*Faculty of Engineering Mansoura University*

*Mechatronics Engineering Department*

*PRE 5311*

*Fundamentals of Mechanical Vibration Analysis*

# Vibration project Report

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*Under the supervision of:*

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## *ABSTRACT*

This project aims to design and implement a simple vibration measurement system using a cantilever beam (ruler), an Analog Piezoelectric Ceramic Vibration Module, an Arduino Nano, and an LCD display. The primary objective is to measure the vibrations induced in the cantilever beam and display the corresponding values on an LCD while also visualizing the vibration data as a waveform on a laptop.

The system operates by manually vibrating a cantilever beam (represented by a ruler), where the Analog Piezoelectric Ceramic Vibration Module senses the induced vibrations. The piezoelectric sensor converts mechanical vibrations into electrical signals, which are then processed by the Arduino Nano microcontroller. The processed data is displayed on an LCD screen in real-time, providing immediate feedback on the vibration intensity.

Additionally, the Arduino Nano interfaces with a laptop to display the vibration data as a waveform, enabling a visual representation of the vibration characteristics over time. This dual-display system (numeric on the LCD and graphical on the laptop) provides comprehensive insight into the vibration behavior of the cantilever beam.

The project encompasses hardware setup, including sensor interfacing and LCD integration, and software development for data acquisition, processing, and visualization. The use of Arduino Nano ensures a compact and efficient solution, making the system suitable for educational demonstrations, basic vibration analysis, and further exploration of vibration phenomena in mechanical structures.

Overall, this project demonstrates the practical application of piezoelectric sensors in vibration measurement and the effectiveness of Arduino-based systems in real-time data acquisition and visualization

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## *INTRODUCTION*

Vibration measurement and analysis play a crucial role in various fields, including mechanical engineering, structural health monitoring, and educational demonstrations. Understanding the behavior of vibrating systems can provide valuable insights into material properties, structural integrity, and dynamic responses. This project focuses on developing a simple and effective vibration measurement system utilizing a cantilever beam, an Analog Piezoelectric Ceramic Vibration Module, an Arduino Nano microcontroller, and an LCD display.

The core objective of the project is to measure the vibrations of a cantilever beam (modeled by a ruler) and present the data in both numerical and graphical formats. The Analog Piezoelectric Ceramic Vibration Module is employed to detect the vibrations of the cantilever beam. When the beam is manually vibrated, the piezoelectric sensor generates an electrical signal proportional to the mechanical vibrations. This signal is then processed by the Arduino Nano.

The Arduino Nano, a compact and versatile microcontroller, is programmed to read the sensor data, convert it into a meaningful vibration value, and display this value on an LCD screen. This real-time numerical display allows users to observe the immediate effects of different vibration intensities on the cantilever beam.

Furthermore, the Arduino Nano is connected to a laptop to visualize the vibration data as a waveform. This graphical representation provides a more comprehensive understanding of the vibration characteristics, including frequency, amplitude, and damping effects over time. Such visualization is essential for more detailed analysis and educational purposes.

This project integrates hardware components, such as the piezoelectric sensor, LCD, and Arduino Nano, with software development for data acquisition and visualization. It demonstrates the practical application of piezoelectric technology in measuring vibrations and highlights the capabilities of Arduino-based systems in real-time monitoring and data presentation.

In summary, this project offers an accessible and informative approach to studying vibrations in mechanical structures. It serves as an excellent tool for educational purposes, enabling students and enthusiasts to explore and understand the principles of vibration measurement and analysis.

## Libraries Used:

### i. Library for LCD_I2C:

```
#include <LiquidCrystal_I2C.h>
#include <Wire.h>
```

The **LiquidCrystal_I2C.h** library is an extension of the standard LiquidCrystal library for Arduino that adds support for LCD displays using the I2C communication protocol. LCD displays are commonly used in Arduino projects for displaying text and graphical information.

The I2C protocol, also known as TWI (Two-Wire Interface), allows for communication between microcontrollers and peripheral devices using only two wires (SDA for data and SCL for clock). Using an I2C interface reduces the number of required pins on the Arduino board, which is beneficial especially when working with projects that have limited available pins.

