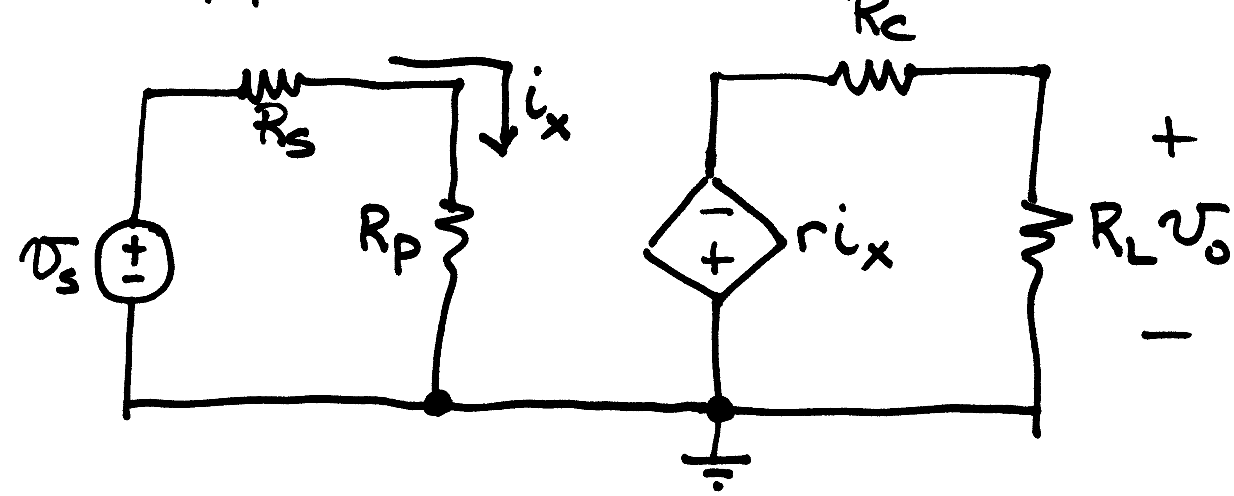
Exercise 4.1



input circuit $\quad i_x = \dfrac{v_s}{R_s + R_p} \quad$ constraint

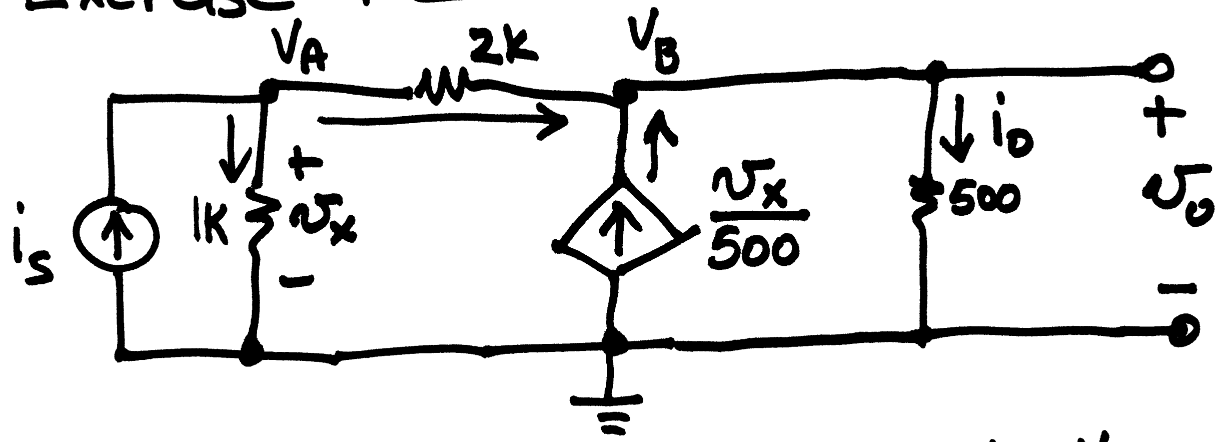
output circuit do by voltage divider

$$v_o = \frac{R_L}{R_c + R_L}\left(-ri_x\right) = \frac{-rR_L}{R_c + R_L}\,\frac{v_s}{R_s + R_p}$$

