WHITE PAPER

Shock and Vibration Testing of the SA.45s Chip Scale Atomic Clock (CSAC) Validation Build Units

INTRODUCTION

The Microsemi SA.45s Chip Scale Atomic Clock (CSAC) is designed for field applications where atomic clocks typically have not been deployed before. It is smaller, lighter and uses less power than any previous atomic clock and is engineered to withstand higher levels of shock and vibration. This paper summarizes a series of mechanical shock and vibration tests to confirm the CSAC's hardware environmental performance.

Five build units were subjected to non-operation mechanical shock testing per MIL-STD-202G, Method 213, exposing the unit to a total of 18 shocks for each shock level. In addition, their Allan Deviation and dynamic phase noise performance were measured using both 0 dB (7.70 grms) and +6 dB (15.40 grms) random vibration profiles.

The testing shows that the SA.45s CSAC will meet the following product specifications:

1. No loss of atomic lock and no damage when subjected to random vibration per Mil-STD-810G, Method 514.6, Procedure I, Category 24, General Minimum Integrity, 7.70 grms. Units tested to higher shock levels of 1500 g and 2000 g were also not damaged from this shock test.
2. Survive (non-operating) 1000 g, 0.5 msec half-sine shock pulse per MIL-STD-202G, Method 213, Test Condition E.
3. No loss of atomic lock when exposed to a random vibration level of 7.70 grms when tested for 30 minutes in each of the three axes.

The effect of vibration on SA.45s CSAC frequency stability is of particular interest as exceptional frequency stability is typically a key reason for using an atomic clock. As the summary plots of Figure 1 show, the Allan Deviation (ADEV) under the 7.70 grms random vibration level is very good. The composite plots of ADEV test results show that for SN 232 (-002 Performance Level) the dynamic performance will meet the static ADEV specification. The ADEV test results for SN 206 (-001 Performance Level) will meet the static ADEV specification, except in the worst-case Z Axis. This exceptional frequency stability under random vibration directly results from the SA.45s CSAC's robust physics package design.

As expected, the CSAC's performance degrades at the higher vibration level of 15.40 grms. But all five CSAC units tested remained locked when exposed to the +6 dB higher level of 15.40 grms. And as the ADEV plots in Appendix C show, some of the CSAC units meet the ADEV static specification in the X Axis vibration at the 15.40 grms vibration level, while the other two axes are above the specification line.

Note that the functional performance of the SA.45s CSAC under vibration is not specified on the Microsemi data sheet since it is impossible to predict how a customer will secure the unit in a particular application. The mechanical resonances of a particular mounting scheme will have a direct effect on the measured performance of the SA.45s CSAC under vibration.

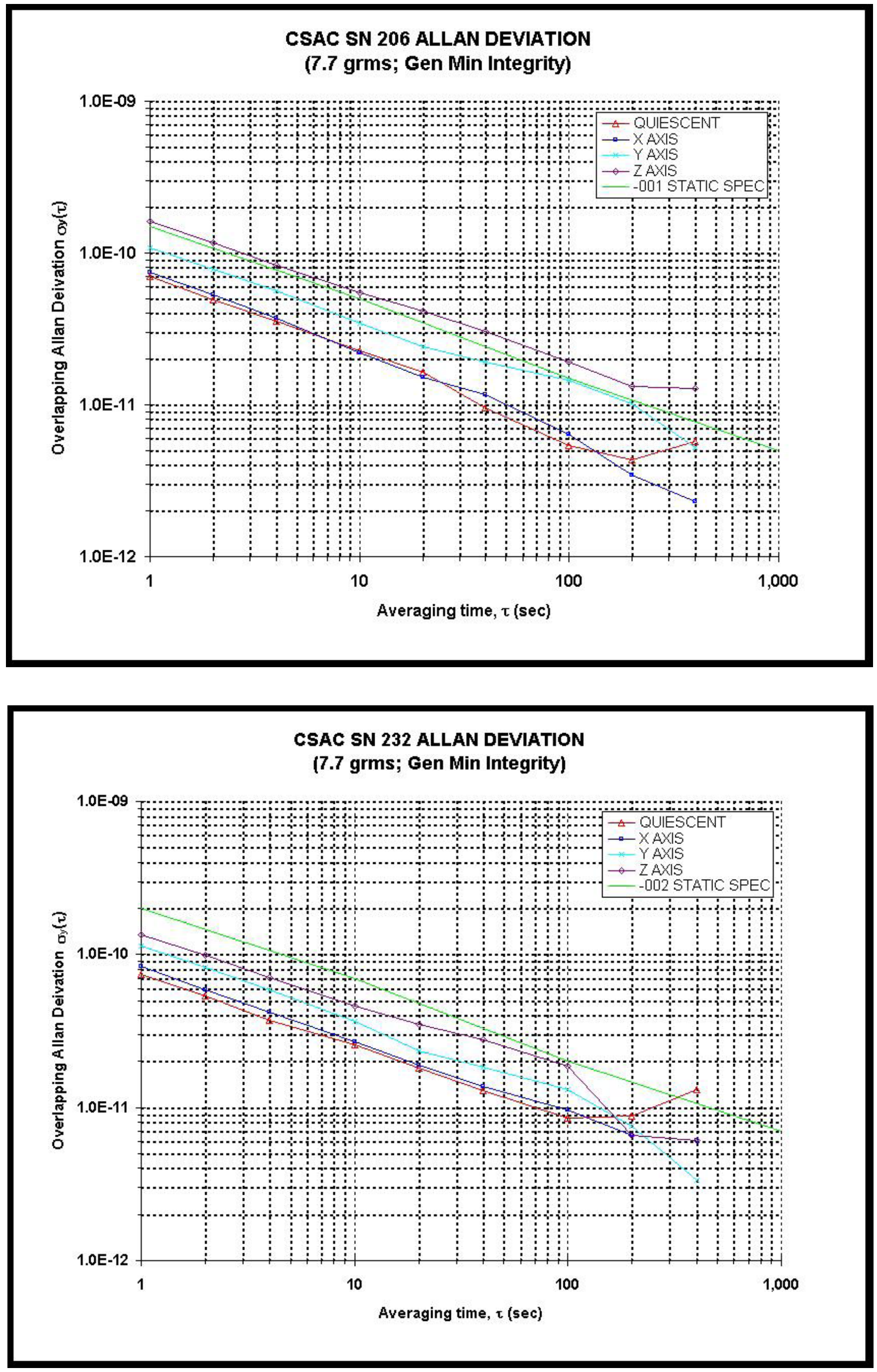


Figure 1. CSAC Allan Deviation Under Vibration

Shock and Vibration Testing of the SA.45s Chip Scale Atomic Clock (CSAC) Validation Build Units

Scope

As discussed in MIL-STD-810G, essentially all materiel will experience vibration, whether during manufacture, transportation, maintenance or operational use. MIL-STD-810G has numerous standard random vibration profiles that address most of the lifecycle situations during which a product is likely to experience vibration. Procedure I is used for materiel to be transported as secured cargo or deployed for use on a vehicle. It applies to ground vehicles as well as fixed and rotary wing aircraft. Performance of the SA.45s CSAC was monitored during the random vibration testing in each of the three mutually perpendicular axes of the unit. Table 1 shows the random vibration profiles employed.

The actual SA.45s CSAC usage environments will be varied, so in order to evaluate the performance under random vibration, the MIL-STD-810 General Minimum Integrity test shown below in Figure 2 was utilized. The general minimum integrity test is intended to provide reasonable assurance that materiel can withstand transportation and handling including field installation, removal and repair. The vibration levels of Method 514.6E-1 are not based on application environments. Rather, experience has shown that materiel that withstands these exposures will function satisfactorily in the field.

The MIL-STD-202 mechanical shock test is conducted for the purpose of determining the suitability of parts and subassemblies of electronic components when subjected to shocks, which may be expected as a result of rough handling, transportation and military operations. The SA.45s CSAC was tested using the standard half-sine shock pulse waveform with three shocks in each direction along the three mutually perpendicular axes of the unit (18 shocks total). The SA.45s CSAC was not operational during the shock testing, but was functionally tested after each shock axis.

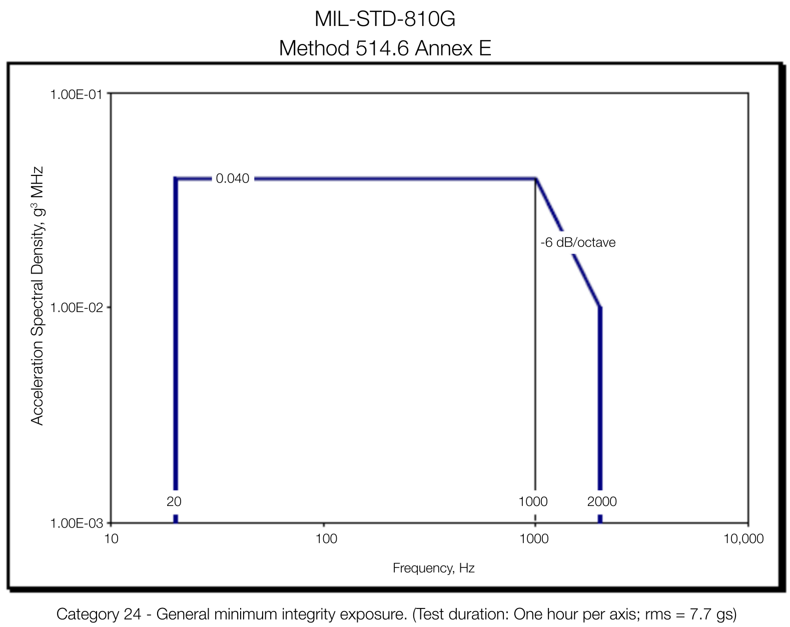


Figure 2. MIL-STD-810G Method 514.6 General Minimum Integrity Vibration

Frequency (Hz)	0 dB Test	+6 dB Test
	PSD Level (g^2/Hz)	PSD Level (g^2 /Hz)
20	0.04	0.16
1000	0.04	0.16
2000	.0100475	0.0401902
Overall (grms)	7.70	15.40

Table 1. Random Vibration Test Profiles

Shock and Vibration Testing of the SA.45s Chip Scale Atomic Clock (CSAC) Validation Build Units

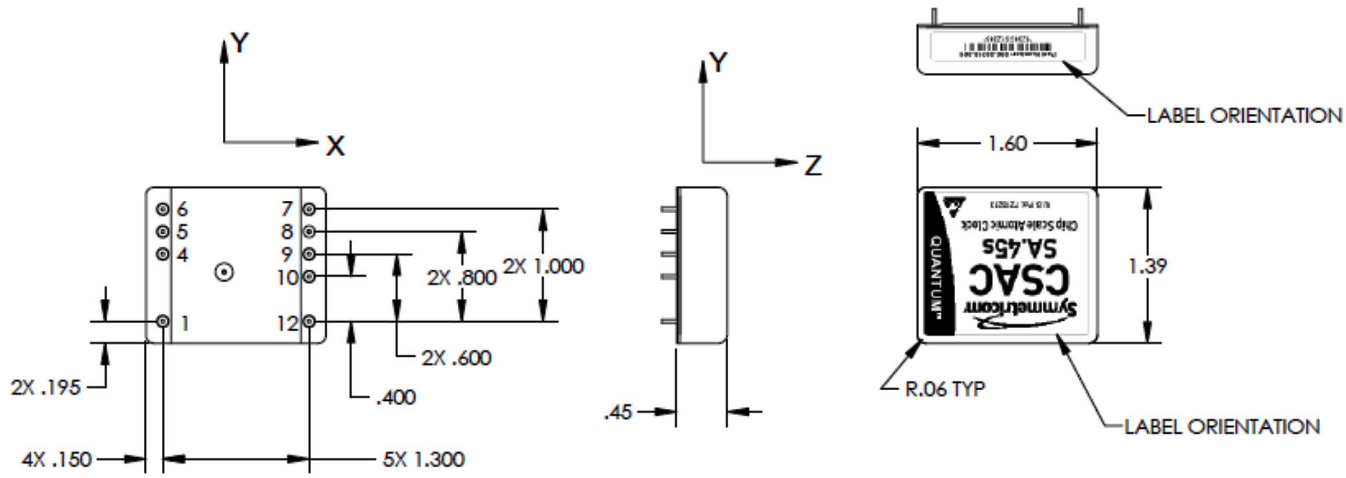


Figure 3. SA.45s CSAC Test Axes Definition

TEST SETUP

The validation build SA.45s CSAC units all passed the standard CSAC production acceptance testing prior to the mechanical testing discussed here. Figure 3 defines the test axes of the SA.45s CSAC used in this mechanical testing.

Shock Test Setup

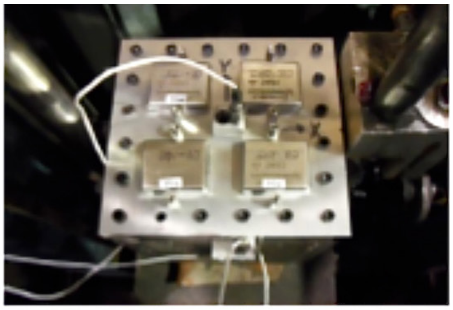
Five SA.45s CSAC units were utilized for the mechanical shock testing at lab ambient at an outside test facility using a standard drop shock tower. The serial numbers and dash condition (performance level) of the units were:

1. 1101CS00180 (-002 unit)
2. 1101CS00195 (-002 unit)
3. 1102CS00206 (-001 unit)
4. 1102CS00207 (-002 unit)
5. 1102CS00242 (-002 unit)

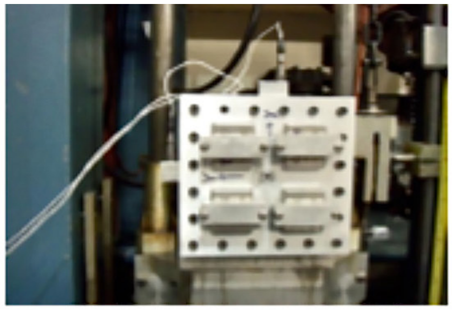
Figure 4 shows the mechanical shock test setup, where up to four SA.45s CSAC units were clamped to the 1.25" thick aluminum test fixture (054-00373-000) that was attached to the shock drop table. The SA.45s CSAC units were subjected to 3 shocks in each direction (+/- Axis), in each test axis for a total of 18 shocks at each shock level. The units were rotated in the fixture to change the direction of a particular shock axis.

The units were tested un-powered and functionally tested after each test axis. To perform the functional test, the UUT (unit-under-test) was plugged into the SA.45s CSAC Test Fixture PCB assembly (089-00300-000). The UUT was powered to insure that the UUT was able to lock and measure RF output frequency with an HP 53132 frequency counter using an LPRO rubidium oscillator as the frequency reference.

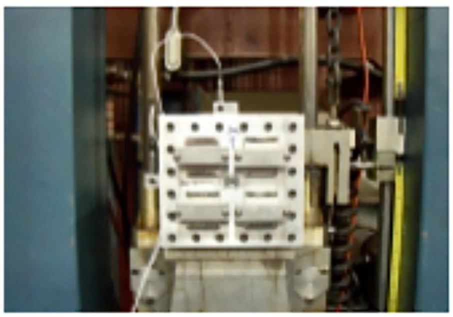
Shock and Vibration Testing of the SA.45s Chip Scale Atomic Clock (CSAC) Validation Build Units



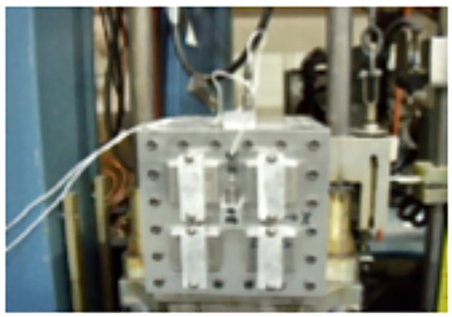
LUTs in fixture without bar clamps.



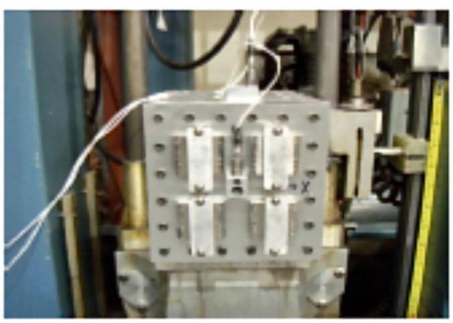
(+) Y-axis Shock (Specified Pulse) Test Setup.



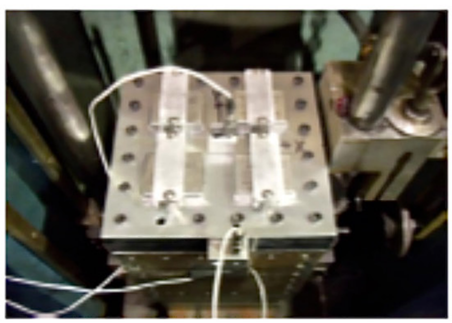
(-) X-axis Shock (Specified Pulse) Test Setup



(+) Y-axis Shock (Specified Pulse) Test Setup.



(-) Y-axis Shock (Specified Pulse) Test Setup



(+) Z-axis Shock (Specified Pulse) Test Setup.

Figure 4: Shock Test Setup

Vibration Test Setup

Five SA.45s CSAC units were utilized for the vibration testing at lab ambient. The serial number and dash condition of the units were:

1. 1101CS00183 (-001 unit)
2. 1102CS00206 (-001 unit; previously tested in shock up to 2000 g, 0.5 msec half-sine pulse)
3. 1102CS00207 (-002 unit; previously tested in shock at 500 g, 1.0 msec half-sine pulse)
4. 1102CS00232 (-002 unit)
5. 1102CS00238 (-002 unit)

For the random vibration testing, the SA.45s CSAC test unit was clamped to the vibration fixture (PN 054-00377-000) in order to apply the vibration directly to the UUT while minimizing the effects of an unknown resonance or undefined mechanical transfer function of a UUT mounted on a printed circuit board. The fundamental resonance of this 1.25" thick aluminum fixture was approximately 1250 Hz. Figure 5 shows the actual vibration fixture test setup with the UUT clamped to the vibration fixture.

