Multipurpose Electric meter based on Arduino Nano Board (Smart meter)

Sooraj Ram [1], Sreejith Dinesh [2], Sarath Raj R [3], Paulson George [4]

[1, 2, 3, 4] Students, Dept. of Electrical and Electronics Engineering, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India

---***---

Abstract - *Device with multiple utilities has a wide market these days. Multipurpose Electric meter based on Arduino Nano Board (Smart meter) differs from an ordinary wattmeter with its versatile nature. An ordinary wattmeter measures the power consumption and additional equipments are required to measure other electrical parameters, which may be expensive. To carry out such measurements reliable and accurate, a cheaper solution is presented here as a Smart meter, which reads fifteen electrical parameters such as voltage, current, standard deviations, energy, active power, reactive power etc. This Smart meter has provisions to measure the voltage and current and keeps track of the measure time. The Arduino Nano Board can be programmed in such a way to calculate all the other parameters. A ZigBee unit is also included in this system to have a wireless transmission of the measured parameters to a distant monitoring system, for example a PC. This system helps to give a quick reference to the users and helps in eliminating the time consuming calculations. As an ideally instrument should do, it makes no distinction between AC and DC.*

Key Words: Multipurpose Electric meter, Voltage, Current, Arduino Nano Board, ZigBee unit, etc…

1. INTRODUCTION

As technology advances and mid - high tech devices become more readily available to engineering and technology students as well as hobbyists, there is an increasing need for reliable, cost effective test equipment. Digital AC Watt meters are one of these increasingly useful pieces of equipment. There are currently many models of Digital AC Watt meters available, that have an impressive amount of capability and functionality. These models are expensive and often have unnecessary capabilities considering the typical applications of undergraduate students and hobbyists. This project arose from the need for an inexpensive, functionally appropriate alternative to currently available Digital AC Watt Meters. Currently available Digital AC Watt Meters that work in the 115V, 1 - 10 amp range are costly, not within the practical price range of electronic enthusiasts and engineering students. Residential AC Watt Meters are available but they are specially tasked (i.e. Home Energy Monitoring Kits, Measure Power at the Plug, Measure Power

of Whole House). These meters do not fit the typical applications of the students and cannot be configured to devices they were not intended to work with. To carry out the measurements reliable and accurate, a special electric meter is required. Because these meters are very expensive, a cheaper solution is presented here as an Electric meter based on Arduino Nano board (Smart meter). The Smart meter measures the current, voltage, standard deviations, real power, apparent power, reactive power, energy etc. It also keeps track of the measure time. These parameters are sent to a distant monitoring system for analysis. In this system, all these calculated parameters are displayed simultaneously for quick reference by the user. All these parameter are mathematically justified. As an ideally instrument should do; it makes no distinction between AC or DC.

2. ABOUT SMART METER

The Smart meter based on Arduino nano board differs from ordinary Watt meter with its versatile nature. In addition to power measurement, it also reads 15 parameters related to electricity. It reduces the space requirements and complexity of using many devices at a time. Also it is very expensive to use multiple devices for measuring multiple parameters. So Multipurpose Electric meter based on Arduino Nano Board (Smart meter) provides an inexpensive way to carry out such measurements. Here is the list of parameters the device is going to measure.

Table -1: List of electrical parameters

SL.NO	PARAMETERS	SYMBOLS	UNITS
1	VOLTAGE	V	V
2	VOLTAGE(RMS)	V rms	V
3	STANDARD DEVIATION VOLTAGE	V sdev	V
4	CURRENT	I	I
5	CURRENT(RMS)	I rms	I
6	REAL POWER	P real	W
7	REACTIVE POWER	Q	var

8	STANDARD DEVIATION CURRENT	I sdev	I
9	APPARENT POWER	S	VA
10	POWER FACTOR	COSΦ	
11	ENERGY	E	J
12	CHARGE	q	C
13	AMPHERE HOURS		Amhr
14	PEACK VOLTAGE	V peak	V
15	AMOUNT		Rupee

