

## **Tin Whisker Acceptance Test Requirements (iNEMI Tin Whisker User Group, July 28, 2004)**

### **1. Introduction**

In spite of more than five decades of research done on tin (Sn) whisker growth (see reference 3.4), a basic understanding of the mechanisms that control whisker growth and prevention remains elusive. Furthermore, both because of this lack of understanding as well as the fact that whisker formation appears to decelerate at temperatures significantly above 60°C, accelerated test conditions and extrapolation models are not yet well established. Pure tin (or other high tin content alloys) are not immune to whisker formation. In spite of the lack of understanding, the industry is moving towards Pb-free electronic devices and assembly. Thus, there is a need to define a specification combining tin whisker mitigation practices and acceptance testing that can be used by suppliers and users to minimize the exposure of tin whiskers in high reliability applications. This document is intended to define a set of mitigation practices plus test conditions and criteria for evaluating devices that have a Sn finish. This document is expected to change as more data and perhaps technical understanding of whisker formation becomes available.

### **2. Scope**

This document addresses the requirements for tin whisker mitigation practices and tin whisker testing necessary for user acceptance of pure tin, or high tin content tin alloy finishes such as SnAg, over base materials typically used in leadframe type applications. Lead-free component finishes that use noble metals such as NiPdAu, and do not contain a high percentage of Sn, do not require tin whisker testing.

The data generated for this acceptance testing may be used to meet the requirements for all customers utilizing the same equipment as detailed in Appendix A.

### **3. References**

- 3.1. Recommendations on Lead-Free Finishes for Components Used in High-Reliability Products\* (updated May 2005), iNEMI Tin Whisker User Group.
- 3.2. JEDEC standard JESD22A121, Test Method for Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes, published May 2005 (based on recommendations of the iNEMI Tin Whisker Accelerated Test Project).
- 3.3. IPC/JEDEC J-STD-020, Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices.

3.4. Annotated Tin Whisker Bibliography & Anthology,\* Dr. George T. Galyon, IBM Server Group, Chair, NEMI Tin Whisker, Modeling Project, September 2003.)

\* All iNEMI documents are available at  
[http://www.nemi.org/projects/ese/tin\\_whisker\\_activities.html](http://www.nemi.org/projects/ese/tin_whisker_activities.html)

#### 4. Background

Because of the lead-free movement in the electronics industry and the European RoHS directive, many component manufacturers are changing from tin-lead (SnPb) to pure tin (Sn) and high-tin content alloys for the final finish of solderable surfaces. Pure tin and high-tin content alloys are subject to tin whisker formation and growth. Reference 3.2 provides a definition of tin whiskers for the purpose of this document. Tin whiskers are believed to grow in order to relieve stress in the tin layer. At this writing, the exact mechanism for whisker growth is unknown.

Tin whiskers are a reliability concern. They can cause electrical shorts, disruption of moving parts, and/or degraded RF/high-speed performance. Tin whiskers may grow between adjacent conductors of different potentials and cause either a transient short circuit as the whisker is burned open, or a permanent short if the whisker remains intact. At shorter lengths, whiskers may also create a stub type effect that degrades performance of high-speed/high-frequency circuits. Additionally, whiskers can potentially break loose, and as debris cause mechanical or other electrical problems.

There are also a number of customer specifications that prohibit the use of pure tin finishes without adequate tin whisker mitigation. This document is written with the intent of providing sufficient test data to address those requirements.

This document requires the use of the tin whisker test and inspection method defined in reference 3.2, Tin Whiskers Growth Tests. In addition, this document adds test lengths, failure criteria, number of parts, and additional bias voltage testing. Since the exact mechanisms for whisker growth are not understood at this writing, and there are not currently any acceleration factors to relate any of these tests to actual field conditions, adherence to this specification does not eliminate the chance of a whisker-related failure in service. However, iNEMI User Group members have accepted that meeting these requirements will reduce the density and length of tin-whiskers. At this time, there is no method known to guarantee the elimination of tin whiskers over the life of a product. Also, as more knowledge is gained, this document will be revised to reflect that knowledge.

#### 5. Tin Finish Requirements

The tin finishes shall be matte tin as specified in reference 3.1. Bright tin finishes are not acceptable. SnCu finishes are generally not preferred and are not always acceptable to all users.

## 5.1. Tin whisker mitigation requirements

Components qualified and accepted by the testing outlined in this document **shall** utilize one of the preferred mitigation practices specified in reference 3.1, Interim Recommendations on Lead-Free Finishes. These are briefly summarized as follows:

- a) Fusing (reflow above 232°C where the tin fully melts) by the component supplier of the tin plating within a short time frame after plating.
- b) Use of a hot dip tin (or tin alloy) finish rather than plating. Hot dip SnAgCu is the preferred alloy.
- c) Use of nickel plated barrier layer between the base material and the tin finish (see reference 3.1).
- d) Annealing/heat treating (150°C for 1 hour) of a matte tin finish within a short time after plating (typically less than 24 hours). See reference 3.1, section III, paragraph 7. This mitigation practice may not be acceptable to all users.
- e) Other acceptable mitigation practices as defined by reference 3.1 section III, paragraph 15.

