FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

FINAL YEAR PROJECT REPORT

DESIGN AND IMPLEMENTATION OF A PREPAID UNIT SHARING MANAGEMENT SYSTEM IN UEDCL LIGHT METERS.

BY

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A final year project report submitted to the Department of Electrical Engineering as a partial fulfilment of the requirements for the award of a Bachelors degree of Science in Electrical Engineering of Busitema University.

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ABSTRACT

Light metering system includes a customer interface unit (CIU) that is easily accessible on the user premises. Upon any payment, a 20-digit token **MUST** be entered to have units loaded into the meter.

This project proposes the design and implementation of a secure, reliable, and user-friendly prepaid electricity unit-sharing platform that enables LIGHT (formerly Yaka) customers under Uganda Electricity Distribution Company Limited (UEDCL) to share or transfer purchased prepaid electricity units between meters. The system will provide a mobile and web-based interface for initiating, approving, and tracking unit transfers, while ensuring compliance with meter token formats and vendor workflows. The platform aims to improve customer flexibility, reduce wasted units, and increase user satisfaction while preserving utility revenue protection and data integrity.

DECLARATION

We declare that this project report is our original work and has not been submitted for the award of any degree in any other university or institution of higher learning.

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DEDICATION

We dedicate this report to our parents, whose unwavering love, support, and encouragement have been the foundation of our academic journey.

APPROVAL

We submit this report of our final year project to the faculty of Engineering and Technology in the Department of Electrical Engineering with the approval of our supervisors

MADAM ~~MUGUME~~ PATIENCE Kisaimire

Signature: ....Patience........

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Signature: ....

Date: 27/06/2026

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CHAPTER ONE

INTRODUCTION

1.1 Introduction:

In 2010, Uganda's largest electricity distribution company, UMEME Limited, initiated a tender for a Prepayment Metering Turnkey Business Solution, which led to the deployment of the Yaka smart electricity meters that revolutionized how Ugandans accessed and paid for electricity. This initiative was intended to address long-standing challenges such as poor payment of electricity bills, high operational costs associated with manual billing, and the need for improved monitoring and management of consumer energy usage. It also sought to minimize electricity fraud, particularly by discouraging the activities of unauthorized technicians who extorted customers through illegal disconnections and reconnections.

By mid-2013, UMEME had successfully migrated about 32,000 customers to the prepaid Yaka system—a number that had nearly doubled by the end of 2014 [1]. The adoption of prepaid metering not only enhanced revenue collection but also empowered consumers with real-time control over their energy expenditure.

However, in 2025, UMEME's concession came to an end, and the responsibility for electricity distribution reverted to the Uganda Electricity Distribution Company Limited (UEDCL). Under this new management, the prepaid electricity service was rebranded as "LIGHT", marking a new era in Uganda's power distribution landscape. LIGHT retains the strengths of the Yaka model but incorporates modernized digital features, enhanced transparency, and improved customer engagement.

This transition presents an opportunity to introduce innovative functionalities, such as secure sharing of prepaid electricity units among customers, a concept that could enhance social and economic efficiency while promoting equitable energy access. The proposed project therefore focuses on the design and implementation of a prepaid electricity unit-sharing platform under UEDCL's LIGHT system, aimed at improving flexibility, accountability, and customer satisfaction across Uganda's power distribution network.

Prepaid electricity meters have become standard in many utility distribution networks. LIGHT (previously Yaka) meters require tokens (numeric codes) to load units onto meters. In many households and communities, customers sometimes need to share surplus units with family, neighbours, or communal entities. Currently, transferring units between different prepaid meters is impossible. A structured platform for securely transferring and sharing units would provide social benefits (reduced waste, support during outages), commercial benefits (increased unit uptake), and operational advantages if integrated appropriately with utility procedures.

This project explores the systems, hardware, communication protocols, and software required to enable authorized transfer of prepaid energy units within UEDCL's operational constraints.

1.2 Background:

In 2010, Uganda's largest electricity distribution company UMEME put out a tender for a Prepayment Metering turnkey Business Solution which led to the deployment of the Yaka smart electricity meters as we know them today.

As a company, UMEME expected to address some challenges like poor payment of electricity bills, high cost of billing as well as create an opportunity for easier monitoring of consumers' meters and energy consumption.

It was also anticipated that this new system will reduce the fraud that has been largely peddled by illegal electricity technicians who prey on unsuspecting customers by extorting money out of them under the guise of disconnecting and reconnecting them. By the first half of 2013, the company had 32,000 customers converted to the pre-paid Yaka system a number that is likely to have doubled by the close of 2014 [1].

A good look at how Smart Meters operate shows a heavy reliance on ICT systems. A smart meter is usually an electronic device that records consumption of electric energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing purposes. Governments globally are rooting for Smarter metering systems in order to encourage better and sustainable usage of the limited electricity energy available. This has led to a sudden boom in the production of smart meters as utility companies are buoyed to take on this direction in response to Government support.

To acquire a YAKA meter, a couple of procedures have to be taken including account opening at a defined cost, customer details registration and premises survey among others. The same procedures are also taken when the meter or account requires unlocking due to reasons which may include but not limited to damaged meter, more than three false tokens entries on CIU, assumed meter tamper with magnetic exposure, clock reject tamper and bypass among others.

1.3 Problem statement:

Customers of LIGHT (UEDCL) lack a standardized, secure, and auditable mechanism to transfer prepaid electricity tokens/units between meters. There is no existing ad-hoc sharing methods with no potential revenue leakages that Light customers can utilise to share power units amongst themselves. There is a need for a technical solution that allows controlled sharing while ensuring meter compatibility, transaction traceability, and compliance with utility regulations.

1.4 Objectives

1.4.1 General objective:

- To design and implement a prototype unit-sharing management system in UEDCL light meters that enables secure, auditable transfer of prepaid electricity units.

1.4.2 Specific objectives:

1. To investigate the current prepaid metering system in light meters especially hexing meters with a unit allocation, transparency and user control.
2. To design and prototype a hardware-based system that enables secure, sharing of prepaid electricity units using RF communication modules (HC-12) between microcontroller devices.
3. To evaluate the system's performance, security, and usability through testing and user feedback.

1.4.3 Research Questions

1. How does the current prepaid metering system operate in terms of unit allocation, transparency, and user control?
2. How can a hardware-based system using RF communication (HC-12) be designed to securely enable sharing of prepaid electricity units between microcontroller devices?
3. How effective, secure and user-friendly is the proposed unit-sharing system when tested in real-world scenarios?

1.5 Scope:

This project focuses on the design and implementation of a prototype platform that enables customers under Uganda Electricity Distribution Company Limited (UEDCL) to share prepaid electricity units within the LIGHT system, formerly known as Yaka, using hardware-to-hardware communication. The core of the project revolves around employing HC-12 RF modules to facilitate secure and direct exchange of units between microcontroller-based devices, providing a practical demonstration of peer-to-peer unit sharing without relying on internet connectivity or web applications.

Each customer will be equipped with a microcontroller-based device interfaced with their meter or serving as a secure intermediary. These devices will communicate directly via the HC-12 wireless link, enabling unit transfers in real-time. The system will handle generation, encryption, transmission, and reception of digital unit tokens, ensuring integrity, security, and non-repudiation of transactions. Transaction records will be maintained locally on each device, creating a reliable log for verification and auditing purposes.

The project will also include visual feedback mechanisms, such as LEDs or a small LCD display, to indicate the status of unit transfers and confirmations, providing users with clear and immediate understanding of successful or failed transactions. By focusing on hardware-level communication, the project emphasizes a practical, scalable, and low-cost solution that is particularly suitable for communities with limited internet or cellular connectivity.

While the prototype will simulate the unit transfer process and meter-side application, it will not modify the existing meter firmware or interfere with official UEDCL operations, ensuring compliance with regulatory requirements. The project will be evaluated based on the accuracy, reliability, security, and usability of the unit-sharing mechanism using HC-12 RF communication.

1.6 Significance:

- Enhanced transparency, consumer flexibility; Allows households and communities to redistribute surplus prepaid units.
- Demonstrates a peer-to-peer, hardware-to-hardware sharing model using HC-12 RF communication.
- Contributes to the broader national goals of ICT-driven energy management and smart grid development and it aligns with Uganda’s objective for digital innovation in utility services.
- Encourages community cooperation, energy access and support.
- Improves electricity access for vulnerable populations, promoting inclusivity and equitable energy distribution.

