ECE 65: Components & Circuits Lab

Lecture 21

Characterization of transistor amplifiers &

Transistor amplifier configurations

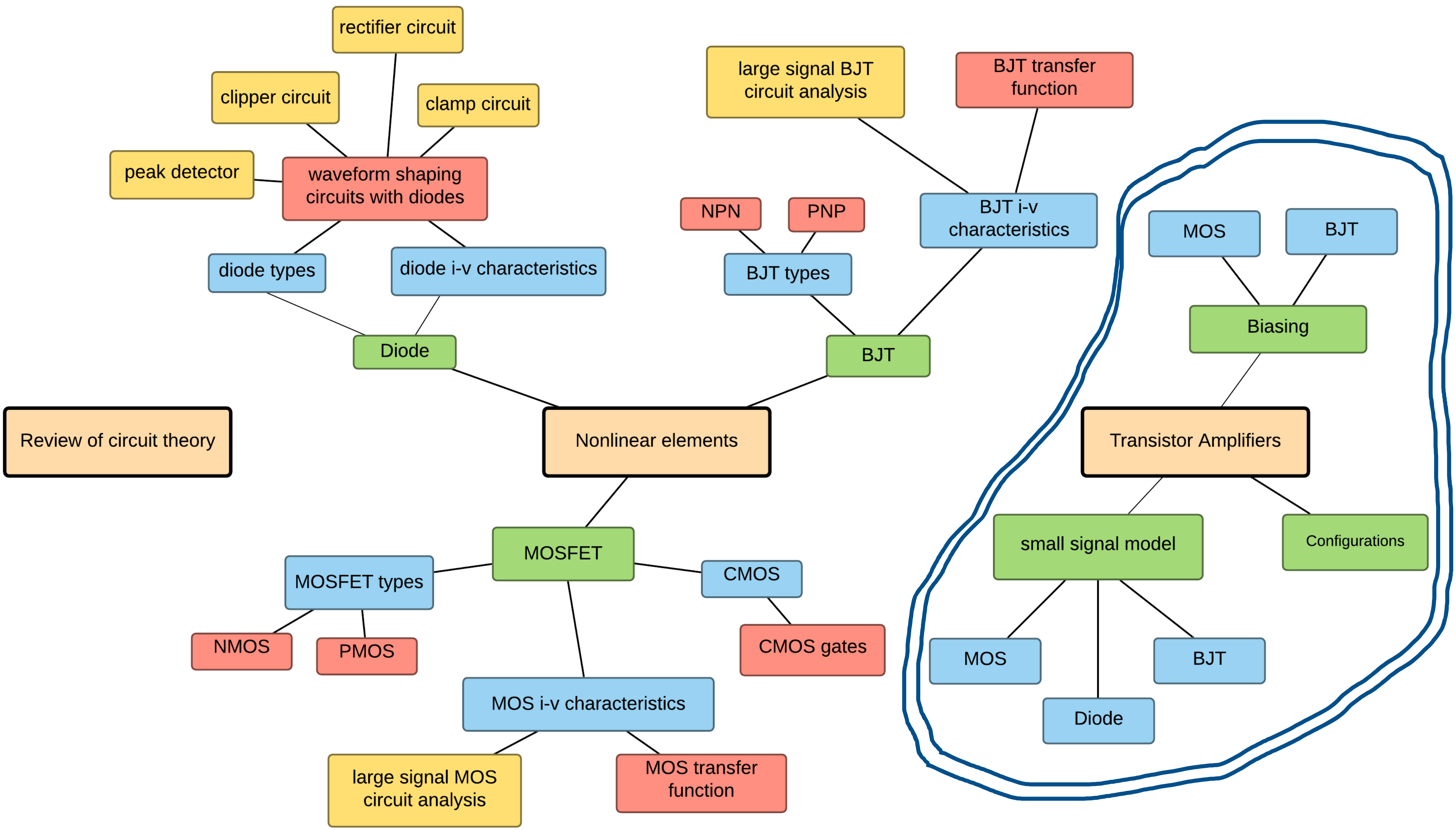
Reference notes: sections 6.1, 6.2

Sedra & Smith (7^{th} Ed): sections 7.3

Saharnaz Baghdadchi

Course map

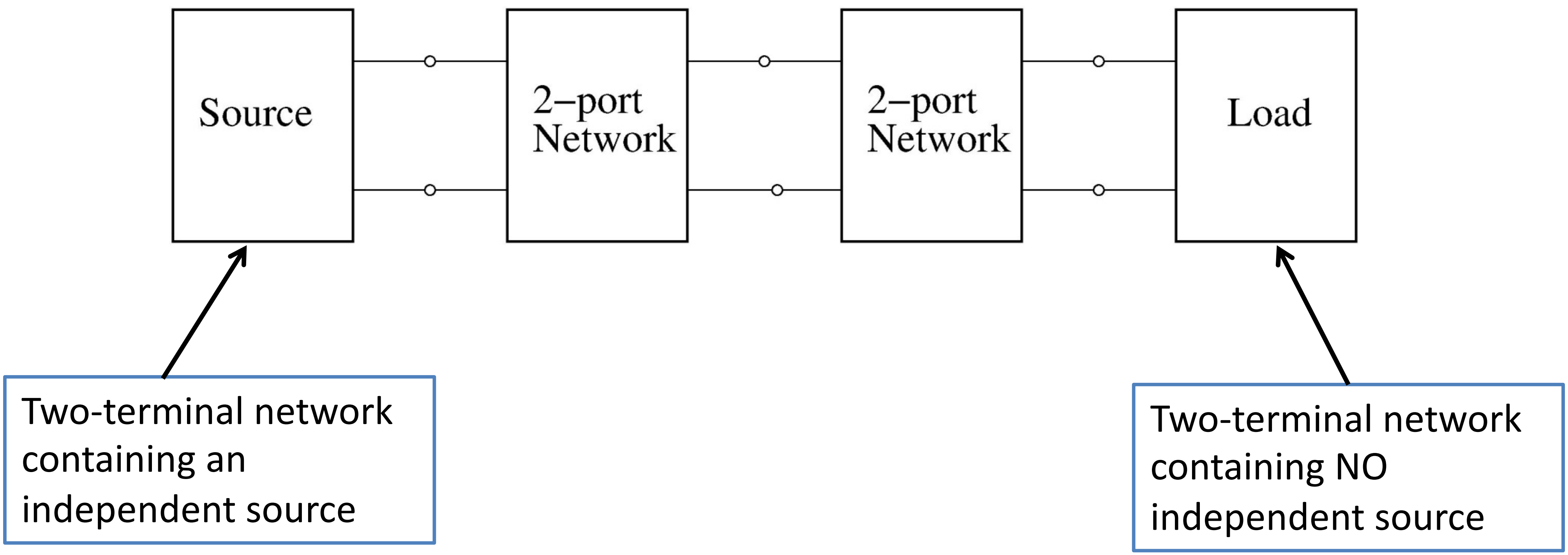
6. Transistor Amplifier Configurations



Characterization of Transistor Amplifiers

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



What are the amplifier parameters?

