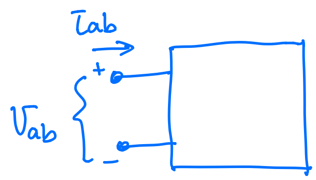
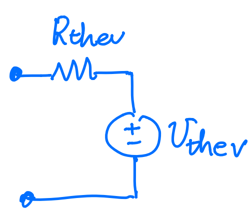
EE105 Midterm-2 : 4/9 (Next Tuesday) In class
same format as Midterm-1
Sample midterms posted
Practice. Solution posted Wed.
4/4 class . Q&A
Topics in midterm, up to today's lectures
Emphasis on materials after Midterm 1

Single Stage Amplifier
↓ Transistor

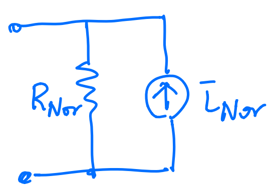
From 16A/B: Circuit model of "one port" circuit



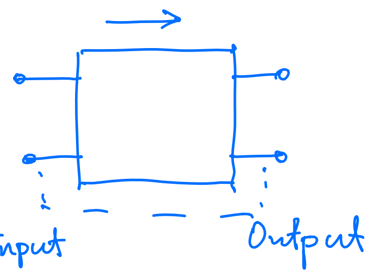
Thevenin Equivalent circuit (small signal)



Norton Equivalent circuit



Two-Port Equivalent Circuit (small signal)



For amplifiers:

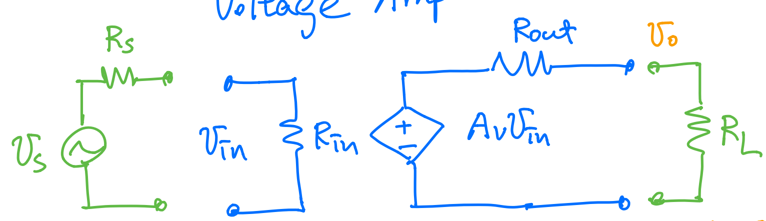
- Linear
- Unilateral: output dep. on input. but input is not affect by output.

General true.

Input	Type	Output	Transfer fx
Voltage	Voltage Amp	Voltage	v_o/v_i
Current	Current Amp	current	i_o/i_i
Voltage	Transconductance Amp.	Current	i_o/v_i [S]
Current	Transresistance Amp (Transimpedence Amp)	Voltage	v_o/i_i [Ω]

Voltage Amp

Ideal Values

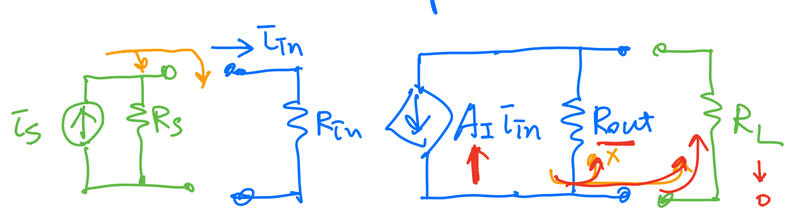


$R_{in} = \infty$ $R_{out} = 0$

$v_{in} = v_s \cdot \frac{R_{in}}{R_s + R_{in}}$

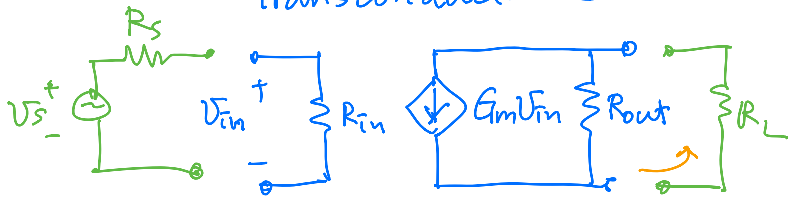
$v_o = A_v v_{in} \frac{R_L}{R_{out} + R_L}$

Current Amp



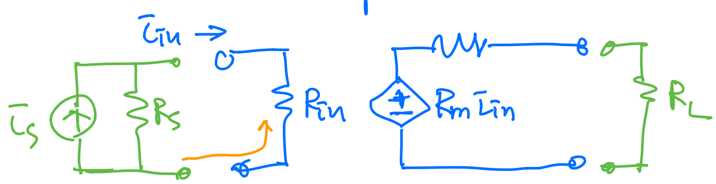
$R_{in} = 0$ $R_{out} = \infty$

Transconductance



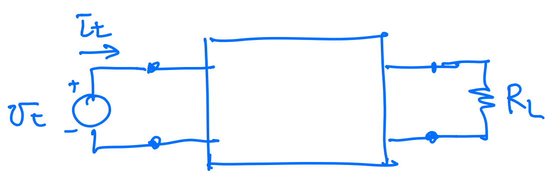
$R_{in} = \infty$ $R_{out} = \infty$

Transimpedence



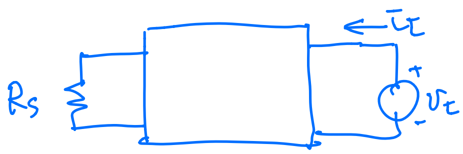
$R_{in} = 0$ $R_{out} = 0$

How do we calculate R_{in} ?



