EE210: Microelectronics-I

Lecture-4
Small Signal Device Model-2

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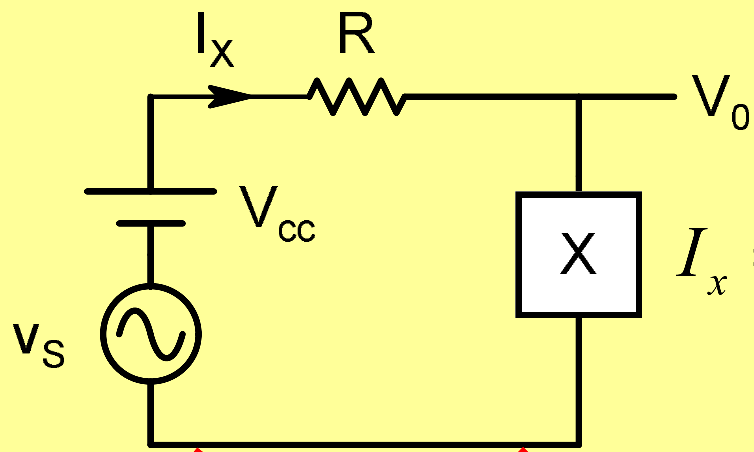
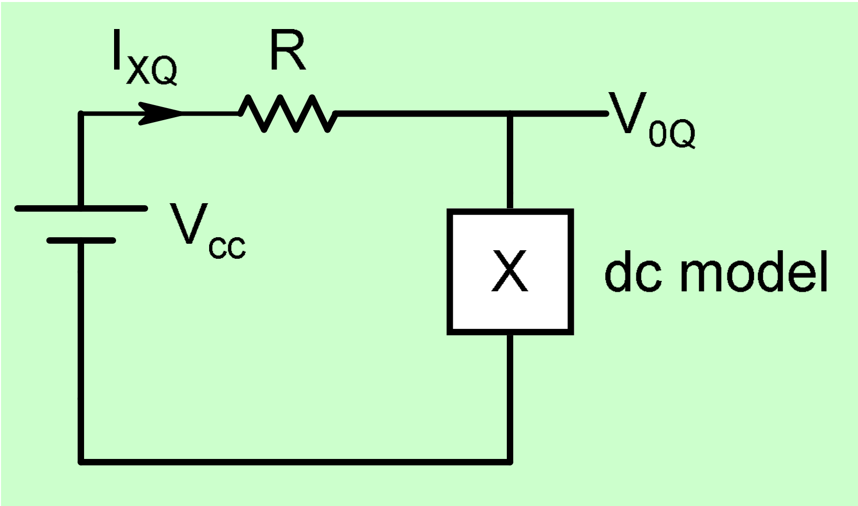
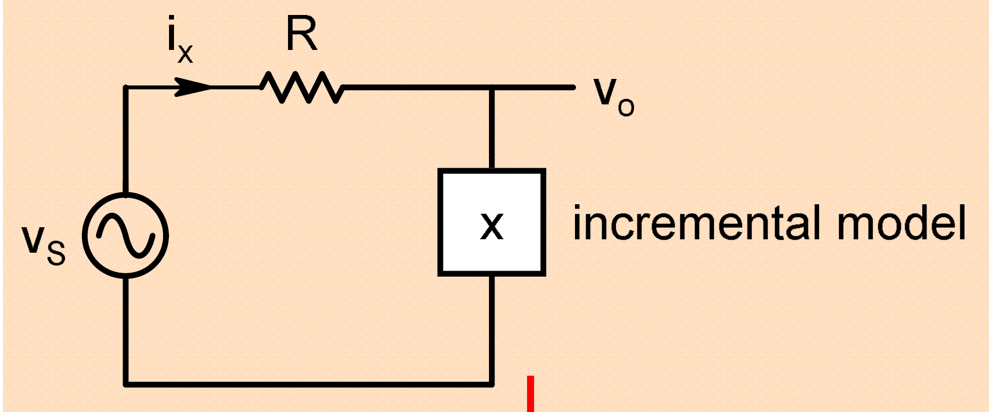


