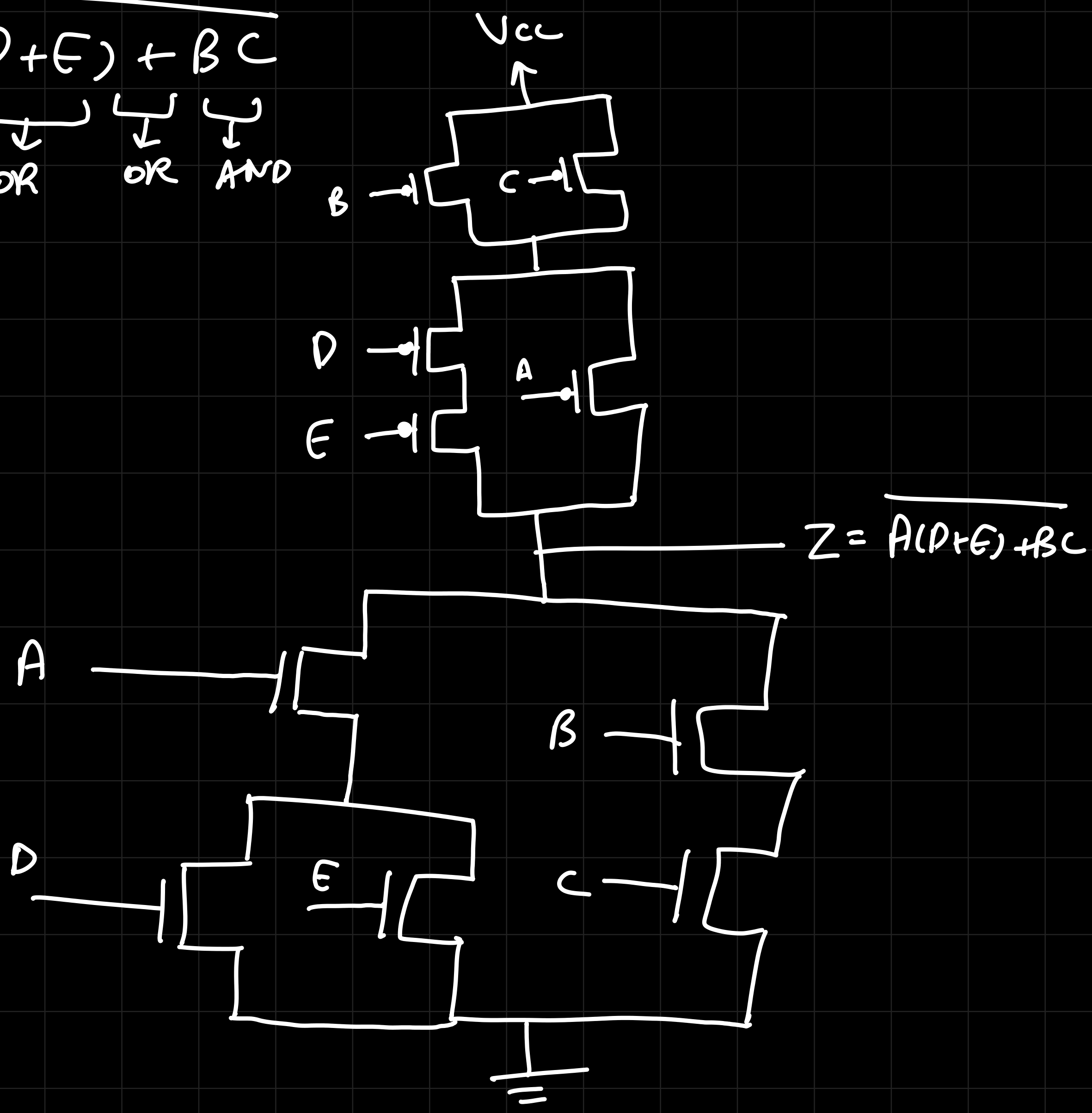
#Lecture / Tut

Q) Bool expression :

