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POWER MONITORING SYSTEM USING MICROCONTROLLER FOR OPTIMUM POWER UTILITY IN HOMES

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ABSTRACT

This project explains the design and implementation of an electronic system based on development of an automated household utility power monitoring system using Arduino. It utilizes the Arduino Nano board intended for use in conjunction with the ATmega328 chip. A current transformer through the sensor circuit is connected for monitoring the power. The system has been designed and used to monitor electrical parameters such as voltage, current and power of household appliances. The system consists of a smart sensing unit that detects and controls the home electrical appliances used for daily activities by following different tariff rates. Results are shown on Nokia Display 5110 which intends that the current transformer is working properly. As the supply and demand of electrical energy is challenged within the context of environmental awareness and which is evaluated by household monitoring. It can reduce costs for the consumers and thereby improve grid stability. A developed prototype has been extensively tested and experimental results have compared with conventional measuring devices.

KEYWORDS: Microcontroller, Power, Voltage Regulator, Current Sensor, Temperature, Power Monitoring System, Power Utility.

INTRODUCTION

Since time immemorial household utilities remain one of the most important priorities among the basic needs of the family most especially in these present times where enabling technologies play significant role in everyday lives. Power consumption overheads spoil budgetary allocations due to irresponsible and unmonitored utilities, thus compromising budgetary concerns. Coupled with the increasing cost of power consumption, economic household capabilities are definitely affected that lead to chaotic financial management. Moreover, the demand for comfort and economic status of the family compels the use of more powered appliances without consciously considering the effects of over utility. Hence, monitoring and control of power utilities are of at most priority.

The electric power systems are unified for economic edges, exaggerated dependableness and reliability and conjointly some operational blessings.

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These necessities limit the chance of observation and dominant, in spite of the very fact that microprocessor-based monitoring systems have determined vital development in their storage and machine power.

The development of compressed algorithms based power quality benefits in the following 2 ways: 1. enable observation of additional points at the same time for giant systems, 2. facilitate in constructing powerful embeddable observation architectures inside tiny power devices, like motors, power drives or a breaker. the fashionable electrical instrumentation includes playacting on-line observation on microcontrollers.

The electrical instrumentation, being characterized by tiny time constants and high risk, so as to develop competitive observation systems.

A study on microcontroller-based power utilities tending machine was utilized for sports utility monitoring. However, the study encountered problem such as input noise occurrence in the prototype. Due to these, technical recommendations are being made such as to eliminate input noise in the prototype. A current transformer through the sensor circuit is connected for monitoring the power. The system has been designed and used to monitor electrical parameters such as voltage, current and power of household appliances.

There are other applications of microcontroller-based control and monitoring, some are utilized in instrumentation and control where measurement and monitoring of temperature of a closed-loop system is vital in an oven. The same microcontrollers are used in the educational and entertainment mobile robotics was utilized to establish autonomous control and other embedded systems.

For monitoring, the hardware is based on current and voltage measuring circuits, a microcontroller unit (MCU) and a control module. The current/ voltage measuring circuit measures the current and voltage and sends the information to the MCU. The MCU checks for power abnormalities and display information on the display board. For control, a relay is added to the power monitoring hardware. In the case of an overheating found by the temperature sensor, the relay cuts the power supply to the electric appliances after receiving the control command.

OBJECTIVE

Our main objectives of this project is measure and give the equivalent price of the power consumed by the household. Constantly monitor and control power conditions in household appliances. It focuses on saving electricity, increasing efficiency and reducing the household impacts on electricity production. Such electric power system is unified for economic benefits, increased reliability. To reduce effects of poor power quality power monitoring should be done flowingly and completely. The user can see the current and power rating conditions of the household appliances on display board.

LITERATURE REVIEW

The electrical equipment, being characterized by small time constants and high risk, impose major efforts in order to develop competitive monitoring systems [2]. Moreover, according to [3] everyone wishes to save energy and money. Minimizing your monthly electricity bill is a good place to start. What makes it difficult is that your bill only tells the total amount of electric energy that was consumed during a long time window, typically one month. Hence, testing the effect of a change in behavior as an energy consumer is not practical. A working solution would be to frequently log the values from your energy meter to a notebook, and then draw a graph to reveal the before-after effect. But things like this need to be automated to become practical. The use of a home personal computer to build a measuring device that can be attached to an electric meter may be feasible to undertake. However, the use of microcontroller may be more practical than the use of personal computer as such may also be cost effective.

DEVICES USED

ARDUINO NANO

We have used an Arduino Nano which is a small user friendly bread board as shown in Figure 1 with the pinouts shown in Table 1. The Arduino Nano is a programed using arduino software (IDE). The technical specifications are shown in Table 2.

