



DATA ACQUISITION IN SUPPORT OF RELIABILITY

FROM STRESS TESTING TO ENGINEERING DECISIONS



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1. INTRODUCTION



In the field of reliability engineering, accelerated stress tests such as Thermal Cycling (TC), Highly Accelerated Stress Testing (HAST), and Temperature Humidity Bias (THB) are only valuable if their effects on the test samples can be accurately measured. Without electrical readings and monitoring of the test conditions, stress testing amounts to blind aging: marginal units cannot be identified, failure onset cannot be determined, and subsequent failure analysis efforts lack clear direction.

Data acquisition therefore serves as the critical link between applied stress and engineering decision-making. It enables comparison of a device's condition before, during, and after testing, facilitates detection of parametric drift and intermittent failures under varying environmental conditions, and provides customers with fully traceable data.

This article presents an overview of the parameters monitored, the data acquisition tools deployed in the C2MI reliability laboratory, and the processing workflow that transforms raw measurements into actionable engineering information.



2. DATA ACQUISITION THROUGHOUT THE RELIABILITY TESTING CYCLE



A reliability test relies on two inseparable components: a stress condition that accelerates aging and a measurement method that captures its effects. Measurement ultimately defines failure. Without a measurable criterion, such as resistance exceeding a threshold, abnormal leakage current, or loss of continuity, it is impossible to distinguish a healthy unit from a marginal one. Test Vehicles (TVs) are specifically designed with this objective in mind: electrical daisy chains interconnect package features to make each section of the assembly observable.

Data acquisition is generally structured around three complementary stages:

- **Initial Readings (T0)** : Baseline measurements are taken before stress exposure to establish the reference value for each daisy chain or net. All subsequent readings are compared against this baseline. Resistance increases, for example, are evaluated relative to the initial condition rather than against an absolute threshold.
- **Readpoint Measurements** : Measurements are performed at predefined intervals, such as after 250, 500, or 1,000 thermal cycles. These checkpoints enable engineers to monitor progressive degradation across a population of devices and to remove a sample for failure analysis at the optimal time, while evidence of the failure mechanism remains intact.
- **In-Situ Monitoring** : Continuous monitoring during stress exposure, under electrical bias, complements periodic measurements. It is the only effective method for capturing intermittent failures, those that occur at elevated temperature and disappear upon cooling, and for accurately determining the time of failure initiation. In-situ monitoring is also essential for observing transient phenomena such as dendritic migration during moisture-related testing (HAST and THB), where a short circuit may appear and disappear within seconds. For leakage and short-circuit detection, absolute criteria are commonly used, such as a resistance threshold of 1 M Ω .

The chosen acquisition strategy depends on the failure mechanism under investigation, the required measurement resolution, and fixturing constraints. This decision subsequently drives instrumentation selection, chamber feedthrough configuration, sampling frequency, and the volume of data to be processed.

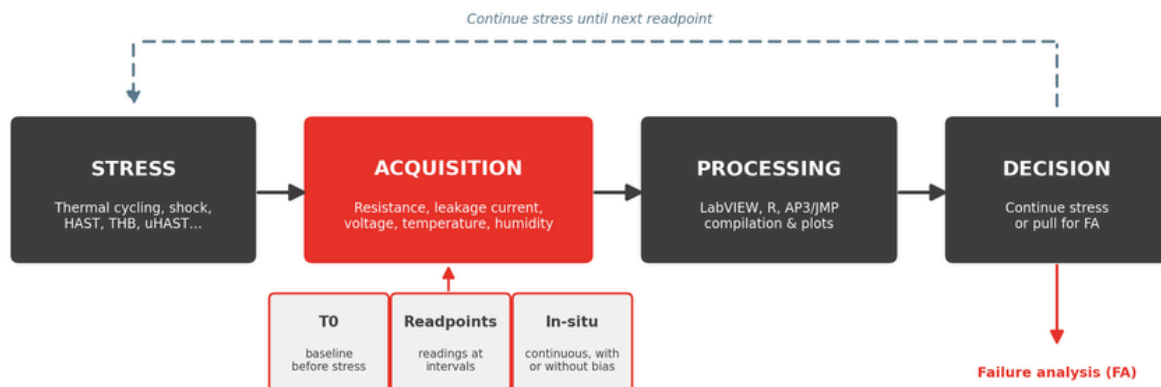


Figure 1: Reliability data acquisition workflow, from accelerated stress testing to engineering decision-making.

2. MEASURED PARAMETERS AND MEASUREMENT METHODS



Resistance Measurements: Two-Wire and Four-Wire Techniques

Resistance is the most commonly monitored parameter in reliability testing because it directly reflects interconnect health.

