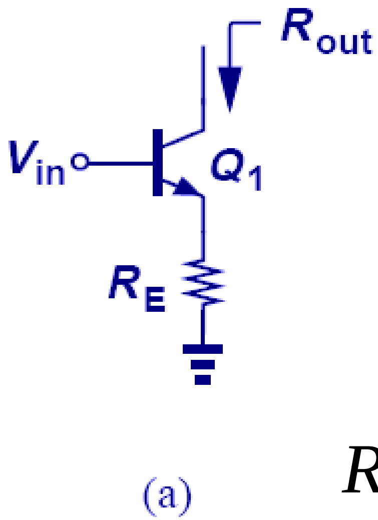
Lecture 8

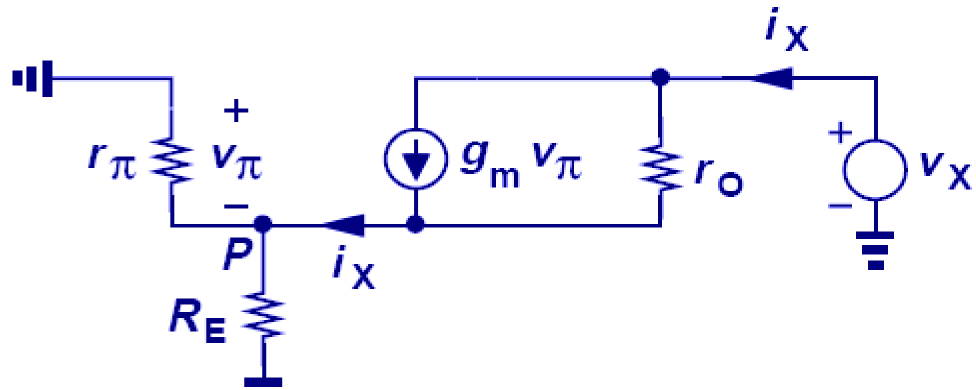
OUTLINE

- Bipolar Amplifier Topologies (Cont'd)
  – Common-Emitter Amplifiers

Reading: Chapter 5.3.1

Output Impedance of Degenerated Stage with Finite V_A

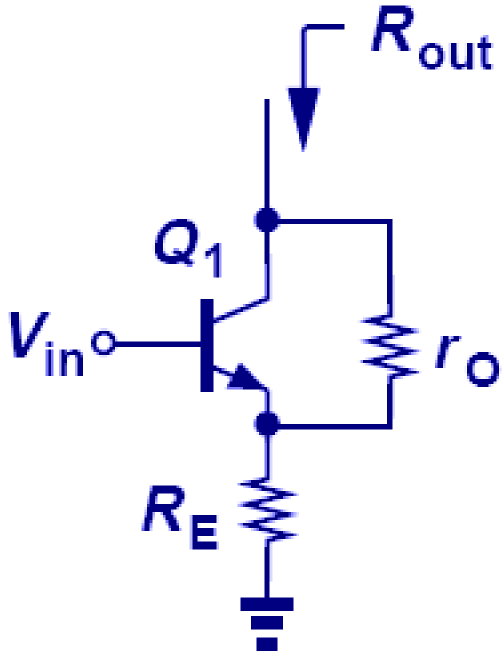




$$R_{out} = \left[1 + g_m (R_E \| r_\pi)\right] r_O + R_E \| r_\pi$$
$$R_{out} = r_O + (g_m r_O + 1)(R_E \| r_\pi)$$
$$R_{out} \approx r_O \left[1 + g_m (R_E \| r_\pi)\right]$$

- Emitter degeneration boosts the output impedance by a factor of $1+g_m(R_E||r_\pi)$.
- This improves the gain of the amplifier and makes the circuit a better current source.

