

AEC - Q006 - REV - A

**QUALIFICATION REQUIREMENTS FOR COMPONENTS USING
COPPER (Cu) WIRE INTERCONNECTIONS**

Automotive Electronics Council

Component Technical Committee

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**QUALIFICATION REQUIREMENTS FOR COMPONENTS USING
COPPER (Cu) WIRE INTERCONNECTIONS**

Text enhancements and differences made since the release of this document are shown as underlined areas.

1. SCOPE

This document contains a set of tests and defines the minimum requirements for qualification of copper (Cu) wire interconnections for components to be used in any automotive electronics application. While the set of tests highlighted here are replicated in AEC-Q100/Q101, this document details any different test conditions and/or durations plus the activity around these tests that are unique requirements for ensuring Cu wire reliability. Use of this document does not relieve the supplier of their responsibility to meet their own company's internal qualification program. In this document, "user" is defined as all customers using a component qualified per this specification. The user is responsible to confirm and validate all qualification data that substantiates conformance to this document.

If a supplier has already qualified Cu wire and is in production with no Cu wire related issues, the supplier does not have to requalify those approved components again per this document.

1.1 Purpose

The purpose of this specification is to determine that a component is capable of passing the specified stress tests and thus can be expected to give a certain level of quality/reliability in the application.

1.2 Reference Documents

Current revision of the referenced documents will be in effect at the date of agreement to the qualification plan. Subsequent qualification plans will automatically use updated revisions of these referenced documents.

1.2.1 Automotive

AEC-Q100 Failure Mechanism Based Stress Test Qualification for Integrated Circuits
AEC-Q101 Failure Mechanism Based Stress Test Qualification for Discrete Semiconductors in Automotive Applications

1.2.2 JEDEC

JESD22 Reliability Test Methods
JESD22-A104 Temperature Cycling (TC)
JESD22-A110 Highly Accelerated Stress Test (HAST)
JESD22-A101 Temperature Humidity Bias (THB) / High Humidity High Temperature Reverse Bias (H3TRB)
JESD22-A105 Power Temperature Cycle (PTC)
JESD22-A103 High Temperature Storage Life (HTSL) / High Temperature Gate Bias (HTGB)
J-STD-035 Acoustic Microscopy for Non-Hermetic Encapsulated Electronic Components
J-STD-020 Moisture/Reflow Sensitivity Classification for Nonhermetic Surface Mount Devices

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1.2.3 Military

MIL-STD-750, Method 1037 Intermittent Operation Life (IOL)
MIL-STD-750, Method 1038 (condition A) High Temperature Reverse Bias (HTRB)

2. EQUIPMENT

Not applicable (see referenced documents)

3. DATA SUBMISSION

3.1 Certificate of Design and Construction

For qualification of components with Cu wire, a Certificate of Design and Construction per AEC-Q100/Q101 is required to determine whether available generic data can apply to the part in question for one or more of the required tests in this document.

If applicable, supplier must document the definition of Cu wire product or technology family. This document should explain the selection of family (worst-case) test vehicle(s). In the list in Section 7.1, critical product, construction and material items for defining Cu wire product or technology families are given.

The relevant items in the Certificate of Design and Construction are highlighted in Section 7.1 for determination of what data is considered acceptable generically.

3.2 Test Results

The following data is to be submitted to the user for approval on request:

- Cu wire stress test qualification results
- Wire pull/ball shear – mean, min, max, standard deviation
- CSAM images before/after stressing
- Electrical/ATE functional/parametric test results before/after stress tests
- Cross-sections of ball/wedge bonds (as needed per Section 5)

4. QUALIFICATION TESTS

The required set of qualification stresses, test conditions and test durations are shown in the following sections, with an enhanced qualification flow described in Tables 3a/3b. Other tests not mentioned in Tables 3a/3b shall be performed as required per AEC-Q100/AEC-Q101.