The two-wire method is the simplest approach. Current is sourced and voltage measured through the same pair of leads. The measured value therefore includes cable and contact resistance, often several hundred milliohms, which can mask small variations in the device under test. However, two-wire measurements remain fully adequate for detecting hard failures such as opens and shorts, where parasitic resistance has negligible impact on failure identification.

The four-wire, or Kelvin, method separates current sourcing and voltage sensing. One pair of leads forces current through the net while a second pair, carrying virtually no current, measures voltage directly across the structure under test (Figure 2). This configuration eliminates parasitic voltage drops and enables milliohm-level measurement accuracy. Such precision is critical in reliability studies: a solder joint undergoing fatigue during thermal cycling will often exhibit a gradual resistance increase of only a few milliohms to several ohms long before a complete open circuit develops. Four-wire measurements allow these early degradation signatures to be detected.

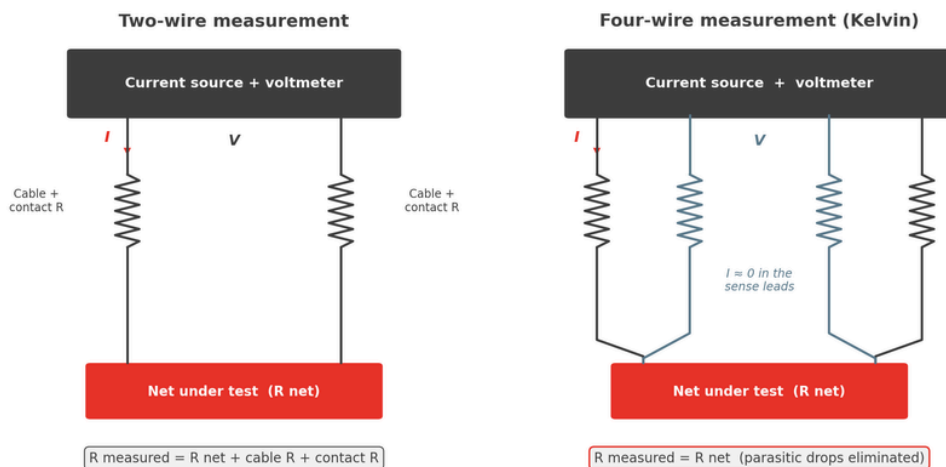


Figure 2: Comparison between two-wire and four-wire (Kelvin) resistance measurements.

Leakage Current, Current, and Voltage Measurements

Leakage current measurement is the natural complement to resistance monitoring. A voltage is applied across two nets intended to remain electrically isolated, and the resulting current, typically in the nanoampere-to-microampere range, is measured. An increase in leakage current indicates insulation degradation resulting from conductive contamination, moisture ingress, or dendritic growth between adjacent conductors. Leakage monitoring is therefore the preferred measurement for humidity-based stress tests such as HAST and THB.

Current consumption, whether DC or AC, can be measured directly by the acquisition instrument or indirectly using a precision shunt resistor when current levels exceed acquisition card capabilities. Voltage measurements are used not only to monitor power supplies but also to determine resistance indirectly. By forcing a known current through a net and measuring the resulting voltage drop, resistance can be calculated using Ohm's law: $R = V / I$.



Temperature and Humidity Monitoring

Temperature serves as the primary indicator of stress validity. Type-T thermocouples installed directly on test samples verify the actual temperature experienced by the device, which may differ significantly from the chamber setpoint, particularly when the sample is electrically biased and self-heating. Chamber temperature and humidity profiles are continuously recorded. Deviations of only a few degrees Celsius or a few percentage points of relative humidity can alter stress acceleration factors and, in extreme cases, invalidate weeks of testing. This requirement for continuous monitoring led to the implementation of a centralized chamber supervision system, discussed in the following section.

Figure 3 illustrates a practical example from the development of a thermal cycling profile for powered devices. Thermocouples installed on samples positioned at three chamber levels recorded temperatures slightly higher than ambient chamber air due to self-heating under bias while remaining within specification limits. Minor temperature variation was also observed as a function of chamber position.

