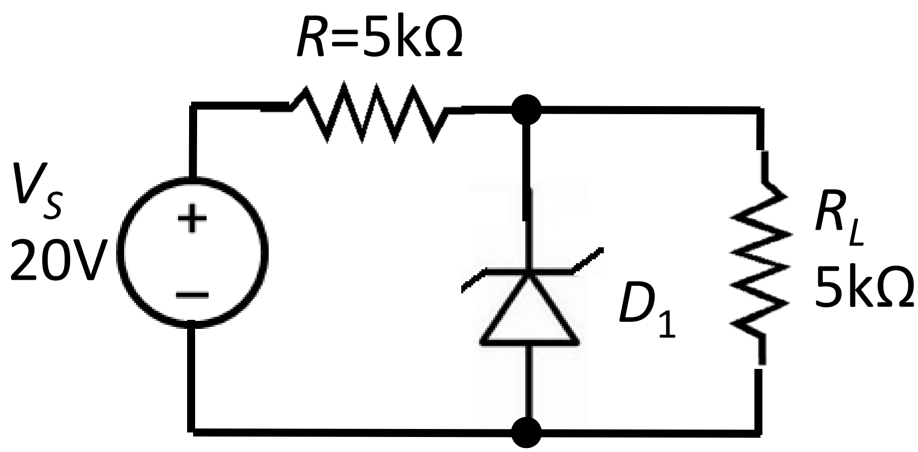
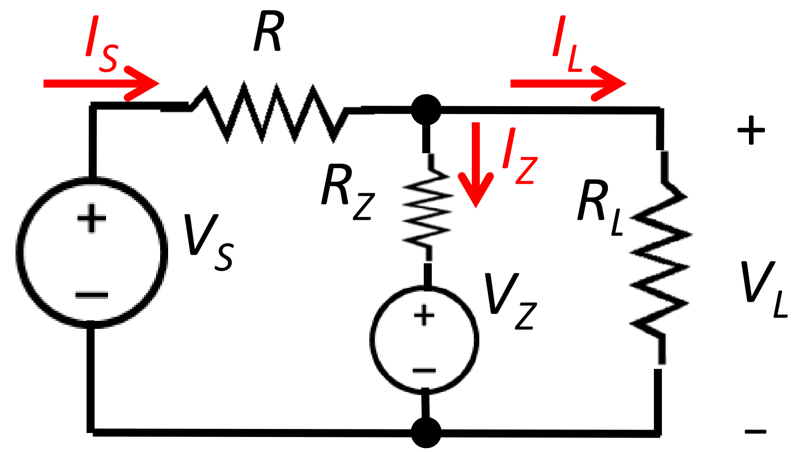
Announcements

- HW #2 due Friday in class.
- Exam #1 on Monday 4/28 (Semiconductors and Diodes, Chapters 2 and 3 plus notes).
- No lecture next Friday (4/25) due to Engineering Discovery Days.
- HW #3 due on 4/25 under door of my office by 12:30pm.

Voltage Regulation ($R_Z \neq 0$)



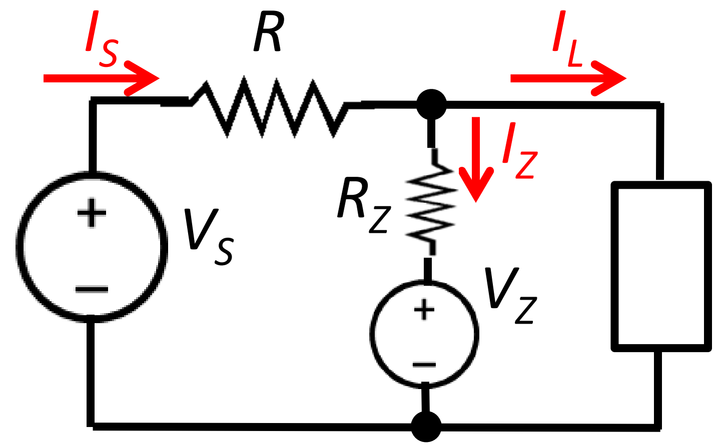


$$I_S = I_Z + I_L \Rightarrow \frac{V_S - V_L}{R} = \frac{V_L - V_Z}{R_Z} + \frac{V_L}{R_L}$$

$$V_L = \left(\frac{V_S}{R} + \frac{V_Z}{R_Z}\right) / \left(\frac{1}{R} + \frac{1}{R_L} + \frac{1}{R_Z}\right)$$

Minimum R_L unchanged (I_Z=0 at threshold).

