

MOTION SENSOR APPLICATIONS IN SMART BUILDINGS

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Abstract: Among the many kinds of applications of today's sensor technology, motion detection play a vital role especially for the safety of human being at their day today rituals. In smart buildings, different types of motion sensors are used to monitor parameters which are critical for the safety of its occupants, equipment and also the behavior of any structural changes against environmental changes.

Accelerometers which are connected to the structure of those buildings, for example can capture the vibrations caused by vehicles on highways nearby, trains passing by, etc., and can be programmed to take necessary preventive actions to protect the occupants, equipment inside the building and the structure. Vibration free platforms like the one presented in this paper, will be a suitable solution.

They can also be used to get a feedback of how the buildings were behaved in the disastrous situations.

Keywords: Accelerometer, MEMS, Controller, Control action, Actuator

1 Introduction

Today the concept of smart buildings has marked a new era of the modern building construction industry. They are designed targeting the security and the luxury of the lives of their residents and surroundings and protection of themselves and the properties inside the building at disastrous situations. Smart buildings are equipped with various types of sensors to monitor various parameters of their environment and control systems to perform various tasks according to the requirements of the people inside the buildings and to control the environmental conditions.

Among the different types of parameters which are captured by the sensors inside a building, vibration level is a very important for the guaranteed lifetime of the building as well as the equipment inside the building which are sensitive to vibrations. Importance of concerning on vibration levels is much more highlighted for the building situated near the roads where heavy vehicles are operating and constructed in the areas having a higher probability of earth quakes. Sensitive equipment which are used in the industrial, medical, research and several other types of businesses can get damaged or become malfunctioning due to frequent vibrations coming from the above sources. Development of a vibration free platform is much more important to safeguard such equipment. Accelerometers placed in such locations can be used for monitoring the vibration levels [1].

The accelerometers used for such purposes should be sensitive enough at least along the axis along which the vibrations are sensed. These accelerometers can be fixed to the platforms of the sensitive equipment. Controllers can be designed to compensate those vibrations using applicable actuators.

2 Objectives and Methodology

Objective of the work is to compensate the vibrations created from the heavy vehicles using a combination of active and passive compensators.

This is simulated with the required models of the controllers, spring damped platforms and the actuators fed by typical vibration waveforms.

3 Theory

3.1 Accelerometer

MEMS accelerometers are used to sense the vibration levels. They are designed with a small proof mass suspended by a spring and a damper system [2]. The mass is free to move in between a certain limits.

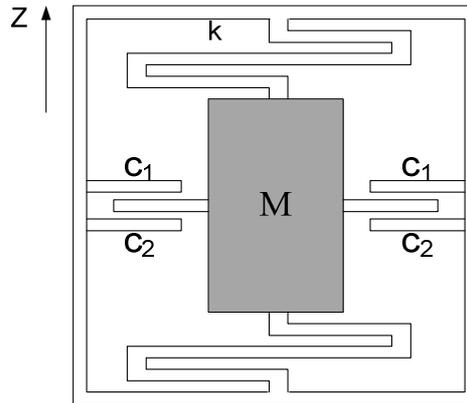


Fig. 1: Structure of a Capacitive MEMS Accelerometer

Capacitors are used to measure the displacement of the spring suspended proof mass of the accelerometer. C_1 and C_2 capacitance values vary with the displacement of the mass. Following equation explains variation of capacitance with the gap between the capacitor plates in a parallel plate capacitor as in the capacitive MEMS accelerometer.

$$C = \epsilon \frac{A}{d} \quad (1)$$

According to the following equation capacitance is inversely promotional to the gap (d) in between the two electrodes. The change of capacitance is measured by the voltage ratio between the two series capacitors (C_1 and C_2).

Acceleration of the proof mass (a) is connected with the displacement (x) according to the following equation. Parameter k represents the spring constant.

$$a = \frac{k}{M} x \quad (2)$$

4 Results

4.1 Active Compensator Design

A vibration free platform driven by an active compensator with linear actuators is designed to protect the vibration sensitive equipments.

