TCAD for electronic devices part 5

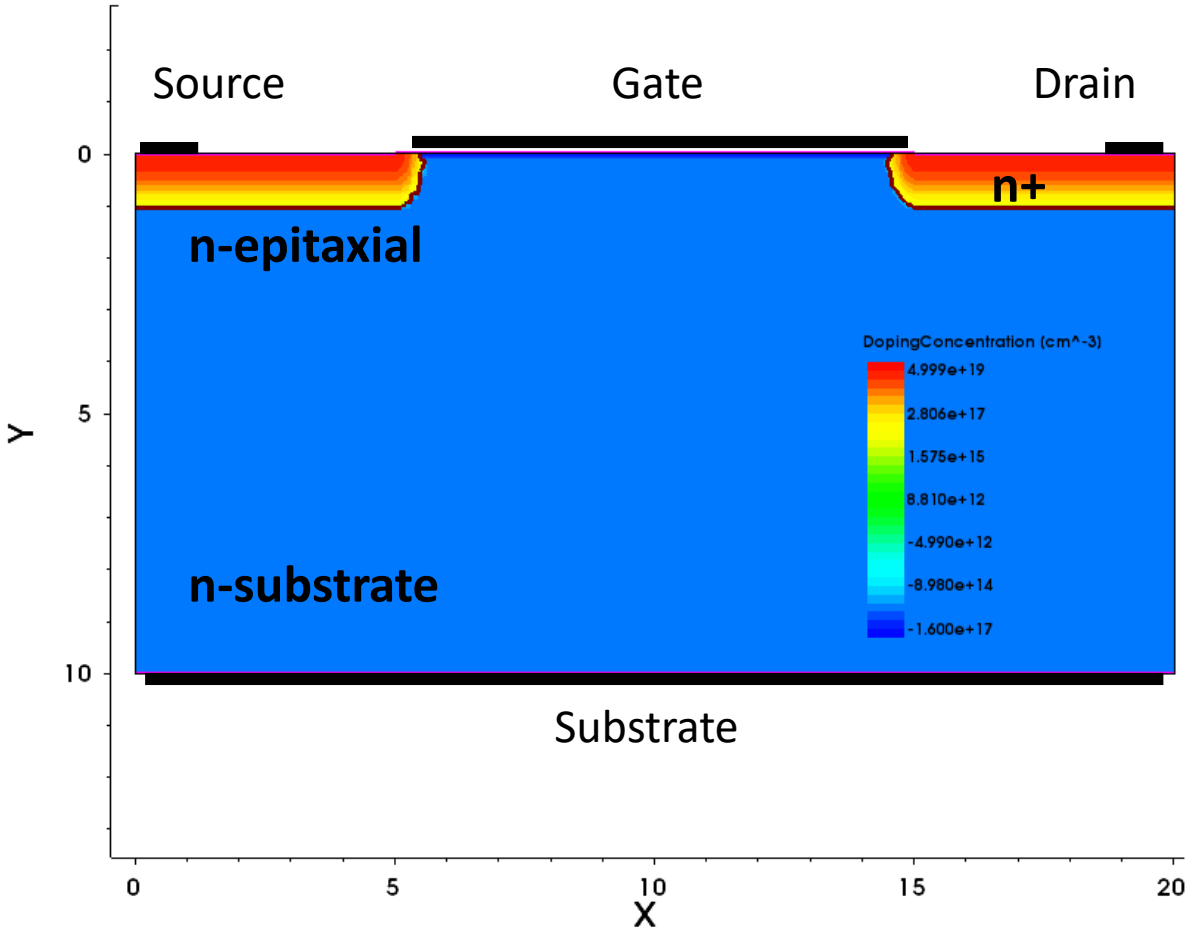
Microelectronics devices, sensors and MEMS

