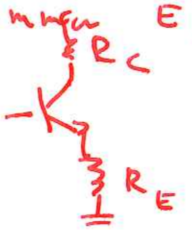
BJT Golden Rules

1) $I_E = I_C$ (ok: $I_E = I_C + I_B$ but generally $I_C \gg I_B$ in fact (see below) $I_C = \beta I_B \Rightarrow I_E = (\beta+1) I_B$)

$V_B = V_E + .6$ (ok: the 'turn-on' voltage of a forward biased PN junction varies with temperature & larger I_B does mean larger V_{BE} but during normal operation V_{BE} typically varies only $\pm \frac{1}{40}$ V — small change)

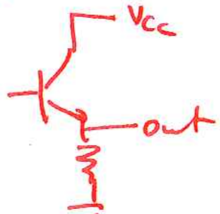
Common Emitter Amp



$$\Delta I_E = \frac{\Delta V_B}{R_E}$$

$$\Delta V_{out} = -R_C \, \Delta I_C = -\frac{R_C}{R_E} \Delta V_B$$

Emitter Follower

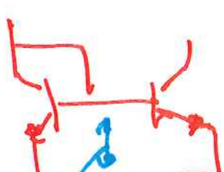


$$\Delta V_{out} = \Delta V_B$$

2) $I_C = \beta I_B$ (but: range of β allowed by specs large. β not constant — varies with I_B)

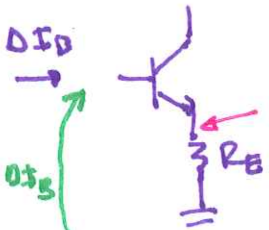
Avoid circuits that depend on a particular value of β — they may not work with replacement transistor.

3) I_B, I_C in fact functions of V_{BE} — match V_{BE} match results. (For a "matched pair")



same V_{BE} — same currents thru device.

Impedance "looking in base"



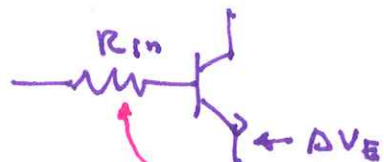
$\Delta V_B = R_E(\beta+1)\Delta I_B$

$\Delta I_E = (\beta+1)\Delta I_B \Rightarrow \Delta V_E = R_E(\beta+1)\Delta I_B$

Note: R_E & r_e could be combined.

So $\dfrac{\Delta V_B}{\Delta I_B} = R_E(\beta+1)$

Impedance "looking in emitter"

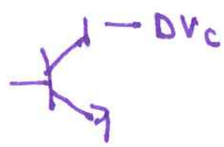


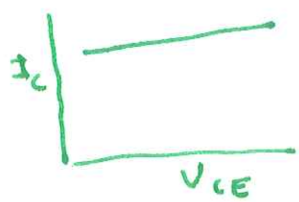
$\Delta I_B = \dfrac{\Delta V_E}{R_{in}}$

$\Delta I_E = (\beta+1)\Delta I_B = \dfrac{\Delta V_E}{R_{in}}(\beta+1)$

$\Rightarrow \dfrac{\Delta V_E}{\Delta I_E} = \dfrac{R_{in}}{(\beta+1)}$

Impedance "looking in collector"





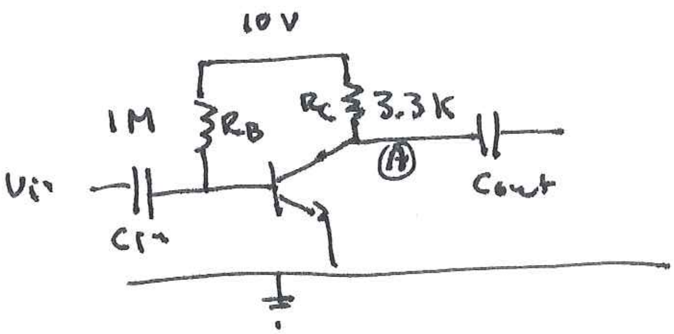
← slope = h_{oe} → small

so $R_o = \dfrac{1}{h_{oe}}$ big

IMPORTANT: words "looking into base" quite different from words "looking from base"

↳ refers to what is upstream from base — re what is connected to base.

