Lecture 28

NMOS, PMOS

R -SUPPLIES [CURRENT-SOURCE SUPPLIES.]

TRANS-CONDUCTANCE

- Last time:
  - Wrap-up MOS single-stage amplifiers : CS, CG, CD.
- Today : || SET OF AMPLIFIERS
  - Bipolar single-stage ampliers: biasing, common-emitter, common-base, common-collector

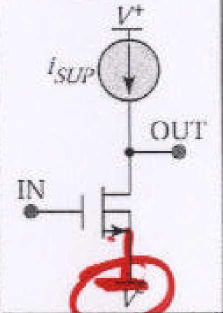
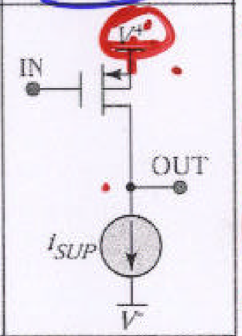
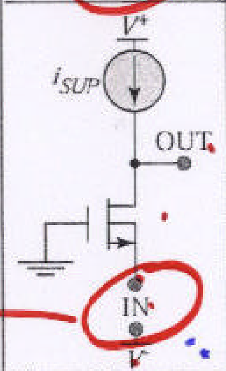
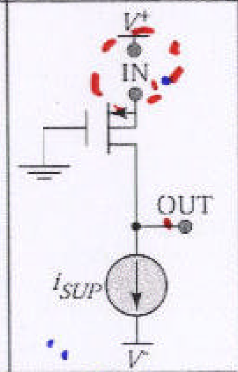
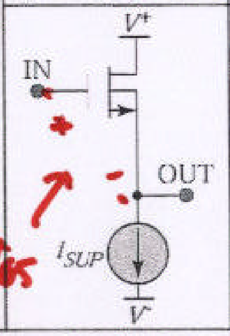
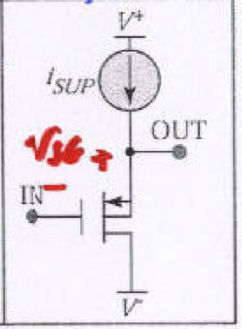
CE CB CC

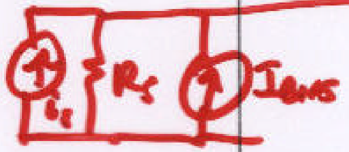
VOLTAGE BUFFER

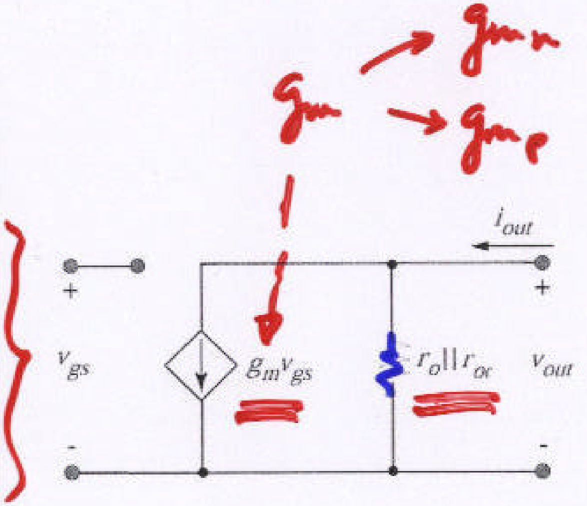
CURRENT BUFFER

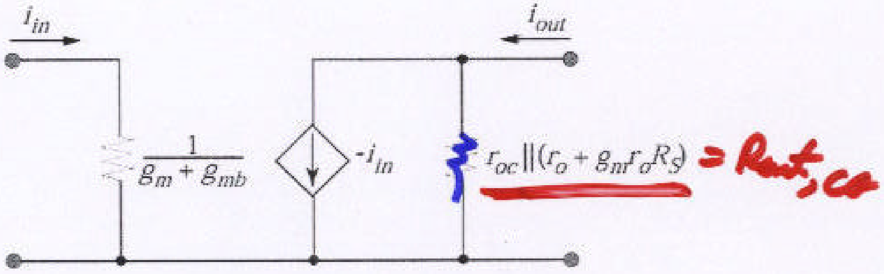
npn VERSIONS

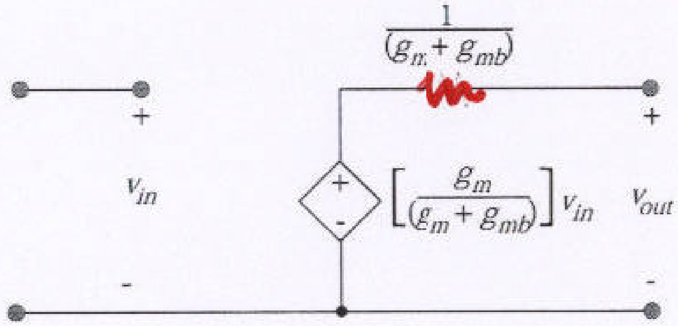
Bi CMOS → IMPORTANT FOR WIRELESS

	Transistor Type	
	NMOS	PMOS
Common Source/ ~~Common Emitter~~ (CS/~~CE~~)		
Common Gate/ ~~Common Base~~ (CG/~~CB~~)		
Common Drain/ ~~Common Collector~~ (CD/~~CC~~) V_{GS}		







