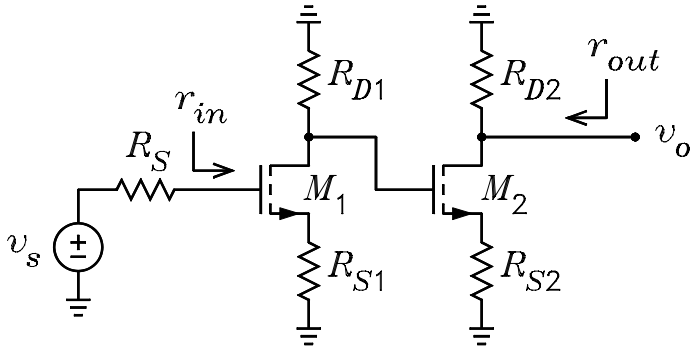
ECE3050 Assignment 11

1. The figure shows the ac signal circuit of a cascade common-source amplifier. For each MOSFET, it is given that $I_D = 2\,\text{mA}$, $r_0 = \infty$, and $K = 0.25 \times 10^{-3}\,\text{A/V}^2$. The circuit element values are $R_S = 1\,\text{k}\Omega$, $R_{S1} = R_{S2} = 510\,\Omega$, $R_{D1} = R_{D2} = 15\,\text{k}\Omega$.



   (a) Show that $g_{m1} = g_{m2} = 1.414\,\text{mS}$ and $r_{s1} = r_{s2} = 707.1\,\Omega$.

   (b) Use the T models or simplified T models to show that the voltage gain is given by

$$\frac{v_o}{v_s} = \frac{-R_{D1}}{r_{s1} + R_{S1}} \times \frac{-R_{D2}}{r_{s2} + R_{S2}} = 152 \;\; (43.6\,\text{dB})$$

   (c) Use the π models to show that the voltage gain is given by

$$\frac{v_o}{v_s} = \frac{-R_{D1}}{\dfrac{1}{g_{m1}} + R_{S1}} \times \frac{-R_{D2}}{\dfrac{1}{g_{m2}} + R_{S2}} = 152 \;\; (43.6\,\text{dB})$$

   (d) Show that the input resistance is given by

$$r_{in} = \infty$$

   (e) Show that the output resistance is given by

$$r_{out} = R_{D2} = 15\,\text{k}\Omega$$

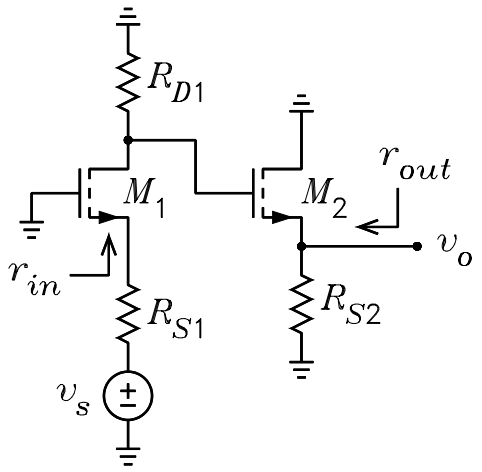
   (f) What would be the new gain if a resistor $R_L = 1\,\text{k}\Omega$ is connected from output to ground? Answer: $v_o/v_s = 9.50$ (19.6 dB), a decrease of 24 dB.

2. The ac signal circuit of a common-gate amplifier driving a common-drain amplifier is shown. For each MOSFET, it is given that $I_D = 2\,\text{mA}$, $r_0 = \infty$, and $K = 0.5\,\text{mA/V}^2$. The circuit element values are $R_{S1} = 220\,\Omega$, $R_{D1} = 15\,\text{k}\Omega$, $R_{S2} = 2\,\text{k}\Omega$.

   (a) Show that $g_{m1} = g_{m2} = 2\,\text{mS}$ and $r_{s1} = r_{s2} = 500\,\Omega$.

   (b) Use the T models or simplified T models to show that the voltage gain is given by

$$\frac{v_o}{v_s} = \frac{R_{D1}}{r_{s1} + R_{S1}} \times \frac{R_{S2}}{r_{s2} + R_{S2}} = 16.67 \;\; (24.4\,\text{dB})$$



(c) Use the π models to show that the voltage gain is given by

$$\frac{v_o}{v_s} = \frac{R_{D1}}{\dfrac{1}{g_{m1}} + R_{S1}} \times \frac{R_{S2}}{\dfrac{1}{g_{m2}} + R_{S2}} = 16.67 \ (24.4\,\text{dB})$$

