Analysis of the Program

We must identify the threshold voltage for the semiconductor device, from its I-V characteristics, where know that V_{th} is the intersection point of the lines which the two branches of the line can be approximated to.

In our program, we choose to iterate V_{th} from about 0 to 6, where it may lie. For each value of V_{th} we calculate the best possible pair of lines by first calculating the best possible m_1 independently and then calculating the best m_2 using the y-coordinate generated by m_1 for V_{th} as follows:

Error for $m_1 = (y - m_1 x)$ as first line is known to pass through the origin $(c = 0)$.
∑ Error^2 from 0 to V_{th} will thus be

$$\sum(y - m_1 x)^2 = \sum(y^2 + m_1^2 x^2 - 2m_1 xy) = \sum(y^2) + m_1^2 \sum(x^2) - 2m_1 \sum(xy)$$

Best m_1 gives us minimum error, so we take derivative of this w.r.t. m_1 and equate to 0.

$$\frac{d(Error)}{dm_1} = 0 + 2m_1 \sum(x^2) - 2\sum(xy) = 0$$

$$m_1 = \frac{\sum(xy)}{\sum(x^2)}$$

Where summation is from $x = 0$ to $x = V_{th}$

Let the current value (y-coordinate) corresponding to V_{th} be I_{th}. Then,

$$I_{th} = m_1 V_{th}$$

Now we must find best m_2 for V_{th} onwards will be found by the same method if we shift our origin to the point (V_{th}, I_{th}), so we follow the same above procedure with a minor modification:

$$\frac{d(Error)}{dm_2} = 0 + 2m_1 \sum((x - V_{th})^2) - 2\sum\big((x - V_{th})(y - I_{th})\big) = 0$$

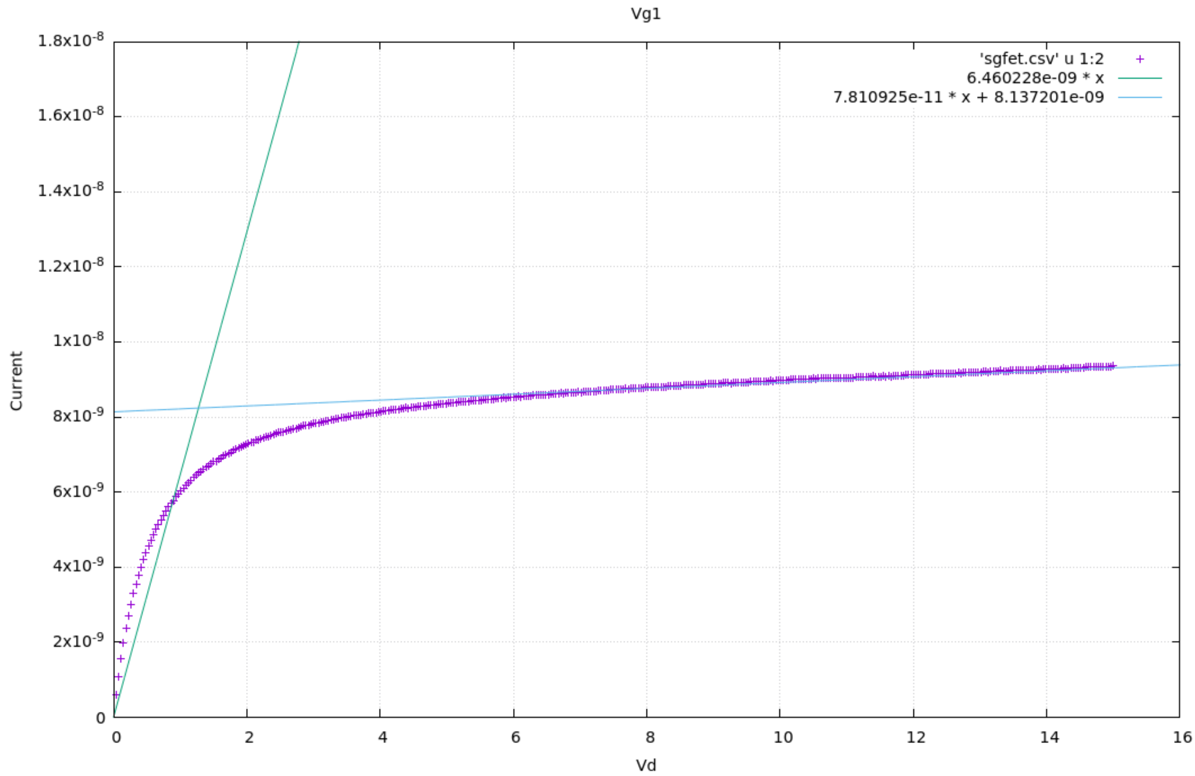
$$m_2 = \frac{\sum\big((x - V_{th})(y - I_{th})\big)}{\sum((x - V_{th})^2)}$$

