APPLICATIONS OF DIODES:

Diodes are used in so many ways that we will not be able to discuss all of them.

The major applications of the diodes that will be discussed are:

(a) Rectifiers
(b) Clippers or Limiters
(c) Clampers
(d) Voltage Multipliers
Half-wave rectifier

\[ v_i = V_m \sin \omega t \]
Fig. 2.45  Conduction region (0 → T/2).
Fig. 2.46  Nonconduction region ($T/2 \rightarrow T$).
Fig. 2.47  Half-wave rectified signal.
Fig. 2.48  Effect of $V_K$ on half-wave rectified signal.
Fig. 2.49  Network for Example 2.16.
Fig. 2.50 Resulting $v_o$ for the circuit of Example 2.16.
**Fig. 2.51** Effect of $V_K$ on output of Fig. 2.50.

\[ 20 \text{ V} - 0.7 \text{ V} = 19.3 \text{ V} \]
Full-wave bridge rectifier
Fig. 2.54  Network of Fig. 2.53 for the period $0 \rightarrow T/2$ of the input voltage $v_i$. 
Fig. 2.55  Conduction path for the positive region of $v_i$. 
Fig. 2.56  Conduction path for the negative region of $v_i$. 
Fig. 2.57  Input and output waveforms for a full-wave rectifier.

\[ V_{dc} = 0.636V_m \]
Fig. 2.58  Determining $V_{o_{\text{max}}}$ for silicon diodes in the bridge configuration.
Full-Wave Rectifier using a center-tapped secondary
Fig. 2.61  Network conditions for the positive region of $v_i$. 
Fig. 2.62  Network conditions for the negative region of $v_i$. 
Fig. 2.64  Bridge network for Example 2.17.
Fig. 2.65  Network of Fig. 2.64 for the positive region of $v_i$. 

![Graph showing a voltage waveform and a circuit diagram]
Fig. 2.66  Redrawn network of Fig. 2.65.
Fig. 2.67   Resulting output for Example 2.17.
CLIPPERS (LIMITERS)

• How to draw the output waveform
• How to draw the transfer function

Series clipper:
Series clipper with a dc supply
Fig. 2.70  Determining the transition level for the circuit of Fig. 2.69.

\[ v_o = i_R R = i_d R = (0)R = 0 \text{ V} \]
Fig. 2.71 Using the transition voltage to define the “on” and “off” regions.
Fig. 2.72  Determining $v_o$ for the diode in the “on” state.
Fig. 2.73  Sketching the waveform of $v_o$ using the results obtained for $v_o$ above and below the transition level.

$v_i = V$ (diodes change state)
Example: Draw $V_{out}$ and sketch the transfer function.
Fig. 2.75  Determining the transition level for the clipper of Fig. 2.74.

\[ v_i \]

\[ v_d = 0 \text{ V} \]

\[ i_d = 0 \text{ A} \]

\[ v_o = v_R = i_R R = i_d R = (0) R = 0 \text{ V} \]
Fig. 2.76  Sketching $v_o$ for Example 2.18.
Fig. 2.77  Applied signal for Example 2.19.
Fig. 2.78 \( v_o \) at \( v_i = +20 \) V.
Fig. 2.79  $v_o$ at $v_i = -10 \text{ V}$. 
Fig. 2.80 Sketching $v_o$ for Example 2.19.
Response to a parallel clipper
Example: draw $V_o$ and the transfer curve
Fig. 2.83 Determining the transition level for Example 2.20.
Fig. 2.84  Sketching $v_o$ for Example 2.20.
Fig. 2.85  Determining the transition level for the network of Fig. 2.82.

\[ v_R = i_R R = i_d R = (0) \quad R = 0 \text{ V} \]

\[ v_i \]

\[ v_o \]

\[ V = 4 \text{ V} \]

\[ V_K = 0.7 \text{ V} \]
Fig. 2.86  Determining $v_o$ for the diode of Fig. 2.82 in the “on” state.
Fig. 2.87  Sketching $v_o$ for Example 2.21.
Clipping circuits

Simple Series Clippers (Ideal Diodes)

POSITIVE

NEGATIVE

Biased Series Clippers (Ideal Diodes)

Simple Parallel Clippers (Ideal Diodes)

Biased Parallel Clippers (Ideal Diodes)
Clamper
Fig. 2.90  Diode “on” and the capacitor charging to $V$ volts.
Fig. 2.91  Determining $v_o$ with the diode "off."
Fig. 2.92  Sketching \( v_o \) for the network of Fig. 2.91.
Example: For the given input signal, sketch the output voltage if:

1- Diode is ideal
2- Diode is silicon
Fig. 2.94  Determining $v_o$ and $V_C$ with the diode in the “on” state.
Fig. 2.95  Determining $v_o$ with the diode in the “off” state.
Fig. 2.96 \( v_i \) and \( v_o \) for the clamper of Fig. 2.93.
Fig. 2.97  Determining $v_o$ and $V_C$ with the diode in the “on” state.
Fig. 2.98 Determining $v_o$ with the diode in the open state.
Fig. 2.99  Sketching $v_o$ for the clamper of Fig. 2.93 with a silicon diode.
Fig. 2.100  Clamping circuits with ideal diodes ($5\tau = 5RC >> T/2$).
Example: Clamping network with a sinusoidal input
Zener Diode

