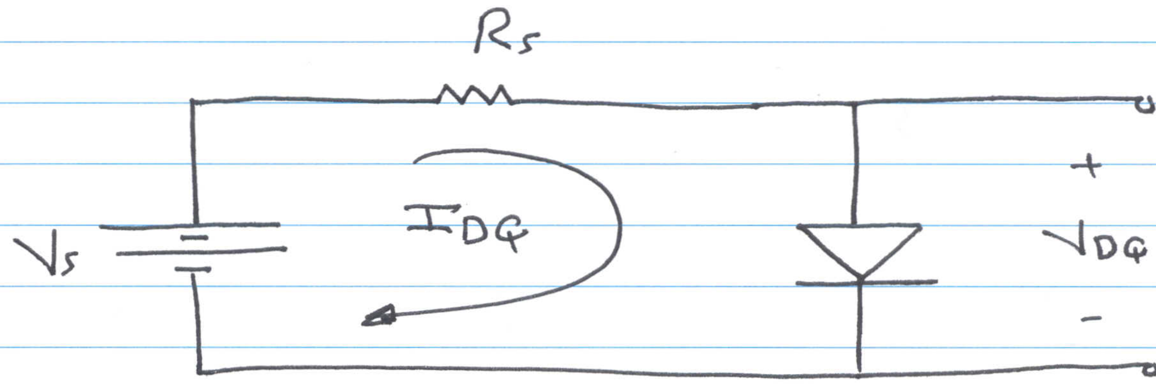
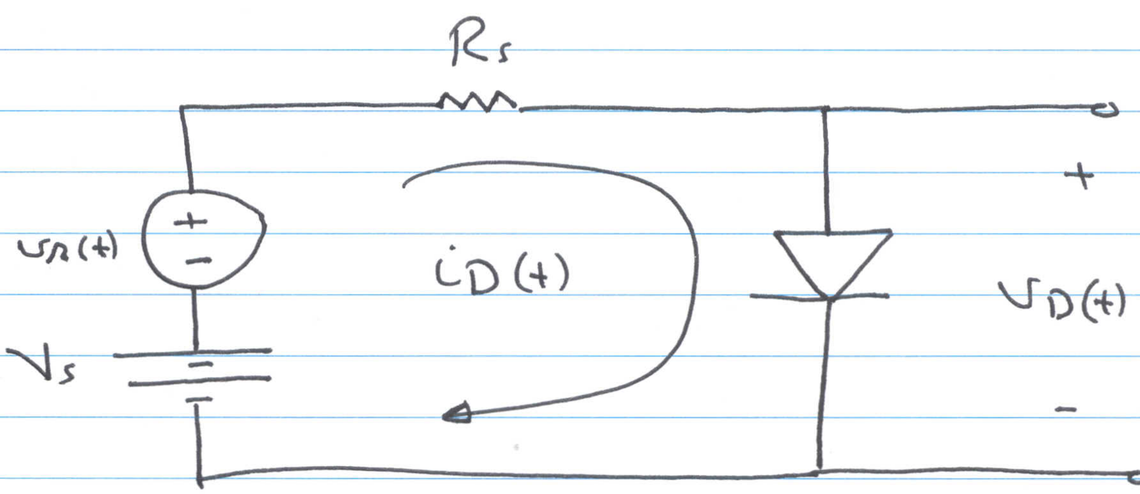
Ac small Signal Analysis



