ECE137A, Notes Set 6: Common Gate, Common Base

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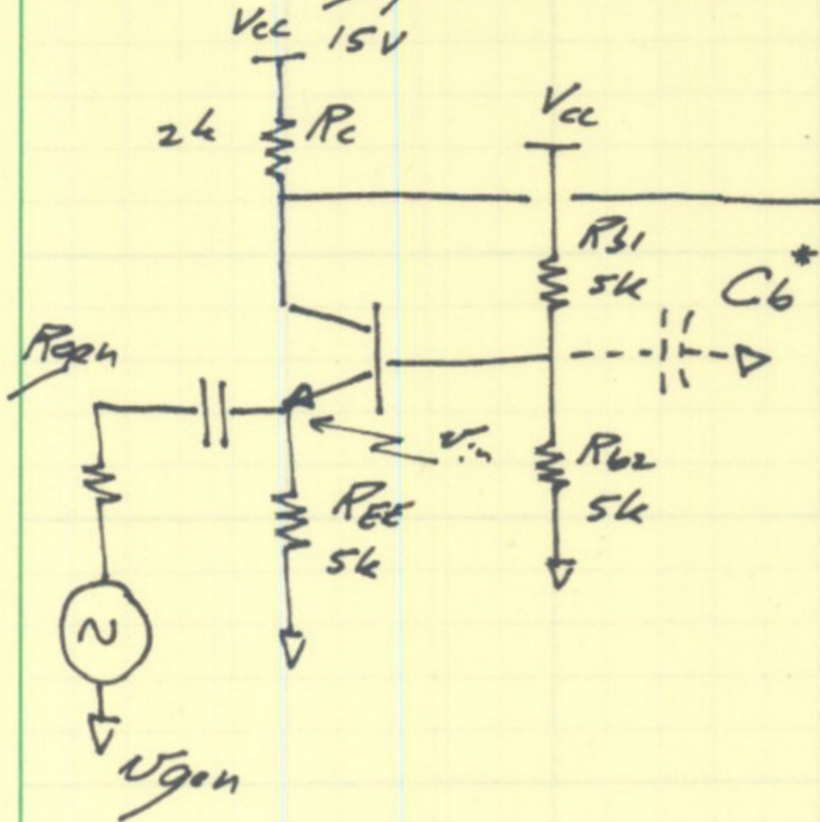
Common-base stage

First - analyze common-base stage:



$\beta = 50$

$V_A = 50V$

* we will presently <u>not</u> ac bypass the base --- but subsequent analysis shows that bypassing is advisable.

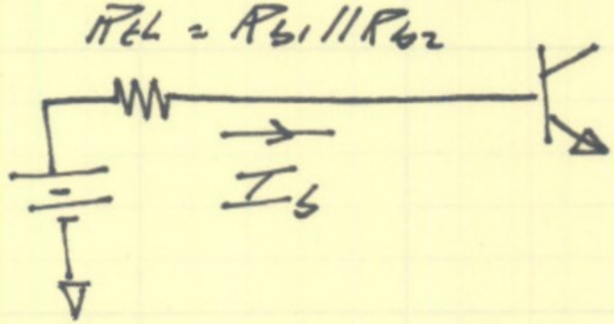
Bias Analysis: Iterative

Assume $\beta \to \infty \Rightarrow I_b = 0 \Rightarrow V_B = 7.5V \Rightarrow V_E = 6.8V$

