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Sound Intensity Measuring Instrument Based on Arduino Board with Data Logger System

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***Abstract*—** *The government set the average sound intensity in the morning and evening around the non-noise places of worship is 55 dB. Measuring instrument the intensity of sounds around places of worship during the day and night is needed to record data during the day and night. Arduino board is a combination of hardware and software with low resource requirements, which allows user to interact with objects (physical quantities) in the vicinity. Keyes- 037 microphone sound sensor module is a high-sensitivity sound detector. SKU-316412 is a data logging system equipped with an SD card interface for memory cards capable of storing 32 MB to 8 GB of data. The arduino and it's both modules can be assembled into a measuring instrument and sound recording intensity to be placed in the desired places.*

***Keywords*— Sound Intensity, Noise Level, Sound Level Meter, Arduino, Microphone Sound Sensor, Data Logger System.**

I. INTRODUCTION

Environmental health is an important factor in this life. In line with the population grows rapidly, unbalanced in the environment increased too. Environmental health can be disturbed by the existence of environmental pollution or so-called pollution. Pollution can be categorized into 4 kinds, namely: air pollution, water pollution, soil pollution, and sound pollution. Sound pollution or we can call it noise is an unwanted noise and may interfere with human hearing[1].

Noise can occur in various places. For example the noise that occurs in places of worship. Noise in the place of worship can be affected by several factors, such as: the busy traffic of vehicles on the highway near by the mosque, the number of people who pass around the mosque, and sound system with a loud voice placed in the mosque. Excessive intensity of this sound can certainly distrub the concentration of worshipers in performing worship. The level of sound intensity can be measured using a measuring instrument called Sound level meter.

Along with the development of the electronics worlds that is growing rapidly, created a digital technology—that became the beginning of the creation of sophisticated devices called microcontrollers. The most popular and widely used microcontroller brand in the world today is the arduino microcontroller. Arduino is designed to facilitate the use of electronic devices in various fields. Based on this, an SLM has been created with an Arduino board based data logger system, which can retrieve and store data within a predetermined time. The main components of SLM consists of sound sensor, devices for display, and system data logger. The captured data can be stored automatically in the system data logger, which consists of SD module and SD card.

II. MAJOR HEADING

1. Sound

Sound is a series of waves propagating from the source of vibration as a result of changes in density and also air pressure[2]. Sound can defined as mechanical vibration waves in air or in solids which in the process produce sound and can be heard by the human ear in normal circumstances ranging from 20-20.000 Hz[3].

There are two aspects of the sound heard by the human ear. This aspect is loudness and altitude. Loudness is related to energy in sound waves. The pitch of the sound states whether the sound is high like the sound of a flute and a violin, or whether the sound is low as the sound of a bass and a drum. Physical quantity that determines altitude is frequency. Human ear hearing range is between 20 Hz to 20,000 Hz. A tendency that the more aged a person, then the person is increasingly unable to hear sounds with high frequency[4].

1.1 Intensity and Sound Intensity Level

Sound intensity is the energy carried by sound waves per unit of time through the change of each unit area. Intensity is comparable with the amplitude of the wave and has a unit of Watt/meter^2 (W/m^2)[5]

$$I = P/A \qquad (1)$$

It is known that the human ear is sensitive with various intensities of sound. Thus a logarithmic intensity scale (β) is used, which is defined by the equation:

$$\beta = (10\ \text{dB}) \log \frac{I}{I_0}$$

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in this equation, I_0 is the specified reference noise intensity of 10^{-12} W/m^2, based on a minimum human hearing threshold of 1000 Hz. The sound intensity level is expressed in decibels (dB). The value of one decibel is equal to $\frac{1}{10}$ bel[6].

The intensity and intensity levels for a number of common sounds are known as follows:

Table.1: Several levels of intensity and intensity levels of sound[7]

The Source of Sound	The Intensity Levels	Intensity of Sound
Jet plane at a distance of 30	140	100
Threshold of pain	120	1
Loud rock concert indoors	120	1
Sirine at a distance of 30 m	100	1×10^{-2}
The interior of the car,	75	3×10^{-5}
Busy road traffic	70	1×10^{-5}
Ordinary conversations,	65	3×10^{-6}
Slow radio	40	1×10^{-8}
Whisper	20	1×10^{-10}
Leaf rustling	10	1×10^{-11}
Hearing limit	0	1

1. Noise

Noise can be defined as an undesired sound where its duration, intensity, and quality lead to various impacts on the physiology or psychological of humans and other creatures[8].

