Automated Energy Meter Reading by Using Radio Frequency Technology

A thesis submitted in partial fulfillment for the requirements
Of MSc degree in Electronic Engineering

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قال تعالى:

سَنَننننيهِمْ مَي اََِاتميَننننا ومننننو فِيَفَنننناِم مَفمنننننو
حَتَّننى تَتَيَننتَََّ لَ هننَي
َيَّنن ه فليحَننَو َمَلَننَي َِِينن م يمَِ منن َ
َيَّ ه عَلَى ِهل م شَويءٍ شَ متد
(53)

[سورة فصلت]
Dedication

This thesis is dedicated to:

The sake of Allah, my Creator and my Master,

My great teacher and messenger, Mohammed (May Allah bless and grant him), who taught us the purpose of life,

My great parents, who never stop giving of themselves in countless ways,

To all my family, the symbol of love and giving,

My friends who encourage and support me,

All the people in my life who touch my heart,

I dedicate this research.

Mohamed
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First and foremost, I must acknowledge my limitless thanks to Allah, the Ever-Magnificent; the Ever-Thankful, for His help and bless. I am totally sure that this work would have never become truth, without His guidance.

I am grateful to some people, who worked hard with me from the beginning till the completion of the present research particularly my supervisor Prof.Ibrahim Khider, who has been always generous during all phases of the research.

I would like to take this opportunity to say warm thanks to all my beloved friends, who have been so supportive along the way of doing my thesis.
Abstract

Radio Frequency based wireless remote control system can be used to control the output load from remote place. In this thesis a circuit of RF module (T_x/R_x) for wireless remote control has been used for automatic collecting data from energy meter which called Automatic meter reading (AMR) instead of using traditional meter reading system for billing. In thesis AMR has been implemented to send and receive data between energy meter and electrical distribution company system. Simulation module has been done with the use of software simulating programs; along with Bascom-AVR language Compilers for the code has been written to the MCU. The simulating program used for this thesis was Proteus Professional. This thesis successfully designed and implemented an efficient way to collect billings for electricity consumptions, and further facilitate the recharge process of meters currently being used.
المستخلص

موجات الراديو اللاسلكية يمكن أن تستخدم للتحكم عن بعد في الحمل الناتج من مكان بعيد. في هذه الظروف، تم استخدام نموذج من دائرة التردد الراديوي التي تمكن من إرسال واستقبال البيانات للاسلكيًا عن بعد بغرور تجميع بيانات عدادات الطاقة تلقائيًا بدلاً من استخدام نظام قراءة العدادات التقليدية للفوائض. في هذه الظروف، تم تنفيذ نظام القراءة التلقائية لتبادل البيانات بين عدادات الطاقة ونظام شركة توزيع الكهرباء. تم عمل نموذج محاكاة للنظام باستخدام برامج المحاكاة حيث استخدمت لغة باسكال لكتابة وترجمة البرنامج لوحدة التحكم (المتحكم الدقيق) بينما استخدم برامج البروتوكول الاحترافي لعمل نموذج المحاكاة. هذه الظروف تم تصميمها وتثبيتها بنجاح كوسيلة فعالة لجمع فوائض استهلاك الطاقة وكذلك لتسهيل عملية أعداد تغذية العداد بالكهرباء مقارنة مع الطريقة المستخدمة حالياً.
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LIST OF ABBREVIATIONS

AC Alternating Current
ADC Analog-to-Digital Converter
AMR Automatic Meter Reading
AREF Analog Reference
AVCC Analog Supply Voltage
CTS Clear To Send
CMOS Complementary Metal Oxide Semiconductor
GND Ground
Hz Hertz
IC Integrated Circuit
I/O Input / Output
LCD Liquid Crystal Display
LED Light Emitting Diode
MCU, μC Microcontroller
MRI Meter Reading Instruments
USART Universal Synchronous and Asynchronous Receiver and Transmitter
USB Universal Serial Bus
V Voltage
VCC Supply Voltage
PC Personal Computer
PIN Personal Identification Number
PLC Power Line Communication
R/W Read/Write
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<td>Rx</td>
<td>Receive</td>
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<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>RAM</td>
<td>Random Access Memory</td>
</tr>
<tr>
<td>ROM</td>
<td>Read Only Memory</td>
</tr>
<tr>
<td>SMS</td>
<td>Short Messaging System</td>
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<tr>
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CHAPTER ONE

INTRODUCTION

1.1 Preface

Electric energy meters, the direct billing interface between utilities and consumers for long, have undergone several advancements in the last decade. The conventional electromechanical meters are being replaced by new electronic meters to improve accuracy in meter reading. Therefore, attempts are being made to automate the billing systems. Even though more accurate and faster meter readings have seen the light of day, bill payment is still based on an old procedure. They require the costumer to come to sales points of the electricity utility and buy electricity, where there are provided with vouchers (or tokens) that are then inserted back at home into the meter through a keypad. But the demand for computing power at all levels of electronic systems is driving advancements in semiconductor chip technology. The AMR and power quality monitoring systems manufacturers are taking advantage of these advances and integrating them into new meters and instruments. The networking technologies are driven by the demand for interconnection of computer users worldwide. The AMR and power monitoring systems are using these advances to expand the monitoring systems. The idea of prepaid metering will be very important for the new research fields of Micro-grid and Smart Grid and is an inevitable step in making any grid smarter than it is now.

1.2 Problem Statement

Every time a customer (end-user of currently used meters) wants to recharge their energy meter, they would have to go all the way to the utility company to buy electricity and receive a voucher that is then must be taken back to the location of the meter and is entered through a keypad. This is a very tiresome process for electricity recharge, especially if the location of the meter is far from the utility company. Moreover, in case the electricity runs out, the period of time the facility where the meter is installed stays offline until it is once more recharged may be critical depending on the facility itself (home, hospital, mainframe server...etc.).
1.3 Objective

The objectives of thesis are:

- To study Radio Frequency (RF) technology.
- To understand Automatic meter reading (AMR).
- To analyze, design, simulation and implementation energy meter.

1.4 Methodology

The method used to carry out this thesis is the principle of wireless communication in collaboration with embedded system. The thesis has an electric meter which will work with RF modem which is the lowest cost technology used for communication. By using Proteus simulation program meter and transceiver circuits were built and tested properly. Real meter and transceiver circuits were designed and worked properly in communion with microcontroller.
1.5 Thesis outlines

This thesis is concerned with the Radio Frequency (RF) based Automatic meter reading. Accordingly, it is divided into the following chapters:

**Chapter one:** is the introduction to this thesis. This chapter discusses the objectives and Methodology. It also provides an outline of the thesis.

**Chapter two:** introduces necessary background overview of the thesis.

**Chapter three:** describes the Hardware component and Software used to implement AMR meter.

**Chapter four:** presents the results and discusses of this study.

**Chapter five:** conclusion and recommendations of the thesis and presents suggestions for future work.
CHAPTER TWO
BA CKGROUND OVERVIEW

2.1 Introduction

The Electrical metering instrument technology has come a long way from what it was more than 100 years ago. From the original bulky meters with heavy magnets and coils, there have been many innovations that have resulted in size & weight reduction in addition to improvement in features and specifications. Resolution and accuracy of the meter have seen substantial improvements over the years. Introduction of the digital meter in the later part of last century has completely changed the way Electrical parameters are measured. Starting with Voltmeters & Ammeters, the digital meter has conquered the entire spectrum of measuring instruments due to their advantages like ease of reading, better resolution and rugged construction. Of particular significance is the introduction of the Electronic Energy Meter in the mid eighties. Now a days, the energy consumption and energy distribution has became a big subject for discussion because of huge difference in energy production and consumption. In this regard, energy consumers are facing so many problems due to the frequent power failures; another important reason for power cuts is due to the un-limited energy consumption of rich people. In this aspect, to minimize the power cuts and to distribute the energy equally to all areas, some restriction should have over the power consumption of each and every energy consumer, and according to that the Government should implement a policy, by introducing Autonomous Energy Meters everywhere in domestic sector. Hence, the need has come to think on this line and a solution has to be emerged out. [1]

2.2 Type of meters

Electricity meters operate by continuously measuring the instantaneous voltage (volts) and current (amperes) to give energy used (in joules, kilowatt-hours etc.). Meters for smaller services (such as small residential customers) can be connected directly in-line between source and customer. For larger loads, more than about 200 ampere of load, current transformers are used, so that the meter can be located other than in line with the service conductors. The meters fall into two basic categories, electromechanical and electronic. [2]
2.2.1 Electromechanical meters

The most common type of electricity meter is the electromechanical induction watt-hour meter. The electromechanical induction meter operates by counting the revolutions of a non-magnetic, but electrically conductive, metal disc which is made to rotate at a speed proportional to the power passing through the meter. The number of revolutions is thus proportional to the energy usage. The voltage coil consumes a small and relatively constant amount of power, typically around 2 watts which is not registered on the meter. The current coil similarly consumes a small amount of power in proportion to the square of the current flowing through it, typically up to a couple of watts at full load, which is registered on the meter.

The disc is acted upon by two sets of coils, which form, in effect, a two phase induction motor. One coil is connected in such a way that it produces a magnetic flux in proportion to the voltage and the other produces a magnetic flux in proportion to the current. The field of the voltage coil is delayed by 90 degrees, due to the coil's inductive nature, and calibrated using a lag coil. This produces eddy currents in the disc and the effect is such that a force is exerted on the disc in proportion to the product of the instantaneous current, voltage and phase angle (power factor) between them. A permanent magnet exerts an opposing force proportional to the speed of rotation of the disc. The equilibrium between these two opposing forces results in the disc rotating at a speed proportional to the power or rate of energy usage. The disc drives a register mechanism which counts revolutions, much like the odometer in a car, in order to render a measurement of the total energy used. [2]

The type of meter described above is used on a single-phase AC supply. Different phase configurations use additional voltage and current coils.
Three-phase electromechanical induction meter, metering 100 A 240/415 V supply. Horizontal aluminum rotor disc is visible in center of meter.

The disc is supported by a spindle which has a worm gear which drives the register. The register is a series of dials which record the amount of energy used. The dials may be of the cyclometer type, an odometer-like display that is easy to read where for each dial a single digit is shown through a window in the face of the meter, or of the pointer type where a pointer indicates each digit. With the dial pointer type, adjacent pointers generally rotate in opposite directions due to the gearing mechanism.

The amount of energy represented by one revolution of the disc is denoted by the symbol Kh which is given in units of watt-hours per revolution. The value 7.2 is commonly seen. Using the value of Kh one can determine their power consumption at any given time by timing the disc with a stopwatch.

\[
P = \frac{3600 \cdot Kh}{t} \quad \text{..................(2-1)}
\]

Where:

\( t \) = time in seconds taken by the disc to complete one revolution,

\( P \) = power in watts.
For example, if \( Kh = 7.2 \) as above, and one revolution took place in 14.4 seconds, the power is 1800 watts. This method can be used to determine the power consumption of household devices by switching them on one by one.

Most domestic electricity meters must be read manually, whether by a representative of the power company or by the customer. Where the customer reads the meter, the reading may be supplied to the power company by telephone, post or over the internet. The electricity company will normally require a visit by a company representative at least annually in order to verify customer-supplied readings and to make a basic safety check of the meter.

In an induction type meter, creep is a phenomenon that can adversely affect accuracy that occurs when the meter disc rotates continuously with potential applied and the load terminals open circuited. A test for error due to creep is called a creep test.

Two standards govern meter accuracy, ANSI C12.20 for North America and IEC 62053. [2]

### 2.2.2 Electronic meters

Electronic meters display the energy used on an LCD or LED display, and some can also transmit readings to remote places. In addition to measuring energy used, electronic meters can also record other parameters of the load and supply such as instantaneous and maximum rate of usage demands, voltages, power factor and reactive power used etc. They can also support time-of-day billing, for example, recording the amount of energy used during on-peak and off-peak hours. [2]
The following are the advantages of electronic energy meter:

**Accuracy**

While electromechanical meters are normally available with Class 2 accuracy, Electronic meters of Class 1 accuracy are very common.

