Clipper & Clamper Circuits

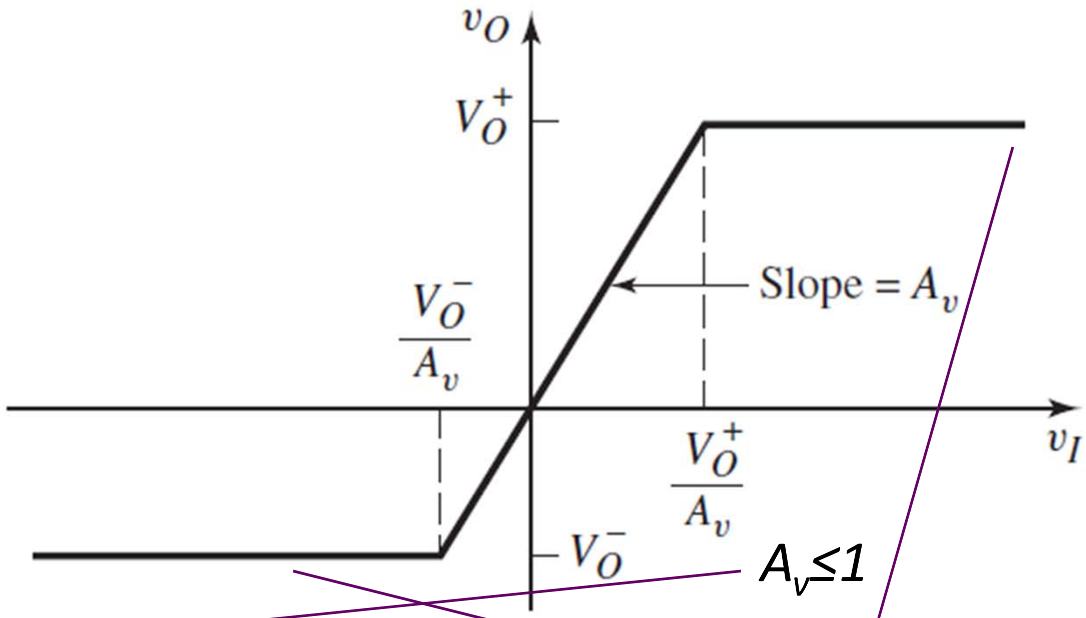
GOAL:

Nonlinear characteristics of diodes to create waveshaping circuits known as clippers and clampers.

Clippers:

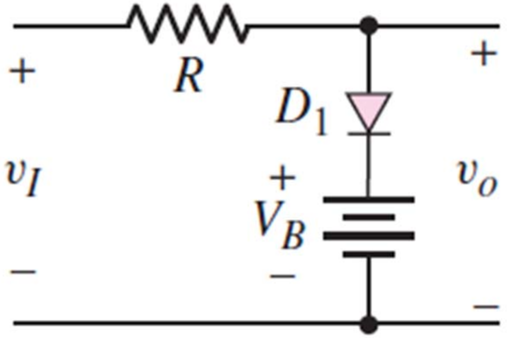
Clipper circuits, also called limiter circuits, are used to eliminate portions of a signal that are above or below a specified level.

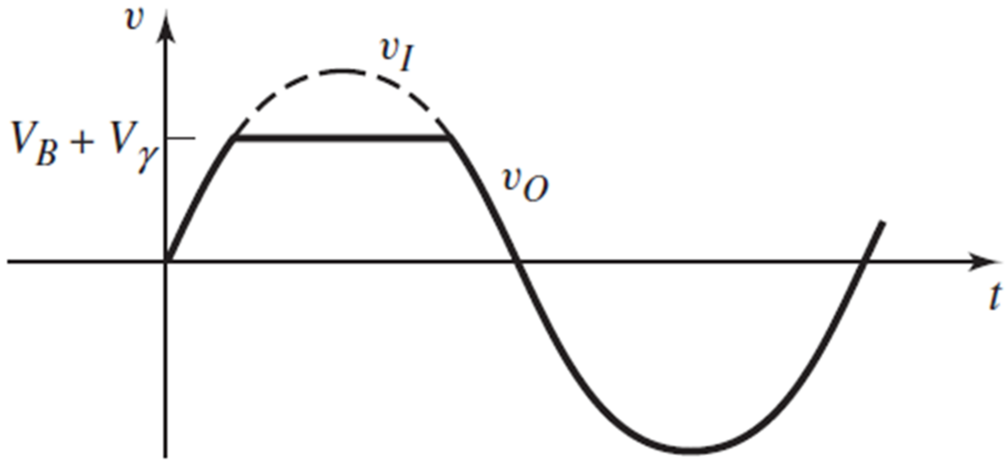
- The half-wave rectifier is a clipper circuit, since all voltages below zero are eliminated.
- An application prevents breakdown of transistors in circuits.



