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Automation of Integrated Circuit Parameters Measurement using LabVIEW

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Abstract: The measurement of electrical parameters, whether AC or DC, is a crucial step in the design, development, and validation of integrated circuits. As integrated circuits continue to evolve, incorporating increasingly complex and diverse functional blocks, the need for comprehensive and thorough measurement becomes increasingly important.

The measurement process involves several key stages. First, functional testing ensures that the IC operates correctly. This is followed by timing and power analysis, which identifies potential timing violations and optimizes power consumption to enhance energy efficiency. Voltage and frequency scaling experiments are also conducted to investigate the IC's performance.

Furthermore, validation and compliance checks are performed to ensure adherence to industry standards and regulatory requirements. Sophisticated simulation techniques play a vital role in facilitating the measurement process, enabling a faster and more cost-effective assessment of the IC's behaviour. Building on this foundation, this paper explores the automation of the measurement process using LabVIEW, with a focus on streamlining and optimizing the testing and validation of integrated circuits.

Keywords: Integrated Circuits, LabVIEW, AC measurement, DC measurement.

I. INTRODUCTION

Bench measurements are typically a non-standard platform and is usually made up of stand-alone equipment hooked up together. The equipment can be used stand-alone. The user must make the connections between the equipment and the setup is highly dependent on the equipment availability. However, since the connections are made manually there is almost no restriction on the way instruments can be connected to perform a test. The basic idea of this paper was to emulate the benefits of an Automation techniques for measurements sacrificing neither the signal integrity nor the flexibility. Measurement Automation Tool (MAT) is a fully automated measurement platform based on NI LabVIEW. It integrates AC and DC measurements into a single platform and is driven from a Test Input File spreadsheet. It is developed to promote reuse in bench measurement and reduce measurement time. MAT refers to the entire system used for measurements including the equipment, the hardware, firmware and the software

II. LITERATURE SURVEY

1] Developing a high-end, scalable, and cost-effective mixed-signal automated test equipment (ATE) production tester that enables wafer sort and final test for ON Semiconductor's new generation image sensors. Customizing the STS T4 system test head concept to meet our requirements for image sensor test of our full product portfolio. This solution is internally called the Pretty Image Sensor Tester from ON Semiconductor (PISTON tester).

[2] Designing a test bench for an automated high-resolution audio codec that integrates analog-to-digital converters and digital-to-analog multichannel converters. Developing a modular solution based on NI PXI instruments to multiplex analog signals, generate and acquire analog and digital signals, and control components via I2C bus.

[3] Improving the measurement speed performance of our RF test benches. These test benches are comprised of traditional rack-and-stack instruments involving multiple platforms. While our existing test system is highly functional, we wanted to reduce system complexity and improve measurement speed without sacrificing measurement accuracy. Using NI PXI instruments to reduce cost and measurement time while improving measurement quality and meeting our goal to reduce test cost and improve characterization time. Using NI PXI instruments to reduce cost and measurement time while improving measurement quality and meeting our goal to reduce test cost and improve characterization time.

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[4] Identifying a cost-effective solution for performing fixture test and repair in line with manufacturing flow that requires minimum overhead and does not affect ATE productivity. Using PXI hardware and TestStand software to develop FlexyTest, which is an easy and versatile solution that maximizes the test fixtures and extends their operating life without affecting the ATE productivity.

[5] Developing a modular test solution that is abstract, scalable, modular, and easy to use; supports test sequencing across hundreds of power management ICs (PMIC); and interacts with multiple instruments, evaluation modules, and source measure units (SMUs). Using NI LabVIEW software and NI TestStand to build a flexible and modular automated test solution that can test several PMICs with different requirements, communications buses, and protocols; and is easy to use for engineers who do not have computer science backgrounds.

[6] Designing an automated test system for functional and parametric control of static and dynamic parameters of high-power IGBT and MOSFET transistors. Using LabVIEW software and the NI PXI platform to create an automated test system to measure the parameters of high-power IGBT and MOSFET transistors with an easy-to-use and intuitive user interface.

[7] Establishing an effective mechanism to share measurement expertise and device, and instrumentation knowledge across validation teams to facilitate accelerated product development and validation cycles driven by growing time-to-market pressure. We developed a novel semiconductor validation framework based on LabVIEW and TestStand, which allows validation teams to increase automaton, increase reuse of their existing software assets and code bases, and easily onboard new members to the validation activity.

