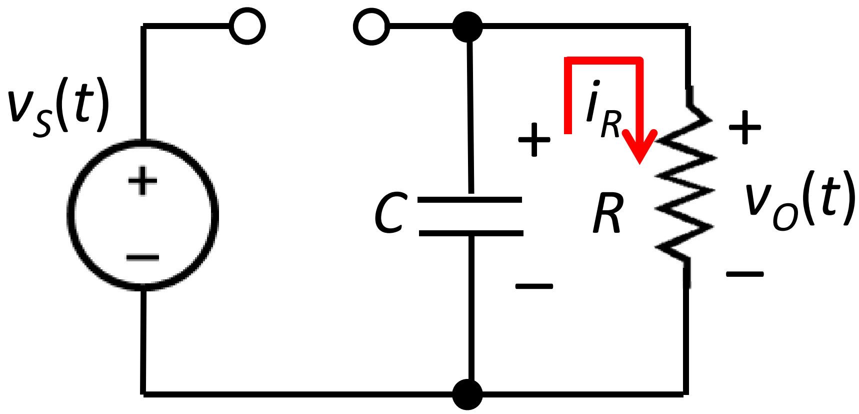
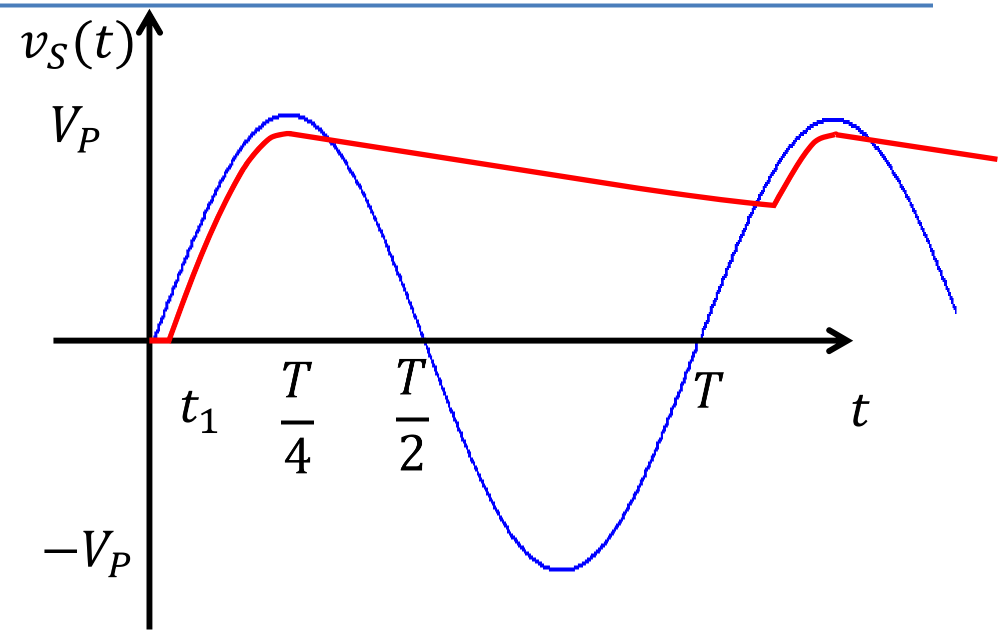
Announcements

- HW #2 due today.

