Transistor Operation

Objectives

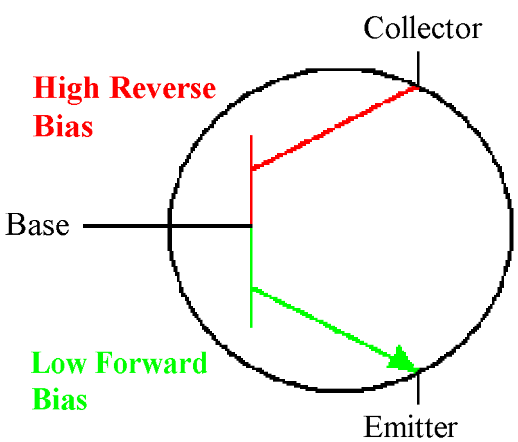
Describe transistor cutoff and saturation.

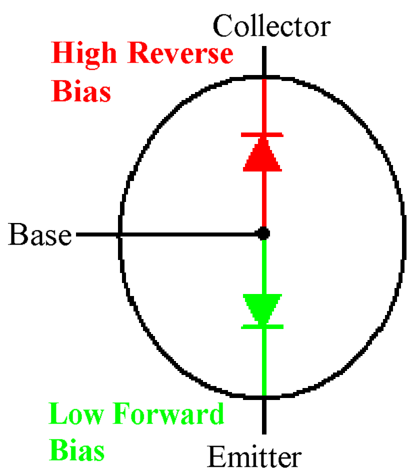
Describe transitor alpha and beta.

Identify fixed, self, and combinational biasing.

A transistor is similar to two diodes tied back-to-back.

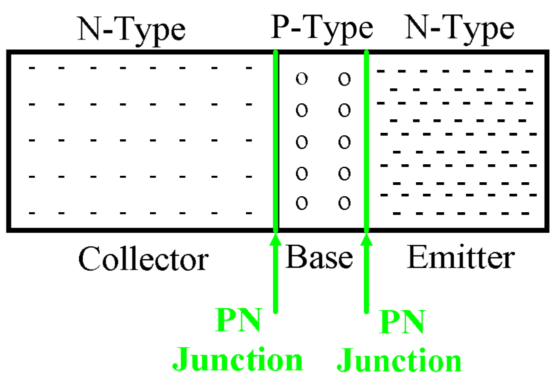
For a transistor to operate properly, the base-to-emitter junction must be forward biased, and the base-to-collector junction must be reversed biased.





Transistors are solid state devices constructed of P-type and N-type dopants.

Solid State Device: An electronic component which operates by the movement of electrons within a solid piece of semiconductor material.

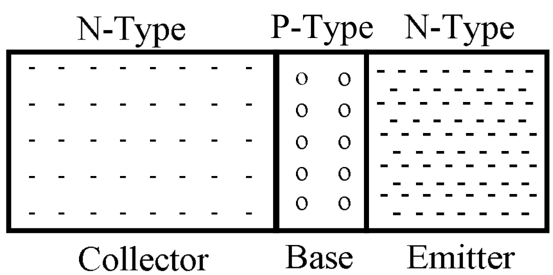


Transistors are made of three different sections and two PN junctions.

Remember, the PN junction between the base and collector are normally reversed biased.

The PN junction between the base and emitter are normally forward biased.

Transistors are made of semiconductors which are elements that have four electrons in their outer valence shell.

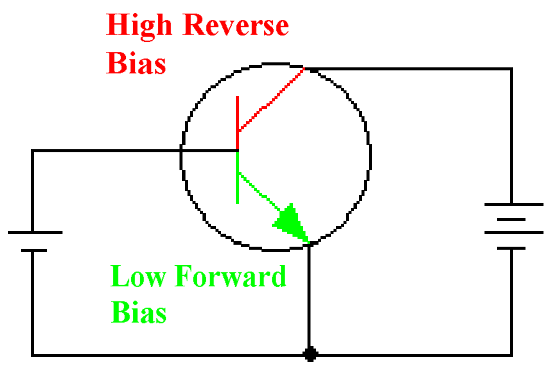


Emitter: **Heavily doped** to produce large numbers of current carriers.

Base: Very thin and **lightly doped**. Passes most of the current carriers from the emitter to the collector.

