BENHA UNIVERSITY
FACULTY OF ENGINEERING AT SHOUBRA

ELC301
Electronic Engineering

Lecture #4
Transistors

Instructor:
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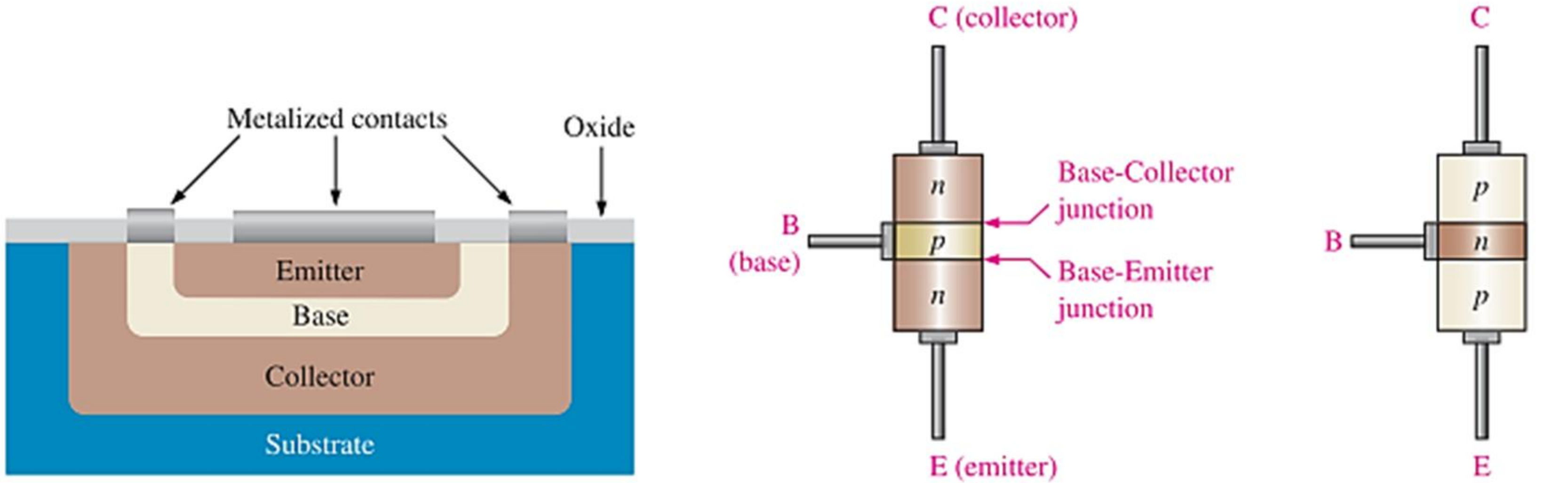
Bipolar Junction Transistor

Agenda

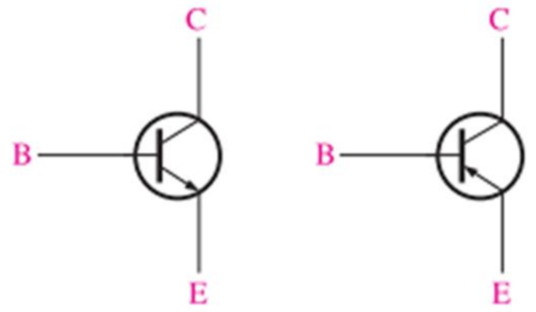
- BJT Structure
- Basic Operation
- Transistor as an Amplifier
- Transistor as a Switch
- DC & AC Analysis

