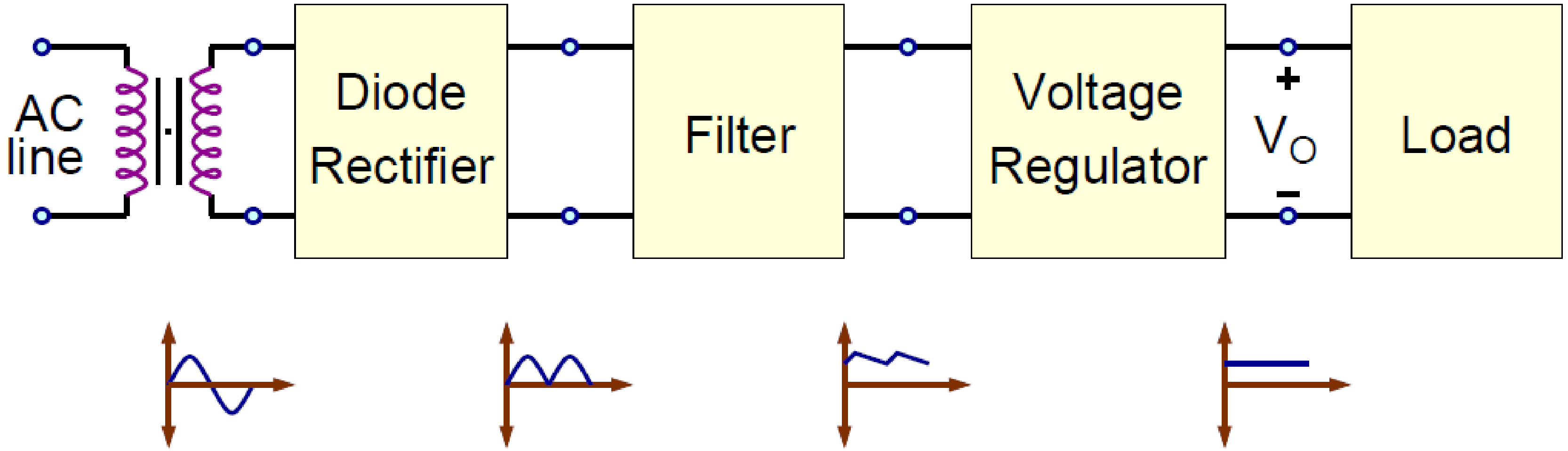
ECEN325: Electronics
Spring 2014

Diode Rectifier Circuits

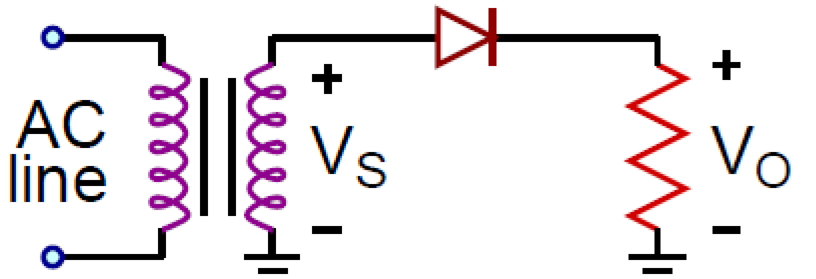
Sam Palermo
Analog & Mixed-Signal Center
Texas A&M University

Rectifier Circuits

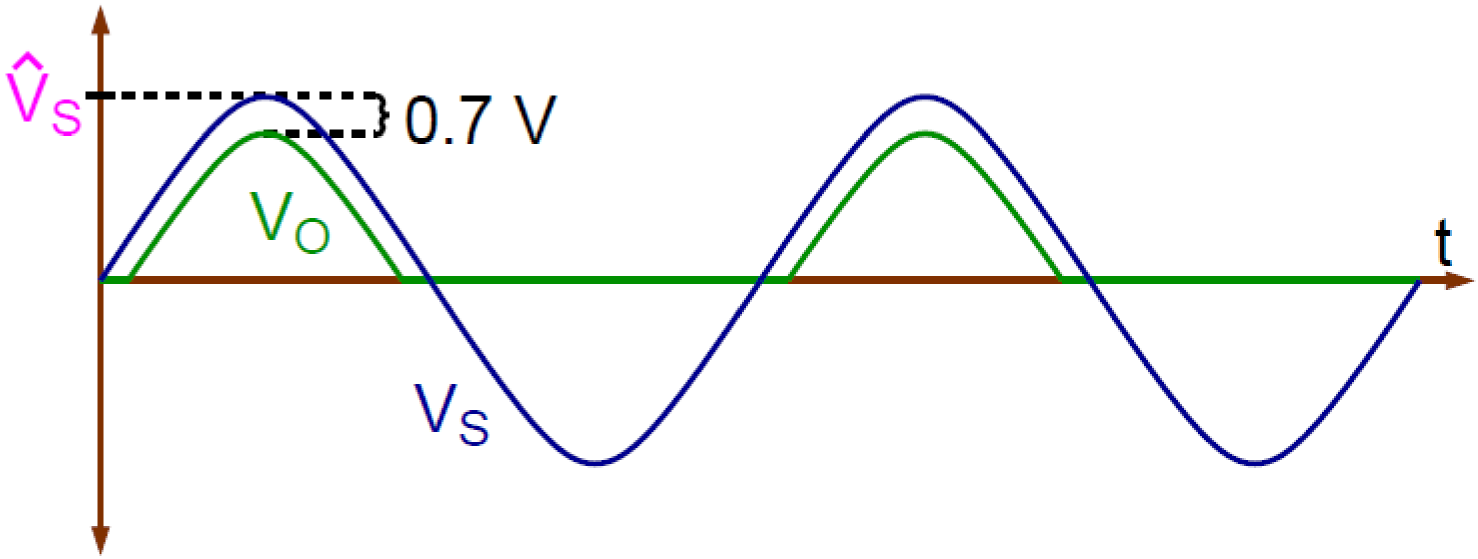
[Karsilayan]