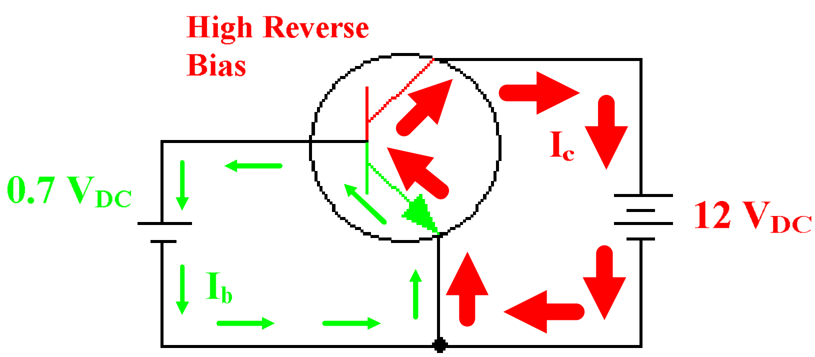
Collector: **Moderately doped** to collect the current carriers from the base. Largest of the three areas to dissipate heat.

Lets discuss transistor bias for a NPN transistor circuit.



The transistor is properly biased when the base-to-emitter junction is forward biased and the base-to-collector junction is reversed bias.

Like a diode, it takes 0.7 VDC to forward bias the base-to-emitter PN Junction for silicon transistors.

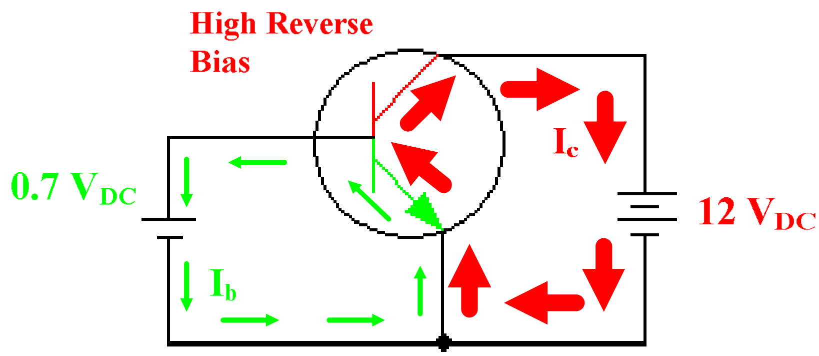


Once the base-to-emitter junction is forward biased, and the base-to-collector junction is reversed biased, current starts to flow.

Transistors are unique in that current flows through high reversed biased PN junction at the collector.

Collector current (I_c) is controlled by base current (I_b).

Base current (I_b) is much smaller than collector current because the base is thin and lightly doped. Most of the current carriers pass on to the collector.



The collector current (I_c)is large because it is large, moderately doped, and therefore attracts most of the electrons moving across the base.

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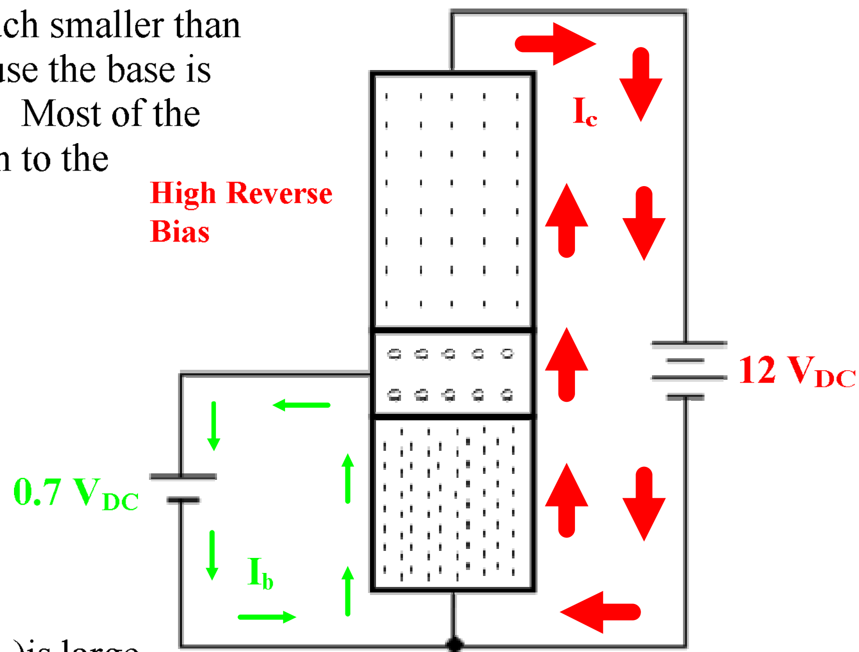
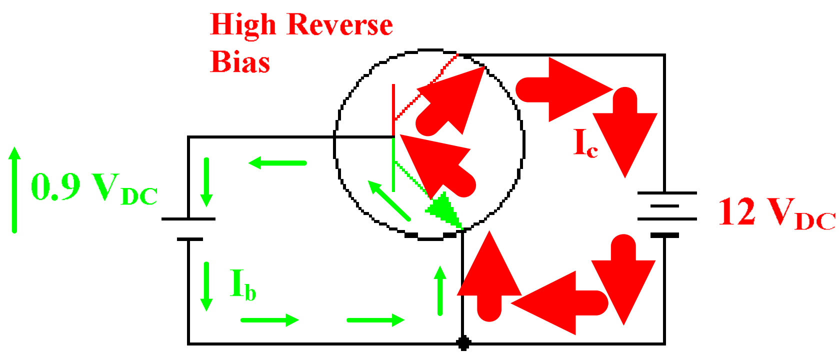


