Lecture 8: Diodes (2)

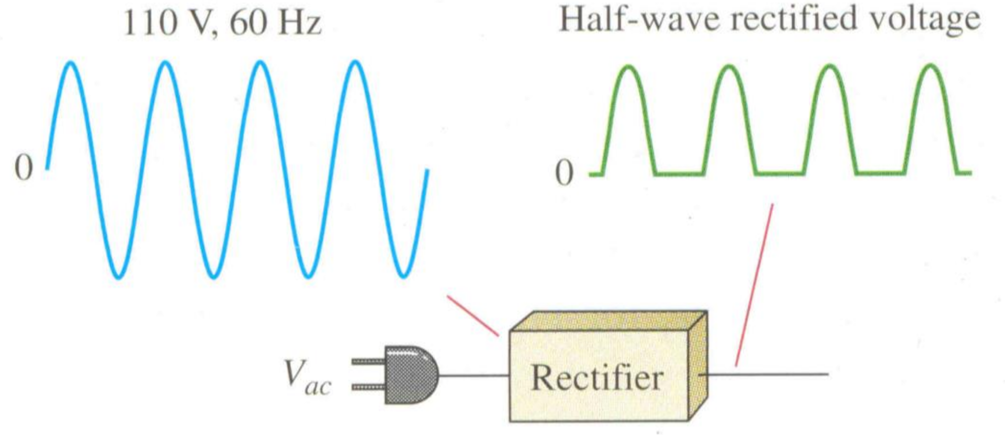
Half-Wave Rectifier, Full-Wave Rectifier, Diode Clippers, Diode Clampers, Examples

Half Wave Rectifier

The *rectifier* is a diode circuit that converts the AC input voltage to a pulsating DC voltage.

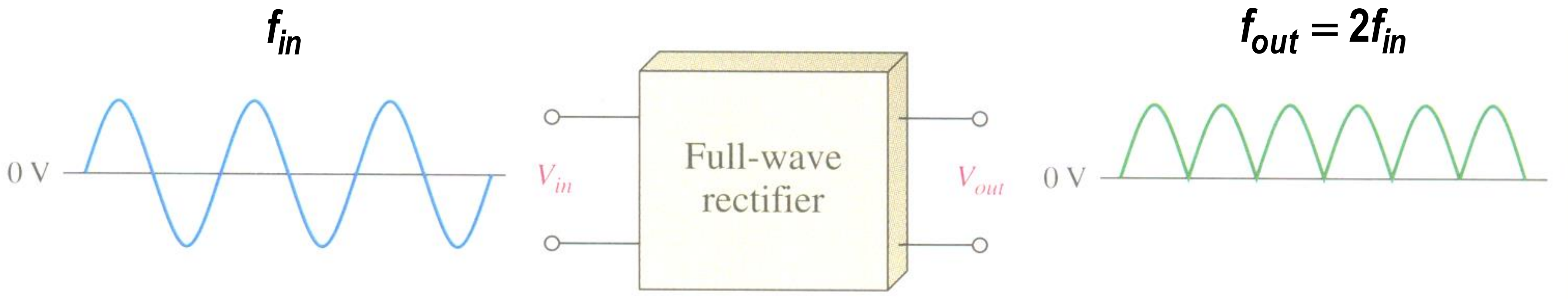
It can be either a *half-wave* or a *full-wave* rectifier:

f_{in} $\quad$ $f_{out} = f_{in}$



The *half-wave* rectifier allows unidirectional current through the load only during *one-half* of the input cycle.

Full-Wave Rectifier



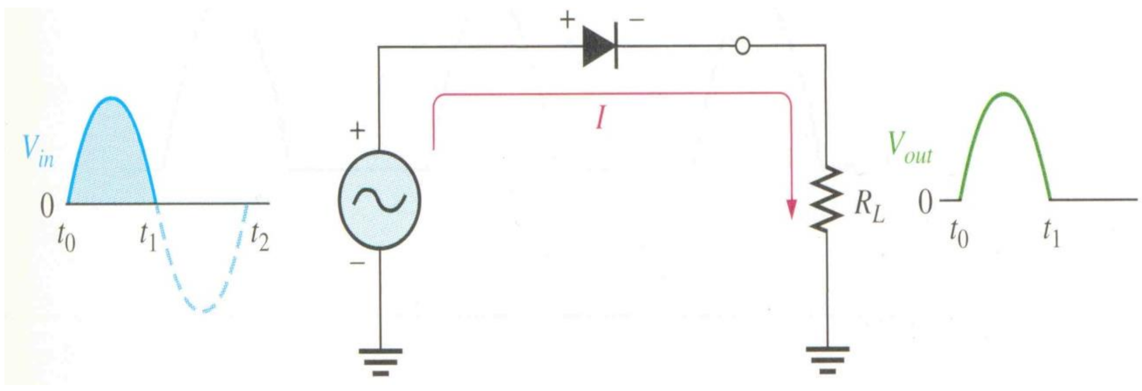
The full-wave rectifier allows unidirectional current through the load during the *entire* input cycle.