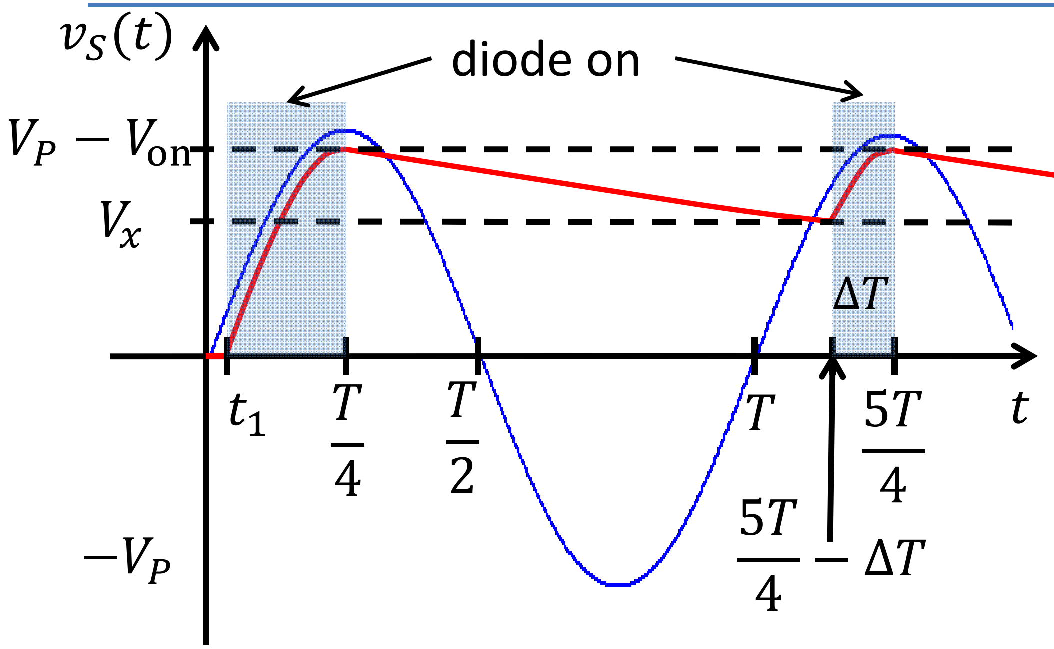
Half-wave rectifier w/ RC Load





After $t = T/4$, diode OFF, capacitor discharge via R, $v_O(t)$ slowly decreases (exponentially), until in the next period, $v_S(t)$ becomes larger than $v_O(t)+V_{on}$ again

Half-wave rectifier w/ RC Load



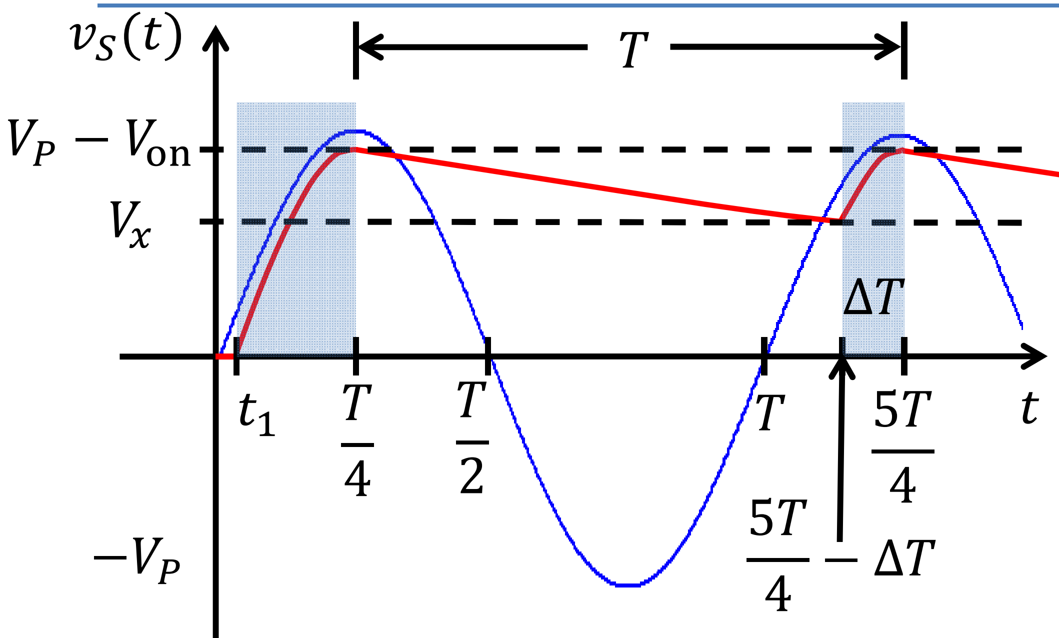
- At $t = \frac{T}{4}$, $v_O(t) = V_P - V_{\text{on}}$
- Between $\frac{T}{4} < t < \frac{5T}{4} - \Delta T$,