There are various sources of noise. Source of noise based on its location is divided into two, such as[9]:

a. An interior noise source is sourced from humans, household appliances, or building machines.

b. Outdoor noise is a noisy source derived from traffic, transportation, industry, mechanical tools seen in buildings, buildings, road works, sports activities and others outdoors or buildings. The main effect of noise is on the senses of the listener, where the damage that occurs consists of: 1) Temporary loss of hearing and can be recovered if the noise can be avoided, 2) People become immune to noise, 3) Buzzing ears, and 4) Settled and not recovered. In addition, noise also causes loss of concentration and increased fatigue at low sound frequencies. While at high frequency can cause misinterpretation when talking to others[10].

At the noise measurement, an instrument called a sound level meter is used. This tool is used to measure noise between 30-130 dB and from frequency 20-20.000 Hz. Sound Level Meter is used to measure the level of sound intensity. The parts consist of microphones, amplifiers, some types of circuits, and a calibration of measurements into decibels[11].

Fig.1: Sound level meter[12]

2. Microcontroller

Spesifically, it can be said that a microcontroller is a digital electronics device that has input, output, and controlled programs that can be written and deleted in a special way. In terms of its use, the microcontroller system is more widely used in deterministic applications. It means that this system is used for certain purposes only, such as a PID controller on industrial instrumentation, data communication controller on distributed control system, and so on[13].

The application of microcontroller among others in the following fields:

a. Automotive: engine control unit, air bag, speedometer, and alarm security system

b. Household and office supplies: remote control, washing machine, and microwave

c. Controlling equipment in the industry

d. Robotics

The most widely used microcontroller is an 8 bit microcontroller, with the brand Motorola 68HC05/11, Intel 8051, Microchip PIC 16, and which is very popular recently from the Atmel AVR family[14].

3. Arduino Board

Arduino is an open source electronic board, based on flexible and easy-to-use software and hardware, aimed at artists, designers, electronics enthusiasts, and anyone interested in creating interactive objects or environments[15].

Fig.2: Arduino IDE Software

Arduino/Genuino Uno is a microcontroller board based

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on ATmega328P, which has 14 digital input/output pins (6 of which can be used as PWM output), 6 analog inputs, 16 MHz crystal oscillator, USB connection, power jack, ICSP header, and button Reset. Detail arduino uno can be seen in Table 2, with the following specifications:

Table.2: Specification arduino uno

Part	Spesification
Mikrocontroller	ATmega328P
Operated voltage	5V
Input voltage	7-12V
Input voltage (limit)	6-20V
Pin digital I/O	14 (provide 6 PWM output)
Pin PWM digital I/O	6
Analog pins input	6
DC current per I/O pin	20 mA
DC current for 3.3V pin	50 mA
Flash Memori	32 KB (ATmega328P) that 0.5 KB used by
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Time velocity	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Fig.3: Arduino uno ATmega328P

4. Sound Sensor

Sound sensor usually used for detecting noise in surrounding environment. Arduino can collect the output signal from the sensor and run it simultaneously. Sound sensor can be used to create multiple interactive works such as "clap and ringer" to find lost keys or create a remote control if a buzzer is added. This sensor works by analyzing the sound. Specification tool as follows[16]:

a. Voltage source: 3.3V to 5V
b. Function: Detects the intensity of the sound quickly
c. Interface: Analog
d. Size: 22 x 32 mm (0.87 x 1.26 inches)

Fig.4: Analog sound sensor type KY-037[17]

5. LED (*Light Emitting Diode*)

Diode is a simple component made of semiconductor materials. Silicon is the most of the materials that used to make diode. Diodes are composed of material relations of type P and type N. These PN junctions only
carry current if given a forward bias voltage, by means of the P type material (as anode) connected to the positive terminal of the power supply, while the N type material (as the cathode) is connected to the negative terminal of the power supply. This characteristic PN junction causes the diode to be used as a current rectifier[18].

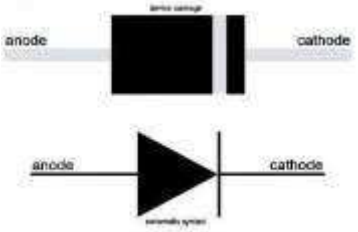

Fig.5: LED shape and emblem (Light Emitting Diodes)[19].

