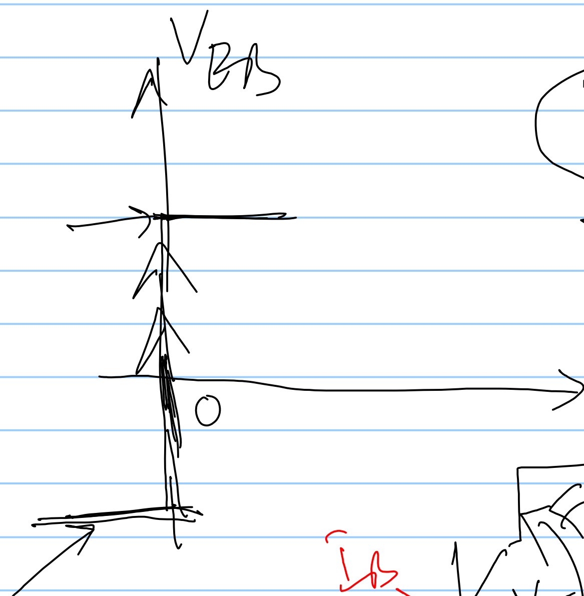
Switching Behaviour in BJTs

21/10/2014



p-n-p transistor

$V_{CB} \rightarrow -ve$

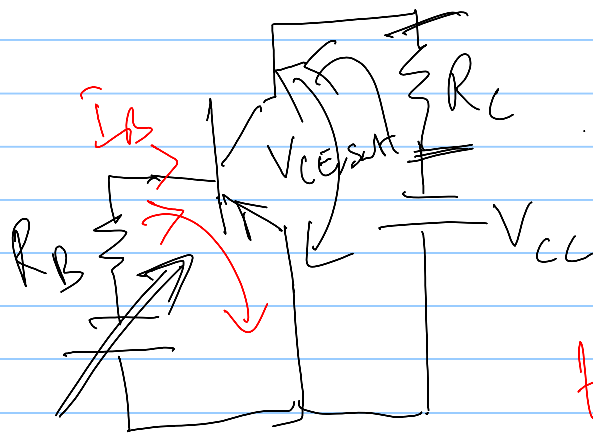
B-C reverse biased

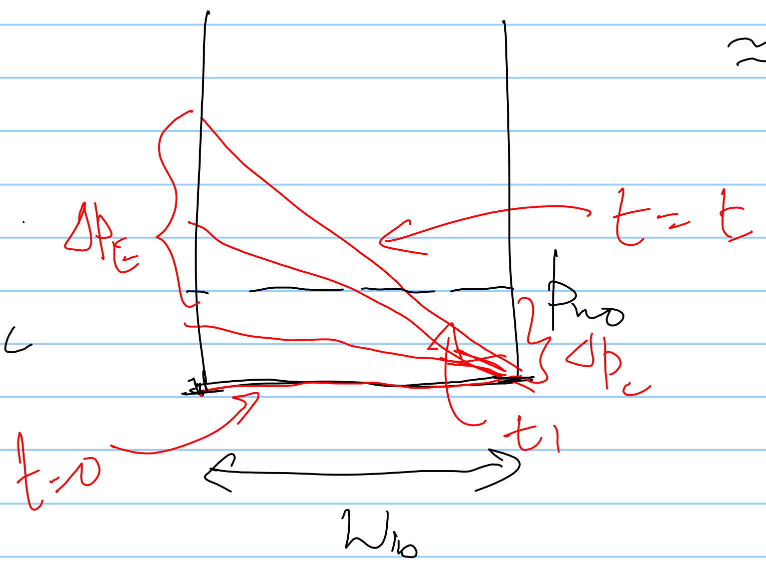
$$\Delta p_C = p_{no}\left(e^{V_{CB}/V_T} - 1\right)$$