$v_O(t)$ drops exponentially:

$$v_O(t) = v_O\left(\frac{T}{4}\right) \exp\left(-\frac{t - \frac{T}{4}}{RC}\right)$$

- At time point $t = \frac{5T}{4} - \Delta T$, we have, $v_S(t) = v_O(t) + V_{\text{on}}$
- Thus: $V_P \sin \omega(T/4 - \Delta T) = (V_P - V_{\text{on}}) \exp\left(-\frac{T - \Delta T}{RC}\right) + V_{\text{on}}$
- ΔT can be solved numerically.

Half-wave rectifier w/ RC Load



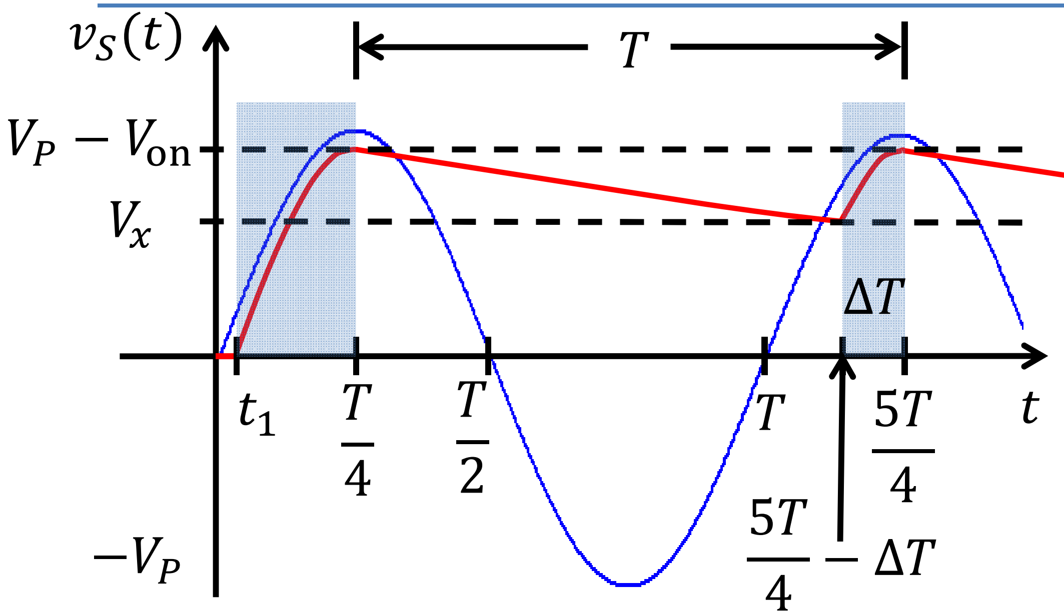
- Approx #1: RC large, $v_O(t)$ drops slowly and thus linearly:
- Between $\frac{T}{4} < t < \frac{5T}{4} - \Delta T$,

$$v_O(t) = (V_P - V_{on})\left(1 - \frac{t - \frac{T}{4}}{RC}\right)$$

$\exp(\epsilon) \cong 1 + \epsilon$ if $\epsilon \ll 1$ $(T \ll RC)$

- Approx #2: Conduction time ΔT much smaller than T $(\Delta T \ll T)$
- Ripple voltage: $V_r = v_O\left(\frac{T}{4}\right) - v_O\left(\frac{5T}{4} - \Delta T\right) \approx \frac{V_P - V_{on}}{RC} T$
- Equivalent DC current: $I_{dc} = \frac{V_P - V_{on}}{R}$

