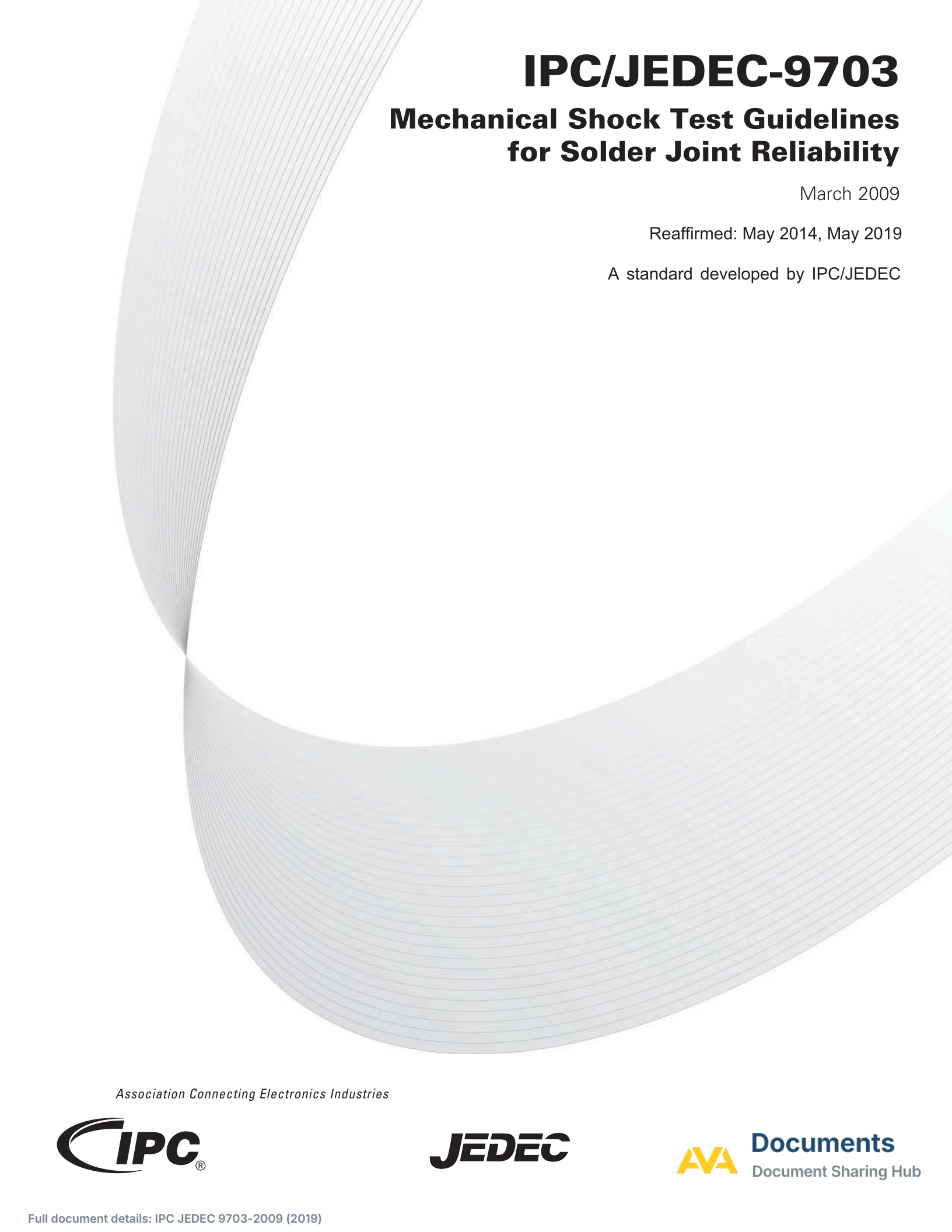




IPC/JEDEC-9703

Mechanical Shock Test Guidelines for Solder Joint Reliability

March 2009

Reaffirmed: May 2014, May 2019

A standard developed by IPC/JEDEC

Association Connecting Electronics Industries



The Principles of Standardization

In May 1995 the IPC's Technical Activities Executive Committee (TAEC) adopted Principles of Standardization as a guiding principle of IPC's standardization efforts.

Standards Should:

- Show relationship to Design for Manufacturability (DFM) and Design for the Environment (DFE)
- Minimize time to market
- Contain simple (simplified) language
- Just include spec information
- Focus on end product performance
- Include a feedback system on use and problems for future improvement

Standards Should Not:

- Inhibit innovation
- Increase time-to-market
- Keep people out
- Increase cycle time
- Tell you how to make something
- Contain anything that cannot be defended with data

Notice

IPC Standards and Publications are designed to serve the public interest through eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and improvement of products, and assisting the purchaser in selecting and obtaining with minimum delay the proper product for his particular need. Existence of such Standards and Publications shall not in any respect preclude any member or nonmember of IPC from manufacturing or selling products not conforming to such Standards and Publication, nor shall the existence of such Standards and Publications preclude their voluntary use by those other than IPC members, whether the standard is to be used either domestically or internationally.

Recommended Standards and Publications are adopted by IPC without regard to whether their adoption may involve patents on articles, materials, or processes. By such action, IPC does not assume any liability to any patent owner, nor do they assume any obligation whatever to parties adopting the Recommended Standard or Publication. Users are also wholly responsible for protecting themselves against all claims of liabilities for patent infringement.

IPC Position Statement on Specification Revision Change

It is the position of IPC's Technical Activities Executive Committee that the use and implementation of IPC publications is voluntary and is part of a relationship entered into by customer and supplier. When an IPC publication is updated and a new revision is published, it is the opinion of the TAEC that the use of the new revision as part of an existing relationship is not automatic unless required by the contract. The TAEC recommends the use of the latest revision. Adopted October 6, 1998

Why is there a charge for this document?

