AUTOSIR
Surface Insulation Resistance Testing System

GEN3 SYSTEMS
ENGINEERING RELIABILITY IN ELECTRONICS
The Auto-SIR represents the latest technology in automated precision Surface Insulation Resistance (SIR) testing. The system was developed by Gen3 Systems (formerly Concoat Systems) in collaboration with the world-renowned British, National Physical Laboratory (NPL).

It is currently used for SIR research and test method development by leading research and commercial laboratories around the world.

- Gen3 Systems actively co-operates with IEC, ISO, IPC, BSI and other official standards authorities to help maintain and develop measurement standards including SIR testing and long term field reliability materials and process characterisation protocols.
- The Auto-SIR performs SIR testing in accordance with all major international standards (above) via a comprehensive range of standard and optional features (see opposite).
Key features include:

- FMTA Automatic frequent monitoring
- Configurable from 1 up to 64, 128 or 256 sites (Auto-SIR 64, 128 and 256 units respectively)
- Standard programmable bias voltages of ±5V, ±10, ±50 V and ±100 V, plus non-standard voltages via an external power supply
- 1 MΩ current limiting resistors to preserve dendrite formations for subsequent failure analysis
- 3 to 500 V selectable measurement voltages
- Power supplies for higher bias and measurement voltages available
- Input and switching control for external power supply up to 300 V
- Accessories include: measurement cables
- CD-ROM instruction and system operation manual
- Options: Temperature humidity measuring probe with software

**AUTO-SIR** Windows® software is designed for repetitive SIR testing to all major test standards

- All SIR test parameters are fully selectable in the software
- Data logging test intervals are fully selectable as defined by the particular test specification in use
- Test can be made by entering number of sample or length of test time
- Standard test templates according to all international standards are part of the software
- User definable templates are easy to configure and re-use. Flexibility allows future test parameters to be defined
- Graph zoom function for easier viewing
- Select any 16 channels for instant data comparison
- Each test channel can be viewed selectively as a single graph. The individual status of each single channel can be printed at any stage of the test
- Selecting an individual plotted data point and right clicking will display the associated time and resistance
- The 32-bit software reads long file names so each data file can have a unique user name and is date stamped for easy retrieval
- All output data is in a delimited data file that can be exported to any spreadsheet software for further evaluation or analysis
- Optional temperature/humidity chamber monitoring – including SIR graphing

**NEW: PROCESS CHARACTERISATION TEST KIT COMPRISING:**

- Test vehicle Gerber file
- Full set of SIR dummy components

Example of completed IEC 61189-5 test vehicle
Basic Principles of SIR Testing

“SIR testing is a methodology used to evaluate electronic assembly materials and processes as one measure of reliability. The goal of SIR testing is to catch dangerous propensities for electrochemical failure mechanisms, such as unacceptable electrical leakage under humid conditions, corrosion or metal migration, before they can occur on produced assemblies.”

Douglas O Pauls: IPC Technical Activities Executive, Chairman of IPC Cleaning & Coating Committee & Senior Process Engineer, Rockwell Collins

Three factors need to be present for electrochemical failure to occur: electrical potential, moisture and an ionic residue. Electrochemical failure can best be visualised using the Venn diagram shown below. Increasing and decreasing these factors can be thought of as increasing and decreasing the diameter of the circles.

In SIR testing, temperature and humidity levels are artificially elevated to accelerate the moisture factor. A voltage is applied to provide a power source. If the test substrate has a low ionic content, then the measured SIR will remain ‘acceptable’. If the ionic content is high, such as from improperly cured solder resist or from flux residues, then ‘unacceptable’ leakage currents, corrosion and metal migration, or dendritic growth will occur. Each SIR test method, standard or specification defines what is ‘acceptable’ and ‘unacceptable’.

SIR testing is usually performed on industry standard test board coupons containing patterns, typically interdigitated combs, designed for the purpose. The insulation resistance of a test pattern is monitored at various intervals as temperature and humidity are varied. Monitored resistance levels may range from $10^6$ to $10^{14}$ Ω. Test specifications can call for several different types of test coupons and test conditions as illustrated in Table 1.
How test pattern, coupon & voltage affect SIR

TEST PATTERN AND COUPON
It is generally recognised that SIR data is dependent on the geometry and design of the SIR test pattern. Recent research by the NPL has shown that pattern geometry differences can cause up to a decade difference in measured results.

When running process evaluations, it is important to choose the same mix of materials in the test coupon and pattern as found in the hardware to be produced (e.g. laminate/mask/metal).

