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# Design And Implementation Of The Hardware Device For Smart Household Energy Management Applications

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*Abstract*— **In this paper, the design and implementation of the hardware device for smart household energy management applications is presented. The design was broken down into the following subsections; the design of the power supply, the input sensors design, the design of the control unit and the control program, the output transducer design, the liquid crystal display design and the printed circuit board (PCB). The description of the design and the requisite mathematical expression for the determination of some of the components values are presented. Specifically, the design is achieved by the use of ACS712 current sensor, ZMPT101B voltage sensor, DS1307 real time clock and buttons connected to the ATMEGA328P-PU and ESP32 microcontrollers respectively. The power supply is a 5V DC regulated source which was designed using a 220V to 12 V step down transformer, a bridge rectifier, a 3300uFsmoothing capacitor and a three pin 5V DC voltage regulator. The resistive voltage sensor is adopted and it was designed with maximum output RMS voltage of 3.53V, the input current-limiting resistor (R1) of 200 $k\Omega$ and the sampling resistor (R2) of 1.765$k\Omega$. The system design used 20x4 LCD display screen for displaying 224 different characters and symbols, where each character is displayed in 5x7 pixel matrix. Specifically, the 20x4 LCD used in this work displays 20 characters per line in 4 lines of the screen. The complete design was implemented using printed circuit boards and packaging frames for holding the system components and providing for output displays and user interface buttons and light indicators.**

*Keywords— ATMEGA328P-PU microcontroller, Household Electric Energy Consumption, Voltage Sensor DS1307, Internet of Things, Smart System, Current Sensor ZMPT101B, Energy Management System*

## 1.0 Introduction

Over the years, the need for green and sustainable energy and the depletion of the popular fossil fuel energy resources have prompted the need for energy management studies [1,2]. Although renewable energy sources such as wind and solar can provide sustainable green energy, they require other resources that deplete by their usage and also the higher their energy output is, the higher the space the power systems occupy [3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19]. In all, energy management mechanism is essential to minimize energy wastage, cut down energy cost and improve on gainful energy utilization [20,21].

Furthermore energy management is particularly essential in Nigeria where the national grid power is grossly inadequate to satisfy the teeming energy consuming population [22,23,24,25,26,27,28]. Moreover, in most case, the heavy losses on the transmission line, the poor voltage profile on the distribution lines, energy theft and other factors make it difficult for those that have access to the national grid to have regular power supply [29,30,31,32,33]. In all these, load management becomes a necessity, as it helps the energy consumers to make best use of the energy when the power supply is available.

Accordingly, in this research, the design and implementation of the hardware device for smart household energy management applications is presented. The household energy management hardware device is a microcontroller-based Internet of Things system that uses some sensors to capture relevant household energy consumption data records and then utilizes embedded firmware program stored in the microcontroller to take appropriate decision on the operation of the system to manage the energy consumption in the housed [34,35,36,37,38,39,40,41,42,43,44,45,46]. Specifically, detailed description of the system operation, the system design, key design diagrams and the requisite mathematical expression for the determination of some of the system components sizes are presented. Also, the snapshots of some notable aspects of the implement system are presented.

## 2.0 Methodology

### 2.1 Description of the hardware device for smart household energy management applications

The complete smart household energy management system is developed in two parts, first, the hardware design and secondly, the design of smartphone application along with associated web application [47,48,49, 50,51, 52,53, 54,55, 56, 57, 58]. This paper focuses on the hardware design and implementation. The hardware device describes the physical components used in implementing the smart household energy management system.

Specifically, the hardware design includes the design of the metering unit which receives the voltage and current signal in analog form from ACS712 and ZMPT 101B AC sensors [59,60]. The analog signal is converted to a digital signal by the analog to digital converter of the microcontroller. The digital signal format is used in computing the energy expended by the electrical appliance. The sensors and the buttons/keypads formed the input sub-system fitted into the microcontroller. The sensors measure the AC voltage, DC voltage and current of the system while the buttons and keypads are used in calibrating and setting of the system parameters. The ESP32 Microcontroller is used in the system [61]. Notably, the ESP32 Microcontroller is a feature-rich microcontroller integrated with analog to digital converter, Wi-Fi and Bluetooth connectivity for a wide range of application. It is used for easy prototyping, implementation and emulation of embedded system.

Automatic switching timer with DS1307 real time clock is the additional feature of this IoT-based system which is used to monitor and control the system output based on time specified by the household [62]. The 20 x 4 LCD screen forms the output sub system used to display the processed information from the system. The relays, which are electromagnetic devices are used to control energy usage by connecting and disconnecting household electronic appliances.

In all, in this paper, the design of the hardware device for smart household energy management applications is presented in the following subsections;

i. The design of the power supply
ii. The input sensors design
iii. The design of the control unit and the control program
iv. The output transducer design
v. Liquid crystal display
vi. The printed circuit board (PCB)

### 2.2 The Design of the Power Supply

A typical power supply can be broken down into a series of blocks (as shown in Figure 1), each of which performs a particular function. The rectifier was used to convert the stepped down AC voltage to DC while the smoothing capacitor was used to smoothens the varying DC voltage output from the rectifier. Eventually, the regulator was used to set the DC output to a fixed voltage.

