Constructing an Audio Frequency Detector with Arduino

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Contents

Abstract

This project focuses on the construction of an audio frequency detector using Arduino technology. The aim is to design a versatile and cost-effective system capable of accurately detecting and analyzing a wide range of audio frequencies. The implementation involves leveraging Arduino's analog input capabilities along with appropriate signal conditioning and processing techniques. The project begins by outlining the basic principles of audio frequency detection and the significance of Arduino in this context. It delves into the hardware components required for the system, including microphones, sensors, and supporting circuitry, and discusses their integration with the Arduino platform. Furthermore, the software aspect is explored, emphasizing the programming techniques essential for acquiring, filtering, and analyzing audio signals. Various algorithms for frequency detection and signal processing are discussed and implemented, highlighting their effectiveness and limitations within the Arduino environment. Throughout the project, attention is paid to calibration methods and accuracy assessment, ensuring reliable frequency detection across diverse audio inputs. Practical applications and potential extensions of this system in fields like sound engineering, music, and automation are also considered. Five forks with different frequencies are used and detected by the device. The results showcase the successful development of an Arduino-based audio frequency detector capable of accurately identifying and analyzing a wide spectrum of audio frequencies. The system's performance, limitations, and potential enhancements are thoroughly discussed, offering insights for further advancements in this domain.

Chapter One

Introduction

Everyday phenomena can be attributed to either human activity or natural occurrences. In the case of sound-related natural events, human hearing frequently detects them; for instance, an individual standing on the road may perceive the approaching siren of an ambulance from a distance. The siren becomes increasingly opulent and decelerates in frequency as the ambulance recedes from the individual (Aprilia et al., 2022). The occurrence within an ambulance serves as an illustration of the Doppler effect on waves. If the source of this vibration vibrates continuously, waves will continue to form, and these waves transfer energy from one location to another (Sirait, 2020). However, it is worth noting that certain natural phenomena can be perceived exclusively through sensory perception, whereas others necessitate the utilization of instruments. Parameters pertaining to the direct observation of natural phenomena can be categorized as tangible or actual phenomena. Conversely, those aspects of natural phenomena that necessitate the use of instruments for observation can be classified as abstract phenomena (Falah and Sehab, 2023).

A wave classified as audio-sonic occurs within the frequency range of 20 Hz to 20,000 Hz. The ability of individuals to perceive and hear these vibrations is contingent upon their age and degree of sensitivity (Milano and Manjavacas, 2020). Vibrational energy propagations that traverse a medium or lack one are referred to as waves. Separated into two categories according to the medium they travel through are mechanical and electromagnetic waves (Banerjee et al., 2019). The emission of sound by a sound source generates a longitudinal mechanical wave. The vibrations of an object create the sound, which then undergoes atmospheric propagation before being detected by the eardrums of living organisms. Sound velocity is expressed in hertz (HZ) (dB), while the amplitude of sound is quantified in decibels (dB) in accordance with physical principles (Newman and Newman, 2008).

There have been numerous endeavors over the decades to create instruments that are dependable, reasonably priced, and easily obtainable. The situation is made possible today with the development of wireless technologies, powerful personal computers, and international standards. These factors also have enabled data acquisition from a wide range of equipment, such as electronic devices and audio frequency detectors. With the advent of technology, IoT-driven bio-acoustic sensors can be utilized (Al-Turjman et al., 2020). As a potentially effective method for detecting audio frequency, numerous devices have been suggested in recent times. Najahy and Supurwoko (2023) constructed and evaluated the Arduino UNO-based Doppler Effect Practicum Tool. The Max4466 Sound Sensor functions as a detector and supplies the Arduino UNO microcontroller with sound inputs, which the Arduino IDE program then processes. An approach to digital sound processing was proposed by (Silva et al., 2015). utilizing the Arduino platform and MATLAB. Using a few examples, the authors demonstrate that the integration of Arduino and MATLAB can facilitate the establishment of a connection between the physical and computational realms. Nur Hudha et al. developed a sufficiently sensitive audiometer utilizing Arduino technology. LCD displays can be incorporated into audiometers to indicate the frequency and intensity of the sound being evaluated. The instrument is controlled by an Arduino Uno R3, and the frequency generator is an IC XR2206 (Wijaya et al., 2021). This research, conducted as a work in progress, centered on the creation of an affordable and portable Arduino-based audio frequency device.

Chapter Two

Materials and Methods

2.1 Materials

The materials used in this study include an Arduino UNO board, five folks, DEVMO microphone sensor high sensitivity sound detection module sensor, and IDE.

2.1.1 Frequency

The concept of frequency pertains to cyclical phenomena, including waves, oscillations, and simple harmonic motion. It is defined as the quantity of cycles or repetitions that occur within a given time unit. The duration required to complete one cycle of an oscillation or rotation is denoted by the period T. The relationship between frequency and period is represented by the equation. The SI unit of frequency is the hertz (Hz) (Crowell, 2000, Bloch, 2013).

$$\boldsymbol{f = \frac{1}{T}}$$

Where f is the frequency and T is period.

