

# 1 Measurements & Parameter Extraction

## 1.1 Line Width/Misalignment

### 1.1.1 Measured line widths

Nominal Linewidth	ACTV (dark field)	POLY (clear field)	CONT (dark field)	METAL (clear field)
$2\mu\text{m}$	3	4	1.869	2.520

### 1.1.2 Misalignment

## 1.2 Four-Point Resistors [2a, 2b]

### 1.2.1 Measurement Setup

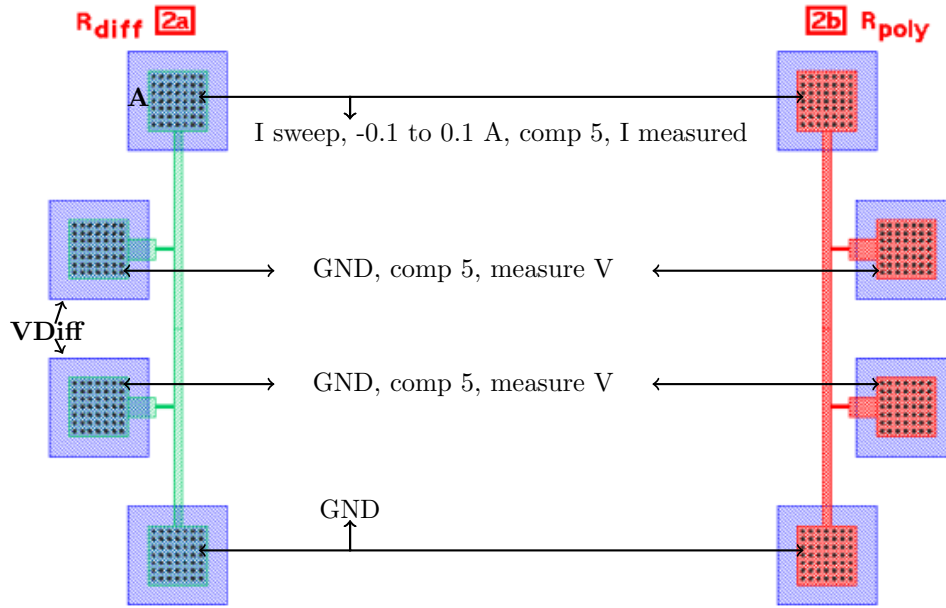


Figure 1: Device 2a is a diffusion resistor and 2b is a poly resistor.

### 1.2.2 I-V plot for the diffusion resistor, 2a

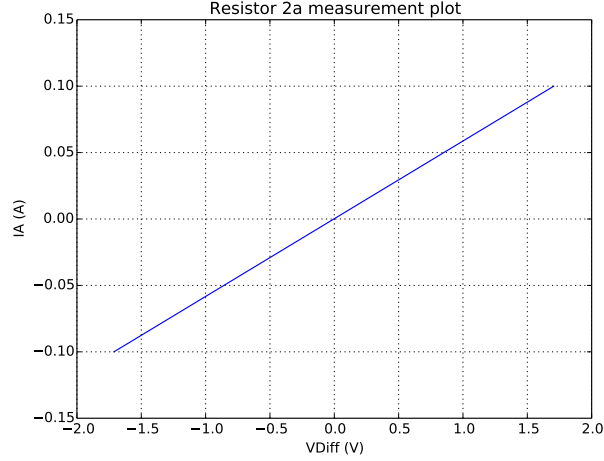


Figure 2: A plot of the measurement data taken for resistor 2a. The plot is based off of 2 data points.

From the plot above we can calculate our resistance. Note that the slope of the above plot will be equal to  $1/R$ . Since  $I = V/R$ , where  $I$  is our dependent variable (y axis) and  $V$  is our independent variable (X axis). A resistance of  $R = 17\ \Omega$  was calculated. Our width and length values are  $10\ \mu m$  and  $200\ \mu m$ . However our final  $2\ \mu m$  line after the ACTV mask was  $3\ \mu m$  which means that we had a overetch of about 50%. This means that

$$R_s = \frac{W}{L} R_{\text{diff}} = \frac{10(1.50)}{200} 17 = 1.28\ \Omega$$

From the previous lab report we have a junction depth of  $1\ \mu m$ . This means that our Resistivity is  $\rho = R_s x_j = 1.07 \times 10^{-4}\ \Omega\text{-cm}$ . Using the Irvin curves in Jaeger [1], we can estimate the surface concentration  $N_0 \approx 10^{21}$ . Now the mobility can be calculated using a table of values from Appendix xx.

$$\mu_e = \mu_{\min} + \frac{\mu_0}{1 + (N/N_{\text{ref}})^\alpha} = 92 + \frac{1268}{1 + (10^{21}/1.3 \times 10^{17})^{0.91}} = 92.4\ \text{cm}^2/V - s$$

### 1.2.3 I-V plot for the poly resistor, 2b

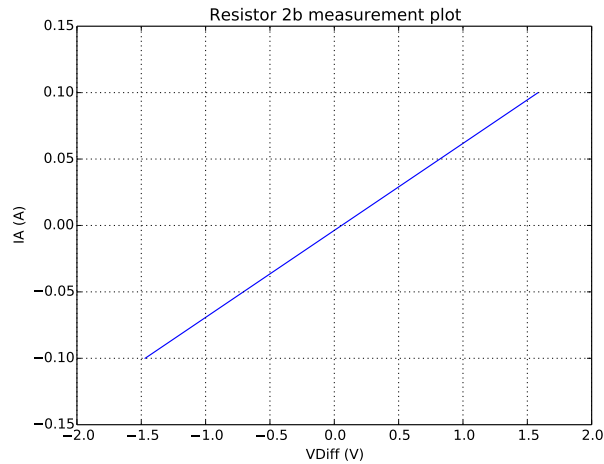


Figure 3: A plot of the measurement data taken for resistor 2b. The plot is based off of 2 data points.

From the plot above we calculate a  $1/\text{slope}$  value of 15. Hense  $R = 15\ \Omega$ . This means that

$$R_s = \frac{W}{L} R_{\text{poly}} = \frac{10(1.26)}{200} 15 = 0.945\ \Omega$$

Our Resistivity is then  $\rho = R_s t_{\text{poly}}$  where  $t_{\text{poly}}$  is the polysilicon thickness which is  $0.4 \mu m$ , Hence  $\rho = 0.378 \Omega\text{-}\mu m$ .

### 1.3 Four-Point Contact Resistor [17a, 17b]

#### 1.3.1 Measurement Setup

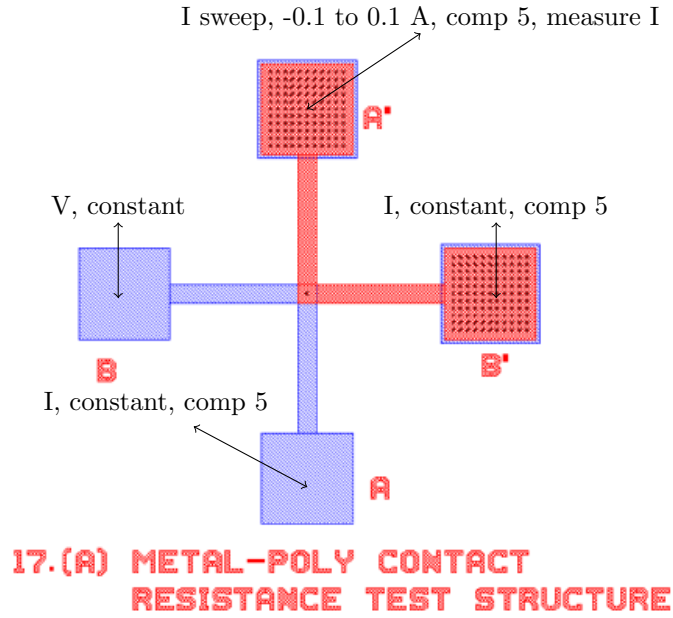


Figure 4: Measurement setup for 17a poly contact resistor. The same setup is used for the diffusion contact resistor, 17b.

#### 1.3.2 I-V plot for 17a, poly reisistor

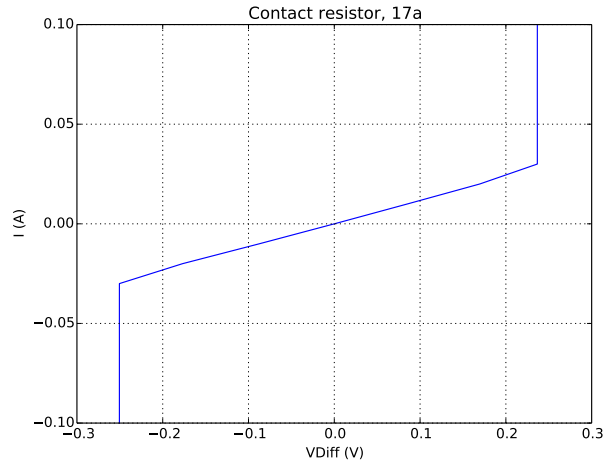


Figure 5: A plot of the measurement data taken for resistor 17a.

From the above plot we calculated a resistance of  $R = 8.54 \Omega$ . Note that the slope above gives us  $1/R$  so we need to take the inverse to find the resistance.

### 1.3.3 I-V plot for 17b, diffusion resistor

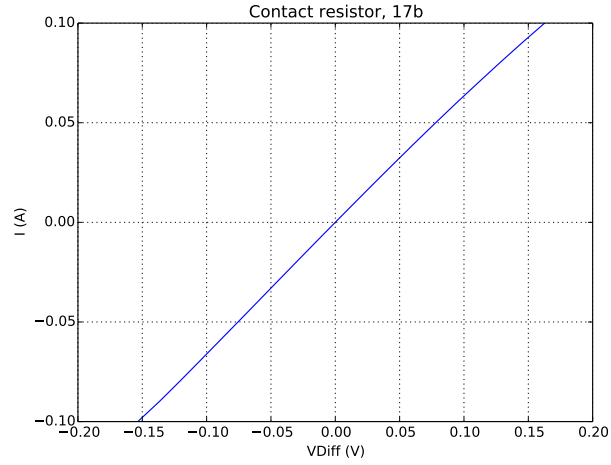


Figure 6: A plot of the measurement data taken for resistor 17b.

Similarly, from the above plot we calculated a resistance of  $R = 1.46\Omega$ .

## 1.4 Four-Point Contact-Chain Resistor [2c, 2d]

### 1.4.1 Measurement Setup

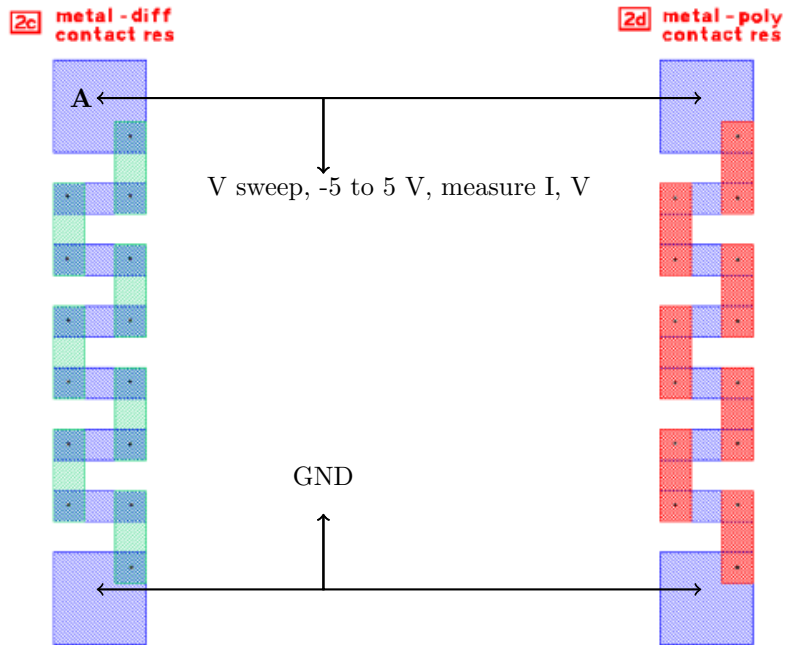


Figure 7: Chain resistor setup for diffusion and poly resistors.

