Lecture 6

EE 420/ECG 620

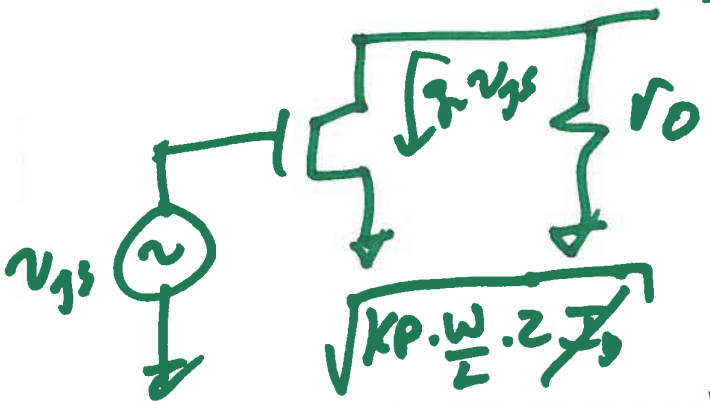
Analog IC Design

How do we select W/L & V_{GS} and thus I_D!

inherent gain of transistor

$$v_{out} = -g_m v_{gs} \cdot r_o$$

$$r_o = \frac{1}{\lambda I_D}$$



open ckt gain

$$= \left|\frac{v_{out}}{v_{gs}}\right| = |-g_m r_o| = \frac{\sqrt{KP \cdot \frac{W}{L} \cdot 2 I_D}}{\lambda \sqrt{I_D}}$$

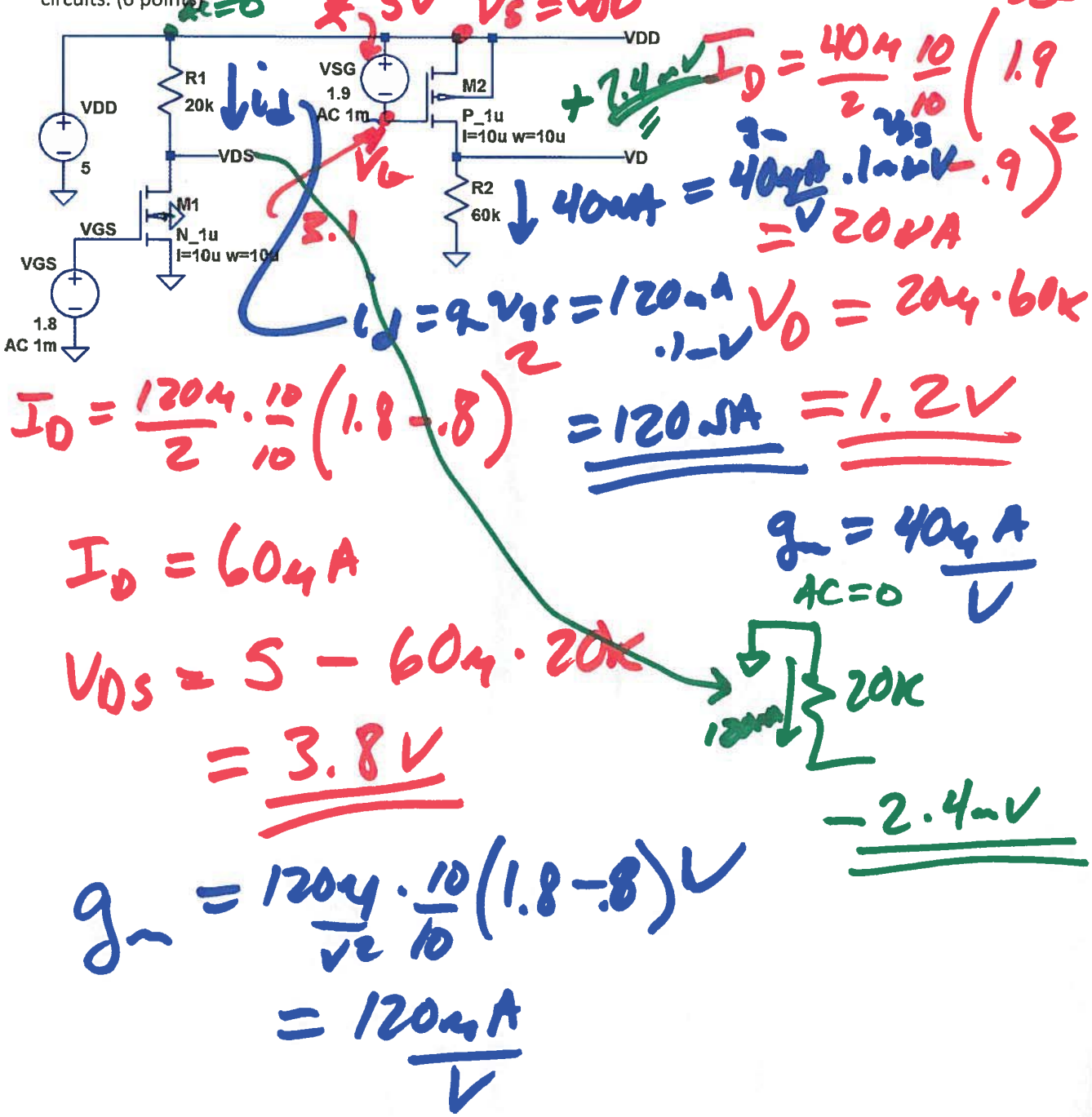
Quiz 4 EE 420/ECG 620 Analog, Spring 2017 Name: _____

