DESIGN AND IMPLEMENTATION OF ENERGY MONITORING DEVICE FOR HOME APPLIANCES.

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DEDICATION

I dedicate this project to the almighty God, the alpha and the omega, the author and the finisher, whom out of his abundant mercy has given me the grace to reach this level of my academic pursuit.

DECLARATION OF ORIGINALITY

This project is all my own work and has not been copied in part or in whole from any other source except where duly acknowledged. As such, all use of previously published work (from books, journals, magazines, internet, etc) has been acknowledged within the main report to an entry in the references list.

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CERTIFICATION

This is to certify that the design and construction of this energy measuring device for home appliances was carried out by AJAYI AYODEJI EZEKIEL of the department of Electrical and Electronics Engineering. Federal university Oye Ekiti, Nigeria.

The project is my own work and has not been submitted to any other university or higher education institution, or for any other academic award in this university. Where other people's work has been used, it has been fully acknowledged and fully referenced.

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Engr. S. O. Sanni (supervisor) Date

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Engr. Dr. J.T. Oricha (H.O.D) Date

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External supervisor Date

ABSTRACT

This project report presents the design and implementation of an energy monitoring device for home appliances. The energy monitoring device allows the user to monitor its energy consumption by giving the energy parameters of any plugged-in appliance. As the need to reduce energy consumption of homes increases, this device can come in handy since it can be used for energy audit of residential homes. The energy monitoring device is capable of giving the energy consumption in real time and also programmed to remotely inform the user the total consumption based on request from the user through the GSM module.

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CHAPTER ONE

INTRODUCTION

1.1.Background of the Study

Electricity plays a very crucial role in our everyday life as it uses not only include home and industrial lighting and heating but also powering of technologies like cell phones, computers, entertainment electronics, life-support systems, machine tools etc. Anything cannot be imagined without electricity.

The consumption of energy and its associated environmental side-effects pervade all aspects of our personal and public life to the point where we have become oblivious to it (Roland stulz, 2011).

The normal state of affairs in today's developing countries is that energy is consumed everywhere at all times. Ten searches on the interment, for example, requires one-kilowatt hour (kwh) of electricity. A similar amount is required for a 30-watt energy saving lamp to burn uninterrupted for 36 hours. About 30kwh of energy are used in the average home for heating, hot water, and electrical appliances every day. In Nigeria, the biggest components of energy consumption is buildings. Roughly 50%-60% of current energy use goes to provide energy services in buildings.

Improvements in energy efficiency are a component of the overall technological change that is the main driver of the economic growth (Saunders, 1992). An increase in energy efficiency is the production of the same energy services (e.g. lumens or amount of visible light) with less energy input (fewer watts of electricity).

The management and regulation of available energy is of utmost importance, as more often than not, the available energy is usually not enough for most developing countries of the world. Presently, primary source of energy for the production of electricity in Nigeria for the past 45 years remains as coal, oil, water and gas. Therefore, the types of power plants functioning in Nigeria are the hydroelectric and the thermal/fossil fuel power plants. The two main types of thermal/fossil fuel power plants are naturally gas-fired and coal fired. However, hydroelectric power systems and gas fired systems are the two main power generating systems used presently. Nigeria as a country is certainly plagued with the issue of sufficient electricity for her teeming populace. There is thus a relatively high demand for the rather unavailable electricity which has often been classified as epileptic.

Furthermore, the issue of metering has over the years being a canker-worm which has eaten deep into the usage and payment for electricity in Nigeria. There exist a vast amount of the populace either using unmetered electricity or currently agitating for considerations made on estimated billing in the form of over billing. In addition there has been an alarmingly upward review of electricity tariff in the past few years thus even those using prepaid energy meters are faced with inability to pay for energy units.

One of the solution often proffered to the aforementioned problems is the usage of energy saving appliances ranging from electricity bulbs to DC based gadgets so as to ensure considerable reduction in energy consumption. Consumers have also been encourage to consciously monitor usage of household appliances so as to reduce wastage of energy and consequently electricity cost.

One of the way to efficiently achieve the latter is the use of embedded electronics interfaced with suitable GSM module. This will not only monitor the energy consumption in real time but can also be programmed to remotely inform the user the total consumption based on request from the user.

The user can also query the system from any location to obtain the current electricity consumption and energy readings of a connected appliance.

1.2 Statement of problem

The importance of effectively monitoring and regulating the consumption of electricity is one that cannot be over-emphasized. The issue of metering has over the years being a canker-worm which has eaten deep into the usage and payment for electricity in Nigeria. There exist a vast amount of the populace either using unmetered electricity or currently agitating for considerations made on estimated billing in the form of over billing. In addition most people pay heavily on electricity bill because of lack of knowledge of their electricity usage. Most people complain on overbilling and high electricity tariff at the end of the month and still waste the electricity because they lack understanding of the energy profile of their homes.

The proposed solution to this problem is an energy monitoring device for home appliances.

This will not only monitor the energy consumption in real time but can also be programmed to remotely inform the user the total consumption based on request from the user.

The user can also query the system from any location to obtain the current electricity consumption and energy readings of a connected appliance.

1.3 Motivation

There has been an alarmingly upward review of electricity tariff in the past few years thus even those using prepaid energy meters are faced with inability to pay for energy units. In addition there exist a vast amount of the populace who did not understand their energy usage and are using high energy consuming appliances for a very long period of time thus incurring high electricity cost. Even those using prepaid meters still have the need to identify high energy consuming appliances in their homes in order to reduce electricity cost. All these and more motivated me in the design of this energy monitoring device for home appliances.

1.4 Significance of the study

The energy monitoring device for home appliances is intended to make user understand the rate of consumption of energy in their homes and to put a check on high energy consuming appliances. Also it is to help the user to reduce cost on electricity bill and as well conserve energy. It does provide the energy parameters of any plugged-in home appliances and the parameters can be accessed by the user anytime, anywhere through the GSM module embedded in the device. The device can be used for energy audit. The device is to help users maintain their energy usage and at large to reduce cost of energy usage.

1.5 Aim and Objectives of the study

The aim of this project is to design and implement a functional energy monitoring device for home appliances. The specific objectives are:

1) To design the power circuit
2) To design a voltage and current sensing circuit
3) To design a GSM module for real time monitoring
4) To simulate the designed functional units
5) To assemble the components to a functional monitoring device.
6) To test the performance analysis of the monitoring device.

1.6 Scope of the project

The energy monitoring device for home appliances will not only monitor the energy consumption in real time but can also be programmed to remotely inform the user the total consumption based on request from the user.

Furthermore, the device also gives the starting current of inductive loads.

Moreover, the user can also query the system from any location to obtain the current electricity consumption and energy readings of a connected appliance.

CHAPTER TWO

2.0 LITERATURE REVIEW

Nigeria has the largest economy in sub-Saharan Africa, but limitations in the power sector has contributed to a very large extent the rather slow economic growth of the country. Despite being endowed with large oil, gas, hydro and solar resource, and having the potential to generate 12,522 Megawatts (MW) of electric power from existing plants, the country in most days is only able to generate around 4,000 MW, which is insufficient (USAID, 2018).

Energy consumption in residential households is very important to consumers. The rise in electricity prices have deemed to consumers the need to conserve energy, with less to no information on their energy consumption patterns. A step towards energy conservation is a real time energy monitoring system which provides feedback to the consumers, thus the consumer will be able to identify the opportunities to adjust and identify how to conserve energy.

The ability to effectively monitor the energy profiles and control the energy usage of desired appliances at home and industrial environment has been of great concern. Over the years, different individuals has presented diverse approaches to achieve the said objectives.

Tang et al, (2010) proposed a peer-to-peer based power monitoring device (PMD) which can be integrated into an Energy management system (EMS) or Smart grid. Power Monitoring devices which can be connected to energy grid to monitor electrical parameters such as voltage, current, real power, reactive power, apparent power etc. often rely on PC servers in the monitoring layer. The servers run power monitoring application software to retrieve, store, organize and display power information in real time (Tang et al., 2010). However, when EMS are installed for a customer with different requirement due to possible environment change or other factors, the PMD often needed to be updated with target patch from a single PC server. This is however time consuming, vulnerable for all type of unknown interruption and quite expensive when there are a number of PMD's to be updated thus the proposed designed of a peer-to-peer communication based PMD.

Sunna (2013), noted that increased energy consumption and consequently increased greenhouse gas emission is one of the worrisome issues currently facing Europe and with ever increasing energy costs, more and more consumers are becoming actively interested in reducing their energy consumption. Though emerging technologies today have shown the possibility of obtaining as much as a 40% reduction in residential energy consumption, consumers are rather unwilling or indisposed to acquire such appliances. With advancement in technology, several companies have introduced varieties of energy efficient, monitoring and control appliances; Whirlpool and LG taken the lead in this regard (Sunna, 2013). The introduction of LG NFC tagged appliances in 2012, consisting of washers, dryers, refrigerators and electric ovens with the LG smart ThinQ technology offered a Home Energy Management System (HEMS) enabling the end-user to manage their appliances in an energy efficient manner. In a similar development , Whirlpool's smart appliances with 6th sense live technology in 2013 brought about devices such as washing machines, dryers, refrigerators and dish washer equipped with features that enables the end user to manage energy usage and control features remotely via Wi-Fi using Smart Phone, tablet or computer (Sunna, 2013).

According to Sunna (2013), several companies have also offered home automation and energy saving appliances such as the plugwise socket to manage to offer home energy management. The Plugwise socket module featured a ZigBee unit which enables the user to create schedules to turn on and of appliances as well as standby power killers. HEP thus provides the end-user with information which will reduce the work of the end-user and could add to the incentive of the end-user by doing more than measuring, the energy usage and possibly reducing the actual usage of individual appliances.

Edwin et al (2013), in their work described a suitable device consisting of several measurement nodes and a central server. The nodes which are basically outlets for the devices to be connected perform the vital function of monitoring and wirelessly transmitting the energy usage of connected AC devices.

These nodes are linked to and controlled by the central server which not only receives information from the nodes but also equipped with the ability to turn on and off individual nodes. The central server also produces a graphical real time display of the energy reading in a suitably designed graphical user interface (GUI). The mode of communication between the server and node was implemented via a suitable short distance wireless communication system; the IEEE 802.15.4 (ZigBee RF), which offers, a low-speed ubiquitous communication between devices at a reasonably low cost, thus making it quite suitable for equipment in need of battery life as long as several months to several years. This was connected to the microcontroller via the UART protocol.

In a similar approach, Elamvazuthi et al (2012), proposed a 3 phase energy monitoring device which can be plugged directly to the power-socket so as to remove the dependency of having to run conventional wires. This approach according the team not only offer easy temporary or permanent installation but also the measurement of power consumption for a single device so as to optimize power usage in a facility (Elamvazuthi et al ., 2012). The project which featured a SD card for data logging, is built around the programmable interface controller (PIC), interfaced with suitable current and voltage measurement sensors.

The device which essentially consists of switches, power and sensor indicators, navigation buttons, and current and voltage measurement unit is capable of measuring the apparent power, voltage and current with acceptable error. This was shown in the comparison of the accuracy of the device with the laboratory data acquisition interface LVDAM-EMS as made by the team.

