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THE DEVELOPMENT AND INSTALLATION OF A HOME APPLIANCES' AC MAINS VOLTAGE FLUCTUATION INDICATOR

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Abstract: Using a multimeter is currently the most practical way to measure the Root Mean Square (RMS) Voltage of a Line Power System. However, instead of using the ground pin, a multimeter uses the measuring probe as the point of contact with an electrical outlet. This could occasionally be quite dangerous. In order to address this issue, this research suggests substitute measuring tools for multimeters that can also clearly display voltage variation. The equipment should be plug-and-play during use, dynamic, accessible, and safe according to the research. The project's equipment will use 12 LEDs as a voltage level indicator rather than the numeric display used in Multimeters, highlighting the equipment's accessibility even more. Each of these LEDs is attached to an Arduino output pin, and each pin is configured to turn on only at a particular voltage value. The results of the tests show a dynamic voltage level indicator. The LED will instantly reflect any changes in voltage level without any discernible delay. Since no harm was caused while operating the circuit during testing, it is also quite safe. The only required action is adjusting the potentiometer, highlighting true plug & play. Despite its success, it has two significant weaknesses. We noticed an unexpected voltage drop between the regulator output and an Arduino input pin. Additionally, the voltage at the Arduino input fluctuates wildly downward. Ideally, the data gathered would contribute to the equipment's improvement.
Keywords: Multimeter, Voltage, LED, Arduino, Electronic, Root Mean Square

1.0 Introduction

Voltage fluctuation is one of the key factors that disturb the quality of the power supply, which in turn leads to a lot of equipment failure, downtime, and breakdown. The voltage range for a 220 V system has a maximum limit of 242 V and a minimum limit of 198 V (10% incremental and decremental) , in accordance with ANSI C84. A survey of American citizens conducted by Georgia Power Co., as shown in Figure 1, revealed that natural phenomena are the main cause of power quality issues, including voltage fluctuations. This natural occurrence may include frequent rainstorms, earthquakes, strong winds, falling trees damaging line cables, and floods.

In order to analyze the presence of disturbance on their power line, an experiment was conducted in the Administration Building of university and college, which is equipped with a voltage stabilizer. The results showed that the voltage is capable of dropping to as low as 209 V under high load, which is very close to the minimum voltage range recommended by ANSI. Flickering lights, insulation failure, overheating, short-circuits, winding loss, or a reduction in the life of the afflicted equipment are just a few of the damages that can result from failing to recognize existing voltage variation.

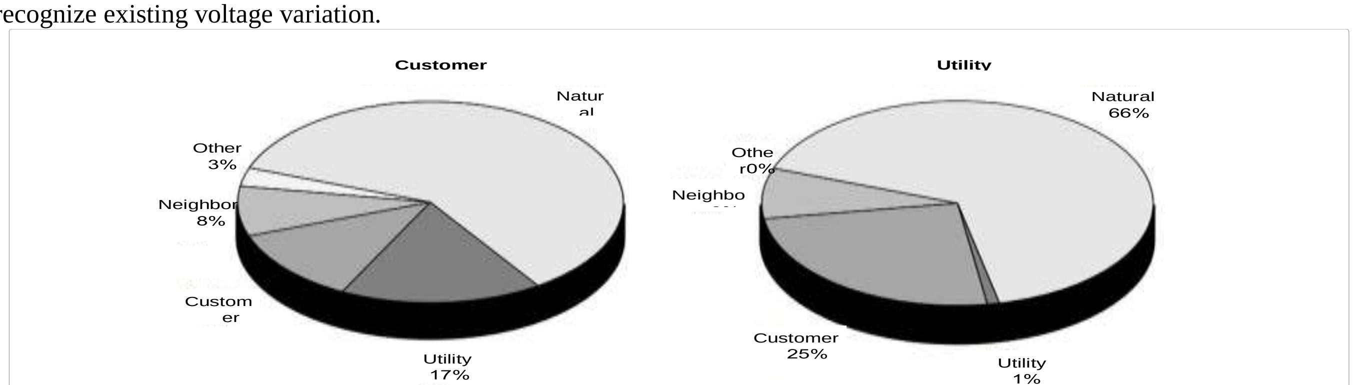

Figure 1: Survey on Source of Power Quality

Thus, there are three main categories for voltage fluctuation:

- Flickering is a phenomena that occurs when there is a sharp variation from the nominal RMS voltage of 90% to 110% or greater. For flickering to be classified as such, the rapid change in light intensity it causes must be noticeable to the human eye. There is evidence that perceived flickering can lead to severe distress and anxiety.
- Overvoltage occurs when a mains voltage is more than 110% of its nominal RMS value for a period of time longer than one minute. Every piece of electrical equipment has a designated rated voltage that can carry a current that is constrained by resistance from various sources but yet sufficient to heat the wire. However, if the voltage increased beyond, wire insulation may begin to deteriorate.
- Under voltage is defined as when the mains voltage falls below 90% of its nominal level.
- RMS value over a longer period of time. Under voltage is most frequently caused by high electrical demand. In order to balance off the increased demand during this period of extreme load, the electrical utility reduces the voltage provided to each load. Current level will thereafter rise in order to maintain wattage level, possibly exceeding its permitted rating.

The author currently thinks that using a multimeter is the most accessible, meaning the easiest and fastest approach to find such a fluctuation. An electrical socket is the point of contact for a multimeter, which uses a measurement probe. It might occasionally be harmful to carry out this. The goal of this research is to address this safety concern by suggesting a safer alternative to the multimeter while stressing even greater accessibility in detecting voltage fluctuation. As a result, the alternative equipment in this project will employ 12 LEDs as a voltage level indicator rather than the numeric display typically used by the multimeter. However, there must be no discernible delay in the dynamic voltage indicator. A further goal of the equipment is for it to be plug-and-play and need little manual labor.

2.0 In Contrast to a Multimeter

A multimeter is a piece of electronic measurement technology that can measure multiple measurement units all at once. Voltage, current, and resistance are often the most popular units that Multimeter can measure. Currently, there are two categories of multimeter:

Table 1: Comparison between Multimeter and our work.

Category	Multimeter	Our work
AC Voltage measurement range	Up to 1000 VAC	170-280 VAC (Adjustable)
Power source	Battery	Power voltage
Measuring contact	Probe cable	Electrical plug
Main visual indicator or display	Pointer or numeric	12 LEDs
Microcontroller	N/A	Arduino Uno
Additional measurement capability	Ampere, Ohm	N/A

3.0 Digital Multimeter

This multimeter uses a moving pointer that oscillates within a range indicator that typically measures current up to microamperes. Many engineers or technicians still favor this Multimeter despite its antiquated design. This is because a digital multimeter may miss or be challenging to read from in many of these situations, whereas an analog multimeter has outstanding sensitivity and tracking capacity to even the smallest change in readings in an electrical circuit.

4.0 Electronic Multimeter

The Multimeter's most popular and most recent design. The values are shown as decimal numbers with embedded decimal points and preset digits. Additionally, certain digital multimeters could include a bar graph display that shows the measurement value. Due to its lower cost and greater accuracy when measuring constant or fixed values, the digital multimeter is increasingly widely used.

By inverting the negative half cycle of an AC waveform in a rectifier, which produces a non-zero DC voltage whose value is the Root Mean Square (RMS) of its peak, both types of multimeters are capable of detecting AC voltage. Table 1 compares some fundamental characteristics and features of a standard multimeter with the device prototype and equipment used by the authors in this project.

5.0 Transformation into DC

The AC voltage will be stepped down into a lesser value for practical and safety reasons, which is subsequently converted into DC voltage. Given that the value necessary to turn on each LED in this project is the resigned down and rectified DC value and that these values must be defined in the Arduino coding for each individual LED, it is essential for the author to theoretically pre-calculate this DC voltage using existing formulas. The first step is to assign a specific RMS Voltage value to each LED, as indicated in Table 2.
Through a series of formulas, these RMS values will be lowered to more tolerable amounts depending on the components that can be employed.

6.0 Lower Transformer Step

Transformers are fundamentally two independent, yet closely spaced windings or coils of insulated wire on an iron core. The “main” winding is the winding that is connected to the power source. The other, known as the “secondary,” transmits the load with the altered power. Magnetic induction is used to transfer energy from one winding to another. When one winding has more turns than the other, it will produce more impedance and, as a result, higher voltage, but at the expense of current. This works the other way around and validates that the power rating remains constant everywhere.
In contrast, a step-down transformer provides lower voltage with a larger current on the secondary side when the secondary winding has fewer turns than the primary winding. As a result, the transformer turns ratio is proportional to the voltage ratio between the windings in accordance with Faraday’s law of induction, as demonstrated in Equation 1 below:
V stands for voltage, N stands for the coil’s turns, and P and S stand for the side of the winding it belongs to. For this project, this formula can be rewritten as Equation 2, which illustrates how to step down the AC line voltage into a safer number.

