

Keysight Technologies

Multi-Channel Parallel Timing-on-the-fly NBTI Characterization Using Keysight B1500A

Application Note





Introduction

Keysight B1500A Semiconductor Device Analyzer

- Parallel NBTI test improves test throughput
- Controlled dynamic recovery with 100 μ s accuracy
- Full- scale resolution of 20,000 counts with 100 μ s intervals assures accurate NBTI characterization

The timing-on-the-fly Negative bias temperature instability (NBTI) test approach, introduced in application note B1500- 6*1, has been well accepted by reliability engineers for evaluating sub 65 nm process technology. NBTI testing generally stresses for more than one thousand seconds, and it takes a considerable amount of time to gather a meaningful amount of NBTI test data for statistical analysis.

One technique to improve test throughput is testing in parallel, but this has had drawbacks such as degraded test quality and higher test system costs. However, the Keysight Technologies, Inc. B1500A Semiconductor Device Analyzer can now overcome these challenges by providing multi- channel parallel NBTI test capability without degrading performance.

This application note introduces a Multi-channel Parallel Timing-on-the-fly NBTI test approach using the advanced features of EasyEXPERT software of the B1500A.

Multi-channel Parallel Timing-on-the-fly NBTI Test

Figure 1 shows the timing diagram of Keysight’s multi-channel parallel timing-on-the-fly NBTI test method and the relation of the output waveform from the multiple drain SMUs and the gate voltage in the stress and measure NBTI test cycles. All the SMU channel voltages for the gate and the drains change simultaneously between the stress-measure cycles. All the drain current measurements are synchronously made prior to the beginning of the Id measurement phase, so that the change in the NBTI transition after the stress cycle can be observed in detail. Figure 2 shows an example of a connection diagram of SMUs and four FETs connected in parallel for NBTI testing. The gates, sources, and substrates of the four FETs each share a common SMU, and independent SMUs are assigned for each Drain terminal for parallel Id measurements. By using a common connection for the Gates, Sources and Substrates, the number of SMUs required for parallel NBTI test is minimized. The gate bias voltage and all the drain voltage assigned to the independent SMUs change at the same time, without any voltage drop, as illustrated in Figure 1.

Device Preparation

When conducting the multichannel parallel Timing-on-the-fly NBTI test, it is important to understand the proper way to connect your device to the SMUs as shown in Figure 3. There is a limit to the total triaxial cable length that can be connected to an SMU due to the fact that too much cable capacitance will cause the SMU to become unstable. When connecting the triaxial cable to the device on a wafer prober, typically a 3 m SMU triaxial cable is used as shown in Figure 3(a), and this connection is suitable for stable NBTI testing. Figure 3(b) shows another example of connecting several gates by using multiple 3 m triaxial cables to one common gate SMU. If two or more 3 m triaxial cables are connected in parallel to an SMU as shown in Figure 3(b), the configuration will exceed the allowable cable capacitance for stable operation of the gate SMU. The SMU will be unable to provide a clean pulsed signal with a fast rise time, and this cable configuration is not recommended. Figure 4 shows how to resolve the SMU cable length problem shown in Figure 3(b). The Figure 4(a) connection, which is the same as Figure 3(b), can be modified as shown in Figure 4(b) by connecting all the gates together on the probe card. The common gate signal can then be connected to the gate SMU using a single triaxial cable. Using this technique, the independent FETs can easily be arranged into a suitable configuration for using the multichannel parallel Timing-on-the-fly NBTI test.

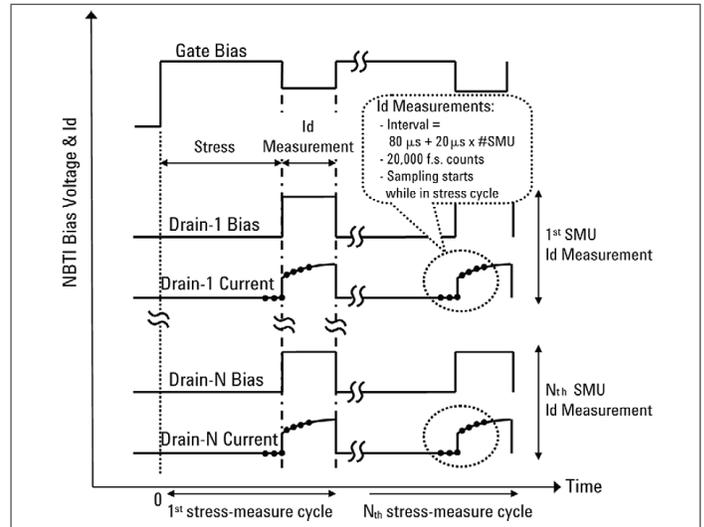


Figure 1. Multi-Channel Timing-on-the-fly NBTI test sequence and the Id measure timing

