PHYSICS 281
EXPERIMENT 8
Diode Power Supply

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OBJECT:

To study the two basic components of a simple power supply: the rectifier and the filter; and to learn how to measure and calculate the ripple factor -- one of the major parameters to measure the quality of a DC power supply.

APPARATUS:

Diode, AC power supply, filter resistor (200 Ω), load resistor (10 kΩ), capacitors (1 μF and 22 μF), oscilloscope.

THEORY:

We have studied the characteristics of a diode in the last experiment, and understood that the non linear characteristics of a diode can be used to rectify an AC voltage into a DC voltage, namely, to allow the current flowing one way only. Such a rectifier can be used to obtain a low frequency signal from its high frequency carrier, or simply used to turn an AC power supply into a DC power supply. Such device is called an AC-DC converter or adapter.

As shown in Figure 1, a sinusoidal AC voltage is applied across the points a and c. A diode D is inserted between the AC power supply and the load resistor R. Because the diode allows the current to run from the point a to the point b only, there is no current when the potential at the point a is negative with respect to the point c. The negative current and voltage is simply cut out of the load resistor R. The waveform of such a rectified voltage is called a half-wave rectified voltage, which is the half of a sinusoidal waveform above the time axis.

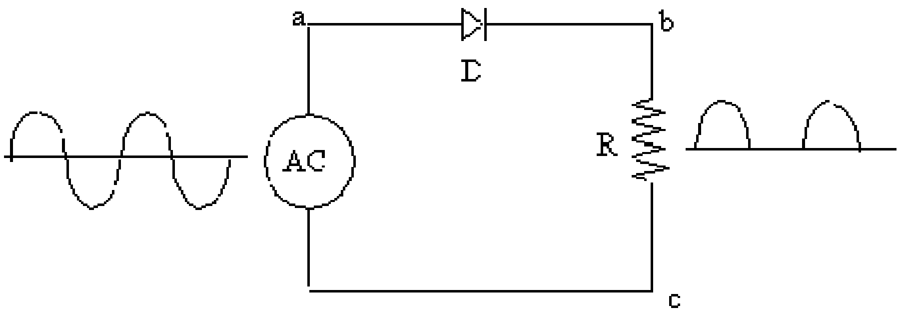

Figure 1

Figure 2 shows a half-wave rectified voltage. As it can be seen, the rectified half-wave form does not look like the DC voltage of a battery at all. The half wave rectified voltage can be called a "DC" voltage all right, because it stays positive all the time and gives a current that flows one way only. However, it is not constant and has an AC component that varies between the sinusoidal peak and zero, as indicated as V_{pp} in Fig. 2. We can define one half of this amount as the amplitude of the residual AC component in the rectified voltage:

$$V_{ac} = 0.5\ V_{pp} \qquad (1)$$

The DC component V_{dc} of the rectified voltage is indicated in Fig. 2 by a line above the time axis, which represents the average value of the rectified voltage over the whole period. If a battery having a voltage equal to this average voltage, V_{dc} is used to drive a DC motor, for instance, it should provide an equivalent power as the rectified waveform does. Experimentally, this DC component can be easily measured by switching the signal input between DC coupling and AC coupling on the oscilloscope panel. When the switch is on the AC coupling, the waveform would move down vertically on the screen exactly by the amount V_{dc}.

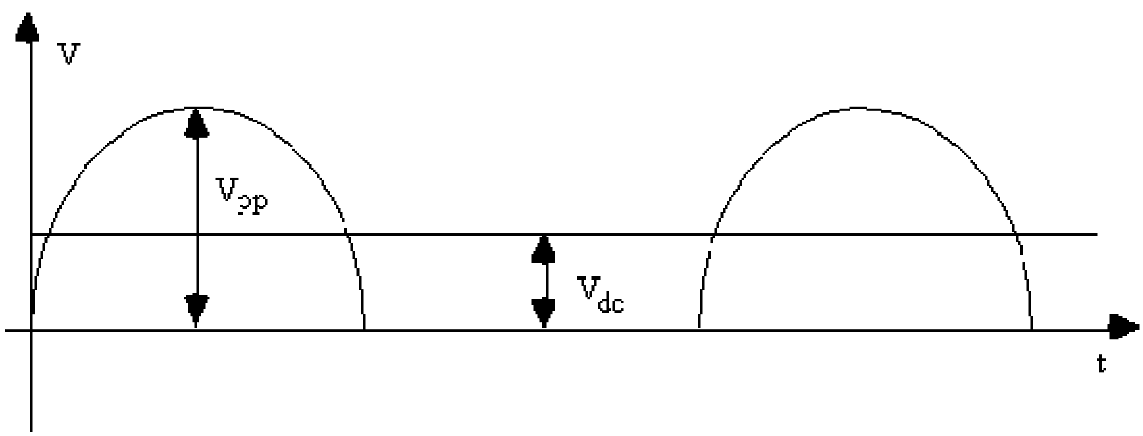

Figure 2

The waveform of Fig.(2) can not be used as a good DC power supply in most applications due to its significant AC component. To make the DC voltage more like the constant voltage of a battery, it is necessary to filter out the AC component. The simplest filter is a capacitor. As shown in Figure 3, a capacitor C is connected in parallel with the load resistor to absorb the fluctuation of the voltage. When the point a is at high voltage, not only the load resistor draws current, the capacitor draws current as well. The capacitor is charged to the peak voltage of the sinusoidal wave form. When the voltage at the point a start to decrease, the capacitor start to discharge through the load resistor. (Why not through the diode?) Namely, the capacitor functions temporarily as a "battery" until the sinusoidal AC voltage becomes higher than the voltage across the capacitor again. The charging and discharging processes repeat themselves every period so that the voltage across the load resistor is kept between certain minimum voltage V_{min} and the maximum voltage V_{max}. (See the waveform in Fig.3)The fluctuation of the voltage is called the ripple voltage, and it is defined as

