ECE 65: Components & Circuits Lab

Lecture 23

Common-emitter / Common-source amplifier parameters

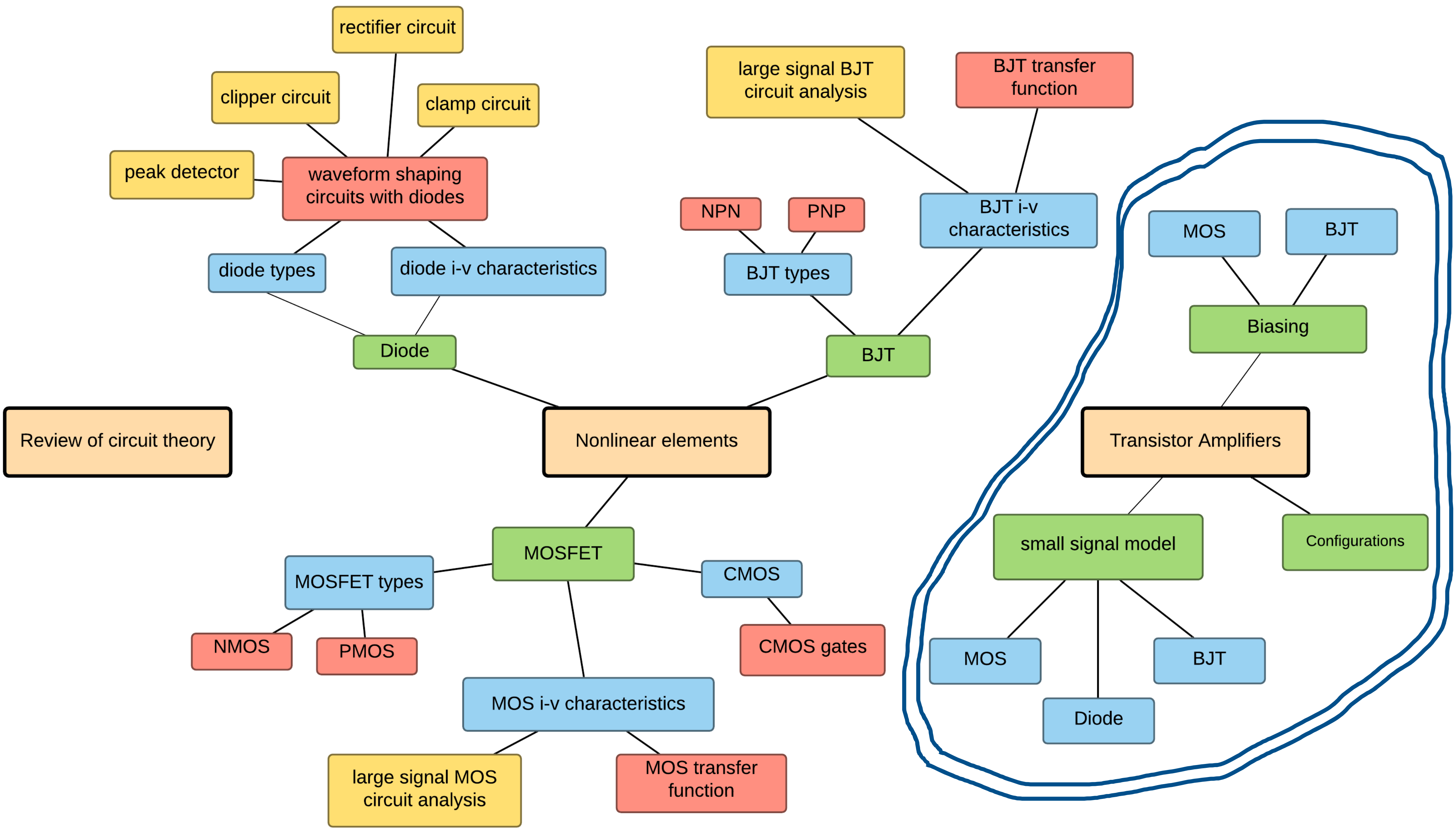
Reference notes: sections 6.1, 6.2

Sedra & Smith (7th Ed): sections 7.3

Saharnaz Baghdadchi

Course map

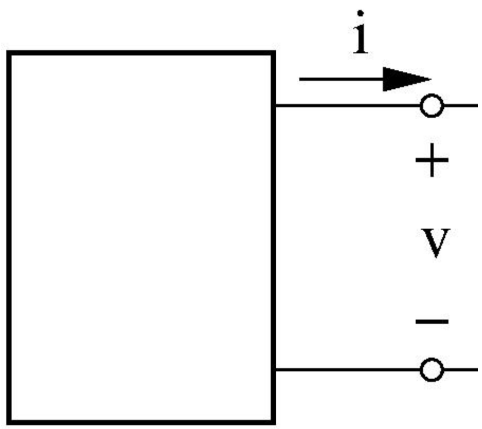
6. Transistor Amplifier Configurations



Review from lecture 2

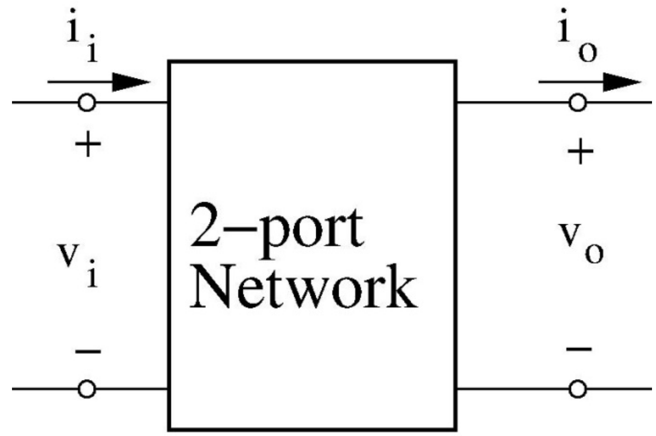
We will analyze many functional circuits

