Slide No:

CDEEP
IIT Bombay

3/2/2011 Thursday

1st Quiz Cum Test

Venue GG1 / GG-2 EE Dept.

Time :— 9.30 PM to 10.30 PM

You Will Sit on your Left on every Desk

Types of Amplifiers

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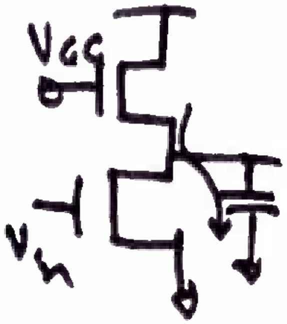
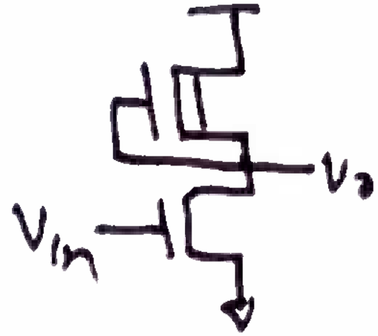
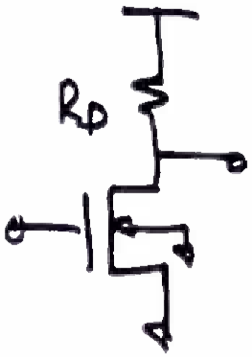
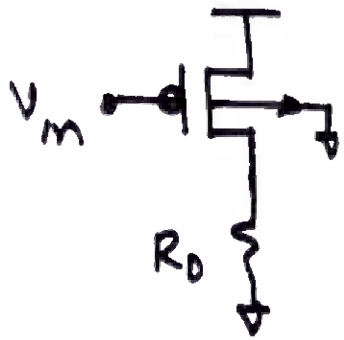