Open book and closed notes.

Show your work for credit.

For the following assume: V_{THN} = 800 mV, V_{THP} = 900 mV, KP_n = 120 uA/V², and KP_p = 40 uA/V².

1. Calculate the DC and AC drain currents and AC and DC drain-source voltages in each of the following circuits. (6 points)



2)

$$\left|\frac{v_{out}}{v_{in}}\right| = g_m r_o = \frac{\sqrt{k_p' \frac{W}{L} \cdot 2 I_D}}{\lambda I_D} = \frac{\sqrt{k_p' \frac{W}{L} \cdot 2}}{\lambda \sqrt{I_D}}$$

$$\sqrt{I_D} = \sqrt{\frac{k_p'}{2}\frac{W}{L}} \cdot (V_{GS} - V_{THN})$$

$\lambda \propto \frac{1}{\text{長} L}$

$$\frac{I}{C} = \frac{dV}{dt}$$

$$\left|\frac{v_{out}}{v_{in}}\right| = g_m r_o = \frac{2}{(V_{GS} - V_{THN})\lambda}$$

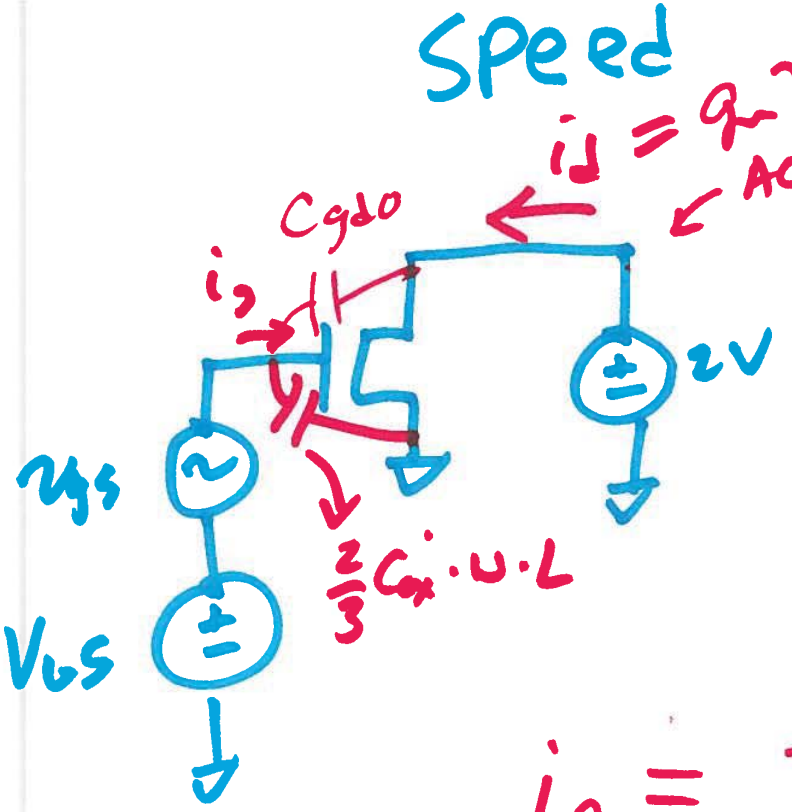
overdrive voltage $= V_{OVN}$

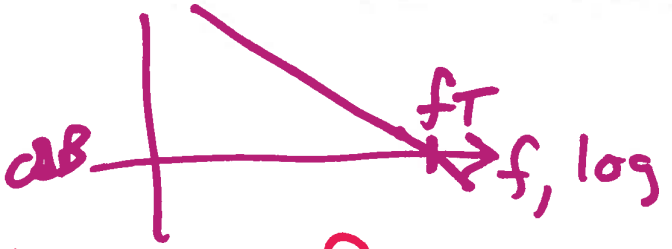
General design

$V_{OVN} = 5\%$ of VDD

$$\left|\frac{v_{out}}{v_{in}}\right| = g_m r_o \propto \frac{2L}{V_{GS} - V_{THN}}$$

Speed

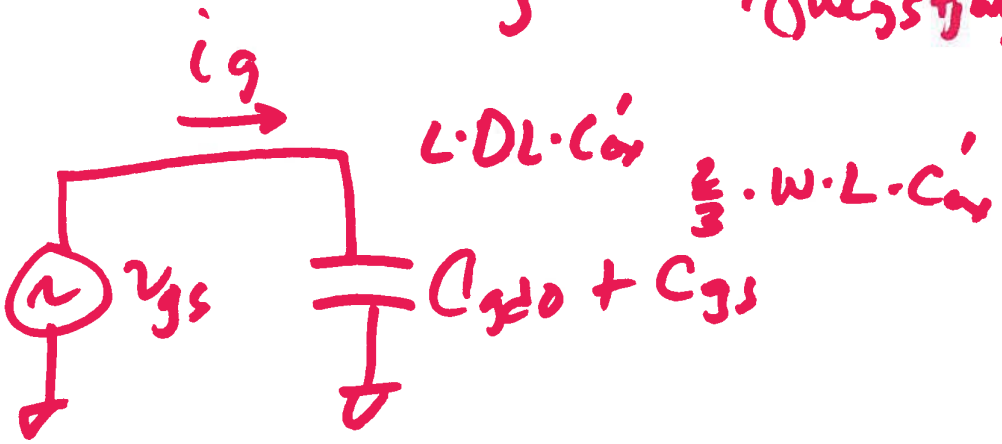




$$\frac{i_d}{i_g} = \frac{g_m}{j 2\pi \cdot f (C_{gs} + C_{gd0})}$$

$$f_T = \frac{g_m}{2\pi (C_{gs} + C_{gd0})}$$

$$i_g = \frac{v_{gs}}{1/(j\omega C_{gs} + j\omega C_{gd0})} = j\omega (C_{gs} + C_{gd0}) \cdot v_{gs}$$



$$f_T = \frac{g_m}{2\pi (C_{gs} + C_{gdo})}$$

$$\Downarrow$$

$$C_{gs} >> C_{gdo}$$

$$\approx \frac{kp' \cdot \frac{W}{L} (V_{GS} - V_{THN})}{2\pi \cdot \frac{2}{3} W \cdot L \cdot C_{ox}'}$$

