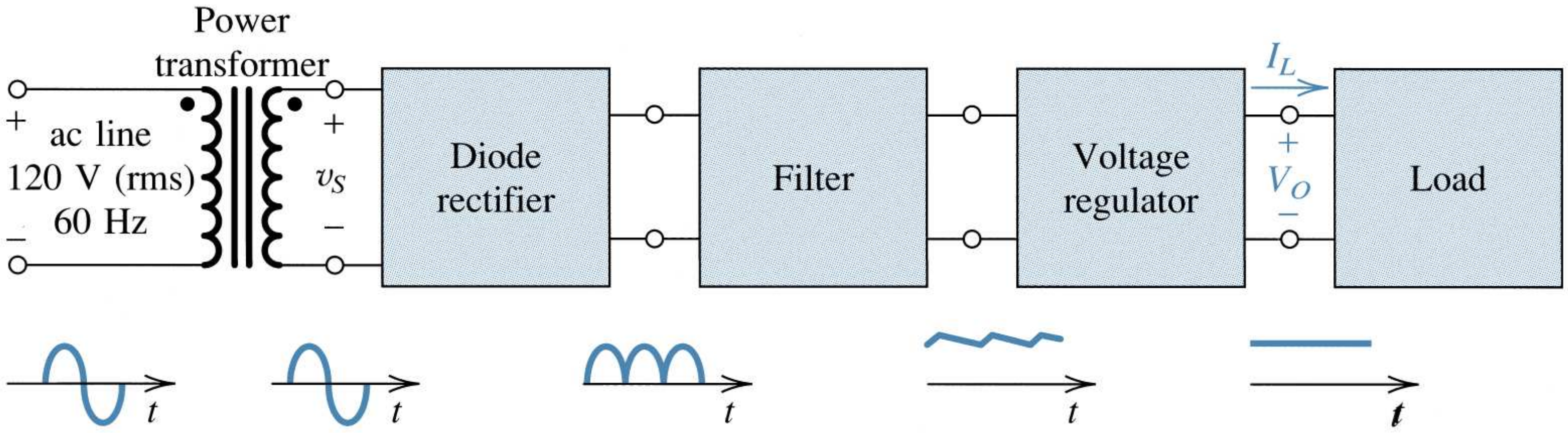
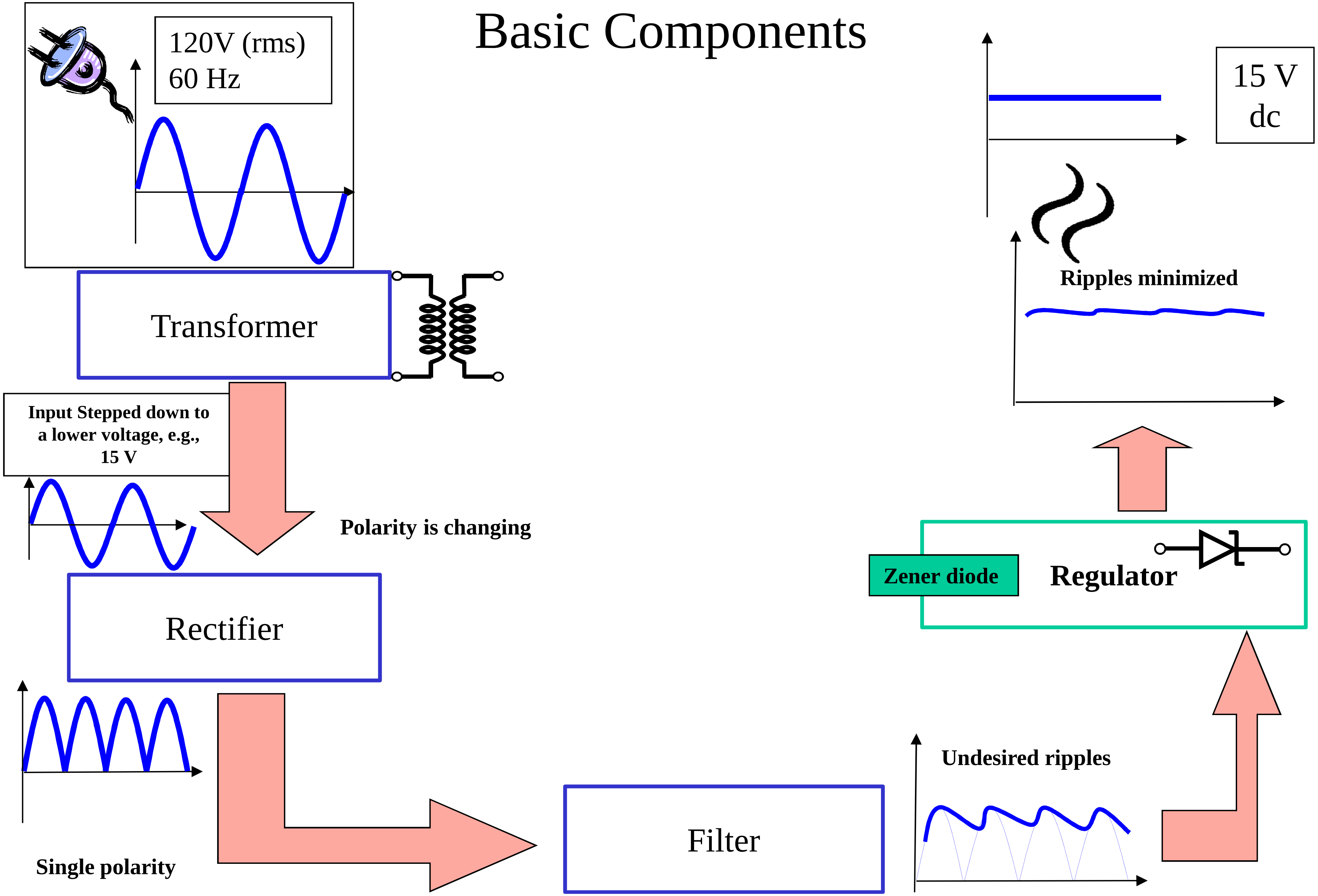


