R. T. Howe

[LAST CHAPTER 8 LECTURE]

Lecture 29

- FALL 2001 MIDTERM II POSTED W/O SOLUTIONS.
- SAMPLE MT. II ... FRIDAY
- REVIEW SESSION M 6-7:30 277 CORY

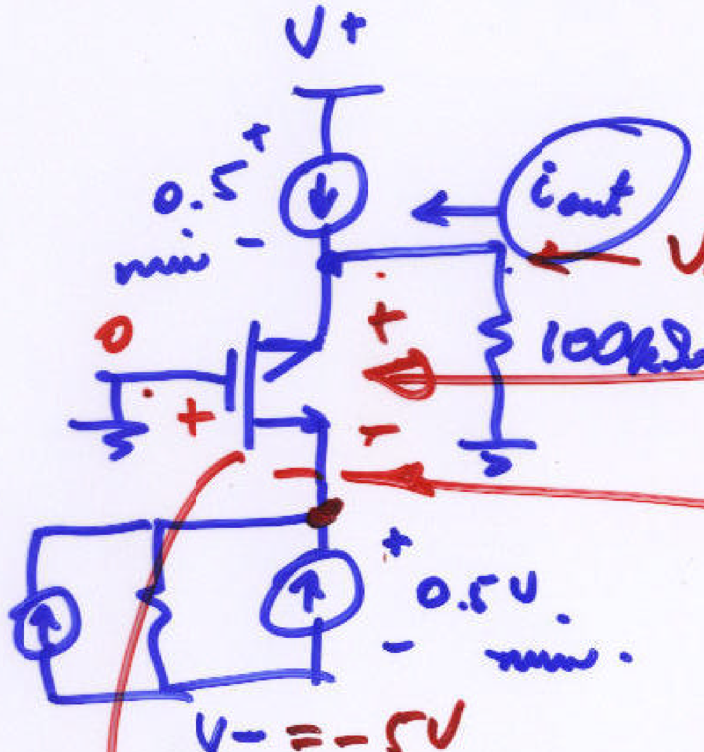
- Last time:
  - Bipolar single-stage ampliers: biasing, common-emitter, common-base, common-collector
- Today :
  - Overview of single-stage amplifiers — CE day
  - ~~Frequency response of CS stage operated as a current amplifier~~

MILLER THEOREM...

FREQUENCY RESPONSE NOW IN LAB!

PHASORS ...

TYPO IN PS 10, #2(e) SOLNS.



$(I_{OUT} = 0A)$

$V_{out}|_{min} = -0.7V$

MOS SAT.

