Spring International Engineering Research Journal: ISSN: 2384-5058
Volume-13 (Issue): 1, January, Pp 55-70, 2025
Accepted 24th December,2024.

Design and Implementation of a Three-User Electrical Energy Meter to Capture Energy Consumption

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Abstract

Energy meters have long been used to present the quantity of electrical energy consumed by users in a given time. In buildings where partitioned apartments are leased to different individuals, the individuals are usually demanded to share an energy supply meter with several other individuals in other apartments in the same building. However, the uniform billing from the distribution companies does not account for the difference in the energy consumed by the diverse users of the energy meter. As such, users are required to equally split the bill and not pay in proportion to the energy individually consumed. This disparity often leads to disputes between tenants, the unlawful power theft in the form of meter tampering, and unpaid bills. To address the aforementioned challenges, this paper designs a low-cost, single-phase, three-user electrical energy meter to present the electrical energy consumed by each user and connect the electrical energy meter that displays the energy consumption of each user connected to the meter. The design utilised an ACS712 (current sensor) and a voltage sensor, which helped in sampling the current and voltage, respectively, and a microcontroller (ATMega328p), as well as other peripheral devices. The construction and testing, conducted for 60 minutes with loads of 1000W, 160W, and 200W, yielded results of 1KWhr, 0.16KWhr, and 0.20KWhr, respectively, at 230V, with corresponding currents of 4.35A, 0.70A, and 0.87A.

Keywords: Energy usage, Three-user energy meter, power theft reduction.

1. INTRODUCTION

Because the demand for and use of electricity is growing so quickly, both homes and businesses need to be able to accurately measure how much energy they use (Onoja, 2019). On this premise, there have been several energy meters designed to measure the energy consumed by the users. An energy meter is an instrument that measures the amount of electrical energy used by the consumers (Rana, 2014). In Nigeria, utility companies install these instruments at load points such as homes, offices, organisations, industries, etc., to charge the electricity consumption by the user's loads. These meters measure the instantaneous voltage and current, calculate their product, and give the value of instantaneous power (Swamy and Pravallika, 2007). This power is integrated over a period, which gives the energy utilised over that time period (Jiang et al. 2009). Energy meters may be single- or three-phase, depending on the supply used by domestic or commercial installations. For small service measurements, like domestic customers, energy meters can be directly connected between line and load. But for larger loads, step-down current transformers must be placed to isolate it from higher currents (Onoja, 2019).

A lot of modifications and development have taken place in the construction and operation of energy meters. High-end processors or microcontrollers use integrated logic circuits to directly measure the power used by loads in digital energy meters (Onoja, 2019). At each billing period, the utility companies usually prepare a bill for energy units consumed by loads. When this bill is brought for each designated meter, the users of the meter share the bill equally among themselves, not minding the exact unit(s) consumed by each user. This poses a challenge, especially for someone whose energy needs are in the order of a few units and who lives among high-energy-demand individuals. In view of this, the project seeks to address this issue by designing an energy meter that provides points where loads from users can be directly connected and their energy units displayed separately. The cumulative units from each load will sum to the total units consumed, for which the bill will be prepared. With this, each user can conveniently pay for units consumed and not be cheated (Onoja, 2019). Based on this idea, the paper shows a three-user electrical energy meter that uses voltage and current sensors to measure the load current and voltage of all three users connected to the meter. The line voltage and current are rated down to signal level using voltage and current transformers. Additionally, further sampling of the load current is done using the current sensor IC-ACS712, converting the current input of each load to a voltage output. The microcontroller ATMEGA328 accepts a pair of voltage inputs that represent the voltage and current of each load connected. Internally these signals are converted to the digital domain using A/D converters. A fixed-function software is implemented to continuously multiply the two signals, their product being proportional to instantaneous power. Furthermore, the microcontroller performs other housekeeping tasks, such as using its timer to keep a record of the interval for which it receives a signal for the calculation of energy units and interacting with other components, like the EEPROM and the LCD, where all parameters are displayed.

The rest of this work is organised as follows: Section 2 presents pertinent literature related to the study. Section 3 presents the circuit analysis and design. Chapter 4 shows the results obtained, while the conclusion is outlined in Chapter 5.

2. LITERATURE REVIEW

This section presents literature related to the management and consumption of energy by users. These are outlined hereunder:

Toa and Wang's (2010) work showed how to make a multi-user electric power management device with a TMS320F2812 CPU and other parts like an MC55, RS485, LCD module, Pulse Collection Interface (PCI), data storage module, power on/off execution module, and power supply module. The MC55 plays a vital role in collecting electric energy from the meter through RS485 PCI, and electric charge calculation is carried out.

Rana et al. (2014) used current and voltage sensors to measure the voltage and load current, neglecting the use of current and voltage transformers. The design of a smart energy meter involves the measuring of load current and voltage using sensors and then feeding them to the energy metering IC, which converts it into the real power consumed by the load. The microcontroller unit (MCU) performs all the necessary arithmetic for the power and energy consumed by the load and displays results or readings on the LCD. With this, communication is done between the meter and the individual users to show their consumed energy and power so as to check the level of their consumption in order to manage and reduce cost/bill.

This paper avoids the problem of non-unique tariffs in partitioned apartments. According to Uzedhe and Ofualagba (2015), partitioned apartments in commercial buildings, particularly in congested environments, share energy supply meters among several users. This often leads to disputes and results in power theft in the form of unpaid bills and meter tampering, which is unlawful. Power theft adversely affects power generation, transmission, and distribution due to potential overloading, which can lead to equipment breakdown and revenue loss for the power company. It is envisaged that the use of this method for electricity distribution in commercial apartments will greatly reduce power theft and increase revenue generation for the power industry. It will also eliminate disputes and possible litigation within the power industry and among users.

According to Parker et al. (2015), the importance of metering is summed up in the maxim, You can't manage what you don't measure. If you don't measure it, you can't improve it. Metering of energy has seen an increase in interest, application, and technology advancement in both the private and the public sectors. The application of multi-user electric meters to individual apartments and energy-intensive equipment provides consumers and operators with real-time information on how much energy has been or is being used. This type of information can be used to assist in residential and equipment operations, in utility procurements, and in building energy budget planning and tracking.

Soni et al. (2017) argued that because of the need for accuracy and efficiency in operation, the dial type (analogue) meters were replaced by the digital type meters. These digital meters register electricity utilisation in terms of kWh. Soni et al. (2017) used the Graphic User Interface (GUI) with VB 2006 to get readings from the collectors' units. The GUI is made up of a computer and a GSM module that are connected via the RS-232 protocol. The GUI will be used to send a request SMS through the GSM modem using the AT command set to the reader unit. The Reader Unit of the system, which will be wired with the meters, will receive the request SMS. Its microcontroller will use a multiplexer and demultiplexer to talk to the meters one at a time and wired asynchronous serial communication to get their readings. The readings will be transmitted in the form of SMSes through a GSM modem using the AT command set to the collector unit. The action of collecting values from the meter is initiated by the collector unit via a GUI that was developed with the aid of VB 2006, which is handled by the utility/distribution company. The collector unit is made up of a computer and GSM module interfaced together via the RS-232 protocol. The GSM module functions to send request SMS through AT commands to the reader unit for collection of required data. The request SMS is sent from the collector unit to the reader unit, which is wired to the meters. The microcontroller helps get readings or values from the meters one at a time through multiplexers and demultiplexers, which is done through asynchronous serial communication. Readings are transmitted via the GSM module as SMS using AT commands to the collector unit. The reader and collector unit will communicate via the antenna.

