IPC's Process Capability, Quality and Relative Reliability (PCQR²) Database

"Standardized PCB Benchmarking Data is Just a Mouse Click Away"

By David Bergman and David Wolf

Increasing technology requirements and shrinking margins mean that your printed circuit board (PCB) supply base can impact your product's quality, reliability, delivery, and profitability more than ever before. Qualifying board suppliers has always been based on instinct, relationships, and limited data. How confident are you in your qualification process?

Site visits are important, but expensive, and generally result in your suppliers showing you their best face. Microsections are interesting but result in extremely limited data. Supplier audits can result in mountains of paperwork, but is there real value to this?

You can maximize your efforts and access critical information quickly and easily by subscribing to the IPC Process Capability, Quality and Relative Reliability (PCQR²) Database. PCQR² was developed in September 2000 when IPC formed the D-36 Subcommittee to establish a family of test patterns, a testing protocol, and a database that details the test results. The Subcommittee's charter is to maintain a family of process capability panel designs using the testing and data analysis techniques developed by **Conductor Analysis Technologies, Inc.**; maintain a standard (IPC-9151) within the IPC family of process control documents; and maintain a database of PCB suppliers' capabilities. Access to the database will allow you to:

- Statistically benchmark your board suppliers' capabilities
- Perform intelligent sourcing
- Select new suppliers
- Ensure design to manufacturability
- Establish realistic design rules

This extensive supply chain management resource – developed for designers, purchasers, assemblers and manufacturers of PCBs – is based on industry developed test patterns, proven test methods and statistical analysis techniques. The program provides quantitative data used to compare and contrast the capability, quality and reliability demonstrated by PCB suppliers. The PCQR² database provides a detailed snapshot of supplier fabrication capabilities in five different areas:

- Conductor and space – Conductor and space yield, and conductor width and height control
- Via registration – Probability of breakout
- Via formation – Via yield, resistance control, and cycles to failure
- Soldermask registration – Probability of encroachment
- Controlled impedance – Impedance control

PCQR² Frequently Asked Questions

What is gained from the database that can't be obtained independently?

The database provides statistical results from a worldwide printed circuit board supply base, with direct comparison among the suppliers. There is no other source for this information. It is based on demonstrated capabilities rather than surveys.

What statistical process capability, quality, and reliability data are reported in the database?

- Conductor and space: conductor and space yield, and conductor width and height control
- Via registration: probability of breakout
- Via formation: via yield, resistance control, and cycles to failure
- Soldermask registration: probability of encroachment
- Controlled impedance: impedance control

What does the thermal stress testing consist of?

Selected via daisy chain coupons from each submission are exposed to six solder reflow cycles and 500 air-to-air thermal shock cycles of -40 C to +145 C.

What solder reflow profile is used as part of the thermal stress testing?

Three solder reflow profiles are available, and one is selected for each submission based on the product type being evaluated. The profiles available are:

- A: Eutectic profile with a peak temperature of 215 C
- B: Lead free profile with a peak temperature of 245 C
- C: Lead free profile with a peak temperature of 260 C

What is included as part of a subscription?

Subscribers receive access to the complete database for a period of twelve months. The database includes summarized process capability, quality, and reliability data for each supplier, supplier comparison and industry statistics charts, and a detailed analysis report on each submission. In addition, subscribers may request submissions from their current and potential supply base, and may request the identity of suppliers within the database.

Can a subscriber share the information in the database with customers, suppliers, or other business partners?

No, the subscription license agreement prohibits sharing of the database information with anyone outside of the subscribing company.

Can a supplier share the information in their analysis report with customers, suppliers, or other business partners?

No, the copyright prohibits sharing the analysis report information unless the customer, supplier or business partner is a current subscriber to the database.

Is there a way to obtain a trial subscription?

There is no trial subscription. However, there is an option to submit test panels on behalf of a supplier by paying the submission fee. Under this scenario, both the sponsor and supplier will receive the analysis report and comparative industry statistics for the submission.

How long does data remain active in the database?

The data from each submission remains active in the database for two years.

How often should a supplier submit test panels to the database?

