



# **Support Component Test Requirements: Environmental and Reliability Testing**

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## Table of Contents

<b>1</b>	<b>Summary</b> .....	<b>5</b>
<b>2</b>	<b>Introduction</b> .....	<b>6</b>
2.1	Equivalent shock and vibration testing.....	6
<b>3</b>	<b>Purpose</b> .....	<b>7</b>
<b>4</b>	<b>Scope</b> .....	<b>7</b>
<b>5</b>	<b>Test platform boards</b> .....	<b>8</b>
<b>6</b>	<b>Test sequence</b> .....	<b>9</b>
<b>7</b>	<b>Shock test</b> .....	<b>9</b>
<b>8</b>	<b>Vibration test</b> .....	<b>11</b>
<b>9</b>	<b>Temperature cycling test</b> .....	<b>13</b>
<b>10</b>	<b>Humidity (non-operating) test</b> .....	<b>13</b>
<b>11</b>	<b>Dimensional verification</b> .....	<b>14</b>
<b>12</b>	<b>Test procedure</b> .....	<b>15</b>
<b>13</b>	<b>Documentation</b> .....	<b>15</b>
<b>14</b>	<b>References</b> .....	<b>16</b>
	<b>Appendix A. Equivalent shock profiles</b> .....	<b>18</b>
A.1.	Equivalent shock pulses.....	21

# 1 Summary

A set of specifications and methodology for environmental reliability of support components is outlined here. Special attention is devoted to consistency for mechanical shock and vibration testing. Tests are to be performed on a motherboard on which the components are mounted, rather than on a separate fixture such as Mil fixture. A more realistic environment is achieved, and the need to understand the fixture transfer function is eliminated. A mechanically “worst” test platform was derived from detailed mechanical analysis and dynamic testing. Special attention is given here to consistency by providing means to achieve equivalent shock pulses of different shapes and by suggesting a procedure to adjust vibration levels for longer duration tests. The following feature-benefit table summarizes major advantages of this specification.

Feature	Benefits
Board-level testing	<ul style="list-style-type: none"><li>• More realistic mechanical environment of motherboard</li><li>• No need to understand fixture transfer function</li></ul>
Single mechanically “worst” board	<ul style="list-style-type: none"><li>• All tests on one type of board for component qualification</li></ul>
Long term reliability vibration testing	<ul style="list-style-type: none"><li>• Equivalent damage testing through reduced vibration levels for longer duration tests</li></ul>
Equivalent shock profiles	<ul style="list-style-type: none"><li>• Test at mechanistically equivalent shock pulses</li><li>• Ability to compare different profiles</li></ul>

## 2 Introduction

Support components, including connectors (sockets or slots), thermal solutions, and attachment mechanisms are required to ensure electrical and thermal performance and provide mechanical integrity. The needed resistance of support components against environmental stress is verified by a set of reliability tests. These environmental tests and the needed test platforms are outlined here for the purpose of support component testing. The complete connector test must be performed according to the respective connector requirements. The more detailed product-specific requirements are outlined in the functional and/or product specifications of the respective product. The purpose of this document is to provide a consistent methodology for testing against environmental stress.

The purpose of the test platform is to ensure that it is mechanically “worst” and that testing on the platform is deemed sufficient to qualify on different motherboards and layouts. An actual microATX form factor board with the “worst” location identified through analysis and testing is suggested as a test platform board. This, along with the following equivalent shock and vibration testing, forms the consistent methodology for mechanical testing. The needed temperature and humidity cycling tests as well as the description of dimensional verification testing are also included.

It is believed that the methodology suggested here will save time, effort, and money by quickly identifying the test platform and performing only the needed tests. The specification provides a consistent set of tests and means to come up with equivalent tests based on the physics of failure.

### 2.1 Equivalent shock and vibration testing

Three different types of shock pulses, namely half sine, sawtooth, and trapezoidal, have been used for shock testing. It has been difficult to compare products tested with different shape pulses. A mechanistically consistent methodology to obtain equivalent pulses of different shapes can be used to compare the different shock pulses. The general methodology and the graphs for obtaining equivalence among the above three pulses are given here in Appendix A.

There has been similar difficulty in comparing the different vibration inputs at different durations of time. There has been a longer duration test used for connectors to represent long-term reliability and address the concerns of fretting corrosion. An approach to reduce the vibration inputs when the duration is changed, and to provide an equivalent vibration test based on the failure mechanisms of fretting and fatigue, is included in Section 8.

### **3 Purpose**

Shock and vibration testing is performed to determine the resistance of a product to dynamic stresses expected in its shipment and application environments. The purpose is to protect the product from damage in shipping and handling, as well as the operational environment. Thermal and mechanical functions of support components must be ensured after going through the shipping and handling environment which forms the basis for the shock and vibration requirements of the support components.

Shock and vibration inputs should be carefully chosen to represent the product environment. *Mil Std 810E Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests* provides a great deal of information on shock and vibration measurements in different environments.

Temperature/humidity tests are needed to ensure reliability against various worldwide environments.

