Setting up the Testing Capability for IPC-9151 Printed Board Process Capability, Quality and Relative Reliability ($PCQR^2$) Benchmark Test Standard and Database

Abstract

IPC (industry association defining most PCB and PCBA standards) has recently released a standard called IPC-9151 Printed Board Process Capability, Quality and Relative Reliability ($PCQR^2$) Benchmark Test Standard and Database. Two consultants of HKPC, were invited as members of the IPC D-36 committee that started to draft this standard in year 2000. In 2002, HKPC was granted an ITF project by the Innovation and Technology Commission of the Hong Kong SAR Government to build up support capabilities to this new standard. Two new large test systems, namely, Panel Test System and Highly Accelerated Thermal Shock (HATS) System, were installed in HKPC. Another test system called the Portable Test System was also purchased. The establishment of IPC-$PCQR^2$ service in HKPC will save the local PCB manufacturers' time and cost in shipping the test panels to USA and they can get feedback and advice from HKPC consultants directly. This paper gives the reader an overview of the standard and its applications. The set-up is unique in Asia, HKPC will help Asia Pacific PCB manufacturers to evaluate their technology capabilities basing on data. The strategy of the set-up has established HKPC as a technology test service centre in Asia to meet new PCB standards. Since PCB miniaturization will grow continuously, this new capability will benefit the industry and the EMS manufacturing significantly in the long term.

An Overview of the IPC-9151 Standard

The IPC-9151 Standard is a document defining a Process Capability, Quality, and Relative Reliability ($PCQR^2$) Benchmark Test Standard and Database subscription system for the evaluation of PCB manufacturing processes and the mechanism that allows the comparative data to be accessible industry wide. This is in accordance with The National Technology Roadmap for Electronic Interconnections 2000/2001 published by IPC, which states that ‘‘For a company to efficiently manage its supply chain it must identify the capability of its suppliers and make certain that their capability for manufacturing a product is consistent with the needs of the customer.’’

Database Components

The most important components of the database are as follows:

§ Supplier Comparison-Detailed data comparing each supplier’s capability, quality, and relative reliability (Figure 1)

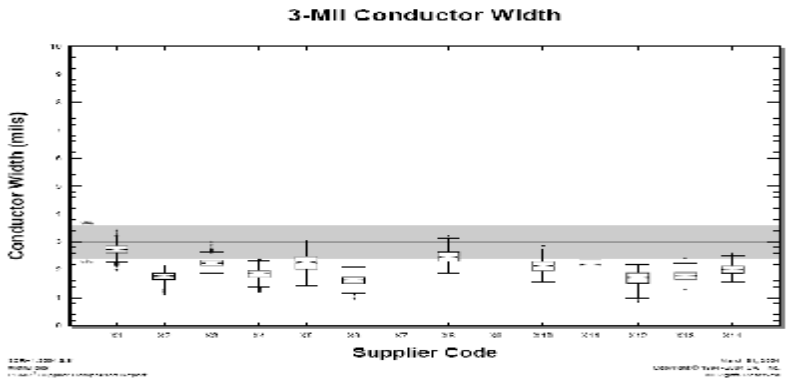


Figure 1 Supplier comparison graph

§ Industry Statistics-Statistical data on the industry's capability, quality and relative reliability (Figure 2)

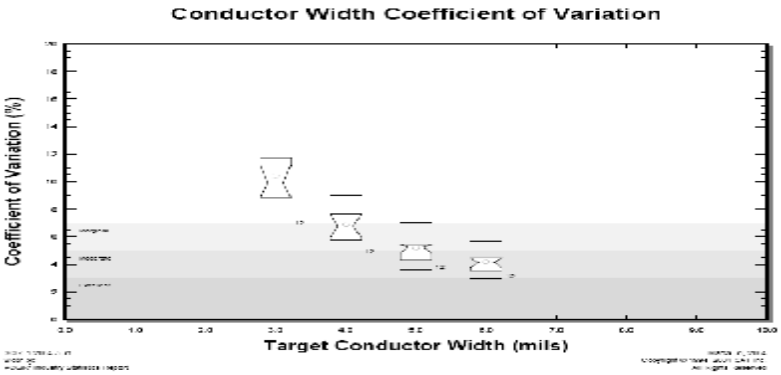


Figure 2 Industry statistics graph

§ Analysis Reports-Detailed data on each supplier's process (Figure 3)

