

Vietnam IBST Table Acceptance Report

December 15, 2008

Forward

After the repair of the shaking table system for the restrictor manifold failure and the water flooding, the following tests were performed to verify the system performance against MTS standards for shaking tables. It should be noted that all of the tests found the table performance at this time to be in line with results from similar shaking tables constructed by MTS for many years and to data taken on this particular system before the manifold failure. Therefore, it is the conclusion of MTS that this system is functioning in the best tradition of MTS equipment world-wide.

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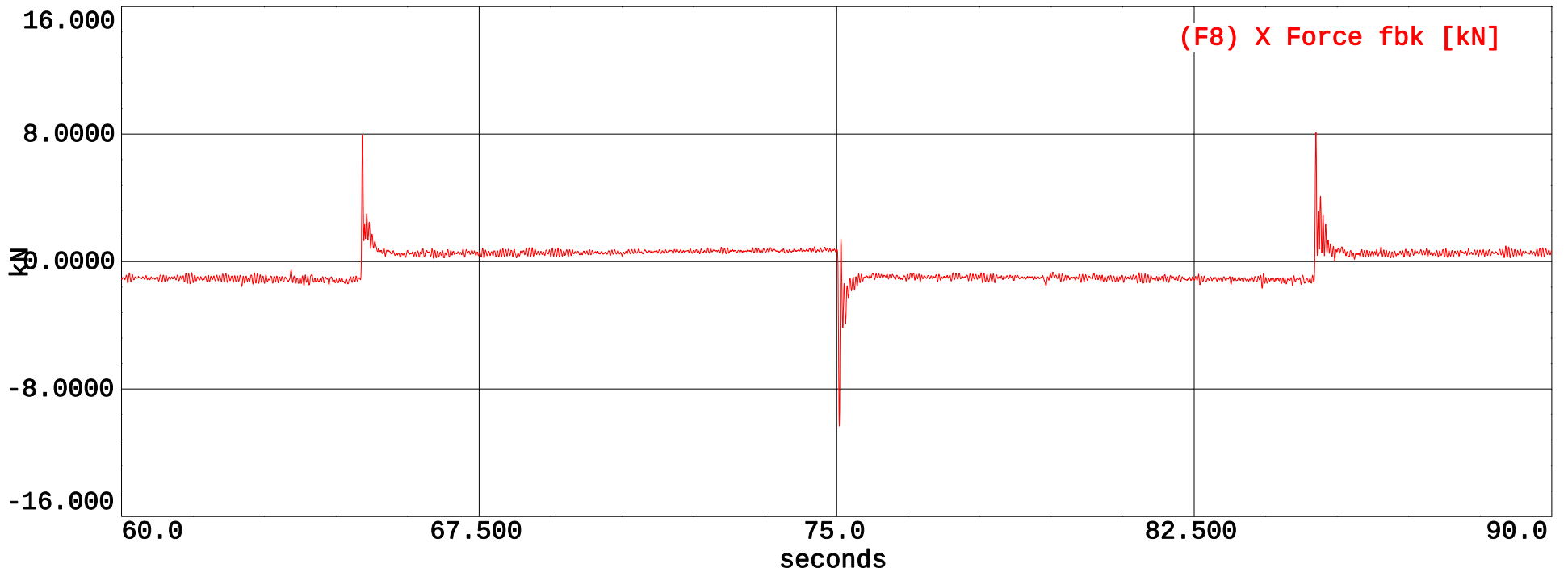
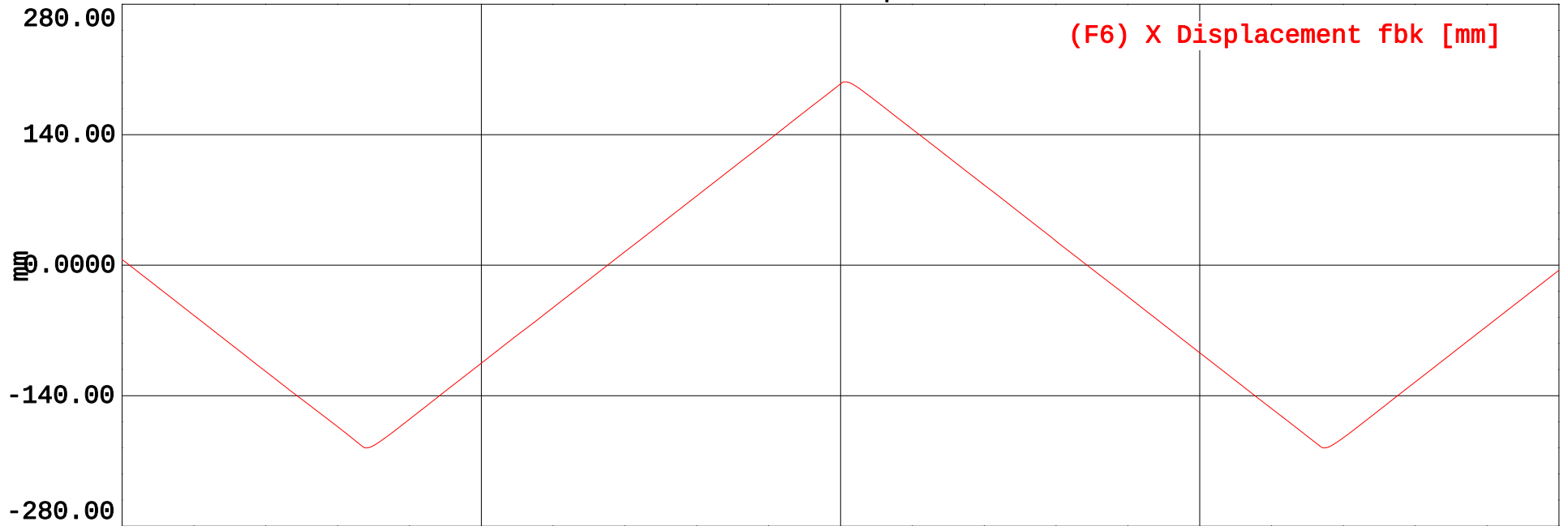
December 15, 2008

Test Results:

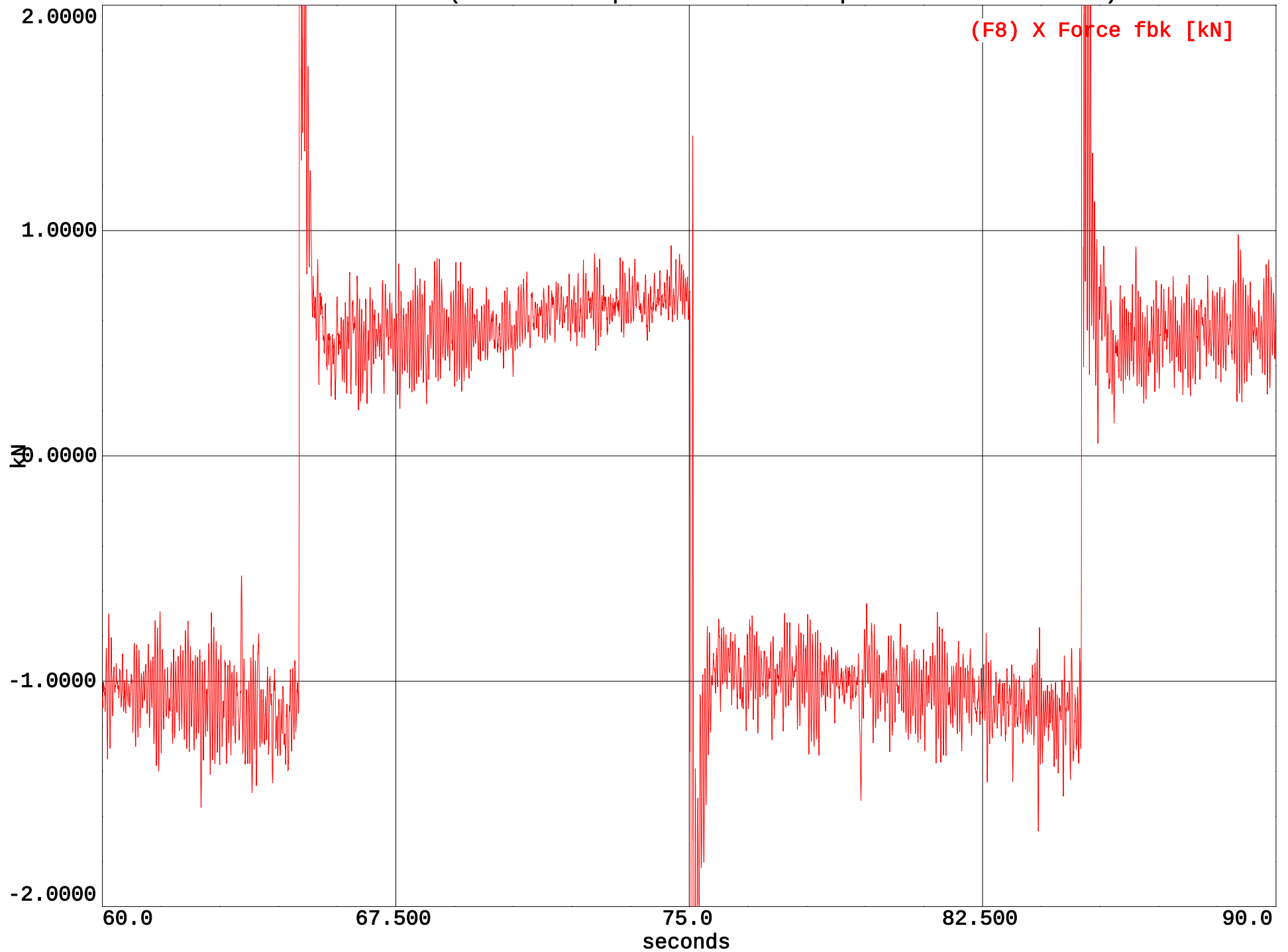
I. Friction Tests

Friction tests were performed on both the X and the Y axis of the IBST Shaking Table. These tests show that the friction force for BOTH axes is about 1 (one) Kilo-Newton (KN) of force. This corresponds to about 13 psi in the actuator to move the cylinder with no load. Since MTS uses 2500 psi as the maximum dynamic pressure for system performance, the friction is about ½ percent of the actuator force capacity. This is very low for such a system. MTS has systems in the field that have less friction but use expensive hydrostatic bearings, but MTS standard systems are usually a bit higher. This is especially true for 6 DOF systems with more actuators and swivels. The friction force there can easily be as large as 30 psi per actuator or about 1.2 % of force capacity. The ½ percent shows that the IBST system is very good for friction errors. The following 4 plots show the friction measurements for the X and Y axes:

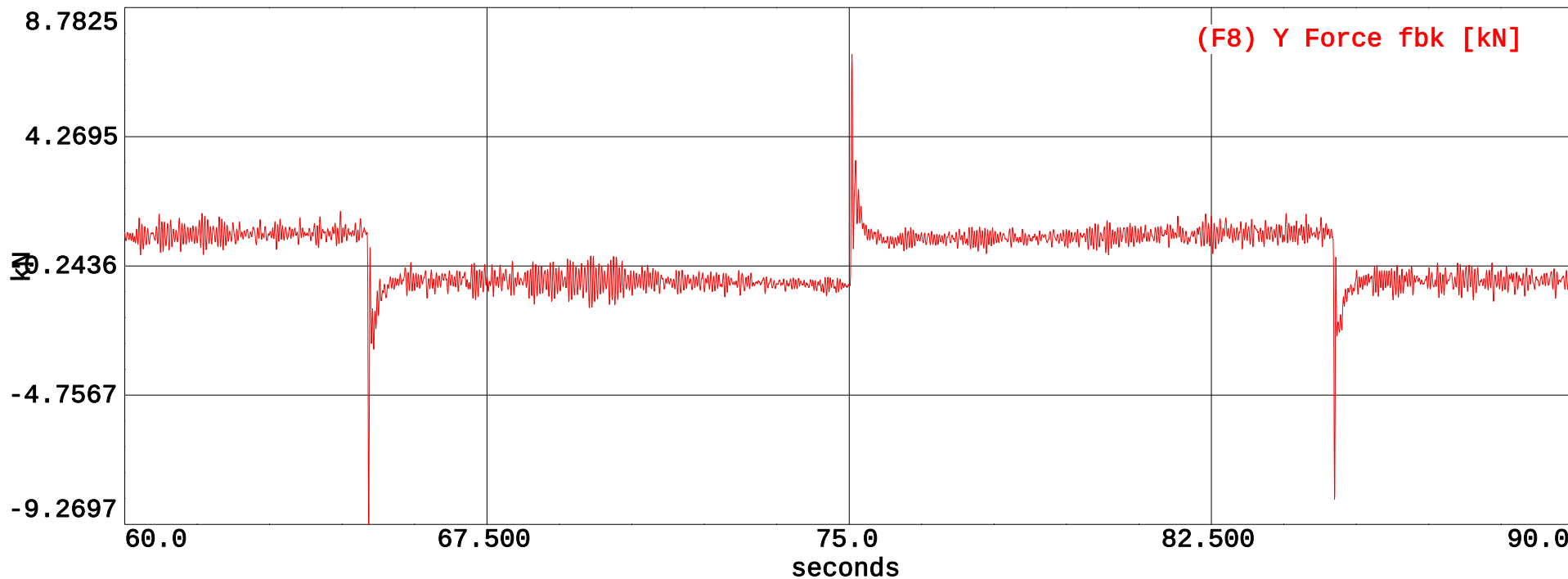
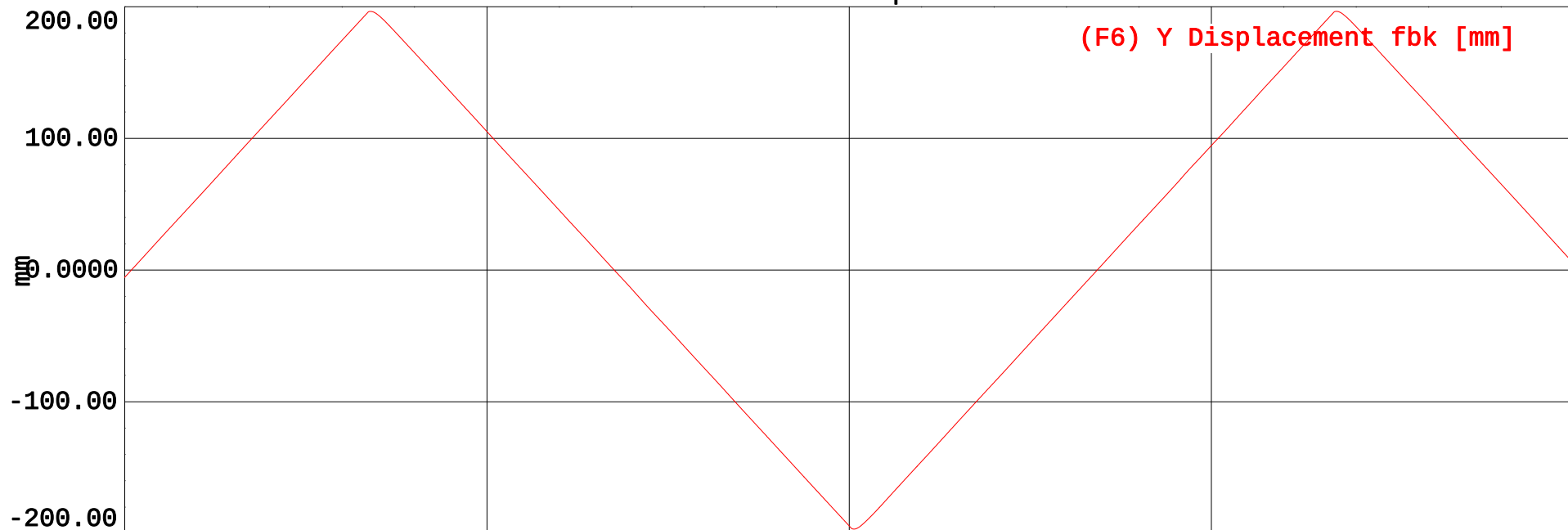
+/- 200 millimeter triangle wave response
Friction force response