Half-Wave Rectifier Using Diodes

+ve Half-Cycle

The diode is forward-biased.

Current can flow through the load.

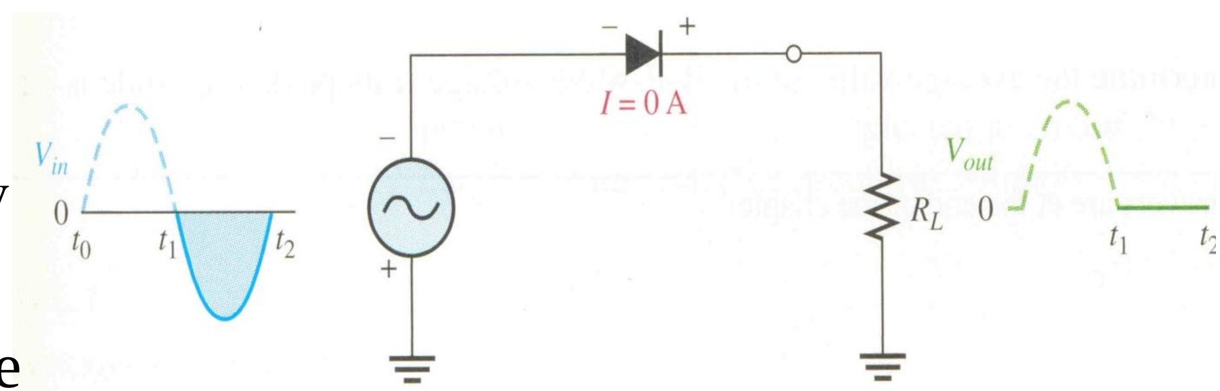


The output voltage equals: $V_{out} = V_{in} - 0.7\text{ V}$

-ve Half-Cycle

The diode is reverse-biased.

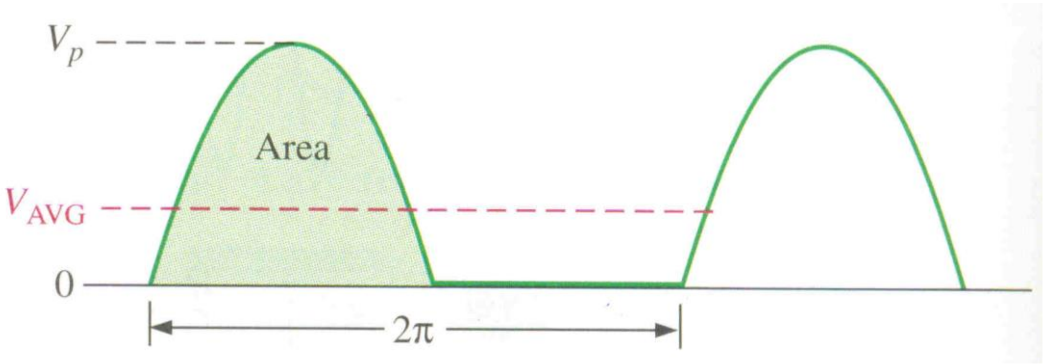
Current can't flow through the load.



