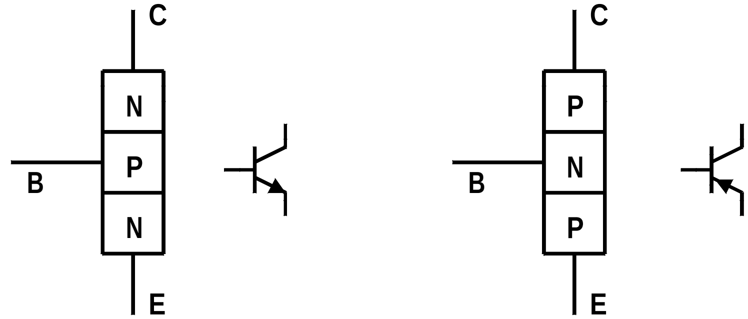
Two types of transistors:— npn and pnp.

A transistor is correctly biased when:—

- The emitter–base junction is forward biased.

- The base–collector junction is reverse biased.

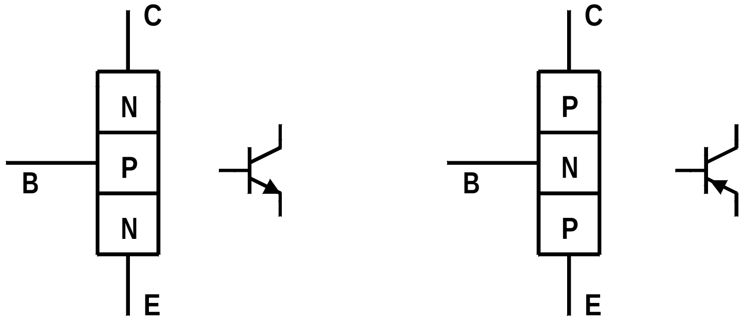
The current gain $= \beta = h_{fe} = \frac{I_C}{I_B}$
Which gives $I_C = \beta \times I_B$
Typical values for β from 30 to 500.
$I_C \approx I_E$.



Bipolar transistor schematic structure

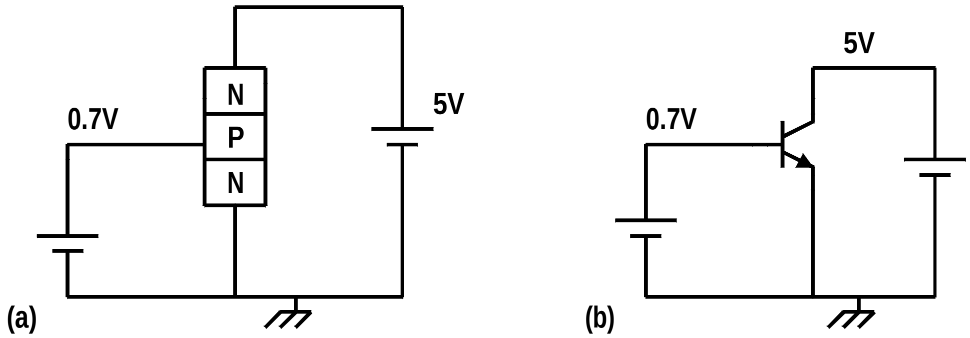
A transistor is a three layer device either an npn or a pnp structure.

Layers called emitter, base and collector



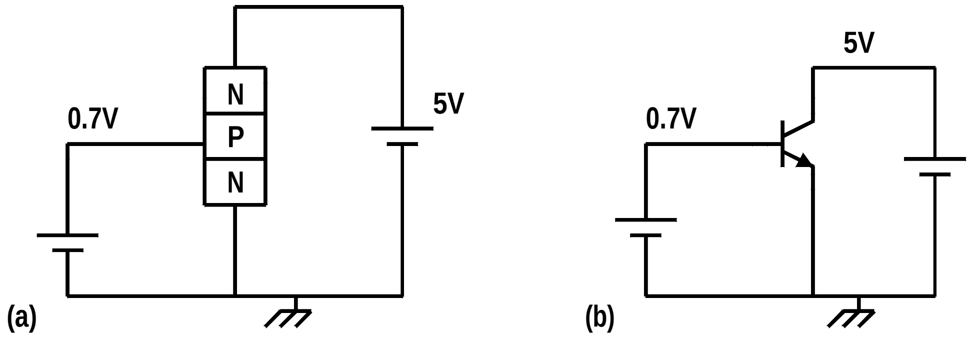
Bipolar transistor schematic structure

Emitter more heavily doped than base or collector
Three layers — two pn junctions
Junctions determine operation of transistor
For correct bias Voltages are applied so that
emitter–base junction forward biased
base–collector junction reversed biased

