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The Series-Pass Voltage Regulator

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A. None

II. List of Figures:

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III. Objectives:

In this experiment, the objective is to learn how to design series-pass voltage regulator circuits, which can provide a stable output voltage from a fluctuating input voltage. In addition to this, the experiment aims to provide hands-on experience in making power supply performance measurements and testing the efficiency and reliability of the power supply using worst-case design techniques. The experiment also aims to provide an opportunity to work with real electronic circuits, which can enhance the practical knowledge and skills of the experimenter. By the end of this experiment, the experimenter should be able to design and analyze voltage regulator circuits and take appropriate steps to improve the efficiency and reliability of the power supply

IV. Equipment Used:

- Oscilloscope
- Transformer
- Breadboard
- Various Electronic Components

V. Preliminary Calculations:

A. The first step was to calculate the resistance needed for the circuit to be operated at full load, as well as the power that the load resistance will dissipate.
   1. The resistance was calculated to 22.75 Ω, while the power dissipated was calculated to be 3.64 W. These full calculations can be observed at the end within **Appendix 1.**

B. Next, a data sheet was found for the TIP31A transistor, and the minimum or "worst-case" value of β was used to calculate the maximum base current needed for the load condition of 400 mA.
   1. The maximum base current needed for a load condition of 400 mA was calculated to be 36.36 mA. These full calculations can be observed at the end within **Appendix 2.**

C. Then the maximum permissible Zener current for the 1N4739 (1 Watt) device was also calculated
   1. The maximum zener current was calculated to be 109.9 mA. These full calculations can be observed at the end within **Appendix 3.**

D. Next the determination of the value needed for RZ to allow at least 10% of Iz(max) to flow through the Zener. This was done by using the KVL loop shown in **Figure 1** below.
   1. Using the KVL, we were able to calculate a zener resistance of 273 Ω. These full calculations can be observed at the end within **Appendix 4.**

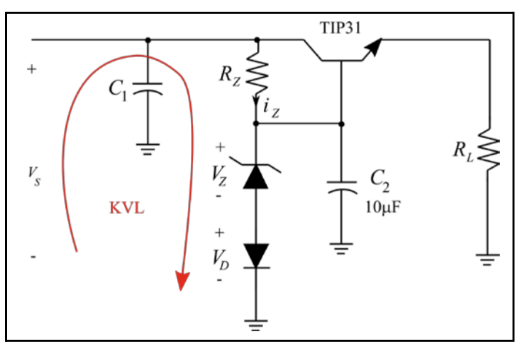

Figure 1: KVL Loop

E. Finally, the next lower standard value of resistor for RZ was then chosen, and the Zener current was checked for the no load condition. A safety margin was ensured by making sure that the current would never exceed 90% of Iz(max).
   1. Given the safety margin, the maximum zener current for the no load condition was calculated to be 98.9 mA. This was calculated using the

next lower standard zener diode of 260 Ω. These full calculations can be observed at the end within **Appendix 5.**

VI. Procedure/Result/Analysis:

01. Problem Statement:

The problem statement for this lab report is to investigate the performance of a basic DC power supply circuit, specifically its ability to regulate output voltage and minimize ripple under varying load conditions. The goal is to determine if the circuit meets the desired specifications and identify any factors that may contribute to higher-than-expected ripple or percent regulation values. Additionally, the report aims to explore potential solutions to improve the circuit's performance, such as adding a beta multiplier circuit or using a different transformer.

02. Procedure:

a. Construct the circuit of **Figure 1** using parts in the laboratory.
b. Calculate the ripple expected to see across the filter capacitor using textbook equations.
c. Check circuit connections, apply AC power to the circuit, measure the load voltage, and use an oscilloscope to measure the peak-to-peak ripple at the output and at C1.
d. Remove the full load resistor and replace it with a 1kΩ (no-load) resistor to simulate a no-load condition. Measure the resulting output voltage, calculate the percent regulation and the percent ripple at full load.
e. Analyze the values obtained from the experiment and compare them with the specifications of the laboratory power supply. Identify the factors that might be contributing to higher values than expected.
f. Calculate the power being supplied at full load and the approximate power being dissipated in the power transistor.
g. Analyze the circuit in **Figure 5** and identify the one specification on the transformer that would need to change to obtain a dual polarity output of 9.1 V.

