A Performance Test of a 3-axis Accelerometer and Modal Analysis

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Key words: Dynamic Range, Earthquake monitoring system, MEMS sensor, Modal Analysis, 3-axis Accelerometer

SUMMARY

In this paper, MEMS based 3-axis accelerometer and a monitoring program for detecting ambient vibration were developed. And data acquisition device with 24 bit ADC (Analog to Digital Converter) was used for the purpose of improving performance of the accelerometer. Accelerometer which was developed in this study and commercial accelerometer were set up in the building model so data was analyzed. This data was accumulated at frequency of 100Hz and this paper focused on detecting ambient vibration of the building. And data trend and various statistics of the 3-axis accelerometer were compared. FFT (Fast Fourier Transform) analysis was performed using data from accelerometer and frequency related to mode shape was extracted using a modal analysis program.

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1. INTRODUCTION

Acceleration sensors have applied for the automobile industry, appliance industry, aerospace industry and structural maintenance industry. Application field of the MEMS acceleration sensor was expanded as MEMS (Micro Electro Mechanical Systems) technology was developed[5]. The acceleration sensor using a silicone was first invented in 1970s[4]. Study of acceleration sensors based on MEMS technology was realized officially since the 1990s. And study about static and dynamic analysis that related to cantilever beam and structure of the mass was performed[7]. Study about changes of dynamic characteristics and study about response of the structure which exerted electrostatic forces and modal analysis was performed for designing MEMS structures in the 2000s[2]. Recently, monitoring technology of geotechnical movements related to earthquake, landslide and volcanic activity have studied using single degree of freedom GPS and MEMS accelerometer[9].
In this paper, the performance test was executed by constructing MEMS based 3-axis acceleration sensor module. And data acquisition device with 24bit ADC (Analog to Digital Converter) was used for improving performance of 3-axis acceleration sensor module.

2. VIBRATION MEASUREMENT SYSTEM

2.1 Components of the Monitoring System

DAQ (Data Acquisition) for converting the output signal and application software which extract the information from converted data are needed for constituting vibration measurement system. Prototype acceleration sensor was made using commercial acceleration sensor which is analog output typed because proposed MEMS acceleration sensor was focused on performance test of sensors. In this case, DAQ board with 24 bit ADC (Analog to Digital Converter) was used because the performance of the entire system is determined according as a resolution of the DAQ as well as the sensor. The application software is composed for performing of a data acquisition function based on a Labview program of the National Instruments.

2.2 Components Selection

Maximum measurement range and resolution of the sensor should be considered for selecting MEMS based acceleration sensor. These two characteristics certainly were needed for expression of the seismic intensity when the earthquake occurred. Also these characteristics were involved in estimation for dynamic range of the acceleration sensor. The Colibrys SF1600 whose dynamic range is 120dB is selected for the MEMS sensor. As DAQ hardware, NI-9239 with the 24 bit ADC is used. NI-9239 is run in the USB platform and it has an

advantage to easy measuring from the outside when it is connected to note PC. Also it is possible to extend wireless data logger due to supporting for wireless DAQ.

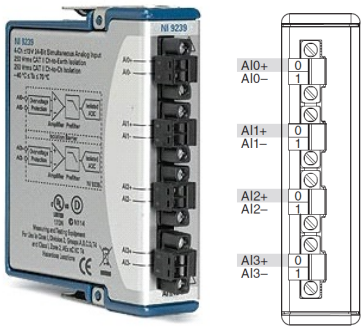


Figure 1. NI-9239

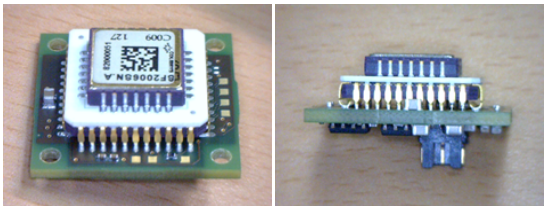


Figure 2. Colibrys SF1600

3. ACCELEROMETER MODULE OF DIGITAL OUTPUT TYPE

Existing analog output type needed to long line to data logger that was located long distance. Besides it is possible to induce the external noise in this line. If data is transmitted on digital pulse train by inserting 24 bit ADC in the sensor module, system will be more powerful to prevent noise.