The collector current (I_c)is large because it is large, moderately doped, and therefore attracts most of the electrons moving across the base.

When base voltage is increased, I_b will increase slightly because of the small amount of current carriers.

However, collector current (I_c) will greatly increase because the emitter has a lot of free electrons to give up and the collector is moderately doped.



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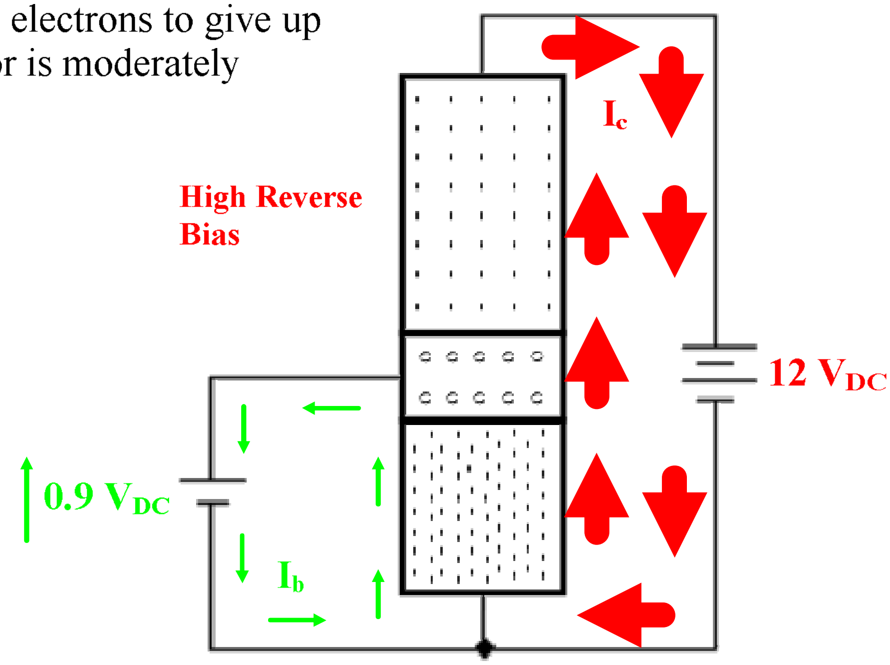
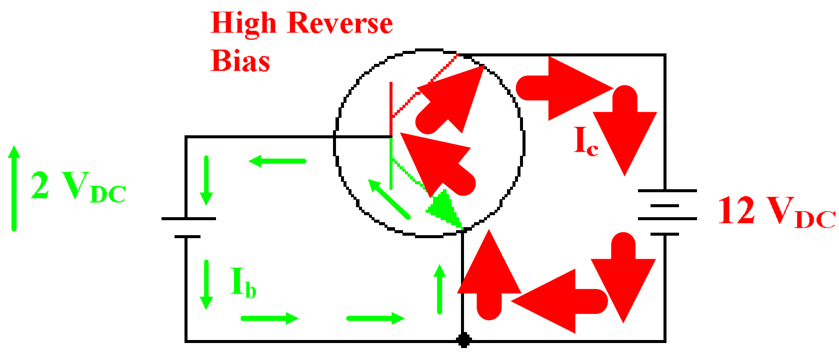