Rectifier Circuits

Rectifiers are devices that convert AC voltage to DC voltage. They use the diodes and make advantage of their characteristic that allows current to flow only in one direction.

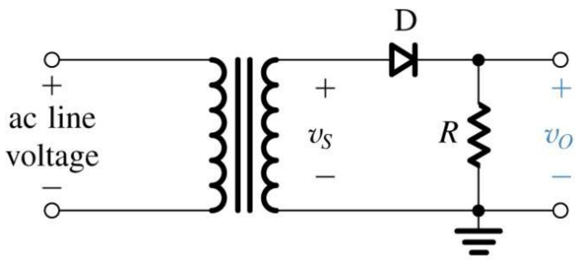
Basic Components



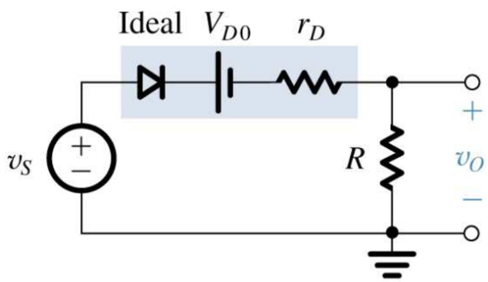
Half-Wave Rectifier

$$v_o = v_s - V_D$$

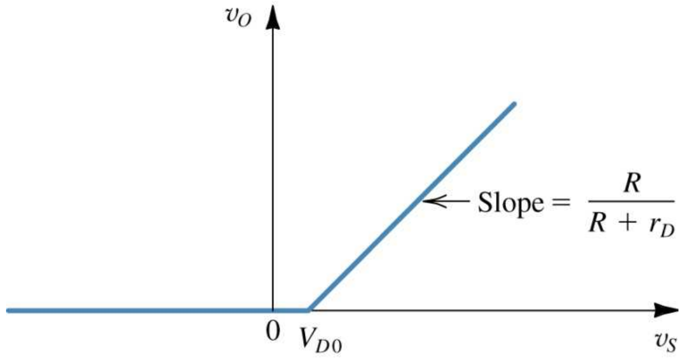
$$PIV = V_s$$



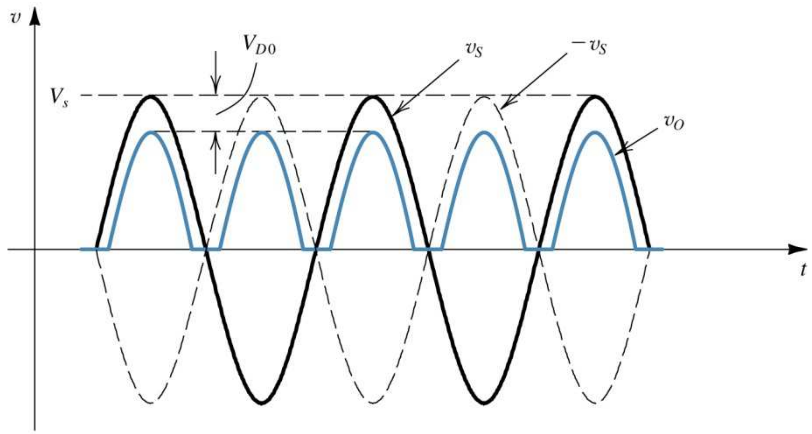
(a)



(b)



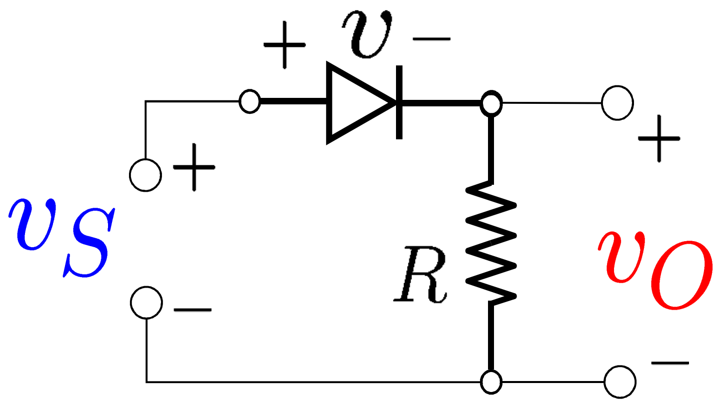
(c)



(c)

Breakdown
How or when can it occur?

Diodes are usually marked by their **PIV** rating. A diode with low PIV rating (i.e., one that breaks down at small negative voltage) is cheaper and easier to manufacture, while another one that has a high PIV rating can sustain a large negative voltage without breakdown



What is PIV?