Where the summation is from $x = V_{th}$ to $x = 15$

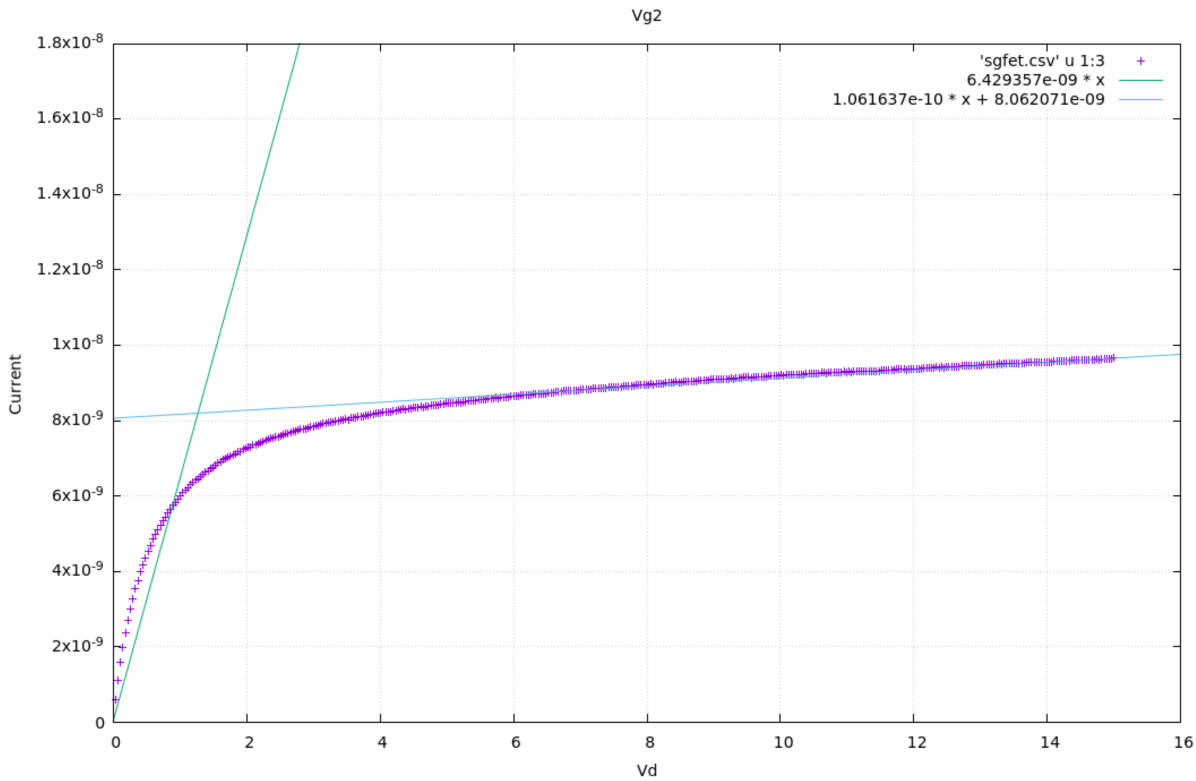
As we have both the straight lines, it is now trivial to calculate the mean square error for our pair of straight lines with loops, and store the guesses in an array.

We then use binary search algorithm to find the index of the minimum value of the error, and that pair of straight lines and V_{th} is our answer for that dataset.
We do this for all 11 V_g given to us.

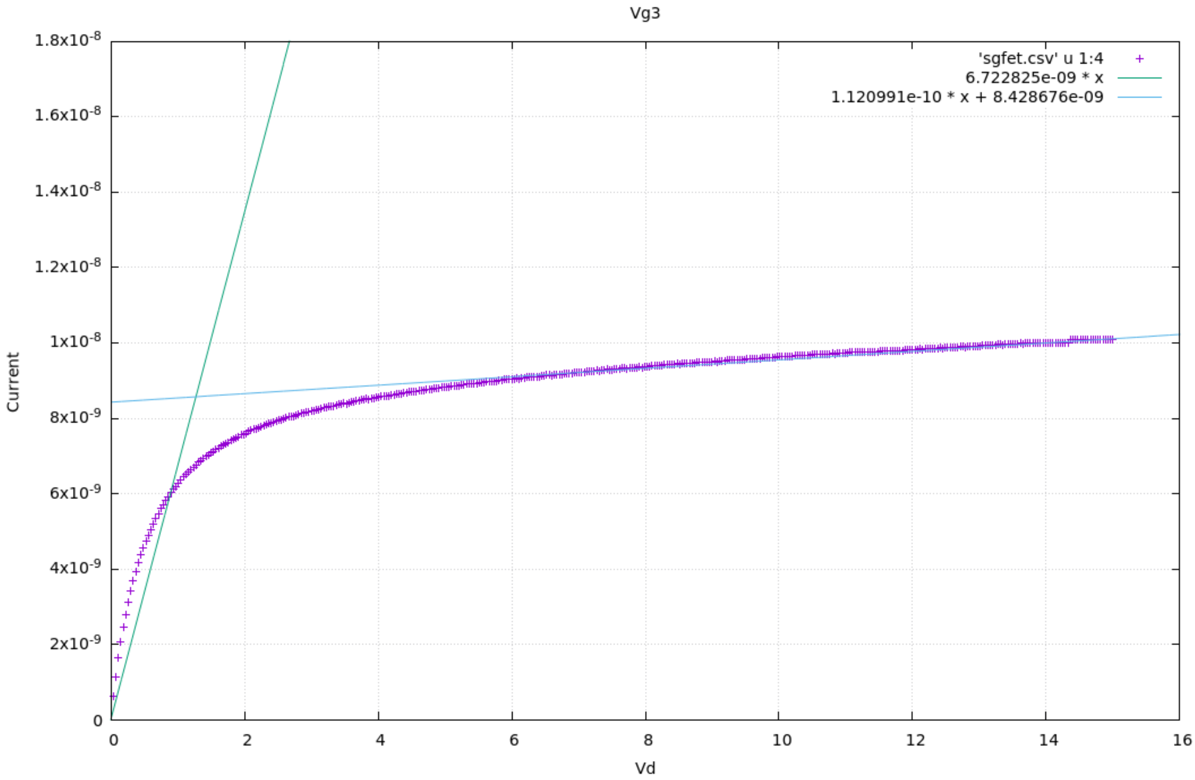
In the following pages, you can find the 11 Current vs V_d graphs corresponding to each V_g, with our pair of line estimations, along with the V_{th} vs V_g graph at the end.