A zener diode is a specially fabricated diode with heavily doped p- and n- type Semiconductors. It has relatively low reverse breakdown voltage. When the inverse voltage applied across s the Zener diode increases beyond its reverse breakdown voltage, the electric field thus created in the depletion cause s some electrons to go across the potent ial barrier.
A zener diode behaves exactly like any other diode when it is forward biased, i.e. the anode voltage is greater than the cathode voltage. There is no reason to use a zener diode for an application that calls for a regular, low-cost diode. Therefore, the zener diode is almost always reverse biased and is expected to carry current in the reverse direction.
Fig. 2.102  Approximate equivalent circuits for the Zener diode in the three possible regions of application.
Fig. 2.106  Basic Zener regulator.
Fig. 2.107  Determining the state of the Zener diode.
Fig. 2.108  Substituting the Zener equivalent for the “on” situation.
Example

In the circuit of Figure 2.37, \( R_L = 2 \text{k}\Omega \) and \( R = 1 \text{k}\Omega \). The breakdown voltage of an ideal zener diode is 10 V. The input voltage varies as shown in Figure 2.38a. Sketch the output voltage.
Let us first sketch the output voltage ignoring the presence of the zener diode. In terms of \( v(t) \) in, the output voltage is

\[
v_o(t) = \frac{R_L}{R_L + R} v_{\text{in}}(t) = \frac{2}{3} v_{\text{in}}(t)
\]

When

\[ v_{\text{in}}(t) = 12 \text{ V}, \quad V_o(t) = 8 \text{ V} \]

Likewise,

\[ v_{\text{in}}(t) = 24 \text{ V}, \quad V_o(t) = 16 \text{ V} \]
Fig. 2.109  Zener diode regulator for Example 2.26.
Fig. 2.110  Determining $V$ for the regulator of Fig. 2.109.
Fig. 2.111  Resulting operating point for the network of Fig. 2.109.
Fig. 2.112  Network of Fig. 2.109 in the “on” state.
Fig. 2.113  Voltage regulator for Example 2.27.

$V_i = 50 \, V$

$V_Z = 10 \, V$

$I_{ZM} = 32 \, mA$

$R = 1 \, k\Omega$

$I_R$

$I_L$

$R_L$
Fig. 2.114 $V_L$ versus $R_L$ and $I_L$ for the regulator of Fig. 2.113.
Fig. 2.115  Regulator for Example 2.28.

\[ V_Z = 20 \text{ V} \]
\[ I_{ZM} = 60 \text{ mA} \]
Fig. 2.116 $V_L$ versus $V_i$ for the regulator of Fig. 2.115.
Half-wave voltage doubler
Fig. 2.119  Double operation, showing each half-cycle of operation: (a) positive half-cycle; (b) negative half-cycle.
Full-wave voltage doubler
Fig. 2.121  Alternate half-cycles of operation for full-wave voltage doubler.
Voltage Tripler and Quadrupler

The circuit diagram shows a voltage tripler and quadrupler. The tripler (3$V_m$) is connected with capacitors $C_1$ and $C_3$ and diodes $D_1$ and $D_3$. The doubler (2$V_m$) is connected with capacitors $C_2$ and $C_4$ and diodes $D_2$ and $D_4$. The quadrupler (4$V_m$) is connected with capacitors $C_1$, $C_2$, $C_3$, and $C_4$. The diagram illustrates the process of doubling and tripling the voltage using diodes and capacitors.
Fig. 2.137 Providing different reference levels using diodes.
Fig. 2.138  (a) How to drive a 6-V load with a 9-V supply (b) using a fixed resistor value. (c) Using a series combination of diodes.
Fig. 2.138 (continued)  (a) How to drive a 6-V load with a 9-V supply (b) using a fixed resistor value. (c) Using a series combination of diodes.
Fig. 2.138 (continued)  (a) How to drive a 6-V load with a 9-V supply (b) using a fixed resistor value. (c) Using a series combination of diodes.

+0.7 V - +0.7 V - +0.7 V - +0.7 V -

\[ + \text{2.8 V} - \]

\[ 9 \text{ V} \]

\[ R_L \]

\[ + \]

\[ \text{6.2 V} \]

\[ \text{with } R_L = 1 \text{ k}\Omega \text{ or } 600 \Omega \]
Fig. 2.139  Sinusoidal ac regulation: (a) 40-V peak-to-peak sinusoidal ac regulator; (b) circuit operation at $v_i = 10$ V.

[Diagram showing sinusoidal input signal, two 20-V Zeners, and the output waveform with a peak of 20 V at $v_i = 10$ V.]
Fig. 2.140  Simple square-wave generator.

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*Electronic Devices and Circuit Theory, 9e*