The **PIV** for this half-wave single diode rectifier is the peak value

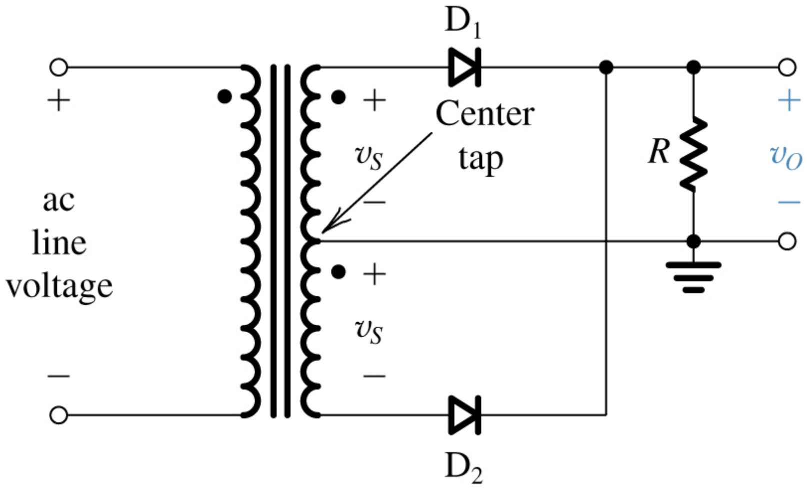
$$\mathrm{PIV} = |v_{\mathrm{min}}| = |-V_S| = V_S$$

In other words, to design a half-wave rectifier using a single diode, we need to use a diode whose PIV is higher than V_S, which is the peak value of the source voltage

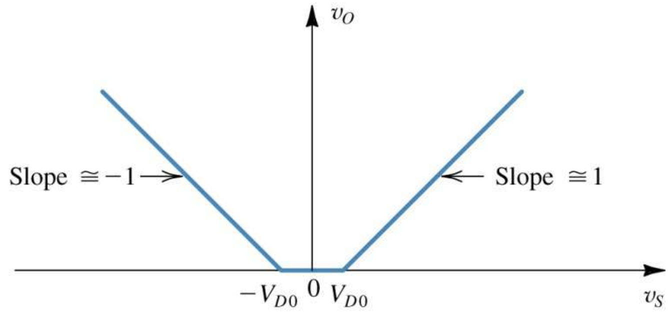
For example, if V_S is 10 V, then it would be safer to choose a diode whose V_{ZK} higher than, e.g. is 40 % bigger than V_S

Full-Wave Rectifier

$$PIV = 2V_s - V_{D0}$$



(a)



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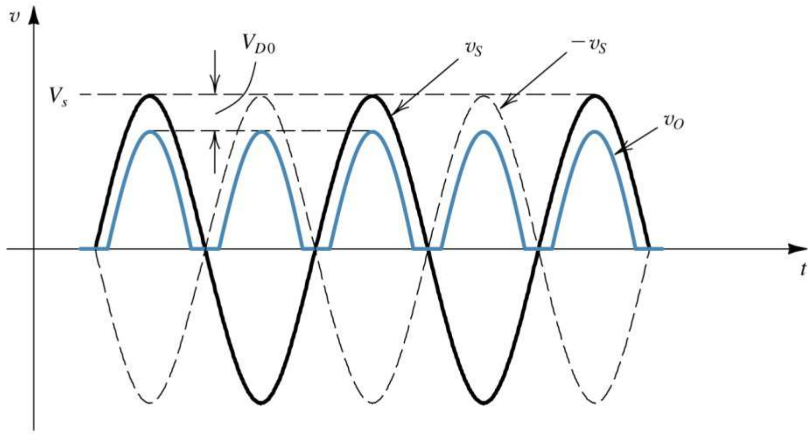


(c)

Comparison Between Half- and Full Wave Rectifier in terms of the PIV

$$PIV_{(\text{ One-diode Half-Wave})} = \boldsymbol{V_S}$$

$$PIV_{(\text{ Two-diode Full-Wave})} = \boldsymbol{2V_S - V_{DO}}$$

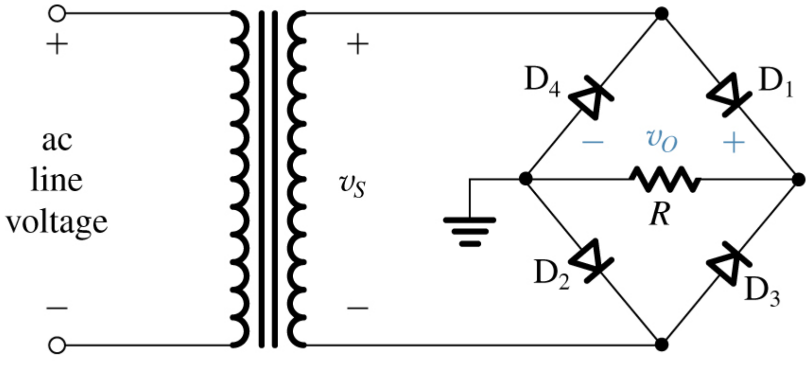
That is bad, because it means that we will need to use a diode with a higher PIV rating