**Low Current Performance**

Most of the electromechanical meters tend to run slow after a few years and stop recording at low loads typically below 40% of their basic current. This is due to increased friction at their bearings. This results in large losses in revenue since most of the residential consumers will be running at very low loads for almost 20 hours in a day. Electronic meters record consistently and accurately even at 5% of their basic current. Also they are guaranteed to start recording energy at 0.4% of their basic current.

**Low Voltage Performance**

Most of the mechanical meters become inaccurate at voltages below 75% of rated voltage whereas electronic meters record accurately even at 50% of rated voltage. This is a major advantage where low voltage problem is very common.
Installation

The mechanical meter is very sensitive to the position in which it is installed. If it is not mounted vertically, it will run slow, resulting in revenue loss. Electronic meters are not sensitive to the position in which they are installed.

Tamper

The mechanical meters can be tampered very easily even without disturbing the Wiring. They can be tampered either by using an external magnet or by inserting a thin film into the meter to touch the rotating disc. In addition to these methods, in the case of a single-phase meter, there are more than 20 conditions of external wiring that can make the meter record less. In the case of a three-phase meter, external wiring can be manipulated in 4 ways to make it slow. Hence, any of these methods cannot tamper electronic meters. Moreover they can detect the tampering of meter by using LED. [1]

2.2.3 Electronic meters New Features

Electronic meters provide many new features like prepaid metering and remote Metering that can improve the efficiency of the utility.

2.2.3.1 Remote Metering of Energy Meters

The introduction of electronic energy meters for electrical energy metering has resulted in various improvements in the operations of utilities apart from the increase in revenue due to better recording of energy consumption. One such additional benefit is the possibility of reading the meters automatically using meter-reading instruments even without going near the meter. Meter reading instruments (MRI) are intelligent devices with built in memory and keyboard. The meter reader can download the energy consumption and related information from the electronic meter into the meter reading instrument either by connecting the MRI physically to the meter using their communication ports or by communicating with the meter from a distance using Radio Frequency (RF) communication media. RF communication method is similar to a cordless telephone, which is quite common these days. The meter and the MRI are provided with an antenna. When the meter reader presses a button on the MRI, it communicates with the meter through RF and asks for all the data that are preset. The meter responds with all relevant data like meter identification number, cumulative energy consumed till that time etc. After reading many meters like that in one
MRI, the meter reader can go to the office and transfer all these data into a computer, which will have all these data for the previous billing period. Using these two data, the computer calculates the consumption for the current billing period and prepares the bill for each consumer.

The use of RF communication enables the utility to install the meters on top of the electric pole out of reach of the consumers thereby eliminating chances of tamper of the meter. Frequencies in the range of 400 MHz to 900 communications can be achieved using low power transmitters at reasonable costs. Power line carrier communication is another method of remote metering. In this method, the meter data is transferred to an MRI or computer by using the power line itself as the medium of transmission. This solution is generally cheaper than RF but needs good quality power lines to avoid loss of data. This method is more attractive for limited distance communication. Third medium of communication possible is telephone line. This is viable only for industrial meters like the Trivector meter because of the cost of Modems required and the need for a telephone line, which may not be available in every house. This medium has the advantage of unlimited distance range. Remote metering is typically not a default option, but something provided for selected customers. The preferred customer base may include suspicious clients or those located very close to others, such as in a high-rise building. In the latter case, tens or hundreds of meters may use RF to send billing data to a common collector unit, which then decodes the data with microcontrollers or computers. [1]

2.2.3.2 Prepayment metering

Yet another advantage of the electronic meter is the possibility of introducing Prepaid metering system. Prepaid metering system is the one in which the consumer pays money in advance to the utility and then feeds this information into his meter. The meter then updates the credit available to the consumer and starts deducting his consumption from available credit. Once the credit reaches a minimum specified value, meter raises an alarm. If the credit is completely exhausted, the meter switches off the loads of the consumer.

Main advantage of this system is that the utility can eliminate meter readers. Another benefit is that they get paid in advance. The consumer benefits due to elimination of penalty for late payment. Also it enables him to plan his electricity bill expenses in a better manner. Due to the
intelligence built in into the electronic meters, introduction of prepaid metering becomes much easier than in the case of electromechanical meters.

Energy meters, the only direct revenue interface between utilities and the consumers, have undergone several advancements in the last decade. The conventional electro-mechanical meters are being replaced with electronic meters to improve accuracy in meter reading. Asian countries are currently looking to introduce prepaid electricity meters across their distribution network, buoyed up by the success of this novel methodology in South Africa. The existing inherent problems with the post-paid system and privatization of state held power distribution companies are the major driving factors for this market in Asia. [1]

Over 40 countries have implemented prepaid meters in their markets In United Kingdom the system, has been in use for well over 70 years with about 3.5 million consumers. The prepaid program in South Africa was started in 1992 since then they have installed over 6 million meters. Other African counties such as Sudan, Madagascar are following the South African success. The concept has found ground in Argentina and New Zealand with few thousands of installations. The prepaid meters in the market today are coming up with smart cards to hold information on units consumed or equivalent money value. When the card is inserted, the energy meter reads it, connects the supply to the consumer loads, and debits the value. The meters are equipped with light emitting diodes (LED) to inform consumers when 75 percent of the credit energy has been consumed. The consumer then recharges the prepaid card from a sales terminal or distribution point, and during this process any changes in the tariff can also be loaded in the smart card. [1]

2.3 Payment methods

There are different ways to pay for energy consumption, and these payment solutions are directly linked with the meter’s capabilities. Among the different payment solutions used globally are:

2.3.1 Coins
This is the most widely established way to pay via a prepaid meter; coins offer a simple way to use a mechanical process to reload energy credit (Figure 2.3). The main disadvantage of this system is the vulnerability of the meter itself. Indeed, there is a risk of theft of the cash, while fraud (with specially designed coins) is not rare. The other negative impact is on the energy supplier or subcontractor companies that need to collect the cash on a regular basis. [3]

![Figure 2.3: Payment by Coins](image)

### 2.3.2 Token or PIN

This is one of the two most important payment solutions used in the metering ecosystem (Figure 2.4). This payment concept is based on simplicity and flexibility. There are different form factors to store the token or PIN. For example, the consumer could buy a ticket, including a token number, from dedicated shops and supermarkets. Alternatively, some solutions allow customers to reload a plastic key or a magnetic strip card via a dedicated vendor machine. [3]

![Figure 2.4: Payment by Token or PIN](image)

### 2.3.3 Memory cards

This is another solution that is in use everywhere in the globe for water, gas and electricity (Figure 2.5). When customers enter the card into the meter, the valve opens (for water)
and water is made available. The display allows the consumer to check credit left on the memory card. Such cards can be recharged by using dedicated software loaded onto a home computer. [3]

Figure 2.5: Payment by Memory Cards

2.3.4 Barcodes

With the deployment of pay-point payment solutions, barcodes could be used as shown in Figure 2.6. The customer would pay with a bank card or cash, with the generated barcode allowing the user to reload energy levels. [3]

Figure 2.6: Payment by Barcodes

2.3.5 Smart cards

Chip cards offer the same behavior as memory card solutions but with improved security (Figure 2.7). Indeed, a mutual authentication will be performed to secure the payment transaction. The form factor could be a bank debit card, credit card or prepaid phone card. [3]
2.3.6 Mobile phone

With the deployment of mobility, mobile devices could also be used as a prepaid payment solution (Figure 2.8). Indeed, solutions such as SMS for payment or even online mobile payment will allow the consumer to receive a credit token to recharge the meter.

All these payment solutions are already available for the prepaid market. Based on the required level of flexibility, security and reliability. [3]

2.4 Electrical Metering Instrument Technology

2.4.1 History of AMR meter

The Automated Meter Reading (AMR) was first conceived in 1962 by AT&T, but this experiment was not successful. After successful experiments, AT&T offered to provide phone system-based AMR services at $2 per meter. The price was four times more than the monthly cost of a person to read the meter-50 cents. Thus the program was considered economically unfeasible.
In 1972, Theodore George “Ted” Paraskevakos, while working with Boeing in Huntsville, Alabama, developed a sensor monitoring system which used digital transmission for security, fire and medical alarm systems as well as meter reading capabilities for all utilities. This technology was a spin off of the automatic telephone line identification system, now known as Caller ID.

In 1974, Mr. Paraskevakos was awarded a U.S. patent for this technology. In 1977, he launched Metretek, Inc., which developed and produced the first fully automated, commercially available remote meter reading and load management system. Since this system was developed pre-internet, Metretek utilized the IBM series 1 mini-computer. For this approach, Mr. Paraskevakos and Metretek were awarded multiple patents.

The modern era of AMR began in 1985, when several major full-scale projects were implemented. Hackensack Water Co. and Equitable Gas Co. were the first to commit to full-scale implementation of AMR on water and gas meters, respectively. In 1986, Minnegasco initiated a 450,000-point radio-based AMR system. In 1987, Philadelphia Electric Co. faced with a large number of inaccessible meters, installed thousands of distribution line carrier AMR units to solve this problem. Thus, AMR is becoming more viable each day. Advances in solid-state electronics, microprocessor components and low cost surface-mount technology assembly techniques have been the catalyst to produce reliable cost-effective products capable of providing the economic and human benefits that justify use of AMR systems on a large, if not full-scale, basis.

The primary driver for the automation of meter reading is not to reduce labor costs, but to obtain data that is difficult to obtain. As an example, many water meters are installed in locations that require the utility to schedule an appointment with the homeowner in order to obtain access to the meter. In many areas, consumers have demanded that their monthly water bill be based on an actual reading, instead of (for example) an estimated monthly usage based on just one actual meter reading made every 12 months. Early AMR systems often consisted of walk-by and drive-by AMR for residential customers, and telephone-based AMR for commercial or industrial customers. What was once a need for monthly data became a need for daily and even hourly readings of the meters. Consequently, the sales of drive-by and telephone AMR has declined in the US, while sales of fixed networks has increased. The US Energy Policy Act of 2005 asks that
electric utility regulators consider the support for a “...time-based rate schedule (to) enable the electric consumer to manage energy use and cost through advanced metering and communications technology.” [4]

Today the metering instrument technology grown up significantly, such that the Consumed energy can be calculated mathematically, displayed, data can be stored, data can be transmitted, etc. Presently the microcontrollers are playing major role in metering instrument technology. The present project work is designed to collect the consumed energy data of a particular energy consumer through wireless communication system (without going to consumer house), the system can be called as automatic meter reading (AMR) system. The Automatic Meter reading system is intended to remotely collect the meter readings of a locality using a communication system, without persons physically going and reading the meters visually. [1]

2.5 Embedded system

An embedded system is a combination of computing H/W & S/W, and perhaps additional mechanical or other parts, designed to perform a specific function. An embedded is a component with in some larger system.

By definition, all embedded system contents a processor and software but what other feature do they have in common? Certainly, in order to have software, there must be a placed to store the executable code and temporary storage for run time data manipulation. This take the form of ROM and RAM, respectively; any embedded system will have the sum of the both. If only a small amount of memory is required, it might be contained whit in the same chip as processor. Otherwise, one or both types of memory will reside in external memory chip. [5] All smart meter it can be classified as embedded system here we mention different technologies developed.
Remote meter reading (or AMR) refers to the system that uses a communication technique to automatically collect the meter readings and other relevant data from utilities’ gas meters, without the need to physically visit the gas meters. The development of AMR technology has catapulted meter data to center stage of the utility business plan. [6]

2.6 Benefits of AMR:-

The automatic meter reading (AMR) technology is very useful in many applications. By using AMR technology we can accommodate a lot of benefits. Some benefits of AMR are as follow.