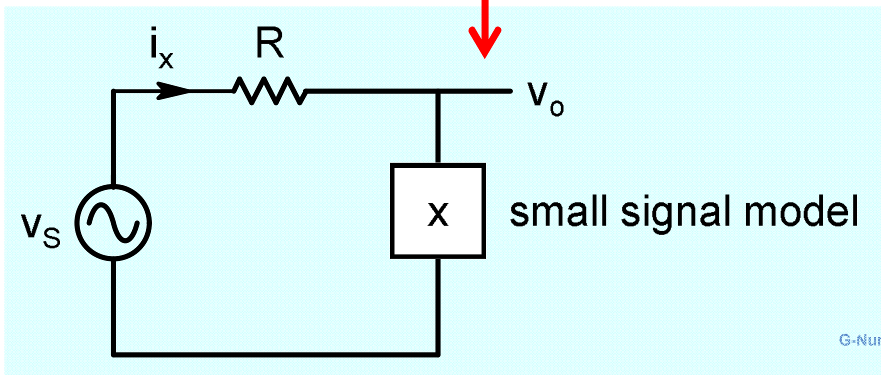
$$I_x = k \times \exp(\frac{V_x}{.026})$$

$$I_{XQ} + i_x = k \times \exp(\frac{V_{XQ} + v_x}{.026})$$





$$I_{XQ} = k \times \exp(\frac{V_{XQ}}{.026})$$



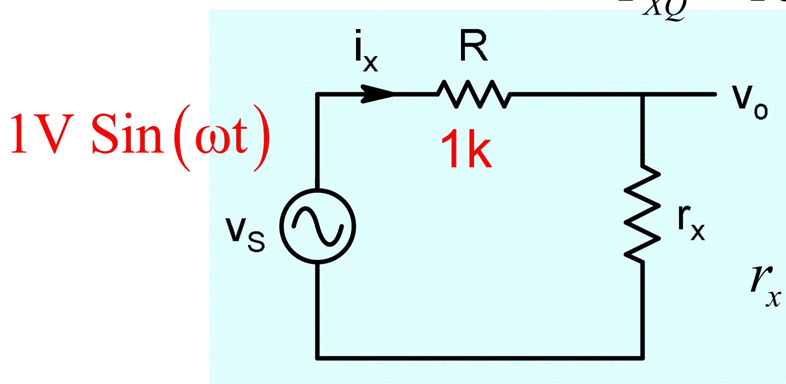
$$I_x = k \times \exp\left(\frac{V_x}{.026}\right) \qquad I_{XQ} + i_x = k \times \exp\left(\frac{V_{XQ} + v_x}{.026}\right)$$

$$i_x = k \times \exp\left(\frac{V_{XQ}}{.026}\right) \times \left\{\exp\left(\frac{v_x}{.026}\right) - 1\right\} \qquad i_x \cong I_{XQ} \times \left(\frac{v_x}{.026}\right)$$