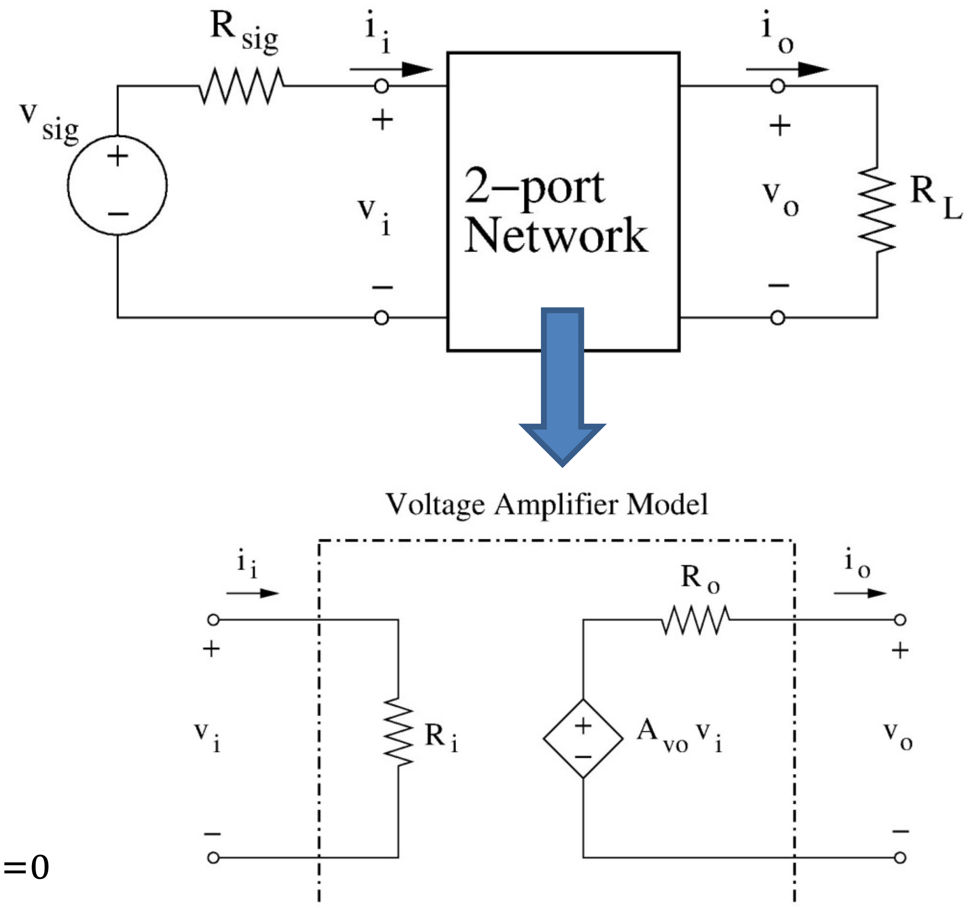
Voltage Gain of the Circuit: $A = \frac{v_o}{v_{sig}}$

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

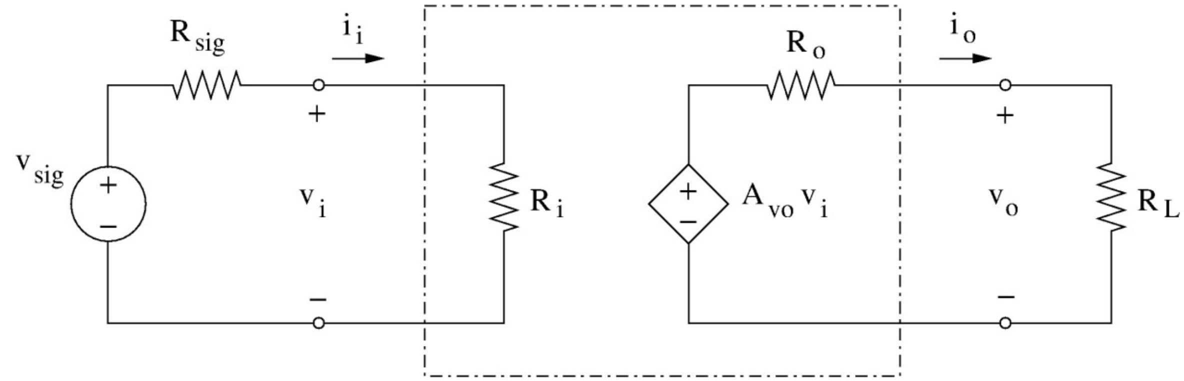
Output Resistance of Amplifier: $R_o = -\left.\frac{v_o}{i_o}\right|_{v_i = 0}$



Observations on the amplifier parameters

Overall Gain:

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



$$\frac{v_i}{v_{sig}} = \frac{R_i}{R_i + R_{sig}}$$

Value of R_i is important.

- For $R_i >> R_{sig}$, $v_i \approx v_{sig}$
- For $R_i = R_{sig}$, $v_i = 0.5\ v_{sig}$
- For $R_i << R_{sig}$, $v_i \approx 0$

Prefer "large" R_i

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

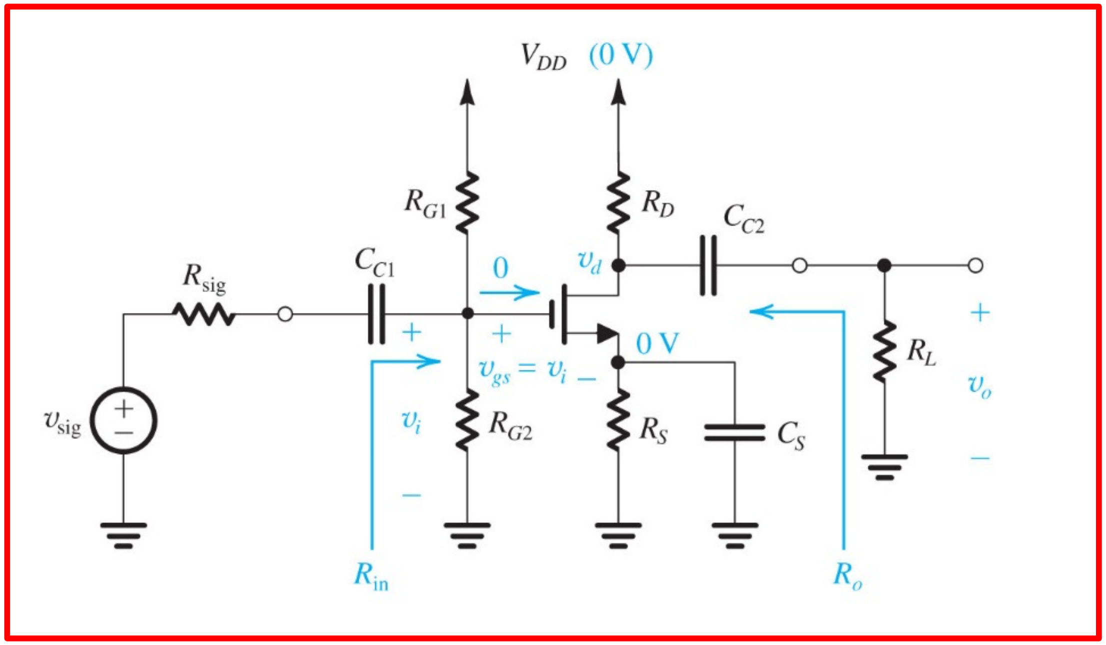
A_{vo} is the maximum possible gain of the amplifier.

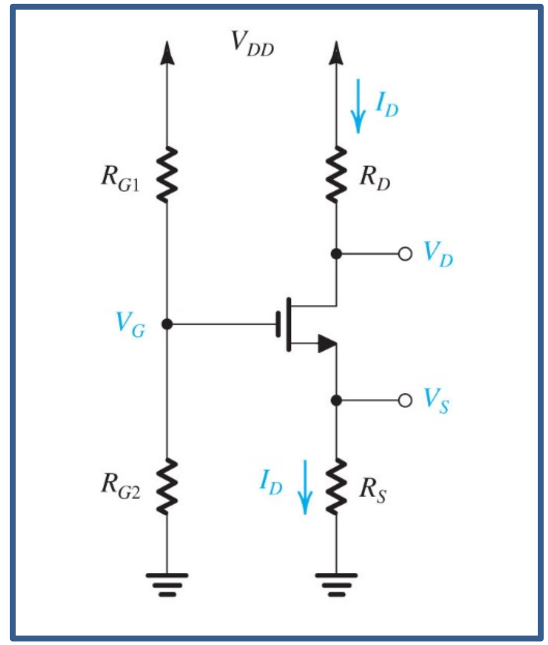
Value of R_o is important.

