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AIM: To understand the concept of a DC regulated power supply and IC voltage regulator

1.0 OBJECTIVES

The objectives of the experiment are:
(a) To design and construct a circuit that transform sinusoidal (AC) voltages to constant (DC) voltages.
(b) To construct a shunt voltage regulator based on the characteristics of a Zener diode.
(c) To demonstrate the operation of an integrated circuit (IC) voltage regulator as a simple, fixed voltage regulator and as an adjustable output regulator.

2.0 THEORY

(a) The Full Wave Rectifier

The first building block in the DC power supply is a full wave rectifier. The purpose of the full wave rectifier is to create a rectified AC output from a sinusoidal AC input signal. Figure 1 shows a full-wave bridge rectifier circuit.

For a bridge full-wave rectifier, the DC output is given by Eq. 1:

$$V_{DC} = \frac{2V_{out(p)}}{\pi}$$  \hspace{1cm} (1)

where the peak output voltage is:

$$V_{out(p)} = V_{in(p)} - 2V_D$$

For each positive and negative cycle of the input voltage, two diodes will be turned ON and the voltage drop across each diode is $V_D$.

Although the output of a rectifier is always positive (or always negative), it is generally not constant, often going from zero to a peak value. Thus, the output of the rectifier must be filtered to obtain a DC output. A capacitor input filter can be connected to the output of a full-wave bridge rectifier to smooth out the pulsating DC output voltage of the rectifier. The capacitor is placed parallel to the load. Figure 2 shows a capacitor filtered full-wave rectifier.
Figure 2: A capacitor filtered full-wave rectifier

The output is now a pulsating DC, with a peak to peak variation called ripple. The magnitude of the ripple depends on the input voltage amplitude and frequency, the filter capacitance (C1), and the load resistance (R_{load}).

One performance measure of a DC power supply is the percent output ripple computed from the ratio of the (peak-to-peak) output voltage to the average (DC) output voltage. Output ripple can be expressed as \( r \) in the Eq. (2):

\[
\% \ r = \frac{V_{r(\text{rms})}}{V_{DC}} \times 100\% \tag{2}
\]

where the peak-to-peak ripple voltage: \( V_{r(p-p)} = \frac{I_{\text{out DC}}}{2fC_1} \approx \frac{V_{\text{out(p)}}}{2fC_1R_{\text{load}}} \)

the average (DC) output voltage: \( V_{DC} = V_{\text{out(p)}} - \frac{V_{r(p-p)}}{2} \)

the rms of the ripple voltage: \( V_{r(\text{rms})} = \frac{V_{r(p-p)}}{2\sqrt{3}} \)

(b) Zener Diode Shunt Regulator

A shunt regulator may be placed between the filtered full wave rectifier (point A) and the load resistance. Its purpose is to minimize the variation in the voltage across the load, as either the input voltage or the output resistance changes. Figure 3 shows a zener diode shunt voltage regulator. The regulator in Figure 3 is called a shunt because it provides an additional path for current to flow, so that some current can bypass the load. The shunt regulator consists of a zener diode and a resistor (R_s). The zener diode has a nearly constant voltage drop V_Z when used in reverse bias. The resistor R_s is chosen to maintain the zener in its proper working region, where it can provide regulation and not exceed a maximum power limit.
Figure 3: Shunt regulator

(c) IC Voltage Regulator

Voltage regulator using a zener diode does not have the ability to handle large load currents. On the other hand, IC regulators offer fixed output voltages with typical load regulation of less than 1% and internal thermal overload protection as well as short-circuit protection. Figure 4 shows IC voltage regulator circuits: (a) a fixed voltage regulator and (b) an adjustable output voltage regulator. The 1 µF capacitor should be connected as closely as possible to the 7805 regulator, as it greatly improves the transient circuitry of the regulator.

\[
V_{out} = V_{REG} + R_2 \left( I_0 + \frac{V_{REG}}{R_1} \right)
\]

where \( I_0 = 7 \) mA (typical value)
3.0 PRELAB

(a) For the full-wave rectifier circuit (Figure 1), determine the peak output voltage and the current through a 5.6 kΩ load with a sinusoidal 12 V(rms), 50 Hz input voltage. Use suitable approximations.