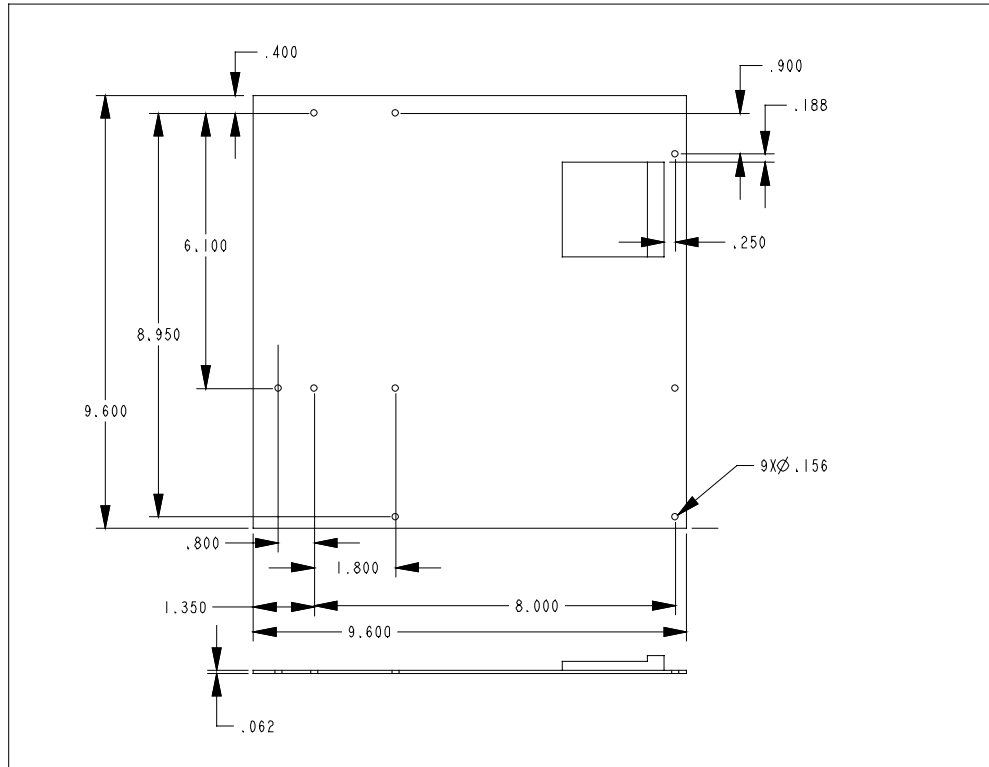
Dimensional verification is needed to ensure that the dimensions are within the prescribed limits so as not to violate any keepout zones and ascertain other thermal and mechanical performance. A brief description of the dimensional verification test is included here.

### **4 Scope**

Support components include the processor socket or slot connector, thermal solution, and mechanical attachment mechanisms. They provide the needed electrical connectivity, heat release, and mechanical integrity. The shock and vibration tests used for support component qualification are outlined in this document. Other environmental tests for temperature and humidity cycling, as well as the dimensional verification tests are included for completeness. Electrical and operating thermal and mechanical tests are not listed here; nor are the post-shock and post-vibration thermal and electrical measurements techniques included. All details needed to select test platforms for shock and vibration testing, to choose corresponding dynamic inputs, and to adjust inputs in a consistent manner when test parameters are changed are included.

The test of processor connectors and sockets must be performed according to the respective connector requirements. The functional specifications and product specifications documents cover product-specific requirements. This document is a reference for both the connector specifications and other support components specifications.

## 5 Test platform boards



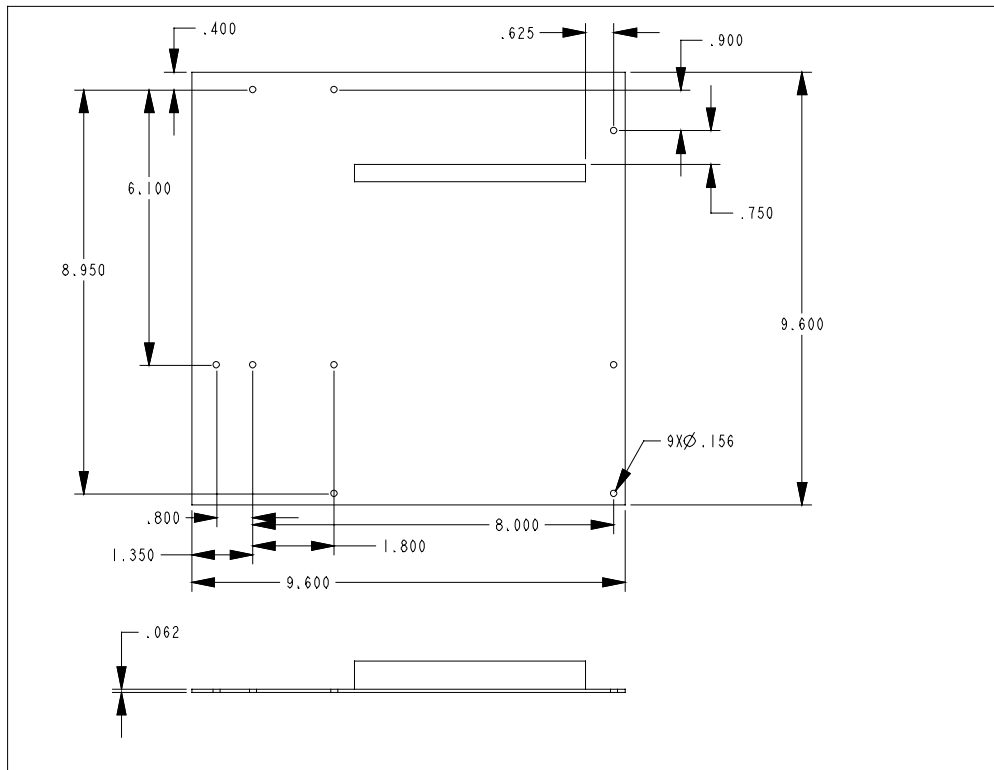
shown. Location of the top-right corner of the socket is fixed with respect to the motherboard.

