EE210: Microelectronics-I

Lecture-8 : Bipolar Junction Transistor-1

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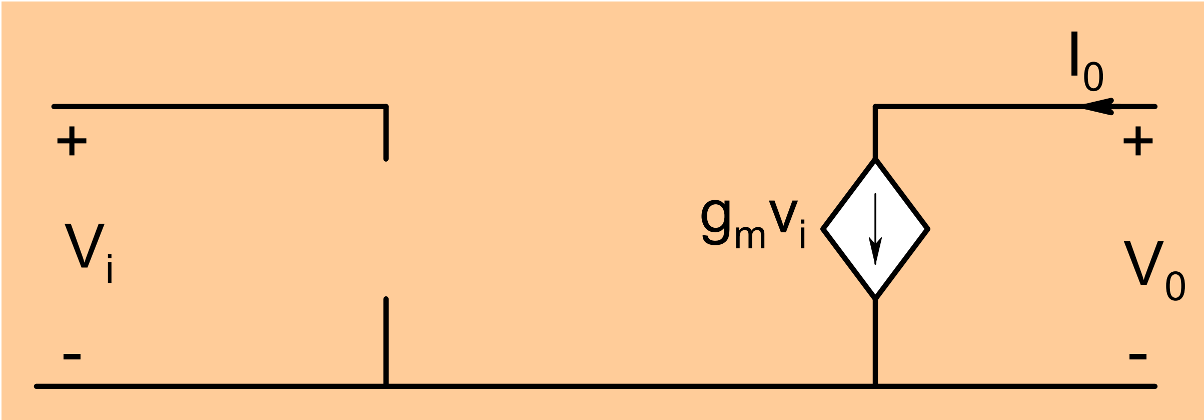
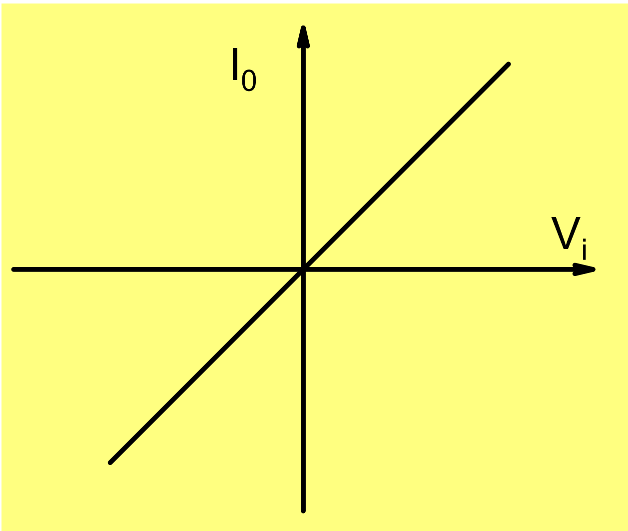
Transistor

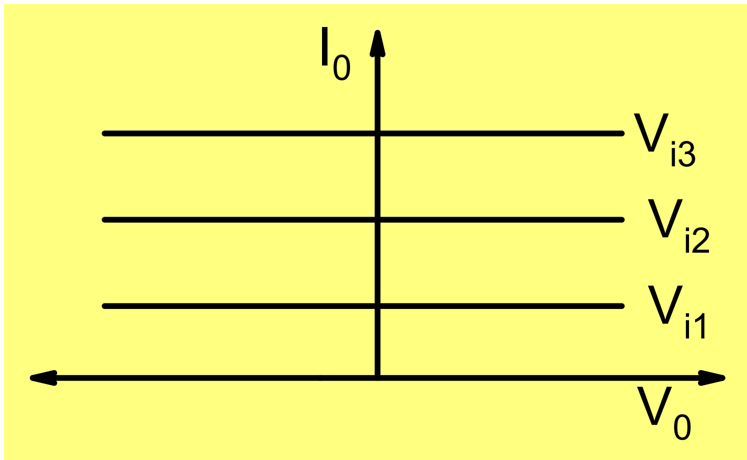
Trans-resistor

Current I_O is much more sensitive to V_{IN} than V_O

"Ideal Transistor"