Here we measure only the voltage and current and the remaining parameters are calculated using the microprocessor. The supply voltage is reduced to a factor by introducing a potential divider in the measuring circuit. This attenuated value of voltage is our input 1. We measure the current using a current sensor ACS712. But the microprocessor input is always voltage. So this current is converted to a proportional voltage value which is our input 2. In the microprocessor the remaining parameters are calculated. So these parameters are less prone to errors and are reliable and accurate. Programming is done by feeding the equations of these parameters to the processor. The microprocessor makes use of the voltage and current value for calculation. Also it keeps track of the consumption time. After the values are calculated it is send to a distant PC through a Zigbee unit. The Zigbee unit consist of a Zigbee transmitter at the Arduino side and Zigbee receiver at the PC side. Thus the parameter values will be received at the PC. The user interface screen displays these quantities simultaneously and is very convenient for analysis. Since measured parameters can be transmitted to a distant monitoring system, the device can be used in hazardous environment. A limit can be set for the power consumption. If the consumption exceeds this predetermined value, the supply will be cut off automatically. This helps to control the power consumption. Thus the Smart meter provides a cost efficient overall monitoring scheme.

3. SMART METER DESIGN AND COMPONENTS

3.1 Block diagram
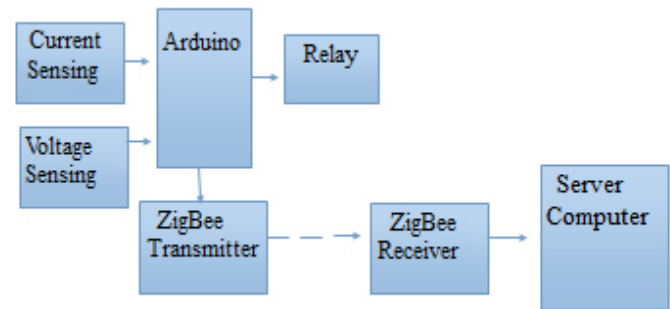
The block diagram of the Smart meter is shown below.

Fig -3.1: Smart meter Block diagram

The block diagram depicts the operation of the Smart meter. We use two sensors. One for measuring the voltage and other for measuring the current. The processor is programmed to calculate the remaining parameters. The Arduino gives the calculated values to Zigbee transmitter which facilitates the transmission to a distant monitoring system, say a PC. The Zigbee receiver at the PC side receives the transmitted data and is displayed in the monitor. The processor also checks if the power consumption exceeds the predefined limit. If the consumption is more than the limit, the processor activates the relay which turns the supply off

3.2 Potential Divider for Voltage Sensing

The voltage and current ranges are fixed and therefore the input circuitries must be adapted to the application wherein the Smart meter is used. When choosing a range, anticipate to higher peak values rather than the nominal value. For instance, when the Smart meter is used for a 12 V PV-system, the battery voltage can reach over 14 V and the open terminal voltage of a PV-panel could be high as 18 V. For the current values this could become much worse due to inrush currents. Keep in mind that the selected range concerns peak values. The peak value of a 100 Veff sinusoidal alternating voltage will be 2 higher.ie, 141 V. The Smart meter is designed to measure a maximum peak value of 500 V. But the input voltage that can be applied to the Arduino Board falls in the range 0-5 V. In order to have the positive and negative half cycles, the voltage range is further limited to 0-2 V. A potential divider circuit must be designed to meet this situation. Potential divider is shown.
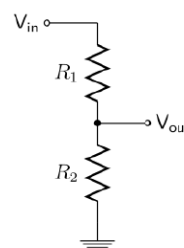
Fig -3.2: Potential Divider

The voltage input attenuator is determined by the resistors R1 and R2. This resistor network will divide the input voltage so that the Arduino measures a 2 V when the peak of the supply is 500V. The resistor R2 has a fixed value of 10 kilo ohm, and the range is set by R1 and is calculated as,

$$V_{out} = V_{in} \cdot \frac{R_2}{R_1 + R_2}$$

The system is designed to give 2 V, for a peak input of 500 V. If R2 is taken as 10 kilo ohm, then the value of R1 is obtained as 1 Mega ohm.

