Diode Circuits Analysis

Problem-solving technique (using piecewise linear model):

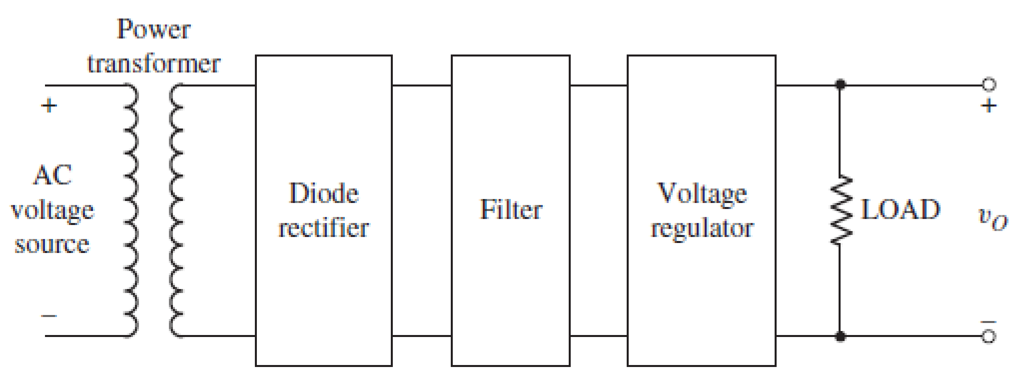
(1) Express the diode voltage in terms of bias and input voltages.

(2) Determine the input voltage condition such that a diode is on. Proceed analysis under this condition.

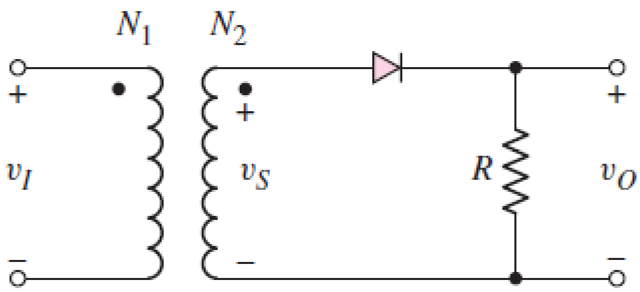
(3) Determine the input voltage condition such that a diode is off. Proceed analysis under this condition.

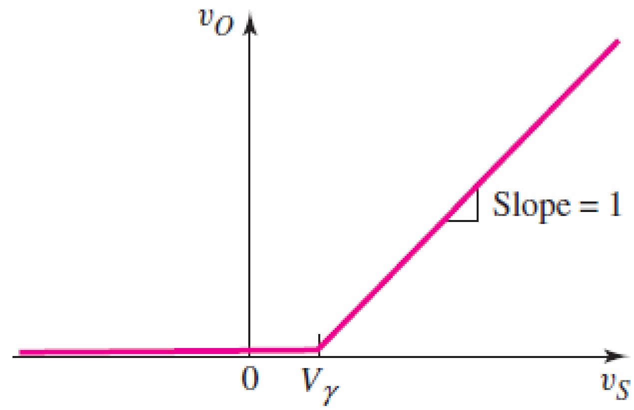
Rectifier Circuits

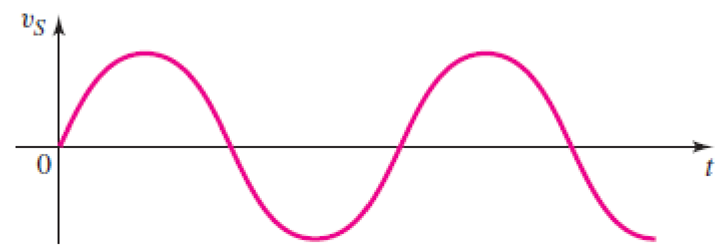
A rectifier circuit converts an ac voltage into one that has only one polarity.