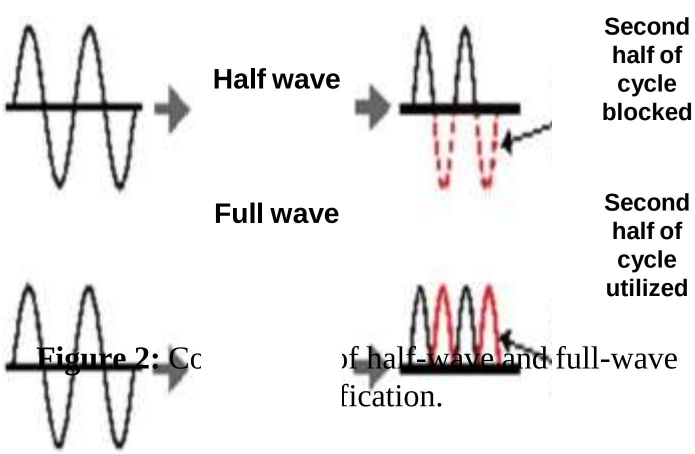

Figure 2: Cc ɔf half-wave and full-wave fication.

7.0 Transformation into DC

Rectifiers are machines that transform AC current, which alternately flows in two directions, into DC, which only flows in one direction. For a greater average voltage output, this project will use full-wave rectification. This is because, unlike half-wave rectification, full-wave rectification changes the negative polarity of the AC wave into the positive. This illustrates the difference between half-wave and full-wave rectification.

$$\textit{Transformer AC Output (RMS)} = \frac{\textit{AC Line Voltage (RMS)}}{\textit{Transfromer Turns Ratio}}$$

Since the transformer the author utilized is not center tapped, rectification will be accomplished using a four-diode bridge design. 90% of the RMS value of the resulting DC voltage is about equivalent. The equation for calculating the RMS value of peak AC voltage is shown in Equation 2:

$$\textit{Transformer AC Output (RMS)} \ \frac{\textit{Transformer AC Output (Peak)}}{\sqrt{2}}$$

Equation 5 illustrates how to calculate a rectifier's average DC output (unsmoothed) in relation to its initial AC peak value. Equation 4 illustrates how to get the rectifier's original AC peak value. We can calculate the average rectified DC voltage by using integration to approximate the area within the sinusoidal AC waveform's curve:

Figure-3 Depicts a Common bridge Rectifier's Arrangement.

D1 and D4 conduct in series during the positive half of the cycle, whereas D2 and D3 are turned OFF due to being reverse biased. The opposite occurs during the cycle's negative half. As indicated in Equation 6, a voltage drop double that of a single diode is present because, at any given state of the cycle, the entire circuit passes through two diodes in forward bias.

Single Diode Voltage Drop = 2 (Bridge Rectifier Voltage Drop)

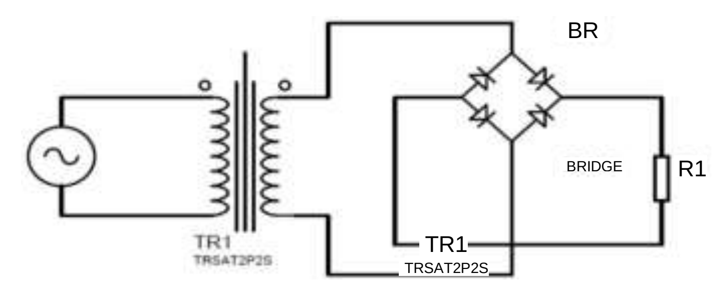

Figure 3: Typical full-wave diode bridge Rectifier Configuration.

