GSM BASED PREPAID ENERGY METER USING ARDUINO WITH AUTOMATIC BILLING & POWER THEFT ALERT SYSTEM

A report submitted to the Department of Electrical and Electronics Engineering, Sonargaon University of Bangladesh in partial fulfillment of the requirements for the Award of Degree of Bachelor of Science in Electrical and Electronics Engineering.

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DECLARATION

It is declared hereby that this thesis paper or any part of it has not been submitted to anywhere else for the award of any degree.

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This is to certify that this project entitled **"GSM Based Prepaid Energy Meter using Arduino with Automatic Billing & Power Theft Alert System"** is done by the following students under my direct supervision. This project has been carried out by them in the laboratories of the Department of Electrical and Electronics Engineering under the Faculty of Engineering, Sonargaon University (SU) in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronics Engineering.

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ABSTRACT

The GSM-based Prepaid Energy Meter using Arduino is an innovative solution designed to automate electricity billing and prevent power theft. Traditional energy meters lack transparency and are prone to human error and electricity pilferage. This project replaces conventional systems with a smart prepaid model, where users recharge energy credits in advance. The Arduino microcontroller monitors real-time energy consumption, automatically deducts used units, and communicates balance updates through a GSM module. When the balance is low or exhausted, the system sends SMS alerts and can disconnect power supply if necessary. Additionally, it incorporates a power theft detection mechanism that identifies unauthorized connections and instantly alerts the utility provider. This system not only ensures accurate and timely billing but also encourages users to conserve energy. By integrating prepaid metering, GSM communication, and theft alerts, the project supports efficient energy management and enhances the security and reliability of power distribution systems.

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CHAPTER 1
INTRODUCTION

1.1 Overview

Electricity has become vital in everyday life. It is tough to imagine a world and human life without electricity. But the vitality of electricity has meant that people consume vast amounts of energy unmindfully and carelessly. The world's energy consumption/capita stands at a staggering 2782 KWh. At this rate the world's energy resources would get depleted very soon. Already a big chunk of fossil fuel resources got exhausted because of lavish and mindless usage.The present system of energy metering uses electromechanical and somewhere digital energy meter have poor accuracy and lack of configurability and also consumes more time and labour. The conventional electromechanical meters are being replaced by new electronic meters to improve accuracy in meter reading.

In smart metering system as proposed in research with the ability to communicate wirelessly, commands are sent to the meter via SMS and the meter replies with the relevant energy consumption readings again via SMS. In this way it allows both the power supply companies and the user to have a better monitoring of the energy consumed by the load. Smart Energy has been an important conceptual paradigm for future energy use. How to make energy use more efficient and effective is very critical for future social and economic developments due to limited availability of non-renewable energy resources and expensive ways of acquiring renewable energies.

Over the last few years, Smart Energy Meter has been proposed as an innovative solution aimed at facilitating affordability and reducing the cost of utilities. The existing energy meter has mechanical construction with various erroneous, tiresome and insecure meter reading methods. The problem with this system is that it requires manpower, time consuming and causes error. So there is a need for a smart energy meter which will provide bills to consumers both as an SMS along with other inbuilt features such as tamper proof, fault detection etc. In addition, the online approach generates alerts about consumption of energy as and when required according to a predefined pricing structure through a call/email/short text message.

Unlike traditional meters, a smart meter is well equipped digitally to provide better power theft-detection. Smart meters have capabilities based on different internet protocols to communication reliably for performing real-time operations like billing, quality assurance, and load notifications. They are digital meters that offer two-way communication, unlike the one-way manual services of traditional meters, allowing for more interactivity between the consumer and utility.

Smart meters are widely used around the world such as UK, Japan, New Zealand, Canada, USA, Italy and Netherlands. A lot of research work is being done on this project in countries abroad as well as in some areas of Pakistan.

1.2 Problem Statement

The traditional energy metering systems are plagued with several inefficiencies, including manual meter reading, billing errors, delayed billing generation, and susceptibility to electricity theft. These systems rely heavily on human intervention, leading to increased labor costs, time consumption, and a lack of transparency for consumers. Additionally, the inability to monitor real-time energy usage prevents users from effectively managing their electricity consumption. With the growing demand for reliable and efficient energy usage, there is a pressing need for a smart, automated system that can monitor usage, generate real-time bills, prevent power theft, and enable prepaid billing. The project aims to address these issues by developing a GSM-based prepaid energy meter using Arduino that ensures accurate, secure, and user-friendly energy management.

1.3 Objectives

The objectives of this project:

- To design and construct a **GSM Based Prepaid Energy Meter using Arduino with Automatic Billing & Power Theft Alert System**.
- To reduce human error and labor dependency in meter reading and bill generation.
- To enable real-time energy consumption monitoring via GSM communication.
- To send low balance and usage alerts to users through SMS.
- To disconnect power automatically when prepaid balance is exhausted.
- To detect and alert power theft or tampering attempts instantly.

- To improve transparency, accuracy, and security in energy billing and management.
- To study the system performance for future reference and improvement purpose.

1.4 Research Methodology

The methodologies we have used to build this project are given below:

- Creating an idea for **GSM Based Prepaid Energy Meter using Arduino with Automatic Billing & Power Theft Alert System.** And designing a block diagram & circuit diagram to know which components need to construct it.
- Collecting all components and programming for the micro controller to control the system.
- Setting all components in a PCB board & soldering. Then assembling the whole block in a board and finally running the system & checking.

1.5 Workflow Diagram

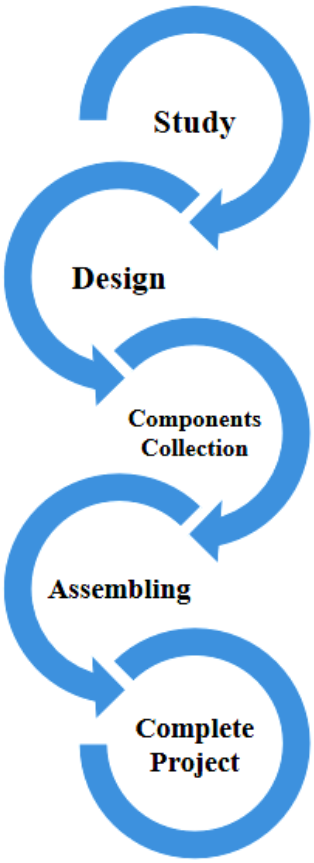


Figure 1.1: Work flow Diagram

1.6 Organization of Report

This project book consists of six chapters. The first chapter contains the statement of the introduction, Problem Statement, objectives of the study in the project, methodology and Workflow Diagram. Chapter two contains literature review. Chapter three describes the Hardware details which is already used to complete this project. Chapter four contains the software details. Chapter five deals with the design of this project, block diagram and circuit diagram, working principle. In the final chapter, we discuss the result, cost estimation, advantages, application, future scope and conclusion of our project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter we discuss our system Background. In this paper they also work about **GSM Based Prepaid Energy Meter using Arduino with Automatic Billing & Power Theft Alert System**. In below section we will describe some previous Related Work.

2.2 Literature Review

In [1] the paper provides smart energy metering with AMR systems without affecting its major advantage of remote monitoring. Integrating this new feature into smart meters provides a robust metering solution. Electricity theft is a common practice in developing countries which cannot be controlled by the governments due to lack of technology. Emerging trends such as Automatic Meter Reading (AMR) eliminate the need of people visiting each house, but this advancement further increase non-technical loss (NTL) because of no regular inspection at the residence. However traditional meter reading by human operators is inefficient to meet the future residential development needs. This paper proposes a new system based on ARM-Cortex M3 processor to protect the energy meter from phase line bypassing, neutral line disconnection, whole meter bypassing and meter tampering. A SMS automatically send to utility server through Global System for Mobile (GSM) network when these measures are detected. In this paper a novel method is proposed to solve the problem.

In [2] this paper explains Every management system is trying to make automatic, portable and remote control. This work presents a novel smart energy meter for an automatic and superior metering and billing system. The integration of the Arduino and GSM Short Message Service (SMS) provides the meter reading system with some automatic functions that are predefined. Firstly, we have simulated the project in PROTEUS 8.0 then successfully implemented on the circuit board in the laboratory. The proposed energy meter system can incorporate with embedded controller and GSM modem to transmit the data like consumed energy in kWh, generated bill, security services (line Cut/On) over GSM mobile network such as data can be then fed and integrated into existing energy management systems located at power companies or organizations to provide the services

among the customers without man-power. Our implemented project can provide all required services remotely for metering and billing with high fidelity.