$$r_x \cong \frac{0.026}{I_{XQ}}$$

v_x (mV)	Error (%)
0.53	1
2.6	4.9
5.4	10
10	18
26	41.8

$$I_{XQ} = 10mA$$



$$r_x = 2.6\Omega$$

$$v_o = 2.6\text{mV}\,\text{Sin}(\omega t)$$

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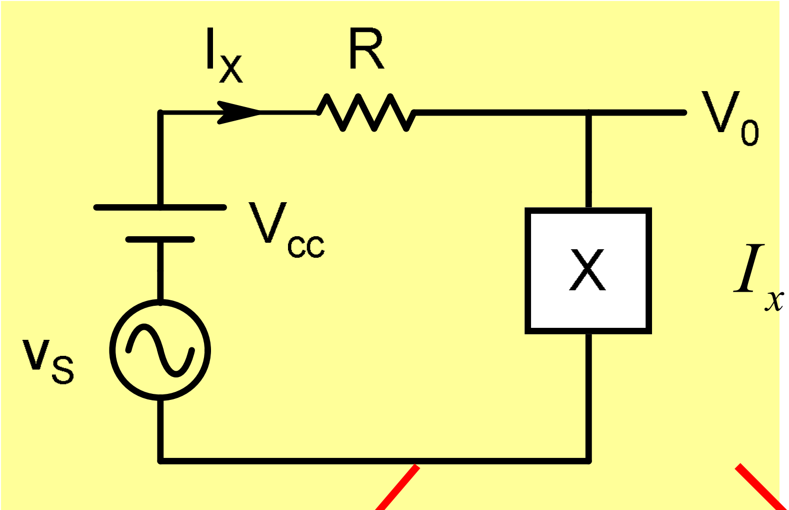
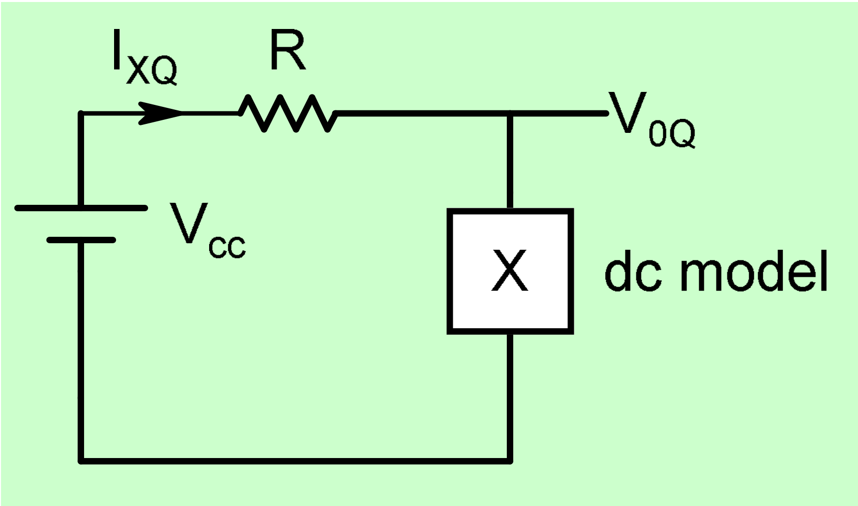
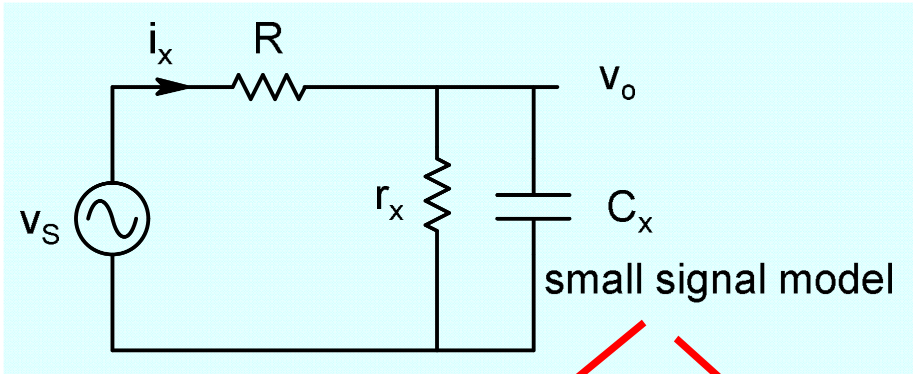


$$I_x = k \times \exp(\frac{V_x}{.026}) + C_X \frac{\partial V_x}{\partial t}$$





$$I_{XQ} = k \times \exp(\frac{V_{XQ}}{.026})$$

Low frequency

High frequency

General approach for obtaining small signal model for a 2-terminal device (not containing capacitor/inductors)