BIPOLAR JUNCTION TRANSISTOR (BJT) STRUCTURE



(a) Basic epitaxial planar structure (b) *npn* (c) *pnp*

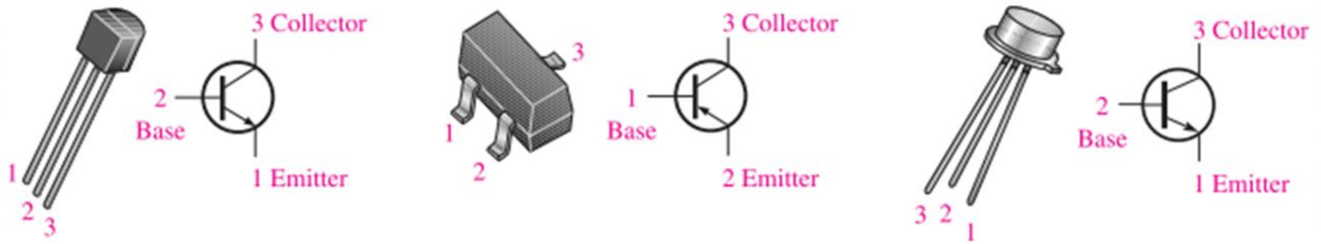
BJT symbol



(a) *npn* (b) *pnp*

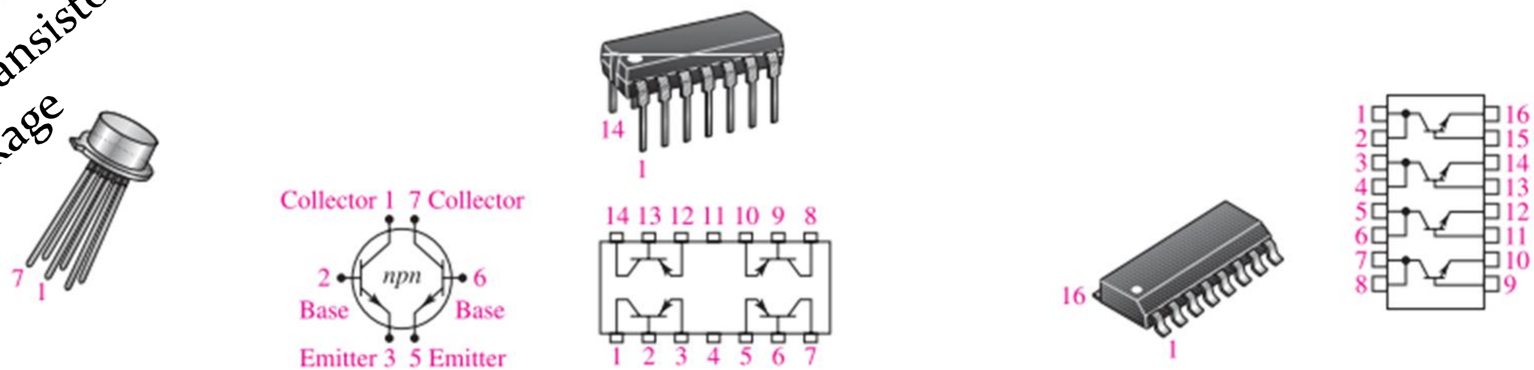
Transistor Packages

General Purpose



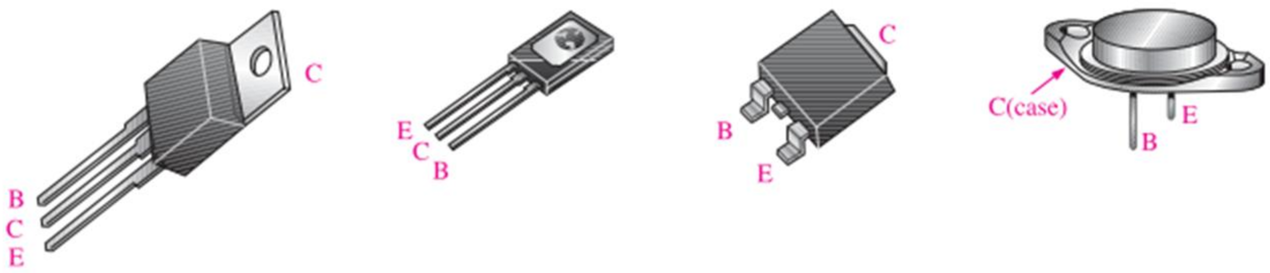
(a) TO-92 (b) SOT-23 (c) TO-18. Emitter is closest to tab.

Multiple Transistor Package



(a) Dual metal can. Emitters are closest to tab. (b) Quad dual in-line (DIP) and quad flat-pack. Dot indicates pin 1. (c) Quad small outline (SO) package for surface-mount technology