Half-Wave Rectifier



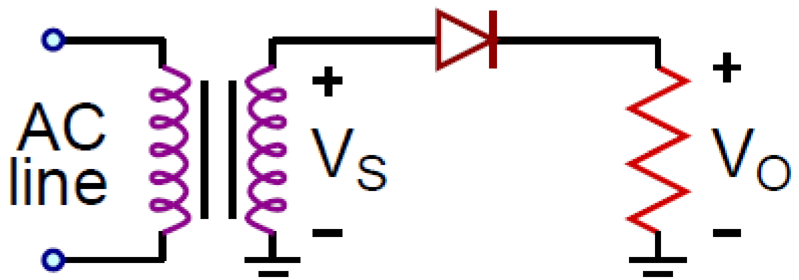
[Karsilayan]



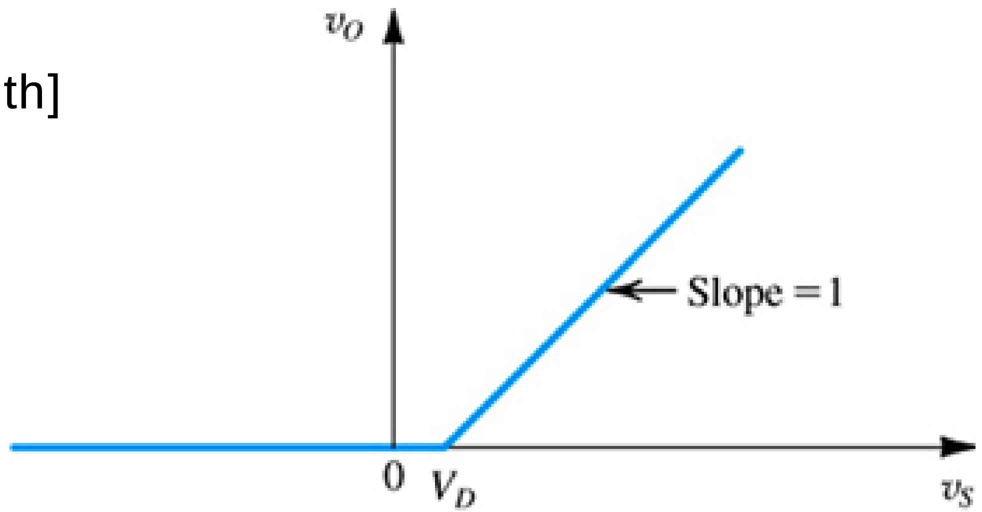
$$\mathbf{PIV} = \hat{V}_S$$

Half-Wave Rectifier Transfer Characteristic

[Karsilayan]

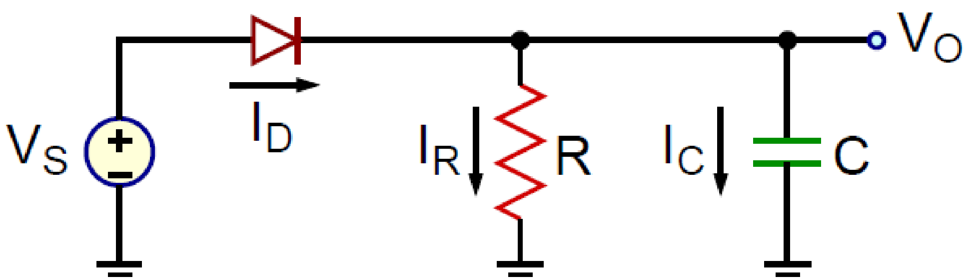


[Sedra/Smith]

