

**DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
UNIVERSITY OF VICTORIA, BC, CANADA**

Energy Monitoring, Analysis and Control with Internet of
Things (IoT) for Home Automation

By

Pavan Arora

A Report Submitted in Partial Fulfilment of the Requirements
for the Degree of MASTER OF ENGINEERING

@ Pavan Arora, 2014
University of Victoria

All rights reserved. This report may not be reproduced in whole or in part, by photocopy or
Other means, without the permission of the author.

Supervisory Committee

Dr. T. Aaron Gulliver, Supervisor

(Department of Electrical and Computer Engineering)

Dr. Hong-Chuan Yang, Departmental Member

(Department of Electrical and Computer Engineering)

Abstract

Energy saving and power optimization techniques are in demand. In this project, a prototype has been developed for smart home automation. This prototype features energy monitoring, analysis and control using Internet of Things (IoT) for home automation. The Internet of Things represents a network of objects which are capable of interacting with other objects over the internet. These objects can be anything that has a unique identifier and the capability of transferring data over the internet. The function of this prototype is to measure voltage, current and frequency and send this information to the server (a web address providing a GUI (Graphical User Interface) for this prototype). The server stores the data and uses data mining to generate information for energy monitoring, analysis and control from the data received. The prototype is designed to be placed in between the power supply and a device (to be observed for energy monitoring, control and analysis). The prototype has been implemented in conjunction with Epsilon Electronics Pvt. Ltd. (Ahmedabad, India).

Table of Contents

Supervisory Committee	ii
Abstract	iii
Table of Content	iv
List of Figures	v
List of Tables	v
Acknowledgements	vi
Dedication	vii
Abbreviations and Acronyms	viii
Chapter 1: Introduction	1
1.1 Problem Definition and Motivation	1
1.2 Internet of Things	2
1.3 Proposed Solution	3
1.4 Report Structure	4
Chapter 2: System Design and Implementation	5
2.1 Circuit Design	5
2.2 Integrated Module	11
2.3 Simulation Results	12
2.4 Implementation	15
Chapter 3: Summary and Future Work	18
Appendix	
A.1 Source Code for the PIC microcontroller	22
Bibliography	29

List of Figures

Figure 1: Energy use (kg of oil equivalent per capita) comparison	1
Figure 2: Voltage measurement module	5
Figure 3: Current measurement module	6
Figure 4: Frequency measurement module	7
Figure 5: PIC 18F4550 Microcontroller	8
Figure 6: The prototype (integrated module)	11
Figure 7: Simulation circuit	13
Figure 8: The LCD during simulation	13
Figure 9: The terminal during simulation	14
Figure 10: Implementation of the prototype	15
Figure 11: Block diagram of prototype interface	16
Figure 12: Working mechanism of a BP life saver	19

List of Tables

Table 1: Cellular and Wi-Fi cost analysis	9
Table 2: Cellular and Wi-Fi plan comparison between India and Canada	10

Acknowledgements

A kite cannot fly on roads, but with proper hands and direction it finds its home in the sky exploring the world. This is my story here in Canada. Giving me a hand, Dr. T. Aaron Gulliver, has given my life a proper direction. During my degree (at each and every step) being the hand to fly my kite, he has always supported my plans (from course work to internship, from senate participation to this project); he is a care taker and a guide for me. I consider it an absolute honour to be a student of such a personality who knows how to make you succeed in your plans. I want to express my sincere thanks to Dr. Gulliver for directing this project from an idea into reality and his diligent reading of this report is also appreciated. I would like to thank Dr. Hong-Chaun Yang for serving on my supervisory committee. I would also like to thank Dr. Mihai Sima for serving as chair of the oral examination committee.

This project was next to impossible without the support of Mr. Hardik Patel (CEO of Epsilon Electronics, Ahmedabad, India). I cannot thank him in words; hence I would like to thank him with this quotation, "Following your courage, I got the courage to think, act and do something unique".

My special gratitude goes to my family and friends for their unending love, support and believing in me all the time. There are many cherished memories during my graduate school journey for which I would like to say, Thank you UVic.

To Mom and Dad

Abbreviations and Acronyms

IoT- Internet of Things

3GPP- 3rd Generation Partnership Project

GUI – Graphical User Interface

GSM –Global System for Mobile Communication

RF – Radio Frequency

Wi-Fi – Wireless Fidelity

QoS – Quality of Service

M2M –Machine to Machine

BP – Blood Pressure

IC – Integrated Circuit

A/D – Analog to Digital

EUSART - Enhanced Universal Synchronous Asynchronous Receiver Transmitter

SPI- Serial Peripheral Interface

I²C - Inter-Integrated Circuit

USB – Universal Serial Bus

TTL - Transistor–Transistor Logic

op amp- Operational Amplifier

LCD – Liquid Crystal Display

Chapter 1: Introduction

1.1 Problem Definition and Motivation

Energy consumption is increasing day by day with increasing numbers of energy consuming machines. To address this issue, government agencies have initiated energy saving campaigns. Recently, the Alberta government approved a two million dollar grant for a municipal climate change action centre [1]. The corporate community is also contributing to this research. The British Columbia energy supplier (BC Hydro) has already taken steps to make our society an energy concerned community. BC Hydro runs programs like the energy saving kit (for qualified low income customers) and an energy conservation assistance program. To attract customers towards energy efficiency, BC Hydro provides incentives in the form of rebates and savings.

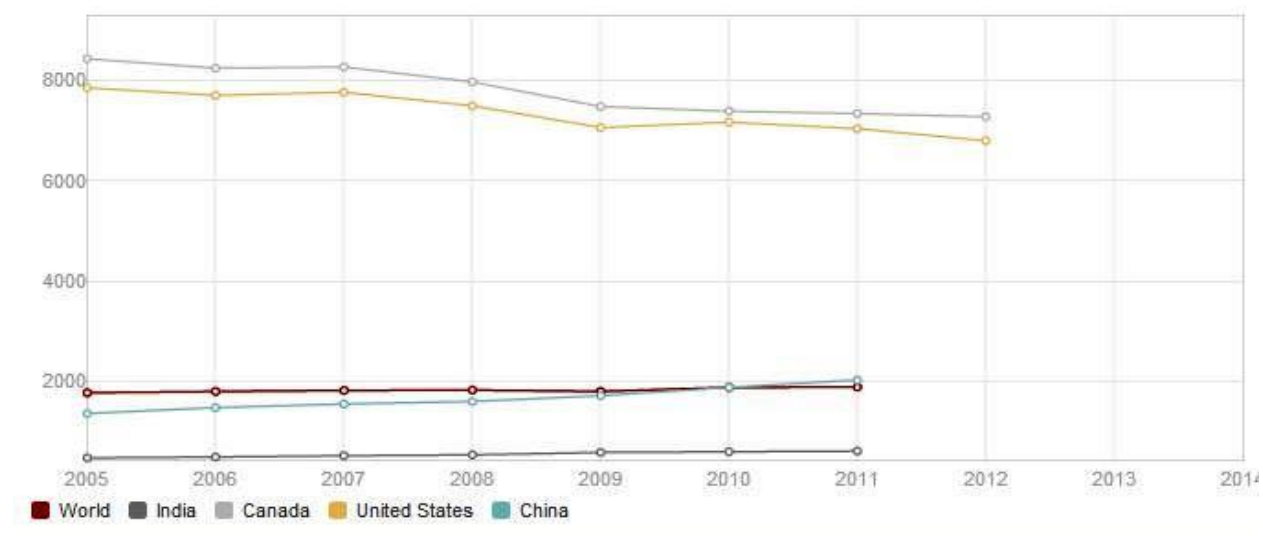


Figure 1: Energy use (kg of oil equivalent per capita) comparison over years [2]

Figure 1 shows the energy consumption of Canada, United States, India, China and the world average. As per Figure 1, Canada and the United States energy consumption is comparatively high with respect to the global average and much higher with respect to developing nations like India and China. To help reduce energy consumption this project considers using smart technology to save energy as the transition is made towards smart homes. With the goal of saving energy and making a consumer realize 'where' and 'how much' energy is used, a consumer controlled device is developed.