A passive limiter. A double limiter, in which both the positive and negative peak values of the input signal are clipped

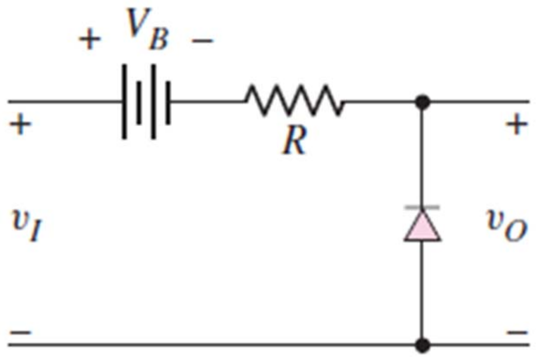
Single diode clipper:

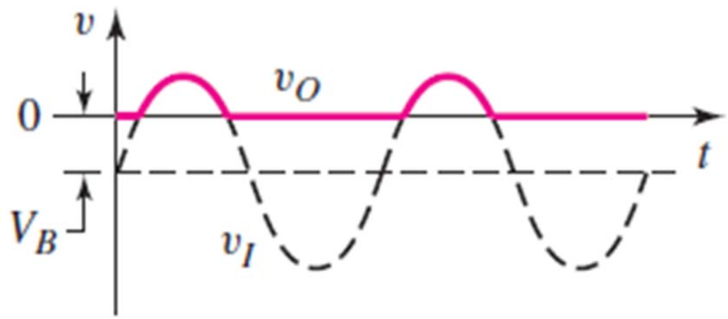




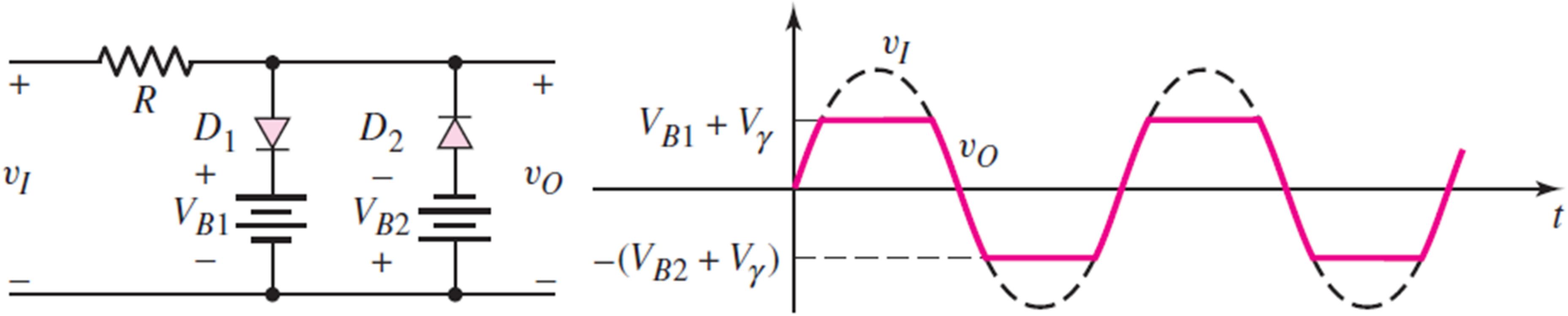
Diode clipper circuits can also be designed such that the dc power supply is in series with the input signal.

If, ideal diode



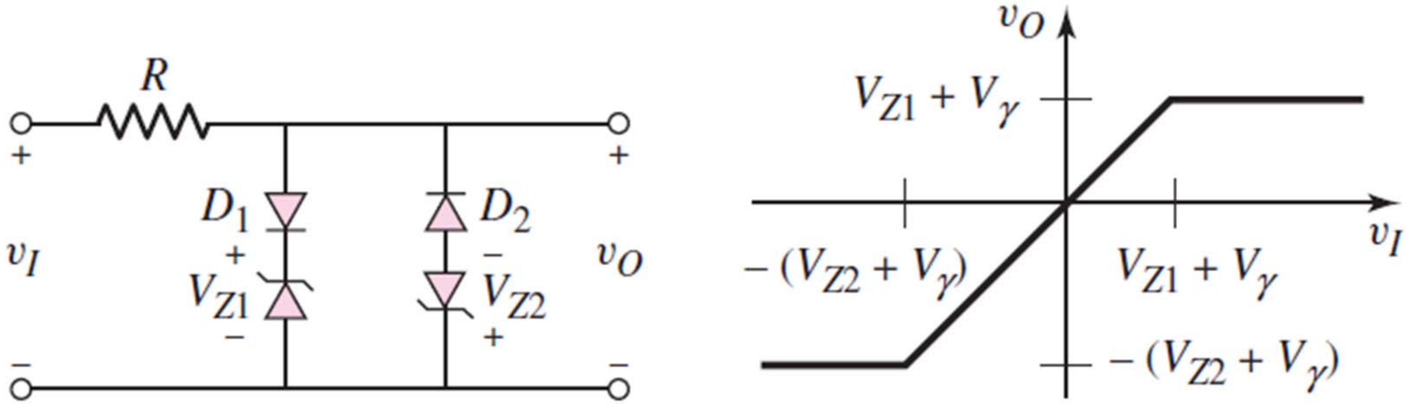


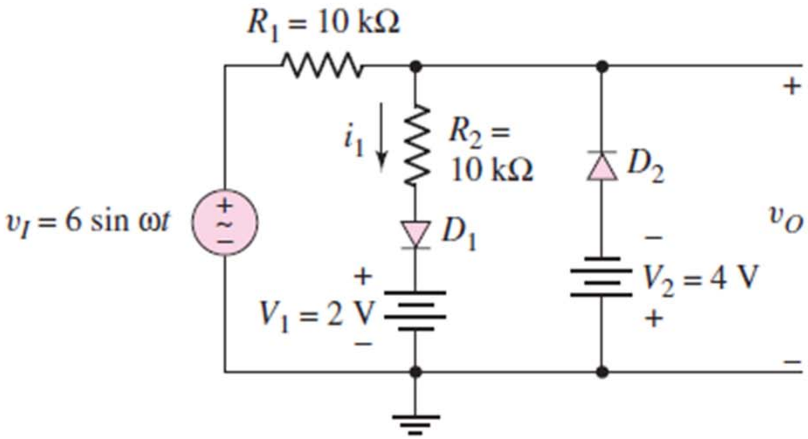
Multiple diode clipper:

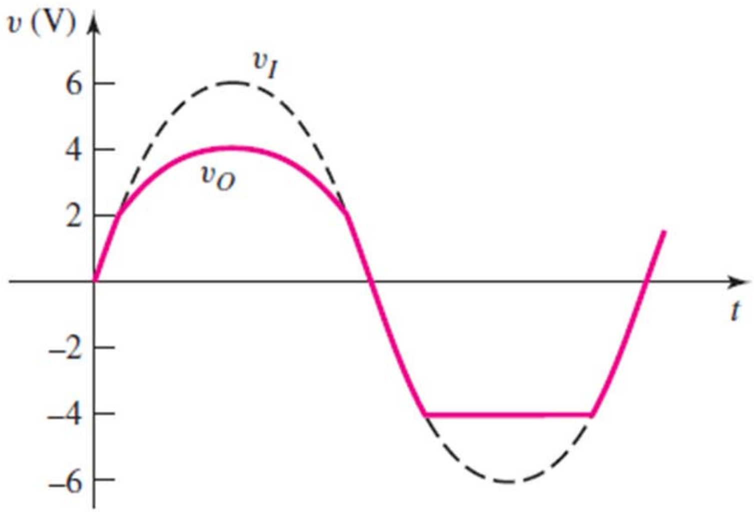


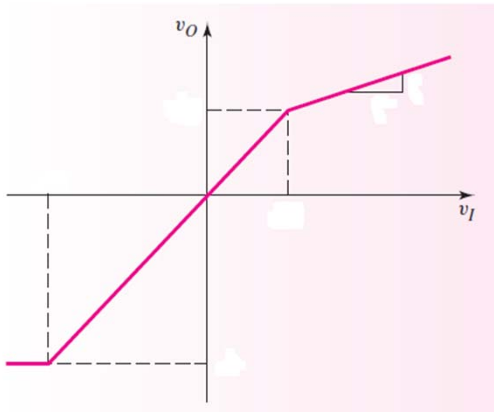
Double limiter or a parallel-based clipper

Zener diodes, operated in the reverse breakdown region, provide essentially a constant voltage drop. So, replace batteries by Zener diodes.









