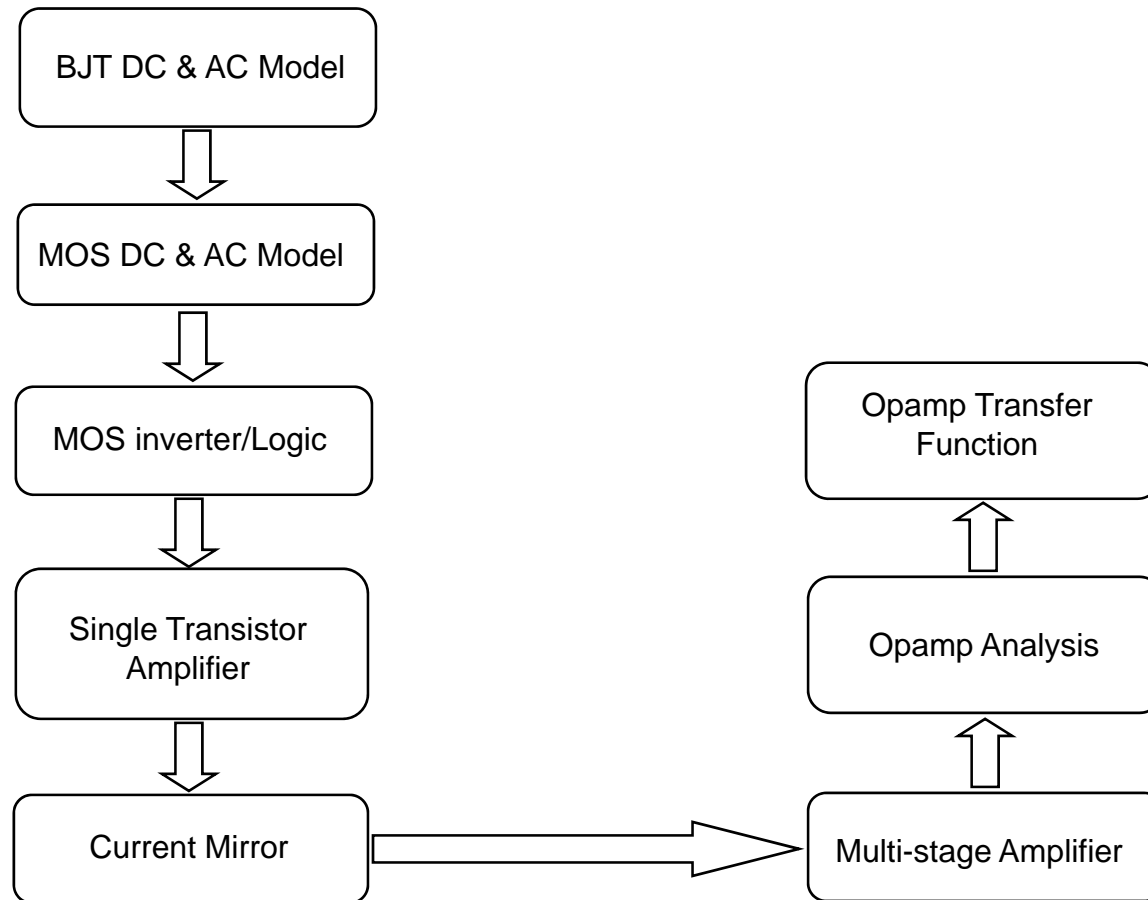


EE2021

Devices and Circuits

Revision

Summary on Materials Covered



Logic Synthesis

$$Y = \overline{(A+B+C) \cdot (D+E) \cdot (F+G)}$$

=

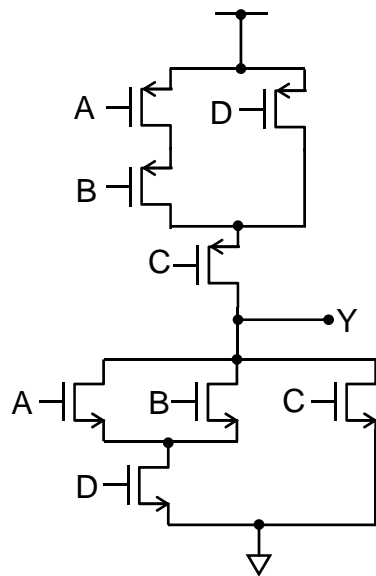
Hint: Demorgan Theorem

=

Pull Down Network

Pull Up Network (Duality)

