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: The half-wave rectifier](image)
$R_L$ 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: The full wave rectifier](image)

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.
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:

$V_T$ 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 $V_T$. 

Figure 3: The bridge rectifier

Figure 4: How to smooth the output
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) $R_LC_S = 0.4$ sec
(b) $R_LC_S = 1/6$ sec
(c) $R_LC_S = 1/60$ 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](image)

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](image)

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: Zener diode circuit](image)

**Experiment G**
Connect the circuit in Figure 7. Use values of $C_S$ and $R_S$ so that the time constant $RC = \frac{1}{30}$ 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: Transistor voltage stabilization](image)

**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: Voltage Doubler Rectifier](image)

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 reviewed by Ruxandra M. Serbanescu in 2020. Previous version: Joe Vise - 1985*