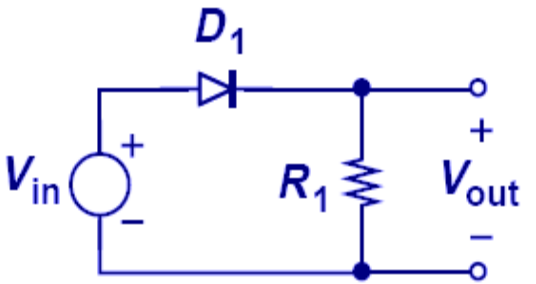
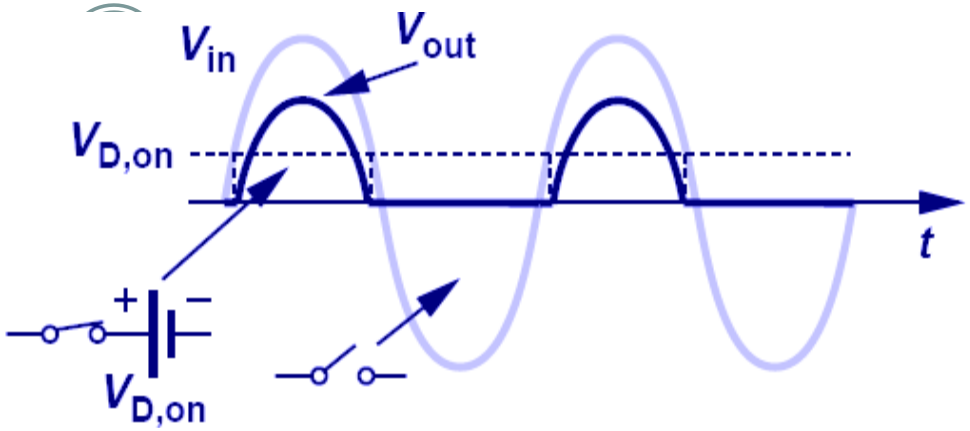
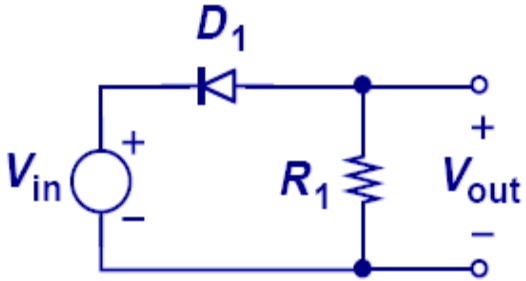
# Semiconductor Diode

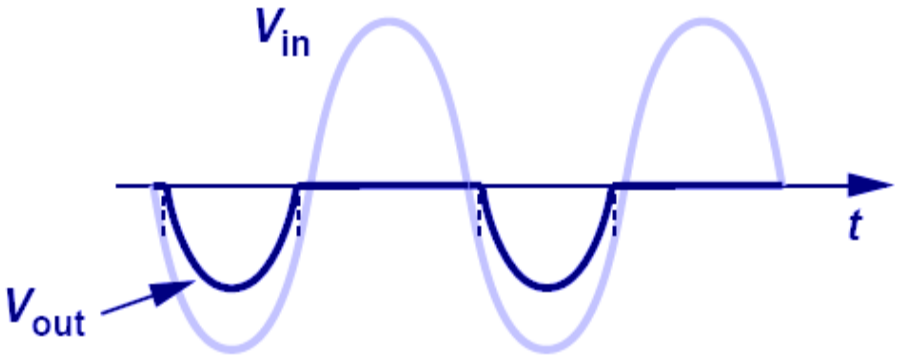
# Applications of Diode

# Half-Wave Rectifier



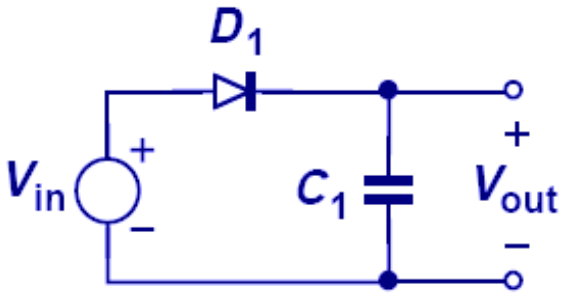



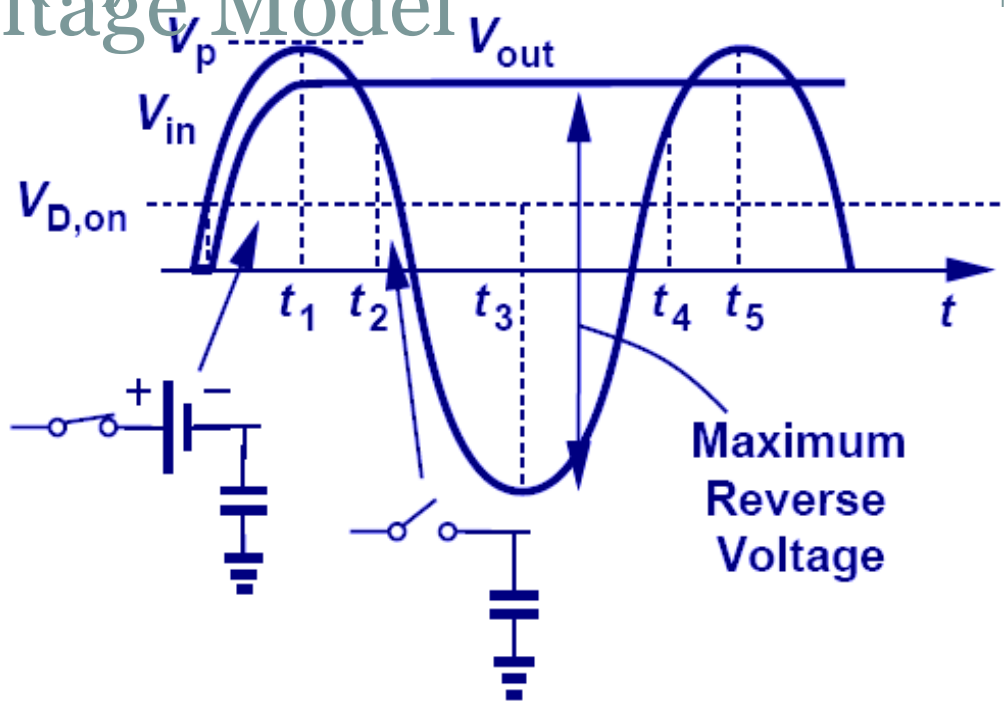




- A very common application of diodes is half-wave rectification, where either the positive or negative half of the input is blocked.
- But, how do we generate a *constant* output?

