Single Phase Intelligent GSM Based Prepaid Energy Meter

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Declaration of originality

I declare that this report entitled — Single Phase Intelligent GSM Based Prepaid Energy Meter is my own work except as cited in the references. The report has not been accepted for any degree and is not being submitted concurrently in candidature for any degree or other award.

Signature: _______________________

Name: _______________________

Date: _______________________

ACKNOWLEDGMENT

First and above all, I praise God, the almighty for providing me this opportunity and granting me the capability to proceed successfully.

To describe this as a journey is an understatement. It has been hard work, ridiculously difficult at times, but extremely rewarding, and I am surprised and amazed to have made it to this point.

I would like to express my gratitude for everyone who helped me during the graduation project starting with endless thanks for my supervisor Dr. Abdulrahman Ali Karrar.

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Lastly, and most importantly, I cannot forget a friend whose support has always been my source of strength and inspiration, cheered me on, and celebrated each accomplishment. Words are short to express my deep sense of gratitude towards my Friend Niemat Alwaleed Osman.

They raised me, supported me, taught me, and loved me …… To them I dedicate this thesis.
In electricity generation, transmission and distribution, energy metering plays a vital role for accurate and precise measurement of electricity. Like any other commodity, energy is being measured and monitored for more than 100 years and many new technologies have evolved to derive more benefit from metering systems.

In this paper, the design and simulation of Intelligent GSM Based Prepaid Energy Meter has been presented. This system enables Short Message Service (SMS) recharge; accurate calculation of facility’s consumed energy and displays the remaining credit.

The energy meter provides the utility company with predefined regular updates of the user’s account through retrieval of the remaining balance of the meter, this is done through SMS. The system enables the utility company to send updated consumption rates to the meter every 12 hours.

This system was designed and implemented using Hardware as well as Software. The hardware consisted of analog and digital electronic components while the software was a code that has been written onto the microcontroller in C programming language. A small load had been used in the system design (100 watt Lamp).

If fully implemented, this system will improve the utility company efficiency, knowledge of electricity demand trends and needs and availability of up to date customers’ consumption data. This system will ensure high customer satisfaction resulting from easy charging, controlled consumption and threshold alarms. This will have overall effect on the rationalization of the country energy consumption and time management.
قياس الطاقة والتحكم فيها موجود منذ أكثر من مائة عام، وقد تم تطوير العديد من التقنيات الجديدة للإستخدام القصوى من أنظمة قياس الطاقة. إن قياس الطاقة يلعب دوراً أساسياً في تحديد كمية الكهرباء بطريقة صحيحة ودقيقة في التوليد والنقل والتوزيع. التناول هذا البحث تصميم ومحاكاة عدد دفع مقدم ذكي مبني على مبدأ شبكة الهاتف اللاسلكية. يمكن بواسطة هذا النظام الشحن عن طريق خدمة الرسائل القصيرة، حساب الطاقة المستهلكة بواسطة أي مؤسسة بدون عرض الرصيد المتبقي من الكهرباء.

النظام المصمم يزود شركة الكهرباء بتحديثات متتالية لحساب العميل في فترات محددة مسبقاً وهذا يتم عن طريق إستخدام خدمة الرسائل القصيرة. كما يمكن الشركة من إرسال معدلات الاستهلاك المحدثة للعداد كل 12 ساعة.

نظام تم تصميمه وتطبيقه باستخدام مكونات ملموسه (Software) وأخرى برمجيه (Hardware). المكونات الملموسه (Hardware) تتمثل في أجزاء رقميه (Digital) وأجزاء تماثليه (analogue)، أما المكونات البرمجيه فهي عبارة عن برنامج مكتوب بلغة البرمجه C تم تحميله على المعالج المتحكم. وقد تم استخدام حمل صغير في تصميم واختبار النظام (لمبه 10 واط).

تطبيق هذا النظام سيؤدي إلى رفع كفاءة الشركة، معرفة احتياجات وإتجاهات طلب الكهرباء وتوفير معلومات استهلاك الكهرباء بصورة مستمرة. كما سيؤدي إلى رضا المستهلك نتيجة لهوسيلة طريقة الشحن وتمكنه من مراقبة وإدارة الاستهلاك ...

وسيكون لذلك التأثير الكلي على ترشيد استهلاك الطاقة القطري وإدارة الوقت.
TABLE OF CONTENTS

Single Phase Intelligent GSM Based Prepaid Energy Meter ........................................... i
Declaration of originality ........................................................................................................ ii
ACKNOWLEDGMENT ........................................................................................................... iii
ABSTRACT ............................................................................................................................ iv
المستخلص ............................................................................................................................. v
TABLE OF CONTENTS .......................................................................................................... vi
List of Figures ......................................................................................................................... vi
List of Tables .......................................................................................................................... x
List of Abbreviations ............................................................................................................. xii

1 Chapter 1: Introduction ..................................................................................................... - 1 -
   1.1 Overview: .................................................................................................................... - 1 -
   1.2 Problem statement ...................................................................................................... - 2 -
   1.3 Motivation .................................................................................................................. - 2 -
   1.4 Objectives .................................................................................................................. - 3 -
   1.5 Report Layout ............................................................................................................. - 3 -

2 Chapter 2: Literature review ............................................................................................ - 1 -
   2.1 Introduction ................................................................................................................ - 1 -
   2.2 Literature Survey ....................................................................................................... - 2 -
   2.3 Study and Analysis ..................................................................................................... - 2 -
   2.4 Evolution of Prepaid Energy Meters ......................................................................... - 3 -
   2.5 History of meters ........................................................................................................ - 4 -
      2.5.1 Electromechanical energy meters ...................................................................... - 4 -
      2.5.2 Electronic meters ............................................................................................... - 5 -
   2.6 Payment Method Options .......................................................................................... - 7 -
   2.7 Payment Solutions ...................................................................................................... - 7 -
# TABLE OF CONTENTS

3 Chapter 3: Design and Methodology ................................................. - 11 -

3.1 Introduction ...................................................................................... - 11 -
3.2 Design Approach .................................................................................. - 11 -
3.3 Methodology ....................................................................................... - 12 -
3.4 Circuit Description .............................................................................. - 13 -
  3.4.1 Power Supply .............................................................................. - 13 -
  3.4.2 Microcontroller ........................................................................... - 13 -
  3.4.3 Liquid Crystal Display (LCD) display ........................................... - 13 -
  3.4.4 Energy meter IC ........................................................................... - 14 -
  3.4.5 GSM (Global System for Mobile Communication) Modem .......... - 14 -
  3.4.6 MAX232 .................................................................................. - 14 -
  3.4.7 Real Time Clock (RTC) ............................................................... - 15 -
  3.4.8 Relay ....................................................................................... - 15 -
  3.4.9 Voltage sensing circuit ............................................................... - 15 -
  3.4.10 Current sensing circuit ............................................................. - 16 -
3.5 Energy meter components ................................................................. - 16 -
  3.5.1 Power Supply .............................................................................. - 16 -
  3.5.2 Atmega32 Microcontroller .......................................................... - 19 -
  3.5.3 16X2 Liquid Crystal Display (16x2 LCD) .................................... - 21 -
  3.5.4 Energy meter IC (AD71056) ....................................................... - 22 -
  3.5.5 GSM Modem ............................................................................. - 26 -
  3.5.6 RS-232 Standard ........................................................................ - 29 -
  3.5.7 Max232 .................................................................................... - 30 -
  3.5.8 Real Time Clock (RTC - DS1307) ............................................. - 31 -
  3.5.9 Relay ....................................................................................... - 32 -
## TABLE OF CONTENTS

3.5.10 Voltage Sensing Circuit .......................................................... - 33 -
3.5.11 Current Sensing Circuit ........................................................... - 33 -
3.6 Software Development for Prepaid Energy Meter ......................... - 35 -
3.7 Complete System Design ............................................................. - 35 -
4 Chapter 4: Testing, Implementation and Discussion ......................... - 37 -
4.1 Testing and Implementation .......................................................... - 37 -
  4.1.1 Block Simulation ................................................................. - 37 -
  4.1.2 System Simulation ............................................................... - 38 -
  4.1.3 Block Testing ..................................................................... - 39 -
  4.1.4 System Testing ................................................................. - 46 -
4.2 Results Discussion ...................................................................... - 48 -
  4.2.1 Simulation results ............................................................... - 48 -
  4.2.2 Hardware testing results ..................................................... - 50 -
5 Chapter 5: Conclusion, Recommendations and Future work ............. - 55 -
  5.1 Conclusion: ............................................................................. - 55 -
  5.2 Recommendations: ................................................................... - 55 -
  5.3 Future work: ........................................................................... - 56 -
Bibliography ...................................................................................... - 57 -
Appendix A ..................................................................................... A-1
Appendix B ..................................................................................... B-1
Appendix C ..................................................................................... C-1
List of Figures

Figure 2.1: Prepayment Metering System ................................................................. - 1 -
Figure 2.2: Electronic Meters ................................................................................. - 6 -
Figure 2.3: Payment By Coins ................................................................................ - 8 -
Figure 2.4: Payment By Token or PIN ................................................................. - 8 -
Figure 2.5: Payment By Memory Card ................................................................. - 8 -
Figure 2.6: Payment By Barcodes ........................................................................... - 9 -
Figure 2.7: Payment By Smart Cards ..................................................................... - 9 -
Figure 2.8: Payment By Mobile Phone ................................................................... - 9 -
Figure 3.1: Power Supply Circuit ........................................................................... - 17 -
Figure 3.2: Main Supply Voltage ........................................................................... - 17 -
Figure 3.3: Power Supply Output ........................................................................... - 17 -
Figure 3.4: Bridge Rectifier Circuit ....................................................................... - 18 -
Figure 3.5: Layout of Atmega3 .............................................................................. - 21 -
Figure 3.6: 16x2 LCD ......................................................................................... - 22 -
Figure 3.7: Functional Block Diagram ................................................................. - 23 -
Figure 3.8: Test Circuit For AD71056 ................................................................. - 23 -
Figure 3.9: AD71056 Pin Configuration ............................................................... - 23 -
Figure 3.10: Interfacing the AD71056 to an MCU ................................................... - 24 -
Figure 3.11: Real Power-to-Frequency Conversion ................................................ - 24 -
Figure 3.12: GSM Modem ................................................................................... - 27 -
Figure 3.13: Pin configuration of DB9 connector for Null modem ..................... - 29 -
Figure 3.14: GSM Interfacing To Atmega Through MAX232 ............................ - 30 -
Figure 3.15: Pin Description of MAX232 ............................................................. - 30 -
Figure 3.16: Relay Switch Connection .................................................................. - 32 -
Figure 3.17: Voltage Sensing Circuit .................................................................... - 33 -
Figure 3.18: Current Transformer ........................................................................... - 34 -
Figure 3.19: Current Sensing Circuit .................................................................... - 35 -
Figure 3.20: Complete Simulation schematic diagram ....................................... - 36 -
Figure 4.1: interfacing with Atmega32 ................................................................. - 37 -
Figure 4.2: RTC interfacing with Atmega32 ........................................................... - 38 -
Figure 4.3: System Simulation ............................................................................... - 39 -
Figure 4.4: Power Supply Circuit ......................................................................... - 40 -
Figure 4.5: Voltage Sensing Circuit ....................................................................... - 40 -
Figure 4.6: Current Sensing Circuit ...................................................................... - 41 -
List of Figures

Figure 4.7: relay connection with load and CT ................................................................. - 42 -
Figure 4.8: LCD Block Test Result .................................................................................. - 42 -
Figure 4.9: Hyper-Terminal window for communication with GSM ................................ - 43 -
Figure 4.10: GSM interfacing to Atmega32 through MAX232 ........................................ - 43 -
Figure 4.11: RTC interfacing with Atmega32 ................................................................. - 44 -
Figure 4.12: AD71056 on a PCB board ........................................................................ - 45 -