$R_{in} = \frac{V_t}{I_t}\Big|$ No R_s, Include R_L

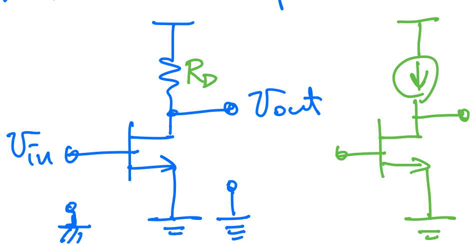
R_{out} ?



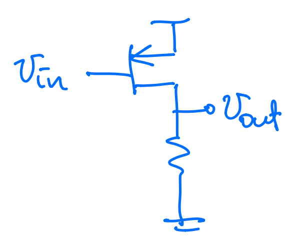
$R_{out} = \frac{V_t}{I_t}\Big|$ No R_L, Include R_s

Single Transistor Circuit. 3 terminals (S, D, G)
2-port circuit 4 ''
↳ One terminal is used in both input and output
← common

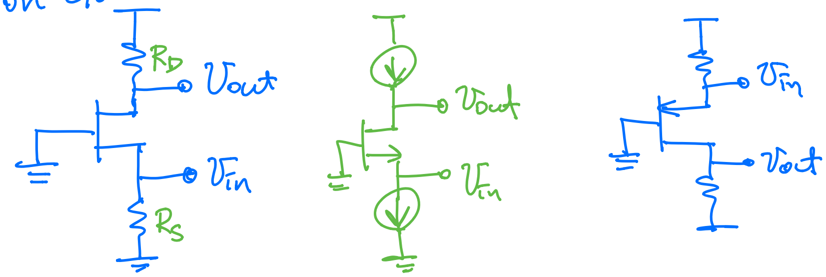
Common Source Amp



PMOS

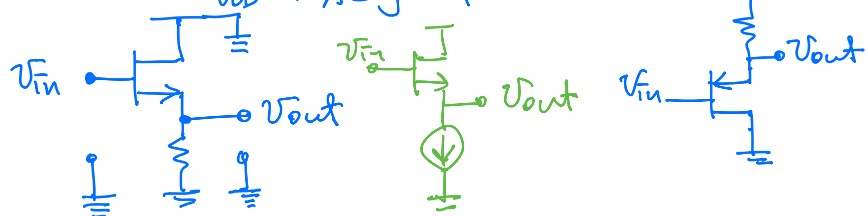


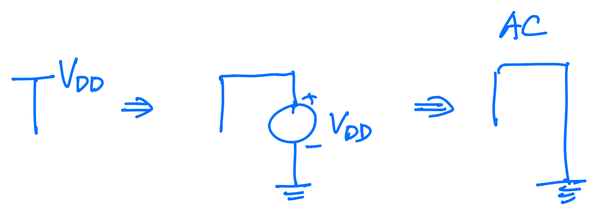
Common Gate



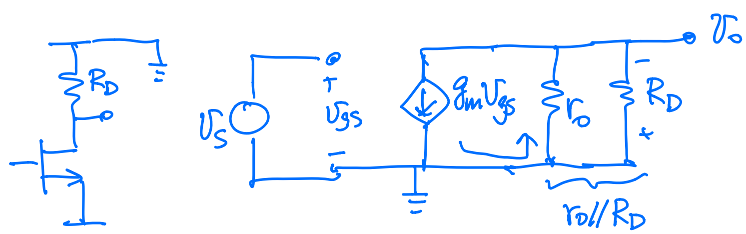
Common Drain

$V_{DD} \rightarrow$ AC ground





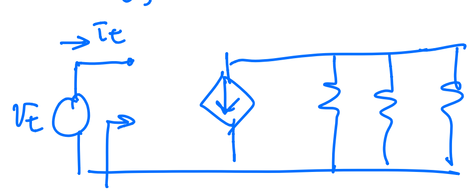
Common Source



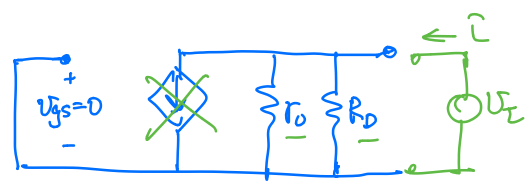
$$v_o = -g_m v_{gs} (r_o // R_D) = -g_m v_s (r_o // R_D)$$

$$A_V = \frac{v_o}{v_s} = -g_m (r_o // R_D)$$

$R_{in} = \infty$



$R_{out} = r_o // R_D$



Typical values.

