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Luxmeter Equipped with Proximity Sensor for Operating Lamp Light Calibration in Hospital

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ABSTRACT The measurement of the operating lamp light on the operating table is very necessary so that the light rays do not glare during surgery and pathological conditions can be recognized easily without any shadows. This study aims to design a tool to measure light intensity equipped with automatic distance measurement. The design of this tool uses an ultrasonic sensor HC-SR04 to measure the distance between the light source and the sensor module and the MAX44009 sensor to measure the light intensity of the operating lamp displayed on the TFT screen. The design of the tool has been tested on operating lamps. In this study, measurements were made on two light sources, namely the GEA brand operating lamp in the Operating Room RSIA Putri Surabaya and lamps in an Electromedical Engineering Workshop on the Surabaya campus. The results of measurements when using a lamp in an electromedical engineering workshop in Surabaya with the distance between the module and the light source using a 75 cm roll meter, it is known that the error value is 0.0127% for a distance of 100 cm as much as 0.0045%. The module error value when measuring the intensity of light between the tool and the lamp in the electromedical engineering workshop with a roll meter distance setting of 75 cm gets an error value of 0.082% lux and at a roll meter distance of 100 cm, the lux error value is 0.055%. The design of a lux meter that is equipped with a proximity sensor can measure the intensity of light and the distance between the device and the light source and can assist in the learning process with a more effective Luxmeter design that will help Electromedical Technician in testing operating lamps in hospitals become more efficient.

INDEX TERMS Operating Lamp, Luxmeter, Proximity Sensor

I. INTRODUCTION

The lighting of the operating/surgical site depends on the quality of the lighting from the overhead light source and the reflection from the curtain[1]. Light is a specific part of the electromagnetic spectrum that creates a response in the human visual system and is characterized by electromagnetic wavelengths (λ) ranging from 380 to 780 nm [2]. Current illumination methods are limited by the lack of mobility, repetitive and time-lengthy adjustments, sterilization, and contamination concerns, nonoptimal illumination, inefficiencies, and time delays [3]. An illuminance meter is a light measuring instrument, this device is used to determine the level of illumination in a room. Currently, many designs of Light meters have been made and developed using several types of sensors and additional measurement methods [4][5][6][7]. The unit of measurement for the illuminance meter is lux or lumen/m^2, which is the intensity of light in an area (area or space) [8]. Each type of activity/work requires a different level of comfort for the human eye, from the illuminance range of 0.01 lux to 20,000 lux. SNI-03-6575-2001 regulates procedures for designing artificial lighting systems (lights) in buildings [9]. This building is a technical guideline for design and development planning requirements and as a guide for building owners/managers to operate and maintain an artificial lighting system to obtain a lighting system that is in accordance with health, safety, and the provisions that apply to buildings. Lighting in the operating room is one of the most important must meet ergonomic factors and high efficiency [10]. Adequate lighting of the operating room and operating table base for safe operation [11]. The lighting in the operating room is usually adjusted to the surgery being performed [12][13][14]. Testing is the entire action that includes physical examination and measurement to compare the instrument measured with the standard, or to determine the magnitude of measurement error [15]. One of the objectives of testing and calibration is to ensure the availability of medical devices that comply with service standards, quality requirements, safety, benefits, safety, and fit for use in health service facilities. one of the medical devices that must be tested and/or calibrated is an operating lamp. According to IEC standard 60601-2-41, the maximum luminance intensity for operating lamp testing is between 40,000 lux – 160,000 lux. The distance from the illuminated area of the light field is 1 meter [16].