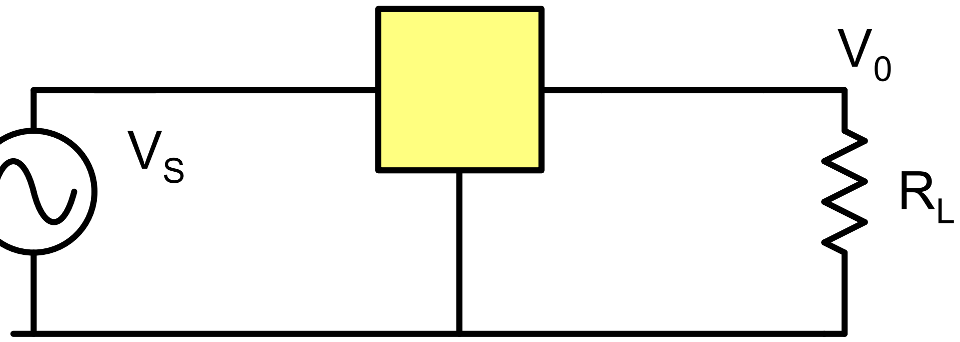


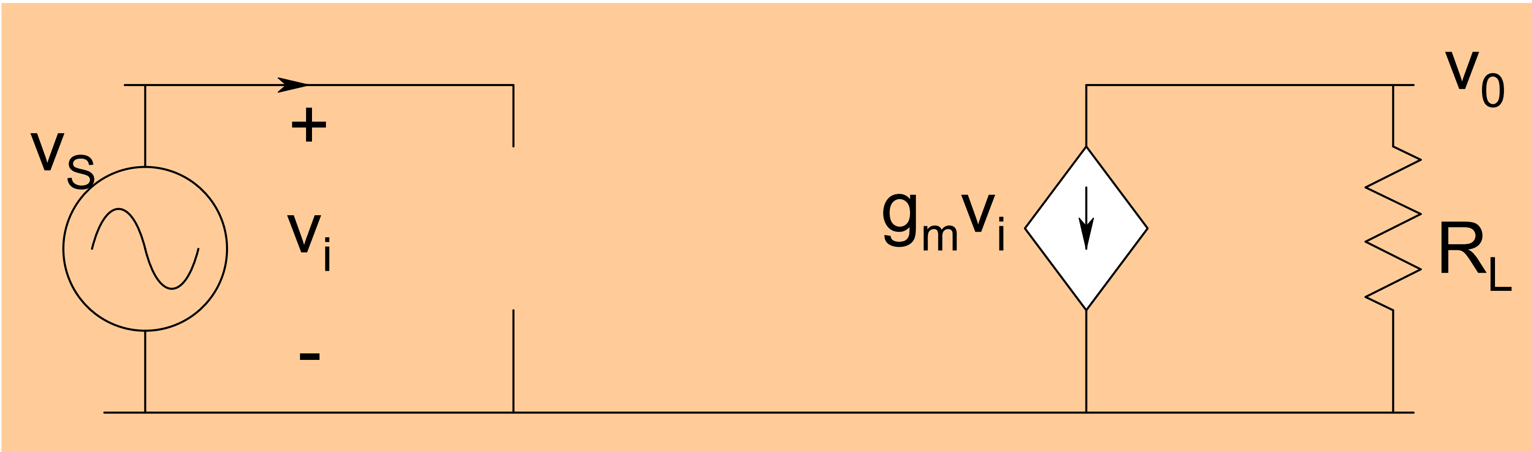




Voltage controlled Current Source (VCCS)

Transistors can be used for AMPLIFICATION

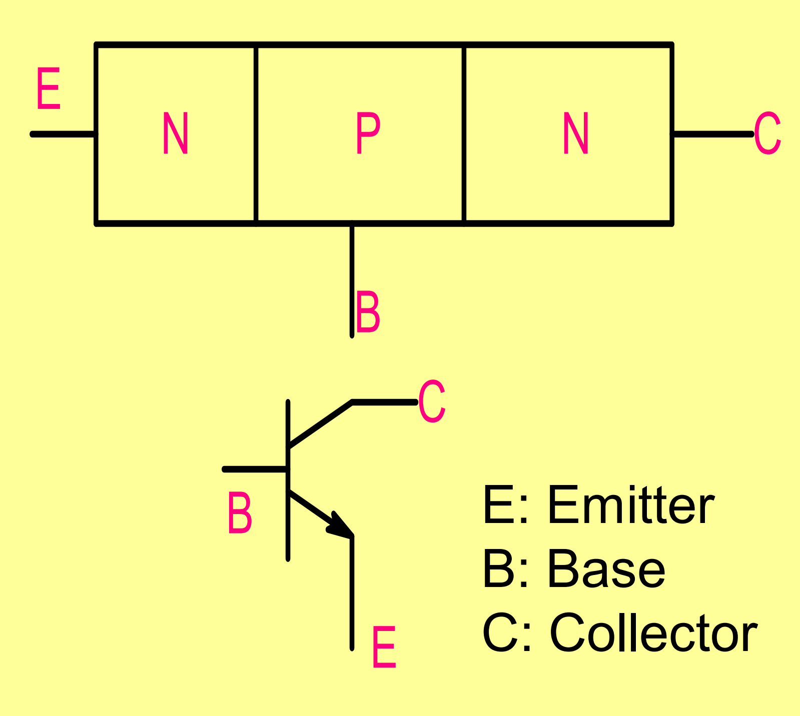




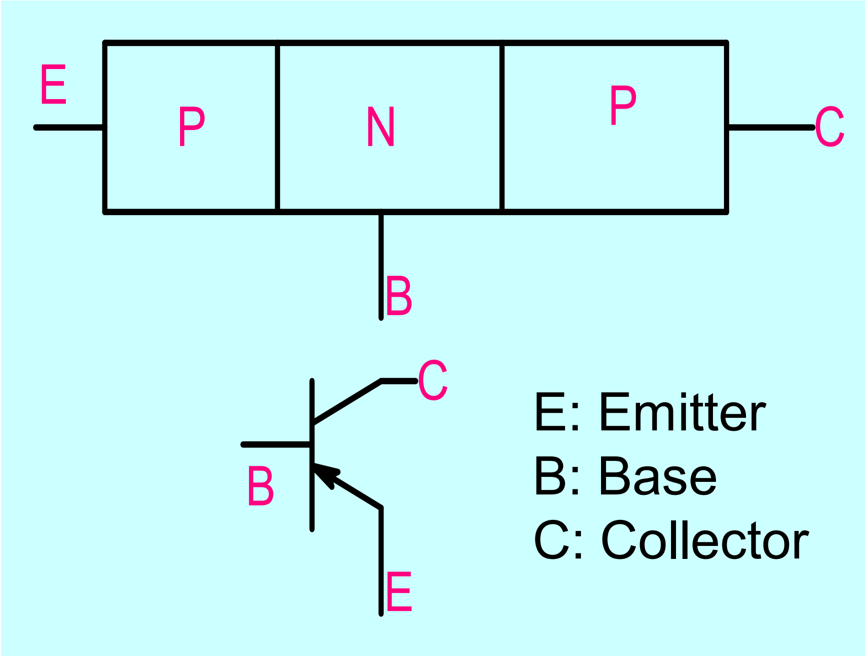
$$A_V = \frac{V_o}{V_s} = -g_m \times R_L$$

