Building Ruggedized Systems with Jetson SoDIMM System on Modules

Technical Brief

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Introduction

In the last few years, we have seen an explosion of the edge computing market. Customers are looking to process more and more data in small form factors. The NVIDIA® Jetson™ family of products includes three modules in our nano form factor, 70 × 45 mm, that use a 260-pin SoDIMM connector. This includes the following:

- Jetson Xavier NX that brings up to 21 TOPS of accelerated computing
- Jetson Nano that is our entry level product ideal for developing mass market AI products
- Jetson TX2 NX that provides 2.5x the performance of the NVIDIA® Jetson Nano™.

AI Automation is increasingly being used in industries like manufacturing, agriculture, construction, energy, government, and more, which require more ruggedized solutions. The goal of this tech brief is to identify the careful system design considerations that can be done with these SoDIMM modules to enable customers to deploy applications in these harsher environments.

Module Considerations

Depending on the harshness of the expected environment the module can be prepared before fitting into the system.

Component Staking for Shock and Vibration Survivability

The best-in-class materials for vibration protection reliability and speed of manufacturing are typically UV-curable staking materials. One example is HumiSeal (UV20Gel), a one-part, dual cure (UV + moisture secondary moisture) material specifically designed for electronic components that require vibration protection or similar material.

Conformal Coating for Humidity and Vibration Survivability

There are also materials for humidity protection as well as vibration protection known as conformal coating materials. One example is HumiSeal 1B73, a fast-curing acrylic coating that is MIL-I-46058C qualified. Click here for a more detailed specification. HumiSeal 1B31 with a 1 to 3 mil thickness, acrylic base resin, and IPC-CC-830A standard coating can also be used. Another conformal coating that can be used for vibration protection is Parylene Type N.

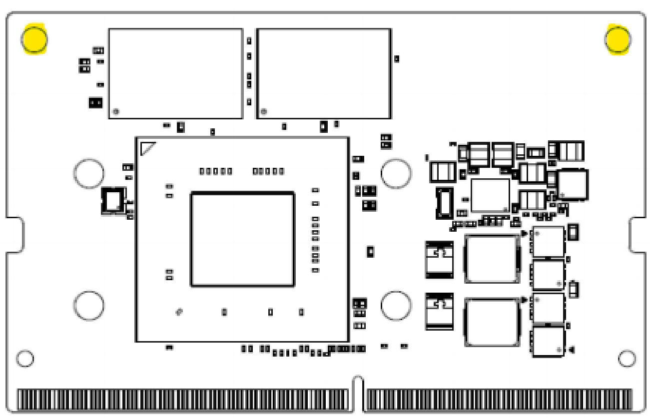
> **Note**: Module modifications such as conformal coating or staking are the responsibility of the design authority applying the process. The module warranty may be violated as a result. Refer to the attached conformal coating considerations document for more details.

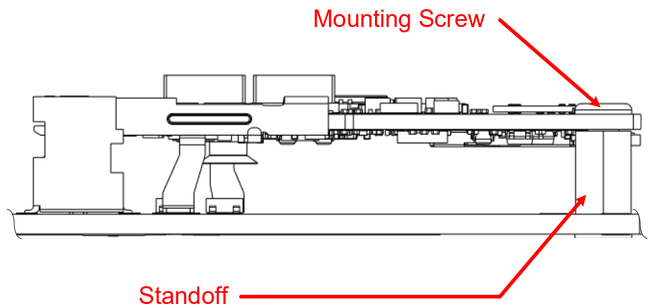
Mechanical Considerations

There are many mechanical challenges in using SoDIMMs in systems where high levels of shock and vibration support are needed. Typically, an SoDIMM is only held in place by the connector itself and the two latch keys on either side. This provides little protection in a system that observes high vibration, or rapid impacts.

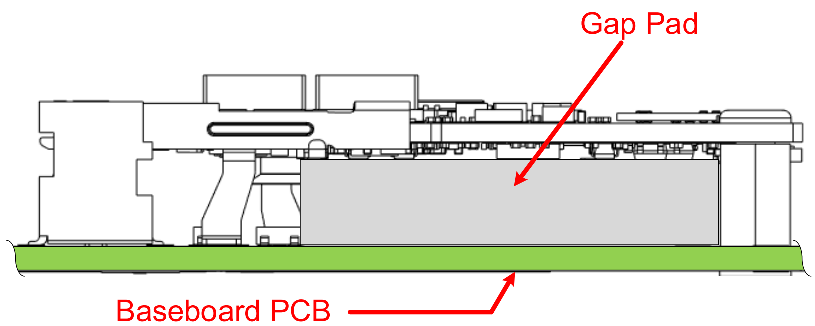
There are typically two types of SoDIMM connectors, vertical and right angled. Only the right-angled versions should be considered for ruggedized systems and are assumed in the points discussed in this tech brief.

To provide additional physical stability in the system Jetson SoDIMM products have two mounting holes (highlighted) on the outside edge of the board to secure to the main carrier board. These should be used to connect the board with standoffs to the main PCB (and chassis). This mounting mechanism provides some strain relief on the connector.





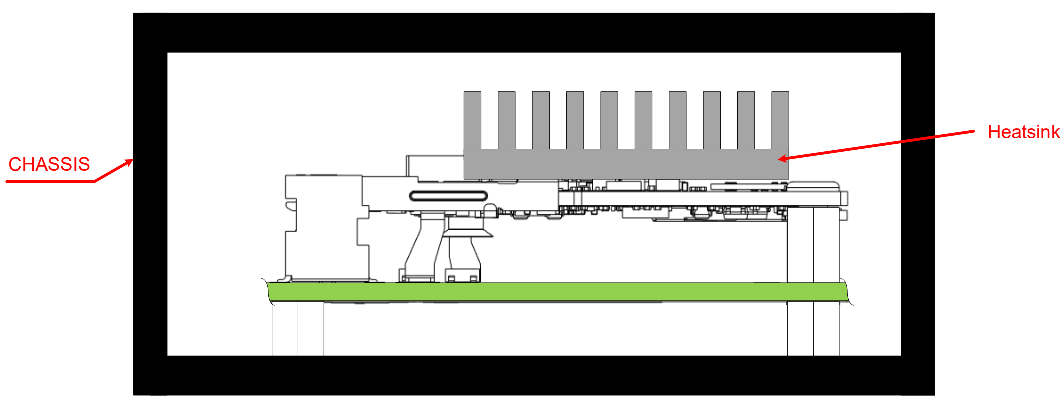
In addition to the mounting holes a gap pad may be placed under the module between the module PCB and the baseboard PCB. This provides further mechanical contact between the module and the baseboard PCB, reducing the strain on the connector and providing further rigidity.



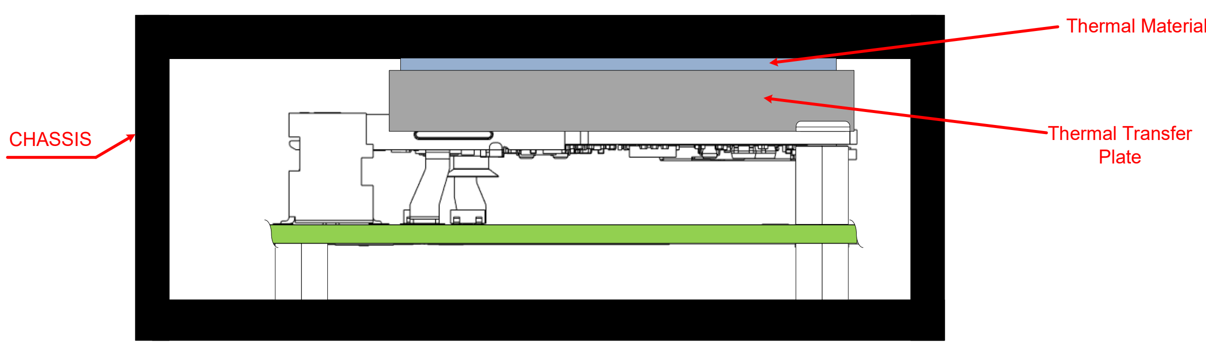
Thermal

A thermal solution is required to be fitted to the top side of the module. This design should carefully be considered to determine how it impacts the mass of the module, which will have an impact on the shock and vibe performance. For example, a heat sink attached with no connection to the external case. Internal solutions like this will require air flow to maintain junction temperatures within limits. To facilitate the airflow, fans may be required, which while technically effective also reduce reliability. If external apertures provide air inlet and outlet, then additional maintenance to replace filters may be required. All of that is undesirable, hence why passive direct connections are best where they can be accommodated. Various thermal solutions are available that fit the SoDIMM modules and allow easy connection to the thermal solution.