Two Special Cases



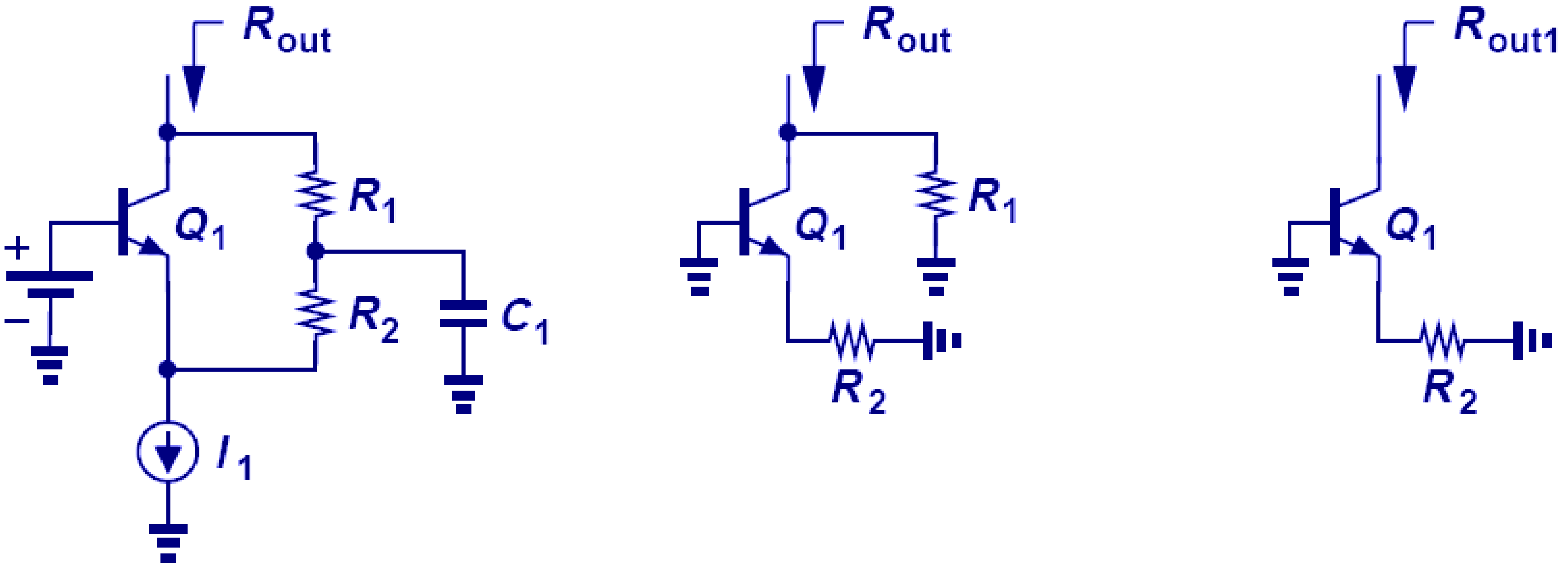
(1) $R_E >> r_\pi$

$R_{out} \approx r_O(1+g_m r_\pi) \approx \beta r_O$

(2) $R_E << r_\pi$

$R_{out} \approx (1+g_m R_E) r_O$

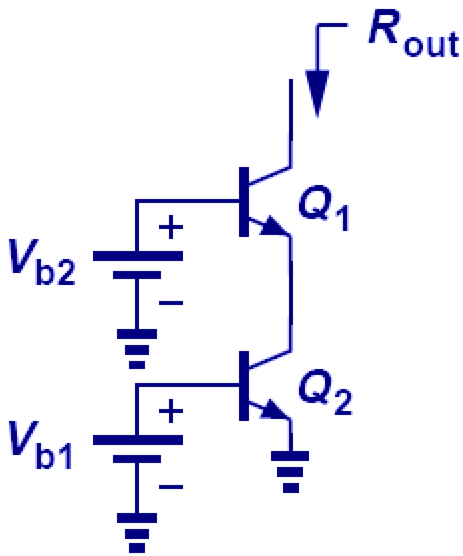
Analysis by Inspection

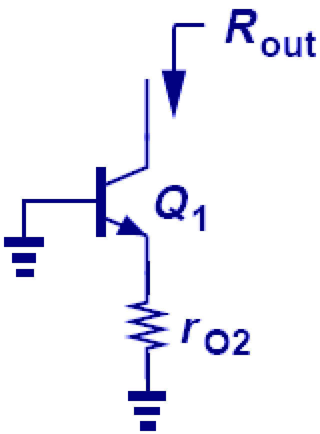


$$R_{out} = R_1 \parallel R_{out1} \Rightarrow R_{out1} = [1 + g_m (R_2 \parallel r_\pi)] r_O \Rightarrow R_{out} = [1 + g_m (R_2 \parallel r_\pi)] r_O \parallel R_1$$

- This seemingly complicated circuit can be greatly simplified by first recognizing that the capacitor creates an AC short to ground, and gradually transforming the circuit to a known topology.

