POWER LINE COMMUNICATION FAULT PASSAGE DETECTOR FOR HV LINES

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

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ABSTRACT

India has one of the largest power grids and greater numbers in the power usage. Unfortunately, our power grid faces faults, insulator punctures, and theft for decades. Finding the fault and rectification of power lines are tedious and time-consuming procedures that involve a manual labor cost and time. Locating line faults with the help of faulted circuit indicators(using powerline communication) will be a great cost-effective solution instead of draining human resources.To monitor faults we are using power-line-communication enabled FPDs (Fault Passage Indicator Device) with locating methods. An FPD measures the current flow in a transmission line by measuring and calibrating the strength of the EM field around transmission lines. If this value crosses the present value, the FPD analyses the type of fault and pulls the data into the power line communication interface.The line current will be monitored using the current transformer method to detect fault current at the event of line to line or line to earth scenarios. The fault current data and other resources are collected and transmitted through Power Line Communication Module PLM0A1 to the receiver module. This information is collected and analyzed to decide the exact fault location and AB switch branch.

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LIST OF ABBREVIATIONS

ADC	Analog to Digital Converter
BOR	Brown out Reset
BPS	Bits per Second
CT	Current Transformer
FPD	Fault Passage Detector
GSM	Global System for Mobile communication
GPRS	General Packet Radio Service
IoT	Internet of Things
I2C	Inter Integrated Circuited
LCD	Liquid Crystal Display
MPPT	Maximum Power Point Technique
MSSP	Master Synchronous Serial Port
PLC	Power Line Communication
PWM	Pulse With Modulation
RISC	Reduced Instruction Set Computer
RTC	Real Time Clock
SIM	Subscriber Identity Module
SIP	Serial Peripheral Interface

USARAT Universal Synchronous /Asynchronous Receiver Transmitter

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

India has one of the largest power grids as well as greater numbers in usage. Unfortunately, our power grid sustains from faults, insulator punctures, and theft for decades. Locating and rectification of power line faults are a tedious time-consuming procedure burning a large chunk of the maintenance budget. Rapid locating and proper maintenance of line faults will be a great cost-effective solution instead of discharging precious energy and draining human resources

CURRENT SCENARIO

Faults can occur due to various reasons. Broadly we can categorize faults into two,

a. Line-Earth Faults:

High volt electricity leaking to earth due to insulator punctures, broken lines, or nearby trees and buildings. As the metallic body of any electrical equipment or device is connected to the earth. So if the live or phase wire touch to the body of the electrical equipment then a huge current will flow through the phase and earth conductor Which is known as Line to Earth Fault.

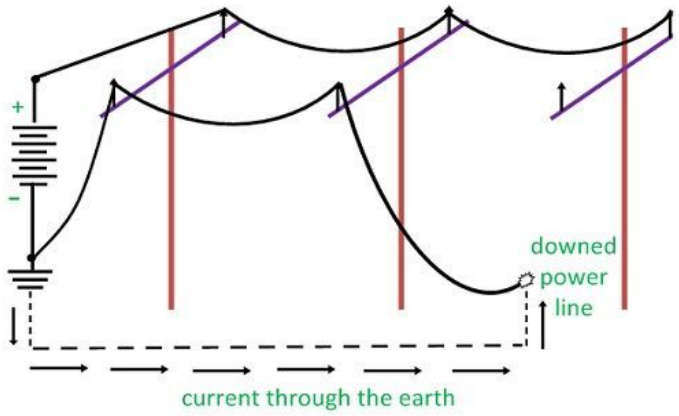


Fig 1.1: Line - Earth fault

When the line to earth fault occurs, a huge amount of current flows so there will be a large voltage drop.

Effects of Earth Faults

When Earth faults occur a huge amount of current flow through the phase and earthing conductor and a large voltage drop occurs. So this will affect the other loads and it may cause the burning of phase or line conductor. Earth fault causes huge sparking, Heat, fire, etc.

b. Line-Line faults:

Short circuit in between the lines due to various environmental or manmade causes. A line to line fault or unsymmetrical fault occurs when two conductors are short circuited. In the figure shown below shows a three phase system with a line-to-line fault phases b and c. The fault impedance is assumed to be Zf. The LL fault is placed between lines b and c so that the fault be symmetrical with respect to the reference phase a which is in-faulted.