Previously made lux meter tool by Muchamad Pamungkas in 2015 about the design and realization of light intensity measuring equipment. In his research using sensor BH1750 and can only measure the value of 65,535 lx, using a microcontroller processor ATMEGA 8 displayed on liquithe d crystal display 16 × 2 [17]. Further research by Ainul Fitroh Istiadzah in 2015 under the title lux meter used microcontroller. The sensor used is TEMT6000 which results in simulations of only up to 10,000 lux, in this study the processor is ATMEGA 8 and researchers chose to display the measurement results on liquid crystal display 2 ×8 [18] Then a lux meter made by Akhmad Akhsin Nasrudin. namely the design and build of flux meter BH1750 application as a microcontroller-based water turbidity measurement tool in 2015 [19], but still has a weakness in the measured value due to the limitations of the design tool related to the measurement of water turbidity and is influenced by poor measurement techniques so that the maximum error value is obtained at 6.35%, in this study the data was processed by ATMEGA 328P and the researchers chose to display the measurement data on a 2×16 liquid crystal display [20]. Herlia Agni made an Arduino Uno-based lux meter tool equipped with a distance meter in 2017, using the GY-302 type BH1750FVI light sensor which has a drawback because the light intensity measurement is only up to 31562 lux in his research. so it still requires the development of the light sensor side, the distance sensor used is the ultrasonic PING sensor, in this study the data was processed using ATMEGA 328 and the researcher chose to display the measurement data on a liquid crystal display 2 × 16 [21]. Abdul Kadir made a lux meter device based on AT mega 328 in 2017, but it still has a weakness in the DFR0026 light sensor which at the time of measurement has a high error presentation at a certain distance. In this study the data was processed by ATMEGA 328 and the researcher chose display measurement data on the liquid crystal display Nokia 5110 [22]. Made Satriya created the design and manufacture of lux meter digital based on El7900 light sensor in 2018, using El7900 light sensor which has a drawback because the measurement of light intensity of blue filter has a high error. In this study the data was processed by the R8C/13 microcontroller and the researchers chose to display the measurement data on liquid crystal display M1632 [23]. Then the research of lux meter tools continued by Royditya Astrawinanta titled design lux meter equipped with Arduino distance sensor in 2019, here researchers use MAX44009 sensor which includes light intensity sensor with readings entering the operating lamp criteria 0.045-188.000 lx and distance sensor used hcsr-04 that can read distance well [24]. The research was processed using Arduino and displayed on a liquid crystal display 16×2. Light is a specific part of the electromagnetic spectrum that creates a response in the human visual and is characterized by electromagnetic wavelengths (λ) ranging from 380 to 780 nm.

From the development of the lux meter that has been done by previous researchers by Muchamad Pamungkas only measure the light intensity with ATMEGA 8, previous researchers by Ainul Fitroh Istiadzah only simulations the light intensity and displayed in liquid crystal, and Akhmad Akhsin Nasrudin developed a lux meter and applied in water turbidity. Herlia Agni made an Arduino Uno-based lux meter. Abdul Kadir made a lux meter device based on AT mega 328 with liquid crystal display Nokia. Made Satriya created lux meter digital based on El7900 light sensor. Royditya Astrawinanta titled design lux meter equipped with Arduino distance sensor with MAX sensor. It can be seen that developments in terms of display on the lux meter device, researchers mostly choose to use LCD as a display tool. Disadvantages in the use of LCDs, namely the limited viewing angle make the resulting image different, the vision must be parallel in front of the monitor. Thus, the object of this research is to develop a lux meter with display TFT LCD to make it easier to use for testing operating lamps to efficient standards, thus helping Engineers in testing operating lamps in health care facilities and also this research using low cost ultrasonic sensor by measuring the distance light intensity.

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

In this study, using the HC-SR04 distance sensor data collection at a distance of 74cm and 100 cm as much as 6x, the MAX4409 light sensor using a luxmeter at a distance of 74cm and 100cm was taken 6x on the operating lamp. In the workshop light, data collection was carried out by the HC-SR04 distance sensor at a distance of 74cm and 100 cm as much as 10 times, the MAX4409 light sensor using a luxmeter at a distance of 74cm and 100cm was taken 10 times.

1) MATERIAL AND TOOL

This study used Arduino to regulate the overall work of the tool, MAX44009 light intensity sensor to measure light intensity (lux) in the operating lamp, HC-SR04 ultrasound sensor to measure the distance between the sensor module and operating lamp, TFT display to display sensor readings, battery for voltage supply in module and circuit, Push Button for page transfer on nextion and to start sensor reading along with holding sensor reading value, and device used to support the workmanship of tools include multimeters, solder, cut pliers, and test pen.

2) EXPERIMENT

In this study, after the design was completed, the syringe pump in this research, after the designed tool has been completed. Therefore, data retrieval is done using a lux meter with light intensity in different operating lamps at different distances. The distances tested were 74cm and 100cm.

B. THE DIAGRAM BLOCK

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In this study, the Arduino microcontroller as the data control center of input and output IC in Arduino will work based on the program code entered into the microcontroller IC. Input data entered on the microcontroller are MAX44009 light sensor, HC-SR04 ultrasonic distance sensor, hold button and reset button. This button is used to set the operation of the tool. The distance and light sensors will send digital data to the Arduino to be processed into values in cm and lux. After reading, the Arduino microcontroller displays the data reading to the Arduino TFT. In this study, the measurement of operating lamps was carried out based on the placement of the tool module which contained a distance sensor and a light intensity sensor with a light irradiation point. The Arduino program was built based on the flowchart as shown in FIGURE 1. When the device is turned on, the microcontroller will initialize. Then read the data from the proximity sensor displayed on the TFT. Proceed to the process of reading data from the light sensor which will be displayed on the TFT. Then press the hold button to hold the reading value during data retrieval.