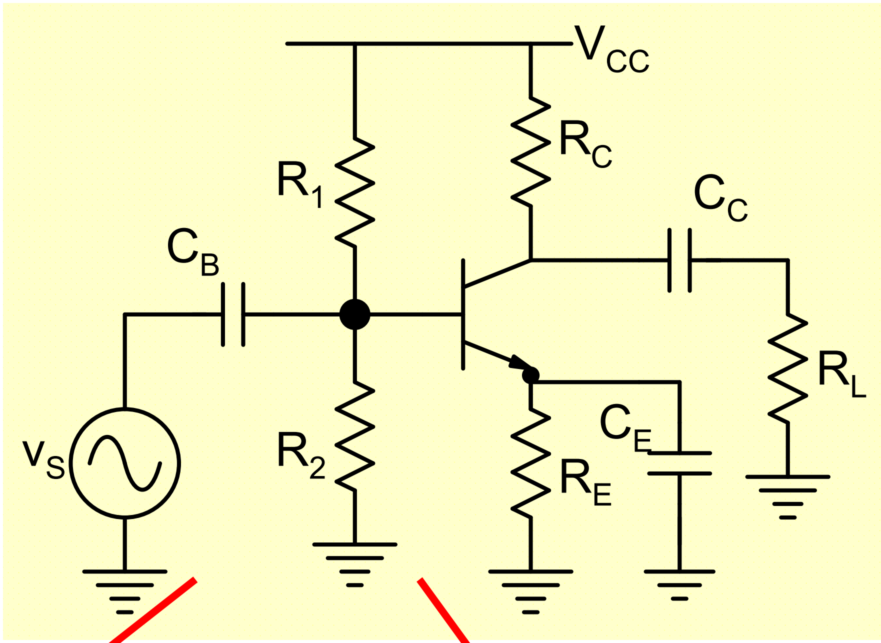
$$I_x = f(V_x)$$

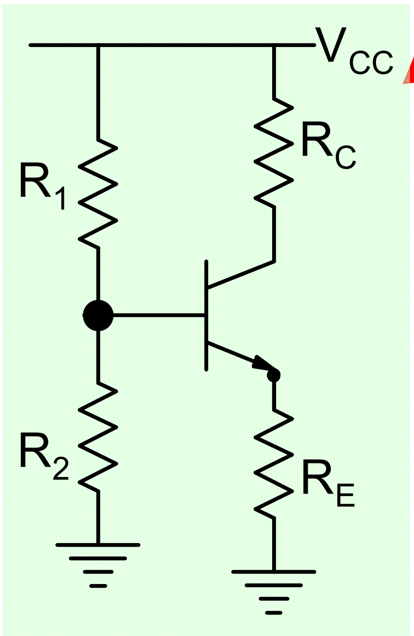
$$I_X + i_x = f(V_X + v_x)$$

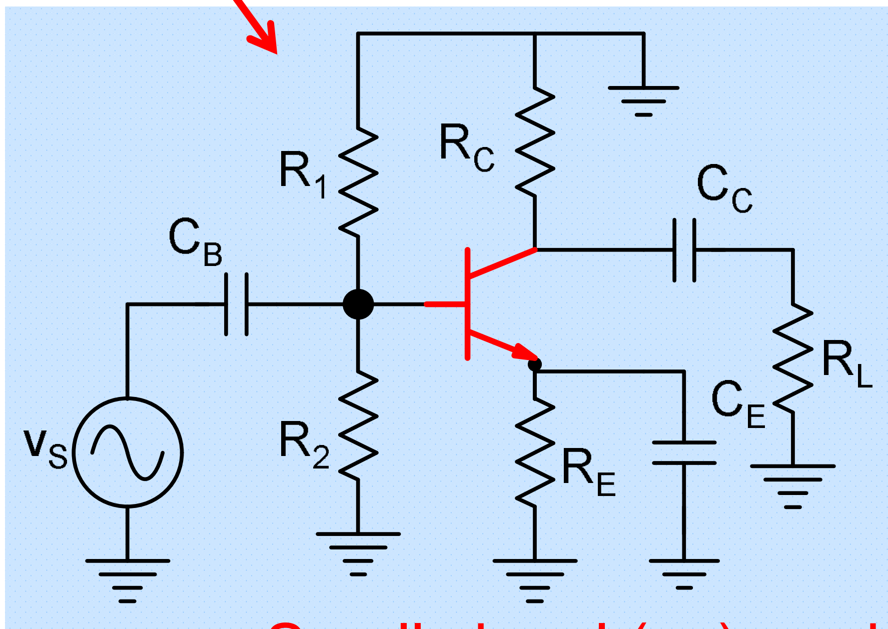
$$= f(V_X) + v_x\left(\frac{df}{dV_x}\right)\Big|_{V_X} + \ldots.$$