The output voltage equals: $V_{out} = 0$

Half-Wave Rectifier (Cont'd)

The time-average value of the output voltage can be calculated as follows:



Condition on peak inverse voltage?

$$V_{AVG(out)} = \frac{1}{2\pi}\int_0^{2\pi} V_{out}(\theta)\, d\theta$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} V_{p(out)} \sin(\theta)\, d\theta + \int_{\pi}^{2\pi} 0\, d\theta\right]$$

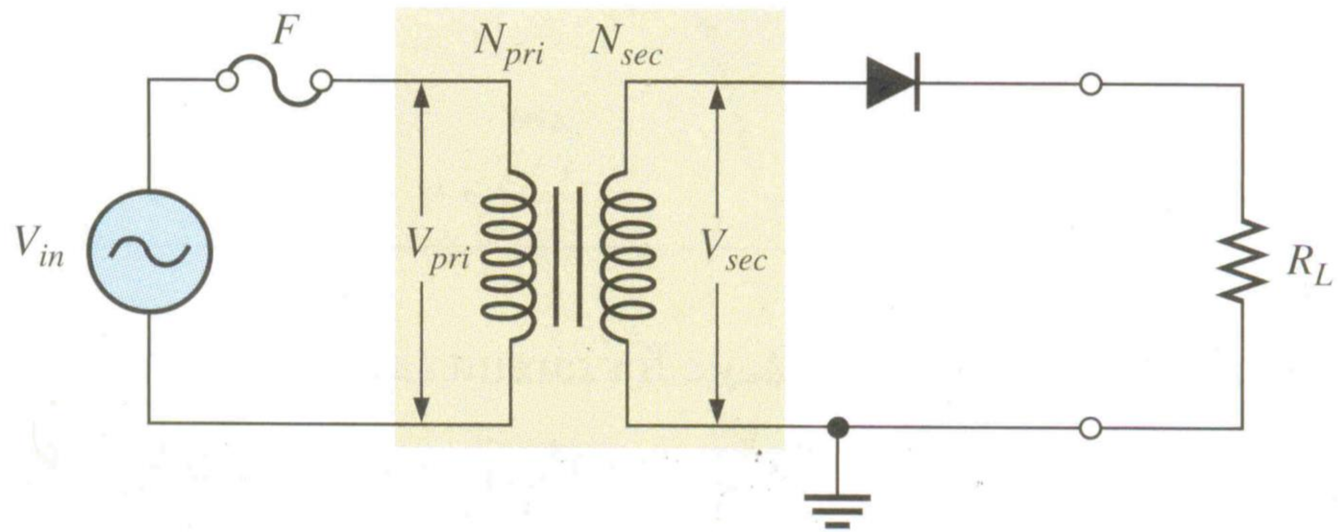
$$= \frac{V_{p(out)}}{2\pi}\left[-\cos(\theta)\right]_0^{\pi} = -\frac{V_{p(out)}}{2\pi}(-1-1) \quad \Rightarrow \quad \therefore V_{AVG(out)}\Big|_{\substack{\text{half-}\\\text{wave}}} = \frac{V_{p(out)}}{\pi}$$

Half-Wave Rectifier (Cont'd)

Usually a transformer is used to couple the AC input voltage from the source to the rectifier

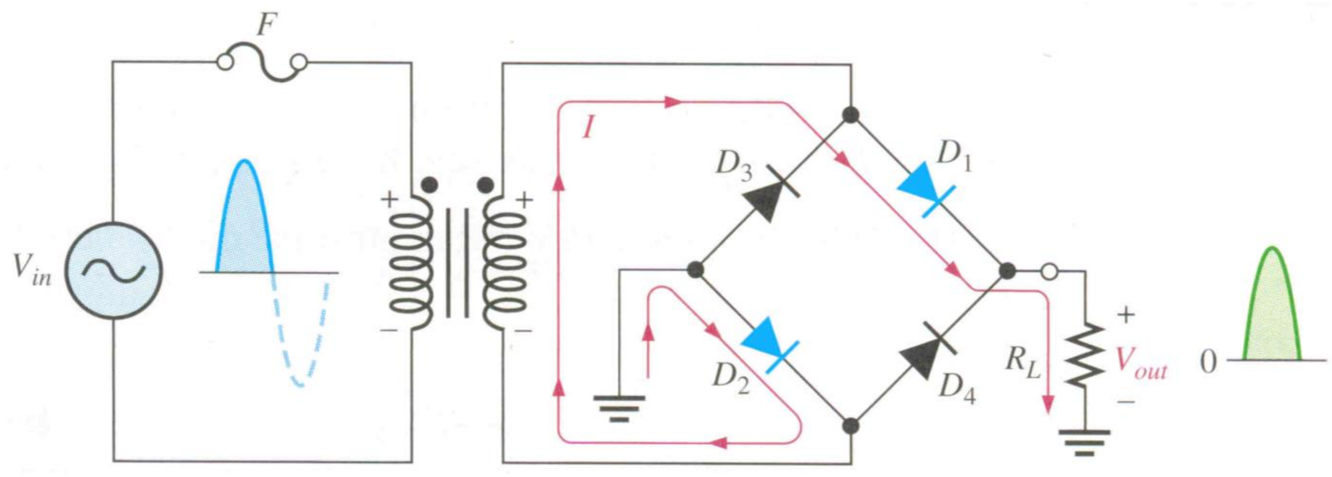
This transformer allows either stepping-up or -down of the input voltage

