

PREDICTIVE THERMAL CONTROL FOR EFFICIENT LDMOS BURN-IN TESTING IN AI-ERA ELECTRONICS MANUFACTURING

Aljun Arizala
Mark Lexter Elacion
Jeffrey Guico

Test Process Engineering

AMPLEON Philippines Inc., Philips Ave. LISP1 Bo. Diezmo Pulo, Cabuyao Laguna
aljun.arizala@ampleon.com, mark.l.elacion@ampleon.com, test.operations@ampleon.com

ABSTRACT

The Burn-In process, essential for identifying early-life failures in semiconductor devices, was previously susceptible to undetected thermal excursions due to chilled water loss. This study presents the development and deployment of a real-time thermal monitoring and alert system designed to prevent temperature-related downtime in Burn-In testing of devices like LDMOS transistors. A Type-T thermocouple array integrated with a VeePower-based data acquisition platform was developed to enable live monitoring, threshold-based alerts, and visual alarms. The deployment of the system eliminated thermal-related shutdowns, reduced operator response time by 66%, and enhanced test reliability, demonstrating how intelligent thermal monitoring supports data-driven decision-making in semiconductor reliability testing.

1. 0 INTRODUCTION

Burn-In testing played a vital role in semiconductor reliability assurance by subjecting components to elevated thermal and electrical stress to screen out early-life failures. This process was particularly important for high-value RF power devices such as Lateral Diffused Metal-Oxide-Semiconductor (LDMOS) transistors, which required strict thermal stability to maintain electrical performance and long-term durability. In high-temperature environments, even minor deviations in thermal control could lead to reduced yield, equipment inefficiency, and compromised product quality.

During the Burn-In test, the team identified recurring thermal reliability issues that disrupted continuous testing. Specifically, four separate incidents occurred in which the system executed automatic shutdowns due to excessive temperature rise. Root cause analysis attributed all incidents to an abrupt loss of chilled water flow—an essential cooling mechanism for the test environment. Although the system included a passive temperature gauge, it lacked an active alert mechanism to notify operators of early deviations while the temperature remained within the acceptable range of $25\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$. As a result, the system-initiated shutdowns only after

the DUT temperature exceeded critical limits, thereby introducing the risk of overheating.

Each shutdown required restarting the 3.5-hour Burn-In process from the beginning, resulting in inefficient scheduling and reduced equipment availability. Over a one-month period, water flow-related failures contributed a total of 6.95 hours of unplanned downtime. This highlighted the need for a proactive thermal monitoring solution capable of identifying anomalies before they escalated to shutdown conditions.

To address this operational gap, the team developed and deployed a real-time thermal monitoring and alarm system. This solution integrated a Type-T thermocouple with a data acquisition (DAQ) interface and a custom VeePower software platform. The system continuously tracked DUT temperature, issued automatic alerts when predefined thresholds were approached, and logged temperature data for post-event analysis. This enabled operators to respond promptly to thermal anomalies, preventing unnecessary interruptions and enhancing test reliability.

The implementation provided a low-cost, scalable enhancement to the Burn-In process. By enabling real-time response and data-driven decision-making, the solution improved operational efficiency and established a framework for minimizing downtime caused by thermal instability in high-reliability semiconductor testing.

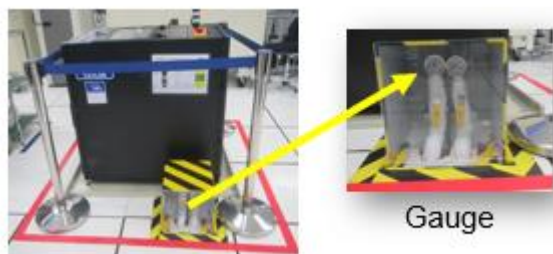


Figure 1. Although the test setup included a temperature gauge, it functioned only as a passive display and failed to provide real-time alerts

2.0 REVIEW OF RELATED WORK

Thermal monitoring in semiconductor reliability testing has received significant attention due to its direct impact on product yield, reliability, and operational continuity. Burn-in processes, which subject devices to elevated temperatures over extended durations, require precise thermal control to avoid excursions that may damage sensitive components such as Lateral Diffused Metal-Oxide-Semiconductor (LDMOS) transistors.

In this study, the following concepts in thermal monitoring were explored: sensor selection and installation, thermoelectric signal processing, and real-time data integration.

2.1 Sensor Selection

Thermocouples were selected for this application due to their robustness, fast response times, and capability to measure a wide range of temperatures, typically from -200 °C to over 2000 °C depending on the type [1]. These attributes make them ideal for high-stress environments such as semiconductor burn-in testing, where rapid and accurate thermal feedback is essential. Among the various types of thermocouples, Type K and Type T are commonly used due to their stability and reliability in industrial applications. The sensor's placement directly on the Device Under Test (DUT) plate was crucial to capturing interface-level thermal behavior, ensuring measurements accurately reflected the thermal dynamics at the device-package boundary. Furthermore, the importance of regular calibration cannot be overstated, as it directly impacts measurement accuracy and consistency. Calibration against a known standard ensures that long-term drift and environmental effects, such as electromagnetic interference, are mitigated effectively [2].