[8] Performing accurate electrical wafer-level tests in the semiconductor R&D fabrication (fab) process flow to detect process-related issues at an early stage. This helps us rework the wafers at the right time to manage yield drops and optimize the R&D process flow, reduce costs, and decrease the time-to-market of the newest chip-manufacturing techniques. Using the NI PXI platform with PXIe-4135 source measure units (SMUs) to build a highly parallel measurement system to use inside the wafer fab, and programming this setup with LabVIEW so that we can keep all the wafers inside and test them, process the results, and make much faster adjustments to the semiconductor process flow.

III. FEATURES OF MEASUREMENT AUTOMATION TOOL(MAT)

A. Runtime Reduction

Optimizing run time is crucial in the measurement process, and one effective approach is to utilize atomic commands to control equipment. An atomic command is the most basic unit of instruction, designed to perform a single, specific task, thereby minimizing the number of commands sent to the equipment. This streamlined approach reduces run time by eliminating unnecessary commands.

Another key strategy to decrease run time is intelligent command parsing, which leverages "State Caching" technology. This innovative method involves capturing the current state of an instrument within its corresponding LVOOP object. When a command needs to be sent to the equipment, it is only transmitted if the present state of the equipment differs from the requested state. This approach proves particularly useful when multiple measurements are taken with a single equipment configuration. By configuring the equipment only once and performing multiple measurements, significant time savings can be achieved.

B. Equipment Independence

The Measurement Automation Tool architecture is designed to be highly flexible and adaptable. One of its key features is the ability to seamlessly interchange equipment with different interfaces, but belonging to the same class, by simply making a single change in the equipment selection within the spreadsheet. Moreover, the tool allows for the effortless substitution of fundamentally different equipment, such as oscilloscopes and multi-meters, to perform a given measurement, again with just a single change in the spreadsheet. For instance, a DC voltage measurement can be easily switched from being performed by a multi-meter to an oscilloscope, or vice versa, with minimal effort and without requiring significant reconfiguration. This flexibility enables users to leverage the strengths of different equipment to achieve their measurement goals.

C. Fully Reusable

The architecture allows the measurement programs to be fully reusable. All equipment specific settings are handled using Test Parameters (TP) in the excel sheet. The measurement programs are developed to allow optimal (not maximum) flexibility to be usable for multiple ICs and not be complex.

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IV. SOFTWARE USED (LABVIEW)

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a powerful graphical programming language and development environment created by National Instruments (now NI), primarily used for test, measurement, and control applications. It provides a user-friendly, graphical approach to building applications that involve data acquisition, signal processing, automation, and hardware interfacing. LabVIEW is widely used in various industries and research fields, such as engineering, science, academia, and manufacturing.

Features

LabVIEW is based on a dataflow programming paradigm, where data determines the execution flow. Its key features and architecture include

1. Graphical Programming: LabVIEW uses graphical icons and wires to represent functions and data flow, making it easy for users to understand and develop complex systems visually.
2. Front Panel and Block Diagram: The graphical interface consists of two main windows: the Front Panel (user interface) and the Block Diagram (code representation). The Front Panel contains controls and indicators for user interaction, while the Block Diagram contains the graphical code that processes data.
3. Modularity and Reusability: LabVIEW promotes modular programming, allowing users to create reusable subVI (sub-Virtual Instruments) for efficient code organization. Extensive Libraries: LabVIEW provides a vast library of built-in functions and toolkits for various tasks, including data acquisition, signal processing, control systems, and communication protocols.
4. Hardware Interfacing: LabVIEW integrates with a wide range of hardware, including data acquisition devices, programmable logic controllers (PLCs), and other measurement instruments.
5. Multithreading Support: LabVIEW supports parallel execution and multithreading, enabling users to perform complex tasks efficiently.

Applications

LabVIEW finds applications in diverse fields, including but not limited to:

1. Test and Measurement: LabVIEW is widely used for automated test and measurement systems, allowing engineers to perform various tests and data analysis efficiently.
2. Data Acquisition: LabVIEW is commonly employed for real-time data acquisition from sensors and measurement devices.
3. Control Systems: LabVIEW enables the design and implementation of control systems for automation and process control applications.
4. Embedded Systems: LabVIEW can be used in the development of embedded systems real-time applications.
5. Academic and Research: LabVIEW is popular in academia and research for conducting experiments, data analysis, and simulation.
6. Industrial Automation: LabVIEW is used in industrial automation and monitoring applications

V. EQUIPMENT SUPPORTED

Equipment's, in this case, refer to the different types of tests and measurement instrumentation, like multi-meters, power supplies, oscilloscopes etc.