BAD



GOOD



Once such solution is the thermal transfer plate (TTP) available from Connect Tech: https://connecttech.com/product/nvidia-jetson-xavier-nx-thermal-transfer-plate/

Component Selection

Selecting a suitable SoDIMM connector that meets the target environment is critical to producing a reliable connection in harsh environments. A connector that meets or is close to the testing requirements of the final product should be selected.

The following table lists the known suitable parts.

Manufacturer	Part Number	Details	Comments
TE Connectivity	2309413-1	260-pin SoDIMM connector	TE 2309413-1
Lotes	ADDR0070	260-pin SoDIMM connector	Lotes SoDIMM Tested to EIA-364 (Test report available from Lotes)
Amphenol	10141730-005RLF	260-pin SoDIMM connector	Different stack heights or configurations could be more appropriate for different kinds of applications. (See "Amphenol SoDIMM Connector" for more details).

Amphenol SoDIMM Connector

The Amphenol connector has been subjected to extensive MIL environmental testing using MIL specification lot sample sizing including the following:

- Contact Resistance
- Dielectric Withstanding Voltage
- Insulation Resistance
- Vibration
- Physical Shock
- P.C. Board Mating Force
- Reliability and Durability
- Thermal shock
- Humidity-Temperature Cycling
- Temperature Life
- Salt Spray
- SO2 Gas
- Resistance to Reflow Soldering heat
- Solderability

For additional information on the Amphenol connectors, see the following references.

Specification: This file contains information on some of the testing performed on the Amphenol connectors: https://cdn.amphenol-icc.com/media/wysiwyg/files/documentation/gs-12-195.pdf

General Information: This file contains a list of Amphenol Right Angle SODIMM part numbers that can be used depending on your height requirements: https://cdn.amphenol-icc.com/media/wysiwyg/files/documentation/datasheet/ssio/ssio_ddr4_sodimm.pdf

Drawing: This document contains a schematic drawing of the Amphenol connectors: https://cdn.amphenol-icc.com/media/wysiwyg/files/drawing/10141998.pdf

Testing and Results

With careful design, it is possible to design systems that will meet stringent test standards, such as

- MIL-STD-810G
- RTCA DO-160G
- IEC 60068

WOLF Testing and Results

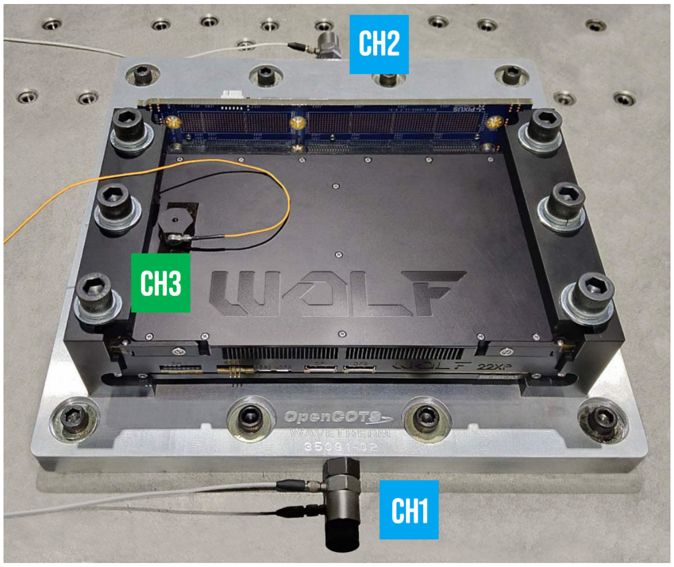
WOLF performed a set of tests on their SOSA Aligned 6U VPX Module with four Jetson Xavier NX modules seen in the following figure. This system contains some of the recommendations including conformal coating (Parylene Type N and Humiseal 1B73 or 1A33), component staking, and an Amphenol connector (10141730-005RLF).

WOLF tested the module to the following MIL-STD 810 levels:

- Shock: 40g, 11ms half-sine shock pulses in xyz axis, 3pos, 3neg
- Vibration Sine: 10g peak 5-2,000 Hz, 10min/axis
- Vibration Random: 0.05 g2/Hz 5-15Hz 0.1 g2/Hz 15-2000Hz, 1hr/

Find more details on the WOLF module at: https://wolfadvancedtechnology.com/products/6u-vpx/vpx6u-nvxavier-6nx

The following figure is a WOLF-22XP test fixture in an ANSI/VITA 48.8 air flow through configuration.



WOLF Environmental Qualification Testing

WOLF subjects all module designs to the Vibration and Environment tests. The standard to which these tests are run is outlined in MIL-STD 810H, "Environmental Test Methods and Engineering Guidelines." The tests are designed as accelerated life testing. The tests expose vulnerabilities or failure conditions in the design or production that reduce reliable when deployed in a harsh environment.

The following test methods are used:

- Random Vibration
- Shock Vibration
- Operational Temperature Testing
- Storage Temperature Testing
- High Altitude (Low Barometric Pressure) and Humidity Testing

Random Vibration Qualification Testing

The Random Vibration profile approximates vibrations that occur in various applications from high performance jet fighters, propeller driven aircraft, helicopters, tanks, and other land vehicles. WOLF successfully passed the Random Vibration test on all three axes.

MIL-STD-810H
METHOD 514.8, ANNEX C

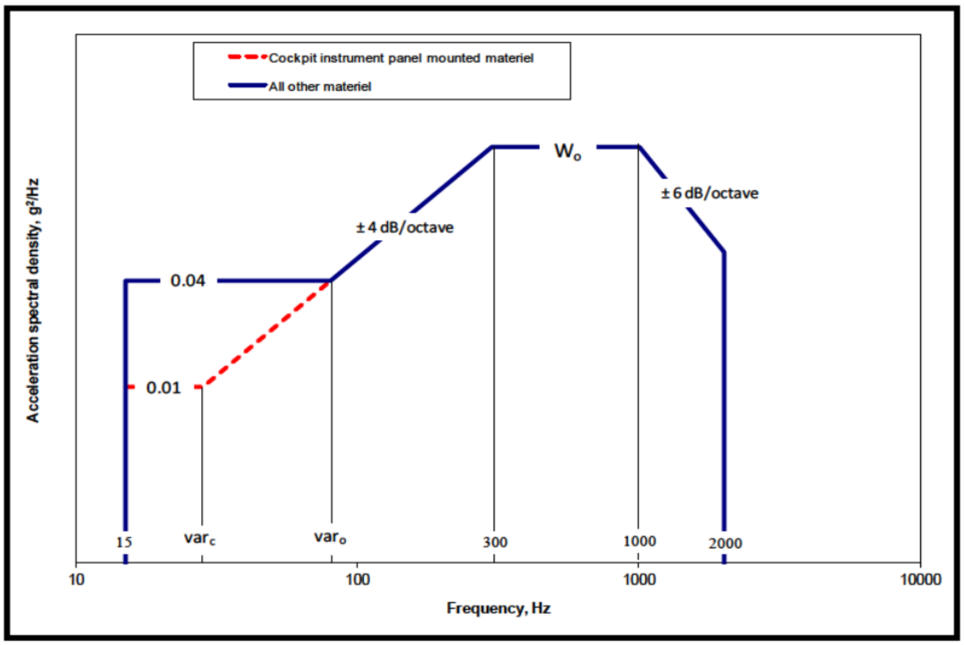


Figure 514.8C-10. Category 7 - Jet aircraft vibration exposure. (Same as Annex D, Figure 514.8D-1.)

Shock Vibration Parameters

Shock Vibration tests are designed to emulate a crash using the Saw-tooth waveform or the operational test using Half Sine wave shock waveform. The Shock test is specified per MIL-STD-810H Method 516.8 and Figure 516.8-5. The test exposes the module to a total of 18 hits, described as 40G, 11msec Saw-Tooth or Half-Sine shock pulses in X, Y, Z axis, 3 positive and 3 negative per axis. The following figures depict the energy applied.