By choosing sufficiently larger load resistance, voltage gain can be obtained

Bipolar Junction Transistor (BJT)

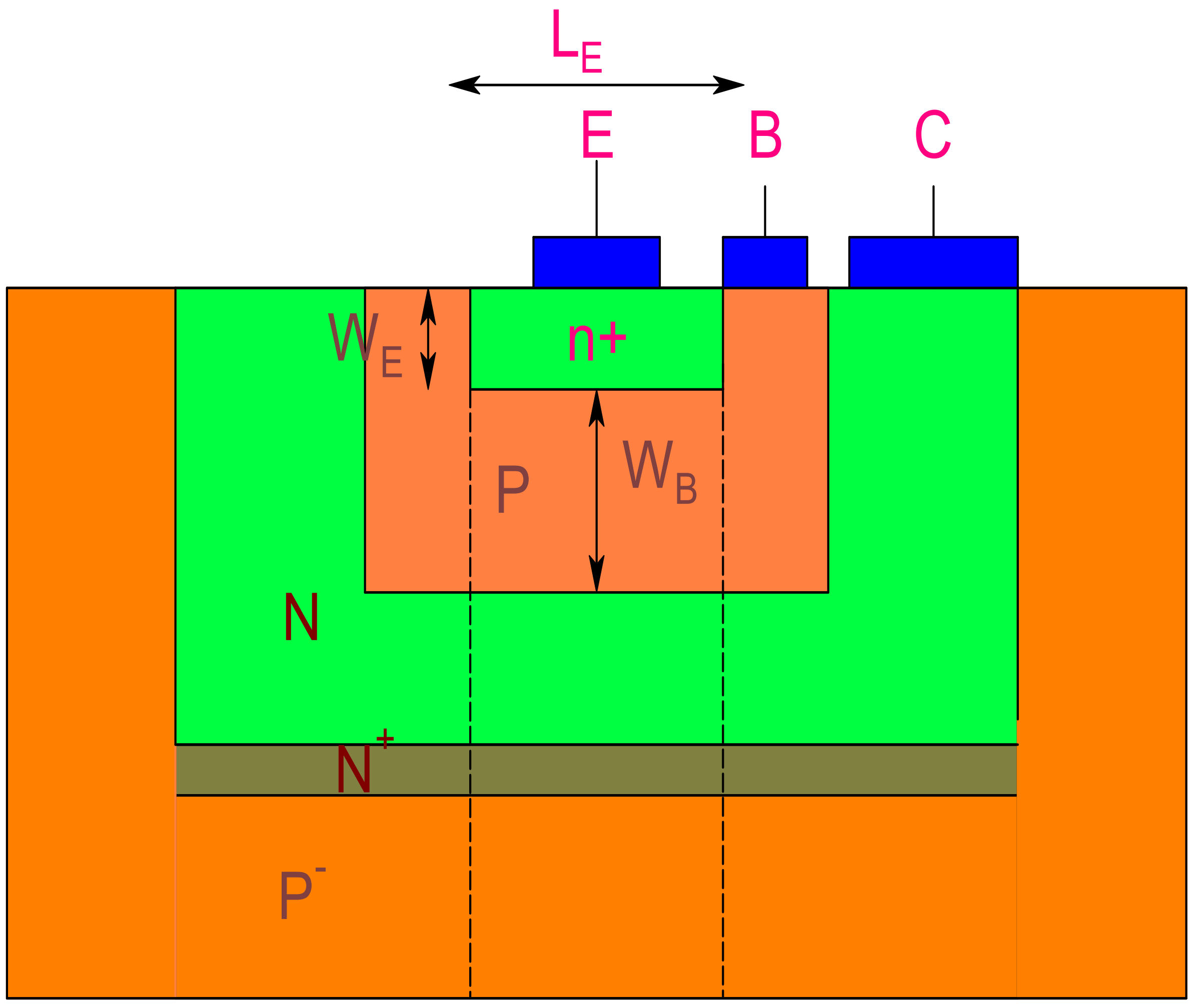


NPN



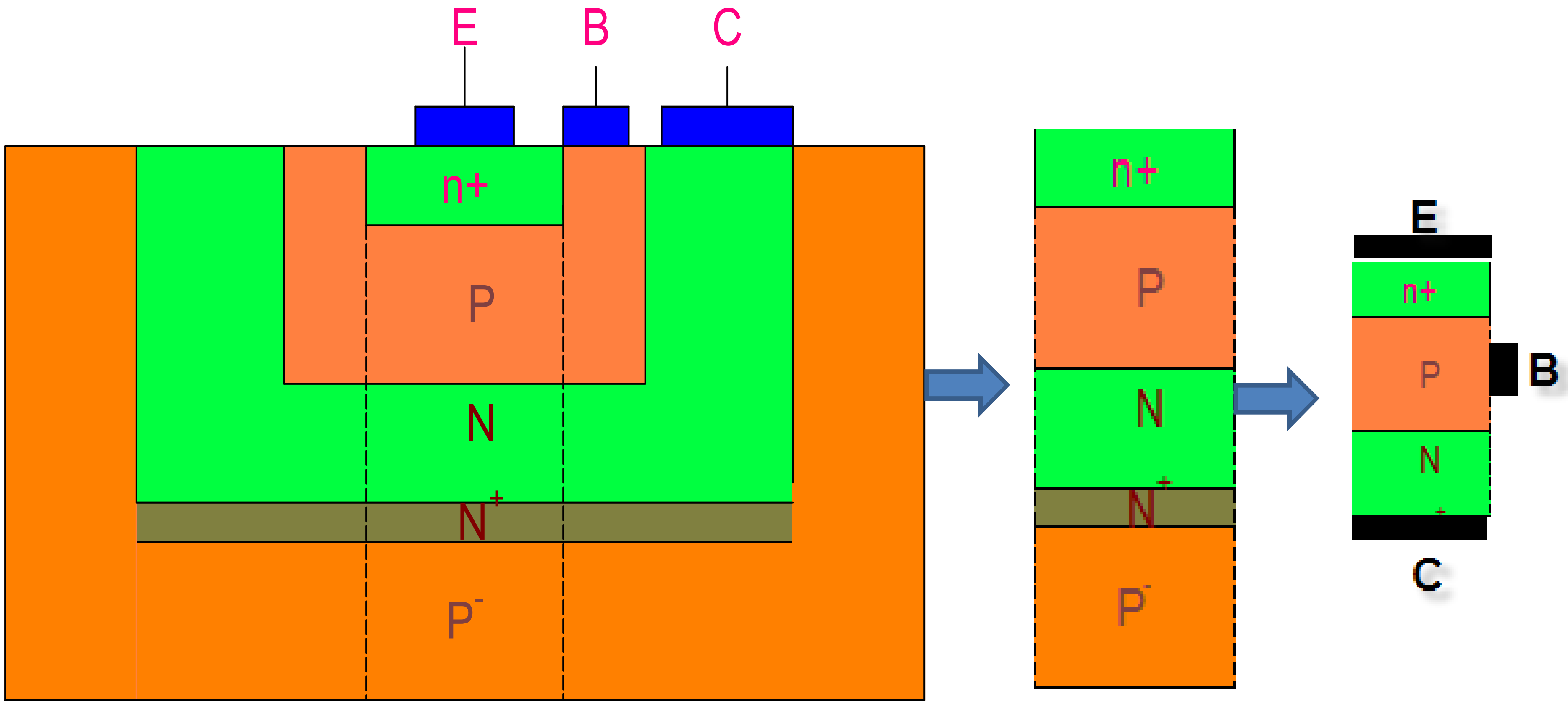
PNP

More Realistic View