The 9.6" x 9.6" microATX boards shown in Figures 1 and 2 and are recommended as test platforms if no information about specific layouts and form factors is available. It should be made from FR4 material with mechanical properties similar to the functional board and should have a thickness of 0.062" (+ 0.007" -0.005"). It has nine mounting holes that are the same as the ones in microATX specifications. The locations of the socket and slot connectors on the board are shown in Figures 1 and 2, respectively, and are chosen to be the "worst" mechanical configurations. These two configurations were selected from a survey of a large number of existing boards and processor locations. Experiments and analysis showed that the most amplification occurs when the processor is closest to the mounting point, due to its tilting. It was realized that the processor cannot be mounted very close to the mounting point, due to keepouts around the mounting hole and possible electrical reasons. The survey has not yielded any board closer to the mounting hole than 1/4"; so the "worst" configuration is defined with the processor around 1/4" away from the mounting hole as shown in Figure 1. Figure 2 accounts for the keepout zone for a retention mechanism.



## 6 Test sequence

There are no guidelines for which sequence of testing to follow, unless the order in which shock, vibration, temperature, and humidity inputs occur is clear from an assessment of the environment. There is also no guideline about which order of axes (X, Y, and Z) to follow for either shock or vibration tests. It is perceivable that order does play a role in determining the failure and that the sequence should again be chosen so as to be worst in some objective or failure sense. If no information is available, any order is acceptable. Thermal testing should generally be performed on a separate set of samples. Order of testing should be included in the test report.



**Figure 2: A recommended test platform microATX board with the "worst" location of slot shown. Location of the slot connector with respect to the motherboard is fixed.**

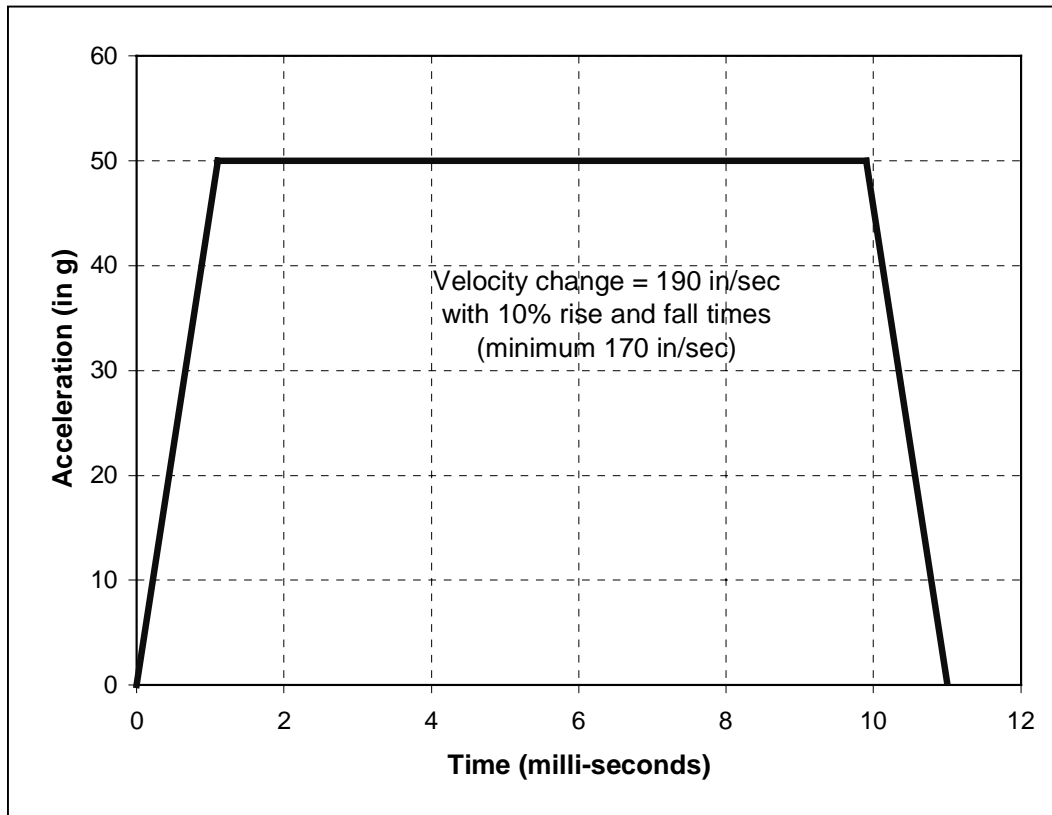
## 7 Shock test

Purpose:

To demonstrate that the product can withstand stresses that may be encountered in shipping and handling of the unit in its unpackaged condition.

Test Profile:

- Trapezoidal shock pulse with 50g peak acceleration as shown in Figure 3.
- Velocity change or the area under the pulse should be minimum 170 inches/sec. Equivalently, the pulse duration should be around 10-11 ms with both rise and fall time to be less than 1 ms.
- Three drops in each of the six directions for each sample.
- If the trapezoidal pulse cannot be generated and the machine is capable of sawtooth or halfsine pulse, graphs in Appendix A can be used to obtain equivalent pulse with



appropriate duration and peak acceleration.

Notes:

- Board must be mounted in a rigid fixture that duplicates the support points in the actual application of the board.
- The fixture must not amplify the stress being applied by the table. The fixture usually consists of a 1 inch aluminum plate with standoffs mounted in the proper position to duplicate the support of the application chassis.
- Care should be taken to use only those support points that will actually be used in the final product.
- Table drop height and 'Programmer' pressure is adjusted to produce the desired velocity change of ~ 170 in/sec and peak acceleration of ~ 50g. The product is then mounted to the table and dropped.
- Three drops in each 6 directions are applied to each sample.

Figure 3: Trapezoidal shock profile with 50g peak acceleration and minimum 170 in/sec velocity change used for shock testing.