Academic Year 2023/2024

Lucio Pancheri

lucio.pancheri@unitn.it

Example 1. MOSFET



Gate oxide thickness: 10nm

Gate channel Boron implantation

File: **`P5EX1_MOSFET_sde.txt`**

Example 1a. Output curves I_D vs. V_{DS}

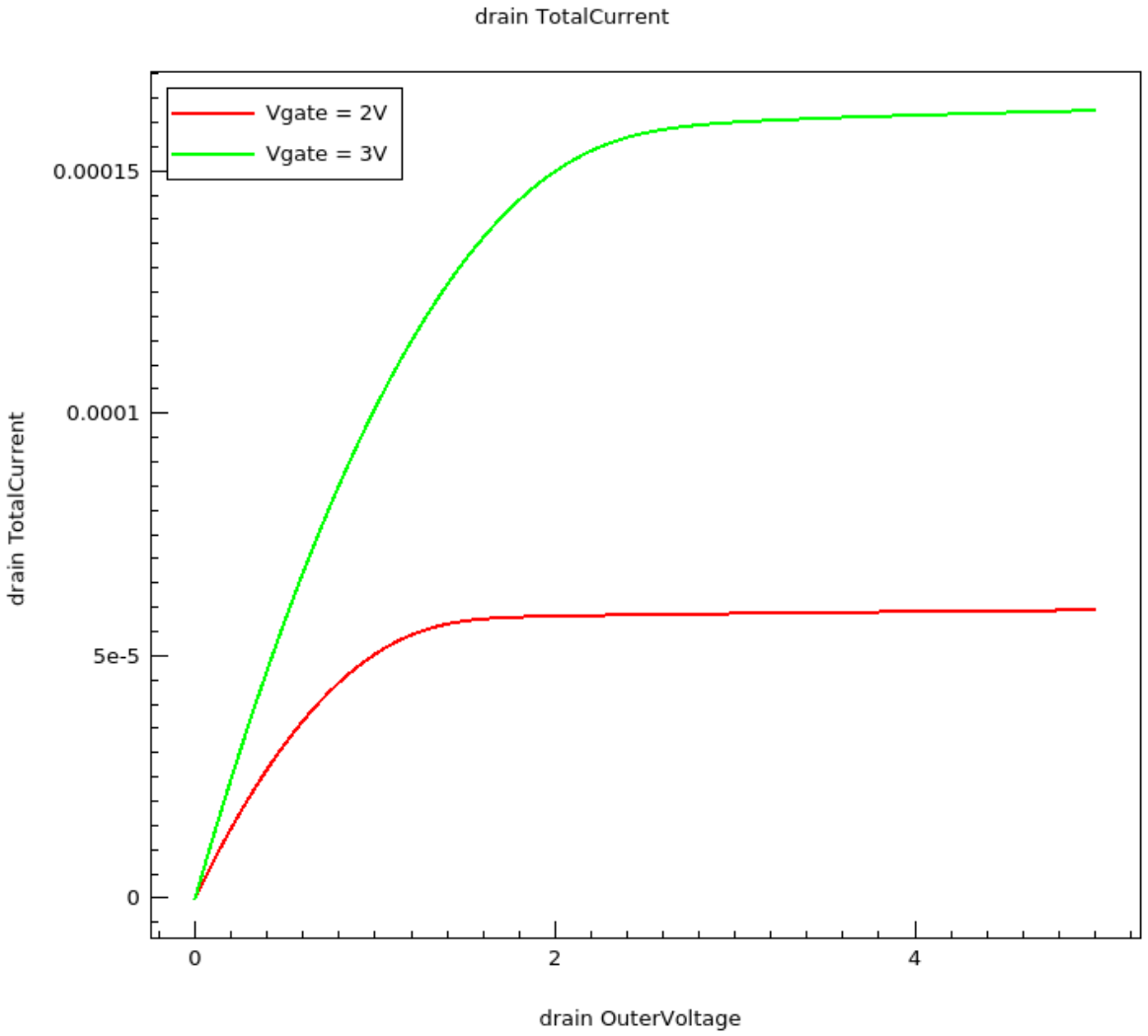
```
Solve {
        Poisson
        Coupled {Poisson Electron Hole}

        # Ramp the gate and save structures
        # First gate voltage
        Quasistationary (InitialStep=0.1 MaxStep=0.1 MinStep=1e-5
                Goal {Name="gate" Voltage=2}
                Plot { Range = (0 1) Intervals =2}
        ) {Coupled {Poisson Electron Hole}}
        Save(FilePrefix="vg1")

        # Second gate voltage
        Quasistationary (InitialStep=0.1 Maxstep=0.1 MinStep=1e-5
                Goal {Name="gate" Voltage=3})
        {Coupled {Poisson Electron Hole}}
        Save(FilePrefix="vg2")

        # Load the saved structures and ramp the drain
        # First curve
        Load(FilePrefix="vg1")
        NewCurrentPrefix="Curve1_"
        Quasistationary (InitialStep=0.01 MaxStep=0.01 MinStep=1e-5
                Goal {Name="drain" Voltage=5})
        {Coupled {Poisson Electron Hole}}

        # Second curve
        Load(FilePrefix="vg2")
        NewCurrentPrefix="Curve2_"
        Quasistationary (InitialStep=0.01 MaxStep=0.01 MinStep=1e-5
                Goal {Name="drain" Voltage=5})
        {Coupled {Poisson Electron Hole}}
}
```