Your purchase of this document contributes to the ongoing development of new and updated industry standards and publications. Standards allow manufacturers, customers, and suppliers to understand one another better. Standards allow manufacturers greater efficiencies when they can set up their processes to meet industry standards, allowing them to offer their customers lower costs.

IPC spends hundreds of thousands of dollars annually to support IPC's volunteers in the standards and publications development process. There are many rounds of drafts sent out for review and the committees spend hundreds of hours in review and development. IPC's staff attends and participates in committee activities, typesets and circulates document drafts, and follows all necessary procedures to qualify for ANSI approval.

IPC's membership dues have been kept low to allow as many companies as possible to participate. Therefore, the standards and publications revenue is necessary to complement dues revenue. The price schedule offers a 50% discount to IPC members. If your company buys IPC standards and publications, why not take advantage of this and the many other benefits of IPC membership as well? For more information on membership in IPC, please visit www.ipc.org or call 847/597-2872.

Thank you for your continued support.



ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES®



IPC/JEDEC-9703

Mechanical Shock Test Guidelines for Solder Joint Reliability

Developed by the JEDEC Reliability Test Methods for Packaged Devices Committee (JC-14.1) and the SMT Attachment Reliability Test Methods Task Group (6-10d) of the Product Reliability Committee (6-10) of IPC.

Users of this publication are encouraged to participate in the development of future revisions.

Contact:

IPC
3000 Lakeside Drive, Suite 309S
Bannockburn, Illinois
60015-1219
Tel 847 615.7100
Fax 847 615.7105

or

JEDEC
3103 North 10th Street, Suite 240S
Arlington, VA 22201
Tel 703 907.7559

This Page Intentionally Left Blank

Table of Contents

[illegible]

Figure 8-2	Example of Correlation of a Board Test to Three Test Systems	17
Figure 8-3	Definition of Board Strain States Plot	17
Figure 8-4	Comparing Board Bend Modes of Board in System Chassis and Mounted to a Fixed Plate	18
Figure 8-5	Settling Time for a Typical System Level Test with High Damping and Rapid Decay in the Strain	18
Figure 8-6	Typical Time History for a Component Board Test with Minimal Damping	18
Figure B-1	Wire (a) Strain Gage Location with Respect to Solder Ball at Package Corner. (b) Orientation of Strain Gages for every Package Corner	22
Figure B-2	Wire Routing should be done So as Not to Affect Results	23
Figure B-3	Wire Artwork Showing Strain Gage Feature and Internal Board Routing	23
Figure B-4	Fast Fourier Transform of an Example System	23
Figure C-1	BGA Solder Joint Failure Modes	26
Figure C-2	Area Array Cross-Section Diagram	26
Figure E-1	Coarse Mesh of Plate	29
Figure E-2	Fine Mesh of Plate	29
Figure E-3	Rack Mounted Test Board	30
Figure E-4	Simplified Satellite Antenna Model	31
Figure E-5	Results for Simplified Satellite Antenna Model	32

Figure E-6	Comparison of Displacement-Time History for Experimental Data and FEA Result	37
Figure E-7	Comparison of Board Strain versus Time History for Experimental Data and FEA Result	37

Tables

Table 4-1	Example of a UC for a Mobile Phone, (Illustrative Only)	3
Table 7-1	Example of Critical Strain Determination Results. Value indicates number of drops at each level. (Shadows indicates electrical failure.)	14
Table 8-1	Recommended Matching Criteria for Selected Use and Test Conditions	16
Table A-1	Test Report Recommendations (Equipment and Materials)	20
Table A-2	Test Report Recommendations (Board Assembly)	20
Table A-3	Test Report Recommendations (Test Results)	21
Table B-1	Recommended Scan Frequencies for Various Systems	23
Table D-1	Sample Size Estimate for a Single Failure Mechanism	28
Table E-1	Full, Symmetric, and Asymmetric Meshes of Plate	30
Table E-2	Comparing Implicit and Explicit Dynamic Solutions	33

Mechanical Shock Test Guidelines for Solder Joint Reliability

FOREWORD

This publication has been drafted as part of a joint working group between the IPC 6-10d task group and the JEDEC JC14.1 subcommittee. It is intended to be used as a general guideline for mechanical drop and shock testing. It is also encouraged that future application specific mechanical shock standards and specifications for IPC and JEDEC should apply the methods proposed herein.

INTRODUCTION

With the growth of electronics and the increased accessibility and portability, drop shock and other mechanical impacts are increasingly a concern. This document attempts to improve upon past mechanical shock test methods, and tie test conditions back to the use-conditions. A method is proposed such that regardless of what level (system, board assembly, simplified single component board testing, etc.) testing is conducted, there should be a correlation back to the use-condition. In order to fulfill this goal, additional metrologies are introduced to aid in these correlations.

Following the requisite introductory sections, the concept of use-conditions is introduced and suggestions are made on how use-condition data may be acquired and applied. Next, the testing methods for fully assembled systems are introduced. Options for test conditions are discussed and the data that should be collected is outlined.

Testing of subassemblies and components mimics actual use configurations less than testing of fully assembled systems; however, the next two document sections outline considerations to ensure that testing done at these levels remains relevant to the intended use-condition.

Specific metrics to aid in correlations are outlined in Section 8. The informative annexes that close the document discuss the common considerations of all mechanical shock testing methods. These include a sample reporting format for test data, use and application of strain gages, accelerometers, and high speed photography. A section on failure analysis is given. Lastly, a review of finite element methods that may be applied to mechanical shock analysis is given to aid in more in-depth study of shock problems.

