



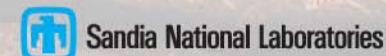
# ***MEMS COMPONENT RELIABILITY TESTING***

**Spring Meeting  
TECHNOLOGY COORDINATION GROUP XIV (TCG XIV)  
Predictive Materials Aging and Reliability  
Albuquerque, NM**

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Sandia National Labs  
Albuquerque, NM

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# PROJECT OVERVIEW

## Background:

- SNL shall assist AMRDEC with ascertaining major causes of COTS-MEMS device failures that are of general interest to weapons design and development to both laboratories.

## Objective:

- Conduct specific mechanical reliability tests and subsequent analysis on failed parts as part of a broad-based reliability study managed by AMRDEC/RDECOM.

## Description:

- Reliability testing will be performed on a single axis, High-G MEMS accelerometer ADXL193 manufactured by Analog Devices Inc.



Analog Devices ADXL193  
AD22283-B-R2

## Milestones:

- 4th quarter of fiscal year FY10 Procurement of devices
- 1st quarter of FY11 Completed [Variable Frequency Vibration Experiments](#)
- 2nd quarter of FY11 Completed [Mechanical Drop, Shock and Cycling Reliability Experiments](#)
- 1st and 3rd quarter of FY11 Reported Results (Presentation)
- 3rd quarter of FY11 Completed Failure Analysis
- 4th quarter of FY11 Completed Final Report

## Deliverables:

- Progress reports
- Final report



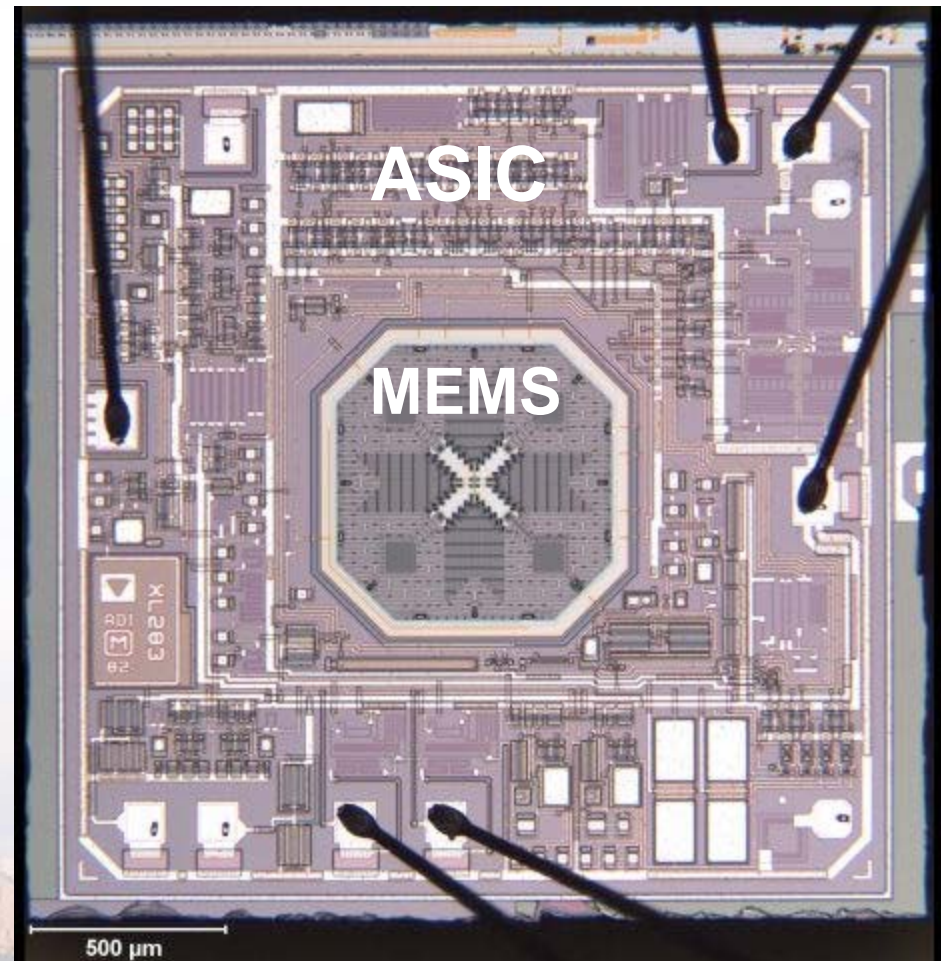
# **MEMS Accelerometer Device**

ADXL193 AD22283-B-R2

- Analog Devices
- $\pm 250g$  full scale range
- $8.0 \pm 0.4 mV/g$  sensitivity
- 8-terminal ceramic LCC package.
- Automotive grade
- MEMS and ASIC on a single monolithic IC
- Surface micro-machined
- $-65^{\circ}C$  to  $+150^{\circ}C$  operating range
- 4000g maximum acceleration