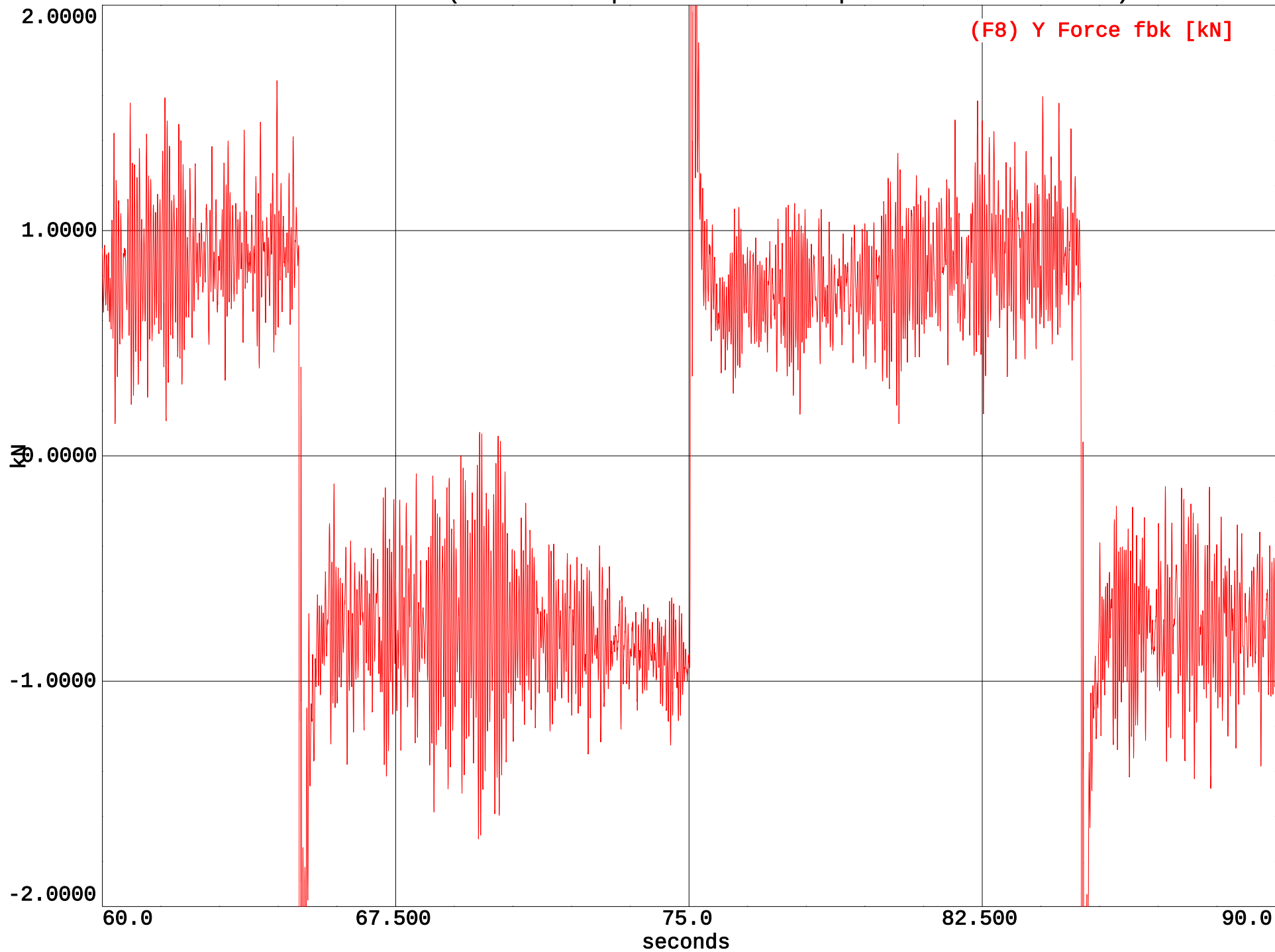
X Friction Force feedback (1 kN = 224 pounds force = 13 psi in actuator force)



+/- 200 millimeter triangle wave response
Friction force response



Y Friction Force feedback (1 kN = 224 pounds force = 13 psi in actuator force)



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Test Results:

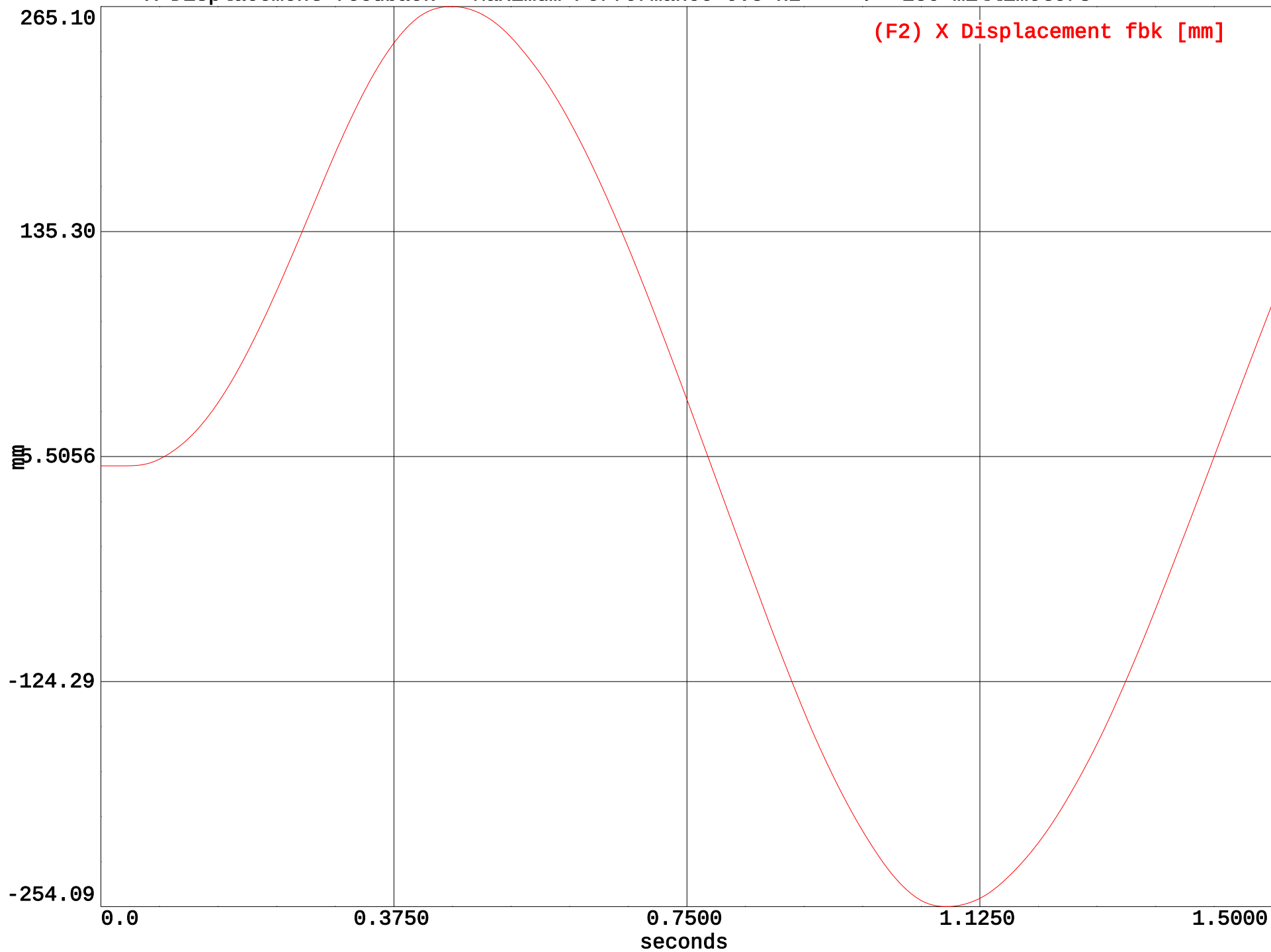
II. Maximum Performance

The maximum performance of the system is according to the performance curves supplied as part of the system quotation. To show that the IBST Shaking Table meets performance, the following tests were performed to verify the following conditions for BOTH the X and Y axes:

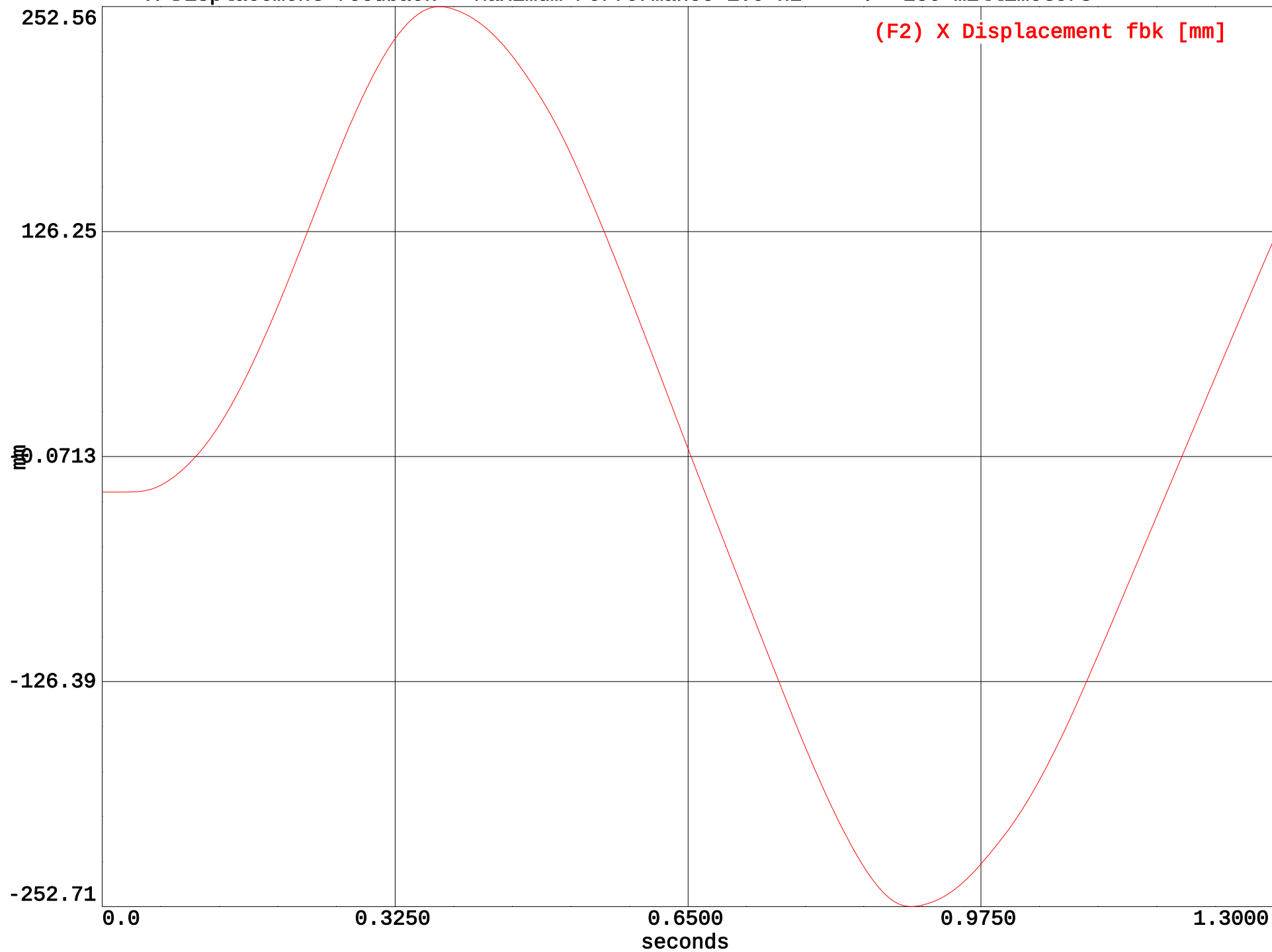
Frequency	Amplitude
0.8 Hz	+/- 250 millimeters displacement
1.0 Hz	+/- 250 millimeters displacement
2.0 Hz	+/- 1.0 meters/second velocity
3.0 Hz	+/- 1.0 meters/second velocity
4.0 Hz	+/- 1.0 meters/second velocity
5.0 Hz	+/- 2.6 G's acceleration
10.0 Hz	+/- 2.6 G's acceleration
20.0 Hz	+/- 2.6 G's acceleration
40.0 Hz	+/- 2.6 G's acceleration

The following Maximum Performance Plots show that the IBST Shaking Table easily achieves the performance indicated for BOTH axes:

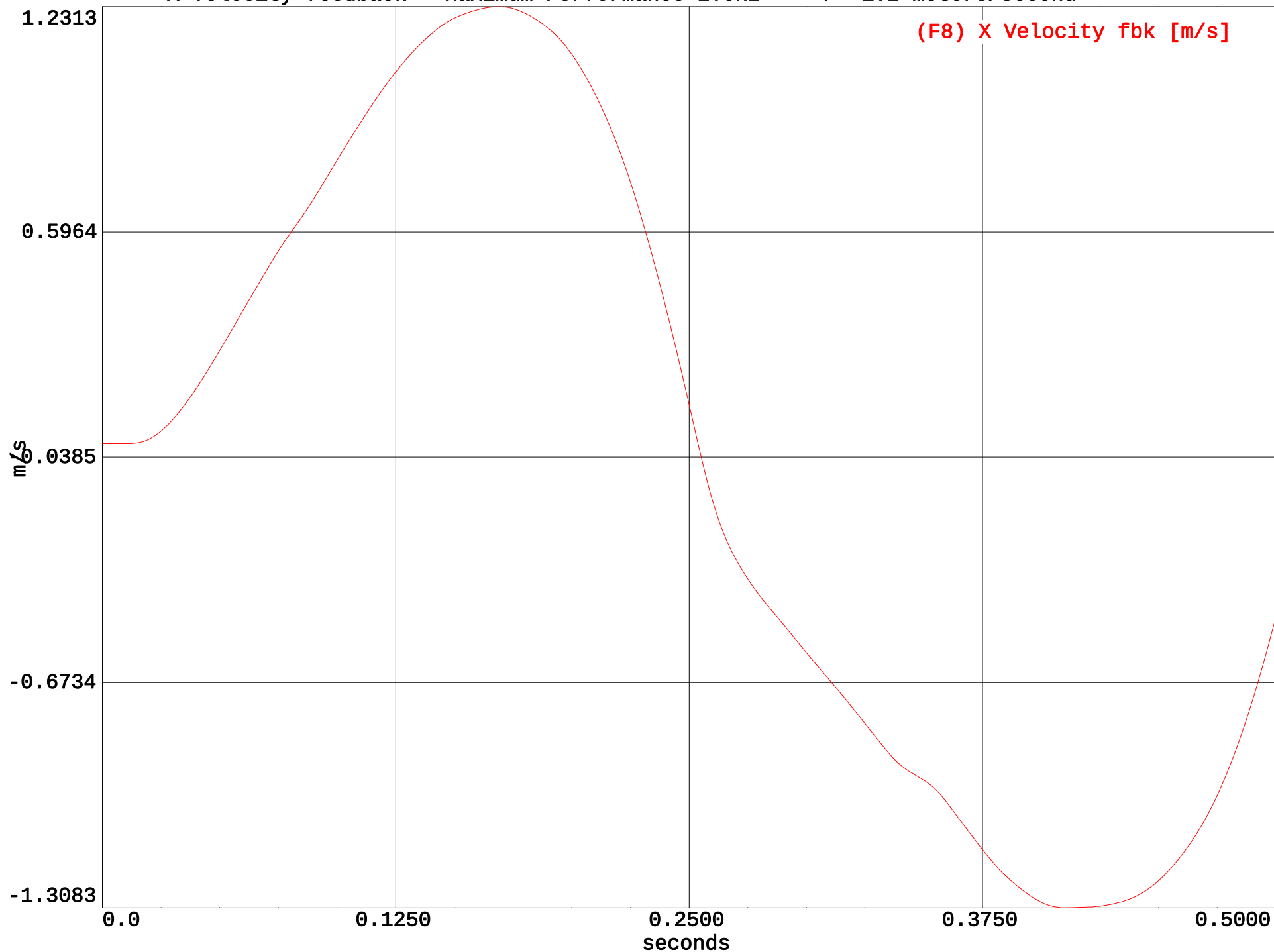
X Displacement feedback - Maximum Performance 0.8 Hz $\geq$ +/- 250 millimeters



