



## Product/Process Change Notice - PCN 24\_0004 Rev. -

Analog Devices, Inc. One Analog Way, Wilmington, MA 01887, USA

This notice is to inform you of a change that will be made to certain ADI products (see Appendix A) that you may have purchased in the last 2 years. **Any inquiries or requests with this PCN (additional data or samples) must be sent to ADI within 30 days of publication date.** ADI contact information is listed below.

|                              |                                                                                                 |
|------------------------------|-------------------------------------------------------------------------------------------------|
| <b>PCN Title:</b>            | Epoxy Change from Henkel 8290 to 8290A for MSOP (3)                                             |
| <b>Publication Date:</b>     | 05-Jun-2024                                                                                     |
| <b>Effectivity Date:</b>     | 05-Jun-2024 <i>(the earliest date that a customer could expect to receive changed material)</i> |
| <b>Revision Description:</b> | Initial Release.                                                                                |

### Description Of Change:

Epoxy formulation change from Henkel 8290 to Henkel 8290A.

### Reason For Change:

8290A is a more robust epoxy with minimal outgassing due to its less volatile fluorocarbon content.

### Impact of the change (positive or negative) on fit, form, function & reliability:

This change will not impact fit, form, function while improving the reliability of the products.

### Product Identification *(this section will describe how to identify the changed material)*

Implementation effectively on parts with date code 2242 onwards.

### Summary of Supporting Information:

Qualification has been performed per Industry Standard Test Methods. See attached Qualification Results.

### Supporting Documents

**Attachment 1: Type:** Qualification Results Summary

[ADI\\_PCN\\_24\\_0004\\_Rev\\_-\\_Automotive\\_Qualification\\_Result\\_Summary\\_ABA3.pdf...](#)

**Attachment 2: Type:** Delta Qualification Matrix

[ADI\\_PCN\\_24\\_0004\\_Rev\\_-\\_PCN-Delta-Qualification-Matrix-ZVEI-5\\_0\\_16.xlsm...](#)

Note: If applicable, the device material declaration will be updated due to material change.

### ADI Contact Information:

For questions on this PCN, please send an email to the regional contacts below or contact your local ADI sales representatives.

| <b>Americas:</b>        | <b>Europe:</b>        | <b>Japan:</b>        | <b>Korea:</b>        | <b>Rest of Asia:</b> |
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## Appendix A - Affected ADI Models:

### Added Parts On This Revision - Product Family / Model Number (1,150)

|                                  |                                    |                                    |                                    |                                    |
|----------------------------------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|
| LTC1403 / LTC1403CMSE#PBF        | LTC1403 / LTC1403CMSE#TRPBF        | LTC1403 / LTC1403HMSE#PBF          | LTC1403 / LTC1403HMSE#TRPBF        | LTC1403 / LTC1403IMSE#PBF          |
| LTC1403 / LTC1403IMSE#TRPBF      | LTC1403-1 / LTC1403CMSE-1#PBF      | LTC1403-1 / LTC1403CMSE-1#TRPBF    | LTC1403-1 / LTC1403IMSE-1#PBF      | LTC1403-1 / LTC1403IMSE-1#TRPBF    |
| LTC1403A / LTC1403ACMSE#PBF      | LTC1403A / LTC1403ACMSE#TRPBF      | LTC1403A / LTC1403AHMSE#PBF        | LTC1403A / LTC1403AHMSE#TRPBF      | LTC1403A / LTC1403AIMSE#PBF        |
| LTC1403A / LTC1403AIMSE#TRPBF    | LTC1403A-1 / LTC1403ACMSE-1#PBF    | LTC1403A-1 / LTC1403ACMSE-1#TRPBF  | LTC1403A-1 / LTC1403AIMSE-1#PBF    | LTC1403A-1 / LTC1403AIMSE-1#TRPBF  |
| LTC1407 / LTC1407ACMSE#PBF       | LTC1407 / LTC1407ACMSE#TRPBF       | LTC1407 / LTC1407AHMSE#PBF         | LTC1407 / LTC1407AHMSE#TRPBF       | LTC1407 / LTC1407AIMSE#PBF         |
| LTC1407 / LTC1407AIMSE#TRPBF     | LTC1407 / LTC1407CMSE#PBF          | LTC1407 / LTC1407CMSE#TRPBF        | LTC1407 / LTC1407HMSE#PBF          | LTC1407 / LTC1407HMSE#TRPBF        |
| LTC1407 / LTC1407IMSE#PBF        | LTC1407 / LTC1407IMSE#TRPBF        | LTC1407-1 / LTC1407ACMSE-1#PBF     | LTC1407-1 / LTC1407ACMSE-1#TRPBF   | LTC1407-1 / LTC1407AIMSE-1#PBF     |
| LTC1407-1 / LTC1407AIMSE-1#TRPBF | LTC1407-1 / LTC1407CMSE-1#PBF      | LTC1407-1 / LTC1407CMSE-1#TRPBF    | LTC1407-1 / LTC1407IMSE-1#PBF      | LTC1407-1 / LTC1407IMSE-1#TRPBF    |
| LTC1440 / LTC1440CMS#PBF         | LTC1440 / LTC1440CMS#TRPBF         | LTC1440 / LTC1440IMS#PBF           | LTC1440 / LTC1440IMS#TRPBF         | LTC1474 / LTC1474CMS#PBF           |
| LTC1474 / LTC1474CMS#TRPBF       | LTC1474 / LTC1474CMS-3.3#PBF       | LTC1474 / LTC1474CMS-3.3#TRPBF     | LTC1474 / LTC1474CMS-5#PBF         | LTC1474 / LTC1474CMS-5#TRPBF       |
| LTC1475 / LTC1475CMS#PBF         | LTC1475 / LTC1475CMS#TRPBF         | LTC1475 / LTC1475CMS-3.3#PBF       | LTC1475 / LTC1475CMS-3.3#TRPBF     | LTC1475 / LTC1475CMS-5#PBF         |
| LTC1475 / LTC1475CMS-5#TRPBF     | LTC1482 / LTC1482CMS#PBF           | LTC1482 / LTC1482CMS#TRPBF         | LTC1502-3.3 / LTC1502CMS-3.3#PBF   | LTC1502-3.3 / LTC1502CMS-3.3#TRPBF |
| LTC1503 / LTC1503CMS-1.8#PBF     | LTC1503 / LTC1503CMS-1.8#TRPBF     | LTC1503 / LTC1503CMS-2#PBF         | LTC1522 / LTC1522CMS#PBF           | LTC1522 / LTC1522CMS#TRPBF         |
| LTC1536 / LTC1536CMS#PBF         | LTC1536 / LTC1536CMS#TRPBF         | LTC1540 / LTC1540CMS#PBF           | LTC1540 / LTC1540CMS#TRPBF         | LTC1540 / LTC1540IMS#PBF           |
| LTC1540 / LTC1540IMS#TRPBF       | LTC1550L / LTC1550LCMS#PBF         | LTC1550L / LTC1550LCMS#TRPBF       | LTC1550L / LTC1550LCMS-2#PBF       | LTC1550L / LTC1550LCMS-2#TRPBF     |
| LTC1550L / LTC1550LCMS-2.5#PBF   | LTC1550L / LTC1550LCMS-2.5#TRPBF   | LTC1550L / LTC1550LCMS-4.1#PBF     | LTC1550L / LTC1550LCMS-4.1#TRPBF   | LTC1551L / LTC1551LCMS#PBF         |
| LTC1551L / LTC1551LCMS#TRPBF     | LTC1551L / LTC1551LCMS-4.1#PBF     | LTC1551L / LTC1551LCMS-4.1#TRPBF   | LTC1623 / LTC1623CMS#PBF           | LTC1623 / LTC1623CMS#TRPBF         |
| LTC1659 / LTC1659CMS#PBF         | LTC1659 / LTC1659CMS#TRPBF         | LTC1659 / LTC1659IMS#PBF           | LTC1659 / LTC1659IMS#TRPBF         | LTC1661 / LTC1661CMS#PBF           |