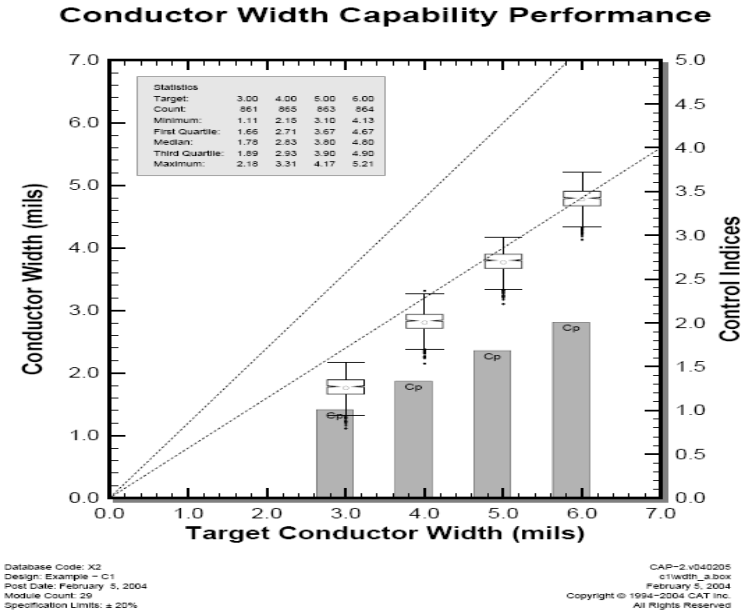


Figure 3 Supplier performance graph

Process Capability Panels

The photo of a process capability panel containing specialized test patterns designed to reproduce the features commonly found in printed circuit boards is shown in Figure 4. For simplicity, process capability panels are also called test panels or just panels in the following sections.

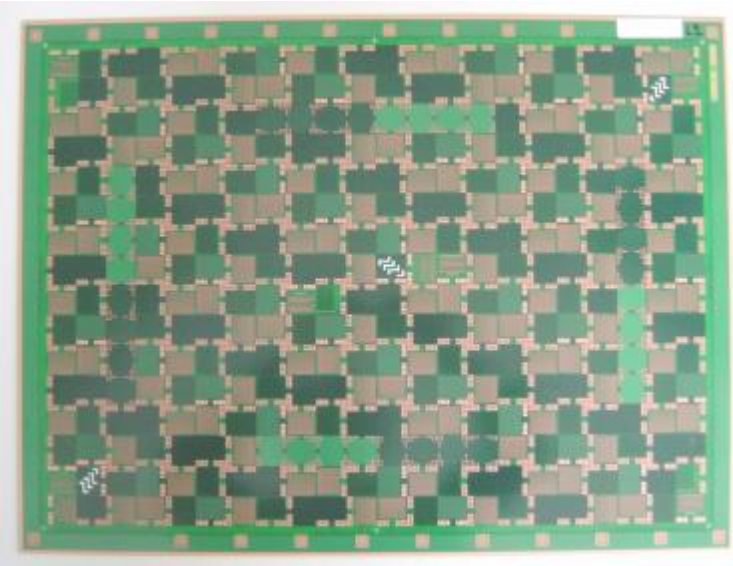
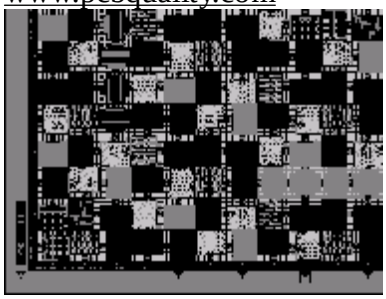


Figure 4 Photo of a process capability panel (Rev C)

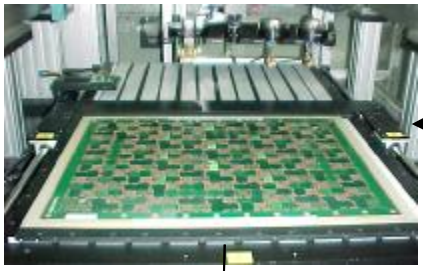
The general process flow of selecting a design and subsequent steps to extract raw capability, quality and reliability data is shown in Figure 5.