The eCOMBAT system as proposed by Olwal et al (2013), was essentially focused on energy saving and monitoring in wireless communication networks. They argued that saving power in base stations, mobile stations and wireless routers as communication devices is the primary focus for green wireless communication. Thus a likely solution would be designing energy-efficient hardware with sleep mode features and energy-aware cooperative base station. Furthermore, these stations are to run on rechargeable batteries which are connected to renewable energy sources ranging from bio-fuels to solar and wind energy. This consequently led to the development of the eCOMBAT system which integrates the rechargeable battery discharge models with various device energy consumption model to achieve a functional and effective energy monitoring device. The eCOMBAT system was implemented using the C++ programming language on a Linux platform and featured a friendly graphical user interface for logging the measured device data

Putra et al (2015), created an energy consumption monitoring device using the laravel php framework and MySQL database web applications. The system which was designated Indigo Smart Home Automation system also featured a responsive GUI which consisted of an Admin. Room and scheduling pages. While the admin has overall access to the entire system operation. the user and guest can only access room pages to monitor and control desired appliances.

The system which essentially comprises the RaspberryPi. Arduino. relay board and current sensor was stated to have the capability to monitor. diagnose. control and monitor connected electrical appliances thus lowering energy usage by 59%.

The "design and implementation of a web-based home energy management system for demand response application" by Md Moshiur Rahman in 2013 described an architectural framework for a web-based demand management system that allows the electric utility to reduce system peak load by automatically managing end-use appliances based on homeowners' preferences. According to Rahman, (2013), the designed system comprises; the human user interface, home energy management (HEM) algorithms, web services for demand response communications, selected ZigBee and smart energy profile features for appliance interface as well as the web security protocols for the system. The device featured an intelligent web based interface accessible from desktop as well as personal mobile devices and offers monitoring, feedback and control of connected appliances locally or remotely.

The aforementioned user interface was stated to be able to dynamically adapt itself based on user inputs and offers visualization and user input for managing the comfort settings related to individual appliances and relevant operational preferences. An intelligent Demand Response algorithm (DR) was also designed to tackle to tackle challenges regarding home energy management. The algorithm was further expanded to perform both single and joint home energy management known as SH-DR and (MHJ-DR) algorithms.

Shajahan (2013). described an Arduino –android smart plug system comprising of an Arduino microcontroller board. An ENC28J60 Ethernet module and a current transformer sensor. The device which employed a non-invasive current sensing technique uploads collected data onto the server using an Ethernet connection and the user interface was developed with the android platform.

The software platform for the microcontroller: an Arduino Duemilanove was made using the Arduino IDE and the result collected showed an energy saving of 15%. Shajahan also noted the device could be further improved to control the connected appliance.

Juhana et al, (2016), proposed a smart non-intrusive power consumption monitoring system using the SCT-013-030 current sensor, Bluetooth Low energy (BLE) and factorial Hidden Markov Model algorithm (FHMM). Sensors to measure the required energy parameters are interfaced at one end and transmitted via the Bluetooth interface to the server which perform disaggregation of the electricity consumption on each load using the aforementioned FHMM algorithm.

Energy consumption in residential households is very important to consumers. The rise in electricity prices have deemed to consumers the need to conserve energy, with less to no information on their energy consumption patterns. A step towards energy conservation is a real time energy monitoring system which provides feedback to the consumers, thus the consumer will be able to identify the opportunities to adjust and identify how to conserve energy.

This project is focused on creating a suitable microcontroller based energy monitoring device which displays the energy parameters of a connected appliance in real time or via remote queries using a GSM module.

CHAPTER THREE

DESIGN METHODOLOGY

3.0 Introduction

This chapter entails the design and construction procedure of the real time Energy monitoring device detailing step by step the theoretical analysis, choice of components and values and construction and packaging materials. Indicating calculations, schematics and drawings. The design procedure is divided into hardware and software design as discussed below.

3.1 System description

The device is essentially an Energy monitoring device designed to capture the real time energy usage of a connected appliance displaying it either via the integrated LCD screen, the developed Serial Emulator software on PC and or via an SMS query via the SIM800L GSM/GPRS module. The energy parameter captured in real time in the device are:

- The Voltage
- The Current
- The Power Consumption
- The energy Consumption

The voltage reading is obtained via the rectified signal from a potential transformer which is then conditioned and fed to a target analog to digital (ADC) pin of the microcontroller. The ACS712 Hall Effect current sensor is connected serially to the applied load to measure the current consumption. The power and energy consumption are derivatives of the measured current and voltage of the connected appliance and this is done by the microcontroller unit and result sent is stored in required registers where it can be fetched for the LCD screen, serial module or the GSM Module as shown in the Fig 3.0 below.

3.2 System block diagrm

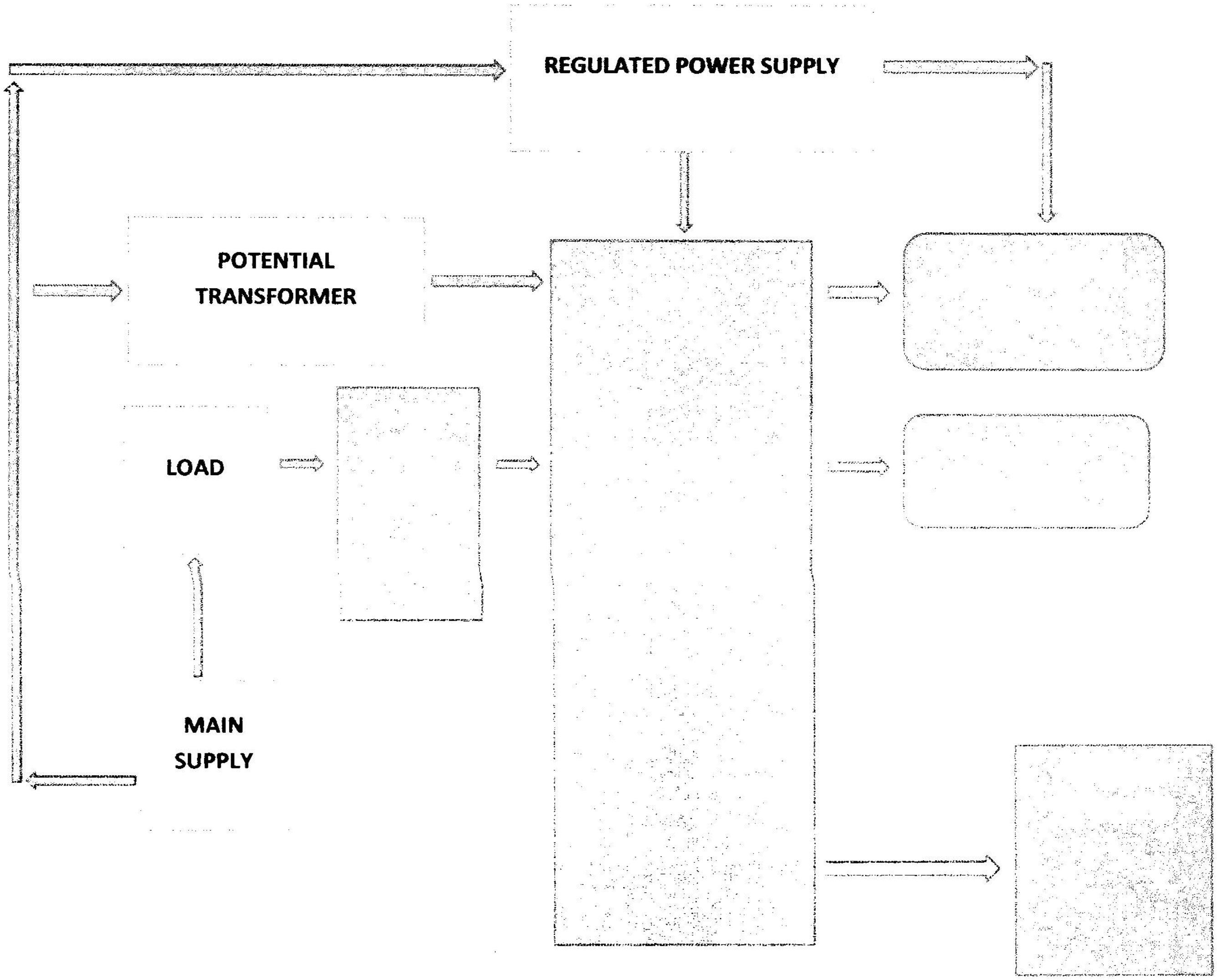

Fig 3.0 Block design of the e-m-d

3.3 Design consideration

The GSM based energy monitoring device is designed to be portable and relatively maintenance free. The device was also designed to be relatively easy to operate, requiring no special expertise or technical know-how to operate. The device was also made from locally sourced materials and designed to be relatively safe to operate via proper isolation of the AC side and DC voltages.

3.4 Hardware design

The design of the hardware was made and simulated using the Proteus design suite 8 by lab center Electronics. Each section of the device was designed and simulated and necessary adjustment made to ensure conformance to desired device objectives.

3.4.1 Circuit analysis

The hardware section is divided into the following essential units

- The current measurement unit
- The voltage measurement unit
- Regulated Power supply unit
- The Microcontroller unit

3.4.2 The current sensing unit

The E-M-D uses the Allegro ACS712 Hall effect current sensor to monitor the current in real time. The Allegro ACS712 current sensor is based on the principle of Hall-effect, which was discovered by Dr. Edwin Hall in 1879. According to this principle, when a current carrying conductor is placed into a magnetic field, a voltage is generated across its edges perpendicular to the directions of both the current and the magnetic field as it is illustrated in fig 3.1 shown below.

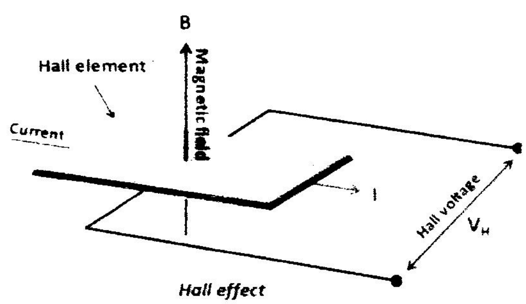

Fig 3.1 the Hall Effect

A thin sheet of semiconductor material (called Hall element) is carrying a current (I) and is placed into a magnetic field (B) which is perpendicular to the direction of current flow. Due to the presence of Lorentz force, the distribution of current is no more uniform across the Hall element and therefore a potential difference is created across its edges perpendicular to the directions of both the current and the field. This voltage is known as Hall voltage and its typical value is in the order of few microvolts. The Hall voltage is directly proportional to the magnitudes of I and B. So if one of them (I and B) is known, then the observed Hall voltage can be used to estimate the other.

The ACS712 device is provided in a small surface mount SOIC8 package. It consists of a precise low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. When current is applied through the copper conductor, a magnetic field is generated which is sensed by the built-in Hall element. The strength of the magnetic field is proportional to the magnitude of the current through the conduction path, providing a linear relationship between the output Hall voltage and input conduction current. The on-chip signal conditioner and filter circuit stabilizes and enhances the induced Hall voltage to an appropriate level so that it could be measured through an ADC channel of a microcontroller. The pin diagram of ACS712 device and its typical application circuit is shown below. Pins 1, 2 and 3, 4 forms the copper conduction path which is used for current sensing. The internal resistance of this path is around 1.2mΩ, thus providing low power loss. As the terminals of this conduction path are electrically isolated from the sensor leads (pins 5 through 8), the ACS712 device eliminates the risk of damaging the current monitoring circuit due to the high voltage on the conduction side. The electrical isolation between the conduction current and the sensor circuit also minimizes the safety concerns while dealing with high voltage systems.