In [3] this paper explains Power utilities in different countries, especially in the developing ones are incurring huge losses due to electricity theft. This paper proposes a prepaid energy metering system to control electricity theft. In this system a smart energy meter is installed in every consumer unit and a server is maintained at the service provider side. Both the meter and the server are equipped with GSM module which facilitates bidirectional communication between the two ends using the existing GSM infrastructure. Consumers can easily recharge their energy meter by sending a PIN number hidden in a scratch card to the server using SMS. This paper presents some measures to control meter bypassing and tampering. The bidirectional GSM communication using SMS ensures the effectiveness of these measures. Pilferage of electricity can be substantially reduced by incorporating the proposed measures along with the prepaid metering scheme. Legal actions against dishonest consumers can also be taken in this System.

V. Preethi and G. Harish mention that the energy meter is a contraption that gauges the proportion of electric energy eaten up by a home, business, or an electrically filled device [4] Noor-E-Jannat, M. O. Islam, and M. S. Salakin mentions that A GSM digitizes and reduces the data, by then sends it down through a channel with two unmistakable surges of client data, each in its own particular timetable opening [5]. L. C. Saikia, H. Das, and T. Malakar mention that The electromechanical enrollment meter works by checking the unrests of a non-drawing in, a metal plate which turns at a speed concerning the power experiencing the meter [6] A. Jain, D. Kumar, and J. Kedia mentions that Electronic meters demonstrate the energy used on an LCD or LED show, and some transmit readings to remote spots [7]. R. G. Sarangle, U. Pandit, K. Prof, and J. Modi mention that the AMR framework is an effect for remote checking and controls private significance meter. AMR framework gives the data of meter dismembering [8] control cut, mean stack utilized, control free and cementing on intrigue, or in many cases especially between times through SMS. The designing of web organizations based customized meter scrutinizing system has delineated. O. Kesav and B. Rahim mention that data sent and gotten by concerned energy Provider Company with the assistance of Global structure for flexible correspondence facilitate. Energy supplier gets the meter surveying inside a second without visiting a man

[9] H. G. R. Tan, C. H. R. Lee, and V. H. Mok mention that In [10], a novel Automatic Meter Reading (AMR) structure has proposed using the IEEE 802.15.4-obvious remote frameworks to visit with energy meter. The work deal with based Automatic Utility Data Collection System (AUDCS) gives a cost-capable design by inquisitive about the self-affiliation, self-settling limits of the work organization, and using semiconductor chips and the radio handsets superb with IEEE 802.15.4 standard. Thousif ahamed and A.Sreedevi mention that Analog signals are seen from the two information channels, which will be changed over into Digital signals by ADC uninhibitedly. With the two affected information signals transmitted to the microcontroller by techniques for SPI custom, dsPIC33F figures the power accordingly, imperativeness ate up will be gathered after a foreordained period. [11] Sarwar Shahidi, Md. Abdul Gaffar, Khosru, and M. Salim mention that AMR is a framework whereby the Energy Meter sends the recorded power usage of a nuclear family in the particular between the time period to a "remotely" related, which could be a (PC) or central server of intensity dispersing affiliations [12] Priyanka Dighe, Tushar Dhanani, and Kumar Gangwani mention that GSM is an approach to remotely screen and control centrality meter readings. Its tendencies to take a gander at imperativeness meters without visiting each house/affiliation [13]. This structure contains a microcontroller, which takes the readings at general breaks and records it in its memory

2.3 Summary

The above has been discussed in detail in the past few literatures which has given us a lot of motivation to do this project.

CHAPTER 3
SYSTEM ARCHITRECTURE

3.1 Introduction

The project Objectives, Methods, Problem Statement, and other details were all clarified in the preceding chapter. The block diagram, circuit diagram, working principle, and final project instrument cost analysis will all be covered in this chapter.

3.2 Block Diagram

Here is the block diagram of the **GSM Based Prepaid Energy Meter using Arduino with Automatic Billing & Power Theft Alert System** with all the essential components. All the components are shown below as a block in this diagram. Here we use Arduino Nano Micro-controller for our project. Other equipment is attached to this micro-controller and works together for perform as our desired outcome.

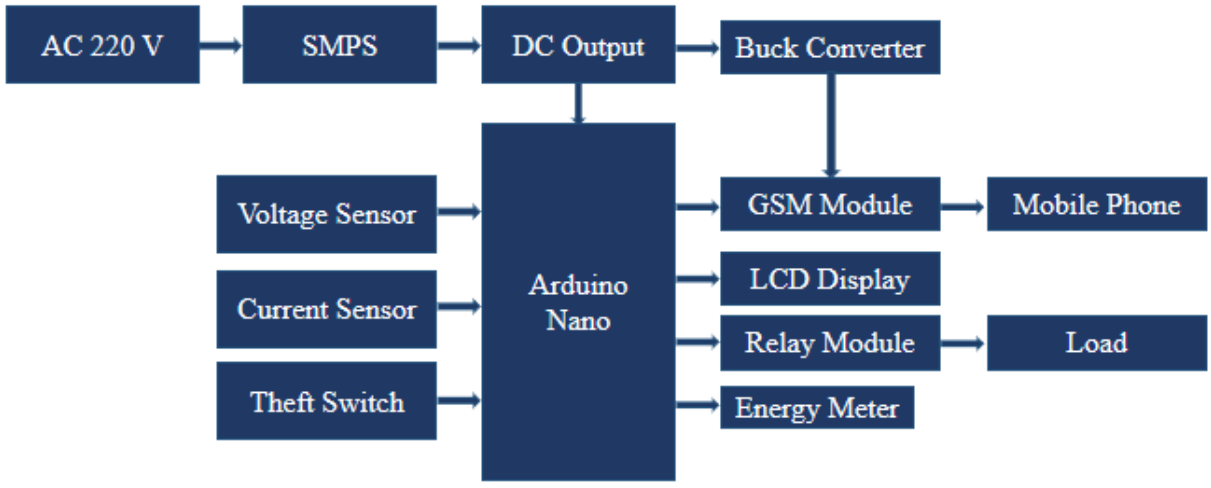


Figure 3.1: Block Diagram of Our Project

3.3 Circuit Diagram

In this part we show our project circuit design and connect out instrument through standard wire.