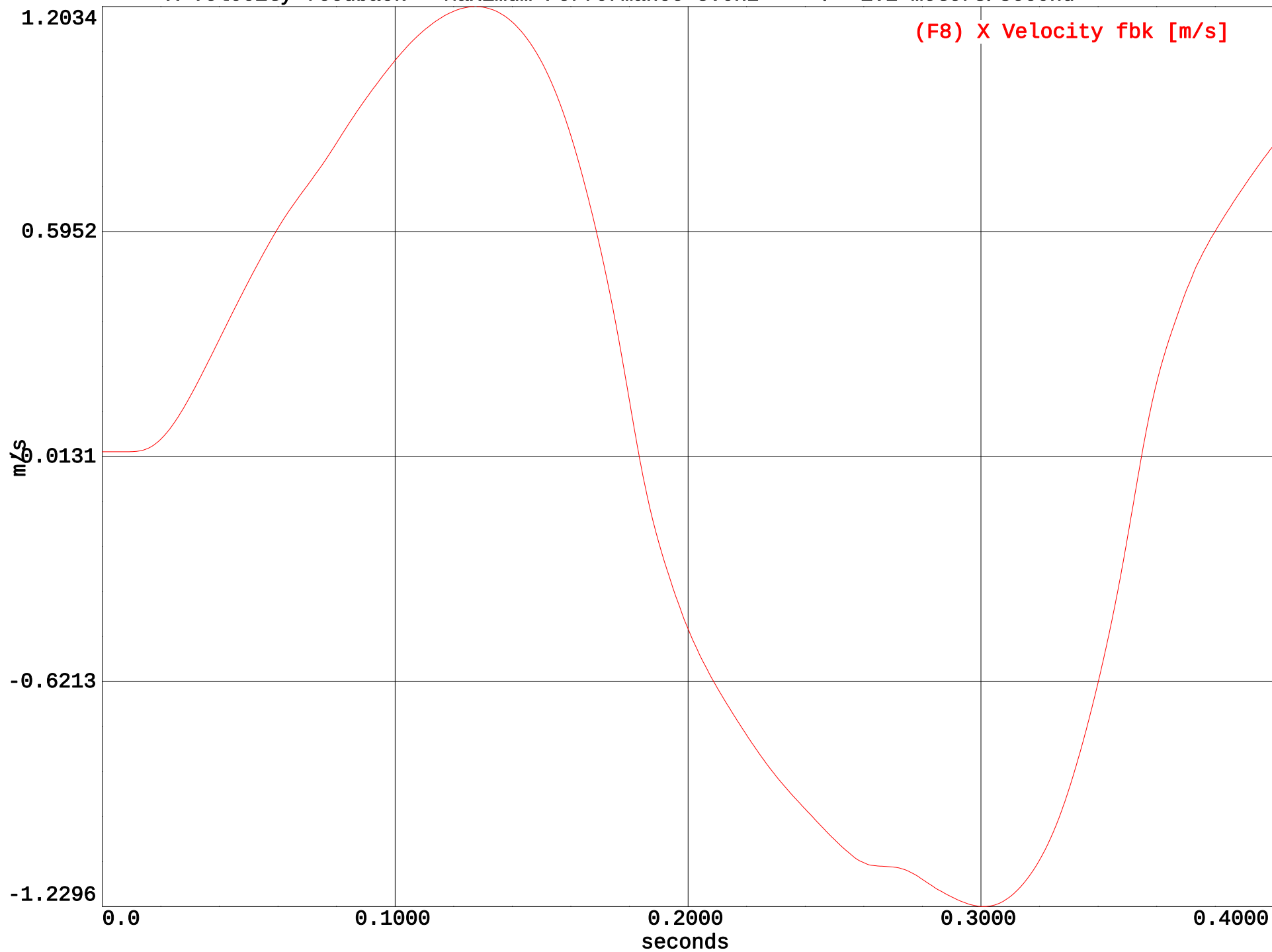
X Displacement feedback - Maximum Performance 1.0 Hz >= +/- 250 millimeters



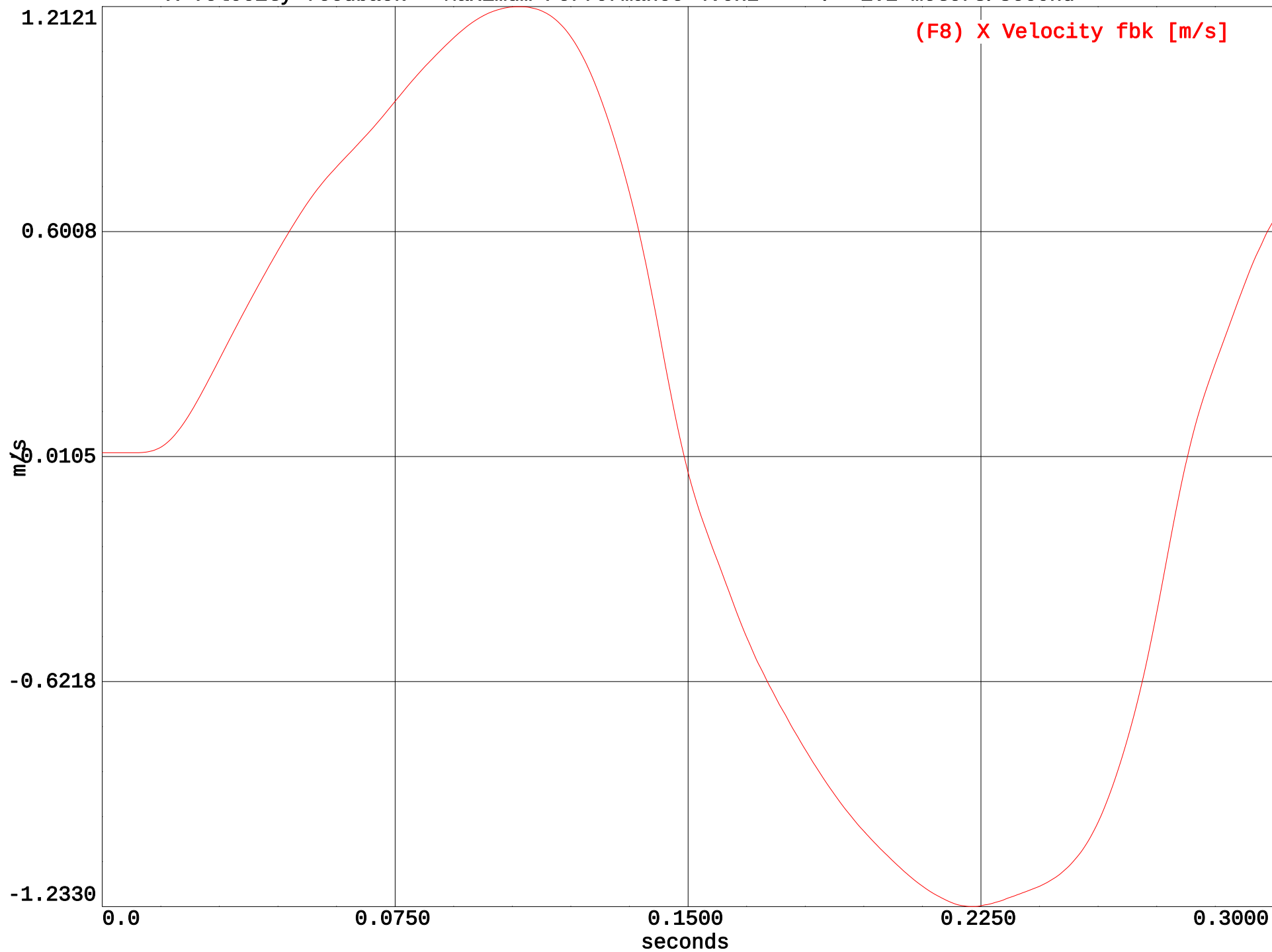
X Velocity feedback - Maximum Performance 2.0Hz >= +/- 1.2 meters/second



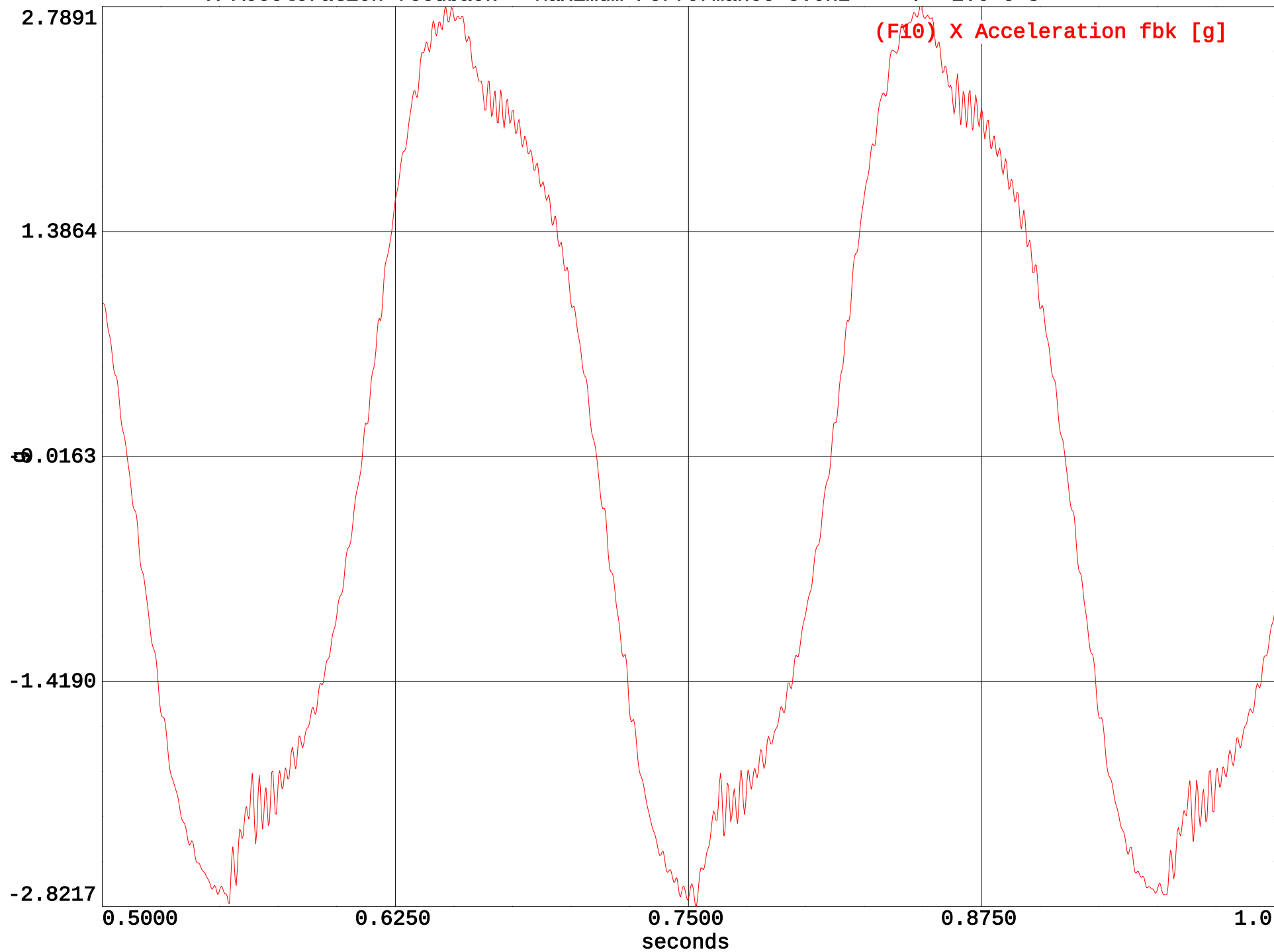
X Velocity feedback - Maximum Performance 3.0Hz >= +/- 1.2 meters/second



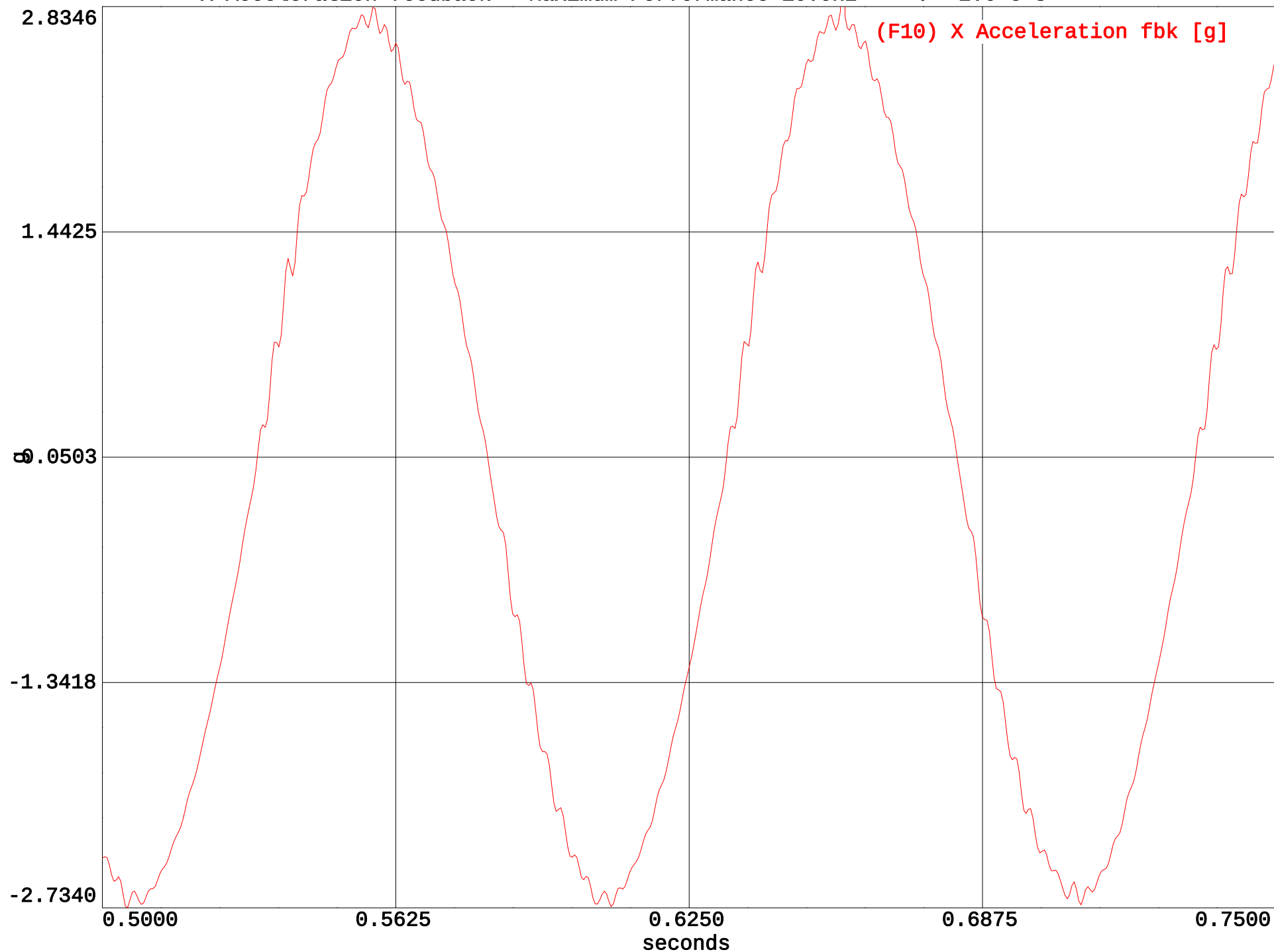
X Velocity feedback - Maximum Performance 4.0Hz >= +/- 1.2 meters/second