Two-terminal Networks



Function is defined by the iv equation

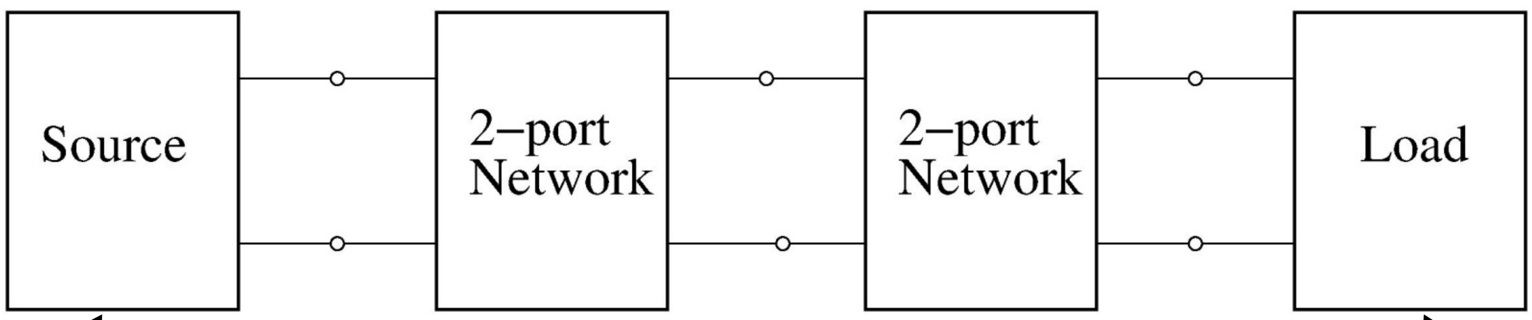
Two-port Networks



Function is defined by the transfer function (e.g., v_o in terms of v_i)

A typical analog circuit contains a load and a source (two-terminal networks) and several two-port networks

We divide the circuit into building blocks to simplify analysis and design



Two-terminal network containing an independent source

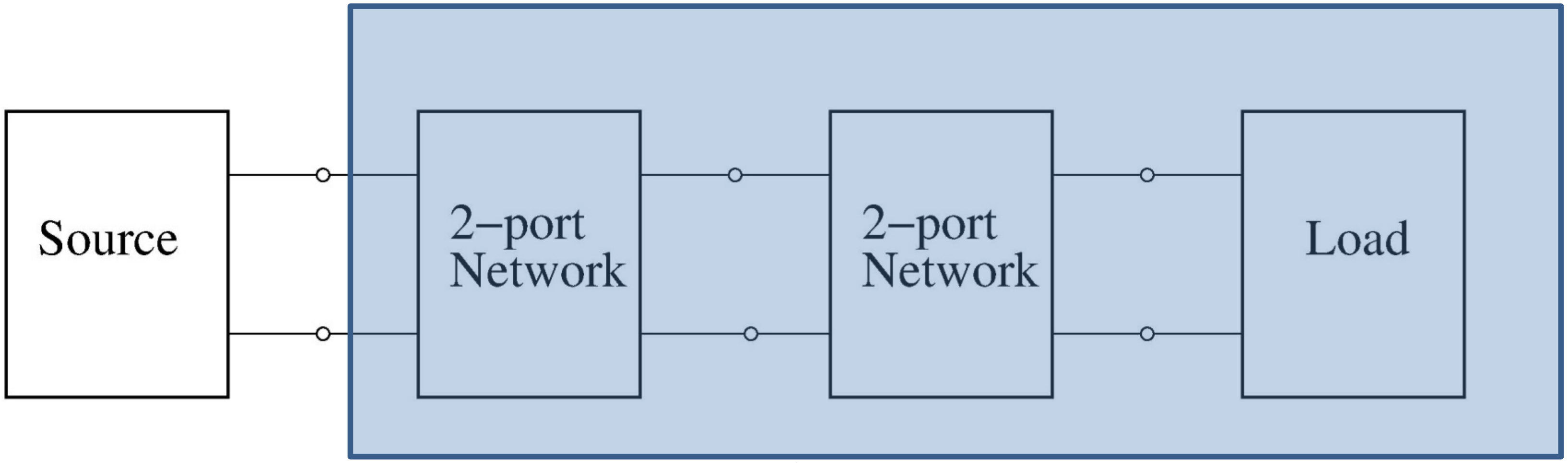
Two-terminal network containing NO independent source

In linear circuits:

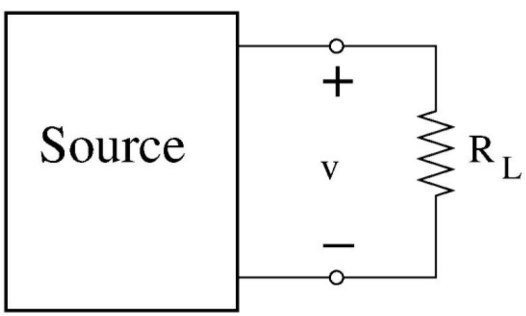
Any two-terminal network can be replaced by its Thevenin equivalent circuit.

If a two-terminal network does not include an “independent source” it will be reduced to a single “impedance” (even if it includes dependent sources).