## 6. Exceptions to these Test Requirements

Users have accepted for approximately 10 years, and many will continue to accept, small discrete resistor and capacitor device components with a matte Sn over Ni finish. These devices are exceptions to the test requirements outlined in this document, but must meet all of the following criteria to be acceptable:

- a) The Sn finish shall be matte tin as specified in reference 3.1.
- b) The Ni under layer shall be at least 2µm (80 micro inches).
- c) The supplier shall have data to substantiate control of his processes to minimize whisker growth (see paragraph 20).
- d) The devices must not require any lead forming or other stress creating operations after final finish.
- e) Tin plating thickness greater 2 µm (80 micro inches) is the minimum acceptable.
- f) New component types must be similar in size and construction to previously accepted components.
- g) Plating of new component types must use the same plating lines, chemistries, etc. that have been previously accepted (see Appendix A).
- h) New component types must also pass this test unless specified by the using company.

## 7. Overview of Testing

The tin whisker acceptance testing recommended by iNEMI consists of three segments in accordance with reference 3.2 (Tin Whiskers Growth Tests): two isothermal tests and one thermal cycling test. This acceptance requirements document extends the required testing to include assembly, preconditioning, and bias to represent actual use conditions. In accordance with reference 3.2, testing must include: 1) a high temperature/humidity aging test for a minimum of 4000 hours, 2) a storage test at ambient conditions for a minimum of 4000 hours, and 3) a thermal

cycle test for a minimum of 1000 cycles. The requirements for these tests include as-plated components, components preconditioned to simulate second level assembly, and components assembled and with a 5-volt bias applied. These tests are representative of true storage and field use conditions. As such, longer test times are preferred than the minimum 4000 hours specified.

## 8. Definitions

### 8.1. Tin finish under test

This is the finish that the component supplier is attempting to qualify. It must use one of the previously mentioned mitigation practices.

### 8.2. Accepted finish

This is the incumbent tin-lead finish that is currently in production and accepted by users. It contains a minimum of 2% Pb.

### 8.3. Reference Components

These are components with the currently accepted finish.

### 8.4. Calibration Specimens

Coupons or components with whiskers used for validation of optical inspection methods. These can be existing samples of whiskers, or may be generated during the testing.

## 9. Test Components

Test components shall be representative of actual products to which the finish shall be applied. For the bias testing, samples must use devices with the minimum lead pitch to be qualified. Parts may be qualified by “like construction.” Like construction includes, for example, but not necessarily limited to, same basis material, same plating process (agitation, chemistry, current density, etc. – see Appendix A for details), and same lead forming processes.

## 10. Plating Method

The plating process and supplier(s) used for the tin finish under test shall be the production plating process and supplier proposed for qualification. Each plating process shall be qualified separately.

## 11. Sample Size

Three components from each of three different plating finish lots are required for each of the various tests. Each lot shall be from a different date code and plated at least one week apart. A total of 81 components are required for each finish under test, along with three reference components. The breakdown of these requirements is

shown in table 1; complete details of each test condition and preconditioning requirement follow.

# Components (leads)/Lot (minimum) <sup>(1)</sup>	# Lots	Precondition <sup>(3)</sup>	Test Condition	Total # Components (leads) (minimum)
3 (30)	3	4 weeks at room temperature	Storage – No Bias	9 (90)
3 (30)	3	4 weeks at room temperature	Aging – No Bias	9 (90)
3 (30)	3	4 weeks at room temperature, then Assembly Simulation @ 215°C	Storage – No Bias	9 (90) <sup>(3)</sup>
3 (30)	3	4 weeks at room temperature, then Reflow @ 255°C	Storage – No Bias	9 (90) <sup>(3)</sup>
3 (30)	3	4 weeks at room temperature, then Assembly Simulation @ 215°C	Aging – No Bias	9 (90) <sup>(3)</sup>
3 (30)	3	4 weeks at room temperature, then Reflow @ 255°C	Aging – No Bias	9 (90) <sup>(3)</sup>
3 (30)	3	4 weeks at room temperature, then Assembly Simulation @ 215°C	Thermal Cycle – No Bias	9 (90)
3 (30)	3	4 weeks at room temperature, then Reflow@ 255°C	Thermal Cycle – No Bias	9 (90) <sup>(3)</sup>
3 (30)	3	4 weeks at room temperature, then Assembly @ 215°C	Storage – Bias	9 (90) <sup>(2)(3)(4)</sup>
			Total Components Required	<b>81 (810)</b>

Table 1: Sample Size and Preconditioning

(1) When number of leads per devices is less than 10, increase the minimum number of components in the sample size until the minimum number of leads (in parenthesis) is met

(2) Not required for 2-lead discrete components such as resistors and capacitors

(3) Not required when nickel under plating of the tin is the mitigation practice used except for compliant pin connectors.

(4) This test is for “technology qualification” and has reduced requirements. See paragraph 16.

## 12. Reference Components

Supplier shall also test reference components (components with the currently accepted finish) through these same tests. The number of lots required to be tested is reduced to one and the number of components per lot is reduced to 1 also. See table 2 requirements. If SnPb reference components do not exist, or are not available, the acceptance requirements of paragraph 18.1 no longer apply and the requirements of paragraph 18.2 are mandatory.