Shock and Vibration Testing of the SA.45s Chip Scale Atomic Clock (CSAC) Validation Build Units

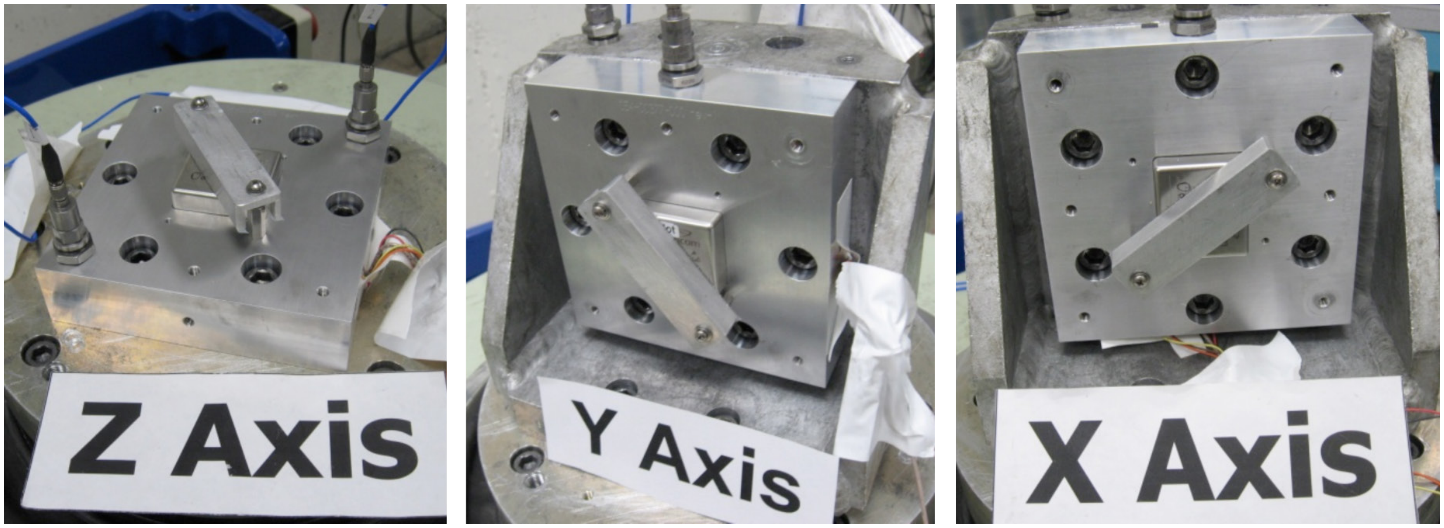


Figure 5: Vibration Fixture Test Setup

The electrical connections to the UUT were made with press-on sockets that were wired to the SA.45s CSAC Test Fixture PCB assembly seen in Figure 6. The RF output connection from the SA.45s CSAC was made using a coaxial connection using RG-174 coaxial cable to minimize spurious signals when measuring phase noise of the UUT.

Figure 6: Vibration Fixture Test Setup

Two control accelerometers were used on the vibration fixture with the vibration control computer averaging their control signals. The electro-dynamic shaker was always powered on before attaching the UUT and always powered down before removing the UUT, ensuring that the magnetic field from the shaker armature and degaussing coils did not adversely affect the UUT. Measurements of the magnetic field showed that the highest level at the UUT was in the Z Axis orientation and that the level at the UUT was 7-10 gauss.

Figure 6 shows the electrical test setup for the vibration testing. To monitor the frequency accuracy of the UUT under vibration, the 10 MHz output from the CSAC Test Fixture PCB assembly was measured on a Microsemi Model 5110A Phase Noise and Allan Deviation Test Set using the House Standard Reference Hydrogen Maser as the frequency reference 10 MHz signal. The 1 second phase data from the Model 5510A was recorded over RS232 to a text file using a custom Labview program to allow for post processing with Stable32 of the UUT phase data. The telemetry data from the UUT was monitored and recorded on a computer by way of the RS-232 connector on the CSAC Test Fixture PCB assembly to allow for failure analysis if needed.

The 5 MHz RF output from the CSAC Test Fixture PCB assembly was used to measure the phase noise performance of the UUT. A Microsemi Model 5120A Phase

Noise and Allan Deviation Test Set were utilized to measure the phase noise of the UUT. A 10 MHz High Performance Crystal Oscillator (TB 5118) was used as the phase noise reference. A custom Labview program controlled the Model 5120A test set by way of an Ethernet connection.

For each phase noise measurement 600 seconds of data were measured to obtain the UUT phase noise. This phase noise data was saved to a text file to allow for post processing. This allowed for the overlaying of dynamic phase noise test results for a UUT in all three axes. Using this phase noise data and assuming that the random vibration profile was the nominal profile as defined in Table 1, the "effective" acceleration sensitivity of the SA.45s CSAC was calculated using the classic formula for phase noise $\mathcal{L}(f)$ under random vibration:

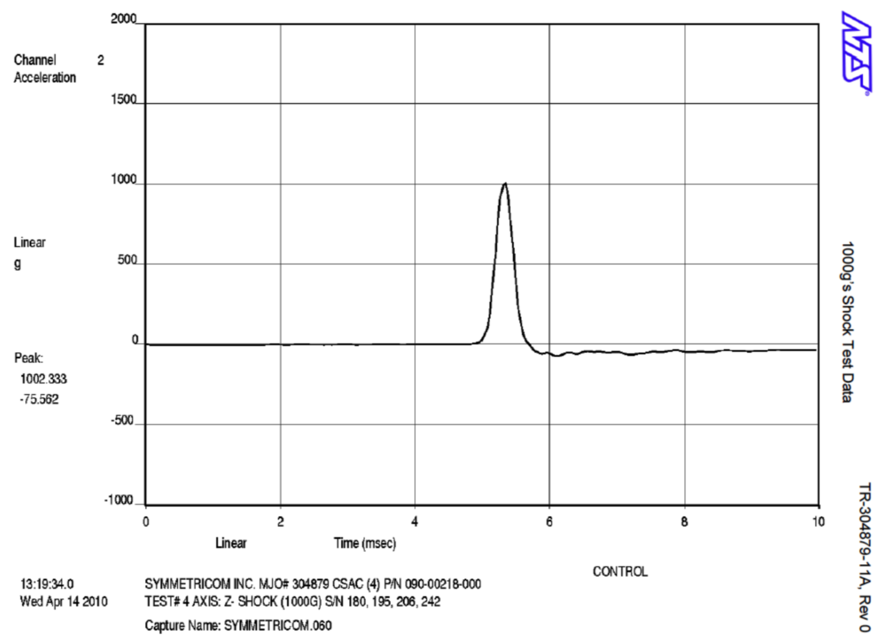


Figure 7: Sample Shock Plot At 1000 g, 0.5 msec

$$\mathcal{L}(f) = 20 \log\left(\frac{\bar{\Gamma} \bullet \bar{A} f_0}{2f}\right), \quad \text{where } |\bar{A}| = [(2)(PSD)]^{1/2}$$

Where f_0 is the nominal oscillator frequency (10 MHz), f is the sideband frequency offset (Hz), and |G| is the acceleration sensitivity (sometimes referred to as g-sensitivity) of the UUT. The random vibration acceleration power spectral density (PSD) for this test is defined in Table 1. Quiescent phase noise measurements were made of the UUT prior to the dynamic phase noise testing with the UUT mounted to the vibration fixture.

SHOCK TEST RESULTS

The MIL-STD-202, Method 213 mechanical shock test sequence began with test condition D (500 g, 1.0 msec half-sine shock pulse). Four units were tested at this shock level. During the functional test after this 500 g shock test, one of the four test units, SN 207 (1102CS00207) appeared to have a problem achieving atomic lock. This UUT was replaced with SN 206 for the subsequent shock testing. It was later discovered that the problem was not with the UUT, but with the plug-in sockets on the Test Fixture PCB assembly. The sockets caused intermittent contact with the UUT pins, preventing the UUT from locking. When tested back at the factory, SN 207 was functioning properly and was then utilized in the vibration testing.

The shock level was then increased to test condition E (1000 g, 0.5 msec half-sine shock pulse) and the four test units all passed this shock level. Figure 7 shows the actual shock pulse from one of the 18 shocks at this 1000 g level.

The shock level was then increased to test condition F (1500 g, 0.5 msec half-sine shock pulse), and finally to a 2000 g, 0.5 msec half-sine shock pulse. After the initial functional test after the Z Axis 2000 g shocks, SN 195 appeared to have a problem locking so it was removed from the testing. It was later found to be operating properly back at the factory.

In summary, all five units tested survived the shock testing with no apparent damage. The shock levels seen by each SA.45s CSAC tested was

1. 1101CS00180 & 1102CS00242 passed the 500 g, 1000 g, 1500 g, 2000 g shocks
2. 1102CS00206 passed the 1000 g, 1500 g, 2000 g shocks
3. 1101CS00195 passed the 500 g, 1000 g, 1500 g shocks
4. 1102CS00207 passed the 500 g shock

The SA.45s CSAC design will meet the Test Condition E, 1000 g, 0.5 msec shock test requirement.

VIBRATION TEST RESULTS

For each UUT test axis, the 1 second phase data file from the Model 5110A test set was recorded on a computer with notations made to insure that the start and stop times for the different random vibration levels were accurately logged. This data file was started prior to starting the random vibration and was not stopped until a few minutes after the vibration was completed. This phase data was subsequently processed using Stable32 to generate the ADEV plots for the SA.45s CSAC units. For all of the random vibration testing a total of 30 minutes at full level were run. For reference, Appendix B shows sample random vibration plots for both the 0 dB level of 7.7 grms and the +6 dB level of 15.4 grms. Of particular interest in these vibration plots are the individual signals from the two accelerometers (input1 and input2) that were averaged to obtain the control signal for the shaker. Note that in the Z Axis plot the fixture resonance is approximately 1800 Hz, while in the Y Axis the fundamental resonance is roughly 900 Hz due to the right angle vibration block.

Figure 8 below illustrates the frequency accuracy for SN 183 under the random vibration test in the Z Axis at the 0 dB level of 7.7 grms and the +6 dB level of 15.4 grms. Note that as the random vibration increases from the 0 dB level to the +6 dB level, the frequency accuracy has a greater perturbation due to the vibration effects on the UUT. The green marker lines in these frequency plots show where the vibration level has changed. Appendix A shows all of the frequency accuracy plots for the five units tested.

To calculate the ADEV for a particular test axis, only the frequency data at the vibration level of interest is used. So in this particular instance, only the ADEV frequency data for the Z Axis at the 7.7 grms level between 11 and 41 minutes was used to calculate the ADEV under vibration. Stable32 allows the user to eliminate data points as needed to calculate the appropriate ADEV values.

Allan Deviation Test Results

As mentioned in the Summary, Figure 1 shows the summary plots of the ADEV results from two CSAC units representing each performance level when tested at the 0 dB vibration level of 7.70 grms. Notice that for the lower -002 performance level unit (SN 232), the ADEV dynamic performance is below the static specification. For the higher -001 performance level unit (SN 206), the ADEV dynamic performance is below the static specification except for the Z Axis. Typically the stability performance of the SA.45s CSAC units depends on the axis tested. The Z Axis is usually the worst performing axis under random vibration, while the X Axis is usually the best performing axis.

Table 2 has the summary ADEV measurements for all of the test units. Allan Deviation for the two vibration levels of 7.7 grms (0 dB level) and 15.4 grms (+6 dB level) along with the quiescent operation (UUT mounted on fixture but shaker turned off) are tabulated. Appendix C. shows the individual ADEV plots for each vibration axis.

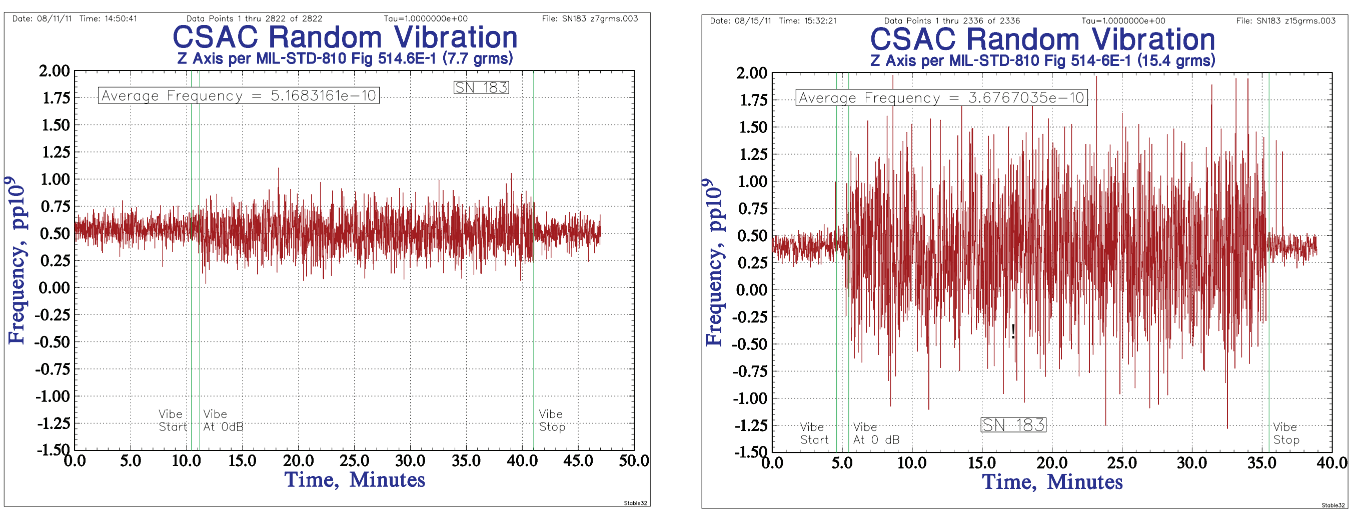


Figure 8: CSAC Frequency Accuracy Under Vibration

Shock and Vibration Testing of the SA.45s Chip Scale Atomic Clock (CSAC) Validation Build Units

CSAC SN	DASH CONDITION	Allan D Deviation Tau	Quiescent	X AXIS		Y AXIS		Z AXIS	
				0 dB (7.7 grms)	+6 dB (15.4 grms)	0 dB (7.7 grms)	+6 dB (15.4 grms)	0 dB (7.7 grms)	+6 dB (15.4 grms)
1101CS00183	001	t =1 sec	NO DATA	8.13E-11	1.10E-10	1.16E-10	1.82E-10	1.54E-10	4.76E-10
		t =10 sec		2.69E-11	3.66E-11	3.75E-11	5.70E-11	5.49E-11	1.67E-10
		t =100 sec		9.03E-12	1.00E-11	8.60E-12	1.96E-11	1.88E-11	5.54E-11
1102CS00206	001	t =1 sec	7.06E-11	7.47E-11	1.33E-10	1.08E-10	2.02E-10	1.61E-10	3.73E-10
		t =10 sec	2.26E-11	2.19E-11	4.27E-11	3.45E-11	6.94E-11	5.45E-11	1.24E-10
		t =100 sec	5.39E-12	6.41E-12	1.34E-11	1.45E-11	1.98E-11	1.92E-11	3.32E-11
1102CS00207	002	t =1 sec	7.39E-11	7.90E-11	NO DATA	1.15E-10	1.89E-09	9.89E-11	3.24E-09
		t =10 sec	2.41E-11	2.86E-11		3.99E-11	5.96E-10	3.49E-11	1.00E-09
		t =100 sec	7.69E-12	9.54E-12		1.42E-11	1.88E-10	1.32E-11	3.37E-10
1102CS00232	002	t =1 sec	6.48E-11	6.87E-11	8.64E-11	1.05E-10	1.81E-10	1.29E-10	3.85E-10
		t =10 sec	2.09E-11	2.32E-11	3.02E-11	3.48E-11	6.12E-11	4.32E-11	1.21E-10
		t =100 sec	6.00E-12	7.31E-12	8.79E-12	1.20E-11	1.92E-11	1.22E-11	3.49E-11
1102CS00238	002	t =1 sec	7.39E-11	8.42E-11	1.01E-10	1.13E-10	1.88E-10	1.34E-10	3.10E-10
		t =10 sec	2.60E-11	2.69E-11	3.37E-11	3.67E-11	6.81E-11	4.61E-11	1.04E-10
		t =100 sec	8.35E-12	9.69E-12	1.08E-11	1.31E-11	2.60E-11	1.87E-11	2.20E-11

Table 2: SA.45s CSAC Allan Deviation Test Results

FOR REFERENCE: STATIC ALLAN DEVIATION SPECIFICATION

Allan Deviation Tau	DASH CONDITION	
	001	002
t =1 sec	1.50E-10	2.00E-10
t =10 sec	5.00E-11	7.00E-10
t =100 sec	1.50E-11	2.00E-11
t =1000 sec	5.00E-12	7.00E-12

Phase Noise Test Results

The dynamic phase noise was measured in all three axes for all five SA.45s CSAC units. The phase noise was measured using a 5120A Phase Noise Test Set with a 10 MHz OCXO as the reference. The quiescent phase noise was taken while the UUT was mounted to the vibration fixture on the lab bench.

The dynamic phase noise test results are shown in Figures 9 through 18 for all the units tested at both vibration levels. The dynamic phase noise performance is shown for all three axes along with a quiescent plot and the static specification for the SA.45s CSAC.

It should be noted that the phase noise results from 1 Hz to 10 Hz shown on these plots suffer from the limited acquisition time of the data (only 5 minutes of data recorded). You can also see some 60 Hz spurs and harmonics showing up on these plots.

From these test results, the "effective" g-sensitivity of the SA.45s CSAC may be calculated assuming that the random vibration input is the nominal value given in Table 1. Appendix D shows all these "effective" g-sensitivity plots. Each plot shows the individual test axis along with the resultant total gamma (RSS of three axes) for each UUT.

CONCLUSIONS

As expected, random vibration degrades the performance of the SA.45s CSAC, as observed in Allan deviation as well as in phase noise. Also as expected, higher levels of vibration stimulate higher levels of degradation (worse performance). The Z Axis was typically the most sensitive in the SA.45s CSAC units tested, while the X Axis performance was the best.