Example: Degeneration by Another Transistor

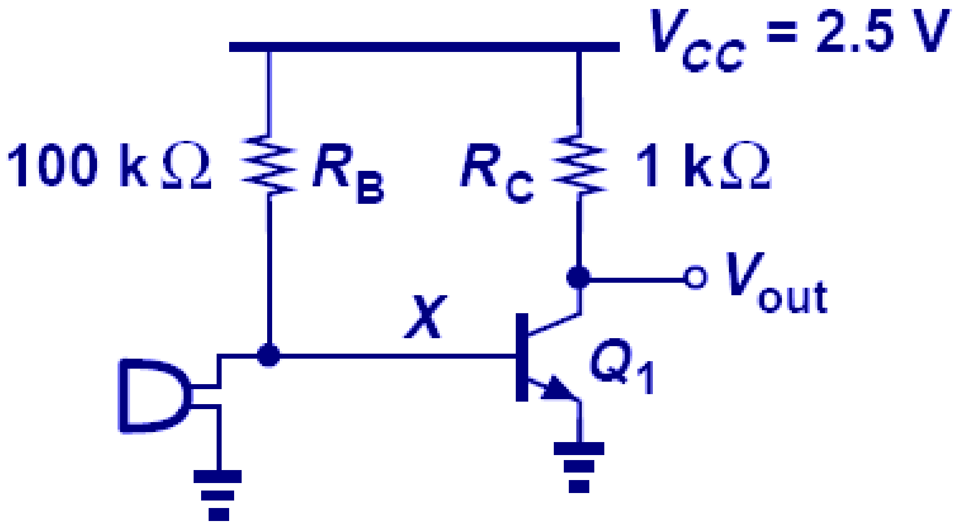




$$R_{out} = \left[1 + g_{m1}(r_{O2} \,\|\, r_{\pi 1})\right] r_{O1}$$

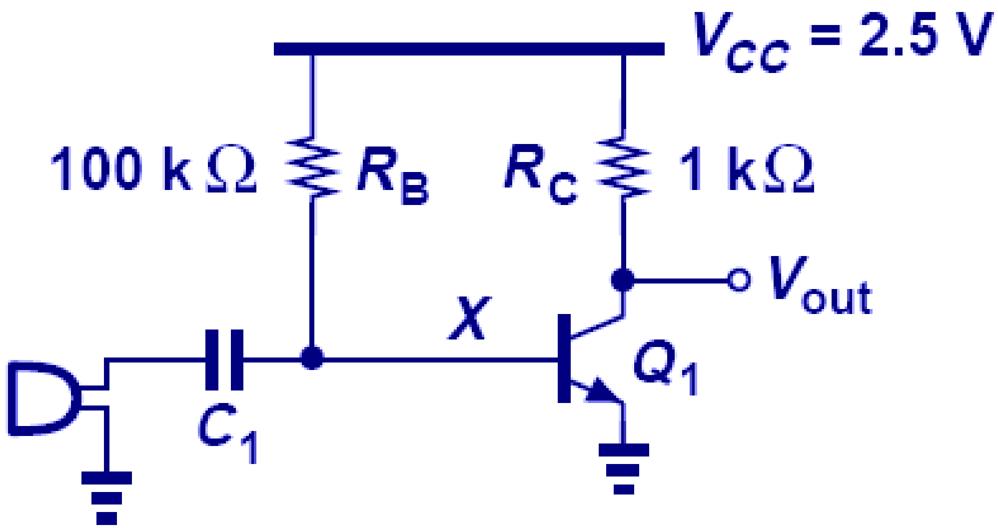
- Called a "cascode", the circuit offers many advantages that are described later in the book.

