### PRINTED WIRING BOARD (PWB)
#### GENERAL REQUIREMENTS

The printed wiring board (PWB) is an essential part of a total electronic circuit packaging system. The design requirements of the PWB must accommodate the various components required to achieve product functionality, while meeting packaging and other product design requirements.

Boards shall be clean and damage-free, with sharply defined conductive patterns. Plated-through holes (PTH) and vias are properly located, are clean and unfilled, and exhibit smooth and uniform plating. Electrical termination areas are bright and shiny. Solder mask exhibits proper registration.

#### PREFERRED
- **GOLD / PRECIOUS METAL CONTACTS**
  - Contact surfaces are clean and bright, with a uniform and smooth finish.
  - Best Workmanship Practice

- **INTERFACIAL CONNECTIONS (VIAS)**
  - **DOUBLE-SIDED PWBs**
    - Vias in double-sided PWBs require the use of filler wire (Z-wire) for support if the PWB coupon has not been evaluated by construction analysis (micro-section).
    - NASA-STD-8739.3 [11.2.4.a]

#### ACCEPTABLE
- **EPOXY / SOLDER FILLED VIAS / PTH**
  - Vias and plated-through holes, not intended for lead insertion, may be plugged by epoxy resin or solder, if documented on the engineering drawings.
  - Best Workmanship Practice

#### UNACCEPTABLE
- **INSUFFICIENT ANNULAR RING**
  - The lower hole is improperly located, causing the annular ring dimension to be less than minimum requirements.
  - Best Workmanship Practice

- **CRAZING**
  - Crazing (whitish, discrete spots or crosses below the laminate surface) which does not bridge uncommon conductors is acceptable.
  - NASA-STD-8739.2 [12.8.2.c.3]

- **TENTED VIAS / PTH**
  - Vias and plated-through holes not intended for lead insertion may be tented by solder mask, if documented on the engineering documentation.
  - Best Workmanship Practice

---

**NASA WORKMANSHIP STANDARDS**

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

**JOHNSON SPACE CENTER**

**HOUSTON, TEXAS USA 77058**

<table>
<thead>
<tr>
<th>Released</th>
<th>Revision:</th>
<th>Revision Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>04.05.2002</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Book:</th>
<th>Section:</th>
<th>Page:</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5.01</td>
<td>1</td>
</tr>
</tbody>
</table>

---

**PRINTED WIRING BOARD (PWB)
GENERAL REQUIREMENTS (cont.)**

- **ACCEPTABLE ANNULAR RING**
  - The hole is not centered in the land, however it is acceptable providing the minimum annular ring requirement is not violated.
  - Best Workmanship Practice

- **UNACCEPTABLE Crazing**
  - Crazing which bridges uncommon conductors is unacceptable.
  - NASA-STD-8739.2 [12.8.2.c.3]
**PREFERRED INTERFACIAL CONNECTIONS (VIAS) MULTI-LAYER PWBs**

Vias in multi-layer PWBs do not require the use of filler wire (Z-wire), nor shall they be solder-filled. No dedicated effort shall be made to remove solder in unused holes.

NASA-STD-8739.3 [ 11.2.4.b ]

**PREFERRED ETCHED LEGENDS / MARKINGS**

Legends / markings are sharply defined, of uniform size and density, correct alignment and polarity, and meet minimum electrical spacing requirements. Markings do not touch or cross solderable surfaces.

**BEST WORKMANSHIP PRACTICE**

**PREFERRED LABELS**

Labels shall exhibit a flat, smooth profile, legible graphics, proper placement, and adhesion. Labels shall be non-conductive, and shall not be placed over components, exposed circuit traces, vias, or solder terminations.

**BEST WORKMANSHIP PRACTICE**

**ACCEPTABLE DISCOLORED CONDUCTORS**

Slight dulling of clean metallic surfaces is acceptable, provided the surface conductivity or solderability is not affected.

