Electronic Devices and Circuit Theory

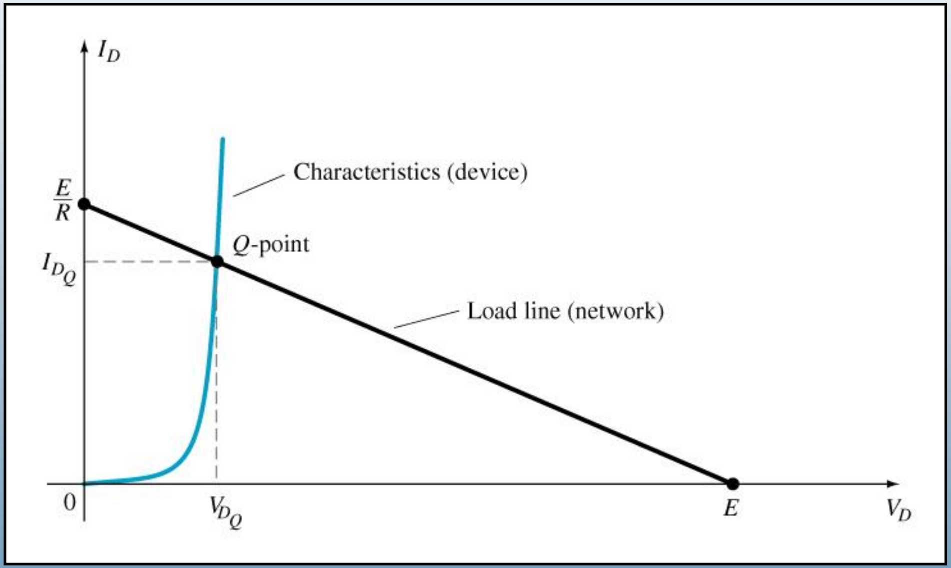
Boylestad

Diode Applications

Chapter 2

Load-Line Analysis

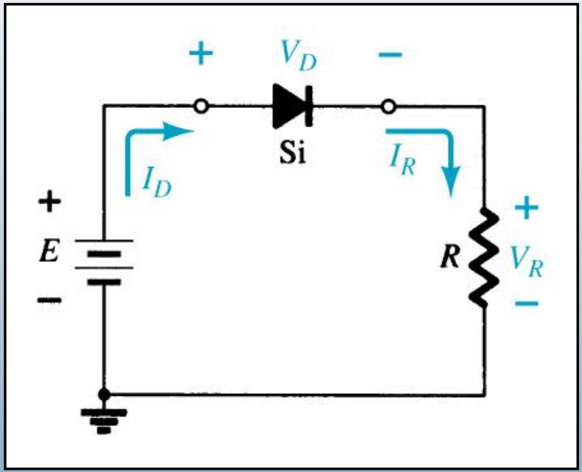
The load line plots all possible combinations of diode current (I_D) and voltage (V_D) for a given circuit. The maximum I_D equals E/R, and the maximum V_D equals E.



The point where the load line and the characteristic curve intersect is the Q-point, which identifies I_D and V_D for a particular diode in a given circuit.

Series Diode Configurations

Forward Bias



Constants

Silicon Diode: V_D = 0.7 V

Germanium Diode: V_D = 0.3 V

Analysis (for silicon)

V_D = 0.7 V (or $V_D = E$ if $E < 0.7$ V)