$$I_{DQ} = I_s \left(e^{\frac{V_{DQ}}{\eta V_T}} - 1 \right)$$

$$I_{DQ} \cong I_s \, e^{\frac{V_{DQ}}{\eta V_T}}$$

now



$$i_D(t) = I_{DQ} + i_d$$

$$v_D(t) = V_{DQ} + v_d$$

$$i_D(t) = I_s \left(e^{\frac{v_D(t)}{\eta V_T}} - 1 \right)$$

and since the diode is forward biased

$$i_D(t) \cong I_s \, e^{\frac{v_D(t)}{\eta V_T}}$$

$$i_D(t) = I_s \, e^{\frac{V_{DQ}+v_d}{\eta V_T}}$$

$$i_D(t) = I_s \, e^{\frac{V_{DQ}}{\eta V_T}} \cdot e^{\frac{v_d}{\eta V_T}}$$

$$i_D(t) = I_{DQ} \cdot e^{\frac{v_d}{\eta V_T}}$$

using $e^{x} \approx 1 + x$; x very small

$$\therefore i_D(t) = I_{DQ}\left(1 + \frac{v_d}{\eta V_T}\right)$$

$$i_D(t) = I_{DQ} + \frac{v_d}{\frac{\eta V_T}{I_{DQ}}}$$

But $i_D(t) = I_{DQ} + i_d$

$$\therefore i_d = \frac{v_d}{\frac{\eta V_T}{I_{DQ}}} = \frac{v_d}{r_d}$$

where $r_d = \frac{\eta V_T}{I_{DQ}} \approx \frac{V_T}{I_{DQ}}$

$\therefore$ If $V_S(t) = V_S + v_s(t)$

$V_S \equiv$ Dc Component

$v_s(t) \equiv$ ac Component

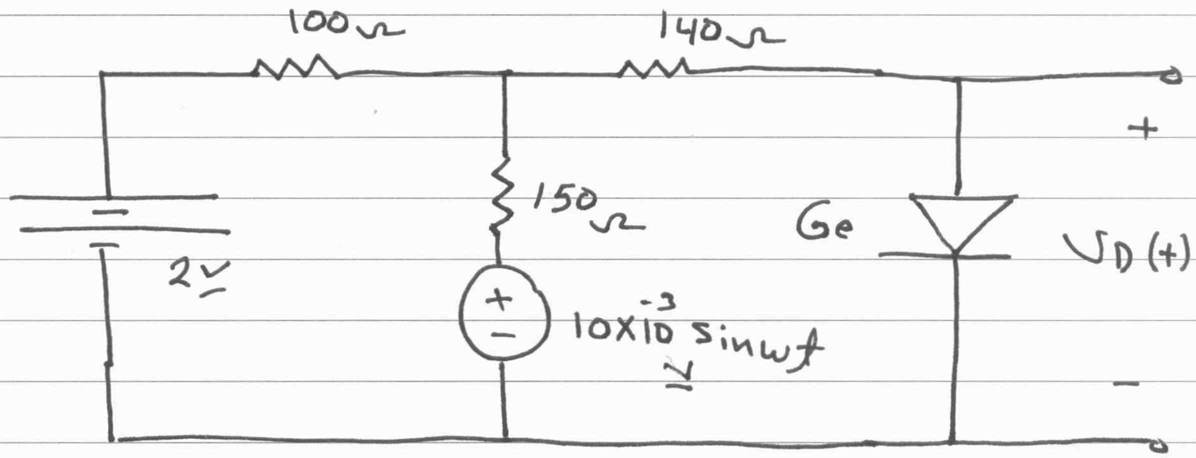
and the amplitude of $v_s(t)$ is small

and the diode is always on ;