The mechanical testing of the SA.45s CSAC units showed that there was indeed some design margin in the unit's published specifications, as it performed above the mechanical specifications listed on the data sheet. But customers should exercise caution in assuming that this small sample of test units guarantees that the SA.45s CSAC will perform above the published environmental specifications without additional testing in a particular application.

Shock and Vibration Testing of the SA.45s Chip Scale Atomic Clock (CSAC) Validation Build Units

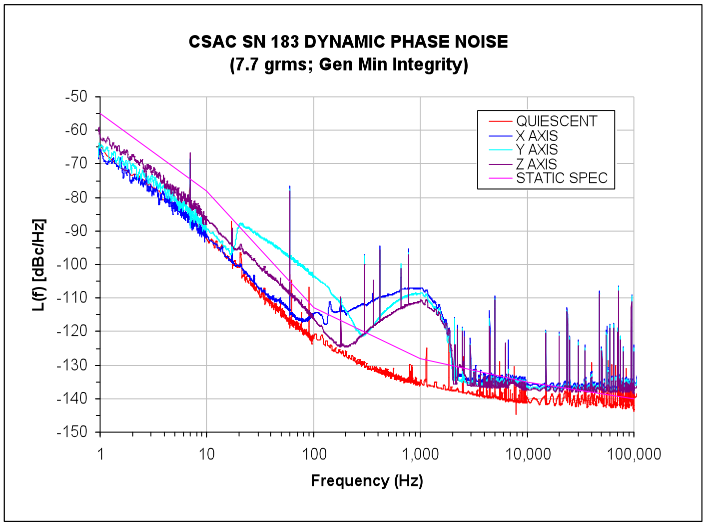


Figure 9. SA.45s CSAC SN 183 Phase Noise Test Results At 7.7 grms

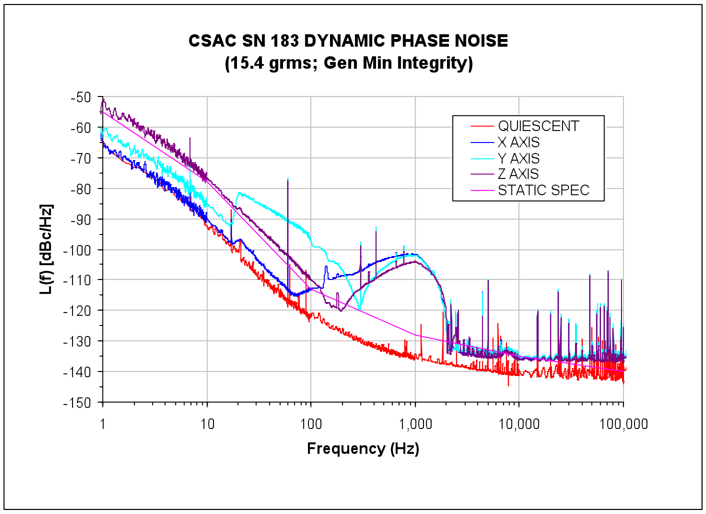


Figure 10. SA.45s CSAC SN 183 Phase Noise Test Results At 15.4 grms

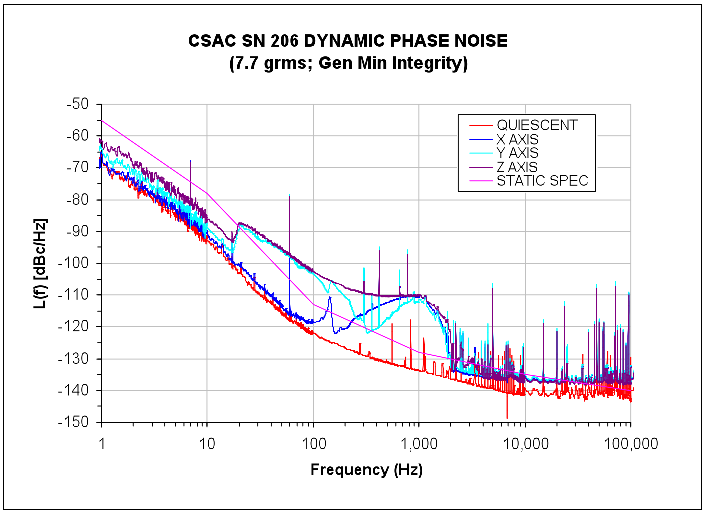


Figure 11. SA.45s CSAC SN 206 Phase Noise Test Results At 7.7 grms

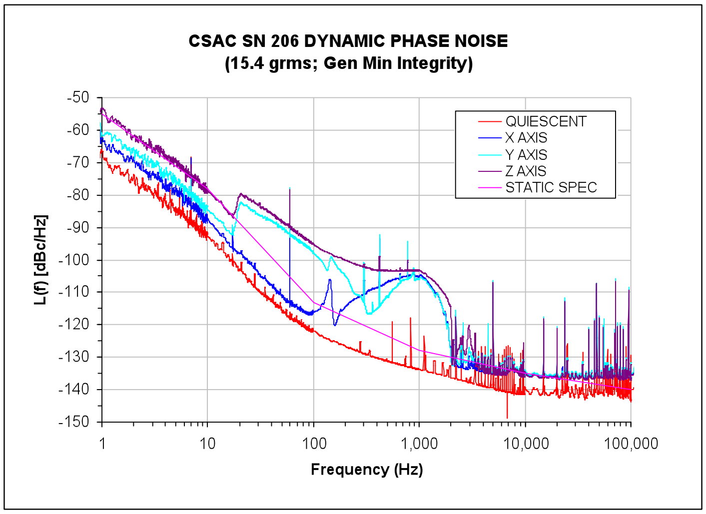


Figure 12. SA.45s CSAC SN 206 Phase Noise Test Results At 15.4 grms

Shock and Vibration Testing of the SA.45s Chip Scale Atomic Clock (CSAC) Validation Build Units

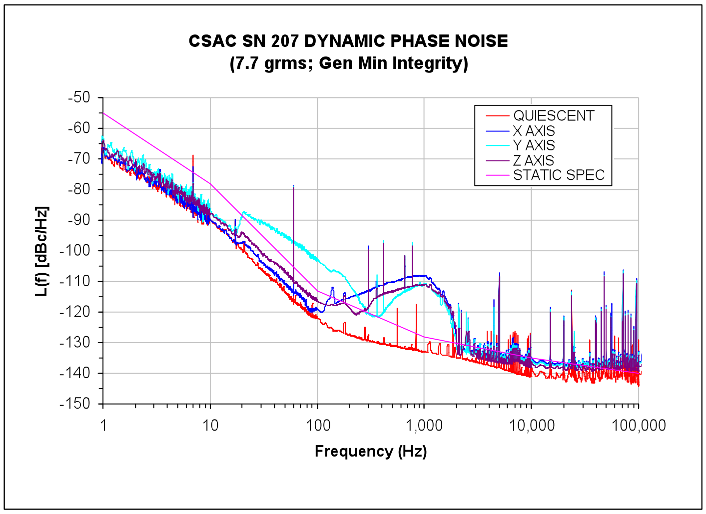


Figure 13. SA.45s CSAC SN 207 Phase Noise Test Results At 7.7 grms

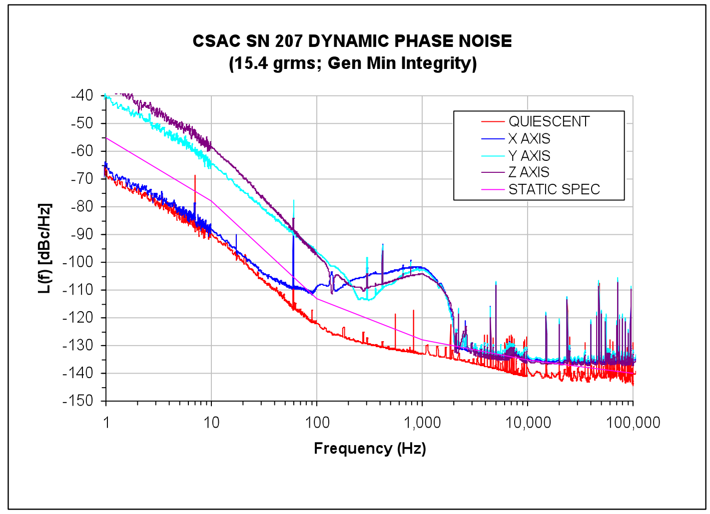


Figure 14. SA.45s CSAC SN 207 Phase Noise Test Results At 15.4 grms

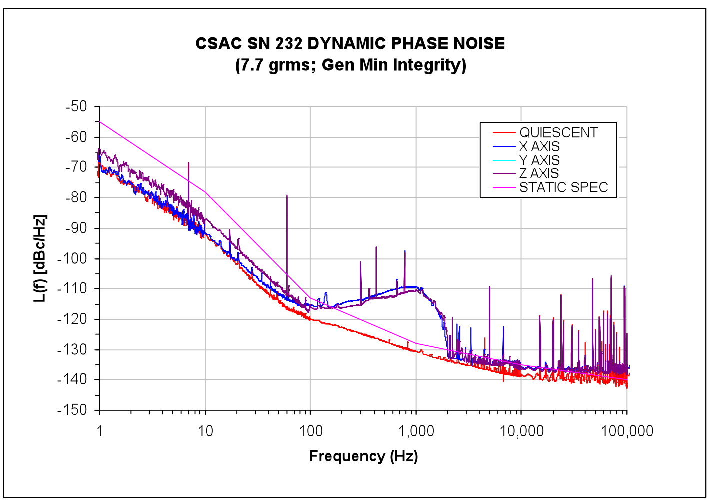


Figure 15. SA.45s CSAC SN 232 Phase Noise Test Results At 7.7 grms

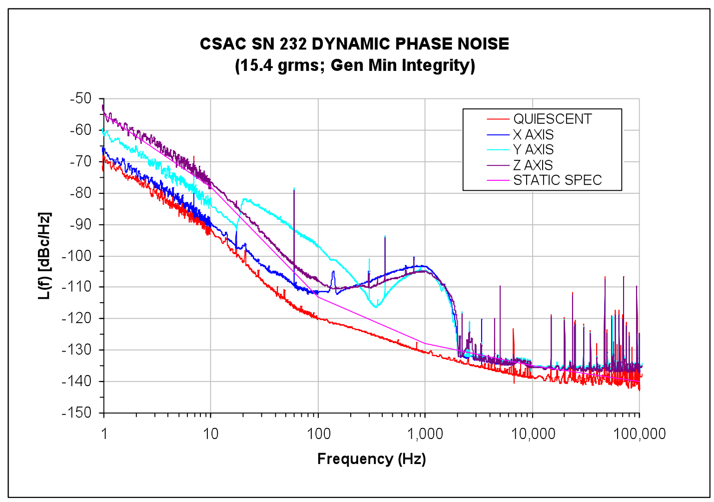


Figure 16. A.45s CSAC SN 232 Phase Noise Test Results At 15.4 grms

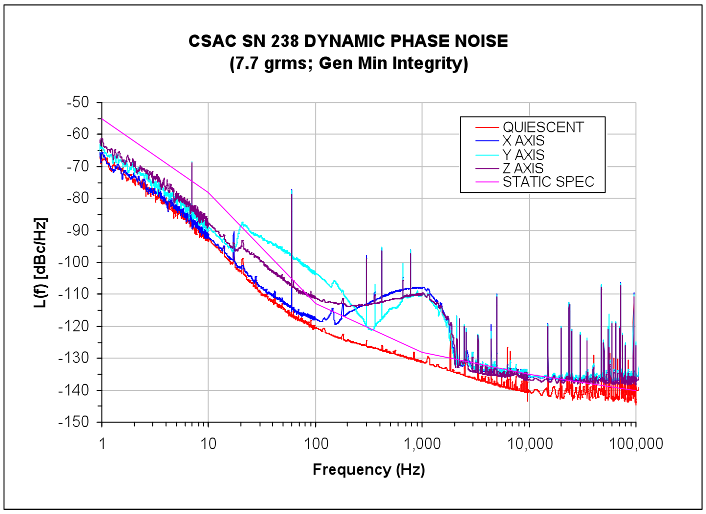


Figure 17. SA.45s CSAC SN 238 Phase Noise Test Results At 7.7 grms

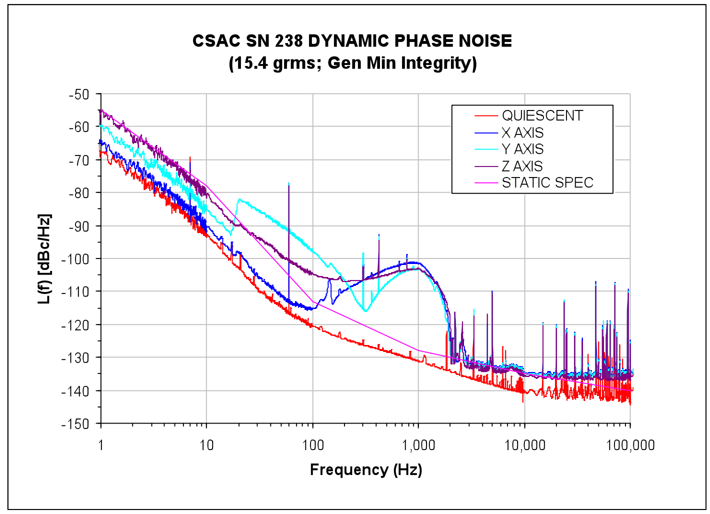
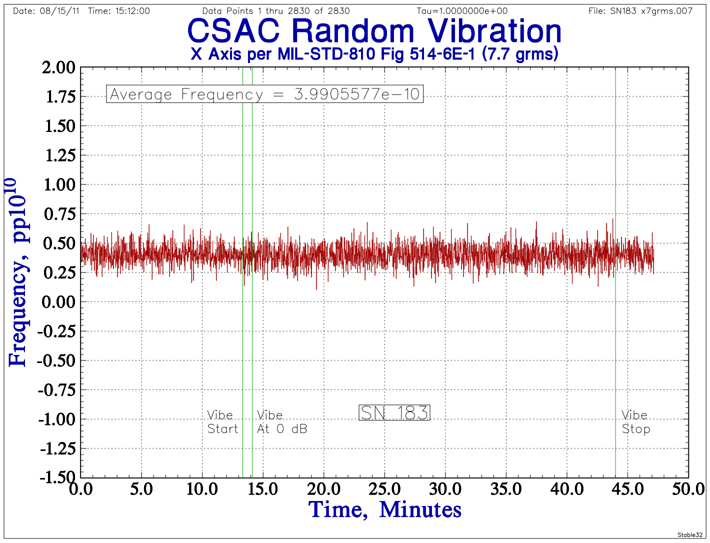


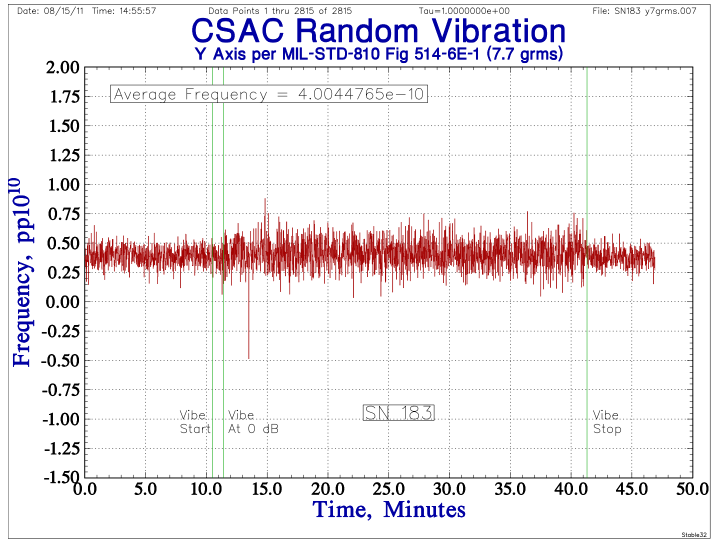
Figure 18. SA.45s CSAC SN 238 Phase Noise Test Results At 15.4 grms