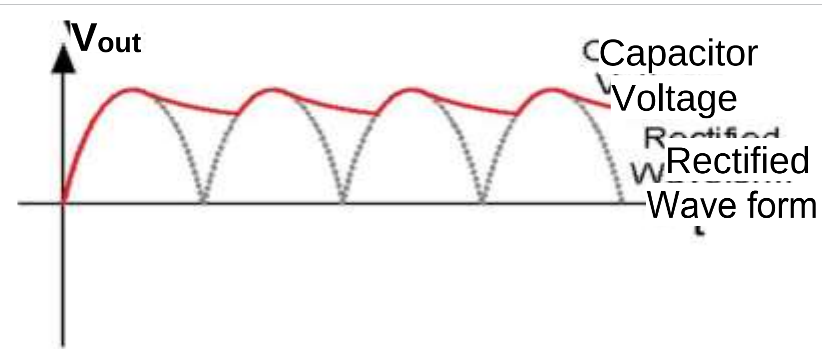

Figure 4: Smoothed DC full-wave Rectification Output

8.0 Capacitor for Smoothing

It is feasible to raise the average output of the DC voltage with the aid of filtering capacitor charge. Figure 3 illustrates that there are still pauses between each half-cycle where the voltage results in zero. Following this attempt to discharge, the fully charged capacitor will try to fill up the gaps, bringing the value closer to its original AC peak value. After the bridge rectifier, the smoothing capacitor is connected in parallel to the load. Figure 4 displays the final DC output following the capacitor's smoothing. Physics Equation is a good approximation for the ripple voltage, a minor residual undesirable variation of the DC output that is still there after filtering through a capacitor. Combining the equations unified equation can be formed into Equation:

9.0 Implementation of Design Specification

The equipment's circuit will be changed for testing purposes. Between the Diode Bridge and Arduino Input, a Variable Voltage Regulator will be used, enabling the VDC input value to be manually modified rather than being reliant on the status or level of the VRMS. The identification of the equipment's significant defects in its existing state will ultimately depend on the success of this upgrade.

Table 3: Apply Equation 9 to each RMS Voltage Value.

LED	AC line voltage (Volt)	V_{DC} (Volt)
1	170	14.99
2	180	15.96
3	190	16.92
4	200	17.88
5	210	18.85
6	220	19.81
7	230	20.78
8	240	21.74
9	250	22.71
10	260	23.67
11	270	24.63
12	280	25.59

9.1 Implementation of Design

The following provides a quick description of how each major element in the schematic functions, along with any relevant calculations.
Reducer transformer: The transformer will be a 220-30 V center tapped transformer. The variable voltage regulator will receive its input from the 30 V tap, and its output will serve as the Arduino's input reading. The half-voltage (15 V) tap will be sent into a series of regulators, whose final output will be utilized to supply power to the Arduino's VCC later on.

Kit for an adjustable voltage regulator (LT-1083): This kit will receive the transformer's output of stepped-down 30 VAC. The following elements are part of the kit:
• A DC rectifier bridge that converts AC input into DC using four 10 A10 diodes
• A string of capacitors to reduce ripple and bring the rectifier's DC output closer to its original AC peak value.
• The LT-1083 variable voltage regulator, which can output voltages ranging from 0 to 30 V.
• W502 potentiometer for regulating the regulator's output.