Source only sees a load resistor

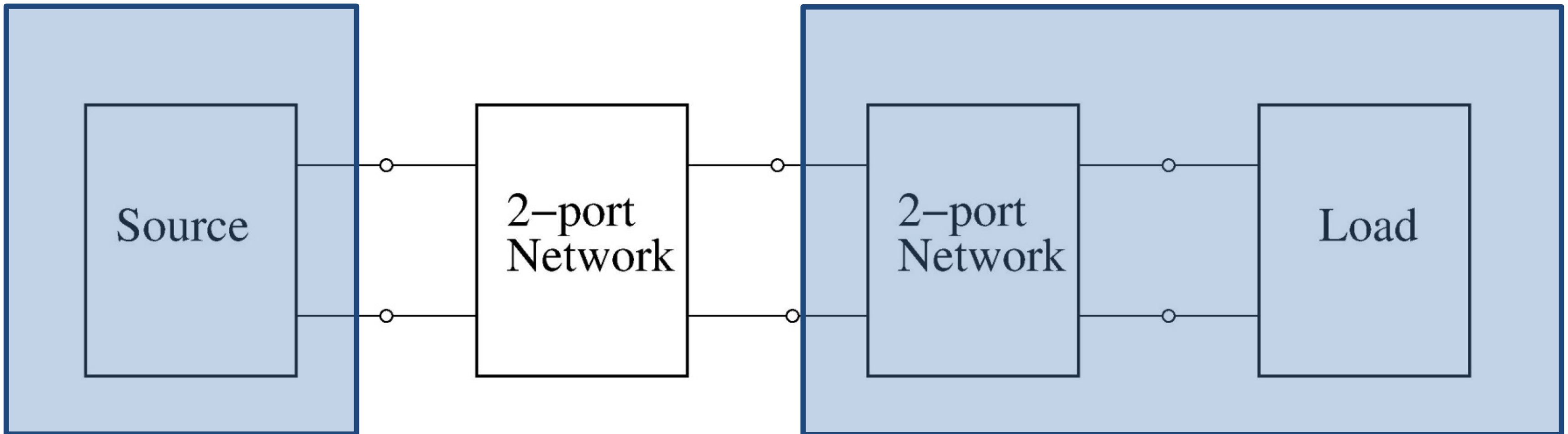


A two-terminal network containing NO independent source



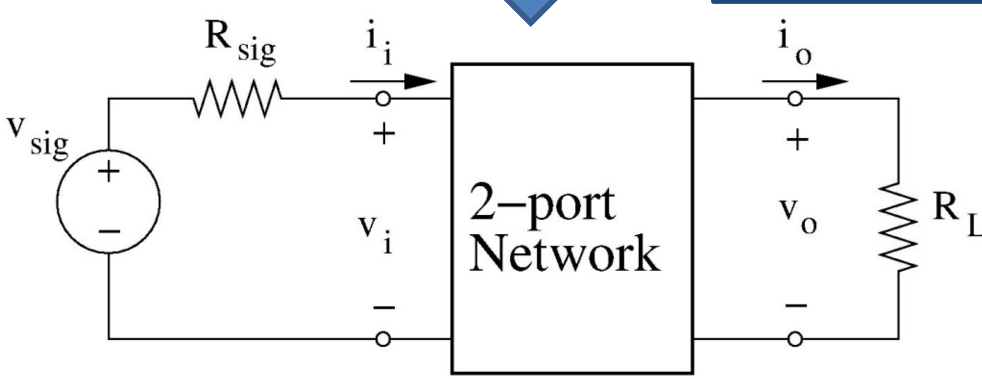
For a linear source, we only find the Thevenin parameters of the source.

Two-port network



A two-terminal network containing an independent source

A two-terminal network containing no independent source



Transfer function of a two-port network can be found by solving the above circuit once.

What are the amplifier parameters?

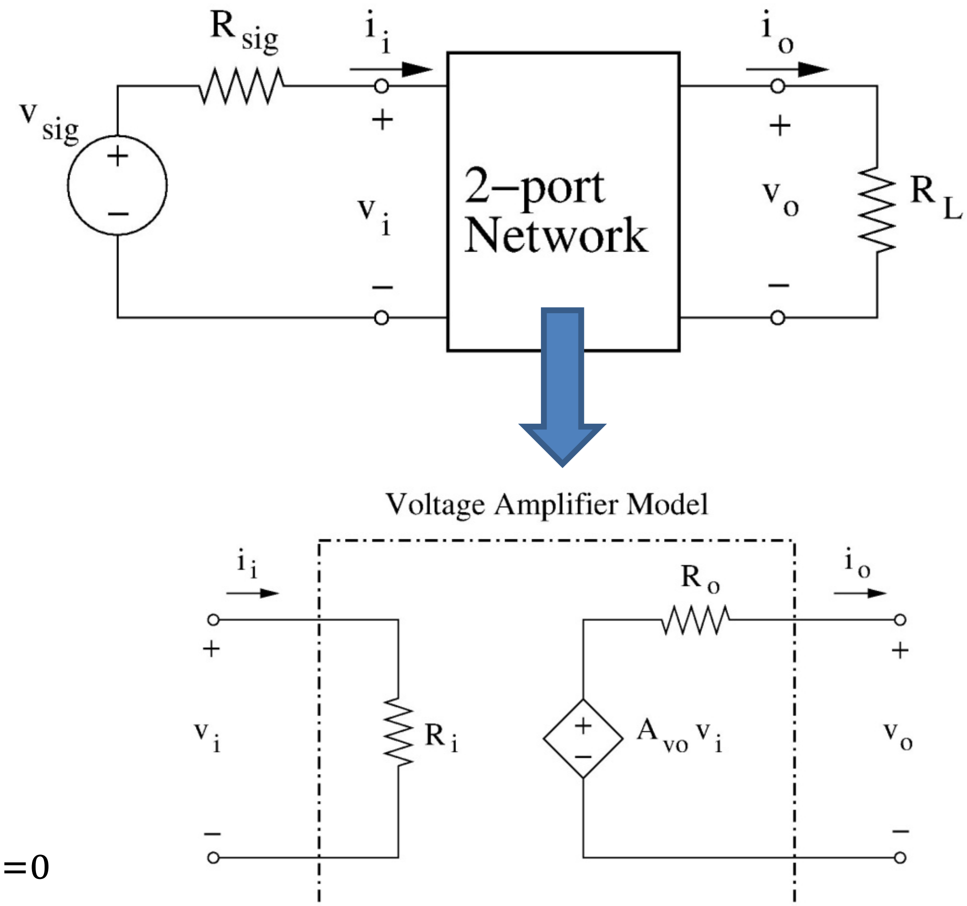
Voltage Gain of the Circuit: $A = \frac{v_o}{v_{sig}}$

Voltage Gain of the Amplifier: $A_v = \frac{v_o}{v_i}$

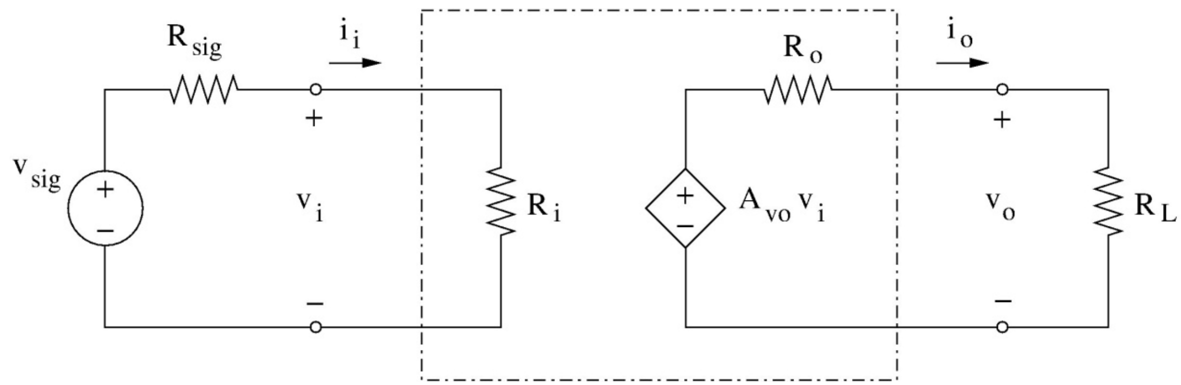
Open-loop Gain: $A_{vo} = \left.\frac{v_o}{v_i}\right|_{R_L \to \infty}$

