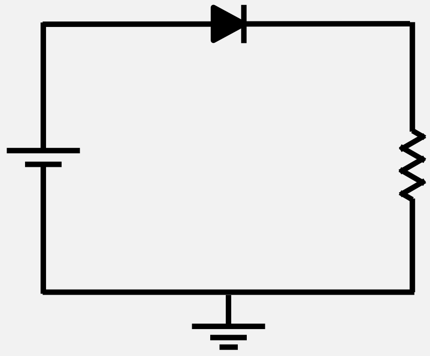
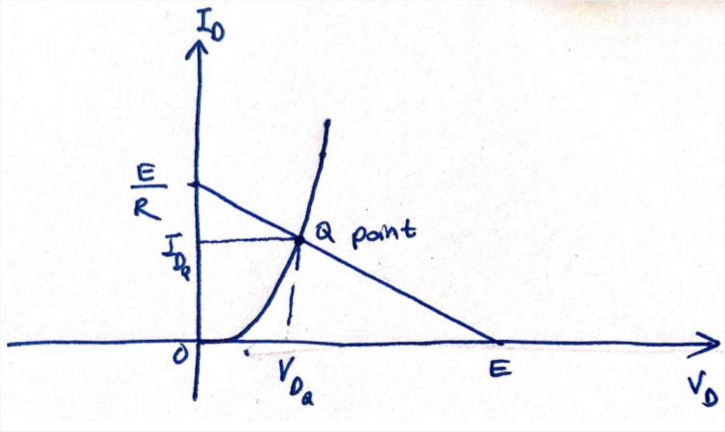
BME 202 Electronics

# Lecture 3: Diode Applications

# Load-Line Analysis

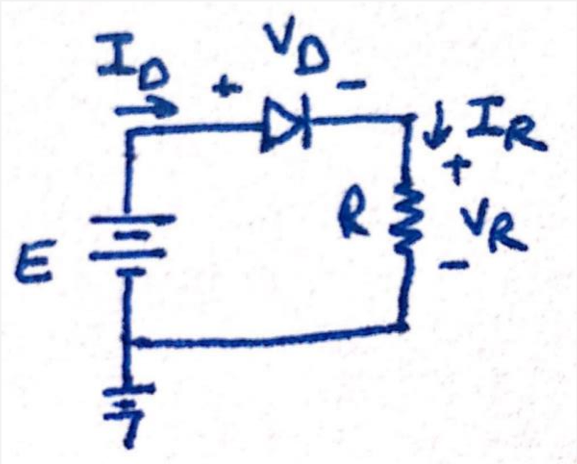


The load line plots all possible combinations of diode current ($I_D$) and voltage ($V_D$) for a given circuit. The maximum $I_D$ equals $E/R$, and the maximum $V_D$ equals $E$.