Bridge Rectifier

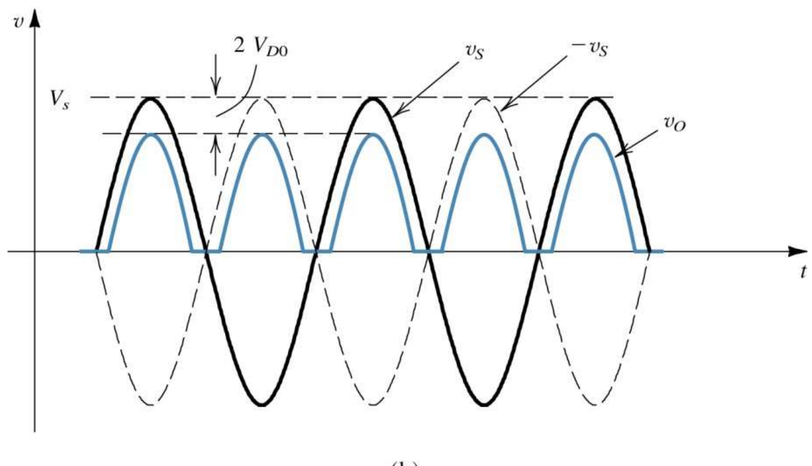
The bridge rectifier acts as a full-wave rectifier. In additions it does suffer from the high PIV requirement needed in the two-diode full-wave rectifier presented earlier.

The Bridge Rectifier

$$PIV = V_s - V_{D0}$$

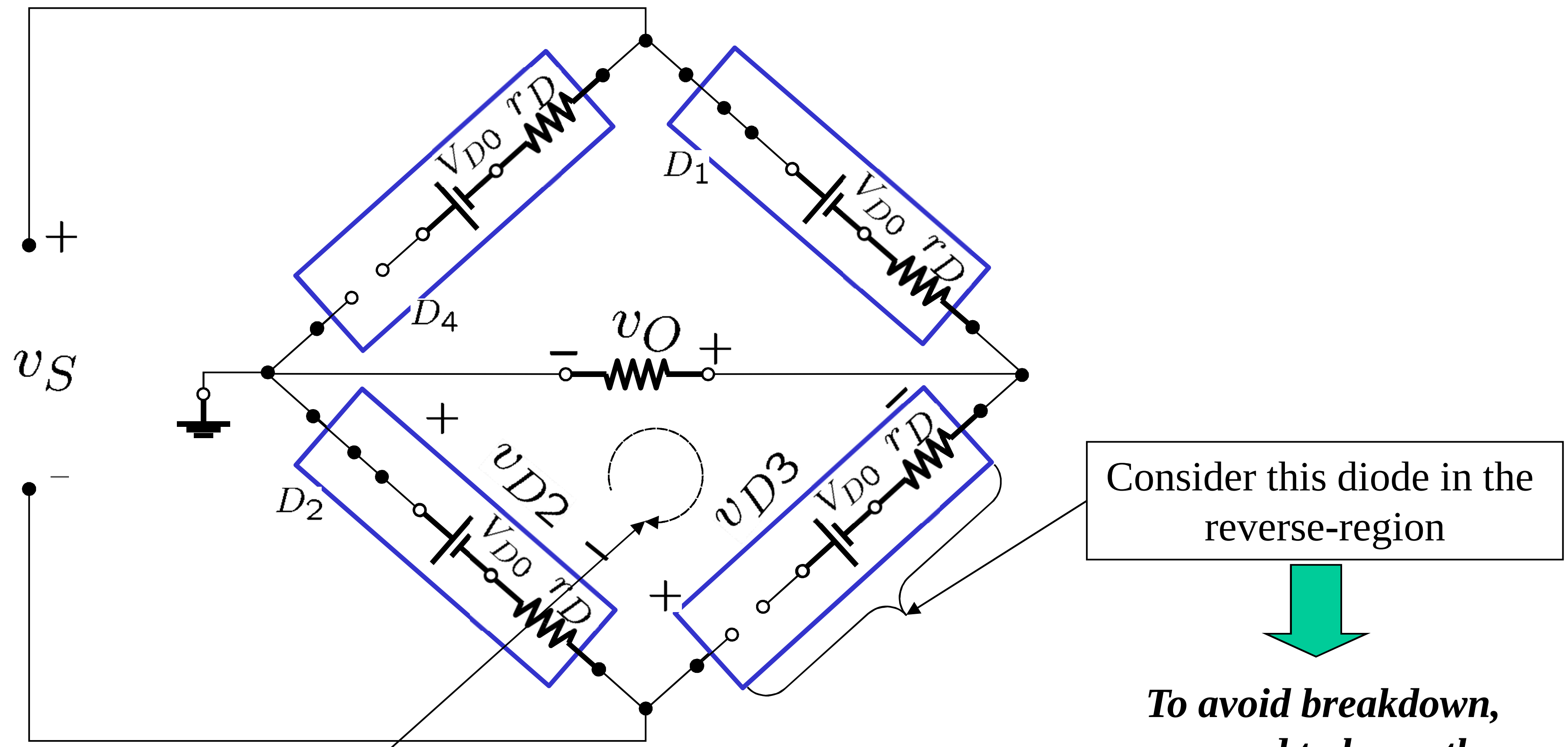


(a)



(b)