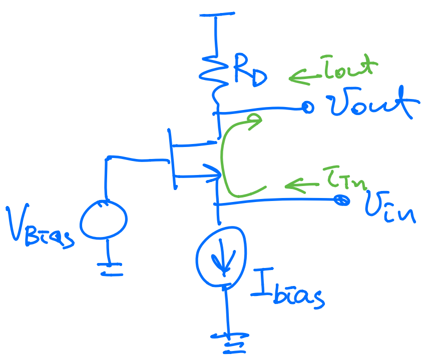
$r_o \sim 200k\Omega$. R_D = a few $k\Omega$

$\Rightarrow r_o // R_D \approx R_D$

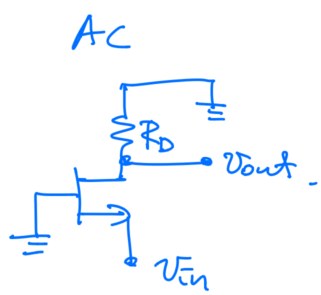
Replace R_D by (↓) $R_D \to \infty$

$R_{out} = r_o // \infty = r_o$

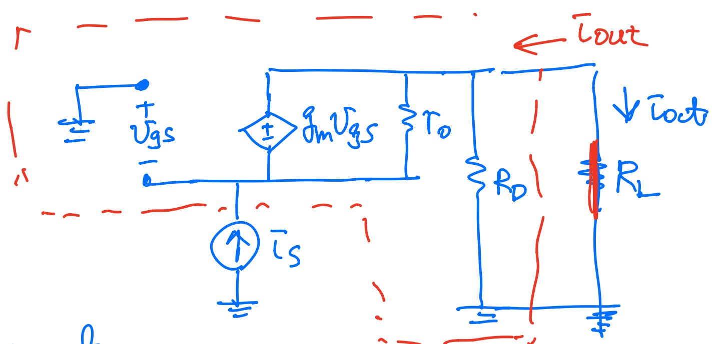
Common Gate



⇒



⇓

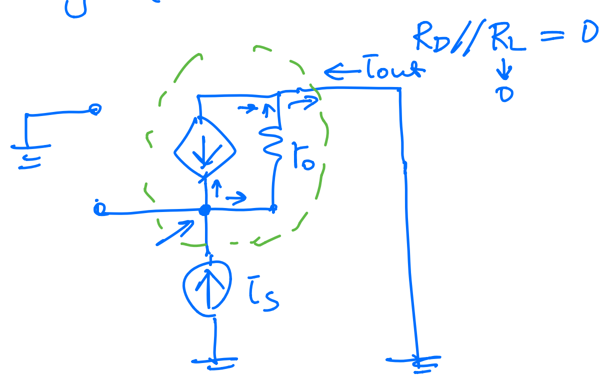


To evaluate A_I = current gain

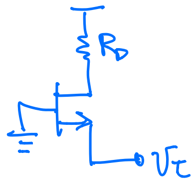
Make $R_L = 0$

$i_{out} = -i_s$

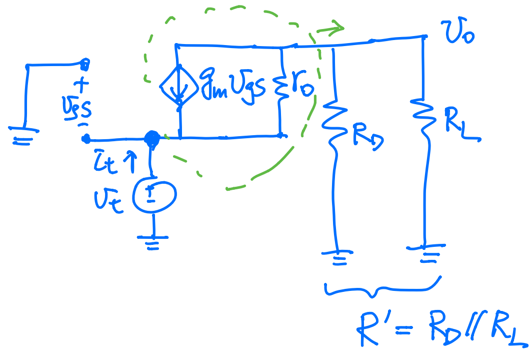
$A_I = \frac{i_{out}}{i_s} = -1$



R_{in}:



$\Rightarrow$



KCL at Source

$$i_t + g_m v_{gs} = \frac{v_t - v_o}{r_o}$$

$$\begin{cases} v_{gs} = 0 - v_t = -v_t \\ v_o = i_t \cdot R' \end{cases}$$

$$i_t - g_m v_t = \frac{v_t}{r_o} - i_t R' \frac{1}{r_o}$$

$$i_t \left(1 + \frac{R'}{r_o}\right) = \left(g_m + \frac{1}{r_o}\right) v_t$$

$$R_{in} = \frac{v_t}{i_t} = \frac{1 + \frac{R'}{r_o}}{g_m + \frac{1}{r_o}} \approx \frac{1}{g_m}$$