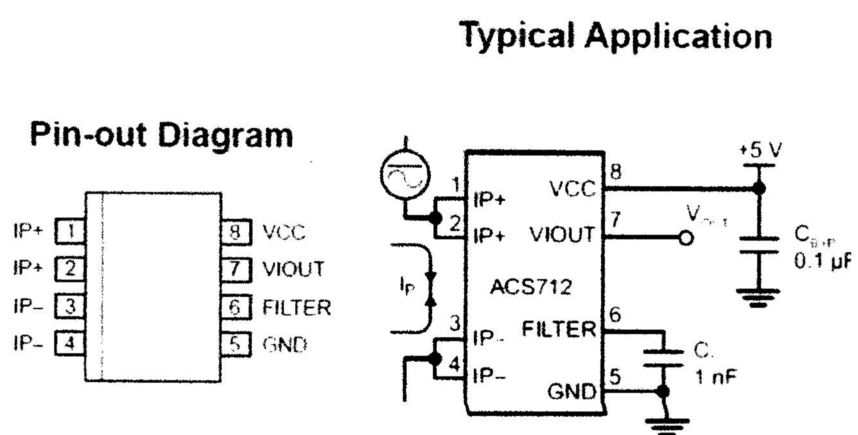

Fig 3.1.1 Pin diagram and a typical application circuit of ACS712

In low-frequency applications, it is often desirable to add a simple RC (resistor capacitor) filter circuit at the output of the device to improve the signal-to-noise ratio. The ACS712 contains an internal resistor (RF) connected between the output of the on-chip signal amplifier and the input of the output buffer stage (shown in fig 3.1.2 below). The other end of the resistor is externally accessible through pin 6 (Filter). With this architecture, users can implement a simple RC filter through the addition of an external capacitor (CF) between the Filter pin and ground. It should be noted that the use of external capacitor increases the rise time of the sensor output, and therefore, sets the bandwidth of the input signal. The maximum bandwidth of the input signal is 80 KHz at zero external filter capacitor. The bandwidth decreases with increasing CF. The datasheet of ACS712 recommends to use 1nF for CF to reduce noise under nominal conditions.

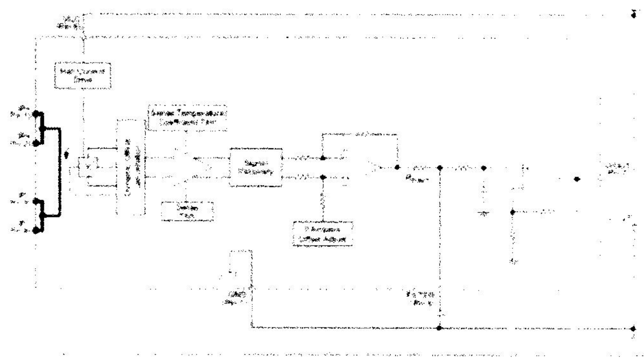

Fig 3.1.2 Functional block diagram of ACS712

3.4.3 Sensitivity and output of ACS712

The output of the device has positive slope when an increasing current flows through the copper conduction path (from pins 1 and 2, to pins 3 and 4). The ACS712 device comes in three variants, providing current range of±5A (ACS712-05B), ±20A (ACS712-20B), and ±30A (ACS712-30A). The ACS712-05B can measure current up to ±5A and provides output sensitivity of 185mV/A (at +5V power supply), which means for every 1A increase in the current through the conduction terminals in positive direction, the output voltage also rises by 185mV. The sensitivities of 20A and 30A versions are 100mV/A and 66mV/A, respectively. At zero current, the output voltage is half of the supply voltage (Vcc/2). It should be noted that the ACS712 provides ratiometric output, which means the zero current output and the device sensitivity are both proportional to the supply voltage, VCC. This feature is particularly useful when using the ACS712 with an analog-to-digital converter. The precision of any A/D conversion depends upon the stability of the reference voltage used in the ADC operation. In most microcontroller circuits, the reference voltage for A/D conversion is the supply voltage itself. So, if the supply voltage is not stable, the ADC measurements may not be precise and accurate. However, if the reference voltage of ADC is same as the supply voltage of ACS712, then the ratiometric output of ACS712 will compensate for any error in the A/D conversion due to the fluctuation in the reference voltage.

Let me explain this with an example. Suppose, an ADC chip uses Vcc = 5.0V as a reference for A/D conversion and the same supply voltage powers an ACS712 sensor chip. The analog output of the ACS712 will be digitized through the ADC chip. When there is zero current through the current sensor, the output is Vcc/2 = 2.5V. If the ADC chip is 10-bit (0-1023), it will convert the analog output from the ACS712 sensor into digital value of 512 count. Now, if the supply voltage drifts and becomes Vcc = 4.5V, then, due to the ratiometric nature, the new output of the ACS712 sensor will be 4.5/2 = 2.25V, which will still be digitized to 512 by the ADC as its reference voltage is also lowered to 4.5V. Similarly, the sensitivity value will also be lowered by a factor of 4.5/5 = 0.9, which means if the ACS712-05B is powered with a 4.5V supply, the sensitivity is reduced to 166.5mV/A, instead of 185mV/A. This concludes that any fluctuation in the reference voltage will not be a source of error in the analog-to-digital conversion of the ACS712 output signals.

The curve below (fig 3.1.3) shows the nominal sensitivity and transfer characteristics of the ACS712-05B sensor powered with a 5.0V supply. The drift in the output is minimum for a varying operating temperature, which is attributed to an innovative chopper stabilization technique implemented on the chip (details can be found on ACS712 datasheet).

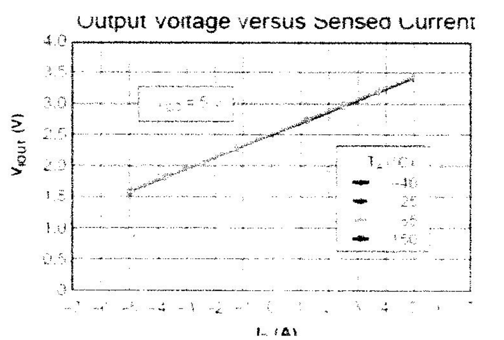

Fig 3.1.3 Output voltage vs sensed current of ACS712-05B at 5.0 V power supply and varying temperature

3.4.4 The potential transformer unit

A Potential transformer is an instrument transformer that is used in power systems to step down primary voltages from a higher potential level to lower secondary potential output voltage level. This transformer can be easily measured by low voltage instrument such as voltmeter, wattmeter, and watt-hour meters, etc. This type of transformer is commonly referred to as a "step-down" voltage transformer, it lowers the voltage of a high voltage circuit to a lower voltage circuit for the intention of measuring voltage drops. Potential transformers are connected across or parallel to the line which is being measured to record phase angle errors or ratio errors.

It is commonly found in electrical metering situations, and is designed to monitor single phase shifting voltages and three-phase terminal voltage. A potential transformer is also known as a voltage transformer (VT). There is still a primary winding and a transformers high voltage secondary winding.

This special type of transformer allows a meter to take readings from electrical service connections with a higher voltage (potential) rating than the meter is normally capable of handling without the potential transformer.

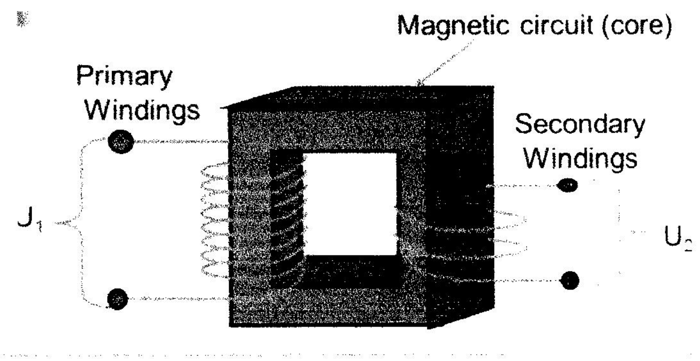

Fig 3.1.4 The Potential transformer

3.4.5 Power supply

The components of the E-M-D device requires different voltage levels to function as listed below:

- 3.3v for Sim800L
- 9V input to Arduino input pin

The main rectified dc voltage is obtained from the 19V AC power adapter, this was chosen because of the high current demand of the Sim800L microcontroller.

3.4.6 Selection of voltage regulator and buck converter

A voltage regulator is used to regulate voltage level. When a steady, reliable voltage is needed, then voltage regulator is the preferred device. It generates a fixed output voltage that remains constant for any changes in an input voltage or load conditions. It acts as a buffer for protecting components from damages. A voltage regulator is a device with a simple feed- forward design and it uses negative feedback control loops. There are mainly two types of voltage regulators: Linear voltage regulators and switching voltage regulators; these are used in wider applications. Linear voltage regulator is the easiest type of voltage regulators. It is available in two types, which are compact and used in low power, low voltage systems. Let us discuss about different types of voltage regulators (www.elprocus.com, 2018).

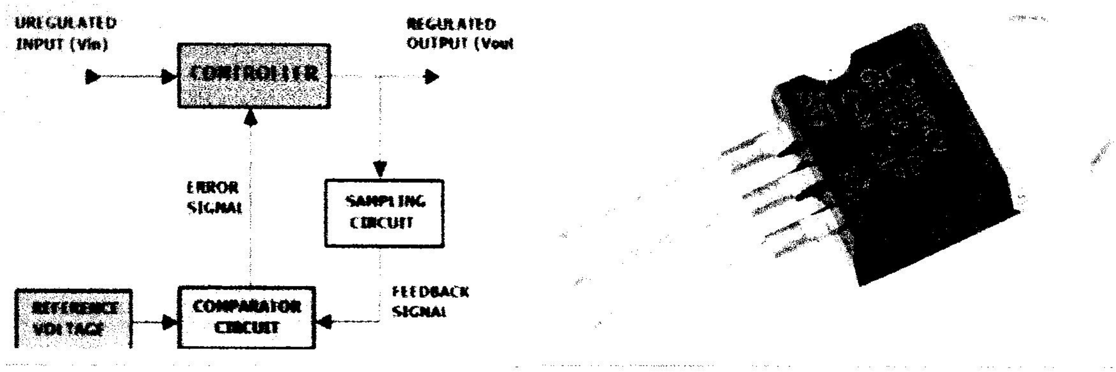

Fig 3.1.8 Voltage regulator

Since the arduino input pin is 9v tolerant and the voltage from the power adapter is 19V, a 9V voltage regulator (L7809CV) was selected. This is to ensure minimal energy loss occurs in form of heat.

3.4.7 Selection of filtering capacitor

There is a simple means of calculating the required size of the input filter capacitor in a basic power supply, or calculating the peak-to-peak ripple voltage in an existing supply (www.electroschematics.com). It works by assuming that the capacitor supplies current to the load approximately 70% of the cycle—the remaining 30% is supplied directly by the rectified voltage and during this period the capacitor is charged as well.

Peak-to peak ripple voltage is a most useful parameter. By knowing this, the minimum head voltage of a voltage regulator may be easily determined. For instance, the LM7812 series regulator requires a minimum of 2.5V across it to function within specifications, which means the valley of the peak-to-peak ripple voltage may not drop below 14.5V.

