Experiment 5

Diode Rectifier Circuits

Objectives:

In this experiment you will learn how to:

- Measure and calculate all the characteristics of the half-wave rectifier.
- Measure, calculate, and compare the characteristics of full-wave rectifiers.
- Measure and calculate the characteristics of a rectifier with a capacitor filter.
- Design a rectifier circuit with a capacitor filter by proper choice of the transformer secondary voltage and the capacitance value.

❶ Define a rectifier.

A rectifier circuit converts an alternating input to a unidirectional output. This may be accomplished by using unidirectional devices, which allow the passage of current in one direction through the device but not in the opposite direction.

The most common types of unidirectional devices are semiconductor diodes. Ideally, a diode behaves as a perfect switch. In the forward direction it has a zero resistance and zero offset voltage. In the reverse direction, it behaves as an open circuit.

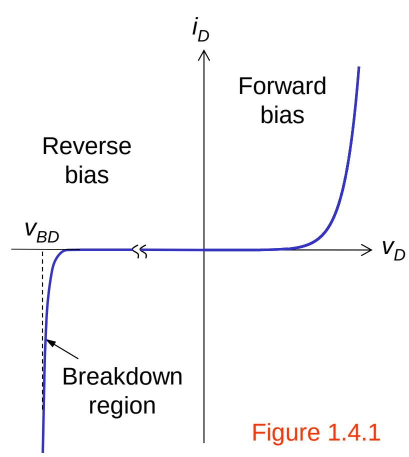


Figure 1.4.1

The half-wave rectifier blocks the negative variations of the input; the output is approximately equal to the input when the input is positive, and is zero otherwise. In the full-wave rectifier, on the other hand, the output is approximately equal to the absolute value of the input.

❷What are the important characteristics of the rectifier?

The most important characteristics which must be specified for a rectifier circuit are:

1. DC output voltage.

The DC output voltage V_{DC} is: (from the highest to the lowest) center-tapped full- wave rectifier, bridge full-wave rectifier (the output is always approximately equal to the absolute value of the input), and then half-wave rectifier (DC output is zero half of the time). The full wave-rectifiers have a greater DC output voltage than the half-wave rectifier.

2. ripple-factor, defined as a ratio of the peak-to-peak ripple (voltage variation in the output) to the average voltage across the load.

The three circuits have approximately the same ripple peak-to-peak voltage. However, the bridge rectifier has a ripple peak-to-peak voltage V_{pp} slightly less due to the two diodes that are conducting at any time.

3. Average and peak currents in each diode.

The average and peak currents in the rectifiers are the greatest in the half-wave rectifier, and they are approximately equal in both full-wave rectifiers since power used is relatively the same amount at the output resistance which is approximately = $P = V_{2rms}^2 / R$.

4. Peak inverse voltage (PIV) for each diode.

The descending order is by the value of the PIV is: center-tapped full- wave rectifier, half-wave rectifier where the PIV equals the peak input voltage; bridge rectifier (equals half that of the center-tap full- wave).

5. Percent regulation, defined as (V_L – V_o / V_o) x 100, where V0 is the no-load voltage and VL is the full-load voltage.

The percent regulation could be represented in the following descending order: the bridge full-wave rectifier, the half-wave rectifier and the center-tapped full-wave rectifier.

6. Transformer requirements, such as the secondary winding voltage and current ratings.

According to the current ratings, we have seen that the half-wave rectifier requires the greatest secondary current while the other two require only half of that value. Therefore, the magnetic polarization is strongest in the half-wave rectifier and the center-tap rectifier.

❸ *Notes:*

It should be carefully noted that these characteristics, depend, in general, upon the type of load connected to the rectifier output, i.e., whether it is resistive, capacitive or inductive.
A transformer is used for stepping-down the input AC voltage. It is a device that transmits AC power from one circuit to another through magnetic coupling, often with no conductive connection. The transformation process obeys the relationships: and, where subscripts 1 and 2 refer to the primary and secondary sides, respectively.