The production of printed circuits involves a complex set of interrelated processes, any

Original Equipment Manufacturers (OEMs) and electronics manufacturing services (EMS) companies benefit from the PCQR² benchmark database by having the added ability to improve board design for manufacturability, lower sourcing costs, raise reliability and on-time delivery. Subscribers are also able to collect quantifiable, statistically significant data on supplier process capabilities; find, screen and select PCB manufacturers based on technology requirements; tailor design for manufacturability (DFM) guidelines; and obtain quantitative data for roadmaps. Conversely, participating PCB manufacturers receive access to potential customers seeking suppliers of excellent quality and detailed quantitative data on their company's manufacturing process capabilities with direct comparisons to other manufacturing sites. Participants can also lower costs by producing one standardized set of test panels, rather than expensive customized panels for a variety of current and potential customers.

Since its inception, the PCQR² program has undergone substantial changes and additions.

Subscribers

Currently there are 15 subscribers to the database:

- **BAE Systems North America**
- **Delphi Corporation**
- **Honeywell International Inc.**
- **IBM Corporation**
- **Infineon Technologies AG**
- **Intel Corporation**
- **Lockheed Martin Corporation**
- **National Aeronautics and Space Administration (NASA)**
- **Naval Surface Warfare Center - Crane Division**
- **Raytheon Corporation**
- **Reptron Manufacturing Services**
- **Rockwell Collins Inc.**
- **Sandia National Laboratories**
- **Teradyne Inc.**
- **Tyco Electronics Printed Circuit Group**

The major business sectors represented by the subscribers include automotive electronics, desktop and mobile computers, low-, mid, and high-level servers, test instruments and defense and aerospace applications. The subscribers provide significant direction for the design of the test patterns, test methods, and results reported by the database.

Suppliers

Thirty-one different PCB facilities have submitted 40 sets of panels during the first 9 months of 2005. Since the inception of the database, there have been a total of 234 database submissions from 94 PCB facilities. The majority of submissions have come from the Asia-Pacific region (66 percent), with many from North America (26 percent) and Europe (7 percent), and some from South America (1 percent).

Suppliers receive detailed reports that document the results of their submission and compare their submission to the industry. The standardized test panel designs provide quantitative data on process capability, quality, and reliability that allows suppliers to accurately state their capabilities and provide a direct comparison to competitors. The

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one of which can change over time. Supplier sites should submit test panels every six to nine months to keep their data current.

Are suppliers identified within the database?

No, each submission is given a unique and anonymous code. This submission code is known only by the supplier who submitted the test panels and by the subscriber who sponsored the submission.

Who pays the submission fee for each set of test panels?

If the submission is requested by a database subscriber, the submission fee is covered by the subscriber's subscription. If a submission is made directly by a supplier, the supplier must pay the submission fee.

How are the test pattern designs obtained?

The test pattern designs and instructions are available at www.pcbquality.com.

What laminate materials can be used for the test panels?

The material selection should be based on the product being evaluated, and the decision should be made by both the subscriber and the supplier.

Can suppliers become subscribers to the database?

Yes, suppliers can become subscribers to the database. Being a subscriber is a cost-effective way for a supplier to benchmark its processes and facilities with respect to a global supply base.

How can a supplier participate in the database other than through a subscription?

Suppliers can submit test panels in response to a request from a database subscriber, or they may submit test panels on their own by paying a submission fee. Suppliers receive a detailed analysis report on each submission and comparative industry statistics.

How will a supplier who has submitted test panels be contacted by interested subscribers?

Subscribers may request the identity of submissions in the database. Once a request has been made, the corresponding supplier is notified. It is then the responsibility of the supplier to contact the requesting subscriber.

Can a supplier resubmit new test panels after an initial submission?

Yes, a supplier can submit a new set of test panels if desired. The data from the initial submission will remain in the database, and the new submission will be assigned a new submission code.

What happens to the test panels after the testing has been completed?

The test panels are the property of the supplier, and if requested will be returned. Suppliers are encouraged to evaluate their panels to determine the cause of defects.

Can the test patterns be used for experiments or development projects?

No, the designs are to be used exclusively to support the database. If experiments or development projects are required, please contact Conductor Analysis Technologies, Inc. at www.cat-test.info.

