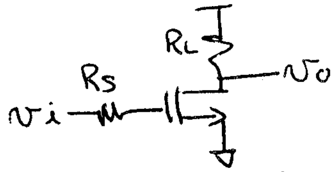
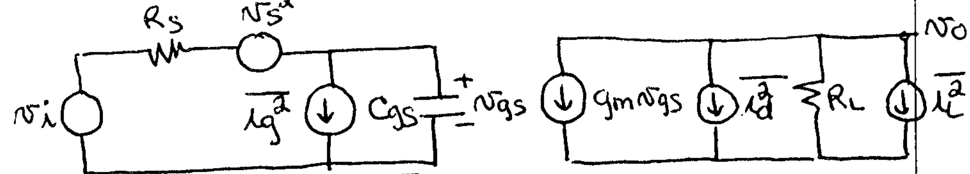
(1)





$\overline{v_s^2} = 4kTR_s\Delta f$

$\overline{i_g^2} = 2qI_G\Delta f \simeq 0$

$\overline{i_L^2} = \dfrac{4kT}{R_L}\Delta f$

$\overline{i_d^2} = 4kT\dfrac{2}{3}g_m\Delta f + \dfrac{g_m^2 K_f \Delta f}{WLC_{ox} f}$

$g_m = \sqrt{2(194)(100)(100)} = 1.97\ \text{mA/V}$

$C_{ox} = \dfrac{3.9\times 8.854\times10^{-14}}{80\times10^{-8}} = 4.3\times10^{-7}\ \dfrac{F}{cm^2} = 4.3\ fF/\mu m^2$

Let $A_v(\omega) = \dfrac{v_o}{v_i}(\omega)$

$A_v(\omega) = -\dfrac{g_m R_L}{1+sC_{gs}R_s}$

$C_{gs} = \frac{2}{3}(100)1(4.3fF) = 287\ fF$

$f_{-3dB} = \dfrac{1}{2\pi C_{gs}R_s} = 5.55\ MHz$

Output noise due to $\overline{v_s^2} = \overline{v_{o1}^2} = A_v^2(\omega)\,\overline{v_s^2}$

Output noise due to $\overline{i_d^2} = \overline{v_{o2}^2} = \overline{i_d^2}\,R_L^2$

Output noise due to $\overline{i_L^2} = \overline{v_{o3}^2} = \overline{i_L^2}\,R_L^2$

At 10 Hz, $|A_v| = 19.7$

$\overline{v_{o1}^2} = (19.7)^2(1.66\times10^{-20})(10^5)\Delta f = 6.44\times10^{-13}\Delta f\ (V^2)$

$\overline{v_{o2}^2} = (1.66\times10^{-20})\frac{2}{3}(1.97\times10^{-3})(10^4)^2\Delta f + \dfrac{(1.97\times10^{-3})^2(3\times10^{-24})\Delta f(10^4)^2}{100(1)(4.3\times10^{-15})\,10}$

$= [2.18\times10^{-15}\Delta f + 2.71\times10^{-10}\Delta f]\ (V^2)$

$\overline{v_{o3}^2} = 1.66\times10^{-20}(10^4)\Delta f = 1.66\times10^{-16}\Delta f\ (V^2)$

$\overline{v_{oT}^2} = \overline{v_{o1}^2} + \overline{v_{o2}^2} + \overline{v_{o3}^2} = 2.72\times10^{-10}\Delta f\ (V^2)$

$\sqrt{\overline{v_{oT}^2}} = 16.5\ \mu V\sqrt{\Delta f}$ (SPICE: $16.4\ \mu V\sqrt{\Delta f}$)

Total input-referred noise $= \sqrt{\overline{v_{iT}^2}} = \sqrt{\overline{v_{oT}^2}}/|A_v| = 837\ nV\sqrt{\Delta f}$

SPICE: $835\ nV\sqrt{\Delta f}$

At 100 kHz $|A_v| \simeq 19.7$

$\overline{v_{o1}^2}$ = same

$\overline{v_{o2}^2} = (2.18\times10^{-15}\Delta f + 2.71\times10^{-14}\Delta f)\ (V^2)$

$\overline{v_{o3}^2}$ = same

$\overline{v_{oT}^2} = 6.73\times10^{-13}\Delta f\ (V^2)$

$\sqrt{\overline{v_{oT}^2}} = 821\ nV\sqrt{\Delta f}$ (SPICE: $817\ nV\sqrt{\Delta f}$)

$\sqrt{\overline{v_{iT}^2}} = 41.7\ nV\sqrt{\Delta f}$ (SPICE: $41.5\ nV\sqrt{\Delta f}$)