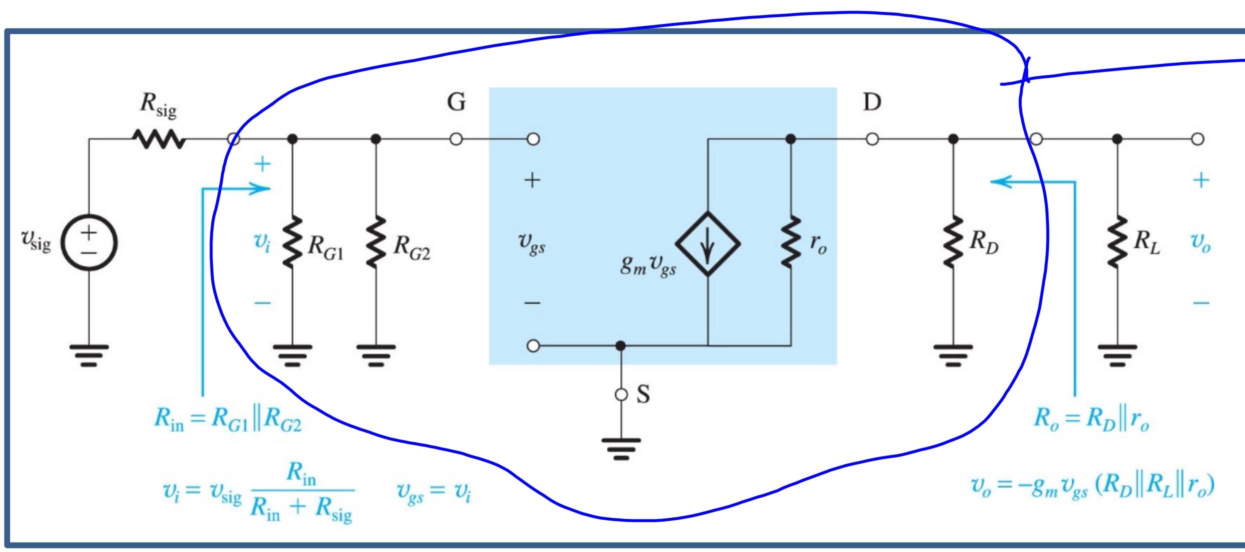
- For $R_o << R_L$, $A_v \approx A_{vo}$
- For $R_o = R_L$, $A_v = 0.5\ A_{vo}$
- For $R_o >> R_L$, $A_v \approx 0$

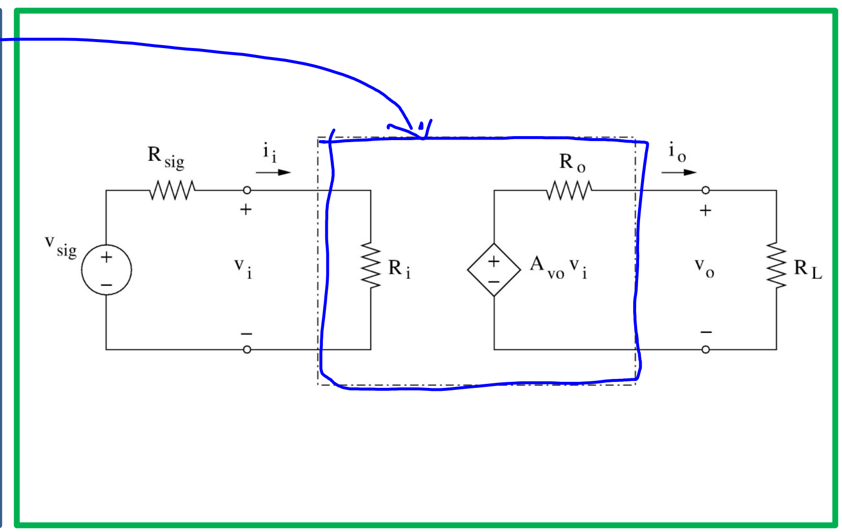
Prefer "small" R_o

From an amplifier circuit to the building block representation

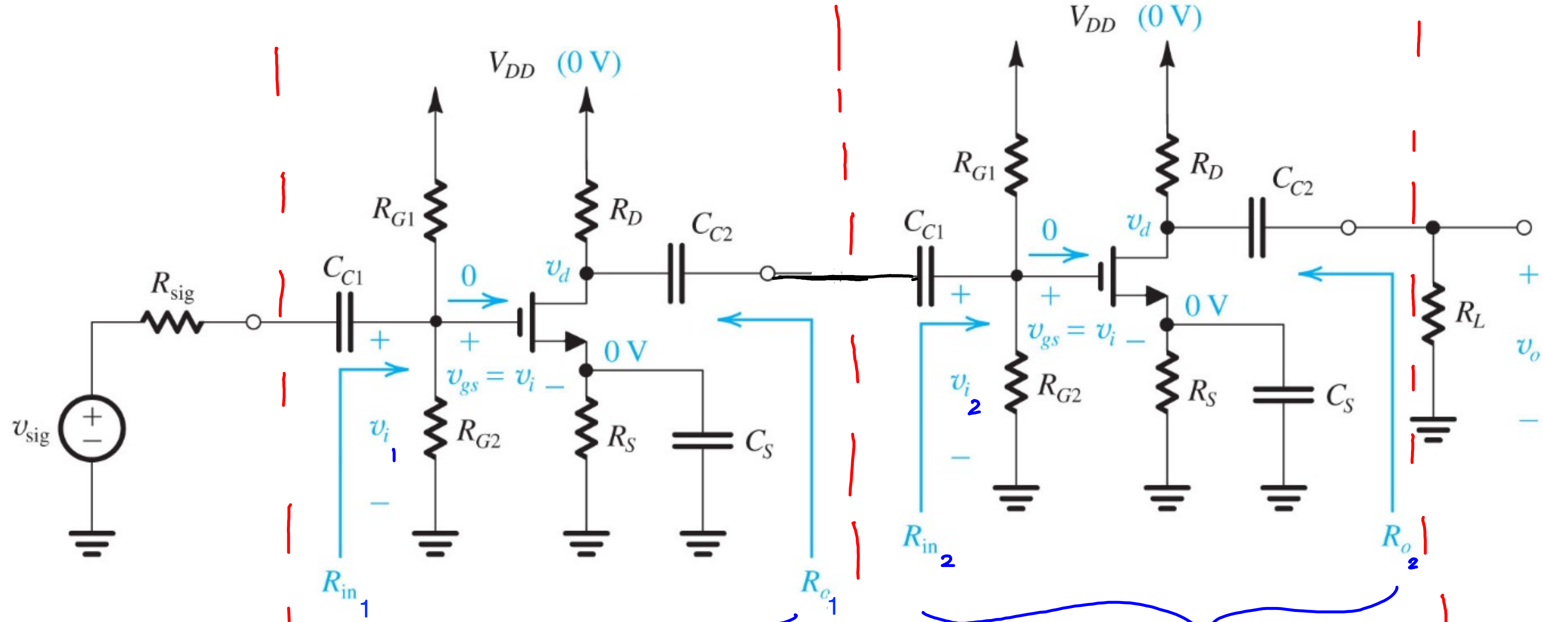


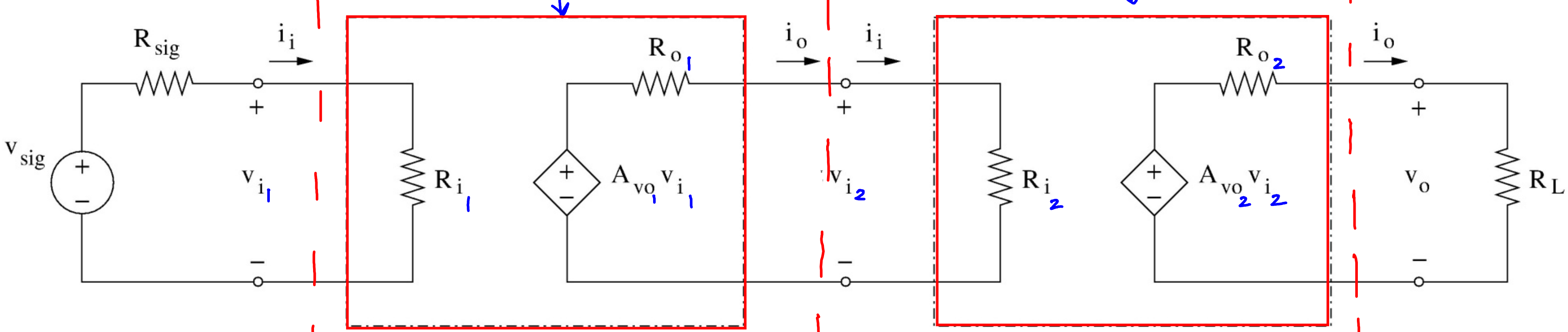






Cascade of amplifiers





$$\frac{v_o}{v_{sig}} = \left(\frac{R_L}{R_L + R_{o_2}} A_{vo_2}\right)\left(\frac{R_{i_2}}{R_{i_2} + R_{o_1}} A_{vo_1}\right)\frac{R_{i_1}}{R_{i_1} + R_{sig}}$$

$$\frac{v_o}{v_{sig}} = \frac{v_o}{v_{i_2}} \cdot \frac{v_{i_2}}{v_{i_1}} \cdot \frac{v_{i_1}}{v_{sig}}$$

Solving the Transistor Amplifier circuits

- Draw the Bias circuit and find the Bias point
- Find the small signal parameters (g_m, r_o, r_π)
- Draw the signal equivalent circuit
- Find the amplifiers parameters (R_i, R_o, A_{v_0})
- Use the voltage amplifier model and the calculated parameters to find the amplifier circuit gain (A).