Voltage Regulation ($R_Z \neq 0$)



If the load sinks a given current I_L, then:

$$I_S = I_Z + I_L \Rightarrow \frac{V_S - V_L}{R} = \frac{V_L - V_Z}{R_Z} + I_L$$

$$V_L = \left(\frac{V_Z}{R_Z} + \frac{V_S}{R} - I_L\right) / \left(\frac{1}{R} + \frac{1}{R_Z}\right)$$

Voltage Regulation (constant I_L)

- $V_L = \left(\frac{V_Z}{R_Z} + \frac{V_S}{R} - I_L\right) / \left(\frac{1}{R} + \frac{1}{R_Z}\right)$
- Line regulation

$$\frac{dV_L}{dV_s} = \frac{R_Z}{R + R_Z}$$

- Load regulation

$$\frac{dV_L}{dI_L} = -\frac{RR_Z}{R + R_Z}$$

EE 331 Devices and Circuits I

Chapter 3

Time Dependent Circuits

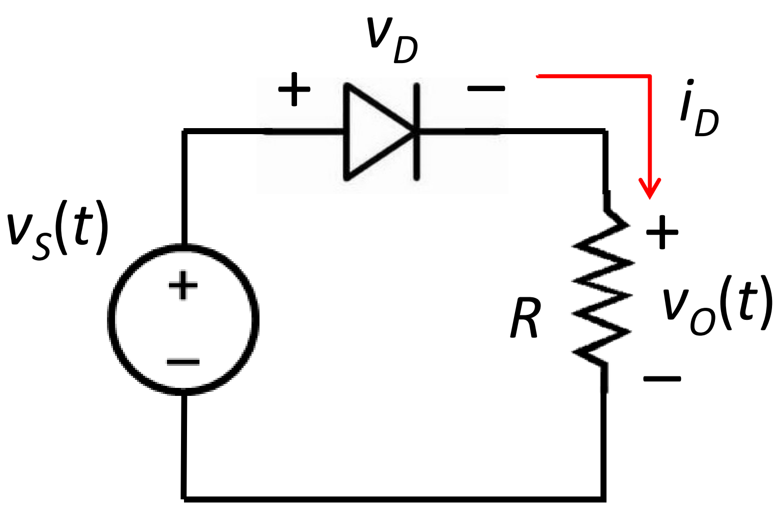
Time-Dependent Circuits

- Two classes:
  - Slow circuits ($C_{load} >> C_D + C_j$): diodes respond almost instantaneously (ignore diode charge storage)
  - Fast circuits ($C_{load} \sim C_D + C_j$): diodes' internal charge storage must be considered (transient response)
- In this class, deal primarily with slow circuits (DC diode model is sufficient)

Rectifier circuits

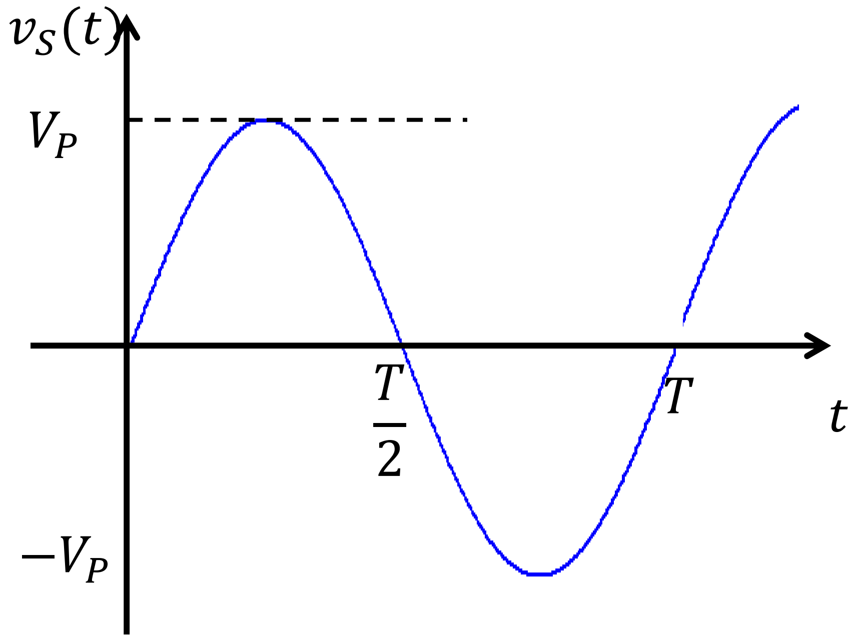
- Device that converts alternating current (AC), to direct current (DC)
- Application:
  - battery chargers (e.g. 120 V-60 HZ AC => 5 V DC)
- How to quantify performance of rectifiers?
  - Ripple voltage (V_r)
  - Power dissipation

Half-wave rectifier (resistive load)