At 1 GHz $|A_v| = 19.7/\sqrt{1+(1000/5.55)^2} = 0.109$

$\overline{v_{o1}^2} = (0.109)^2(1.66\times10^{-20})(10^5)\Delta f = 1.98\times10^{-17}\Delta f\ (V^2)$

$\overline{v_{o2}^2} = 2.18\times10^{-15}\Delta f + 2.71\times10^{-18}\Delta f$

$\overline{v_{o3}^2}$ = same

$\overline{v_{oT}^2} = 2.37\times10^{-15}$

$\sqrt{\overline{v_{oT}^2}} = 48.7\ nV\sqrt{\Delta f}$ (SPICE: $48.5\ nV\sqrt{\Delta f}$)

$\sqrt{\overline{v_{iT}^2}} = 48.7\ nV\sqrt{\Delta f}/0.109 = 446\ nV\sqrt{\Delta f}$ (SPICE: $445\ nV\sqrt{\Delta f}$)

Therefore,

At 10 Hz, 1/f noise dominates

At 100 Hz, thermal noise from R_s dominates

At 1 GHz, thermal noise from the transistor dominates

(2)

$K_p' = \mu_p C_{ox} = 150(4.3\times10^{-7}) = 64.7\ \mu A/V^2$

$K_n' = \mu_n C_{ox} = 450(4.3\times10^{-7}) = 194\ \mu A/V^2$

$g_{m1} = \sqrt{2(64.7)(150/0.72)(100)} = 1.64\ mA/V$

$g_{m3} = \sqrt{2(194)(50/0.72)(100)} = 1.64\ mA/V = g_{m1}$

Noise is dominated by $M_1 - M_4$

At 100 Hz

$M_{1,2}$ thermal: $\frac{2}{3}\frac{4kT}{g_{m1}}\Delta f = \frac{2}{3}\frac{(1.66\times10^{-20})}{1.64m} = 6.75\times10^{-18}\Delta f\ (V^2)$

$M_{1,2}$ flicker: $\frac{K_f\Delta f}{WLC_{ox}f} = \frac{3\times10^{-24}\Delta f}{150(0.72)(4.3\times10^{-15})100} = 6.46\times10^{-14}\Delta f\ (V^2)$

$M_{3,4}$ thermal: $\frac{2}{3}\frac{4kT}{g_{m3}}\frac{g_{m3}^2}{g_{m1}^2}\Delta f = \frac{2}{3}\frac{(1.66\times10^{-20})}{1.64m} = 6.75\times10^{-18}\Delta f\ (V^2)$

$M_{3,4}$ flicker: $\frac{K_f\Delta f}{WLC_{ox}f}\frac{g_{m3}^2}{g_{m1}^2} = \frac{3\times10^{-24}\Delta f}{50(0.72)(4.3\times10^{-15})100} = 1.94\times10^{-13}\Delta f\ (V^2)$

$\overline{v_{iT}^2} = 2\left[6.75\times10^{-18} + 6.46\times10^{-14} + 6.75\times10^{-18} + 1.94\times10^{-13}\right]\Delta f$

$= 5.17\times10^{-13}\Delta f\ (V^2)$

$\sqrt{\overline{v_{iT}^2}} = 719\ nV\sqrt{\Delta f}$ (SPICE: $699\ nV\sqrt{\Delta f}$)

Flicker noise is dominant, especially from $M_3 + M_4$

At 1 kHz

$M_{1,2}$ thermal = same

$M_{1,2}$ flicker $= 6.46\times10^{-15}\Delta f\ (V^2)$

$M_{3,4}$ thermal = same

$M_{3,4}$ flicker $= 1.94\times10^{-14}\Delta f\ (V^2)$

$\overline{v_{iT}^2} = 5.17\times10^{-14}\Delta f\ (V^2)$

$\sqrt{\overline{v_{iT}^2}} = 227\ nV\sqrt{\Delta f}$ (SPICE: $221\ nV\sqrt{\Delta f}$)

At 10 kHz

$M_{1,2}$ thermal = same

$M_{1,2}$ flicker $= 6.46\times10^{-16}\Delta f\ (V^2)$

$M_{3,4}$ thermal = same

$M_{3,4}$ flicker $= 1.94\times10^{-15}\Delta f\ (V^2)$

$\overline{v_{iT}^2} = 5.20\times10^{-15}\Delta f\ (V^2)$

$\sqrt{\overline{v_{iT}^2}} = 72.1\ nV\sqrt{\Delta f}$ (SPICE: $70.0\ nV\sqrt{\Delta f}$)