DRIVING INNOVATION THROUGH AUTOMATION: "INTEGRATING THE INDUCTIVE SWITCHING TEST (IST) MODULE INTO FINAL TEST HANDLER TO IMPROVE COST EFFICIENCY AND YIELD IN GaN DEVICE TESTING"

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ABSTRACT

Innovation and automation are distinct yet interconnected forces in modern manufacturing. Innovation drives the development of new ideas, solutions, and products, often utilizing automation to realize their full potential. Conversely, automation focuses on streamlining and enhancing existing processes, frequently serving as a platform for innovation. This project demonstrates how automation can act as a catalyst for innovation, yielding higher efficiency, cost savings, and a stronger competitive advantage.

This technical paper presents the initiative undertaken by the Nexperia Philippines team to transform a traditionally manual process into a fully automated system through innovative thinking and strategic collaboration.

The Inductive Switching Test (IST) was previously conducted as a manual process at a subcontractor (subcon) facility outside the Nexperia Philippines plant. To improve efficiency and reduce manual handling, the team initiated a collaboration with ITEC to develop and introduce an Automated Inductive Switching Test (IST) Module.

This new IST module will be integrated directly into the existing Final Test setup at the ATCB (Assembly, Test, and Component Building). As a result, the manual testing process at the subcon site will be eliminated, transitioning to a fully automated solution within the in-house test environment. This initiative enhances test accuracy, reduces time spent on handling, and brings the process fully under Nexperia's control.

The successful deployment of the Automated IST Module led to:

- Elimination of subcon testing costs
- Die-Free Package Cost (DFPC) reduction of 3.30%

1. 0 INTRODUCTION

The Inductive Switching Test (IST) is a dynamic reliability and screening test that is performed to assess the high-speed, high-current, and high-voltage switching capabilities of GaN FET (Gallium Nitride Field-Effect Transistors) devices. This test is specifically designed to replicate the electrical stresses that may be encountered under real-world application conditions.

During the IST, the Device Under Test (DUT) is used to charge a large inductor using a series of short high-current pulses, with a bus voltage of up to 400V and a current level of up to 25A. The switching behavior of the DUT is continuously monitored throughout the test. Any malfunction or deviation in performance is detected in real-time. Upon completion of the stress test, a functional switching test is applied to verify the integrity and continued operation of the DUT.

This test is considered essential for identifying early-life failures and latent defects that may not be captured during standard electrical testing. Key device

characteristics such as gate control stability, interconnect robustness, and dynamic performance are evaluated during IST. It is used both as a qualification and screening tool for reliability assurance, particularly in high-performance power applications.

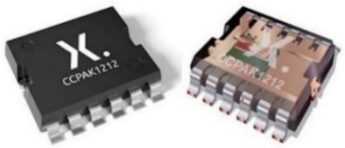

Figure 1: CCPak1212 device for IST (inductive Switching Test)

The GaN CCPAK1212 represents Nexperia's first GaN device introduced at the Philippines site. As part of the qualification and reliability assurance for this new package, the Inductive Switching Test (IST) is included as a critical test process.

1.1 Manual IST at Subcon

The IST is being conducted manually at a subcontractor (subcon) location. See Figure 2 for the Process flow of Manual IST.

Figure 2: CCPak1212 Process Flow with Manual IST

The Manual IST (Inductive Switching Test) setup utilizes external equipment connected directly to the IST PCB board. This external setup is essential for executing the test process and includes the following key functions:

- *Voltage Supply:* Provides the necessary power input for the test.
- *Waveform and Pulse Monitoring:* Captures and analyzes the switching waveforms and pulse behavior during testing.
- *Test Control Interface*: Sends the required test commands to initiate and manage the IST sequence.

This configuration, while functional, involves significant manual handling and equipment setup, which the automated IST solution aims to eliminate for improved efficiency, consistency, and reliability.

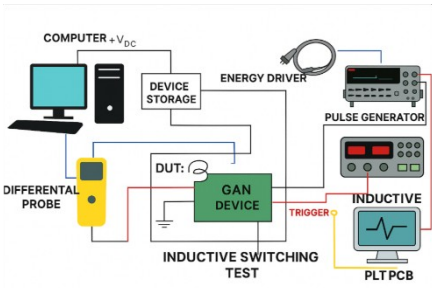

Figure 3: Manual IST Hardware connections

The team has identified the Inductive Switching Test (IST) process as a key area for improvement in the GaN CCPAK1212 product line. The following factors have highlighted the need for process enhancement:

- *Low Units Per Hour (UPH):* The manual operation limits throughput per hour, impacting overall efficiency.
- *Sub-optimal Yield:* The current process is yielding only 97%, which falls short of target reliability metrics.
- *High Subcon Cost:* The outsourcing of IST incurs a significant additional cost per kpcs., increasing the cost of test and manufacturing.