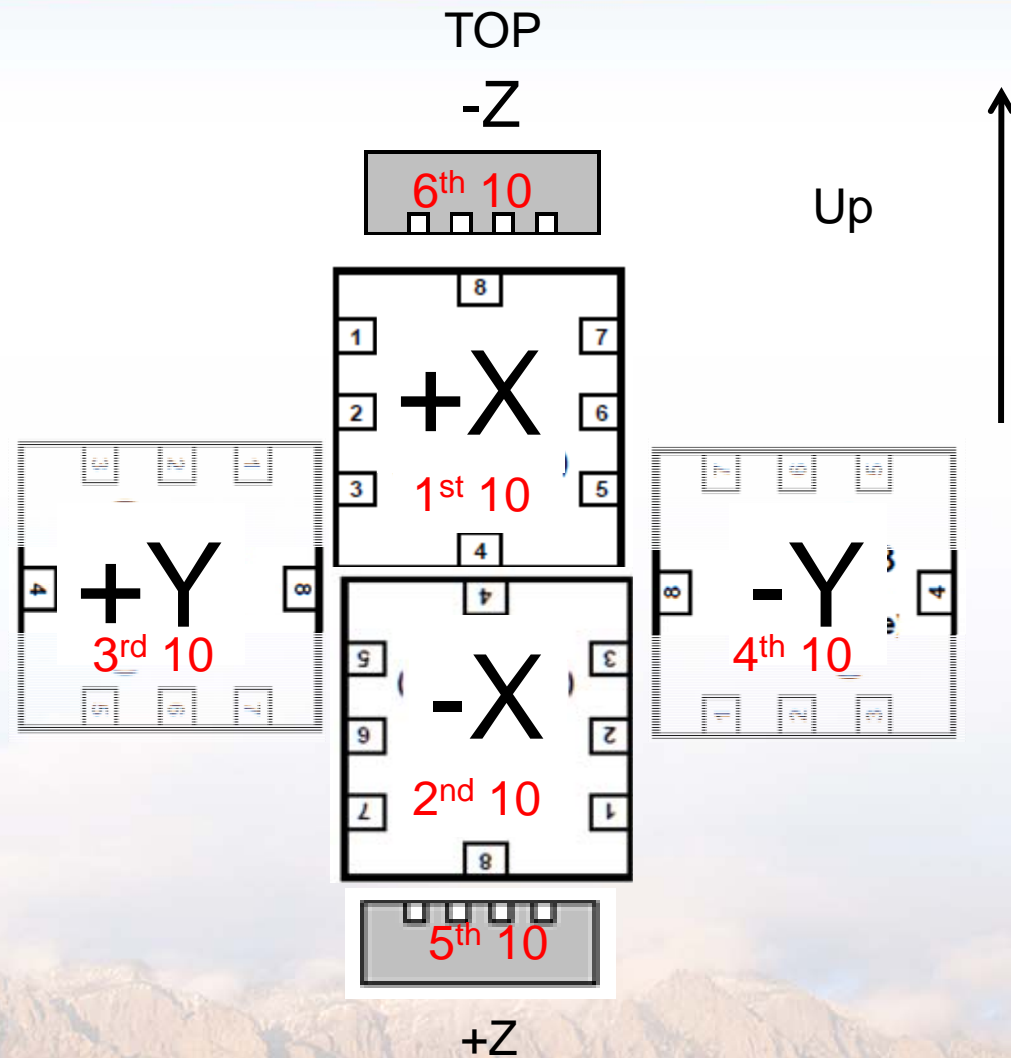
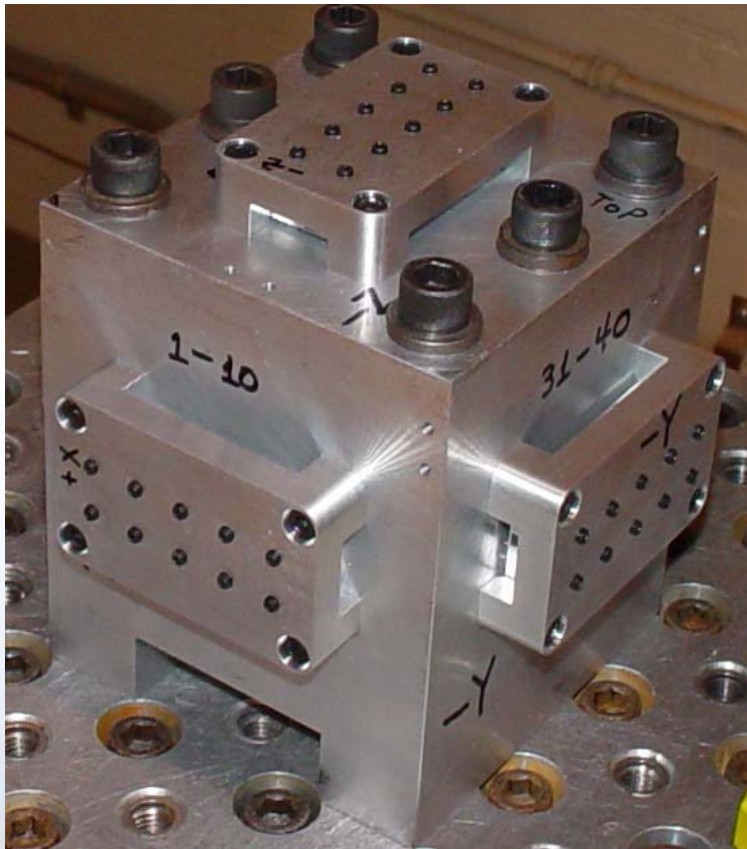
Similar De-lidded Device



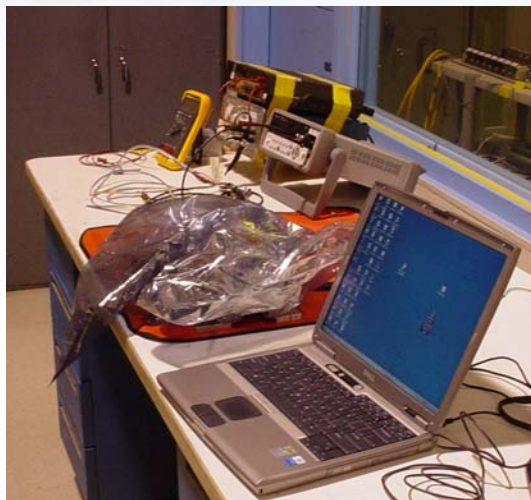
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# Part Orientation

