



VICTORIA UNIVERSITY OF
WELLINGTON
TE HERENGA WAKA
NEW ZEALAND

Final Exam Review

XMUT204 Electronic Design

Final Exam Topics Overview

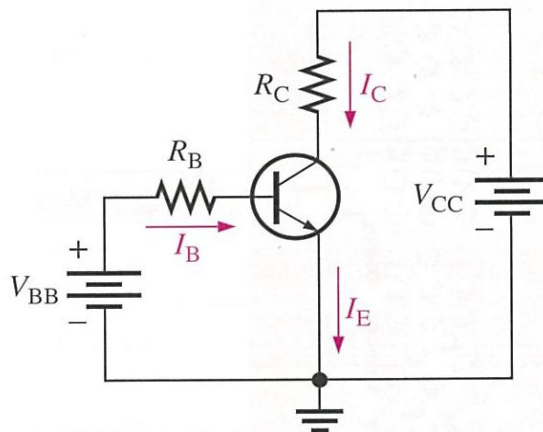
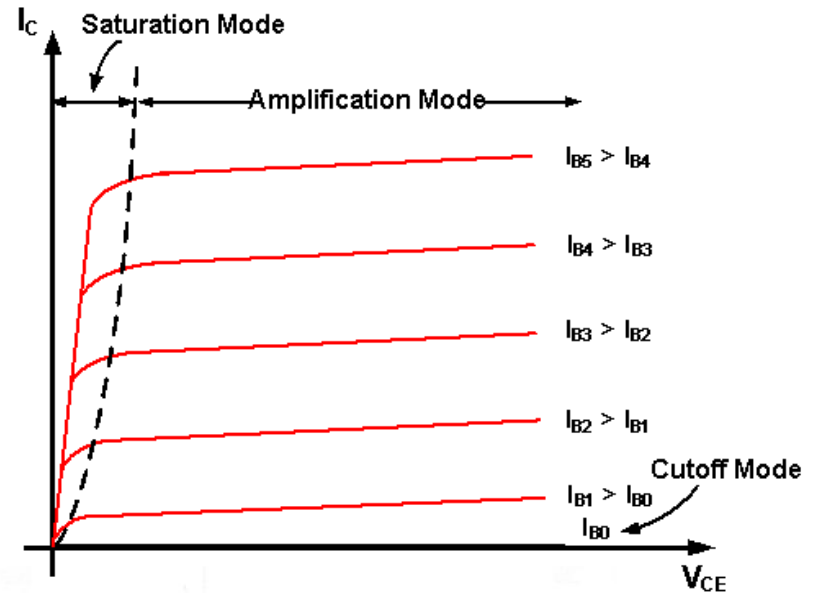
- BJT characteristics and biasing.
- BJT switching applications.
- BJT amplifiers (e.g. DC analysis, AC analysis, and frequency response).
- BJT further circuits (e.g. other models of BJT configurations, cascaded amplifier, and other BJT circuits).

Final Exam Format

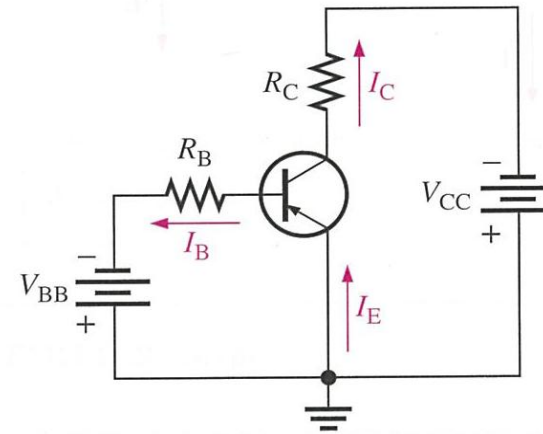
- It covers ALL second-half contents.
- 2 hours duration.
- Theoretical, analytical, and design questions.
- A list of selected formulas and constants are provided.
- Bring to the exam:
 - Dictionary.
 - Calculator.
 - Ruler for sketching.

BJT Characteristics and Biasing

- Characteristics and properties of BJT transistor:
 - Forward biased.
 - Reverse biased.
- NPN and PNP types of BJT transistor.



NPN



PNP

BJT Characteristics and Biasing

Dual voltage source biasing circuit analysis and design:

- Currents in the BJT:

$$I_E = I_C + I_B$$

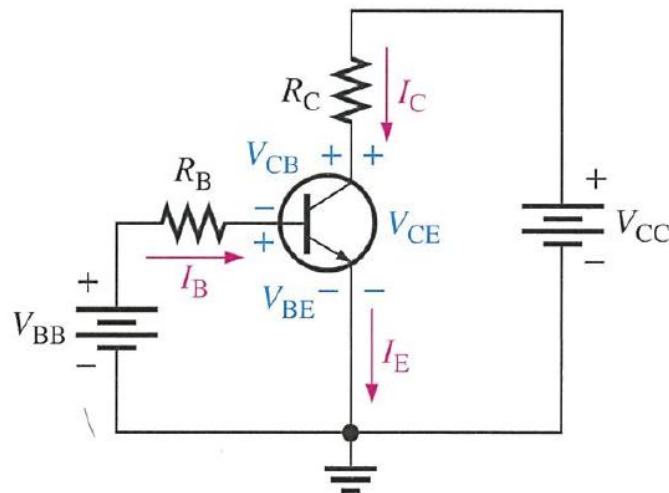
- Current gain of BJT:

$$\beta_{DC} = \frac{I_C}{I_B}$$

- Currents and voltages:

$$I_B = \frac{V_{BB} - V_{BE}}{R_B}$$

$$I_E = (1 + \beta_{DC})I_B$$



$$V_C = V_{CC} - I_C R_C$$

$$V_C = \frac{V_{CC} - V_{CE}}{R_B}$$

BJT Characteristics and Biasing

Potential divider bias circuit analysis and design:

- Thevenin resistance:

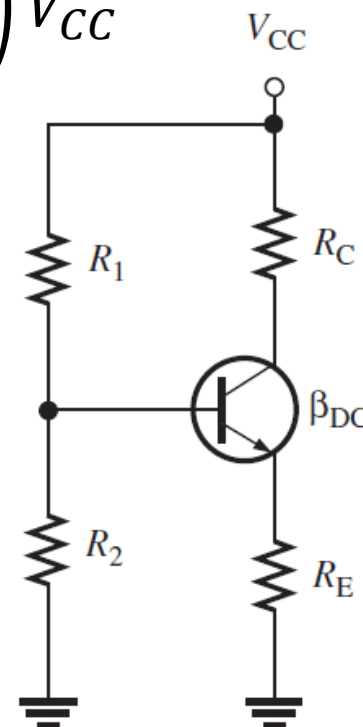
$$V_{Th} = \frac{R_1 R_2}{R_1 + R_2} \quad \text{and} \quad V_{Th} = \left(\frac{R_2}{R_1 + R_2} \right) V_{CC}$$

