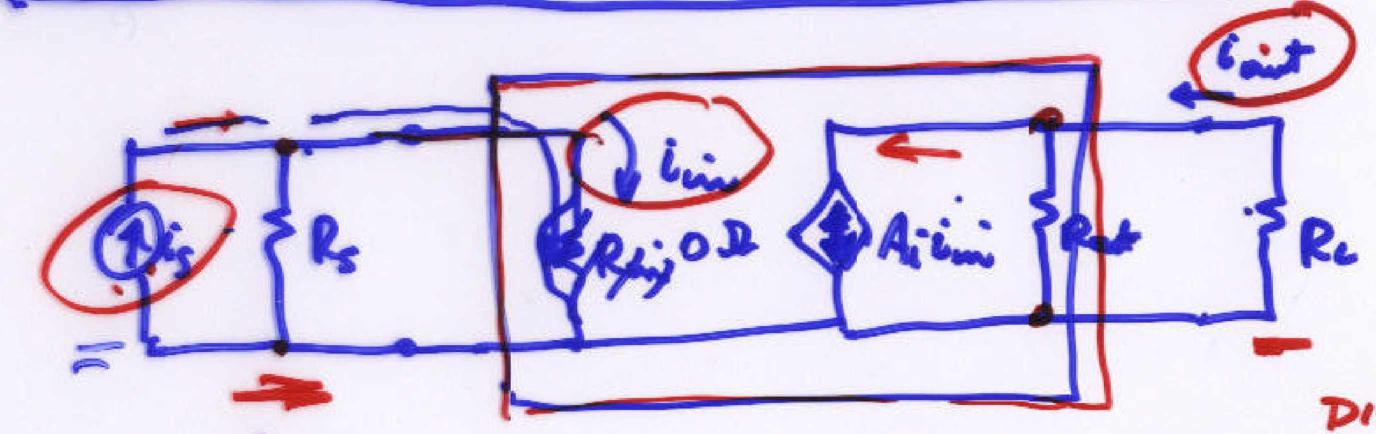
Lecture 25

- Last time: CHAPTER 8 (LEC. 22, 23 ...)
  LEC. 24 ... CHAP. 8
  - Two-port small-signal models of amplifiers

SMALL-SIGNAL ○ ← TWO-PORT S.S MODELS

- Today :
  - START? Finish methods for finding two-port model parameters
  - Start common-source amplifier

WHAT'S MAKES A GOOD CURRENT AMP?



$$\frac{i_{out}}{i_{in}} =$$

DIVIDER

$$\frac{i_{in}}{i_s} = \frac{R_s}{R_{in}+R_s}.$$

$$\frac{i_{out}}{(A_i i_{in})} = \frac{R_{out}}{R_L+R_{out}}$$

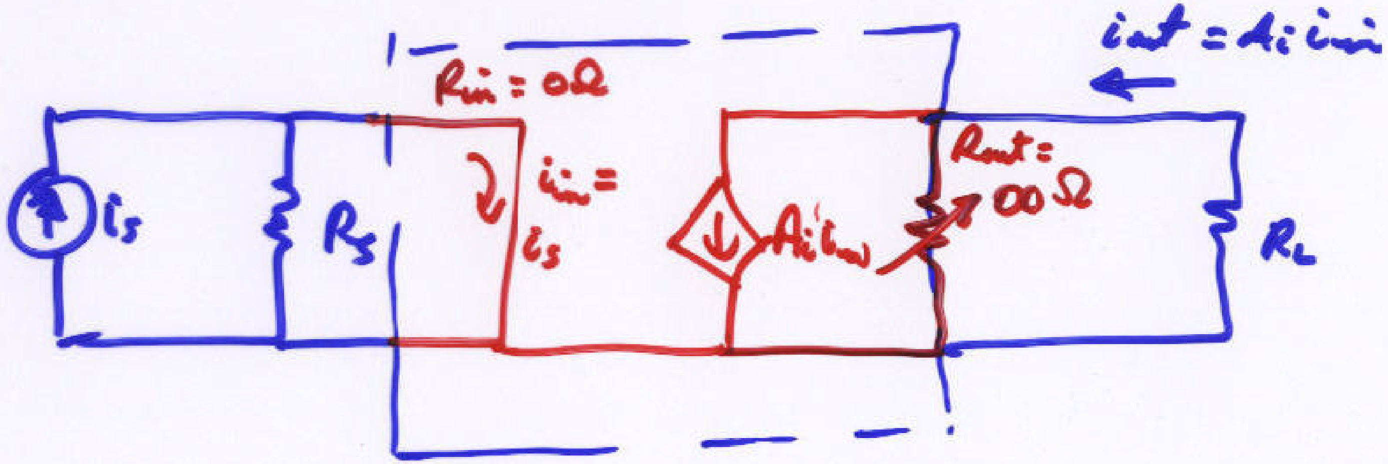
LARGE. 10,000!