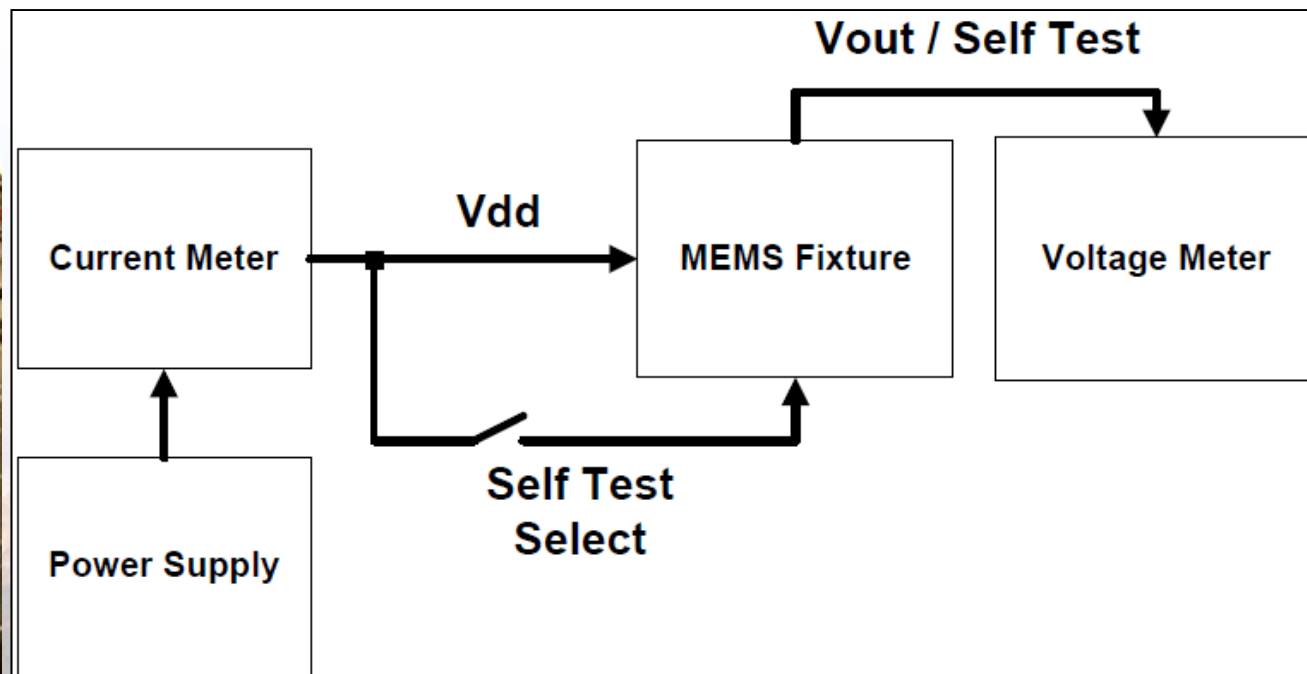
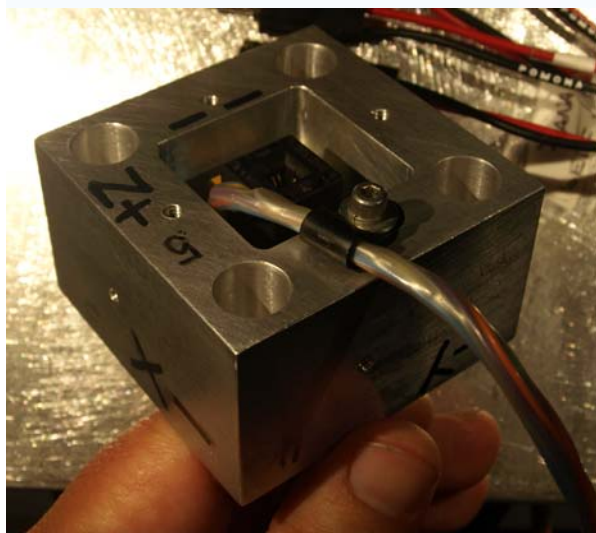
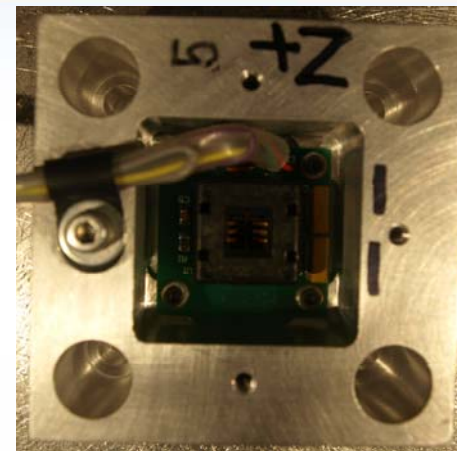


# Electrical Testing



## Tested Parameters:

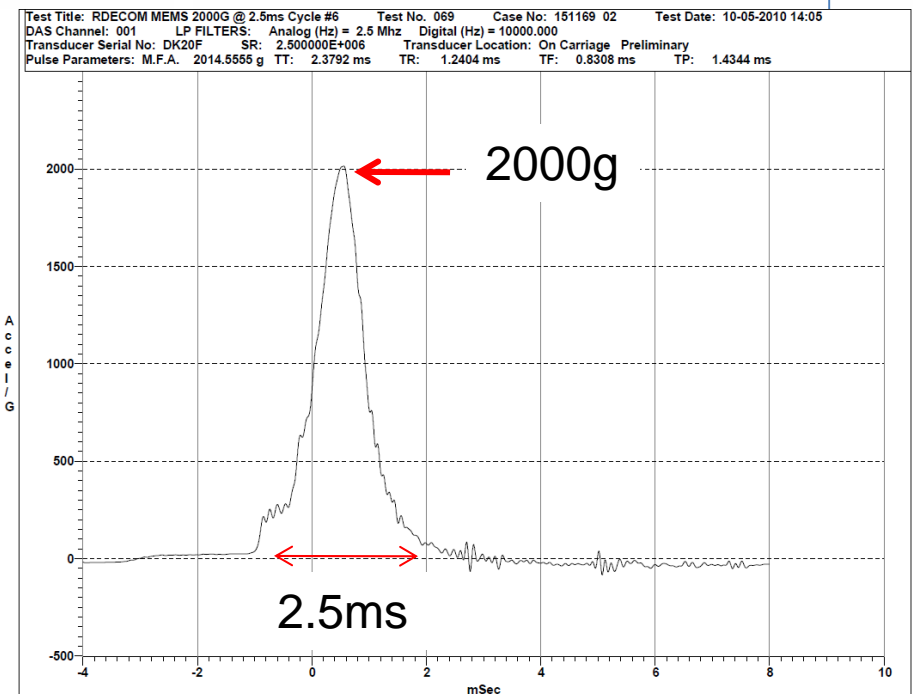
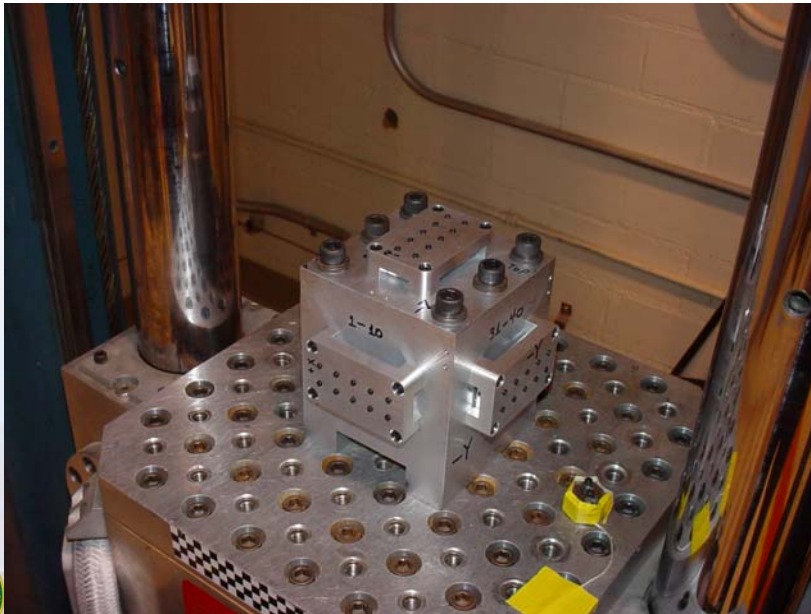
- $V_{out}$  for 6 orientations,
- Supply Current,
- $V_{out}$  for activated self test.