1. NMOS Amplifier
2. PMOS Amplifier
3. CMOS Amplifier

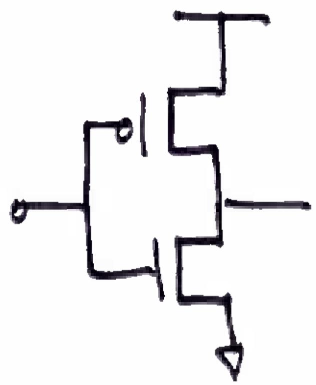




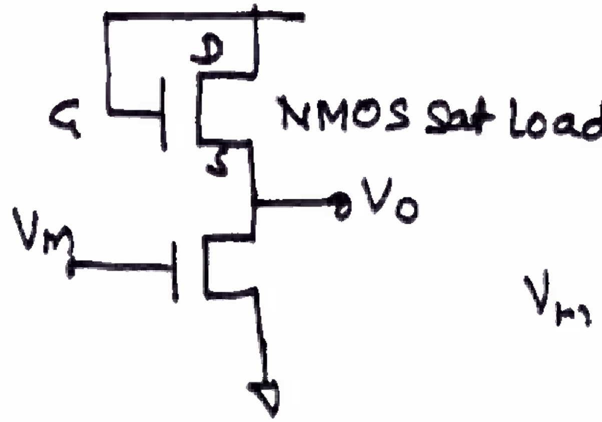
NMOS

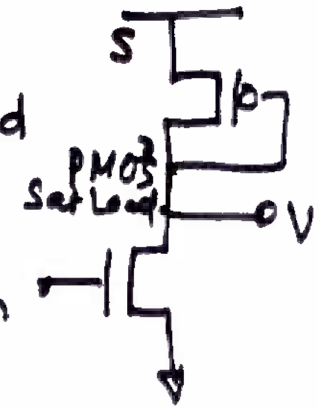


PMOS



CMOS





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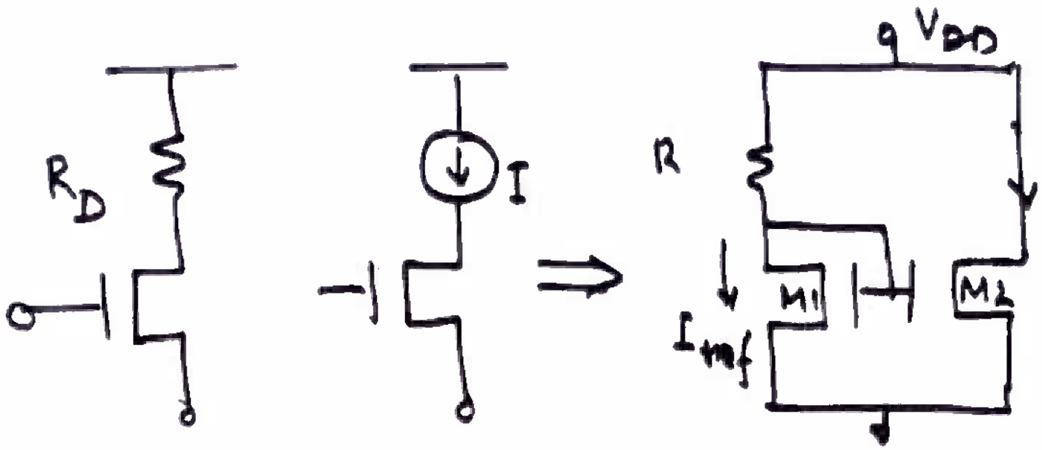
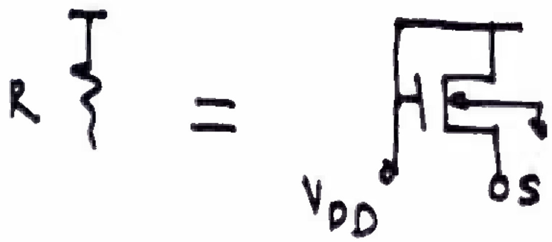
Loads in MOS Amplifiers



$$I_D = \frac{(W/L)_2}{(W/L)_1} I_{ref}.$$



Diode Connected Load

Device in Saturation

$$I_{DS} = \beta'(W/L)\left[V_{GS}-V_T\right]^2(1+\lambda V_{DS})$$

$$V_{GS} = V_{DS} = V_{DD} \quad \therefore (V_{GS}-V_T < V_{DS})$$

$$\therefore \frac{\partial I_{DS}}{\partial V_{DS}} = \beta\left[V_{DD}-V_T\right]^2\lambda = \text{constant}$$

$$\therefore R = \frac{1}{\beta\lambda\left[V_{DD}-V_T\right]^2}$$

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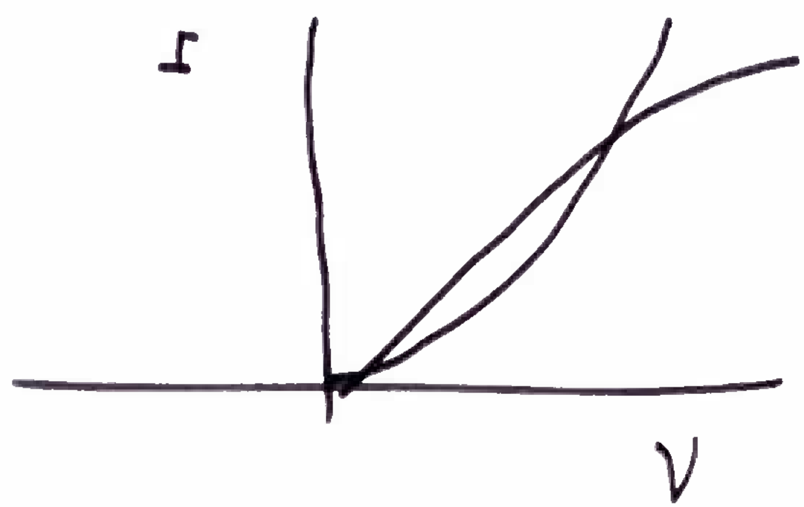

Course Name
Analog Circuits

Lecture No. 7

Instructor's Name
Prof. A. N. Chandorkar

(Circuit Basis)

Types of Amplifiers with MOSFETs.