$$i_X = v_X / r_X \qquad r_x = \frac{1}{\left.\frac{df}{dV_x}\right|_{V_X}}$$

Small signal model is a resistor







dc model

Small signal (ac) model

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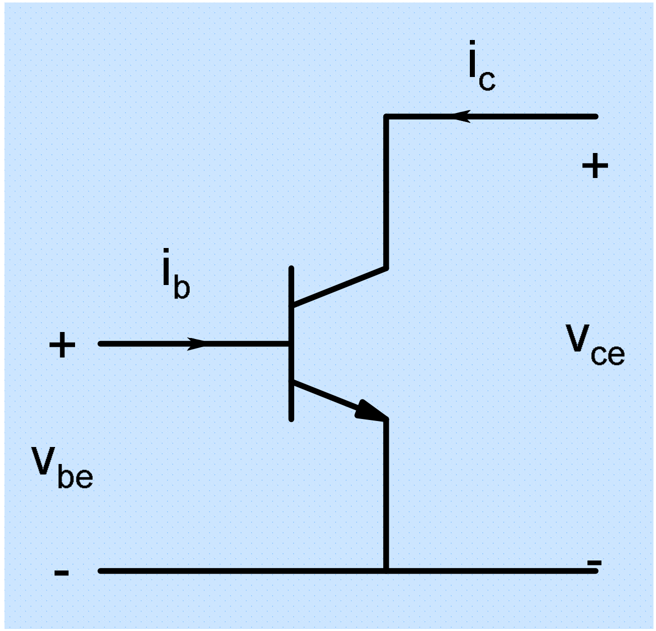
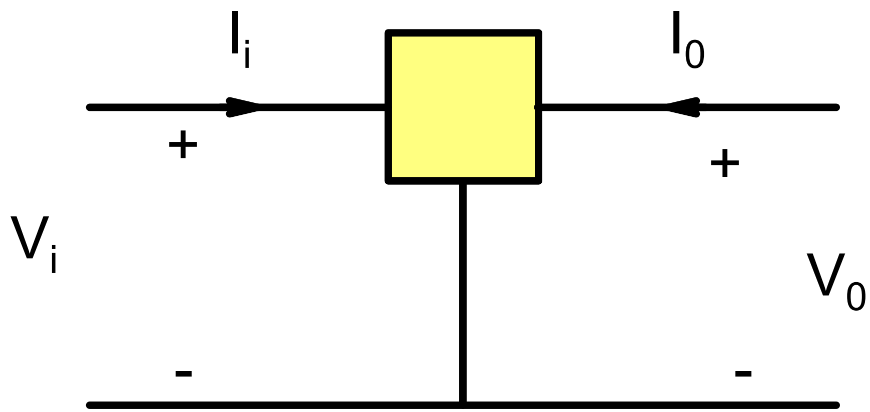
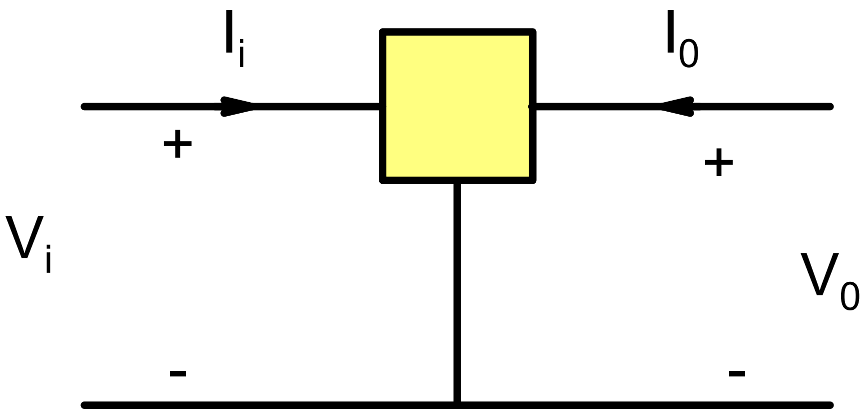
Small signal model of a three terminal device





General approach for obtaining small **signal model** for a 3-terminal unilateral device



Unilateral:

(Output does not affect the input)

