6. Logical Operations, Transistors, BJT, CB Configuration

21 September 2023 09:42

LOGICAL OPERATIONS

- OR GATE

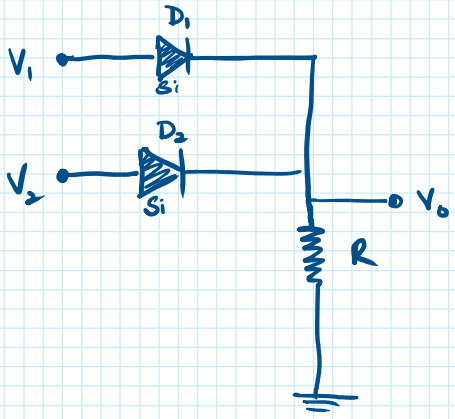
A	B	Y
0	0	0
1	0	1
0	1	1
1	1	1

Binary levels from voltage

0 → 0

1 → 4-5 V (say)

0 → 0-1 V

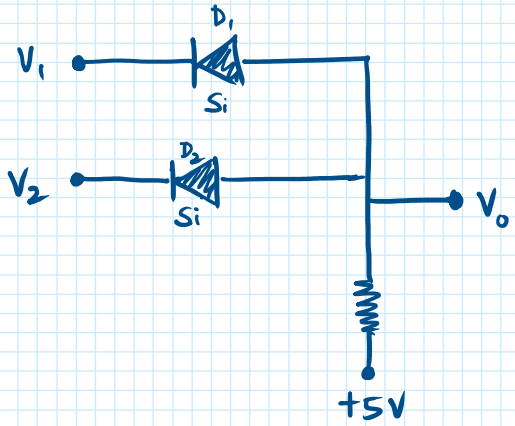


V_1	V_2	V_o
0V [0]	0V [0]	0V [0]
0V [0]	5V [1]	4.3V [1]
5V [1]	0V [0]	4.3V [1]
5V [1]	5V [1]	4.3V [2]

equivalent logic levels

- AND GATE

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1



V_1	V_2	V_o
0V [0]	0V [0]	0.7V [0]
0V [0]	5V [1]	0.7V [0]
5V [1]	0V [0]	0.7V [0]
5V [1]	5V [1]	5V [1]

EDA tools :
to check analysis of circuits
LTspice

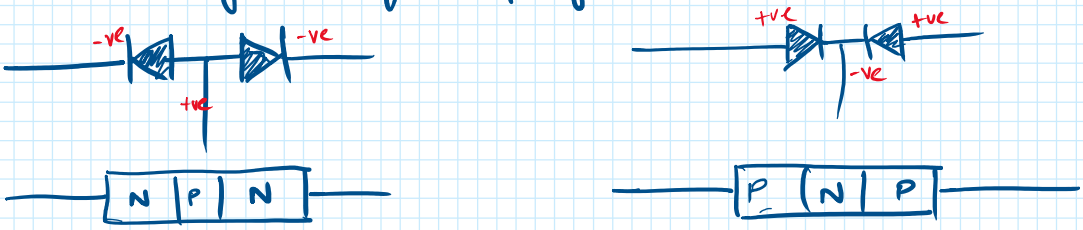
TRANSISTORS

"transfer + resistance"

Transfer of current from a low resistance region to a high resistance region

① Bipolar Junction Transistor (BJT)

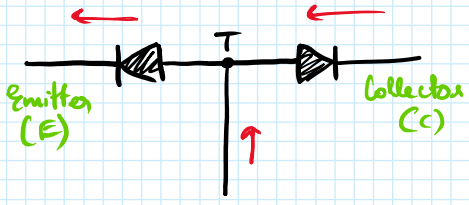
- Three terminal devices
- Constructed by connecting two p-n junctions back to back

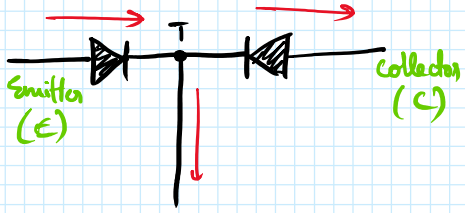


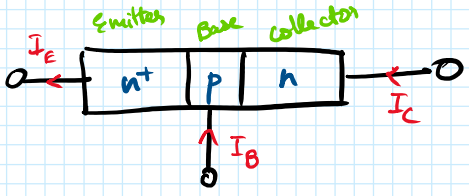
- p-type / n-type sandwiched between two of its opposite types
- Bipolar —why→ both majority and minority carrier actively participate in its operation