MIL-STD-810H
METHOD 516.8

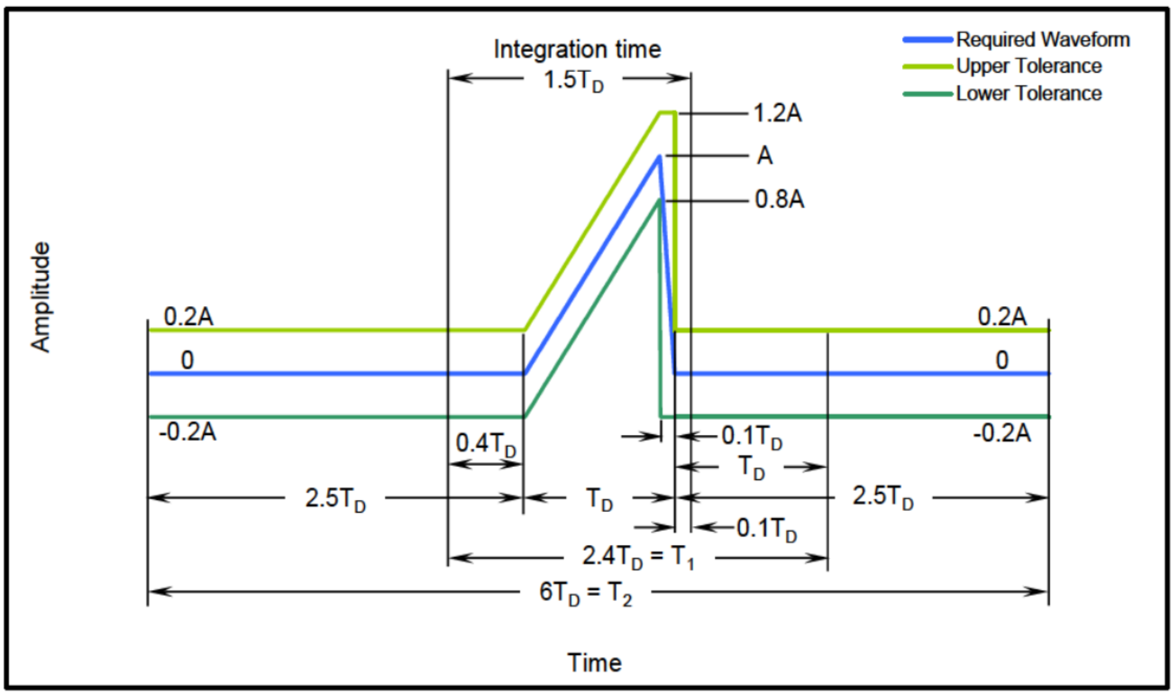


Figure 516.8-3. Terminal peak sawtooth shock pulse configuration and its tolerance limits.

MIL-STD-810H
METHOD 516.8

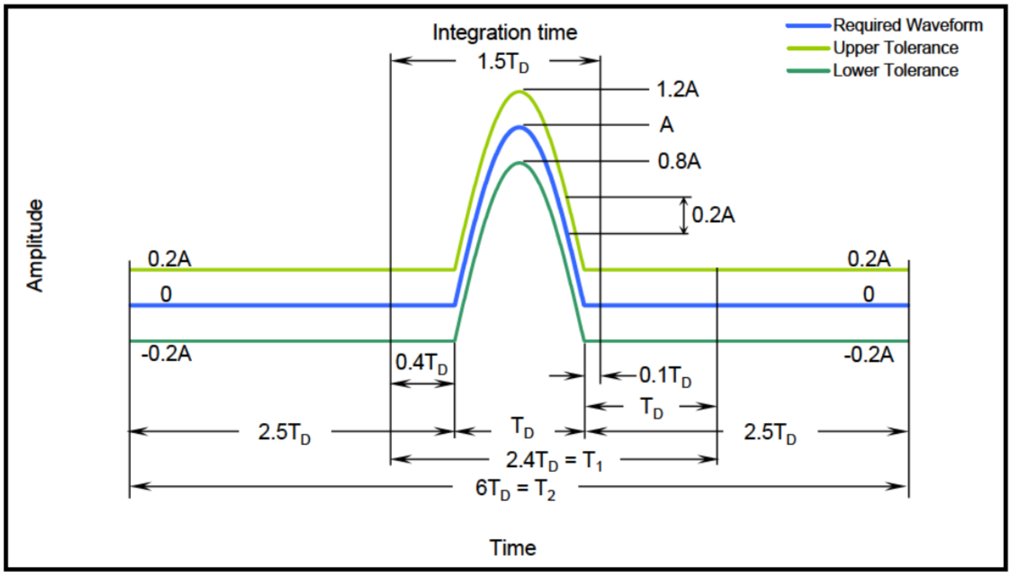


Figure 516.8-5. Half-Sine shock pulse configuration and tolerance limits.

Key to Figures 516.8-3 through 516.8-5:

T_D: duration of nominal pulse (tolerance on T_D is ± 10%).

A: peak acceleration of nominal pulse

T_1: minimum time duration which the pulse shall be monitored for shocks produced using a conventional mechanical shock machine.

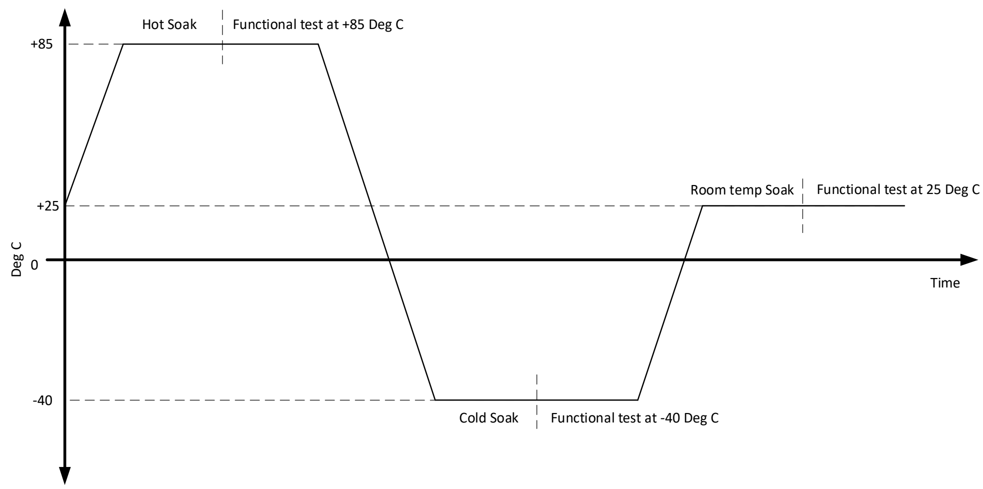
T_2: minimum time during which the pulse shall be monitored for shocks produced using a vibration exciter.

The duration associated with the post-pulse slope of a terminal peak sawtooth and durations associated with the pre and post slopes of a trapezoidal pulse should be less than 10% T_D.

The tolerance on velocity, due to combined effects of any amplitude and/or duration deviations from the nominal pulse, is limited to +/- 20% of the pulse's nominal velocity.

Environmental Stress Screening at temperature

Operational testing involves functionally testing the modules at the rated extreme temperatures. The functional tests are run after the module soaks at the design thresholds. The following figure depicts a typical cycle. Using the methods described in this brief, the WOLF module is exposed to up to 12 hours of this cycle.



Storage Temperature Testing

Storage testing involves emulating the survivability of the module during storage of the deployed product in a depot or the transportation of the module to the deployment location. The modules were functionally tested after exposure to the extreme storage temperatures.

Connect Tech Testing and Results

Connect Tech has also tested systems built using these guidelines ("Mechanical Considerations" and "Thermal Guidelines") and tested the units for shock and vibration as well as temperature.

Shock and Vibration Tests

The Shock and Vibration testing was done to meet the following specifications.

- IEC 60068-2-6 (2007) Annex. C Table C.1
- IEC 60068-2-27 (2008)

The tests were conducted by the National Technical Systems SLMT. Room ambient temperature used unless otherwise noted.