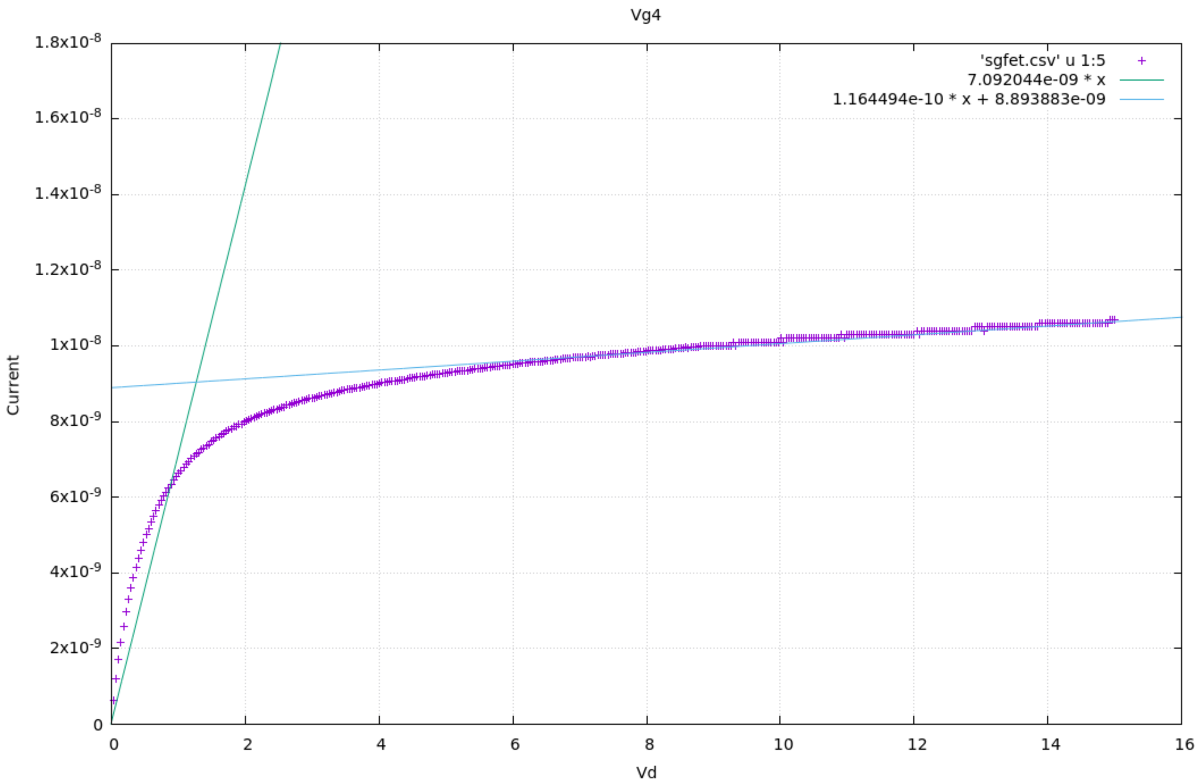


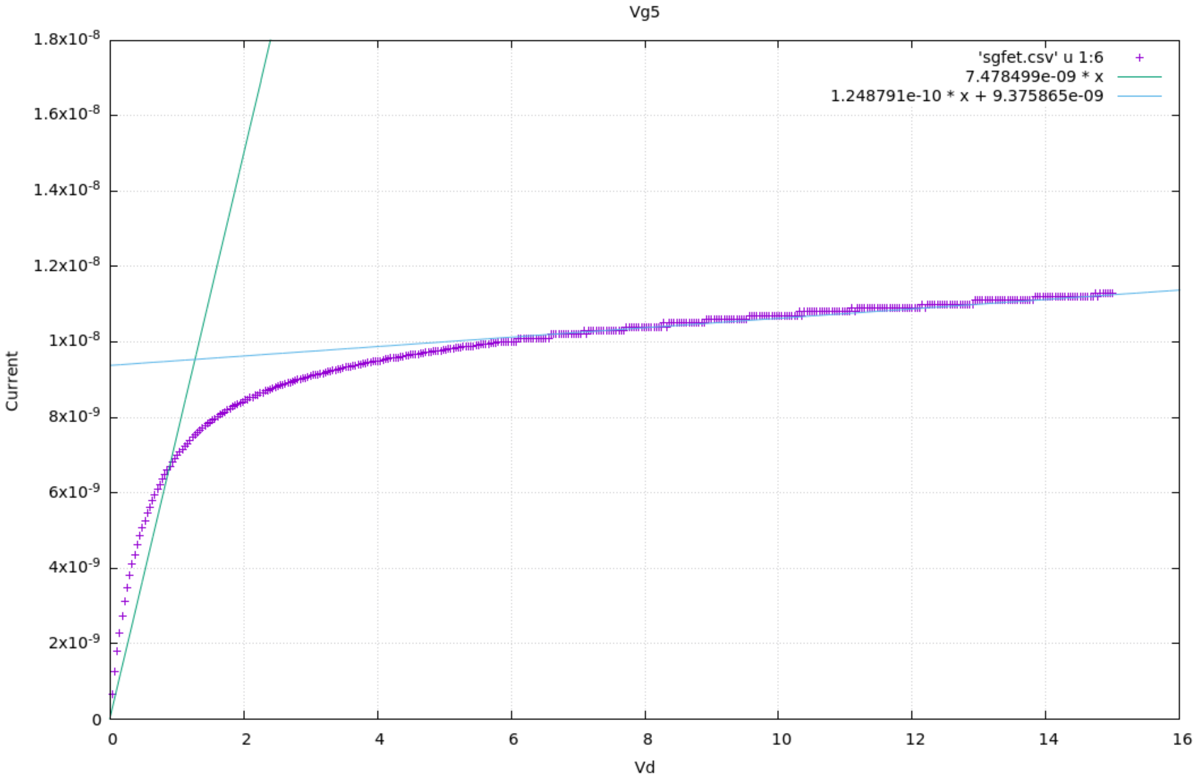
Vg1
'sgfet.csv' u 1:2
6.460228e-09 * x
7.810925e-11 * x + 8.137201e-09
Current
Vd
1.8x10-8
1.6x10-8
1.4x10-8
1.2x10-8
1x10-8
8x10-9
6x10-9
4x10-9
2x10-9
0
2
4
6
8
10
12
14
16