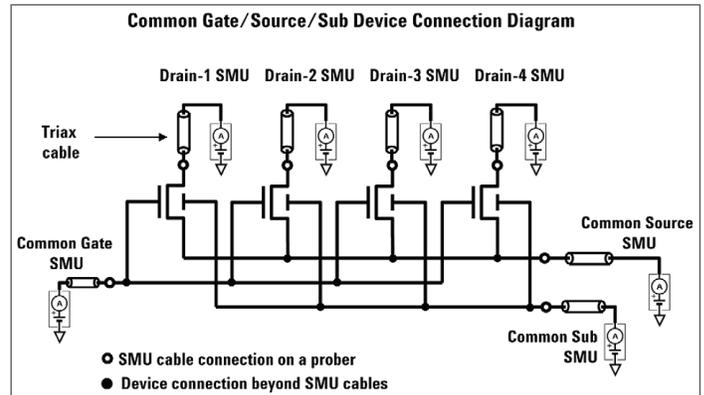


Figure 2. Device connection for multi-channel Timing-on-the-fly NBTI test

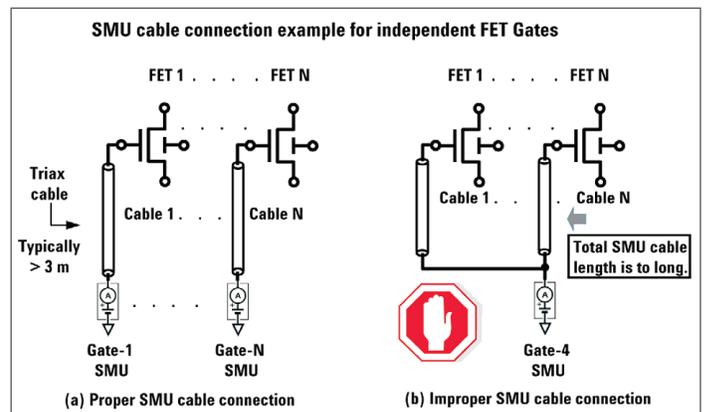


Figure 3. Tips for SMU cabling for parallel NBTI test

General Purpose NBTI System Setup

Figure 5 shows a general purpose test station setup scheme that can be used for both parallel NBTI and other DC parametric test applications. This setup connects the Ground Unit (GNDU) to the source and substrate connections through a switching matrix. Since the source and the substrate are typically connected to ground during the NBTI test, the GNDU can be used for these connections without having to worry about the cable capacitance restrictions of the SMU. The ground unit allows parallel cable connection directly to device terminals. It requires eight SMUs for connecting to gates and drains for testing four independent FETs in parallel NBTI test. There is a tradeoff between the system cost and the freedom in the setup of the test system.

Multi-channel Timing-on-the-fly NBTI Test Library

Multi-channel parallel Timing-on-the-fly NBTI test is an enhancement of the single device Timing-on-the-fly NBTI test. The following are the differences between two solutions:

1. Parallel simultaneous Id measurements can be performed.
2. A longer sampling interval is required for multi-Id measurements.

The Multi-channel parallel Timing-on-the-fly NBTI sample test library introduced in this application note supports four FETs in parallel NBTI measurements using seven SMUs. If the library is modified to use the GNDU, then more parallel drain measurements can be achieved. The minimum Id sampling interval increases when additional drain SMUs are added for parallel NBTI measurements. The necessary sampling interval is determined by a simple formula. Using 100 μ s as the base sampling interval for one drain SMU, add an additional 20 μ s to the sampling interval for each additional SMU. In other words, the minimum sampling interval is 100 μ s for one drain SMU, 120 μ s for two parallel drain SMUs, 140 μ s for three parallel SMUs, and so on.

Figure 6 shows the user interface of the sample Multi-channel Timing-on-the-fly NBTI library supplied for the B1500A EasyEXPERT software. You can set the NBTI characterization parameters for both the stress and Id measurement phase, including the sampling parameters. The stress time list can also be specified.

