Similar to GHum 7.1 but replace BJTs with MOS Transistors

\[ q_m = \sqrt{\frac{260}{0.10} \times 500 \text{ mA}} = 1.9 \text{ mA/V} \]
\[ A_f = 9 \text{ mV} \]
\[ f_T = \frac{9 \text{ mV}}{\sqrt{2 \pi (C_{gs} + C_{gd})}} \]
\[ C_{gs} = \frac{q_f}{w \cdot L \cdot C_{ox}} = 2 \frac{1}{3} (100) (16) C_{ox} \]
\[ C_{gd} = q_f \frac{w \cdot L \cdot C_{ox}}{100 (0.2) C_{ox}} = 1 \frac{9}{10} \text{ mF/V} \]
\[ C_{gs} = (100) (10 + 20) \text{ mF/V} \]
\[ C_{gd} = 20 (0.7) = 14 \text{ mF/V} \]

Use Miller Effect for \[ \left| P_1 \right| = \frac{2 \pi \left( R_S \right) [C_{gs} + C_{gd} (1 - A_f)]}{2 \pi (102) [89 + 14 (10)]} = \frac{1}{(67) \text{ MHz}} \]

**DO NOT USE Miller Effect to calculate 2nd Pole!**

From Eq 7.26, \[ \left| P_2 \right| = \frac{\pi M \pi R_L \pi R_S \pi C_{gs} \pi C_{gd}}{2 \pi (\pi x 6.7) (52) (102) [2.5] (2.4) (16) (3.15) (65)] = \frac{1}{(67) \text{ MHz}} \]

The result here is the same as in (1) except that \( C_{gd} \) is included here.

\[ V_0 = 10 - 0.3 \text{ (5k) } = 7.5 \text{ V} \]
\[ C_{db} = 5 (100 \times 0.4) + 100 (0.4) = 240 \text{ FF} \]
\[ C_{db} = 240 / 117.5 / 0.6 = 65 \text{ FF} \]

So the output voltage constant is \[ 5 \text{ x (65)} = 0.3 \text{ nS} \]

So the time constant is \( 1 / [2 \pi (67 \text{ MHz})] = 2.4 \text{ nS} \]

\[ f_{-3dB} = \frac{1}{2 \pi (2.4 \text{ nS})} = 59 \text{ MHz} \]

Iterate to find bias current. Start with \( V_{o3} = 0 \)

Then \( I_3 = (10 - V_3) / 30k = 9 \text{ mA} / 30k = 300 \text{ mA} \)

Then \( I_3 = (10 - 1 - 0.24) / 30k = 290 \text{ mA} \)

\( V_{o3} = 0.24 \text{ V} \) so this is close enough.

Now \( V_{ds} = 10V \), \( V_{ds} = 1.24V \rightarrow AU_{bb} = 9.8 \text{ V} \rightarrow I_1 = I_2 = 290 (1 + \frac{0.2}{10}) = 315 \text{ mA} \)

\[ q_{m1} = \frac{2 (20) (100) (0.4) 315}{2 \text{ M/10}} = 2.0 \text{ M/10} \]
\[ q_{m2} = \frac{2 (20) (100) (0.4) 315}{2 \text{ M/1100}} = 2.5 \text{ M/10} \]
\[ q_{m3} = \frac{2 (20) (100) (0.4) (290)}{2.5 \text{ M/10}} = 2.4 \text{ M/10} \]
\[ I_3 = \frac{2 (20) (100) (0.4) (290)}{2.5 \text{ M/10}} = 3.0 \text{ M/10} \]

\[ A = - (119m) q_f (R_{o1} R_{o2}) = - (100k) / 320k = -110 \text{ k/110} \]

\[ C_{gs} = 2 (20) (100) (0.4) (0.7) + 200 (0.2) (0.7) = 384 \text{ FF} \]

\[ R(C_{gs}) = 119m = 500 \text{ k} \]

\[ R(T_{gs}) = (0.084) (0.5) = 0.04 \text{ ns} \] (very small)

\[ C_{db} = 5 (20) (0.2) + 200 (0.2) = 240 \text{ FF} \]

\[ C_{db} = 5 (100) (0.4) + 100 (0.4) = 240 \text{ FF} \]

So \( C_{db} = \frac{240}{110} \approx 57 \text{ FF} \)

\[ T_{db} = f_{-3dB} \]