1.7 Justification:

- This project is justified by the urgent need to enhance equity, transparency and energy access.
- By designing a prepaid electricity unit sharing system compatible with existing Light metering infrastructure, the project will empower users to monitor and manage their energy consumption independently, reduce reliance on informal practices. It also aligns with Uganda's broader goals of ICT integration in utility services and supports the evolution towards smarter, more inclusive energy systems and innovations.
- The solution has potential to be implemented across the country, making it both technically relevant and socially impactful.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction:

Recent trends in digital technologies have resulted to monumental developments in wireless communications which clearly shows that the place of Global System for Mobile Communications (GSM) technology cannot be over-emphasized.

Automatic meter reading and remoter meter telemetry technics have been embraced throughout the world, and in Uganda, power utility companies including UETCL and UMEME have embraced such systems though not at full scale. In a move to quicken the meter reading process in far remote isolated metering infrastructure, UETCL has deployed sample remote meter reading infrastructures in Northern Uganda. Other developers over the past have also made tremendous moves that can't be over looked as discussed below:

2.2 Related works

Prepaid meters can also make use of state of art technologies like WiMAX owing to the idea of centralized accounting, monitoring and charging. It brings telecommunication to the core of its activities to support more Smart Grid applications such as Demand Response and Plug-in electric vehicles [4]. Prepayment polyphase electricity metering systems have also been developed consisting of local prepayment and a card reader-based energy meter [5]

In their paper, Maheswari and Sivakumar (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 [7].

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 [6].

Amit. J 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 [8].

2.3 Current YAKA metering infrastructure:

In 2010, Uganda's largest electricity distribution company UMEME put out a tender for a Pre-Payment Metering turnkey Business Solution which led to the deployment of the Yaka smart electricity meters as we know them today [1].

As a company, UMEME expected to address some challenges like poor payment of electricity bills, high cost of billing as well as create an opportunity for easier monitoring of consumer meters and energy consumption. It was also anticipated that this new system will reduce the fraud that has been largely peddled by illegal electricity technicians who prey on unsuspecting customers by extorting money out of them under the guise of disconnecting and reconnecting them. By the first half of 2013, the company had 32,000 customers converted to the pre-paid Yaka system a number that is likely to have doubled by the close of 2014 [1].

2.4 Conceptual Framework.

Key Concepts

Inputs

- **User Registration Data**
  (Account ID, meter ID, user information)
- **Purchased Prepaid Units**
  (Number of units bought through mobile app, web portal, vendor)
- **Sharing Instructions**

  (Recipient meter ID, number of units to share)

Process/ System Components

- **Authentication and Verification**
  Ensures valid user and meter identification.
- **Prepaid Unit Management System**
  Stores, deducts and updates unit balances
- **Unit Sharing Algorithm**
  Processes unit transfers between meters
- **Meter Communication Module**

Sends unit update to the physical meter

- **Monitoring and Notifications System**
  Sends SMS/app notification on usage, transfers and low balance

Outputs

- **Updated Meter Unit Balance**
  (For both sender and recipient)
- **Usage and Sharing Reports**
  (Transaction history)
- **Improved User Control and Transparency**
  (Users can track and manage unit consumption)

Conceptual Framework.

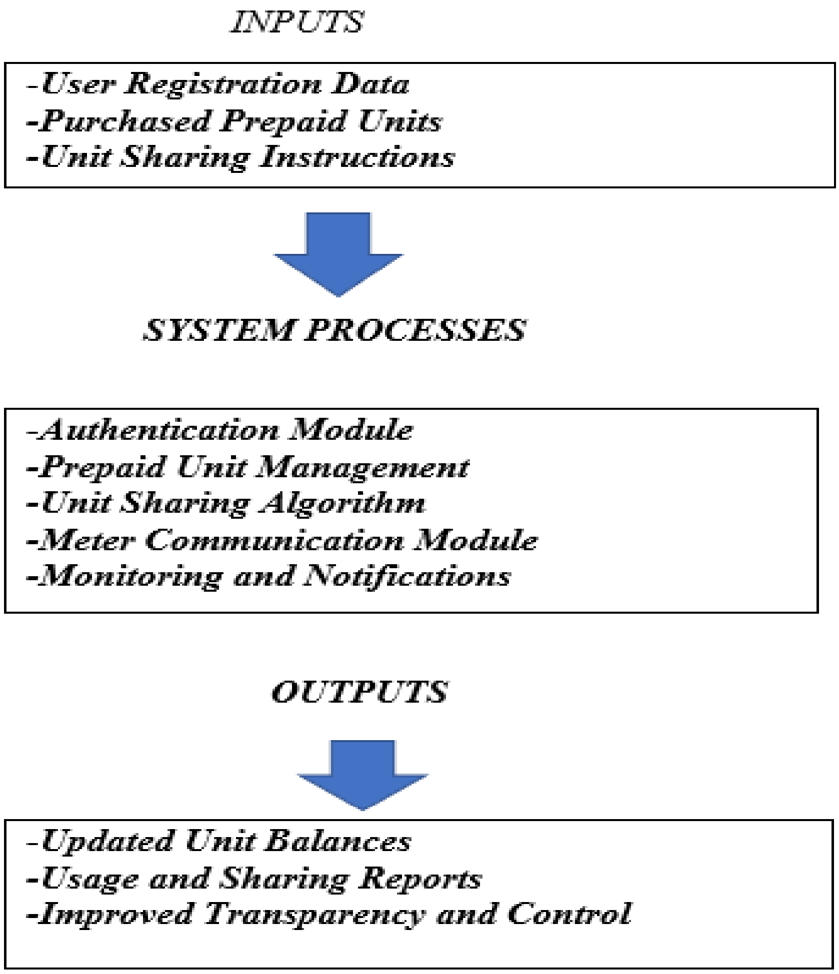

Figure 1 Shows the conceptual framework.

CHAPTER THREE

METHODOLOGY

3.1 Requirements Gathering

A number of research methods will be utilized to gather information about the research topic. The research focus areas shall include the cellular airtime sharing used by data service providers. The major methods will include;

3.1.1 Observation

This method implies the collection of information by the way of own observation, without interviewing the respondents. Here several field visits to airtime service providers including MTN, AIRTEL, UTL among others will be carried out. We shall as well engage with UEDCL metering teams in Lugogo to fully understand the mode of operation of current light.

3.1.2 Interview:

This method involves mainly interviewing the UEDCL technical staff on key issues but not limited to challenges faced in the current pre-paid metering systems, why units sharing is not enabled yet, challenges attributed to on-net meter control among others. This will help identify new requirements necessary for the development of an ideal system to solve problems currently faced by customers using pre-paid meters from UEDCL.

3.1.3 Literature search:

This method involves reading important documents such as textbooks, articles, journals, magazines, newspapers and websites over the internet. This can help give a broad knowledge about international testing standards and design procedures among others.

3.2 Requirement Analysis

The data collected will be cross-checked for consistence basing on the objectives of the study. Data will then be analysed according to the objectives in order to come up with actual system requirements and make effective recommendations.

3.3 System design

The research will focus on design and implementation of a prototype platform that enables customers under Uganda Electricity Distribution Company Limited (UEDCL) to share prepaid electricity units within the LIGHT system, formerly known as Yaka, using hardware-to-hardware communication. The core of the project revolves around employing HC-12 RF modules to facilitate secure and direct exchange of units between microcontroller-based devices, providing a practical demonstration of peer-to-peer unit sharing without relying on internet connectivity or web applications. The prototype will be fully a breadboard concept with circuits and logical flow diagrams developed.

The schematic design will then be transferred to the breadboard and then tested for functionality. On meeting the design specifications, the design will there after transferred and firmly soldered onto the copper board.

3.4 Testing and validation

The system will be tested immediately after implementing it to ensure that the functionality of the entire system was as per the objectives of the study pre-described. Validation is necessary in case of system misbehaviour to ensure that the main goal of the study is clearly reflected and achieved.

