The MOSFET

MOSFET is another type of Field Effect Transistor whose Gate input is electrically insulated from the main current carrying channel. It is called an Insulated Gate Field Effect Transistor.

MOSFET is Metal Oxide Semiconductor Field Effect Transistor.

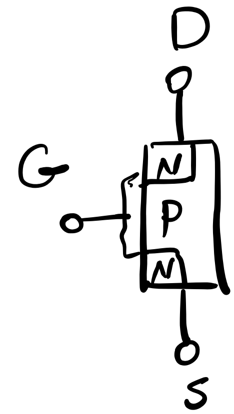
The MOSFET is a voltage controlled field effect transistor that differs from JFET in that it has a "Metal Oxide" Gate electrode which is electrically insulated from the main semiconductor n-channel or p-channel by a very thin layer of insulating material usually silicon dioxide.

MOSFETs are three terminal devices with a Gate, Drain, and Source and both P-channel and N-channel MOSFETs are available.

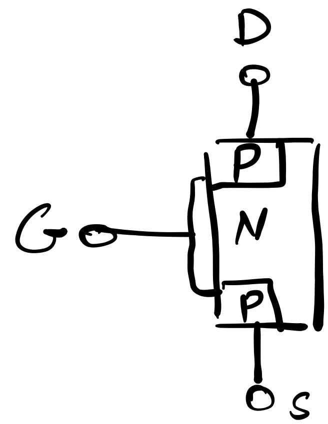
There are two basic forms:

- Depletion Type: The transistor requires a Gate-Source voltage, (V_{GS}) to switch the device "OFF" (equivalent to normally closed switch)
- Enhancement type: The transistor requires a Gate-Source voltage (V_{GS}) to switch the device "ON" (equivalent to Normally open switch).

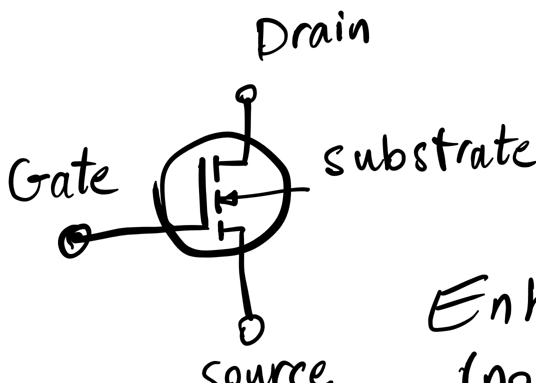
The symobols and basic construction for both configurations of MOSFETs are shown below.

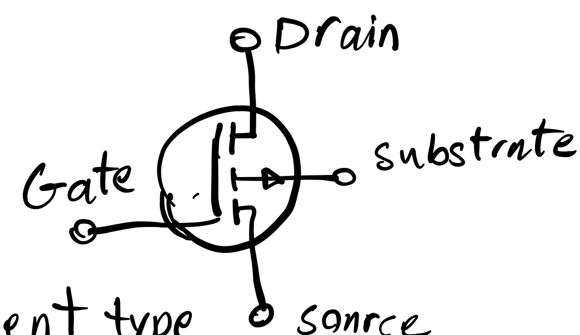


N-channel

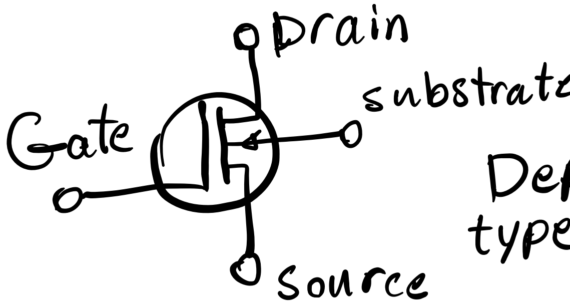


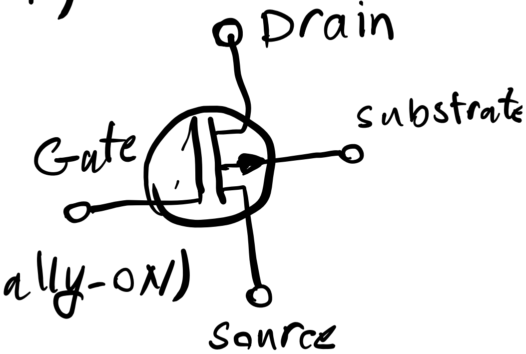
P-channel





Enhancement type (normally-OFF)





Depletion type (normally-ON)

The four MOSFET symbols above shown an additional terminal called the substrate and is not normally used as either an iput or an output connection but instead it is used for grounding the substrate. It connects the main semiconductive channel through a diode junction to the body or metal tab of MOSFET.

