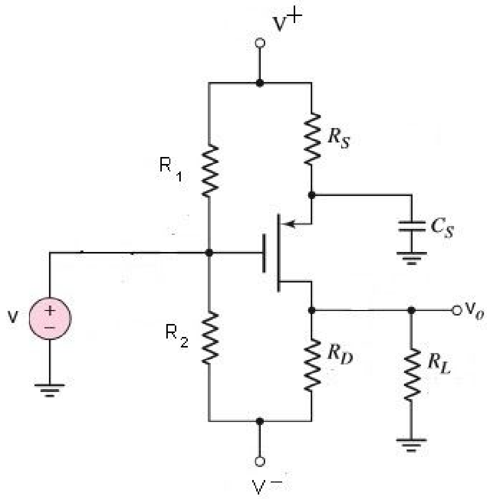
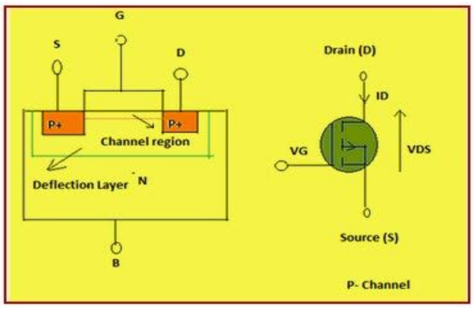
EE-212 Electronics I
Project Report

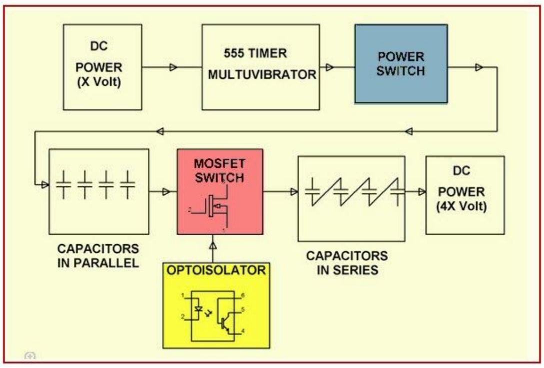
250206008 Berke EREN
250206039 Korkut Emre ARSLANTÜRK



PMOS common-source circuit

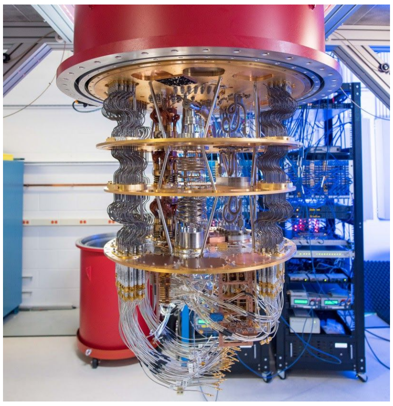


The MOSFET (Metal Oxide Semiconductor Field Effect Transistor) is a semiconductor device which is widely used for switching and amplifying electronic signals in the electronic devices. The MOSFET has four terminal: source(S), gate (G), drain (D) and body (B). The MOSFET is an important element in embedded system design which is used to control the loads as per the requirement.



Many of electronic projects developed using MOSFET such as light intensity control, motor control and max generator applications. The MOSFET is very far the most common transistor and can be used in both analog and digital circuits. It will have P-channel and N-channel. It consists of a source, gate and drain. MOSFETs provide greater efficiency while operating at lower voltages. The P-Channel MOSFET consist negative ions so it works with negative voltages.