System Block Diagram

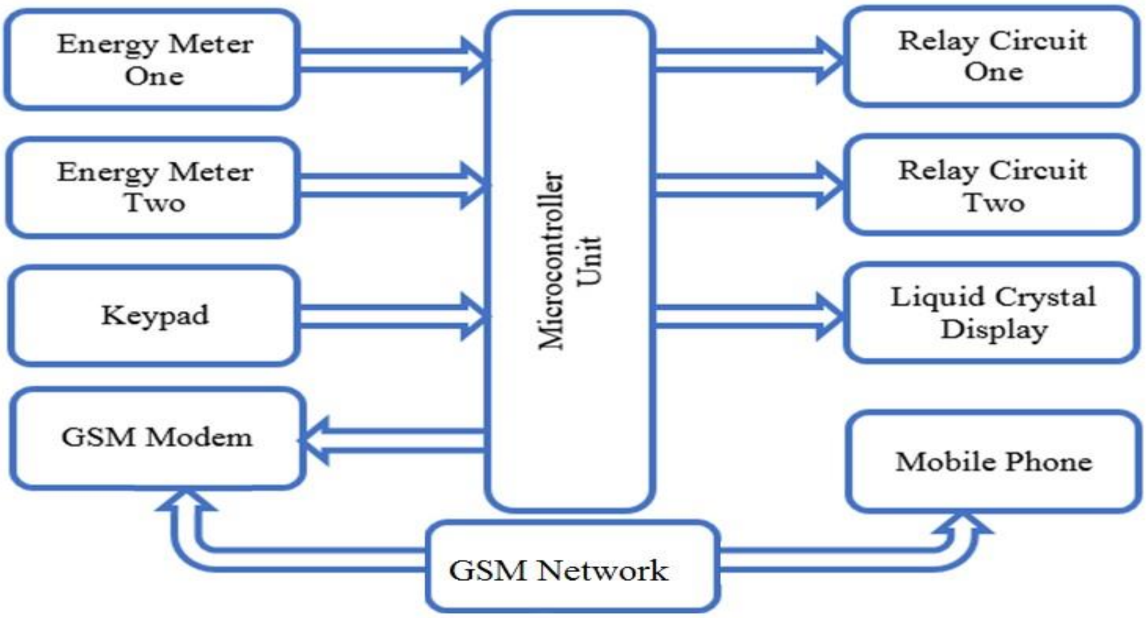

Figure 2 Shows the System Block Diagram

System Circuit Diagram:

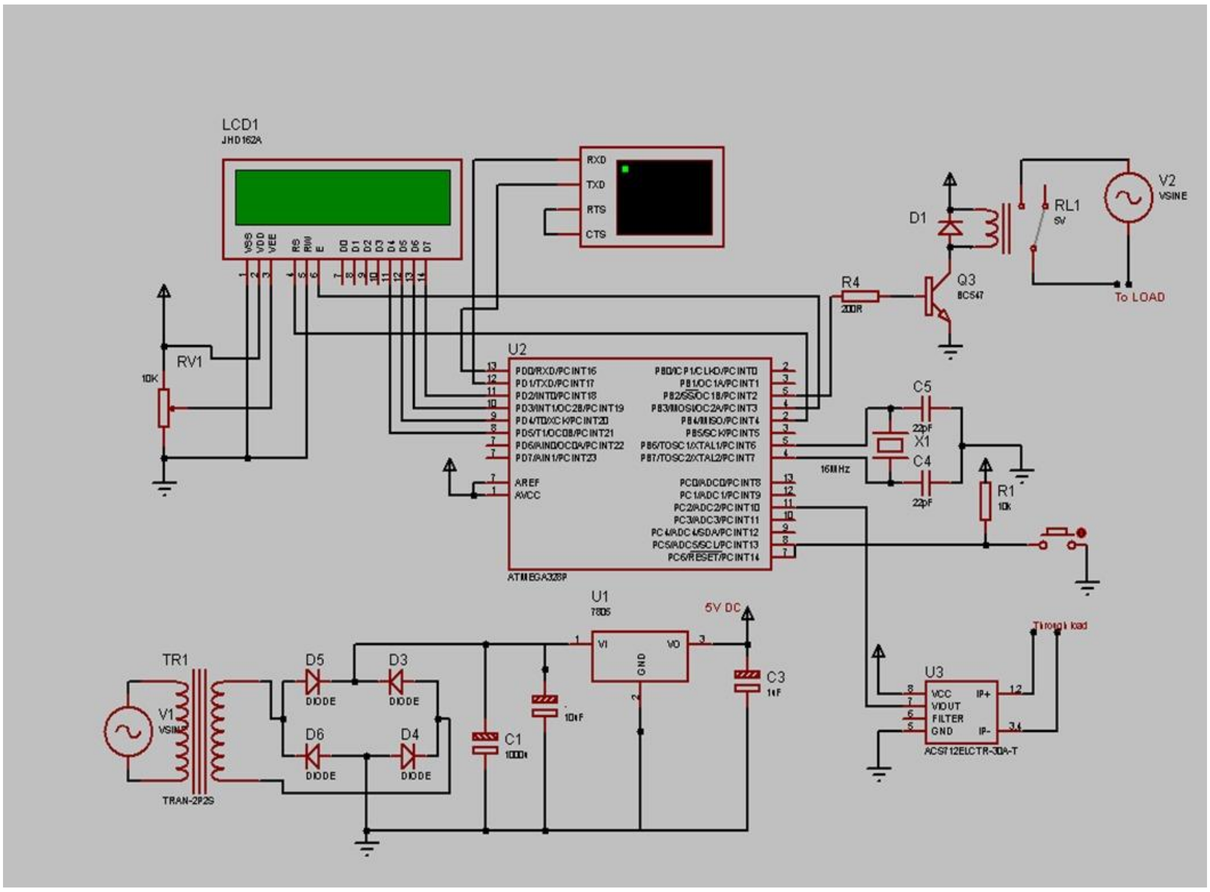

Figure 3 Shows the Circuit diagram

CHAPTER FOUR

DESIGN

4.1 Introduction

System analysis and design give a more elaborative description and analysis of the developed system, project requirements, project design and its implementation in detail.

4.2 System Requirements Specification

This chapter involves specifying the relevant requirements for the design and implementation of the system. The chapter includes among other things analysis of the functional and non-functional requirements.

4.2.1 Functional Requirements

These requirements are used to come up with a functional model detailing all the hierarchical breakdown of the major functional blocks of the system. The main functional requirements for this project included;

- The system to be able to automatically load units without user 20-digit input.
- The system to provide an accurate metering infrastructure.
- The system should be able to share units with a deduction on giver and increase on receiver.

4.2.2 Nonfunctional Requirements

- The system should be reliable that it doesn't fail to receive and pronounce the received data.
- The system should have a high degree of correctness that it should never give an alert signal when no data has been received.

4.3 Components used and their specifications.

The major hard ware components that were used in the system development include the following;

4.3.1 ATMEGA328P-PU MCU:

The ATmega328P is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the Atmega328P achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed. The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

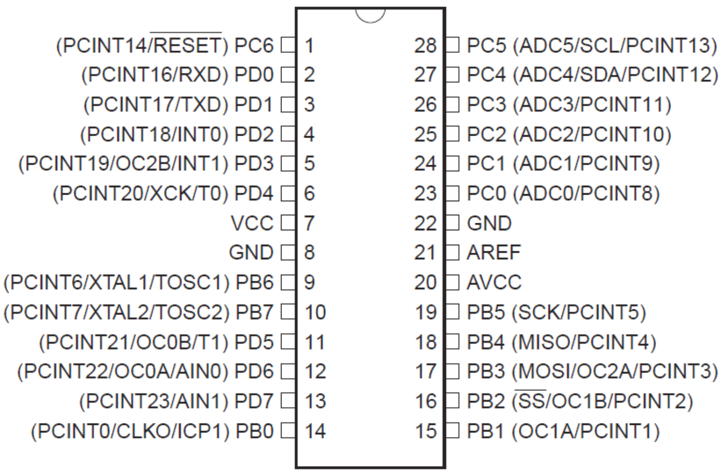

Figure 4 shows ATMEGA328P 28-DIP Top-view

The Atmega328P provides the following features: 32Kbytes of In-System Programmable Flash with Read-While-Write capabilities, 1Kbytes EEPROM, 2Kbytes SRAM, 23 general purpose I/O lines (figure 3), 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte-oriented 2-wire Serial Interface, an SPI serial port, a 6-channel 10-bit ADC (8 channels in TQFP and QFN/MLF packages), a programmable Watchdog Timer with internal Oscillator, and five software selectable power saving modes. The Idle mode stops the CPU while allowing the

SRAM, Timer/Counters, USART, 2-wire Serial Interface, SPI port, and interrupt system to continue functioning.