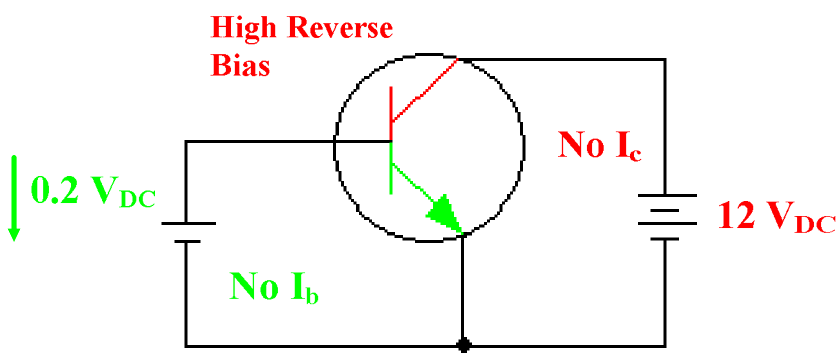
If base bias is increased too much, collector current (I_c) will reach **saturation** and remain constant because all available current carriers in the emitter are used up.



Saturation: Point when collector current (I_c) no longer increases although base bias voltage increases.

Transistor acts like a short between the collector and emitter during saturation.

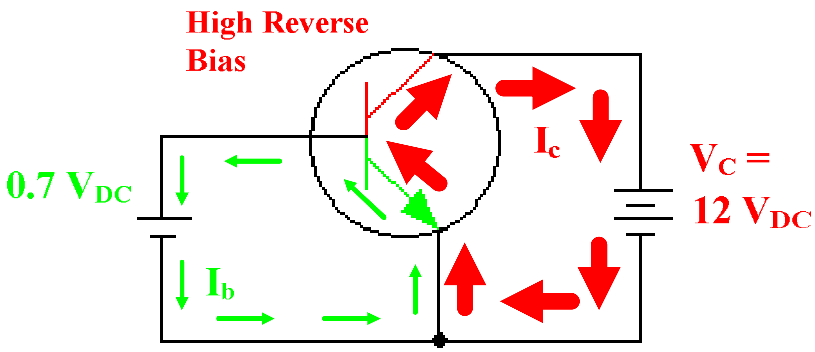
If base bias is decreased below the forward bias level (0.7V), base current (I_b) and collector current (I_c) will **cut off**.



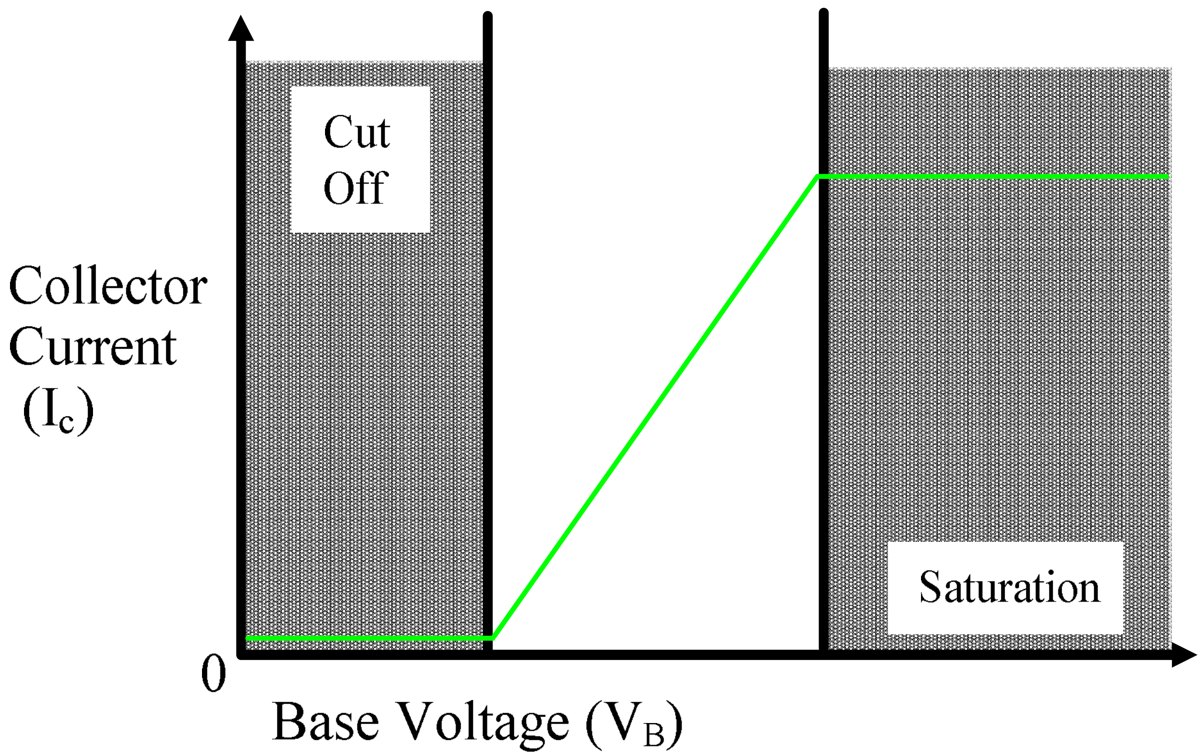
Cut off: Point when collector current (I_c) no longer flows and the transistor is turned off because the base-to-emitter junction is reversed biased.