Qualification of Cu wire components to standard AEC-Q100/Q101 requirements for temperature cycling can be conducted if board level stress test (Section 4.5) was performed with no issues or fails observed. Otherwise, the supplier must perform the enhanced qualification flow described in Tables 3a/3b on a family/technology specific component at a minimum.

If a supplier has already qualified Cu wire and is in production with no Cu wire related issues, the supplier does not have to requalify those approved components again per this document.

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4.1 Temperature Cycling (TC)

This test highlights the differences in the coefficient of thermal expansion of package materials with Cu along with the increased hardness of Cu with respect to gold (Au).

Perform per the test requirements in AEC-Q100/Q101. The only exception is for Q100 Grade 0 as shown below:

Grade 0: -55°C to +150°C for 1500 cycles or equivalent for step 6 (Stress 1X) of Table 3 and 3000 cycles for step 11 (Stress 2X) of Table 3.

4.2 Biased Humidity (HAST/THB/H3TRB)

This test can exacerbate corrosion along the Cu/bond pad intermetallic compound (IMC) interfaces.

Perform per the test requirements in AEC-Q100/Q101.

4.3 Power Temperature Cycle (PTC) / Intermittent Operation Life (IOL)

This test can accelerate wearout by the combination of current/voltage and temperature.

Perform per the test requirements in AEC-Q100/Q101 if applicable to the part type being tested (e.g., PowerMOS).

4.4 High Temperature Storage Life (HTSL) / High Temperature Gate Bias (HTGB) / High Temperature Reverse Bias (HTRB)

This test can accelerate IMC growth along the Cu/Aluminum (Al) interface to yield an open bond failure. It can also degrade the mechanical performance of the stitch (wedge/second bond) bond. This is especially important for high temperature applications.

Perform per the test requirements in AEC-Q100/Q101.

4.5 Board Level Stress Test

Performance of this board-level temperature cycling test along with the test conditions, sample sizes and bill of materials to be used is to be agreed to between the user and supplier and justified by data.

5. ANALYTICAL TESTS

5.1 Delamination/CSAM

Delamination of the mold compound over the Cu ball or stitch bond could lead to joint fatigue failure at either weld joint. The delamination criteria for various stages of qualification testing are shown in Table 1. Delamination of the mold compound at a wire bond location is an indicator of risk but may not be a cause of failure within the useful life portion of the device. For example, there are many small discrete devices that may exhibit delamination at the stitch bond location at various points and in changing magnitudes in the test sequence or useful life but exhibit no reliability concerns in the field.

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Table 1: Delamination Criteria

	Read Point	Mold Compound Delamination Acceptance Criteria	Electrical
Qualification Requirements	T ₀	No delamination at first (ball) or second (stitch/wedge) bonds unless otherwise agreed between supplier and user. ⁽¹⁾	All components passing production test
	Post MSL PC	No delamination at first (ball) or second (stitch/wedge) bonds unless otherwise agreed between supplier and user. ⁽¹⁾	All components passing production test
	1X for <u>AEC Q100</u> grade X or <u>AEC Q101</u>	No delamination at first (ball) bond. If any second (stitch/wedge) bond delamination found – no heel cracks. ⁽¹⁾	All components passing production test
	2X for <u>AEC Q100</u> grade X or <u>AEC Q101</u> (TC included if no BLR performed)	Evaluate the severity of any bond delamination found per Sections 5.2 and 5.3. ⁽²⁾	All components passing production test ⁽³⁾
Minimum CSAM sample size: EITHER the same 11 components per lot through each readpoint (preferable) OR 22 random components per lot at each readpoint.			

Notes:

- (1) Agreement between the supplier and user would be achieved via the exchange of data that demonstrates that the form of delamination seen is not an issue for this part based on supporting data (field, monitor, in-process, etc.).
- (2) Method of evaluation to be determined by the user and supplier.
- (3) At 2X TC read point, passing production test means zero systematic Cu wire related issues. For example, if a failure was found to be related to solder ball or substrate, that is not considered a valid Cu wire failure.