Simulate I_D-V_{DS} curves with:
V(gate) = 2 and
V(gate) = 3

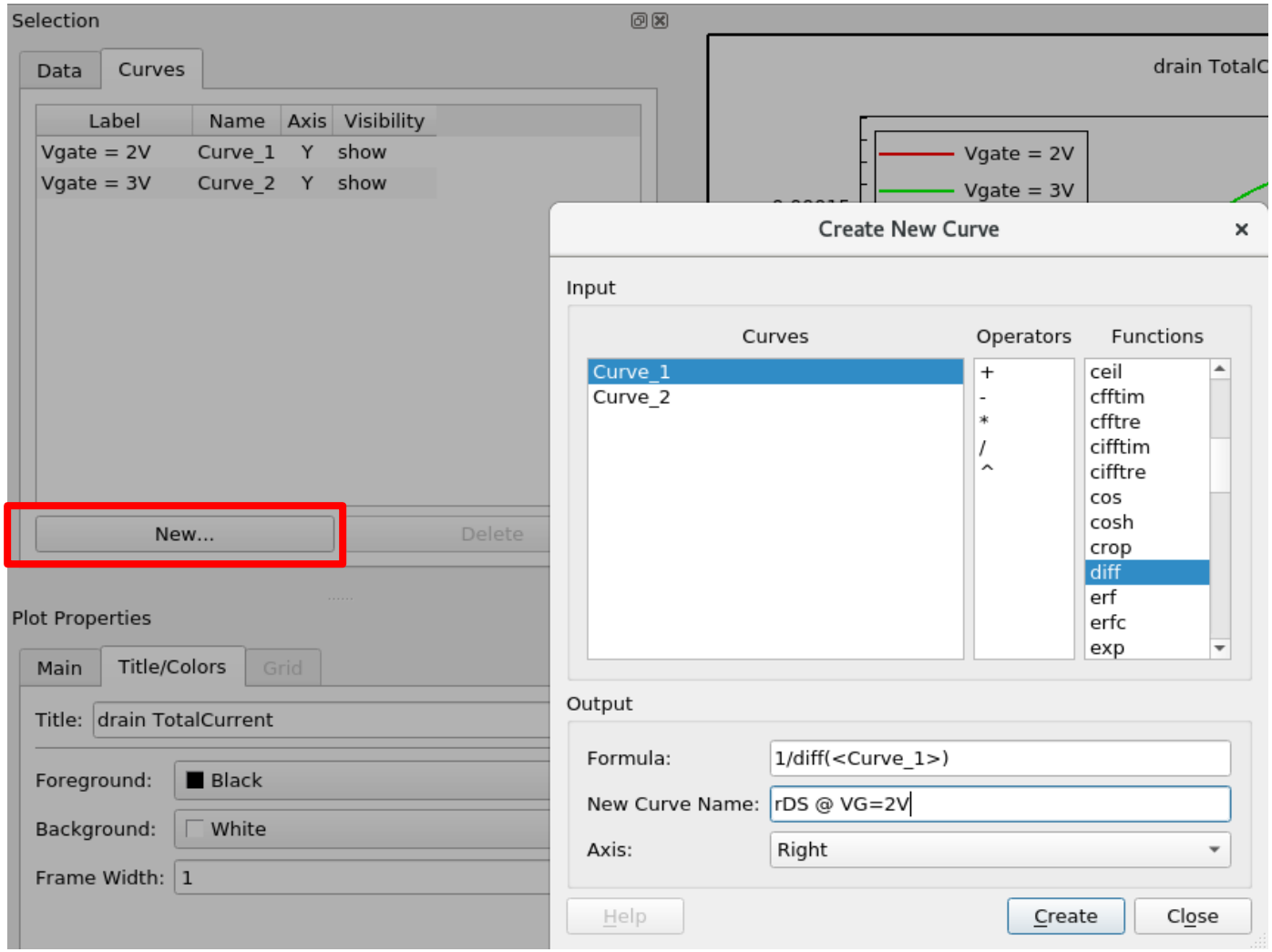
Save the I_D-V_{DS} curves for the 2 different gate voltages:
File names starts with prefix "Curve1_" and "Curve2_"

