Improving Reliability of Semiconductor Devices

Major semiconductor manufacturer

KEYSIGHT

Organization • Major semiconductor manufacturer **Challenges** • Ensuring process reliability • Measuring large amounts of RTN data	**Solutions** • Keysight B1500A Semiconductor Device Parameter Analyzer • Software to automate RTN testing **Results** • Automated RTN testing

Semiconductors permeate all the devices we use today, and we take for granted that they will function reliably. However, in modern semiconductor processes, the random telegraph noise (RTN) phenomenon has become a critical parameter affecting device reliability.

What is RTN?

A random telegraph signal is a stochastic process that flips between 1 and +1 with the number of zero crossings in any period (0,t) described by a Poisson process.
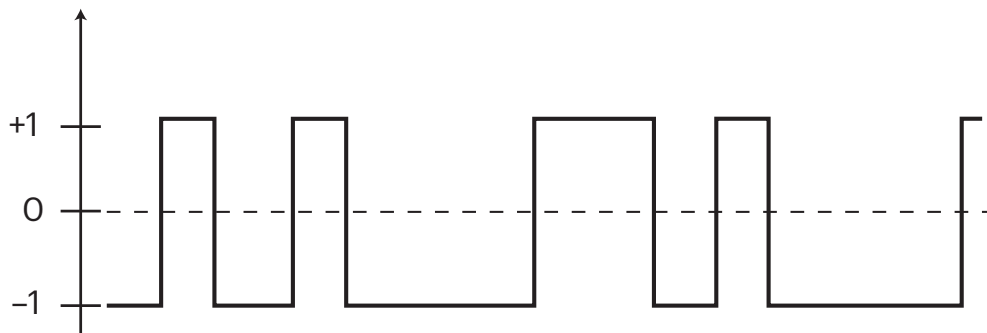

Figure 1. A random telegraph signal

Random telegraph noise in a MOSFET appears as random variations in the drain current under constant applied gate-to-source (V_{GS}) and drain-to-source (V_{DS}) voltage bias. Electron trapping/detrapping is the presumed cause of RTN. It is innate to semiconductor MOSFET devices, and it has always been present in MOS processes.
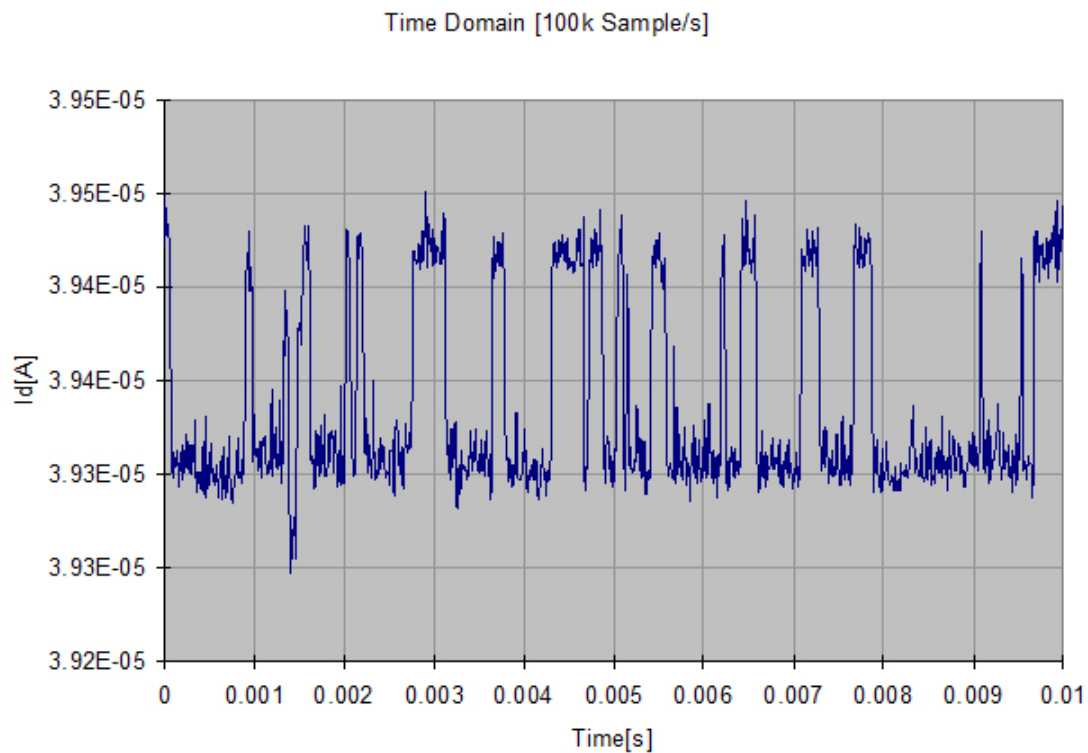

Figure 2. Random telegraph noise in a MOSFET

Until recently, RTN was mainly a concern of CMOS image sensor manufacturers, as it would generate erroneous white spots in what should be dark areas. However, as operating voltages have decreased and lithographies have continued to shrink, RTN has begun to impact the stability of SRAM cells. Since virtually all integrated circuits use SRAM for their cache memory, this is critically important to the semiconductor industry. Virtually all the major industry players now must evaluate their processes for susceptibility to RTN.