Test Procedure

Sinusoidal Vibration Testing:

Jetson Xavier NX assembly secured to vibration plate with M6 customer supplied bolts thereafter secured to vibration bottom plate with M4 bolts. Tri-axial monitoring accelerometer adhered to the center of the unit. While operational, unit exposed to (20) Sinusoidal cycles in each axis, where (1) cycle consists of 10-150-10 Hz Sinusoidal vibration at 7g with a rate of 1 Octave/minute. 5-2000 Hz, 0.5g resonance sweeps performed before and after each axis. Connect Tech personnel onsite for duration of vibration testing. Testing sequence: Z → X → Y

Shock Testing:

Jetson Xavier NX assembly secured to vibration plate with M6 customer supplied bolts thereafter secured to vibration bottom plate with M4 bolts. Tri-axial monitoring accelerometer adhered to the center of the unit. While operational, Assembly exposed to (4) negative and (4) positive shocks of 20g and 13ms in each of (3) orthogonal axes. Connect Tech personnel onsite for duration of shock testing. Testing sequence: Z → X → Y

Test Results

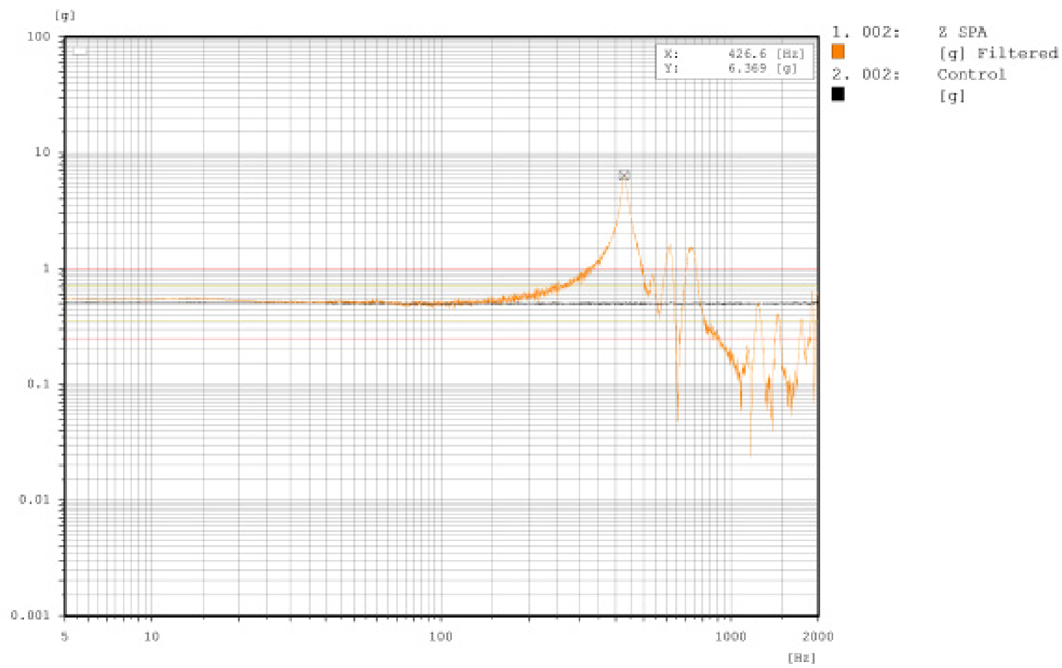
At test completion, there was no change observed to the Jetson Xavier NX assembly. Initial and Final QPT checks were performed onsite by a Connect Tech representative.

Test Data

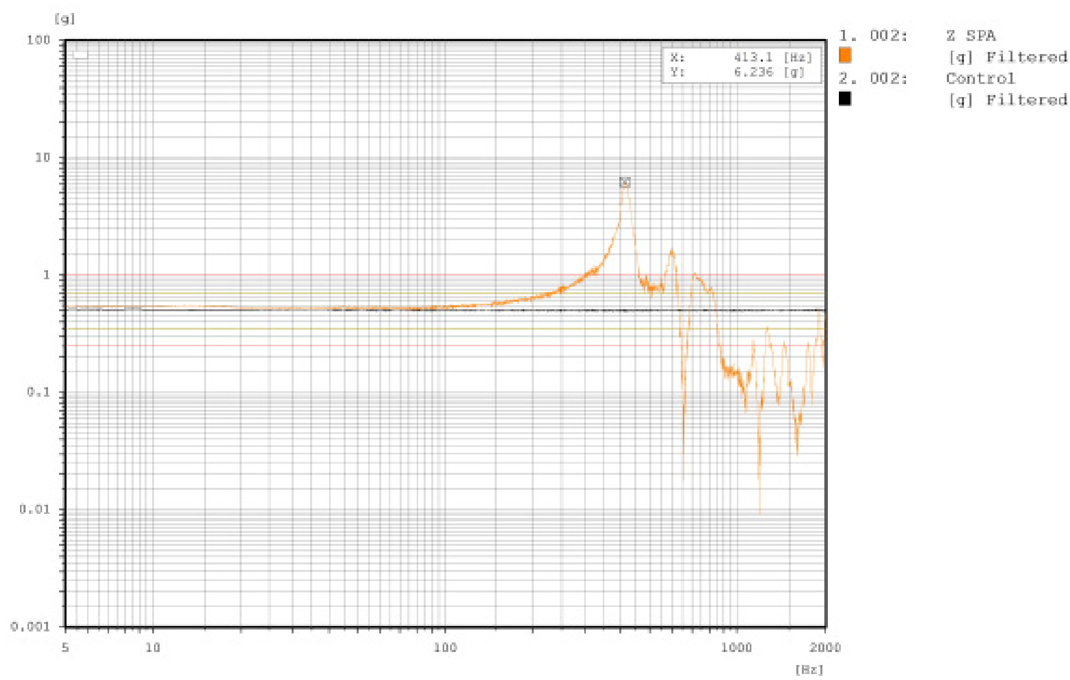
The following figures represent the test data.

