CHAPTER 2B: 
DIODE AND APPLICATIONS

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Negatively charged electrons orbit the nucleus in discrete energy levels.
CHAPTER 2B:
OBJECTIVES

• Analyze the operation of 3 basic types of rectifiers
• Describe the operation of rectifier filters and IC regulators
• Analyze the operation of diode limiters and clampers
HALF WAVE RECTIFIERS

- A rectifier is an electronic circuit that converts AC into pulsating DC.
- The voltage conversion process is known as half-wave rectification.
- When the sinusoidal input voltage goes positive, the diode is forward-biased and conducts current to the electrical load (resistor in Figure 2-15(a)).
FIGURE 2-15 Operation of half-wave rectifier. The diode is considered ideal.

(a) Half-wave rectifier

(b) Operation during positive alternation of the input voltage; diode conducts.

(c) Operation during negative alternation of the input voltage. Diode does not conduct; therefore, the output voltage is zero.

(d) Half-wave output voltage for three input cycles
HALF WAVE RECTIFIERS...

• The output voltage is equal to the peak voltage less one diode drop.

EQ1: \( V_{p(out)} = V_{p(in)} - 0.7V \)

• The current produces a voltage across the load, which has the same shape as the positive half-cycle of the input voltage.
HALF WAVE RECTIFIERS...

• In working with diode circuits, it is sometimes practical to neglect the diode drop when the peak value is much greater than the barrier potential.

• This analysis technique is equivalent to the using the Ideal diode model for electronic product diagnostics and validation.
FULL WAVE RECTIFIERS

• The difference between Full Wave and Half wave rectification is the full wave rectifier allows unidirectional current to the load during the entire input cycle.

• The half wave rectifier allows current only during one-half of the cycle.

• The result of the full wave rectification is a dc output voltage that pulsates every half cycle of the input. (See Figure 2-18.)
FIGURE 2-18  Full-wave rectification.
FIGURE 2-16
THE CENTER-TAPPED FULL WAVE RECTIFIER

- The center-tapped (CT) full wave rectifier uses 2 diodes connected to the secondary of a center-tapped transformer (See Figure 2-19).

- The input signal is coupled through the transformer (AC Electronics) to the secondary.

- Half of the total secondary voltage appears between the center tap and each of the secondary windings as shown in Figure 2-19.
FIGURE 2-19  A center-tapped (CT) full-wave rectifier.

[Diagram of a center-tapped full-wave rectifier]
EFFECTS OF THE TURN RATIO ON THE FULL WAVE OUTPUT VOLTAGE

• If the turns ratio of the transformer is 1, the peak value of the rectified output equals half the peak value of the primary input voltage less one diode drop.

• Value occurs because half of the input voltage appears across each half of the secondary voltage.

• In order to obtain a peak output voltage equal to the peak input voltage (less the barrier potential), a step up transformer with a turns ratio of 2 (1:2) is used.
PEAK INVERSE VOLTAGE

• Each diode in the full wave rectifier is alternatively forward-biased and then reversed biased.

• The maximum reverse voltage that each diode must withstand is the peak value of the total secondary voltage ($V_{sec}$).

• The peak inverse voltage either diode in the center tapped full wave rectifier is:

$$\text{EQ2: } \text{PIV} = V_{p(out)}$$
BRIDGE RECTIFIERS

• The bridge rectifier uses 4 diodes as shown in Figure 2-23.

• The most popular arrangement for power supplies because it does not require a center-tapped transformer.

• The four diodes are available in a single package, already wired in a bridge configuration.

• The bridge rectifier is a type of full wave rectifier because each half of the sine wave contributes to the output.
FIGURE 2-23  Operation of the full-wave rectifier. Conducting paths in the secondary are shown in color.

(a) During positive half-cycle of the input, $D_1$ and $D_2$ are forward-biased and conduct current. $D_3$ and $D_4$ are reverse-biased.

(b) During negative half-cycle of the input, $D_3$ and $D_4$ are forward-biased and conduct current. $D_1$ and $D_2$ are reverse-biased.
BRIDGE OUTPUT VOLTAGE

• Neglecting the diode drops, the total secondary voltage, $V_{sec}$ appears across the electrical load.

\[
\text{EQ3: } V_{\text{out}} = V_{\text{sec}}
\]

• If these diode drops are taken into account, the output voltage (with Si diodes) is:

\[
\text{EQ4: } V_{\text{out}} = V_{\text{sec}} - 0.7V
\]
PEAK INVERSE VOLTAGE (PIV)

• When $D_1$ and $D_2$ are forward bias, the reverse voltage is across $D_3$ and $D_4$.

• Visualizing $D_1$ and $D_2$ as shorts (ideally), the PIV is equal to the peak secondary voltage.

EQ5: $PIV = V_{p(out)}$
CAPACITOR-INPUT FILTER

• A half wave rectifier with a capacitor input filter is shown in Figure 2-24.

• During the positive first quarter-cycle of the input, the diode is forward biased, allowing the capacitor to charge to within a diode drop of the input peak.

• When the input begins to decrease below its peak, the capacitor retains its charge and the diode becomes reverse bias.

• During the remaining part of the cycle and the beginning of the next cycle, the capacitor can discharge only through the load resistance at a rate determined by the RC time constant.
FIGURE 2-24  Operation of a half-wave rectifier with a capacitor-input filter.

(a) Initial charging of capacitor (diode is forward-biased) happens only once when power is turned on.