Bad Input Connection



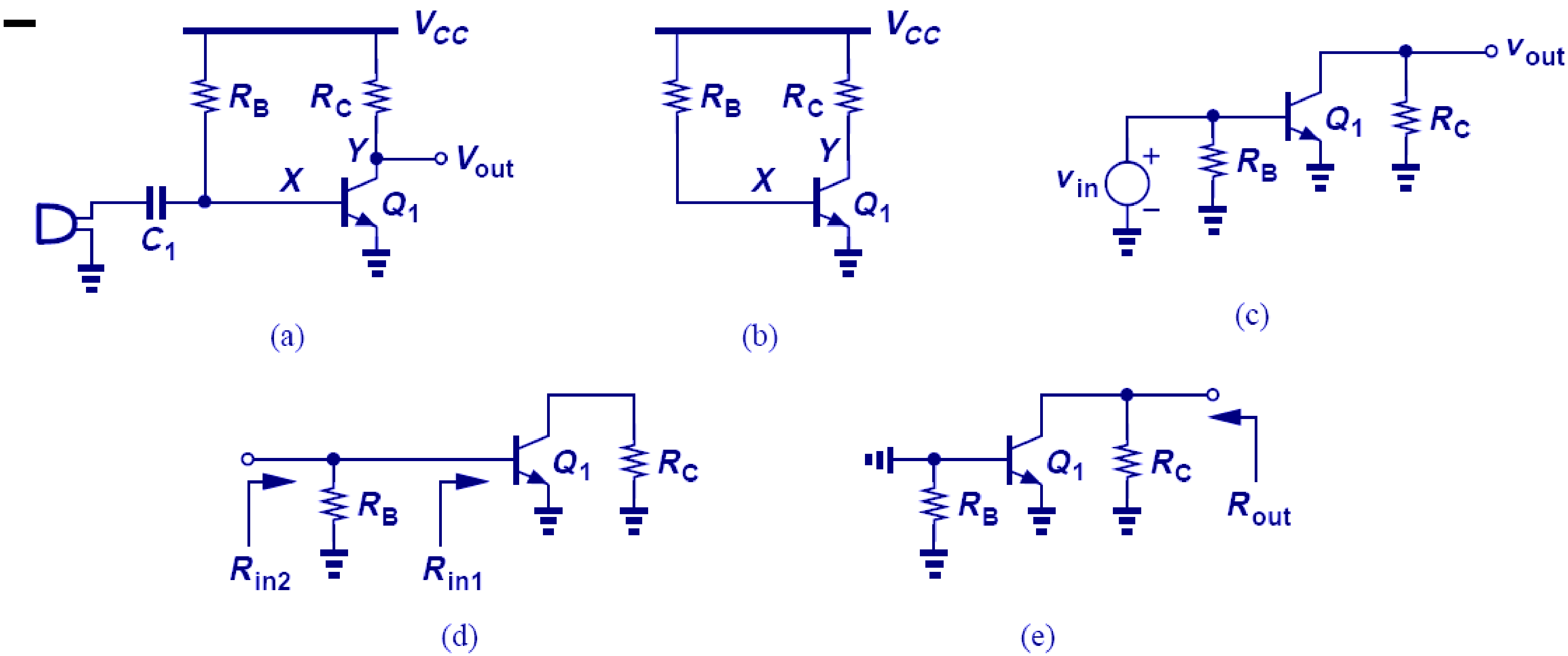
- Since the microphone has a very low resistance that connects from the base of Q_1 to ground, it attenuates the base voltage and renders Q_1 without a bias current.

Use of Coupling Capacitor



- Capacitor isolates the bias network from the microphone at DC but shorts the microphone to the amplifier at higher frequencies.