Z-Axis Resonance Sweeps

Initial

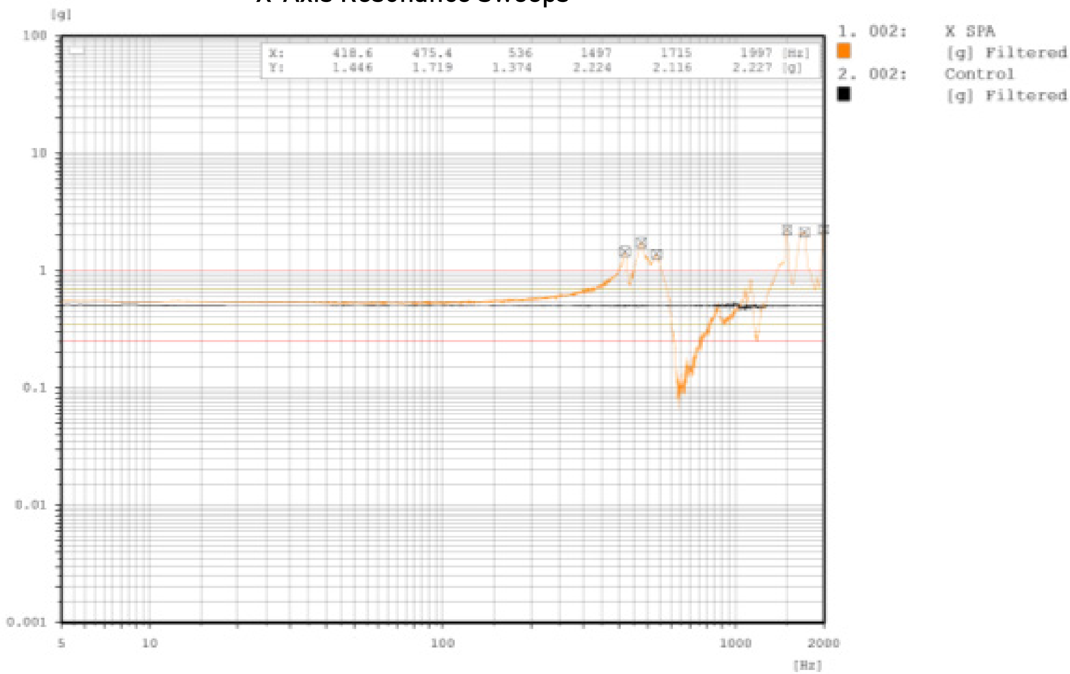


Final

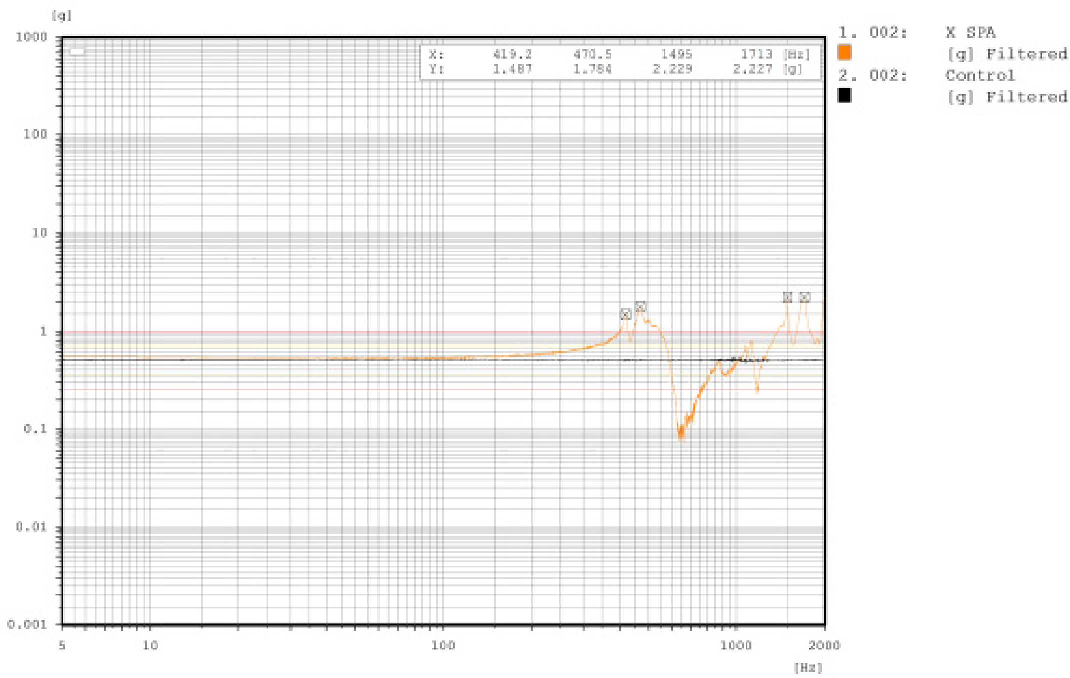


X-Axis Resonance Sweeps

Initial

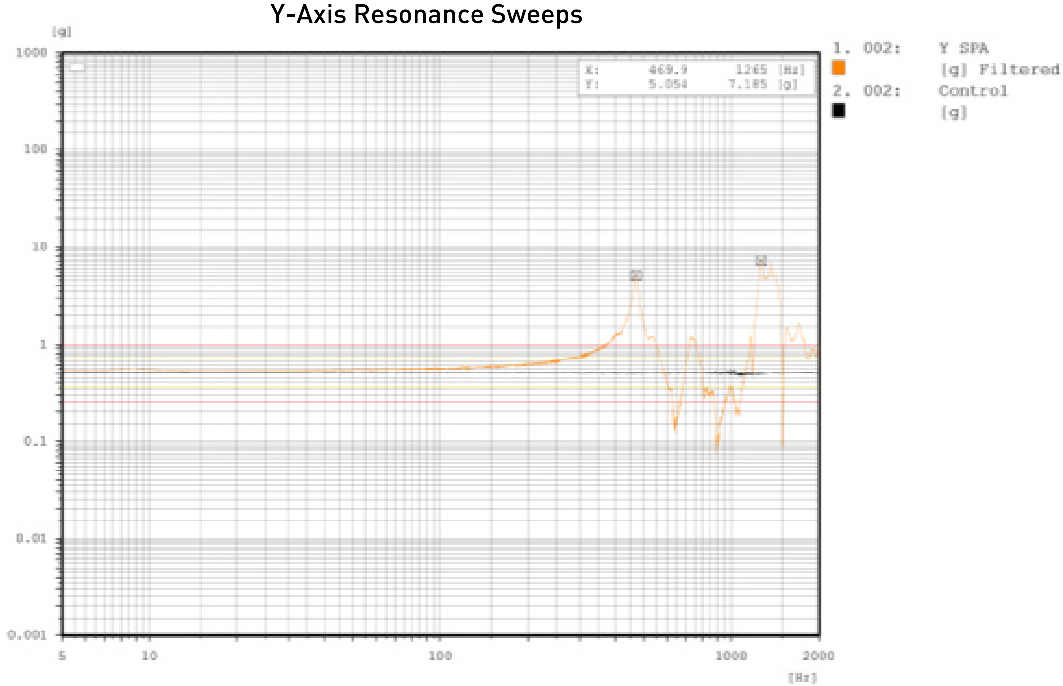


Final

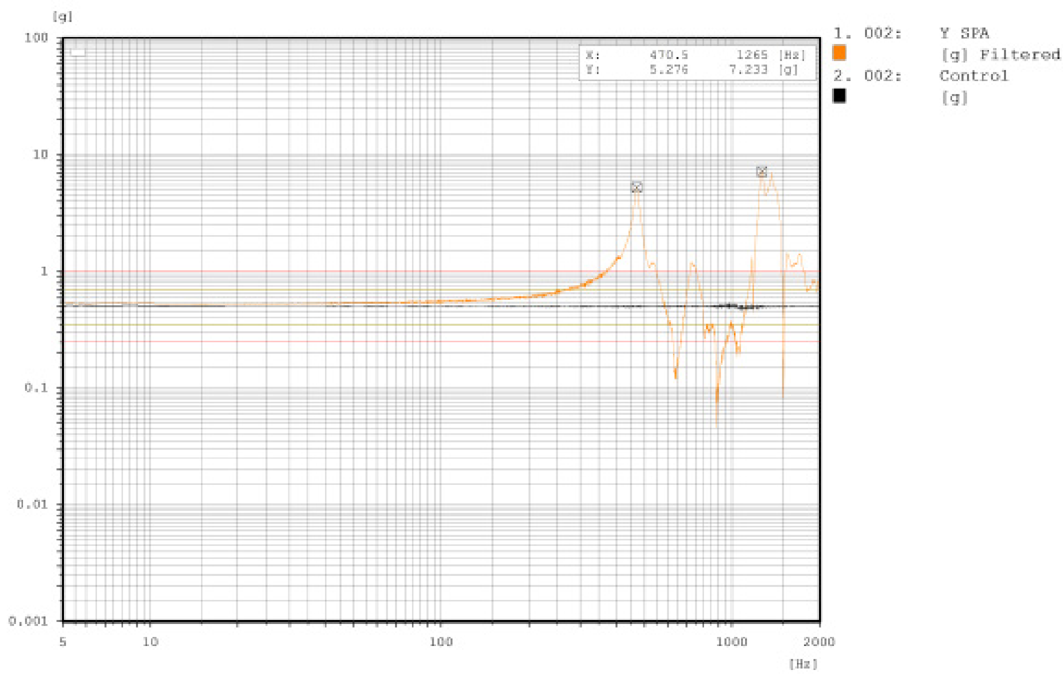


Y-Axis Resonance Sweeps

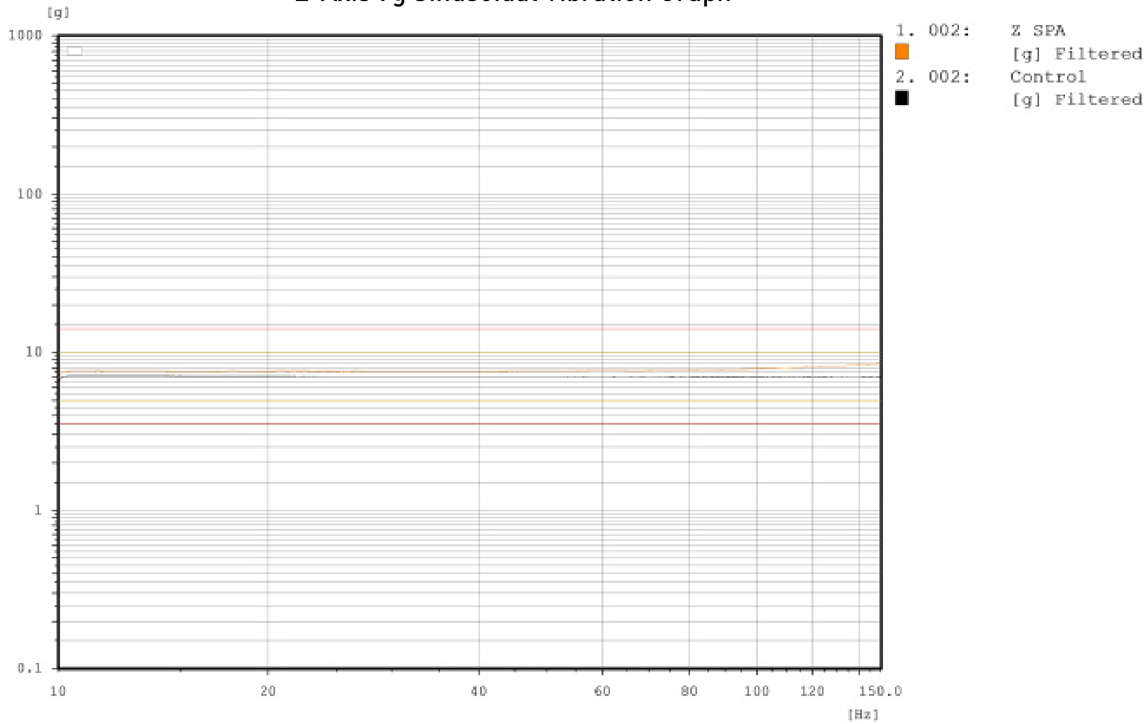
Initial



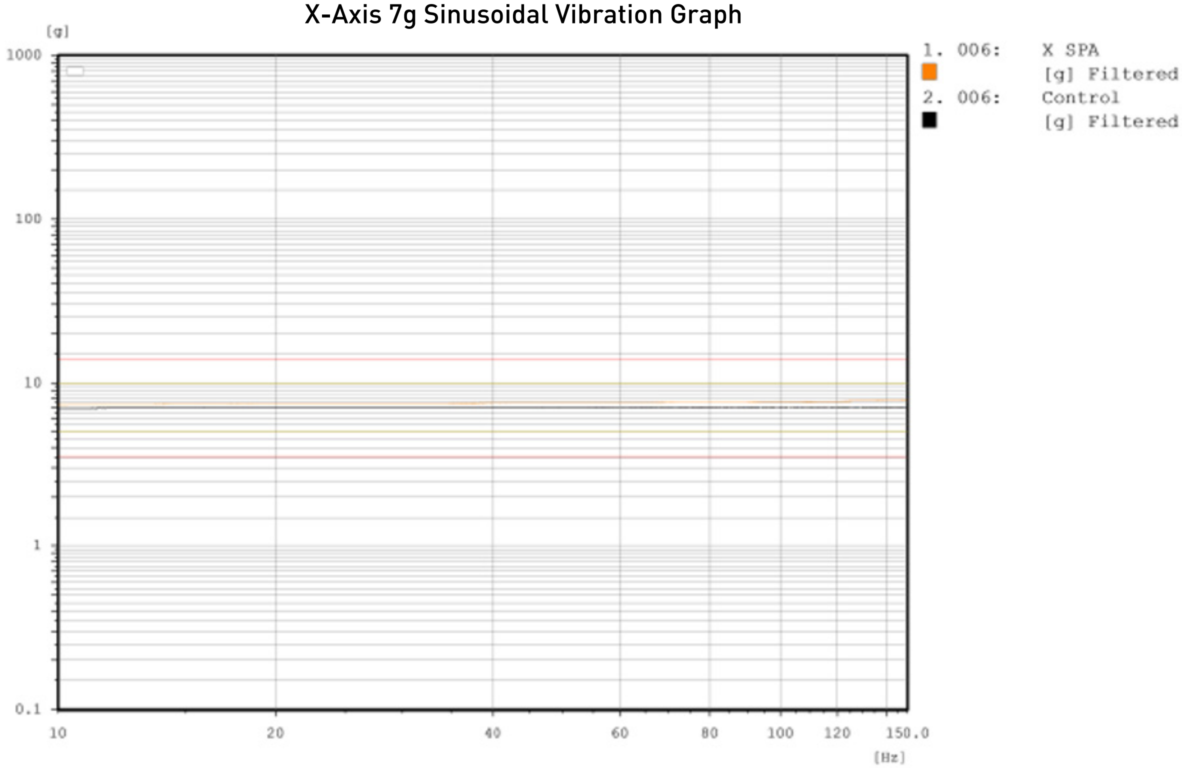
Final



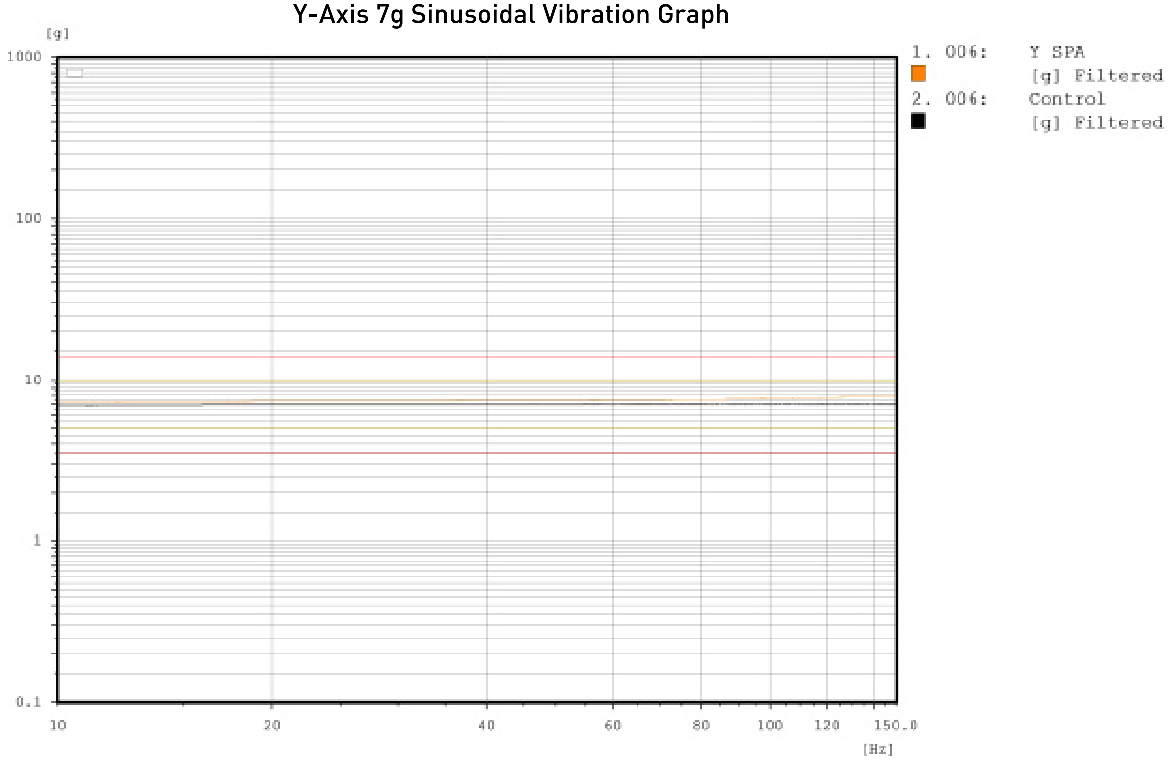
Z-Axis 7g Sinusoidal Vibration Graph



X-Axis 7g Sinusoidal Vibration Graph

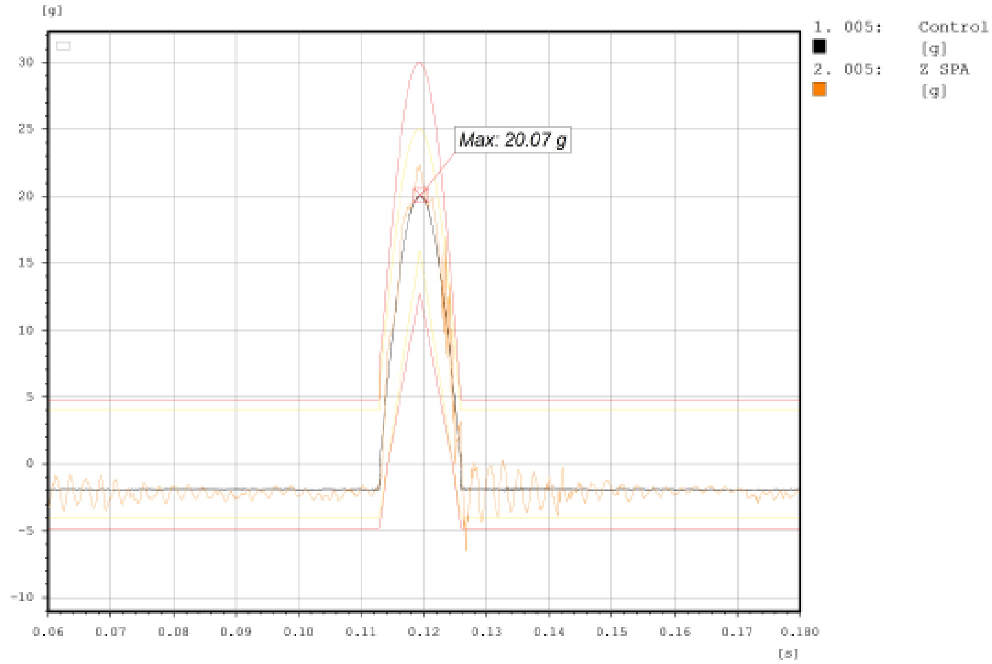


Y-Axis 7g Sinusoidal Vibration Graph

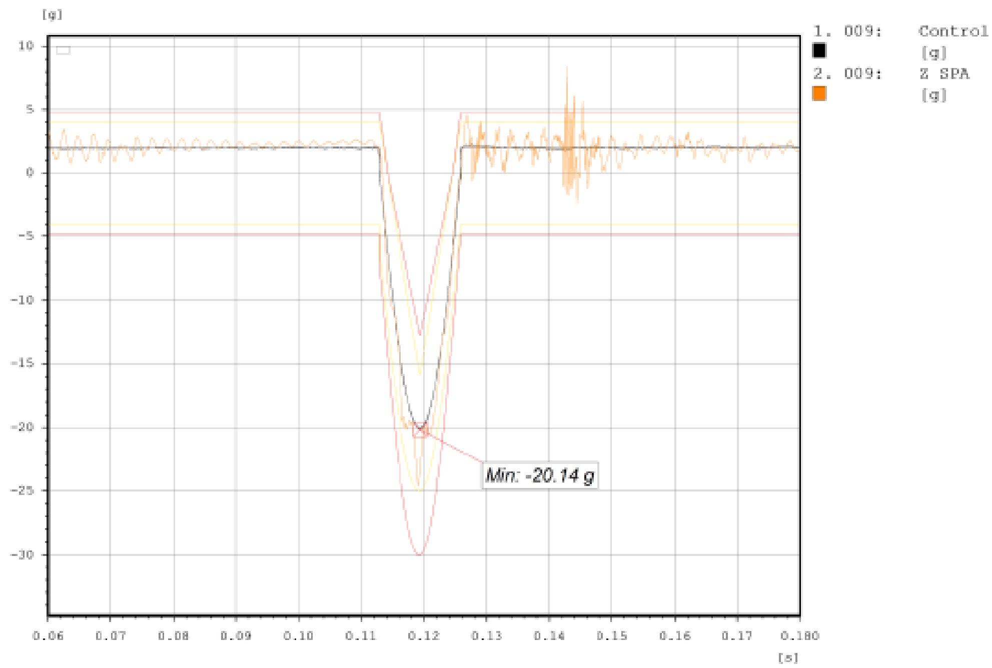


Z-Axis Representative Shock Graphs

Positive

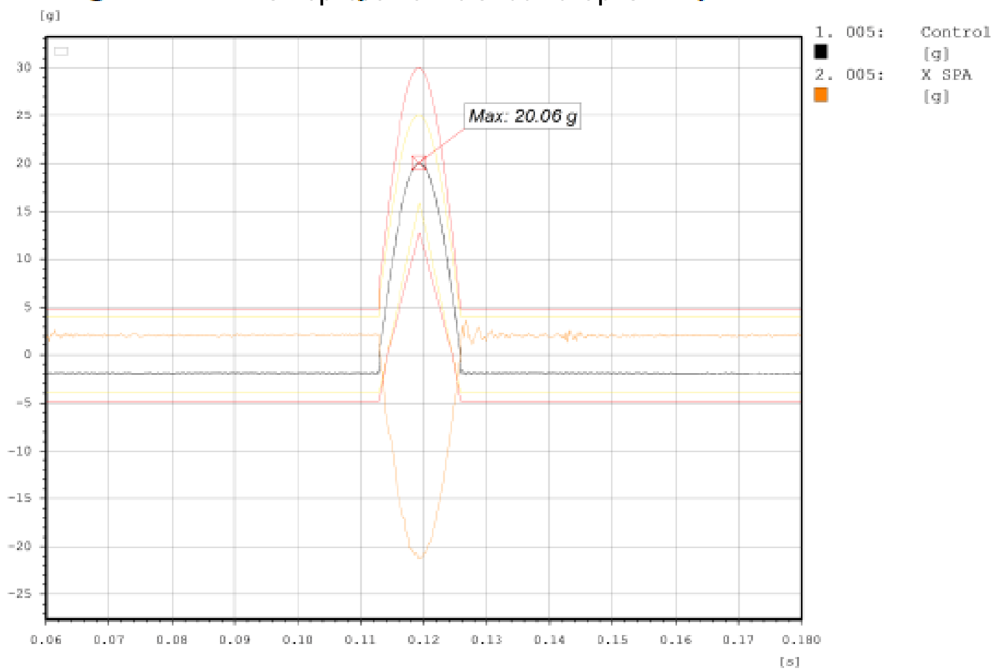


Negative

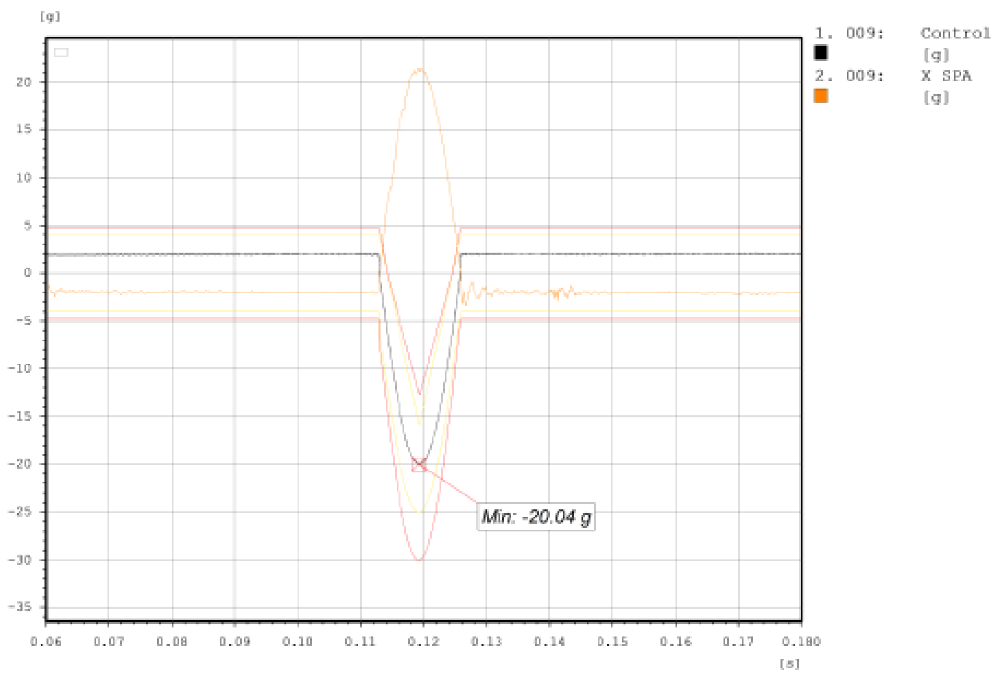