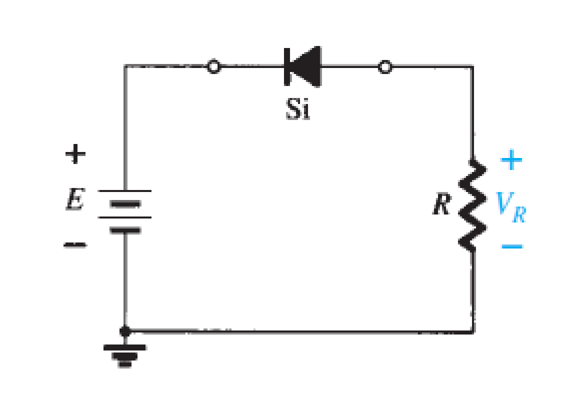
$V_R = E - V_D$

$I_D = I_R = I_T = V_R / R$

Series Diode Configurations

Reverse Bias

Diodes ideally behave as open circuits

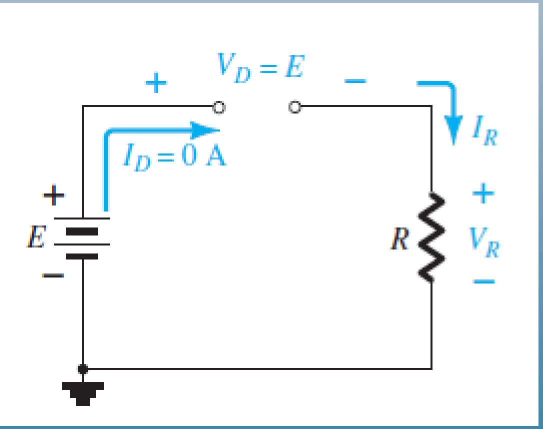


Analysis

$V_D = E$

$V_R = 0$ V

$I_D = 0$ A



Parallel Diode Configurations

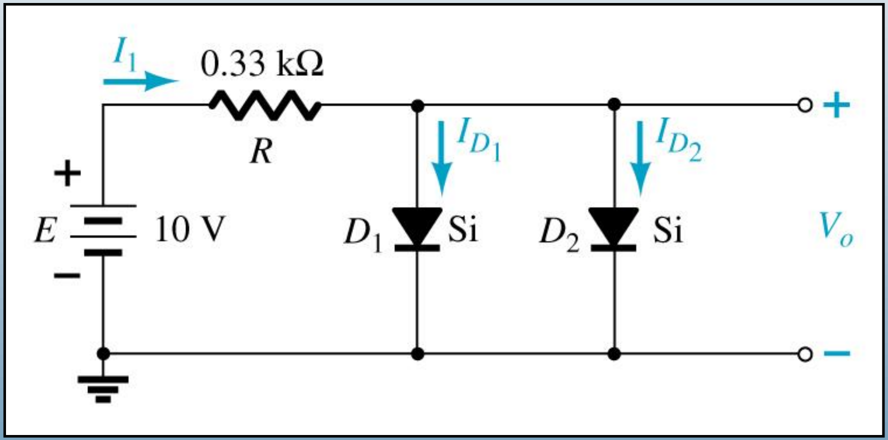
$$V_D = 0.7V$$

$$V_{D1} = V_{D2} = V_o = 0.7V$$

$$V_R = 9.3V$$

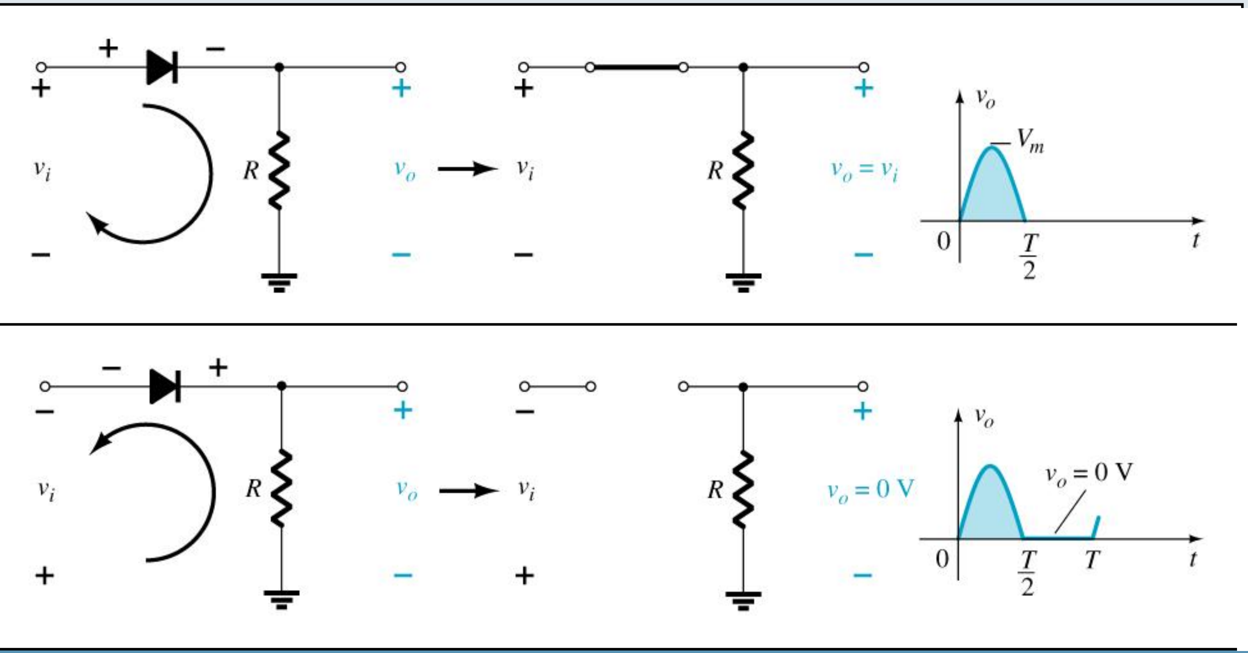
$$I_R = \frac{E - V_D}{R} = \frac{10V - .7V}{.33\,k\Omega} = 28\,mA$$

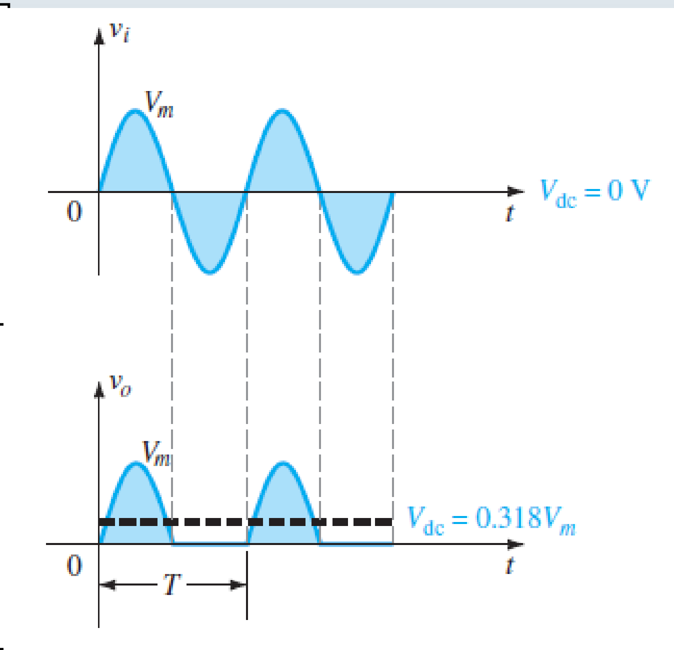
$$I_{D1} = I_{D2} = \frac{28\,mA}{2} = 14\,mA$$



Half-Wave Rectification

The diode conducts only when it is forward biased, therefore only half of the AC cycle passes through the diode to the output.





The DC output voltage is (1/π) x V_m = $0.318V_m$, where V_m = the peak AC voltage.

PIV (PRV)

Because the diode is only forward biased for one-half of the AC cycle, it is also reverse biased for one-half cycle.

It is important that the reverse breakdown voltage rating of the diode be high enough to withstand the peak, reverse-biasing AC voltage.

$$\textbf{PIV (or PRV)} > V_m$$

Where **PIV** = Peak inverse voltage

PRV = Peak reverse voltage

V_m = Peak AC voltage

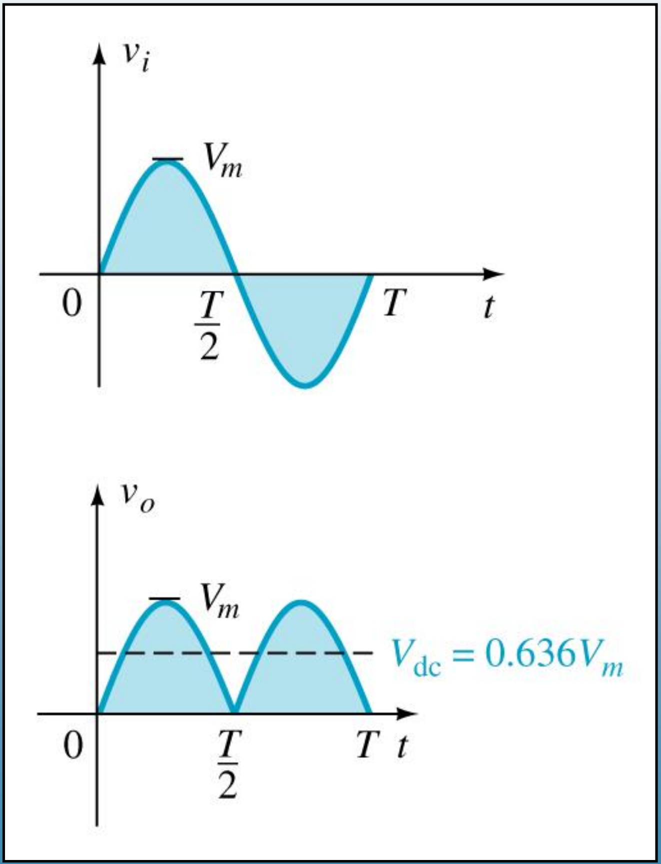
Full-Wave Rectification

The rectification process can be improved by using a full-wave rectifier circuit.