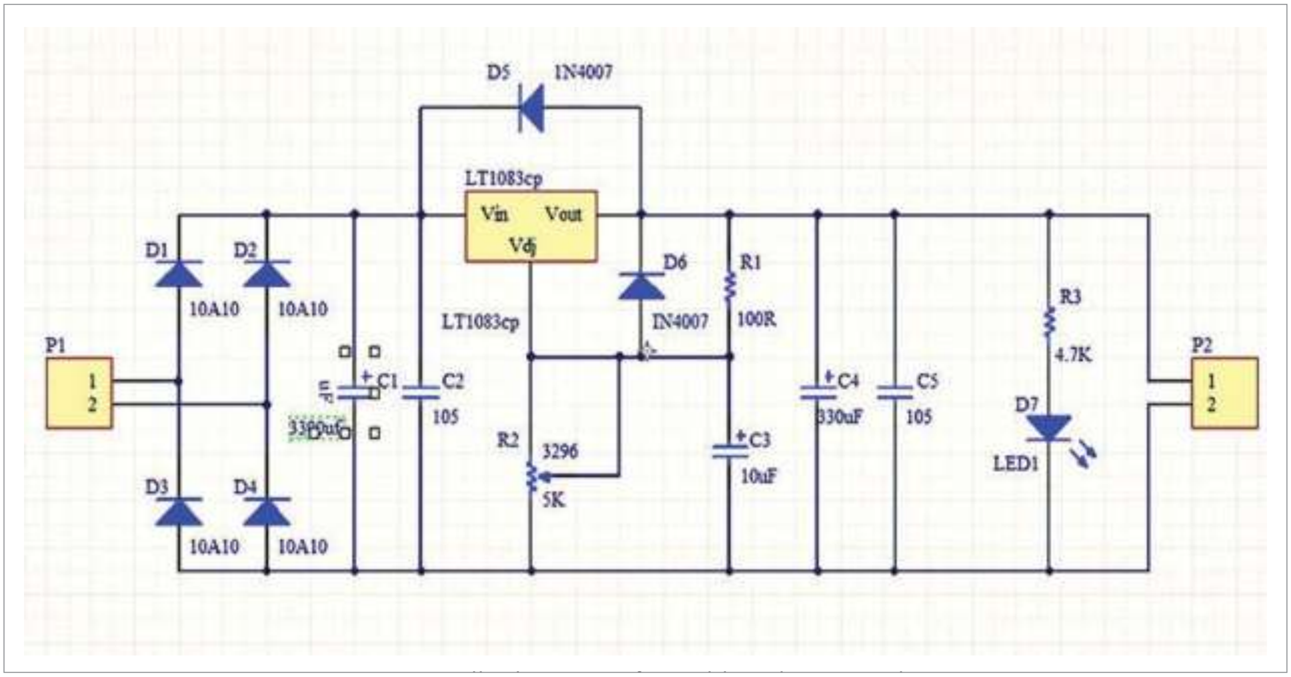

Figure 4: Full Schematic of Variable Voltage Regulator.

9.2 Design implementation

The electrical socket will initially supply the machine with input from the power line (220 V). A multi-tap transformer then steps down this input into 30 VAC and 15 VAC. The 15 VAC output is rectified into DC using a diode bridge, and then it is smoothed closer to its AC peak value using a capacitor. After that, the transistor LM7812 regulates the resulting DC voltage to 12 VDC. Using the transistor LM7805, this regulator's output is once more controlled into 5 VDC. The justification for the two step regulation rather than a single direct regulation is output stability and the prevention of overheating. The Arduino Uno's VCC and I2 C LCD are both powered by the 5 VDC output.

On the other hand, a kit for a variable voltage regulator receives the 30 VAC from the transformer. This portion uses a diode bridge to rectify the 30 VAC into DC voltage and capacitors to smooth it into its AC peak value. The variable regulator LT-1083's input pin receives the generated DC voltage. By connecting the LT-1083's adjustable pin to the W502 potentiometer, it is possible to use the potentiometer itself to change the output pin's voltage from 0 to 30 V in DC. To display the current voltage level at this specific location, a digital voltmeter module is paralleled to this regulator's output. The author chose to use a voltage divider to scale down the voltage because the input voltage to an Arduino pin cannot be greater than 5 V. This is accomplished by passing the output of the variable regulator through two resistors in series, R1 (150 k) and R2 (10 k).