APPENDIX A: FREQUENCY ACCURACY PLOTS

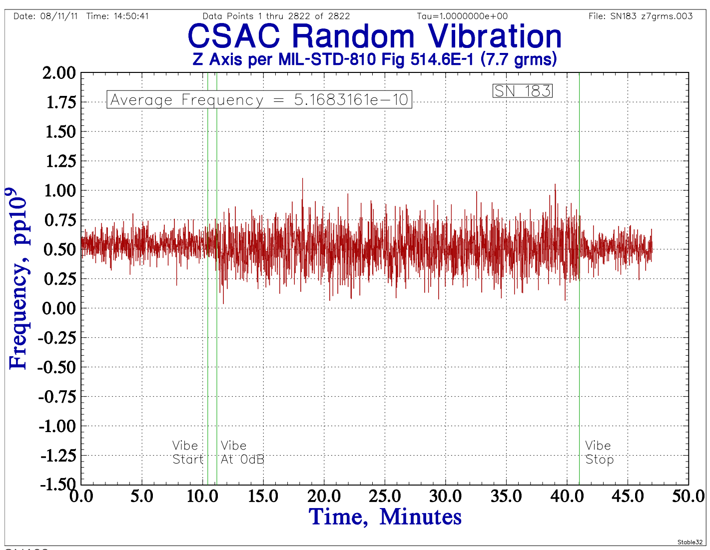
7.7 grms



SN183



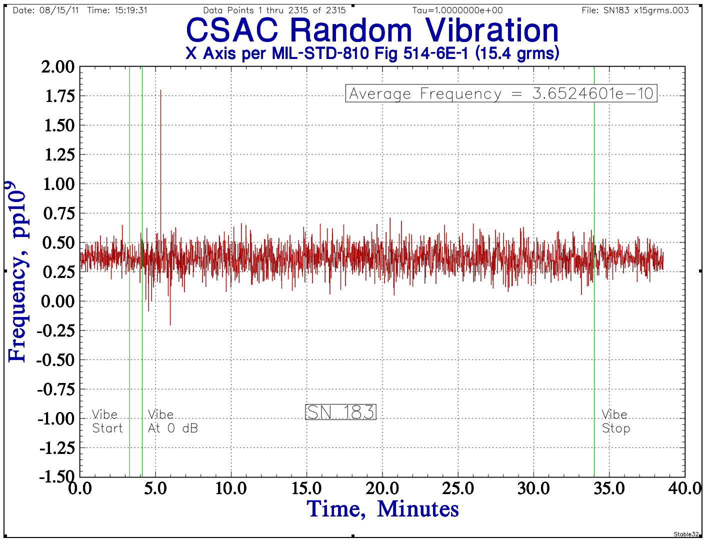
SN183



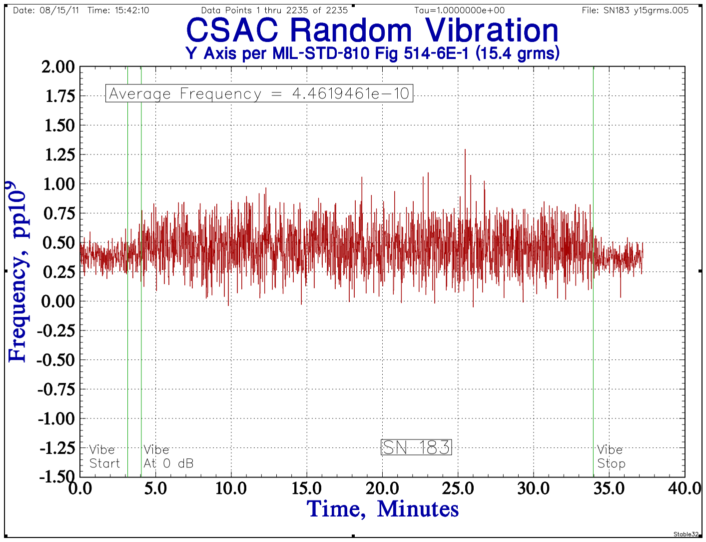
SN183

APPENDIX A: FREQUENCY ACCURACY PLOTS

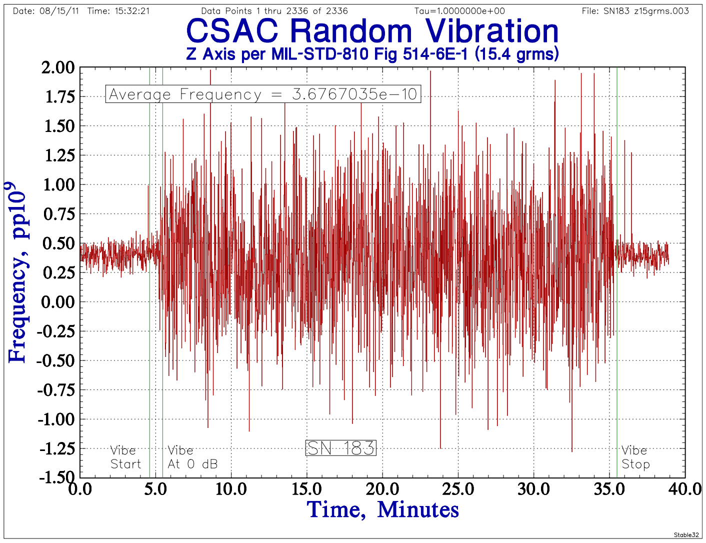
15.4 grms



SN183



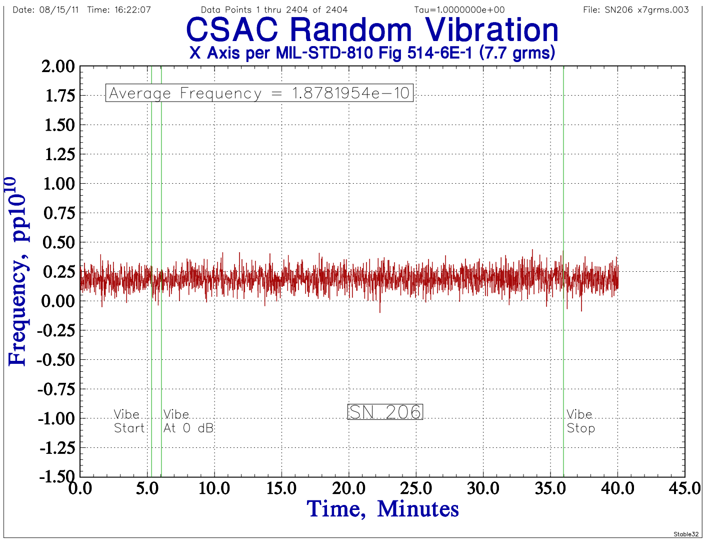
SN183



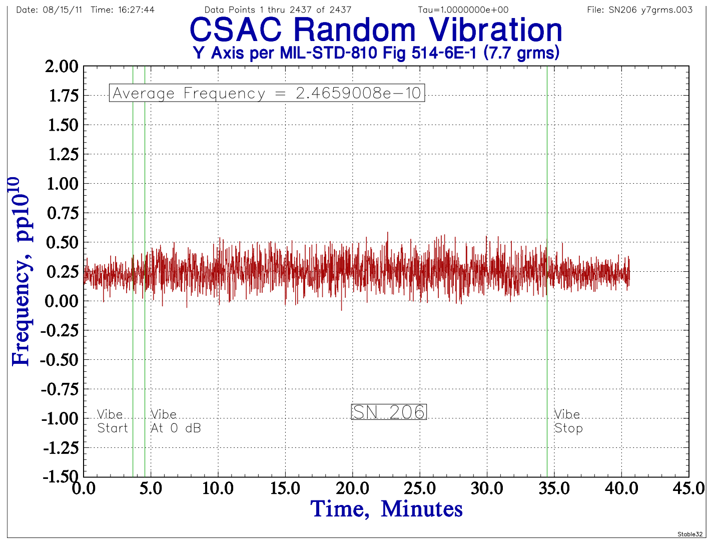
SN183

APPENDIX A: FREQUENCY ACCURACY PLOTS

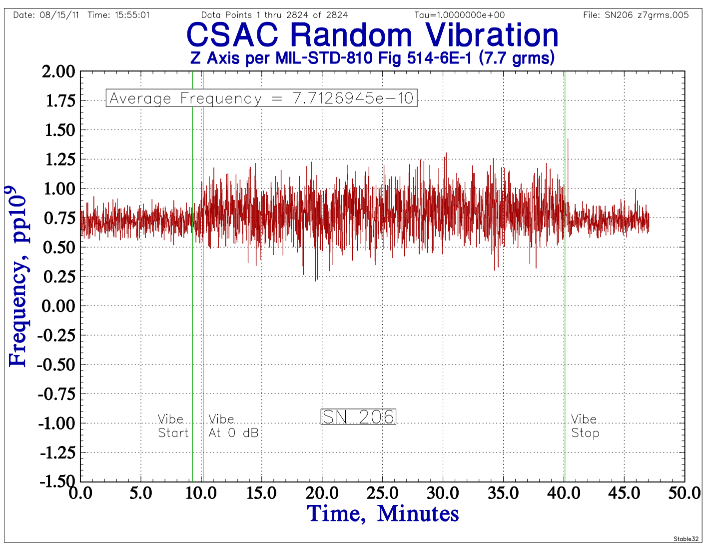
7.7 grms



SN 206

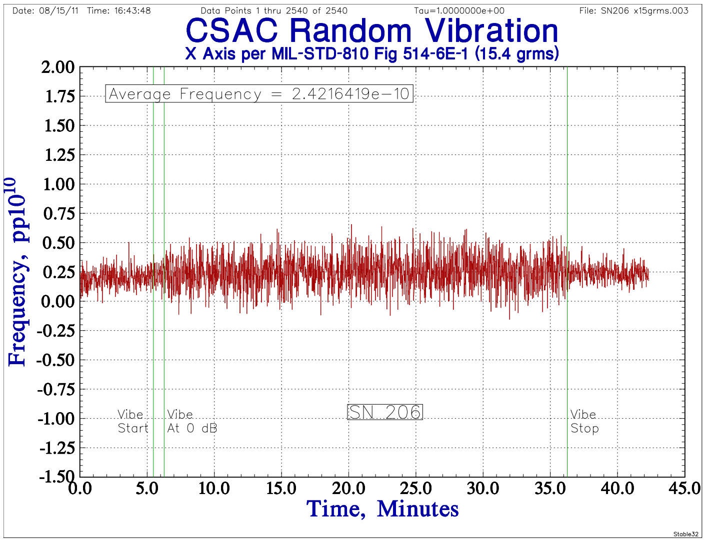


SN206

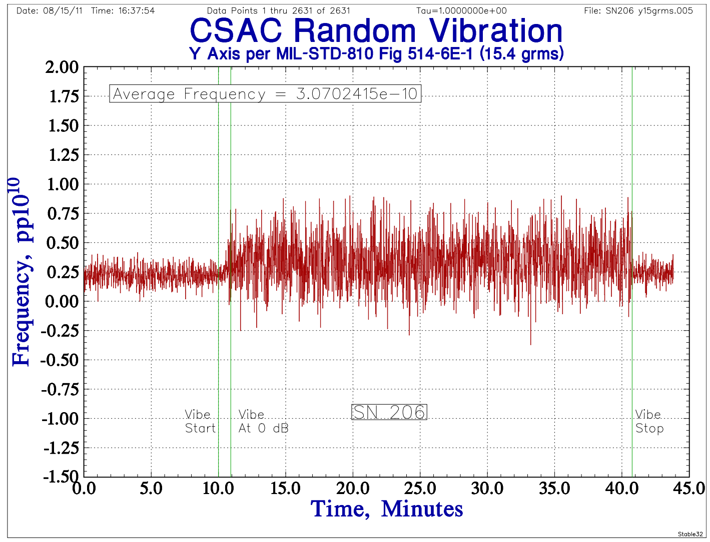


SN 206

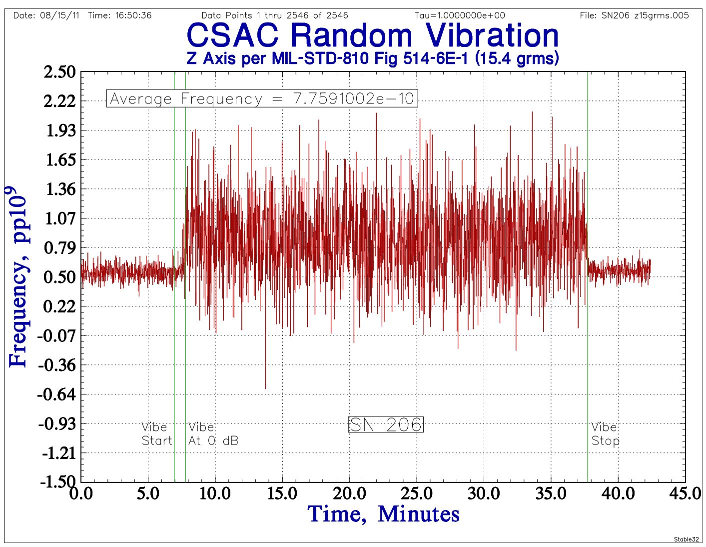
APPENDIX A: FREQUENCY ACCURACY PLOTS
15.4 grms