$\Rightarrow I_E = 6.8V / 5k\Omega = 1.36\ mA$

Now assume $\beta = 50 \Rightarrow I_b = I_E / \beta = 27\mu A$

$$V_{th} = V_{cc} \frac{R_{b2}}{R_{b1} + R_{b2}}$$



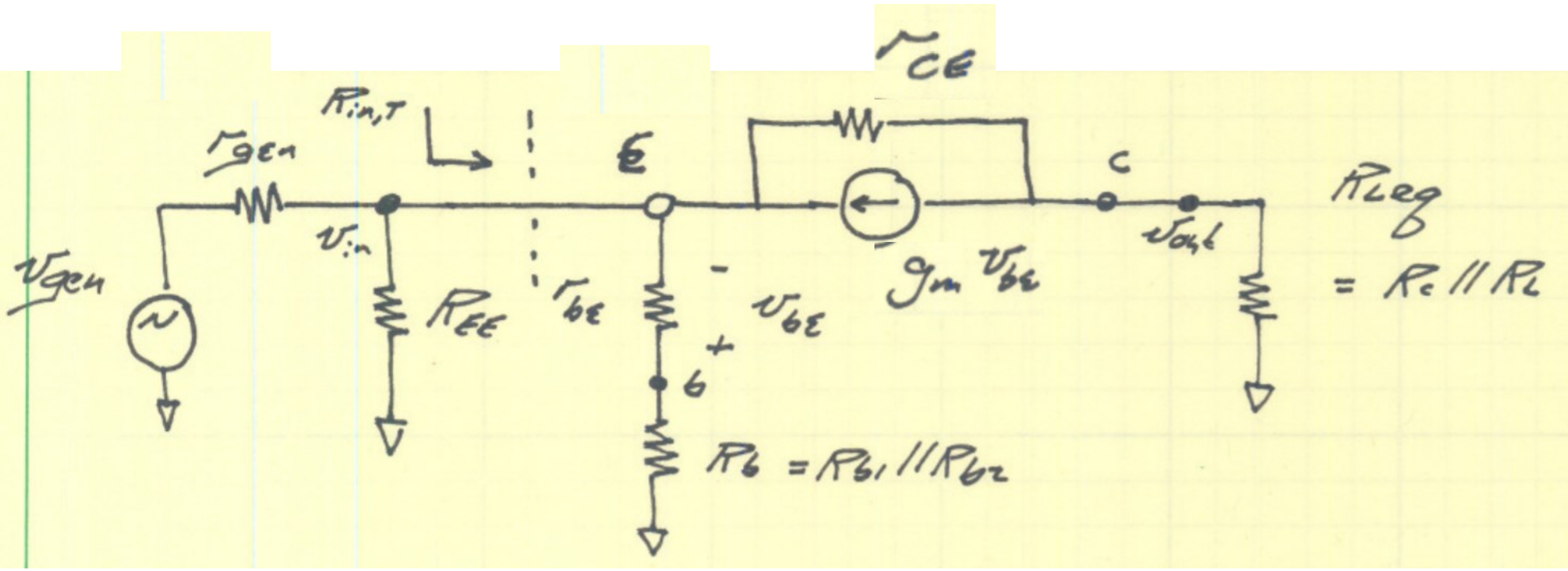
$\Rightarrow V_E = 7.5V - I_b \cdot R_{th} = 7.5V - 2.5k\Omega \cdot 27\mu A$

