B.J.T. : THREE TERMINAL

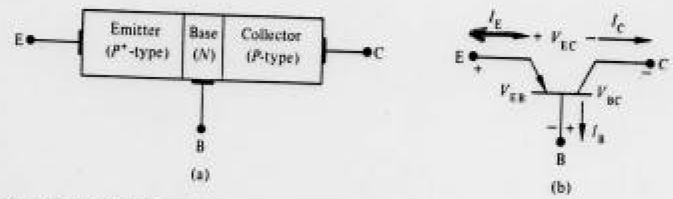


Fig. 1.1 *pnp* bipolar transistor: (a) semiconductor types: (b) circuit symbol with active region voltage and current polarities.

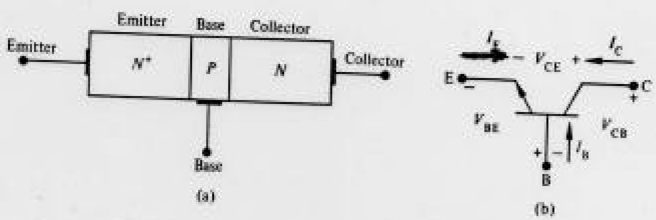


Fig. 1.2 *npn* bipolar transistor.

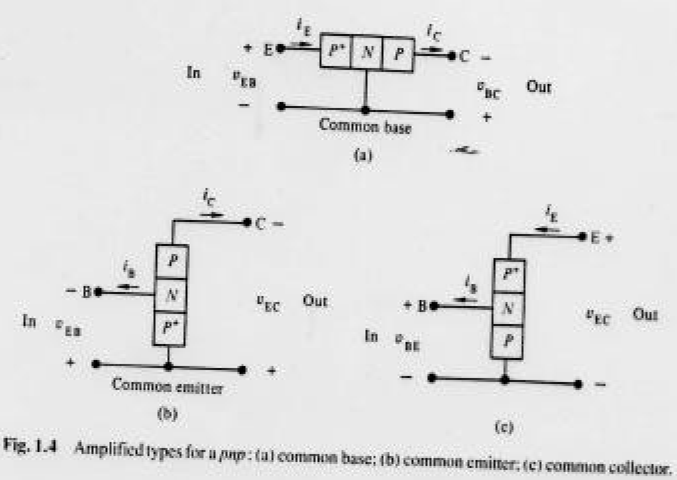
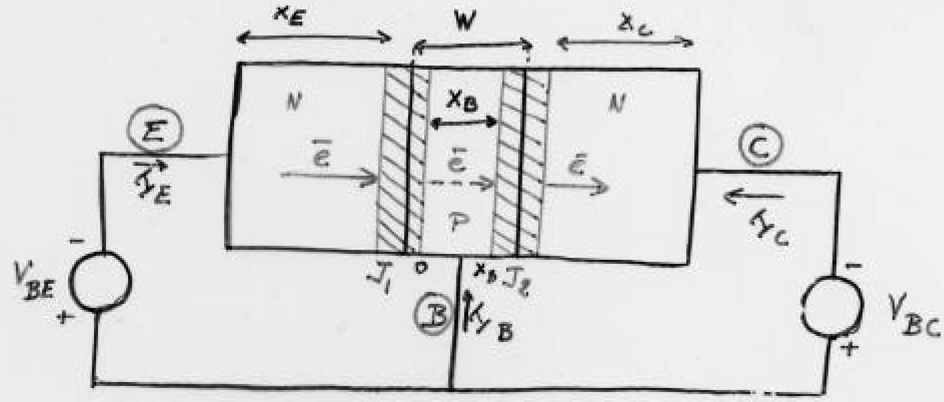
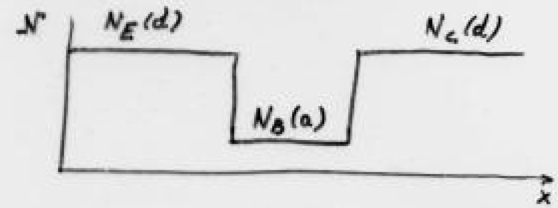


Fig. 1.4 Amplified types for a *pnp*: (a) common base; (b) common emitter; (c) common collector.