# Components (leads)/Lot (minimum) <sup>(1)</sup>	# Lots	Precondition	Test Condition	Total # Components (leads) (minimum)
1 (10)	1	None	Storage – No Bias	1 (10)
1 (10)	1	None	Aging – No Bias	1 (10)
1 (10)	1	None	Thermal Cycle – No Bias	1 (10)
			Total Components Required	<b>3 (30)</b>

Table 2: Reference Component Sample Size and Preconditioning

(1) When number of leads per devices is less than 10, increase the minimum number of components in the sample size until the minimum number of leads (in parenthesis) is met

## 13. Calibration Specimens

Three tin whisker specimens for optical calibration are required as follows; One specimen with whiskers below 15 µm in length, one specimen with tin whiskers in the range of 30-50 µm in length, and one specimen with whiskers greater than 60 µm in length. These calibration specimens are only required if SEM is not used for detailed inspection. See paragraph 17. In this case, calibration specimens shall be used to calibrate and confirm that optical inspection can consistently and accurately find and measure tin whisker length compared to SEM. This shall be done statistically and need only be done one time for any given optical inspection and measurement method. Once this is proven, calibration specimens are no longer required. These calibration specimens can be created during the testing, or can be from existing tin-whisker examples.

## 14. Post Finishing Inspection

Prior to assembly, reflow or any testing, a representative sample of the test, reference and control specimens shall be inspected in accordance with reference 3.2, paragraph 3.2, for the presence of "whisker like" features (such as dendrites) that are a function of the finish itself and might be mistaken for whiskers in the post testing inspections. If any of these are noted, they should be recorded and photographed for reference and comparison to any final inspections. The inspection procedure is detailed in reference 3.2.

## 15. Preconditioning

Test and reference components shall be preconditioned at room temperature for a minimum of 4 weeks after finishing, as defined by the tables above and the following. Preconditioning is not required for devices with nickel under plating.

### 15.1. Assembly simulation @ 215°C

Subject the reflow simulation components to one typical SMT reflow profile for SnPb assembly (reflows SnPb, but not the tin finish under test). (See J-STD-020 if more details are required.) Peak temperature shall be 215°C +/- 5°C. Temperature should be measured using thermocouples on the lead surface.

### 15.2. Reflow @ 255°C

Subject the reflow @ 255°C components to one typical SMT reflow profile for SnAgCu assembly. (See J-STD-020 if more details are required.) Peak temperature shall be 255°C +/- 5°C. Temperature should be measured using thermocouples on the lead surface.

### 15.3. Assembly @ 215°C

Assemble the components requiring preconditioning as “assembly @ 215°C” to the test board used for the bias testing using SnPb solder. (See appendix C for test board design suggestions.) The solder stencil thickness shall be a maximum of 5 mils (125µm) with the intent of maximizing the exposure of the original component finish after reflow. Reflow shall be a typical SMT reflow profile for SnPb assembly. (See J-STD-020 if more details are required.) Peak temperature shall be 215°C +/- 5°C. Temperature should be measured using thermocouples on the lead surface. It is acceptable for bias testing to be performed in a socket, rather than assembled to a circuit board, at supplier’s option. In this case, precondition the parts prior to testing using the assembly simulation @ 215°C as defined in paragraph 15.1. If this testing is to be performed in a socket, the supplier must ensure that removal from the socket for inspection will not damage any tin whiskers that form during this testing. Additionally, the sockets used must not abrade the entire lead surface. Unaffected areas of the lead must remain for whisker inspection. It should also be noted that the added mechanical stress of socket mounting may adversely affect whisker growth

### 15.4. Compliant pin connectors or other non-soldered components

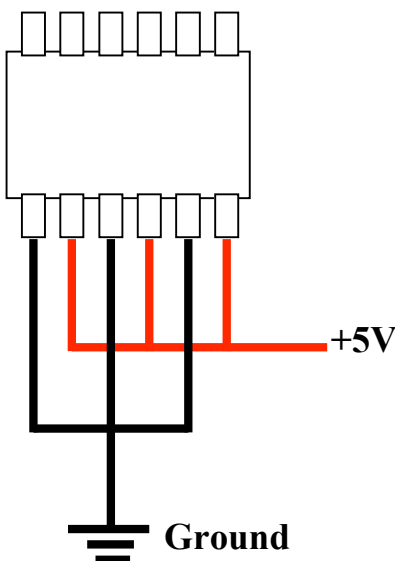
These preconditioning steps do not apply to compliant pin connectors or other non-soldered components.

## 16. Tests

### 16.1. Bias testing

Bias Testing applies to components only. It does not apply to test coupons. Two-lead components such as resistors and capacitors are exempt from the bias testing requirement. Components with matte tin over nickel, except for compliant pin connectors due to the added mechanical stress condition, are exempt from bias testing.

Bias testing is specifically for technology qualification. Only a single package type is required for this test. Each different substrate material must also be tested. (See specific additional requirements for compliant pin connectors in section 16.1.1.) This test is to determine if whisker growth for the tin plating is affected by bias or not. The preference is that whisker growth not be affected by bias. If bias is found to affect whisker growth with a given process, a more thorough analysis is required. Components that require bias testing for tin whiskers shall be of the minimum lead pitch to be qualified for a given substrate, chemistry, alloy, plating process (see Appendix A). A +5 volt bias shall be established between adjacent leads of the device and maintained through the entire test process. A rough block diagram of the test PCB setup is shown below. (Note – dummy components with shorted lead frames will not work for this test.) Multiple components may be assembled on a single test board. It is recommended that at least        of the leads on the devices under test be biased. In any case, a minimum of three pairs of leads is required to be biased – even if multiple components are required to achieve this. See Appendix C for additional test PCB design guidance.



