Analog & Digital Electronics

Course No: PH-218

Lec-4: Clampers, Voltage multipliers, & Zener diode

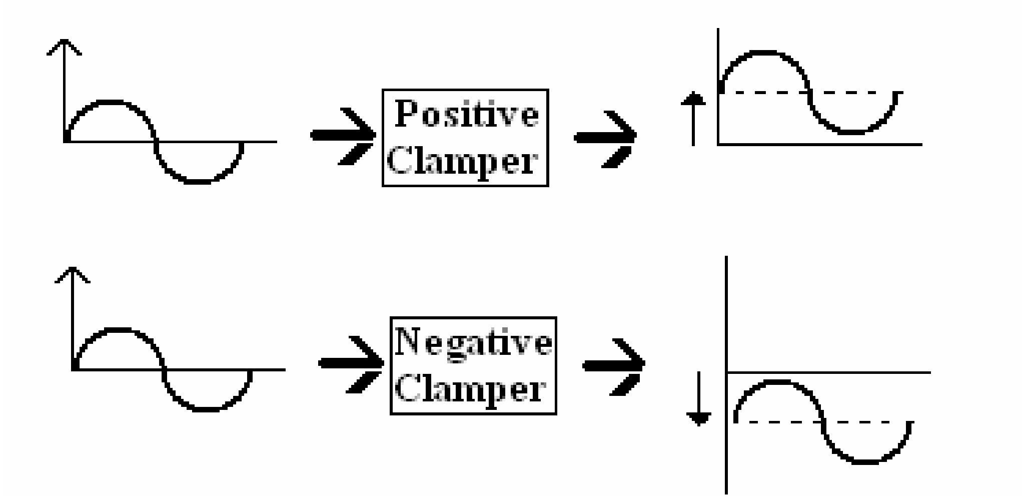
Course Instructors:

- **Dr. A. P. VAJPEYI**

Department of Physics,
Indian Institute of Technology Guwahati, India

Clampers:

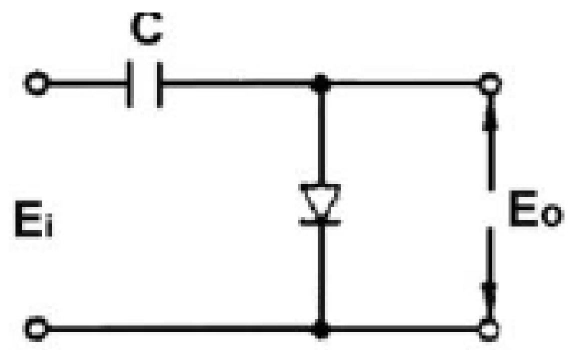
➢ **Clamping is a process of introducing a dc level into a signal.**



➢Clamper circuit consist of diode and capacitor that shifts the input waveform to different dc level without changing the appearance of the applied waveform.

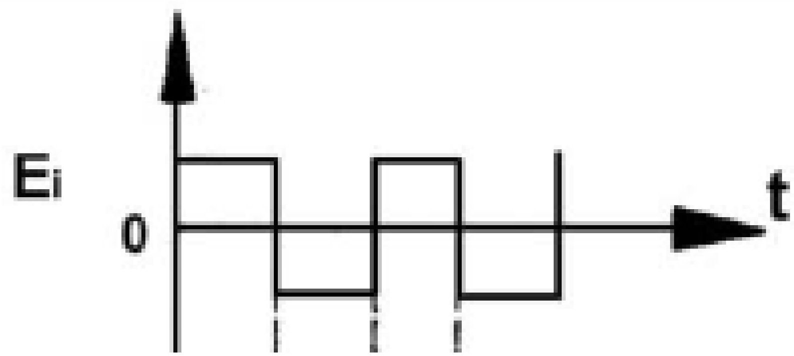
➢ When the diode is forward biased, it will conduct and charge the capacitor. The output voltage across the diode is zero (0.7V).