Bipolar Transistors
{ – Amplification
– Switching

1. Transistor Action (prototype transistor)





BECAUSE $N_a \ll N_d$: $J_p = 0 = q\mu_p p\mathcal{E} - qD_p \frac{dp}{dx}$ IN THE BASE

$$\Rightarrow \mathcal{E} = \frac{kT}{q}\frac{1}{p}\frac{dp}{dx}$$ BASE $\mathcal{E}$-FIELD.

ELECTRON CURRENT $J_n = q\mu_n n\mathcal{E} + qD_n \frac{dn}{dx}$ IN THE BASE

$$= kT\mu_n \frac{n}{p}\frac{dp}{dx} + qD_n \frac{dn}{dx}$$

$$= \frac{qD_n}{p}\left(n\frac{dp}{dx} + p\frac{dn}{dx}\right) = \frac{qD_n}{p}\frac{d}{dx}(np)$$

$$\Rightarrow J_n \frac{p\,dx}{qD_n} = d(np)$$

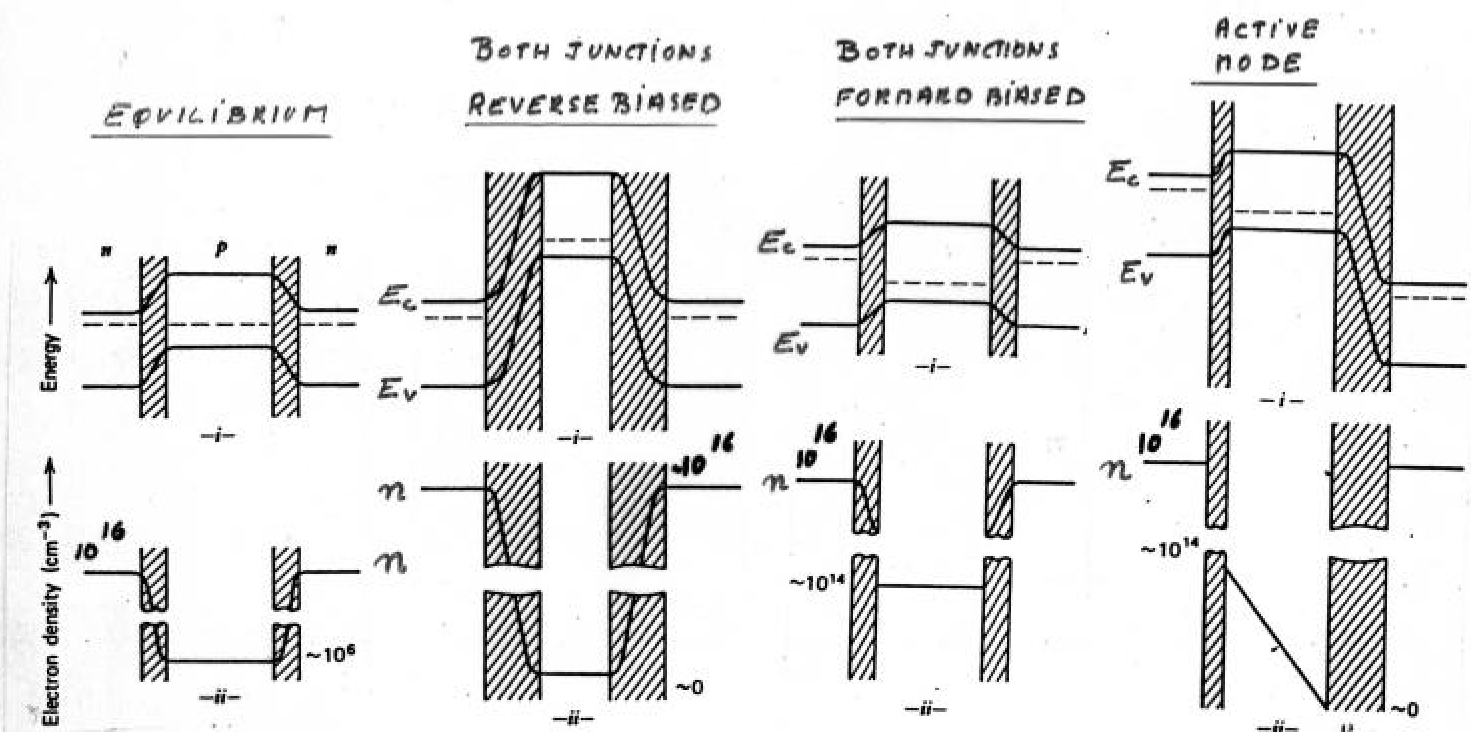
$$J_n \int_0^{x_B} \frac{p\,dx}{qD_n} = n(x_B)p(x_B) - n(0)p(0)$$