If, ideal diode

$$i_1 = \frac{v_I - 2}{10 + 10}$$

$$v_O = i_1 R_2 + 2 = \tfrac{1}{2}(v_I - 2) + 2 = \tfrac{1}{2}v_I + 1$$

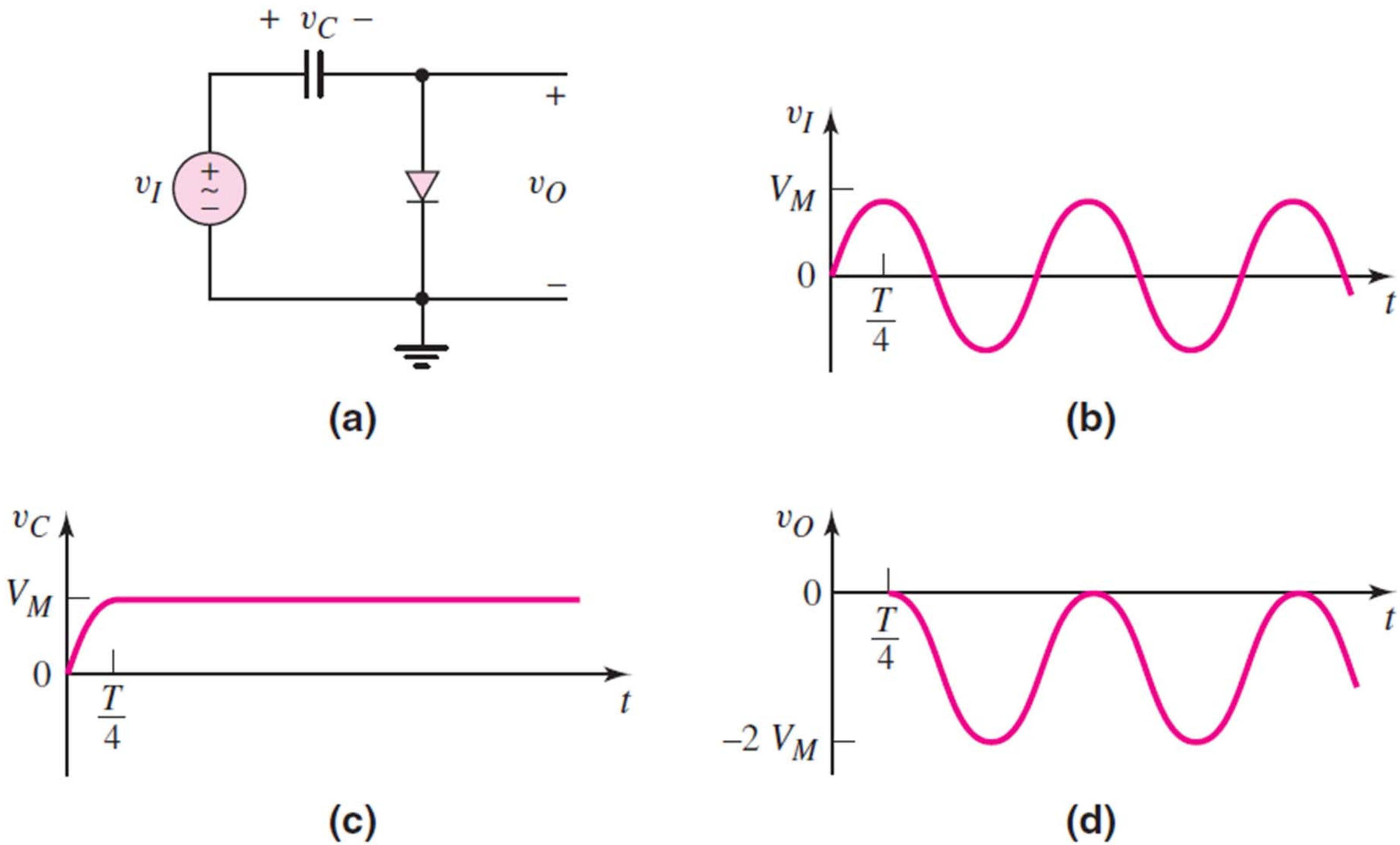
Linear relation

Clampers:

Clamping shifts the entire signal voltage by a dc level.

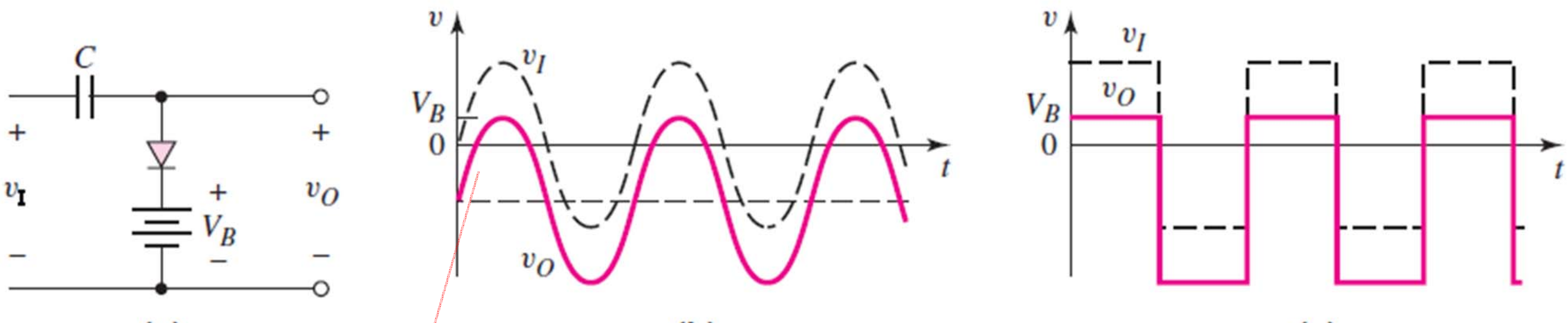
It adjusts the dc level without needing to know the exact waveform

Analysis assuming ideal diode (diode resistance and cut-in voltage is 0) and capacitor in steady-state (does not discharge!)



$$v_O = -v_C + v_I = -V_M + V_M \sin \omega t$$

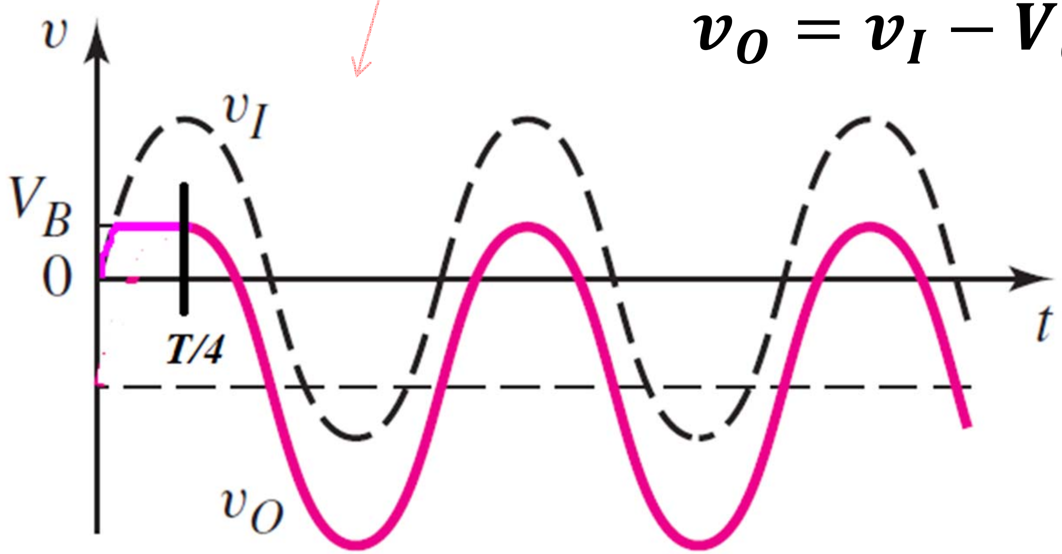
Output voltage is “clamped” at zero volts.