# Diode-Capacitor Circuit: Constant Voltage Model



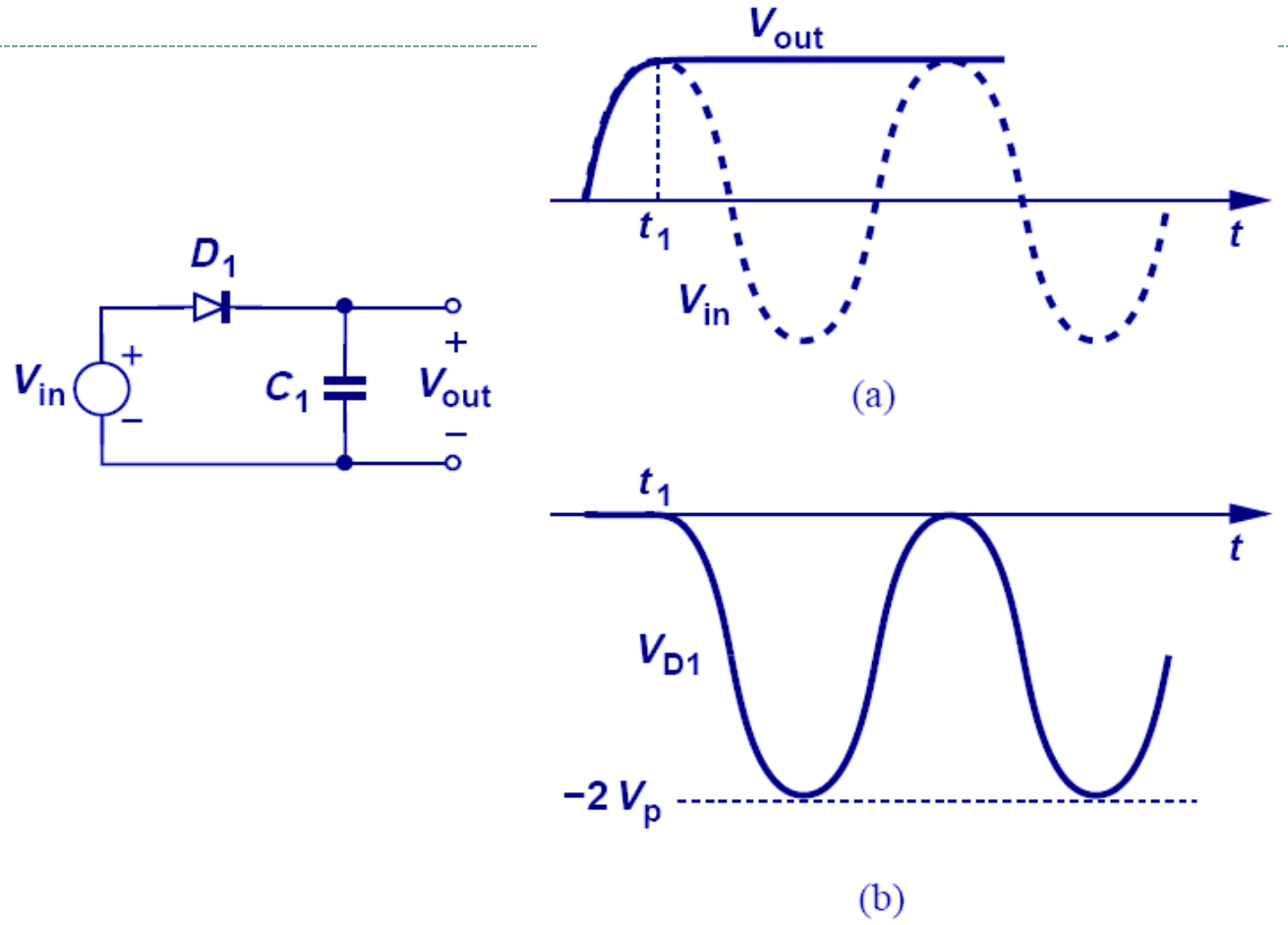

(a)




(b)

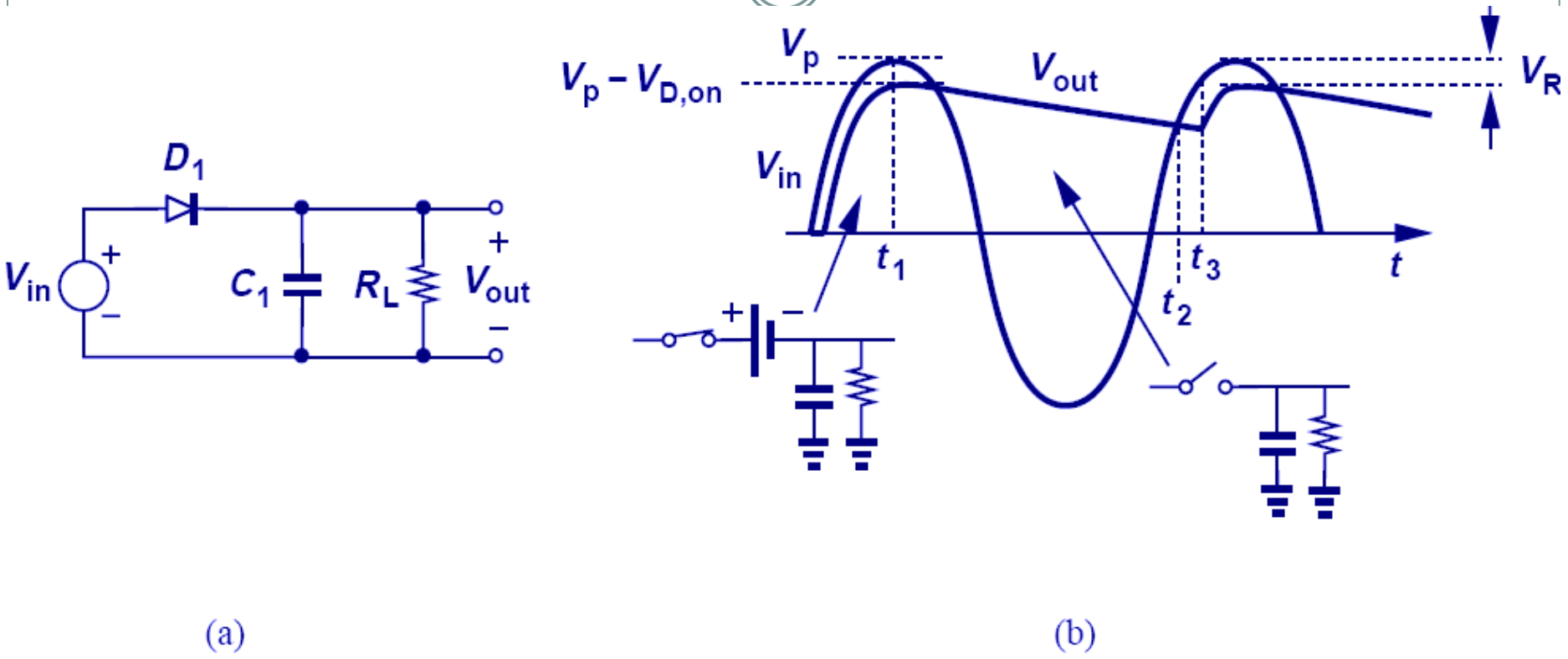
- If the resistor in half-wave rectifier is replaced by a capacitor, a fixed voltage output is obtained since the capacitor (assumed ideal) has no path to discharge.