#### 16.1.1. Compliant pin connectors

For compliant pin connectors (and similar devices), the connectors (or devices) used for bias testing shall be inserted one time into a 1.6 mm (.062 inch) thick (or



the minimum thickness that the compliant pin configuration supports) and the bias applied across the minimum pitch of the connector. Compliant pin connections shall not be soldered. Each separate type of compliant pin, substrate material, finish type, pin size, and/or action type (eye of the needle, action pin, etc.) shall be tested separately. The bias testing need only be done on a single action type. However, in all cases, all action types shall be tin whisker tested inserted into an actual board as above, regardless of whether or not the bias testing is required.

#### 16.2. Storage test (ambient conditions)

Components, after preconditioning, both with and without bias as required, shall be stored per the ambient storage conditions of reference 3.2 for a minimum of 4000 hours or as required by paragraph 18.2. After storage, inspect for whiskers per the

#### 16.3. Aging test (temperature/humidity)

Components, after preconditioning, both with and without bias as required, shall be aged per the temperature/humidity requirements of reference.2 for a minimum of 4000 hours or as required by paragraph 18.2. After aging, inspect for whiskers per the requirements of reference 3.2.

#### 16.4. Thermal cycle test (temperature cycling)

Components, after preconditioning, shall be temperature cycled per the requirements of reference 3.2 for a minimum of 1000 cycles or as required by paragraph 18.2. After thermal cycling inspect for whiskers per the requirements of reference 3.2.

### 17. Inspection Requirements

Prior to the inspection of reference 3.2 the test specimens shall be prescreened for the presence of whiskers using an optical microscope or SEM and detailed evaluation of the whisker length of representative areas containing the longest whiskers, based on this prescreening, shall be done per the methods of reference 3.2.

When optical inspection only, and not SEM, is used for the detailed inspection, the optical inspection method shall be qualified against the SEM using the calibration samples as defined in paragraph 13. The optical measurement technique shall be studied and compared using SEM measurements as the standard. A minimum of five whiskers shall be measured using SEM. These shall include one whisker < 15 µm in length, three whiskers in the range of 30-50 µm in length, and one whisker > 60 µm in length. These same whiskers shall also be inspected optically. The optical measurements shall be repeated for each whisker a minimum of three times (a complete setup of the optical microscope/measuring equipment). When multiple inspectors are used for optical inspection, this variation shall be included in the repetitions. The accuracy and repeatability of the optical measurements shall be within 5µm of the SEM measurements at the +/-3 sigma limits. This study need only be done one time for a given optical inspection technique.

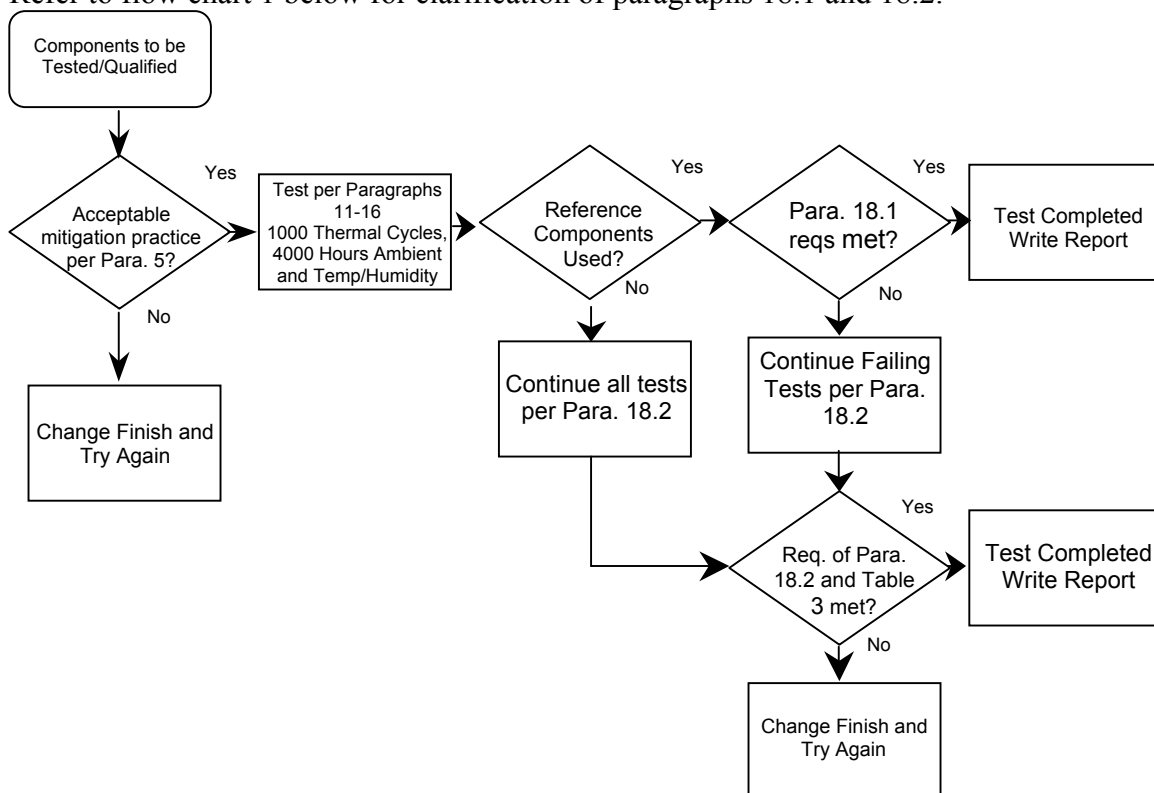
Inspection and reporting shall be per the requirements of reference 3.2 except as modified following: The inspection of components in the bias testing is only required at the 4000