2.6.1 Electrical Company Benefits:-

- Smart automated processes instead of manual work.
- Accurate information from the network load to optimize maintenance and investments.
- Customized rates and billing dates.
- Streamlined high bill investigations.
- Detection of tampering of Meters.
- Accurate measurement of transmission losses.
- Better network performance and cost efficiency.
- Demand and distribution management.
- More intelligence to business planning.
- Better company credibility. [6]

2.6.2 Customer Benefits:-

- Precise consumption information.
- Clear and accurate billing.
- Automatic outage information and faster recovery.
- Better and faster customer service.
- Flag potential high consumption before customer gets a high bill. [6]

2.7 AMR Applications:-

As technology continues to improve in price/performance, the number of municipal
utilities implementing automatic meter reading (AMR) systems continues to grow. Today, most AMR deployments are “walk-by” or “drive-by” systems. A battery-operated transmitter in each meter sends a radio frequency (RF) signal that is read by a special receiver either carried by hand or mounted in a vehicle. These solutions require a much smaller staff of meter readers, who merely need to walk or drive by the many meters in any neighborhood. Although this form of AMR is an enormous improvement over manual meter reading, continued high labor and vehicle costs are driving the industry to an even better solution. [6]

Among the many advantages are the ability to monitor daily demand, implement conservation programs, create usage profiles by time of day, and detect potentially hazardous conditions, such as leaks or outages. But there is still one drawback with these AMR deployments: the costly network backhaul required by leased lines or cellular services from a local telephone company, or Power Line Carrier (PLC) solutions from the local power company.

AMR is the remote collection of consumption data from customers’ utility meters using telephony, radio frequency, power lines and satellite communications technologies. AMR provides water, gas and electric utility-service companies the opportunity to increase operational efficiency, improve customer service, reduce data-collection costs and quickly gather critical information that provides insight to company decision-makers. [6]

2.8 Different AMR Technologies:-

There are many different technologies which are used in the AMR. Using these technologies data can be send from transmitting end to the receiving end. In our thesis we are using RF technology for transmitting the meter reading from one point to other point. The different types of technologies are described below. Out of which handheld technology is uses rarely. [6]

2.8.1 Handheld:-

In handheld AMR, a meter reader carries a handheld computer with a built-in or attached receiver/transceiver (radio frequency or touch) to collect meter readings from an AMR capable meter. This is sometimes referred to as “walk-by” meter reading since the meter reader walks by
the locations where meters are installed as they go through their meter reading route. Handheld computers may also be used to manually enter readings without the use of AMR technology. [6]

2.8.2 Touch Based:-

With touch based AMR, a meter reader carries a handheld computer or data collection device with a wand or probe. The device automatically collects the readings from a meter by touching or placing the read probe in close proximity to a reading coil enclosed in the touchpad. When a button is pressed, the probe sends an interrogate signal to the touch module to collect the meter reading. The software in the device matches the serial number to one in the route database, and saves the meter reading for later download to a billing or data collection computer. [6]

2.8.3 Mobile:-

Mobile or “Drive-by” meter reading is where a reading device is installed in a vehicle. The meter reader drives the vehicle while the reading device automatically collects the meter readings. With mobile meter reading, the reader does not normally have to read the meters in any particular route order, but just drives the service area until all meters are read. Components often consist of a laptop or proprietary computer, software, RF receiver or transceiver, and external vehicle antennas.[6]

2.8.4 Fixed Network:-

Fixed Network AMR is a method where a network is permanently installed to capture meter readings. This method can consist of a series of antennas, towers, collectors, repeaters, or other permanently installed infrastructure to collect transmissions of meter readings from AMR capable meters and get the data to a central computer without a person in the field to collect it.

There are several types of network topologies in use to get the meter data back to a central computer. A star network is the most common, where a meter transmits its data to a central collector or repeater. Some systems use only collectors which receive and store data for processing. Others also use a repeater which forwards a reading from a more remote area back to a main collector without actually storing it. A repeater may be forwarded by RF signal or
sometimes is converted to a wired network such as telephone or IP network to get the data back to a collector. Some manufacturers are developing mesh networks where meters themselves act as repeaters passing the data to nearby meters until it makes it to a main collector. A mesh network may save the infrastructure of many collection points, but is more data intensive on the meters. One issue with mesh networks it that battery operated ones may need more power for the increased frequency of transmitting. [6]

2.8.5 Radio Frequency Network:-

Radio frequency based AMR can take many forms. The more common ones are Handheld, Mobile, and Fixed network. There are both two-way RF systems and one-way RF systems in use that use both licensed and unlicensed RF bands. In a two-way or “wake up” system, a radio transceiver normally sends a signal to a particular transmitter serial number, telling it to wake up from a resting state and transmit its data. The Meter attached transceiver and the reading transceiver both send and receive radio signals and data. In a one-way “bubble-up” or continuous broadcast type system, the transmitter broadcasts readings continuously every few seconds. This means the reading device can be a receiver only, and the meter AMR device a transmitter only.

Data goes one way, from the meter AMR transmitter to the meter reading receiver. There are also hybrid systems that combine one-way and two-way technologies, using one-way communication for reading and two way communication for programming functions. RF based meter reading usually eliminates the need for the meter reader to enter the property or home, or to locate and open an underground meter pit. The utility saves money by increased speed of reading, has lower liability from entering private property, and has less chance of missing reads because of being locked out from meter access. [6]

2.8.6 Power Line Communication:-

PLC AMR systems use power line communications (PLC) technology to provide comprehensive two-way communications over the existing electricity supply network. This system enables utilities to implement cost-effective AMR solutions.

A Power Line Communication (PLC) /AMR is a method where electronic data is transmitted over power lines back to the substation, then relayed to a central computer in the utility's main office. This would be considered a type of fixed network system -- the network
being the distribution network which the utility has built and maintains to deliver electric power. Such systems are primarily used for electric meter reading. Some providers have interfaced gas and water meters to feed into a PLC type system.

The Power Line /AMR system remotely reads customer meters at real time and then transfers the data into the billing system. [6]

![Diagram of PLC AMR systems](Figure 2.9: PLC AMR systems)

### 2.8.7 Wireless Fidelity (Wi-Fi)

Today many meters are designed to transmit using Wi-Fi even if a Wi-Fi network is not available, and they are read using a drive-by local Wi-Fi hand held receiver. Narrow-banded signal has a much greater range than Wi-Fi so the numbers of receivers required for the project are far fewer the number of Wi-Fi access points covering the same area. These special receiver stations then take in the narrow-band signal and report their data via Wi-Fi. Most of the automated utility meters installed in the Corpus Christi area are battery powered. Compared to narrow-band burst telemetry, Wi-Fi technology uses far too much power for long-term battery-powered operation. Thus Wi-Fi is the efficient mean of communication in AMR technologies, which allows communication between the central data base and the end users, and defines the efficient reliability of the system. Thus offering a ultimate mean to fulfill the requirement. [6]
In general AMR can be implemented using a variety of technologies. Depending on the scope, available infrastructure and network topologies, many technologies could be employed to realize AMR systems. Generally however, these technologies are divided into three groups:

(a) Legacy Options:
These comprises traditionally available technologies used in communication systems today, such as POTS (Plain Old Telephone System), Public Wireless (Paging, GSM, CDMA, GPRS, etc) and Satellite (Low Orbit Communication Satellites)

(b) Broadband Options:
Newer technologies used for large bandwidth data communication such as Broadband over Power lines (BPL) and Wireless Broadband (Wi-Fi, WiMax, etc).

(C) Cost-Effective Options:
These are the technologies of choice for low bandwidth; cost sensitive applications using Private Wireless (licensed & Unlicensed ISM Band) and Narrowband Power Line Communication (PLC). [7]
CHAPTER THREE

AUTOMATIC ENERGY METER READING DESIGN
AND SIMULATION

3.1 Hardware part

This thesis is useful for billing purposes in Electricity board. Instead of going to every house &
taking the readings, by just click on button the readings of the house can be received and the electric bill
can be recharged. And the consumer must send value from meter by using meter keypad to recharge.
This will reduce illegal power using without paying money.

The component used to build electrical energy meter system describe as below:

3.1.1 (4x4) Matrix Membrane Keypad

This 16-button keypad provides a useful human interface component for microcontroller projects.

Convenient adhesive backing provides a simple way to mount the keypad in a variety of applications.

3.1.1.1 Features

- Ultra-thin design
- Adhesive backing
- Excellent price/performance ratio
- Easy interface to any microcontroller
- Example programs provided for the BASIC
- Stamp 2 and Propeller P8X32A Microcontrollers
3.1.1.2 Key Specifications

- Maximum Rating: 24 VDC, 30 mA
- Interface: 8-pin access to 4x4 matrix
- Operating temperature: 32 to 122 °F (0 to 50°C)

3.1.1.3 Dimensions

Keypad, 2.7 x 3.0 in (6.9 x 7.6 cm)

Cable: 0.78 x 3.5 in (2.0 x 8.8 cm)

3.1.1.4 Application Ideas

- Security systems
- Menu selection
- Data entry for embedded systems

3.1.1.5 How it Works

Matrix keypads use a combination of four rows and four columns to provide button states to the host device, typically a microcontroller. Underneath each key is a pushbutton, with one end connected to one row, and the other end connected to one column. These connections are shown in Figure (3.2).
In order for the microcontroller to determine which button is pressed, it first needs to pull each of the four columns (pins 1-4) either low or high one at a time, and then poll the states of the four rows (pins 5-8). Depending on the states of the columns, the microcontroller can tell which button is pressed. For example, say your program pulls all four columns low and then pulls the first row high. It then reads the input states of each column, and reads pin 1 high. This means that a contact has been made between column 4 and row 1, so button ‘A’ has been pressed. [15]

3.1.2 Liquid Crystal Display

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.
The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD. [16]

Figure 3.3: LCD

3.1.2.1 Pin configuration

Table 3.1 Character LCD type HD44780 Pin diagram

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin no. 1</td>
<td>VSS</td>
<td>Power supply (GND)</td>
</tr>
<tr>
<td>Pin no. 2</td>
<td>VCC</td>
<td>Power supply (+5V)</td>
</tr>
<tr>
<td>Pin no. 3</td>
<td>VEE</td>
<td>Contrast adjust</td>
</tr>
<tr>
<td>Pin no. 4</td>
<td>RS</td>
<td>0 = Instruction input</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Data input</td>
</tr>
<tr>
<td>Pin no. 5</td>
<td>R/W</td>
<td>0 = Write to LCD Module</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 = Read from LCD module</td>
</tr>
<tr>
<td>pin No.</td>
<td>Name</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Pin no. 1</td>
<td>D7</td>
<td>Data bus line 7 (MSB)</td>
</tr>
<tr>
<td>Pin no. 2</td>
<td>D6</td>
<td>Data bus line 6</td>
</tr>
<tr>
<td>Pin no. 3</td>
<td>D5</td>
<td>Data bus line 5</td>
</tr>
<tr>
<td>Pin no. 4</td>
<td>D4</td>
<td>Data bus line 4</td>
</tr>
<tr>
<td>Pin no. 5</td>
<td>D3</td>
<td>Data bus line 3</td>
</tr>
<tr>
<td>Pin no. 6</td>
<td>D2</td>
<td>Data bus line 2</td>
</tr>
<tr>
<td>Pin no. 7</td>
<td>D1</td>
<td>Data bus line 1</td>
</tr>
<tr>
<td>Pin no.</td>
<td>Label</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>8</td>
<td>D0</td>
<td>Data bus line 0 (LSB)</td>
</tr>
<tr>
<td>9</td>
<td>EN1</td>
<td>Enable signal for row 0 and 1 (1st controller)</td>
</tr>
<tr>
<td>10</td>
<td>R/W</td>
<td>0 = Write to LCD module, 1 = Read from LCD module</td>
</tr>
<tr>
<td>11</td>
<td>RS</td>
<td>0 = Instruction input, 1 = Data input</td>
</tr>
<tr>
<td>12</td>
<td>VEE</td>
<td>Contrast adjust</td>
</tr>
<tr>
<td>13</td>
<td>VSS</td>
<td>Power supply (GND)</td>
</tr>
<tr>
<td>14</td>
<td>VCC</td>
<td>Power supply (+5V)</td>
</tr>
<tr>
<td>15</td>
<td>EN2</td>
<td>Enable signal for row 2 and 3 (2nd controller)</td>
</tr>
<tr>
<td>16</td>
<td>NC</td>
<td>Not Connected</td>
</tr>
</tbody>
</table>

### 3.1.3 MAX232

The MAX232 converts from RS232 levels to TTL voltage levels, and vice versa. One advantage of the MAX232 chip is that it uses a +5 v power source which is the same as the source voltage for the microcontroller chip. In other words, with a single +5 v power supply we can power both the microcontroller and MAX232 chip, with no need for the dual power supplies that are common in many older systems.