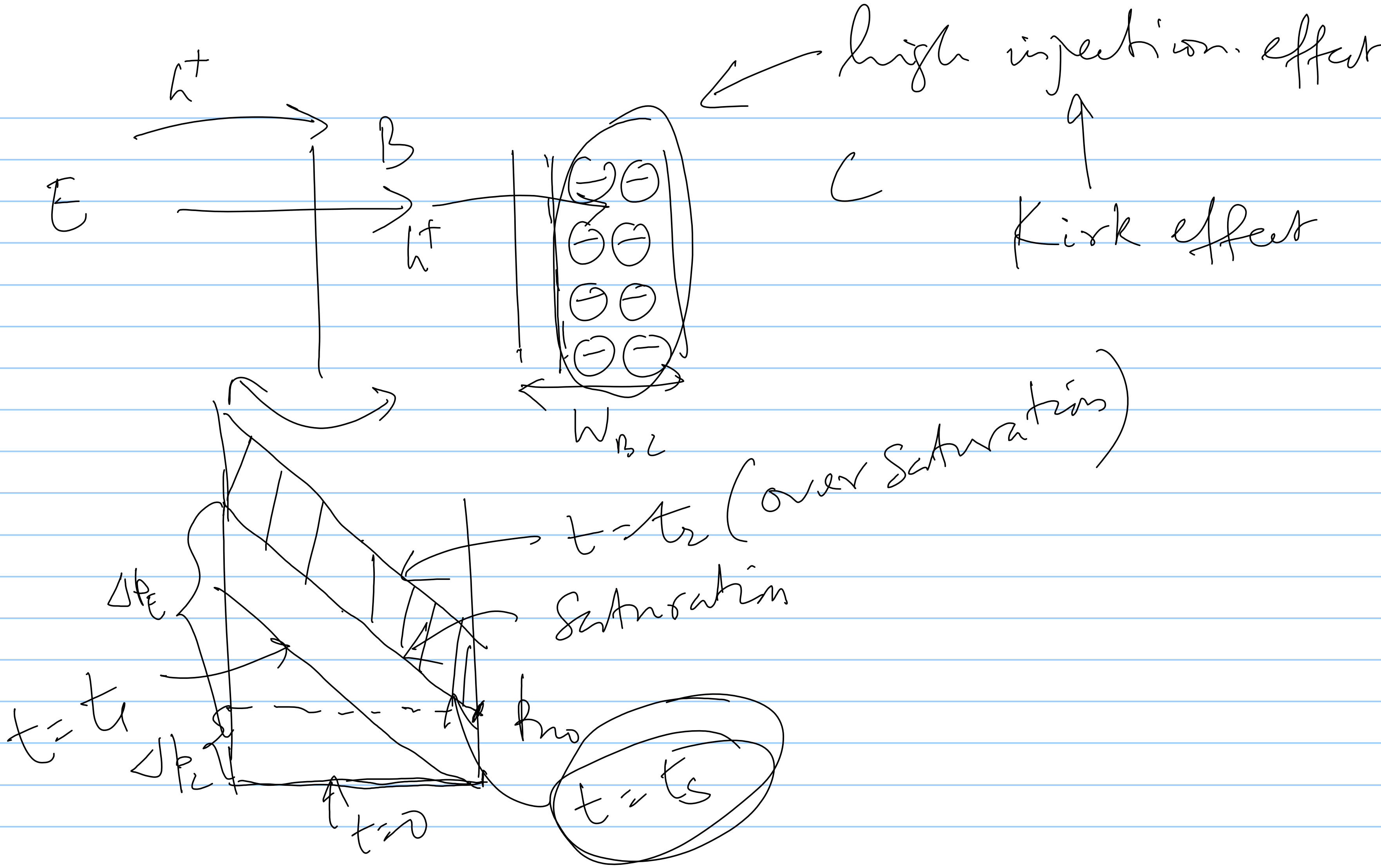
$$\approx -p_{no}$$

$$\Delta p_E = p_{no}\left(e^{V_{EB}/V_T} - 1\right)$$

$$\approx -p_{no}$$

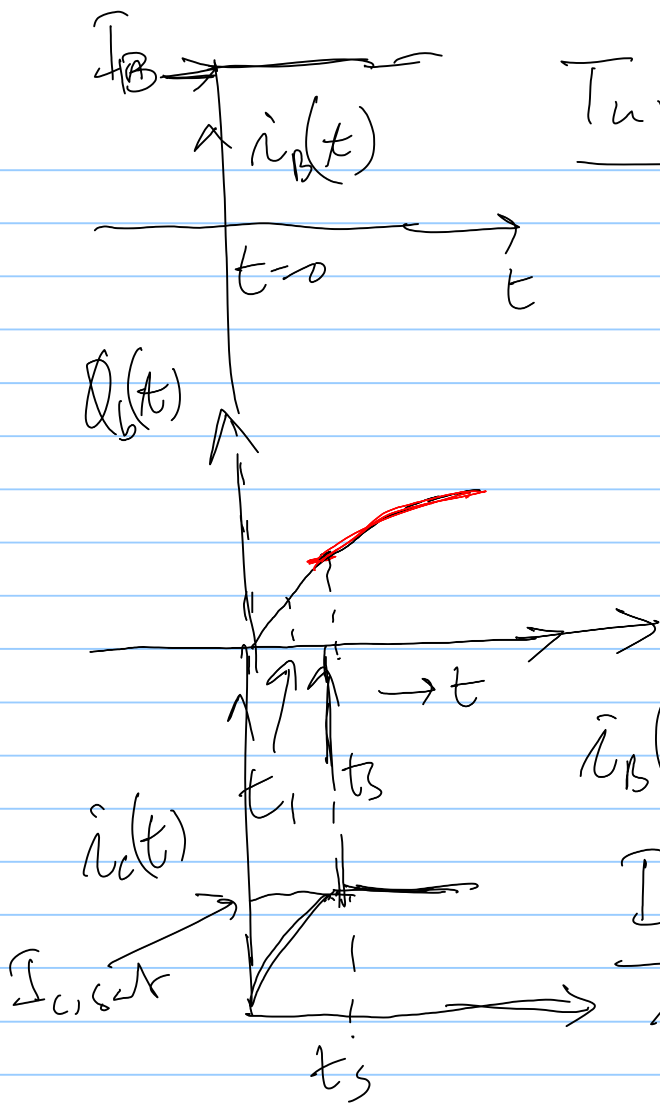


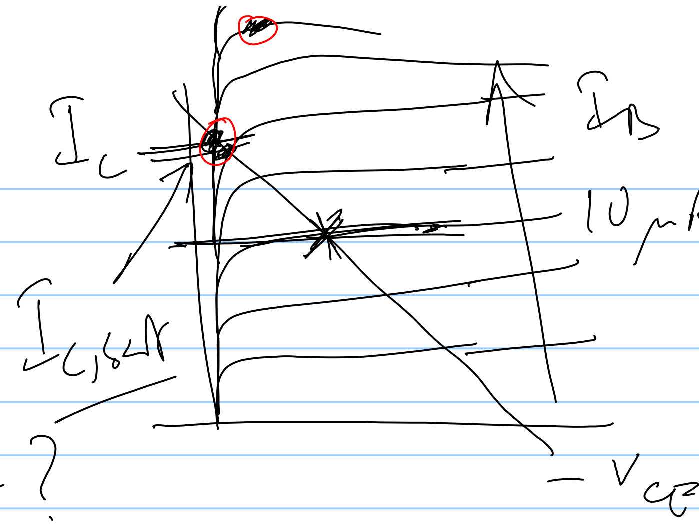




high injection effect
Kirk effect
E
B
C
n^+
n^+
W_{BC}
$t = t_2$ (over saturation)
saturation
Δp_E
$t = t_1$
Δp_C
p_{no}
$t = 0$
$t = t_s$

Turn-On





$Q_b(t) = ?$

$\gamma = 1$

$$i_B(t) = \frac{Q_b(t)}{\tau_p} + \frac{d}{dt}Q_b(t)$$

$$\frac{I_B}{s} = \frac{Q_b(s)}{\tau_p} + sQ_b(s) - Q_b(0)$$

$Q_b(0) = 0$

$$Q_b(s) = \frac{I_B}{s\left(s+\frac{1}{\tau_p}\right)} = I_B \tau_p \left(\frac{1}{s} - \frac{1}{s+\frac{1}{\tau_p}} \right)$$

$$Q_b(t) = I_B \tau_p \left(1 - e^{-t/\tau_p}\right)$$

$$i_c(t) = \frac{Q_b(t)}{\tau_t} = \frac{I_B \tau_p}{\tau_t} \left(1 - e^{-t/\tau_p}\right)$$