$$n(0)p(0) = n_i^2 e^{\frac{qV_{BE}}{kT}}$$

$$n(x_B)p(x_B) = n_i^2 e^{\frac{qV_{BC}}{kT}}$$

$$\Rightarrow J_n = \frac{n_i^2}{\int_0^{x_B} \frac{p\,dx}{qD_n}}\left(e^{\frac{qV_{BC}}{kT}} - e^{\frac{qV_{BE}}{kT}}\right)$$

Transistor Action: (Prototype Transistor)



$$\delta n_B = n_{p0}\left[e^{\frac{qV_{BE}}{kT}}\left(1 - \frac{x}{x_B}\right) - 1\right]$$

$$J_n = -\frac{q D_n n_i^2}{N_a x_B} \exp\left(\frac{qV_{BE}}{kT}\right)$$

Transistors for Integrated Circuits

Planar Process

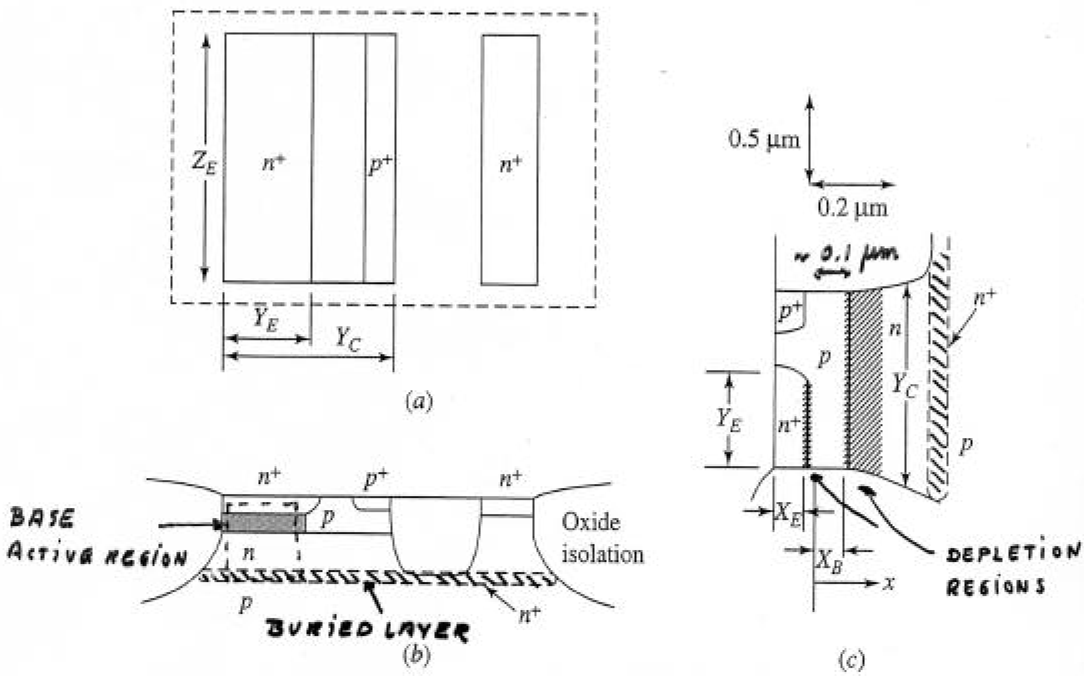


FIGURE 6.3 Top view (*a*) and cross sections (*b* and *c*) of an oxide-isolated *npn* IC transistor. The region dominating transistor action is shaded in (*b*), and the area bounded by the base diffusion is rotated 90° and expanded in (*c*); *x* and *y* scales are indicated for (*c*) only.