SN206



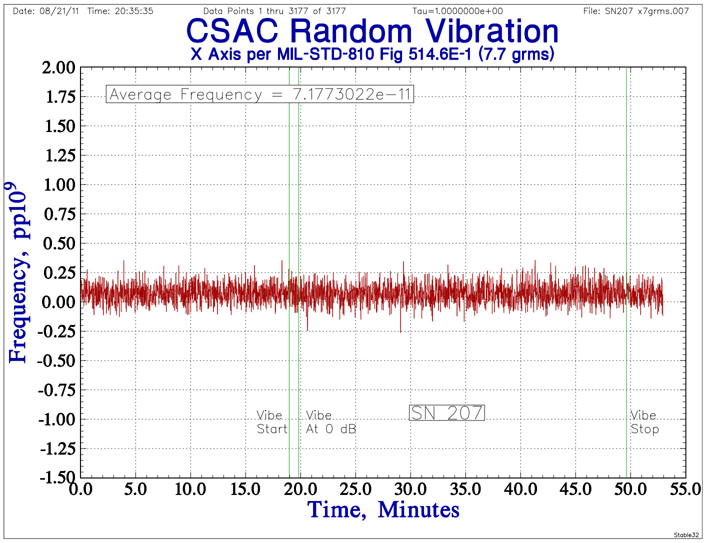
SN206



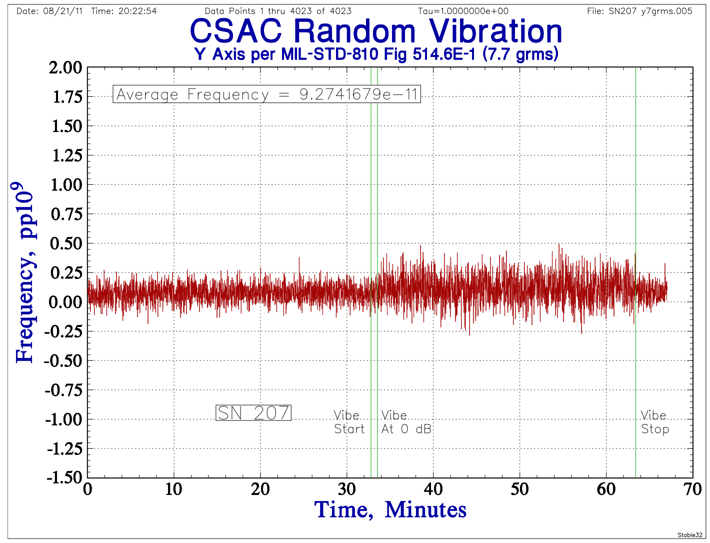
SN206

APPENDIX A: FREQUENCY ACCURACY PLOTS

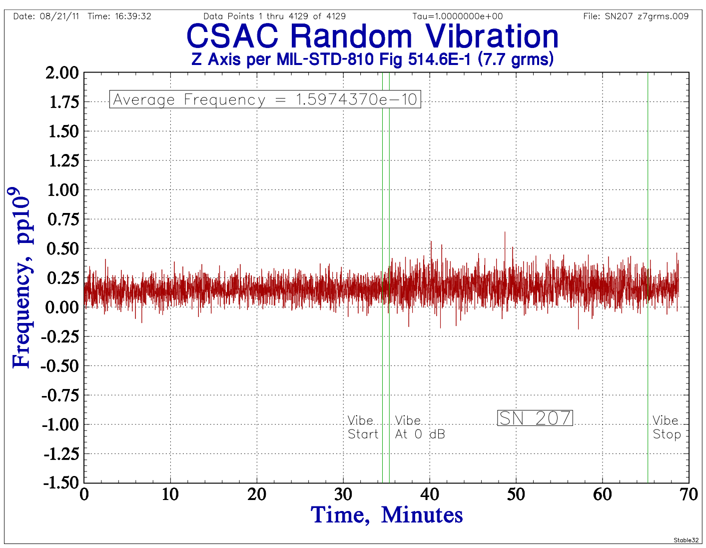
7.7 grms



SN207



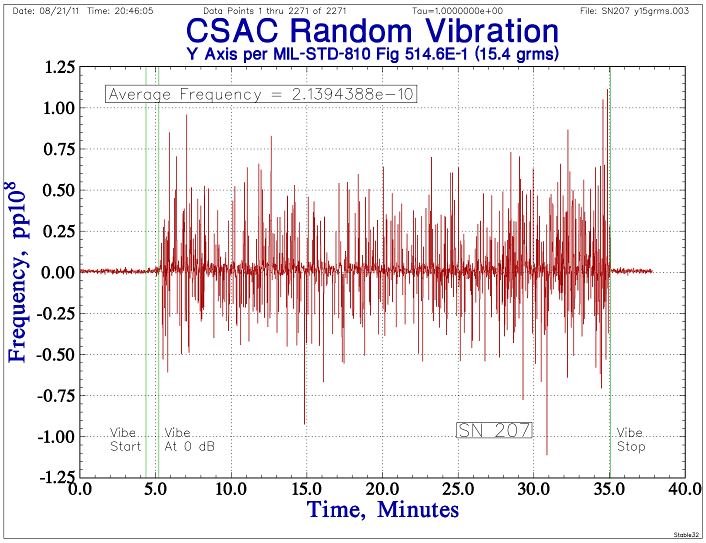
SN207



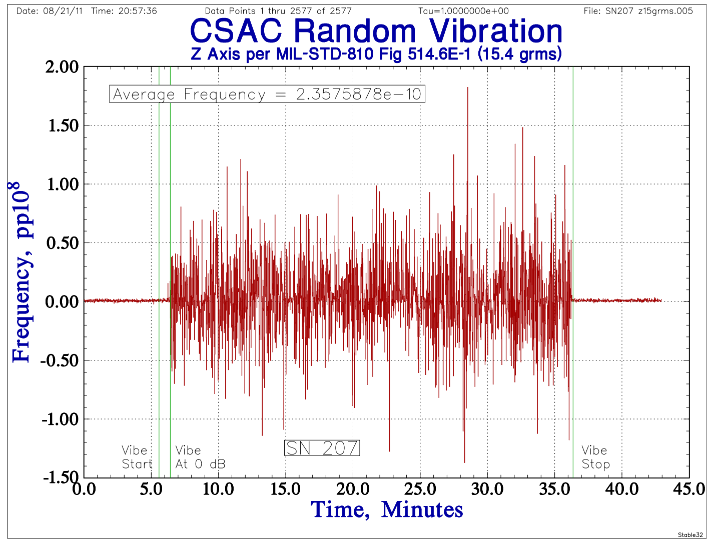
SN207

APPENDIX A: FREQUENCY ACCURACY PLOTS

15.4 grms



SN207

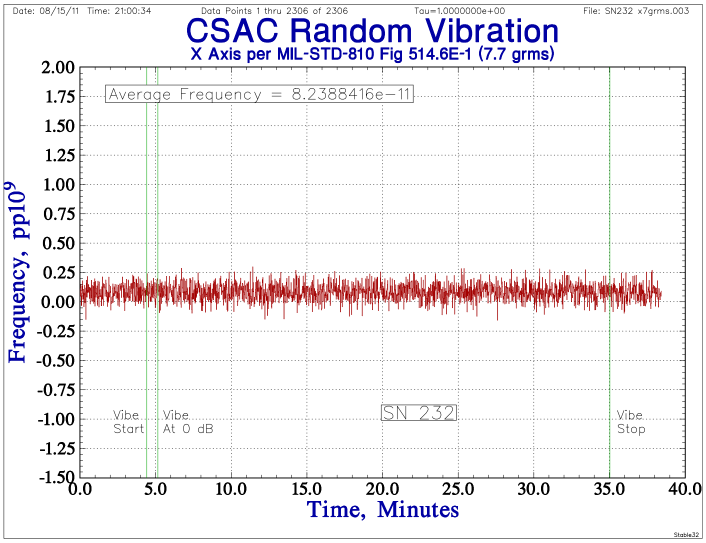


SN207

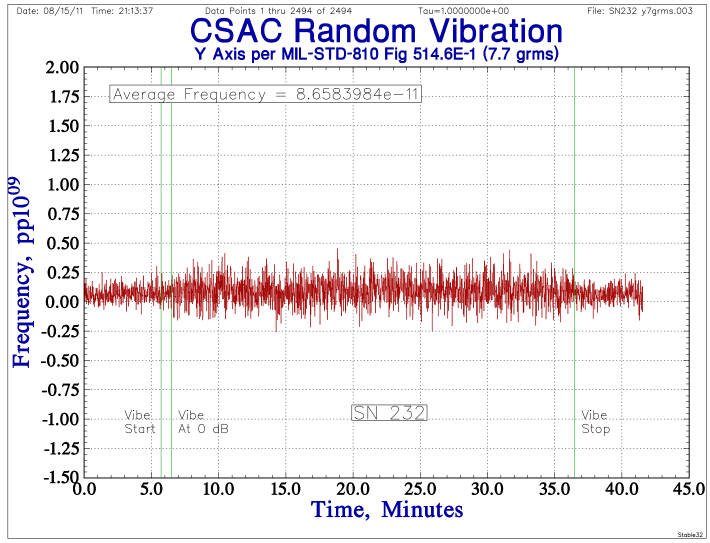
no X Axis Data for SN 207 at 15.4 grms

APPENDIX A: FREQUENCY ACCURACY PLOTS

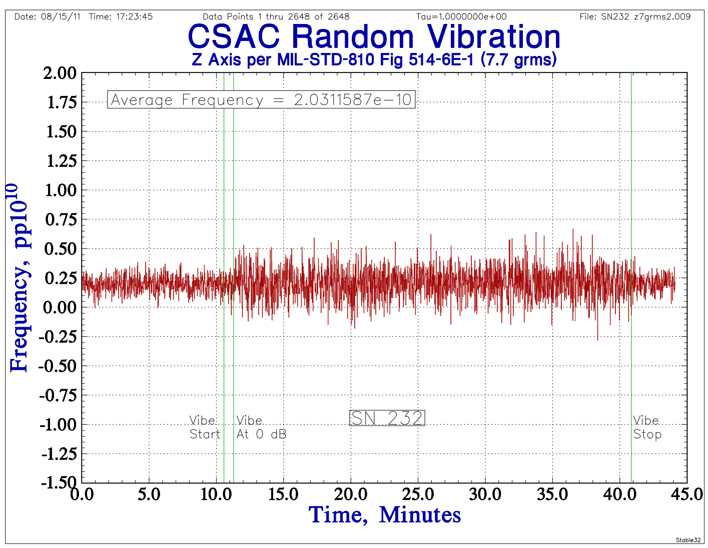
7.7 grms



SN232



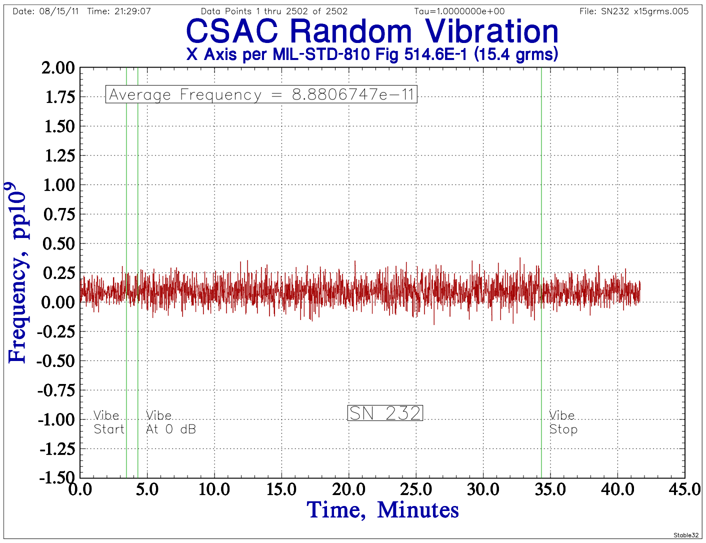
SN232



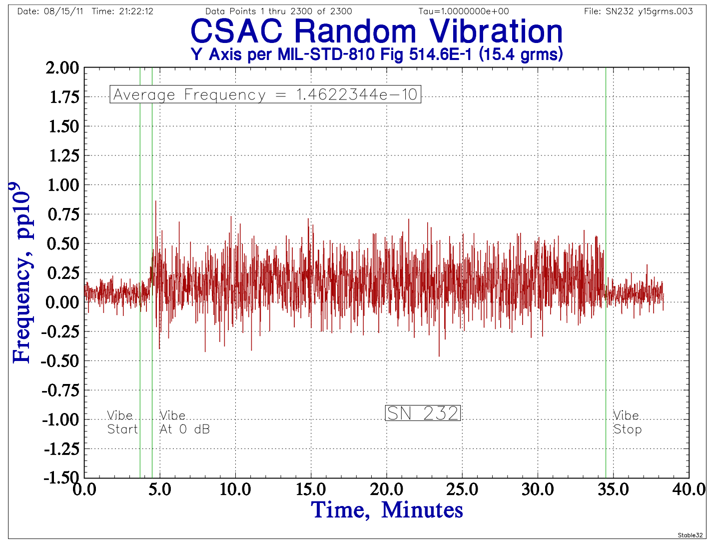
SN232

APPENDIX A: FREQUENCY ACCURACY PLOTS

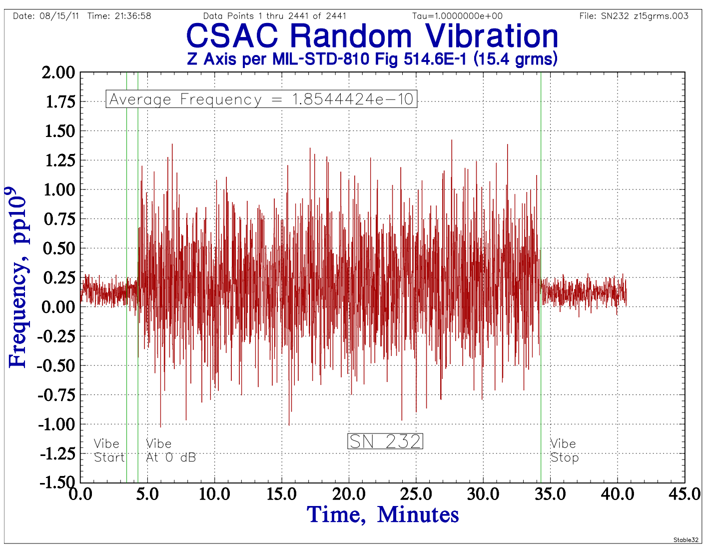
15.4 grms



SN232



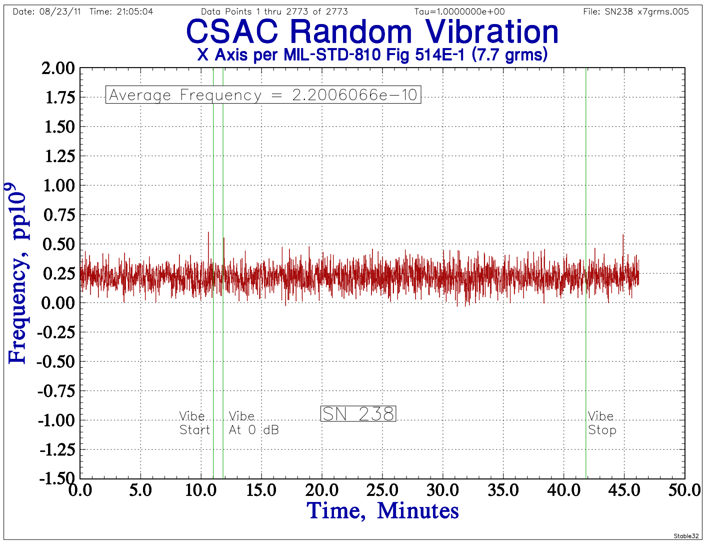
SN232



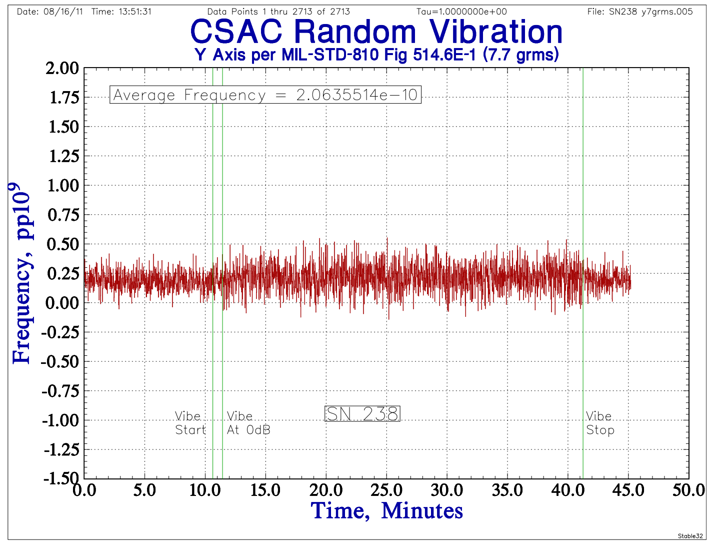
SN232

APPENDIX A: FREQUENCY ACCURACY PLOTS

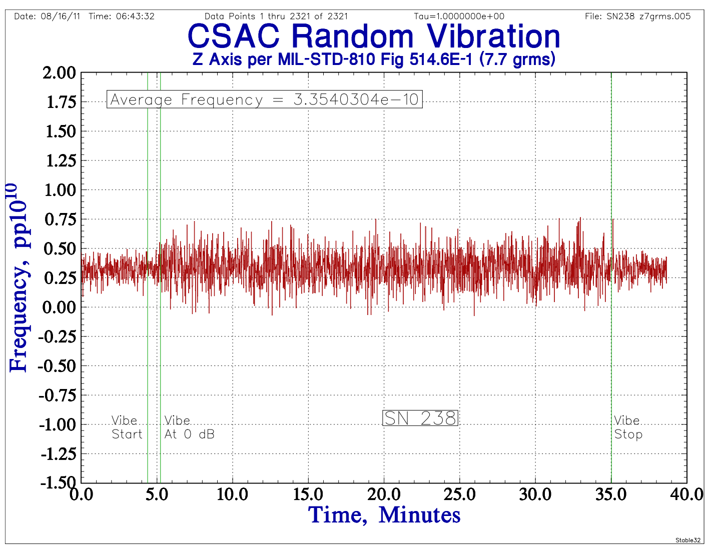
7.7 grms



SN238



SN238

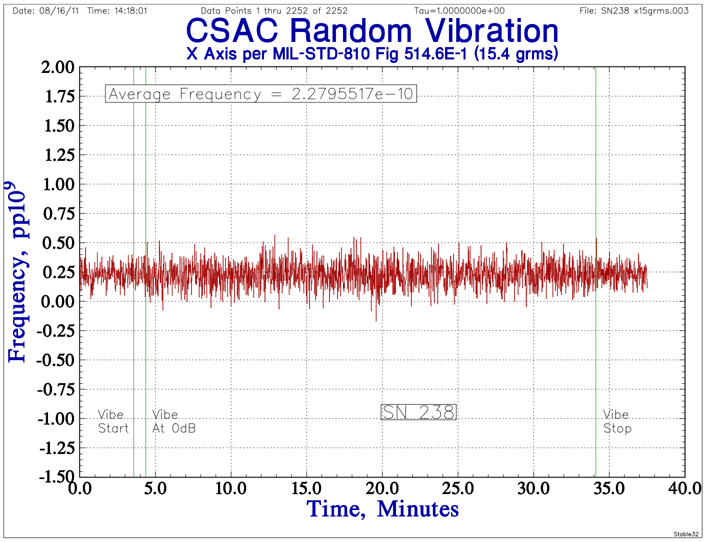


SN238

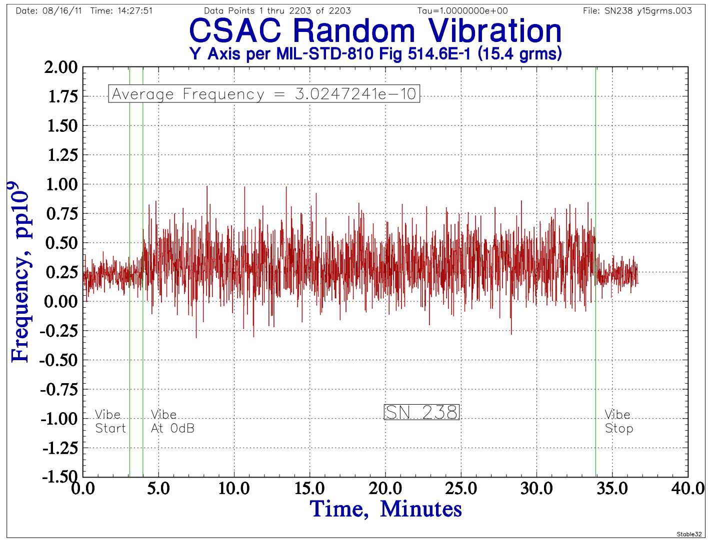
Shock and Vibration Testing of the SA.45s Chip Scale Atomic Clock (CSAC) Validation Build Units

APPENDIX A: FREQUENCY ACCURACY PLOTS

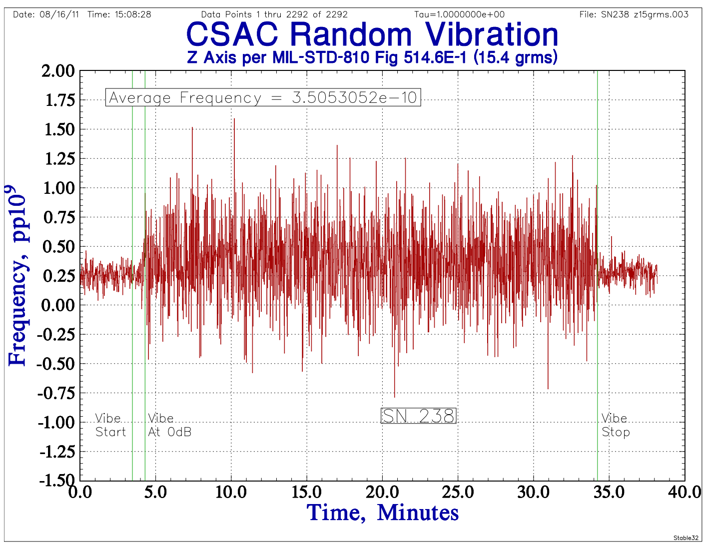
15.4 grms



SN238

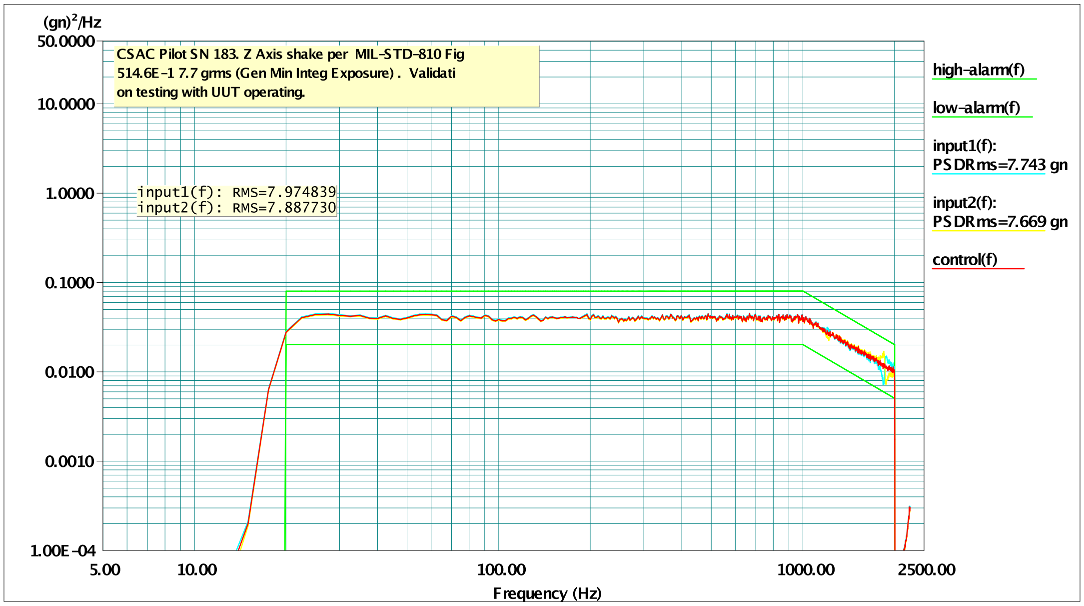


SN238



SN238

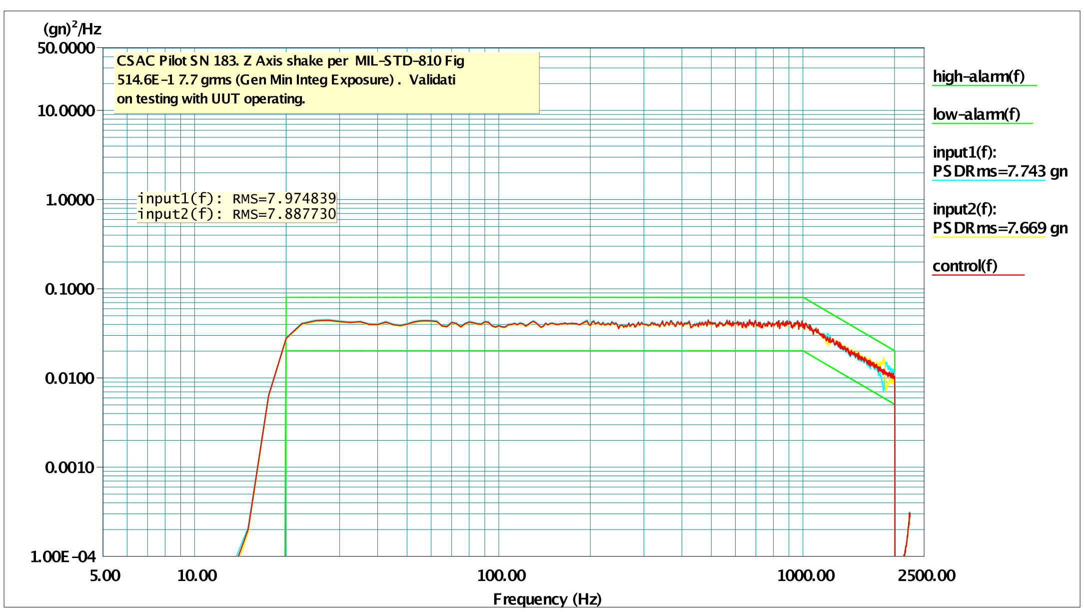
APPENDIX B: SAMPLE VIBRATION PLOTS



Level: 0 dB
Control RMS: 7.706172 gn   Full Level Elapsed Time: 00:30:00   Lines: 800   Frame Time: 0.400000 Seconds
Demand RMS: 7.699163 gn   Remaining Time: 00:00:00   DOF: 500   dF: 2.500000 Hz

