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ELECTRICAL QUANTITY MEASUREMENT AND REGULATION EMPLOYING INTERNET OF THINGS

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ABSTRACT

In this paper an attempt is made to measure electrical parameters such as Current, Voltage, Power, Frequency and Power Factor employing Internet of Things. The paper also describes how the data that is wirelessly received on the consumer's mobile enables the user to switch appliances on and off to save power. The Android application which was self-developed acts as the link between the measurement and display.

KEYWORDS: Power, Power Factor, Bluetooth, Arduino, Iot, Android Application, Relay

INTRODUCTION

Laboratories make use of analog and in a few cases digital meters for various measurement purposes. These techniques are now outdated, hence an effort is required to further digitize this and make reading and measurement easy and smart.

In a country where power is a luxury, wastage and misuse of such a resource can be considered a cardinal sin. India is severely lacking in the energy monitoring and conservation fields. Hence, the opportunity for development is immense. Consumers have no idea of exactly how much power their devices consume and how much can be conserved. Even with the advent of smart meters, the situation really hasn't improved.

Internet of Things basically consists of a network of objects embedded with sensors and interconnectivity among them which enables them to exchange data with one another. It helps control devices remotely resulting in improved efficiency and economic benefits. IoT thus plays a huge role in the whole concept of energy management. If implemented correctly, this would bring rapid cost cuts and energy saving. A collaboration of data analytics with this (i.e. IoT) would improvise it further.

The device we have designed aims to help determine exactly how much each appliance consumes and control them remotely in order to minimize such consumption. It could be done automatically through a cloud-based server without any effort from the consumer's end.

Energy data is presented instantaneously. Targets can be set for daily consumption. A historical data view helps you identify high and low consumption periods for economic and efficient management. The consumer will also be able to identify a faulty device based on its erroneous consumption and replace it if necessary.

For example, consider the case of nobody being at home and a device such as a fan left on. The application shows this consumption which can be understood to be a wastage of power and allows the user to turn it off if he/she wishes to.

OBJECTIVES AND SCOPE

Our aim is to create a device which can be placed at the electric panel level - i.e. attached to every socket where the appliance would be plugged in. The consumption information is then received by a microcontroller and can be transmitted by Bluetooth to the user's smart phone which facilitates him to monitor the usage in real time. Our intention is to keep the user informed about the rate of power consumption of the appliances in his home and make informed decisions about their needs. This would help curb unnecessary usage of power.

We have used Bluetooth because of concerns of privacy and security in their usage. Since Bluetooth can connect to only one person at a time and its range being around 10–15 m, it makes it a lot more difficult to hack into. The wireless connectivity can be improved depending on the location and type of application. If connectivity over a larger area is required, Wi-Fi could be used instead. It could also be connected to the Internet if cloud computing and server connectivity is required.

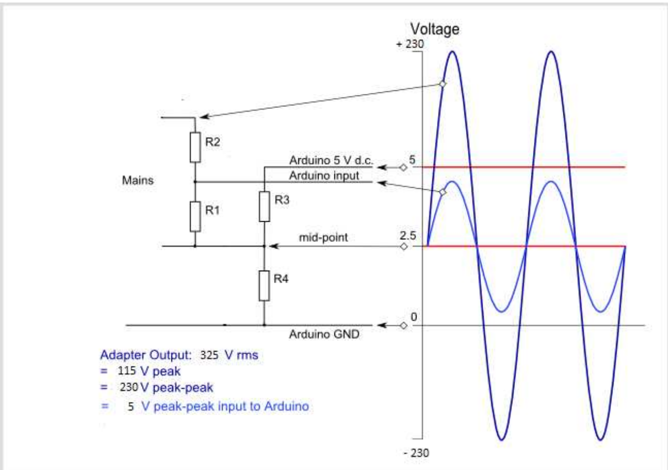
TECHNICAL SPECIFICATIONS

Voltage Measurement

The measurement of Voltage is an integral part of this meter. As the Arduino microcontroller cannot measure 230 V directly, it is stepped down to 5 V Peak to Peak using a voltage divider circuit. The board can detect only the positive part of the signal and cancels out the negative part. Since the input ac is of alternating type (i.e. sinusoidal), the input ac wave has to be given an offset of 2.5 V. This would bring the wave up to 0 - 5 V with 2.5 V as the reference.

Resistors	Values
R1	10k Ω
R2	1670k Ω
R3	10k Ω
R4	10k Ω

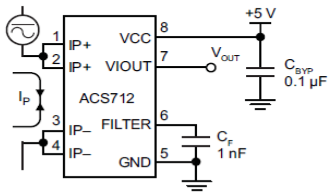
Thus the voltage divider ratio is 168:1.



Current Measurement

Rated maximum at 5 A (Peak), the current sensor (ACS 712) is based on the Hall Effect. The advantages of using Hall Effect sensor in current measurement are that the Hall Effect sensor is able to measure DC and AC currents. Apart from that, it is very reliable and it provides electrical isolation to the measurement circuit for safety in operation. The sensor consists of a precise, low-offset, linear Hall circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which the Hall IC converts into a proportional voltage (185 mV per ampere in this case). Sensor accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. The Max current rating is limited by the sensor and can be extended with the use of a better rated sensor.

Current sensor ACS 712



Application 1. The ACS712 outputs an analog signal, V_{OUT}, that varies linearly with the uni- or bi-directional AC or DC primary sampled current, I_P, within the range specified. C_F is recommended for noise management, with values that depend on the application.