Input Resistance: $R_i = \frac{v_i}{i}$

Output Resistance of Amplifier: $R_o = -\left.\frac{v_o}{i_o}\right|_{v_i=0}$



Observations on the amplifier parameters



$$A = \frac{v_o}{v_{sig}} = \frac{v_i}{v_{sig}} \times \frac{v_o}{v_i} = \frac{R_i}{R_i + R_{sig}} A_v$$

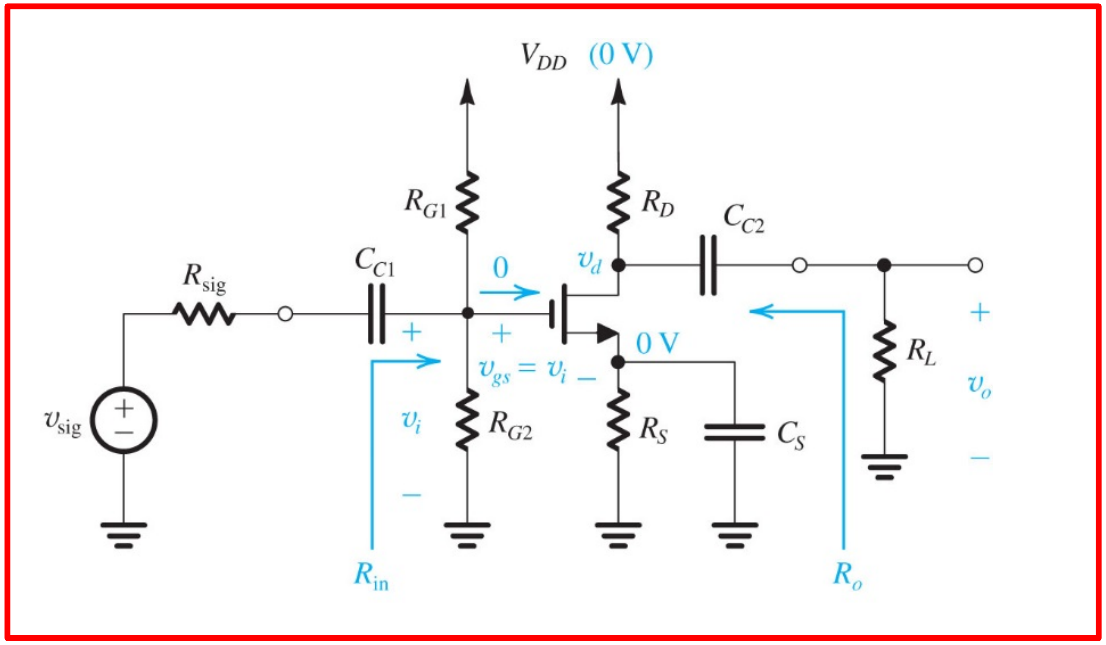
When $R_{sig} = 0, A = A_v$

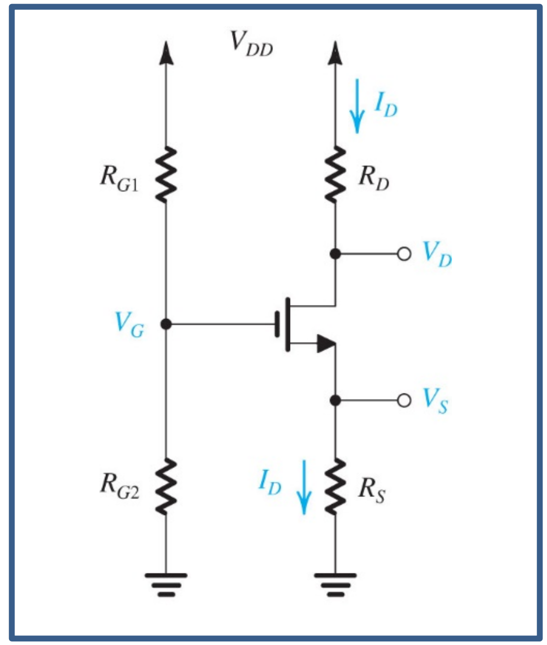
$$A_v = \frac{v_o}{v_i} = \frac{R_L}{R_L + R_o} A_{vo}$$