**NASA WORKMANSHIP STANDARDS**

[Table with NASA standards and definitions]
### Printed Wiring Board (PWB) General Requirements (cont.)

#### Unacceptable Laminate Scratches
Scratches that expose glass fiber are an indication of improper process control and/or handling.
- [NASA-STD-8739.2](#) [8.7.4.c], [12.8.2.c.6]

#### Acceptable Laminate Scratches
Scratches, scrapes, gouges, nicks, and/or cuts to the laminate that do not expose glass fiber or reduce electrical spacing are acceptable.
- [NASA-STD-8739.2](#) [8.7.4.c], [12.8.2.c.6]

#### Unacceptable Laminate Voids
Laminate voids located less than 0.003 inch (0.080 mm) from the periphery of a plated-through hole, and sized greater than 0.003 inch (0.080 mm) in any dimension, are not allowed.
- [NASA-STD-8739.2](#) [12.8.2.c.10]
- [NASA-STD-8739.3](#) [13.6.2.c.10]

#### Acceptable Laminate Voids
Laminate voids located a minimum of 0.003 inch (0.080 mm) from the periphery of a plated-through hole, and sized less than 0.003 inch (0.080 mm) in any dimension, are allowable.
- [Best Workmanship Practice](#)

#### Unacceptable Weave Textures
Weave exposure reduces the dielectric properties between conductive patterns to less than the minimum electrical clearance.
- [NASA-STD-8739.2](#) [12.8.2.c.3]

#### Acceptable Weave Texture
Weave texture is a visual condition in which a weave pattern is apparent, but where the glass cloth is completely covered by resin and not exposed.
- [Best Workmanship Practice](#)

#### Unacceptable Plating
Irregular or skipped plating is an indicator of improper process control, and/or contamination.
- [NASA-STD-8739.2](#) [12.8.2.c.4]
- [NASA-STD-8739.3](#) [13.6.2.c.4]

#### Acceptable Plating
Plating is uniform and smooth. Luster may vary from bright to slightly dull. Minor scratches, scuffing, and solder on non-contact areas of fingers are allowable.
- [Best Workmanship Practice](#)

#### Unacceptable Blistering
Blistering between any of the laminate layers, or between the laminate and the metallization, is not allowed.
- [NASA-STD-8739.2](#) [12.8.2.c.10]
- [NASA-STD-8739.3](#) [13.6.2.c.10]

#### Acceptable Blistering
Blistering between any of the laminate layers, or between the laminate and the metallization, is allowable.
- [Best Workmanship Practice](#)

#### Unacceptable Bridging
Bridging of conductive surfaces is an indication of improper process control.
- [NASA-STD-8739.2](#) [12.8.2.c.4]
- [NASA-STD-8739.3](#) [13.6.2.c.4]

#### Acceptable Bridging
Bridging of conductive surfaces is allowable.
- [Best Workmanship Practice](#)

#### Unacceptable Contamination
Contamination is a reliability concern.
- [NASA-STD-8739.2](#) [12.8.2.b.9]

#### Acceptable Contamination
Contamination is allowable.
- [Best Workmanship Practice](#)

---

**NASA Workmanship Standards**

<table>
<thead>
<tr>
<th>National Aeronautics and Space Administration</th>
<th>Released: 04.05.2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johnson Space CenterHouston, Texas USA 77058</td>
<td>Revision: 5.01</td>
</tr>
<tr>
<td>Book: 5</td>
<td>Revision Date:</td>
</tr>
<tr>
<td>Section: 5.01</td>
<td>Page: 5</td>
</tr>
</tbody>
</table>