Select one Process Capability Panel design and download the CAD files from www.pcbquality.com



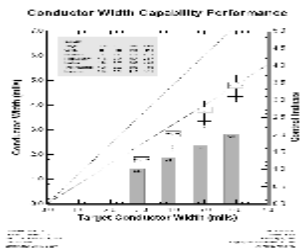
PCB supplier produces the 30-Rev C or 15-Rev D panels in at least 3 lots

Test center measures the panel parameters



PCB supplier delivers the panels

I. Analysis report delivered to database subscriber and PCB supplier (if subscriber initiated the submission), or,
II. Analysis report delivered to PCB fabricator only (self-submission by a PCB supplier)



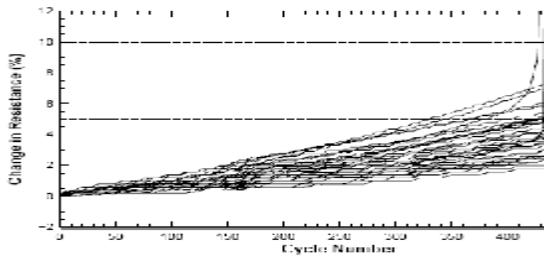
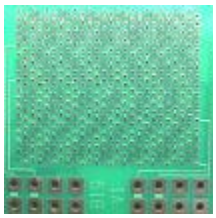


Figure 5 Process flow of a panel submission

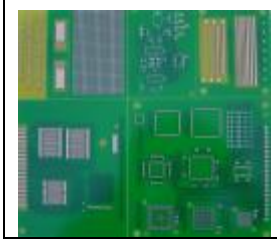
PCQR^2 Relative Reliability

Via modules have two functions in the PCQR^2 methodology. One function is explained in the preceding section. The other function is to evaluate relative reliability under the following conditions:



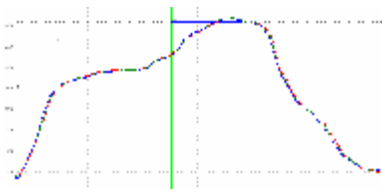
Assembly simulation (preconditioning): 6 passes, eutectic or lead-free solder profile	Highly Accelerated Thermal Shock (HATS): Air-to-air (-40 to +145C), 500 cycles or until 10% resistance change

Importance in terms of failure cost impact is illustrated in Figure 6.

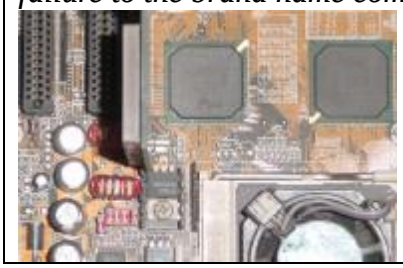


Quality of PCB is relatively easy to be monitored while latent defects due to the manufacturing process or wrong selection of materials may be difficult to be detected. *Cost of failure in a PCB fabrication plant is moderately low.*

Peak reflow temperature of 220 or 225 degree C may lead to cracks in the improperly formed copper barrels of via holes. *Cost of failure to the PCB assembly plant is moderately high.*



After certain cycles of temperature changes while unit is powered on and powered off, weak copper barrels in via holes will crack first. *Cost of early field failure to the brand name company is very high.*



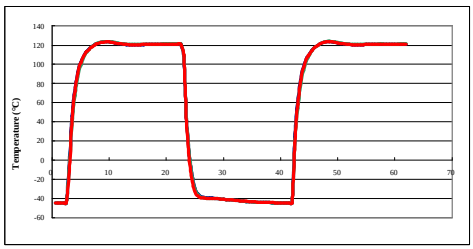


Figure 6 Importance of reliability in terms of failure cost impact

Via Registration Modules

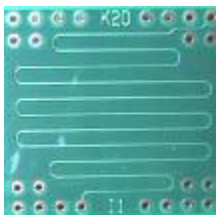
The purpose of this module is to evaluate the probability of different degrees of mis-registration. Breakout happens when poor registration between the hole and the pad on a printed circuit board to the degree that the hole is not within the area of the pad.