File: **P5EX1_MOSFET_sdevice.txt**

Example 1a. Output curves I_D vs. V_{DS}



Example 1a. Calculate r_{DS}



Create new curves to calculate r_{DS}:

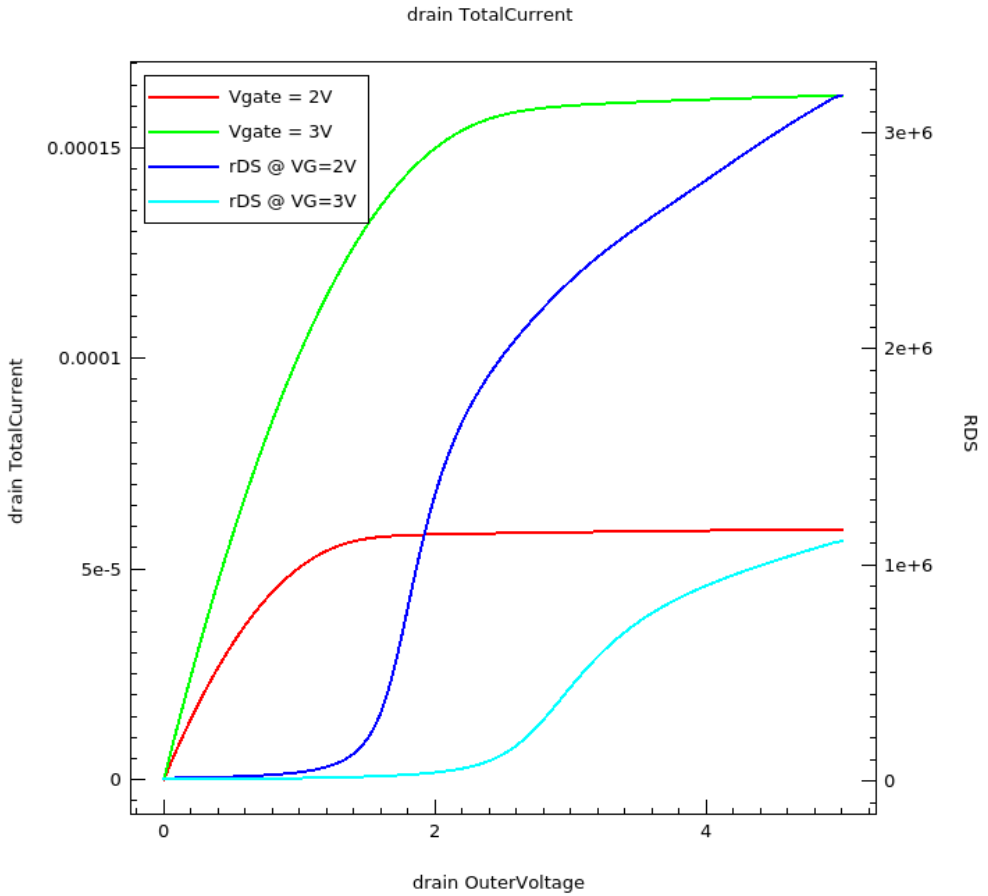
$$r_{DS} = \frac{1}{\frac{dI_D}{dV_{DS}}}$$

Example 1a. Calculate r_{DS}

Probe

3.99813

Curve	Value	Axis
Curve_1	5.91029e-5	Y
Curve_2	0.000161508	Y
rDS @ VG=2V	2.78075e+6	Y
rDS @ VG=3V	903555	Y



Report the value of r_{DS} at V_{DS}=4V in the shared spreadsheet: https://docs.google.com/spreadsheets/d/1vW4nCf_KBdLVrjY8NMgzHi5-FspXIOoXXMD3CAkGAG8/edit?usp=sharing