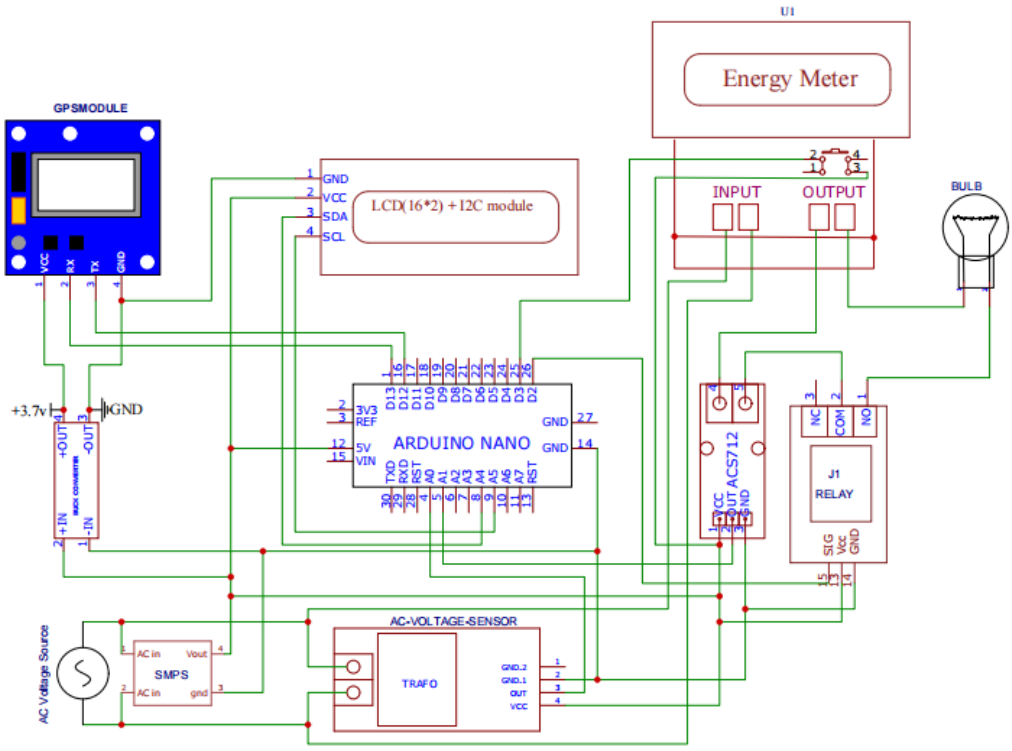


Figure 3.2: Circuit Diagram of Our Project

3.4 Working Principle

The GSM-based Prepaid Energy Meter using Arduino Nano is designed to automate billing, monitor energy usage, and detect power theft. The system is powered by an SMPS, while a buck converter ensures a stable Voltage supply to the GSM module. The voltage and current sensors continuously measure power consumption, and the Arduino Nano calculates the total energy used. This information is displayed on an LCD screen for user reference. The energy meter logs consumption in real-time. When the prepaid balance is low or exhausted, the relay module disconnects the load automatically, ensuring controlled energy usage. The GSM module sends SMS alerts for low balance, consumption status, and recharge confirmations. A theft switch is incorporated to detect unauthorized access or tampering; upon detection, the system immediately alerts the user and utility provider via GSM. This intelligent system ensures secure, efficient, and transparent energy management with reduced human intervention.

3.5 Cost Analysis

Table 1: List of Component with Price

Sl. no	Particulars	Specification	Qty.	Unit Price (Taka)	Total Price (Taka)
1	Arduino Nano	IC AT mega328P	1	600	600
2	SMPS	5v 5a	1	550	550
3	Voltage Sensor	SR-04	1	250	250
4	Current Sensor		1	250	250
5	LCD Display	16*2	1	400	400
6	GSM Module		1	450	450
7	Buck Converter	LM2596	1	150	150
8	Relay Module	6 Channel	1	500	500
9	Energy Meter	Single Phase	1	1600	1600
10	Others				700
				Total	5450/=

CHAPTER 4

HARDWARE & SOFTWARE ANALYSIS

4.1 Introduction

In this section, we will discuss elaborately about "**GSM Based Prepaid Energy Meter using Arduino with Automatic Billing & Power Theft Alert System**" and the component description, features, working procedure of our all equipment.The system hardware fabricates composed of power unit, source unit, power store unite, and many more related components.

4.2 Hardware & Software

Hardware

- SMPS
- Arduino Nano
- Voltage Sensor
- Current Sensor
- Buck Converter
- Relay Module
- LCD display
- Energy Meter
- GSM

4.3 Switch Mode Power Supply (SMPS)

A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a DC or AC source (often mains power) to DC loads, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. A hypothetical ideal switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time (also known as duty cycles). In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor.

This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switch-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight.



Figure 4.1: SMPS

Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weight are required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor. Switched-mode power supplies are classified according to the type of input and output voltages. The four major categories are:

- AC to DC
- DC to DC
- DC to AC
- AC to AC

A basic isolated AC to DC switched-mode power supply consists of:

- Input rectifier and filter
- Inverter consisting of switching devices such as MOSFETs
- Transformer
- Output rectifier and filter
- Feedback and control circuit

The input DC supply from a rectifier or battery is fed to the inverter where it is turned on and off at high frequencies of between 20 KHz and 200 KHz by the switching MOSFET or power transistors. The high-frequency voltage pulses from the inverter are fed to the transformer primary winding, and the secondary AC output is rectified and smoothed to

produce the required DC voltages. A feedback circuit monitors the output voltage and instructs the control circuit to adjust the duty cycle to maintain the output at the desired level.

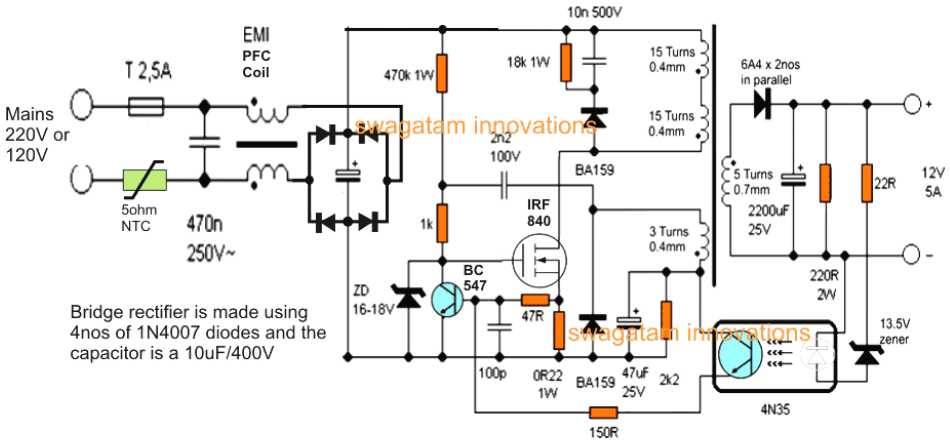


Figure 4.2: SMPS Circuit

Basic working concept of an SMPS

A switching regulator does the regulation in the SMPS. A series switching element turns the current supply to a smoothing capacitor on and off. The voltage on the capacitor controls the time the series element is turned. The continuous switching of the capacitor maintains the voltage at the required level.

Design basics

AC power first passes through fuses and a line filter. Then it is rectified by a full-wave bridge rectifier. The rectified voltage is next applied to the power factor correction (PFC) pre-regulator followed by the downstream DC-DC converter(s). Most computers and small appliances use the International Electrotechnical Commission (IEC) style input connector. As for output connectors and pin outs, except for some industries, such as PC and compact PCI, in general, they are not standardized and are left up to the manufacturer.

There are different circuit configurations known as topologies, each having unique characteristics, advantages and modes of operation, which determines how the input power is transferred to the output. Most of the commonly used topologies such as flyback, push-pull, half bridge and full bridge, consist of a transformer to provide isolation, voltage

scaling, and multiple output voltages. The non-isolated configurations do not have a transformer, and the power conversion is provided by the inductive energy transfer.

Advantages of switched-mode power supplies

- Higher efficiency of 68% to 90%
- Regulated and reliable outputs regardless of variations in input supply voltage
- Small size and lighter
- Flexible technology
- High power density
- Disadvantages:
- Generates electromagnetic interference
- Complex circuit design
- Expensive compared to linear supplies

Switched-mode power supplies are used to power a wide variety of equipment such as computers, sensitive electronics, battery-operated devices and other equipment requiring high efficiency. Linear voltage IC regulators have been the basis of power supply designs for many years as they are very good at supplying a continuous fixed voltage output. Linear voltage regulators are generally much more efficient and easier to use than equivalent voltage regulator circuits made from discrete components such a Zener diode and a resistor, or transistors and even op-amps. The most popular linear and fixed output voltage regulator types are by far the 78… positive output voltage series, and the 79… negative output voltage series.

These two types of complementary voltage regulators produce a precise and stable voltage output ranging from about 5 volts up to about 24 volts for use in many electronics circuits. There is a wide range of these three-terminal fixed voltage regulators available each with its own built-in voltage regulation and current limiting circuits. This allows us to create a whole host of different power supply rails and outputs, either single or dual supply, suitable for most electronic circuits and applications. There are even variable voltage linear regulators available as well providing an output voltage which is continually variable from just above zero to a few volts below its maximum voltage output.