# Mechanical Drop Test

## Per MIL STD 810 Method 516.5F

- Max acceleration of 2000g and a pulse duration of 2.5 mS.
- Performed test on 10 devices mounted in the +/-x, +/-y, and +/- z orientations.
  - 60 devices total
- Repeat experiment until 100 cycles are completed.
  - Perform electrical tests at 10 cycle increments.
    - Self-test,
    - +1g and -1g response tests



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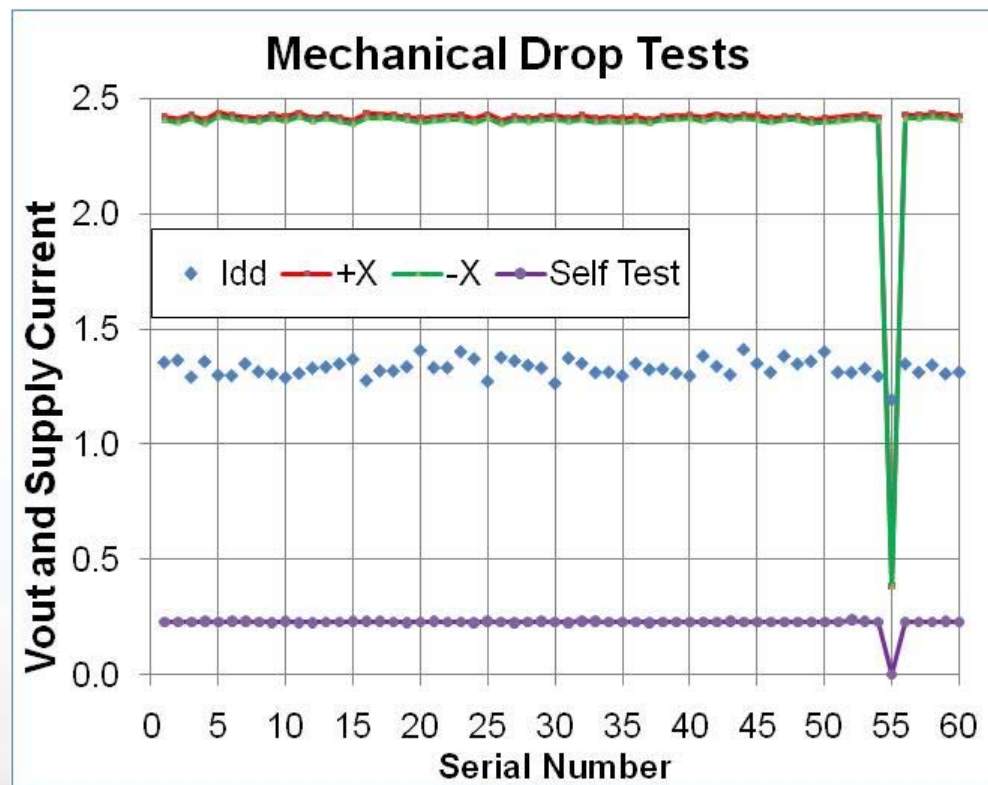


# Mechanical Drop Test Results

One failure out of 60 devices occurred after 100 drops

- $\pm 1g$   $V_{out}$  failed for all 6 axes
- Self test failed
- Measured drop in current draw
- Device was in  $-Z$  drop orientation

Drop  
Direction

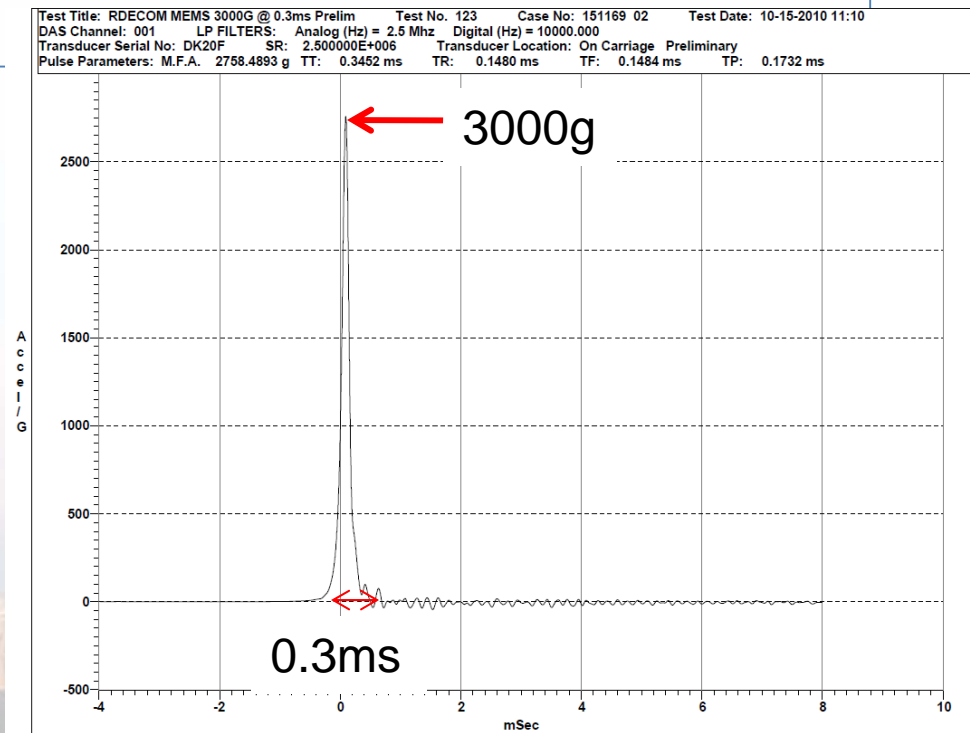
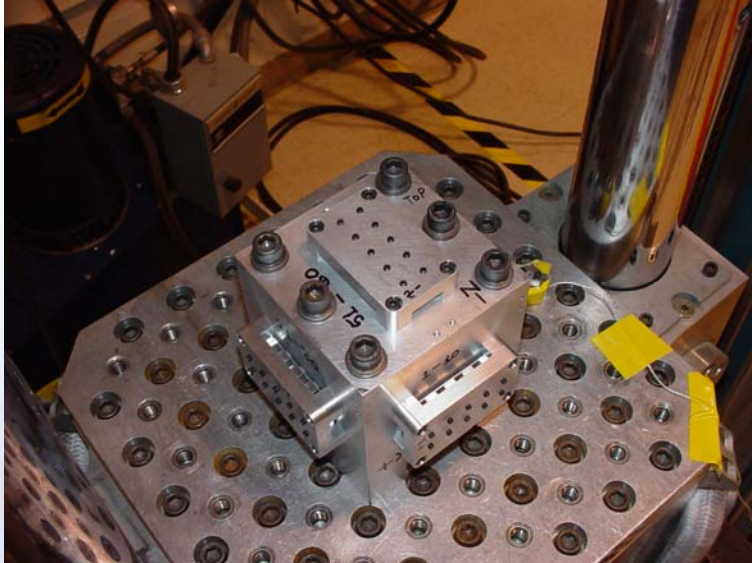