PIV for the Bridge Rectifier



To avoid breakdown, we need to know the maximum negative voltage that v_{D3} can experience

KVL $v_{D3} = -(v_{D2} + v_O)$

Since $r_D << \rightarrow v_{D2} \approx V_{D0}$

Also $v_O \approx (v_S - 2V_{DO})$ $\rightarrow$ Hence $v_{D3} = -v_S + V_{D0}$

PIV for the Bridge Rectifier

$$v_{D3} = -v_S + V_{D0}$$

Becomes the lowest negative, when

$$v_S$$

reaches its maximum or peak value of

$$V_S$$

$$v_{D3_{\min}} = -V_S + V_{D0}$$

Hence,

$$\mathrm{PIV} = \left|v_{D3\,\min}\right| = V_S - V_{D0}$$

Comparison Between Rectifiers in terms of their PIV voltages

$$PIV_{(\text{ One-diode Half-Wave})} = \boldsymbol{V_S}$$

$$PIV_{(\text{ Two-diode Full-Wave})} = \boldsymbol{2V_S - V_{DO}}$$ Worst

$$PIV_{(\text{ Bridge rectifier})} = \boldsymbol{V_S - V_{DO}}$$ Better

The Half-Wave Peak Rectifier

$$I_L = \frac{V_p}{R}$$

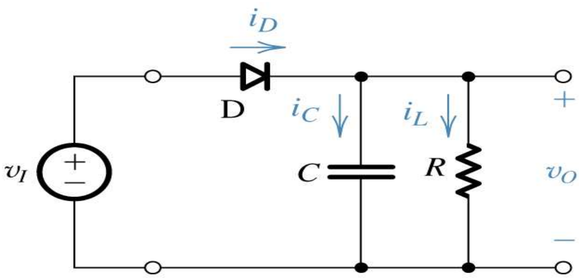
$$V_o = V_p - \frac{1}{2}V_r$$

$$v_o = V_p e^{-t/CR}$$

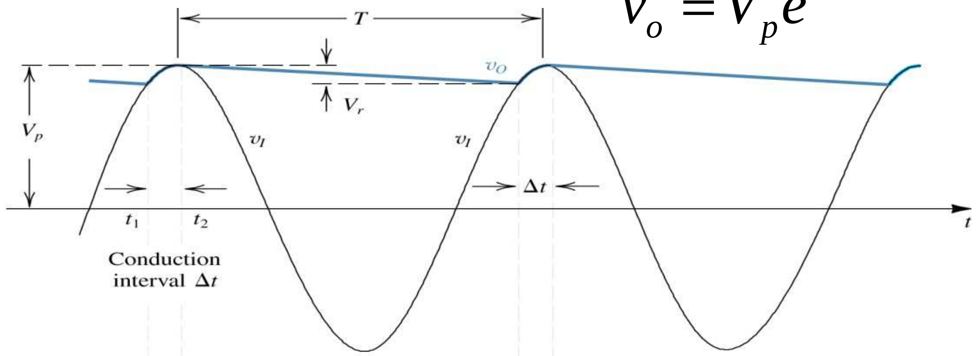
$$i_L = \frac{v_0}{R}$$

$$i_D = i_C + i_L$$

$$i_D = C\frac{d_{vI}}{dt} + i_L$$



(a)



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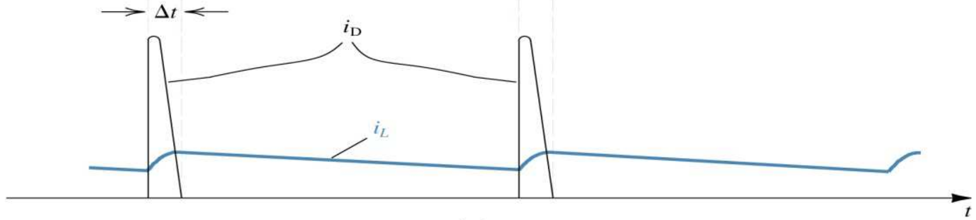


(c)