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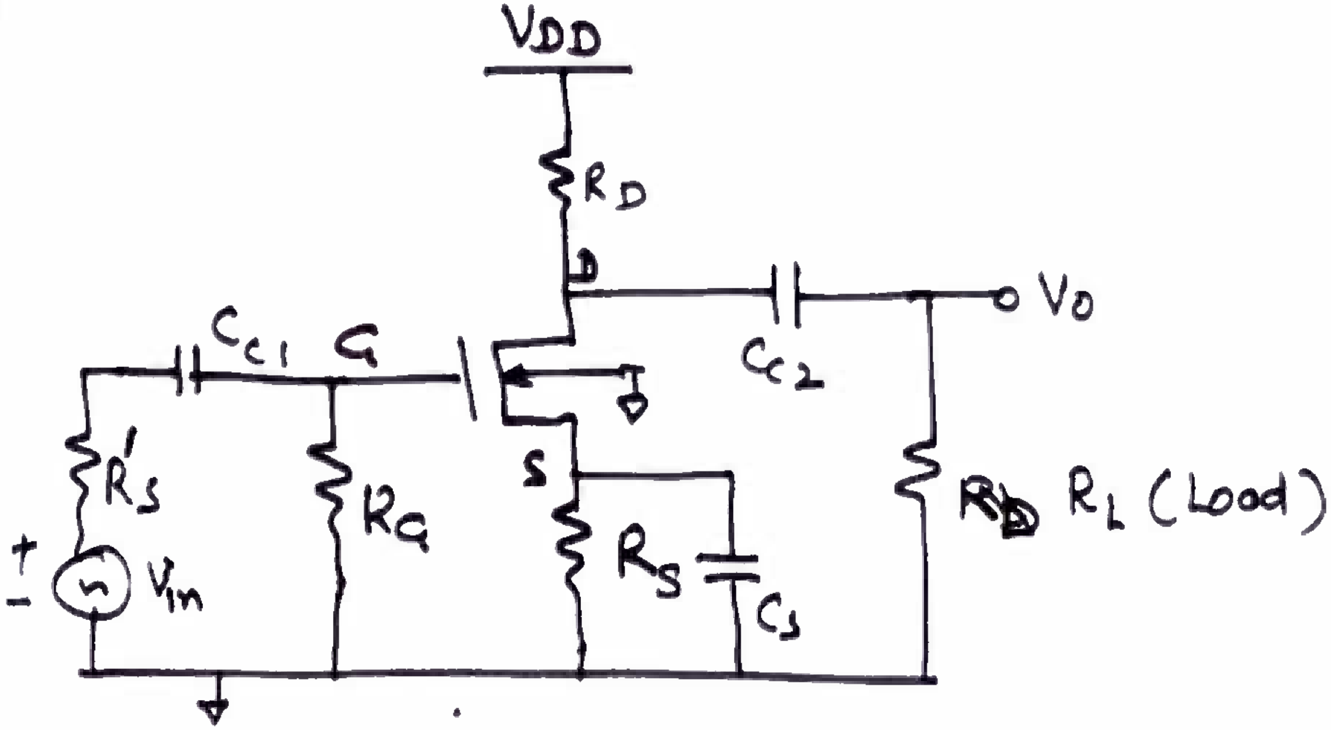
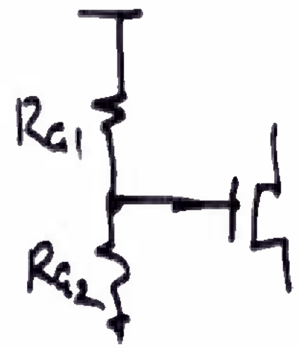
1. Common Source — Mostly Used
2. Common Gate — Wider Bandwidth but Low Gain
3. Common Drain (Source Follower)

Common Source Amplifier



$R_G = R_{G1} \| R_{G2}$



Find $\frac{V_o}{V_{in}} = A_V$ of the Amplifier.