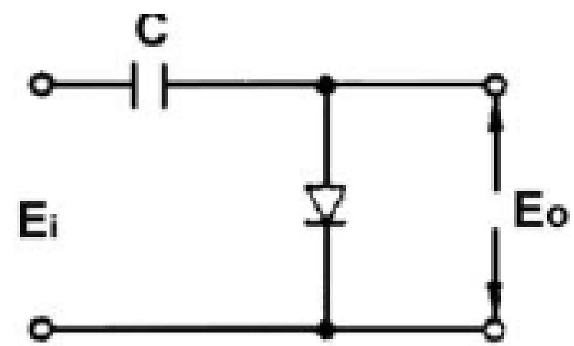
➢ **The capacitor is charged to peak input voltage quickly because of small time constant of the circuit.**



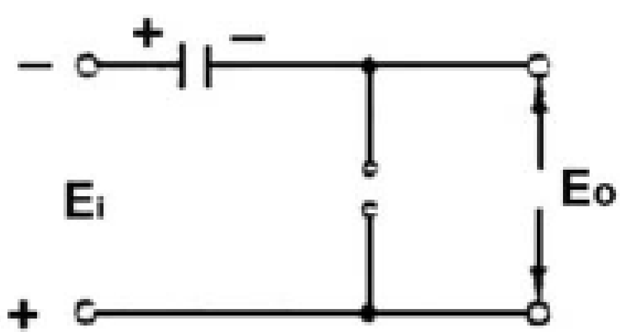
➢ During the –ve cycle when diode is reverse bias, the diode becomes to its off state. In this case, the output voltage equals to the sum of the input voltage and the voltage across the terminals of the capacitor which have the same polarity with each other

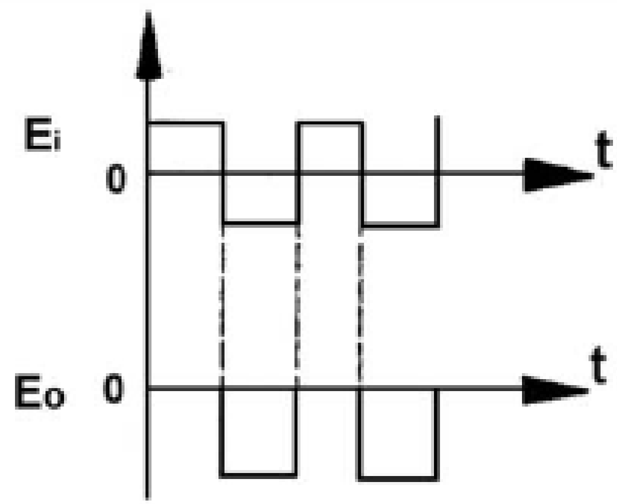
During positive half cycle

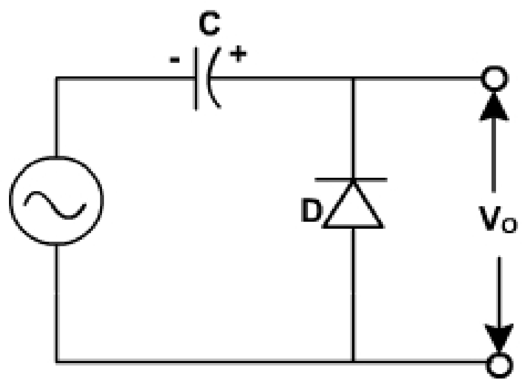


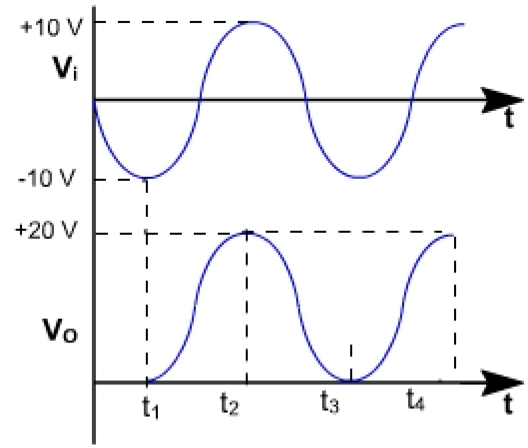


During negative half cycle









- During 0 to t_1, the input voltage is negative, diode is forward biased and conducts so V_o is zero and the capacitor is charged to –10 V with the polarity as shown.

- During t_1 to t_2, diode becomes reverse biased and open circuit and at t_2, when V_i is 10V total voltage change is 20V.

During negative half cycle:

Diode will be forward biased and Capacitor will be charged by 15V.