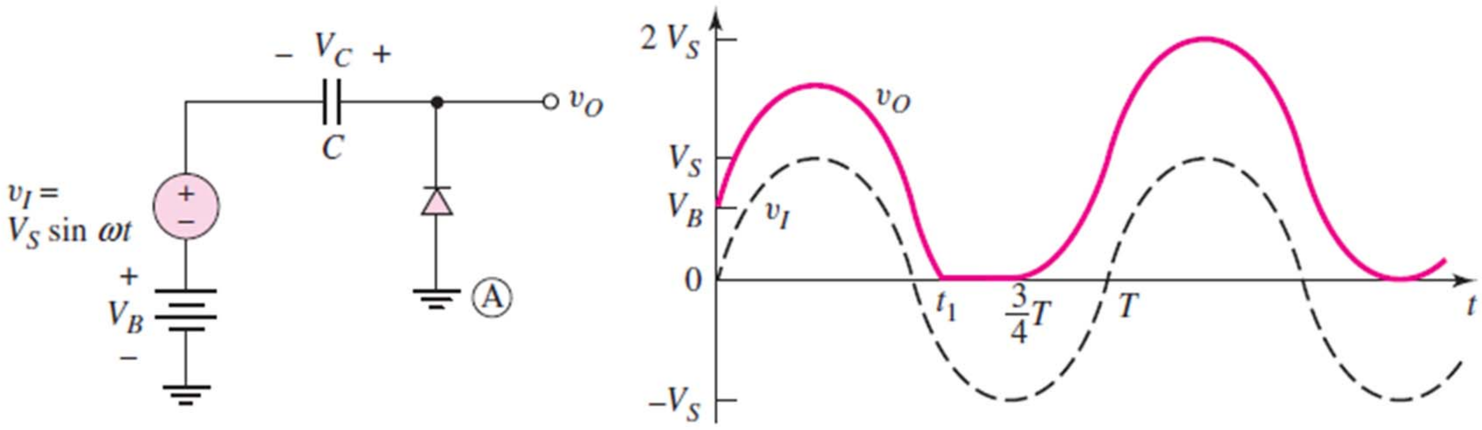


(a) (b) (c)

R_LC →very large (so that uncharged capacitor does not charge when diode is reversed biased)

$$v_o = v_I, \text{diode r. bias}$$
$$v_o = V_B, \text{diode f. bias}$$
$$v_O = v_I - V_C = v_I - (V_M - V_B)$$