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




**Analysis (for silicon)**

*Forward Bias*

$$V_D = 0.7\text{ V} \ \ (\text{or } V_D = E \ \text{ if } \ E < 0.7\text{ V})$$

$$V_R = E - V_D$$

$$I_D = I_R = I_T = V_R / R$$

*Reverse Bias*

$$V_D = E$$

$$V_R = 0\text{ V}$$

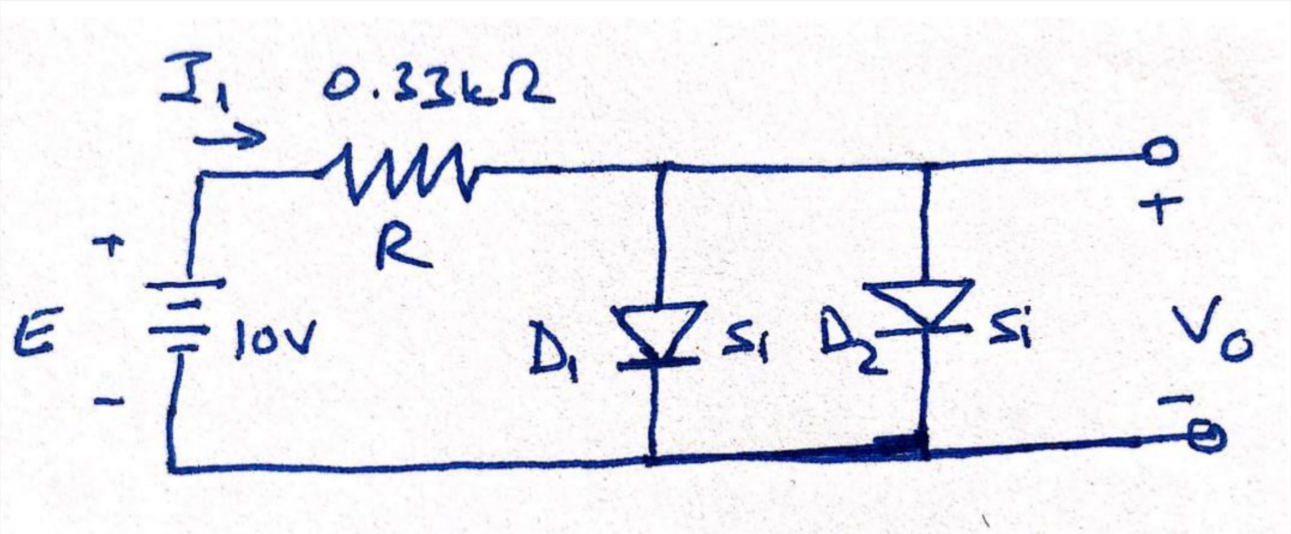
$$I_D = 0\text{ A}$$

*Constants*

Silicon Diode: $V_D = 0.7$ V

Germanium Diode: $V_D = 0.3$ V

# Paralel Diode Configurations



# Half Wave Rectifier

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 $0.318V_m$, where $V_m$ = the peak AC voltage.

# PIV (PRV)

The diode is only forward biased for one-half of the AC cycle and is reverse biased for the other 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.

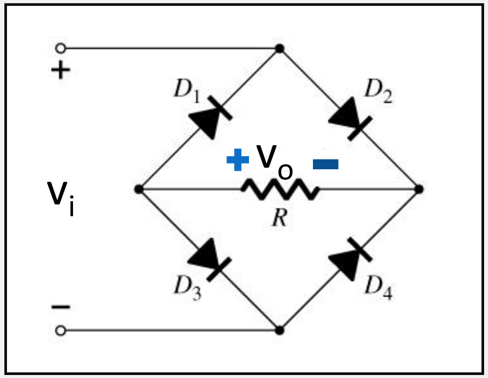
$$\mathbf{PIV\ (or\ PRV)} > V_m$$

where, **PIV** : Peak inverse voltage

**PRV** : Peak reverse voltage

$V_m$ : Peak AC voltage

# Full Wave Rectifier

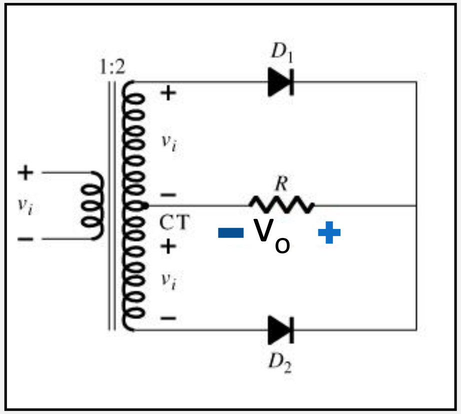



## Bridge Rectifier

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

$$V_{DC} = 0.636V_m$$

# Full Wave Rectifier




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 | $V_{DC} = 0.636V_m$ | $V_{DC} = 0.636V_m - 0.7\ V$ |

# Clippers

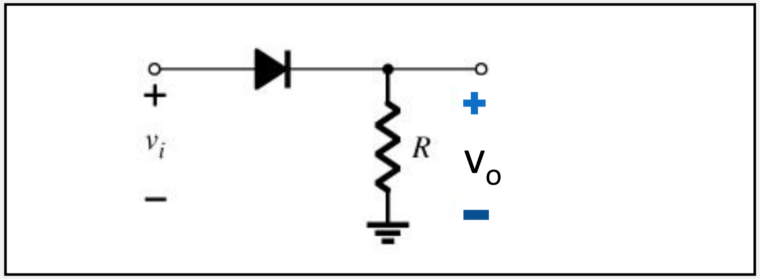
Clippers are networks that employ diodes to "clip" away a portion of an input signal without distorting the remaining part of the applied waveform.

