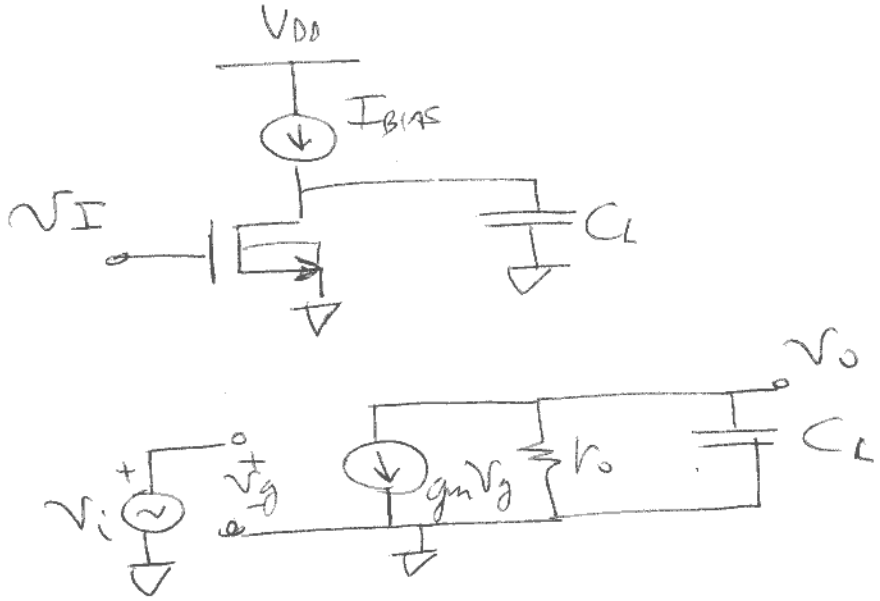
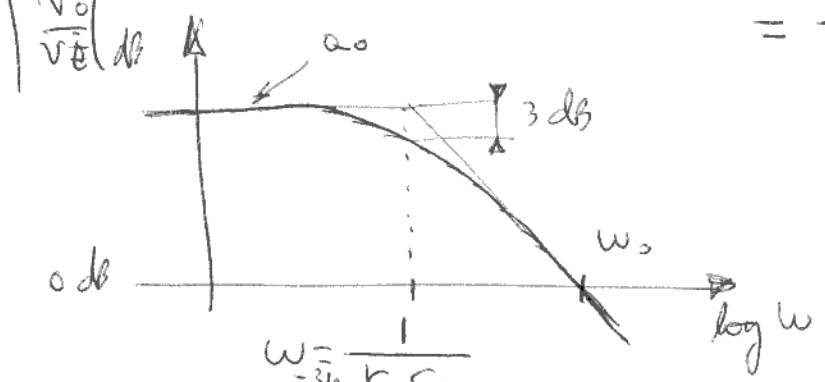
INTRINSIC GAIN STAGE WITH CAPACITIVE LOAD



$$\frac{V_o}{V_i} = -g_m \frac{1}{\frac{1}{r_o} + j\omega C_L} = -g_m r_o \frac{1}{1 + j\omega C_L r_o}$$

$$= -\underbrace{\frac{g_m}{I_D} V_A}_{\substack{\text{LOW-FREQ} \\ \text{GAIN} \\ a_0}} \frac{1}{1 + j\omega C_L \frac{V_A}{I_D}}$$



$$\omega_{-3dB} = \frac{1}{r_o C_L} = \frac{I_D}{C_L V_A}$$

$$\omega_0) \quad 1 \simeq \frac{g_m}{I_D} V_A \times \frac{1}{\omega_0 C_L \frac{V_A}{I_D}}$$

$$\boxed{\omega_0 \simeq \frac{g_m}{C_L}}$$

OBSERVATIONS

$$\omega_0 = a_0 \omega_{-3dB}$$

- BANDWIDTH IMPROVES WITH $I_{BIAS}\uparrow$
- ω_0 INCREASES WITH g_m, NOT $\left(\frac{g_m}{I_D}\right) \Rightarrow \omega_0$ IS GREATER IN STRONG INVERSION:

$$g_m = \frac{2 I_S}{n V_T}\left(\sqrt{1 + if} - 1\right)$$

EXAMPLE: GIVEN A CS STAGE WITH $C_L = 1pF$, CALCULATE W AND I_{BIAS} FOR $|a_0| \geq 150$ AND THE MAXIMUM POSSIBLE ω_0.

$I_{SQ} = 100nA$, $V_{th} = 400mV$, $n = 1.25$, $\begin{cases} V_A = 20V \\ L = 1\mu m \end{cases}$

$C_W = 1.4\frac{fF}{\mu m}$, $C_L = 0.08pF$

$$|a_0| = \frac{g_m}{I_D} V_A = \frac{2}{nV_T}\frac{V_A}{\left(\sqrt{1+i_f}+1\right)} \Rightarrow i_{f_{MAX}} = 50.9$$

$$\omega_0 = \frac{g_m}{C_L + WC_W} = \frac{\frac{g_m}{W}}{\left(\frac{C_L}{W} + C_W\right)}$$

DRAIN CAPACITANCE INCREASES WITH W

$$\omega_0 = \frac{2 I_{SQ}\frac{W}{L}}{n V_T W}\left(\sqrt{1+i_f}-1\right)\frac{1}{\left(\frac{C_L}{W}+C_W\right)}$$

∴ MAX ω_0 OBTAINED WITH $i_{f_{max}}$ AND $\frac{C_L}{W} \ll C_W$

MAKE $W \gg \frac{C_L}{C_W} = 57\mu m \rightarrow W = 500\mu m$

$$\omega_0\Big|_{\substack{W=500\mu m \\ i_f = 50}} = 3.86\times10^9 \times 2\times\pi \ s^{-1} = 3.86GHz \times 2\pi$$

$$I_{BIAS} = I_{SQ}\frac{W}{L} \times i_f = \boxed{2.5mA}$$

FAST; BUT LARGE CURRENT NEEDED

- REDUCING $W = 10\mu m \Rightarrow \begin{cases} \omega_0 = 2\pi \times 640MHz \\ I_{BIAS} = 50\mu A \end{cases}$ SLOWER BUT LESS CONSUMPTION