Switch Mode Power Supply

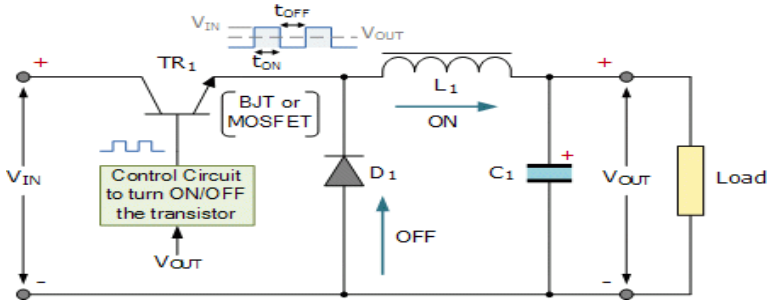


Figure 4.3: SMPS Circuit Connection

Most d.c.power supplies comprise of a large and heavy step-down mains transformer, diode rectification, either full-wave or half-wave, a filter circuit to remove any ripple content from the rectified d.c. producing a suitably smooth d.c. voltage, and some form of voltage regulator or stabilizer circuit, either linear or switching to ensure the correct regulation of the power supplies output voltage under varying load conditions. Then a typical D.C. power supply would look something like this:

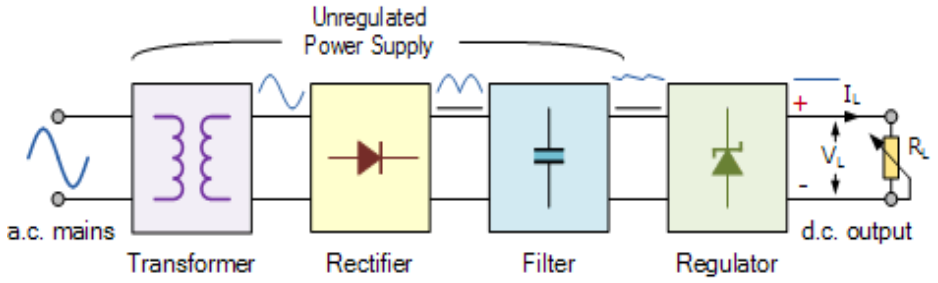


Figure 4.4: DC Power supply way

These typical power supply designs contain a large mains transformer (which also provides isolation between the input and output) and a dissipative series regulator circuit. The regulator circuit could consist of a single Zener diode or a three-terminal linear series regulator to produce the required output voltage. The advantage of a linear regulator is that the power supply circuit only needs an input capacitor, output capacitor and some feedback resistors to set the output voltage.

4.4 Arduino Nano

Arduino is open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling Lights, motors, and other actuators.

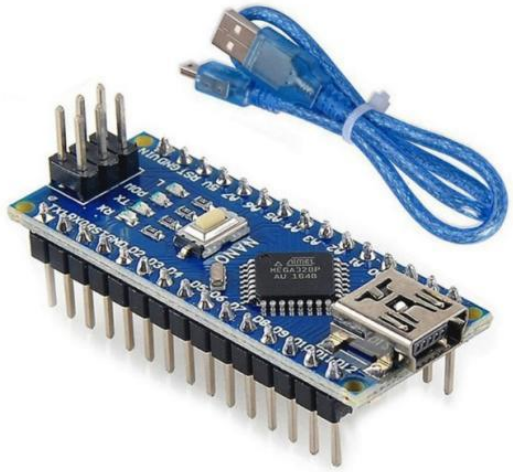


Figure 4.5: Arduino Nano

The micro-controller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone, or they can communicate with software on running on a computer (e.g. Flash, Processing, Maxims). Arduino Nano is a surface mount breadboard embedded version with integrated USB. It is a small, complete, and breadboard friendly component. It has everything that Decimal/ Duemilanove has (electrically) with more analog input pins and onboard +5V AREF jumper. Physically, it is missing power jack. Nano can automatically sense and switch to the higher potential source of power.

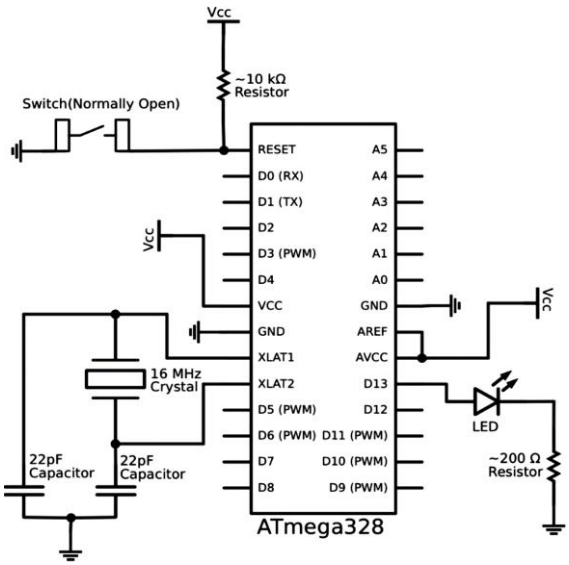


Figure 4.6: Arduino Nano Schematic Diagram

Nanos got the breadboard-ability of the Boarding and the Minibus with smaller footprint than either, so users have more breadboard space. It's got a pin layout that works well with the Mini or the Basic Stamp (TX, RX, ATN, and GND on one top, power and ground on the other). This new version 3.0 comes with ATMEGA328, which offers more programming and data memory space. It has two layers. That makes it easier to hack and more affordable. One of the best features of Arduino Nano is, it's easy to use, compact and small.

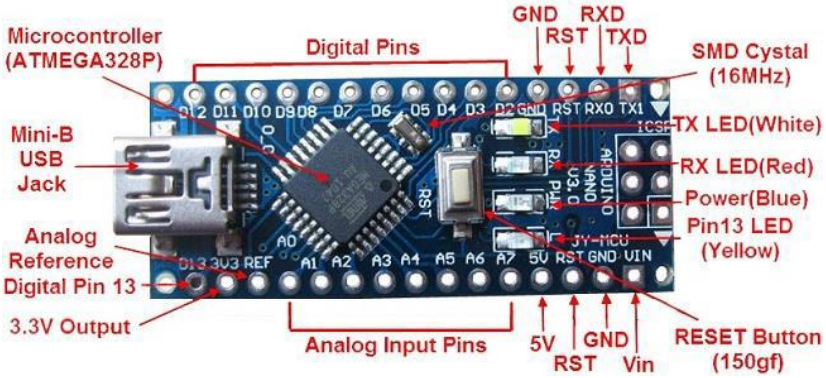


Figure 4.7: How Arduino Nano looks like

Specifications

- Micro-controller: Atmel ATmega328
- Operating Voltage (logic level): 5 V
- Input Voltage (recommended): 7-12 V
- Input Voltage (limits): 6-20 V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 8
- DC Current per I/O Pin: 40 mA
- Flash Memory: 32 KB (of which 2KB used by boot loader)
- SRAM: 2 KB
- EEPROM: 1 KB
- Clock Speed: 16 MHz
- Dimensions: 0.70” x 1.70”

Features

- Automatic reset during program download
- Power OK blue LED
- Green (TX), red (RX) and orange (L) LED
- Auto sensing/switching power input
- Small mini-B USB for programming and serial monitor
- ICSP header for direct program download
- Manual reset switch

Micro-controller IC ATmega328p

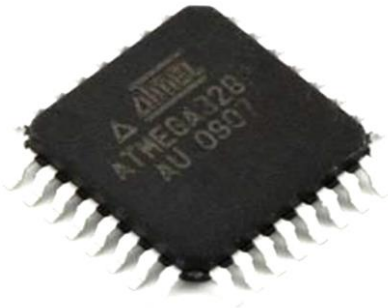


Figure 4.8: Micro-controller IC AT mega 328p

The high-performance Microchip Pico Power 8-bit AVR RISC-based micro-controller combines 32KB ISP flash memory with read-while-write capabilities, 1024B EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, a 6-channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts. By executing powerful instructions in a single clock cycle, the device achieves throughput's approaching 1 MIPS per MHz, balancing power consumption and processing speed.

4.5 Current Sensor

ACS712 Current Sensor Module - 20A can sense up to 20A of current flow. Sensing and controlling the current flow are a fundamental requirement in wide variety of applications, which includes over-current protection circuits, battery chargers, switching mode power supplies, digital watt meters, programmable current sources, etc.



Figure 4.9: DC Current Sensor

ACS712 Current Sensor Module - 20A Specification

- Supply Voltage: 4.5V ~ 5.5V DC
- Measure Current Range: -20A ~ 20A
- Sensitivity: 100mV/A

4.6 Voltage Sensor

ZMPT101B AC Single Phase voltage sensor module is based on a high precision ZMPT101B voltage Transformer. ZMPT101B AC Voltage Sensor is the best for the purpose of the DIY project, where we need to measure the accurate AC voltage with a voltage transformer.