$= 7.5V - 68mV$

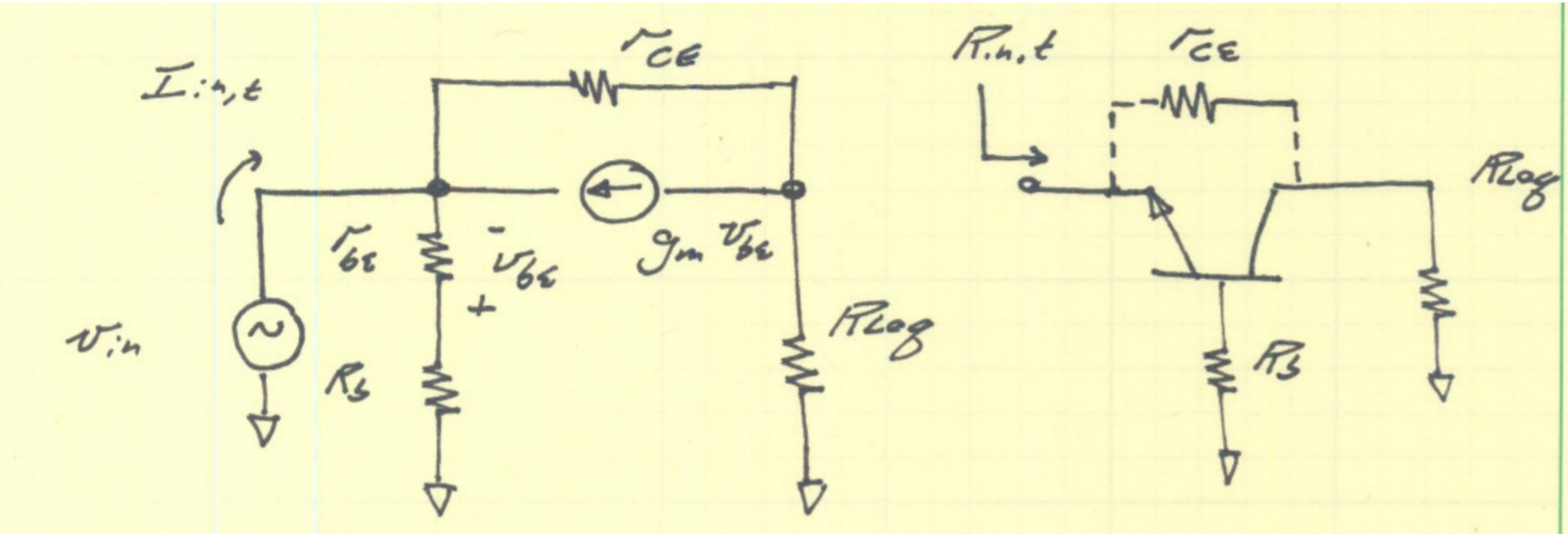
a negligible correction

$\rightarrow$ need not further analyze for corrections in I_E.

Nearly exact small-signal analysis



Finding transistor input impedance:

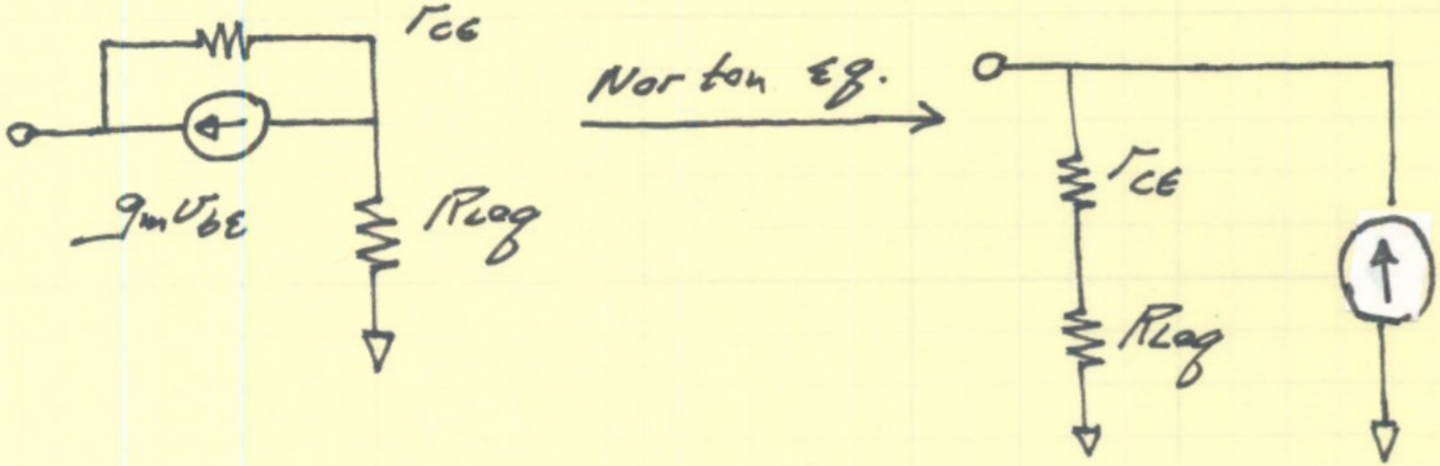


$v_{in} / I_{in,t} \triangleq R_{in,T}$

Finding transistor input impedance:

To simplify, and to understand,

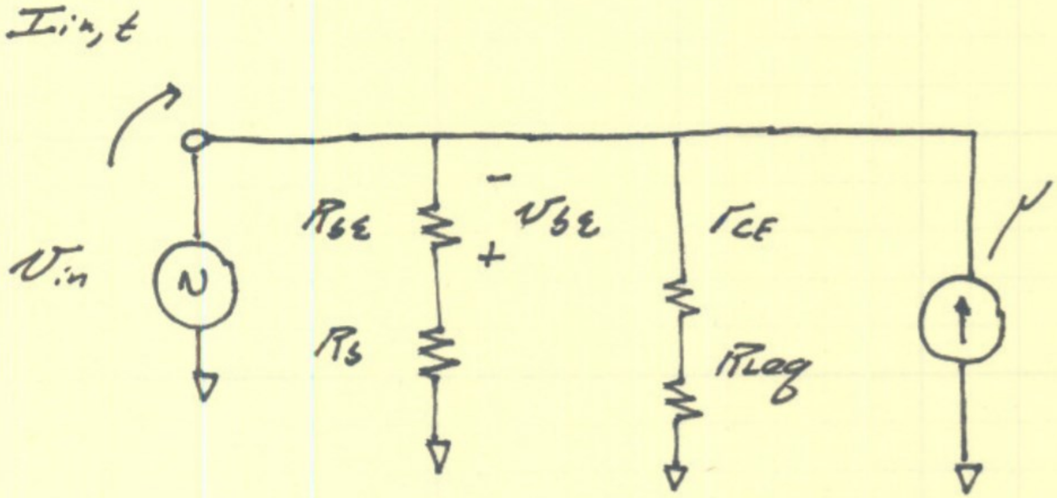
recognize the current divider in the circuit:



$$g_m V_{be} \cdot \frac{R_{CE}}{R_{CE} + R_{Leq}}$$

Finding transistor input impedance:

So we are trying to find R_{in} of the network below:



$$I = g_m V_{be} \cdot \frac{R_{CE}}{R_{CE} + R_{Leq}}$$

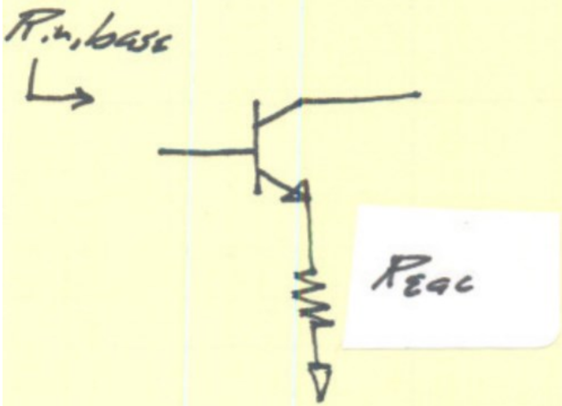
$$= -g_m V_{in} \cdot \frac{R_{BE}}{R_{BE} + R_B} \cdot \frac{R_{CE}}{R_{CE} + R_{Leq}}$$