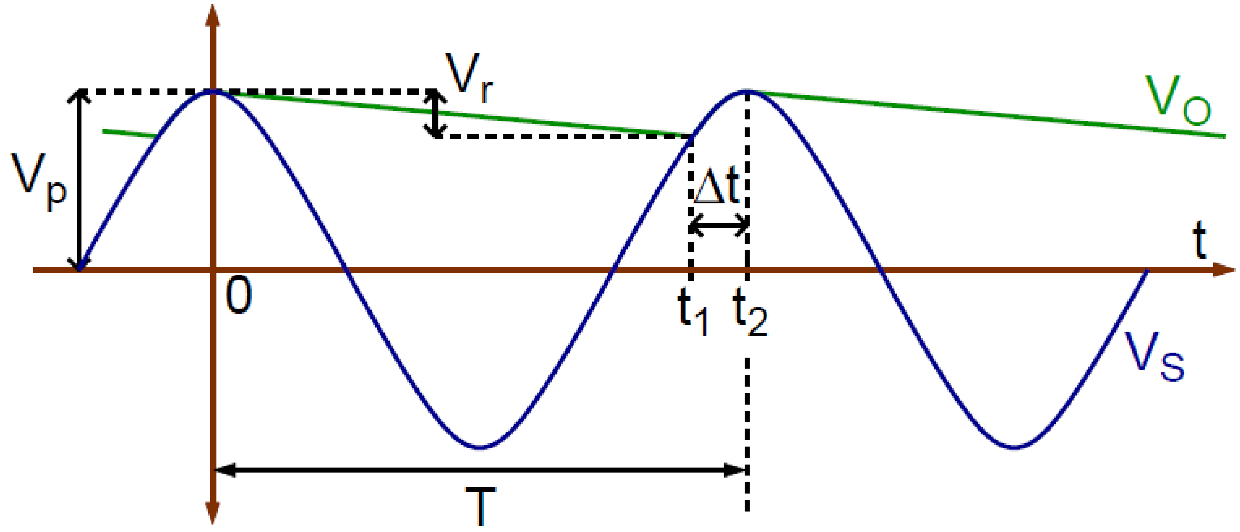


- Only rectifies positive half of the input signal
- Lose one diode voltage drop from the peak value

Half-Wave Rectifier w/ a Filter Cap



[Karsilayan]



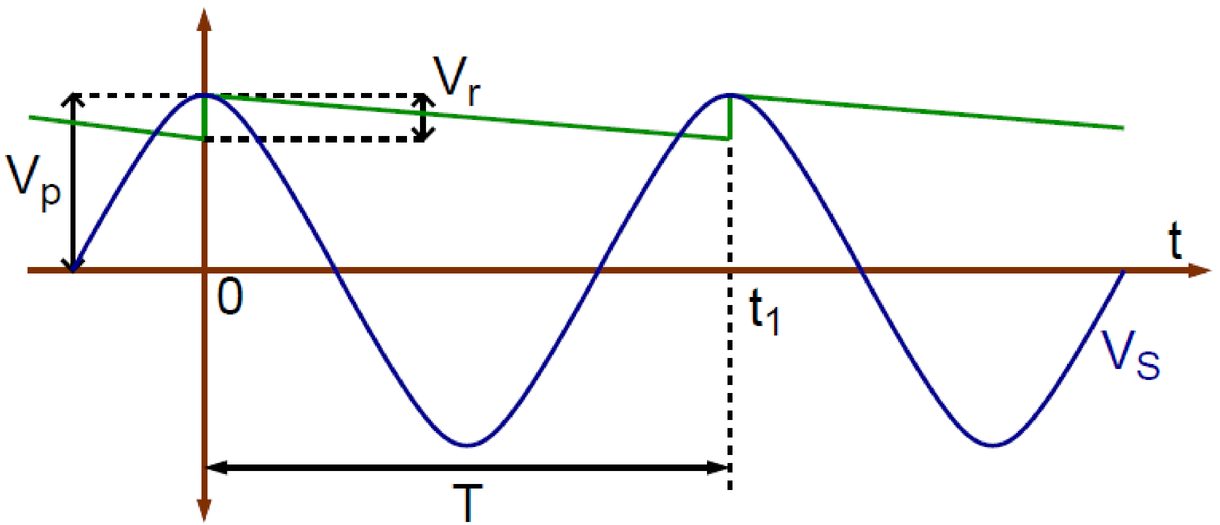
$$V_o(t) = \begin{cases} V_s(t) - 0.7V & , t_1 < t < t_2 \\ V_p e^{-\frac{t}{RC}} & , 0 < t < t_1 \end{cases} \Rightarrow V_o(t_1) = V_p e^{-\frac{t_1}{RC}}$$

Half-Wave Rectifier w/ a Filter Cap

For a properly designed filter:

[Karsilayan]

$$\left.\begin{array}{lll} t_1 \approx T & \Rightarrow & V_O(t_1) \approx V_p\, e^{-\frac{T}{RC}} \\ RC \gg T & \Rightarrow & e^{-\frac{T}{RC}} \approx 1 - \frac{T}{RC} \end{array}\right\} \Rightarrow V_O(t_1) = V_p\left(1 - \frac{T}{RC}\right)$$