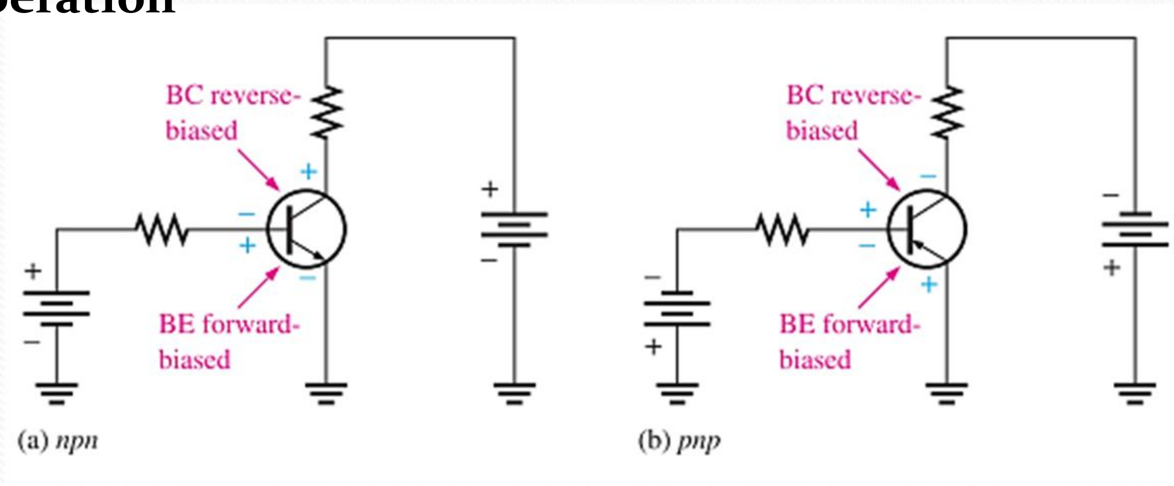
Power Transistors



(a) TO-220 (b) TO-225 (c) D-Pack (d) TO-3

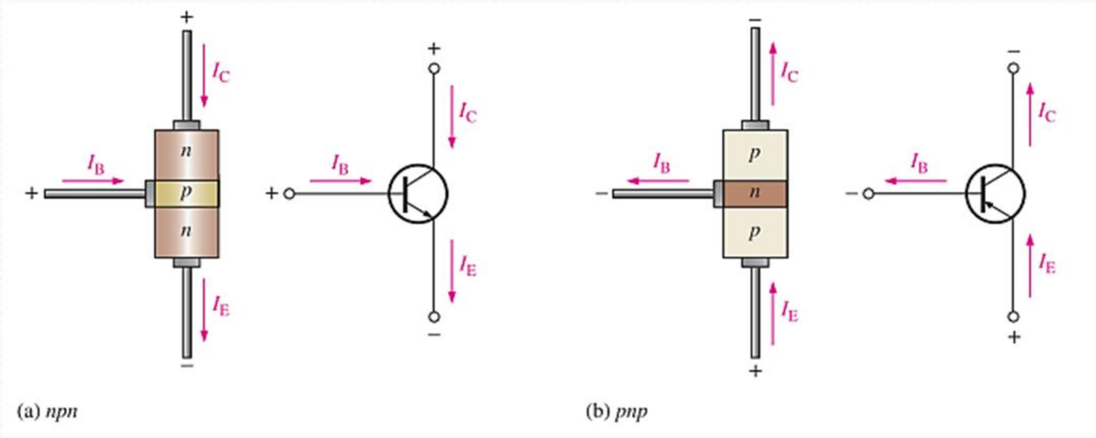
Basic Operation

- **Biasing & Operation**



- **Transistor Currents**

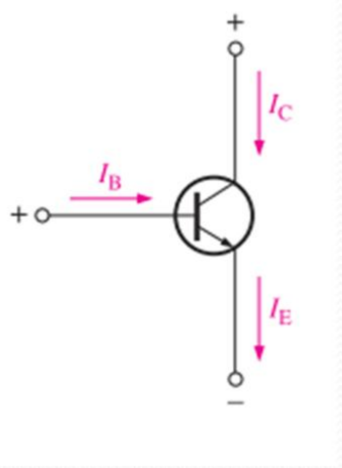
$$I_E = I_C + I_B$$



BJT Configurations

Configuration	Input	Output	gain
Common Emitter	Base	Collector	-ve gain
Common Base	Emitter	Collector	+ve gain
Common Collector	Base	Emitter	Unity gain

- Base terminal can't be output
- Collector terminal can't be input



BJT Parameters

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

- The dc current gain of a transistor is the ratio of the dc collector current (I_C) to the dc base current (I_B) and is designated dc **beta** (β_{DC}).

$$h_{FE} = \beta_{DC}$$

- Typical values of β_{DC} range from less than 20 to 200 or higher.
- β_{DC} is usually designated as an equivalent hybrid (h) parameter, h_{FE}, on transistor datasheets.

$$\alpha_{DC} = \frac{I_C}{I_E}$$

- The ratio of the dc collector current (I_C) to the dc emitter current (I_E) is the dc alpha (α_{DC}).