FEATURES of ZMPT101B AC Single Phase Voltage Sensor Module

- Voltage up to 250 volts can be measured
- Light weight with on-board micro-precision voltage transformer
- High precision on-board op-amp circuit
- Operating temperature: 40ºC ~ + 70ºC
- Supply voltage 5 volts to 30 volts



Figure 4.10: Voltage Sensor

ADVANTAGES of ZMPT101B AC Single Phase Voltage Sensor Module

- Analog output corresponding quantity can be adjusted.
- Pcb board size: 49.5 (mm) x19.4 (mm)
- Good consistency, for voltage and power measurement
- Very efficient and accurate

4.7 Relay

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

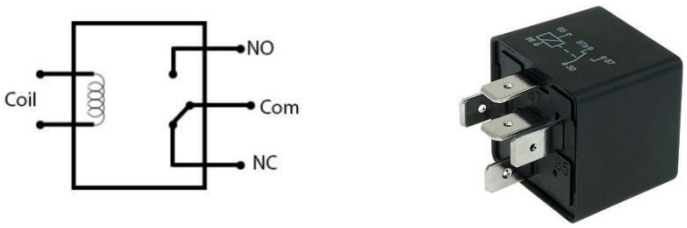


Figure 4.11: Relay

Mains voltage connections:

In relation to mains voltage, relays have 3 possible connections:

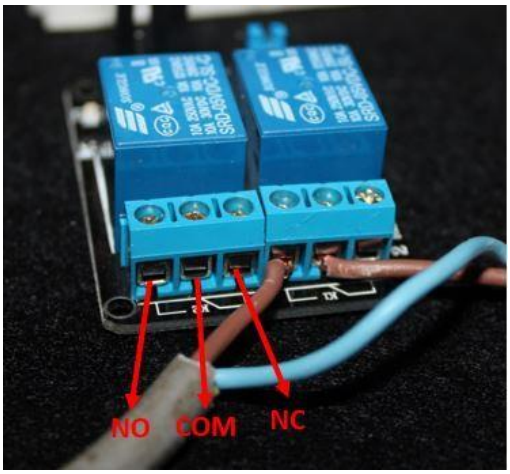


Figure 4.12: Pin diagram of Relay Module

COM: Common pin

NO (Normally Open): There is no contact between the common pin and the normally open pin. So, when you trigger the relay, it connects to the COM pin and supply is provided to a load

NC (Normally Closed): There is contact between the common pin and the normally closed pin. There is always a connection between the COM and NC pins, even when the relay is turned off. When you trigger the relay, the circuit is opened and there is no supply provided to a load.

Pin wiring

The connections between the relay module and the Arduino are simple:

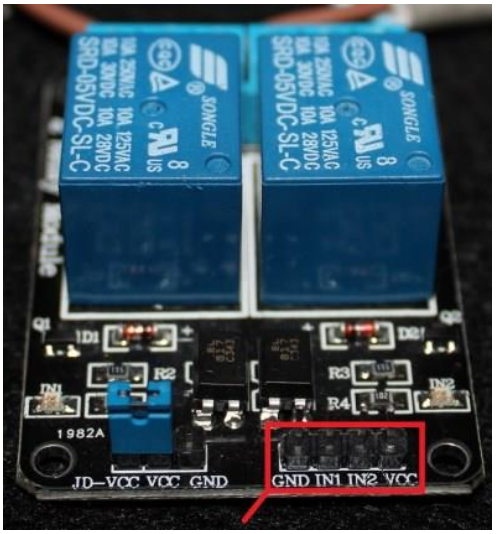


Figure 4.13: Main Voltage Connection

- **GND**: Goes to ground
- **IN1**: Controls the first relay (it will be connected to an Arduino digital pin)
- **IN2**: Controls the second relay (it should be connected to an Arduino digital pin if you are using this second relay. Otherwise, you don't need to connect it)
- **VCC**: Goes to 5V

4.8 LCD Display

The LCD (liquid crystal display) screen is an electronic display module and looks for various applications. A 16x2 LCD display is a very basic module and it is very commonly used in various devices and circuits. These modules are preferred over seven sections and many other segments.



Figure 4.14: 16*2 LCD Display

The reasons for having LCD are economic; Easily programmable, special and even custom characters (different in seven sections), there are no restrictions on displaying animations. A 16x2 LCD means it can display 16 characters per line and contains 2 lines. Each character on this LCD is displayed in a 5x7 pixel matrix.

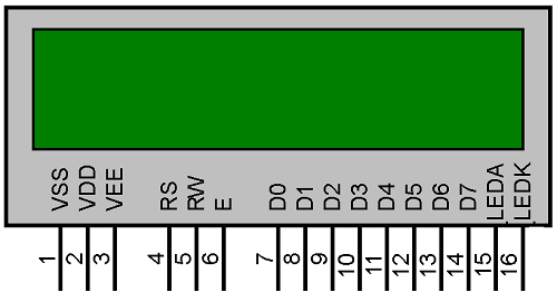


Figure 4.15: Pin out of 16*2 LCD Display

This LCD contains two articles called Command and Data. The command register stores the command instructions on the LCD. The command is a command given to the LCD to perform a predefined task such as starting it, clearing its screen, locating the cursor, controlling the display, etc.

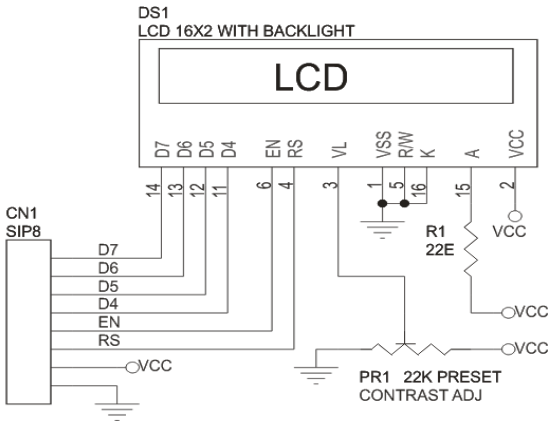


Figure 4.16: 16*2 LCD Display interfacing with Arduino

Feature

The features of this LCD mainly include the following.

- The operating voltage of this LCD is 4.7V-5.3V
- It includes two rows where each row can produce 16-characters.
- The utilization of current is 1mA with no backlight

- Every character can be built with a 5×8-pixel box
- The alphanumeric LCDs alphabets & numbers
- Its display can work on two modes like 4-bit & 8-bit
- These are obtainable in Blue & Green Backlight
- It displays a few custom generated characters

4.9 Buck Converter

A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while drawing less average current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). It is called a buck converter because the voltage across the inductor “bucks” or opposes the supply voltage.

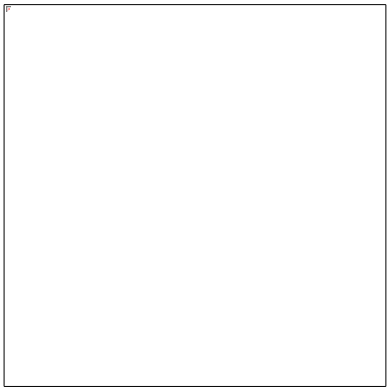


Figure 4.17: DC -DC Buck Converter

DC-DC Buck Converter Step Down Module LM2596 Power Supply is a step-down(buck) switching regulator, capable of driving a 3-A load with excellent line and load regulation. These devices are available in fixed output voltages of 3.3 V, 5 V, 12 V, and an adjustable output version. The LM2596 series operates at a switching frequency of 150kHz, thus allowing smaller sized filter components than what would be required with lower frequency switching regulators.

Specifications of DC-DC Buck Converter Step Down Module LM2596 Power Supply

- Conversion efficiency: 92%(highest)
- Switching frequency: 150KHz
- Output ripple: 30mA9maximum)
- Load Regulation: ± 0.5%
- Voltage Regulation: ± 0.5%
- Dynamic Response speed: 5% 200uS
- Input voltage:4.75-35V
- Output voltage:1.25-26V(Adjustable)
- Output current: Rated current is 2A, maximum 3A (Additional heat sink is required)
- Conversion Efficiency: Up to 92% (output voltage higher, the higher the efficiency)
- Switching Frequency: 150KHz
- Rectifier: Non-Synchronous Rectification
- Module Properties: Non-isolated step-down module (buck)
- Short Circuit Protection: Current limiting, since the recovery
- Operating Temperature: Industrial grade (-40 to +85) (output power 10W or less)

4.10 GSM Module

At the heart of the module is a SIM800L GSM cellular chip from Sim Com. 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.