Table 1. Summary of IST Manual condition

Indices	Remarks
UPH (Unit per Hour)	Low throughput
Unit Cycle Time	Long unit cycle time
Process method	Manual Operation
Test Cost (kpcs)	Additional subcon cost
Location	External - subcon

These challenges further support the transition to a fully automated IST setup, aimed at improving productivity and reducing dependency on external test resources.

To address the limitations of the current manual IST process, the team has proposed an innovative solution - Integrating the IST process directly into a Test Handler machine located at ATCB (in-house).

1.2 Proposed AUTOMATIC IST set-up

A project was initiated by the team to transition the existing Manual Inductive Switching Test (IST) process into a fully automated system, with the objective of improving efficiency, consistency, and throughput. A comprehensive evaluation was conducted, involving close coordination with multiple equipment suppliers.

Following a detailed assessment and technical review, ITEC Equipment (Netherlands) was selected as the preferred partner for the automated IST solution. The selection was driven by key factors such as proven technical capability, integration feasibility, and strong supplier support.

Importantly, the existing test handler targeted for integration was also supplied by ITEC Equipment, ensuring full system compatibility and simplifying the overall implementation process.

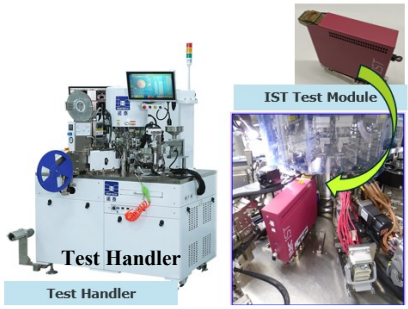

Figure 4: Actual IST Module integrated into a Test Handler

1.3 Challenges in the Automatic IST set-up

Key Technical Requirements and Considerations:
To ensure optimal performance and seamless integration, the following critical conditions must be considered:

- Low-Inductance PCB Test Socket: A socket design with minimal contact length to the PCB is required to achieve the lowest possible stray inductance. This is vital for reliable and accurate IST measurements. Refer to Figure 5.

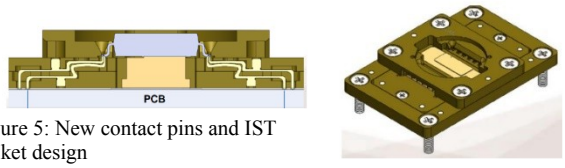

Figure 5: New contact pins and IST socket design

- Test Handler Space Limitations: The IST module must be integrated within a narrow installation space, requiring careful mechanical planning and possible adjustments.

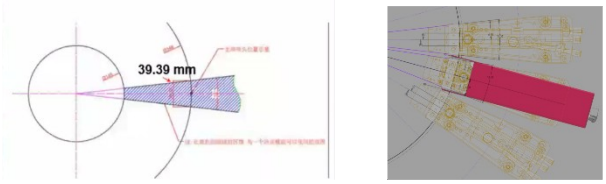

Figure 6: Actual simulation of IST Module to fit-in narrow space in Test Handler.

- Device Movement Tolerance: The socket must accommodate limited device movement during operation, factoring in the socket's opening mechanism and contact stability. This is to reduce or eliminate the contact issues between the package leads and socket contact pins that may result to Kelvin (contact fails) rejects.

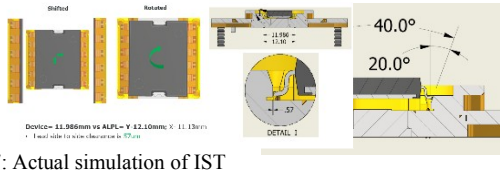

Figure 7: Actual simulation of IST Socket opening to resolve the contact issue between package leads and contact pins.

2. 0 REVIEW OF RELATED WORK

"Not Applicable"

3.0 METHODOLOGY

3.2 Qualification Plan

To ensure the reliability and robustness of the newly integrated Automatic IST (Inductive Switching Test) setup, the team has established a comprehensive process qualification. This qualification phase is critical to validating system performance under production conditions and ensuring the setup meets all electrical, mechanical, and operational requirements.

Successful qualification will serve as the foundation for releasing the automated IST process into full production.