# Diode-Capacitor Circuit: Ideal Model



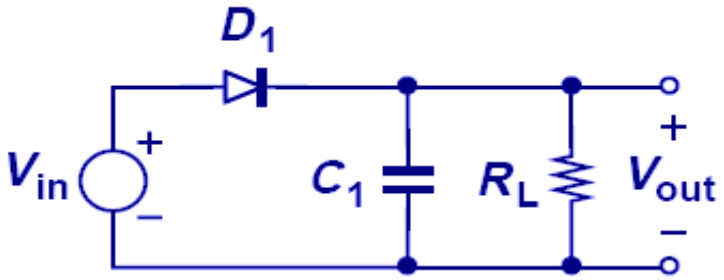

- Note that (b) is just like $V_{in,}$ only shifted down.

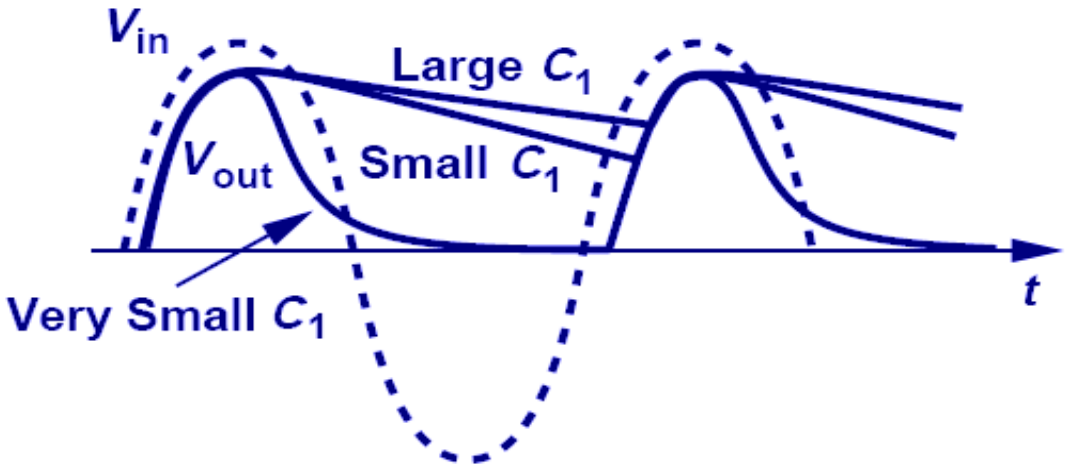
# Diode-Capacitor With Load Resistor




- A path is available for capacitor to discharge. Therefore, $V_{out}$ will not be constant and a ripple exists.

# Behavior for Different Capacitor Values




- For large $C_1$, $V_{out}$ has small ripple.

# Peak to Peak amplitude of Ripple

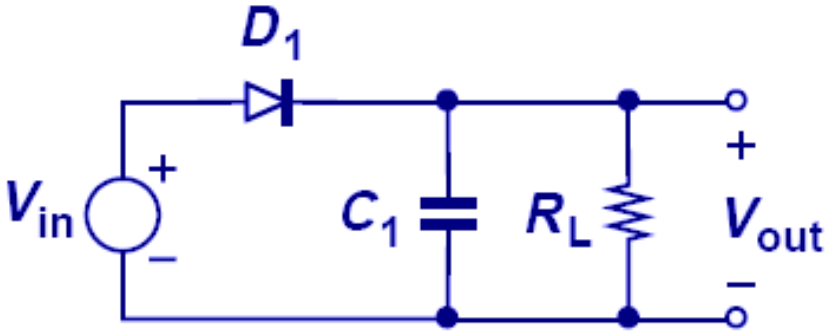
$$V_{out}(t) = (V_p - V_{D,on}) \exp \frac{-t}{R_L C_1} \qquad 0 \le t \le T_{in}$$

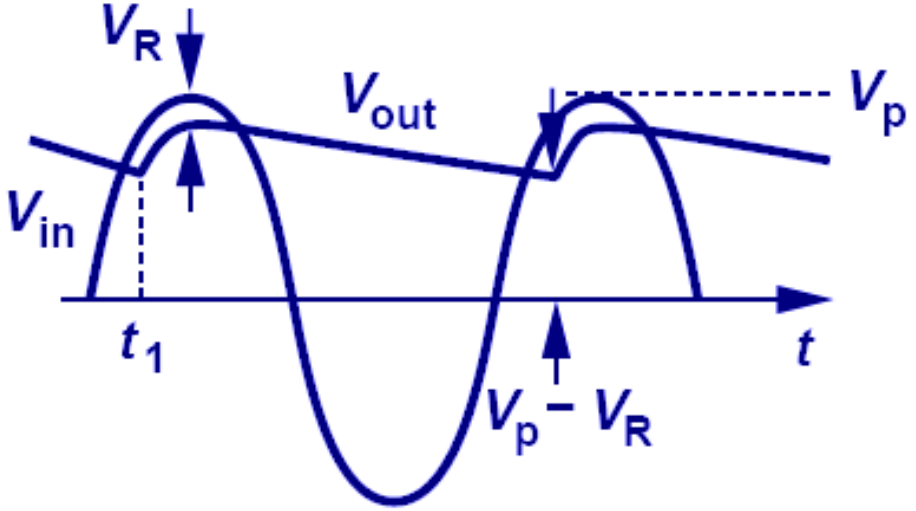
$$V_{out}(t) \approx (V_p - V_{D,on})(1 - \frac{t}{R_L C_1}) \approx (V_p - V_{D,on}) - \frac{V_p - V_{D,on}}{R_L} \frac{t}{C_1}$$

$$V_R \approx \frac{V_p - V_{D,on}}{R_L} \cdot \frac{T_{in}}{C_1} \approx \frac{V_p - V_{D,on}}{R_L C_1 f_{in}}$$

- The ripple amplitude is the decaying part of the exponential.
- Ripple voltage becomes a problem if it goes above 5 to 10% of the output voltage.