Transistor acts like a open between the collector and emitter during cut off.

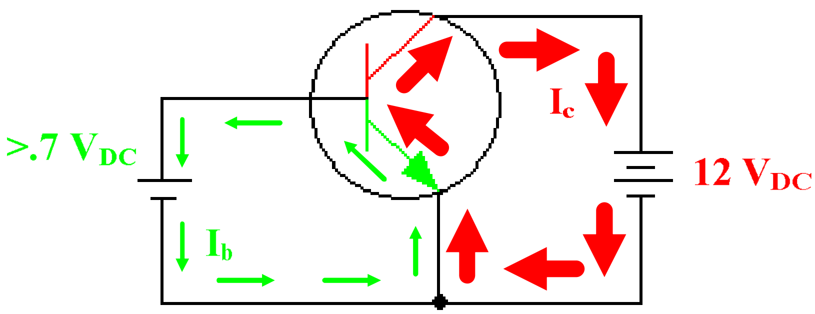
We did not discuss the collector bias voltage. It has very little effect on collector current (I_c).



This is because the collector-to-base PN junction is reversed biased, and all available current carriers in the base are already attracted to the collector.


Cut
Off
Collector
Current
(Ic)
Saturation
0
Base Voltage (VB)

The three currents in a transistor are related. Remember that the small base current (I_b) controls the larger collector current (I_c).

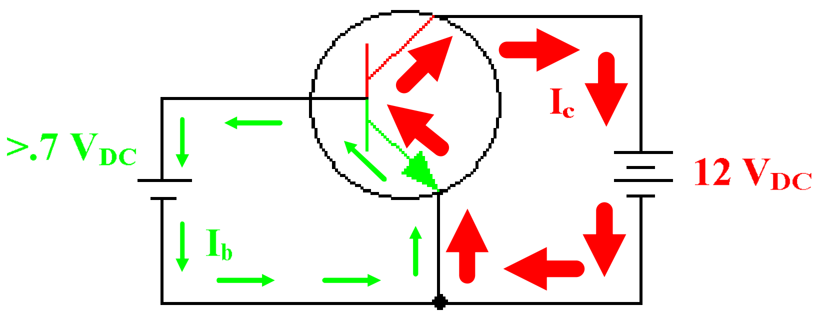


Kirchoff's current law shows:

$$I_e = I_b + I_c$$

This means that I_b and I_c flow through the emitter.

Although these three currents are variable based on base voltage and circuit operation, they will change proportionally to each other.

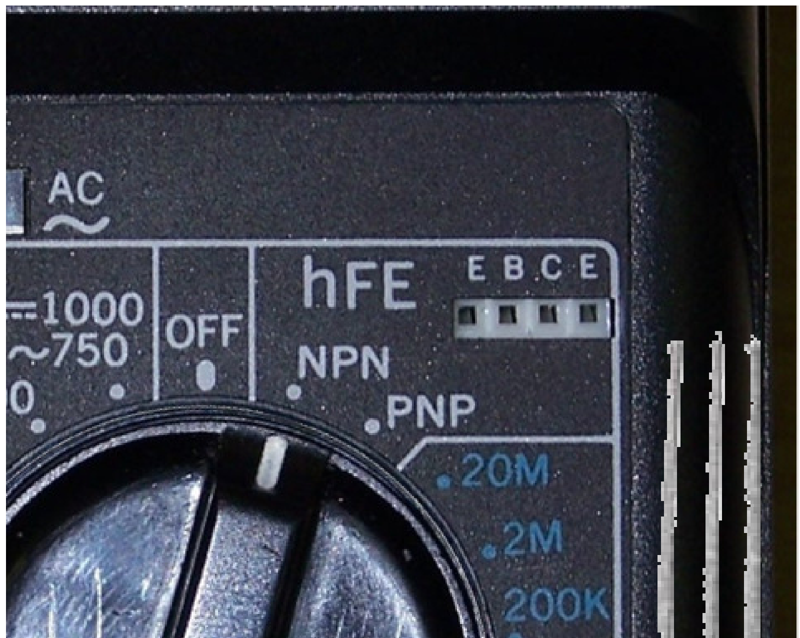


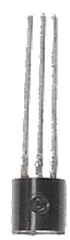
These proportional current changes are expressed in ratios that are constant for each type of transistor.

