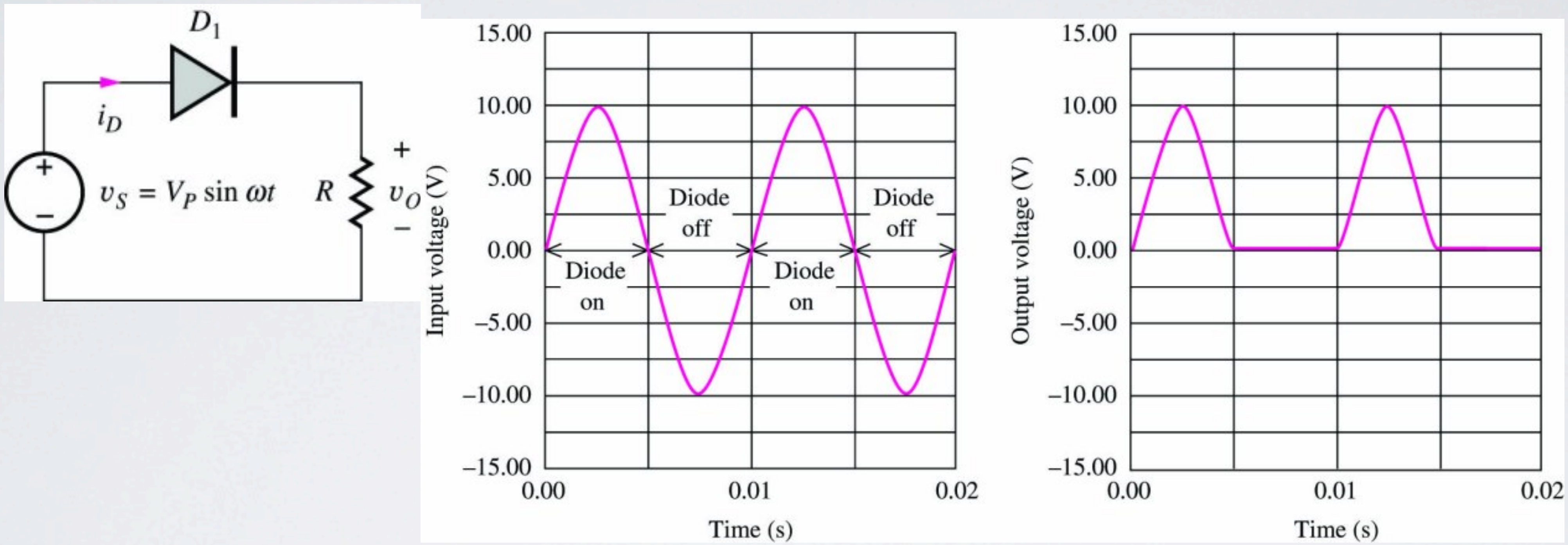
RECTIFIERS

INEL4076 - Spring 2013

Half-Wave Rectifier Circuit with Resistive Load



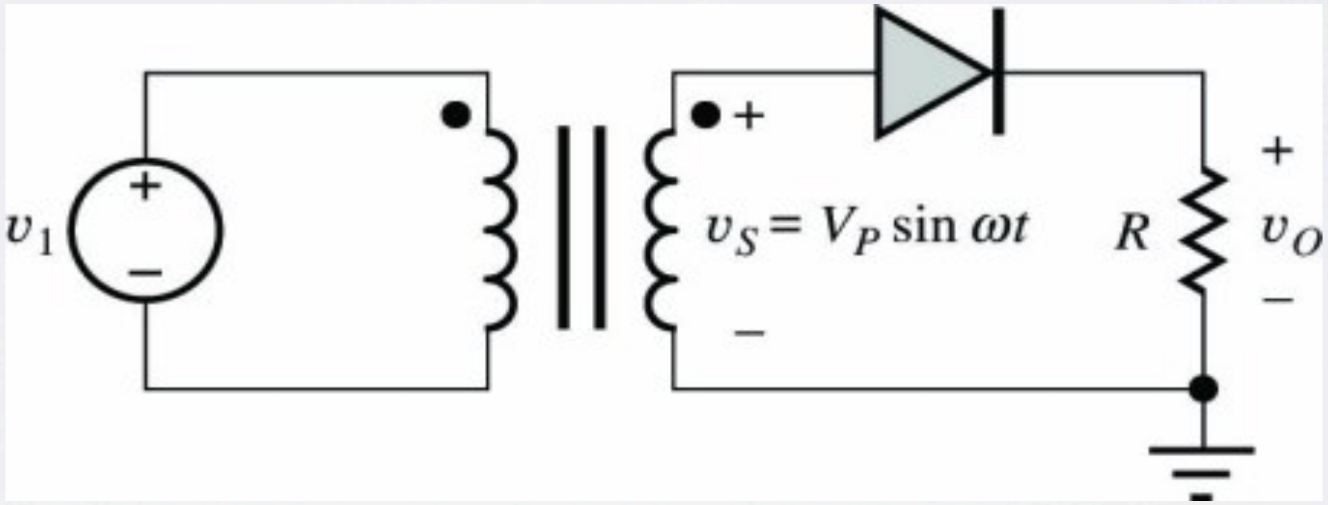
For positive half-cycle of input, source forces positive current through diode, diode is on, $v_o = v_s$.(assuming $v_D = 0$. Otherwise $v_O = v_S - v_D$ when $v_S > v_D$)