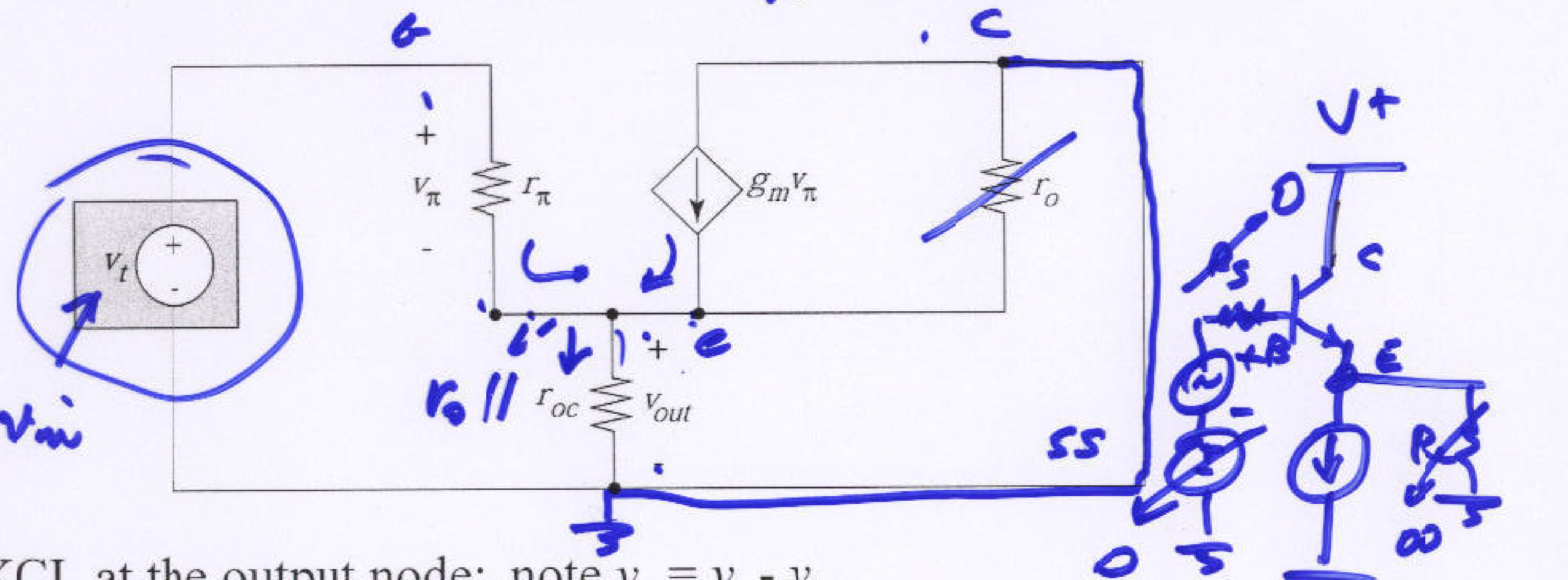
$V_{DS_{min}} = V_{DS_{SAT}} = V_{GS} - V_{Tn} = 1.8 - 0.7 = 1.1V$

$-1.8V$ PINNED

$$V_{GS} = V_{Tn} + \sqrt{\frac{2I_D}{\mu_n C_{ox}(W/L)}} = 1.8V$$

$$\hat{i}_{out_{min}} = \frac{0.7}{100k\Omega} = 7\mu A.$$

Common-Collector Voltage Gain



KCL at the output node: note $v_\pi = v_t - v_{out}$

$$v_{out} = v_\pi \left[\frac{1}{r_\pi} + g_m \right] \cdot r_o \| r_{oc}$$

$$v_\pi = \frac{v_{out}}{\left(\frac{1}{r_\pi} + g_m\right)(r_o \| r_{oc})} \qquad g_m r_o = \frac{V_A}{V_{th}}$$

$$\frac{\beta}{g_m} \ldots \frac{1}{r_\pi} = \frac{g_m}{\beta} \qquad r_o = \frac{V_A}{I_C}$$

$$v_t = \frac{v_{out}}{[\,MESS\,]} + v_{out}$$

$$g_m (r_o \| r_{oc}) = \frac{I_C}{V_{th}} \; 0.5\,mS \cdot (200\,k\Omega) = 100.$$