The turns ratio (n) controls the voltage supplied to the rectifier, such that: $V_{sec} = n\ V_{pri},\quad$ where $n \equiv$ turns ration $= N_{sec}/N_{pri}$



Full-Wave Bridge Rectifier

+ve Half-Cycle

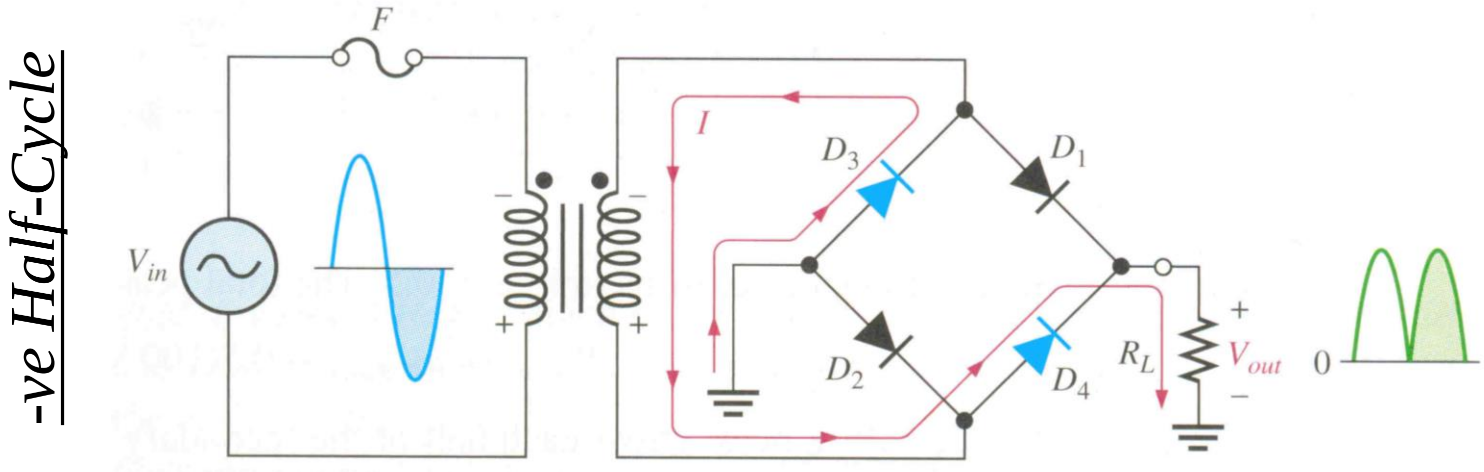


D_1 and D_2 are forward-biased, while D_3 and D_4 are reverse-biased.

Current flows in the load from node *A* toward ground.

Output voltage equals: $V_{out} = V_{sec} - 1.4 \text{ V}$

Full-Wave Bridge (Cont'd)

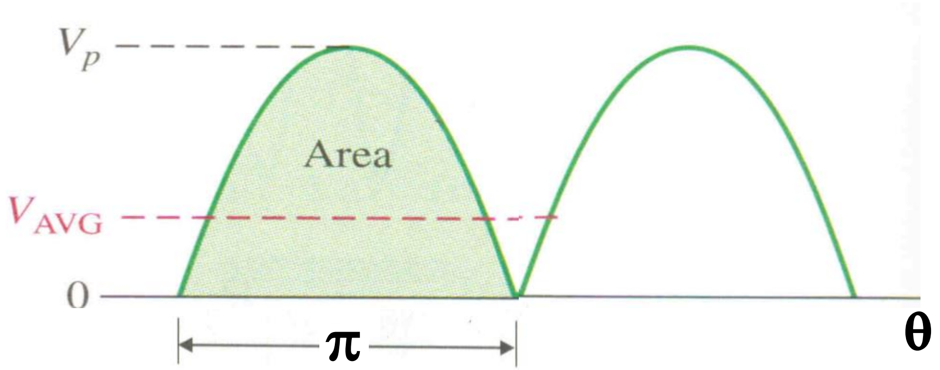


D_1 and D_2 are reverse-biased, while D_3 and D_4 are forward-biased.