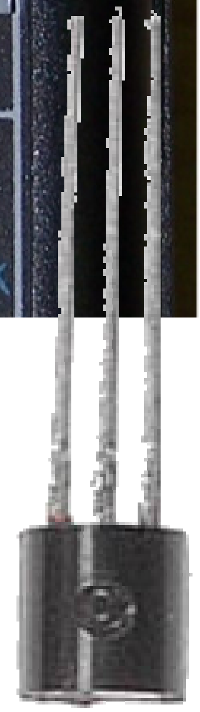
These ratios, α (Alpha) and β (Beta), describe transistor operation under any condition and bias level and are given in a transistor's data sheet.

On data sheets, α (Alpha) is somtimes listed as hFB and β (Beta) is listed as hFE.

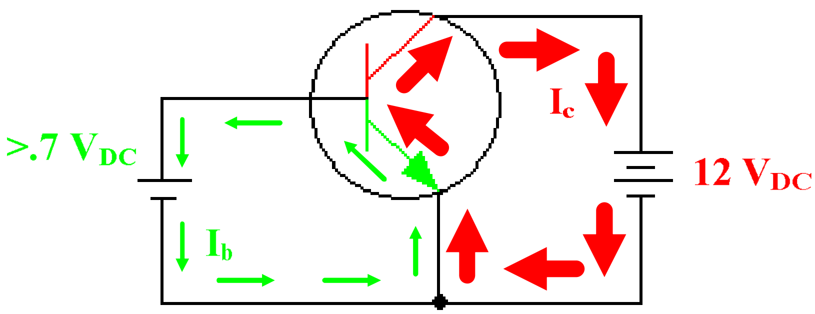

TRIPLETT 2202
DC
AC
OFF
hFE
E B C E
NPN
PNP
1000
750
200
20
2
200m
20M
2M
200K
20K
2K
200
200m
20m
2m
200µ
1.5V
9V
BATT
MAX10A
MAX 500V
MAX 1000V 750V
10A
COM
V Ω A


AC
hFE
E B C E
1000
750
OFF
NPN
PNP
20M
2M
200K



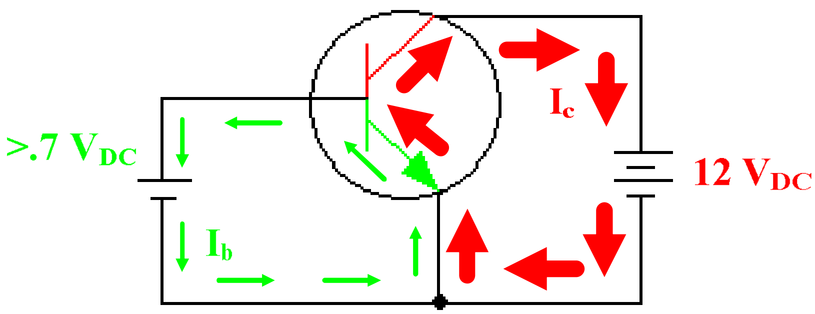


α (Alpha) is the ratio of collector current (I_c) divided by emitter current (I_e).



$$\alpha = \frac{(I_c)}{(I_e)}$$

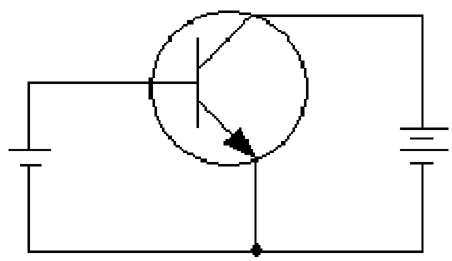
β (Beta) is the ratio of collector current (I_c) divided by base current (I_b).



