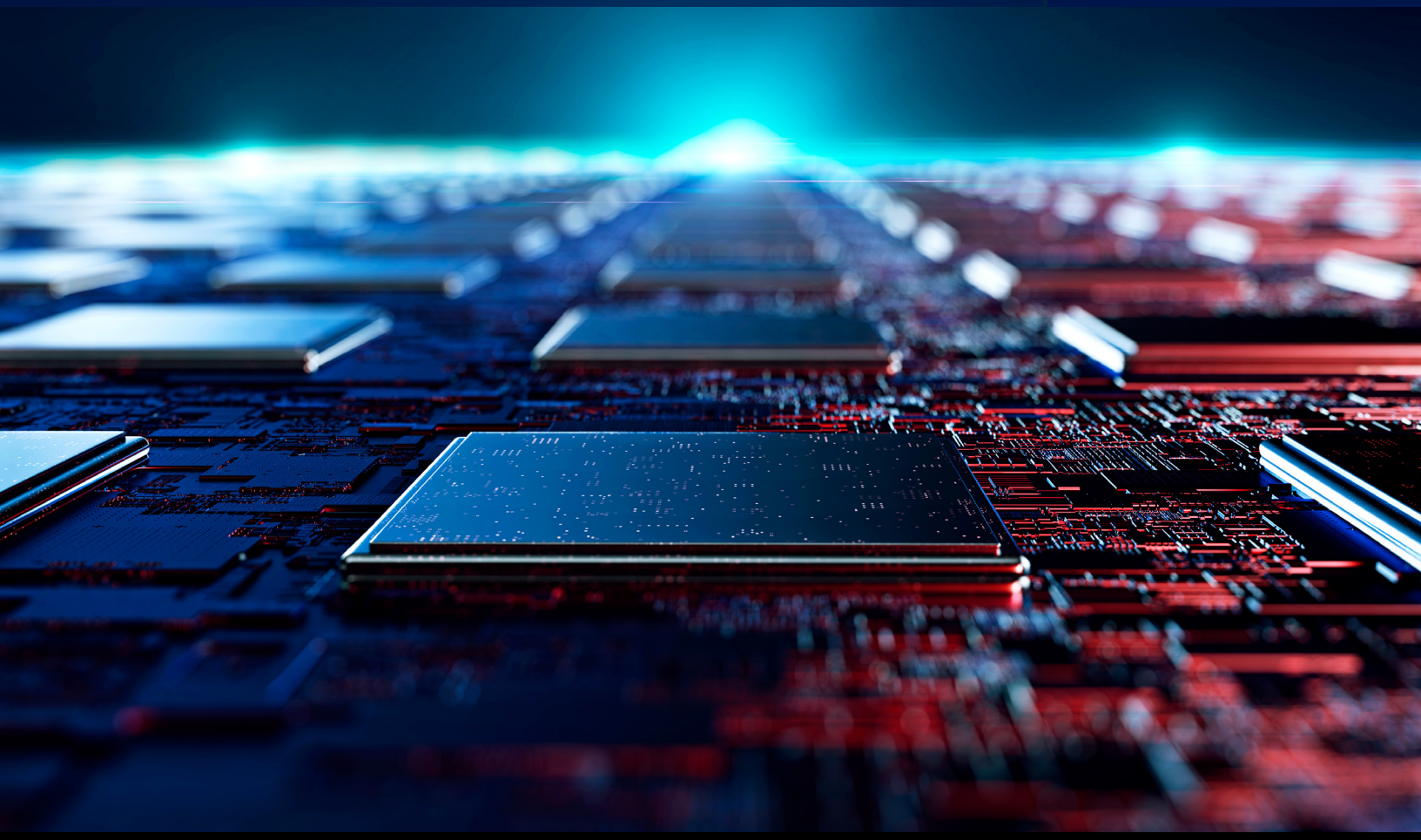
CASE STUDY



IIT Delhi Professor Automates Reliability Characterization

KEYSIGHT

Organization

- Indian Institute of Technology, Delhi

Challenges

- Characterization of RF complementary metal-oxide-semiconductor (CMOS) from mid- to high-frequency devices and circuits.
- Complex and manual involvement for DC and RF measurements that are sometimes prone to human error.

Solutions

- Keysight's B1500 semiconductor device parameter analyzer / semiconductor characterization system with network analyzer and probing station.