$$v_o = -\frac{rR_L}{(R_c + R_L)(R_s + R_p)}\,v_s$$

OUTPUT GAIN INPUT

Exercise 4-2



KCL@A $\sum_{+in} i=0$ $\qquad +i_s - \dfrac{V_A - 0}{1K} - \dfrac{V_A - V_B}{2K} = 0$

KCL@B $\sum_{+in} i=0$ $\qquad + \dfrac{V_A - V_B}{2K} + \dfrac{\overset{V_A}{v_x}}{500} - \dfrac{V_B}{500} = 0$

constraint $v_x = V_A$

$$\left(\frac{1}{1K} + \frac{1}{2K}\right) V_A - \frac{1}{2K} V_B = i_s$$

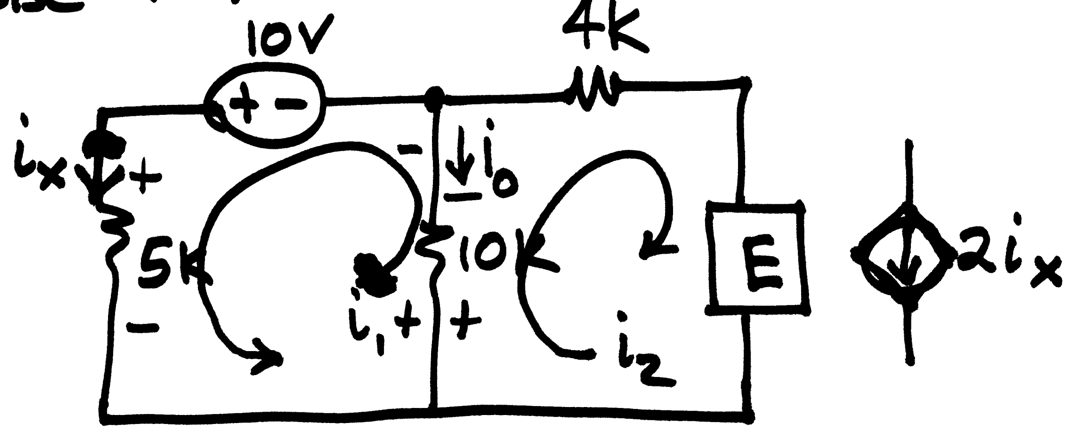
$$\left(\frac{1}{2K} + \frac{1}{500}\right) V_A - \left(\frac{1}{2K} + \frac{1}{500}\right) V_B = 0$$