| LTC1661 / LTC1661CMS#TRPBF       | LTC1661 / LTC1661IMS#PBF           | LTC1661 / LTC1661IMS#TRPBF         | LTC1663 / LTC1663-8CMS#PBF         | LTC1663 / LTC1663-8CMS#TRPBF       |
| LTC1663 / LTC1663-8IMS#PBF       | LTC1663 / LTC1663-8IMS#TRPBF       | LTC1663 / LTC1663IMS#PBF           | LTC1663 / LTC1663IMS#TRPBF         | LTC1669 / LTC1669-8IMS#PBF         |
| LTC1669 / LTC1669-8IMS#TRPBF     | LTC1669 / LTC1669IMS#PBF           | LTC1669 / LTC1669IMS#TRPBF         | LTC1682 / LTC1682CMS#PBF           | LTC1682 / LTC1682CMS#TRPBF         |
| LTC1682 / LTC1682CMS-3.3#PBF     | LTC1682 / LTC1682CMS-3.3#TRPBF     | LTC1682 / LTC1682CMS-5#PBF         | LTC1682 / LTC1682CMS-5#TRPBF       | LTC1682 / LTC1682IMS#PBF           |
| LTC1682 / LTC1682IMS#TRPBF       | LTC1682 / LTC1682IMS-3.3#PBF       | LTC1682 / LTC1682IMS-3.3#TRPBF     | LTC1682 / LTC1682IMS-5#PBF         | LTC1682 / LTC1682IMS-5#TRPBF       |
| LTC1690 / LTC1690CMS#PBF         | LTC1690 / LTC1690CMS#TRPBF         | LTC1693 / LTC1693-3CMS#PBF         | LTC1693 / LTC1693-3CMS#TRPBF       | LTC1693-5 / LTC1693-5CMS#PBF       |
| LTC1693-5 / LTC1693-5CMS#TRPBF   | LTC1697 / LTC1697EMS#PBF           | LTC1697 / LTC1697EMS#TRPBF         | LTC1699 / LTC1699EMS-80#PBF        | LTC1699 / LTC1699EMS-80#TRPBF      |
| LTC1699 / LTC1699EMS-81#PBF      | LTC1699 / LTC1699EMS-81#TRPBF      | LTC1699 / LTC1699EMS-82#PBF        | LTC1699 / LTC1699EMS-82#TRPBF      | LTC1700 / LTC1700EMS#PBF           |
| LTC1700 / LTC1700EMS#TRPBF       | LTC1710 / LTC1710CMS#PBF           | LTC1710 / LTC1710CMS#TRPBF         | LTC1726 / LTC1726EMS-2.5#PBF       | LTC1726 / LTC1726EMS-2.5#TRPBF     |
| LTC1726 / LTC1726EMS-5#PBF       | LTC1726 / LTC1726EMS-5#TRPBF       | LTC1726 / LTC1726HMS-5#PBF         | LTC1726 / LTC1726HMS-5#TRPBF       | LTC1727 / LTC1727EMS-2.5#PBF       |
| LTC1727 / LTC1727EMS-2.5#TRPBF   | LTC1727 / LTC1727EMS-5#PBF         | LTC1727 / LTC1727EMS-5#TRPBF       | LTC1729 / LTC1729CMS-4.1#PBF       | LTC1729 / LTC1729CMS-4.1#TRPBF     |
| LTC1729 / LTC1729CMS-4.2#PBF     | LTC1729 / LTC1729CMS-4.2#TRPBF     | LTC1729 / LTC1729CMS-8.2#PBF       | LTC1729 / LTC1729CMS-8.2#TRPBF     | LTC1729 / LTC1729CMS-8.4#PBF       |
| LTC1729 / LTC1729CMS-8.4#TRPBF   | LTC1731-4.1 / LTC1731EMS-4.1#PBF   | LTC1731-4.1 / LTC1731EMS-4.1#TRPBF | LTC1731-4.1 / LTC1731EMS-4.2#PBF   | LTC1731-4.1 / LTC1731EMS-4.2#TRPBF |
| LTC1731-8.2 / LTC1731EMS-8.2#PBF | LTC1731-8.2 / LTC1731EMS-8.2#TRPBF | LTC1731-8.2 / LTC1731EMS-8.4#PBF   | LTC1731-8.2 / LTC1731EMS-8.4#TRPBF | LTC1732-4 / LTC1732EMS-4#PBF       |
| LTC1732-4 / LTC1732EMS-4#TRPBF   | LTC1732-4 / LTC1732EMS-4.2#PBF     | LTC1732-4 / LTC1732EMS-4.2#TRPBF   | LTC1732-8.4 / LTC1732EMS-8.4#PBF   | LTC1732-8.4 / LTC1732EMS-8.4#TRPBF |
| LTC1751 / LTC1751EMS#PBF         | LTC1751 / LTC1751EMS#TRPBF         | LTC1751 / LTC1751EMS-3.3#PBF       | LTC1751 / LTC1751EMS-3.3#TRPBF     | LTC1751 / LTC1751EMS-5#PBF         |
| LTC1751 / LTC1751EMS-5#TRPBF     | LTC1771 / LTC1771EMS#PBF           | LTC1771 / LTC1771EMS#TRPBF         | LTC1773 / LTC1773EMS#PBF           | LTC1773 / LTC1773EMS#TRPBF         |
| LTC1860 / LTC1860CMS#PBF         | LTC1860 / LTC1860CMS#TRPBF         | LTC1860 / LTC1860HMS#PBF           | LTC1860 / LTC1860HMS#TRPBF         | LTC1860 / LTC1860IMS#PBF           |
| LTC1860 / LTC1860IMS#TRPBF       | LTC1860L / LTC1860LCMS#PBF         | LTC1860L / LTC1860LCMS#TRPBF       | LTC1860L / LTC1860LIMS#PBF         | LTC1860L / LTC1860LIMS#TRPBF       |
| LTC1861L / LTC1861LCMS#PBF       | LTC1861L / LTC1861LCMS#TRPBF       | LTC1861L / LTC1861LIMS#PBF         | LTC1861L / LTC1861LIMS#TRPBF       | LTC1864 / LTC1864ACMS#PBF          |
| LTC1864 / LTC1864ACMS#TRPBF      | LTC1864 / LTC1864AHMS#PBF          | LTC1864 / LTC1864AHMS#TRPBF        | LTC1864 / LTC1864AIMS#PBF          | LTC1864 / LTC1864AIMS#TRPBF        |