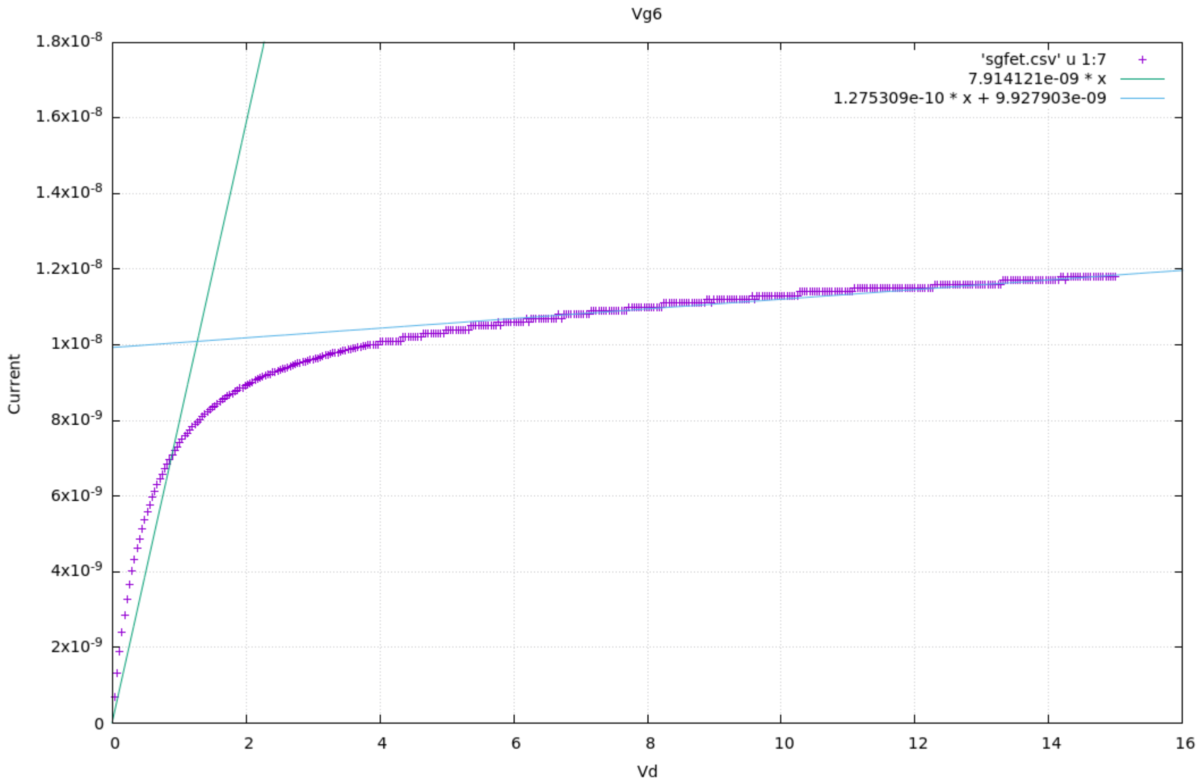


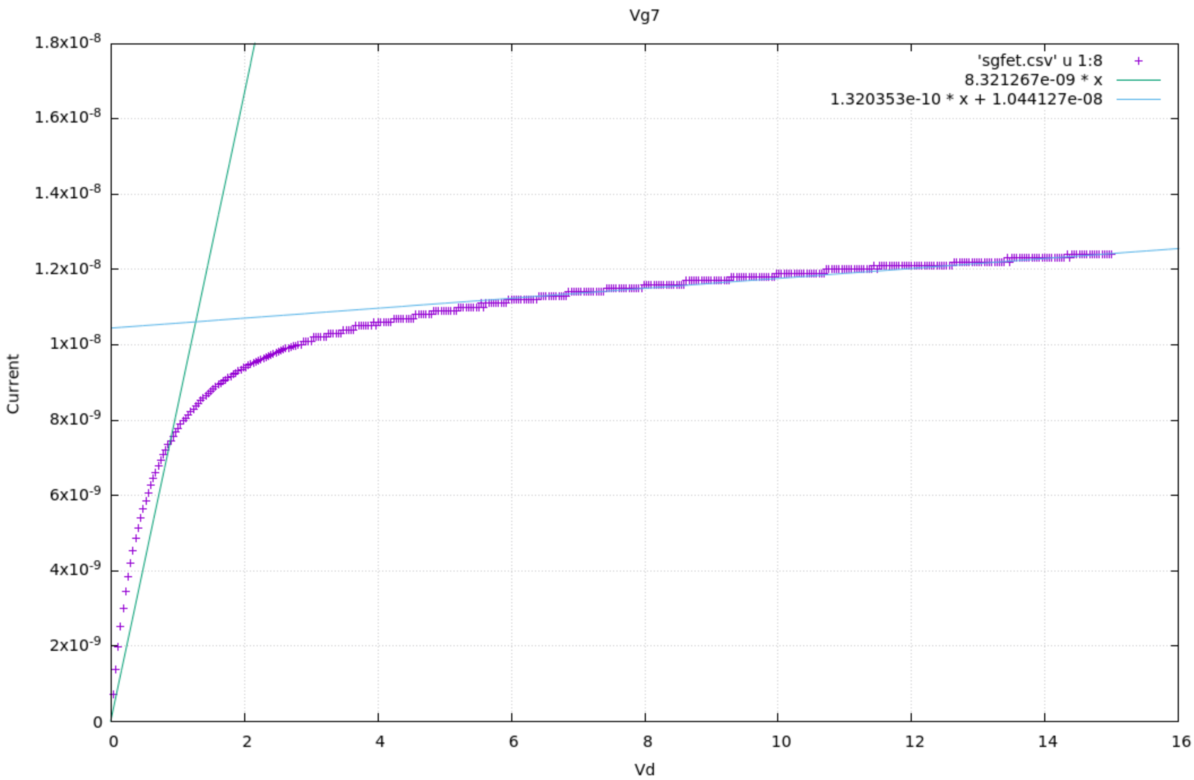
Vg2
'sgfet.csv' u 1:3
6.429357e-09 * x
1.061637e-10 * x + 8.062071e-09
Current
Vd
1.8x10-8
1.6x10-8
1.4x10-8
1.2x10-8
1x10-8
8x10-9
6x10-9
4x10-9
2x10-9
0
2
4
6
8
10
12
14
16