- AFG: Arbitrary Function Generator (AFG) is a class of equipment used to source AC signals. It is usually used to generate square wave to be used for ICs. It can also source various other functions, like sine, ramp and pulse. It supports burst mode, external as well as internal trigger.
- DMM: Digital Multi-Meter (DMM) is a class of equipment used to measure DC voltages and currents.
- SMU: Source Measure Unit (SMU) is a class of equipment that integrates source and measurement operations. It operates across all four voltage-current quadrants. It simultaneously sources voltage or current to a pair of terminals and measures the current or voltage, respectively, across those terminals.
- Scope: An oscilloscope is used to do various AC/DC measurements. It is used to measure frequency, rise time, fall time, delay, mean voltage etc.

VI. WORKING OF MEASUREMENT AUTOMATION TOOL

The Measurement Automation Tool is built upon a hierarchical, four-level architecture, comprising the User Level, Test-Level, Function-Level, and Equipment Level. This structured approach ensures a clear and organized data flow, as VIs

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(Virtual Instruments) at each level can only interact with VIs one level above or below them. This means that VIs at a given level can only call VIs at the level directly below, and conversely, can only be called by VIs at the level directly above. This hierarchical design facilitates efficient development and debugging, as the data flow is clearly defined and easily traceable, allowing developers to focus on specific components without worrying about the overall system's complexity.

Equipment Level

The Equipment VI is the lowest level of the hierarchical architecture, responsible for directly communicating with the equipment and providing a simplified, abstracted interface to the upper-level VIs. To achieve this, atomic commands are employed to interact with the equipment, ensuring that each command performs a single, specific task, thereby enhancing reusability.

The Equipment VIs are implemented using LabVIEW Object-Oriented Programming (LVOOP) concepts. In this context, the variables associated with a piece of equipment, such as GPIB address and range, are defined as Member Variables. The methods that operate on these variables and perform tasks like measuring voltage or powering down are designated as Member Functions. A key benefit of this approach is that the Member Variables can only be accessed through the Member Functions, which provides a safeguard against inadvertent modification of the variables. This ensures that improper data handling is prevented at the upper levels of the hierarchy, thereby maintaining data integrity and reliability.

Function Level

Function VIs are designed to perform equipment-level functions, essentially serving as a cohesive collection of equipment commands that work together to achieve a specific task. These VIs typically involve the execution of multiple equipment commands in a particular sequence. A prime example of a Function VI is the "Measure Voltage" function, which is comprised of a series of equipment commands, including "Set Range", "Set Integration Time", and "Measure Voltage". It is essential to differentiate between the "Measure Voltage" function as a VI and as a standalone equipment command. While the equipment command simply triggers a measurement operation on a digital multimeter (DMM), the Function VI takes a more comprehensive approach, configuring the DMM and then initiating the measurement, thereby providing a higher-level abstraction and simplifying the measurement process.