Results

- Integrated setup to perform stress / measure / stress cycles for "n" number of hours; "n" not a constraint.
- Use case applications; 5G, Wi-Fi 6, and more.

Semiconductor technology continues to evolve, time-to-market cycles are shrinking, and the need for even greater accuracy is increasing. Over the years, integrated circuits have been moving towards miniaturization with overall performance improvement. The increasing demand is due to the requirement of a compact form factor or decreased product size.

Many of the latest products must accommodate multiple technology chips that include a considerable amount of space for batteries. But it is not only about the size. The industry is also looking for higher performance, efficiency, and advanced specifications in accuracy, speed, and more. These designs require integrating millions of transistors and other components ready for test without any scope for error.

Instead of running tests for multiple days, the goal is to reduce the test duration while accommodating all scenarios which might affect the devices over time. The dense circuits also require various test parameters — multiple test tools and different combinations of test scenarios can make it complicated. Spending too much time on test and validation rather than the design and debug process is not efficient.

The Organization

Professor Abhisek Dixit leads the device and wafer-level modeling and characterization group at the Indian Institute of Technology, Department of Electrical Engineering, located in New Delhi, India. This group's focus is reliability characterization and process design kit (PDK) modeling of complementary metal-oxide-semiconductor (CMOS) devices and circuits. His team is actively pursuing reliability characterization of advanced CMOS devices and circuits fabricated by various global industry collaborators.

The Challenges

The importance of reliability for digital CMOS operation where stressing fields for DC or AC in very high frequency (VHF) / ultra-high frequency (UHF) / L / S bands is critical. Routine techniques exist to measure reliability components, such as the hot-carrier stress, bias temperature instability, and time-dependent dielectric breakdown.

However, in RF CMOS circuits operating in the frequency range of 6 to 7 GHz for Wi-Fi and 28 GHz for 5G and beyond technologies, stress is often due to high-frequency RF signals. Degradation is a time-dependent phenomenon that affects carrier trapping / de-trapping, interface state generation, and more.

A measurement setup is necessary to characterize these new RF reliability effects to enable:

- Applications for several types of stress voltages — DC, pulse, and RF control for the stress test duration, periodic termination, and resumption at specific time intervals.
- Measurements of the DC, IV, small, and large-signal RF performance in the time window between successive stress cycles.
- Delays your measurement with precise control; see Figure 1[1]

1 Gupta et al., IEEE TED, 66(5), 2019]. (Anshul 2019)
https://ieeexplore.ieee.org/iel7/16/8694031/08681718.pdf

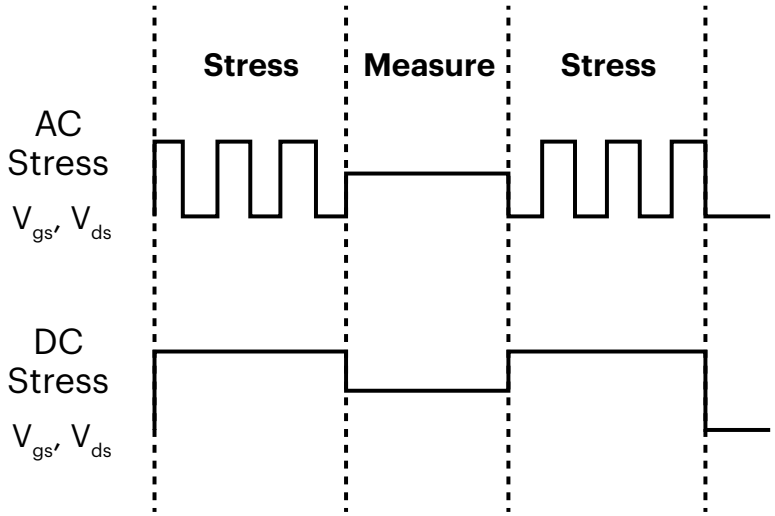


Figure 1. Schematic of stress-measure-stress test waveforms

> Reliability endurance tests are performed for long durations of time, often over many days at a single stretch. It is imperative that test conditions are precisely controlled throughout the measurement. Even a vibration or a noisy supply/ground can adversely affect these tests by introducing erroneous results. Performing such tests without appropriate measurement equipment and automation is unfeasible.
>
> Professor Dixit

The Solution

Professor Dixit and his team worked for two years with industry collaborators to continuously cross-check reliability data before producing an innovative, integrated setup to perform these stress / measure / stress reliability cycles. See Figure 2 for the schematic process flow using this setup to perform DC, small, and large-signal measurements. The interfaces and SCPI commands make these highly programmable for automation requirements.