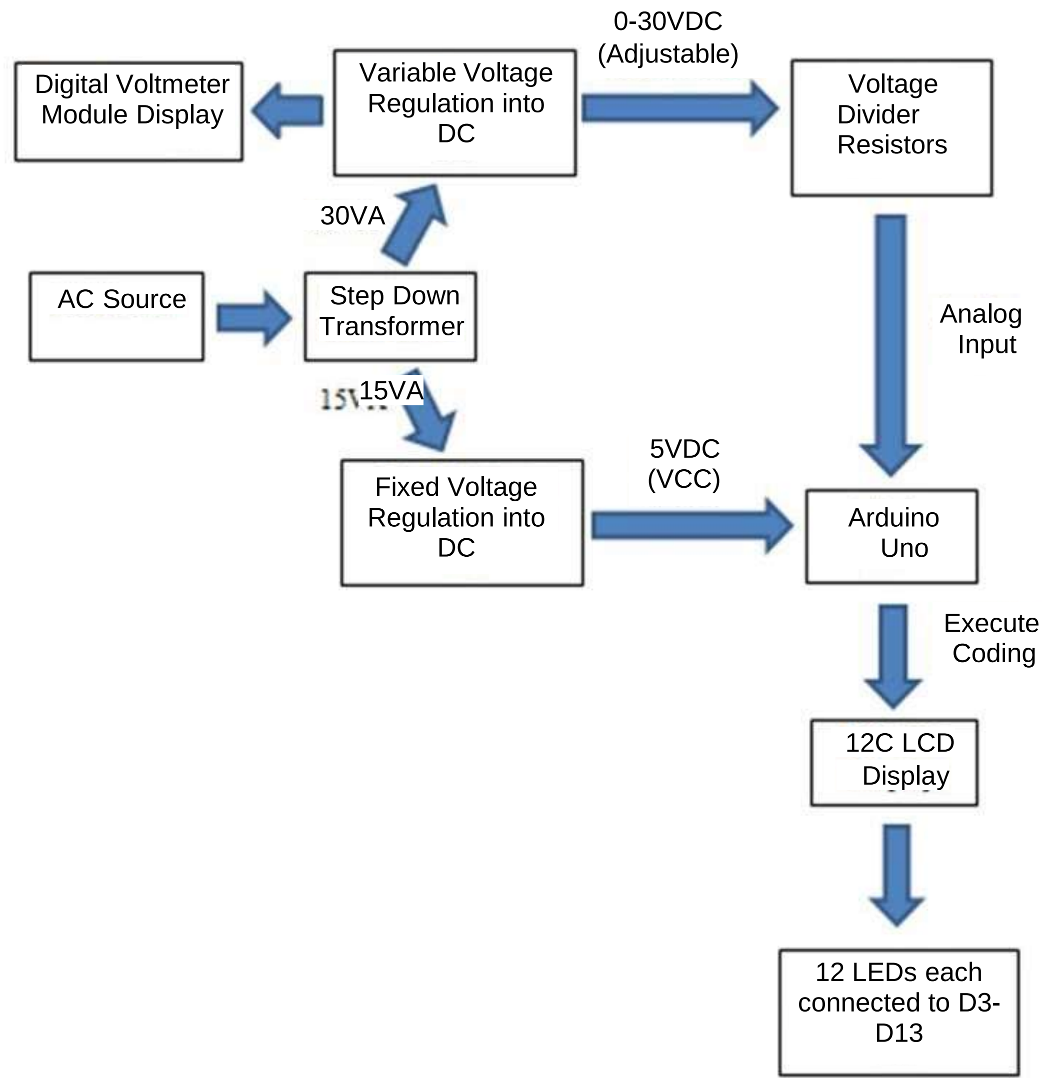

Figure 5: Block Diagram of the Device Prototype.

The voltage divider's newly scaled-down output now conforms to Equation 10. The Arduino's A0 analog pin is now attached to the voltage that was scaled down as a result, and it will serve as the input. Please be aware, however, that this value will later be doubled or scaled up to become its original amount using Arduino programming. A 16 x 2 I2C LCD uses the SCL and SDA pin, which is coupled to the matching pin, to show the input voltage at pin A0. This display will be used to contrast the value with the digital voltmeter module's display. With the aid of a male to female adapter, the digital pins D2 through D13 are each connected to 12 5 mm LEDs. Each LED has a resistor limiter to keep the current flowing into it from exceeding the allowed rating. The final step is to connect the AREF pin to a capacitor and ground in order to filter any potential noise that may be present when analog reading the input in A0.

10.0 Conclusions and Analysis/Results

From three different points of view—the Digital Voltmeter Module, the I2C LCD, and the 12 LEDs—the images on Figures 12, 13, and 14 below depict observations at three voltage intervals. Please take note that LEDs 1 through 12 are readable from right to left.

Upon inspection, each LED does indeed turn ON at each predetermined minimum voltage level specified in Table 2 at each interval. Comparing the data from the I2C display to those from the Digital Voltmeter Module, however, revealed that there appeared to be unexplained voltage between them at all voltage points. Table 4 shows this voltage loss at a random voltage point between each consecutive voltage requirement point.

