Diode models and Diode Logic

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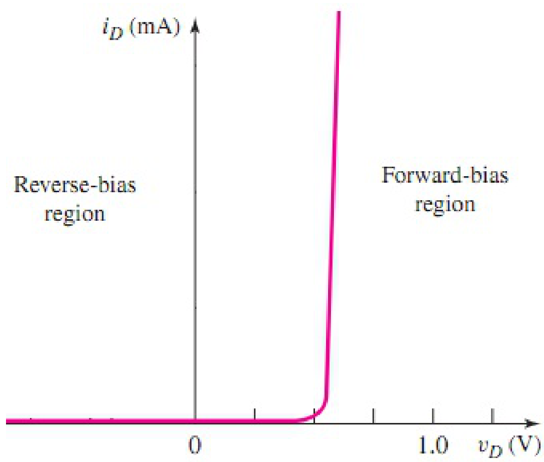
1 Diode DC Model - Shockley diode model



The Shockley diode model equation is

$$i_D = I_S \left[e^{\frac{V_D}{nV_T}} - 1 \right] \qquad v_D = nV_T \ln \left(\frac{i_D}{I_S} + 1 \right)$$

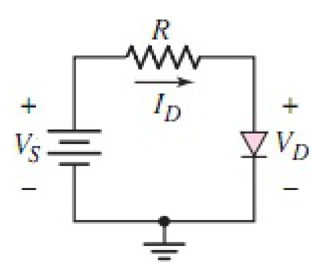
V_D : Diode Voltage
i_D : Diode Current
I_S : Reverse-bias saturation current $10^{-15} \sim 10^{-13} A$
V_T : Thermal voltage $V_T = \dfrac{kT}{q} \approx 26mV_{300\text{K}}$
n : Ideality factor, $n \in [1, 2]$

1.1 Diode block reverse current

$$i_D = 10^{-14} \left[e^{\frac{V_D}{0.026}} - 1 \right] \quad \begin{cases} \text{Forward biase} \quad V_D = 0.7V \qquad i_D = 10^{-14} \left[e^{\frac{0.7}{0.0026}} - 1 \right] \approx 4.93mA \neq 0 \\ \text{Reverse biase} \quad V_D = -0.7V \qquad i_D = 10^{-14} \left[e^{\frac{-0.7}{0.0026}} - 1 \right] \approx -10^{-14} A = 0 \end{cases}$$

So diode can be treated as a blocker of reverse current

1.2 Standard Diode-Resistor DC circuit



Standard equations of DR circuit $\begin{cases} V_S = i_D R + v_D \\ i_D = I_S \left[e^{\frac{V_D}{nV_T}} - 1 \right] \end{cases}$

$$\iff \qquad V_S = I_S R \left[e^{\frac{V_D}{nV_T}} - 1 \right] + v_D \qquad V_S = i_D R + V_T \ln \left(\frac{i_D}{I_S} + 1 \right)$$

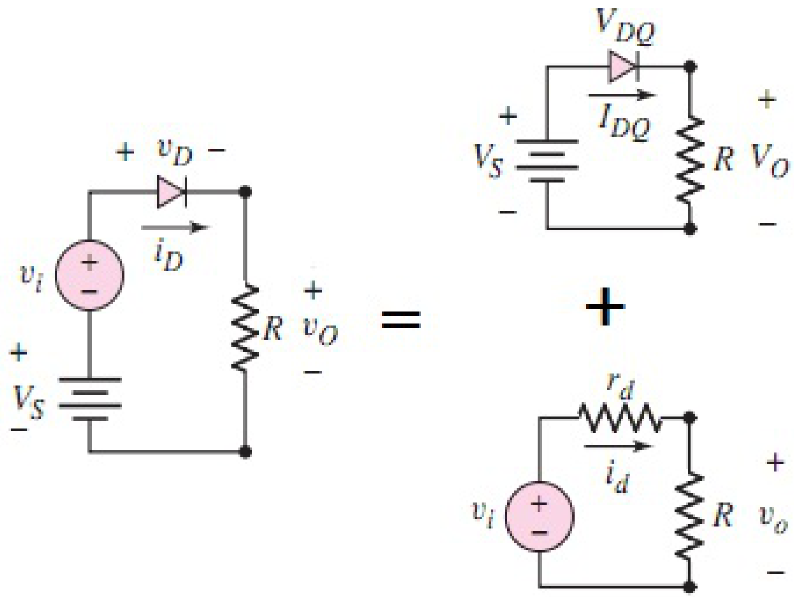
Both equations are transcendental , can be solved by using special functions or numerical methods.