During negative half cycle, negative current can't exist in diode, diode is off, current in resistor is zero and $v_o = 0$.

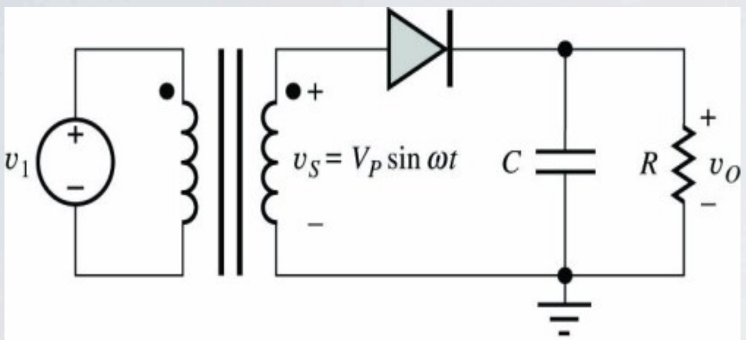
CVD = constant voltage drop

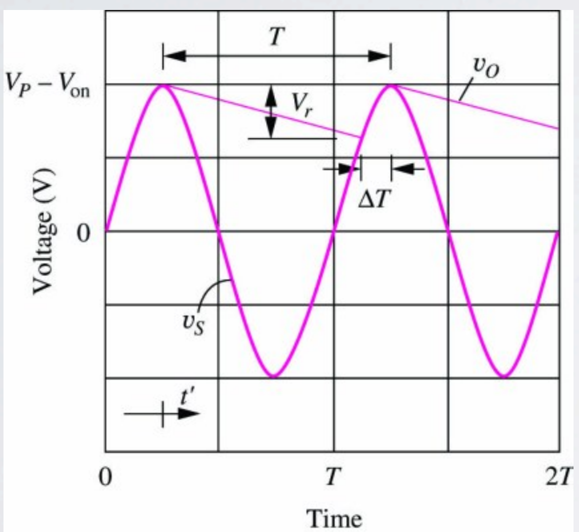
Using CVD model, during on state of diode $v_o = (V_P \sin\omega t) - V_{on}$. Output voltage is zero when diode is off.

Often a step-up or step-down transformer is used to convert 120 V-60 Hz voltage available from power line to desired ac voltage level as shown.



Time-varying components in circuit output are removed using filter capacitor.





Ripple voltage V_r: peak-to-peak value of variations of load voltage.

$$i_C = C\frac{\Delta v_C}{\Delta t} = \frac{v_{L,dc}}{R}$$

Let $v_{L,dc} \simeq V_{L,peak} - V_r/2$ and $\Delta t = 1/f$ where f is the frequency

$$V_r \simeq \Delta v_C = \frac{v_{L,dc} \times \Delta t}{RC} \simeq \frac{v_{L,peak} - V_r/2}{fRC}$$

$$\boxed{V_r \simeq \frac{v_{L,peak}}{fRC}\frac{1}{1 + \frac{1}{2fRC}}}$$

If $V_r << V_{L,peak}$,

$$\boxed{V_r \simeq \frac{v_{L,peak}}{fRC}}$$

To select C to obtain a specific V_r, use

$$\boxed{C = \frac{v_{L,peak} - V_r/2}{fRV_r}}$$

Example: Find ripple voltage if the secondary voltage $V_{S,rms} = 12.6V$, $f = 60Hz$, $R = 15\Omega$, $C = 25,000\mu F$, and the diode's voltage drop $V_{ON} = 1V$.

