The DC Power Supply

This experiment consists of 9 separate sections, each investigating aspects of D.C. supplies. You may do all or only a few of these experiments. Before beginning, read through the whole of these instructions and decide which sections you will do. Guidelines: Exercises 1-4: 2 weights, Exercises 5-6: one additional weight.

Introduction

Electric energy is most often delivered in the form of alternating current, i.e. the voltage and the current alternate sinusoidally between two extremes. This cycle is repeated 60 times a second (50 times a second in Europe). Very often, however, and particularly for electronic circuits, direct current is desired, i.e. voltage and/or current which are stable in time. The degree of stability of the voltage varies according to how the DC is produced. A dry cell, for example, gives a very good short term stability i.e. there are no fast fluctuations but the long term stability is poor because the cell runs down. A power supply converting AC to DC may, on the other hand, have a good long term stability but rather poor short term stability. In this case, fast but often small variations called ripples originate from the AC input leaking through the AC to DC converter.

When designing a DC power supply, the aim is to get an output voltage with good stability.
A DC supply consists of the following parts:
- A transformer to change the voltage as required and to isolate the DC circuit from the line.
- A rectifier consisting of one or more diodes, to change AC to DC.
- A smoothing circuit using inductors and capacitors.
- An electronic stabilizer which improves the stability of the output voltage and/or current.

1. **Experiment A: Half-wave rectifier**

   The transformer delivers an alternating voltage. In order to get DC we must get rid of one half of the voltage. This can be done by using a diode which permits current to flow only in one direction, thus acting as some sort of non-return valve (recall the diode characteristics you have already measured in one of the lab exercises).

   The simplest half wave rectifier is shown in Figure 1.

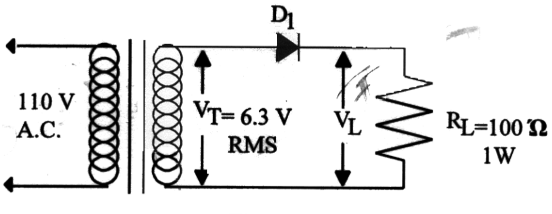

Figure 1

Figure 1: The half-wave rectifier

R_L is a load resistor representing the device which requires DC. Connect the circuit above and observe simultaneously on the oscilloscope the transformer voltage V_T, and the output voltage, V_L.

Using a multimeter observe the AC values of V_L, V_T.

Notes:

1. Switch off the supply voltage to the transformer before doing any alterations.
2. The vertical sensitivity of the oscilloscope should be set so the full sine wave from the transformer output is within the size of the screen.
3. Operate the oscilloscope in the DC mode.
4. Draw all oscilloscope displays directly in your lab report, indicating voltages, or take a photo of the screen, also indicating voltage scales.

This method of rectification just stops the flow in one direction and is called half wave rectification.

Question: Why does the oscilloscope trace for V_L follow about 0.7 Volts lower than the positive half of the trace for V_T, rather than being identical to the positive half of V_T?

2. **Experiment B: Full-wave rectifier**

   If there is a centre tap on the transformer, a full wave rectifier circuit may be used as in Figure 2.

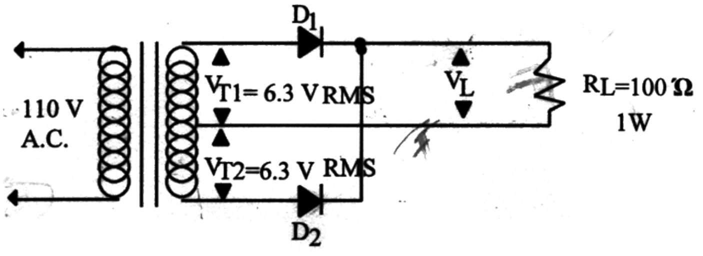

Figure 2

Figure 2: The full wave rectifier

Connect the circuit and observe and record V_{T1}, V_{T2} and V_L using the oscilloscope and the multimeter as you did in experiment A. As in experiment A, observe V_L on the oscilloscope simultaneously with V_{T1}, and then V_{T2}. Notice how the oscilloscope trace for V_L changes as you connect and disconnect the diode D_2.

3. **Experiment C: Bridge rectifier**

   A useful full wave rectifier circuit can be built up by four diodes. Connect the circuit of Fig. 3 and observe V_T and V_L using the oscilloscope and your multimeter as you did in Experiment A.

   Connect the circuit of Figure 3 and observe V_T and V_L using the oscilloscope and your multimeter as you did in experiment A.

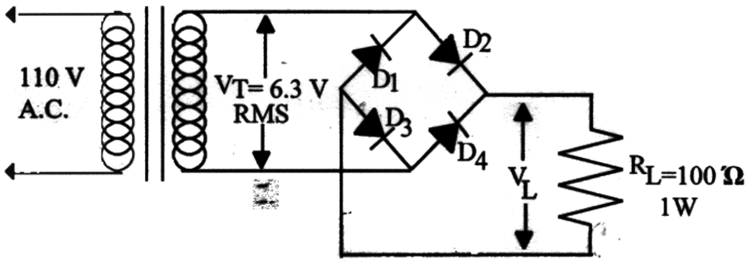

Figure 3

Figure 3: The bridge rectifier

CAUTION! Note that because there is no common connection between V_T and V_L, it is not possible to observe V_T and V_L simultaneously on the oscilloscope. An attempt to do so would short-circuit one of the diodes. Explain why!