hour point and need not be taken at every interval specified in reference 3.2. If the bias testing does not result in tin whiskers that are longer than those found in the same condition without bias, continuation of this test leg is not required. If tin-whisker growth is longer with bias than without bias, this test must be continued per the requirements of paragraph 18.2. At supplier's option, whisker inspections may be delayed until after completion of the minimum 1000 thermal cycles or 4000 hours (and not done periodically during the testing). Note that this may increase the test times as whisker length may saturate prior to these intervals being met (see paragraphs 18.1 and 18.2).

## 18. Acceptance Requirements

Whisker acceptance requirements are based on the maximum length whisker observed.

Refer to flow chart 1 below for clarification of paragraphs 18.1 and 18.2.



Flow Chart 1

### 18.1. Equivalent performance

The “tin finish under test” shall perform equivalently to or better than, the “accepted finish” (tin-lead alloy reference components) that it is replacing in all tests after 1000 thermal cycles, and 4000 hours in each of the storage and aging tests as further defined in section 16. If reference components are not used or available, all tests must continue per paragraph 18.2, treating all tests as if this requirement has not been met. Data from reference components

previously tested in identical test conditions per this specification may be used in subsequent tests.

## 18.2. Additional testing required

If the requirements of Section 18.1 above are not met for any one of the test segments described in Section 16, the tests shall be continued per the following requirements. Only the tests, in which the “plating under test” did not perform as well as the “accepted finish” must be continued (for instance, thermal cycling after preconditioning).

18.2.1. The thermal cycle test will be continued to a minimum of 2000 thermal cycles or until 2 additional consecutive measurements (a total of 3 consecutive measurements), at 500 thermal cycle intervals, whichever is longer, of tin whisker length show no increase. It is recommended that the same parts are used and the same locations inspected and measured each time. If this is not possible, the sample size shall be sufficient to show statistical significance to the data using F and T type tests with 95% confidence levels. Whisker measurements shall be made every 500 thermal cycles until the test is completed.

18.2.2. The aging and storage tests shall be continued until a minimum of 5000 hours or until 2 additional consecutive measurements (a total of 3 consecutive measurements), at 1000 hour intervals, whichever is longer, of tin whisker length show no increase. It is recommended that the same parts are used and the same locations inspected and measured each time. If this is not possible, the sample size shall be sufficient to show statistical significance to the data using statistics “F” and “T” tests with 95% confidence levels.

18.2.3. The maximum whisker length requirements of Table 3 below shall be met.

<b>Maximum Whisker Length</b>			
<b>Device Considerations</b> (Package type, lead pitch or operating frequency)	<b>Class 1</b>	<b>Class 2</b>	<b>Class 3</b>
<b>Discrete Device (2 pins)</b>	Pure tin and high tin content alloys not acceptable.	40 $\mu\text{m}$	67 $\mu\text{m}$ <sup>(1)</sup>
<b>Multi-lead packages</b>			(Minimum gap between leads - .05mm)/3 or 67 $\mu\text{m}$ , whichever is smaller <sup>(1)(2)(3)</sup>
<b>Operating Frequency &gt; 6GHz (RF) <sup>(4)</sup> or <math>t_{\text{rise}} &lt; 59</math> psec (digital)</b>			50 $\mu\text{m}$

**Table 3: Whisker Length Limits**

Notes for Table 3:

- (1) Many of these devices are used in high frequency/high speed applications and must also meet those requirements.
- (2) This spacing does not account for dam bar protrusion, which is a risk area.
- (3) This spacing accounts for up to 0.05mm bent leads. The maximum of 67 $\mu\text{m}$  accounts for adjacent discrete devices.
- (4) The susceptibility to degradation associated with tin whiskers increases with frequency. The maximum frequency analyzed to arrive at this limit was 20GHz.

### 18.3. Class definitions for Table 3

It is up to the discretion of the company purchasing components to classify its products. Below are general guidelines for product classes. However, these guidelines may not apply in all cases.

#### 18.3.1. Class 1

Mission/Life Critical High-Reliability Applications — military, space and medical applications. Pure tin and high tin content alloys not acceptable.

#### 18.3.2. Class 2

High-Reliability Business Applications — telecom infrastructure equipment, high-end servers, etc. which require long product lifetimes and minimal downtime. Products such as disc drives typically fall into this category. Breaking off of a tin whisker is a concern.

### 18.3.3. Class 3

Consumer Products — with relatively short product lifetimes (typically five years maximum). No major concerns by the user that the tin whiskers might break off and cause problems elsewhere in the product.