5.2 Wire Bond Integrity

The tests described below and where they are performed are a good gauge of the bond strength and weld formation of the ball and stitch bonds. They are done to demonstrate adequate process control with acceptable bond integrity. The location of the hook for bond pull should be over the contact of interest (i.e., over the ball and over the stitch/wedge).

- Ball shear – ball bond area versus shear force (pre-packaged)
- Ball and Stitch/Wedge bond wire pull (pre-packaged)
- Perform wire pull/ ball shear on first bond and wire pull for stitch/wedge bond (post packaged)
- Pad cratering test (pre-packaged)

Wire pull / ball shear is performed after stress testing and decapsulation. A recommended process flow is described below:

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1. Select components per the sample size specified in AEC-Q100/Q101 for wire pull and shear. Selecting worst-case components based on CSAM after 2X stress is desirable.
2. Carefully decapsulate these components so as to not damage or adversely affect the wire bonds but enough to be able to reliably conduct wire pulls and/or bond shears.
3. The wire pull hook should be situated as close as possible over the stitch/wedge bond for stitch/wedge bond pull and over the ball for ball bond pull. Stitch/wedge bond pull force results after stress testing may not be a reliable gauge of bond quality, as the act of pulling a stitch/wedge might not be repeatable and/or reproducible.
4. Compare these results with production or qualification data (i.e., before mold via WBP/WBS or after decap) to assess the level of degradation in the distribution of the data. If there are positively biased wires required in the test, ensure that they are included in this analysis, as they are thought to be more susceptible to corrosion.
5. In conjunction with pull/shear after decapsulation, a thorough inspection of the stitch/wedge bonds should take place to look for heel cracks or precursors for failure.

For temperature cycling, pulls and shears at corner locations of the die/package are preferable. For moisture stressing, selecting random balls/stitches is acceptable (uniform moisture penetration) but ensure that both biased and unbiased pins are selected. Determination of which wires per device undergo ball shear, ball pull or stitch/wedge pull is left to the supplier to determine as long as the intent of inspecting all types of bonds is adequately addressed.

5.3 Cross-Sectioning Inspection

For initial supplier qualification of a new die/package (interaction) family/technology, selecting worst-case components based on CSAM after 2X stress is desirable. The sample sizes and test conditions are specified in the overall process qualification flow shown in Tables 3a/3b.

Areas of examination:

- Ball bond area
 - Amount and distribution of intermetallic - an alternative planar analysis method to evaluate ball bond IMC formation is also acceptable.
 - Crack initiation/propagation
 - Corrosion after 1X stress
- Stitch/Wedge bond area
 - Amount of contact
 - Wire angle to stitch/wedge
 - Crack initiation/propagation
 - Corrosion after 1X stress
 - Intermetallics formed in the bond area

6. COMPONENT CHANGES

6.1 Qualification Test Requirements for Cu Wire Changes

The requirements for qualification of changes to already qualified and released components can be found in AEC-Q100/Q101. An agreement has to be arrived at between the user and supplier as to whether the change should be qualified to Q100/Q101 or Q006 requirements for the applicable test to be considered.

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In cases where wire is changing to copper (including coated copper wire), relevant stress tests and physical analysis steps must be performed per Q006 Table 3a/3b conditions, unless internal and external data for already-qualified Cu wire parts is provided with technical justification to support the equivalent robustness of the material and design changes and is agreeable to the customer.

7. QUALIFICATION REQUIREMENTS FOR Cu WIRE COMPONENTS

The sections below describe the individual steps required in a qualification flow for Cu wire components and the sample sizes required for each stress test.

7.1 Family Data Usage

The qualification can be performed on a technology basis, defined as sharing the same characteristics described below. Technology family is qualified using the technology driver (or lead product) most representative of the technology family. Product family is the subset of (functional specific) parts (or follow-on parts) under the technology driver part. Passage of the technology family allows subsequent components in the product family(ies) used for the technology qualification to then be qualified by association. See Table 2 for the qualification requirements per different cases of the technology family criteria.