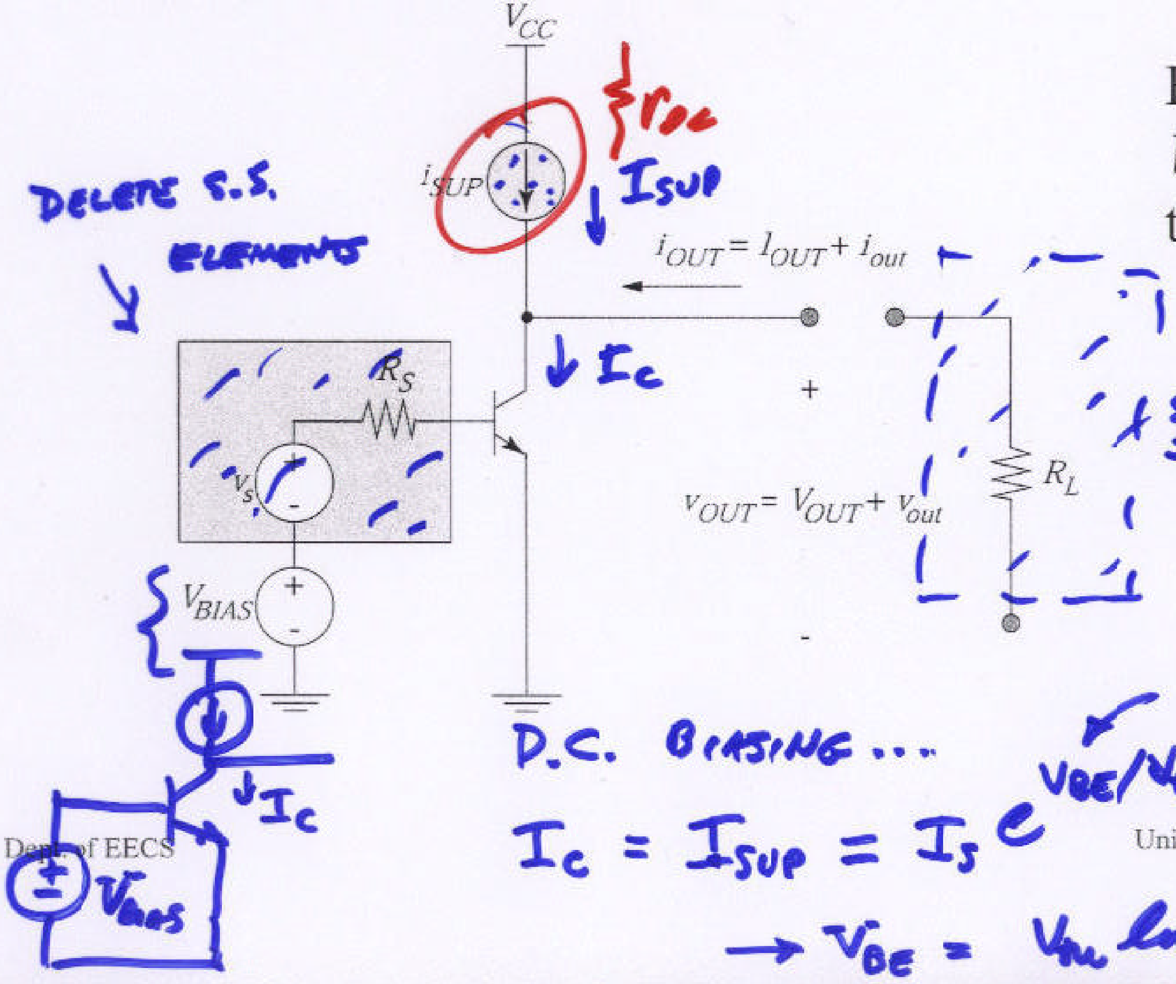


"PATTERNS"
CONFIGURATIONS

Bipolar Amplifiers

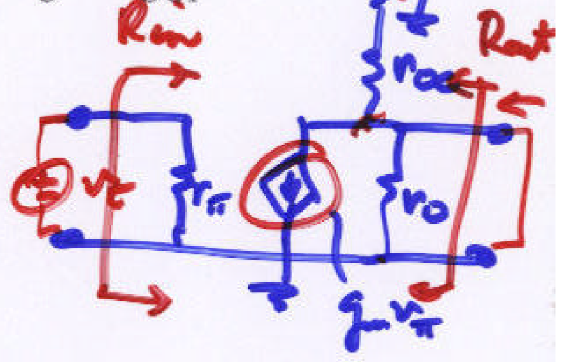
Common-emitter amplifier:

DELETE S.S. ELEMENTS



Biasing: adjust $V_{BIAS} = V_{BE}$ so that $I_C = I_{SUP}$.