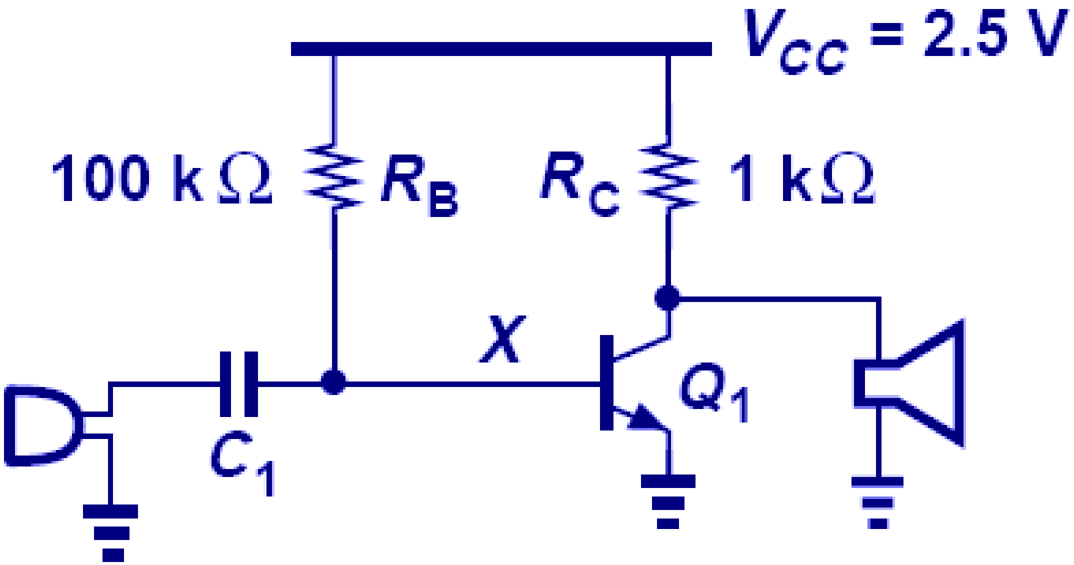
DC and AC Analysis



$$A_v = -g_m (R_C \parallel r_O)$$
$$R_{in} = r_\pi \parallel R_B$$
$$R_{out} = R_C \parallel r_O$$

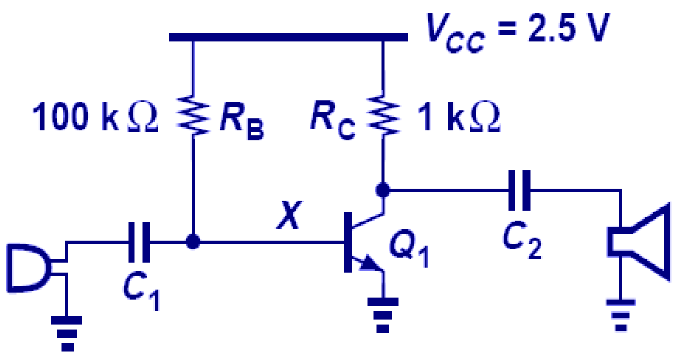
- Coupling capacitor is open for DC calculations and shorted for AC calculations.

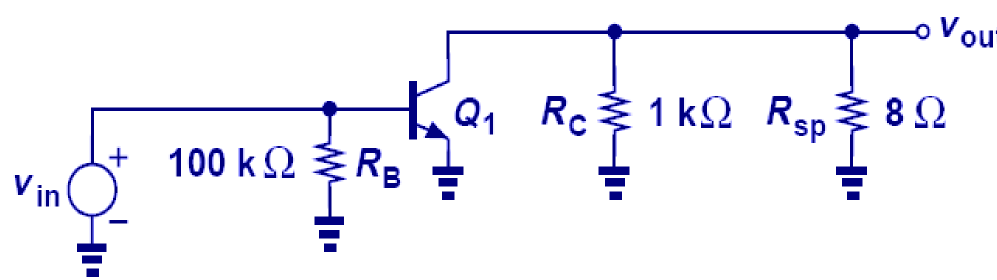
Bad Output Connection



- Since the speaker has an inductor, connecting it directly to the amplifier would short the collector at DC and therefore push the transistor into deep saturation.

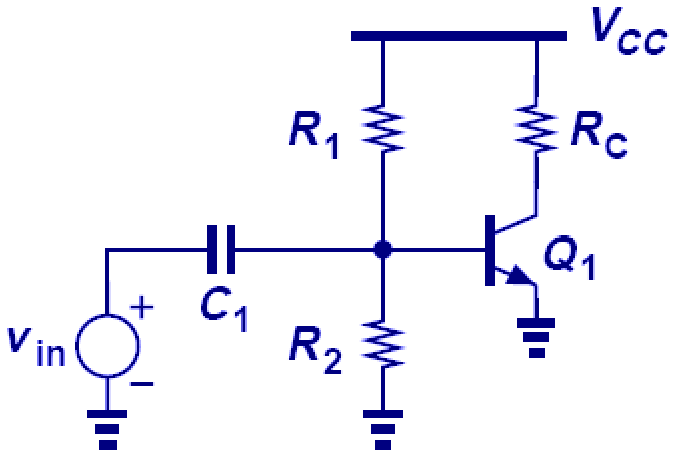
Still No Gain!!!