$$\frac{i_{out}}{i_s} = \left(\frac{\text{"}\underline{\text{OVERALL}}\text{ I-GAIN"}}{\text{"}\underline{\text{LOADED}}\text{ I-GAIN"}}\right) = \boxed{\frac{R_s}{R_{in}+R_s}} A_i \boxed{\frac{R_{out}}{R_L+R_{out}}} \to A_i$$

= BIG (WE HOPE!)

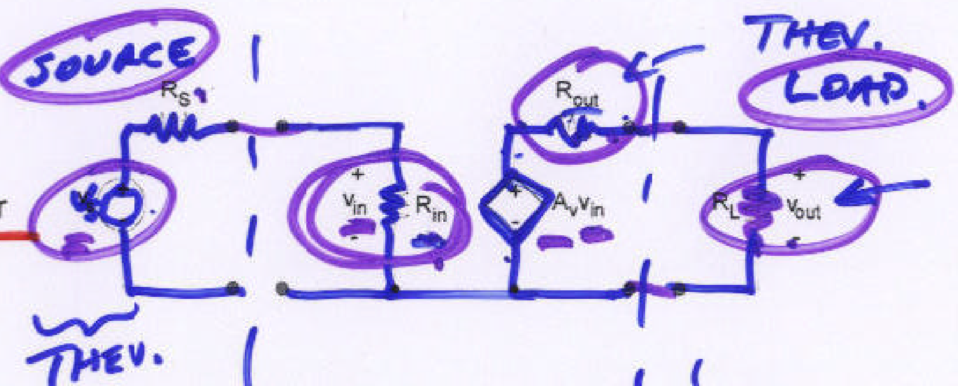
$\underline{\text{DIVIDERS}}$ ... MAX = 1. ⇒ $R_{in} = 0\Omega$; $R_{out} = \infty\Omega$.

IDEAL CURRENT AMP:

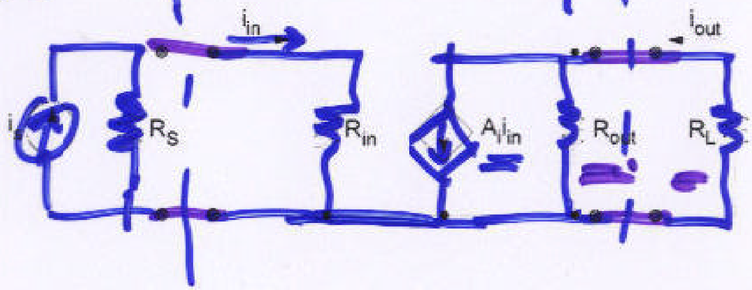


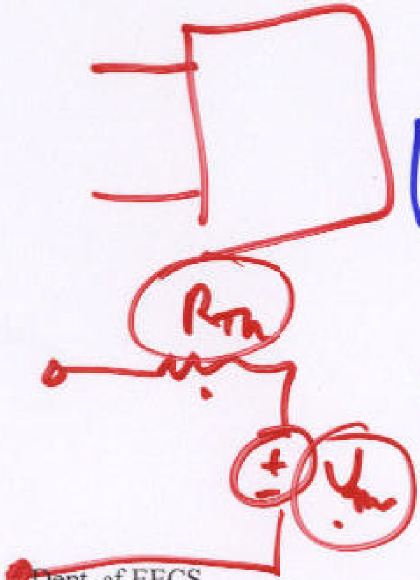
Two-Port Small-Signal Amplifiers

Voltage Amplifier

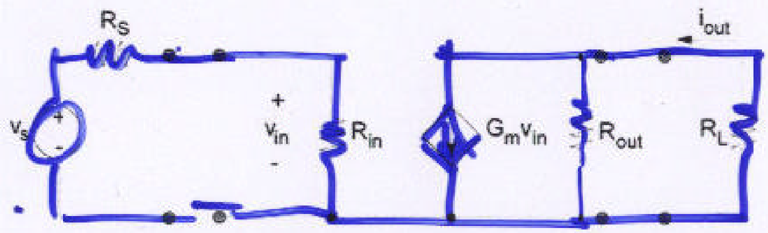


Current Amplifier

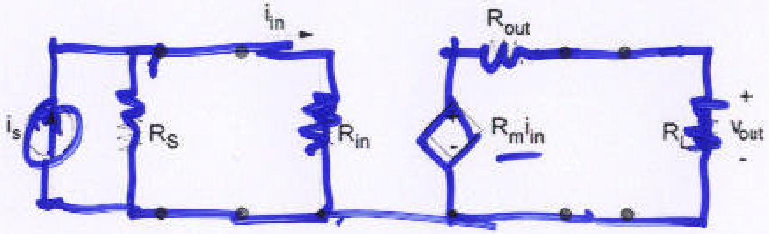




Transconductance Amplifier



Transresistance Amplifier



"EXPERIMENT"