The current in the right-most branch is dominant, so

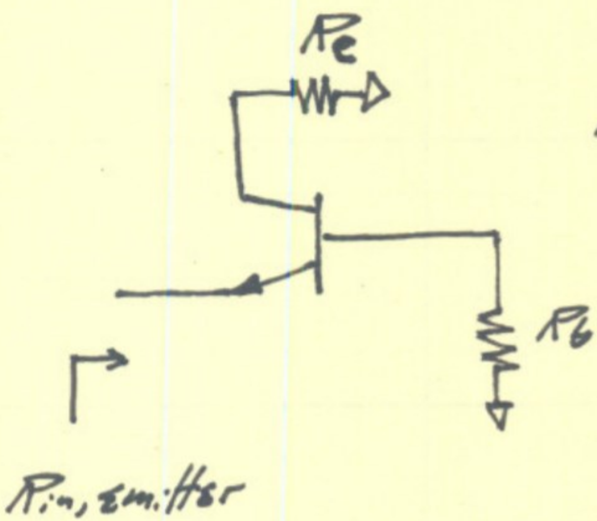
$$R_{in,T} \cong \frac{V_{in}}{I} = \frac{R_{BE} + R_B}{g_m R_{BE}} \frac{R_{Leq} + r_{CE}}{r_{CE}} = \left(r_E + \frac{R_B}{\beta}\right)\left(\frac{R_{Leq} + R_{CE}}{R_{CE}}\right)$$

$$\boxed{R_{in,T} \cong \left(r_E + \frac{R_b}{\beta}\right)\left(\frac{R_{Leq} + R_{CE}}{R_{CE}}\right) = \left(\frac{1}{g_m} + \frac{R_b}{\beta}\right)\left(\frac{R_{Leq} + R_{CE}}{R_{CE}}\right)}$$

Some pictures:



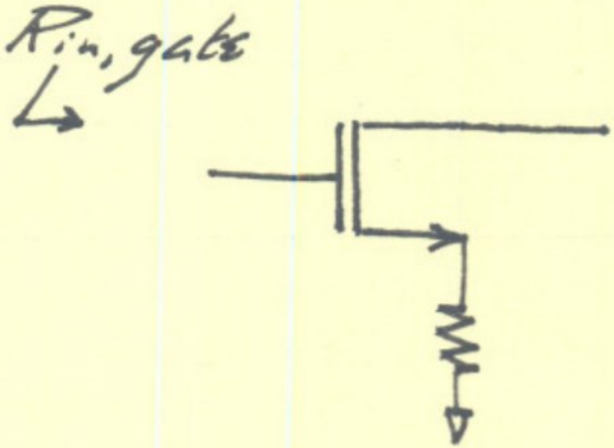
$$R_{in,base} \cong \beta(r_E + R_{Eac})$$



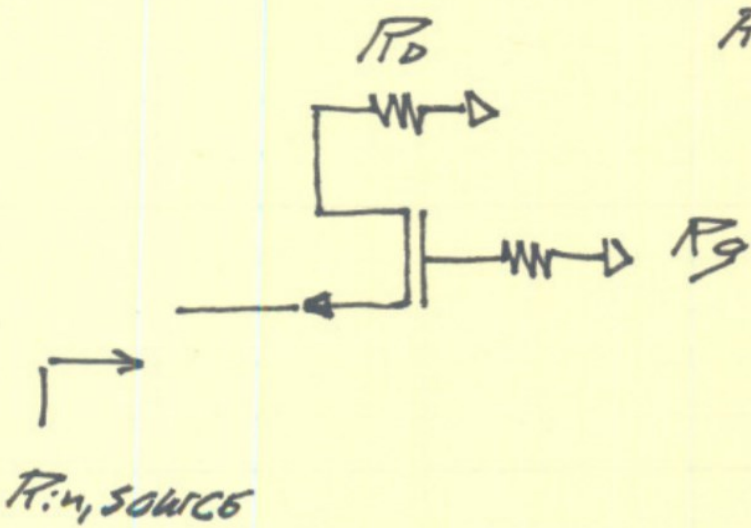
$$R_{in,emitter} \cong \left(\frac{1}{g_m} + \frac{R_b}{\beta}\right)\left(\frac{R_{CE} + R_c}{R_{CE}}\right)$$

$$= \frac{1}{g_m} + \frac{R_b}{\beta} \quad \text{for } R_c << R_{CE}$$

Some pictures:



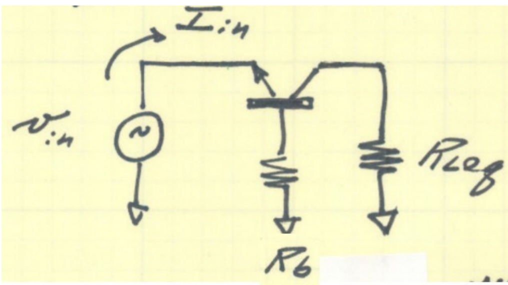
$R_{in,gate} = \infty$, of course

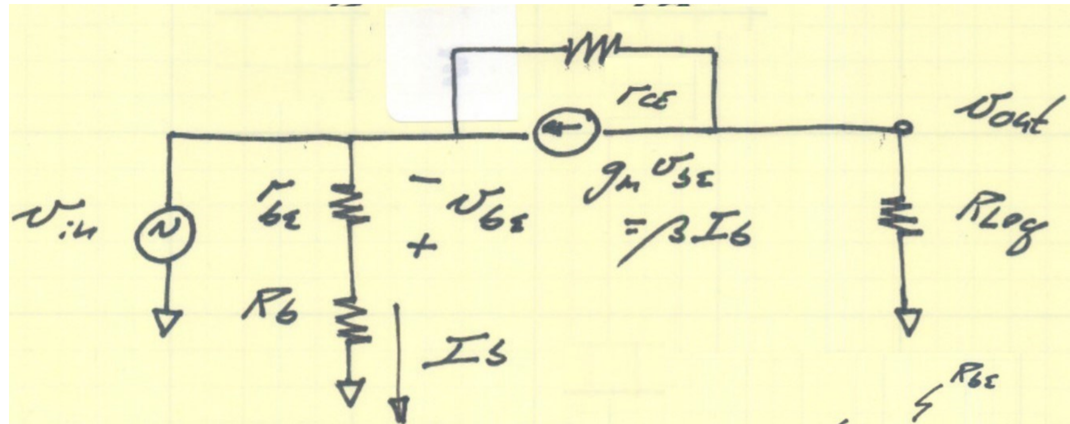


$$R_{in,source} = \frac{1}{g_m}\left(\frac{R_{ds} + R_D}{R_{ds}}\right)$$

$$= \frac{1}{g_m} \text{ for } R_D << R_{DS}$$

Common-base voltage gain





$$I_b = -v_{in}/(\beta \overset{R_{bE}}{r_E} + R_b)$$

nodal equation at v_{out}:

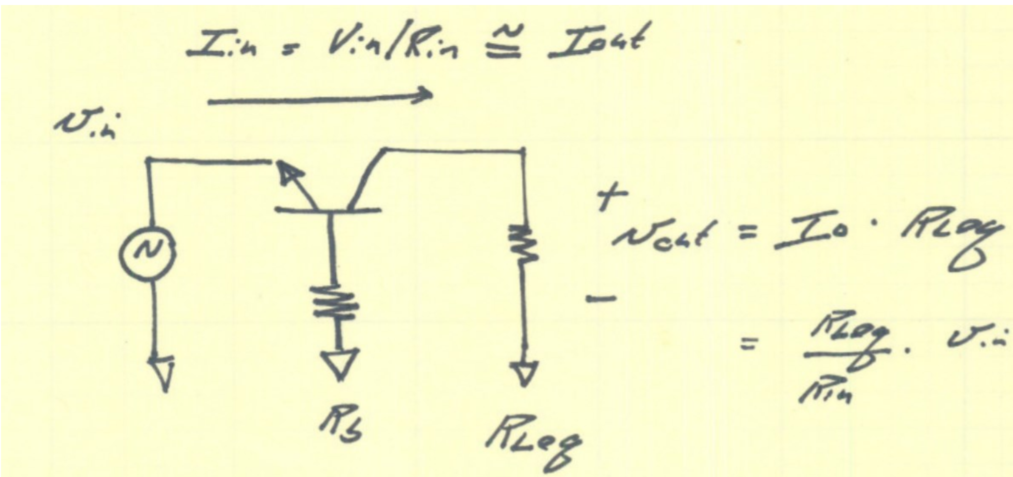
$$0 = v_{out}\left(1/R_{Leq} + 1/r_{CE}\right) + v_{in}\left(-1/r_{CE} - \frac{\beta}{\beta r_E + R_b}\right)$$