Soldermask Registration Modules

The function of soldermask is to avoid soldering onto unwanted conductor surface but soldermask must be accurately located so that quality of solder will not be adversely affected. The purpose of this module is to evaluate the probability of different degrees of mis-registration. .

Impedance Modules

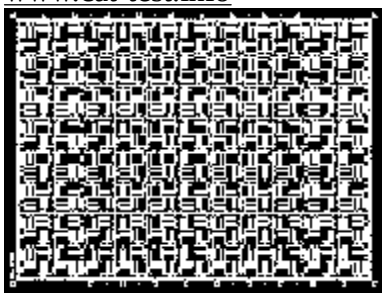
Signal integrity is an important consideration when designing a PCB. Impedance control capability of the PCB fabrication process must meet the design tolerance requirement. Otherwise the electronic system cannot function properly due to distortion of signals.



Process Improvement Directions Using IPC-9151

A PCB fabricator can first measure their overall process performance by using one PCQR^2 panel design, followed by using special test patterns and Portable Test System for individual process improvement. By following the process flow shown below , an etching process can be improved to a higher degree of uniformity (e.g. adjust the spray pressure) by using the conductor/space test panels. They are test panels filled with conductor/space modules only.

PCB fabricator selects one conductor/space panel design and download the CAD files from www.pcbquality.com or www.cat-test.info

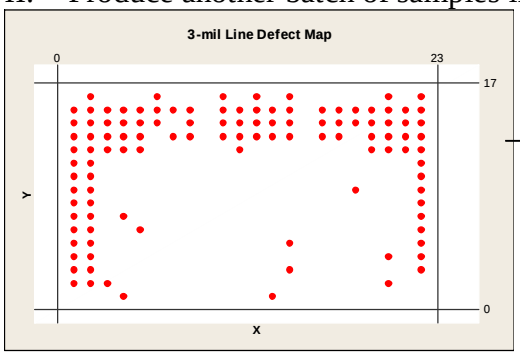


Note: 18 x 24 inch standard panel size

PCB supplier produces the appropriate number of panels e.g. 10

Use the Portable System to measure the panel parameters

I. Based on the measured data to adjust the process parameters
II. Produce another batch of samples if necessary



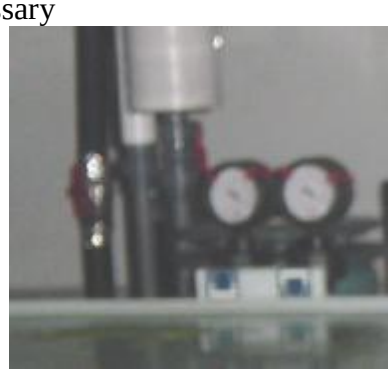
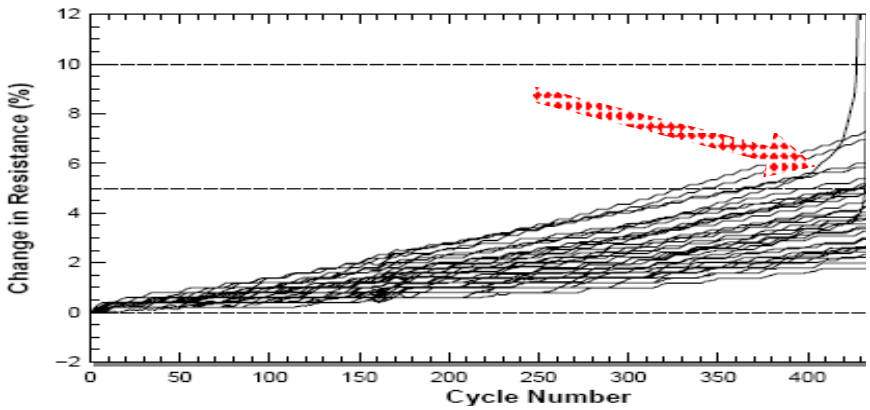


Figure 7 Process flow of an manufacturing process improvement project

Via Hole Reliability Analysis Graphs

The IPC-9151A standard defines a failure at change of resistance greater than 10%. The graph in Figure 8 shows that the resistance of one via net increases rapidly at cycle 420. The crack is seen to have formed at approximately the 400th temperature cycle. The crack formation is due to the difference in coefficient of thermal expansion of copper and epoxy.



