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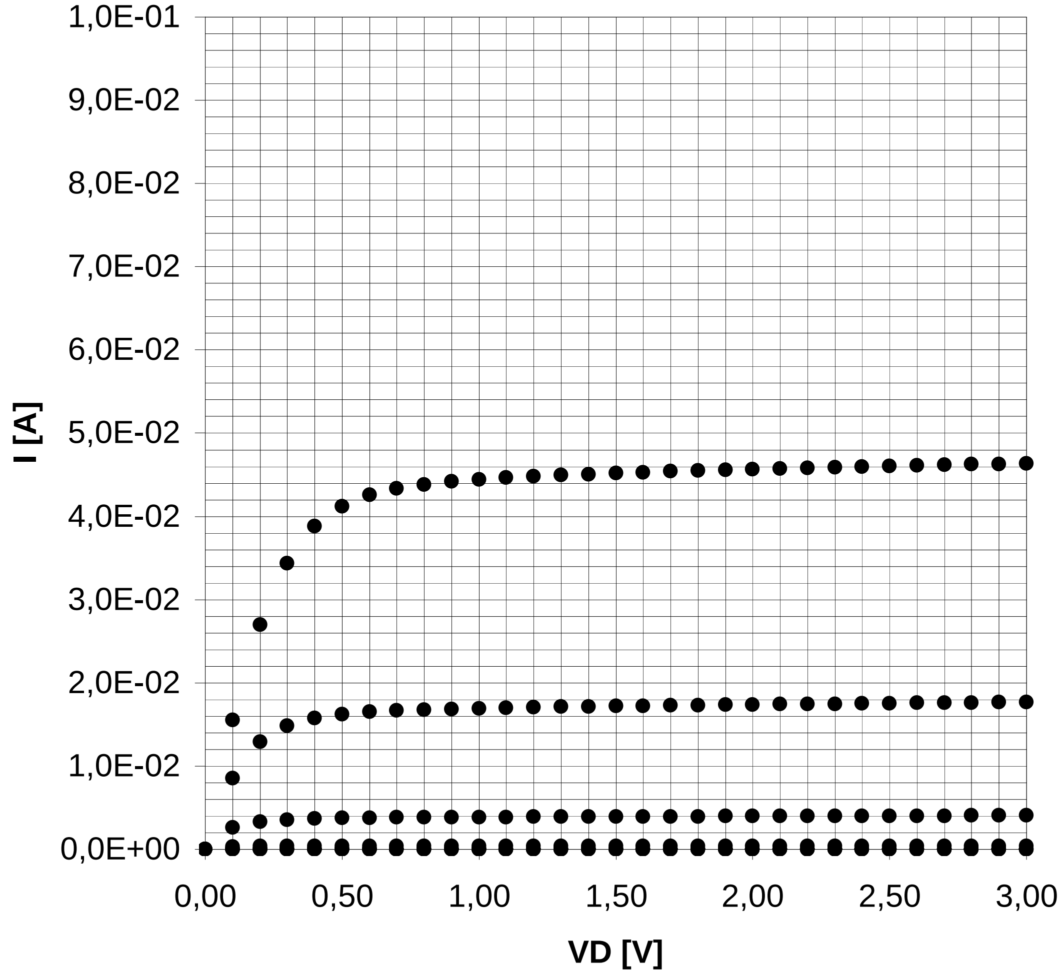
Physical electronics diagnostic exercise

MOSFET I-V Characteristics



The figure above displays the drain current, I, as a function of drain voltage, VD, (source grounded) for an nMOSFET with gate voltages from 0 V up to 3 V in increments of 0.25 V. Use this data to model the device accurately enough to be able to predict within ±20% the value of the drain voltage when the drain is connected to +3 V with resistors in the range 3-30 Ω and for applying gate voltages between 0 V and 3 V.

Correction Name...

Solution approaches

Failure

NOT being able to apply concepts/models/methods from the course on a problem in a sensible manner

Examples

- A suggested model that will result in VD-values outside the range 0 V- 3 V is not sensible. Not giving appropriate units is an example of this!

- Failure to take even a first step in handling the problem. Merely quoting a relevant equation is not a first step (no application made).

- Using a concept that cannot lead towards the solution of the problem; for example trying to apply a formula concerning breakdown in diodes to treat the problem.

- Describing/interpreting the problem in a way which is inconsistent with the text of the assignment.

Grade 3

being able to apply concepts/models/methods from the course on a problem in a sensible manner

Examples

- Quoting a formula/equation for current as a function of voltages for an appropriate transistor and starting to use it in the problem situation.

- Setting up an equivalent circuit for the situation and starting to draw conclusions from this.

- Using the data in the figure to determine parameters of an applied model (relevant for solving the problem).

Grade 4

connect more than one part of the course to the constructive treatment of a problem employing technically reasonable assumptions.