11.0 Discussions

The results, as indicated by the photos above, suggested that the test-use version of the apparatus, which was programmed using Arduino, is indeed capable of turning on each LED only when a particular voltage level is reached, which is increasingly different for each LED. Without any discernible over-delay, the next appropriate LED turns ON as soon as the next voltage requirement is met. As soon as the circuit is powered up with 220 VAC through the electrical plug, the Digital Voltmeter Module, I2C LCD, and all LEDs also switch ON without any discernible overload or short circuit indication. This clearly demonstrated how safe the circuit is to use. Based on data collection and the author's visual evaluation of the Digital Voltmeter Module and I2C LCD, the apparatus does, however, appear to have two significant defects upon closer study. The first is an unanticipated voltage difference between the voltage at the variable regulator and the actual voltage received and detected at the Arduino input, which is already extensive documentation in Table 4. The author assumed that the Arduino analog pin's intrinsic resistance or impedance was to blame for this. Plotting a line graph between A (I2C LCD) and B (Digital Voltmeter Module) could be a surefire way to solve the first issue. Utilizing information from Table 4, Figure 16 displays the generated line graph.

Table 5: I2C LCD values multiplied with gradient 1.0281.

LED That Turns ON	I2C LCD/A (Volt)	Digital voltmeter module/B (Volt)	A multipliedby gradient (Volt)
0	14.78	15.2	15.19532
1	15.00	15.4	15.4215
2	16.09	16.5	16.54213
3	17.03	17.5	17.50854
4	18.05	18.5	18.55721
5	19.14	19.5	19.67783
6	20.00	20.5	20.562
7	20.94	21.4	21.52841
8	21.87	22.4	22.48455
9	22.81	23.4	23.45096
10	23.75	24.4	24.41738

11	24.69	25.4	25.38379
12	25.70	26.4	26.42217

The authors' observation of a random downward fluctuation of value in the B or I2C LCD during data gathering is the second significant fault. This may be a result of the Arduino's internal analog pin impedance producing noise. Although it was hoped that the capacitor linked to the AREF pin would lessen this volatility, it appears that it still occurs. Furthermore, the author's choice of inaccurate resistors as voltage dividers may also be to blame for this. The authors offer two potential fixes: using a capacitor with a higher capacitance to charge it more quickly, or lengthening the wait before the value is displayed on the I2C LCD so that the capacitor can finish charging completely first. For reference, the author uses a 1 millisecond delay while showing voltage value on an I2C LCD.

12.0 Intensity and Fragility

- The project's advantages are:
- The apparatus is composed of materials that are easily accessible.
- Plug and play: Depending on the voltage input level at the time the circuit is powered up, the LEDs will turn ON immediately.
- This equipment may be used virtually anyplace in Indonesia that provides electricity thanks to the use of a conventional electrical plug, which makes it safer to use than a multimeter.
- Make the equipment available to everyone, even those with little to no history in studying electricity, with the observation being in the form of the number of LEDs turning ON. However, in these circumstances, labeling of the unsafe voltage level may be necessary.
- The dynamic, delay-free ON/OFF transition of LEDs when voltage levels change from one another.
- Other than the transformer, the apparatus is completely transportable.

13.0 The Project's Shortcomings are as Follows:

- When comparing a digital voltmeter module and an I2C LCD, it is clear that the provided Arduino coding does not take into account additional voltage drop.
- At the analog pin input of the Arduino, there is a 5% voltage variation that occurs at random. Despite the fact that it is insignificant.
- The transformer the author chose is unsuitable for mounting on a PCB since it is too big and hefty. It makes things less portable.
- The test-use version of the apparatus constructed for this project leaves some of the schematic outside the plastic chassis enclosure. Additionally, this makes things less portable.
- The equipment's only function is to provide indication and, at most, warning. Therefore, there is no protection system in place.
- The equipment's home-use version has not yet undergone actual field testing.
- The Arduino does not store the results of observations.

13.0 Recommendation

- Here are a few ideas for potential follow-up research on this project:
- To calibrate the voltage dips, use the equation ($Y = 1.0281x - 0.0492$) obtained from the linear regression study into the Arduino code.
- Testing a version of the apparatus without the variable voltage regulator is necessary for next studies. Since the DC Voltage input at the analog pin will be based on the current level of the V.RMS, this will test the equipment's capacity to detect real-world voltage changes from the power line.
- To give the equipment protection capability, a protective relay that is programmed to activate at a specific voltage level can be fitted in conjunction with the LEDs.

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