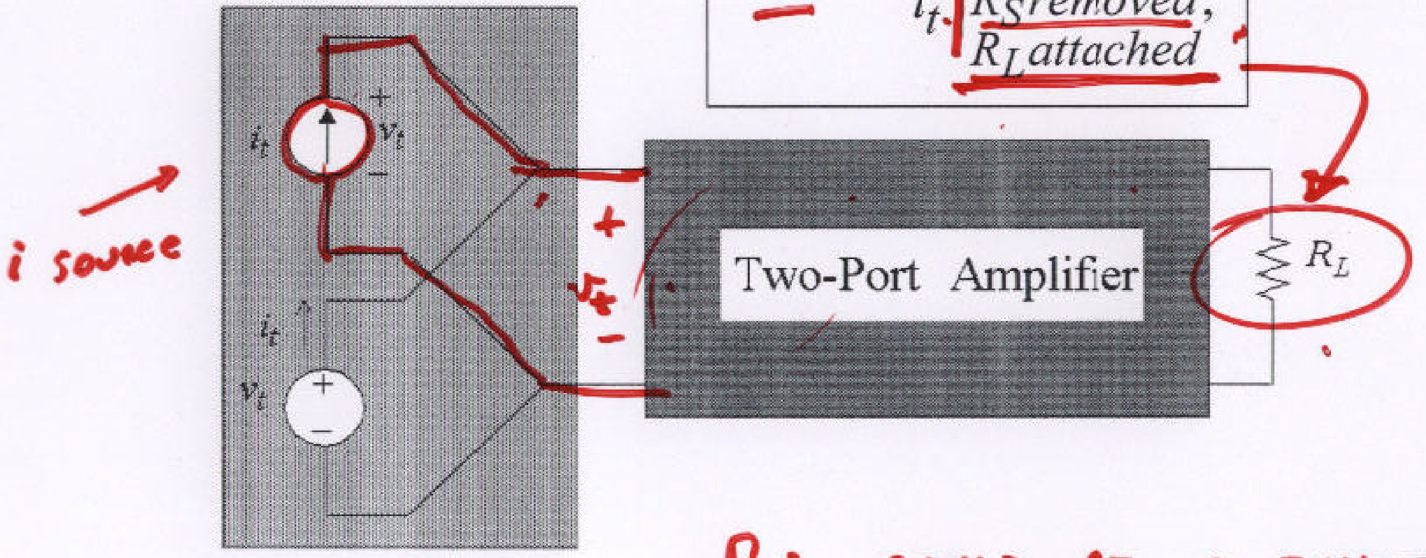
DEFINITION.

Input Resistance R_{in}

Looks like a Thevenin resistance measurement, but note that the output port has the load resistance attached