### 1.4.2 b. I-V plot for diffusion resistor, 2c

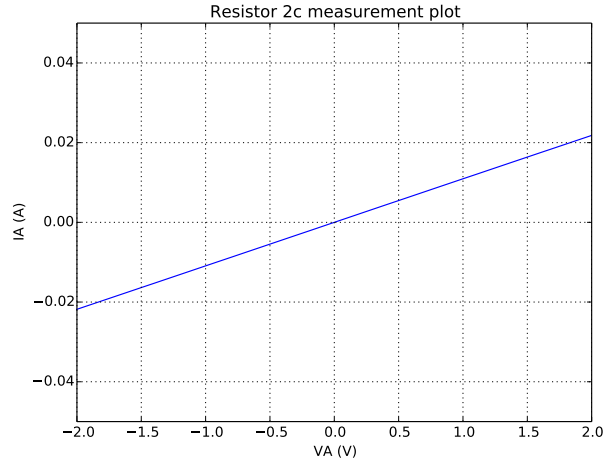


Figure 8: A plot of the measurement data taken for resistor 2c. The plot is based off of 2 data points.

The resistance calculated from the graph here is  $R = 91.2\Omega$ . Using sheet resistance from 2a/b and the total resistance from the slope above, we can solve for the contact resistance

$$R_{\text{total diff}} = 7(\eta R_{\text{S diff}} + R_{\text{C diff}}) \Rightarrow R_{\text{C diff}} = \frac{1}{7}R_{\text{total diff}} - \eta R_{\text{S diff}} = \frac{1}{7}(91.2\Omega) - 2.3(1.07\Omega) = 10.6\Omega$$

### 1.4.3 b. I-V plot for poly resistor, 2d

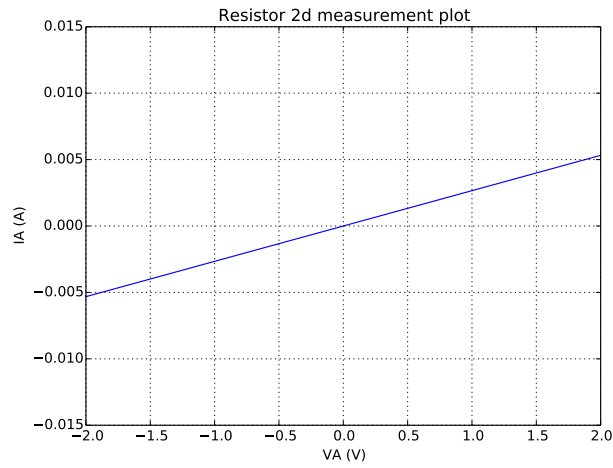


Figure 9: A plot of the measurement data taken for resistor 2d. The plot is based off of 2 data points.

The resistance calculated from the graph here is  $R = 370\Omega$ . Using sheet resistance from 2a/b and the total resistance from the slope above, we can solve for the contact resistance

$$R_{\text{total poly}} = 7(\eta R_{\text{S poly}} + R_{\text{C poly}}) \Rightarrow R_{\text{C poly}} = \frac{1}{7}R_{\text{total poly}} - \eta R_{\text{S poly}} = \frac{1}{7}(370\Omega) - 2.3(0.945\Omega) = 50.7\Omega$$

## 1.5 Gate Oxide Capacitor, 4

### 1.5.1 Measurement Setup

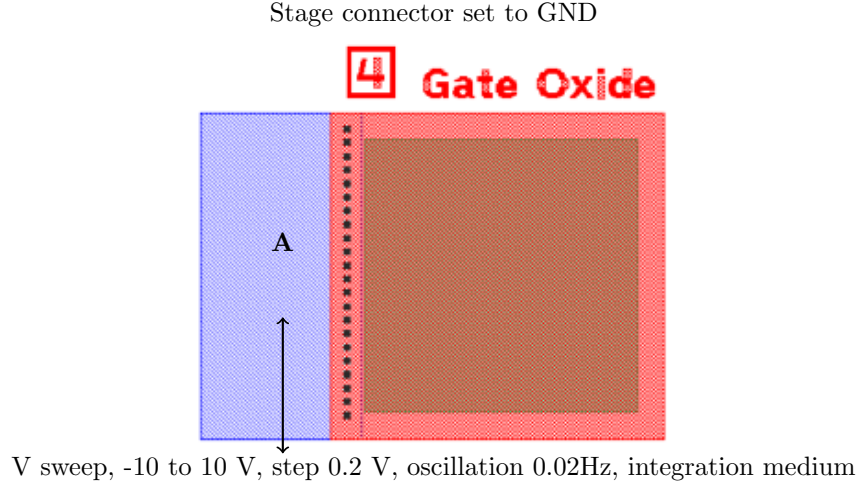


Figure 10: Gate capacitor setup.

### 1.5.2 C-V plot of gate oxide capacitor w/ lights ON

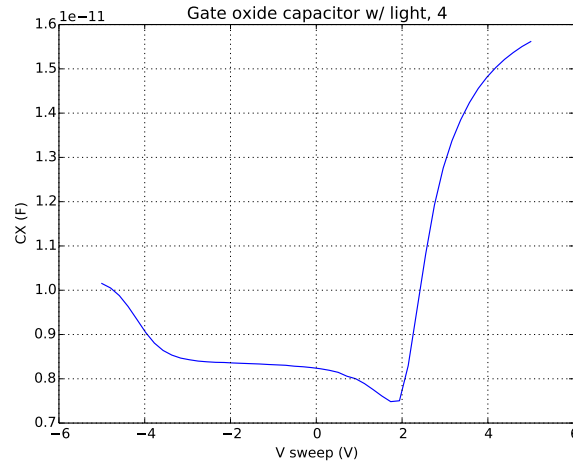


Figure 11: A plot of the measurement data taken for the gate capacitor, 4. Lights on.

The minimum capacitance from the plot above is 7.48 pF. The accumulation region capacitance at about 5 V is 15.7 pF. The active area is  $200 \mu\text{m}$  by  $200 \mu\text{m}$  while the pad+ring area is  $240 \mu\text{m}$  by  $335 \mu\text{m}$ . Also note the gate oxide thickness calculated below for the field oxide capacitors is  $1.15 \mu\text{m}$ .

$$C_{\text{measured}} = A_{\text{active}} \frac{\epsilon_{\text{ox}}}{t_{\text{gox}}} + A_{\text{pad-ring}} \frac{\epsilon_{\text{ox}}}{t_{\text{fox}}}$$

$$t_{\text{gox}} = \left[ \frac{1}{A_{\text{active}}} \left( \frac{C_{\text{measured}}}{\epsilon_{\text{ox}}} - \frac{A_{\text{pad-ring}}}{t_{\text{fox}}} \right) \right]^{-1} = \left[ \frac{1}{4 \times 10^{-8}} \left( \frac{15.7 \times 10^{-12}}{(3.9)8.85 \times 10^{-12}} - \frac{8.04 \times 10^{-8}}{1.15 \times 10^{-6}} \right) \right]^{-1} = 0.104 \mu\text{m}$$

The capacitance per unit area in this case would be  $15.7 \text{ pF} / (240 \mu\text{m} \times 335 \mu\text{m})$ .  $C/\text{area} = 1.95 \text{ pF}/\mu\text{m}$ . Now in order to calculate the maximum depletion region we use an equation from lecture notes. Note the max and min capacitance we calculated earlier,

$$\frac{1}{C_{\text{min}}} = \frac{1}{C_{\text{max}}} + \frac{1}{A_{\text{pad-ring}} C_{\text{Dmin}}}, \text{ where } C_{\text{Dmin}} = \frac{\epsilon_{\text{si}}}{x_{\text{dmax}}} \quad (1)$$

Solving for the maximum depletion region we get,

$$x_{\text{dmax}} = A_{\text{pad-ring}} \epsilon_{\text{si}} \left( \frac{1}{C_{\text{min}}} - \frac{1}{C_{\text{max}}} \right) = (8.04 \times 10^{-8})(11.7 \times 8.85 \times 10^{-12}) \left( \frac{1}{7.48 \times 10^{-12}} - \frac{1}{15.7 \times 10^{-12}} \right) = 0.583 \mu\text{m}$$

Another equation from lecture will help us solve for the substrate doping concentration,

$$x_d = \sqrt{\frac{2\epsilon_{\text{si}}}{q} \frac{1}{N_A} |\psi_s|} \quad (2)$$

where  $\psi_s$  is the potential drop and has a typical value of 0.3,  $q$  is the charge of an electron  $1.602 \times 10^{-19}$  C, and  $N_A$  is the doping concentration.

$$N_A = \frac{2\epsilon_{\text{si}} |\psi_s|}{q x_d^2} = \frac{2(11.7 \times 8.85 \times 10^{-12})(0.3)}{1.602 \times 10^{-19} (0.583 \times 10^{-6})^2} = 1.14 \times 10^{21} \text{ cm}^{-3}$$

From the curve above (Figure 11) we can see that the flatband voltage is  $V_{FB} \approx 5.5$  and the corresponding  $C_{FB} \approx 15.5 \text{ pF}$ . To find the charge per unit area at the oxide silicon interface we can use the  $Q = CV$  equation.

$$\frac{Q_{ss}}{A} = \frac{C_{FB} V_{FB}}{A_{\text{pad-ring}}} = \frac{(5.5)(15.5 \times 10^{-12})}{8.04 \times 10^{-8}} = 1.06 \text{ mF/m}^2$$

To calculate the threshold voltage we will assume that  $V_{SB} = 0$ . First we must also calculate  $Q_{BO}$  which is the charge stored in the depletion region,

$$Q_{BO} = \sqrt{2q\epsilon_{\text{si}} N_B 2\phi_F} = \sqrt{2(1.602 \times 10^{-19})(11.7 \times 8.85 \times 10^{-12})(1.14 \times 10^{21})(2 \times 0.3)} = 1.51 \times 10^{-4} \text{ C/m}^2$$

Now to calculate/estimate threshold voltage. Note that the work function  $\phi_{ms}$  is zero for n+ doped poly gate.

$$V_t = \phi_{ms} - 2\phi_f - \frac{Q_{ss}}{C_{\text{max}}} - \frac{Q_{BO}}{C_{\text{max}}} = 0 - 0.6 - \frac{2.06 \times 10^{-3}}{15.7 \times 10^{-15}} - \frac{1.51 \times 10^{-4}}{15.7 \times 10^{-15}} = -1.41 \times 10^{11} \text{ V}$$

### 1.5.3 C-V plot of gate oxide capacitor w/ lights OFF

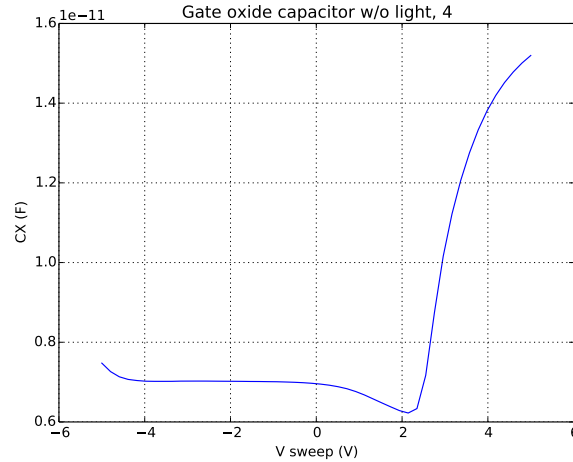


Figure 12: A plot of the measurement data taken for the gate capacitor, 4. Lights off.

