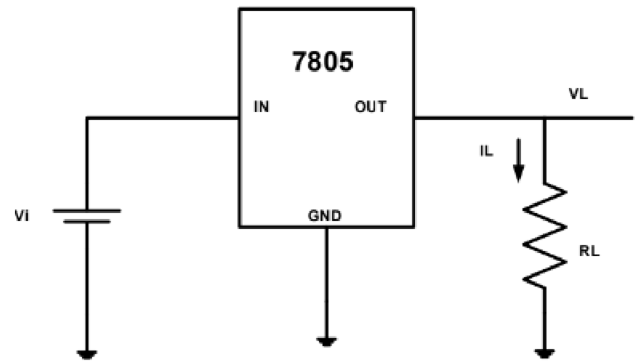


Figure 3.3.1: three terminal fixed voltage regulator circuit

First Vi was set to 10v, then IL and VL was measured for each value of RL listed in Table6.

RL(ohm)	VL(V)	IL(mA)
25	5.01	194
50	5.01	96.6
100	5.01	49.18
200	4.96	24.8
400	4.78	12.5
600	4.57	8.21
800	4.5	6.1
1000	4.51	4.9

Table6: values of VL and IL when RL changes

Note that the load regulation of the 7805 $= \Delta VL / \Delta IL = 5.01-5.01/ 96.6 -194 = 0$

After that RL was set to 100 ohm and Vi was changed as listed in Table7, then VL and IL was measured for each value of Vi.

Vi(V)	VL(V)	IL(Ma)
8	5.01	49.4
9	5.01	49.4
10	5.01	49.4
11	5.01	49.4
12	5.01	49.4
13	5.01	49.3
14	5.01	49.3
15	5.01	49.3

Table7: values of VL and IL when RL=100 ohm

Note that the values of VL and IL still constant and not changed when we changed the Vi and set RL to 100.

Note that the line regulation of the 7805 = ΔVL/ΔVi= 5.01-5.01/ 15-8 = 0

3.4. THE LM317 ADJUSTABLE VOLTAGE REGULATOR

In this part the circuit was connected as shown in Figure 3.4.1 below

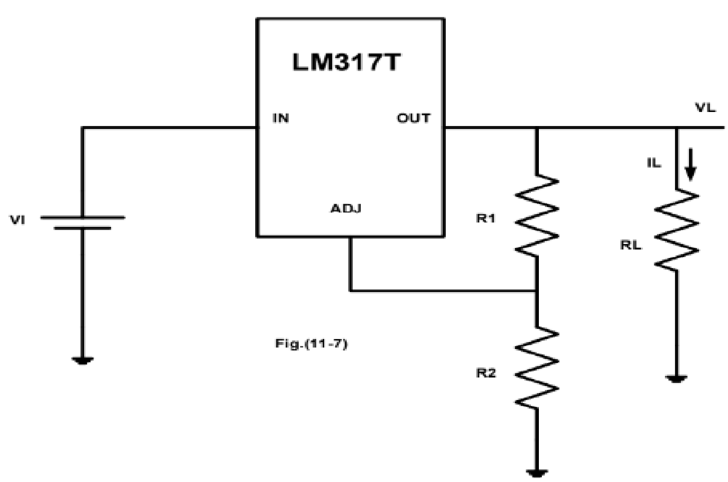


Figure 3.4.1: LM317 adjustable voltage regulator circuit

First Vi was set to 10v, R1 =100 ohm, RL was changed as shown in Table8 below, then VL and IL was measured for each value of R2.

R2(ohm)	VL(V)	IL(mA)
0	1.25	1.538
100	2.53	2.5
200	3.8	3.8
300	5.05	5.02
500	7.04	7.5

Table8: values of VL and IL when Vi= 10v

The output voltage of the LM317T is determined by ratio of the two feedback resistors R1 and R2 which form a potential divider network across the output terminal as shown below.

$Vo = 1.25*(1+(R2/R1))$

Note that increasing the R2 values cause increasing in output voltage.