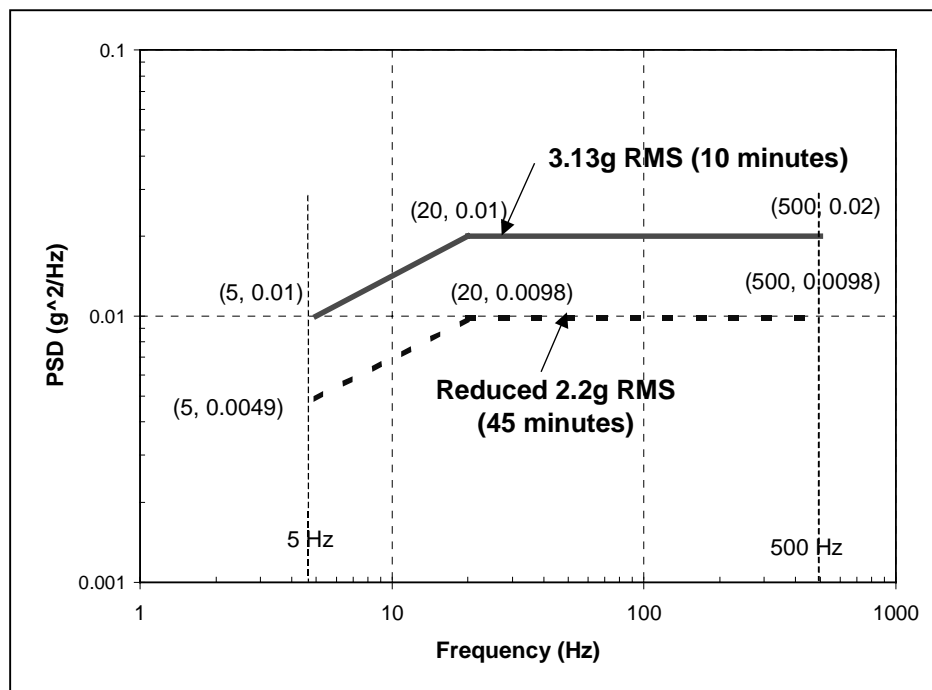
Pass criteria:

- The product must operate normally after the completion of the test.
- No visible damage such as cracking of board and components.
- No displaced components, heat sinks or cables.
- No components hitting one another.

## 8 Vibration test

Purpose:

To demonstrate that the product can withstand stresses that may be encountered in the transport and user environment in its unpackaged condition. Test the product resistance against failures such as fatigue and fretting caused by cyclic motions encountered in transportation and application environments.



**Figure 4: Random vibration power spectral density profile for board-level testing. A reduced one with 2.2g RMS may be used for 10 minutes test.**

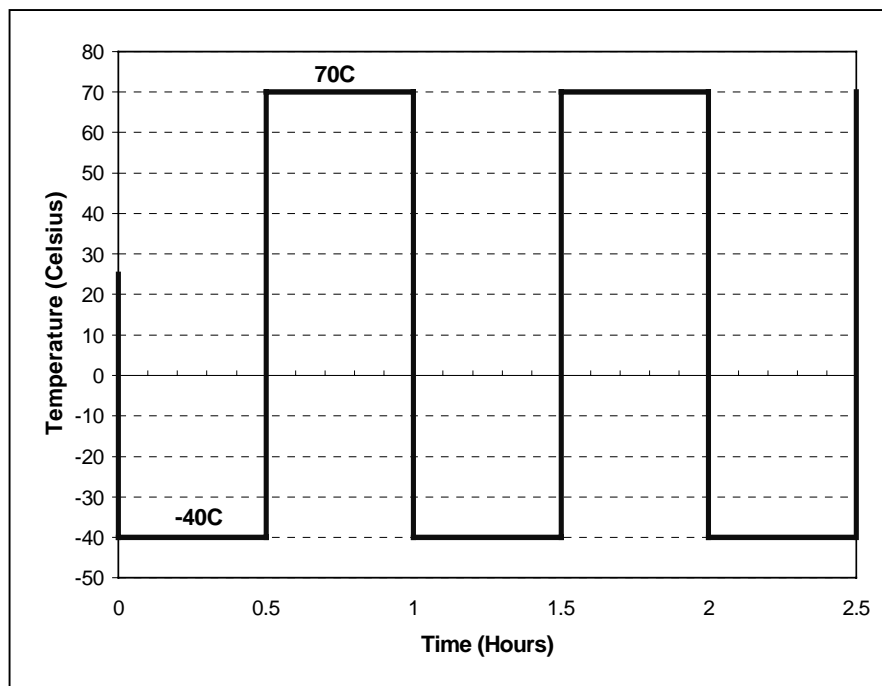
Test Profile:

- Random vibration with the following power spectral density (PSD) profile as shown in Figure 4.
  - 5 Hz to 20 Hz            0.01 g<sup>2</sup>/Hz sloping up to 0.02 g<sup>2</sup>/Hz
  - 20 Hz to 500 Hz        0.02 g<sup>2</sup>/Hz (flat)
- Control limit for random vibration is  $\pm 3$  db; actual PSD level at all frequencies should be within this limit.

- Area under the PSD curve or RMS value is 3.13 g.
- 10 minutes for each of the three axes for each sample.
- An alternative longer duration test may be performed to address long-term reliability issues with 45 minutes per axis at reduced PSD levels. The reduction of PSD is done by 30%, as shown in Figure 4, to have 2.2 g RMS for 45 minutes test.

Notes:

- Board must be mounted in a rigid fixture that duplicates the support points in the actual application of the board.
- The fixture must not amplify the stress being applied by the table. The fixture usually consists of a 1-inch aluminum plate with standoffs mounted in the proper position to duplicate the support of the application chassis.
- Care should be taken to use only those support points that will actually be used in the final product.
- Vibrate per the profile for 10 minutes per axis. Duration for the long-term reliability test is 45 minutes per axis.
- Board to be inspected for damage and full functional test performed after the test.



