Lab 2
HW 3

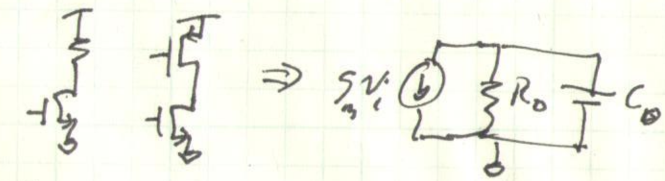
Midterm 1 : 2 weeks from today, in class

Single pole systems

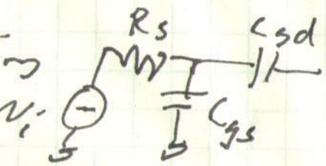
gain vs. freq

transient step response

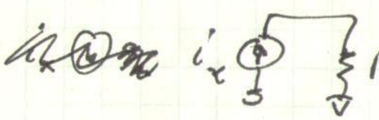
Last time: lots of things look like single pole amps



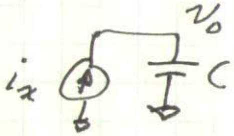
[iff source resistance is low

we are ignoring ]

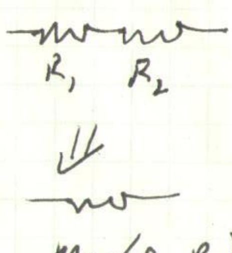
so $\frac{v_o}{v_i} = H(s) = \frac{-g_m R_o}{1 + s/\omega_p}$ $\omega_p = \frac{1}{R_o C_o}$

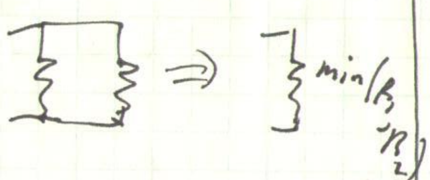


$v_o = i_x R$



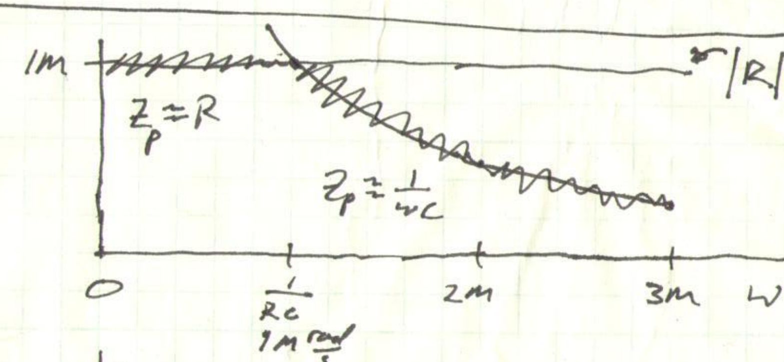
$v_o = i_x \frac{1}{sC}$ or $= i_x \frac{1}{j\omega C}$