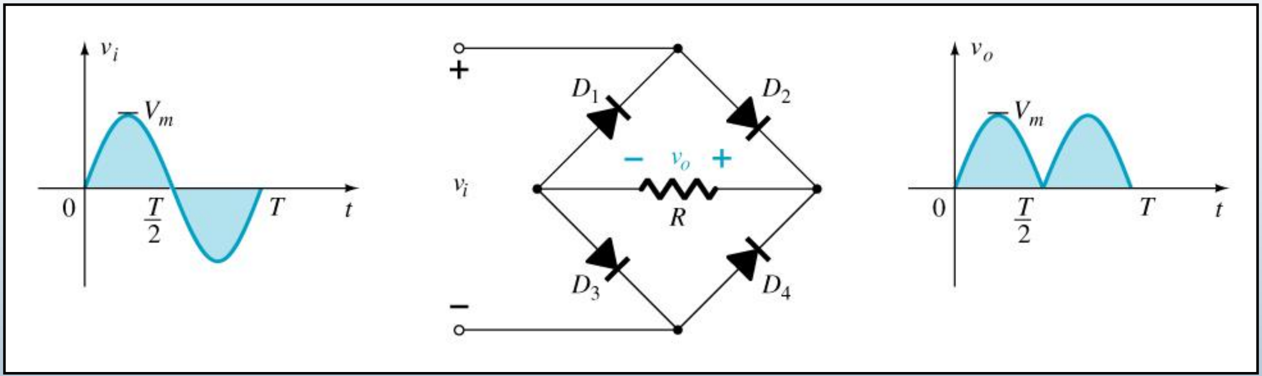
Full-wave rectification produces a greater DC output:

Half-wave: $V_{dc} = 0.318V_m$

Full-wave: $V_{dc} = 0.636V_m$



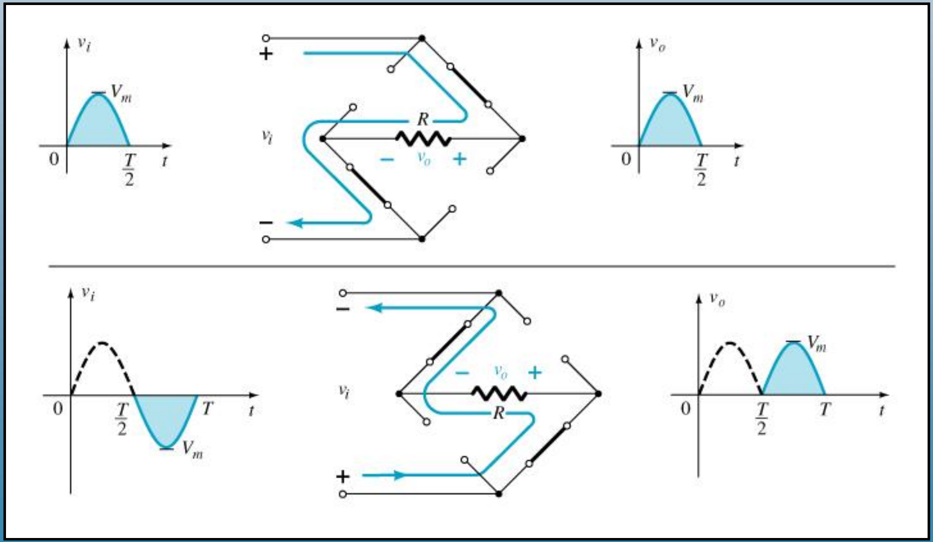
Full-Wave Rectification



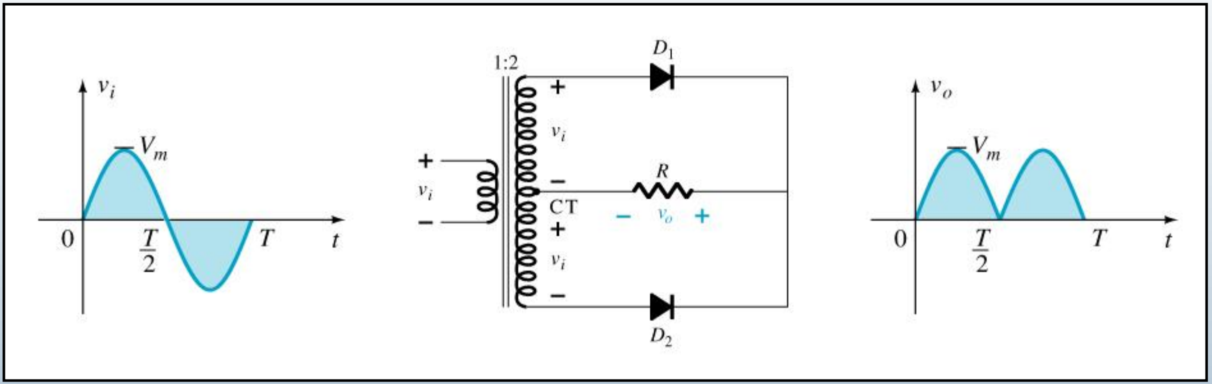
Bridge Rectifier

A full-wave rectifier with four diodes that are connected in a bridge configuration