S.S.



D.C. BIASING ...

$$I_c = I_{SUP} = I_S e^{V_{BE}/V_{th}}$$

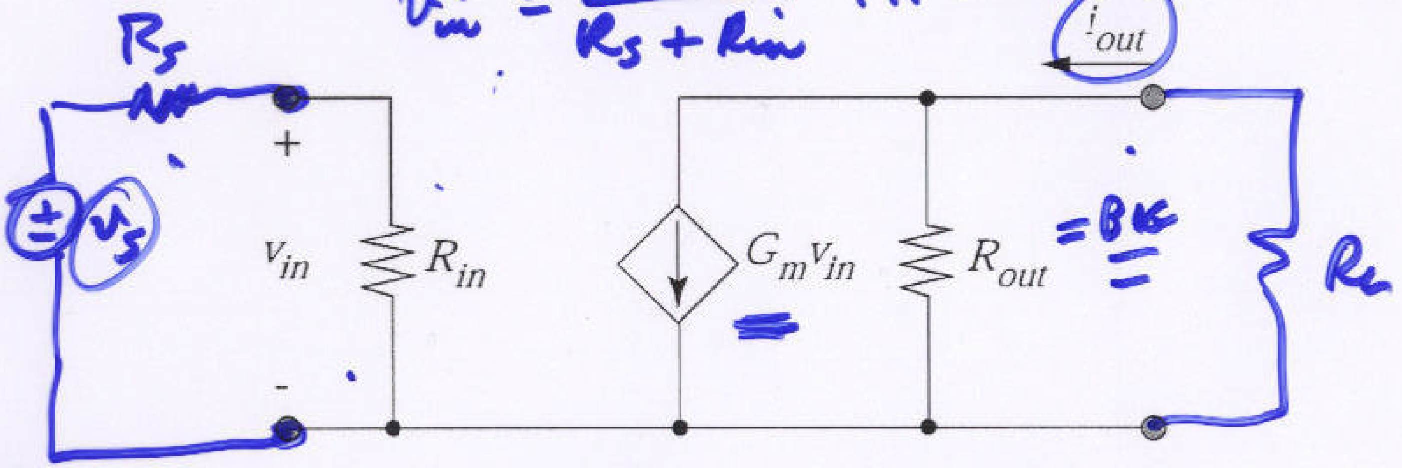
$\approx 0.7V.$

VERY SENSITIVE.

$$\rightarrow V_{BE} = V_{th} \ln\left[\frac{I_{SUP}}{I_S}\right]$$

Small-Signal Two-Port Model

$v_{in} = \frac{R_{in}}{R_S + R_{in}} \cdots \quad R_{in} = r_\pi$



$\frac{\beta_o}{g_m}$

- Parameters:

$R_{in} = r_\pi$ = 5-10 kΩ. = 25 kΩ. MODERATE

$R_{out} = r_{oc} \| \cancel{r_o}$ $\frac{V_{An}}{I_C}$

$G_m = \boxed{g_{m\,BJT}}$ I_C / V_{th} BIG

- C.F. C.S. :