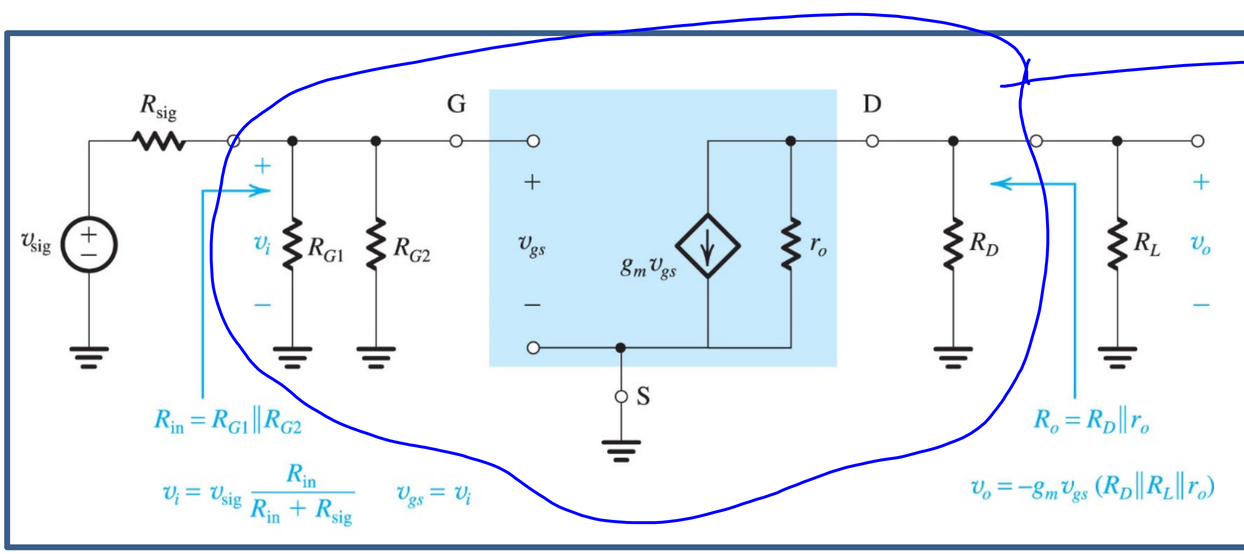
When $R_L = \infty, A_v = A_{vo}$

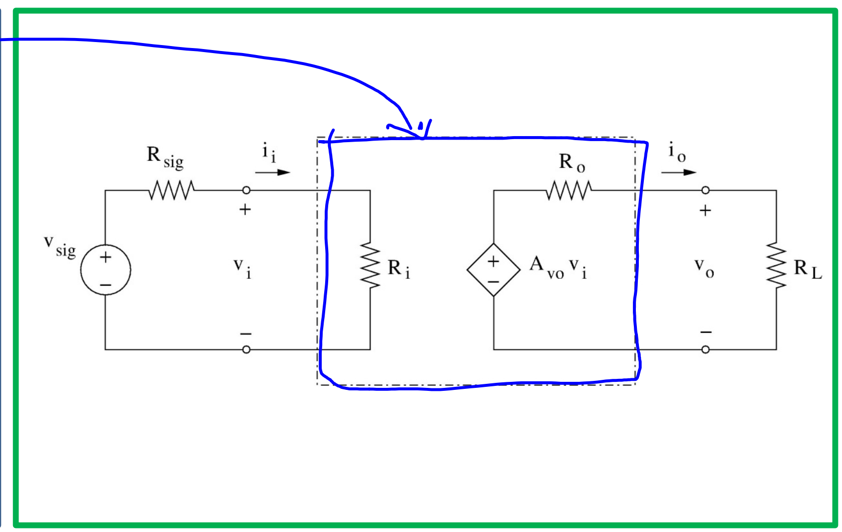
A_{vo} is the maximum possible gain of the amplifier

From an amplifier circuit to the building block representation



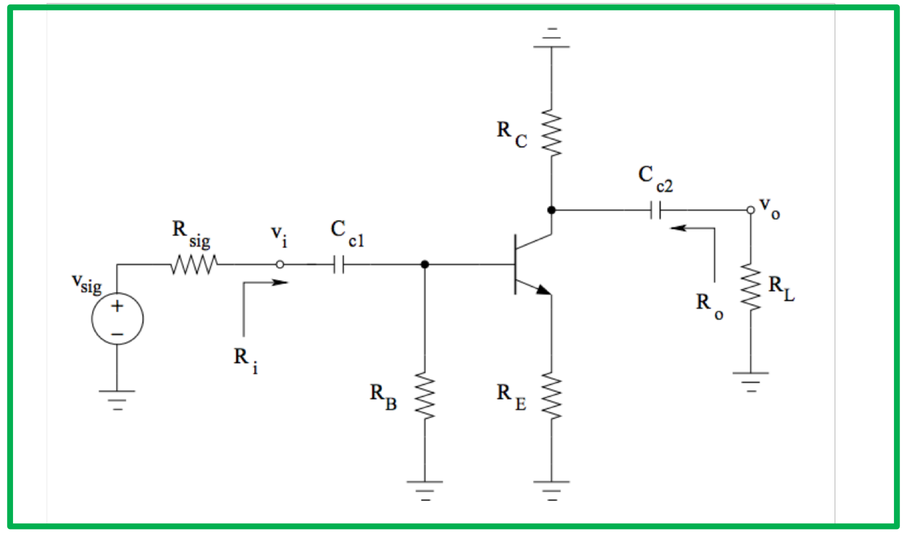






Equations of A_{vo}, R_o, R_i for the common-emitter with an emitter resistance BJT amplifier

Please follow the derivations of the below parameters from the reference notes.

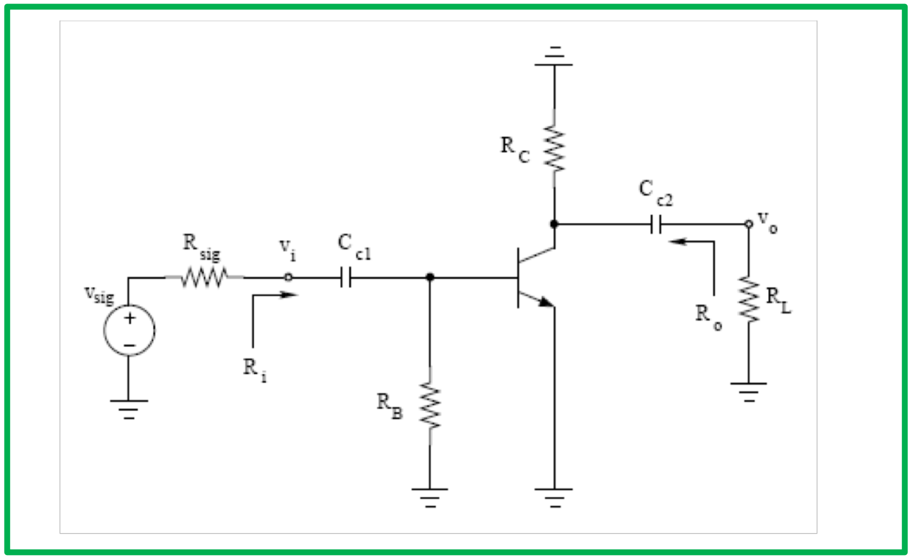


$$A_{vo} = \frac{-R_C}{R_E + (1 + R_C / r_o)\,\dfrac{R_E + r_\pi}{\beta}}$$

$$R_o = \left[\frac{\left(\dfrac{1}{g_m}\right) || \, r_o}{R_C \, || \, r_o} + \frac{r_\pi || \, R_E}{R_C}\right]^{-1} [(r_\pi \, || \, R_E) + (1/g_m) \, || \, r_o]$$

$$R_i = R_B \, || \left[R_E + r_\pi + \frac{\beta R_E}{1 + (R_E + R_C || \, R_L)/\, r_o} \right]$$

Common-emitter BJT amplifier parameters



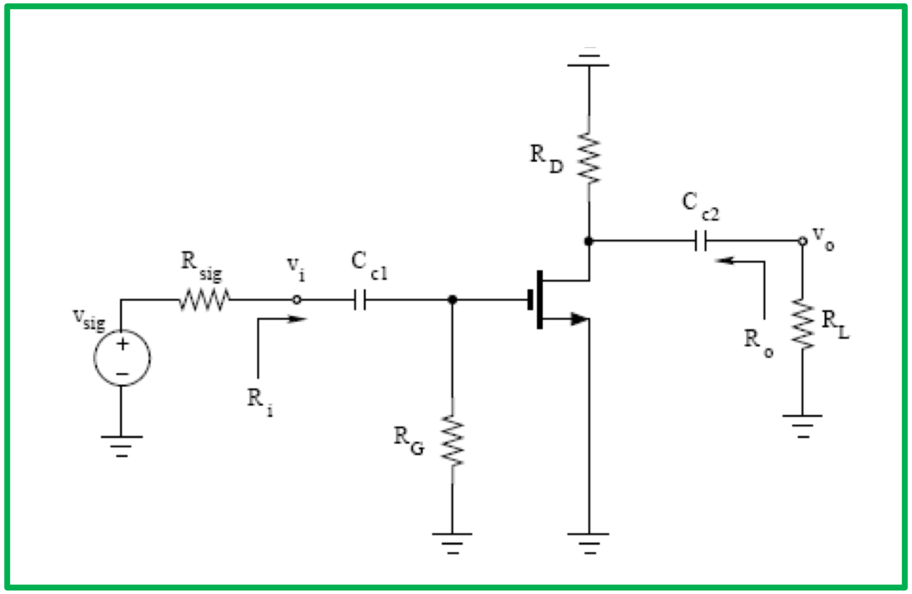
The amplifier parameters derived for the common emitter amplifier with an emitter resistor can be used for this amplifier by setting $R_E = 0$.