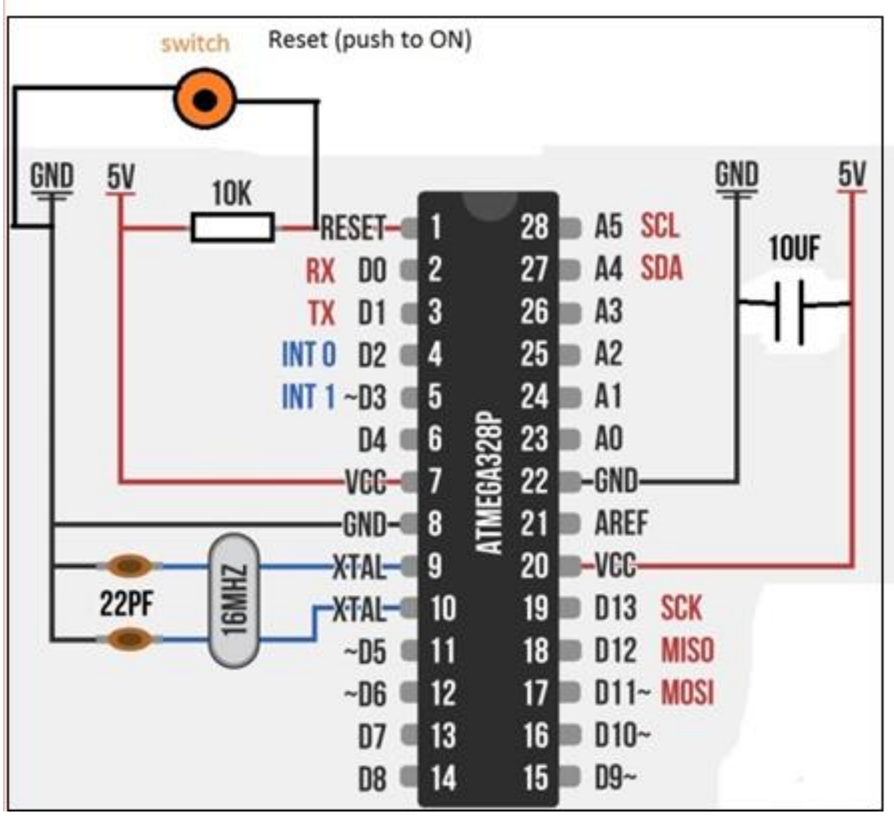

Figure 5 Shows AVR interfacing with crystal clock

The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or hardware reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low power consumption.

AVR reset:

The AVR RESET mode is an active low module on RESET pin. Pulling the RESET pin HIGH disables the unwanted system resets. Pull-up resistors on the dW/(RESET) line**,** must not be smaller than 10k (datasheet page 256). The pull-up resistor is not required for debug WIRE functionality. However, connecting the RESET pin directly to VCC will not work in disabling the reset mode.

Clock Sources

The device has the following clock source options, selectable by Flash Fuse bits as shown below. The clock from the selected source is input to the AVR clock generator, and routed to the appropriate modules.

Table 1: Device Clocking Options Select. Source: device datasheet

Device Clocking Option	CKSEL3...0
Low Power Crystal Oscillator	1111 - 1000
Full Swing Crystal Oscillator	0111 - 0110
Low Frequency Crystal Oscillator	0101 - 0100
Internal 128kHz RC Oscillator	0011
Calibrated Internal RC Oscillator	0010
External Clock	0000
Reserved	0001

Note: 1. For all fuses "1" means unprogrammed while "0" means programmed.

The device is shipped with internal RC oscillator at 8.0MHz and with the fuse CKDIV8 programmed, resulting in 1.0MHz system clock. The startup time is set to maximum and time-out period enabled. (CKSEL = "0010", SUT= "10", CKDIV8 = "0"). The default setting ensures that all users can make their desired clock source setting using any available programming interface.

Low Power Crystal Oscillator

Pins XTAL1 and XTAL2 (figure 5) are input and output, respectively, of an inverting amplifier which can be configured for use as an On-chip Oscillator.

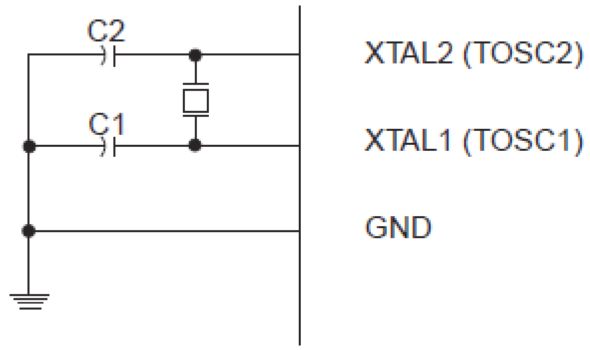

Figure 6 Shows Crystal Oscillator Connections

Either a quartz crystal or a ceramic resonator may be used. This Crystal Oscillator is a low power oscillator, with reduced voltage swing on the XTAL2 output. It gives the lowest power consumption, but is not capable of driving other clock inputs, and may be more susceptible to noise in noisy environments. C1 and C2 should always be equal for both crystals and resonators. The optimal value of the capacitors depends on the crystal or resonator in use, the amount of stray capacitance, and the electromagnetic noise of the environment. Some initial guidelines for choosing capacitors for use with crystals are given in table 2 below:

Table 2: Low Power Crystal Oscillator Operating Modes. Source: *Table 9-3 on Page 30 of device datasheet.*

Frequency Range (MHz)	Recommended Range for Capacitors C1 and C2 (pF)	CKSEL3...1[(1)]
0.4 - 0.9	–	100[(2)]
0.9 - 3.0	12 - 22	101
3.0 - 8.0	12 - 22	110
8.0 - 16.0	12 - 22	111

For ceramic resonators, the capacitor values given by the manufacturer should be used.

4.3.2 Power supply design:

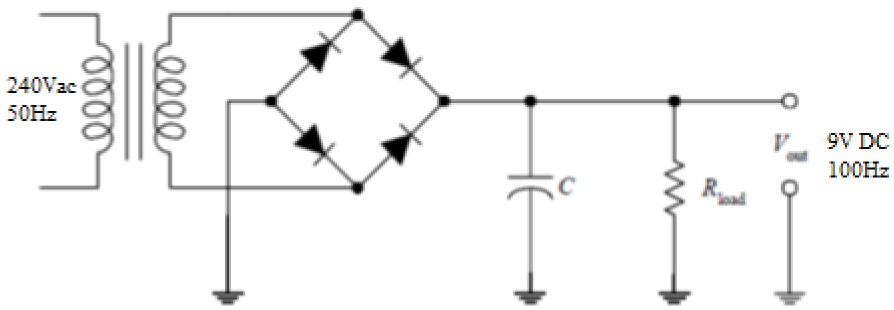

Figure 7 Shows 240Vac to 9Vdc circuit

By using a transformer and a full-wave bridge rectifier, a simple ac-to-dc power supply has been constructed. The transformer acts to step down the voltage, and the bridge rectifier acts to convert the ac input into a pulsed dc output. A filter capacitor is then used to delay the discharge time and hence "smooth" out the pulses [12].

If the above circuit is used in a power supply application, the capacitor must be large enough to store a sufficient amount of energy to provide a steady supply of current to the load. If the capacitor is not large enough or is not being charged fast enough, the voltage will drop as the load demands more current. A general rule for choosing C is to use the following relation [12]:

RloadC >> 1/f

where f is the rectified signal's frequency (100 Hz). The ripple voltage (deviation from dc) is approximated by

Vripple = Iload/fC.

One explanation of 'smoothing' is that the capacitor provides a low impedance path to the AC component of the output, reducing the AC voltage across, and AC current through, the resistive load. In less technical terms, any drop in the output voltage and current of the bridge tends to be cancelled by loss of charge in the capacitor. This charge flows out as additional current through the load. Thus, the change of load current and voltage is reduced relative to what would occur without the capacitor. Increases of voltage correspondingly store excess charge in the capacitor, thus moderating the change in output voltage / current [12].

The capacitor and the load resistance have a typical **time constant $\tau = RC$,** where C and R are the capacitance and load resistance respectively. As long as the load resistor is large enough so that this time constant is much longer than the time of one ripple cycle, the above configuration will produce a smoothed DC voltage across the load [12].

4.3.3 7805 Voltage regulator

The L7805 series of three-terminal positive regulators is available in TO-220 TO-220FP TO-3 and D2PAK packages and 5V fixed output voltage, making it useful in a wide range of applications. These regulators can provide local on-card regulation, eliminating the distribution problems associated with single point regulation. This regulator type employs internal current limiting, thermal shut-down and safe area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents. The device outputs a stable 5V for any input in range of 7V to 18V DC.

