Midterm 1 in class F wk 5 3:10–4:00

Midterm 2 in class F wk 10 3:10–4:30

1 page, 2 sides notes

CS amp design

Design an amplifier w/ low freq gain of >100 up to at least 1 MHz w/ $C_L = 1pF$

swing ≥ C_{in} <

in a technology where $\mu_n C_{ox} = 200 \frac{\mu A}{V^2}$ $\mu_p C_{ox} = 100 \frac{\mu A}{V^2}$

$|V_{th}| = 0.5V$ $\lambda = \frac{1}{2V}\left(\frac{0.1\mu m}{L}\right)$ $L_{min} = 0.1\mu m$

$C_{ox} = 5 \frac{fF}{\mu m^2}$, $C'_{ol} = 0.1 \frac{fF}{\mu m}$ $V_{DD} = 2V$

$A_{vo} = 100$ $\omega_p > 2\pi\, 10^6 Hz \approx 10^7 \frac{rad}{s}$

$\omega_u = A_{vo}\omega_p = 10^9 \frac{rad}{s}$

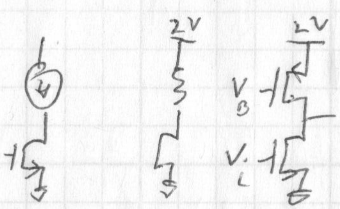
$\omega_u = \frac{g_m}{C_L}$ $g_m > \omega_u C_L = 10^9 \frac{rad}{s} 10^{-12} F = 10^{-3} S$

$g_m = \frac{2 I_D}{V_{ov}}$ pick $V_{ov} = 100mV$

(roughly lower limit on quadratic model)
(lowest current)
(will reexamine this choice)

$I_D = \frac{V_{ov}}{2} g_m = \left(\frac{100mV}{2}\right)(1mS) = 50\mu A$

$A_{vo} = g_m R_o$ $R_o \geq \frac{A_{vo}}{g_m} = \frac{100}{1mS} = 100K$



$\hookrightarrow r_{o,n} = R_o = 100k = \frac{1}{\lambda_n I_D} = \left(2V \frac{L}{0.1\mu m}\right)\frac{1}{50\mu A}$

$= 40k\Omega \cdot \left(\frac{L}{0.1\mu m}\right)$

$\Rightarrow L_n = 0.25\mu m$

resistive load: ① make $R_L >> r_o$

say $1M\Omega$ (vs. 100K)

with $50\mu A$ flowing, need

$V_{DD} > (50\mu A)(1M\Omega) = 50V$

NO too big

② make $r_o >> R_L$, let $R_L = 100K$

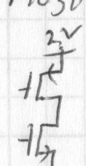
$\Rightarrow$ need $V_{DD} = (50\mu A)(100K) = 5V$

NO still too big

③ less current? NO, can't get needed g_m

$\Rightarrow$ can't use resistive load.

must use CMOS (PMOS load)



$R_o = 100K = r_{on} \| r_{op}$ pick $r_{on} = r_{op}$

$r_{on} = r_{op} = 200K \Rightarrow \lambda = 0.1 \frac{1}{V} \Rightarrow L_n = L_p = 0.5\mu m$

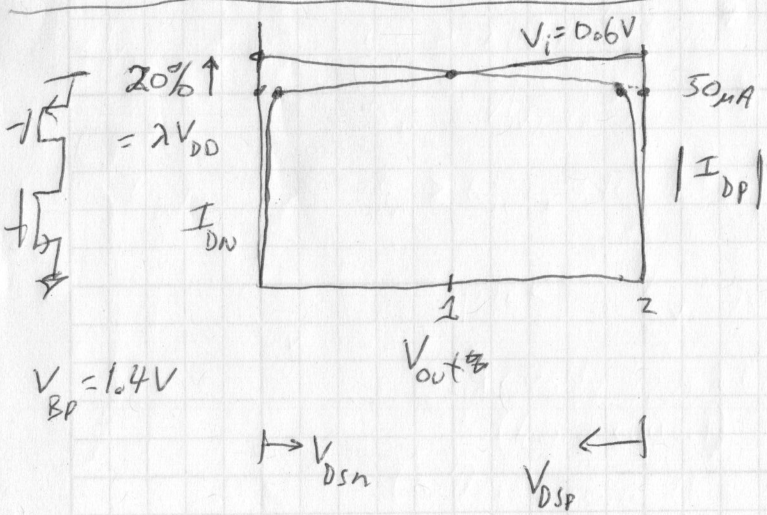
$I_D = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_n V_{ov}^2 (1+\lambda V_{DS})$

↳ ignoring here because we ... is needed in r_o calc.