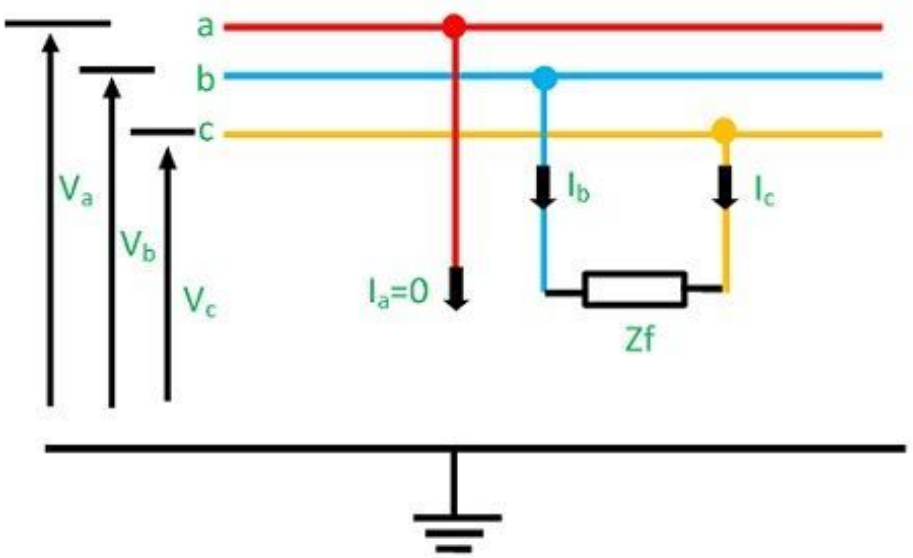


Fig1.2: Line - Line fault

1.2 Transmission Line Insulator puncture

A puncture is a breakdown and conduction of the material of the insulator, causing an electric arc through the interior of the insulator. Simply, it means electrical discharge occurs from conductor to pin through the body of the insulator.Generally, the pin insulator is designed with a factor of safety. Safety factor of an insulator is the ratio of puncture voltage to flash voltage. Due to this factor of safety, the flash-over takes place before the insulator gets punctured and by that it protects from complete damage. Basically, insulator puncture will occur due to switching over voltage and lightning. In the rainy season lightning is one major cause of failures of insulators.

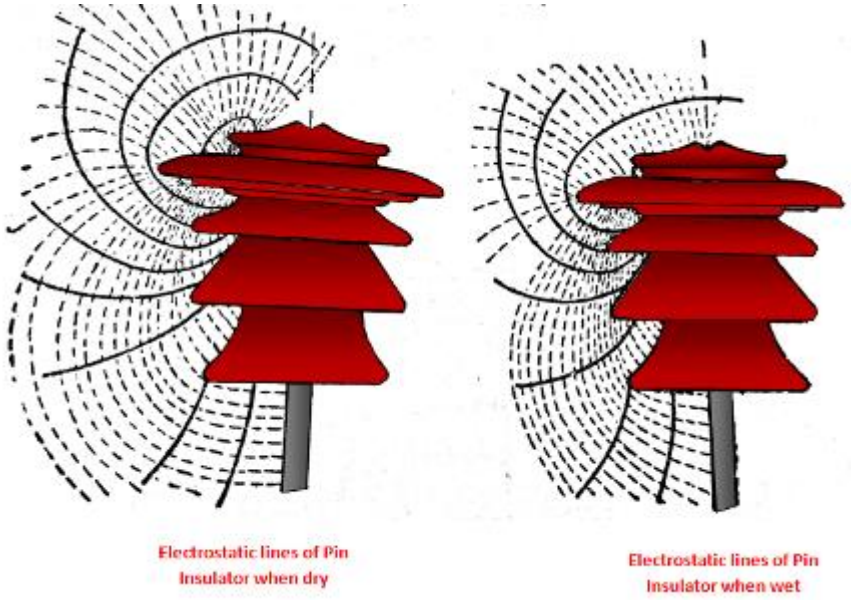


Fig 1.3: Electrostatics in insulators

2.a Power Line Fault Rectification Procedure

In practical electricity, people use the trial and error method to detect the fault location (Line to line fault / line to ground fault) of a transmission line. They feed supply at the single end at a time by dividing that transmission line into two parts and check the fault up to that section. These processes go on until they find the fault area. After checking if they found anything, then it is ok to go forward.This process is done from both ends and they sort out the exact location. For finding out the fault phase, they use megger (check the value of

resistance between the line to ground and Line to Line for each phase). These technologies take more human effort and consume more time.