$$v_I + V_B \geq 0$$

$R_L C \to \infty$ **Capacitor does not charge**

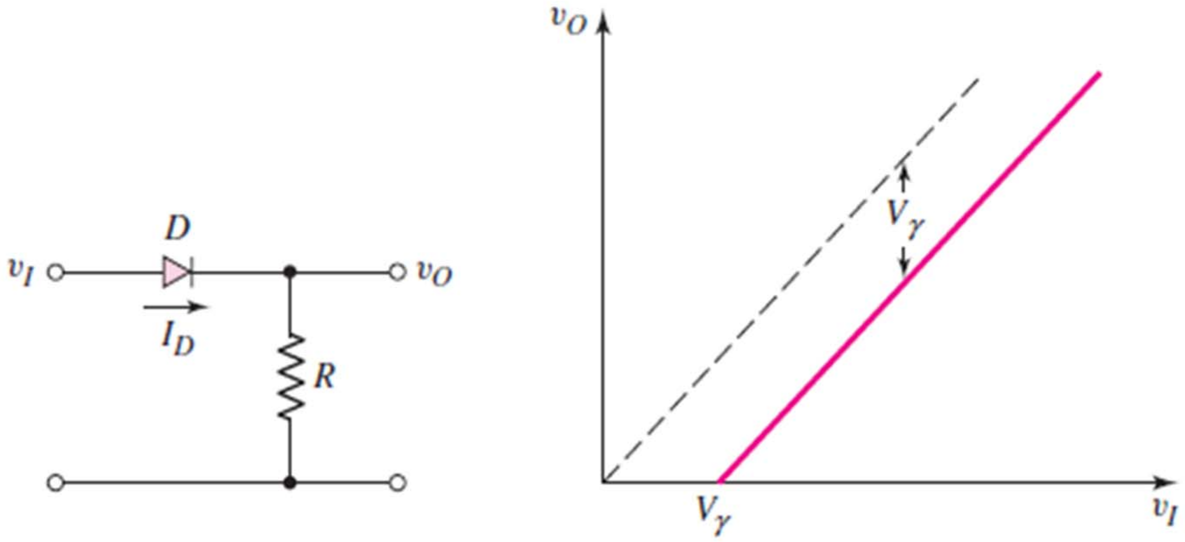
Output: $v_O = v_I + V_B$

$v_I + V_B < 0$ **Output:** $v_O = 0$ $V_C = V_S - V_B$

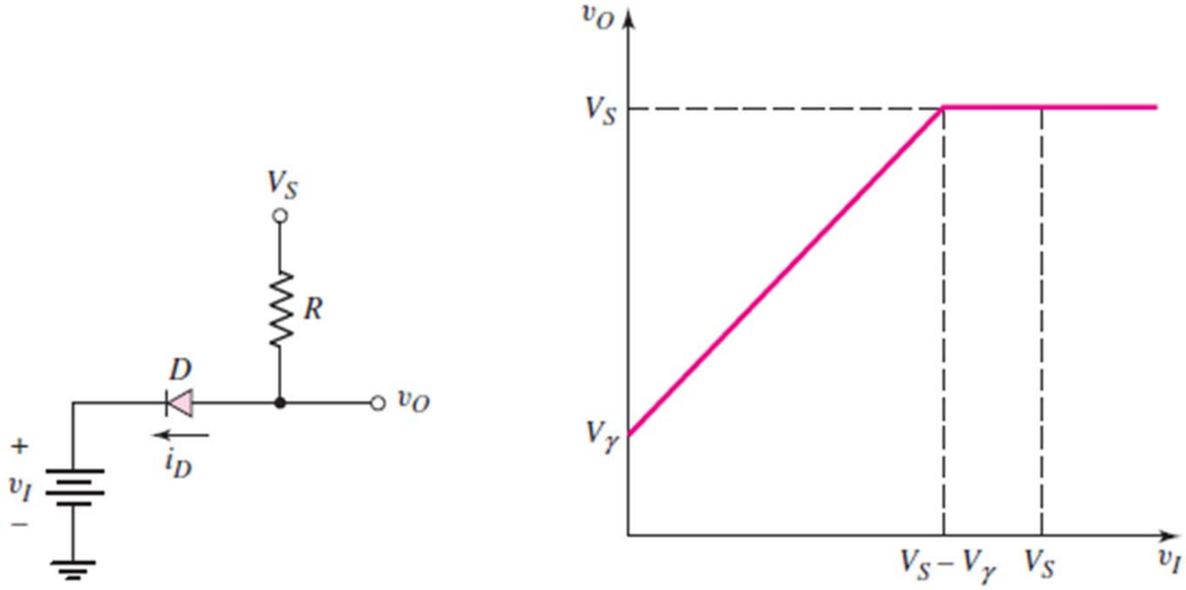
$$v_I > -V_S + V_B$$

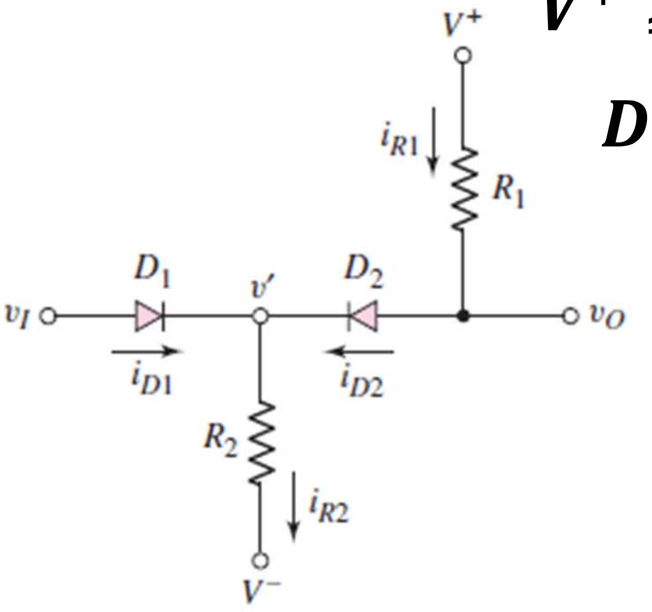
Output: $v_O = v_I + V_B + V_C = v_I + V_S$

Multiple-Diode Circuits



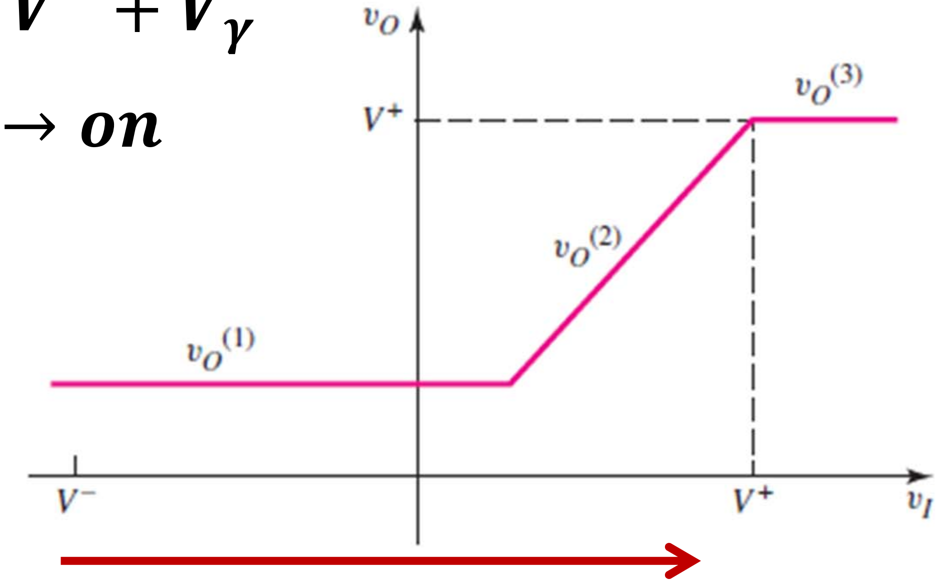
Piecewise linear nature of the diode and the diode circuit