*e.g. Half wave rectifier*

*Categories of Clippers*

- *Series*
- *Parallel*

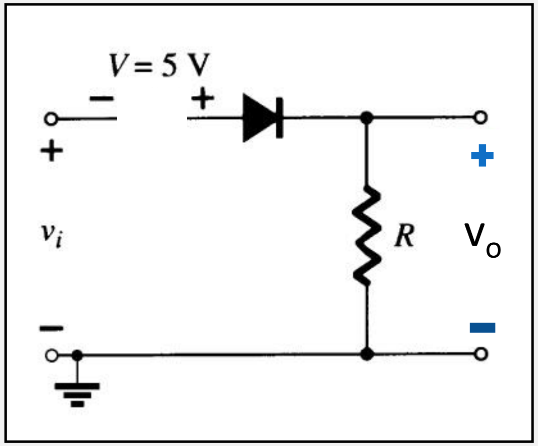
# Clippers




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

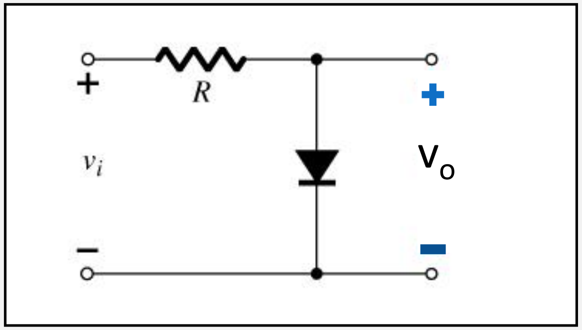
- A reverse-biasing polarity
- A forward-biasing polarity less than 0.7 V (for a silicon diode)

# 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.

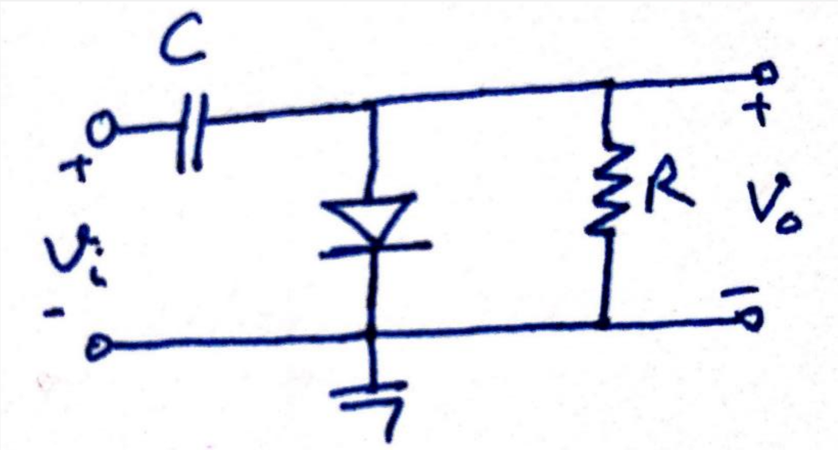
DC biasing can be added in series with the diode to change the clipping level.

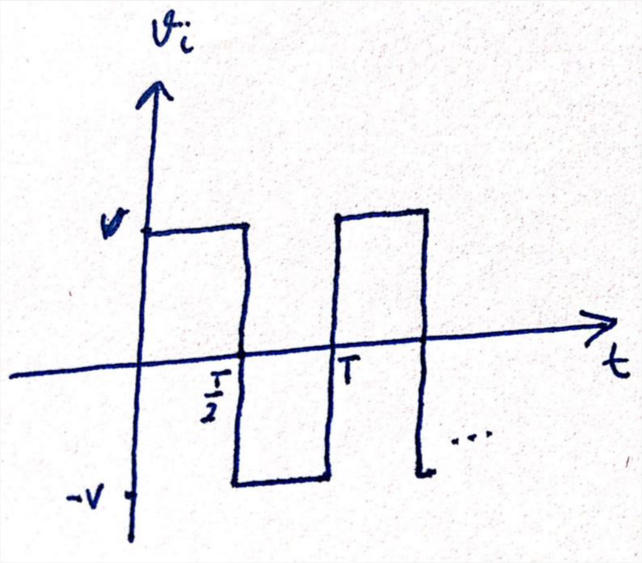
# Clampers

A clamper is a network constructed of a diode, a resistor, and a capcitor that shifts a waveform to a different DC level without changing the appearance of the applied signal.