Q = C * V, C = capacitance in farads, Q = charge in coulombs, V = voltage potential

Q = I * T, I = current flow in amps, Q = charge in coulombs, T = time in seconds

F = 1 /T, F = frequency in Hz, T = period in seconds

Therefore,

I * T = C * V, or C = (I * T) /V

The delta "Δ" symbol indicates a change, such as a change in voltage or a change in time

C = I * ΔT / ΔV

In this case, ΔT = 1 /F e.g. the time period of a 50 Hz waveform = 1 /50 Hz = 0.02seconds

Therefore,

C = I / (ΔV * F)

Now including the 70% factor we get the final relationship:

C = 0.7 * I / (ΔV * F)

C = capacitance in farads, I = current in amps, ΔV = peak-to-peak ripple voltage, F = ripple frequency in Hz

Note that ripple frequency in a full-wave rectifier is double line frequency. For half-wave rectification, the ripple frequency is the line frequency.

Solving for ΔV

ΔV = 0.7 * I /(C * F)

3.4.8 Sim800l microcontroller

SIM800L GSM/GPRS module is a miniature GSM modem that can be integrated into a great number of IoT projects. This module can be used to accomplish almost anything a normal cell phone can; SMS text messages, Make or receive phone calls, connecting to internet through GPRS, TCP/IP, e.t.c. To top it off, the GSM module supports quad-band GSM/GPRS network, meaning it works much better anywhere in the world.

At the center of the module is a SIM800L GSM cellular chip from SimCom. The operating voltage of the chip ranges from **3.4V to 4.4V**, which makes it an ideal candidate for direct LiPo battery supply. This makes it a very good choice for embedding into projects without a lot of space.

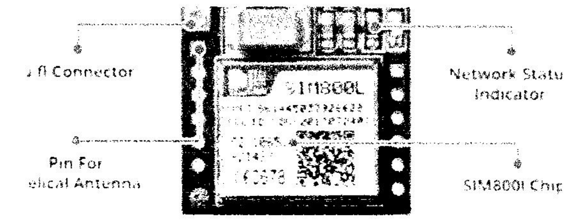

Fig 3.1.5 SIM800L GSM Module

All the important data pins of SIM800L GSM chip are broken out to a 0.1″ pitch headers. This includes pins required for communication with a microcontroller over **UART**. The module supports baud rate within the range of **1200bps** to **115200bps** with Auto-Baud detection.

The module needs an external antenna to connect to a network. The SIM800L GSM module usually comes with a **Helical Antenna** and solders directly to NET pin on the PCB. The board also has a U.FL connector facility in case we want to keep the antenna away from the board.

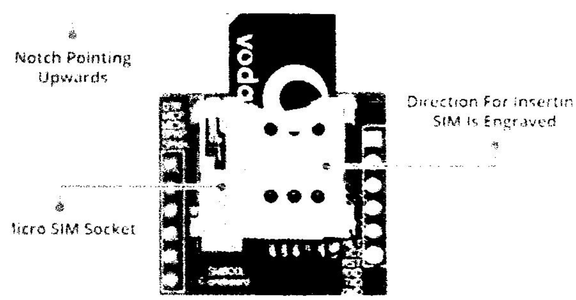

Fig 3.1.6 features of the SIM800L

There's a SIM socket on the back! Any activated, **2G micro SIM card** would work perfectly well. Correct direction for inserting SIM card is usually engraved on the surface of the SIM socket. This SIM800L GSM module measures only 1inch^2 but packs a surprising amount of features into its little frame.

There is a LED on the top right side of the SIM800L Cellular Module which indicates the status of the cellular network. It'll blink at various rates to show what state it's in:

Blink every 1second, the module has made contact with the cellular network & can send/receive voice and SMS. An antenna is required to use the SIM800L GSM module for any kind of voice or data communications as well as some SIM commands. So, selecting an antenna might be very important. There are two ways we can add an antenna to the SIM800L module.

The first one is a Helical GSM antenna which usually comes with the module and solders directly to the NET pin on PCB. This antenna is very useful for projects that need to save space but struggles in getting connectivity especially if the project is indoors.

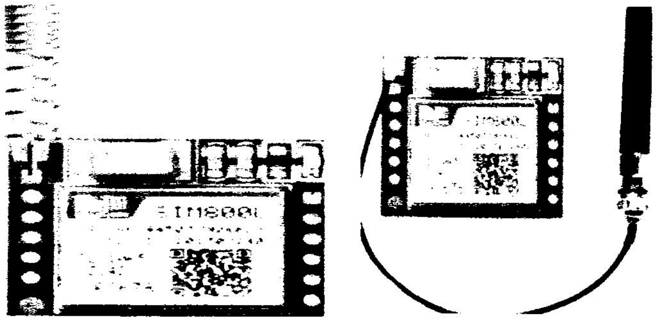

Fig 3.1.7 The SIM800L antenna

The second one is any 3dBi GSM antenna along with a U.FL to SMA adapter which can be gotten online for less than $3. We can snap-fit this antenna to small U.FL connector located on the top-left corner of the GSM module. This type of antenna has a better performance and allows putting the module inside a metal case – as long as the antenna is outside.

One of the most important parts of getting the SIM800L module working is supplying it with the required power.

Depending on which state it's in, the SIM800L module can be a relatively power-hungry device. The maximum current draw by the module is around 200mA during transmission burst. It usually won't pull that much, but it may require around 216mA during phone calls or 80mA during network transmissions. This chart from the datasheet summarizes what we may expect:

Table 3.1 Power Consumption for different processes of the SIM800L

Current consumption of SIM800L module at different states		
	Frequency	**Current Consumption**
Power down		60 Ua
Sleep mode		1 Ma
Stand by		18 Ma
Call	GSM850	199 Ma
	EGSM900	216 Ma
	DCS1800	146 mA
	PCS1900	131 mA
GPRS		453 Ma
Transmission burst		200mA

Since SIM800L module doesn't come with onboard voltage regulator, an external power supply adjusted to voltage between 3.4V to 4.4V (Ideal 4.1V) is required. The power supply should also be able to source 2A of surge current. otherwise the module will keep shutting down. Here are some options you can consider to correctly power your GSM module.

3.4.9 Selection of zener diode for zener diode regulator

A Semiconductor Diode blocks current in the reverse direction, but will suffer from premature breakdown or damage if the reverse voltage applied across becomes too high. However, the Zener Diode or "Breakdown Diode", as they are sometimes referred too, are basically the same as the standard PN junction diode but they are specially designed to have a low and specified Reverse Breakdown Voltage which takes advantage of any reverse voltage applied to it.

The Zener diode behaves just like a normal general-purpose diode consisting of a silicon PN junction and when biased in the forward direction, that is Anode positive with respect to its Cathode, it behaves just like a normal signal diode passing the rated current.

However, unlike a conventional diode that blocks any flow of current through itself when reverse biased, that is the Cathode becomes more positive than the Anode, as soon as the reverse voltage reaches a pre-determined value, the zener diode begins to conduct in the reverse direction.

This is because when the reverse voltage applied across the zener diode exceeds the rated voltage of the device a process called *Avalanche Breakdown* occurs in the semiconductor depletion layer and a current starts to flow through the diode to limit this increase in voltage.

The current now flowing through the zener diode increases dramatically to the maximum circuit value (which is usually limited by a series resistor) and once achieved, this reverse saturation current remains fairly constant over a wide range of reverse voltages. The voltage point at which the voltage across the zener diode becomes stable is called the "zener voltage", (Vz) and for zener diodes this voltage can range from less than one volt to a few hundred volts.

The point at which the zener voltage triggers the current to flow through the diode can be very accurately controlled (to less than 1% tolerance) in the doping stage of the diodes semiconductor construction giving the diode a specific *zener breakdown voltage*, (Vz) for example, 4.3V or 7.5V. This zener breakdown voltage on the I-V curve is almost a vertical straight line.

The **Zener Diode** is used in its "reverse bias" or reverse breakdown mode, i.e. the diodes anode connects to the negative supply. From the I-V characteristics curve below, we can see that the zener diode has a region in its reverse bias characteristics of almost a constant negative voltage regardless of the value of the current flowing through the diode and remains nearly constant even with large changes in current as long as the zener diodes current remains between the breakdown current I_Z (min) and the maximum current rating I_Z (max).

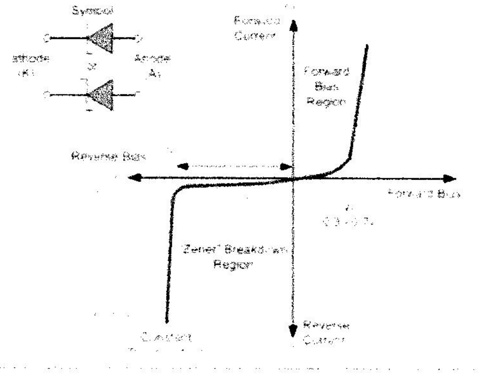

Fig 3.1.9 Zener Diode I-V Characteristics

This ability to control itself can be used to great effect to regulate or stabilize a voltage source against supply or load variations. The fact that the voltage across the diode in the breakdown region is almost constant turns out to be an important characteristic of the zener diode as it can be used in the simplest types of voltage regulator applications.

The function of a regulator is to provide a constant output voltage to a load connected in parallel with it in spite of the ripples in the supply voltage or the variation in the load current and the zener diode will continue to regulate the voltage until the diodes current falls below the minimum I_Z (min) value in the reverse breakdown region.

Zener Diodes can be used to produce a stabilized voltage output with low ripple under varying load current conditions. By passing a small current through the diode from a voltage source, via a suitable current limiting resistor (RS), the zener diode will conduct sufficient current to maintain a voltage drop of V_{out}.

We remember from the previous tutorials that the DC output voltage from the half or full-wave rectifiers contains ripple superimposed onto the DC voltage and that as the load value changes so does the average output voltage. By connecting a simple zener stabilizer circuit as shown in Fig 3.2.0 below across the output of the rectifier, a more stable output voltage can be produced.

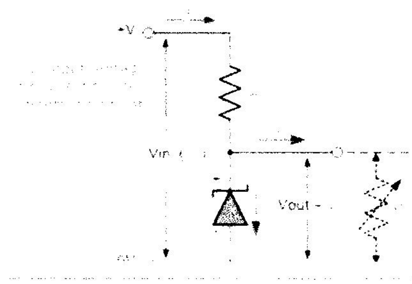

Fig 3.2.0 Zener Diode regulator

The resistor, RS is connected in series with the zener diode to limit the current flow through the diode with the voltage source, VS being connected across the combination. The stabilized output voltage Vout is taken from across the zener diode. The zener diode is connected with its cathode terminal connected to the positive rail of the DC supply so it is reverse biased and will be operating in its breakdown condition. Resistor RS is selected so to limit the maximum current flowing in the circuit.

With no load connected to the circuit, the load current will be zero, (IL = 0), and all the circuit current passes through the zener diode which in turn dissipates its maximum power. Also a small value of the series resistor RS will result in a greater diode current when the load resistance RL is connected and large as this will increase the power dissipation requirement of the diode so care must be taken when selecting the appropriate value of series resistance so that the zener's maximum power rating is not exceeded under this no-load or high-impedance condition.

The load is connected in parallel with the zener diode, so the voltage across RL is always the same as the zener voltage, (VR = VZ). There is a minimum zener current for which the stabilization of the voltage is effective and the zener current must stay above this value operating under load within its breakdown region at all times. The upper limit of current is of course dependent upon the power rating of the device. The supply voltage VS must be greater than VZ.

One small problem with zener diode stabilizer circuits is that the diode can sometimes generate electrical noise on top of the DC supply as it tries to stabilize the voltage. Normally this is not a problem for most applications but the addition of a large value decoupling capacitor across the zener's output may be required to give additional smoothing.

For the E-M-D, the zener diode regulator is applied in the following areas;

- Production of a stabilized 5V from the half-wave rectified voltage from the potential transformer

- Production of stabilized 4.7 volt (surge protection) for DC bulk supply to the SIM800l GSM module.

