ECE 2200L
Introduction to Microelectronics Circuits Laboratory

Experiment 8
MOSFET Biasing Stability and Signaling

Report

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Objective

To design a 4-resistor biasing circuit to meet specification with a pre existing MOSFET from the earlier Lab (Lab7).

Prelab

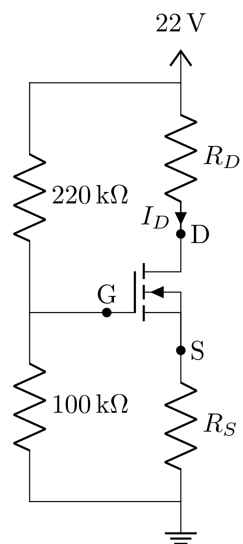

Figure 1: Circuit of Step 1 and Step 2

Given $V_T = 1.6\,\mathrm{V}$ and $K_n = 0.1\ \mathrm{mAV^{-2}}$, we can determine the value of R_D and R_S such that the circuit is biased to a Q-point of $I_{Dq} = 2.5\,\mathrm{mA}$ and $V_{DSq} = 8\,\mathrm{V}$

$$V_G = (22\,\mathrm{V})\frac{100000}{220000 + 100000} = 6.875\,\mathrm{V} \tag{1}$$

$$I_D = \frac{K_n}{2}\left(V_{GS} - V_T\right)^2 \tag{2}$$

$$2.5 = \frac{0.1}{2}\left(V_{GS} - 1.6\right)^2 \tag{3}$$

$$V_{GS} = 1.758\,\mathrm{V} \tag{4}$$

$$V_S = V_G - V_{GS} = 5.117\,\mathrm{V} \tag{5}$$

$$R_S = \frac{5.117\,\mathrm{V}}{2.5\,\mathrm{mA}} = 2.05\,\mathrm{k\Omega} \approx 2.2\,\mathrm{k\Omega} \tag{6}$$

$$R_D = \frac{22 - V_D}{I_D} = \frac{(22 - (8 + 5.117))\,\mathrm{V}}{2.5\,\mathrm{mA}} = \frac{8.885\,\mathrm{V}}{2.5\,\mathrm{mA}} = 3.553\,\mathrm{k\Omega} \approx 3.9\,\mathrm{k\Omega} \tag{7}$$

Procedure

Step 1

Circuit in figure 1 was constructed with MOSFET with $V_T = 1.6\,\text{V}$ and $K_n = 0.1\,\text{mAV}^{-2}$. V_D, V_G and V_S was measured in order to determine Q-point parameter I_{Dq} and V_{DSq}.

$$
\begin{aligned}
V_D &= 13.00\,\text{V} \\
V_G &= 6.8\,\text{V} \\
V_S &= 5.01\,\text{V}
\end{aligned}
$$

From the above values I_{Dq} and V_{DSq} can be found

$$
\begin{aligned}
V_{DSq} &= 13.00 - 5.01 = 7.99\,\text{V}, \text{ a -0.125\% difference from specification} \\
I_{Dq} &= \frac{22 - 13.00}{3900} = 2.3\,\text{mA}, \text{ a -8\% difference from specification}
\end{aligned}
$$

Step 2

Circuit 1 was then constructed with a ddifferent MOSFET. V_D, V_G and V_S was measured in order to determine Q-point parameter I_{Dq} and V_{DSq}.

$$
\begin{aligned}
V_D &= 12.67\,\text{V} \\
V_G &= 6.8\,\text{V} \\
V_S &= 5.2\,\text{V}
\end{aligned}
$$

From the above values I_{Dq} and V_{DSq} can be found

$$
\begin{aligned}
V_{DSq} &= 12.67 - 5.2 = 7.47\,\text{V}, \text{ a -6.51\% difference from} \\
I_{Dq} &= \frac{22 - 12.67}{3900} = 2.39\,\text{mA}, \text{ a 3.91\% difference from specification}
\end{aligned}
$$