$$V_{DC} = 0.636V_m$$



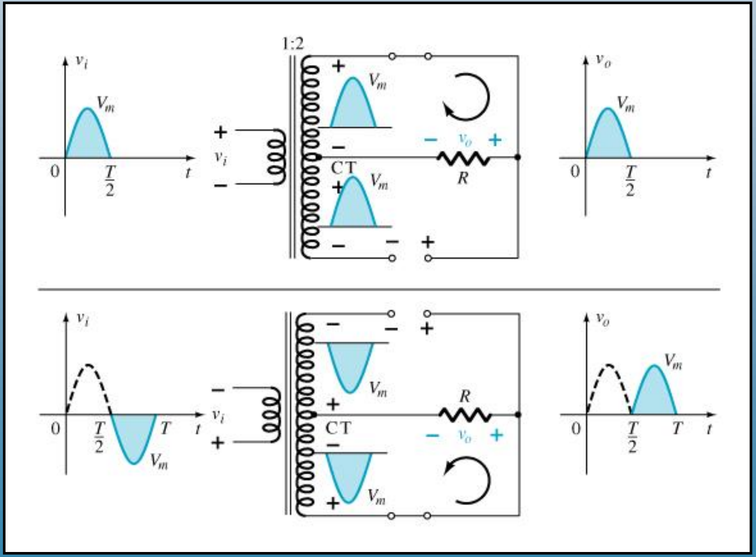
Full-Wave Rectification



Center-Tapped Transformer Rectifier

Requires two diodes and a center-tapped transformer

$$V_{DC} = 0.636V_m$$



Summary of Rectifier Circuits

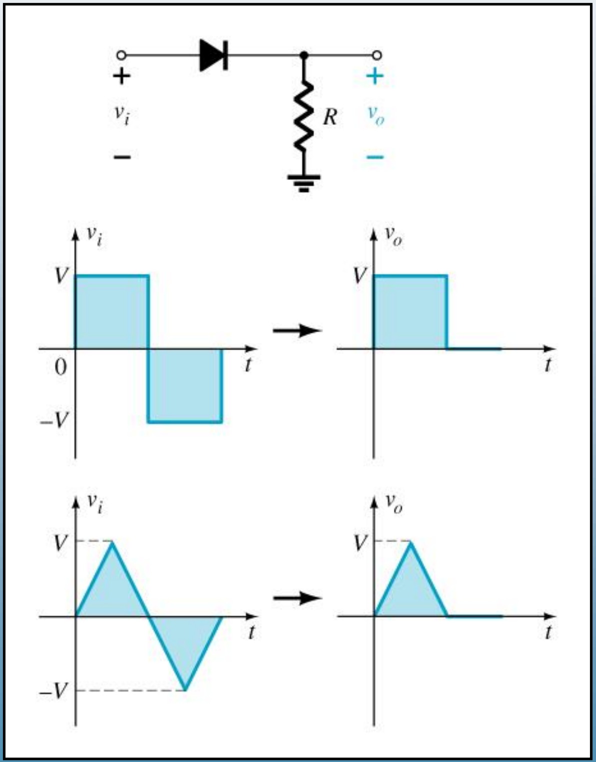
Rectifier	Ideal V_{DC}	Realistic V_{DC}
Half Wave Rectifier	$V_{DC} = 0.318V_m$	$V_{DC} = 0.318V_m - 0.7$
Bridge Rectifier	$V_{DC} = 0.636V_m$	$V_{DC} = 0.636V_m - 2(0.7\ V)$
Center-Tapped Transformer Rectifier	$V_{DC} = 0.636V_m$	$V_{DC} = 0.636V_m - 0.7\ V$

V_m = the peak AC voltage

Diode Clippers

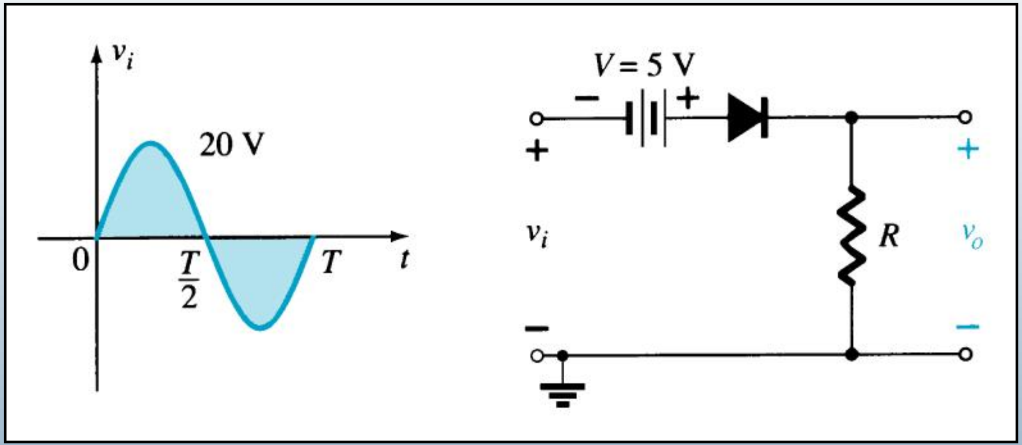
The diode in a series clipper "clips" any voltage that does not forward bias it:

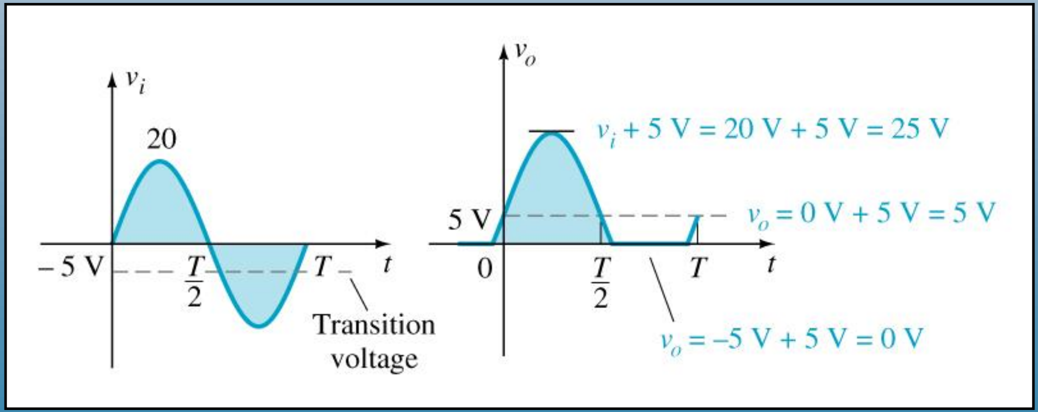
- A reverse-biasing polarity
- A forward-biasing polarity less than 0.7 V (for a silicon diode)



Biased Clippers

Adding a DC source in series with the clipping diode changes the effective forward bias of the diode.