(4.7V Zener Diode - 1N4732A) **4.7 volt from 9V for surge protection of SIM800L buck converter**

a). The maximum current flowing through the zener diode

$$\text{Max. Current} = \frac{Watts}{Voltage} = \frac{1.3W}{4.7} = 270mA$$

b). the minimum value of the series resistor, RS

$$\frac{V_s - V_z}{I_z} = \frac{9-4.7}{193\text{mA}}$$

$$= \frac{4.3}{0.193} = 22.27\Omega$$

Thus from the above it could be seen a minimum value of 22 ohms is required for appropriate functioning.

The above is also applicable in the design of the 5V stabilized supply from the potential transformer.

3.4.10 The arduino nano micro-controller

The Arduino Nano is a compact, complete and bread-board friendly microcontroller board. The Nano board weighs around 7grams with dimensions of 4.5cms to 1.8cms (Length to Breath). This section discusses about the technical specs most importantly the pinout and functions of each and every pin in the Arduino Nano board.

Arduino Nano has similar functionalities as Arduino Duemilanove but with a different package. The Nano is inbuilt with the ATmega328P microcontroller, same as the Arduino UNO. The main difference between them is that the UNO board is presented in PDIP (Plastic Dual-In-line Package) form with 30 pins and Nano is available in PQFP (plastic quad flat pack) with 32 pins. The extra 2 pins of Arduino Nano serve for the ADC functionalities, while UNO has 6 ADC ports but Nano has 8 ADC ports.

The Nano board doesn't have a DC power jack as other Arduino boards, but instead has a mini-USB port. This port is used for both programming and serial monitoring. The fascinating feature in Nano is that it will choose the strongest power source with its potential difference, and the power source selecting jumper is invalid.

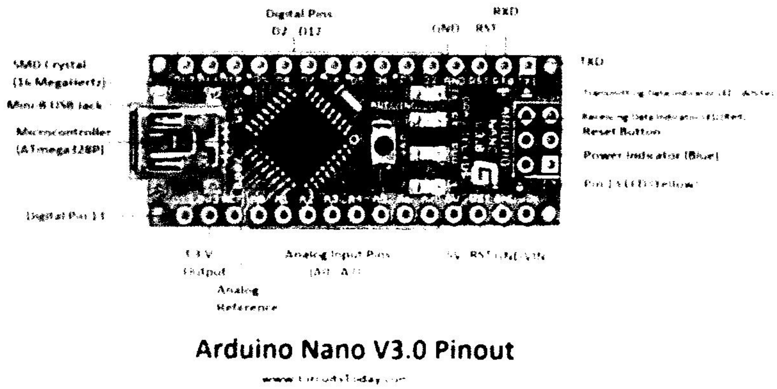

Fig 3.2.1 Arduino Nano Microcontroller

Table 3.2 Arduino Nano Microcontroller features

Arduino Nano	**Specifications**
Microcontroller	ATmega328P
Architecture	AVR
Operating Voltage	5 Volts
Flash Memory	32 KB of which 2 KB used by Bootloader
SRAM	2KB
Clock Speed	16 MHz
Analog I/O Pins	8
EEPROM	1 KB
DC Current per I/O Pins	40 milliAmps
Input Voltage	(7-12) Volts

3.4.11 The liquid crystal display (lcd)

A liquid-crystal display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals. Liquid crystals do not emit light directly.

LCDs are used in a wide range of applications including computer monitors, televisions, instrument panels, aircraft cockpit displays, and signage. They are common in consumer devices such as DVD players, gaming devices, clocks, watches, calculators, and telephones, and have replaced cathode ray tube (CRT) displays in most applications. They are available in a wider range of screen sizes than CRT and plasma displays, and since they do not use phosphors, they do not suffer image burn-in. LCDs are, however, susceptible to image persistence.

Fig 3.2.2 the 16*4 LCD screen

3.5 Circuit analysis

The AC Source from the main is fed into the transformer TR1 which steps it down to 12V which is further reduced to about 6V via the voltage divider network R1 and R4. This resulting voltage is then fed to the diode D3 for a half wave rectification, after which it is regulated to 5V via the zener diode rectification circuit. The rectified voltage is then sent to an analog input of the microcontroller for ADC measurement as illustrated below:

Given that 5V represent an analog value of 1023 when input voltage is 240VAC, then 1023 corresponds to 220V and any value of voltage in between can be via: $Ac\,volts = \frac{240}{1023} \times n\ Volts$

The current consumed by the load is measured via the ACS712 sensor which is connected in series to it and the resulting proportional Hall Effect Dc voltage is also sent to the analog input of the arduino microcontroller.

3.5.1 Circuit diagram

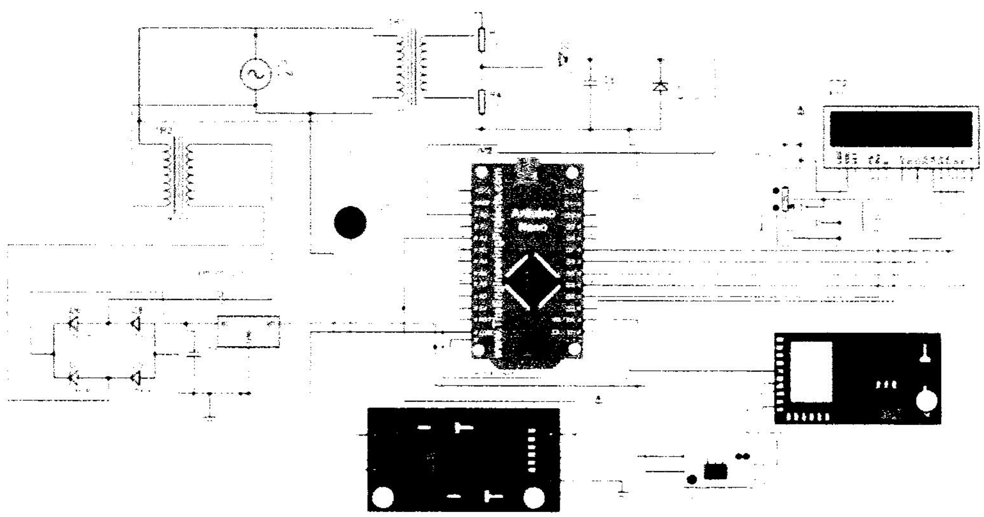

Fig 3.2.3 Circuit Diagram of E-M-D

3.5.2 The hardware

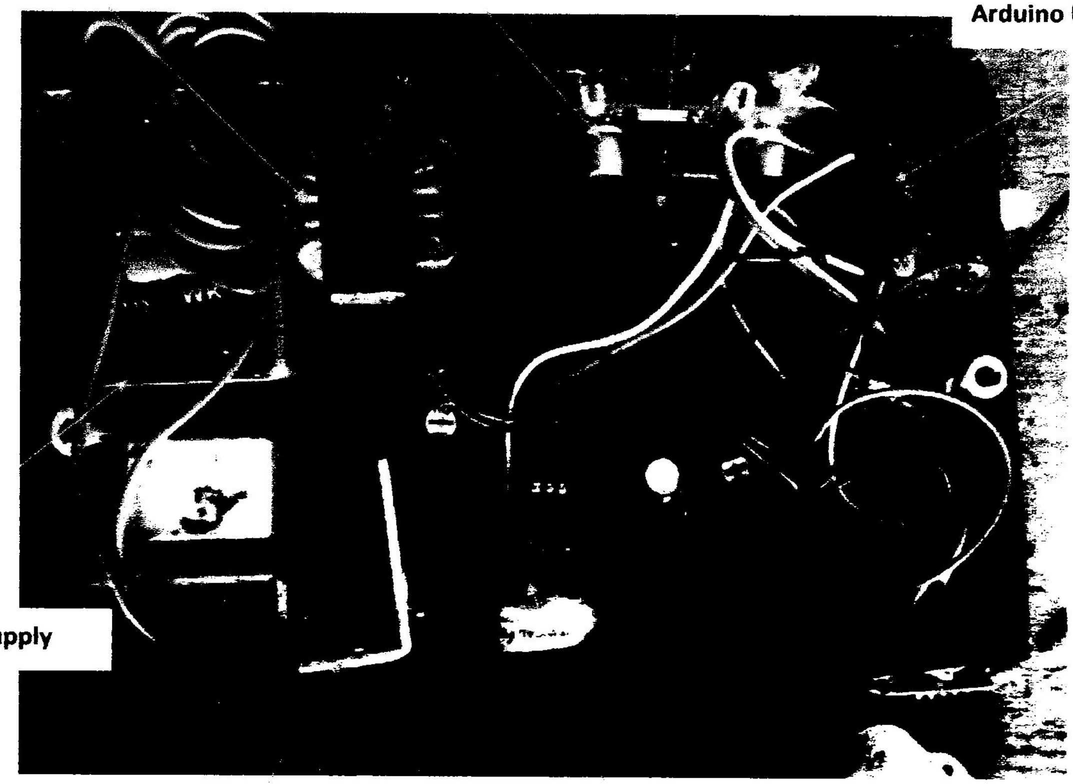

Fig 3.2.4 the hardware at a glance

3.6 Software design

The E-M-D software is comprised of two sections; software controlling the embedded Arduino microcontroller and the PC serial terminal software for real-time monitoring via the user PC.

The Arduino Nano microcontroller which features an ATmega 328P processor is programmed via the arduino integrated development environment ; an open source IDE written majorly in java and processing for writing microcontroller codes often referred to as sketches.

The pc serial terminal interface was developed using the visual basic 6 software and basic polls interfaces the arduino microcontroller to the pc via an integrated USB to serial port converter.

Fig 3.2.5 software programming interface

CHAPTER FOUR

TESTING, ANALYSIS OF RESULT AND DISCUSSION

4.0 Testing of the energy monitoring device

The Energy monitoring device (E-M-D) was tested for efficiency and conformance to the following objectives:

- Ability to measure the current of a connected appliance in real time and display the data on the LCD screen
- Measure the voltage from the AC source
- Calculate the power and energy consumption
- Display energy consumption on the LCD screen
- Send the measured and calculated energy parameters to a target phone number on query via the SIM800L GSM module.

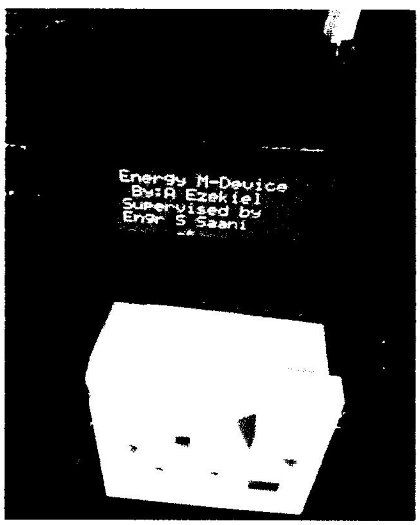

Fig 4.0 Assembled Energy Monitoring Device (E=M-D)

4.1 Current measurement testing

The E-M-D device was designed to measure both the startup current and real time current consumption of a connected appliance. To measure the startup current, the following steps are recommended:

- Ensure the E-M-D device is powered off and connect it to an AC power supply

- Without switching on the device, connected the desired appliance to be measured and switch on the E-M-D output without switching on the AC source. This is to ensure that powered is supplied to the target appliance immediately the E-M-D is switched on
- Switch on the E-M-D and allow the device to obtain the startup current and other energy parameters.