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} \text{ and } \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

A capacitor can be connected *in parallel* at the output of the rectifier to smooth the voltage variations. An approximate

analysis for a full-wave rectifier with a capacitor filter gives the following:

$$\text{PEAK-TO-PEAK RIPPLE VOLTAGE: } V_r \approx \frac{V_{2max}}{2fR_LC}$$

$$\text{DC VOLTAGE: } V_{DC} \approx V_{2max} - \frac{V_r}{2}$$

$$\text{DC CURRENT: } I_{DC} = \frac{V_{DC}}{R_L}.$$

Where V_{2max} is the peak AC input voltage (at the secondary of the transformer), RL is the load resistance, C is the filter capacitance, and f is the frequency of the AC voltage.

❹ *Definition*: **rectifier circuit converts an alternating, or bidirectional, current or voltage to a unidirectional one.**

Half- Wave Rectifier:

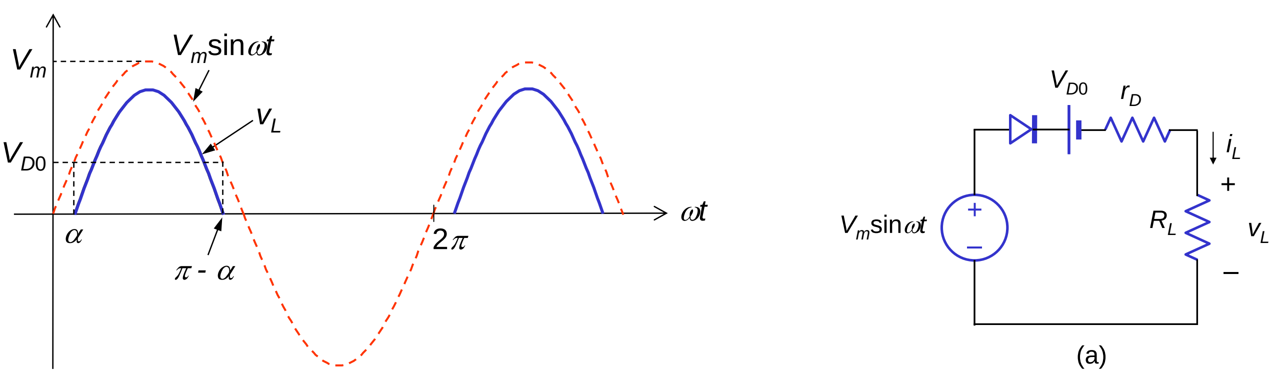


Figure 1.3.1 (b)

Full- wave Rectifier:

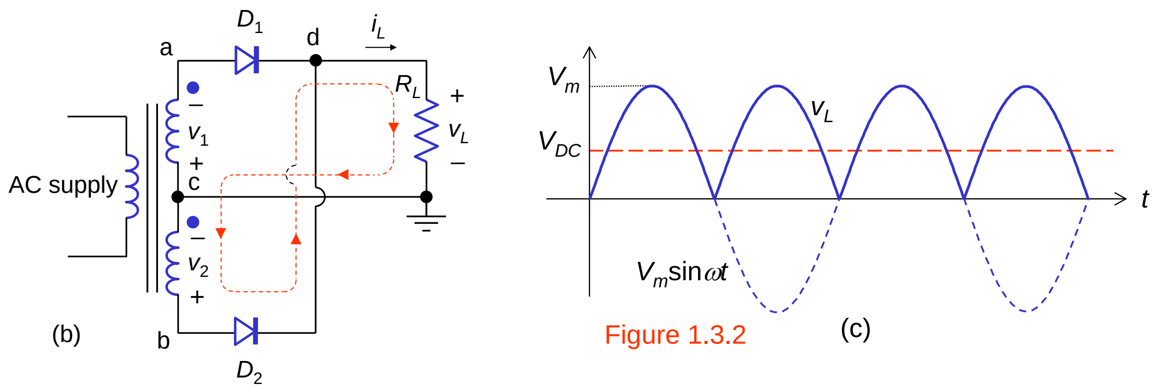
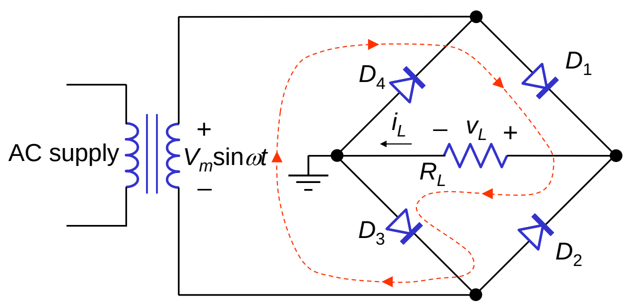