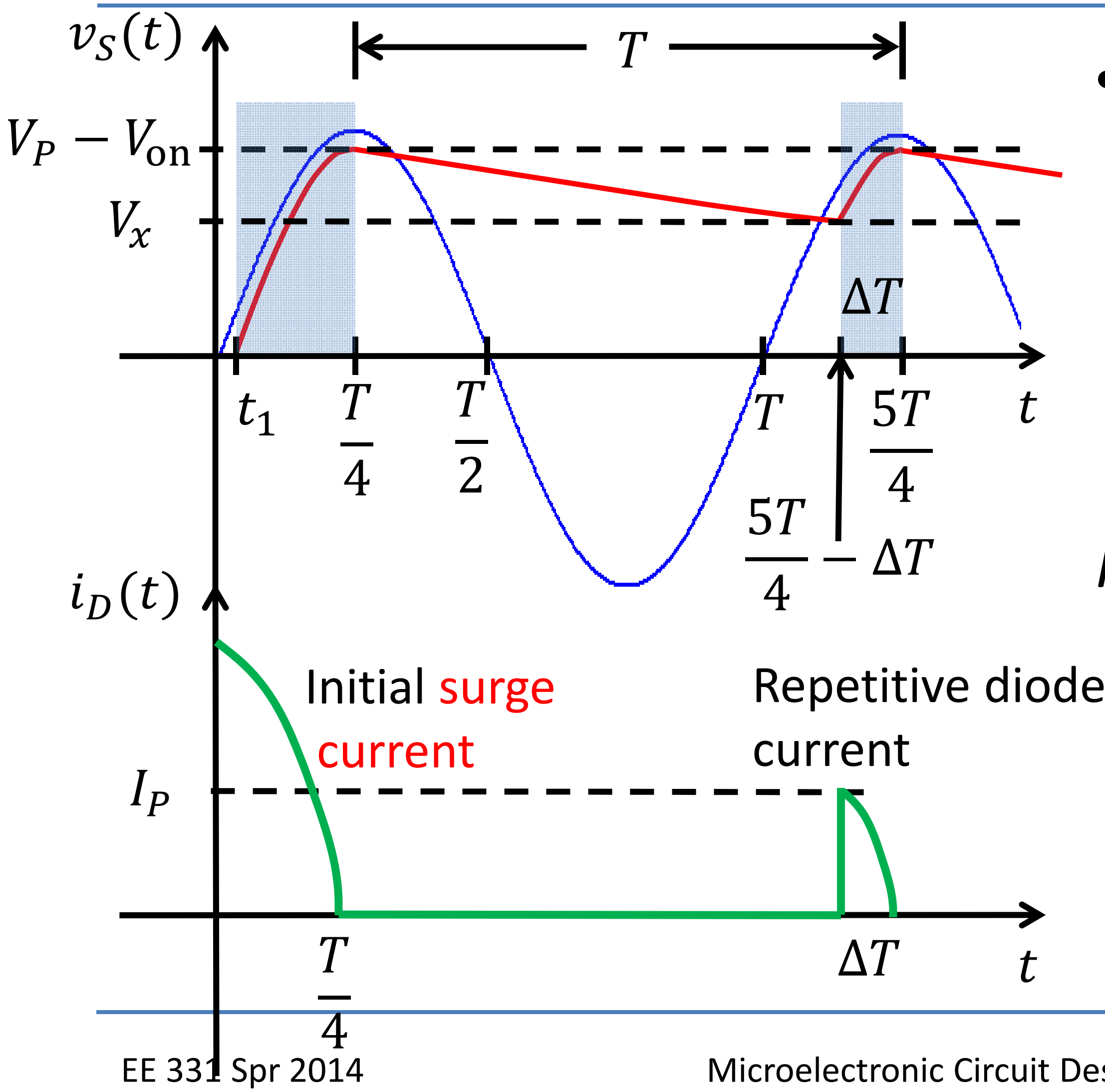
Half-wave rectifier w/ RC Load



- To Find ΔT, look at time point $t_2 = \frac{5T}{4} - \Delta T$:
- $v_S(t_2) - V_{on} = V_x$