# Maximum Diode Current

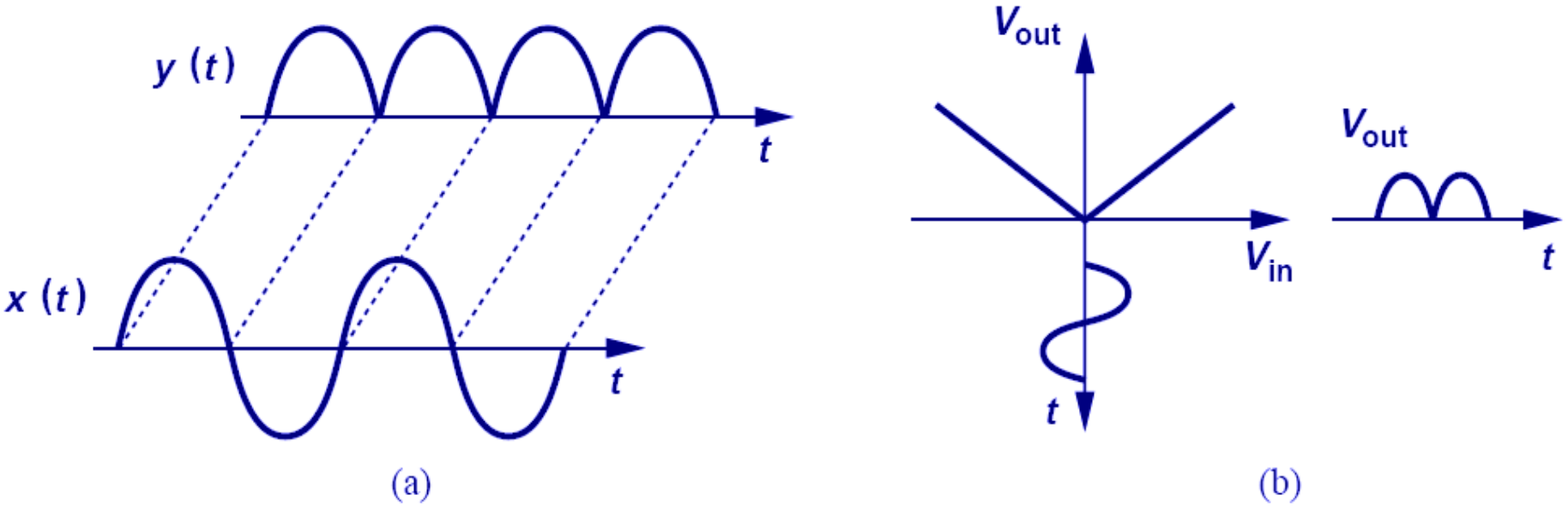


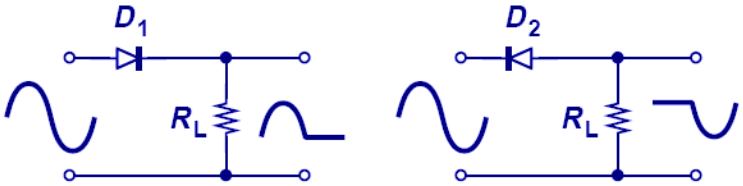

$$I_p \approx C_1 \omega_{in} V_p \sqrt{\frac{2V_R}{V_p}} + \frac{V_p}{R_L} \approx \frac{V_p}{R_L}\left(R_L C_1 \omega_{in} \sqrt{\frac{2V_R}{V_p}} + 1\right)$$

- The diode has its maximum current at $t_1$, since that's when the slope of $V_{out}$ is the greatest.
- This current has to be carefully controlled so it does not damage the device.

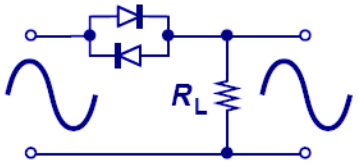
# Full-Wave Rectifier



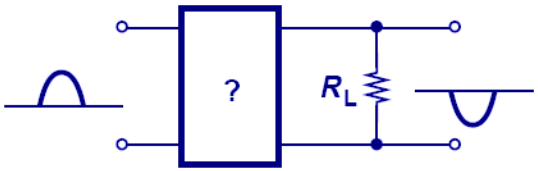

- A full-wave rectifier passes both the negative and positive half cycles of the input, while inverting the negative half of the input.
- As proved later, a full-wave rectifier reduces the ripple by a factor of two.



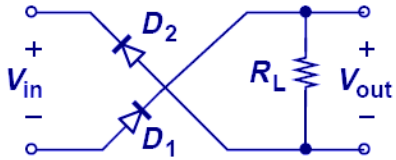

(a)



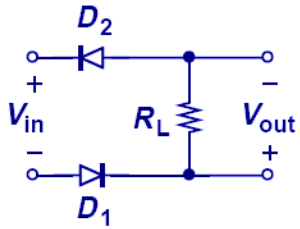

(b)



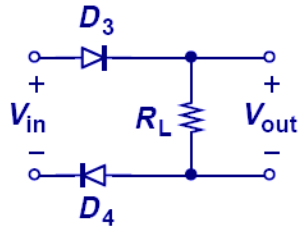

(c)




(d)