Resistance of one via net increases rapidly at approximately the 420th temperature cycle

Figure 8 Graph showing change of resistance of via nets versus number of -40 degree C and 145 degree C temperature cycles

Equipments in HKPC

Testing facilities

There are two large testing systems installed in HKPC for performing PCQR and related tests. They are the Panel Test System and the Highly Accelerated Thermal Shock (HATS) Test System.

Panel Test System

This test system is equipped with one precision resistance measurement probe, one TDR measurement single-end probe and one TDR measurement differential probe. The Panel Test System is shown in Figure 9 and the 3 probes are shown in Figure 11-12. The test system is controlled by a computer with friendly and easy to use human interface. The impedance measurements are performed with the Tektronix TDS8000 High Speed Digital Sampling Oscilloscope (Figure 10).

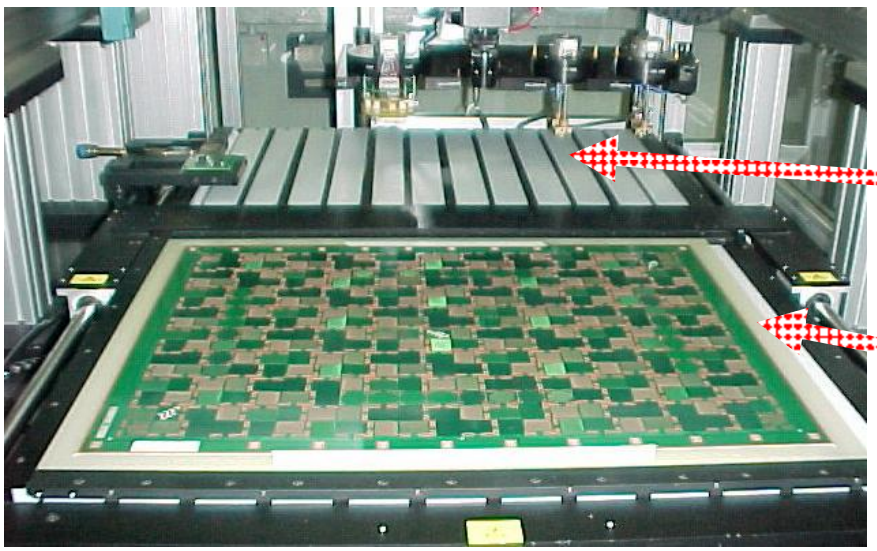


Figure 9 Panel Test System

Figure 10 Tektronix TDS8000 High Speed Digital Sampling Oscilloscope

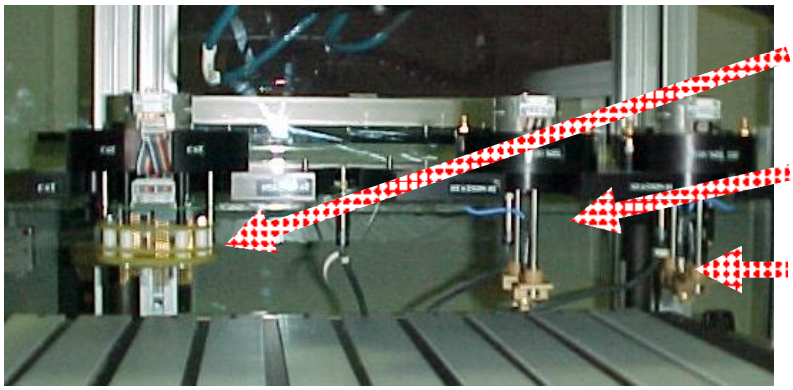