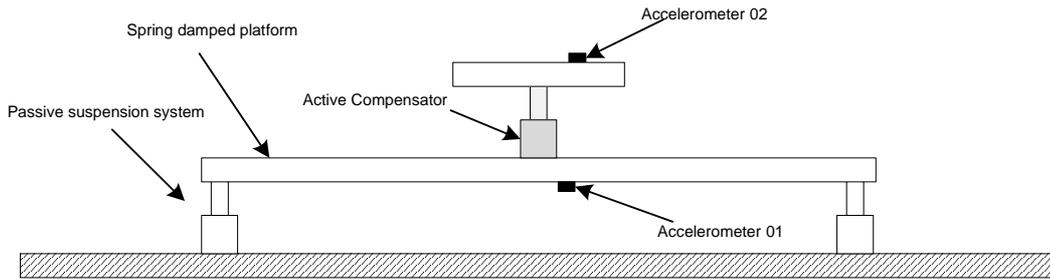


Fig. 2: Structure of the vibration free platform connected to an active compensator and spring-mass damper.

Accelerometers are used to sense the vibrations and feed the signals to the controller of the active compensator. Two accelerometers are fixed as one on the spring-mass damper and another on the vibration free platform as in Fig.2. The spring-mass damper smooth out the vibrations and the controller drives the linear actuator to compensate the damped oscillations of the spring damped platform.

Fig. 3 illustrates the block diagram of the controller.

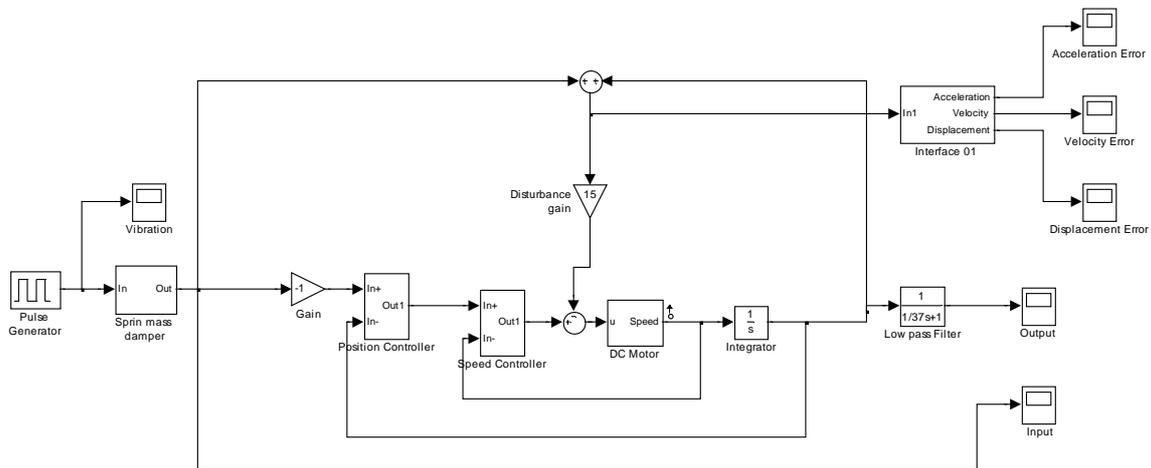


Fig. 3: Controller block diagram.

Output of the feed forward accelerometer placed on the spring damped platform which is used to smooth out the vibrations is inverted and fed as the reference point of the controller. Disturbance input of the system which is obtained from the second accelerometer placed on the vibration free platform is directly fed into the motor to correct the uncompensated movements of the vibration free platform as illustrated on fig. 3.

Fig. 4 illustrates the model of the mass spring damper subsystem [4] which is used to damp out the vibrations before coming to the accelerometer 01. This method cuts off the high frequency components of the vibrations to be matched with the bandwidth of the actuator system as well as reduce the amplitude of the vibration. Fig. 5 illustrates the input and the corresponding output of the spring mass damper subsystem [4].