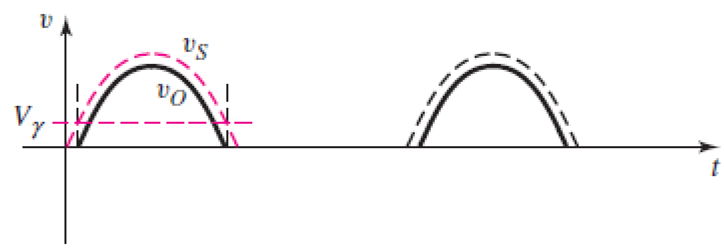


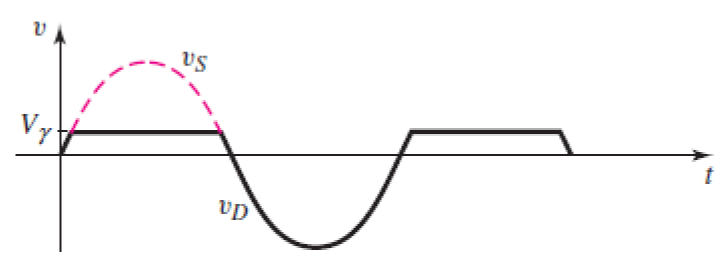
Half-Wave Rectification



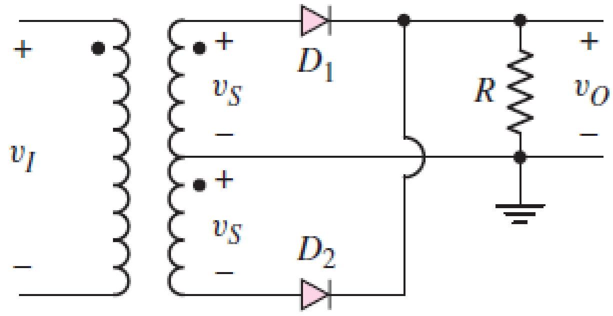


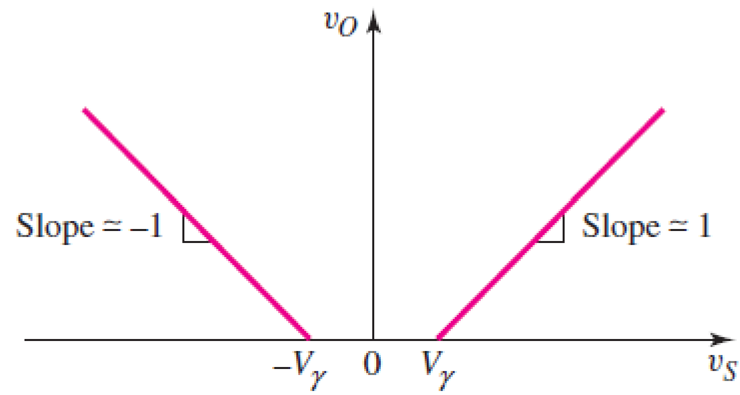


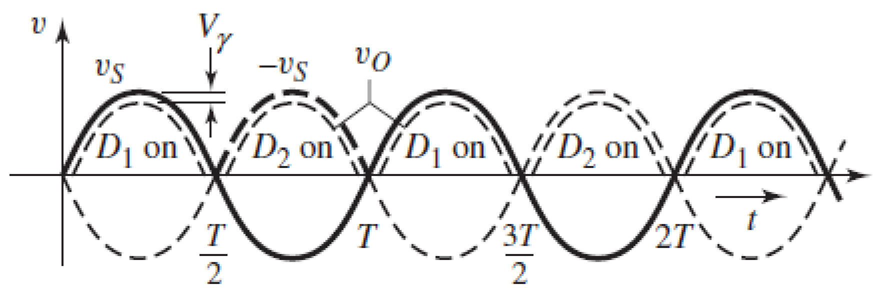




Full-Wave Rectification

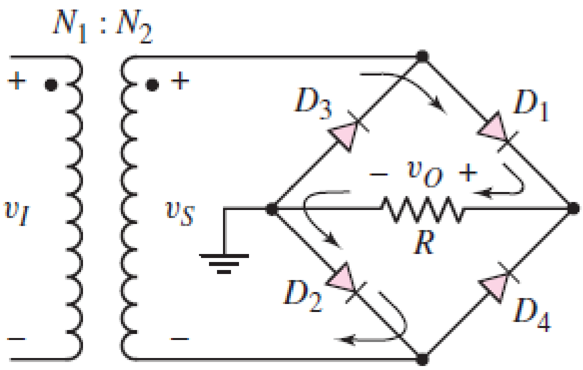


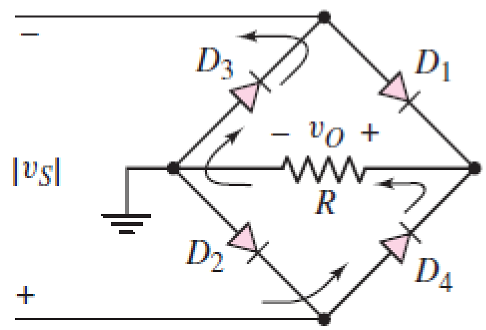