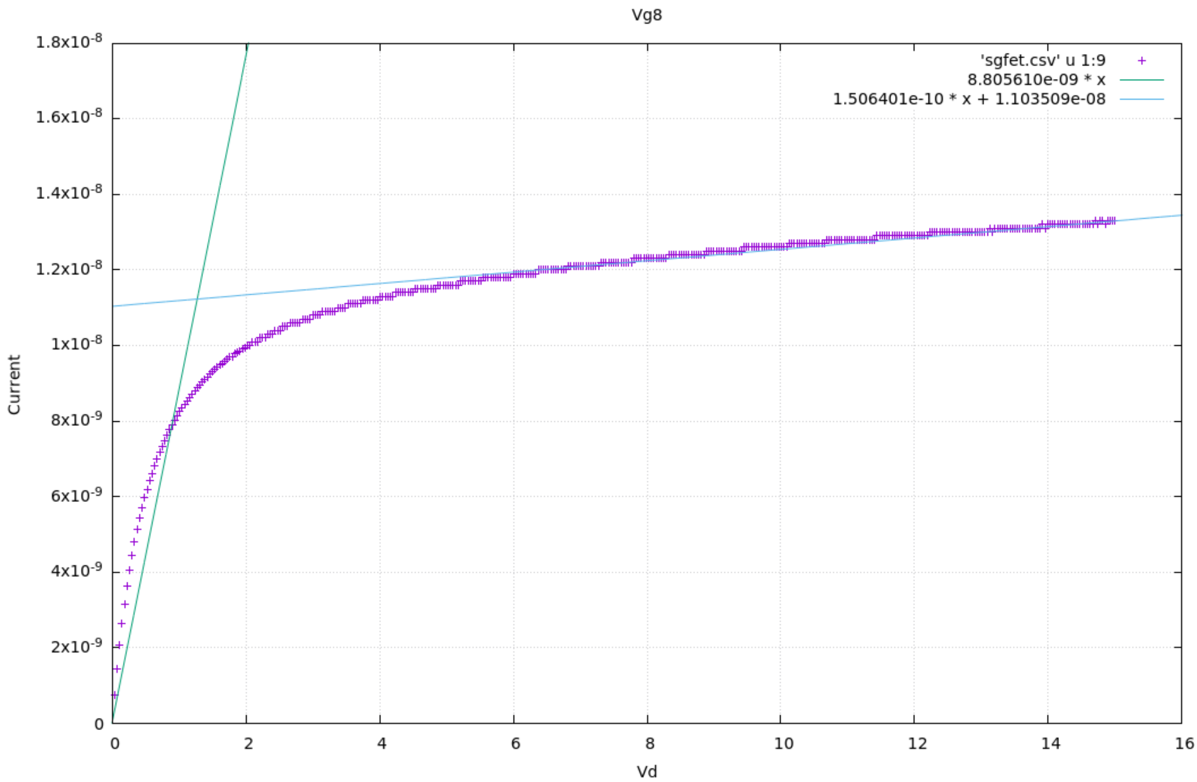

Vg3
'sgfet.csv' u 1:4
6.722825e-09 * x
1.120991e-10 * x + 8.428676e-09
Current
Vd
1.8x10-8
1.6x10-8
1.4x10-8
1.2x10-8
1x10-8
8x10-9
6x10-9
4x10-9
2x10-9
0
0
2
4
6
8
10
12
14
16