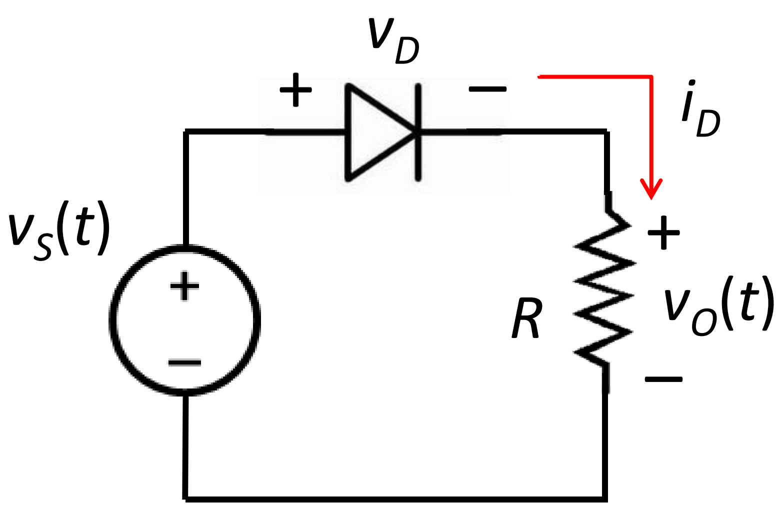
$v_S(t) = v_D(t) + v_O(t)$

$$v_s(t) = V_P \sin \omega t,\ T = \frac{2\pi}{\omega}$$

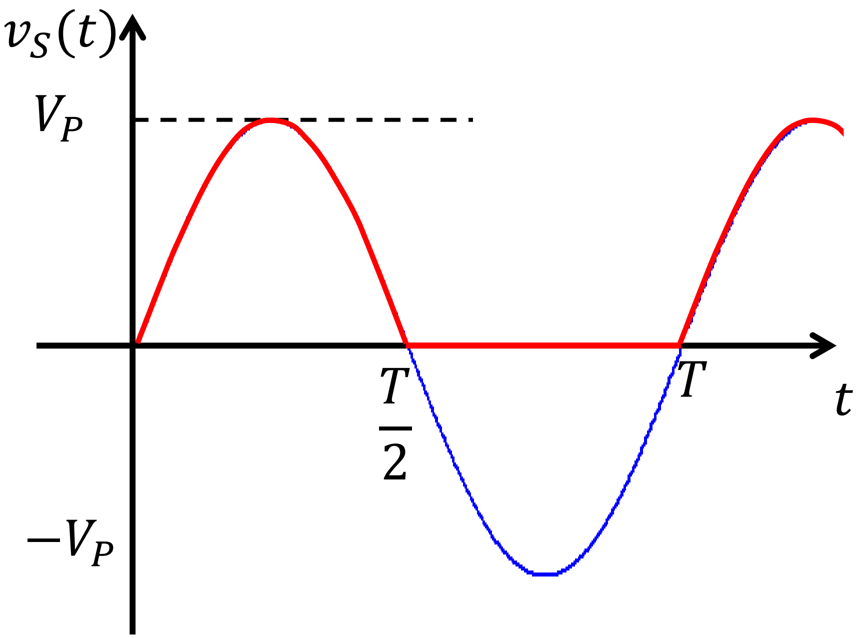


Goal: Find $v_O(t)$ based on diode circuit analysis models

Half-wave rectifier (resistive load)
Ideal Diode