Transistor DC Model

I_B: dc base current

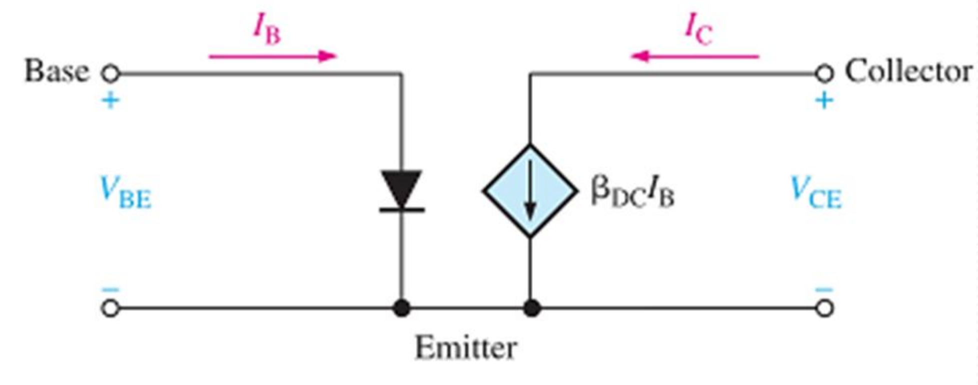
I_E: dc emitter current

I_C: dc collector current

V_{BE}: dc voltage at base with respect to emitter

V_{CB}: dc voltage at collector with respect to base

V_{CE}: dc voltage at collector with respect to emitter



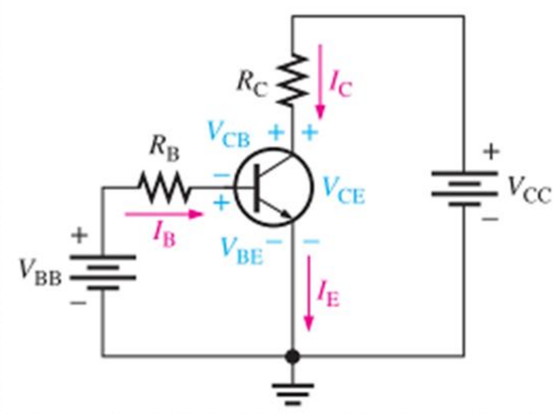
$$V_{BE} \cong 0.7\ V$$

$$V_{R_B} = V_{BB} - V_{BE}$$

$$V_{R_B} = I_B R_B$$

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

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