1.2 Internet of Things

Energy saving is achieved by monitoring electrical parameters like voltage, current and frequency and controlling energy usage via an analysis of the data. In order to do this efficiently the concept Internet of Things (IoT) is used.

The Internet of Things is a novel paradigm that is rapidly gaining ground in modern wireless telecommunications. The basic idea of this concept is the pervasive presence of a variety of things or objects such as Radio-Frequency IDentification (RFID) tags, sensors, actuators, mobile phones, etc., which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbours to reach common goals [3].

This paradigm finds application in many different domains, such as home automation, industrial automation, medical aids, mobile health care, elderly assistance, intelligent energy management and smart grids, automotive and traffic management [4]. Cisco estimates that 50 billion devices and objects will be connected to the Internet by 2020 [5].

Internet of Things for smart cities covers the implementation of IoT at a much larger scale [6]. This paper explains the vision of technocrats for the next decade (smart cities). It covers smart city concept and services, urban IoT architecture for a smart city, and the experimental study of Padova as a smart city. The European Union has already approved a project called IoT-A [7], which aims to design and define a standard for IoT to be used globally.

1.3 Proposed Solution

In this project, a smart home automation prototype is developed for energy monitoring, control and analysis using IoT. The prototype measures electrical parameters like voltage, current and frequency for the device under observation. This can be any device which requires energy monitoring, control and analysis. The prototype is placed between a power supply (source) and the device under observation. It measures voltage, current and frequency from the source and sends it to the microcontroller. The microcontroller processes these signals and converts them into numerical values. These values (measurement information of voltage, current and frequency) are then transferred to the server using an RF module. A server is a running instance of an application (software) capable of accepting requests from the client and giving responses accordingly. The server presents the values in useful ways using objects like charts and tables.

Automation and user friendly features have been considered in developing the prototype. A ping can be sent anytime by the server to obtain the measurement values. A ping is a command sent from the server to the RF module requesting information. The RF module receives the ping request and sends it to the microcontroller, which is programmed to reply to the ping request with values of voltage, current and frequency.

The proposed solution provides a user with data regarding the energy consumption of the devices under observation. The prototype is also adaptive to smart commands (via a ping) programmed into it. For example, a user can program a temperature setting with a string "my favourite". Following reception of the command "my favourite" the prototype automatically adjusts the temperature setting to the one programmed into it with that command.

There are switches connected to the microcontroller in order to provide user control of energy consumption. A control message received from the user (through the server) is processed to turn the device off through the switch.

Considering people are typically away from home 6 hours a day (for a working professional), this prototype can save 15-22% of the energy usage in a home. For example, a one ton air conditioner when turned off remotely for 4 hours a day can save 91 dollars (1300 kWh energy)

per year. This prototype can be used with a variety of home appliances like home security systems, thermostats, coffee makers, lights, TV, air conditioning, etc. From another prospective, it can be modified for use in Industrial applications to monitor, analyze and control data from a different location (even on a different continent). Hence, this prototype can be regarded as a general purpose monitoring, control and analysis device for a wide range of applications. Statistically the energy and money saving figures can be very high if this prototype is connected to various home appliances like refrigerator, air conditioning and thermostat.

1.4 Report Structure

The remainder of this report is organized as follows. In Chapter 2, the system design and its implementation are discussed. The system design covers the selection of components, circuit design and working mechanism of the prototype. This is followed by a cellular versus Wi-Fi technology analysis. Then the simulation results are discussed. The implementation of the prototype into a physical product is also described. In Chapter 3, a summary of the report is given and future work is discussed.

Chapter 2: System Design and Implementation

2.1 Circuit Design

The function of this prototype is to measure voltage, current and frequency information for the device under observation and then transfer this information over the internet to the server.

2.1.1 Voltage Measurement Module

Whenever the electrical load changes, the supply voltage is affected. Many people have seen this occur in their homes. For example, when the refrigerator or furnace starts, the lights may dim. If a large enough change occurs, such as the start-up of a large industrial motor, lights can dim or brighten, not only for the customer, but over a large area [8]. To add a layer of safety and control during voltage fluctuations, voltage measurements are obtained. For example, automatically turning off the device under observation during high fluctuations of voltage.

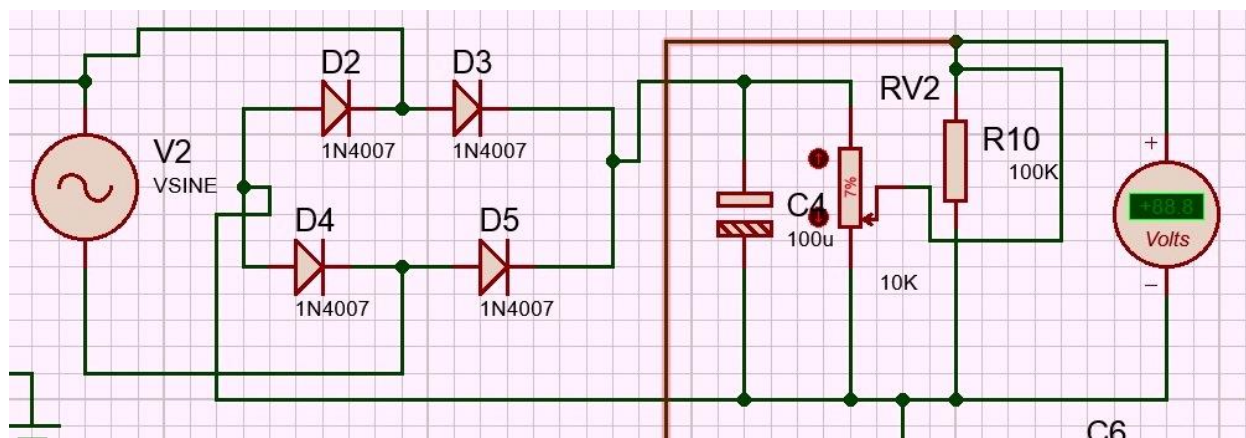


Figure 2: Voltage measurement module

The input signal for this module is the signal going from the source (power supply) to the device under observation. A circuit diagram of the voltage measurement module is shown in Figure 2. As shown in Figure 2, voltage V2 generated from the source is passed to the rectifier (D2 D3 D4 D5). The output from the rectifier is pulsating DC (direct current). This pulsating DC is converted to pure DC by filter capacitor C4. Resistor R10 is used to drop the voltage across it and then supply that voltage signal to the microcontroller. The input limitation of the microcontroller is addressed by this voltage drop. A variable resistor RV2 is used for calibration purposes. A variable resistor is a device for which the resistance can be adjusted. The calibration using RV2 makes the analog voltage sensing range of this prototype from 90V to 230V.

2.1.2 Current Measurement Module

Utility costs (energy usage) are typically billed in terms of power used. To calculate power two parameters are needed; voltage and current. In order to generate power usage monitoring and analysis for the consumer, this prototype measures current. The consumer can easily perform an energy comparison when analyzing utility bills using the data from the prototype.

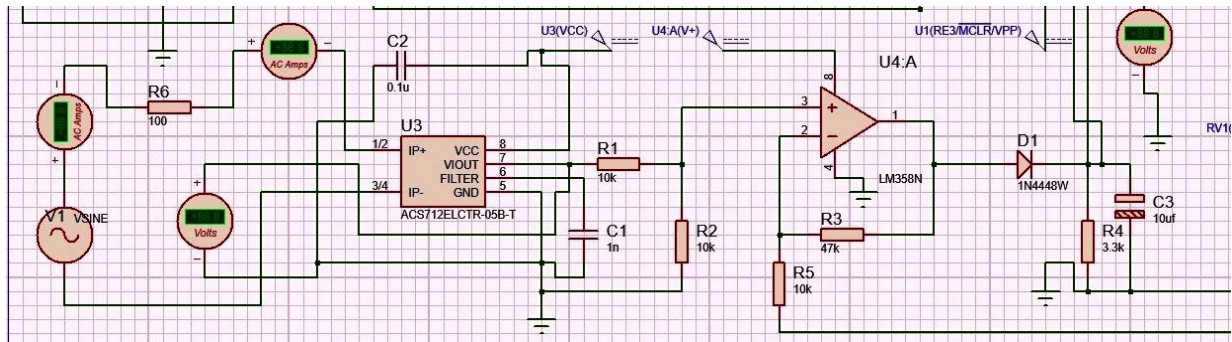


Figure 3: Current measurement module

The input signal coming from the source (power supply) is connected across the pins of the current sensing IC (Integrated Circuit) ACS712ALLERGO. A circuit diagram of the current measurement module is shown in Figure 3. This current sensing IC (ACS712ALLERGO) is excellent for extracting the current in the form of a voltage. This IC works on the concept called the “Hall Effect” [10], namely, when an electrical current passes through a device placed in a magnetic field, a potential proportional to the current and to the magnetic field is developed across the device in a direction perpendicular to both the current and to the magnetic field [9].