$$v_t = v_{out} \left[1 + \frac{1}{MESS} \right]$$

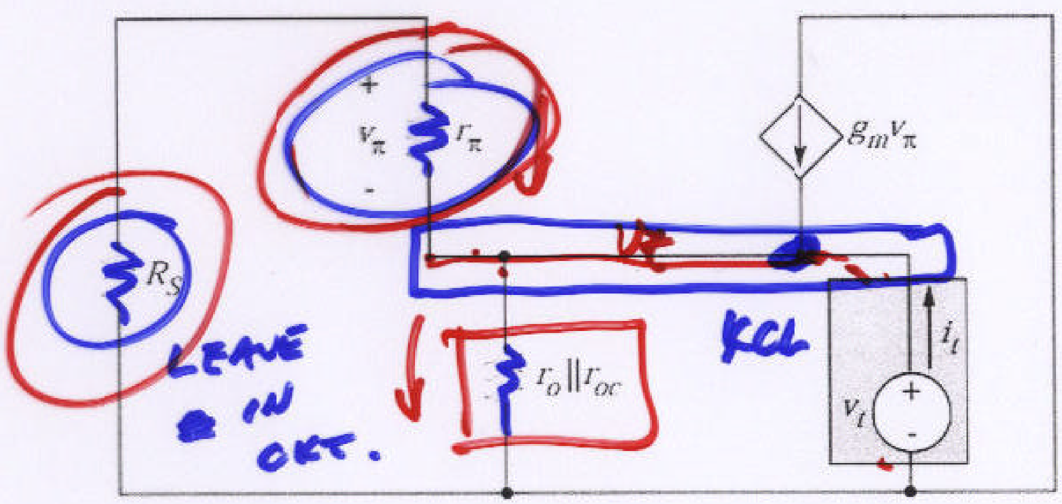
$$A_v = \frac{v_{out}}{v_t} = \left(\frac{1}{1 + \frac{1}{MESS}} \right) \approx 1$$

β 10?

$$\Rightarrow \underline{MESS} = \left(\frac{1}{r_\pi} + g_m \right) \cdot r_o \| r_{oc} \approx 100$$

Common-Collector Output Resistance

SMALL. $\approx \frac{1}{g_m}$.



$R_{out} = \frac{v_t}{i_t}\Big|_{\text{w/ } R_L, R_S}$

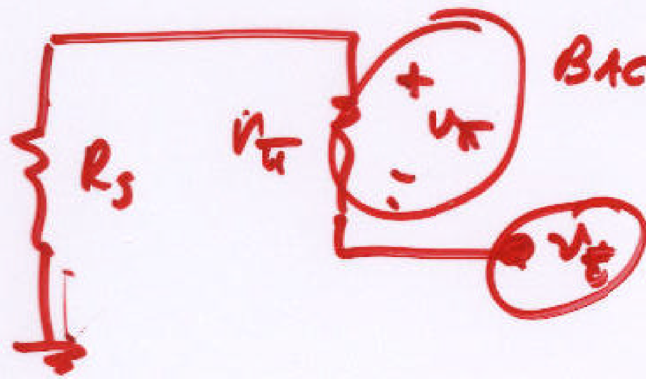
Divider between v_t and v_π

$i_t + g_m v_\pi + \frac{v_\pi}{r_\pi} - \frac{v_t}{r_o || r_{oc}} = 0.$

100X SMALLER

WANT v_t/i_t ... get rid of v_π.

$$v_\pi = -v_t \left[\frac{r_\pi}{r_\pi + R_S}\right]$$



BACKWARDS

$$i_t + g_m\left[\frac{-v_t r_\pi}{r_\pi + R_S}\right] - \frac{v_t}{r_o \| r_{oc}} = 0$$