Find v_o & i_o in terms of i_s

$$v_o = v_B = 1000\, i_s$$

$$i_o = \frac{v_B}{500} = \frac{1000\, i_s}{500} = 2 i_s$$

Exercise 4-4



constraint $i_1 = i_x$

$i_2 = 2i_x$

$i_0 = -(i_1 + i_2)$

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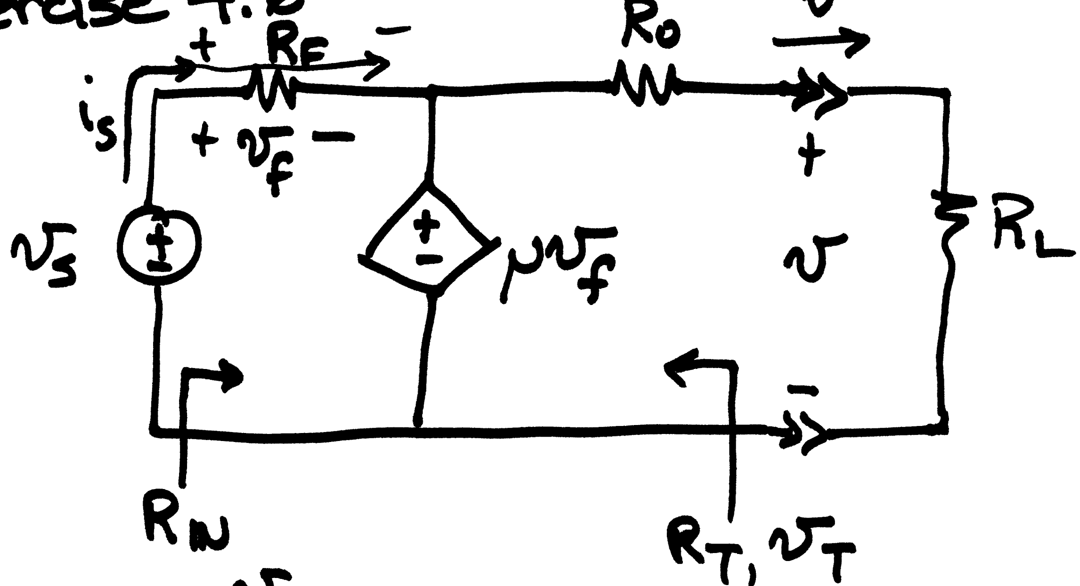
mesh1 $\quad -5000\, i_1 + 10 - 10000\, i_1 - 10000\, i_2 = 0$

$2i_x$

$2(i_1)$

Exercise 4.6



$$R_{IN} = \frac{v_s}{i_s}$$

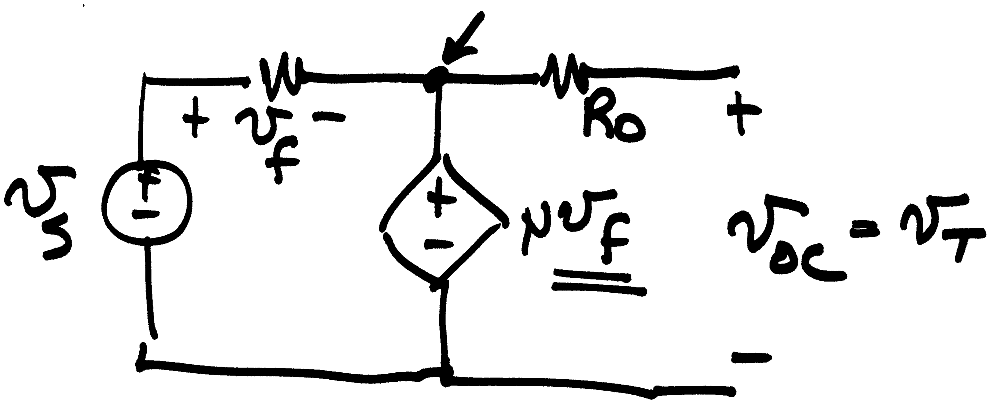
$$i_s = \frac{v_s - \mu v_f}{R_F} = \frac{v_s - \mu (i_s R_F)}{R_F}$$

$$i_s R_F = v_s - \mu R_F i_s$$

$$i_s (1+\mu) R_F = v_s$$

$$i_s = \frac{v_s}{(1+\mu) R_F}$$

$$R_{IN} = \frac{v_s}{i_s} = \frac{\cancel{v_s}}{\frac{\cancel{v_s}}{(1+\mu)R_F}} = (1+\mu) R_F$$