Figure 5.1: AD71056 output connected to an oscilloscope......................................... - 45 -
Figure 5.2: Complete Meter Circuit ................................................................................ - 46 -
Figure 5.3: Energy Meter with Balance on Display ....................................................... - 47 -
Figure 5.4: Low Credit Alarm through virtual terminal ............................................... - 49 -
Figure 5.5: Power Disconnection When No Balance ...................................................... - 49 -
Figure 5.6: Recharge Through Virtual Terminal ............................................................ - 50 -
Figure 5.7: Incorrect IC Output ....................................................................................... - 53 -
## List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 2.1</td>
<td>Payment Solution Features Comparison Table</td>
<td>10</td>
</tr>
<tr>
<td>Table 3.1</td>
<td>f1 ....4 Selection Table</td>
<td>25</td>
</tr>
<tr>
<td>Table 3.2</td>
<td>Pin description of a DB9 connector</td>
<td>29</td>
</tr>
<tr>
<td>Table 3.3</td>
<td>Voltage levels of RS232</td>
<td>31</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>IPEM</td>
<td>Intelligent Prepaid Energy Meter</td>
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<tr>
<td>AMR</td>
<td>Automatic Meter Reading</td>
<td></td>
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<tr>
<td>PLC</td>
<td>Power Line Carrier</td>
<td></td>
</tr>
<tr>
<td>WiFi</td>
<td>Wireless Fidelity</td>
<td></td>
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<tr>
<td>GSM</td>
<td>Global System Mobile</td>
<td></td>
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<tr>
<td>SCADA</td>
<td>Supervisory Control And Data Acquisition</td>
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<tr>
<td>ICT</td>
<td>Information Communication Technology</td>
<td></td>
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<tr>
<td>SMS</td>
<td>Short Messaging System</td>
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<tr>
<td>BEST</td>
<td>Brihanmumbai Electricity Supply and Transport</td>
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<tr>
<td>DSP</td>
<td>Digital Signal Processing</td>
<td></td>
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<tr>
<td>PC</td>
<td>Personal Computer</td>
<td></td>
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<tr>
<td>MAS</td>
<td>Multiple Agent Systems</td>
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<tr>
<td>GPRS</td>
<td>General Packet Radio Service</td>
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<tr>
<td>SIM</td>
<td>Subscriber Identity Module</td>
<td></td>
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<tr>
<td>AC</td>
<td>Alternating Current</td>
<td></td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standard Institute</td>
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<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
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<tr>
<td>LCD</td>
<td>Liquid Crystal Display</td>
<td></td>
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<tr>
<td>LED</td>
<td>Light Emitting Diode</td>
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</tr>
<tr>
<td>RTC</td>
<td>Real Time Clock</td>
<td></td>
</tr>
<tr>
<td>ADC</td>
<td>Analog to Digital Converter</td>
<td></td>
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<tr>
<td>ATM</td>
<td>Automatic Teller Machine</td>
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<tr>
<td>NFC</td>
<td>Near Field Communication</td>
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</tbody>
</table>
### List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIN</td>
<td>Personal Identification Number</td>
</tr>
<tr>
<td>TTL</td>
<td>Transistor-Transistor Logic</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>MODEM</td>
<td>Modulator-Demodulator</td>
</tr>
<tr>
<td>MCU</td>
<td>MicroController Unit</td>
</tr>
<tr>
<td>OTP ROM</td>
<td>One Time Programmable Random Access Memory</td>
</tr>
<tr>
<td>RAM</td>
<td>Random Access Memory</td>
</tr>
<tr>
<td>SRAM</td>
<td>Static Random Access Memory</td>
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<tr>
<td>IC</td>
<td>Integrated Circuit</td>
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<tr>
<td>USB</td>
<td>Universal Serial Bus</td>
</tr>
<tr>
<td>AT</td>
<td>ATtention</td>
</tr>
<tr>
<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
</tr>
<tr>
<td>RX</td>
<td>Receiver</td>
</tr>
<tr>
<td>TX</td>
<td>Transmitter</td>
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<tr>
<td>CTS</td>
<td>Clear To Send</td>
</tr>
<tr>
<td>RTS</td>
<td>Request To Send</td>
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<tr>
<td>GND</td>
<td>Ground</td>
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<td>I/O</td>
<td>Input-Output</td>
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<tr>
<td>Vcc</td>
<td>Supply Voltage</td>
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<tr>
<td>REF</td>
<td>Reference</td>
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<tr>
<td>PDU</td>
<td>Protocol Data Unit</td>
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<tr>
<td>EIA</td>
<td>Electronic Industries Association</td>
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<tr>
<td>BCD</td>
<td>Binary Coded Decimal</td>
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<tr>
<td>EMF</td>
<td>Electro-Magnetic Force</td>
</tr>
</tbody>
</table>
List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
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<tbody>
<tr>
<td>EMI</td>
<td>Electromagnetic Interference</td>
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<tr>
<td>CT</td>
<td>Current Transformer</td>
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<tr>
<td>VT</td>
<td>Voltage Transformer</td>
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<tr>
<td>PT</td>
<td>Potential Transformer</td>
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<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
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<tr>
<td>CF</td>
<td>Calibration Frequency Logic Out</td>
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Chapter 1: Introduction

1.1 Overview:

Over the last few years, the prepayment meters have been proposed as an innovative solution to facilitate affordability and reduce utilities’ cost.

Traditional meter reading for electricity consumption and billing is done by human operator from house to house and building to building. This requires huge number of labour operators and long working hours to achieve complete area data reading and billing. Human operator billing are prone to reading error and is sometimes restricted and slowed down by bad weather condition. The increase development in residential housing and commercial building in the developing countries require more human operators and long working hours to complete the meter reading task and this increase the energy provider operation costs for meter reading.

Automatic Meter Reading system (AMR) plays an important role to address the above mentioned problems. AMR is an effective mean of data collection that allow substantial saving through the reduction of meter re-read, greater data accuracy, allow frequent reading, improved billing and customer service, timely energy profiles and consumption trends update and better deployment of human resource.

Efficiency and reliability of retrieving meter reading in the AMR system was a major challenge and with the advent of digital technology, analogue electro-mechanical meters were replaced by digital electronic meters. Digital energy meter offer greater convinces to implement and establish automatic meter reading electronically. Various AMR technologies using power line carrier (PLC) communications, supervisory control and data acquisition (SCADA), telephone modem, internet, Ethernet, WiFi, Bluetooth and ZigBee were established and developed to provide and demonstrate the solution of efficiency, reliability and effectiveness of AMR. The above mentioned methods are expensive to implement and operate, require complex setup of infrastructure, require short operating distant, require field intervention of human operators and prone to error and reliability issues due to the transmission lines’ noise or weather condition.

With the rapid development of Global System Mobile (GSM) infrastructure and Information Communication Technology (ICT) in the past few decades, wireless automatic meter reading system became more reliable and possible.
Chapter 1: Introduction

The GSM Automatic Power Meter Reading System presented in this paper takes advantage of the available GSM infrastructure in the country and the short messaging system (SMS) cell broadcasting feature to retrieve individual houses and building power consumption meter reading back to the energy provider wirelessly. The store and forwarding features of SMS allow reliable meter reading delivery when GSM signal is affected by poor weather condition. The stored SMS is archived in the mobile operator and can be later retrieved for billing verification purpose.[1]

The project’s idea is simply that with the help of GSM modem one can set in a feature of prepaid through mobile and can also recharge the energy meter by SMS. The GSM modem loads the recharge amount in one of the registers of controller. For each pulses received at the controller, it decrement the content of the register which is equivalent to the recharged amount left. If the content of the register falls below the predetermined threshold level, the controller activates the GSM to send a message to the user which indicates that the amount left in the meter is low. Once the purchased amount expires, the connection will be terminated automatically using a relay within the meter itself.

1.2 Problem statement

Since energy meter is the medium between an individual household and the utility company for conducting money transactions, and since billing systems deal with a large amount of data relating to businesses and people, people are aiming for a better performance and secure and accurate billing system must be developed.

Energy should be seen as a treasure and a rare resource, and should be used and managed in a clever way. The adoption of the GSM prepaid meters is able to generate a completely different way for managing energy consumption efficiently, provide customer satisfaction and offer innovative solutions for utility companies.

1.3 Motivation

Time is valuable, and everyone these days wants to be out of the long billing queues, this project is a scheme of recharging power meters just as we charge our cellular phones (mobiles).
Chapter 1: Introduction

In this system the consumers are required to purchase the electricity before consuming it, by recharge through SMS service. Advancement in Energy meters enables the customers to see the energy consumed and to manage the energy efficiently.

This paper work displays energy monitoring and controlling by implementing GSM based prepaid system. It is hoped that introducing automatic power meter reading and automatic Energy billing through the SMS using GSM, improves the consumers’ energy management and improves the utility consumers’ data availability and hence power needs forecasting.

1.4 Objectives

The objectives of this project are:

- To improve the present trend of electricity billing systems.
- To cancel the power service provision costs through eliminating the man power.
- To improve the customer satisfaction since the customer can recharge his account wirelessly from his home.
- To provide accurate meter reading and billing.
- To provide the utility companies’ with frequent electricity consumption data. This will help them to plan ahead.

1.5 Report Layout

This report is organized into five chapters:

Chapter 2: This chapter takes a quick glance on prepaid energy meters. It also shows the history and revolution of prepaid meters and the available payment methods.

Chapter 3: This chapter shows the design methodology by giving a detailed description of the meter components and introducing the entire system scheme.
Chapter 1: Introduction

**Chapter 4:** This chapter is about testing; Block Testing And System Testing. It also discusses the results that were obtained.

**Chapter 5:** This chapter contains conclusions and recommended future work.

**Appendix A:** contains an algorithm for energy metering system at the consumer’s end and the C-Code that has been written onto the microcontroller.

**Appendix B:** shows the PCB design for the energy meter IC (AD71056) and contains the Pin Description table for the IC.

**Appendix C:** Contains the Pin Description Of the Liquid Crystal Display (LCD).
Chapter 2: Literature review

2.1 Introduction

Energy Meter is a device that measures the amount of electrical energy consumed by a residence, business, or an electrically powered device. They are typically calibrated in billing units and the most common one is the kilowatt hour, which is equal to the amount of energy used by a load of one kilowatt over a period of one hour, or 3,600,000 joules. Electricity meters operate by continuously measuring the instantaneous voltage (volts) and current (amperes). The product of which gives the instantaneous electrical power (watts) which is then integrated against time to give energy used.

A Prepaid Energy Meter enables power utilities to collect electricity bills from the consumers prior to its consumption. The prepaid meter is also attributed with prepaid recharging ability and information exchange with the utilities pertaining to customer’s consumption details.

![Prepayment Metering System](image)  
*Figure 2.1: Prepayment Metering System*
Chapter 2: Literature review

2.2 Literature Survey

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. Countries such as Thailand, Bangladesh, Singapore, and Iran have been showing increased interest in adopting prepaid system.

In India, the State of West Bengal has decided to introduce the smart card operated prepaid energy meters in remote islands of Sunderbans. In Mumbai, pre-paid power is provided by the Brihanmumbai Electricity Supply and Transport (BEST) Undertaking.

2.3 Study and Analysis

Over the last few years, Prepaid Energy Meter has been proposed as an innovative solution aimed at facilitating affordability and reducing the cost of utilities. This mechanism requires the users to pay for the electricity before its consumption. In this way, consumers hold credit and then use the electricity until the credit is exhausted. If the available credit is exhausted then the supply of electricity is cutoff by a relay. But their use is still controversial. On one hand, those that support the diffusion of prepaid meters claim that they benefit both consumers and utilities because they help users to consume more efficiently and to improve the management of their budget, while allowing firms to reduce financial costs, as well as the costs of operation and bad debts. On the other hand, those that are against prepaid meters argue that their adoption is expensive for firms and risky for low income consumers, as the insecurity and volatility of their income may force them to make little use of the service, or ultimately, bring about involuntary self-disconnection.