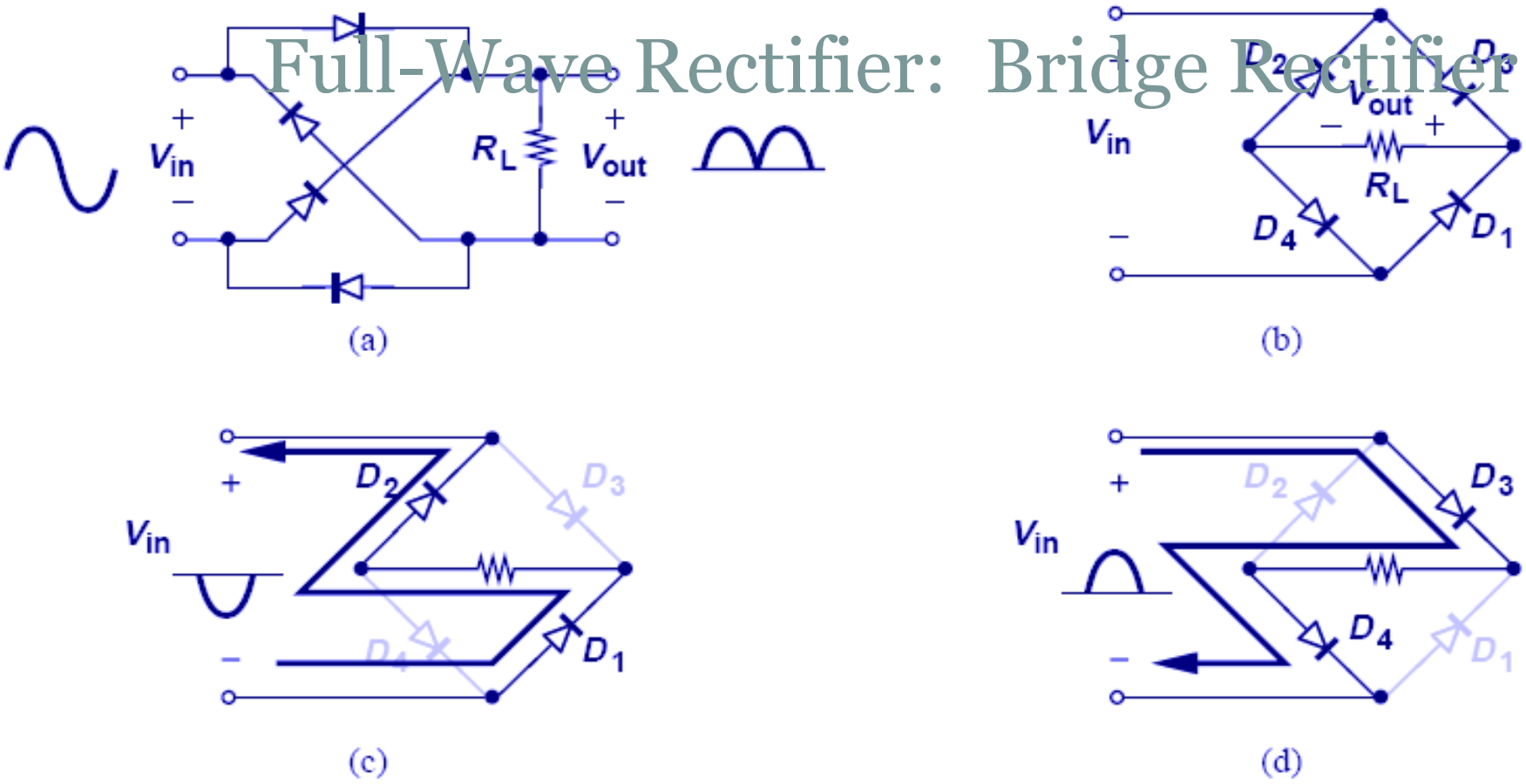

(e)




(f)

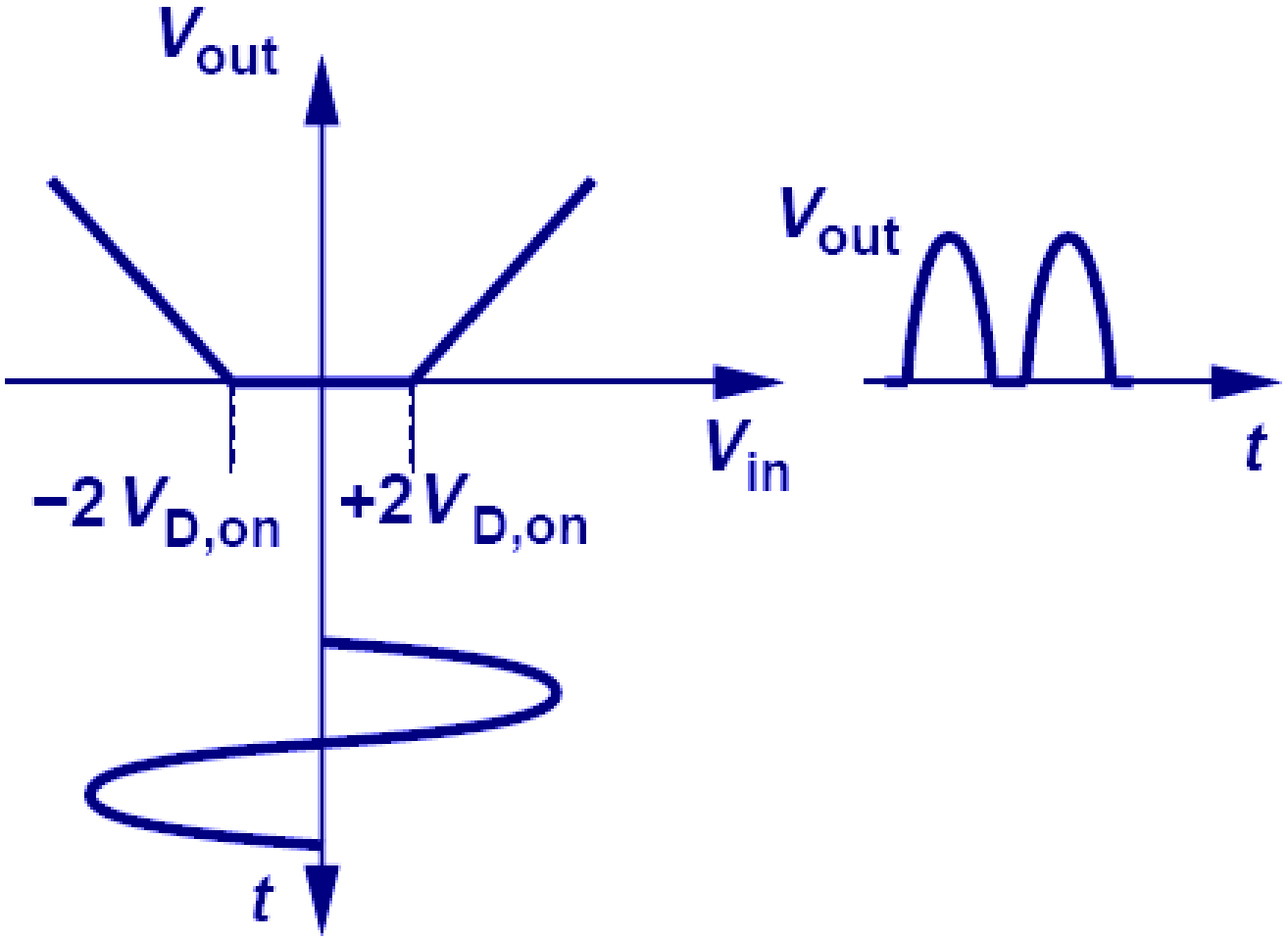
- Figures (e) and (f) show the topology that inverts the negative half cycle of the input.