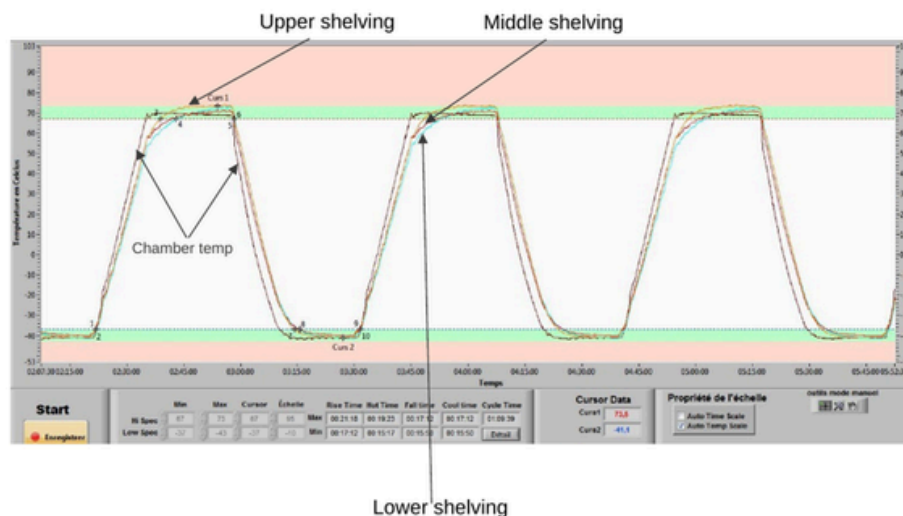


Figure 3: Thermal cycling profile development. Temperatures recorded on electrically biased devices located on three chamber shelves compared with chamber air temperature.

4. DATA ACQUISITION TOOLS IN THE LABORATORY



The C2MI reliability laboratory operates a comprehensive suite of acquisition systems ranging from chamber-level monitoring to measurements performed directly at individual BGA solder balls.

Centralized Chamber Monitoring. Temperature, humidity, and pressure profiles from all environmental chambers are consolidated into a central monitoring station accessible from a single consolidated view. Operators can instantly view chamber status, active test profiles, real-time process data, and alarm notifications indicating out-of-specification conditions. Continuous monitoring ensures both stress integrity and test condition traceability.

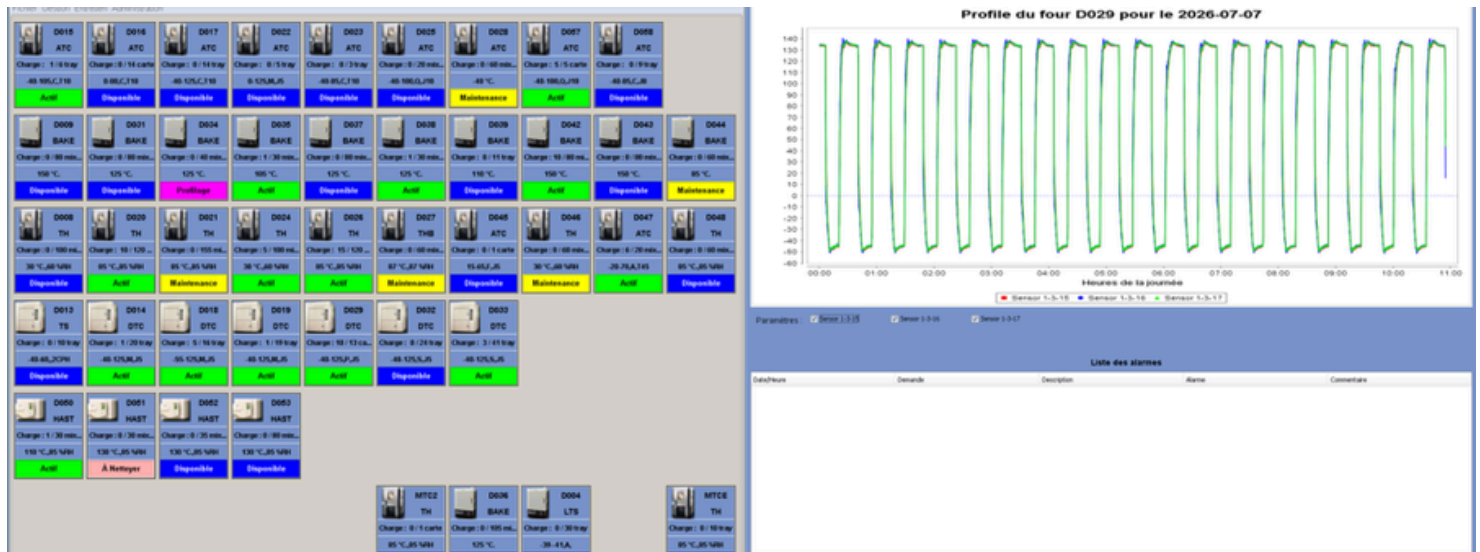
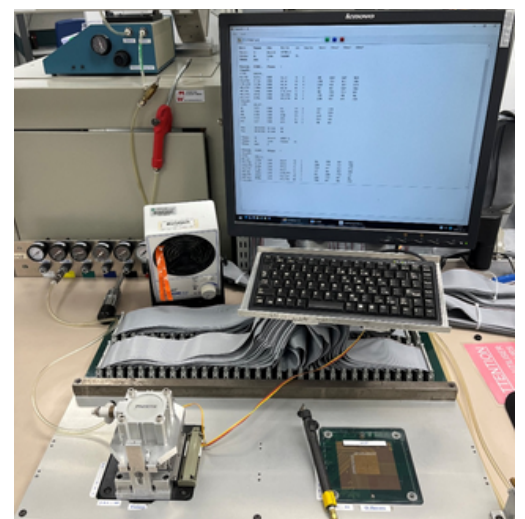


Figure 4: Floor control system displaying chamber status (left), furnace temperature profile, and active alarms (right).