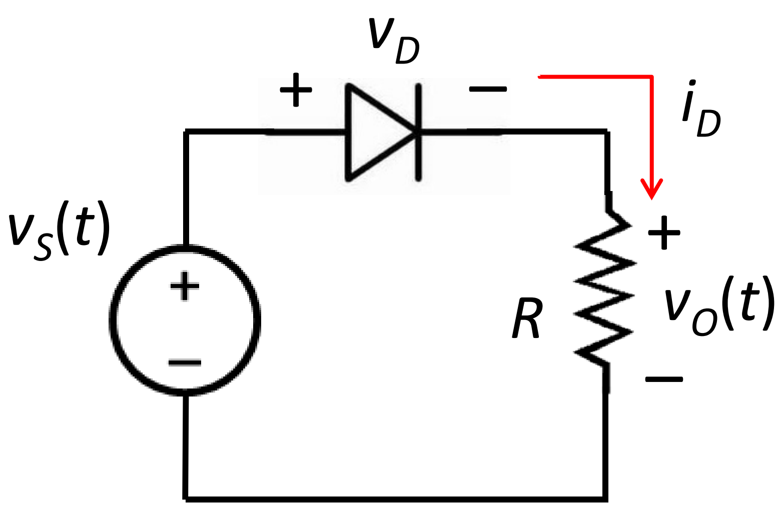
$v_S(t) = v_D(t) + v_O(t)$



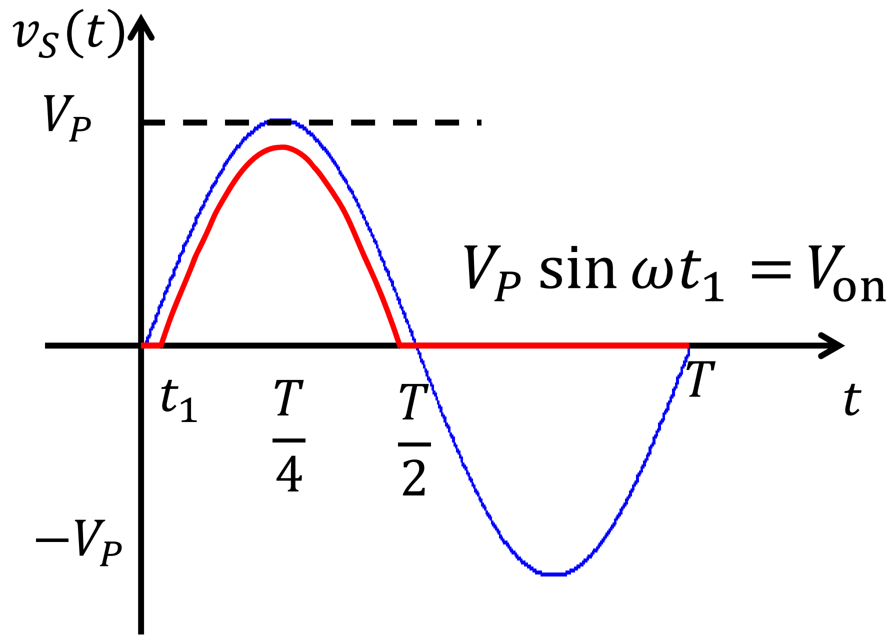
Case 1: if $v_S(t) > 0$, then D = ON. $v_D = 0$, $i_D > 0$, $v_0(t) = v_S(t)$.
Case 2: if $v_S(t) < 0$, then D = OFF. $i_D = 0$, $v_D = v_S$, $v_0(t) = 0$.