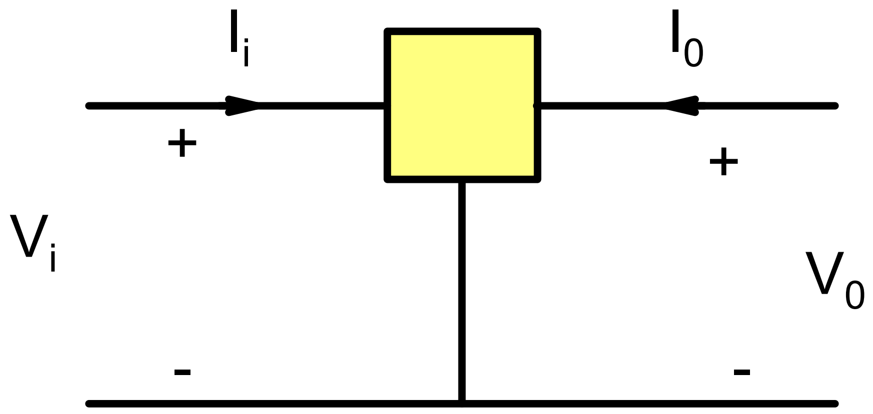
$$I_O = f_O(V_i, V_O)$$
$$I_i = f_i(V_i)$$

$$I_i = f_i(V_i)$$
$$I_I + i_i = f_i(V_I + v_i)$$

$$\Rightarrow i_i = v_i \left.\frac{\delta f_i}{\delta V_i}\right|_{V_I} = \frac{v_i}{r_i}$$

$$r_i = \frac{1}{\left.\dfrac{\delta f_i}{\delta V_i}\right|_{V_I}}$$

From the input port, the device appears as a resistance



Output port:

$$I_O = f_O(V_i, V_O)$$

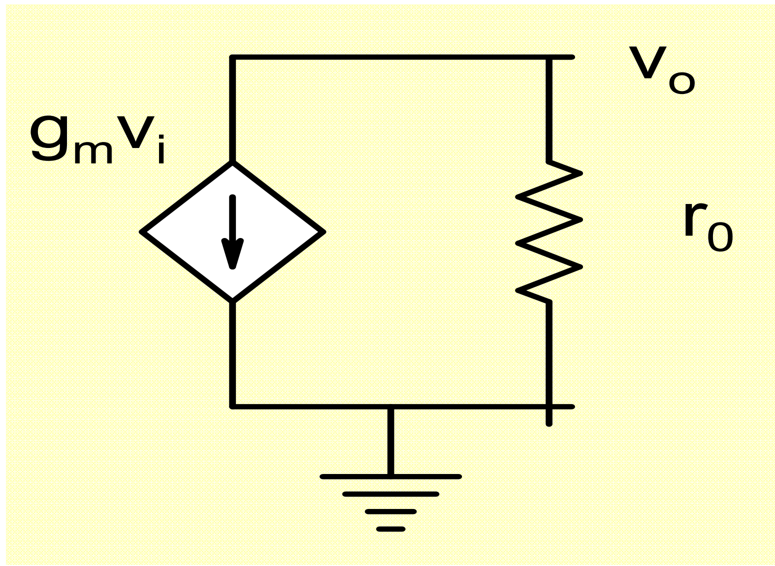
$$I_O + i_o = f_O(V_i + v_i, V_O + v_o)$$

$$I_O + i_o = f_o(V_i, V_o) + v_i \frac{\delta f_0}{\delta V_i}\Big|_{V_o} + v_o \frac{\delta f_0}{\delta V_0}\Big|_{V_I} + \ldots$$

$$i_o \cong v_i \frac{\delta f_0}{\delta V_i}\Big|_{V_o} + v_o \frac{\delta f_0}{\delta V_0}\Big|_{V_I}$$

$$i_o = g_m v_i + \frac{v_o}{r_o}$$

$$g_m = \frac{\delta f_0}{\delta V_i}\Big|_{V_o} \qquad r_0 = \frac{1}{\frac{\delta f_0}{\delta V_0}\Big|_{V_I}}$$