$$V_p - V_r = V_p e^{-T/RC}$$

$$V_r \approx V_p \frac{T}{RC}$$

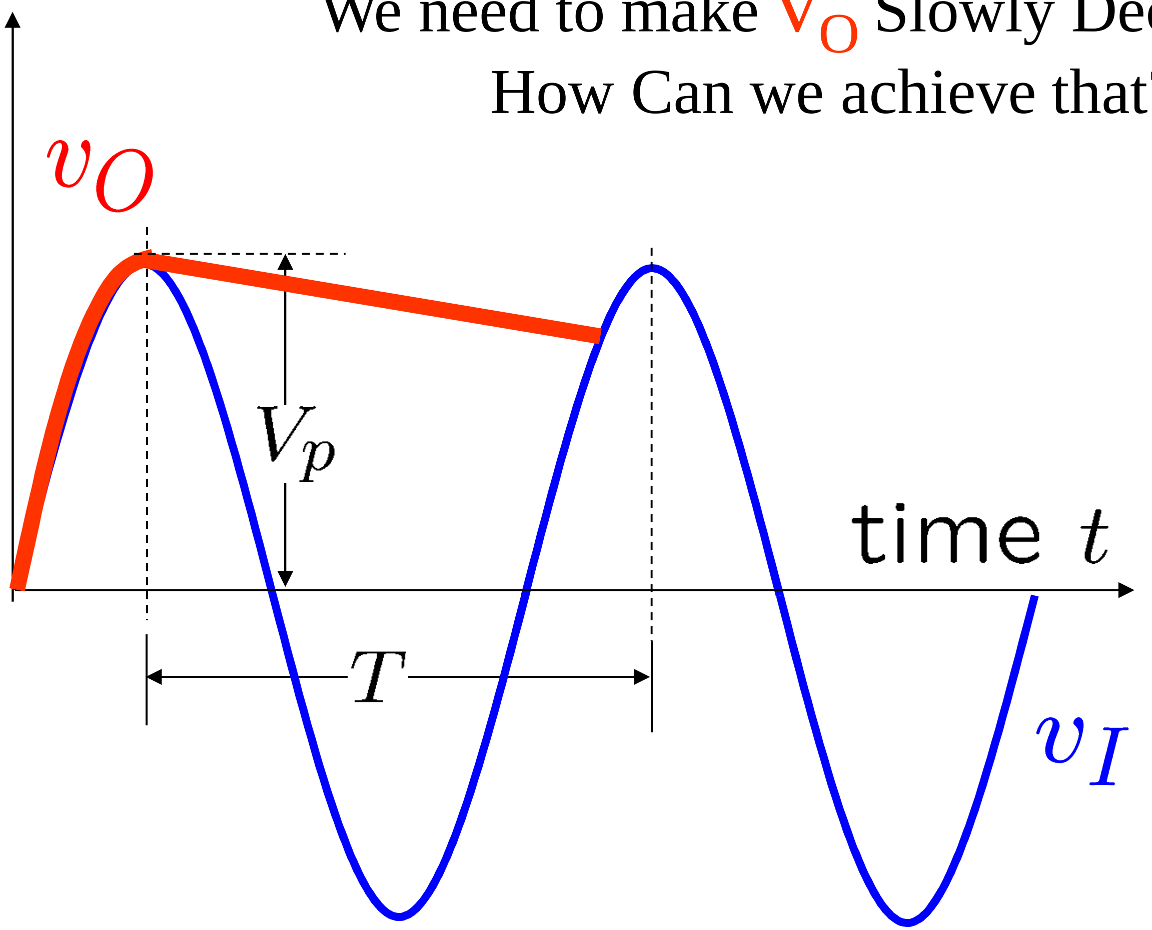
$$V_r = \frac{V_p}{fCR}$$

$$i_{Dav} = I_L\left(1 + \pi\sqrt{2V_p / V_r}\right)$$

$$i_{D\max} = I_L\left(1 + 2\pi\sqrt{2V_p / V_r}\right)$$

$$v_O = V_p e^{-t/RC}$$

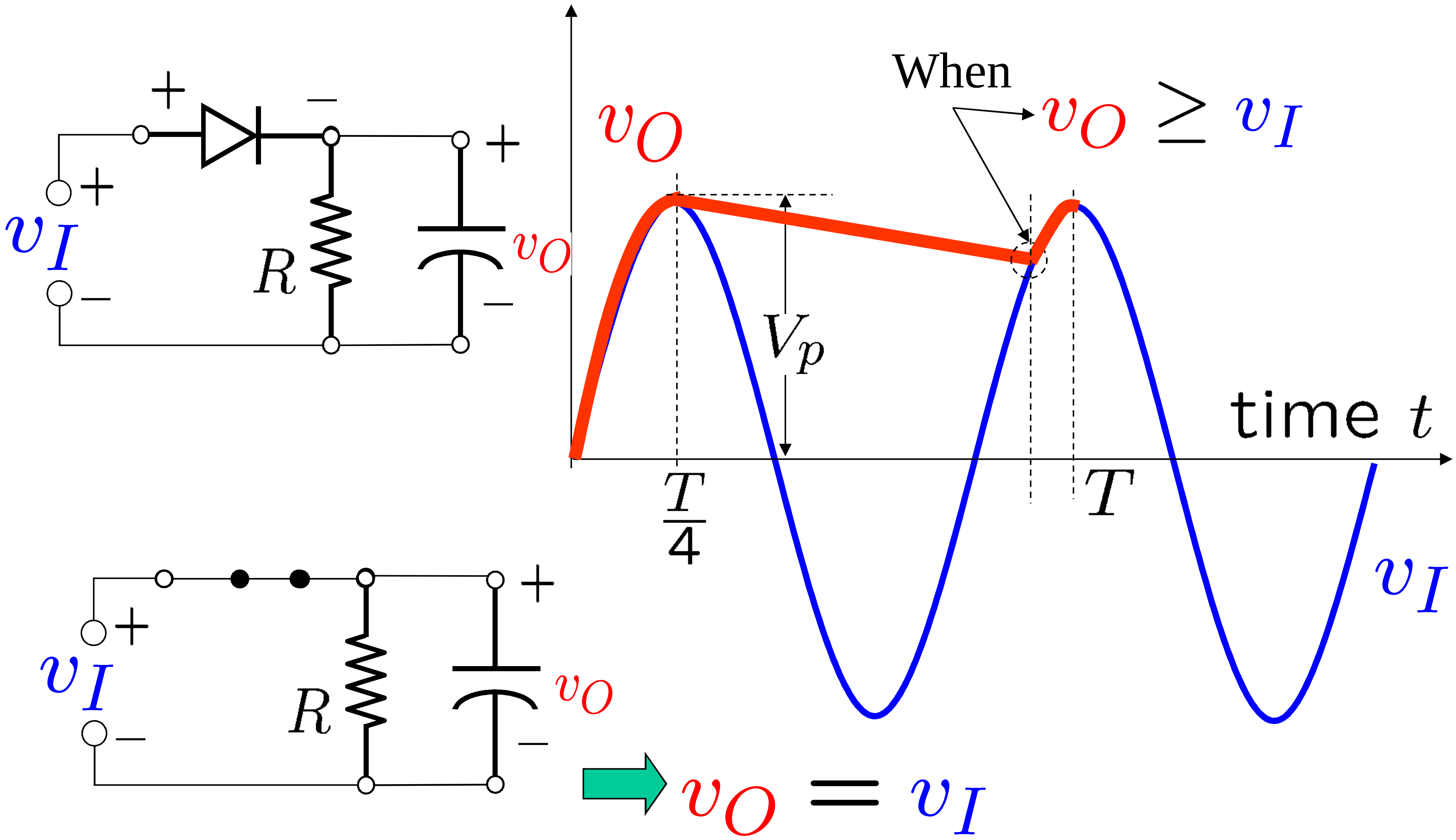
We need to make v_O Slowly Decaying,
How Can we achieve that?