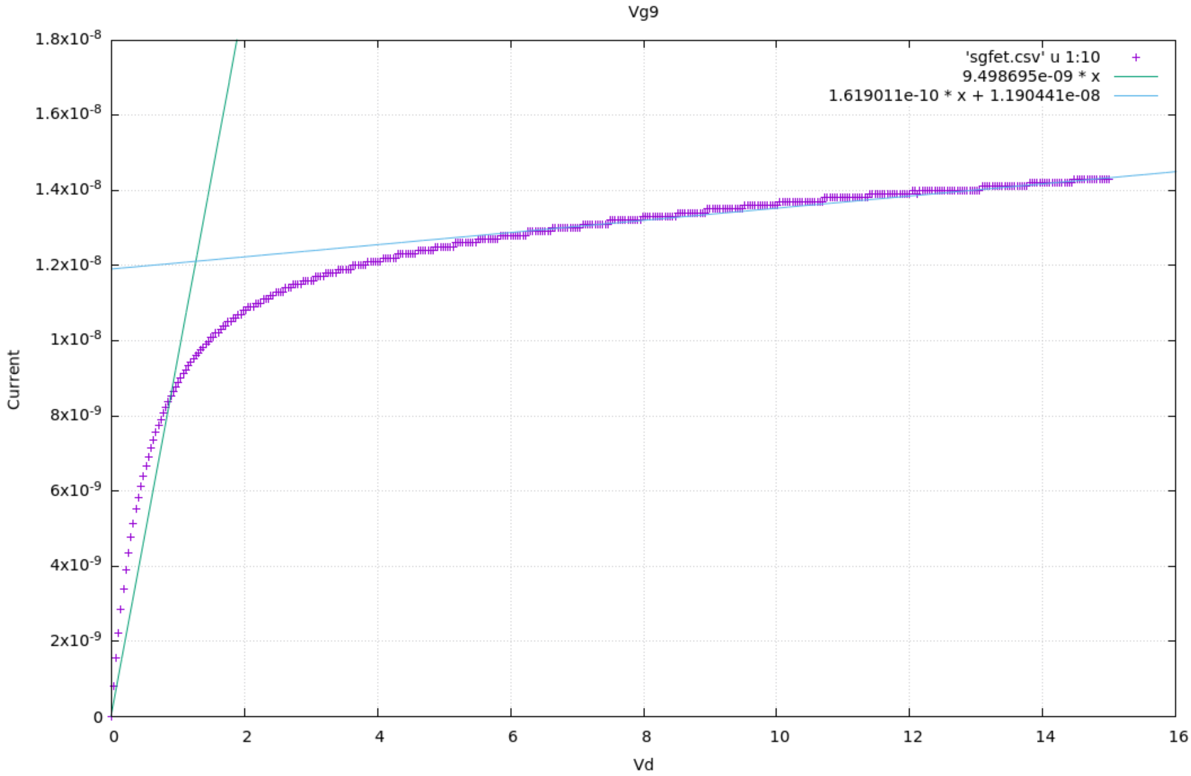

Vg4
'sgfet.csv' u 1:5
7.092044e-09 * x
1.164494e-10 * x + 8.893883e-09
Current
Vd
1.8x10-8
1.6x10-8
1.4x10-8
1.2x10-8
1x10-8
8x10-9
6x10-9
4x10-9
2x10-9
0
0
2
4
6
8
10
12
14
16