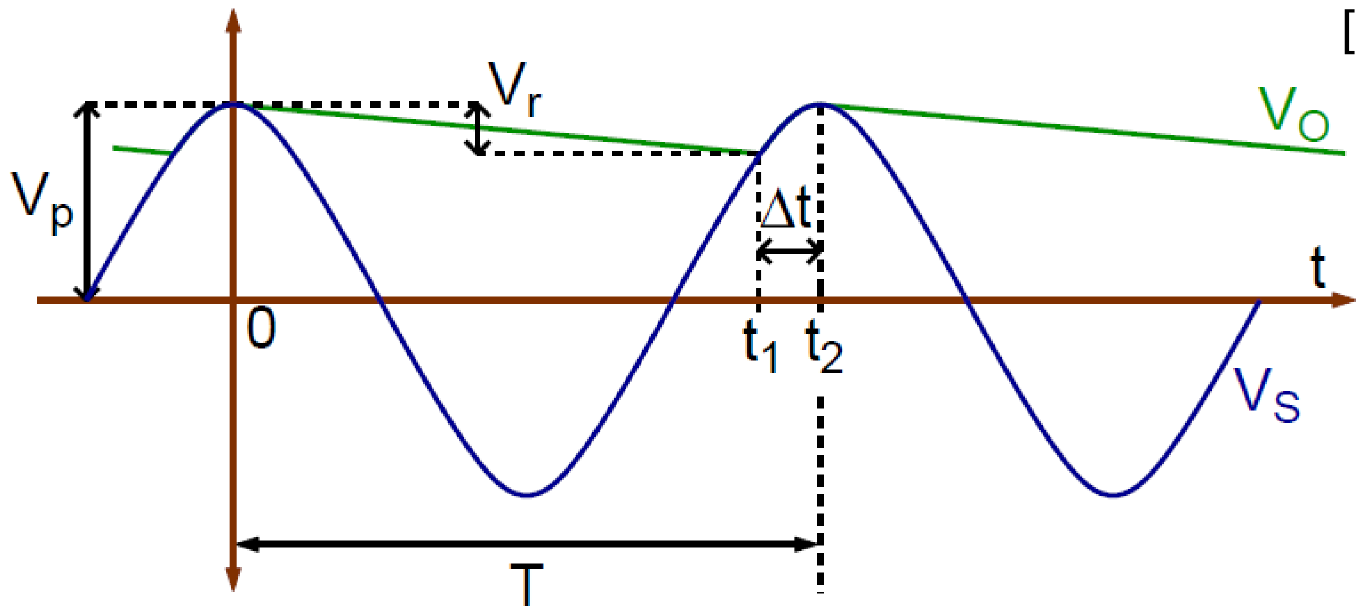


Peak-to-peak ripple voltage:

$$V_r = V_p - V_O(t_1) = V_p - V_p\left(1 - \frac{T}{RC}\right) \Rightarrow V_r = V_p\,\frac{T}{RC}$$

Half-Wave Rectifier w/ a Filter Cap

[Karsilayan]



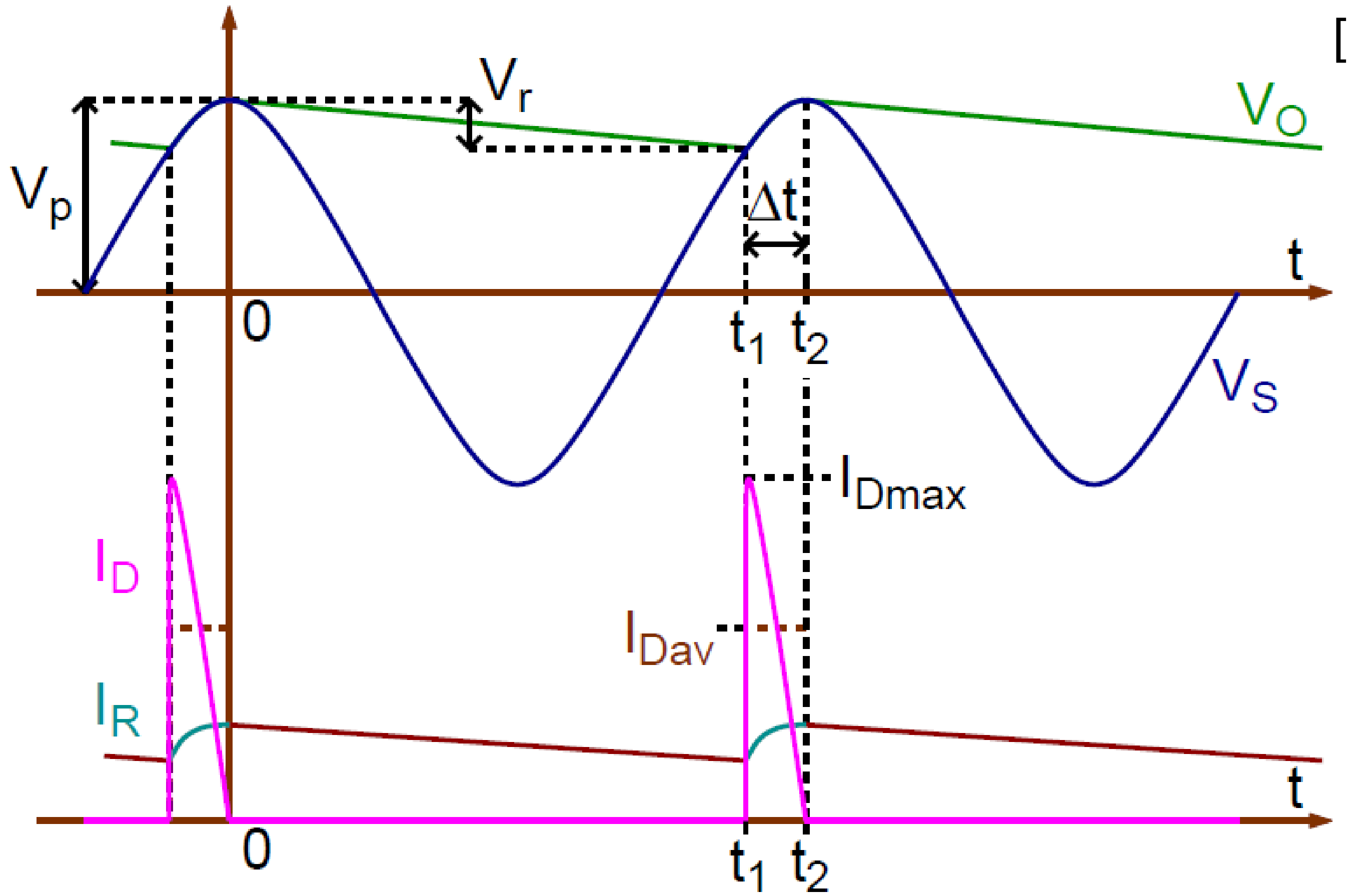
$$V_p \cos(\omega \Delta t) = V_p - V_r$$