Use of family generic data for new designs into the family requires a consideration of a combination of family attributes. This section provides a list of relevant items for consideration. In this case for use of Cu wire, a family consists of 1) silicon die related attributes, 2) package related attributes and 3) assembly factory related attributes. Table 2 provides an overview of those attributes that characterize a Technology Family.

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Table 2: Technology Family Criteria

The qualification requirements per different cases of the technology family criteria.

Note that in each case only the difference(s) is highlighted and all other attributes are the same unless specified otherwise.

<u>Case</u>	<u>Silicon die related attributes</u>	<u>Package related attributes</u>	<u>Assembly site location related attributes</u>	<u>Requirements in addition to Q100/Q101</u>
<u>1</u>	<u>different</u>	<u>different</u>	<u>different</u>	<u>Q006 (Tables 3a/3b), 3 lots</u>
<u>2a</u>	<u>different bond pad base/layered materials (e.g., Al vs. plated Al vs. Cu)</u>	<u>same</u>	<u>same</u>	<u>Q006 (Tables 3a/3b), 3 lots</u>
<u>2b</u>	<u>new component has a die diagonal size of >115% of the technology qual vehicle</u>	<u>same</u>	<u>same</u>	<u>Q006 (Tables 3a/3b for TC), 3 lots</u>
<u>2c</u>	<u>different dielectric composition and thickness under the bond pad</u>	<u>same</u>	<u>same</u>	<u>Q006 (Tables 3a/3b for TC) 3 lots</u>
<u>3a</u>	<u>same</u>	<u>different mold compound materials</u>	<u>same</u>	<u>Q006 (Tables 3a/3b), 3 lots</u>
<u>3b</u>	<u>same</u>	<u>different bond wire materials (e.g., bare Cu vs. coated Cu)</u>	<u>same</u>	<u>Q006 (Tables 3a/3b), 3 lots</u>
<u>3c</u>	<u>same</u>	<u>different lead frame/substrate material surface at stitch (e.g., NiPdAu vs. Cu vs. Alloy42 vs Ag strike)</u>	<u>same</u>	<u>Q006 (Tables 3a/3b), 3 lots</u>
<u>3d</u>	<u>same</u>	<u>different package types (e.g., QFP vs. SOIC)</u>	<u>same</u>	<u>Q006 (Tables 3a/3b), 3 lots</u>
<u>4a</u>	<u>same</u>	<u>same</u>	<u>Different assembly site locations</u>	<u>Q006 (Tables 3a/3b), 3 lots</u>
<u>5</u>	<u>new component has a die diagonal size of <115% of the technology qual vehicle</u>	<u>same</u>	<u>same</u>	<u>1 lot per Q100/Q101 requirements (need generic or part-specific data up to item #10 in Tables 3a/3b)</u>

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7.2 Integrated Circuit Qualification Requirements

Table 3a below describes the test requirements and sequence for Cu wire qualification of integrated circuit devices in addition to or replacement of the normal qualification requirements per AEC-Q100. The sample sizes in the table define the number of lots times the number of samples per lot.

Table 3a: Integrated Circuit Qualification Test Requirements based on AEC-Q100

Sequence #	Stress Test Qualification Step	TC	HAST/THB	PTC	HTSL
1	Initial sampling	Sample sizes as required			
2	CSAM @ T0 ⁽¹⁾	Sample sizes as required			
3	Preconditioning to MSLx	3x77	3x77	1x45	---
4	CSAM after PC ⁽¹⁾	3x22	3x22	1x22	---
5	ATE Test	3x77	3x77	1x45	3x45
6	Stress 1X	3x77	3x77	1x45	3x45
7	ATE Test	3x77	3x77	1x45	3x45
8	CSAM post-1X stress ^(1,5)	3x22	3x22 ⁽⁶⁾	---	---
9a	Ball + Stitch/Wedge pull	3x3 ^(4,7)	3x3 ^(4,7)	---	---
9b	Ball shear	3x3 ^(4,7)	3x3 ^(4,7)	---	---
10	Cross-section	3x1 ⁽⁷⁾	3x1 ⁽⁷⁾	---	3x1
11	Stress 2X	3x70 ⁽²⁾	3x70	1x45	3x44
12	ATE Test	3x70 ^(2,3)	3x70 ⁽³⁾	1x45 ⁽³⁾	3x44 ⁽³⁾
13	CSAM post-2X stress ⁽¹⁾	3x22 ⁽²⁾	3x22	---	---
14a	Ball + Stitch/Wedge pull	3x2 ^(2,4)	3x2 ⁽⁴⁾	---	---
14b	Ball shear	3x2 ^(2,4)	3x2 ⁽⁴⁾	---	---
15	Cross-section	3x1 ⁽²⁾	3x1	---	3x1