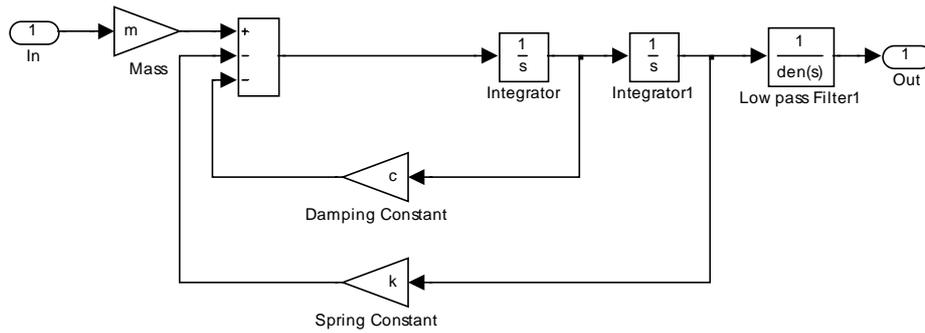


Fig. 4: Spring mass damper subsystem

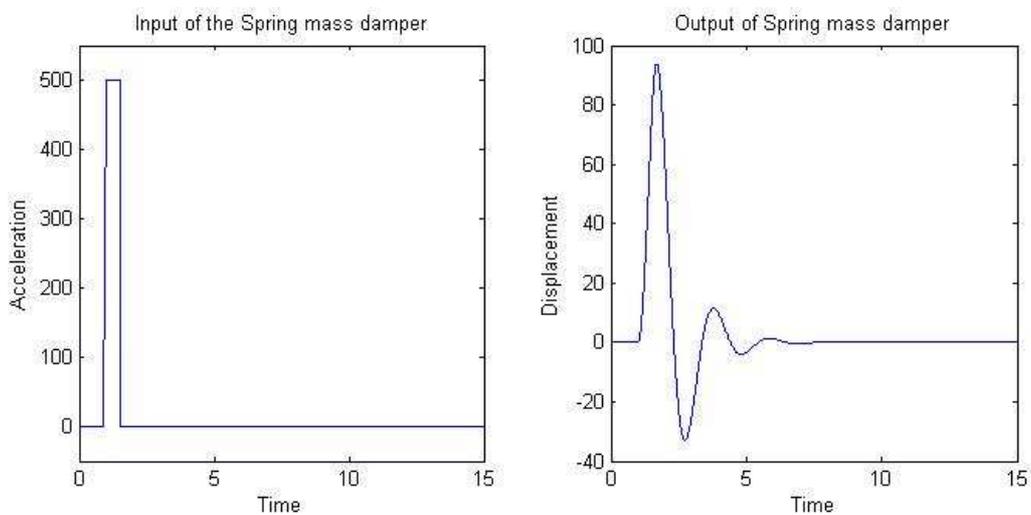


Fig. 5: Input and the corresponding output of the spring mass damper subsystem

Output of the spring mass damper is inverted and fed into the position controller of the system which is a PID controller. A linear encoder is used to sense the displacement of the vibration free platform which is used to generate the feedback of the position controller. Output of the position controller is used as the input to the speed controller.

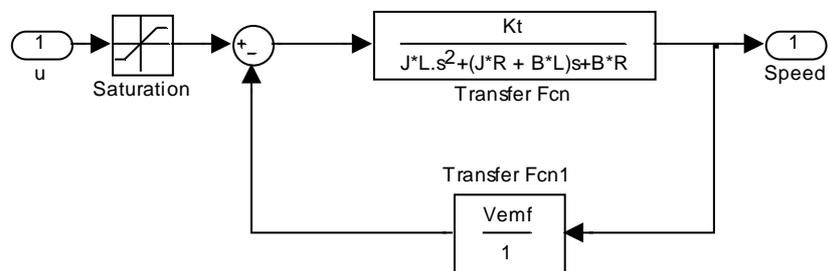


Fig. 6: Motor model

A model of a DC motor [3] is used to drive the vibration free platform. Rotational movement of the motor has to be converted to a linear movement using a rack and pinion gear arrangement and a gear reduction of about 1/5. A disturbance input to the DC motor is generated using the second

accelerometer placed on the vibration free platform, which is the error of the compensator. Feeding the disturbance input directly into the motor will increase the performance of the compensator.

Fig. 7 illustrates the input to the controller which is the output of the accelerometer 01 which is placed on the spring damped platform and the control action of the actuator which is converted to a linear motion to compensate the vibration.