## 19. Qualification Test Report

The final qualification test report shall detail the components, tests, processes, equipment and finish characteristics used in this testing. Specific requirements in the report include, but are not limited to the following:

- Plating facility, line, chemistry, etc. as defined by Appendix A
- Component package type, under layer plating (if any), and lead frame base material(s)
- Plating and under layer plating (if any) thicknesses
- Date of plating of each lot and lot identification
- Tin and under layer plating requirements of reference 3.2 Appendix B
- Preconditioning reflow profile details
- Date of preconditioning
- Bias test board description
- Sample sizes
- Inspection equipment details including SEM make and model and magnifications used.
- Whisker length results for each test graphed at the specified intervals
- If applicable, the optical inspection qualification data per paragraph 17 shall be supplied.
- A summary of the test results versus the requirements of this specification. Each test condition, including the preconditioning and bias requirements as applicable shall be addressed. Sufficient data, such as graphs, SEM photographs, etc. shall be provided such that user acceptance can be clearly determined per the requirements of this specification.

## 20. Process Controls and Periodic Testing

The following requirements shall be met in addition to the above for any Pb-free, Sn-based finishes.

### 20.1. Process Limits

Supplier shall define acceptable values and tolerances for plating process parameters. These parameters will include current density, voltage, acidity, bath chemistry (sulfate vs. MSA), bath contamination with Cu, Zn, Pb, Ni, Fe, and added carbon-based compounds. Plating process parameter values or tolerances will not be mandated, but require that platings made with supplier-defined acceptable values and tolerances pass the whisker testing requirements specified previously. The process parameters shall be recorded for the lots tested, and maintained on subsequent lots. Carbon content shall be kept below 0.05%. Copper content (except for SnCu alloys) should be kept below 0.5%.

## 20.2. Process Controls

Supplier will establish a system to measure and to control (within established tolerances) plating process parameters known or suspected to influence whisker growth (as defined by supplier in requirement #1).

## 20.3. Plating Characteristics

Supplier will establish a system to measure and to control (within established tolerances) characteristics of the tin plating known or suspected to influence whisker growth. These characteristics will include plating thickness, stress in the plating, plating grain size, plating carbon content, plating crystallographic texture, and plating alloy percentage (if appropriate).

## 20.4. Process Changes

Whenever a change is made to any of the process variables defined by Appendix A, this testing shall be repeated to the extent required to address the changes made.

## 20.5. Ongoing Tin Whisker Monitoring

Supplier will establish a system to periodically monitor the performance of the processes for whisker generation. The specifics of this system are left to the supplier however the following minimum guidelines are suggested.

- A representative sample of components should be taken for each designated time period
- The time period for these samples should be at least monthly
- The storage conditions for these components should include a relative humidity of 60% or greater. Using the ambient test conditions of reference 3.2 is preferred.
- The samples should be inspected for whiskers 6 months from the date of plating.
- Results should be compared to baseline measurements. If these are exceeded, supplier should take appropriate corrective actions.

## Appendix A: Whisker Test by Similarity Determination Matrix

	Example/Notes	Separate Whisker Test Required?
<b>Assembly Process</b> <sup>(1)</sup>	Different Trim and Form methods	Yes
<b>Lead Form</b>	<u>For IC packages:</u> The gull wing configuration (if applicable) shall be tested. If not applicable, select the lead form that has the most extreme case of tin deformation due to trim and form operations. <u>For connectors or other packages:</u> Select the product for testing that has the most extreme case of tin deformation due to trim and form operations	Select per Notes column
<b>Lead Dimension</b>	0.25mm wide, 0.18mm wide...	No
<b>Pin Count</b>	52, 64, 80...	No
<b>Basis Materials</b> <sup>(2)</sup> <b>(Leadframe Material/Under plating)</b>	The material directly under the tin. Cu alloy C19400 (CuFe2), C70250 (CuNiSi), Alloy42 (FeNi42), Ni barrier plating	Yes
<b>Finish Alloy</b>	Sn, Sn/3.5Ag, Sn/3.0Bi, Sn/1.0Cu, Sn/3.0Cu...	Yes
<b>Bath Chemistry</b>	Supplier A, XXX; Supplier A, YYY; Supplier B, ZZZ...	Yes
<b>Plating Process</b> <sup>(3)</sup> <b>or Dip Process</b> <sup>(4)</sup>	High speed reel to reel, High speed belt, Low speed rack/barrel/cassette or Jet plating. Agitation, Current density, Bath Temperature...	Yes
<b>Equipment</b>	Supplier A; Supplier B...	No
<b>Factory</b>	Factory A, Factory B...	Yes
<b>Plating Line</b>	Line 1, Line 2... in same or different factory (provided process is the same per above)	No

Notes:

(1) If post finishing assembly processes (typically trim and form) can be shown to be essentially identical where the mechanical and thermal stresses added to the component are similar, then one set of tests can be done to address them all.

(2) If a nickel barrier is used, then a change to the copper alloy under the nickel does not necessitate a new whisker qualification

(3) The plating process includes variables suspected to affect whisker growth such as agitation, additive levels, metal content, acid content, temperature, current density, impurity levels. These factors should be evaluated to the edges of the acceptable process control window to ensure whisker control over the entire process spectrum. These can be evaluated through a design of experiments approach and tested to the conditions outlined in this document. If the supplier cannot test qualification samples to the edge of the

process window, then any changes to the plating process (e.g., current density, agitation, etc.) will require re-qualification.