Step 3

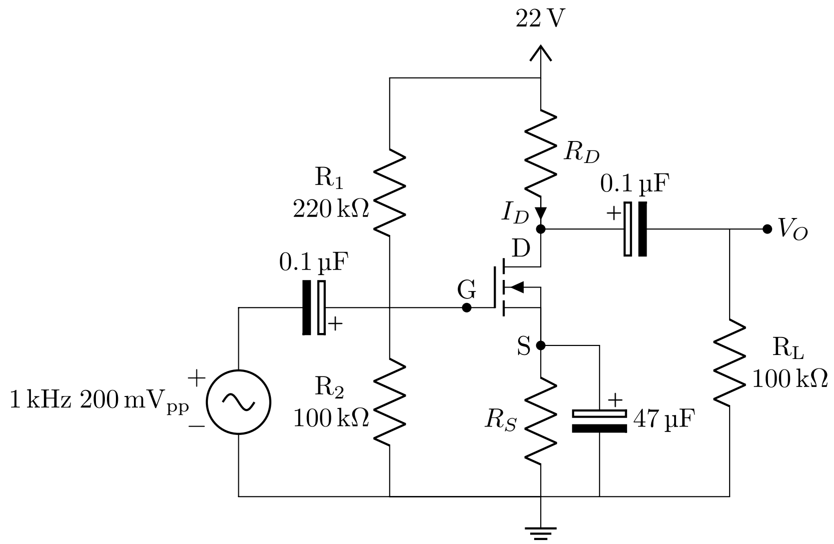

Figure 2: Circuit of Step 3

Given $V_T = 1.6\,\mathrm{V}$ and $K_n = 0.1\,\mathrm{mAV}^{-2}$ and a Q-point at $I_{Dq} = 2.5\,\mathrm{mA}$ and $V_{DSq} = 8\,\mathrm{V}$, we can calculate the small signal transconductance g_m as follow

$$I_D = \frac{K_n}{2}\left(V_{GS} - V_T\right)^2$$

$$\sqrt{\frac{2}{K_n} I_D} = \left(V_{GS} - V_T\right)$$

$$g_m = \frac{\delta I_D}{\delta V_{GS}} = K_n \left(V_{GS} - V_T\right) = \sqrt{2 K_n I_{Dq}} = 22.36\,\mathrm{mS}$$

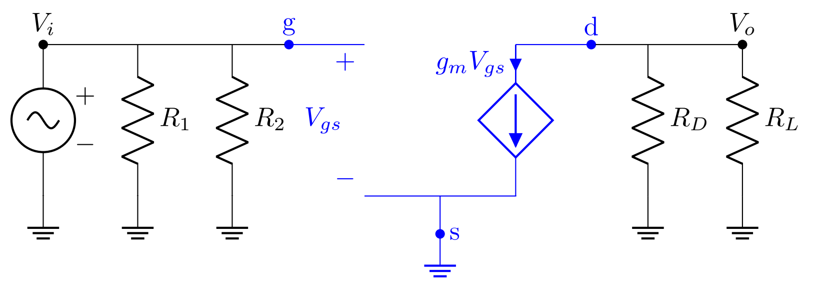

Figure 3: Circuit in Step 3 using small signal model MOSFET (blue)

Using the small signal model, $A_V = \frac{V_o}{V_i}$ can then be derived

$$
\begin{aligned}
V_i &= V_{gs} \\
V_o &= -g_m V_{gs} \left(R_D || R_L\right) \\
A_V &= \frac{V_o}{V_i} = -g_m \left(R_D || R_L\right) \\
A_V &= -(22.36\,\mathrm{mS})(3.9\,\mathrm{k\Omega} || 100\,\mathrm{k\Omega}) = -83.93
\end{aligned}
$$