$$R_{in} = \frac{v_t}{i_t}\Big|_{R_S \text{ removed},\ R_L \text{ attached}}$$

SHORTED



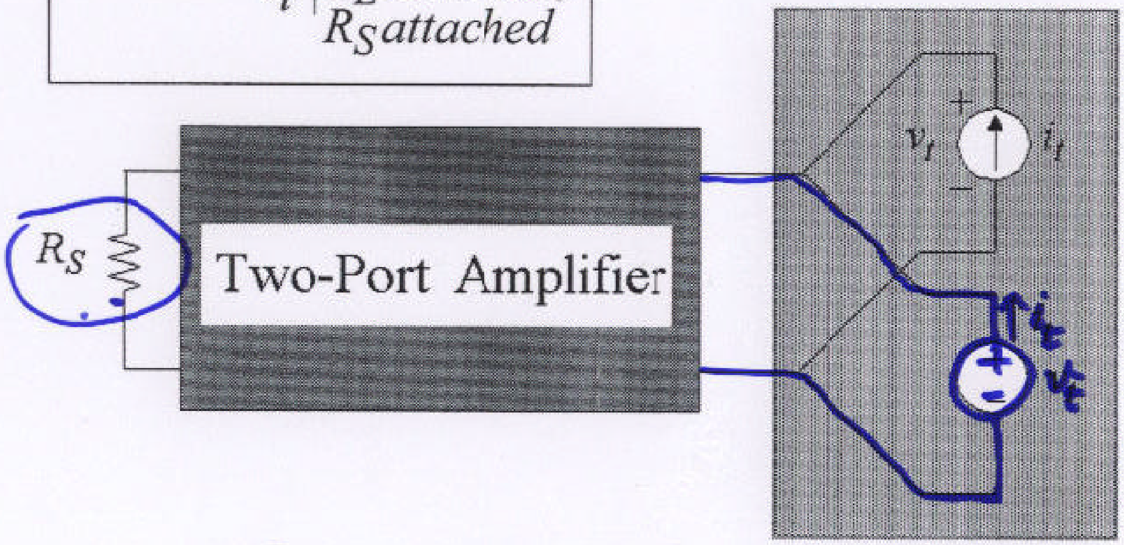
R_{in} COULD BE A FUNCTION OF R_L

Output Resistance R_{out}

Looks like a Thevenin resistance measurement, but note that the *input* port has the *source* resistance attached

$$R_{out} = \frac{v_t}{i_t}\bigg|_{R_L\,removed,\ R_S\,attached}$$

→ OPENED



R_{out} COULD BE A FUNCTION OF R_S

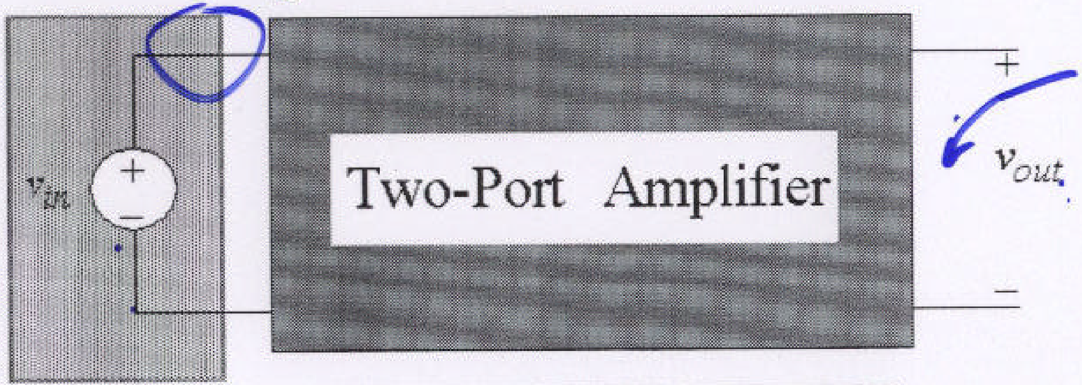
NEVER R_L

RULE / PROCEDURE / EXP. / METHOD.

Finding the Voltage Gain A_v

Key idea: the output port is open-circuited and the source resistance is shorted

$R_S \to 0$



$R_L \to \infty$.

$$A_v = \left.\frac{v_{out}}{v_{in}}\right|_{R_S = 0,\, R_L \to \infty}$$

PURE / IDEAL ($R_S \to 0\Omega$) V-SOURCE

- BOTH DIVIDERS ARE = 1.0.

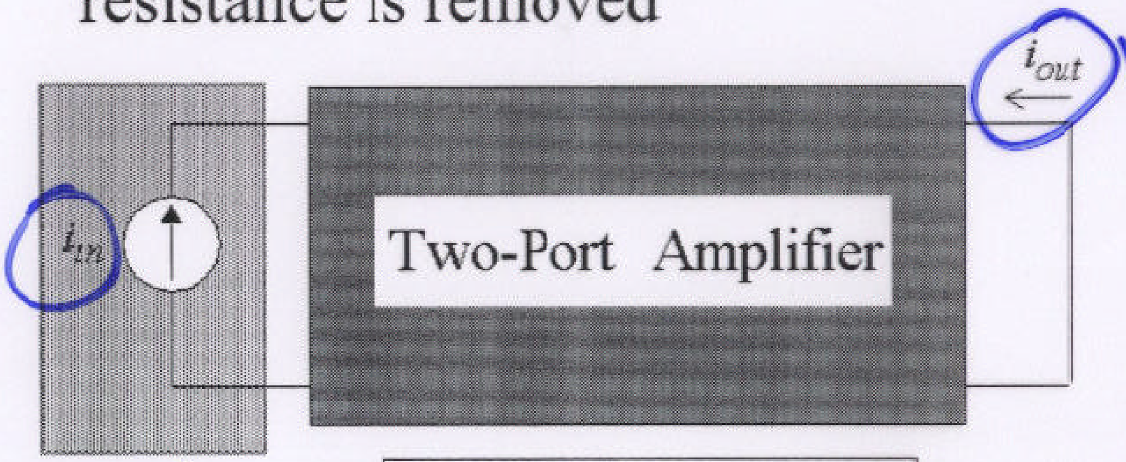
Finding the Current Gain A_i

SMALL-SIGNAL.