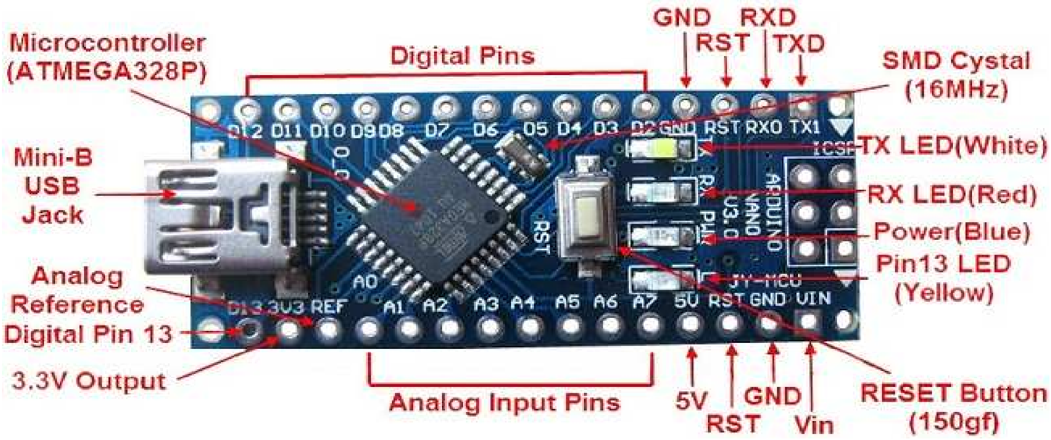


Figure 1.Arduino Nano

Table 1.Arduino Nano Pinouts

Digital I/O , PWM	14 Pins
For Analog Functions	8 Pins
Pins Power	1 Pin(Vin)
SPI(Apart from Digital I/O Section)	3 Pins
Reset	3 Pins

Table 2.Technical Specifications

S.N	Component	Specifications
1	Microcontroller	Atmel ATmega168 or ATmega328
2	Operating Voltage(logic level)	5 V
3	Input Voltage(limits)	6-20 V
4	Input Voltage(recommended)	7-12 V
5	Analog Input Pins	8
6	Digital I/O Pins	14 (of which 6 provide PWM output)
7	DC Current per I/O Pin	40 mA
8	SRAM	2 KB (ATmega328)
9	Flash Memory	32 KB (ATmega328)
10	EEPROM	1 KB (ATmega328)
11	Clock Speed	16 MHz

ICSP PINS

ICSP pins are used for programming Arduino boards. In cases where the bootloader is absent, the ICSP pins works efficiently. We can also use one Arduino to program another Arduino by using this ICSP. The Table 3. shows the Arduino Nano ICSP Pins.

Table 3.Arduino Nano ICSP Pins

Arduino Nano ICSP Pin Name	Type	Function
MISO	Input or Output	Master In Slave Out
Vcc	Output	Supply Voltage
SCK	Output	Clock from Master to Slave
MOSI	Output or Input	Master Out Slave In
RST	Input	Reset (Active Low)
GND	Power	Supply Ground

CURRENT TRANSFORMER

In our project we have used CT as shown in Figure 2.

The current transformer output is 50mA rms

= 70.7mA peak

= 141.4mA peak to peak

Generates a voltage of

= 141.4mA peak to peak x 33Ω

=4.666V peak to peak input to Arduino.

Figure 2.Current Transformer

NOKIA DISPLAY

The Nokia display are cheap, small but readable, having resolution of 84x48 and needs only a few digital I/O pins as shown in Figure 3. Table 4 shows the pins description and Figure 4 shows the Nokia Display pins connected with ATmega8.

Specification:

- 48 x 84 Dot LCD Display
- Serial Bus Interface with maximum high speed 4.0 Mbits/S ƒ
- Internal Controller No.PCD8544 ƒ LED Back-Light ƒ
- Run at Voltage 2.7 -5.0 Volt ƒ
- Low power consumption; it is suitable for battery applications
- Temperature range from -25˚C to +70˚C
- Support Signal CMOS Input

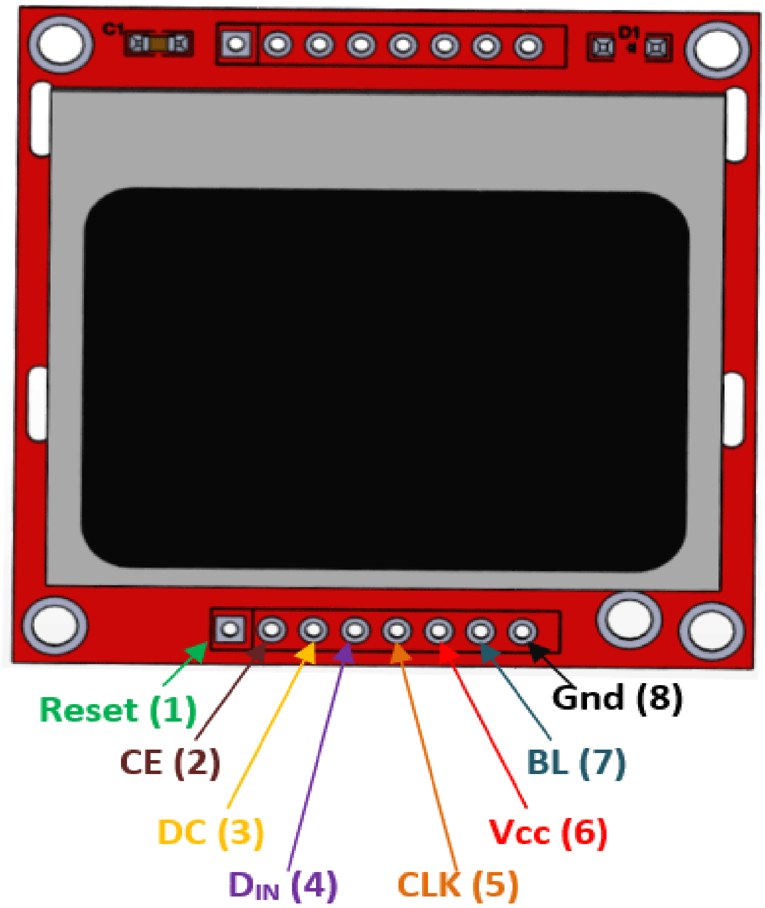


Figure 3.Nokia Display

Table 4.Pins Description

No.	Pins	Description
1	Reset	This pin resets the module. It an active low pin (resets when 0V is provided)
2	Chip Enable (CE)	This pin is made low (0V) to select this particular display when more than one SPI peripherals are used.
3	Data/Command (DC)	This pin is used to switch between Data mode (high) and Command mode (low)
4	Serial Input (DIN)	This is the input pin (MOSI) through which serial instructions are sent
5	Clock (CLK)	All SPI modules require a common clock, this clock source is supplied to this pin
6	Power (Vcc)	This pin is used to power the display the supply voltage is from 2.7V to 3.3V
7	Back Light (BL)	This pin powers the backlight of the display (3.3V maximum).
8	Ground (Gnd)	Connects to the ground of the circuit.