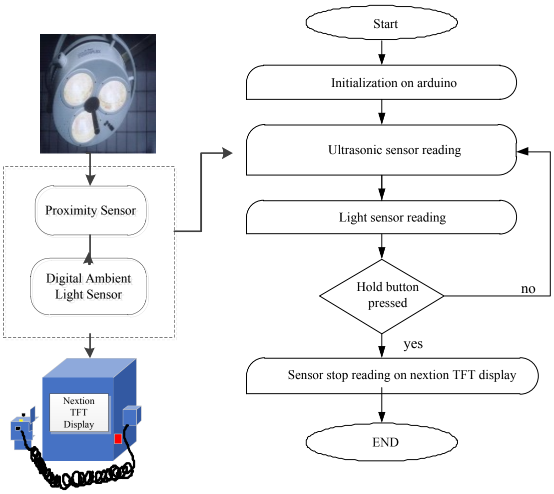

FIGURE 1. Luxmeter Design diagram Equipped with Proximity Sensor

C. COMPONENT ARRANGEMENT IN TOOLS

An important part of this research is the circuit described in Figure 2 (microcontroller circuit and display), This circuit is used to process light sensor data and proximity sensor data from the output sensor to the nextion display

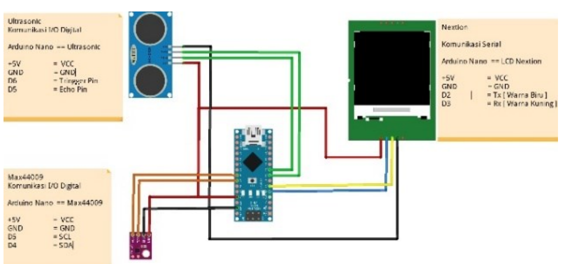

Figure 2. Connection Of Each Component Microcontroller Circuit And Display

III. RESULT

The results of the module design for measuring light intensity as shown in FIGURE 3 and FIGURE 4 are a front view image of the lux meter design equipped with a proximity sensor displayed on the TFT LCD.

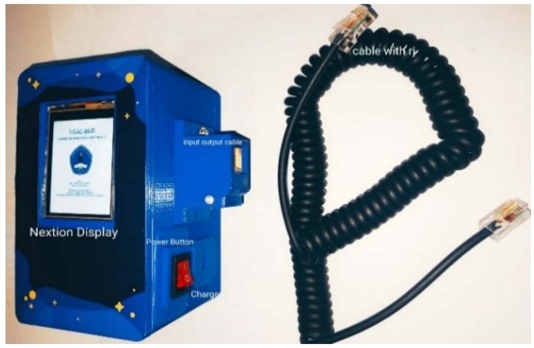

FIGURE 3. Design Module For Measuring Light Intensity

FIGURE 4. The Part of Sensor Module For Measuring Light Intensity

1) DESIGN MODULE

As in Figure 3 and Figure 4 When the design of this module is turned on, the Arduino Microcontroller as the center for controlling the input and output IC data on the Arduino will work based on the program code that is entered into the microcontroller IC. The input data that enters the microcontroller is the MAX44009 light sensor, the HC-SR04 ultrasonic distance sensor, and the hold button. This button is used to set the operation of the tool. The proximity and light sensors will send digital data to Arduino to be processed into values in cm and lux. After reading, the Arduino microcontroller will display the data reading to the Arduino TFT.

2) THE LISTING PROGRAM FOR ARDUINO

In program pseudocode there is a program for sending frequency audio signal waves then frequency audio waves will be received and then the delay in sending and receiving time will be converted into distance. There is also a program for a digital light sensor, the sensor reading starts from 0. If the lux reading time is >100mS then lux will reset the timer "lux = myLux.getLux();" and will be repeated continuously "return lux;".