1.3 Diode DC Approximation

When $v_D > 4V_T \approx 0.1V \qquad i_D = I_S \left[e^{\frac{V_D}{nV_T}} - 1 \right] \approx i_D = I_S e^{\frac{V_D}{nV_T}}$

2 Diode AC Circuit

For AC circuit with $V_{DQ} > 0.1V$



(Principle of Superposition)

$$v_D = V_{DQ} + v_d$$

$$i_D = I_S e^{\frac{V_D}{V_T}} \qquad \rightarrow \qquad i_D = I_S e^{\frac{V_{DQ}+v_d}{V_T}}$$

$$i_D = \left(I_S e^{\frac{V_{DQ}}{V_T}}\right) e^{\frac{v_d}{V_T}}$$

$$\approx I_{DQ}\left(1 + \frac{v_d}{V_T}\right)$$

$$= I_{DQ} + I_{DQ}\frac{v_d}{V_T}$$

$$= I_{DQ} + i_d$$

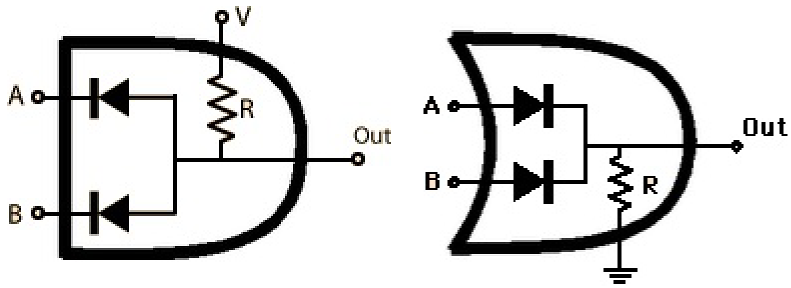
Thus

$$i_d = \frac{I_{DQ}}{V_T} v_d \qquad i_d = g_d i_d \qquad g_d = \frac{I_{DQ}}{V_T}$$

Or

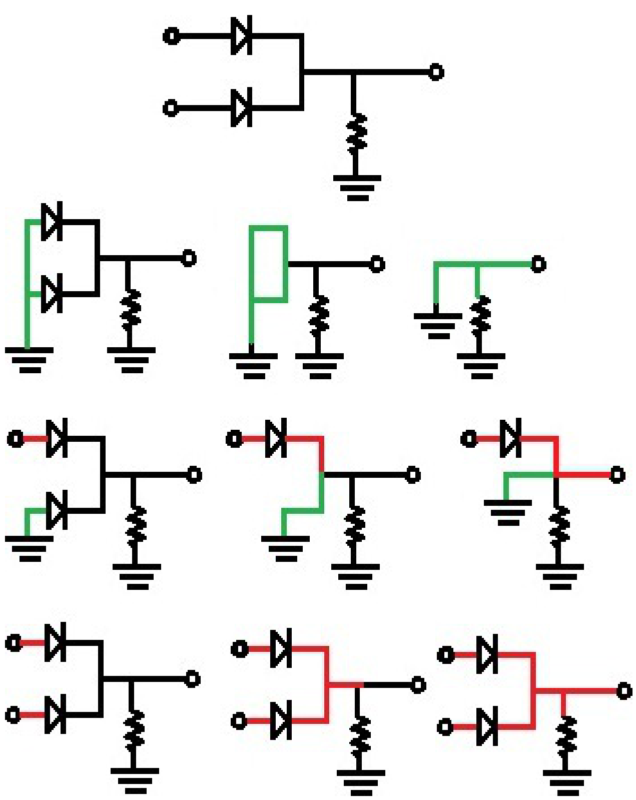
$$v_d = r_d i_d \qquad r_d = \frac{1}{g_d} = \frac{V_T}{I_{DQ}}$$

3 Diode-Resistor Logic

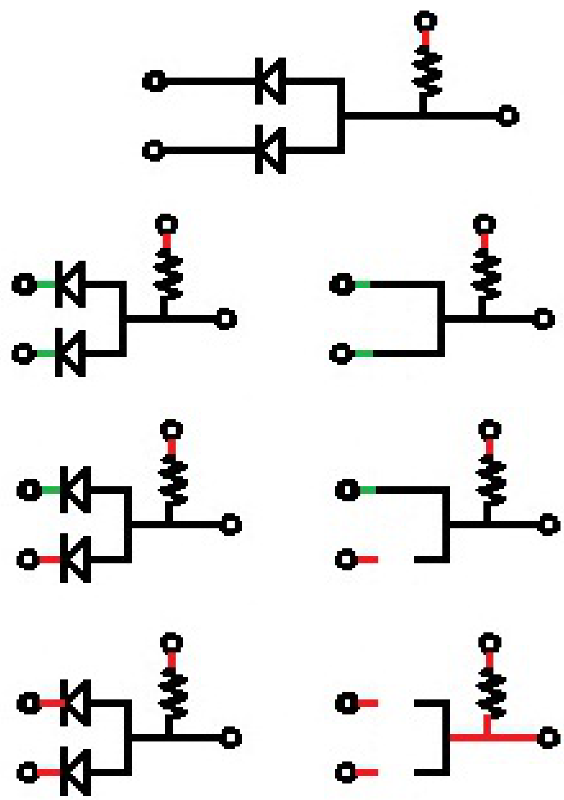


3.1 OR Logic

Red means logic high, 5V , Green means logic low, 0V



3.2 And Logic



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