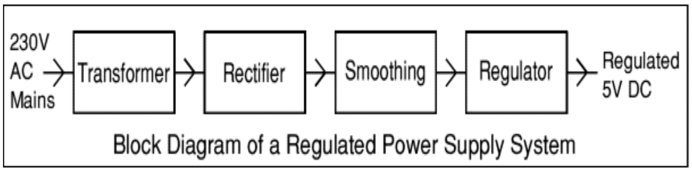



**Figure 1 The schematic diagram of the** power supply used in the system

For the transformer, Power out = power in and the turn ratio is given as;

$$\text{Turn ratio} = V_p/V_s = N_p/N_s \quad (1)$$

$$V_s \times I_s = V_p \times I_p \quad (2)$$

Where $V_p$ = Primary voltage, $N_p$= Number of turns in primary coil, $I_p$ = Primary (input) current, Vs=Secondary (output) Voltage and $N_s$= Number of turns on secondary Coil.. The transformer steps the AC voltage from 220 V to 12 V and the rectifier converts this to DC voltage of 12V. For the 12 volts step down transformer needed for this IoT-based system, the turn ratio is 220/12. The 12V DC voltage contains some AC harmonics (ripples) which are eliminate using a smoothing capacitor. The value of the capacitor is determined from the ripple voltage equation given as;

$$V_r = V_p/2RCF = I_o/2CF \quad (3)$$

Hence

$$C = \frac{Io}{2(V)(F)} \quad (4)$$

Where C= capacitance of smoothening capacitor, F= AC frequency, $V_p$= Peak voltage of rectified DC output, $V_r$= Ripple voltage and $I_o$ = Output current.But ripple factor, r

$$r = V_r / V_{p,} \quad (5)$$

Therefore

$$V_r = r \times V_p \quad (6)$$

Assume that $V_{dc} = V_p$ and a ripple factor of 12% (r =0.12), F = 50Hz and $I_o$ = 500mA = 0.5A, then Vr = 0.12 x 12 = 1.44 V , therefore,

$$C = \frac{0.5}{(2 \, x \, 1.44x \, 50)} = 0.00347F = 3470\text{uF}.$$

Since it is difficult to get this value of capacitor in the market, we chose a value very close to it, which was 3300uF and it can do the smoothening job comfortably. The output voltage across the smoothing capacitor is connected to a 5V DC voltage regulator.

### 2.3 The Input Sensors Design

The schematic diagram of the input subsystem design is shown in Figure 2. The input subsystem design includes the design of the current sensor unit, the voltage sensor unit, the real time clock and the button or key design.

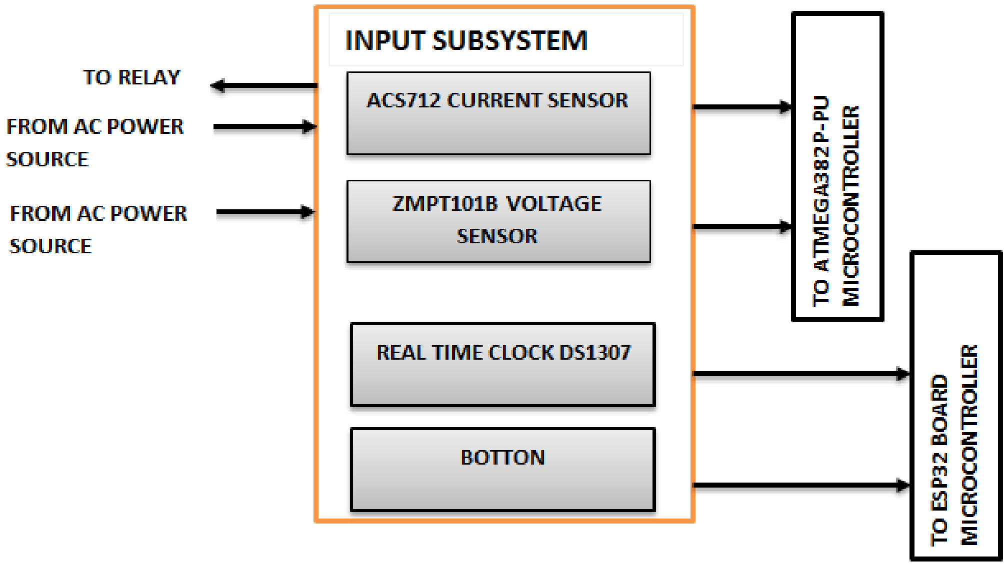



**Figure 2 The schematic diagram of the input subsystem design**

Specifically, the input subsystem is a circuitry that enables the system to fetch signal (changes in current and voltage) from the monitored electrical and electronic devices. Its design is achieved by the use of ACS712 current sensor, ZMPT101B voltage sensor, DS1307 real time clock and buttons connected to the ATMEGA328P-PU and ESP32 microcontrollers respectively. The VCC pin of the current sensor and the voltage sensor are connected to the power supply which give a supply voltage of 5volts. The modules ground pin (GND pin) is connected to the ground of the direct current power source. The analog output pin of ZMPT101B and ACS712 sensors are connected to pin A0 and A1 of ATMEGA328P-PU respectively. A 16MHZ crystal oscillator interface pin 9 and 10 of ATMEGA328P-PU in series with 22pf capacitor. Both pins connected to the ground for stability of the clock. The RX (pin2) and TX (pin3) of the microcontroller is connected to the RX2 and TX2 pins of ESP32 microcontroller using voltage divider principle to achieve optimum performance of 3.5 V which is the operational voltage of the ESP32 board.

The ACS712 current sensor (Figure 3 and Figure 4) can measure AC or DC current ranging from +5A to -5A, +20A to -20A and +30A to -30A. The user will select the current range for the IoT-based system. This modules outputs analog voltage (0 - 5V) based on the current flowing through the appliances. This makes it possible to interface this module with any microcontroller.

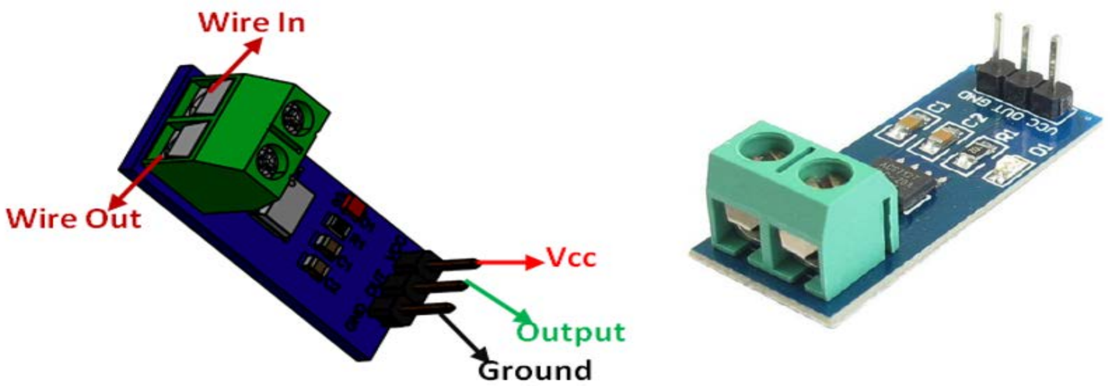



**Figure 3 The image of the ACS712 Current Sensor**

**Figure 4: Pin-out diagram for the ACS712 current sensor**

The voltage sensor used in this work is ZMPT 101B AC voltage sensor (**Figure 5)**. It forms part of the input subsystem. The sensor monitors the changes in alternating current voltage and direct current voltage.