The positive and negative terminals of the source are connected to pins 1-2 and 3-4 of the current sensing IC, as shown in Figure 3. Hence, the current coming from the source is the same as that flowing across the IC. The current sensing IC generates a voltage equivalent to the current flowing across it based on the Hall Effect. The output signal from the IC is weak and needs to be amplified. An op amp (LM 358-n) is used for amplification. The major factor in selecting the LM 358-n is the large DC voltage gain of 100 dB [11]. The price of the LM 358-n is also very low. The output signal from the op amp is connected to the microcontroller.

2.1.3 Frequency Measurement Module

In industry there are many capacitive or inductive loads where a small change in the frequency affects the load impedance. This change in frequency can lead to an impedance mismatch at the output. Hence, the frequency measurement feature was included in this prototype.

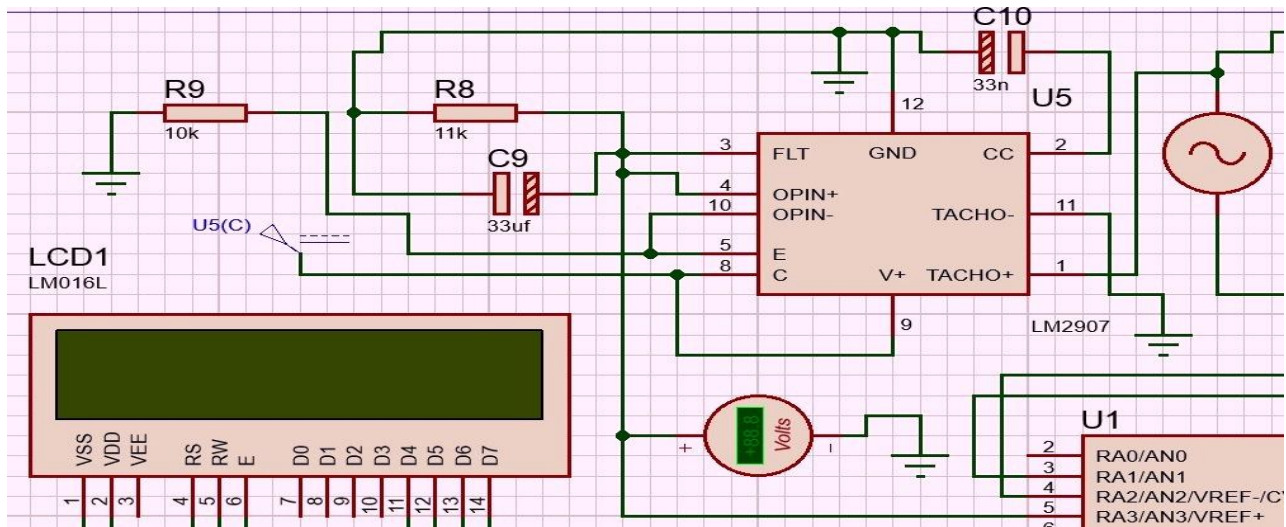


Figure 4: Frequency measurement module

The input signal for the module is the signal from the source (power supply) to the device under observation. A circuit diagram of the frequency measurement module is shown in Figure 4. The input signal from the source is connected to pin 1 of the frequency to voltage converter IC, LM2907-n. The LM2907-n is a frequency to voltage converter that is used to measure the line frequency. There are many alternatives to the LM2907, but the main advantage of using the LM2907-n is that it has a high gain op amp which can be used to directly control relays, lamps, or other loads when the input frequency goes beyond certain limits. Another advantage of the LM2907-n is that it has a low current consumption (25 mA) during operation [12].

The circuit shown in Figure 4 is built upon the design given in the application section of the LM2907-n data sheet [12]. The output signal containing frequency information in the form of a voltage is input to the microcontroller. Thus, there is a voltage signal at one input pin (pin 4), frequency information in the form of a voltage at another input pin (pin 5) and current

and flash. It has three external interrupts and 20 internal interrupts, making it a preferred choice for the prototype [14].

As shown in Figure 5, the output signals from the voltage measurement, current measurement and frequency module are connected to the analog input pins of the microcontroller. The microcontroller is programmed to extract the voltage, current and frequency values. These values are passed to the MAX 232 IC using pins 25 and 26 as shown in Figure 5. For display purposes, the LCD (Liquid Crystal Display) panel is connected to pins 15, 16, 17, 27, 28, 29 and 30 of the microcontroller.

2.1.5 RF Module

The prototype was developed to transmit and receive information over the internet through an RF module. The output signal from the microcontroller containing voltage, current and frequency values is in the form of TTL (Transistor to Transistor Logic). TTL is a class of digital circuits built from bipolar junction transistors (BJT) and resistors. It is called TTL because both the logic gating function (e.g., AND) and the amplifying function are performed by transistors [15]. The output signal from the microcontroller is connected to MAX 232 IC [16]. The MAX 232 IC synchronizes the RS 232 logic (in the range of -25V to +25V) and TTL (in the range of -5 V to +5 V). This IC converts one type of signal to another.

In this project, the output from the microcontroller is TTL and the input for the RF module must also be TTL. Hence, the use of MAX 232 is not mandatory for this prototype, but by using MAX 232 this prototype can also be directly connected to a computer system (RS 232 standard) and perform monitoring, control and analysis. For this application, the functionality (RS 232 – TTL) of this IC would come into effect. Hence, the prototype can function with an RF module and also with a computer system if needed.

Cellular modem	Quad band, supports RS 232 – CAD 25
Wi-Fi router	802.11 b/g/n, speed 150 Mbps – CAD 15

Table 1 Cellular and Wi-Fi cost analysis

As this prototype was developed considering the Indian commercial market, a cost analysis was done in order to decide between cellular and Wi-Fi technology for the RF modem. A price comparison of a cellular modem and a Wi-Fi router is shown in Table 1. The comparison shows that there is a very small difference in the initial investment. However, the service cost differs depending on the location and the plans available. The cellular data and Wi-Fi plans are compared for the Indian and Canadian markets in Table 2. The data shown in Table 2 is the average price calculated from telecom operators like Vodafone, Airtel and BSNL in India, and from operators like TELUS, Rogers and Bell in Canada. The data for Wi-Fi is calculated considering plans offered by BSNL in India and TELUS in Canada. As shown in Table 2, cellular data is cheaper for the Indian market, while Wi-Fi plan is cheaper in the Canadian market. The Indian market price of a SIM card is also negligible.

	Cellular data	Wi-Fi plans
India	CAD 3 for 1GB data.	CAD 45 for 100 GB of data.
Canada	CAD 30 for 1 GB of data.	CAD 20-30 for 150 GB of data.

Table 2 Cellular and Wi-Fi plan comparison between India and Canada

A prime factor behind the selection of cellular over Wi-Fi was the reliability of the cellular network. The QoS of cellular services is better, as the service providers control network traffic and have congestion management. In a paper comparing cellular with Wi-Fi it was stated that, “consistency in latency is often better with cellular access” [17].

2.2 Integrated Module

To demonstrate the function of the prototype, Figure 6 shows the circuit diagram used for simulation using Proteus design suite software (version 8). The speciality of Proteus 8 is that it provides simulation, schematic capture and PCB layout features. The individual design of the voltage measurement, current measurement, frequency measurement, microcontroller and RF module were given in Section 2.1.