Key idea: the output port is shorted and the source resistance is removed

D.C. VOLTAGE ...

SMALL-SIGNAL SHORT.

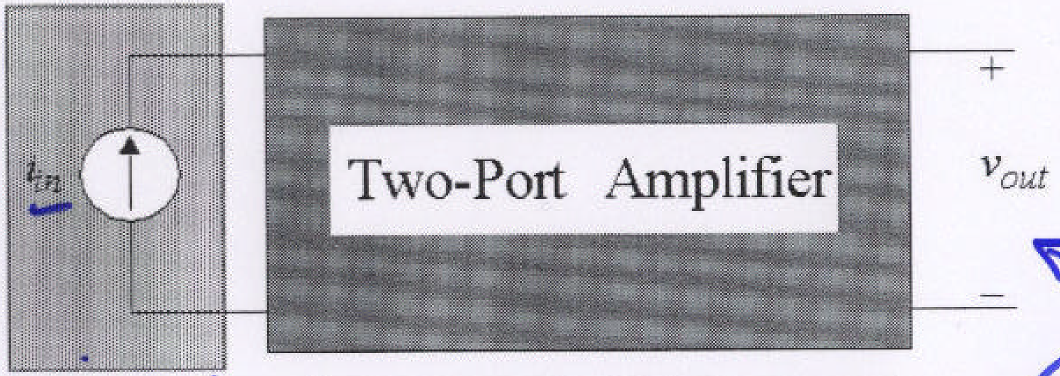


IDEAL ...

$R_S \to \infty$

$$\boxed{A_i = \left.\frac{i_{out}}{i_{in}}\right|_{\underbrace{R_S \to \infty}, \underbrace{R_L = 0}}}$$

Finding the Transresistance R_m



PURE CURRENT

$R_S \to \infty$

$$R_m = \frac{v_{out}}{i_{in}}\Big|_{R_S \to \infty,\, R_L \to \infty} \quad \Omega$$

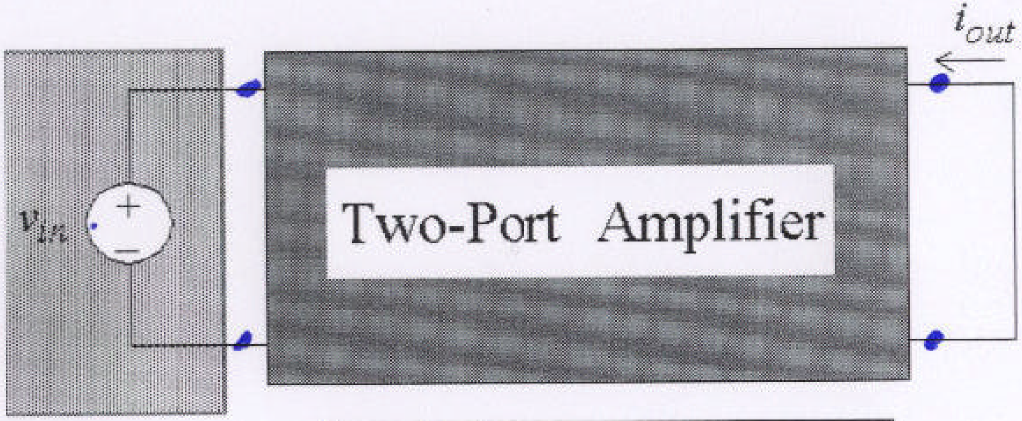
OPEN ...
$R_L \to \infty$.

NO "LOADING" ...

