Transistors

Bipolar transistor:
is a semiconductor device which can be used for switching or amplification.

Diodes are made up from two pieces of semiconductor material to form a simple PN junction. If we join together two indiridual diodes back-to-back, this will give us two PN-junctions connected in series which would share a common positive (P) or negative (N) terminal. The fusion of these two diodes produces a three layer, two junction, three terminal device forming the basis of a Bipolar Junction Transistor, or BJT for short.

Transistors are three terminal devices made from different semiconductor materials that act as an insulator or a conductor by the application of a small signal voltage. The transistor's ability to change between these two states enables it to have two basic functions: "switching" (digital electronics) or "amplification" (analogue electronics).

Bipolar transistors have the ability to operate within three different regions:

- Active region - the transistor operates as an amplifier and

$$I_c = \beta I_b$$

- saturation - the transistor is

"Fully-ON" operating as a switch and $I_C = I$ (saturation)

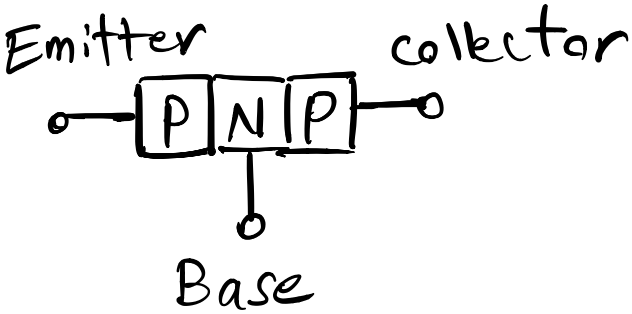
-cut-off - the transistor is "Fully-OFF" operating as a switch and $I_C = 0$

The tree terminals of bipolar transistor are known and labelled as Emitter (E), the base (B) and the collector (C) respectively.

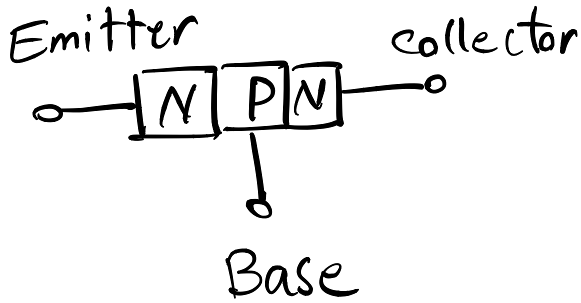
Bipolar Transistors are current regulating devices that control the amount of current flowing through them from the emitter to the collector terminals in proportion to the amount of biasing voltage applied to their base terminal, thus acting like a current controlled switch. As a small current flowing into the base terminal controls a much larger collector current forming the basis of transistor action.

Bipolar Transistor Construction:

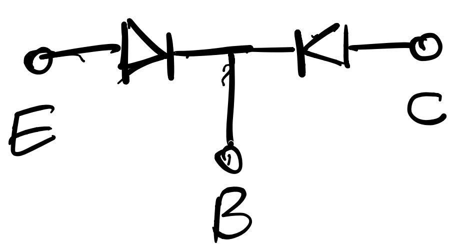
PNP Transistor

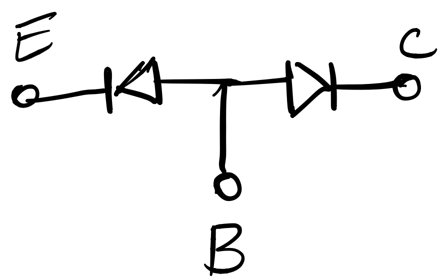


NPN Transistor

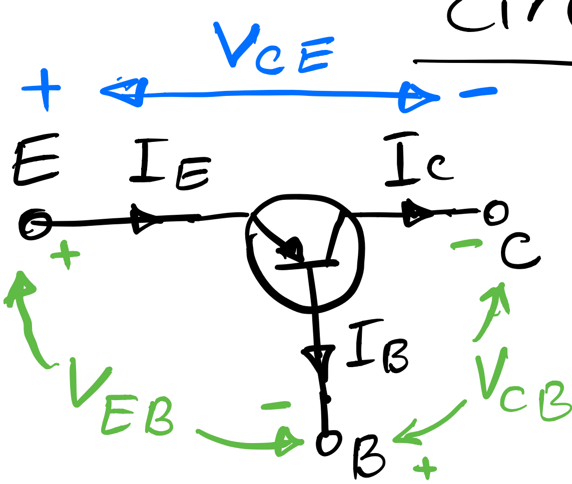


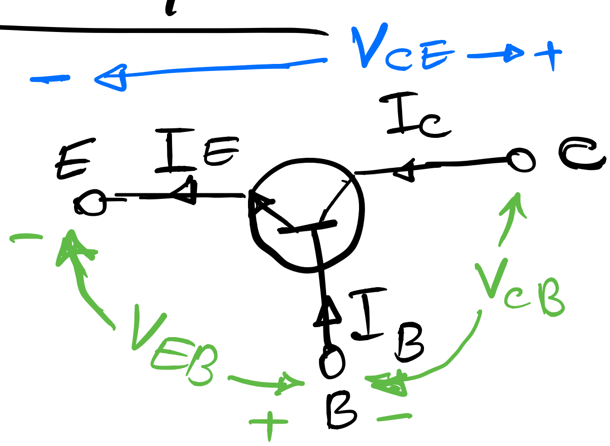
Two-diode analogy





circuit symbol





The arrows show the direction of "conventional current flow". The direction of arrow is from the positive P-type region to negative N-type region.

Bipolar transistor configurations

- Common base configuration has voltage gain but no current gain
- Common Emitter configuration has both current and voltage gain

- common collector configuration has current gain but no voltage gain

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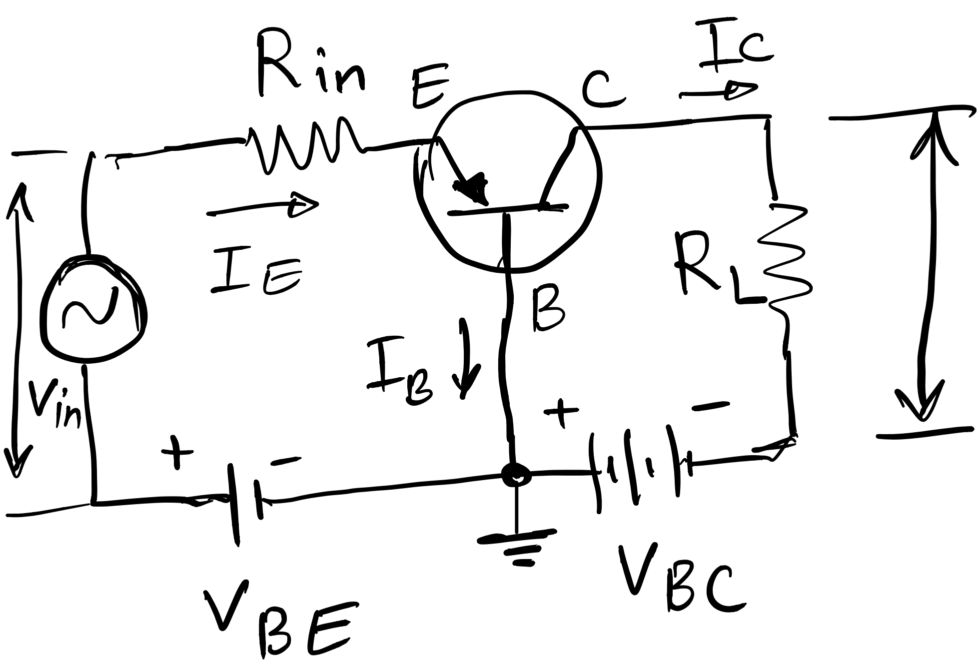
The common Base (CB) configuration



This is an amplifier configuration

(non-inverting voltage amplifier),
This type is not very common due to its unusually high voltage gain.

Common Bas voltage gain

$$A_v = \frac{V_{out}}{V_{in}} = \frac{I_C \times R_L}{I_E \times R_{IN}}$$

where $\frac{I_C}{I_E}$ is the current gain, called alpha (α), and $\frac{R_L}{R_{IN}}$ is the resistance gain.