$\boxed{R_{in} = \infty}$

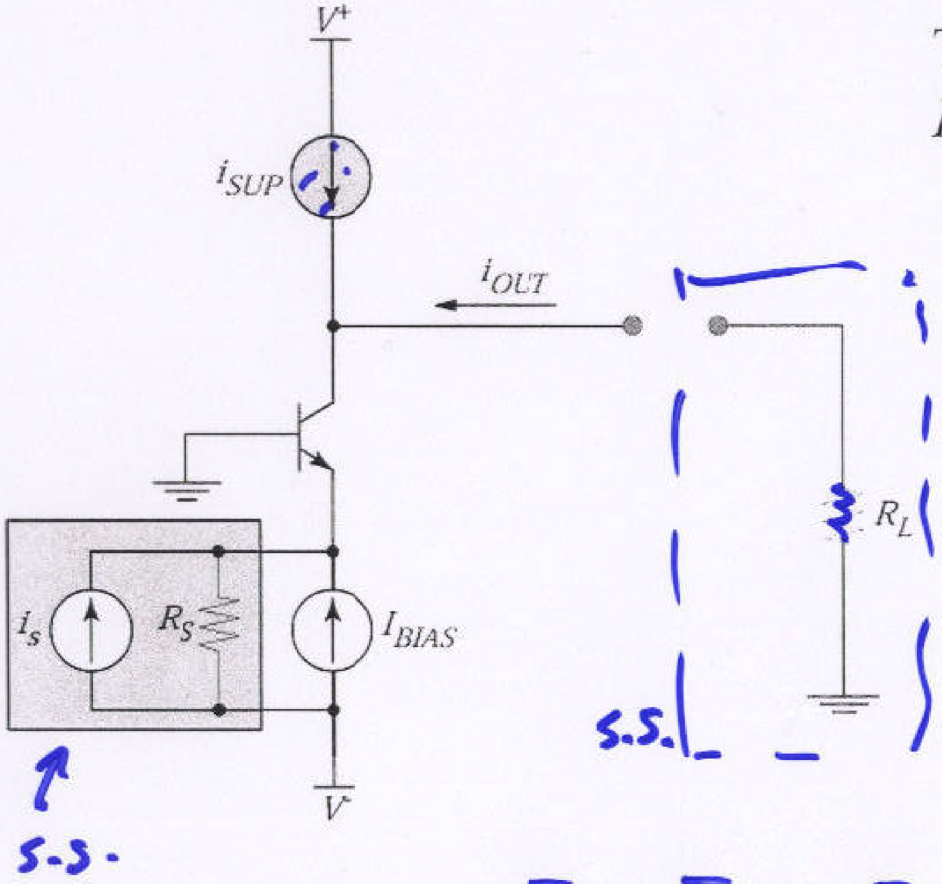
$R_{out} = r_{oc} \| \cancel{r_o}$ $\frac{1}{\lambda_n I_D}$

$G_m = g_{m\,MOS} = \frac{I_D}{2(V_{GS} - V_{Tn})}$ BIG

CE ✓

Common-Base Amplifier

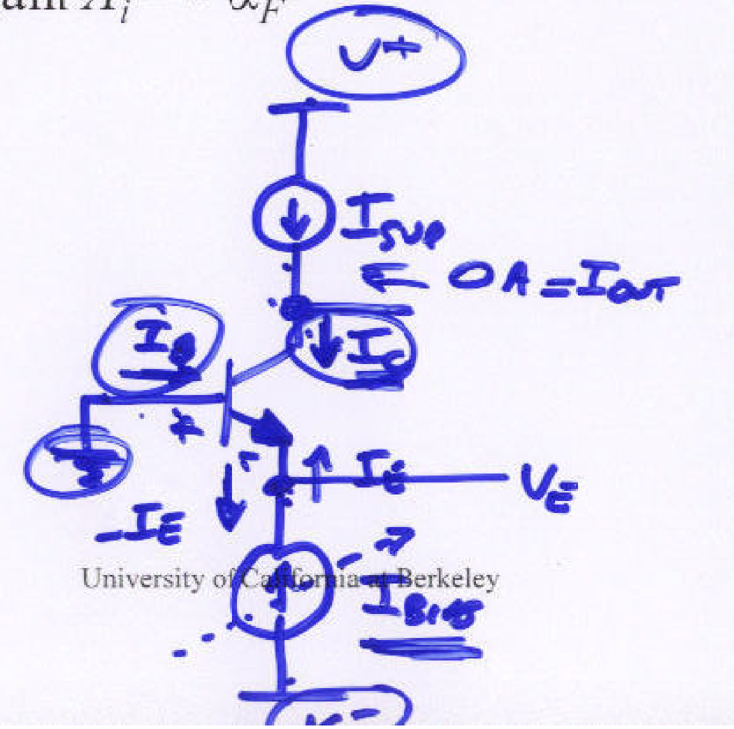
$V_E = 0 - V_{BE} \approx -0.7\,V$



To find I_{BIAS}, note that

$I_{BIAS} = I_E = \boxed{-(1/\alpha_F)I_C} = \underbrace{-1.01\,I_C} = (-1.01)I_{SUP}$