Logic Function



$Y =$

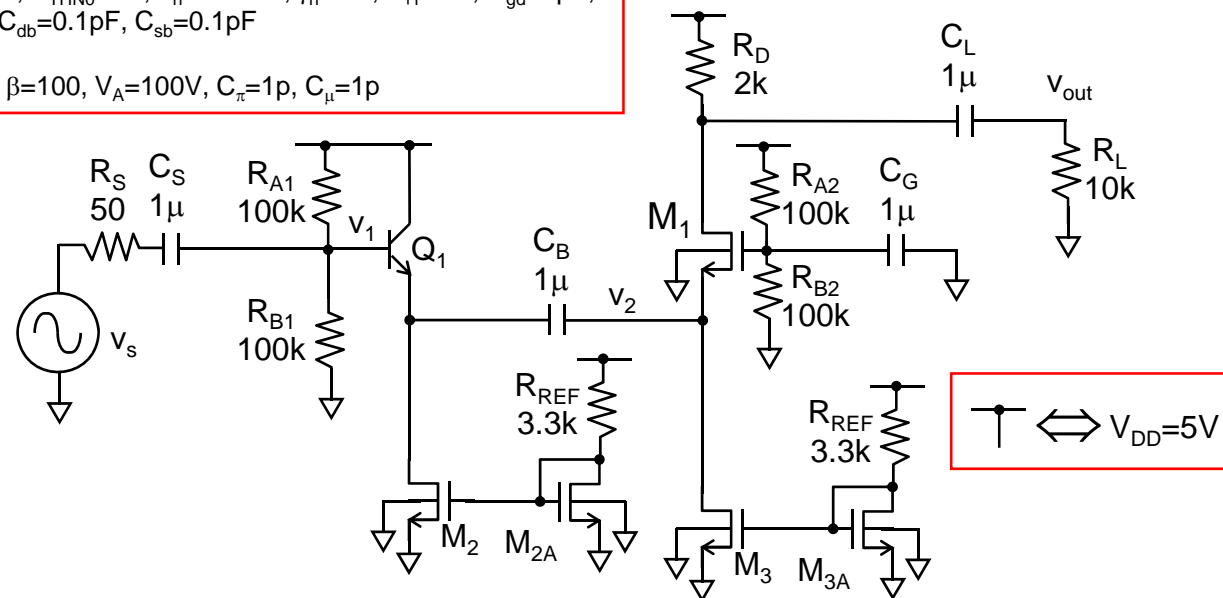
DC Analysis : Identifying

NMOS :

$K_n=2\text{mA/V}^2$, $V_{THN0}=1\text{V}$, $\lambda_n=0.01\text{V}^{-1}$, $\gamma_n=0.5$, $2\phi_f=0.6$, $C_{gd}=1\text{pF}$,
 $C_{gs}=1\text{pF}$, $C_{db}=0.1\text{pF}$, $C_{sb}=0.1\text{pF}$

BJT :

$I_S=10^{-15}\text{A}$, $\beta=100$, $V_A=100\text{V}$, $C_\pi=1\text{p}$, $C_\mu=1\text{p}$



- Identify AC source, load and non-ideal current source

DC Analysis : DC Biasing

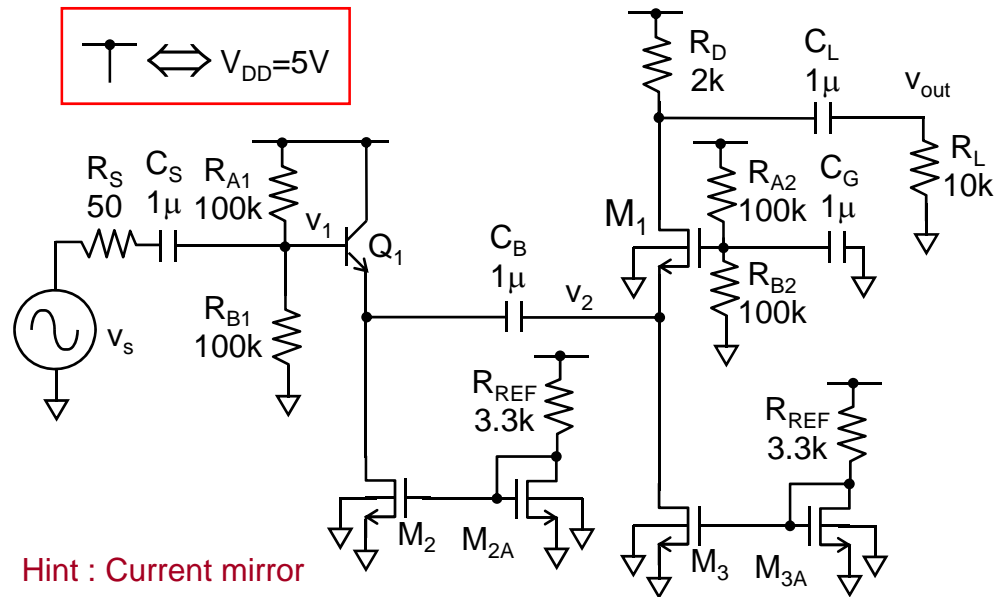
NMOS :