Test Cycle	SN	$\pm 1g$ $V_{out}$ Failure?	Failed Axes	Self Test Failure?	$\Delta I_{dd}$ ?	Drop Direction
Final 9 Drops	55	Yes	All 6	Yes	Yes	Minus Z



# Mechanical Shock Test

- 3000g max. acceleration and approximately 0.3 ms pulse width.
- Performed test on 10 devices mounted in the +/-x, +/-y, and +/- z orientations.
  - 60 devices total
- Repeat experiment until 100 cycles are completed.
  - Perform electrical tests at 10 cycle increments.
    - Self-test,
    - +1g and -1g response tests



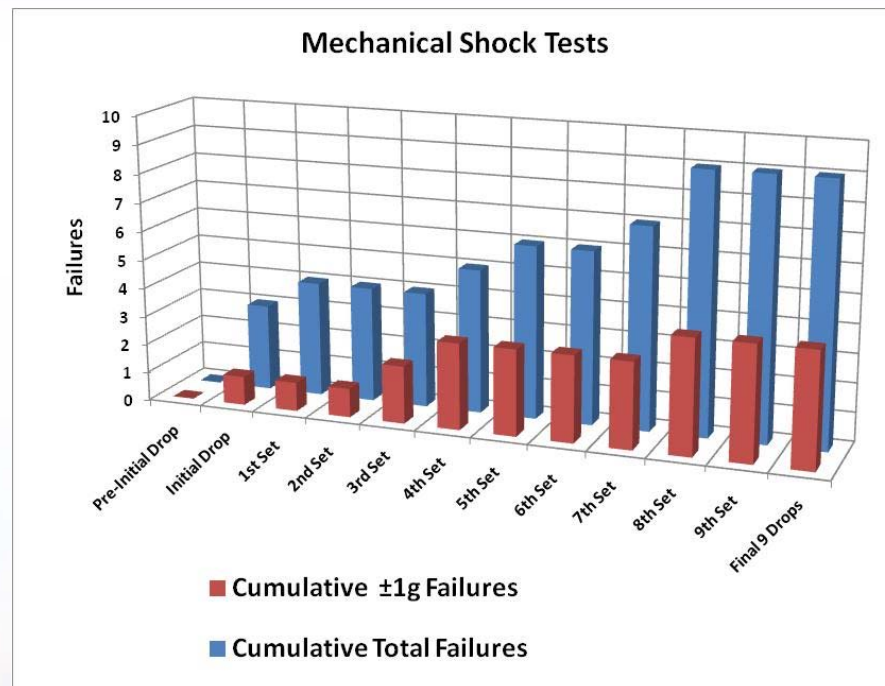
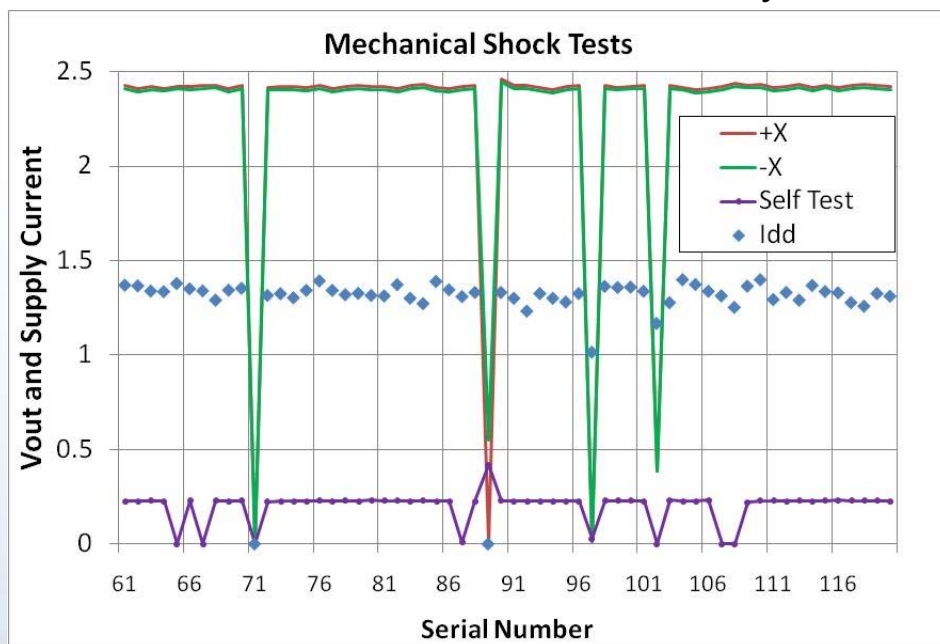