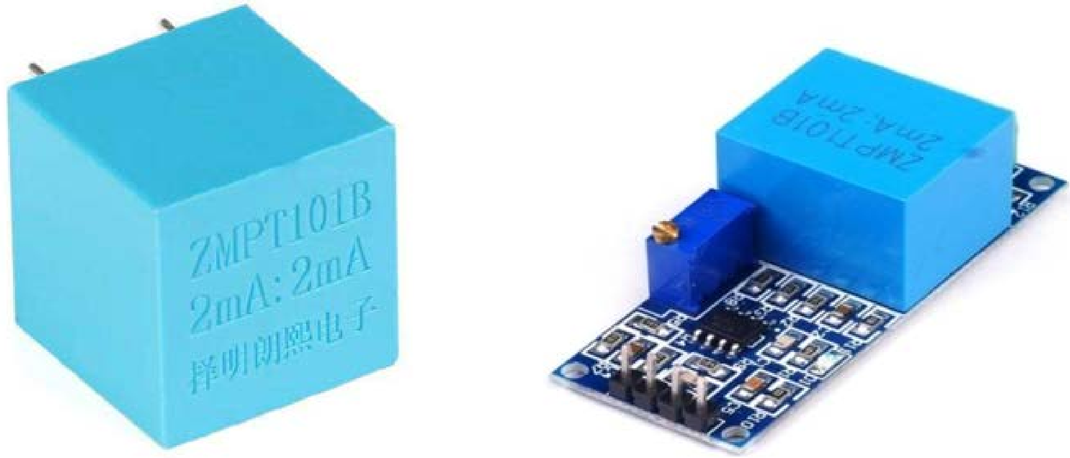
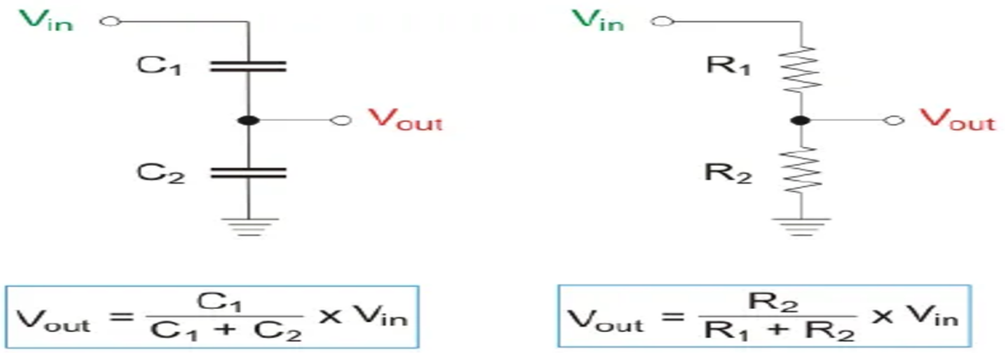



**Figure 5 The image of the ZMPT 101B AC Voltage Sensor**

The voltage sensor used to monitor the amount of voltage in an appliance determines the AC voltage or DC voltage level based on a voltage divider rule which can be capacitive voltage sensor and resistive voltage sensor, as shown in Figure 6.




(a) capacitive voltage sensor (b) resistive voltage sensor

Figure 6 The Capacitive voltage sensor and the Resistive voltage sensor

In this paper, the resistive voltage sensor (Figure 6 b) is adopted. The steps used to determine the values of R1 and R2 are given as follows;

**Step 1: Determine the maximum output RMS voltage**

The Voutmax is determined by the ADC (analog to digital converter) used with the microcontroller.

Hence, if bipolar-based ADC the Voutmax is computed as;

$$\text{Voutmax} = \frac{peak\ voltage}{\sqrt{2}}$$

For example: if ±5v ADC is the maximum rms voltage of the transformer

$$\text{Voutmax} = \frac{peak\ voltage}{\sqrt{2}} = \frac{5v}{\sqrt{2}} = 3.53\text{V} \qquad (7)$$

Hence, if 0 – 5V ADC is the maximum rms voltage of the transformer, then,

$$\text{Voutmax} = \frac{peak\ voltage}{\sqrt{2}} = \frac{5v}{\sqrt{2}} = 3.53\text{V}$$

However, if unipolar-based ADC the Voutmax is computed as;

$$\text{Voutmax} = \frac{peak\ voltage}{2\sqrt{2}} \qquad (8)$$

Hence, if 0 – 5V ADC is the maximum rms voltage of the transformer, then,

$$\text{Voutmax} = \frac{peak\ voltage}{2\sqrt{2}} = \frac{5v}{2\sqrt{2}} = 1.16\text{v}$$

**Step 2: Determine the value of R1 (the input current-limiting resistor)**

$$\text{R1} = \frac{\text{Vin}}{I} \qquad (9)$$

Where Vin denotes the input voltage; I denotes the rated operating current which for the ZMPT101B sensor the rated current is 1~2mA. Now if rated input voltage ≤ 100V, the operating current I = 2mA and if the rated input voltage ≥ 22 the operating current is chosen such that 1 mA ≤ I ≤ 2 mA. Hence, for V = 100V, I = 2 mA, then,

$$R1 = \frac{Vin}{I} = \frac{100}{0.002} = 50k\Omega$$

Again, if V = 220V, I = 1.1 mA, then

$$R1 = \frac{Vin}{I} = \frac{220}{0.0011} = 200k\Omega$$

**Step 3: Determine the value of R2 ( the sampling resistor )**

$$R2 = \frac{Voutmax}{I} = \frac{Voutmax}{Vin} \times R1\ \Omega \quad (10)$$

Hence, Vout max = 3.53V, Vin = 100V, then,

$$R2 = \frac{Voutmax}{I} = \frac{Voutmax}{Vin} \times R1 = \frac{3.53}{100} \times 50\ k\Omega = 1.765k\Omega$$