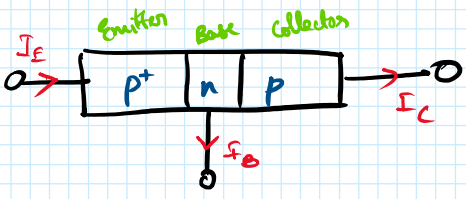
Terminals

Three terminals : Emitter, base, collector



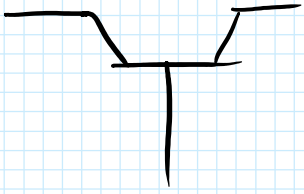


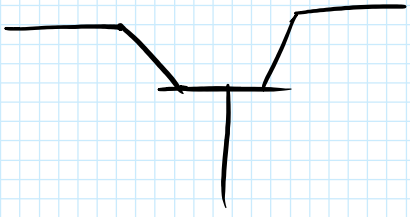




NOTE

p^+, n^+ → more doped





Emitter (E)

- supplies charge carriers
- heavily doped
- moderate in size

Base (B)

- middle portion; forms two p-n junctions b/w E, C
- lightly doped
- smallest in width
- controls no. of charge carriers emitted

Collector (C)

- collects charge carriers
- moderately doped
- widest of all regions; maximum heat dissipated here

Transistor Biasing

- Transistor has two p-n junctions :

TRANSISTOR BIASING

- Transistor has two p-n junctions:
  1. Emitter - base (EB)
  2. Collector - base (CB)
- Each of these can be biased independently

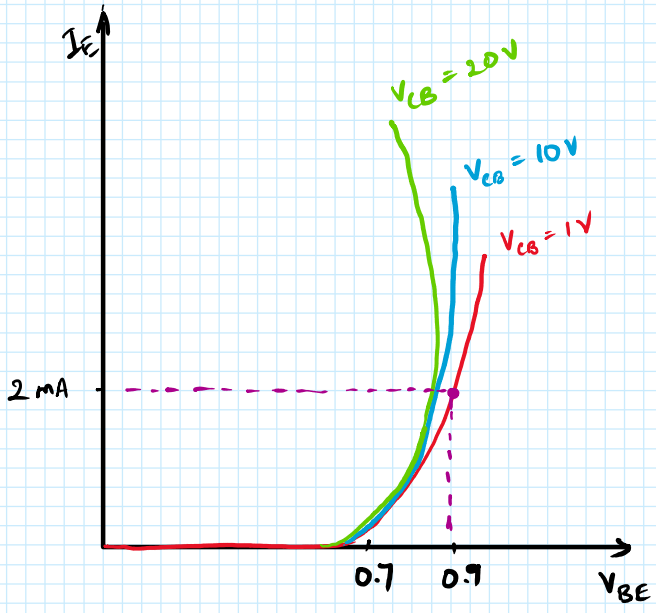
Thus we have the following regions of operation:

	EB junction	CB junction	Application
Active region (common)	Forward	Reverse	Works as amplifier
Saturation region	Forward	Forward	ON - switch (digital)
Cut-off region	Reverse	Reverse	OFF - switch (digital)
Inverse active region (rare)	Reverse	Forward	Attenuator

ACTIVE REGION

- Emitter current = $I_E = I_C + I_B$
- Collector current = $I_C = I_{C(majority)} + I_{C(minority)}$

CB INPUT CHARACTERISTIC CURVE



Input impedance (resistance) = $\frac{\Delta V_{BE}}{\Delta I_E}$

Using pt. from graph,

EARLY EFFECT / BASE WIDTH MODULATION

Curve shifting towards the left or inwards ⟶ "Early Effect"

[OR]

Base Width Modulation

BWM

NOTE: Base width

[fill]