| LTC1864 / LTC1864CMS#PBF         | LTC1864 / LTC1864CMS#TRPBF         | LTC1864 / LTC1864HMS#PBF           | LTC1864 / LTC1864HMS#TRPBF         | LTC1864 / LTC1864IMS#PBF           |
| LTC1864 / LTC1864IMS#TRPBF       | LTC1864L / LTC1864ACMS#PBF         | LTC1864L / LTC1864ACMS#TRPBF       | LTC1864L / LTC1864AIMS#PBF         | LTC1864L / LTC1864AIMS#TRPBF       |
| LTC1864L / LTC1864LCMS#PBF       | LTC1864L / LTC1864LCMS#TRPBF       | LTC1864L / LTC1864LIMS#PBF         | LTC1864L / LTC1864LIMS#TRPBF       | LTC1865 / LTC1865ACMS#PBF          |
| LTC1865 / LTC1865ACMS#TRPBF      | LTC1865 / LTC1865AHMS#PBF          | LTC1865 / LTC1865AHMS#TRPBF        | LTC1865 / LTC1865AIMS#PBF          | LTC1865 / LTC1865AIMS#TRPBF        |
| LTC1865 / LTC1865CMS#PBF         | LTC1865 / LTC1865CMS#TRPBF         | LTC1865 / LTC1865HMS#PBF           | LTC1865 / LTC1865HMS#TRPBF         | LTC1865 / LTC1865IMS#PBF           |
| LTC1865 / LTC1865IMS#TRPBF       | LTC1865L / LTC1865ACMS#PBF         | LTC1865L / LTC1865ACMS#TRPBF       | LTC1865L / LTC1865AIMS#PBF         | LTC1865L / LTC1865AIMS#TRPBF       |
| LTC1865L / LTC1865LCMS#PBF       | LTC1865L / LTC1865LCMS#TRPBF       | LTC1865L / LTC1865LIMS#PBF         | LTC1865L / LTC1865LIMS#TRPBF       | LTC1871 / LTC1871EMS#PBF           |
| LTC1871 / LTC1871EMS#TRPBF       | LTC1871 / LTC1871IMS#PBF           | LTC1871 / LTC1871IMS#TRPBF         | LTC1871-1 / LTC1871EMS-1#PBF       | LTC1871-1 / LTC1871EMS-1#TRPBF     |
| LTC1871-1 / LTC1871IMS-1#PBF     | LTC1871-1 / LTC1871IMS-1#TRPBF     | LTC1871-7 / LTC1871EMS-7#PBF       | LTC1871-7 / LTC1871EMS-7#TRPBF     | LTC1871-7 / LTC1871IMS-7#PBF       |
| LTC1871-7 / LTC1871IMS-7#TRPBF   | LTC1877 / LTC1877IMS#PBF           | LTC1877 / LTC1877IMS#TRPBF         | LTC1878 / LTC1878EMS#PBF           | LTC1878 / LTC1878EMS#TRPBF         |
| LTC1992 / LTC1992-10CMS#PBF      | LTC1992 / LTC1992-10CMS#TRPBF      | LTC1992 / LTC1992-10HMS#PBF        | LTC1992 / LTC1992-10HMS#TRPBF      | LTC1992 / LTC1992-10IMS#PBF        |
| LTC1992 / LTC1992-10IMS#TRPBF    | LTC1992 / LTC1992-1CMS#PBF         | LTC1992 / LTC1992-1CMS#TRPBF       | LTC1992 / LTC1992-1HMS#PBF         | LTC1992 / LTC1992-1HMS#TRPBF       |
| LTC1992 / LTC1992-1IMS#PBF       | LTC1992 / LTC1992-2IMS#TRPBF       | LTC1992 / LTC1992-2CMS#PBF         | LTC1992 / LTC1992-2CMS#TRPBF       | LTC1992 / LTC1992-2HMS#PBF         |
| LTC1992 / LTC1992-2HMS#TRPBF     | LTC1992 / LTC1992-2IMS#PBF         | LTC1992 / LTC1992-2IMS#TRPBF       | LTC1992 / LTC1992-5CMS#PBF         | LTC1992 / LTC1992-5CMS#TRPBF       |
| LTC1992 / LTC1992-5HMS#PBF       | LTC1992 / LTC1992-5HMS#TRPBF       | LTC1992 / LTC1992-5IMS#PBF         | LTC1992 / LTC1992-5IMS#TRPBF       | LTC1992 / LTC1992CMS#PBF           |
| LTC1992 / LTC1992CMS#TRPBF       | LTC1992 / LTC1992HMS#PBF           | LTC1992 / LTC1992HMS#TRPBF         | LTC1992 / LTC1992IMS#PBF           | LTC1992 / LTC1992IMS#TRPBF         |
| LTC2051 / LTC2051CMS10#PBF       | LTC2051 / LTC2051CMS10#TRPBF       | LTC2051 / LTC2051CMS#PBF           | LTC2051 / LTC2051CMS#TRPBF         | LTC2051 / LTC2051HMS#PBF           |
| LTC2051 / LTC2051HMS#TRPBF       | LTC2051 / LTC2051HMS#TRPBF         | LTC2051 / LTC2051HVCMS10#PBF       | LTC2051 / LTC2051HVCMS10#TRPBF     | LTC2051 / LTC2051HVCMS#PBF         |
| LTC2051 / LTC2051HVCMS#TRPBF     | LTC2051 / LTC2051HVHMS#PBF         | LTC2051 / LTC2051HVHMS#TRPBF       | LTC2051 / LTC2051HVIMS10#PBF       | LTC2051 / LTC2051HVIMS10#TRPBF     |
| LTC2051 / LTC2051HVIMS#PBF       | LTC2051 / LTC2051HVIMS#TRPBF       | LTC2051 / LTC2051IMS10#PBF         | LTC2051 / LTC2051IMS10#TRPBF       | LTC2051 / LTC2051IMS#PBF           |