OUTPUT VOLTAGE DIVIDER

$$\left(\frac{R_L}{R_{out} + R_L}\right) \to 1.$$

Finding the Transconductance G_m

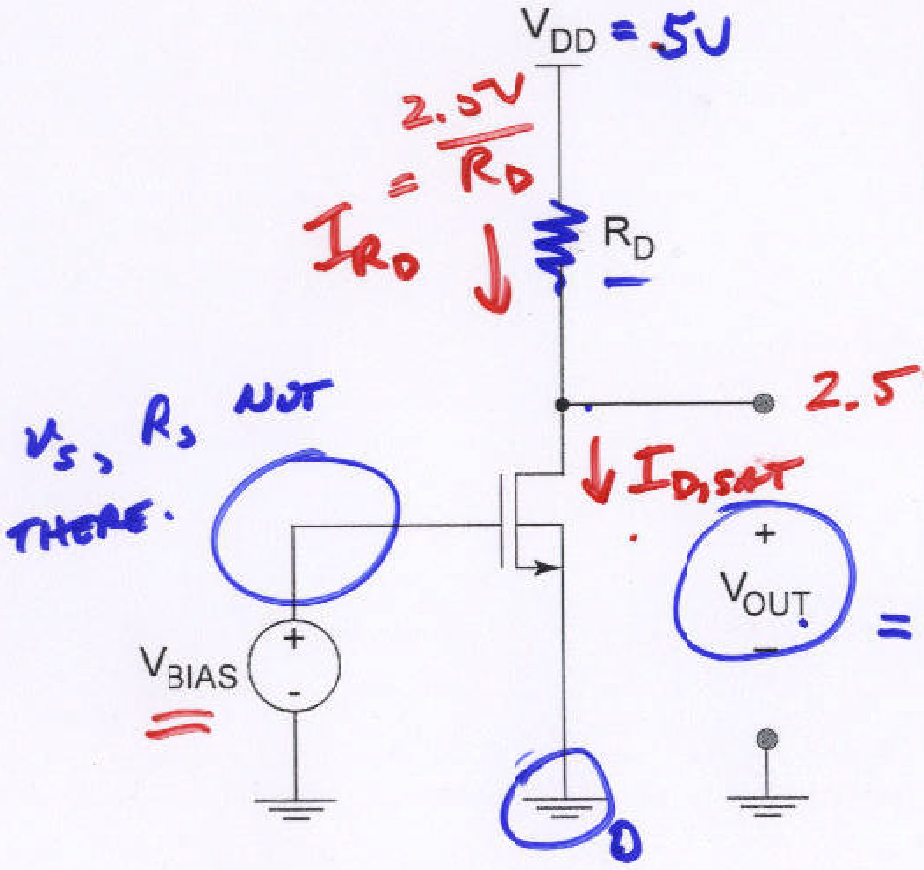


SHORT-CKT.
OUTPUT.
$R_L \Rightarrow 0\Omega$.