2.2 Signal Processing

Thermocouples operate on the Seebeck effect, generating millivolt-level signals corresponding to temperature differences between the measurement (hot) junction and the reference (cold) junction. These low-level signals require precise amplification and cold junction compensation (CJC) to produce accurate and usable temperature readings. This is typically achieved through specialized thermocouple amplifiers or integrated data acquisition (DAQ) systems with built-in CJC capabilities. High-accuracy signal conditioning circuits, such as those found in National Instruments or Omega DAQ modules, play a critical role in filtering noise, adjusting gain, and linearizing the sensor output [3]. In environments with rapidly changing thermal conditions, such as during thermal cycling in burn-in testing, robust signal processing ensures that transient temperature spikes are accurately captured and logged, maintaining the integrity of the thermal profile data.

2.3 Real-time Data Monitoring

Effective burn-in testing demands real-time temperature monitoring to prevent over-temperature damage and ensure devices are exposed to consistent stress conditions. Modern DAQ systems, such as the DI-2008 from Dataq Instruments, integrate seamlessly with thermocouple arrays and offer high-resolution, multi-channel data logging with configurable sampling rates and digital alarms. These systems provide operators with the ability to set programmable thresholds, triggering alerts or automatic shutdowns when temperatures exceed predefined limits [4]. Such features are instrumental in maintaining process stability and avoiding catastrophic equipment or product failures. Additionally, real-time dashboards and remote monitoring interfaces allow operators to track temperature data continuously and intervene promptly when anomalies are detected. These capabilities significantly reduce downtime and contribute to predictive maintenance strategies in thermal test operations.

Previous implementations demonstrated that thermocouple-based monitoring, combined with intelligent alert mechanisms and proper signal processing, enhanced process control in temperature-critical operations such as semiconductor burn-in testing.

3.0 METHODOLOGY

3.1 System Overview

This study aimed to eliminate temperature-related downtime during Burn-In testing of LDMOS transistors by implementing a real-time thermal monitoring system. The approach focused on accurately detecting thermal anomalies caused by chilled water flow loss and triggering immediate operator alerts. The system integrated thermocouple sensors with a data acquisition interface and a custom VeePower program to enable live monitoring, visual alarms, and data logging.

3.2 Materials and Sensors Configuration

A Type-T thermocouple (Omega Engineering, Model: TMQSS-125G-6) was selected for its precision in low to moderate temperature ranges (-200°C to $+350^{\circ}\text{C}$) and its stability in moist environments, making it suitable for monitoring chilled water-related conditions. The sensor featured a metal junction and a stainless-steel sheath with a 1.6 mm diameter. It was mounted on the aluminum Device Under Test (DUT) plate—measuring $200\text{ mm} \times 150\text{ mm} \times 10\text{ mm}$ —which acted as the heat interface platform. Thermally conductive adhesive ensured secure attachment and optimal heat transfer between the DUT plate and the thermocouple.

To simulate operational conditions, the DUT plate was subjected to ambient temperatures of 125°C —representative of actual Burn-In cycles. Prior to deployment, thermal coupling accuracy was validated through baseline calibration using a Fluke 724 temperature calibrator. The results confirmed alignment among the manual thermometer, the machine's built-in sensor, and the VeePower monitoring program, as shown in Figure 2.

Unit	Manual Thermometer ($^{\circ}\text{C}$)	Machine Sensor ($^{\circ}\text{C}$)	Monitoring Program ($^{\circ}\text{C}$)
1	24	24	24
2	25.01	25	25.02
3	23.6	23.5	23.5
4	24.7	24.6	24.7
5	26.2	26.1	26.1

Figure 2. Temperature correlation among the manual thermometer, the machine's built-in sensor, and the VeePower monitoring program. The calibration confirmed consistent readings across all three measurement methods, ensuring system accuracy.

3.3 Experimental Setup and Signal Processing

The thermocouple output was routed to a National Instruments USB-6210 DAQ module, which digitized the analog millivolt signals into readable temperature data. Signal sampling occurred at a rate of 1 Hz with a resolution of $\pm 0.05^{\circ}\text{C}$.

The DAQ interfaced with the VeePower 1.4 software—a LabVIEW-based platform configured for real-time acquisition, visualization, and alarm processing. The program displayed live temperature plots, computed rate-of-change values, and supported user-defined thresholds for event triggering.

