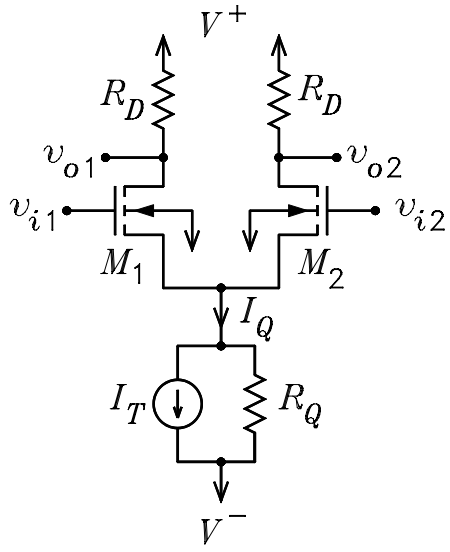
ECE3050 Assignment 12

1. The figure shows a differential amplifier. Each MOSFET has the parameters $g_m = 1/400\,\text{S}$, $r_0 = 40\,\text{k}\Omega$, and $\chi = 0.5$. It is given that $R_D = 10\,\text{k}\Omega$ and $R_Q = 20\,\text{k}\Omega$. The answers given assume the r_0 approximations.



   (a) Show that the resistance seen looking out of each source is $R_{ts} = 263.16\,\Omega$, the resistance seen looking into each drain is $r_{id} = 79.74\,\text{k}\Omega$, and the output resistance seen looking into the two outputs with $v_{i1} = v_{i2} = 0$ is $r_{out1} = r_{out2} = 8.886\,\text{k}\Omega$.

   (b) For the differential inputs $v_{i1} = v_{id}/2$ and $v_{i2} = -v_{id}/2$, show that $v_{o1}/v_{id} = -v_{o2}/v_{id} = -11.11$.

   (c) For the common-mode inputs $v_{i1} = v_{icm}$ and $v_{i2} = v_{icm}$, show that $v_{o1}/v_{icm} = v_{o2}/v_{icm} = -0.147$.

2. For a MOSFET diff amp, show that the body effect cancels out with differential inputs if there is no external resistor in series with the source leads, i.e. $R_S = 0$. Hint: For differential inputs, the currents can be calculated with the sources connected to signal ground. This is the case in the preceding problem.

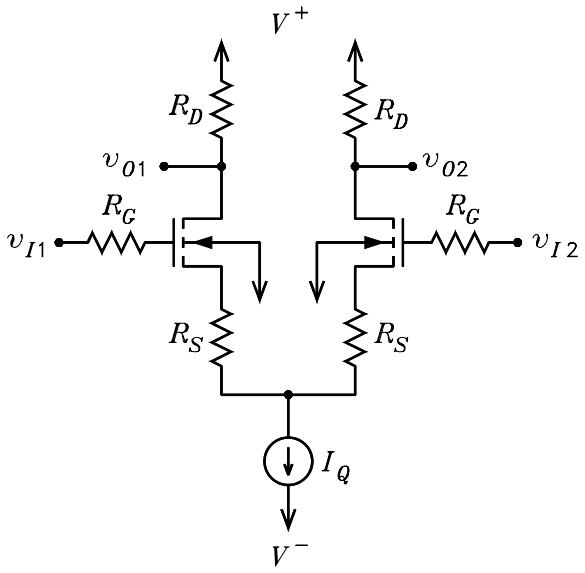
3. The figure shows a MOSFET differential amplifier. For the MOSFETs, it is given that $k' = 0.008\,\text{A/V}^2$, $W/L = 1$, $V_{TO} = 1.5\,\text{V}$, $\lambda = 0$, and $\chi = 0.4$. For the circuit, it is given that $V^+ = 20\,\text{V}$, $V^- = -20\,\text{V}$, $I_Q = 2.5\,\text{mA}$, $R_G = 5\,\text{k}\Omega$, $R_S = 100\,\Omega$, and $R_D = 12\,\text{k}\Omega$. Assume the dc components of each input are zero, i.e. $V_{I1} = V_{I2} = 0$.

   (a) With $v_{I1} = v_{I2} = 0$, calculate V_{GS} for each transistor. Answer: $V_{GS} = 1.956\,\text{V}$.

   (b) With $v_{I1} = v_{I2} = 0$, calculate V_D for each transistor. Answer: $V_D = 5\,\text{V}$.

   (c) Use the value of V_{GS} found in part (a) and the value of V_D found in part (b) to solve for V_{DS} for each transistor. Verify that $V_{DS} > V_{GS} - V_{TO}$. Answers: $V_{DS} = 6.956\,\text{V}$ and $V_{GS} - V_{TO} = 0.456\,\text{V}$.

   (d) Calculate g_m, r_s, r_s', r_0, and the resistance R_{ts} seen looking out of each source. Answers: $g_m = 5.477\,\text{mS}$, $r_s = 182.6\,\Omega$, and $r_s' = 130.4\,\Omega$, $r_0 = \infty$, and $R_{ts} = 330.4\,\Omega$.



(e) With $v_{i2} = 0$, show that

$$\frac{v_{o1}}{v_{i1}} = -\frac{v_{o2}}{v_{i1}} = -18.6 \qquad r_{out} = 12\,\text{k}\Omega$$

(f) With $v_{i1} = 0$, use the Norton drain circuit to show that

$$\frac{v_{o2}}{v_{i2}} = -\frac{v_{o1}}{v_{i2}} = -18.6 \qquad r_{out} = 12\,\text{k}\Omega$$

(g) For the differential input signals $v_{i1} = v_{id}/2$ and $v_{i2} = -v_{id}/2$, show that

$$\frac{v_{o1}}{v_{id}} = -\frac{v_{o2}}{v_{id}} = -18.6$$

(h) For the common mode inputs $v_{i1} = v_{i2} = v_{icm}$, why is the common-mode gain equal to zero? Answer: Because the tail supply is a perfect current source.