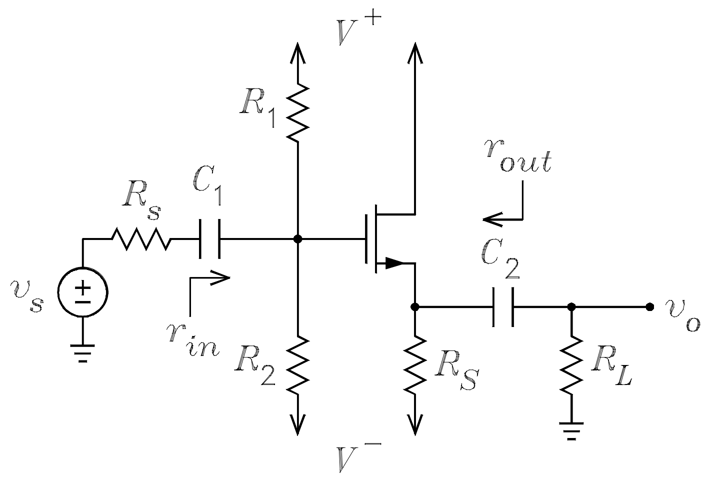
Common-Drain Amplifier Example

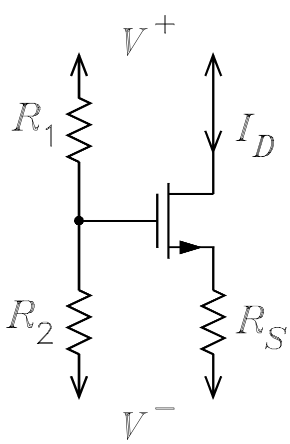
$K_{prime} := 0.002$ $W := 1$ $L := 1$ $V_{TO} := 1.75$ $\lambda := 0.016$ $\chi := 0$

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

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



DC Bias Solution



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

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

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

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

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

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

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

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

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

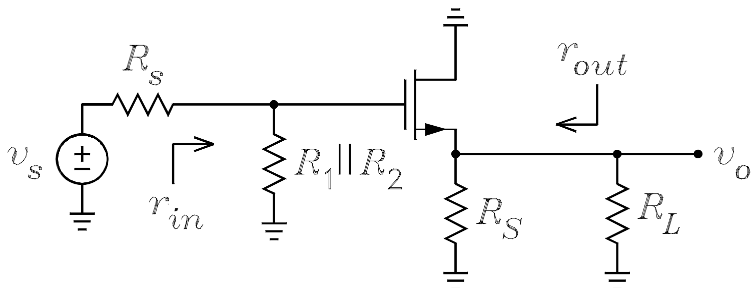
Here is an exact solution for the drain current. Note that MathCad requires numbers for everything except the variable being solved for. The drain-source voltage in the equation is $48 - I_D \cdot 13 \cdot 10^3$

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

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

$\dfrac{I_D - .0017441295129196544703}{.0017441295129196544703} \cdot 100 = -5.135$ This is the percentage error in neglecting the Early effect in solving for the drain current.

Now for the ac solution.



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

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

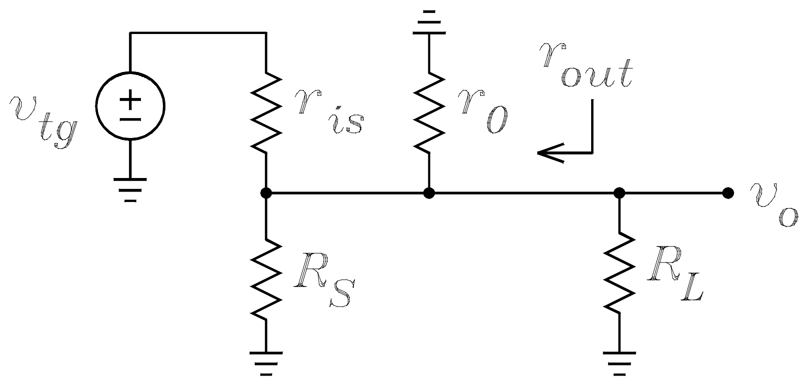
$r_{is} := \frac{r_s}{(1 + \chi)}$ $r_{is} = 299.135$ No body effect because the body lead is connected to the source lead. Thus $\chi = 0$ in the equations.

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

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

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

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



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

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

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

An Alternate Solution using the Thevenin equivalent circuit looking into the source.
Note that $R_{td} = 0$ in the formulas for v_{soc} and r_{iso}.

$v_{soc} := v_{tg} \cdot \dfrac{r_0}{r_{is} + r_0}$ $\quad v_{soc} = 0.989$

$r_{iso} := R_p(r_{is}, r_0)$ $\quad r_{iso} = 297.738$

$v_o := v_{soc} \cdot \dfrac{R_p(R_S, R_L)}{r_{iso} + R_p(R_S, R_L)}$ $\quad v_o = 0.888$

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