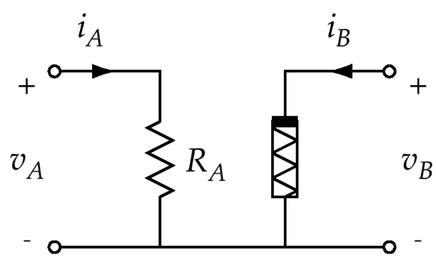
Inter American University of Puerto Rico
Bayamón Campus
School of Engineering
Department of Electrical Engineering

ELEN 3311 – Electronics I

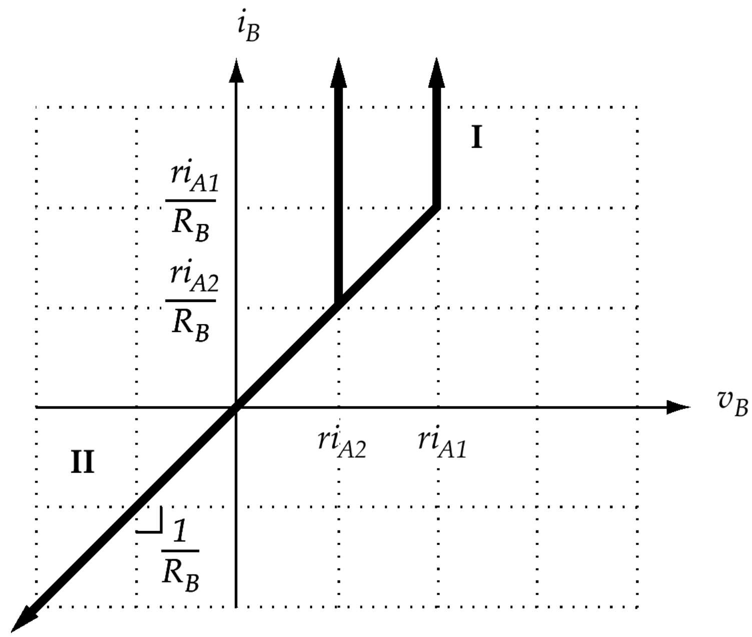
Final Exam Review Problems with Solutions

Problem 1: The nonlinear resistor inside the three-terminal device shown below is characterized by the equations:

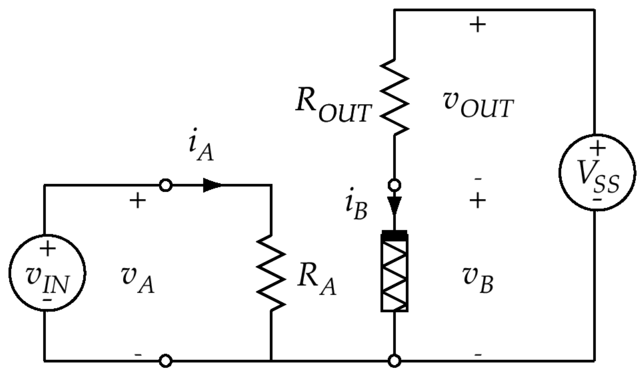
$v_B = ri_A$	$i_B \geq \dfrac{r}{R_B} i_A$	Region I
$i_B = \dfrac{v_B}{R_B}$	$v_B \leq ri_A$	Region II



These equations trace the following curves in the v_B-i_B plane for $i_{A1} > i_{A2} > 0$:

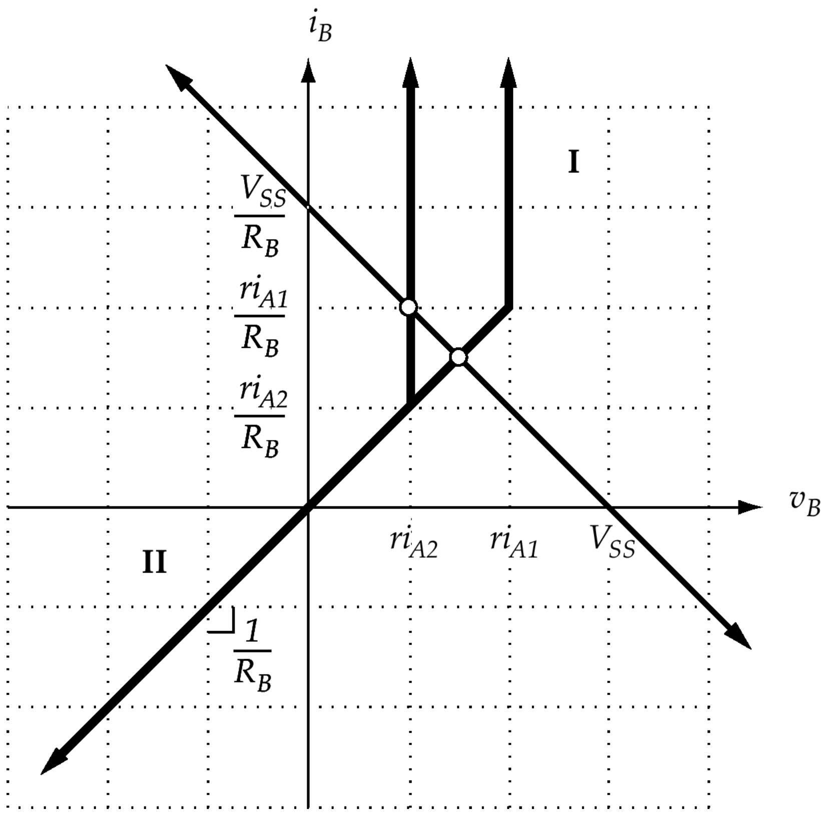


The three-terminal resistor is placed inside the circuit shown below:



(A) Find an algebraic equation for the v_B-i_B constraint imposed by the external circuit and graph this load line in the v_B-i_B plane. Mark the points corresponding to solutions of the circuit.

$$v_B + R_{OUT} i_B = V_{SS}$$



(B) Find an algebraic expression for the v_{IN}-v_{OUT} relation in each region. Find the small-signal gain $\frac{v_{out}}{v_{in}}$ for each region using these expressions assuming all the necessary large-signal values.

Region I:

$$v_{OUT} = V_{SS} - \frac{r}{R_A} v_{IN}$$

Small-signal gain $\frac{v_{out}}{v_{in}}$:

$$-\frac{r}{R_A}$$

Region II:

$$v_{OUT} = \frac{R_{OUT}}{R_{OUT} + R_B} V_{SS}$$

Small-signal gain $\frac{v_{out}}{v_{in}}$:

$$0$$

(C) Find the range of v_{IN} for which the circuit is operating in each region independently and verify that the regions complement each other.

Region I:

$$v_{IN} \leq \frac{R_A}{r} \frac{R_B}{R_{OUT} + R_B} V_{SS}$$

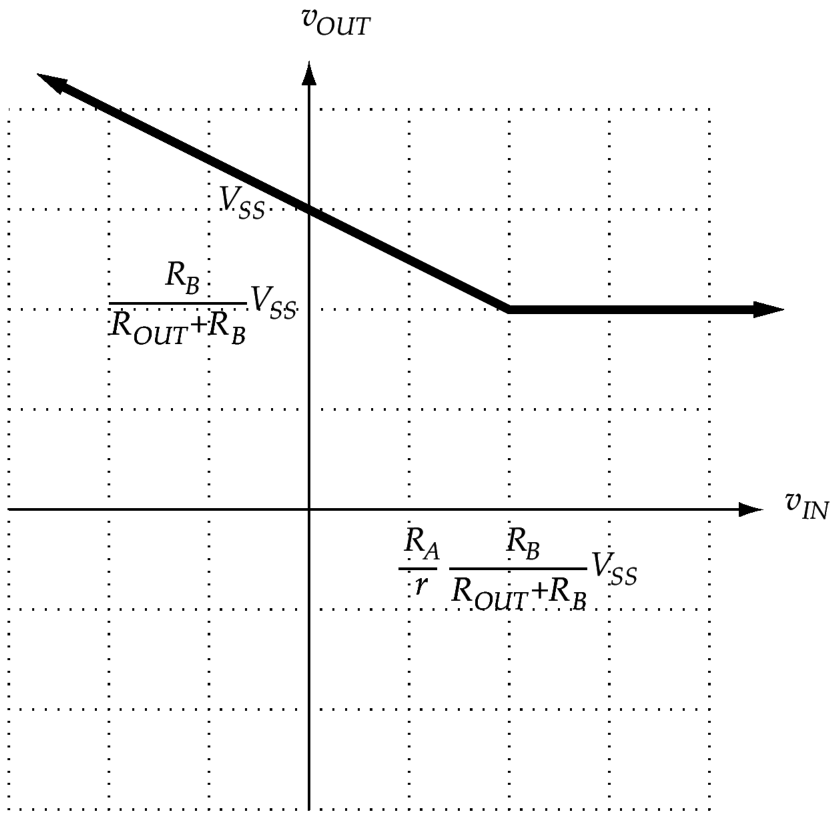
Region II:

$$v_{IN} \geq \frac{R_A}{r} \frac{R_B}{R_{OUT} + R_B} V_{SS}$$

(D) Find the value of v_{OUT} at each transition between regions of operation independently and verify that the values of v_{OUT} are the same.

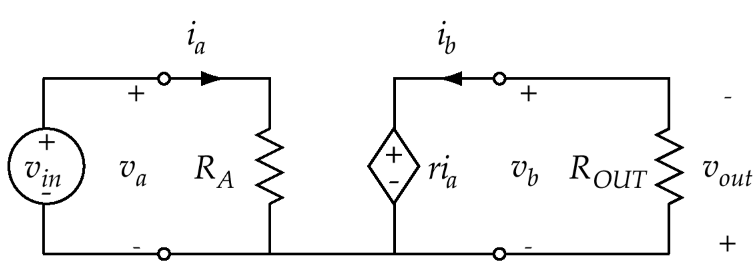
$$v_{OUT} = \frac{R_{OUT}}{R_{OUT} + R_B} V_{SS}$$

(E) Plot the v_{IN}-v_{OUT} relation showing clearly all transition values, any intercepts and/or any asymptotes.



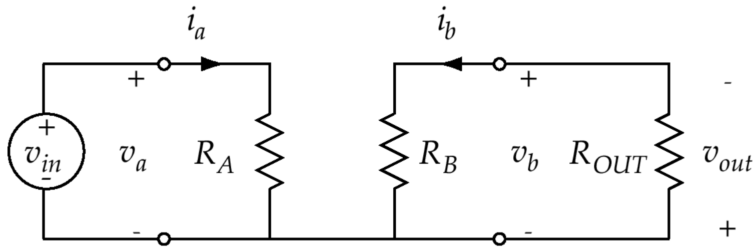
(F) Draw the small-signal circuit diagram for each region and find the small-signal gain. Verify that each gain is the same as the one found before. Remember that all elements in the small-signal circuit must be linear.

Region I:



$$v_{out} = -\frac{r}{R_A}v_{in}$$

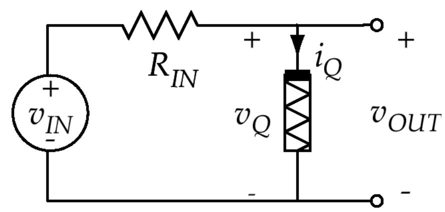
Region II:



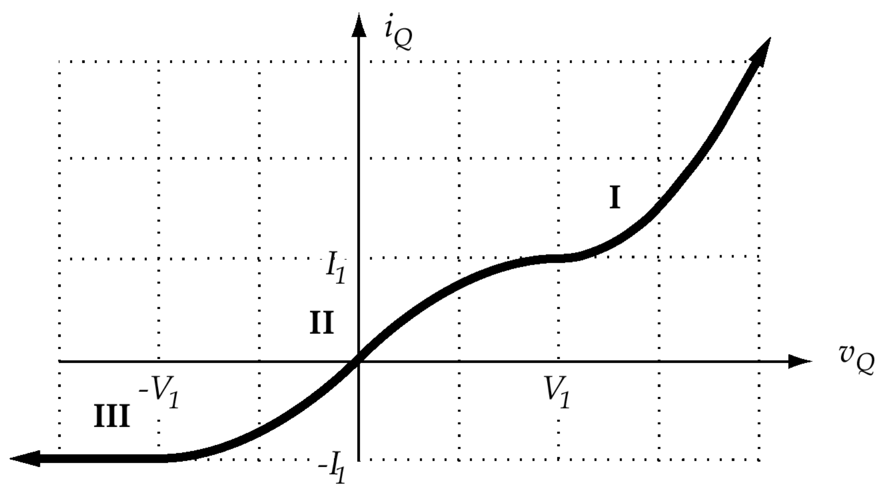
$v_{out} = 0$

Problem 2: The nonlinear resistor inside the circuit shown below is characterized by the equations:

$i_Q = \alpha(v_Q - V_1)^2 + I_1$	$v_Q \geq V_1$	Region I
$i_Q = I_1 \sin\left(\frac{\pi}{2}\frac{v_Q}{V_1}\right)$	$-V_1 \leq v_Q \leq V_1$	Region II
$i_Q = -I_1$	$v_Q \leq -V_1$	Region III

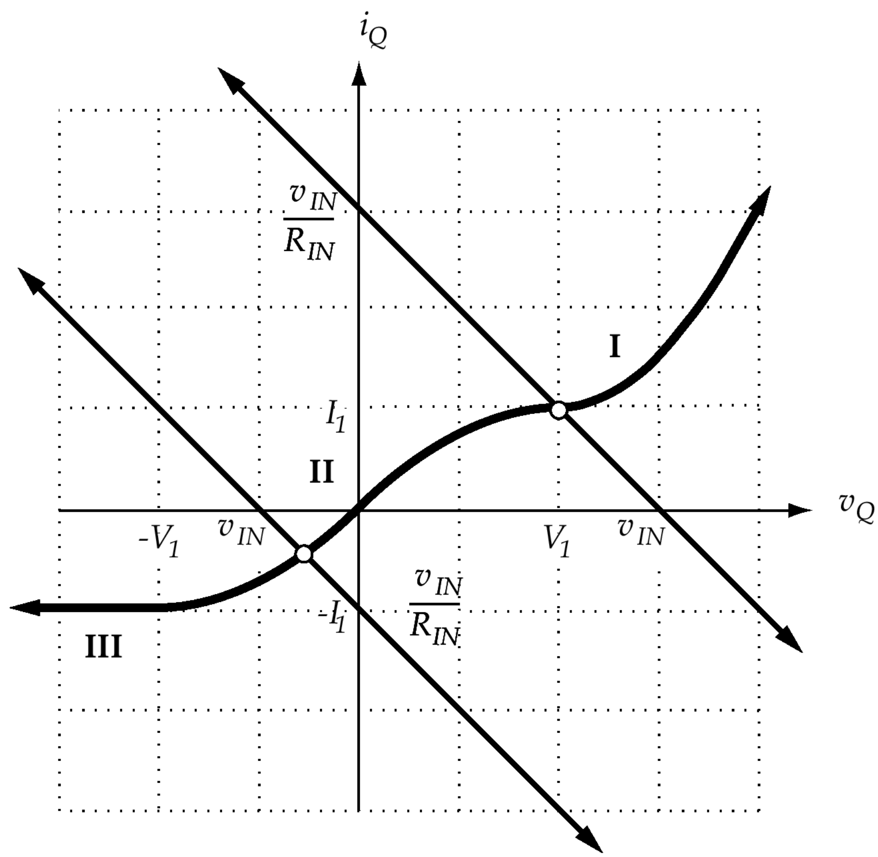


These equations trace the following curve in the v_Q-i_Q plane:



(A) Find an algebraic equation for the v_Q-i_Q constraint imposed by the external circuit and graph these load lines in the v_Q-i_Q plane for $v_{IN} > 0$ and $v_{IN} < 0$. Mark the points corresponding to solutions of the circuit.

$$v_{IN} = R_{IN} i_Q + v_{OUT}$$



(B) Find an algebraic expression for the v_{IN}-v_{OUT} relation in each region. Do not solve the equations for v_{OUT} (for some regions, you can't!). Find the small-signal gain $\frac{v_{out}}{v_{in}}$ for each region using these expressions assuming all the necessary large-signal values. Remember that $\frac{v_{out}}{v_{in}} = \left[\frac{v_{in}}{v_{out}}\right]^{-1}$, but $\frac{dv_{OUT}}{dv_{IN}} \neq \left[\frac{dv_{IN}}{dv_{OUT}}\right]^{-1}$!

Region I:

$$v_{IN} = R_{IN}\alpha(v_{OUT} - V_1)^2 + R_{IN}I_1 + v_{OUT}$$

Small-signal gain $\frac{v_{out}}{v_{in}}$:

$$\frac{1}{1 + 2R_{IN}\alpha(V_{OUT} - V_1)}$$

Region II:

$$v_{IN} = R_{IN} I_1 \sin\left(\frac{\pi}{2} \frac{v_{OUT}}{V_1}\right) + v_{OUT}$$

Small-signal gain $\frac{v_{out}}{v_{in}}$:

$$\frac{1}{1 + \frac{\pi}{2} R_{IN} \frac{I_1}{V_1} \cos\left(\frac{\pi}{2} \frac{v_{OUT}}{V_1}\right)}$$

Region I:

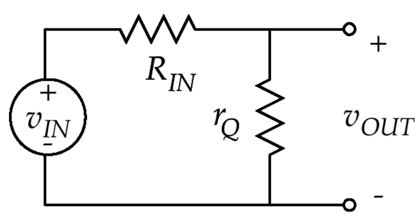
$$v_{IN} = -R_{IN} I_1 + v_{OUT}$$

Small-signal gain $\frac{v_{out}}{v_{in}}$:

$$1$$

(C) Draw the small-signal circuit diagram for each region and find the small-signal gain. Verify that each gain is the same as the one found before. Remember that all elements in the small-signal circuit must be linear.

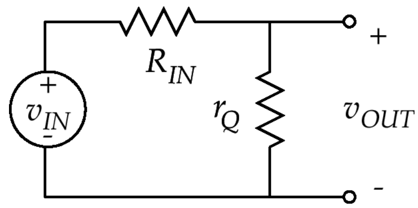
Region I:



$$r_Q = \frac{1}{2\alpha(V_{OUT} - V_1)}$$

$$v_{out} = \frac{1}{1 + 2R_{IN}\alpha(V_{OUT} - V_1)} v_{in}$$

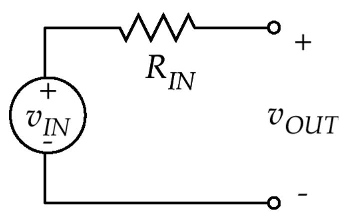
Region II:



$$r_Q = \frac{1}{\frac{\pi}{2}\frac{I_1}{V_1}\cos\left(\frac{\pi}{2}\frac{v_{OUT}}{V_1}\right)}$$

$$v_{out} = \frac{1}{1+\frac{\pi}{2}R_{IN}\frac{I_1}{V_1}\cos\left(\frac{\pi}{2}\frac{v_{OUT}}{V_1}\right)}v_{in}$$

Region III:



$$v_{out} = v_{in}$$