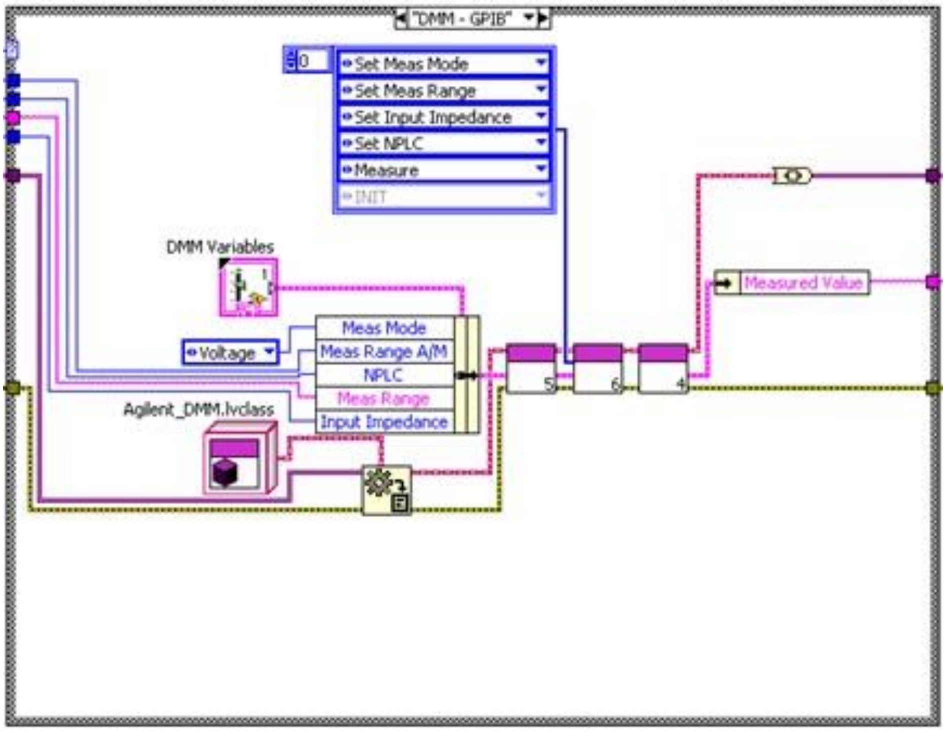

Figure1: Function VI for Measuring DC Voltage using DMM Equipment

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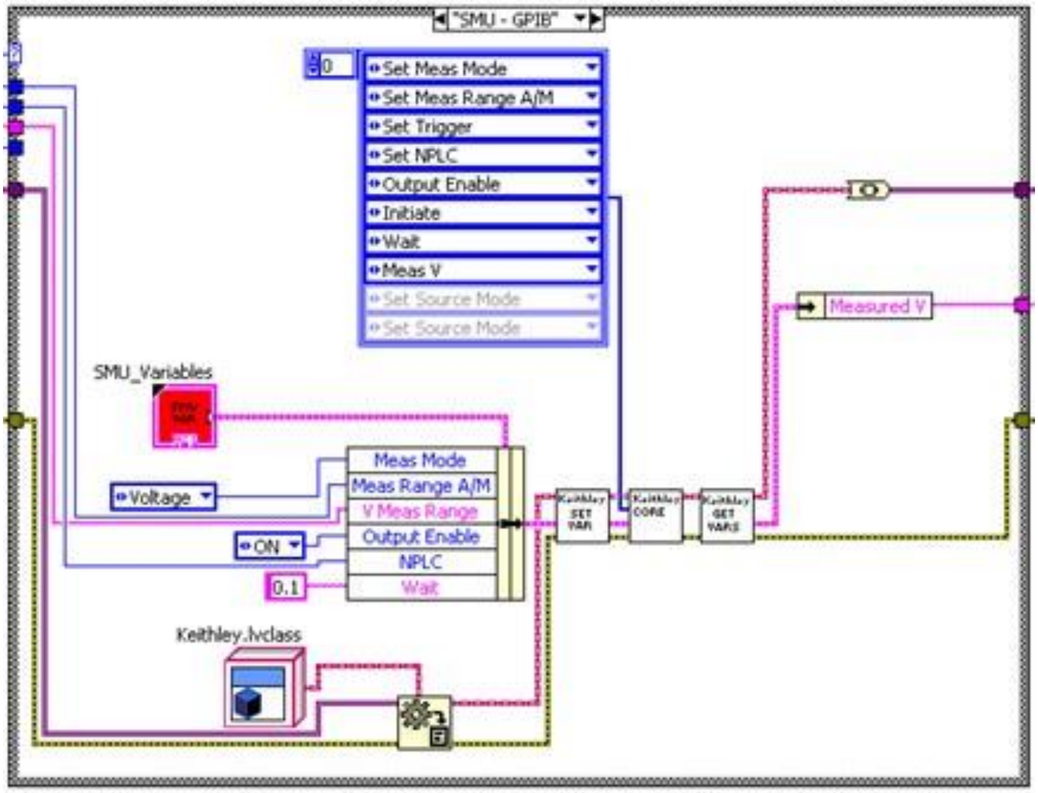

Figure2: Function VI for Measuring DC Voltage using SMU Equipment

Need for Function VI

One of the primary benefits of incorporating Function VIs is the enhanced adaptability of the software to changes in the setup. For example, a voltage measurement can be performed using various classes of equipment, such as Source Measurement Units (SMUs), Digital Multimeters (DMMs), and Oscilloscopes.