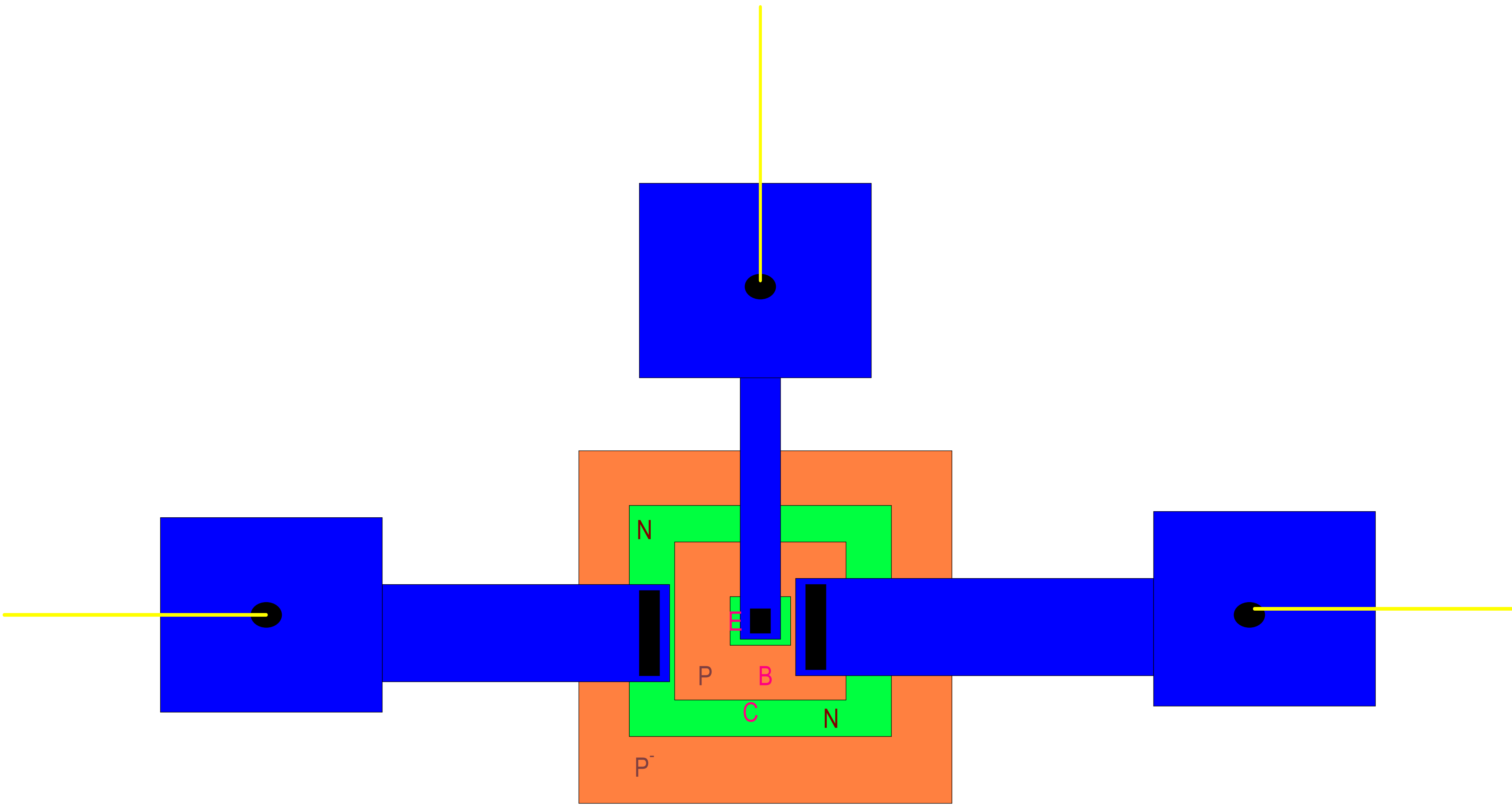
$$N_{DE} \sim 10^{19}\,cm^{-3}$$
$$N_{AB} \sim 10^{17}\,cm^{-3}$$
$$N_{DC} \sim 10^{16}\,cm^{-3}$$
$$W_B \sim 2000\,A^\circ$$
$$W_E \sim 1000\,A^\circ$$
$$L_E \sim 1\mu m$$

