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# Development of An Audio Frequency Meter with Arduino and MAX4466 Sound Sensor

Jufrida[1], Hebat Shidow Falah[1*], Nanda Hasbullah Sehab[1]

[1] Physics Education, Faculty of Teacher Training and Education, Universitas Jambi, Jambi, Indonesia.

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Corresponding Author:
Hebat Shidow Falah
hebatshidowfalah@unja.ac.id

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**Abstract:** Sound is one of the areas of study in physics education. Based on the data, it was found that there were difficulties in students' understanding and misconceptions in studying the concept of sound and its parameters. The aim of this research is to design a sound frequency measuring instrument that can visualize one of the parameters in the sound concept: frequency. The research carried out is a type of development research with a 4D model. The results of this research are a series of sound frequency measuring instruments based on Arduino and a Max4466 sound sensor. The validity of the tool was tested with an average validation value of 0.95 in a very good category. The results of calibration using a tuning fork show that the Audio Frequency Meter can consistently measure sound frequencies with an average measurement deviation of 0.514 Hz. Through the results of this research, it is hoped that it can become a reference in developing practical tools for sound concepts.

**Keywords:** Arduino; Frequency meter; Max4466 sensor; Measuring tool.

## Introduction

Physics is a field of study that is based on phenomena in the universe. Natural phenomena can be observed through the human senses. However, it turns out that some natural phenomena can be observed directly through the senses, while others can be observed with the help of tools. Parameters in observing natural phenomena that can be observed directly can be classified as concrete/real phenomena. On the other hand, parameters of natural phenomena that require the tools to observe can be classified as abstract phenomena. Based on these two phenomena, concrete phenomena can be more easily understood because the behavior of objects can be observed clearly. On the other hand, abstract phenomena have relatively higher difficulty in understanding because students require deeper understanding and visualization (high-order thinking).

Several studies found difficulties and misconceptions in learning abstract physics (Rico et al., 2021). Only 50% of students in Taiwan were able to understand the concept of sound correctly (Eshach at al., 2016). Students' difficulties in understanding the concept of sound is a problem that often occurs. Several studies show students' learning difficulties in abstract material, one of which is the concept of sound (Tanahoung, et al., 2009; Aygün & Hacıoğlu, 2022). Therefore, learning activities related to the concept of sound should use tools that can demonstrate the nature/behavior of sound. This is because not all the students are able to construct their knowledge abstractly (they are unable to convert abstractions into knowledge). Furthermore, students need media that can help illustrate the concept of sound. Several media that can help students understand include using analogies, etc (de-Almeida et al., 2014).

Sound is a phenomenon that has no form, but its symptoms can be captured using sensors that can sense vibrations. By understanding the behavior of sound and the parameters that accompany it, we can capture/measure the sound parameters and measure its value. This research is motivated by the fact that audio frequency meters are not available in several laboratories in Indonesia. In fact, an audio frequency meter is needed as a medium/practical tool to help students understand the concept of sound (Antoniadou

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et al., 2023; Barański & Wszołek, 2013; Bean, 1989; Nascimento et al., 2018).

The concept of sound frequency is an important concept for students to understand. This is because many physics concepts use the concept of sound: vibration frequencies, basic tones in organ pipes, and the Doppler effect. Apart from that, many things in everyday life use the concept of sound frequency: the measurement of the pitch of vocal, musical instrument scales, etc. There are various scales on modern musical instruments: there are diatonic, pentatonic, and chromatic.

Several developments in measuring instruments using Arduino on the sound concept have resulted in a sound level meter (Hanusukma et al., 2021; Donofre et al., 2018; Eridani et al., 2022; Jaewijarn & Wuttiprom, 2021; Mello et al., 2021), and the development of an Arduino-based instrument with MAX4466 sensor to measure audio noise levels (Chennareddy & Reka, 2021; Nadar & Sangam, 2019; Sousa et al., 2020). A simple microcontroller is needed to carry out the sound frequency calculation command. One that is quite popular is Arduino for measuring air quality (William et al., 2022; Piedrahita et al., 2014; Jha, 2020; Pasupuleti et al., 2020), measuring water quality (Jo et al., 2019; Mabrouki et al., 2020; Saravanan et al., 2018), measuring sound parameters (Çoban et al., 2019), etc. What has not been done is the development of an Arduino-based sound frequency measuring instrument using the MAX4466 sensor. We are trying to develop a frequency measurement tool using the Arduino Uno base using the MAX4466 sound sensor.