Figure 4.18: GSM Module

All the necessary data pins of SIM800L GSM chips are broken out to 0.1″ pitch headers. This includes pins required for communication with a microcontroller over UART. The module supports a 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.

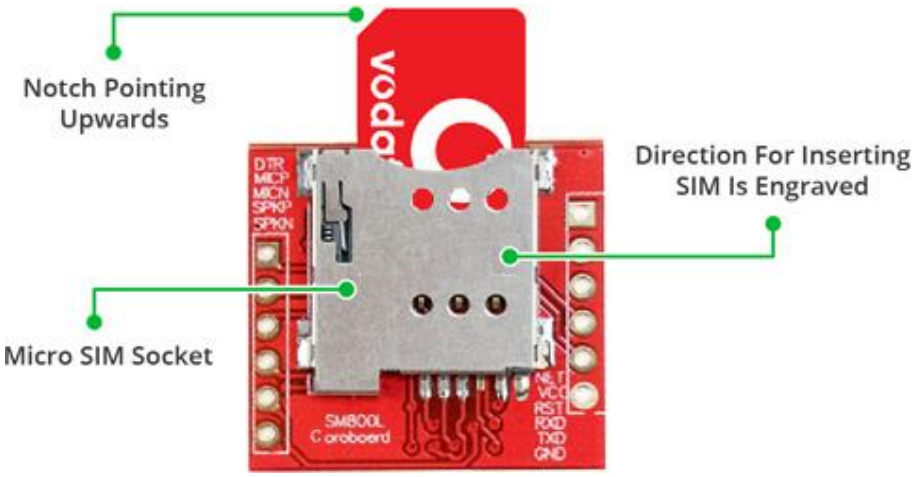


Figure 4.19: GSM Module Introducing

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. This module measures only 1-inch² but packs a surprising amount of features into its little frame. Some of them are listed below:

- Supports Quad-band: GSM850, EGSM900, DCS1800 and PCS1900
- Connect onto any global GSM network with any 2G SIM
- Make and receive voice calls using an external 8Ω speaker & electret microphone
- Send and receive SMS messages
- Send and receive GPRS data (TCP/IP, HTTP, etc.)
- Scan and receive FM radio broadcasts
- Transmit Power:
    - Class 4 (2W) for GSM850
    - Class 1 (1W) for DCS1800
- Serial-based AT Command Set
- FL connectors for cell antennae
- Accepts Micro SIM Card

SIM800L GSM Module Pinout

The SIM800L module has a total of 12 pins that interface it to the outside world. The connections are as follows:



Figure 4.20: GSM Module Pinout

- 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 at 3.3 V! An external power source like Li-Po battery or DC-DC buck converters rated 3.7V 2A would work.
- RST (Reset) 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.

4.11 Energy Meter

A single-phase 220VAC energy meter is an electrical measuring device used to monitor and record the energy consumption of residential and small commercial setups operating on 220V AC supply. It measures the total power consumed in kilowatt-hours (kWh) by calculating the product of voltage and current over time. This meter is designed for single-phase electrical systems, which are commonly used in households. It features terminals for input (from the power source) and output (to the load), ensuring accurate energy measurement. Modern versions may include digital displays, tamper detection, and compatibility with smart systems for automated monitoring and billing.



Figure 4.21: Single Phase Energy meter

Features

- ac 1 Phase 2 Wire Static Energy Meter
- IS: 13779:1999 complaint.CM/L no. 8700102513
- 220V, Frequency 50 Hz
- Rating 5-30A/10-60A
- Fully Electronic design
- Bright LCD with backlit
- Anti-Tamper features
- Compact & reliable.
- Microcontroller based design
- Capacitive touch for scrolling
- High design and production life
- Battery back-up for meter reading.

SOFTWARE

4.12 Arduino Software

The digital micro-controller unit named Arduino Nano can be programmed with the Arduino software IDE. There is not any requirement for installing software other than Arduino. Firstly, Select "Arduino Nano from the Tools, Board menu (according to the micro controller on our board). The IC used named as ATmega328 on the Arduino Nano comes pre burned with a boot loader that allows us to upload new code to it without the use of an external hardware programmer. Communication is using the original STK500 protocol (reference, C header files). We can also bypass the boot loader and program the micro controller through the ICSP (In Circuit Serial Programming) header. The ATmega16U2 (or 8U2 in the rev1 and rev2 boards) firmware source code is available. The ATmega16U2/8U2 is loaded with a DFU boot loader, which can be activated by:

On Rev1 boards: connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2. On Rev2 or later boards: there is a resistor that pulses the 8U2/16U2 HWB line to ground, making it easier to put into DFU mode. The Arduino Nano is one of the latest digital micro controller units and has a number of facilities for communicating with a computer, another Arduino, or other micro-controllers. The ATmega328 provides UART TTL at (5V) with serial communication, which is available on digital pins 0 -(RX) for receiving the data and pin no.1 (TX) for transmit the data. An ATmega16U2 on board channels this serial communication over USB and appears as a virtual comport to software on the computer. The '16U2' firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, an .in file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board.

The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial Communication on pins 0 and 1). A Software Serial library allows for serial communication on any of Nano's digital pins. The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus. Arduino programs are written in C or C++ and the program code written for Arduino is called sketch. The Arduino IDE uses the GNU tool chain and AVR Lab to compile programs.

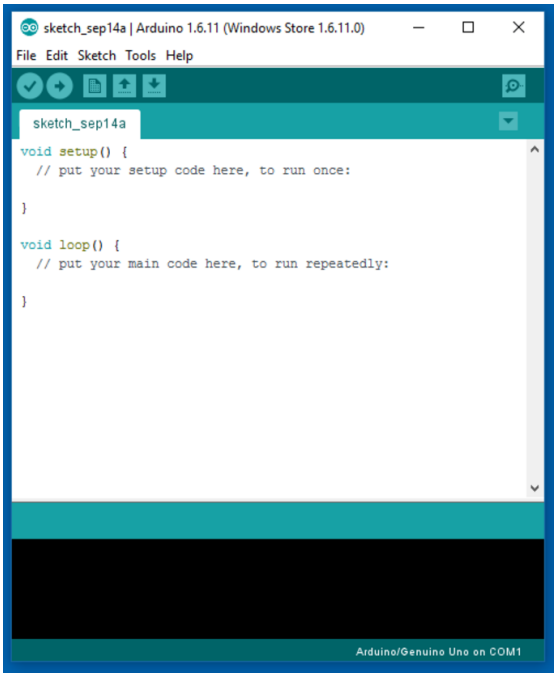


Figure 4.22: Arduino Software Interface IDE

Writing Sketches

Programs written using Arduino Software (IDE) are called sketches. These sketches are written in the text editor and are saved with the file extension. ino. The editor has features for cutting/pasting and for searching/replacing text. The message area gives feedback while saving and exporting and displays errors. The console displays text output by the Arduino Software (IDE), including complete error messages and other information. The bottom righthand corner of the window displays the configured board and serial port. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.

Libraries

Libraries provide extra functionality for use in sketches, e.g. working with hardware or manipulating data. To use a library in a sketch, select it from the Sketch > Import Library menu. This will insert one or more #include statements at the top of the sketch and compile the library with your sketch. Because libraries are uploaded to the board with your sketch, they increase the amount of space it takes up. If a sketch no longer needs a library, simply delete its #include statements from the top of your code.

There is a list of libraries in the reference. Some libraries are included with the Arduino software. Others can be downloaded from a variety of sources or through the Library

Manager. Starting with version 1.0.5 of the IDE, you can import a library from a zip file and use it in an open sketch. See these instructions for installing a third-party library.

Third-Party Hardware

Support for third-party hardware can be added to the hardware directory of your sketchbook directory. Platforms installed there may include board definitions (which appear in the board menu), core libraries, bootloaders, and programmer definitions. To install, create the hardware directory, then unzip the third-party platform into its own sub-directory. (Don't use "Arduino" as the sub-directory name or you'll override the built-in Arduino platform.) To uninstall, simply delete its directory.