Prepaid meters are usually installed by electricity supplier, if it feels that the customer cannot keep up payments on their energy bill. However, they can also be requested by the customer themselves - and are often seen as a good method of budgeting. Generally speaking they are used by lower income households, such as people on welfare benefits, lone parents or those with no bank account.
From a technological point of view, the prepayment system consists of three well differentiated components. The first is a service meter installed at the unit where energy will be consumed, such as a household dwelling or a store. In general, these meters consist of a user’s interface unit and a current measuring set. The interface unit is a device installed inside the building, which allows the user to interact with the meter, and the metering unit is the intelligent component that stores credit and consumption information, and makes up the element that either clears or switches off electricity supply. The second component of the system is the so-called credit dispensing unit, which is the vending machine where consumers can purchase electricity credit and which is generally located at the utility’s commercial offices. The third component is the supporting device that links the various sales outlets to the utility’s management system.

2.4 Evolution of Prepaid Energy Meters

The use of electronic token prepayment metering has been widely used in UK for customers with poor record of payment. Shwehdi and Jackson (1996) in their paper presented the Digital Tele-wattmeter System as an example of a microcontroller-based meter. The meter was implemented to transmit data on a monthly basis to a remote central office through dedicated telephone line and a pair of modems. Zhang et al (1998) utilized a DSP-based meter to measure the electricity consumption of multiple users in a residential area. A Personal Computer (PC) at the control centre was used to send commands to a remote meter, which in turn transmitted data back, using the power Line Communication (PLC) technique. The major problem with this system is that it cannot detect tampering by consumers.

Koay et al (2003) in their work, designed and implemented a Bluetooth energy meter where several meters are in close proximity, communicated wirelessly with a Master PC. Distance coverage is a major set-back for this kind of system because the Bluetooth technology works effectively at close range.

Hong and Ning (2005) in their paper, proposed the use of Automatic Meter Reading (AMR) using wireless networks. Stanescu et al (2006) present a design and implementation of SMS-based control for monitoring systems. Maheswari and Sivakumar their paper (2009) aimed to develop an energy efficient and low cost solution for street lighting system using Global System for Mobile communication [GSM] and General Packet Radio Service [GPRS]. The whole set-up
provides the remote operator to turn off the lights when not required, regulate the voltage supplied to the streetlights and prepare daily reports on glowing hours.

Sharma and Shoeb (2011), in their paper suggested a method where we utilize telecommunication systems for automated transmission of data to facilitate bill generation at the server end and also to the customer via SMS, Email. Amit and Mohnish (2011) suggested in their paper a prepaid energy meter behaving like a prepaid mobile phone. The meter contains a prepaid card analogous to mobile SIM card. The prepaid card communicates with the power utility using mobile communication infrastructure. Once the prepaid card is out of balance, the consumer load is disconnected from the utility supply by the contactor. The power utility can recharge the prepaid card remotely through mobile communication based on customer requests.

2.5 History of meters

Over the past years electric energy meters have undergone phenomenal changes and are expected to become even more sophisticated, offering more and more services. The electromechanical based energy meters are rapidly being replaced by digital energy meters which offer high accuracy and precision. Now the generation of electric energy meters is of AMRs.

Various features are offered by AMR are given below:

a) Improved load profile.

b) Automatic billing invoice.

c) Alarm warning.

d) Remote power switches ON/OFF.

e)

2.5.1 Electromechanical energy 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 coils. 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, in order to render a measurement of the total energy used.

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 occur 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.

2.5.2 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. They can also support time-of-day billing.
Chapter 2: Literature review

The meter has a power supply, a metering engine, a processing and communication engine (i.e. a microcontroller), and other add-on modules such as RTC, LCD display, communication ports/modules and so on.

The metering engine is given the voltage and current inputs and has a voltage reference, samplers and quantizers followed by an ADC section to yield the digitized equivalents of all the inputs. These inputs are then processed using a digital signal processor to calculate the various metering parameters such as powers, energies etc.

The largest source of long-term errors in the meter is drift in the preamp, followed by the precision of the voltage reference. Both of these vary with temperature as well, and vary wildly because most meters are outdoors. Characterizing and compensating for these is a major part of meter design.

The processing and communication section has the responsibility of calculating the various derived quantities from the digital values generated by the metering engine. This also has the responsibility of communication using various protocols and interface with other add-on modules connected as slaves to it.

RTC and other add-on modules are attached as slaves to the processing and communication section for various input/output functions. On a modern meter most if not all of this will be implemented inside the microprocessor, such as the real time clock (RTC), LCD controller, temperature sensor, memory and analog to digital converters.

![Electronic Meters Block Diagram](image)

Figure 2.2: Electronic Meters
2.6 Payment Method Options

PREPAID - AN ATTRACTIVE PAYMENT SOLUTION

Electronic meters can be either postpaid meters or prepaid meters. In the case of postpaid meters, consumers receive bills based on regular meter readings—monthly, or even more often. This will have a positive impact on the accuracy of the bills.

In the case of prepaid meters, as their name suggests, consumers pay prior to actual consumption. Traditionally, prepaid meters have been targeted at low-income segments. The overall uptake of prepaid meters is low, principally because the service is seen as inconvenient.

In general, prepaid consumers had to approach payment points to “re-charge” their meters. The payment points are usually managed by the utility company or a third party and tend to be scarce. However, as the utilities’ smart grids visions become a reality, we expect to see a greater number of prepaid smart meters.

Payment methods for prepaid smart meters are expected to be more diverse than for regular prepaid meters. Smart prepaid meters are likely to leverage the proliferation of other technologies, such as the Internet and smart phones. New solutions will enable consumers to “re-charge” their meters through a wider range of electronic or online payments (instead of “recharging” through the scarce payment points).

Besides Internet-based payments, either through a desktop computer or a mobile device, contactless payment is seen as a user-friendly payment method for consumers. A number of form factors can be used to enable contactless payments, but smart cards and mobile phones are at the forefront of industry advancements.

2.7 Payment Solutions

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:
2.7.1 Coins
This is the simplest and the most widely established way to pay via a prepaid meter. 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 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.

2.7.2 Token or PIN

This is one of the most important payment solutions used in the metering ecosystem. This payment concept offers 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.

2.7.3 Memory cards

This is another solution that is in use everywhere in the globe for water, gas and electricity. When customers enter the card into the meter, the valve opens and electricity is made available. The display allows the consumer to check credit left on the memory card.
2.7.4 Barcodes

With the deployment of Paypoint payment solutions, barcodes could be used. The customer would pay with a bank card or cash, with the generated barcode allowing the user to reload energy levels.

Figure 2.6: Payment By Barcodes

2.7.5 Smart cards

Chip cards offer the same behavior as memory card solutions but with improved security. 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. Organization cannot conduct a fair assessment of its security posture due to its preexisting knowledge of security weaknesses, security infrastructure, and the value of target systems.

Figure 2.7: Payment By Smart Cards

2.7.6 Mobile phone

With the deployment of mobility, mobile devices could also be used as a prepaid payment solution. 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.

Figure 2.8: Payment By Mobile Phone
Chapter 2: Literature review

All these payment solutions are already available for the prepaid market. Based on the required level of flexibility, security and reliability. The table below helps you select your payment solution for prepaid meters.

**Table 2.1: Payment Solution Features Comparison Table**

<table>
<thead>
<tr>
<th>Type of Prepaid Payment Solution</th>
<th>Flexibility</th>
<th>Security</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coins</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>Metal Token</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>USB Token or PIN</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>Barcodes</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>Memory Cards</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>Smart Cards</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>Mobile Phone</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
</tbody>
</table>
Chapter 3: Design and Methodology

3.1 Introduction

This project is useful for billing purposes in Electricity board. By just sending an SMS the reading of the house meter can be received and the electric bill can be recharged.

The microcontroller and the GSM unit are interfaced with the energy meter of each house. Every house has a separate number, which is given by the corresponding authority. The GSM unit is fixed in the energy meter. The amount of consumption is stored in the microcontroller’s memory and available to the authority as SMS. Using this software, SMS can be sent through the GSM Modem to a particular number which is assigned by the authority and wait for the response. On other end, the modem will receive the data in the form of a command and informs the controller to do the readings. After the readings the controller will send data to the modem. The modem, in turn sends data to the other end. In the office the GSM unit will receive the data and the total consumption information. The number assigned by the authorities is unique.

Using GSM, the response can be obtained very fast, due to which time is saved. After consumption of the balance on the meter, the power will be cut-off and the consumer must send an SMS to recharge.

This will reduce illegal power using without paying money.

3.2 Design Approach

The energy metering system consists of Energy Meter chip, Microcontroller, Voltage and Current sensing unit, Smart card, GSM Module, MAX232, Real-Time Clock (RTC), power supply, Relay and Liquid Crystal Display (LCD).

- Energy Meter IC generally produces electrical pulses proportional to the power consumed by the consumer, and this pulses goes to the microcontroller.
- Microcontroller calculates the energy consumed by the consumer utilizing the output of Energy Meter Chip and a program is loaded on the microcontroller.
Voltage and Current sensing units feed the actual current and voltage of load connected to consumer side to the energy meter chip.

Smart Card along with the GSM Module interfaces with the microcontroller unit in which the number of units recharged by the consumer is written.

MAX232 is used to convert the voltage levels between the RS-232 used to connect the GSM and the Microcontroller (TTL).

RTC is used to supply the system with the real time and date for coordination with the utility company for retrieval of status of energy meter and consumption rates updates.

Power supply is used to supply the system with the appropriate voltage levels (5V DC) to the different electronic components of the meter.

Relay mainly performs the opening and closing of a connection between the energy meter and load through supply mains depending upon the number of units present in the smart card at a moment.

Liquid Crystal Display shows the energy consumption by displaying the remaining balance. [2]

### 3.3 Methodology

The method used to carry out this project is the principle of serial communication in collaboration with embedded system. The project has an electric meter which will work and a GSM modem which is the latest technology used for communication between MODEM and embedded systems.

The modem will send a message as and when desired to the electricity officials through Subscriber Identity Module inserted inside the MODEM.
3.4 Circuit Description

3.4.1 Power Supply

As we all know any invention of latest technology cannot be activated without source of power so in this fast moving world we deliberately need a proper power source which will be apt for particular requirement. The power supply section is the most important one for circuit operation. It provides requirement power supply for every one blocks and it produce constant 5 volts DC voltage.

3.4.2 Microcontroller

A microcontroller (sometimes abbreviated µC, uC or MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. A Program memory in the form of NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM.

Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. [3]

3.4.3 Liquid Crystal Display (LCD) display

The LCD (liquid crystal display) is based upon the liquid crystal technology. By applying Voltage to the LCD it becomes opaque, but before that it was a transparent material. The above property is main operating principle of LCD. The LCD display is used for displaying account balance and power usage; It also acts as an interface between user and power meter. [6]
3.4.4 Energy meter IC

The Energy meter IC is a high accuracy, electrical energy metering IC with a precise oscillator circuit that serves as a clock source to the chip. The energy meter IC supplies average real power information on the low frequency outputs. These outputs either directly drive an electromechanical counter or interface with an MCU. The high frequency CF logic output, ideal for calibration purposes, provides instantaneous real power information. [5]

3.4.5 GSM (Global System for Mobile Communication) Modem

A GSM Modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. From the mobile operator perspective, a GSM modem looks just like a mobile phone. When a GSM modem is connected to a computer, this allows the computer to use the GSM modem to communicate over the mobile network. While these GSM modems are most frequently used to provide mobile internet connectivity, many of them can also be used for sending and receiving SMS and MMS messages. A GSM modem can be a dedicated modem device with a serial, USB or Bluetooth connection, or it can be a mobile phone that provides GSM modem capabilities. Communication with the GSM is done using a series of machine instructions used to activate features on an intelligent modem known as AT commands set. The AT command set is the standard set of instructions for configuring and controlling modems. The commands are short sequences of ASCII characters. All command strings (i.e., sequences of characters) must be prefaced by the letters AT, an abbreviation for attention, thereby accounting for the name of the set. [4]

3.4.6 MAX232

The MAX232 is an IC that converts signals from an RS-232 serial port to signals suitable for use in TTL compatible digital logic circuits. The MAX232 is a dual driver/receiver and typically converts the RX, TX, CTS and RTS signals.