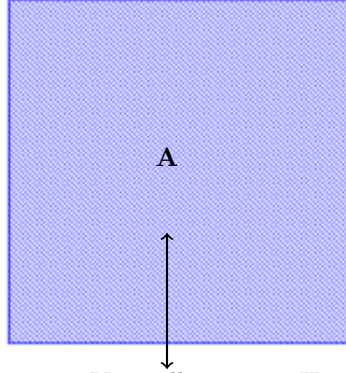
minimum capacitance ...

## 1.6 Field Oxide Capacitor, 3

### 1.6.1 Measurement Setup

Stage connector set to GND

**3 Field Oxide**



V sweep, -5 to 5 V, step 0.2 V, oscillation 0.02Hz, integration medium

Figure 13: Field oxide capacitor setup.

### 1.6.2 C-V plot of field oxide capacitor

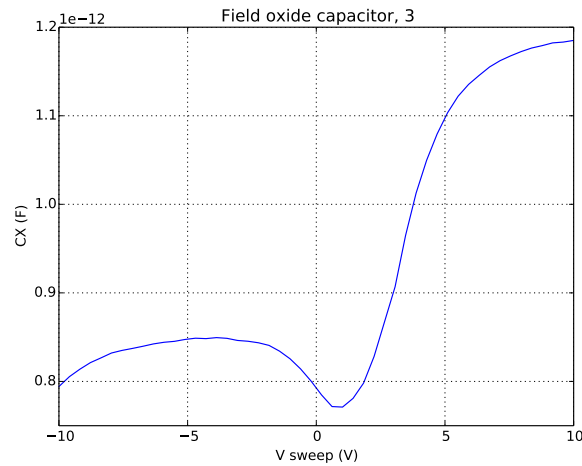


Figure 14: A plot of the measurement data taken for the field oxide capacitor, 3

From the plot above we see that at the accumulation region of  $\approx 10$  volts we have a corresponding capacitance of  $C \approx 1.2\text{pF}$ . Noting that the area of the capacitor plate is  $200\text{ }\mu\text{m}$  by  $200\text{ }\mu\text{m}$ , we can now solve for the dielectric (oxide) thickness.

$$C = \frac{A\epsilon_{\text{ox}}}{t_{\text{fox}}} \Rightarrow t_{\text{fox}} = \frac{3.9A\epsilon_0}{C} = \frac{3.9(4 \times 10^{-8})(8.85 \times 10^{-12})}{1.2 \times 10^{-12}} = 1.15\text{ }\mu\text{m}$$



## 1.7 Intermediate Oxide Capacitors, 5

### 1.7.1 Measurement Setup

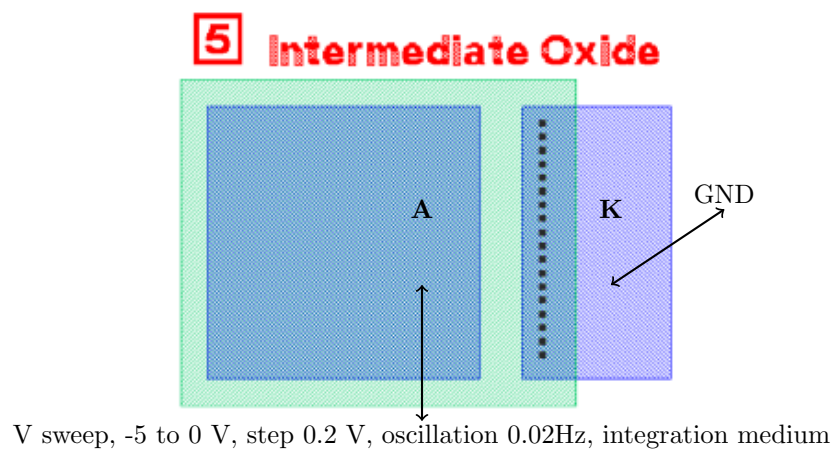


Figure 15: Intermediate oxide capacitor setup.

### 1.7.2 C-V plot of intermediate oxide capacitor

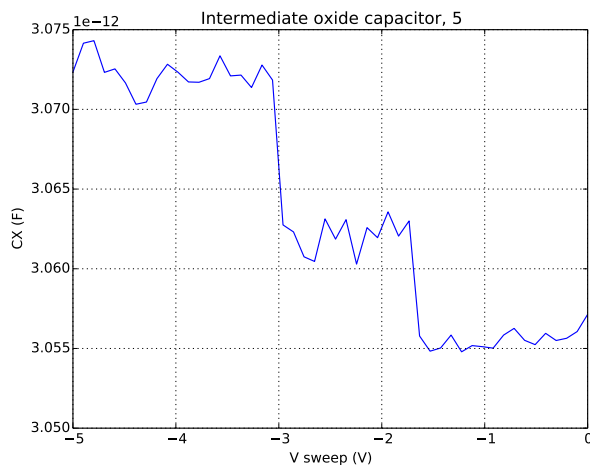


Figure 16: A plot of the measurement data taken for the Intermediate oxide, 5

The capacitance at the accumulation region of  $\approx 5$  V is about 3.0725 pF.

## 1.8 Diode, 7

### 1.8.1 Measurement setups for forward and reverse operations

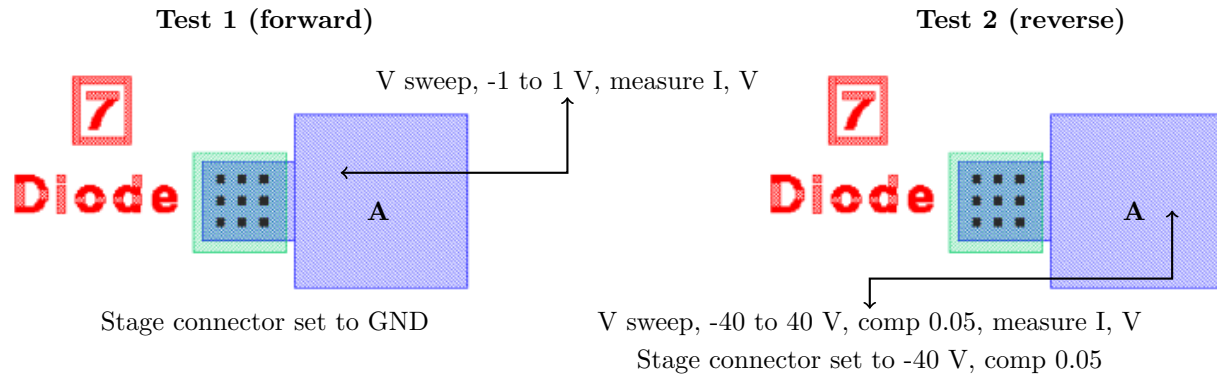


Figure 17: Two tests were performed on this diode; both measurement setups are shown above.

### 1.8.2 I-V plots for forward and reverse operation

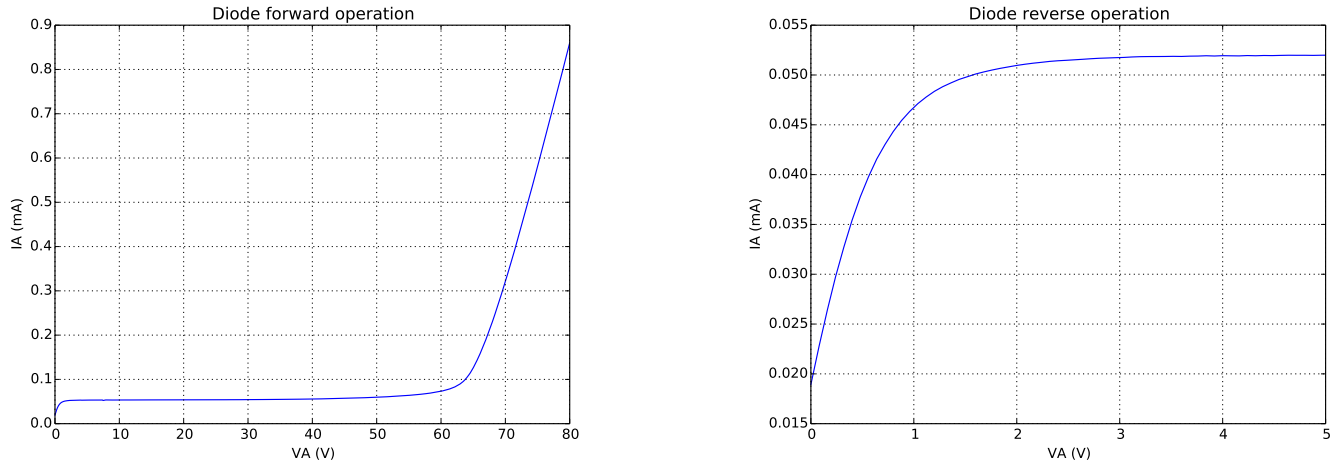


Figure 18: Plots of forward and reverse operation of Diode 7.

Looking at the plots above, the forward turn on voltage is  $V_F \approx 70V$  while the reverse bias turn off voltage is about  $V_{RB} \approx 0.5V$ . To calculate the series resistance in the forward bias we look at the region of the curve where  $V$  is greater than 65 V. The inverse of the slope there results in  $R = 17.8 k\Omega$ . Similarly for the reverse bias plot, looking at the region below 0.5 Volts, we find that the inverse of the slope is  $R = -22.1 k\Omega$ .