Example — (DO NOT BUILD THIS CIRCUIT!)



$V_{CC} = 10\text{ V}$
$R_C = 3.3\text{ k}\Omega$
$R_B = 1\text{ M}\Omega$

$f = \underbrace{100}_{\text{important part}} - 10\text{k Hz}$
$B = 100$

Find V_{CE}, A_V (voltage gain – AC)
C_{out}, C_{in}

$V_B = .6V \Rightarrow I_B = \frac{(V_{CC} - V_B)}{R_B} = \frac{(10 - .6)}{10^6} = 9.4\ \mu A$

$I_C = B I_B = .94\text{ mA}$

$V_C = V_{CC} - R_C I_C = 10 - 3.3(.94) = 6.9V$

$r_e = \frac{25}{(B+1) I_B} = \frac{25}{(101)\ 9.4\mu A} = 26.3\ \Omega$

$A_v = -\frac{R_c}{r_e} = -125$

Just as with FET impedance "looking in from A"

is $R_c \parallel \frac{1}{h_{oe}} \simeq R_c$

It is expected that circuit output connects to device with much greater input impedance

so $X_{C_{out}} \leq R_c$ does little harm —

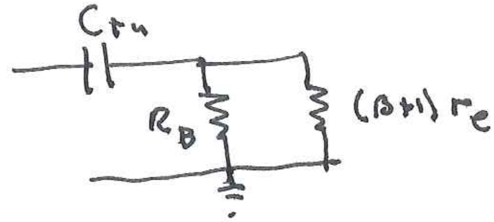
$\frac{1}{\omega C_{out}} \leq R_c$

use smallest ω as larger ω satisfies even more

$\frac{1}{2\pi f R_c} \leq C_{out}$

$\frac{1}{2\pi \cdot 100 \cdot 3.3\times10^3} = .48\ \mu F$

Looking in from V_{in} see:



seek small input impedance.
avoid having C_{in} double it.

$$\frac{1}{\omega C_{in}} \le \frac{1}{10}\left(\underbrace{R_B}_{1M\Omega} \parallel \underbrace{(\beta+1) r_e}_{2.66\,k\Omega}\right) \approx .266\,k\Omega$$

$$\frac{1}{2\pi f \cdot (266\Omega)} \le C_{in}$$

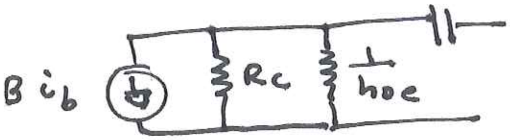
$$\parallel$$

$$\frac{1}{2\pi 100\,(266)} = 6\ \mu F$$

Build this circuit!