$$V_{CE} = V_{CC} - V_{R_C}$$

$$V_{R_C} = I_C R_C$$

$$I_c = \beta I_B$$

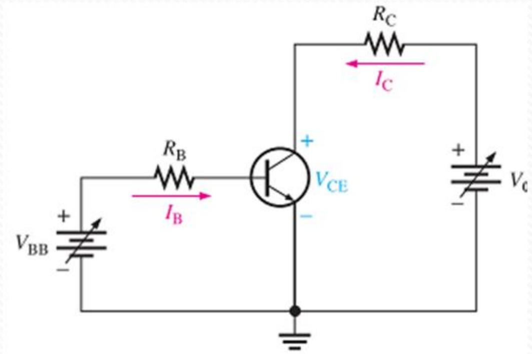
$$V_{CE} = V_{CC} - I_C R_C$$

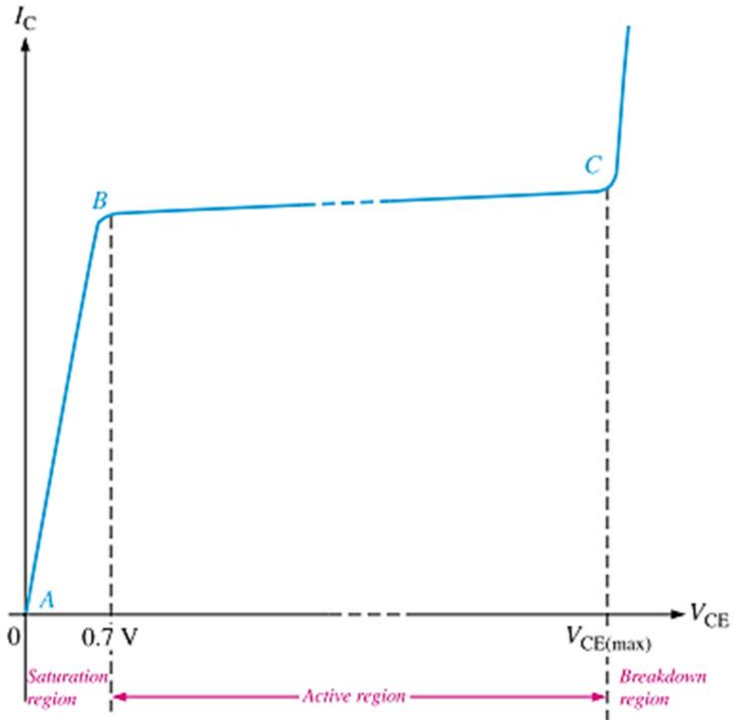
$$V_{CB} = V_{CE} - V_{BE}$$

Collector characteristic curves

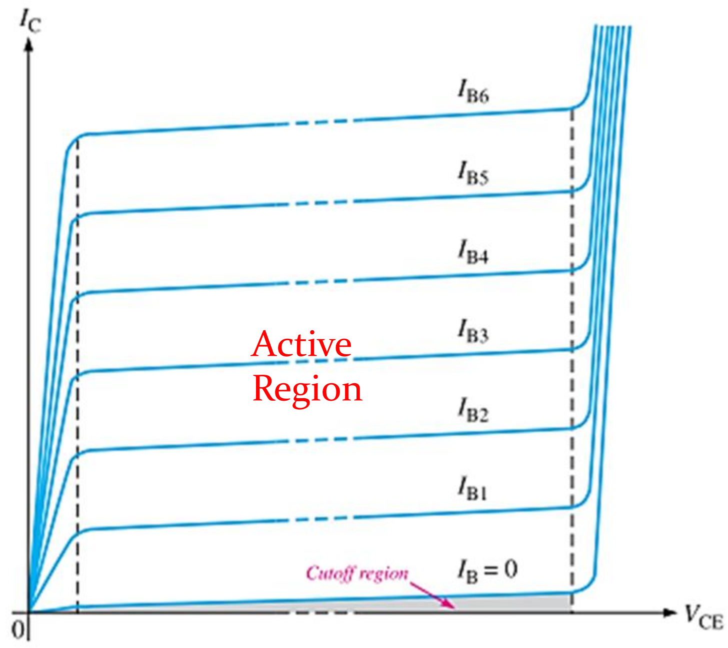
Operation Regions

- Active
- Cut-off
- Saturation



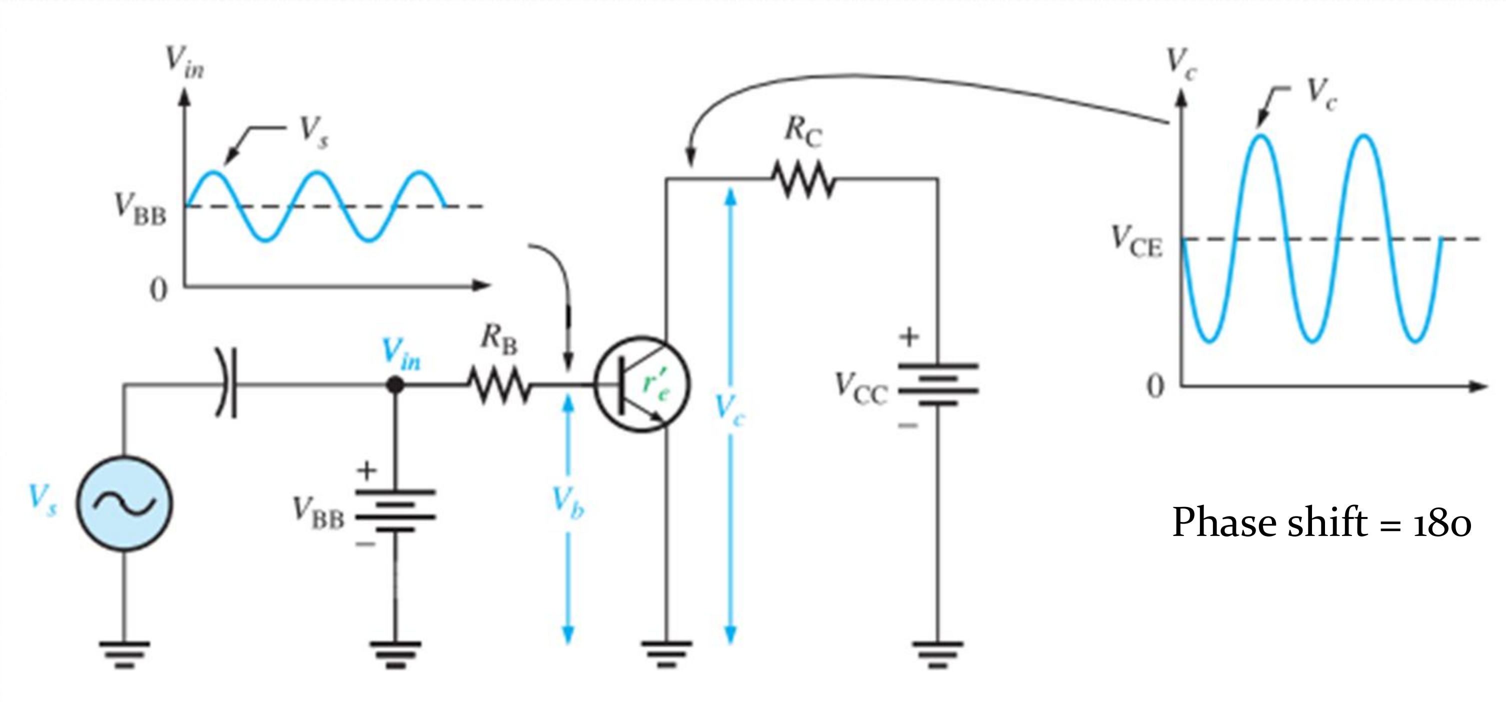


(b) I_C versus V_{CE} curve for one value of I_B



(c) Family of I_C versus V_{CE} curves for several values of I_B ($I_{B1} < I_{B2} < I_{B3}$, etc.)