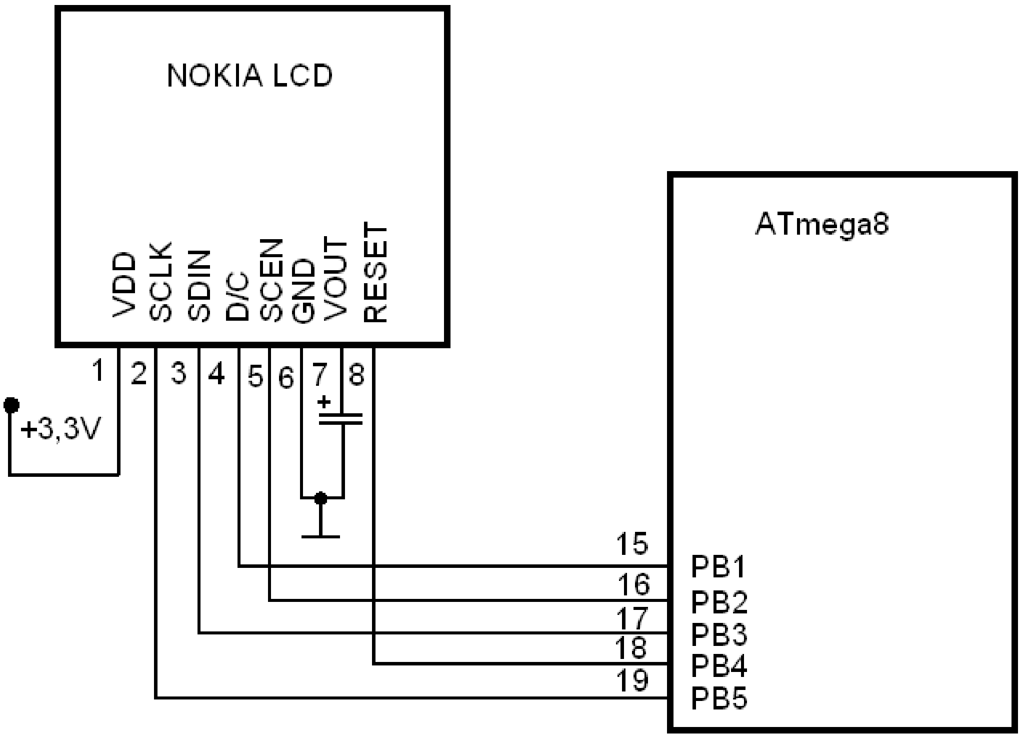


Figure 4.Nokia Display pins connected with ATmega8

POWER SUPPLY CIRCUIT

The rectifier power supply circuit converts AC to DC. We have converted 230 V AC to 5 V DC using the power supply circuit shown in Figure 5.

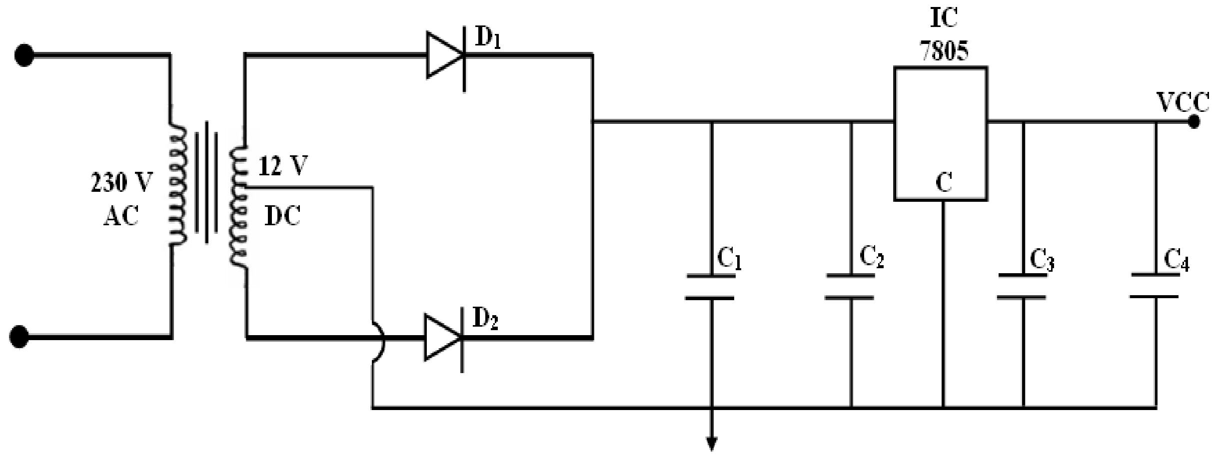


Figure 5.Power Supply Circuit

POWER SUPPLY CIRCUIT

The power supply circuit was built using the following components:

- *Voltage Regulator IC 7805:*
- *DIODE IN 4007:*
- *LM35 Temperature Sensor*

LM35 Temperature Sensor with the pin configuration shown in Table 5.