**Figure 5: Temperature variation profile for thermal cycling test.**

Pass criteria:

- The product must operate normally after completion of the test.
- No visible damage such as cracking of board and components.
- No displaced components, heat sinks, or cables.
- The connector or socket must meet the appropriate contact resistance requirements.

## 9 Temperature cycling test

### Purpose:

To demonstrate that boards can withstand non-operating (i.e. storage) high temperature, low temperature, and numerous thermal cycles. The test combines high temperature storage, low temperature storage, and thermal shock conditions.

### Test profile:

- Temperature limits: -40° C & 70° C
- Thermal cycling: 50 cycles between limits at 15° to 30° C/minute
- High/low temperature storage: 25 hours at each limit (50 one-half hour intervals)
- Sequence (as shown in Figure 5)
  - Begin each cycle with temperature at 25° C
  - Ramp the temperature to -40° C and hold for 30 minutes
  - Ramp the temperature to 70° C and hold for 30 minutes
  - Ramp temperature to 25° C
  - Repeat 49 more time

### Notes:

- All units are to be visually inspected and functionally tested prior to and after this test.
- This is a non-operating test, and power is not applied during the test.

### Pass criteria:

- No visible damage to the products.
- No failure during the functional test.
- No solder ball or connector failure.

## 10 Humidity (non-operating) test

### Purpose:

To demonstrate product resistance to humidity problems in non-operating storage environment.

### Test profile:

- Relative humidity: 50% to 92% (at temperatures of 25° C and 55° C)
- Relative humidity ramp rate: 8.22% per hour (temp. ramp rate ≤ 15° C/hour)
- Sequence (as shown in Figure 6)
  - Begin each 24 hours cycle with temperature at 25° C and humidity at 50%.
  - In first 2 hours, ramp temperature up to 55° C while holding humidity at 50%.
  - Hold temperature at 55° C and ramp humidity up to 92% in 4.5 hours.
  - Hold temperature at 55° C and hold humidity at 92% for 8 hours.

- Ramp both temperature and humidity down in next 4.5 hours; temperature to 25° C and humidity to 50%.
- Hold temperature at 25° C and hold humidity at 50% for 5 hours.
- Repeat 24 hours cycle 4 more times.

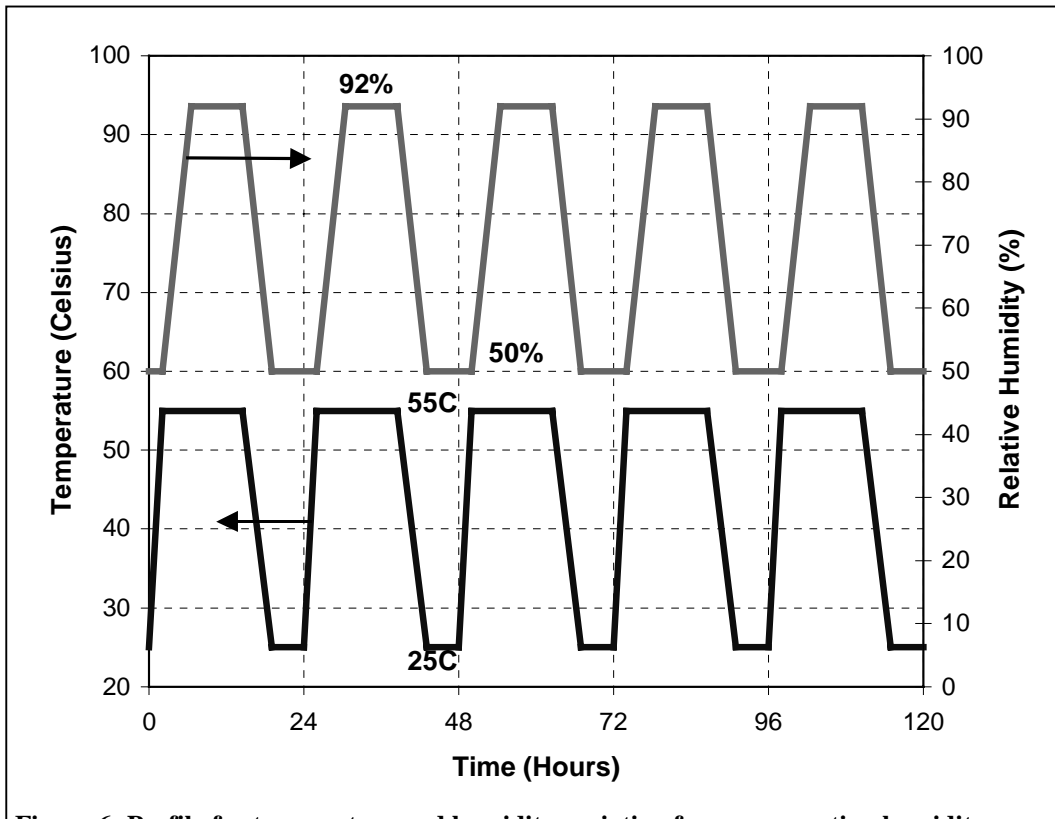


Figure 6: Profile for temperature and humidity variation for non-operating humidity test.

Pass criteria:

- No visual damage to the products.
- No failures during functional test.
- No failures due to corrosion or contamination of metallic surfaces such as solder balls or connectors.

## 11 Dimensional verification

Purpose: To ensure that critical-to-function (CTF) dimensions are within the required limits as specified by the functional and/or product specifications.