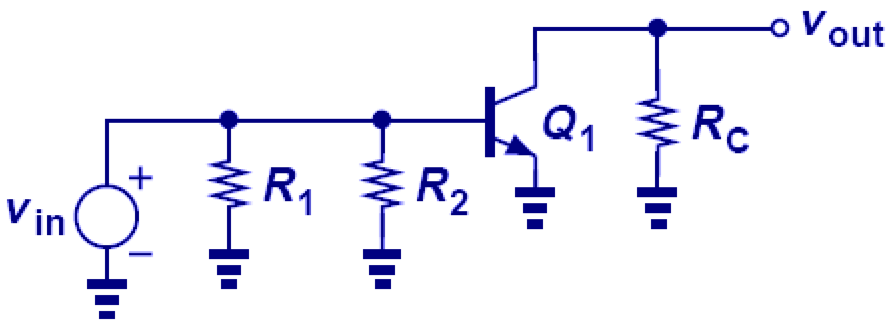




- In this example, the AC coupling indeed allows correct biasing. However, due to the speaker’s small input impedance, the overall gain drops considerably.

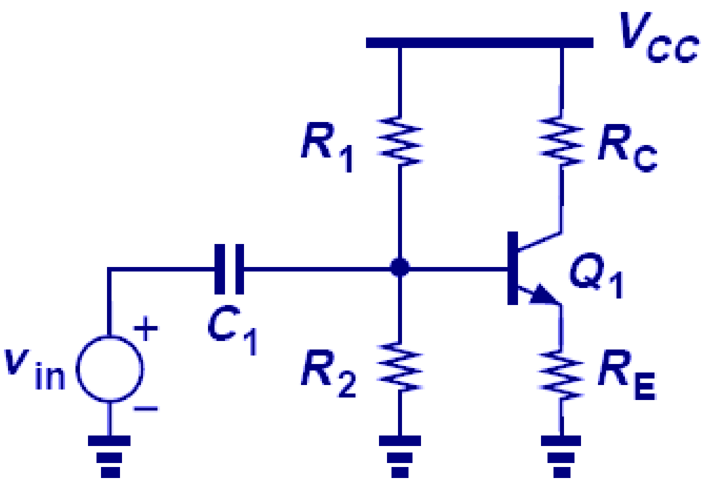
CE Stage with Biasing

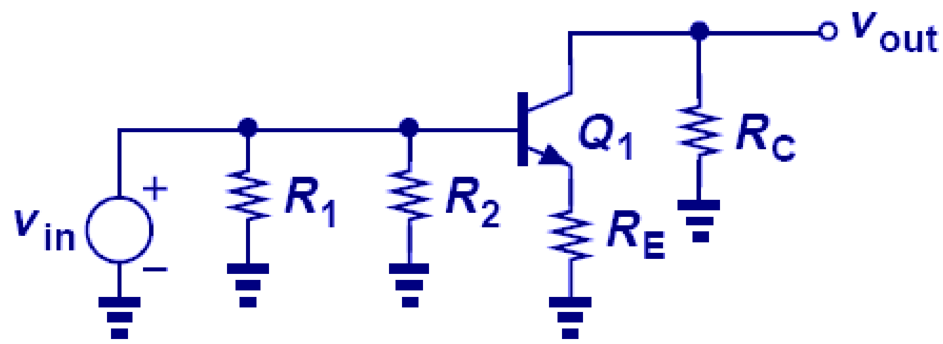




$$A_v = -g_m (R_C \| r_O)$$
$$R_{in} = r_\pi \| R_1 \| R_2$$
$$R_{out} = R_C \| r_O$$

