# EE236: Experiment No. 11
# Mobility of Charge Carriers in N-channel MOSFET and Temperature Dependence

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## 1 Lab Experiment

### 1.1 Characterizing the NMOS

$I_D$ was measured varying $V_{GS}$ from 0 to 2.5V with a $V_{DS}$ of 5V at 25°C. The voltage at which NMOS started conducting $V_T = 0.89\,V$.

#### 1.1.1 I-V Characteristics Calculation

| $V_{GS}$ (V) | $I_D$ (mA) | $I_D$ (A) | $\sqrt{I_D}$ |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0.67 | 0 | 0 | 0 |
| 0.85 | 0 | 0 | 0 |
| 0.89 | 0.001 | 0.000001 | 0.001 |
| 0.96 | 0.006 | 0.000006 | 0.00244949 |
| 1.02 | 0.022 | 0.000022 | 0.004690416 |
| 1.08 | 0.07 | 0.00007 | 0.0083666 |
| 1.3 | 1.256 | 0.001256 | 0.03544009 |
| 1.5 | 5.6 | 0.0056 | 0.074833148 |
| 1.67 | 10.93 | 0.01093 | 0.10454664 |
| 1.78 | 14.97 | 0.01497 | 0.122351951 |
| 2.01 | 24.9 | 0.0249 | 0.157797338 |

Table 1: Table of $V_{GS}$, $I_D$ in mA and A, and $\sqrt{I_D}$

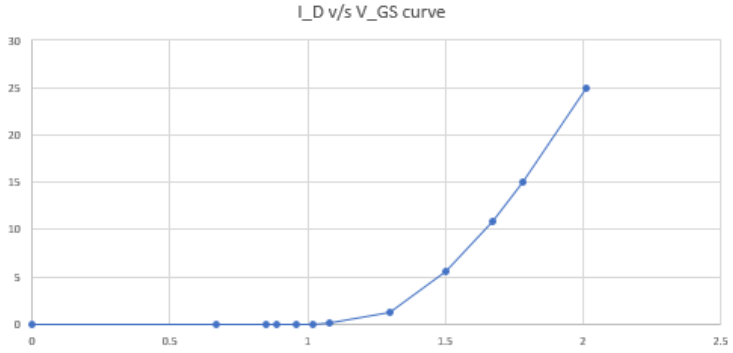


Figure 1: $I_D$ vs $V_{GS}$

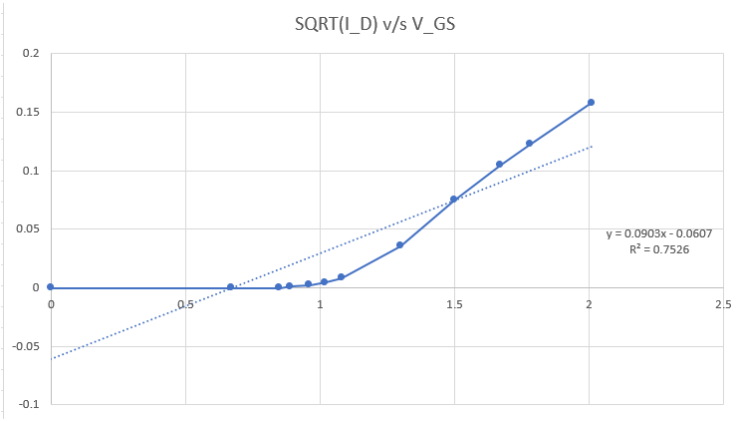


Figure 2: $\sqrt{I_D}$ vs $V_{GS}$

## 1.2 Mobility Extraction

### 1.2.1 Circuit Used

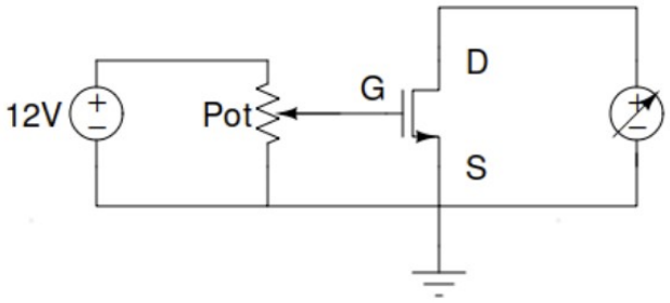


Figure 3: Circuit Used

$V_{DS}$ was fixed at 0.6V, and $V_{GS}$ varied from $0.6 + V_T$ to 10V. $I_D$ values were recorded across temperatures (30, 50, and 70°C). $\beta$ was calculated using:

$$\beta = \frac{I_D}{V_{DS}(V_{GS} - V_T - 0.5V_{DS})}$$

### 1.2.2 Readings Obtained for 30°C

| $V_{GS}$ (V) | $I_D$ (mA) | $I_D$ (A) | Beta |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1.5 | 5.3 | 0.0053 | 0.028494624 |
| 1.68 | 10.64 | 0.01064 | 0.036190476 |
| 1.8 | 14.9 | 0.0149 | 0.040710383 |
| 2.14 | 23 | 0.023 | 0.040350877 |
| 2.41 | 25.4 | 0.0254 | 0.034699454 |
| 2.66 | 26 | 0.026 | 0.029478458 |
| 2.96 | 26.4 | 0.0264 | 0.024858757 |
| 3.12 | 26.6 | 0.0266 | 0.022970639 |
| 3.43 | 26.7 | 0.0267 | 0.019866071 |
| 3.77 | 27.3 | 0.0273 | 0.017635659 |
| 4.29 | 27.5 | 0.0275 | 0.014784946 |
| 5.04 | 27.6 | 0.0276 | 0.011948052 |
| 6.02 | 27.6 | 0.0276 | 0.00952381 |
| 7 | 27.5 | 0.0275 | 0.007888698 |
| 8 | 27.9 | 0.0279 | 0.006828194 |
| 9 | 28 | 0.028 | 0.005975245 |
| 10 | 28 | 0.028 | 0.005297011 |

Table 2: Data at 30°C for $V_{GS}$, $I_D$ in mA and A, and Beta

### 1.2.3 Readings Obtained for 50°C

| $V_{GS}$ (V) | $I_D$ (mA) | $I_D$ (A) | Beta |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1.51 | 6.3 | 0.0063 | 0.06 |
| 1.75 | 13.7 | 0.0137 | 0.026550388 |
| 1.8 | 15.3 | 0.0153 | 0.028021978 |
| 2 | 21 | 0.021 | 0.031531532 |
| 2.25 | 24.6 | 0.0246 | 0.030147059 |
| 2.6 | 25.9 | 0.0259 | 0.025243665 |
| 2.84 | 26.2 | 0.0262 | 0.022393162 |
| 3.19 | 26.5 | 0.0265 | 0.019202899 |
| 3.4 | 26.6 | 0.0266 | 0.017662683 |
| 3.65 | 26.7 | 0.0267 | 0.016123188 |
| 3.7 | 26.7 | 0.0267 | 0.015836299 |
| 3.92 | 26.8 | 0.0268 | 0.014741474 |
| 4.08 | 26.8 | 0.0268 | 0.01400209 |
| 5 | 27 | 0.027 | 0.010948905 |
| 6.07 | 27.1 | 0.0271 | 0.008719434 |
| 7.06 | 27.1 | 0.0271 | 0.007320367 |
| 8 | 27.1 | 0.0271 | 0.006352555 |
| 9 | 27.1 | 0.0271 | 0.005569256 |
| 10 | 27.2 | 0.0272 | 0.004976217 |