PCB Net Verification System. A commercial test platform performs two-wire and four-wire continuity verification through board input/output connectors using programs customized for each test vehicle. The system is particularly effective for validating card attach integrity by rapidly identifying open and short circuits while also tracking resistance evolution during scheduled readpoints.

BGA-Level Measurements Using Pogo Pins. A custom-built fixture enables direct electrical access to individual nets. The system supports leakage current measurements, two-wire and four-wire resistance measurements, and voltage measurements under forced-current conditions. This flexible addressing capability allows engineers to target specific suspect interconnects, creating a direct link between electrical anomalies and subsequent failure analysis findings.

Figure 5: Laboratory acquisition setup — custom in-house fixture for pogo-pin readpoint measurements.





Acquisition Tower. For customized applications, multiplexed acquisition systems, such as the Agilent 34970A, combined with internally developed LabVIEW applications, are used to measure current, voltage, and temperature across dozens of channels simultaneously. These platforms support both in-situ chamber monitoring and complete system characterization activities.

5. FROM SIGNAL TO INFORMATION: DATA PROCESSING

Data collection is only half the task: An in-situ monitoring campaign involving dozens of channels over several hundred hours can easily generate CSV files containing millions of raw data points. In their native form, such datasets are impractical to interpret.

Internally developed scripts, particularly in R, automatically process and consolidate these data by: Segmenting operating modes; Calculating trends for each chain or channel; Generating summary visualizations. Figure 6 presents an example of a 500-hour in-situ monitoring campaign in which temperature, voltage, and current data are consolidated into a single view, enabling rapid identification of setpoint changes and thermal events. Automation also ensures systematic detection of criterion violations without relying on manual review of large datasets.

For advanced analysis, statistical tools such as AP3 (system designed internally) and JMP are used for distribution analysis, population comparisons, and report preparation. The final deliverable provides customers with fully traceable results, where every datapoint displayed in a graph can be traced back to its original measurement and associated stress conditions.

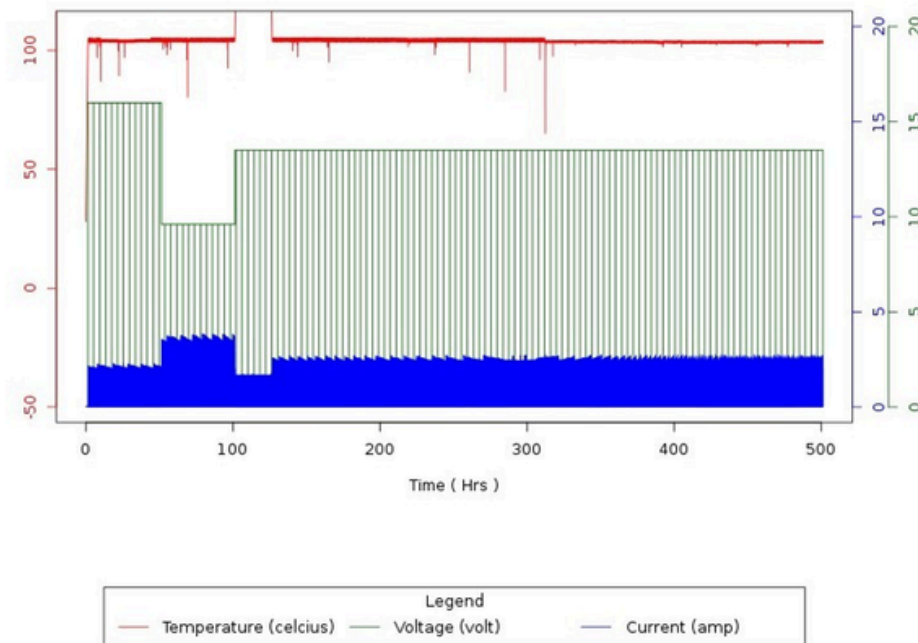


Figure 6: R-based compilation of 500 hours of in-situ monitoring, consolidating temperature, voltage, and current data into a single visualization.

6. CONCLUSION



Data acquisition is the thread that connects reliability stress testing to sound engineering decisions. Whether performed periodically through baseline and readpoint measurements or continuously through in-situ monitoring, it enables early detection of marginal units, guides failure analysis efforts, and supports the generation of fully traceable datasets.

C2MI provides both the expertise and execution capabilities required to develop custom data acquisition solutions, including stress instrumentation, in-situ monitoring systems, chamber supervision, and automated data processing. Our experts can design a tailored data acquisition strategy aligned with your product requirements, whether your technology is in development or already in production.

Contact our team to learn more.



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