↑ small input resistance

Typical values

$g_m \sim 0.5\, mS$

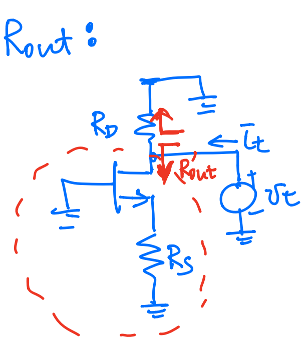
$r_o \sim 200\, k\Omega$ $\quad \frac{1}{r_o} = \frac{1}{2 \times 10^5} = 5\, \mu S$

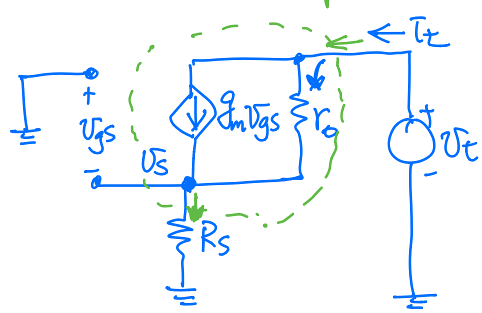
$R' = R_D // R_L$

$\hookrightarrow \sim k\Omega$

$R' \ll r_o$

R_{out}:





KCL at Drain

$$i_t = g_m v_{gs} + \frac{v_t - v_S}{r_o}$$

$$\begin{cases} v_{gs} = 0 - v_S = -v_S \\ v_S = i_t \cdot R_S \end{cases}$$

$$i_t = -g_m i_t \cdot R_S + \frac{v_t - i_t R_S}{r_o}$$

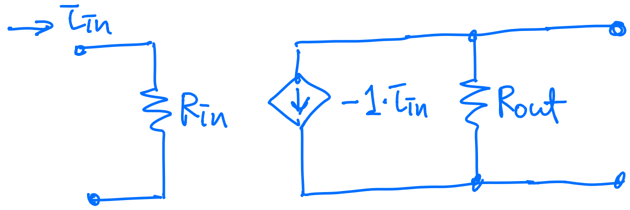
$$i_t \left(1 + g_m R_S + \frac{R_S}{r_o}\right) = \frac{v_t}{r_o} \Rightarrow R_{out} = \frac{v_t}{i_t} = r_o + g_m R_S r_o + R_S$$

$r_o \sim 200k\Omega$
$g_m \sim 0.5\,mS$ } $g_m r_o \sim 100 \gg 1$

$R_S \sim k\Omega$ (?)

$R'_{out} = r_o + g_m r_o \cdot R_S \Rightarrow$ Very large out resistance

2-Port for CG:



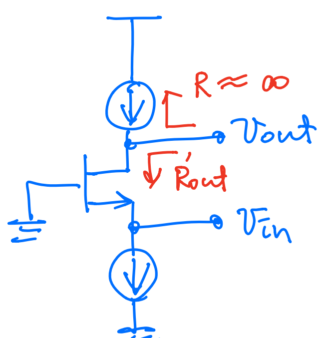
$R_{in} = \frac{1}{g_m}$ small

$R'_{out} = r_o + g_m r_o \cdot R_S$ large

$R_{out} = R'_{out} \,//\, R_D = R_D \,//\, (r_o + g_m r_o R_S)$

$R_D \sim k\Omega \ll r_o$

$R_{out} \approx R_D$

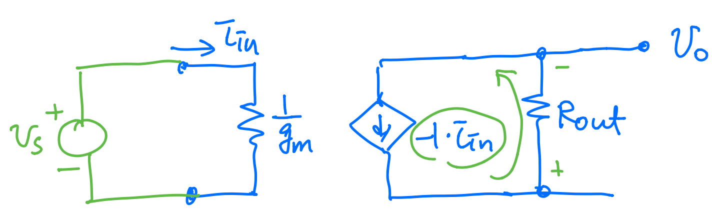


$R_{out} = R'_{out} \,//\, \infty = R'_{out}$

$= r_o + g_m r_o \cdot R_S$

Preserve large output resistance.

CG as a voltage amplifier



$v_o = -(-1 \cdot i_{in}) \cdot R_{out} \Rightarrow v_o = i_{in} \cdot R_{out} = g_m v_s \cdot R_{out}$

$i_{in} = \dfrac{v_s}{\left(\frac{1}{g_m}\right)} = g_m v_s$

$R_{out} = r_o + g_m r_o \cdot R_s \gg r_o$

$\Rightarrow$ higher gain in CG

$A_v = \dfrac{v_o}{v_s} = g_m R_{out}$

Recall for CS amplifier: $A_v = -g_m (r_o // R_D)$

$R_D \rightarrow \infty$ for 

$= -g_m r_o$