EECS 240

HW #3 SOLUTIONS

#1 $\left(\frac{W}{L}\right) = \frac{50}{0.25} = 200$

$$\overline{i^2_{d,1/f}} = \frac{K_f I_D}{L^2 C_{ox}} \frac{\Delta f}{f}$$

$K_f = 4.5 \times 10^{-29}$

$C_{ox} = 8.4 \times 10^{-3}$

$g_m = 100\,\mu S \qquad V^* = 0.2V$

$$I_D = \frac{g_m V^*}{2} = 10\,\mu A$$

$$\overline{v_i^2} = \frac{\overline{i^2_{d,1/f}}}{g_m^2} \qquad \frac{I_D}{g_m^2} = \frac{I_D}{(2I_D)^2}(V^*)^2 = \frac{V^{*2}}{4I_D} = \frac{V^*}{2g_m}$$

$$\overline{v^2_{i,T}} = \frac{K_f}{L^2 C_{ox}} \frac{V^*}{2g_m} \ln\left(\frac{f_{hi}}{f_{lo}}\right)$$

The numbers: $\sqrt{\overline{v^2_{i,T}}} = 42.1\,\mu V$ (1Hz)
$57\,\mu V$ (1 year)

The change is pretty minor.

#2) INPUT REF NOISE OF NMOS WITH PMOS LOAD

$$\overline{i_o^2} = \overline{i_{dn}^2} + \overline{i_{dp}^2}$$

$$\overline{v_i^2} = \frac{\overline{i_o^2}}{g_{mn}^2} = 4kT\left(\frac{\gamma}{\alpha}\right)\frac{(g_{mn} + g_{mp})}{g_{mn}^2}$$

$$= 4KT\left(\frac{\gamma}{\alpha}\right)\frac{1}{g_{mn}}\left(1 + \frac{g_{mp}}{g_{mn}}\right)$$

$$= \underbrace{4kT\left(\frac{\gamma}{\alpha}\right)\frac{1}{g_{mn}}}_{\text{INPUT REF NOISE OF M1}}\left(1 + \underbrace{\frac{V_n^*}{V_p^*}}_{\text{PENALTY FOR PMOS LOAD}}\right)$$

MAKE V_p^* LARGE TO MINIMIZE NOISE IMPACT. NOTE THAT V_p^* IS ALSO IMPORTANT FOR OUTPUT SWING (DYNAMIC RANGE). FOR FLICKER NOISE, USE LONG L_p.

FLICKER NOISE $\qquad \overline{i_{1/f}^2} = \frac{K_f I_D}{L^2 C_{ox}}\frac{\Delta f}{f}$

$$\overline{v_i^2} = \frac{\overline{i_{1/f,n}^2} + \overline{i_{1/f,p}^2}}{g_m^2} = \left(\frac{K_{fn}}{L_n^2 C_{oxn}} + \frac{K_{fp}}{L_p^2 C_{oxp}}\right) \times \frac{I_D \frac{\Delta f}{f}}{g_m^2}$$

$$= \frac{I_D K_f}{L_n^2 C_{oxn}}\frac{\Delta f}{f}\left\{1 + \underbrace{\frac{K_{fp}}{K_{fn}}\frac{C_{oxn}}{C_{oxp}}}_{\text{FIXED}}\left(\frac{L_n}{L_p}\right)^2\right\}\frac{1}{g_m^2}$$

#3 BJT NOISE

$$\overline{v_o^2} = |H|^2 \, \overline{v_i^2}$$

$$H = \frac{r_\pi}{r_\pi + R_S} g_m R_L \qquad \text{(LOW FREQ)}$$

$$\overline{v_o^2} = \overline{i_b^2} \, R_S^2 \cdot |H|^2 + \overline{i_c^2} \cdot R_L^2$$

$$\overline{v_i^2} = \overline{i_b^2} \cdot R_S^2 + \overline{i_c^2} \, \frac{(r_\pi + R_S)^2}{r_\pi^2 g_m^2}$$

$$= R_S^2 \left\{ \overline{i_b^2} + \overline{i_c^2} \left(\frac{1 + \frac{r_\pi}{R_S}}{\beta} \right)^2 \right\}$$

$$= R_S^2 \cdot 2q \cdot I_C \left\{ \frac{1}{\beta} + \frac{\left(1 + \frac{r_\pi}{R_S}\right)^2}{\beta^2} \right\}$$

MOS SINCE $i_g \simeq 0$ $\quad \overline{v_i^2} = \frac{\overline{i_d^2}}{g_m^2} = 4kT\frac{\gamma}{\alpha}\frac{1}{g_m}$

$$\overline{v_i^2} = 4\frac{kT}{q} q \frac{\gamma}{\alpha} \frac{V^*}{2I_D}$$

SET $I_D = I_C = 150\mu A$, $\beta = 250$, $V^* = 0.2V$

$\gamma/\alpha = 1.5$ ⇒ SOLVE FOR EQUAL

NOISE ⇒ $R_S^* = 8.6 k\Omega$

IF $R_S < R_S^*$ ⇒ BJT IS BETTER

$R_S > R_S^*$ ⇒ MOS IS BETTER