Common-base current gain $A_i = -\alpha_F$

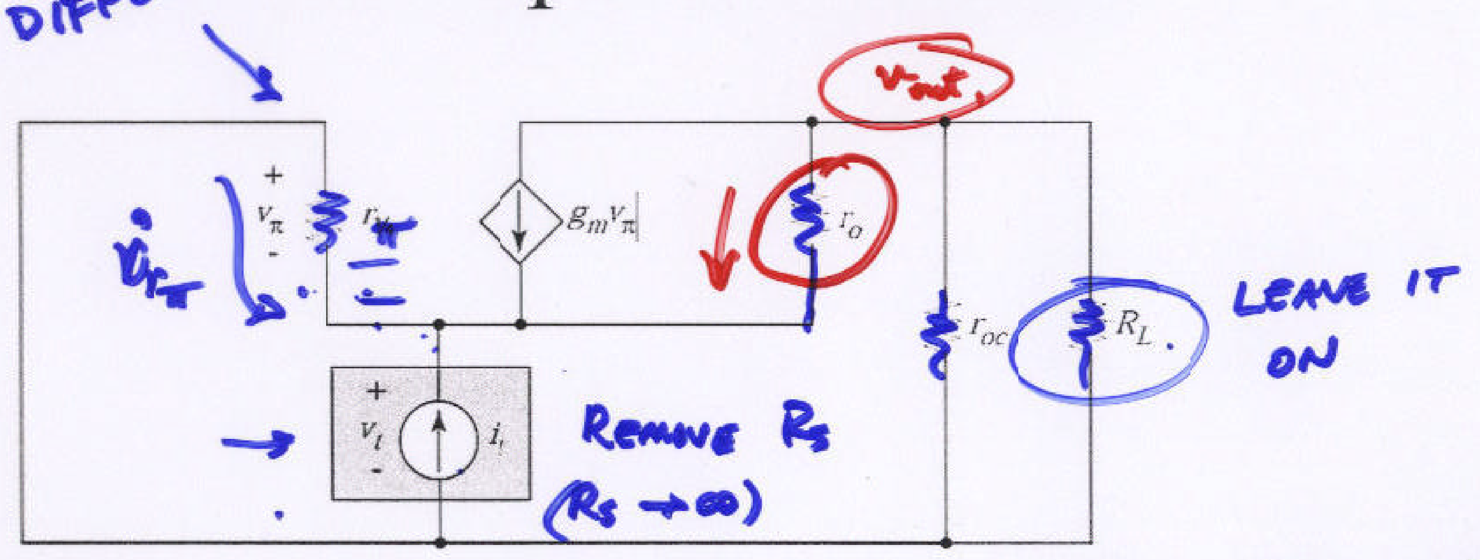


$I_B + I_C = -I_E$

$I_C\left[\frac{1}{\beta_F} + 1\right] = \frac{I_C}{\beta_F} + I_C = \underline{-I_E}$

Current gain $\boxed{A_i = -\alpha_F \approx -1}$

CB Input Resistance



Summing currents at the input node:

CG: $R_{in_{CG}} \cong \frac{1}{g_m + \cancel{g_{mb}}}$

$\boxed{= \frac{1}{g_m}}$

r_π is in ∥ with

SMALL

KCL at input node: $v_\pi / r_\pi = -v_t / r_\pi$

$$\approx 0 \leftarrow \frac{v_{out} - v_t}{r_o} + i_t + g_m v_\pi + i_{r_\pi} = 0.$$

$$i_t + g_m v_t - \frac{v_t}{r_\pi} = 0$$

$$i_t = \left(g_m + \frac{1}{r_\pi}\right) v_t$$

$$\frac{v_t}{i_t} = R_{in} = \frac{1}{\boxed{g_m} + \boxed{\frac{1}{r_\pi}}} = \frac{1}{g_m + \cancel{\frac{g_m}{\beta_0}}}$$