If the SIR test pattern incorporates component mounting pads, then it is critical that the components mounted on these pads have NO internal connections. Typical dummy components contain blown dies internal to the package and are unsuitable for SIR testing.

If SIR patterns are being designed, the ends of each conductor should be rounded to avoid sharp discontinuities where electromigration can initiate. In addition, a well designed test pattern will have guard/ground traces to completely isolate power lines from ground planes.

VOLTAGE GRADIENT (FIELD STRENGTH)
The voltage gradient is the applied voltage level divided by the spacing between the conductors, usually expressed in volts per mm (V/mm). Most test methods specify the voltage to be applied, but this voltage may be applied to patterns with different conductor spaces, leading to multiple voltage gradients on the same test substrate.

An example is the IPC-B-36 test board in which a 50 V bias is applied to the test pattern. Some patterns have a 0.15 mm spacing (333 V/mm) and others have a 0.64 mm spacing (78 V/mm). Some test methods also specify reversing voltage polarity between bias and measurement phases.

Recent research has indicated an optimum voltage gradient of 25 V/mm, with no reverse polarity and lower bias/measure voltages (5 V) for SIR testing. This research has also found that SIR testing does not precisely obey Ohm's Law and it is therefore important that any new characterisation testing take this issue into account.

All graphs courtesy of NPL and the EU Collaborative SIR Research Programme.
Test intervals

Most current SIR test methods evolved from manual measurement techniques and so have infrequent measurement intervals, such as 24 hours. It has been shown in many cases that electromechanical failures can occur frequently between measurement intervals, often leaving no trace that a failure event has occurred.

Therefore, the more frequent the measurement, the greater the probability of catching failures. In addition, if the measurement pathway contains current limiting resistors (e.g. 1 MΩ), a dendrite is usually preserved for detection in post-test visual examination. The Auto-SIR can be programmed with measurement intervals as low as 1 minute and as great as 7 days.

Test environment

SIR levels generally decrease as temperature and humidity increase due to the formation of monolayers of moisture on the test surface. The addition of ionic material to the moisture, either from the substrate or surface residues, will further reduce SIR levels. Temperature and humidity levels vary greatly between different specifications, dependent upon the test goals.

Some specifications simulate end-use conditions, others accelerate electromechanical failure mechanisms, such as leakage currents, corrosion, and metal migration. The selection of the test environment is a critical factor in materials/process evaluations. Research shows that lower test temperatures (e.g. 40 °C) are a more stringent test for easily volatilised residues such as low residue fluxes.

For process characterisation (such as the IEC 61189-5 specification) the test temperature and humidity should reflect typical anticipated operating conditions for the end product.

How the AUTO-SIR works

The Gen3 Systems Auto-SIR system represents a dramatic improvement over existing SIR test alternatives, and its shielded precision electronics allows state-of-the-art accuracy resistance measurements to be made up to $10^{14}$ Ω.

One Auto-SIR chassis can hold between 1 to 16 measurement cards and can monitor up to 256 x 2-point test patterns or 78 x 5-point test patterns, or 32 x 9-point test patterns at selectable intervals from minutes to days. Each channel is current limited (1 MΩ), ensuring that dendrites are preserved for failure analysis. The frequent monitoring capability provides a full picture of the electrochemical reactions taking place on a circuit assembly, and provides early trend analysis enabling tests to be curtailed, thus saving considerable test time and money.

A unique feature of the Auto-SIR system is Frequent Monitoring Trend Analysis (FMTA). This methodology is used to examine SIR trends over time, primarily to detect in-situ dendritic growth at each ‘wet process’ manufacturing stage. Gen3 Systems has also developed an extended software package to make measurements within the environmental chamber. This optional independent temperature-humidity monitoring records the environmental conditions next to the coupon under test, as the data is gathered, for more accurate data analysis.

The Auto-SIR instrument is delivered complete with:

- Auto-SIR 64 instrument (expandable in increments of 64 channels to a maximum of 256)
- Operating software
- ALL interconnecting cables (screened halogen-free)
- Optional test racks simplify SIR testing and reduce test time and test costs.