We can choose

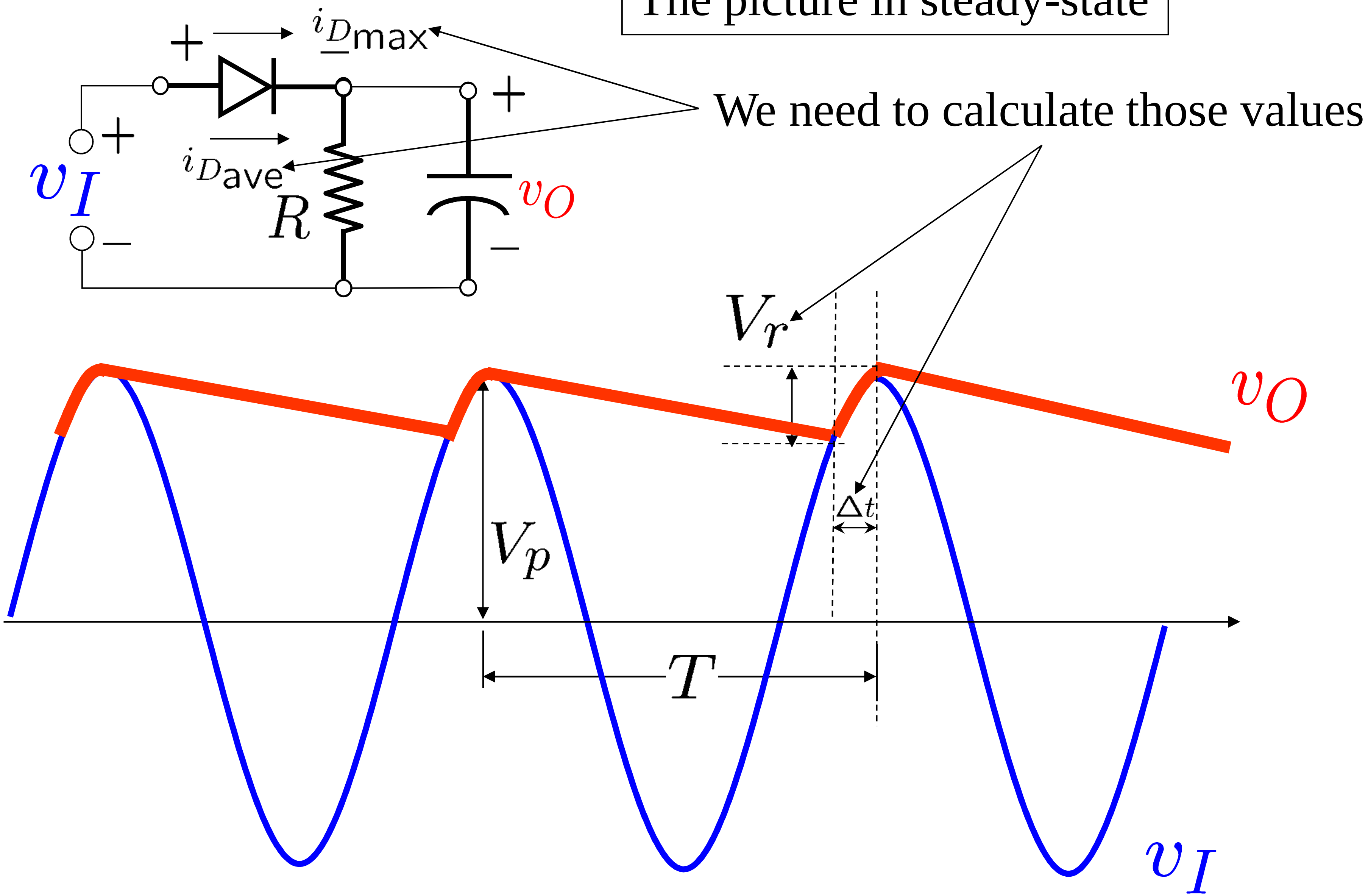
$$RC >> T$$

This will make the discharge time longer and the output voltage will not decay quickly