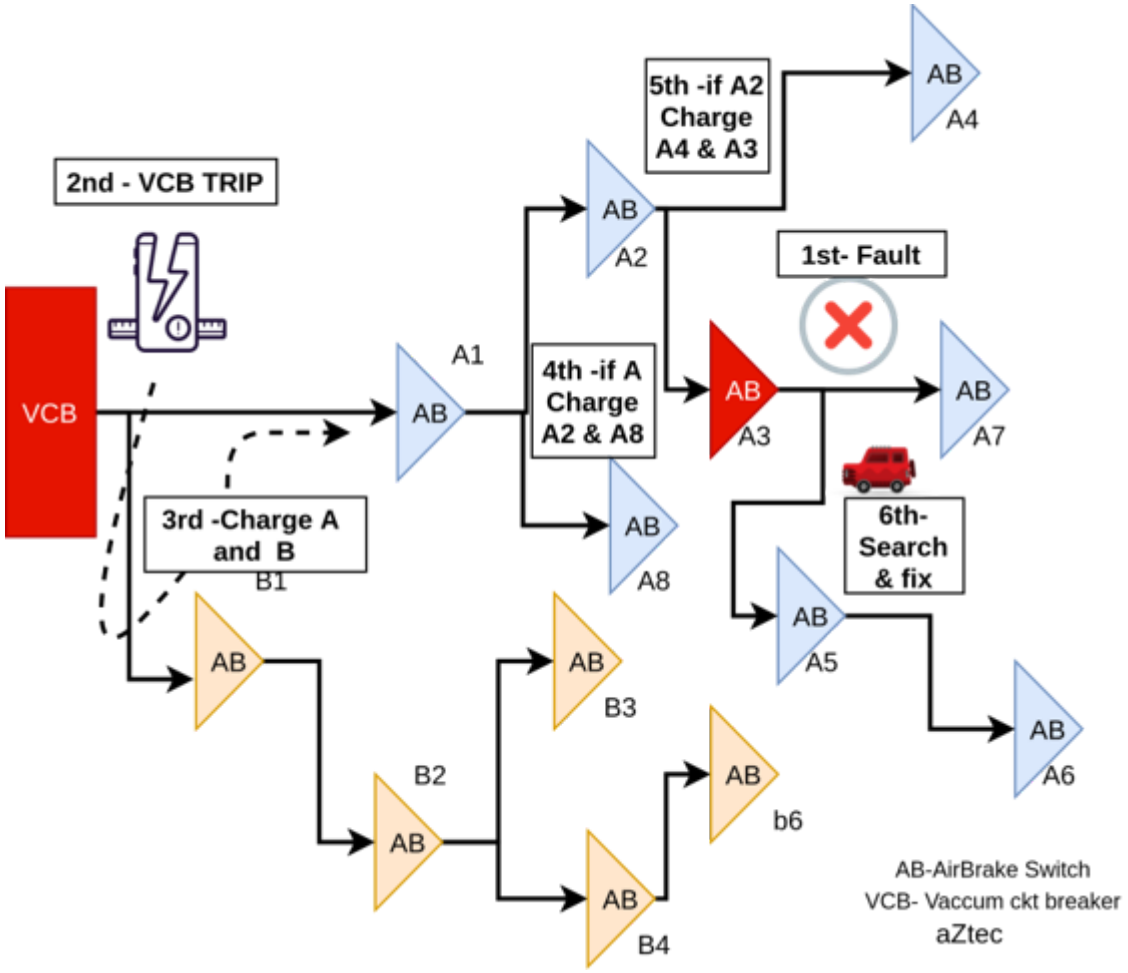


Fig 1.4: Fault rectification procedure

1.3 Aim

Faults in the power distribution lines are the major challenge faced by the over head indian power lines which not only increases the maintenance budget but also cause long power outages in industrial areas and hospital zones affecting overall economy. Locating the faults in overhead lines instantly is the solution to reduce the damage.

In this project, we are introducing a method to locate and identify the fault type to transmit the information at the power line communication without a service provider expenses.

1.4 Objective

- To detect the fault incident and type.
- To locate the fault AB branch.
- Transmit the data through the power line using PLC.