The MAX232 has two sets of line drivers for transferring and receiving data. The line drivers used for TxD are called T1 and T2, while the line drivers for RxD are designated as R1 and R2. In many applications only one of each is used. For example, T1 and R1 are used together for TxD and RxD of the 89s52, and the second set is left unused. [24]
3.1.3.1 Types of MAX232

1) MAX232N where “N” represent PDIP package style this package is easy to sold and most widely used.

2) MAX232D where “D” indicates the SOIC package which is difficult to sold and required a trained professional to be used correctly.

![MAX232 Chip Diagram]

Figure 3.4: MAX232

Table 3.3 Function Tables Each Driver

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIN</td>
<td>TOUT</td>
</tr>
<tr>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
</tr>
</tbody>
</table>
### Table 3.4 Function Tables Each Receiver

<table>
<thead>
<tr>
<th>Input RIN</th>
<th>Output ROUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>H</td>
<td>L</td>
</tr>
</tbody>
</table>

H = high level, L = low level

#### 3.1.3.2 Construction of MAX232

Mostly MAX232 used in 16-pin DIP package. It consist of 3 major blocks. It can only be powered by 5 volts to make it power supply compatible with most of the embedded systems. First block is the voltage double in this ic switched capacitor techniques is used to make the voltage double. Once the voltage is doubled second block will converts that voltage to +10 and -10. The third block consists of 2 transmitters and 2 receivers which actually convert the voltage levels.

Max232 requires minimum 4 external capacitor. Their Value can range from 1uf to 10uf and 16 volts or more rating. There are many different versions of this versatile IC available each of them Require different capacitor value for proper working. [24]
3.1.3.3 Application and uses of MAX232

Preliminary MAX232 is used in Serial communication. Problem arises when we have to communicate between TTL logic and CMOS logic based systems. RS232 is internationally defined standard named as EIA/TIA-232-E and in this standard logic 0 is the voltage between +3 to +15 and
logic 1 is defined as the voltage between -3 to -15. In TTL logic 0 is defined is by 0 volt and 1 is defined by 5 volt so in this scenario this is a very handy IC to be incorporated. [24]

3.1.3.4 Other Applications & Uses

- Battery Powered RS 232 Systems
- Interface Translation
- Low Power Modems
- RS 232 Networks (Multidrop)
- Portable Computing

3.1.3.5 PC Serial PORT communication by using MAX232 IC:

Desktop and some old Laptops have Serial port which comes in DB9 package. In Most of the Circuits designer is concerned about the Tx and Rx pins only so the function of the rest of the pins are not used here mostly.

In the above circuit only one Driver is used and second driver can be used for other purpose. TTL data is available on pin 12 and pin 11 and these pins can be attached to Microcontroller or any system which accept TTL logic. [24]
3.1.4 RF Modules

The XBee and XBee-PRO RF Modules were engineered to meet IEEE 802.15.4 standards and support the unique needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of data between devices. The modules operate within the ISM 2.4 GHz frequency band and are pin-for-pin compatible with each other.

The XBee radios can all be used with the minimum number of connections – power (3.3 V), ground, data in and data out (UART), with other recommended lines being Reset and Sleep. Additionally, most XBee families have some other flow control, I/O, A/D and indicator lines built in. A version of the XBees called the programmable XBee has an additional onboard processor for user’s code. The programmable XBee and a new surface mount (SMT) version of the XBee radios were both introduced in 2010. [17]

3.1.4.1 XBee Series
• **XBee Series 1** (also called XBee 802.15.4) - These are the easiest to work with, they don’t need to be configured, although they can benefit from it. Because they are easy to work with we recommend these especially if you are just starting out. For point to point communication.

• **XBee Znet 2.5** (Formerly Series 2) Retired - Series 2 modules must be configured before they can be used. They can run in a transparent mode or work with API commands, but this all depends on what firmware you configure these with. These also can run in a mesh network making them highly configurable and awesome modules. It also makes them harder to use modules. These modules are in no way compatible with the Series 1 modules. These modules are no longer sold but are being replaced with the mostly compatible ZB modules.

• **ZB** (the current Series2ish module) - Basically the Znet2.5 hardware with new firmware. Meaning they can also run in a transparent mode or work with API commands. They can also run in a mesh network making them highly configurable and awesome modules. You can grab the new firmware and upgrade them yourself. The firmware between the two is not compatible (but is easily interchangeable) so you will have to pick which firmware you want to use on your network and stick with it. These are often call Series 2 modules, but it does distinguish these from the Series 1 modules which is usually all people want to know. These modules will not work in any way shape or form with the Series 1 so stop thinking about it.

• **2B**(the even more current Series2ish module) - These new modules improve on the hardware of the Series 2 modules improving things like power usage. They run the ZB firmware but because the hardware has been changed they can no longer run the Znet2.5 firmware. So if you are looking to add this to an existing 2.5Znet network beware. Currently some of our boards are 2B and others are ZB

• **900MHz** - Technically not a series but it is a family just like the others. The 900s can run 2 different types of firmware, the DigiMesh firmware and the Point to Multipoint firmware. Digi actually sells both modules, the hardware is the same just with different firmware. Sparkfun only sells the point to multipoint version, but you can change the firmware yourself. These modules should be more or less plug and play but of course can benefit from all the cool features you can configure.
• **XSC** - Basically these are 900 modules that sacrifice data rate for range. The regular 900 modules have a data rate of 156KBps (the others are all around 250Kbps) but the XSC module is only about 10Kbps. On the other hand if you attach a high gain antenna you can get a range of about 15 miles and 6 miles with a regular antenna. These modules do not require configuration out of the box and have some other differences including a different command set so make sure you check out the datasheet.

• **XSC S3B** - This is an upgraded version of the XSC modules which is less power-hungry than the previous generation despite having a higher selectable transmitting power of 250mW. This higher Tx power allows for line-of-sight range up to 28 miles with the right antenna. The S3B modules also feature higher-throughput than the previous generation XSC modules.[32]

### 3.1.4.2 Key Features for XBee series 1

**A- Long Range Data Integrity**
- Indoor/Urban: up to 100’ (30 m)
- Outdoor line-of-sight: up to 300’ (90 m)
- Transmit Power: 1 maw (0 dBm)
- Receiver Sensitivity: -92 dBm

**B- Low Power**
- TX Peak Current: 45 ma (@3.3 V)
- RX Current: 50 ma (@3.3 V)
- Power-down Current: < 10 a

**C- ADC and I/O line support**

- Analog-to-digital conversion, Digital I/O/Line Passing

**D- Advanced Networking & Security**

- Retries and Acknowledgements DSSS (Direct Sequence Spread Spectrum)
  - Each direct sequence channels has over 65,000 unique network addresses available Source/Destination Addressing
  - Unicast & Broadcast Communications Point-to-point, point-to-multipoint and peer-to-peer topologies supported.
E- Easy-to-Use

No configuration necessary for out-of box RF communications Free X-CTU Software (Testing and configuration software) AT and API Command Modes for configuring module parameters Extensive command set small form factor. [17]

3.1.4.3 Pin configuration

Table 3.6 RF pin configuration
<table>
<thead>
<tr>
<th>Pin #</th>
<th>Name</th>
<th>Direction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VCC</td>
<td>-</td>
<td>Power supply</td>
</tr>
<tr>
<td>2</td>
<td>DOUT</td>
<td>Output</td>
<td>UART Data Out</td>
</tr>
<tr>
<td>3</td>
<td>DIN / CONFIG</td>
<td>Input</td>
<td>UART Data In</td>
</tr>
<tr>
<td>4</td>
<td>DO8*</td>
<td>Output</td>
<td>Digital Output 8</td>
</tr>
<tr>
<td>5</td>
<td>RESET</td>
<td>Input</td>
<td>Module Reset (reset pulse must be at least 200 ns)</td>
</tr>
<tr>
<td>6</td>
<td>PWM0 / RSSI</td>
<td>Output</td>
<td>PWM Output 0 / RX Signal Strength Indicator</td>
</tr>
<tr>
<td>7</td>
<td>PWM1</td>
<td>Output</td>
<td>PWM Output 1</td>
</tr>
<tr>
<td>8</td>
<td>[reserved]</td>
<td>-</td>
<td>Do not connect</td>
</tr>
<tr>
<td>9</td>
<td>DTR / SLEEP_RQ / DI8</td>
<td>Input</td>
<td>Pin Sleep Control Line or Digital Input 8</td>
</tr>
<tr>
<td>10</td>
<td>GND</td>
<td>-</td>
<td>Ground</td>
</tr>
<tr>
<td>11</td>
<td>AD4 / DI04</td>
<td>Either</td>
<td>Analog Input 4 or Digital I/O 4</td>
</tr>
<tr>
<td>12</td>
<td>CTS / DI07</td>
<td>Either</td>
<td>Clear-to-Send Flow Control or Digital I/O 7</td>
</tr>
<tr>
<td>13</td>
<td>ON / SLEEP</td>
<td>Output</td>
<td>Module Status Indicator</td>
</tr>
<tr>
<td>14</td>
<td>VREF</td>
<td>Input</td>
<td>Voltage Reference for A/D Inputs</td>
</tr>
<tr>
<td>15</td>
<td>Associate / AD5 / DI05</td>
<td>Either</td>
<td>Associated Indicator, Analog Input 5 or Digital I/O 5</td>
</tr>
<tr>
<td>16</td>
<td>RTS / AD6 / DI06</td>
<td>Either</td>
<td>Request-to-Send Flow Control, Analog Input 6 or Digital I/O 6</td>
</tr>
<tr>
<td>17</td>
<td>AD3 / DI03</td>
<td>Either</td>
<td>Analog Input 3 or Digital I/O 3</td>
</tr>
<tr>
<td>18</td>
<td>AD2 / DI02</td>
<td>Either</td>
<td>Analog Input 2 or Digital I/O 2</td>
</tr>
<tr>
<td>19</td>
<td>AD1 / DI01</td>
<td>Either</td>
<td>Analog Input 1 or Digital I/O 1</td>
</tr>
<tr>
<td>20</td>
<td>AD0 / DI00</td>
<td>Either</td>
<td>Analog Input 0 or Digital I/O 0</td>
</tr>
</tbody>
</table>
3.1.4.4 Flow control

Figure 3.8: internal data flow diagram

3.1.4.5 DI (Data In) Buffer

When serial data enters the RF module through the DI pin (pin 3), the data is stored in the DI Buffer until it can be processed. Hardware Flow Control (CTS). When the DI buffer is 17 bytes away from being full; by default, the module de-asserts CTS (high) to signal to the host device to stop sending data [refer to D7 (DIO7 Configuration) parameter]. CTS is re-asserted after the DI Buffer has 34 bytes of memory available.

How to eliminate the need for flow control:

1. Send messages that are smaller than the DI buffer size (202 bytes).

2. Interface at a lower baud rate [BD (Interface Data Rate) parameter] than the throughput data rate.

Case in which the DI Buffer may become full and possibly overflow:

If the module is receiving a continuous stream of RF data, any serial data that arrives on the DI Pin is placed in the DI Buffer. The data in the DI buffer will be transmitted over-the-air when the Module is no longer receiving RF data in the network. [17]
3.1.4.6 DO (Data Out) Buffer

When RF data is received, the data enters the DO buffer and is sent out the serial port to a host device. Once the DO Buffer reaches capacity, any additional incoming RF data is lost. Hardware Flow Control (RTS). If RTS is enabled for flow control (D6 (DIO6 Configuration) Parameter = 1), data will not be sent out the DO Buffer as long as RTS (pin 16) is de-asserted.