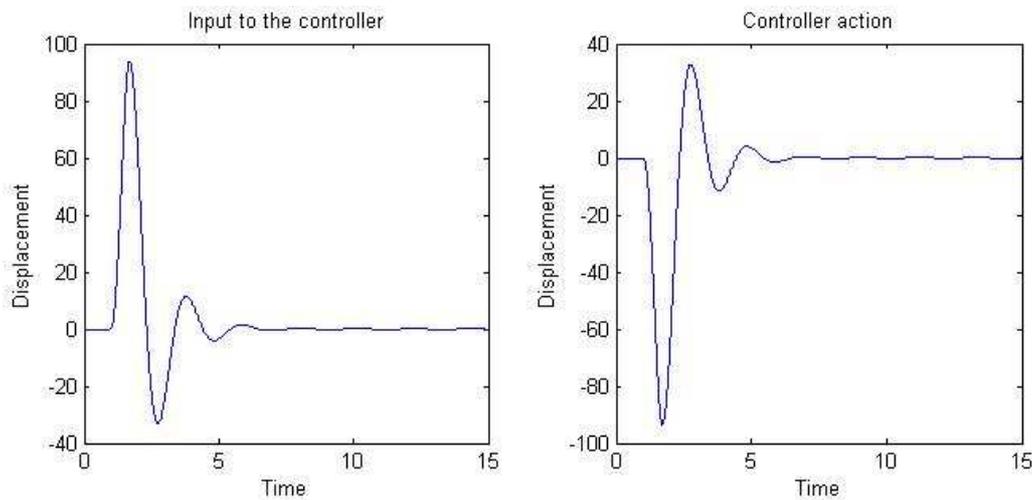


Fig. 7: Input to the controller and corresponding control action

Fig. 8 illustrates the reading of the second accelerometer which is placed on the vibration free platform which detects the uncompensated vibrations sensed on the vibration free platform which is the error of the compensator.

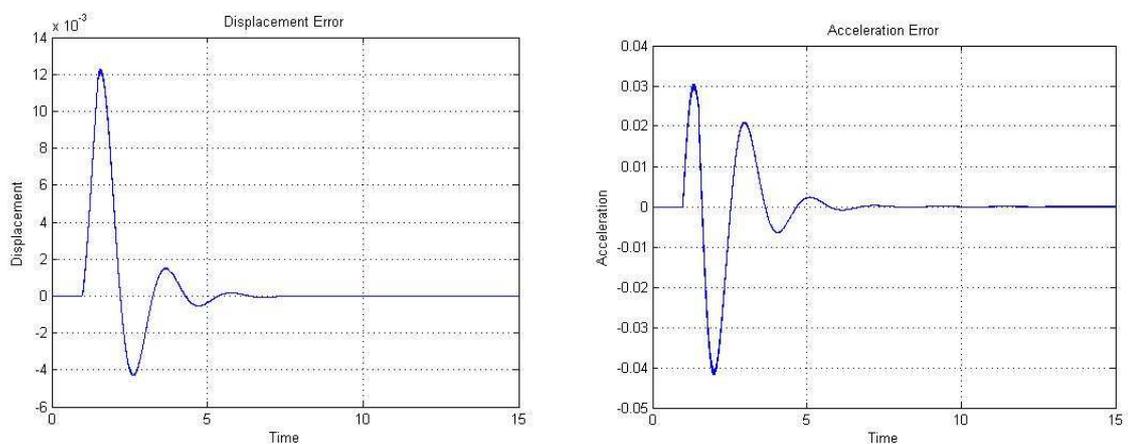


Fig. 8: Movements of the vibration free platform

5 Discussion

According to Fig. 8 the compensation error of the system which is the output of accelerometer 02 is very small compared to the amplitudes of the acceleration waveforms of the input to the controller and the corresponding controller action at Fig. 9. According to Fig. 10 It is clear that the main reason for the control error is a time delay of the control action which might be different with the physically implemented system from the simulation model.