---

**NASA Workmanship Standards**

<table>
<thead>
<tr>
<th>National Aeronautics and Space Administration</th>
<th>Released: 04.05.2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johnson Space CenterHouston, Texas USA 77058</td>
<td>Revision: 5.01</td>
</tr>
<tr>
<td>Book: 5</td>
<td>Revision Date:</td>
</tr>
<tr>
<td>Section: 5.01</td>
<td>Page: 7</td>
</tr>
</tbody>
</table>
UNACCEPTABLE CONTAMINATED PLATING
Plating is not uniform, smooth, bright, and/or shiny. Solder or other contamination on the contact area shall be cause for rejection.
Best Workmanship Practice

UNACCEPTABLE CORROSION
Corrosion is a reliability concern.
NASA-STD-8739.2 [ 7.4.1.d ]

ACCEPTABLE MEASLING
Measling (whitish, discrete spots or crosses) below the laminate surface that do not bridge uncommon conductors is acceptable.
NASA-STD-8739.2 [ 12.8.2.c.3 ]

UNACCEPTABLE MEASLING
Measling (whitish, discrete spots or crosses below the laminate surface) which bridges uncommon conductors is unacceptable.
NASA-STD-8739.2 [ 12.8.2.c.3 ]

UNACCEPTABLE CRACKED / RINGED BARREL
Cracks or ringing in the barrel are cause for rejection.
Best Workmanship Practice

UNACCEPTABLE CUT / DAMAGED PATTERN
Repaired or damaged printed wiring conductor pattern shall be cause for rejection.
NASA-STD-8739.2 [ 12.8.2.c.9 ]
NASA-STD-8739.3 [ 13.6.2.6.9 ]

ACCEPTABLE SMOOTH TOOL IMPRESSION MARKS
Scratches, scrapes, gouges, nicks, and / or cuts to the printed wiring pattern that do not expose base metal or reduce cross-sectional area are acceptable.
NASA-STD-8739.2 [ 12.8.2.c.5 ]

UNACCEPTABLE SCRATCHES (PRINTED WIRING)
Scratches that expose base metal are an indication of improper process control and/or handling.
NASA-STD-8739.2 [ 12.8.2.c.5 ]

UNACCEPTABLE DEMETALLIZATION / LEACHING
Boards exhibiting leaching or loss of metallization shall be rejected.
Best Workmanship Practice

UNACCEPTABLE DISCOLORATION
Contamination or improper drying typically causes discoloration of the laminate or solder mask in the patterns depicted. Re-cleaning / demoisturizing may correct this problem, provided no other damage is apparent.
Best Workmanship Practice

ACCEPTABLE SOLDER MASK
Minor waves, ripples, or wrinkling which do not reduce the coating below minimum thickness requirements, isolated bubbles or voids, which do not bridge conductive patterns or reduce electrical spacing requirements.
Best Workmanship Practice

UNACCEPTABLE SOLDER MASK DEFECTS
Solder mask tackiness, cracking, flaking, or separation from the substrate or conductors.
NASA-STD-8739.2 [ 12.8.2.e.8 ]
NASA-STD-8739.3 [ 13.6.2.e.8 ]

NASA WORKMANSHIP STANDARDS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JOHNSON SPACE CENTER
HOUSTON, TEXAS USA 77058

Released: 04.05.2002
Revision: 5
Page: 8
UNACCEPTABLE EDGE DELAMINATION
Edge delamination is an indicator of improper tooling, process control, or handling.
NASA-STD-8739.2 [12.8.2.c.7]

UNACCEPTABLE EDGE PROJECTIONS
Edge projections that reduce electrical separation below minimum requirements are rejectable.
Best Workmanship Practice

UNACCEPTABLE EXCESSIVE BOW / TWIST
Excessive bow or twist may inhibit proper mounting and may result in mechanical interference or shorting to adjacent assemblies or chassis.
Best Workmanship Practice

UNACCEPTABLE EXPOSED / PROTRUDING GLASS FIBERS
Exposed glass fiber in the laminate indicates a process control problem and is a long-term reliability concern.
NASA-STD-8739.2 [12.8.2.c.6]