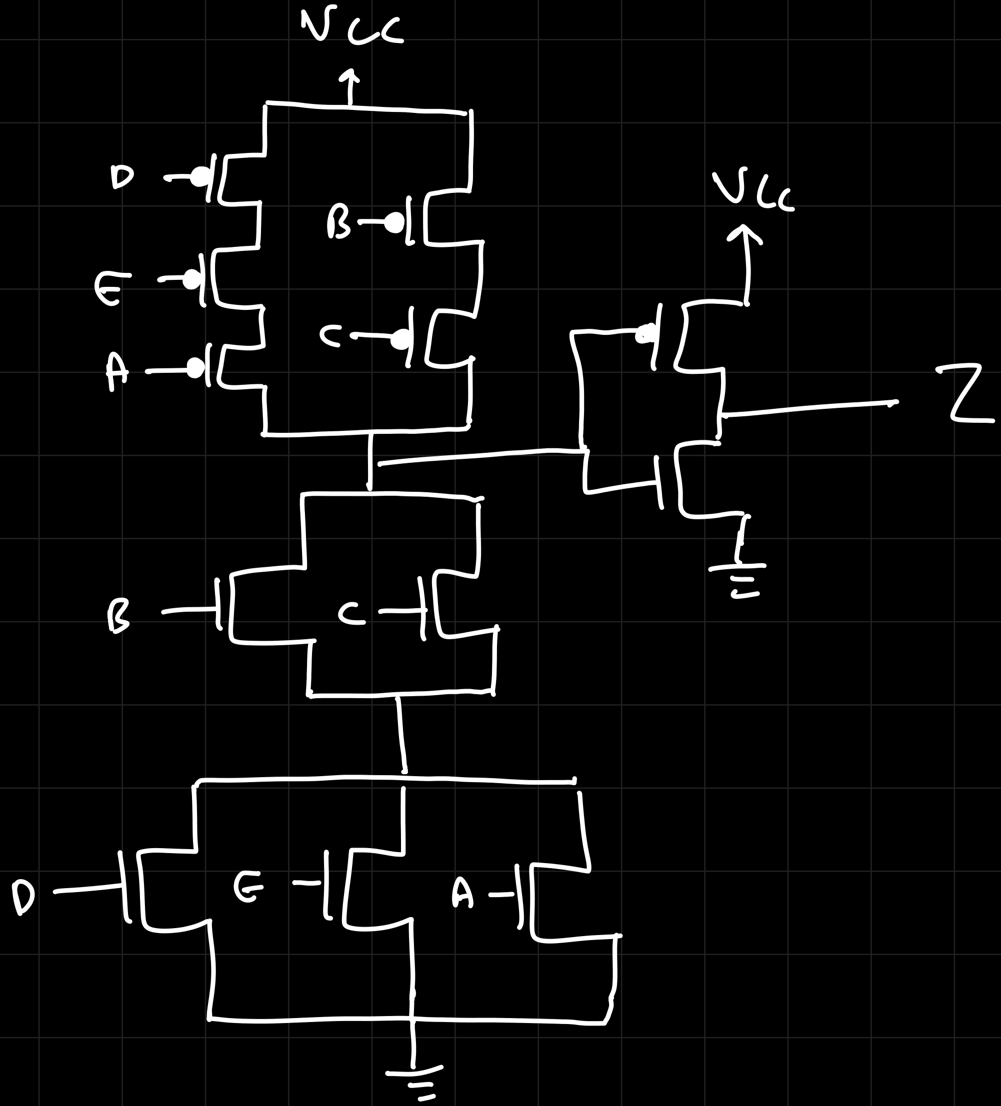
$$Z = \overline{A(D+E)+BC}$$

realize Z with CMOS →

$$\overline{\underbrace{A}_{\text{AND}}\underbrace{(D+E)}_{\text{OR}}\underbrace{+}_{\text{OR}}\underbrace{BC}_{\text{AND}}}$$



g) $Z = (D + E + A)(B + C)$



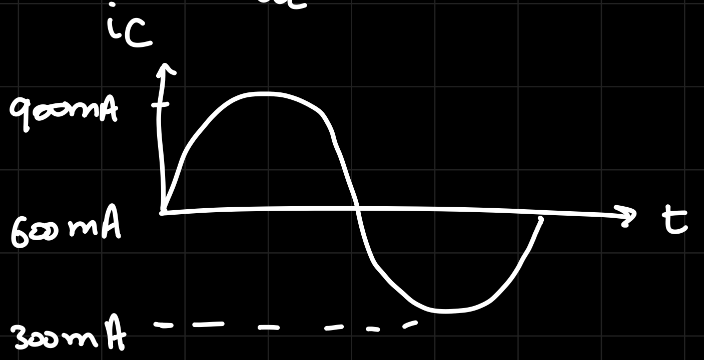
Q) for a single stage transformer coupled power amplifier, the supply voltage is 20V (DC) and the DC voltage at Q point = 10V and the DC current at Q point = 600mA
Reflected Load = 16Ω
AC current varies 300mA peak
Calculate η.