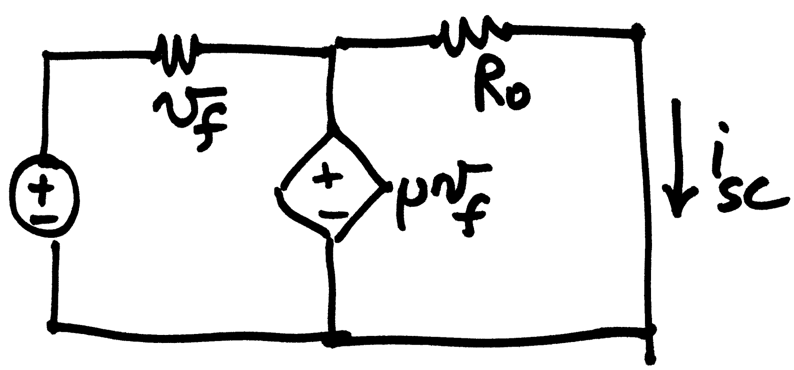


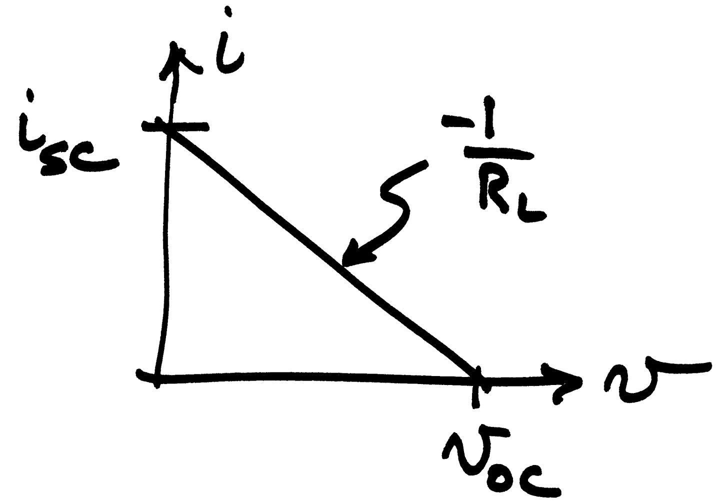
do KVL at input $\quad -v_s + v_f + \mu v_f = 0$

$$-v_s + (1+\mu) v_f = 0$$

$$v_f = \frac{v_s}{1+\mu}$$

$$v_{oc} = \mu v_f = \frac{\mu}{1+\mu} v_s$$

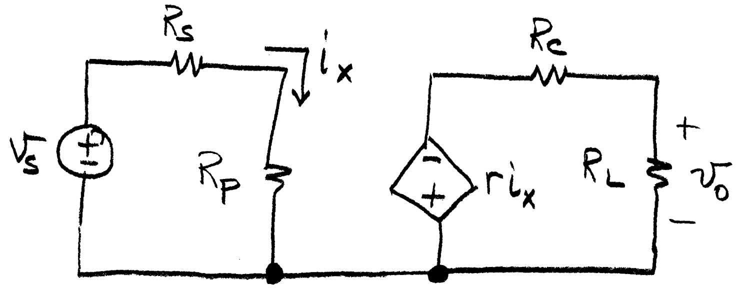




i
i_{sc}
$\frac{-1}{R_L}$
v
v_{oc}

Exercise 4.1

Find the output v_o in terms of the input v_s in the circuit below.



For the input circuit $\quad i_x = \dfrac{v_s}{R_s + R_p}$

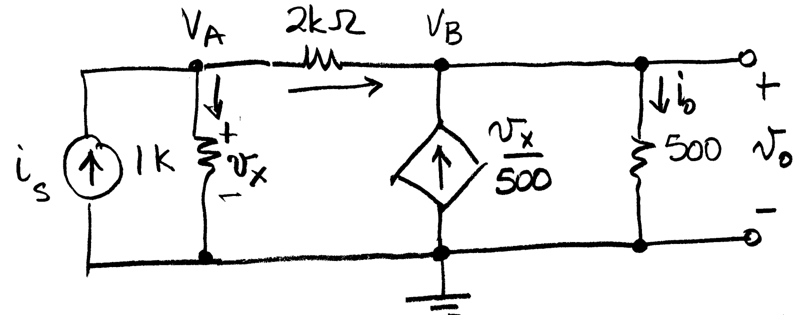
For the output circuit use a voltage divider

$$v_o = \frac{R_L}{R_L + R_c}(-ri_x) = \left[\frac{-r R_L}{(R_L + R_c)(R_s + R_p)}\right] v_s$$

Exercise 4-2

(a) Formulate node-voltage equations for the circuit below.