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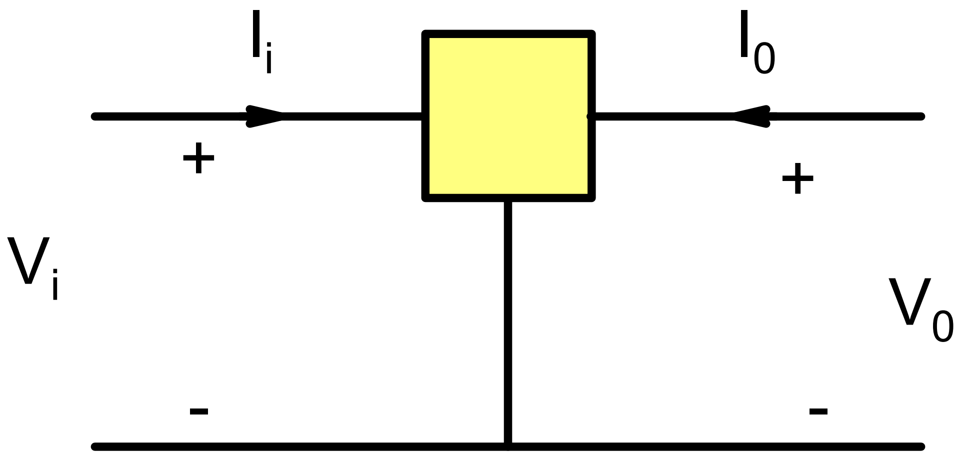
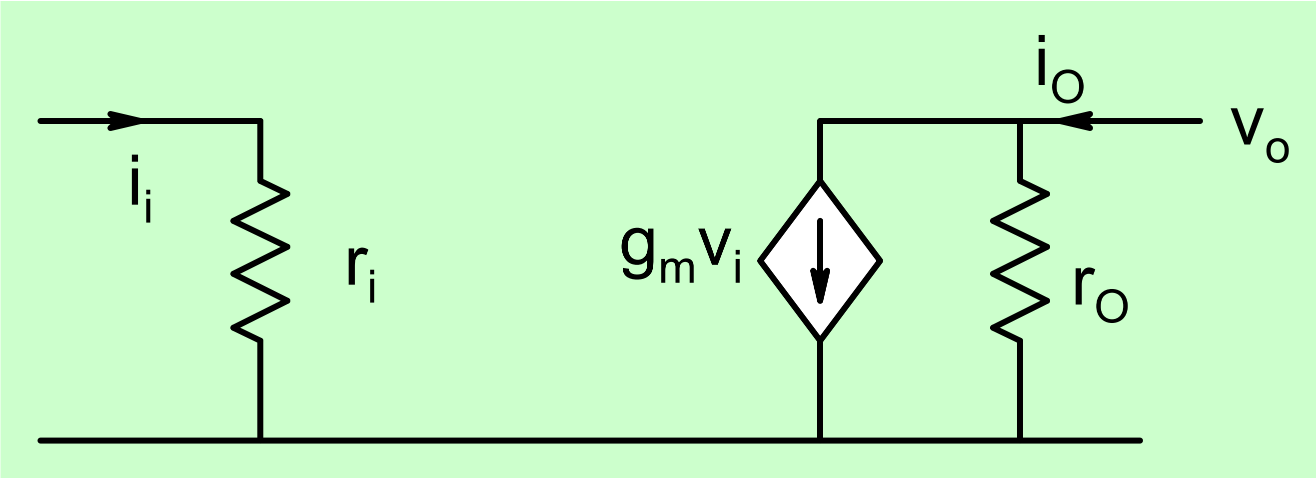
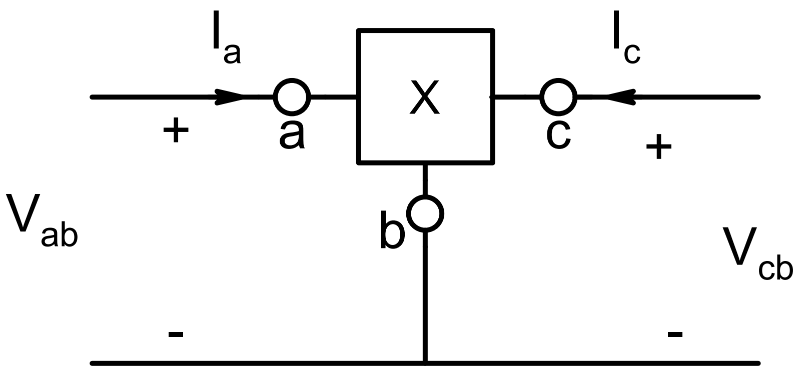
Complete small signal model (dc) for a 3-terminal unilateral device.

