



Physics Experiment using Arduino Microcontroller: Sound Intensity Level Measurement

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ABSTRACT :

Experiments need to be properly resourced as they are an essential teaching tool and learning process in physics education. But unfortunately, most faculties and high schools lack technical resources like a laboratory and do not have the appropriate equipment. Specially to filter unwanted sound frequency. Noise is one of the foremost common health hazards. It can cause hearing system disorders, disruption of concentration, stress, interference with auditory communication, and blood pressure increased. In worse case hearing impairment or total hearing loss. Therefore, a measuring system is required to display or monitor noise levels and study the physical properties of sound. The aim of this research is to invent a sound level meter tool monitoring noise levels in decibels. The information acquisition system consists of a Keyes-038 microphone sound sensor module, Arduino Uno microcontroller, display LCD and display LED. The microphone converts the sound intensity to audio voltage. Sound detection using the module is an electret microphone condenser with a sensitivity of -66 dB relative to 1V/ μ bar. The output from the microphone sound sensor is then connected to the Arduino Uno board. The measurement results are displayed on LCD. The result shows that at 1 kHz frequency produces an instantaneous sound pressure level of 94 dB. Additionally, there are seven LED indicators. So, 7 settings for managing LED display in Arduino. The result of the research will develop an instrument that is capable of detecting and displaying sound amplitude with a measuring range of 44-105 dB.

Keywords: Microphone Sound Sensor, Arduino Uno, Sound Intensity, Sound Level, Sound Level Meter

Introduction

Understanding the properties of sound for the students in high school is not easy. What is a sound? Sound is a mechanical wave that travels through air and is perceived by the human ear, but it can be noise, unwanted sound frequencies that can be very annoying (Lapono & Pingak, 2018). The noise and sound are different depending upon the sound frequency required by listener and the range of frequencies emitted. Noise can occur in various places, for example, in the work zone, dense population or busy traffic. Environmental health requires the monitoring of sound to avoid sound pollution. Sound pollution is one of 4 kinds pollution; noise is all unwanted sound frequency sourced from tools used in production processing in the work place that can at certain levels cause hearing loss. The level of sound intensity can be measured using a measuring instrument called a sound level meter (Nurjannah, Harijanto, & Supriadi, 2017). But unfortunately, in our faculty and in many schools in Laos, we don't have these instrument for measuring sound level. But surprising with the development of the electronics world that is growing rapidly, creating a digital technology that becomes the beginning of the creation of sophisticated devices called microcontrollers. The most popular and widely used microcontroller is the Arduino Uno microcontroller. Arduino is designed to facilitate the use of electronic devices in various fields at and low cost. Based on this, we will create a sound level meter with an Arduino Uno board and used it in teaching physics.

The purpose of this study is to create a sound intensity level meter using an Arduino Uno microcontroller to detect sound and measure its amplitude in decibels.

Sound intensity and sound pressure level

Sound: Sound wave is created by perturbation of the medium. It is a mechanical propagated vibration wave transmitted through a medium, gas, liquids or solids or combination. It transfers energy from one molecule to the other. But it doesn't transport a physical material only vibration frequency. Sound can be detected or heard by the human ear in a normal circumstance ranging from 20 Hz-20 kHz (see figure 1). The human ear hears 2 aspects of sound, loudness/amplitude and frequency/pitch. Loudness is related to energy in sound waves which is amplitude. The pitch is frequency of the sound. If it is high like the sound of violin or flute, or whether the sound is low as the sound of a bass and a drum. Normally that the more aged a person then the person is unable to hear sound with high frequency (Nurjannah, Harijanto, & Supriadi, 2017). Sound intensity is the energy carried by sound waves per unit of time through the change of each area, the intensity is comparable with the amplitude of the wave, express as W/m^2 and define by:

$$I = P/A = P/(4\pi r^2) \quad (1)$$

It is well known that the human ear is sensitive to different intensities of sound. Thus, a logarithmic intensity scale (β) is used, which is defined as (Nurjannah, Harijanto, & Supriadi, 2017), (Young & Freedman, 2020):