Table 5.Pin Configuration

Pin No.	Pin Name	Description
1	Vcc	Input voltage is +5V for typical applications
2	Analog Out	There will be the increase in 10mV for raise of every 1°C. Can range from -1V(-55°C) to 6V(150°C)
3	Ground	Connected to ground terminal of the circuit

LM35 Temperature Sensor Circuit Diagram is as shown in Figure 6

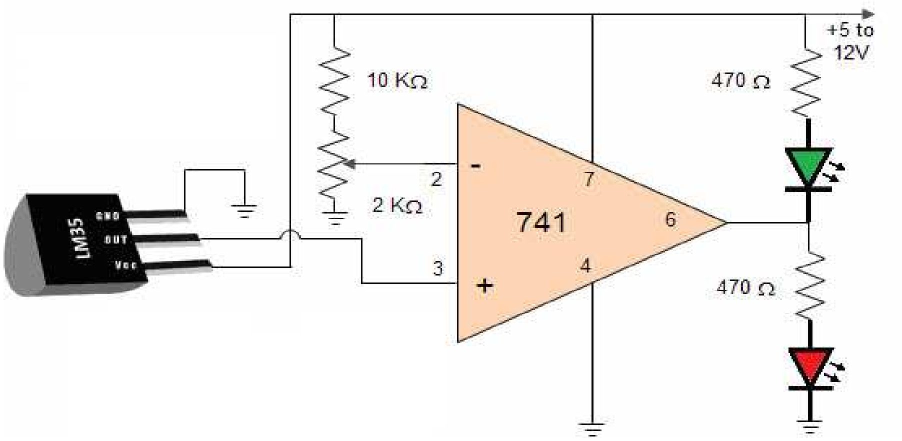


Figure 6.LM35 Temperature Sensor Circuit Diagram

- Relays
- Transformer *(12-0-12)*

Centre Tapped Transformer Specifications

- Step-down Centre tapped Transformer
- Input Voltage: 220V AC at 50Hz
- Output Voltage: 24V, 12V or 0V
- Output Current: 1A
- Vertical mount type
- Low cost and small package

The description of transformer terminals is as shown in Table 6.

Table 6.Transformer Terminal Description

No:	Terminal Name	Description
1	I1 and I2	These are the input wires for the transformer, it is connected to the phase and neutral of AC mains
2	T1 and T3	There are the output terminals of the Transformer, the voltage across it will be 24V AC
3	T2	This is the centre tapped wire of the transformer; this wire can be combined with either T1 or T3 to get 12V AC across it. It's very useful for rectifier circuits

SYSTEM DESIGN AND IMPLEMENTATION

PCB DESIGNING

INTRODUCTION

PCB was basically design as an interconnection method suitable for mass production. This scheme is reduced with size and weight of equipment and also helped to reduce the wiring errors. PCB design is very essential to make products that are reliable and competitive in market. The following check list uses the major areas of concern in process of PCB design:

a) Optimum size and shape of board should be ensured.
b) The substrate should be selected properly by taking into considerations its cost, mechanical properties and electrical properties.
c) Layout of conductor pattern should be taking care of from crosstalk, leakage sheilding, number of jumpers required and their placements.
d) Selection of conductor width, thickness and spacing should be done after analyzing their placement.
e) Single sided board:
The single sided PCB's arte mostly used in entertainment electronics where manufacturing cost has to be kept minimum.
f) Double sided PCB's can be made with or without plated through holes:

The production boards with plated holes are fairly expensive. Therefore, plated through whole board are only chosen where the circuit complexity and density does not give any other choice.

SUBSTRATE MATERIAL SELECTION

The mechanical properties that should be considered are water absorption, coefficient of thermal expansion, thermal ratings, tensile strength, shear strength, impact strength etc. For most PCB applications the dielectric base material is chosen from one of the four items given below-

1. Phenolic Resin impregenated paper
2. Acrylic polyster impregenated fibre glass, cloth
3. Epoxy impregenated paper
4. Epoxy impregnated fibreglass cloth

Some of the important technical consideration involved in selecting coating materials are-

1. Effects of humidity and temperature on installation resistance of coating material.
2. Flexibility of material
3. Resistance to tracking during thermal shock
4. Ease of application on PCB and also the ease with which it can be removed while preparing the PCB.

ARTWORK PREPARATION

The generation of PCB artwork should be considered as the first step of PCB manufacturing process. Different procedures are available to prepare a good network. Among them the black taping on transparent base foil is widely used in industries.

PCB PREPARATION

The prepared PCB layout is as shown in Figure 7.