There are a lot of important invention in history and one of the most important is transistors. Transistors are the fundamental electronic components present in any device. Computers, phones, space travels, internet, wireless charging, automation, electric vehicles, planes, satellites or in future artificial intelligence, augmented reality, interstellar journeys, information age, all of them is possible thanks to transistors. Today we had come to the last level of Moore's law(Moore's Law states that the number of transistors on a microchip doubles about every two years.). In the future, we have to leave the classical physics behind us and enter the quantum world in order to make the transistors smaller and use them in nanoscale. Unlike classical computers, quantum computers use qubits, not bits and thanks to superposition, quantum computers can use both of 1 and 0 at same time because of that quantum computers can faster do operations which, classical computers spend a lot of time. In 2016, Google announces the completion of the simulation of the hydrogen molecule and a company called IonQ recently simulated the water molecule. Molecule simulation means understanding the quantum universe, this is not possible with classic computers. When you can simulate molecules, an incredible door opens in physics, chemistry and medicine. A fully developed quantum computer can simulate your body at the atomic level, it can find the problems and instantly simulate the necessary medications to solve the problems. it can reduce take years of medicine tests to seconds. It can plan any material at the atomic level for any business and contribute to its production. In summary, quantum computers are opening a new era for humanity and mosfet and other transistors can be key of this era.



In this study, we aimed to analyze the PMOS common-source circuit. We will design the circuit based on the DC analysis using Mosfet information we have studied in the lessons. In addition to this design, we will calculate the Miller capacitance by applying the Miller approach to circuit and Based on the frequency response information, we will calculate the upper corner frequency.

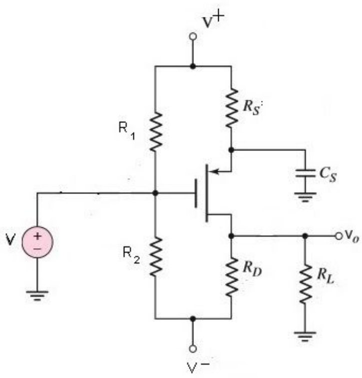
Firstly, we calculate V_{SG} on saturation region.

$$V_G = V; I_{DQ} = K_P (V_{SG} + V_{TP})^2 \quad I_{DQ} = (V^+ - V_{SG} - V_G) / R_S$$

When we calculate V_{SG} we can calculate I_{DQ}: $\quad I_{DQ} = K_P (V_{SG} + V_{TP})$

->To verify the saturation region;

$$V_{SDQ}(sat) = V_{SGQ} + V_{TP} \qquad V_{SDQ} > V_{SDQ}(sat)$$



>Now we calculate, R_1 and R_2 resistors;

$$(V^+ - V_G)/R_1 = (V_G - V^-)/R_2$$

-> Now we calculate drain voltage;

$$V^+ - V_{GS} - V_{SD} = V_D$$

->Drain resistor;

$$R_D = (V_D - V^-)/ I_{DQ}$$

-> V_{RD} and I_A;

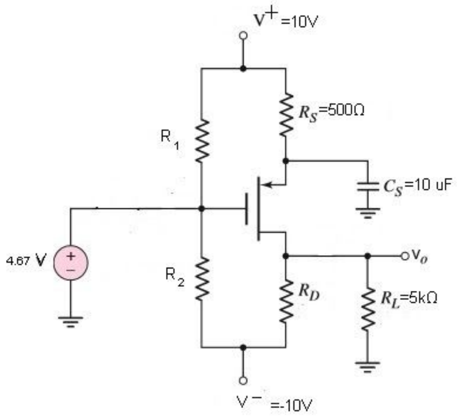
$$V_{RS} = I_{DQ} * R_S \qquad I_A = (V_D - V^-)/R_D$$

This capacitive effect, which is effective in the gate-drain joint at high frequencies, is called the Miller capacitance.

$$G_M = 2K_P(V_{SGQ} + V_{TP}) \qquad C_M = C_F(1 + G_M(R_D||R_L))$$

->Upper corner frequency (3 dB);

$$t = R_{EQ} (C_G + C_M) \qquad f_H = 1 / (2\pi t)$$



We assume that: V^{+}=10V, V^{-}=10V, V_{SDQ}= 3V, V_{TP}=-2V , V_{GS}= 0.4V, K_P = 1 mA/V² , V = 4.67 V , C_G = 3 pF , Cg = 15 pF , R_L= 5k ohm, R_S= 0.5 k ohm , C_S = 10 uF;