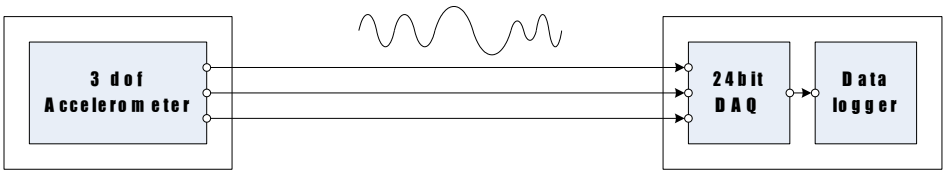


Figure 3. Existing analog output type

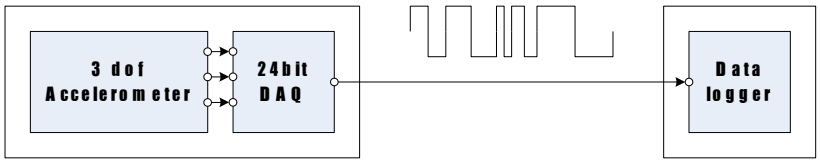


Figure 4. Digital output type

Three MEMS acceleration sensors were equipped with exact orthogonal state. Also all-in-one acceleration sensor module was composed by adding the DAQ board and power supply. As

seen in the figure 5, the dimensions of this module are 85×75×57 mm^3.

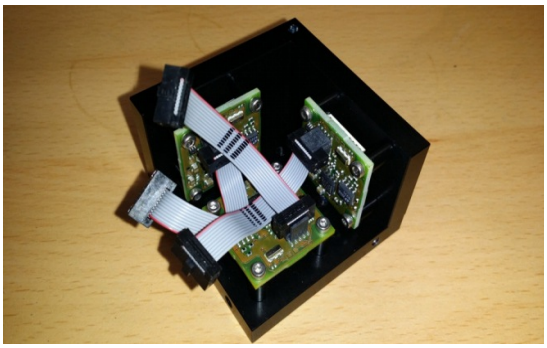


Figure 5. Inner structure of the sensor module

The dimensions of 24 bit DAQ board are 70×80×20 mm^3 and this board was arranged right next to the 3-axis sensor.

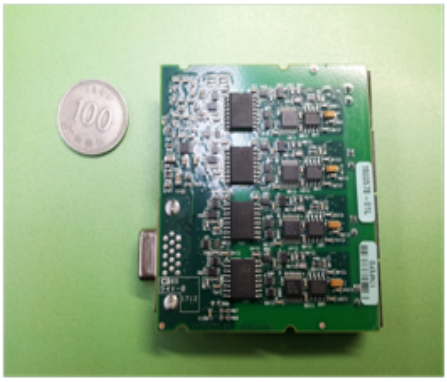


Figure 6. DAQ board

As seen in the figure 7, DAQ power supply was equipped in the 185×105×55 mm^3 housing.

Figure 7. 3-axis accelerometer of digital output type

4. PERFORMANCE TEST OF THE SENSOR MODULE

Vibration test was performed using a shaker for evaluating performance of the proposed

MEMS based 3-axis accelerometer. This test focused on performance comparison of the proposed accelerometer and commercial accelerometers. Proposed MEMS based 3-axis accelerometer, AS-GB of the Kyowa Electronic Instruments Co., Ltd., AC-23 of the GeoSIG Ltd. and GST-63-M of the ICPDAS Co., Ltd. were installed at the second story in a five story building model. And results were compared through two times test. Measurement was performed with 100Hz frequency and analysis was performed using 30000 sample data which saved in five minute. 1Hz sine wave that have 2gal amplitude was generated in the first test and 10Hz sine wave that have 4gal amplitude was generated in the second test.