3. CIRCUIT ANALYSIS AND DESIGN

Electrical circuits and devices are designed, built and constructed with the help of fundamental theories and laws guiding the flow of electric charges. These theories and laws follow basic principles and rules to design circuits that are dependable and reliable. Discussed hereunder are several electrical components used in the energy meter circuitry.

3. 1. Circuit Analysis

The design work is divided into six blocks namely: power supply unit, current sensor, voltage sensor, power factor, microcontroller and the display unit

3. 1. 1. Analysis of power supply unit

In most electronic works, power supply is needed to convert mains AC voltage into regulated DC voltage through rectification. For making a power supply, design of each and every component is essential as shown in Figure 1.

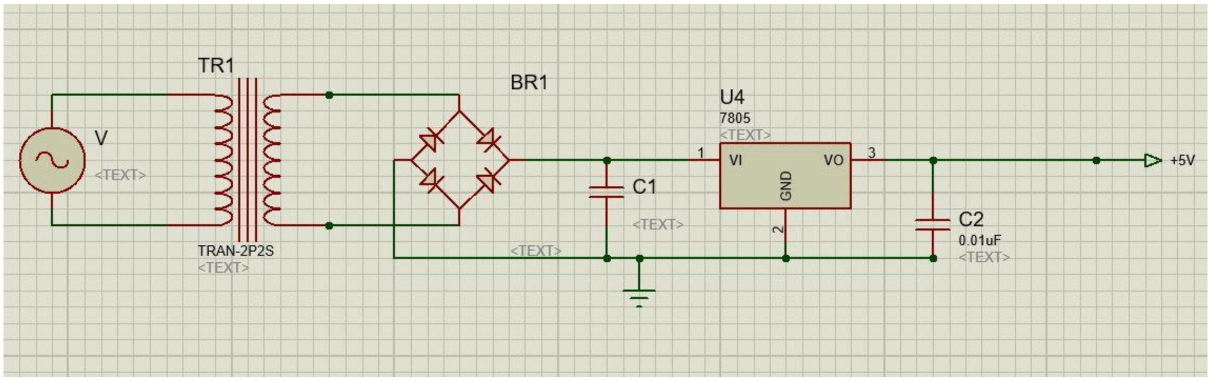

Figure 1: Power Supply Unit

The circuit of choice is a DC power supply with 5V output as shown in Figure 1. Each component in this circuit has particular function aimed at achieving a very stable output voltage.

i. Selection of transformer:

Selecting a suitable transformer is of great importance in designing DC power circuit. This is because the current rating and the secondary voltage of the transformer depends on the current requirements of the load. In view of this, 230/9V transformer is selected for this work.
The RMS value of primary voltage is 230V
The RMS value of secondary voltage is 9V
The peak value of secondary voltage is $V\_max=\sqrt{2}\times 9V_{rms}=12.7279V$

The specifications of the transformer are given below:
Current rating: 500mA
Power output rating: 6.3VA
Frequency: 50Hz

ii. Rectifier Circuit

This work makes use of full wave rectification using bridge arrangement of diodes, as shown in Figure 2. This is advantageous over the half wave rectifier because transformer utilization factor is high and it is also advantageous over full wave rectification using center-tapped transformer because the peak inverse voltage is low.

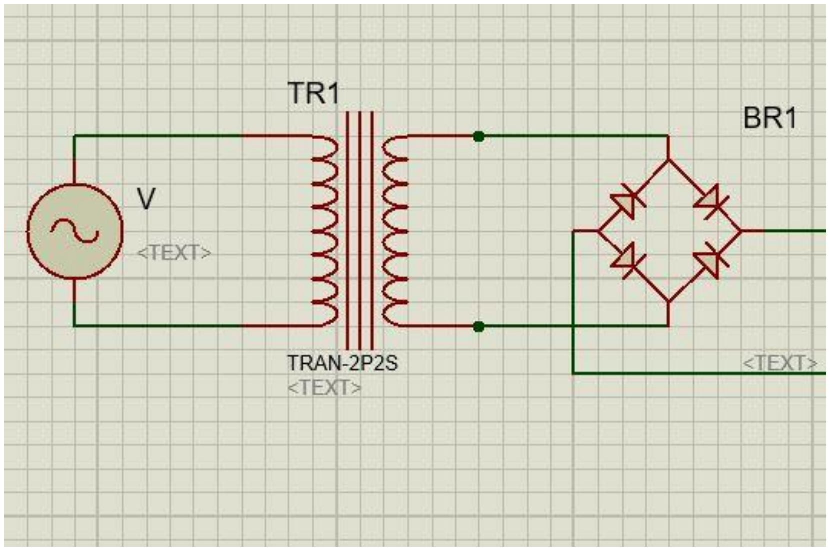

Figure 2: Transformer and Rectifier stage

The selection of the diodes used in the bridge circuit is done such that each diode can withstand the peak inverse voltage at the secondary of the transformer.

The peak voltage expected at the secondary of the transformer is 12.7V, therefore diodes with peak inverse voltage greater than 12V and forward current greater than 500mA are chosen and used for this work. Therefore, the diode 1N4001 with peak inverse voltage of 50V and forward current of 1A was used for this work.

Voltage drop across each silicon diode $V_d = 0.7V$

Voltage drop across the rectifier for each cycle $V_d = 0.7V \times 2 = 1.4V$

Output voltage of rectifier $V = 12.7V - 1.4V = 11.3V$

iii. Selection of filter capacitor

The output waveform of the rectifier is a pulsating DC containing some level of AC component also known as ripple. To keep these fluctuations at their barest minimum, the filter circuit is required. The purpose of the filter is to remove or smoothen out the ripple in the rectified DC voltage. The filter circuit of choice is capacitor input filter. This filter circuit depends its operation on the property to charge during conducting half cycle and discharge during non-conducting half cycle depicted in Figure 3.

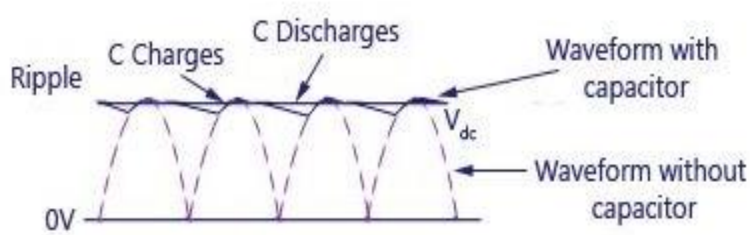

Figure 3: Output Waveform of the Rectifier

The capacitance of filter is calculated using the formula

$$C = \frac{I_{dc}}{4\times\sqrt{3}\times F\times\gamma\times v_{ip}} \quad (1)$$

Where

I_{dc} is the load current = 500mA

γ is the ripple factor

V_{ip} is the peak rectifier output voltage

F is the frequency of supply

Assuming a 6% ripple factor, the value of the filter capacitor is obtained as

$$C = \frac{0.5}{4\times\sqrt{3}\times 50\times 0.06\times 11.33} \quad (2)$$

$\boldsymbol{C = 2123.24\ \mu F}$

A capacitor with capacitance of 2, 200µF is selected.

iv. The voltage regulator

In order to keep the output voltage fairly constant at 5V, a voltage regulator is required. This regulator is needed to maintain a constant 5V DC across the load irrespective of variations in the input voltage.