Table 2: Summary of Test Qualifications

Test	Conditions	Sample Size	Criteria
Synchronization Test	1x unit tested and followed on every Test Site if it responds accordingly. Test results shows on the tester screen monitor.	1 unit	Tester and handler communications synch
Pass-Fail Check	Testing of randomly arranged known good samples and known rejects on the machine. Good parts should go to Bin1 and Reject parts should go to Reject Bins.	11 good units, 16 short units	No miss-sorting or miss binning.
Gage R&R	Testing of 30units with 3x repetition.	30units	Total GR&R less than 10%.
Test Consistency	Retesting of Known Good parts	100units Known Good	100% Yield.
Attribute Analysis Agreement	Randomly testing 50 samples known good and shorts, tested 2x per appraiser.	50 samples	Percent Accuracy acceptable value is > / Repeatability is > / = to 90%
Test Yield	Testing on Manual IST and Automatic IST	2 lots	Manual IST yield is > 96.50%.
Reliability Test	High Temperature Gate Bias (HTGB) Standard Level: Tj = 175°C, Vgs= 20V, Vds=0V	300 units	Zero (0) fails
	High Temperature Negative Gate Bias (HTNGB) Standard Level: Tj = 175°C, Vgs= -20V, Vds=0V	300 units	Zero (0) fails

To validate the integrity and consistency of the Automatic IST process, several key evaluations and test verifications were conducted:

- Synchronization-Test:
  This test ensured proper synchronization between the tester and the handler and verified the Pass-Fail signaling to confirm that there were no cases of miss-sorting or miss-binning of units.
- GR&R (Gage Repeatability and Reproducibility),

  This statistical analysis was performed to assess the repeatability, reproducibility, and data distribution of the test process, ensuring that results are both reliable and consistent across different operators, test runs, and equipment.
- Attribute Agreement Analysis (also known as Attribute Agreement Study or Attribute MSA – Measurement System Analysis) is a statistical method used to evaluate the consistency and accuracy of inspection or measurement systems when dealing with qualitative (attribute or categorical) data.
- IST Test Yield comparison between Manual IST and Automatic IST.
- Reliability-Testing:
  To further evaluate the long-term performance and stability of the devices that pass through the Automated IST process, Reliability Testing will be conducted. This will determine how consistently the devices perform their intended function over time and under specified environmental and operational conditions.

4.0 RESULTS AND DISCUSSION

4.1 Synchronization Test

The unit moved with the measurement result accordingly.
Tester and Test Handler were synchronized - PASSED.

4.2 GR & R (Gage Repeatability and Reproducibility).

GR&R is Acceptable on IST.

Figure 8: Gage R & R

4.3 Attribute and Agreement Analysis results

Attribute Agreement Analysis (or Attribute MSA) results reveal Automatic IST is significantly better in terms of Repeatability and Accuracy.

Methodology :

- Total of 50 samples, 5 known good 5 shorted samples and 40 devices reject on manual IST.

Results:

- Consistency (Repeatability): 100% consistent on Automatic IST vs. 94% on Manual IST.
- Appraiser vs standard (Accuracy): 100% in agreement in Automatic IST, only 82% in Manual IST.
- The Automatic IST is more repeatable and Accurate compared to Manual IST.

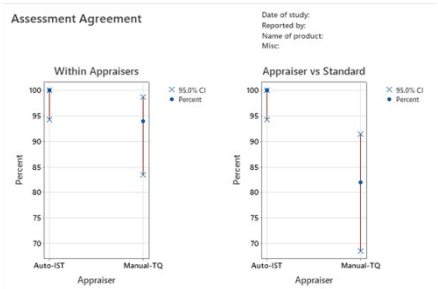

Figure 9: Assessment Agreement results

4.4 Result of Reliability Test

Reliability tests were conducted at read points of 168 hours, 504 hours, and up to 1008 hours. All results were recorded as "PASSED" and even exceeded the required testing conditions.

Table 3: Results of Reliability Test

Attributes	Tests	Sample size	Duration	Current Status	Results
BOM: LF based Metal – Cu LF plating (inside/outside)-Cu/NiPd Clips Precon/Reflowed	High Temperature Gate Bias (HTGB) Standard Level: Tj = 175°C, Vgs= 20V, Vds=0V	2 x 77	504hrs	Passed	All measurements within the parametric limits
	High Temperature Negative Gate Bias (HTNGB) Standard Level: Tj = 175°C, Vgs= -20V, Vds=0V	2 x 77	504hrs	Passed	All measurements within the parametric limits
	High Temperature Gate Bias (HTGB) Standard Level: Tj = 175°C, Vgs= 20V, Vds=0V	1 x 77 (control)	504hrs	Passed	All measurements within the parametric limits
	High Temperature Negative Gate Bias (HTNGB) Standard Level: Tj = 175°C, Vgs= -20V, Vds=0V	1x 77 (control)	504hrs	Passed	All measurements within the parametric limits

4.5 Summary of Qualification results

All required tests and conditions were successfully executed, and all results were recorded as "PASSED".