$K_n=2\text{mA/V}^2$, $V_{THN0}=1\text{V}$, $\lambda_n=0.01\text{V}^{-1}$, $\gamma_n=0.5$, $2\phi_f=0.6$, $C_{gd}=1\text{pF}$,
 $C_{gs}=1\text{pF}$, $C_{db}=0.1\text{pF}$, $C_{sb}=0.1\text{pF}$

BJT :

$I_S=10^{-15}\text{A}$, $\beta=100$, $V_A=100\text{V}$, $C_\pi=1\text{p}$, $C_\mu=1\text{p}$

$\text{---} \rightleftharpoons V_{DD}=5\text{V}$



Hint : Current mirror

- Find the DC biasing current for Q_1 and M_1

Determine DC Biasing

$$I_{D,M2A} =$$

$$I_{D,M1} =$$

$$\Rightarrow I_{C,Q1} \approx$$

$$\Rightarrow I_{D,M1} =$$

AC Analysis : Simplify the Circuit and Find Out AC Small Signal Parameter

Replace current mirror with non-ideal current source

Simplify the circuit for AC analysis

Determine AC small signal parameter

$$g_{m,M1} =$$

$$g_{mb,M1} =$$

$$r_{o,M1} = r_{o,M3} = r_{o,M2} =$$

$$g_{m,Q1} =$$

$$r_{\pi,Q1} =$$

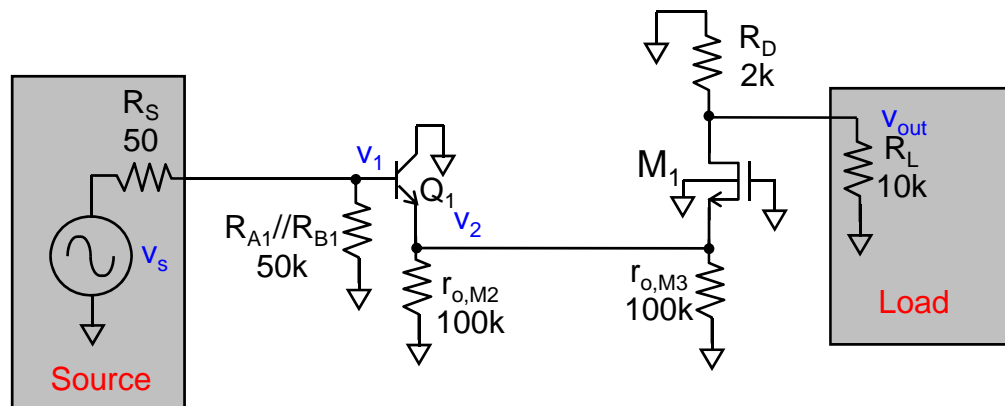
$$r_{o,Q1} =$$

Hint :

- 1) DC voltage source → AC ground
- 2) DC current source → Open circuit
- 3) DC block/bypass capacitor → AC short circuit

- Simplify the circuit for AC analysis by replacing current mirror with non-ideal current source
- Find out the AC small signal parameters (g_m , r_{π} , r_o) for transistors Q_1 , M_1 , M_2 , M_3

AC Analysis : Identify Amplifier



1st stage amplifier configuration :