Transistor Amplifier configurations

Possible BJT amplifier configurations

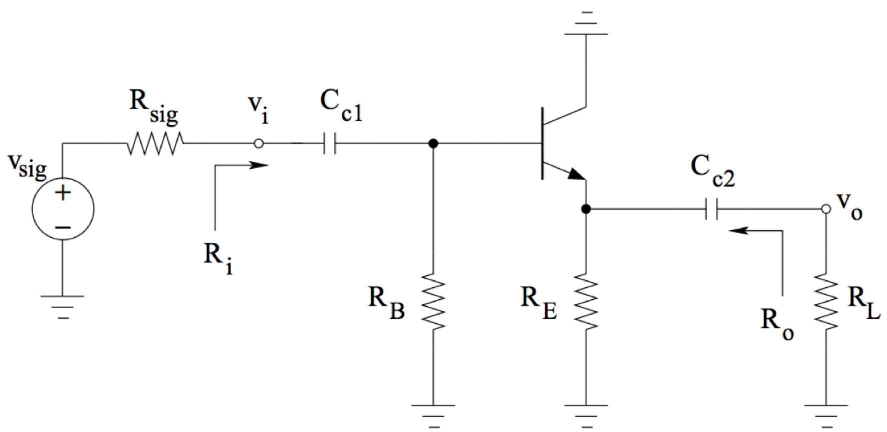
- Common-Collector or Emitter Follower
- Common-Emitter
  - Common-Emitter with an Emitter resistor
- Common-Base

Possible BJT amplifier configurations

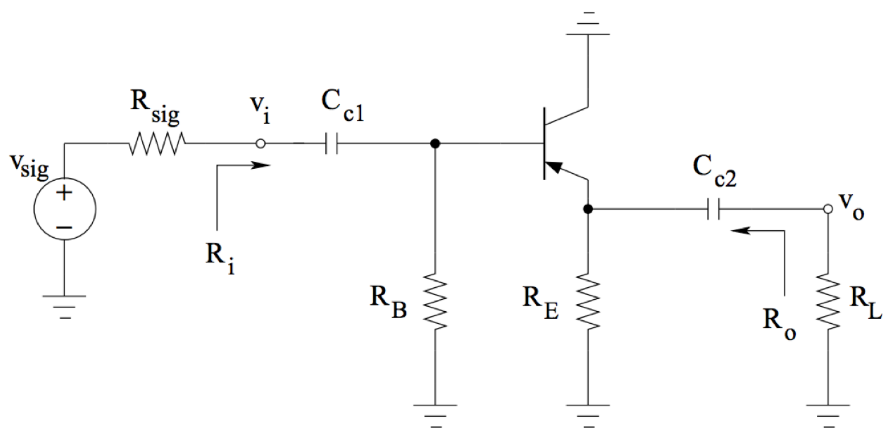
Common-Collector or Emitter Follower

The input is applied at the base and the output is taken at the emitter.

NPN BJT

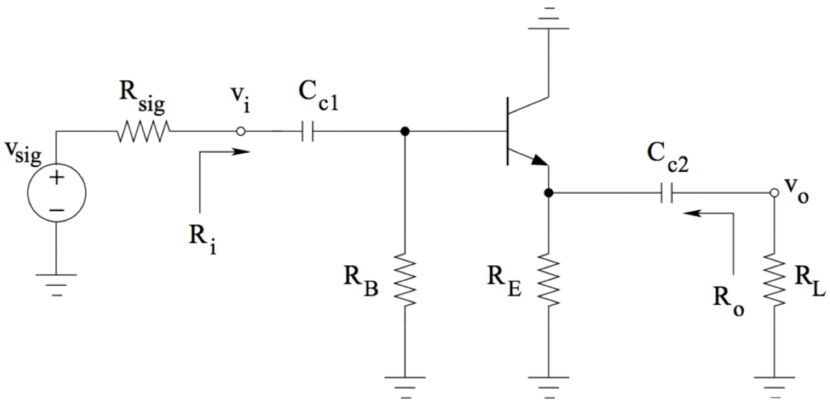


PNP BJT

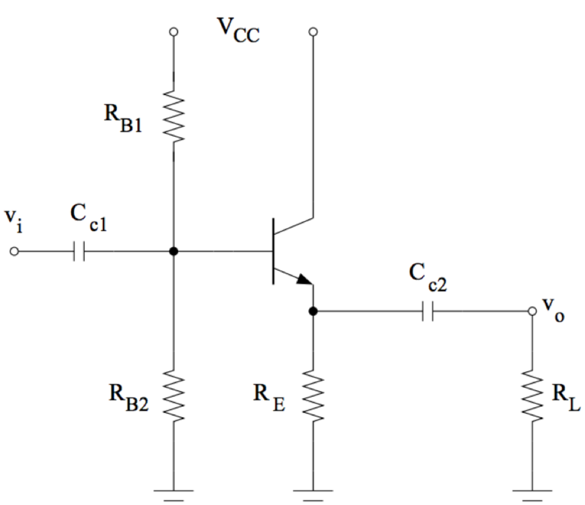


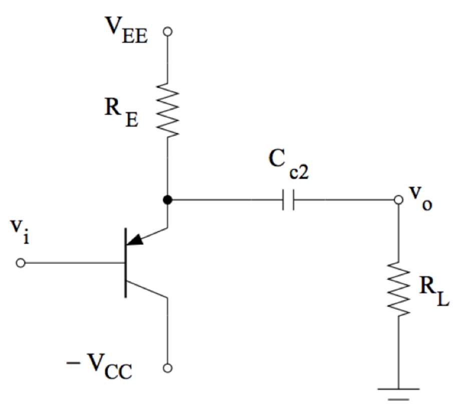
Possible BJT amplifier configurations

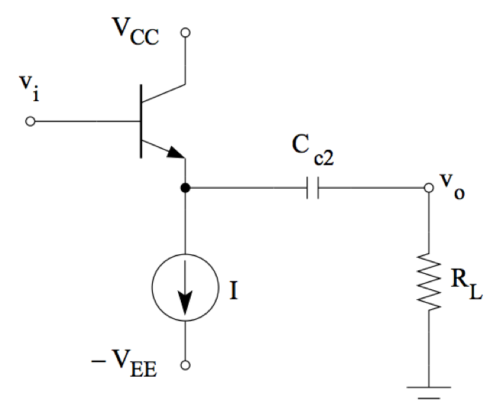
Common-Collector or Emitter Follower



Some example (Bias + Signal) circuits in Common-Collector configuration:



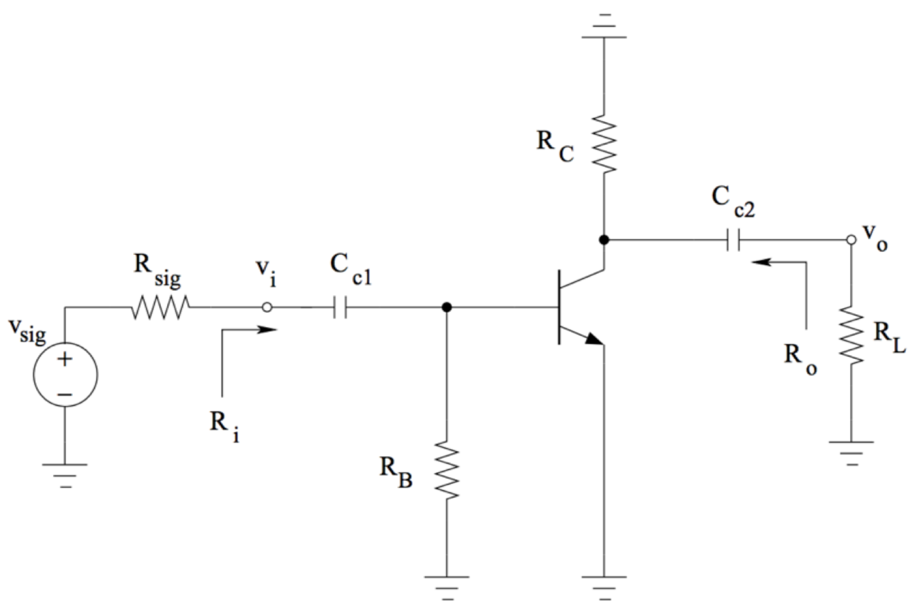


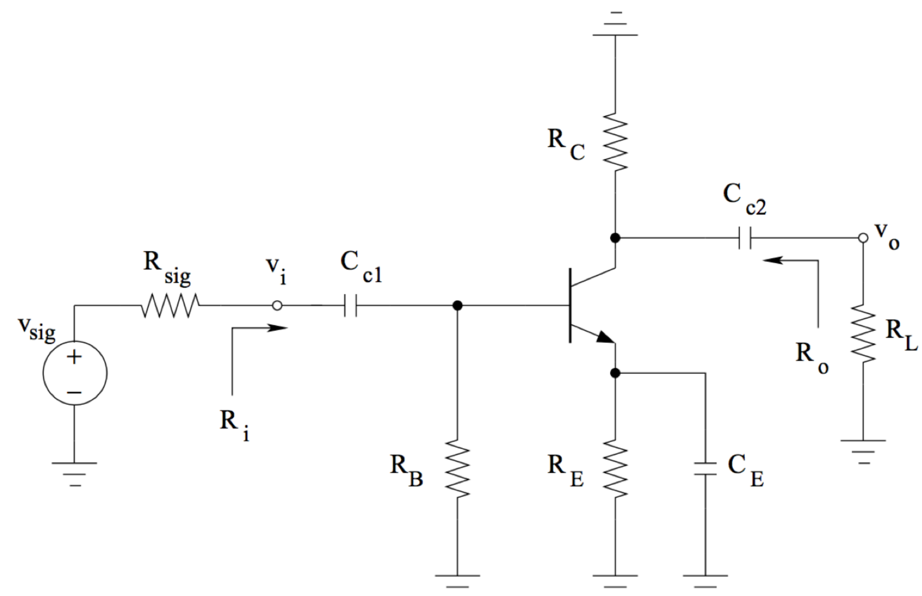


Possible BJT amplifier configurations

Common-Emitter

The input is applied at the base and the output is taken at the collector.



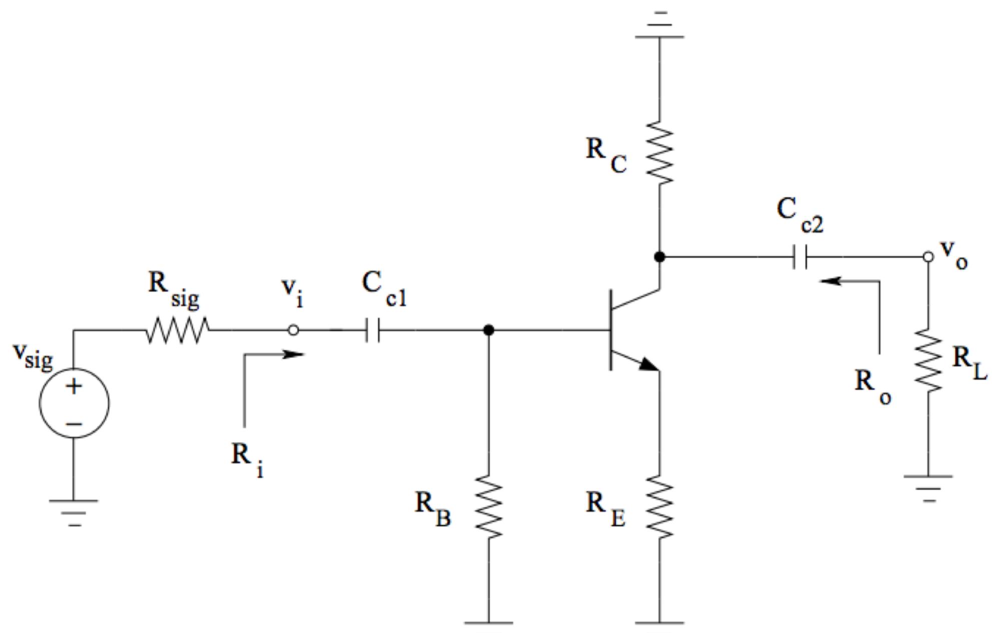


An emitter resistor is used for the Bias, but it is shorted in the signal circuit

Possible BJT amplifier configurations

Common-Emitter with an Emitter resistor

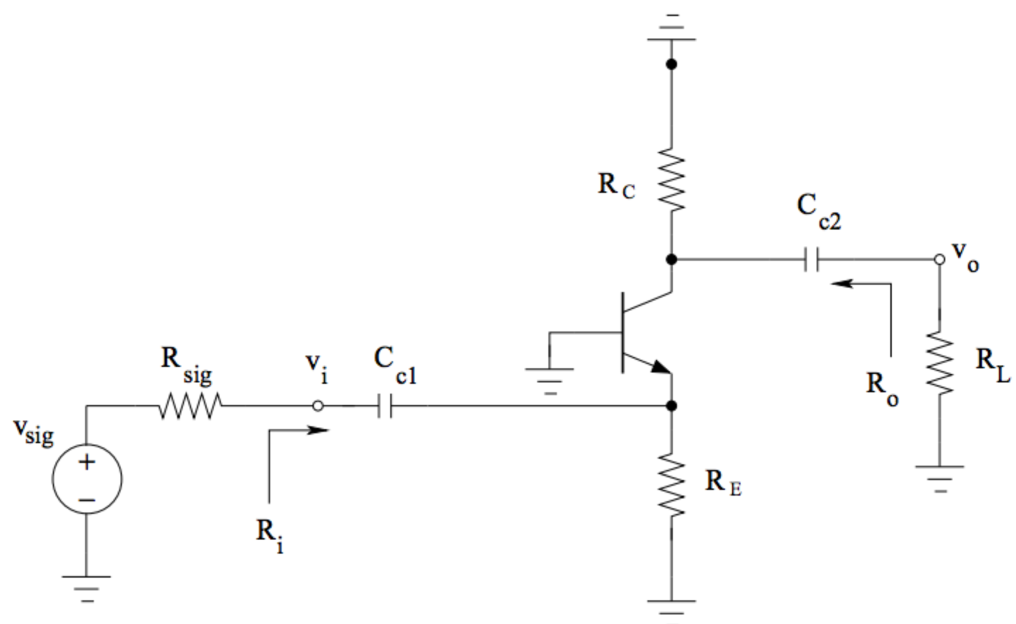
The input is applied at the base and the output is taken at the collector.



Possible BJT amplifier configurations

Common-Base

The input is applied at the emitter and the output is taken at the collector.



Possible MOS amplifier configurations

Common-Drain or Source Follower

Common-Source

- Common-Source with a Source resistor

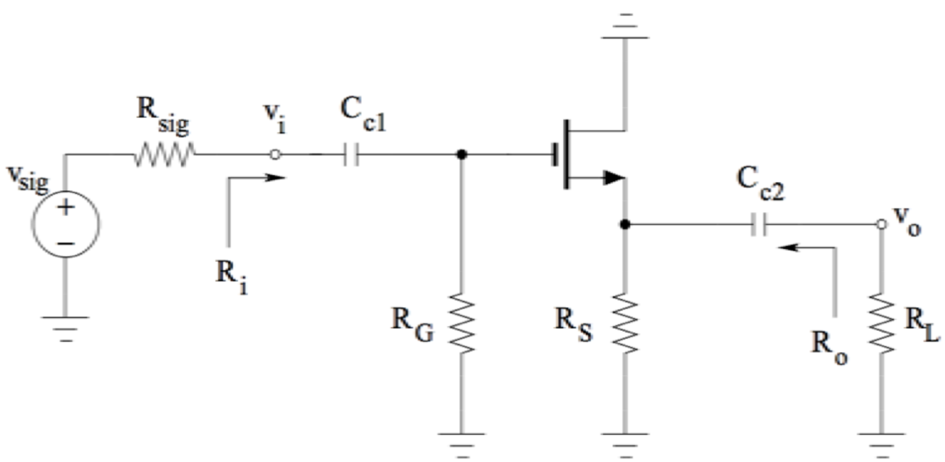
Common-Gate

Possible MOS amplifier configurations

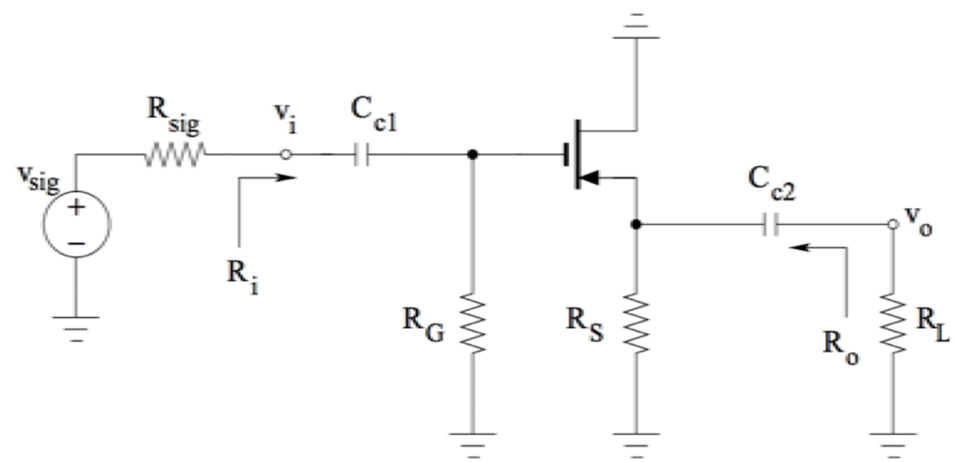
Common-Drain or Source Follower

The input is applied at the gate and the output is taken at the source.