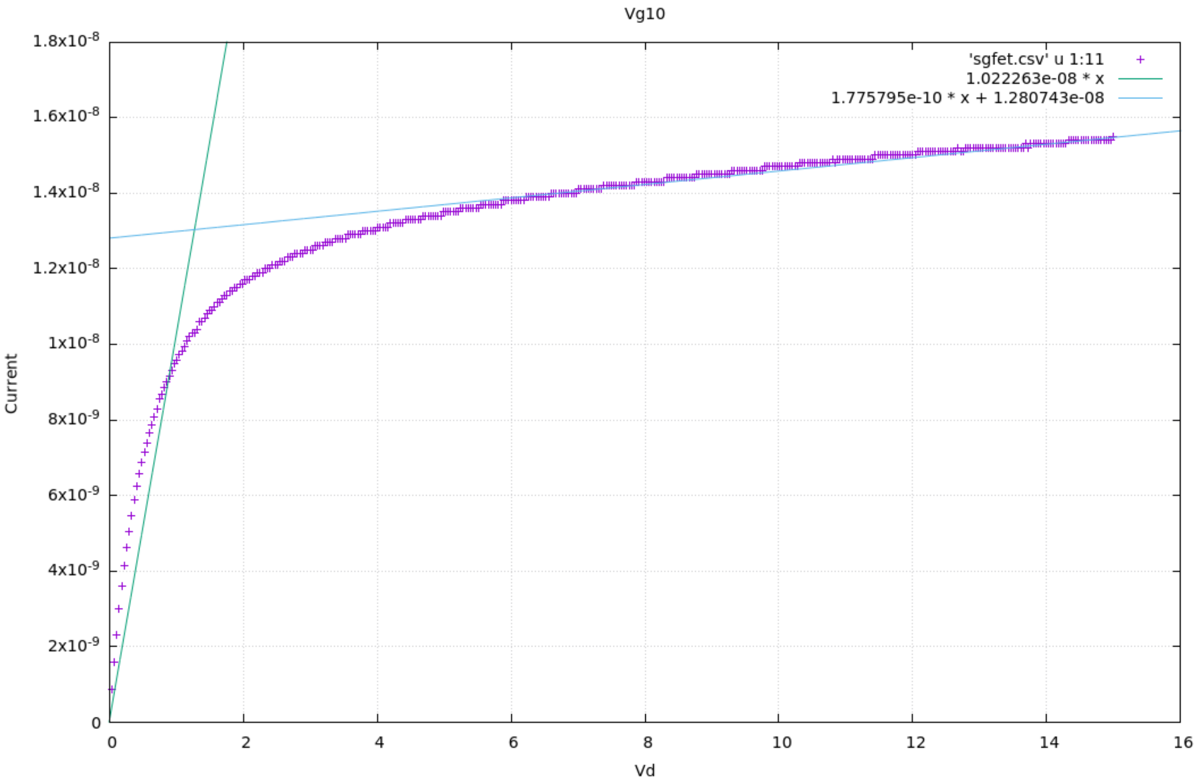

Vg5
'sgfet.csv' u 1:6
7.478499e-09 * x
1.248791e-10 * x + 9.375865e-09
Current
Vd

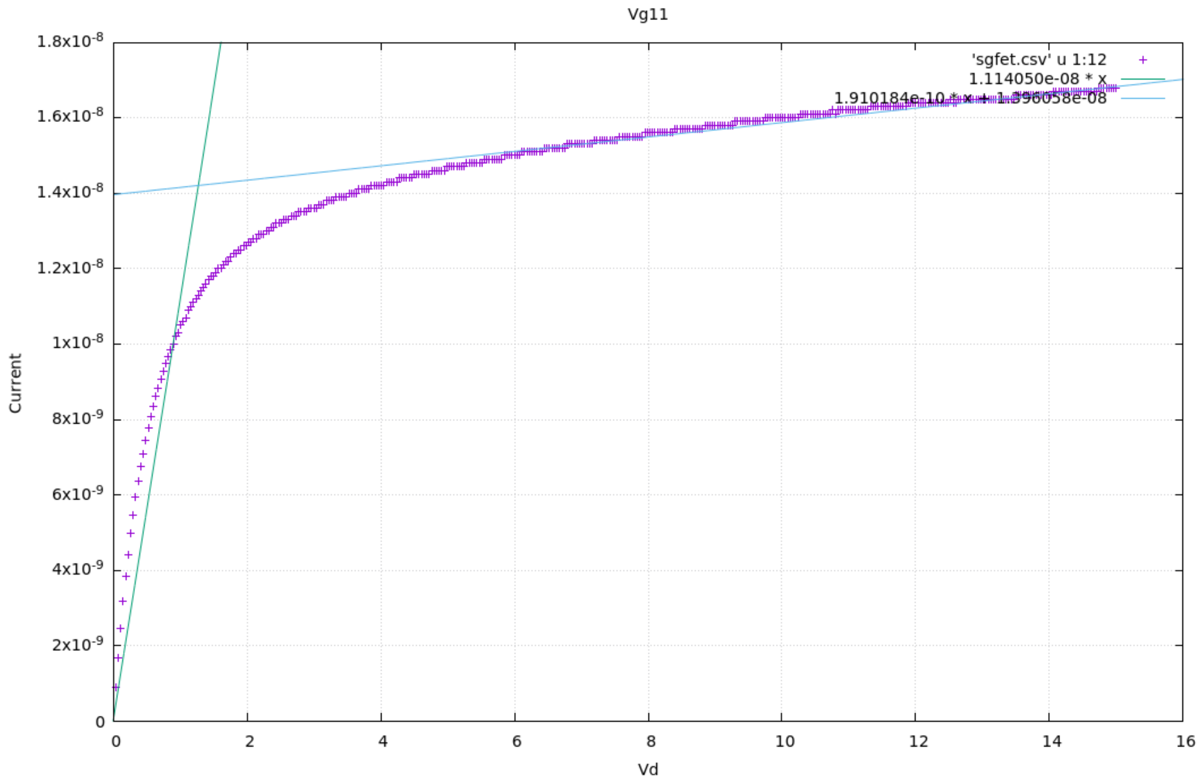

Vg6
'sgfet.csv' u 1:7
7.914121e-09 * x
1.275309e-10 * x + 9.927903e-09
Current
Vd

