How can a user of printed circuit boards know that they have received what they specified? Recently, a field failure called into question some of the traditional means of insuring product performance when the failure was traced back to a printed circuit board. During analysis of the product failure, an inconsistency was found between the quality report supplied by the fabricator and the root cause revealed by laboratory analysis.

**Most Accurate Measurement**

An important factor here is that the cross section analysis of a plated hole is the most accurate way to measure the copper thickness. However, the derived measurement is only valid if the cross section is precisely in the center of the plated hole. As the cross section location moves from the geometric center, the copper measurement will increase, leading to a false prediction of the actual copper thickness.

The PCB in question was produced to meet the IPC-6012C-2010 Class 2 performance specification. The fabricator had supplied a quality report and mounted cross sections (“pucks”) with the lot. The quality report indicated that the minimum copper thickness for Class 2 had been met. The supplied puck, when measured with an inverted stage metallurgical microscope, yielded a measurement that was 21 micro inches above the required minimum thickness of 709µ-in. Why is this measurement of copper plating significant, and does 21µ-in. really make a difference?

During the 1970s, the US auto industry devoted many research hours seeking definitive rules that could be used to predict the performance of printed circuit boards in the unforgiving environment of an automobile engine compartment. Much of that work has evolved to become industry guidelines even though the origins are becoming lost in history. The one element that was determined to be absolutely essential to product performance was the thickness of the through-hole copper plating. The reason is that in all epoxy-glass base printed circuit boards, there is a significant mismatch between the coefficient of thermal expansion (CTE) of the epoxy resin and the copper through-hole plating.

For this reason, wide changes in the ambient temperature (without consideration of the I 2R heating within the PCB) create stress in the plated barrel as the epoxy-glass expands at a higher rate than the through-hole copper. Extensive testing with 0.062-in. (1.57mm) thick FR4 (Flame retardant epoxy resin) has evolved into an industry expectation that a plated hole, with an aspect ratio of less than 6:1, is able to withstand 1000 temperature cycles from -55 to +125°C. (See IPC-TM-650 section 2.6.7.2B and IPC 4101C/26.) Without oversimplifying a complex set of interrelated factors, it needs to be understood that the thickness of the copper plating is one of several variables in achieving 1000 thermal cycles. However experimentation has proven this one variable to be the most significant.

**Increased Aspect Ratio**

As the aspect ratio (board thickness: finished hole size) increases, plating throwing power ([hole copper plating/surface plating] x 100) decreases. When the throwing power drops below 85 percent, it results in the through-hole plating resembling a “dog-bone” (copper plating in the hole is thick at the upper and lower ends).

*Continued on next page*
Buying PC Boards...
Continued from previous page

Experts will have significant

performance vs Copper thick-

dors. Two failed the 709µ-in. mini-

tors, including the vendor of the

boards, with no knowledge of the test,

achieved. As there was no way to prove or dis-

gup of the high end or high volume

product performance. This predictive

capability has long been the domain of

mal cycles by an equivalent percent-


d not to provide a reli-

mal PCB board

requirements may not be

environments, such as an

Just meeting IPC PC board

In the case of the product failure analy-

two questions were raised. First, was copper plating at the IPC Class 2

minimum a factor in the failure, and

second, did the design require a higher

number of thermal cycles than the rule

of thumb was predicting? The analysis determined that the root

cause was the copper plating, but

that the design expectations did not violate the rule of thumb for thermal

cycles. How could this be? The reason

was that the copper plating in the thru-holes when measured on the

failed PCB fell significantly below 709µ-in., not the 730µ-in. predicted

by the supplier “puck”.

This revelation called into ques-

tion the ability of the supplied quali-

data to predict the performance of

the manufacturing lot. One obvious

explanation is that the lot was mixed
(two or more manufacturing lots interwoven and shipped as one).

This explanation, while plausible, is

far too “convenient”. Therefore, the mixed lot explanation was set aside as

there was no way to prove or dis-

prove the assertion with only one failed PCB.

A correlating experiment was

devised to look at the product per-

formance by a number of PCB ven-

dors, including the vendor of the

failed unit. By using multiple ven-

dors, with no knowledge of the test,

one could exclude a mixed lot theory

if the data from multiple vendors

exhibited a lack of correlation between quality data and actual

board within the lot.

The test concept was to use 10 vendors and evaluate the supplied

boards within the lot.

If the data from multiple vendors

could exclude a mixed lot theory,

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The test concept was to use 10 vendors and evaluate the supplied

boards within the lot.

If the data from multiple vendors

could exclude a mixed lot theory,

did the design require a high-
mum when pucks were actually

measured, and the vendor in ques-
tion was over by 11µ-in. The two fail-

ures were not “radical”. Both failed by

19µ-in.

A very interesting statistic

evoluted from the quality data. Of the

10 vendors, the largest margin of

“excess copper” over the 709µ-
in, was only 121µ-in. None of the ven-
dors approached the automotive

standard of 1000µ-in.

DOE Test Method

Five (5) PC boards from each
vendor were examined, with three
cross sections from each board. When
this data was evaluated (test methodology described in the test
report), three of the 10 vendors failed the
minimum of 709µ-in., and the
vendor in question was exactly 700µ- in. Only one vendor failed both the
puck measurements and the sample
product measurements.

The test results infer that there
is vendor-to-vendor variation in their
correlation of quality data and actual
product performance. Further, the results suggest it is not prudent to rely
solely on supplier quality data to
determine the performance of critical
products.

Product Assurance Testing

An emerging model in the PCB
industry is to provide Product
Assurance Testing (Individual Lot
Validation) to enhance the reliability of
product quality while reducing the
risk of a field failure and the result-
ing impact on the end user or cus-
tomer. This model is a natural evolu-
tion of the venerable PPAP (Pro-
duction Part Approval Process) for
the auto industry or the PPAP (First
Piece Approval Process) for general
industry. The model allows the high-
er mix/lower volume consumer of
PCBs to use quality data to predict
product performance. This predictive
capability has long been the domain
of only the high end or high volume
users of Printed Circuit Boards.

Contact: DIVSYS International,
LLC, 8110 Zionsville Road,
Indianapolis, IN 46268
☎ 317-405-9427 fax:317-663-0729
Web: www.divsys.com

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