**The DS1307 REAL TIME CLOCK :** In this IoT-based system the DS1307 serial real-time clock (RTC) is used. The DS1307 is a low power, binary-coded decimal (BCD) clock/calendar with 56 bytes of non-volatile static random access memory (SRAM). The clock is a circuitry of the input subsystem. The DS1307 the clock is connected to the ESP32 microcontroller to provide seconds, minutes, hours, days, dates, months, and year information. At the end of the month, the date is automatically adjusted for months with fewer than 31 days, including corrections for leap year.

**The Buttons :** The buttons often called keys is an input device used to give command to the system. The 4-buttons in this IoT-based system provide useful human interface for data input into the system. It is used for calibrating and setting of the system parameters. The button (**Figure 7)** is connected to the microcontroller.

**Figure 7Button**

## 2.4 The Design of the Control Unit and the Control Program

Control unit also known as control module does the central processing of the energy management system. It regulates, communicates, integrates and interprets the operation of input system (detection system), output transducer and the goggle fire base. It selects and retrieves signals from various components in proper sequence and interprets them so as to activate the other functional elements of the system at the appropriate moment. The control unit in this IoT-based system made use of two microcontrollers interfaced with other components and the microcontroller based control program which interprets the input signal qualifies to produce the desired output.

## 2.5 The Microcontroller Unit

The IoT-based system made use of two microcontrollers; namely, the ATMEGA328P-PU (Figure 8) and the ESP32 board (Figure 9). Atmega328p-pu microcontroller is used in the IoT-based system for accuracy of analog to digital converter embedded in the microcontroller. The input sensors circuitry (ACS712 current sensor and ZMPT101B voltage sensor) interfaced with the microcontroller to feed-in the analog signal through the input/output pins of the microcontroller. The microcontroller then transmits the signal through the transmitter pin (TX) to the receiver pin (RX) of the ESP32 board for signal interpretation. The Atmega328 is connected to the ESP32 board using voltage divider rules with one kilo ohm, two kilo ohm and ten kilo ohm resistors to divide the current transmitted to the ESP32 board. The ESP32 board receives a supply voltage of 3.5 volts from the power supply unit as the operational voltage while Atmega328p operates on 5 volts.


**Figure 8 Atmega328p microcontroller**

**Figure 9 Esp32 microcontroller**

## 2.6 The Light-emitting-diodes (LED) and the output transducer design :

In the IoT-based system, four LEDs are used to assist in the control of the four socket outlets. The schematic diagram of the output subsystem design is shown in Figure 10. The output interface which is a transducer circuit (20 X 4 LCD screen) receives the processed signal from the control unit. A parallel port outputs an active high signal that serves as an input to a transistor switch connected to a relay circuit, the relay circuit thus, switches the appliances connected to the relay. In this work, the Songle relay (Figure 11) is used while ULN2003 (Figure 12) is the Integrated Circuit (IC) that drives the arrays of the songle relay modules used in this work.

Liquid Crystal Display: The IoT-based system design used 20x4 LCD display screen (Figure 13) for displaying 224 different characters and symbols. Each character is displayed in 5x7 pixel matrix. The 20x4 LCD used in this work displays 20 characters per line in 4 lines of the screen.