Note: need $V_Z > V_P$

Half-wave rectifier (resistive load) Constant voltage drop



constant voltage drop V_{on}

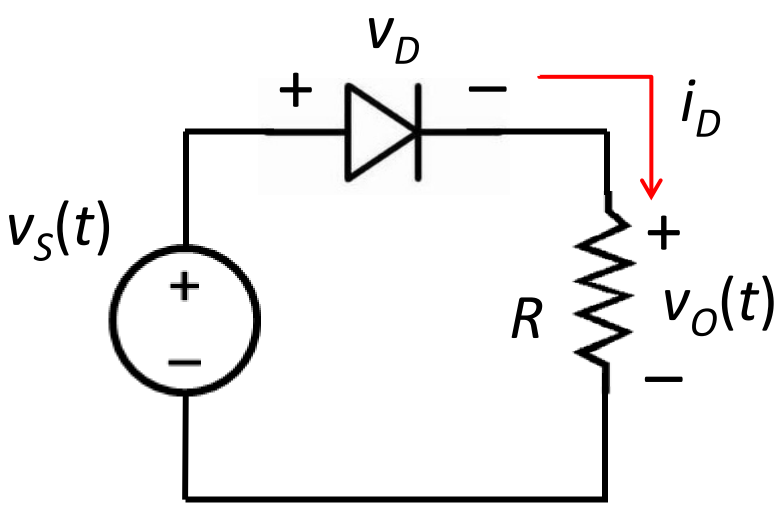


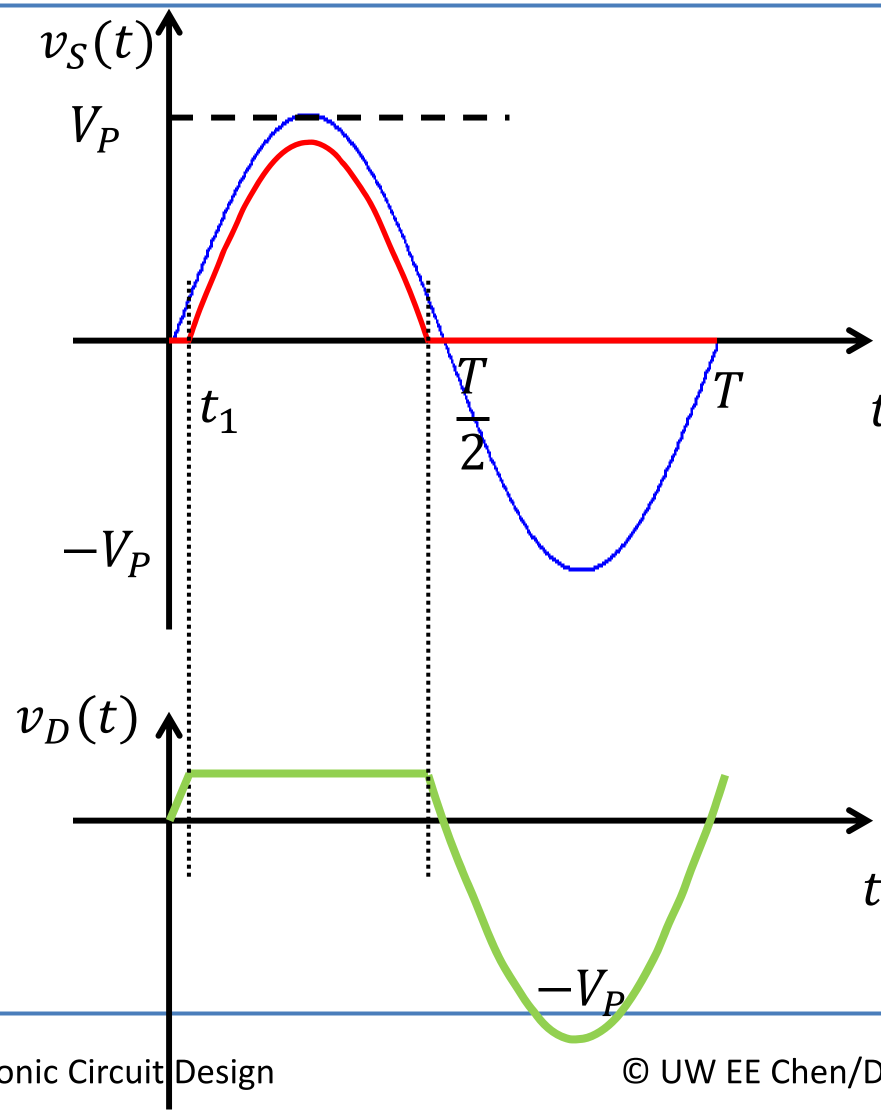
Case 1: if $v_S(t) > V_{\mathrm{on}}$, then D = ON. $v_D = V_{\mathrm{on}}$, $i_D > 0$,

$v_0(t) = v_S(t) - V_{\mathrm{on}}$.

Case 2: if $v_S(t) < V_{\mathrm{on}}$, then D = OFF. $i_D = 0$, $v_D = v_S$, $v_0(t) = 0$.

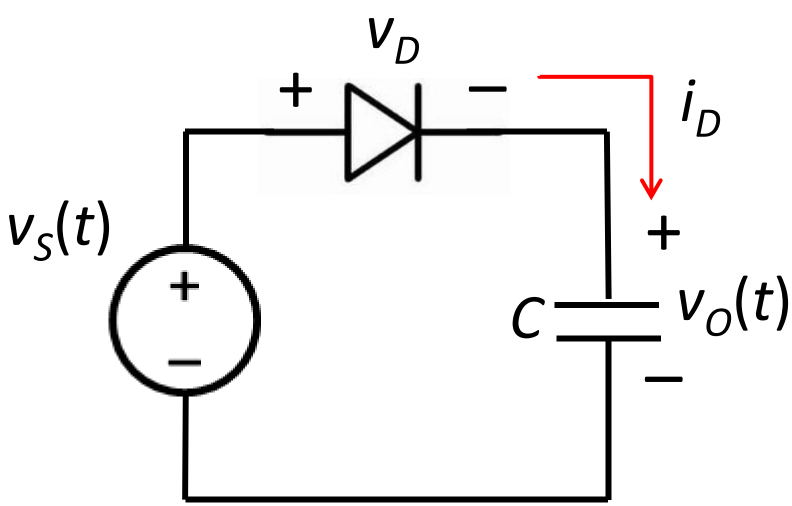
Half-wave rectifier (resistive load) Constant voltage drop