$$\omega \Delta t \text{ is small} \Rightarrow \cos(\omega \Delta t) \approx 1 - \frac{1}{2}(\omega \Delta t)^2$$

$$\Rightarrow \omega \Delta t \approx \sqrt{\frac{2V_r}{V_p}} \Rightarrow \Delta t \approx \frac{T}{2\pi}\sqrt{\frac{2V_r}{V_p}}$$

Half-Wave Rectifier w/ a Filter Cap

[Karsilayan]



$$I_R \approx \frac{V_p}{R}$$

During conduction (t_1-t_2): $Q_{supplied} = Q_{lost}$

$I_{Cav}\Delta t = CV_r$

Half-Wave Rectifier w/ a Filter Cap

Substitute Δt in $I_{Cav}\Delta t = CV_r$ [Karsilayan]

$$I_{Cav}\,\frac{T}{2\pi}\sqrt{\frac{2V_r}{V_p}} = CV_r \;\Rightarrow\; I_{Cav} = \frac{2\pi CV_r}{T}\sqrt{\frac{V_p}{2V_r}}$$

$$I_{Dav} = I_R + I_{Cav} = I_R + \frac{2\pi CV_r}{T}\sqrt{\frac{V_p}{2V_r}}$$

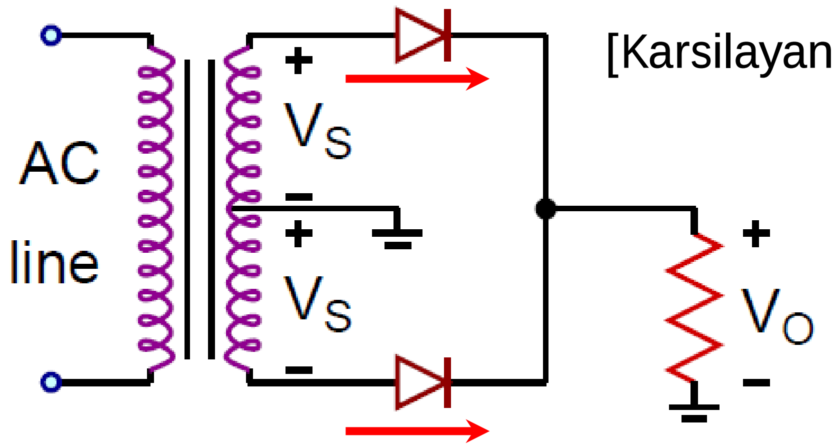
$$V_r = V_p\,\frac{T}{RC} \;,\quad V_p \approx I_R R \;\Rightarrow\; V_r = I_R\frac{T}{C}$$

$$I_{Dav} = I_R + 2\pi I_R\sqrt{\frac{V_p}{2V_r}} = I_R\left(1 + \pi\sqrt{\frac{2V_p}{V_r}}\right)$$

$$I_{Dmax} = I_R\left(1 + 2\pi\sqrt{\frac{2V_p}{V_r}}\right)$$

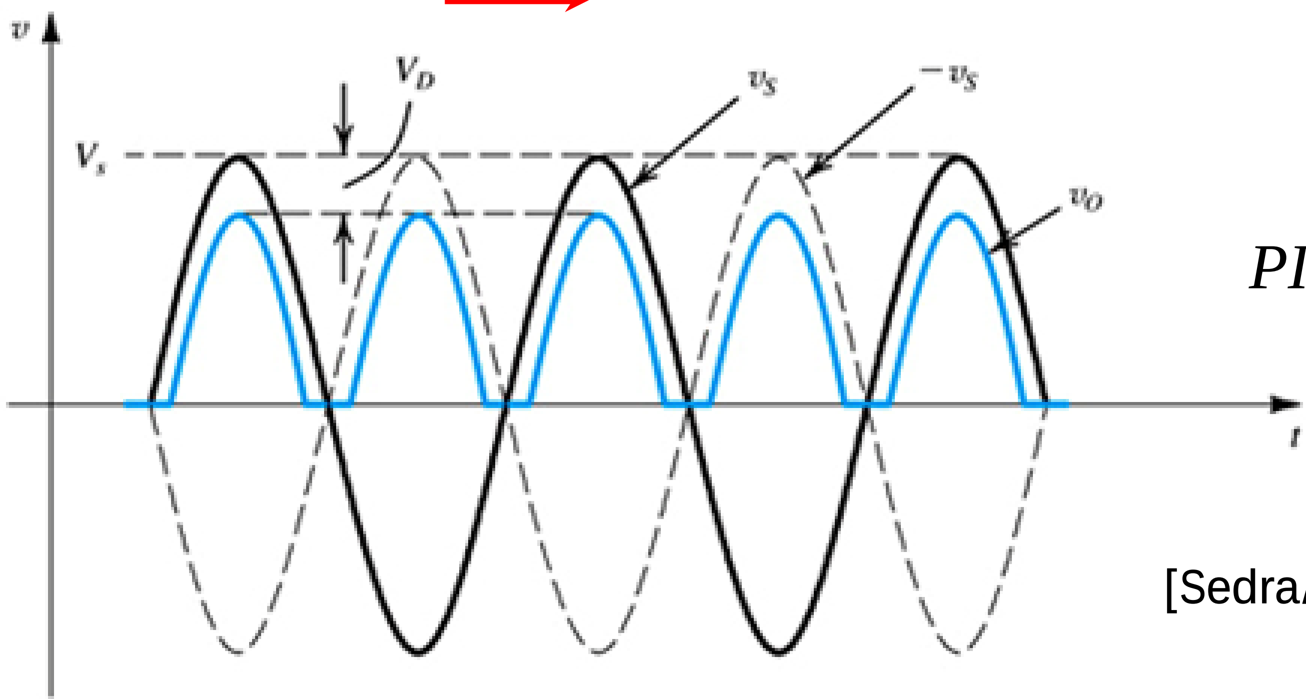
(assuming a triangular capacitive current profile)