# Full-Wave Rectifier: Bridge Rectifier



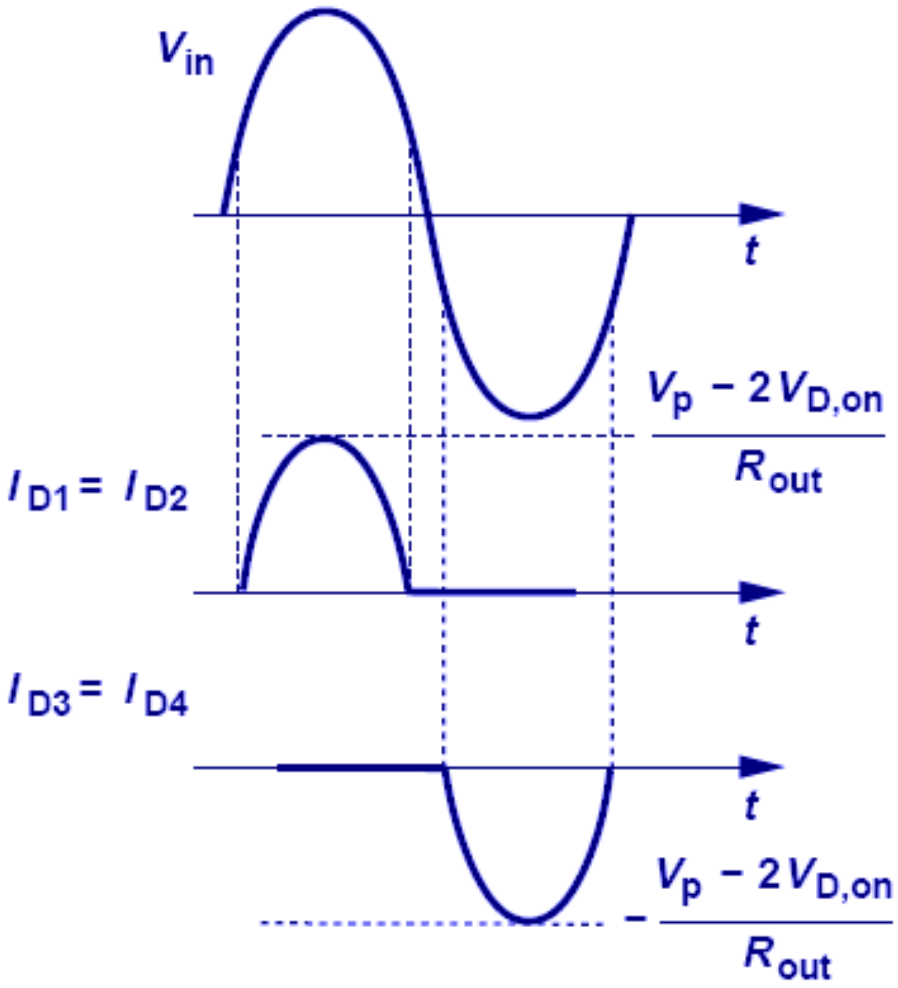

- The figure above shows a full-wave rectifier, where $D_1$ and $D_2$ pass/invert the negative half cycle of input and $D_3$ and $D_4$ pass the positive half cycle.

