

Improving the Measurement Speed and Overall Test Time of the Model 4200-SCS Semiconductor Characterization System

Introduction

Electronic device test and characterization isn't what it used to be. Whether they're at work at a giant semiconductor manufacturing plant or a small research facility, today's engineers are making more complex, high precision measurements than ever before. Equipped with leading-edge measurement instruments, they use the best of today's technology to produce the technology of tomorrow. Paradoxically, unleashing the full power of the modern instruments isn't always that critical. Quite often, the data is being acquired in higher volumes and with higher accuracy than necessary. In the realm of high impedance, ultra-low current measurements, accuracy inevitably comes at the price of time. While it may not be possible to avoid a compromise between the two, there are plenty of other factors, often overlooked, that can help boost the overall system performance.

This Tech Note offers users of the Model 4200-SCS Semiconductor Characterization System guidance on avoiding the most common pitfalls, achieving better test speeds, and reducing overall measurement times.

Optimizing the number of measurement points

The most common task performed on a semiconductor parameter analyzer is a current-voltage (I-V) sweep across a device under test (DUT), resulting in some device characteristic. A simple linear sweep is programmed by establishing the start and stop values and the step size (**Figure 1**). The system then calculates the number of measurement points based on this formula:

$$\text{Number of points} = \frac{\text{Stop Value} - \text{Start Value}}{\text{Step Size} + 1}$$

The overall sweep time is directly proportional to the number of measurement points, so reducing the sweep range and increasing the step size will result in a faster overall measurement. To illustrate the test time gains this technique allows, we modified a standard 4200-SCS test called Vgs-Id. In this test, the gate of an n-MOSFET is swept from 0V to 5V, while the current through the drain under a 0.5V bias is measured. Using built-in analysis tools, the 4200-SCS then determines the transistor's threshold voltage (Vth) (**Figure 2**). The default sweep had 101 points, and the overall test time was 18 seconds. Simply doubling the sweep step size reduced the sweep to 51 points, and the test took 13 seconds to complete, while the Vth stayed within 0.22% of the previous reading. An even more spectacular improvement was achieved by subsequently reducing the sweep range to 0.5 – 2.5V. At 21 sweep points, the test time was reduced to four seconds, while the Vth was

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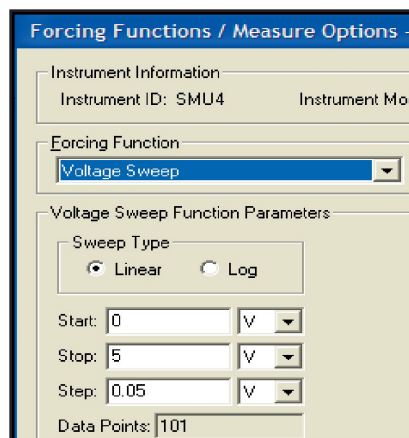