In this automated setup, each function of DC, small, and large-signal measurements work independently to resolve any fixed delays between them. During the study of hot carriers, the team took note of the results between stress and measure cycles to remove the inclusion effects of bias temperature instability (BTI) by setting the appropriate delay value, depending on the requirement.

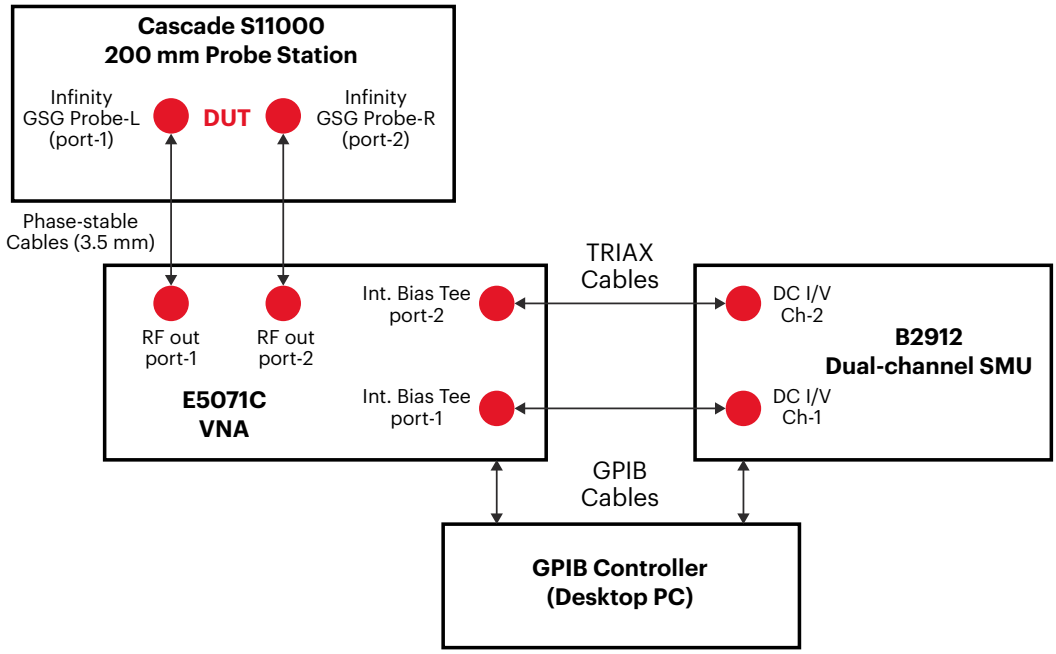


Figure 2. Integrated setup using a Keysight network analyzer, source measure unit, and cascade probing station

In its effort to correlate large-signal RF figures of merit with DC reliability trackers, the team was able to reproduce in-field operating conditions for RF circuits and even accelerate the aging processes in the lab. Once the team understood the physics, the knowledge was incorporated in the form of a degradation model and is now available for use by the circuit designers as a PDK element.

Professor Dixit

The Results

A typical configuration for a DC to RF test system includes a semiconductor device parameter analyzer, probing station, and a network analyzer. Apart from these, the test bench may need an additional power supply and an oscilloscope. It can take weeks or even months before you can execute your first measurements with confidence to confirm data correlation and measurement accuracy.

Keysight is the only test and measurement solution provider that provides all the instruments for DC-RF characterization. The Keysight B1500 semiconductor device parameter analyzer / semiconductor characterization system ensures accurate and efficient current to voltage measurements that provide clear insight into IV characteristics across a wide range of applications. Powerful characterization software and integrated source and measurement units (SMUs) make it quick and simple to obtain accurate IV characterization.

Keysight's extensive range of benchtop and compact network analyzers offer unrivaled measurement excellence, specifications, and accuracy. FormFactor, Inc., a Keysight solution partner, has multiple years of installation experience and can easily integrate and support this solution platform. Test instruments from a single source offer the right integration compatibility that Professor Dixit's team needed.