If the DUT temperature exceeded 28°C (above the $25^{\circ}\text{C} \pm 3^{\circ}\text{C}$ limit), the system issued an automatic logic command that activated a stack-type signal light at the operator's console. This provided an immediate visual alert, enabling operators to take corrective action before an overtemperature shutdown could occur.

Figures 3a and 3b illustrate the system architecture, including thermocouple placement, DAQ integration, data monitoring, and the alert mechanism.

Created Temp. Monitoring DASHBOARD

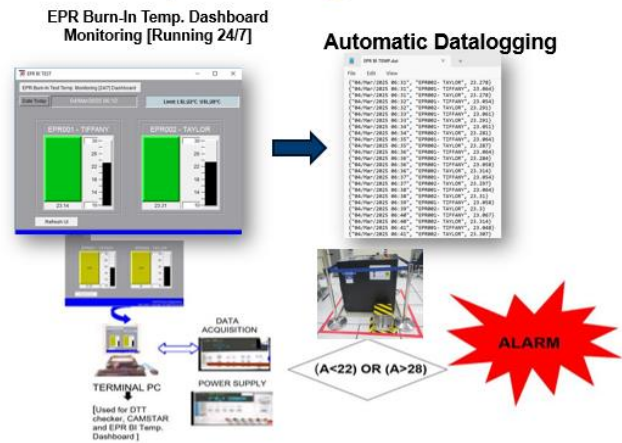


Figure 3a. Real-time Temperature Monitoring Dashboard for Burn-In Testing – Shows a 24/7 system with automatic datalogging and alarm triggers when temperature falls below 22°C or exceeds 28°C . The setup includes DUT, data acquisition, terminal PC, and power supply.

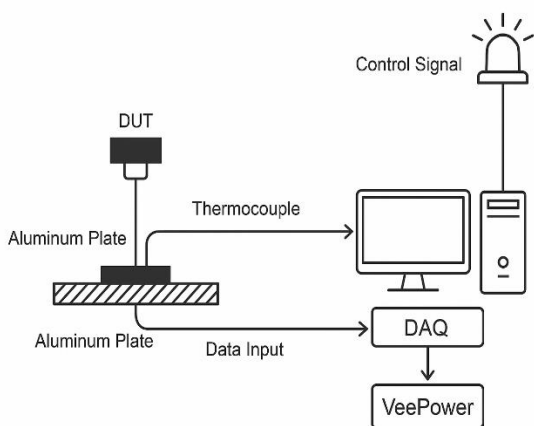


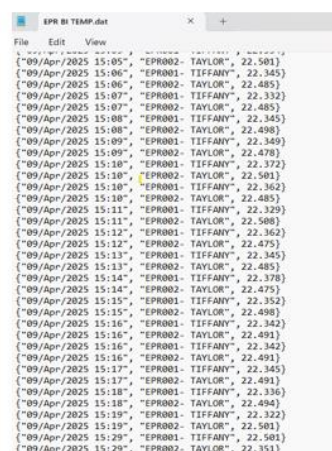
Figure 3b. Schematic Diagram of the Thermal Monitoring Setup – Illustrates the connection of a thermocouple from the DUT (Device Under Test) on an aluminum plate to a computer for real-time temperature monitoring. Data is acquired via DAQ and processed using VeePower software, with a control signal triggering an alarm if temperature thresholds are exceeded.

3.4 Data Logging and Analysis

The system continuously recorded temperature values into a time-stamped CSV file, enabling long-term traceability and post-process review. These logs were analyzed to detect patterns of thermal fluctuation across pre-, mid-, and post-Burn-In phases. This temporal segmentation allowed for identification of abnormal thermal behavior linked to cooling system performance or DUT-specific variations.

The VeePower software included built-in scripting tools that automatically calculated average temperatures, identified peak values, and flagged deviations from the acceptable range. These data analytics features enhanced the ability to perform root cause analysis following unexpected events, such as shutdowns or temperature spikes.

Figure 4 displays a sample of the real-time temperature data generated and visualized by the VeePower monitoring system.



Real time auto generated data

Figure 4. Screenshot of real-time temperature data auto-generated by the VeePower monitoring system during Burn-In testing. The system logs include time-stamped entries with corresponding DUT identifiers and recorded temperatures, enabling traceability and post-process analysis.

4.0 RESULTS AND DISCUSSION

Following the deployment of the thermal monitoring and alert system in the Burn-In process for LDMOS transistors, significant improvements were observed in operational stability and response efficiency.

4.1 Downtime Elimination

One of the key outcomes was the complete elimination of thermal-related downtime incidents. Prior to implementation (October–November 2024), the system recorded an average of 4.0 ± 1.0 incidents per month. After implementation (February–March 2025), this dropped to 0 incidents, based on shift logs and automated fault records. This result, as shown in Fig 5, indicates a 100% reduction in incident frequency, affirming the system's effectiveness in thermal anomaly detection.