The **LiquidCrystal_I2C.h** library simplifies the process of interfacing with I2C-enabled LCD displays, providing functions for initializing the display, writing text to specific positions, controlling the cursor, and more.

Key features of the **LiquidCrystal_I2C.h** library include:

1. **Easy Initialization**: The library makes it easy to initialize the LCD display with the appropriate I2C address and dimensions.

2. **Flexible Text Display**: Developers can easily write text to the LCD display at specific positions, allowing for the creation of custom user interfaces and menus.

3. **Cursor Control**: The library provides functions for controlling the position and visibility of the cursor on the LCD display.

4. **Backlight Control**: If the LCD display has a backlight, the library typically includes functions for controlling its brightness or turning it on/off.

## Defining Variables:

### i. Defining Constant Pins:

```
const int sensorPin = A3;
```

**Avoiding Errors:** Using constants helps prevent accidental changes to pin assignments during the development process. If a pin assignment needs to be changed, developers can update the constant value once, rather than having to find and update every occurrence of the pin number in the code, which reduces the risk of errors.

### ii. Defining Variable Pins:

```
LiquidCrystal_I2C lcd(0x27, 16, 2);
```

We use this way to define LCD variable and define we use LCE_I2C with kind (16x2).

## Setup Pins:

```
void setup() {
  Serial.begin(9600);
  lcd.init();
  lcd.backlight();
  lcd.clear();
}
```

We defined the variables we use :

First for serial screen to provide Waves form vibration , then LCD initialization and light if LCD.

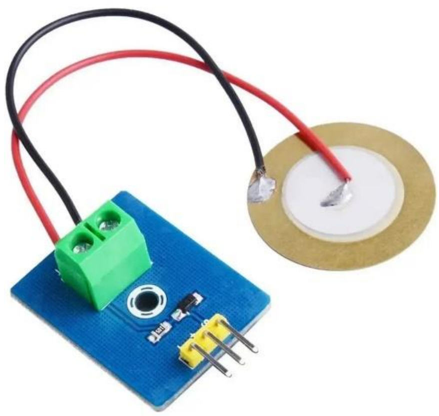
## Loop Part:

### i. Explanation in of The Code in C Programming Language:

```
void loop() {
  int sensorValue = analogRead(sensorPin);

  float minFreq = 100.0;
  float maxFreq = 1000.0;
  float frequency = map(sensorValue, 0, 1023,
minFreq, maxFreq);

  Serial.println(frequency);

  lcd.setCursor(0, 0);
  lcd.print("Frequency: ");
  lcd.print(frequency);

  delay(400);
}
```

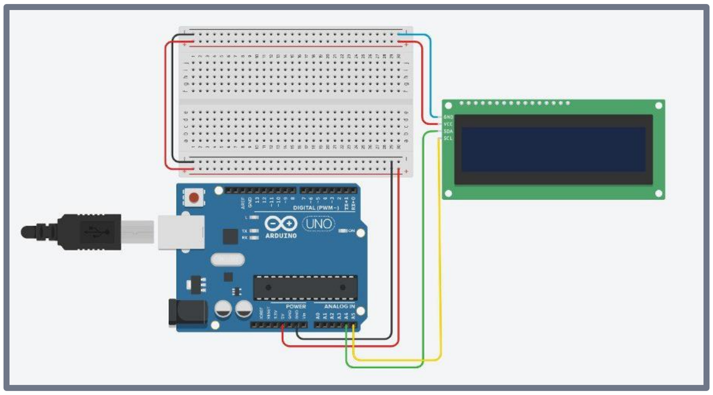
# The Used Hardware Components:

## i. Components List:

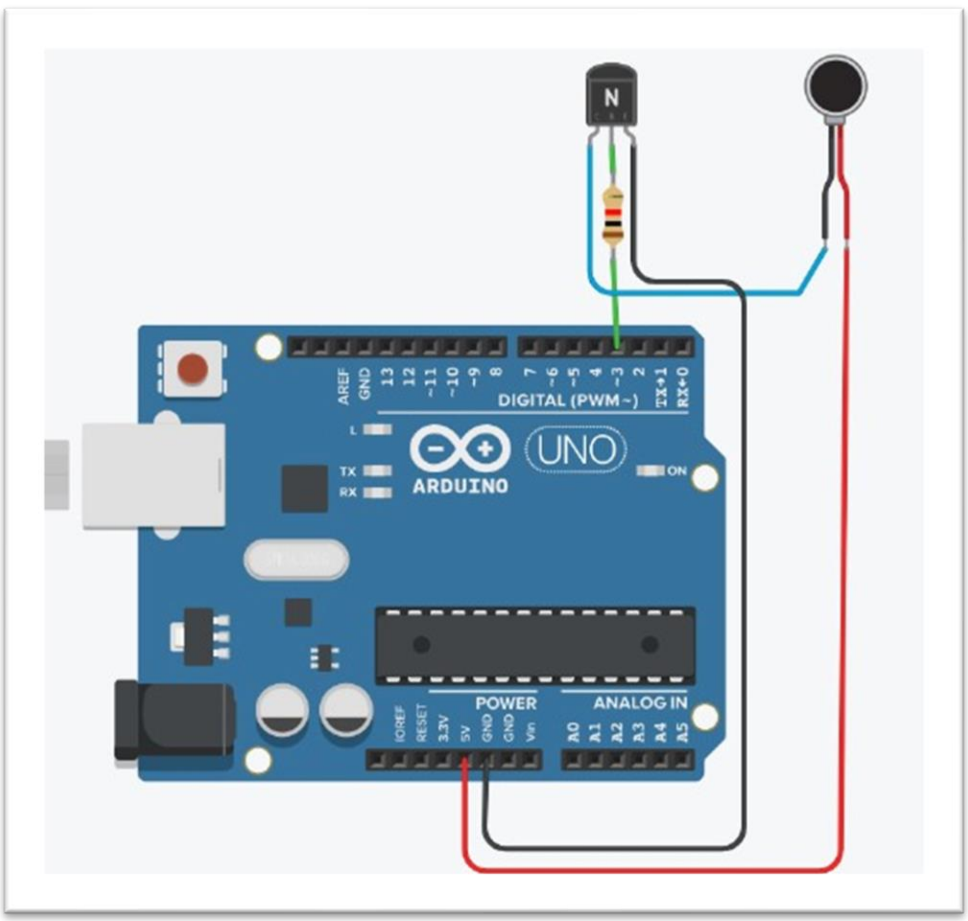
| Component | Description | Function |
|---|---|---|
|  | ***Arduino Nano:*** compact microcontroller board based on the ATmega328P microcontroller, similar to the Arduino Uno but in a smaller form factor | We use it to provide our code on it |
|  | ***Analog Piezoelectric Ceramic Vibration Module:*** omponent that can detect vibration or mechanical pressure and convert it into an electrical signal. | They provide precise control over vibration intensity and frequency, making them versatile components in various industries including consumer electronics, automotive, and medical devices. |
|  | ***LCD_12C:*** A display module that consists of a classic parallel LCD and an I2C LCD adapter. | We use it to provide the measures of frequences of vibrations |

## ii. Connections:

- **Connecting the LCD_12C:**



- **Connecting the *Analog Piezoelectric Ceramic Vibration Module:***



## Introduction on The Designed Parts:

### Design and Fabrication Process

Our project involved designing a cantilever system to measure vibrations using an Analog Piezoelectric Ceramic Vibration Module, with data displayed on an LCD and visualized on a laptop using an Arduino Nano. The process encompassed several key steps, from initial design to final fabrication and assembly.

### Initial Design

The project started with a conceptual design on paper, where we outlined the specifications and dimensions of the cantilever beam setup. This included:

1. **Cantilever Beam**: Represented by a ruler, this component was designed to vibrate under manual excitation.
2. **Mounting System**: A secure placement for the ruler to act as a cantilever beam.
3. **LCD Display Holder**: A designated area to mount the LCD for real-time display of vibration data.