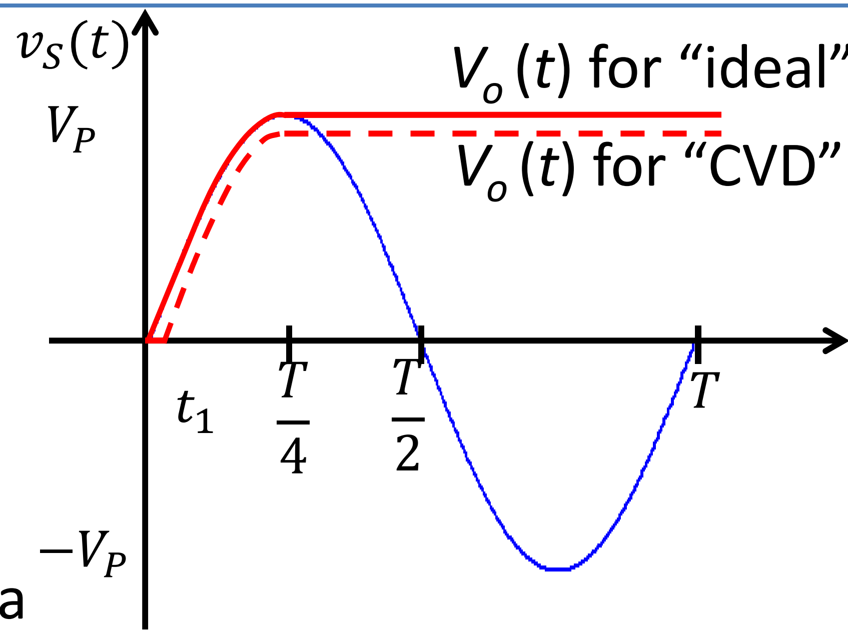




$$v_D(t) = v_S(t) - v_0(t).$$

Peak-detector circuit





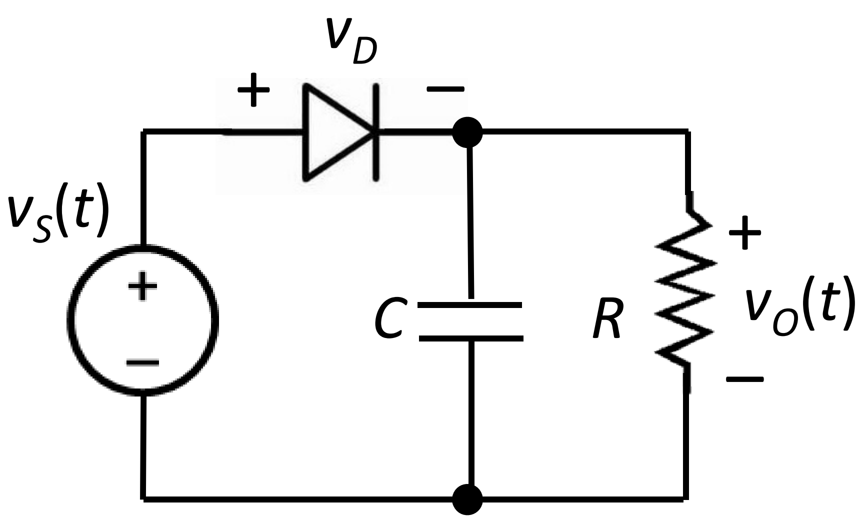
Now replace the resistor with a capacitor, at t = 0, $v_O(t) = 0$.

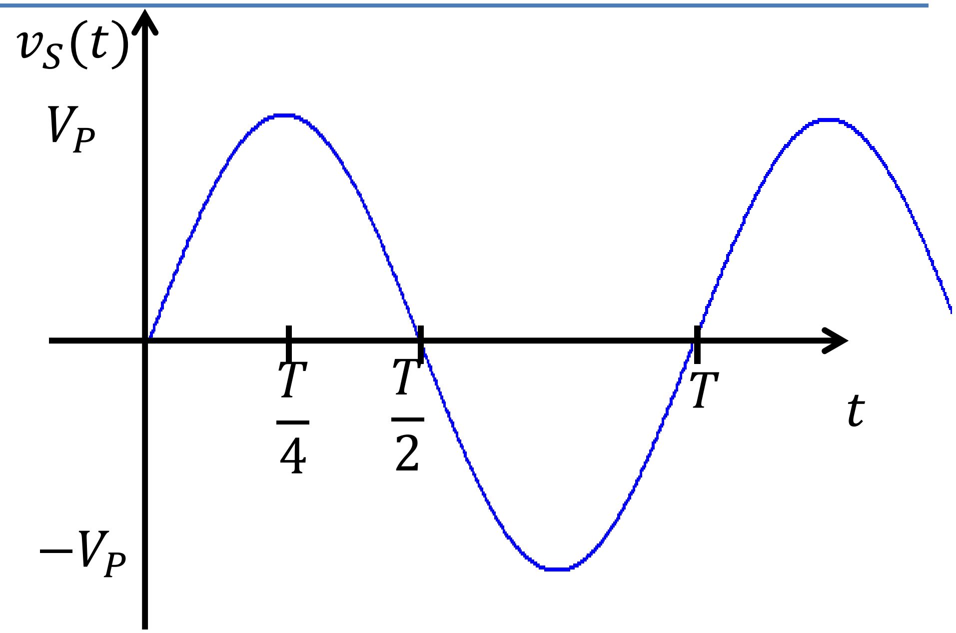
D1 ON: charging capacitor

D1 off: no route to discharge. V_O remains constant.