- Voltages and currents:

$$I_E = V_{Th} - \frac{V_{BE}}{R_E + R_{Th}/\beta_{DC}}$$

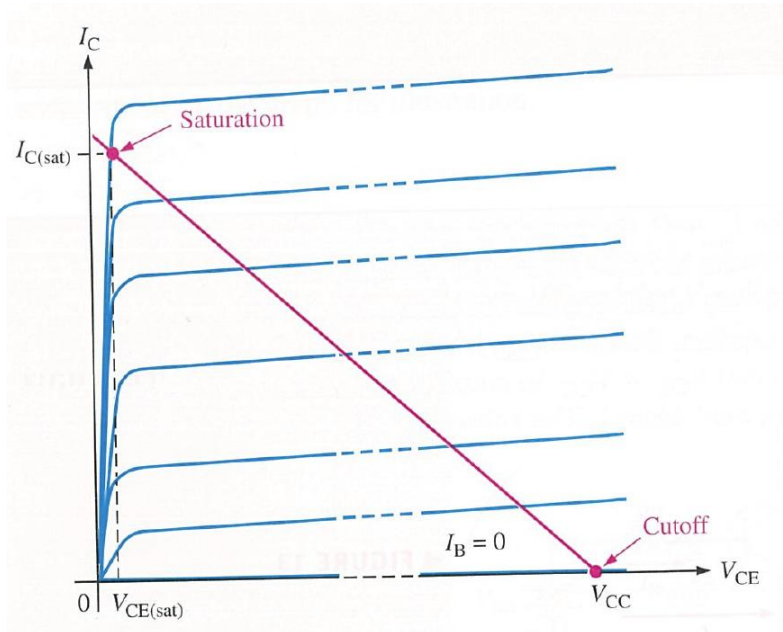
$$I_C = I_E$$

$$V_E = I_E R_E$$



BJT Characteristics and Biasing

- Load lines of circuit and Q-point.



$$Q\text{-point} = (V_{CQ}, I_{CQ})$$

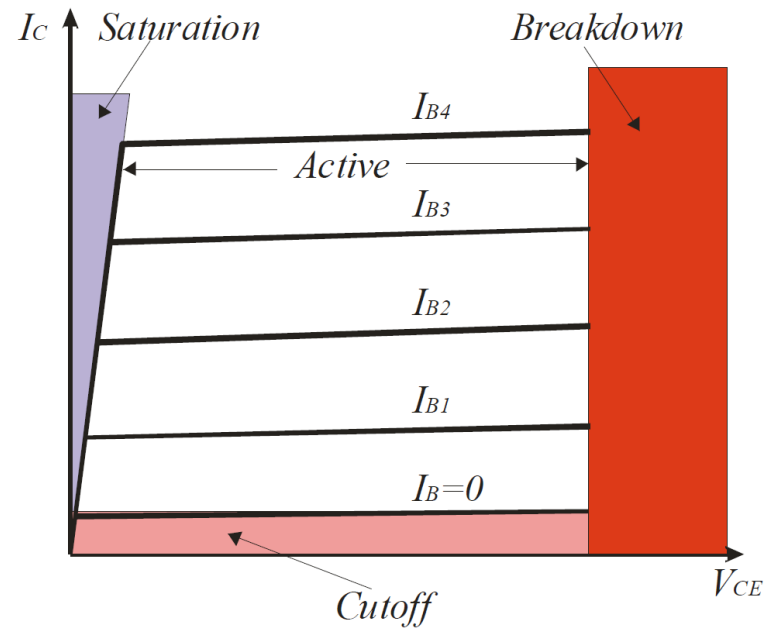
- For given Q-point, the extreme points in load line:

$$I_{C(sat)} = \frac{V_{CC}}{R_C} \quad \text{and} \quad V_{CE(\text{cutoff})} = V_{CC}$$

BJT Characteristics and Biasing

BJT regions of operation:

- Cut-off region.
- Saturation region.
- Active region.
- Breakdown region.

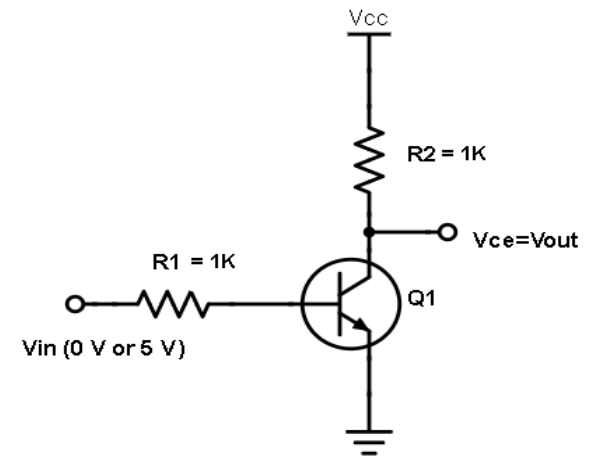
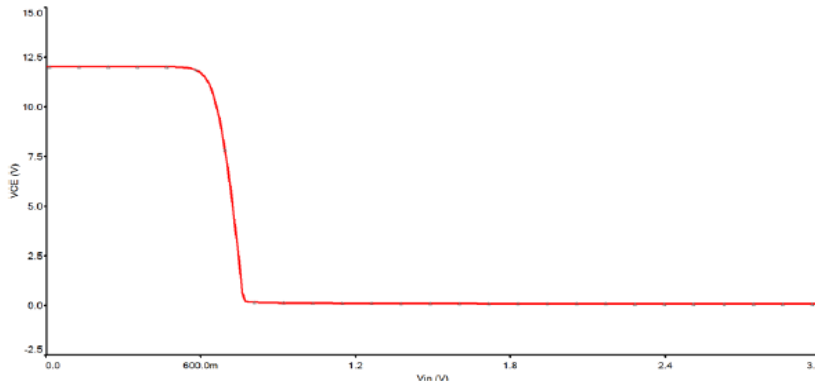


BJT applications:

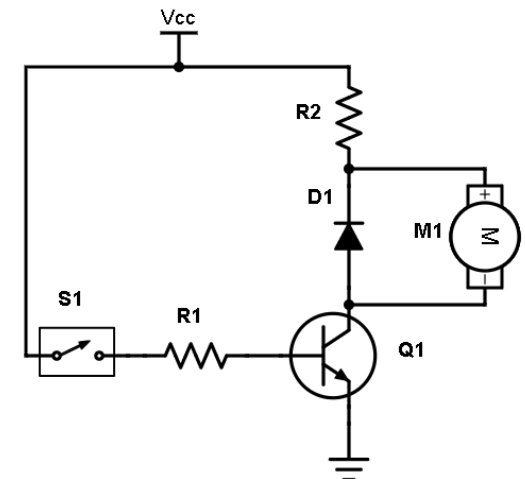
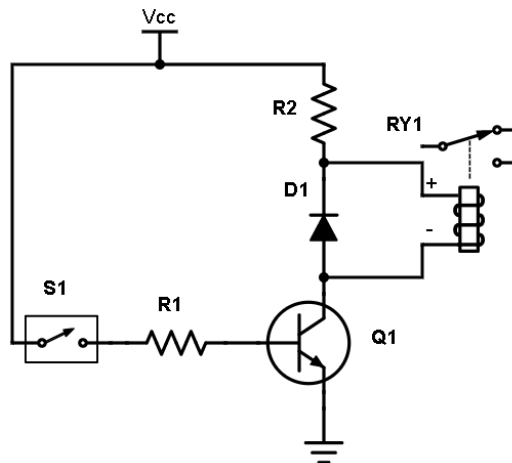
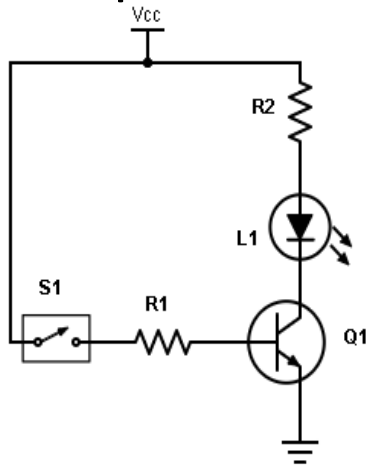
- Switching application -> cut-off and saturation region.
- Amplifier application -> active region.