NMOS

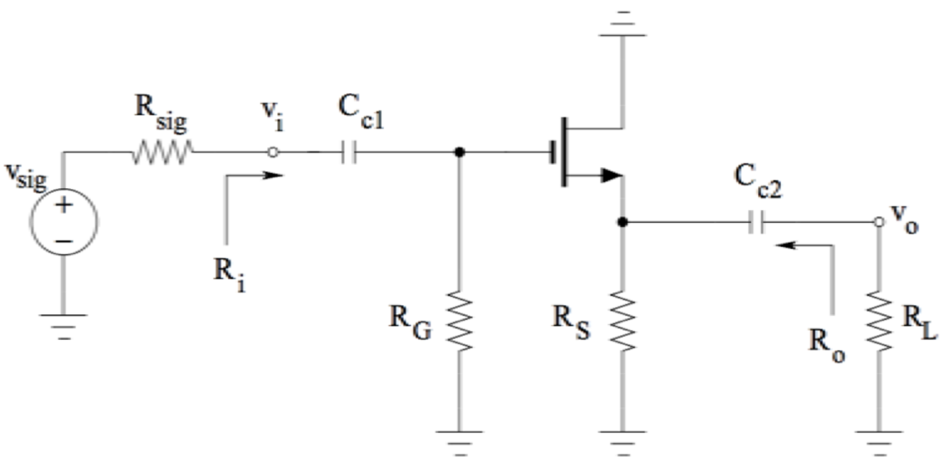


PMOS

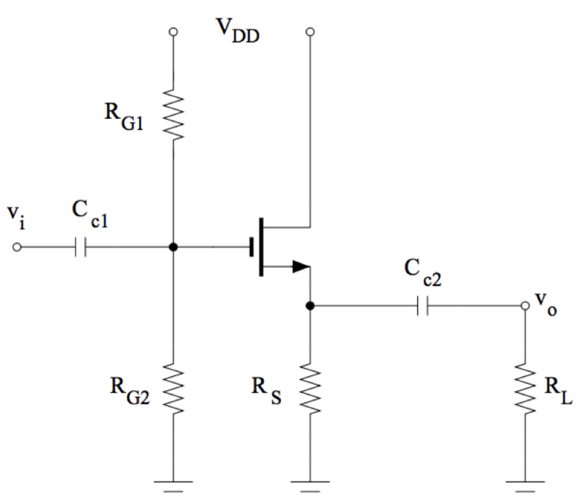


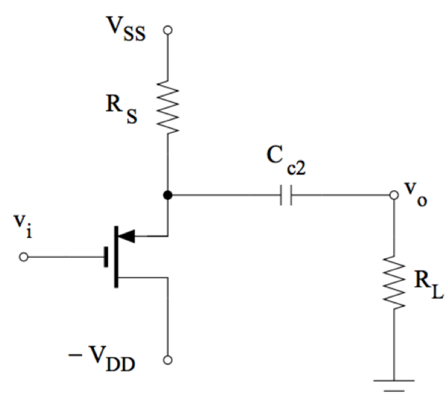
Possible MOS amplifier configurations

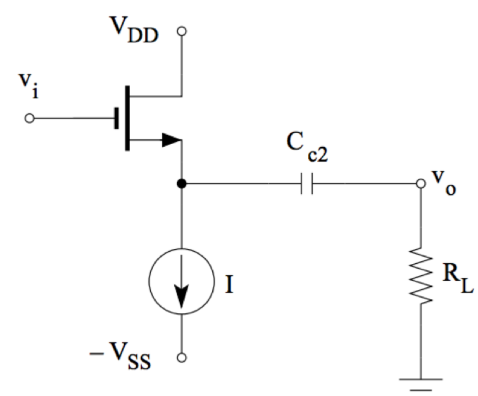
Common-Drain or Source Follower



Some example (Bias + Signal) circuits in Common-Drain configuration:



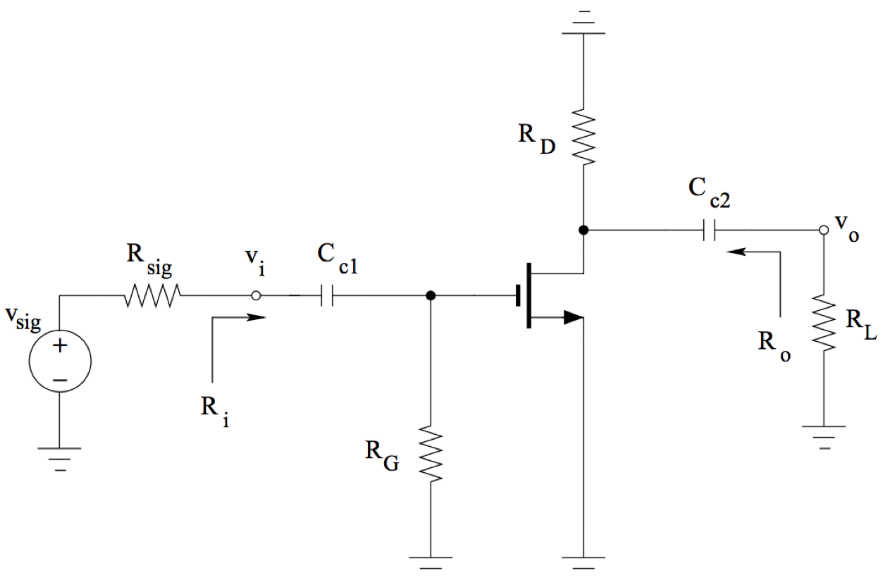


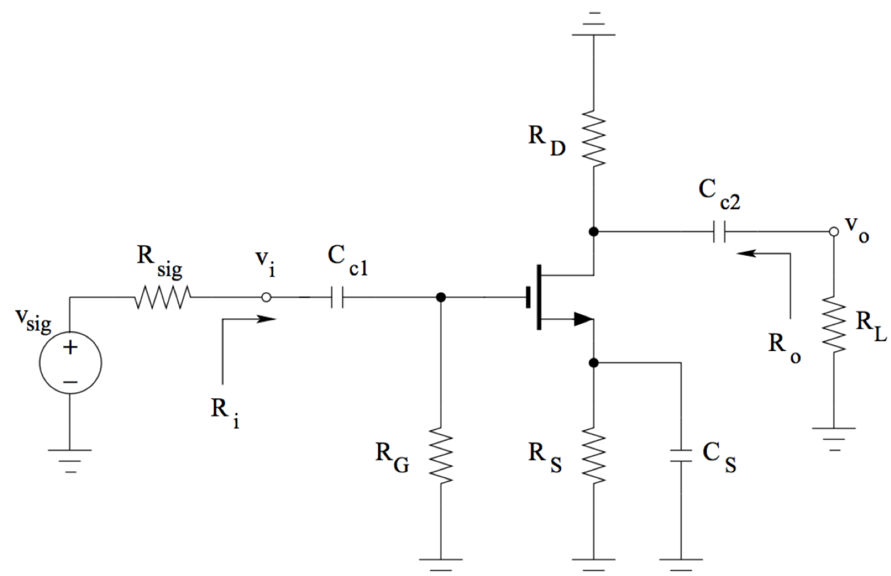


Possible MOS amplifier configurations

Common-Source

The input is applied at the gate and the output is taken at the drain.