3.3 Arduino Nano Board

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The micro controller on the board is programmed using the Arduino programming language. The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 or ATmega168. The Nano was designed and is being produced by Gravitech. The Arduino Nano can be powered via the Mini-B USB connection, 5V regulated external power supply. The ATmega328 has 32 KB. The ATmega328 has 2 KB of SRAM and 1 KB of EEPROM. Each of the 14 digital pins on the Nano can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. The Arduino Nano has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega168 and ATmega328 provide UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will ash when data is being transmitted via the FTDI chip and USB connection to the computer. Figure of an Arduino Nano Board is shown,

Fig -3.3: Arduino Nano Board

3.4 ACS712 for Current Sensing

The ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include
motor control, load detection and management, switched mode power supplies, and overcurrent fault protection. The device is not intended for automotive applications.
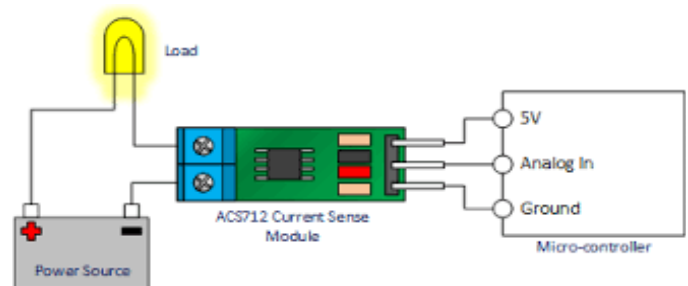

Fig -3.4: ACS712 for Current Sensing

Device consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. Applied current owing through this copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional voltage is provided by the low-offset, chopper-stabilized BiC-MOS Hall IC, which is programmed for accuracy after packaging. The output of the device has a positive slope when an increasing current flows through the primary copper conduction path which is the path used for current sensing. The internal resistance of this conductive path is 1.2 m typical, providing low power loss. The thickness of the copper conductor allows survival of the device at up to 5 times overcurrent conditions. The terminals of the conductive path are electrically isolated from the sensor IC leads. This allows the ACS712 current sensor IC to be used in applications requiring electrical isolation without the use of opto isolators or other costly isolation techniques.

3.5 ZigBee

ZigBee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios. The technology defined by the ZigBee specification is intended to be simpler and less expensive than other wireless personal area networks (WPANs), such as Bluetooth or Wi-Fi. Applications include wireless light switches, electrical meters with in-home-displays, traffic management systems, and other consumer and industrial equipment that requires short-range low-rate wireless data transfer.
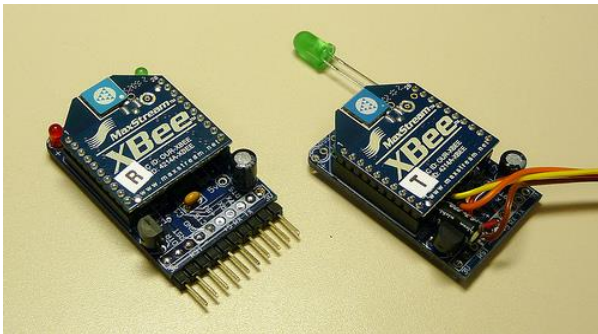
Fig -3.5: ZigBee unit

The ZigBeee unit consist of a transmitter and receiver. Data from a processor can be easily transmitted through ZigBee transmitter and can be received by the ZigBee receiver at a receiver station like a PC. Its low power consumption limits transmission distances to 10100 meters line-of-sight, depending on power output and environmental characteristics. ZigBee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. ZigBee is typically used in low data rate applications that require long battery life and secure networking. ZigBee has a defined rate of 250 kbps, best suited for intermittent data transmissions from a sensor or input device.