X-Axis Representative Shock Graphs

Positive



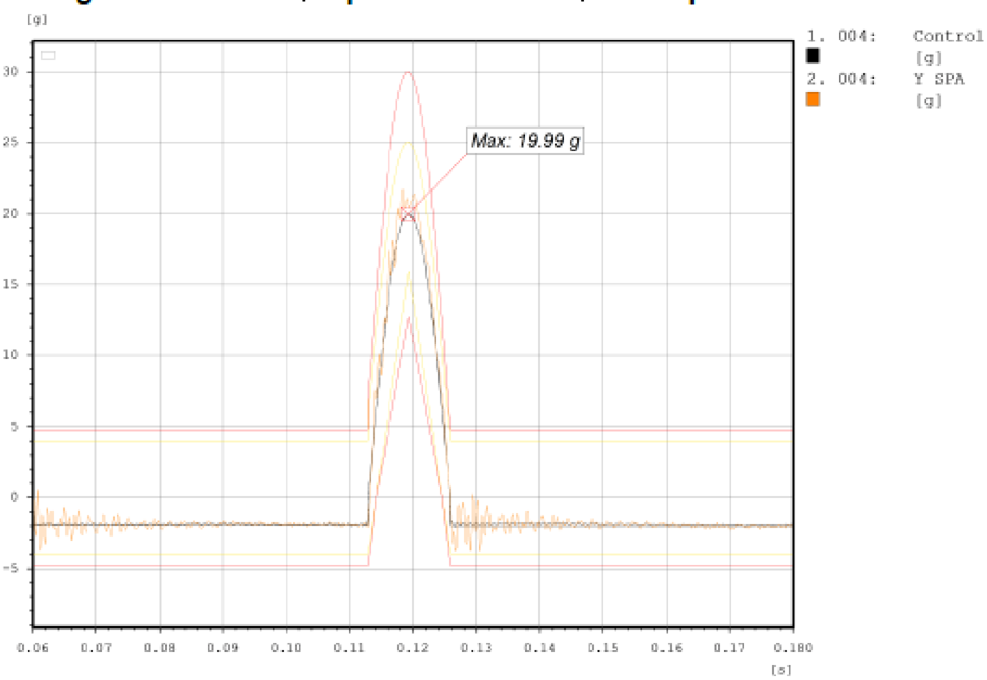
Negative



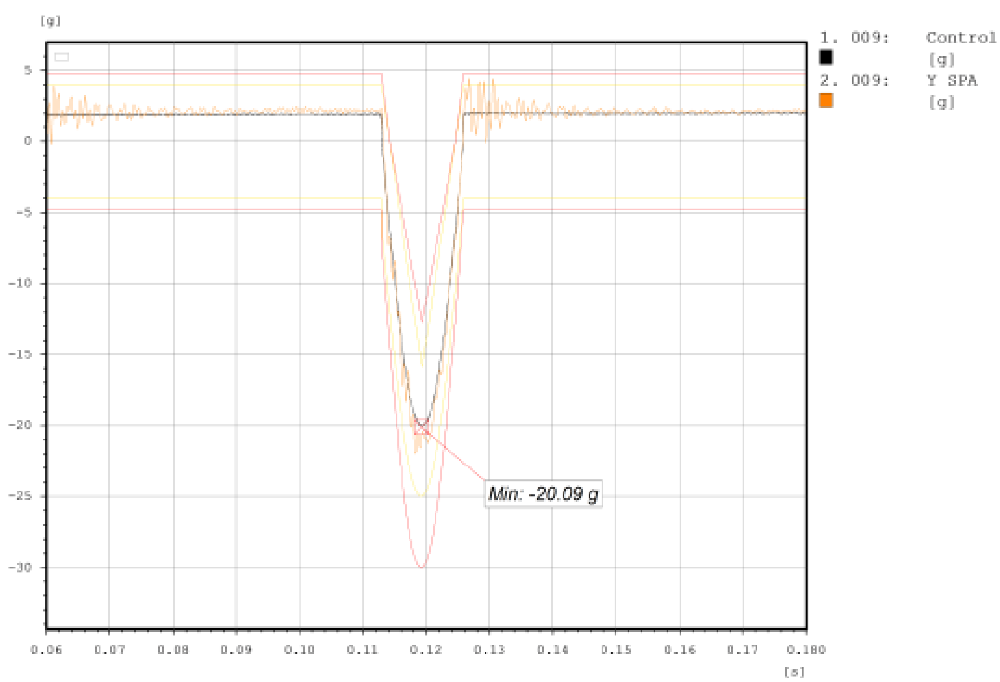
Note: Xavier Monitoring Accelerometer mounted in reverse polarity as control

Y-Axis Representative Shock Graphs

Positive



Negative



Temperature Tests

The following temperature tests were performed.

- **Temperature Tests with Rudi-NX System**
  - **Operating Temperature:** -20 °C to +80 °C operating
  - See Page 24 of the CTI manual for more details: https://connecttech.com/ftp/pdf/CTIM-ESG602_Manual.pdf
- **Temperature Tests with Custom NX System**
  - **Operating Temperature:** 5 °C to 55 °C operating and 20 °C to 80 °C storage
  - **Relative Humidity:** Soak 40 °C at 95% RH for 240 hours

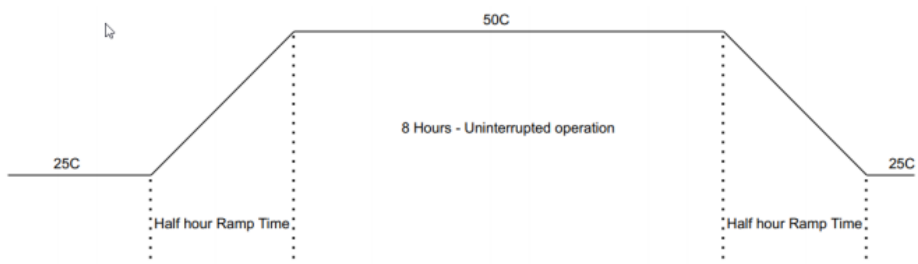