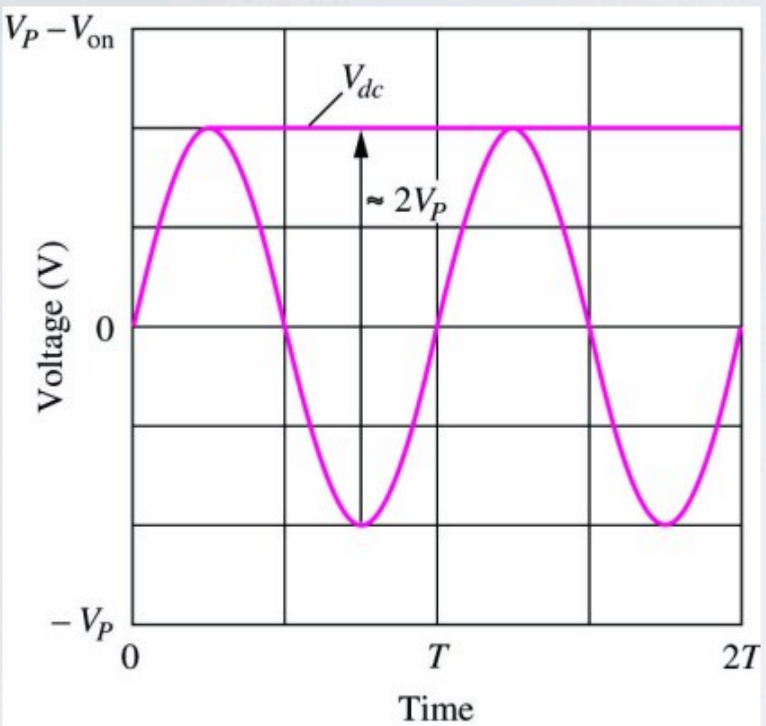
$$\begin{aligned}
V_{S,peak} &= \sqrt{2} \times V_{S,rms} = 12.82V \\
v_{L,peak} &= V_{S,peak} - V_{ON} = 11.82V \\
fRC &= 60 \times 15\Omega \times 25 \times 10^{-3}F = 22.5 \\
V_r &= \frac{v_{L,peak}}{fRC} \frac{1}{1 + \frac{1}{2fRC}} = \frac{11.82V}{22.5} \frac{1}{1 + \frac{1}{2 \times 22.5}} = \boxed{0.52V}
\end{aligned}$$

Example: Find C necessary to obtain $V_r = 0.2V$ if $V_{S,rms} = 12.6V$, $f = 60Hz$, $R = 15\Omega$, and $V_{ON} = 1V$.

$$C = \frac{V_{L,peak} - V_r/2}{fRV_r} = \frac{11.82V - 0.1V}{60 \times 15\Omega \times 0.2V} \simeq \boxed{65000\mu F}$$

Example: Find C necessary to obtain $V_r = 0.2V$ if $V_{S,rms} = 12.6V$, $f = 60Hz$, $R = 1k\Omega$, and $V_{ON} = 1V$.

$$C = \frac{V_{L,peak} - V_r/2}{fRV_r} = \frac{11.82V - 0.1V}{60 \times 1k\Omega \times 0.2V} \simeq \boxed{1000\mu F}$$