Figure 1

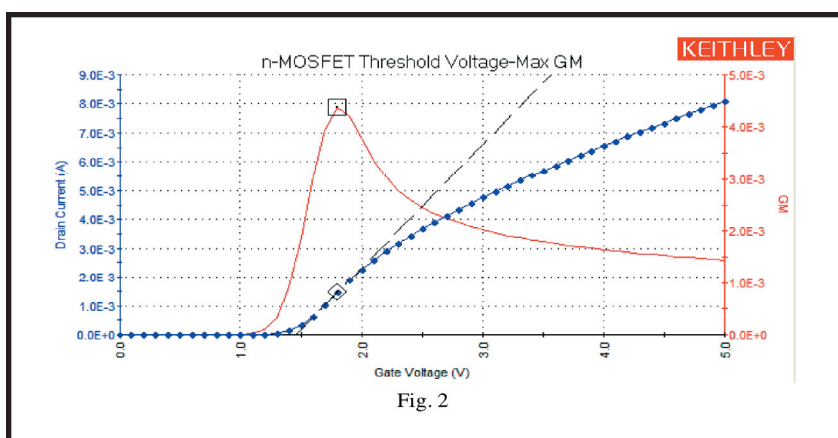


Figure 2

| Definition Sheet Graph Status | | | |
|-------------------------------|-------------------------|-------------------|--------------------|
| G3 | | | |
| | A | B | C |
| 1 | Default 101 pts 0 - 5 V | 51 pts 0 - 5 V | 21 pts 0.5 - 2.5 V |
| 2 | VT | VT | VT |
| 3 | 1.4624E+0 | 1.4591E+0 | 1.4589E+0 |
| 4 | | | |
| 5 | Test time: 18 sec | Test Time: 13 sec | Test Time: 4 sec |
| 6 | | | |
| Data Calc Settings | | | |
| vgs-id#1@1 | | | |

Figure 3

within 0.24% (**Figure 3**). In this way, we reduced the overall test time by 450% without sacrificing the essential accuracy of the result.

Removing unneeded measurements

When a user configures a new interactive test module (ITM) in the 4200-SCS, the natural tendency is to accept as many of the default settings as possible. While this may seem like an intuitive choice, it can lead to measuring too many parameters, and consequently, to a longer test.

For example, using the same Vgs-Id test optimized to run in four seconds, note that the only measurements enabled are the drain current (DrainI) and the gate voltage (GateV), which are necessary for calculating the threshold voltage. However, if this

test were configured with all available measurements turned on (DrainI, DrainV, GateI, GateV, SourceI, SourceV are all enabled by default), the total test time would be 31 seconds. An increase of almost 800% is a high price to pay for information that adds no particular value. In this case, the culprit is the gate current measurements, which are set by default at Limited Auto 100pA range. The actual gate leakage current of 5–25fA forced the source-measure unit (SMU) assigned to the gate terminal to stay on the lowest allowed range of 100pA for the duration of the sweep, thereby acting as a pace limiter for the entire test.

Going over each SMU setting and turning off unwanted measurements takes just a few extra seconds, but may save hours or even days in the long run.

Optimizing measurement precision

In the previous example, we witnessed how unnecessary ultra-low current measurements led to significantly longer test times. But what if the test does actually require the SMU to perform a measurement in the low current region? To return to our Vgs-Id test example, the SMU making drain current (DrainI) measurements

| | A | B | C |
|----|-------------------------|--------------------|---------------------|
| 1 | Default | | |
| 2 | 101 pts, 0 - 5 V | 51 pts, 0 - 5 V | 21 pts, 0.5 - 2.5 V |
| 3 | Vt = 1.4624 | Vt = 1.4591 | Vt = 1.4589 |
| 4 | Test time: 18 sec | Test Time: 13 sec | Test Time: 4 sec |
| 5 | | | |
| 6 | All measurements ON | | |
| 7 | 101 pts, 0 - 5 V | 51 pts, 0 - 5 V | 21 pts, 0.5 - 2.5 V |
| 8 | Vt = | Vt = 1.4629 | Vt = 1.4629 |
| 9 | Test Time = 103 sec | Test Time = 60 sec | Test Time: 31 sec |
| 10 | | | |
| 11 | DrainI "LtdAuto 100 nA" | | |
| 12 | 101 pts, 0 - 5 V | 51 pts, 0 - 5 V | 21 pts, 0.5 - 2.5 V |
| 13 | Vt = 1.4660 | Vt = 1.4630 | Vt = 1.4630 |
| 14 | Test Time: 6 sec | Test Time: 4 sec | Test Time: 2 sec |
| 15 | | | |