$$\beta = 10 \log (I/I_0) \quad (2)$$

Where $I_0 = 10^{-12} \text{ W/m}^2$ is the reference sound intensity based on a human hearing threshold of 20 Hz, I the actual sound intensity, the maximum human hearing is 20 kHz relate to $I = 1 \text{ W/m}^2$. Sound intensity levels (β) are expressed in **decibels (dB)**. A decibel is 0.1 of a *bel (B)*, a unit named for Alexander Graham Bell. The bel is inconveniently large for most purposes and the decibel is the usual unit of sound intensity level (Young & Freedman, 2020). The auditory field of human hearing is 0-120 dB figure 1.

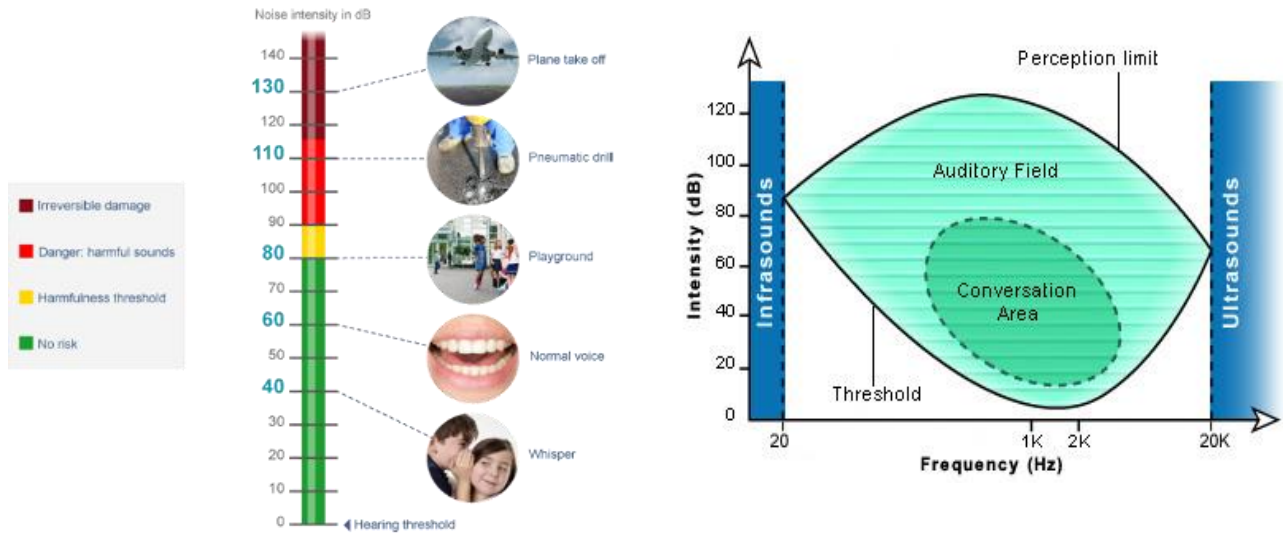


Figure 1 Human auditory field (Pujol, 2018)

Sound pressure level (SPL): Sound pressure level or acoustic level is a logarithmic scale, measure of the effective pressure of a sound relative to a reference value. It is denoted L_P and measured in decibel above a standard reference level:

$$L_P = 20 \log (P/P_0) \quad (3)$$

Where L_P is sound pressure level in dB, P is the effective sound pressure in Pa and P_0 is the standard reference sound pressure ($P_0 = 2 \times 10^{-5} \text{ Pa}$, which is corresponding to the human hearing at 1 kHz).

Microphone Sensitivity: The microphone only converts changes in sound pressure into audio voltage. Microphone sensitivity is defined as the amplitude of the output signal at an incident sound pressure of 1 Pa (94 dB) at 1 kHz. Sensitivity is measured in dB relative to 1V/Pa. Some microphones are measured with a microbar (μbar). Like Pascal, the microbar is a measure of pressure. The international standard defines 1Pa as 94 dB SPL. The microbar references 74 dB SPL (Lapono & Pingak, 2018). The voltage level (L_V) is defined as follows:

$$L_V = 20 \log (V/V_0) \quad (4)$$

Where V is the voltage being measured and V_0 is the voltage reference level.