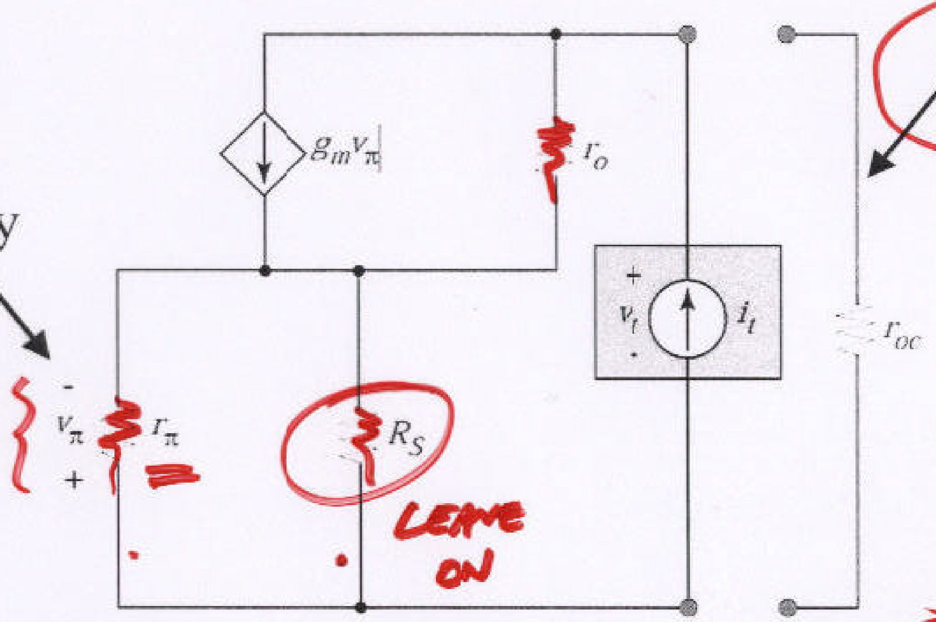
$$\simeq 0$$

$$r_\pi = \beta_0 / g_m$$

$$\boxed{= \frac{1}{g_m}}$$

CB Output Resistance

note
polarity



put r_{oc} back in
after finding v_t / i_t

HUGE

Same topology as CG amplifier, but with $r_\pi \| R_S$ rather than R_S

$$R_{out} \cong r_{oc} \| \left\{ r_o \left(1 + g_m \underline{(r_\pi \| R_S)} \right) \right\}$$ ✓

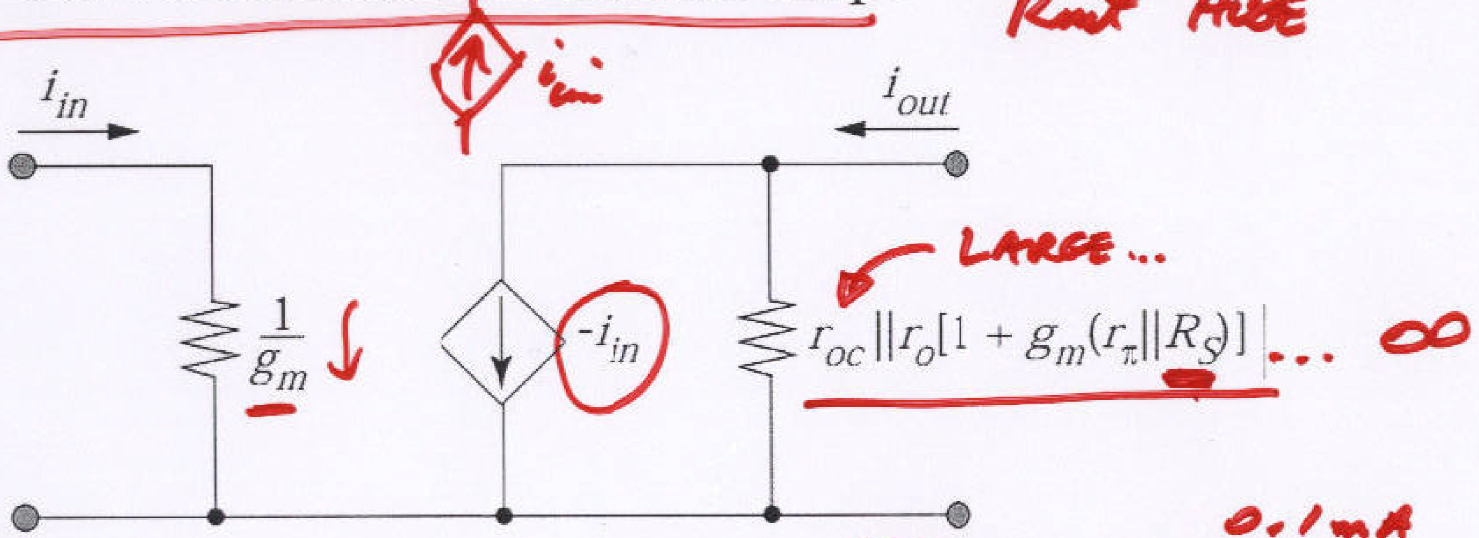
SPECIAL CASE $\underline{r_\pi \ll R_S}$ $\Rightarrow$ $r_\pi \| R_S \cong r_\pi$ $\Rightarrow$ $R_{out} = r_{oc} \| \{ r_o (1 + \overset{\beta_o \downarrow}{g_m r_\pi}) \}$

$= r_{oc} \| \{ r_o (1 + \beta_o) \}$

Common-Base Two-Port Model

- Why did we consider it a current amp?

