Printed Circuit Board Quality Assurance

Bhanu Sood
Reliability and Risk Assessment Branch
Quality and Reliability Division
Outline

• Introduction to PCBs
• PCB requirements and quality verification
• Risk assessment
• Example
What is a PCB? Classification of PCBs

• Printed circuit boards are the baseline in electronic packaging – they are the interconnection medium upon which electronic components are formed into electronic systems.
  – PCB materials are glass reinforced PCBs, organic polyimide reinforced with woven glass.

• Classified on the basis of
  – Dielectrics used
  – Reinforcement
  – Circuit type
  – Component types
  – Board construction
  – Design complexity
Typical Polyimide Laminate Supply Chain

Glass Raw Materials (Silica, Limestone, Clay, Boric Acid)

Glass Fiber Production (Formation, Coating/Binders, Yarns)

E-Glass Plies/Fabrics

Polyimide Raw Materials (Petrochemical Derivatives)

Flame Retardants Fillers and Additives

Prepregs/Cores

Consumables (e.g., etchants, cleaners)

Copper Foil

Solder Mask/Silk Screen

Oxide Coatings

Design and Coupon Data

Drill Bits

ENIG/HASL/ENEPIG/OSP/other Plating

Assembly Processes

Printed Circuit Board Panels w/Coupons
PCB Quality

- NASA uses IPC standards (e.g., IPC-6012, 6013)
- Inspection, testing and requirements include:
  - External visual examination
  - Microsection evaluation
  - Electrical continuity and isolation
  - Solderability
  - Surface finish evaluation
  - Cleanliness
Significance of Board Requirements

- The requirements and coupons are a “front door”.
- Examples:
  - Internal Annular Ring:
    - Egregious violations indicate there may have been a serious problem in development of the board.
    - Minor violations don’t likely indicate any risk at all (IPC-6012DS)
  - Negative etchback:
    - With modern cleaning processes and flight experience can result in higher reliability with negative etchback.
  - Wicking of copper:
    - Requirements are conservative based on broad statistics.
    - A basic analysis of the board layout can indicate directly if there is risk or not, regardless of requirements violations.
Microsectioning

• Suppliers perform microsectioning and inspect per specifications.
• Secondary GSFC independent microsection analysis yielded 20-30% inspection rejects, caused by:
  – Screening escapes:
    • Test sample quality not consistent
    • Supplier microsection process
  – Requirement interpretations
  – Requirements flow-down issues
    • Alternative specifications (MIL, ECSS)
    • Buying heritage and off-the-shelf designs
Impact of Non-conformances

- Bare boards cost $$ and build schedules – expensive!!
- But failures are even more expensive!
- Test sample nonconformance is not the same as PCB failure.
- Risk-based decisions are used for disposition of non-conformances.
- Non-conformances may have little to no impact per application.
- Began to explore origins and merit of requirements (more later).
Risk Assessment

- Traceable PCB test coupons (designed per specs. such as IPC-2221B) are submitted to GSFC or to a GSFC-assessed laboratory.
- Reports that indicate nonconformance are dispositioned by risk assessment performed prior to refabricating or populating the PCB.
  - If risk assessment indicates elevated risk due to the nonconformance, then use is dispositioned by MRB.
- More than a 100 PCB lots assessed for risk since 2014, 95% dispositioned as UAI, significant cost and schedule savings.
- Risk assessment process eliminates waste and saves money and schedule, lowers overall risk for the project.
- The process reduces the need for repeated attempts to refabricate.
Example: PTH Copper Wrap Thickness Requirement

Per IPC-6012D for through-holes:

<table>
<thead>
<tr>
<th>Class</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>AABUS</td>
</tr>
<tr>
<td>Class 2</td>
<td>5 µm [197 µin]</td>
</tr>
<tr>
<td>Class 3 &amp; 3/A</td>
<td>12 µm [472 µin]</td>
</tr>
</tbody>
</table>

AABUS = As Agreed Between User and Supplier

• Thermal cycle stresses act on interfaces, outer layers experience the greatest stress.
• Reason: materials selection and geometry.

Note: Cap plating, if required, over filled holes is not considered in wrap copper thickness measurements.
PTH Copper Wrap Thickness: Disposition

- Mission had populated and integrated board with zero wrap, wrap planarization can cause 0.3mil or more variance in panel; manufacturers must target more wrap.
  - Wrap cannot be achieved at required thickness for designs with tight line-width spacing and/or with multiple lamination/plating steps
- Requirement was introduced to IPC with minimal data
  - Reliability reported to be better with wrap vs. butt joint
  - Half of barrel plating thought to be “good enough”
  - Higher quality limit used as safety margin against manufacturing variation during planarization
- GSFC Studies: Determined the impact of copper wrap plating thickness on PCB reliability, as characterized by thermal cycles to failure.
  - Able to determine acceptability of wrap defect based on reliability testing and analysis in context of mission environment and duration.
  - IPC voted to change the requirement (amendment in Rev. D and revisions in Rev. E).
PCB Assurance: Summary

- PCB assurance actives are informed by risk in context of the Project.
- Lessons are being applied across Projects for continuous improvements.
- Newer component technologies, smaller/high pitch devices: tighter and more demanding PCB designs:
  - Identifying new research areas.
  - New materials, designs, structures and test methods.
Thank you!

Bhanu Sood
Commodity Risk Assessment Engineer
Code 371 – Reliability and Risk Assessment Branch
NASA Goddard Space Flight Center
Phone: (301) 286-5584