Figure 1.3.2

Bridge Rectifier:



(a)

❺𝒰nder what conditions would each of the circuits be most advantageous?

Full- wave rectifiers are most advantageous for applications that need power for small amounts of time.

Bridge- full- wave rectifiers are cheaper and easier to build than center-tapped ones.

Half- wave rectifier is advantageous for:

- **Applications such as charging a battery because this operation takes more time (twice the time of a full-wave rectifier.**
- **Simplicity and cheap cost.**

❻ *Note:*

For each of the circuits in Figs 1, 2, and 3 we adjust the load resistor to get I_{DC} = 50 mA and we observe the output across the load on the *oscilloscope*.

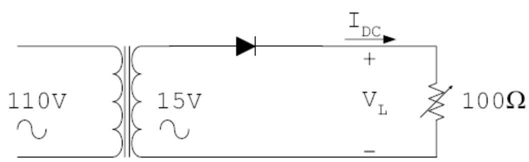


Fig. 1

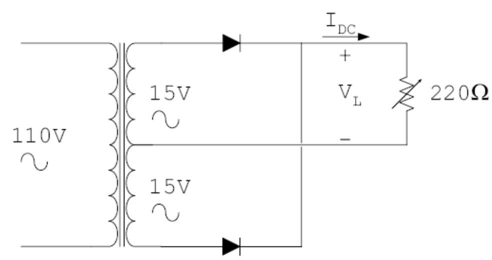


Fig. 2

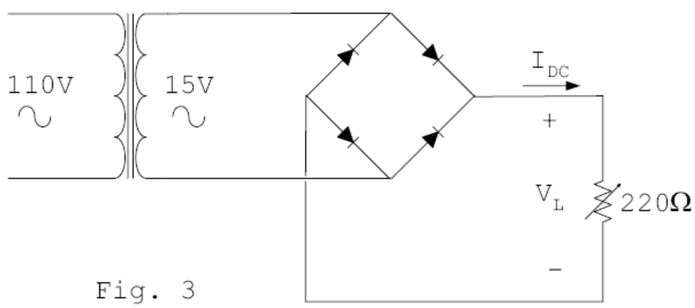
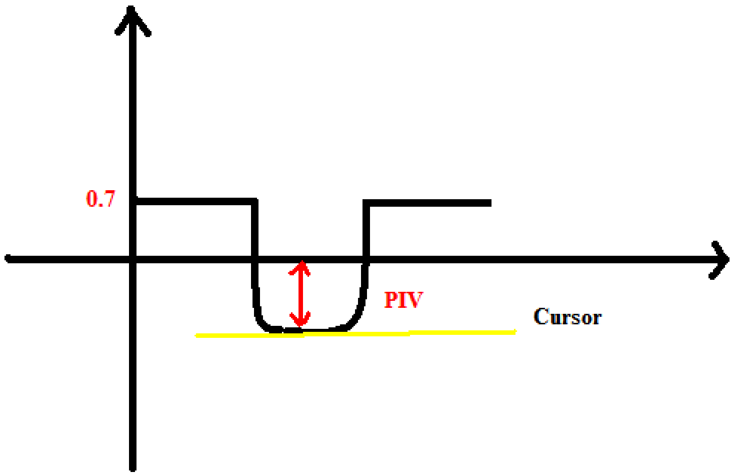


Fig. 3

❼ *H*ow do we find the different quantities mentioned in the Theory section?

