EE236: Lab 9
Mobility of Charge Carriers in N-channel MOSFET and Temperature Dependence

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1 Aim of the experiment

1. To characterize a discrete nMOS at room temperature by measuring I_D for a constant V_{DS} and varying V_{GS}. Using this we calculate β.
2. To observe the variation of β at different temperature for constant V_{DS} and varying V_{GS}.

2 Design & Working

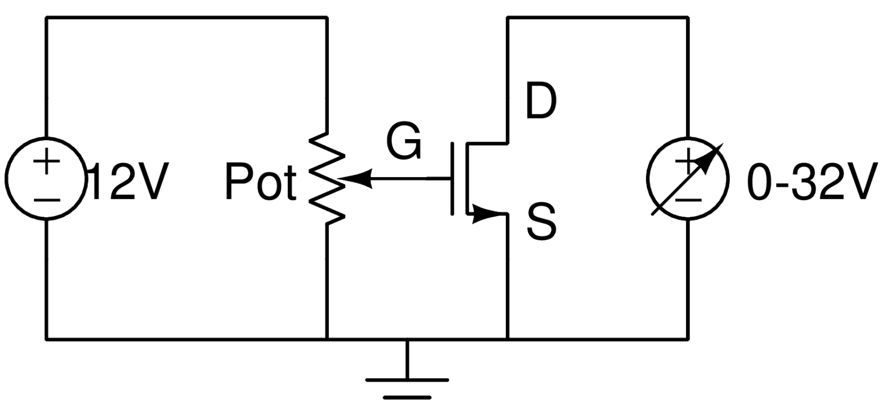

Fig. Circuit for characterizing an nMOS

3 Experimental Results

For an nMOS in saturation, the square root of the Drain current is given as:

$$\sqrt{I_D} = \sqrt{\frac{\beta}{2}}(V_{GS} - V_T) \tag{1}$$

For the above equation,

$$\beta = 2 \times (\frac{\partial\sqrt{I_D}}{\partial V_{GS}})^2 \tag{2}$$

Given below are my readings for I_D and V_{GS} with the transistor biased in Saturation region ($V_{DS} = 5V$):

V_{GS} (in V)	I_D (in A)
0	0
1.27	1.00E-03
1.3	2.00E-03
1.4	7.00E-03
1.5	1.90E-02
1.6	4.00E-02
1.7	6.80E-02
1.8	1.22E-01
1.9	1.81E-01
2	2.40E-01
2.1	3.16E-01
2.2	3.81E-01
2.3	4.37E-01
2.4	4.89E-01
2.5	5.47E-01

Given below is the plot for I_D vs V_{GS} for the given bias of $V_{DS} = 5V$

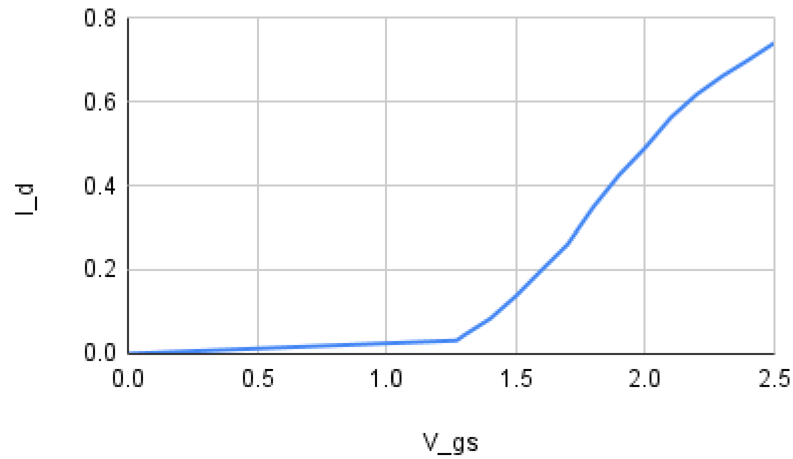

Fig. I_D vs V_{GS} Characteristics for Saturation region at room temperature

We obtain $\beta = 0.9381A/V^2 = 938.1mA/V^2$ and threshold voltage $V_T = 1.27V$.

Given below are my readings for I_D and V_{GS} with the transistor biased in Linear region ($V_{DS} = 0.6V$) and a varying temperature of 30°, 50° and 70°:

V_{GS}	I_D (30°)	I_D (50°)	I_D (70°)
1.8	8.20E-02	8.40E-02	9.00E-02
2	1.53E-01	1.51E-01	1.58E-01
2.2	1.99E-01	1.94E-01	1.91E-01
2.4	2.22E-01	2.15E-01	2.10E-01
2.6	2.36E-01	2.27E-01	2.23E-01
2.8	2.46E-01	2.36E-01	2.30E-01
3	2.53E-01	2.43E-01	2.37E-01
3.2	2.58E-01	2.49E-01	2.42E-01
3.4	2.63E-01	2.53E-01	2.47E-01
3.6	2.67E-01	2.57E-01	2.50E-01
3.8	2.71E-01	2.60E-01	2.53E-01
4	2.74E-01	2.63E-01	2.56E-01
5	2.84E-01	2.73E-01	2.66E-01
6	2.91E-01	2.79E-01	2.73E-01
7	2.96E-01	2.84E-01	2.77E-01
8	2.99E-01	2.87E-01	2.80E-01
9	3.02E-01	2.90E-01	2.82E-01
10	3.04E-01	2.92E-01	2.84E-01

β can be estimated from the following formula:

$$\beta = \mu_n C_{ox} \frac{W}{L} = \frac{I_D}{V_{DS}(V_{GS} - V_T - 0.5V_{DS})} \tag{3}$$