Also \( R(C_{db}) = R(C_{db}) = 100 \text{ k/110} = 110 \text{ k/110} \)

\[ C_{gd} = w \text{ L/10} = 100 (0.2) (0.7) = 14 \text{ FF} \]

\[ R(C_{gd}) = (19m) / 110k / 320k + R_{o1} R_{o2} + 9m \times (200k / 320k) / (R_{o1} R_{o2}) \]

\[ = 2 (R_{o1} R_{o2}) = 220k \text{ k} \]

\[ T_{gd} = 0.04 (220) = 3 \text{ ns} \]

\[ C_{gd} = w \text{ L/10} = 200 (0.2) (0.7) = 28 \text{ FF} \]

\[ R(C_{gd}) = (19m) / 110k = 0.028 (220) = 6.2 \text{ ns} \]

So \( f_{-3dB} = \frac{1}{2 \pi (1.25 + 2.25 + 0.73)} = 7.3 \text{ MHz} \)

Note that none of the time constants dominates here.
Solution to HW 7

(3b)

\[ C_{gd} = 20pF + 28\, \text{fF} = 20pF \]
\[ R(C_{gd}) \text{ still is } 22\, k \]
\[ f_{-3dB} = \frac{1}{2\pi (4400\, \text{ns})} = \frac{36}{763}\, \text{kHz} \]

(3.13) 

Similar to 6HA.3, except replace all JFET with NMOS
Current source in tail of M2 & M3 is ideal; therefore, cm gain = 0 → use differential half ckt

(a)

\[ N \left( \frac{10K}{2} \right) = M_1 \quad \frac{N \left( \frac{5K}{2} \right)}{2} = M_2 \]
\[ v_{dd} \]
\[ m_1 = \text{source follower with perfect current source, } \lambda = 0, \text{ and no body effect. } \rightarrow \text{Gain} = 1 \]
\[ m_2 = \text{CS Amp} \]
\[ m_1 = \frac{-9m_2(5K)}{10} = -9.6 \]
\[ q_{m1} = \frac{\sqrt{2(60)(100/1.6)(10)}}{270/44} = 1.9 \, \text{mA/V} \]
\[ q_{m2} = \frac{\sqrt{2(60)(100/1.6)(500)}}{270/44} = 1.9 \, \text{mA/V} \]

(b) Since M1 is an ideal source follower, its gain = 1. Therefore, the voltage across Cgs1 doesn’t change, so ignore Cgs1. Note that if you include Cgs1, ZUTC only predicts the pole. (It ignores the zero.)

\[ C_{gd1} = \frac{wL}{d} \cos^{-1} \left( \frac{100(0.2)(0.7)}{100} \right) = 14\, \text{fF} \]
\[ R(C_{gd1}) = 10K, \quad T_{gd1} = 100(0.14) = 14\, \text{ns} \]
\[ C_{sbo1} = 5(100)(0.1) + 100(0.4) = 240\, \text{fF} \quad \text{Need DC voltage at source of M1} \]
\[ V_{S1} = 0 - V_{T1} - V_{DD1} V_{T1} = \sqrt{2(60)(100)(0.04/1.6)} = 0.07\, \text{V} \]
\[ V_{S1} = 0 - 0.1 - 0.07 = -0.17\, \text{V} \]
\[ C_{sb1} = 240/\left[ 1 + (-0.17 - (-0.8))/0.6 \right] = 80\, \text{fF} \]
\[ R(C_{sb1}) = 1/q_{m1} = 3.7\, \text{K} \quad ; \quad T_{csb1} = 0.08(3.7) = 0.30\, \text{ns} \]

\[ C_{gs2} = 2/3(100)(1.6)(0.1) + 100(0.2)(0.7) = 90\, \text{fF} \]
\[ R(C_{gs2}) = 1/q_{m1} = 3.7\, \text{K} \quad ; \quad T_{csb1} = 0.08(3.7) = 0.33\, \text{ns} \]

\[ C_{db2} = 5(100)(0.4) + 100(0.4) = 240\, \text{fF} \quad \text{Need DC voltage V}_{DD2} \]
\[ V_{OD2} = 6 - 5K(0.5\, \text{mA}) = 3.5\, \text{V} \]
\[ C_{db2} = 240/\left[ 1 + (3.5 + 0.6)/0.6 \right] = 60\, \text{fF} \]
\[ R(C_{db2}) = 5K, \quad T_{db2} = 0.06(5K) = 0.30\, \text{ns} \]

\[ C_{gd2} = \frac{wL}{d} \cos^{-1} \left( \frac{100(0.2)(0.7)}{100} \right) = 14\, \text{fF} \]
\[ R(C_{gd2}) = 1/q_{m1} + 5k + q_{m2}(1/q_{m1})5k = 44\, \text{K} \quad ; \quad T_{gd2} = 0.014(44) = 0.62\, \text{ns} \]
\[ f_{-3dB} = \frac{1}{2\pi (0.1 + 0.30 + 0.33 + 0.30 + 0.62)} = 94\, \text{MHz} \]

Comment: In working ZUTC problems, it pays to be careful, organized, & neat.