REPORT LAB1 29/11/2023

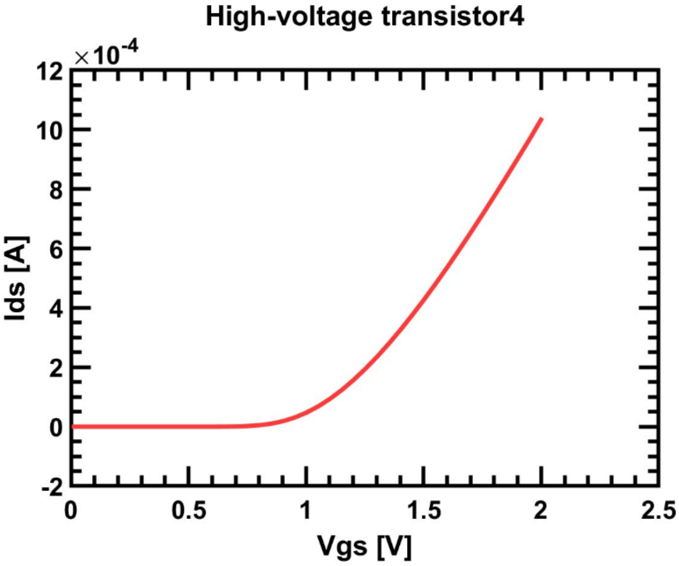
Ciobanu Florin, Santolupo Salvatore, Zerbini Daniele

For this experiment our aim is to investigate the output resistance of different transistors when it is biased with a different V_{DS}. Each of them has different W and L, as reported in the table.

Transistor	W [µm]	L [µm]
T2	10	10
T3	0.5	0.6
T4	10	0.6

In order to investigate the resistance, first of all we need to plot the device characteristic; the first step is to compute the value of the threshold voltage of the transistors, so we can apply an appropriate V_{GS} to work in the ON-state regime.

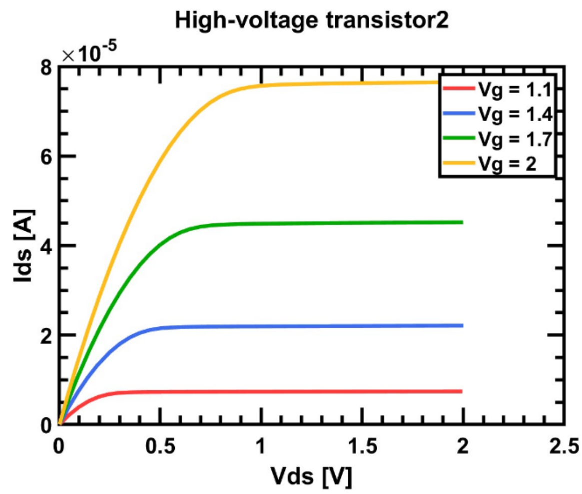
$$V_T = V_{FB} + 2|\Phi_B| + \frac{\sqrt{2\varepsilon_{Si} q N_a 2|\Phi_B|}}{C_{ox}}$$

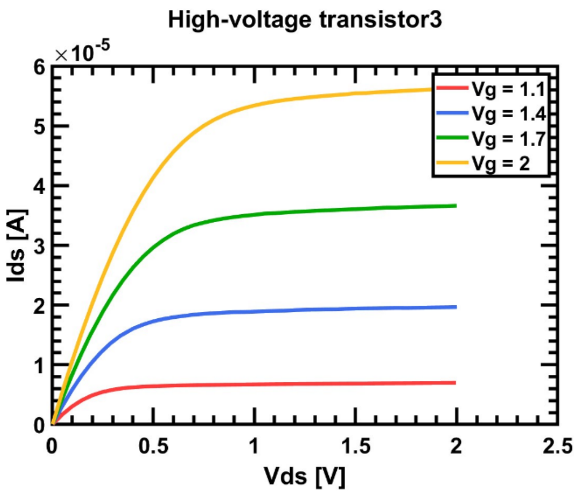


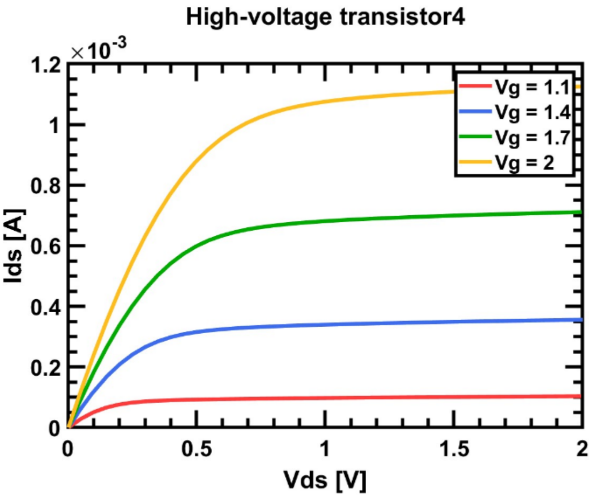
Knowing that $t_{ox} = 10.5\,nm$, $N_a = 2 * 10^{17} cm^{-3}$, $\varepsilon_{ox} = 3.9\varepsilon_0$ and that we can assume that the Fermi level of the metal is aligned to the conduction band of the silicon, we can easily calculate $V_{FB} = -\left(\frac{E_{GAP}}{2q} + \frac{kT}{q}\ln\left(\frac{N_a}{n_i}\right)\right)$, $C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$ which lead to $V_T \cong 0.6$.

Our calculation is comparable to the V_T that we can extract from a measurement on the transcharacteristic, shown on the left for transistor 4 and a $V_{DS} = 1V$.

In order to explore the ON-state regime we selected 4 different values of V_{GS} above V_T. Then we performed a sweep on the drain bias, as shown in the following pictures. We chose $V_{GS} = 1.1\,V, 1.4V, 1.7V, 2V$.







As we expected, we can see a transition from linear to parabolic, and from parabolic to saturation regime, where the I_{DS} curve is slightly dependent on the V_{DS}, due to shift of the pinch off point.

This output resistance can be calculated as $\frac{1}{r_0} = \left(\frac{\partial I_{DS}}{\partial V_{DS}}\right)$.

From the theory discussed during the lessons we can say that $r_0 \cong \frac{LF_p}{I_{DS}^{sat}}$. Of course, the dependence on I_{DS}^{sat} can be seen since, focusing on the same transistor, if we increase the V_{GS}, we increase I_{DS}^{sat} and the curves show that for higher V_{GS} the slope of the curve increases, meaning that r_0 is decreasing. Such dependence can be verified in the experimental trend, shown in the following figures (the trend of transistor 2 may be affected by error in the extraction procedure), where the lowest point is related to the highest V_{GS}. In particular, the plots show the trend of r_0 vs$\frac{1}{I_{sat}}$, highlighting linear the dependence.

Meanwhile the dependence on L can be seen comparing T2 and T4. The two transistors have the same W but T_2 has a higher value of L. Indeed, looking at the r_0 vs $\frac{1}{I_{sat}}$ plots, we can see that a longer channel yields a much larger slope, in qualitative agreement with the model.

Finally, the dependence on the W can be seen comparing $T3$ and $T4$. Indeed, for the same value of V_{GS} we see differences in orders of magnitude in I_{sat}, thus in r_0.