1.5 Scope

- Time required to locate the fault is drastically reduced.
- Decrease in maintenance budget.
- Human resources can be allocated to more productive works.
- Instant fault data without service provider charges using PLC.
- Line current data monitoring.

1.6 Power line communication

Powerline communication (PLC) is a technique in which existing electricity supply networks are re-used for communication. The primary benefit of PLC is the reduction of costs in the realization of new communication networks. That is the AC electric power conductor is also used simultaneously for transmission of data. The existing public and private wirings can be efficiently used to transmit data regarding power usage and device status. The power line media is free of cost than Narrow Band (single fixed radio frequency) GSM and less attenuated than wide Wi-Fi networks. Soon PLC will have more adaptation for applications like lighting applications (for traffic light control, LED dimming, etc.), industrial applications (for irrigation control, etc.), machine-to-machine applications (like for vending machines or a hotel's reception-to-room communication). The data transmission in the power line can be done various methods and protocols. The signal to be transmitted is modulated to FM analog signal. The digital one value is represented by the high-frequency components and the digital low value is converted to low-frequency components. Both frequencies are at the range of Kilo Hz (varying for protocols and methods from 10KHz to 130 kHz).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter we present the literature review of the power line communication fault passage detector for HV lines

2.1.1 "Power line communication – IEEE (2004)" A. Majumder, Jr. Caffery J

This article overviews the power line communication, which was originally devised to transmit electric power from a small number of sources to a large number of sinks. Initially the first data transmission over power lines was primarily done only to protect sections of the power distribution system in case of faults. This paper also studies the performance of power lines for high bit rate applications. DMT technology adopted by the homeplug standard can theoretically provide data rates of 100Mb/s. However, products based on the standard only have achieved data rates up to 14 Mb/s. To protect against the severe noisy conditions and fading in the powerline channel, very high levels of error control coding need to be provided. The efforts of the homeplug alliance and home networking technology growth in the US portend a very bright future for DMT-based PLC home networking.

2.1.2 “Power line fault detection and localization using high frequency impedance measurement” (13 April 2017) -Federico Passerini, Andrea M. Tonello

The reliability and quality of electrical power networks are affected by the occurrence of electrical faults. In this paper, we propose a novel method to identify the occurrence of faults in distribution networks, based on impedance measurements performed at the central distribution office. The measurements can be performed using PLC modems that belong to the energy metering infrastructure. The fault is detected by means of continuous impedance monitoring and afterwards its distance from the central office is estimated using the same measurement traces, without requiring additional information. Different type of faults are tested, and the effect of the measurement bandwidth and the electrical noise on the measurement is also assessed.

2.1.3 “High impedance fault passage using power line communication techniques”- IEEE (2015) byA. N. Milioudis,G. T. Andreou and D.P Labridis

Occurrence of High Impedance Faults in urban overhead power distribution networks can cause economical and safety issues for both the public and the utility. These faults may hardly be detected using conventional protection methods, so as sophisticated system has to be developed to deal with the problem. In this work the usage of high frequency ranges and specifically the Cenelec A Band frequency range is examined for the detection of such kind of faults by monitoring the input impedance of the system. High impedance faults can cause significant deviation to the overall impedance at specific frequencies. Several branched overhead Medium Voltage topologies are examined and significant conclusions are extracted. Furthermore, a parametric analysis is conducted with respect to the earth’s electromagnetic properties, i.e. ground resistivity and relative permittivity, regarding their impact on the efficacy of the method. Finally, the occurrence of fault at all possible locations of a transmission line is examined and also analyzed

2.1.4 "Current measurement method for characterization of fast switching power semiconductors with Silicon Steel Current Transformer" – IEEE 2019, Helong Li; Szymon Beczkowski, Stig Munk-Nielsen; Kaiyuan Lu, Qian Wu

This paper proposes a novel current measurement method with Silicon Steel Current Transformer (SSCT) for the characterization of fast switching power semiconductors. First, the existing current sensors for characterization of fast switching power semiconductors are experimentally evaluated regarding three essential qualities: high bandwidth, suitable physical size, and galvanic isolation. Then, the proposed current measurement method with SSCT is mathematically analyzed, which proves that the proposed method has the capability of measuring fast switching current. Simultaneously, it compensates the mechanical size limitations of the Pearson current monitor. Finally, experimental studies are carried out with both discrete Silicon Carbide (SiC) MOSFET and high current (1000A) Silicon (Si) IGBT power modules. The experimental results validate the effectiveness of the proposed method