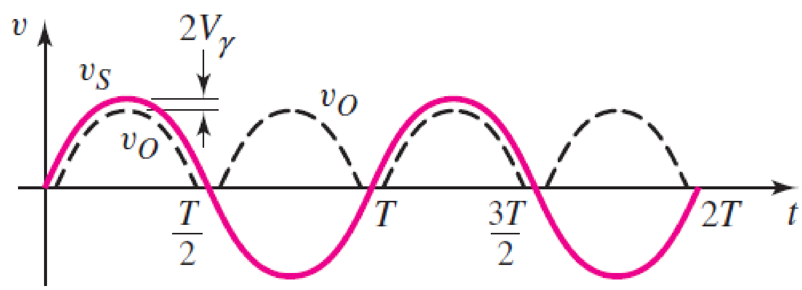


Rectified output voltage appears during both positive and negative cycles.

Full-Wave Bridge Rectifier

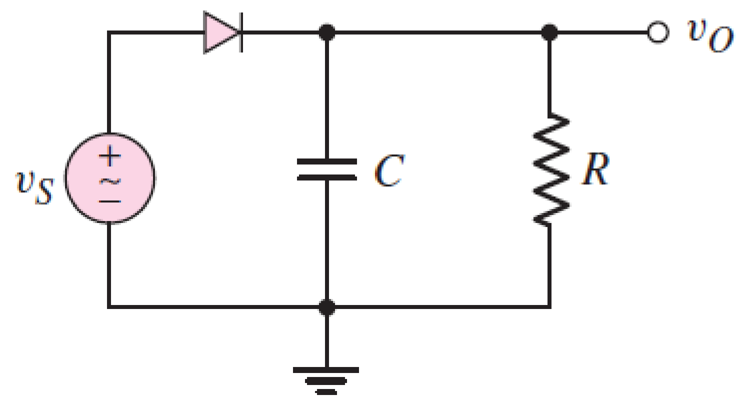






Filtering and Ripple Voltage

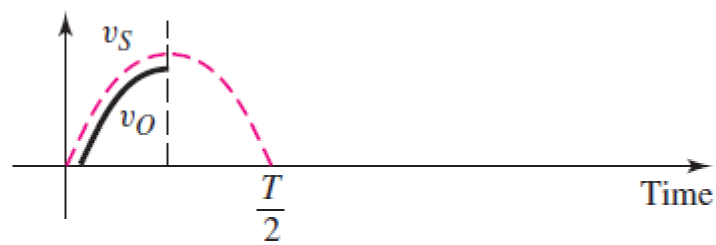
A capacitor low-pass filter can filter out most of ac components in the rectified signal