(b) The capacitor discharges through $R_L$ after peak of positive alternation when the diode is reverse-biased. This discharging occurs during the portion of the input voltage indicated by the solid colored curve.

(c) The capacitor charges back to peak of input when the diode becomes forward-biased. This charging occurs during the portion of the input voltage indicated by the solid colored curve. Notice that the diode is not forward-biased on the second cycle until the capacitor voltage is overcome.
RIPPLE VOLTAGE

• The variation in the capacitor voltage due to the charging and discharging is called the **ripple voltage**.

• The smaller the ripple voltage, the better the filtering action.

• For a given input frequency, the output frequency of a full wave rectifier is twice that of a half wave rectifier.

• As a result, a full wave rectifier is easier to filter because of the shorter time between peaks.
FIGURE 2-25  Comparison of ripple voltages for half-wave and full-wave rectifier outputs with the same filter capacitor and derived from the same sinusoidal input.
SURGE CURRENT IN THE CAPACITOR
INPUT FILTER

• When the power is first applied to a power supply, the filter capacitor is uncharged.

• At the instant the switch is closed, voltage is connected to the rectifier and the uncharged capacitor appears as a short.

• This case is illustrated for a bridge circuit in Figure 2-26(a).

• An initial surge of current is produced through the forward-biased diodes.
FIGURE 2-26  Surge current in a capacitor-input filter follows the path drawn in color.
SURGE CURRENT IN THE CAPACITOR

INPUT FILTER...

• It is possible that the surge current could destroy the diodes, for this reason a surge-limiting resistor $R_{\text{surge}}$, is sometimes connected. (See Figure 2-26(b)).

• The value of this resistor must be small to avoid a significant voltage drop across it.

• The diode must have a forward current rating that can handle the momentary surge of current.
IC REGULATORS

• The most effective filter is a combination of a capacitor-input filter with an IC regulator.

• In general, and IC (Integrated Circuit) is a complete functional circuit constructed on a single, tiny chip of silicon.

• An integrated circuit regulator is an IC that is connected to the output of rectifier an maintains a constant output voltage or current despite changes in the input.
FIGURE 2-27  The 7800 series three-terminal fixed positive voltage regulators.

(a) Standard configuration

(b) The 7800 series

<table>
<thead>
<tr>
<th>Type number</th>
<th>Output voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>7805</td>
<td>+5.0 V</td>
</tr>
<tr>
<td>7806</td>
<td>+6.0 V</td>
</tr>
<tr>
<td>7808</td>
<td>+8.0 V</td>
</tr>
<tr>
<td>7809</td>
<td>+9.0 V</td>
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<tr>
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<td>+15.0 V</td>
</tr>
<tr>
<td>7818</td>
<td>+18.0 V</td>
</tr>
<tr>
<td>7824</td>
<td>+24.0 V</td>
</tr>
</tbody>
</table>

(c) Typical metal and plastic packages

Pins 1 and 2 are electrically isolated from case. Case is third electrical connection.
IC REGULATORS...

• Three terminal regulators designed for a fixed output voltage require only external capacitors to complete the regulation portion of the power (See Figure 2-27(a)).

• Filtering is accomplished by a large-value capacitor between the input voltage and ground.

• Sometimes a second smaller-value input capacitor is connected in parallel, especially if the filter capacitor is not close to the IC regulator to prevent transients and internal oscillation.
FIGURE 2-28  A basic +5.0 V(fixed) power supply.

**IC REGULATORS: 7805**

$D_1-D_4$ are 1N4001 silicon rectifier diodes.
FIGURE 2-29  A basic power supply with a **variable** output voltage (from 1.25 V to 6.5V).

**IC REGULATORS: LM317**

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D₁–D₄ are 1N4001 silicon rectifier diodes.
• Diode circuits, called limiters, or clippers are sometimes used to clip off portions of the signal voltages above or below certain levels.

• Another type of diode circuit, called a clamper, is used to restore a dc level to an electrical signal.
DIODE LIMITERS

Diode Limiter is an electronic circuit that limits or clips off the positive or negative part of the input signal. See Figures 2-30(a) and (b).

• The negative or positive signal limiting function is based on if the diode is wired in a forward or reverse biased mode.
FIGURE 2-30  Diode limiting (clipping circuits).

(a) Limiting of the positive alternation; diode conducts on positive alternation.

(b) Limiting of the negative alternation; diode conducts on negative alternation.
DETERMING $V_{OUT}$

• Whenever the input is below 0.7V, the diode is reversed biased and appears as an open.

• The output voltage $V_{OUT}$ looks like the negative part of the input, but with a magnitude determined by the voltage divider formed by $R_1$ and $R_L$, as follows:

$$EQ5: V_{OUT} = \left(\frac{R_L}{R_1+R_L}\right) \times V_{IN}$$

• If $R_1$ is small compared to $R_L$, then $V_{OUT} \approx V_{IN}$
DIODE CLAMPERS

• Diode Clamper adds a dc level to an ac signal.

• Clampers are sometimes known as dc restorers. See Figure 2-40.

• The net effect of the clamping action is the capacitor retains a charge approximately equal to the peak value of the input less the diode drop.
FIGURE 2-40  Positive clamping. The diode allows the capacitor to charge rapidly. The capacitor can discharge only through $R_L$. 

(a) Diode conducts and charges $C$.

(b) When $C$ is charged, it acts like a battery.

(c) The capacitor voltage adds to the ac input voltage.