

Active Vibration Damper

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Many high precision experiments are limited not by the precision of the components involved, but by external fluctuations in ambient conditions, such as temperature, pressure, and electromagnetic fields. An important such limiting factor are the inevitable vibrations of laboratory equipment. Our device will be able to reliably damp micro-scale vibrations on a one dimensional track.

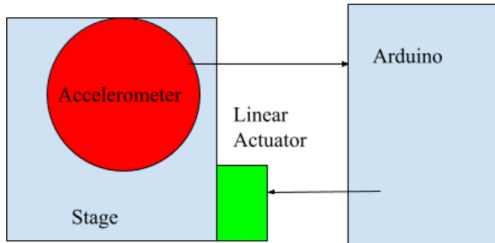


FIG. 1. Block Diagram

I. DESIGN

A. Mechanical Design

The goal of this device is to sense a vibration, communicate that information to a computer by transferring data, and have the computer send a signal based on this data to trigger an actuator which would damp said vibrations on a rigid platform.

Specifically, an accelerometer¹ will sit on a small ($\sim 3 \times 3$ cm) rigid platform. Based on the voltage signal from one of the three outputs on the accelerometer, an Arduino UNO² with C code uploaded to it will send out a Pulse-Width Modulated signal to a Piezo Linear Actuator³ to apply the appropriate force to the platform to dampen its vibrations (Figure 1).

Given that the Piezo Linear Actuator extends by $0 \mu\text{m}$ at 0V and $10 \mu\text{m}$ at 150V one must be careful when trying to capture the full $10 \mu\text{m}$ range in 1 dimension. Ideally, the extension of the actuator would be centered at $5 \mu\text{m}$ so that the platform could move back and forth by $5 \mu\text{m}$. This would, however, require an input signal to the actuator which would be centered at 75V . The Arduino UNO cannot output such a voltage, meaning that an amplifier would be required.[1]

B. Circuit Design

Figure 2 is a Digi-Key schematic of the circuit in this device. The signal from the Xout pin, which is centered at $\sim 1.7\text{V}$, of the accelerometer is passed through a capacitor to allow for a DC voltage input of 0 to the Operational Amplifier.⁴ The signal is then passed through a non-inverting amplifier, allowing for variable gain. The

output of this amplifier is centered at 0V and clipped at $+$ and -2.5V , given the $0-5\text{V}$ range of the Arduino analog input pins. The signal from the amplifier is then passed through a capacitor to a voltage divider to allow for a signal which is centered at 2.5V . Finally, the signal is passed through a low-pass filter to get rid of high-frequency electromagnetic noise ($>20,000\text{Hz}$).

Based on this signal, which is conveniently clipped at 0 and $+5\text{V}$, the Arduino outputs a PWM signal on a Digital output pin to the Linear Actuator. This must be done through an amplifier to capture the full range of the actuator ($0-150\text{V}$).

One may notice that before the input to the Operational Amplifier and after the output of the amplifier there are two high-pass filters as a consequence of the signal passing through a capacitor for DC voltage adjustment. Given that mechanical vibrations occur at the audio frequencies ($20-20,000\text{Hz}$), one must be careful to not filter out any of the accelerometer signal. For this reason, a 3dB point of $\sim 10\text{Hz}$ is chosen for the two high-pass filters in the circuit.

Since amplifiers draw more current than an Arduino pin can provide (40mA), an external power supply is used.

C. Code

The C code uploaded to the Arduino extracts the original voltage coming from the accelerometer, converts this to an acceleration, multiplies this by the mass of the platform and accelerometer to convert this to a force, and writes the appropriate voltage (scaled by the amplifier) to the digital output pin leading to the linear actuator. This calculation is done at a fixed sampling rate which is limited to $\sim 10\text{kHz}$ by the speed of the C code on the Arduino.

II. LIST OF PARTS

- adafruit ADXL335 Accelerometer, <https://www.adafruit.com/product/163>
- Arduino UNO, <http://store-usa.arduino.cc/products/arduino-uno-rev3>
- Piezo Linear Actuator,

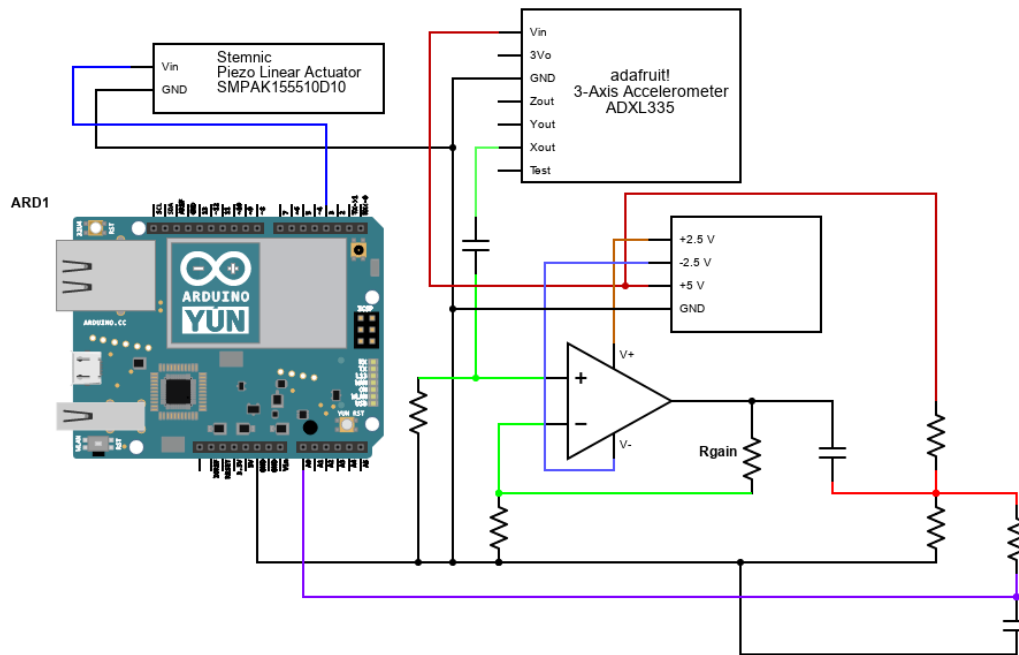


FIG. 2. Circuit Schematic

<https://www.steminc.com/PZT/en/stack-piezo-actuator-5x5x10mm-10um-displacement>

4. LF411 Operational-Amplifier,
<https://www.ti.com/product/LF411>

III. PLAN OF IMPLEMENTATION

- Week 1: Order parts and become familiar with accelerometer

- Week 2: Begin writing code and building circuit
- Week 3: Finalize code and circuit. Begin testing linear actuator
- Week 4: Construct stage and test device.

[1] For initial tests a signal generator with 0-20 V range will be used.