1 SCOPE

This document establishes mechanical shock test guidelines for assessing solder joint reliability of Printed Circuit

Board (PCB) assemblies from system to component level.

The three main categories discussed within this document follow:

1. Methods to define mechanical shock use-conditions.
2. Methods to define system level, system board level and component test board level testing that correlate to the use-conditions.
3. Guidance on the use of experimental metrologies for mechanical shock tests.

2 APPLICABLE DOCUMENTS

2.1 IPC¹

IPC-6012 Qualification and Performance Specification for Rigid Printed Boards

IPC-9252 Requirements for Electrical Testing of Unpopulated Printed Boards

2.2 American Society for Testing and Materials²

ASTM D3332 Standard Test Methods for Mechanical-Shock Fragility of Products, Using Shock Machines

3 TERMS AND DEFINITIONS

For the purposes of this document, the following terms and definitions apply:

Accelerometer An electronic device that converts mechanical deformation of an internal structure caused by acceleration into electrical signals that can be sensed by a data acquisition system.

Component Board Level Test A test conducted on a simplified test board which contains only one type of component, although multiple samples of the same component may be present. This board need not be similar to the final system board.

ODM Original design manufacturer.

OEM Original equipment manufacturer.

PWB Printed wiring board, also known as printed circuit board (PCB).

SRS A shock response spectrum is an analysis of the acceleration output signal into the frequency domain.

1. www.ipc.org
2. www.astm.org

Strain Gage A sensor of mechanical deformation consisting of one or more small serpentine structures whose electrical resistance is changed by deformation of the material to which the gage has been attached.

System Board Level Test Test of a system board with all major components being represented either by the actual components or equivalent test devices.

System Level Test Test of a fully assembled system including chassis or a major subassembly that is received by the end customer as a unit, (e.g., server modules). This may also include the packaging used during shipment of the system.

UC Use Conditions, a description of the expected events and frequency of occurrence during the life of the product.

4 USE CONDITIONS OVERVIEW

Historically, shock testing has been based on a few standardized acceleration conditions. This approach, while simple, is not optimal for the following reasons:

- One set of reliability requirements may not apply to all market segments.
- Testing to standards based tests, or military-based specifications may be unrealistic since it may not be cost effective for products with more mild requirements.
- Accelerated tests with fixed pass/fail requirements offer little insight into the likely lifetime of a product in the actual end-user environment.

This proposal employs market segment based use-conditions (UC). Market segment based use-condition testing offers several advantages:

- A better understanding of robustness and reliability for a specific product segment or for products and components in a specific application.
- Avoidance of over-engineering to meet a standardized acceleration condition, which could add cost.
- Scalability across multiple product form factors; meaning, portions of a usage behavior from one product type might be applicable to usage behaviors of a new product type.

4.1 Scope and Application of UCs For the scope of this document, the most valuable use-conditions are those that have direct impact on interconnection (e.g., solder joint) reliability.

Applicable UCs can typically be categorized into the major stages of a product's life cycle. Those stages include: assembly, shipping, storage, end-user environment and possibly returns and repairs due to issues in the field. Figure 4-1 gives examples of where these events may occur for several distinct system types. It should be expected that the types of events seen during the product life cycle may vary based on the market segment. Furthermore, UCs may

change over time, and/or UCs may become void and/or new UCs may become appropriate to capture. Periodic review is suggested.

4.2 Capturing UC Data Different parameters should be captured in order to completely define the use-condition. A mobile phone end-user drop UC example is given in Table 4-1. Number of drops, drop height, drop surface and drop orientation together completely characterize the end-user drop behavior.

4.3 Methods for Developing UCs Various methods may be used to define product or product segment UCs, as listed below. Thinking about the best approach to define UCs is often a useful starting point.

- If the UC has a strong impact on certification requirements, it may be appropriate to collect actual data.
- If a new product segment is similar to an existing segment, it may be appropriate to scale existing UCs to the new product segment.
- If time or budget is limited, collaboration of data sharing with existing UCs may be appropriate.
- Existing industry data may be leveraged based either on expected differences to the target application or may often be based on customer/user expectations.

Finally, if existing data offers insight into specific stages of the UC (e.g., the human handling portion of a shipping shock study), judgment can often be used to extrapolate those UCs to a new application.