When diode is on, capacitor charging,

$$v_o(t) = v_s(t) - V_\gamma$$

$$v_o(max) = V_M - V_\gamma$$

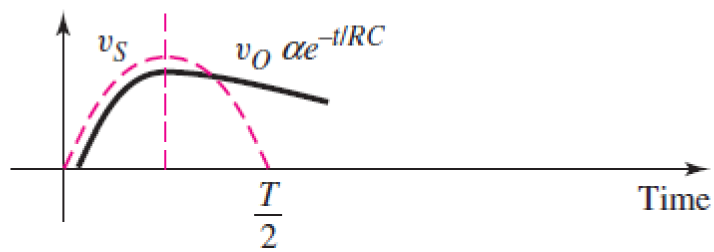


When diode is off, capacitor discharging,

$$v_o(t) = v_o(max)e^{-t/RC}$$

$$v_o(min) = v_o(max)e^{-\frac{\Delta t_2}{RC}}$$

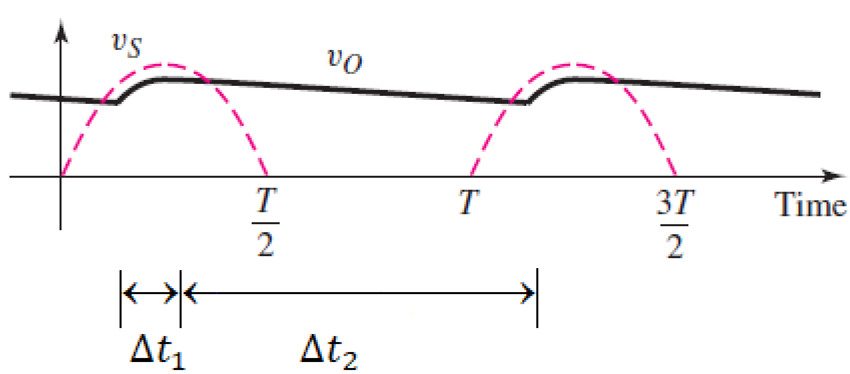
$$\approx v_o(max)\left(1 - \frac{\Delta t_2}{RC}\right)$$



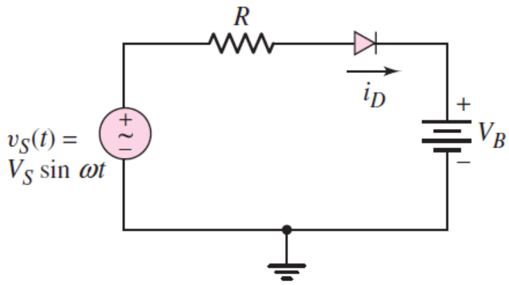
If $RC \gg T_p$ (period), discharging is very slow. $\rightarrow$ Output voltage is smoothed.

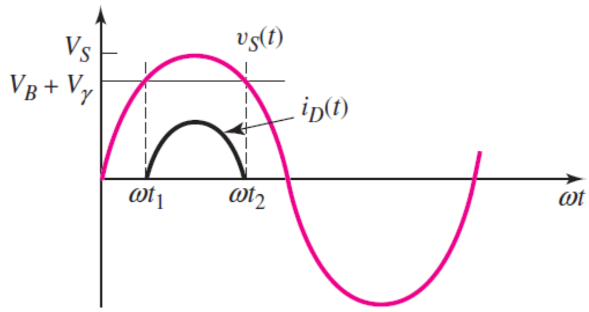
$$V_{ripple} = v_o(max) - v_o(min) \cong v_o(max)\frac{\Delta t_2}{RC} \approx v_o(max)\frac{T_p}{RC}$$

Steady-state waveform



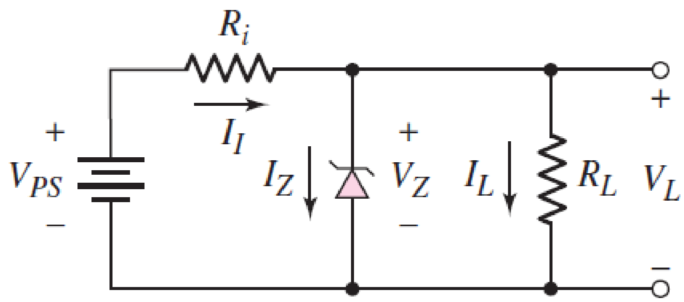
Charging battery





Zener Diode Circuits

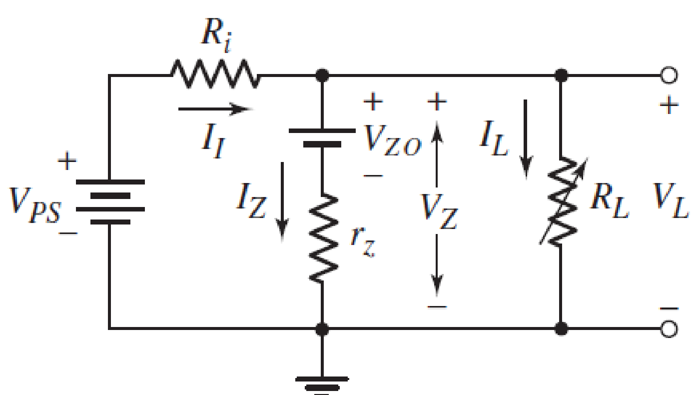
Zener diode is useful in a voltage regulator, or a constant-voltage reference circuit.