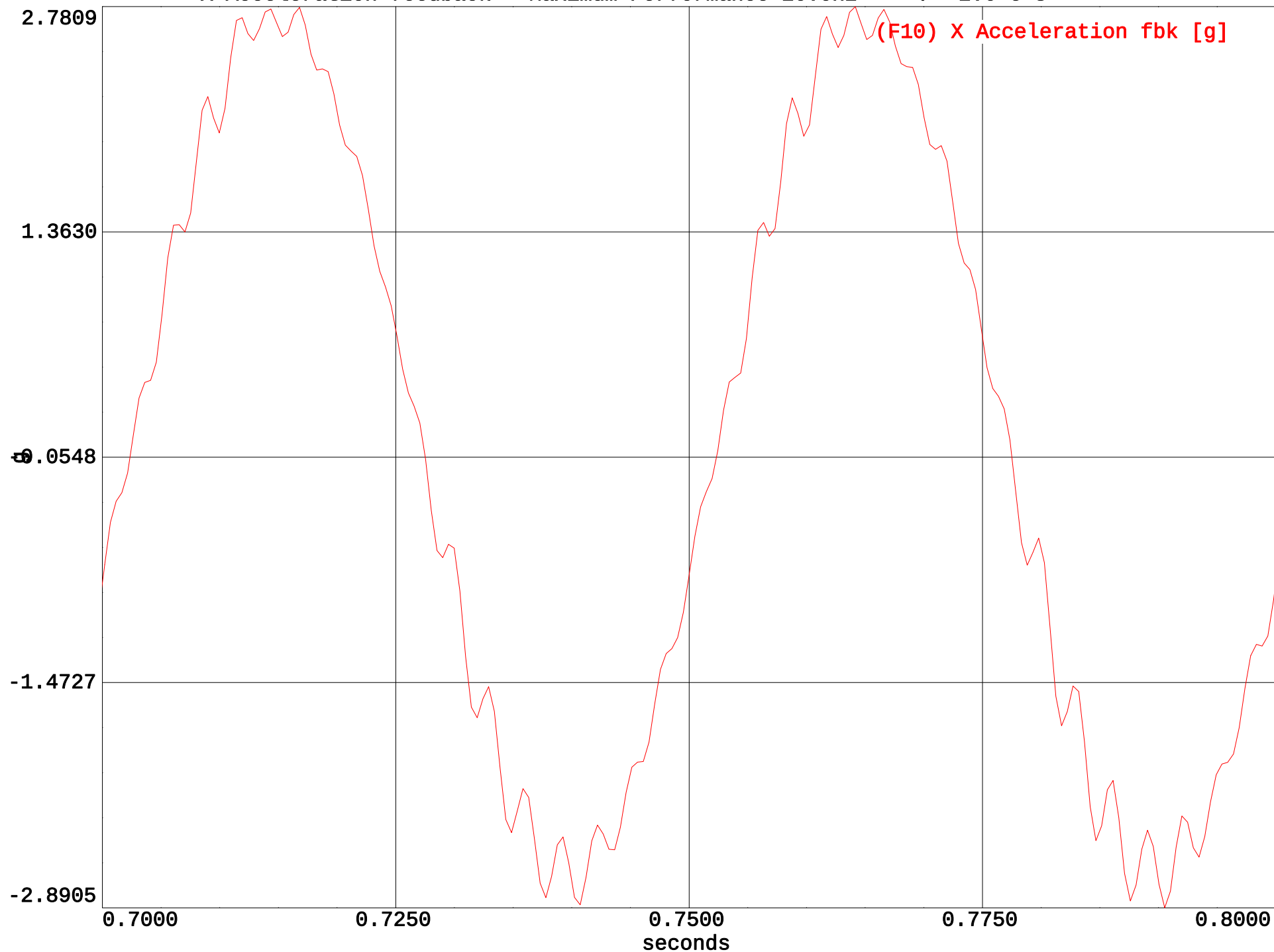
X Acceleration feedback - Maximum Performance 5.0Hz >= +/- 2.6 G's



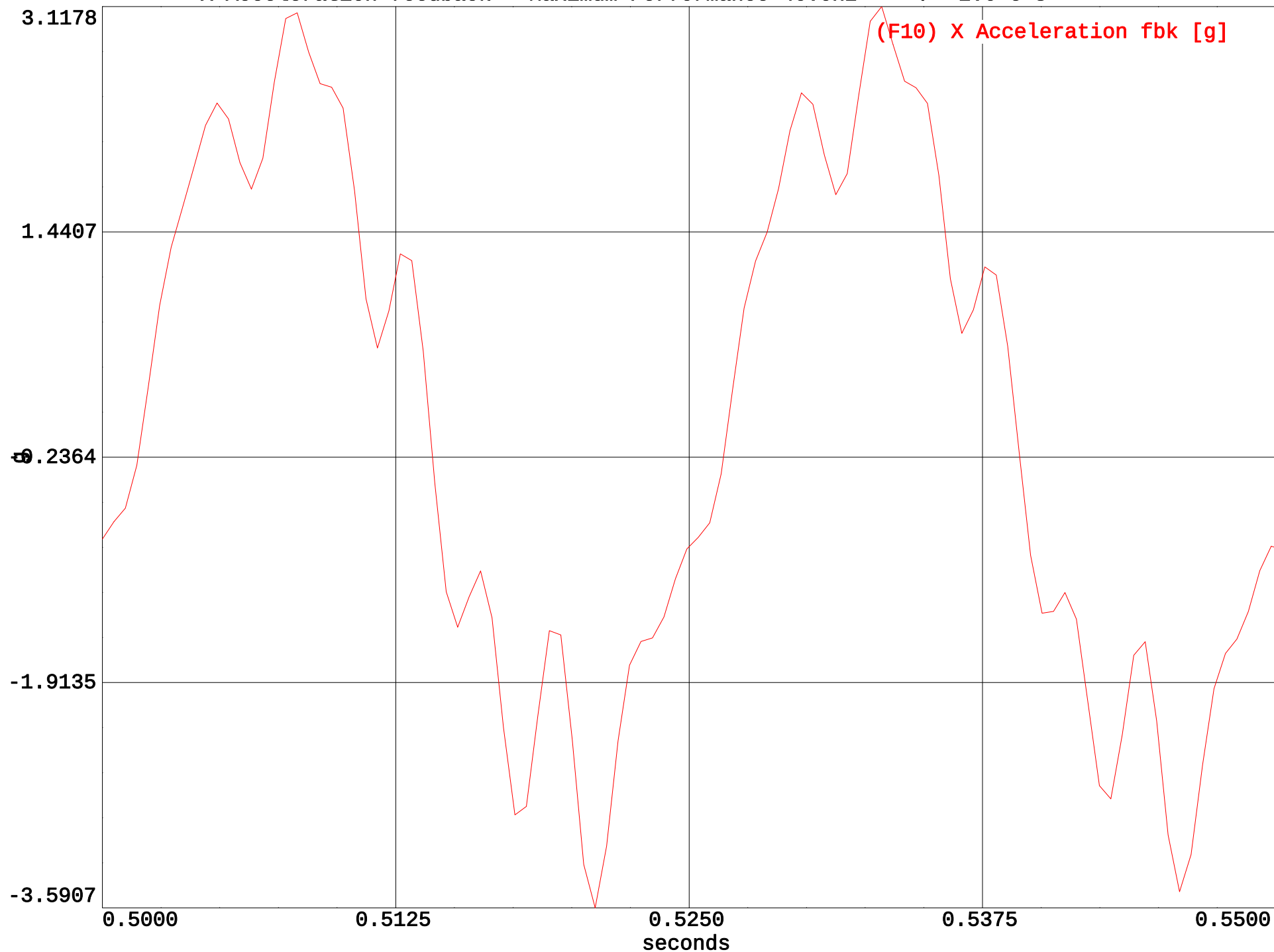
X Acceleration feedback - Maximum Performance 10.0Hz $\geq$ $\pm$ 2.6 G's



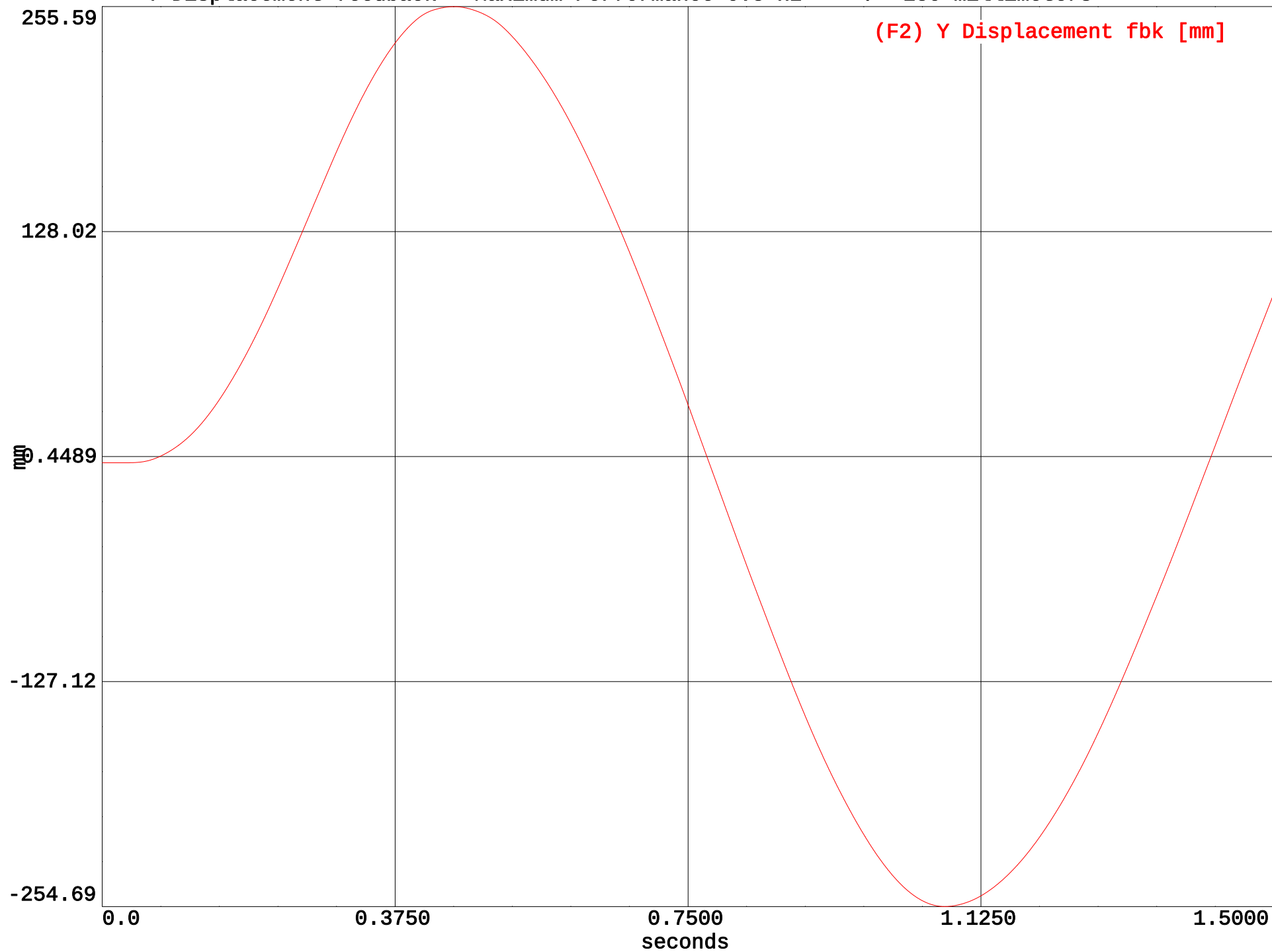
X Acceleration feedback - Maximum Performance 20.0Hz >= +/- 2.6 G's



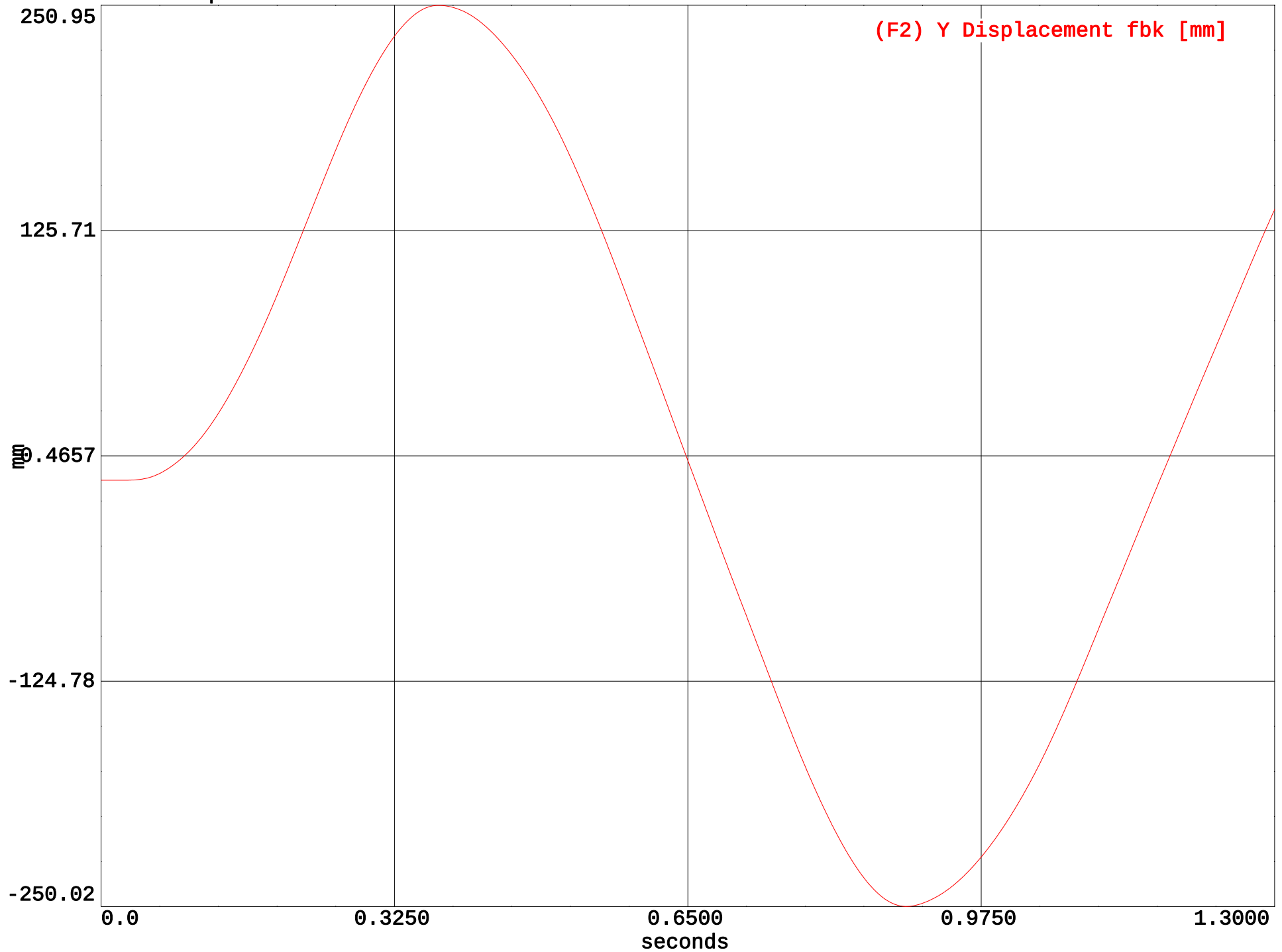
X Acceleration feedback - Maximum Performance 40.0Hz $\geq$ $\pm$ 2.6 G's