Design tools: hardware and software

3.1 design of hardware:

The design of this sound level measurement device composed a microphone sound sensor module, an Arduino Uno microcontroller, display LCD, LED and breadboard. The microphone sound sensor will capture the sound from the sound surrounding (or sound source) and will produce a signal. The signal will be sent to the Arduino Uno microcontroller that is connected to the display LCD and LED indicator. The block diagram of system shows in figure 2:



Figure 2 Block diagram of the system

Microphone sound sensor is based on analog and digital type Keyes-038. The voltage source is 3.3-5V, it has 4 connections, detail can be seen in the figure 3. The functionality of the sensor, it has 3 main components on its circuit board. First the sensor unit at the front of the module which measures the area physically and send an analog signal to the second unit, the amplifier. The amplifier amplifies the signal, according to the resistant value of the potentiometer and sends the signal to the analog output of module. The third component is a comparator which switches the digital out and the LED if

the signal falls under a specific value. We can control the sensitivity by adjusting the potentiometer. This sensor doesn't show absolute value. It is relative measurement (Joy-IT, n.d.).

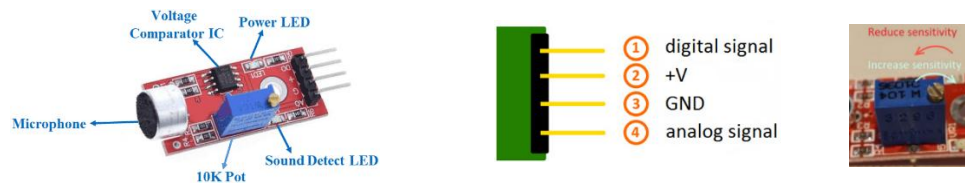


Figure 3 Microphone sound sensor module type KY-038 (Majju, n.d.)

Arduino Uno board: There are several kinds of Arduino boards available, the original board is more expensive than the clone one. So, in this research use the Arduino Uno clone board based on ATMEGA328P CH340, its components are show in the figure 4. There are 14 digital input/output pins and 6 analogs input pins. The Arduino Uno board is powered from your computer's USB port or by connecting 9V AC adapter or 9 V battery 2.1mm jack. Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino board are able to read inputs - light on a sensor and turn it into an output - turning on an LED. We can tell our board what to do by sending a set of instructions to the microcontroller on the board. To do so we use the Arduino programming language and the Arduino software (IDE), based on processing (Arduino, n.d.).

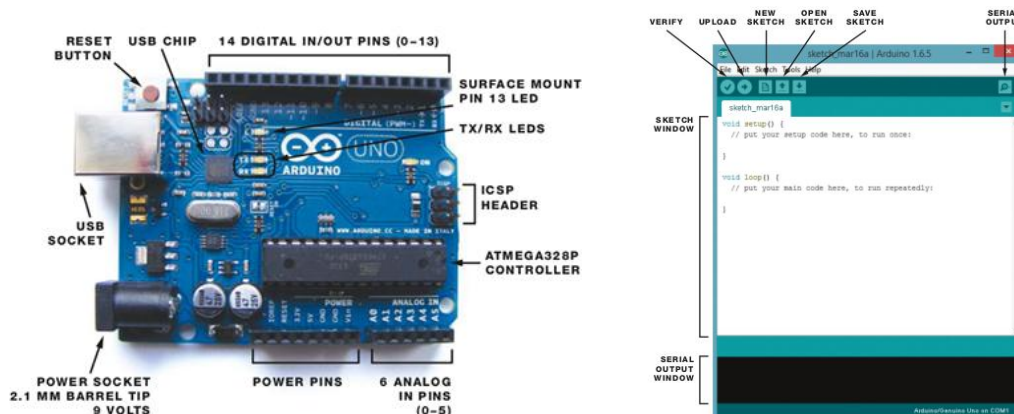


Figure 4 Arduino Uno microcontroller (Geddes, 2016)

LCD screen: LCD display is an electrical device that has been configured in a plastic or glass container so on provide the looks of dots, lines, symbols letters, numbers and image. LCD function to display a data of the detection by the sensor, display text or display the menu within the microcontroller application, in this research, we used an LCD module with 16 columns and 2-line display with low power consumption (Amazon, n.d.) figure 5.