BJT is not symmetric: emitter and collector cannot be simply interchanged

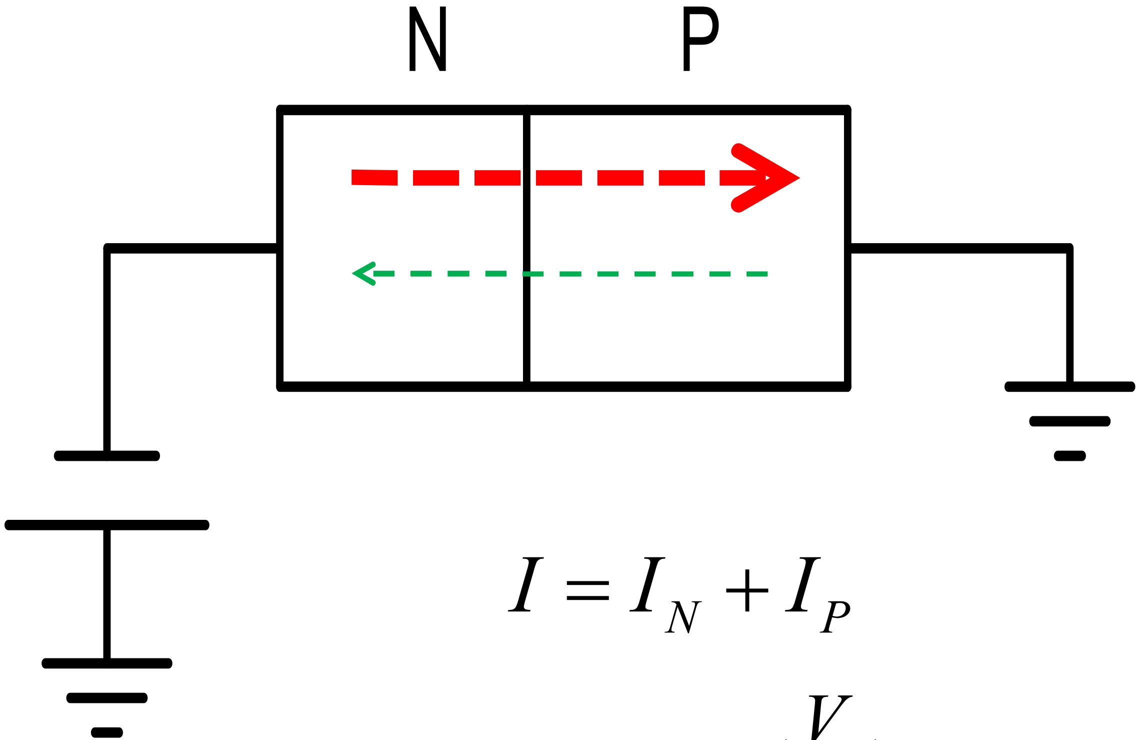


E
B
C
n+
P
N
N+
P-
n+
P
N
N+
P-
E
n+
P
B
N
C

Top View



Background

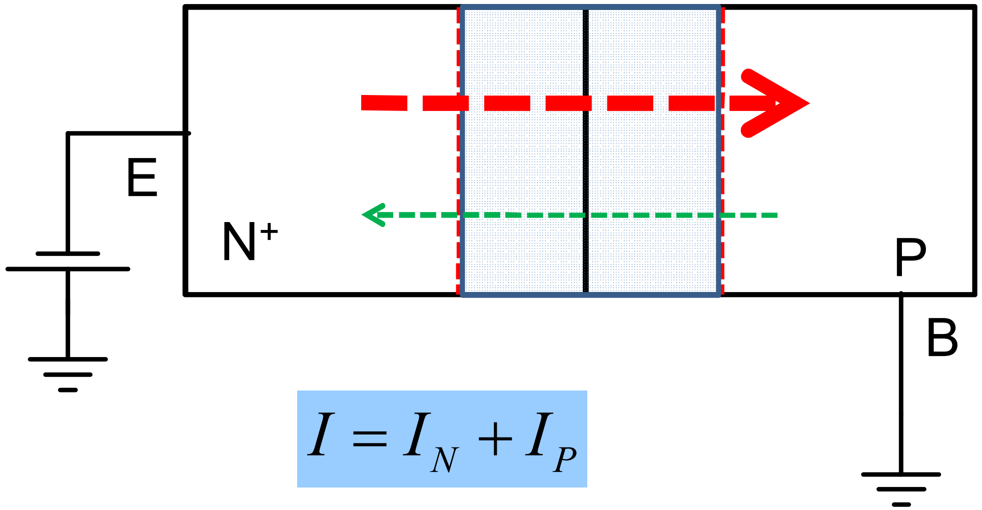


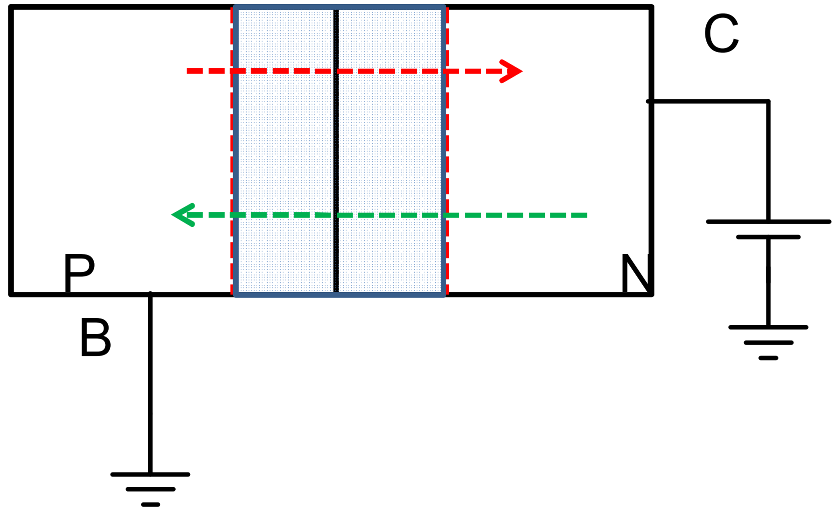
$$I = I_N + I_P$$

$$I_N ; I_P \propto \exp(\frac{V}{V_T})$$