BJT Switching Applications

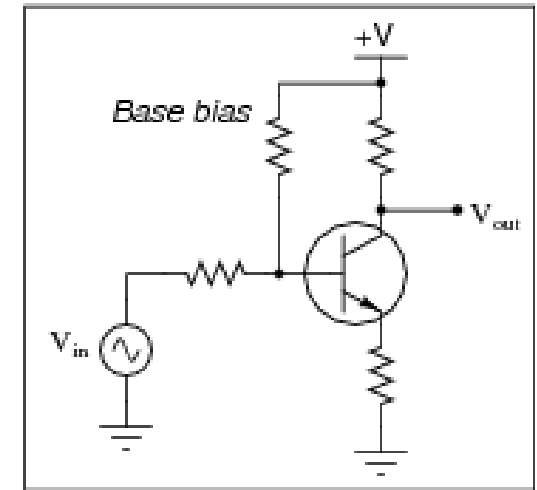
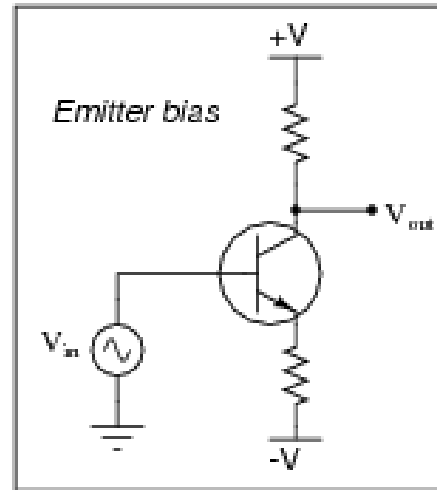
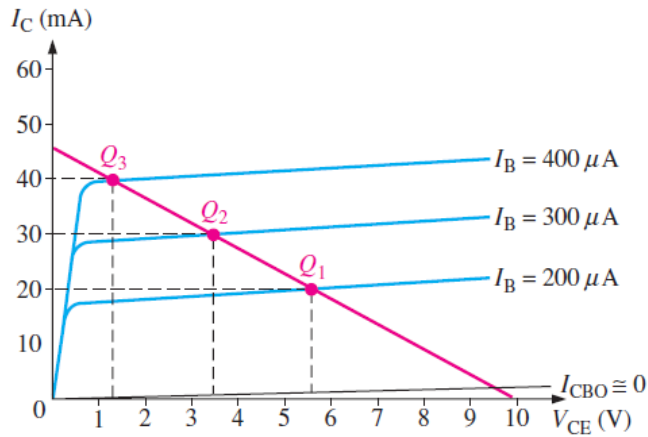
- Characteristics and properties (i.e. saturation and cutoff).



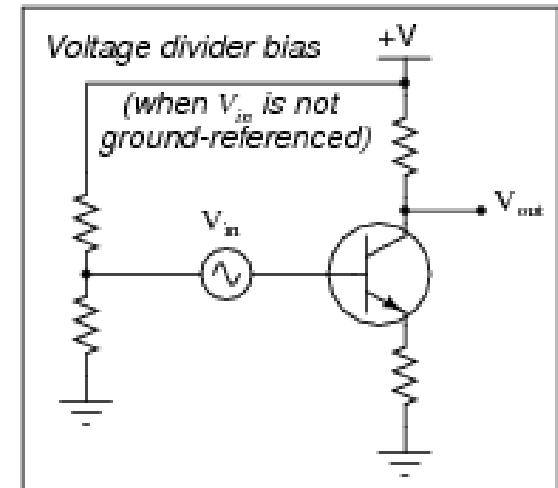
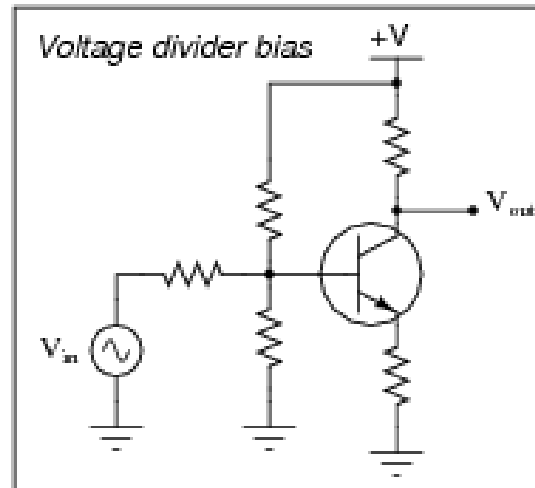
- Examples of switching application.



BJT Amplifiers (DC Analysis)

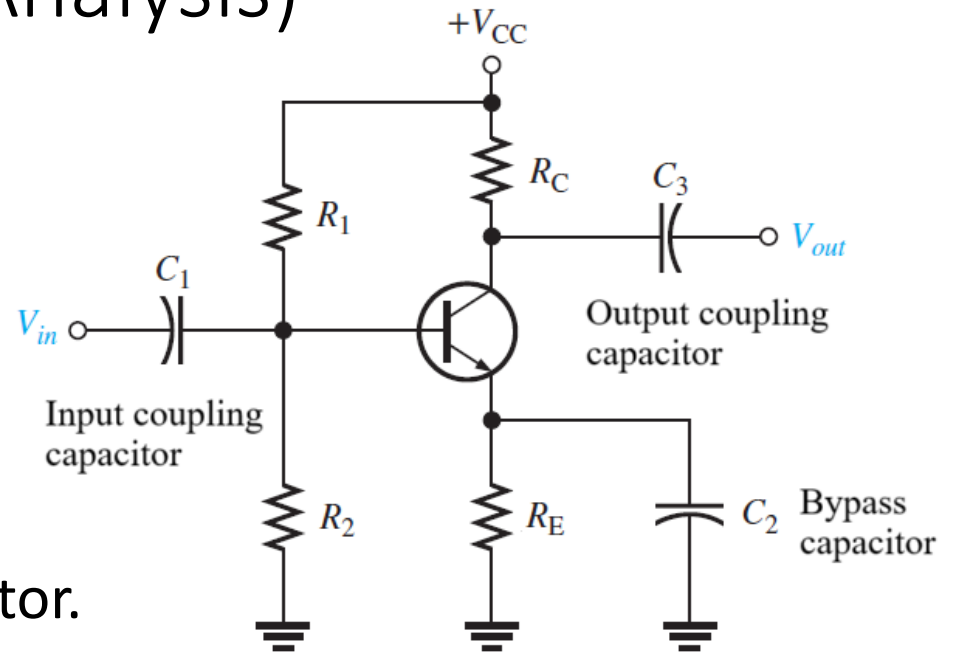


- DC gain of the amplifier.
- Input biasing.
- Output biasing.



BJT Amplifiers (AC Analysis)

- Input resistance.
- Output resistance.
- AC gain of the amplifier:
 - With emitter capacitor.
 - Without emitter capacitor.