Is technical support available as part of a subscription?

Yes, technical support is available by phone to subscribers and their suppliers. Additionally, on-site technical support on a consulting basis is available from Conductor Analysis Technologies, Inc. to subscribers and suppliers.

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reports pinpoint strengths and weaknesses in their processes, providing direction for allocating resources aimed at process improvements. Further, the reports provide data for establishing and maintaining road maps and design guidelines.

Process Capability Panel Designs

The family of test patterns underwent its fourth revision in March 2005, consolidating 23 designs down to 16 designs. The design matrix for the latest revision, which is summarized in Table 1, includes four types of designs:

- Rigid board
- Via board
- Package substrate
- Rigid-flex

The table lists the number of layers, design name, and elements within each design – indicated by a '√' or '•' in the table.

Testing

Four-wire precision resistance measurements are collected from conductor/space and via daisy-chain patterns, single-ended and differential TDR measurements from impedance patterns, and continuity measurements from registration patterns. After initial testing is completed, representative via coupons of each via type are extracted from the panels for reliability testing. These coupons are subjected to one of three unique assembly simulation profiles depending on the application:

- 215 C max. (eutectic tin-lead)
- 245 C max. (lead free)
- 260 C max. (lead free)

After six assembly simulation cycles, the coupons are subjected to 500 highly accelerated thermal shock (HATS™) cycles from -40 C to +145 C, while sampling the precision resistance of each daisy chain every 15 seconds.

Database

Flexibility and power have been added to the database, which consists of an interactive **Microsoft®** Excel workbook that contains results from all database submissions over the past two years. The subscriber may filter the submissions by design, material, and process criteria – thereby comparing submissions that are relevant to their application.

The IPC PCQR² program has evolved and grown since its inception in 2000, providing cost-effective, market-critical data to members of the electronics industry leading to products with improved quality and reliability. For more information, visit www.pcbquality.com or attend the D-36, Printed Board Process Capability, Quality and Relative Reliability Benchmark Test Subcommittee meeting on Monday, October 24, at IPCWorks® in Las Vegas (www.ipc.org/IPCWorks).

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Table 1: PCQR² Revision D Design Matrix

# Layers	Design Name	CS	Via Registration						Via Formation									SR	Impedance	
			TV	1D	2D	3D	BB	SC	TV	BD	1D	2D	3D	BB	SV	BC	SC		SE	D
18" x 24" Rigid Board Designs																				
2	IPC-2R-D	√							√									√		
4	IPC-4R-D	√	√	√					√		√							√	√	√
6	IPC-6R-D	√	√	√					√		√							√	√	√
10	IPC-10R-D	√	√	√					√		√							√	√	√
14	IPC-14R-D	√	√	√					√		√							√	√	√
18	IPC-18R-D	√	√	√					√		√							√	√	√
18" x 24" Via Board Designs																				
10	IPC-10VA-D	•	√	√	√	√			√		√	√	√							
10	IPC-10VB-D	•	√	√	√			√	√		√	√					√			
14	IPC-14VA-D	•	√	√	√	√			√	√	√	√	√			√				
14	IPC-14VB-D	•	√	√	√			√	√	√	√	√				√	√			
24	IPC-24VA-D	•	√	√	√	√			√	√	√	√	√			√				
24	IPC-24VB-D	•	√	√	√			√	√	√	√	√					√			
24	IPC-24VC-D	•	√	√	√			√	√	√	√	√					√			
18" x 16" Package Substrate Designs																				
4	IPC-4P-D	√	√	√					√		√					√		√	√	√
6	IPC-6P-D	√	√	√			√	√	√		√			√	√	√	√	√	√	√
18" x 12" Rigid Flex Design																				
12	IPC-12RF-D	√	√						√									√	√	√

KEY:
CS Conductor / Space
TV Through Via
BD Back Drill Via
1D 1-Deep Blind Via
2D 2-Deep Blind Via
3D 3-Deep Blind Via
BB Blind Buried Via
SV Stacked Via
BC Buried Core Via
SC Subcomposite Via
SR Soldermask Registration
SE Single-ended Impedance
D Differential Impedance
• Limited data for conductor height only