Figure 4

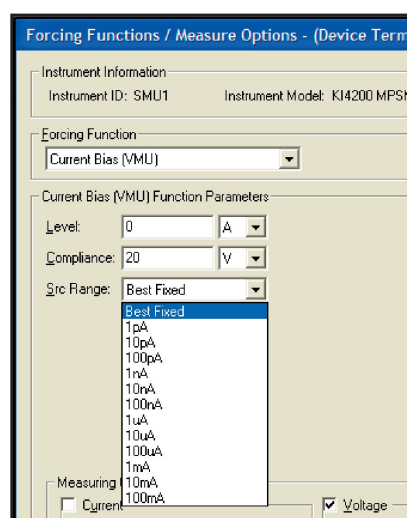


Figure 5

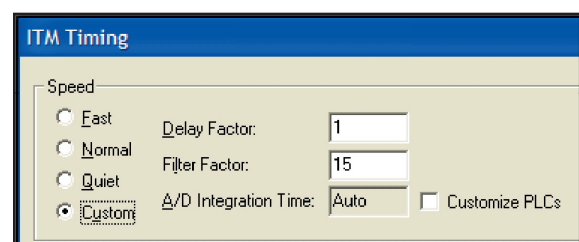


Figure 6

goes through several current ranges, beginning from the lowest (and slowest) allowed range of 100pA. If that SMU were set to the Auto range, the sweep would start on an even slower 1pA range, returning data with the ultimate resolution of 0.1fA. Note, however, that the DrainI values at which Vth extraction takes place are in the hundreds of microamperes. Therefore, the low current “tail” of the sweep has little value, other than to show that the transistor has no anomalies in that region.

Further optimizing the test settings, we then chose to set the drain terminal SMU to measure current on the Limited Auto 100nA range, which provides a 100fA resolution, which is more than sufficient for the task at hand. As the comparison table in **Figure 4** shows, this technique produced test time improvements of 100% to 300%, depending on the number of sweep points, with Vth values staying within a fraction of a percent of each other.

Using an SMU as a voltmeter

Some test setups require a SMU to perform the voltmeter function. This can be achieved by programming the SMU to force a constant zero current (**Figure 5**).

Sourcing zero current is done by default on the “Best Fixed” range, and most often, this setting is left unchanged. The best fixed range to source (and measure) zero current happens to be the 1pA range (on systems with PreAmps). As we have already seen, selecting such a low range slows the SMU significantly. In most cases, however, the SMU can perform the voltmeter function quite well while sourcing the zero current on a higher fixed range (for example, 1μA).

Taking advantage of the timing controls

Every ITM (Interactive Test Module) in the 4200-SCS allows a user to select the desired test speed. The three settings—Fast, Normal, and Quiet—can be selected directly from the Definition page of the ITM. While those settings provide a quick and easy way to change measurement speed, selecting **Custom** in the ITM Timing dialog window offers a further opportunity to optimize the test.

Taking a closer look at the ITM Timing dialog reveals that every speed setting is a combination of the following three components: Delay Factor, Filter Factor, and the A/D Integration Time (**Figure 6**).

The **Delay Factor** allows the user to control settling time, which is the time necessary for both the SMU and the DUT to stabilize after a change in current or voltage, such as during a sweep. The actual applied delay time is a multiple of the pre-programmed, range-dependent default delay time, and the value of the **Delay Factor**. An

additional delay (compared to a normal value of 1.0) may be required for highly capacitive devices, especially in low current measurements. The **Delay Factor** may be set to a value anywhere from zero to 100, with a zero setting resulting in no delay.

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The **Filter Factor** controls the degree of filtering or averaging of multiple readings to make one measurement. Filtering is often necessary to deal with noise, which is present to some degree in all measurements. As a rule of thumb, doubling the **Filter Factor** halves the measurement noise. A user can specify the **Filter Factor** to be any value from zero to 100, with zero resulting in no filtering.

The **A/D Integration Time** reflects the time that the analog-to-digital converter on board the SMU has to “look” at the signal. A short integration time for each A/D conversion results in a relatively fast measurement speed at the expense of noise. Conversely, a long integration time results in a relatively low noise reading at the expense of speed. The integration time setting is based on the number of power line cycles (PLCs). A user can specify a custom **A/D Integration Time** (between 0.01 and 10 PLC), or leave it on the Auto setting (recommended), which allows the system to optimize its value based on the range and other conditions.

For many users, these timing controls represent an advanced level of measurement optimization, and may be discarded as not worth the time needed to learn how to use them. However, depending on the scope of the task, the time invested in optimizing measurement timing settings might be paid back with significant speed improvements. It's important to note, however, that increasing SMU measurement speed generally results in reduced measurement accuracy; at some point, speed increases may be restricted by fundamental theoretical limits.

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