Full-Wave Rectifier



[Karsilayan]

- Positive ½ cycle
  - Top diode on
- Negative ½ cycle
  - Bottom diode on

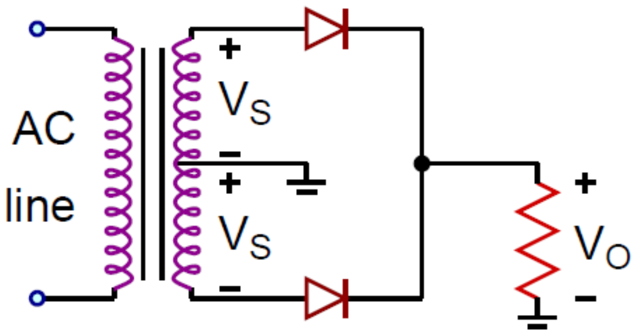


$$PIV = 2\hat{V}_s - 0.7V$$

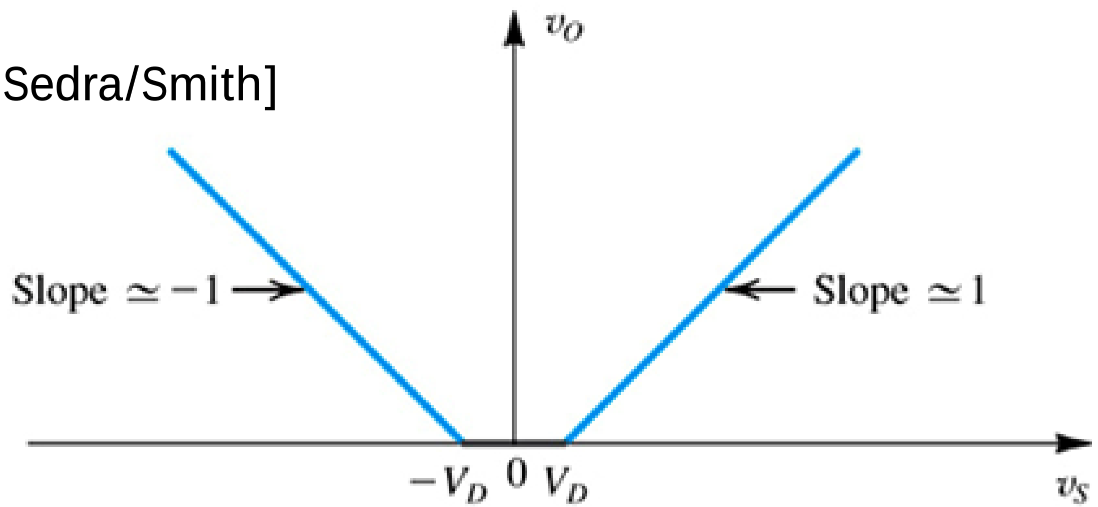
[Sedra/Smith]

Full-Wave Rectifier Transfer Characteristic

[Karsilayan]



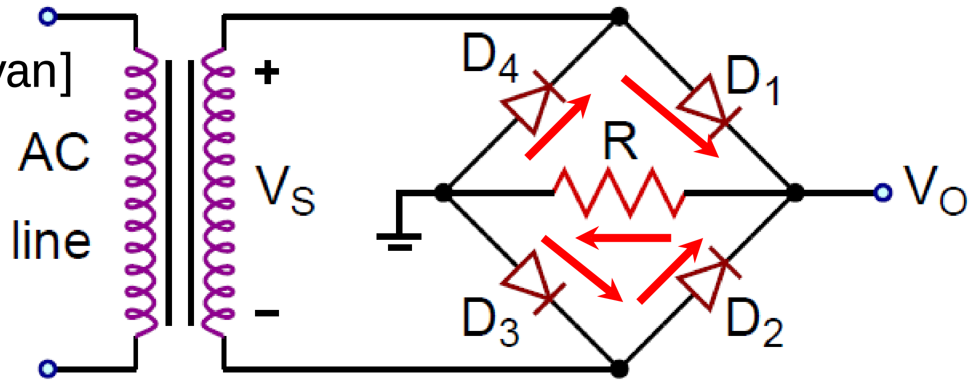
[Sedra/Smith]