$$G_m = \left.\frac{i_{out}}{v_{in}}\right|_{R_S = 0,\, R_L = 0}$$

"PURE"
VOLTAGE
IN
$R_S \rightarrow 0\Omega$

DC Bias



Load line analysis:

← NO LOAD RESISTOR.

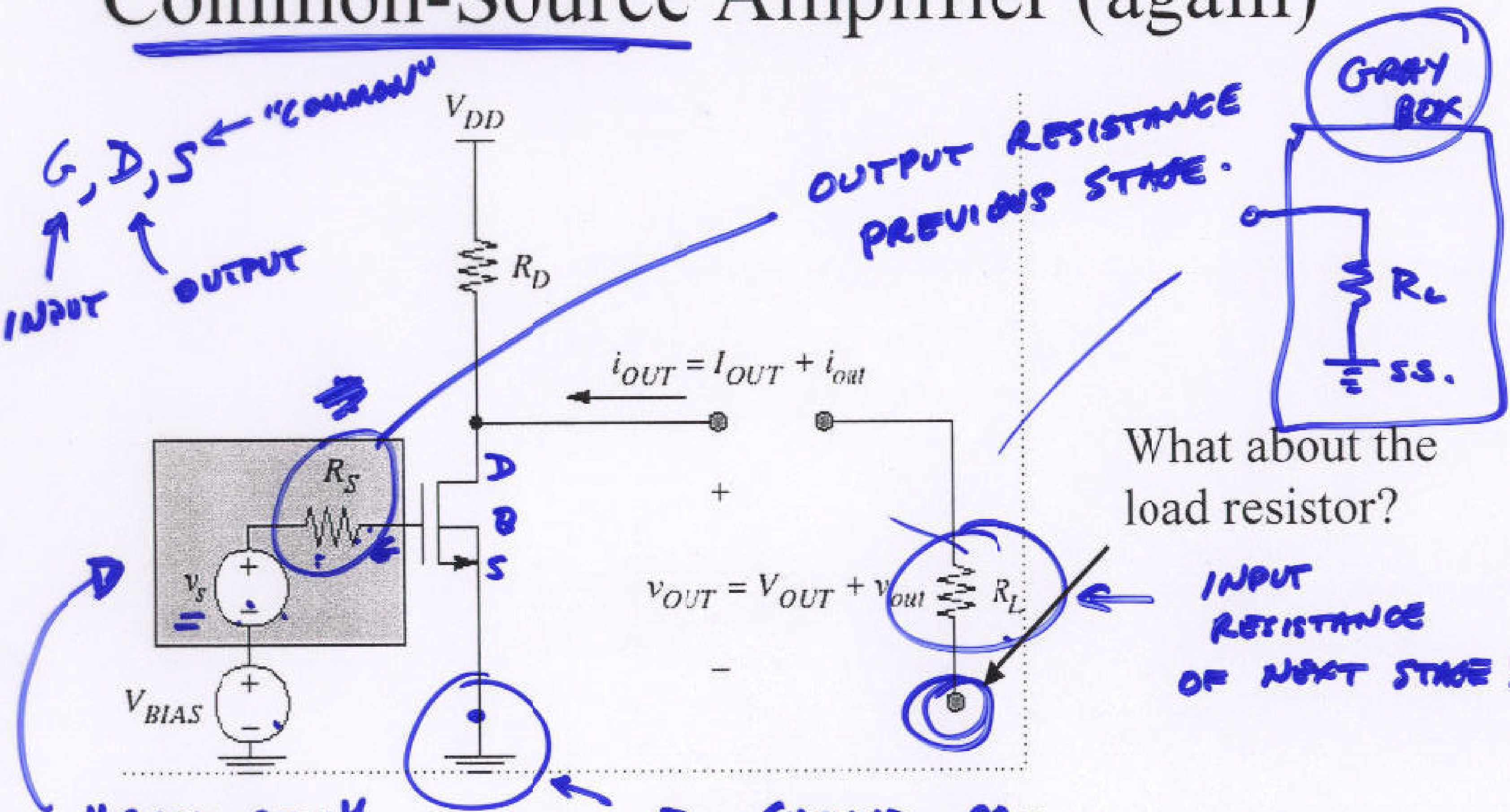
$$= \frac{V_{DD} - 0}{2} = \frac{5V}{2}$$