Applying KVL: $V_{in}+V_c+V_{supply}=0$

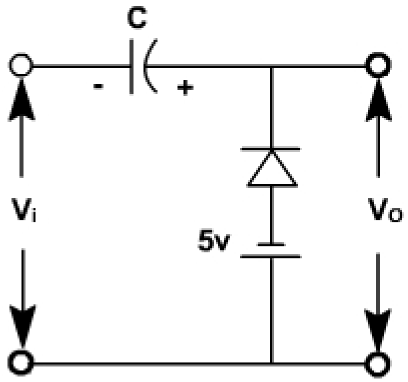
$-10V+V_c+5V=0$; $V_c = 5V$

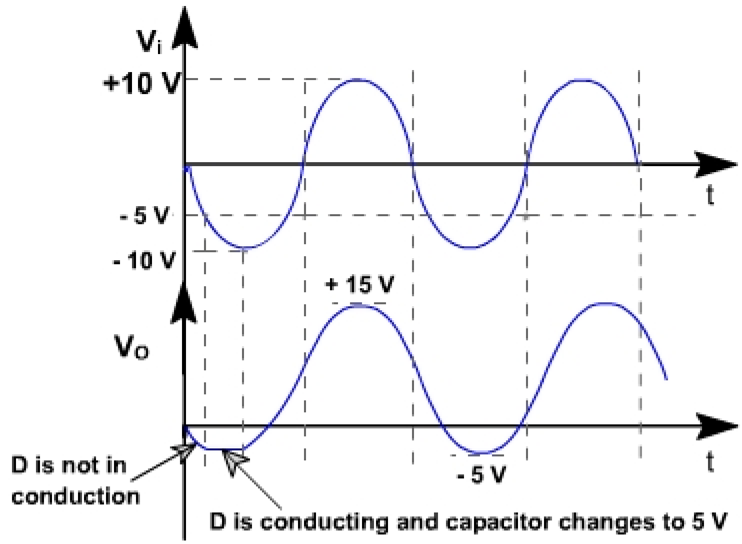
During positive half cycle:

Diode will be reverse biased and diode will be open circuit.

Applying KVL: : $V_{in}+V_c+V_{supply}=0$

$10V+5-V_o=0$; $V_o = 15V$





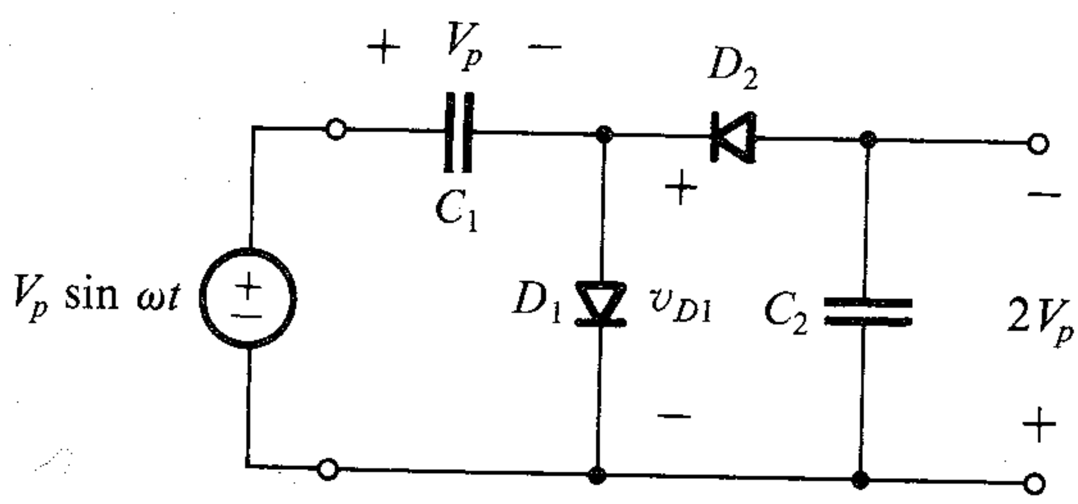
Voltage Multipliers:

➢ **Voltage multipliers are the circuit which provide a dc output that is multiple of the peak input ac voltage.**

➢ **Voltage doubler** will provide a dc output that is twice the peak input ac voltage and **voltage tripler** will provide a dc output that is three times the peak input ac voltage.

➢ The basic idea in voltage multiplier circuit is to charge each capacitor to the peak input ac voltage and to arrange the capacitor so that their stored voltages will add.

Voltage doubler:



Voltage doubler:

➢ During the positive half cycle, diode D_1 is forward biased and diode D_2 is reverse biased, that will charge capacitor C_1 to peak value of input voltage.