Figure 8. Five story building model

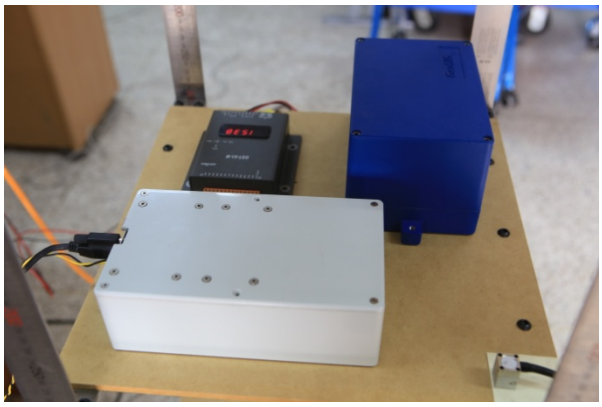
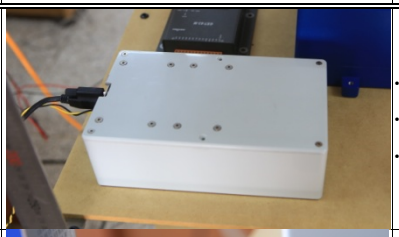
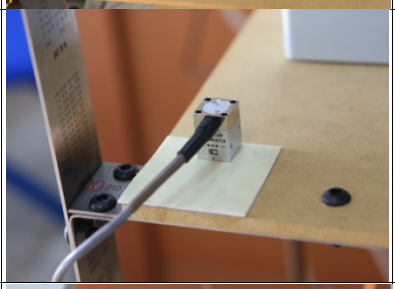
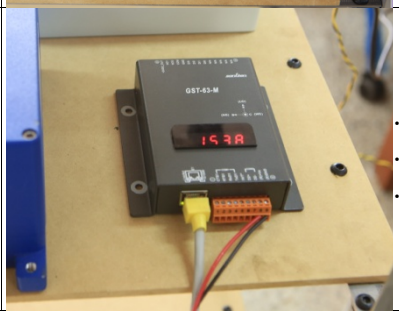


Figure 9. Installed accelerometers

Table 1. Accelerometers for a vibration test

Accelerometer	Picture	Features
1. MEMS based 3-axis accelerometer prototype		· Type : Tri-axial MEMS · Range : ±2g · Frequency Response : DC-50Hz
2. KYOWA AS-GB		· Type : Uni-axial · Range : ±2g · Frequency Response : DC~60Hz
3. GeoSIG AC-23		· Type : Tri-axial Force Balanced · Range : ±2g · Frequency Response : 0.1~50Hz
4. ICPDAS GST-63-M		· Type : Bi-axial MEMS · Range : ±2g · Frequency Response : DC~20Hz

As seen in the figure 10, data of the prototype and two commercial accelerometers almost corresponded. 1Hz data was expressed exactly because sine wave was 1000 samples in data account from 500 to 1500 (100Hz, 10 second). In each case, FFT analysis were performed. All three cases have about 1Hz natural frequency.