When the aforementioned steps where followed, the following results were obtained

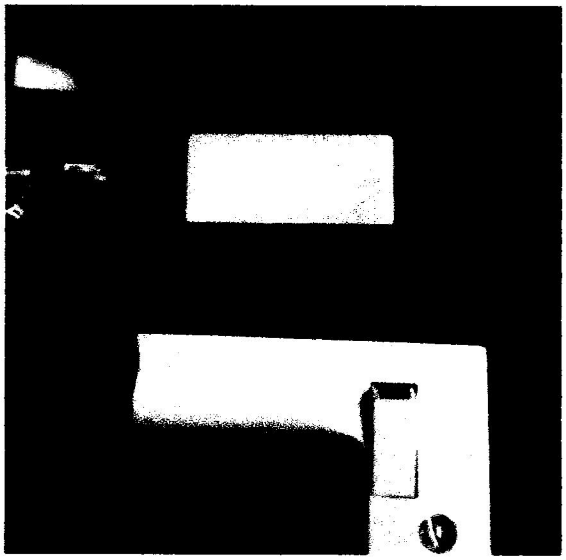

Fig 4.1 Startup Current Measurement Device (E=M-D)

The real time current reading of the appliance can be measured once the device is running and readings have stabilized.

4.1.1 Energy consumption measurement of the E-M-D

To measure the source voltage, connect the E-M-D device to an AC source and allow it to stabilize, then read off the voltage displayed on the LCD screen. The energy readings are obtained from the current and voltage readings and calculated by the microcontroller. The resulting values are displayed on the integrated LCD screen as seen below.

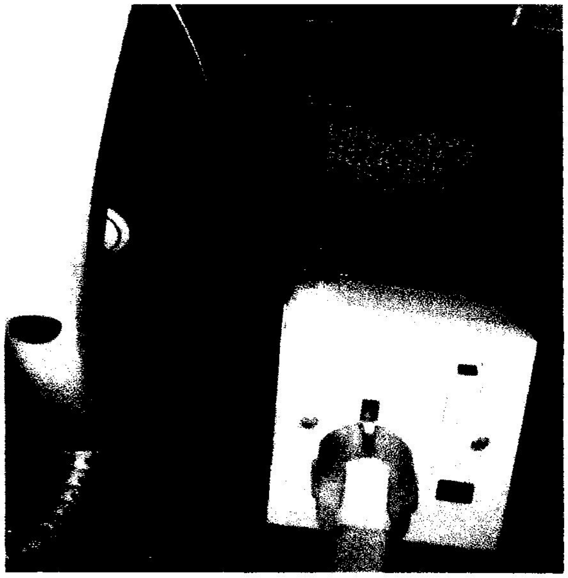

Fig 4.2 E-M-D current measurement

4.1.2 Remote access via sim800l

The energy parameters of a connected appliance can be accessed remotely by sending the preprogram SMS keyword "**FUOYE**" to the phone number of an inserted SIM card.

This however should be done after the GSM module indicates successful connection to the appropriate network via a steady LED blink at every 3 seconds. A continuous blinking of the connection status LED at every 800ms indicates the device is currently searching for network. This could be due to the following reasons:

- Poor network reception
- SIM card not properly inserted

The desired SIM card should also be preloaded with sufficient SMS credit unit or subscribed to an unlimited data plan to ensure delivery of sent data to the target user by the device

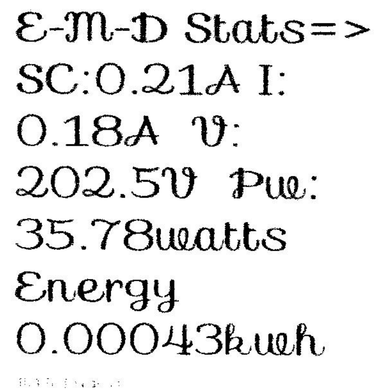

Fig 4.3 Energy Status Report of the E-M-D for a connected appliance

4.2 Performance evaluation and analysis

The energy Parameters of several appliances were obtained via the Energy Monitoring device and compared to the manufacturer rating of each appliances as shown in table 4.0 below

Table 4.0 Household Electrical appliances testing

S/N	Electrical appliances	Manufacturer rating			Measured values			
		Power (W)	Current (A)	Voltage (V)	Power (W)	Current (A)	Standby mode current (A)	Voltage (V)
1	IRON	1100W	-	240V	828.33W	4.06A	-	204.1V
2	MOBILE PHONE	-	0.20A	100-240V	111.00W	0.50A	-	222V
3	STANDING FAN	65W	-	230V	50.07W	0.24A	-	204.6V
4	BLENDER	350W	-	230V	337.9W	1.55A	-	218V
5	LAPTOP	336W	-	100-240V	124.64W	0.76A	-	164.0V
6	LONTOR LAMP	10W	-	110-230V	24.65W	0.15A	-	164.3V
7	CHEST FREEZER	1300W	-	220V	1141.09W	5.62A	0.31A	204.3V

8	TV	56W	–	100-240V	74.05W	0.36A	0.08A	206.1V
9	RADIO	21.5W	–	220V	28.47W	0.14A	-	205.9V
10	PORTABLE SPEAKER	60W	–	110-220V	26.39W	0.13A	0.06A	205.6V
11	DVD PLAYER	25W	–	100-240V	20.65W	0.10A	–	205.1V
12	DSTV DECODER	66W	–	100-240V	28.47W	0.14A	–	205.9V
13	CLIPPER	10W	–	220-240V	35.78W	0.18A	–	202.5V

Looking critically into the table 4.0. we can notice some discrepancies between the measured values and the manufacturer's rating. this is because the voltage supply to homes from the national grid is not always 220v. In addition. due to ageing of appliances the manufacturer ratings and the measure values might not be equal.

4.3 Schedule/project management

Table 4.1 Schedule/project management

Week 1	05/03/2018	11/03/2018	Block diagram
Week 2	12/03/2018	18/03/2018	Proteus simulation
Week 3	19/03/2018	25/03/2018	Order for components
Week 4	26/03/2018	01/04/2018	Waiting for components
Week 5	02/04/2018	08/04/2018	Waiting for components
Week 6	09/04/2018	15/04/2018	Components arrival
Week 7	16/04/2018	22/04/2018	Assembling of components
Week 8	23/04/2018	29/04/2018	Assembling of components
Week 9	30/04/2018	06/05/2018	System programming
Week 10	07/05/2018	13/05/2018	System programming
Week 11	14/05/2018	20/05/2018	System programming
Week 12	21/05/2018	27/05/2018	Running the program
Week 13	28/05/2018	03/06/2018	System coupling
Week 14	04/06/2018	10/06/2018	System coupling
Week 15	11/06/2018	17/06/2018	System coupling
Week 16	18/06/2018	24/06/2018	Testing and verification
Week 17	25/06/2018	01/07/2018	Testing and verification
Week 18	02/07/2018	08/07/2018	Typing progress report
Week 19	09/07/2018	15/07/2018	Typing progress report
Week 20	16/07/2018	22/07/2018	Submitting project design and report.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.0 CONCLUSION

The GSM based Energy Monitoring device (E-M-D) consist basically the Arduino Uno microcontroller, the LCD screen, the ACS712 current sensor (20A), the potential transformer, the SIM 800L GSM unit and DC bulk to bulk converter and other passive electronic components.

The E-M-D which was designed to measure the current, voltage and other energy parameters of a connected appliance in real time was tested and found to meet the target design objective. The measured parameters include, the source voltage (volts, V), the current consumption of the connected appliance or device (ampere, I) and the generated parameters include the power (watts, P) and the energy consumption (joules, E) in KWH.

5.1 RECOMMENDATION

For future work, the following improvements can be considered; the integration of a suitable zero crossing detector in the device to ensure a more accurate measurement of the power factor; which though remains unity (1) for resistive loads, differs slightly for reactive load (less than 1) . This is to further improve the overall accuracy of the device when measuring the energy parameters of reactive loads.

In addition, an SD card can be integrated into the system to allow for data logging over a long period of time, this will consequently make it possible to generate and visualize the energy profile or trend of an appliance via charts and other provisions present in software such as Microsoft Excel, Meguno-link, serial plotter and other specialized software.

Also in addition to the existing serial terminal software created to access the generated energy parameters via the USB to serial converter features of the arduino microcontroller, a wireless module such as the ESP8266 Wi-Fi module can be integrated to the E-M-D system and connected to a pc via a suitable web-api to enable real time visualization and logging of energy parameters.

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APPENDIX

Appendix 1: Cost analysis of component

Name	Unit price(naira)	Quantity	Total(naira)
12v Potential Transformer	1000.00	1	1000.00
1604 LCD Screen	3500.00	1	3500.00
LM 2856 DC-DC Regulator	2000.00	1	2000.00
Arduino Uno unit	5000.00	1	5000.00
SIM 800L GSM Module	5200.00	1	5200.00
ACS712 current Sensor	5000.00	1	5000.00
Heat Sink for 9V Voltage Regulator	50.00	1	50.00
19V DC Power Supply	1500	1	1500.00
Variable resistor	50.00	2	100.00
1N4733A Zener diode	70.00	1	70.00
13A socket	200.00	1	200.00
3×3 patress	70.00	1	70.00
Cable connector	50.00	1	50.00
1n4148 Diode	50.00	5	250.00
10kΩ Resistor	10.00	2	20.00
Sim card	100.00	1	100.00
1nF Capacitor	20.00	2	40.00
Casing	800.00	1	800.00
TOTAL(naira)			**#24,950.00**