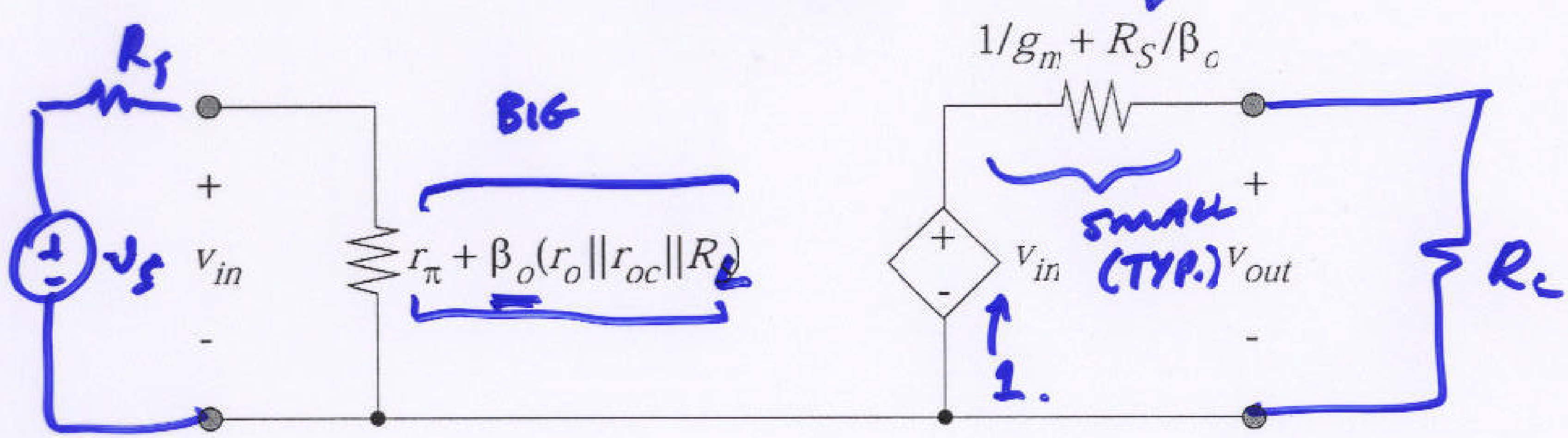
$$i_t = \left[\frac{g_m r_\pi}{r_\pi + R_S} + \frac{1}{r_o \| r_{oc}}\right] v_t$$

$$R_{out} = \frac{v_t}{i_t} = \frac{1}{\frac{g_m r_\pi}{r_\pi + R_S} + \frac{1}{r_o \| r_{oc}}}$$

$$R_{out} \cong \frac{r_\pi + R_S}{g_m r_\pi} = \frac{1}{g_m} + \frac{R_S}{\beta_o} \leftarrow g_m r_\pi$$

Common-Collector Two-Port Model

FIG. 8.47 H & S

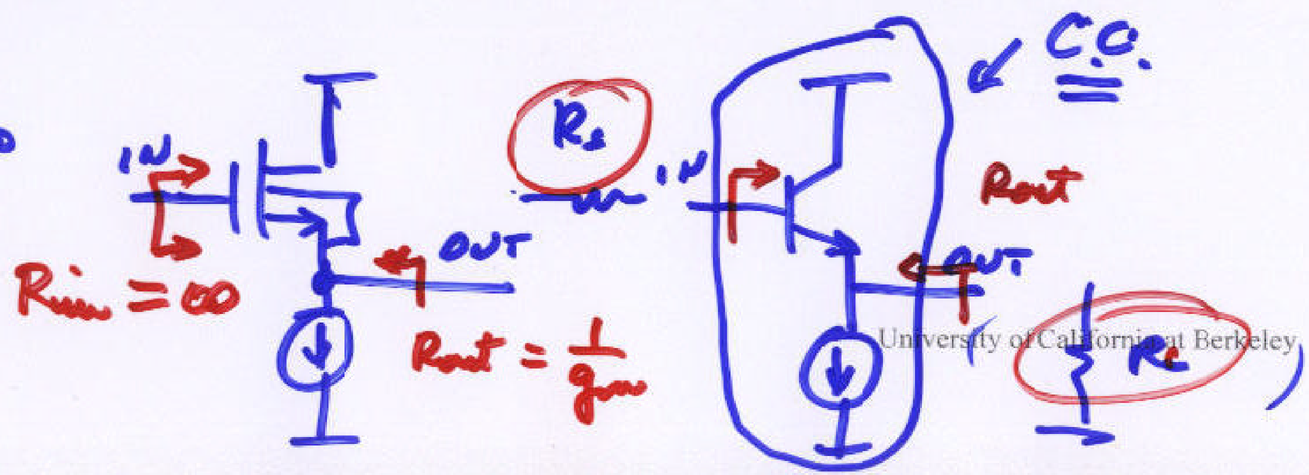


BIG 100's of kΩ
MOD 10's of kΩ
SMALL ≲ 1 kΩ.