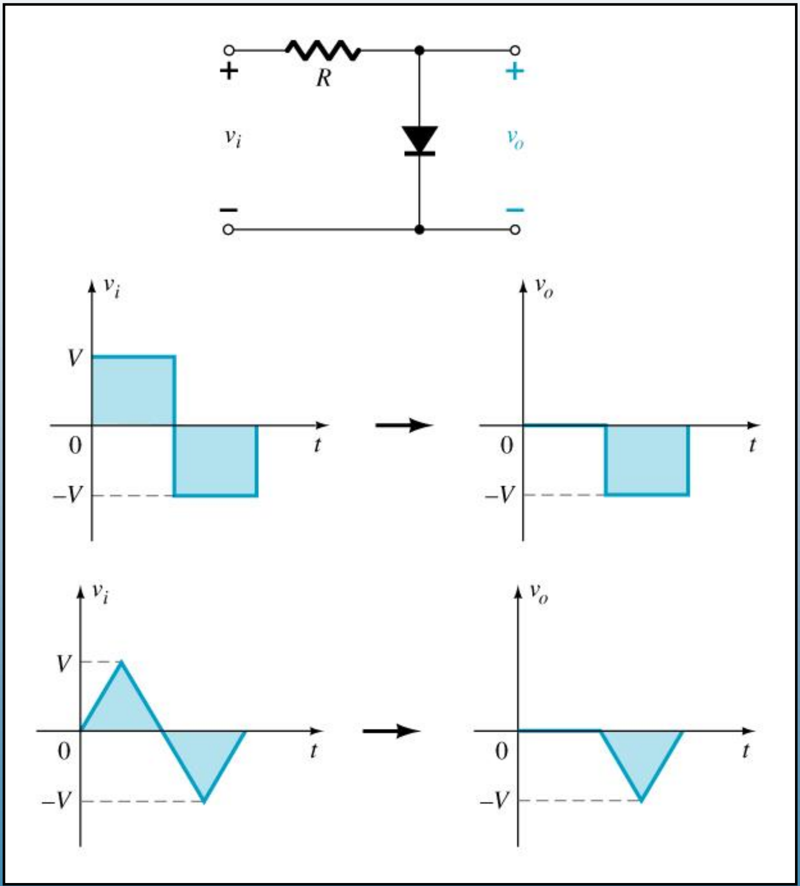




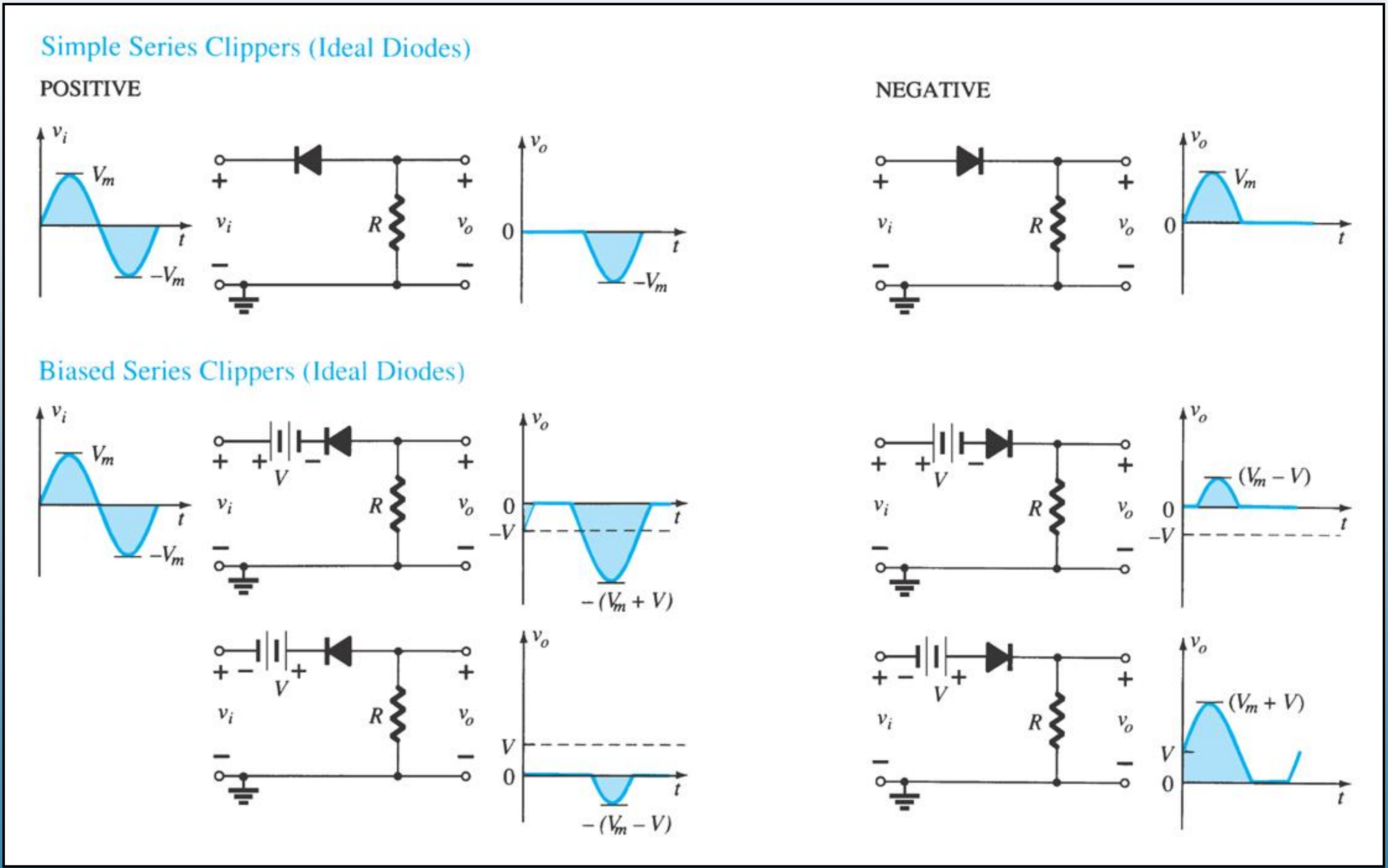
Parallel Clippers

The diode in a parallel clipper circuit "clips" any voltage that forward biases it.

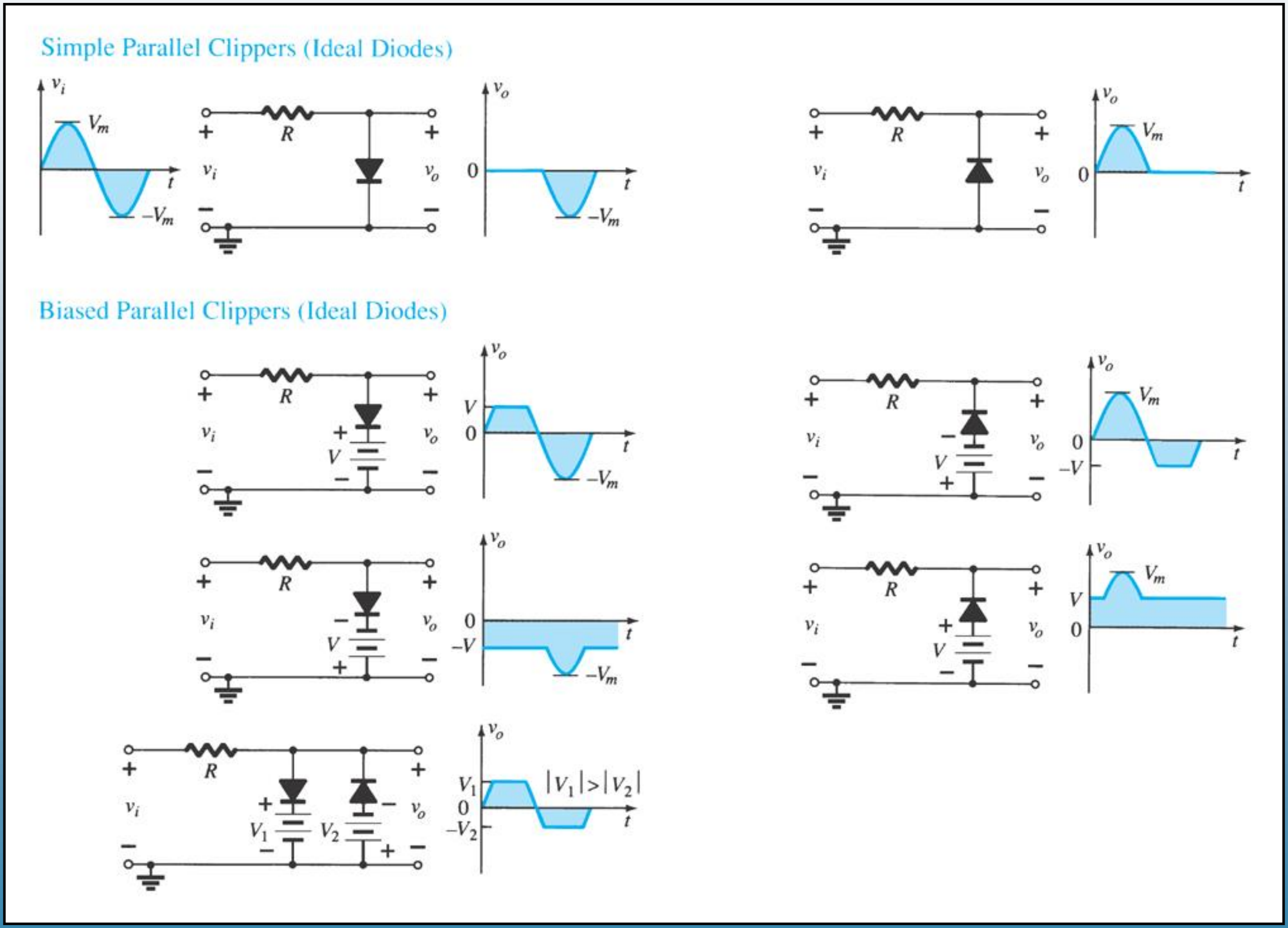
DC biasing can be added in series with the diode to change the clipping level.