(b) For the capacitor filtered full-wave rectifier in Figure 2, assume a 5.6 kΩ load with a sinusoidal 12 V(rms), 50 Hz input voltage. Design the circuit by determining the capacitor value so that the output ripple voltage is 0.6 V<sub>P-P</sub>.

(c) For the shunt voltage regulator circuit in Figure 3, if a 6.8 V Zener diode (1N751A or equivalent) is used to regulate the output of the filtered rectifier circuit, determine the minimum load that could be applied for maintaining the output voltage regulation.

(d) Calculate the output of the adjustable voltage regulator circuit (Figure 4(b)) if R<sub>2</sub> is 47 Ω. Then calculate again if the value of R<sub>2</sub> is changed to 100 Ω, 150 Ω, and 220 Ω.

4.0 COMPONENT & EQUIPMENT LIST

- Resistors: 47 Ω, 100 Ω (2), 150 Ω, 220 Ω, 1 kΩ, 5.6 kΩ
- Capacitors: 1 µF, 47 µF
- Diode 1N4004 (4)
- Zener diode (V<sub>z</sub> = 6.8 V) 1N751A or equivalent
- IC Regulator 7805
- 12 V or 9 V Transformer
- Variable DC power supply 15 V
- Dual Trace Oscilloscope
- Multimeter, breadboard and jumper wires

5.0 PROCEDURE

PART 1: ZENER DIODE SHUNT REGULATOR

(a) Construct the circuit in Figure 1 with a 5.6 kΩ load and 12 V(rms) of 50 Hz as the input voltage. Use oscilloscope to record the output waveform (V<sub>out</sub>). Draw and label the waveform obtained. Compare the experimental result with the calculated value in Prelab.

(b) Design and construct a capacitor filtered full-wave rectifier circuit (Figure 2) so that the output ripple voltage is 0.6 V<sub>P-P</sub>. Use sinusoidal wave of 12 V(rms) at 50 Hz as the input voltage and 5.6 kΩ load.
   (i) Draw and label the output waveform obtained. Analyse the waveform obtained by comparing it with the output waveform in step 5(a).
   (ii) Record and measure the ripple voltage of the output voltage (V<sub>r(p-p)</sub>). Does this voltage achieve the targeted design value? If not, justify your answer.
   (iii) Explain what will happen to the output waveform if a capacitor with a larger value than the calculated value obtained is used.

(c) Modified the circuit in step 5(b) by adding a 100 Ω resistor (R<sub>s</sub>) and a zener diode as a shunt regulator as shown in Figure 3. Using oscilloscope, observe and draw the voltage waveforms at point A and B. Discuss the result obtained.

(d) Repeat the measurement in step 5(c) but change the load (R<sub>load</sub>) to a 100 Ω resistor. Analyse the waveform obtained by comparing with the result obtained in step 5(c).
PART 2: IC VOLTAGE REGULATOR

(a) Construct the fixed output voltage regulator circuit in Figure 4(a). Connect the 1 µF capacitor as closely as possible to the 7805 regulator. Explain the function of the capacitor.

(b) Vary the input voltage (\(V_{IN}\)) for the circuit in Figure 4(a) from 1 V to 15 V, with at least 10 measurements in between, and record the output voltage (\(V_{OUT}\)). Record and table the results and explain how the output changes with the input. Verify that the output voltage of IC 7805 in Figure 4(a) is a fixed DC of 5 V and state the term or condition to get this value.

(c) Plot the graph for measured output voltage versus the input voltage of the voltage regulator as obtained in step (b). This is the voltage regulator’s drop out characteristic curve. The drop out voltage is the voltage below which the regulator stops regulation. Comment on the plotted graph.

(d) Construct the adjustable output voltage regulator shown in Figure 4(b). Measure the DC output voltage (\(V_{OUT}\)) for resistor’s value of \(R_2\) that varies from 47 Ω to 220 Ω. Compare the measured \(V_{OUT}\) with the expected \(V_{OUT}\) (from prelab). Discuss the findings. Describe the observation made when resistor \(R_2\) is 220 Ω.

6.0 CONCLUSION

Write a concise conclusion for the experiment.

Data Sheet

**KA78XX/KA78XXA**

**Features**
- Output Current up to 1 A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24 V
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

**3-Terminal 1A Positive Voltage Regulator**

**Description**

The KA78XX/KA78XXA series of three-terminal positive regulator are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1 A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.