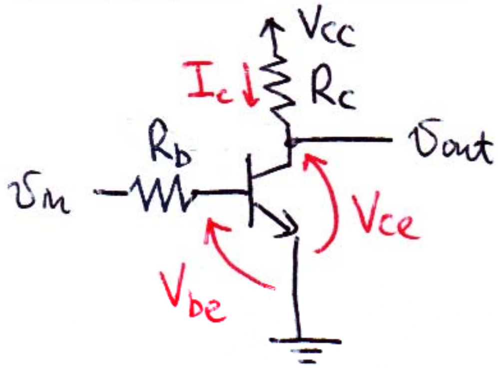
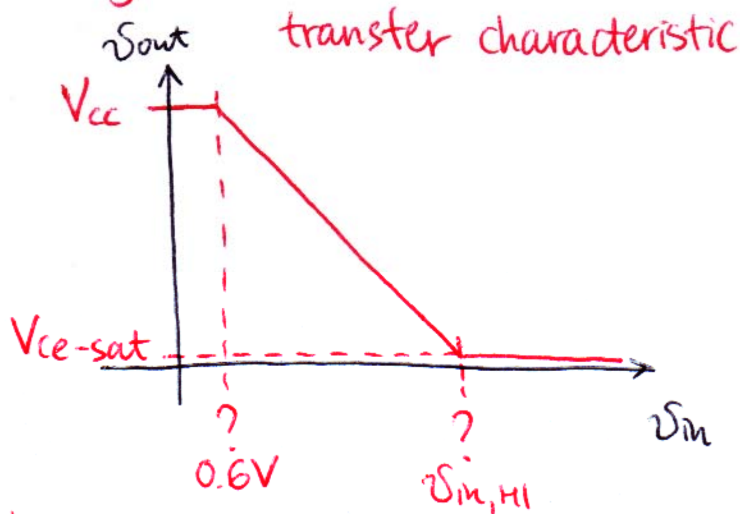
Lecture 17

## Transistor circuits (contd)

Recall : we are looking @ common emitter config.




$v_{in,HI}$ : point where transistor goes from active to saturation, i.e. $\beta \cdot I_b = (I_c)_{max}$

$$\beta \frac{v_{in,HI} - 0.6V}{R_b} = \frac{V_{cc} - V_{ce\text{-}sat}}{R_c}$$

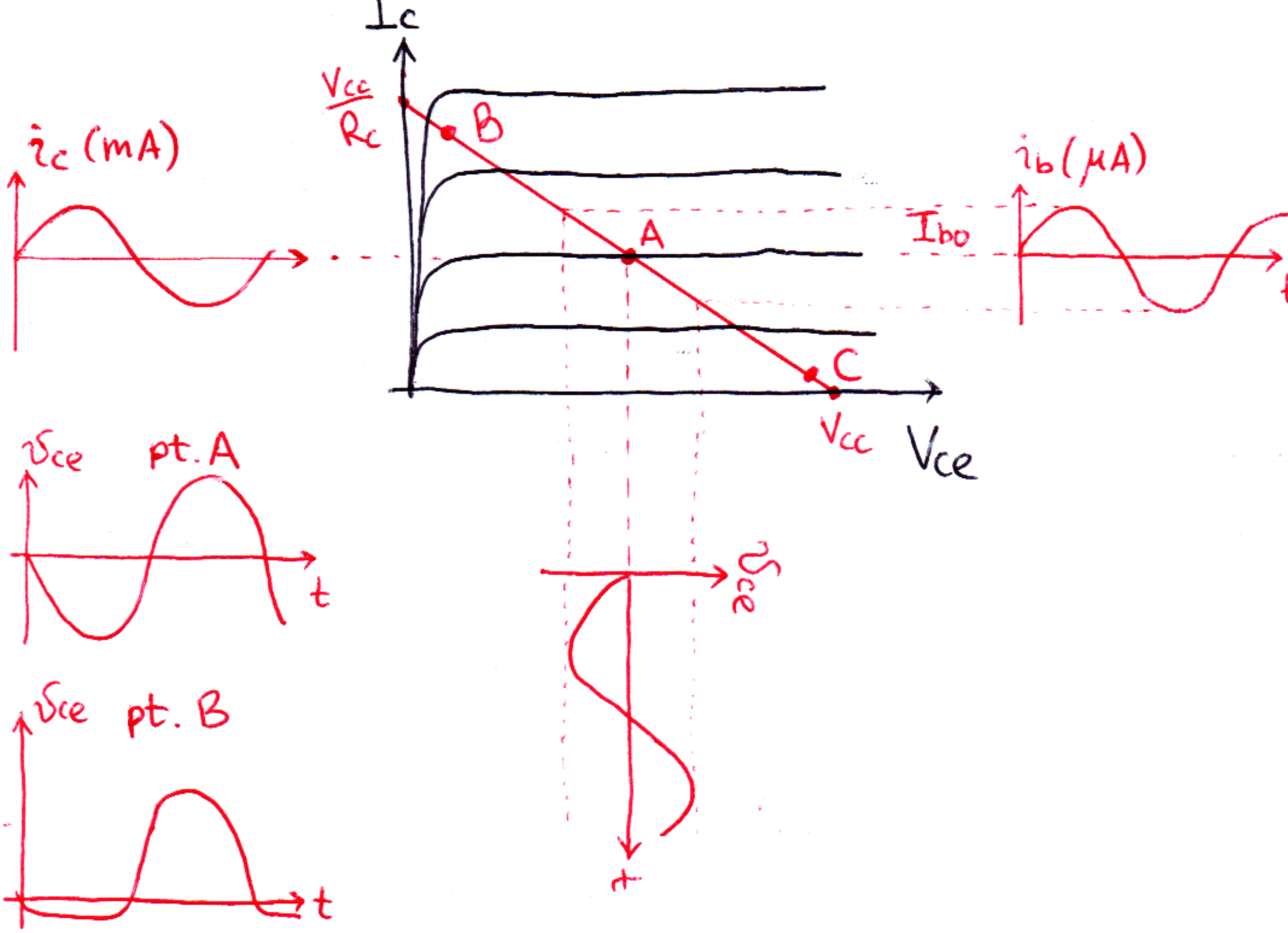
$$\Rightarrow v_{in,HI} \approx 0.6V + \frac{V_{cc}}{\beta}\frac{R_b}{R_c}$$