The CTF dimensions are generally listed in functional and product specifications, along with the needed tolerances. The measured dimensions should be within the tolerance limits for a part to be acceptable. The CTF dimensions generally include linear dimensions, angles, coplanarity requirements, and roughness. Tolerance requirements for

some dimensions may be only uni-directional (lower/upper bound). Care should be taken to ensure that the instrument measurement accuracy is much higher than the prescribed tolerances.

## 12 Test procedure

A step-by-step procedure to facilitate overall testing of support components is provided here. All essential steps, with suitable reference within this document are provided.

1. Use the recommended test platform: microATX form factor boards shown in Figures 1 and 2 with the suggested socket or slot location for all testing.
2. Perform the dimensional verification tests on all components, as well as on the test platform board before accepting the components for testing. The test platform board thickness must be within the prescribed limits of 0.062" (-0.005" +0.007").
3. Perform the shock test per Section 7 with trapezoidal pulses with 50g peak acceleration and 11 ms duration and 170 in/sec of velocity change. If the capabilities for trapezoidal pulse generation are not available and sawtooth or halfsine pulses are available, the equivalent profiles can be obtained from Appendix A.
4. Perform the vibration test per Section 8 with random vibration PSD of 3.13 g RMS shown in Figure 4 for 10 minutes per axis. If fretting or fatigue failure mechanisms due to cyclic loading and long-term reliability are of concern, a longer duration test for 45 minutes per axis may be performed at a reduced level of vibrations.
5. Perform the temperature cycling test per Section 9 with temperatures ranging from 40 to 70° C for 10 days. This test is to be done generally on a separate set of samples from that used for mechanical testing. Results here are not expected to be sensitive to the type of board, so any board can be used.
6. Perform the humidity test per Section 10 with temperatures ranging from 25 to 55° C and relative humidity ranging from 50% to 92%, as shown in Figure 6.
7. Generate the test report based on the pass/fail verification after all of the above tests. All test details listed in the next section must be included in the report.

## 13 Documentation

The following parameters should be documented as a part of the test report.

- Test platform board
  - Board used: Recommended one in Figure 1 or 2
- Dimensional verification test
  - Components (pass/fail)
    - If fail, note which CTF dimension and reject the respective component
  - Test platform board (pass/fail)
    - If fail, note which dimension and reject the test platform board
- Shock test

- Pulse type (trapezoidal, sawtooth, or halfsine)
  - Actual peak acceleration
  - Actual pulse duration
  - Actual velocity change
  - Order of testing (e.g., X, Y, and Z; top-bottom, front-back, side-side). Z axis is always defined as normal to the board.
  - Number of drops per axis if different from 3
  - Pass/fail evaluation and failure mechanism if applicable
- Vibration test
    - Actual PSD profile
    - RMS acceleration value (in g's)
    - Actual duration per axis
    - Order of testing (e.g., X, Y, and Z; top-bottom, front-back, side-side). Z axis is always defined as normal to the board.
    - Percent reduction in PSD levels if longer duration test is performed and basis on which the reduction was evaluated if it is not 30%.
    - Pass/fail evaluation and failure mechanism if applicable.
- Temperature cycling test
    - Actual temperature limits
    - Actual relative humidity
    - Actual duration and number of cycles
    - Any interruptions during the test
    - Pass/fail evaluation and failure mechanism if applicable
- Humidity (non-operating) test
    - Actual temperature and humidity measures
    - Actual duration and number of cycles
    - Any interruptions during the test
    - Pass/fail evaluation and failure mechanism if applicable

## 14 References

*Mil Std 810E (1995), Department of Defense Test Method Standard for Environmental Engineering Guidelines and Laboratory Tests.*

ATX specifications, Version 2.01, <http://www.keyport.com/~atx/>, Intel Corporation, 1997.

microATX specifications, Version 1, <http://www.keyport.com/~microatx/>, Intel Corporation, 1997.



NLX motherboard specifications, Release 1.2, <http://www.keyport.com/~nlx/>, Intel Corporation, 1997.

Steinberg, D. S. (1988), "Vibration analysis for electronic equipment", John Wiley & Sons, New York.

## Appendix A. Equivalent shock profiles

Three different types of shock pulses, namely trapezoidal, sawtooth, and half-sine, have primarily been used by different test facilities. It has been difficult to compare the mechanical integrity of products tested with different type of pulses. The drop-test machines used for shock testing are generally meant to generate only one type of pulse, making the need to compare the different shock profiles even greater. There are several off-hand ways used for comparing different pulses based on peak acceleration and total velocity change, but they lack strong physical basis.