$V_{dc} = V_P$ (Ideal) or $V_P - V_{on}$ (CVD)

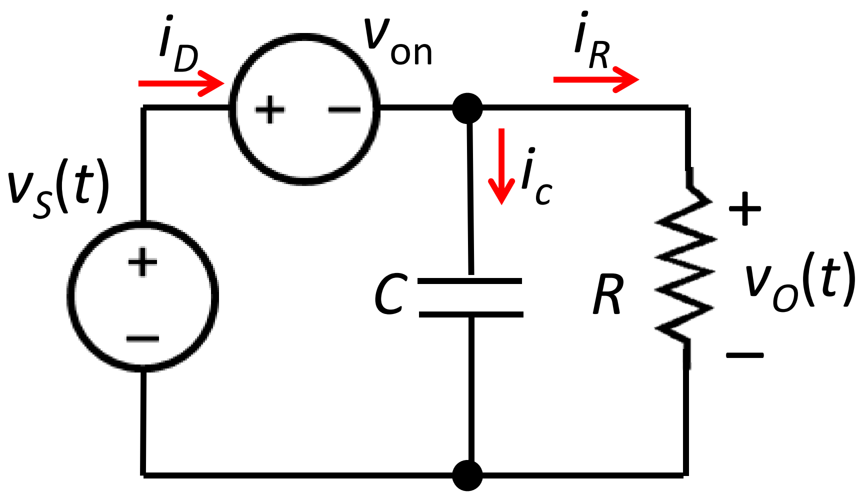
Half-wave rectifier w/ RC Load

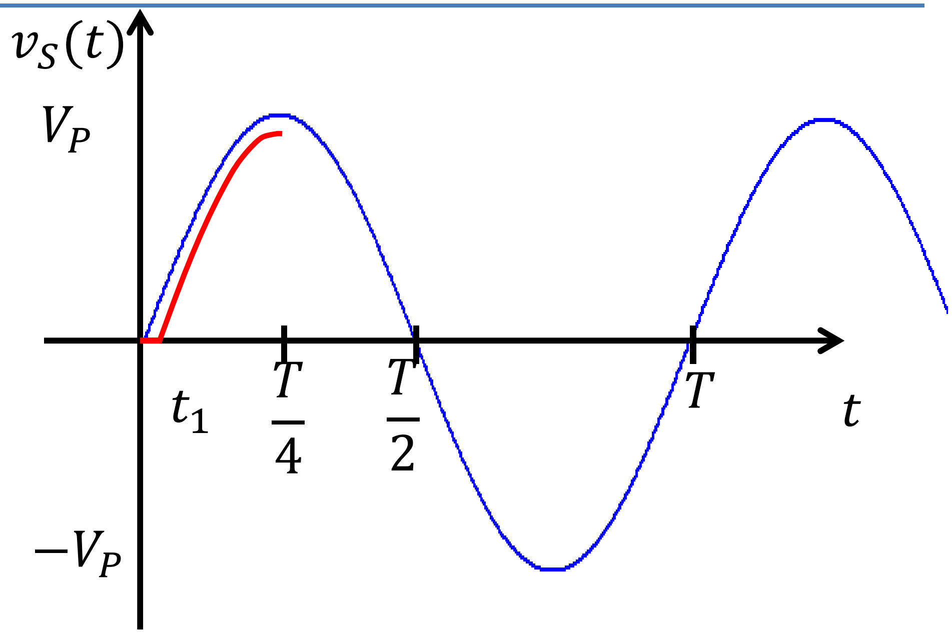




R/C in parallel. Assume nonzero V_{on} for the diode

Half-wave rectifier w/ RC Load