Figure 5 LCD 16x2 display

LED (Light Emitting Diode): diode is a simple component produced by semiconductor material. Most of material used to make diode is that the silicon. diode is composed of P-type and N-type. these PN junctions only carry current if given a forward bias voltage, the anode of power supply is connected to the P-type, while the cathode is connected to the N-type. This characteristic PN junction causes the diode to be used as a current rectifier. LED pole setting should not be inverted because if it's reversed LED won't activate. In keeping with the resulting of color character, the allowed current ranges are 20-40mA and a voltage of 1.6-3.5V (Nurjannah, Harijanto, & Supriadi, 2017).

Table 1 Connection of LED and Arduino Uno

Pin of Arduino Uno	4	5	6	7	8	9	10
Pin of LED	LED1	LED2	LED3	LED4	LED5	LED6	LED7

3.2 Design of software:

The Arduino C program (Arduino IDE) consists of 2 functions, namely setup () and loop (). The setup () function is run every time the Arduino board is turn on. While the loop () function is run continuously as long as the Arduino board lives. The computer will send measurement command to the microcontroller vis serial communication. The flowchart for Arduino Uno programming is show in the Figure 6.

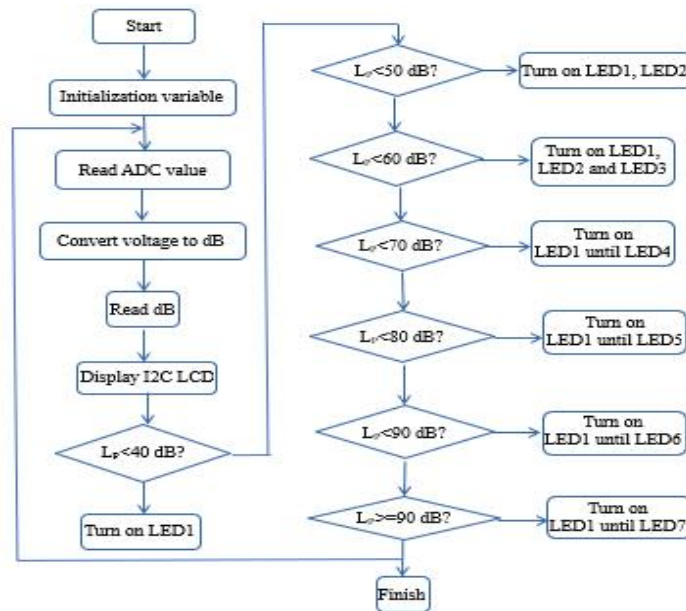


Figure 6 Flowchart for sketch

Result and discussion

Microphone sound sensor module testing:

To determine the sound level, take the signal's peak to peak amplitude and convert it to voltage (V), then to decibel (dB). The electret condenser microphone in the microphone sound sensor module type Keyes-038 has a sensitivity of -66 dB in 1V/ μ bar. In comparison to the microbar indicator, it will increase 20 dB in pascal. As a result, -66 dB (0dB=1V/ μ bar) sensitivity is similar to -46 dB (0dB=1V/Pa). The transfer factor is calculated by (sengpielaudio, n.d.):

$$\text{Transfer factor} = 10^{(\text{sensitivity}/20)} = 10^{(-46/20)} = 0.005012 \text{ V/Pa}$$