# Mechanical Shock Test Results

## Nine failures out of 60 tested devices

Four devices failed  $\pm 1g$   $V_{out}$  for all 6 axes and Self Test

- Measured drop in current
- Five devices failed Self test only



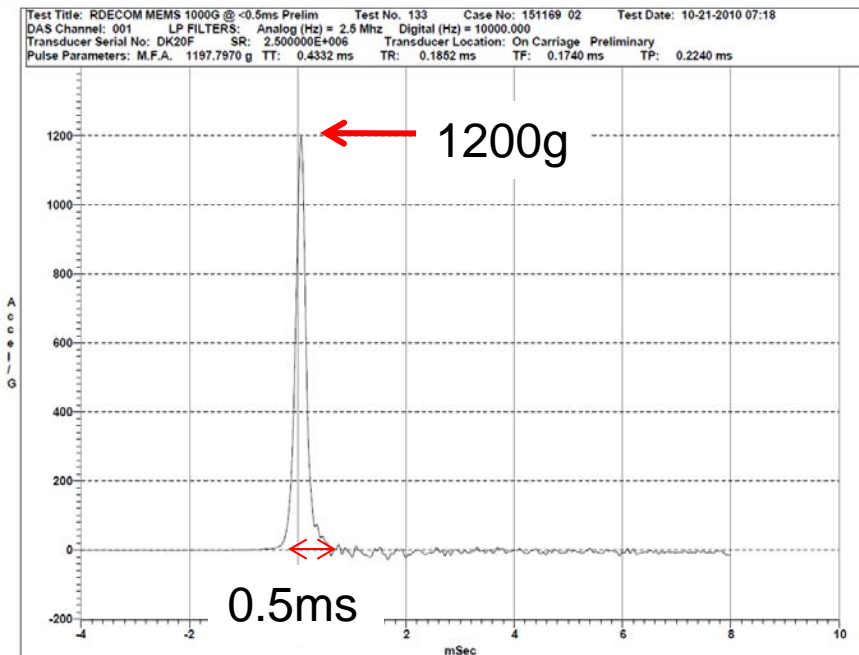
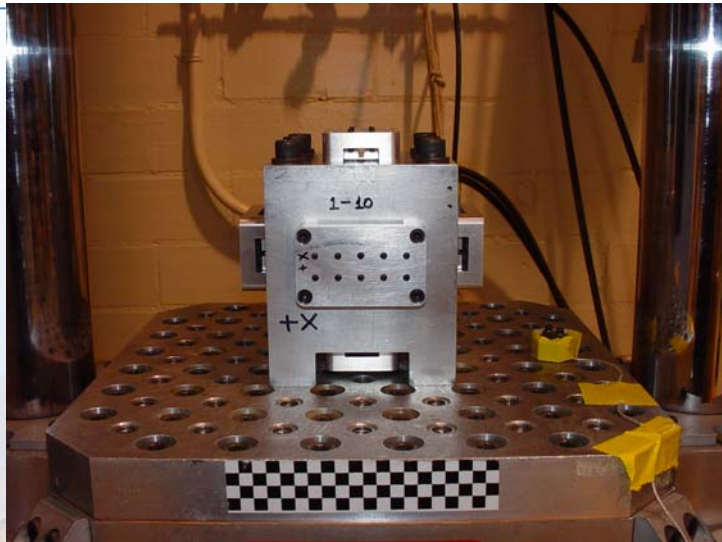
Test Cycle	Initial Drop			1st Set	4th Set	5th Set	7th Set	8th Set	
SN	102	65	107	67	71	97	87	89	108
Drop Direction	plus Z	plus x	plus z	plus x	minus x	minus y	plus y	plus y	plus z



# Mechanical Cycling Test

## Per MIL STD 810 Method 516.5F

- Shock pulses with max. accelerations between 1000g and 10000g, at 1000g intervals with a pulse width not exceeding 0.5 ms.
- Performed test on 10 devices mounted in the +/-x, +/-y, and +/- z orientations.
  - 60 devices total
- Repeat experiment until failure or until 100 cycles are completed.
  - Perform electrical tests at 10 cycle increments.
    - Self-test,
    - +1g and -1g response tests

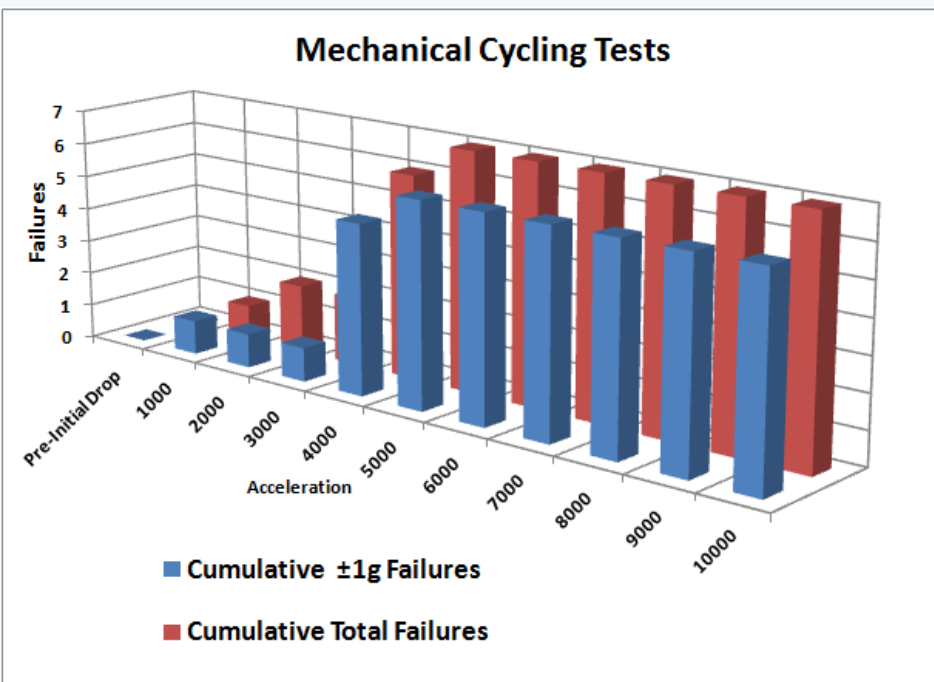
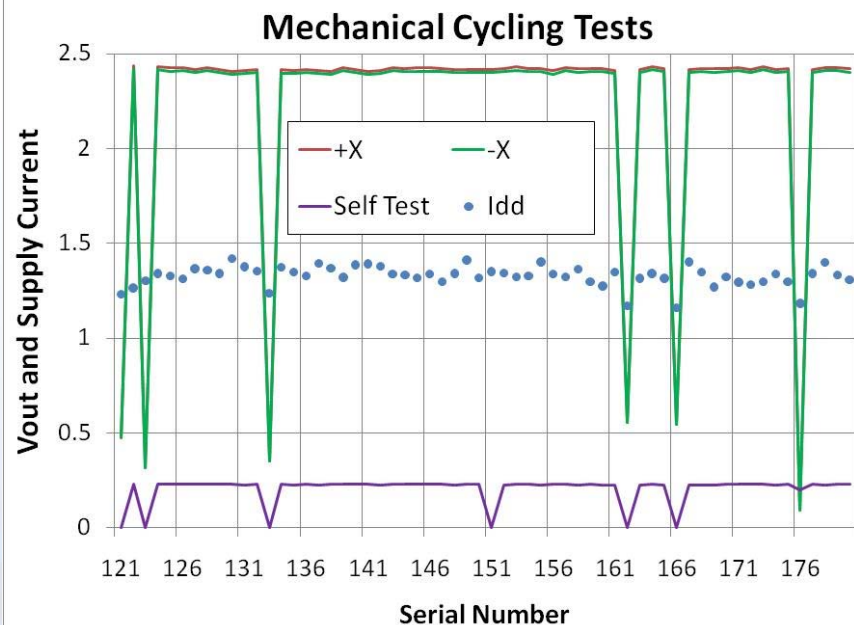