(4) Changes in solder dipping processes would include items such as, but not necessarily limited to, flux or any other chemistry change that would affect impurity levels or content in the solder dip baths, immersion rate, cooling rate, or any other variable that is suspected to affect tin whisker growth.



## Appendix B: Brief Summary of Rationale for Mitigation Practice and End Item Requirements

Historical data (reference 3.4) does not support matte tin over copper as whisker free or as a viable whisker mitigation practice for electronic components. The following summarizes results of whisker length data compared to mitigation practices.

Mitigation Practice	Maximum Historical Data on Tin Whisker Length
Reflowed Tin	<100 $\mu\text{m}$
Hot Dipped Tin (or tin alloy)	<100 $\mu\text{m}$
Matte Tin over Nickel	<100 $\mu\text{m}$
Annealed Matte Tin over Copper	<100 $\mu\text{m}$
Matte Tin over Copper	800 $\mu\text{m}$

Test data also shows significant variability in whisker performance for finishes with similar mitigation practices plated under different conditions. This makes it clear that **both** a viable mitigation practice and testing of the finish are required to reduce the risk of tin whiskers to the end user.

To determine the end item requirements, a number of questions need to be answered:

- 1) What is the maximum whisker length we can allow without a short?

In the worst case, the maximum allowable whisker length is equal to \_ the distance from a lead to another lead or lead on another component or 1X the distance to the nearest trace on the PCB. The worst case assumes that two whiskers grow directly toward each other. The table below provides example real numbers for this condition.

- 2) What happens if a tin whisker breaks off? Where does it go?
- 3) What is the maximum whisker length that can be allowed without an adverse affect on RF/high-speed performance?

This was modeled by Alcatel's microwave group. It is a complex function of whisker length, whisker density, and operating frequency. The negative effect starts at 6 GHz RF or higher or roughly  $t_{\text{rise}}$  of 58 psec or less in a digital circuit. To simplify the test requirements for whisker growth, it was determined that if the maximum whisker length could be kept below 75 $\mu\text{m}$  the effect was negligible.

- 4) What are the sources of error in the testing and what safety factor is required to accommodate for these sources of error in setting final length requirements?

Some of the sources of error identified in this test method are:

- a) Sample size – it is not possible to be sure that the whiskers identified are truly representative of the longest whisker. A much larger sample size combined with statistical analysis would increase the confidence in the results but would dramatically increase the effort and the cost of testing.
- b) The measuring accuracy of the SEM/optical microscope analysis.
- c) The angle of the whisker relative to the measurement direction in the SEM/optical microscope when attempting to determine its length.
- d) Since the fundamentals of whisker growth are unknown, there is no way to ensure that these tests truly reflect long field life requirements of products such as the 25 year life requirement for some Telecom Infrastructure equipment.
- e) The tests drive the whisker growth to “saturation” in that measurement of whisker length must remain unchanged for three consecutive measurements. However, due to measurement inaccuracy, it is impossible to know with confidence that very slow whisker growth is not still occurring. Additionally, there is no way to know if these tests are truly representative of field conditions. Nothing guarantees that whisker growth will truly saturate in field conditions.
- f) The tests as defined do not account for any possible damage to the components such as scratches in the finish that might exacerbate tin whisker growth.

### Whisker Length Based on Shorting Potential

<b>Device Pitch</b>	<b>Typical Minimum gap between leads<sup>(1)</sup></b>	<b>Maximum allowable whisker length in application (=1/2 min typical gap)</b>	<b>Maximum allowable whisker length in testing (safety factor = 2/3 maximum distance)</b>	<b>Maximum allowable whisker length in testing (safety factor = _ maximum distance)</b>
<b>Discrete Device (2 pin)</b>	200 $\mu\text{m}$	100 $\mu\text{m}$	67 $\mu\text{m}$	50 $\mu\text{m}$
<b>2.54 mm or greater</b>	889 $\mu\text{m}$ (shoulder to shoulder on a DIP)	444 $\mu\text{m}$	296 $\mu\text{m}$	222 $\mu\text{m}$
<b>1.27 mm to &lt; 2.54 mm</b>	500 $\mu\text{m}$ (1.27mm pitch SOIC JEDEC MS-012)	254 $\mu\text{m}$	169 $\mu\text{m}$	127 $\mu\text{m}$
<b>0.65 mm to &lt; 1.27 mm</b>	150-200 $\mu\text{m}$ <sup>(2)</sup> (JEDEC MS-204)	75 – 100 $\mu\text{m}$	51 – 67 $\mu\text{m}$	38-50 $\mu\text{m}$
<b>0.5mm to &lt; 0.65 mm</b>	125–150 $\mu\text{m}$ <sup>(2)</sup> (JEDEC MS-204)	63 -75 $\mu\text{m}$	42-51 $\mu\text{m}$	32-38 $\mu\text{m}$
<b>0.4mm to &lt; 0.5mm</b>	120 $\mu\text{m}$ <sup>(2)</sup> (JEDEC MO-194B)	60 $\mu\text{m}$	40 $\mu\text{m}$	30 $\mu\text{m}$
<b>Typical nearest distance to surface trace</b>	356 $\mu\text{m}$ (accounts for horizontal plus vertical)	178 $\mu\text{m}$ – not counting for bent leads.	119 $\mu\text{m}$	89 $\mu\text{m}$

(1) Numbers in table do not account for dambar protrusion – which is a risk area.