2.1.5 "IEC and NEMA/IEEE ratings of current transformers (CTs) in medium voltage application" – IEEE- Jan 2020, by EDVARD

A medium voltage current transformer can have up to three independent secondary winding sets. The entire current transformer assembly is encapsulated in resin, inside an insulated casing. Current transformers are used for metering or protection purposes.The accuracy class and size depends on the individual application – for example, revenue metering would use high accuracy metering CTs.Just to note, it's very important . This creates extremely high voltages which pose a real danger to personnel.Ok, let's get on the IEC and later NEMA ratings of a current transformer. Some rating explanations have exercises and real examples, which I hope it will help for better understanding.

2.1.6 “ Modeling and simulation of optical current transformer using operational amplifier ”-IEEE (2017) Hafiz Muhammad Ashraf ,Ghulam Abbas; Usman Ali; Saif ur Rehman

The importance of Conventional Current Transformer (CCT) for the monitoring and protection in power systems is not ignorable. Although there has been an extensive use of CCT for a long time but a lot of problems and issues such as inrush current, saturation, current transformer ratios, etc. faced by CCT make its use quite limited. Issues arising in CCTs have pulled the attraction of researchers and protection engineers towards a new instrument technology based on Opto-Electromagnetics. An Optical Current Transformer (OCT) model based on the simulation has been proposed here which follows the Faraday's law of Electromagnetics. The use of OCT will resolve almost all issues that were being faced by CCTs. So this new designed model of OCT can replace easily the CCTs for both the protection and metering purposes. This simulation model of OCT using operational amplifiers is being proposed here just to motivate the protection and design engineers especially in Pakistan to adopt the new technology of OCT for the measurement of current in place of CCT. In addition to resolving all issues related to CCT, OCT will also make the power quality better. Three types of outputs can be obtained from an OCT which are: low energy analog output (LEA), high energy analog output (HEA) and digital output. Due to sampling rate limitations involved, a digital output is hard to use to avail the wider bandwidth option. To use all the benefits of an OCT, a low energy output signal will be used here for the simulation requirement here. After the required OCT model development, simulation results will be included to prove that CCT can be replaced by the OCT.

2.2 Existing Systems

There Fault Passage Indicator available in foreign markets. These equipments are meant to indicate (By blinking indicator lights at the bottom) the occured fault by measuring the line current. The fault area can be located by patrolling the transmission branches.

2.2.1 Products available in market

FPD (Fault Passage Detectors) are available widely at high costs in market. These are some of the online available FPDs

A.Pressure Spring Type led indicator fault passage indicator

Fig 2.1: LED indicator FPD

Price: US$45.00
Joint Type: Pressure Spring Type
Application: Overhead 6-35KV High Voltage Cable
Applicable wire current: I≤1200A

A. Pole-mounted or clipped on the MV overhead lines from Schneider Electric SE

Fig 2.2: Pole-mounted FPD

Flite 110-SA : ammetric FPI clipped on the MV line for resistive or solidly earthed neutral.

2.2.2 Disadvantages of existing products

- Unaffordable price for indian power sector.
- Data transmission is not available. Manual patrolling needed for finding the FPD with fault.
- FPDs integrated with GSM comes at higher cost and service maintenance charges.