➢ During the negative half cycle, diode D_2 is forward biased and diode D_1 is reverse biased, that will charge capacitor C_2 to the twice the peak value of input voltage because capacitor C_1 (charged to V_p) and input voltage (V_p) now act as series aiding voltage source.

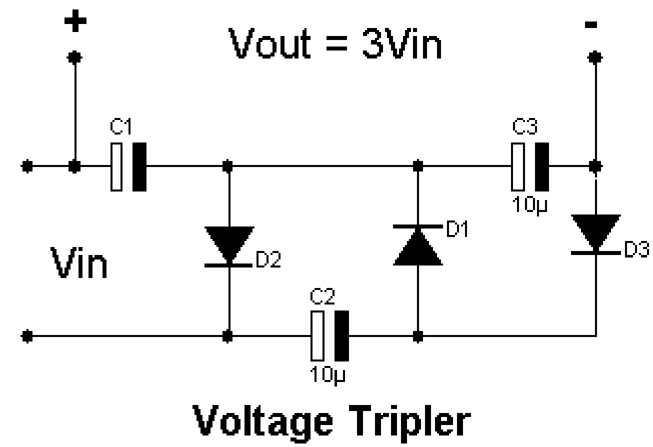
➢ When input voltage returns to its original polarity, diode D_2 is again reverse biased (off), and then the capacitor C_2 will be discharged through the load R_L

➢ The time constant ($R_L C_2$) is so adjusted that C_2 has little time to loose any of its charge before the input polarity reverses again.

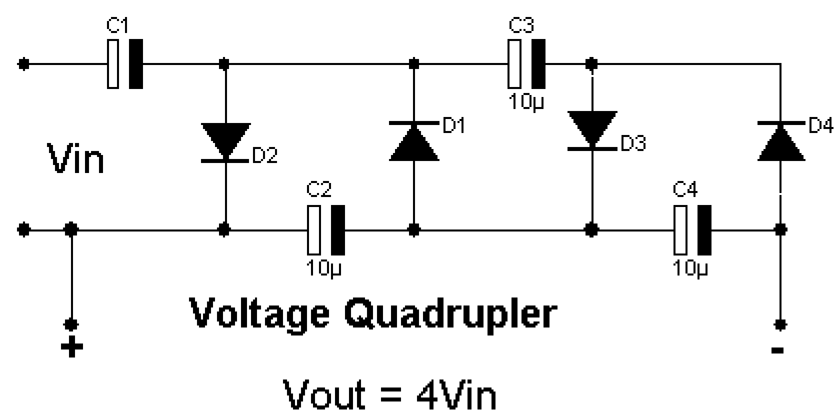
➢ During the negative half cycle, diode D_2 is turned on , capacitor C_2 will be recharged again until voltage across it is again equal to $2V_p$.

Voltage Multipliers:

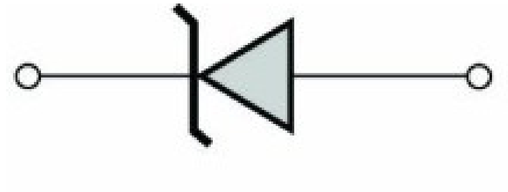
Voltage Tripler



Voltage Quadrupler



Zener diode:



- A zener diode is a special type of diode that is designed to operate in the reverse breakdown region.

- A properly doped (heavily doped) junction diode which has a sharp breakdown voltage is known as zener diode.

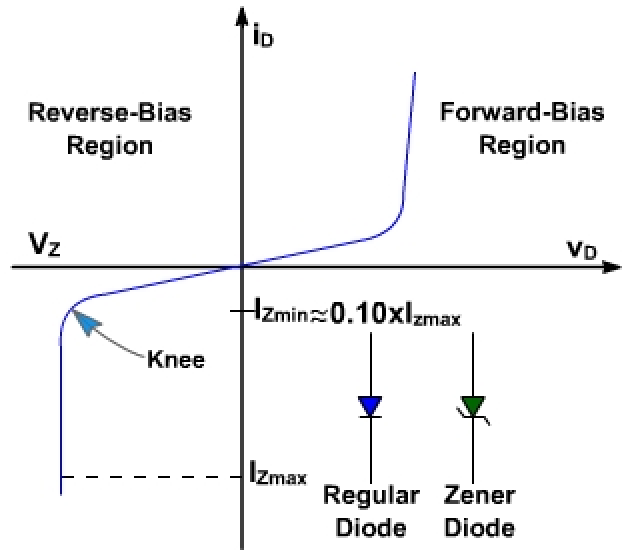
- Heavy doping causes a very thin depletion layer which results in sharp breakdown voltage.