3.6 Relay

A simple electromagnetic relay consists of a coil of wire wrapped around a soft iron core, an iron yoke which provides a low reluctance path for magnetic flux, a movable iron armature, and one or more contacts (there are two contacts in the relay pictured). The armature is hinged to the yoke and mechanically linked to one or more sets of moving contacts. It is held in place by a spring so that when the relay is de-energized there is an air gap in the magnetic circuit. When an electric current is passed through the coil it generates a magnetic field that activates the armature, and the consequent movement of the movable contact either makes or breaks a connection with a fixed contact. If the set of contacts was closed when the relay was de-energized, then the movement opens the contacts and breaks the connection, and vice versa, if the contacts were open. Most relays are manufactured to operate quickly. In a low-voltage application this reduces noise, in a high voltage or current application it reduces arcing.

4. SIMULATION

The simulation is done in Proteus software. The circuit is made as per the design. The resistor values are so chosen to give the required voltage attenuation for input to the Arduino. The current sensor ACS712 is used to sense the

current and to convert the current to a proportional voltage. The Zigbee unit is connected for transmission to a distant PC.
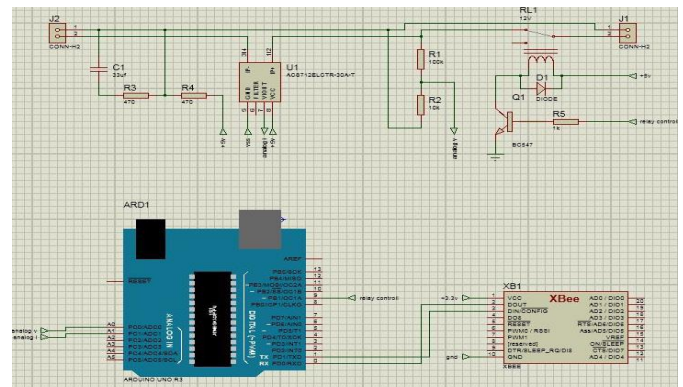

Fig -4.1: Simulation in Proteus

The result of simulation is observed using a software called Processing. The Processing software is actually an interface between the ZigBee receiver and the PC. A set of readings were displayed in the Processing window which shows that the transmission through ZigBee was successful. The microprocessor calculated the parameters and are successfully received at the PC.

5. HARDWARE IMPLEMENTATION AND RESULTS

Before implementing the actual hardware, we designed the system using a software named Fritzing. Fritzing is an application that helps to design the circuit in breadboard very easily.
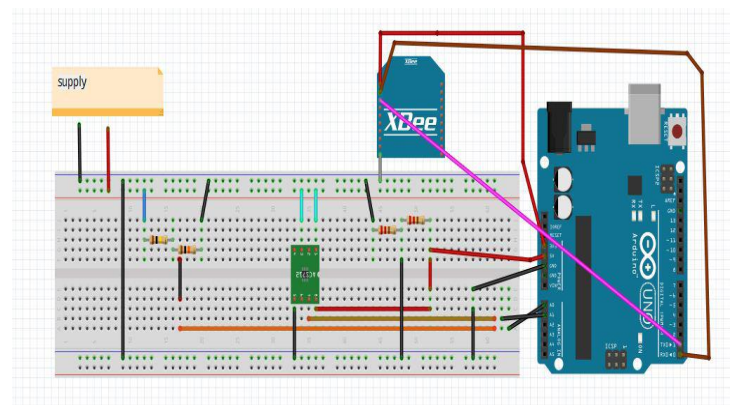