CHAPTER 3
POWER LINE COMMUNICATION

3.1 Power line communication

3.1.1 Introduction

Powerline communication (PLC) is a technique in which existing electricity supply networks are re-used for communication. The primary benefit of PLC is the reduction of costs in the realization of new communication networks. That is the AC electric power conductor is also used simultaneously for transmission of data. The existing public and private wirings can be efficiently used to transmit data regarding power usage and device status. The power line media is free of cost than Narrow Band (single fixed radio frequency) GSM and less attenuated than wide Wi-Fi networks. Soon PLC will have more adaptation for applications like lighting applications (for traffic light control,LED dimming, etc.), industrial applications (for irrigation control, etc.), machine-to-machine applications (like for vending machines or a hotel's reception-to-room communication). The data transmission in the power line can be done various methods and protocols. The signal to be transmitted is modulated to FM analog signal. The digital one value is represented by the high-frequency components and the digital low value is converted to low-frequency components. Both frequencies are at the range of Kilo Hz (varying for protocols and methods from 10KHz to 130 kHz). The frequency switching technique is also called FSK (Frequency shift keying) since the digital signal is transmitted through the discrete of the carrier signal. The frequency changed modulated signal then coupled with the AC power line via 'High pass filters' which reject the low frequency 50Hz AC signal and make the wire available for the transmission of data. When multiple devices are interconnected in the PLC network, we use the multiplexing technique called FDM. FDM (Frequency Division Multiplexing) is an encoding method of digital data on multiple carrier frequencies. This method allows simultaneous data transfer on the available frequency range. FDM assigns frequency divisions for each device to enable multiplexing. Digital data consist of start code, letter code, and number code. The start code will poke the receiver and make it ready to read the data. The letter code consist of transmitting device address and number code enclose the data. Further for more application

parameters, the data sequence can be extended. Here we use the following data sequence for efficient AMR and power theft detection.

- Start Code = 4 bits
- House code = 4 bits
- Extended code 1 = 5 bits (01111)
- Unit code (device code) = 4 bits
- Data = 8 bits
- Command = 8 bits

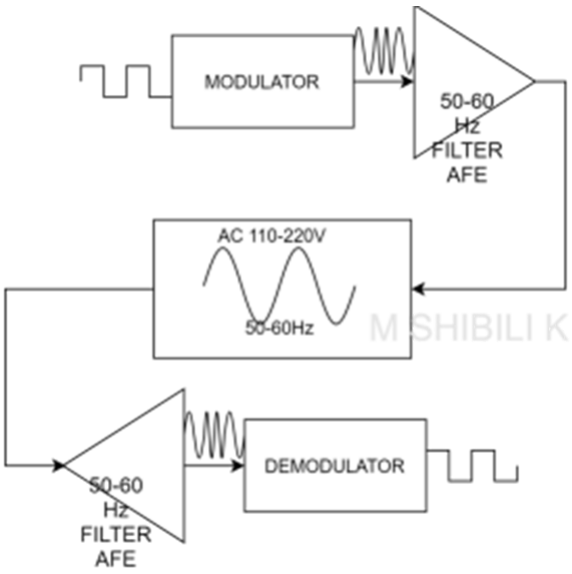


Fig 3.1: Power line communication methodology

(digital bits are converted to analog frequency/sine wave e.g. bit 1 is converted to a sine wave of 20 Khz bit 0 is converted to the sine wave of 10Khz). To "clear" the Mains frequency and make the wire available for the transmission of data the 50/60Hz signal is filtered. This filter clears any signal of 50Hz to 60Hz. The transmitted data then are free to travel over the Mains. When they find their destination another 50 to 60Hz filter is involved. After the filter pass, the remaining signal is the modulated transmitted data. This signal is then demodulated and converted to digital bits at the receiver side.

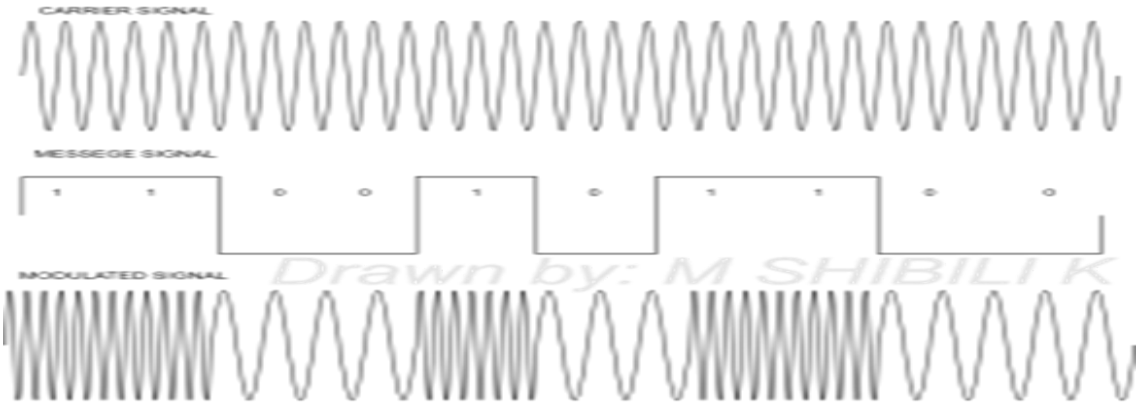


Fig 3.2: FSK modulation (frequency modulation)

