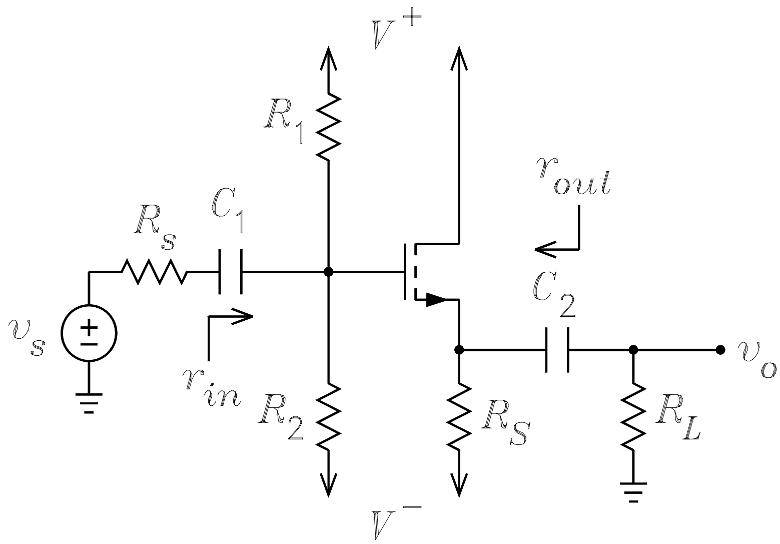
Common-Drain Amplifier Example

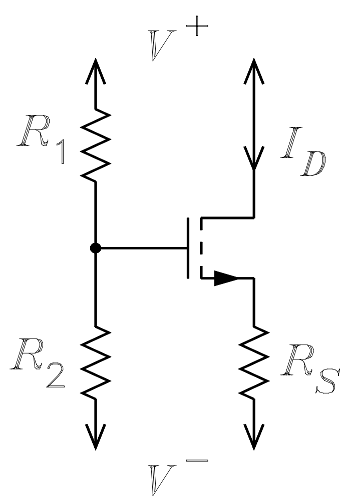
$K_{prime} := 0.002$ $W := 1$ $L := 1$ $V_{TO} := 1.75$ $\lambda := 0.016$

$V_{plus} := 24$ $V_{minus} := -24$ $R_1 := 5 \cdot 10^6$ $R_2 := 1 \cdot 10^6$

$R_S := 3 \cdot 10^3$ $R_L := 20 \cdot 10^3$ $R_s := 5 \cdot 10^3$ $R_p(x, y) := \dfrac{x \cdot y}{x + y}$



DC Bias Solution



$$V_{GG} := \frac{V_{plus} \cdot R_2 + V_{minus} \cdot R_1}{R_1 + R_2} \qquad V_{GG} = -16 \qquad V_{SS} := V_{minus} \qquad R_{SS} := R_S$$

$$V_1 := V_{GG} - V_{SS} - V_{TO} \qquad V_1 = 6.25$$

We neglect the Early effect, i.e. set $\lambda = 0$ to solve for the drain bias current.

$$K := K_{prime} \cdot \frac{W}{L}$$

$$I_D := \frac{1}{2 \cdot K \cdot R_S^{\,2}} \cdot \left(\sqrt{1 + 2 \cdot K \cdot V_1 \cdot R_S} - 1\right)^2 \qquad I_D = 1.655 \cdot 10^{-3}$$

$$V_D := V_{plus} \qquad V_D = 24 \qquad V_S := V_{minus} + I_D \cdot R_S \qquad V_S = -19.036$$

$$V_{DS} := V_D - V_S \qquad V_{DS} = 43.036$$

$$V_{GS} := V_{GG} - V_S \qquad V_{GS} = 3.036 \qquad V_{GS} - V_{TO} = 1.286$$

Because $V_{DS} > V_{GS} - V_{TO}$, the MOSFET is in the active or saturated state.