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Equivalent Ckt for Low frequency operation

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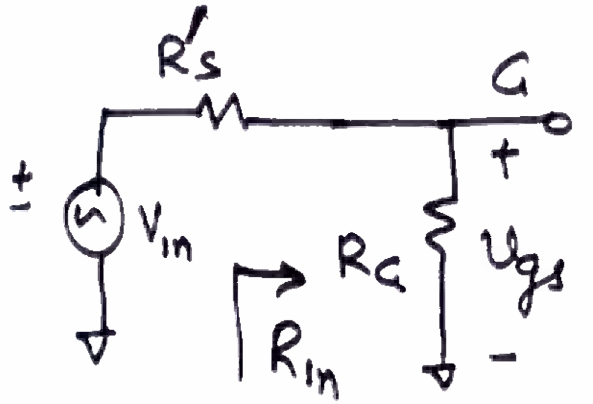

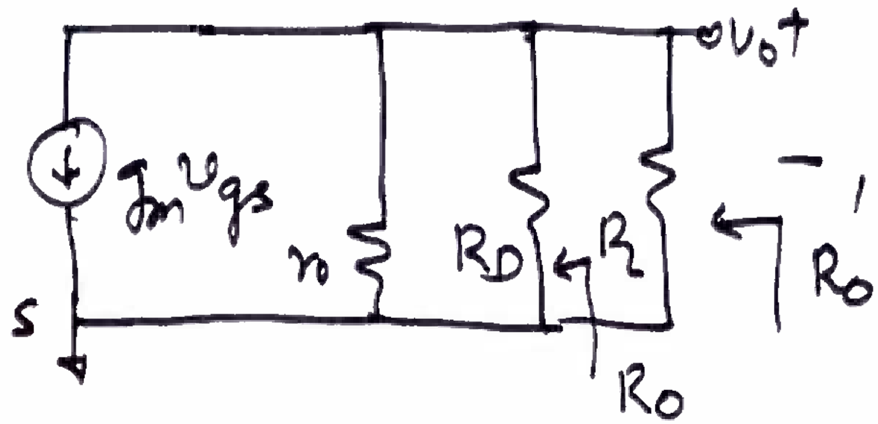

$$v_{gs} = \frac{R_G}{R_G + R_s'} \cdot v_{in} \cong v_{in} \quad \text{if} \quad R_G >> R_s'$$

$R_G \downarrow$ MΩ — 100's of Ω

$$\therefore \; v_o = -\, g_m (r_o \| R_D \| R_L) v_{in}$$

$$\therefore \; A_v = \frac{v_o}{v_{in}} = -\, g_m (r_o \| R_D \| R_L) \left[\frac{R_G}{R_G + R_s'} \right]$$