# Mechanical Cycling Test Results

## Seven failures out of 60 tested devices

Six devices failed  $\pm 1g$   $V_{out}$  for all 6 axes and Self Test

- Measured drop in current
- One device failed Self test only



Test Cycle	1000	2000	4000				5000
SN	166	151	121	123	133	176	162
Drop Direction	plus z	minus y	plus x	plus x	minus x	minus z	plus z

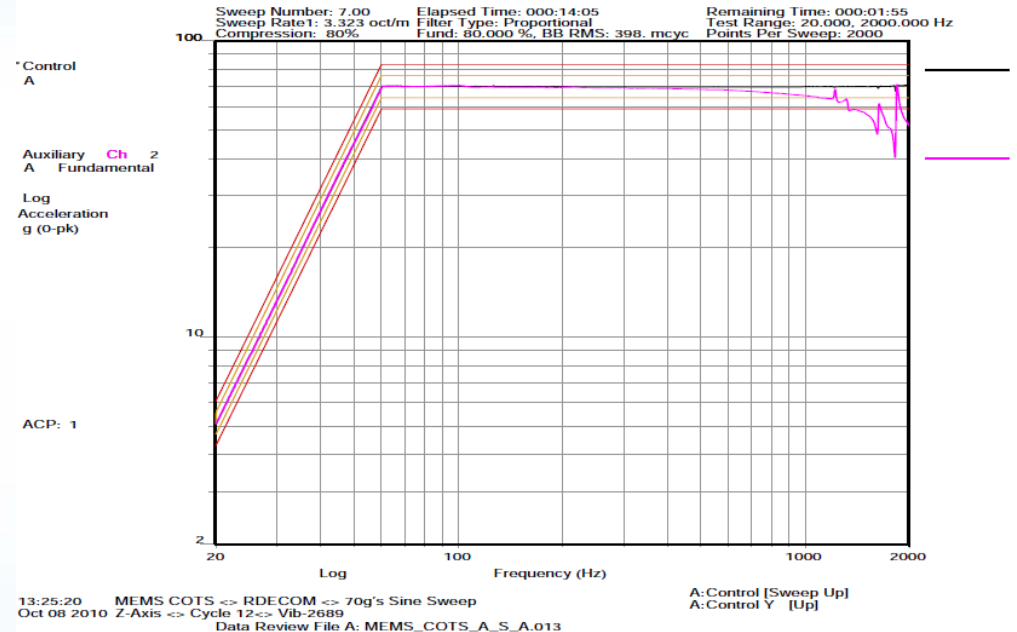




# Variable Frequency Vibration Test

## Per Mil-Std 883 2007.3

- Peak acceleration of 70g.
- Vary frequency range across 20-2000Hz range in approximately logarithmic intervals.
- Traverse frequency range 20-2000 Hz then return to 20 Hz in 4 minutes.
- Perform test on 10 devices mounted in the x, y, and z orientations.
  - 30 devices total
- Repeat experiment until failure or until 12 cycles are completed.
  - Perform electrical tests at 1 cycle increments.
    - Self-test,
    - +1g and -1g response tests



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# Variable Frequency Vibration Test Results

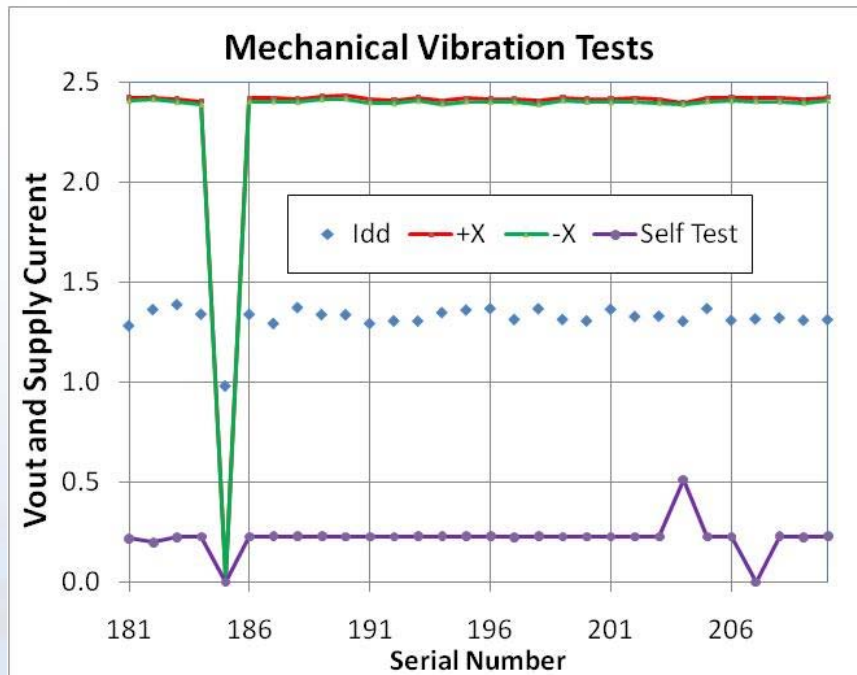
## Four Failures out of 30 tested devices

One Failed  $\pm 1g$   $V_{out}$  after 9<sup>th</sup> sweep for all 6 axes and Self Test