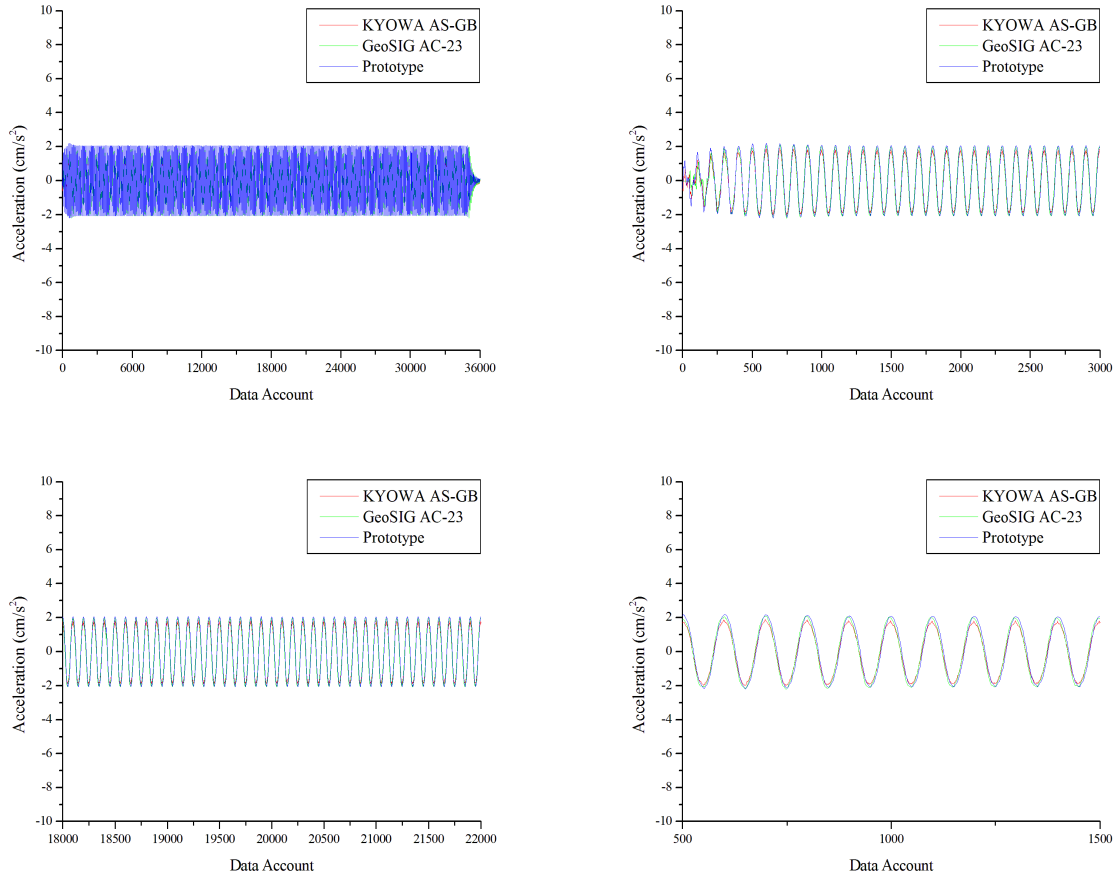
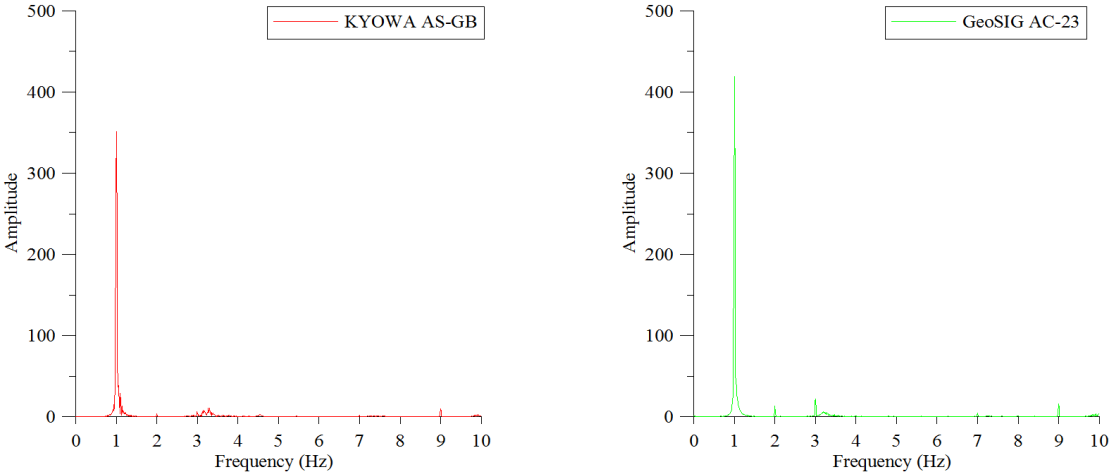


Figure 10. Time series data of accelerometers (1Hz, 2gal)



