ECE 445

SENIOR DESIGN LABORATORY

PROPOSAL

# MEMS-based Feedback Controller

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# Contents

# 1. Introduction

## 1.1 Problem:

Seismic activity can cause significant damage to buildings and infrastructure. Vibrations caused by seismic activity can result in a range of problems, such as structural damage, equipment failure, and even collapse, which can lead to serious safety risks and financial losses. A feedback controller can help to mitigate these risks by providing a mechanism for actively controlling the vibrations of the building model. The controller receives feedback from sensors that measure the vibration of the building model and uses this information to adjust the input to the shake table. This allows the controller to actively suppress the vibrations of the building model, reducing the risk of damage or failure.

## 1.2 Solution:

We are aiming to develop a feedback controller for this purpose involves designing a control algorithm that can accurately and efficiently control the vibration of the building model. The model response is measured by a MEMS-based accelerometer, which is a type of accelerometer that uses micro-electromechanical systems (MEMS) technology to measure acceleration.
And we choose Active Mass Driver (AMD) control system as our feedback controller. AMD control systems have been used in a variety of applications, including high-rise buildings, long-span bridges, and large industrial structures. They are particularly effective in reducing the effects of seismic activity on structures, which can be critical in earthquake-prone areas. By reducing the vibrations and seismic responses of structures, AMD control systems can improve the safety and performance of civil engineering structures, as well as reduce maintenance costs and extend their lifespan.

## 1.3 Visual Aid:

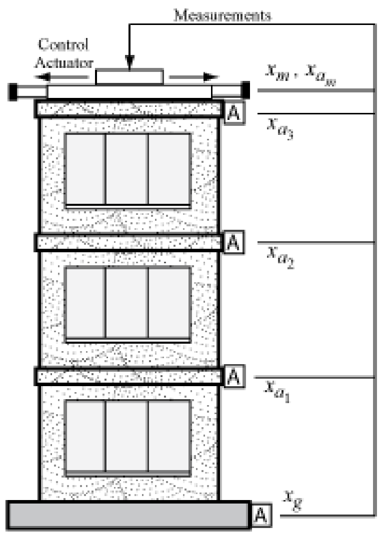


Fig.1. Visual Aid of MEMS-based Feedback Controller

## 1.4 High-Level requirements list:

Reliability: The feedback controller must be reliable and have a high level of availability, with minimal downtime and maintenance requirements. Feedback controller can detect seismic excitation correctly, and overall weight is no more than 10% of the floor mass.

Accuracy： It can make reaction to a slight vibration and must be able to effectively reduce the vibrations and seismic responses of the structure to within specified limits.

Selectivity: Maximum acceleration of floor response is no more than 0.01 g under various seismic excitations.

Safety: The feedback controller must be designed to ensure the safety of the structure and its occupants, and to prevent any potential hazards that may arise from its o

# 2. Design

## 2.1 Block Diagram

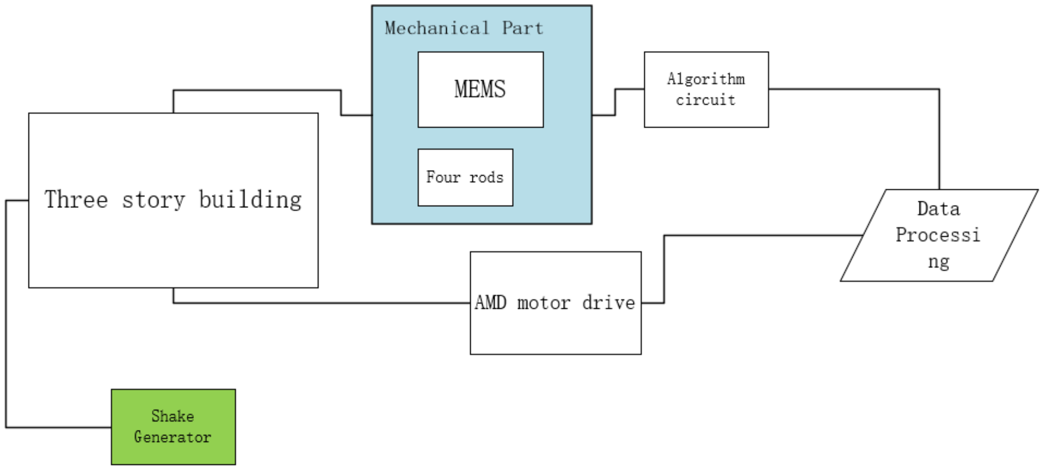


Fig.2. Block Diagram of MEMS-based Feedback Controller

## 2.2 Subsystem Overview

Algorithmic circuit: we need to design the reading circuit that can completely know how the capacitor of MEMS accelerometer changed. We can use some RC circuit like the RC latch to save the signal and then transmit it to another place. What we need to do is to lower the delay of this process. And we need to complete the synchronization in this subsystem, which at least include the 10 model for the control part and 28 states evaluation model for analysis and simulation.