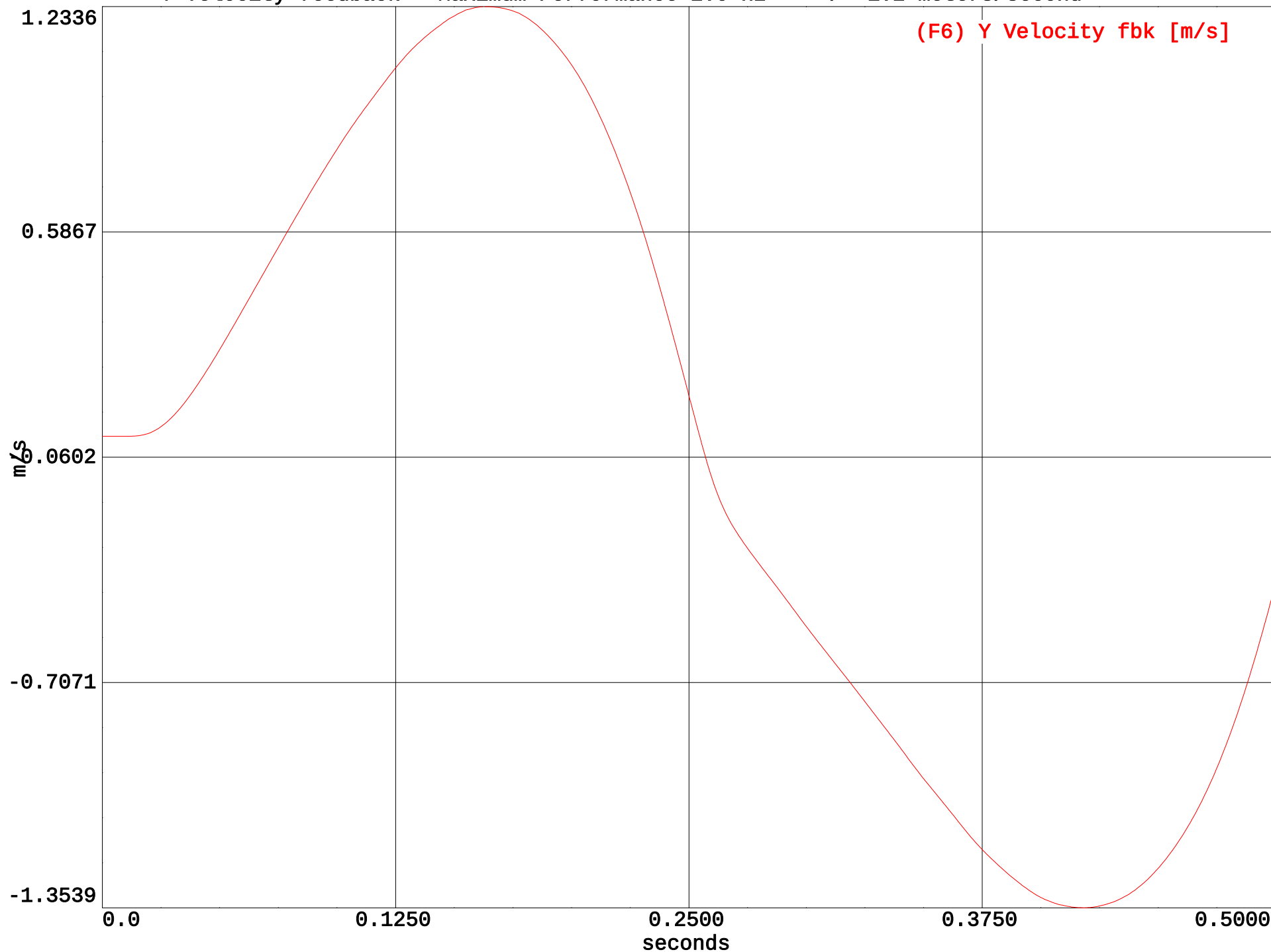
Y Displacement feedback - Maximum Performance 0.8 Hz >= +/- 250 millimeters



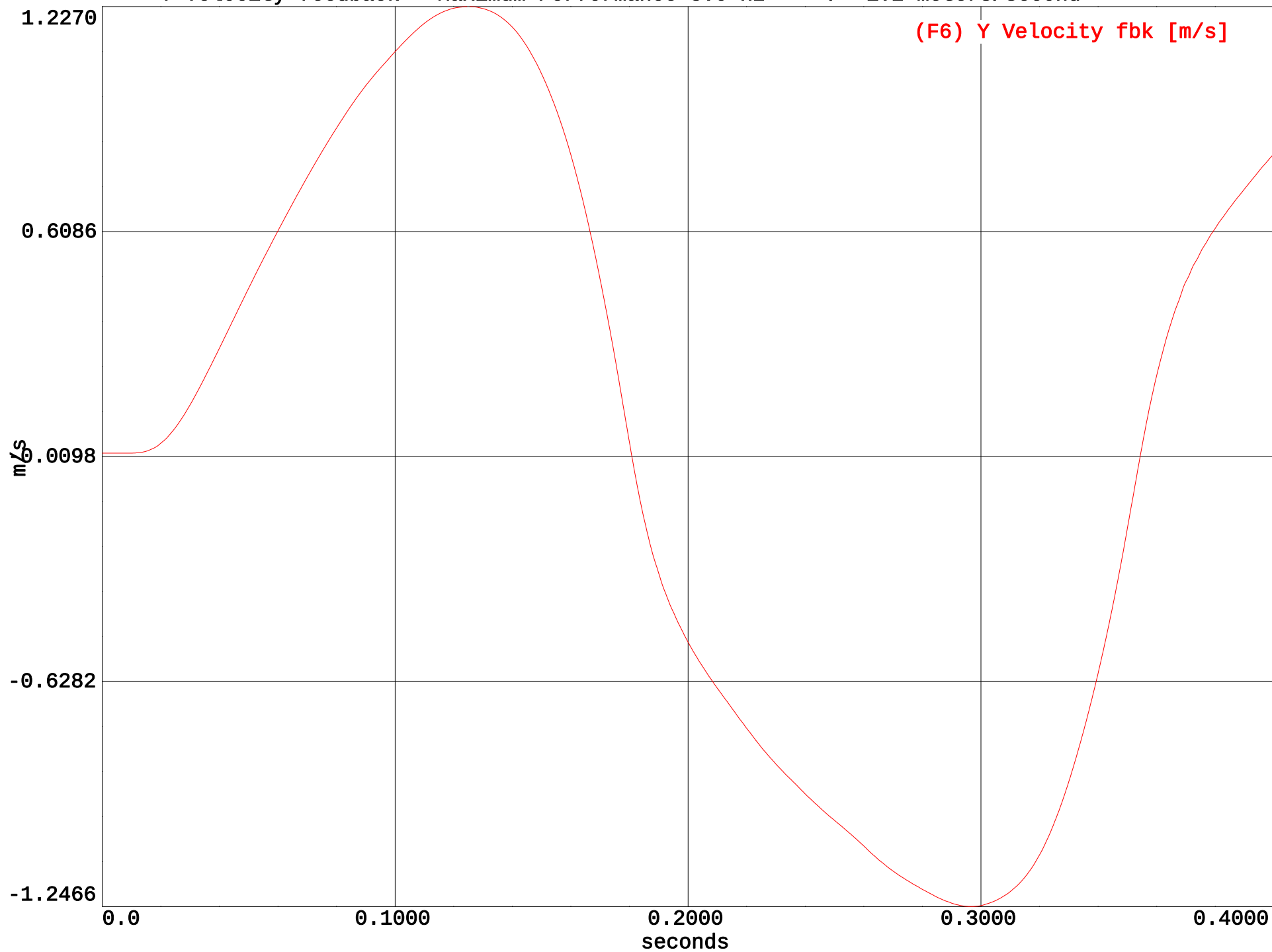
Y Displacement feedback - Maximum Performance 1.0 Hz $\geq$ $\pm$ 250 millimeters



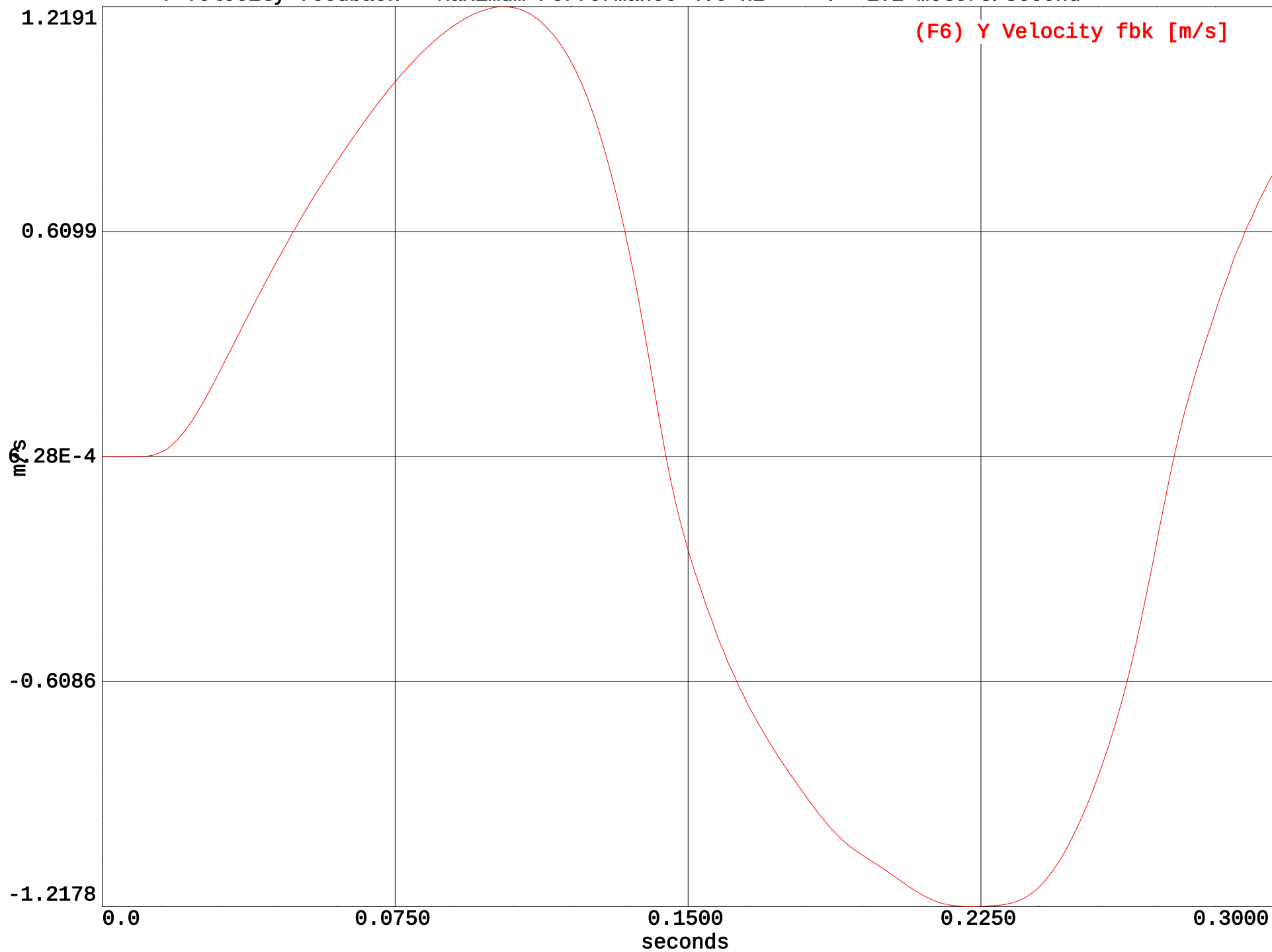
Y Velocity feedback - Maximum Performance 2.0 Hz $\geq$ $\pm$ 1.2 meters/second



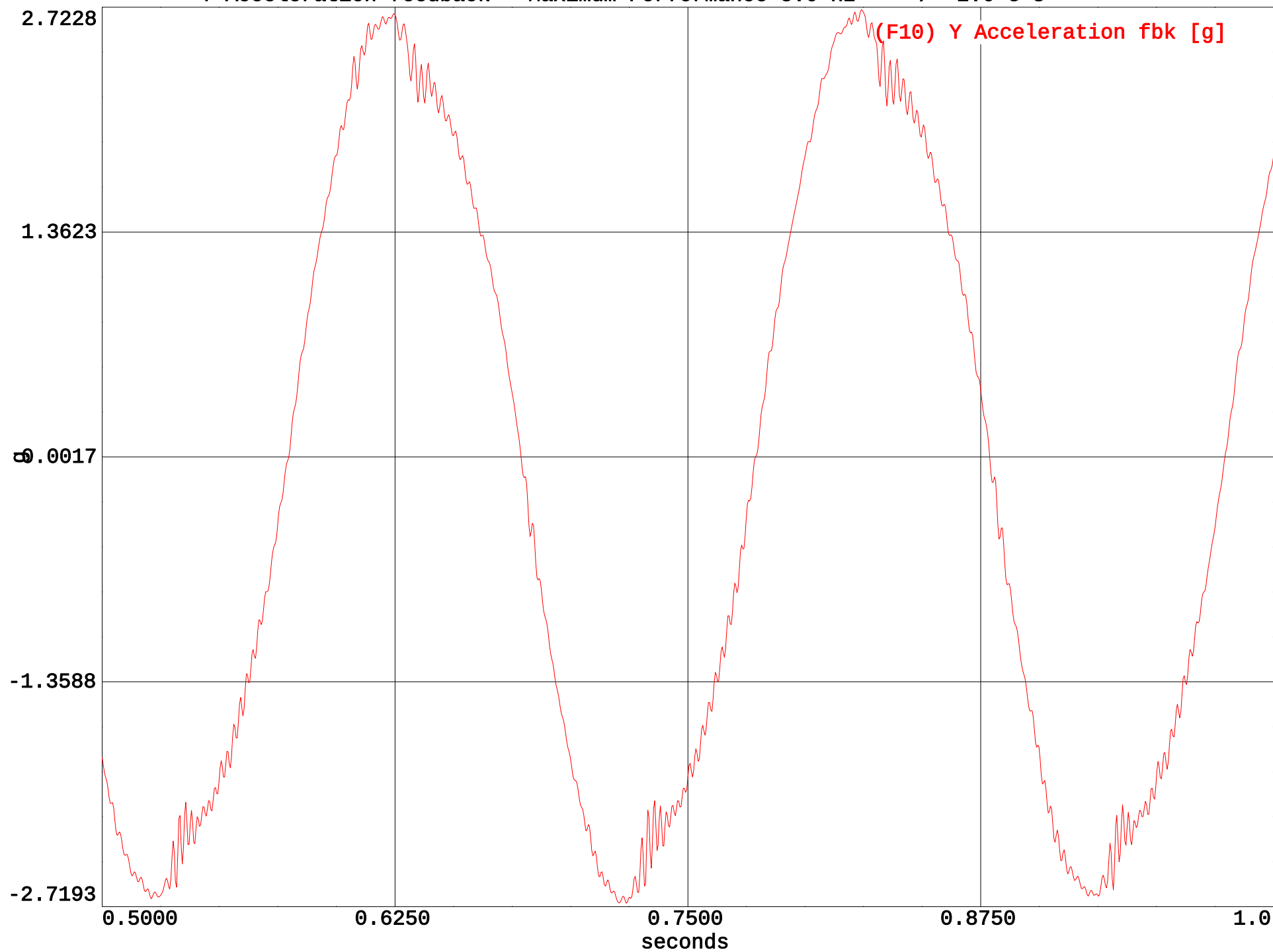
Y Velocity feedback - Maximum Performance 3.0 Hz $\geq$ +/- 1.2 meters/second