$K_P(V_{SG}+V_{TP})^2=(V^{+}-V_{SG}-V_G) / R_S$

$=> 0.5\text{-}V_{SG}^2 - V_{SG} - 4.33 = 0$

$V_{SG} = 4.1$ V

$I_{DQ} = K_P(V_{SG} + V_{TP})^2 \;=>\; I_{DQ} = 1\,(4.1 - 2)^2 = 4.41$ mA

$V_{SDQ}(sat) = V_{SGQ} + V_{TP} = 2.1$ V $\quad V_{SDQ} > V_{SDQ}(sat) \;=>\; 3 > 2.1$

$(V^{+}-V_G)/R_1 = (V_G-V^{-})/R_2$ Lets say R_1= 8k ;

$(10 - 4.67) / 8 = (10 + 4.67) / R_2 \;=>\;$ R2= 22.01 k ohm

$V_{RS} = I_{DQ} * R_S \;=>\; V_{RS}$= 0.5k * 4.41m = 2.21 V

$V_D = V^{+} - V_{GS} - V_{SD} \;=>\; V_D$= 10 -0.4 – 3 = 6.6 V

$R_D = (V_D - V^{-})/ I_{DQ} \;=>\; R_D$ = (6.6 + 10) / 4.41 = 4.8 k ohm

$I_A = (V_D-V^{-})/R_D \;=>\; I_A$= (6.6 + 10)/ 4.8 = 3.45 mA

$G_M=2K_P(V_{SGQ}+V_{TP}) \;=>\; G_M$=2*1(4.1-2)=4.2 mAV (Transconductance)

$C_M = C_F(1 + G_M(R_D||R_L)) =>$ 3*(1+(4.2)(4.8||5)) = 29.55 pF (Miller capacitance)