Table 3: Data at 50°C for $V_{GS}$, $I_D$ in mA and A, and Beta

### 1.2.4 Readings Obtained for 70°C

| $V_{GS}$ (V) | $I_D$ (mA) | $I_D$ (A) | Beta |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 1.5 | 6.9 | 0.0069 | 0.06969697 |
| 1.7 | 12.6 | 0.0126 | 0.025925926 |
| 1.8 | 16.5 | 0.0165 | 0.03021978 |
| 1.94 | 19.4 | 0.0194 | 0.030793651 |
| 2.09 | 22.2 | 0.0222 | 0.030833333 |
| 2.26 | 23.9 | 0.0239 | 0.029075426 |
| 2.56 | 25 | 0.025 | 0.0249501 |
| 2.7 | 25.3 | 0.0253 | 0.023296501 |
| 2.95 | 25.6 | 0.0256 | 0.020711974 |
| 3.23 | 25.8 | 0.0258 | 0.018376068 |
| 3.52 | 25.9 | 0.0259 | 0.016413181 |
| 3.78 | 25.9 | 0.0259 | 0.014936563 |
| 4.03 | 26 | 0.026 | 0.013800425 |
| 5.04 | 26.2 | 0.0262 | 0.010522088 |
| 6.03 | 26.3 | 0.0263 | 0.008527886 |
| 7 | 26.4 | 0.0264 | 0.007201309 |
| 8 | 26.4 | 0.0264 | 0.006188467 |
| 9 | 26.4 | 0.0264 | 0.005425401 |
| 10.02 | 26.4 | 0.0264 | 0.004819277 |

Table 4: Data at 70°C for $V_{GS}$, $I_D$ in mA and A, and Beta

### 1.2.5 Variation of $\beta$ with Temperature and $V_{GS}$

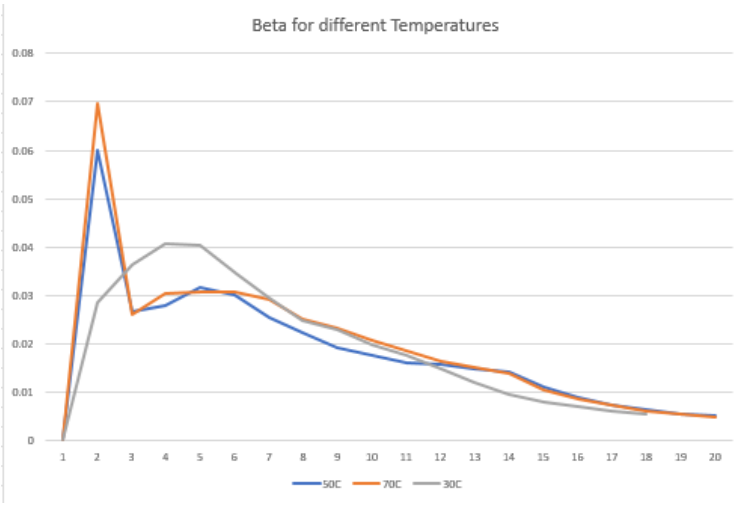


Figure 4: Plot for Variation of $\beta$ with Temperature

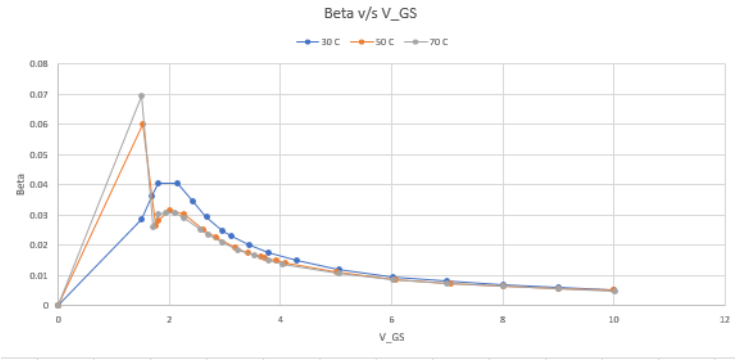


Figure 5: Plot for Variation of $\beta$ with $V_{GS}$

## 1.3 Quantification of Temperature Dependence

From the plots and tables, we observe that $\beta$ is approximately constant with respect to temperature at specific constant $V_{GS}$

| Temperature (°C) | $V_{GS} = 1.8$ V | $V_{GS} = 8$ V |
|---|---|---|
| 30 | 0.0407 | 0.00683 |
| 50 | 0.02802 | 0.00635 |
| 70 | 0.03022 | 0.00619 |