Fig -5.1: Breadboard design using Fritzing

Voltage is attenuated using the potential divider and is given to the first input pin of Arduino. ACS712 is provided to detect the current and to produce a voltage proportional to the current. This voltage is given to the second input pin of Arduino Board. The RXD and TXD pins of Arduino are respectively connected to the TXD and RXD pins of Zigbee.
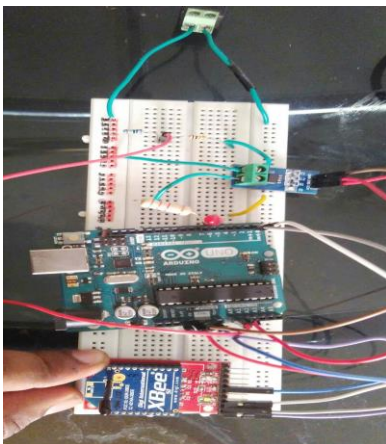
Fig -5.2: Hardware Implementation in Breadboard

The final output window is prepared using Coral Draw software. Any design pattern can be adopted according to the users choice. While operating with AC supply, the DC parameters will show error and vice versa. To avoid this, we can make separate windows for displaying AC and DC parameters. Here is an example of the final user interface window, when the supply is AC. Here we use a 370 ohm, 1.1A rheostat as the load.
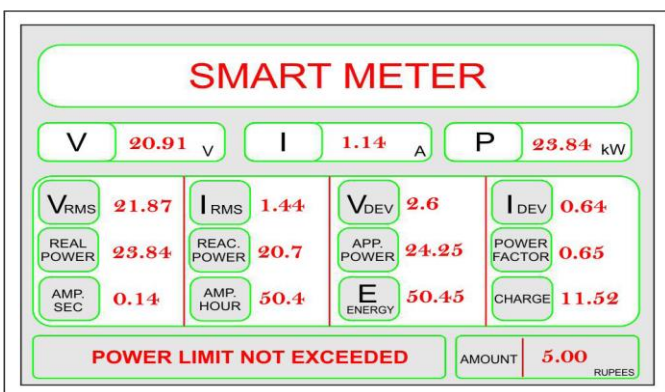

Fig -5.3: User Interface Window

6. CONCLUSION

Smart meter based on Arduino Nano Board facilitates the measurements of multiple electrical parameters. Smart meter makes no distinction between AC and DC. It takes voltage and current as inputs and calculate a number of electrical parameters accurately. Thus it reduces the cost and complexity of using several devices at a time. The measured parameters are sent to a distant monitoring system for analysis. A ZigBee unit handles this data transmission and has a capability to penetrate through a few concrete walls. All the measured parameters are displayed

simultaneously for quick reference by the user. Smart meter can be used in hazardous environment as the monitoring is done from a distant location. Smart meter find its application in electrical laboratories, as it reduces time consuming calculations. In substations, Smart meter can be used as an overall monitoring device and for residential purpose, it saves electricity by controlling the usage. The Smart meter has got sufficient scope of expansion. The present system can be modified by merely changing the Arduino program. Thus a number of additional electrical parameters can be calculated, if their equation depends on voltage, current and time. By modifying the hardware, it is possible to make the device work with three phase supply.

REFERENCES

[1] The DIY Digital AC Watt Meter, Curtis J Dietrich, in Conference. Rec. IEEE

[2] Bjorn Karlsson, Ingvar Jonsson, Microprocessor based energy consumption meter, Microelectronika publications, Mar./Apr. 2007.

[3] The Arduino based wireless power meter proposed by Christopher McNally, International Journal of Innovative Technology and Engineering (IJITEE), Vol 3,Issue 7, May 2010

[4] The Zigbee based Wireless Energy Meter reading and logging system on PC by B.D. Moorthy, Wireless and automation, Jun. 2010.

[5] http://meettechniek.info/diy-instruments/arduino-wattmeter.html

[6] http://ieeexplore.ieee.org/xpl/freeabsalljsparnumber=553382abstractAccess=nouserType=inst

[7] http://ieeexplore.ieee.org/xpl/login.jsp?tp=arnumber=4159555url=http