To produce a constant 5V at the output, the LM7805 regulator is used for this research. The LM7805 is a voltage regulator with three terminals; input, output and ground. The regulator has the following parameters outlined in Table 1.

Table 1: LM7805 is a Voltage Regulator Parameters

Parameters	Values
Input voltage range	7V - 35V
Output voltage (V_max)	5.2V
Output voltage (V_min)	4.8V
Current Rating	1A

The data sheet of the LM7805 prescribes to use a 0.01µF capacitor at the output of the regulator. This capacitor is added to avoid transient changes in the voltage due to changes in load current. Therefore, the capacitor C2 is added.

3. 1. 2. Analysis of current sensor

Load current sampling is very important in the design of energy meters. In this work, the Allegro's ACS71205B IC is used to sample the load current. The device is a linear hall effect circuit with a copper conduction path near the surface of the die. Figure X shows how the IC is used to sense the load current. The IC is connected to sample each of the load current. Here, each load is represented by its equivalent resistance R.

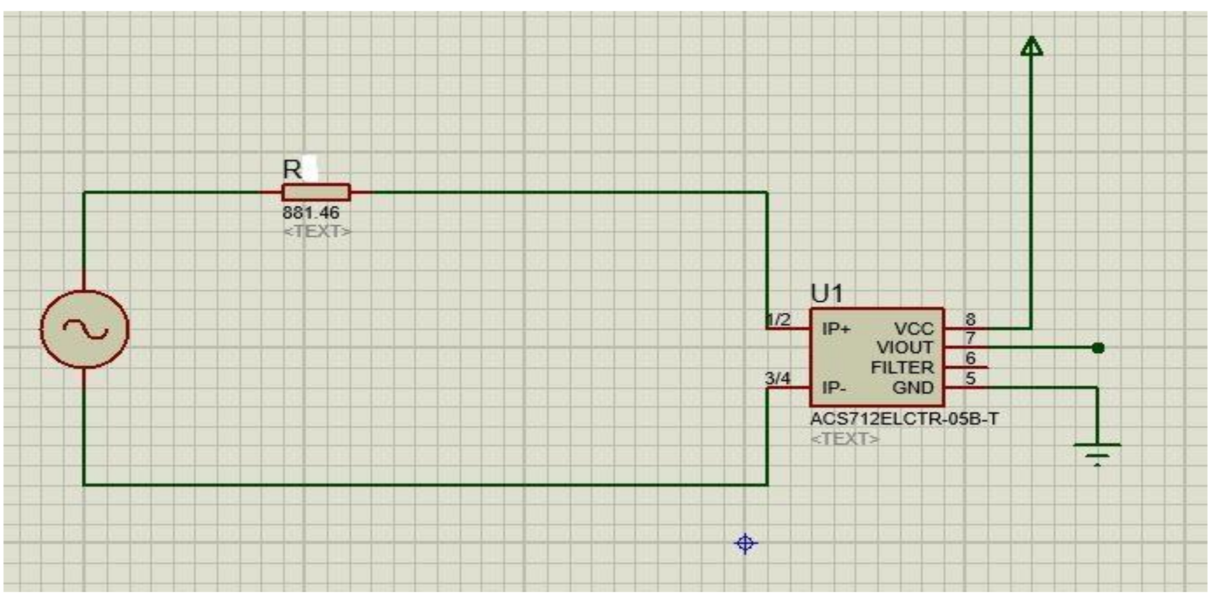

Figure 4. Current Sens4r Circuit

The sensitivity of the IC is specified at 185mV/A, while at zero input current the output voltage is also the primary conductor resistance is specified as 1.2mΩ.

3. 1. 3. Analysis of voltage sensor

The voltage sensor implemented in this work circuit diagram shown in Figure 9.

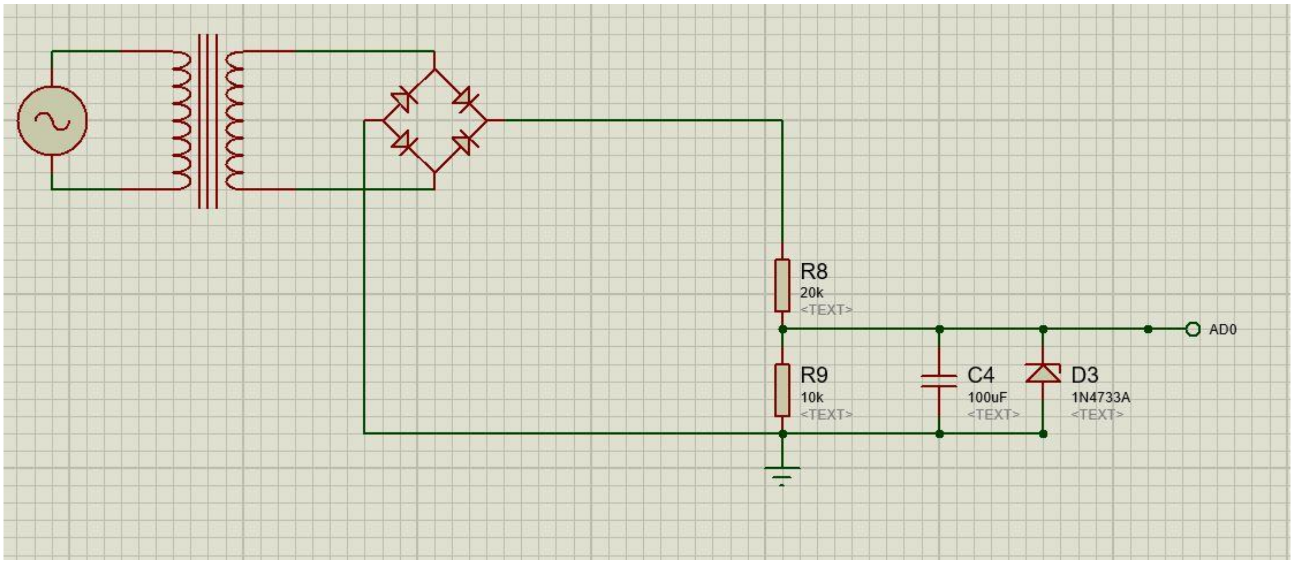

Figure 5: Voltage Sensor Circuit

It is desired to provide an output voltage range of 0V - 5V DC that fluctuates with changes in input voltage range from 0V – 230V AC. In view of this, the transformer T_2 is a 230/9V step down transformer with 500mA current rating.