03. Experiment:

a. We started this experiment by constructing the circuit shown above within **Figure 1.** We were asked to calculate the expected ripple voltage that we should observe within this output. Our calculated expected value was shown to be approximately 0.69 V. This calculation can be observed within **Appendix 6.** The next step was to measure the load voltage across the output using the oscilloscope, as well as measure the peak to peak ripple voltage across C1. This oscilloscope output can be observed within **Figure 2 & 3** respectively below. It can be observed within the image that our peak to peak was approximately 0.189 V. With this observation we can answer the 2 questions presented within the manual. We were first asked whether or not we can deduce that the regulator reduced the ripple. Since the observed ripple was about 0.5 V lower than the calculated we concluded that yes the regulator did reduce the ripple. Using simple division of these calculated and observed values we were able to decide that the reduction was by a factor of about 3.5 times.

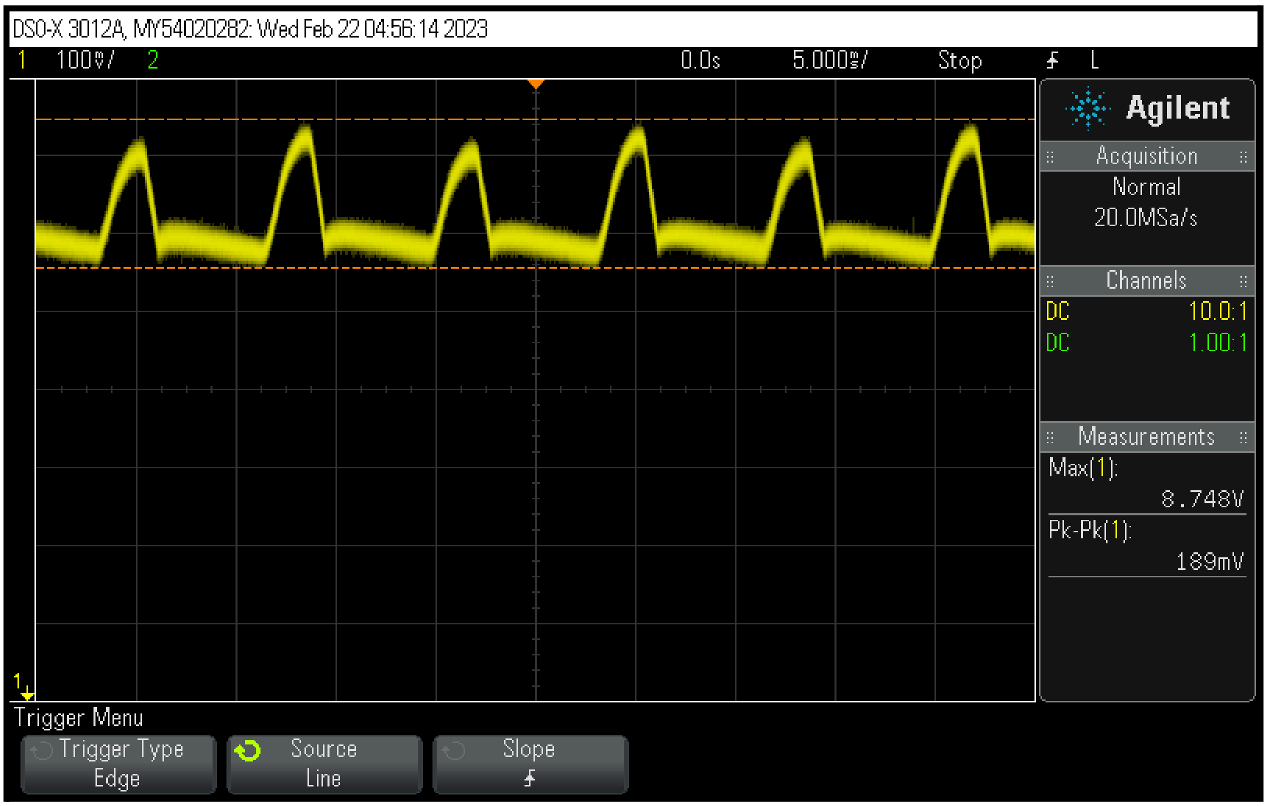

Figure 2: Load Ripple Output

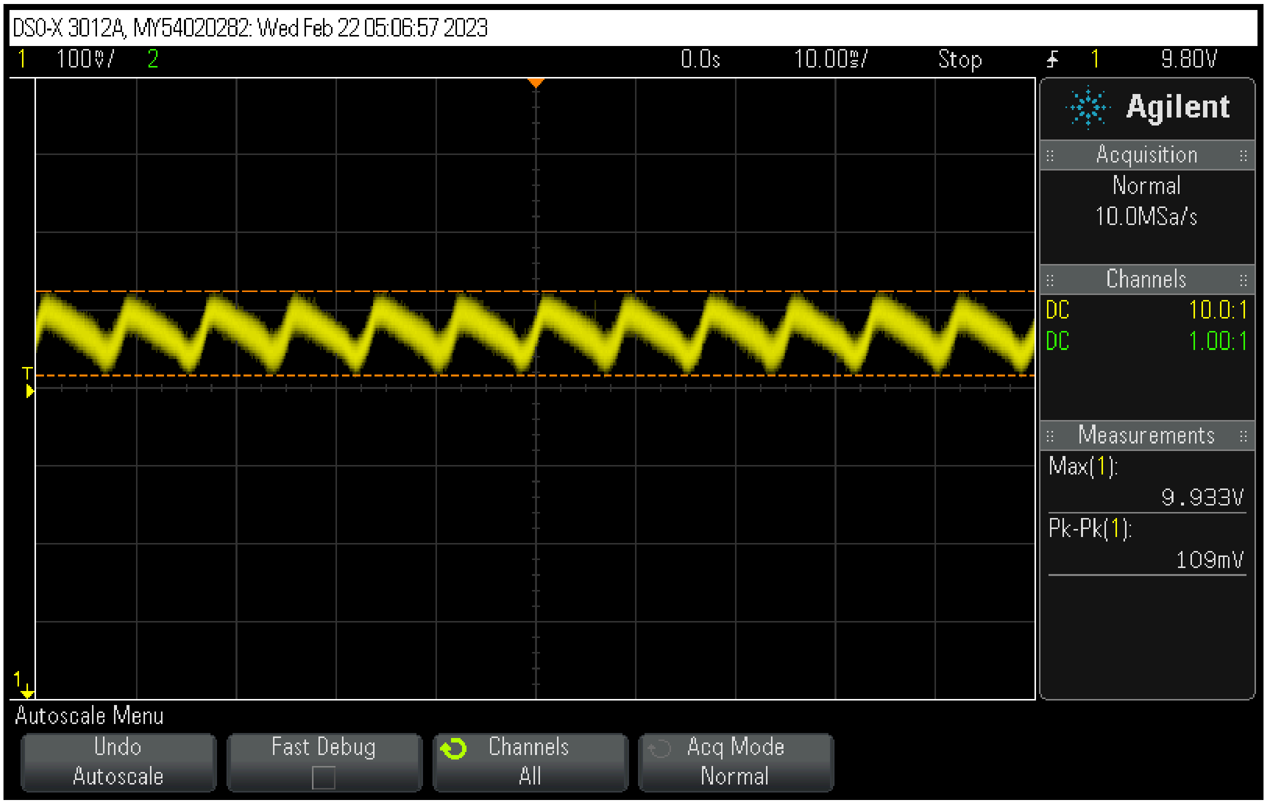

Figure 3: C1 Ripple Oscilloscope

b. For the next part of this experiment we were asked to remove the full load resistor and replace it with a much higher resistance of 1 KΩ. We then measured the output once again which can be observed below within **Figure 4.** There were then 2 calculations we were asked to perform which was to determine the percent regulation of the power supply and also the percent ripple at a full load. The percent regulation of the power supply was shown to be 4%, while the percent ripple at a full load was shown to be 2.16%. These full calculations can be observed within **Appendix 7.** There were following questions asked within the manual. The first question was asked whether or not these percentages are considered good values. From a little research it was found that a low percent regulation and percent ripple is considered good. Indicating that it can deliver stable and precise output voltage even under varying load conditions. Regarding the factors that might contribute to higher values of percent regulation and percent ripple, several factors can affect the performance of a power supply, such as the quality of the components, the design of the circuit, the thermal management, and the load conditions. For example, a poorly designed circuit may suffer from voltage drop and thermal issues, leading to higher percent regulation and percent ripple. The next question asked for us to determine the power supplied to the load. This was calculated within the **Appendix 8,** to be 3.5 Watts. To add to this, the power dissipated within the transistor was also calculated which required us to take Vce and Ic to achieve this, which was calculated below in **Appendix 8** to be 0.12 Watts.