Two cases in which the DO Buffer may become full and possibly overflow:

1. If the RF data rate is set higher than the interface data rate of the module, the module will receive data from the transmitting module faster than it can send the data to the host.

2. If the host does not allow the module to transmit data out from the DO buffer because of being held off by hardware or software flow control. [17]

3.1.4.7 Modes of Operation

XBee®/XBee-PRO® RF Modules operate in five modes.

A. Idle Mode

When not receiving or transmitting data, the RF module is in Idle Mode. The module shifts into the other modes of operation under the following conditions:

• Transmit Mode (Serial data is received in the DI Buffer)

• Receive Mode (Valid RF data is received through the antenna)

• Sleep Mode (Sleep Mode condition is met)

• Command Mode (Command Mode Sequence is issued) [17]
B. Transmit/Receive Modes

RF Data Packets

Each transmitted data packet contains a Source Address and Destination Address field. The Source Address matches the address of the transmitting module as specified by the MY (Source Address) parameter (if MY >= 0xFFF), the SH (Serial Number High) parameter or the SL (Serial Number Low) parameter. The <Destination Address> field is created from the DH (Destination Address High) and DL (Destination Address Low) parameter values. The Source Address and/or Destination.

Address fields will either contain a 16-bit short or long 64-bit long address. The RF data packet structure follows the 802.15.4 specification. [17]

Direct and Indirect Transmission

There are two methods to transmit data:
• Direct Transmission - data is transmitted immediately to the Destination Address

• Indirect Transmission - A packet is retained for a period of time and is only transmitted after the destination module (Source Address = Destination Address) requests the data.

Indirect Transmissions can only occur on a Coordinator. Thus, if all nodes in a network are End Devices, only Direct Transmissions will occur. Indirect Transmissions are useful to ensure packet delivery to a sleeping node. The Coordinator currently is able to retain up to 2 indirect messages. [17]

C. Sleep Mode

Sleep Modes enable the RF module to enter states of low-power consumption when not in use. In order to enter Sleep Mode, one of the following conditions must be met (in addition to the module having a non-zero SM parameter value):

• Sleep_RQ (pin 9) is asserted and the module is in a pin sleep mode (SM = 1, 2, or 5)

• The module is idle (no data transmission or reception) for the amount of time defined by the ST (Time before Sleep) parameter. [NOTE: ST is only active when SM = 4-5.]

The SM command is central to setting Sleep Mode configurations. By default, Sleep Modes are disabled (SM = 0) and the module remains in Idle/Receive Mode. When in this state, the module is constantly ready to respond to serial or RF activity. [17]

D. Command Mode

To modify or read RF Module parameters, the module must first enter into Command Mode – a state in which incoming characters are interpreted as commands. Two Command Mode options are supported:

AT Command Mode and API Command Mode. [17]

3.1.5 Timers

Timers are those circuits, which provide periodic signals to a digital system which change the state of that system. In other words, those circuits, which work on the base of multivibrator changes or a device, which can be used as multivibrator is called Timer. [25]

3.1.5.1 Types of Timers

There are two basic types of 555 Timer with respect to function and operation.
1. 555 Timer as Astable Multivibrator
2. 555 Timer as Monostable Multivibrator

3.1.5.2 (555) Timer

555 Timer is a digital monolithic integrated circuit which may be used as a clock generator. In other words, 555 Timer is a circuit which may be connected as a stable or monostable multivibrator.

555 Timer is a versatile and most usable device in the electronics circuits and designs which work for both stable and monostable states. It may provide time delay from microseconds up to many hours. [25]

The pin diagram of DIP (Dual inline Package) 555 timer with 8 pins. shown in figure (3.10).

Figure 3.10: 555 Timer construction & pin out

555 timer is a very cheap IC which works for wide range of potential difference (typically, from 4.5 to 15V DC) and the different provided input voltages do not affect the timer output.

555 Timer is a linear device and it can be directly connected to the CMOS or TTL (Transistor – Transistor Logic) digital circuits due to its compatibility but, interfacing is must to use 555 timer with other digital circuits. [25]
3.1.5.3 (555) Timer Construction

There are lots of manufacturers who manufacture 555 timer which included the number 555 e.g. NE555, CA555, SE555, MC14555 etc. typically, two 555 timers sandwiched inside a single chip which is called 556. Nowadays, chips are available with four 555 timers in it. These devices are available in circular IC with eight (8), DIP (Dual inline Package) with 8 pins or DIP with 14 pins.

Explanation of the 8 pins of 555 Timer:

1. Ground (GND)
   It’s the common ground point of the circuit. The ground terminal of external circuit as well as power supply (Vcc) ground terminal is connected with this i.e. GND (Ground) terminal of 555 timer.

2. Trigger
   When Trigger terminal gets one –third (1/3) of the supply voltage i.e. Vcc/3 equal amplitude’s negative trigger pulse, then the circuit output changes form Low to High.

3. Output
   This terminal is used for getting output and connected with load. At any instant, its value is low or high.

4. Reset
   Without taking into account the previous state of output, by providing a trigger pulse to this terminal resets the device. I.e. Its output becomes low.

5. Control Voltage
   There are two third positive voltages of the total Supply voltages (Vcc) at control voltage terminal. Thus, it becomes a part of the comparator circuit. Generally, a capacitor is connected between ground and voltage control terminals.

6. Threshold Voltage
   Threshold voltage and control voltage is the two inputs of comparator circuit. The circuit compares the available voltage at threshold voltage terminal to the available reference voltage at control terminal.

If the available voltage at threshold terminal (Pin 6) is greater than the control voltage i.e. two-third of Vcc, then the output would be low, otherwise, it would be high.
7. Discharge

When output is low, then Discharge terminal provides a low resistance discharge path to the externally connected capacitor. However, it acts an open circuit, when output is high.

8. +Vcc (Supply Voltage Terminal)

Supply voltage is provided at this terminal for timer operation.

A simple 555 timer circuit is shown below in fig _ which shows the internal construction of 555 timer. According to the fig, the timer contains on two comparators, an RS flip flop, an Output stitch (output buffer) and a Discharge Transistor Q1.

In addition, there are three 5kΩ resistors are connected in series with 5kΩ resistor which first end is connected with Vcc (Pin 8 = Supply voltage) and the other end is connected with ground (GND = Pin 1).

Good to Know: due to the three 5kΩ series connected resistors, this IC timer chip is called 555 Timer J. [25]
In the 555 Timer block or functional diagram, comparators are those devices which output is high, when their positive input voltage is greater than their negative input voltage and vice versa.

The voltage divider in the circuit (which contains on three series connected 5kΩ resistors), which provides the trigger level of one-third of Vcc (Vcc/3) and two-third (2/3) of threshold voltage. To understand this point, suppose the input value is 15V. In this case, the value of trigger level would be 5V as (Vcc/3 = 15V/3 = 5V). And the value of threshold level would be 10V as (Vcc x 2/3 = 15V x (2/3)) = 10V.

When needed, the trigger level and threshold can be adjusted by using the Control Voltage terminal (Pin 5) i.e. by changing the control voltage at Pin 5; we may change the trigger level and
threshold voltage according to the required specification. However, in this case, the value of trigger and threshold would be remain equal to 1/3 Vcc and 2/3 Vcc respectively.

When the normal high trigger input value instantaneously reduce then the 1/3 Vcc, Then the output of Comparator B becomes High from Low, as a result, RS latch or RS Flip flop goes to “set”. When flip flop goes to set, then Output (at Point 3) becomes high. Simultaneously, the discharge transistor Q1 gets off and The output remains high until the value of normally low threshold input does not increase then the 2/3 Vcc.

As soon as the threshold input increase than the 2/3Vcc, then the output of comparator A becomes Low, as a result, RS flip flop get reset (because the output of comparator is directly connected to the RS flip flop’s input R as shown in the fig). When flip flop gets reset, output becomes low and discharge transistor Q1 goes to on.

The flip flop can be reset by applying external input reset without threshold circuit. Note that, the trigger and threshold inputs (Pin 2 and Pin 6) are controlled by externally components and the 555 timer can be used for stable or monostable operation by controlling the trigger and threshold inputs with the help of those external components. [25]

3.1.5.4 Astable operation

Astable circuits produce pulses. When the circuit is connected as shown in Figure (3.12) (pins 2 and 6 connected) it triggers itself and free runs as a multi-vibrator. The external capacitor charges through R1 and R2 and discharges through R2 only. Thus the duty cycle can be set accurately by adjusting the ratio of these two resistors. In the astable mode of operation, C1 charges and discharges between 1/3 VCC and 2/3 VCC. As in the triggered mode, the charge and discharge times and, therefore, frequencies are Independent of the supply voltage. [33]
3.1.6 Relay

The relay takes advantage of the fact that when electricity flows through a coil, it becomes an electromagnet. The electromagnetic coil attracts a steel plate, which is attached to a switch. So the switch's motion (ON and OFF) is controlled by the current flowing to the coil, or not, respectively.

A very useful feature of a relay is that it can be used to electrically isolate different parts of a circuit. It will allow a low voltage circuit (e.g. 5VDC) to switch the power in a high voltage circuit (e.g. 100 VAC or more).

The relay operates mechanically, so it cannot operate at high speed. [18]
3.1.6.1 Type of Relays

There are many kinds of relays. You can select one according to your needs. The various things to consider when selecting a relay are its size, voltage and current capacity of the contact points, drive voltage, impedance, number of contacts, resistance of the contacts, etc. The resistance voltage of the contacts is the maximum voltage that can be conducted at the point of contact in the switch. When the maximum is exceeded, the contacts will spark and melt, sometimes fusing together. The relay will fail. The value is printed on the relay. [18]

3.1.7 ATMEGA32 microcontroller

3.1.7.1 Introduction

Microcontroller often serves as the “brain” of a mechatronic system. Like a mini, self-contained computer, it can be programmed to interact with both the hardware of the system and the user. Even the most basic microcontroller can perform simple math operations, control digital outputs, and monitor digital inputs. As the computer industry has evolved, so has the technology associated with microcontrollers. Newer microcontrollers are much faster, have more memory, and have a host of input and output features that dwarf the ability of earlier models. Most modern controllers have analog-to-digital converters, high-speed timers and counters; interrupt capabilities, outputs that can be pulse-width modulated, serial communication ports, etc. The ATmega32 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16 achieves
throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

– Power-down Mode: < 1 μA. [19]

3.1.7.2 Pin configuration:

![ATMEGA32 microcontroller pin configuration](image)

Figure 3.14: ATMEGA32 microcontroller pin configuration

The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC
microcontrollers.

With In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega32 is a powerful microcontroller that provides a highly-flexible and cost-effective solution to many embedded control applications. The ATmega32 AVR is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, in-circuit emulators, and evaluation kits. [19]

### 3.1.7.3 Pin Descriptions Details

**CC** Digital supply voltage.

**GND** Ground.

**Port A (PA7..PA0)** Port A serves as the analog inputs to the A/D Converter. Port A also serves as an 8-bit bi-directional I/O port, if the A/D Converter is not used. Port pins can provide internal pull-up resistors (selected for each bit). The Port A output buffers have symmetrical drive characteristics with both high sink and source capability. When pins PA0 to PA7 are used as inputs and are externally pulled low, they will source current if the internal pull-up resistors are activated. The Port A pins are tri-stated when a reset condition becomes active, even if the clock is not running.

**Port B (PB7..PB0)** Port B is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running. Port B also serves the functions of various special features of the ATmega32.

**Port C (PC7..PC0)** Port C is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port C output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running. If the JTAG interface is enabled, the pull-up resistors on pins PC5(TDI), PC3(TMS) and PC2(TCK) will be activated even if a reset occurs. Port C also serves the functions of the JTAG interface and other special features of the ATmega32.

**Port D (PD7..PD0)** Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and
source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running. Port D also serves the functions of various special features of the ATmega32.

**RESET** Reset Input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running. The minimum pulse length is given in Table (1) on appendix A. Shorter pulses are not guaranteed to generate a reset.