- **A zener diode is always connected in reverse bias mode**.

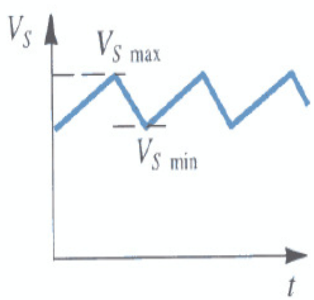
- The use of a sufficiently strong electric field at the junction can cause a direct rupture of the bond. If the electric field exerts a strong force on a bound electron, the electron can be torn from the covalent bond thus causing the number of electron-hole pair combinations to multiply. This mechanism is called Zener breakdown.

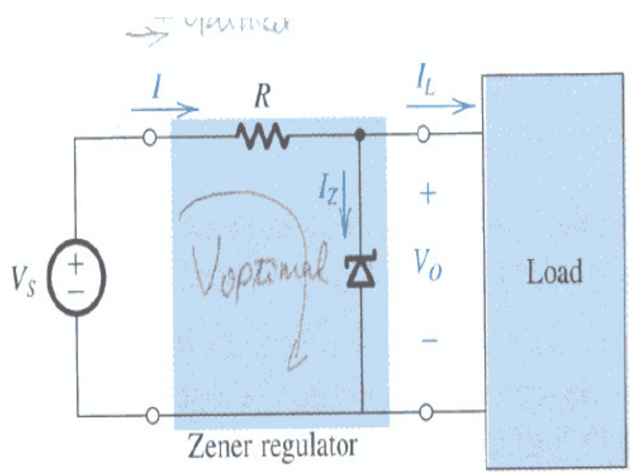
Zener diode as a voltage regulator:

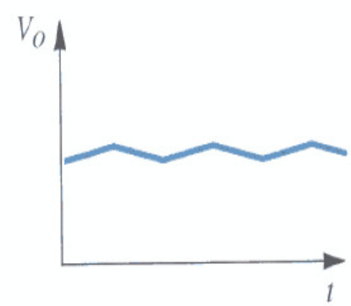
➢ The zener diode operated in the breakdown region have a constant voltage regardless the value of the current through the device, that allows zener diode to be used as a voltage regulator.



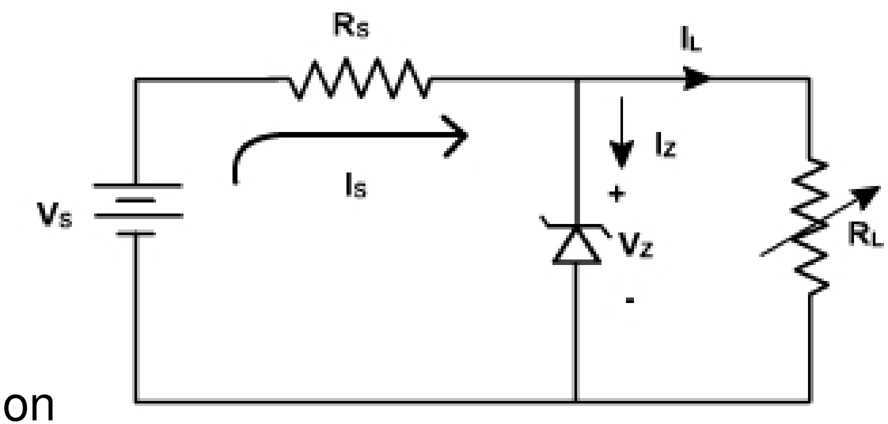
➢ Voltage stabilizer circuit that maintain a constant voltage across the load when the source voltage or the load current vary, shown below.







Zener diode as a voltage regulator:



➢ First calculate the thevenin voltage across the zener diode.

$$V_{TH} = V_S \frac{R_L}{R_S + R_1}$$

➢ Zener will work in the breakdown region only if the Thevenin voltage across zener is more than V_Z

➢ If zener is operating in breakdown region, the current through R_S is given by

$$I_S = \frac{V_S - V_Z}{R_S} \qquad I_L = \frac{V_Z}{R_L}$$

➢ I_L is load current and I_s is total current. **$I_s = I_L + I_z$**

Ripple factor of diode rectifier:

➢ The effectiveness of a rectifier depends upon the magnitude of ac component in the output; smaller the ac component, the more effective is the rectifier.