BJT as an Amplifier

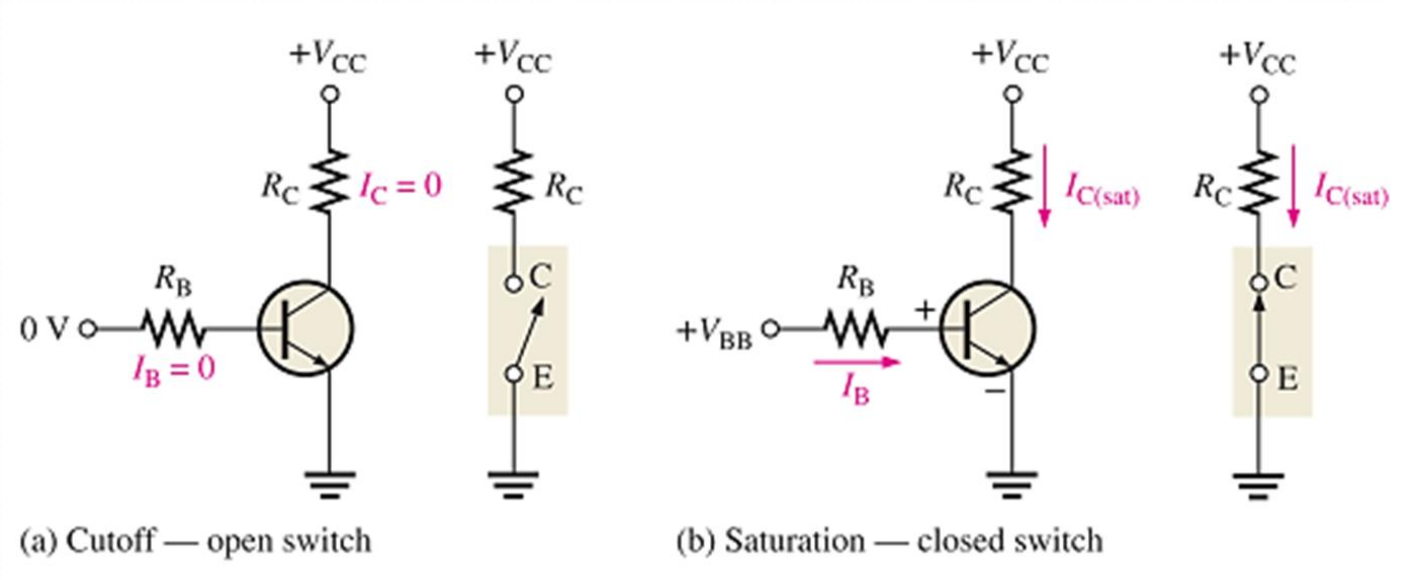


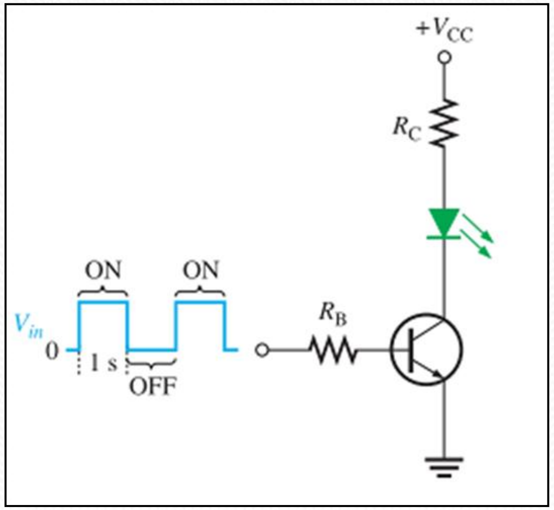
Phase shift = 180

Voltage gain magnitude: $A_v \cong \dfrac{R_C}{r'_e}$

r_e = 26 mv/ I_E
$I_E = I_C + I_B$

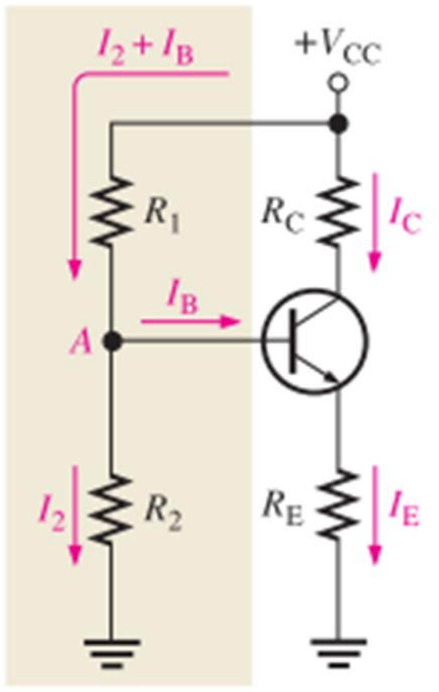
BJT as a Switch





Transistor Bias Circuit

VOLTAGE-DIVIDER BIAS



$$V_B \cong \left(\frac{R_2}{R_1 + R_2}\right)V_{CC}$$

$$V_E = V_B - V_{BE}$$