By using equation (4), for example, if the peak-to-peak voltage is 3.3V, the voltage level is:

$$L_p = 20 \log (3.3/0.005012) = 56.37 \text{ dB.}$$

So, the sound pressure level (SPL) is: SPL = -46+56.37+94=104.37 dB

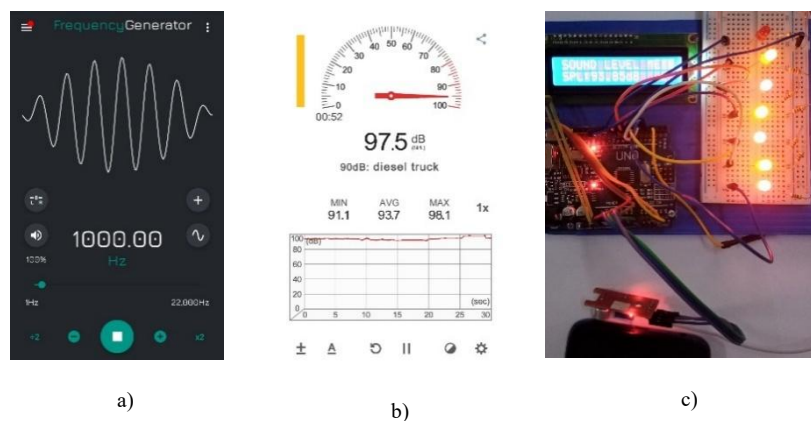


Figure 7 sound source, sound testing with Android application and microphone sound sensor

1 Pa equal 94 dB at 1kHz frequency, according to the standard sound pressure level reference. The microphone sound sensor will be tested based on this, and if given a sound source with a frequency of 1 kHz, it will output 94 dB. A sound sensor with a frequency of 1kHz is used to calibrate the

Testing the LCD Display: To test this LCD display, you need to create a sketch that tells the Arduino to read the output of the sound sensor and display the results on the LCD. The display accuracy is 2 digits. The output of the sound sensor is read every second, and a reading example is shown in Figure 9.

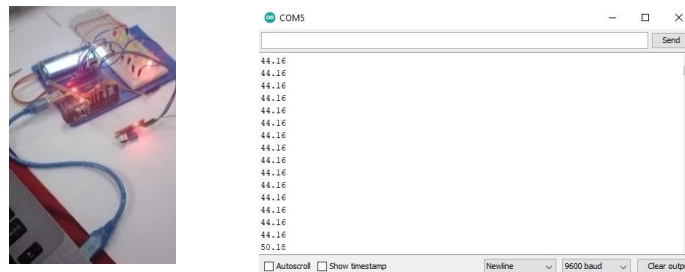


Figure 8 set up and result test the sketch for analog microphone sound sensor type keyes-038

L _p (dB)	LED1	LED2	LED3	LED4	LED5	LED6	LED7
<50	ON	OFF	OFF	OFF	OFF	OFF	OFF
<60	ON	ON	OFF	OFF	OFF	OFF	OFF
<70	ON	ON	ON	OFF	OFF	OFF	OFF
<80	ON	ON	ON	ON	OFF	OFF	OFF
<90	ON	ON	ON	ON	ON	OFF	OFF
<99	ON	ON	ON	ON	ON	ON	OFF
>=99	ON	ON	ON	ON	ON	ON	ON