R_{in} SMALL
R_{out} HUGE



R_{in} = small

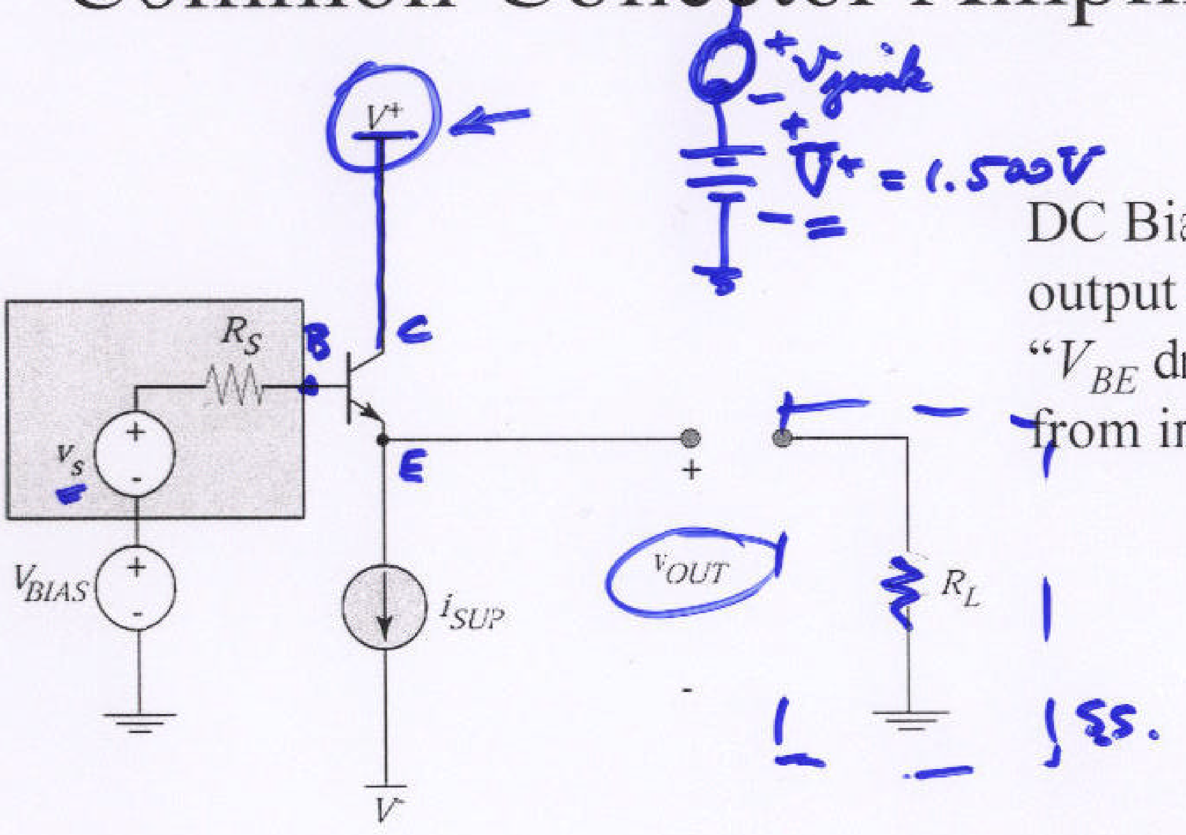
$= \frac{1}{g_m} = 250\Omega$

$g_m = \frac{I_C}{V_{th}} = \frac{100\mu A}{25 mV}$ 0.1 mA $\boxed{62°F}$

$= \frac{1}{250} S'$

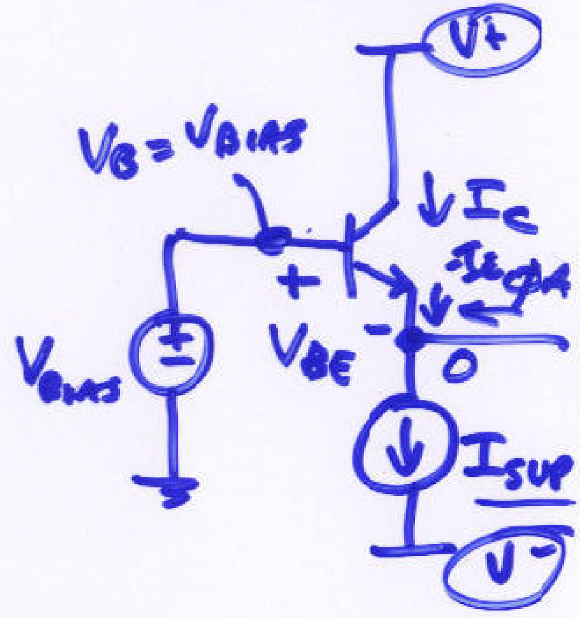
CE ✓
CB ✓

Common-Collector Amplifier



DC Bias:
output is one
"V_{BE} drop" down
from input

DC BIASING



$= V_E$

$\underline{\underline{V_{OUT}}} \approx 0V$ ... TARGET.