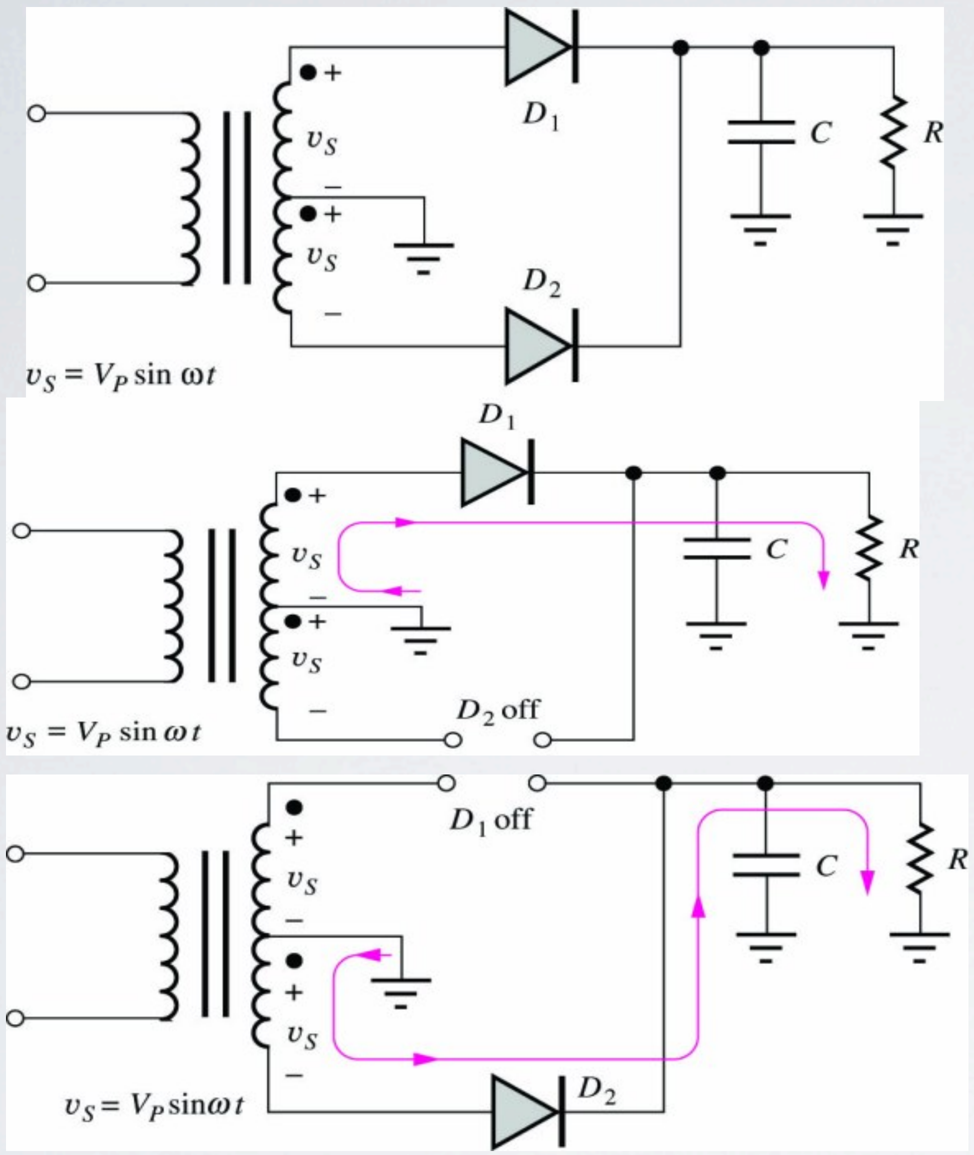
Peak inverse voltage (PIV) rating of the rectifier diode gives the breakdown voltage.

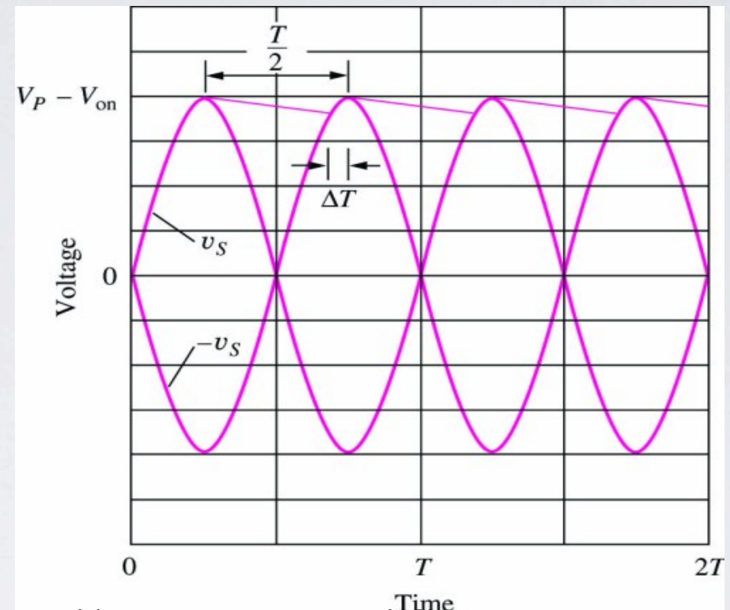
When diode is off, reverse-bias across diode is V_{dc} - v_s. When v_s reaches negative peak,

$$PIV \simeq 2\,V_{S,\,PEAK}$$

PIV value corresponds to minimum value of Zener breakdown voltage for rectifier diode.