Without Function VIs, Parameter VIs would need to directly call Equipment VIs, which would require modifications to the software if a SMU were replaced with a DMM. However, by introducing Function VIs, the software remains unaffected by such changes, as the Function VI can seamlessly adapt to the new equipment. Given that the number of Test VIs is significantly greater than the number of Function VIs, the additional layer of abstraction provided by Function VIs proves to be a valuable investment, enabling greater flexibility and maintainability in the software architecture.

Test Level

Test VIs are the core VIs responsible for executing the actual test and measurement processes. They receive input from the user and invoke the necessary Function VIs to perform the required tasks. A key design constraint is that Test VIs are not permitted to directly call Equipment VIs, ensuring a clear separation of concerns and promoting modularity.

Each Parameter VI is associated with multiple configurable settings, which can be customized by the user. These settings are then passed to the Test VI through the Test Parameters (TPs) defined in the Test Requirements Document (TRD), allowing for flexible and user-defined test configurations.

VII. RESULTS

Both DC and AC Parameters are tested for STM32F446RE microcontroller for GPIO IP across different voltages (VDD) Below Table shows the list of parameters measured.

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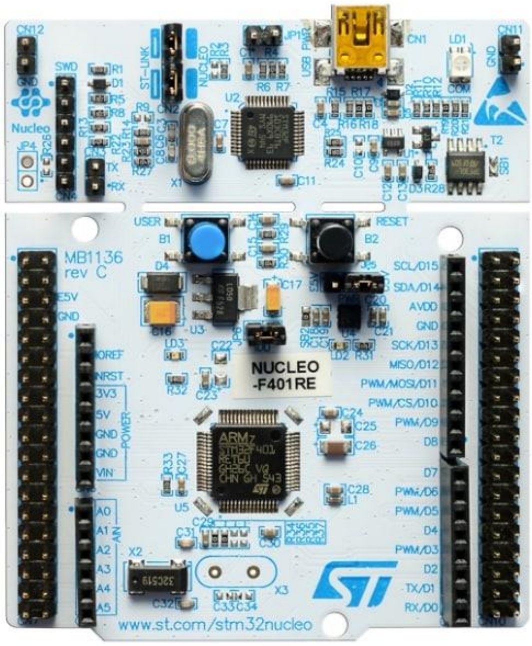
Board used for measurement



Parameters measured

Parameter Type	Parameter Measured	VDD(V)
DC	VOL	5
		4,5
		5.6
	VOH	2.6
		3.3
		4.5
		5.6
	VIL,VIH & VHS	2.6
		3.3
		4.5
		5.6
AC	Frequency	2.6
		3.3
		4.5
		5.6
	DutyCycle	2.6
		3.3
		4.5
		5.6
	High Amplitude	2.6
		3.3
		4.5
		5.6
	Low Amplitude	2.6
		3.3
		4.5
		5.6

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Output

Measurement data will be logged as .txt format,

STM32F446RE	VOL	5	1.16E-01
STM32F446RE	VOL	4.5	1.25E-01
STM32F446RE	VOL	5.6	1.09E-01
STM32F446RE	VOH	2.6	1.18E-01
STM32F446RE	VOH	3.3	9.36E-02
STM32F446RE	VOH	4.5	7.32E-02
STM32F446RE	VOH	5.6	6.34E-02
STM32F446RE	Vh	2.6	5.32E+01
STM32F446RE	Vh	2.6	4.40E+01
STM32F446RE	Vh	2.6	9.153846
STM32F446RE	Vh	3.3	5.16E+01
STM32F446RE	Vh	3.3	4.45E+01
STM32F446RE	Vh	3.3	7.090909
STM32F446RE	Vh	4.5	5.03E+01
STM32F446RE	Vh	4.5	4.44E+01
STM32F446RE	Vh	4.5	5.888889
STM32F446RE	Vh	5.6	4.97E+01
STM32F446RE	Vh	5.6	4.39E+01
STM32F446RE	Vh	5.6	5.803571
STM32F446RE	RISETIME	2.7	2.58E-09
STM32F446RE	FALLTIME	2.7	2.61E-09
STM32F446RE	RISETIME	3.3	2.09E-09
STM32F446RE	FALLTIME	3.3	1.98E-09
STM32F446RE	RISETIME	5	8.99E-10
STM32F446RE	FALLTIME	5	1.23E-09
STM32F446RE	RISETIME	5.5	7.67E-10
STM32F446RE	FALLTIME	5.5	1.07E-09
STM32F446RE	FREQUENCY	2.7	1.81E+07
STM32F446RE	DUTYCYCLE	2.7	49.3376
STM32F446RE	HIGH-AMPLITUDE	2.7	107.437037
STM32F446RE	LOW-AMPLITUDE	2.7	4.174548
STM32F446RE	FREQUENCY	3.3	1.81E+07
STM32F446RE	DUTYCYCLE	3.3	49.8474
STM32F446RE	HIGH-AMPLITUDE	3.3	107.872727
STM32F446RE	LOW-AMPLITUDE	3.3	3.382458
STM32F446RE	FREQUENCY	4.5	1.81E+07
STM32F446RE	DUTYCYCLE	4.5	50.2778
STM32F446RE	HIGH-AMPLITUDE	4.5	108.211111
STM32F446RE	LOW-AMPLITUDE	4.5	2.256604