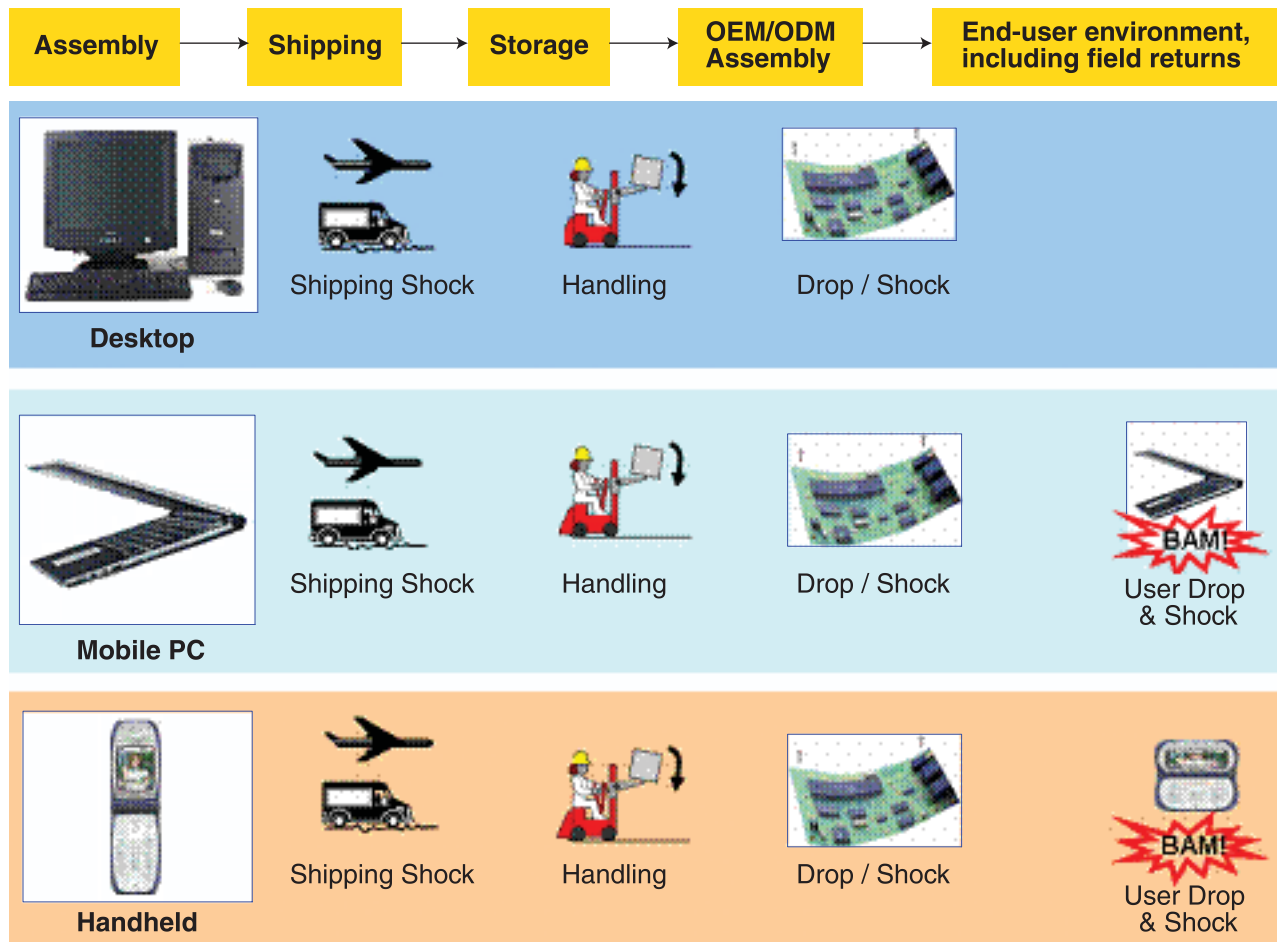
4.3.1 Approach 1 – UC Derivation Approach In this approach direct data collection is used to derive the UCs. This may be accomplished using user surveys, field observation of handling behavior, data logging tools, or other direct means. There are some limitations that should be considered in adopting this approach:

- Behavior will vary by distribution channel.
- Uncontrollable variables may be missed or may skew the results.
- Cost may be significant to obtain statistically valid data.

Example of Approach 1: For the example of shipping shock/drop, data collection is a viable and useful study to undertake, while being aware of its limitations mentioned above. Hardware is readily available in the industry to enable data logging of shipping shock/drop conditions. Some variations and modulators of results are to be expected, including:

- Development level of country.
- Road conditions, use of automated handling.
- Shipping method.
- Expedited air delivery, truck, train, etc.

Mechanical Drop / Shock Use Conditions Flow



IPC-9703-4-1

Figure 4-1 Typical UCs where Mechanical Shock May be Expected for a Few Representative Products

Table 4-1 Example of a UC for a Mobile Phone, (Illustrative Only)

UC	Value	Justification
Number of Drops	Three drops	Based on expected use
Drop height	1.50 meters	Based on human factors information
Drop surface	Concrete	Worst-case assumption
Drop orientation	Face-down	Worst-case assumption

Using data loggers attached to accelerometers inside the shipping box, one can determine the height and number of drops experienced by a single package during shipment. By repeating this shipping study with multiple routes and conditions, it is possible to develop a model of the shipping use-conditions.

4.3.2 Approach 2 – Leveraging Existing Data to Usage Model A usage model describes the interactions between a user and a product. It is based on the user needs (e.g., a FedEx® package handler vs. a corporate employee), user behaviors (e.g., drop on the floor, hard dock of a laptop

onto the docking station), product design (e.g., form factors) and the environment (concrete floor vs. laminate desk surface).

An understanding of specific usage scenarios will lead to identifying critical use-condition events of interest. Existing literature data (from publications) can often be leveraged to define the UCs that are relevant to a given market segment.

Example of Approach 2: Portable music player or barcode scanner manufacturers may have published certain drop heights, e.g., 1 meter, corresponding to waist height (relevant to their expected usage model). This data can be used to define a drop height of a mobile phone based on human figure proportions (e.g., ear height is ~1.5X waist height).

4.3.3 Torture Tests “Torture tests” such as a 762.0 mm [30.0 in] drop or “coffee spill” test for Mobile PCs, are sometimes used to evaluate performance against perceived or observed severe behavior and usage models. In most instances, torture tests may not be derived from actual

UC model or behavior. For torture tests, or other extreme usage models, care must be taken to balance reasonable expectations of performance against device survivability and acceptable costs necessary to enable increased robustness and reliability.

5 SYSTEM TESTS

The purpose of system level shock testing can be to either demonstrate the ability of the product to survive relatively infrequent, nonrepetitive shocks encountered during the intended UCs or to determine the products fragility level so that appropriate packaging can be designed. The goal of system testing is to replicate the UC environment utilizing laboratory equipment. These tests should be correlated to the UC environment.