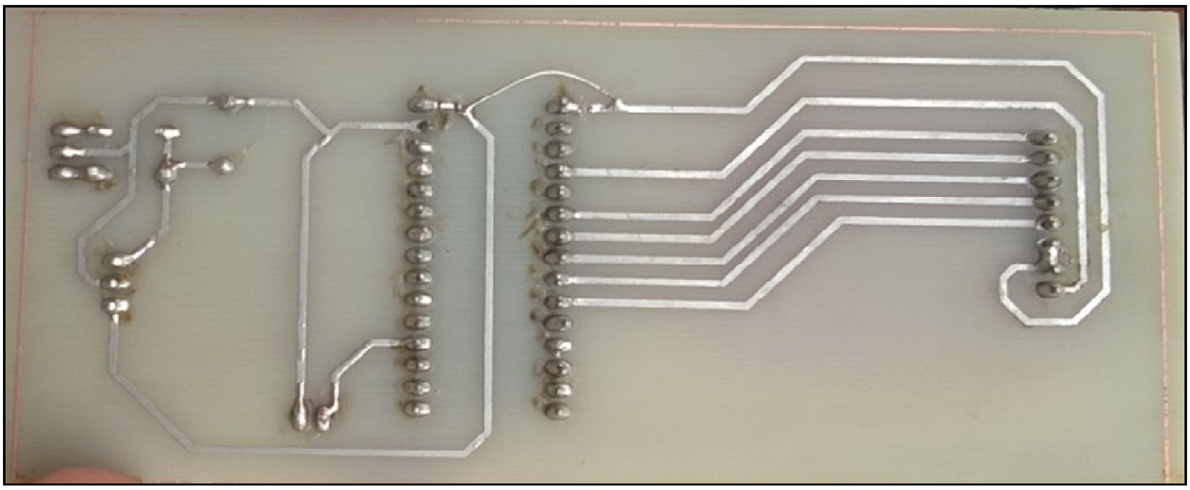


Figure 7.PCB Layout

ETCHING

Final copper pattern is formed by selective removal of all unwanted copper, which is not protected by each resistor. Under etching and over etching complicate the matter. Etching can be obtained by two methods:

a) Over hang
b) Spray etching

ETCHANTS

Amount of etchants available, foil was the earliest one use on a major scale with availability of etching which can be regenerated and which are compatible with the common metal. Etch resist foil is still use for small PCB facility where etching is occasionally carried out for small boards.

Following reactions takes place in the period of etching process

$FeCl3 + Cu= FeCl2 + CuCl \downarrow$

Cuporous chloride further oxidised in etching solution to cupric chloride

$FeCl3 + CuCl= CuCl3 + FeCl2$

The build up cupric chloride itself reacts also with copper and forms cuprous chloride.

$CuCl2 + Cu= 2 CuCl.$

Due to high corrosive FeCl3 the etching is faster and little under etching over the ferric chloride contaminates the surface which can be cleaned by water.

DRILLING

Drilling of component mounting holes into PCB is most important mechanical machining operation in PCB production process. Holes are made by drilling whenever a superior hole finish for plated through whole is required and where the tooling cost fit a punching tool cannot be justified. Therefore, drilling is applied by a professional grade PCB manufacturer are generally in at smaller PCB production plants and labs.

The important of hole drilling into PCB has further gone up with electronic component miniaturization and its need for smaller hole diameter. Diameter less than half the board thickness and higher package density where hole punching is practically rules out.

COMPONENTS MOUNTING

Mounting of component goes a long way in enhancing the reliability of PCB special provision should be for holding a large component. Noisy component should b e properly shielded. The mounting of all components has to confirm to accept practices. The components are mounted as shown in Figure 8.

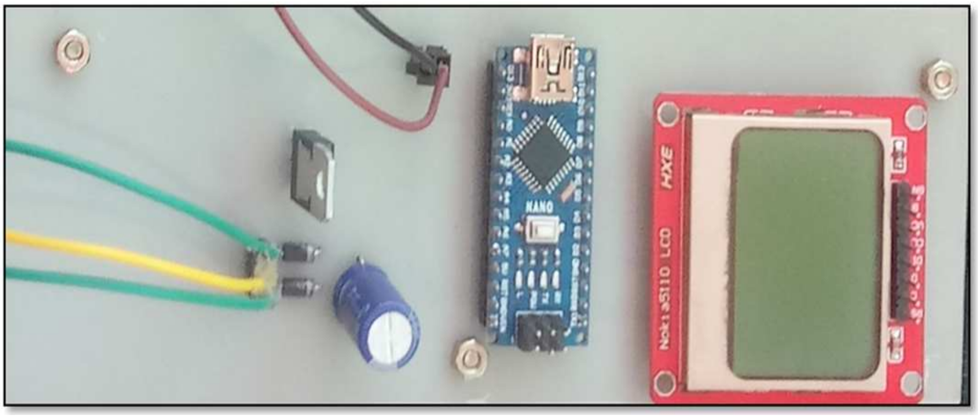


Figure 8.PCB with component soldered

Smaller component does not need special provision. The solder joint provides the mechanical fixation. Bigger and heavier components are adequately secured with clamps or clips and suitable space has to be provided in the layout. A guideline to avoid mechanical over tracking of solder joint is a maximum of ten a load per solder joint in a board without plated through holes for a reliable and easy assembly, all components of the same type should be mounted in the same direction and same orientation. Any rectangular shape component should be mounted only in one of the two main direction of the board preferably in rows.

SOLDERING IRON AND SOLDERING TECHNIQUES

For making reliable electrical connections between component lead and copper track soldering is essential. For electric soldering wire of lead or tin is used. This alloy wire melts at relatively low temperature that is about 200 degrees Celsius.

For this purpose, soldering iron is used. It forms a molecular bond with the component track.

SOLDERING IRON: The soldering iron is used for home construction purpose. This is typically consisting of thermally and electrically insulated handle from which protrudes a stainless steel shaft containing a ceramic encapsulated electrical heating element.

SOLDERING TECHNIQUES: Having chosen a suitable iron and correct bit for the job it is important to use solder of correct diameter for general purpose use 18W for fine work use 22W solder. When soldering components into PCB, following sequence should be followed:

1. Any terminal pin of component should first be inserted into the load.
2. To solder components, apply tip of iron to the component lead and the pad simultaneously ran solder into both. When sufficient solder has run into joint remove the solder and the iron and callow the joint to cool.
3. To improve the appearance of the board any excess flux can then be removed with methalyted spirit.
4. If the component has to be removed from the board for any reason, use “Solder Sucker” before inserting a new component. It is essential that the entire hole should be free of solder.