(b) Solve the node-voltage equations for v_o and i_o in terms of i_s.



KCL @ A $\sum_{\text{in}} i = 0$ $\qquad +i_s - \dfrac{V_A - 0}{1K} - \dfrac{V_A - V_B}{2K} = 0$

KCL @ B $\sum_{\text{in}} i = 0$ $\qquad + \dfrac{V_A - V_B}{2K} + \dfrac{v_x}{500} - \dfrac{V_B}{500} = 0$

The constraint is $v_x = V_A$.

Substitute and solve

$$2000 \quad \left(\frac{1}{1K} + \frac{1}{2K}\right) V_A - \frac{1}{2k} V_B = i_s$$

$$2000 \quad \left(\frac{1}{2K} + \frac{1}{500}\right) V_A - \left(\frac{1}{2K} - \frac{1}{500}\right) V_B = 0$$

$$(2+1) V_A - V_B = 2000 i_s$$
$$(1+4) V_A - (1-4) V_B = 0$$

$$3 V_A - V_B = 2000 i_s$$
$$5 V_A - 5 V_B = 0 \Rightarrow V_A = V_B$$

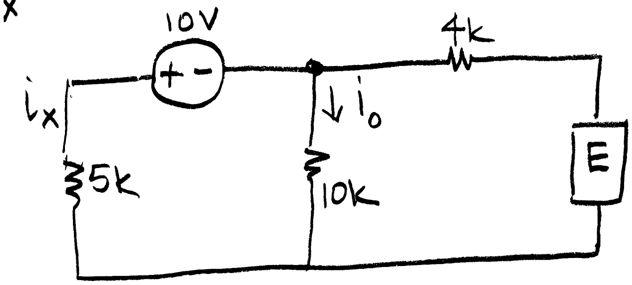
$$3 V_B - V_B = 2000 i_s$$
$$2 V_B = 2000 i_s$$
$$V_B = 1000 i_s$$

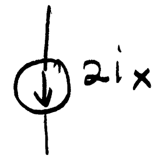
By inspection $\quad v_o = V_B = 1000 i_s$

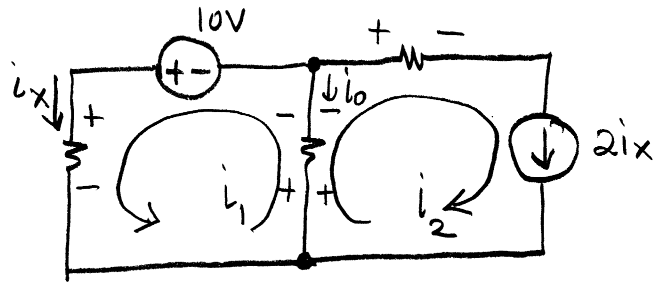
$$i_o = \frac{V_B}{500} = \frac{1000 i_s}{500} = 2 i_s$$

Exercise 4-4

Use mesh analysis to find the current i_o in the circuit below when the element E is a dependent current source $2i_x$ with the reference arrow directed down.