- **V_{DC}: DC output voltage measured by the mean value on the oscilloscope screen**
- **V_{ripple}: peak to peak value on the oscilloscope screen**
- **I_{DC}= 50 mA (given) determined by the digital multimeter**
- **I_{peak}= V_{peak}/R (R found by adjusting the rheostat)**
- **PIV: peak inverse voltage. It could be calculated by the oscilloscope across the diode**



- **By the oscilloscope place the horizontal cursor adjust the VOLT/DIV and SEC/DIV settings to get stable traces**

Note: **Vr<<V_{DC} so we need to amplify the ripple**

❽Does V_{DC} increase appreciably with C for all values of C? Does V_r decrease appreciably with C for the values of C used in the experiment?

V_{DC} increases exponentially as C increases.
V_r decreases exponentially but not appreciably.

❾How does the presence of the capacitor affect the regulation of the circuit?

The presence of a capacitor in parallel with the load stabilizes and maintains the output voltage. Moreover, the presence of a capacitor decreases Vr and thus decreases the ripple voltage.

How do we measure the DC open circuit voltage?

- **Remove the resistor**
- **Measure the mean value across the output by the oscilloscope**

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For certain required ripple voltage and DC voltage/current at the load:

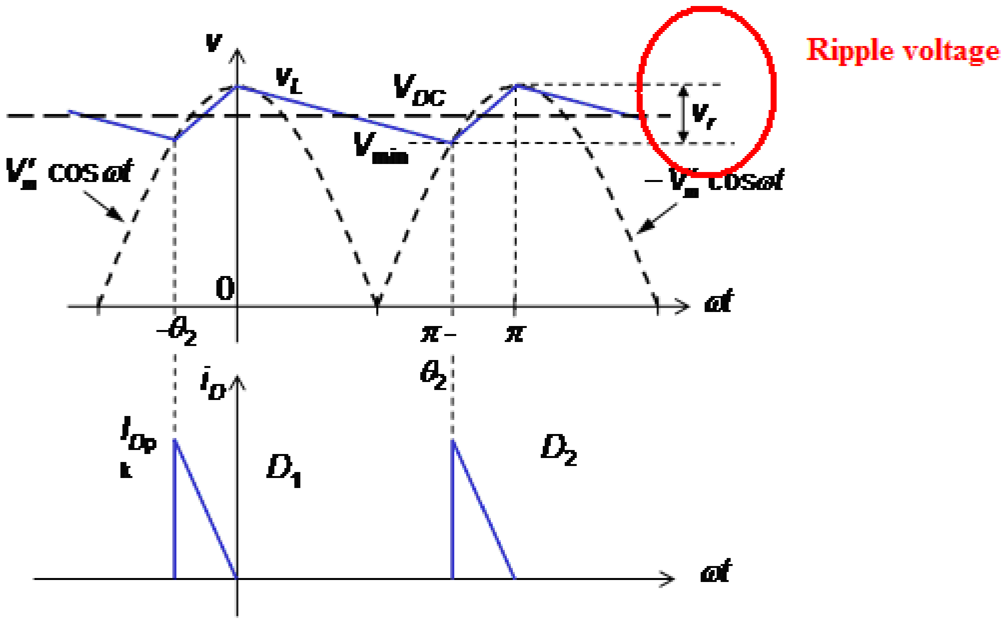
❶⓿What should be the RMS voltage rating of the secondary of the transformer?

Using the formulas from the Theory section we have that:

$$V_{DC} = V_{2\max} - V_r/2 \;\rightarrow\; V_{2\max} = V_{DC} + V_r/2$$

What should be the value of the capacitor?

$$V_r = \frac{V_{2\max}}{2fR_L C} \;\rightarrow\; C = \frac{V_{2\max}}{2fR_L V_r}$$



Ripple voltage
v
v_L
V_DC
V_min
V'_m cos ωt
−V'_m cos ωt
v_r
0
−θ2
π−θ2
π
ωt
i_D
I_Dpk
D1
D2
ωt