Table 4: Summary of Qualification results

Test	Conditions	Sample Size	Criteria	Results	Remarks
Synchronization Test	1x unit tested and followed on every Test Site if it responds accordingly. Test results shows on the tester screen monitor.	1 unit	Tester and handler communications synchronized.	No Error	PASS
Pass-Fail Check	Testing of randomly arranged known good samples and known rejects on the machine. Good parts should go to Bin1 and Reject parts should go to Reject Bins.	11 good units, 16 short units	No mis-sorting or mis-binning.	Zero (0) mis-binning	PASS
Gage R&R	Testing of 30units with 3x repetition.	30units	Total GR&R less than 10%.	Less than 10%	PASS
Test Consistency	Retesting of Known Good parts	100units Known Good	Greater or equal to 99% Yield.	100%	PASS
Attribute Analysis Agreement	Randomly testing 50 samples known good and shorts, tested 2x per appraiser.	50 samples	Percent Accuracy acceptable value is > / = to 90% Repeatability is > / = to 90%	100%	PASS
Test Yield	Testing on Manual IST and Automatic IST	2 lots	Manual IST yield is > 96.50%.	99.78%	PASS
Reliability Test	High Temperature Gate Bias (HTGB) Standard Level: Tj = 175°C, Vgs= 20V, Vds=0V	300 units	Zero (0) fails	Zero (0) fails	PASS
	High Temperature Negative Gate Bias (HTNGB) Standard Level: Tj = 175°C, Vgs= -20V, Vds=0V	300 units	Zero (0) fails	Zero (0) fails	PASS

4.6 UPH comparison and cost improvement

Assessment on the UPH on the manual and auto IST revealed Improved the UPH of 800%, Subcon Test Cost reduction of 12.2% and DFPC reduction of 3.3% .

5.0 CONCLUSION

Beyond cost benefits, the IST automation also resulted in improved test accuracy, and enhanced process control - solidifying the value of integrating automation as a tool for operational innovation.

- The Automatic IST Module was successfully Installed and Qualified in Test Handler Machine at Nexperia Philippines Inc. - ATCB.
- Eliminate the Manual IST process at subcon and transfer in Nexperia Philippines Inc. - ATCB (in-house).
- The Auto IST Module has better Repeatability and Accuracy at 100% as per Attribute Analysis compared with Manual IST with 94 and 82% respectively.
- All Evaluation and Qualifications were DONE and PASSED the criteria.
- No fails at Reliability Test even on extended hours (1008hrs).
- Attained Yield is 99.80% with 2.80% improvement compared to Manual IST.
- With 12.20% reduction in Subcon Test cost and DFPC Savings Improvement of 3.30%

Table 5: Comparison of Manual and Automatic IST Improvement Indices

	Indices	Before (Manual IST)	After (Auto IST)
1	Location	Subcon	Nexperia Philippines Inc. - ATCB (In-house)
2	Test Methodology	Manual IST set-up	Automatic IST set-up - integrated at Nortech machine FTNR-003
3	Attribute MSA Consistency	**94%**	**100%**
4	Attribute MSA Accuracy	**82%**	**100%**
5	Test Yield	**97%**	**99.80%** (**2.80%** improvement)
6	UPH (unit per hour)	**XXX** pcs.	**800%** improvement
7	Subcon Test Cost (per kpcs)	**$XXX**	**12.20%** reduction
8	DFPC (per kpcs)	**$XXX**	**3.30%**

Benefits of IST Integration:

- Increased Efficiency: Higher UPH through full automation.
- Improved Yield: Enhanced process stability and control.
- Cost Savings: Elimination of subcon-related expenses
- In-House Capability: Greater control, quicker response to issues, and easier scalability.

6.0 RECOMMENDATIONS

With the successful integration of the Automatic IST (Inductive Switching Test) process into the existing Test Handler machine, the project has reached a significant milestone. This achievement not only enhances test efficiency and reliability but also lays groundwork for further optimization.

7.0 ACKNOWLEDGMENT

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8.0 REFERENCES

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