- Role of decoupling and bypass capacitors:
 - Input capacitor
 - Output capacitor
 - Emitter capacitor

BJT Amplifiers (AC Analysis)

- Internal emitter resistance:

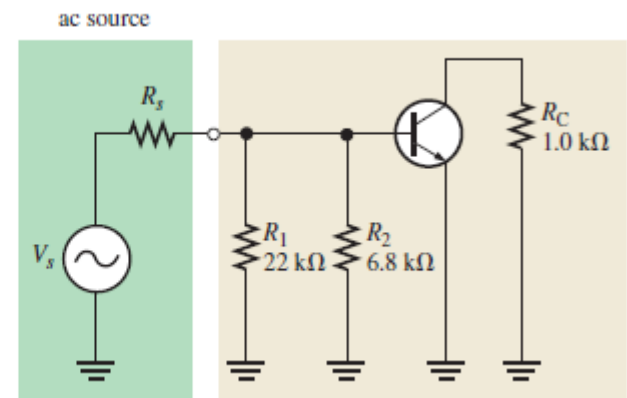
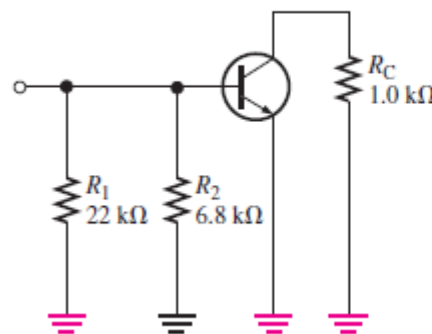
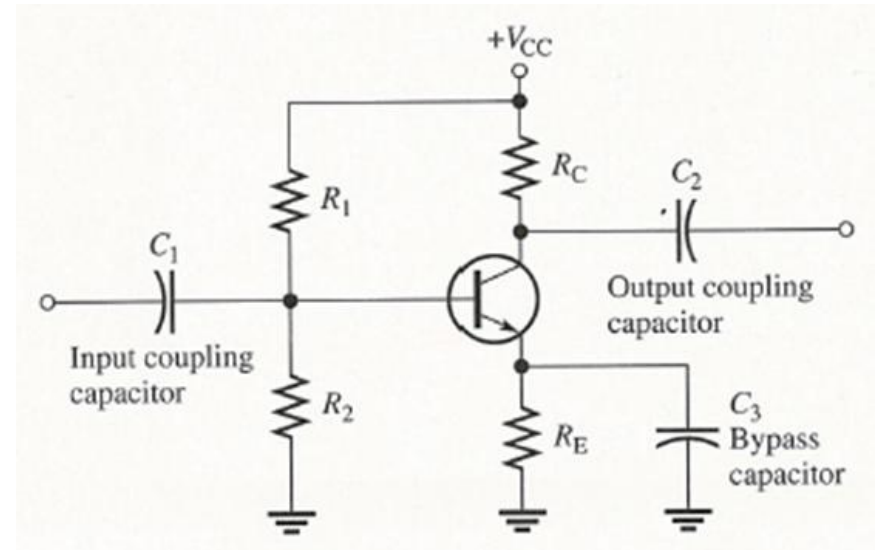
$$r_e \cong \frac{25 \text{ mV}}{I_E}$$

- Total input resistance into transistor:

$$R_{in(\text{tot})} = R_1 \parallel R_2 \parallel R_{in}$$

- AC input resistance into the base:

$$R_{in} \cong \beta_{ac} r_e$$



BJT Amplifiers (AC Analysis)

- Total output resistance of transistor:

$$R_{out} \cong R_C \parallel R_L$$

- Total gain of amplifier:

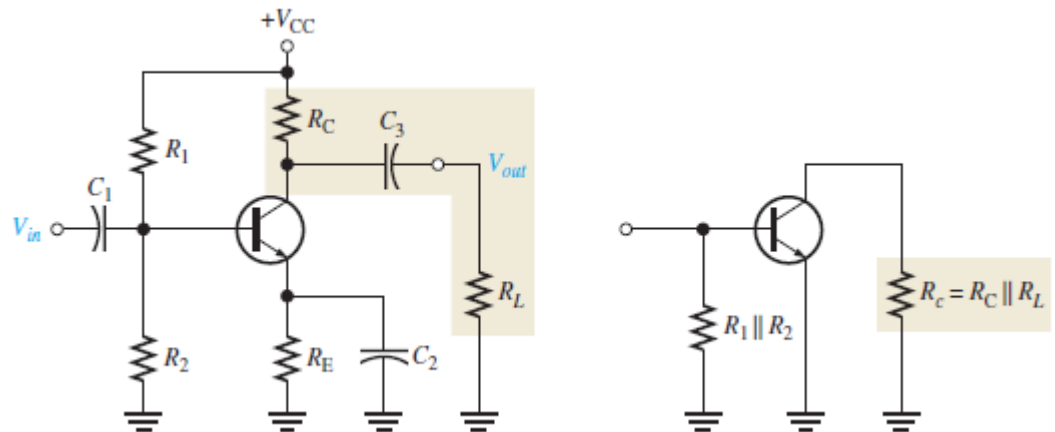
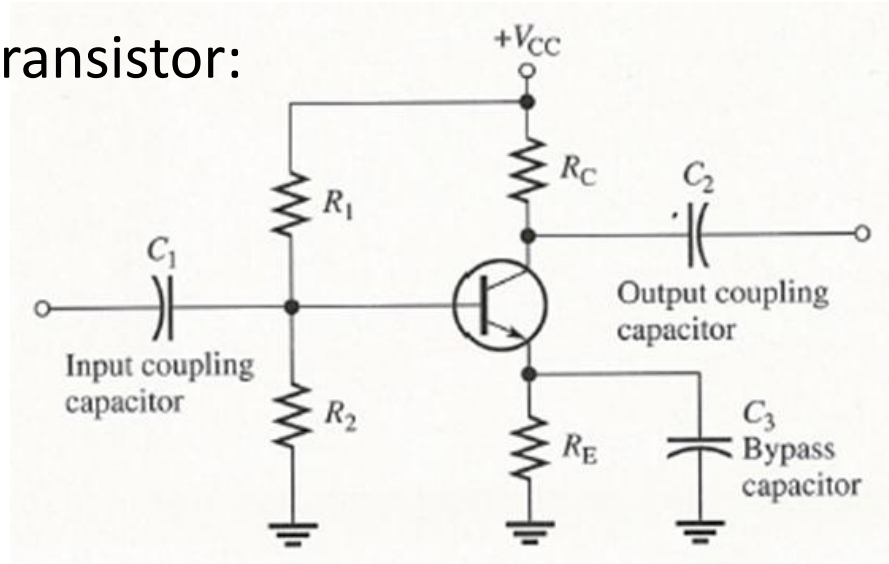
$$A_v = \frac{R_{out}}{r_e + R_E}$$

Or

$$A_v = \frac{R_{out}}{r_e}$$

- Power gain:

$$A_p = A_v A_i$$



BJT Amplifiers (Frequency Response)

Lower frequency cut-off ($f_C = 1/2\pi RC$):

- Input decoupling capacitor.