## 1.9 MOSFETs of Varying Length, [8a-d]

### 1.9.1 Measurement setups

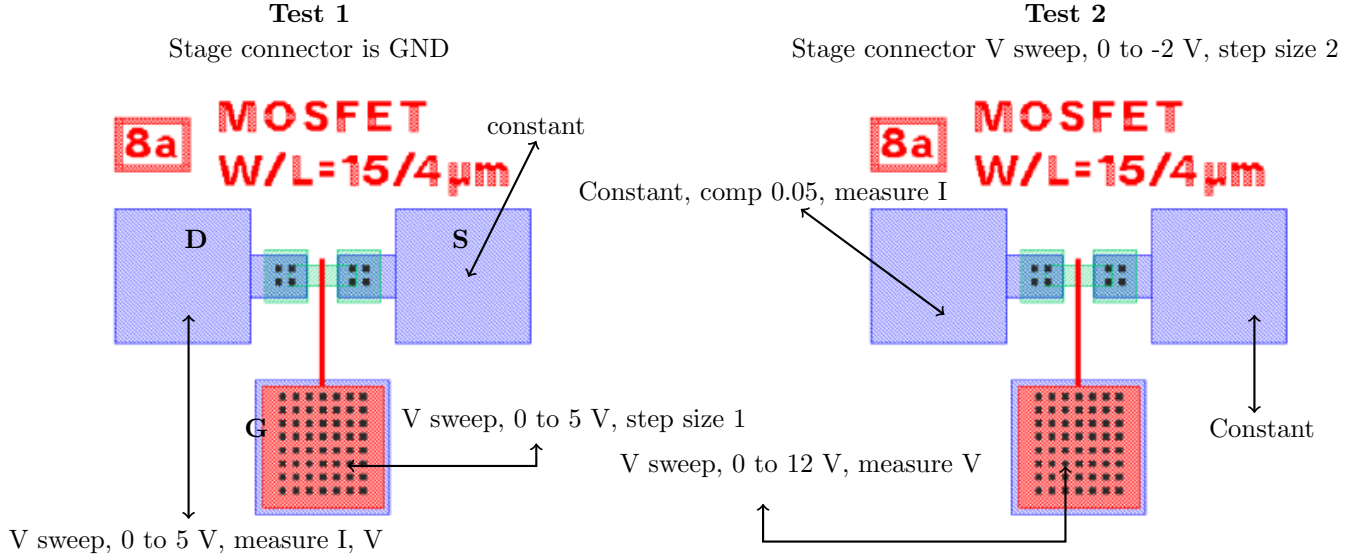


Figure 19: Measurement setup for Mosfet 8a. The same setup is used for Mosfets 8a-d. The only difference is the channel length which changes from 4 (8a) to 6 (8b) to 8 (8c) to 10 (8d) microns.

### 1.9.2 Plots of $I_D$ - $V_D$ , sweeping $V_G$

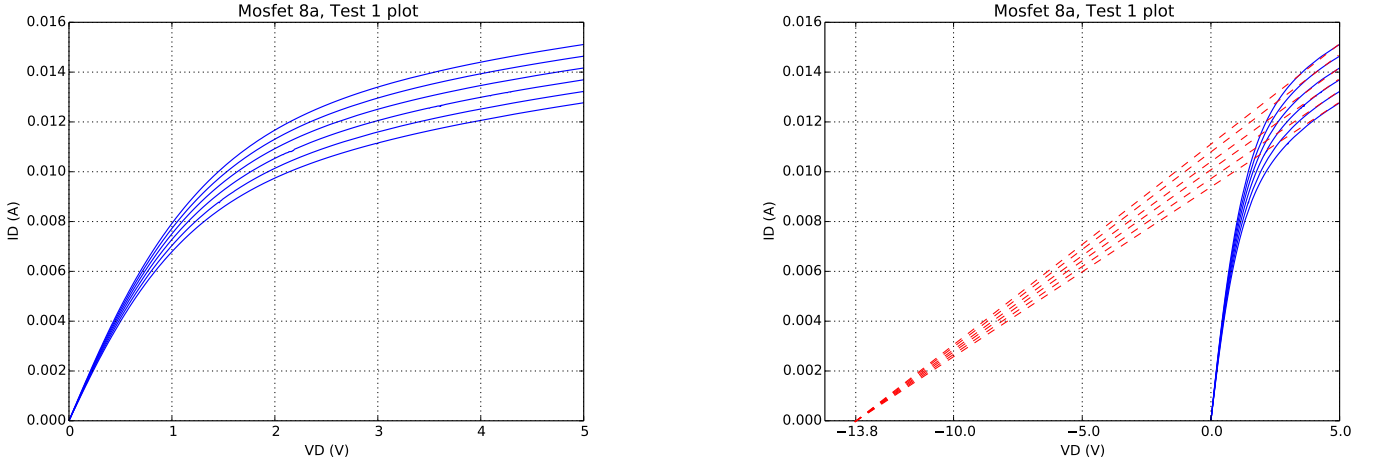


Figure 20: Test 1 for Mosfet 8a with extended x axis range in order to calculate lambda.

We see that everything intersects at about -13.8 V. This corresponds to  $\lambda = \frac{1}{-13.8} = -0.0725$ .

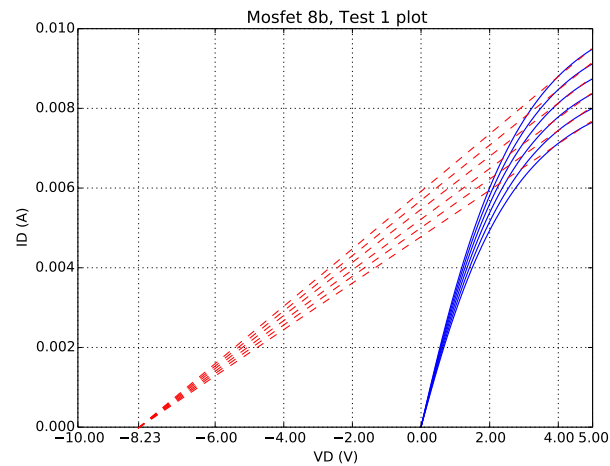
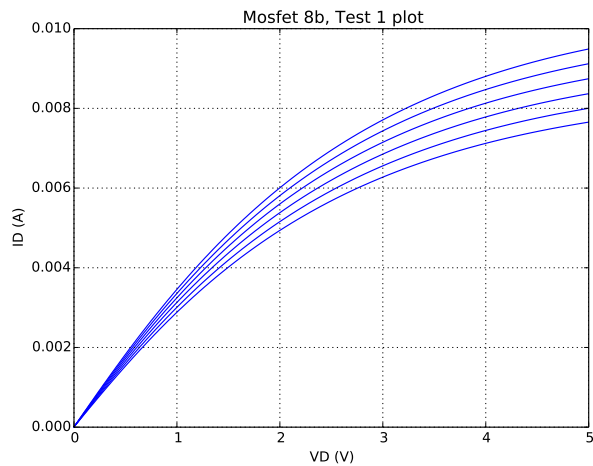


Figure 21: Test 1 for Mosfet 8b with extended x axis range in order to calculate lambda.

We see that everything intersects at about -8.23 V. This corresponds to  $\lambda = \frac{1}{-8.23} = -0.122$ .

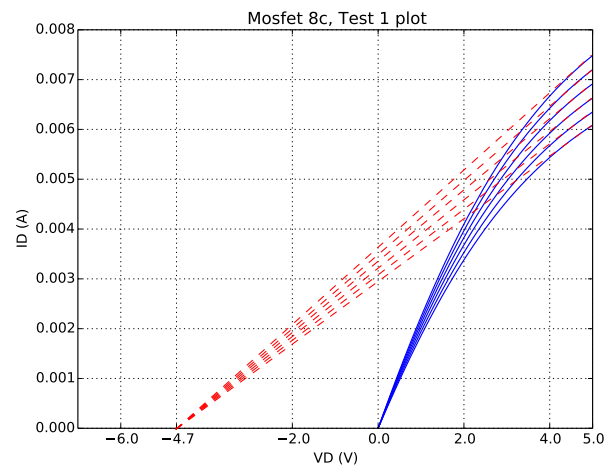
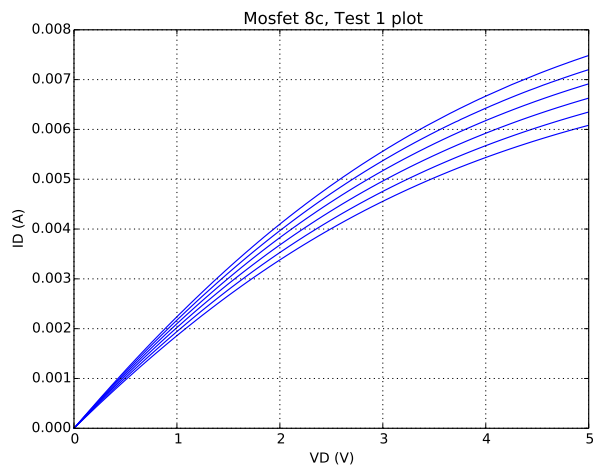


Figure 22: Test 1 for Mosfet 8c with extended x axis range in order to calculate lambda.

We see that everything intersects at about -4.70 V. This corresponds to  $\lambda = \frac{1}{-4.70} = -0.213$ .

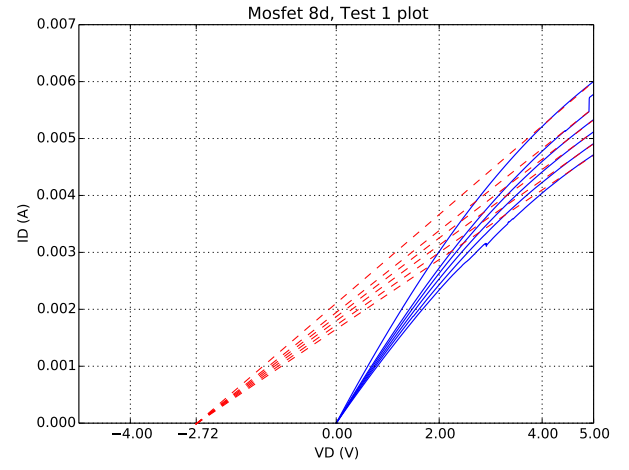
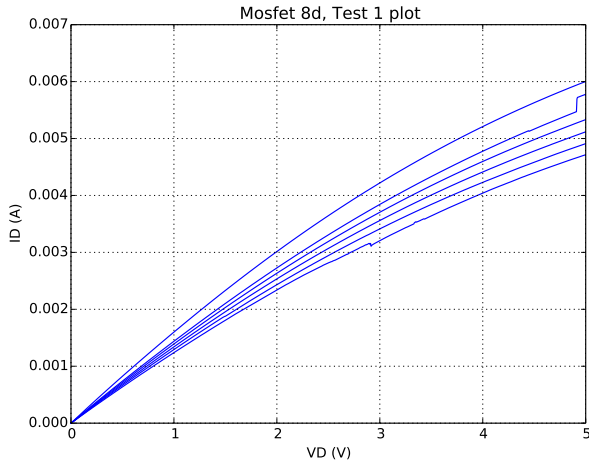


Figure 23: Test 1 for Mosfet 8d with extended x axis range in order to calculate lambda.

We see that everything intersects at about -2.72 V. This corresponds to  $\lambda = \frac{1}{-2.72} = -0.368$ .

### 1.9.3 $\lambda$ vs $L_{\text{Drawn}}$

To summarize, here is a table of all  $\lambda$  values calculated,

MOSFET device	$\lambda$ ( $V^{-1}$ )	$L_{\text{drawn}}$ ( $\mu m$ )	Fig #
8a	-0.0725	4	<a href="#">20</a>
8b	-0.122	6	<a href="#">21</a>
8c	-0.213	8	<a href="#">22</a>
8d	-0.368	10	<a href="#">23</a>

Figure 24: all  $\lambda$  values for mosfets 9a-d along with gate lengths.