3) GRAPH RESULT FROM DATA DISPLAYED ON TFT

The result is made by measurement from workshop lamp with lux meter standard. Before the luxmeter was tested on the lamp, the device was calibrated using Konica Manolta from BPFK FIGURE 5 shows the graphic from the ambient light sensor and proximity sensor. FIGURE 5 shows the measurement from the equipment that has been developed in this research and from the standart device. This research measure two kinds of distance, from 30 cm and 70 cm. The measurement shown the intensity (LUX) for the standart tools are 71.38 LUX until 98.00 LUX in 30 cm distance. The 98.00 LUX until 100.59 LUX in 10 cm. From the measurement of the standart equipment shows that the higher the intensity value, the closer the distance.

FIGURE 5 in orange line shows the measurement from equipment that has been developed in this research shows that 71.98 LUX until 98.00 LUX are from the 60 until 65 cm and there is an increase in the intensity value when the measurement distance is closer. It can be concluded that the measurement value will be higher the closer the measurement distance is. To get the maximum value of light intensity is around 98.41 LUX to 100.59 LUX, so measurements must be made at a distance of 10 cm using standard tools and a distance of 30 cm using the tools made in this study.

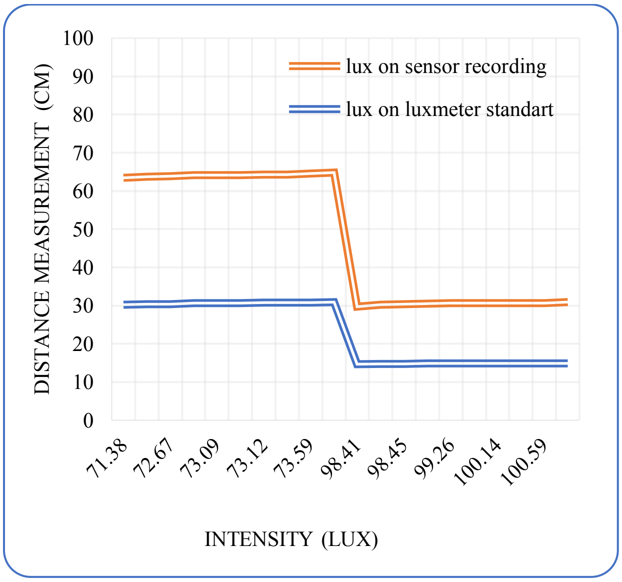

FIGURE 5. Sensor Recording from the ambient light sensor and proximity sensor

4) RESULTS OF MEASUREMENT AND TESTING PERFORMANCE OF LUXMETER BRAND AMPROBE

Testing and measurement of lux meter performance are done to determine the performance of the lux meter. Validate the distance value shown on the nextion TFT display compared to the roll meter. The error is shown in TABLE 1.

TABEL 1
The Error of measurements for the distance parameter between luxmeter and luxmeter brand (Amprobe luxmeter). Notes: SL is surgery lamp and TL is tube lamp

HC-SR04 (cm)	Error(%)
74 (SL)	0,002913871
100 (SL)	0,035840066
74 (TL)	0,012796825
100 (TL)	0,004500161

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TABLE 1 shows the measurement of TL (Tube Lamp) and SL (Surgery Lamp) using the HC-SR04 sensor (proximity sensor). Based on the measurement results, the highest error value is 0.035840066% at a distance of 100 cm on the Surgery Lamp. While the lowest error value is 0.002913871% at a distance of 74 cm on the Surgery Lamp. In measurements using TL (Tube Lamp) the lowest error value is 0.004500161 % at a distance of 100 cm, while the highest error value in measurements with TL is 0.012796825 % at a distance of 74 cm.

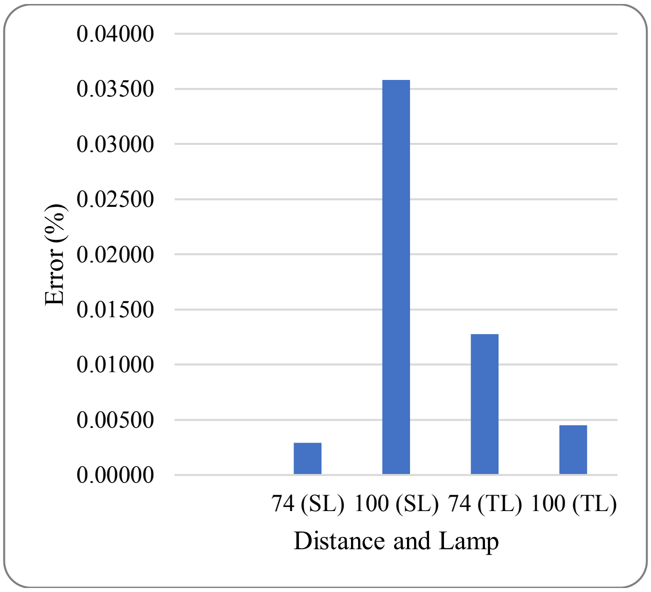

FIGURE 6. **Measurement and testing performance of luxmeter**

Based on the measurement results shown in TABLE 1 It can be said that the measurement using the proximity sensor (HC-SR04) for testing the performance of the lux meter, namely the smallest error value can be obtained using the type of surgery lamp at a measurement distance of 74 cm.