- Ideal Zener Voltage Reference Circuit ($r_Z = 0$)

$$V_L = V_Z = V_{Z0}$$

- Non-Ideal Zener Voltage Regulation Circuit ($r_Z \neq 0$)



$$V_Z = V_{z0} + r_Z I_Z$$

Percent Regulation

Variations of V_{PS} and load (R_L or I_L) lead to variation of V_L.

- Source regulation (load fixed)

$$Source\ regulation = \frac{\Delta v_L}{\Delta v_{PS}} \times 100\%$$

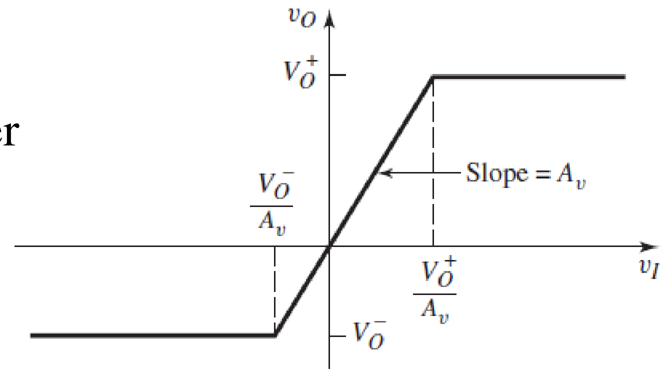
- Load regulation (V_{PS} fixed)

$$Load\ regulation = \frac{v_{L,no\ load} - v_{L,full\ load}}{v_{L,full\ load}} \times 100\%$$

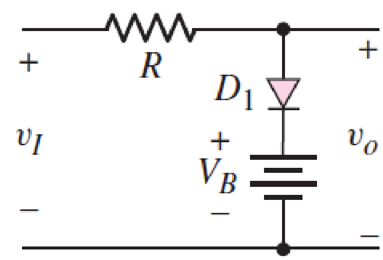
Clipper and Clamper Circuits

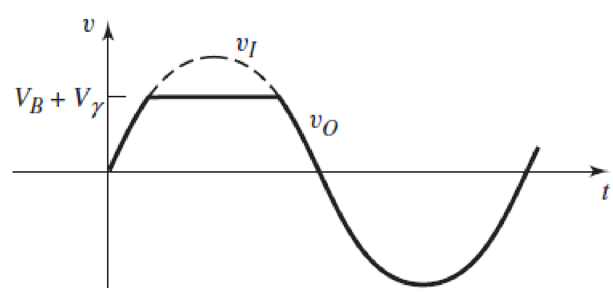
Clipper Circuits

Clipper circuits, also called limiter circuits, are used to eliminate the upper and/or lower portions of a signal.

