

## Electronic Circuits

Prof. Nizamettin AYDIN

[naydin@yildiz.edu.tr](mailto:naydin@yildiz.edu.tr)

<http://www.yildiz.edu.tr/~naydin>

Dr. Gökhan Bilgin

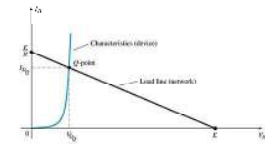
[gokhanb@ce.yildiz.edu.tr](mailto:gokhanb@ce.yildiz.edu.tr)

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## 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.



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## Series Diode Configurations

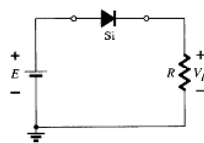
### Forward Bias

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)
- $V_R = E - V_D$
- $I_D = I_R = I_T = V_R / R$



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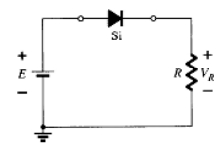
## Series Diode Configurations

### Reverse Bias

Diodes ideally behave as open circuits

Analysis

- $V_D = E$
- $V_R = 0$  V
- $I_D = 0$  A



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## Parallel Configurations

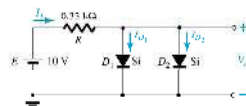
$$V_D = 0.7 \text{ V}$$

$$V_{D1} = V_{D2} = V_O = 0.7 \text{ V}$$

$$V_R = 9.3 \text{ V}$$

$$I_R = \frac{E - V_D}{R} = \frac{10 \text{ V} - 0.7 \text{ V}}{.33 \text{ k}\Omega} = 28 \text{ mA}$$

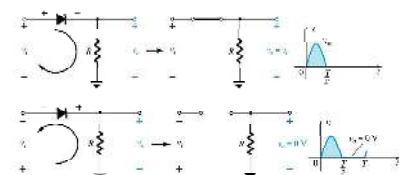
$$I_{D1} = I_{D2} = \frac{28 \text{ mA}}{2} = 14 \text{ mA}$$



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## Half-Wave Rectification

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



The DC output voltage is  $0.318V_m$ , where  $V_m$  is the peak AC voltage.

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## 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.

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

- PIV = Peak inverse voltage
- PRV = Peak reverse voltage
- $V_m$  = Peak AC voltage

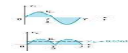
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## Full-Wave Rectification

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

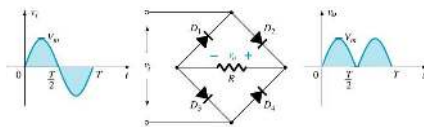
Full-wave rectification produces a greater DC output:

- Half-wave:  $V_{dc} = 0.318V_m$
- Full-wave:  $V_{dc} = 0.636V_m$



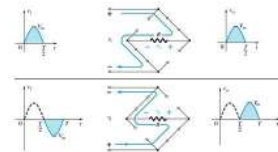
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## Full-Wave Rectification



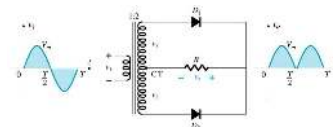
### Bridge Rectifier

- Four diodes are connected in a bridge configuration
- $V_{DC} = 0.636V_m$



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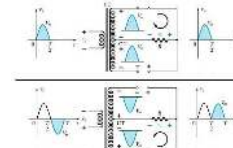
## Full-Wave Rectification



### Center-Tapped Transformer Rectifier

- Requires
  - Two diodes
  - Center-tapped transformer

$$V_{DC} = 0.636V_m$$



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## 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	$V_{DC} = 0.636V_m$	$V_{DC} = 0.636V_m - 2(0.7 \text{ V})$
Center-Tapped Transformer Rectifier	$V_{DC} = 0.636V_m$	$V_{DC} = 0.636V_m - 0.7 \text{ V}$

$V_m$  = peak of the AC voltage.

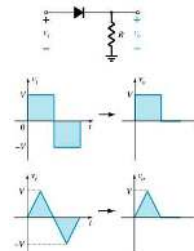
In the center tapped transformer rectifier circuit, the peak AC voltage is the transformer secondary voltage to the tap.