$t = R_{EQ}(C_G + C_M) =>$ (8||22)(15+29.55)*10^{-12} = 2.61 *10^{-7} s

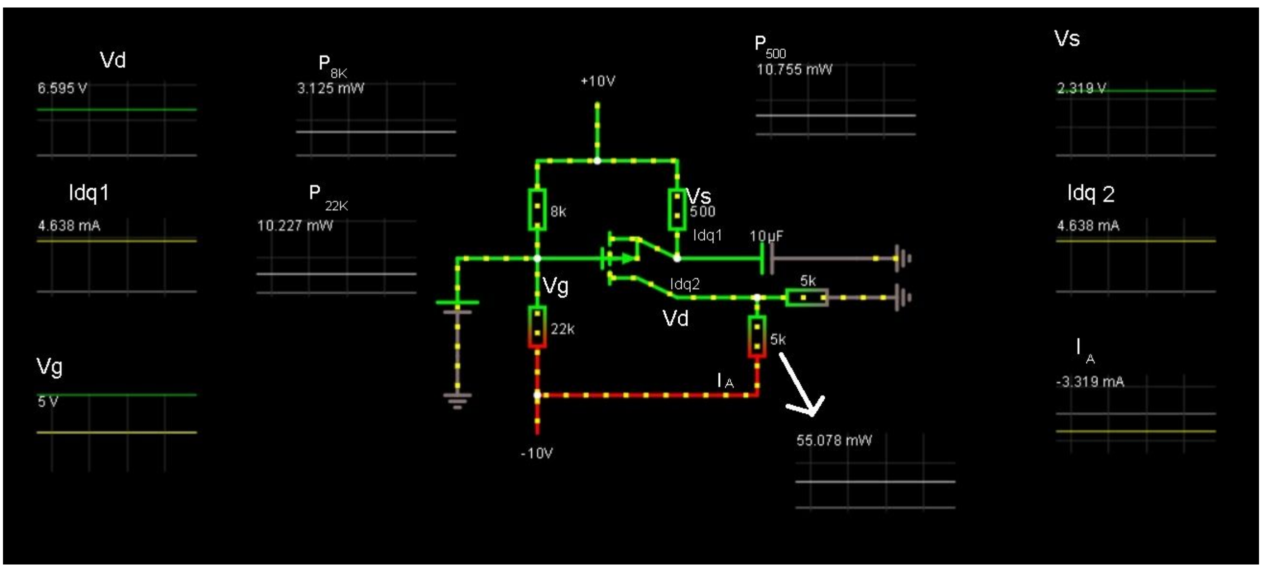
$f_H = 1 / (2\pi t)$ = 6.1 MHz

$P_{8k\Omega}=(V-V^{+})^2/R_1=(5V-10V)^2/8000\Omega$=3.125mW

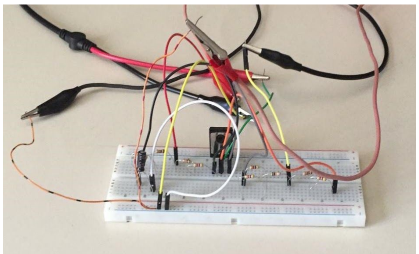
$P_{22k\Omega}=(V-V^{-})^2/R_2=(5V+10V)^2/22000\Omega$=10.227mW

$P_{500\Omega}=(I_{DQ})^2 * R_S=(4.41)^2*500$=10.755mW

$P_{5k\Omega}=(V_D-V^{-})^2/R_D=(6.6V+10V)^2/5000$=55.078mW



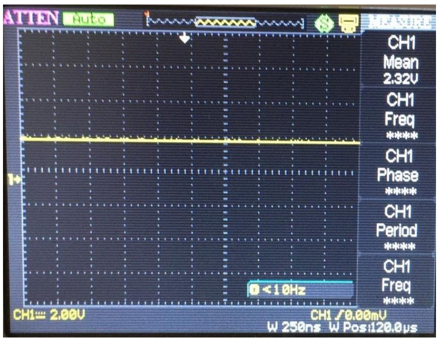
Simulation Result(using Paul Falstad Circuit Simulator)



Our circuit

V_G

V_D



V_S

I_{DQ1-2}

I_A

	V_D	V_S	I_{DQ1-2}	I_A
Analyze	**6.6V**	**2.21 V**	**4.41mA**	**-3.45mA**
Simulation	**6.59V**	**2.319V**	**4.63mA**	**-3.319mA**
Measured	**6.56V**	**2.32V**	**4.72mA**	**-3.36mA**
error between analyze and simulation	**%0.15**	**4.70**	**4.75**	**3.94**
error between analyze and measured	**%0.61**	**4.74**	**6.5**	**2.67**

The main reasons for seeing different results in our transactions:

- In our analysis, the results we get due to decimal rounding during operations vary step by step depending on each other for the parts after the comma. Therefore, the results we found analysis differ from the simulation and measured values.
- On the other hand, when measuring, we find results depending on the internal resistance of the circuit elements or measuring device but in our analysis, we do not take them into our operations.
- Measured values change due to small errors caused by non ideal measuring devices or caused by the of not ideal environment. Because of that measured values can be different from simulation result and analysis.
- Analytic analysis gives support to your idea theoretically and in mathematical equation. On the other hand simulation analysis shows that your idea is physically implementable or not. If both results are well agreed, the analytical model is quite accurate. For this circuit we can see simulation result and analysis result are well agreed.

References

https://link.springer.com/article/10.1007/s00502-017-0534-y

https://www.electronics-notes.com/articles/electronic_components/fet-field-effect-transistor/power-mosfet.php

https://en.wikipedia.org/wiki/PMOS_logic#:~:text=P%2Dtype%20metal%2Doxide%2D,an%20n%2Dtype%20transistor%20body.

https://pnpntransistor.com/applications-of-mosfet/

https://electricalfundablog.com/mosfet-working-types-applications-advantages-disadvantages/

https://en.wikipedia.org/wiki/MOSFET#Applications

https://www.typesnuses.com/types-of-mosfet-applications/

https://www.elprocus.com/mosfet-as-a-switch-circuit-diagram-free-circuits/#:~:text=The%20MOSFET%20(Metal%20Oxide%20Semiconductor,signals%20in%20the%20electronic%20devices.

https://www.prnewswire.com/news-releases/future-of-transistor-technology-300581617.html#:~:text=Transistors%20are%20the%20fundamental%20electronic,years%20in%20size%20and%20performance.&text=Transistors%20are%20being%20developed%20in,wireless%20charging%20and%20energy%20conversion.

250206039_KorkutEmre_Arslanturk.circuit.js