- $V_x = V_P - V_{on} - V_r = (V_P - V_{on})(1 - \frac{T}{RC})$ ①
- $V_x = V_P \sin\omega\left(\frac{5T}{4} - \Delta T\right) - V_{on} = V_P \cos\omega\Delta T - V_{on} \approx V_P(1 - \frac{[\omega\Delta T]^2}{2}) - V_{on}$ ②
- ① = ② => $\Delta T = \frac{1}{\omega}\sqrt{\frac{2V_r}{V_P}}$ => conduction angle: $\theta_c = \omega\Delta T = \sqrt{\frac{2V_r}{V_P}}$

Diode Currents



- Charge lost due to discharging replenished by charging current during ΔT:

$$Q = I_{dc}T \approx I_P \frac{\Delta T}{2}$$

$$\Rightarrow \; I_P \approx I_{dc} \frac{2T}{\Delta T}$$

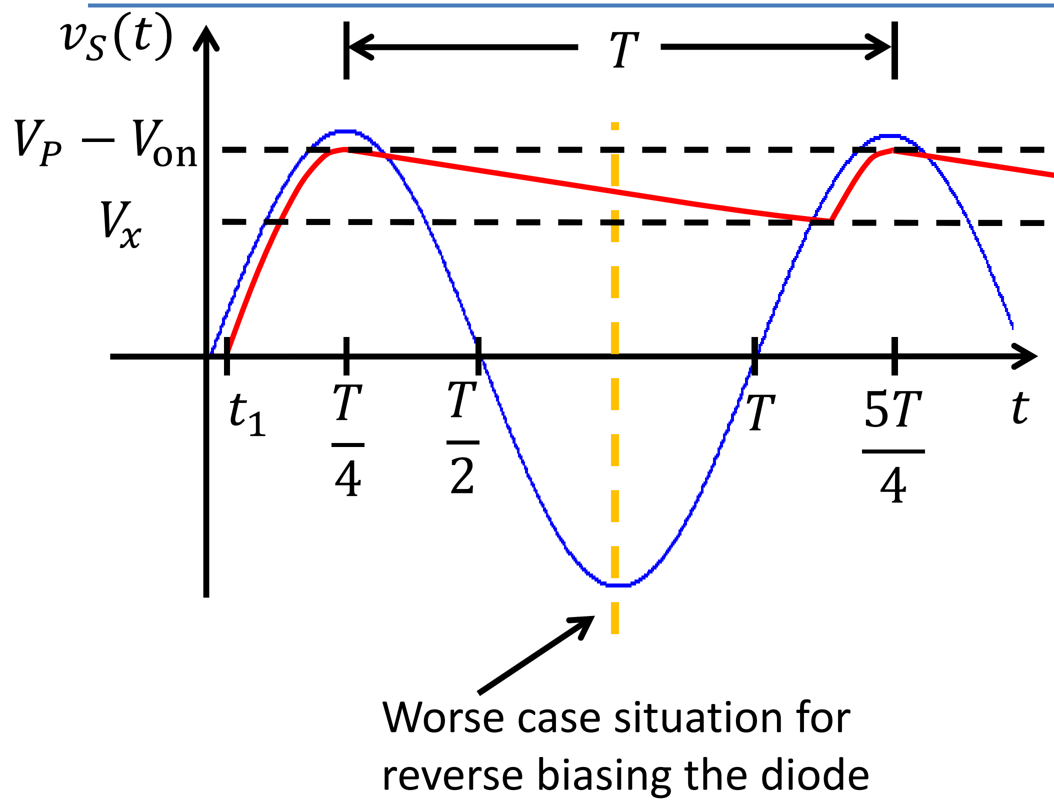
I_P usually large (tens of A!)