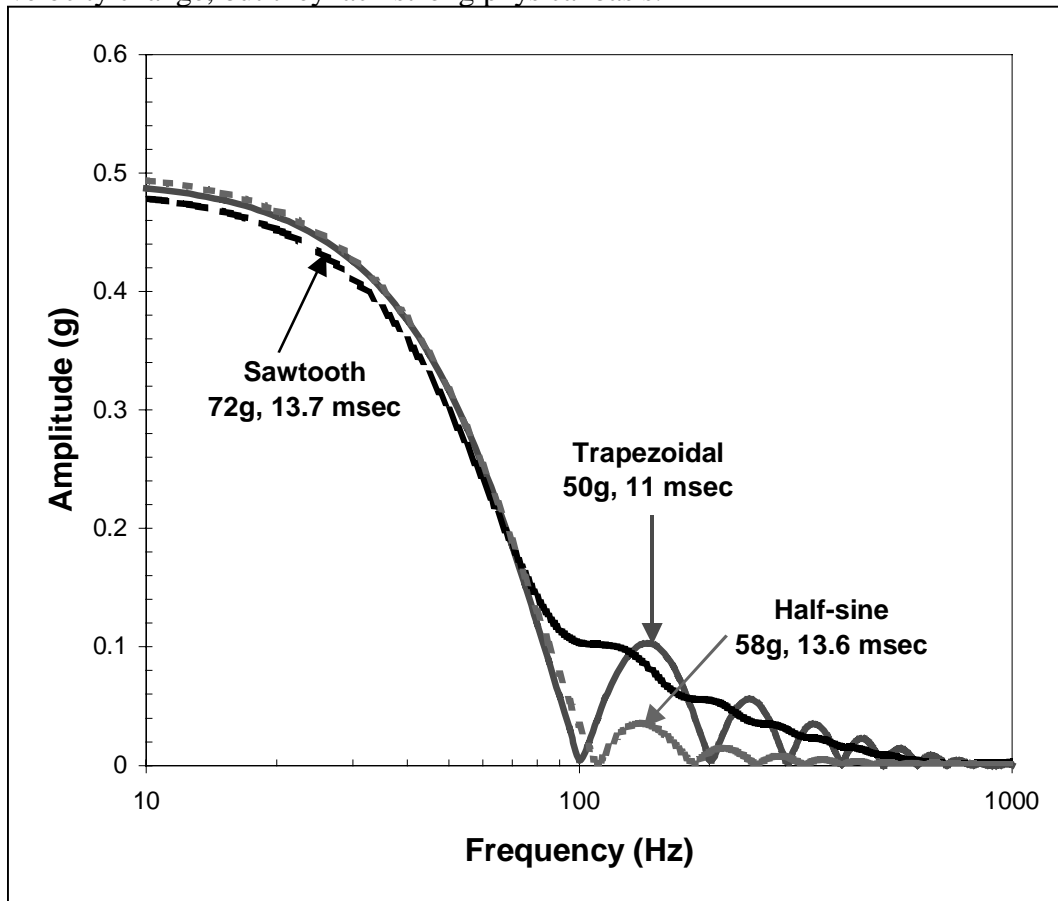
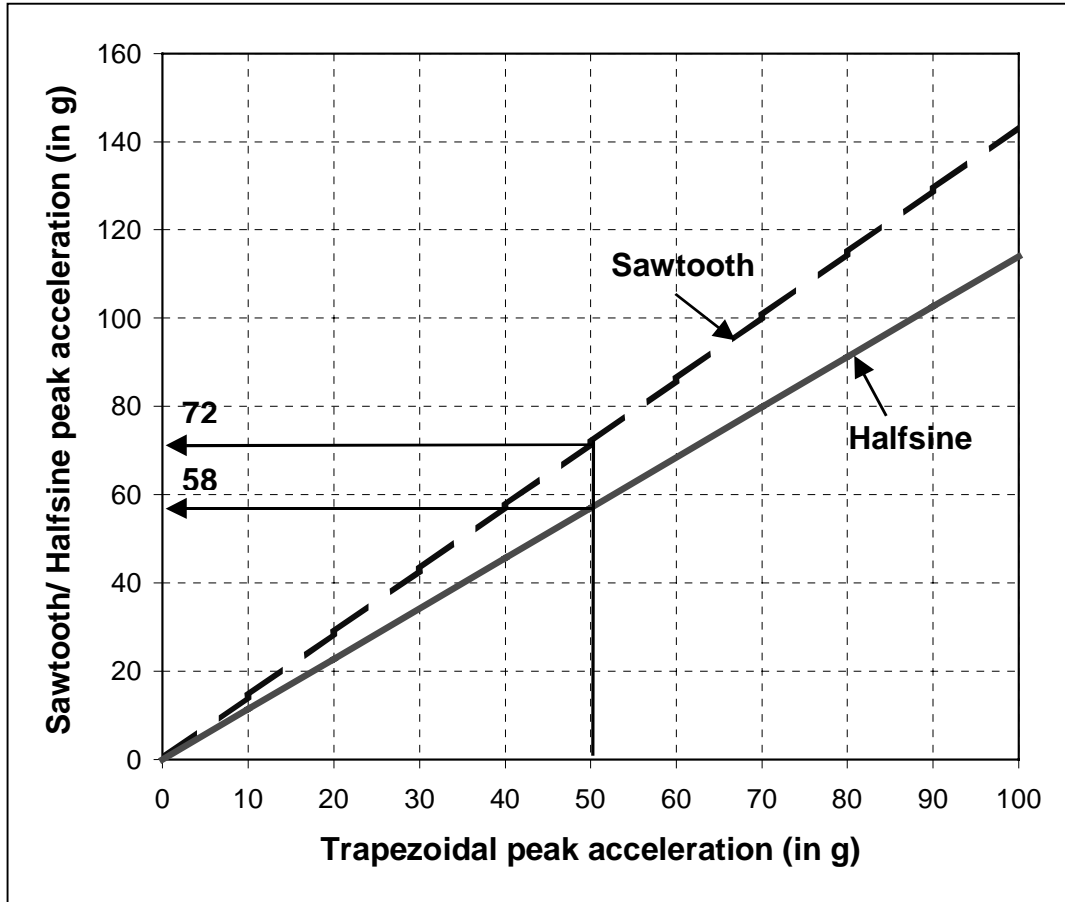


Figure 7: Equivalent peak acceleration for half-sine and sawtooth pulses for a given trapezoidal pulse obtained through curve-fitting of frequency-amplitude relationships.

Mil Std 810E (Section 516.4-I-3.3.c(1) (b)) prescribes that if in frequency domain amplitudes at all frequencies of pulse A are higher than pulse B, then pulse A covers pulse B and is necessarily at least as “bad” as pulse B. We can generalize this concept and consider two pulses equivalent if they have the similar frequency-amplitude curves within some reasonable engineering sense. A criterion for equivalency of pulses is established by least square fitting of the corresponding frequency-amplitude curves with no large deviation in amplitudes at all frequencies. This criterion is used for defining equivalent pulses of different types. The graphical method to select the equivalent is also presented.