Data saved at 04:15:41 PM, Tuesday, April 26, 2011   Report created at 04:15:59 PM, Tuesday, April 26, 2011

Random Vibration Plot of SN 183 at 0 dB (7.7 grms)



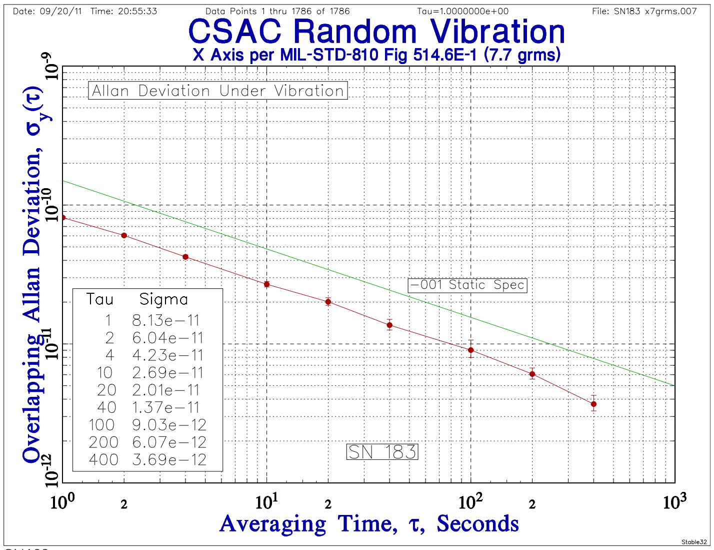
Level: 0 dB
Control RMS: 7.706172 gn   Full Level Elapsed Time: 00:30:00   Lines: 800   Frame Time: 0.400000 Seconds
Demand RMS: 7.699163 gn   Remaining Time: 00:00:00   DOF: 500   dF: 2.500000 Hz

Data saved at 04:15:41 PM, Tuesday, April 26, 2011   Report created at 04:15:59 PM, Tuesday, April 26, 2011

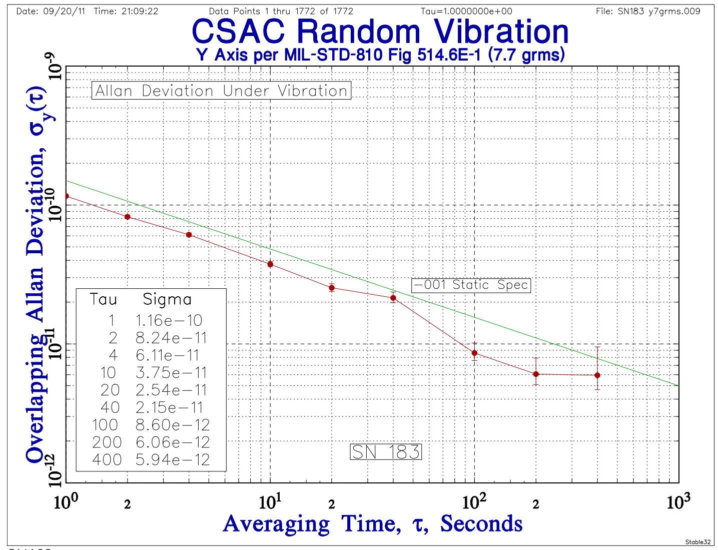
Random Vibration Plot of SN 206 at +6 dB (15.4 grms)

APPENDIX C: ALLAN DEVIATION PLOTS

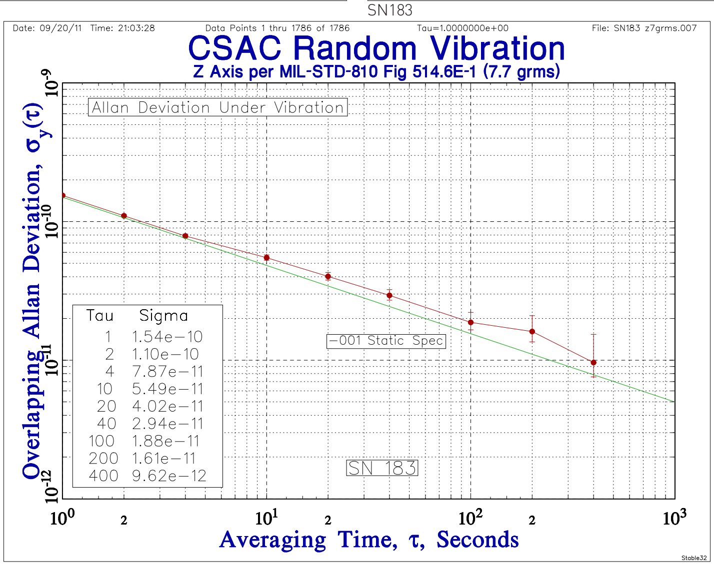
7.7 grms



SN183



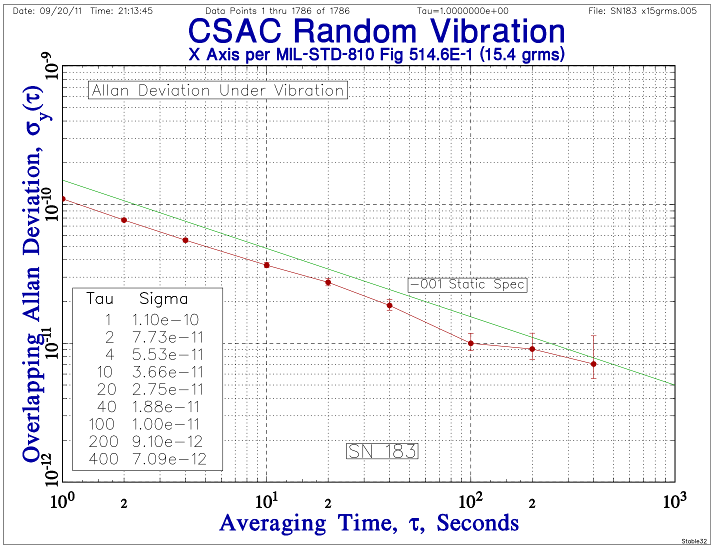
SN183



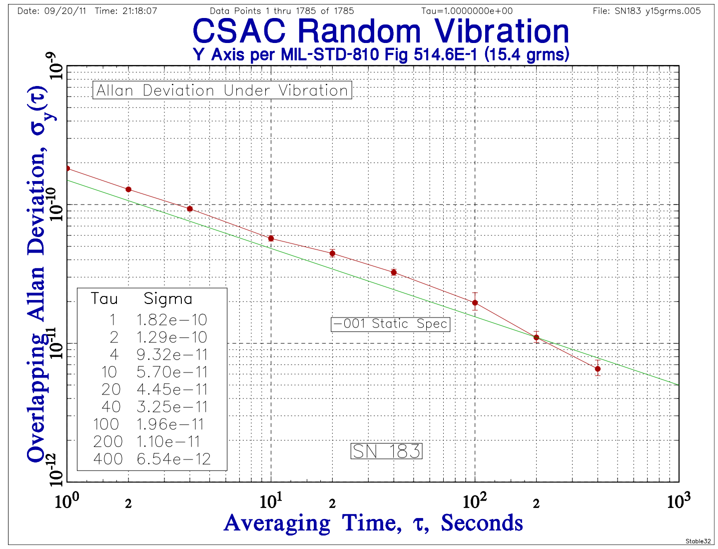
SN183

APPENDIX C: ALLAN DEVIATION PLOTS

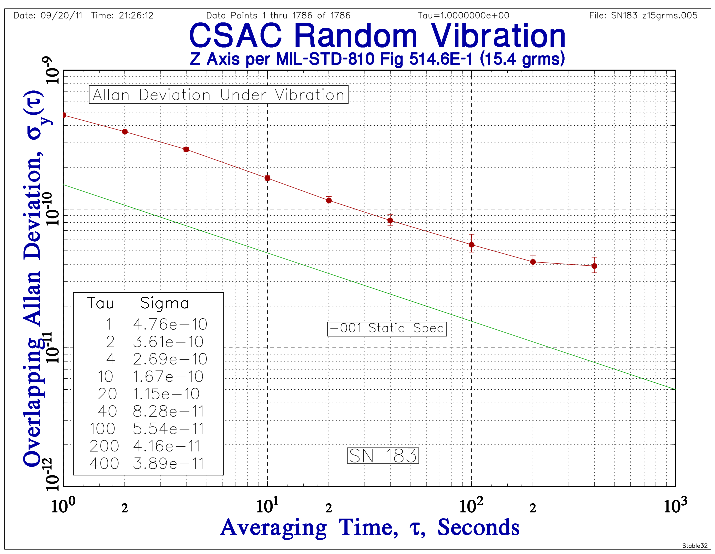
15.4 grms



SN183

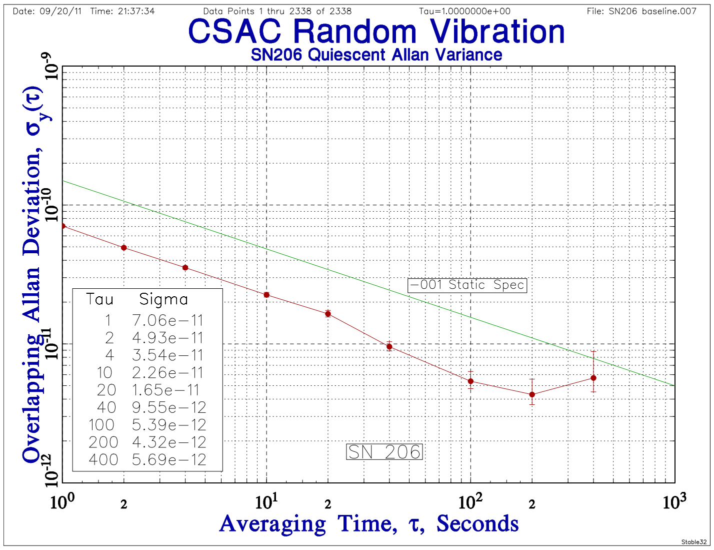


SN183

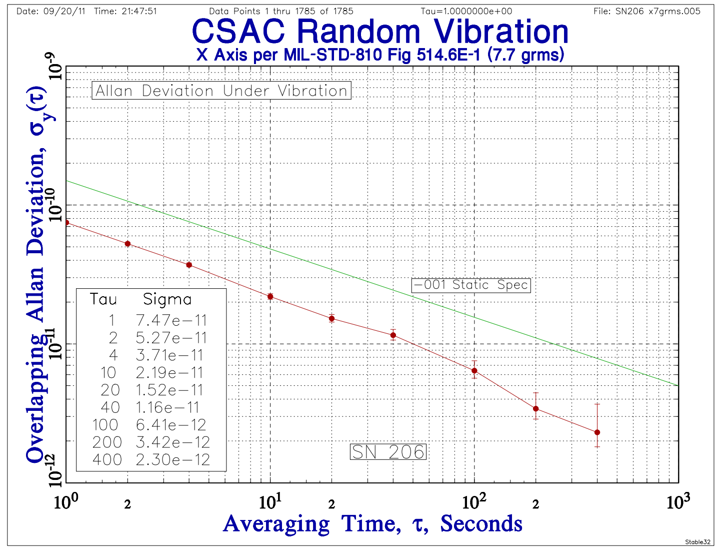


SN183

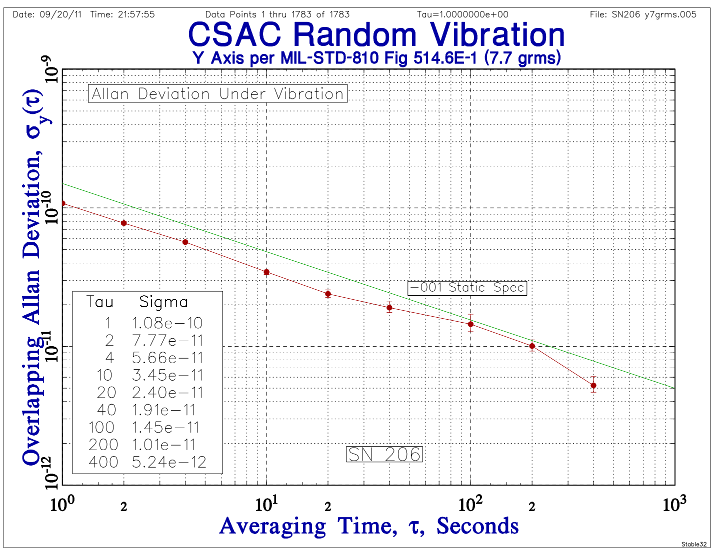
APPENDIX C: ALLAN DEVIATION PLOTS
7.7 grms