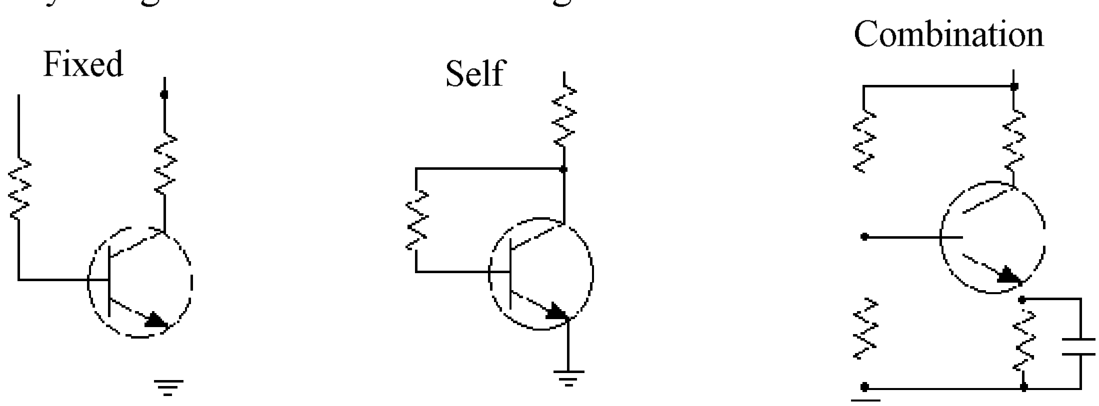
$$\beta = \frac{(I_c)}{(I_b)}$$

Bias Circuits

Using batteries to bias a transistor is not practical.



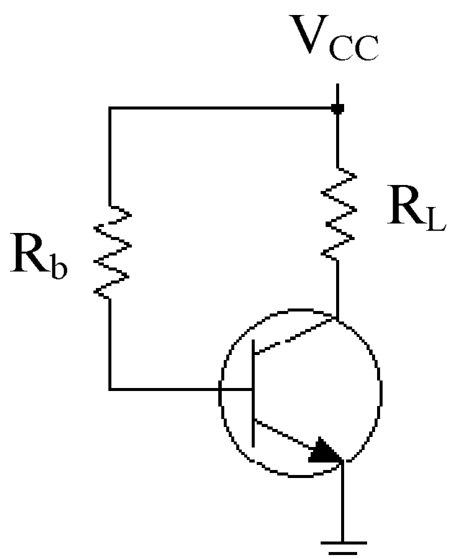
Instead, one power supply (referred as V_{CC}) is reduced to the correct bias levels by using resistors in certain configurations.



Fixed Bias Circuit

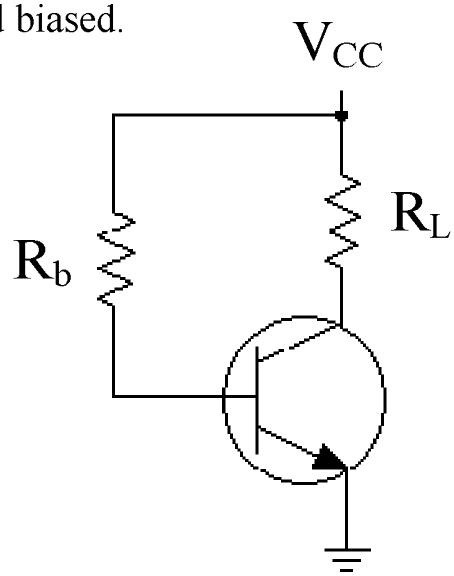
R_L is a load resistor connected between the collector and V_{CC}.

R_b is the base resistor connected between the base and V_{CC}.



Fixed Bias Circuit

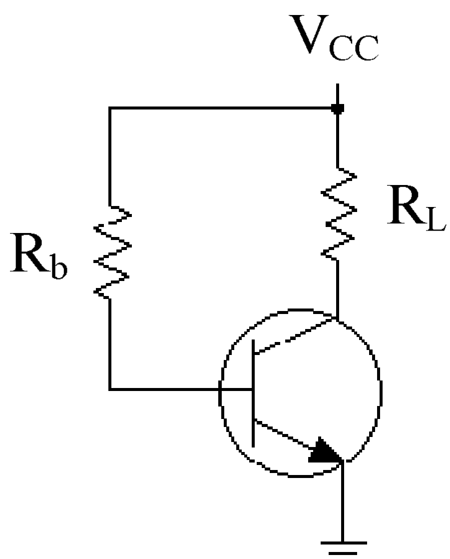
The value of each resistor is selected to drop a larger voltage on the collector (V_C) compared to the voltage on the base (V_B). This will cause the base-to-emitter junction to be forward biased and the base-to-collector junction to be reversed biased.



$V_B < V_C$

Fixed Bias Circuit

Fixed biasing is sensitive to small changes in base current due to temperature changes. These small changes on the base create larger changes on the collector.