Test Summary

The following is a summary of the tests performed on the device under test.

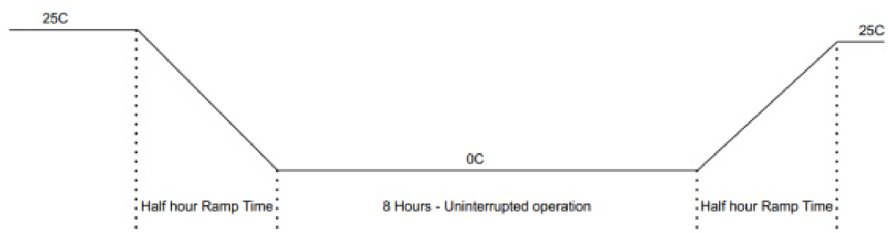
Test Case	Test Description	Purpose
1	Room temperature start, bring temperature up to 50 °C, run until components at steady state, keep it running for 8 hours	Characterize the device at normal temperature boot, moving into high temperature
2	Room temperature start, bring temperature up to 0 °C, run until components at steady state, keep it running for 8 hours	Characterize the device at lowest ambient temperature required to be tested with
3	Cold start -5 °C	Characterize the device at cold temperature
4	Hot start, 55 °C	Characterize the device at high temperature
5	Temperature ramp test between -5 °C and 55 °C	Characterize the device with airflow while stressed