Therefore, $V_{s(rms)} = 9V$

Where

$V_{s(\max)} = \sqrt{2} \times 9V = 12.7279V$

Where $V_{s(max)}$ is the peak voltage across the secondary of the transformer.

Diodes used for bridge circuit are selected to have peak inverse voltage (PIV) greater than 12.7279V. Therefore, the 1N4001 diode with 50V PIV and forward current of 1A is used.

Voltage drop across diodes per cycle is $V_d = 0.7V \times 2 = 1.4V$

Therefore, voltage after rectification $V = 12.7279 - 1.4 = 11.3279V$

The resistor divider R_1 and R_2 is used to further rate down the value.

Here a maximum DC output voltage of 4.5V at 230V is desired and selected.

Therefore,

$$\boldsymbol{V_{out}} = \left(\frac{\boldsymbol{R_1}}{\boldsymbol{R_2+R_1}}\right)\boldsymbol{V_{in}} \quad 3$$

where V_{out} is the desired output voltage equal to 4.5V DC and V_{in} is the voltage across the divider equal to 11.3279V

Thus,

$$\boldsymbol{R_2} = \frac{\boldsymbol{V_{in}}}{\boldsymbol{V_{out}}}\boldsymbol{R_1} - \boldsymbol{R_1} \quad 4$$

Selecting the value of $R_1 = 10K\Omega$, with the required $V_{out} = 4.5V$ and $V_{in} = 11.3279V$

Therefore,

$$\boldsymbol{R_2} = \frac{\mathbf{11.3279}}{\mathbf{4.5}} \times \mathbf{10} - \mathbf{10} = \mathbf{15.2}\boldsymbol{K}\Omega$$

The closest value to 15.2KΩ is 20KΩ therefore $R_2 = 20K\Omega$ is used.

The capacitor C_1 is used to eliminate ripple.

The Zener diode (1N7433A) is added to keep the output voltage at V_z, the voltage across the Zener diode. From the datasheet,

$$V_{z(\max)} = 5.1V$$
$$I_{z(max)} = 178mA$$
$$P_{z(\max)} = 1W$$

In order to optimize the code used to calculate the voltage, a scatter plot was performed for the fluctuation in input voltage from 100V to 240V in interval of 5V. Using linear regression, a model of the form shown below was obtained.

$$y = mx + c$$

Where

y signifies the output voltage,

x represents the input voltage

m and c are constants given as 149.327477 and 44.12187757, respectively.

3. 1. 4. Analysis of Power Factor Unit

The circuit in Figure 10 is designed to measure the power factor using zero cross detection method.

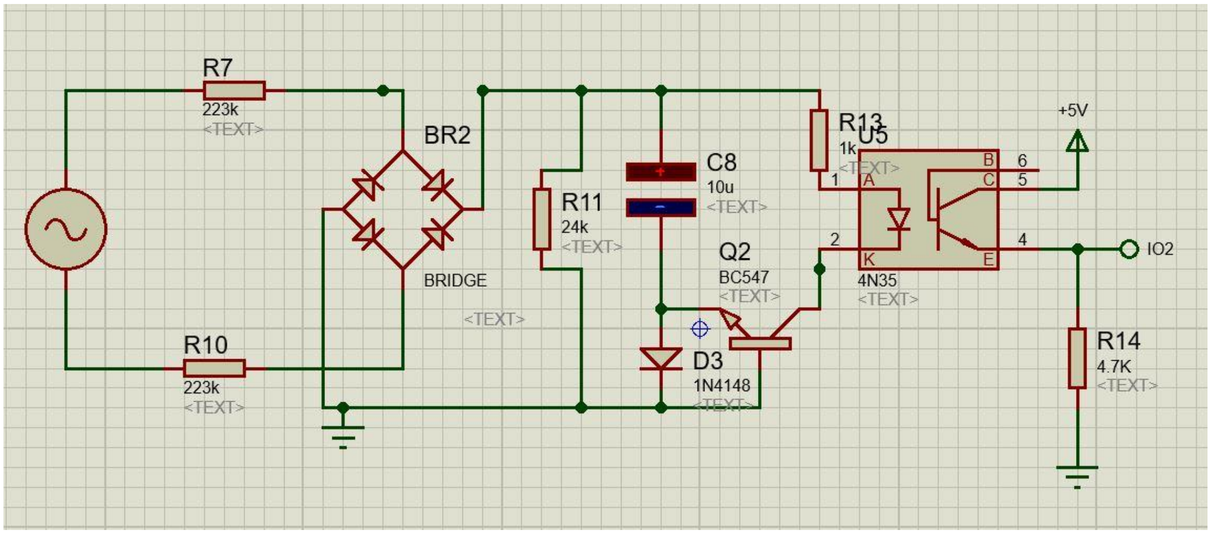

Figure 6: Circuit to Detect Zero Crossing

The voltage zero crossing detector circuit is low power circuit of <32mW, the zero crossing detector circuit is simple, efficient and very compact. It consist of voltage to current converting resistor R7-R10, full wave bridge rectifier, a voltage averaging and storing capacitor C8, the optocoupler U5 and the transistor Q2 functions as a voltage comparator. During charging stage (0-90 degrees) of the capacitor, the capacitor is charged through the path R7-R10 and D3 (preventing the reverse biasing of the transistor). Whenever the main voltage (divided by $\left(\frac{R7+R10}{R11}\right)$) is lower than the voltage across the capacitor, the transistor turns on and feed current to the optocoupler throug R9 from the capacitor during the discharging period (90-180 degrees). The optocoupler turns ON at a point where the mains voltage is close to Zero.

The output of the optocoupler is connected to the micro controller I/O pin. When ever the LED of the optocoupler is activated the output transitor is then bias and in turns allow current to flow into the microcontroller through the connected pin. A 4.7K resitor is connected at the emitter of the optocoupler transistor to limit the current entry the microcontroller through its pin.

Optocoupler unit:
Vcc=5V
Ip=1mA (current selected from the range of 0-40mA)
$(R = (Vcc/Ip) = 5K\Omega)$
R=4.7KΩ

3. 1. 5. Overview of the Microcontroller (ATMEGA328P)

ATMega328p is an 8-bit single chip microcontroller based on the advanced virtual RISC (AVR) architecture. It is a high performance, low power controller designed for embedded applications. The choice of this controller is based on the above features which are most desirable in any measuring instrument. The “p” in the name denotes pico-power.

ATMega328p has three ports (B, C and D) with 28 pins as shown in Figure 7. The pins are bi-directional, with many pins having more than one functions.