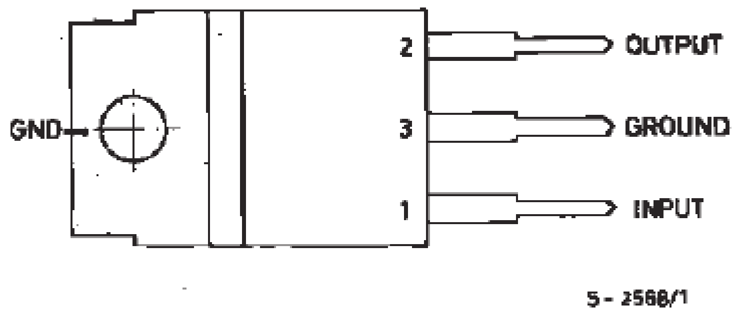

Figure 8 Shows 7805 TOP VIEW. LM7805 datasheet

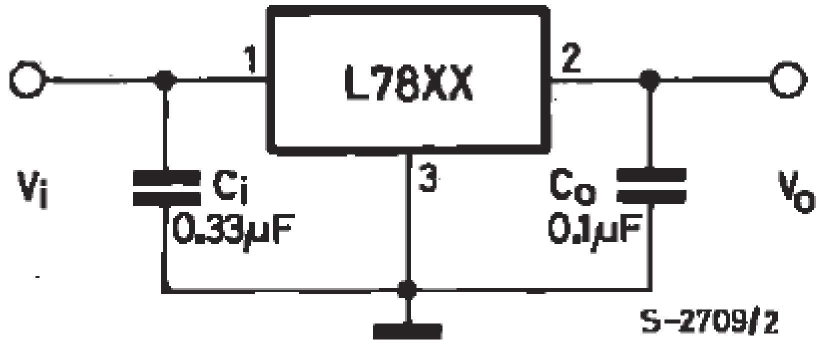

Figure 9 Shows 7805 typical application circuit. Source: LM7805 datasheet

4.3.4 Zener Diodes:

A Zener diode is a device that acts as a typical pn-junction diode when it comes to forward biasing, but it also has the ability to conduct in the reverse-biased direction when a specific breakdown voltage (VB) is reached. Zener diodes typically have breakdown voltages in the range of a few volts to a few hundred volts (although larger effective breakdown voltages can be reached by placing Zener diodes in series).

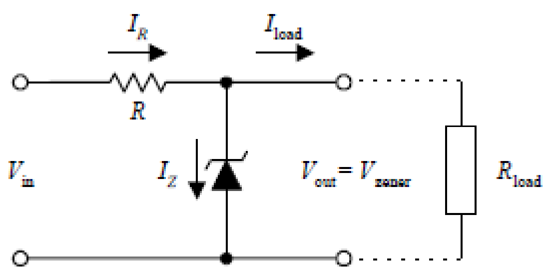

Figure 10 Shows Zener diode as a voltage regulator

In this project design, a 5V Zener diode is used to regulate the voltage supplied to a load. When Vin attempts to push Vout above the Zener diode's breakdown voltage (Vzener) as in figure 9, the Zener diode draws as much current through itself in the reverse-biased direction as is necessary to keep Vout at Vzener, even if the input voltage Vin varies considerably [12].

4.3.5 SIM800l GSM modem:

SIM800L GSM/GPRS module is a miniature GSM modem, which can be integrated into a great number of IoT projects. You can use this module to accomplish almost anything a normal cell phone can; SMS text messages, Make or receive phone calls, connecting to internet through GPRS, TCP/IP, and more! To top it off, the module supports quad-band GSM/GPRS network, meaning it works pretty much anywhere in the world.

Figure 11 Shows SIM900 GSM modem. Source: www.simcom.com

At the heart of the module is a SIM800L GSM cellular chip from SIMcom. The operating voltage of the chip is from **3.4V to 4.4V**, which makes it an ideal candidate for direct LiPo battery supply. This makes it a good choice for embedding into projects without a lot of space. All the necessary data pins of SIM800L GSM chip are broken out to 0.1″ pitch headers. This includes pins required for communication with a microcontroller over UART. The module supports baud rate from 1200bps to 115200bps with Auto-Baud detection.

The module needs an external antenna to connect to a network. The module usually comes with a Helical Antenna and solders directly to NET pin on PCB. The board also has a U. FL connector facility in case you want to keep the antenna away from the board. There's a SIM socket on the back! Any activated, **2G micro-SIM card** would work perfectly. Correct direction for inserting SIM card is normally engraved on the surface of the SIM socket.

LED Status Indicators:

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

Blink every 1s: The module is running but hasn't made connection to the cellular network yet.

Blink every 2s: The GPRS data connection you requested is active.

Blink every 3s: The module has made contact with the cellular network & can send/receive voice and SMS.

Selecting Antenna

An antenna is required to use the module for any kind of voice or data communications as well as some SIM commands. So, selecting an antenna could be a crucial thing. There are two ways you can add an antenna to your SIM800L module.

The first one is a Helical GSM antenna as seen in figure 11 which usually comes with the module and solders directly to NET pin on PCB. This antenna is very useful for projects that need to save space but struggles in getting connectivity especially if your project is indoors.

Figure 12 Shows SIM800L Helical antennae

The second one (figure 12) is any 3dBi GSM antenna along with a U. FL to SMA adapter which can be obtained online for less than $3. You can snap-fit this antenna to small u.fl connector located on the top-left corner of the module. This type of antenna has a better performance and allows putting your module inside a metal case – as long the antenna is outside.

Figure 13 Shows SIM800L 3dBi GSM antenna along with a U. FL to SMA adapter

Supplying Power for SIM800L module

One of the most important parts of getting the SIM800L module working is supplying it with enough power. Depending on which state it's in, the SIM800L can be a relatively power-hungry device. The maximum current draw of the module is around 2A during transmission burst. It usually won't pull that much, but may require around 216mA during phone calls or 80mA during network transmissions.

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

SIM800L GSM Module Pinout:

The SIM800L module has total 12 pins that interface it to the outside world as shown in the following figure. The connections are as follows:

Figure 14 Shows SIM800 modem pin out

NET is a pin where you can solder Helical Antenna provided along with the module.

VCC supplies power for the module. This can be anywhere from 3.4V to 4.4 volts. Remember connecting it to 5V pin will likely destroy your module! It doesn't even run on 3.3 V! An external power source like Li-Po battery or DC-DC buck converters rated 3.7V 2A would work.

Reset (RST) is a hard reset pin. If you absolutely got the module in a bad space, pull this pin low for 100ms to perform a hard reset.

RxD (Receiver) pin is used for serial communication.

TxD (Transmitter) pin is used for serial communication.

GND is the Ground Pin and needs to be connected to GND pin on the Arduino.

RING pin acts as a Ring Indicator. It is basically the 'interrupt' out pin from the module. It is by default high and will pulse low for 120ms when a call is received. It can also be configured to pulse when an SMS is received.

DTR pin activates/deactivates sleep mode. Pulling it HIGH will put module in sleep mode, disabling serial communication. Pulling it LOW will wake the module up.

MIC is a differential microphone input. The two microphone pins can be connected directly to these pins.

SPK is a differential speaker interface. The two pins of a speaker can be tied directly to these two pins.

4.3.6 DC Buck Converter

Any 2A-rated DC-DC buck converter like **LM2596** (figure 14) would work. These are much more efficient than a liner voltage regulator like LM317 or LM338.

Figure 15 Shows LM2596 buck converter

Warning: You should be very careful to not to disconnect the GND before the VCC and always connect GND before VCC. Otherwise, the module can use the low voltage serial pins as ground and can get destroyed instantly.

4.3.7 Indicators LEDs:

This allows current to flow in only one direction. By convention, current can only flow from the anode (positive) to the cathode (negative).

Current is what determines how bright a LED is. More current means more light. LED current should typically be between 10 to 20mA.Therefore a current limiting resistor is used to keep the bias current in the above range.

When current flows through the LED; a forward voltage drop of about 1.6V will develop between its pins, depending on the current. So, this of this resistor as a valve - reduce it to increase LED brightness, or increase it to limit wasted power in the circuit.

Consider an LED at maximum brightness. To achieve this, a typical LED current required. Now we need to calculate the forward voltage drop across this diode with this current. Forward voltage drop is not just a function of current, but also LED color and temperature (because of the different LED chemistries) as shown in the table 1 below.

Table 3: LED color PD definition

LED color	Potential difference/V
Infrared	1.6 V
Red	1.8 V to 2.1
Orange	2.2 V
Yellow	2.4 V
Green	2.6 V
Blue	3.0 V to 3.5 V
White	3.0 V to 3.5 V
Ultraviolet	3.5 V

To keep the bias current in between 10 and 20mA, the following applies [12].

- 5V Supply generated by LM7805 chip has been used in this system.

Using Ohm's Law (V=IR);

(Voltage applied - Forward voltage drop) / Forward current = Resistor value
(5V - vdV) / idA = Rd ohms

Where 5V is the applied voltage and idA is the forward bias current in amperes of the LED, vdV is the drop across the LED dependent on color and Rd is the current limiting resistor of the diode

4.3.8 LCD (JHD162A):

JHD162A is a 16×2 LCD module based on the **HD44780 driver from Hitachi**. The JHD162A LCD module has 16 pins (figure 15) and can be operated in 4-bit mode or 8-bit mode. Here we are using the LCD module in 4-bit mode. Before going in to the details of the project, let's have a look at the JHD162A LCD module. The schematic of a JHD162A LCD pin diagram is given below.