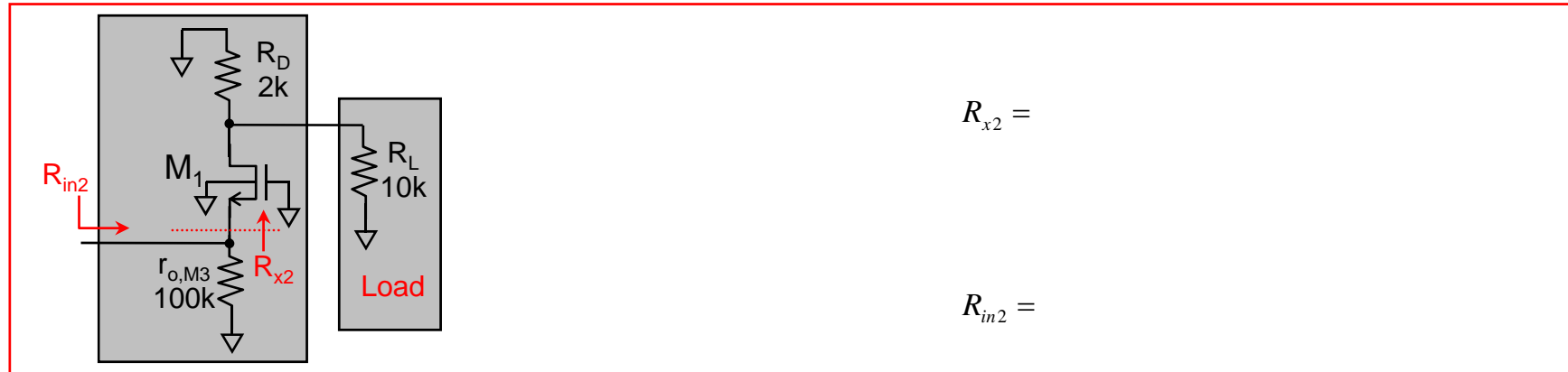
2nd stage amplifier configuration :

1st stage amplifier G_{m1} :

2nd stage amplifier G_{m2} :

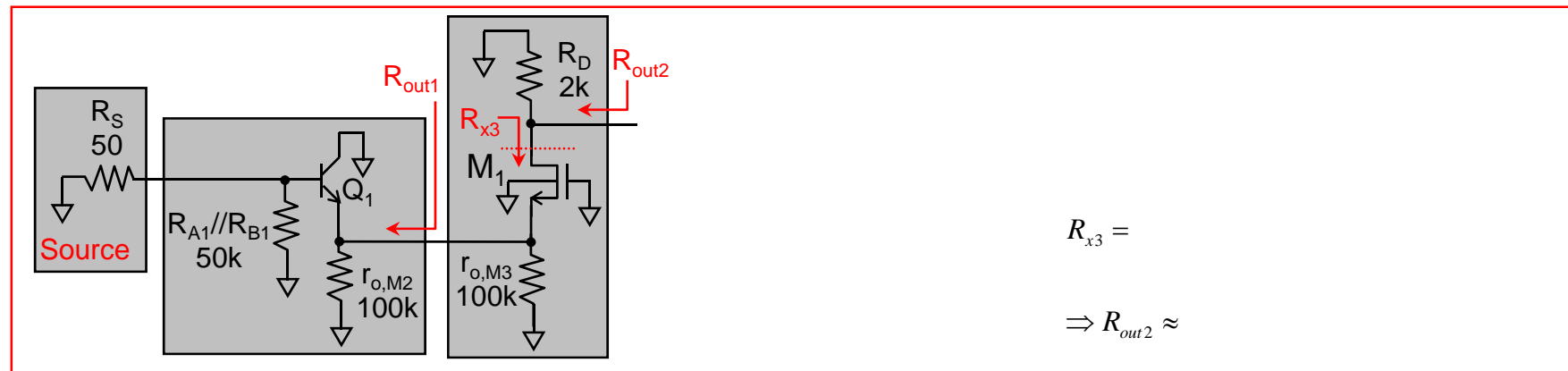
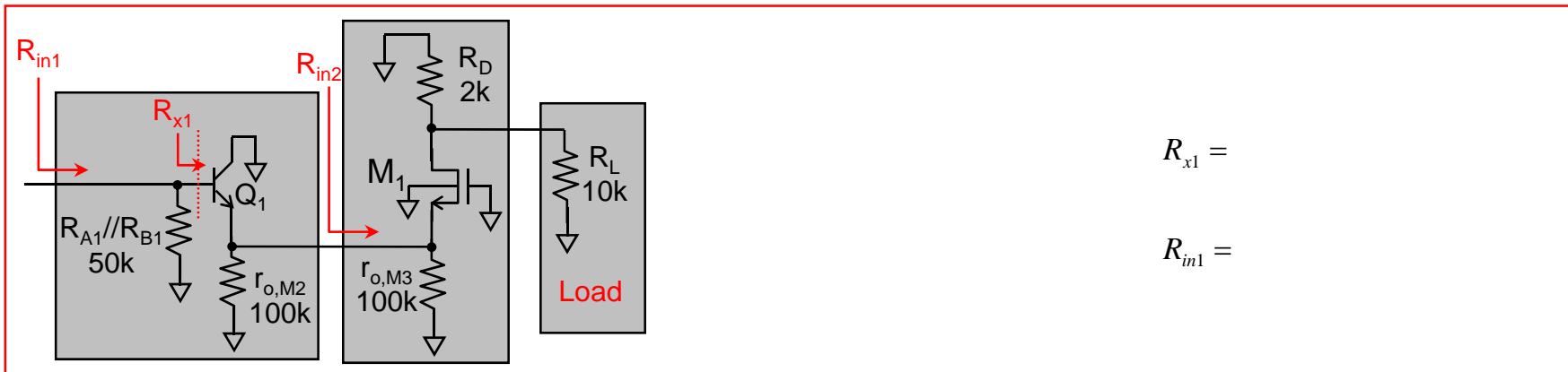
- Identify the 1st and 2nd stage amplifiers by drawing rectangular box surrounding them
- Write down the corresponding two ports-network parameters