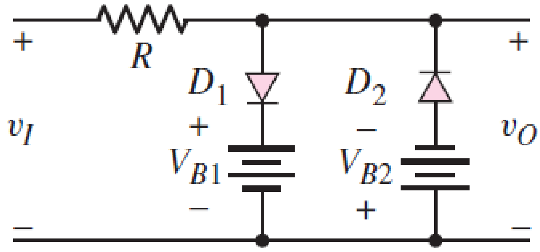


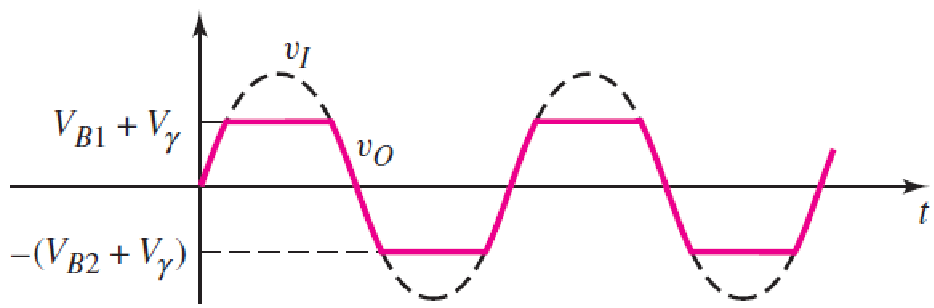
General transfer characteristics



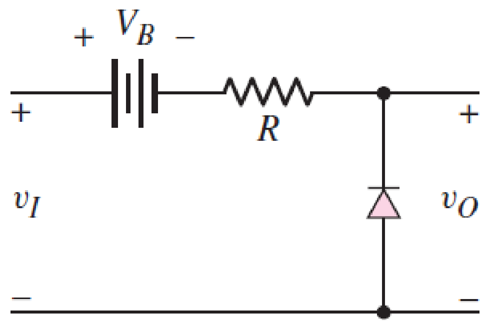


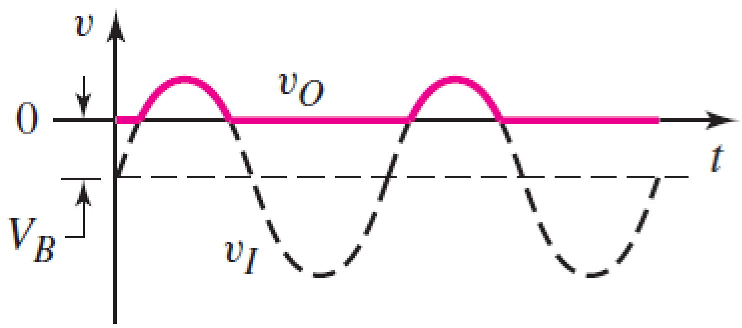
Clipper Example



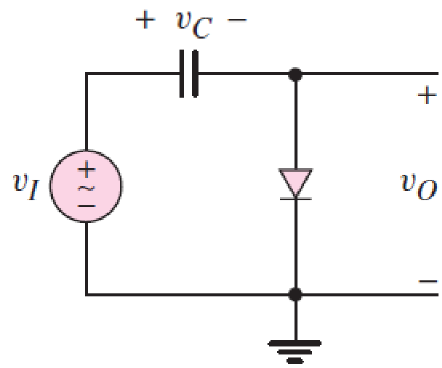


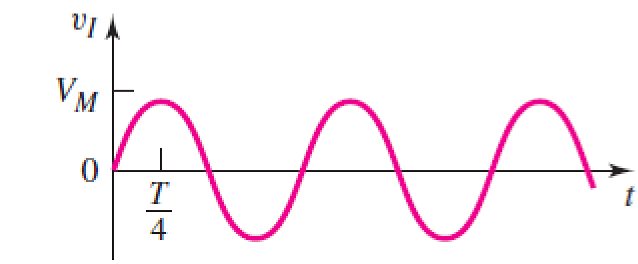
Clipper Example





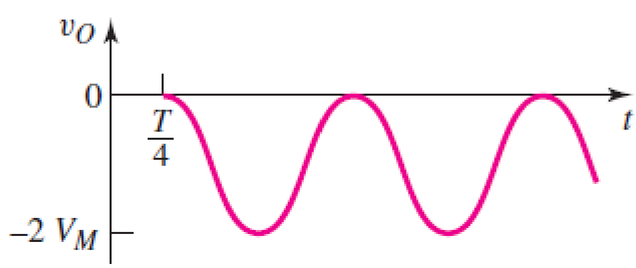
Clamper Circuits





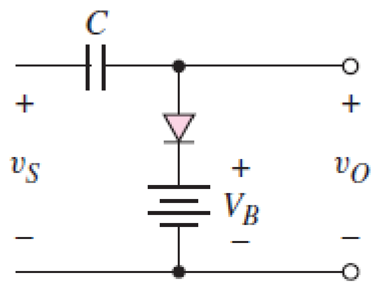
Diode on, capacitor charging. Diode off, capacitor cannot discharge. $v_C(t) \cong v_{C,\max}$