$$I_C \cong I_E = \frac{V_E}{R_E}$$

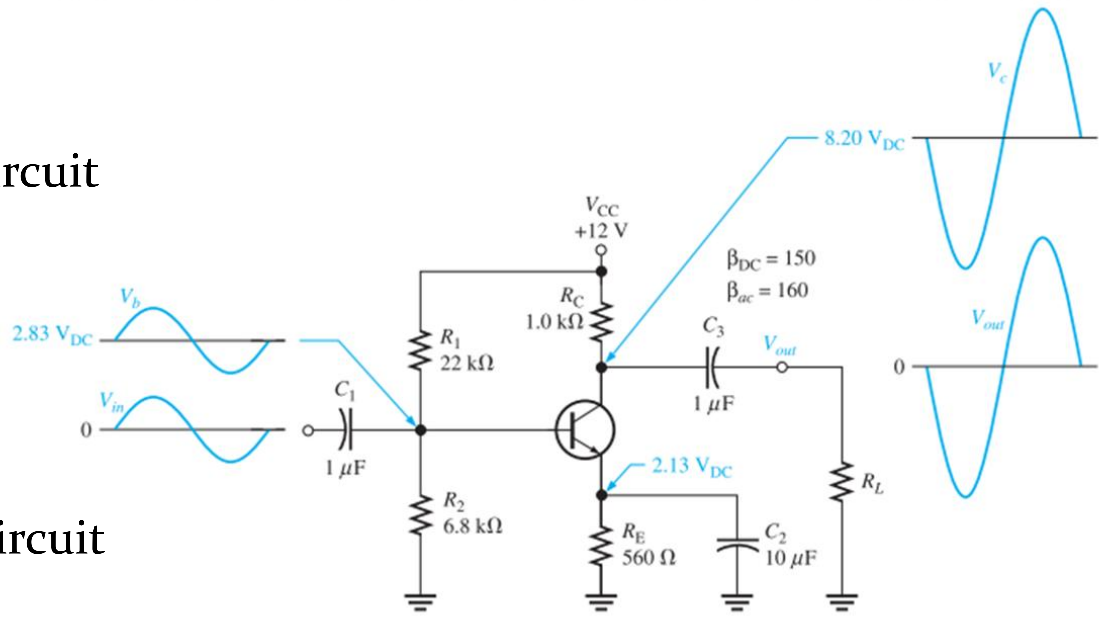
$$V_C = V_{CC} - I_C R_C$$

$$V_{CE} = V_C - V_E$$

C.E. AC Analysis

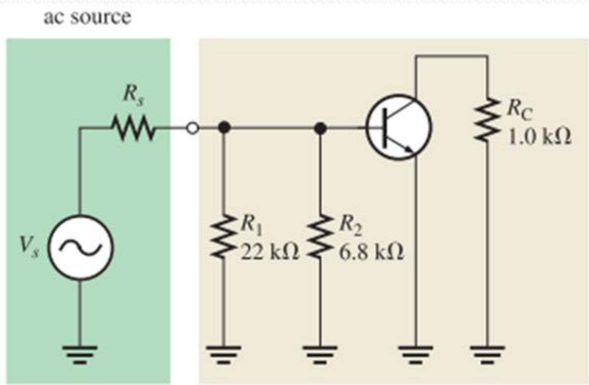
- **DC Analysis:**

Capacitors → Open Circuit
(See before)



- **AC Analysis:**

Capacitors → short Circuit
DC supply → ground



AC r-parameter Model

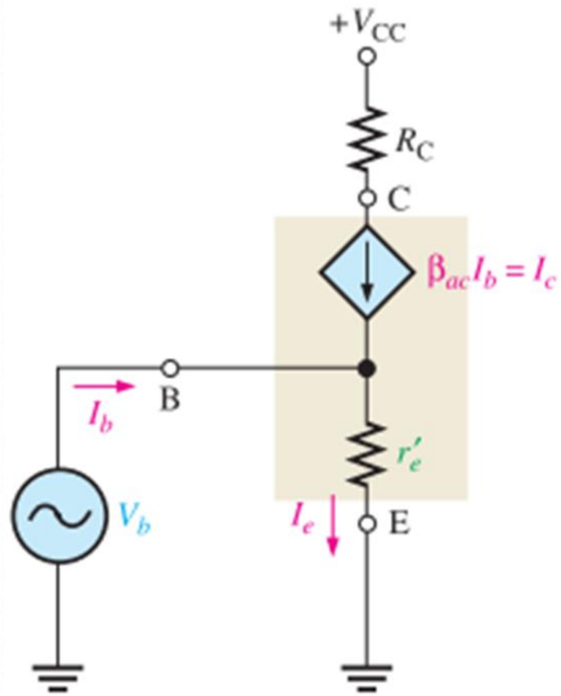
Input resistance $R_{in(base)} = \beta_{ac} r'_e$