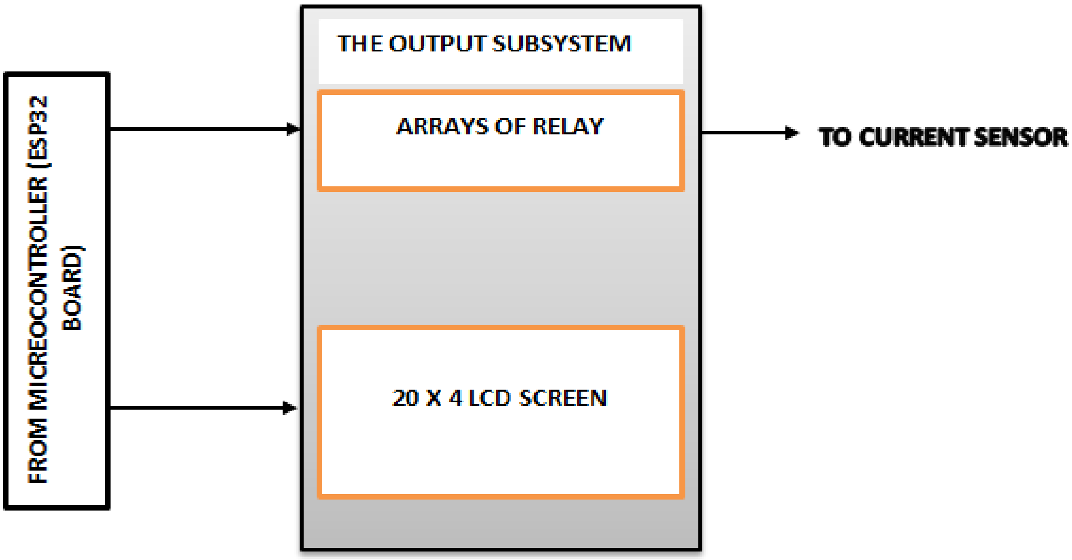



**Figure 10 The schematic diagram of the output subsystem**

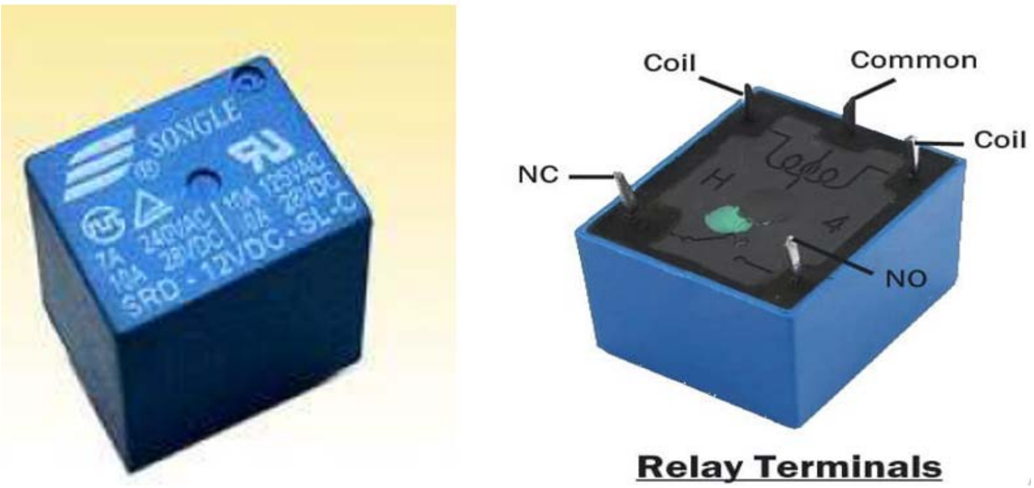



**Figure 11 The diagram of the Songle relay**

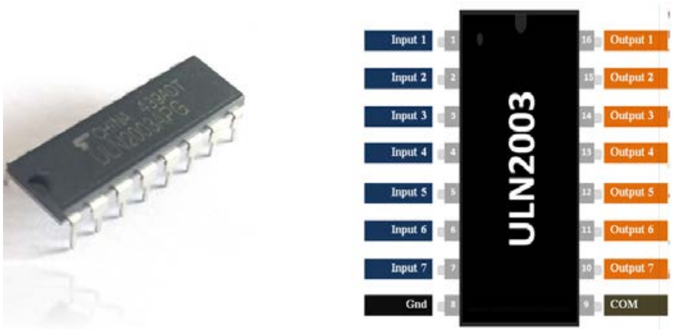



**Figure 12:** ULN2003 IC for driving the relay and its Pin-out

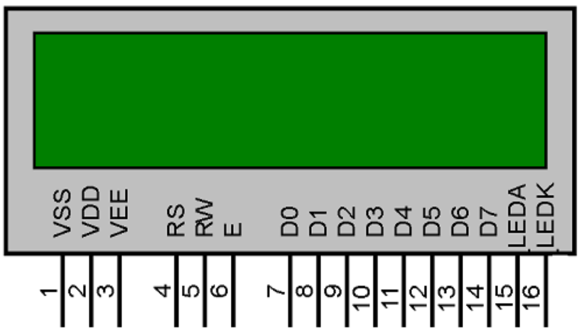



**Figure 13 the image of the 20x4 LCD display module**

### 2.7 PRINTED CIRCUIT BOARD (PCB)

The system was first designed with a breadboard to analyze the behavior of the system in real time situations when fully completed. On performing the desired aim, the design and implementation process began.

In the IoT-based system design, breaded board was used to assemble the components and then transferred to the Printed Circuit Board (PCB) which mechanically support and electrically connect electronic components using conductive pathways. Components used in the design are connected through the conductive material below a non-conductive board, the common conductive material used in packaged PCBs are usually copper, since copper is cheap and common.

Customized PCB was used for design compatibility. Secondly, it's more convenient to use, since one can decide where to put space on the board. Also, the board is stronger unlike those ready-made IoT-based system boards which are full of holes. (PCB instructions guide)

## 3. Result and Discussion

The circuit components were first assembled and tested on a breadboard after which they were transferred and soldered on the printed circuit board. The picture of a segment of the hardware circuit showing some components soldered on the circuit board is shown in Figure 14. A picture of the hardware device showing the device front pane with the LED, the buttons , the LCD display and four sockets is presented in Figure 15. The four 13 ampere socket outlets are the electrical outlets where electronic home appliances are connected to, enabling smart home automation control as shown in Figure 15 and Figure 16. The information from the output port of the microcontroller is displayed on the 20 x 4 LCD screen (as shown in Figure 17).

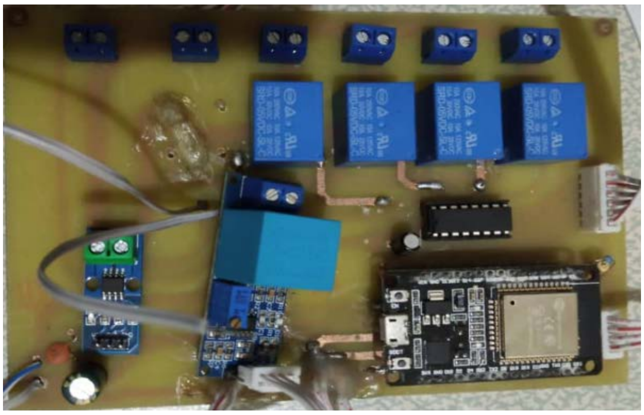


**Figure 14 A picture of a segment of the hardware circuit showing some components soldered on the circuit board**

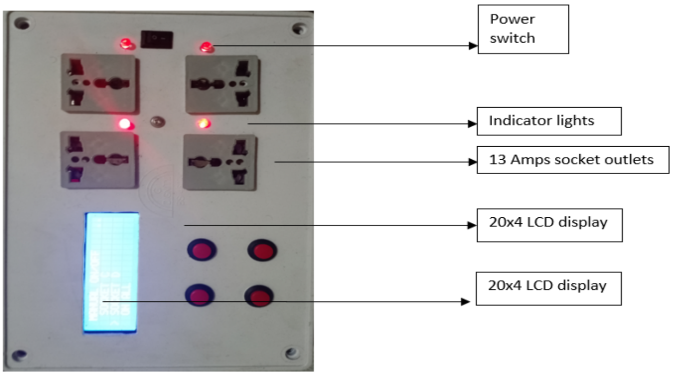



**Figure 15 A picture of the hardware device showing the device front pane with the LED , the buttons , the LCD display and four sockets**