$$V_{rip} = 0.5\ (V_{max} - V_{min}) \qquad (2)$$

The smaller the ripple voltage, the better the DC power supply. We can therefore define a parameter called the "ripple factor" as one of the criteria of the quality of the power supply:

$$\text{Ripple Factor} = (V_{rip} / V_{dc}) \times 100\% \qquad (3)$$

Apparently, the larger the capacitance, the small the ripple factor and the better the power supply. In order to keep the voltage almost constant, the product of the capacitance and the load resistance needs to be much greater than the period of the AC voltage. (Why?)

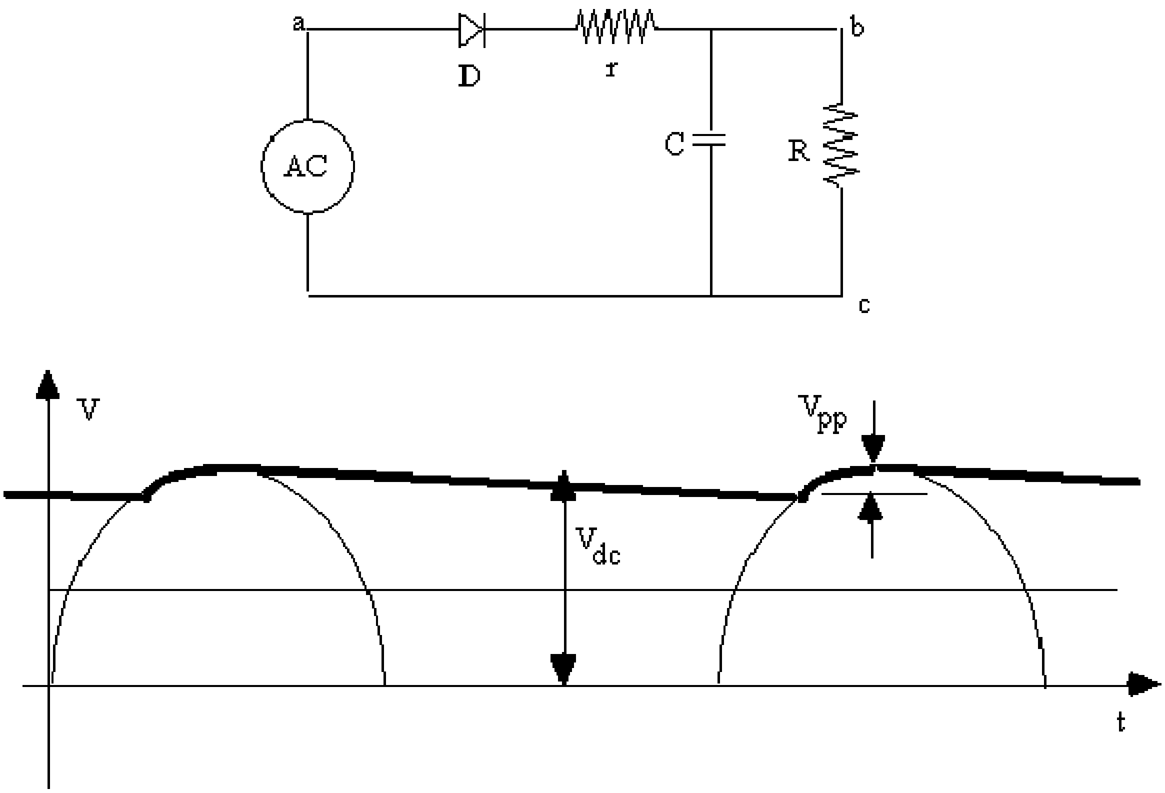

Figure 3

Because the capacitor can draw a current much greater than that passing through the load resistor, a protective resistor r is usually connected in series with the diode to protect the device. This resistor can also improve the filtering function. The disadvantage is that it reduces the maximum voltage and consumes power.

PROCEDURE:

1. Construct a circuit as shown in Fig.(1). Observe the AC waveform before the diode and the rectified waveform across the load resistor. Include a sketch of the rectified waveform in your report. Measure the DC and AC components of the rectified voltage. Calculate the ripple factor.

2. Now insert the RC filter in the circuit as shown in Fig.(3), using the capacitor of 1 μF. Observe the waveform across the load resistor again. Note that waveform would look like the bold curve shown in Fig.(3). The sinusoidal shape is no longer observable. Measure the DC and AC component of the voltage with the capacitor filter. Now the DC component is relatively easy to measure. But AC voltage is too small to measure directly on the same screen with the DC voltage. To get more accurate measurement of the AC component, switch the input coupling to "AC" to show the AC component only, and use the Y-offset adjustment to center the waveform

vertically. Now you can use more sensitive input scale to enlarge the waveform vertically for more accurate measurement of the AC voltage. Calculate the ripple factor for the circuit with filter.

3. Replace the 1 μF capacitor with the 22 μF capacitor. Repeat Step 2 and find the ripple factor for the filter with the larger capacitor.

DATA ANALYSIS

1. Answer the questions

1. Can you design a circuit of full-wave rectifier ?

2. Why is the time constant of the filter equal to RC instead of r C ? (R is the load and r is the charging resistor before the capacitor.)

Reminder: Check you math, check the units, check your graph, do not forget to follow the format for your lab report (see syllabus).