The following diagrams are the thermal profiles set in the thermal chamber for each test case.

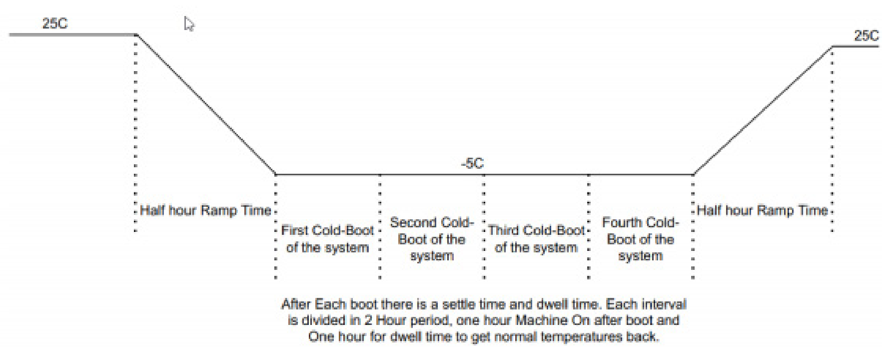
Test Case 1



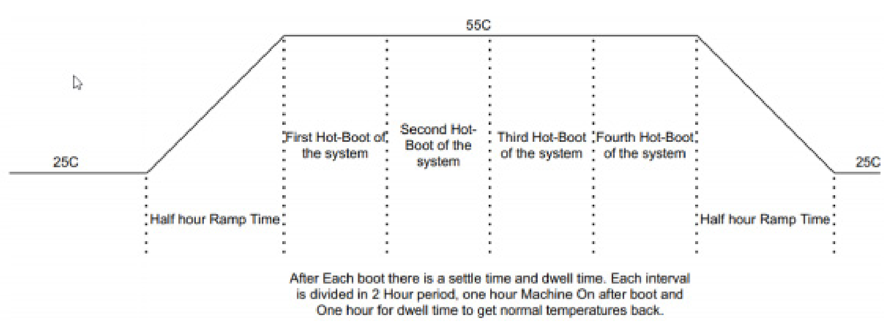
Test Case 2

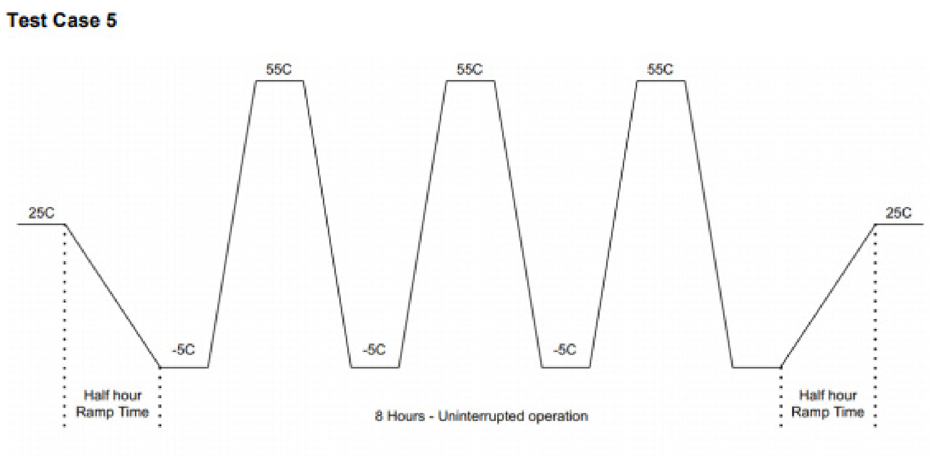


Test Case 3



Test Case 4





Thermal Test Results

To summarize the thermal results, the temperature values monitored while performing the tests temperature matched the characterization values. The application involving all the critical peripherals in the system ran smoothly without any failures, indicating the system passed the thermal operating requirement from 0 °C to 50 °C.

Test Case	Outcome
1	Pass
2	Pass
3	Pass
4	Pass
5	Pass

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