**Figure 8: Frequency-amplitude relationships for trapezoidal 50g, 11 ms and equivalent halfsine and sawtooth pulses. The equivalents were obtained by curve fitting.**

Least square curve fitting for frequency-amplitude curves is used to minimize the differences between the two curves to define the equivalency. There are two parameters that are generally adjustable, namely peak acceleration and pulse duration. The least-square methodology adjusts these two parameters until the curve is closest to the target curve. Mathematically, curves cannot be brought any closer by any other values of these two parameters. There may be other adjustable shape parameters such as fall and rise times for trapezoidal and sawtooth pulses. Most specifications require these times to be less than 10% of the total pulse duration. We assume both rise and fall times to be 10% for identifying the pulse equivalents.

Figure 7 shows the trapezoidal shock pulse with 50g peak acceleration and 11 milliseconds duration in frequency domain, along with the corresponding curve-fitted sawtooth and halfsine pulses. The curve fitting seems reasonable and the definition of equivalency is assumed to be satisfied. The sawtooth pulse with 72g peak acceleration and 13.6 ms duration and halfsine pulse with 58g peak and 13.6 ms duration are equivalents to the 50g, 11ms trapezoidal pulse. It is clear that the comparison based on peak acceleration alone would have greatly underestimated the results for sawtooth and halfsine pulses.

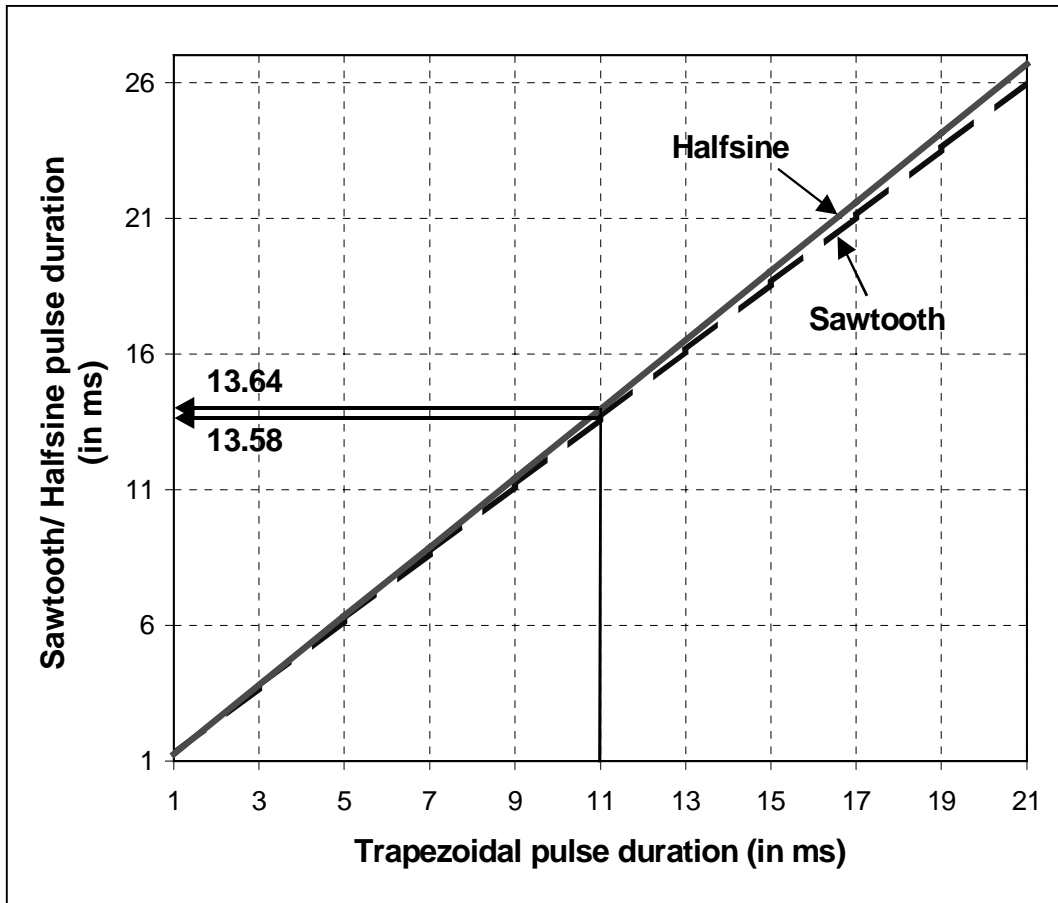


Figure 9: Equivalent pulse duration for halfsine and sawtooth pulses for a given trapezoidal pulse obtained through curve-fitting of frequency-amplitude relationships.

### A.1. Equivalent shock pulses

Based on the curve fitting for a range of shock pulses, two figures are provided to identify the equivalent profiles (Figures 8 and 9). It was found that both the peak acceleration and pulse duration scale by a constant factor for an equivalent profile. For example, to get an equivalent sawtooth profile from a trapezoidal profile, multiply the peak acceleration by a factor of 1.43 and multiply the duration by 1.27. Figure 8 provides peak acceleration for sawtooth and halfsine shock profiles for a given trapezoidal peak acceleration. If equivalent sawtooth or halfsine pulse is needed from halfsine or sawtooth, then the graphs have to be used in two steps by identifying first the equivalent trapezoidal pulse and then finding the needed type equivalent pulse. The equivalent pulse duration for all three shapes is plotted in similar way in Figure 9 and the same methodology to identify the equivalent pulse duration applies.



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