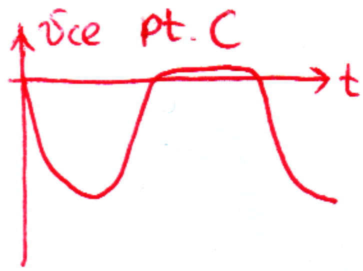
### Transistor amplifier

suppose $i_b = \underbrace{I_{b0}}_{\text{bias}} + \underbrace{i_{b1} \sin \omega t}_{\text{signal}}$

Q: what about $v_{out} = V_{ce}$ ?

A: constrained to lie on "load line" + $I_c$



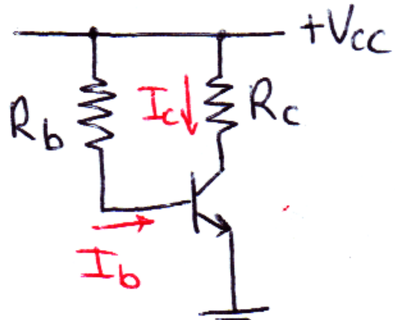




- pts. B & C distort the signal
- choose Q-pt so that max input swing produces output with no distortion

## Transistor biasing

= setting Q-pt (DC values $I_b, I_c, V_{ce}$)

simple-minded approach: fix $I_b$




$$\left.\begin{array}{l}(I_c)_{min} \sim 0 \\ (I_c)_{max} \sim \dfrac{V_{cc}}{R_c}\end{array}\right\} \text{set Q-pt in the middle } I_c \sim \frac{1}{2}\frac{V_{cc}}{R_c}$$

$\Rightarrow I_b = \frac{I_c}{\beta} = \frac{1}{2\beta}\frac{V_{cc}}{R_c}$, or choose $R_b = \frac{V_{cc} - 0.6V}{I_b \approx \frac{1}{2\beta}\frac{V_{cc}}{R_c}}$

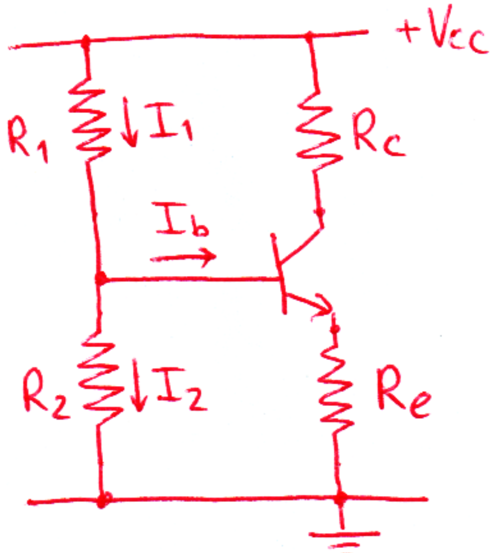
$R_b$ fixes $I_b$, which fixes $I_c$ & $V_{ce}$.

Problem: Q-pt sensitive to $\beta$! E.g. $\beta(T=80°C) \sim 2\beta(T=20°C)$

$\Rightarrow I_c(80°C) = 2I_c(20°C) = (I_c)_{sat}$ !