Notes:

- (1) Either 11 marked or 22 random parts per lot per Table 1 CSAM sample size criteria.
- (2) Performed only if board level reliability testing is NOT being performed.
- (3) Any failures beyond 1X must directly relate to the Cu wire bonding system for them to count as a legitimate failure requiring further evaluation (i.e., the projected lifetime of failure, effect of fail mode on product lifetime, corrective/preventive action). The method of approval is determined between the user and supplier.
- (4) Pull/shear as many as is possible per the number of wires per device to be qualified up to a maximum of 30 wires/balls from the total sample size specified.
- (5) CSAM may be waived for parts in cases where parts need to be mounted on test boards to perform the stress and where the die are mounted upside down. This arrangement makes it impossible to image the interfaces of concern without dismounting them from the test board and remounting them after CSAM is performed.
- (6) Skip this step if you are performing to 2X. Include this step if you are performing per case 5 of Table 2.
- (7) If agreed, sample for this test can be set aside unless an issue is found at 2X.

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7.3 Discrete Device Qualification Requirements

Table 3b below describes the test requirements and sequence for Cu wire qualification of discrete devices in addition to or replacement of the normal qualification requirements per AEC-Q101. The sample sizes in the table define the number of lots times the number of samples per lot. See Q101 for the applicability of each test per device function (i.e., LEDs and zeners do not require HTRB/HTGB).

Table 3b: Discrete Qualification Test Requirements based on AEC-Q101

Sequence #	Stress Test Qualification Step	TC	HAST/H3TRB	IOL	HTRB/HTGB ⁽⁸⁾
1	Initial sampling	Sample sizes as required			
2	CSAM @ T0 ⁽¹⁾	Sample sizes as required			
3	Preconditioning to MSLx	3x77	3x77	3x77	---
4	CSAM after PC ⁽¹⁾	3x22	3x22	3x22	---
5	ATE Test	3x77	3x77	3x77	3x77
6	Stress 1X	3x77	3x77	3x77	3x77
7	ATE Test	3x77	3x77	3x77	3x77
8	CSAM post-1X stress ^(1,5)	3x22	3x22 ⁽⁶⁾		
9a	Ball + Stitch/Wedge pull	3x3 ^(4,7)	3x3 ^(4,7)	---	---
9b	Ball shear	3x3 ^(4,7)	3x3 ^(4,7)	---	---
10	Cross-section	3x1 ⁽⁷⁾	3x1 ⁽⁷⁾	---	3x1
11	Stress 2X	3x70 ⁽²⁾	3x70	3x77	3x76
12	ATE Test	3x70 ^(2,3)	3x70 ⁽³⁾	3x77 ⁽³⁾	3x76 ⁽³⁾
13	CSAM post-2X stress ⁽¹⁾	3x22 ⁽²⁾	3x22		
14a	Ball + Stitch/Wedge pull	3x2 ^(2,4)	3x2 ⁽⁴⁾	---	---
14b	Ball shear	3x2 ^(2,4)	3x2 ⁽⁴⁾	---	---
15	Cross-section	3x1 ⁽²⁾	3x1	---	3x1

Notes:

- (1) Either 11 marked or 22 random parts per lot per Table 1 CSAM sample size criteria.
- (2) Performed only if board level reliability testing is NOT being performed.
- (3) Any failures beyond 1X must directly relate to the Cu wire bonding system for them to count as a legitimate failure requiring further evaluation (i.e., the projected lifetime of failure, effect of fail mode on product lifetime, corrective/preventive action). The method of approval is determined between the user and supplier.
- (4) Pull/shear as many as is possible per the number of wires per device to be qualified up to a maximum of 30 wires/balls from the total sample size specified.
- (5) CSAM may be waived for parts where the die are mounted upside down, making it impossible to image the interfaces of concern with out dismounting them from the test board and remounting them after CSAM is performed.
- (6) Skip this step if you are performing to 2X. Include this step if you are performing per case 5 of Table 2.
- (7) If agreed, sample for this test can be set aside unless an issue is found at 2X.
- (8) This test can be performed unbiased to more resemble an HTSL-type test.

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APPENDIX 1: Cu Wire Process and Technology Characterization Guideline

This appendix is meant to be used as a guideline for users of components assembled using Cu wire for the internal interconnects. This guideline is a broad outline of generic items and issues suppliers should address to ensure a reliable Cu wire process in production.

This guideline is meant to illustrate the technical items that need discussion between supplier and user to determine the level of competence in the supplier's development process for Cu wire production. This discussion can involve data from design of experiments, stress tests, historical data, models, etc.

A.1 Failure Mechanisms Related to Copper Wire and Causes/Risk Factors:

- Chipout under ball bond (AEC Q100-001)
 - The pad and underlying structures have higher risk of damage/cracking due to the extra ball bonding force required for Cu wire
 - Bonding over layered active area circuitry
 - Thin passivation layer under bond pad
- Corrosion along Cu/Al IMC interface
 - Trace contaminants/additives in mold compound in presence of moisture
- Insufficient Cu/Al IMC
 - Al bondpad splash from overbonding force
 - Poorly optimized bonding parameters for bonding temperature/frequency/force during thermosonic bonding
 - Oxidation of free air ball during ball bonding
- Crack at stitch/wedge heel
 - Delamination at/near the lead tip where stitch/wedge located
 - Adequate mold compound cure
 - Mold lock techniques
 - Large CTE mismatch among package materials
 - Mismatch of material properties (e.g., Tg, CTE, elastic modulus) of component and with customer circuit boards
- Wire neck severance
 - Die/mold compound delamination near/at the ball bond

A.2 Best Practices:

- Inert environment around Cu wire
 - During wire storage
 - During free air ball formation
 - (Pd) Plated Cu wire
- Tighter controls/limits for wire pull/shear metrics
 - USL/UCL and LSL/LCL
 - Ball shear and wire pull near/over stitch
 - Production monitor using unmolded parts
 - Pull/shear after stress testing and careful decapsulation
- Capillary
 - More frequent replacement/maintenance
 - Designed specifically for Cu wire
- Thermosonic bonding
 - Tighter parameters for frequency, temperature, force
 - Reliability data collection at bond recipe corners of Force and Frequency

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- Mold Compound Material Requirements
 - Sufficiently high pH (generally greater than 5)
 - Cl extracted content (generally less than 15ppm)
- Safe Launch (i.e., initial production period) period for new Qualification and Changes
 - Sample first lots for reliability test
- Bond Pad Construction including active circuits under pad if applicable
 - Selecting the most sensitive bond pad known for analysis
- Ball Bond: IMC contact area after wire bonding
 - Quantify smallest contact area below which there would be a bonding problem
- Stitch/Wedge Bond: delamination response after TC
 - Quantify the largest amount of delamination change allowed

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Revision History

<u>Rev #</u>	<u>Date of change</u>	<u>Brief summary listing affected sections</u>
-	June 8, 2015	Initial Release.
<u>A</u>	<u>July 1, 2016</u>	<u>Complete Revision. Revised sections 3.1, 4, 4.1, 4.2, 4.3, 4.4, 5.1, 5.2, 5.3, 6.1, and 7, Tables 1, 3a, and 3b, Appendix 1, and Revision History. Added new sections 7.1, 7.2, and 7.3, and Table 2.</u>