*Fig.6: LED (Light Emitting Diode)[20].*LED pole installation should not be inverted because if it is reversed, LED will not turn on. If higher current flowing on the LED, the brighter light will be generated. However, the allowed current ranges between 20 mA - 40 mA and a voltage of 1.6 Volt - 3.5 Volt according to the resulting color character. Here is a working voltage on an LED, based on the resulting color[21]:

1. Infrared : 1.6 V
2. Red : 1.8 V - 2.1 V
3. Orange : 2.2 V
4. Yellow : 2.4 V

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5. Green : 2.6 V
6. Blue : 3.0 V - 3.5 V
7. White : 3.0 V - 3.6 V
8. Ultraviolet : 3.5 V

7. LCD (Liquid Crystal Display)

LCD (Liquid Crystal Display) is an electronic device that has been configured in a plastic or glass container so as to provide the appearance of dots, lines, symbols, letters, numbers, and images. LCD is divided into two kinds based on the shape and appearance, namely Text-LCD and Graphic-LCD. Display on Text-LCD in the form of letters and numbers. While the shape of the display on the Graphic-LCD in the form of dots, lines, and images[22].

LCD function to display a value of the detection by the sensor, display text, or display the menu in the microcontroller application. LCD used in this research is a type of LCD M1632. The M1632 LCD is an LCD module with a 16 x 2 line display with low power consumption[23].

Fig.7: LCD Display[24]

8. Micro SD Module

SD module or SD Card Shield is a module used to send data to SD card. Pinout from SD module can be connected to arduino and other microcontroller, so it is useful to increase data storage and data logger (data logger system). This module can be directly connected to the arduino. The specialty of this SD module is[25]:

a. There are modules for standard SD card and micro SD (TF) cards
b. There is a switch to select a flash card slot
c. Can be connected directly to arduino
d. Can be used for other microcontoller

Micro SD Module suitable with TF SD card (used in mobile phone) and it is the smallest card in the market. SD module can be used for various applications such as data logger, audio, video, and graphics. This module will greatly expand the arduino capacity with small memory usage. This module has SPI interface and 5V power supply in accordance with arduino UNO/Mega. SD Card Shield or SD Module is the solution to send data to SD card. The features of this Micro SD Module are[26]:

a. Working on voltage : 5V
b. Size : 20 x 28mm (0.79 x 1.10 ")
c. Interface : SPI
d. Suitable used for : MicroSD(TF)

Fig.8: SD module type SKU-316412[27]

9. Micro SD

One example of external memory is the SD Card. SD Card is one part to compile a data logger system.

We can store long-term data on SD card. Comparison of storage capacity on arduino and SD card chips is very much different. An arduino chip has a permanent storage EEPROM that has a capacity of only a few hundred bytes, very small if we compared it with the capacity of data that can fit an SD card of several gigabytes. The price of SD card is very cheap and easy to obtain in various electronics stores. SD card is the right choice for long- term data storage with large capacity[28].

Fig.9: SD card [29]

10. Resistors

In a circuit of electronics, resistor has various functions, such as current limiting, voltage dividers, and current measurements. Each electronics component has a maximum current limit that can pass through it. Current limiting resistors are used to prevent excessive current damage. Examples of resistors as current limiting are used in LED current limiters[30].

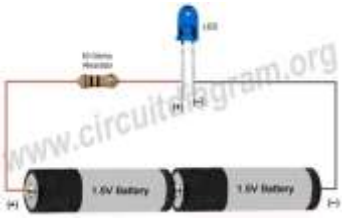

Fig.10: Resistor circuit as LED current limiter[31]

The resistor value as LED current limiter can be used using the following formula:

$$R = \frac{V_c - V_{LED}}{i} \quad (3)$$

where R is the resistor value (Ω), Vc is the source voltage (volts), VLED is the voltage reducing by the LED (volt),

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and *i*is the ideal current required by the LED (20-40 mA)[32].

III. METHODOLOGY

1. Place and Time of Research

The process of planning, designing tools, and taking data are located at the author's residence, at the Advanced Physics Laboratory in Physics FKIP University of Jember (UNEJ), and in Sunan Kalijaga Mosque Jember. The research will be conducted in the even semester of the academic year 2016/2017.