### CAD Modeling

We then translated the paper design into a detailed 3D model using SOLIDWORKS, a sophisticated CAD software. This step allowed us to refine our design with precise dimensions and integrate all necessary components:

1. **Cantilever Beam Mount**: Ensuring the ruler could be securely fixed in place, allowing for free vibration.
2. **Sensor Placement**: Designing a spot for the Analog Piezoelectric Ceramic Vibration Module to be attached for optimal vibration detection.
3. **LCD Display Integration**: Creating a stable and visible mount for the LCD to display vibration readings.

### CNC Machining

After finalizing the SOLIDWORKS model, we moved to the fabrication stage. The design was sent to a workshop equipped with CNC machining capabilities, where it was precisely cut from thin wood. The CNC machine provided high accuracy and consistency, crucial for the following reasons:

1. **Dimensional Accuracy**: Ensured all parts fit together perfectly, with accurate placements for the ruler and LCD.
2. **Sturdy Construction**: Produced a reliable structure capable of withstanding repeated vibrations.

**Assembly**

Once the parts were cut, we assembled the components:

1. **Mounting the Ruler**: The ruler was securely fixed in the designated cantilever mount, allowing it to vibrate freely.
2. **Attaching the Sensor**: The Analog Piezoelectric Ceramic Vibration Module was strategically placed to detect vibrations effectively.
3. **LCD Mounting**: The LCD display was mounted in the designed holder, ensuring clear visibility of the data.

**Considerations**

During the design and fabrication process, several considerations were taken into account to ensure the success and safety of the project:

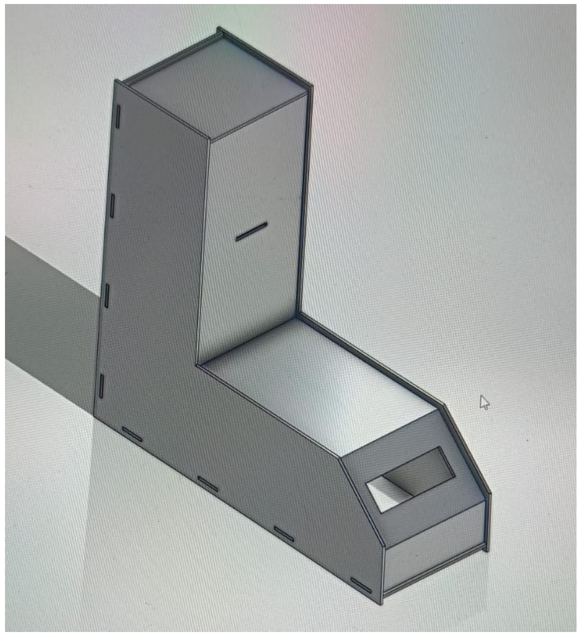
1. **Material Selection**: Wood was chosen for its ease of machining and appropriate mechanical properties.
2. **Ease of Assembly**: The design was modular to facilitate easy assembly and disassembly, which is beneficial for demonstrations and modifications.
3. **Safety**: All edges were smoothed, and parts were securely attached to prevent any loose components during operation.

**Integration and Testing**

After assembly, the electronic components were integrated:

1. **Arduino Nano**: Programmed to read signals from the vibration module and process the data.
2. **Data Display**: Real-time vibration data displayed on the LCD screen.
3. **Data Visualization**: Data sent to a laptop for visualization as a waveform, providing comprehensive analysis of the vibration characteristics.

## i. Design in Solid



## ii. After printing in CNC machine:

## Discussion

The development and implementation of the vibration measurement system using a cantilever beam, an Analog Piezoelectric Ceramic Vibration Module, an Arduino Nano microcontroller, and an LCD display offer several key insights into the intersection of mechanical design, CNC machining, and electronic integration.

Mechanical Design and Fabrication

**Strengths:**

1. Precision and Accuracy: The use of SOLIDWORKS for CAD modeling allowed for the precise definition of the cantilever system's geometry, ensuring accurate dimensions and integration points for sensors and displays.
2. CNC Machining: Utilizing CNC machining ensured high precision in cutting the wooden components, which resulted in a robust and reliable physical model. The CNC process minimized human error and ensured consistent quality across all parts.