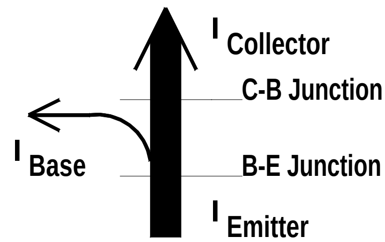


Correct biasing of npn transistor

Reverse biased pn junction is reversed biased for majority carriers only
The reverse current is due to flow of minority carriers across the junction
Reverse current is small because there are few minority carriers present
Collector current should be small since the base–collector junction is reverse biased



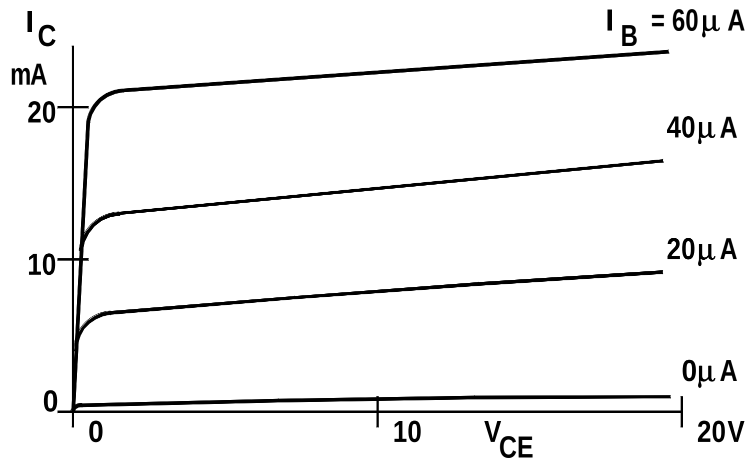
Correct biasing of npn transistor
Forward biased emitter–base diode
n type doping of the emitter region is heavier than the p type doping of the base region
Current across the emitter–base junction mostly due to electrons flowing into the base region
Electrons diffuse until they reach the base–collector junction
At the base–collector junction electrons are swept across the junction to give a collector current
Typically the base region is 0.2 microns thick.



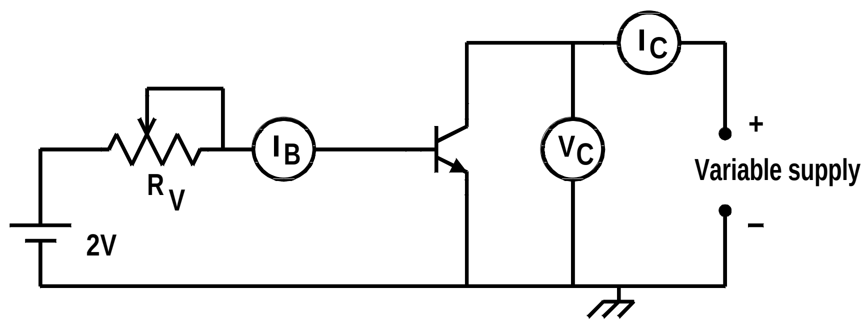
Current is proportional to line thickness

$$I_C \approx I_E$$

A fraction of electrons injected into base from emitter recombine with p type holes in the base
Charging up of the base region to give an emitter–base junction which is no longer forward biased
A base current compensates for this
Base current controls the larger emitter current and gives transistor its amplification properties.



BC109 Transistor output characteristic

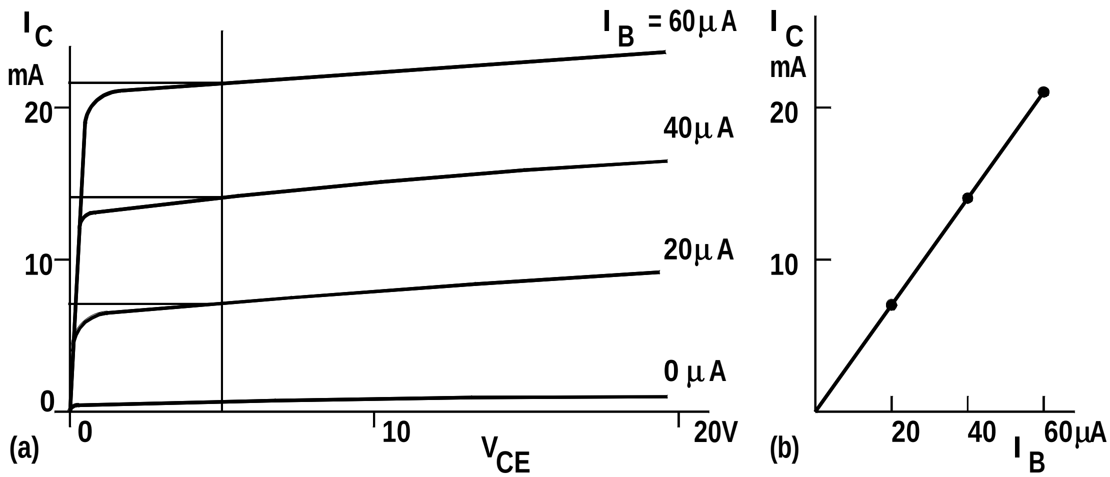


Circuit for measuring output characteristic

Two very important results

- The collector current is relatively independent of the collector voltage.