FIGURE 6 shows the measurement of performance using a lux meter brand Amprobe by using two types of lamps, namely sugery lamps and tube lamps with a combination of two types of distance, namely 74 cm and 100 cm. Based on the measurement results, it was found that the highest error value was obtained at a distance of 100 cm using a surgery lamp, while the lowest error value was measured at a distance of 74 cm using a sugery lamp.

Based on FIGURE 6, it can be concluded that with the use of a surgery lamp at a distance of 100 cm, the highest error value is 0.035840066%. While the use of a tube lamp is better because it is proven by a lower error value than the surgery lamp, which is 0.004500161% at a distance of 100 cm.

TABEL 2
The error of measurement for the Lux parameter between the LUXMETER and Standard Unit (Amprobe lux meter).

Distance (cm)	Error (%)
74	0,08296513
100	0,055626435

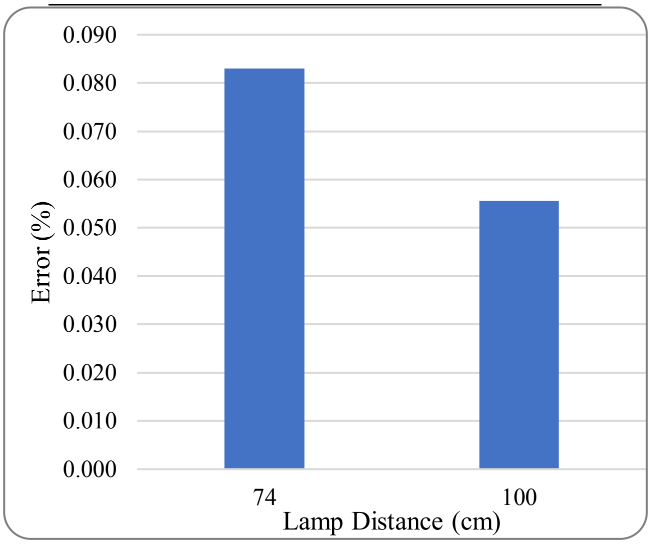

FIGURE 7. Measurement and Testing Performance of Luxmeter Distance

The measurement of the light intensity value where the lux from the electromedical engineering workshop lamp is also compared in this study, between the Luxmeter design and the standard Luxmeter. The results are shown in TABLE 2. it can be seen that the error value at a distance of 74 cm is 0.08296513%, while at a distance of 100 cm the error value is 0.055626435%, it can be concluded that the longer the measurement distance, the lower the error value obtained.

TABLE 2 shows the standard lux meter used is the amprobe lux meter with two types of distance differences, namely 74 cm and 100 cm. the lower the measurement distance, the lower the error value obtained. measurement results at shorter distances show a higher error value.

FIGURE 7 shows the value of the distance performance measurement on the amprobe luxmeter. This performance measurement is at a distance of 74 cm and 100 cm. Based on the results of measurements carried out in this study, the results obtained were the highest error value of 0.08296513% was obtained at a shorter distance of 74 cm.

Measurements at a distance of 74 cm and 100 cm in this study were adjusted to the specifications of the standard tool used as a comparison for the tools made in this study namely the Amprobe lux meter. Based on the measurement results shown in FIGURE 7, it can be concluded that if you want to get a low error value, you must measure at a distance that is getting farther away.

IV. DISCUSSION

In this study, there were measurements on 2 light sources, namely the GEA brand operating lamp at RSIA Putri Surabaya and the Surabaya electromedical engineering campus workshop lamp. Measurement of the two light sources includes measuring the distance from the light source with a lux meter and measuring the intensity of light emitted by the light source. Measurements are made with the right focus of light on the lux meter (central illumination). For distance measurement, the writer compares it with a standard roll meter tool and for measuring light intensity it is compared with a standard lux meter device.