Full-wave rectifier with center-tap transformer





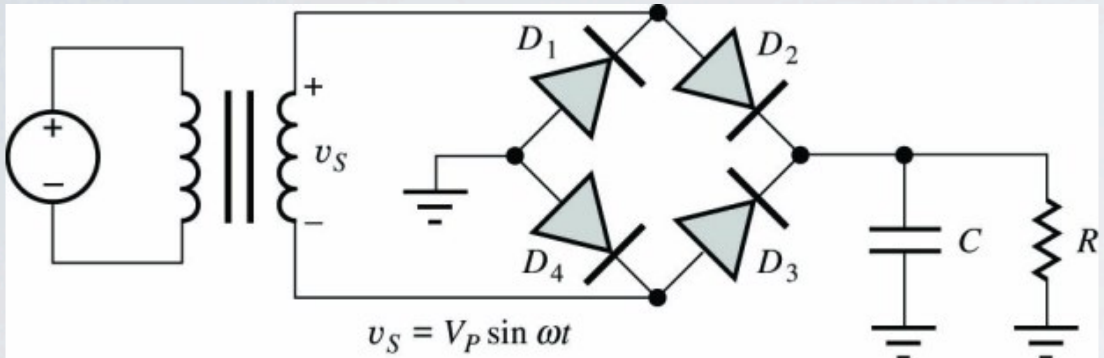
Full-wave rectifiers cut capacitor discharge time in half and require half the filter capacitance to achieve given ripple voltage. All specifications are same as for half-wave rectifiers.

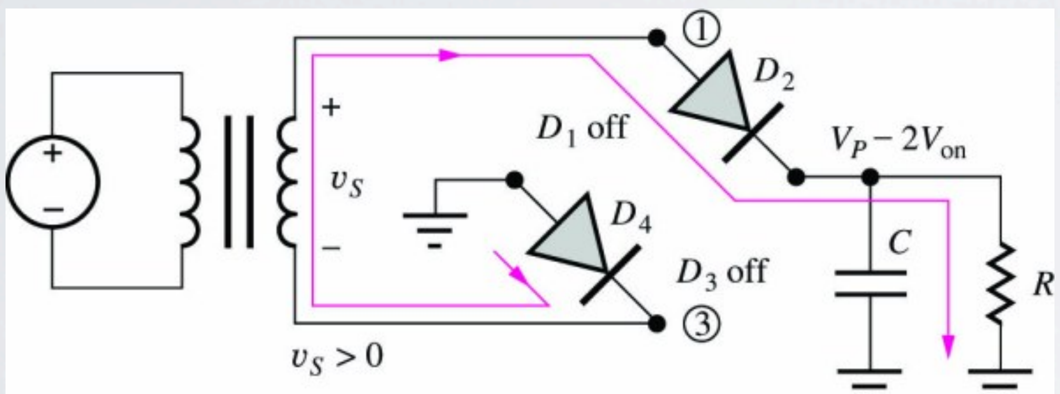
Reversing polarity of diodes gives a full-wave rectifier with negative output voltage.

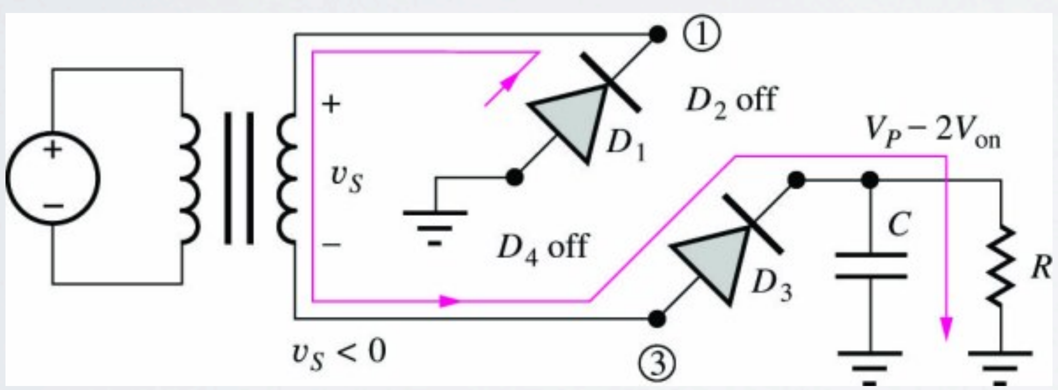
To find C or V_r use same formulae with f = 120Hz

$PIV \simeq 2V_{S,\,PEAK}$

Full-wave rectifier with bridge circuit







Requirement for a center-tapped transformer in the full-wave rectifier is eliminated through use of 2 extra diodes.All other specifications are same as for a half-wave rectifier except PIV=V_P.

Rectifier Topology Comparison

- Filter capacitor is a major factor in determining cost, size and weight in design of rectifiers.

- For given ripple voltage, full-wave rectifier requires half the filter capacitance as that in half-wave rectifier. Reduced peak current can reduce heat dissipation in diodes. Benefits of full-wave rectification outweigh increased expenses and circuit complexity (a extra diode and center-tapped transformer).

- Bridge rectifier eliminates center-tapped transformer, PIV rating of diodes is reduced. Cost of extra diodes is negligible.