by inspection the constraints are

$i_1 = i_x$

$i_o = -(i_1 + i_2)$

$$-5000\,i_1 + 10 - 10000\,i_1 - 10000\,i_2 = 0$$

$$i_2 = 2i_x = 2i_1$$

$$-5000\,i_1 + 10 - 10000\,i_1 - 10000\,(2i_1) = 0$$

$$-5000\,i_1 + 10 - 10000\,i_1 - 20000\,i_1 = 0$$

$$35000\,i_1 = 10$$

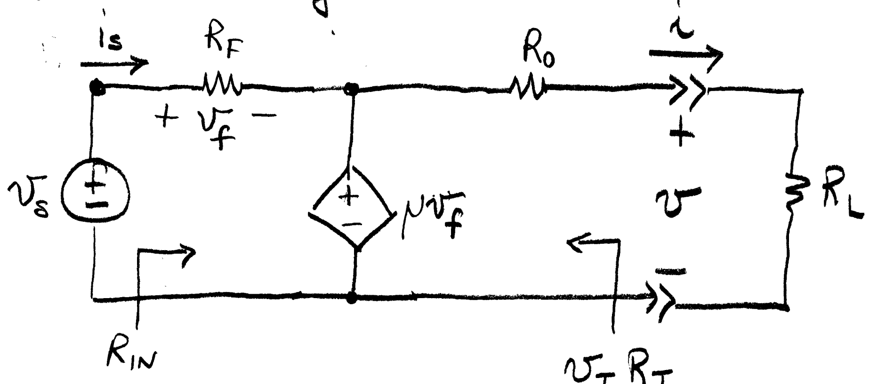
$$i_1 = \frac{10}{35000} = 2.857 \times 10^{-4}\ \text{A.}$$

$$i_2 = 2i_1 = 2(2.857 \times 10^{-4}) = 5.714 \times 10^{-4}\ \text{A}$$

$$i_o = -(i_1 + i_2) = -8.571 \times 10^{-4}\ \text{mA}$$

Exercise 4.6

Find the input resistance and output Thevenin equivalent circuit of the circuit given below.



Find $R_{IN} = v_s / i_s$

$$i_s = \frac{v_s - \mu v_f}{R_F} \qquad v_f = i_s R_F$$

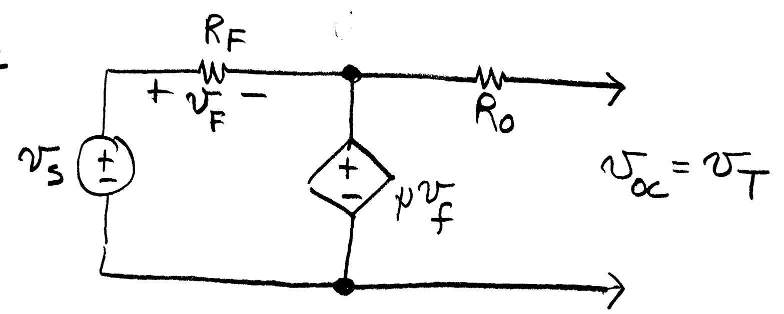
$$i_s = \frac{v_s - \mu i_s R_F}{R_F}$$

$$i_s R_F = v_s - \mu i_s R_F$$

$$i_s(R_F + \mu R_F) = v_s \Rightarrow i_s = \frac{v_s}{R_F(1+\mu)}$$

$$R_{IN} = \frac{v_s}{i_s} = \frac{v_s}{\frac{v_s}{R_F(1+\mu)}} = R_F(1+\mu)$$

Find v_{oc}



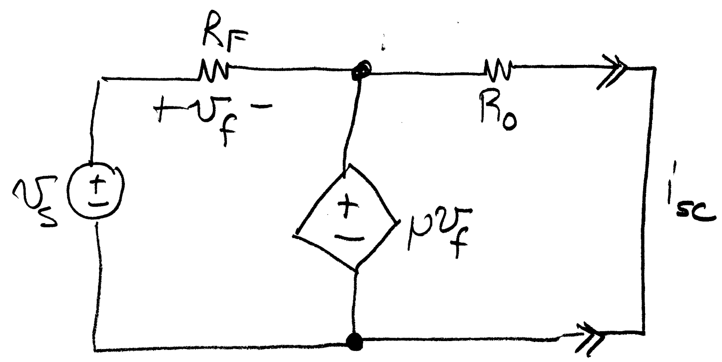
$$-v_s + v_F + \mu v_F = 0$$

$$-v_s + (1+\mu) v_F = 0$$

$$(1+\mu) v_F = v_s$$

$$v_F = \frac{v_s}{1+\mu} \Rightarrow v_T = \mu v_f = \frac{\mu}{1+\mu} v_s$$

To find R_T we must calculate i_{sc} as well.