The drivers provide RS-232 voltage level outputs (approx. ± 7.5 V) from a single + 5 V supply via on-chip charge pumps and external capacitors. This makes it useful for implementing RS-232
in devices that otherwise do not need any voltages outside the 0 V to +5 V range, as power supply design does not need to be made more complicated just for driving the RS-232 in this case. The receivers reduce RS-232 inputs (which may be as high as ±25 V), to standard 5 V TTL levels. These receivers have a typical threshold of 1.3 V, and a typical hysteresis of 0.5 V. [7]

3.4.7 Real Time Clock (RTC)

A real-time clock (RTC) is a computer clock that keeps track of the current time. RTCs are present in almost any electronic device which needs to keep accurate time.

Although keeping time can be done without an RTC, using one has benefits:

- Low power consumption (important when running from alternate power).
- Frees the main system for time-critical tasks.
- Sometimes more accurate than other methods. [8]

3.4.8 Relay

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

3.4.9 Voltage sensing circuit

The voltage sensor is needed to measure voltage and the phase angle of the voltage across the load accurately, and is expected to behave linearly in some specific voltage range. The voltage sensor module was designed to be connected to the power supply on the input side and to the energy meter IC on the output side.
3.4.10 Current sensing circuit

The current sensor is needed to monitor the current flow by measuring and reporting the actual current usage and the current phase angle to the microcontroller. It is also needed to operate accurately and linearly in order to obtain the accurate usage and consequently the accurate power usage. The current sensor was designed to connect directly to the load on the input side and to the energy meter IC on the output side. The input to the entity is the value of the voltage drop across a shunt resistor and the output to the meter IC is the voltage that is proportional to the input voltage. The ratio of the input and output voltage would depend on the model of the current transformer used in the circuit.

3.5 Energy meter components

3.5.1 Power Supply

There are many different types of power supplies, but generally the design of a power supply is to convert a high voltage AC to a much lower voltage DC. This conversion of voltage allows the resulting power to be used for electronic circuits, computers, and most other devices. The power supply completes this task by four elements; the transformer, rectifier, filter, and voltage regulator. Normally, the task of the transformer in a power supply is to step down or reduce the inputted AC voltage to an acceptable range. The rectifier’s function is to utilize the dropped down voltage received by the transformer and essentially convert the AC to a varying DC voltage. Now that the current is flowing in one direction, it is sent to the filter to smooth varying voltage. The filter’s purpose is to take the varying DC voltage and create a much smaller “ripple” varying wave. Finally, this rippled signal is sent to the voltage regulator to maintain a constant voltage to be outputted to the device that is connected to the power supply.
Figure 3.1: Power Supply Circuit

Figure 3.2: Main Supply Voltage

Figure 3.3: Power Supply Output
3.5.1.1 Transformer

The transformer is split into two sets of windings; primary and secondary. The input voltage is applied to the primary windings and the reduced outputted voltage is produced from the secondary winding. In between the primary and secondary windings is an iron core that helps create a varying magnetic flux on the primary windings and a varying magnetic field through the secondary winding. This transformer takes high voltage-low current power from the primary side and converts to low voltage-high current on the output of the secondary side. Step down transformers are primarily used to convert from 220VAC to 110VAC because this is the required voltage by most electronic equipment.

3.5.1.2 Bridge rectifier

The bridge rectifier is the most commonly used rectifier. During the positive swing of the AC voltage, both D1 and D3 are forward biased while D2 and D4 are reverse biased. This is vice versa for the negative half cycle.

The bridge rectifier is the ideal rectifier for most power supplies.

![Bridge Rectifier Circuit](image-url)
3.5.1.3 RC filter

The filter is important for smoothing the DC signal produced by the bridge rectifier. A filter capacitor or RC filter is the filter used for smoothing the waveform in power supplies.

When a capacitor is placed across (parallel) the load, it charges rapidly during the positive half of the cycle. During the negative half of the cycle, the capacitor will discharge through the load which will create the desired ripple effect. The higher the value of the resistor at the load the slower the discharge or otherwise the smoother the line, while if you choose a lower resistor the faster the discharge thus creating more ripple in the waveform. By using large resistance values of both the capacitor and the resistor, a small ripple voltage can be outputted by the filter.

3.5.1.4 Voltage Regulator (7805)

The 7805 is self-contained fixed linear voltage regulator integrated circuit. It is commonly used in electronic circuits requiring a regulated power supply due to its ease-of-use and low cost. The 7805 is a positive voltage regulator; it produces a voltage that is positive relative to a common ground. 7805 IC does not require additional components to provide a constant, regulated source of power.

3.5.2 Atmega32 Microcontroller

In our days, there have been much advancement in the field of Electronics and many cutting edge technologies are being developed every day, but still 8 bit microcontrollers have its own role in the digital electronics market dominated by 16-32 & 64 bit digital devices. Although powerful microcontrollers with higher processing capabilities exist in the market, 8bit microcontrollers still hold its value because of their easy-to-understand-operation, very much high popularity, ability to simplify a digital circuit, low cost compared to features offered, addition of many new features in a single IC and interest of manufacturers and consumers.

Features:

- **PIN count:** Atmega32 has got 40 pins, two for power (pin no.10: +5V, pin no. 11: GND), two for oscillator (pin 12, 13), one for reset (pin 9), three for providing necessary power and reference voltage to its internal ADC, and 32 (4×8) I/O pins.
 **About I/O pins:** ATmega32 is capable of handling analogue inputs. Port A can be used as either DIGITAL I/O Lines or each individual pin can be used as a single input channel to the internal ADC of ATmega32, plus a pair of pins AREF, AVCC & GND together can make an ADC channel.

 **Digital I/O pins:** ATmega32 has 32 pins (4portsx8pins) configurable as Digital I/O pins.

 **Timers:** 3 Inbuilt timer/counters, two 8 bit (timer0, timer2) and one 16 bit (timer1).

 **ADC:** It has one successive approximation type ADC in which total 8 single channels are selectable.

 **Communication Options:** ATmega32 has three data transfer modules embedded in it. They are
  - Two Wire Interface.
  - USART.
  - Serial Peripheral Interface.

 **External Interrupt:** 3 External interrupts are accepted. Interrupt sense is configurable.

 **Memory:** It has 32Kbytes of in-system self-programmable Flash program memory, 1024 Bytes EEPROM, 2Kbytes internal SRAM.

 **Clock:** It can run at a frequency from 1 to 16MHz. Frequency can be obtained from external Quartz Crystal, Ceramic crystal or an RC network. Internal calibrated RC oscillator can also be used.

 **Programming:** Atmega32 can be programmed either by in-system programming via Serial Peripheral Interface or by Parallel programming.

 **More Features:**

(i) Most of the instruction executes in a single cycle.

(ii) Two cycle on-chip multiplication.

(iii) $32 \times 8$ General Purpose Working Register. [11]
3.5.3 16X2 Liquid Crystal Display (16x2 LCD)

A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. 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. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD, and 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.
3.5.4 Energy meter IC (AD71056)

The two ADCs in the AD71056 digitize the voltage signals from the current and voltage sensors. These ADCs are 16-bit, Σ-Δ with an oversampling rate of 450 kHz. This analog input structure greatly simplifies sensor interfacing by providing a wide dynamic range for direct connection to the sensor and also simplifies the antialiasing filter design. A high-pass filter in the current channel removes any dc component from the current signal. This eliminates any inaccuracies in the real power calculation due to offsets in the voltage or current signals. The real power calculation is derived from the instantaneous power signal. The instantaneous power signal is generated by a direct multiplication of the current and voltage signals. To extract the real power component (that is, the dc component), the instantaneous power signal is low-pass filtered.
Consequently, the resulting output frequency is proportional to the average real power. This average real power information is then accumulated (for example, by a counter) to generate real energy information. Conversely, due to its high output frequency and, hence, shorter integration time, the CF output frequency is proportional to the instantaneous real power.
Chapter 3: Design and Methodology

Figure 3.10: Signal Processing Block Diagram

Figure 3.11: Real Power-to-Frequency Conversion

Figure 3.12: Interfacing the AD71056 to an MCU
Basic Data Acquisition and Energy Calculation:

- Data Acquisition for Calculating Power

The Energy Meter IC AD71056 produces an output frequency that is proportional to the time average value of the product of two voltage signals. The input voltage signals are applied across pin 2, 3 and pin 4, 5 of Energy Meter IC. The Energy Meter IC also provides an output frequency at pin 15 &16 of Energy Meter IC equal to the output power that can be calculated using an equation as

\[
Freq = \frac{494.75 \times V_{1\text{rms}} \times V_{2\text{rms}} \times f_{1-4}}{V_{\text{REF}}^2}
\]

Where

Freq= output frequency on F1 and F2 (Hz).

VREF= Nominal reference voltage for Energy Meter IC =2.45 volts.

f1-4= one of four possible frequencies selected by using Logic Input S0 and Logic Input S1 (See Table 3.1)

V1rms= Differential rms voltage signal on Channel V1 (V).

V2rms= Differential rms voltage signal on Channel V2 (V).

<table>
<thead>
<tr>
<th>S1</th>
<th>S0</th>
<th>OSC Relation</th>
<th>f1...4 at Nominal OSC (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>OSC/219</td>
<td>0.86</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>OSC/218</td>
<td>1.72</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>OSC/217</td>
<td>3.43</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>OSC/216</td>
<td>6.86</td>
</tr>
</tbody>
</table>

1. f1...4 is a binary fraction of the internal oscillator frequency (OSC).
2. Values are generated using the nominal frequency of 450 kHz.
Chapter 3: Design and Methodology

This output frequency is proportional to the real power information.

- Energy Calculation

The complete equation for determining the energy or units consumed from Power, P is obtained as follows

\[
1 \text{ WattSec} = \frac{1 \text{kWSec}}{1000} \\
1 \text{ WattSec} = \frac{1 \text{kWh}}{1000 \times 3600} \\
\text{Energy} = \frac{P \times \text{Sec}}{1000 \times 3600} \text{ Units} \\
\text{Energy} = \frac{3000 \times X \times \text{Sec}}{3600000} \text{ Units}
\]

3.5.5 GSM Modem

A GSM modem is a wireless modem that works with a GSM wireless network. A wireless modem behaves like a dial-up modem. The main difference between them is that a dial-up modem sends and receives data through a fixed telephone line while a wireless modem sends and receives data through radio waves. The working of GSM modem is based on commands, the commands always start with AT (which means ATtention) and finish with a <CR> character. The AT commands are given to the GSM modem with the help of PC or controller. The GSM modem is serially interfaced with the controller with the help of MAX232. Here MAX232 acts as driver which converts TTL levels to the RS-232 levels. For serial interface, GSM modem requires the signal based on RS-232 levels. The T1_OUT and R1_IN pin of MAX232 is connected to the TX and RX pin of GSM modem.
**AT Commands**

AT command set is the fundamental interface with the modem. An AT command is simply a string of characters preceded by the AT prefix that is sent to the modem. The commands typically instruct the modem to perform some action or set some characteristic within the modem. The modem has two states: command state and on-line state. In command state, the modem will accept and respond to AT commands. In the on-line state, the modem will transmit data, but ignore AT commands.

AT commands has the following format:

- The command is prefixed with AT (Attention)
- The command is terminated by a carriage return <CR> (except the A/ command and escape sequence).
- The commands can be entered in upper case or lower case.
- The AT prefix can be in upper case or lower case, but both the A and the T must be the same case.
- Multiple commands can be strung together on a single line and spaces may be included between commands but are not necessary.

Several standard AT commands can be used for Test And Design, But in this project the only commands used are:
Chapter 3: Design and Methodology

- AT: To check GSM connection.
- AT+CMGS: To send the message.
- AT+CMGF: To Set Text mode.