Example 1b. Transfer curve I_D vs. V_{GS}

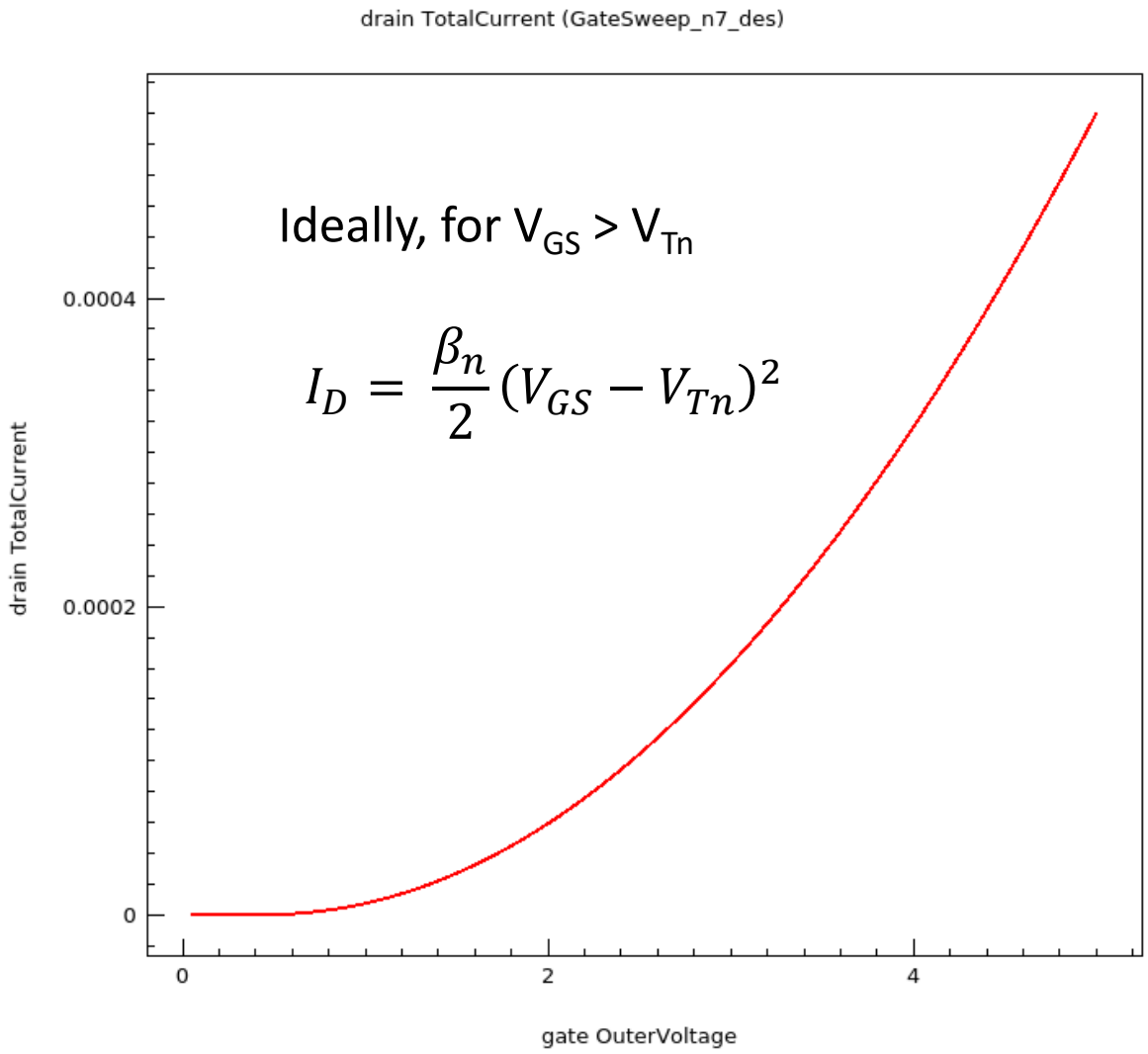
```
Solve {
        Poisson
        Coupled {Poisson Electron Hole}

        # Ramp the drain voltage
        Quasistationary (InitialStep=0.1 MaxStep=0.1 MinStep=1e-5
                Goal {Name="drain" Voltage=5}
        ) {Coupled {Poisson Electron Hole}}


        # Ramp the gate voltage
        NewCurrentPrefix="GateSweep_"
        Quasistationary (InitialStep=0.01 Maxstep=0.01 MinStep=1e-5
                Goal {Name="gate" Voltage=5})
        {Coupled {Poisson Electron Hole}}
}
```