Arduino is an open-source platform used to construct and program many devices, and uses the simplified C++ programming language Arduino is an open-source platform used to construct and program many devices, and uses the simplified C++ programming language (Minns, 2013; Badamasi, 2014). We use Arduino Uno R3 which is a simple Arduino equipped with an ATmega328P microcontroller with 28 pins with a USB connection and can be operated using AC electricity using an adapter. This was chosen so that the Arduino Uno could be used flexibly (Barrett, 2013). We combine the MAX4466 sensor with Arduino to capture the frequency parameters of the sound.

It is important to develop this tool in an effort to improve the quality and increase the variety of measuring tools available in physics education laboratories. With the development of this instrument, learning activities and practical activities in the laboratory related to sound frequency parameters can be held. As a learning tool/media, this instrument can show the relationship between sound wave frequency and the pitch. This can help students to be able to construct their understanding through direct experience/observation. Thus, the abstract concept of sound can be studied more easily through its measurable parameters. For activities in the laboratory, the development of Audio Frequency Meter is very useful in increasing the wealth of measuring instruments that can be used in practical activities, or as instruments in research.

This initial research aims to develop a tool based an Arduino Uno and MAX4466 sensor that can measure sound frequency parameters. With this tool, we hope that it can become a visualization medium or imagination tool that can help students understand the concept of sound. Based on this background, research was carried out aimed at designing an audio frequency meter that can measure sound waves using Arduino and a MAX4466 sound sensor.

## Method

The research was conducted using the R&D method. We use 4D development model according to (Thiagarajan et al., 1974). This research model was chosen because it is related to the development of tools in the field of education. The development stages follow the 4D steps: define, design, develop, and dissemination. At the define stage, the steps taken are front-end analysis, learner analysis, task analysis, concept analysis, and specifying instructional objectives. At the design stage, the steps taken are constructing criterion-referenced tests, media selection, format selection, and initial design. At the development stage, the steps taken are expert appraisal and developmental testing. At the dissemination stage, the steps taken are validation testing, packaging, diffusion, and adoption.

Research activities were carried out at the Basic Laboratory of the Physics Education Study Program at Jambi University. The data used is calibration data for an audio frequency meter using a tuning fork. The tools used are Arduino Uno, MAX4466 sound sensor, Liquid Crystal Display (LCD), cables, and Arduino 1.8.16 software. The schematic instructions for the 4D development model in this research are presented in Figure 1.


**Figure 1.** Schematic instruction in 4D model

## Result and Discussion

Description of instrument development using the 4D development model are described below. At the define stage, a front-end analysis, learner analysis, task analysis, concept analysis, and specifying instructional analysis is carried out. These analyzes are conducted on the needs. Based on the front-end analysis, it was concluded that a tool was needed are developing an instrument that could facilitate the delivery of sound concepts in physics learning. On the learner analysis, an analysis of the characteristics of students who will be the targets for tool needs is carried out. Based on the needs and depth of material on the concept of sound, the target tools to be developed are students at the senior high school level, college students, or other parties who will carry out experiments related to sound. Based on this, the designed tool will be suitable if used as a practical tool in a basic physics laboratory. This conclusion is in accordance with research that shows that abstract concepts, including sound, can be helped using learning media/tools (Khasanah et al., 2019; Kusdiastuti et al., 2016; Rahayu, 2015; Susilawati et al., 2022).

At the task analysis, the analysis is carried out which aims to determine the media used. At this stage, it was concluded that the media used was Arduino-based electronic media with a MAX4466 sound sensor. This media was chosen because it has flexibility in power supply (can use an adapter or USB cable), and the compactness of the equipment, so it can be used in learning and practical activities. Thus, this tool will be in accordance with its initial purpose of facilitating the understanding of sound concepts.