The circuit diagram for the prototype (integrated module) is as shown in Figure 6. The top-right section represents the voltage measurement module as explained in Section 2.1.1. The top-left section represents the frequency measurement module as explained in Section 2.1.3. The bottom section represents the current measurement module as explained in Section 2.1.2. The central area represents the microcontroller as explained in Section 2.1.4. The RF module is represented by the centre-right area as explained in Section 2.1.5. The centre-left area is the LCD for display purposes.

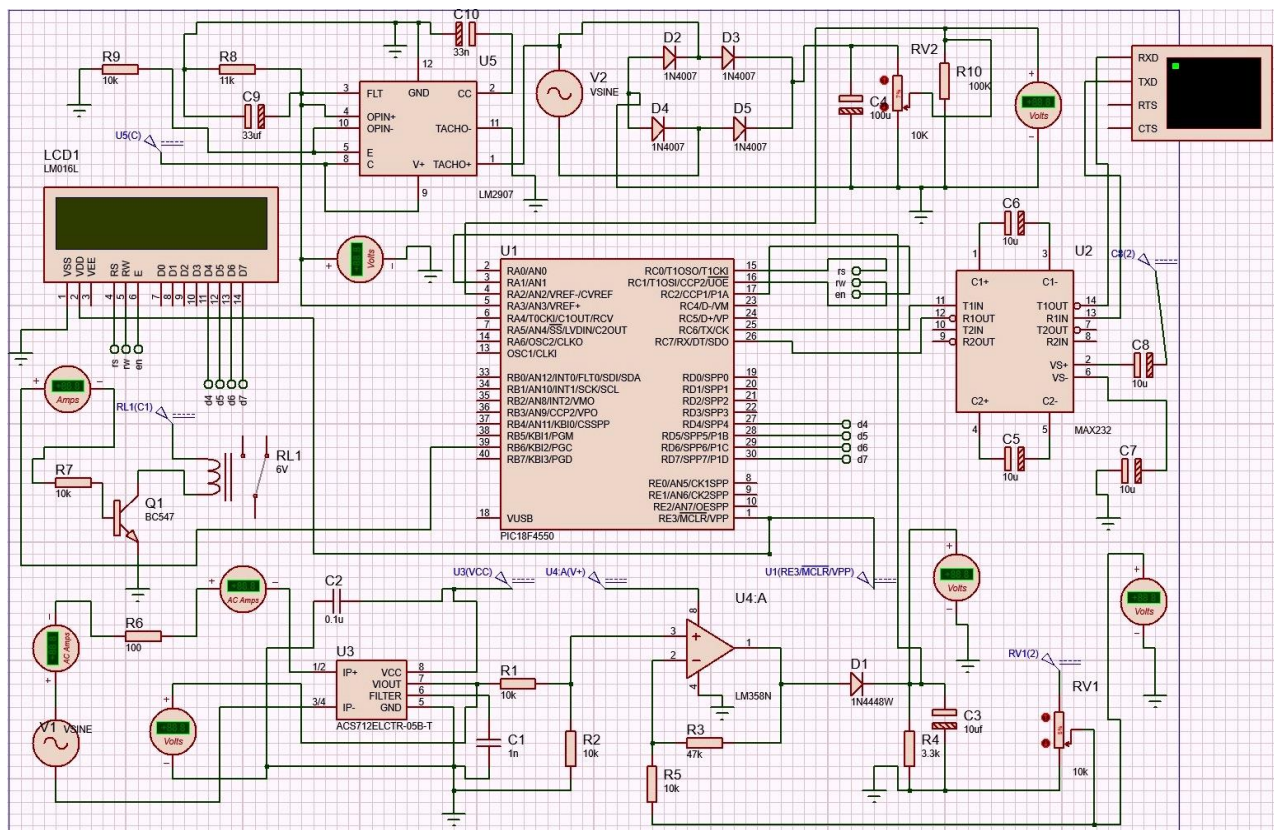


Figure 6: The prototype (integrated module)

2.3 Simulation Results

As this prototype was developed to be placed between the source (power supply) and the device under observation, the simulation begins with supplying input signals (source) to the prototype. The three modules (voltage, current and frequency measurement) measure their respective parameters and send the information in the form of voltage signals to the microcontroller. The microcontroller has built in A/D converters, eliminating the need of external A/D converter circuits. As per the program code (C language code given in Appendix A.1 converted into machine level .hex format) the microcontroller extracts the voltage, current and frequency information. These values are sent to the LCD module for display and are also sent to the RF module. The simulation in progress is shown in Figure 7.

For simulation purposes the terminal (black window in Figure 7) is assumed to be the RF modem. The output signal from the MAX 232 IC which is to be sent to the RF modem is the same as that shown in the terminal. As a regulatory approved RF modem is to be used, the functionality of the RF modem need not be checked in the simulation. The terminal (RF modem in the simulation) can also be considered as the server (a web address providing the GUI for a user to monitor, control and analyze the power consumption) assuming that the regulatory tested and approved RF modem is in place. In particular, the assumption is that the data sent through the RF modem will reach the server and data (command signals) from the server will reach the RF modem.

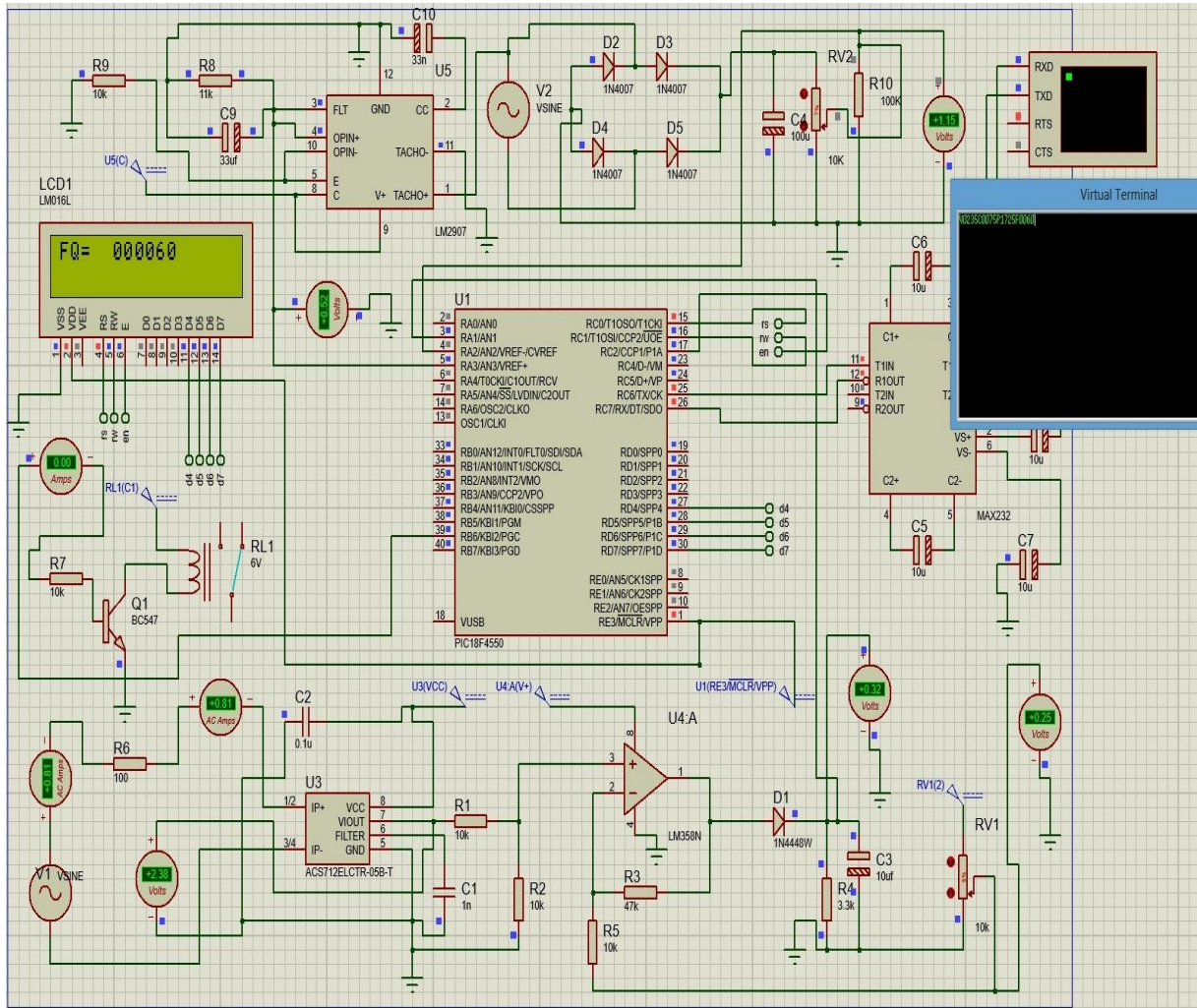


Figure 7: Simulation circuit

During the simulation, the microcontroller sends information for the LCD module to display. The LCD module displays individual parameter information as shown in Figure 8. The LCD module display for a 60 Hz signal during simulation is shown in Figure 8.