$$V_{BE} = \overset{V_B}{\cancel{V_{BIAS}}} - V_E = V_{BIAS} - V_{OUT}.$$

$$\underline{I_{SUP} = -I_E =} \boxed{\frac{1}{\alpha_F}} I_C \approx I_C$$

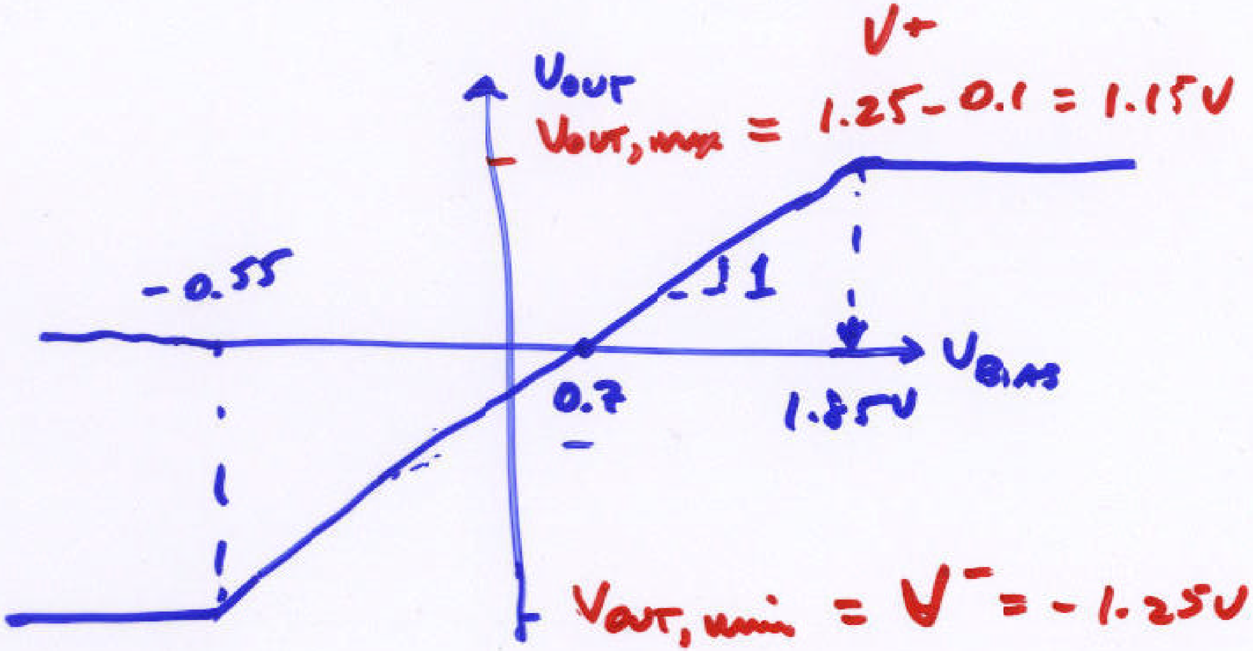
$$\frac{1}{0.99} = 1.01$$

$$I_C = I_{SUP}; \quad \underline{\underline{I_C}} = \underline{I_S} e^{V_{BE}/V_{th}} = I_{SUP}.$$

$$V_{BE} = V_{th} \ln\left(\frac{I_{SUP}}{I_S}\right)$$

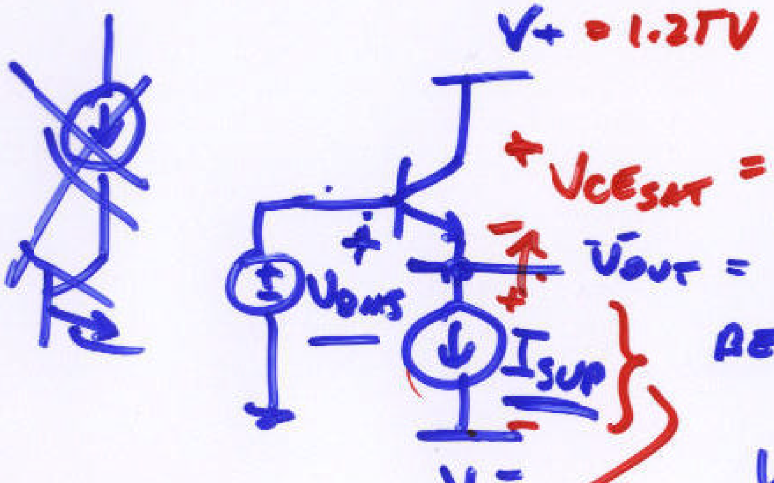
$$\cong 0.7V.$$

$$V_{BIAS} \approx 0.7V$$



$V_{OUT,max} = 1.25 - 0.1 = 1.15V$

$V_{OUT,min} = V^{-} = -1.25V$



V_{OUT} = "FOLLOWS" V_{BIAS}

BECAUSE V_{BE} FIXED @

$V_{th} \ln(I_{SUP}/I_S)$