$$V^{+} \geq V^{-} + V_{\gamma}$$

$$D_2 \rightarrow on$$



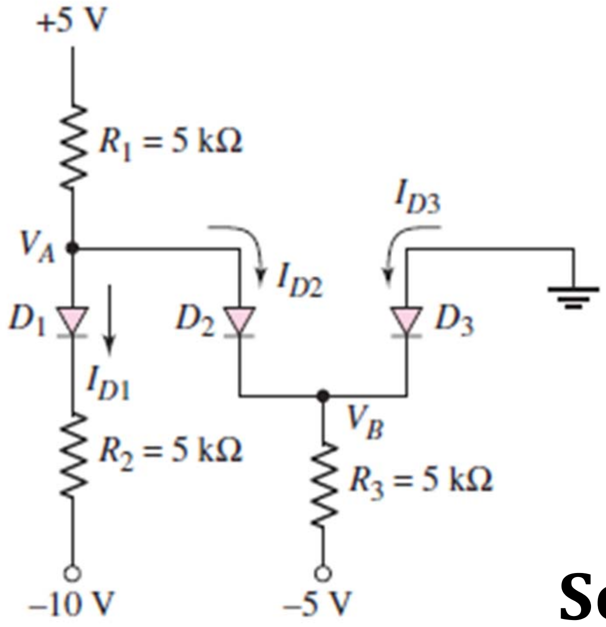
$$v_I = V^{-} : D_1 \rightarrow off, \text{as } v' \geq V^{-}$$

$$V^{+} - v_O = i_{R1} R_1$$

$$V^{+} - V_{\gamma} - V^{-} = (R_1 + R_2) i_{R1}, i_{R1} = i_{R2} = i_D$$

$$v' = v_O - V_{\gamma}, \qquad v_I < v' + V_{\gamma} = v_O : D_1 \rightarrow off$$

$$v_I = v_O : D_1 \rightarrow on \text{ till } v_I < V^{+}. \;\; v_I \geq V^{+}, v_O = V^{+}$$



Assume $D_1, D_2 \& D_3$ conducting

$$V_A, V_B, I_{R1}, I_{D1} \rightarrow I_{D2} = -ive$$

So assume only $D_1 \& D_3$ conducting

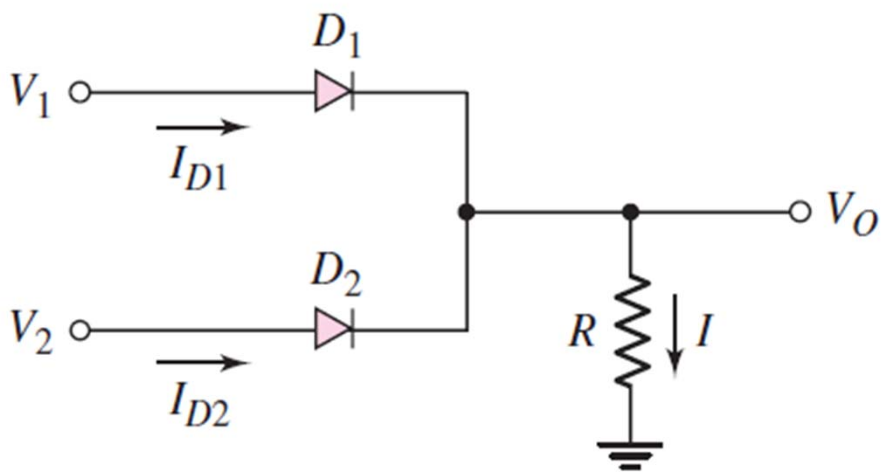
Leads to $I_{D1} = +ive \;\&\; I_{D3} = +ive \;\&\; I_{D2} = 0$

Tutorial

They key is to judiciously guess the initial diodes' states for a given circuit (considering least input) & check whether the guess was right or wrong!

Diode Logic Circuits:

OR gate

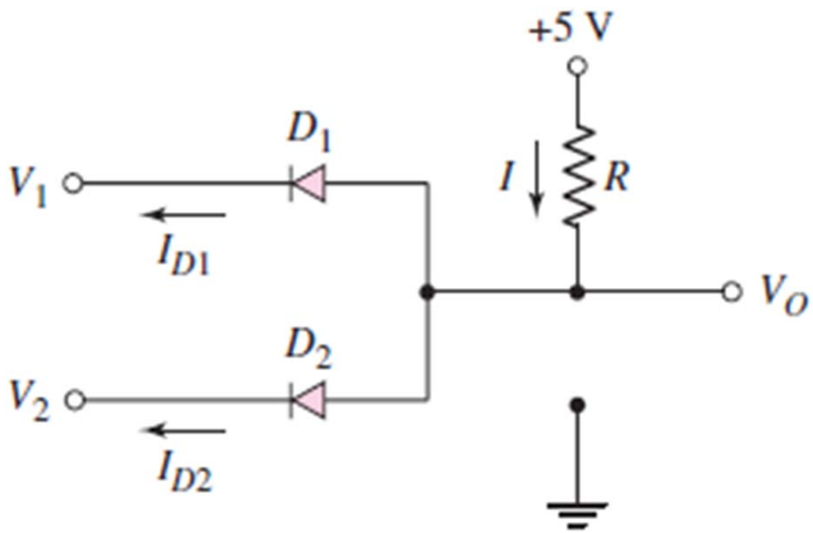


Two-diode OR logic circuit response

V_1 (V)	V_2 (V)	V_o (V)
0	0	0
5	0	4.3
0	5	4.3
5	5	4.3

Voltages in parallel equals that one voltage whose associated serial resistance is the smallest