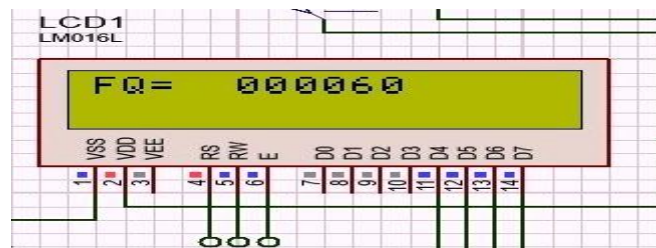


Figure 8: The LCD during simulation

While the simulation is in progress the parameters are measured and stored in memory. Keeping power optimization in mind, the microcontroller is programmed in such a way that it transmits data over the internet (using the RF modem) to the server only when the server requests the data. For example, when a command “e” is entered into the terminal, numerical values of voltage, current, frequency and power are displayed in the terminal. The command “e” was programmed as the server request for data command, only for the simulation purpose. A user can assign any character or number as a command from the server to send measurement data. This is one of the user defined characteristics of the prototype. The terminal during simulation for such a request to send data (“e”) from the server is shown in Figure 9. The terminal displays four values voltage, current, power and frequency in a series along with their respective start codes. As per Figure 9, the terminal displays V0235C0075P1725F0060, which means, voltage is 235 V, current is 0.75 A, power consumption is 172.5 W and frequency is 60 Hz.

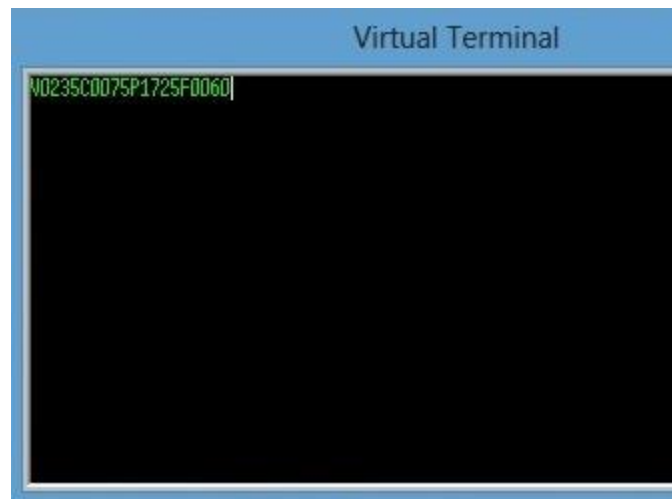


Figure 9: The terminal during simulation

The server which is the platform for monitoring, control and analysis of power consumption can be designed in various ways, depending on the user requirements.

2.4 Implementation

The prototype has been implemented as a physical product. The product is shown in Figure 10.

The details of the product are given below.

Size	50 mm (length) x 30 mm (width) x 2 mm (thickness)
Cost	CAD 100 (may reduce to 50 for bulk production)
Analog sensing voltage	80 V (minimum) to 240 V (maximum)
Analog sensing current	5 A
Power consumption of the device	10 Watt (for transmitting every 5 seconds), 7.5 Watt for transmitting six times in a hour)

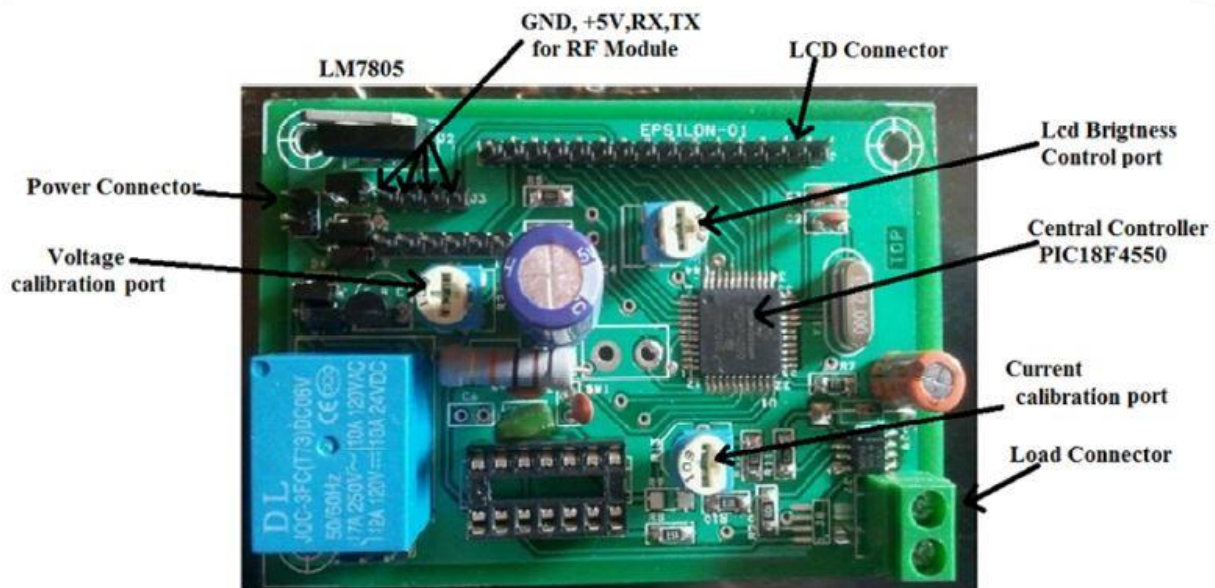


Figure 10: Implementation of the prototype

The prototype is to be placed between the power supply and the device under observation. A block diagram is shown in Figure 11 to demonstrate the application interface of the prototype.