If doping in N region is much larger than doping in p region then $I_N >> I_P$

Basic Transistor Operation





$$I = I_N + I_P$$

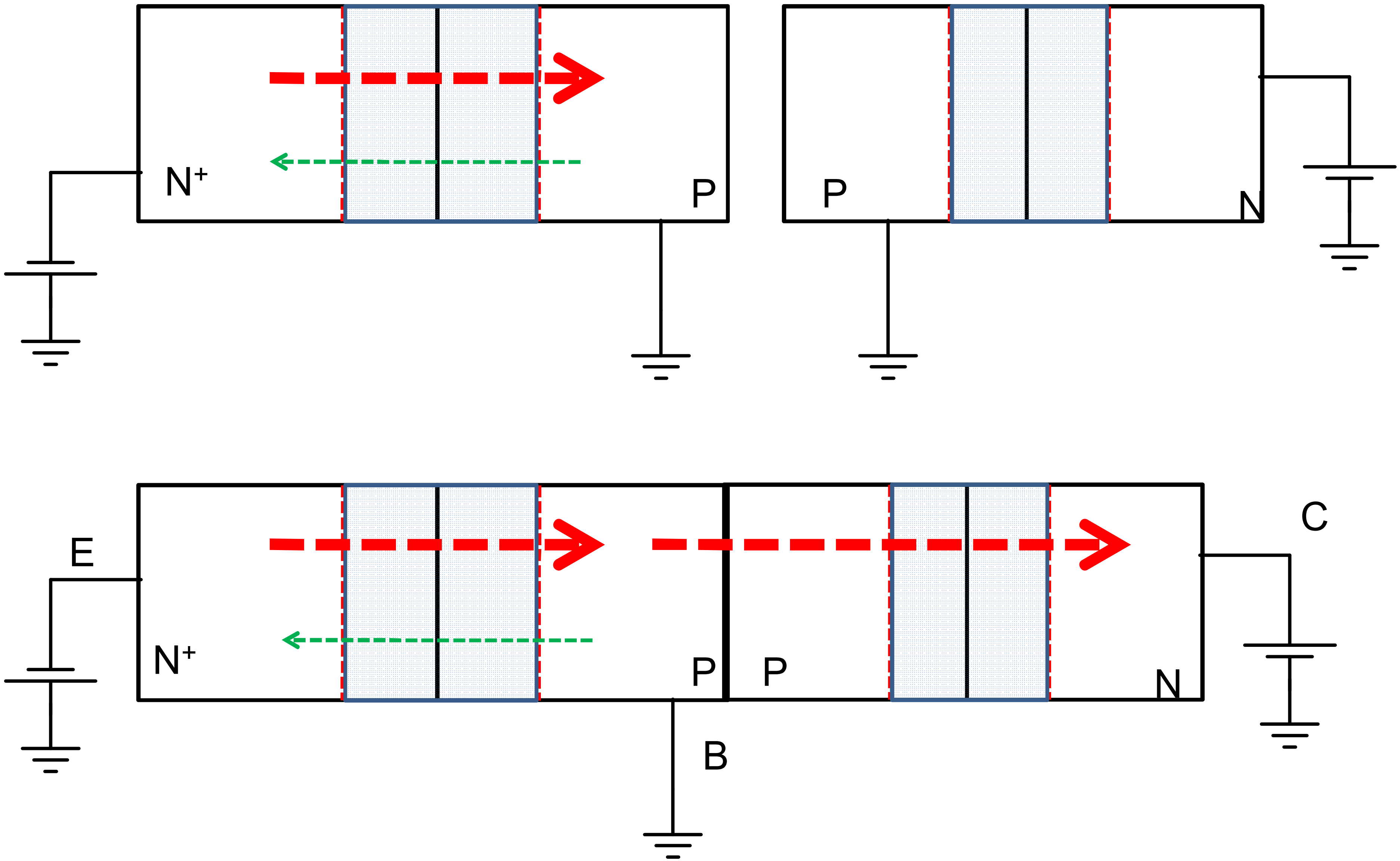
We will assume that doping in emitter is much more than base so that electron current is much larger than hole current