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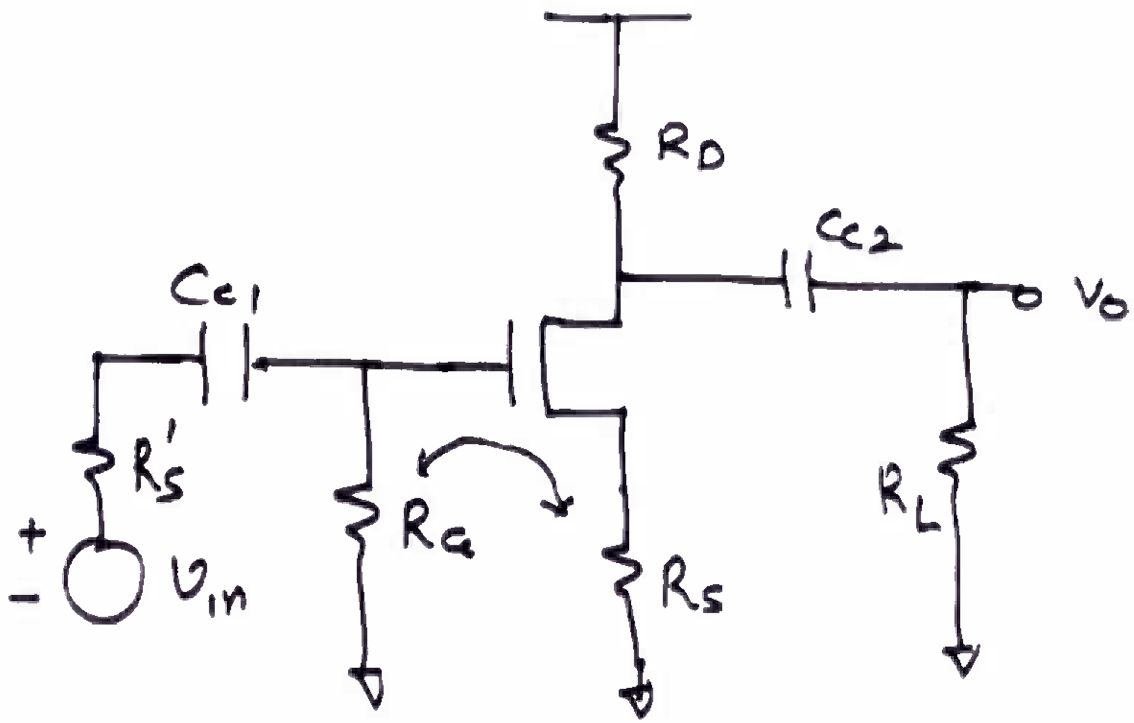
Input Impedance $R_{in} = R_i = R_G$

