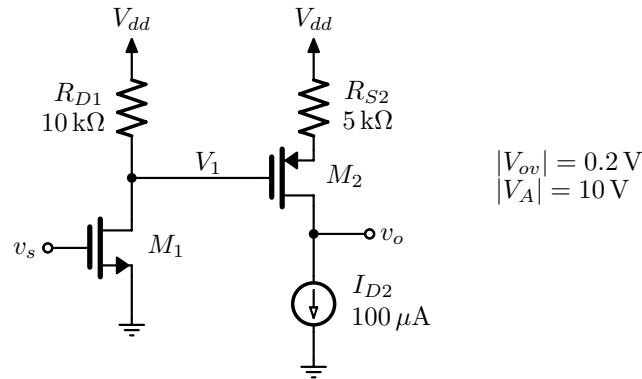


Problem Set 2

Q1. For the figure shown below, all transistors (including the current source which is assumed to be made of a single transistor) has $|V_{ov}| = 0.2 \text{ V}$ and $|V_A| = 10 \text{ V}$. Assume $I_{D1} = 100 \mu\text{A}$.



- Find v_1/v_s , v_o/v_1 and v_o/v_s .
- Find R_{out} .

Solution

First the gain v_1/v_s is calculated:

$$g_{m1} = 2 * I_{D1} / |V_{ov}| = 1 \text{ mA/V}$$

$$r_{o1} = |V_A| / I_{D1} = 100 \text{ k}\Omega$$

$$V_1/V_s = -g_{m1} * (R_{D1} || r_{o1}) = -(1e-3) * ((10e3) || (100e3)) = -9.091 \text{ V/V}$$

$$V_1/V_s = -9.091 \text{ V/V}$$

Next we can take a look at M_2 :

$$g_{m2} = 2 * I_{D2} / |V_{ov}| = 1 \text{ mA/V}$$

$$r_{o2} = |V_A| / I_{D2} = 100 \text{ k}\Omega$$

Looking into the drain of transistor M_2 , we get:

$$R_x = r_{o2} + R_{S2} * (1 + g_{m2} * r_{o2}) = (100e3) + (5e3) * (1 + (1e-3) * (100e3)) = 605 \text{ k}\Omega$$

As such, the output impedance is:

$$R_{out} = R_x || r_{o2} = (605e3) || (100e3) = 85.82 \text{ k}\Omega$$

$$R_{out} = 85.82 \text{ k}\Omega$$

The the gain v_o/v_i can be calculated:

$$V_o/V_1 = -1 / (R_{S2} + 1/g_{m2}) * R_{out} = -1 / ((5e3) + 1/(1e-3)) * (85.82e3) = -14.3 \text{ V/V}$$

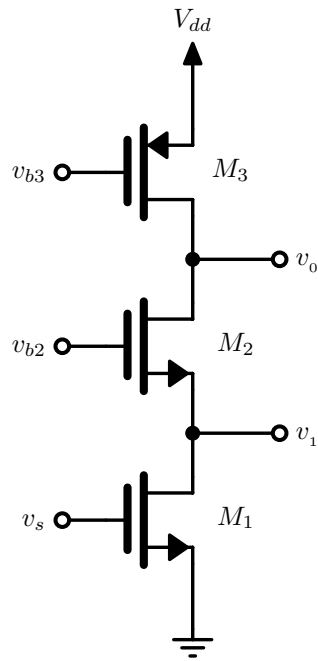
$$V_o/V_1 = -14.3 \text{ V/V}$$

Finally, the total gain can be calculated:

$$V_o/V_s = V_1/V_s * V_o/V_1 = (-9.091) * (-14.3) = 130 \text{ V/V}$$

$$V_o/V_s = 130 \text{ V/V}$$

Q2. For the figure shown below, all transistors (including the current source which is assumed to be made of a single transistor) has $|V_{ov}| = 0.2 \text{ V}$ and $|V_A| = 10 \text{ V}$. Assume $I_{D1} = 100 \mu\text{A}$.



- a) Find v_1/v_s , v_o/v_1 and v_o/v_s .
 b) Find R_{out} .

Solution

First g_m and r_o can be calculated:

$$g_{m1} = 2 * I_{D1} / |V_{ov}| = 1 \text{ mA/V}$$

$$g_{m2} = g_{m1} = 1 \text{ mA/V}$$

$$g_{m3} = g_{m1} = 1 \text{ mA/V}$$

$$r_{o1} = |V_A| / I_{D1} = 100 \text{ k}\Omega$$

$$r_{o2} = r_{o1} = 100 \text{ k}\Omega$$

$$r_{o3} = r_{o1} = 100 \text{ k}\Omega$$

Next, the impedance looking into the source of M2 can be calculated:

$$R_{xs} = (r_{o3} + r_{o2}) / (1 + g_{m2} * r_{o2}) = 1.98 \text{ k}\Omega$$

Next, the impedance looking into the drain of M2 can be calculated:

$$R_{xd} = r_{o2} + r_{o1} * (1 + g_{m2} * r_{o2}) = 10.2 \text{ M}\Omega$$

The impedance of node V_1 is as follows:

$$R_{x1} = R_{xs} || r_{o1} = 1.942 \text{ k}\Omega$$

The impedance of node V_o which is also R_{out} is as follows:

$$R_{out} = R_{xd} || r_{o3} = 99.03 \text{ k}\Omega$$

$$R_{out} = 99.03 \text{ k}\Omega$$

Finally, the transfer function gains can be calculated:

$$V_1/V_s = -g_{m1} * R_{x1} = -(1e-3) * (1.942e3) = -1.942 \text{ V/V}$$

$$V_1/V_s = -1.942 \text{ V/V}$$

$$V_o/V_s = -g_{m1} * R_{out} = -(1e - 3) * (99.03e3) = -99.03 \text{ V/V}$$

$$V_o/V_s = -99.03 \text{ V/V}$$

$$V_o/V_1 = (V_o/V_s)/(V_1/V_s) = ((-99.03))/((-1.942)) = 51 \text{ V/V}$$

$$V_o/V_1 = 51 \text{ V/V}$$