CE Stage with Robust Biasing



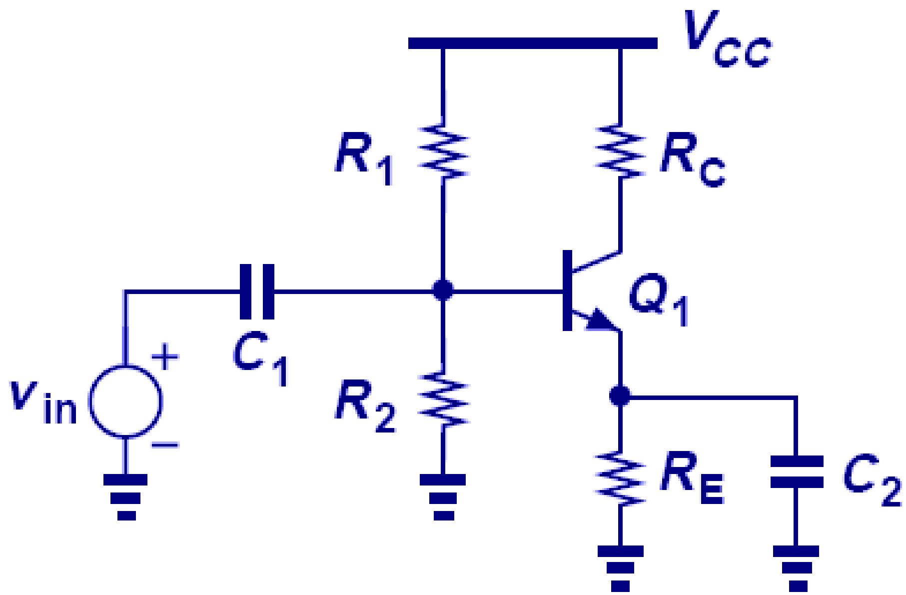


$$A_v = \frac{-R_C}{\frac{1}{g_m} + R_E}$$

$$R_{in} = \left[r_\pi + (\beta+1)R_E\right] \| R_1 \| R_2$$

$$R_{out} = R_C$$

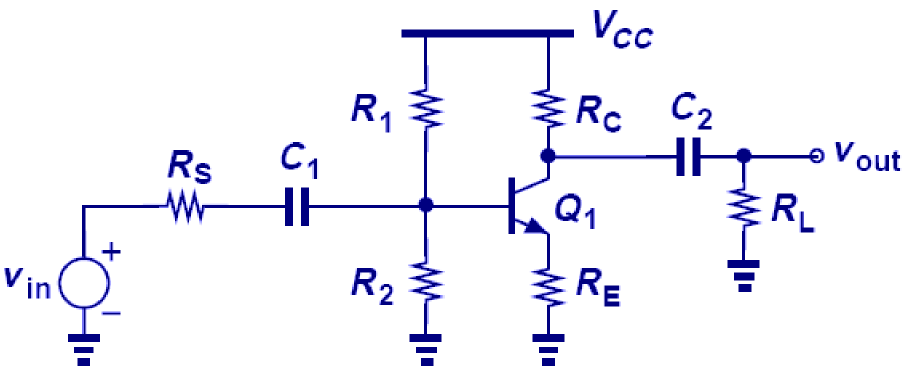
Removal of Degeneration for Signals at AC



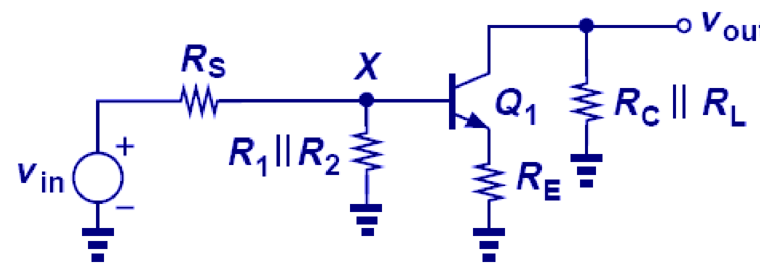
$$A_v = -g_m R_C$$
$$R_{in} = r_\pi \parallel R_1 \parallel R_2$$
$$R_{out} = R_C$$

- Capacitor shorts out RE at higher frequencies and removes degeneration.

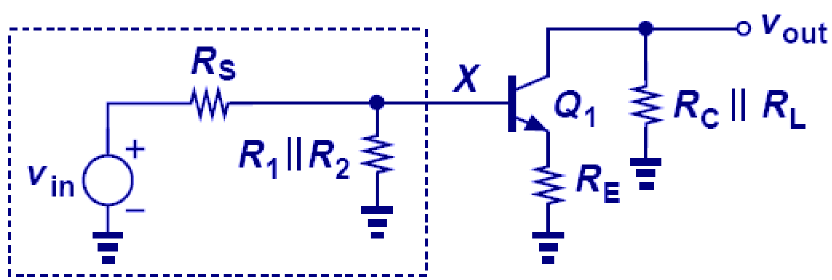
Complete CE Stage



(a)



(b)



(b)

$$A_v = \frac{-R_C \parallel R_L}{\frac{1}{g_m} + R_E + \frac{R_s \parallel R_1 \parallel R_2}{\beta + 1}}$$

Summary of CE Concepts