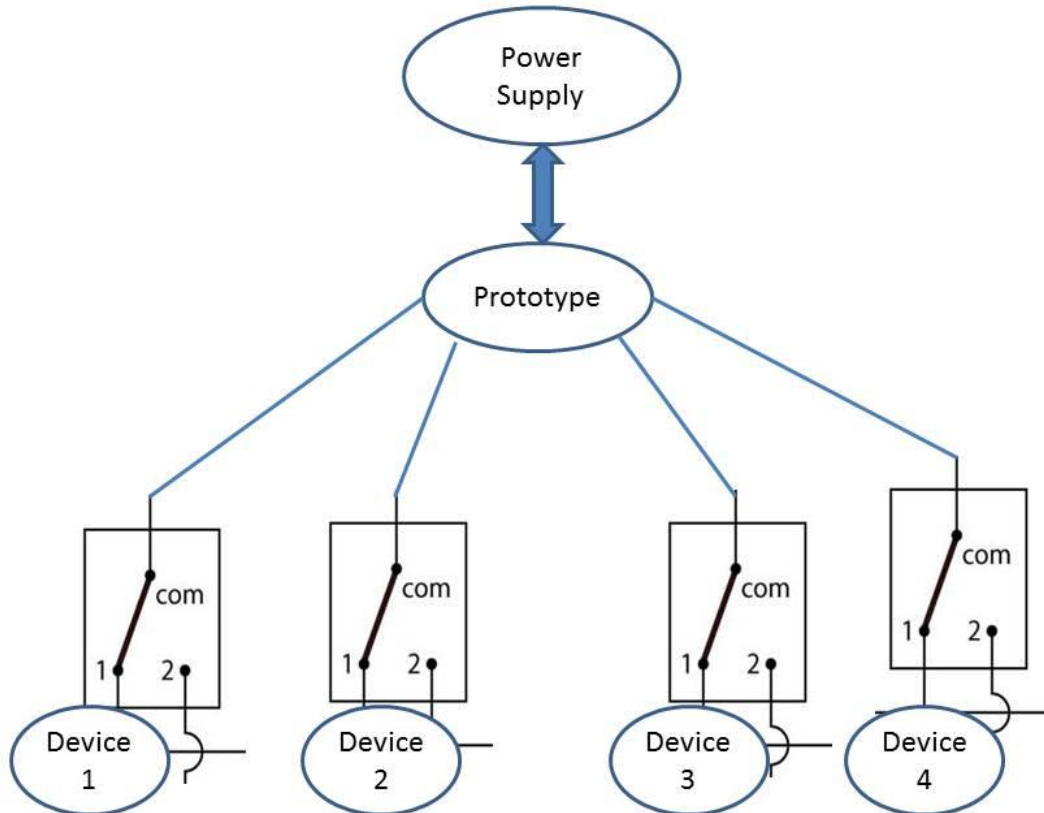


Figure 11: Block diagram of prototype interface

As shown in Figure 11, there are 4 devices connected to the prototype which is further connected to the power supply. The microcontroller has 13 A/D channels and hence the prototype can have a maximum of 4 devices connected as each device occupies 3 channels for voltage, current and frequency measurement. Each device is connected to the prototype through a switch (position 1 or 2) in order to provide full control. Hence, when a user wants to remotely turn off (position 2) or turn on (position 1) any device and control energy consumption, a user needs to send a control message to the RF module. The RF module will pass the message to the microcontroller which is programmed to turn the switch accordingly. When more than 4 devices are to be connected, multiple prototype circuits (excluding the RF module) can be used and all the circuits connected to a single RF module. For internal

connection of various prototype circuits to a single RF module, there are two possible solutions, power line communications and Wi-Fi. Power line communication devices are not readily available but Wi-Fi chips are easily available.

To differentiate devices and their respective data, the data is transferred to the server with headers. For example when 12 devices are connected through 3 prototype circuits to a single RF module, the microcontroller needs to be programmed to send data for device 1 as V1xyzC1xyzP1xyzF1xyz, for device 2 as V2xyzC2xyzP2xyzF2xyz and for device 12 as V12xyzC12xyzP12xyzF12xyz respectively. By doing so, the need for different IP addresses is eliminated as only one RF module is used. Here xyz refers to the specific measured value of voltage, current, power and frequency. When a control command is received, for example "STOP1", the microcontroller is programmed to turn device 1 off and it activates the switch for device 1 to position 2 as shown in Figure 11.

Chapter 3: Summary and Future Work

Chapter 1 provided an introduction to the high energy usage in Canada and the need for power monitoring and optimization. The paradigm Internet of Things was explained in brief along with the energy efficiency requirements. Then the prototype was introduced. This prototype monitors, controls and analyzes the energy consumption of the device(s) under observation.

Chapter 2 provided a detailed explanation of the circuit design of the prototype. The circuit design section covered the goals of the circuit, selection of the components and the designs for the respective modules. The integration module combining all the modules and its function were discussed. Further, simulation results were presented. The chapter concluded with the implementation of the prototype along with its specifications.

3.1 Future Work:-

Future work could include adding features like a remote control for various devices and user defined commands. FPGA implementation of the prototype can also be done. Some applications based on the concept of the prototype are given below to conclude the report.

Application 1: - BP (Blood Pressure) Life Saver

The average emergency response time in BC is 9-15 minutes [18]. As per statistics Canada, 19% of the adult population is above the normal limit of BP. A high BP can cause a heart attack or strokes. A human heart ceases in less than 4 minutes and a human brain is permanently damaged within 4-6 minutes after breathing stops. The use of an Automated External Defibrillator (AED) can save the lives of 30% or more of those who suffer cardiac arrest. When defibrillation is delayed, survival rates decrease to approximately 50% at 5 minutes [19]. The average emergency response time being 9-15 minutes, the effects of stroke within 6 minutes and the survival rate proportional to defibrillation delay indicates there are lives in danger. An application similar to the prototype could be a device called BP life saver. The device BP life saver refers to a BP Meter + Cell phone combined in the size of a watch. Cellphones of this size are available for 100 dollars and a BP meter in a watch shape is for 50 dollars.

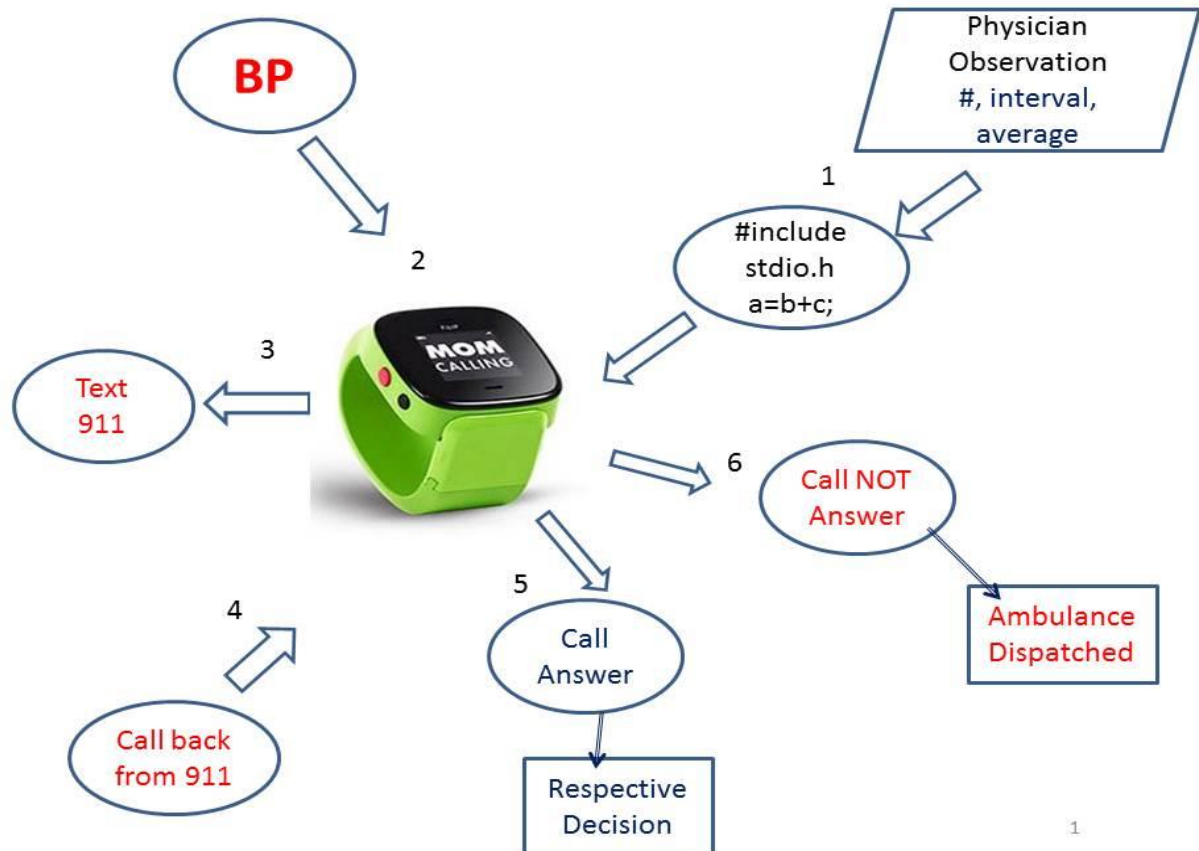


Figure12: Working mechanism of a BP life saver

Figure 12 shows the working mechanism of the proposed BP life saver. The center of Figure 12 shows a watch size cellphone already sold in United States by AT&T Inc. The numbers in Figure 12 represents the steps sequence. Below is the step by step functioning of the proposed device.

