MOSFET Differential Amplifier Example
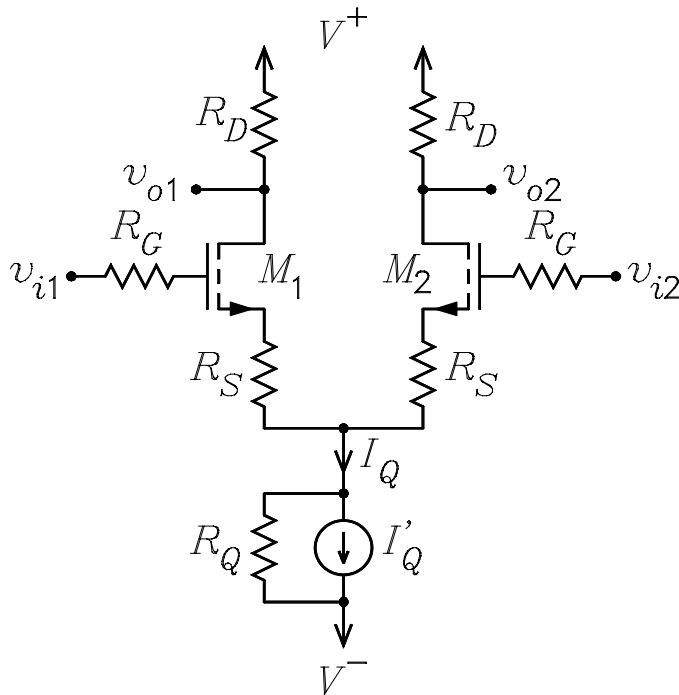
$$R_p(x,y) := \frac{x \cdot y}{x+y}$$

$I_Q := 0.0015 \quad R_Q := 40000 \quad R_S := 50 \quad R_D := 18000 \quad V_p := 20 \quad V_n := -20$

$K := 0.0025 \quad V_{TO} := 1.2 \quad \lambda := 0.01$

DC Bias Solution

$$I_D := \frac{I_Q}{2} \qquad I_D = 7.5 \bullet 10^{-4} \qquad V_{GS} := V_{TO} + \sqrt{\frac{I_D}{K}} \qquad V_{GS} = 1.748$$

$$V_{DS} := V_p - I_D \cdot R_D + V_{GS} \qquad V_{DS} = 8.248$$

$\sqrt{\dfrac{I_D}{K}} = 0.548$ This is equal to $V_{GS} - V_{TO}$ which is less than V_{DS}. Thus active mode.

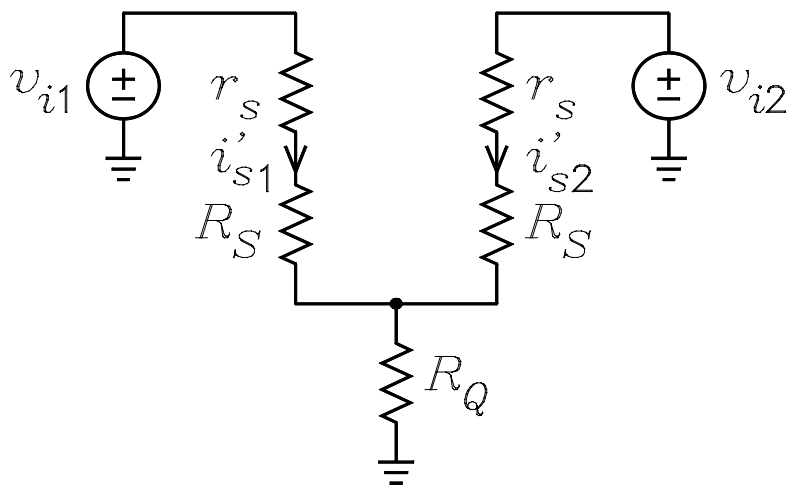**Small-Signal AC Solution** Use the r_0 approximations.

