Bilkent University

EEE313 Lab 2 Report

Zener Regulator

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Introduction

Purpose

This lab aims to obtain a voltage regulator using a Zener diode. The 5.1V Zeners in the lab were used. R_L is the load resistor which determines the load current. The overall view of the circuit is as follows.

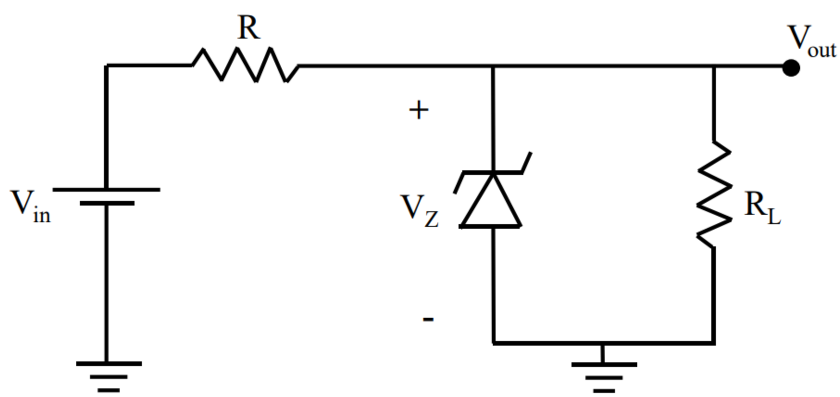

Figure 1: Circuit to be used in this lab

Preliminary Work

1 The maximum and minimum current for the Zener diode

Zener diodes function like regular diodes but have a constant breakdown voltage. The Zener breakdown voltage for this circuit is 5.1 volts. When a voltage greater than the breakdown voltage value is applied, it enters the breakdown state, allowing the current to flow freely through it, and the voltage remains constant. The maximum current that can pass through the Zener diode without damaging it is limited by r_Z, which is the internal resistance of the diode. There is also a minimum current value that will keep the Zener diode constant in the breakdown state.

2.1 The Source Regulation

The source regulation can be defined as the percentage of output voltage change due to the change in input voltage. The following formula can obtain this value:

$$SR = \frac{\Delta V_{out}}{\Delta V_{in}} \cdot 100$$

2.2 The Load Regulation

The load regulation can be defined as the ability of the power supply to provide constant voltage to the output, regardless of the change in load. Ideally, this value is expected to be equal to zero. The following formula can obtain this value:

$$LR = \frac{V_{no,load} - V_{full,load}}{V_{full,load}} \cdot 100$$

Hardware

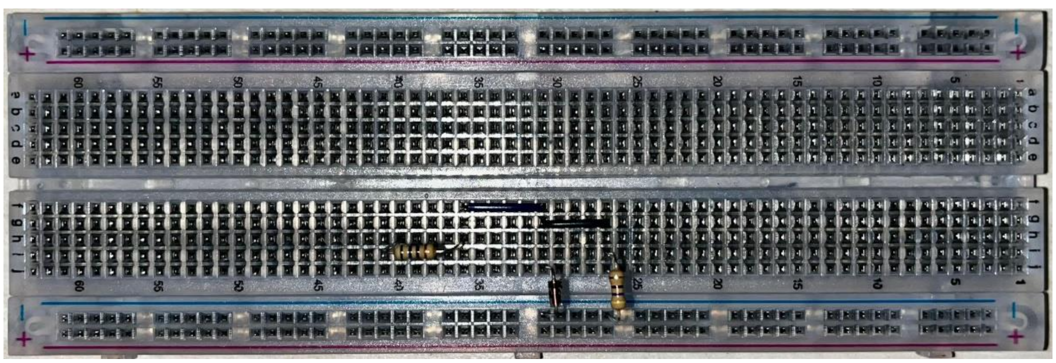

Figure 2: The Circuit

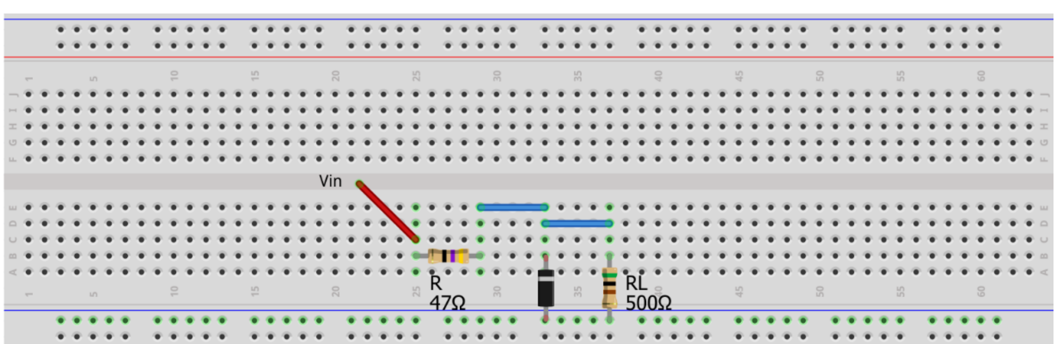

Figure 3: Schematic of the Circuit

a) Finding the range for R

In this part, while the $R_L = 500$ and V_{in} value varies between 9V and 11V, a range will be found for R values that will limit the Zener current between 10mA and 100mA. For this, four R values will be found by taking the V_{in} value as 9V and 11V for both Zener current values.