Appendix 2

Appendix 2: Program codes

frmMain - 1

```
Option Explicit
' program logic control
Private bLocalEcho As Boolean
Private bMessageMode As Boolean
' constants for setting the LED images,
' used as an index for imgLED()
Private Const RedOff As Long = 0
Private Const RedOn As Long = 1
Private Const GreenOff As Long = 2
Private Const GreenOn As Long = 3
' the sendmessage API is used to write
' to the textbox to reduce flicker, this
' not required for serial communications.
' Win32 API constants
Private Const EM_GETSEL As Long = &HB0
Private Const EM_SETSEL As Long = &HB1
Private Const EM_GETLINECOUNT As Long = &HBA
Private Const EM_LINEINDEX As Long = &HBB
Private Const EM_LINELENGTH As Long = &HC1
Private Const EM_LINEFROMCHAR As Long = &HC9
Private Const EM_SCROLLCARET As Long = &HB7
Private Const WM_SETREDRAW As Long = &HB
Private Const WM_GETTEXTLENGTH As Long = &HE
' Win32 API declarations
Private Declare Function SendMessage Lib "user32" Alias "SendMessageA" _
(ByVal hwnd As Long, ByVal wMsg As Long, ByVal wParam As Long, lParam As Long) As Long
Private Sub Form_Load()
' just in case the default port won't open
On Local Error Resume Next
```

```
' disply the startup message in the terminal window
'txtTerminal.Text = "Reveived data will be displayed here." & vbCrLf & _
' "Keys will be transmitted as you press them." & vbCrLf & _
'"If you are connected to a modem it should echo" & vbCrLf & _
'"each key press." & vbCrLf & vbCrLf & _
' "To change the comm settings use the OPTIONS|SETTINGS menu." & vbCrLf
' move the cursor to the end of text
txtTerminal.SelStart = Len(txtTerminal)
' set the startup color for the Rx & Tx LED's
Set imgRx.Picture = imgLed(GreenOff).Picture
Set imgTx.Picture = imgLed(GreenOff).Picture
Me.Show
Me.Refresh
' setup the default comm port settings
MSComm1.CommPort = 1 ' comm port 1
MSComm1.RThreshold = 1 ' use 'on comm' event processing
MSComm1.Settings = "9600,n,8,1" ' baud, parity, data bits, stop bits
MSComm1.SThreshold = 1 ' allows us to track Tx LED
MSComm1.InputMode = comInputModeBinary ' binary mode, you can also use
' comInputModeText for text only use
' open the port
MSComm1.PortOpen = True
' display status
ShowInfo
'mnuMode_Click (0)
'mnuMode_Click (3)
picinstruct.Print ("ENERGY MONITORING DEVICE" & vbCrLf & _
"NAME: EZEKIEL " & vbCrLf & _
"SUPERVISOR: ENGR SANNI SHEREEFDEEN" & vbCrLf &

frmMain - 2
"*****************************************" & vbCrLf & _
"Check for Connected Port Number of the Device in Device Manager" & vbCrLf & _
"Click on Options Menu and Comm Settings " & vbCrLf & _
```

```
"Select The desired Port Number and Click on Ok" & vbCrLf)
End Sub
Private Sub Form_Resize()
' resize the display controls to match the form
picInfo.Move 0, Abs((Me.Height - 1135) / 1.5), Abs(Width - 120), 315
txtTerminal.Move 0, 0, Abs(Width - 120), picInfo.Top
imgfuoye.Left = picinstruct.Width - imgfuoye.Width
End Sub
Private Sub imgDTR_Click()
' DTR & RTS are output lines on the comm control
' clicking the DTR LED will toggle the DTR line
MSComm1.DTREnable = MSComm1.DTREnable Xor &HFFFF
SetLEDs
End Sub
Private Sub imgRTS_Click()
' DTR & RTS are output lines on the comm control
' clicking the RTS LED will toggle the RTS line
MSComm1.RTSEnable = MSComm1.RTSEnable Xor &HFFFF
SetLEDs
End Sub
Private Sub lblText_Click()
End Sub
Private Sub mnuClear_Click()
' clear the terminal window
txtTerminal.Text = ""
End Sub
Private Sub mnuLocalEcho_Click()
' toggle local echo, if true, keypress's
' will be written to the terminal window
mnuLocalEcho.Checked = mnuLocalEcho.Checked Xor &HFFFF
If mnuLocalEcho.Checked Then
bLocalEcho = True
Else
```

```
bLocalEcho = False
End If
End Sub
Private Sub mnuLoopBack_Click()
' toggle on/off a timer that will send characters out the comm port for
' a simple loop back test. Connect pins 2 & 3 together to see the data
mnuLoopBack.Checked = mnuLoopBack.Checked Xor &HFFFF
If mnuLoopBack.Checked Then
tmrLoopBack.Enabled = True
Else
tmrLoopBack.Enabled = False
```



```
End If
End Sub
Private Sub mnuSettings_Click()
Dim bLoaded As Boolean
Dim frm As Form
' open the comm settings form
frmSettings.CommSettings Me.MSComm1, "Communications Port Settings"
' wait for the settings form to unload
' modal is not used so multi port apps can
' continue while the settings form is visible.
' this is only required because we want to
' capture the new settings & display them.
Do
bLoaded = False
For Each frm In Forms
If frm.Name = "frmSettings" Then bLoaded = True
Next
DoEvents
Loop While bLoaded
' display the new settings
```

```
ShowInfo
End Sub
Private Sub MSComm1_OnComm()
'*****************************************************************************
' Synopsis: Handle incoming characters, 'On Comm' Event
'
' Description: By setting MSComm1.RThreshold = 1, this event will fire for
' each character that arrives in the comm controls input buffer.
' Set MSComm1.RThreshold = 0 if you want to poll the control
' yourself, either via a TImer or within program execution loop.
'
' In most cases, OnComm Event processing shown here is the prefered
' method of processing incoming characters.
'
'*****************************************************************************
Static sBuff As String ' buffer for holding incoming characters
Const MTC As String = vbCrLf ' message terminator characters (ususally vbCrLf)
Const LenMTC As Long = 2 ' number of terminator characters, must match MTC
Dim iPtr As Long ' pointer to terminatior character
' OnComm fires for multiple Events
' so get the Event ID & process
Select Case MSComm1.CommEvent
' Received RThreshold # of chars, in our case 1.
Case comEvReceive
' read all of the characters from the input buffer
' StrConv() is required when using MSComm in binary mode,
' if you set MSComm1.InputMode = comInputModeText, it's not required
sBuff = sBuff & StrConv(MSComm1.Input, vbUnicode)
' a typical application would buffer characters here waiting for
' an end of message sequence like vbCrLf, that's why sBuff is declared
' as Static and the statement above sets sBuff = sBuff & MSComm1.Input
' When an end of message string is received the messages are passed
' through a parser routine. Here, we show processing a character at
```

```
' time and 'message parsing' options. MEssage parsing varies depending
frmMain - 4
' on what you're doing but would look something like this:
If bMessageMode Then
' in message mode we wait for the message terminator
' before processing. This is typcal of a command & control
' program that interfaces with an external device and
' must decode data coming from the device. Most devices will
' use a start / end sequennce to ID each message. You
' would process the messages by calling your message parser and
' passing the message just like the message is passed to the
' PosTerminal routine below. Some device's use character count
' to ID messages instead of start/end characters. this method is
' too machine specific to be shown here.
' look for message terminator
iPtr = InStr(sBuff, MTC)
' process all queued messages
Do While iPtr
' pass each message to the message parser
' in our case, it just gets displayed. To decode
' specific messages, you would pass the string
' Mid$(sBuff, 1, iPtr + LenMTC - 1)
' to a message decoder routime
PostTerminal Mid$(sBuff, 1, iPtr + LenMTC - 1)
' remove from the message queue
sBuff = Mid$(sBuff, iPtr + LenMTC)
' look for another message
iPtr = InStr(sBuff, MTC)
Loop
Else
' in character mode we just pass each character to
' the parser as it comes in. The parser is responsibe
' for collecting the characters and assembling any messages.
```

```
' For our simple terminal example, character mode works fine.
PostTerminal sBuff
sBuff = vbNullString
End If
' flash the Rx LED
Set imgRx.Picture = imgLed(GreenOn).Picture
tmrRxLED.Enabled = True
' Change in the CD line.
Case comEvCD
SetLEDs
' Change in the CTS line.
Case comEvCTS
SetLEDs
' Change in the DSR line.
Case comEvDSR
SetLEDs
' Change in the Ring Indicator.
Case comEvRing
' An EOF charater was found in the input stream
Case comEvEOF
' There are SThreshold number of characters in the transmit buffer.
Case comEvSend
Set imgTx.Picture = imgLed(GreenOn).Picture
tmrTxLED.Enabled = True
' A Break was received.
Case comEventBreak
lblError = "Break"
tmrClearError.Enabled = True
frmMain - 5
' Framing Error
Case comEventFrame
lblError = "Framing"
tmrClearError.Enabled = True
```

```
' Data Lost.
Case comEventOverrun
lblError = "Overrun"
tmrClearError.Enabled = True
' Receive buffer overflow.
Case comEventRxOver
lblError = "Overflow"
tmrClearError.Enabled = True
' Parity Error.
Case comEventRxParity
lblError = "Parity"
tmrClearError.Enabled = True
' Transmit buffer full.
Case comEventTxFull
lblError = "Tx Full"
tmrClearError.Enabled = True
' Unexpected error retrieving DCB]
Case comEventDCB
lblError = "DCB Error"
tmrClearError.Enabled = True
End Select
End Sub
Public Sub PostTerminal(ByVal sNewData As String)
' display incoming characters in the
' textbox 'terminal' window. API is
' used only to reduce flicker.
Dim lPtr As Long
' this is faster and has less flicker but requires use of the Win API
With txtTerminal
lPtr = SendMessage(.hwnd, EM_GETLINECOUNT, 0, ByVal 0&)
If lPtr > 550 Then
'LockWindowUpdate .hWnd
Call SendMessage(.hwnd, WM_SETREDRAW, False, ByVal 0&)
```

```
lPtr = SendMessage(.hwnd, EM_LINEINDEX, 100, ByVal 0&)
.SelStart = 0
.SelLength = IIf(lPtr > 0, lPtr, 1000)
.SelText = vbNullString
Call SendMessage(.hwnd, WM_SETREDRAW, True, ByVal 0&)
' LockWindowUpdate 0
End If
.SelStart = SendMessage(.hwnd, WM_GETTEXTLENGTH, True, ByVal 0&)
.SelText = sNewData
.SelStart = SendMessage(.hwnd, WM_GETTEXTLENGTH, True, ByVal 0&)
End With
End Sub
Private Sub tmrClearError_Timer()
lblError = ""
tmrClearError.Enabled = False
End Sub
Private Sub tmrPolledMode_Timer()
' example of polled mode. This is an alternative to using
frmMain - 6
' the MSComm1 OnComm Event for receiving characters.
' collect characters here when the Timer fires. See
' the comments in MSComm1 OnComm Event for information
' on more complex processing. message mode has not been
' implimented here, see MSComm1 OnComm Event for example
' of message mode operation.
If MSComm1.InBufferCount Then
PostTerminal StrConv(MSComm1.Input, vbUnicode)
Set imgRx.Picture = imgLed(GreenOn).Picture
tmrRxLED.Enabled = True
End If
End Sub
Private Sub tmrRxLED_Timer()
Set imgRx.Picture = imgLed(GreenOff).Picture
```

```
tmrRxLED.Enabled = False
End Sub
Private Sub tmrTxLED_Timer()
Set imgTx.Picture = imgLed(GreenOff).Picture
tmrTxLED.Enabled = False
End Sub
Private Sub tmrLoopBack_Timer()
' use this timer to send some characters out so we can test our receive code...
' this is only here for the loop back demo, it is not required for communications
If MSComm1.PortOpen Then
MSComm1.Output = Me.Caption & Format$(Timer. " ###.##0.000") & vbCrLf
End If
End Sub
Private Sub txtTerminal_KeyPress(KeyAscii As Integer)
' send keys out the comm port. convert vbCr to vbCrLf
Select Case KeyAscii
Case 13
If MSComm1.PortOpen Then MSComm1.Output = vbCrLf
Case Else
If MSComm1.PortOpen Then MSComm1.Output = Chr$(KeyAscii)
End Select
If Not bLocalEcho Then KeyAscii = 0
End Sub
Private Sub ShowInfo()
' display status info
lblSettings = UCase$(MSComm1.Settings)
lblPort = "Port " & MSComm1.CommPort
lblOpen = IIf(MSComm1.PortOpen, "Open", "Closed")
lblError = ""
SetLEDs
End Sub
Private Sub SetLEDs()
' set the status LED's
```

```
Set imgCD.Picture = IIf(MSComm1.CDHolding, imgLed(RedOn).Picture, imgLed(RedOff).Picture)
Set imgCTS.Picture = IIf(MSComm1.CTSHolding, imgLed(RedOn).Picture, imgLed(RedOff).Picture)
Set imgDSR.Picture = IIf(MSComm1.DSRHolding, imgLed(RedOn).Picture, imgLed(RedOff).Picture)
Set imgRTS.Picture = IIf(MSComm1.RTSEnable, imgLed(RedOn).Picture, imgLed(RedOff).Picture)
frmMain - 7
Set imgDTR.Picture = IIf(MSComm1.DTREnable, imgLed(RedOn).Picture, imgLed(RedOff).Picture)
End Sub
frmSettings - 1
Option Explicit
'*****************************************************************************
' Synopsis: Form to change communications settings
'
' Usage: main program calls the 'CommSettings' sub on this form, passing
' the name of the communications control and an optional title.
'
' Description:
' Scans machine for all available comm hardware and then allows user
' to select the communications settings. Re-open port when finished
'
'*****************************************************************************
Dim CommCntrl As Control ' the communications control
Dim PORT As Variant ' Comm port number
Dim Baud As Variant ' baud rate
Dim StopBits As Variant ' stop bits
Dim Parity As Variant ' parity
Dim DataBits As Variant ' data bits
Dim Handshake As Variant ' handshaking
Dim bNoComm As Boolean
Private Const MAX_COMM = 32 ' max port # to check
' Win32 API
' we're using the API to scan for available harware.
' you could use the passed comm control but this is
' much faster and less prone to errors
```

```
Private Const GENERIC_READ = &H80000000
Private Const GENERIC_WRITE = &H40000000
Private Const OPEN_EXISTING = 3
Private Const FILE_FLAG_OVERLAPPED = &H40000000
Private Const INVALID_HANDLE_VALUE = -1
Private Declare Function CreateFile Lib "kernel32" Alias "CreateFileA" _
(ByVal lpFileName As String, ByVal dwDesiredAccess As Long, _
ByVal dwShareMode As Long, ByVal lpSecurityAttributes As String, _
ByVal dwCreationDisposition As Long, ByVal dwFlagsAndAttributes As Long, _
ByVal hTemplateFile As String) As Long
Private Declare Function CloseHandle Lib "kernel32" (ByVal hObject As Long) As Long
Private Declare Function SetWindowPos Lib "user32" _
(ByVal hwnd As Long, ByVal hWndInsertAfter As Long, ByVal X As Long, _
ByVal Y As Long, ByVal cx As Long, ByVal cy As Long, ByVal wFlags As Long) As Long
Public Sub CommSettings(cntrl As Control, Optional msg As String = "Communications Settings")
'*****************************************************************************
' Synopsis: Entry point for the Form
'
' Usage: main program calls here, passing the name of the communications
' control and an optional title. The controls settings are modified
' per the users input.
'
'*****************************************************************************
Dim iCntr As Integer ' loop counter
Dim sSettings() As String ' comm settings array
Dim hRet As Long ' api return value
Dim sCom As String ' comm port name
On Local Error Resume Next
' was a control passed...
If cntrl Is Nothing Then
MsgBox "No serial communications control specified.", vbOKOnly + vbCritical, Me.Name
Unload Me
Exit Sub
```

```
End If
frmSettings - 2
Set CommCntrl = cntrl
Err = 0
' close the port if it's open
If CommCntrl.PortOpen = True Then
CommCntrl.PortOpen = False
DoEvents
Else
bNoComm = True
End If
' simple check for comm control
If Err = 438 Then
MsgBox "Passed control is not a serial communications control.", vbOKOnly + vbCritical, Me.Name
Err = 0
Unload Me
Exit Sub
End If
OnTop Me. True
Screen.MousePointer = vbHourglass
cboPort.AddItem "<none>"
' scan for all possible hardware so we can
' display all available ports in the combo box
' this dynamically adjusts for PC's with addin cards
For iCntr = 1 To MAX_COMM
' try to open the port
' \\.\ required for ports > 9, works for all ports
sCom = "\\.\Com" & CStr(iCntr) & vbNullChar
hRet = CreateFile(sCom, GENERIC_READ Or GENERIC_WRITE, 0, vbNullString,
OPEN_EXISTING, FILE_FL
AG_OVERLAPPED, vbNullString)
If hRet <> INVALID_HANDLE_VALUE Then
hRet = CloseHandle(hRet)
```

```
cboPort.AddItem Str(iCntr)
Else
' dll error 5 = already open
' dll error 2 = no harware
If Err.LastDllError = 5 Then
cboPort.AddItem Str(iCntr) & " - Not Available"
End If
End If
Next
' get all of the current settings
If bNoComm Then PORT = 0 Else PORT = CommCntrl.CommPort
sSettings = Split(CommCntrl.Settings, ",")
Baud = sSettings(0)
Parity = sSettings(1)
DataBits = sSettings(2)
StopBits = sSettings(3)
Handshake = CommCntrl.Handshaking
' populate the form with the current settings....
' port number
For iCntr = 0 To cboPort.ListCount - 1
cboPort.ListIndex = iCntr
If PORT = Trim$(cboPort) Then Exit For
cboPort.ListIndex = 0
Next
' baud rate
For iCntr = 0 To cboBaud.ListCount - 1
cboBaud.ListIndex = iCntr
If cboBaud.Text = Baud Then Exit For
Next
' parity
Select Case UCase$(Parity)
Case "E": optParity(0).Value = True
frmSettings - 3
```

```
Case "O": optParity(1).Value = True
Case "N": optParity(2).Value = True
End Select
' data bits
Select Case DataBits
Case 7: optDataBits(0).Value = True
Case 8: optDataBits(1).Value = True
End Select
' stop bits
Select Case StopBits
Case 1: optStopBits(0).Value = True
Case 2: optStopBits(1).Value = True
End Select
' handshaking
If Handshake >= 0 And Handshake <= 3 Then
optHandshake(Handshake).Value = True
End If
' clean up
Screen.MousePointer = vbNormal
' ready
With Me
.Caption = msg
.cmdAction(0).Enabled = True
.cmdAction(1).Enabled = True
End With
End Sub
Private Sub cmdAction_Click(Index As Integer)
Dim strCtrlName As String
On Local Error Resume Next
strCtrlName = CommCntrl.Name & Trim$(Str$(CommCntrl.Index))
Select Case Index
' OK pressed
Case 0
```

```
Do While CommCntrl.PortOpen = True
CommCntrl.PortOpen = False
DoEvents
Loop
' did user select 'none' or a port that is already in use?
If InStr(cboPort.Text, "none") Then
SaveSetting App.EXEName, strCtrlName, "Port", "0"
bNoComm = True
Unload Me
Exit Sub
ElseIf InStr(cboPort.Text, "not") Then
MsgBox "Port" & Mid$(cboPort.Text, 1, 2) & " is already open by another process. Pleas
e select a different Comm port.", vbOKOnly, Me.Caption
Exit Sub
End If
' get all of the settings
If optDataBits(0).Value = True Then DataBits = 7 Else DataBits = 8
If optStopBits(0).Value = True Then StopBits = 1 Else DataBits = 2
If optParity(0).Value = True Then
Parity = "E"
ElseIf optParity(1).Value = True Then
Parity = "O"
Else
Parity = "N"
frmSettings - 4
End If
Baud = CVar(cboBaud.Text)
PORT = CVar(Trim$(cboPort.Text))
CommCntrl.CommPort = PORT
CommCntrl.Settings = Baud & "." & _
Parity & "." & _
Trim$(CStr(DataBits)) & "." & _
Trim$(CStr(StopBits))
```

```
CommCntrl.Handshaking = Handshake
' save settings for later
SaveSetting App.EXEName, strCtrlName, "Settings", CommCntrl.Settings
SaveSetting App.EXEName, strCtrlName, "Port", CommCntrl.CommPort
SaveSetting App.EXEName, strCtrlName, "Handshaking", CommCntrl.Handshaking
bNoComm = False
' Cancel pressed
Case 1
End Select
If Not bNoComm Then If CommCntrl.PortOpen = False Then CommCntrl.PortOpen = True
Unload Me
End Sub
Private Sub Form_Load()
With Me
.Caption = "Scanning available comm hardware..."
.cmdAction(0).Enabled = False
.cmdAction(1).Enabled = False
.Left = (Screen.Width - Width) / 2
.Top = (Screen.Height - Height) / 2
.Show
.Refresh
End With
' load the baud rate combo box
cboBaud.AddItem "600", 0
cboBaud.AddItem "1200", 1
cboBaud.AddItem "2400", 2
cboBaud.AddItem "4800", 3
cboBaud.AddItem "9600", 4
cboBaud.AddItem "19200", 5
cboBaud.AddItem "38400", 6
cboBaud.AddItem "57600", 7
cboBaud.AddItem "115200", 8
End Sub
```

```
Private Sub Form_Unload(Cancel As Integer)
Set CommCntrl = Nothing
End Sub
Private Sub optDataBits_Click(Index As Integer)
If optDataBits(1).Value = True Then
optStopBits(0).Value = True
optStopBits(1).Enabled = False
Else
optStopBits(1).Enabled = True
End If
End Sub
Private Sub optHandshake_Click(Index As Integer)
If optHandshake(Index).Value = True Then Handshake = Index
End Sub
frmSettings - 5
Private Sub OnTop(frm As Form, bAction As Boolean)
'****************************************************************************
'
' Synopsis: Force a form to float 'On Top' of other forms
'
' Parameters: frm - name of the form to modify
' bAction - set 'ontop' property to true/false
'
' Return: nothing
'
' Description:
'
' Using the SetWindowPos API, send a message to a form,
' setting the form's topmost property
'
'****************************************************************************
Const HWND_TOPMOST As Long = -1
Const HWND_NOTOPMOST As Long = -2
```

```
Const SWP_NOMOVE As Long = 2
Const SWP_NOSIZE As Long = 1
Const flags As Long = SWP_NOMOVE Or SWP_NOSIZE
If bAction Then
SetWindowPos frm.hwnd, HWND_TOPMOST, 0, 0, 0, 0, flags
Else
SetWindowPos frm.hwnd, HWND_NOTOPMOST, 0, 0, 0, 0, flags
End If
End Sub
```