Measurement of operating lamps at RSIA Putri Surabaya, in this measurement the author uses 2 distances to measure light intensity, the first distance is 74 cm on a standard roll meter and the ultrasonic sensor error value HC-SR04 is 0.002913871%, the second distance is 100 cm on a standard roll meter and the ultrasonic sensor error value HC-SR04 is 0.035840066%. From the measurement results for the distance parameter with a distance setting of 74 cm and 100 cm, namely the GEA 15+12 brand operating lamp still meets the standard because the lux value is still within the allowed limits. According to the standards of the directorate of medical support services and health facilities, the directorate of health efforts of the ministry of health of the Republic of Indonesia in 2012, regarding the technical guidelines for operating room hospital buildings, operating lamps generate intensive light with a range from 10,000 lux to 20,000 lux, and at standard IEC 60601-2-41, the maximum luminance intensity for operating lamp testing is between 40,000 lux – 160,000 lux. After the measurements were made, the results of measuring the lux value on the GEA 15+12 brand operating lamp were within that range. After taking measurements, it was found that the average value of the data taken on the GEA 15+12 brand operating lamp was in the specified range so it can be concluded that the tool can still function properly. Measurement of lamps at the Surabaya electromedical engineering campus workshop, in this measurement the author uses 2 distances to measure light intensity, the first distance is 74 cm on a standard roll meter and the ultrasonic sensor error value HC-SR04 is 0.012796825%, the second distance which is 100 cm on a standard roll meter and the ultrasonic sensor error value of HC-SR04 is 0.004500161%. Then the central light intensity measurement was carried out at the Surabaya electromedical engineering campus workshop lamp at 2 different distances, the first measurement used a measuring distance of 74 cm and the results of the MAX4009 type (GY-49) digital light sensor error were 0.08296513%, the measurement of light intensity at a distance of 100 cm, the error result of the digital light sensor MAX4009 type (GY-49) is 0.055626435%. From the results of the measurement of the lamp at the

Surabaya electromedical engineering campus workshop, it can be seen in the results of the measurement graph that the farther the measuring distance between the light source and the tool, the smaller the light intensity value obtained. Therefore, this lux meter equipped with a TFT display distance sensor can function properly.

However, to ensure the correctness of the measurement test that has been conveyed above, the next stage must still be carried out, namely comparing the luxmeter module with a lux meter that has been properly calibrated so that it can be seen that the operating lamp that has been measured is suitable for use or not. Errors in the tool can be caused by human error, and the lifetime of the operating lamp can also affect the measurement results.

Therefore, this lux meter equipped with a TFT display distance sensor can assist in measuring light intensity more effectively with the automatic reading of the distance sensor without the need to use a rolling meter again, the output results displayed on Nextion can also help readings more effectively and with a design a simpler tool such as a lux meter on the market so that the use of a lux meter can be more efficient.

In this research, there were several weakneses, including not conducting tests on the life time of the two lamp samples used in this study, namely the surgical lamp and tube lamp, which will also affect the intensity value of the lamp being measured. Another weakneses in this research is that it does not calibrate the lux meter used for measurements in this research, the uncalibrated lux meter used in this study will also affect the results of the reading of the intensity value on the instrument being tested.

Some of the weakneses in this study are expected to be a reference for further research, so it is hoped that improvements will be made in further research. Also to perform more variations in distance measurements in order to obtain more variations in measurement values, so that a more in-depth analysis of reading values can be carried out.

V. CONCLUSION

This research has succeeded in making a lux meter to measure the calibration distance between the light source and the central illumination and measure the light intensity at the central illumination using a digital light intensity sensor using Arduino nano for data processor and Nextion TFT display to display sensor readings in real time. time is equipped with a hold button to hold the sensor reading value. With an average error of 74 cm distance testing of 0.007855348%, an average of 100 cm distance testing error of 0.0201701135%, and testing on light intensity getting error values of 0.08296513% and 0.055626435%. The error results are influenced by different human readings (human error), untraceable comparison tools, and the lifetime of the light source. Developments that can be done from this research area using the latest light and distance sensors and having high accuracy and measuring range values, comparing the results of the lux meter module with the original calibrated and usable lux meter and adding an easier data retrieval system using an application on a cellphone. So that it can be easier for the user, to upgrade the tool by adding the features of Kelvin, room temperature, and humidity for testing more modern operating lamps.

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Attachment:

a. Schematic+Board:
https://drive.google.com/drive/u/0/folders/1LktesiSUccqdbea4GhlWUNUIO36uagCZ

b. Listing Program :
https://drive.google.com/drive/u/0/folders/1PRm5y0HKqC0JgVzDgBhHkmQbhb2xikLO