Ans) $V_{CC} = 20V$ $\quad V_{CE,Q} = 10V$

$I_{CQ} = 600mA$

$i_c = 300mA$

$R_L' = 16\Omega$



$$\eta = \frac{P_{ac}}{P_{dc}} \rightarrow \quad P_{ac} = V_{rms} I_{rms} = I_{rms}^2 R_L'$$

$$P_{dc} = V_{CC} I_{CQ} = 20 \times 600m = 12W$$

$$P_{ac} = \frac{I_m^2}{2} \times 16 = 8 I_m^2 = 0.72W$$

$$8 \times 0.09 = 0.72W$$

$$\eta = 6\%$$

$R_{FC} \Rightarrow$ Inductor

Class C Amp

condition : $V_{BB} <$ AC input swing

$$\eta = \left[1 - \frac{V_{min}}{V_{CC}}\right] \times 100\%$$

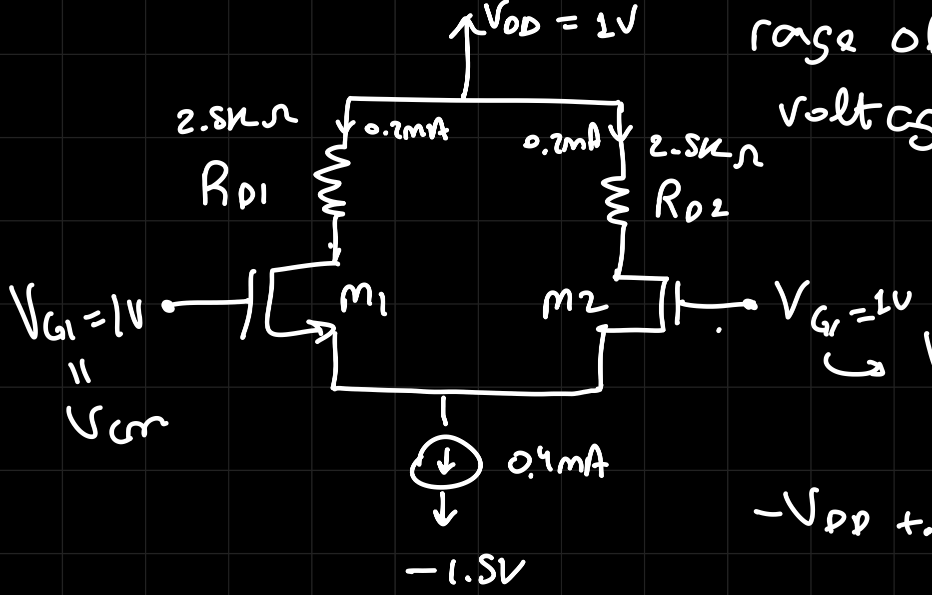
Conduction angle : $< 180\%$

Q) Differential Amplifier

i. calculate V_{ov} and V_{GS} of each Q, and Q_2

(V_{ov} ↳ overdrive voltage)

ii. calculate V_S, I_{d1}, I_{d2}, V_{d1}, V_{d2} when the common mode voltage = +1V



range of min → max voltage : common mode voltage

↳ $V_{cm} = 1V$

$V_{TN} = 0.5V$

$-V_{DD} + .5 + V_{DS} - 1.5 = 0$

$V_{D1} = V_{DD} - I_{D1}R_{D1} = 1.5 - 0.5 = 1 = V_{D2}$ $\quad \mu_n C_{ox}\frac{W}{L} = 4mAV^{-2}$

$$I_D^{sat} = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} V_{ov}^2$$

$$\cancel{10^{-3}} \times \overset{0.1}{\cancel{0.2}} = \frac{1}{2} \times \overset{2}{\cancel{4}} \times \cancel{10^{-3}} \times V_{ov}^2$$