$$r_0 := \frac{\lambda^{-1} + V_{DS}}{I_D} \qquad r_0 = 1.443 \bullet 10^5$$

$$g_m := 2 \cdot \sqrt{K \cdot I_D} \quad g_m = 2.739 \bullet 10^{-3} \qquad r_s := \frac{1}{g_m} \qquad r_s = 365.148$$

$$R_{ts} := R_S + R_p\left(R_Q, R_S + r_s\right) \qquad R_{ts} = 460.884$$

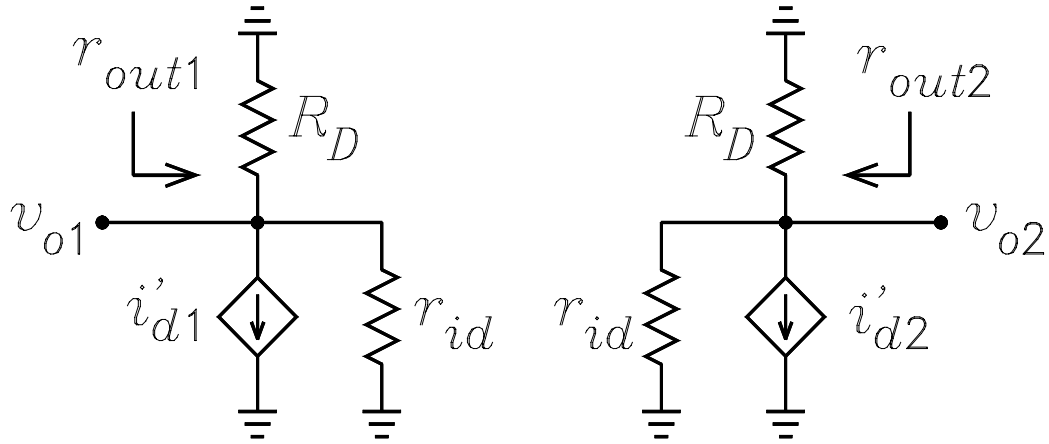$$r_{id} := r_0 \cdot \left(1 + \frac{R_{ts}}{r_s}\right) + R_{ts} \qquad r_{id} = 3.27 \bullet 10^5$$

Emitter equivalent circuit.

$$A_{v11} = \frac{v_{o1}}{v_{i1}} \qquad A_{v11} := \frac{1}{r_s + R_{ts}} \cdot -R_p\left(R_D, r_{id}\right) \qquad A_{v11} = -20.654$$

$$A_{v12} = \frac{v_{o2}}{v_{i1}} \qquad A_{v12} := -A_{v11} \cdot \frac{R_Q}{R_Q + R_S + r_s} \qquad A_{v12} = 20.442$$

Drain equivalent circuit

$$A_{v22} = \frac{v_{o2}}{v_{i2}} \qquad A_{v22} := \frac{1}{r_s + R_{ts}} \cdot -R_p(R_D, r_{id}) \qquad A_{v22} = -20.654$$

$$A_{v21} = \frac{v_{o1}}{v_{i2}} \qquad A_{v21} := -A_{v22} \cdot \frac{R_Q}{R_Q + R_S + r_s} \qquad A_{v21} = 20.442$$

$$r_{out} := R_p(r_{id}, R_D) \qquad r_{out} = 1.706 \cdot 10^4$$

For the v_{o1} output.

$$A_{v1d} := \frac{R_p(r_{id}, R_D)}{r_s + R_S + R_p(R_Q, r_s + R_S)} \cdot \frac{2 \cdot R_Q + r_s + R_S}{R_Q + r_s + R_S} \qquad A_{v1d} = 41.096 \qquad \text{differential gain}$$

$$A_{v1cm} := \frac{R_p(r_{id}, R_D)}{r_s + R_S + R_p(R_Q, r_s + R_S)} \cdot \frac{r_s + R_S}{R_Q + r_s + R_S} \qquad A_{v1cm} = 0.212 \qquad \text{common-mode gain}$$

$$CMRR_{dB} := 20 \cdot \log\left(\frac{A_{v1d}}{A_{v1cm}}\right) \qquad CMRR_{dB} = 45.743 \qquad \text{dB}$$