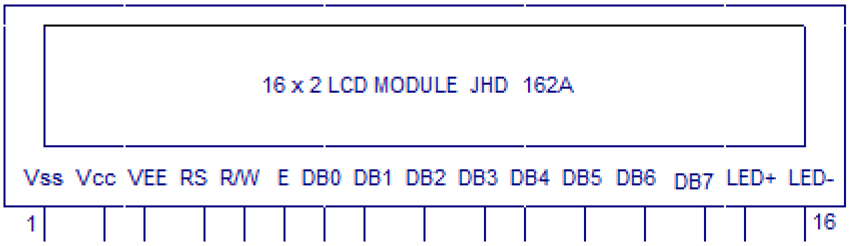

Figure 16 Shows LCD pin map. Source: HD44780 Character LCD datasheet

The name and functions of each pin of the 16×2 LCD module is given below.

- Pin1 (Vss): Ground pin of the LCD module.
- Pin2 (Vcc): Power to LCD module (+5V supply is given to this pin)
- Pin3 (VEE): Contrast adjustment pin. This is done by connecting the ends of a 10K potentiometer to +5V and ground and then connecting the slider pin to the VEE pin. The voltage at the VEE pin defines the contrast. The normal setting is between 0.4 and 0.9V.
- Pin4(RS): Register select pin. The JHD162A has two registers namely command register and data register. Logic HIGH at RS pin selects data register and logic LOW at RS pin selects command register. If we make the RS pin HIGH and feed an input to the data lines (DB0 to DB7), this input will be treated as data to display on LCD screen. If we make the RS pin LOW and feed an input to the data lines, then this will be treated as a command (a command to be written to LCD controller – like positioning cursor or clear screen or scroll).
- Pin5 (R/W): Read/Write modes. This pin is used for selecting between read and write modes. Logic HIGH at this pin activates read mode and logic LOW at this pin activates write mode.
- Pin6 (E): This pin is meant for enabling the LCD module. A HIGH to LOW signal at this pin will enable the module.
- Pin7 (DB0) to Pin14(DB7): These are data pins. The commands and data are fed to the LCD module though these pins.
- Pin15 (LED+): Anode of the back light LED. When operated on 5V, a 560-ohm resistor should be connected in series to this pin.
- Pin16 (LED-): Cathode of the back light LED.

RS pin of the LCD module is connected to PB1. R/W pin of the LCD is grounded. Enable pin of the LCD module is connected to PB2. In this project, the **LCD module and AVR controller**

are interfaced in the 4-bit mode as depicted on the system circuit. This means only four of the digital input lines (DB4 to DB7) of the LCD are used. This method is very simple, requires less connections and you can almost utilize the full potential of the LCD module. Digital lines DB4, DB5, DB6 and DB7 are interfaced to digital pins PD5, PD6, PD7, and PB0. The 10K potentiometer is used for adjusting the contrast of the display.

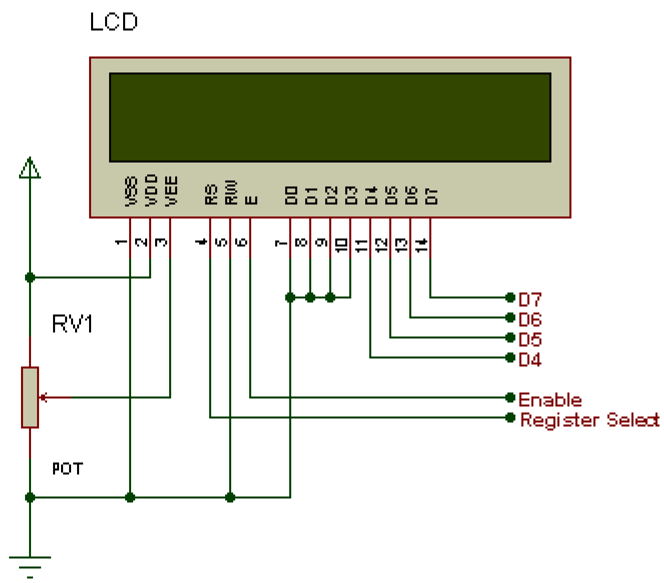

Figure 17 Shows LCD interface circuit

4.3.9 Current measurement using ACS712 Current sensor:

The current is measured in two directions. What this means is that if we sample fast enough and long enough, we sure to find the peak in one direction and the peak in another direction.

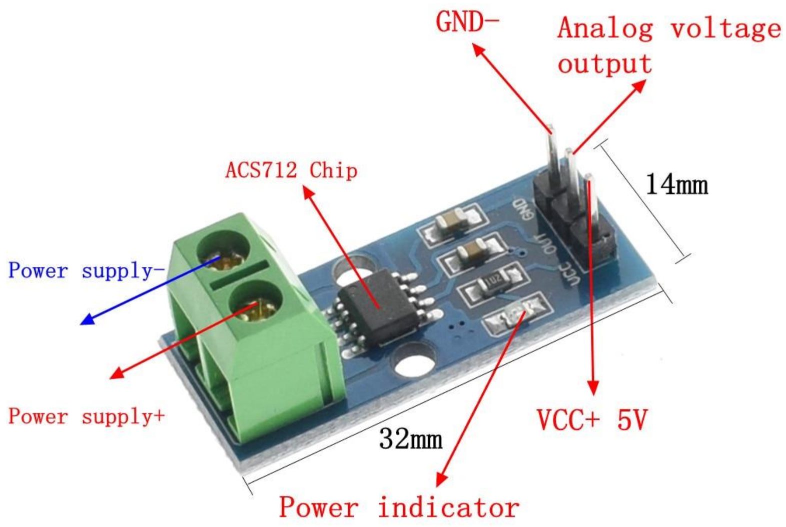

Figure 18 Shows ACS712 current sensor. Source: Device datasheet

With both peaks known (figure 18), it is a matter of knowing the shape of the waveform to calculate the current. In the case of line or mains power, we know that waveform to be a SINE wave. Knowing that allows us to apply a basic electronic formula to yield a decent result.

In most cases, an expression of AC current is in a value known as RMS. In order to use the ACS712 current sensor to measure AC current, it is important to understand how to calculate an RMS current value from the device readings.

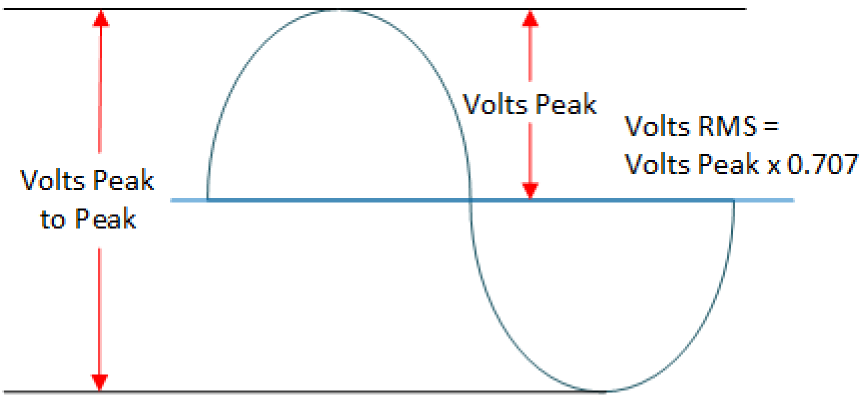

Figure 19 Shows Sine curve shows peak voltage

With an ACS712, current measurements are reported with a voltage output as shown in figure 19. In this project, we calculated the RMS volts and applied the ACS712 scale factor.

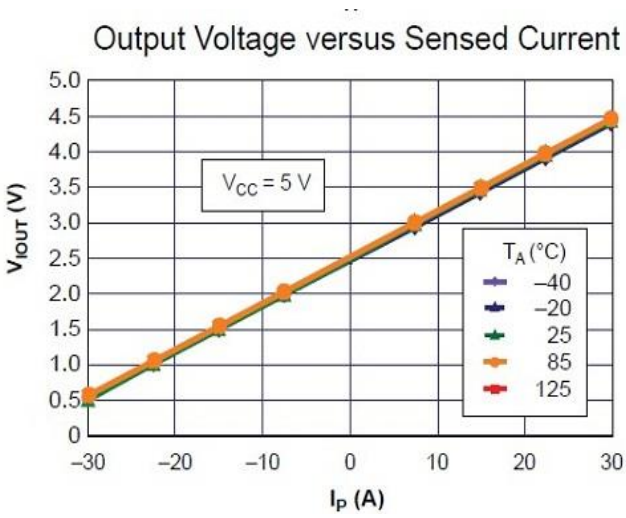

Figure 20 Shows Output voltage Vs sensed current. Source: ACS712 datasheet

Conversion for a sine wave with a zero-volt offset (like your mains or line power) is performed as follows:

1) Find the peak-to-peak voltage (Volts Peak to Peak)

2) Divide the peak-to-peak voltage by two to get peak voltage (Volts Peak)
3) Multiply the peak voltage by 0.707 to yield rms volts (Volts RMS)

Having Calculated RMS voltage, is simply a matter of multiplying by the scale factor of the particular ACS712 to yield the RMS value of the current being measured.