4.13 Easy EDA

Easy EDA is a web-based EDA tool suite that enables hardware engineers to design, simulate, share-publicly and privately-and discuss schematics, simulations and printed circuit boards. Other features include the creation of a bill of materials, Gerber files and pick and place files and documentary outputs in PDF, PNG and SVG formats. Easy EDA allows the creation and editing of schematic diagrams, SPICE simulation of mixed analogue and digital circuits and the creation and editing of printed circuit board layouts and, optionally, the manufacture of printed circuit boards.

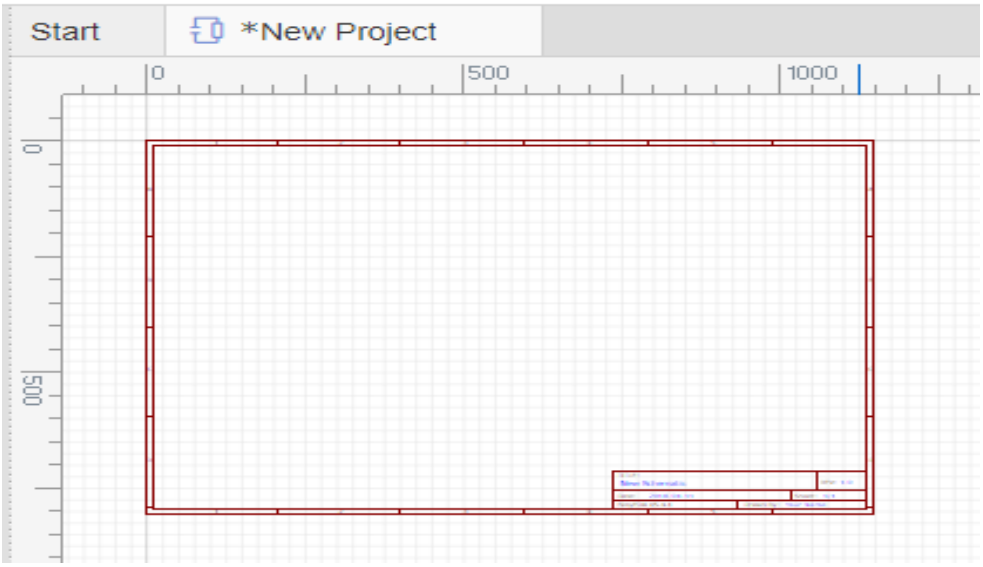


Figure 4.23: Easy EDA Software Interface

Subscription-free membership is offered by the public plus a limited number of private projects. The number of private projects can be increased by contributing high quality public projects, schematic symbols, and PCB footprints and/or by paying a monthly subscription. Registered users can download Gerber files from the tool free of charge; but for a fee, Easy EDA offers a PCB fabrication service. This service is also able to accept Gerber file inputs from third party tools.

CHAPTER 5

RESULT & DISCUSSION

5.1 Result Analysis

After finally completing this project, we ran it & we observed the output of this project. We can see that it is working well as expected. After doing our project we observe it very carefully. It works as we desire. Our project gives output perfectly and all equipment work perfectly. We check how much it works, and we get perfect output from this project.

- Finally, we have completed our project successfully & check our project its run accurately according to our objective.
- First, we start our system.
- Successfully monitored real-time energy consumption using voltage and current sensors.
- Arduino Nano accurately calculated and deducted units based on usage.
- GSM module reliably sent SMS alerts for low balance, consumption updates, and recharge confirmations.
- Relay module effectively disconnected load upon zero balance, ensuring prepaid control.
- Theft switch detected unauthorized access and triggered instant alerts.
- LCD display provided real time status of units, balance, and system activity.
- System reduced manual intervention, billing errors, and power theft risks.
- Demonstrated potential for scalable implementation in residential and commercial settings.

5.2 Final Project

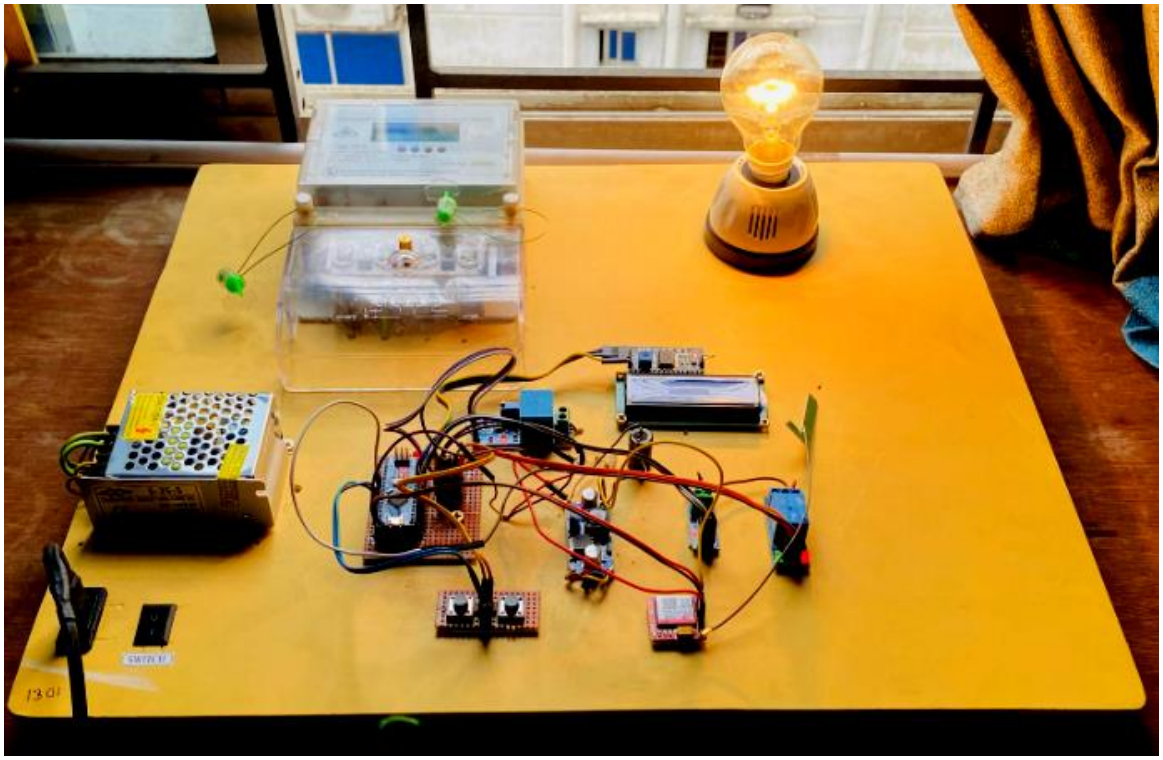


Figure 5.1: Project Prototype Image

5.3 Advantages

There are many advantages of the project. Some of these are given below:

- The whole system is automatic.
- Easy to use.
- Lowered Operation Costs
- Real-time Monitoring
- Automatic Billing
- Prepaid Energy Control
- Power Theft Detection
- GSM Communication
- Reduced Manual Labor
- Tamper Alert System
- Remote Alerts via SMS
- User-Friendly Interface
- Load Control Automation

Disadvantage

High initial setup cost

Dependence on network connectivity

Cybersecurity risks

Customer resistance

Maintenance and downtime

Limited flexibility for special cases

5.4 Application

This project has applications in many fields due to its necessity. We have selected a few of them and they are given below:

- Residential Homes
- Apartments and Housing Societies
- Commercial Buildings
- Environmental monitoring
- Temporary Power Installations
- Educational Institutions

5.5 Limitation

Though the project has many advantages it has also some limitations, they are given below:

- This project can now be only used for small scale purposes
- GSM module requires strong mobile network for SMS alerts; weak signals may cause delays.
- Used cheap Chinese products for the prototype so there's some processing delay present in the circuit.
- No energy backup.

5.6 Discussion

While working on our project, we did face some difficulties as it is a very complex system but the end results, we came up with were quite satisfactory. We have put the whole system through several tasks to validate our work and also have taken necessary notes for future improvements. Some future recommendations that we have involves improvement in system design and wiring, adding features for more efficiency.