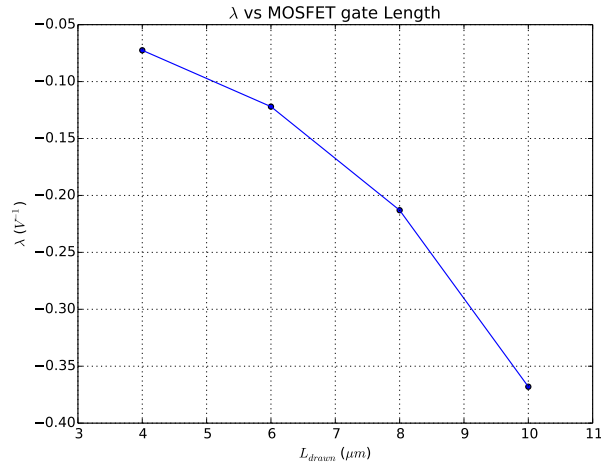


Figure 25:  $\lambda$  for each 8a-d device vs the gate length.

### 1.9.4 Plots of $I_D$ - $V_G$ , sweeping $V_B$

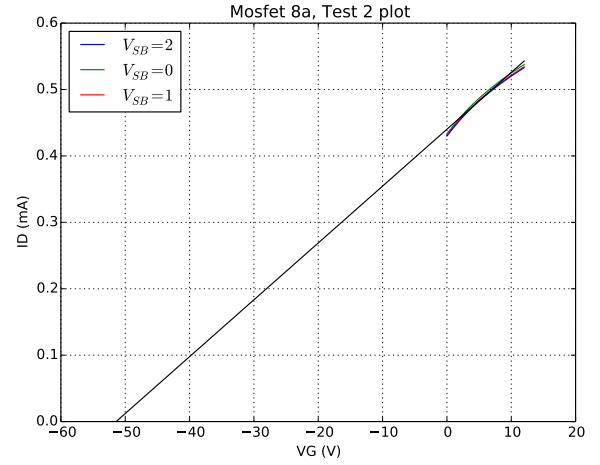
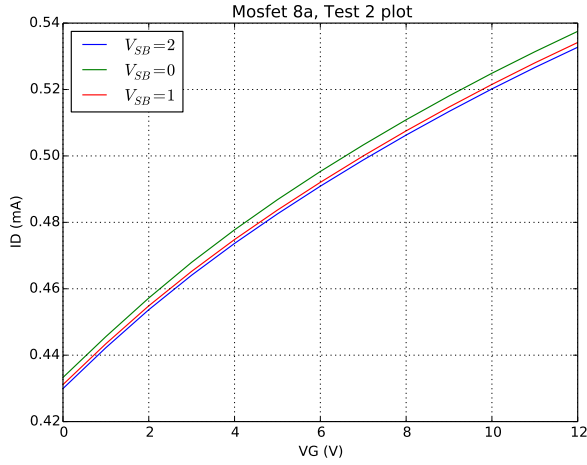


Figure 26: Test 2 for Mosfet 8a. On the right side we did a linear regression on the  $V_{SD} = 0$  line in order to get a estimate of the threshold voltage.

Since it is quite difficult to see where a slope change occurs in order to find the threshold voltage, we can do a linear regression using the  $V_{SD} = 0$  line. With linear regression,  $V_t = -51.4$  V. One reason why there is no slope change might have to do with the fact that most of our MOSFETS show characteristics of junction leakage.

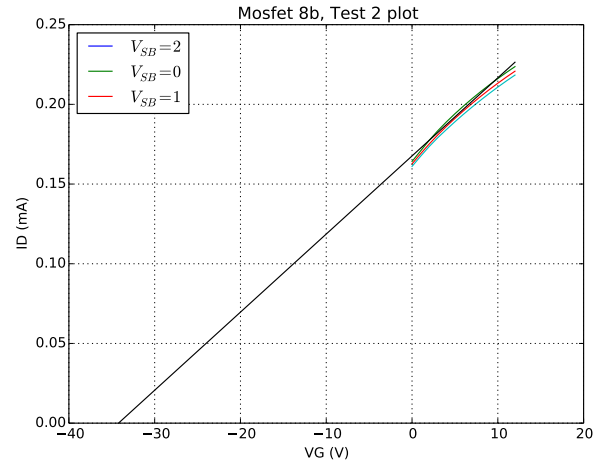
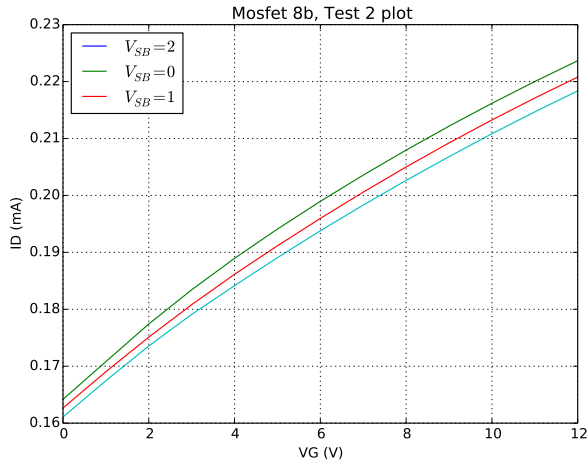


Figure 27: Test 2 for Mosfet 8b. On the right side we did a linear regression on the  $V_{SD} = 0$  line in order to get a estimate of the threshold voltage.

Similarly, the threshold voltage is not clear in the figure above. Using linear regression again with  $V_{SD} = 0$  we get  $V_t = -34.2$ .

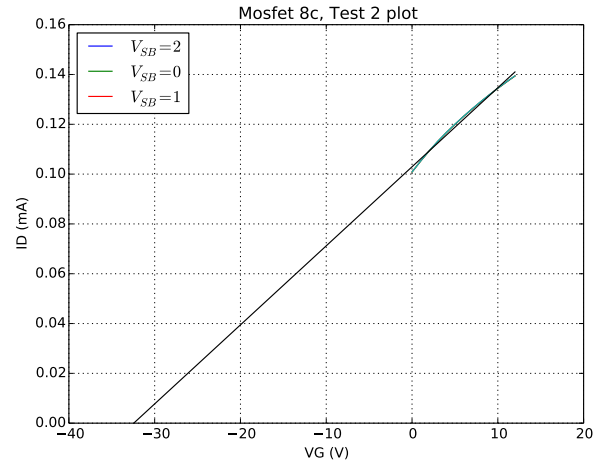
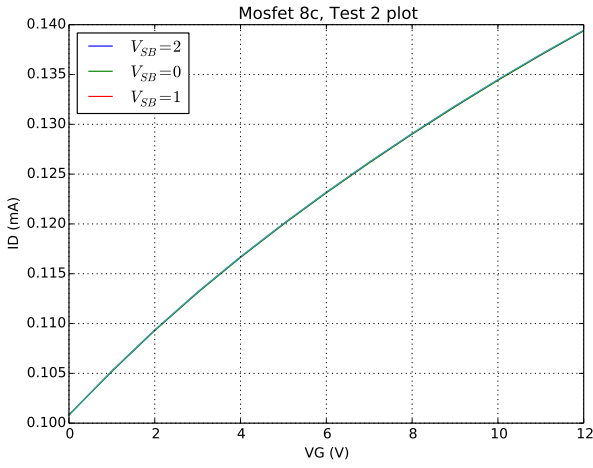


Figure 28: Test 2 for Mosfet 8c. On the right side we did a linear regression on the  $V_{SB} = 0$  line in order to get a estimate of the threshold voltage.

Similarly, the threshold voltage is not clear in the figure above. Using linear regression again with  $V_{SB} = 0$  we get  $V_t = -32.4$ .

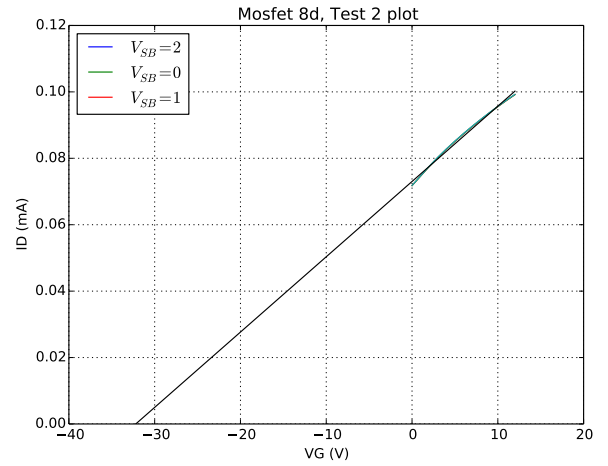
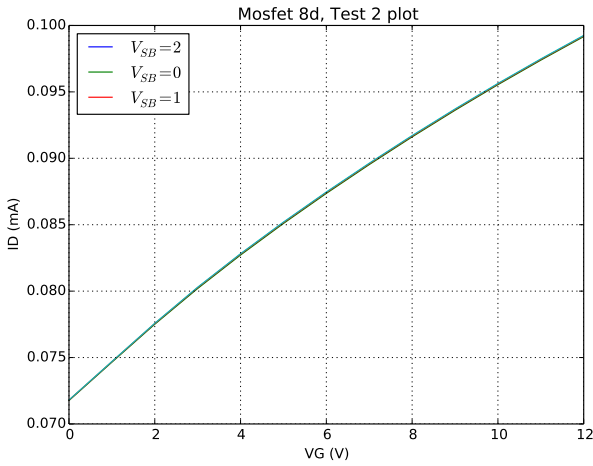


Figure 29: Test 2 for Mosfet 8d. On the right side we did a linear regression on the  $V_{SB} = 0$  line in order to get a estimate of the threshold voltage.

Similarly, the threshold voltage is not clear in the figure above. Using linear regression again with  $V_{SB} = 0$  we get  $V_t = -32.2$ .

### 1.9.5 Estimate of $\Delta L$

To summarize the threshold voltages calculated in the last section,

MOSFET device	$V_t(V)$	$L_{\text{drawn}} (\mu m)$	Fig #
8a	-51.4	4	<a href="#">26</a>
8b	-34.2	6	<a href="#">27</a>
8c	-32.4	8	<a href="#">28</a>
8d	-32.2	10	<a href="#">29</a>

Figure 30: Threshold voltages for all MOSFET 8 devices.