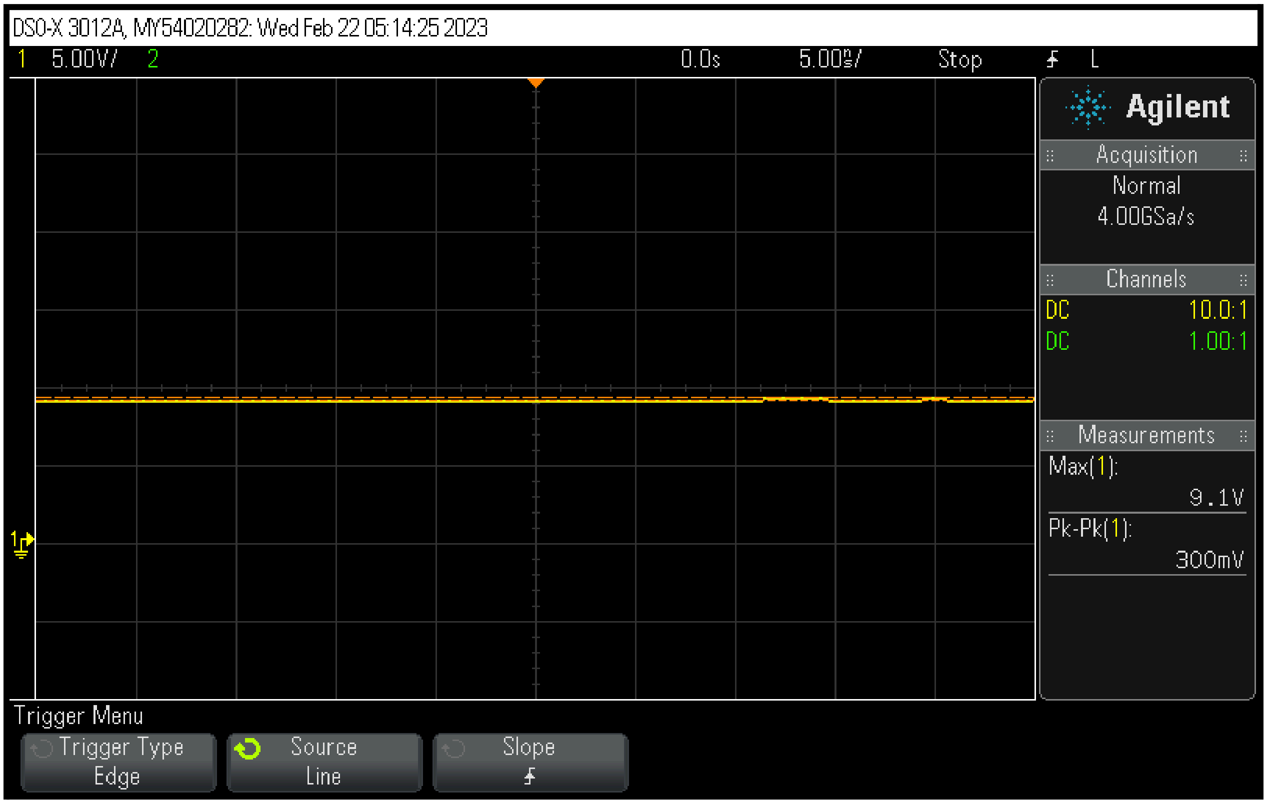

Figure 4: Oscilloscope No load 1kΩ

c. Finally, On the last page of the manual, there is a circuit that is a dual polarity output of 9.1 V. This can be observed below within **Figure 5.** Using this circuit we were asked to decide what is the one specification on the transformer that you would need to change? We decided that to change the output voltage of the dual polarity power supply shown in Figure 4, you would need to modify the turns ratio of the transformer. The turns ratio determines the voltage transformation ratio between the primary and secondary windings of the transformer.

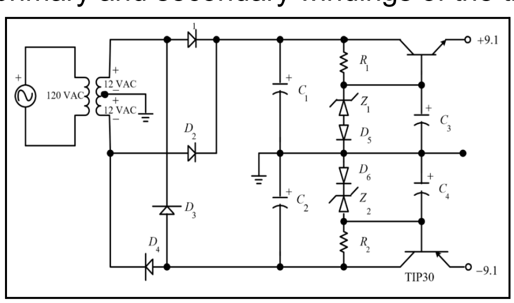

Figure 5: : A Regulated Dual Power Supply.

VII. Conclusion:

In conclusion, this lab provides hands-on experience for designing and constructing a series-pass voltage regulator circuit. The objectives of this lab include learning how to design a regulator circuit with discrete components, making power supply performance measurements, improving efficiency and reliability using worst-case design techniques, and gaining experience working with real electronic circuits. Through the preliminary calculations and experiment, students will learn how to choose appropriate values for components, calculate the maximum