Questions

- What is the advantage of this circuit, called a bridge rectifier, compared to that one in experiment B?
- Why is the peak amplitude of V_L approximately 1.4 Volts lower than the amplitude of V_T?
- How does the output voltage, V_L in this experiment compare to that in experiment B?
- Compare the peak inverse voltage requirements of the diodes in experiments A, B and C.

4. **Experiment D - Smoothing**

Introduction

The insertion of a capacitor C_S, after the diode and across the load provides smoothing, as shown in Figure 4:

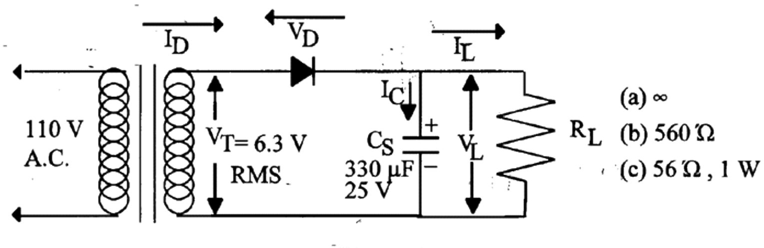

Figure 4

Figure 4: How to smooth the output

V_T varies, both positively and negatively. Whenever $V_T > V_L$, so that V_D is positive, then current I_D flows through the diode, providing current I_C to charge the smoothing capacitor C_S, and current I_L to the load R_L. When $V_T < V_L$, V_D is negative, and $I_D = 0$, so that C_S discharges through R_L, and $I_C = -I_L$. If the time constant $C_S R_L$ is considerably greater than the time for one cycle ($\frac{1}{60}$ s), then V_L will drop only slightly during the cycle, and will be recharged during the positive peak of the cycle, to a value equal to the amplitude of V_T.

NOTE: Be careful when observing polarity of electrolytic capacitors.

Experiment D

Connect the circuit as in Fig. 4 and measure V_T and V_L using the oscilloscope and your multimeter as you did in experiment A. Measure three values of R_L, so that:

(a) $R_L C_S = 0.4$ sec

(b) $R_L C_S = 1/6$ sec

(c) $R_L C_S = 1/60$ sec

Figure 5 shows a method of measuring currents I_D, I_C, I_L . Insertion of the small resistances R_1 and R_2 makes this possible, since $V_1 = -I_D R_1$, and $V_2 = I_C R_2$, and $V_L = I_L R_L$.

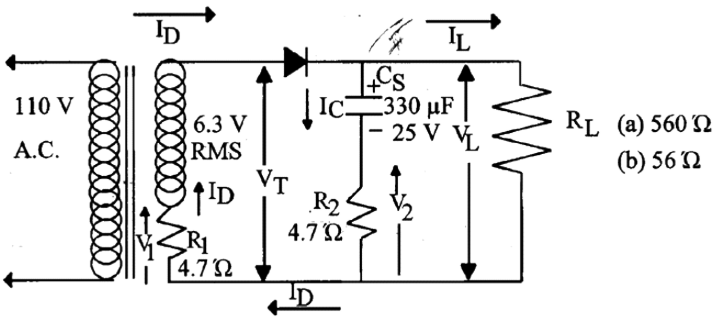

Figure 5

Figure 5: How to measure the output currents

Connect the circuit in Figure 5 and measure I_D, I_C, I_L using the oscilloscope.

5. **Experiment F - Filter Circuits**

Introduction

A low pass filter can be used to further reduce ripples as in Figure 6. L is a choke of inductance between 1 H and 10 H and internal series resistance less than 80 ohms. (Check this resistance with an ohmmeter).

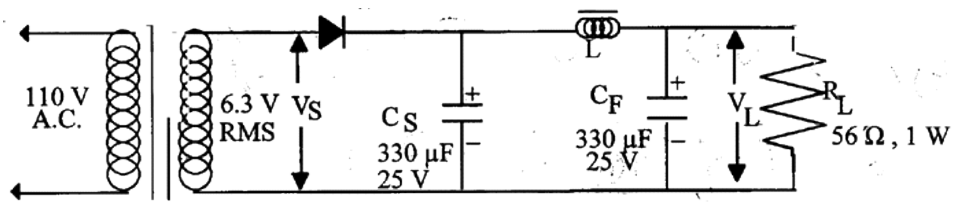

Figure 6

Figure 6: A low pass filter

Experiment F

Connect the circuit in Figure 6, using the same values of C_S and R_L you used in experiment D.

Observe V_S and V_L using the oscilloscope. Compare the magnitudes and phases of these two voltages.

Calculate the percent ripple in V_S and V_L. Explain your results and comment on the usefulness of the filter.