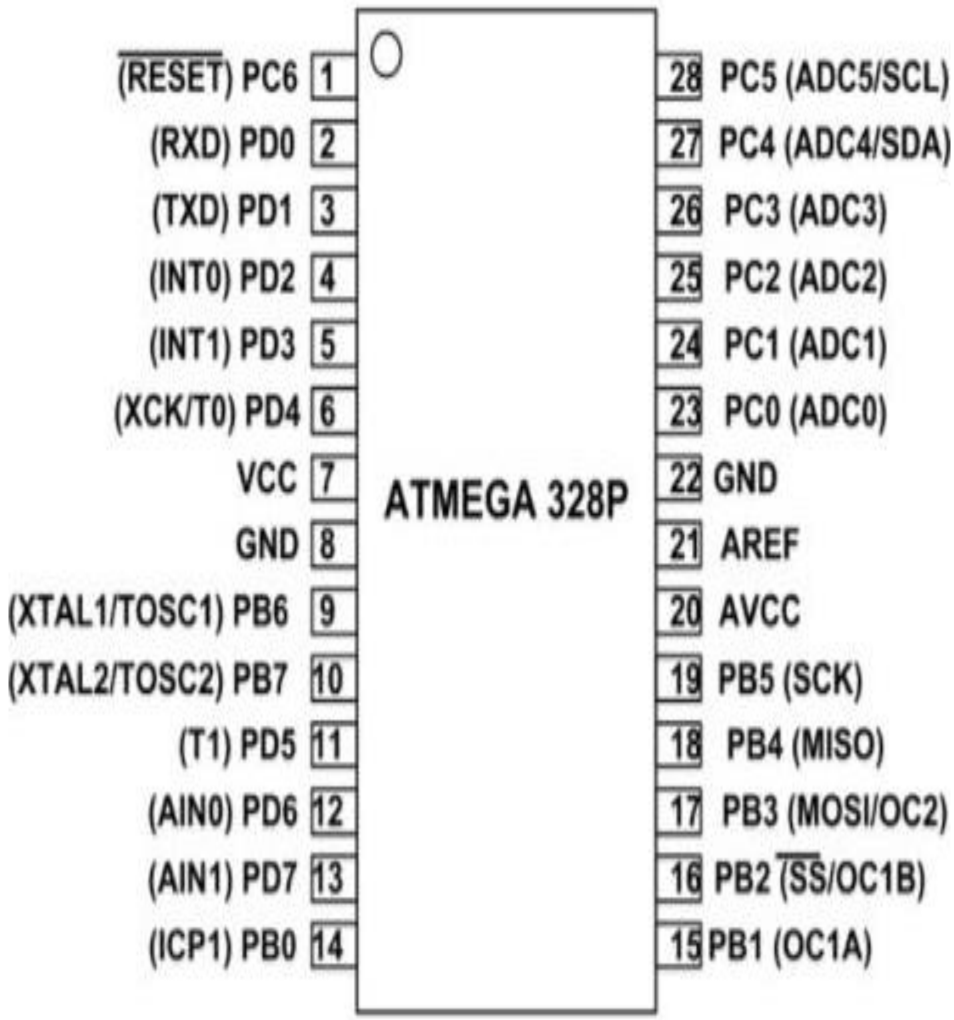

Figure 7: Pin Configuration of ATMega328p

The ATMega328p combines 32KB of in-service programmable Flash memory with read-while-write capabilities, 1KB Electrically Erasable Programmable Read Only Memory (EEPROM) and 2KB Static Random Access Memory (SRAM), from which the energy meter stores and retrieves data. Other features of the controller include 23 general purpose I/O lines, 32 general working registers, 6-channel 10-bit ADC, Real Time Counter (RTC), 3 flexible timers with compare modes and 2-wire serial interface (12 C).

ATMega328 is commonly used in many projects. Common among them are in Arduino Uno, Nano and Micro boards. Also, they are found in industrial control systems, digital data processing, analogue signal measuring and embedded systems.

Furthermore, the coding or programming of this microcontroller is easier and compilers are readily available.

Table **X** shows the pin description of the microcontroller.

Table 2: Pin Description for ATMega328p

Pin No	Pin Name	Description	Secondary Function
1	PC6	Pin6 of PORTC	RESET pin by default, used as I/O when RSTDISBL fuse is programmed.
2	PD0	Pin0 of PORTD	RXD (Data input pin for USART)
3	PD1	Pin1 of PORTD	TXD (Data output pin for USART)
4	PD2	Pin2 of PORTD	External interrupt source0
5	PD3	Pin3 of PORTD	External interrupt source1
6	PD4	Pin4 of PORTD	T0 (timer0, external counter)
7	Vcc		Connected to positive voltage
8	GND		Connected to ground
9	PB6	Pin6 of PORTB	XTAL1 (chip clock oscillator pin 1 or external clock input)
10	PB7	Pin7 of PORTB	XTAL2 (chip clock oscillator pin 2)
11	PD5	Pin5 of PORTD	T1 (timer1, external counter input)
12	PD6	Pin6 of PORTD	AIN0 (analogue comparator positive I/P)
13	PD7	Pin7 of PORTD	AIN1 (analogue comparator negative I/P)
14	PB0	Pin0 of PORTB	ICP1 (timer/counter1 input capture pin)
15	PB1	Pin1 of PORTB	OC1A (timer/counter1 output compare match A output)
16	PB2	Pin2 of PORTB	SS (SPI slave select input)
17	PB3	Pin3 of PORTB	MOSI (master output slave input)
18	PB4	Pin4 of PORTB	MISO (master input slave output)
19	PB5	Pin5 of PORTB	SCK (SPI bus serial clock)
20	AVcc		Power for internal ADC converter
21	AREF		Analog reference pin for ADC
22	GND		Ground
23	PC0	Pin0 of PORTC	ADC0 (ADC Input channel0)
24	PC1	Pin1 of PORTC	ADC1 (ADC Input channel1)
25	PC2	Pin2 of PORTC	ADC2 (ADC Input channel2)
26	PC3	Pin3 of PORTC	ADC3 (ADC Input channel3)
27	PC4	Pin4 of PORTC	ADC4 (ADC input channel4)
28	PC5	Pin5 of PORTC	ADC5 (ADC input channel5)

3. 1. 6. Flowchart

The flow chart is a sequential explanation of the program written to the ATMega328p to effectively carry out the execution of the work as shown in Figure 8.

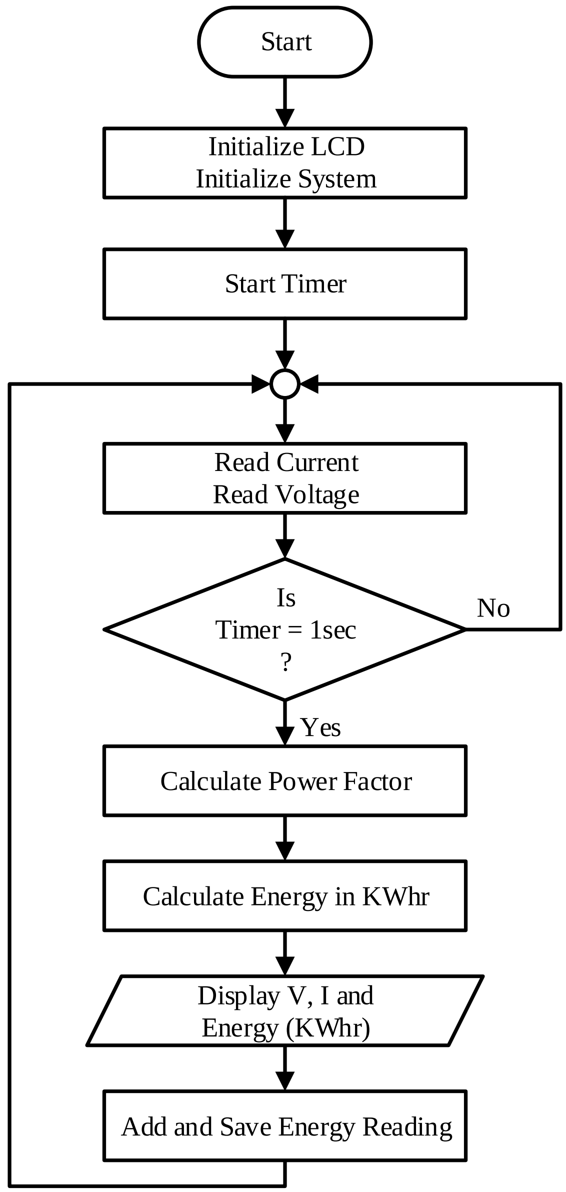

Figure 8: Flowchart

3. 1. 7. Programming

The program was written on the Arduino IDE version 8.8. The IDE was chosen because of its ease of use and diverse libraries that support a lot of peripheral functions necessary for the work.