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|                               |                                 |                              |                               |                                 |
|-------------------------------|---------------------------------|------------------------------|-------------------------------|---------------------------------|
| LTC2946 / LTC2946IMS#TRPBF    | LTC2946 / LTC2946IMS-1#PBF      | LTC2946 / LTC2946IMS-1#TRPBF | LTC2946 / LTC2946MPMS#PBF     | LTC2946 / LTC2946MPMS#TRPBF     |
| LTC2946 / LTC2946MPMS-1#PBF   | LTC2946 / LTC2946MPMS-1#TRPBF   | LTC2956 / LTC2956CMS-1#PBF   | LTC2956 / LTC2956CMS-1#TRPBF  | LTC2956 / LTC2956CMS-2#PBF      |
| LTC2956 / LTC2956CMS-2#TRPBF  | LTC2956 / LTC2956IMS-1#PBF      | LTC2956 / LTC2956IMS-1#TRPBF | LTC2956 / LTC2956IMS-2#PBF    | LTC2956 / LTC2956IMS-2#TRPBF    |
| LTC2965 / LTC2965CMS#PBF      | LTC2965 / LTC2965CMS#TRPBF      | LTC2965 / LTC2965HMS#PBF     | LTC2965 / LTC2965HMS#TRPBF    | LTC2965 / LTC2965IMS#PBF        |
| LTC2965 / LTC2965IMS#TRPBF    | LTC2990 / LTC2990CMS#PBF        | LTC2990 / LTC2990CMS#TRPBF   | LTC2990 / LTC2990IMS#PBF      | LTC2990 / LTC2990IMS#TRPBF      |
| LTC2991 / LTC2991CMS#PBF      | LTC2991 / LTC2991CMS#TRPBF      | LTC2991 / LTC2991IMS#PBF     | LTC2991 / LTC2991IMS#TRPBF    | LTC3026 / LTC3026EMSE#PBF       |
| LTC3026 / LTC3026EMSE#TRPBF   | LTC3026 / LTC3026IMSE#PBF       | LTC3026 / LTC3026IMSE#TRPBF  | LTC3026-1 / LTC3026EMSE-1#PBF | LTC3026-1 / LTC3026EMSE-1#TRPBF |
| LTC3026-1 / LTC3026IMSE-1#PBF | LTC3026-1 / LTC3026IMSE-1#TRPBF | LTC3103 / LTC3103EMSE#PBF    | LTC3103 / LTC3103EMSE#TRPBF   | LTC3103 / LTC3103IMSE#PBF       |
| LTC3103 / LTC3103IMSE#TRPBF   | LTC3104 / LTC3104EMSE#PBF       | LTC3104 / LTC3104EMSE#TRPBF  | LTC3104 / LTC3104IMSE#PBF     | LTC3104 / LTC3104IMSE#TRPBF     |
| LTC3105 / LTC3105EMS#PBF      | LTC3105 / LTC3105EMS#TRPBF      | LTC3111 / LTC3111EMSE#PBF    | LTC3111 / LTC3111EMSE#TRPBF   | LTC3111 / LTC3111HMSE#PBF       |
| LTC3111 / LTC3111HMSE#TRPBF   | LTC3111 / LTC3111IMSE#PBF       | LTC3111 / LTC3111IMSE#TRPBF  | LTC3111 / LTC3111MPMSE#PBF    | LTC3111 / LTC3111MPMSE#TRPBF    |