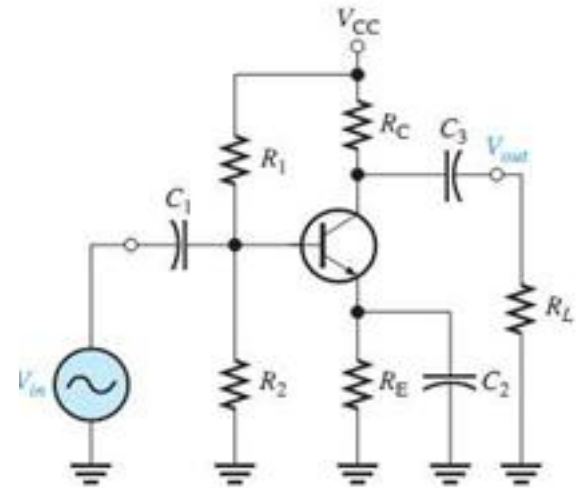
$$f_{C(input)} = \frac{1}{2\pi(R_1 \parallel R_2 \parallel \beta_{ac}r'_e)C_1}$$

- Emitter bypass capacitor.

$$f_{C(emitter)} = \frac{1}{2\pi \left[r'_e + \frac{(R_1 \parallel R_2)}{\beta_{ac}} \parallel R_E \right] C_2}$$

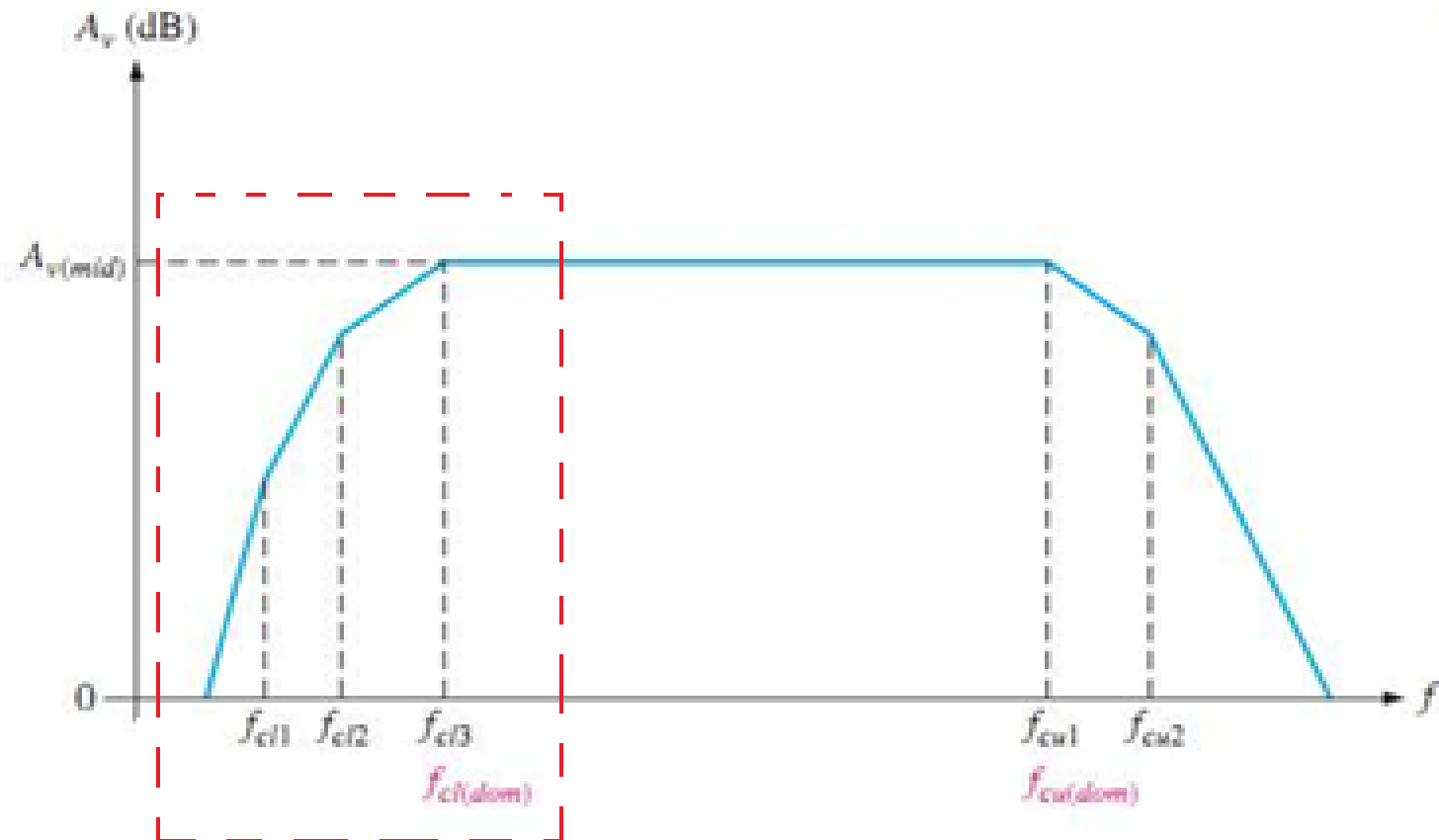
- Output decoupling capacitor.

$$f_{C(output)} = \frac{1}{2\pi(R_C + R_L)C_3}$$



BJT Amplifiers (Frequency Response)

- Lower frequency cut-off due to input and output coupling capacitor (f_{cl1} and f_{cl2}) and emitter bypass capacitor (f_{cl3}).



BJT Amplifiers (Frequency Response)

Upper frequency cut-off:

- From datasheet of the BJT:

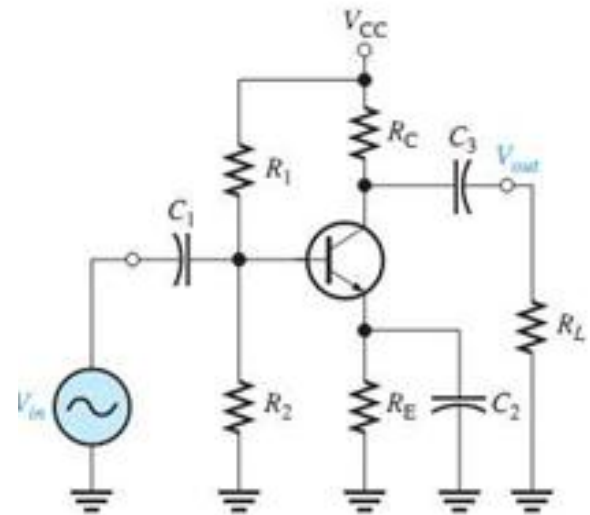
C_{bc} = BJT output capacitance

- Input parasitic capacitance:

$C_{in(Miller)} = C_{bc}(A_v - 1)$

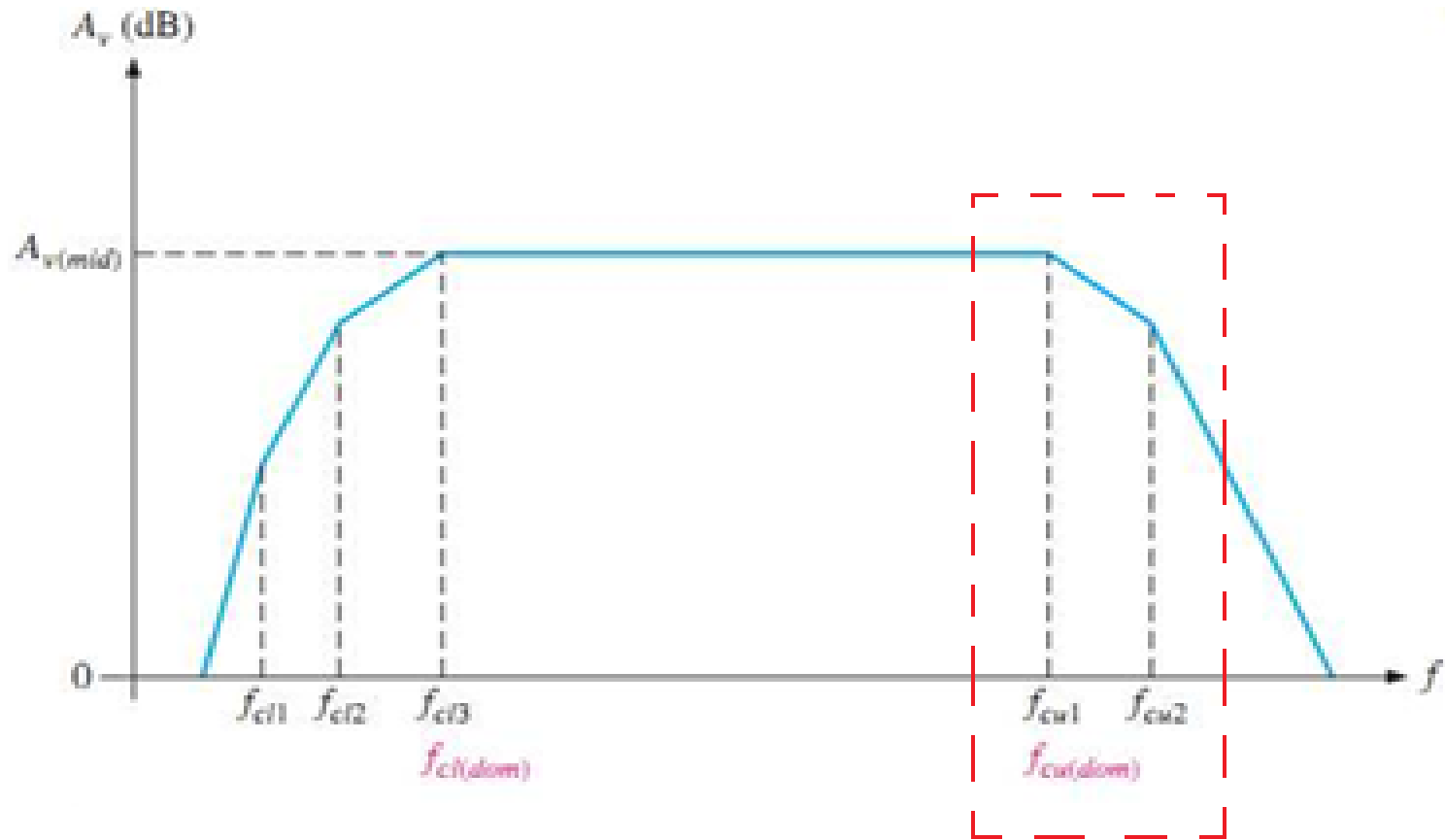
- Output parasitic capacitance:

$C_{out(Miller)} = C_{bc} \left(\frac{A_v + 1}{A_v} \right)$



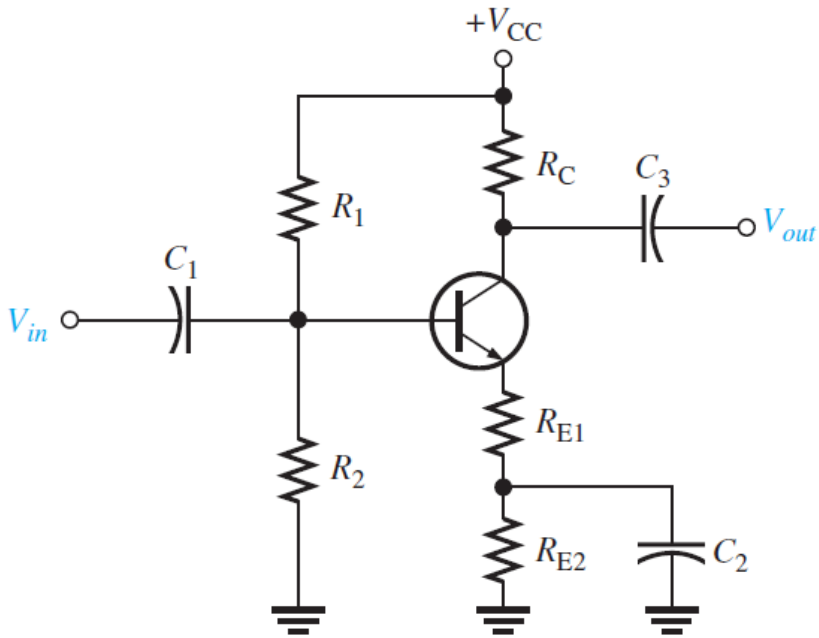
BJT Amplifiers (Frequency Response)

- Upper frequency cut-off due to input and output parasitic capacitances (f_{cu1} and f_{cu2}).



BJT Further Circuit

- Common-Emitter Amplifier (with Swamping)



- Gain of Common-Emitter Amplifier (without Swamping)

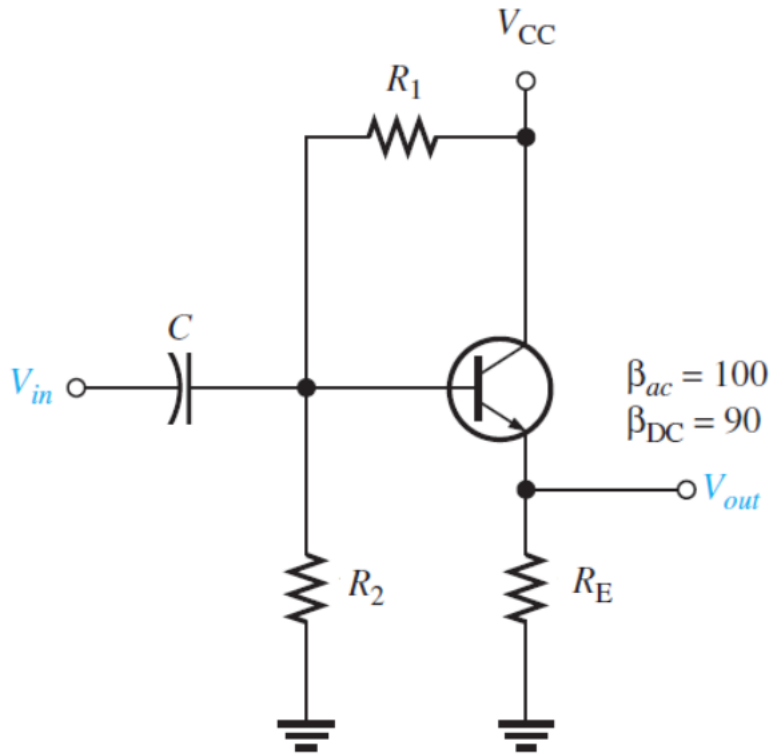
$$A_v = \frac{R_C}{r'_e}$$

- Gain of Common-Emitter Amplifier (with Swamping)