Example

Using both an equivalent circuit and an (analytical) equation for current as a function of voltage(s) for the transistor and stating non-obvious assumptions; e g that the model used is only applicable to dc (steady state) conditions

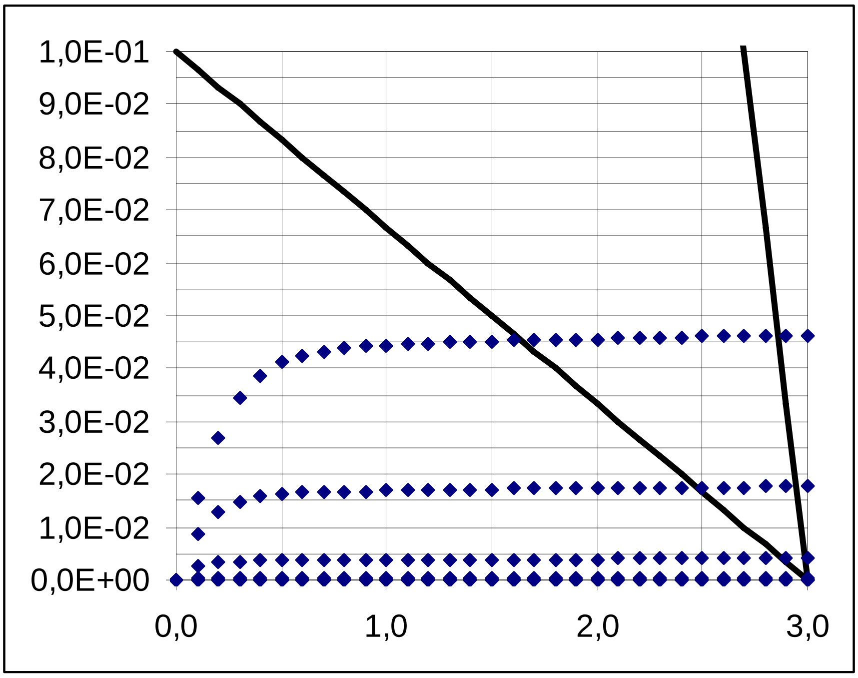
Grade 5

be able to evaluate alternative approaches to solving a problem, being able to discriminate what is more important in a particular context.

Example

Motivating the use of a model which is (as) simple (as possible), yet delivers what is asked for.

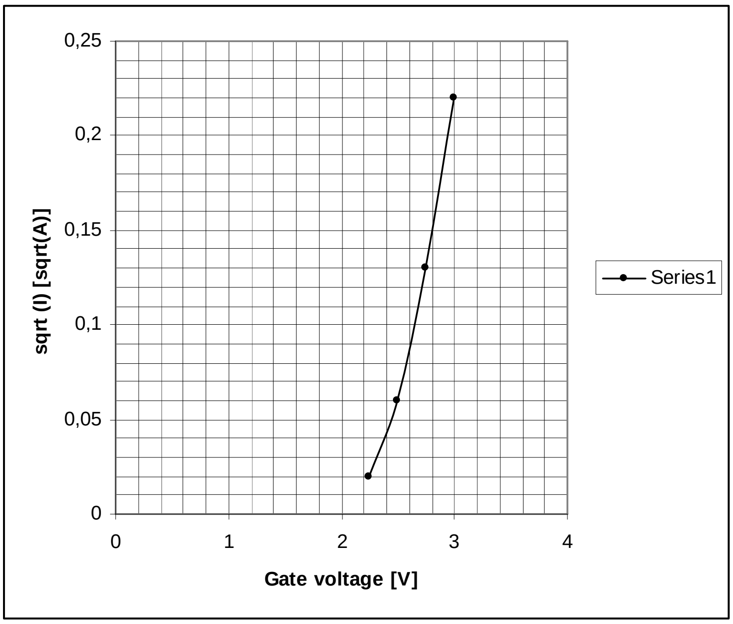
Suggestion for solution to the problem



The load lines for resistors in the range 3-30 Ω lie between the straight lines. We need to model ID as a function of VD and VG in this range. We see that ID is nearly independent with regards to VD in this range, so we go for a simple expression of ID determined by VG only. According to any textbook we would expect a quadratic dependence of the current on the gate voltage in the saturation region on the form:

$$ID = \frac{k}{2}(VG - VT)^2$$

If we plot the square-root of the current as a function of gate voltage, we should (hopefully) see a straight line with an extension intercepting the voltage axis at VG=VT. Plotting below gives a VT of approximately 2,5 V and a k of 0,4 A/V^2 .



Using this model for VG=3 V and an R of 30 Ω we get a VD of 1,5 V where we can see in the graph with load-lines that the experimental result gives approximately 1,7 volts which makes a result within 20%, and for VG=2,75 V and R=30 Ω we and up with a VD of 2,6 V where the graph gives 2,5 V, so it looks quite OK in the range we are considering.