(d) Show that the input resistance is given by

$$r_{in} = 500\,\Omega$$

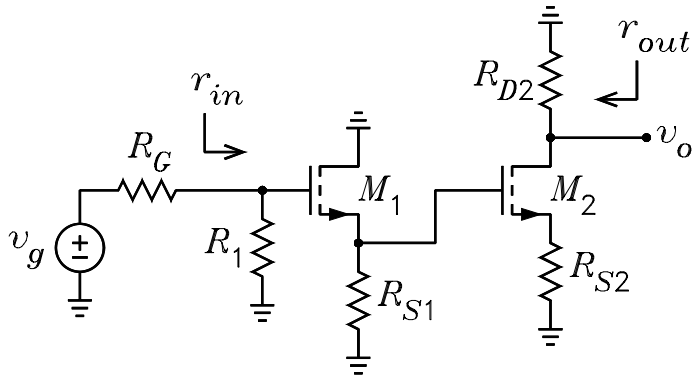
where $R_{td1} = R_{D1}$.

(e) Show that the output resistance is

$$r_{out} = 400\,\Omega$$

(f) What would be the new gain if a resistor $R_L = 300\,\Omega$ is connected from output to signal ground? Answer: $v_o/v_s = 7.143$ (17.1 dB), a decrease of 7.36 dB.

3. The figure shows a common-drain amplifier followed by a common-source amplifier. For each MOSFET, it is given that $I_D = 1.5\,\text{mA}$, $r_0 = \infty$, and $K = 0.5\,\text{mA/V}^2$. The circuit element values are $R_G = 10\,\text{k}\Omega$, $R_1 = 1\,\text{M}\Omega$, $R_{S1} = 2\,\text{k}\Omega$, $R_{S2} = 470\,\Omega$, and $R_{D2} = 20\,\text{k}\Omega$.



(a) Show that $g_{m1} = g_{m2} = 1.732\,\text{mS}$ and $r_{s1} = r_{s2} = 577.4\,\Omega$.

(b) Use the T models or simplified T models to show that the voltage gain is given by

$$\frac{v_o}{v_s} = \frac{R_1}{R_G + R_1} \times \frac{R_{S1}}{r_{s1} + R_{S1}} \times \frac{-R_{D2}}{r_{s2} + R_{S2}} = -14.8$$

(c) Use the π models to show that the voltage gain is given by

$$\frac{v_o}{v_s} = \frac{R_1}{R_G + R_1} \times \frac{R_{S1}}{\dfrac{1}{g_{m1}} + R_{S1}} \times \frac{-R_{D2}}{\dfrac{1}{g_{m2}} + R_{S2}} = -14.8$$

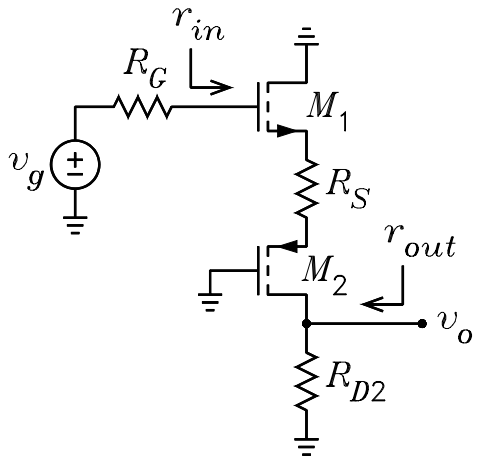
(d) Show that the input resistance is given by

$$r_{in} = 1\,\mathrm{M\Omega}$$

(e) Show that the output resistance is given by

$$r_{out} = R_{D2} = 20\,\mathrm{k\Omega}$$

4. The figure shows a common-drain stage driving a common-gate stage. For each MOSFET, it is given that $I_D = 2\,\mathrm{mA}$, $r_0 = \infty$, and $K = 0.5 \times 10^{-3}\,\mathrm{A/V^2}$. The circuit element values are $R_G = 1\,\mathrm{M\Omega}$, $R_S = 200\,\Omega$, $R_{D2} = 20\,\mathrm{k\Omega}$.



(a) Show that $g_{m1} = g_{m2} = 2\,\mathrm{mS}$ and $r_{s1} = r_{s2} = 500\,\Omega$.

(b) Use the T models or simplified T models to show that the voltage gain is given by

$$\frac{v_o}{v_s} = \frac{R_{D2}}{r_{s1} + R_S + r_{s2}} = 16.67$$

(c) Use the π models to show that the voltage gain is given by

$$\frac{v_o}{v_s} = \frac{R_{D2}}{\dfrac{1}{g_{m1}} + R_S + \dfrac{1}{g_{m2}}} = 16.67$$

(d) Show that the input resistance is given by

$$r_{in} = \infty$$

(e) Show that the output resistance is given by

$$r_{out} = R_{D2} = 20\,\mathrm{k\Omega}$$