A major semiconductor manufacturer needed a reliable means to evaluate the impact of RTN on its processes, and Keysight was able to provide a solution.

The Challenge: Automating RTN Measurement

Measuring RTN requires equipment capable of measuring current rather fast (in nanoseconds) and with sufficient storage to record hundreds of thousands or even millions of data points. In addition, you need equipment with a noise floor of at least 1×10^{-23} A^2/Hz at 20 Hz (which is about two decades above what is necessary to measure 1/f noise).

Besides the hardware, there are some practical considerations when measuring RTN. The first of these is that the phenomenon is truly random; not all devices will show it. More importantly, RTN is highly dependent on the V_{GS} voltage bias. Changing the V_{GS} by 100 mV or less can cause RTN to appear or disappear on a given device. These facts mandate that to truly characterize a process for RTN behavior, you need to measure many devices at multiple V_{GS} values. The only practical way to do this is on-wafer using some sort of test automation.
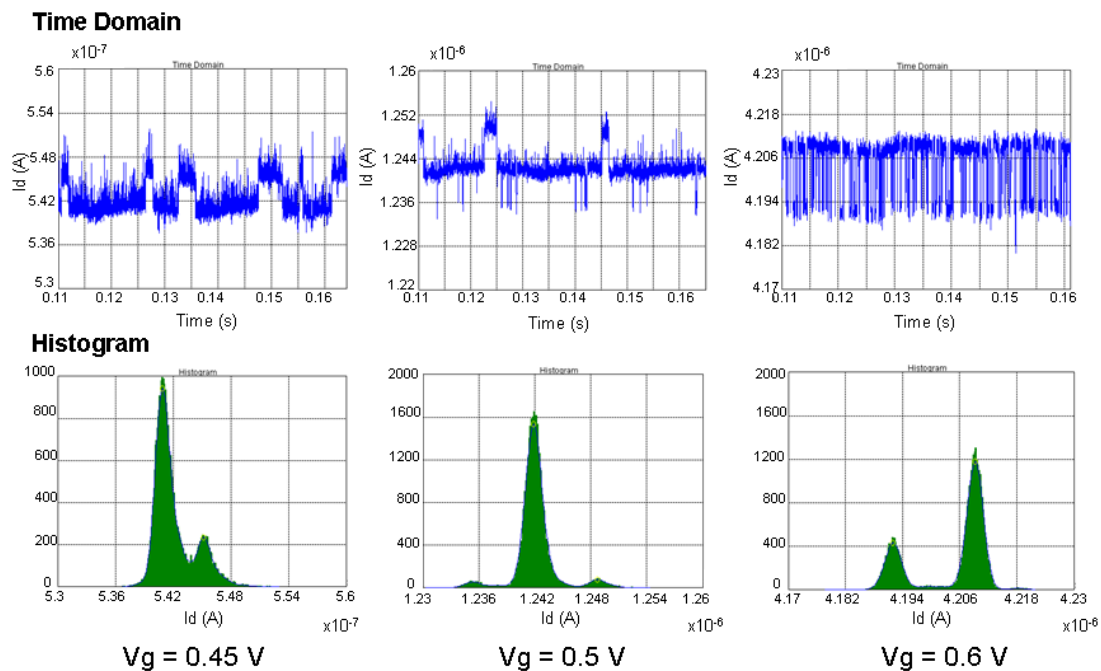

Figure 3. The dependence of RTN on gate voltage

Keysight's B1500A Semiconductor Device Parameter Analyzer supports a waveform generator/fast measurement unit (WGFMU) module that can measure RTN. It comes with software that allows a user to measure and analyze RTN data for a single device. However, it did not support test automation – a critical need for this semiconductor manufacturer.

The Solution: A Custom Solution Using Keysight Products

The local Keysight application engineer worked with the test engineers at the semiconductor manufacturer to develop an automated RTN test solution. The WGFMU module supports an API that allows the semiconductor manufacturer to develop automated test routines in C#.

Together, they defined a solution with two key components:

- The B1500A with the WGFMU module installed
- Drivers for this customer's existing test shell to control the B1500A remotely

Fully addressing this customer's requirements required a custom solution. However, the engineers built the resulting integrated solution around off-the-shelf Keysight hardware and software.

The Results: Reliable RTN Measurement

This semiconductor manufacturer is now using the Keysight solution in its development labs, and has purchased multiple B1500A units with the WGFMU module option. It adopted this solution as its standard solution for RTN measurement throughout the company.

Going Forward

Keysight realized that there was an industry need for an off-the-shelf solution for characterizing RTN across semiconductor wafers. The key challenge is that the solution needed to support a wide variety of semiautomatic and automatic wafer probers. Since Keysight's WaferPro Express software has this capability, the only missing piece was a driver to control the B1500A's WGFMU module from WaferPro Express. To meet this need, Keysight developed the E4727E3 automated RTN software for the B1500A.

Key E4727E3 features include the following:

- Automated RTN measurement and data analysis
- Wafer mapping
- Multiple data overlapping display
- System noise floor display and data clipping

Related Information

- Application note: "Random Telegraph Noise (RTN) Measurement of Advanced MOSFET using B1500A WGFMU Module," 5990-3705EN
- Brochure: WaferPro Express Software, 5991-4460EN

www.keysight.com/find/B1500A