- Initial surge current even larger (> 100 A!)

$$I_{SC} = \omega C V_P$$

Series resistances reduce this current

Diode Peak-Inverse-Voltage (PIV) Rating



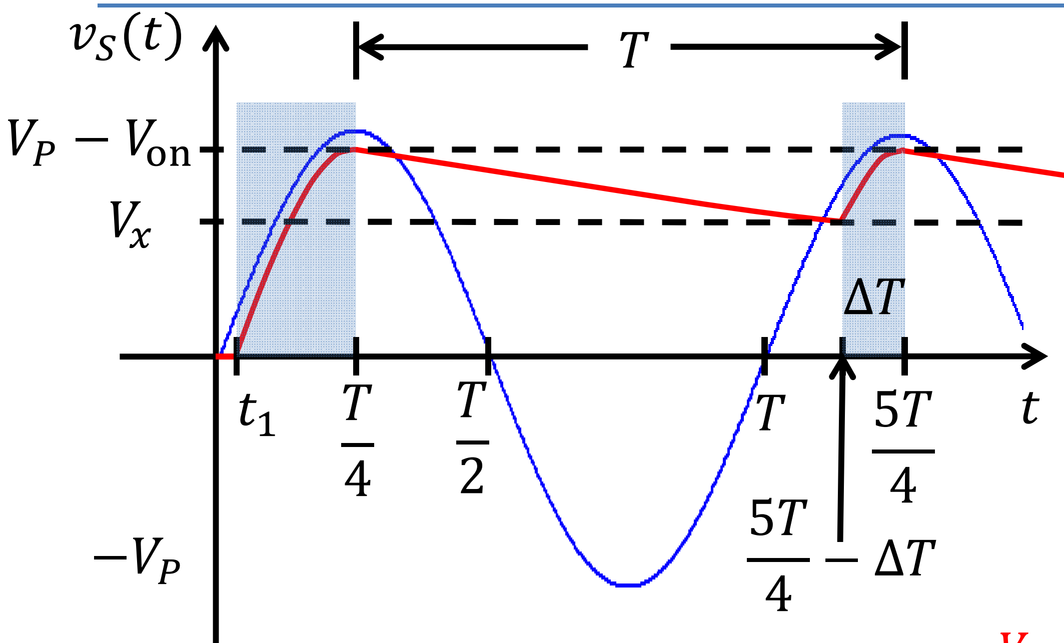
- $\text{PIV} \geq V_{dc} - v_I^{\min} = V_P - V_{on} - (-V_P) \approx 2V_P$

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

Safety margin of 25-50 % is usually specified for the diode PIV.

$$V_Z > (1 + SM)2V_P$$

Example: HWR w/ RC Load



$V_P \approx$ 12 V @ 60 Hz,
R = 5 kΩ, C = 100 µF, I_s = 10 pA
T = 1/60 s = 0.0167 s
I_d ~ 0.1 A, $v_{on} \approx V_T \ln(10^{10})$ = 0.6 V

$$V_r \approx \frac{V_P - V_{on}}{RC} T = 0.38 \text{ V}$$

- Equivalent DC current: $I_{dc} = \frac{V_P - V_{on}}{R} = 2.28 \text{ mA}$
- Conduction angle: $\theta_c = \omega \Delta T = \sqrt{\frac{2V_r}{V_P}} = 0.25 \text{ rad}, \Delta T = 0.04\, T$
- $I_P \approx I_{dc} \frac{2T}{\Delta T} = 114 \text{ mA}; \; I_{SC} = \omega C V_P = 0.45\, A$