After that RL was set to 1K, R1=100 ohm, R2=220 ohm, and Vi was changed as shown in Table9

Then VL and IL was measured for each value of Vi.

Vi(V)	VL(V)	IL(mA)
10	4.04	4.01
12	4.04	4.018
14	4.04	4.018
15	4.04	4.019
16	4.04	4.018
17	4.04	4.019

Table9: values of VL and IL when RL =1K

Note that changing the input voltage has no effect on the output voltage.

Line regulation for the LM317 = $\Delta VL/\Delta Vi$=4.04-4.04/17-10 = 0

After that Vi was set to 10v, R1=100 ohm, R2=220 ohm, then VL and IL was measured for each value of RL listed in Table10 below.

RL (ohm)	VL(V)	IL (mA)
100	3.96	39
200	3.9	18.87
400	3.89	9.7
500	3.9	7.8
600	3.908	6.52
700	3.92	5.6
1000	3.93	3.93

Table10: values of VL and IL

Note that the output voltage did not change, that means the load resistor has no effect on the output resistor. However, the output current is changed because IL=VL/RL.

4.Conclusion

In conclusion, after we finished this experiment we became know the use of Zener diode as voltage regulator, and how does the voltage regulator work, and we became know the I-V characteristic of zener diode, also the difference between fixed and adjustable voltage regulator, and the meaning of load and line regulation and what do we mean by them.

5.References

[1] https://uk.rs-online.com/web/content/discovery/ideas-and-advice/zener-diodes-guide

(accessed date 8/28/2023)

[2] https://uk.rs-online.com/web/content/discovery/ideas-and-advice/zener-diodes-guide

(accessed date 8/29/2023)

[3] https://uk.rs-online.com/web/content/discovery/ideas-and-advice/zener-diodes-guide

(accessed date 8/29/2023)

[4] https://uk.rs-online.com/web/content/discovery/ideas-and-advice/zener-diodes-guide

(accessed date 8/30/2023)

[5] https://uk.rs-online.com/web/content/discovery/ideas-and-advice/zener-diodes-guide

(accessed date 8/30/2023)

6.Appendices

Experiment #11 **ENEE2103**

Zener Diodes and Voltage Regulators

Objectives:

1. To construct the I.V characteristic of a zener diode.
2. To demonstrate the use of zener diode as voltage regulator.
3. To examine the operation of the voltage regulator.

Pre-lab Work:

You have to apply PSPICE simulation to all practical circuits shown in the procedure below, and you have to do all necessary calculation you will need in the lab.

Procedure:

I.ZENER DIODE.

Connect the circuit shown in Fig(11-2).

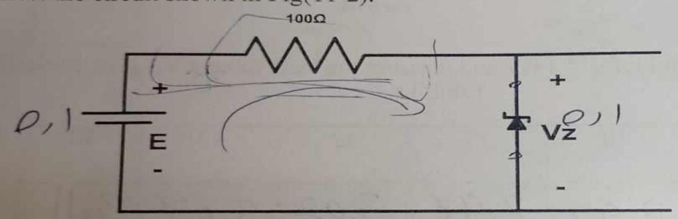


Fig.(11-2)

0

1K A

A K

2318

Set the applied voltage E to (0.1, 0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10,11,12,13,14,15)V.
For each value of E, measure the voltage across the zener diode and calculate the current through the zener diode. **(Fill in Table 11.2)**

Table 11.2

Set	Measure	Calculate	
E(V)	V_Z(V)	V_R(V)	I(m A)
0.1	0,1		
0.2	0,2		
0.3	0,27		
0.4	0,43		
0.5	0,45		
0.6	0,57		
0.7	0,66		
0.8	0,74		
0.9	0,89		
1	0,98		
2	1,78		
3	2,48		
4	2,85		
5	3,06		
6	3,19		

1. Using the results obtained in steps 3 and 6 constitute a graph of the characteristic of the zener diode.
2. Connect the circuit shown in Fig(11-3).