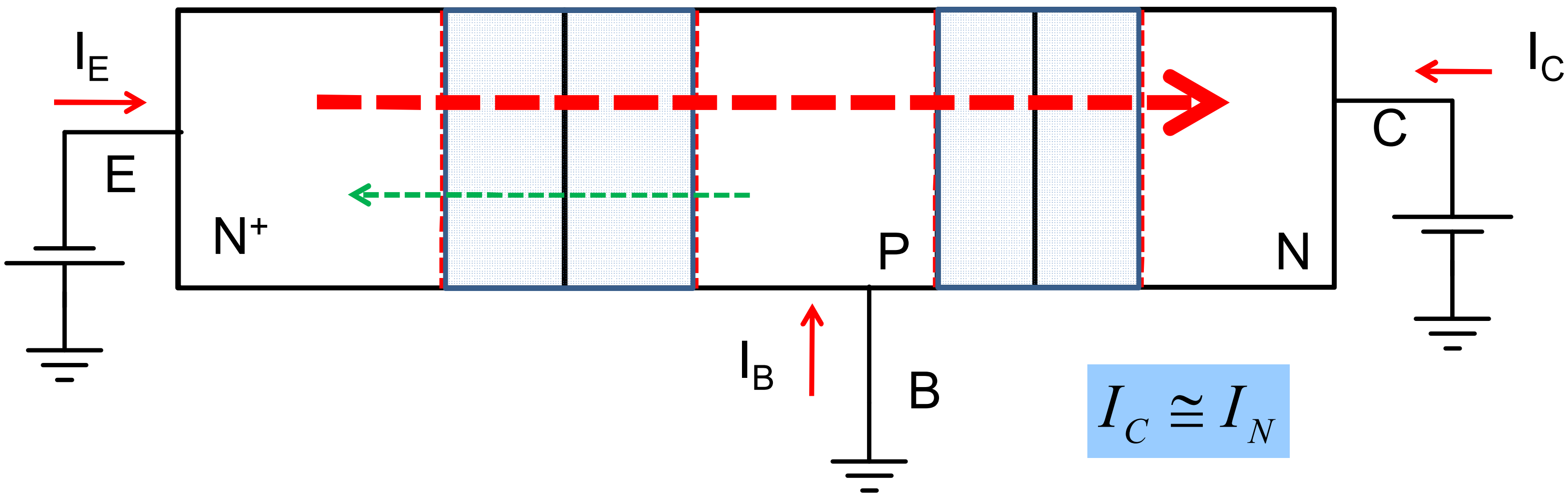
$$I_N >> I_P$$

In the reverse biased junction current is small because there are very few electrons in P and holes in N-region