➢ **Ripple factor is a measure of effectiveness of a rectifier circuit and defined as a ratio of rms value of ac component to the dc component in the rectifier output.**

$$Ripple factor = \frac{I_{ac}}{I_{dc}}$$

$$I_{rms} = \sqrt{I_{dc}^2 + I_{ac}^2}$$

$$\frac{I_{ac}}{I_{dc}} = \sqrt{\frac{I_{rms}^2}{I_{dc}^2} - 1}$$

Ripple factor of diode rectifier:

For half wave rectifier:

$$I_{rms} = \frac{I_m}{2} \qquad I_{dc} = \frac{I_m}{\Pi}$$

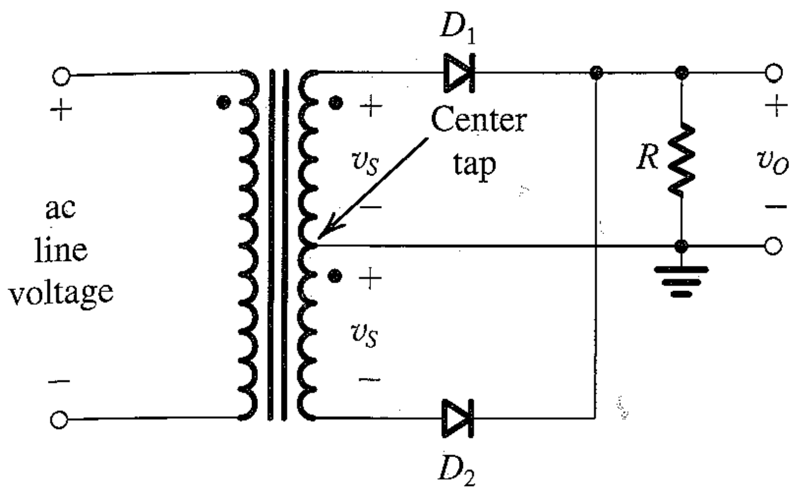
Ripple factor = 1.21

For full wave rectifier:

$$I_{rms} = \frac{I_m}{\sqrt{2}} \qquad I_{dc} = \frac{2I_m}{\Pi}$$

Ripple factor = 0.48

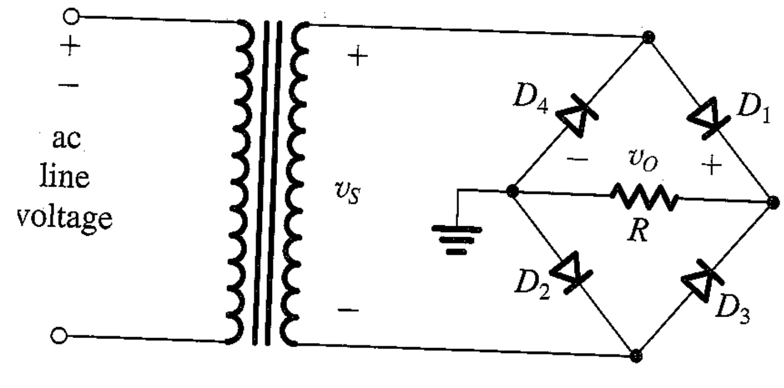
PIV diode full wave rectifier:



To find the PIV of the diodes in the full-wave rectifier circuit, consider the situation during the positive half-cycles. Diode D_1 is conducting, and D_2 is cut off. The voltage at the cathode of D_2 is v_O, and that at its anode is $-v_S$. Thus the reverse voltage across D_2 will be $(v_O + v_S)$, which will reach its maximum when v_O is at its peak value of $(V_s - V_D)$, and v_S is at its peak value of V_s; thus,

$$\text{PIV} = 2V_s - V_D$$

PIV full wave Bridge rectifier:



(a)

To determine the peak inverse voltage (PIV) of each diode, consider the circuit during positive half-cycles. The reverse voltage across D_3 can be determined from the loop med by D_3, R, and D_2 as

$$v_{D3}\text{ (reverse)} = v_O + v_{D2}\text{ (forward)}$$

us the maximum value of v_{D3} occurs at the peak of v_O and is given by

$$\text{PIV} = V_s - 2V_D + V_D = V_s - V_D$$