The definition of a system may be a fully assembled system as well as sub-systems. (e.g., server modules, board assembly handled out of system, etc.)

System tests may be performed on either packaged or unpackaged systems. Packaged system tests are usually performed to demonstrate that the system and packaging can withstand shocks that may be encountered in the shipping and distribution environment. Unpackaged system tests are performed to either ensure the system has enough robustness to withstand handling shocks in a cost effective shipping package or to ensure the system can survive shock events experienced in a typical end-user environment.

The major factors to consider when defining a system shock test are as follows:

- Equipment that provides the appropriate environment.
- Input profiles that are correlated to use-condition profiles.
- Requirements that ensure the proper test article configuration and desired confidence level.
- Procedures that ensure proper test conditions and order of testing.
- Post test analysis that provides relevant and meaningful information.
- Reporting recommendations that include data necessary for follow-on testing or condition evaluation.

5.1 Shock Test Equipment

5.1.1 Drop Testers Package drop testers are simple machines that allow for repeatable dropping of packages in terms of height and orientation. Package drop testers can be either swing arm testers, drop platform testers, or large package quick release testers.

Swing Arm Testers: The swing arm tester is typically used when the package is small or light weight and the drop height is relatively large. Drop heights typically range from 30 to 150 cm [12 to 60 in]. The swing arm tester is usually

supplied with a motor hoist to automatically raise and lower the drop arm with package in place, a micro switch to preset the drop height for repeatable drops, a drop height indicator, and a remote hand switch to actuate the system. The tester should incorporate a small vertical drop prior to drop arm swing to ensure that the package is not subjected to rotation. Packages may be released from any angle but special procedures may be required to assure landing in the same position. The advantages of a swing arm tester is that it is fast and easy to use, provides for easy test article set up, and is relatively inexpensive. They are easy to install and require no facility modification. Their disadvantage is that test articles are limited in size and weight and there is a minimum drop height restriction.

Drop Platform Testers: Drop platform testers are typically used when the package is of moderate size and weight accommodating large products and packages weighing up to 227 Kg [500 Lbs]. They are capable of performing drops as low as 2.5 cm [1.0 in] and as high as 1.8 m [6 ft]. They are designed to ensure the flattest impacts possible but, in addition, they allow drop testing to be performed on the package's edges and corners for complete performance evaluation. The drop platform is raised and lowered by an electric hoist and released via an air actuator. During the drop test stage, the drop platform is accelerated downward, thereby allowing the package to free fall while the drop platform descends into slots below the impact surface. Rebound of the drop platform is prevented, usually by a hydraulic damper at the bottom of the slots. The advantages of the drop platform testers are that they can accommodate large packages, perform over a wide range of drop heights, and provide better guidance of edges and corners than other types of drop testers. The disadvantages are that they are relatively expensive and often require facility modifications to allow for the platform to drop below the impact surface. Because of the large size and heavy weights, they can pose a personnel safety risk and often require protective enclosures with safety interlocks.

Large Package Quick Release: The quick release drop testers are designed to drop test larger, bulkier packages than those possible with drop platform testers. They can perform repeatable free-fall drop tests (flat, edge and corner) on packages of virtually any size and shape and can accommodate packages weighing up to 1360 Kg [3,000 lbs]. Drop test height is limited only by the lifting device used (forklift, winch, etc.). The quick release drop testers consist of a quick release mechanism, a lifting ring, and a foot switch. Straps are wrapped around the test item from a sling that is attached to the lifting ring, which is placed in the jaws of the quick release mechanism. The quick release mechanism and package are then raised to a predetermined height by a forklift, winch, or other lifting device.

The foot switch activates a solenoid in the mechanism, causing the latch jaws to open and the test package to be released.

The advantages of the quick release drop tester is that it is relatively inexpensive compared to the other methods, provided the lab already has the lifting device. If the lab does not have a heavy duty lifting device then the cost increases considerably. The major disadvantage of this method is that it is difficult to maintain orientation of the object during the drop.

5.1.2 Shock Machines Shock tests are used to accurately measure the fragility of products and to evaluate protective packaging by applying a controlled acceleration profile. This test data is key information necessary to ensure that the product is capable of withstanding its “real world” environment. Shock machines are used to accurately and repeatedly produce shock profiles that are correlated to the environment that a system experiences in its shipping and in-use environments. Shock testing with controlled shock inputs is essential to discovering and understanding the risk area of a product.

Shock Test Systems – Large Format Shock Testers: Large format shock test systems have the ability to test items weighing up to 1,134 kg [2,500 lbs] with a footprint dimension up to 95 x 115 cm [37.4 x 45.3 in]. They can perform a wide variety of shock tests to a maximum acceleration of 600 G. The system consists of a shock table that is guided by two solid guide rods. The two guide rods are rigidly attached to a massive, isolated base that helps to attenuate any shock energy that would otherwise be transmitted to the surrounding building through the laboratory floor. Also mounted to the base are two damage boundary programmers, which allow the operator to generate both half sine and trapezoidal shock pulse waveforms.

At the start of a shock test the shock table is raised until it reaches the programmed drop height. Upon initiation of the drop sequence, the lifting mechanism is retracted clear of the shock table and the brake system releases, allowing the shock table to free fall. The shock table impacts the damage boundary programmer(s), creating the desired shock pulse waveform. As the shock table rebounds the brakes reengage to prevent any secondary impacts. The parameters that can be controlled in the operation of the shock system are drop height and programmer stiffness. The two types of damage boundary programmers commonly used are elastomeric impact cylinders and gas actuated plunger assemblies. The elastomeric impact cylinders are used to generate half sine profile shock pulses. The amplitude and duration of the half sine pulse can be controlled by the drop height of the table free fall and the geometry and durometer hardness of the elastomeric cylinders. The gas actuated plunger assemblies are used to generate square wave or trapezoidal wave shock pulses. The drop height of the table

free fall and the pressure in the plunger impact cylinder(s) control the amplitude and duration of the square wave pulse. The disadvantages of the large format shock test system are the cost and the limitations of acceleration profiles. The acceleration level is limited by the height of drop and free fall acceleration. Higher acceleration levels can be reached by the use of special adapter kits or by the use of High G shock machines.