now $r_{CE} \gg r_E + R_b/\beta$ unless R_b is really big...

$$\Rightarrow \frac{v_{out}}{v_{in}} = \frac{1}{r_E + R_b/\beta} \cdot \frac{1}{1/R_{Leq} + 1/r_{CE}}$$

Common-base voltage gain

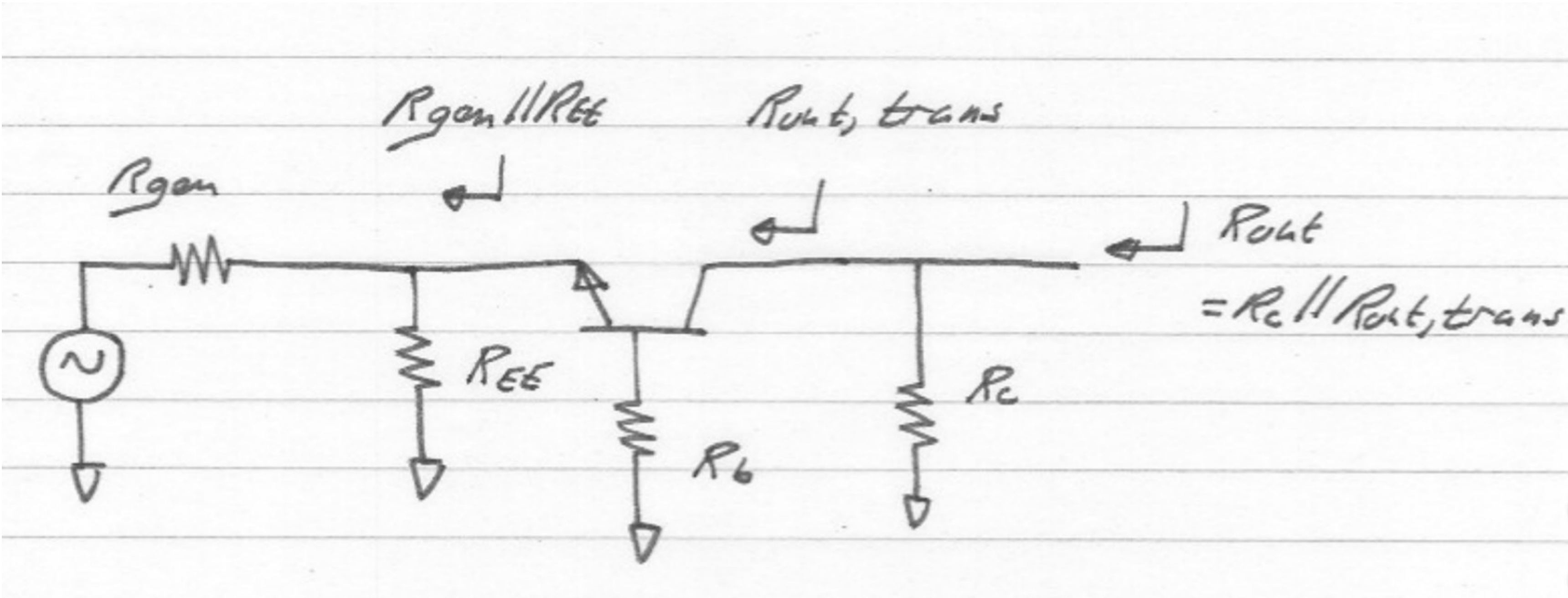
$$\frac{V_{out}}{V_{in}} = \frac{R_{Leq}}{r_e + R_b / \beta} \cdot \frac{R_{ce}}{R_{ce} + R_{Leq}} = \frac{R_{Leq}}{R_{in,emitter}}$$