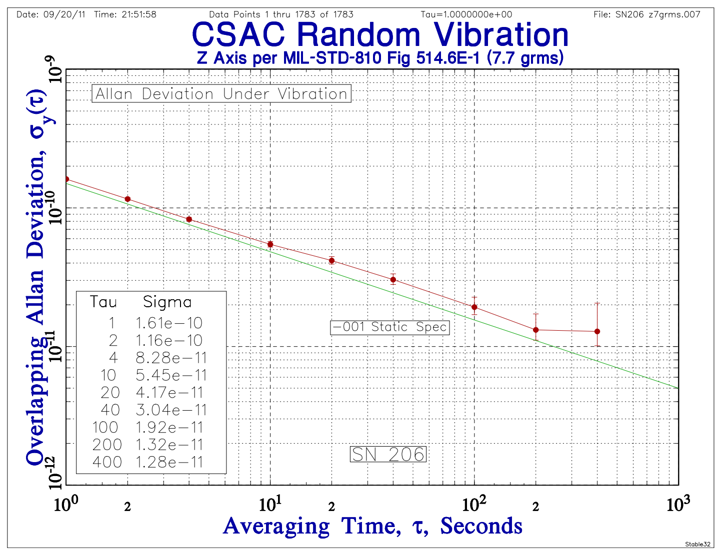
SN206



SN206



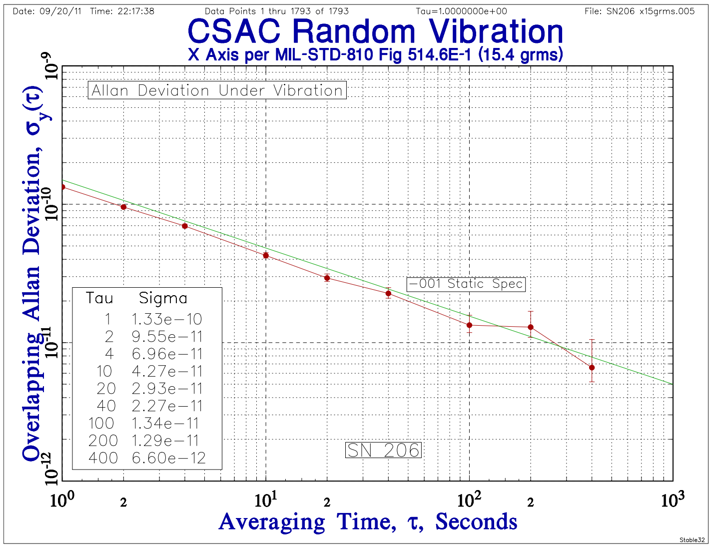
SN206



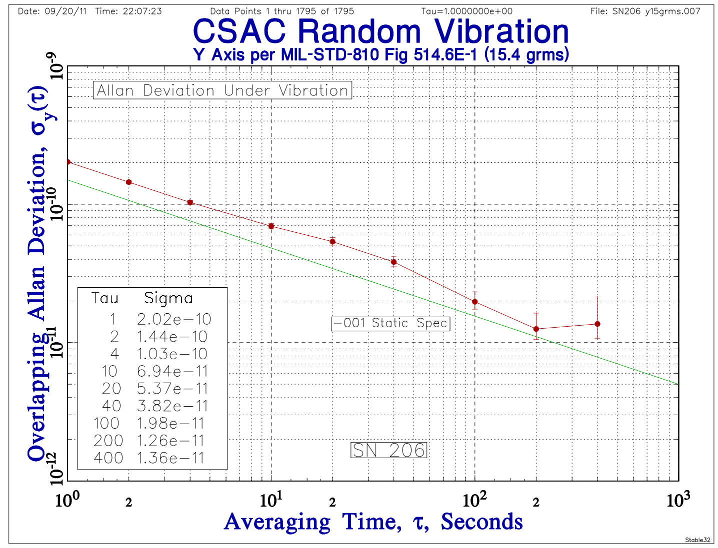
SN206

APPENDIX C: ALLAN DEVIATION PLOTS

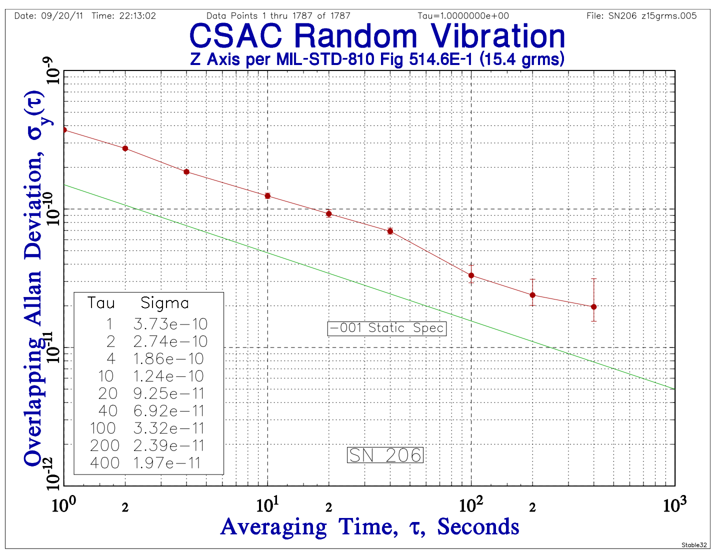
15.4 grms



SN206



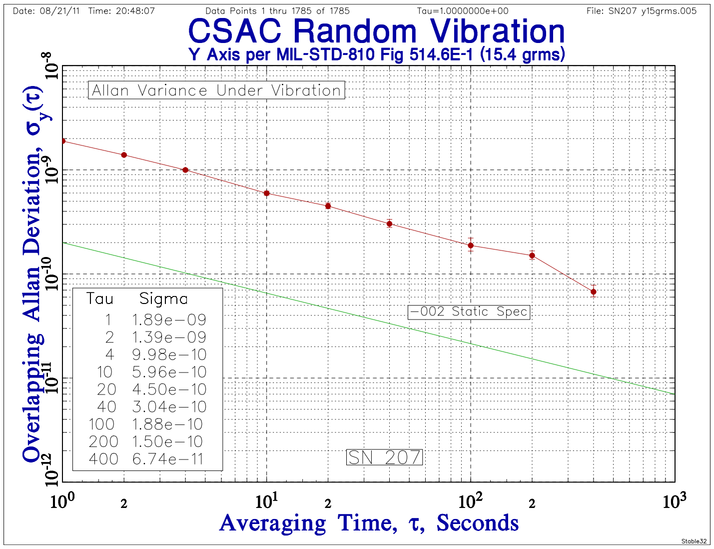
SN206



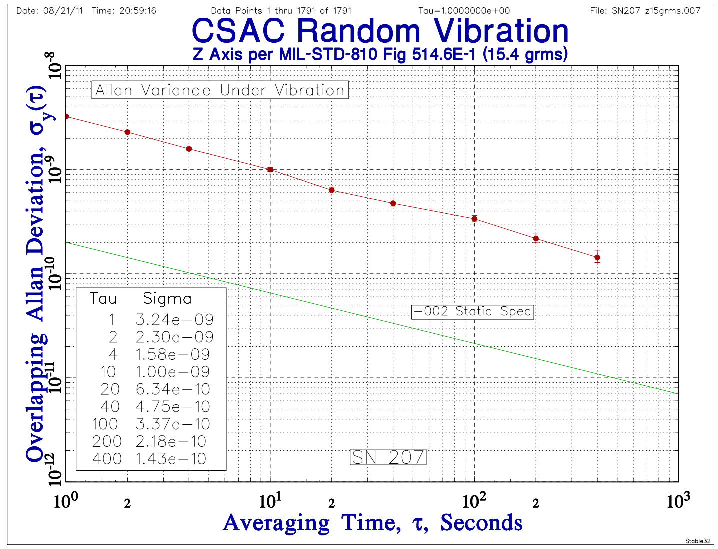
SN206

APPENDIX C: ALLAN DEVIATION PLOTS

15.4 grms



SN207

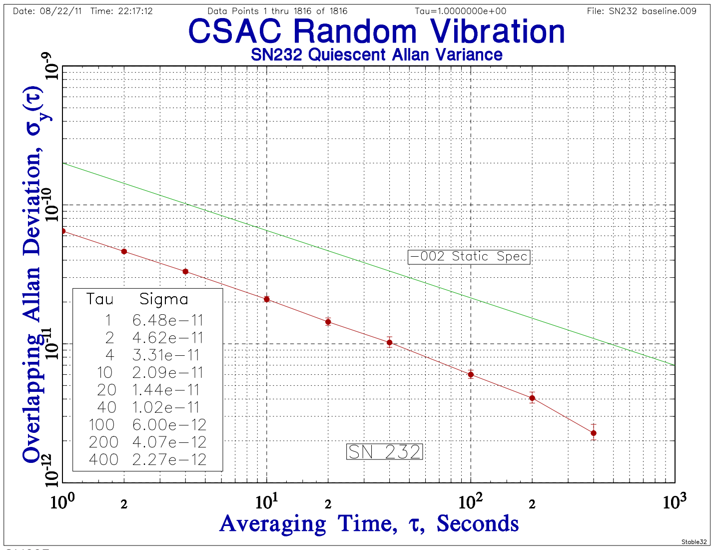


SN207

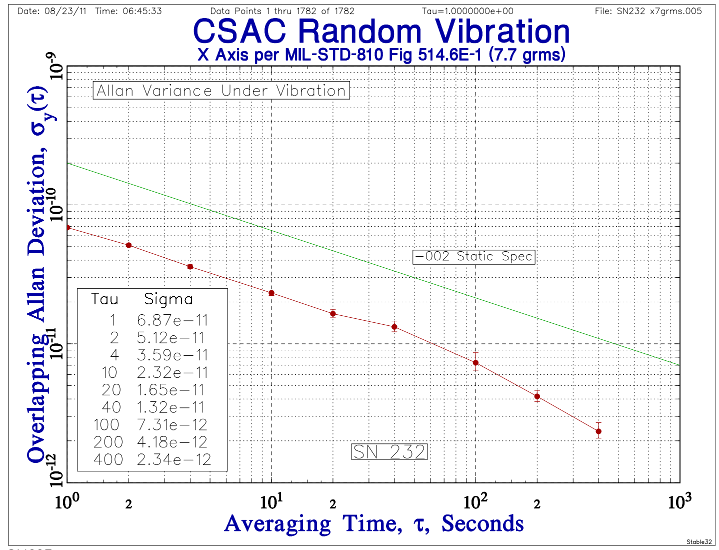
No X Axis Data for SN 207 at 15.4 grms

APPENDIX C: ALLAN DEVIATION PLOTS

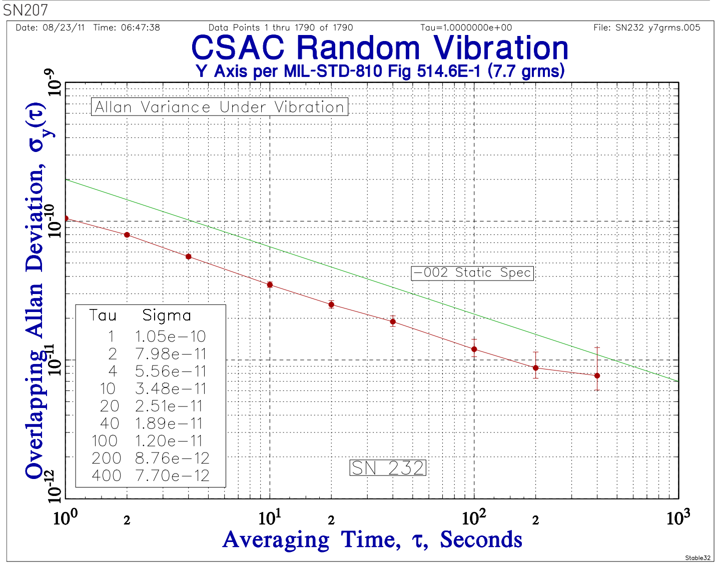
7.7 grms



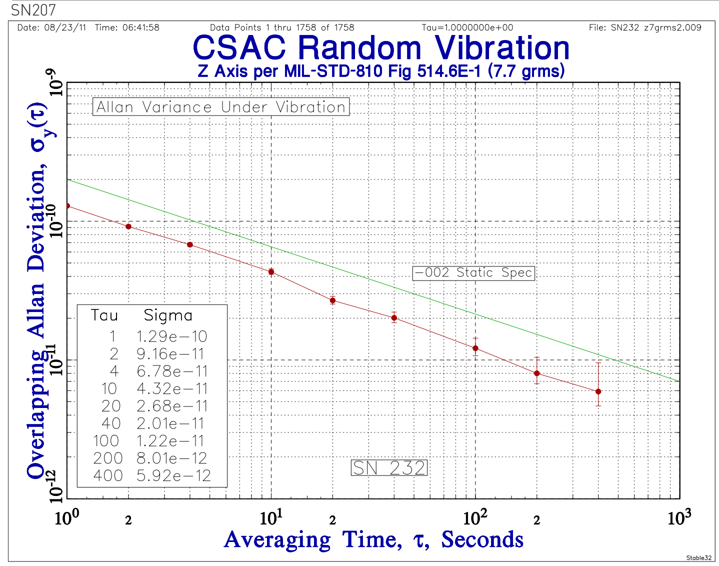
SN207



SN207



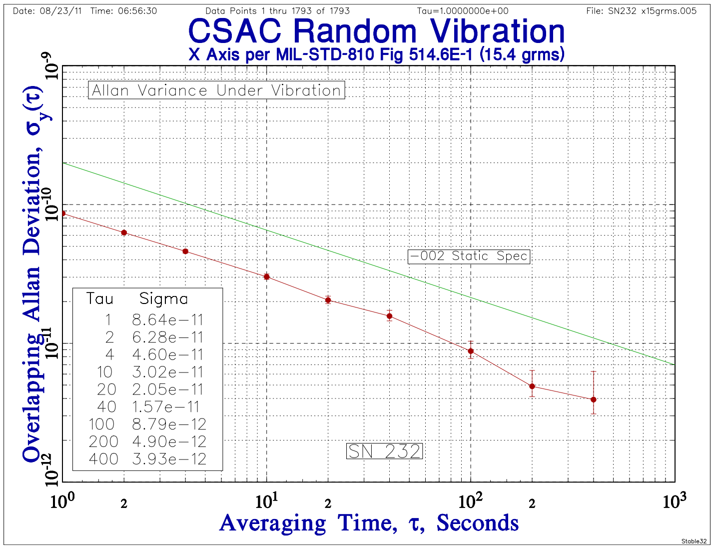
SN207



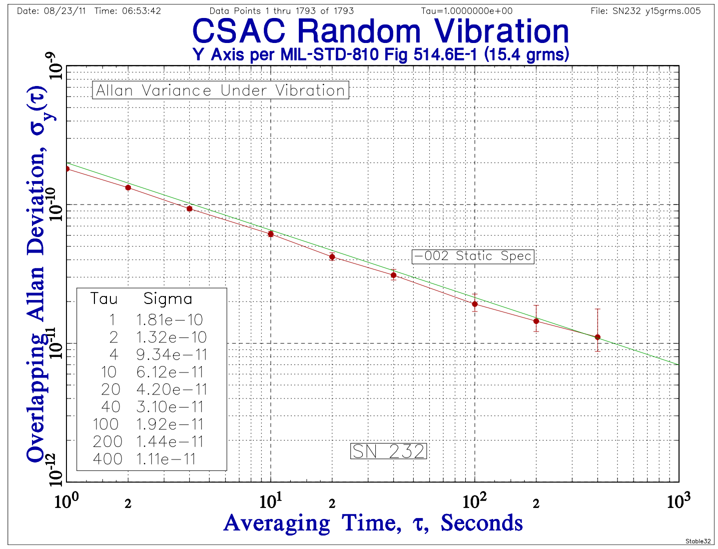
SN207

APPENDIX C: ALLAN DEVIATION PLOTS

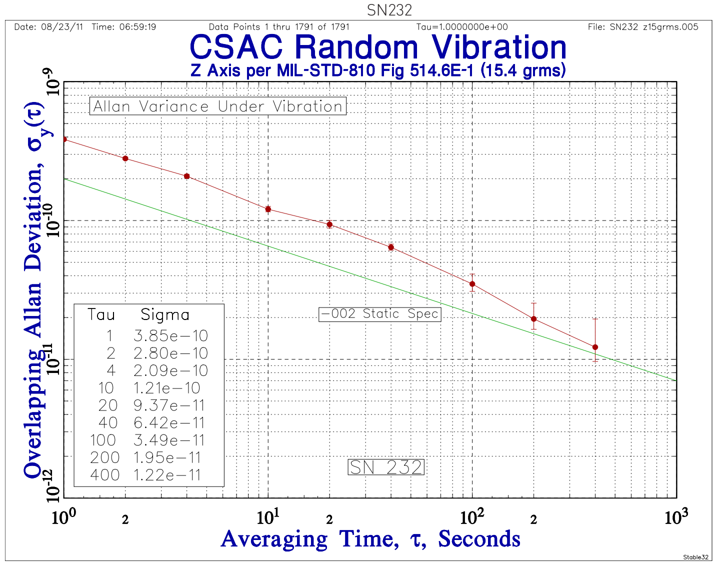
15.4 grms



SN232



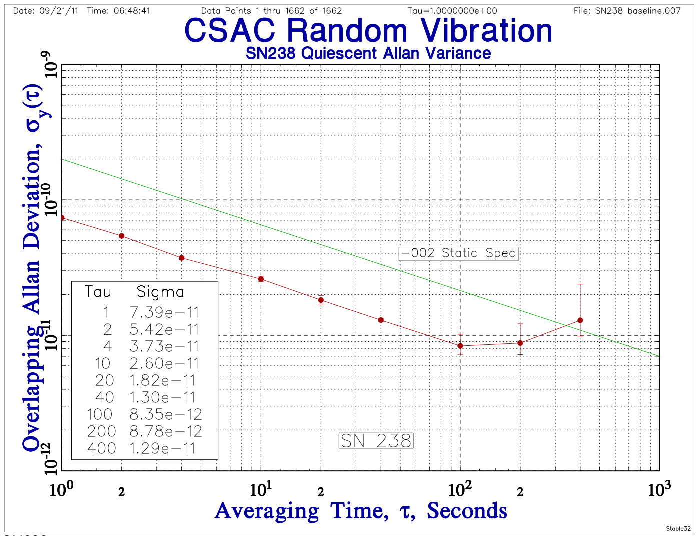
SN232



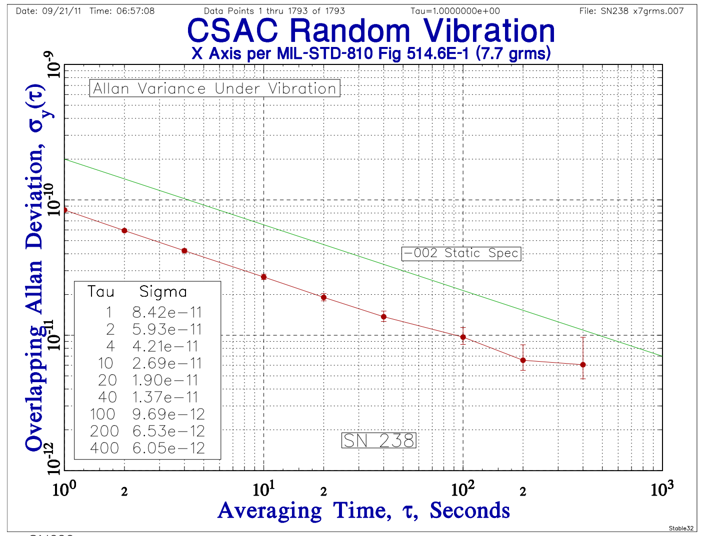
SN232

APPENDIX C: ALLAN DEVIATION PLOTS

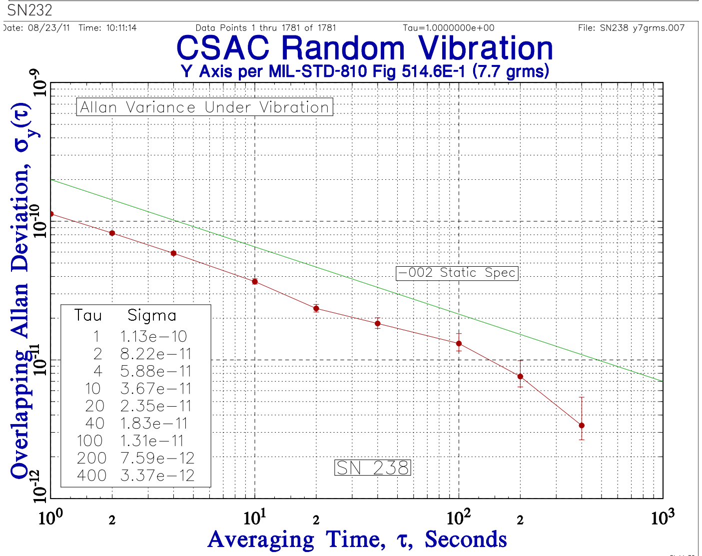
7.7 grms



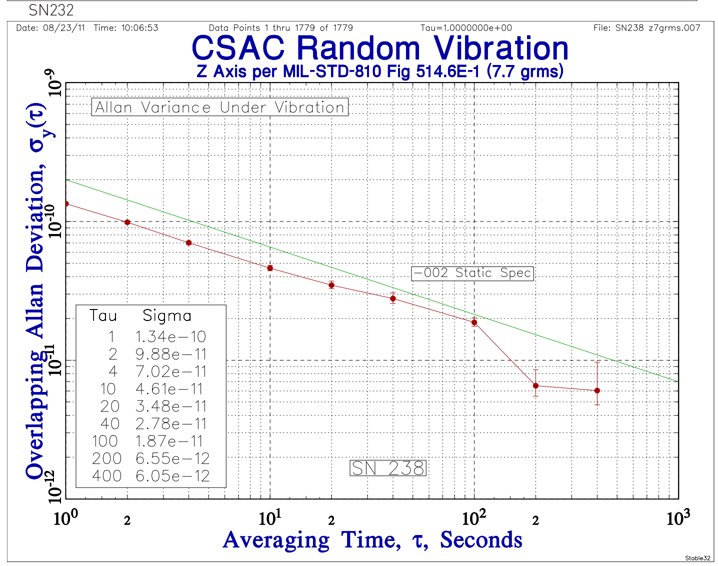
SN232



SN232



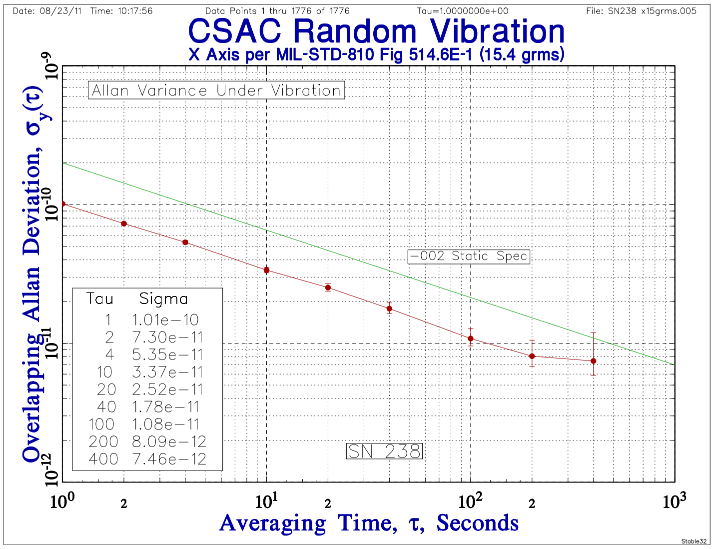
SN232



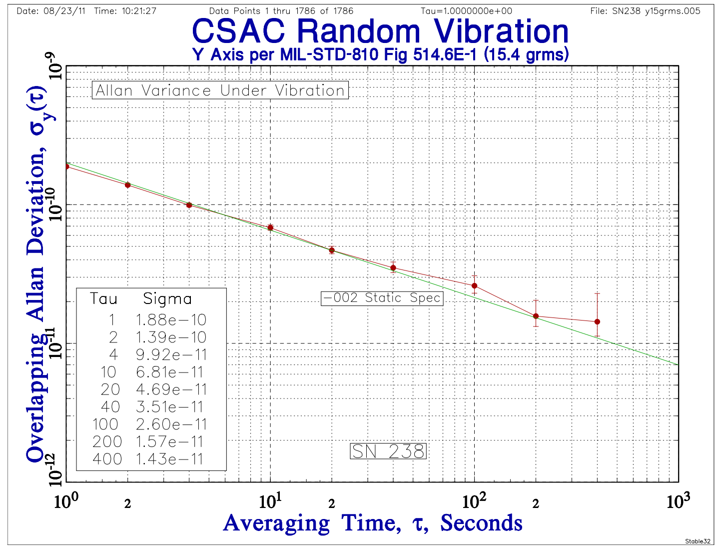
SN232

APPENDIX C: ALLAN DEVIATION PLOTS