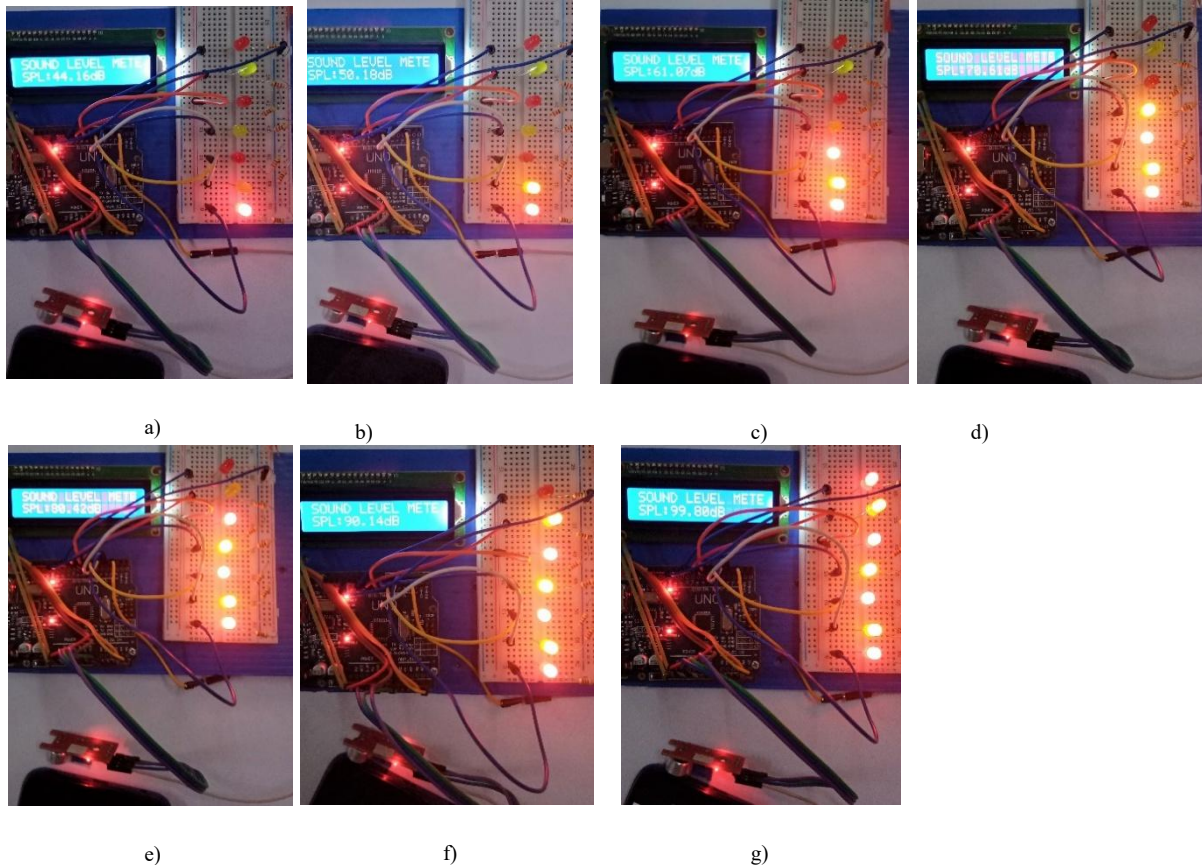


Figure 9 result of measurement when sound level is at a) 44 dB, b) 50 dB, c) 61 dB, d) 70 dB, e) 80 dB, f) 90 dB and g) 99 dB. This is the outcome of the table 2 setting.

Checking the LEDs array: using the Arduino Uno microcontroller, up to 7 configurations can be selected from table 1. Only LED1 will be activated if the sound level is lower than 50 decibels (dB). Two LEDs will turn on if the sound level is below 60 dB. Three LEDs are turned on if the sound level is less than 70 dB. Four LEDs will turn on if the sound level is less than 80dB. If the sound level is lower than 90 decibels, five LEDs turn on. Six LEDs are activated if the sound level is below 99dB. If the sound level exceeds 99 decibels, all LEDs illuminate. The summary is shown in table 2.

Discussion:

advantage of using a smartphone and an Arduino microcontroller include: A smartphone is widely accessible by students, portable, and has no time constraints, and there are numerous built-in sensors with high precision available. While an Arduino microcontroller is very inexpensive, it is simple to program, there are several sensor kinds to choose from, it is possible to combine sensor, it is portable, has no time constraints, and is an open-source platform. There are several advantages, including lower capital costs for equipment, reduced time and personnel costs for experiment setup, adjustable location and time for repeated experiments, individual students' hand-on learning experiences, and STEM education in high school. The long-term objective is to empower instructors and students to design their own experiments and engage them in a self-sustaining internet of things mode (IOT).

Conclusion

Based on the results of the research, by comparing of result between design tools and sensor via application on mobile phone show results that are quite similar. So, it was concluded that the design tool can work well. With ability of the device to measure the 44-105 dB range with notification in 7 LED indicators.

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