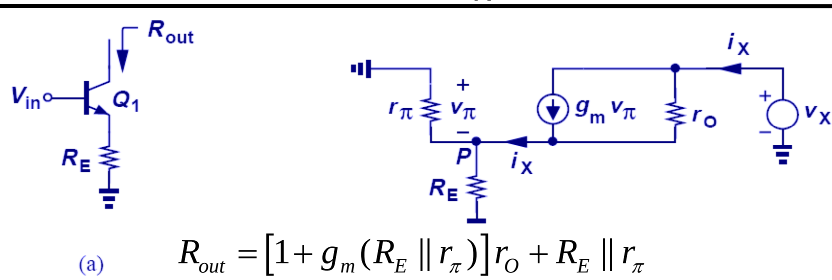
Lecture 8

OUTLINE

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

Reading: Chapter 5.3.1

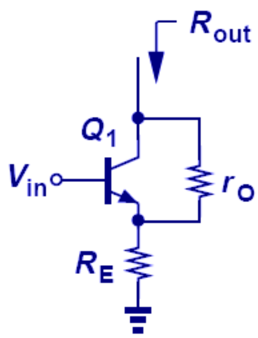
Output Impedance of Degenerated Stage with Finite V_A



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

- 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) $R_E << r_\pi$
$R_{out} \approx (1+g_m R_E) r_O$

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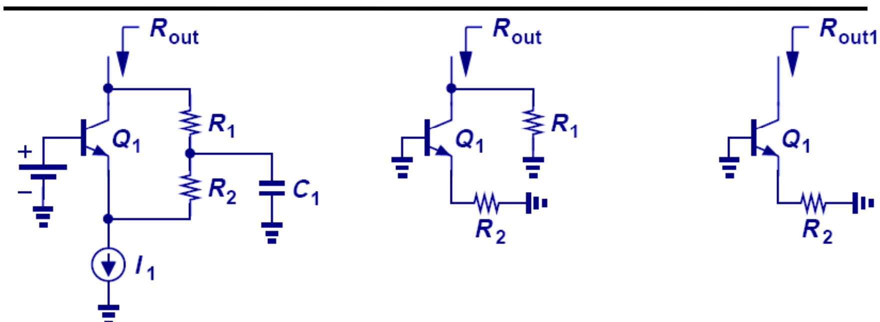
Analysis by Inspection



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

- 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.

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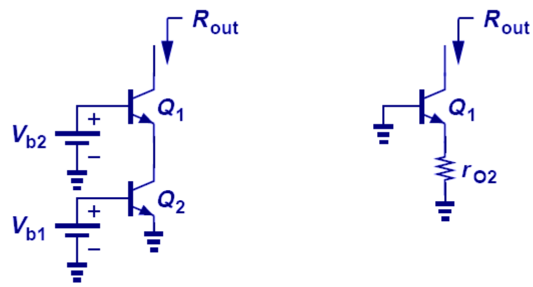
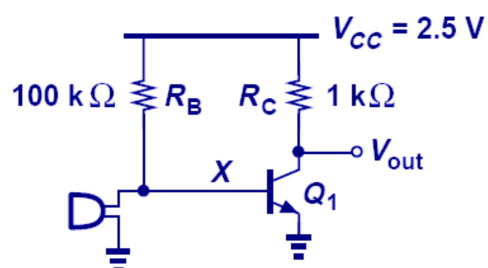
Example: Degeneration by Another Transistor



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

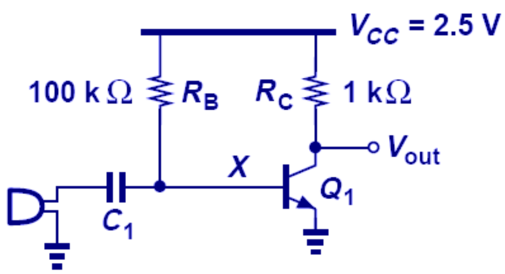
- Called a “cascode”, the circuit offers many advantages that are described later in the book.

Bad Input Connection



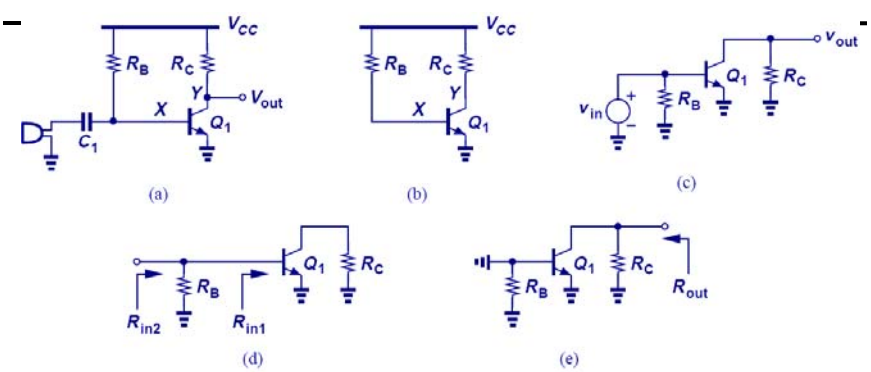
- Since the microphone has a very low resistance that connects from the base of Q_1 to ground, it attenuates the base voltage and renders Q_1 without a bias current.