**XTAL1** Input to the inverting Oscillator amplifier and input to the internal clock operating circuit.

**XTAL2** Output from the inverting Oscillator amplifier.

**AVCC** AVCC is the supply voltage pin for Port A and the A/D Converter. It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter.

**AREF** AREF is the analog reference pin for the A/D Converter. [19]

### 3.1.8 Power supply

Every electronic circuit needs power supply for its operation, basically microcontrollers, Liquid crystal display and relays operate on ±5 volts we have used a mobile phone charger to supply power for meter circuit component and we supply power for electrical company module from USB of laptop. [21]

Xbee module needs ±3.3 volts for operation we used regulator to give this level of voltage as shown in Figure (3-15).
Figure 3.15: voltage regulator
3.1.9 Complete System Design

The transceiver of electrical company and meter block diagrams shown in figure (3.16) & (3.17).

Figure 3-16: transceiver circuit block diagram
Putting all the mentioned components together gives the complete Energy Meter system design shown in Figure (3-18).
Figure 3.18: System Design Details
Figure 3-19: transceiver circuit Design Details
The meter circuit and transceiver of electrical company had been shown in figure (3.20) & (3.21).

Figure 3-20: Meter circuit
3.2 Software part

3.2.1 BASCOM-AVR language

BASCOM-AVR is the original Windows BASIC COMPILER for the AVR family. It is designed to run on W95/W98/NT/W2000/XP and Vista

Key Benefits

- Structured BASIC with labels.
- Structured programming with IF-THEN-ELSE-END IF, DO-LOOP, WHILE-WEND, SELECT-CASE.
- Fast machine code instead of interpreted code.
- Variables and labels can be as long as 32 characters.
- Bit, Byte, Integer, Word, Long, Single, Double and String variables.

Figure 3-21: transceiver circuit
• Support for the Double. Not found in any AVR compiler, BASCOM gives you the advantage to crunch huge numbers with the Double (8 byte Floating Point).
• Large set of Trig Floating point functions.
• Date & Time calculation functions.
• Compiled programs work with all AVR microprocessors that have internal memory.
• Statements are highly compatible with Microsoft’s VB/QB.
• Special commands for LCD-displays, I2C chips and 1WIRE chips, PC keyboard, matrix keyboard, RC5 reception, software UART, SPI, graphical LCD, send IR RC5, RC6 or Sony code.
• TCP/IP with W3100A chip.
• Local variables, user functions, library support.
• Integrated terminal emulator with download option.
• Integrated simulator for testing.
• Integrated ISP programmer (application note AVR910.ASM).
• Integrated STK200 programmer and STK300 programmer. Also supported is the low cost Sample Electronics programmer. Can be built in 10 minutes! Many other programmers supported via the Universal Interface.
• Editor with statement highlighting.
• PDF datasheet viewer
• Context sensitive help.
• Perfectly matches the following boards:
  o MAVRIC and the MAVRIC-II from BDMICRO.
  o AVR robot controller (ARC 1.1) from L. Barello
  o Active Mega8535 Micro Board from Active Robots
• DEMO version compiles 4KB of code. Well suited for the ATmega48.
• English and German Books available
• Special TCP/IP library, AT mouse simulator, AT keyboard simulator and others are available as add on.

To make a program takes just a few steps:

• Write the program in BASIC
• Compile it to fast machine binary code
• Test the result with the integrated simulator (with additional hardware you can simulate the hardware too).

• Program the chip with one of the integrated programmers.
  (hardware must be purchased separately)

The program can be written in a comfortable MDI color coded editor. Besides the normal editing features, the editor supports Undo, Redo, Bookmarks and block indentation.

[20]

![Bascom code interface](image)

Figure 3.22: Bascom code interface

### 3.2.2 Matlab
For company side we design graphical user interface (GUI) to manage meter side by using visual studio software.

A user interface (UI) is a graphical display in one or more windows containing controls, called components that enable a user to perform interactive tasks. The user does not have to create a script or type commands at the command line to accomplish the tasks. Unlike coding programs to accomplish tasks, the user does not need to understand the details of how the tasks are performed.

UI components can include menus, toolbars, push buttons, radio buttons, list boxes, and sliders—just to name a few. UIs created using MATLAB tools can also perform any type of computation, read and write data files, communicate with other UIs, and display data as tables or as plots. [22]

### 3.2.3 Simulation Design:

After design of the meter was completed, the next phase was initiated. This was the simulation and testing phase. Simulation was done with the use of software simulating programs, along with BASCOM-AVR language Compilers for the code written to the MCU. The simulating program used for this thesis was Proteus 7.1 Professional, and for coding, Code Vision AVR 2.05. Several separate code blocks were written for different blocks of the meter in order to simulate and test them separately before integration and system simulation and testing.

#### 3.2.3.1 Proteus VSM Definition

Proteus Virtual System Modeling (VSM) combines mixed mode SPICE circuit simulation, animated components and microprocessor models to facilitate co-simulation of complete microcontroller based designs. For the first time ever, it is possible to develop and test such designs before a physical prototype is constructed.

This is possible because you can interact with the design using on screen indicators such as LED and LCD displays and actuators such as switches and buttons. The simulation takes place in real time (or near enough to it): a 1GHz Pentium III can simulate a basic 8051 system clocking at over 12MHz. Proteus VSM also provides extensive debugging facilities including breakpoints, single stepping and variable display for both assembly code and high level language source. [23]
Screen shot of the schematic editor showing a fully functional virtual representation of the Microchip™ PICDEM2+ Evaluation Board, containing PIC18F452, Alpha LCD, TC74 temp sensor, 24LC256 I2C EEPROM, RS232 terminal and various buttons, pots, LED’s etc.

3.2.3.2 VSM Advantage

The Proteus Design Suite is wholly unique in offering the ability to co-simulate both high and low-level micro-controller code in the context of a mixed-mode SPICE circuit simulation. With this Virtual System Modeling facility, you can transform your product design cycle, reaping huge rewards in terms of reduced time to market and lower costs of development.

If one person designs both the hardware and the software then that person benefits as the hardware design may be changed just as easily as the software design. In larger organizations where the two roles are separated, the software designers can begin work as soon as the schematic is completed; there is no need for them to wait until a physical prototype exists.
In short, Proteus VSM improves efficiency, quality and flexibility throughout the design process. [23]

Figure 3.24: VSM Advantage

### 3.2.3.3 Diagnostic Messaging

Proteus is equipped with comprehensive diagnostic or trace messaging. This allows you to specify which components or processor peripherals that are of interest at any given time and receive detailed textual reporting of all activity and system interaction. This is invaluable as a debugging aid, allowing you to locate and fix problems in both software and hardware much faster than you could when working on a physical prototype.
Diagnostic Setup and Simulation Advisor showing trace messages from the Alphanumeric LCD Display model [23]

### 3.2.3.4 Peripheral Model Libraries

In addition to the microprocessor models for each supported family, and literally thousands of 'standard' models for passives, TTL/CMOS, memories, etc. Proteus VSM is equipped with a comprehensive library of embedded peripheral models, from alphanumeric and graphical LCD displays, through DC, BLCD and servo motors to Ethernet controller chips. A summary listing of the peripheral models included with Proteus can be found here.

Whilst we believe Proteus VSM is functionally so far ahead of any other product that it really has no competition, you may also want to look at our competitive analysis to compare features against other offerings on the market or read some existing customer comments. [23]
By using Proteus VSM meter system was built and testing as shown in Figure (3.26)

Figure 3.26: Proteus VSM meter system testing
Also, by using Proteus VSM meter system simulation was done and connection load was observed by LED lamp as shown in figure (3.27).
Figure 3.27: Proteus VSM meter system simulation with led lamp
CHAPTER FOUR
CASES STUDY

4.1 Simulation Case

As shown in figure (3-27) AMR meter simulation we demonstrate that user can enter amount of electrical price by using keypad and display the value over LCD when he press (*) the microcontroller send value of price to management system server through xbee module.

management system server chick the meter number and calculates the amount of electrical and send the amount of electrical to the meter through xbee module, the value of electrical received by xbee module at meter side and microcontroller displayed it over LCD and send signal to relay to connect load circuit after that the amount of electrical decrement by load until reach zero then microcontroller send signal to relay to disconnect the load circuit. Red led start flashing when relay connect load and stop flashing when load disconnect.

Server side can read the value from meter and displayed it over virtual terminal.

4.2 Hardware Cases
As shown in figure (3-18) of real circuit design for AMR meter we demonstrate that at customer side. The amount of price can be enter by keypad of meter then microcontroller displayed it over LCD when the user press “*” the value send to management system server by using Transmitter of xbee module.

At company section the value of price received by xbee module and max232 converts’ value from TTL levels to RS232 levels and by using Visual Studio 2010 graphical user interface was built (GUI) software checks the meter number, costumer credit and calculates the amount of electrical and passed to max232 which convert the amount of electrical to TTL levels then passed to xbee module to transmit it to the meter.

At meter side the xbee module receives the amount of electrical and pushes it down to the microcontroller which displays the amount of electrical over LCD.

User could recharge before the meter run out off balance by press “#” from meter keypad.

Microcontroller known amount of electrical as frequencies (pulses) it observe the 555 timer output which connect to microcontroller as input to observe decrement of unit of electric consumed by load (Variable resistance) until reach zero then microcontroller send signal to relay to disconnect the load circuit.

By using a graphical user interface request meter reading at any time could be done and displayed it over GUI.

Here are some cases of insert different value of price:
First case user was sent value consists of one digit as shown in figure (4.1)

![Figure (4.1) Meter with price 8 SDG](image)

The MMS multiply one digit by four to give amount of electrical and send it to customer meter. Microcontroller displays the value on LCD as shown in figure (4.2).

![Figure (4.2) Meter with units bought by 8 SDG](image)

Second case user was sent value consists of two digits as shown in Figure (4.3).
The MMS multiply one digit by four to give amount of electrical and send it to customer meter. Microcontroller displays the value on LCD as shown in figure (4.4).

Third case user was sent value consists of three digits as shown in figure (4.5).
The MMS multiply three digits by four to give amount of electrical and send it to costumer meter. Microcontroller displays the value on LCD as shown in figure (4.6).
At company side system manager could use GUI interface below to recharge customer meter and read the amount of electrical at any time.

Figure (4.7) GUI interface at company side
Figure (4.8) GUI interface at company side show instant meter reading

From above cases, concluded that embedded AMR based on RF has been successfully implemented.
Chapter Five
Conclusion and Recommendations

5.1 Conclusion

Regarding low efficiency of traditional meters management, among them: high costs of gathering information, the need to be at the meter's installing location and low accuracy due to the man's role in data aggregation.

Upgrade the existing Energy system to radio frequency automatic meter reading (AMR) technology is an excellent idea; therefore I tried to propose a cost efficient AMR system. If this system is implemented in country the corruption of electricity sector will be reduced as well as the loss will also be reduced.

A new automated measurement and billing system Electricity has been designed and tested by using simulation program. Data has been changed between meter and electrical company.

Meter circuit has been implemented and tested by sending and receiving data that has been changed between meter and electrical company.

5.2 Recommendations

The most important recommendation is Integrate electrical billing system, GSM system and bank system to transfer money from user account to electrical company account, notify user when his balance is low and user could recharge Any time anywhere. This becomes possible as the system works on keypad based technology, hence user could recharge through phone, SMS or web at any time and at any place.

Another recommendation is connected Xbee network with Wi-Fi network.

Build circuit to calculate power consumptions by AC load.