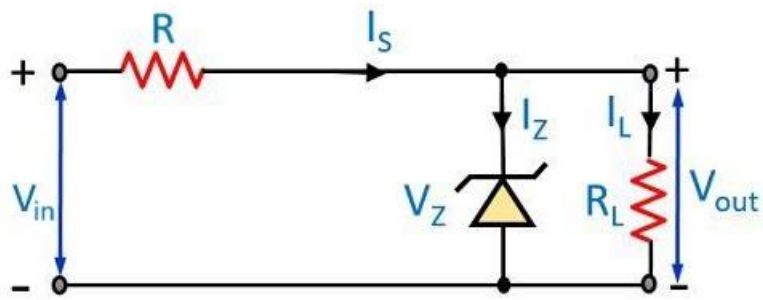

Figure 4: Zener Regulator Circuit

These values can be obtained by performing KCL on the output node through the circuit above, as follows:

$$R = \frac{V_{in} - V_Z}{I_S}$$

$$I_S = I_Z + I_L$$

$$I_L = \frac{V_Z}{R_L} = \frac{5.1\ V}{500\ \Omega} = 10.2\ mA$$

$I_Z = 10mA$ $I_S = 20.2\ mA$		$I_Z = 100mA$ $I_S = 110.2\ mA$	
$V_{in} = 9\ V$	$V_{in} = 11\ V$	$V_{in} = 9\ V$	$V_{in} = 11\ V$
$R_1 = \frac{9V - 5.1V}{20.2mA}$	$R_2 = \frac{11V - 5.1V}{20.2mA}$	$R_3 = \frac{9V - 5.1V}{110.2mA}$	$R_4 = \frac{11V - 5.1V}{110.2mA}$
$R_1 = 193\ \Omega$	$R_2 = 292\ \Omega$	$R_3 = 35\ \Omega$	$R_4 = 54\ \Omega$

As a result of these values, the range for R values is determined as follows:

$$54\,\Omega < R < 193\,\Omega$$

If the R value is selected as $100\,\Omega$, when I_Z value is measured using a multimeter, the minimum I_Z value is $26.3\,mA$ and the maximum I_Z value is $45.9\,mA$ as Vin is 9V and 11 V, respectively. Thus, it is verified that the selected R value does not fall outside the desired range.

b) Finding Source Regulation

In this part, source regulation was asked to be found when $V_{in} = 9.5 + 0.1\sin(wt)\,V$ where $f = 100\,Hz$. Afterward, the series resistance of the Zener (r_Z) will be calculated using this value.

The initially selected $100\,\Omega$ R resistor was replaced with $47\,\Omega$ due to the waveform generator's $50\,\Omega$ internal resistance, and the circuit was installed on the breadboard with this value. After adjusting the waveform generator with 4.75 V offset for 9.5 V DC voltage and other necessary values, the V_{in} and V_{out} values measured with the oscilloscope are as follows.

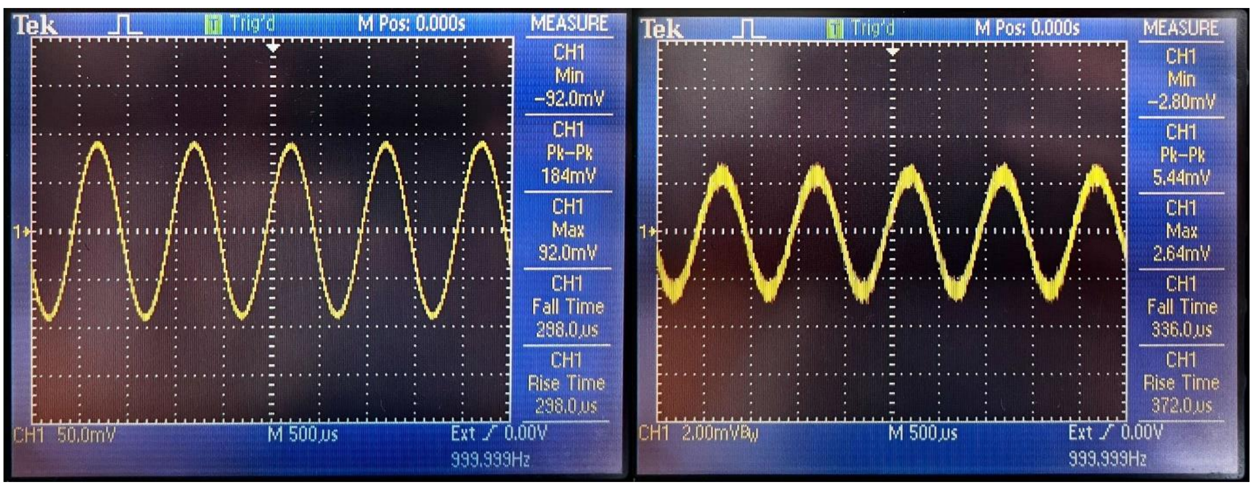

Figure 5: The V_{in} and V_{out} values, respectively

Using these values, source regulation can be calculated as follows:

$$SR = \frac{\Delta V_{out}}{\Delta V_{in}} \cdot 100 = \frac{5.44\,mV}{184\,mV} \cdot 100 = 2.96\,\%$$