Now the first step in calculating  $\Delta L$  is to find the extended Resistance. We can do this by plotting the measured resistance vs gate Length at various voltages (from lecture). This plot looks like the following:

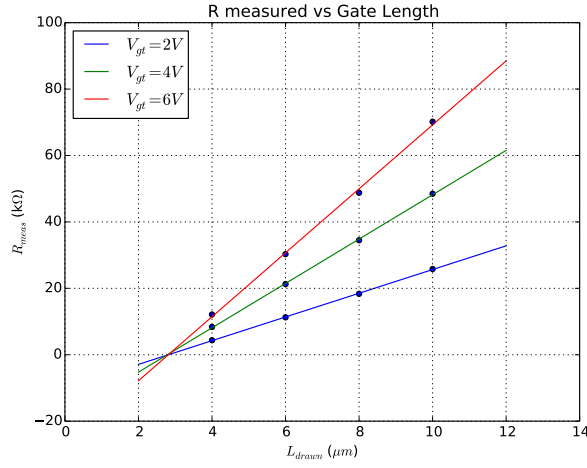


Figure 31: Measured Resistance vs Gate length for various lengths and voltages

The Y value from the origin (0) to the point of intersection would be the extended Resistance value. However in our case the lines intersect at just about 0; this means that  $R_{ext} \approx 0$ . Now we can solve for  $\Delta L$  by using the following equation from lecture:

$$R_{meas} = \frac{L_{drawn} - \Delta L}{\mu W C_{gox} (V_{gs} - V_t)} + R_{ext} \quad (3)$$

Solving for  $\Delta L$  and noting that from earlier that  $C_{gox} = 1.95 \text{ pF}/\mu m^2$  and  $\mu_n = 92.4 \text{ cm}^2/\text{V-s}$ . We will also choose  $V_{gs} - V_t = 2V$ ,  $L_{drawn} = 4 \mu m$ , and  $R_{meas} = 8.368 \text{ k}\Omega$ . Note that  $W = 15 \mu m$  and  $R_{ext} = 0$ .

$$\Delta L = L_{drawn} - R_{meas} \mu_n C_{gox} (V_{gs} - V_t) = (8.368 \times 10^3 \Omega)(92.4 \text{ cm}^2/\text{V-s})(15 \times 10^{-6} \text{ m})(1.95 \times 10^{-7} \text{ F/cm}^2)(2V) = 1.59 \mu m$$

## 1.10 MOSFETs of varying width [9a-c]

### 1.10.1 Measurement setup

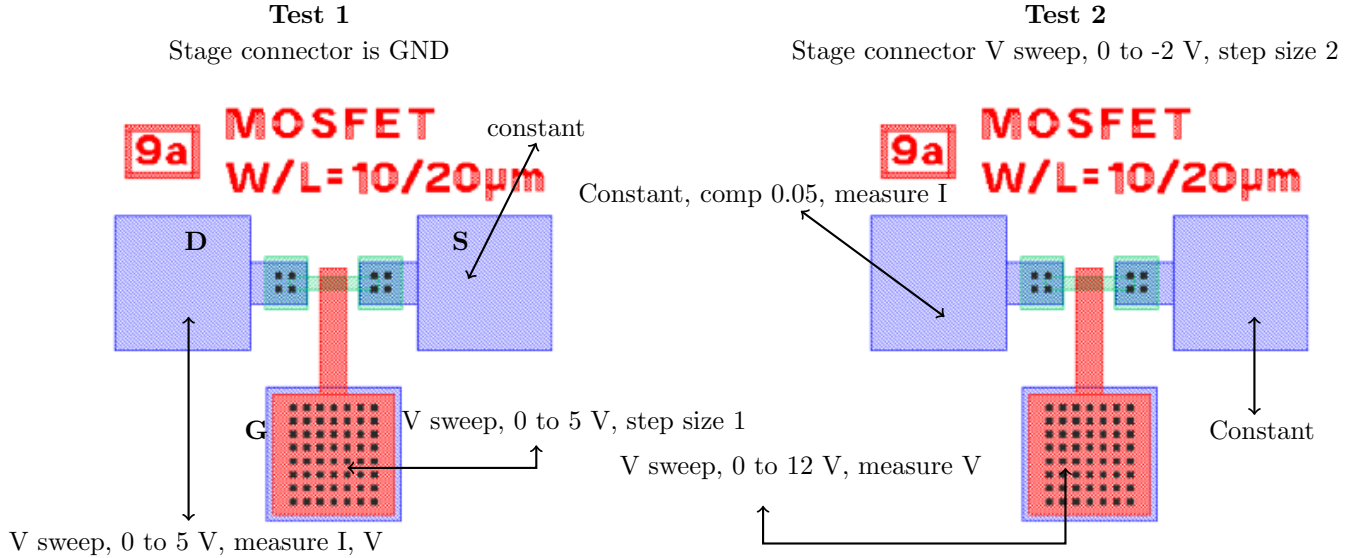


Figure 32: Measurement setup for Mosfet 9a. The same setup is used for Mosfets 9a-c. The only difference is the channel widths which changes from 10 (9a) to 15 (9b) to 20 (9c) microns.



### 1.10.2 Plots of $I_D$ - $V_D$ , sweeping $V_G$

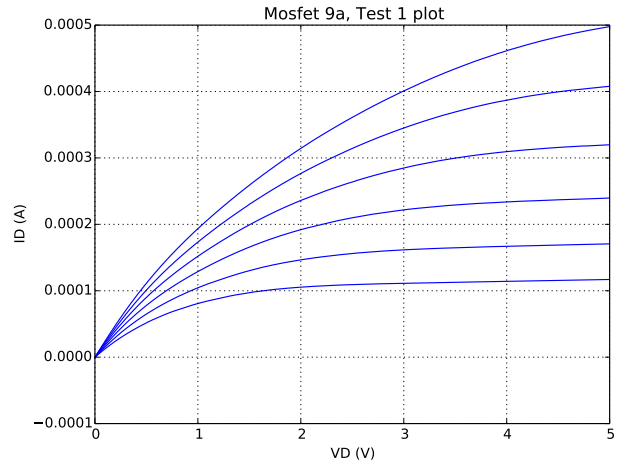


Figure 33: Test 1 for Mosfet 9a

Calculate stuff here...

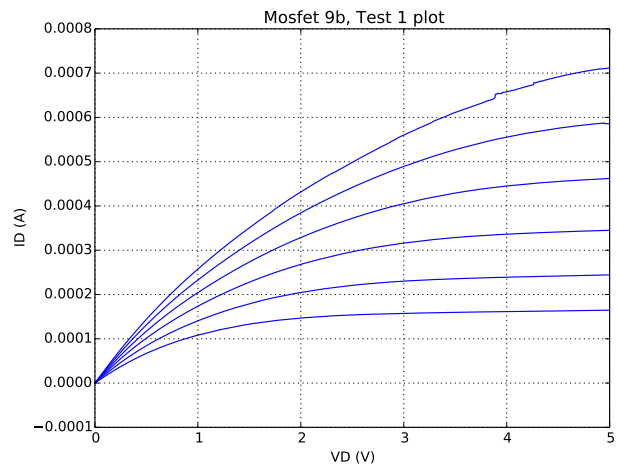


Figure 34: Test 1 for Mosfet 9b

Calculate stuff here...

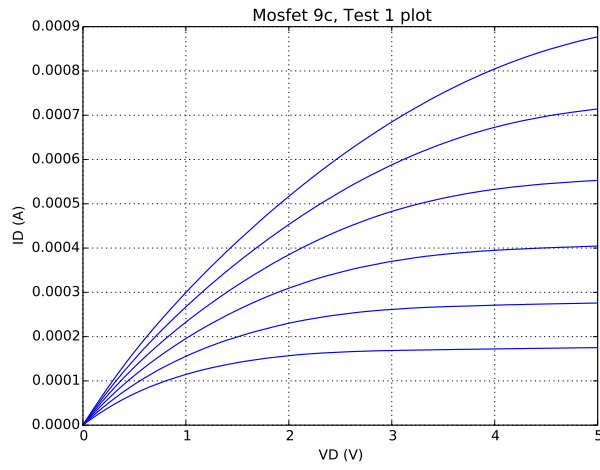


Figure 35: Test 1 for Mosfet 9c

Calculate stuff here...

### 1.10.3 Plots of $I_D$ - $V_G$ , sweeping $V_B$

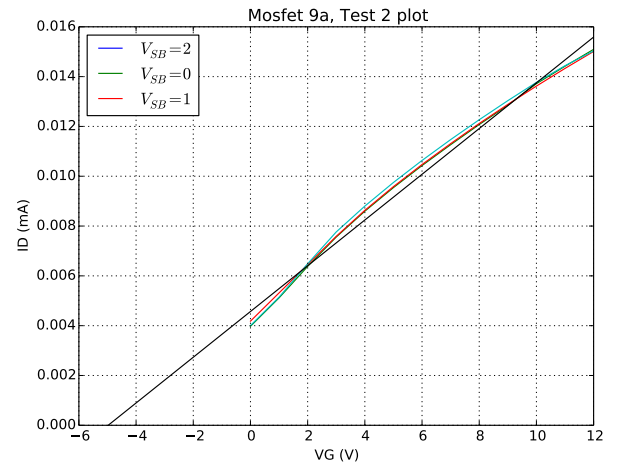
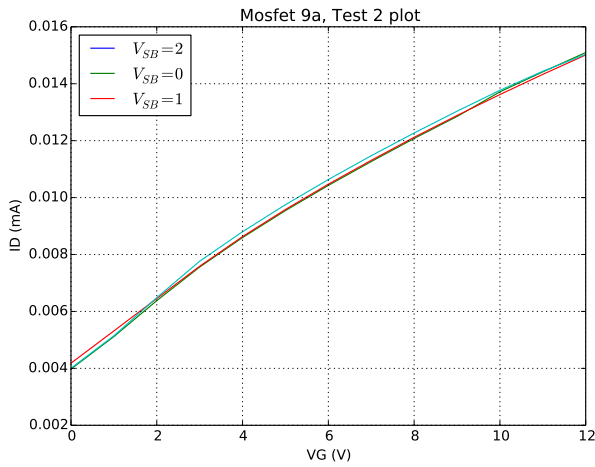


Figure 36: Test 2 for Mosfet 9a. On the right side we did a linear regression on the  $V_{SD} = 0$  line in order to get a estimate of the threshold voltage.

Using linear regression, we calculated a threshold voltage of  $V_t = -4.98$ .

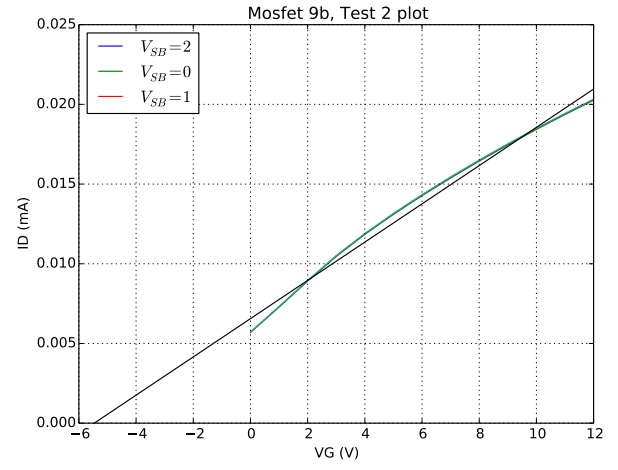
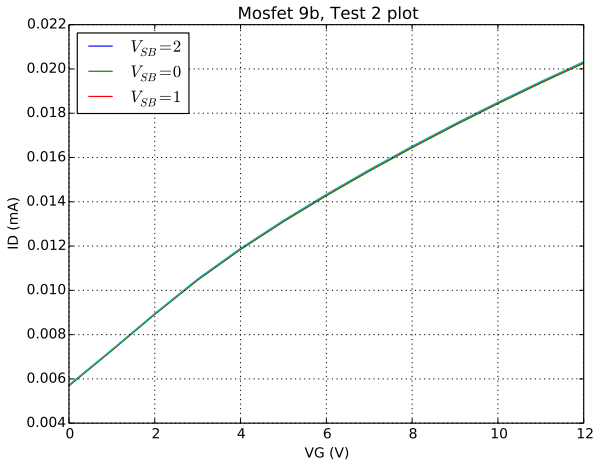


Figure 37: Test 2 for Mosfet 9b. On the right side we did a linear regression on the  $V_{SB} = 0$  line in order to get a estimate of the threshold voltage.

Using linear regression, we calculated a threshold voltage of  $V_t = -5.46$ .