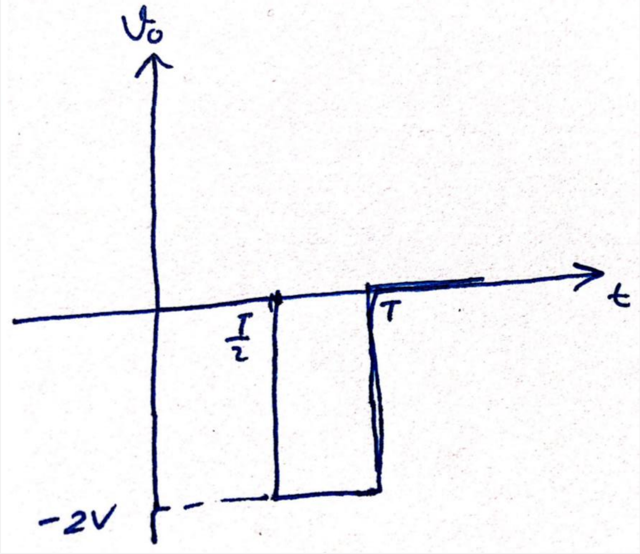
Clamping networks have a capacitor connected directly from input to output with a resistive element in parallel with the output signal. The diode is also in paralel with the output signal but may or may not have a series DC supply as an added element.

# Clampers



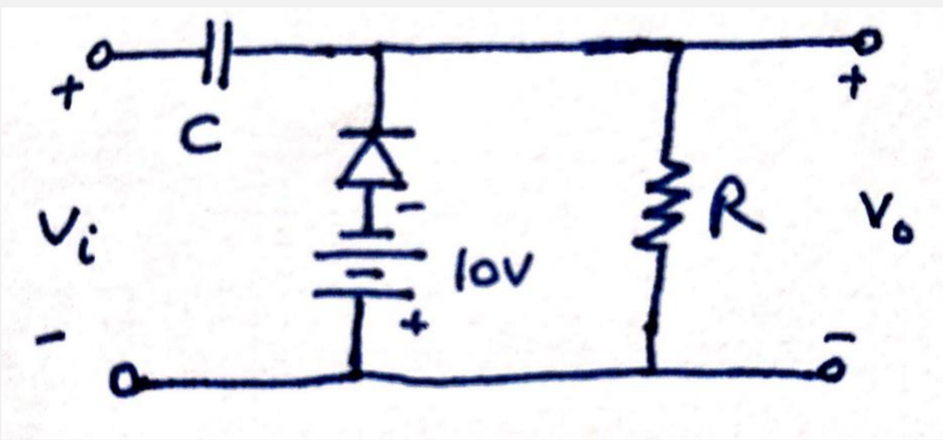



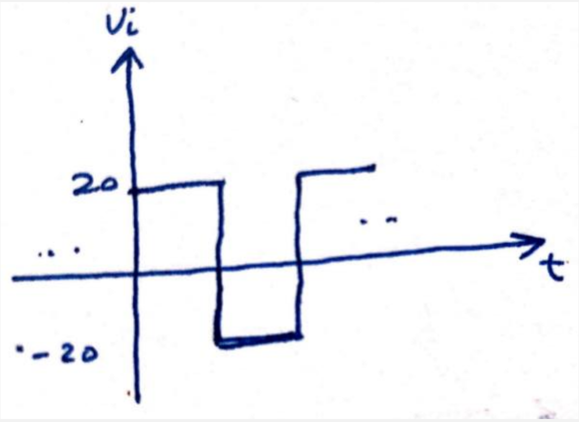

A diode and capacitor can be combined to "clamp" an AC signal to a specific DC level.