Here is an exact solution for the drain current. Note that MathCad requires numbers for everything except the variable being solved for. The drain-source voltage in the equation is $48 - I_D \cdot 13 \cdot 10^3$

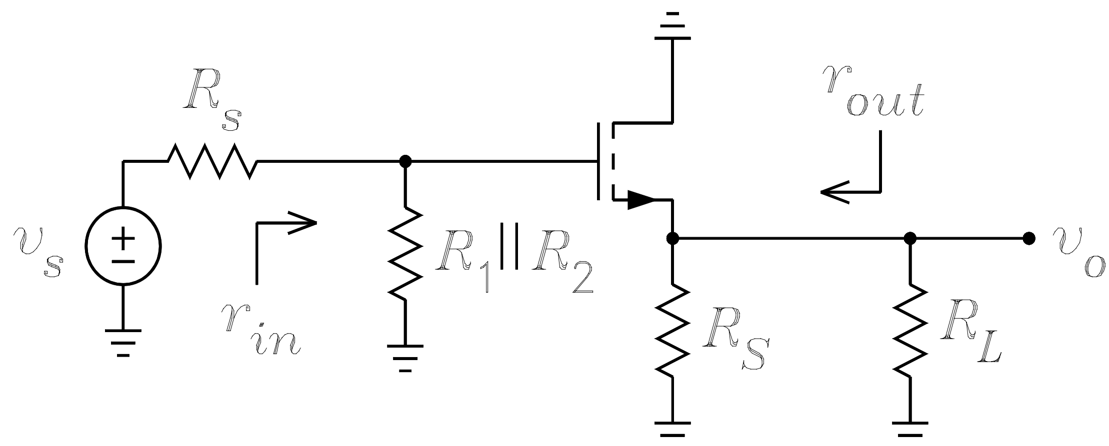
$$I_D = \frac{1}{4 \cdot 10^{-3} \cdot \left[1 + 0.016 \cdot \left(48 - I_D \cdot 3 \cdot 10^3\right)\right] \cdot 3000^2} \cdot \left[\sqrt{1 + 4 \cdot 10^{-3} \cdot \left[1 + \left[0.016 \cdot \left(48 - I_D \cdot 3 \cdot 10^3\right)\right]\right] \cdot 6.25 \cdot 3000} - 1\right]^2$$

.0017441295129196544703 This is the exact solution for I_D including the Early effect. We will use the approximate solution for the ac analysis below.

$$\frac{I_D - .0017441295129196544703}{.0017441295129196544703} \cdot 100 = -5.135$$

This is the percentage error in neglecting the Early effect in solving for the drain current.

Now for the ac solution.



$K := K_{prime} \cdot \frac{W}{L} \cdot (1 + \lambda \cdot V_{DS})$ $\quad K = 3.377 \cdot 10^{-3}$ $\quad g_m := \sqrt{2 \cdot K \cdot I_D}$ $\quad g_m = 3.343 \cdot 10^{-3}$

$r_s := \frac{1}{g_m}$ $\quad r_s = 299.135$

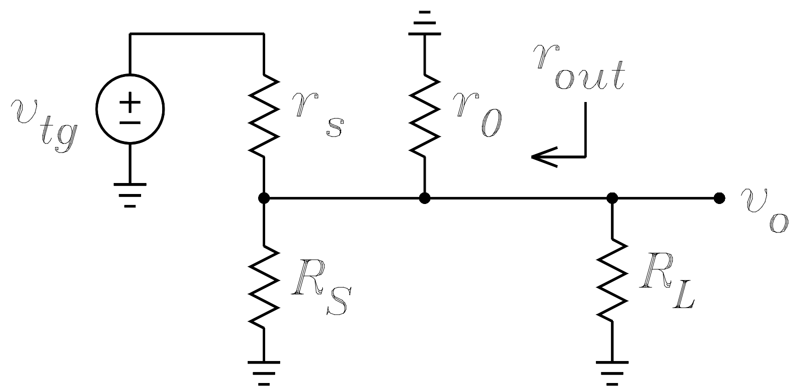
$r_0 := \frac{\lambda^{-1} + V_{DS}}{I_D}$ $\quad r_0 = 6.378 \cdot 10^4$

$v_s := 1$ This makes the gain equal to v_o.

$v_{tg} := v_s \cdot \frac{R_p(R_1, R_2)}{R_s + R_p(R_1, R_2)}$ $\quad v_{tg} = 0.994$

$R_{tg} := R_p(R_s, R_p(R_1, R_2))$ $\quad R_{tg} = 4.97 \cdot 10^3$

Model r_0 as an external resistor connected from source to ground. Thus the r_0 approximations do not need to be used.



$v_o := v_{tg} \cdot \frac{R_p(r_0, R_p(R_S, R_L))}{r_s + R_p(r_0, R_p(R_S, R_L))}$ $\quad v_o = 0.888 \quad$ This is the voltage gain.

$r_{out} := R_p(R_S, R_p(r_s, r_0))$ $\quad r_{out} = 270.857$

$r_{in} := R_p(R_1, R_2)$ $\quad r_{in} = 8.333 \cdot 10^5$