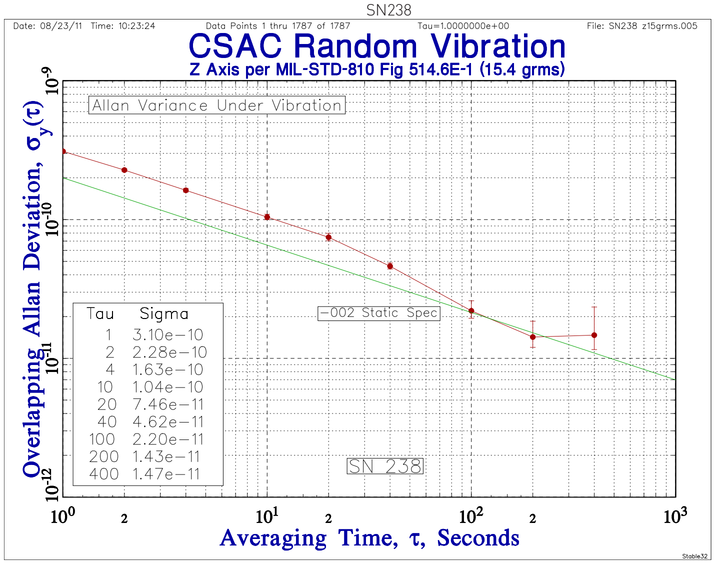
15.4 grms



SN238



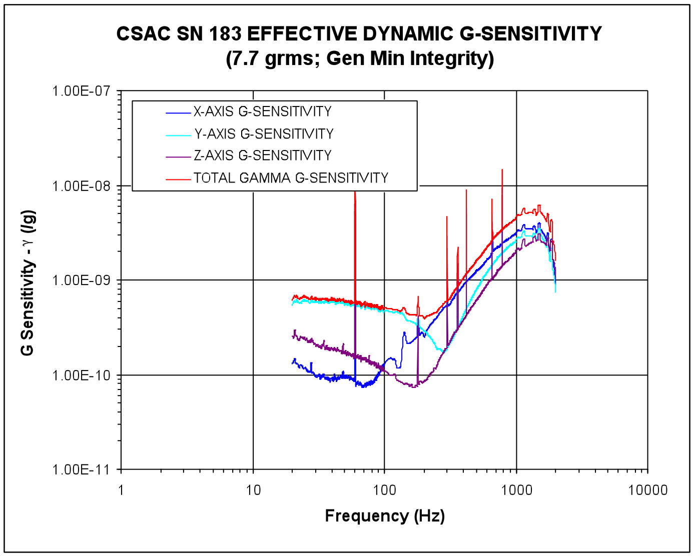
SN238

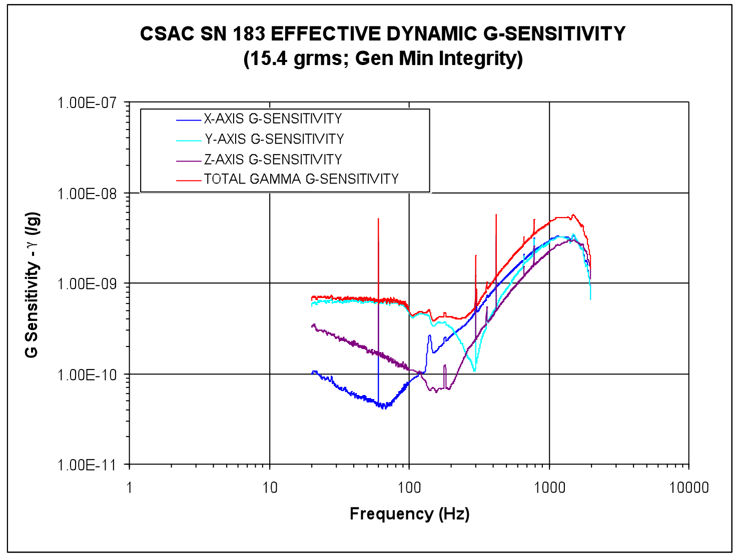


SN238

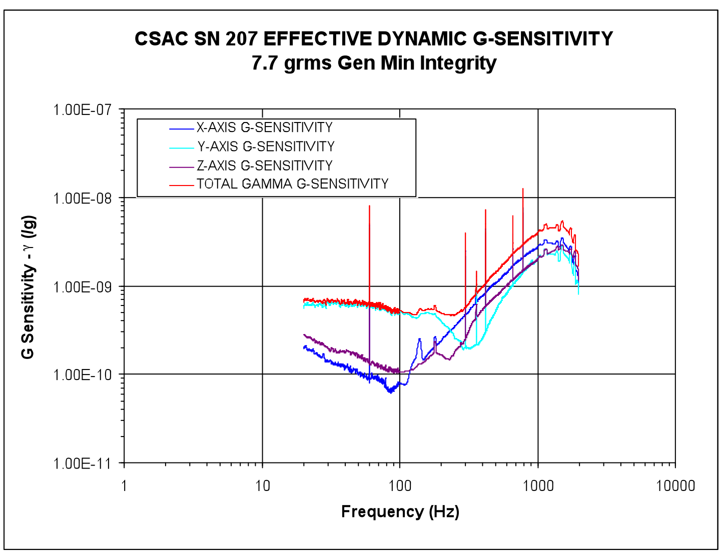
Shock and Vibration Testing of the SA.45s Chip Scale Atomic Clock (CSAC) Validation Build Units

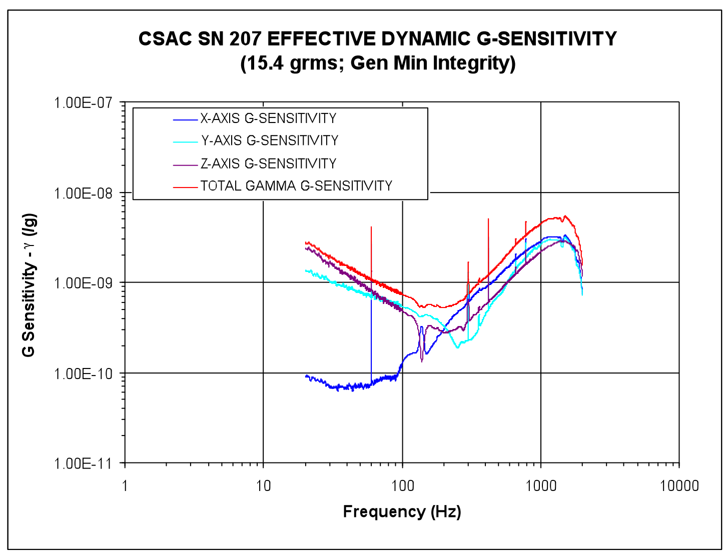
APPENDIX D: EFFECTIVE G-SENSITIVITY PLOTS





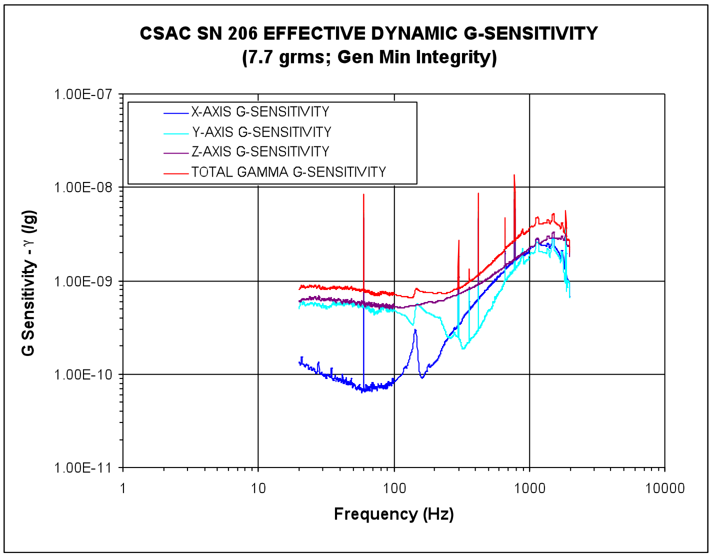
Effective G-Sensitivity Plots For SA.45s CSAC SN 183

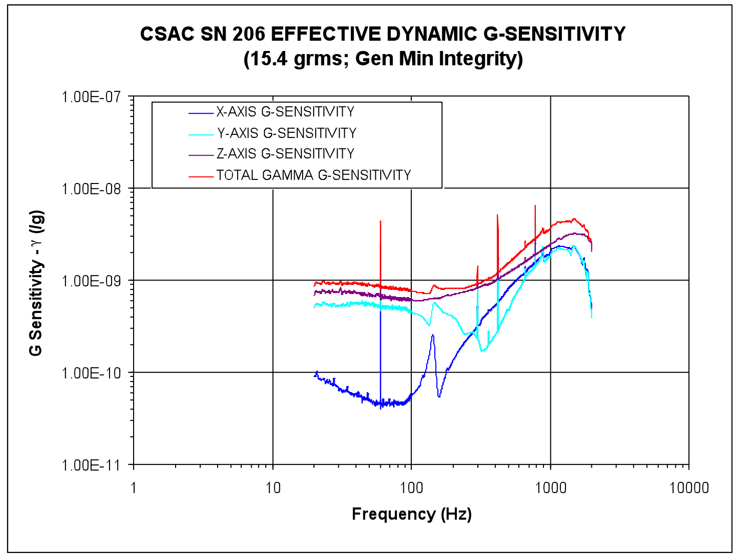




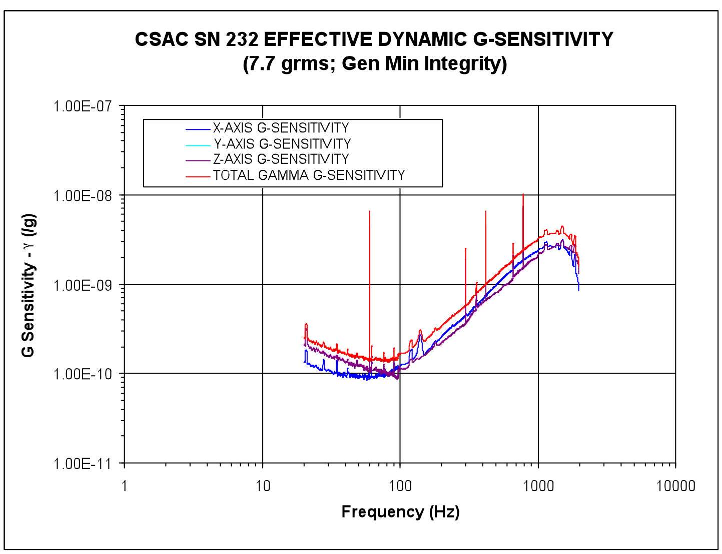
Effective G-Sensitivity Plots For SA.45s CSAC SN 207

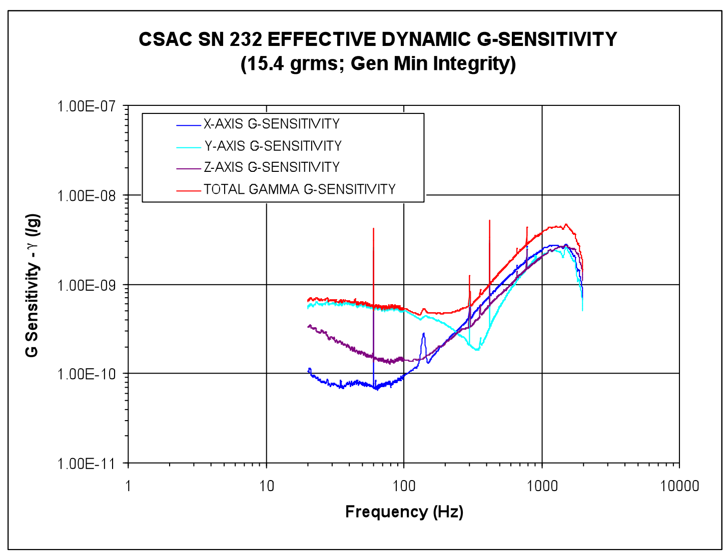
APPENDIX D: EFFECTIVE G-SENSITIVITY PLOTS





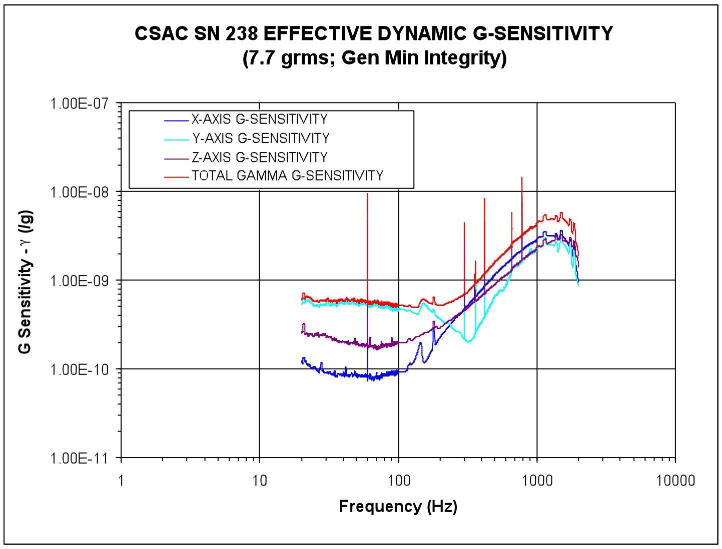
Effective G-Sensitivity Plots For SA.45s CSAC SN 206

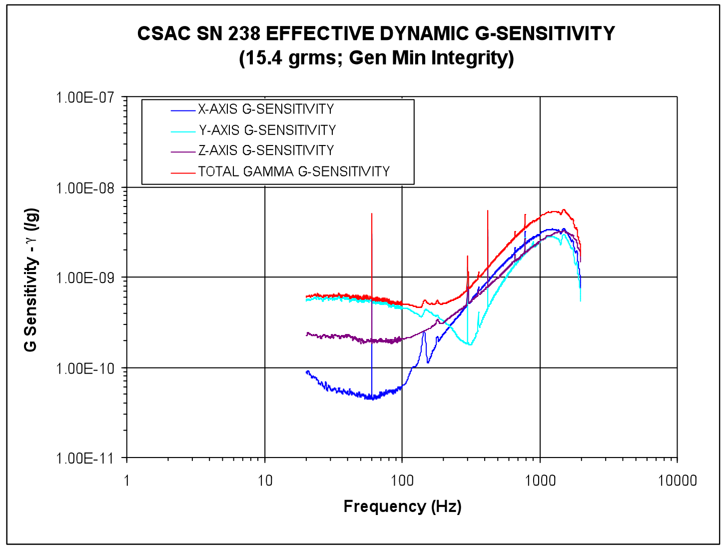




Effective G-Sensitivity Plots For SA.45s CSAC SN 232

APPENDIX D: EFFECTIVE G-SENSITIVITY PLOTS





Effective G-Sensitivity Plots For SA.45s CSAC SN 238

Microsemi Corporate Headquarters
One Enterprise, Aliso Viejo CA 92656 USA
Within the USA: +1 (800) 713-4113
Outside the USA: +1 (949) 380-6100
Sales: +1 (949) 380-6136
Fax: +1 (949) 215-4996
E-mail: sales.support@microsemi.com