2. Tools and Components

It takes some tools and equipment components to make SLM design. The required tools and components are listed in Table 3 below:

Table.3: Tools and Components

No.	Component Type	Spesifications	Total
1.	*Sound Level Meter* (type SL-	30-130 dB	1
2.	Arduino uno	-	1
3.	*Sound sensor* type KY-038	-	1
4.	SD *Module* tipe SKU-316412	-	1
5.	SD *Card*	8 GB	1
6.	LED	Output colors: red, yellow, and	3
7.	LCD	16 x 2	1
8.	Trimpot	1KΩ	1
9.	*Power Bank*	*Output voltage* 5V	1
10.	Resistor	330 Ω	3
11.	Jumper cable	*male to male* dan *female to male*	sufficiently
12.	*Project Board*	-	1
13.	Length meter	-	1
14.	Solder	-	1
15.	Lead	50 cm	1

(Source: author)Basic Concepts of System Design

The design of this tool is determined by measuring the level of sound intensity with a distance of few meters from the sound source with a different state of time and atmosphere, utilizing SLM factory production as calibrator and sound sensor as sound source input controlled by arduino uno microcontroller, with output display on LED , LCD, and data logger.

3. The Descriptions of System Work

Broadly, the designed of Sound Level Meter (SLM) equipped with data logger system based on arduino board is made to measure the level of sound intensity in a place, so that the noise level in that place can be detected and impact on the increased comfort in our activity and reduce damage hearing due to excessive exposure to noise.

The design of this tool begins with try to understand of indoor sound acoustics, with different air temperatures, and predetermined spacing. The tool is calibrated using SLM factory production as a calibrator. Then, the results analyzed and processed into tabel and observational charts.

4. System Block Scheme

The design of diagram block is shown in the following figure:

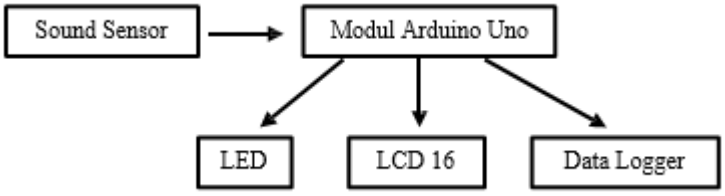

Fig.11: Block diagram of the tool design

5. Design of circuit tools

Draw a set of tools in the following drawings:

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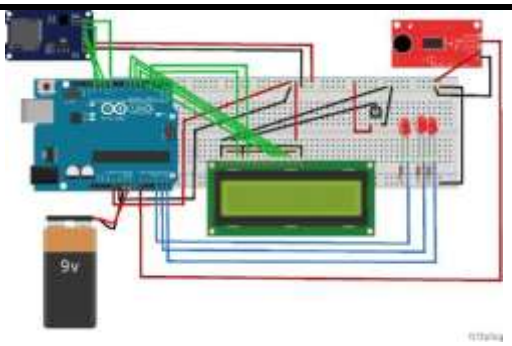

Fig.12: Design tool

6. Data retrieval

There are 2 kinds of data taken. The first data is assembled assembly calibration data compared to SLM production factory. The second data is a sample of data measuring the intensity of sound at Sunan Kalijaga Mosque
in Jember during the day and night. Data are placed in Table 4 and Table 5.

IV. RESULT AND DISCUSSION

In this chapter will be discussed about the results of calibration of SLM tools of researchers design with SLM production factory. In addition, we also discussed the sample data taken at the Sunan Kalijaga Mosque during the day and night, as described in the methodology chapter.

1. Tool Circuit

Sound Level Meter with Arduino Board based on Data Logger system has been created, with the following series:

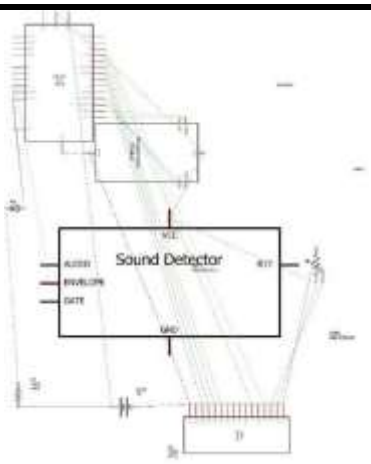

Fig.13: Tool circuit made with Fritzing software[33]