Transistor Biasing

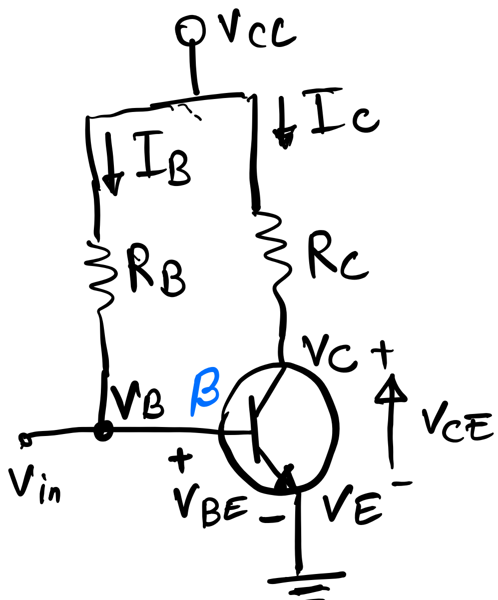
Transistor Biasing is the process of setting a transistor DC operating voltage or current to correct level so that an AC input can be amplified correctly by the transistor.

Base biasing a Common Emitter Amplifier

one of the most frequently used biasing circuits for a transistor circuit with the self-bias circuit where one or more biasing resistors are used to set up the initial DC values for the transistor currents I_B, I_C, and I_E.

Examples of transistor Base bias Configurations from a single supply (V_{CC}).

Fixed Base Biasing a Transistor



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

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

$$V_E = 0\,V$$

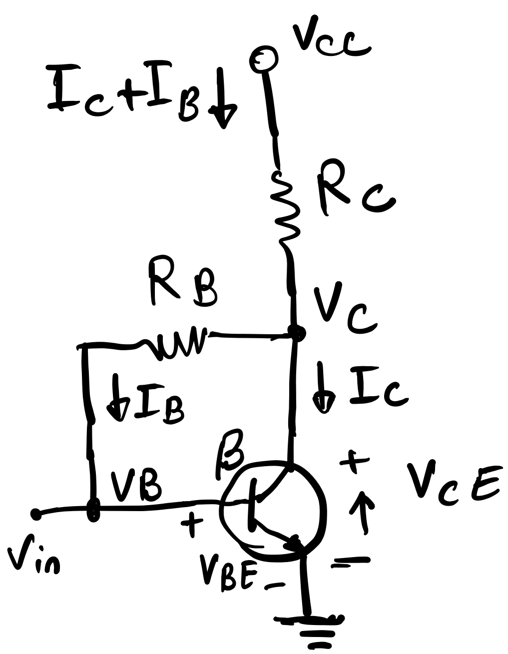
$$V_B = V_{BE}$$

$$I_C = \beta I_B$$

$$I_E = (I_C + I_B) \cong I_C$$

The Transistor base current, I_B remains constant for a given value of V_{CC}.

Callector Feedback Biasing a Transistar



$$V_C = V_{CC} - R_C (I_C + I_B)$$

$$V_E = 0 \text{ V}$$

$$V_B = V_{BE}$$

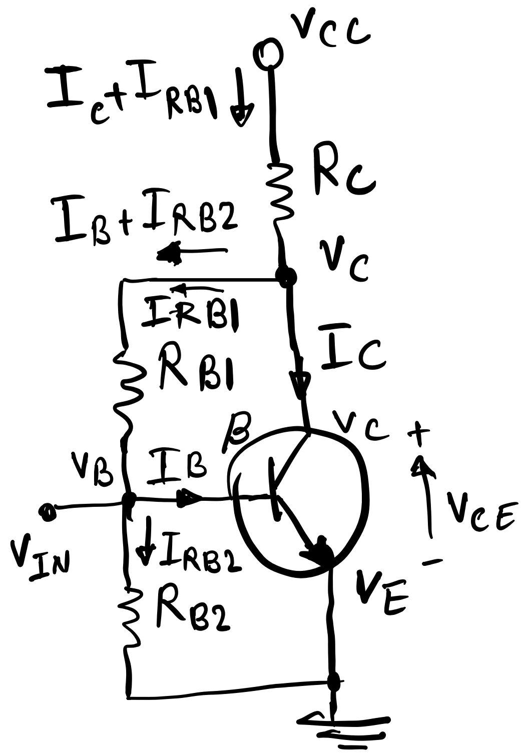
$$I_B = \frac{V_C - V_B}{R_B}$$

$$I_C = \beta I_B$$

$$I_E = I_C + \underset{\text{small}}{I_B} \cong I_C$$

The collector to base feedback configuration ensures that the Transistor is always biased in the active region regardless of the value of Beta (β). The DC base bias voltage is derived from the collector voltage, thus providig good stability.