ENCLOSURE DESIGN

Proper system enclosure design can increase electrostatic discharge immunity both directly and indirectly. The guidelines for enclosure design include are:

1. Enclosure design should allow the I/O devices to remain close to I/O connector and each other.
2. Try to locate the I/O cable entry point in a central portion on each enclosure.
3. No shot or hole should have a large dimension greater than 2cm.
4. Use several small openings instead of one large opening.
5. The space between openings must be equal to the large dimension of the opening.

NEED OF ENCLOSURES

1. Safety from mechanical problems.
2. Safety from high voltages and shock hazards.
3. Safety from ingress of dust, liquids and unwanted gases.
4. Safety of the outside equipment from the enclosed equipment.
5. Prevention from problems like Electromagnetic Interferences, etc
6. Protection against pests

The easiest solution to all the problems seems to be enclose the equipment completely. But, this is practically impossible.

For using the equipment, it is necessary to have input output connections like cables, wires, pipes, etc. For servicing, the enclosure should have an arrangement of easy opening.

Also in most cases, the equipment will have meters and switches mounted on it. Furthermore, proper air circulation is needed, to cure the heat dissipation problem. When the equipment is in clear environment like laboratories and control rooms and away from the shop floor, i.e. no shocks, vibrations, no dust oil or grease, the enclosure design is not difficult, but the materials used for enclosure construction will depend on factors like EMI/EMC.

METHODOLOGY AND WORKING

DATA GATHERING

This section involves the investigation of the related studies and literature to come up with an Arduino-based automated household utility power monitoring system. Benchmarking activities were conducted to gather significant information on various locally made microcontroller-based power monitoring system while technical related literature were explored to reinforce the design concept of the study. In conjunction, the locally distributed electrical bills were also studied thoroughly to get the pricing per average watt electrical consumption since the generation charges, transmission charges, distribution revenues, government revenues and other charges were not clearly emphasized on the bill.

POWER MONITORING SYSTEM DESIGN

This section deals with the design and simulation processes of the device in order to develop the complete prototype of the Arduino-based microcontroller in accordance to the application as an automated household utility power monitoring system. The system circuit design of the device, as shown in Figure 9, is designed to perform monitoring of power rate consumption. The hardware will be using Arduino microcontroller board, which will act as the central controlling device, current transformer, Nokia display, temperature sensor, bulb and the Sensor Circuit design, that includes the AC voltage measurement and AC measurement.

Modules are mounted together with the Arduino microcontroller board on Printed Circuit Board or PCB layout that comprise the overall assembly and desired complete prototype. Testing and troubleshooting will be conducted to check the proper operation and functionality of each sections of the device using an experimental board. While Simulation and compilation includes the development of algorithm intended for the overall functionality of the device where actual coding of task using the Arduino microcontroller will be programmed accordingly as shown in Figure 10. The system block diagram along with the arduino sketches.

The Arduino-based microcontroller will utilize the open-source software or the Arduino sketch which is the piece of software that runs on the Arduino.

The principle on how the device works begins from taking raw data using the current transformer from the AC main line which is then converted as digital input to the Arduino microcontroller. By accessing the registers for both the voltage and current channels sequentially and scaling these according to the calibration done during the testing of the device. Arduino will then process the data to get the updated power consumed and its corresponding price.

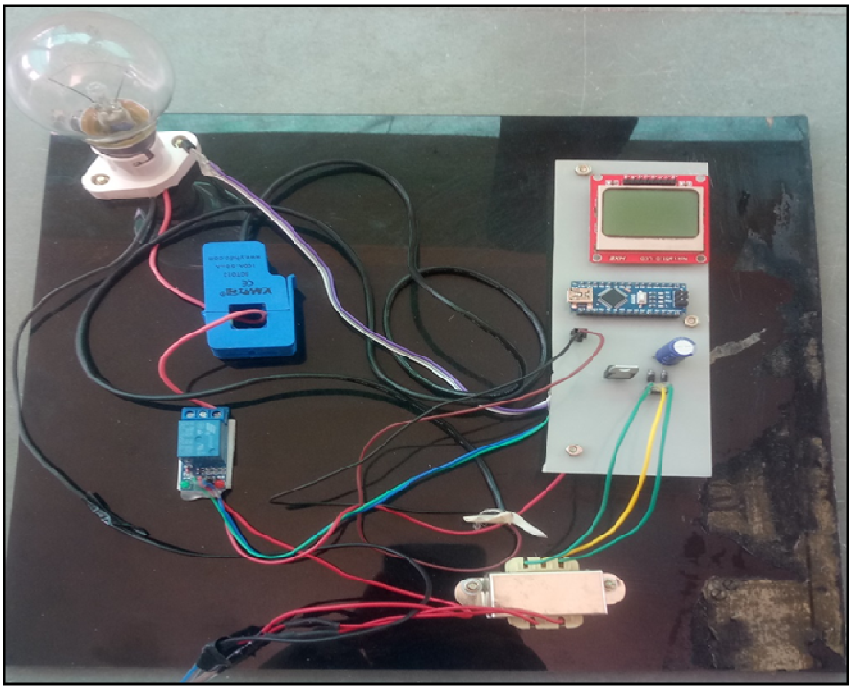


Figure 9.System Circuit Diagram

These are then displayed on the nokia display 5110 section of the device. Thus, this device will allow the consumer to monitor its power consumption from time to time and eventually help him manage his electric bill. Therefore, before the device would proceed in acquiring the next set of values the device has to wait for the specific time.