Simulate I_D-V_{GS} curve with V(drain) = 5V

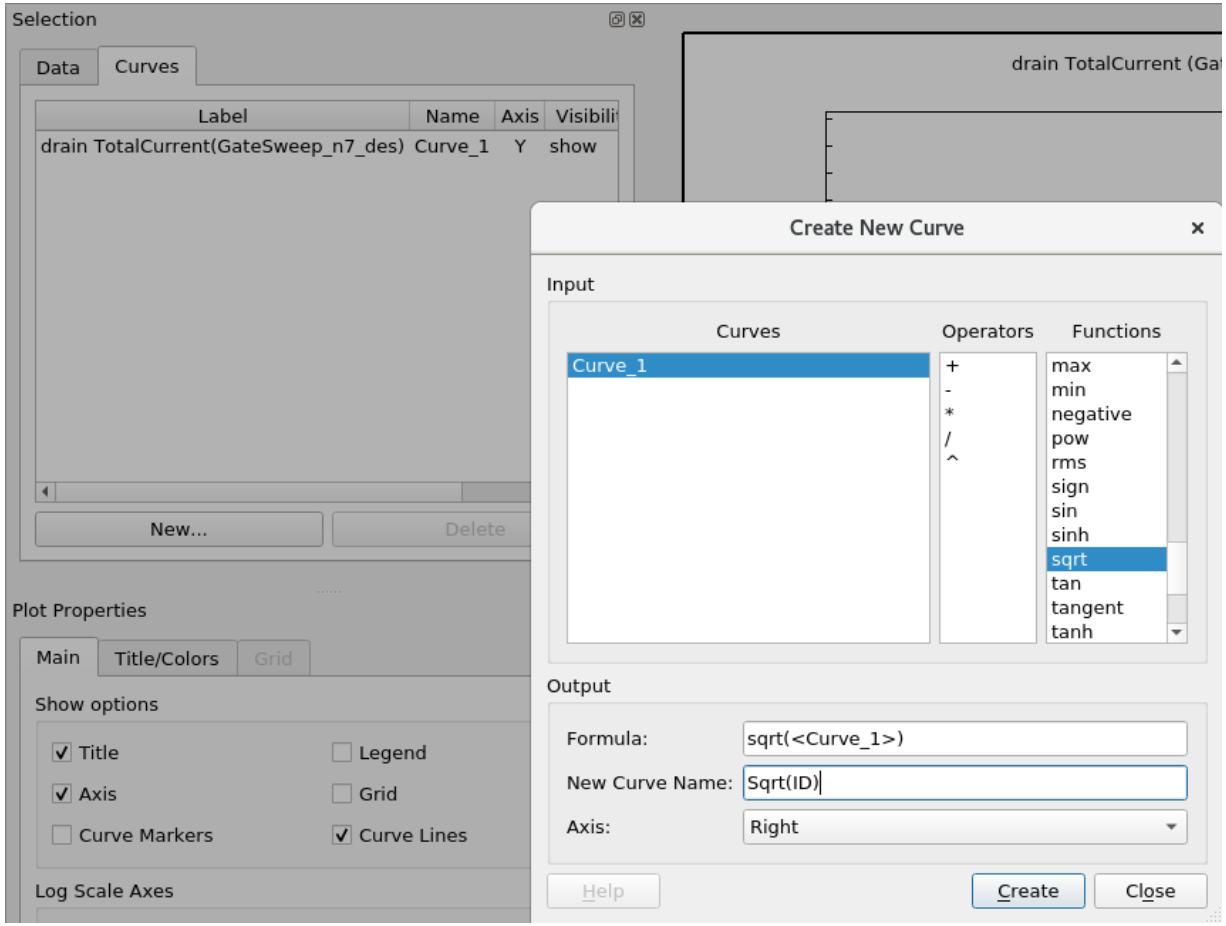
Save the I_D-V_{GS} curve: File names starts with prefix “GateSweep_”