Output resistance $R_{out} \cong R_C$

Voltage gain $A_v = \dfrac{R_C}{r'_e}$

Current gain $A_i = \dfrac{I_c}{I_s} = -Av\,\dfrac{Zin}{Rc}$

Power gain $A_p = A'_v A_i$

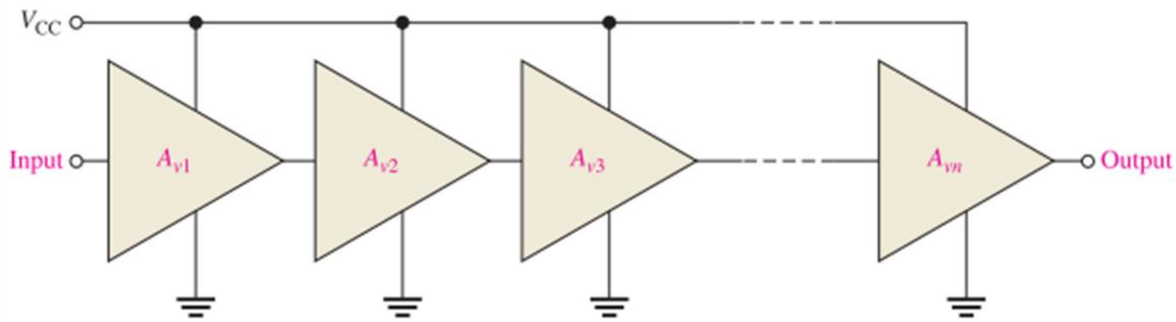


Multistage Amplifier

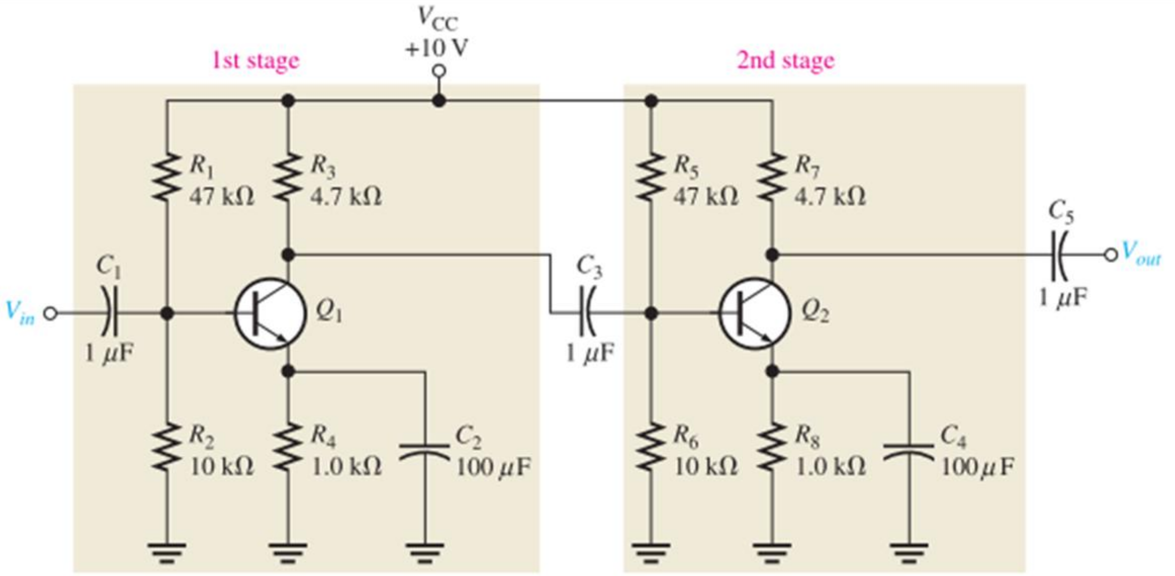
$$A'_v = A_{v1}A_{v2}A_{v3}\ldots A_{vn}$$

$$A_{v(\text{dB})} = 20 \log A_v$$

$$A'_{v(\text{dB})} = A_{v1(\text{dB})} + A_{v2(\text{dB})} + \cdots + A_{vn(\text{dB})}$$



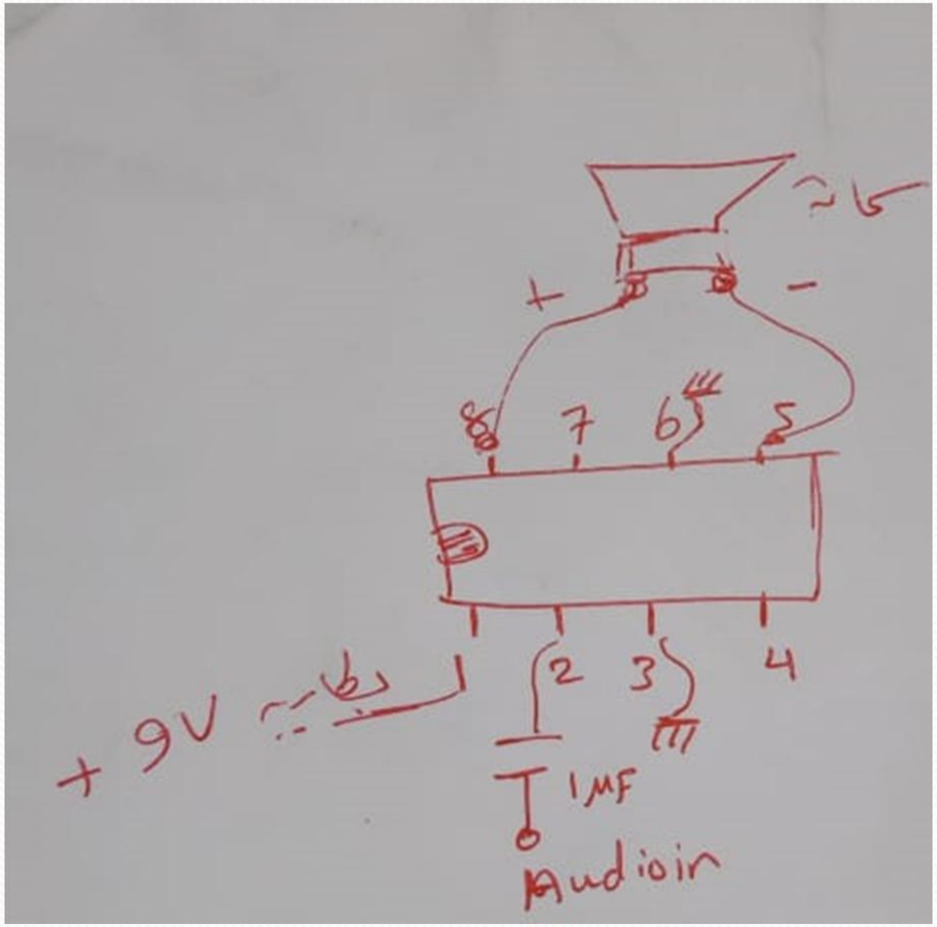
- A two-stage common-emitter amplifier.



$\beta_{DC} = \beta_{ac} = 150$ for Q_1 and Q_2

Project

Audio amplifier



TDA 7052
1uF capacitor
Speaker 4 -32 ohm
Audio jack (AUX) mono
Battery 9V
Wires
board