IMPORTANT NOTE: Test racks are coupon specific

All cabling in the Auto-SIR is PTFE insulated with wires shielded from EMI. The design of the data acquisition cards minimises channel-to-channel leakage. This is important because the extremely low levels of current involved in SIR measurement means any stray currents (including electromagnetic noise or leakage between wire insulations) can significantly affect measurement accuracy.
Test Standards & Methods

Table 1

<table>
<thead>
<tr>
<th>STANDARD</th>
<th>IEC 61189-5</th>
<th>ISO 9455-17</th>
<th>J-STD-001C</th>
<th>IPC-TM-650</th>
<th>IPC-TM-650 2.6.3</th>
<th>Bellcore 2.6.3.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature/ Humidity</td>
<td>40°C/93% RH (No Clean)</td>
<td>85°C/85% RH</td>
<td>85°C/85% RH</td>
<td>Class 1 - 35/90°C at 98% RH for 4 days static Class 2 - 50/90°C at 98% RH for 7 days static Class 3 - 25/60°C at 90/98% RH for 7 days cycling</td>
<td>85°C/85% RH</td>
<td>35°C/85% RH</td>
</tr>
<tr>
<td>Test Duration</td>
<td>Not less than 72 Hours</td>
<td>168 Hours</td>
<td>168 Hours</td>
<td>168 Hours</td>
<td>168 Hours</td>
<td>120 Hours</td>
</tr>
<tr>
<td>Measurement Frequency</td>
<td>Measured at 20min intervals</td>
<td>Measured twice a day</td>
<td>Measured at 24hrs, 94hrs and 168hrs</td>
<td>Measured at 24hrs, 94hrs and 168hrs</td>
<td>Measured at 24hrs, 94hrs and 168hrs</td>
<td>Measured at 25hrs and 120hrs</td>
</tr>
<tr>
<td>Test Voltage Bias</td>
<td>5V +5V</td>
<td>50V +50V</td>
<td>100V -50V</td>
<td>100V -50V</td>
<td>100V -50V</td>
<td>100V -50V</td>
</tr>
<tr>
<td>Test Coupon</td>
<td>IPC-B-52</td>
<td>IPC-B-24</td>
<td>IPC-B-36</td>
<td>IPC-B-25A</td>
<td>IPC-B-24</td>
<td>IPC-B-25A</td>
</tr>
</tbody>
</table>

The Table above illustrates how greatly the requirements of the most common SIR test standards vary in terms of duration of the test, the applied voltages, the measurement frequency, the temperature and humidity levels used and the acceptance criteria.

Due to the extremely low currents involved, SIR testing has several critical factors in reaching accurate conclusions. It is recommended that reference be made to ‘IPC-9201 The SIR Handbook’ for further detailed guidance on the subject.

Gen3’s technical personnel have taken an active and continuing part in the development of modern ISO, IEC and ANSI/IPC SIR test methods, standards and specifications.

PROCESS CHARACTERISATION TESTING

When running process evaluations, the selection of the materials for SIR testing has a major impact on the end result. If a materials characterisation test is being performed, such as flux evaluations per ANSI J-STD-004, then the laminate and metalisation is fixed (FR4 and bare copper, respectively) in order to provide a consistent evaluation platform.

If SIR testing is used as part of an engineering process evaluation, however, it is important to choose the same mix of materials in the test coupon and pattern as found in the hardware to be produced (e.g. laminate, solder resist, metalisation, flux, paste, adhesive, coating, etc.). Gen3 Systems can also supply a process characterisation test kit.

The Auto-SIR was developed in conjunction with industry technical experts, as well as major research and commercial test laboratories, to accurately accommodate all current SIR test methods, as well as anticipate future SIR test method evolution.

TECHNICAL SPECIFICATION

| TEST VOLTAGE: | 5V, 10V, 50V, 100V – OR WITH EXTERNAL P.S. UP TO 500V |
| BIAS VOLTAGE: | 5V, 10V, 50V, 100V, –50V, –100V – OR WITH EXTERNAL P.S. UP TO 500V |
| MEASUREMENT RANGE: | 10^6 Ω TO 10^14 Ω |
| SYSTEM TOLERANCE AS PER IEC 61189-5 (I.E. TOTAL MEASUREMENT SYSTEM): | UP TO 10^10 Ω ± 5 % |
| FROM 10^10 Ω TO 10^11 Ω ± 10 % |
| ABOVE 10^11 Ω ± 20 % |
| LOGGING FREQUENCY: | (2 SECONDS/CHANNEL) AUTO-SIR 64 APPROXIMATELY 2 MINUTES |
| TEST CABLES: | SCREENED HALOGEN-FREE |
| POWER SUPPLY: | 240V, 50 Hz or 110V, 60 Hz |
| SOFTWARE | AUTO-SIR FMTA TESTING (STANDARD) |
| | BELLCORE TESTING (OPTIONAL) |
| | IPC B25A TESTING (OPTIONAL) |
| CONTROL INTERFACE: | USB |
| COMPUTER REQUIREMENTS (MINIMUM): | 1GHz Processor, 512MB RAM, 5GB HARD DRIVE, 1USB Port, Windows XP or Windows 7 (32bit or 64 bit) |
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