File: **P5EX1_MOSFET_sdevice1.txt**

Example 1b. Transfer curve I_D vs. V_{GS}



Example 1b. Extract threshold voltage



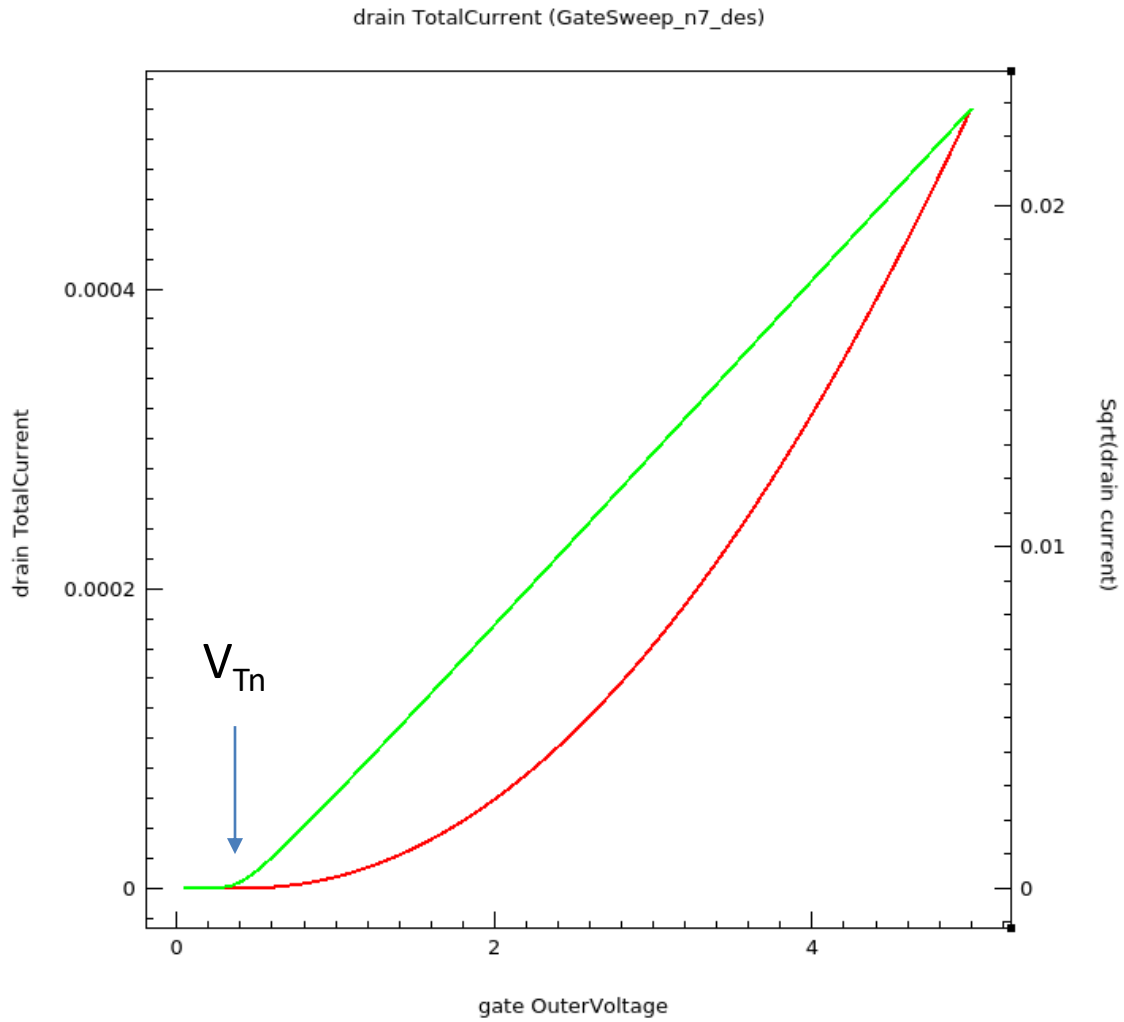
Plot $\sqrt{I_D}$ vs. V_{GS} on the right axis

Example 1b. Extract threshold voltage

Probe

0.370934

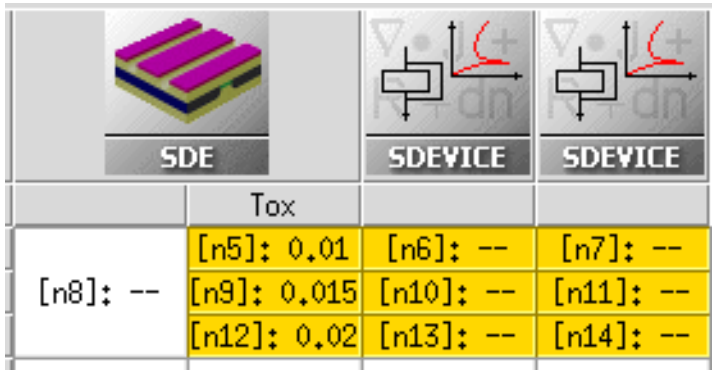
Curve	Value	Axis
Curve_1	1.94272e-8	Y
Sqrt(ID)	0.000131291	Y



V_{Tn}: intercept of the best fit curve for $\sqrt{I_D}$ vs. V_{GS} with the x-axis