Basic Transistor Operation

$$I = I_N + I_P$$



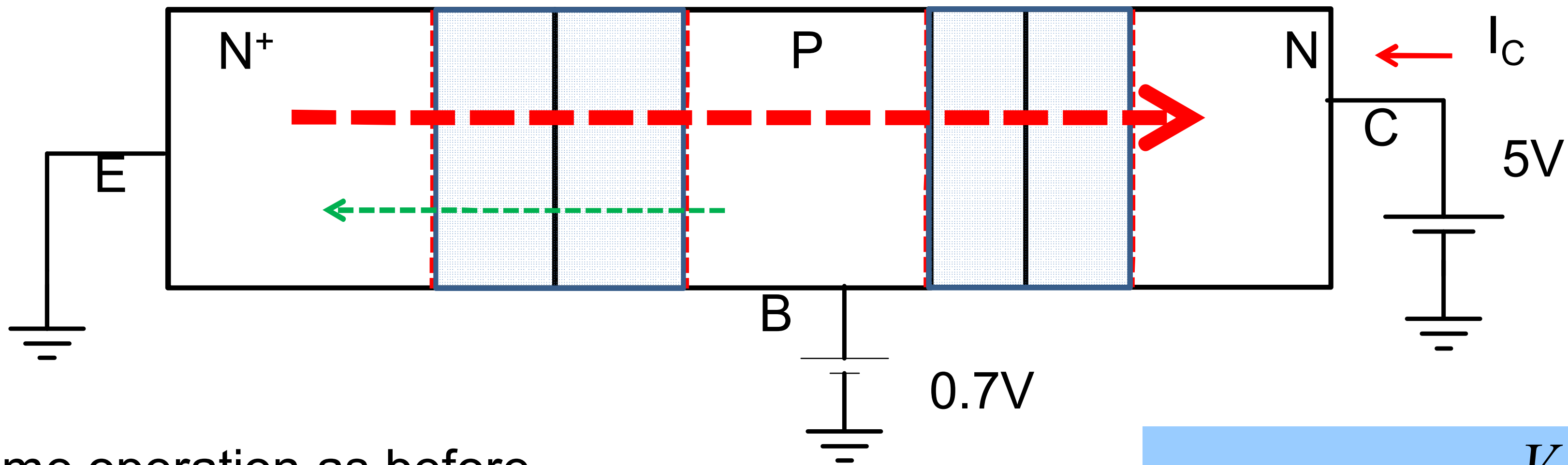


$$I_C \cong I_N$$

$$I_E = I_N + I_P$$

$$I_B \cong I_P$$

$$\textit{Current Gain} \;:\quad \beta = \frac{I_C}{I_B} = \frac{I_N}{I_P} >> 1$$

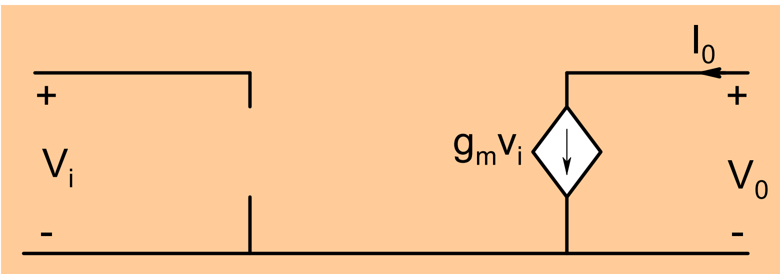


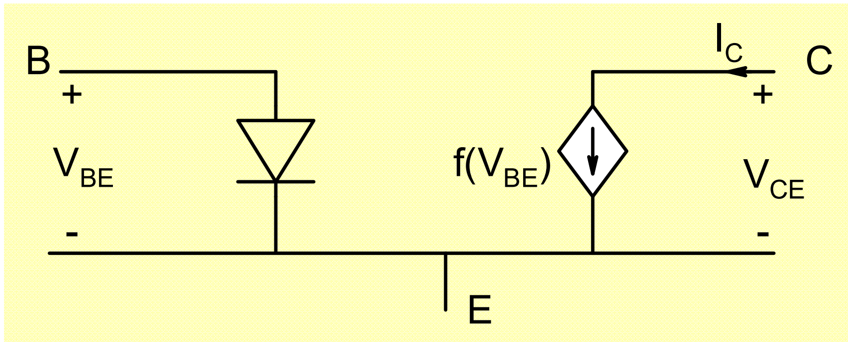
Same operation as before

$$I_C = I_N \propto \exp(\frac{V_{BE}}{V_T})$$

Transistor action

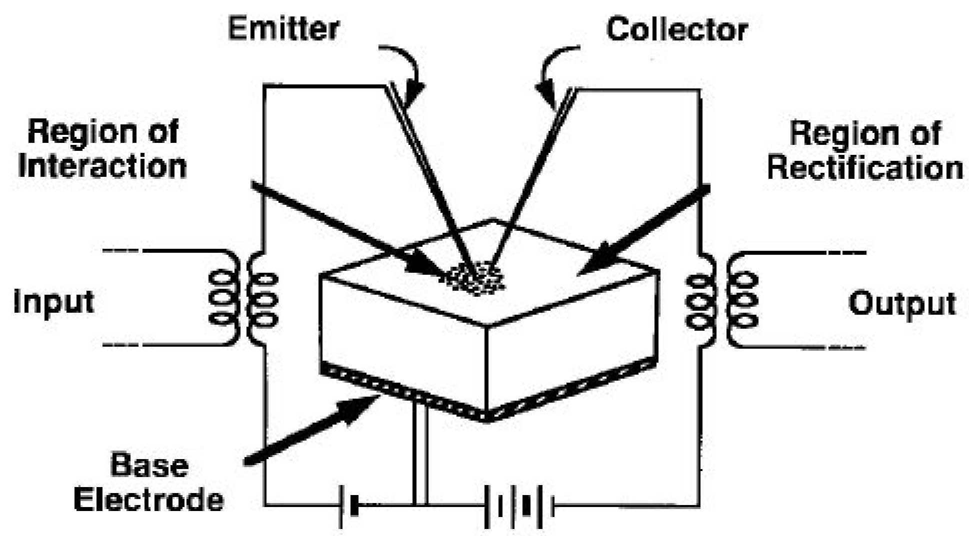
Current is affected by base-emitter voltage and not by collector-base voltage





Invention of the Transistor

John Bardeen, William Shockley, and Walter Brattain.



Schematic diagram of the first transistor.

By late November 1947, Bardeen and Brattain managed to make a working transistor. It must be said that it was very crude, but they improved it from late November through the first part of December. By December 16, 1947, they had a working point-contact transistor. They were able to gradually improve it and actually make a circuit to demonstrate to Bell Labs management on Christmas Eve. Of course, this was a very big event. During the next six months at Bell Labs, Bardeen and Brattain spent a lot of time making sure they had patents filed and then clearing it for release to the public with the military. It was interesting that at one stage, the military was threatening to classify this discovery as top secret. Fortunately, Bell Labs management worked around that. By June 30, 1948, Bell Labs had a press conference in New York City which was quite elaborate.

https://www.youtube.com/watch?v=kLBIl5x43P0