Summary of Clipper Circuits

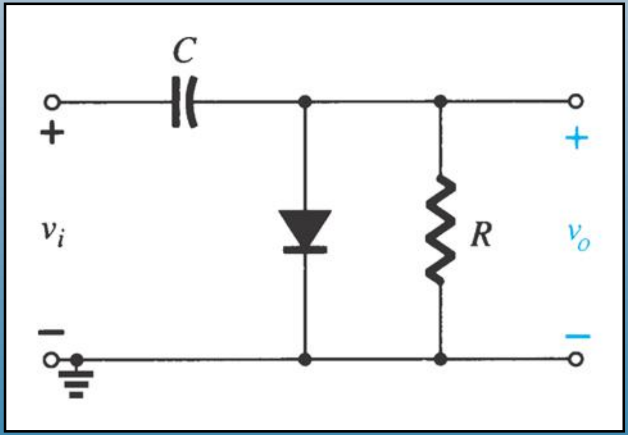


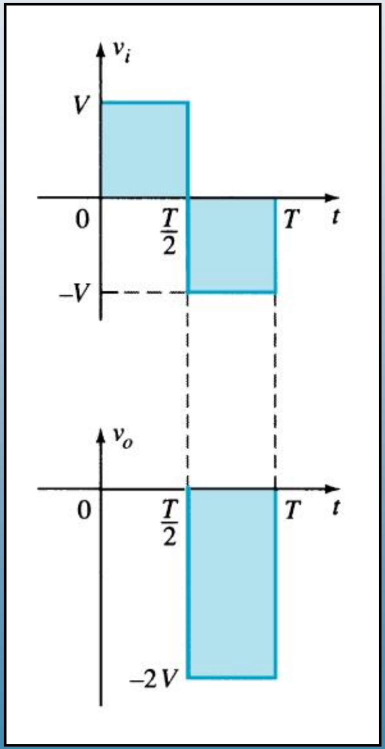
Summary of Clipper Circuits



Clampers

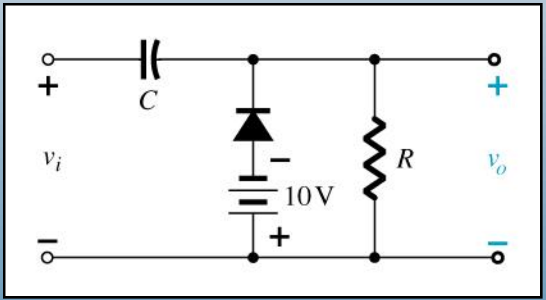
A diode and capacitor can be combined to "clamp" an AC signal to a specific DC level.