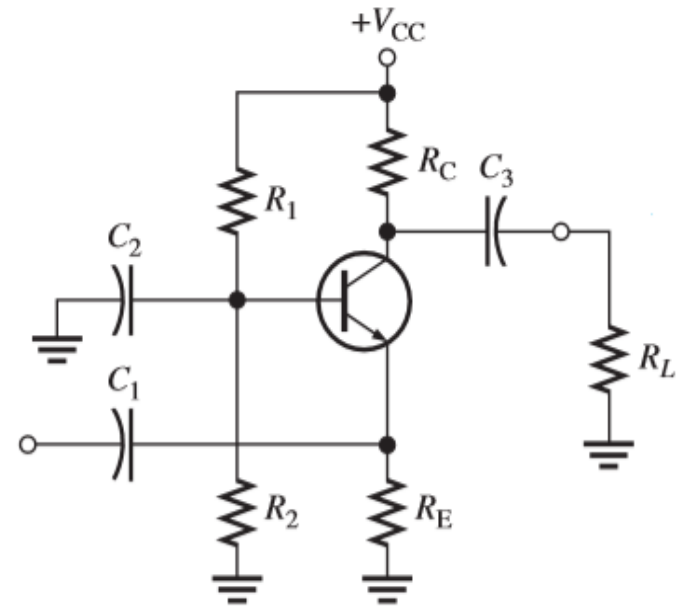
$$A_v = \frac{R_C}{r'_e + R_{E1}}$$

BJT Further Circuit

- Other BJT circuit configurations:



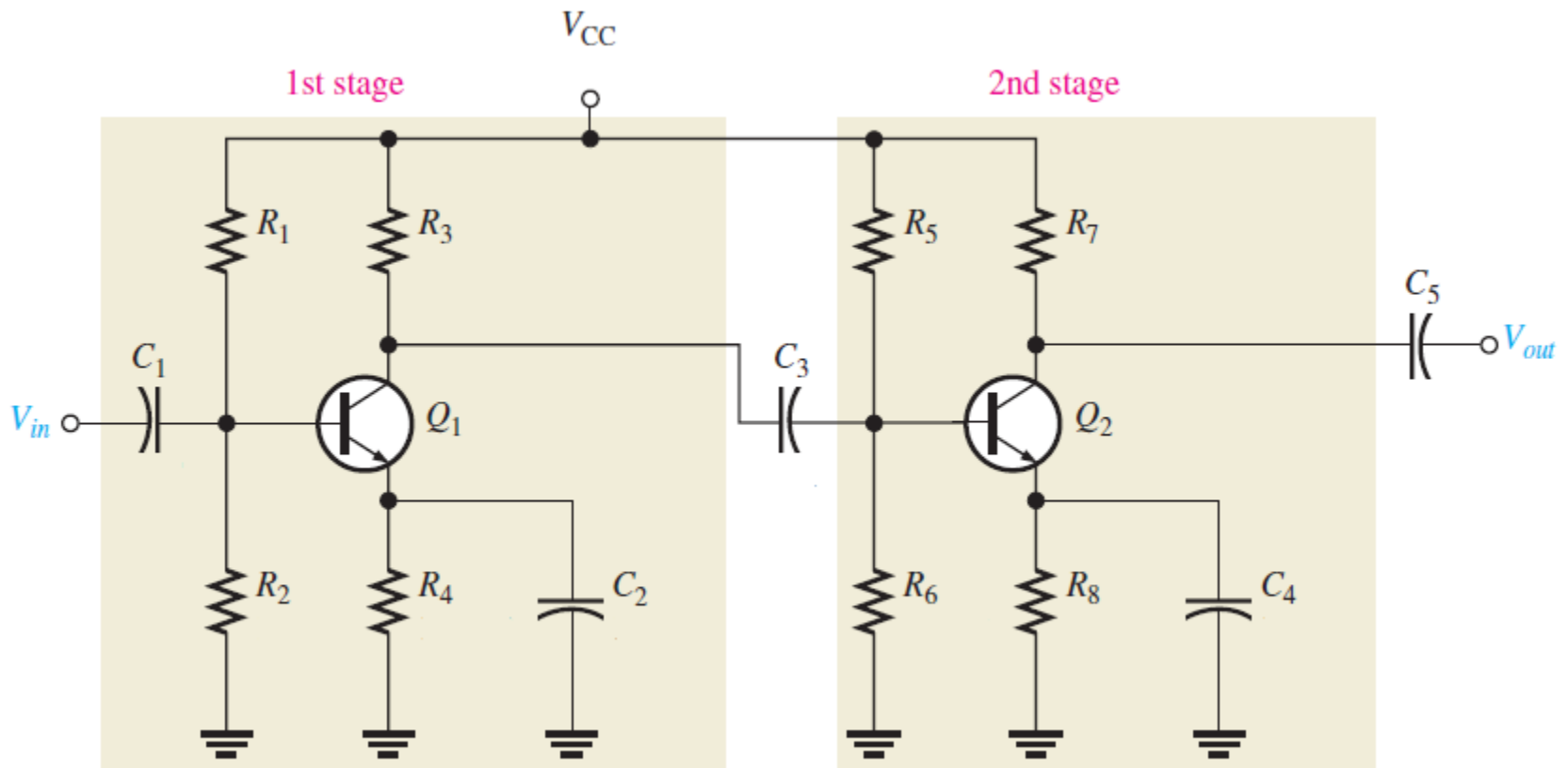
Common-Collector Amplifier



Common-Base Amplifier

BJT Further Circuit

- Capacitively Coupled Multistage BJT Amplifiers



BJT Further Circuit

- AC resistance:
 - 1st stage: $R_{C1} = R_3 \parallel R_5 \parallel R_6 \parallel R_{in(base2)}$
 - 2nd stage: $R_{C2} = R_7$
- Gain of the amplifier:

- 1st stage voltage gain:

$$A_{v1} = \frac{R_{C1}}{r'_e}$$

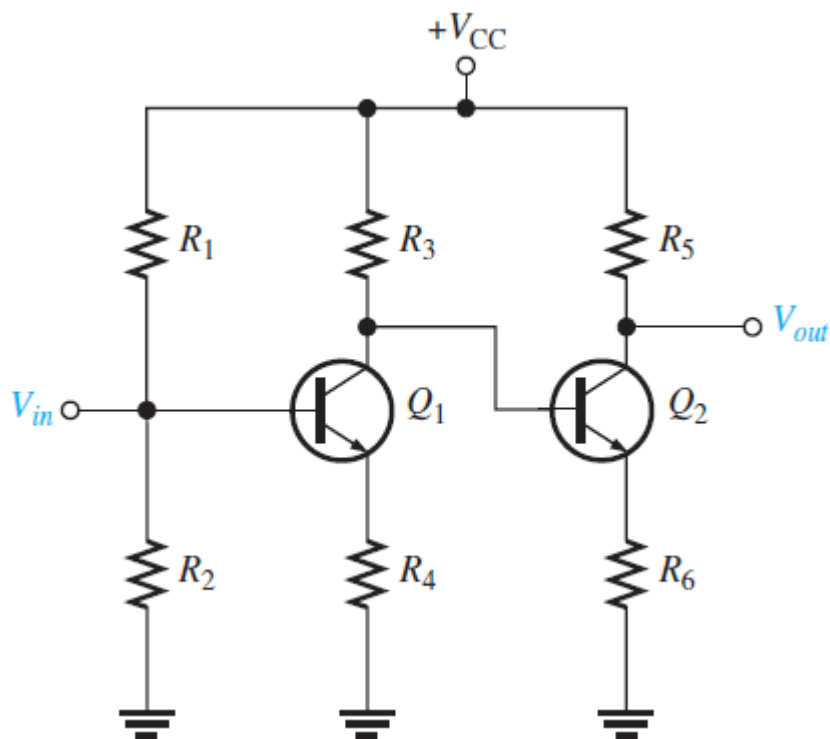
- 2nd stage voltage gain:

$$A_{v2} = \frac{R_7}{r'_e}$$

- Overall gain: $A_{v(total)} = A_{v1}A_{v2}$

BJT Further Circuit

- Direct Multistage BJT Amplifiers



- 1st stage voltage gain:

$$A_{v1} = \frac{R_3 \parallel R_{in2}}{r'_{e1} + R_4}$$

Where: $R_{in2} = \beta_{ac} r'_{e2}$

- 2nd stage voltage gain:

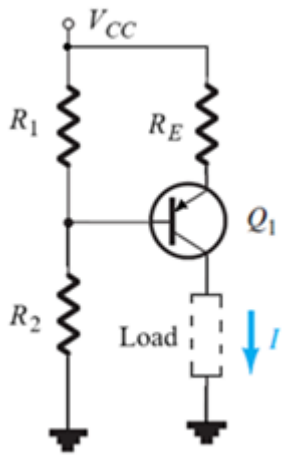
$$A_{v2} = \frac{R_5}{r'_{e2} + R_6}$$

- Overall gain:

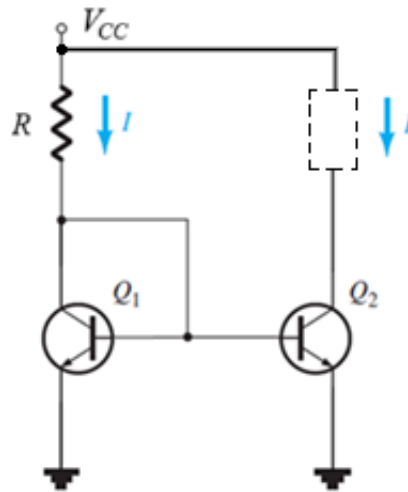
$$A_{v(total)} = A_{v1} A_{v2}$$

BJT Further Circuit

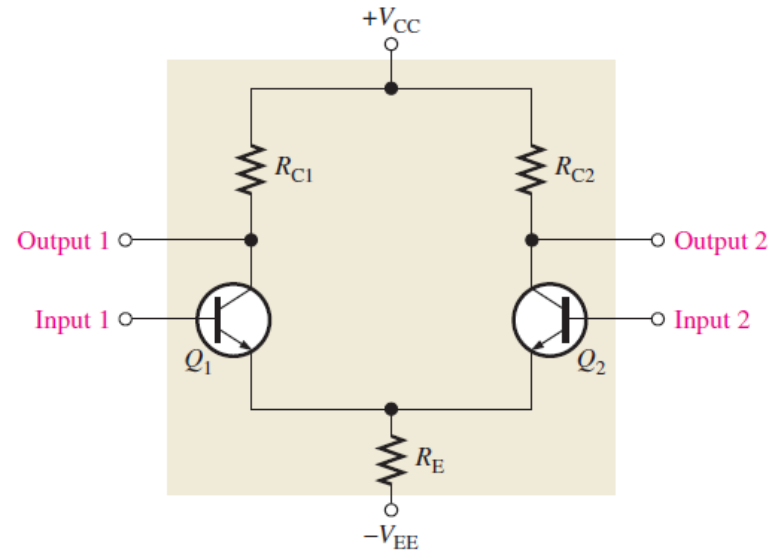
- Other BJT circuit applications:



Current Source



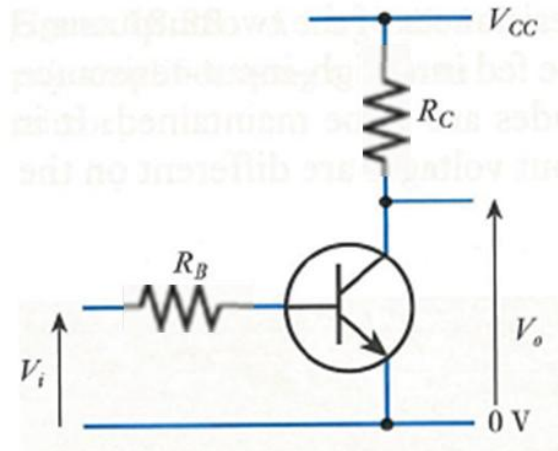
Current Mirror



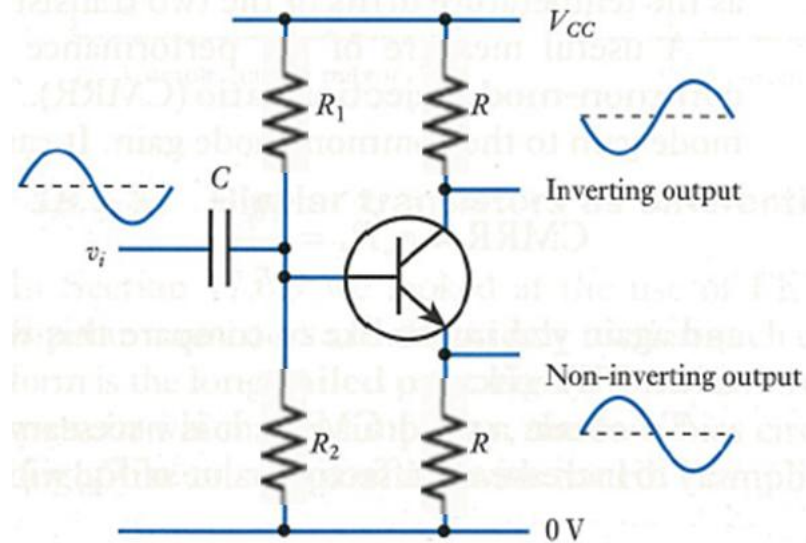
Differential Amplifier

BJT Further Circuit

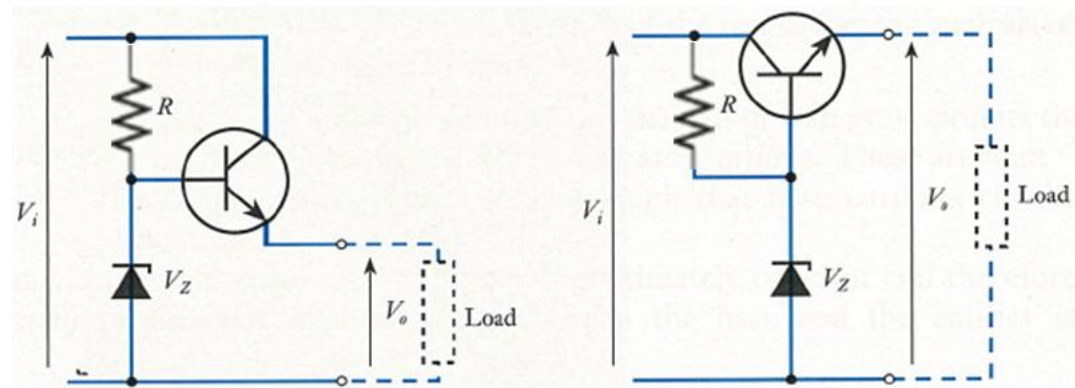
- Other BJT circuit applications:



Switches and Logic Gates



Phase Splitter



Voltage Regulators