FOR $I_C, I_D \approx 100\,\mu A$.

Common-Collector Summary

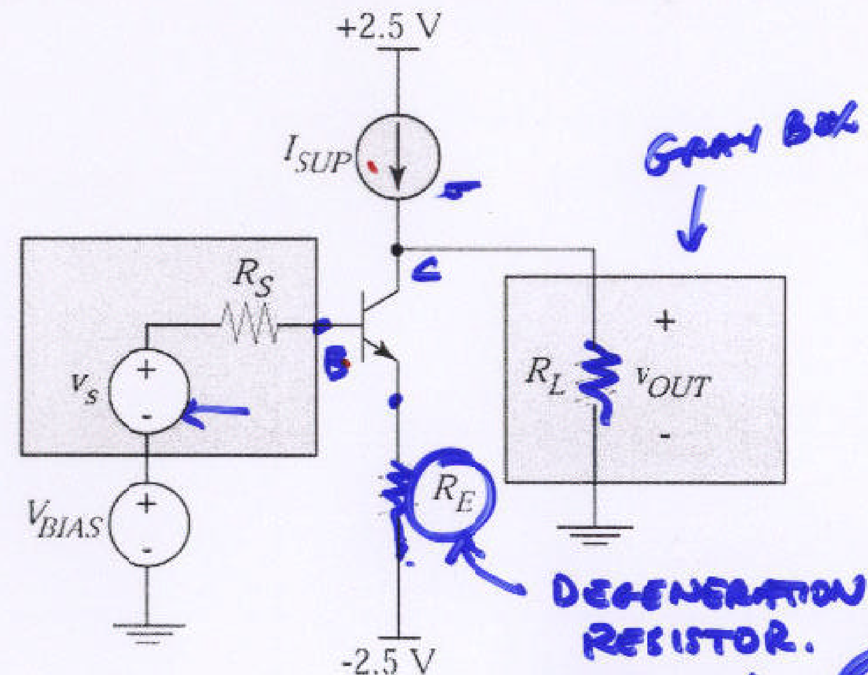
- Typo in Fig. 8.47 in text … R_{in} can't depend upon R_S!
- Input and output resistances depend on load and source resistances, respectively
- See Appendix to Chapter 8 for limits to using this model with very low values of R_L



Summary of Two-Port Parameters for CE/CS, CB/CG, CC/CD Amplifiers

Amplifier Type	Controlled Source	Input Resistance R_{in}	Output Resistance R_{out}
Common Emitter	$G_m = g_m$	r_π	$r_o \parallel r_{oc}$
Common Source	$G_m = g_m$	infinity	$r_o \parallel r_{oc}$
Common Base	$A_i = -1$	$1 / g_m$	$r_{oc} \parallel [(1 + g_m(r_\pi \parallel R_S))\, r_o]$, for $g_m r_o >> 1$
Common Gate	$A_i = -1$	$1 / g_m$, $(v_{sb} = 0)$ -otherwise- $1 / (g_m + g_{mb})$	$r_{oc} \parallel [(1 + g_m R_S) r_o]$, $(v_{sb}=0)$ -otherwise- $r_{oc} \parallel [(1 + (g_m + g_{mb}) R_S)\, r_o]$ both for $r_o >> R_S$
Common Collector	$A_v = 1$	$r_\pi + \beta_o(r_o \parallel r_{oc} \parallel R_L)$	$(1 / g_m) + R_S / \beta_o$
Common Drain	$A_v = 1$ if $v_{sb} = 0$, -otherwise- $g_m / (g_m + g_{mb})$	infinity	$1 / g_m$ if $v_{sb} = 0$, -otherwise- $1 / (g_m + g_{mb})$