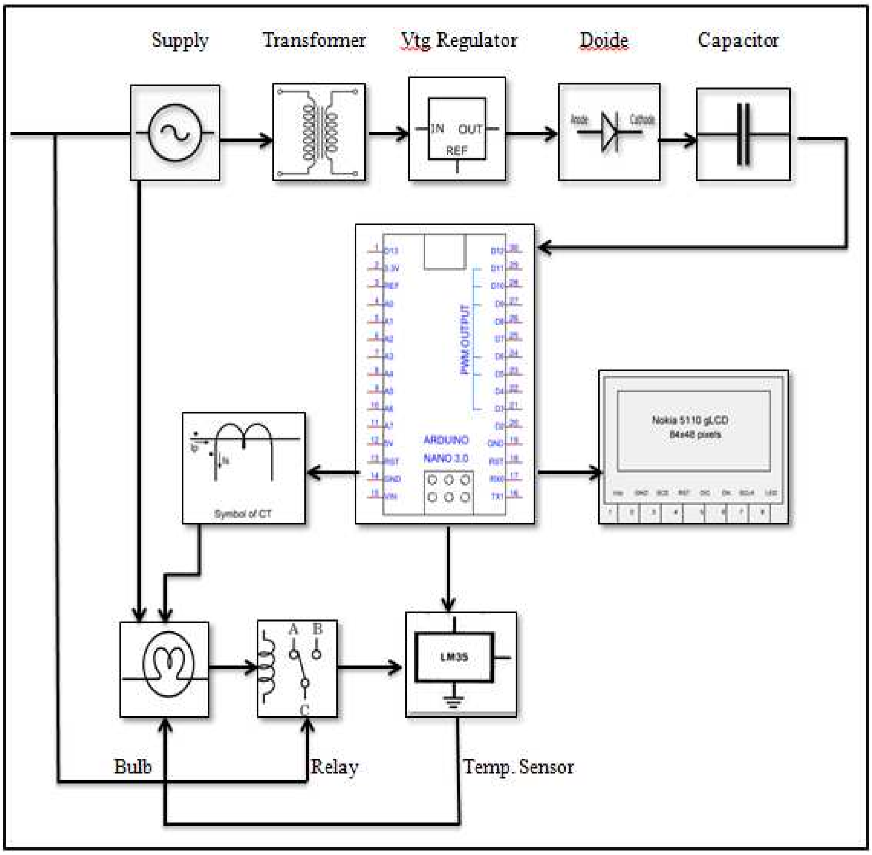


Figure 10.System Block Diagram

POWER MONITORING SYSTEM DEVELOPMENT

Each module is developed separately and each of which is evaluated individually before it is interfaced with the main board. The size of the prototype area was also considered in the development to fully utilize the area while accommodating the Arduino Nano Microcontroller board along with its modules, its external supply and its wire connection to computer interface which is used to program the board. Thus, it must be properly placed for it to be accessible for connection. The Voltage AC-AC adapter used 9Vac output as an Analog Voltage Source that is plugged in directly to the AC main line. The Current Transformer is connected to one of the line of AC main wire. It is both biased with correct values of resistor before connecting to the analog pins of Arduino Nano that contributed the signal for voltage and current (RMS values) computing the real power as well as computing the total power consumption of a single household.

EVALUATION AND ANALYSIS

The most important output of this work is its ability to measure the current through current transformer and its corresponding power. Moreover, this work is designed to have data logging capabilities. The software developed in the Arduino sketch will be built around the interpretation of the data. The software will primarily act as a plotter for the logged data. It will simultaneously plot all the line parameters that are saved. The main program of Arduino sketch includes the data logging development to plot current, power and temperature is recorded and displayed on Nokia board. The supply is given to the Arduino and simultaneously to the bulb then Arduino send command to the current transformer and in second row of display the power of bulb is shown. The temperature of bulb is going to display on the third row, which is sense by the temperature sensor lm35.

RESULTS AND DISCUSSION

Considering the main function of this automated household utility power management system, which is to measure and give the equivalent price of the power consumed by the household. It is by then very much important to check the ability of the voltage and current sensors to work accurately. After the careful system circuit design, testing of the developed system prototype and the PCB lay outing is done. Then follows the etching and fabrication, to make the complete hardware prototype of the AHU-PMS as shown in Figure 11. The Arduino Nano 3.0 Microcontroller, Voltage Regulator, Doide IN4007 and 48 x 84 Nokia Display must be properly mounted to each specified pin headers assignment located in the PCB layout. The Sensor Circuit (Current and Voltage Sensor) was carefully soldered directly in the PCB. Cautious with attentive soldering of these types of components was done to ensure the integrity of the overall device. Also, make sure that the copper paths must be checked by performing a continuity test on each node to ensure circuit integrity.

The pin assignment of Analog INPUT and Digital OUTPUT signal of the Arduino board is checked to its corresponding interface of each device as the circuit is set-up in the experimental board (breadboard) for testing and interfacing. Although the libraries of each device can be easily downloaded, it's important to change and setting up the initialization of pins in the program proper where it is located. The Prototype is tested in actual measured values of signal in the Analog Pins (A3 and A4) of the Arduino board.