$$A_{vo} = -g_m(R_C || r_o)$$

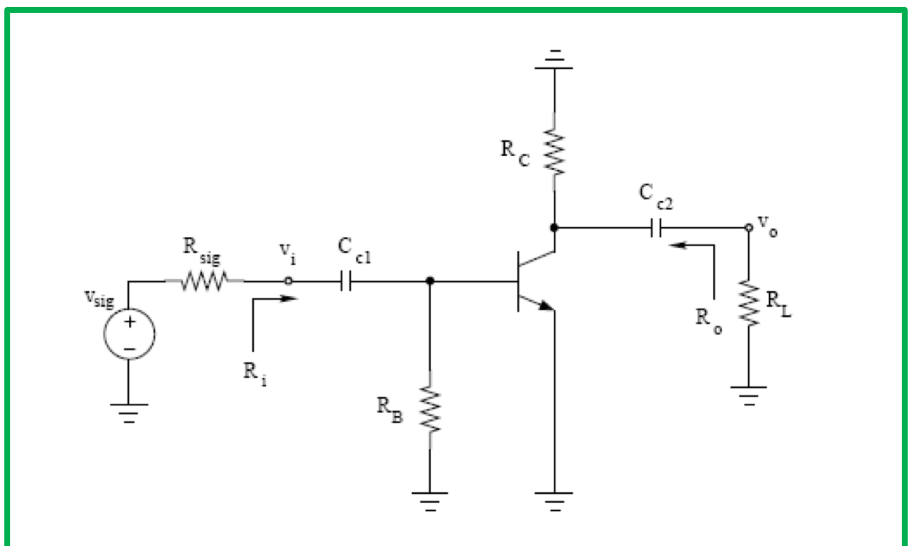
$$R_o = R_C || r_o$$

$$R_i = R_B || r_\pi$$

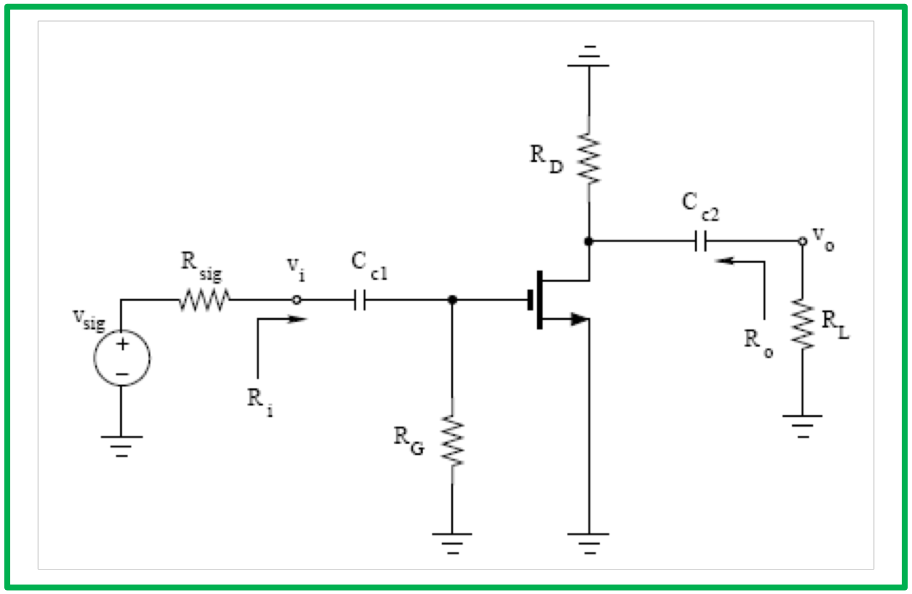
Common-Source MOS amplifier parameters



Compare it with the signal circuit for the common-emitter BJT amplifier:



Common-source MOS amplifier parameters



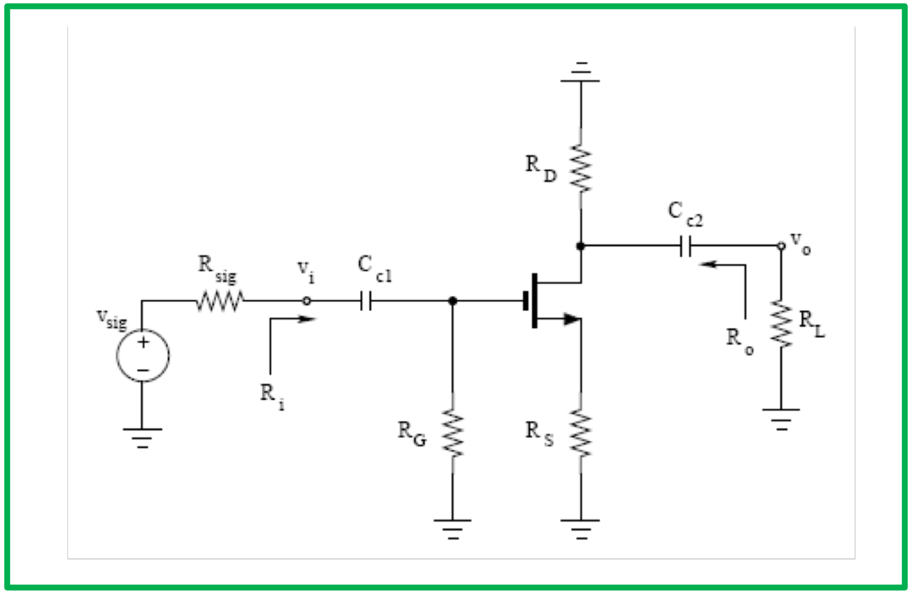
The common emitter BJT amplifier parameters can be used for this amplifier when R_B is replaced with R_G, and R_C is replaced with R_D, and $r_\pi \to \infty$.