The values out of the ACS712 are constantly changing when measuring AC Current. In order ensure that you have come very close to finding the peaks, you need to sample fast enough and long enough. Because mains or line power is at a frequency of 50 to 60 Hz, the Arduino will be fast enough provided it takes consecutive samples with little or no interruption.

- For ASC712 VCC - 5V, when there is no current flowing through the IP+ and IP- terminals, the output voltage at VIOUT of ACS712 is 2.5V (Offset).
- Now, in order to calculate the current, divide this value with the sensitivity of the sensor (185mV/A for 5A Sensor, 100mV/A for 20A Sensor and 66 mV/A for 30A Sensor).

- **A dc Value** = analog Read (current Pin);
- **A dc Voltage** = (a dc Value / 1024.0) * 5000;
- **Current Value** = ((a dc Voltage – offset Voltage) / sensitivity);

CHAPTER FIVE

5.1 Challenges:

- The ACS712 30A current sensor had fluctuating offset voltage which could exhibit a leakage current in the readings at no load. The sensor datasheet specifies a 2.5V offset voltage when no load is connected to the sensor. However, the sensors were showing a fluctuating offset that could cause an error in the readings.
- The SIM800L GSM modem had delays in connecting to the network and the micro controller was programmed to execute GSM modem initialization commands after 20s at boot up as an average network connection time. On connection delay, the modem could fail to respond as commands MUST be passed when the modem is fully connected to the network.
- Most of the parts were not on local market and sill hard to locate online e.g. ACS712 current sensor and SIM800L GSM modem
- Some components were of low quality and were not giving results as expected especially the ACS712 30A current sensor.
- High cost of supplies summed up with customs duties for parts purchased outside Uganda.
- Lack of technical knowledge about most of the parts and concepts involved meant a slow process at start.
- We used the trial version of NOWsms gateway which limited us with the rich features available and hence made PHP processing nearly impossible.

5.2 Recommendation

The project has been done to demonstrate the concepts as defined in the project objectives. However, it will be a good move if the university further assigns another team to make remarkable improvements on the current device design especially on the server side of the application to have two-way communications much more reliable.

5.3 Conclusion

Despite challenges with test to speech sound quality, the device development was a total success. The project objectives were all achieved as listed in chapter one.

CHAPTER SIX

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CHAPTER SEVEN

APPENDICES:

7.1 Appendix one: Project budget:

NO.	ITEM	UNIT PRICE
1.	Prototyping supplies	300,000/=
2.	Stationary	100,000/=
3	Miscellaneous	100,000/=
	TOTAL	500,000

Table 4: Projected budget:

7.2 Appendix two: Project Timeline:

Activity	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May
Generating ideas and writing the proposal									
Literature review									
Research and consultation									
Design, developing and testing									
Project presentation									

Table 5: Project timeline

7.3 Appendix four: Pictures during Implementation.

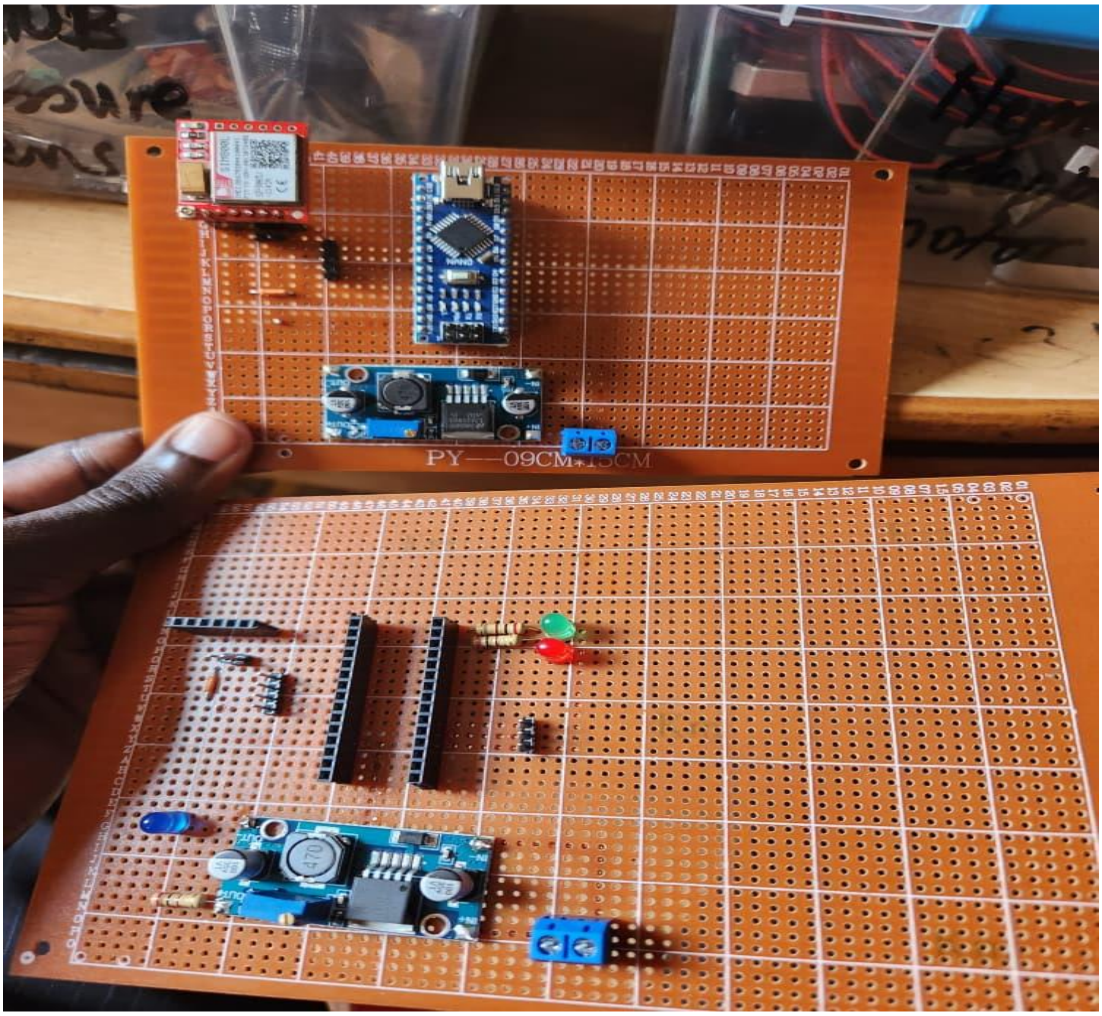

Figure 21 Shows Design and Soldering of the Prototype.

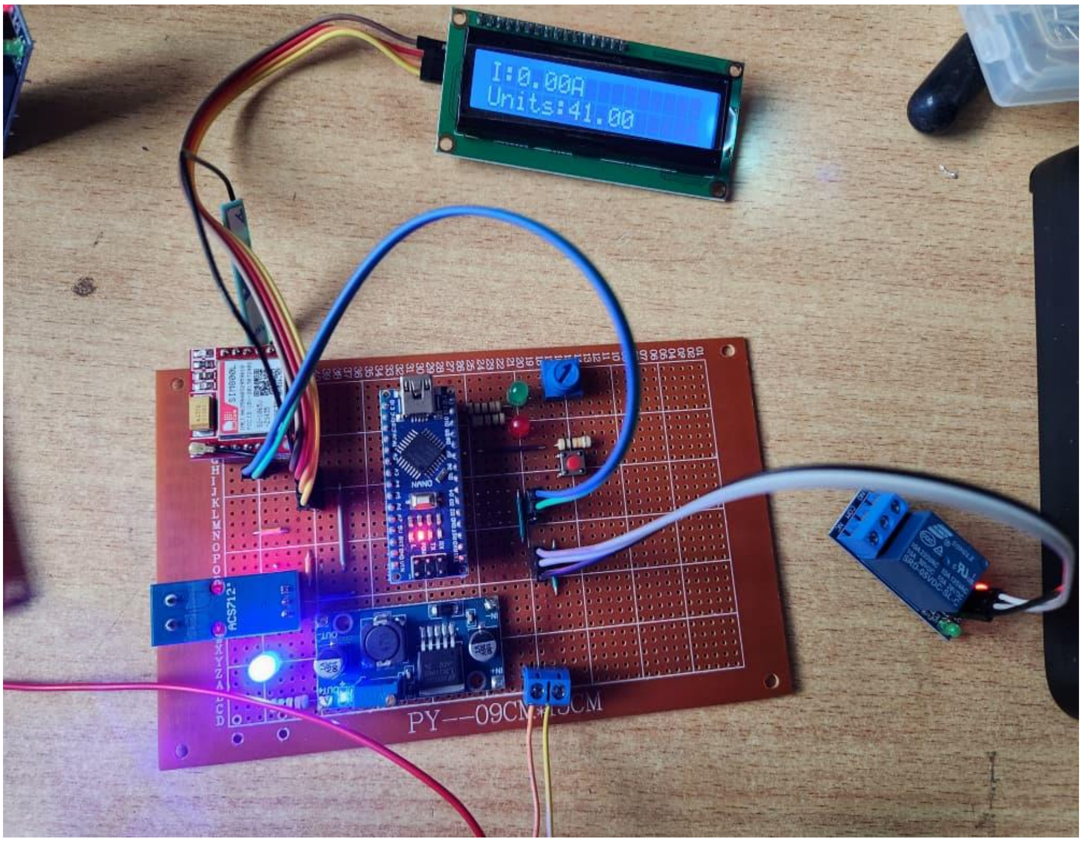

Figure 22 Shows Final Developed Prototype.