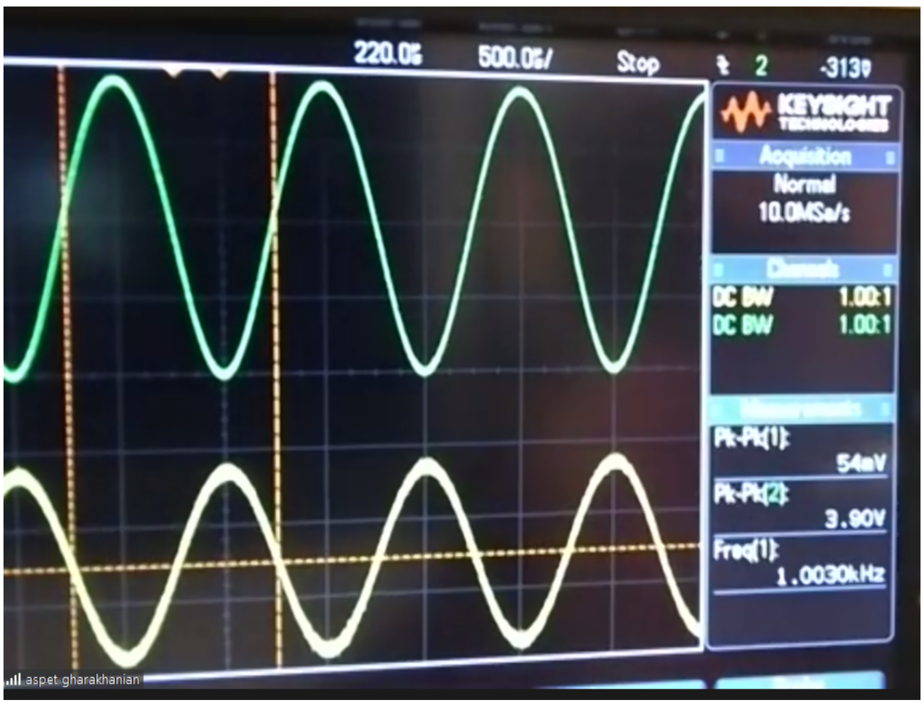

Figure 4: Oscilloscope output of Step 3 circuit (Figure 2) showing $V_{i_{pp}} = 54\,\mathrm{mV}$ and $V_{o_{pp}} = 3.90\,\mathrm{V}$

From the Oscilloscope the experimental value of A_V can be calculated

$$A_V = -\frac{3900}{54} \approx -72.22, \text{ a -14.0\% difference from theoretical value}$$

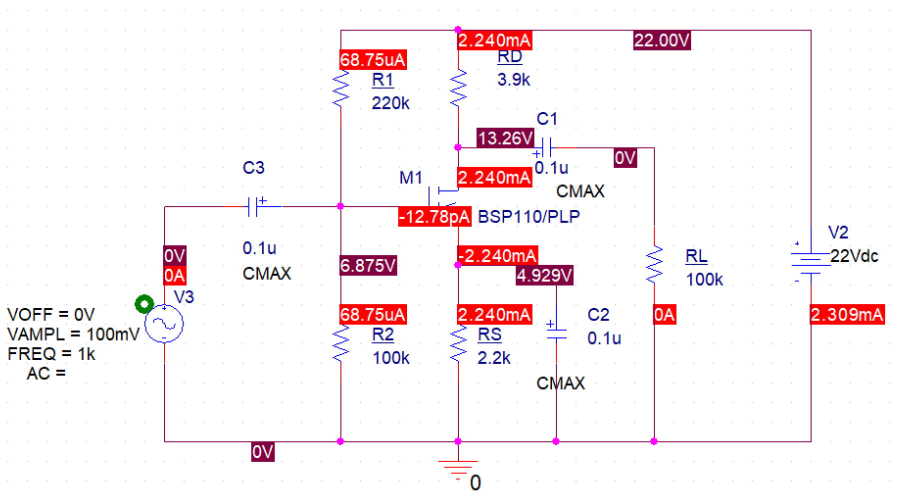

Figure 5: PSpice simulation of Step 3 circuit

Conclusion

As demonstrated above, change in K_n and V_T in a bias circuit designed for a specific MOSFET affects the resulting Q-point parameters.