ECE 310 – Lecture 28

Monday, April 2, 2018 10:34 AM

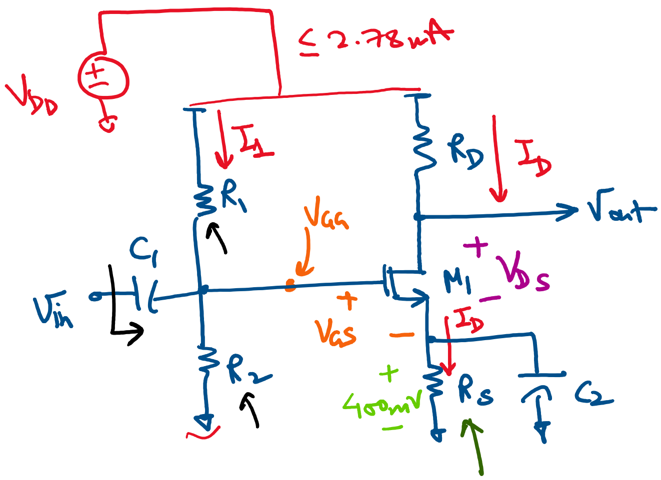
Ex. 17-28 Design a CS stage for $A_v = 5$

$R_{in} = 50\,k\Omega$, Power Budget = 5 mW

$KP_n = \mu_n C_{ox}' = 100\,\frac{\mu A}{V^2}$

$V_{Thn} = \cancel{0.4V}$ 0.5V

$V_{DD} = 1.8V$



* Assume voltage drop of 400mV across R_S

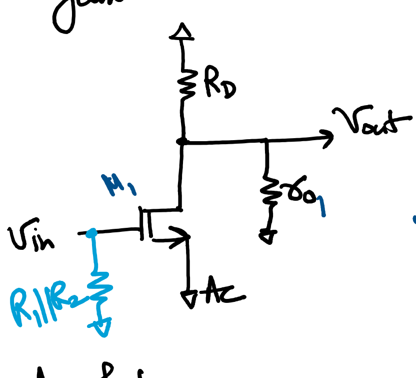
C_1, C_2 are large for AC coupling.

Total current $(I_D + I_1) \le \frac{P}{V_{DD}} = \frac{5mW}{1.8V} = \boxed{2.78mA}$

Initial guess: Lets allocate $\boxed{I_D = 2.7mA}$ leaving 80 µA for I_1

$$R_S = \frac{400mV}{2.7mA} = \boxed{148\,\Omega}$$

* Gain



AC picture

$\lambda = 0$

$\Rightarrow r_o = \frac{1}{\lambda I_{Dsat}} \rightarrow \infty$

$$A_v = -g_{m1} \cdot (R_D \| r_{o1})$$

$$\simeq -g_{m1} R_D$$

$$A_v = -g_m R_D = -5$$

$$\boxed{g_m R_D = 5}$$

Lets choose $V_{GS} = 1V$ $\Rightarrow$ $g_m = \dfrac{2I_D}{V_{GS} - V_{THN}} = \dfrac{2 \times 2.7mA}{1 - 0.5} = \boxed{\dfrac{1}{92.6\Omega}}$

$R_D = \dfrac{5}{1/926} = \boxed{463\Omega}$

* M_1 is in SAT

$$\underbrace{I_D}_{2.7mA} = \frac{1}{2} KP_n \cdot \left(\frac{W}{L}\right) \underbrace{(V_{GS} - V_{THN})^2}_{(0.5)^2}$$

$$\boxed{\frac{W}{L} = 218}$$

Now, verify if M_1 is in SATURATION.

$V_{DS} > V_{DS,sat}$

$V_{DS,sat} \rightarrow V_{GS} - V_{THN} = 0.5V$

$V_{DS} = 1.8 - 2.7mA\,(R_D + R_S)$
$= 0.150\,V$

M_1 is in TRIODE :(

* We have chosen an excessively large R_D & R_s values.

$5 = g_m \times R_D$

$R_D \downarrow 2\times$

$g_m \uparrow 2\times$

$$g_m = \sqrt{2 KP_n \left(\frac{W}{L}\right) I_D}$$

$g_m \rightarrow 2\times$

$\frac{W}{L} = \cancel{218} \xrightarrow{4\times 4} 864$

$\downarrow$ $2x$ $\downarrow$ $4x$

$\frac{W}{L} = \cancel{2}18 \rightarrow$ 864

$g_m = \sqrt{2 k'_n \left(\frac{W}{L}\right) I_D} = \frac{1}{463\Omega}$

$\Rightarrow V_{GS} - V_{THN} = 250mV$

$\Rightarrow V_{GS} = \boxed{0.75V}$

Check for saturation

$V_{DS} = V_{DD} - I_D \times (R_D + R_S)$

$= 1.8 - 2.7mA \left(\frac{463}{2} + 148 \right) = 0.775V$

$V_{DS} = 0.775V > V_{DS,sat} = 250mV$

$\hookrightarrow$ M_1 is in SAT

$V_{GS} = 750mV$

$\frac{W}{L} = 864$

$I_D = 2.7mA$

$R_D = \frac{463}{2}\Omega$

$R_S = 148\Omega$

$V_{GG} = 750mV + 400mV \Rightarrow 1.15V = V_{DD} \times \frac{R_2}{R_1 + R_2}$

$1.8 \times \frac{R_2}{R_1 + R_2} = 1.15V \longrightarrow (1)$

$R_{in} = 50k\Omega$

$$R_{in} = R_1 \| R_2 = \frac{R_1 R_2}{R_1 + R_2} = 50\,k\Omega \rightarrow (2)$$