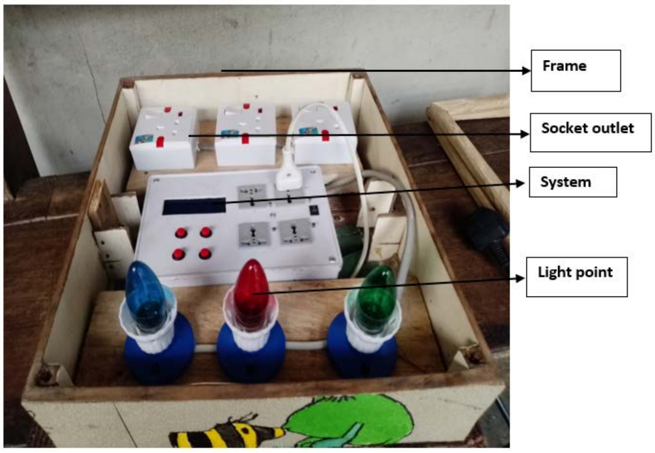



**Figure 16 Another picture of the hardware device showing another view and components of the hardware device.**


A. *Figure 17 Output interface showing the screen display and the socket outlets*

## 4. Conclusion

The design of microcontroller-based hardware device for smart household energy management applications is presented. The design was broken down into the following subsections;

i. The design of the power supply
ii. The input sensors design
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v. Liquid crystal display
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## References

1. Oyedepo, S. O. (2012). Energy and sustainable development in Nigeria: the way forward. *Energy, Sustainability and Society*, *2*(1), 1-17.
2. Owusu, P. A., & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering*, *3*(1), 1167990.
3. Amrouche, S. O., Rekioua, D., Rekioua, T., & Bacha, S. (2016). Overview of energy storage in renewable energy systems. *International journal of hydrogen energy*, *41*(45), 20914-20927.
4. Archibong, Ekaette Ifiok, Ozuomba, Simeon, Etinamabasiyaka Edet Ekott (2020) "Sizing Of Stand-Alone Solar Power For A Smart Street Light System With Vandalisation Monitoring And Tracking Mechanism." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 7, July - 2020*
5. Kannan, N., & Vakeesan, D. (2016). Solar energy for future world:-A review. *Renewable and sustainable energy reviews*, *62*, 1092-1105.
6. Idorenyin Markson, Simeon Ozuomba, Iniobong Edifon Abasi-Obot (2019) Sizing of Solar Water Pumping System for Irrigation of Oil Palm Plantation in Abia State. *Universal Journal of Engineering Science* 7(1): 8-19, 2019
7. Ikpe Joseph Daniel, Ozuomba Simeon, Udofia Kufre (2019) Google Map-Based Rooftop Solar Energy Potential Analysis For University Of Uyo Main Campus . *Science and Technology Publishing (SCI & TECH) Vol. 3 Issue 7, July - 2019*
8. Simeon, Ozuomba.(2019) "An assessment of solar-powered soybean farm basin irrigation water supply system." *Science and Technology Publishing (SCI & TECH) Vol. 3 Issue 4, April - 2019*
9. Deele, L. B., Ozuomba, Simeon, & Okpura, N. (2019). Design and Parametric Analysis of a Stand-Alone Solar-Hydro Power Plant with Pumped Water Storage Technology. *International Journal of Engineering & Technology, 4(1), 9-23.*
10. Usah, Emmamuel Okon, Simeon Ozuomba, Enobong Joseph Oduobuk (2020). "Pvsyst Software-Based Comparative Techno-Economic Analysis Of PV Power Plant For Two Installation Sites With Different Climatic Conditions." *International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 7, July - 2020*
11. Ozuomba, Simeon, Edifon, Iniobong, and Idorenyin Markson (2019). Impact of the optimal tilt angle on the solar photovoltaic array size and cost for A 100 Kwh solar power system In Imo State. International *Journal of Sustainable Energy and Environmental Research, 8(1), 29-35.*
12. Umoette, A. T., Ozuomba, Simeon, & Okpura, N. I. (2017). Comparative Analysis of the Solar Potential of Offshore and Onshore Photovoltaic Power System. *Mathematical and Software Engineering*, *3*(1), 124-138
13. Simeon, Ozuomba, Kalu Constance, and Okon Smart Essang (2020). Assessment Of The Effect Of The Water Pump Connection Configuration On The Electric Power Demand For A Solar Powered Groundnut Farm Furrow Irrigation System *International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 9, September - 2020*
14. Usah, Emmamuel Okon, Simeon Ozuomba, and Etinamabasiyaka Edet Ekott. (2020). "Design And Construction Of Circuits For An Integrated Solar-Wind Energy *System With Remote Monitoring And Control Mechanism." Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 6, June - 2020*
15. Usah, Emmamuel Okon, Simeon Ozuomba, and Etinamabasiyaka Edet Ekott. (2020). "Spatial Regression Models For Characterizing The Distribution Of Peak Sun Hours, PV Daily Energy Yield And Storage Battery Capacity For Standalone Photovoltaic (PV) Installations Across Nigeria." Delta 5, no. 5.808841: 4-53. *Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 6 Issue 7, July – 2020*

16. Usah, Emmamuel Okon, Simeon Ozuomba, Enobong Joseph Oduobuk, and Etinamabasiyaka Edet Ekott. (2020). "Development Of Analytical Model For Characterizing A 2500 W Wind Turbine Power Plant Under Varying Climate Conditions In Nigeria." *Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 6, June - 2020*

17. Lemene B. Deele, Ozuomba, Simeon, Okon Smart Essang (2020) SIZING OF AN OFF-GRID PHOTOVOLTAIC POWER SUPPLY SYSTEM WITH BATTERY STORAGE *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 8, August - 2020*

18. Victor Etop Sunday, Ozuomba Simeon and Umoren Mfonobong Anthony (2016). Multiple Linear Regression Photovoltaic Cell Temperature Model for PVSyst Simulation Software, International Journal of Theoretical and Applied Mathematics, 2(2): pp. 140-143

*19.* Lemene B. Deele, Ozuomba, Simeon, Nseobong Okpura (2020). Comparative Life Cycle Cost Analysis Of Off-Grid 200 KW Solar-Hydro Power Plant With Pumped Water Storage And Solar Power Plant With Battery Storage Mechanism *International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 8, August – 2020*

20. Zhou, B., Li, W., Chan, K. W., Cao, Y., Kuang, Y., Liu, X., & Wang, X. (2016). Smart home energy management systems: Concept, configurations, and scheduling strategies. *Renewable and Sustainable Energy Reviews*, *61*, 30-40.