**AT commands for SMS messaging:**

The SMS message can be up to 160 characters long, where each character is represented by 7 bits according to the 7-bit default alphabet. The mobile phone or GSM/GPRS modem may operate in two SMS modes:

(i) The text mode.
(ii) The PDU (Protocol Data Unit) mode.

The mode the mobile phone or modem is operating in determines the syntax of some of the AT commands and the format of the responses returned after execution.

There are two commands available only in the SMS text mode: set text mode parameters (+CSMP) and show text mode parameters (+CSDH).

- **The text mode:**

The text mode of SMS messaging is enabled by using the AT command “AT+CMGF”=1.

The syntax of the AT command for sending the SMS message in the text mode is as follows:

```plaintext
AT+CMGS= "09XXXXXXXX" <CR> message <Ctrl+Z>, where “09XXXXXXXX” is the recipient’s number.
```

- **The PDU mode:**

In the PDU mode the SMS message is represented as a binary stream of information, what it can be very useful to send compressed or binary data. This mode is the default mode of SMS messaging and can be enabled by using the command “AT+CMGF=0”. [13]
3.5.6 RS-232 Standard

RS-232 is an electrical signaling specification published by the Electronic Industries Association (EIA). Although not identified in the specification, the 9-pin (DB9) connector, with specific pin assignments, is commonly accepted as the RS-232 connector or the serial connector. This standard interface provides connection for only modest transmission rates & is often used with modems. In this project, it connects the GSM Modem to the MCU through the MAX232.

The general voltage assignment is:

- Signal = 0 (LOW) > +3.0V
- Signal = 1 (HIGH) < -3.0V

The Table below Shows the Pin Description of DB9 connector

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Name</th>
<th>Notes/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DCD</td>
<td>Data Carrier Detect</td>
</tr>
<tr>
<td>2</td>
<td>RD</td>
<td>Receive Data (a.k.a RxD, Rx)</td>
</tr>
<tr>
<td>3</td>
<td>TD</td>
<td>Transmit Data (a.k.a TxD, Tx)</td>
</tr>
<tr>
<td>4</td>
<td>DTR</td>
<td>Data Terminal Ready</td>
</tr>
<tr>
<td>5</td>
<td>SGND</td>
<td>Ground</td>
</tr>
<tr>
<td>6</td>
<td>DSR</td>
<td>Data Set Ready</td>
</tr>
<tr>
<td>7</td>
<td>RTS</td>
<td>Request To Send</td>
</tr>
<tr>
<td>8</td>
<td>CTS</td>
<td>Clear To Send</td>
</tr>
<tr>
<td>9</td>
<td>RI</td>
<td>Ring Indicator</td>
</tr>
</tbody>
</table>
3.5.7 Max232

The MAX232 device is a dual driver/receiver that includes a capacitive voltage generator to supply RS-232 voltage levels from a single 5-V supply. Each receiver converts RS-232 inputs to 5-V TTL/CMOS levels. Each driver converts TTL/CMOS input levels into RS-232 levels. A MAX232 chip is used to do the level shifting and this chip is required to send data serially to a GSM Modem which requires voltage levels as per RS-232 standard. The GND of the serial cable and circuit should be same. The TX/Rx (transmitter/receiver) pin (pin number 11 and 12) should be connected to the microcontroller. In microcontroller the receiver line from MAX232 should be connected to PD.0 and the Tx from MAX 232 should be connected to PD.1. Also GND of all the circuits should be the same.

Figure 3.15: GSM Interfacing To Atmega Through MAX232

Figure 3.16: Pin Description of MAX232
Chapter 3: Design and Methodology

Voltage levels

It is helpful to understand what occurs to the voltage levels. When a MAX232 IC receives a TTL level to convert, it changes TTL logic 0 to between +3 and +15 V, and changes TTL logic 1 to between -3 to -15 V, and vice versa for converting from RS-232 to TTL. This can be confusing when you realize that the RS-232 data transmission voltages at a certain logic state are opposite from the RS-232 control line voltages at the same logic state. To clarify the matter, see the table below.

Table 3.3: Voltage levels of RS232

<table>
<thead>
<tr>
<th>RS232 line type and logic level</th>
<th>RS232 voltage</th>
<th>TTL voltage to/from MAX232</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data transmission (Rx/Tx) logic 0</td>
<td>+3 V to +15 V</td>
<td>0 V</td>
</tr>
<tr>
<td>Data transmission (Rx/Tx) logic 1</td>
<td>-3 V to -15 V</td>
<td>5 V</td>
</tr>
<tr>
<td>Control signals (RTS/CTS/DTR/DSR) logic 0</td>
<td>-3 V to -15 V</td>
<td>5 V</td>
</tr>
<tr>
<td>Control signals logic 1</td>
<td>+3 V to +15 V</td>
<td>0 V</td>
</tr>
</tbody>
</table>

3.5.8 Real Time Clock (RTC - DS1307)

This is used to maintain the current time in off line processing. The DS1307 Serial Real-Time Clock is a low power; full binary-coded decimal (BCD) clock/calendar. The clock/calendar provides seconds, minutes, hours, day, date, month, and year information. The end of the month date is automatically adjusted for months with fewer than 31 days, including corrections for leap year. The clock operates in either the 24-hour or 12-hour format with AM/PM indicator. The DS1307 has a built-in power sense circuit that detects power failures and automatically switches to the battery supply.

RTC uses I2C protocol and it counts seconds, minutes, hours, date of the month, month, date of the week and year with leap-year compensation valid up to 2100.
Chapter 3: Design and Methodology

**Vital role of Real-time clock in** ‘Remote billing of energy meter using GSM modem’ is that it is used to get the real time and date for correct tariff (consumption rates) update during the day.

### 3.5.9 Relay

The relay is an electromagnetic device, which consists of solenoid, moving contacts (switch) and restoring spring and consumes comparatively large amount of power. It is possible for the interface IC to drive the relay satisfactorily and to enable this, a driver circuitry which will act as a buffer circuit is to be incorporated between them. The driver circuitry senses the presence of a high level at the input and drives the relay from another voltage source. Hence the relay is used to switch the electrical supply to the appliances.

From Figure 3.20, when we connect the rated voltage across the coil the back EMF opposes the current flow but after a short time the supplied voltage will overcome the back EMF and the current flow through the coil increase. When the current is equal to the activating current of relay the core is magnetized and it attracts the moving contacts. Now the moving contact leaves its initial position denoted “(N/C)” normally closed terminal which is a fixed terminal. The common contact or moving contact establishes the connection with a new terminal which is indicated as a normally open terminal “(N/O)”.

Whenever, the supply coil is withdrawn the magnetizing force is vanished. Now, the spring pulls the moving contact back to its initial position, where it makes a connection with N/C terminal. However, it is also to be noted that at this time also a back EMF is produced. The withdrawal time may be in microsecond, the back EMF may be in the range of few kilovolts and in opposite polarity with the supplied terminals. [14]

![Figure 3.17: Relay Switch Connection](image-url)

<table>
<thead>
<tr>
<th>NC: Normally Connected</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO: Normally Open</td>
</tr>
<tr>
<td>COM: Common</td>
</tr>
</tbody>
</table>
Chapter 3: Design and Methodology

3.5.10 Voltage Sensing Circuit

The AD71056 normally uses a resistor divider as voltage input channel. The three 261kΩ resistors will ensure that a high voltage transient will not bypass the resistor. These three resistors also reduce the potential across the resistors, thereby decreasing the possibility of arcing.

The following resistors are used as the resistor divider when the mains voltage is present:

- R2 + R3 + R4 = 783kΩ, and
- R6 = 500Ω.

C2 and (R8 + R9) create a filter which prevents Electromagnetic Interference (EMI) created by the circuit from migrating onto the Line or Neutral.

![Figure 3.18: Voltage Sensing Circuit](image)

3.5.11 Current Sensing Circuit

A current transformer (CT) is used for measurement of alternating electric currents. Current transformers, together with voltage transformers (VT) are known as instrument transformers. When current in a circuit is too high to directly apply to measuring instruments, a current transformer produces a reduced current accurately proportional to the current in the circuit, which can be conveniently connected to measuring and recording instruments. Current transformers are commonly used in metering and protective relays in the electrical power industry.
Chapter 3: Design and Methodology

Like any other transformer, a current transformer has a primary winding, a magnetic core, and a secondary winding. The alternating current flowing in the primary produces an alternating magnetic field in the core, which then induces an alternating current in the secondary winding circuit. An essential objective of current transformer design is to ensure that the primary and secondary circuits are efficiently coupled, so that the secondary current bears an accurate relationship to the primary current.

Usage

Current transformers are used extensively for measuring current and monitoring the operation of the power grid. Along with voltage leads, revenue-grade CTs drive the electrical utility's watt-hour meter on virtually every building with three-phase service and single-phase services greater than 200 amps.

Care must be taken that the secondary of a current transformer is not disconnected from its load while current is flowing in the primary, as the transformer secondary will attempt to continue driving current across the effectively infinite impedance up to its core saturation voltage. This may produce a high voltage across the open secondary into the range of several kilovolts, causing arcing, compromising operator with equipment safety, or permanently affect the accuracy of the transformer.

Accuracy

- The accuracy of a CT is directly related to a number of factors such as the burden\(^1\), rating factor, load, external electromagnetic field, temperature, physical configuration …. Etc [15]

\(^1\) Burden is the secondary load of a current transformer. It is usually called the "burden" to distinguish it from the load of the circuit whose current is being measured.
3.6 Software Development for Prepaid Energy Meter

The system software is implemented by C language and the developed code is edited, compiled and debugged by Win-AVR software.

- For the developed code and the metering algorithm refer to appendix A.

3.7 Complete System Design

Putting all the mentioned components together gives the complete Energy Meter design shown in Figure 3.4
Figure 3.21: Complete Simulation schematic diagram
Chapter 4: Testing, Implementation and Discussion

4.1 Testing and Implementation

This chapter is about simulation and testing. Simulation was done with the use of software simulating program “Proteus 7.1 Professional”, along with C language Compiler “CodeVisionAVR 2.05” for the code written to the MCU. 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.

Some of the hardware components of the meter could not be simulated due to their unavailability on simulation programs, such as the Current Transformer (CT) and the Energy Meter IC AD71056.

4.1.1 Block Simulation

4.1.1.1 Simulation of LCD with the MCU

A code was written to the MCU to continually output a character ‘c” on the LCD every 2 seconds. The LCD was connected to PORT C of the MCU, which was later switched to PORT B to comply with the meter’s design, and also because PORT C will be used to connect the RTC.

![Figure 4.1: interfacing with Atmega32](image-url)
4.1.1.2 Simulation of RTC with the MCU

The RTC was connected to the MCU at PORT C to pin0 (SCL) and pin1 (SDA), with pull-up resistors connected to pin5 (SDA) and pin6 (SCL) of the RTC as shown in Figure (4.2). The operation of the RTC requires to have those pull up resistors, along with a crystal oscillator of 32.786kHz for the internal clocking circuit. It is recommended to connect a battery to pin3 (3 volts VBAT) of the RTC because in case of power disconnection, the date and time obtained by the RTC will be lost and reset to the default values on repowering in the absence of the battery. An LCD was connected to PORT B to display the Time & Date, and a code was written into the MCU to carry this operation.

4.1.2 System Simulation

The entire circuit could not be simulated on software due to the previously mentioned reasons. The Energy Meter IC was replaced with a signal generator to simulate the output from the IC to the MCU at pin0 of PORT A (thus, removing the need to simulate the sensing circuits). Moreover, the system simulation excluded the GSM part because it can only be tested by physically connecting the Modem to the circuit, and the power supply circuit was also removed from system simulation for its insignificance to software simulation. The relay was connected to pin7 of PORT D as shown in Figure (4.3) and an animated Lamp was connected to the relay to
simulate the Load (only for purposes of simulating the connection/disconnection of the relay to the load, and not for calculation of energy by the meter). A LED was connected to pin6 of PORT D to indicate the disconnection of the GSM when initializing the meter and checking for the Modem’s connection. A code was written into the MCU to carry this operation.