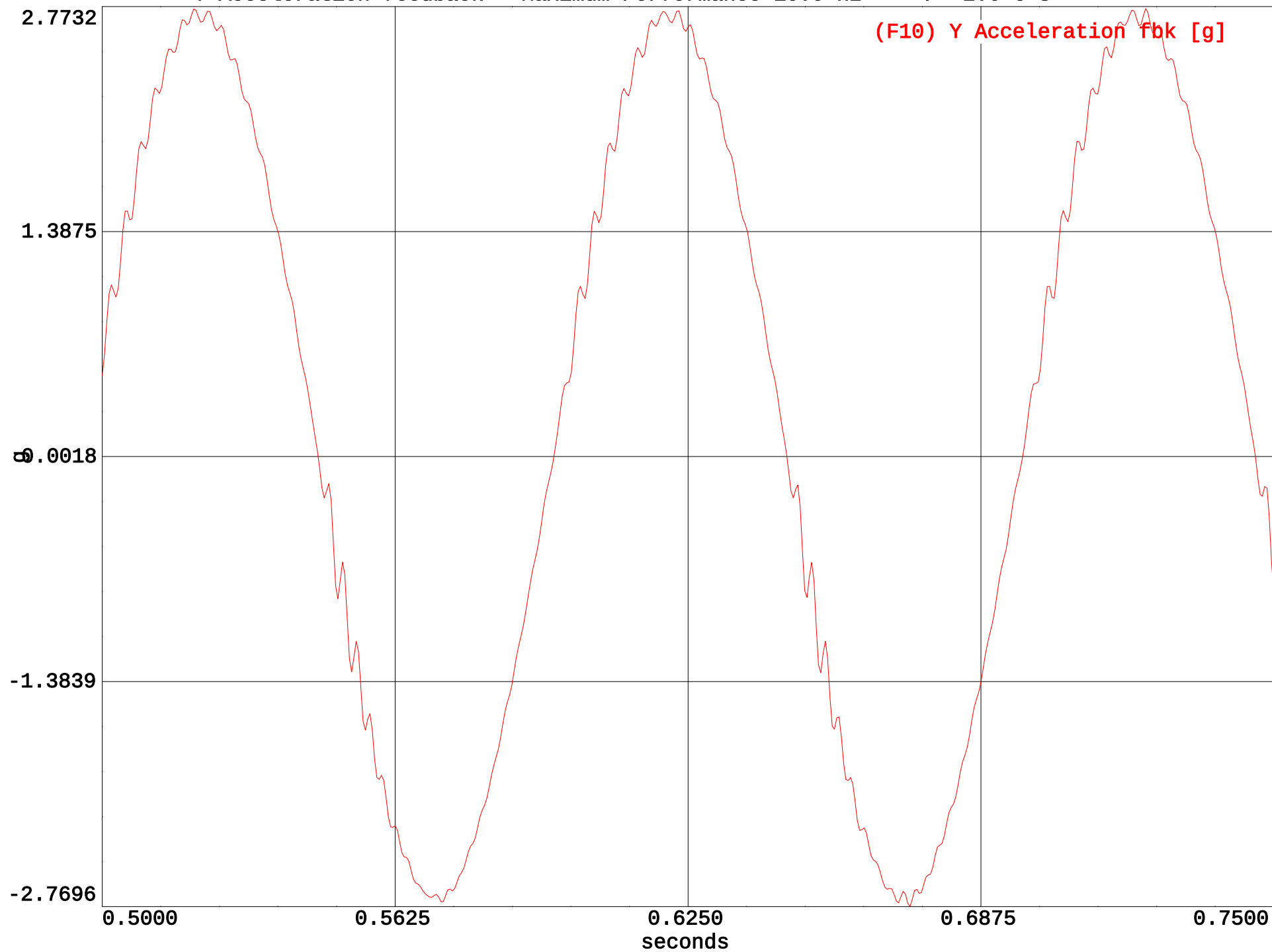
Y Velocity feedback - Maximum Performance 4.0 Hz $\geq$ $\pm$ 1.2 meters/second



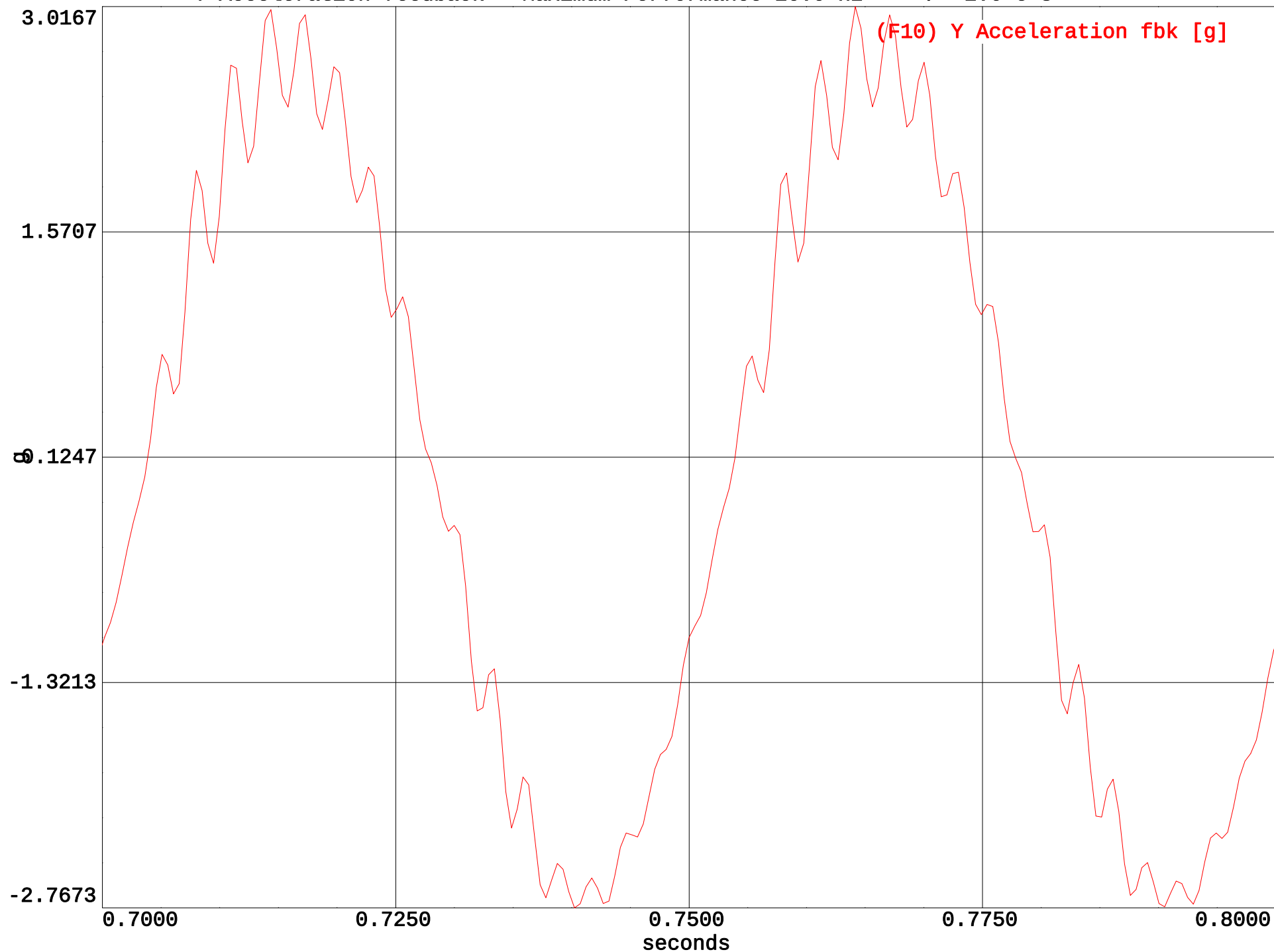
Y Acceleration feedback - Maximum Performance 5.0 Hz $\geq$ $\pm$ 2.6 G's



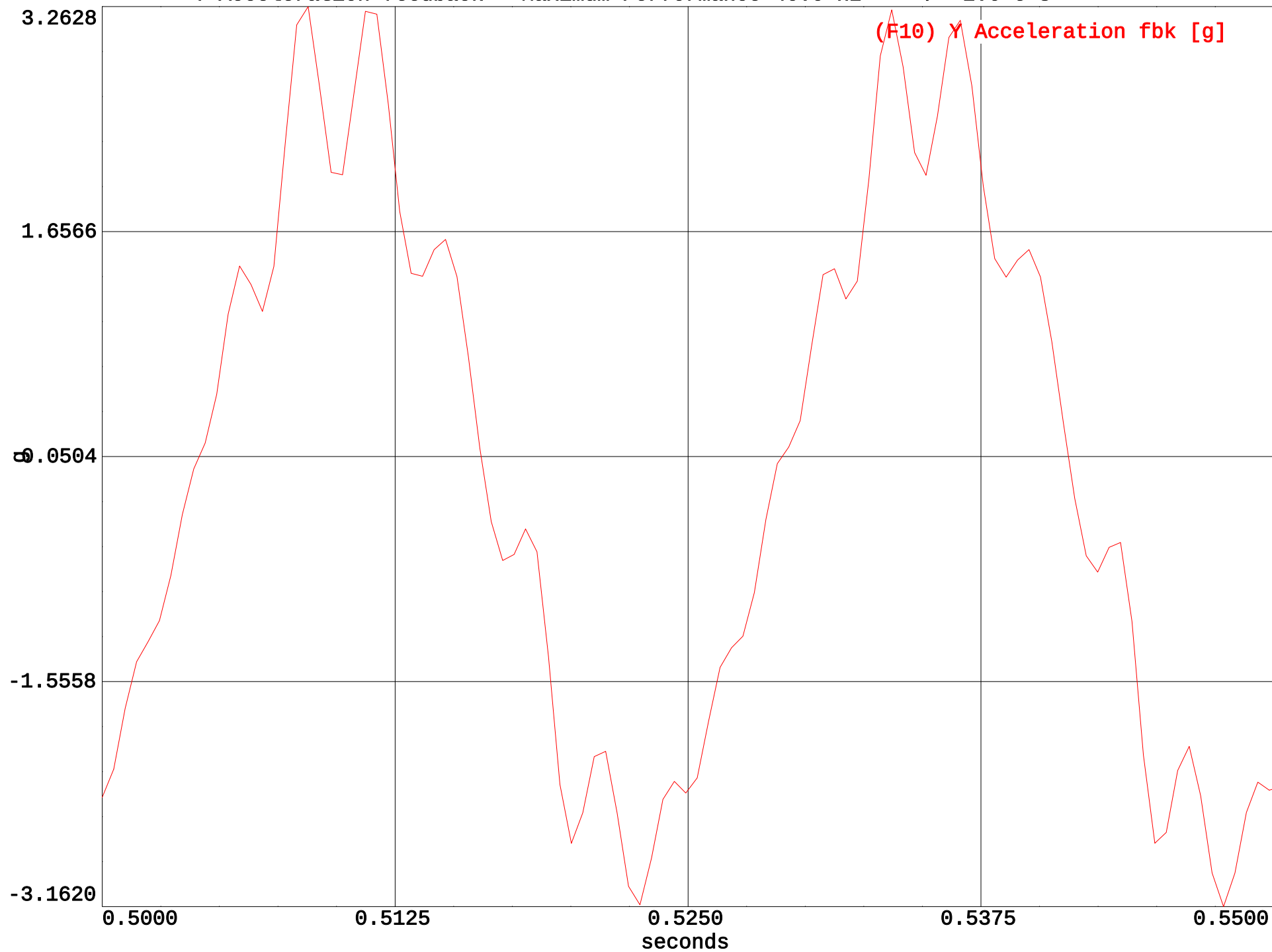
Y Acceleration feedback - Maximum Performance 10.0 Hz $\geq \pm 2.6$ G's



Y Acceleration feedback - Maximum Performance 20.0 Hz >= +/- 2.6 G's



Y Acceleration feedback - Maximum Performance 40.0 Hz >= +/- 2.6 G's



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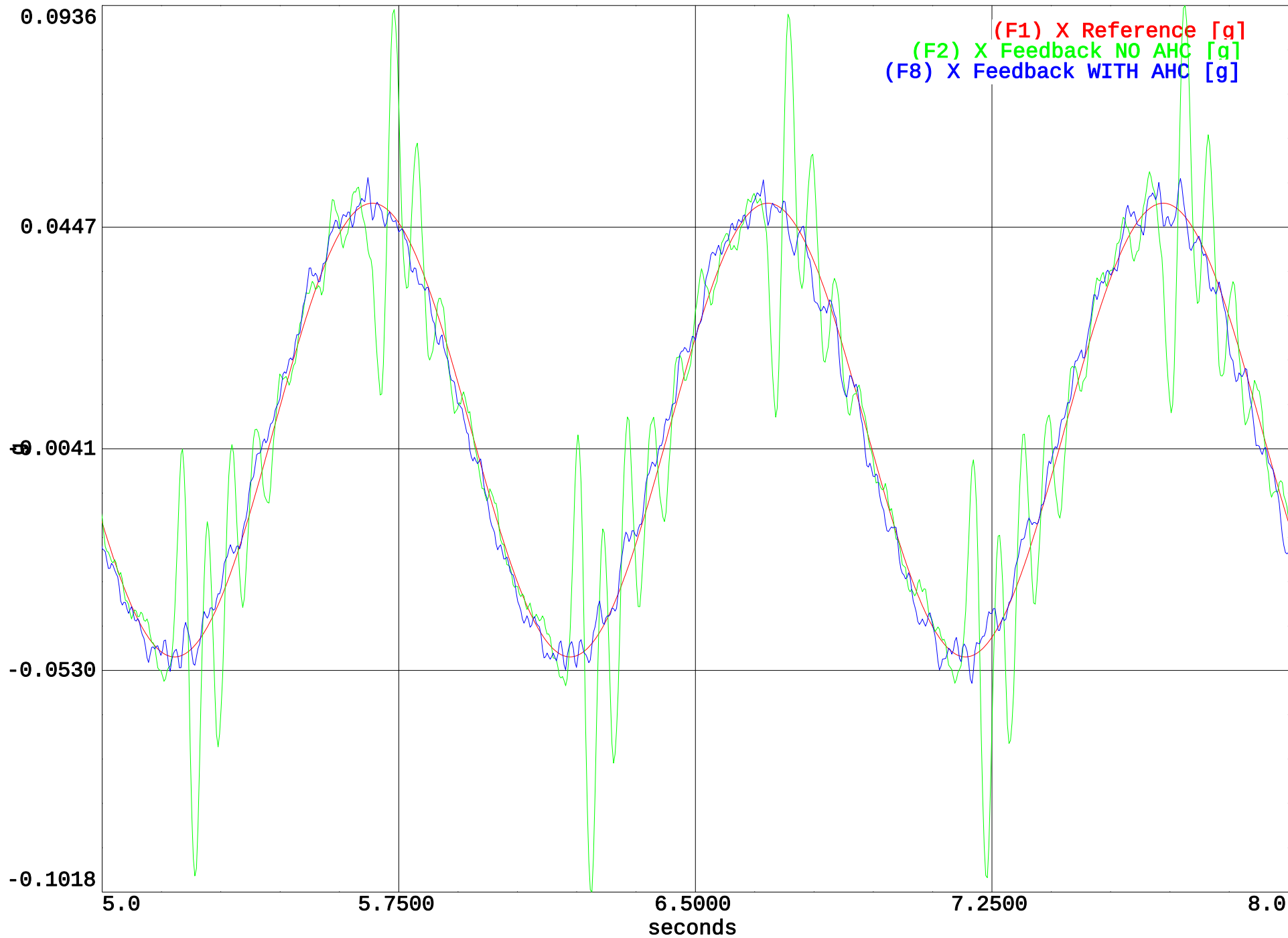
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Test Results:

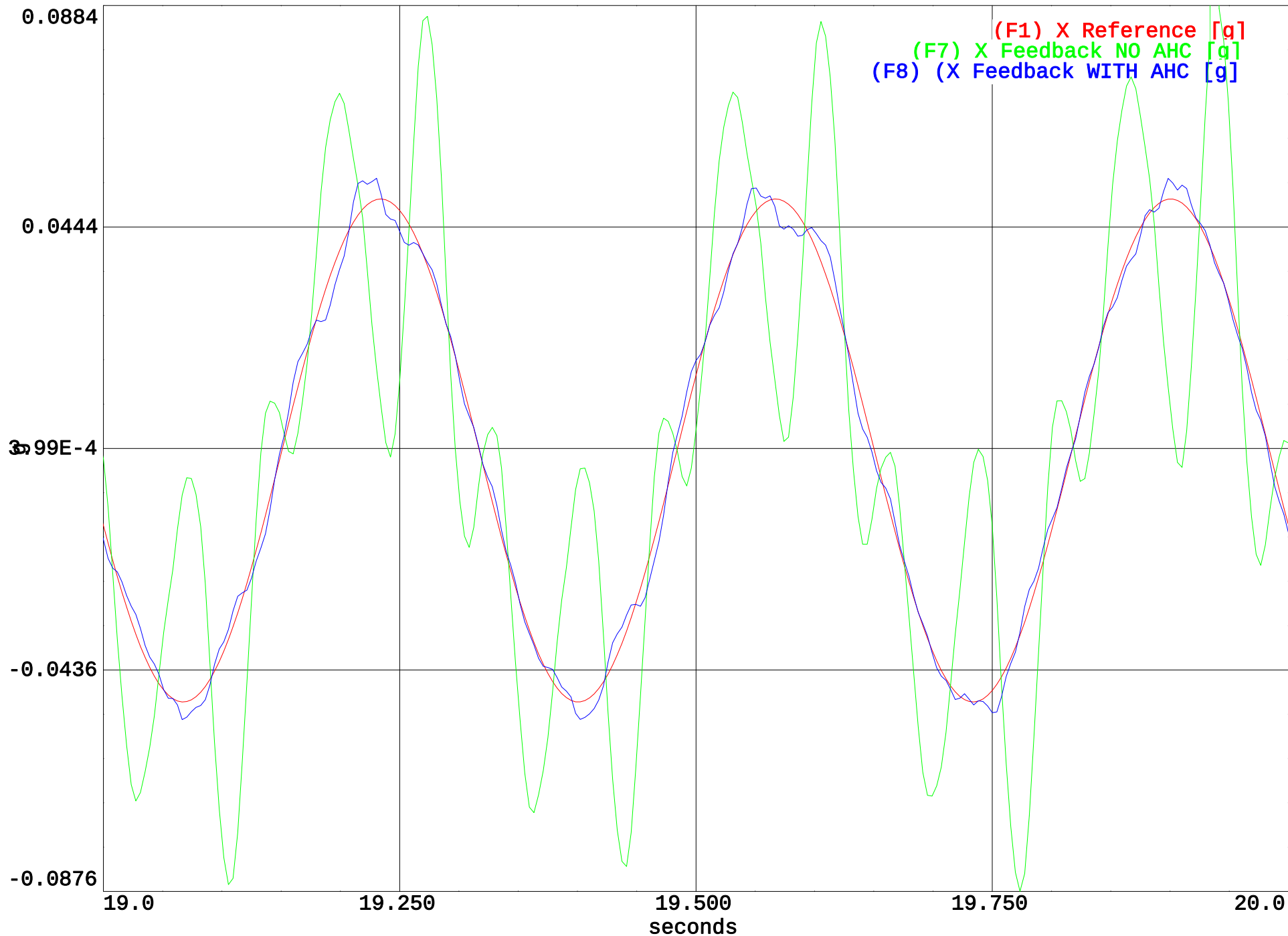
III. Acceleration Distortion

The IBST Shaking Table was tested for Acceleration distortion. Because the oil column frequency on each axis can distort a sine wave badly when running at the 1/3 oil column frequency, tests were performed at exactly that frequency as well as lower and higher. About 1/3 oil column frequency (> 3.8 Hz), the system will generate small distortions. Below 1/3 oil column frequency, the distortion is significant but less than that at 1/3 oil column. In general, the distortion rises from DC to 1/3 oil column frequency then rapidly decreases for higher frequency thereafter. The following tests also show that the adaptive controls for the 469D Controller (APC/AHC) can effectively remove the harmonic distortion from the acceleration response. The tests show that 1 Hz and 3.8 Hz improve a lot for using these adaptive controls and that 20 Hz does not need them at all at that frequency. The IBST system should be able to reproduce accelerations using APC/AHC that are below 5 % Total Harmonic Distortion. The Distortion tests prove that the IBST meets this criterion:

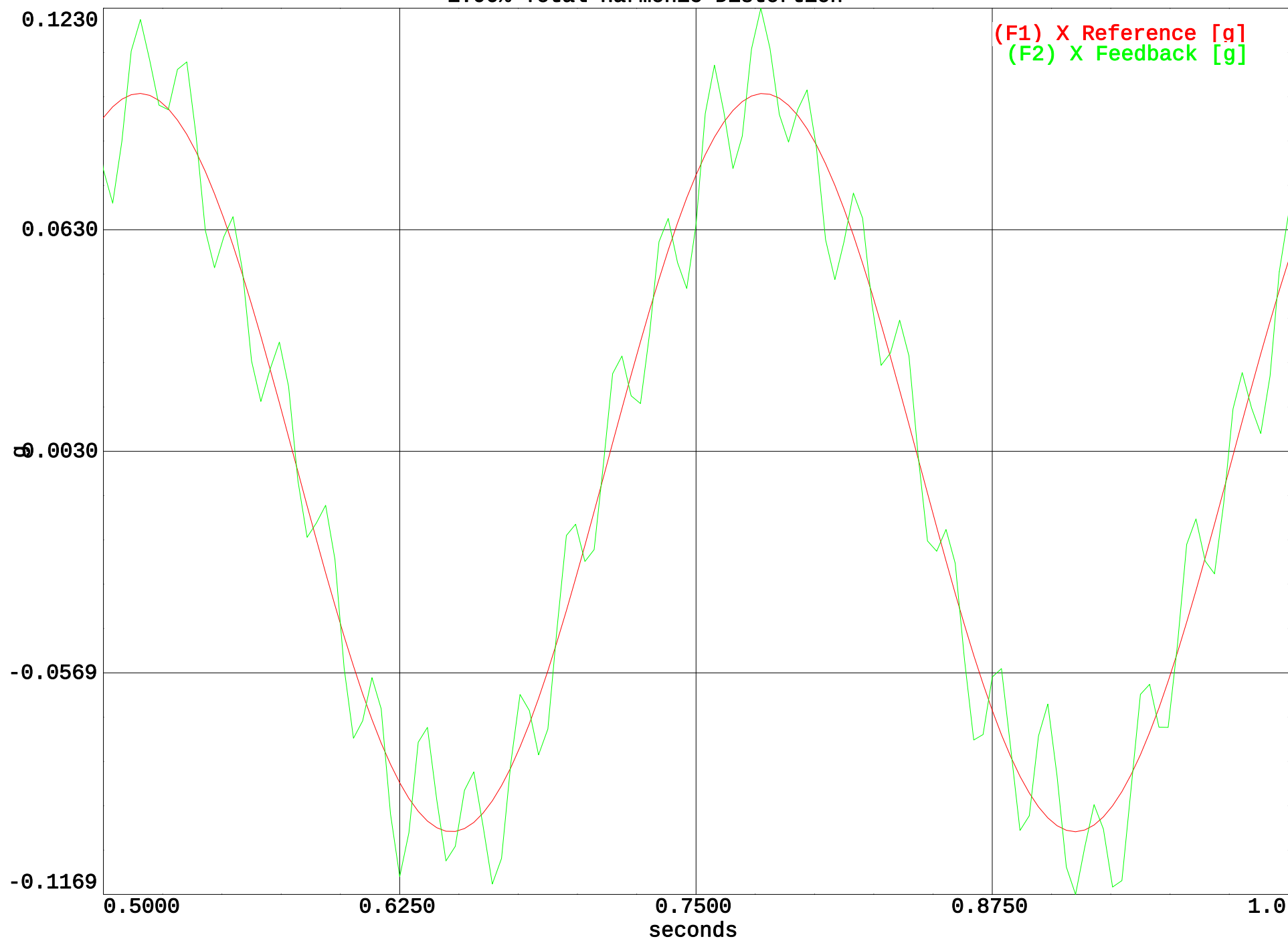
X Reference, X Feedback NO AHC, X Feedback WITH AHC at 0.05 G at 1.0 Hz
24.7% and 0.89% Total Harmonic Distortion



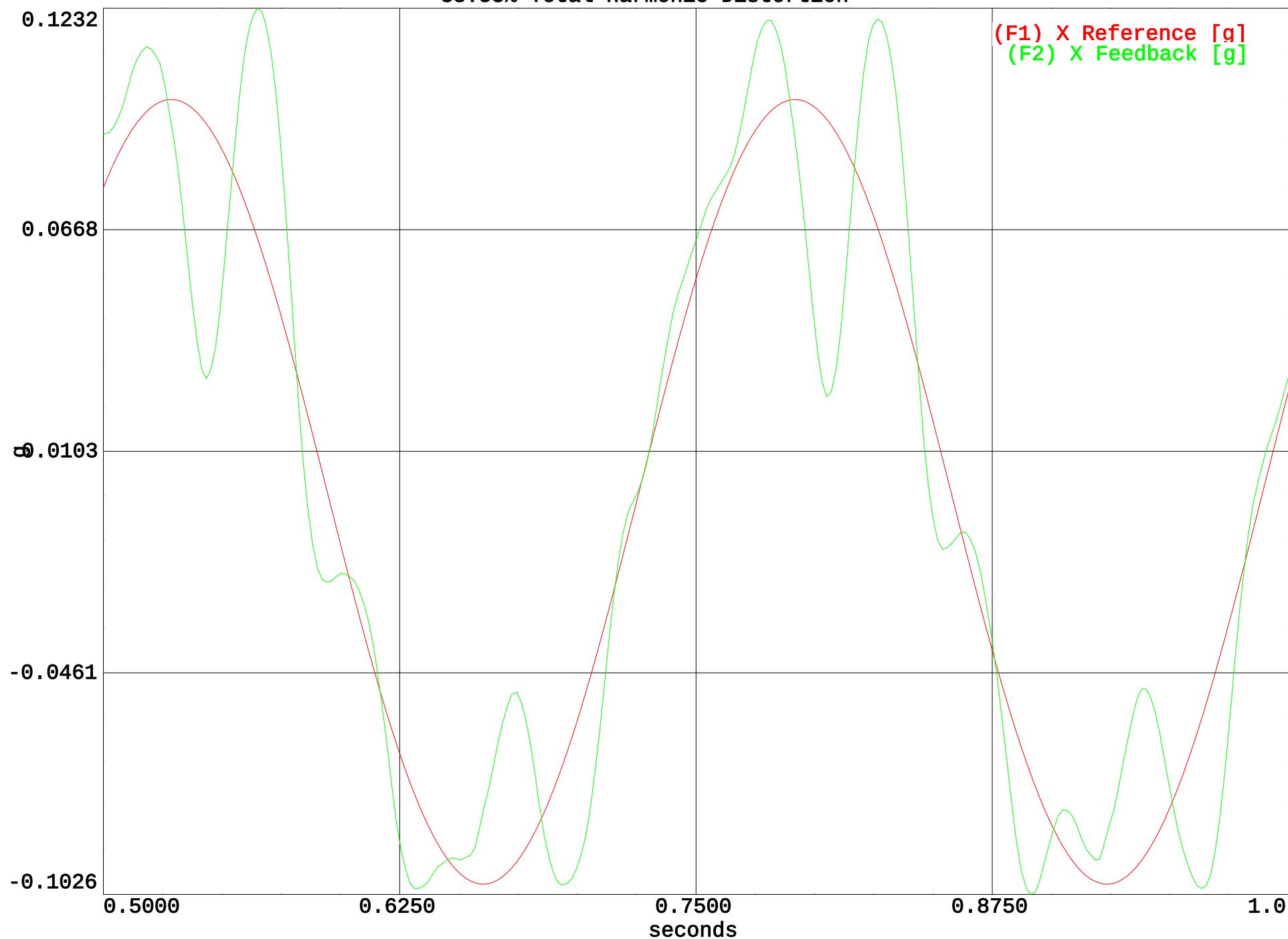
X Reference, X Feedback NO AHC, X Feedback WITH AHC at 0.05 G at 3.0 Hz
77% and .53% Total Harmonic Distortion



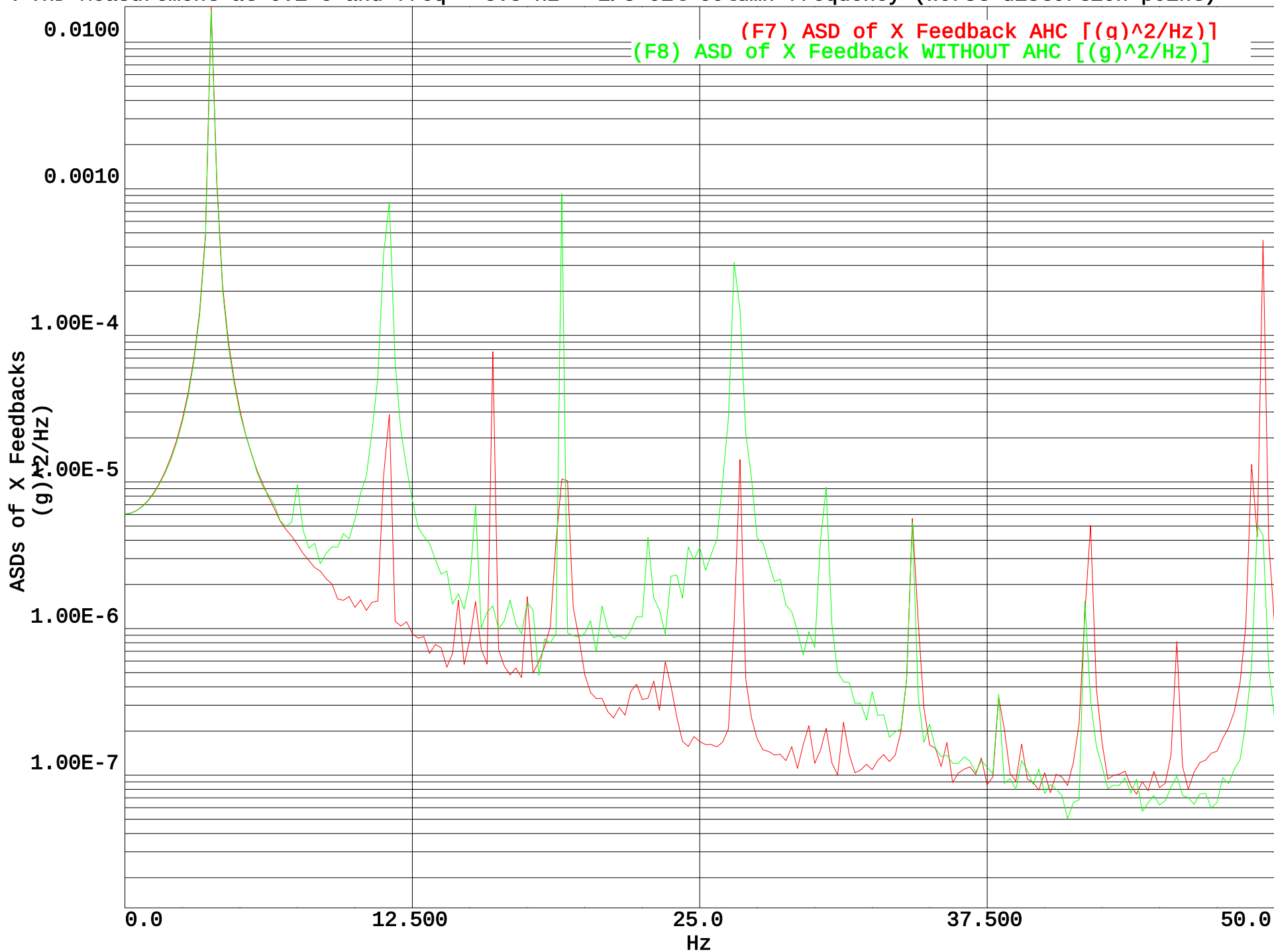
X Accelerations at 1/3 oil column frequency = 3.8 Hz with APC/AHC Compensation
1.06% Total Harmonic Distortion