High Acceleration (G) Shock Testers: The high G shock testers are similar to large format shock testers but are outfitted with a bungee cord acceleration system which more than doubles the velocity change capability. When using them in free fall mode-without the acceleration system-the maximum payload can be as high as 1,360 kg [3,000 lbs]. While in the accelerated mode, the maximum payload is limited to 113 kg [250 lbs]. They have a smaller test platform and can only accommodate test items with a footprint dimension up to 46 cm [18 in] square. A maximum velocity change of 25 m/sec [82 ft./sec] and a peak acceleration of 7,500 G can be obtained with specimens weighing up to 45 kg [100 lbs].

High G Shock Amplifiers: Another method of producing high G shocks is the use of a shock amplifier. Shock amplifiers produce high acceleration shocks on a spring loaded table. One such system, the mousetrap amplifier, consists of a base plate mounted on the top surface of the shock machine carriage, a specimen mounting carriage which is supported by soft springs and a resilient decelerating pad between the shock machine and its carriage. As the main carriage accelerates down, impacts upon its resilient pad and decelerates up, the specimen mounting carriage continues to travel downward (or in the opposite direction of the main carriage) as they collide. The resultant acceleration at impact is much greater than would be achievable if only the main carriage impacted against a stationary base. The mousetrap shock amplifier can be used for two primary purposes: as an amplifier to produce increased velocities or, because the mousetrap amplifier is supported on springs, the springs act as a “mechanical filter” which serve to reduce the ringing associated with short time duration pulses.

Vibration Machines: Electrodynamic, hydraulic, and pneumatic vibration machines can also be used to provide a source of shock pulses as long as the pulse requirements do not exceed the force and motion capabilities of the machine. These pulses are typically half sine pulses and can be on the order of a few milliseconds in duration and less than 100G in amplitude. The major drawback to this method is the pre- and post-pulse conditioning required to generate the shock pulse.

5.1.3 Inclined Impact The purpose of the inclined impact test is to demonstrate that the packaging and palletizing methods, wrapping and strapping methods

product will protect them from damage due to side impacts. Inclined impact simulates pallet collision with walls, truck bulkheads, or other loads experienced during loading of a truck, airplane, or transport of product in a storage area. The inclined impact test apparatus consists of a wheeled carriage, guided by steel rails, upon which the test item is placed. The rails are inclined at 10 degrees and there is an impact “backstop” at the low end, with its surface perpendicular to the carriage’s direction of travel. When the carriage is pulled up the rails and released, it freely rolls down the track and the specimen impacts the backstop.

5.1.4 Fixturing Test article fixturing refers to the method of holding the test article while subjecting it to the shock environment. It needs to simulate the boundary conditions of the use environment as much as possible. Care must be taken to not suppress the failure mode or vibration mode of interest.

Drop Test Fixturing: The fixturing for drop testing of packaged systems is the simplest since it only requires holding the package prior to the drop. The fixturing should not interfere with the motion of the package at impact, as this will impart unwanted loads into the test article. The standard practice for orienting the package before free fall drop is to ensure the desired impact location is aligned with the center of gravity of the packaged item. This is usually easy to achieve in flat edge drops but may require careful balancing for edge or corner drops.

The fixturing for drop testing of unpackaged systems is considerably more difficult. The system must be constrained to impact at the desired location while preventing any rotational motion of the test article. In addition, the fixturing must not impede the free fall motion of the system. It must also release the test article before impact so as to avoid any attenuation of the shock input upon impact.

Shock Table Fixturing: The method of fixturing the unpackaged system to the shock table should represent the use-condition that the test is simulating. Unpackaged system tests that are used to validate robustness to survive packaged drops should be fixtured to represent the structural support that the system would have in the packaging. System packaging typically supports the unit only at the corners or along the edges, and so the fixturing should only support the system at the same locations. Blocking may be required to hold the system off of the table so that it only contacts at these support areas. The blocking material should be selected to minimize the amount of damping that is imposed between the table and the system. Typical materials are metal (usually aluminum or steel) but sometimes wood or a plastic material is required. The advantage that wood or plastic offers is that it can be easily machined or molded to the profile of the test item but these materials are much more compliant, and therefore would provide considerable damping and signal attenuation. Unpackaged system

tests that are used to validate the performance of the unit in end user drop would be fixtured directly to the table so that the entire surface is exposed to the shock input.

5.2 Correlation Criteria System test input profiles are a critical component of test procedures. These test profiles must accurately represent or be correlated to the use-condition that is being represented. These profiles are straightforward in the case of packaged system test conditions that are representative of transportation and distribution handling. The test profiles are specified as a number of drops in different orientations from specified heights that are representative of measured or observed events for packages of similar size and weight and can be performed using drop test equipment.

The test profiles are more complex for unpackaged system testing. The unpackaged system test profile must be correlated to the environment that is being represented. In the case of the test that is conducted in order to ensure the system is sufficiently robust to withstand shocks in a cost effective shipping package, the test profile must be correlated to the response that the system experiences in its packaging during the transportation and distribution environment. If the purpose of the test is to ensure the system can survive shock events experienced in a typical end user environment, the test profile must be correlated to the response that the system experiences due to drops, kicks, and bumps associated with the end user use-conditions.