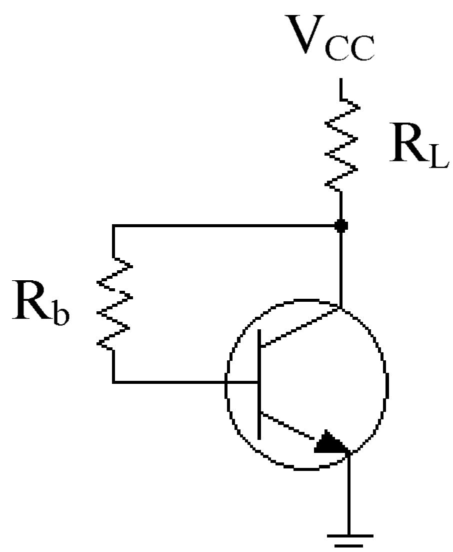


These temperature changes are caused by the transistor heating up from the movement of electrons through the transistor. Heat is a form of energy and causes more current carriers through the emitter.

Self Bias Circuit

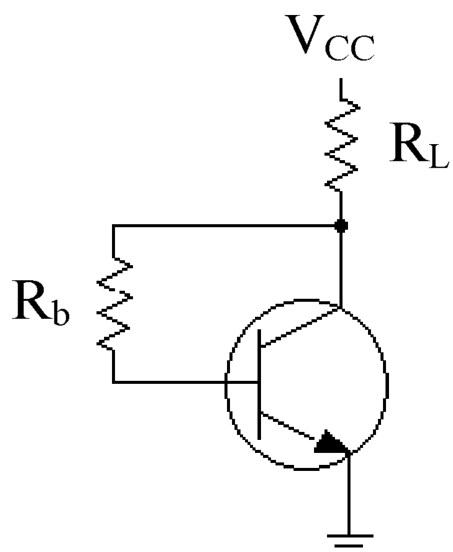
R_L is a load resistor connected between the collector and V_{CC}.

R_b is the base resistor connected between the base and collector.



Self Bias Circuit

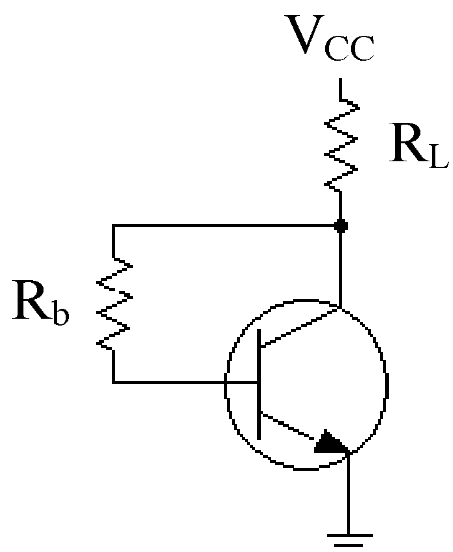
Self biasing overcomes the temperature disadvantage of fixed biasing. If collector current (I_C) increases due to heat, the E_{RL} increases. This causes E_{Rb} to decrease its voltage.



When E_{Rb} decreases, the forward bias between the base-to-emitter decreases. This causes the impedance between the emitter-to-collector to increase, making the collector current (I_C) to return to normal.

Self Bias Circuit

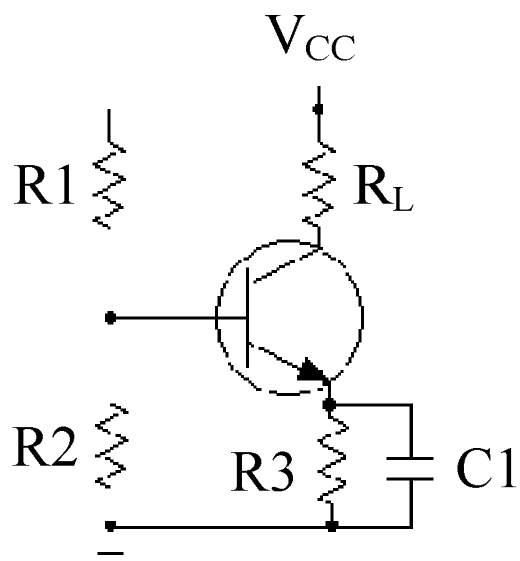
The disadvantage of self biasing is the reduced control of base biasing over the collector current, β (Beta).



Combination Bias Circuit

R1 and R2 make a voltage divider and creates fixed bias on the base.

R_L creates collector bias.



R3 creates a self bias on the emitter bias

C1 stabilizes the DC bias voltages by shorting any AC signals on the emitter.