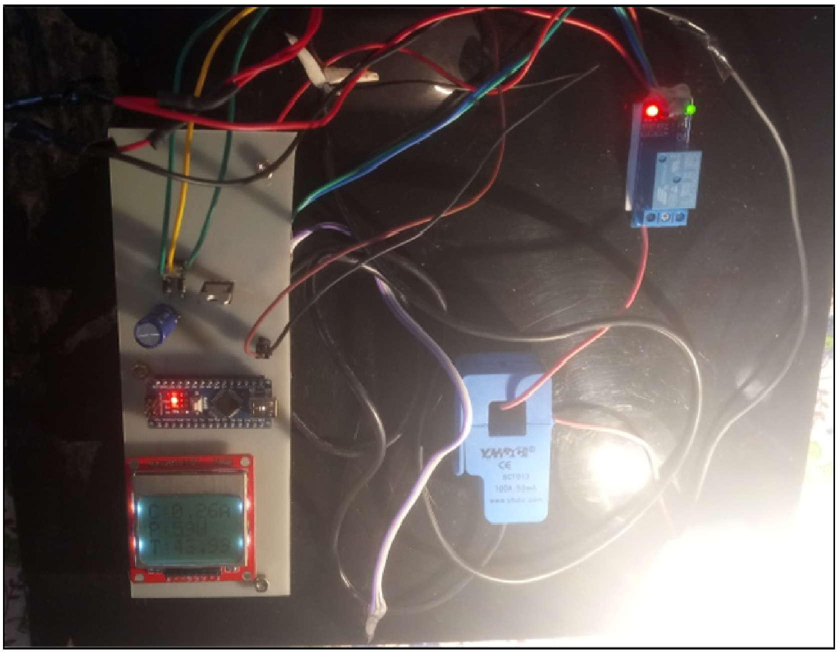


Figure 11.The final AHU-PMS package.

In order for the device to provide the consumer with the results that has the least errors, the raw data acquired from the initial testing of the device was scaled and calibrated according to the dumped data (estimated measurement) from different resistive and reactive loads with varying magnitudes. This final step of this part is very crucial to the actual performance of the device. Numerous data were dumped during testing with loads that yielded distinct results. All those values mentioned are used in compiling the main program reflecting the exact calculations of voltage and current through RMS (root-mean-square) values for accurate energy monitoring. The reading recorded from the power monitoring system for electrical bulb having rating (40W,60W,100W) is as shown in Table 7.

Table 7.Reading Recorded from The Power Monitoring System

Sr. No.	**Bulb (W)**	**Voltage (V)**	**Current (A)**	**Power (W)**	**Temperature(^{0})**
1.	40	230	0.19	44	41.54
2.	60	230	0.25	59	43.06
3.	100	230	0.59	134	47.03

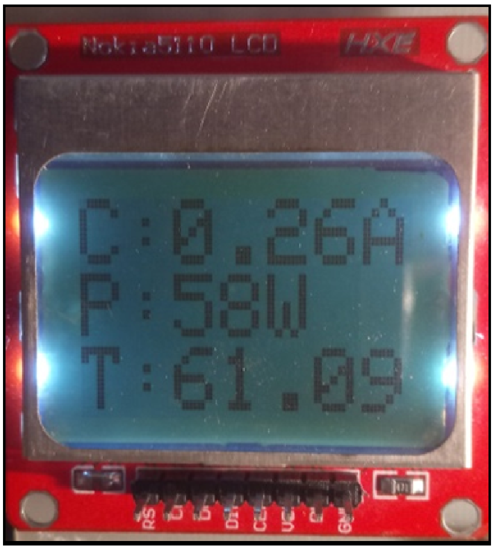
Case I:

In this case, the temperature is below 60^0 i.e. 43.50^0 then the bulb is ON.

Case II:

In this case, the temperature is above 60^0 i.e. 61.09^0 then the bulb is OFF.

In above cases, the temperature sensor is connected to Nokia display. The ON/OFF of the bulb is depend upon the temperature sensor. The values of temperature are continuously monitoring by the sensor and showing on the display. In above Figure 12 the reading is taken of 60W bulb. In this system, if the temperature of the bulb is below 60 degrees then the bulb is in ON condition while the temperature rises above 60 degrees then the bulb is OFF. After the temperature decreases the bulb glows ON again.



Case I **Case II**

Figure 12.Nokia display showing Temperatures

ADVANTAGES AND DISADVANTAGES

ADVANTAGES

- Electric utilities that make use of automated power system are known to supply better quality power compared to other.
- Once you have identified the inefficiencies in your power consumption, you can take the necessary step to design and implement energy-saving programs.
- Not only that, but you will be able to track the effectiveness of your efforts and see for yourself how much money you save.
- Automated systems are capable of working more closely with distribution networks, pushing them to the edge of their physical limits and reducing investment by a considerable margin.
- They even help extend the life of your equipment by mitigating or preventing power quality-related incidents.

DISADVANTAGES

- No self-test system to detect malfunction of sensors.
- Requires uninterrupted power supply.

CONCLUSION AND FUTURE SCOPE

CONCLUSION

Based on the results and discussions, the researchers concluded the following:

- First, the development of an Arduino-based microcontroller is proven necessary in automating and monitoring the household power rate consumption in realtime and displayed through human-machine interface thus providing the immediate visual information of the consumer.
- Second, the device performance was measured through a series of testing, configuration, experimentation, and calibration. The device was able to come up a ± 10% accuracy in real-time measuring compared to the actual billing of the Electric Company. Thus the device was performing well.
- Finally, when you look at the advantages and disadvantages of the Arduino-based over conventional based cited as well as the cost of materials invested on the device it is very practical to use the prototype over the conventional way.

FUTURE SCOPE

- A survey should be conducted to evaluate the system's performance of the household power utility system based on acceptable assessment instrument that focuses on its acceptability, performance and marketability.

APPLICATIONS

- A study on microcontroller-based power utilities tending machine was utilized for sports utility monitoring.
- The use of these microcontrollers may also be explored to establish measurement and monitoring of household power utilities to effectively track down real time power consumption.
- Monitoring the power utility in commercial buildings allows for proactive action against damage to system.
- Due to power monitoring system, the manufacturing and process-based operations are reliant and the equipment running correctly and efficiently.

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