21. Kanchev, H., Lu, D., Colas, F., Lazarov, V., & Francois, B. (2011). Energy management and operational planning of a microgrid with a PV-based active generator for smart grid applications. *IEEE transactions on industrial electronics*, *58*(10), 4583-4592.

*22.* Effiong, Clement, Simeon Ozuomba, and Udeme John Edet (2016). Long-Term Peak Load Estimate and Forecast: A Case Study of Uyo Transmission Substation, Akwa Ibom State, Nigeria. *Science Journal of Energy Engineering 4(6), 85-89.*

23. Suberu, M. Y., Mustafa, M. W., Bashir, N., Muhamad, N. A., & Mokhtar, A. S. (2013). Power sector renewable energy integration for expanding access to electricity in sub-Saharan Africa. *Renewable and Sustainable Energy Reviews*, *25*, 630-642

24. Kalu, C., Ezenugu, I. A. & Ozuomba, Simeon. (2015). Development of matlab-based software for peak load estimation and forecasting: a case study of faculty of engineering, Imo State University Owerri, Imo state, Nigeria. *European Journal of Engineering and Technology*, *3 (8)*, 20-29.

25. Uko, Sampson Sampson, Ozuomba Simeon, and Ikpe Joseph Daniel (2019). Adaptive neuro-fuzzy inference system (ANFIS) model for forecasting and predicting industrial electricity consumption in Nigeria. *Advances in Energy and Power*, 6(3), 23-36.

26. Oseni, M. O. (2012). Improving households' access to electricity and energy consumption pattern in Nigeria: Renewable energy alternative. *Renewable and Sustainable Energy Reviews*, *16*(6), 3967-3974.

27. Effiong, Clement, Ozuomba Simeon, and Fina Otosi Faithpraise (2020). "Modelling And Forecasting Peak Load Demand In Uyo Metropolis Using Artificial Neural Network Technique." *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 3, March – 2020*

28. Stephen, Bliss Utibe-Abasi, Ozuomba Simeon, and Sam Bassey Asuquo. (2018) "Statistical Modeling Of The Yearly Residential Energy Demand In Nigeria." *Journal of Multidisciplinary Engineering Science Studies* (JMESS) Vol. 4 Issue 6, June – 2018

29. Ozuomba Simeon , S.T Wara, C. Kalu and S.O Oboma (2006) ; *Computer Aided design of the magnetic circuit of a three phase power transformer, Ife Journal of Technology Vol.15, No. 2 , November 2006 , PP 99 – 108*

30. Okakwu, I. K., Ogujor, E. A., & Oriaifo, P. A. (2017). Load flow assessment of the Nigeria 330-kV power system. *American Journal of Electrical and Electronic Engineering*, *5*(4), 159-165.

31. Eti-Ini Robson Akpan, Ozuomba Simeon, Sam Bassey Asuquo (2020). POWER FLOW ANALYSIS USING INTERLINE POWER FLOW CONTROLLER *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 5, May – 2020*

32. Abdulkareem, A., Somefun, T. E., Awosope, C. O. A., & Olabenjo, O. (2021). Power system analysis and integration of the proposed Nigerian 750-kV power line to the grid reliability. *SN Applied Sciences*, *3*, 1-15.

33. Ozuomba, Simeon, Victor Akpaiya Udom & Jude Ibanga. (2018). Iterative Newton-Raphson-Based Impedance Method For Fault Distance Detection On Transmission Line. Education, 2020. *International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 5, May - 2020*

34. Archibong, Ekaette Ifiok, Simeon Ozuomba, and Etinamabasiyaka Edet Ekott. (2020). "Design And Construction Of The Circuits For An Iot-Based, Stand-Alone, Solar Powered Street Light With Vandalisation Monitoring And Tracking Mechanism." *Science and Technology Publishing (SCI & TECH) Vol. 4 Issue 7, July - 2020*

35. Archibong, E. I., Ozuomba, Simeon, & Ekott, E. E. (2020). Life Cycle Cost And Carbon Credit Analysis For Solar Photovoltaic Powered Internet Of Things-Based Smart Street Light In *Uyo. International Multilingual Journal of Science and Technology (IMJST) Vol. 5 Issue 1, January - 2020*

36. Archibong, Ekaette Ifiok, Simeon Ozuomba, and Etinamabasiyaka Ekott. (2020) "Internet of things (IoT)-based, solar powered street light system with anti-vandalisation mechanism." *2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS)*. IEEE, 2020.

37. Chikezie, Aneke, Ezenkwu Chinedu Pascal, and Ozuomba Simeon. (2014). "Design and Implementation Of A Microcontroller-Based Keycard." *International Journal of Computational Engineering Research (IJCER) Vol, 04 Issue, 5 May – 2014*

38. Otumdi, Ogbonna Chima, Kalu Constance, and Ozuomba Simeon (2018). "Design of the Microcontroller Based Fish Dryer." *Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 4 Issue 11, November - 201*

39. Ozuomba, Simeon, and Etinamabasiyaka Edet Ekott. (2020). "Design And Implementation Of Microcontroller And Internet Of Things-Based Device Circuit And Programs For Revenue Collection From Commercial Tricycle Operators." *Science and Technology Publishing* (SCI & TECH) Vol. 4 Issue 8, August – 2020

40. Ozuomba, Simeon, Ekaette Ifiok Archibong, and Etinamabasiyaka Edet Ekott (2020). Development Of Microcontroller-Based Tricycle Tracking Using Gps And Gsm Modules. *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 1, January - 2020*

41. Maduka, N. C., Simeon Ozuomba, and E. E. Ekott. . (2020) "Internet of Things-Based Revenue Collection System for Tricycle Vehicle Operators." *2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS)*. IEEE, 2020.