Still in the define stage, the next step is concept analysis. This step examines the working concept of the tool to be developed, namely the audio frequency meter. This tool captures sound waves produced by a sound source. The sound waves captured by the MAX4466 sound sensor will be transmitted to Arduino to calculate the wave frequency. The results of the wave frequency calculation obtained are then forwarded to be displayed on the LCD.

The conclusion at the Define stage is the formulation of needs and objectives in an effort to improve the quality of learning on sound concepts, namely by using an audio frequency meter which can visualize sound parameters in the form of frequency numbers that can be notated. This tool is intended to be used in learning activities, both in class and in practical/experimental activities.

The next stage is the design stage. This stage begins with constructing criterion-referenced tests and media selection. The media chosen is electronic media with materials/hardware, audio frequency meter, and content/software. In this medium, tools are needed in the form of Arduino Uno, MAX4466 sound sensor, Liquid Crystal Display (LCD), cables, and Arduino 1.8.16 software.

In the format selection stage, we determining the media format for its use. The tools developed include computer-based formats. The final step in the design stage is the initial design. At this stage, an initial design is carried out regarding the tool to be made, in the form of a schematic and tool circuit design. The schematic circuit and initial circuit design is presented in Figure 2.

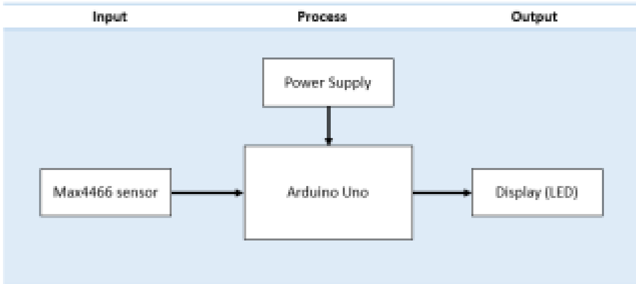


**Figure 2.** Schematic Circuit

At the development stage, the steps taken are expert assessment and developmental testing. At the expert appraisal stage, the validation was carried out by two experts on term of validity, practicality, and safety of the tool. Based on the validation data on Table 1, we found that the average validation from the expert are 0.95, which is in the range of very good category. Researchers also received suggestions for further tool development.

This stage is followed by the developmental testing stage, that carrying out trials on the tools that have been assembled. The developmental testing stage is carried out using instrument calibration on a tool that produces consistent pitch: a tuning fork. Based on the results of instrument calibration table (Table 2), an average measurement deviation of 0.514 Hz was obtained, and a maximum measurement deviation of 0.752 Hz. Based on the calibration data in Table 2, we found that the average measuring value on tuning fork 1 is 275.638 Hz with a deviation of ±0.062 Hz. The average measuring value on tuning fork 2 is 340.150 Hz with a deviation of ±0.430 Hz. The average measuring value on tuning fork 3 is 428.324 Hz with a deviation of ±0.511 Hz. The average measuring value on tuning fork 4 is 519.562 Hz with a deviation of ±0.297 Hz.

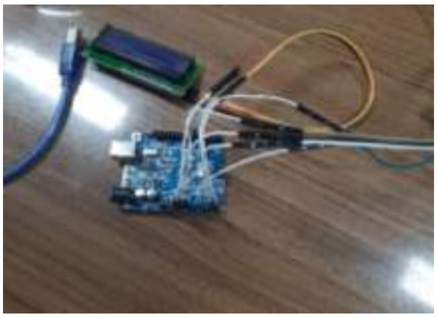

**Figure 3**. Initial circuit design

**Table 1.** Validation Score from Expert (Development stage)

| Evaluation items | Validation score A | Validation score B |
|---|---|---|
| In accordance with learning objectives | 4 | 4 |
| As required in the experiment guide | 3 | 4 |
| According to target users | 4 | 4 |
| The instrument components are complete | 4 | 4 |
| Easy to use | 4 | 4 |
| Easy to move | 3 | 4 |
| Easy to repair | 4 | 3 |
| Doesn't fall easily | 4 | 3 |
| Doesn't break easily | 4 | 4 |
| Do not use hazardous substances/gases | 4 | 4 |
| Sum | 38 | 38 |

The tuning fork used and the results of the instrument calibration using the tuning fork are presented in Figure 4 and Figure 5. At the dissemination stage, the product was packaged and distributed to the physics education laboratory at the Faculty of Teacher Training and Education, Jambi University. The working mechanism of this audio frequency meter can be divided into three main stages: input, processing, and output. In the first/input stage, sound waves are captured by the MAX4466 sound sensor and then transmitted in the form of a signal to the Arduino. At the processing stage, the received signal is processed using commands that have been entered into the Arduino. The processing results will be forwarded to the output using an LCD which will display the frequency numbers.