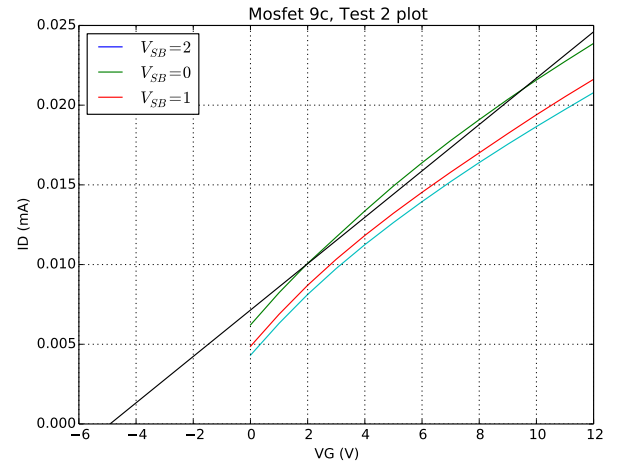
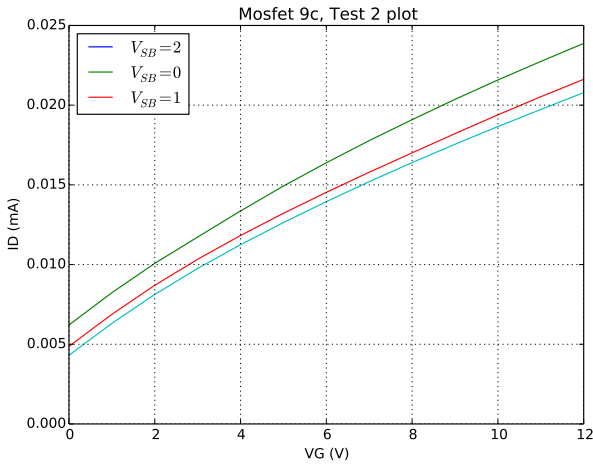


Figure 38: Test 2 for Mosfet 9c. On the right side we did a linear regression on the  $V_{SB} = 0$  line in order to get a estimate of the threshold voltage.

Using linear regression, we calculated a threshold voltage of  $V_t = -4.91$ .

#### 1.10.4 W calculation and plot

To summarize the threshold voltages calculated in the last section,

MOSFET device	$V_t(V)$	$W_{\text{drawn}} (\mu m)$	Fig #
9a	-4.98	10	36
9b	-5.46	15	37
9c	-4.91	20	38

Figure 39: Threshold voltages for all MOSFET 8 devices.

Now to calculate the channel width we first plot the reciprocal of the measured resistance vs channel width (from lecture).

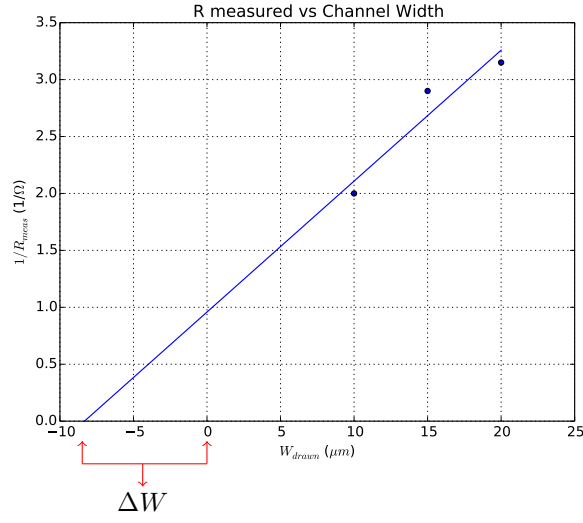


Figure 40:  $1/R$  vs the channel Width. A linear regression was used to fit the data points. Note that it intersects zero at a negative length.

The line above intercepts the x axis at  $-8.33 \mu$ . Hence our  $\Delta W = -8.33 \mu m$ . Now to plot the threshold voltage vs the effective channel width we can use Figure 39. Note that  $W_{eff} = W_{drawn} - \Delta W$ .

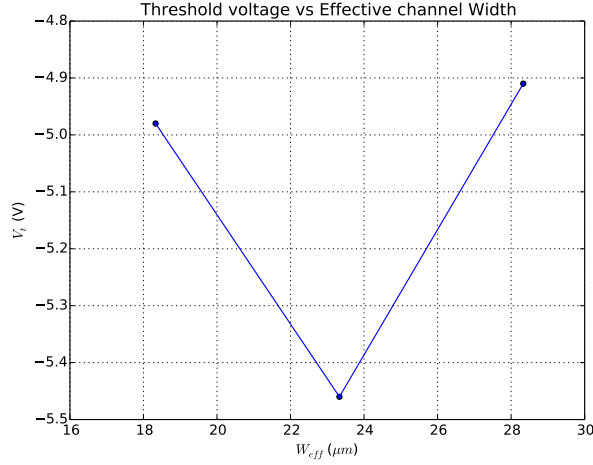


Figure 41: Channel threshold voltage vs the channel width. Note the odd V shape which appears because of the calculated threshold voltages.

## 1.11 Large MOSFET, 10

### 1.11.1 Measurement setup

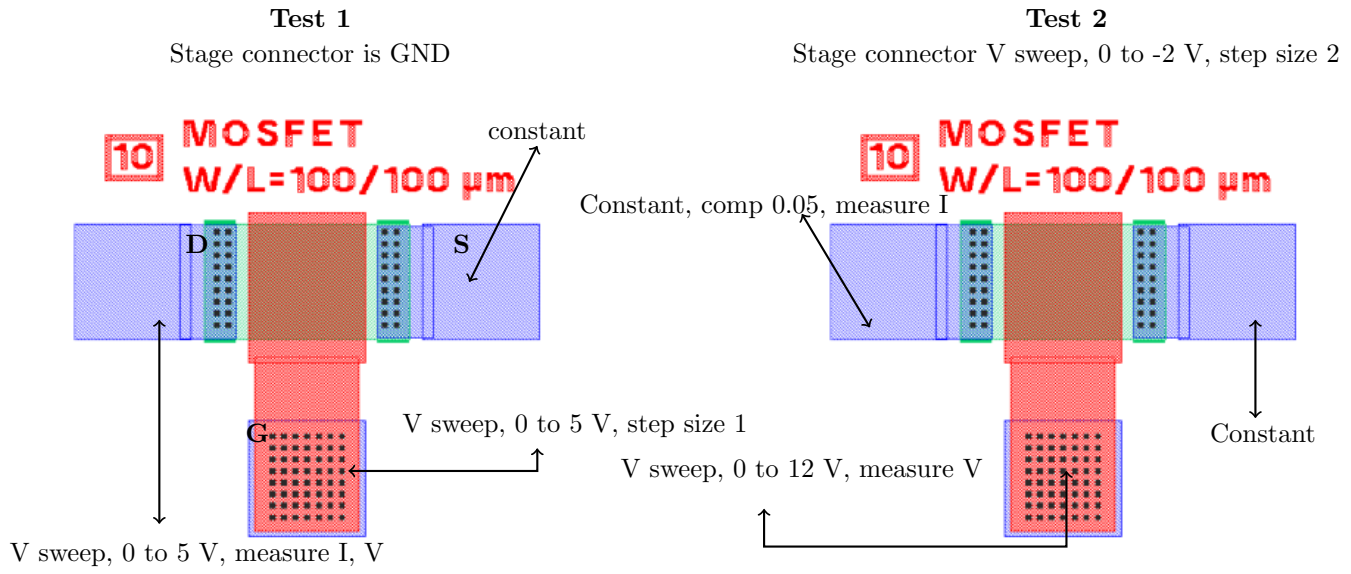


Figure 42: Measurement setup for Mosfet 10. This mosfet has very large dimensions compared to others.

### 1.11.2 Plots of $I_D$ - $V_D$ , sweeping $V_G$

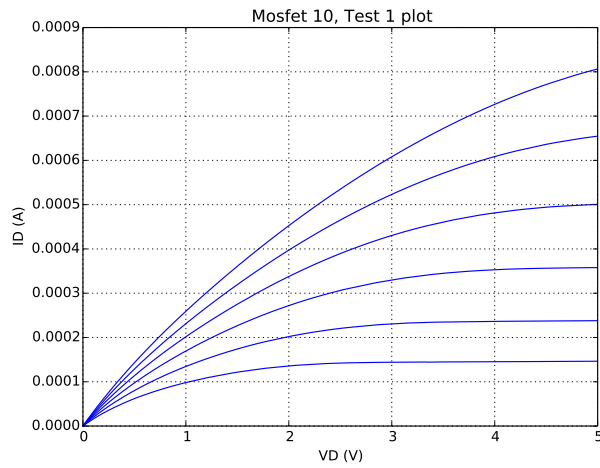


Figure 43: Test 1 for Mosfet 10

### 1.11.3 Plots of $I_D$ - $V_G$ , sweeping $V_B$

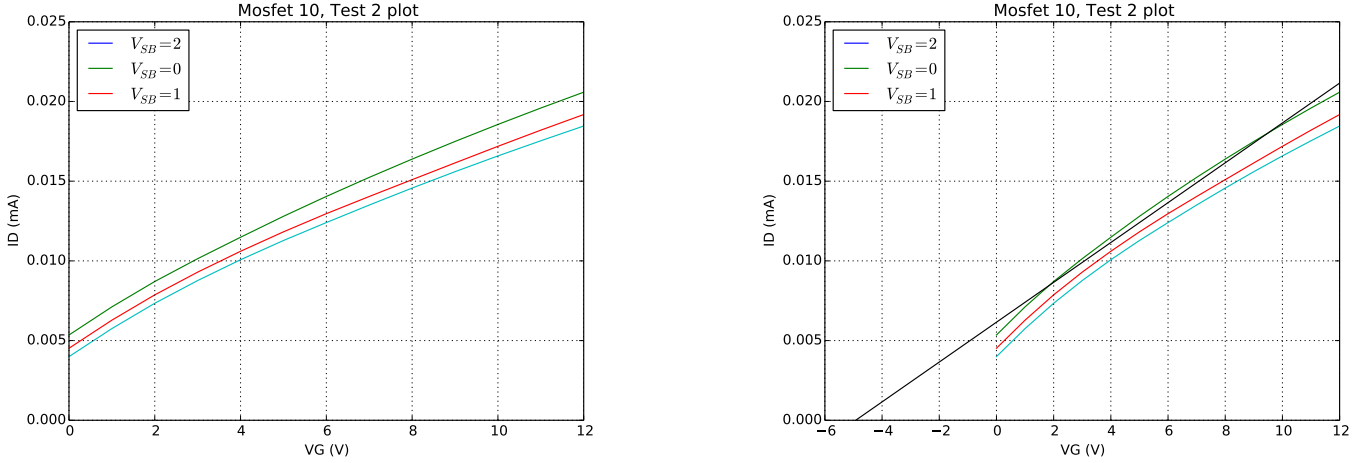


Figure 44: Test 2 for Mosfet 10. On the right side we did a linear regression on the  $V_{SB} = 0$  line in order to get a estimate of the threshold voltage.

The threshold voltage here is  $V_t = -4.92V$ .