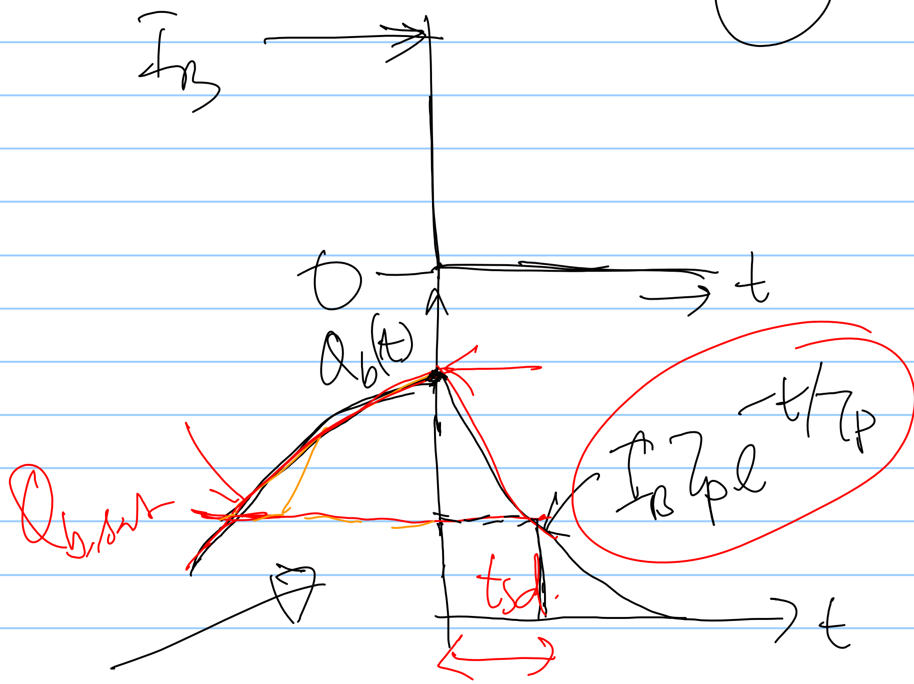
$$i_c(t)\Big|_{t=t_s} = I_{c,sat} = \frac{I_B \tau_p}{\tau_t} \left(1 - e^{-t_s/\tau_p}\right)$$

($\frac{\tau_p}{\tau_t}$ ← β)

$$1 - e^{-t_s/\tau_p} = I_{c,sat} / \beta I_B \Rightarrow t_s = \tau_p \ln\left[\frac{1}{1 - \frac{I_{c,sat}}{\beta I_B}}\right]$$

$$t_s = \tau_p \ln\left[\frac{1}{1 - \frac{I_{C,sat}}{\beta I_B}}\right]$$

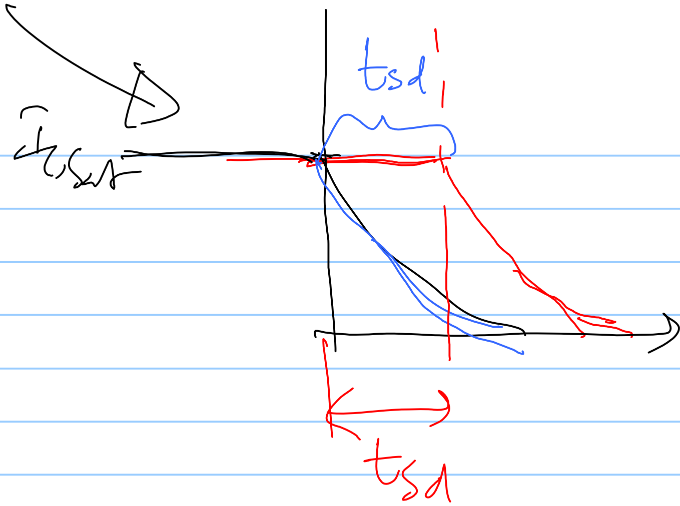
To have small t_s, $\Rightarrow$ small τ_p, $\beta I_B \gg I_{C,sat}$



$$i_B(t) = \frac{Q_b(t)}{\tau_p} + \frac{d}{dt} Q_b(t)$$

$$0 = \frac{Q_b(s)}{\tau_p} + s Q_b(s) - I_B \tau_p$$

$$Q_b(s) = \frac{I_B \tau_p}{s + \frac{1}{\tau_p}} \Rightarrow Q_b(t) = I_B \tau_p e^{-t/\tau_p}$$



$$\frac{Q_p(t)}{\tau_t} = i_c(t) \neq \frac{I_B \tau_p e^{-t/\tau_p}}{\tau_t}$$

$$i_c(t) = \frac{I_B \tau_p}{\tau_t} e^{-(t-t_{sd})/\tau_p}$$

$$I_{c,sat} = I_B \beta e^{-t_{sd}/\tau_p}$$

$$t_{sd} = \tau_p \ln\left(\frac{\beta I_B}{I_{c,sat}}\right)$$

For smaller t_{sd}

$\Downarrow$

smaller τ_p.