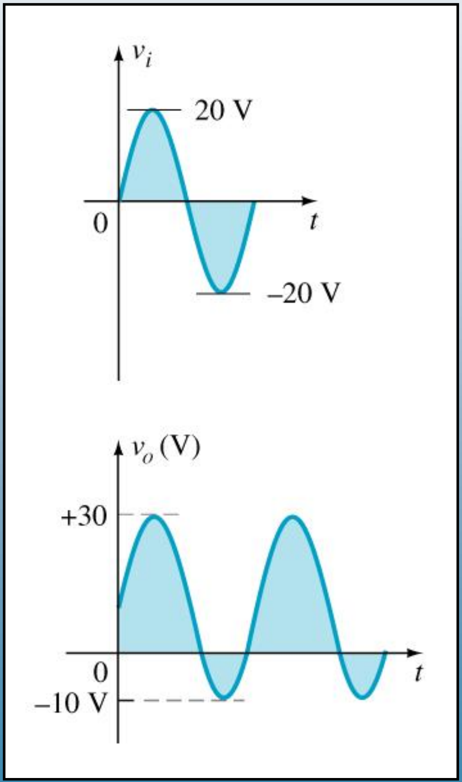




Biased Clamper Circuits

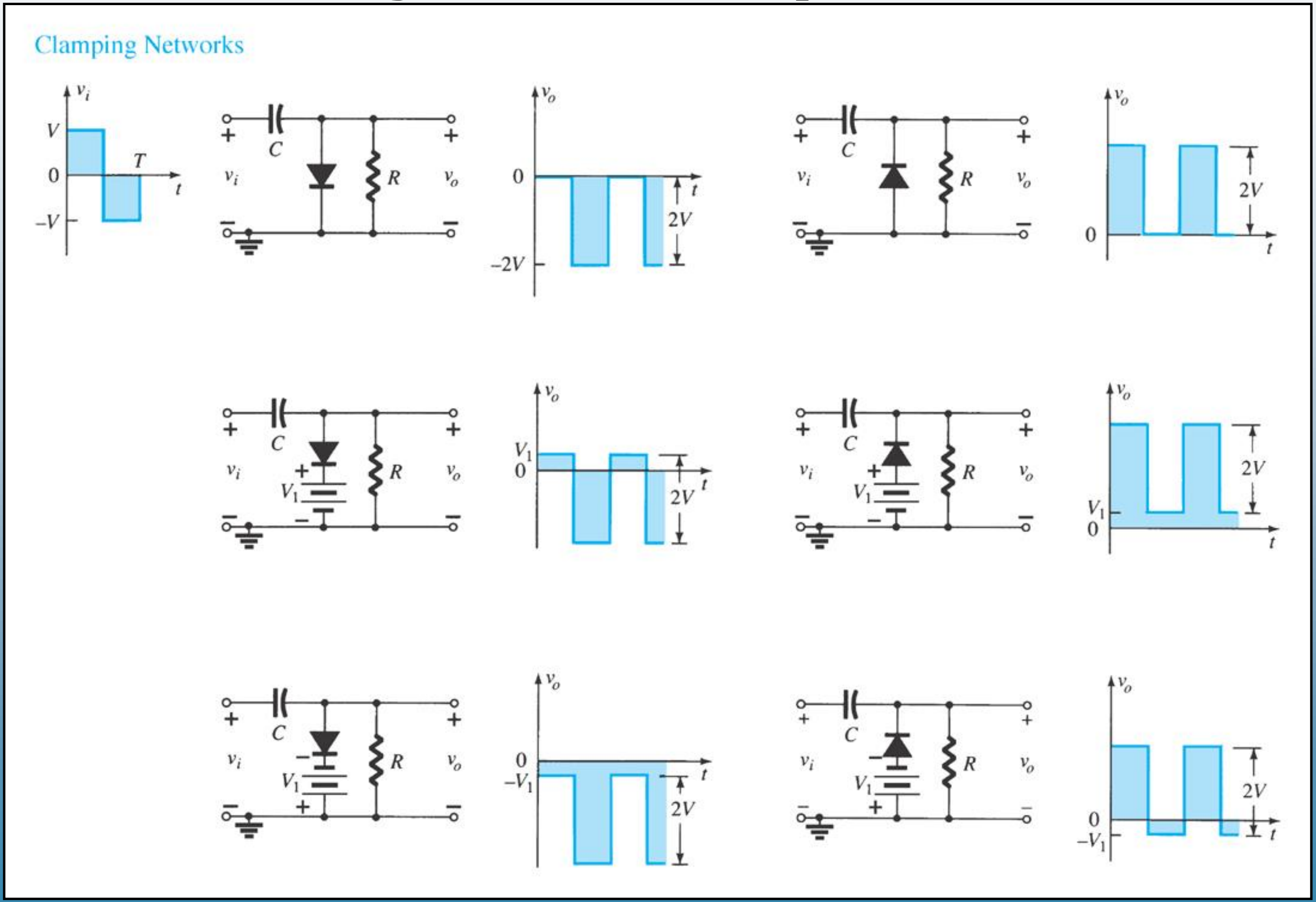
The input signal can be any type of waveform such as a sine, square, or triangle wave.





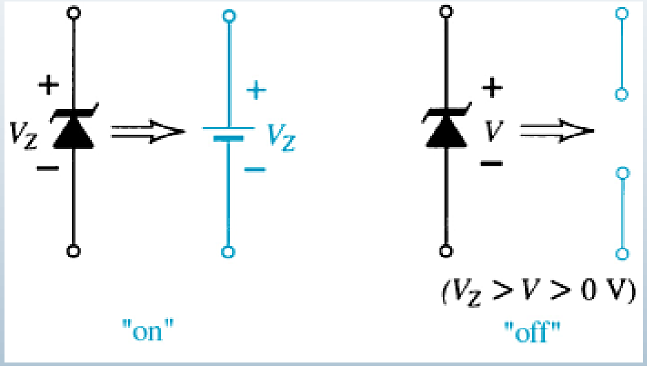
The DC source lets you adjust the DC camping level.

Summary of Clamper Circuits



Zener Diodes

The Zener is a diode that is operated in reverse bias at the Zener Voltage (V_z).

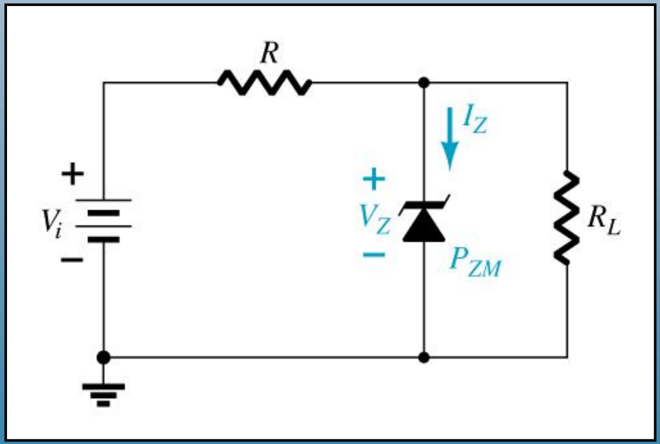


When $V_i \geq V_Z$

- The Zener is on
- Voltage across the Zener is V_Z
- Zener current: $I_Z = I_R - I_{RL}$
- The Zener Power: $P_Z = V_Z I_Z$

When $V_i < V_Z$

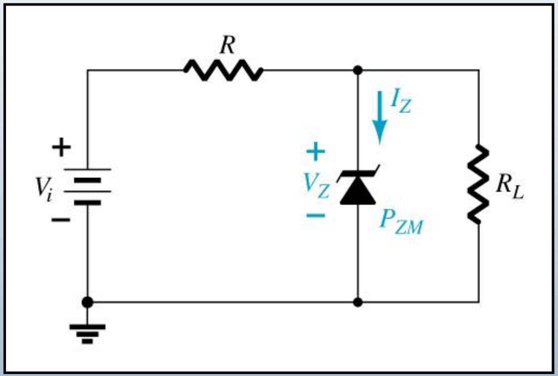
- The Zener is off
- The Zener acts as an open circuit