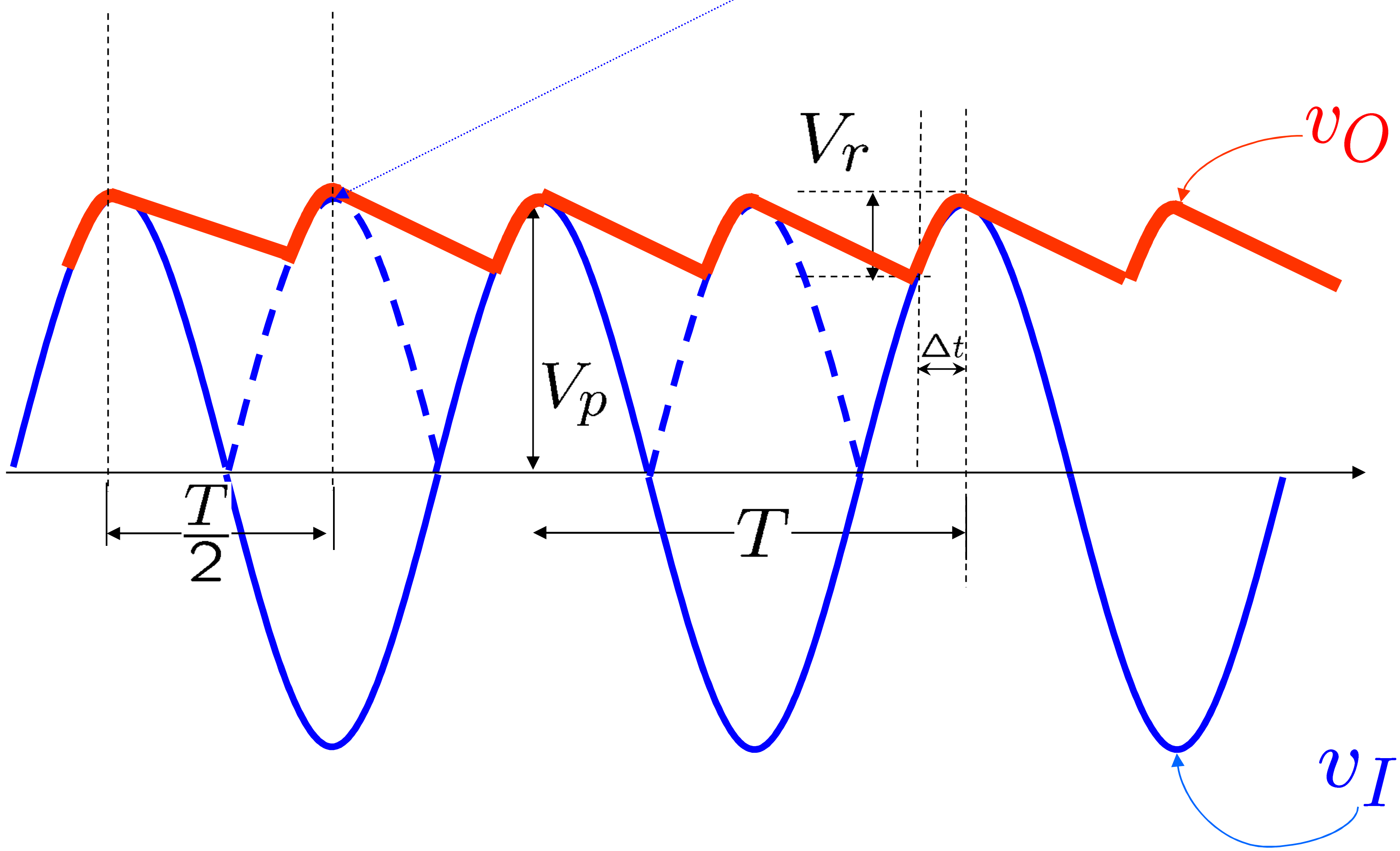
+
−
+
+
v_I
−
R
v_O
−
v_O
When
$v_O \geq v_I$
V_p
time t
$\frac{T}{4}$
T
v_I
+
+
v_I
−
R
v_O
−
$v_O = v_I$

The picture in steady-state



The picture at Steady-State

As if the output is following the peak of the shadow of negative cycle in the input waveform



Full-Wave Peak Rectifier Ideal Diodes

Half-wave Peak Rectifier		Full-wave Peak Rectifier
$V_r = \frac{V_p T}{RC} = \frac{V_p}{fRC}$	Gets halved	$V_r = \frac{V_p T}{2RC} = \frac{V_p}{2fRC}$
$\omega \Delta t \simeq \sqrt{(2V_r/V_p)}$	Same	$\omega \Delta t \simeq \sqrt{(2V_r/V_p)}$
$i_{D\mathsf{ave}} = I_L(1 + \pi\sqrt{2V_p/V_r})$	Same	$i_{D\mathsf{ave}} = I_L(1 + \pi\sqrt{2V_p/V_r})$
$i_{D\mathsf{max}} = I_L(1 + 2\pi\sqrt{2V_p/V_r}$	Same	$i_{D\mathsf{max}} = I_L(1 + 2\pi\sqrt{2V_p/V_r})$