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## Diode Clippers

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

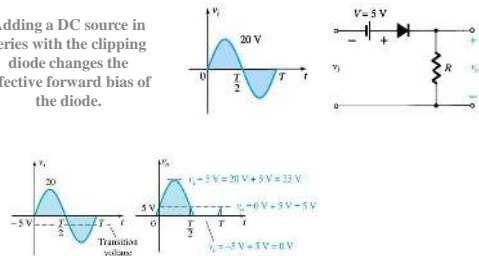
- A reverse-biasing polarity
- A forward-biasing polarity less than 0.7 V (for a silicon diode)



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## Biased Clippers

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

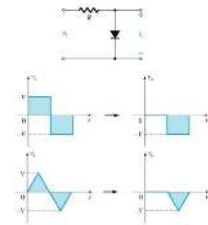


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## Parallel Clippers

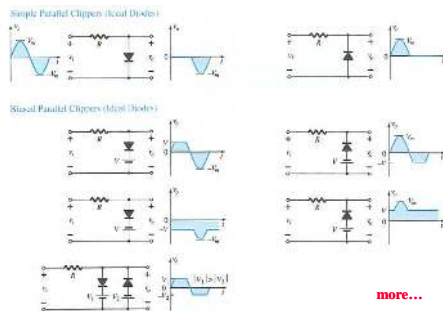
The diode in a **parallel clipper** circuit "clips" any voltage that forward bias it.

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



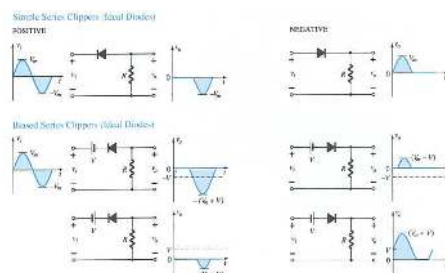
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## Summary of Clipper Circuits



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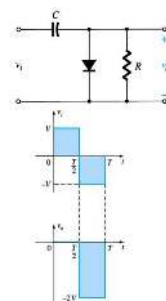
## Summary of Clipper Circuits



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## Clampers

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

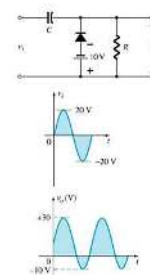


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## Biased Clamper Circuits

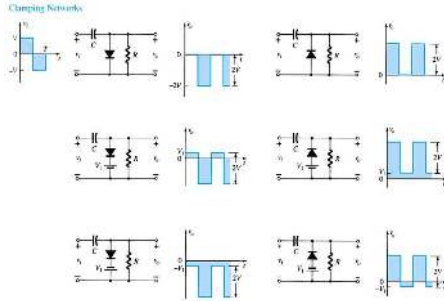
The input signal can be any type of waveform such as sine, square, and triangle waves.

The DC source lets you adjust the DC clamping level.



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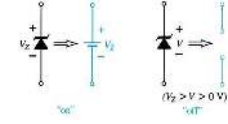
## Summary of Clamper Circuits



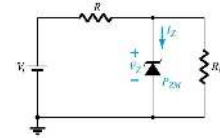
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## Zener Diodes

The Zener is a diode 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



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## Zener Resistor Values

If  $R$  is too large, the Zener diode cannot conduct because the available amount of current is less than the minimum current rating,  $I_{ZK}$ . The minimum current is given by:

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

The maximum value of resistance is:

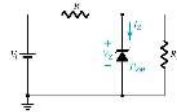
$$R_{Lmax} = \frac{V_Z}{I_{Lmin}}$$

If  $R$  is too small, the Zener current exceeds the maximum current rating,  $I_{ZM}$ . The maximum current for the circuit is given by:

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

The minimum value of resistance is:

$$R_{Lmin} = \frac{RV_Z}{V_i - V_Z}$$



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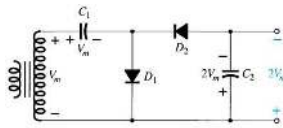
## Voltage-Multiplier Circuits

Voltage multiplier circuits use a combination of diodes and capacitors to step up the output voltage of rectifier circuits.

- Voltage Doubler
- Voltage Tripler
- Voltage Quadrupler

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## Voltage Doubler



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

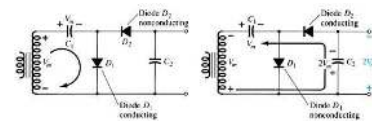
$$V_{out} = V_{C2} = 2V_m$$

where  $V_m$  = peak secondary voltage of the transformer

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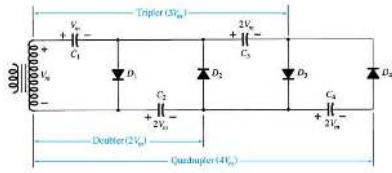
## Voltage Doubler

- Positive Half-Cycle
  - o  $D_1$  conducts
  - o  $D_2$  is switched off
  - o Capacitor  $C_1$  charges to  $V_m$
- Negative Half-Cycle
  - o  $D_1$  is switched off
  - o  $D_2$  conducts
  - o Capacitor  $C_2$  charges to  $V_m$



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## Voltage Tripler and Quadrupler



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## 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

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