AC Analysis : Identify Two-ports Network Parameters (R_{in2} , R_{out1})



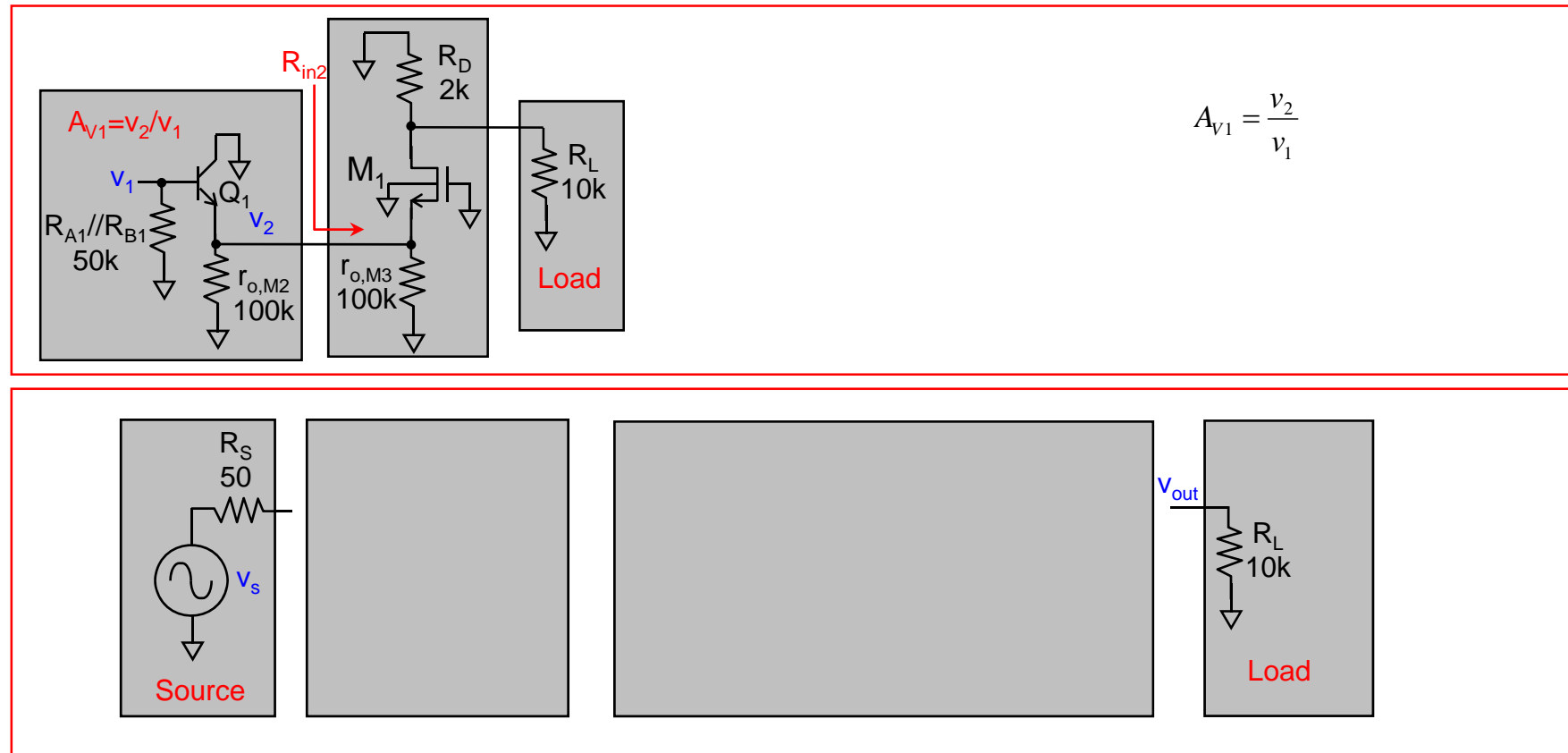
- Estimate R_{in2} and R_{out1} (Throw away half the circuit)