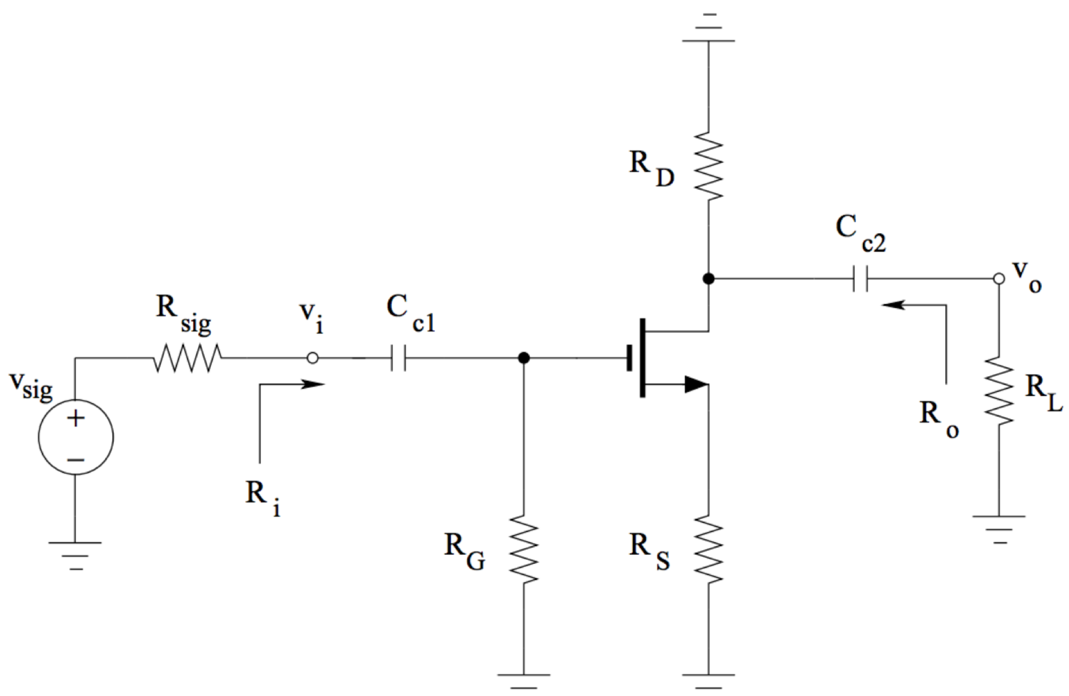


A source resistor is used for the Bias, but it is shorted in the signal circuit

Possible MOS amplifier configurations

Common-Source with a Source resistor

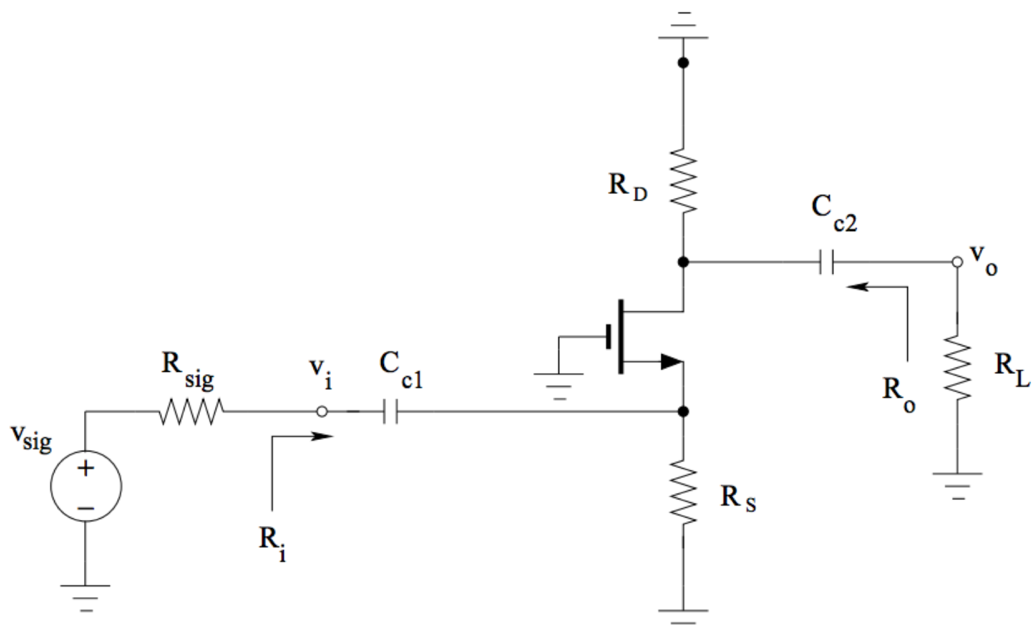
The input is applied at the gate and the output is taken at the drain.



Possible MOS amplifier configurations

Common-gate

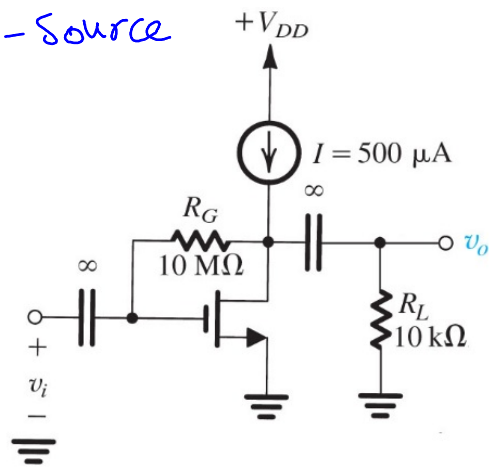
The input is applied at the source and the output is taken at the drain.



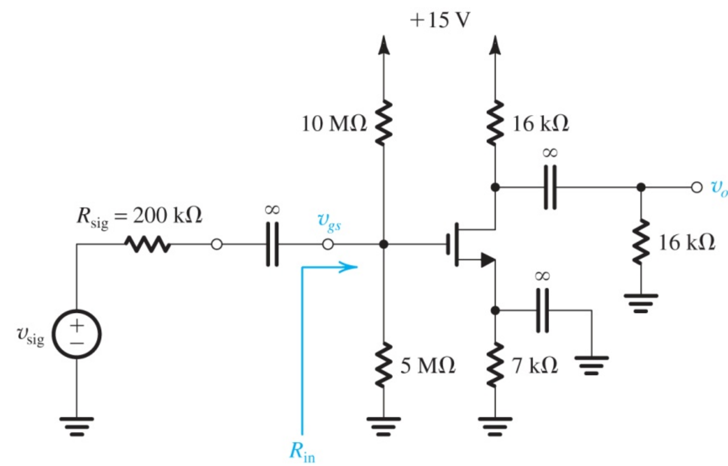
Lecture 21 reading quiz

Which one of the answers is correct about the configuration of the given amplifiers:

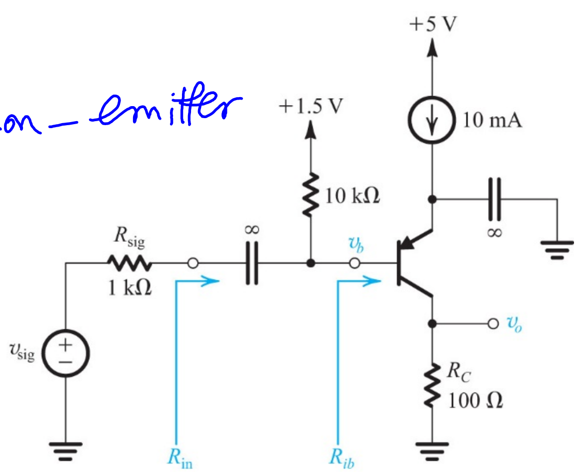
common-Source



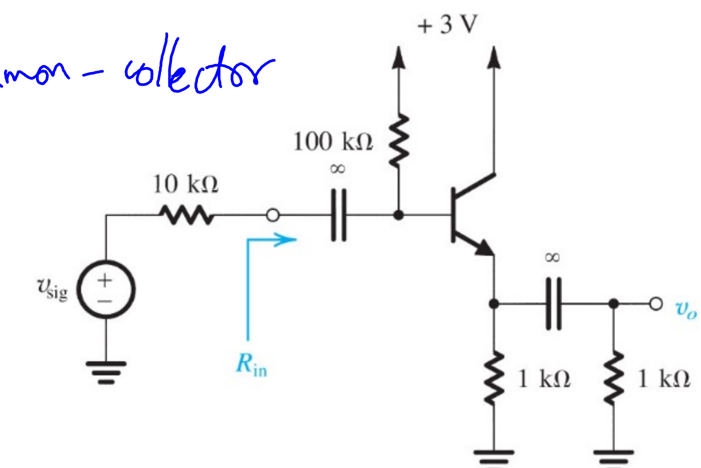
common Source



Common-emitter



Common-collector



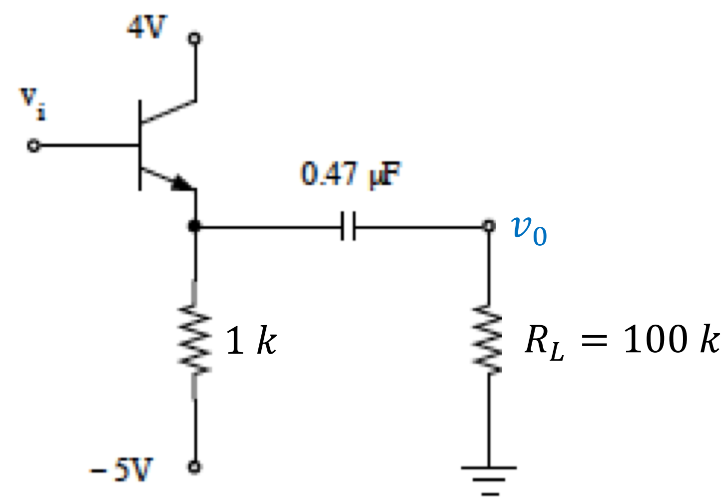
Clicker question 1.

What is the amplifier configuration for the following circuit?

A. Common-Base

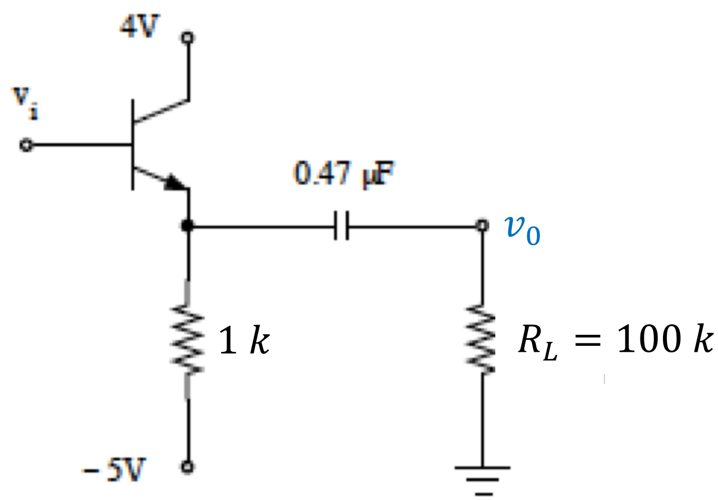
B. Common-Emitter

C. Common-Collector



Clicker question 2.

Draw the signal circuit and find the open loop voltage gain of the amplifier ($A_{vo} = \left.\frac{v_o}{v_i}\right|_{R_L\to\infty}$) for this circuit. Let $\beta = 100,\ \ V_T = 25\ mV,\ V_A = 150\ V$.



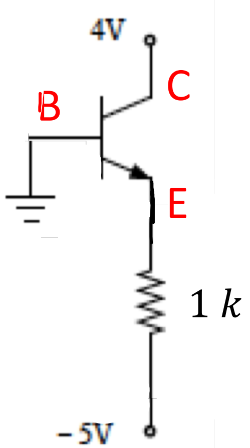
A. $A_{vo} = 0.67\ \ V/V$

B. $A_{vo} = 0.99\ \ V/V$

C. $A_{vo} = 0.53\ \ V/V$

D. $A_{vo} = 0.49\ \ V/V$

Bias circuit, Bias point and small signal parameters:



$$I_C \approx I_E = 4.3\ mA$$

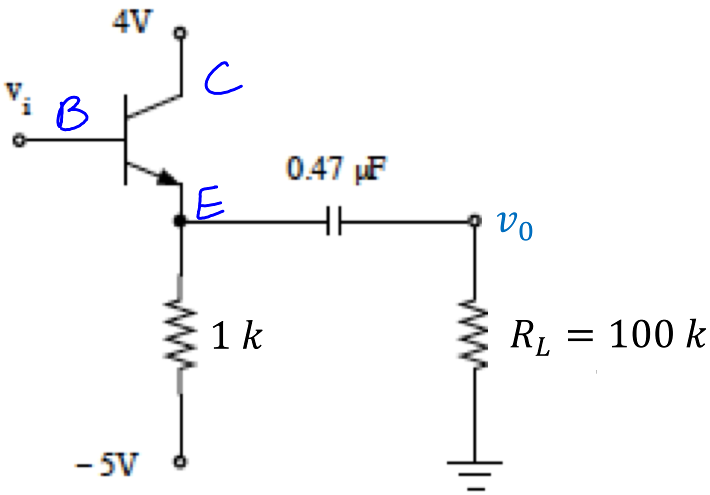
$$V_{CE} = 4.7\ V$$

$$r_\pi = \frac{V_T}{I_B} = 581.4\ \Omega$$

$$g_m = \frac{I_C}{V_T} = 0.172\ \ A/V$$

$$r_o = \frac{V_A}{I_C} \approx 35\ k\Omega$$

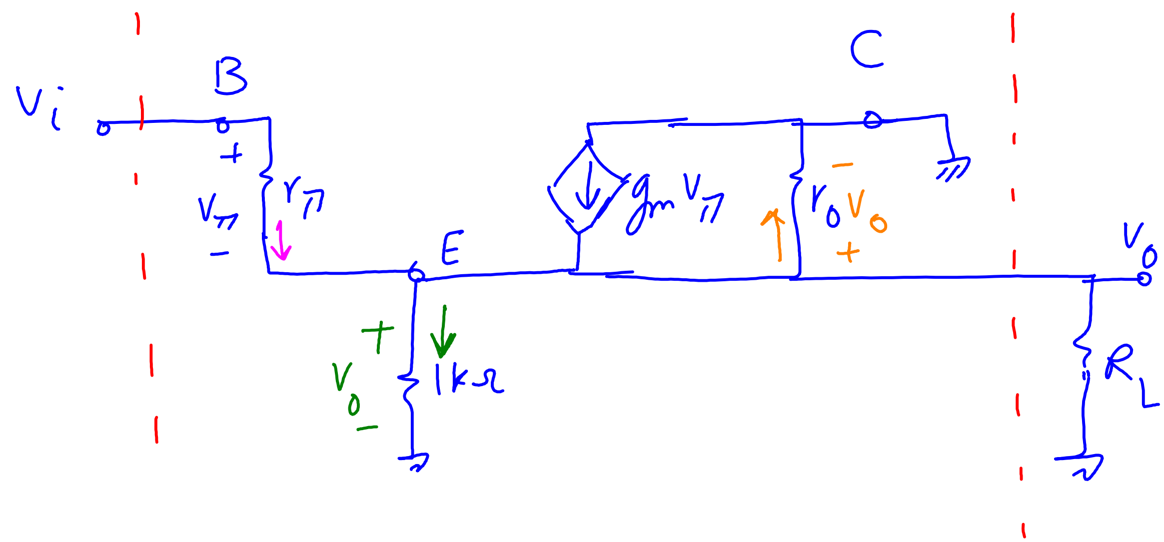
Clicker question 2.



$$r_\pi = \frac{V_T}{I_B} = 581.4\ \Omega \qquad r_o = \frac{V_A}{I_C} \approx 35\ k\Omega$$

$$g_m = \frac{I_C}{V_T} = 0.172\ A/V$$

small signal circuit:



$$A_{v_0} = \left.\frac{V_0}{V_i}\right|_{R_L \to \infty}$$

KCL at node E:

$$\boxed{\frac{V_0}{r_0}} + \boxed{\frac{V_0}{1k\Omega}} - g_m V_\pi - \boxed{\frac{V_\pi}{r_\pi}} = 0$$

$$V_\pi = V_i - V_0 \longrightarrow \text{when } R_L \to \infty : \quad \frac{V_0}{V_i} = \frac{g_m + \frac{1}{r_\pi}}{g_m + \frac{1}{r_\pi} + \frac{1}{r_0} + \frac{1}{1k}}$$

$$\boxed{A_{v_0} \simeq 0.99\ V/V}$$