For the FET, we have the same relationship:

$$\frac{V_{out}}{V_{in}} = \frac{R_{Leq}}{1/g_m} \cdot \frac{R_{DS}}{R_{DS} + R_{Leq}} = \frac{R_{Leq}}{R_{in,source}}$$

Output impedance: Common-Base



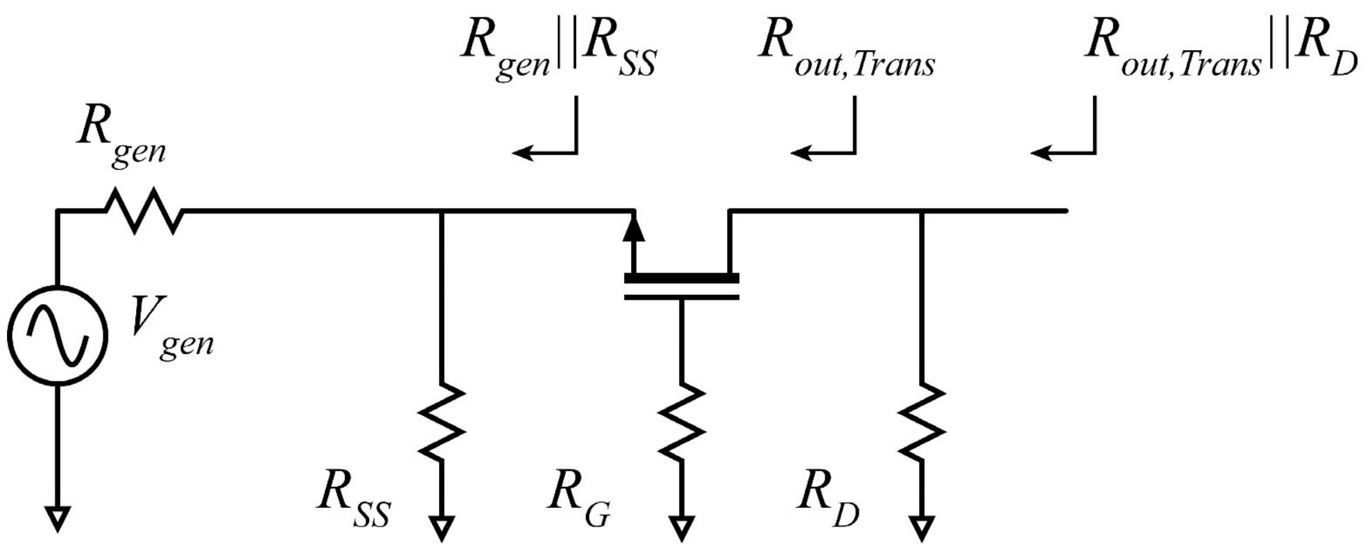
$$R_{out,Trans} = R_{CE}\left[1+\frac{R_{gen}\,\|\,R_{EE}}{1/g_m}\,\frac{R_{be}}{R_{be}+R_b+R_{gen}\,\|\,R_{EE}}\right] \simeq \left[\frac{R_{gen}\,\|\,R_{EE}}{1/g_m}\right]$$

this is the same analysis as the common-emitter +degeneration output impedance

For the FET this becomes

$$R_{out,Trans} = R_{DS}\left[1+\frac{R_{gen}\,\|\,R_{SS}}{1/g_m}\right]$$

Output impedance: Common-Gate



For the FET, the analysis is identical

(except for the absence of R_{be}) and hence:

$$R_{out,Trans} = R_{DS}\left[1+\frac{R_{gen} \,||\, R_{SS}}{1/g_m}\right]$$