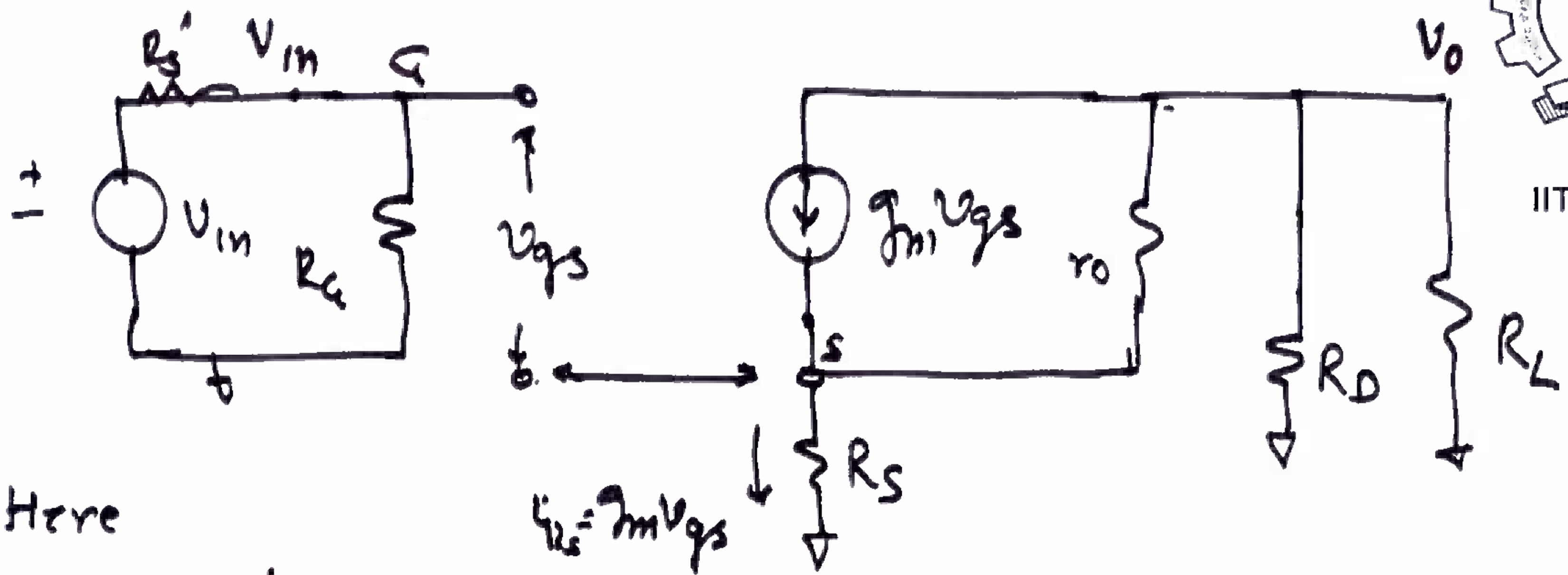
Output Impedance $R_o = r_o \| R_D$

If R_G is not $>> R_s'$

then $A_v = -\dfrac{R_G}{R_G + R_s'} \cdot g_m (r_o \| R_D \| R_L)$

CS Amplifier with Source Degeneration





Here

$R_G >> R_s'$ $\quad r_o \to$ V. High (λ very low)

We

$$v_{in} = v_{gs} + g_m v_{gs} \cdot R_s = v_{gs}(1 + g_m R_s)$$

$$\therefore \quad v_{gs} = \frac{v_{in}}{1 + g_m R_s}$$

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Now $v_o = -g_m v_{gs} \cdot (R_D \| R_L)$

or $v_o = -g_m (R_D \| R_L) \cdot \dfrac{v_{in}}{1 + g_m R_S}$

$\therefore \quad A_v = \dfrac{v_o}{v_{in}} = -\dfrac{g_m}{1 + g_m R_S} \cdot (R_D \| R_L)$

If $g_m R_S >> 1$ then

$$A_v = -\frac{R_D \| R_L}{R_S}$$

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Given $R_{G1} = 165k$ $V_{DD} = 5\ V$

$R_{G2} = 35k\Omega$ $V_{SS} = -5V$

$R_D \| R_L = 7k$ $R_S = 0.5\ k\Omega$

$R_S' = 0$ $\beta_n = 2\ mA/V^2$ & $\lambda = 0$, $V_{Tn} = 0.8V$

$R_G = R_{G1} \| R_{G2}$

From DC analysis, $V_{GSQ} = 1.5\ V$

$V_{DSQ} = 6.25V$ $I_{DSQ} = 0.5\ mA$

$V_{DSQ} > V_{GSQ} - V_t$
Device in Sat.

$\therefore\ g_m = \sqrt{2\beta_n I_{DSQ}} = 1.4\ mA/V$

Also $r_o = \frac{1}{\lambda I_{DS}} = \infty$

$$\therefore A_v = -\frac{g_m}{1+g_m R_s}(R_D \| R_L)$$

$$= -\frac{1.4\times10^{-3}}{1+1.4\times10^{-3}\times0.5\times10^{3}}(7\times10^{3})$$

