Discussion 3

Large-Signal vs. Small-Signal Analysis

Large-Signal:

1. DC Analysis; finding operating point and the bias conditions (Voltages and Currents at different nodes) of circuit.
2. Use current and voltage equations that govern the behavior of the device (e.g. $I_D=I_s(\exp(V_{BE}/V_T)-1)$, and KVL/KCL to find the bias points.
3. Large signal values are used to find "small-signal" parameters.

   *NOTE: Circuit may contain non-linear devices (e.g. diodes, BJTs), so never "linearize" these devices, i.e. do not think of them as dependent sources or resistors.
4. Voltages applied here are usually several volts to several tens of volts. They are "large" values.

Small-Signal:

1. AC Analysis; tweak around the bias condition, i.e. around the DC bias of the circuit, add a small AC source that slightly increases and decreases the bias point.
2. "Linearize" the device. Replace the non-linear device with linear ones. Why can you treat non-linear devices as linear when small-signal values are applied? Because if you take the instantaneous slope of the IV curve at a particular DC point and zoom into it, for values very close to this DC point, the IV curve looks quite linear.
3. Construct the small-signal model using values for the parameters that you found in Step 3 of Large-Signal Analysis.
4. Use this model to find things like gain, input and output resistances.

Large-Signal and Small-Signal Analysis on BJTs

DC Equations for BJTs: (Reminder)

$$I_C = I_S\left(e^{(V_{BE}/V_T)} - 1\right)$$
$$I_C = \beta I_B$$
$$I_E = I_C + I_B = (1+\beta)I_B$$

Small-Signal Paramters for BJTs: (Reminder)

* If there is time, you may want to draw I_C vs. V_{CE} curves for 3 different V_{BE} values and pick one point as the DC operating point and show how incremental changes in V_{BE}, i.e. if the new V_{be} becomes $V_{BE}+v_{be}$, changes I_c to I_C+i_c and show how this is modeled as a voltage dependent current source, $g_m v_{be}$. Similarly, you can do this for incremental changes in V_{CE} and show its effect and why that's a resistor. So, basically derive where the small-signal model comes from.

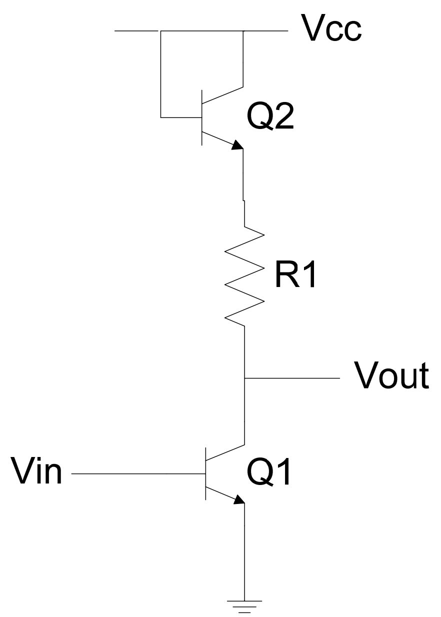
$$g_m = \frac{I_c}{V_T}$$
$$r_\pi = \frac{\beta}{g_m}$$
$$r_o = \frac{V_A}{I_C}$$

Ex. 1

For the circuit below, find the DC operating point, i.e. find **I_C and $V_{BE,1}$ and $V_{BE,2}$**, such that V_{out} is 3V. (Suppose V_{CC} and R_1 values are given). *You don't actually need to find numbers, just go through the KVL/KCL and device behavior equations that would provide the final answer for I_C, $V_{BE,1}$, and $V_{BE,2}$.

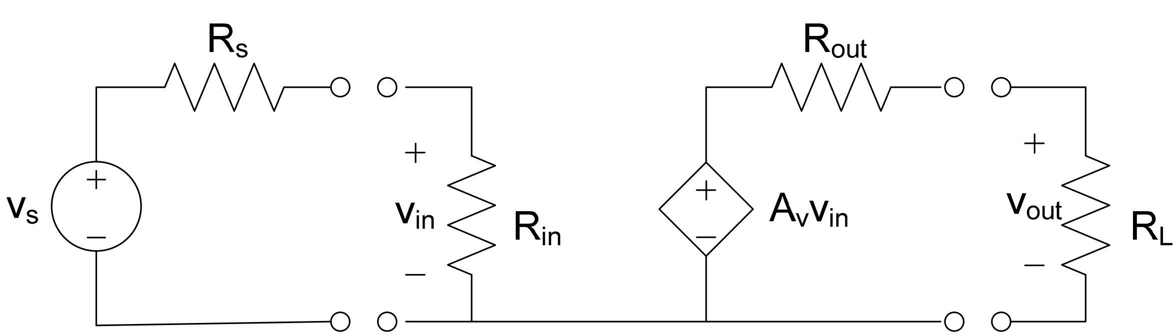
Then, **evaluate the small-signal parameters**. *Again, just go through the steps of how you would find these parameters.

Finally, **draw the small-signal model**. *Draw the entire model out. Note: You can replace $g_m V_{BE}$ dependent current source for Q2 with a resistor having a value $1/g_m$ since the collector and base are tied together.