The common base circuit is generally used only in single stage amplifier circuits such as microphone pre-amplifier or radio frequency (RF) amplifiers due to its good high frequency response

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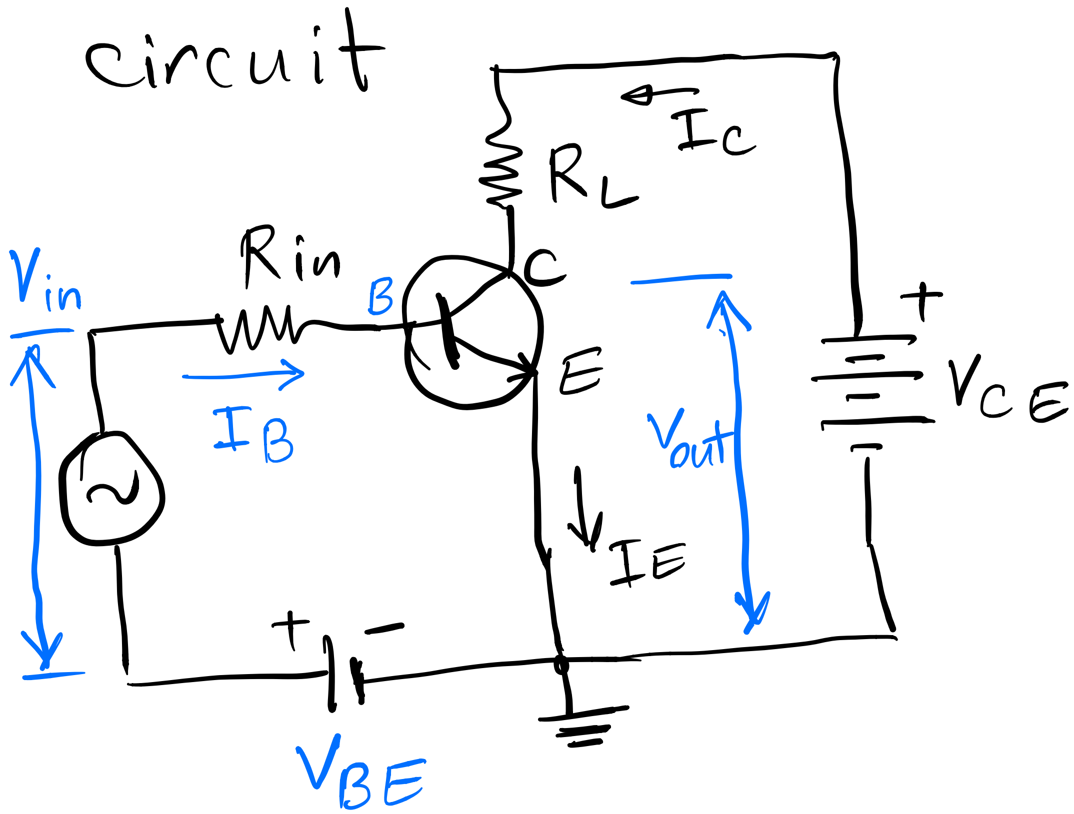
The common Emitter (CE) configuration.

In CE the input is applied between the base and the Emitter, and the output is from between the collector and the emitter.

This type is used for transistor based amplifiers.

The common emitter amplifier produces the highest current and power gain.

The cammon Emitter amplifier circuit



In this type, the current flowing out of the transistor must be equal to the currents flowing into the transistor as the Emitte current is given as

$$I_E = I_C + I_B$$

As the load resistor R_L is cannected in series with the collector, the current gain of the common Emitter transistor is quite large. The ratio is

$$\beta = \frac{I_C}{I_B}$$

The ratio of I_C to I_E is α ; $\alpha = I_C / I_E$

Note that α will always be less than unity.

The mathematical reletionships:

$$\alpha = \frac{I_C}{I_E} \qquad \beta = \frac{I_C}{I_B}$$

$$I_C = \alpha I_E = \beta I_B$$

$$\alpha = \frac{\beta}{\beta + 1} \qquad \beta = \frac{\alpha}{1 - \alpha}$$

$$I_E = I_C + I_B$$

I_B → current into the base

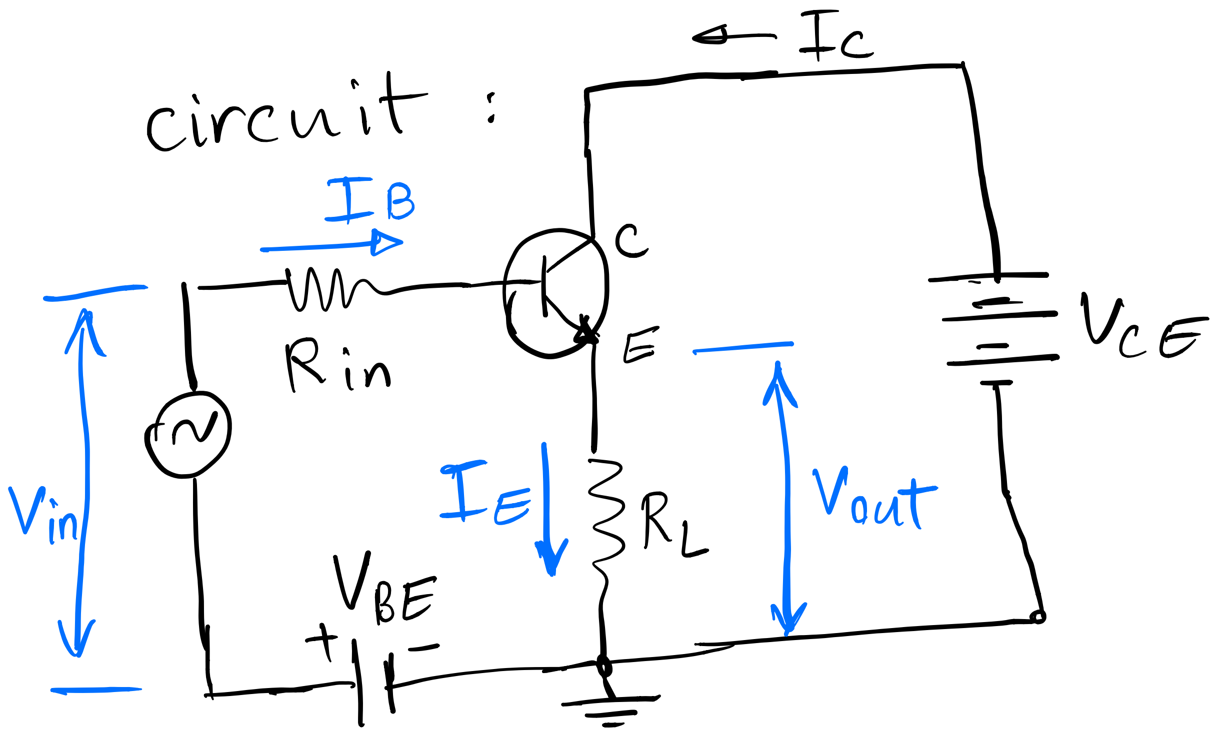
I_C → current into the calletor

I_E → Current out of Emitter

The common collector (cc) configuration

This type Known as Voltag Follower or Emitter Follower circuit.

The common collector Transistor circuit :



The cammon collector current Gain:

$$I_E = I_C + I_B$$

$$A = \frac{I_E}{I_B} = \frac{I_C + I_B}{I_B}$$

$$B = \frac{I_C}{I_B} + 1$$

$$A = B + 1$$

The load resistance of the cammon collector transistor reciever both the base and collector currents giving a large current gain, therfore, providing good current amplification with very little voltage gain.

The characteristics of the different transistor configurations are given in the following table:

Characteristic	Common Base	Common Emitter	Common Collector
Input impedance	very High	High	Low
Phase shift	0°	180°	0°
Voltage Gain	High	Medium	Low
Current Gain	Low	Medium	High
Power Gain	Low	very High	Medium

Example

A bipolar NPN transistor has a DC current gain $\beta = 200$.

Calculate the base current I_B required to switch a resistive load of 4 mA.

$$I_B = \frac{I_C}{\beta} = \frac{4 \times 10^{-3}}{200} = 20\,\mu A$$

Note: There is a voltage drop between the Base and the Emitter terminal of Bipolar NPN Transistors of about 0.7 V (one diode volt drop).

Example

An NPN transistor has a DC base bias voltage, V_B of 10 V and an input base resistor, R_B of $100\ k\Omega$.

what will be the base current into the transistor?

$$I_B = \frac{V_B - V_{BE}}{R_B} = \frac{10 - 0.7}{100\ k\Omega}$$

$$I_B = 93\ \mu A$$