At start, all peripherals are initialized, functions are called to sample load current and voltages multiple times and average values taken while calculations are performed simultaneously and energy units displayed. The whole process is looped continuously while storing energy units consumed periodically.

The modelling of the scatter plot was done on Pycharm using the Python programming language while the design was done on Proteus 8 Professional version 8.8.

3. 1. 8. Simulation Model

The circuit diagram that shows the simulation model is displayed in Figure 9.

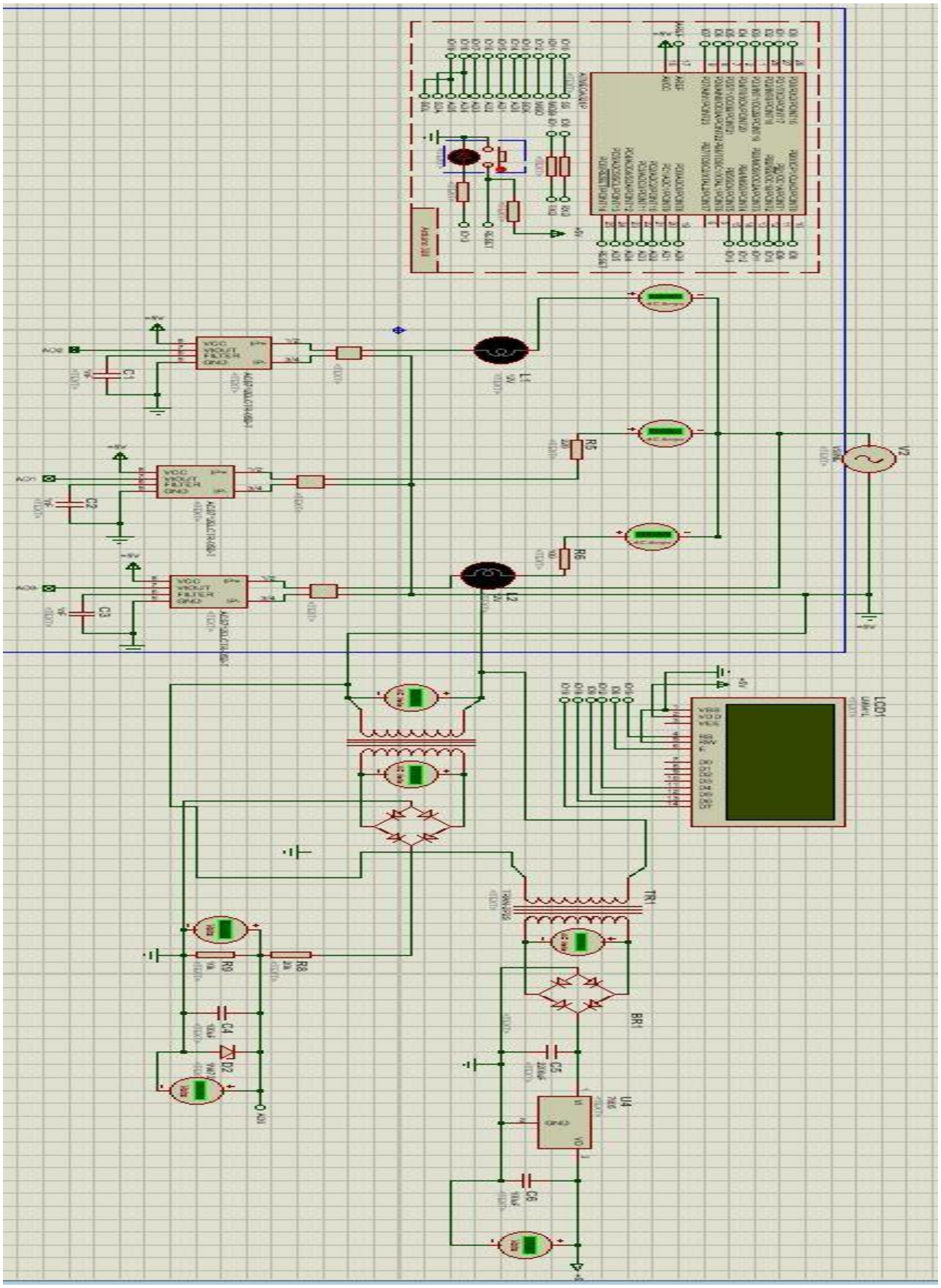

Figure 9: Circuit Diagram

4. RESULTS

The three user electrical energy meter was prototyped on a breadboard to determine the response of the proposed system, while the primary construction of the system was carried out on a vero-board.

4. 1. 1 List of Components Used in the Construction

The electrical energy meter circuit was constructed using various electrical components. To realize a standard construction, the quantity and ratings of all components used must be available and understood. Therefore, it is on this basis that the various components used for the realization of this work are tabulated as shown in Table 3.

Table 3. List of Components and their Ratings

S/N	Components	Quantity	Rating
1	Microcontroller (ATMega328p)	1	
2	Current sensor (ACS712)	3	
3	Voltage sensor (ZMPT101B)	1	
4	Resistors	5	1K, 4.7K, 24K, 220K
5	Capacitors	9	1nF, 100uF, 2200uF, 0.1uF
6	Diodes (1N4007)	8	50V, 1A
7	Transformer	1	230/9V
8	Regulator (LM7805)	1	35V, 1A
9	Optocoupler (4N25)	1	
10	Transistor (BC547)	1	
11	Load	3	60W, 100W, 200W
12	Liquid Crystal Display	1	4x20

4. 1. 2 Construction on Breadboard

Temporary implementation was carried out on the breadboard by mounting each component of the design circuit at its appropriate position as shown in Plate 1. The implementation was carried out in successive stages, starting with the power supply unit, zero cross detection unit, interfacing sensors (Current and Voltage sensors) with Microcontroller, the display unit and finally the connection of loads. The various components were interconnected in order to test and ensure the workability of the design.