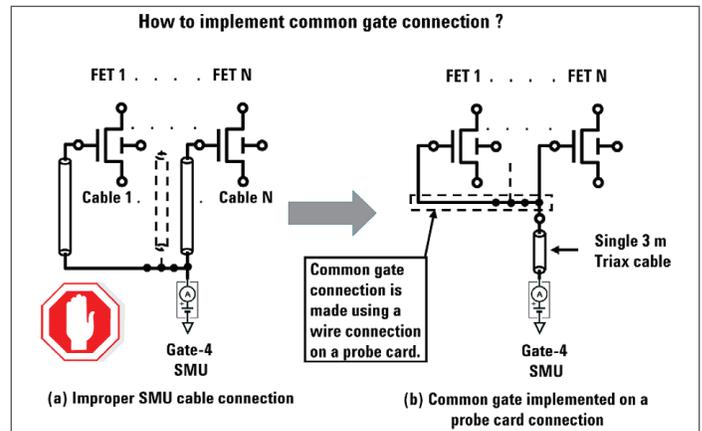


Figure 4. Tips for SMU cabling for parallel NBTI test

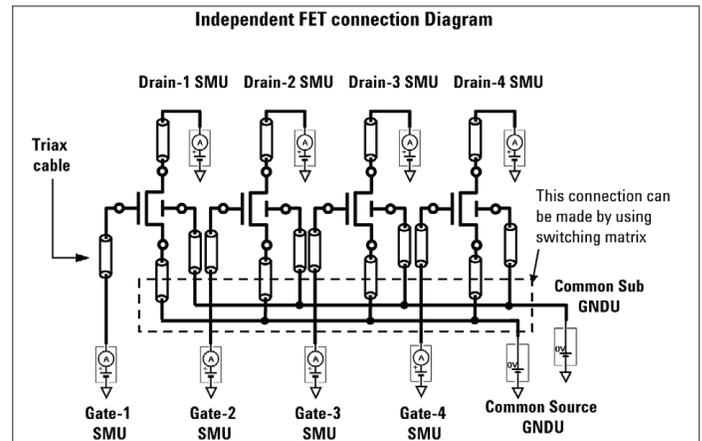


Figure 5. Device connection for multi-channel Timing-on-the-fly NBTI test

Figure 6. B1500A Multi-Channel Timing-On-the-fly NBTI sample library

Figure 7 shows output waveforms of the multi-channel parallel timing-on-the-fly NBTI test. The upper half of the oscilloscope screen capture shows the initial 10 second stress and the next parallel Id measurement cycle. The bottom half is an enlarged capture of the Id parallel measurement for the gate and three Id drain waveforms. The fourth Id waveform is not shown due to limitations on the available number of oscilloscope channels. The waveform traces demonstrate that all the output waves of the multiple drain and the gate channels change at the exact same time and that there is no droop to ground in the transition from the stress phase to the measurement phase. Details showing how the drain current is sampled have been added in the bottom of the figure for easier understanding of the test method.

The final output of this sample library shows a plot Id of Drain1 SMU versus log stress time for quick monitoring of the test. The Multi-channel Id sampling data can be easily exported in a spreadsheet format, and the final NBTI analysis is expected to be done on the spreadsheet.

Conclusion

The Multi-channel parallel Timing-on-the-fly NBTI test library for the Keysight B1500A EasyEXPERT software improves NBTI characterization time without sacrificing test quality.

The sample application test definition, multi-channel timing-on-the-fly NBTI*², introduced in this application note can be downloaded from the Keysight B1500A web site at www.keysight.com/see/B1500A.

1. *Keysight part number 5989-5711EN
2. *This library can be used on the Keysight B1500A EasyEXPERT software revision A.02.10 or later.

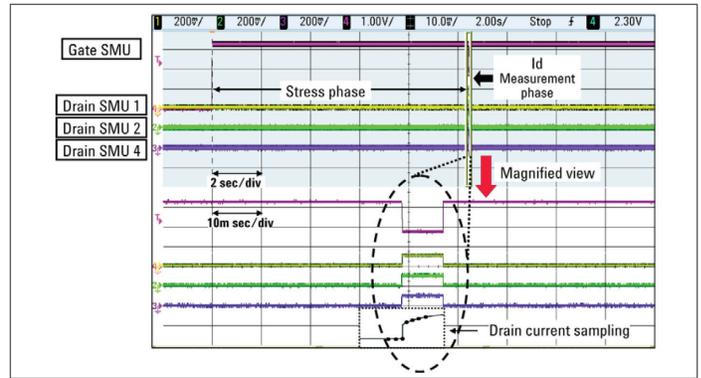


Figure 7. Waveform of the Multi-channel Timing on-the-fly NBTI test of the B1500A EasyEXPERT software

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