$$= 2.5 V.$$

(W/L), $\mu_n C_{ox}$, V_{Tn}, ~~X~~

[TOO TRIVIAL
TOO FAMILIAR]

First Example: the Common-Source Amplifier (again)



G, D, S ← "COMMON"
INPUT
OUTPUT

OUTPUT RESISTANCE PREVIOUS STAGE.

GRAY BOX

What about the load resistor?

INPUT RESISTANCE OF NEXT STAGE !!

"GRAY BOX"
SMALL-SIGNAL ELEMENTS

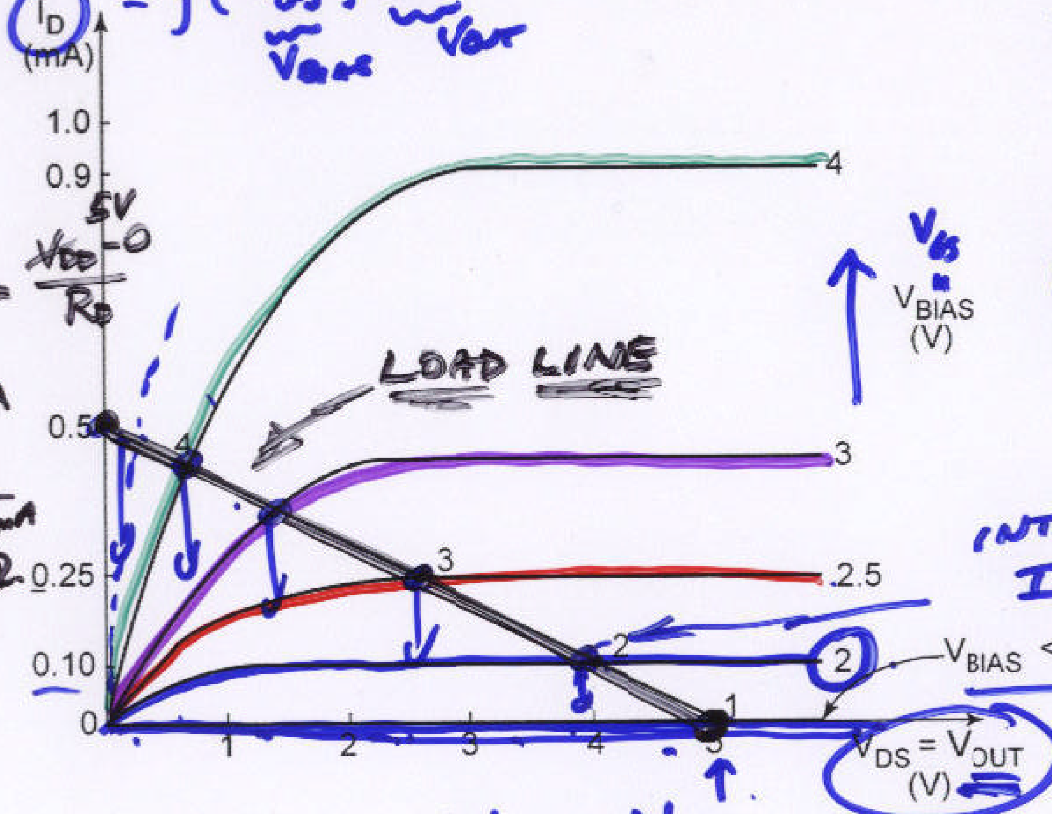
DC GROUND -OR- BATTERY

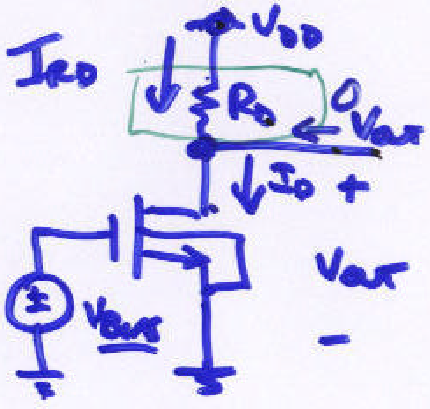
Load-Line Analysis to find *Q*

$I_D = f(\underset{V_{BIAS}}{V_{GS}}, \underset{V_{OUT}}{V_{DS}})$

$500\mu A = \frac{V_{DD} - 0}{R_D}$ (5V)

$R_D = \frac{5V}{0.5mA} = 10k\Omega$





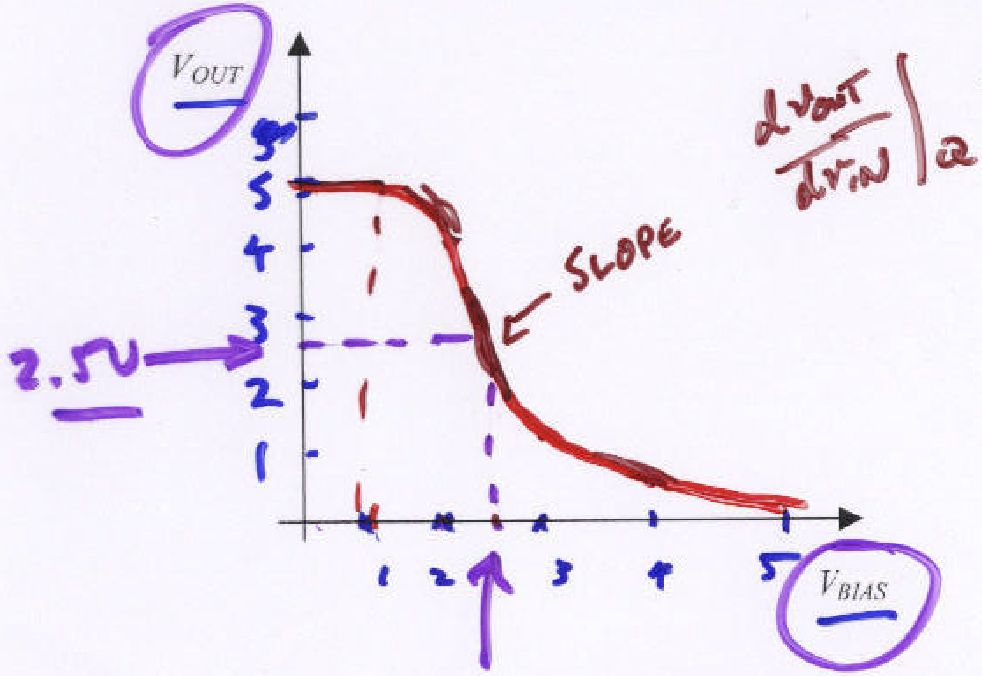
INTERSECTION

$I_{RD} = I_D$.

$I_{RD} = \frac{V_{DD} - V_{OUT}}{R_D}$ ... PLOT IT!

EE 40

DC Transfer Function



$\frac{dv_{OUT}}{dv_{IN}}\Big|_Q = A_v.$

V_{BIAS}	V_{OUT}
0	5V
1	5V
2	4
2.5	2.5
3	1.25
4	0.5
5	≈ 0.25

V_{BIAS} = 2.5V ... HIGHER THAN NORMAL