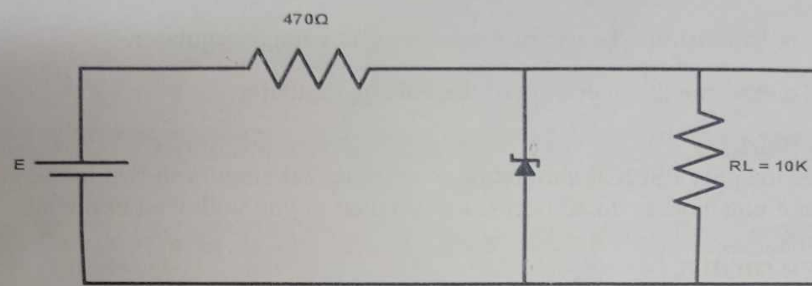


Fig.(11-3)

1. Set E to (10,11,12,13,14)V and measure the load voltage V_L. (Fill Table 11.3)

Table 11.3

E	10	11	12	13	14
V_L	2,92	2,97	3,02	3,07	3,11

3. With E set to 10V measure the load voltage V_L for R_L=(8.2K,6.8K,4.7K,2.2K) and Fill in Table 11.4

Table 11.4

R_L	8.2k	6.8k	4.7 k	2.2k
V_L	2,92	2,92	2,91	2,88

II. THE VOLTAGE REGULATED POWER SUPPLY.

1. connect the circuit of Fig.(11-4).

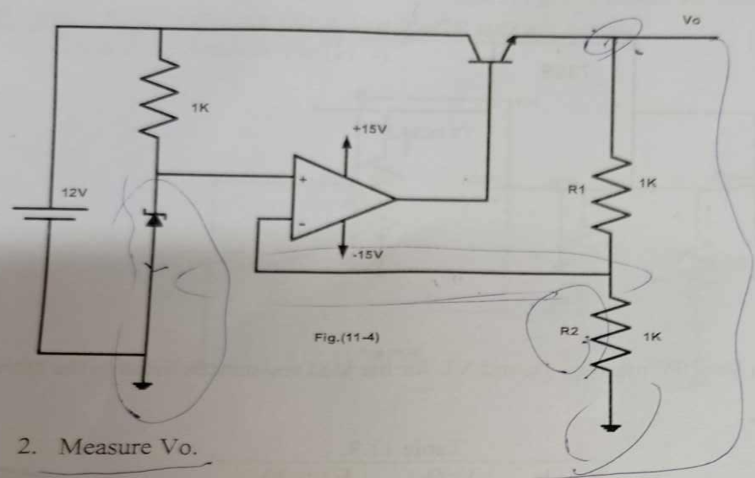


Fig.(11-4)

2. Measure Vo.
3. Attach a 1k load resistor to the output. Measure Io and Vo.
4. Repeat step 3 for load resistance RL = (680 , 470 , 220 , 100) ohm.

Table 11.5

5,78 5,79 5,78 5,784/5,7 5,7 5,6

R_L	open	1kΩ	680 Ω	470 Ω	220 Ω	100 Ω	50Ω
Vo	~~10,56~~	~~5,31~~	~~70mV~~	~~52,8mV~~	~~28mV~~	~~13,6mV~~	~~7mV~~
Io	Zero	~~66,8MA~~	~~72uA~~	~~78uA~~	84uA	~~87,8u~~	89,3uA

5,8 8,5 12,3 26,3 57,3 112,6

5. Set RL back to 1K .Change the value of R2 to 470 ohm . What is the new output voltage.
6. Change R2 to 2.2k. What is the output voltage now

Table 11.6

RL	R2	Vo
1kΩ	470 Ω	~~135,9mV~~ ~~5,73mV~~ 8,977
1kΩ	2.2kΩ	~~127,5mV~~ 4,19

II. THREE TERMINAL FIXED VOLTAGE REGULATOR 7805.

1. Connect the circuit of Fig (11.6).

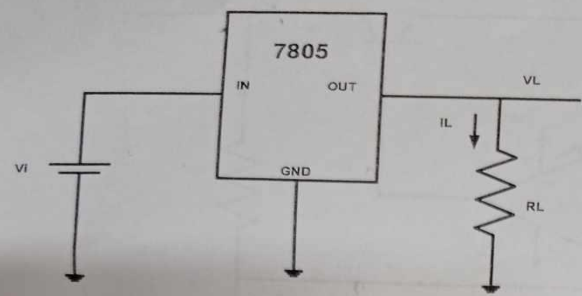


Fig.(11-6)

2. With Vi=10V measure IL and VL for the load resistances listed in the table 11.9.

Table 11.9.