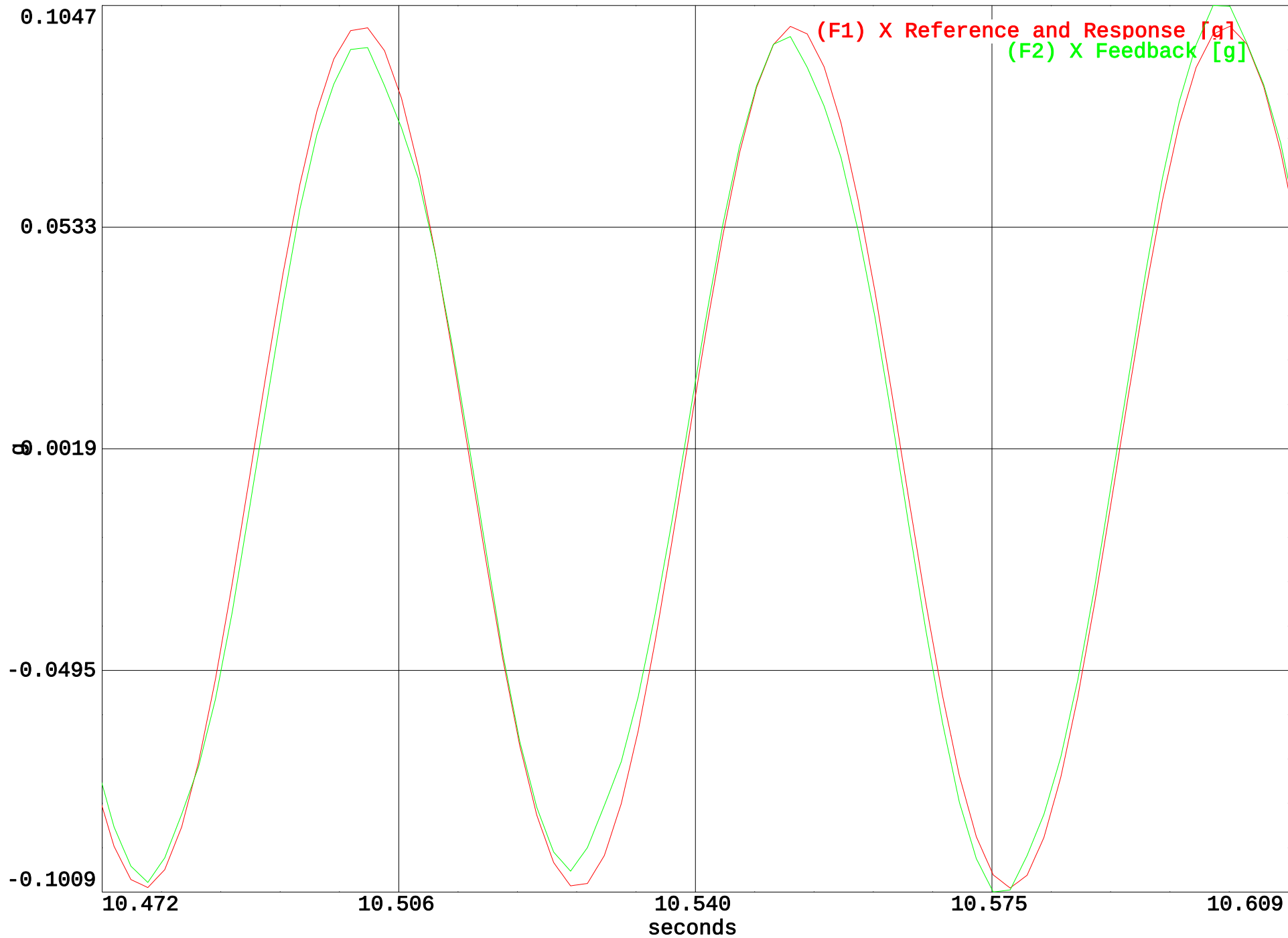
X Accelerations at 1/3 oil column frequency = 3.8 Hz with NO APC/AHC Compensation
38.53% Total Harmonic Distortion



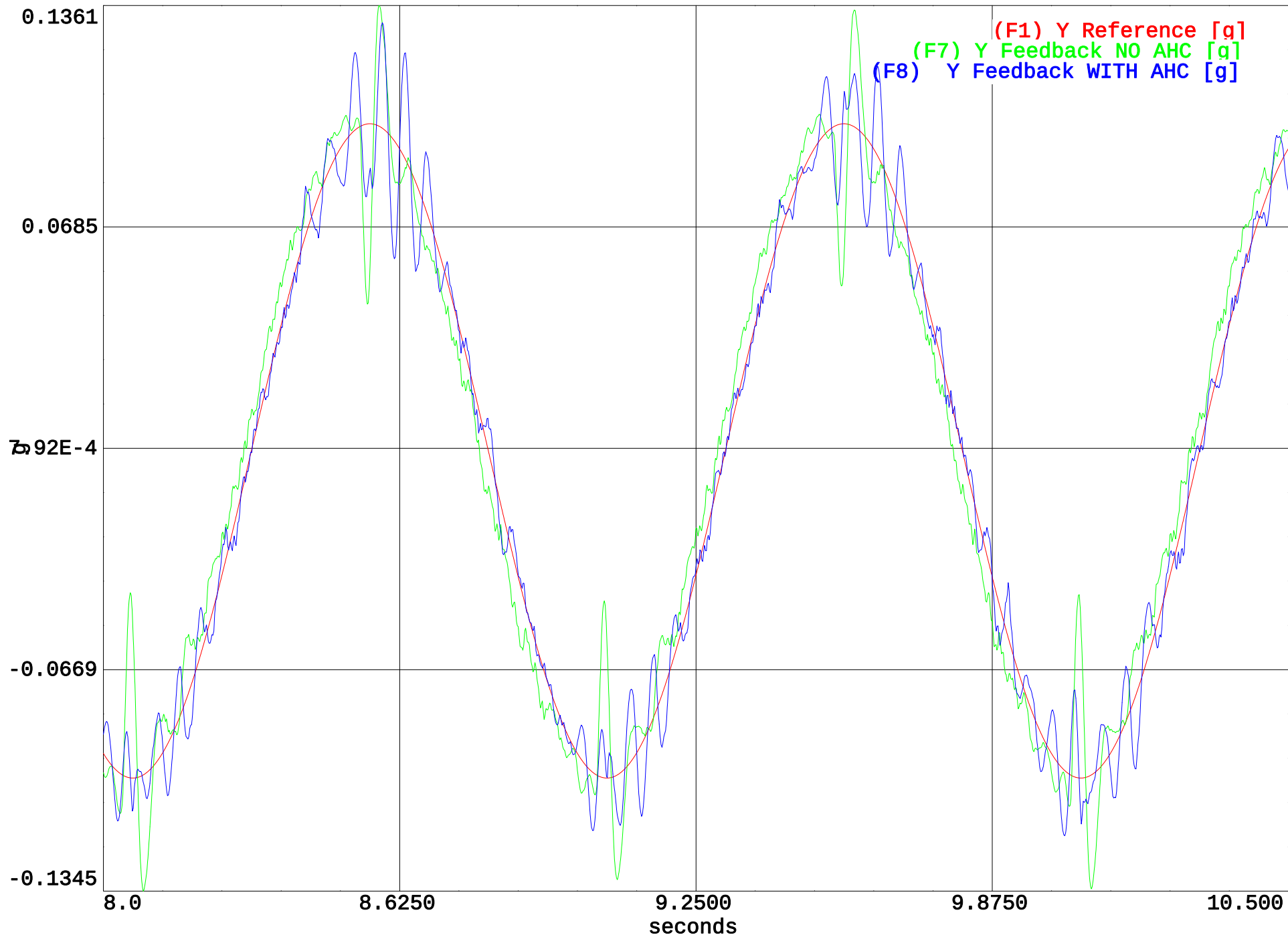
< THD Measurement at 0.1 G and freq = 3.8 Hz = 1/3 oil column frequency (worst distortion point)



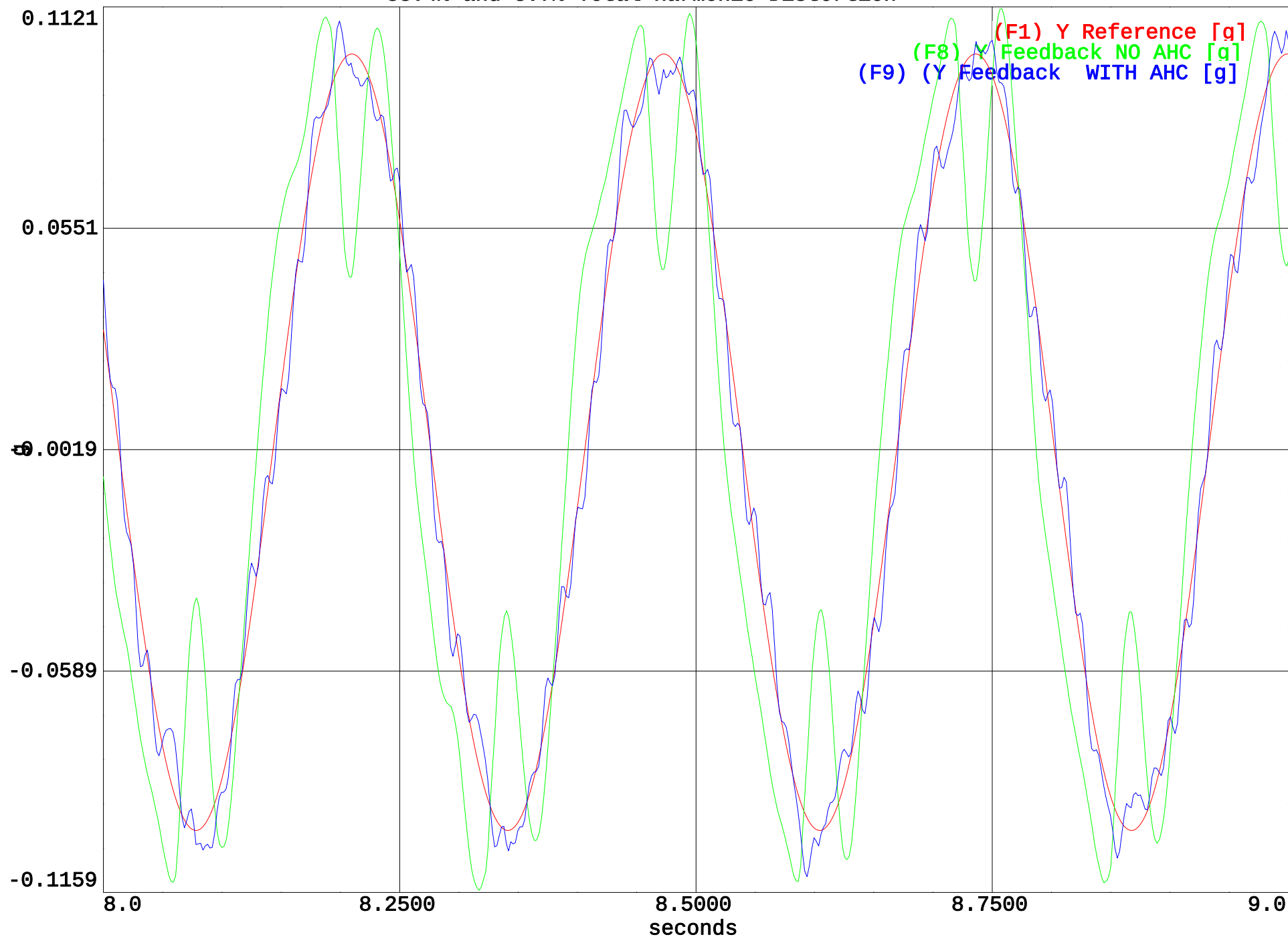
X Reference and Response - 0.1 G at 20 Hz - NO AHC
2.26% Total Harmonic Distortion



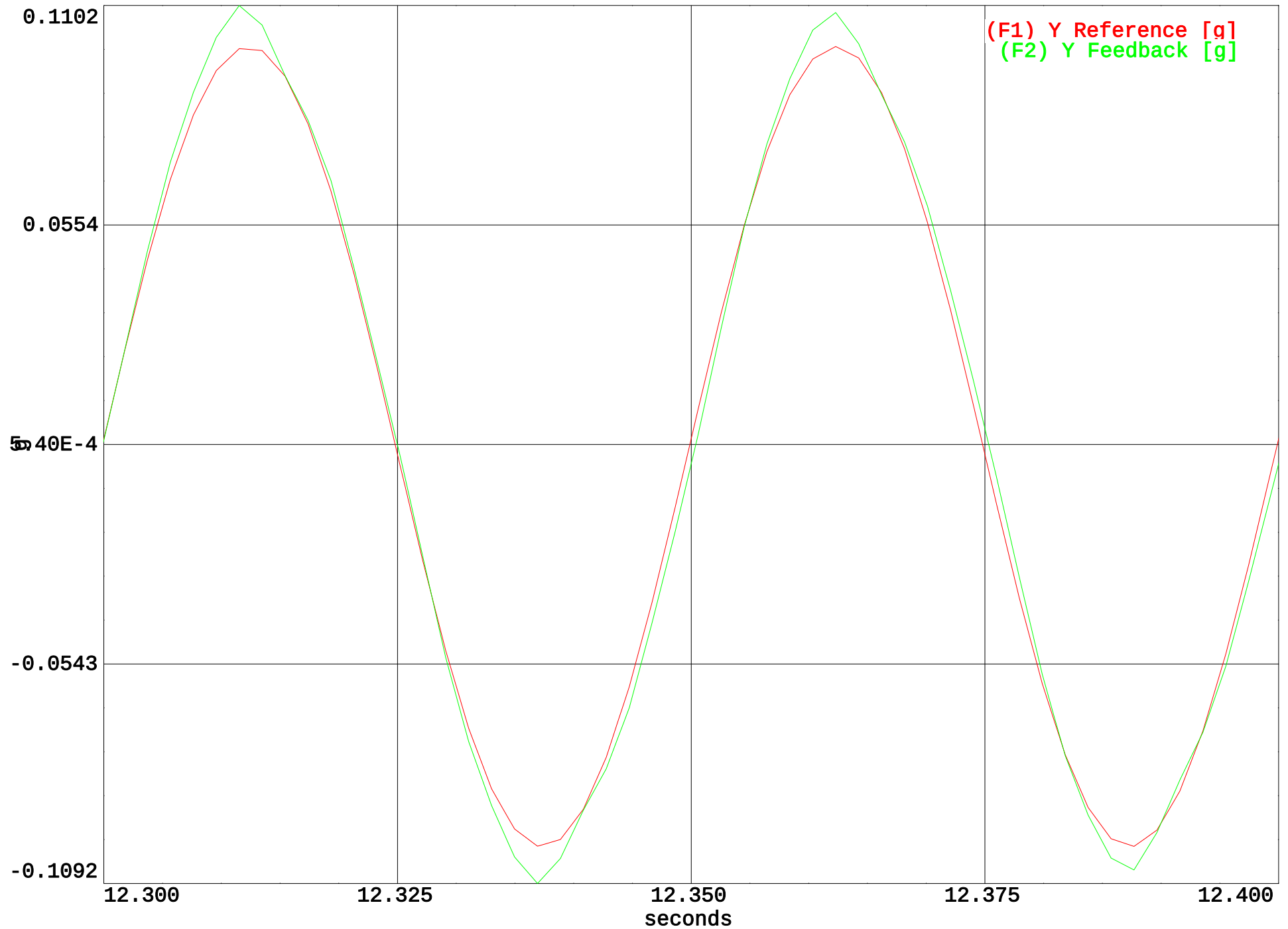
Y Reference, Y Response NO AHC, Y Response WITH AHC at 0.1 G and 1.0 Hz
9.2% and 2% Total Harmonic Distortion



Y Reference, Y Feedback NO AHC, Y Feedback WITH AHC at 1/3 oil column frequency = 3.8 Hz
33.4% and 3.7% Total Harmonic Distortion



Y Reference and Y Feedback at 0.1 G at 20 Hz - NO AHC
3.6% Total Harmonic Distortion



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Conclusions:

MTS is proud to state that the IBST Shaking Table meets all of our standard criteria for Shaking Table Performance according to our contract commitments and our historical experience. Congratulations on having one of the finest shaking tables in Southeast Asia.

All Tests Conducted By:

Rod Larson

 **MTS Systems Corporation**
Sr. Systems Engineer