Figure 11 Three Probing heads for PCQR testing

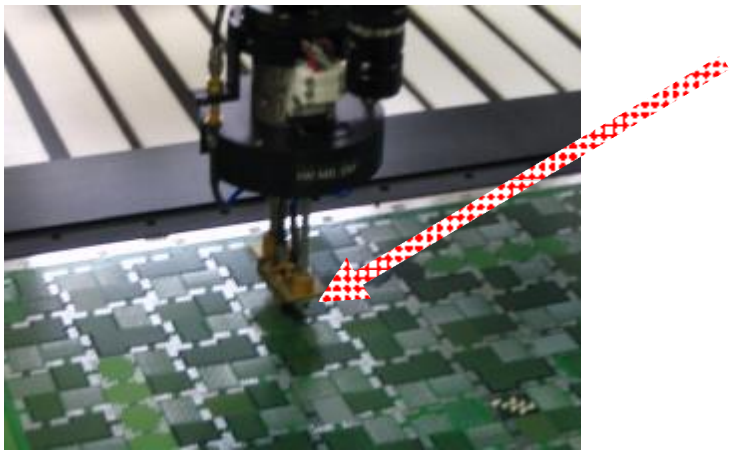


Figure 12 Differential probe probing the pads on the impedance module

Highly Accelerated Thermal Shock (HATS) Test System

The purpose of this test system is stress the via modules under low and high temperature conditions (Figure 13-14). The equipment capability is -55 degree

C to 160 degree C although the IPC-9151A standard only requires the temperature swing from -40 degree C to 145 degree C. This test system also has a precision resistance measurement system so that the system can be set to alert the operator when the resistance change of a particular module is over 10%. The IPC-9151A standard only requires to test the via module up to 500 cycles or 10% in resistance value. The graph in Figure 8 shows that the resistance value of a module exceeded 10% at approximately 420 cycles.

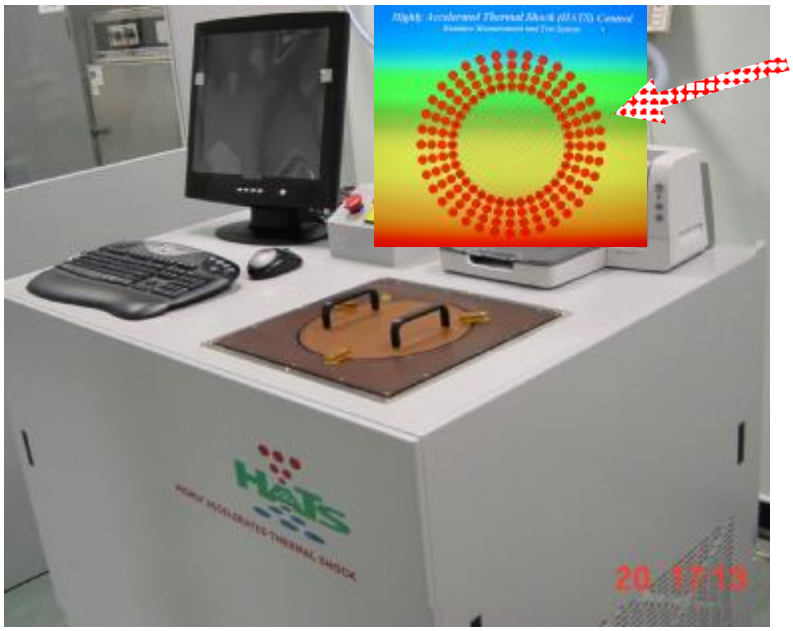


Figure 13 Highly Accelerated Thermal Shock (HATS) Test System

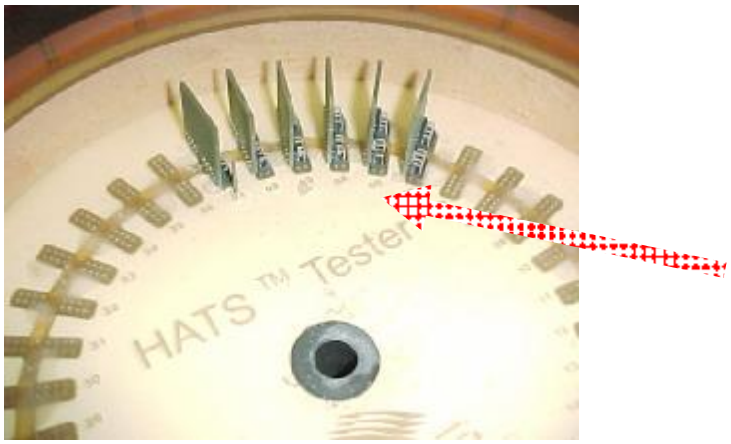


Figure 14 Testing chamber of the Highly Accelerated Thermal Shock (HATS) Test System