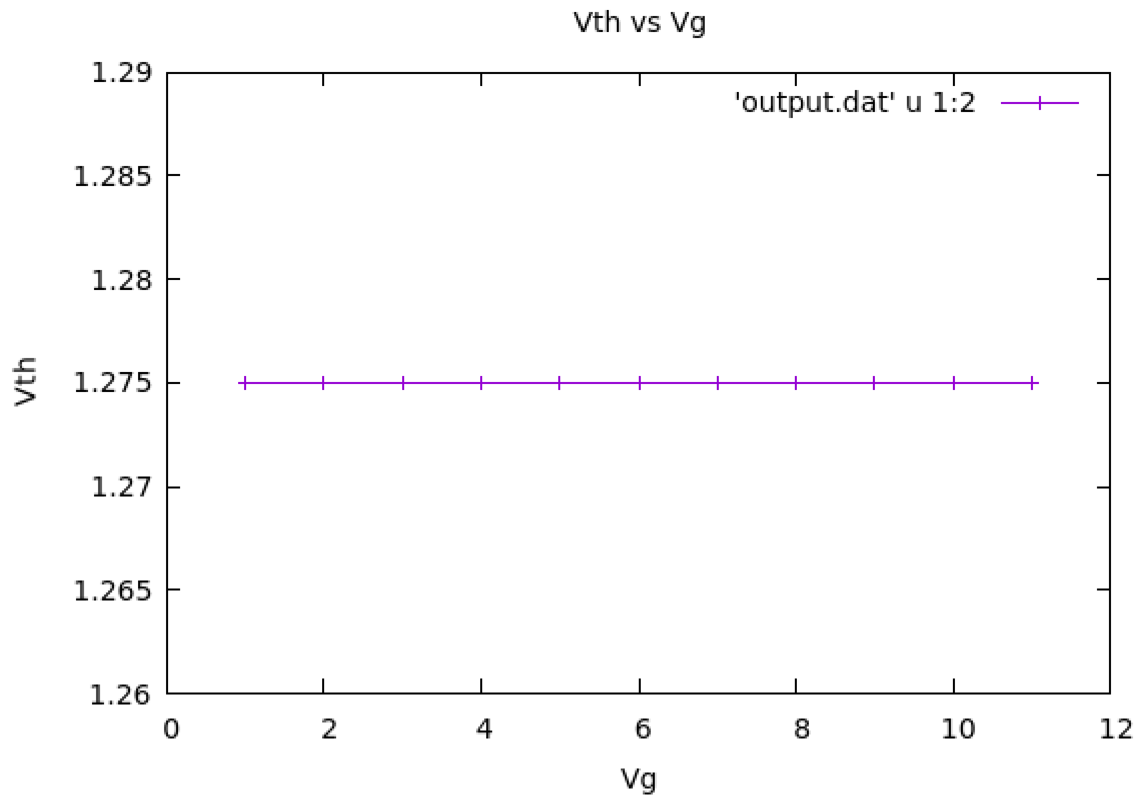

Vg7
'sgfet.csv' u 1:8
8.321267e-09 * x
1.320353e-10 * x + 1.044127e-08
1.8x10-8
1.6x10-8
1.4x10-8
1.2x10-8
1x10-8
8x10-9
6x10-9
4x10-9
2x10-9
0
Current
0
2
4
6
8
10
12
14
16
Vd


Vg8
'sgfet.csv' u 1:9
8.805610e-09 * x
1.506401e-10 * x + 1.103509e-08
1.8x10-8
1.6x10-8
1.4x10-8
1.2x10-8
1x10-8
8x10-9
6x10-9
4x10-9
2x10-9
0
Current
0
2
4
6
8
10
12
14
16
Vd


Vg9
'sgfet.csv' u 1:10
9.498695e-09 * x
1.619011e-10 * x + 1.190441e-08
1.8x10-8
1.6x10-8
1.4x10-8
1.2x10-8
1x10-8
8x10-9
6x10-9
4x10-9
2x10-9
0
Current
0
2
4
6
8
10
12
14
16
Vd


Vg10
'sgfet.csv' u 1:11
1.022263e-08 * x
1.775795e-10 * x + 1.280743e-08
1.8x10-8
1.6x10-8
1.4x10-8
1.2x10-8
1x10-8
8x10-9
6x10-9
4x10-9
2x10-9
0
Current
0
2
4
6
8
10
12
14
16
Vd





We see that the value of V_{th} is constant for all V_g, which is expected as all the 11 Current vs V_g graphs only differ by some factor along the y-axis, i.e. they seem to be merely stretched vertically. As V_{th} is the x-coordinate of the intersection point, it will remain unchanged after any purely vertical stretching of the graph.

This is in accordance with the physical significance of V_{th} for semiconductor devices.