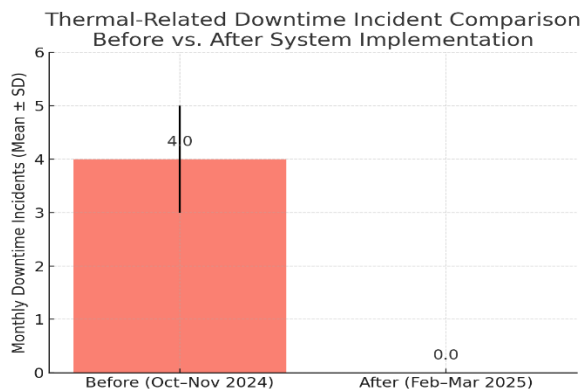


Fig 5. Thermal-Related Downtime Incident Comparison Before vs. After System Implementation showing 100% reduction in incident frequency.

4.2 Operator Response Time Improvement

The introduction of the system enabled the swift identification of critical temperature deviations. When an alarm condition was triggered, operators received immediate visual cues from a signal tower, prompting rapid intervention.

As a result shown in Fig.6, the operator response time improved by approximately 66.7%, decreasing from a pre-implementation average of 90.2 ± 5.1 seconds to 30.1 ± 3.7 seconds post-implementation. This significant improvement was confirmed through a two-sample t-test, which yielded a p-value < 0.01 , indicating strong statistical significance. The 95% confidence interval for the mean difference in response times ranged from 55.6 to 62.1 seconds, affirming the reliability of the observed improvement.

Faster operator response times contributed to reduced device exposure to excessive temperatures, minimized the risk of batch rejections, and enhanced overall process reliability during Burn-In testing.

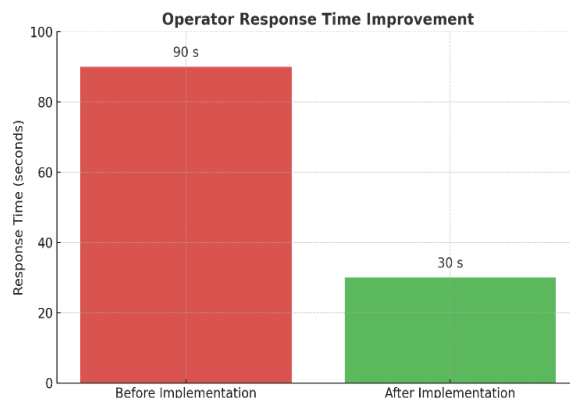


Fig 6. Operator Response Time Improvement Diagram showing shortened operator response time from 90 to 30 seconds.

5.0 CONCLUSION

The intelligent thermal monitoring system reduced Burn-In test downtime from 6.95 hours/month to zero and shortened operator response time from 90 to 30 seconds. These improvements enhanced throughput, reduced batch rejection risk, and uncovered latent cooling inefficiencies. This system offers a scalable model for deploying real-time process monitoring across other thermally sensitive semiconductor operations.

6.0 RECOMMENDATIONS

To expand the impact of this system, the following are recommended: (1) MES Integration: Connect with Camstar MES for traceable, real-time thermal logging and event-triggered decision-making.

(2) AI Optimization: Implement machine learning to predict thermal anomalies and suggest optimal process adjustments.

(3) Scalability Study: Evaluate use in other test stages such as HTOL or biased soak to broaden implementation.

7.0 ACKNOWLEDGMENT

The author would like to thank the whole Test Engineering family. Special thanks to my Senior Engineer– Myra C. Bagadiong for the entire support to make this project possible.

8.0 REFERENCES

- [1] J. Bentley, Principles of Measurement Systems, 4th ed., Pearson Education, 2005.
- [2] R. Pallás-Areny and J. G. Webster, Sensors and Signal Conditioning, 2nd ed., Wiley-Interscience, 2001.
- [3] Omega Engineering, "Temperature Measurement Handbook," Omega, 2023.
- [4] Dataq Instruments, "DI-2008 Voltage and Thermocouple Data Acquisition System," 2024.

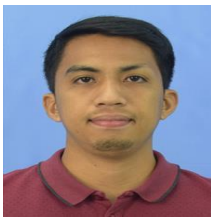
9.0 ABOUT THE AUTHORS



Aljun Arizala is currently employed as a Test Process Technician. His professional background includes several years of experience as a production operator and as a member of the quality assurance team, equipping him with a strong foundation in process improvement and manufacturing reliability.



Mark Lexter Elacion is currently employed as a Test Process Technician. He is responsible for addressing test process line issues and driving continuous process improvements to enhance efficiency and reliability in testing operations.



Jeffrey Guico is currently employed as a Test Equipment Technician, where he is responsible for providing technical support in line sustaining activities. His role involves maintaining test equipment functionality and troubleshooting hardware issues.