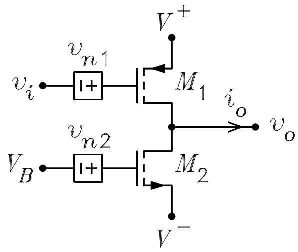
ECE 6416 Assignment 5

1. The figure shows a CMOS amplifier consisting of a p-channel input transistor M_1 and an n-channel load transistor M_2 biased by a fixed gate voltage V_B.



(a) Show that the small-signal voltage gain is given by

$$\frac{v_o}{v_i} = -g_{m1}\left(r_{ds1} \| r_{ds2}\right)$$

(b) Show that the small-signal short-circuit output current is given by

$$i_{o(sc)} = -g_{m1}\left(v_i + v_{n1}\right) - g_{m2} v_{n2}$$

(c) If only flicker noise is modeled, show that the mean-square equivalent noise input voltage is given by

$$v_{ni}^2 = \frac{K_{f1}\Delta f}{2\mu_p L_1 W_1 C_{ox}^2 f}\left[1 + \frac{K_{f2}}{K_{f1}}\left(\frac{L_1}{L_2}\right)^2\right]$$

How should the W and L for each device be chosen to minimize the noise? (L_2 and W_1 should be large and L_1 and W_2 should be small)

2. The following MOSFET data are given

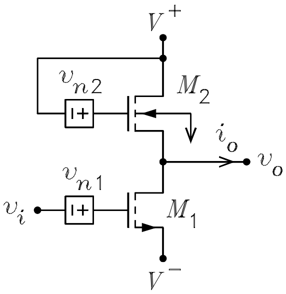
	n-Channel (M_2)	p-Channel (M_1)
$\frac{\mu_0 C_{ox}}{2}$	$7\,\mu\text{A}/\text{V}^2$	$3\,\mu\text{A}/\text{V}^2$
$\frac{K_f}{2\mu_0 C_{ox}^2}\int_{20}^{20k}\frac{df}{f}$	$380 \times 10^3\,(\mu\text{V} \times \mu\text{m})^2$	$48 \times 10^3\,(\mu\text{V} \times \mu\text{m})^2$

If the value of C_{ox} is the same for both MOSFETs in the circuit of Problem 1, calculate v_{ni} for the following values of W and L:

	W_1	L_1	W_2	L_2
Case 1	$1000\,\mu$m	$5\,\mu$m	$400\,\mu$m	$4\,\mu$m
Case 2	$1000\,\mu$m	$5\,\mu$m	$200\,\mu$m	$8\,\mu$m
Case 3	$500\,\mu$m	$10\,\mu$m	$400\,\mu$m	$4\,\mu$m

($16.9\,\mu$V, $8.88\,\mu$V, and $33.4\,\mu$V)

3. The figure shows an n-channel NMOS enhancement-mode common-source amplifier with an active n-channel NMOS enhancement-mode load. The two transistors are biased at the same drain current I_D and have the same value for C_{ox}.



(a) Show that the small-signal short-circuit output current is given by

$$i_{o(sc)} = -g_{m1}\left(v_i + v_{n1}\right) + g_{m2}v_{n2}$$

(b) Show that the small-signal output resistance is given by

$$r_{out} = r_{ds1} \| r_{ds2} \| \left(\frac{1}{g_{m2}\left(1+\chi_2\right)}\right)$$

(c) Show that the open-circuit output voltage is given by

$$v_{o(oc)} = \left(-g_{m1}\left(v_i + v_{n1}\right) + g_{m2}v_{n2}\right) \times r_{ds1} \| r_{ds2} \| \left(\frac{1}{g_{m2}\left(1+\chi_2\right)}\right)$$

(d) If only flicker noise is modeled, show that the mean-square equivalent noise input voltage is given by

$$v_{ni}^2 = \frac{K_{f1}\Delta f}{2\mu_n C_{ox}^2 L_1 W_1 f}\left[1 + \left(\frac{L_1}{L_2}\right)^2\right]$$

It is obvious that W_1 should be large to minimize the noise. What should L_1 be to minimize the noise? ($L_1 = L_2$)

(e) If only thermal noise is modeled, show that the mean-square equivalent noise input voltage is given by

$$v_{ni}^2 = \frac{4kT\Delta f}{3\sqrt{K_1 I_D}}\left[1 + \sqrt{\frac{L_1 W_2}{L_2 W_1}}\right]$$

How should the W and L for each device be chosen to minimize the noise? (L_2 and W_1 should be large and L_1 and W_2 should be small)

4. Repeat problem 2 for part (d) of problem 3. (14.0 μV, 10.3 μV, and 23.5 μV)