Use of Coupling Capacitor



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

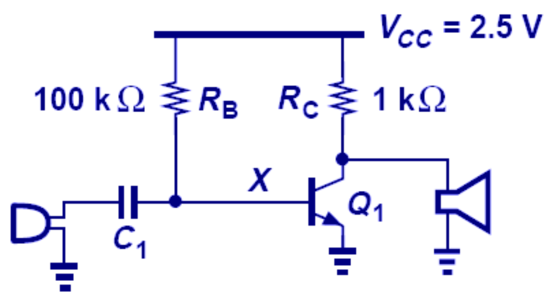
DC and AC Analysis



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

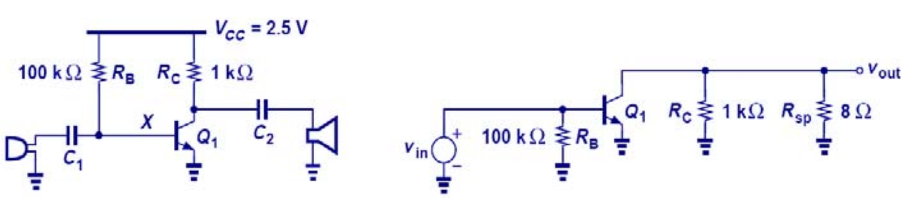
- Coupling capacitor is open for DC calculations and shorted for AC calculations.

Bad Output Connection



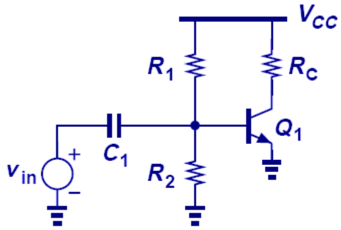
- Since the speaker has an inductor, connecting it directly to the amplifier would short the collector at DC and therefore push the transistor into deep saturation.

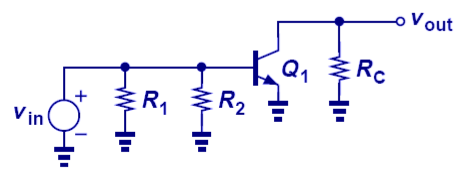
Still No Gain!!!



- 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





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

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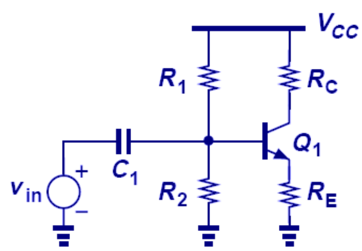
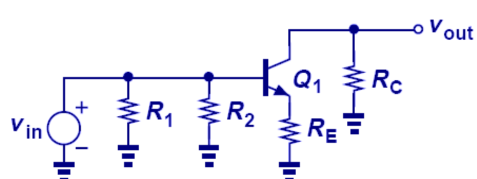
CE Stage with Robust Biasing





$$A_v = \frac{-R_C}{\frac{1}{g_m} + R_E}$$
$$R_{in} = \left[r_\pi + (\beta + 1) R_E \right] \parallel R_1 \parallel R_2$$
$$R_{out} = R_C$$

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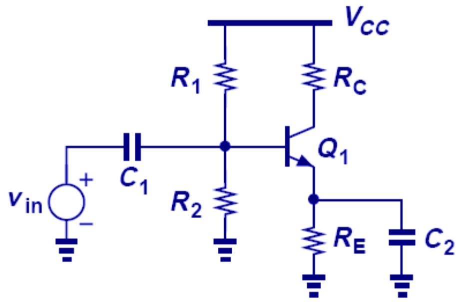
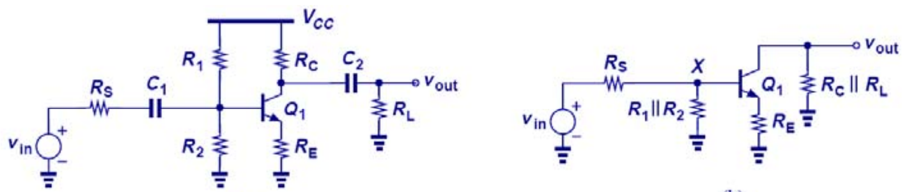
Removal of Degeneration for Signals at AC



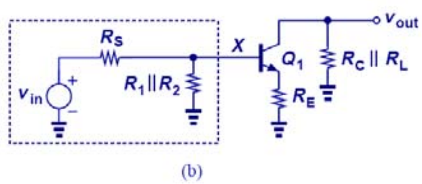
$$A_v = -g_m R_C$$
$$R_{in} = r_\pi \,||\, R_1 \,||\, R_2$$
$$R_{out} = R_C$$

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

Complete CE Stage



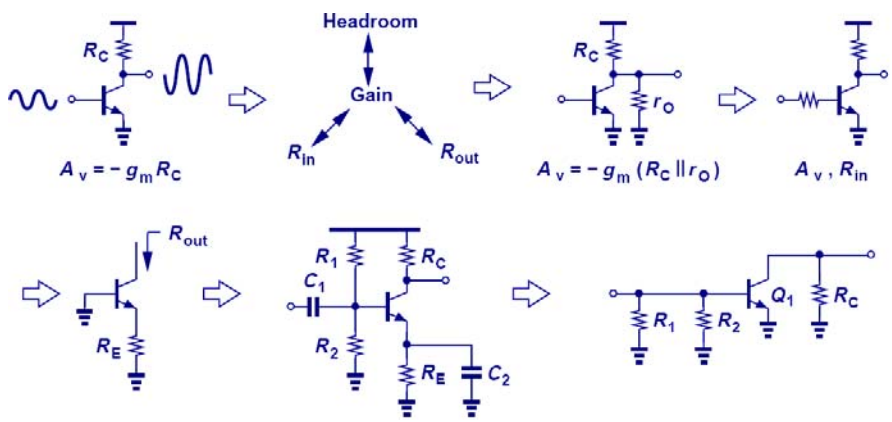
(a) (b)



(b)

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

Summary of CE Concepts



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