$$V_{ov}^2 = 0.1$$

$$V_{ov} = \sqrt{0.1} = 0.316V$$

$$V_{ov} = V_{GS} - V_T$$

$$V_{GS} = 0.816V$$

$$V_S = V_G - V_{GS}$$

$$= 1 - 0.82 = \underline{0.18V}$$

$$V_{cm}^{max} = V_T + V_{DD} - I_D R_D$$

$$= 0.5 + 1.5 - 0.5 = \underline{1.5V}$$

$$V_{cm}^{min} = V_{SS} + V_{CS} + V_t + V_{ov}$$

$$= (-1.5) + 0.4 + 0.5 + 0.316$$

$$= -0.284$$

$$-0.284 \leq V_{cm} \leq 1.5V$$

V_{CS} is voltage needed across the current source

if V_{CS} is not given then consider ideal current source i.e. no drop across the current source
↳ $V_{CS} = 0$

In this numerical consider → $V_{CS} = 0.4V$

CMRR : common mode Rejection Ratio

↳ The $\dfrac{\text{difference mode gain}}{\text{common mode gain}} = \dfrac{A_d}{A_c}$

$$CMRR_{dB} = 20\log \frac{A_d}{A_c} \text{ dB}$$

$$\left.\begin{aligned} V_d &= V_1 - V_2 \\ V_c &= \frac{V_1 + V_2}{2} \end{aligned}\right\} V_o = \text{common mode} + \text{difference mode}$$

$$\frac{V_o}{V_i} = A_v \rightarrow V_o = A_d V_d + A_c V_c$$

for 2 stage → $V_o = A_1 V_1 + A_2 V_2$

$$V_1 = \frac{V_d + 2V_c}{2} \qquad \left\{ \begin{aligned} V_d &= V_1 - V_2 \\ V_c &= \frac{V_1 + V_2}{2} \end{aligned} \right.$$

$$V_2 = \frac{2V_c - V_d}{2}$$

$$v_o = A_1\left[\frac{V_d + 2V_c}{2}\right] + A_2\left[\frac{2V_c - V_d}{2}\right]$$

$$= V_d\left[\frac{A_1 - A_2}{2}\right] + V_c\left[A_1 + A_2\right]$$

$$= V_d A_d + V_c A_c$$

$$A_d = \frac{A_1 - A_2}{2}, \quad A_c = A_1 + A_2$$

for practical case → CMRR is very high

for ideal case → CMRR = ∞

$$g_m = \frac{2I_D}{V_{ov}}$$

$$A_d = g_m R_D$$

$$A_{cm} = \frac{V_{od}}{V_{icm}} = -\frac{\Delta R_D}{R_{SS}}$$

$$A_d = g_m R_D$$

$$CMRR = \frac{|A_d|}{|A_c|} = \frac{g_m \cancel{R_D}}{\frac{\cancel{R_D}}{2R_{SS}} \times \frac{\Delta R_D}{R_D}} = \frac{2 g_m R_{SS}}{(\Delta R_D / R_D)}$$

↳ error

EZ topic for endsem
↳ cmos realization
↳ Power amplifier
↳ current mirror

moderate topic →
↳ Differential Amp

Tough →
cascade + cascode

$$CMRR = \frac{2g_m R_s}{(\Delta g_m / g_m)} = \frac{2g_m R_s}{(\Delta R_D / R_D)}$$

Q) cmos diff pair
bias current : 0.8mA

$\frac{W}{L} = 100$ $\mu_n C_{ox} = 0.2\ mA/V^2$

$\lambda = 20m$

$R_D = 5k\Omega$ $R_{SS} = 25k\Omega$

(i) find differential gain, A_d
common mode gain A_c
when the R_D have 1% mismatch
(ii) also find CMRR

Ans) $g_m = \sqrt{2K I_d} = \sqrt{20m \times 0.4m \times 2} = 4 \times 10^{-3}$

note : $I_d = \frac{I_{bias}}{2} = 0.4m$

$A_d = g_m R_d = 4 \times 10^{-3} \times 5 \times 10^{3} = 20 V/v$

$A_c = \frac{-\Delta R_d}{2R_{SS}} = \frac{0.01 \times 5 \times 10^{3}}{2 \times 25 \times 10^{3}} = 10^{-3}$

$CMRR = \frac{20}{10^{-3}} = 20K$

$CMRR_{dB} = 20 \log_{10}(20k) = 20 \times 4 \log_{10} 2$

$= 86 dB$