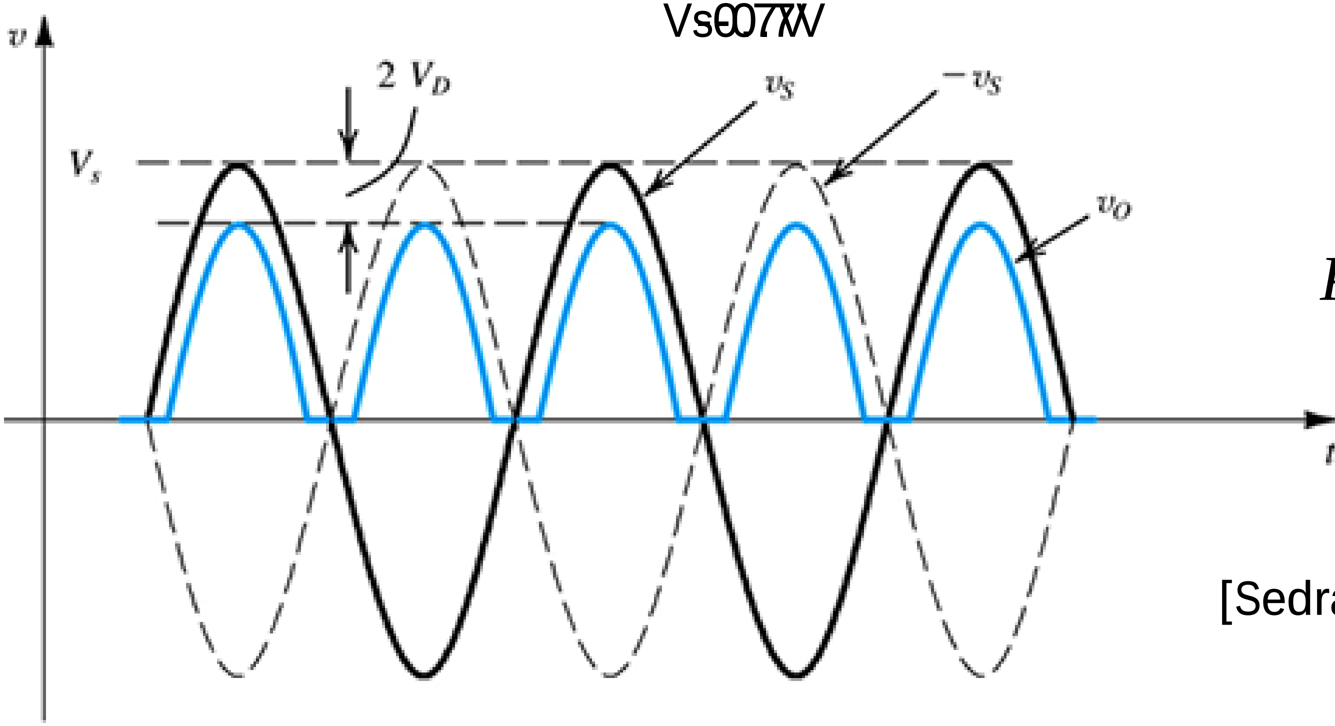
- Rectifies all of the input signal
- Lose one diode voltage drop from the peak value

Bridge Rectifier

[Karsilayan]