Several parameters are of interest when matching test conditions to use-conditions. Most real world shock events, i.e., use-conditions, are quantifiable with acceleration profiles. Drop events can be characterized by system sizes, drop heights, and impact surface. These events can be quantified by the acceleration profile of the system and its characteristic parameters, e.g., amplitude, pulse shape, duration, frequency content, etc.

5.2.1 Unpackaged System Input Correlated to Packaged System Environment The acceleration profile experienced by a package in a drop environment can typically be represented by a half sine pulse. However, the acceleration profile experienced by the system inside the packaging is modified by the crushing of the packing material intended to protect the product. This profile is commonly represented by a trapezoidal or square wave. The trapezoidal pulse is characterized by the velocity change and the faired acceleration. Faired acceleration is defined as the average of the oscillation amplitudes between the first time that the response goes negative and the last time that the response goes positive. The velocity change is the area under the time history curve and is typically the faired acceleration level times the pulse width. The trapezoidal input pulse can be correlated to measured responses pulses either by using time domain comparisons or frequency domain shock response spectrums.

Time Domain Correlation: The trapezoidal input pulse should envelope the majority of the pulse peaks (80% or more) measured at several locations in the system near the contact points with the packaging material. This technique accounts for the acceleration amplitude and velocity change but does not consider the frequency content of the pulse. See Figure 5-1.

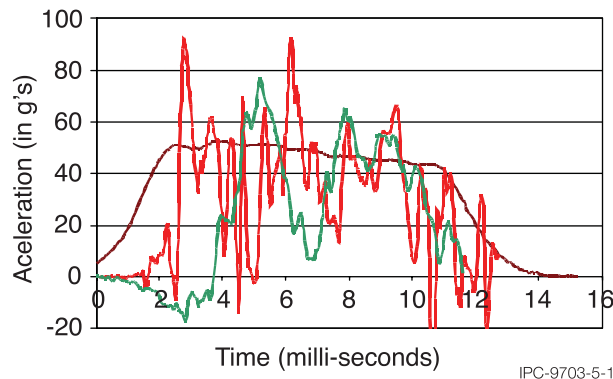


Figure 5-1 Example of the Time History Response Showing the Input from the Shock Table (trapezoidal shape) and the Response at Two Locations on the PCB

Frequency Domain Correlation: The shock response spectrum (SRS) of the trapezoidal input pulse should envelope the SRS of the responses measured at several locations in the system near the contact points with the packaging material. The spectra used for the measured responses should be the composite spectra for both positive and negative directions. The analyses should be performed for a $Q = 10$ at a sequence of natural frequencies at intervals of $1/6$ octave or smaller to span at least 5 to 500 Hz. This method accounts for the amplitude, frequency, and energy in the measured input that is likely to cause damage in the system. This is illustrated by the examples shown in Figure 5-2.

5.2.2 Unpackaged System Input Correlated to End User Use-Conditions The acceleration profile experienced by an unprotected system in a drop, kick or bump environment can typically be represented by a half sine pulse. The half sine pulse is characterized by the pulse amplitude and the velocity change. The velocity change is the area under the time history curve and is calculated as twice the amplitude times the period divided by π . The half sine input pulse can also be correlated to measured response pulses either by using time domain comparisons or frequency domain shock response spectrums. Methods similar to those described in the previous section can be used.

Time Domain Correlation: The half sine input pulse should envelope the majority of the pulse peaks measured at several locations in the system in the direction of the input (drop or bump direction). The duration of the pulse should envelope the maximum duration of the response

pulses. This technique accounts for the acceleration amplitude and velocity change but does not consider the frequency content of the pulse.

Frequency Domain Correlation (SRS): The SRS of the half sine input pulse should envelope the SRS of the responses measured at several locations in the system in the direction of the input (drop or bump direction). The spectra used for the measured responses should be the composite spectra for both positive and negative directions. The analyses should be performed for a $Q = 10$ at a sequence of natural frequencies at intervals of $1/6$ octave or smaller to span at least 5 to 500 Hz. This method accounts for the amplitude, frequency, and energy in the measured input that is likely to cause damage in the system.