$50\mu A = \left(\frac{100\mu A}{V^2}\right)\left(\frac{W}{L}\right)(0.1V)^2$

$\frac{W}{L} = 50$ $W_n = 25\mu m$ $W_p = 50\mu m$

$L_n = 0.5\mu m$ $L_p = 0.5\mu m$



if V_{in} decreases, I_{DN} decreases, V_{out} increases

need I_{DN} to decrease 20% from $V_{ov} = 0.1V$

to hit $V_{out,max} = V_{DD} - |V_{DSatp}| = 1.9V$

$I_D \sim V_{ov}^2$ $(V_{ov} + \Delta V)^2 \approx V_{ov}^2 + 2\Delta V V_{ov}$

$\approx V_{ov}^2\left(1 + \frac{2\Delta V}{V_{ov}}\right)$

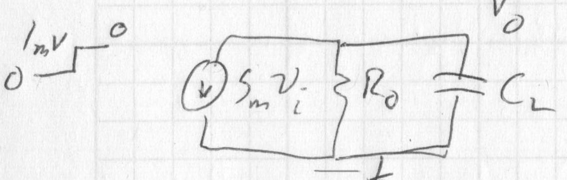
so 20% decrease in current

$\Rightarrow$ ~~10%~~ decrease in V_{ov} = 10mV

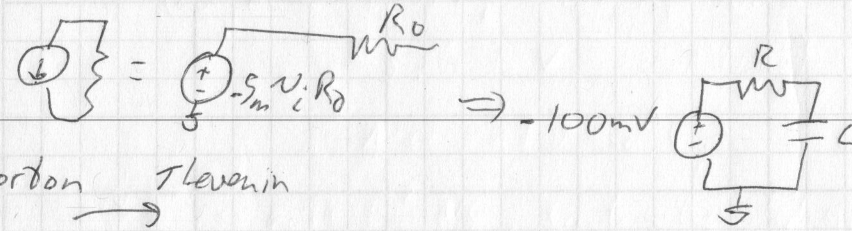
or $\Delta I = 10\mu A = g_m \Delta V \Rightarrow \Delta V = \frac{10\mu}{1m} = 10mV$

or $\Delta V_{out} = A_{vo} \Delta V_{in} \Rightarrow \Delta V = \frac{0.9V}{100} = 9mV$

1mV step response



$\tau = (100k)(10^{-12})$
$= 10^{-7}$ s



Norton → Thevenin

single pole step response

error ~ $e^{-t/\tau}$

progress ~ $1 - e^{-t/\tau}$

t/τ	progress	error
1	63%	37%
3	95%	5%
5	99%	1%
7	99.9%	0.1%

"must settle to within 1% in X seconds"
$\Rightarrow 5\tau < X$

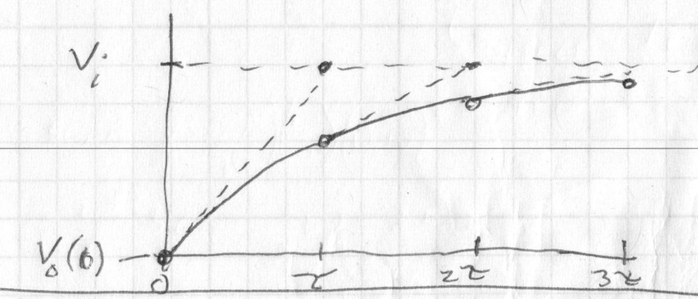
"switched cap gain error < 0.1%"
$\Rightarrow 7\tau$ settling

initially ($t=0$) $V_0 = 0$

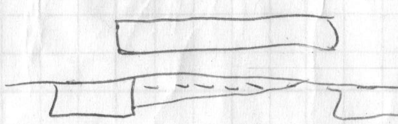
$I = \frac{V_i - V_0}{R} = C\frac{dV}{dt}$

$\frac{dV}{dt} = \frac{V_i - V_0}{RC} = \frac{V_i - V_0}{\tau}$

slope always points to destination in 1τ!



output capacitance



$C_{gs} = \frac{2}{3}WLC_{ox} + C'_{ol}W$

$C_{gd} = C'_{ol}W$

$C_{gdn} = (0.1\frac{fF}{\mu m})\, 25\mu m = 2.5fF$

$C_{gdp} = (0.1\frac{fF}{\mu m})(50\mu m) = 5fF$

amp adds 7.5fF to output
negligible