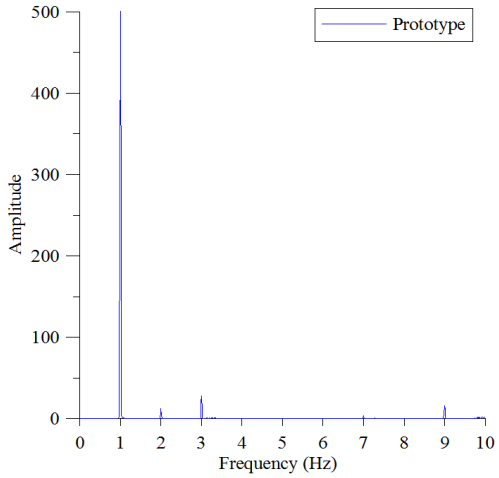


Figure 11. Results of FFT analysis (1Hz)

As seen in the figure 12, data of the prototype and three commercial accelerometers almost corresponded. 10Hz data was expressed exactly because sine wave was 100 samples in data account from 500 to 600 (100Hz, 1 second). In each case, FFT analysis were performed. All four cases have about 10Hz natural frequency.

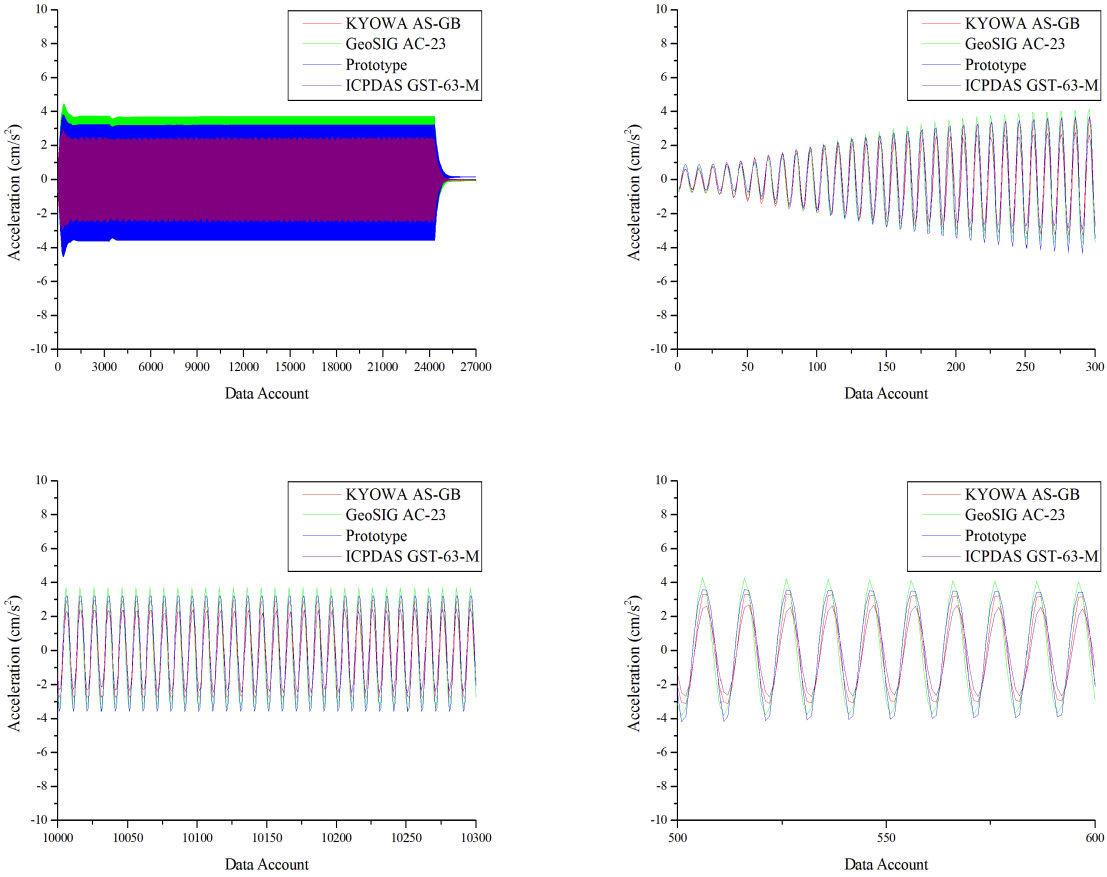


Figure 12. Time series data of accelerometers (10Hz, 4gal)