$$A_v = -5.76$$

If we use $1+g_m R_s = g_m R_s$

$$A_v = -\frac{7\times10^{3}}{0.5\times10^{3}} = -14$$

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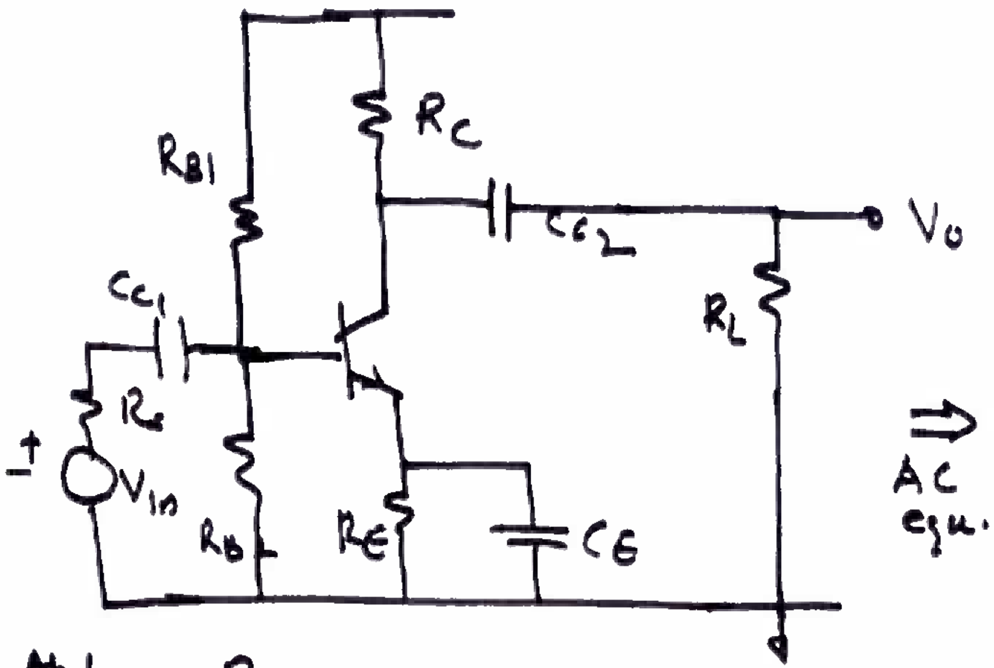
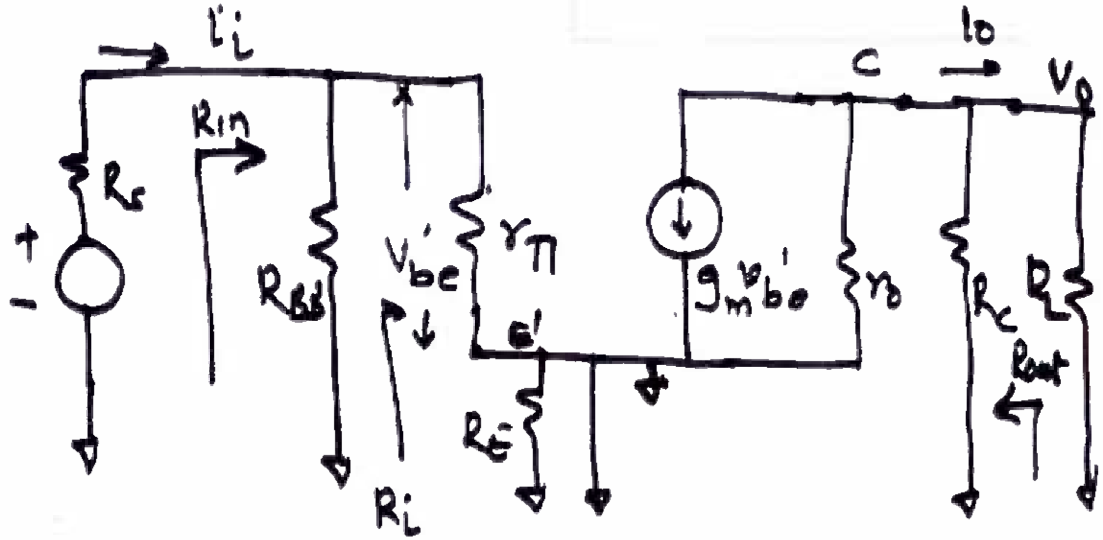
A BJT Amplifier { Low frequency operation }



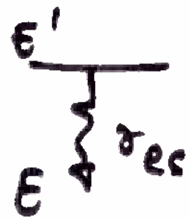
$\Rightarrow$ AC equ.