# Input/Output Characteristics of a Full Wave )

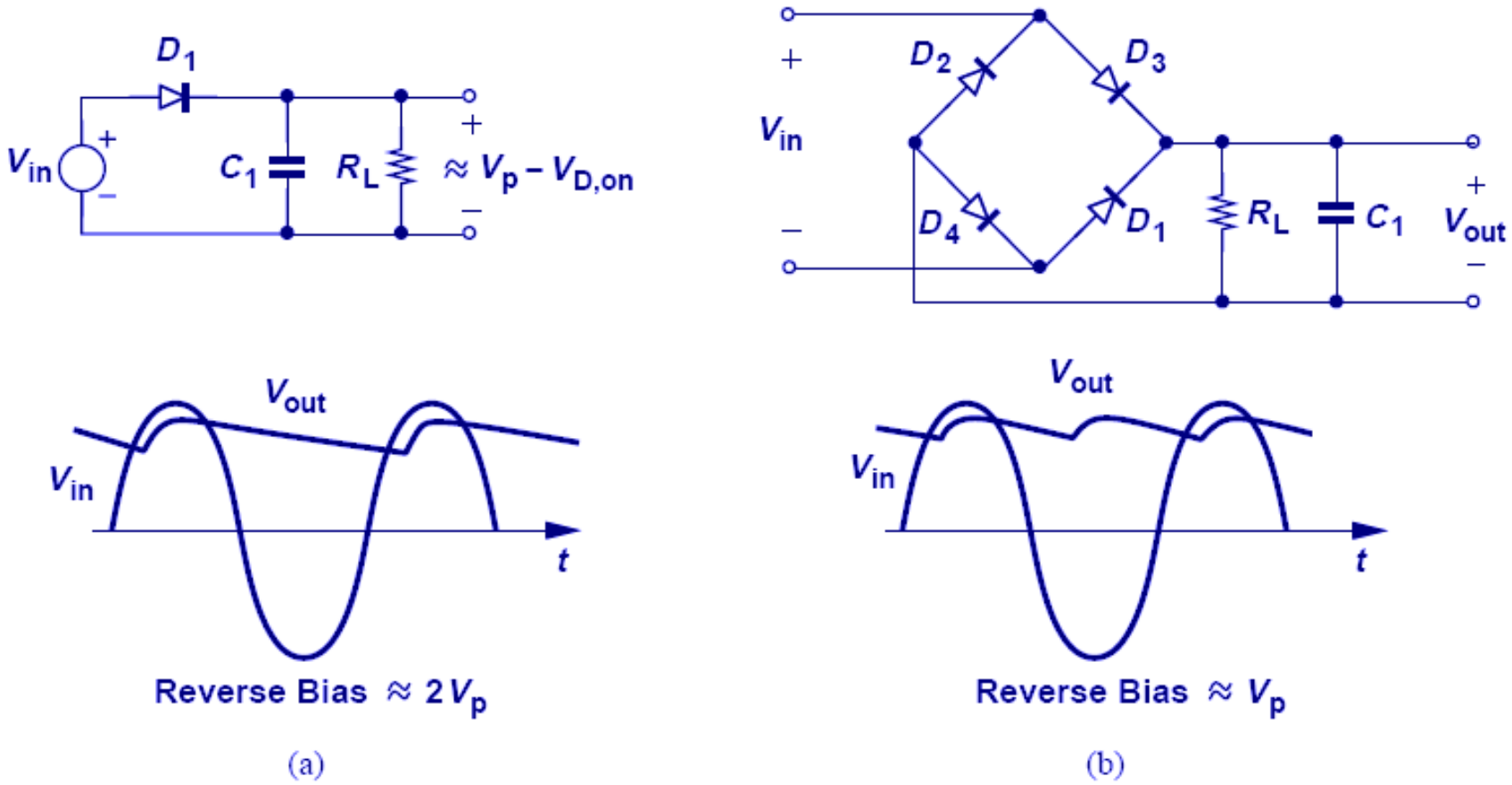



- The dead-zone around $V_{in}$ arises because $V_{in}$ must exceed 2 $V_{D,ON}$ to turn on the bridge.

# Cur e Rectifier

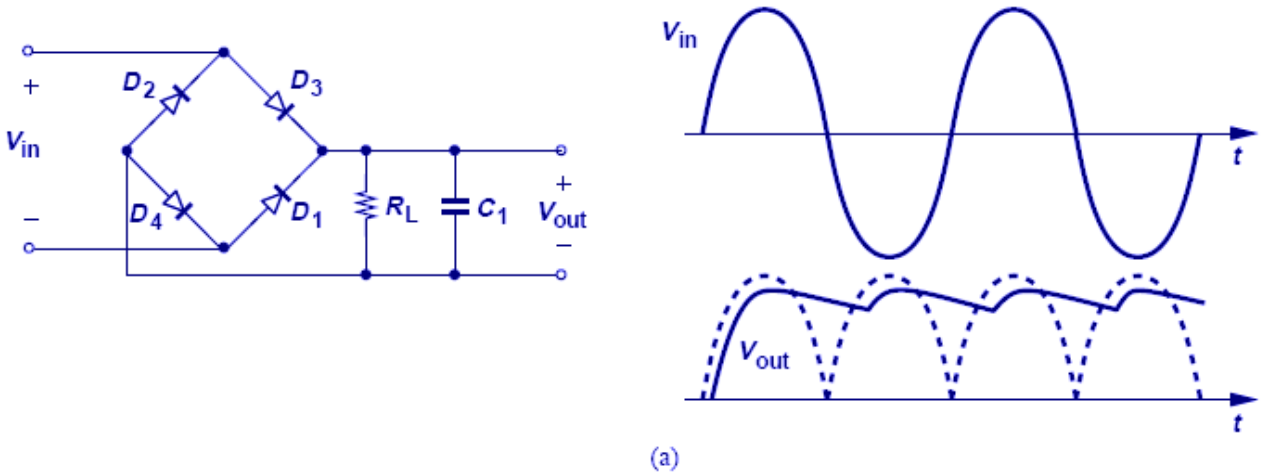


# Summary of Half and Full-Wave

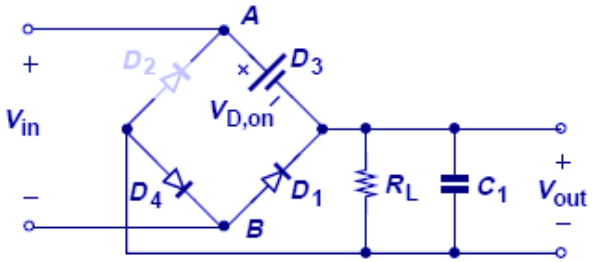



- Full-wave rectifier is more suited to adapter and charger applications.

# Complete Full-Wave Rectifier




(a)

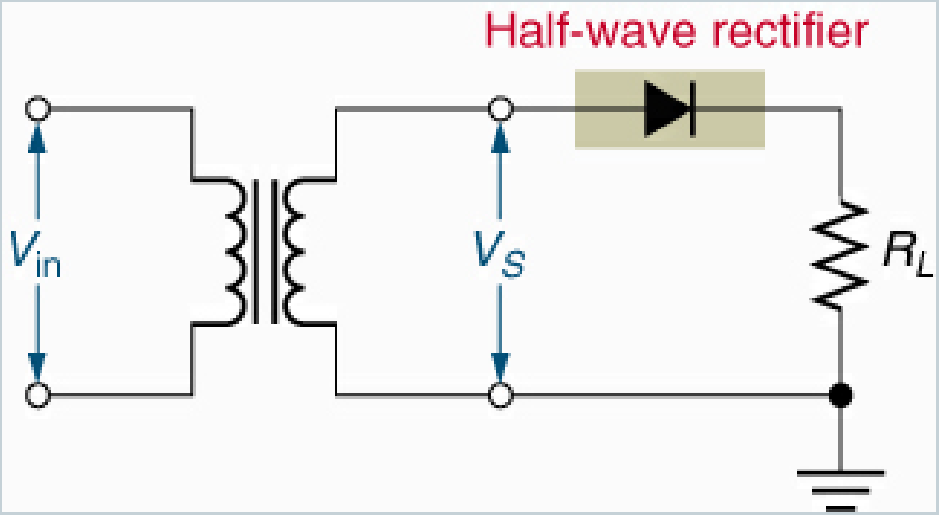



(b)

- Since $C_1$ only gets ½ of period to discharge, ripple voltage is decreased by a factor of 2. Also (b) shows that each diode is subjected to approximately one $V_p$ reverse bias drop (versus $2V_p$ in half-wave rectifier).