To calculate the series resistance of the Zener (r_Z), the voltage divider for V_{out} will be applied in the created circuit, and the $\frac{\Delta V_{out}}{\Delta V_{in}}$ value will be substituted.

$$\Delta V_{out} = \frac{r_Z//R_L}{r_Z//R_L + R} \Delta V_{in}$$

$$\frac{\Delta V_{out}}{\Delta V_{in}} = \frac{\frac{r_Z . R_L}{r_Z + R_L}}{\frac{r_Z . R_L}{r_Z + R_L} + R}$$

$$SR = \frac{\Delta V_{out}}{\Delta V_{in}} \cdot 100 = 2.96 = \frac{\frac{r_Z . 500}{r_Z + 500}}{\frac{r_Z . 500}{r_Z + 500} + 100} \cdot 100$$

When this equation is solved, the series resistance of the Zener is found as follows:

$$r_Z = 3.07\ \Omega$$

c) Finding Load Regulation

In this part, we are asked to find the load regulation when $V_{in} = 10\ V$ and $R_L = 100\ \Omega$. Firstly, the R value was changed to $100\ \Omega$, and the required values were measured using a multimeter. The measurements made with and without the resistance in the load are as follows:

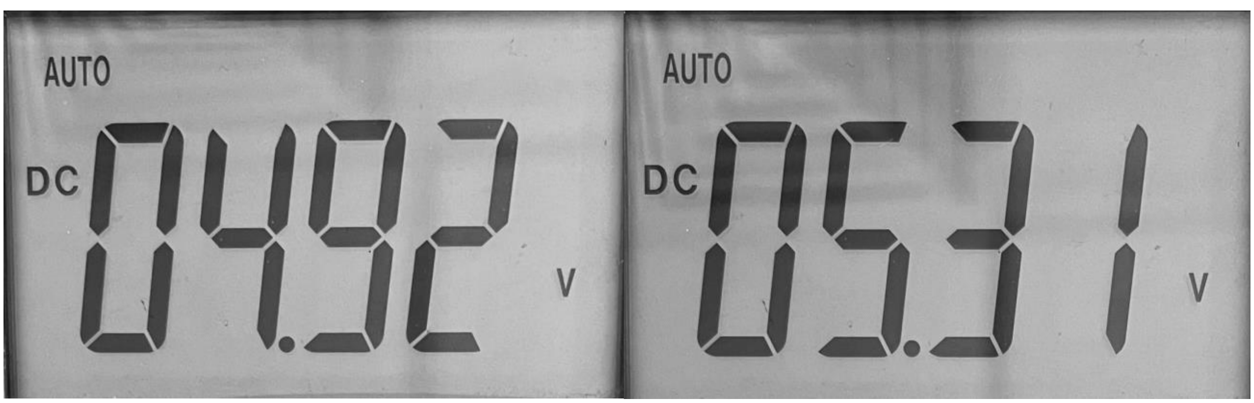

Figure 5: the $V_{full,load}$, and $V_{no,load}$ values, respectively

The obtained $V_{no,load}$ (measurement without R_L) and $V_{full,load}$ (measurement with R_L)values were substituted in the equation in the preliminary part, and the load regulation was calculated as follows:

$$LR = \frac{\Delta V_{no,load} - \Delta V_{full,load}}{\Delta V_{full,load}} \cdot 100 = \frac{5.31 - 4.92}{4.92} \cdot 100 = 7.16\%$$

Conclusion

The purpose of this lab is to become familiar with the use of Zener diodes. A voltage regulator was obtained using a Zener diode, and the concepts of source regulation and load regulation were studied through this circuit. After calculating the appropriate range for the source resistance, the circuit was created with the selected value and tested whether the range was met. Afterward, the necessary measurements were made with the different desired input and resistance values. As a result, the series resistance of the Zener (r_Z), source regulation, and load regulation values was obtained.

There were no significant difficulties during the lab. The only mistake was calculating the r_Z value first from the voltage value measured with the oscilloscope. After learning this was wrong, the measurement was made using a multimeter, and the correct result was obtained. Some minor errors occurred due to the non-ideal Zener diode, imprecise component values, and the material quality or sensitivity of the oscilloscope, signal generator, multimeter, and breadboard. Thanks to this lab, the working logic of Zener diodes and the voltage regulator circuits obtained with it were learned, and information about source regulation and load regulation was developed.

References

Zener diode basic operation and applications - digi-key electronics. Available at: https://www.digikey.com/en/maker/tutorials/2016/zener-diode-basic-operation-and-applications (Accessed: 19 October 2023).