The mechanical part: To imitate the image from the description, we need to place four rods on the system and place the MEMS accelerometer on the surface. And keep it stable to avoid the intrinsic vibration, which will cause the error in our system.

Data processing program: To simulate the vibration of the building or other vibrations, we need to precisely capture and analyze data collected. It can be built using Simulink, MATLAB. After our computer got the data, like signals. We need to process it by filtering some signal of different type of wavelength and fetch what we need to create the feedback controller system.

## 2.3 Subsystem Requirements

2.3.1 Algorithmic circuit

As this part is the most vital part of the MEMS-based Feedback Controller, we searched a lot of sources through Google Scholar. And we decided to use 6 available measurements for feedback: accelerometers at the base of the structure, on each story, and on the actuator mass and an LVDT displacement sensor attached to the actuator.

And the potential model in this subsystem is also essential, that's why we determined to figure out 10 model for the control part and 28 states evaluation model for analysis and simulation. And we decided to come up with equations to deal with measurements collected from the MEMS accelerometer, which are part of the model. And the eventual thing we need to handle is the synchronization. We decided to add delays in some part of the models to ensure that the system is functioning simultaneously.

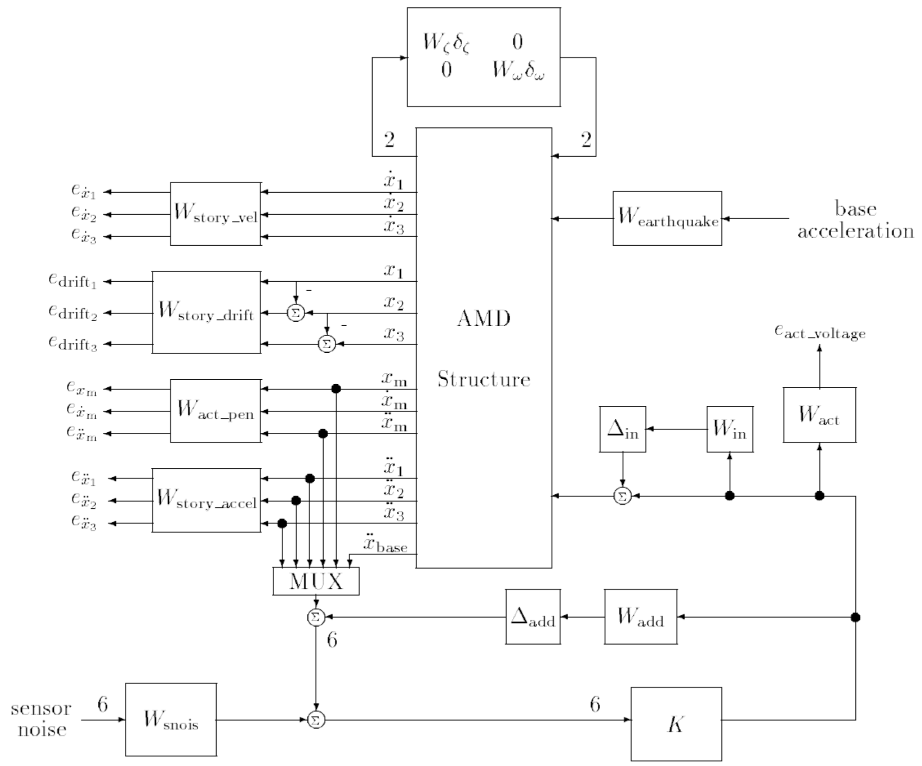


Fig.3. Sample of Interconnection Structure of the AMD Control Problem

2.3.2 The mechanical part

After designing the Algorithmic circuit. We need to handle with the drivers, which at least 12 according to the sample of Interconnection Structure of the AMD Control Problem. And after investigation, we decided to use servo motors in our mechanical part, since the servo motors have the advantage of high accuracy, high efficiency, high output power relative to their size, quiet operation.

2.3.3 Data processing program

Since in the Algorithmic circuit, there will be some calculation that's too comprehensive for the circuit we need to design, we decided to import the computer to complete the data processing process. For instance, each weighting models all includes matrix calculations, and some weighting models have 3×3 or 6×6 matrix.

We decided to use the MATLAB to perform those calculations and then import those calculations outcome into the algorithmic circuit.

## 3. Ethics and Safety

Ethics and safety are a crucial part of product planning. For Ethics, we have carefully read the relevant code of ethics of IEEE and must ensure that MEMS will not violate the rules. All product-related data must be true, which is related to the privacy of users. Invading the privacy of others is strictly prohibited.

For safety, firstly, the production of products needs a long time of welding work. We need to follow the laboratory rules to improve the accuracy of products and avoid scalding of operators. Secondly, MEMS technology needs to be controlled by electricity. We should be careful about electric shock accidents caused by touching the wire connecting the sensor during the experiment.

# Reference

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G. J. Balas, "Synthesis of controllers for the active mass driver system in the presence of uncertainty," in Proceedings of the 1997 ASCE Structures Congress, Portland, OR, USA, 13-16 Apr. 1997, pp. 1087-1090.