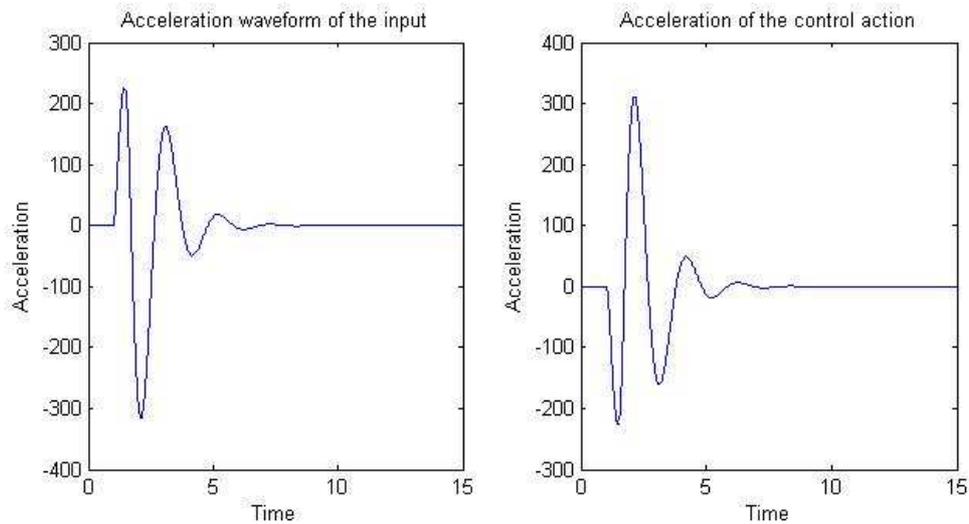


Fig. 9: Acceleration waveforms of the input to the controller and corresponding control action

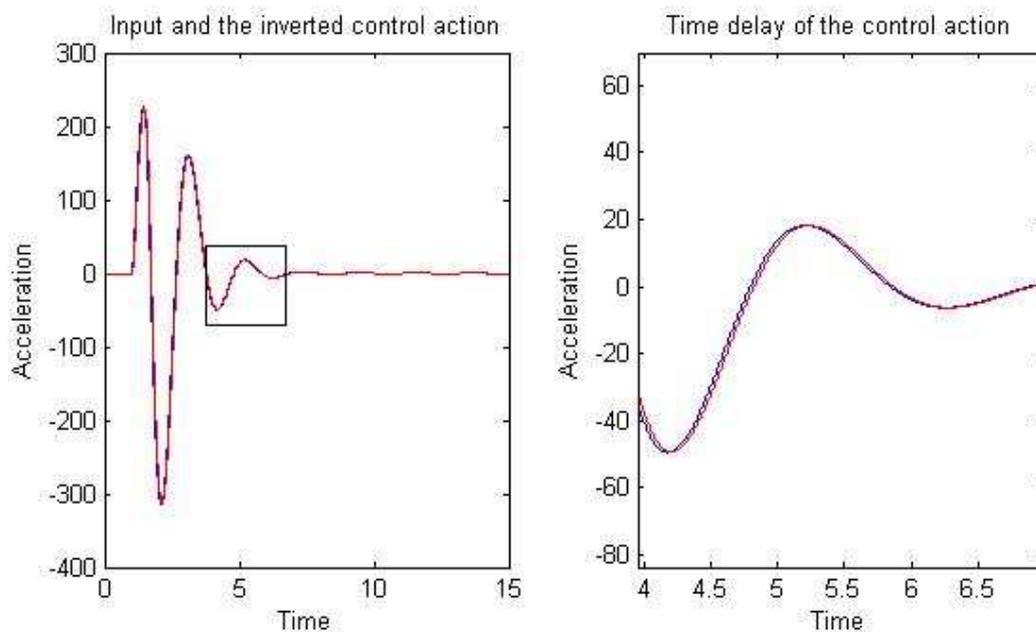


Fig. 10: Time delay of the inverted acceleration waveform of the control action

6 Conclusions

The presented vibration compensation system is highly applicable not only in the area of smart buildings but also in many numbers of applications including automobile, healthcare etc. Considering the smart building applications this is very much effective to protect the vibration and shock sensitive equipments as a vibration free platform for those equipments. This can be scaled up to have several actuators and sensors at different places on a much larger platform to perform the same task.

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