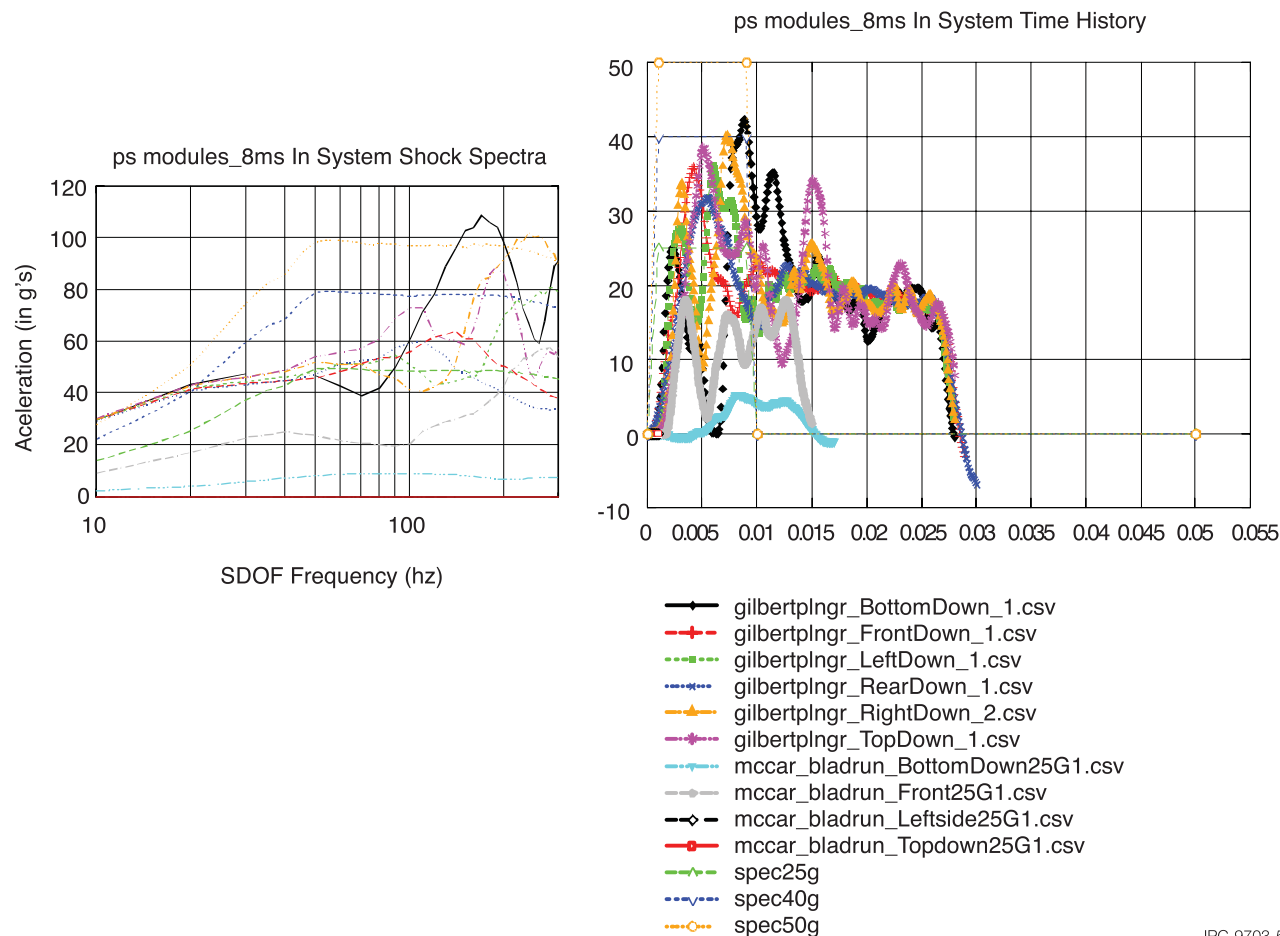
5.3 Test Recommendations

5.3.1 Testing Sample Recommendations

Test Sample Condition/Configuration: Samples need to represent final system configuration in terms of mass, stiffness, geometry and peripheral hardware. The peripheral hardware that is normally supplied in the system must be included in system tests because the mass, stiffness, and structural characteristics of this hardware can have a significant impact on the dynamic performance of the system in shock testing. As an example, any add-in cards that plug into card guides on the processor mother board and also interface to the chassis side wall should be included in the system test, as they will change the dynamic response of the mother board to the shock environment and the resulting stresses on the component solder ball attachments.

Test samples should be randomly selected from production materials that make up the test system. Selecting all materials from the same production lot will not take into account production variability that may have a significant effect on the dynamic performance of any structural hardware in the system. For example, differences in weld quality in chassis manufacturing will alter the dynamic response of the motherboard mounted in the chassis. Not all of the hardware used in system testing need be of operational quality. Mechanical surrogate components can be used in place of those not being electrically tested, but the configuration, layout, and attachment methods must be consistent with their operational counterparts. As an example, daisy chain connectivity of CPU sockets may be required for in-situ electrical monitoring of solder integrity during shock testing. However, the geometry, mass, and stiffness of the interposer used in the CPU socket must be identical to the processor that it is replacing.

Some systems may be available in multiple configurations and the cost required to test all configurations may be prohibitive. In this case it is acceptable to test a smaller number of systems deemed to be worst case configurations.



IPC-9703-5-2

Figure 5-2 Example of Shock Response Spectra (left) Derived from the Time History

designation of worst case configuration is an engineering call that must be addressed on a case by case basis and will depend on the purpose of the test and the anticipated failure modes.

All test articles used in system testing, including peripherals, should be labeled for ease of identification and reporting. This is especially important for investigations into causes of failures.

Sample Size Recommendations: Not all defects are intrinsic to the product, so multiple units should be tested. The number of units included in the test series, the sample size, should balance the cost of the test articles and the confidence level with which one desires to know the true failure rate of the product. The preferred sample size for x% failure rate at y% confidence level can be computed using the statistical approach included in Annex D.

5.4 Test Flow The recommended test flow for system testing will vary depending on the type of testing being performed. Packaged system tests, performed to demonstrate the system and packaging can withstand shocks in shipping and distribution, are performed in representative

packaging configurations. Unpackaged system tests are performed to determine the fragility level of the product, to ensure the system has enough robustness to withstand handling shocks in a cost effective shipping package, or to ensure the system can survive shock events experienced in a typical end-user environment.

5.4.1 Packaged System Testing Shock tests for these systems are performed by dropping the fully packaged system from a prescribed height that is based on the weight and configuration of the system. Large systems that are mounted on pallets for shipping are normally handled using fork lifts or pallet handling trucks. These packages are rarely dropped on any surface other than the palletized surface.

Unpalletized systems are manually handled and may be dropped on any surface. The test flow for packaged system testing is therefore dependent on whether the system is palletized or unpalletized for shipment. Packaged product will normally not be dropped more than once from the required test height, so it is usually acceptable to change package components, cushioning material, cardboard, or test sample during the test.