AND gate



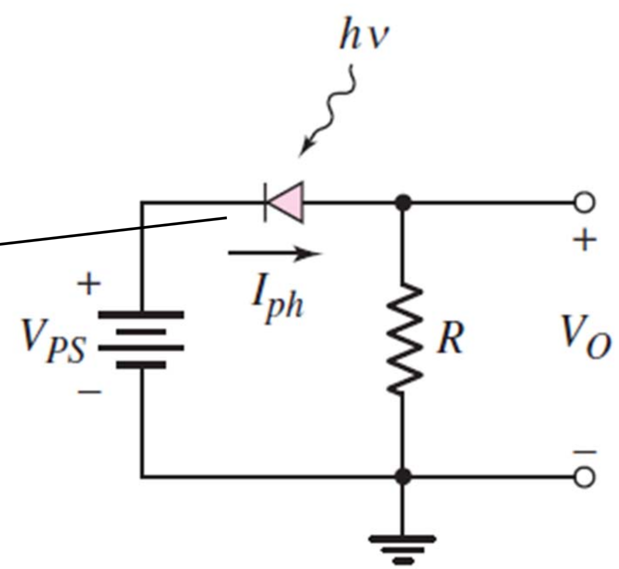
Two-diode AND logic circuit response

V_1 (V)	V_2 (V)	V_o (V)
0	0	0.7
5	0	0.7
0	5	0.7
5	5	5

Photodiode & LED Circuits

Photodiode circuit:

Reverse bias condition



- Photons striking the diode create excess electrons and holes in the space-charge region

- Electric field quickly sweeps carriers out of the space-charge region, thus creating a photocurrent in the reverse-bias direction.

$$I_{ph} = \eta e \Phi A$$

Quantum efficiency

Electronic charge

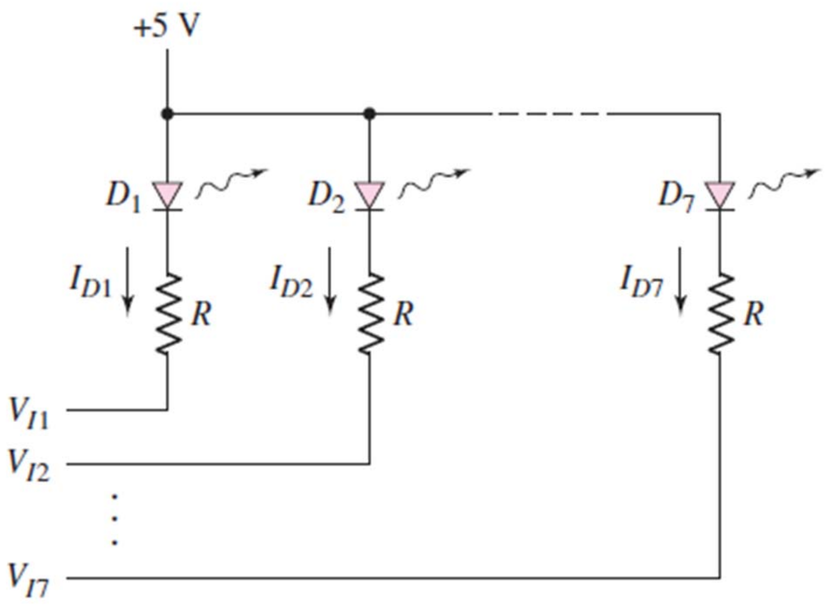
Photon flux density

Junction area

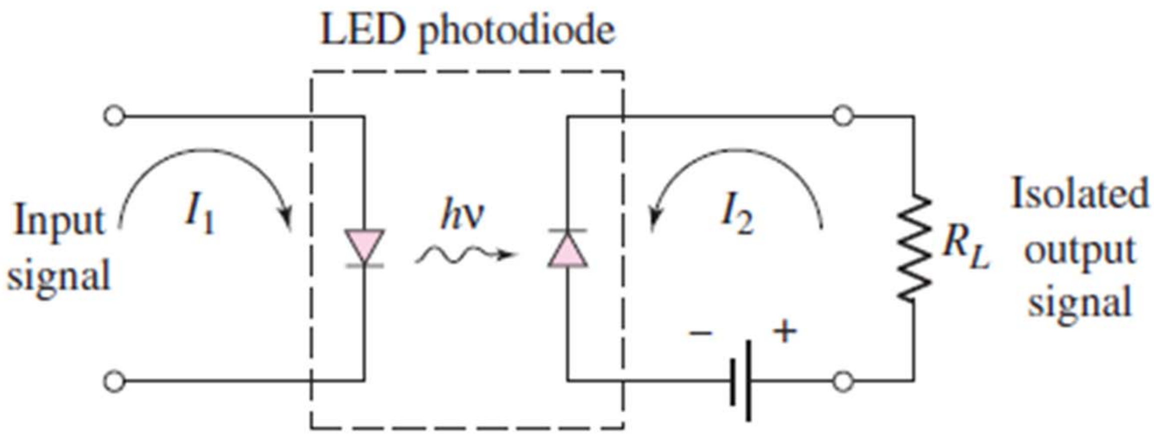
Linear relationship between photocurrent and photon flux is based on the assumption that the reverse-bias voltage across the diode is constant

LED circuit:

Common-anode display



Application of Photodiode & LED put together



- Opto-isolators, in which the input signal is electrically decoupled from the output
- Opto-isolators prevent high voltages from affecting the system receiving the signal