Dual Feedback Transistor biasing



$$V_C = V_{CC} - R_C(I_C + I_{B1})$$

$$V_E = 0 \text{ V}$$

$$V_B = V_{BE}$$

$$I_{RB2} = \frac{V_B}{R_{B2}}$$

$$I_{RB1} = I_B + I_{RB2} = \frac{V_C - V_B}{R_{B1}}$$

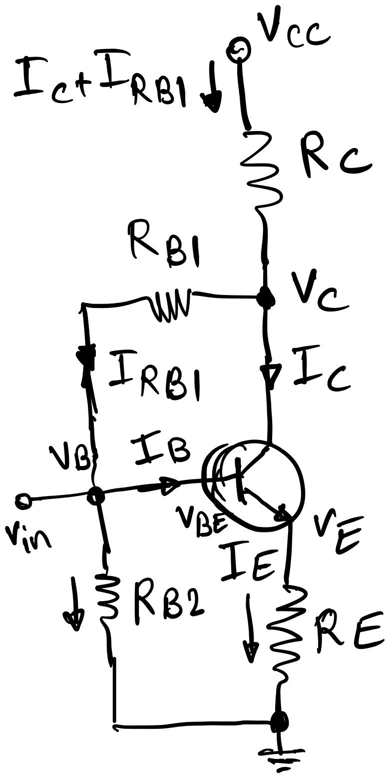
$$I_C = \beta I_B$$

$$I_E = I_C + \underset{\text{small}}{I_B} \cong I_C$$

Adding an additional resistor to the base bias network improves the stability even more with respect to variations in Beta (β) by increasing the current flowing through the base biasing resistors

The current flowing through R_{B1} is generally set at a value equal to about 10% of collector current, I_C. One of the advantages is that the two resistors provide both automatic biasing and feedback at the same time.

Transistor Biasing with Emitter Feedback



$$V_C = V_{CC} - R_C(I_C + I_{B1})$$

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

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

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

$$I_{RB1} = I_B + I_{RB2} = \frac{V_C - V_B}{R_{B1}}$$

$$I_C = \beta I_B$$

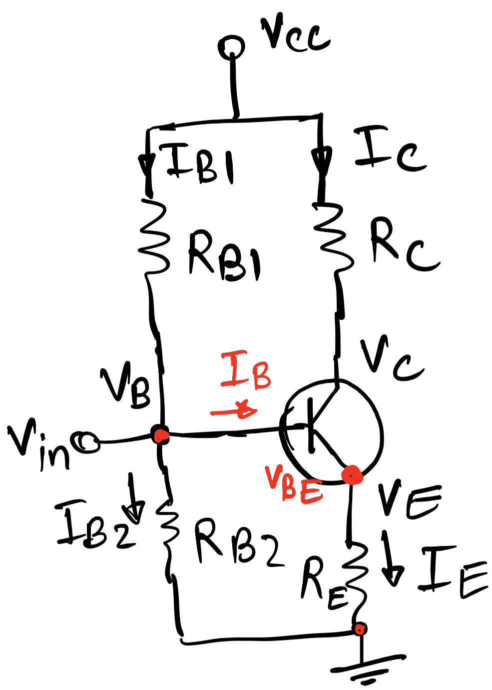
$$I_E = (I_C + I_B) \cong I_C$$

(I_B → small)

This transistor configuration uses both emitter and base-collector feedback to stabilize the collector current even further. This is because R_{B1} and R_E are connected in series with the supply voltage, V_{CC}.

The downside of this emmitter feedback configuration is that it reduces the output gain due to the base resistor connection.