Appendix 3

Appendix 3: Data sheet

The Voltages Available allow these Regulators to be used in Logic Systems, Instrumentation, Hi-Fi Audio Circuits and other Solid State Electronic Equipment

ABSOLUTE MAXIMUM RATINGS (T_a=25°C)

DESCRIPTION	SYMBOL	VALUE	UNIT
Input Voltage	V_{IN}	35	V
		40	
Power Dissipation	P_D	15	W
Operating Temperature	T_{amb}	- 20 to +80	°C
Storage Temperature Range	T_{stg}	- 55 to +150	°C

ELECTRICAL CHARACTERISTICS (T_a=25°C unless specified otherwise)

V_{IN}=18V, I_O=100mA, T_a=25°C

DESCRIPTION	SYMBOL	TEST CONDITION	MIN	TYP	MAX	UNIT
Output Voltage	V_O	I_O=5mA ~ 1.5A V_{IN}=12 ~ 24V, P_D 15W	8.65		9.35	V
Line Regulation	R_{EGV}	V_{IN}=11.5 ~ 26V			90	mV
Load Regulation	R_{EGL}	I_O=5mA ~ 1.5A			90	mV
Quiescent Current	I_Q				8.0	mA
Quiescent Current Change	I_Q	V_{IN}=11.5 ~ 26V			1.0	mA
		I_O=5mA ~ 1A			0.5	mA
Input Voltage	V_{IN}		11.5		26	V
Ripple Rejection Radio	R_R	V_{IN}=12 ~ 22V, f=120Hz	56			dB
Max Output Current	I_{OM}	T_J=25°C		2.2		A
Output Voltage Drift	$V/_T$	I_O=5mA , T_J=0 ~ 125°C		- 0.5		mV/°C
Output Noise Voltage	V_{NO}	f=10Hz ~ 100KHz		10		μV
Short Circuit Current Limit	I_{SC}	T_J=25°C		2.0		A