2.1.2 Audio Frequency

Audio frequency refers to the frequency or rate at which sound waves oscillate, typically measured in Hertz (Hz). Human hearing generally ranges from 20 Hz to 20,000 Hz, although this range can vary among individuals. Frequencies below 20 Hz are referred to as infrasound, while those above 20,000 Hz are known as ultrasound. In audio systems, the audible frequency range is typically divided into bands for practical purposes, such as bass (20-250 Hz), midrange (250 Hz - 4 kHz), and treble (4 kHz - 20 kHz). Audio frequency is fundamental to the perception of sound and is crucial in various applications including music, telecommunications, and speech processing (Talbot-Smith, 2012).

2.1.3 Tuning Forks

Tuning forks are two-pronged acoustic resonators, with the prongs (tines) constructed from a U-shaped bar of elastic metal, typically steel. Once the high overtones diminish, the fork emits a pure tone and resonates at a particular, constant pitch when set in motion by impacting it against a surface or an object. The length and mass of the two prongs regulate the pitch of a tuning fork. The fork shape is preferred over many other types of resonators primarily because it generates a tone that is extremely pure, with the majority of vibrational energy concentrated at the fundamental frequency.

2.1.4 Arduino UNO Board

Arduino UNO (Fig. 1) is an electronic device that interacts with connected devices with processing power, memory, and IO ports. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analogue inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Uno board is the first in a series of USB Arduino boards and the reference model for the Arduino platform; for an extensive list of current, past, or outdated boards, see the Arduino index of boards (Pranava Madan, 2019). The Arduino board can also be used to upload a new code to the Arduino board by using a USB cable to upload (Ismailov and Jo‘Rayev, 2022).

Fig. 1. Arduino UNO board.

2.1.5 DEVMO Microphone Sensor

Sensors are an indispensable component of any modern automation system. Furthermore, among all sensors, the sound sensor is among the most frequently employed. In general, the function of the sound sensor is to determine the intensity of the sound. Sound is a form of energy that is transmitted via vibrations. The aforementioned waves originate from mechanical vibrations. The nature of the sound is typically determined by the frequency of the wave. The sound sensor (Fig. 2) consists of a microphone to detect the sound, a potentiometer to adjust the sensitivity, and an audio amplifier to amplify the sound signals before sending it to the Arduino board. The potentiometer determines the decibel threshold. The sensor's output will remain elevated until the sound intensity surpasses the predetermined threshold value. Once the sound intensity surpasses the predetermined threshold, the sensor's output will diminish (Frank, 2013). It operates on a 5V DC power supply and has two outputs: AO, an analog output, and a real-time output voltage signal from the microphone. In addition, a power indicator light is present.

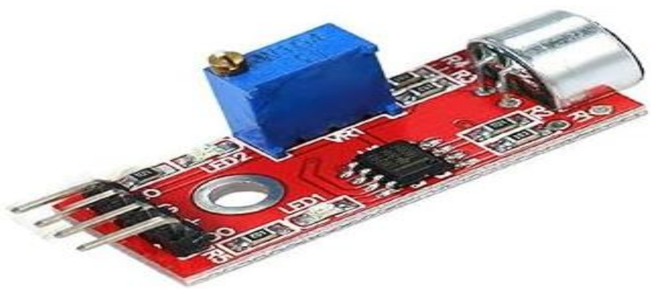

Fig. 2. The microphone sensor.

2.1.6 Arduino Integrated Development Environment (IDE)

IDE is open-source and allows users to write, upload, and compile the code to any Arduino board. Arduino IDE is written in Java and is compatible with Windows, macOS, and Linux operating systems. The IDE environment mainly contains two basic parts: editor and compiler. The former is used for writing the required code and later is used for compiling and uploading the code into the given Arduino Module (Fezari and Al Dahoud, 2018).

2.2 Methods

2.2.1 Working Principle of Microphone Sensor

The sound sensor operates similarly to how the human ear operates. A receiver is called a diaphragm. A membrane located within the ear converts vibrations into signals, which are then transmitted to the brain. In the same way, a microphone is composed of a magnetic diaphragm affixed to a metal coil. The diaphragm begins to vibrate when sound waves strike it, and the metal coil converts those vibrations into electrical signals. The output of this sensor is digital. The human ear has a diaphragm. It is a membrane inside the ear which translates vibrations into signals. And then sends those signals into the brain. Similarly, a microphone has a magnetic diaphragm and a metal coil attached to it. As the sound waves come into the contact with the diaphragm, it starts vibrating and the metal coil turns those vibrations into electrical signals. This sensor gives out digital output. The operational principle is uncomplicated, as this merely involves interfacing. Sound is transmitted as waves, and upon reaching the magnetic diaphragm, it initiates a process of vibration. The magnet is affixed to a metal coil, which records these vibrations. This coil converts the vibrations to electrical signals. The Arduino board receives these electrical signals to perform processing. Subsequently, the data is transmitted by the Arduino board and displayed on a Serial Monitor.