Using pt. from graph,

$$r_i = \frac{0.9 - 0.6}{2mA - 0.5mA} = \frac{0.3}{1.5mA}$$

$$r_i = 200\,\Omega$$

Thus, r_i value is less.

$$I_c = I_{c_{majority}} + I_{c_{minority}}$$
$$= \alpha I_E + I_s$$

$$I_c = \alpha I_E + I_{CBO}$$

I_{CBO} → current from collector to base

→ denotes that emitter terminal is Open

$$\boxed{I_c = \alpha I_E}$$

$\alpha = \frac{I_c}{I_e}$ } Current gain / Current amplification factor

$\alpha \rightarrow 0.9$ to 0.99; ideally assume $\alpha = 1$

Hence in ideal case,

$$\boxed{I_c \approx I_E}$$

∴ BJT is a current controlled device in active region.

NUMERICALS

Q: In a CB connection, current amplification factor is 0.9, $I_E = 1mA$. Find base current.

Soln: $\alpha = \frac{I_c}{I_E}$

$$I_c = (1mA)(0.9)$$
$$= 0.9\,mA$$

$$I_E = I_c + I_B$$

$$I_B = I_E - I_C = 1mA - 0.9\,mA$$
$$= 0.1\,mA$$

$I_B = I_E - I_C = 1\,mA - 0.9\,mA$

$= 0.1\,mA$

(OR)

$= 100\,\mu A$

Q: $I_C = 0.95\,mA$

$I_B = 0.05\,mA$

$\alpha = ?$

Soln: $I_E = I_C + I_B$

$I_E = 1\,mA$

$\alpha = \frac{I_C}{I_E} = \frac{0.95}{1} = 0.95$ → no units

Q: In CB connection, $I_E = 1\,mA$, $\alpha = 0.92$. If emitter circuit is open, the collector current $I_{CBO} = 50\,\mu A$. Find total I_C.

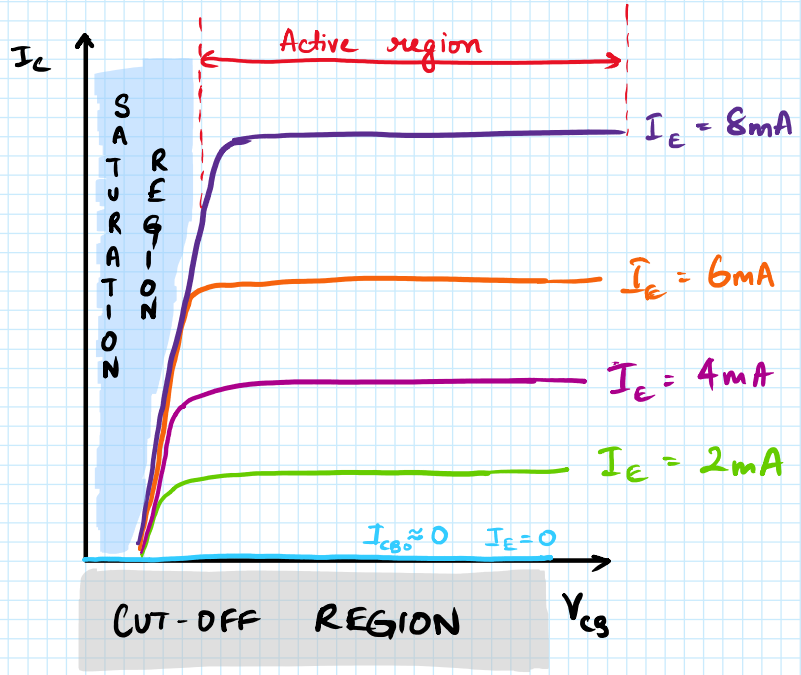
Soln: $I_C = \alpha I_E + I_{CBO}$

$= 0.92(1 \times 10^{-3}) + (50 \times 10^{-6})$

$= 9.7 \times 10^{-4}$

$= 0.97\,mA$

CB Output or Collector Characteristics



$$r_o = \frac{\Delta V_{CB}}{\Delta I_C} = \frac{15-5}{(6-6)\,mA} = \infty$$] infinity as we have taken $\alpha = 1$

r_o ⟶ output impedance ⟶ very high