- Positive ½ cycle
  - D1 & D3 on
- Negative ½ cycle
  - D2 & D4 on

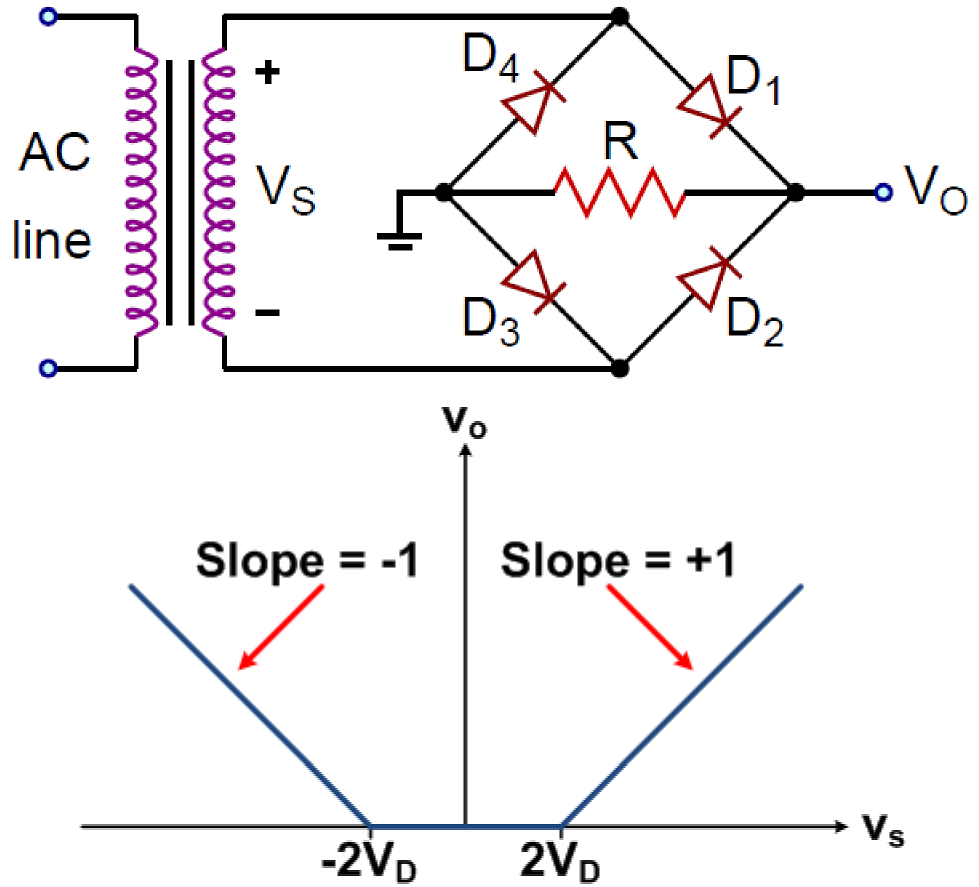


$$PIV = \hat{V}_s - 0.7V$$

[Sedra/Smith]

Bridge Rectifier Transfer Characteristic

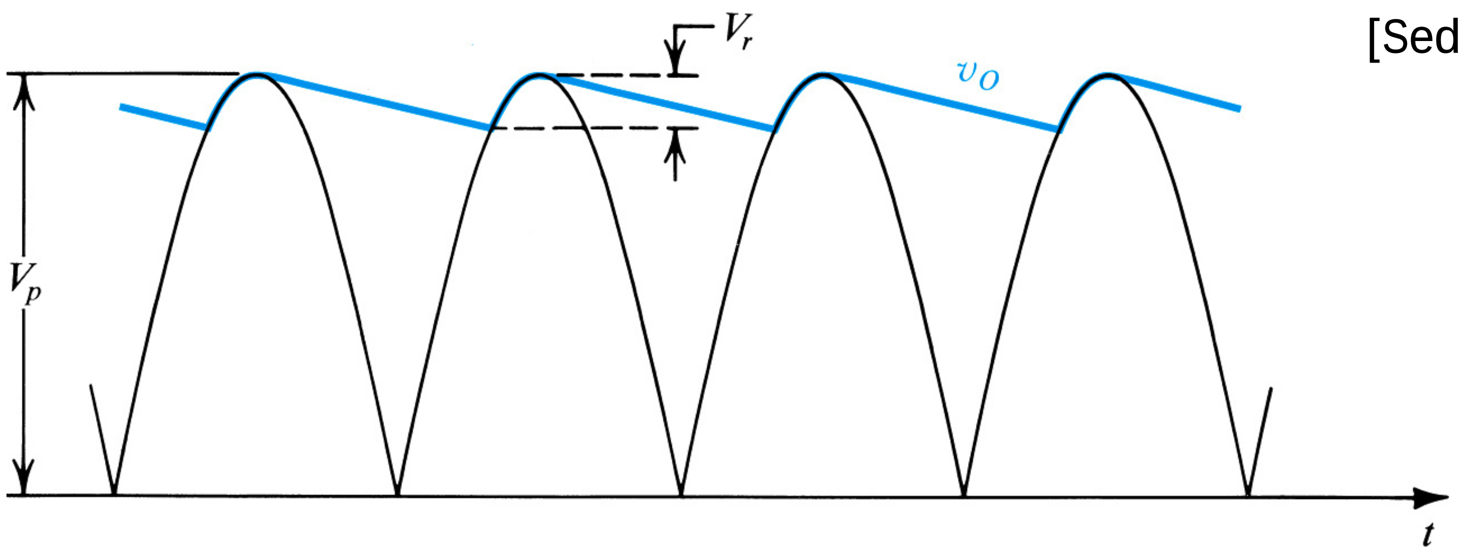
[Karsilayan]



- Rectifies all of the input signal
- Lose two diode voltage drops from the peak value

Full-Wave & Bridge Rectifier w/ a Filter Cap

[Sedra/Smith]



- The capacitor only discharges for T/2
  - Results in ½ Cap size for a given ripple
  - Roughly ½ diode current

$$V_r = V_p \frac{T}{2R_L C_L} \qquad I_{Davg} = I_R\left(1+\pi\sqrt{\frac{V_p}{2V_r}}\right) \qquad I_{D\max} = I_R\left(1+2\pi\sqrt{\frac{V_p}{2V_r}}\right)$$

Rectifier Trade-Offs

- Half-Wave Rectifier
  - \+ Simplest design with fewest components
  - \- Requires largest capacitor for a given ripple
- Full-Wave Rectifier
  - \+ Reduces capacitor size by ½ relative to half-wave
  - \- Requires center-tapped transformer
  - \- PIV almost double that of half-wave
- Bridge Rectifier
  - \+ Reduces capacitor size by ½ relative to half-wave
  - \+ Save PIV as half-wave rectifier
  - \- Lose two diode voltage drops in peak value