Power

The RMS values of current and voltage are multiplied respectively to get the apparent power in VA. For the real and reactive powers, the Power Factor is calculated. This cannot be done by soft methods as there is an inherent delay of the order of 40 microseconds in sensing Current and Voltage by the Arduino. This delay causes an error in the calculation of instantaneous power and hence a need for a hardwired circuit arises.

Frequency

The voltage signal (Sine wave) is converted to a square wave using a Zero Crossing Detector (ZCD). By counting the number of pulses it receives, the Arduino directly gives us the value of input frequency.

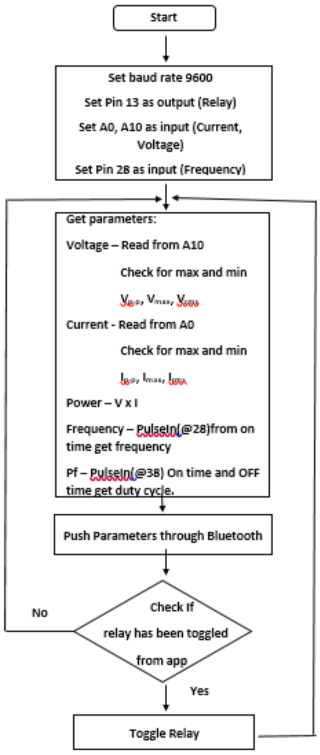
Power Factor

Using ZCD current and Voltage signals are converted to square waves which are in phase with the respective quantities. The difference between the square waves corresponding to voltage and current is a square wave whose duty cycle is inversely proportional to power factor. By measuring this duty cycle the Arduino directly gives us the Power factor.

CODING

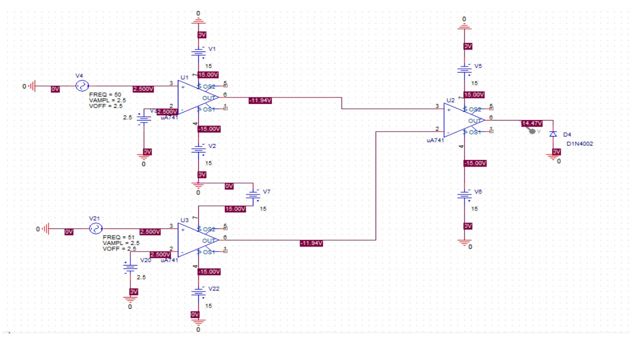
The Arduino SDK was used to develop the program for measurement of the various parameters. The MIT app inventor 2 tools were used to develop the android application. The power factor circuit was simulated using PSPICE software.

Flowchart



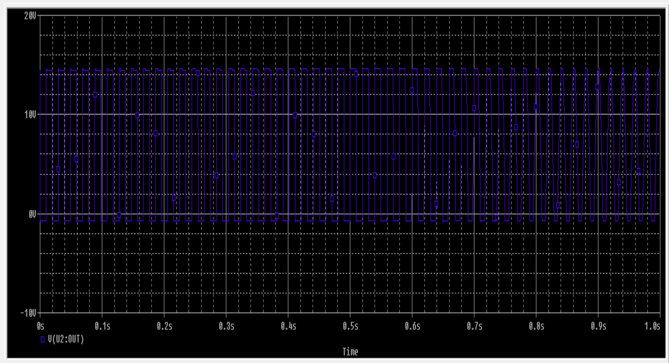
Simulation

The circuit to determine power factor was simulated using PSPICE. The circuit and the waveforms are as shown below.



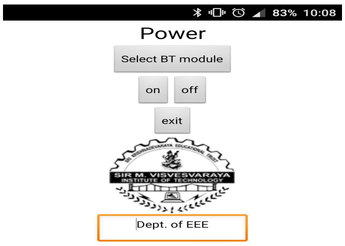
The IC's U1 and U3 get the input from the current sensor and voltage sensor respectively. They convert it to square waves which are in phase with the input waveforms. In the IC U2 the square waves corresponding to Current is subtracted from the square wave corresponding to Voltage. This gives an output signal which is a square wave whose duty cycle is inversely proportional to power factor. By measuring this duty cycle the Arduino directly gives us the Power factor.

For simulation two square of different frequency were compared as seen from this waveform as the two cycles vary the duty cycles go out of phase.



Application

The app was developed using an online tool called MIT app Inventor 2. The application was developed for android smart phones. It connects to the microcontroller through the Bluetooth radio and displays the power consumption data along with the voltage and current values in real time. The application has provisions for toggling the relay. The Application was named PQ monitor.



PQ monitor application Screenshot

DATA AND TABULATION

The readings obtained for an electric kettle rated at 810 W 3.5A. This was verified with an analog wattmeter.

This is tabulated as follows:

Voltage	Current	Power (Device)	Power (Wattmeter)
242 V	2.40 A	580.80 VA	505 W
237 V	2.76 A	654.12 VA	570 W

RESULTS AND CONCLUSIONS

Tests were conducted on an electric kettle and incandescent bulb. The readings obtained were found to be satisfactory.

Simulation was performed for an inductive load. Which also gave satisfactory results. The error in readings was found to be 14%. These errors are due to non-inclusion of Power Factor and Magnetic Noise picked up by the Hall Effect sensor.

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