Several methods can be used to capture sound frequencies. One of the simplest is to use the tuning fork resonance method. This method is quite often used as a sound experiment in schools. The weakness of this experiment is that this method can only be carried out if the sound source has the same frequency as the tuning fork. If this were not the case, the tuning fork would not resonate.

**Table 2.** Callibration data on The Tuning Fork (Design stage)

| Tuning fork number | n-th measurement | Measurement value (Hz) | Average value (Hz) |
|---|---|---|---|
| 1 | 1 | 275.598 | 275.638 |
| | 2 | 275.700 | |
| | 3 | 275.695 | |
| | 4 | 275.655 | |
| | 5 | 275.543 | |
| 2 | 1 | 340.140 | 340.150 |
| | 2 | 339.920 | |
| | 3 | 340.580 | |
| | 4 | 340.100 | |
| | 5 | 340.010 | |
| 3 | 1 | 428.295 | 428.324 |
| | 2 | 428.205 | |
| | 3 | 428.835 | |
| | 4 | 428.083 | |
| | 5 | 428.204 | |
| 4 | 1 | 519.416 | 519.562 |
| | 2 | 519.559 | |
| | 3 | 519.859 | |
| | 4 | 519.369 | |
| | 5 | 519.609 | |

**Figure 4.** Tuning fork

**Figure 5.** Calibration data using tuning fork

The tool designed by researchers is an audio frequency meter with a MAX4466 sound sensor connected to an Arduino. This instrument is functioned as a frequency meter produced by a sound source. This tool is a measuring tool that can show the frequency related to the pitch of a musical instrument. One of the sound analyzer developments was carried out by (Mello et al., 2021), who developed a prototype of a noise monitoring device using a digital I2S MEMS microphone and a microcontroller compatible with Arduino.

The results obtained show that the designed tool is capable of measuring the frequency captured from a particular sound source. In this way, the concept of sound can be visualized, especially those related to pitch notes in the form of sound frequency numbers. This is expected to improve the visualization and understanding of abstract physics concepts in the concept of sound. Furthermore, sound frequency parameters can be explored and identified in more depth by students in learning activities.

Based on the sensor specifications used (MAX4466), the frequency interval that can be measured is in the range 20-20,000 Hz. This range corresponds to the range of sound frequencies that can be heard by the human ear. Thus, the main objective of this instrument, namely labeling sound frequencies heard by the human ear, has been achieved. The sensitivity of the instrument will depend on the sensitivity level of the sensor used, and the noise around the device. The louder the sound around the device, the less the device's sensitivity will be. Based on calibration data that has been carried out using a tuning fork, the audio frequency meter is quite accurate in measuring sound frequencies (Table 1). The maximum measurement deviation occurs at tuning fork number 3, with a deviation value of ±0.511 Hz.

## Conclusion

The result was the development of an Arduino-based sound frequency measuring instrument with a MAX4466 sound sensor. This audio frequency meter has been validated with an average value of 0.95 in the very good category. Based on experiments and calibration using a tuning fork, accurate measurement results were obtained with an average measurement deviation of 0.514 Hz and a maximum measurement deviation of 0.752 Hz. This measuring instrument can be used as a medium that can assist learning activities in the form of demonstration media, practical media, or as an experimental tool in the laboratory. Suggestions for further research include variations in sensors and other combinations of components, for example by adding a screen that can display waveforms and parameters.

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**Author Contributions**
Conceptualization: J., H. S. F., and N. H. S.; formal analysis: J., H. S. F., investigation: N. H. S.

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**Conflicts of Interest**
The authors of this article declare no conflict of interest.

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