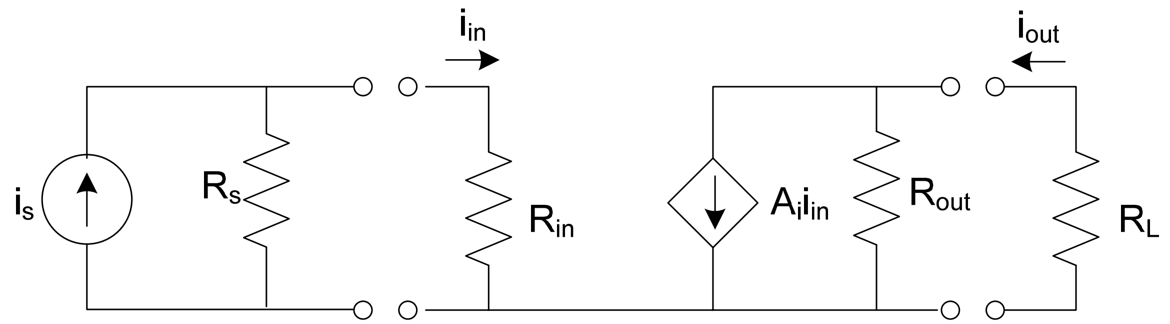


Amplifiers: Introduction to 2-port models and going over ideal voltage amplifiers, ideal current amplifiers, ideal transconductance amplifiers, and ideal transresistance amplifiers, i.e. what should R_{in} and R_{out} be (large or small) for each of these ideal amplifiers. *You may want to use an analogy of 2-port model with Thevenin and Norton equivalent circuits.

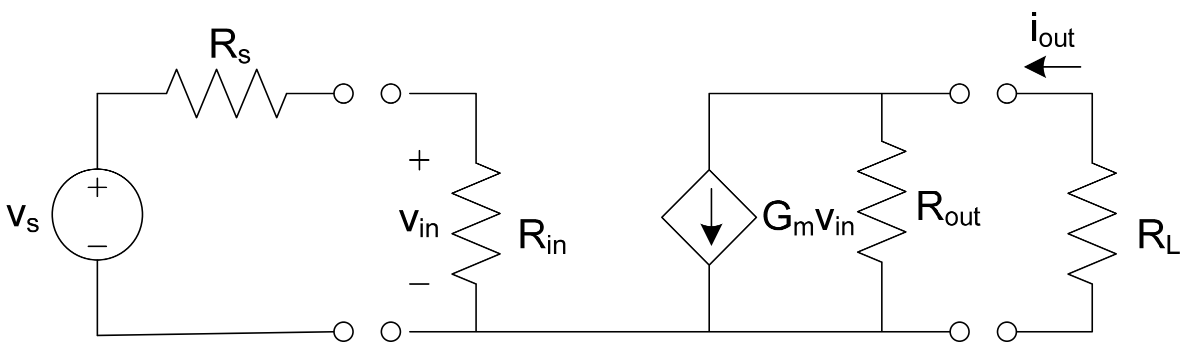
Ideal Voltage Amplifier: (High R_{in}, Low R_{out})



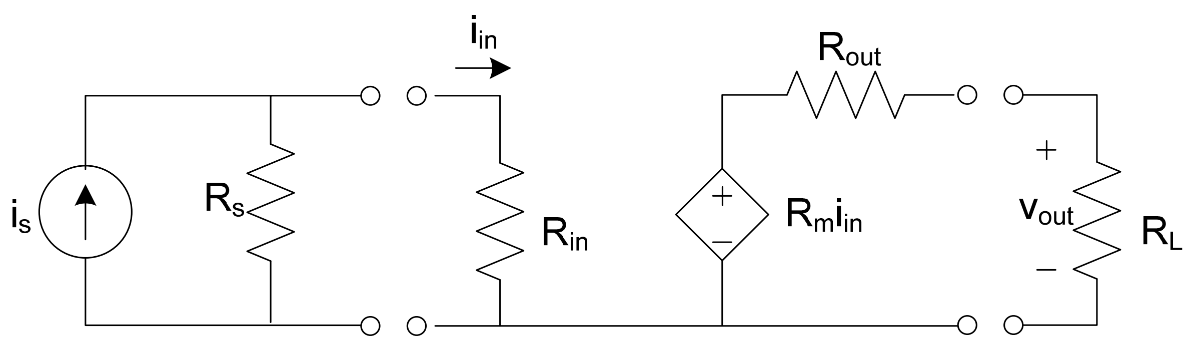
Ideal Current Amplifier: (Low R_{in}, High R_{out})



Ideal Transconductance Amplifier: (High R_{in}, High R_{out})



Ideal Transresistance Amplifier: (Low R_{in}, Low R_{out})



Calculating A_v, A_i, G_m, R_m, R_{in}, R_{out}:

A_v: Apply ideal voltage source at the input (i.e. a source with no source resistance), and measure the open-circuit output voltage.

A_i: Apply ideal current source at the input (i.e. a source with no source resistance), and measure the short-circuit output current going back into the circuit.

G_m: Apply ideal voltage source at the input (i.e. a source with no source resistance), and measure the short-circuit output current going back into the circuit.

R_m: Apply ideal current source at the input (i.e. a source with no source resistance), and measure the open-circuit output voltage.

$\underline{R_{in}}$: Apply ideal voltage source at the input (i.e. a source with no source resistance), keep R_L attached at the output, and measure the current that flows out of this ideal input source.

$\underline{A_v}$: Apply ideal voltage source at the output (i.e. a source with no source resistance), zero any input source (voltage sources become short and current sources become open), keep R_s attached at the input, and measure the current that flows out of this ideal output source:

*If there is more time, do an example of a simple Common-Emitter Amplifier going through the steps of finding A_v, R_{in}, and R_{out}.