Report the value of V_{Tn} in the shared spreadsheet

Exercise 1c. Effect of t_{OX} on V_{Tn}

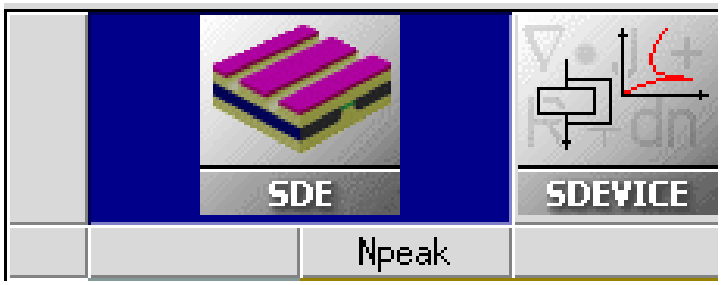


Transform the gate oxide thickness Tox in a parameter

Simulate the transfer curve with different oxide thickness and estimate the value of V_{Tn} for
Tox =15nm and Tox = 20nm

Report the values of V_{Tn} in the shared spreadsheet

Exercise 1d. Effect of threshold adjustment implantation on V_{Tn}



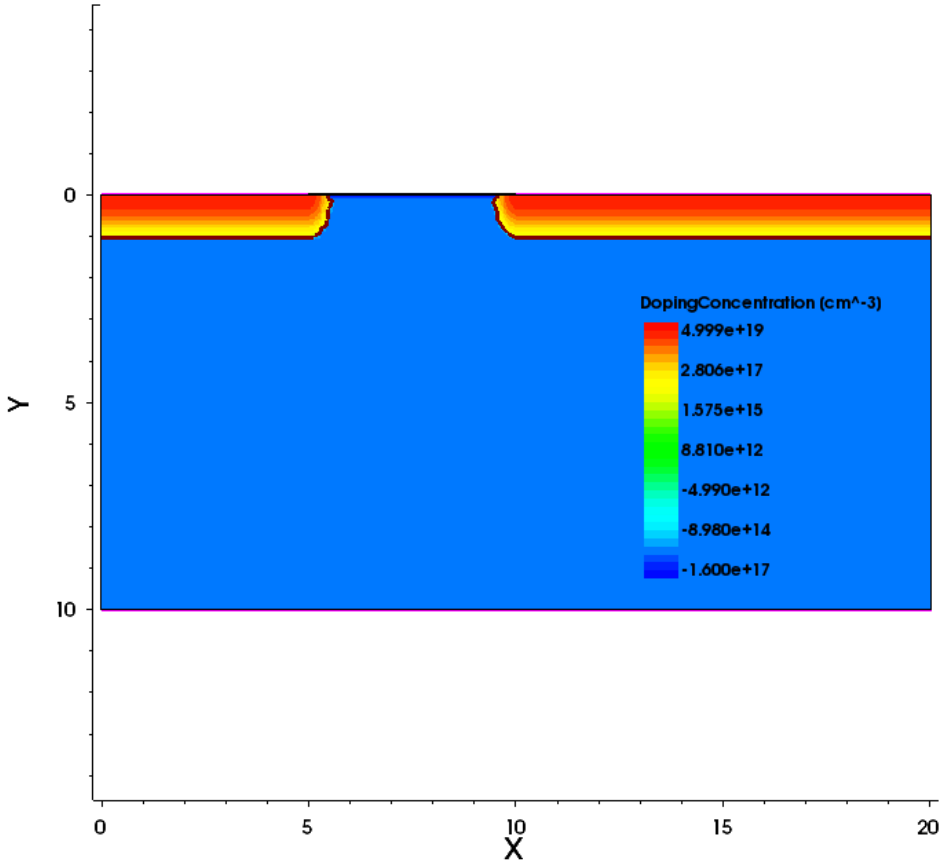
Change the value of the peak of the threshold adjustment implantation Npeak to obtain a threshold voltage V_{Tn} around 1V

Proceed by iteration if needed

```
(sdedr:define-gaussian-profile "Pch_prof" "BoronActiveConcentration" "PeakPos" 0
"PeakVal" @Npeak@ "ValueAtDepth" 1e16 "Depth" 0.1 "Gauss" "Factor" 0.5)
```

Report the value of Npeak that sets V_{Tn} = 1V in the shared spreadsheet

Exercise 1e. Effect of channel length on r_{DS}



Modify the MOSFET geometry to reduce the channel length from 10um to 5um.

Simulate the output curves and extract the values of of r_{DS} at V_{DS}=4V for both V_{GS} = 2V and V_{GS} = 3V

Report the values of r_{DS} in the shared spreadsheet