ES116: Project Report
Project: Musical Keyboard

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***Abstract*– The aim of this project is to design a working model of a mini piano or musical keyboard. By integrating ultrasonic sensing for octave control and employing push buttons and piezo buzzers, the device offers a dynamic and customizable auditory experience. The circuit design and code implementation are detailed, alongside discussions on experimentation and innovative approaches. The project underscores the fusion of curiosity-driven inquiry and hands-on exploration in understanding musical instrument mechanics.**

I. INTRODUCTION

Throughout this course, we have studied various signals in different domains. However, the most intriguing and melodious ones are the audio signals called music, produced by various musical instruments. Thus, through this project, we are trying to understand and create one such device called Piano. The project is an Arduino-based mini piano or keyboard-like musical instrument that can generate a range of frequencies based on the input through momentary buttons. The musical keyboard incorporates features such as adjustable loudness and adjustable octaves.

II. COMPONENTS

1. Arduino Uno
2. Momentary buttons
3. Piezo buzzers
4. Operational amplifier
5. Potentiometer
6. Breadboard
7. Distance sensor
8. Some resistors and wires

III. THEORY

A. Ultrasonic Sensor:

Ultrasonic sensing is based on the principle of sound waves that travel through the air at a frequency above the range of human hearing. The sensor emits ultrasonic waves that bounce off objects and return to the sensor. The time it takes for the sound waves to return to the sensor is used to calculate the object's distance from the sensor. The ultrasonic sends has four pins: Vcc, Trig Pin, Echo Pin, and Gnd. The Trig Pin produces a 10-microsecond pulse of ultrasonic waves that hit and reflect back from a surface. The Echo Pin of the sensor then picks up the reflected waves. This pin records the pulse duration for going and coming back in milliseconds. The distance (in cm.) is then calculated as

$$d = (t * 0.034)/2$$

The 343 m/s accounts for the speed of sound in air.

B. Push Buttons:

Push buttons consist of metal contacts and a spring mechanism. Pressing them completes electrical circuits momentarily. Debouncing circuits mitigate rapid contact bouncing, ensuring reliable operation. Push buttons play a crucial role in controlling electronic systems and user interactions.

C. Piezo Buzzers:

Piezo buzzers utilize the piezoelectric effect, where certain materials generate voltage when mechanical stress is applied. When an alternating voltage is applied to a piezoelectric crystal inside the buzzer, it vibrates, creating sound waves. The frequency of the sound depends on the frequency of the applied voltage. Piezo buzzers are compact, lightweight, and commonly used in electronic devices for producing audible alerts and tones.

IV. DESIGN AND WORKING

A. *Taking Input:* Like a usual piano, our model has different keys assigned to different notes and frequencies, so the input signal is taken through keys. We have seven push buttons to represent the seven notes of the piano.

B. *Processing the input through Arduino:* After taking the digital input, it is processed using the code in the Arduino and then, according to the input, a signal is sent out through the digital input.

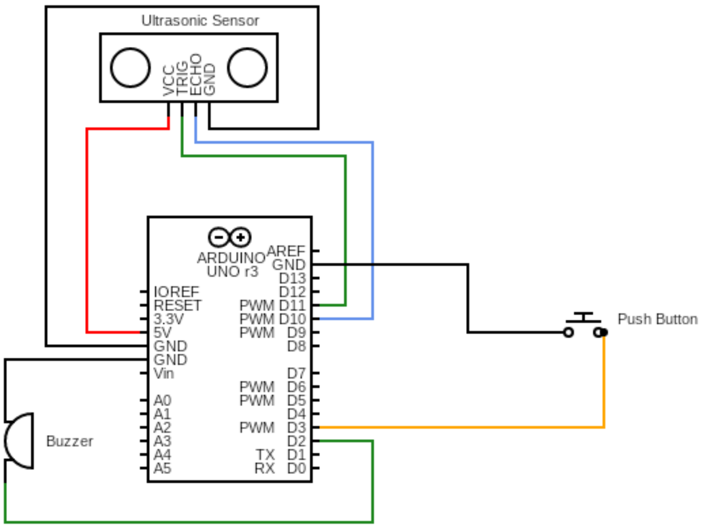

Fig. 1. Circuit diagram of the piano, showcasing only one push button.

C. *Attenuating the signal:* The signal given by the Arduino is then passed through the resistors, which reduce the voltage across the output buzzer, thus reducing the volume.

D. *Changing Octave:* For changing the octave, we have an Ultrasonic Sensor that measures the distance of the nearest obstacle and maps that distance to find a multiplication factor that eventually changes the octave.

E. *Final Output:* For producing the final output sound using the processed signal, we use piezo buzzers, which can produce sound using piezoelectric materials based on the magnitude of the voltage across it.

V. PROCEDURE

1. *Gathering Components:* We gather the necessary components, including an Arduino board, push buttons, a distance sensor (if applicable), piezo buzzers, resistors (10, 70, 150 ohms), wires, a breadboard, and a power supply.

2. *Connecting Keys to Arduino:* We wire the push buttons to digital input pins on the Arduino board, assigning each button to a specific note or frequency.