$$A_{vo} = -g_m(R_D || r_o)$$

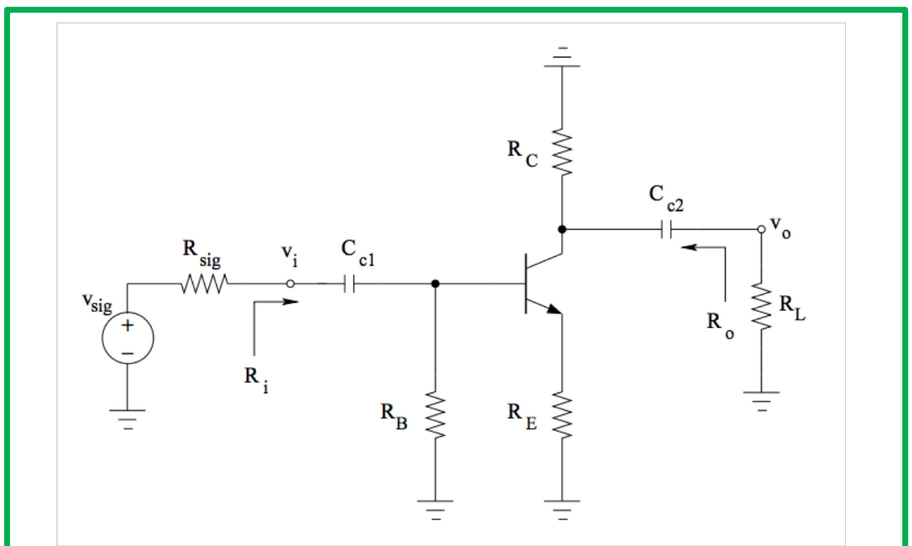
$$R_o = R_D || r_o$$

$$R_i = R_G$$

Common-source MOS with a source resistance amplifier parameters

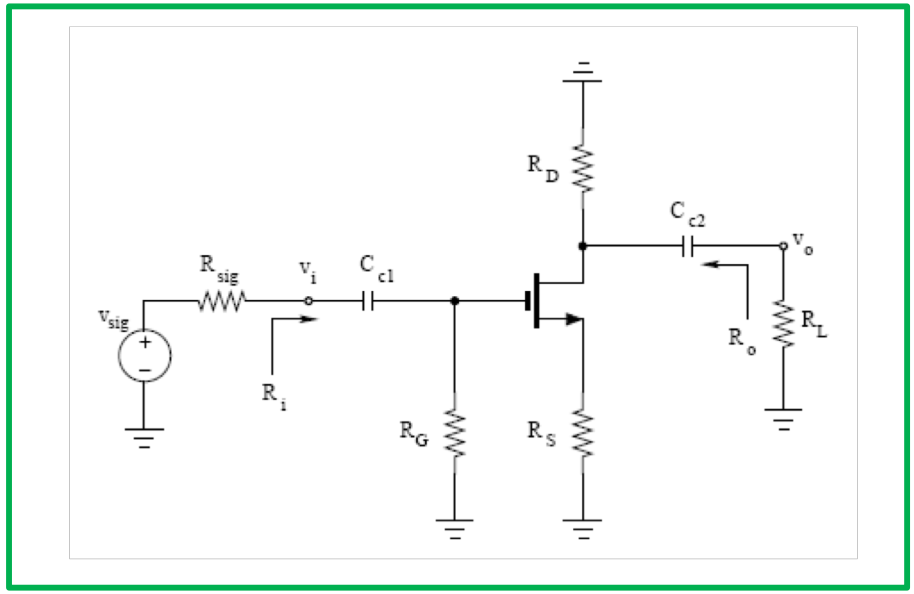


Compare it with the signal circuit for the common-emitter with an emitter resistor BJT amplifier:



Common-source MOS with a source resistance amplifier parameters

The common-emitter with an emitter resistor BJT amplifier parameters can be used for this amplifier when R_B is replaced with R_G, R_C is replaced with R_D, R_E is replaced with R_S, β/r_π is replaced with g_m and $r_\pi \to \infty$.



$$A_{vo} = \frac{-g_m R_D}{1 + g_m R_S + R_D \,/\, r_o}$$

$$R_o = R_D \,||\, [\, r_o(1 + g_m\, R_S)]$$

$$R_i = R_G$$

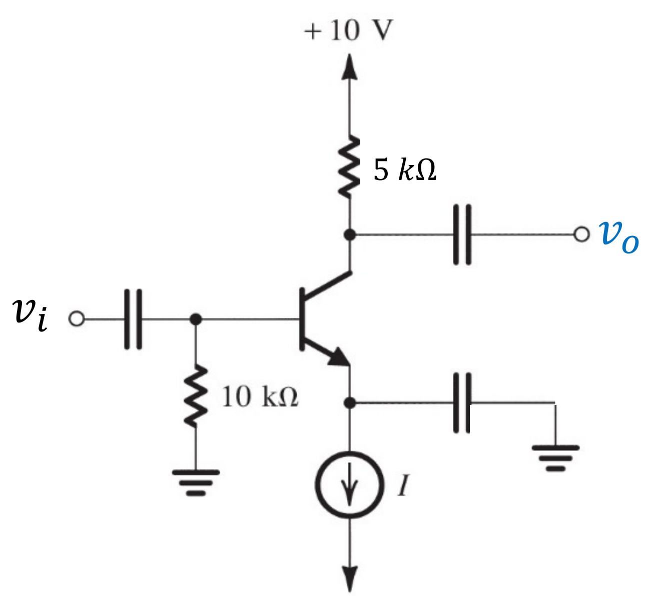
Some notes on *common-emitter* (CE) and *common-source* (CS) amplifiers:

- They have a high voltage gain.
- Ignoring R_G, CS has an infinite input resistance.
- Ignoring R_B, CE has a modest input resistance.
- Both CE and CS have a rather high output resistances.
- Adding R_S to the source of a CS or R_E to the emitter of a CE amplifier can have the benefits of raising the input resistance of CE amplifier, increasing linearity and increasing the amplifier bandwidth.

Lecture 23 reading quiz.

The below BJT common-emitter amplifier with β = 100 is fed with a signal source having a resistance of 5 kΩ. A load resistor of 5 kΩ is connected to the output. In this amplifier, $R_i = 2$ kΩ, and $R_o = 5$ kΩ. $V_T = 25\ mV$.