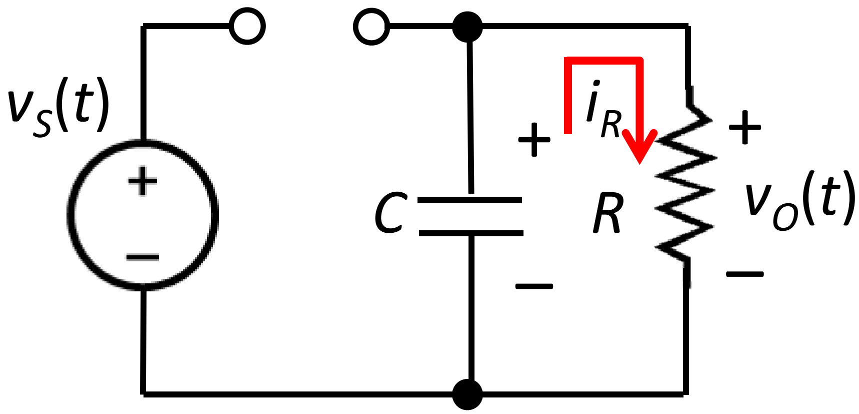


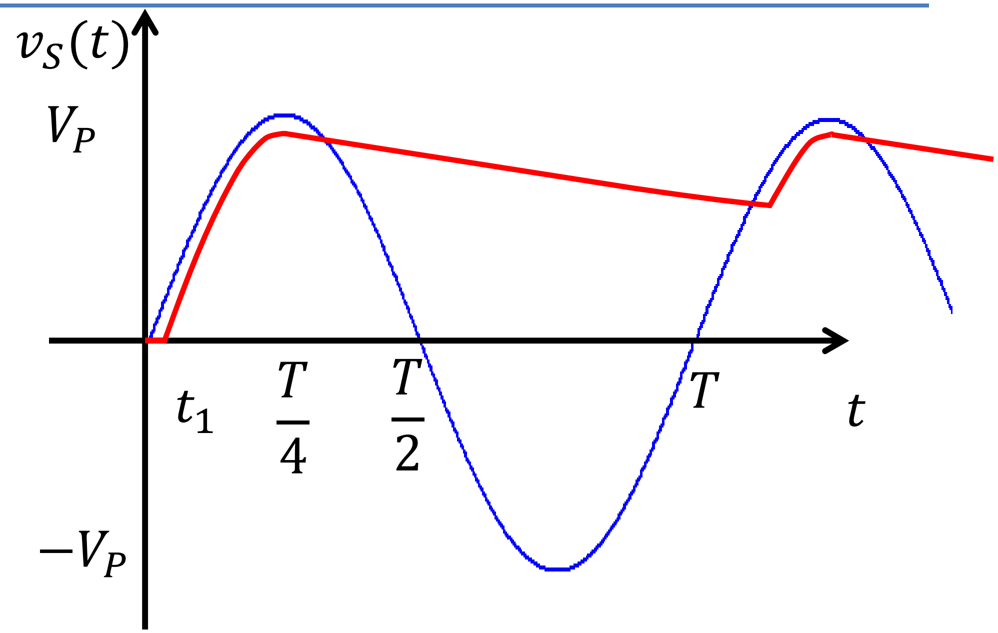


When $t < T/4$, diode ON, charging capacitor,

$v_O(t) = v_s(t) - V_{on}$

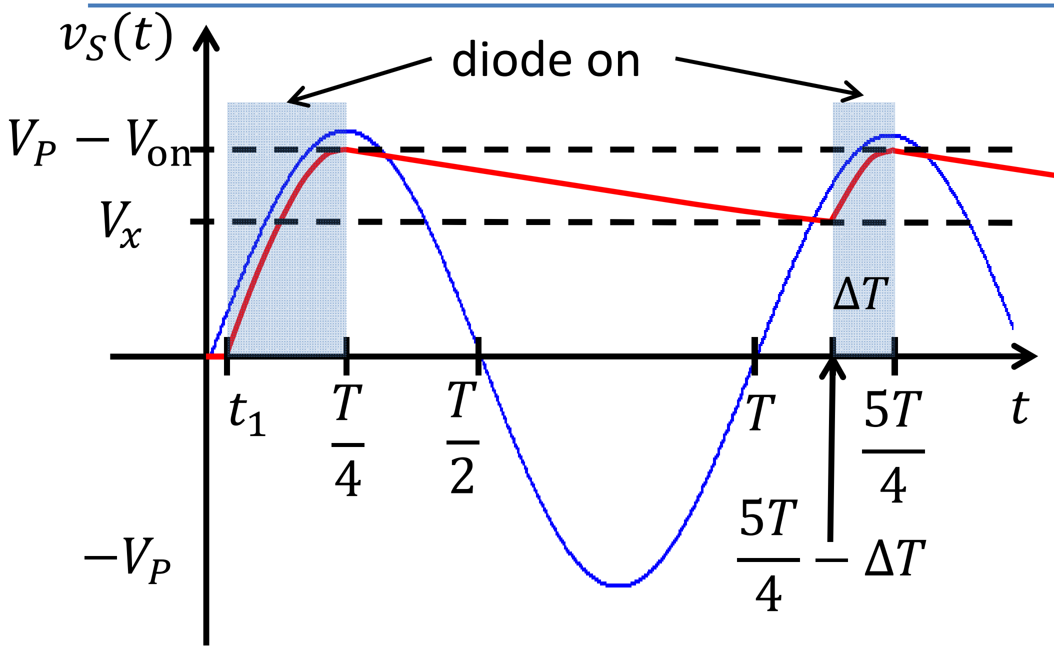
Half-wave rectifier w/ RC Load





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