Voltage Divider Transistor Biasing



$$V_C = V_{CC} - R_C I_C$$
$$= V_E + V_{CE}$$

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

$$V_{CE} = V_C - V_E$$
$$= V_{CC} - (I_C R_C + I_E R_E)$$

$$V_B = V_{BE} + V_E = V_{RB2}$$

$$= \frac{R_{B2}}{R_{B1} + R_{B2}} V_{CC}$$

$$I_{B2} = \frac{V_B}{R_{B2}}$$

$$I_{B1} = I_B + I_{B2} = \frac{V_{CC} - V_B}{R_{B1}}$$

$$R_B = \frac{R_{B1} \times R_{B2}}{R_{B1} + R_{B2}}$$

$$I_C = \beta I_B$$

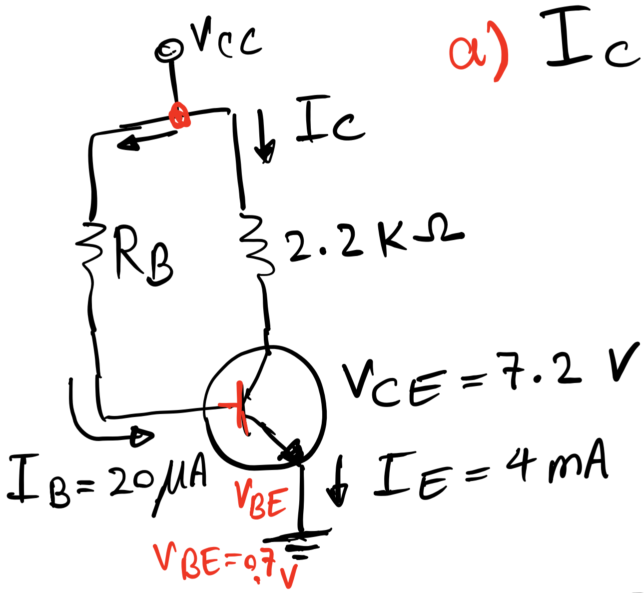
$$I_E = I_C + I_B = \frac{V_E}{R_E}$$

Here, voltage divider network is used to increase stability.

R_{B1} and R_{B2} form a voltage divider network across the supply with their center point junction connected to the transistor base terminal.

Example

Given the information in the circuit find a) I_c, b) V_{cc}, c) β, d) R_B



a) $I_c = I_E - I_B$

$= 4\ mA - 20\ \mu A \simeq 4\ mA$
$= 3.98\ mA$

b) $V_{cc} = I_c R_c + V_{CE}$

$V_{cc} = 3.98 \times 2.2 + 7.2$
$= 16\ V$

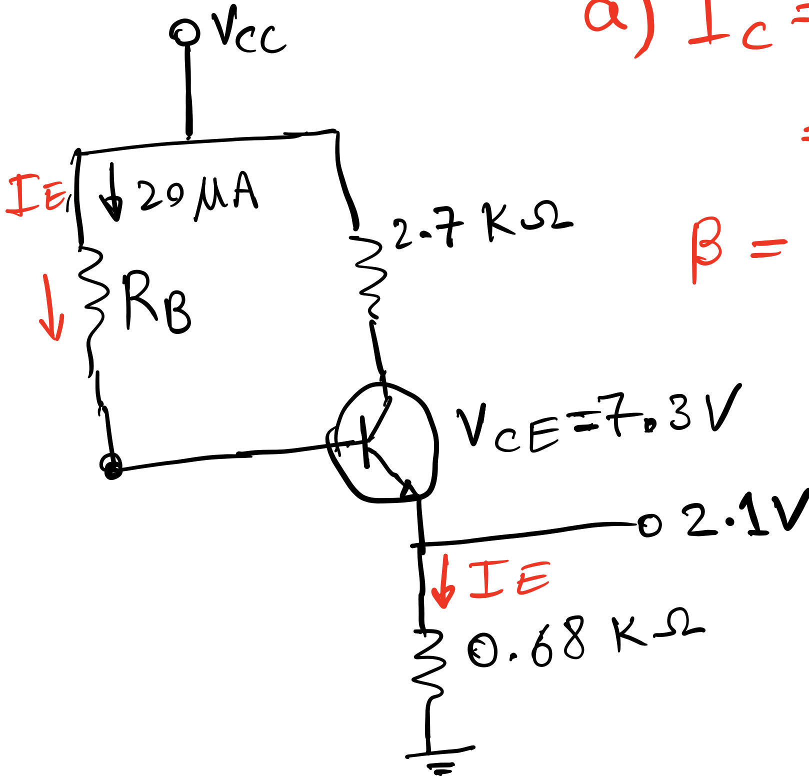
c) $\beta = \dfrac{I_c}{I_B} = \dfrac{3.98\ mA}{20\ \mu A} = 199$

d) $R_B = \dfrac{V_{RB}}{I_B} = \dfrac{(16 - 0.7)}{20\ \mu A} = 763\ K\Omega$

Example

In the circuit below, find

a) β , b) V_{CC} , c) R_B .



a) $I_C = I_E = \frac{2.1}{0.68K}$

$= 3.09 \text{ mA}$

$\beta = \frac{I_C}{I_E} = \frac{3.09 \text{ mA}}{20 \, \mu A}$

$\beta = 155$

b) $V_{CC} = I_C R_C + 7.3 + 2.1$

$= 3.09 \times 2.7 + 9.4 = 17.7 \, V$

c) $R_B = \frac{V_{RB}}{I_B} = \frac{17.7 - 0.7 - 2.1}{20 \, \mu A} = 747 \, K\Omega$