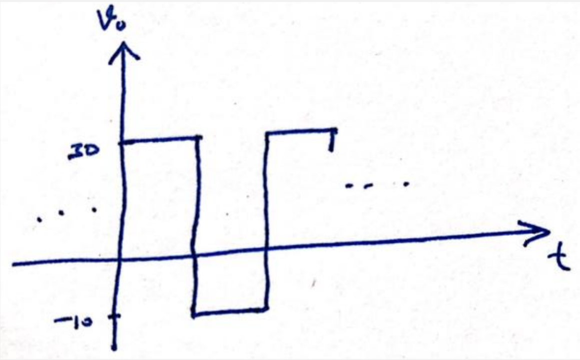
# Biased Clamper Circuits

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



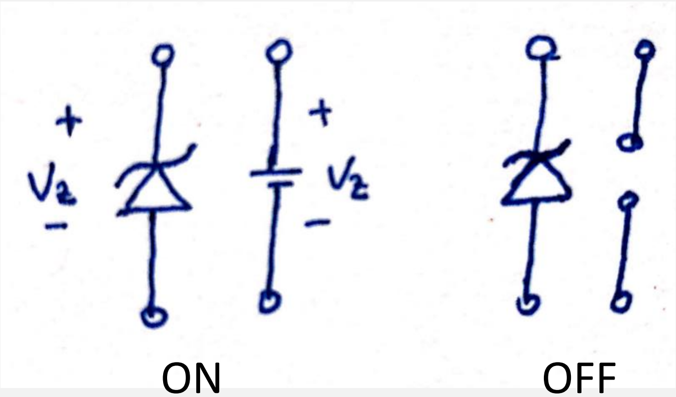




*The DC source lets you adjust the DC camping level.*



# Zener Diodes

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

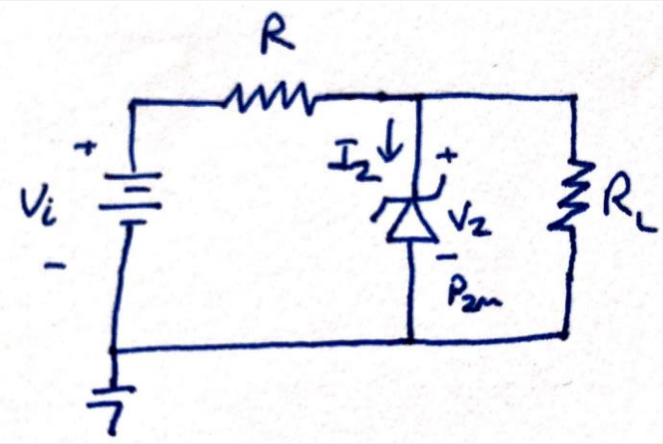



**When $V_i \geq V_Z$**

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

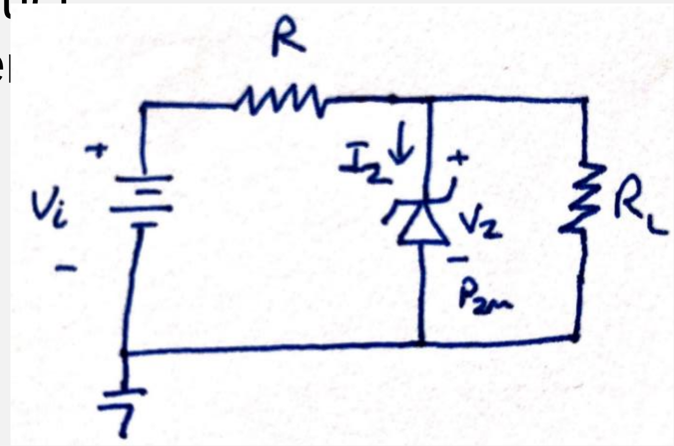
**When $V_i < V_Z$**

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



# Zener Diodes

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

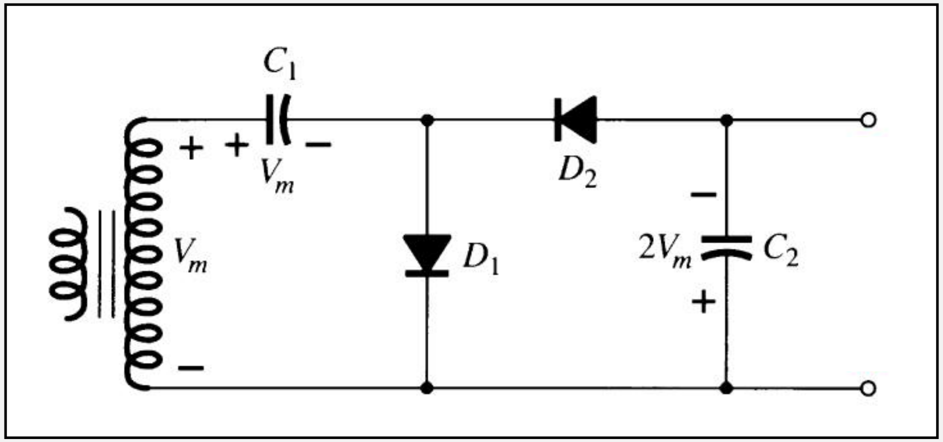
Voltage multiplier circuits use a combination of diodes and capacitors to step up the output voltage of rectifier circuits. Three common voltage multipliers are the:

*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 $V_m$

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

# 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