Step 1: A physician would decide the limits of the BP measurements, beyond which it will be an emergency situation (as per the patient profile) and program the limits into the prototype. The diagram shows a C language code (to represent programming) which will take these limits as its inputs. The patient will wear this BP life saver on their wrist as the device will be a cell phone in the shape of a watch with the BP meter built into it.

Step 2: The BP readings are recorded into the phone memory at periodic intervals. The device compares all the recorded measurements with the physician programmed limits. When the BP

of the patient increases or decreases beyond the programmed limits the device would enter into emergency mode.

Step 3: In emergency mode, the device would send a text to Emergency Services (911). Text to 911 services were approved by the CRTC earlier this year and are already available in Metro Vancouver, Calgary, Squamish, The sunshine coast and other areas.

Step 4: On reception of the text, as per the protocol, the emergency services office would call the device.

Step 5: If the person answers the call, then it becomes a normal 911 call.

Step 6: If the person does not answer the call, emergency services will dispatch an ambulance directly to the patient using the location of the device. This should reduce the time between observing an emergency situation and calling 911.

To conclude, this prototype can save lives due to an absence of a person nearby to call emergency services. An added feature can be the periodic collection of BP measurement data which can be sent to the server. This will allow access to real time patient data via the internet, which can be used by doctors for future medical treatment.

Application 2: - Emergency Medical Professional Service

The second application is the extended version of the BP life saver (Application 1). A specialized medical service can be implemented for emergency patients. This service can be formed with X emergency service care professionals for Y patients, depending on geographical and medical research. There will be a network of emergency medical professionals in various locations covering the area and a monitoring station. When the BP life saver or similar device sends an emergency message, the message is received by the monitoring station. The monitoring station then finds the nearest medical professional available, informs them of the emergency, and marks their availability as busy in the system. The professional goes to the patient location and takes care of the emergency.

Once the emergency is handled and the emergency medical professional is free, he/she would manually change their availability to available for future emergency patients. This availability change would be directly reflected at the monitoring station in order to accommodate the next emergency request in the area. The latest research from Delft University regarding an ambulance drone [21], directs the future of health care towards IoT. When emergency services receive a cardiac arrest call, this unmanned, autonomously navigating aeroplane (ambulance drone) can quickly deliver a defibrillator to the emergency scene. Via a live video and audio connection, the drone can also provide direct feedback to emergency services and the persons on site can be instructed how to treat the patient. The drone finds the patient location (through the caller's mobile phone signal), and travels there using GPS [21].

Application 3 Energy Usage Overview for upgrading instruments in a Pulp Company

The recent launch of energy-efficiency investments to reduce costs for pulp and paper producers [22] program by BC hydro is projected to reduce electricity costs for pulp producers. The pulp industry is being provided with funding in order to reduce their power consumption. The primary step in reducing their power consumption is to eliminate the non-essential power consumption. In order to analyze individual power consumption of machinery, the prototype presented in this report can be used along with external controllers designed with a PLC (programmable logic controller). This method would provide efficient and accurate measurements as compared to manual reading at certain intervals. The measurement engineer can also control all the activities of his research and export graphical (GUI) or tabular data in order for the company to set reference standards for future use. An engineer can even travel outside the city and still control and analyze the data and observations to be recorded.

Appendix A.1 Source Code for the PIC microcontroller (C language)

```

//#define rs LATC.RC0
//#define rw LATC.RC1
//#define en LATC.RC2
//#define relay LATB.RB6
//#define lcdport LATD
#define FREQ 12000000 // Frequency
#define baud 9600
#define spbrg_value (((FREQ/64)/baud)-1) // Refer to the formula for Baud rate calculation in Description tab

//void lcdcmd(unsigned char);
//void lcddata(unsigned char);
//void lcd_ini();
//void dis_cmd(unsigned char);
//void dis_data(unsigned char);
void adc_con(unsigned int);
unsigned char rx_data(void);
void adc(unsigned char);
void convert();
void convert2();
void txd(unsigned char);

/*unsigned char data0[30]="EPSILON";
unsigned char ldata[15]="P=";
unsigned char ldata1[15]="V=";
unsigned char ldata2[15]="CU=";
unsigned char ldata3[15]="FQ="; */

unsigned int out[10],digital_out[10],avg_output=0,temp;
unsigned int Y,i,h,u,k=0;
unsigned int t=0;
unsigned char tr[4];
unsigned char cp;
unsigned char data_value1;
unsigned char cmd_value1;
//unsigned long int z=0;
char position;

void main()
{ int s=0;
// To enable continuous reception
TRISA=0xff; // Configure RA0 as input pin
//LATA=0;
TRISB=0; // Configure Port B as output port
LATB=0;
//TRISD=0;
//LATD=0;
TRISC.RC0=0;
TRISC.RC1=0;
TRISC.RC2=0;
TRISC.RC4=0;

```

```

TRISC.RC5=0;
TRISC.RC6=1;
TRISC.RC7=1;
//INTCON.GIE=0;
//INTCON.PEIE=0;
SPBRG=spbrg_value;           // Fill the SPBRG register to set the Baud Rate
RCSTA.SPEN=1;                // To activate Serial port (TX and RX pins)
TXSTA.TXEN=1;
TXSTA.SYNC=0;
RCSTA.CREN=1;
//LATC=0;
//lcd_ini();    // LCD initialization

i=0;
/* while(data0[i]!='\0')
{
    dis_data(data0[i]);
    Delay_ms(20);
    i++;
} */

delay_ms(350);
//dis_cmd(0x01);

adc(0x04);    //ADC Initialization
while(1)
{
    cp=rx_data();
    /* if(cp!='e')
    {
        RCSTA.CREN=0;
        delay_ms(3000);
        RCSTA.CREN=1;
        delay_ms(1000);
    } */

    adc(0x08);    //voltage
    h=3;
    convert2();
    Delay_ms(500);
    adc(0x04);    // current
    convert();
    Delay_ms(500);
    h=4;
    adc(0x0C);    //freq
    convert2();
    Delay_ms(500);
}
}

```

```

void convert()
{  unsigned int z=0;

    temp=0;
    for(i=0;i<10;i++)
    {
        ADCON0.GO=1;           // Start A/D conversion
        while(ADCON0.GO==1);   // Wait until conversion gets over
        digital_out[i]=((ADRESL)|(ADRESH<<8)); // Store 10-bit output into a 16-bit variable
        Delay_ms(20);
        temp=temp+digital_out[i];
    }
    avg_output=temp/10;
    avg_output=(avg_output);
        // Take average of ten digital values for stability
    dis_cmd(0x01);
    i=0;
    while(ldata2[i]!='\0')
    {
        dis_data(ldata2[i]); // Call lccdata function to send character one by one from 'data' array
        i++;
    }
    k=3;
    if(avg_output<6)
    {avg_output=(avg_output-1);}
    else
    { if(6<=avg_output<9)
    {avg_output=(avg_output+2);}
    if(10<=avg_output<19)
    {avg_output=(avg_output-4);}
    if(20<=avg_output<29)
    {avg_output=(avg_output+4);}
    if(30<=avg_output<39)
    {avg_output=(avg_output+4);}
    if(40<=avg_output<49)
    {avg_output=(avg_output+4);}
    if(49<=avg_output)
    {avg_output=(avg_output);}
    }

    adc_con(avg_output);
    Delay_ms(500);
    dis_cmd(0x01);
    i=0;
    while(ldata[i]!='\0')
    {
        dis_data(ldata[i]); // Call lccdata function to send character one by one from 'data' array
        i++;
    }
}