Use your oscilloscope on AC input to compare V_L and V_S. Why is this meaningful?

What is the effect of the internal series DC resistance in the choke? Notice the relative *phase* of the ripple on V_L and V_S.

6. **Experiment G: Zener Diode Regulation**

   Introduction

   A Zener diode will maintain a more or less constant voltage across it in the reverse direction independent of current passing through it for a wide range of currents. This property may be used to stabilize a power supply against variations in input supply voltage and in load current drawn.

   The Zener diode may be connected as in Figure 7.

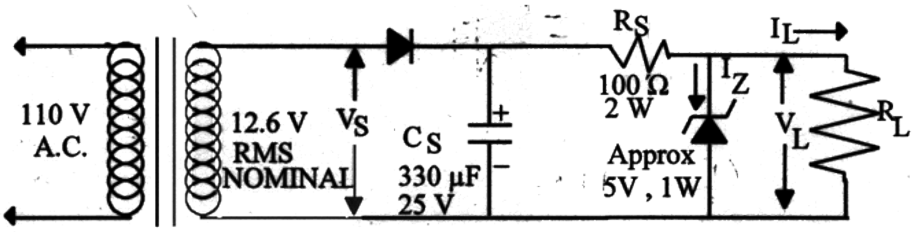

Figure 7

Figure 7: Zener diode circuit

   Experiment G

   Connect the circuit in Figure 7. Use values of C_S and R_S so that the time constant $RC = 1/30$ sec. Observe V_L and V_S on the oscilloscope and also with your multimeter on a DC volts range, as you vary the line supply voltage from 85 Volts to 110 Volts to 130 Volts, for $R_L = 100\Omega$ so that the transformer secondary voltage varies from 9.7 to 12.6 to 14.9 Volts. Also with a line supply voltage of 110 volts, observe V_L and V_S as R_L is varied to change I_L from 0 mA to 60 mA to 90 mA. Comment on the stabilization provided by the Zener diode.

7. **Experiment H - Transistor Voltage Stabilization**

   Introduction

   As you will find when you'll study Electronics, a transistor used in conjunction with a Zener Diode can provide a better stabilization than a simple Zener diode.

   In Figure 8 you can see a simple regulator supply circuit, in which the transistor is in an "emitter follower circuit", so that the Zener diode accurately regulates the voltage with little change of current through it, and the transistor passes on this regulation so that V_C stays constant for a wide variation in I_L.

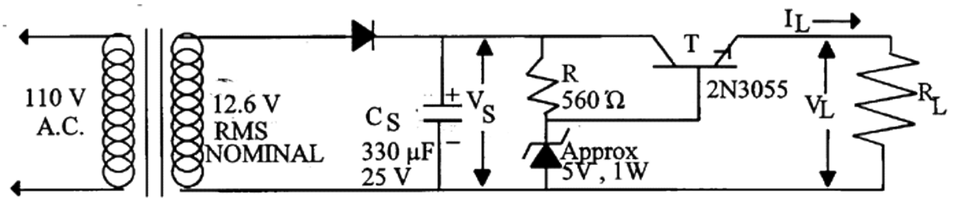

Figure 8

Figure 8: Transistor voltage stabilization

Experiment H

Repeat experiment G, but using the circuit of Figure 8.

8. **Experiment I - Voltage Doubler Rectifier**

A voltage doubler rectifier circuit is shown in Figure 9.

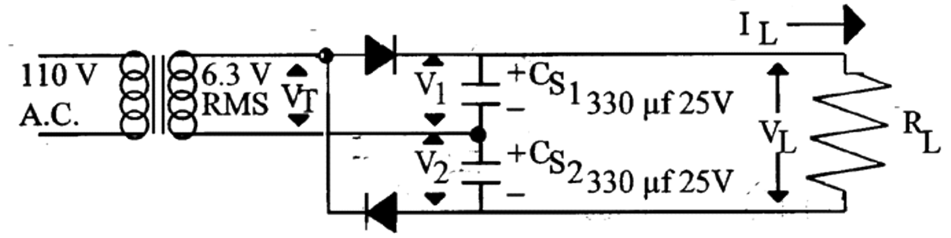

Figure 9

Figure 9: Voltage Doubler Rectifier

Connect the circuit in Figure 9 and observe V_L, V_T, V_1, and V_2 using the oscilloscope for values of R_L of 2.7 kΩ, 1.0 kΩ, and 270 Ω. Explain the operation of this circuit.

Compare the peak inverse voltage and peak current requirements for the diodes in this circuit, compared to those for the circuit in Fig. 2 for the same output voltage V_L and output current I_L.

NOTE: In all parts of this experiment, carefully and systematically record your observations. All drawings or pics of oscilloscope curves for any given section should be included on the same page, with magnitudes of voltages or currents indicated, and with the relative timing of "phase" of the various curves indicated. In all cases comment on your observations, and compare them to theory in as much detail as possible.

This guide sheet has been reviwed by Ruxandra M. Serbanescu in 2020. Previous version: Joe Vise - 1985