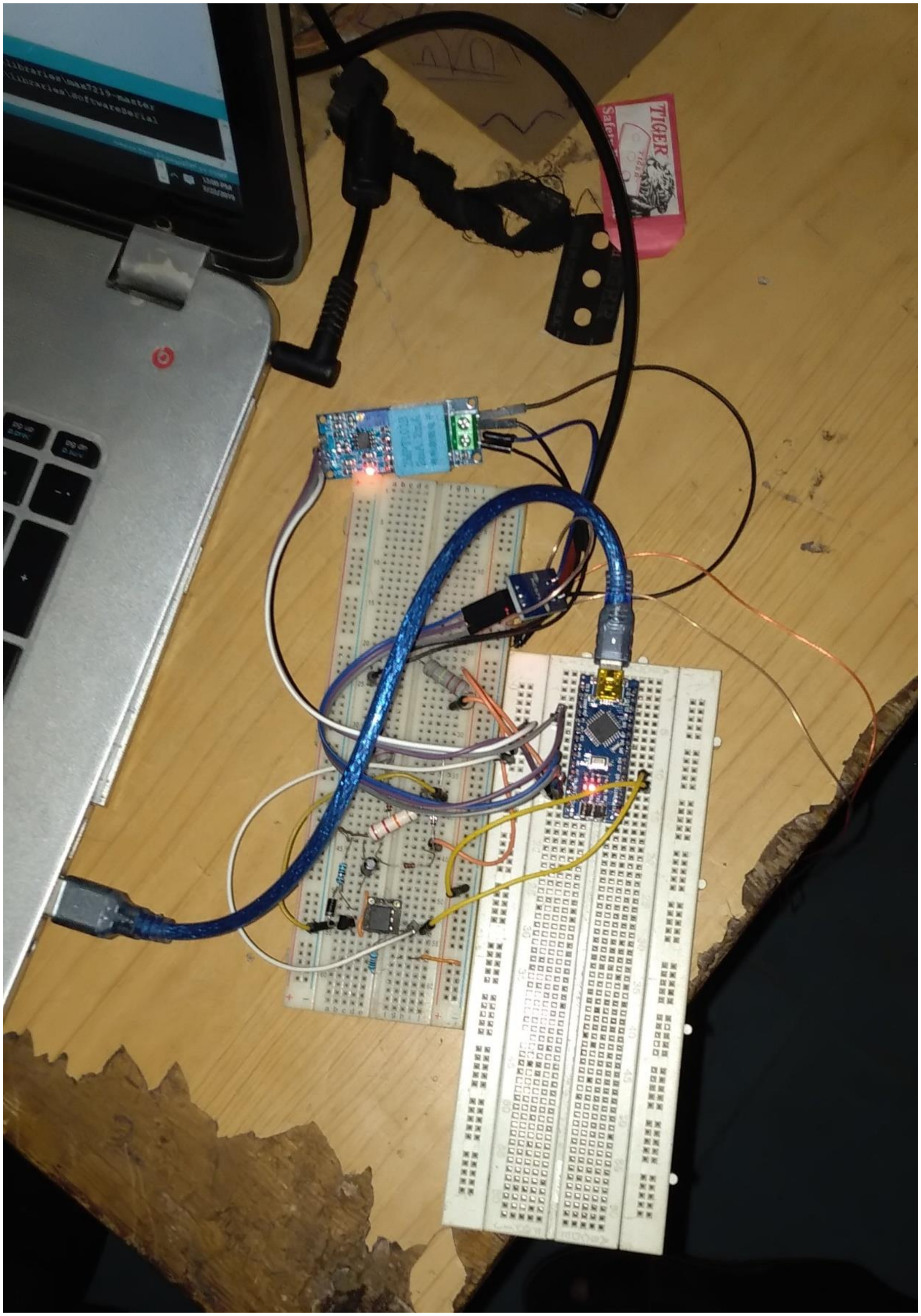

Figure 10: Breadboard Construction

4. 1. 3 Construction on Vero-Board

This is the permanent and final construction where all necessary connections and soldering are done before packaging. The construction entails transferring the construction from the bread board to the Vero-Board where it is permanently soldered, tested and packaged as shown in Plate 2.