2. SLM Calibration Results Researcher Design with Standard SLM Calibrator

The SLM accuracy test of the research design is done by calibrating the measuring result using the calibrator of SLM DEK-O type SL-130. Demonstrated graph of normality as follows:

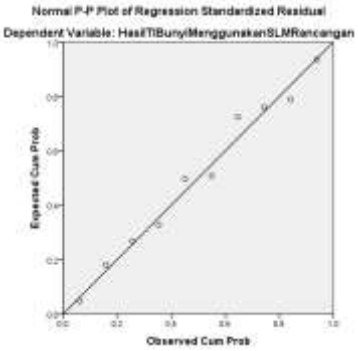

Fig.14: Normalized graph from data

The output from both device were normalized to measure the sound intensity level.
Below is a calibration data table:

Table.4: Calibration Data Used Standard SLM

Pengukuran ke-	Hasil TI Bunyi Menggunakan SLM Pabrik	Hasil TI Bunyi Menggunakan SLM Rancangan	%error
1	72.4	76.33	0.05149
2	72.9	70.88	-0.0285
3	79.6	73.55	-0.0823
4	74.2	73.02	-0.0162
5	73.7	74.49	0.01061
6	73.7	76.33	0.03446
7	73.4	73.55	0.00204
8	73.4	72.48	-0.0127
9	73.4	78.01	0.05909
10	73.4	75.91	0.03307

(Source: author)

3. The Sample Result of measuring Sound Intensity Level In Sunan Kalijaga Mosque

The Sample result from Measuring Sound Intensity Level in Sunan Kalijaga Mosque is shown below:

Table.5: The Sample result from Measuring Sound Intensity Level in Sunan Kalijaga Mosque

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The Number of Measure	Sound Intensity Level at d	Sound Intensity Level at night
1	62.2	66.34
2	57.39	68.3
3	69.26	59.43
4	66.23	57.13
5	61.05	71.19
6	74.12	66.34
7	58.54	57.39
8	62.37	64.15
9	63.09	66.18
10	74.85	67.57
11	78.7	63.57
12	66.23	63.26
13	69.11	62.37
14	62.37	61.47
15	63.71	77.08
16	77.55	73.37
17	78.74	74.96
18	63.26	69.65
19	75.36	73.34
20	63.99	64.6
21	62.37	71.33
22	76.97	74.85
23	59.43	70.07
24	67.57	86.56
25	66.79	76.19
26	68.84	57.39
27	66.87	71.25
28	73.34	61.47
29	71.87	64.88
30	74.23	77.08
AVERAGE	67.88	67.95866667

(Source: author)

Graph of the Sample result from measuring sound intensity level in Sunan Kalijaga Mosque at day and

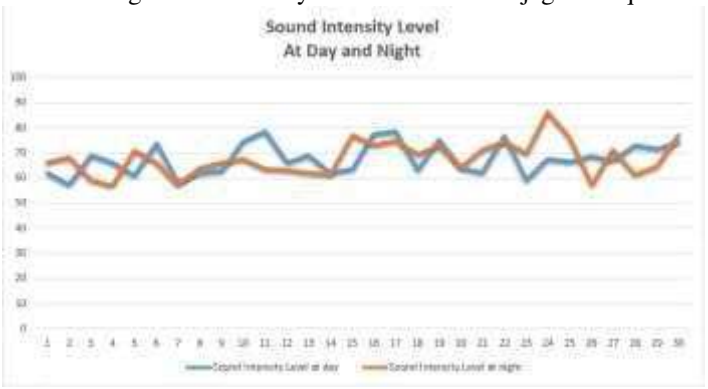

Fig.15: Graph of sample data from measuring sound intensity level

(Source: author)

V. CONCLUSION

Based on the data obtained from the calibration, it can be concluded the output data from SLM that made by the researcher are near by the output data from SLM standart that produced by factory. This is verify that SLM that made by the researcher has been successfully performed as a sound intensity level measuring devices.

In the data at the second table, we found that the intensity level in the Sunan Kalijaga mosque in the morning and the evening have a fluctuating value, depending on the number of sound sources. In this research, the source of sound is a vehicle that passes on the highway. Results can be seen on the graph. In addition, it can

be concluded also to increase the average in the Sunan Kalijaga mosque in the morning and evening exceed the standard level for places of worship set by the government, which is 55 dB[34].

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