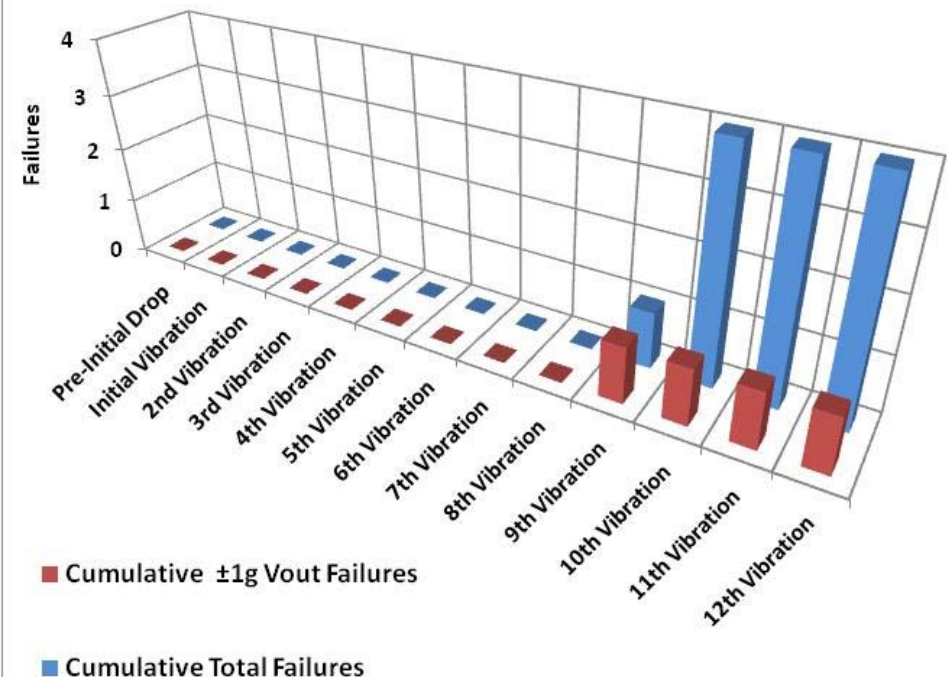
- Measured decrease in current
- X orientation

## Three Additional Failures after 10<sup>th</sup> Sweep

- Failed Self test only
- X and Z orientation



## Vibration Tests



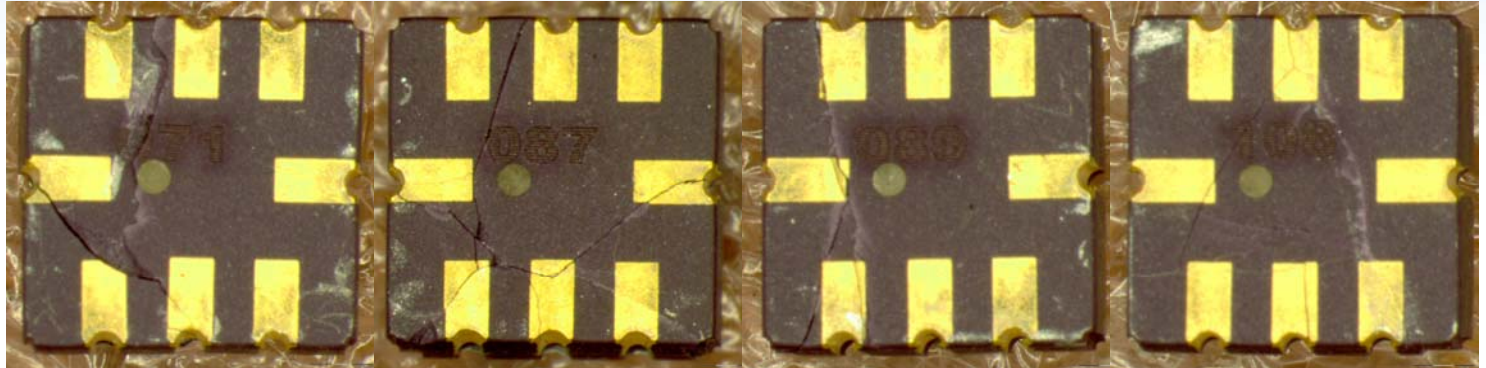
Test Cycle	Post 9th Vibration		Post 10th Vibration	
SN	185	182	204	207
Orientation	X	X	Z	Z



# Package Failures

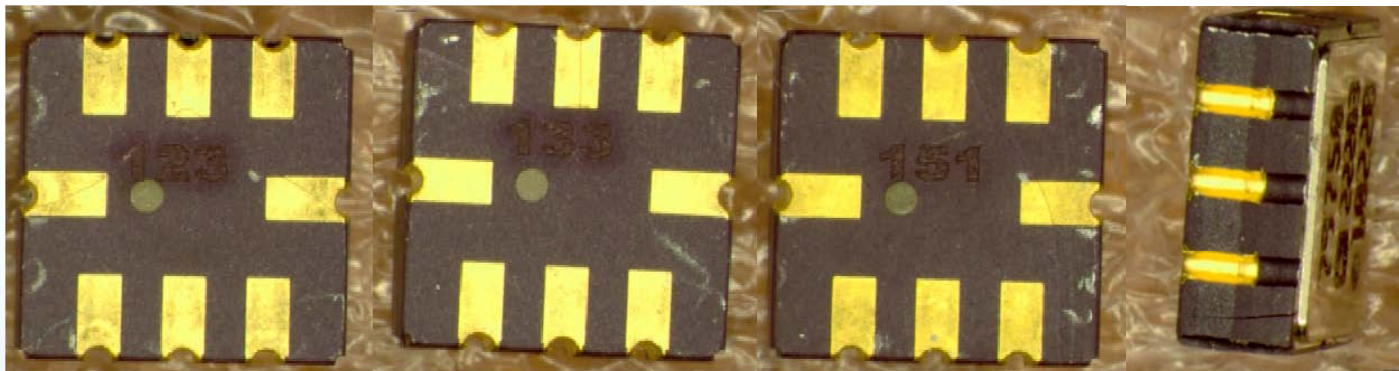
## Mechanical Shock Test

SN 71	SN 87	SN 89	SN 108
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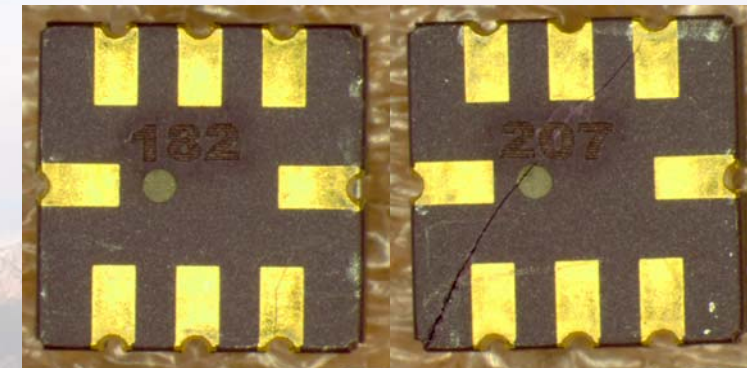
## Mechanical Cycling Test

SN 123	SN 133	SN 151	SN 176
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## Vibration Test

SN182	SN207
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# Pending Activities

- Perform failure analysis on selected failed devices.
- Communicate with AMRDEC counterparts for feedback.
- Final Report.