Zener Resistor Values

If *R* is too large, the Zener diode cannot conduct because $I_Z < I_{ZK}$. The minimum current is given by:

$$I_{Lmin} = I_R - I_{ZK}$$



The *maximum* value of resistance is:

$$R_{Lmax} = \frac{V_Z}{I_{Lmin}}$$

If *R* is too small, $I_Z > I_{ZM}$. The maximum allowable current for the circuit is given by:

$$I_{L\max} = \frac{V_L}{R_L} = \frac{V_Z}{R_{L\min}}$$

The *minimum* value of resistance is:

$$R_{L\min} = \frac{RV_Z}{V_i - V_Z}$$

Voltage-Multiplier Circuits

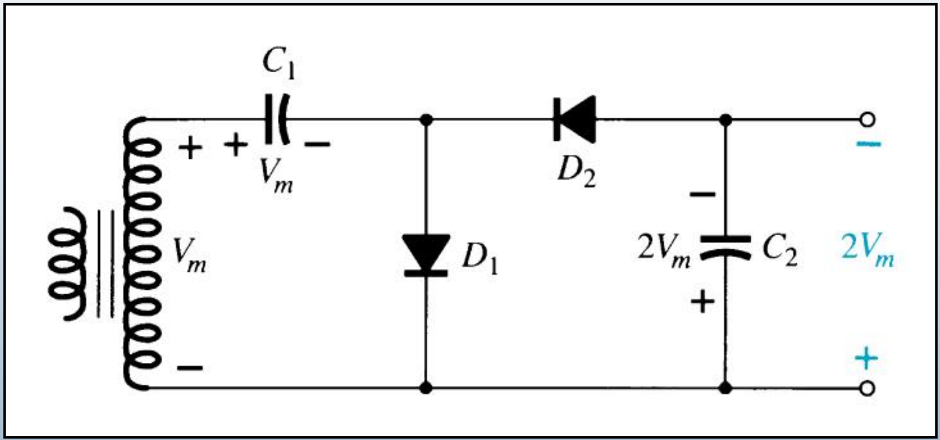
Voltage multiplier circuits use a combination of diodes and capacitors to step up the output voltage of rectifier circuits. Three common voltage multipliers are the:

Voltage Doubler

Voltage Tripler

Voltage Quadrupler

Voltage Doubler



This half-wave voltage doubler's output can be calculated using:

$$V_{out} = V_{C2} = 2V_m$$

where V_m = peak secondary voltage of the transformer

Voltage Doubler

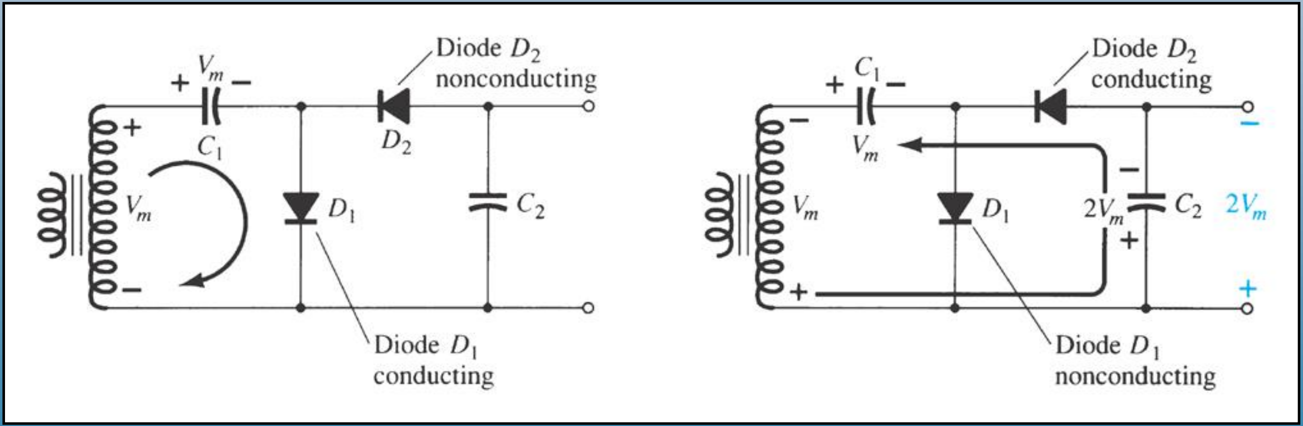
Positive Half-Cycle

D_1 conducts
D_2 is switched off
Capacitor C_1 charges to V_m

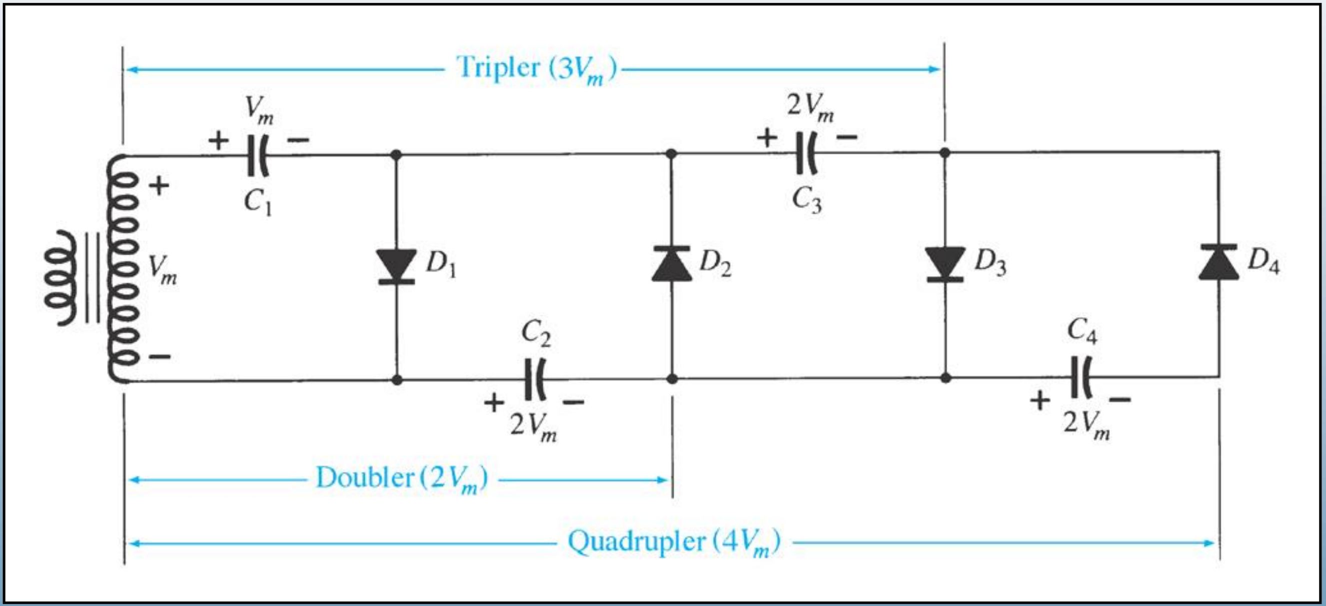
Negative Half-Cycle

D_1 is switched off
D_2 conducts
Capacitor C_2 charges to V_m

$V_{out} = V_{C2} = 2V_m$



Voltage Tripler and Quadrupler



Practical Applications

Rectifier Circuits

Conversions of AC to DC for DC operated circuits
Battery Charging Circuits

Simple Diode Circuits

Protective Circuits against
Overcurrent
Polarity Reversal
Currents caused by an inductive kick in a relay circuit

Zener Circuits

Overvoltage Protection
Setting Reference Voltages