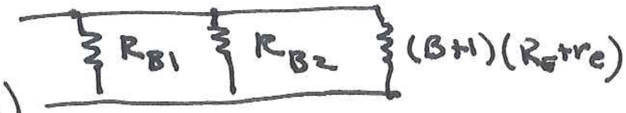
AC as viewed from collector

$Z_{out} = R_C \parallel \frac{1}{h_{oe}} \approx R_C$

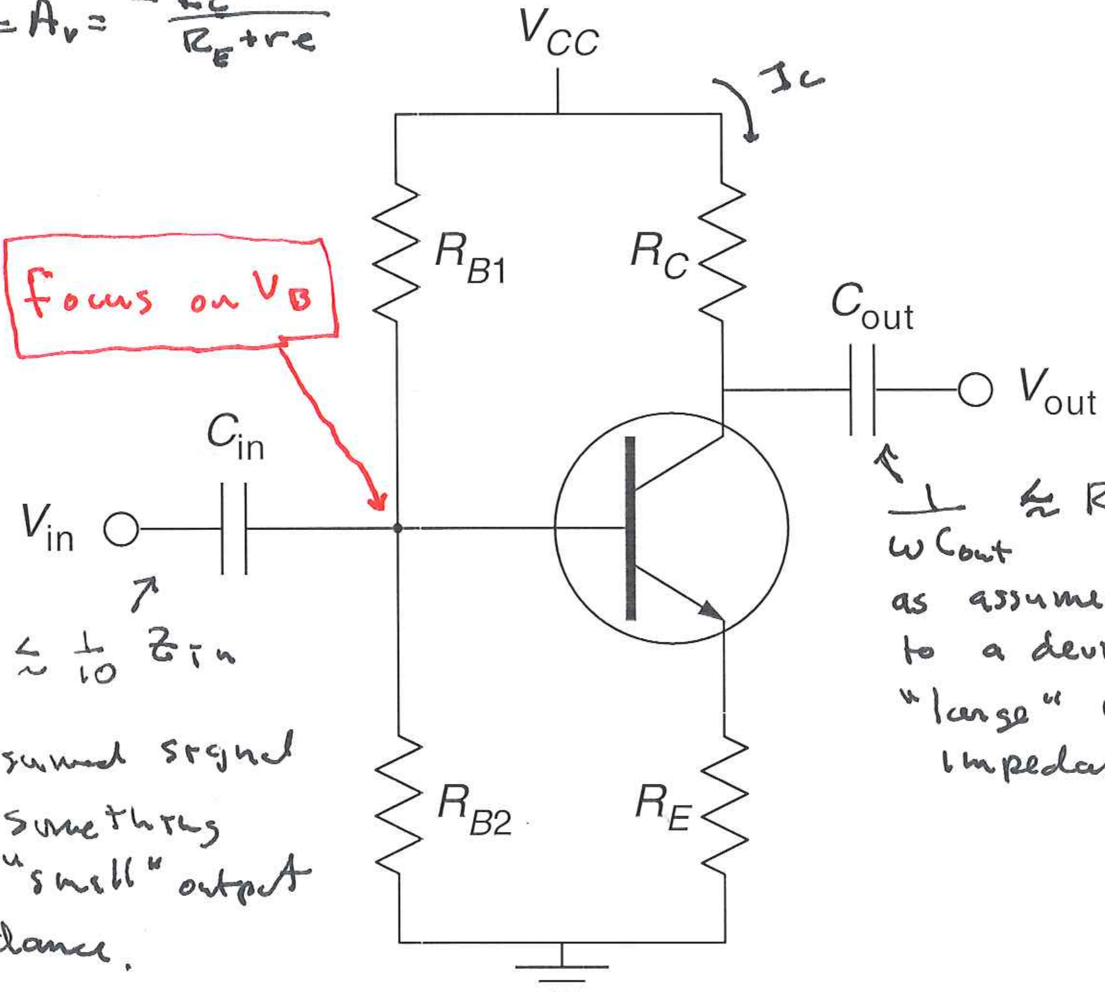


AC as viewed from base

$Z_{in} = R_{B1} \parallel R_{B2} \parallel (\beta+1)(R_E + r_e)$



$\text{Gain} = A_v = \frac{-R_C}{R_E + r_e}$



$\frac{1}{\omega C_{out}} \lessapprox R_C$

as assumed connected to a device with "large" input impedance

$\frac{1}{\omega C_{in}} \lessapprox \frac{1}{10} Z_{in}$

as assumed signal from something with "small" output impedance.

Design: $V_{CE} = \frac{1}{2} V_{CC} \Rightarrow \frac{1}{2} V_{CC}$ divided between R_C & R_E

$I_E = \frac{\frac{1}{2} V_{CC}}{R_E + R_C}$

$V_E = \frac{1}{2} V_{CC} \frac{R_E}{R_E + R_C} = \frac{1}{2} V_{CC} \frac{1}{1 + |A_v|}$

Now: $\frac{\Delta V_{CE}}{V_{CE}} = \frac{-\Delta I_E (R_E + R_C)}{V_{CC}/2} = -\frac{\Delta I_E}{I_E} = -\frac{\Delta V_E}{V_E}$ ← circumstances inside BJT [Temp, V_{CE}] can change this by $\pm .1V$

to assure accurately set — use large V_E ... 1V?, $\frac{1}{3} V_{CC}$?, $\frac{1}{20} V_{CC}$?