AC Analysis : Identify Two-ports Network Parameters (R_{in1} , R_{out2})



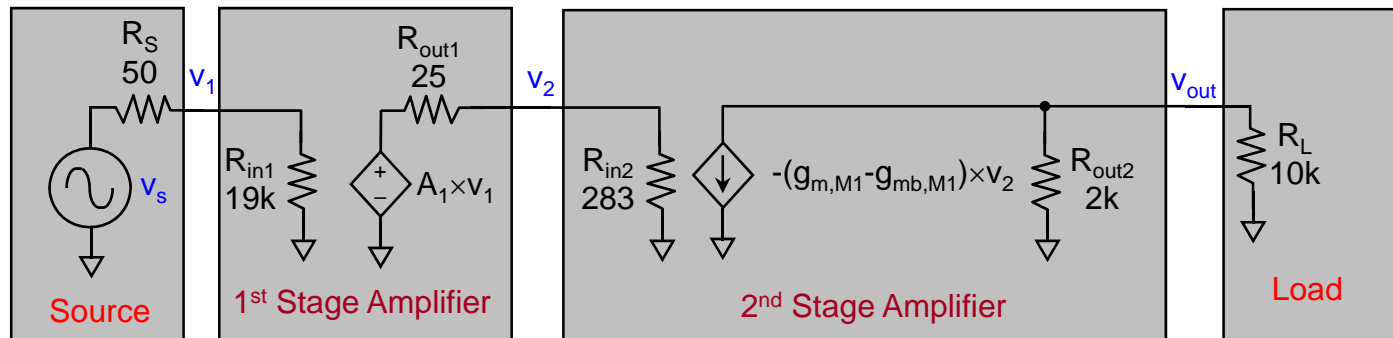
- Estimate R_{in1} and R_{out2}

AC Analysis : Identify $A_{v1} = v_2/v_1$



- Estimate $A_{v1} = v_2/v_1$
- Draw out two-ports network equivalent

AC Analysis : Overall Gain $A_V = v_{out}/v_s$



$$V_1 =$$

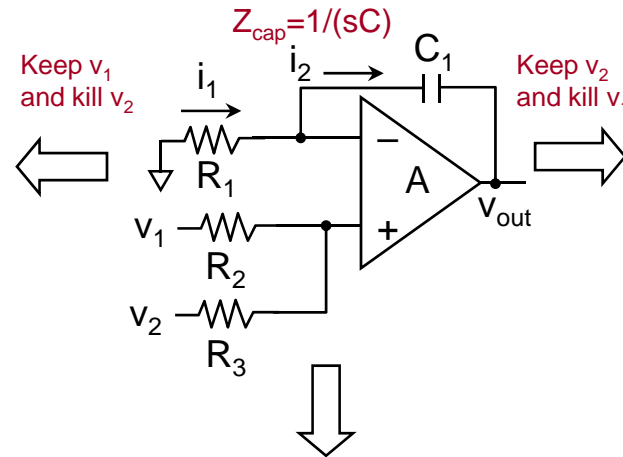
$$V_2 =$$

$$V_{out} =$$

$$A_V = \frac{V_{out}}{V_s} =$$

- Estimate overall gain $A_V = v_{out}/v_s$

Opamp Circuit Analysis



Superposition :

$$v_{out} =$$

$$v_+ =$$

$$\Rightarrow v_{out} =$$

$$= v_1 \times$$

$$v_+ =$$

$$\Rightarrow v_{out} =$$

$$= v_2 \times$$

- Virtual short ($v_+ \approx v_-$)
- Infinite input resistance ($i_+ = i_- = 0$)
- Superposition