4.1.3 Block Testing

Here, the circuit components were physically tested to assure compliance with design.

4.1.3.1 Power Supply

A ready power supply circuit was used (similar to a mobile phone charger) which contained all components of the power supply circuit on a PCB except the 7805 Voltage Regulator. Wires were welded onto the inputs and outputs of the board (for ease of connection) and the outputs were connected to the regulator as shown in Figure (4.4)
4.1.3.2 Voltage Sensing Circuit

The circuit shown in Figure (4.5) was connected, with slight variations in the values of the resistors and capacitors due to the unavailability of the exact values. The circuit was connected on a high durability test board because the normal laboratory test boards cannot handle high voltages such as those of the main supply and might get damaged.

4.1.3.3 Current Sensing Circuit (CT)

The CT with ratings of 300/5 was connected to a 5Ω resistor as shown in Figure (4.6) and the output voltage representing the input to the Energy Meter IC for the current inputs (V1N, V1P)
was taken across the burden resistor. The Load (Lamp) was connected to the primary of the CT (the wires connecting the load to the main supply goes through the hole of the CT) as shown in figure.

Figure 4.6: Current Sensing Circuit

4.1.3.4 Relay (Latch for load)

The latch’s magnetizing coils were connected to the MCU (to control the latching action by a 5V signal from the MCU) at pin7 of PORT D. for this test, a power supply of 5V DC was used instead of the MCU to supply the controlling signal of the latch. The main supply connected to the load and going through the CT was connected to the NC pin of the latch, with the COM pin connected to the neutral of the main supply as shown in Figure (4.7)
4.1.3.5 Interfacing the LCD with Atmega32

The circuit below was connected to test for the interface of the LCD with the MCU for any problems that might occur. The LCD was connected to PORT B of the MCU as explained above. The result is as shown in Figure (4.8).
4.1.3.6 MAX232

The MAX232 was tested by connecting it to a PC using RS-232 and establishing a connection with it using the Hyper-Terminal. The TTL Rx and Tx of the MAX232 that should be connected to the serial communication pins of the MCU (RXD, TXD), are connected to each other so that the output through the Tx pin (converted voltage level from RS-232 to TTL) serves as an input to the Rx pin. This connection helps in testing the operation of the MAX232, by typing any random characters on the Hyper-Terminal, a response should appear on the terminal because it gets converted through the MAX232 to TTL voltage levels then sent back to it and converted again to RS-232 voltage levels to appear as response characters on the terminal.

4.1.3.7 Interfacing the GSM with Atmega32

The GSM modem was tested in two phases: Test of Functionality, using Hyper-Terminal and test of interfacing with Atmega32.

For the functionality test, the GSM Modem was connected to a PC using RS-232 and the Hyper-Terminal was used to test this functionality. A SIM Card was inserted into the GSM and a connection with the terminal was established as shown in Figure (4.10).

For the second test, the GSM Modem was connected to the MCU through the MAX232, where the MAX232 was connected to pins 0 and 1 of PORT C of the MCU (RXD, TXD respectively) as shown in Figure (4.9). A code was written into the MCU to test for the communication with the GSM.
4.1.3.8 Interfacing the RTC with Atmega32

The same code written before for the simulation into the MCU was used again in the physical connection to test the real operation of the block. Figure (4.11) show the physical connection of the RTC with the MCU.

![RTC interfacing with Atmega32](image)

Figure 4.11: RTC interfacing with Atmega32

4.1.3.9 Energy meter IC

Before physically testing the Energy Meter IC, some considerations were taken. Because of the very small dimensions of the Energy Meter IC (10x5.8mm) and the fact that it is a surface mount IC, a PCB board was fabricated for it in order to be able to connect it to the rest of the circuit, since the very small pins have a spacing of 1.27mm from each other. Figure (4.12) shows the IC welded to the PCB.
Secondly, before connecting the voltage sensing circuit and current sensing circuit to the inputs of the IC, and the CF output to the MCU, connections shown in Figure (3.8) were made, with the exception of the opto-coupler at the CF output and the resistor and LED at the REVP pin. These connections are made to optimize the operation of the IC. The resistors and capacitors used slightly varied from the ideal ones shown in the figure due to unavailability.

Finally, the input signals were connected to the Energy Meter IC and the CF output was connected to an oscilloscope to display the signal that represents the energy calculated by the IC and consumed by the load. Figure (4.13) shows the connection of the IC to the oscilloscope.
Figure 5.1: AD71056 output connected to an oscilloscope

5.1.1 System Testing

The circuit shown below was connected with the line connecting the load to the main supply goes through the CT first (primary windings). Between the CT and the load, the relay is connected to disconnect the power in case the user runs out of balance, and finally the line is connected back to the neutral. The complete final code was written into the MCU, controlling the operation of the entire system, and it was run to test the meter. Figure (4.14) shows the complete meter circuit.

![Complete Meter Circuit](image)

Figure 5.2: Complete Meter Circuit

Lastly, Figure (4.15) shows the customer’s balance on the display after the connection of the circuit in Figure (4.14) and after the complete code was written into the MCU.
Figure 5.1: AD71056 output connected to an oscilloscope

Figure 5.3: Energy Meter with Balance on Display
5.2 Results Discussion

5.2.1 Simulation results

5.2.1.1 Block Simulation

Both LCD and RTC worked perfectly as expected:

- For the LCD: the character ‘c’ was displayed every 2 seconds as shown in figure (4.1).
- For the RTC: after the data formats (unsigned char, integer, ASCII) between the variables of the RTC functions were taken into consideration, Date and time were displayed correctly on the LCD as obtained by the RTC as shown in Figure (4.2).

5.2.1.2 System Simulation

Here the system was simulated using signal generator instead of the Energy Meter IC with the exception of power supply circuit, sensing circuits and the GSM modem. The complete code was written into the microcontroller and the output from the signal generator was connected to PORT A. The frequency of the inputted signal was calculated by counting the zero crossings and then this frequency was multiplied by the current consumption rate which was considered to be constant because the GSM was omitted in this part.

The result of the multiplication represents the amount of balance consumed during the period of frequency calculation; hence this result is subtracted from the previous remaining balance to obtain the new remaining balance which was successfully displayed on the LCD.

Virtual terminal (instead of the GSM) was used to check for the threshold alarms and for the reception of the recharge through SMS:

- When the credit felt below the threshold level (10 SDG), the meter notified the user to recharge while the power was still on (the Blue LED)
Figure 5.1: AD71056 output connected to an oscilloscope

Figure 5.4: Low Credit Alarm through virtual terminal

- When the balance became zero, the power was disconnected (Figure 4.17) and after the user had recharged through SMS the power was reconnected (Figure 4.18)

Figure 5.5: Power Disconnection When No Balance
5.2.2 Hardware testing results

5.2.2.1 Block Testing

Generally, when using real hardware electronic and analog components, it needs to be taken into consideration that working with these components could have a lot of trouble such as them being sensitive to noise, variations from ideal operation and faulty outputs, resulting in deviation from expected operation.

- Outputs from power supply circuit, voltage sensing circuit and current sensing circuit were exactly as expected:
  - The power supply circuit on the PCB produced 12 Volts and by using the voltage regulator (7805), the desired 5 Volt DC output was obtained.
  - The voltage sensing circuit gave 110mV which is within the maximum range of the voltage inputs for the Energy meter IC (±165mV).
  - The current sensing circuit output was 15mV (output of the CT was 3mA with the shunt resistor of 5Ω) and this is within the range of the IC (±30mV).
- The operation of the relay was direct and simple.
Interfacing the LCD to the MCU was such a hard job. It might seem very easy and simple to connect this circuit, but this was not the case and it was a bit tricky. In most literature, the third pin of the LCD is left unconnected, but actually the LCD does not display anything on the screen unless this PIN is connected to ground. After this was done, things went very smoothly and the expected result was obtained.

Connection of MAX232 is easy and straightforward but care must be taken to ensure that all the wires are tied well. No other problems in the connection of max232.

Interfacing the GSM Modem with Atmega32:

(i) Hyper-Terminal Test: the GSM was connected to the PC and:
- The AT command (AT) was sent to check the connection of the Modem. The Modem responded with (OK).
- The text mode was set by sending the Command (AT+CMGF=1) to the GSM modem, and the Modem responded with (OK).
- The command (AT+CMGS= 09xxxxxxxx <CR>) was sent to the Modem to send an SMS message to the number provided in the command. The Modem replies with a blinking cursor asking for the content of the message. The Modem then replies with (OK) to indicate message is sent.
- Finally, command (AT+CMGR= 8) was sent to the Modem, which is a command that reads the message received and saved in location “8” of the SIM Card memory. The Modem replies with the message present in that location along with the number of the sender and the time of receiving, and marks the message as “READ”.

(ii) Interfacing the GSM with Atmega32: by incorporating the AT Commands mentioned above in the code written into the MCU, the interface was tested. The code contains the parts where it checks the connection of the Modem, sets the Mode, and sends a message to the utility (status update) or the user (notification of low or no balance) and receives a message, containing either the recharge amount, consumption rate...
Figure 5.1: AD71056 output connected to an oscilloscope

according to the current time of day, status request from the utility or balance acquiring from the user. The most common problem in interfacing of the GSM to the MCU is the formats and their conversions i.e. upon a request for the remaining balance, the remaining balance should be converted from float to ascii so that the GSM can handle it.

- Interfacing the RTC with the MCU is simple and direct but a 3Volt battery must be connected to the RTC in order to keep the correct time and date.

- Energy Meter IC AD71056:
  - First and above all, figure (3.8) must be connected with the exact capacitors and resistors values in order to obtain an output from the IC. Secondly, Care must be taken in connecting ground Pins (AGND and DGND). The third important thing is that is IC is very sensitive to noise, hence noise levels must be decreased as much as possible.
  - Selection pins S0 and S1 have a direct impact on the selection of the right frequency for CF output.
  - After all this precautions, the display of the oscilloscope did not show the signal representing the energy consumption and due to the lack of information about the IC, the reason couldn’t be known and the solutions could not be adopted. The output frequency of the IC was replaced by a signal generator and the system implementation continued.
5.2.2.2 System Testing

After the entire circuit was integrated and assembled together, and the complete code was written into the MCU, the meter was run. As expected, the meter was initialized by displaying the start message first, followed by the real date and time supplied by the RTC. The GSM connection is then checked, and on successful connection, the GSM Mode is set to Text Mode.

After checking the connection, the MCU checks the current amount of remaining balance available in the meter. If it is lower than a certain level, it displays on the LCD that the balance is low and must be recharged, and sends a notification message to the user’s number. If the balance is zero, the meter sends a signal to the latch, thus disconnecting the power from the load until it receives a new recharge from the user through the GSM.
Figure 5.1: AD71056 output connected to an oscilloscope

In case it checks the balance and it wasn’t below a certain level, the meter continues operation normally. The AD71056 IC is supposed to calculate the consumption of the load and inputs it to the MCU in the form of a frequency that it uses to calculate the consumption and updates the remaining balance on the LCD. However, after multiple trials and many efforts, the Energy Meter IC didn’t operate in the expected manner. So, the output of the meter was replaced by a function generator that simulates the consumption obtained from the IC, The MCU continuously checks the amount of remaining balance in case it goes below the low level. It also checks the register that holds the received message from the GSM when a message is received, in case of a recharge, balance query from the user or status request or rate update from the utility.

Figure (4.15) shows the meter with the balance on Display.
Chapter 5: Conclusion, Recommendations and Future work

6.1 Conclusion:

This paper presented a prepaid energy meter using mobile communication. It was an effort towards upgrading existing electrical energy meters; thus improving the revenue collection for the scheduled supply. The main achievement was that a power measurement system was successfully built. An LCD display was interfaced as well as a GSM modem with the proposed system and also a user-friendly interface program was successfully implemented. This user interface notifies the user of his current account balance and assists him in recharging his account. The GSM module was also successfully tested using the Hyper-Terminal program available on a PC. However, on a hardware point of view, the system did not operate to the expected functionality because the information on the energy meter IC was not enough. The proposed prepaid meter was successfully implemented on a software model which was simulated with the help of Proteus 7.1 Professional and CodeVisionAVR 2.05.