**Challenges:**

1. Material Limitations: While wood was chosen for its ease of machining and cost-effectiveness, its mechanical properties—such as damping and variability—may limit the accuracy and reliability of vibration measurements. Future iterations could explore materials like metals or composites to improve performance.
2. Design Complexity: Ensuring that all parts fit together seamlessly required several iterations and adjustments in the design phase. Balancing the complexity of the design with ease of assembly and functionality was a significant challenge.

Sensor Integration and Data Processing

**Strengths:**

1. Effective Sensor Placement: Careful planning of the sensor's placement on the cantilever beam maximized the sensitivity and accuracy of vibration detection, ensuring reliable data collection.
2. Real-Time Feedback: The integration of an Arduino Nano and an LCD display provided immediate visual feedback, enhancing the educational value of the system by allowing users to observe the effects of different vibration inputs in real-time.

**Challenges:**

1. Signal Noise: Processing the analog signals from the piezoelectric sensor required careful filtering and calibration to ensure that the vibration data was accurate and meaningful. Addressing signal noise and ensuring reliable data transmission were key technical challenges.
2. Data Visualization: Developing a system to visualize the vibration data on a laptop required additional software development. Ensuring that the data was transmitted accurately and represented clearly added complexity to the project.

Educational and Practical Implications

**Strengths:**

1. Hands-On Learning: The project serves as a powerful educational tool, illustrating key concepts in vibration analysis, sensor technology, and the integration of mechanical and electronic systems. It provides a tangible, hands-on learning experience.

2. Modular Design: The modular nature of the design allows for easy assembly, disassembly, and modification, making it adaptable for different educational settings and experimental requirements.

**Challenges:**

1. Scalability: Scaling the system for larger or more complex applications presents new challenges, including the need for more robust sensors and enhanced data processing capabilities.
2. Durability: The wooden components, while suitable for initial prototypes, may not withstand prolonged use. Exploring more durable materials and construction methods would improve the system’s longevity and reliability.

## Conclusion

This project demonstrates the successful integration of mechanical design, precise fabrication, and electronic components to create a functional vibration measurement system. The process involved:

1. Designing a cantilever system using SOLIDWORKS to ensure precise dimensions and integration points.
2. Fabricating the design using CNC machining to achieve high accuracy and consistent quality.
3. Integrating an Analog Piezoelectric Ceramic Vibration Module and an Arduino Nano to measure and display vibration data in real-time.
4. Providing educational value through a hands-on, tangible representation of vibration analysis principles.

The project highlighted several strengths, including the precision of the CAD design, the accuracy of CNC fabrication, and the effectiveness of real-time data display. However, it also faced challenges related to material limitations, signal noise, and the complexity of data visualization.

Future work could focus on exploring alternative materials to enhance the durability and performance of the system, incorporating more advanced sensors for improved accuracy, and developing more sophisticated data processing algorithms. Additionally, scaling the design for larger or more complex applications could broaden its practical applications.

Overall, this project serves as a valuable educational tool and a foundation for further exploration in vibration measurement and analysis, demonstrating the effective combination of modern design, fabrication techniques, and electronic integration.

S, M., & B, M. K. (n.d.). Smart Home Automation System. *International Journal on Integrated Education*, *2*(5), 222–229.

1. **Official Arduino Website**: https://www.arduino.cc/
   - The official website provides a wealth of information, including documentation, tutorials, project ideas, and forums.
2. **Arduino Forum**: https://forum.arduino.cc/
   - A community-driven forum where you can ask questions, share projects, and interact with other Arduino enthusiasts.
3. **Arduino Datasheets:**
   - ATmega328P Datasheet: https://www.digipart.com/
   - Arduino Uno Datasheet: UNO R3 | Arduino Documentation

   Datasheet for the microcontroller used in Arduino Uno and many other Arduino boards, providing comprehensive information on features, registers, and electrical characteristics.

## Sensor Resources:

**Analog Piezoelectric Ceramic Vibration Module**

https://www.alldatasheet.com/datasheet-pdf/pdf/1186644/CUI/CPT-2746-L100.html