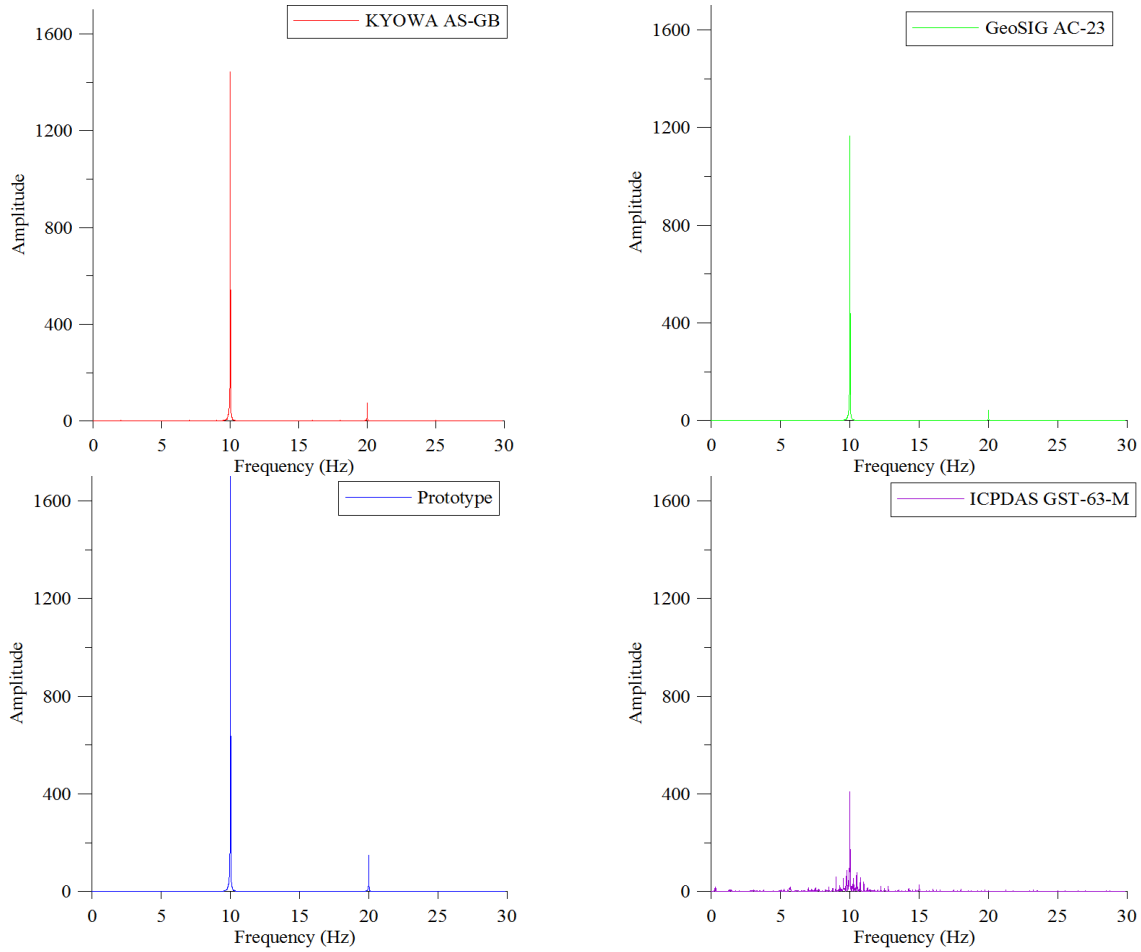


Figure 13. Results of FFT analysis (10Hz)

5. CONCLUSION

In this study, 3-axis accelerometer was developed using MEMS acceleration sensor and efficiency test of the accelerometer was performed. Also resolution of the DAQ was improved using DAQ board with 24 bit ADC. Vibration test was performed using a shaker for the purpose of evaluating performance of the proposed MEMS based 3-axis accelerometer. As a result, data trend of the prototype and commercial accelerometers almost corresponded. As carried in FFT analysis results, natural frequency of the vibration that was generated from the shhaker was extracted exactly in cases of prototype and commercial accelerometers.

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