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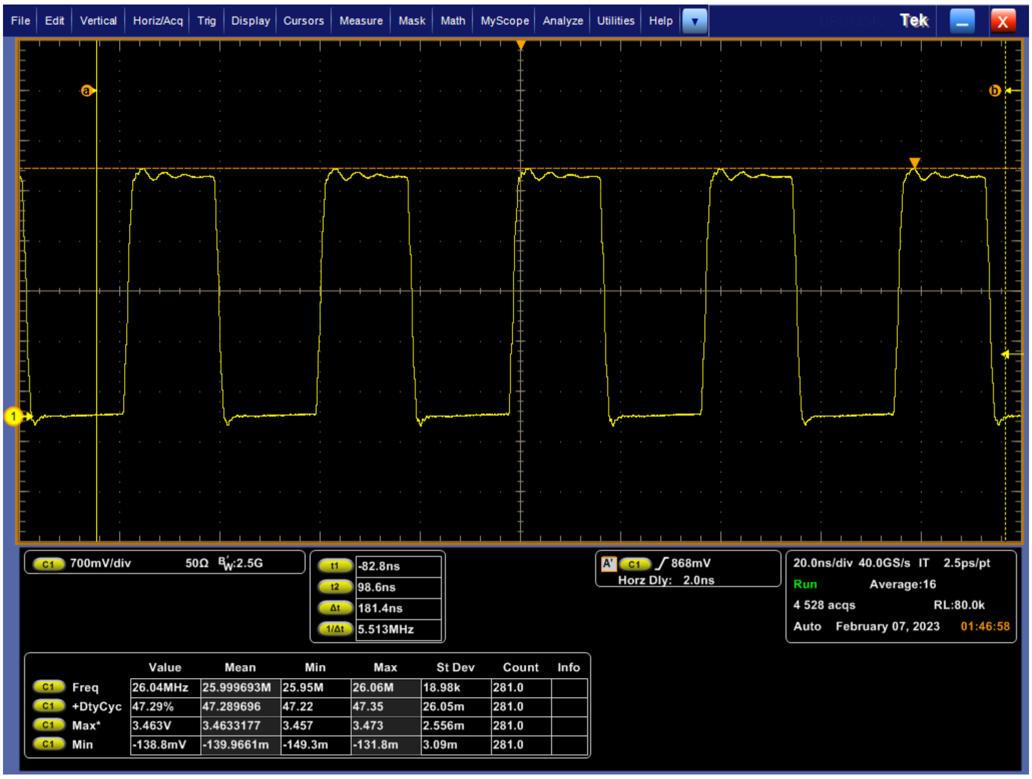
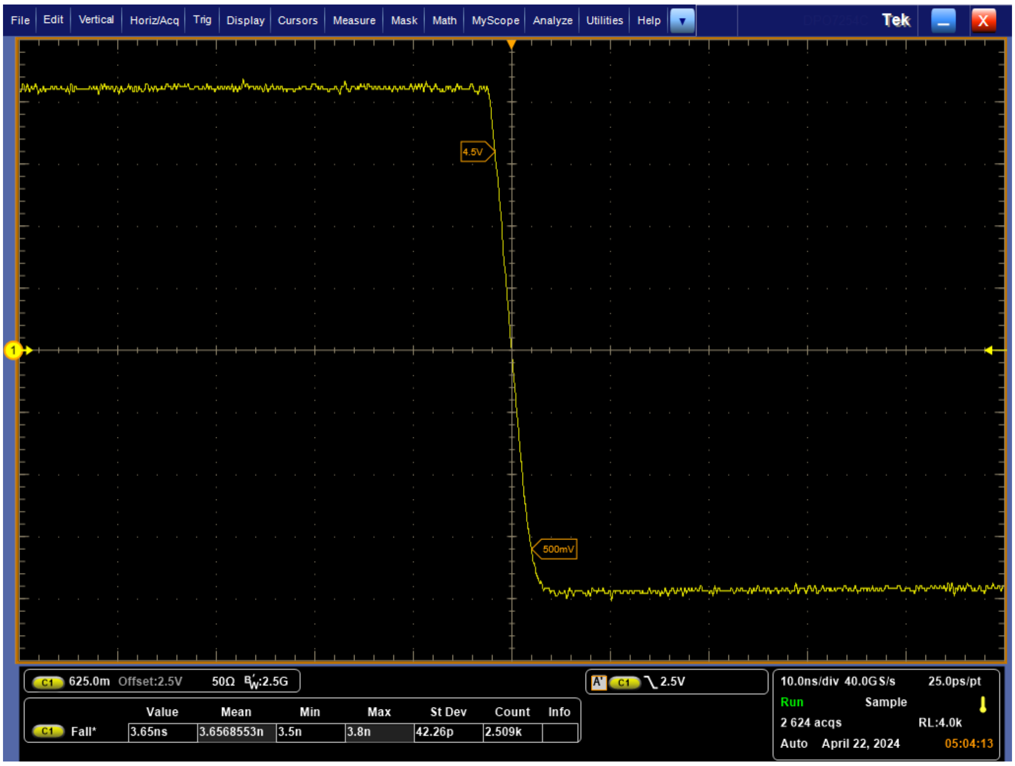
WAVEFORMS