Solve $R_1 + R_2 = (\qquad)$

$> 50\,k\Omega$

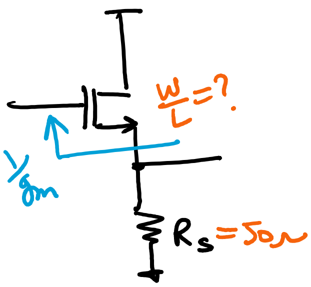
$$I_1 = \frac{V_{DD}}{R_1 + R_2} \leq 80\,\mu A$$

Ex. 17.38

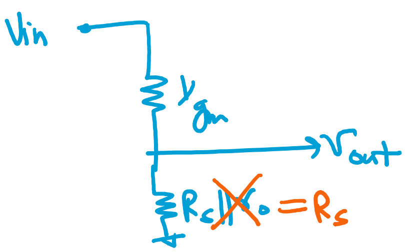
Design a source follower to drive a 50Ω load with a voltage gain = 0.5 and a power budget of 10mW.

$\lambda = 0$

$$I_D = \frac{P}{V_{DD}} = \frac{10\,mW}{1.8V} = \boxed{5.26\,mA}$$



$$A_v = \frac{v_{out}}{v_{in}} = \frac{R_s}{\frac{1}{g_m} + R_s} = 0.5$$



$$\frac{50}{\frac{1}{g_m} + 50} = 0.5$$

$$\boxed{g_m = \frac{1}{50\Omega}}$$

$$g_m = \sqrt{2\beta I_D} = \sqrt{2\, K'_n \left(\frac{W}{L}\right) I_D}$$

Solve for $\frac{W}{L} = \underline{\underline{360}}$ Ans.

$I_D = 1mA$

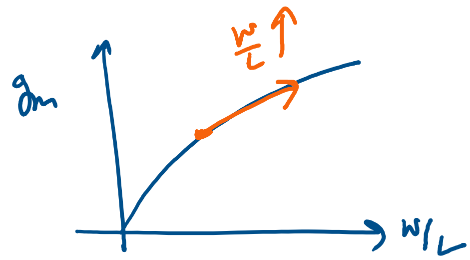
$g_m \uparrow 2x$

g_m

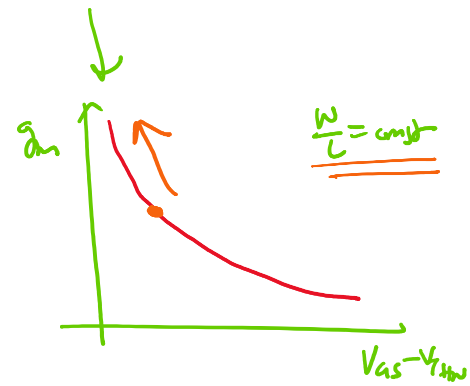
$$g_m = \sqrt{2\beta I_D} = \frac{2 I_D}{V_{GS} - V_{Tth}} = \beta V_{ov}$$

V_{GS} const.

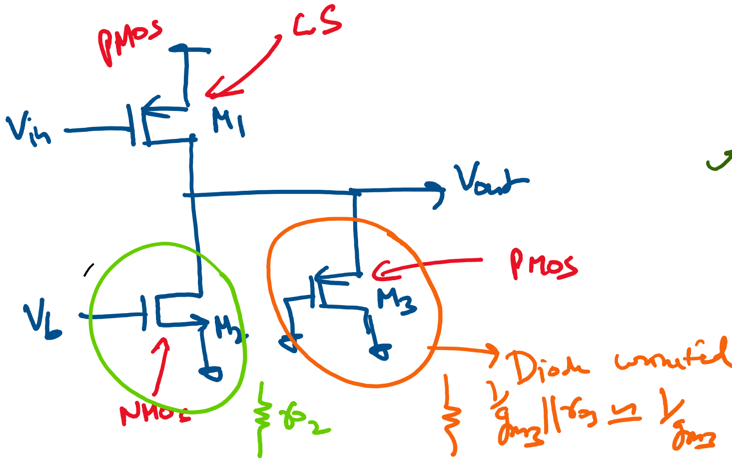
$\frac{W}{L} = \text{const}$



$V_{GS} = \text{const}$

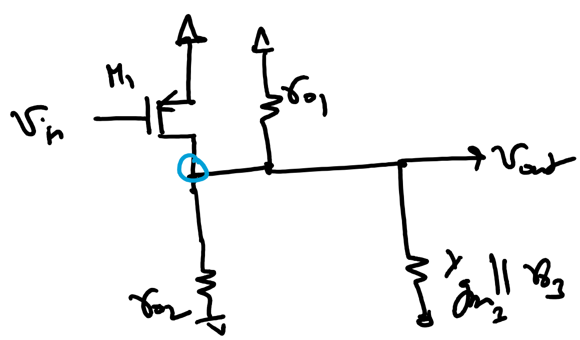


Cf. **17.40**



A_{v2}?

Ac picture.



$$A_v = -g_{m1} \cdot R_L$$

$$= -g_{m1} \cdot r_{o1} \| r_{o2} \| \frac{1}{g_{m3}} \| r_{o3}$$

$$\frac{1}{g_m} \ll r_o$$

$$\simeq -\frac{g_{m1}}{g_{m3}}$$