permissible Zener current, choose standard values of resistors, and construct and test the circuit. By keeping a detailed lab notebook, students will be able to reproduce the lab and use it as a reference for future projects. Overall, this lab provides valuable practical skills for electronic circuit design and analysis.

VIII. References:

Not applicable

IX. Appendix:

Preliminary 1:

$$V_L = I_L R_L \Rightarrow R_L = \frac{9.1\,V}{400\,mA} = 22.75\,\Omega$$

$$P_L = V_L I_L = 9.1\,V \cdot 400\,mA = 3.64\,W$$

Preliminary 2:

$$I_{B(Max)} = \frac{I_E}{1+\beta} = 36.36\,mA$$

Preliminary 3:

$$I_{Z(Max)} = \frac{P_z}{V_z} = 109.9\,mA$$

Preliminary 4:

$$\text{KVL Loop } R_z = \frac{V_s - V_z - V_D}{0.1 \cdot I_{z(Max)}} = 273\,\Omega$$

Preliminary 5:

$$0.9 I_{Z(Max)} = 98.9\text{ mA}$$

$$R_{ZStandard} = R_{Zold} 0.95 = 260\,\Omega$$

$$I_z = \frac{V_{ps} - V_{zo} - V_{D4}}{R_{zStandard}} = 97.66\,mA$$

Appendix 6:

$$V_r = \frac{V_m}{2fRC} = 0.69\,V$$

Appendix 7:

$$\zeta = \frac{V_{No\ Load} - V_{Full\ \ Load}}{V_{Full\ \ Load}} \times 100\% = 4\%$$

$$\rho = \frac{V_{Full\ Load\ Peak\ to\ Peak\ ripple}}{V_{Full\ \ Load\ DC\ Out}} \times 100\% = 2.16\%$$

Appendix 8:

$$P_L = V_L I_L = 8.75 \cdot 0.4 = 3.5\ Watts$$

$$P_D = V_{CE} I_C = 1.2 \cdot 0.0989 = 0.12\ Watts$$