Solution: fix $I_c$ ($I_e$) instead of $I_b$

H-biasing




In active range $V_e = V_b - 0.6V$

and $I_e = \frac{V_e}{R_e} = \frac{V_b - 0.6V}{R_e}$

Fix $V_b$: this fixes $V_e$ and $I_e$

$I_b \ll I_1, I_2$ (e.g. $I_1 \simeq I_2 \gtrsim 10 I_b$)

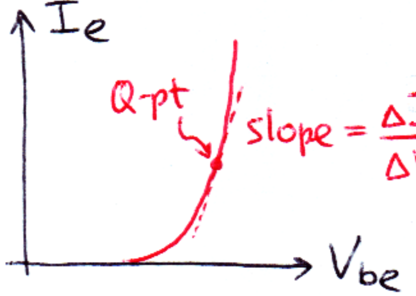
volt. divider $(V_b)_Q = \frac{R_2}{R_1 + R_2} V_{cc}$

$R_e$ provides negative feedback stabiliz. $I_e$ against var. in $\beta$

Let $\beta\uparrow$, then $I_e = (\beta+1) I_b \uparrow$ and $V_e = R_e I_e \uparrow$. Since $V_b$ is held const, $V_{be} = V_b - V_e \downarrow$. $I_b(V_{be})$ = diode eqn, so $V_{be}\downarrow$ brings down $I_b$, and $I_b\downarrow$ produces $I_e\downarrow$

Transistor small signal equivalent

Recall $I_b = f(V_{be})$ diode eqn; $I_e \simeq I_b(\beta+1) = f'(V_{be})$ diode eqn.




$$\text{slope} = \frac{\Delta I_e}{\Delta V_{be}} = \frac{1}{r_e}$$

$$\boxed{I_e \approx I_o\, e^{\frac{V_{be}}{V_T^*}}}$$

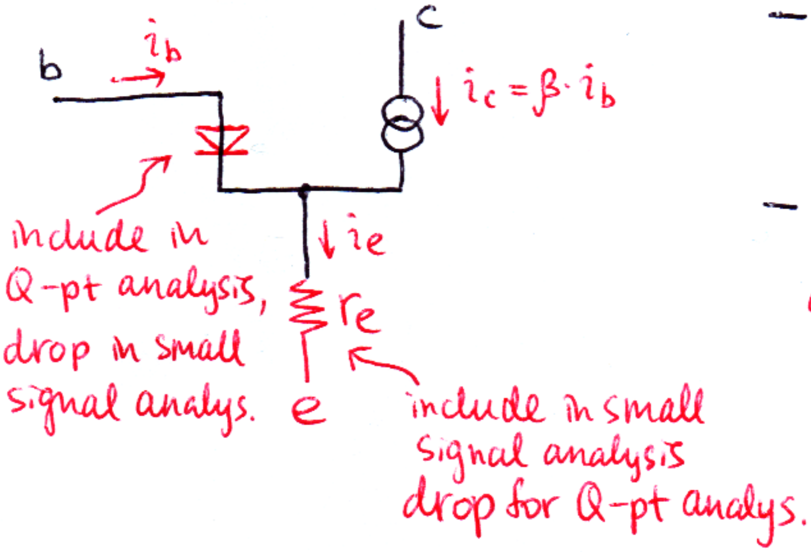
For small signals only

$$\boxed{r_e = \left(\frac{\partial I_e}{\partial V_{be}}\right)^{-1} = \left(\frac{I_o}{V_T^*}\, e^{\frac{V_{be}}{V_T^*}}\right)^{-1} = \frac{V_T^*}{I_e} \simeq \frac{V_T^*}{I_c}}$$

e.g. if $I_e \sim 4\,mA$, $\Rightarrow$

$$r_e \simeq \frac{40\,mV}{4\,mA} = 10\,\Omega \quad \text{(small)}$$

## equivalent circuit (Q = active)




- dynamic small-signal re inside the transistor
- ignore re for Q-pt analysis

## Transistor circuit analysis (amplifiers)

usually $\left|\frac{\Delta v}{V_{ce}}\right| \ll 1$, then analysis can be separated into two simpler parts (~ indep.)

1) Set $\Delta V_{in} = v_{in} = 0$. Solve for DC to find $I_Q$'s & $V_Q$'s (transistor should be active if amplifier) non-linear

2) Add small $v_{in} \neq 0$. $I_Q$'s & $V_Q$'s remain the same. Set DC values to zero. Treat small signals as pert. Superposition works for linearized circuits $\boxed{v_{tot} = V_Q + v_{ss}}$

$r_e = r_e(Q_{pt})$