Current flows in the same direction from node *A* toward ground.

Output voltage equals: $V_{out} = V_{sec} - 1.4\text{ V}$

Full-Wave Bridge (Cont'd)



$$V_{AVG(out)} = \frac{\text{area under a complete cycle}}{\text{period of a complete cycle}}$$

$$= \frac{\text{area of the half-wave rectifier}}{\pi}$$

$$= 2 \times V_{AVG(out)}\Big|_{\substack{\text{half-}\\\text{wave}}}$$

$$\therefore V_{AVG(out)}\Big|_{\substack{\text{full-}\\\text{wave}}} = 2V_{p(out)} / \pi$$

What is the Peak Inverse Voltage?

Diode Limiters

The diode *limiter (clipper)* is a circuit that passes to the output port that part from the input waveform that falls either above or below certain reference level. It is very useful for *protection*.

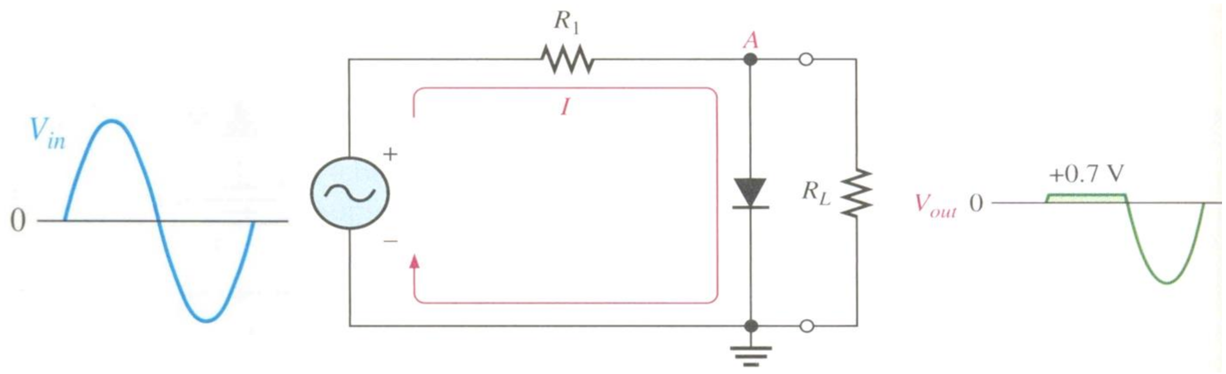
D is FB, $V_D = 0.7$,

$V_{out} = 0.7$

$V_{in} \rightarrow -V_{p(in)}$:

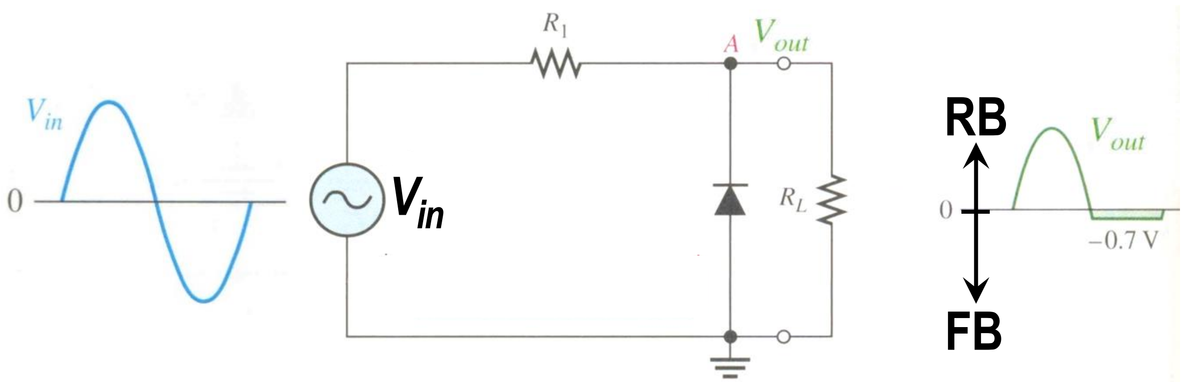
D is RB, $I_D = 0$

$V_{out} = V_{in} R_L / (R_1 + R_L) \underset{R_1 << R_L}{\cong} V_{in}$



Positive Limiter

Diode Limiters (Cont'd)