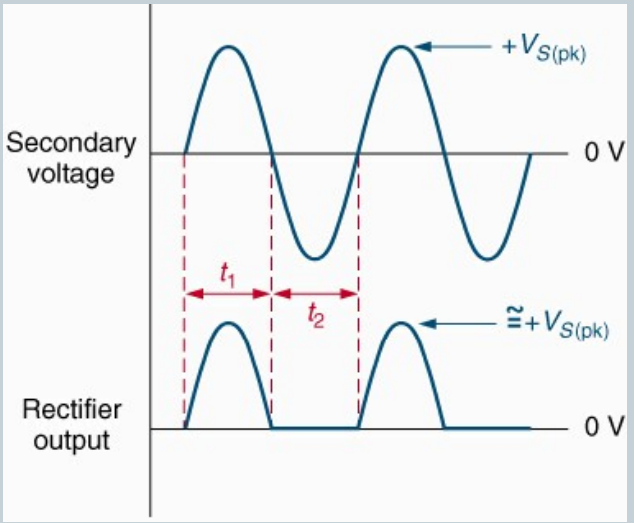
# Half-wave Rectifiers

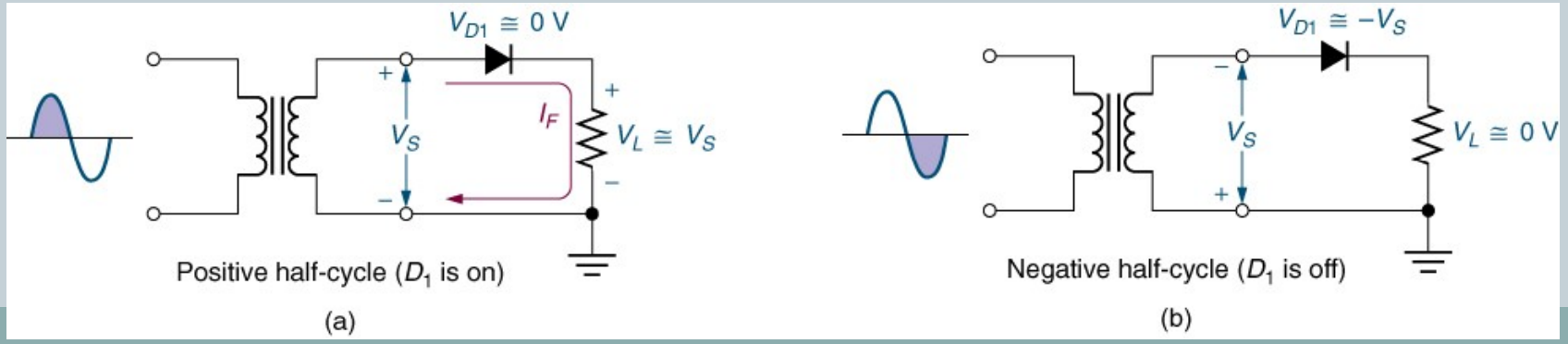
- Half-wave rectifier – A diode placed in series between a transformer (or ac line input) and its load.



# Positive Half-wave Rectifiers

This circuit converts an ac input to a series of positive pulses.



# Average Load Voltage and Current

- Average voltage ($V_{ave}$) – The dc equivalent of a voltage waveform.
- Average current ($I_{ave}$) – The dc equivalent of a current waveform.

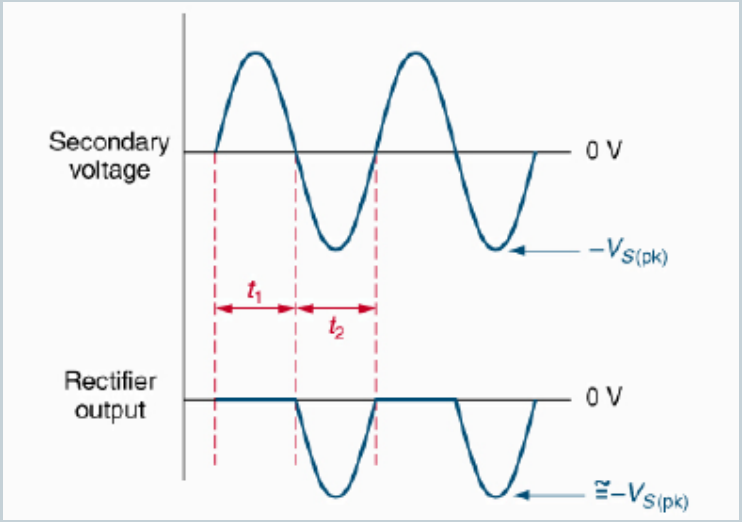
For the output from a *half-wave* rectifier:

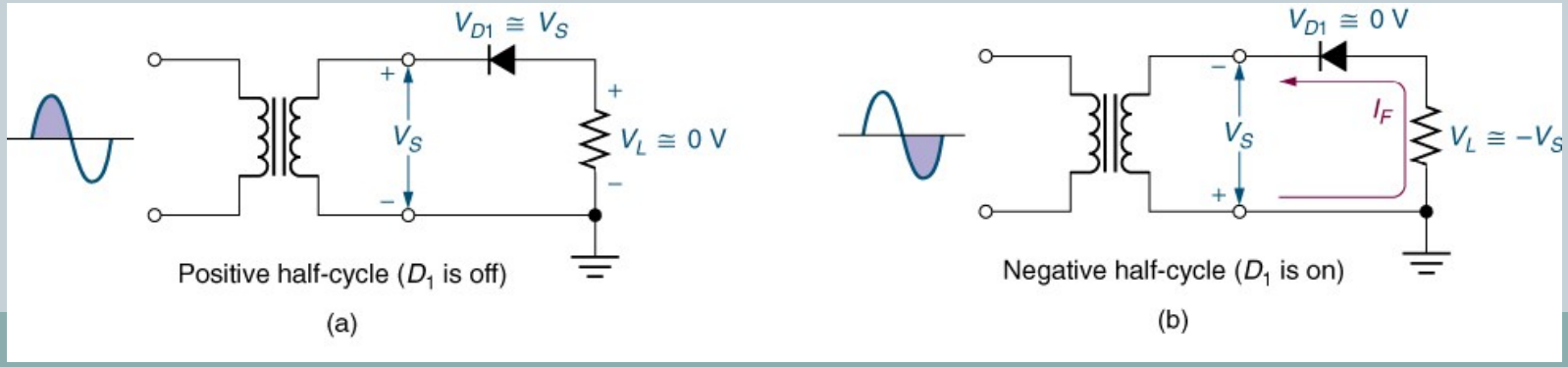
$$V_{ave} = \frac{V_{pk}}{\pi}$$

$$I_{ave} = \frac{I_{pk}}{\pi}$$

# Negative Half-wave Rectifiers

This circuit converts an ac input to a series of negative pulses.



# Peak Inverse Voltage (PIV)

Peak inverse voltage (PIV) – The maximum diode reverse bias produced by a given circuit.

For the diode in a half-wave rectifier:

$$\text{PIV} = V_{S(\text{pk})}$$