3. *Programming the Arduino:* Using Arduino IDE, we wrote code for the Arduino, enabling it to read digital inputs from the buttons, process the data to generate digital signals corresponding to the notes, and control octave changes using the distance sensor. The whole of the code is present here- https://github.com/AnuragSingh0000/Musical-Keyboard.git

```
int mapDistanceToFrequency(int distance) {
    if (distance <= 5) {
        return 1;
    } else if (distance <= 10) {
        return 4;
    } else if (distance <= 15) {
        return 6;
    } else {
        return 1; // Return 0 if distance is out of range
    }
}
```

Fig. 2. Code created to map the distance to the multiplication factor to change the octave.

```
  // Button C
if (buttonStateC == LOW) {
  Serial.println("ButtonC pressed!");
  // Activate the buzzer
  int frequency = f[0]*mapDistanceToFrequency(measuredDistance);
  for (int i=frequency-5; i<frequency+5; i++) {
    tone(buzzerPin, i); // 1000 Hz frequency
    delay(10); // Optional debounce delay
  }
  // Stop the buzzer
  noTone(buzzerPin);
}
```

Fig. 3. Code created to map each button to a note.

4. *Implementing the Circuit:* We designed the circuit using all the components and wires according to the previous circuit diagram.

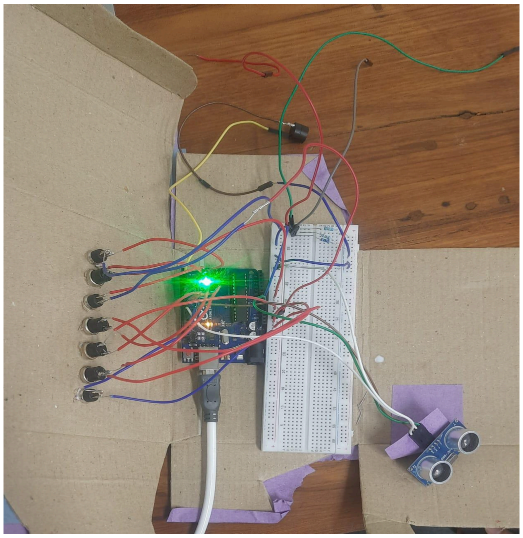

Fig. 4. Inner circuit of the piano.

5. *Connecting Piezo Buzzers:* We connect the piezo buzzers to the output, ensuring proper polarity alignment to generate sound waves effectively.

6. *Testing, Fine-tuning and Calibration:* After individual component testing, we evaluate the entire system for functionality. Then, we fine-tune the code, circuit, and components as necessary to optimize performance and achieve the desired sound quality and functionality.

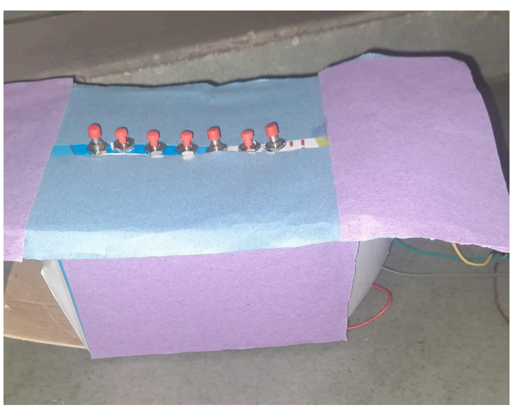

Fig. 5. Final model of our musical keyboard

VI. RESULT

The culmination of our efforts yields a harmonious outcome: each press of a button produces a unique musical note, completing the symphony of seven distinct tones. With the simplicity of seven buttons, the entirety of the musical scale unfolds, granting the user the ability to compose melodies effortlessly.

Also, integrating an ultrasonic sensor introduces a dynamic element to our musical creation. As the obstacle before the sensor advances, the buttons produce higher octaves

Moreover, toggling between pins modifies the sound's volume, offering a range of three levels: high, medium, and low. Thus ensuring a dynamic and customizable auditory experience.

VII. DISCUSSIONS

The idea of this project originated from the curiosity to know how a piano or musical keyboard produces sound.

Trying different methods and devices:
We experimented with many things to get the desired output from our model.

- We tried different things for varying the loudness of sound, like opamp, using a rheostat and potentiometer and then chose the most suitable method.
- For producing melodious sounds we tried using a piezo speaker, speaker module, and piezo buzzer. All of this helped us to gain great insights into the workings of these devices.

Unique ideas:

- We have developed an innovative idea for producing a large range of frequencies using a limited number of buttons. The idea did not come from the internet it was thought by our team.
- For varying the sound, we have used three different resistors, which attenuate the signal by different amounts.

VIII. CONCLUSION

In summary, our project successfully creates a mini piano with just seven buttons, offering a wide range of musical tones. Integration of an ultrasonic sensor introduces dynamic octave control, while volume adjustment provides a customizable auditory experience. This demonstrates technology's role in democratizing musical expression.

IX. REFERENCES

[1]*Arduino. cc*, 2024. https://docs.arduino.cc/programming/

[2]“ROBOT. HEAD to TOE Product User’s Manual -HCSR04 Ultrasonic Sensor User’s Manual ROBOT. HEAD to TOE Product User’s Manual -HCSR04 Ultrasonic Sensor Index,” 2013. Available: https://web.eece.maine.edu/~zhu/book/lab/HC-SR04%20User%20Manual.pdf

[3]“Arduino - Piezo Buzzer | Arduino Tutorial,” *Arduino Getting Started*. https://arduinogetstarted.com/tutorials/arduino-piezo-buzzer#google_vignette (accessed Apr. 19, 2024).