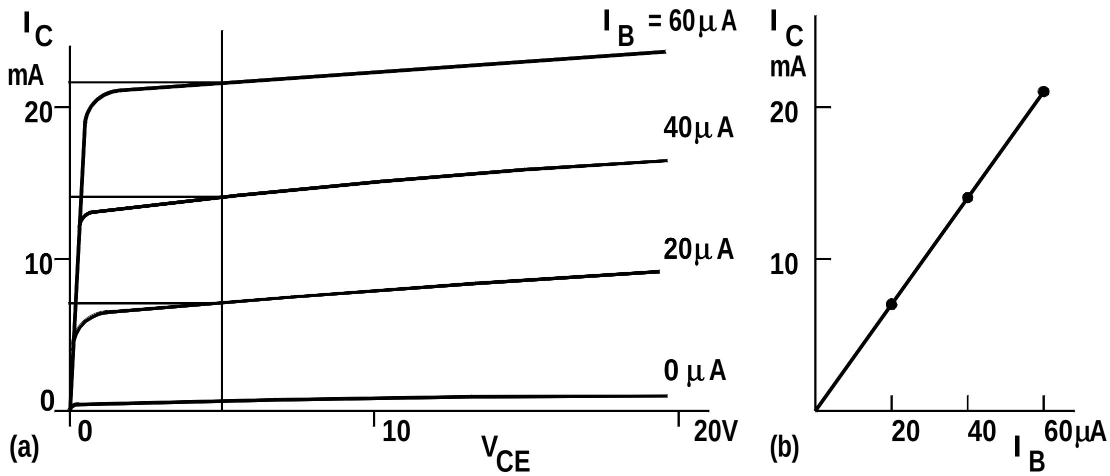
- The collector current is $\beta \times I_B$ where β is the current gain for the transistor. In some data sheets the value of β is quoted as h_{fe} where h_{fe} is used in the h parameter matrix method of transistor specification.



Calculate the current gain at $V_{CE} = 5V$

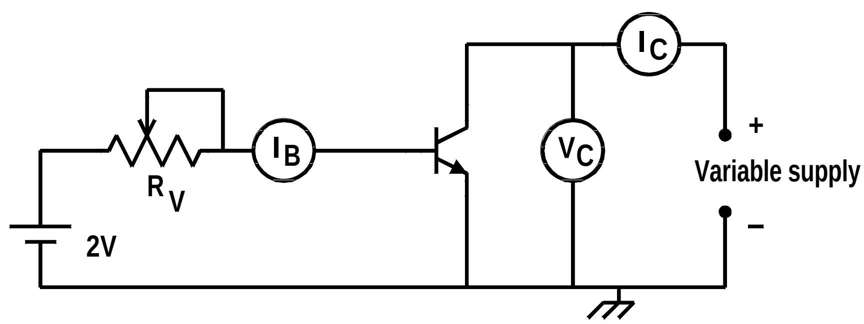
Draw a vertical line at 5V
Note the collector current, I_C
for $I_B = 0\mu A,\ 20\mu A,\ 40\mu A,$ and $60\mu A$.
Plot these values for I_C as a function of I_B

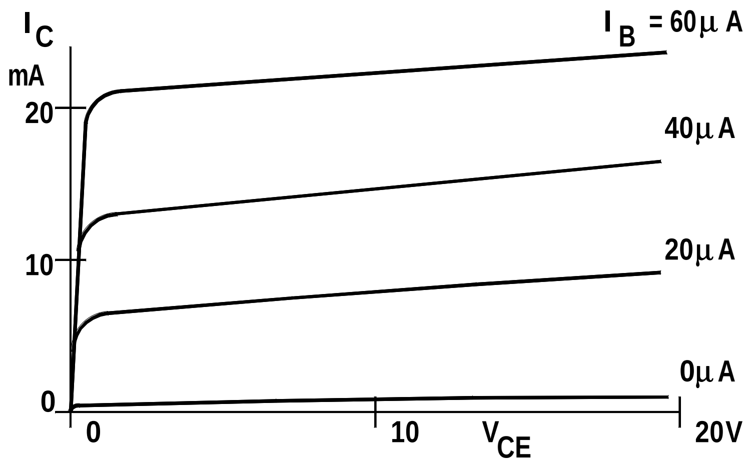
$$\beta = \frac{dI_C}{dI_B} \approx \frac{20mA}{55\mu A} = 363$$



I_C
mA
20
10
0
0
10
20V
V_{CE}
(a)
I_B = 60μ A
40μ A
20μ A
0 μ A
I_C
mA
20
10
(b)
20
40
60μA
I_B

Unit 30 Transistor structure and operation





I_C
mA
20
10
0
I_B = 60μ A
40μ A
20μ A
0μ A
0
10
V_{CE}
20V