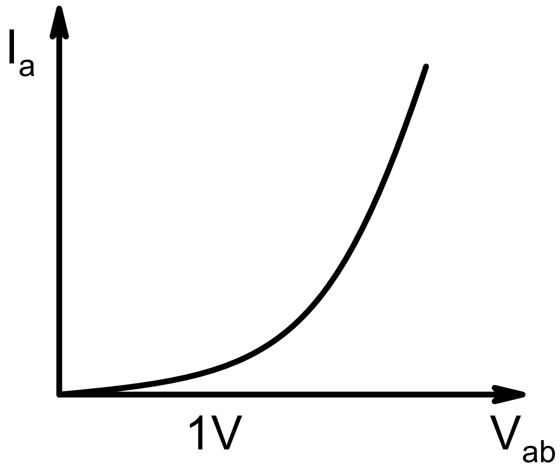


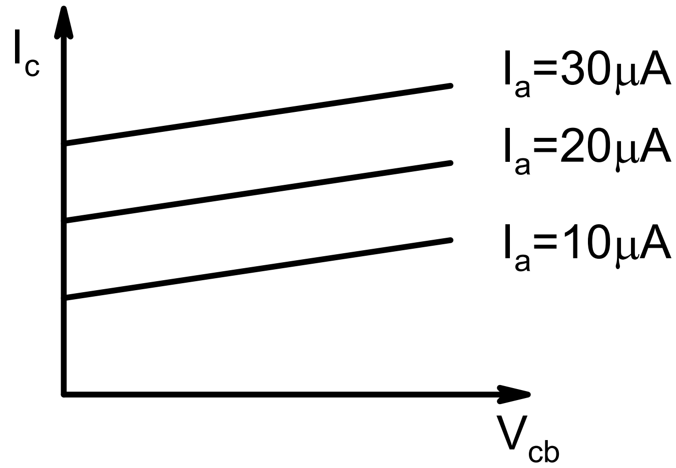


Example Build a small signal model around the bias point

$$V_{ab} = 1V \,;\, V_{cb} = 2V$$



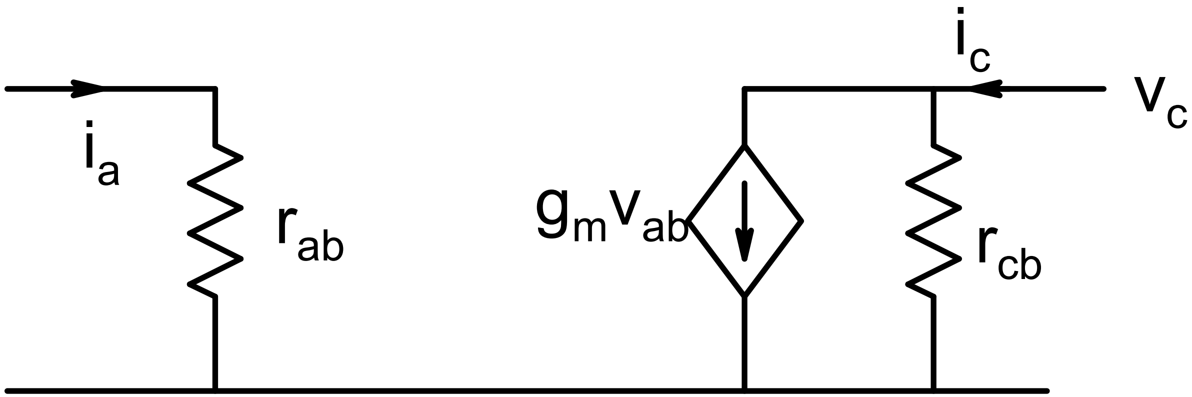




$$I_a = 10^{-5} \times V_{ab}^2$$

$$I_a = 100 \times I_a + 10^{-5} \times V_{cb}$$

Bias point: $V_{ab} = 1V$; $V_{cb} = 2V$



$$I_a = 10^{-5} \times V_{ab}^2$$

$$I_a = 100 \times I_a + 10^{-5} \times V_{cb}$$

$$I_i = f_i(V_i)$$

$$I_O = f_O(V_i, V_O)$$

$$r_i = \frac{1}{\left.\frac{\delta f_i}{\delta V_i}\right|_{V_I}}$$

$$r_{ab} = \left.\frac{1}{\frac{\partial I_a}{\partial V_{ab}}}\right|_{V_{ab}=1V}$$

$$g_m = \frac{\delta f_0}{\delta V_i}\Big|_{V_O}$$

$$r_0 = \frac{1}{\frac{\delta f_0}{\delta V_0}\Big|_{V_I}}$$