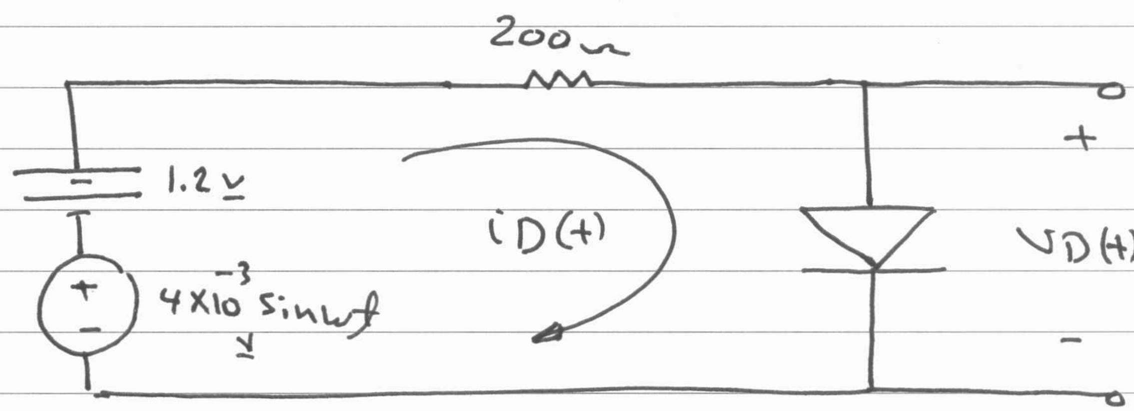
we Could use the superposition

theorem to find the response $(i(t), v(t))$

Example

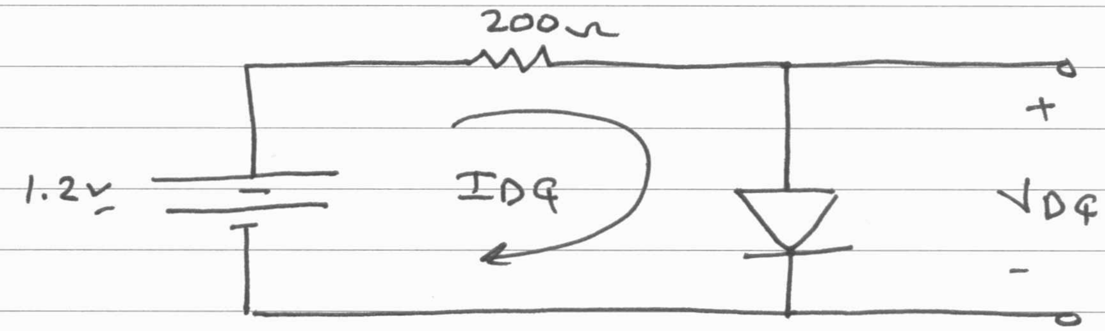


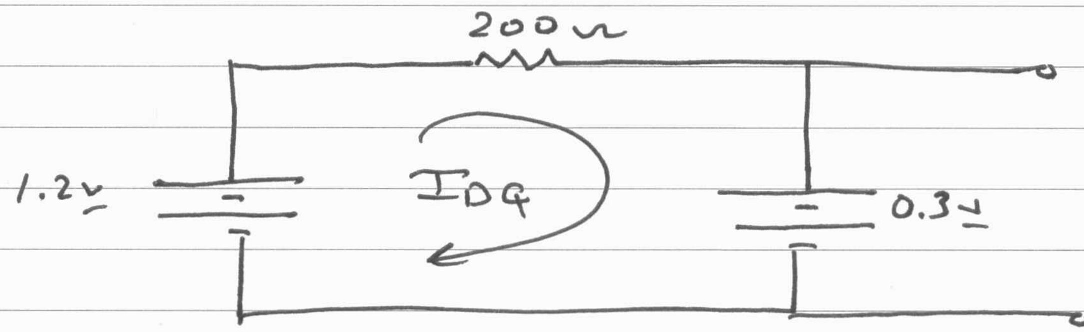
Find $V_D(t)$.



Since we have a dc source (1.2 V) and an ac signal ($4\times10^{-3}\sin\omega t$ V) and the diode in always on; we use Superposition theorem to find $V_D(t)$

1) To Find V_{DQ} (DC Analysis)



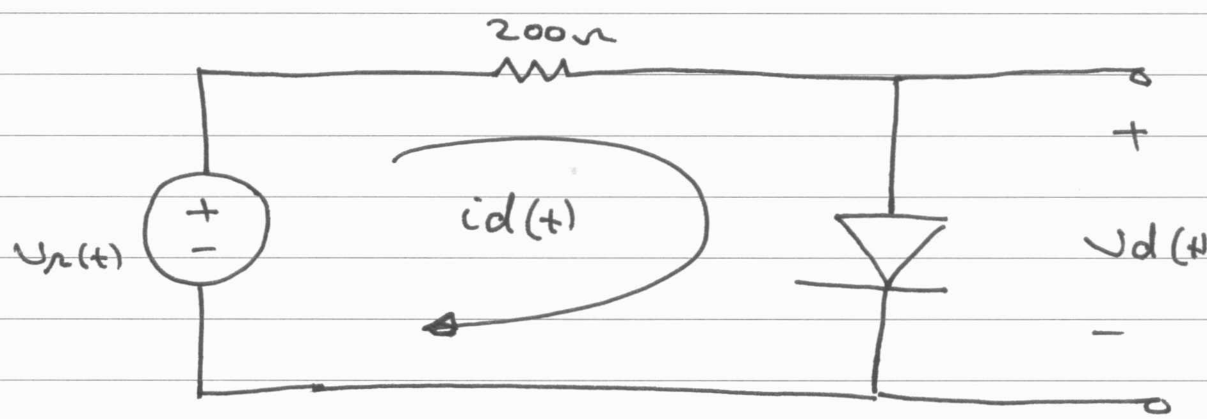


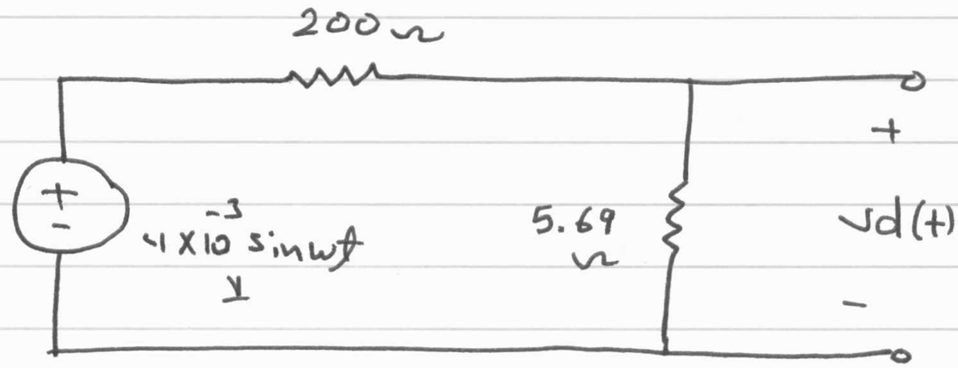
$$\therefore V_{DQ} = 0.3\ V$$

$$\text{and } I_{DQ} = \frac{1.2v - 0.3v}{200\Omega} = 4.5mA$$

$$\therefore r_d = \frac{V_T}{I_{DQ}} = \frac{25.69\,mv}{4.5\,mA} = 5.69\,\Omega$$

2) To find $v_d(t)$ (ac small signal analysis)





$$v_d(t) = \frac{5.69}{200 + 5.69} \cdot 4 \times 10^{-3} \sin\omega t \ \text{V}$$

$$v_d(t) = 0.1165 \times 10^{-3} \sin\omega t \ \text{V}$$

$$\therefore \ v_D(t) = V_{DQ} + v_d(t)$$

$$v_D(t) = \left(0.3 + 0.1165 \times 10^{-3} \sin\omega t\right) \ \text{V}$$