If the peak value of v_π (denoted by $\hat{v}_\pi$) is to be limited to 5mV, what are the corresponding peak values of v_{sig} (denoted by $\hat{v}_{sig}$), and v_o (denoted by $\hat{v}_o$)?

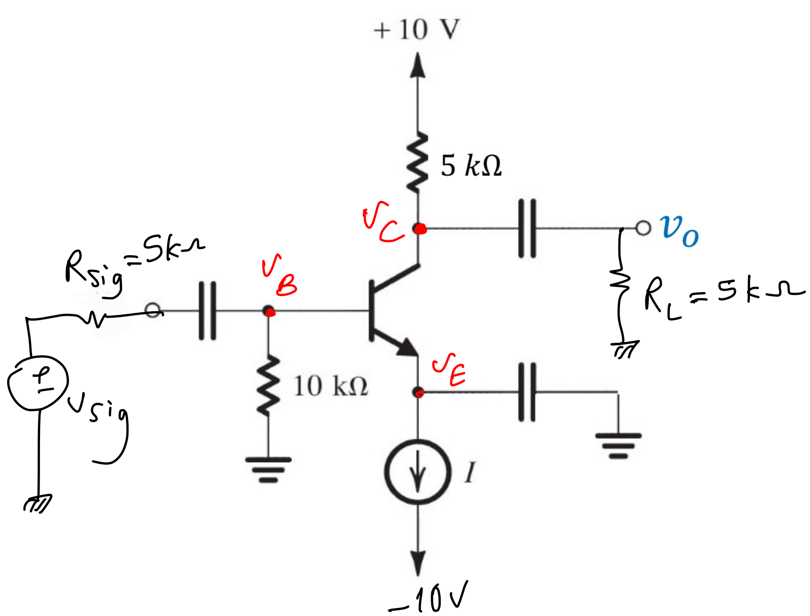


If v_{sig} is a sine wave with peak amplitude of 7 (mV),

$v_{sig} = 7 \sin(\omega t)$ (mV),

find and sketch all the instantaneous node voltages.

Assume $V_{D_0} = 0.7$ V

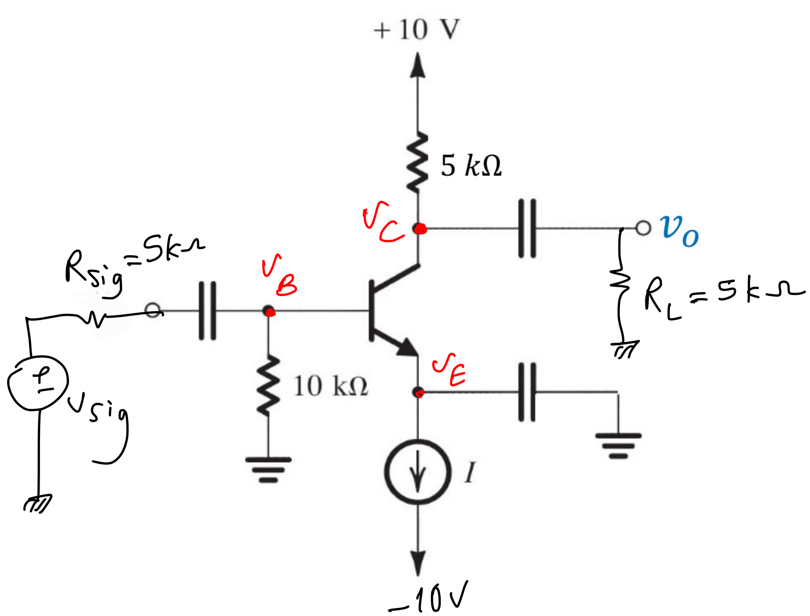


Hints:

If v_{sig} is a sine wave with peak amplitude of 7 (mV),

$$v_{sig} = 7 \sin(\omega t) \text{ (mV)}$$

find and sketch all the instantaneous node voltages



- We need to find the DC and AC components of all node voltages.

- To find the DC components, draw the bias circuit and solve it. Note that
  - the BJT will be in active mode.
  - the circuit parameters are the same as what you used/calculated in the reading quiz.
    - you can use the calculated g_m value to find I_C (the DC collector current).

- Draw the signal circuit (small signal equivalent circuit) and solve the circuit to find equations relating v_{sig} to v_b, v_e, and v_c.

- Using the given v_{sig} waveform, find the Ac components of all node voltages.

- Draw the instantaneous or total node voltages.

Clicker question 1.

Amplifier design problem

The PMOS in the below common-source amplifier circuit has $V_{tp} = -0.7\ V$ and $\lambda = 0$.

1. Select a value for R_S to bias the transistor at $I_D = 0.3\ mA$ and $V_{OV} = 0.3\ V$.

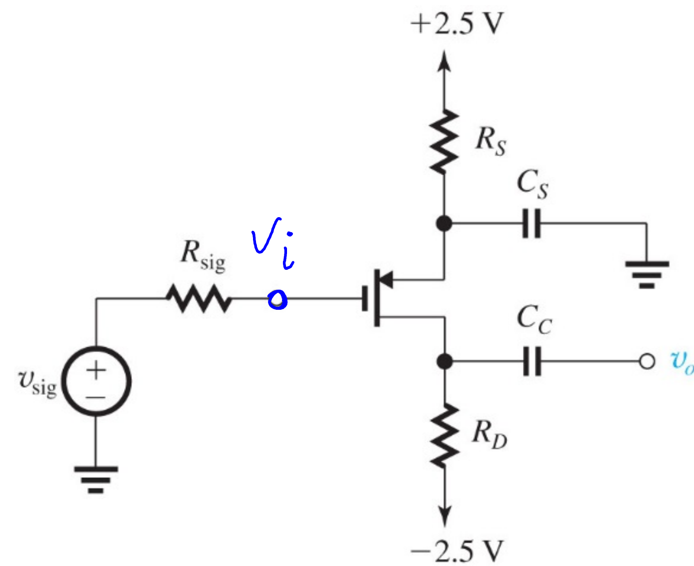
2. Select a value for R_D that results in $A_V = -10\ V/V$.

   A. $R_D = 1\ k\Omega$

   B. $R_D = 5\ k\Omega$

   C. $R_D = 0.5\ k\Omega$

   D. $R_D = 10\ k\Omega$



Hint:

$$g_m = \frac{2\ I_D}{V_{OV}}$$

$$r_o \approx \frac{1}{\lambda . I_D}$$

$$A_{vo} = -g_m (R_D ||\ r_o)$$

$$R_o = R_D ||\ r_o$$

$$R_i = R_G$$