$R_L(\Omega)$	$V_L(V)$	$I_L(mA)$
25	5,01	~~[illegible]~~ 194
50	5,01	96,6
100	5,01	49,18
200	4,96	24,8
400	4,78	~~[illegible]~~ 12,5
600	4,57	8,21
800	4,5	6,1
1000	4,51	4,9

3. Using the results of table 9.2 , determine the load regulation of the 7805.knowing that load regulation = $\Delta V_L / \Delta I_L$

4. Set RL=100 ohm , adjust the input voltage Vi as listed in table 11.10. Measure V_L and I_L for each input voltage in the table.

Table 11.10

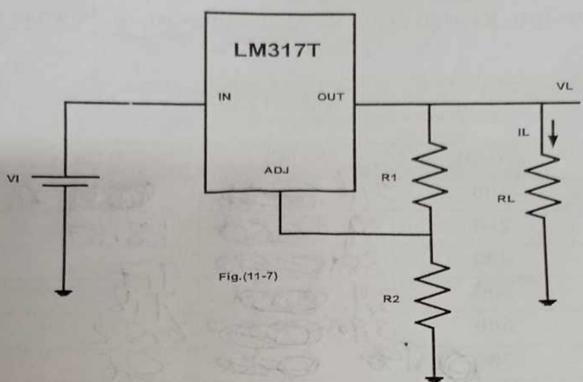
Vi(V)	$V_L(V)$	$I_L(mA)$
8	5,01	49,4
9	5,01	49,4
10	5	49,4
11		
12		
13		
14		
15		

Using the results of table 11.10 , determine the line regulation of the 7805 .

line regulation $= \Delta V_L / \Delta Vi$

III. THE LM317 ADJUSTABLE VOLTAGE REGULATOR.

1. Connect the circuit of Fig.(11.7).



2. With Vi=10V, R1=100Ω, RL=1k , adjust R2 as shown in table 11.11.

Table 11.11

$R_2(\Omega)$	$V_L(V)$	$I_L(mA)$	VL(V)	IL(mA)
0	~~0.01~~	~~12.6~~	1,27	1.538
100	~~1.27~~	~~12.6~~	2,53	2,5
200	~~2.53~~	~~12.6~~	3,8	3,8
300	~~3.8~~	~~12.6~~	5,05	5,02
500 7,	~~6.31~~		7,04	7,5

3. Measure and record VL,IL for each R value.

4. With RL =1k , R1=100 ohm , R2=220 , adjust Vi as listed in table 11.12.

Table 11.12

Vi(V)	$V_L(V)$	$I_L(mA)$
10	4,04	4,01
12	4,0	4,018
14		4,018
15		4,019
16		4,018
17		4,019

5. Measure and record the load voltage and current for each input voltage value.

6. Using your results, calculate the line regulation for the LM317T voltage regulator.

7. With Vi=10V, R1=100 0hm , R2=220 , adjust RL as shown in table 11.13.

Table 11.13

$R_L(\Omega)$	$V_L(V)$	$I_L(mA)$
100	3,96	39.
200	3,9	18.87
400	3,89	9,7
500	3,9.	7,8
600	3,908	6,52
700	3,9	5,6
1000	3,93	3,93

8. Measure and record V_L,I_L for each R_L value.

1k → بني-اسود-احمر-ذهبي

2k → احمر - احمر - احمر - ذهبي

10k → بني-اسود-برتقالي-ذهبي

470Ω → اصفر, بنفسجي, بني - ذهبي