UNACCEPTABLE ROUGH / UNEVEN EDGES (LAMINATE)
Edges which are rough or uneven present a handling, or sharp edge / protrusion hazard. Additionally, the presence of a rough or uneven edge may increase the potential for delamination of multi-layer boards.
Best Workmanship Practice

UNACCEPTABLE HALO EFFECT
A lightened area around a hole or via, typically induced by mechanical stress. Haloing which bridges uncommon conductors is unacceptable.
NASA-STD-8739.2 [12.8.2.c.3]

UNACCEPTABLE IMPROPER HOLE LOCATION
The improper location of holes (i.e.: component lead, via, mounting, etc.) is caused by misregistration during the drilling process.
Best Workmanship Practice

UNACCEPTABLE REDUCED CROSS-SECTIONAL AREA
Conductors that exhibit reductions in cross-sectional area are incapable of carrying the designed current load, and are susceptible to reduced reliability.
Best Workmanship Practice

UNACCEPTABLE REPAIRED CONDUCTOR PATTERN
Reparis to damaged printed wiring conductor pattern shall only be made after authorization, and by approved process.
NASA-STD-8739.2 [12.8.2.c.9]

UNACCEPTABLE REPOIRED CONDUCTOR PATTERN
NASA-STD-8739.3 [13.6.2.c.9]

UNACCEPTABLE SOLDER SPLATTER / WEBBING
Solder splatter and webbing is typically caused by moisture contamination or improper laminate bake-out, and is a reliability and short-circuit concern.
NASA-STD-8739.2 [12.8.2.c.4]

UNACCEPTABLE SOLDER MASK MISREGISTRATION
Solder mask misregistration violating minimum annular ring requirements. Presence of mask material in plated-through holes designated to be soldered.
Best Workmanship Practice

UNACCEPTABLE UNDER-ETCH
Under-etch is an indicator of improper process control / improper chemistry during etching. Under-etch can result in bridging between traces, resulting in short circuits.
Best Workmanship Practice

NASA WORKMANSHIP STANDARDS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JOHNSON SPACE CENTER HOUSTON, TEXAS USA 77098
Released: 04.05.2002
Book: 5 Section: 5.01 Page: 9

NASA WORKMANSHIP STANDARDS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JOHNSON SPACE CENTER HOUSTON, TEXAS USA 77098
Released: 04.05.2002
Book: 5 Section: 5.01 Page: 11
UNACCEPTABLE
PINK RING
Pink ring is caused by a thinning of the oxide coating on the copper layer in the through-hole / inner-layer interface zone, and is considered an indicator of a process control problem.
Best Workmanship Practice

UNACCEPTABLE
LAMINATE CRACKS
Cracks in the laminate are cause for rejection.
NASA-STD-8739.2 [ 12.8.2.c.6 ]

UNACCEPTABLE
LAYER DELAMINATION
Delamination between any of the laminate layers, or between the laminate and the metallization, is not allowed.
NASA-STD-8739.2 [ 12.8.2.c.7 ]

UNACCEPTABLE
NON-WETTING
Tin, tin/lead reflowed or solder coated surfaces, exhibiting non-wetting on any conductive surface where a solder connection will be required shall be rejected.
Best Workmanship Practice

UNACCEPTABLE
OVER-ETCH
Conductors that are over-etched are incapable of carrying the designed current load, and are susceptible to reduced reliability.
Best Workmanship Practice

NASA WORKMANSHIP STANDARDS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JOHNSON SPACE CENTER
HOUSTON, TEXAS USA 77568

PRINTED WIRING BOARD (PWB)
GENERAL REQUIREMENTS (cont.)

PRINTED WIRING BOARD (PWB)
GENERAL REQUIREMENTS (cont.)

PRINTED WIRING BOARD (PWB)
GENERAL REQUIREMENTS (cont.)

PRINTED WIRING BOARD (PWB)
GENERAL REQUIREMENTS (cont.)

THIS PAGE IS INTENTIONALLY BLANK.