7.3 Appendix three: Embedded code.

```
#include <LiquidCrystal_I2C.h>

#include <SoftwareSerial.h>

#include <EEPROM.h>

#include <math.h>


// -------------------- LCD --------------------

LiquidCrystal_I2C lcd(0x27, 16, 2);


// -------------------- mySerial --------------------

SoftwareSerial mySerial(2, 3);   // RX, TX

const char phoneNumber[] = "+256794039285";//put in small board

int shad;

// -------------------- Relay & LEDs --------------------

const int relayPin = 4;

const int greenLED = 12;

const int redLED   = 11;

const int button   = 8;


// -------------------- Current Sensor --------------------

const int currentPin = 3;

const float sensitivity = 185.0;   // 5A version

const float offsetVoltage = 2500.0;

const float supplyVoltage = 5000.0;


// -------------------- Energy Variables --------------------

float ampsRMS = 0;

float watts = 0;
```

```
float energy_Wh = 0;
float energy_kWh = 0;

unsigned long lastTime = 0;

// -------------------- EEPROM --------------------
int balanceUnits = 0;

String readMSG()
{
  String ret = "";
   while( mySerial.available() )
    {
       char ccc =mySerial.read();
       ret = ret + ccc;
    }
    ret.trim();
   return ret;
}

// ========================================================
// READ CURRENT (ACS712)
// ========================================================
float readCurrent()
{
  float maxValue = 0;

  for (int i = 0; i < 500; i++)
  {
    float value = analogRead(currentPin);
    if (value > maxValue)
```

```
    maxValue = value;
  }

  float voltage = (maxValue / 1024.0) * supplyVoltage;
  float current = (voltage - offsetVoltage) / sensitivity;
  current = current / sqrt(2);

  if (current < 0.15)
    current = 0;

  return current;
}

// ========================================================
// SEND SMS
// ========================================================
void sendSMS(String message)
{
  mySerial.println("AT+CMGF=1");
  delay(500);

  mySerial.print("AT+CMGS=\"");
  mySerial.print(phoneNumber);
  mySerial.println("\"");
  delay(500);

  mySerial.print(message);
  delay(500);

  mySerial.write(26);  // CTRL+Z
  delay(3000);
```

```
}

// ============================================================
// READ SMS
// ============================================================
String readSMS()
{
  String msg = "";

  while (mySerial.available())
  {
    char c = mySerial.read();
    msg += c;
  }

  msg.trim();
  return msg;
}

// ============================================================
// SETUP
// ============================================================
void setup()
{
  pinMode(relayPin, OUTPUT);
  pinMode(greenLED, OUTPUT);
  pinMode(redLED, OUTPUT);
  pinMode(button, INPUT);
digitalWrite(relayPin, HIGH);
  lcd.begin();
  lcd.backlight();
```

```
lcd.print("LIGHT SHARING");
lcd.setCursor(0, 1);
lcd.print("SYSTEM");
delay(3000);

  mySerial.begin(4800);
  delay(1000);
  mySerial.println("AT");
  delay(1000);
  mySerial.println("AT+CMGF=1");  // set SMS mode to text
  delay(100);
  mySerial.println("AT+CNMI=2,2,0,0,0");
  delay(500);
  mySerial.println("AT+CREG?");
  delay(500);

while (!(mySerial.available()))
{
   lcd.clear();
   lcd.print("CHECK MODEM and ");
   lcd.setCursor(0,1);
   lcd.print("retry....");
    delay(1000);

}
  String response=mySerial.readString();
  while(!(response.indexOf("+CREG: 0,1")>-1))
  {
    mySerial.println("AT+CREG?");
    response=mySerial.readString();
```

```
      lcd.clear();
      lcd.print("Connecting......");
      delay(3000);

    }

    if(response.indexOf("+CREG: 0,1")>-1)
    {
      mySerial.println("AT+CREG?");
      response=mySerial.readString();
      lcd.clear();
      lcd.print("  CONNECTED");
      delay(1000);


    }

    mySerial.println("AT");
    delay(1000);
    mySerial.println("AT+CMGF=1");  // set SMS mode to text
    delay(100);
    mySerial.println("AT+CNMI=2,2,0,0,0");
    delay(2000);

  // Load balance from EEPROM
  EEPROM.get(0, balanceUnits);

  sendSMS("System Online");

  lastTime = millis();
}
```

```
// ==========================================================
// LOOP
// ==========================================================
void loop()
{
  if(digitalRead(button)==LOW)
  {
    lcd.clear();
    lcd.print("YAKA SHARE");
    lcd.setCursor(0,1);
    lcd.print("SESSION");
    delay(1000);
   long B=millis();
 do{

    int N=analogRead(A0);
    shad=map(N,0,1023,0,15);
    lcd.clear();
    lcd.print("YAKA SHARE");
    lcd.setCursor(0,1);
    lcd.print("SENDING:");lcd.print(shad);
    delay(1000);

   }
    while((millis()-B)<15000);
     sendSMS("yaka" + String(shad));
      balanceUnits -= shad;
    EEPROM.put(0, balanceUnits);

 }
```

```
// ---------- Check for Incoming SMS ----------

if(mySerial.available()>0)
{
   String incoming_char = readMSG();
  // String incoming_char=mySerial.readString();
   lcd.clear();
   lcd.print(incoming_char);

   delay(2000);
   incoming_char = incoming_char.substring(  incoming_char.lastIndexOf("\n")+1,
incoming_char.length() );
  lcd.clear();
  lcd.print(incoming_char);
  delay(5000);
 if(incoming_char.indexOf("yaka")>-1)
 {
   //lcd.clear();
   //lcd.print("NEW VALID");
   //mySerial.println("VALID");
 //mySerial.print(incoming_char);
   delay(500);
   incoming_char.replace("yaka", "");
   String inData=incoming_char;
   int units=(inData.toInt());

   balanceUnits += units;
```

```
    EEPROM.put(0, balanceUnits);

    lcd.clear();
    lcd.print("Payment OK");
    lcd.setCursor(0,1);
    lcd.print("Units:");
    lcd.print(balanceUnits);

    sendSMS("Units Added: " + String(units));


    lcd.clear();
    lcd.print("PAYMENT RECEIVED");
    lcd.setCursor(0,1);
    lcd.print("UNITS:");lcd.print(units);
    lcd.print("kWh");
    delay(1000);

  }
  }

  // ---------- Energy Calculation ----------
  unsigned long currentTime = millis();
  float deltaTime = (currentTime - lastTime) / 1000.0;
  lastTime = currentTime;

  ampsRMS = readCurrent();
  watts = 230.0 * ampsRMS;

  energy_Wh += (watts * deltaTime) / 3600.0;
  energy_kWh = energy_Wh / 1000.0;
```

```
  float remaining = balanceUnits - energy_kWh;

  // ---------- Relay Control ----------
  if (remaining <=0)
  {
    digitalWrite(relayPin, HIGH);
    digitalWrite(redLED, HIGH);
    digitalWrite(greenLED, LOW);
    remaining = 0;
  }
  else
  {
    digitalWrite(relayPin, LOW);
    digitalWrite(redLED, LOW);
    digitalWrite(greenLED, HIGH);
  }

  // ---------- Display ----------
  lcd.clear();
  lcd.print("I:");
  lcd.print(ampsRMS,2);
  lcd.print("A");

  lcd.setCursor(0,1);
  lcd.print("Units:");
  lcd.print(remaining,2);

  delay(500);
}
```