One of the research limitations is the inability of using the energy meter IC (AD71056) which is considered a crucial part of the design and the unavailability of this IC in the simulator program.

Nevertheless, working on energy meters was interesting and gave a huge amount of knowledge and information regarding the components, equipments used during design, testing and implementation of the meter due to the fact that the researcher spends much time and effort to accomplish this project.

This was a wonderful opportunity to promote to the consumer a new approach to energy consumption. Based on real-time concepts, and with the option of payment via a mobile handset for better flexibility, this could prove the best solution to manage energy efficiently.

6.2 Recommendations:

- Availing required research equipments to enable the researchers; PCs, Integrated circuits, measuring instruments, signal generators ….. etc.
• Establishing agreements with local companies e.g. the electricity corporation, other specialized companies to avail PCBs and other needed equipments.
• Further training of lab technicians and more researches on Energy Meter ICs, to have and document more information to be able to work with.

6.3 Future work:

• Monitoring the meter and power performance by using SMS for power status reporting, e.g. power failure and power instability.
• Enabling the utilities to charge the customer account directly upon predetermined request format in case of zero credit in the meter.
• Establishing an agreement between the utility company and the telecommunication company about recharge through credit transfer.
• Adding an anti-tempering system for theft protection “the system will send a signal to utility company when someone tries to manually open the meter box.
Bibliography


Appendix A

Algorithm for Energy Metering system at consumer’s end

1. Start
2. Initialize the display and RTC.
3. Display date and time.
4. Check GSM Connection and set to Text Mode.
5. If GSM disconnected, display that on LCD and turn LED ON.
6. Receive Utility number and set it for communication.
7. Decide whether the number of units in Microcontroller is sufficient or not. If the balance is insufficient then disconnect the load from supply and send message to user number notifying of balance recharge otherwise connect to the load to supply.
8. Count the number of pulses initiated from Energy Meter IC AD71056 /*with the help of counter0*/ when the load consumes power.
9. Measure time with the help of timer1.
10. Calculate power, \( P \)
11. Calculate energy using the following equation where X denotes the frequency of pulses that is produced by the Energy Meter IC.

\[
\text{Energy} = \frac{3000 \times X \times \text{Sec}}{3600000} \text{ Units}
\]

13. Store energy and power reading into the EEPROM of ATmega32 Microcontroller for future use.
14. Check for updates from GSM for rate updates according to real time.
15. Check Received messages for recharge update or status request from utility.
16. If received recharge, update balance, if status request, send current remaining balance to utility.
Appendix A

C- Code:

Chip type : ATmega32
Program type : Application
Clock frequency : 4.000000 MHz
Memory model : Small
External SRAM size : 0
Data Stack size : 512

#include <mega32.h>
#ifndef __SLEEP_DEFINED__
#define __SLEEP_DEFINED__
.EQU __se_bit=0x80
.EQU __sm_mask=0x70
.EQU __sm_powerdown=0x20
.EQU __sm_powersave=0x30
.EQU __sm_standby=0x60
.EQU __sm_ext_standby=0x70
.EQU __sm_adc_noise_red=0x10
.SET power_ctrl_reg=mcucr
#endif
#include <ctype.h>
#include <string.h>
#include <stdlib.h>
// Standard Input/Output functions
#include <stdio.h>
// I2C Bus functions
#include <asm>
Appendix A

.equ __i2c_port=0x15 ;PORTC
.equ __sda_bit=1
.equ __scl_bit=0

#include <i2c.h>

// DS1307 Real Time Clock functions
#include <ds1307.h>

// Alphanumeric LCD Module functions

.equ __lcd_port=0x18 ;PORTB

#include <lcd.h>
#include <delay.h>

 returnType

GSM Variables

char setnum[10], convert[20], sdg[4], input[20], number[10], read[20], set[]="AT+CMGF=1", command[]="AT+CMGS=\n", ENTER[]="\n", notify[]="\nCredit Low! Please Recharge \n";

unsigned char ctrlZ[]={26};
char *str;

Frew Calculation Variables

char *st;
long count=0;
long c=0, overflow=0, frequency;
int a, flag=0;

Balance Variables

float RBalance=13.00 ,Balance, rate=0.1;

RTC variables

unsigned char h, m, sec;
unsigned char d, mon, y;
Appendix A

///////////////////////////////////////////////////////////////////////////////////GSM Functions///////////////////////////////////////////////////////////////////////////////////
///////////////////////////////////////////////////////////////////////////////////Send///////////////////////////////////////////////////////////////////////////////////
void SendPacket(char *str, int length)
{
    int i;
    for (i = 0; i < length; i++)
    {
        while(UCSRA.5==0);
        UDR = str[i];
    }
///////////////////////////////////////////////////////////////////////////////////Receive///////////////////////////////////////////////////////////////////////////////////
void ReceivePacket(int count)
{
    int i= 0;
    for(i=0;i<count;i++)
    {
        while(UCSRA.7==0);
        read[i]=UDR ; }
}
///////////////////////////////////////////////////////////////////////////////////string to ascii///////////////////////////////////////////////////////////////////////////////////
char* stascii(char* str,int length){
    int i;
    for(i=0;i<length;i++){
        convert[i]=toascii(str[i]);
    }
    return convert; }
///////////////////////////////////////////////////////////////////////////////////
// External Interrupt 0 service routine
interrupt [EXT_INT0] void ext_int0_isr(void)
{
    char c;
    // Place your code here
    int j=0,i;
    switch (c)
    { case '$':
    //int j=0,i;
for(i=11;i<15;i++)
{
    sdg[j]=input[i];
    j++; }

RBalance=RBalance+ ((sdg[0]-48)*1000.0+(sdg[1]-48)*100.0+(sdg[2]-48)*10.0+(sdg[3]-48)*1.0);
break;
case '*':
    ftoa(RBalance,7,str);
    SendPacket(stascii(command,8),8);
    SendPacket(stascii(number,10),10);
    SendPacket(ENTER,1);
    SendPacket(stascii(str,15),15);
    SendPacket(ctrlZ,1);
    break;
case '0':
    for(i=0;i<9;i++)
    setnum[i]=number[i];
    default:
    lcd_putsf("Error");
        delay_ms(1000);
        lcd_clear();
        break;}}

// Timer 0 overflow interrupt service routine
interrupt [TIM0_OVF] void timer0_ovf_isr(void)
{
    // Place your code here
        count++; }
#define ADC_VREF_TYPE 0x20

// Read the 8 most significant bits
Appendix A

// of the AD conversion result

unsigned char read_adc(unsigned char adc_input)
{
    ADMUX = adc_input | (ADC_VREF_TYPE & 0xff);
    // Delay needed for the stabilization of the ADC input voltage
    delay_us(10);
    // Start the AD conversion
    ADCSRA |= 0x40;
    // Wait for the AD conversion to complete
    while ((ADCSRA & 0x10) == 0);
    ADCSRA |= 0x10;
    return ADCH; /*
    // Declare your global variables here
    // GSM Variables
    char convert[20], sdg[4], input[20], number[10], send[] = "AT+CMGR=8", read[20], set[] = "AT+CMGF=1", command[] = "AT+CMGS="", ENTER[] = "\n", notify[] = "\nCredit Low! Please Recharge \0";
    unsigned char ctrlZ[] = {26};
    char *str;

    // Check Connection
    int CheckConnection()
    {char input[10], output[10] = "AT";
     SendPacket(stascii(output, 2), 2);
     SendPacket(ENTER, 1);
     ReceivePacket(2);
     // ascii to string
     strcpy(input, read);
     if (input[0] == 'O' && input[1] == 'K')
     {return 1;}
     else {lcd_putsf("GSM Disconnected");}
Appendix A

delay_ms(500);
return 0;}}

void GSMTextMode()
{
    char input[20];
    // string to ascii
    SendPacket(stascii(set,9),9);
    ReceivePacket(2);
    // ascii to string
    strcpy(input,read);
    if (input[0]=='O'&& input[1]=='K')
    {lcd_putsf("Mode Set");
        delay_ms(500);
        lcd_clear();  }
    else {lcd_putsf("Error");
        delay_ms(500);  }
}

void CheckReceived()
{
    ReceivePacket(16);
    // ascii to string
    strcpy(input,read);
    if (input[0]=='$'&& input[15]=='*')
    {lcd_clear();
        lcd_putsf("Recharge Received");
        PORTD.6=1;
        PORTD.4=1;
        PORTD.4=0;
        delay_ms(500);  }
Appendix A

lcd_clear();

        input[4]=='#')
{ PORTD.4=1;
  PORTD.4=0;
  ReceivePacket(2);
  //ascii to string
  strcpy(input,read);
  if (input[0]=='O'&& input[1]=='K')
  { lcd_putsf("Status Sent");
    delay_ms(1000);
    lcd_clear(); }
  else lcd_putsf("Error"); }

lcd_putsf("Balance:");
lcd_puts(str); }

void SendNotification()
{
char input[20];
  //STRING TO ASCII
  SendPacket(stascii(command,8),8);
  SendPacket(stascii(number,10),10);
  SendPacket(ENTER,1);
  SendPacket(stascii(notify,30),30);
  SendPacket(ctrlZ,1);
  ReceivePacket(2);
  //ascii to string
  strcpy(input,read);
  if (input[0]=='O'&& input[1]=='K')
Appendix A

```c
{    lcd_clear();
    lcd_putsf("Notification Sent");
    delay_ms(1000);
    lcd_clear(); }

else { lcd_putsf("Error");
    delay_ms(1000);
    lcd_clear(); }

lcd_putsf("Balance:"; )

					 ascertain User Number
								

void SetNumber()
{    int i;
    ReceivePacket(10);
    //ASCII TO STRING
    strcpy(setnum,read);
    if (setnum[0]=='0')
    { for(i=0;i<9;i++)
        number[i]=setnum[i];   }   }

					 Frequent Calculation
								
long CalcFreq()
{ a=read_adc(0);       // read the voltage signal which is required to
    // measure its frequency
    if(a>128 && flag==0)  // save the time (no. of overflows) when
        { c=count;      // transition from positive values to negative values happens
            flag=1;   // triggering the flag    }
        if(a<128 && flag==1)  // detecting the end of the half cycle
            { overflow = count-c;
                frequency=1000000/(2*256*overflow);
                flag=0;
```
void DisplayBal(float);

void CheckForUpdate()
{
    char no[]="0923061189",input[20];

    rtc_get_time(&h,&m,&sec);
    if (h==6 || h==7 || h==8 || h==9 || h==10 || h==11 || h==12 || h==13 || h==14
        || h==15 || h==16 || h==17 || h==18 & m==0 & sec==0)
    {
        rate = 0.26;
    }
    else if( h==19 || h==20 || h==21 || h==22 || h==23 || h==0 || h==1 || h==2
            || h==3 || h==4 || h==5 & & m==0 & & sec==0){ rate = 0.15;}
    ftoa(RBalance,7,str);
    SendPacket(stascii(command,8),8);
    SendPacket(stascii(no,10),10);
    SendPacket(ENTER,1);
    SendPacket(str,15);
    SendPacket(stascii(str,15),15);
    SendPacket(ctrlZ,1);
    ReceivePacket(2);
    //ascii to string
    strcpy(input,read);
    if (input[0]=='O'&& input[1]=='K')
    {
        lcd_clear();
        lcd_putsf("Balance Sent");
        delay_ms(500);
        lcd_clear();
    }
    else { lcd_putsf("Error");
        delay_ms(500); } /*
Appendix A