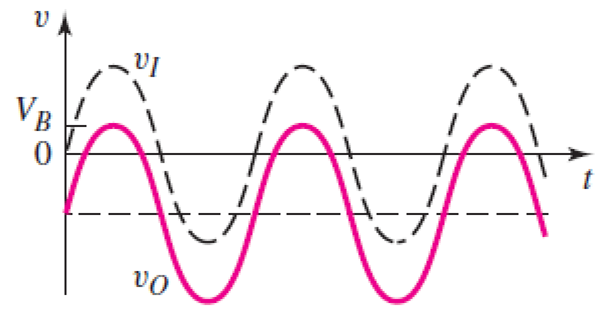
$v_O(t)$ is shifted

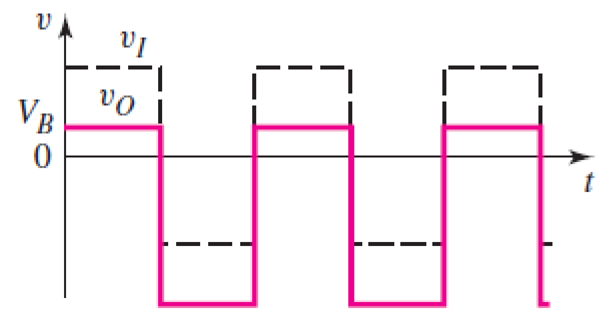


- Capacitor is charged to and maintains at $v_C(t) \cong v_{C,\max}$
- $v_O(t)$ has the same waveform as $v_I(t)$, but is shifted by a constant level.

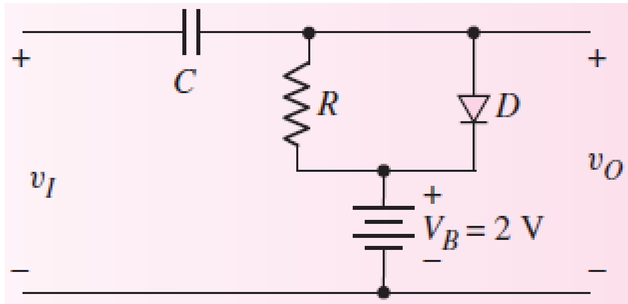
Clamper Example







Clamper Example



Other Diode Circuit

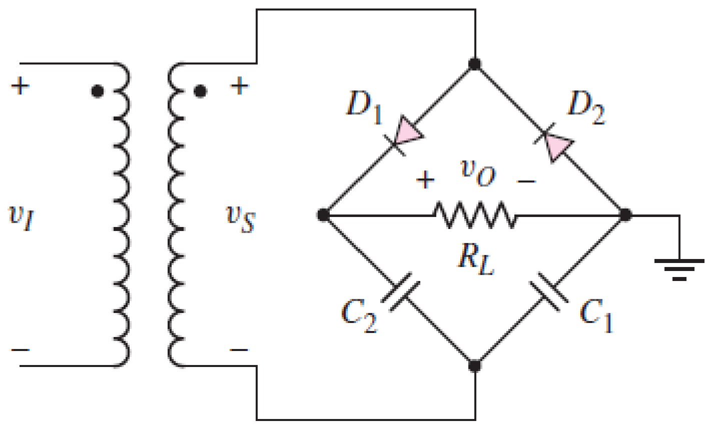
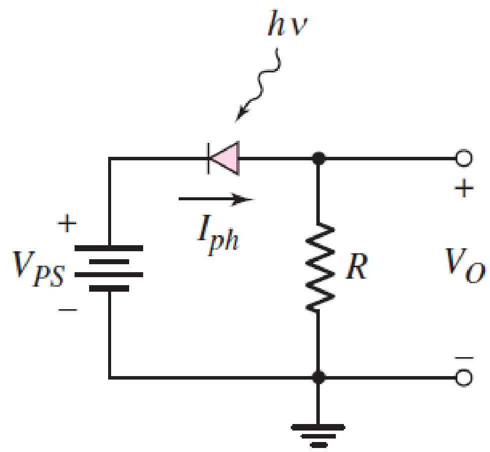
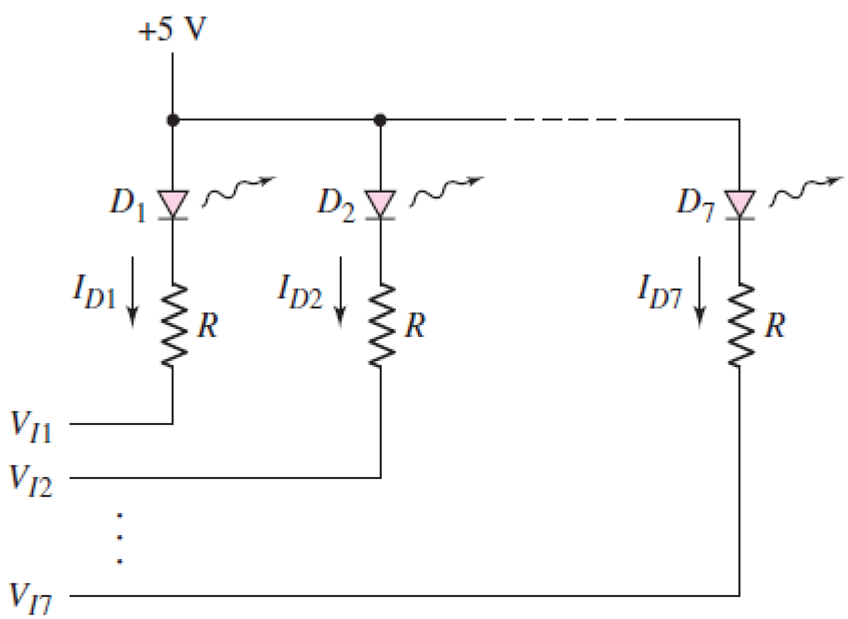