### 1.11.4 Calculating mobility, threshold, and other parameters

To calculate the effective electron mobility we will use the following equation,

$$\mu_{\text{eff}}(V_G) = \frac{I_D}{\frac{W_{\text{eff}}}{L_{\text{eff}}} C_{\text{gox}} (V_{GS} - V_t) V_{DS}} \quad (4)$$

Note that  $I_D$  depends on  $V_G$  from the previous plot. For  $\Delta W$  and  $\Delta L$  we will use values calculated earlier ( $-8.33$  and  $1.59 \mu\text{m}$ ). MOSFET 10 has a  $W$  and  $L$  value of  $100 \mu\text{m}$ . Threshold voltage was calculated as  $V_t = -4.92V$  and  $V_{DS} = 0.05V$ .  $C_{\text{gox}}$  was also calculated earlier as  $1.95\text{pF}/\mu\text{m}^2$ .

$$\mu_{\text{eff}}(V_G) = \frac{I_D}{\frac{W_{\text{eff}}}{L_{\text{eff}}} C_{\text{gox}} (V_{GS} - V_t) V_{DS}} = \frac{I_D(V_G)}{\frac{(100+8.33) \times 10^{-6}}{(100-1.59) \times 10^{-6}} (1.95 \times 10^{-15}) (V_{GS} + 4.92) (0.05)} = \frac{I_D(V_G)}{1.07 \times 10^{-8} (V_{GS} + 4.92)} \text{cm}^2/\text{V-s}$$

Now we plot  $\mu_{\text{eff}}(V_G)$  vs  $V_G$  using the values for  $I_D(V_G)$  from the previous graph (Figure 44).

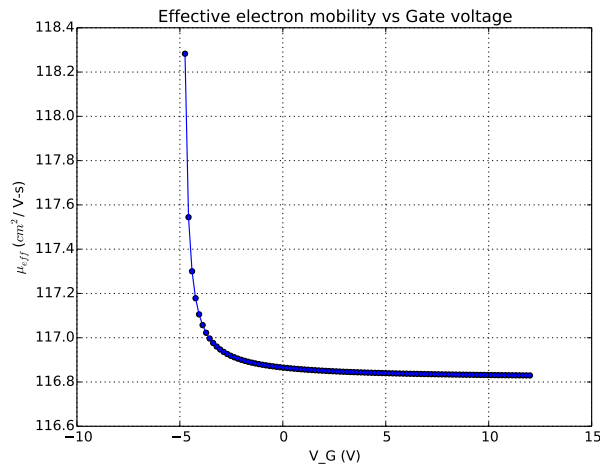


Figure 45: Note how the graph levels off almost immediately. The first few data points are right above the threshold voltage.

Now if we do a linear fit to each line in Figure 44 we get the following results,

$V_{SB}$ (V)	$V_t$ (V)
0	-4.92
1	-4.55
2	-4.18

Figure 46: Results from doing a linear fit to each line in Figure 44 above.

With this data we can now make a  $V_t(V_{SB})$  vs  $\sqrt{V_{SB} + 0.7}$  plot in order to estimate our body effect parameter  $\gamma$ .

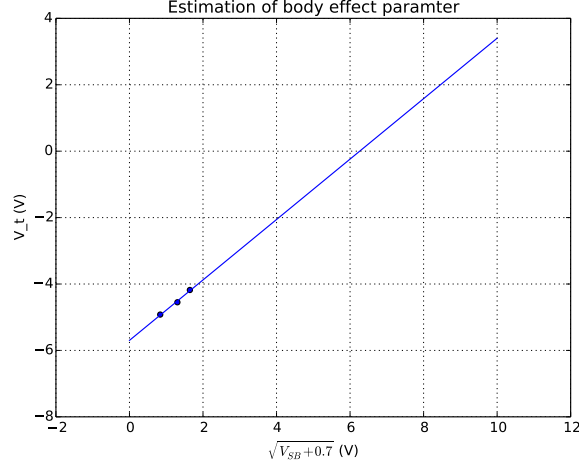


Figure 47: The slope of the above plot is our body effect parameter

Since we only have 3 data points for  $V_{SB}$  our plot is not very accurate and does not show the change of slope as would be present in the theoretical case. Nonetheless, the slope for the above plot is  $\gamma = 0.910$ . The equation for  $\gamma$ , the body effect parameter, is:

$$\gamma = \frac{\sqrt{2\epsilon_{si}qN_A}}{C_{gox}} = \quad (5)$$

Solving for the surface concentration and using previous values of  $C_{gox} = 0.195\mu\text{F}/\text{cm}^2$ .

$$N_A = \frac{(\gamma C_{gox})^2}{2q\epsilon_{si}} = \frac{(0.910 * 0.195 \times 10^{-6})^2}{2(1.602 \times 10^{-19})(11.7 \times 8.85 \times 10^{-12})} = 9.49 \times 10^{14} \text{cm}^{-3}$$

Finally, we plot a log plot of the data in Figure 44.

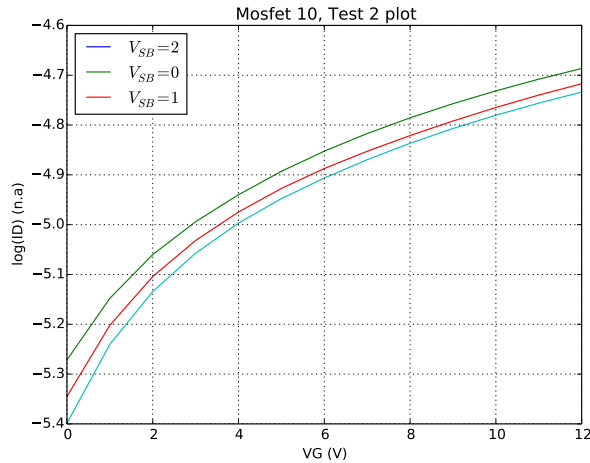


Figure 48: Log plot of Figure 44.

The subthreshold slope was calculate between  $V_G = 0$  and  $V_G = 1$ . This slope was calculated to be  $0.12 (V^{-1})$ .

## 1.12 Inverter, 14

### 1.12.1 Measurement setup

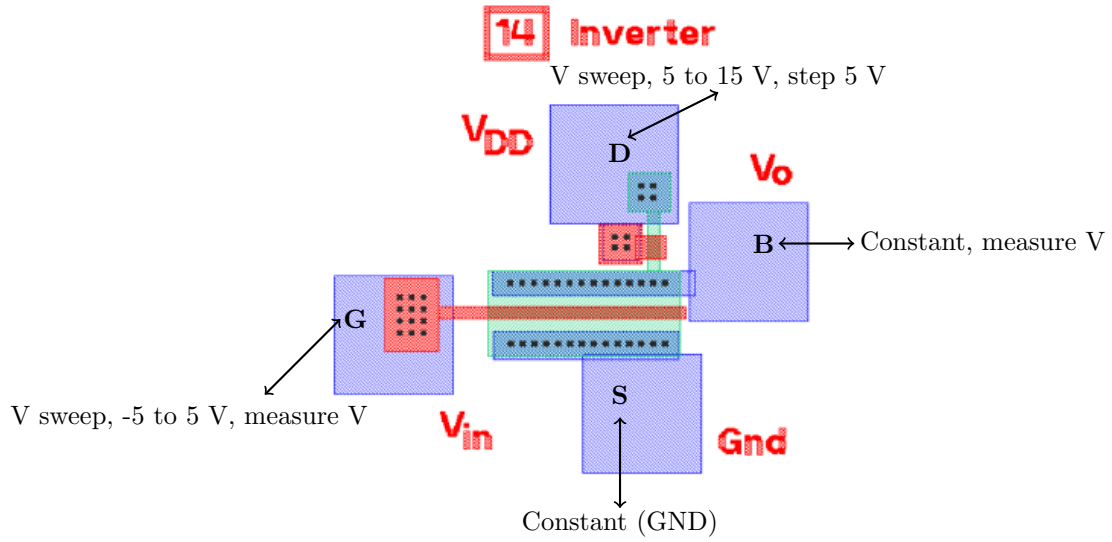


Figure 49: Setup for the inverter. Note that the source is connected to a GND and not the stage connector.

### 1.12.2 b. $V_{in} - V_{out}$ plot

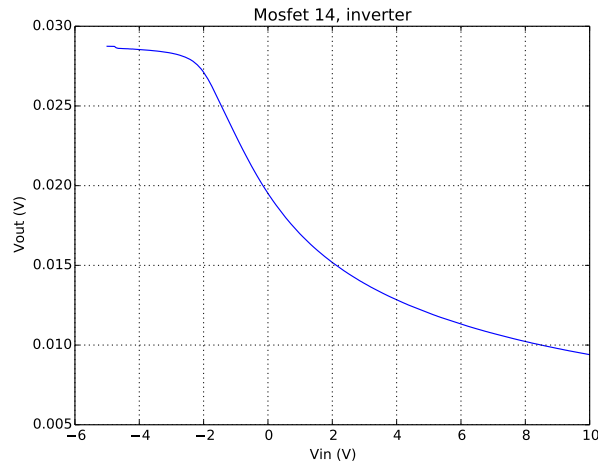


Figure 50: Plot for Inverter. Note both axis are in units of Volts.

To find the point where  $V_{IN} = V_{OUT}$  we ran a simple loop to find the closest point. We calculated  $V_M = 0.025V$ . At that voltage  $|V_{OUT} - V_{IN}|$  is minimized.



## 2 Theoretical Calculations

### 2.1 Measured Physical Dimensions and Parameters

Parameter	Measured Value
Field $t_{\text{ox}}$	477.2 nm
Gate $t_{\text{ox}}$	86.5 nm
Intermediate $t_{\text{ox}}$	320 nm
$X_j$	1000 nm
$X_{j,\text{lateral}}$	880 nm
$N_D$	$10^{21} \text{ cm}^{-3}$

### 2.2 Resistors [2a,2b]

### 2.3 Contact Resistances [17a,17b]

From jaeger Figure 7.6 [1] we that the specific contact resistivity  $10^{-2} \mu\Omega\text{-cm}^2$ . The contact area of resistors 17a and 17b is  $5\mu\text{m}$  by  $5\mu\text{m}$ . This means the theoretical contact resistance for our contact resistors is

$$R_c = \frac{\rho_c}{A} = \frac{10^{-2} \mu\Omega - \text{cm}^2}{25\mu\text{m}} = \frac{10}{25} = 0.4\Omega$$

### 2.4 Contact-Chain Resistors [2c, 2d]

#### 2.4.1 Diffusion chain resistor, 2c

$R_c$  is the contact resistance calculated earlier and  $R_s$  is the sheet resistance calculate for the diffused resistor.  $\eta$  is a geometrical constant that has a value of 2.3

$$R_{\text{total}} = 7(\eta R_s + R_c) = 7((2.3)(R_s) + (0.4)) = ?$$

#### 2.4.2 Poly chain resistor, 2d

$R_c$  is the contact resistance calculated earlier and  $R_s$  is the sheet resistance calculate for the poly resistor.  $\eta$  is a geometrical constant that has a value of 2.3

$$R_{\text{total}} = 7(\eta R_s + R_c) = 7((2.3)(R_s) + (0.4)) = ?$$

### 2.5 Gate/Field Oxide Capacitors[3,4]

### 2.6 Diode

### 2.7 MOSFETs

#### 2.7.1 MOSFETs of varying length [8] and width [9]

#### 2.7.2 Large MOSFET

### 2.8 Inverter

## 3 Discussion

## 4 Optional Questions

## 5 Appendix

## 6 References

1. Jaeger, Richard. *Introduction to microelectronic fabrication*. New Jersey: Prentice Hall, 2002. Print.