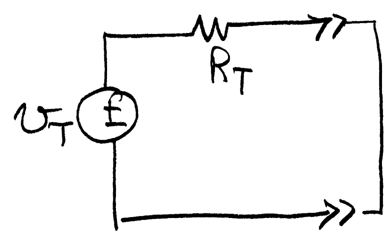


$$-v_s + v_f + \mu v_f = 0$$

$$v_f = \frac{v_s}{1+\mu}$$

$$i_{sc} = \frac{\mu v_f}{R_o} = \frac{\mu\left(\frac{v_s}{1+\mu}\right)}{R_o} = \frac{\mu}{1+\mu}\,\frac{v_s}{R_o}$$

For a Thevenin circuit



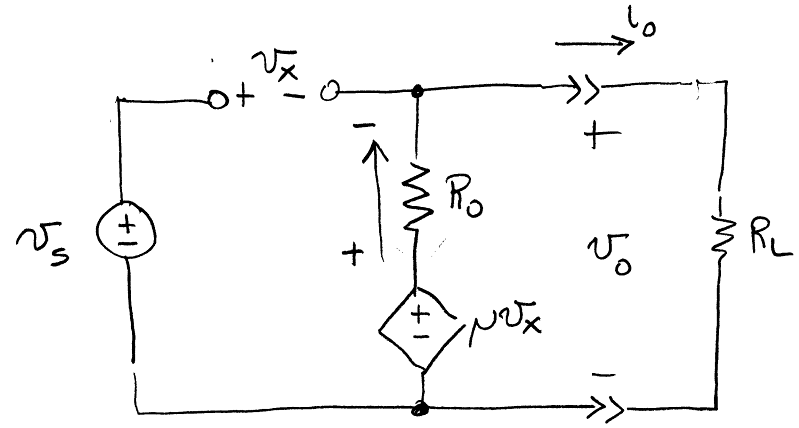
$$i_{sc} = \frac{v_T}{R_T} \quad \text{but} \quad v_T = \frac{\mu}{1+v}\, v_s$$

$$\therefore\ i_{sc} = \frac{v_T}{R_o}$$

$$\Rightarrow R_T = R_o$$

Example 4-8

Find the Thevenin equivalent at the output interface of the circuit given below.



Do KVL across input $\quad -v_s + v_x + v_o = 0 \Rightarrow v_x = v_s - v_o$

Do KCL at node $\quad \underset{+\text{in}}{\sum i = 0} \quad + \dfrac{\mu v_x - v_o}{R_o} - i_o = 0$

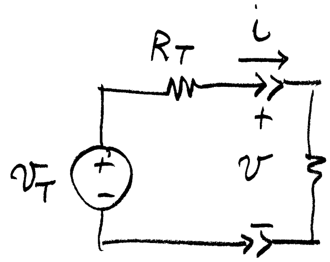
$$\frac{\mu(v_s - v_o) - v_o}{R_o} = i_o$$

$$\mu v_s - \mu v_o - v_o = i_o R_o$$

$$\mu v_s - (\mu+1) v_o = i_o R_o$$

$$(\mu+1) v_o + i_o R_o = \mu v_s$$

$$v_o = \frac{\mu}{\mu+1} v_s - \frac{R_o}{\mu+1} i_o$$



do KVL $\quad -v_T + iR_T + v = 0$

$$v = v_T - iR_T$$

$$\Rightarrow v_T = \frac{\mu}{\mu+1} v_s \qquad R_T = \frac{R_o}{\mu+1}$$