(2) Allowance included in numbers for bent leads.

## **Appendix C – Bias Test Board Design Considerations**

The Bias test board design should be kept as simple as possible.

Board thickness:

Board thickness is not critical. 1.6 mm (.062 inches) is recommended.

Board size:

The board must be small enough to fit in a SEM for inspection. A maximum recommended size is 38 mm (1.5 inches) x 76 mm (3 inches). To simplify assembly and bias connections, these should be designed into a larger assembly panel and carefully removed for test and/or inspection.

Components:

Multiple components may be assembled on the same circuit board.

Number of circuit layers:

The number of circuit layers should be kept to as few as possible. Typically two layers are sufficient.

Copper weight on circuit layers:

Copper weight on circuit layers is not critical. One-half ounce starting copper weight is recommended.

Trace widths and spacing:

Trace widths and spacing are not critical as the voltage is low and there is no current flow requirement. Trace widths of 200  $\mu\text{m}$  and spacing not less than 150  $\mu\text{m}$  are recommended for manufacturability reasons.

5 volt and ground connections:

Plated through holes should be used to connect the voltage and ground connections. The hole size should be based on the wire diameter required.

Bare board finish:

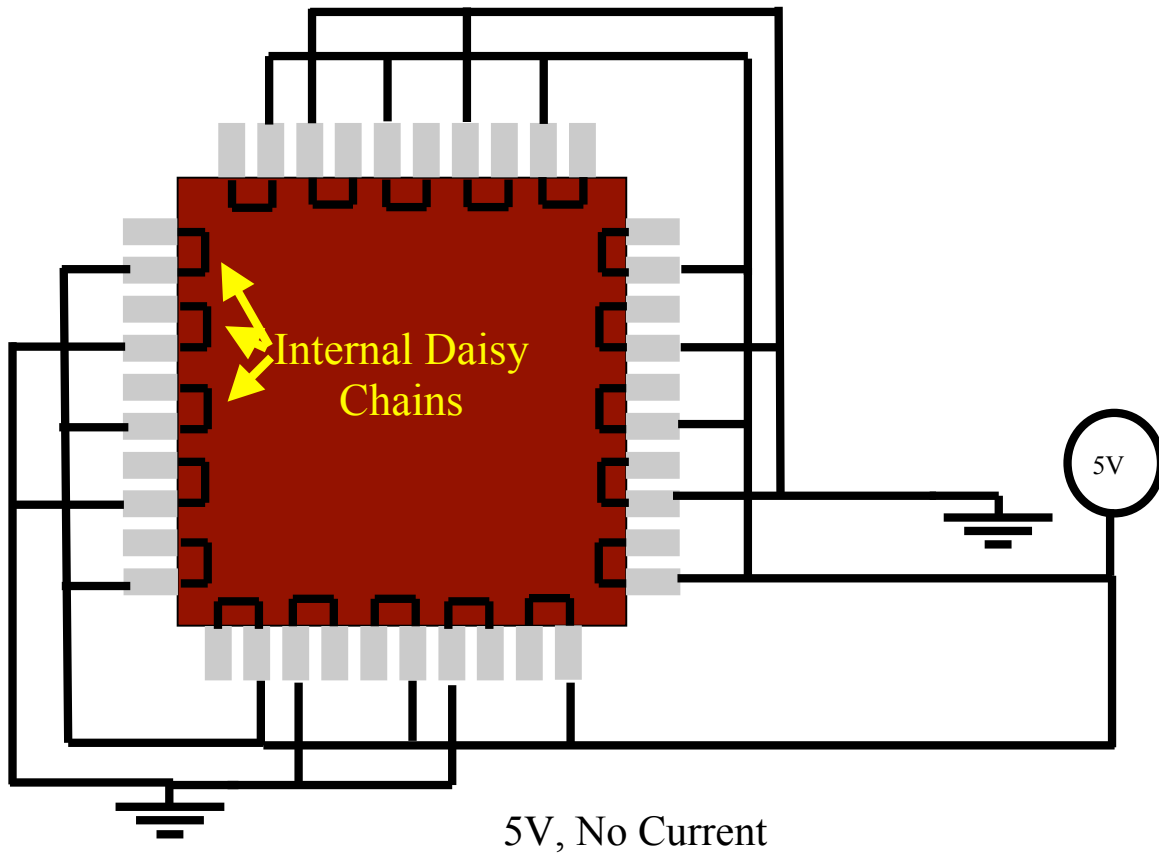
The finish of solderable circuits on the board is not critical. HASL (hot air solder leveling), OSP (organic solder preservative), ENIG (electroless nickel/immersion gold) immersion tin, or immersion silver finishes are all acceptable.

Solder mask:

The use of LPI (liquid photo-imageable) solder mask is recommended.

Example schematic:

Below is a simplified representative schematic for bias testing assuming the use of a daisy-chain QFP (quad flat pack). Note – it is not required that daisy chain components be used. It is required that adjacent terminals be biased. The daisy chain device is just given as an example.



--- End of Specification ---