The GSM-based prepaid energy meter using Arduino automates billing and monitors energy usage. Users recharge credit via GSM, and power supply cuts off when balance depletes. It ensures transparency, prevents overdue payments, and reduces manual meter reading. The system also detects power theft attempts and sends instant alerts, promoting secure, efficient, and reliable electricity distribution.

CHAPTER 6
CONCLUSION

6.1 Conclusion

The GSM-based prepaid energy meter using Arduino Nano offers a smart and efficient solution for modern energy management. By integrating real-time monitoring, prepaid billing, and theft detection into a single system, it eliminates the need for manual meter reading and billing processes. The system ensures that energy usage remains within the prepaid limit, automatically disconnecting the load upon balance exhaustion, thus promoting responsible consumption. The GSM module enhances user convenience by providing timely alerts about usage, low balance, and recharges via SMS. Additionally, the inclusion of a theft detection mechanism adds a layer of security by preventing unauthorized access and notifying both the user and utility provider immediately. This project not only improves transparency and billing accuracy but also reduces operational costs for utility providers. Overall, it contributes to building a smarter, more secure, and energy-efficient power distribution infrastructure for residential and commercial use.

6.2 Future Scope

As we have already discussed the limitations of our project definitely there's room for improvement and thus, we have lots of future scope of work available to us for this project. Some of these are listed below

- In the future we are looking forward to improving our whole system design to make it more efficient.
- In future, we will try to apply it in real field.
- In Future we will add extra power system.
- In future develop Control on IoT System

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APPENDIX

Programmed Code:

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <SoftwareSerial.h>

LiquidCrystal_I2C lcd(0x27, 16, 2);
SoftwareSerial gsm(9, 10); // RX, TX for GSM module

const int sensorIn = A1;
int mVperAmp = 10;
double Voltage = 0;
double VRMS = 0;
double AmpsRMS = 0;
int volt = 220;
int power = 0;
double energy = 0;
unsigned long lastTime = 0;

int relayPin1 = 2;
int relayPin2 = 3;
int relayPin3 = 4;
int relayPin4 = 5;

const int buttonPin1 = 6;
const int buttonPin2 = 7;
const int theftSwitchPin = 8;

bool countdown1Started = false;
bool countdown2Started = false;
int countdownValue1 = 100;
int countdownValue2 = 80;
unsigned long lastCountdownUpdate1 = 0;
unsigned long lastCountdownUpdate2 = 0;

bool lowBalanceSent = false;
bool theftSent = false;
bool rechargeSent1 = false;
bool rechargeSent2 = false;

const int numReadings = 2;
float readings[numReadings];
int readingIndex = 0;

void setup() {
  Serial.begin(9600);
```

```
  gsm.begin(9600);
  lcd.init();
  lcd.backlight();
  lcd.clear();

  pinMode(sensorIn, INPUT);
  pinMode(relayPin1, OUTPUT);
  pinMode(relayPin2, OUTPUT);
  pinMode(relayPin3, OUTPUT);
  pinMode(relayPin4, OUTPUT);
  pinMode(buttonPin1, INPUT_PULLUP);
  pinMode(buttonPin2, INPUT_PULLUP);
  pinMode(theftSwitchPin, INPUT_PULLUP);

  digitalWrite(relayPin1, HIGH);
  digitalWrite(relayPin2, HIGH);
  digitalWrite(relayPin3, HIGH);
  digitalWrite(relayPin4, HIGH);

  lastTime = millis();
}

void sendSMS(String message) {
  gsm.println("AT+CMGF=1");
  delay(100);
  gsm.println("AT+CMGS=\"+8801857376748\""); // Replace with your phone number
  delay(200);
  gsm.print(message);
  delay(200);
  gsm.write(26); // End SMS
  delay(1000);
}

void loop() {
  unsigned long currentMillis = millis();

  // Theft Detection
  if (digitalRead(theftSwitchPin) == HIGH) {
    if (!theftSent) {
      sendSMS("⚠ Theft Detected! Power has been shut off.");
      theftSent = true;
    }

    digitalWrite(relayPin1, HIGH);
    digitalWrite(relayPin2, HIGH);
    digitalWrite(relayPin3, HIGH);
    digitalWrite(relayPin4, HIGH);
    lcd.setCursor(0, 1);
    lcd.print("Theft Detected  ");
    return; // Skip rest of loop
```

```
}

// Reset theft flag if restored
if (digitalRead(theftSwitchPin) == LOW && theftSent) {
  theftSent = false;
}

// Recharge Detection
if (digitalRead(buttonPin1) == HIGH && !countdown1Started) {
  countdown1Started = true;
  countdownValue1 = 100;
  lastCountdownUpdate1 = currentMillis;
  sendSMS("✅ Recharged with 100TK.");
  rechargeSent1 = true;
  lowBalanceSent = false;
}

if (digitalRead(buttonPin2) == HIGH && !countdown2Started) {
  countdown2Started = true;
  countdownValue2 = 80;
  lastCountdownUpdate2 = currentMillis;
  sendSMS("✅ Recharged with 80TK.");
  rechargeSent2 = true;
  lowBalanceSent = false;
}

// Sensor reading
float result;
int readValue;
int maxValue = 0;
int minValue = 1024;

uint32_t start_time = millis();
while ((millis() - start_time) < 1000) {
  readValue = analogRead(sensorIn);
  if (readValue > maxValue) maxValue = readValue;
  if (readValue < minValue) minValue = readValue;
}

result = ((maxValue - minValue) * 5.0) / 1024.0;
readings[readingIndex] = result;
readingIndex = (readingIndex + 1) % numReadings;

float averageReading = 0;
for (int i = 0; i < numReadings; i++) {
  averageReading += readings[i];
}
averageReading /= numReadings;

Voltage = averageReading;
```

```
VRMS = (Voltage / 2.0) * 0.707;
AmpsRMS = ((VRMS * 1000) / mVperAmp) / 28;
power = AmpsRMS * volt;

unsigned long elapsedTime = currentMillis - lastTime;
lastTime = currentMillis;
energy += (power * elapsedTime) / 3600000000.0;

// LCD Display
lcd.setCursor(0, 0);
lcd.print("P:");
lcd.print(power);
lcd.print(" U:");
lcd.print(energy, 3);
lcd.print("kWh");

// Balance Management
lcd.setCursor(0, 1);

if (countdown1Started) {
  if (currentMillis - lastCountdownUpdate1 >= 1000) {
    lastCountdownUpdate1 = currentMillis;
    countdownValue1--;
    if (countdownValue1 < 0) {
      countdown1Started = false;
      lcd.print("No Balance       ");
      if (!lowBalanceSent) {
        sendSMS("❌ Balance Exhausted! Power turned off.");
        lowBalanceSent = true;
      }
    }
  }
  if (countdownValue1 >= 0) {
    lcd.print("blnc: ");
    lcd.print(countdownValue1);
    lcd.print("TK     ");
  }
} else if (countdown2Started) {
  if (currentMillis - lastCountdownUpdate2 >= 1000) {
    lastCountdownUpdate2 = currentMillis;
    countdownValue2--;
    if (countdownValue2 < 0) {
      countdown2Started = false;
      lcd.print("No Balance       ");
      if (!lowBalanceSent) {
        sendSMS("❌ Balance Exhausted! Power turned off.");
        lowBalanceSent = true;
      }
    }
  }
```

```
    if (countdownValue2 >= 0) {
      lcd.print("blnc: ");
      lcd.print(countdownValue2);
      lcd.print("TK     ");
    }
  }

  // Relay Control
  if ((countdown1Started && countdownValue1 <= 0) || (countdown2Started &&
countdownValue2 <= 0)) {
    digitalWrite(relayPin1, HIGH);
    digitalWrite(relayPin2, HIGH);
    digitalWrite(relayPin3, HIGH);
    digitalWrite(relayPin4, HIGH);
  } else if (countdown1Started || countdown2Started) {
    digitalWrite(relayPin1, LOW);
    digitalWrite(relayPin2, LOW);
    digitalWrite(relayPin3, LOW);
    digitalWrite(relayPin4, LOW);
  }

  // Serial Monitor
  Serial.print("Current: ");
  Serial.print(AmpsRMS);
  Serial.print(" A | Power: ");
  Serial.print(power);
  Serial.print(" W | Energy: ");
  Serial.print(energy, 4);
  Serial.println(" kWh");
}
```