// lcd_putsf("Balance:");
//DisplayBal(RBalance);//

///////////Balance Calculation///////////

float CalcBalance(long x)
{
  //CheckForUpdate();
  x=10 ; rate = 0.1;
  Balance=x*rate;
  RBalance = RBalance - Balance;
  return RBalance;
}

///////////Balance Display///////////

void DisplayBal(float y)
{
  char st[7];
  lcd_gotoxy(0,1);
  ftoa(y,0x02,st);
  lcd_puts(st);
  lcd_putsf(" SDG ");
  delay_ms(5000); }

///////////Balance Check///////////

void CheckBalance(float x)
{
  if(x < 10.0 && x>8.0)
  { SendNotification();
    PORTD.6=1;
    lcd_gotoxy(0,0);
    lcd_putsf("Low Balance:");
    delay_ms(500); }
  else if (x <= 0.0)
  { lcd_clear();
    lcd_putsf("No Balance,");
Appendix A

```c
lcd_gotoxy(0,1);
lcd_putsf("Please Recharge");
delay_ms(500);
x=0.0;
PORTD.6=0;
CheckReceived();  }
}

void StartMessage()
{
lcd_clear();
lcd_putsf("Hello World");
delay_ms(500);
lcd_clear();
lcd_putsf("E&M Energy Meter");
delay_ms(500);
lcd_clear();  }

void DisplayD_T()
{
  int day,month,year,hour,minute,second;
  day=d;
  month=mon;
  year=y;
  hour=h;
  minute=m;
  second=sec;
  lcd_clear();
lcd_putsf("Date: ");
itoa(day,st);
lcd_puts(st);
```
Appendix A

lcd_putsf("/");
itoa(month,st);
lcd_puts(st);
lcd_putsf("/");
itoa(year,st);
lcd_puts(st);
delay_ms(500);
lcd_clear();
lcd_putsf("Time: ");

itoa(hour,st);
lcd_puts(st);
lcd_putsf(":");

itoa(minute,st);
lcd_puts(st);
lcd_putsf(":");

itoa(second,st);
lcd_puts(st);
delay_ms(500);
lcd_clear();

void main(void)
{
    // Declare your local variables here
    int CC; long freq;

    // Input/Output Ports initialization
    // Port A initialization
// Func7=In Func6=In Func5=In Func4=In Func3=In Func2=In Func1=In Func0=In
// State7=T State6=T State5=T State4=T State3=T State2=0 State1=T State0=T
PORTA=0x00;
DDRA=0x00;

// Port B initialization
// Func7=In Func6=In Func5=In Func4=In Func3=In Func2=In Func1=In Func0=In
// State7=T State6=T State5=T State4=T State3=T State2=T State1=T State0=T
PORTB=0x00;
DDRB=0x00;

// Port C initialization
// Func7=In Func6=In Func5=In Func4=In Func3=In Func2=In Func1=In Func0=In
// State7=T State6=T State5=T State4=T State3=T State2=T State1=T State0=T
PORTC=0x00;
DDRC=0x00;

// Port D initialization
// Func7=Out Func6=Out Func5=In Func4=Out Func3=In Func2=In Func1=In Func0=In
// State7=0 State6=0 State5=T State4=0 State3=T State2=T State1=T State0=T
PORTD=0x00;
DDRD=0x00;

// Timer/Counter 0 initialization
// Clock source: System Clock
// Clock value: 4000.000 kHz
// Mode: Normal top=FFh
// OC0 output: Disconnected
TCCR0=0x01;
TCNT0=0x00;
OCR0=0x00;

// Timer/Counter 1 initialization
// Clock source: System Clock
// Clock value: Timer 1 Stopped
// Mode: Normal top=FFFFh
// OC1A output: Discon.
// OC1B output: Discon.
// Noise Canceler: Off
// Input Capture on Falling Edge
// Timer 1 Overflow Interrupt: Off
// Input Capture Interrupt: Off
// Compare A Match Interrupt: Off
// Compare B Match Interrupt: Off
TCCR1A=0x00;
TCCR1B=0x00;
TCNT1H=0x00;
TCNT1L=0x00;
ICR1H=0x00;
ICR1L=0x00;
OCR1AH=0x00;
OCR1AL=0x00;
OCR1BH=0x00;
OCR1BL=0x00;
// Timer/Counter 2 initialization
// Clock source: System Clock
// Clock value: Timer 2 Stopped
// Mode: Normal top=FFh
// OC2 output: Disconnected
ASSR=0x00;
TCCR2=0x00;
Appendix A

TCNT2=0x00;
OCR2=0x00;
// External Interrupt(s) initialization
// INT0: On
// INT0 Mode: Rising Edge
// INT1: Off
// INT2: Off
GICR|=0x40;
MCUCR=0x03;
MCUCSR=0x00;
GIFR=0x40;
// Timer(s)/Counter(s) Interrupt(s) initialization
TIMSK=0x01;
// USART initialization
// Communication Parameters: 8 Data, 1 Stop, No Parity
// USART Receiver: On
// USART Transmitter: On
// USART Mode: Asynchronous
// USART Baud Rate: 9600
UCSRA=0x00;
UCSRB=0x18;
UCSRC=0x86;
UBRRH=0x00;
UBRRL=0x19;
// Analog Comparator initialization
// Analog Comparator: Off
// Analog Comparator Input Capture by Timer/Counter 1: Off
ACSR=0x80;
Appendix A

SFIOR=0x00;

// ADC initialization
// ADC Clock frequency: 1000.000 kHz
// ADC Voltage Reference: AREF pin
// Only the 8 most significant bits of
// the AD conversion result are used
ADMUX=ADC_VREF_TYPE & 0xff;
ADCSRA=0x82;
SFIOR&=0x1F;

// I2C Bus initialization
i2c_init();

// DS1307 Real Time Clock initialization
// Square wave output on pin SQW/OUT: Off
// SQW/OUT pin state: 0

rtc_init(3,1,0);
rtc_get_time(&h,&m,&sec);
rtc_get_date(&d,&mon,&y);

// LCD module initialization
lcd_init(16);

// Global enable interrupts
#asm("sei")

StartMessage();
DisplayD_T();
CC=CheckConnection();
if(CC==1)
PORTD.6=1;
GSMTextMode();
//SetNumber();
///////////////////////////////////////////////////////////////////////////
lcd_clear();
lcd_putsf("Balance:");
lcd_gotoxy(0,1);
lcd_putsf("__ SDG");
while (1)  {  // Place your code here
    freq=CalcFreq();
    RBal=CalcBalance(freq);
    CheckBalance(RBal);
    DisplayBal(RBal);
    //CheckForUpdate();
    CheckReceived();}
Appendix B

Energy Meter IC (AD71056) PCB Design:

AD71056 Pin Description Table:

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Mnemonic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VCC</td>
<td>Power Supply. This pin provides the supply voltage for the circuitry in the AD71056. Maintain the supply voltage at 5 V ± 5% for specified operation. Decouple this pin with a 10 µF capacitor in parallel with a ceramic 100 nF capacitor.</td>
</tr>
<tr>
<td>2, 3</td>
<td>V2P, V2N</td>
<td>Analog Inputs for Channel V2 (Voltage Channel). These inputs provide a fully differential input pair. The maximum differential input voltage is ±165 mV for specified operation. Both inputs have internal ESD protection circuitry; an overvoltage of ±6 V can be sustained on these inputs without risk of permanent damage.</td>
</tr>
<tr>
<td>4, 5</td>
<td>V1N, V1P</td>
<td>Analog Inputs for Channel V1 (Current Channel). These inputs are fully differential voltage inputs with a maximum signal level of ±30 mV with respect to the V1N pin for specified operation. Both inputs have internal ESD protection circuitry and, in addition, an overvoltage of ±6 V can be sustained on these inputs without risk of permanent damage.</td>
</tr>
<tr>
<td>6</td>
<td>AGND</td>
<td>Analog Ground. This pin provides the ground reference for the analog circuitry in the AD71056, that is, the ADCs and reference. Tie this pin to the analog ground plane of the PCB. The analog ground plane is the ground reference for all analog circuitry, such as antialiasing filters, current and voltage sensors, and so forth. For accurate noise suppression, connect the analog ground plane to the digital ground plane at only one point. A star ground configuration helps to keep noisy digital currents away from the analog circuits.</td>
</tr>
<tr>
<td>7</td>
<td>REFINOUT</td>
<td>Reference Voltage. The on-chip reference has a nominal value of 2.45 V and a typical temperature coefficient of 20 ppm/°C. An external reference source can also be connected at this pin. In either case, decouple this pin to AGND with a 1 µF tantalum capacitor and a 100 nF ceramic capacitor. The internal reference cannot be used to drive an external load.</td>
</tr>
<tr>
<td>8</td>
<td>SCF</td>
<td>Select Calibration Frequency. This logic input selects the frequency on the Calibration Output CF. Table 7 shows calibration frequency selections.</td>
</tr>
<tr>
<td>9, 10</td>
<td>S1, S0</td>
<td>Conversion Frequency Logic Input Selection. These logic inputs select one of four possible frequencies for the digital-to-frequency conversion. With this logic input, designers have greater flexibility when designing an energy meter. Table 5 shows conversion frequency selections.</td>
</tr>
<tr>
<td>11</td>
<td>RCLKIN</td>
<td>On-Chip Clock Enable. To enable the internal oscillator as a clock source to the chip, a precise low temperature drift resistor at a nominal value of 62 kΩ must be connected from this pin to DGND.</td>
</tr>
<tr>
<td>12</td>
<td>RDVP</td>
<td>Negative Power Indicator. This logic output goes high when negative power is detected, such as when the phase angle between the voltage and current signals is greater than 90°. This output is not latched and is reset when positive power is once again detected. The output goes high or low at the same time that a pulse is issued on CF.</td>
</tr>
<tr>
<td>13</td>
<td>DGND</td>
<td>Digital Ground. This pin provides the ground reference for the digital circuitry in the AD71056, that is, the multiplier, filters, and digital-to-frequency converter. Tie this pin to the digital ground plane of the PCB. The digital ground plane is the ground reference for all digital circuitry, for example, counters (mechanical and digital), MCUs, and indicator LEDs. For accurate noise suppression, connect the analog ground plane to the digital ground plane at one point only—a star ground.</td>
</tr>
<tr>
<td>14</td>
<td>CF</td>
<td>Calibration Frequency Logic Output. The CF logic output provides instantaneous real power information. This output is for calibration purposes (also see the SCF pin description).</td>
</tr>
<tr>
<td>15, 16</td>
<td>F2, F1</td>
<td>Low Frequency Logic Outputs. F1 and F2 supply average real power information. The logic outputs can be used to directly drive electromechanical counters and 2-phase stepper motors. See the Transfer Function section.</td>
</tr>
</tbody>
</table>
## Appendix C

**LCD Pin Description Table**

<table>
<thead>
<tr>
<th>Pin No</th>
<th>Function</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ground (0V)</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>Supply voltage; 5V (4.7V – 5.3V)</td>
<td>Vcc</td>
</tr>
<tr>
<td>3</td>
<td>Contrast adjustment; through a variable resistor</td>
<td>VEE</td>
</tr>
<tr>
<td>4</td>
<td>Selects command register when low; and data register when high</td>
<td>Register Select</td>
</tr>
<tr>
<td>5</td>
<td>Low to write to the register; High to read from the register</td>
<td>Read/write</td>
</tr>
<tr>
<td>6</td>
<td>Sends data to data pins when a high to low pulse is given</td>
<td>Enable</td>
</tr>
<tr>
<td>7</td>
<td>8-bit data pins</td>
<td>DB0</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>DB1</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>DB2</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>DB3</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>DB4</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>DB5</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>DB6</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>DB7</td>
</tr>
<tr>
<td>15</td>
<td>Backlight V&lt;sub&gt;CC&lt;/sub&gt; (5V)</td>
<td>Led+</td>
</tr>
<tr>
<td>16</td>
<td>Backlight Ground (0V)</td>
<td>Led-</td>
</tr>
</tbody>
</table>