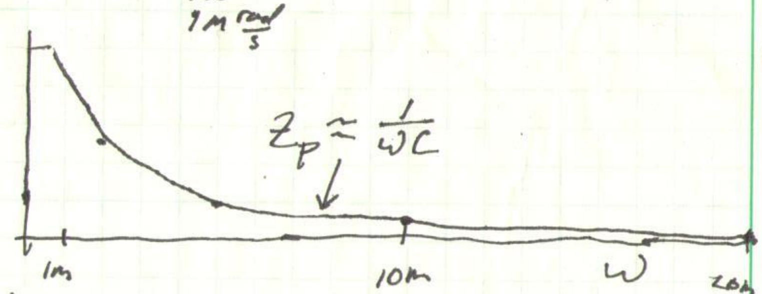




worst case error: $2^{\pm 1}$

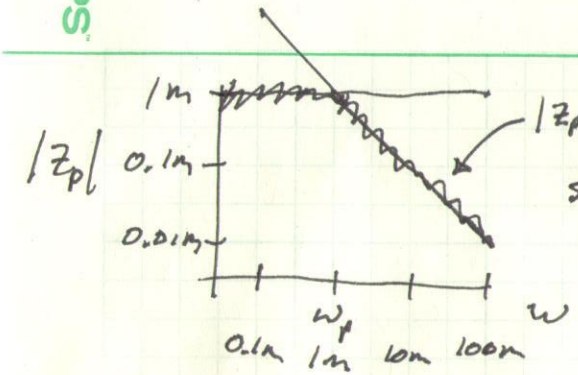
R = 1M
C = 1pF



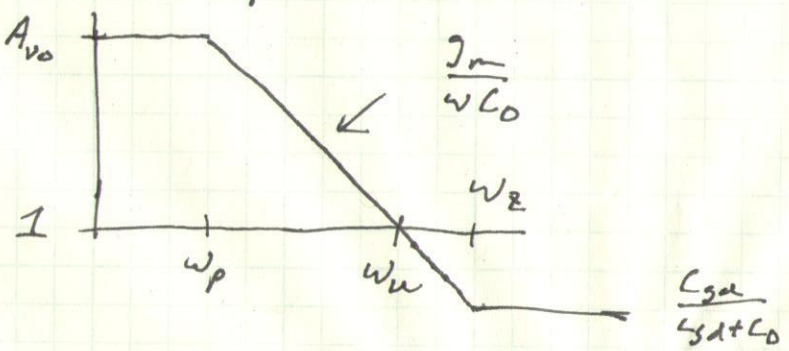


error: $(\sqrt{2})^{\pm 1}$

not super helpfull far above ω_p



$$A_V = H(s) = \frac{-g_m R_O \left(1 + s/\omega_z\right)}{1 + s/\omega_p}$$



$$|H(j\omega_u)| = 1 \quad \text{unity gain}$$

$$\left|\frac{g_m R_O}{1 + j\omega/\omega_p}\right| \simeq \left|\frac{g_m R_O}{\frac{j\omega}{\omega_p}}\right| = \frac{g_m R_O}{\omega R_O C_O} = \frac{g_m}{\omega C_O}$$

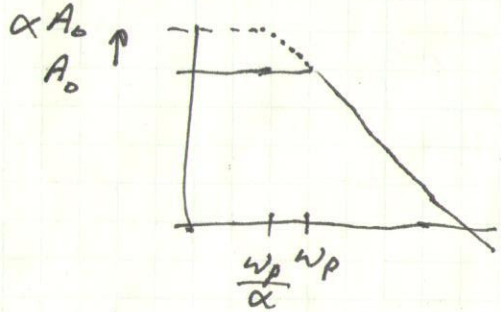
$$\frac{g_m}{\omega C_O} = 1 \Rightarrow \omega = \frac{g_m}{C_O}$$

$$\omega_u = A_{Vo}\,\omega_p$$

$$\omega_u = \frac{g_m}{C_O}$$

$$\omega_p = \frac{1}{R_O C_O}$$

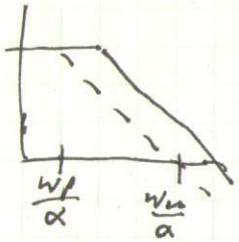
$$|A_{Vo}| = g_m R_O$$



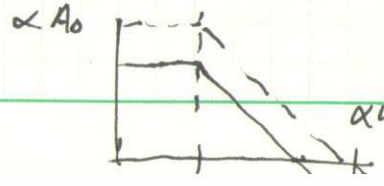
increase R_O by multiple α

more gain, lower pole

gain above pole remains unchanged.



increase C_O by α



increase g_m by α

ω_p unchanged.

more gain, more BW

good!

Ex:	g_m	R_0	C_0	A_{vo}	ω_p	ω_u
	$1_m S$	$1M\Omega$	$1pF$	10^3	10^6	10^9
			$1pF$			10^9
				10^3		10^9

low freq gain is 100. Unity gain is 10^6

$\omega_p = ?$ gain at 10^5? 10^7? 10^{37}? 500K?

when $\omega_p < \omega < \omega_u$ $A_v(j\omega) = \frac{\omega_u}{\omega}$

Knowing ω_u and C_0 puts a lower bound on current.

$\omega_u = \frac{g_m}{C_0}$ $\quad g_m = \omega_u C_0$

$g_m = \begin{cases} \frac{I_C}{V_{TH}} & \text{Bipolar} \\ \frac{I_D}{n V_{TH}} & \text{MOS sub-}V_t \\ \frac{2I_D}{V_{OV}} & \text{MOS quadratic} \\ \frac{I_D}{V_{OV}} & \text{MOS scl.} \end{cases}$

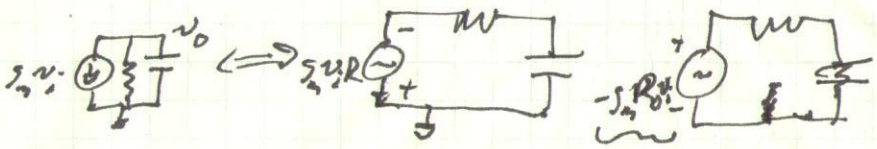
best case, $I_D \geq n V_{TH} g_m = n V_{TH} \omega_u C_0$

Why do anything other than "best case"?

Need to quantify region of operation and sub-V_t current.

Rough estimate is that sub-V_t and inversion currents are equal at $V_{OV} = V_{GS} - V_t = 10mV$ and quadratic model looks good above 100mV

Step response



$\frac{dV}{dt} = \frac{i_C}{C}$ $\quad i_C = \frac{v_R}{R}$ $\quad v_R = (v_{in} - v_o)$

$\frac{dV}{dt} = \frac{v_{in} - v_o}{RC} = \frac{v_{in} - v_o}{\tau}$