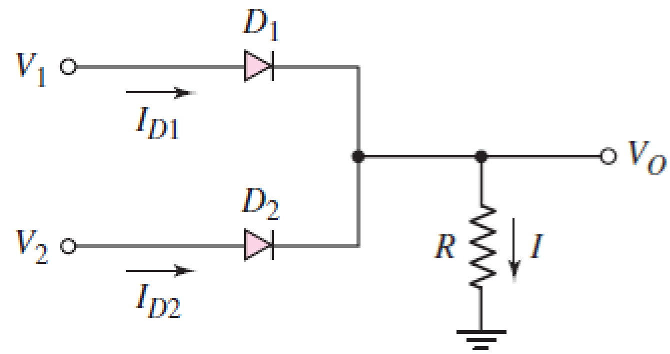
Photo-diode Detector Circuit

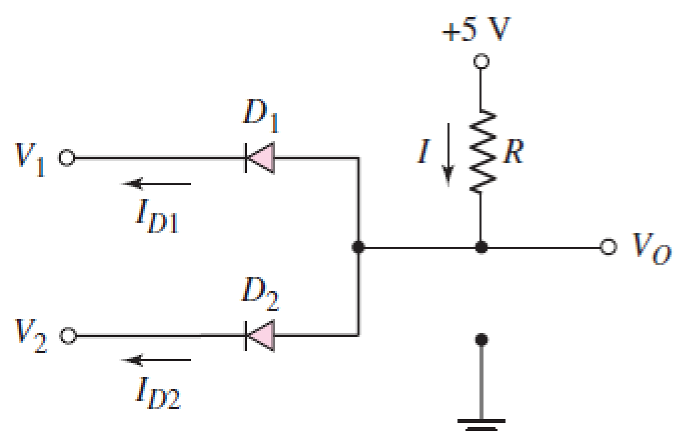


LED Circuit



Diode Logic Circuits

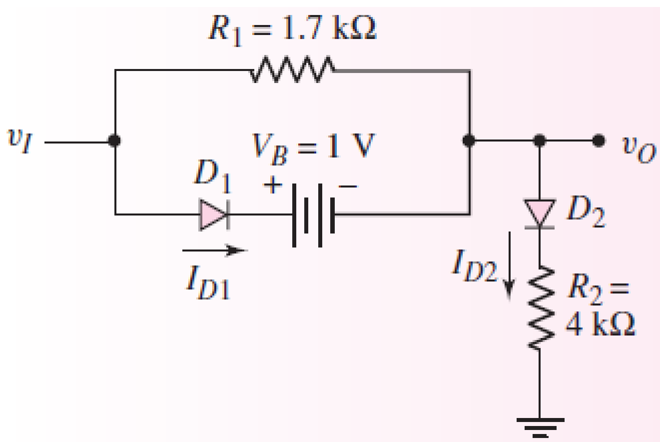




Multiple-Diode Circuits

In multiple-diode circuits, each diode may be either "on" or "off". Do a best-guessing of each diode state first, and see if the results are consistent with the assumptions. If not, do it second round.

Example 1



Example 2