$\underline{V_{in} \rightarrow V_{p(in)}:}$

D is RB, $I_D = 0$

$$V_{out} = V_{in} R_L / (R_1 + R_L) \underset{R_1 << R_L}{\cong} V_{in}$$

$\underline{V_{in} \rightarrow -V_{p(in)}:}$

D is FB, $V_D = 0.7$,

$V_{out} = -0.7$

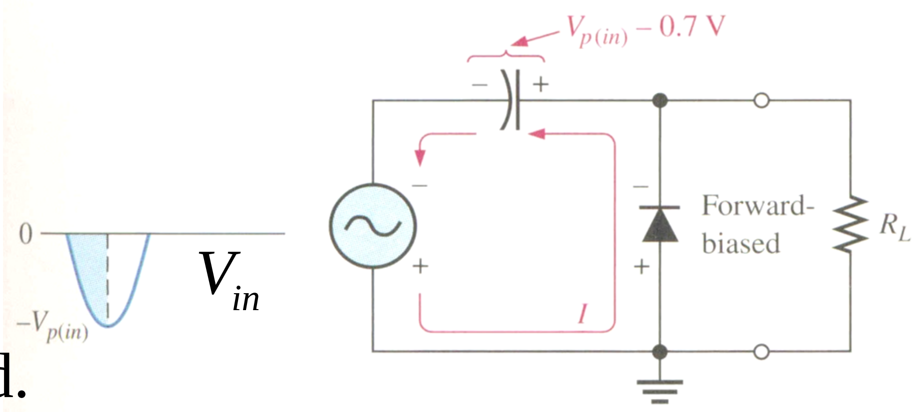
Negative limiter

Diode Clamper

The diode *clamper* is a circuit that *adds a DC level* (positive or negative) to an AC voltage.

The circuit below is a *positive* clamper which adds a +ve DC level to the input voltage.

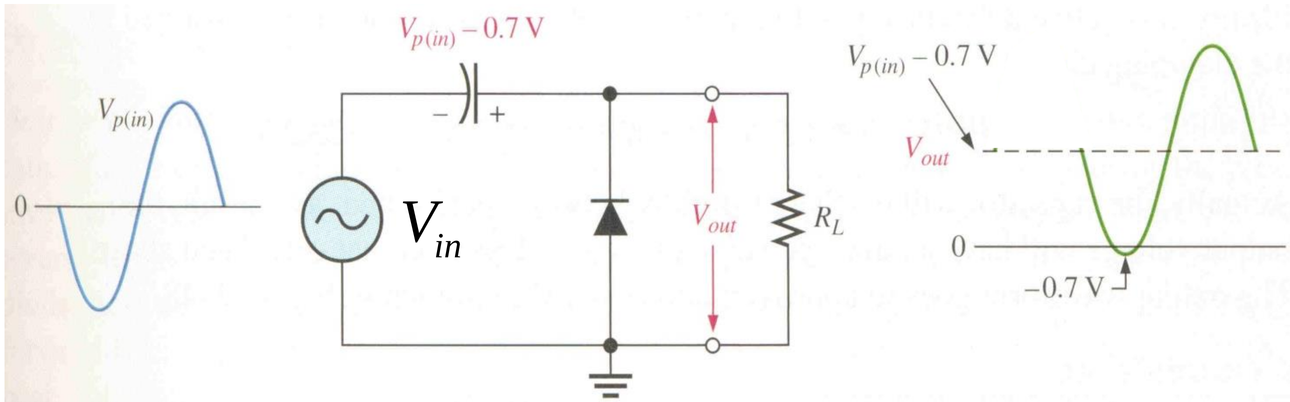
First Quarter Cycle



The diode is forward-biased.
$\tau = r'_d C$ is small.
The capacitor is *fastly* charging up to $V_C = V_{p(in)}$ - 0.7V.

Diode Clamper (Cont'd)

Rest of Cycles



V_{pn} = -V_{in} - V_C = -V_{in} - $V_{p(in)}$ + 0.7 < 0.7 *Diode* is reverse-biased.

The *large* *C* is discharging *very slowly* through R_L.

C can be considered as a battery with constant voltage of $V_C = V_{p(in)}$ - 0.7.

$V_{out} = V_{in} + V_C = V_{in} + V_{p(in)}$ - 0.7V.