**Appendix B - Revision History:**

| Rev    | Publish Date | Effectivity Date | Rev Description  |
|--------|--------------|------------------|------------------|
| Rev. - | 05-Jun-2024  | 05-Jun-2024      | Initial Release. |

## Automotive Qualification Results Summary of Epoxy change from Henkel 8290 to 8290A

| QUALIFICATION RESULTS                                                    |                            |             |         |
|--------------------------------------------------------------------------|----------------------------|-------------|---------|
| TEST                                                                     | SPECIFICATION              | SAMPLE SIZE | RESULTS |
| Highly Accelerated Stress Test (HAST)*                                   | JEDEC <i>JESD22-A110</i>   | 3x77        | Pass    |
| Temperature Cycle (TC)*                                                  | JEDEC <i>JESD22-A104</i>   | 3x77        | Pass    |
| Solder Heat Resistance (SHR)*                                            | JEDEC/IPC <i>J-STD-020</i> | 3x11        | Pass    |
| High Temperature Storage Life (HTSL)                                     | JEDEC <i>JESD22-A103</i>   | 1x77        | Pass    |
| Electrostatic Discharge<br><i>Field-Induced Charged<br/>Device Model</i> | JEDEC <i>JESD22-C101</i>   | 3/voltage   | Pass    |

\* These samples were subjected to preconditioning (per J-STD-020 Level 1) prior to the start of the stress test. Level 1 preconditioning consists of the following: 1. Bake – 24 hours at 125°C; 2. Soak – unbiased soak for 168 hours at 85°C, 85%RH; 3. Reflow – three passes through a reflow oven with a peak temperature of 260°C. TC samples were subjected to wire-pull test after 500 cycles with results within specification limits.