$kp = C_{ox}' \cdot \mu_n$

$$= \frac{kp' \cdot \frac{3}{L^2} (V_{GS} - V_{THN})}{C_{ox} \frac{2\pi \cdot 2}{}} !$$

$$f_T = \frac{\mu_n \cdot 3}{4\pi L^2} \cdot (V_{GS} - V_{THN})$$

↑ short-channel

Figure of MERIT

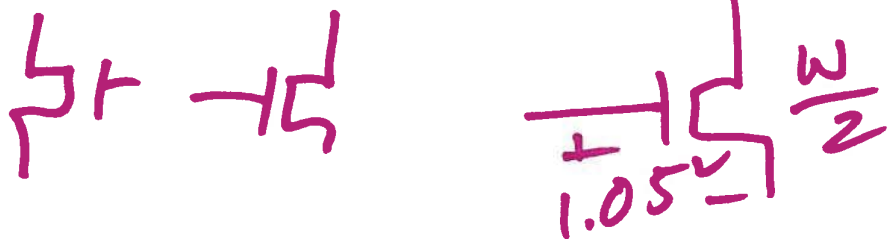
GAIN · f_T product = GFT

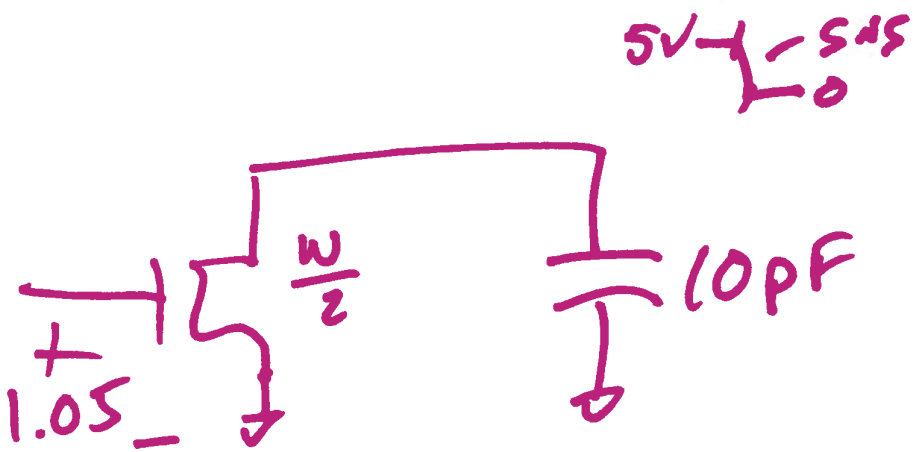
$$GFT = \frac{2}{(V_{GS}-V_{THN})} \cdot \frac{\mu_N \cdot 3}{4\pi \cdot L^2} \cdot (V_{GS}-V_{THN})$$