In the future, the ultimate objective behind a fully functional AMR is to serve all kinds of meters, electricity, water and gas, under one communication technology and one protocol standard.
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ATMEGA32 microcontroller Features

Features

• High-performance, Low-power AVR® 8-bit Microcontroller Advanced RISC Architecture
  – 131 Powerful Instructions – Most Single-clock Cycle Execution
  – 32 x 8 General Purpose Working Registers
  – Fully Static Operation
  – Up to 16 MIPS Throughput at 16 MHz
  – On-chip 2-cycle Multiplier

• Nonvolatile Program and Data Memories
  – 32K Bytes of In-System Self-Programmable Flash Endurance: 10,000 Write/Erase Cycles
  – Optional Boot Code Section with Independent Lock Bits In-System Programming by On-chip Boot Program
  – True Read-While-Write Operation
  – 1024 Bytes EEPROM Endurance: 100,000 Write/Erase Cycles
  – 2K Byte Internal SRAM
  – Programming Lock for Software Security

• JTAG (IEEE std. 1149.1 Compliant) Interface
  – Boundary-scan Capabilities According to the JTAG Standard
  – Extensive On-chip Debug Support
  – Programming of Flash, EEPROM, Fuses, and Lock Bits through the JTAG Interface

• Peripheral Features
  – Two 8-bit Timer/Counters with Separate Prescalers and Compare Modes
  – One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  – Real Time Counter with Separate Oscillator
  – Four PWM Channels
  – 8-channel, 10-bit ADC
8 Single-ended Channels

7 Differential Channels in TQFP Package Only

2 Differential Channels with Programmable Gain at 1x, 10x, or 200x

- Byte-oriented Two-wire Serial Interface
- Programmable Serial USART
- Master/Slave SPI Serial Interface
- Programmable Watchdog Timer with Separate On-chip Oscillator
- On-chip Analog Comparator

• Special Microcontroller Features

- Power-on Reset and Programmable Brown-out Detection
- Internal Calibrated RC Oscillator
- External and Internal Interrupt Sources
- Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby And Extended Standby

• I/O and Packages

- 32 Programmable I/O Lines
- 40-pin PDIP, 44-lead TQFP, and 44-pad MLF

• Operating Voltages

- 2.7 - 5.5V for ATmega32L
- 4.5 - 5.5V for ATmega32

• Speed Grades

- 0 - 8 MHz for ATmega32L
- 0 - 16 MHz for ATmega32

• Power Consumption at 1 MHz, 3V, 25°C for ATmega32L

- Active: 1.1 am
- Idle Mode: 0.35 am
– Power-down Mode: < 1 μA
Block Diagram
Figure (A.1) Block Diagram of microcontroller atmega32
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Condition</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{\text{POT}} )</td>
<td>Power-on Reset Threshold Voltage (rising)</td>
<td></td>
<td>1.4</td>
<td>2.3</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Power-on Reset Threshold Voltage (falling)(^{(1)})</td>
<td></td>
<td>1.3</td>
<td>2.3</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>( V_{\text{RST}} )</td>
<td>RESET Pin Threshold Voltage</td>
<td>( 0.1 , V_{\text{CC}} )</td>
<td></td>
<td></td>
<td>( 0.9 , V_{\text{CC}} )</td>
<td>V</td>
</tr>
<tr>
<td>( t_{\text{RST}} )</td>
<td>Minimum pulse width on RESET Pin</td>
<td></td>
<td></td>
<td></td>
<td>1.5</td>
<td>( \mu \text{s} )</td>
</tr>
<tr>
<td>( V_{\text{BOT}} )</td>
<td>Brown-out Reset Threshold Voltage(^{(2)})</td>
<td>BODLEVEL = 1</td>
<td>2.5</td>
<td>2.7</td>
<td>3.2</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BODLEVEL = 0</td>
<td>3.7</td>
<td>4.0</td>
<td>4.2</td>
<td>V</td>
</tr>
<tr>
<td>( t_{\text{BOD}} )</td>
<td>Minimum low voltage period for Brown-out Detection</td>
<td>BODLEVEL = 1</td>
<td>2</td>
<td></td>
<td></td>
<td>( \mu \text{s} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BODLEVEL = 0</td>
<td>2</td>
<td></td>
<td></td>
<td>( \mu \text{s} )</td>
</tr>
<tr>
<td>( V_{\text{HYST}} )</td>
<td>Brown-out Detector hysteresis</td>
<td></td>
<td>50</td>
<td></td>
<td></td>
<td>( \text{mV} )</td>
</tr>
</tbody>
</table>
1-Bascom code

$regfile = "m32def.dat"
$crystal = 8000000
$baud = 9600
Config Lcd = 16 * 2
Config Lcdpin = Pin, Db4 = Portb.4, Db5 = Portb.5, Db6 = Portb.6, Db7 = Portb.7, E = Portb.2, Rs = Portb.0
Config Com1 = Dummy, Synchrone = 0, Parity = None, Stopbits = 1, Databits = 8, Clockpol = 0

Dim Bt As Byte
Dim I As Word
Dim X As Long
Dim Xx As Long
Dim Xxx As Long
Dim Xxxx As Long
Dim Xxxxx As Long
Dim Xxxxxx As Long
Dim Xxxxxxx As Long
Dim Nnnnn As Long
Dim N As Long
Dim P As Long
Dim Pp As Long
Dim F As Integer
Dim Yi As Long
Dim Yyi As Long
Dim Yyyi As Long
Dim Yyyyi As Long
Dim Yyyyyi As Long
Dim Y As Long
Dim Yy As Long
Dim Yyy As Long
Dim Yyyy As Long
Dim Yyyyy As Long
Dim Yyyyyy As Long
Dim Yyyyyyy As Long
Dim K As Long
Dim Kk As Long
Dim Kkk As Long
Dim Kkkk As Long
Dim Kkkkk As Long
Dim Kkkkkk As Long
Dim L As Integer
Dim Q As Integer
Dim Z As Long
Dim Zz As Long
Dim A As Byte
Dim B As Byte
Dim C As Byte
Dim S As Byte
Dim V As Integer
Dim Ii As Integer
Dim M As Byte
Dim Key As Byte
Config Portd.2 = Output
Config Pind.3 = Input
Config Kbd = Porta, Debounce = 200

Do
  Print " Welcome"
  Waitms 200

H:
  Locate 1, 1
  Lcd "ENTER PRICE"
  Waitms 300
  Lowerline

B:
  Key = Getkbd()
  B = Lookup(key, Eee)
  If B < 16 Then
    Y = B
  
  Lcd Y
  Waitms 500
  Gosub Z
  Waitms 500
Elseif B >= 16 Then

Goto B

End If

Waitms 500

Bb:

Key = Getkbd()

B = Lookup(key, Eee)

If B < 16 Then

Yy = B

Lcd Yy

Waitms 500

Gosub Zz

Waitms 500

Elseif B >= 16 Then

Goto Bb

End If

Waitms 500

Bbb:
Key = Getkbd()
B = Lookup(key, Eee)
If B < 16 Then
    Yyy = B
    Lcd Yyy
    Waitms 500
    Gosub Zzz
    Waitms 500
Elseif B >= 16 Then
    Goto Bbb
End If
Waitms 500
Bbbb:
Key = Getkbd()
B = Lookup(key, Eee)
If B < 16 Then
    Yyyy = B
Lcd Yyyy
Waitms 500
Gosub Zzzz
Waitms 500

Elseif B >= 16 Then

Goto Bbbb

End If

Waitms 500

Bbbbbb:

Key = Getkbd()

B = Lookup(key, Eee)

If B < 16 Then

Yyyyy = B

Lcd Yyyyy

Elseif B >= 16 Then

Goto Bbbbbb

End If

Waitms 500

Bbbbbbb:

Key = Getkbd()

B = Lookup(key, Eee)
If B < 16 Then

Yyyyyy = B

Lcd Yyyyy

Elseif B >= 16 Then

Goto Bbbbb

End If

Waitms 500

Bbbbbbb:

Key = Getkbd()

A = Lookup(key, Eee)

If A < 16 Then

Xxxxxxx = A

Cls

Lcd Xxxxxxx

Elseif A >= 16 Then

Goto Bbbbb

End If
Waitms 500

Loop

K:

Cls

Waitms 500

Locate 2 , 1

Yi = Y * 4

Lcd "Price= " ; Y ; " SDG                 

Waitms 500

Waitms 500

Gosub Display11

Return

Kk:

Cls

Waitms 500

Locate 2 , 1

K = Y * 10

Kk = Yy + K

Yyi = Kk * 4

Lcd "Price= " ; Kk ; " SDG                 

Waitms 500
Waitms 500

Gosub Display2

Return

Kkk:

Cls

Waitms 100

Locate 2, 1

K = Y * 100

Kk = Y * 10

Kkk = K + Kk

Kkkk = Kkk + Yyy

Yyyi = Kkkk * 4

Lcd "Price= " ; Kkk ; " SDG                        "

Waitms 500

Waitms 500

Gosub Display3

Return
Kkkk:
Cls
Waitms 100
Locate 2, 1
K = Y * 1000
Kk = Yy * 100
Kkkk = Yyy * 10
Kkk = K + Kk
Kkkkk = Kkk + Kkkk
Kkkkkk = Kkkkk + Yyyy
Yyyy = Kkkkk * 4

Lcd "Price= " ; Kkkkk ; " SDG                 "
Waitms 500
Waitms 500
Gosub Display4
Return

Z: 
Key = Getkbd()
M = Lookup(key , Eee)
If M < 16 Then
L = M
Waitms 300
If L = 10 Then
Gosub K
Else
Goto Bb
End If

Elseif M >= 16 Then

Goto Z
End If

Waitms 100
'Goto Bb
Return

Zz:
Key = Getkbd()
M = Lookup(key , Eee)
If M < 16 Then
L = M

Waitms 300
If L = 10 Then
Gosub Kk

Else

    Goto Bbb

End If

Elseif M >= 16 Then

    Goto Zz

End If

Waitms 100

' Goto Bbb

    Return

Zzz:

Key = Getkbd()

M = Lookup(key, Eee)

If M < 16 Then

    L = M

    Waitms 300

    If L = 10 Then

        Gosub Kkk

    Else

        Goto Bbbb

Else

Gosub Kkk

Elseif M >= 16 Then

    Goto Zz

End If

Waitms 100

' Goto Bbb

    Return

Zzz:

Key = Getkbd()

M = Lookup(key, Eee)

If M < 16 Then

    L = M

    Waitms 300

    If L = 10 Then

        Gosub Kkk

    Else

        Goto Bbbb
End If

Elseif M >= 16 Then

Goto Zzz

End If

Waitms 100

' Goto Bbbb

Return

Zzzz:

Key = Getkbd()

M = Lookup(key, Eee)

If M < 16 Then

L = M

Waitms 300

If L = 10 Then

Gosub Kkkk

Gosub Kkkk

Else

Goto Bbbbb

End If
Elseif M >= 16 Then

  Goto Zzzz

End If

Waitms 100

  'Goto Bbbbbb

  Return

Display11:

    Print " User Mohammed Need Accept For Active Energey Meter "

Inputbin Bt

If Chr(bt) = "a" Then

  Waitms 500

  Gosub N

End If

Return

Display2:

    Print " User Mohammed Need Accept For Active Energey Meter "
Inputbin Bt

If Chr(bt) = "a" Then
Waitms 500
Gosub Nn

End If
Return

Display3:
   Print " User Mohammed Need Accept For Active Energy Meter "

Inputbin Bt

If Chr(bt) = "a" Then
Waitms 500
Gosub Nnn

End If
Return

Display4:
   Print " User Mohammed Need Accept For Active Energy Meter "

Inputbin Bt

If Chr(bt) = "a" Then
Waitms 500
Gosub Nnnn

End If

Return

N:
Cls
Waitms 100
P = Yi
Cls
Waitms 100

If P > 0 Then
Portd.2 = 1
Do
For I = 0 To Yi

Bf:
If Pind.3 = 1 Then
Print P
Waitms 100
Decr P
If P = 0 Then
Portd.2 = 0

Yi = 0
P = 0

Print " User Mohammed Empty Energy Meter "
Goto H
End If

Waitms 100
Locate 1 , 1

Lcd P ; " KW "
End If
Key = Getkbd()
B = Lookup(key , Eee)
If B < 16 Then
F = B
Lcd Y
Elseif B >= 16 Then
Goto Bf
End If
If F = 12 Then
Gosub H
End If
Return

Next I
Loop
Else
Port.d.2 = 0
End If

Return

Nn:

P = Yyi
Cls
Waitms 100
If P > 0 Then

Port.d.2 = 1
Do
For I = 0 To Yyi

Bf1:
If Pind.3 = 1 Then
Print P
Waitms 100
Decr P

Waitms 100

Locate 1, 1

Lcd P; " KW ";

If P = 0 Then

Portd.2 = 0

Yyi = 0

P = 0

Print " User Mohammed Empty Energy Meter "

Goto H

End If

Key = Getkbd()

B = Lookup(key, Eee)

If B < 16 Then

F = B

Lcd Y

Elseif B >= 16 Then

Goto Bf1

End If

If F = 12 Then

Gosub H
End If
Return
End If
Next I

Loop
Else
Portd.2 = 0
End If

Return
Nnn:

Cls
Waitms 100
P = Yyyi
If P > 0 Then
Portd.2 = 1
Do
For I = 0 To Yyyi

Bf2:
If Pind.3 = 1 Then
Print P
Waitms 100
Decr P

If P = 0 Then
  Portd.2 = 0
Yyyi = 0
P = 0
Print " User Mohammed Empty Energey Meter "
Goto H
End If
Waitms 100
Locate 1, 1
Lcd P ; " KW "
End If
Key = Getkbd()
B = Lookup(key , Eee)
If B < 16 Then
  F = B
  Lcd Y
Elseif B >= 16 Then
  Goto Bf2
  Goto Bf2
End If
If F = 12 Then
  Gosub H
  Gosub H
End If
Return
Next I
Loop

Else
Portd.2 = 0
End If
Return
Nnnn:

Cls
Waitms 100
P = Yyyyi
Locate 1, 1
Lcd P
If P > 0 Then
Portd.2 = 1
Do
For I = 0 To Yyyyi

Bf3:
If Pind.3 = 1 Then
Print P
Waitms 100
Decr P
If P = 0 Then
Portd.2 = 0


Yyyiy = 0
P = 0
Print "   User Mohammed Empty Energy Meter "
Goto H
   End If
   Waitms 100
   Locate 1, 1
   Lcd P ; "KW  
     "
   End If
Key = Getkbd()
B = Lookup(key, Eee)
If B < 16 Then
  F = B
  Lcd Y
Elseif B >= 16 Then
  Goto Bf3
End If
If F = 12 Then
  Gosub H
End If
Return
Next I
Loop
Else
Portd.2 = 0
End If

Return

Eee:

Data 1, 4, 7, 10, 2, 5, 8, 0, 3, 6, 9, 12, 15, 0, 13, 14

GUI matlab code:

function varargout = finally(varargin)
    gui_Singleton = 1;
    gui_State = struct('gui_Name', mfilename, ...
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end
if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end

function finally_OpeningFcn(hObject, eventdata, handles, varargin)
    handles.output = hObject;
    guidata(hObject, handles);

function varargout = finally_OutputFcn(hObject, eventdata, handles)
    s=serial('com12');
    set(s,'baudrate',9600);
    fopen(s);
    a = fscanf(s);
    h=msgbox(a,'KW');
    fclose(s);
    varargout{1} = handles.output;

function pushbutton1_Callback(hObject, eventdata, handles)
clear all;
s=serial('com12');
set(s,'baudrate',9600);
fopen(s);
fprintf(s,'%s','a');
fclose(s);

function pushbutton2_Callback(hObject, eventdata, handles)
s=serial('com12');
set(s,'baudrate',9600);
fopen(s);
a = fscanf(s);
h=msgbox(a);
fclose(s);
k=1

function edit1_Callback(hObject, eventdata, handles)
dfilt.delay(5)
    s=serial('com12');
set(s,'baudrate',9600);
fopen(s);
a = fscanf(s);
h=msgbox(a);
fclose(s);
dfilt.delay(5)

function edit1_CreateFcn(hObject, eventdata, handles)
    if ispc && isequal(get(hObject,'BackgroundColor'),get(0,'defaultUicontrolBackgroundColor'))
        set(hObject,'BackgroundColor','white');
    end
### Xbee Series:

<table>
<thead>
<tr>
<th>XBee Device</th>
<th>Range</th>
<th>Power Consumption</th>
<th>Frequency</th>
<th>Protocol</th>
<th>Tx Power</th>
<th>Data Rate</th>
<th>Antenna</th>
</tr>
</thead>
<tbody>
<tr>
<td>XBee 1mW Chip Antenna - Series 1</td>
<td>300 Ft</td>
<td>50mA @ 3.3v</td>
<td>2.4GHz</td>
<td>802.15.4</td>
<td>1mW</td>
<td>250kbps</td>
<td>Chip</td>
</tr>
<tr>
<td>XBee 1mW U.FL Connection - Series 1</td>
<td>300 Ft</td>
<td>50mA @ 3.3v</td>
<td>2.4GHz</td>
<td>802.15.4</td>
<td>1mW</td>
<td>250kbps</td>
<td>Ext./Not Included</td>
</tr>
<tr>
<td>XBee 1mW Wire Antenna - Series 1</td>
<td>300 Ft</td>
<td>50mA @ 3.3v</td>
<td>2.4GHz</td>
<td>802.15.4</td>
<td>1mW</td>
<td>250kbps</td>
<td>Wire</td>
</tr>
<tr>
<td>XBee 1mW Trace Antenna - Series 1</td>
<td>300 Ft</td>
<td>50mA @ 3.3v</td>
<td>2.4GHz</td>
<td>802.15.4</td>
<td>1mW</td>
<td>250kbps</td>
<td>PCB</td>
</tr>
<tr>
<td>XBee 2mW PCB Antenna - Series 2</td>
<td>400 Ft</td>
<td>40mA @ 3.3</td>
<td>2.4GHz</td>
<td>ZigBee Mesh</td>
<td>2mW</td>
<td>250kbps</td>
<td>PCB</td>
</tr>
<tr>
<td>Model Description</td>
<td>Distance</td>
<td>Max Current @ Voltage</td>
<td>Frequency</td>
<td>Protocol</td>
<td>Power Rating</td>
<td>Data Rate</td>
<td>Ext./Not Included</td>
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<tr>
<td>-----------------------------------------------</td>
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<tr>
<td>XBee 2mW RPSMA - Series 2</td>
<td>400 Ft</td>
<td>40mA @ 3.3</td>
<td>2.4GHz</td>
<td>ZigBee Mesh</td>
<td>2mW</td>
<td>250kbps</td>
<td>Ext./Not Included</td>
</tr>
<tr>
<td>XBee 2mW U.FL onnection - Series 2</td>
<td>400 Ft</td>
<td>40mA @ 3.3</td>
<td>2.4GHz</td>
<td>ZigBee Mesh</td>
<td>2mW</td>
<td>250kbps</td>
<td>Ext./Not Included</td>
</tr>
<tr>
<td>XBee 2mW Wire Antenna - Series 2</td>
<td>400 Ft</td>
<td>40mA @ 3.3</td>
<td>2.4GHz</td>
<td>ZigBee Mesh</td>
<td>2mW</td>
<td>250kbps</td>
<td>Wire</td>
</tr>
<tr>
<td>XBee Pro 63mW PCB Antenna - Series 2B</td>
<td>1 Mile</td>
<td>295mA @ 3.3v</td>
<td>2.4GH</td>
<td>ZigBee Mesh</td>
<td>63mW</td>
<td>250kbps</td>
<td>PCB</td>
</tr>
<tr>
<td>XBee Pro 63mW RPSMA - Series 2B</td>
<td>1 Mile</td>
<td>295mA @ 3.3v</td>
<td>2.4GH</td>
<td>ZigBee Mesh</td>
<td>63mW</td>
<td>250kbps</td>
<td>Ext./Not Included</td>
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<td>XBee Pro</td>
<td>Power Consumption</td>
<td>Frequency</td>
<td>Protocol</td>
<td>Power</td>
<td>Data Rate</td>
<td>Antenna Type</td>
<td>Ext./Not Included</td>
</tr>
<tr>
<td>---------------------</td>
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</tr>
<tr>
<td>50mW U.FL Connection - Series 2</td>
<td>295mA @ 3.3v</td>
<td>2.4GHz</td>
<td>ZigBee Mesh</td>
<td>50mW</td>
<td>250kbps</td>
<td>Wire</td>
<td>Included</td>
</tr>
<tr>
<td>63mW Wire Antenna - Series 2B</td>
<td>295mA @ 3.3v</td>
<td>2.4GHz</td>
<td>ZigBee Mesh</td>
<td>63mW</td>
<td>250kbps</td>
<td>Wire</td>
<td></td>
</tr>
<tr>
<td>60mW PCB Antenna - Series 1</td>
<td>215mA @ 3.3v</td>
<td>802.15.4</td>
<td>60mW</td>
<td>250kbps</td>
<td></td>
<td>PCB</td>
<td></td>
</tr>
<tr>
<td>60mW U.FL Connection - Series 1</td>
<td>215mA @ 3.3v</td>
<td>802.15.4</td>
<td>60mW</td>
<td>250kbps</td>
<td></td>
<td>Ext./Not Included</td>
<td></td>
</tr>
<tr>
<td>60mW Wire Antenna - Series 1</td>
<td>215mA @ 3.3v</td>
<td>802.15.4</td>
<td>60mW</td>
<td>250kbps</td>
<td></td>
<td>Wire</td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>Range</td>
<td>Current @ 3.3v</td>
<td>Frequency</td>
<td>Mode</td>
<td>Power</td>
<td>Data Rate</td>
<td>Included/Not Included</td>
</tr>
<tr>
<td>------------------------------</td>
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<td>-----------------------</td>
</tr>
<tr>
<td>XBee Pro 900 RPSMA</td>
<td>6 Miles</td>
<td>210mA @ 3.3v</td>
<td>900MHz</td>
<td>Multi-Point</td>
<td>50mW</td>
<td>156kbps</td>
<td>Ext./Not Included</td>
</tr>
<tr>
<td>XBee Pro 900 U.FL Connection</td>
<td>6 Miles</td>
<td>210mA @ 3.3v</td>
<td>900MHz</td>
<td>Multi-Point</td>
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<td>XBee Pro 900 Wire Antenna</td>
<td>6 Miles</td>
<td>210mA @ 3.3v</td>
<td>900MHz</td>
<td>Multi-Point</td>
<td>50mW</td>
<td>156kbps</td>
<td>Wire</td>
</tr>
<tr>
<td>XBee Pro 900 XSC RPSMA</td>
<td>15 Miles</td>
<td>256mA @ 3.3v</td>
<td>900MHz</td>
<td>Multi-Point</td>
<td>100mW</td>
<td>9.6kbps</td>
<td>Ext./Not Included</td>
</tr>
<tr>
<td>XBee Pro 900 XSC U.FL (retired)</td>
<td>15 Miles</td>
<td>256mA @ 3.3v</td>
<td>900MHz</td>
<td>Multi-Point</td>
<td>100mW</td>
<td>9.6kbps</td>
<td>Ext./Not Included</td>
</tr>
<tr>
<td>XBee Pro 900 XSC Wire (retired)</td>
<td>15 Miles</td>
<td>256mA @ 3.3v</td>
<td>900MHz</td>
<td>Multi-Point</td>
<td>100mW</td>
<td>9.6kbps</td>
<td>Wire</td>
</tr>
<tr>
<td>XBee Pro 900 XSC S3B Wire</td>
<td>28 Miles</td>
<td>215mA @ 3.3v</td>
<td>900MHz</td>
<td>Multi-Point</td>
<td>250mW</td>
<td>10 or 20 Kbps</td>
<td>Wire</td>
</tr>
<tr>
<td>---------------------------</td>
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<td>---------------</td>
<td>------</td>
</tr>
<tr>
<td>XTend 900 1W RPSMA</td>
<td>40 Miles</td>
<td>730mA @ 5v</td>
<td>900MHz</td>
<td>Multi-Point</td>
<td>1W</td>
<td>9,600 or 115,200bps</td>
<td>Ext./Not Included</td>
</tr>
</tbody>
</table>