ELECTRON BASE CURRENT

$$J_n = \frac{n_i^2}{\int_0^{x_B} \frac{p\,dx}{q D_n}} \left(e^{q\frac{V_{BC}}{kT}} - e^{q\frac{V_{BE}}{kT}} \right)$$

LET US SET : $J_S = \dfrac{n_i^2}{\int_0^{x_B} \frac{p\,dx}{q D_n}}$: SATURATION CURRENT

IF $\displaystyle\int_0^{x_B} \frac{p\,dx}{q D_n} = \frac{1}{q^2 \tilde{D}_n}\, q\int_0^{x_B} p\,dx \simeq \frac{1}{q^2 \tilde{D}_n}\, q\int_0^{x_B} N_B(x)\,dx$

$$= \frac{Q_B}{q^2 \tilde{D}_n}$$

Q_B : BUILT-IN BASE CHARGE $= q\,GN$

GN : GUMMEL NUMBER : $\int_0^{x_B} N_B\,dx$ $[cm^{-2}]$

$\tilde{D}_n = \dfrac{\int_0^{x_B} p\,dx}{\int_0^{x_B} \frac{p\,dx}{D_n}}$ AVERAGE VALUE OF DIFFUSION COEFFICIENT

$p = p(x)$; $D_n = D_n(x)$

$$J_n = J_s \left(e^{q\frac{V_{BC}}{kT}} - e^{q\frac{V_{BE}}{kT}} \right)$$

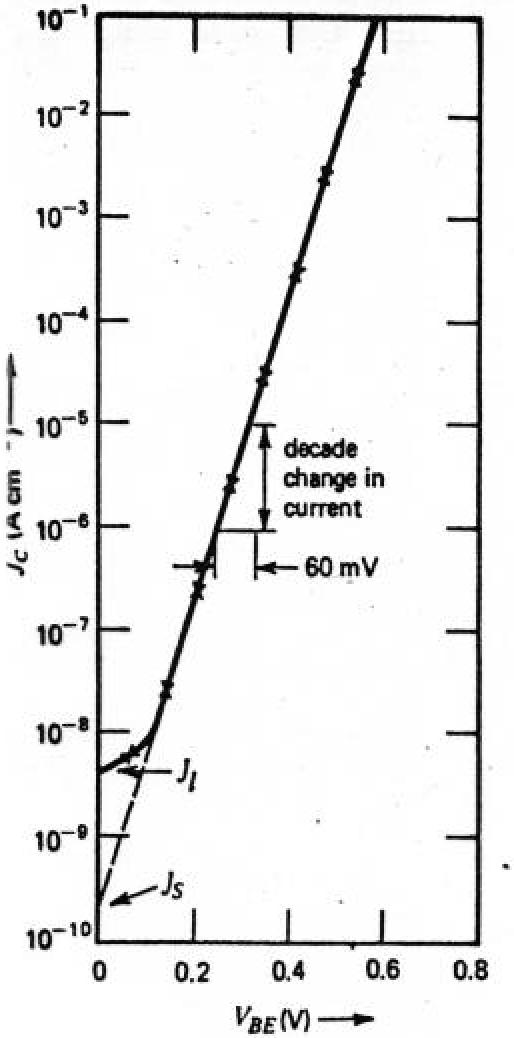
$$J_S = \frac{q^2 n_i^2}{Q_B} \tilde{D}_n$$

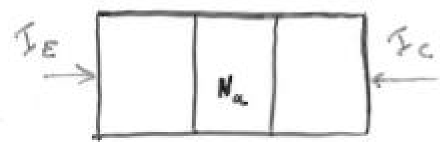
J_n : SENSITIVE FUNCTION OF V_{BC} AND V_{BE}

→ CURRENT FLOWING FROM THE FIRST JUNCTION TO THE SECOND JUNCTION.

ACTIVE BIAS $V_{BC} < 0$

$$J_n = -J_s \, e^{\frac{qV_{BE}}{kT}}$$





$$J_s = \frac{q^2 n_i^2 \tilde{D}_n}{Q_B} \propto \frac{1}{GN}$$

$$GN = \int_0^{x_B} N_a(x)\,dx = \frac{Q_B}{q}$$

$$= \frac{q n_i^2 \tilde{D}_n}{J_s}$$: TOTAL BASE DOPING

⇒ HIGH C CURRENT : LOW GN

BUT HIGH LEVEL INJECTION : PERFORMANCE DEGRADATION