High-speed → Minimum L

general design → L = 2~5 times Minimum L

Longer devices match better

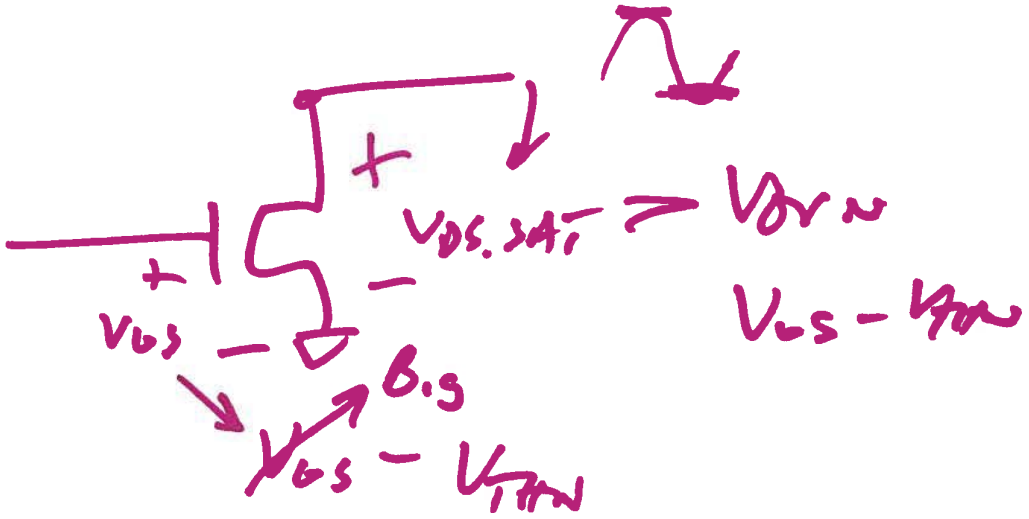


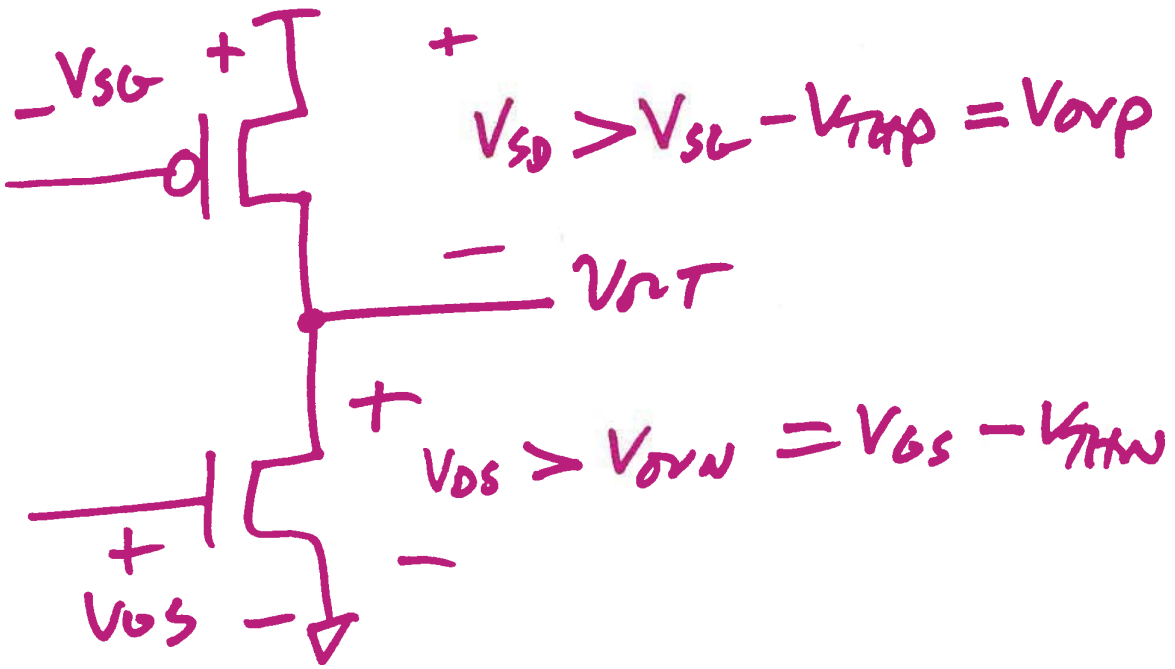


$$I = C\frac{dV}{dt}$$

$$I = 10pF \cdot \frac{5}{5ns}$$

$$I = 10\ mA$$




$-V_{SG}$
+
+
$V_{SD} > V_{SG} - V_{tp} = V_{ovp}$
−
V_{out}
+
$V_{DS} > V_{ovn} = V_{GS} - V_{tn}$
+
V_{DS}
−
−

$$I_D = \frac{\mu_n \cdot C_{ox}'}{2} \cdot \frac{W}{L} \left(V_{GS} - V_{THN} \right)^2$$