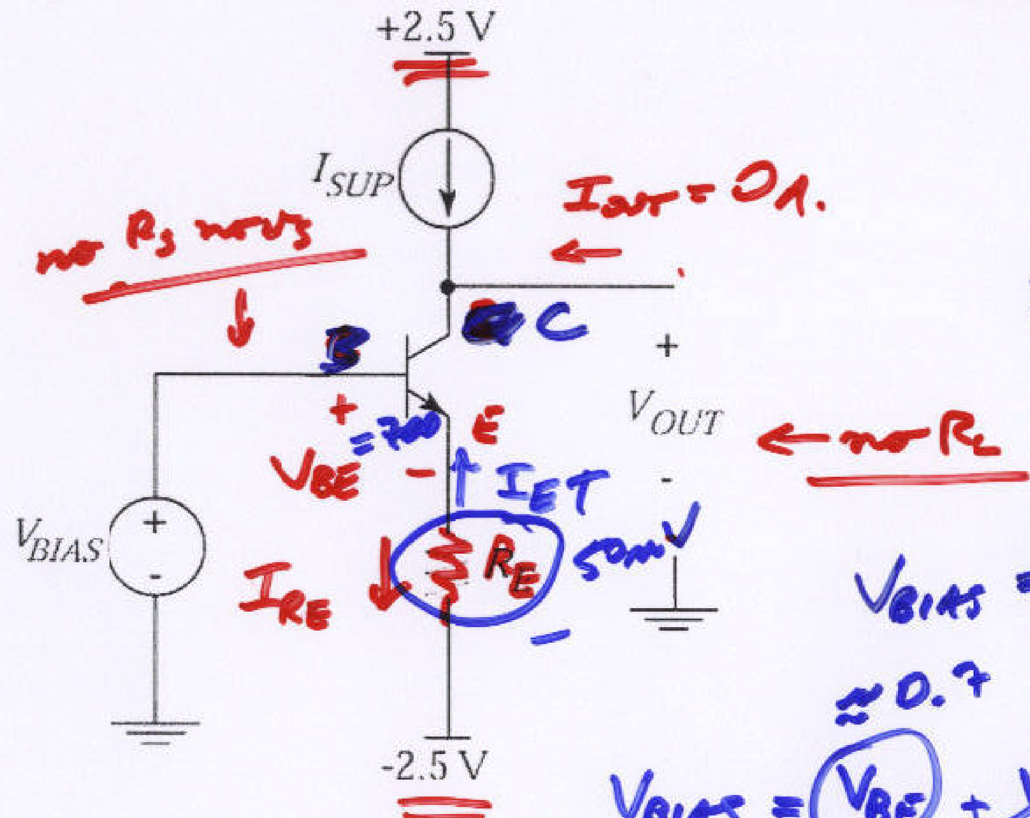
The "Chapter 8" Method for Single-Stage Amplifier Analysis



1. What is it? ✓ NOTHING IS "COMMON"
2. DC Bias
3. Small-signal 2-port model R_{in}, R_{out}, G_m
4. Output swing

input on base
output on collector
⇒ emitter

DC Bias for CE_{deg}



TYP.

$R_E = 500\,\Omega$

$I_C R_E = 100\mu A \cdot 500\,\Omega = 0.05V.$

$V_{BIAS} = \left\{ V_{th} \ln\left[\frac{I_C}{I_S}\right]\right\} + I_C R_E.$

$V_{BIAS} = V_{BE} + V_{RE}$, with $V_{BE} \approx 0.7$

$I_{RE} \cdot R_E \approx I_C R_E$

$= I_{SUP}$

$I_{RE} = -I_E = \frac{1}{\alpha_F} I_C \approx I_C$, with $0.99^{-1} = 1.01$

Two-Port Model for CE_{deg}

- Input looks like CC → $R_{in} \cong R_{in_{CC}}$
- Output looks like CB (see p. 504 for details) → $R_{out} \cong$
- Transconductance: $G_m =$