2.2.2 The Connection Between Arduino and Microphone Sensor

The Microphone sensor consists of four pins (GND, Operating Voltage: 3.3 to 5V, AO, DO), but three of them were connected. Therefore, it was connected to an Arduino board, which was then connected to a computer. The GND, 5 v, and AO were wired to GND, 5 v, A0, respectively (Fig. 3). This Arduino project displays the approximate frequency of the loudest sound detected by a sound detection module. Moreover, codes are required to operate any Arduino circuits. Therefore, the code has been compiled and uploaded to the Arduino board. After connecting the circuit and running the code, the five tuning forks with different frequency (256 Hz, 288 Hz, 341 Hz, 480 Hz, 512 Hz) were applied to the device.

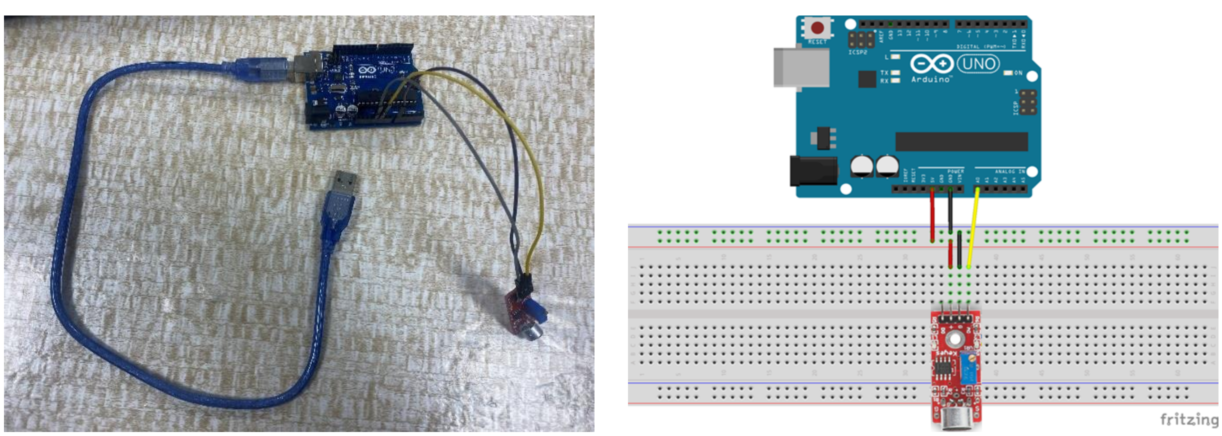

Fig. 4. Circuit connection consists of Arduino UNO and Microphone sensor.

Chapter Three

Results and Discussion

The approximate frequency of the loudest sound detected by a sound detection module is displayed in this Arduino project. The analogue audio signal detected by the sound module detector is transmitted to A0 of the Arduino Uno for the purposes of this project. Before becoming digital, the analog signal is quantized and sampled. Next, the digitized data are subjected to a Fast Fourier Transform (FFT). The FFT transforms the approximate discrete-time domain result into digital data. The approximate discrete-time domain result's utmost frequency is subsequently calculated and displayed through the Arduino IDE Serial Monitor.

Furthermore, this study proposed a portable, low-cost device for detecting audio frequency using Arduino. This is possible with a programmed high sensitivity sound detection Module for that is highly sensitive to detect audio frequency. After connecting the circuit and uploading the code to the Arduino Uno, five tuning forks with varying frequencies (256 Hz, 288 Hz, 341 Hz, 480 Hz, 512 Hz) were tried on the device. The device was able to accurately read their sensitivity and successfully detect them.

A limited number of studies were undertaken to construct a compact device utilizing Arduino for the purpose of detecting sound waves and frequency. Furthermore, the device can function as a sound detector, as Najahy and Supurwoko (2023) constructed a Doppler effect practicum instrument based on Arduino Uno that incorporates a sound sensor for detecting the frequency of sound. In addition, Arduino was utilized in another study (Silva et al., 2015) for digital sound processing. Therefore, it is crucial to develop and utilize Arduino-based devices that are portable, sensitive, and cost-effective for the purpose of frequency detection over various ranges.

Chapter Four

Conclusion and Future Work

In this work, an audio frequency system was constructed using Arduino to detect frequencies. The result indicated that the developed device could detect the audio frequency at different ranges which help in advocating a better monitoring system. The project is based on a high sensitivity sound sensor in which five tuning forks with different frequencies tested on the device. In the future, more audio frequencies at different ranges will be examined. Additional devices can be developed using a straightforward and cost-effective technology that facilitates the advancement of scientific study in the field of frequency detection across various sectors. The Arduino platform can also be utilized in conjunction with other programs, such as MATLAB, to enhance the detection of audio frequencies with greater sensitivity.

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