Given below are the calculated values for β (in A/V^2) and V_{GS} with the transistor biased in Linear region ($V_{DS} = 0.6V$) and a varying temperature of 30°, 50° and 70°:

V_{GS}	β (30°)	β (50°)	β (70°)
1.8	5.94E-01	6.09E-01	6.52E-01
2	5.93E-01	5.85E-01	6.12E-01
2.2	5.26E-01	5.13E-01	5.05E-01
2.4	4.46E-01	4.32E-01	4.22E-01
2.6	3.82E-01	3.67E-01	3.61E-01
2.8	3.33E-01	3.20E-01	3.12E-01
3	2.95E-01	2.83E-01	2.76E-01
3.2	2.64E-01	2.55E-01	2.47E-01
3.4	2.40E-01	2.30E-01	2.25E-01
3.6	2.19E-01	2.11E-01	2.05E-01
3.8	2.03E-01	1.94E-01	1.89E-01
4	1.88E-01	1.80E-01	1.76E-01
5	1.38E-01	1.33E-01	1.29E-01
6	1.09E-01	1.05E-01	1.03E-01
7	9.09E-02	8.72E-02	8.50E-02
8	7.75E-02	7.44E-02	7.26E-02
9	6.77E-02	6.51E-02	6.33E-02
10	6.01E-02	5.77E-02	5.61E-02

Given below is the plot for β vs V_{GS} for the given bias of $V_{DS} = 0.6V$

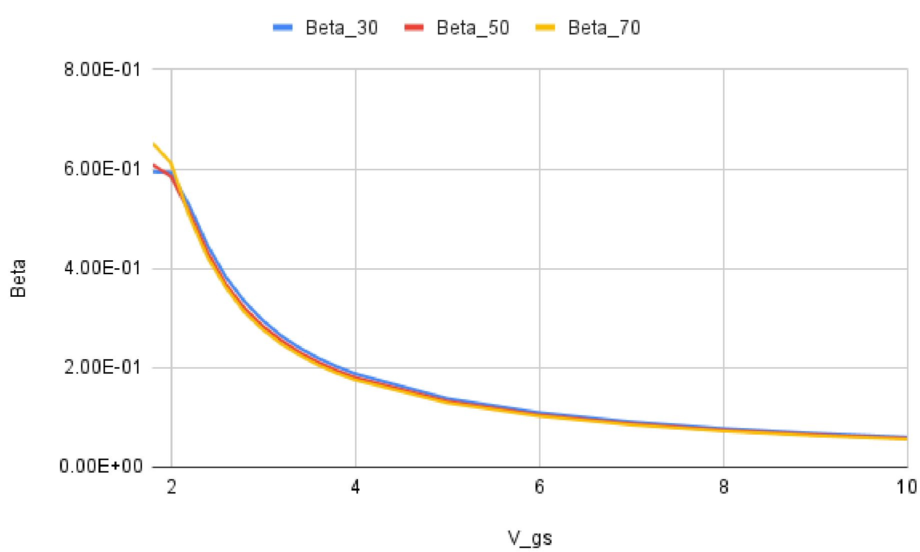

Fig. β vs V_{GS} Characteristics for Linear region at varying temperature

Given below are the observed readings for β (in mA/V^2) for varying temperatures and $V_{GS} = 2V, 8V$.

Temperature	β (for $V_{GS} = 2V$)	β (for $V_{GS} = 8V$)
30°	593	77.5
50°	585	74.4
70°	612	72.6

Given below is the plot for β vs Temperature:

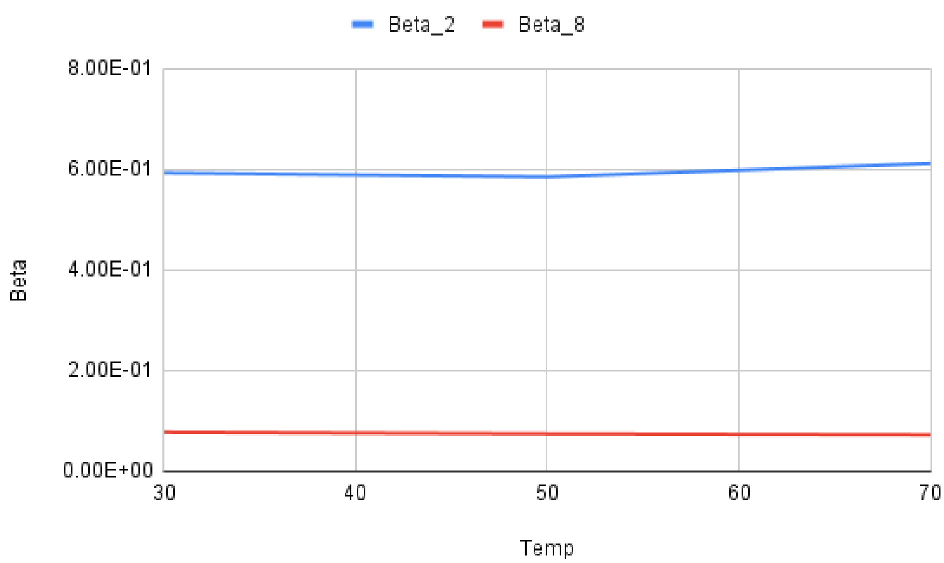

Fig. Temperature dependence of β

We know that $\beta = \mu_n C_{ox}(W/L)$ where μ_n is the only variable term. For low values of V_{GS} (2V), we are in the low field region, and the dominant scattering method is Coulomb scattering. Therefore we observe the mobility, and therefore β slightly increasing with increase in temperature ($\propto T^{3/2}$). For high values of V_{GS} (8V), we are in the high field region, and the dominant scattering method is Phonon scattering. Therefore we observe the mobility, and therefore β slightly decreasing with increase in temperature ($\propto T^{-3/2}$).