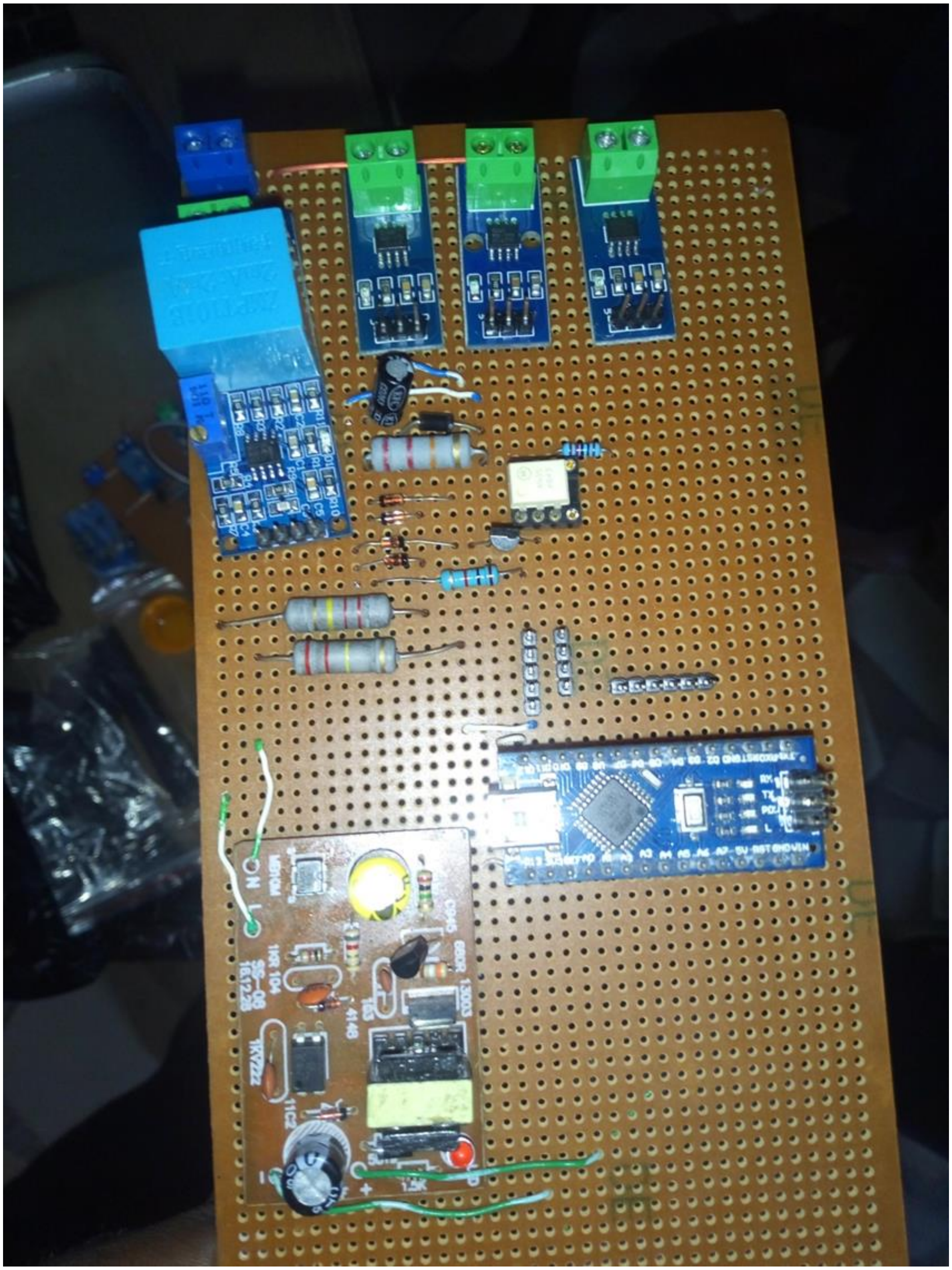

Plate 2: Vero-board Construction

4. 1. 4 Coupling of the Construction

Encasing is a way of packaging the construction on the Vero-Board specially to protect it. The packaging can either be done using metallic, plastic or wooden materials. In this work, plastic material was used to encase the construction. The plastic case was purchased and shaped to desired form to suit the construction. Then the construction on the Vero-Board was permanently screwed on a pedestal to allow for air space between the meter circuit and the plastic housing.

The design was encased after the construction in order to make the finished work portable and to reduce the risk of electrical shock. Encasing is also carried out for the physical protection of the often-sensitive components such as integrated circuit. The final package is shown in Plate 3

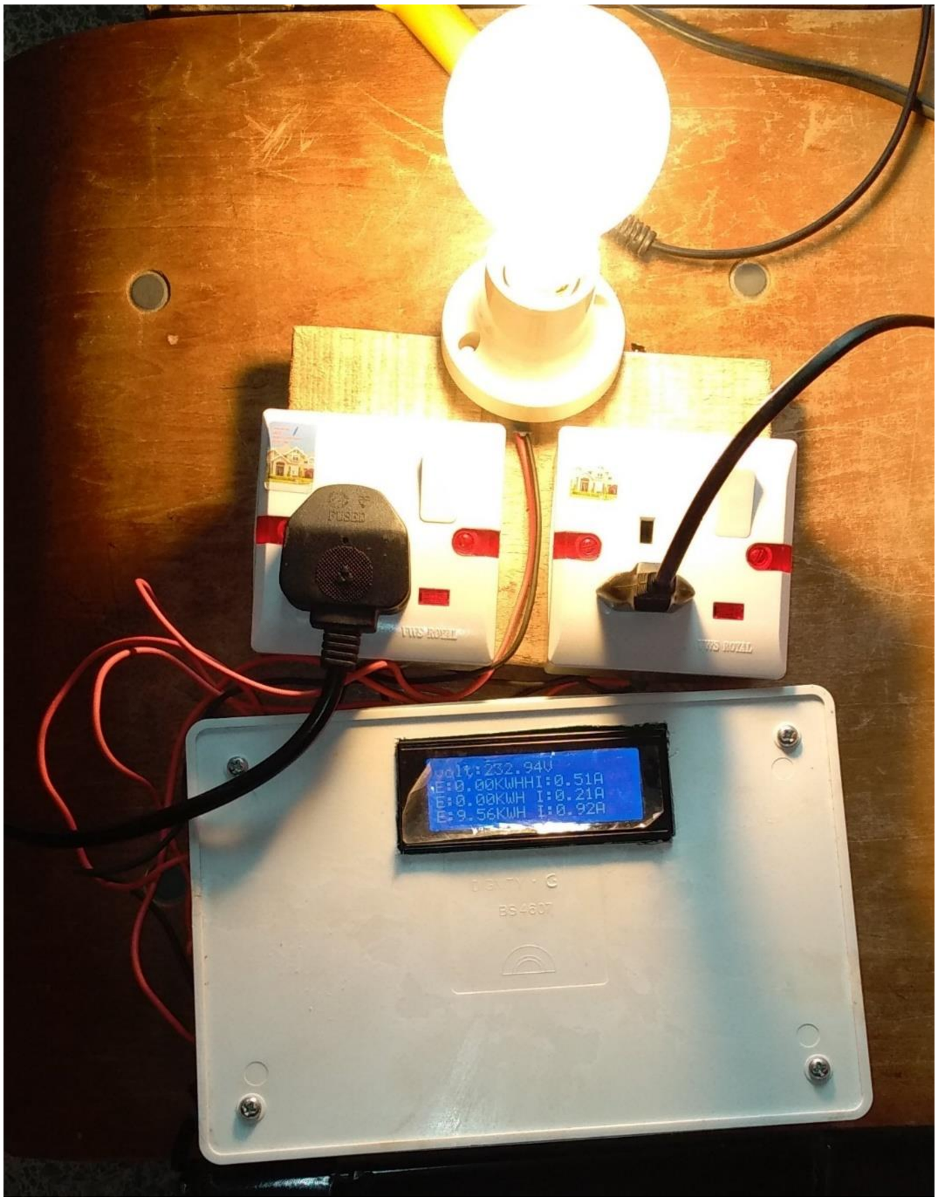

Plate 3: Final Packaging

4. 1. 5 Testing

It is important for every component to be tested before and after soldering using a multimeter in the laboratory. At every stage, a continuity test was also carried out with the aid of the multimeter, and all lapses were cleared before proceeding to the next stage. Finally, the work was test-run and confirmed to be working. We conducted the testing using the 230V AC power supply in the laboratory. Three loads, a 160W electric fan, a 1000W electric iron, and a 200W bulb, labelled 1 to 3, were connected to serve as users. The loads were tested for a period of thirty minutes.

4. 2. Results

During the implementation of the various blocks that make up the system, results were obtained after testing before final connection. The power supply block generates 5V DC, a voltage that powers the other blocks of the system. Also, calibration of the sensors was carried out to balance offset voltage and current. The results obtained for each of the loads after a period of sixty minutes are displayed in Tabl. The voltage supplied to each of the loads was 230V.

Table 4: Result of Construction Testing.

Loads	Energy Consumed	Current
160W fan	0.16KWhr	0.70A
1000W electric iron	1.00KWhr	4.35A
200W bulb	0.20KWhr	0.87A

5. CONCLUSIONS

In this paper, a multi-user electrical energy meter has been designed and implemented to continuously measure the energy consumption of each connected load. This meter addresses the issue of shared bills and gives total control of energy consumption to each user.

The ATMega328p microcontroller was used in the design of this energy meter to control various operations, calculations, and other housekeeping tasks. The program code embedded in the microcontroller was written using Arduino Version 1.6 Integrated Development Environment (IDE). Sampling of load current was done using the ACS712-20A-T while the voltage uses the ZMPT101 sensor. Also, a compatible 5V DC power supply was designed using full-wave rectification to power the whole unit.

The energy meter was designed, constructed, and its operations observed. The circuit of the meter was simulated using Proteus Version 8.6 software to validate the accuracy of the system and implemented in hardware. This system will be very helpful, especially in apartments where tenants are to be connected to a single meter. The energy meter was made to handle a maximum load current of 5A per channel. This means that advanced metering ICs could be used. In the future, different ways to separate line current from circuitry will be looked at in order to meet higher demands.

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