At Low Frequency

$\frac{1}{C_E s} \rightarrow 0$; $\frac{1}{C_{c_1} s} = \frac{1}{C_{c_2} s} \rightarrow 0$

$\frac{1}{s(C_{je}+C_\pi)} \rightarrow \infty$ $\quad \frac{1}{C_\mu s} \rightarrow \infty$



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Course Name: Analog Circuits
Lecture No. 7
Instructor's Name: Prof. A. N. Chandorkar

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$$R_{in} = \frac{v_{in}}{i_i} = R_B \| R_i \qquad R_B = R_{B1} \| R_{B2}$$

(Very High Value)

where $R_i = r_\pi$ as $R_B >> r_\pi$

$$\therefore \; R_{in} = R_i = r_\pi$$

Now

$$v_{be'} = \frac{R_{in}}{R_{in} + R_s} \cdot v_{in} = v_{in} \frac{(R_B \| r_\pi)}{R_s + (R_B \| r_\pi)}$$

$$= \frac{r_\pi}{r_\pi + R_s} v_{in} \qquad \text{if } R_B >> r_\pi$$

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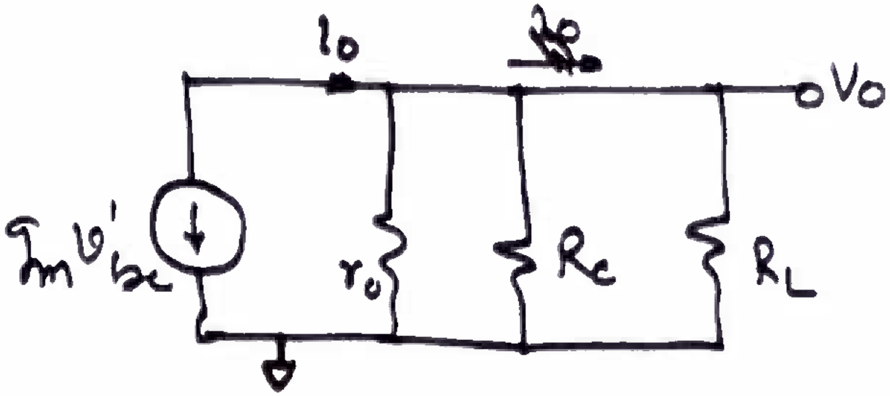
At the Output node Eq. Ckt is



$$i_o = -g_m v'_{be}$$

$$v_o = i_o(r_o \| R_c \| R_L) = -g_m(r_o \| R_c \| R_L)\, v'_{be}$$

$$\therefore \frac{v_o}{v'_{be}} = A'_{vo} = -g_m(r_o \| R_c \| R_L)$$

or $$v_o = -g_m(r_o \| R_c \| R_L) \cdot \frac{r_\pi}{r_\pi + R_s} \cdot v_{in}$$

$$\therefore A_v = \frac{V_o}{V_{in}} = -\frac{g_m r_\pi}{r_\pi + R_s}(r_o \| R_c \| R_L) = -\frac{\beta(R'_L)}{r_\pi + R_s} = -\frac{\beta(\text{Eq. Load})}{R_i + R_s}$$

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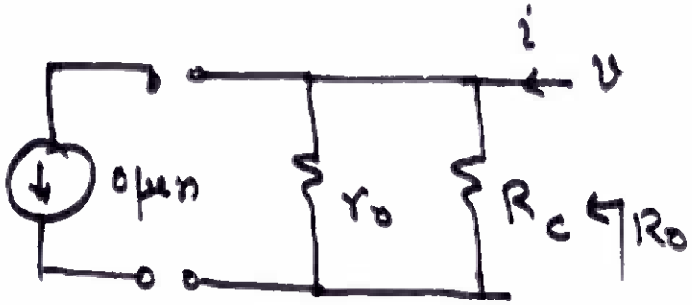
$R_o = R_{out}$



$$R_o = \frac{v}{i}$$

$$\therefore \; R_o = (r_o \,||\, R_c)$$