```

```

    z=(avg_output*(Y/10));
    // position=0X86;
    k=4;

    adc_con(z);
    Delay_ms(500);
}

void convert2()
{
    t=0;
    for(i=0;i<10;i++)
    {
        ADCON0.GO=1;           // Start A/D conversion
        while(ADCON0.GO==1);   // Wait until conversion gets over
        out[i]=((ADRESL)|(ADRESH<<8)); // Store 10-bit output into a 16-bit variable
        Delay_ms(20);
        t=t+out[i];
    }
    avg_output=t/10;

    if(h==3)
    {

        /*dis_cmd(0x01);
        i=0;
        while(ldata1[i]!='\0')
        {
            dis_data(ldata1[i]); // Call lccdata function to send character one by from 'data' array
            i++;
        } */
        Y=avg_output;
        k=5;
        adc_con(avg_output); }

    if(h==4)
    {
        /*dis_cmd(0x01);
        i=0;
        while(ldata3[i]!='\0')
        {
            dis_data(ldata3[i]); // Call lccdata function to send character one by from 'data' array
            i++;
        } */
        k=6;

        adc_con((avg_output-47)); }
}

void adc(unsigned char q)

```

```

{
  ADCON1=0x0B;           // Make RA0/AN0 pin as analog pin (Other pins remain to be digital I/O)
  ADCON0=q;             // Select Channel0 & ADC off
  ADCON2=0x8A;         // Left justified, 2TAD acquisition time, Fosc/32 clock option
  ADCON0.ADON=1;       // Enable ADC
}

/*void lcd_ini()
{
    dis_cmd(0x02);      // To initialize LCD in 4-bit mode.
    delay_ms(5);
    dis_cmd(0x28);      // To initialize LCD in 2 lines, 5x7 dots and 4bit mode.
    delay_ms(5);
    dis_cmd(0x0C);
    delay_ms(5);
    dis_cmd(0x06);
    delay_ms(5);
    dis_cmd(0x01);
    delay_ms(5);
    dis_cmd(0x80);
    delay_ms(5);
}
void dis_cmd(unsigned char cmd_value)
{
    cmd_value1 = (cmd_value & 0xF0);    // Mask lower nibble because RB4-RB7 pins are being used
    lcdcmd(cmd_value1);
    delay_ms(5);           // Send to LCD
    cmd_value1 = ((cmd_value<<4) & 0xF0);    // Shift 4-bit and mask
    lcdcmd(cmd_value1);    // Send to LCD
    delay_ms(5);
}

void dis_data(unsigned char data_value)
{
    data_value1=(data_value&0xF0);
    lcddata(data_value1);
    delay_ms(5);
    data_value1=((data_value<<4)&0xF0);
    lcddata(data_value1);
    delay_ms(5);
} */

void adc_con(unsigned int adc_out)
{
  int l=0;
  unsigned int adc_out1;
  int i=0;

  position=0X8A;

```

```

//txd('a');
delay_ms(100);
if(cp=='e')
{
if(k==3)
txd('C');
else if(k==4)
txd('P');
else if(k==5)
txd('V');
else if(k==6)
txd('F');
}

//k=0;
for(i=0;i<=5;i++)
{
adc_out1=adc_out%10;           // To extract the unit position digit
adc_out=adc_out/10;

tr[i]=adc_out1;
/* if(k==4)
{ if(i==1)
{dis_cmd(0x89);
dis_data('.');
position--;

k=0;}
}

if(k==3)
{ if(i==2)
{dis_cmd(0x88);
dis_data('.');
// position=0x88;
position--;
k=0; }
} */

/* last one if(k==6)
{ if(i==1)
{dis_cmd(0x89);
dis_data('.');
// position=0x88;
position--;
k=0; }
} */
/* dis_cmd(position);
dis_data(48+adc_out1);
position--; */
}
if(cp=='e')
{ for(l=3;l>=0;l--)

```

```

    {txd(48+tr[l]);
      delay_ms(10);
    }
  }
}

/*void lcdcmd(unsigned char cmdout)
{
  lcdport=cmdout;    //Send command to lcdport=PORTB
  rs=0;
  rw=0;
  en=1;
  Delay_ms(10);
  en=0;
}
void lcddata(unsigned char dataout)
{
  lcdport=dataout; //Send data to lcdport=PORTB
  rs=1;
  rw=0;
  en=1;
  Delay_ms(10);
  en=0;
}*/
unsigned char rx_data(void)
{
  if(PIR1.RCIF==1)
  { PIR1.RCIF==0;
    return RCREG;
    //return RCREG;
  }
  Delay_ms(10);
  // Wait until RCIF gets low
  // Retrieve data from reception register
}
void txd(unsigned char ba)
{
  // To enable transmission
  TXREG=ba;          // Store data in Transmit register
  while(PIR1.TXIF==0);
  //while(PIR1.TRMT==0);

  // Wait until TXIF gets low

```

Bibliography

- [1] <http://alberta.ca/release.cfm?xID=37372D843D2E2-910A-4153-36287ED863175A1F>, cited November 19, 2014.
- [2] <http://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE/countries/1W-IN-CA-US-CN?display=graph>, cited November 8, 2014.
- [3] D. Giusto, A. Iera, G. Morabito, L. Atzori (Eds.), *The Internet of Things*, Springer, 2010. ISBN: 978-1-4419-1673-0
- [4] P. Bellavista, G. Cardone, A. Corradi, and L. Foschini, "Convergence of MANET and WSN in IoT urban scenarios," *IEEE Sens. J.*, vol. 13, no. 10, pp. 3558–3567, Oct. 2013.
- [5] <http://www.cisco.com/web/solutions/trends/iot/indepth.html>, cited November 8, 2014.
- [6] *Zanella A, Bui, N, Castellani A. Vangelista L, Zorzi M; "Internet of Things for Smart Cities", Internet of Things Journal, IEEE, Volume 1, Issue 1, Pg 22-32, 2014.*
- [7] <http://www.iot-a.eu/public>, cited November 8, 2014.
- [8] Power Quality, A guide to voltage fluctuation and light flicker, Available: http://www.bchydro.com/content/dam/hydro/medialib/internet/documents/psbusiness/pdf/power_quality_a_guide_to_voltage_fluctuation_and_light_fl.pdf
- [9] ACS712 data sheet. Available: <http://www.allegromicro.com/en/Products/Current-Sensor-ICs/Zero-To-Fifty-Amp-Integrated-Conductor-Sensor-ICs/ACS712.aspx>
- [10] Hall, E. H., "On a new action of the magnet on electric currents", *American Journal of Mathematics* 2, No. 3, pages 287–292 (1879).
- [11] LM 358-n datasheet. Available: <http://www.ti.com/lit/ds/symlink/lm358-n.pdf>

- [12] LM 2907-n datasheet. Available: <http://www.ti.com/lit/ds/symlink/lm2907-n.pdf>
- [13] http://ww1.microchip.com/downloads/en/Market_Communication/nanowatt1jan03.pdf, cited November 8, 2014.
- [14] PIC 18F4550 datasheet. Available:
<http://ww1.microchip.com/downloads/en/devicedoc/39632c.pdf>
- [15] http://www.princeton.edu/~achaney/tmve/wiki100k/docs/Transistor%E2%80%93transistor_logic.html, cited November 8, 2014.
- [16] MAX 232 datasheet. Available: <http://www.ti.com/lit/ds/symlink/max232.pdf>
- [17] *Joel Sommers, Paul Barford*; "Cell vs. WiFi: On the Performance of Metro Area Mobile Connections", IMC'12, Pages: 301-314, November 2012, Boston, Massachusetts, USA.
- [18] <http://www.nrcan.gc.ca/science/expert/video/1499>, cited November 8, 2014.
- [19] <http://www.cupe.bc.ca/news/958>, cited November 8, 2014.
- [20] http://www.steinbach.ca/resource/File/Parks_Recreation/Canadian_RedCross_Fact_Sheet.pdf, cited November 8, 2014.
- [21] <http://www.tudelft.nl/en/current/latest-news/article/detail/ambulance-drone-tu-delft-vergroot-overlevingskans-bij-hartstilstand-drastisch/>, published October 27, 2014.
- [22] http://www2.news.gov.bc.ca/news_releases_2013-2017/2014MEM0018-001057.htm, cited November 23, 2014.