42. Ezenugu, I. A, Ogu R. E and Ikwueze S. N, (2013), “Microcontroller Based Water Controller for Optimum Water Supply’’ International Journal of Engineering Research & Technology, Vol 2 No 12, pp2122-2128. www.ijert.org

*43.* Dr. D. O. Dike, R.E. Ogu, Dr. L. O. Uzoechi and Ezenugu, I. A (2016) “Development of an Internet of Things based Electricity Load Management System” American Journal of Engineering Research (AJER) Vol 5 No 8, pp 199-205.

44. Ogu R.E, Chukwudebe G. A and Ezenugu, I. A (2016), “An IoT Based Tamper Prevention System for Electricity Meter” American Journal of Engineering Research,

45. Thompson, E., Simeon, O., & Olusakin, A. (2020). A survey of electronic heartbeat electronics body temperature and blood pressure monitoring system. Journal of Multidisciplinary Engineering Science Studies (JMESS) Vol. 6 Issue 8, August – 2020

46. Zion, Idongesit, Simeon Ozuomba, and Philip Asuquo. (2020) "An Overview of Neural Network Architectures for Healthcare." *2020 International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS)*. IEEE, 2020

47. Gordon, O., Ozuomba, Simeon. & Ogbajie, I. (2015). Development of educate: a social network web application for e-learning in the tertiary institution. *European Journal of Basic and Applied Sciences, 2 (4)*, 33-54.

*48.* Ozuomba, Simeon, Kalu, C., & Anthony, U. M. (2015). Map Mashup Application And Facilitated Volunteered Web-Based Information System For Business Directory In Akwa Ibom State. *European Journal of Engineering and Technology Vol*, *3*(9).

49. Akpasam Joseph Ekanem, Simeon Ozuomba, Afolayan J. Jimoh (2017) Development of Students Result Management System: A case study of University of Uyo. *Mathematical and Software Engineering*, Vol. 3, No. 1 (2017), 26-42.

50. Inyang, Imeobong Frank, Simeon Ozuomba, and Chinedu Pascal Ezenkwu.(2017) "Comparative analysis of Mechanisms for Categorization and Moderation of User Generated Text Contents on a Social E-Governance Forum." *Mathematical and Software Engineering* 3.1 (2017): 78-86.

51. Mathew-Emmanuel, Eze Chinenye, Simeon Ozuomba, and Constance Kalu. (2017) "Preliminary Context Analysis of Social Network Web Application for Combating HIV/AIDS Stigmatization." *Mathematical and Software Engineering* 3.1 (2017): 99-107

52. Ozuomba, Simeon, Constant Kalu, and Akpasam Joseph. (2018). Development of Facilitated Participatory Spatial Information System for Selected Urban Management Services. *Review of Computer Engineering Research, 5(2), 31-48.*

53. Bassey, M. U., Ozuomba, Simeon, & Stephen, B. U. A. (2019). DEVELOPMENT OF A FACILITATED CROWD-DRIVEN ONLINE PROFIT-MAKING SYSTEM. *European Journal of Engineering and Technology Vol, 7(5).*

54. Ibanga, Jude, and Ozuomba Simeon, Obot, Akaniyene. B. (2020) "Development of Web-Based Learning Object Management System." Development 7, no. 3 (2020). *Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. 7 Issue 3, March - 2020*

55. Simeon Ozuomba , Gloria A. Chukwudebe , Felix K. Opara and Michael Ndinechi (2014)Chapter 8: Social Networking Technology: A Frontier Of Communication For Development In The Developing Countries Of Africa . *In Green Technology Applications for Enterprise and Academic Innovation (Chapter 8).* IGI Global, Hershey, PA 17033-1240, USA

56. Ezenkwu, Chinedu Pascal, Simeon Ozuomba, and Constance Kalu. (2013). "Strategies for improving community policing in Nigeria through Community Informatics Social Network." *2013 IEEE International Conference on Emerging & Sustainable Technologies for Power & ICT in a Developing Society (NIGERCON)*. IEEE, 2013.

57. Nicholas A. E., Simeon O., Constance K. (2013) Community informatics social e-learning network: a case study of Nigeria *Software Engineering 2013; 1(3): 13-21*

58. Ozuomba Simeon and Chukwudebe G. A.(2011) ; *Strategies For Improving Software Development And Acquisition Practices in Developing Countries*. The paper was presented in the 1ST International Conference of IEEE NIGERCON 2010, 17 th – 19th 2010. It was then published in the Proceeding of the 1ST INTERNATIONAL Confrence of IEEE NIGERCON, Vol 1 No. 1, Page 38 -47

59. Hudan, I. S., & RIJANTO, T. (2019). Rancang Bangun Sistem Monitoring Daya Listrik Pada Kamar Kos Berbasis Internet Of Things (Iot). *Jurnal Teknik Elektro*, *8*(1).

60. Ardiansyah, A. (2020). *Monitoring Daya Listrik Berbasis IoT (Internet of Things)* (Doctoral dissertation, Universitas Islam Indonesia).

61. Babiuch, M., Foltýnek, P., & Smutný, P. (2019, May). Using the ESP32 microcontroller for data processing. In *2019 20th International Carpathian Control Conference (ICCC)* (pp. 1-6). IEEE

62. Khan, S. R., Kabir, A., & Hossain, D. A. (2012). Designing smart multipurpose digital clock using real time clock (RTC) and PIC microcontroller. *International Journal of Computer Applications*, *41*(9), 40-42.