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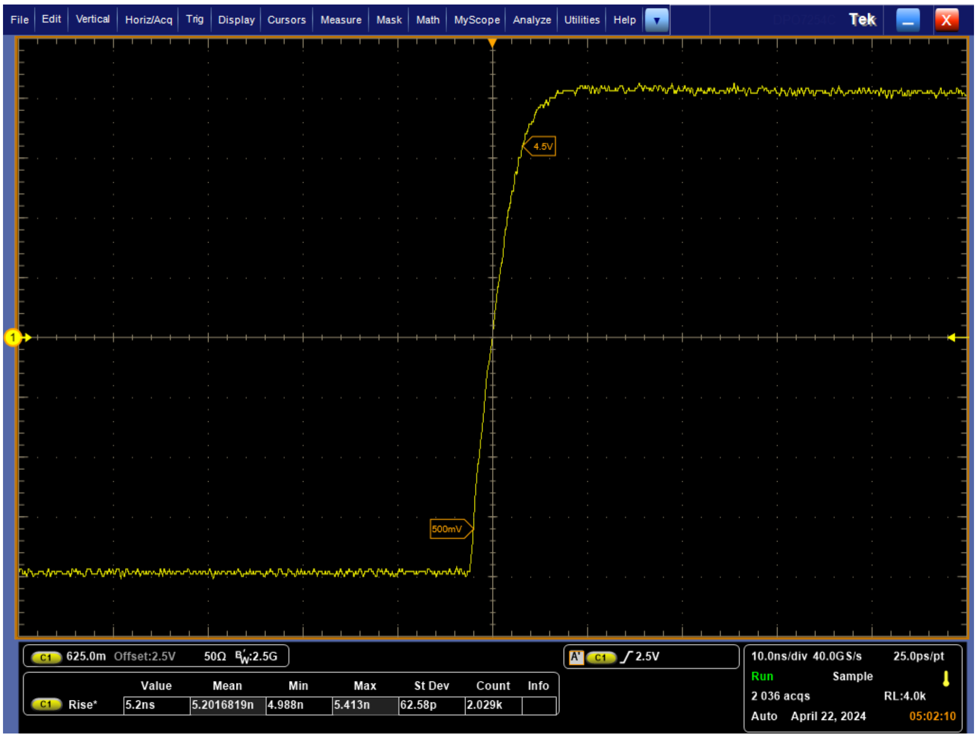

VIII. CONCLUSION

Throughout the development and implementation, the tool has demonstrated significant benefits, such as improved incident resolution times, increased operational efficiency, and seamless integration with existing equipment.

The tool’s automation capabilities have led to faster and more accurate incident detection, analysis, and response. As a result, the user can proactively measure the IC’s electrical parameters using this method.

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