BJT Equivalent Resistance Summary (Table 1)

Blue: look into collector terminal

Red: look into base terminal

Green: look into emitter terminal

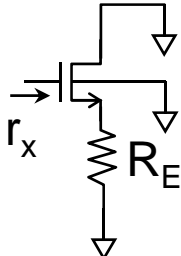
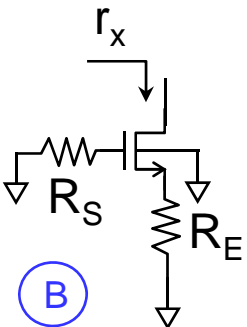
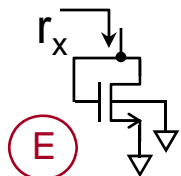
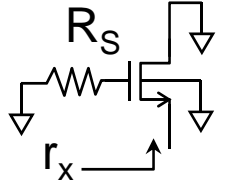
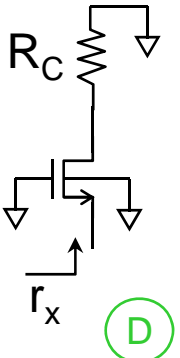
Conf	r_x	Conf	r_x	Conf	r_x
	$r_\pi + (1 + \beta)R_E$ $\approx r_\pi (1 + g_m R_E)$		$r_o \left\{ 1 + g_m \left[(r_\pi + R_S) \parallel R_E \right] \left(\frac{r_\pi}{r_\pi + R_S} \right) \right\}$ <p>If $R_S = 0$ and $r_\pi \ll R_E$ $\Rightarrow r_{x,\max} = r_o (\beta + 1)$</p>		$\frac{1}{g_m}$
	$\frac{R_S + r_\pi}{1 + \beta} \parallel r_o$ $\approx \frac{R_S}{1 + \beta} + \frac{1}{g_m}$		$\frac{1}{g_m} \times \frac{r_o + R_C}{r_o + \frac{R_C}{\beta}}$		

MOS Equivalent Resistance Summary (Table 2)

Blue: look into drain terminal

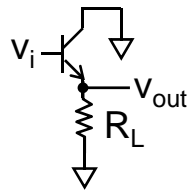
Red: look into gate terminal

Green: look into source terminal

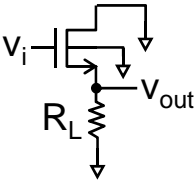
Conf	r_x	Conf	r_x	Conf	r_x
 <p>(A)</p>	∞	 <p>(B)</p>	$r_o [1 + (g_m - g_{mb}) R_E]$	 <p>(E)</p>	$\frac{1}{g_m}$
 <p>(C)</p>	$\frac{1}{g_m - g_{mb}}$	 <p>(D)</p>	$\frac{1}{g_m - g_{mb}} \times \frac{r_o + R_C}{r_o}$		

BJT Summary (Table 3)

BJT	G_m	A_v
CE (A)	g_m	Derive Based on 2-ports Network
CB (B)	$-g_m$	Derive Based on 2-ports Network
CC (C)	Not Applicable	$\frac{g_m R_L}{1 + g_m R_L}$
CE with Emitter Degeneration (D)	$\frac{g_m}{1 + g_m R_E}$	Derive Based on 2-ports Network



MOS Summary (Table 4)

MOS	G_m	A_v
CS (A)	g_m	Derive Based on 2-ports Network
CG (B)	$-(g_m - g_{mb})$ <i>Drop g_{mb} if no body effect</i>	Derive Based on 2-ports Network
CD (C) 	Not Applicable	$\frac{g_m R_L}{1 + (g_m - g_{mb}) R_L} \approx \frac{g_m}{g_m - g_{mb}}$ <i>Drop g_{mb} if no body effect</i>
CS with R_E (D)	$\frac{g_m}{1 + (g_m - g_{mb}) R_E}$ <i>Drop g_{mb} if no body effect</i>	Derive Based on 2-ports Network