3.2 Advantages of power line communication

- Low Implementation Cost: It is the major advantage PLC, it does not require any installation of new wires which as a result, would significantly reduce the deployment costs.
- Large Reach: It delivers data wherever the power reaches. PLC can access communication with hard to reach nodes where the RF wireless signal suffers from high levels of attenuation like in the concrete buildings or underground structures, or places like hospitals where the wireless signal is undesirable due to the EMI issues.
- Lower Running Cost: PLC provides a low cost solution compared to the other existing technologies such as Wi-Fi or Narrow Band (single fixed radio frequency) GSM.

3.3 Modulation Schemes

A variety of modulation schemes can be used in PLC. Some of these are Orthogonal Frequency Division Multiplexing (OFDM), Binary Phase Shift Keying (BPSK), Frequency Shift Keying (FSK), Spread-FSK (S-FSK) and proprietary schemes too (for example Differential Code Shift Keying (DCSK) from Yitran). In the table below, BPSK, FSK, SFSK and OFDM are compared on the basis of two important criteria – bandwidth efficiency and complexity (cost).

Modulation Scheme	Bandwidth efficiency	Complexity
BPSK	Medium	Low
FSK	Medium	Low
SFSK	Low	Medium
OFDM	High	High

Table 3.1: comparison of modulation schemes

OFDM in particular offers high data rates, but requires computational horsepower to churn out Fast Fourier Transforms (FFT) and Inverse-FFT (IFFT), as required by the scheme. On the other hand, BPSK, FSK are robust and simple but offer lower data rates. The current trend is to move towards OFDM with PSK modulation (G3 and probably P1901.2). Such heavy computation will require DSP capability, whereas FSK, PSK and SFSK can be accomplished by a microcontroller.

3.3.1 Standards

Various standards have been developed in order to ensure reliable communications and inter-operability, especially for the smart grid and home networking. Examples of such standards are:

Standard	Technology	Frequency band	Bit rate (kbps)
G3-PLC	OFDM	36-90.6kHz	5.6-45
PRIME	OFDM	42-89kHz	21.4-128.6
IEEE P1901.2	OFDM	9-500kHz	Coming Soon
ANSI/EIA 709.1,.2	BPSK	86, 131kHz	3.6-5.4
KNX	S-FSK	125-140kHz	1.2
IEC61334	S-FSK	CENELEC-A	2.4

Table 3.2: specification of PLC standards

These, along with the organizations that govern them like CENELEC, FCC, ARIB, Homeplug Power Alliance specify ranges for operation of PLC. If a worldwide standard for PLC were to be established, this would have a positive impact on adoption of PLC. So far, the G3-PLC standard is touted as the most robust scheme available, and the IEEE 1901.2 working group is committed to developing a universally acceptable standard.

3.3.2 Frequencies

Different regions of the world have different frequency bands allocated to narrowband PLC. The table below summarizes the different frequencies available for narrowband PLC communication in the respective region.

Table 4. Narrowband PLC frequency ranges for various regions

Region	Regulatory Body	Frequency Band	Note
Europe	CENELEC	3-95kHz	A – Energy providers
		95-125kHz	B –Reserved for users
		125-140kHz	C – Reserved for users, regulated CSMA access
		140-148.5kHz	D –Reserved for users
Japan	ARIB	10-450kHz	
China	EPRI	3-90kHz	Not Regulated
		3-500kHz	
USA	FCC	10-490kHz	

Table 3.3: Narrowband PLC regional frequency ranges

CENELEC – European Committee for Electrotechnical Standardization.
ARIB – Association of Radio Industries & Businesses
EPRI – Electric Power Research Institute
FCC – Federal Communications Commission

3.4 APPLICATIONS

Earlier, we saw that PLC is widely used in the Smart Grid and in micro-inverters. As the market gets familiar with this technology, PLC should see wider adoption in other applications like lighting (e.g. traffic light control, LED dimming), industrial (e.g. UPS communicating to a network device, irrigation control), machine-to-machine (e.g. vending machines, a hotel's reception-to-room communication), telemetry (e.g. offshore oil rigs) and transport.

CHAPTER 4

METHODOLOGY

4.1 Block Diagram

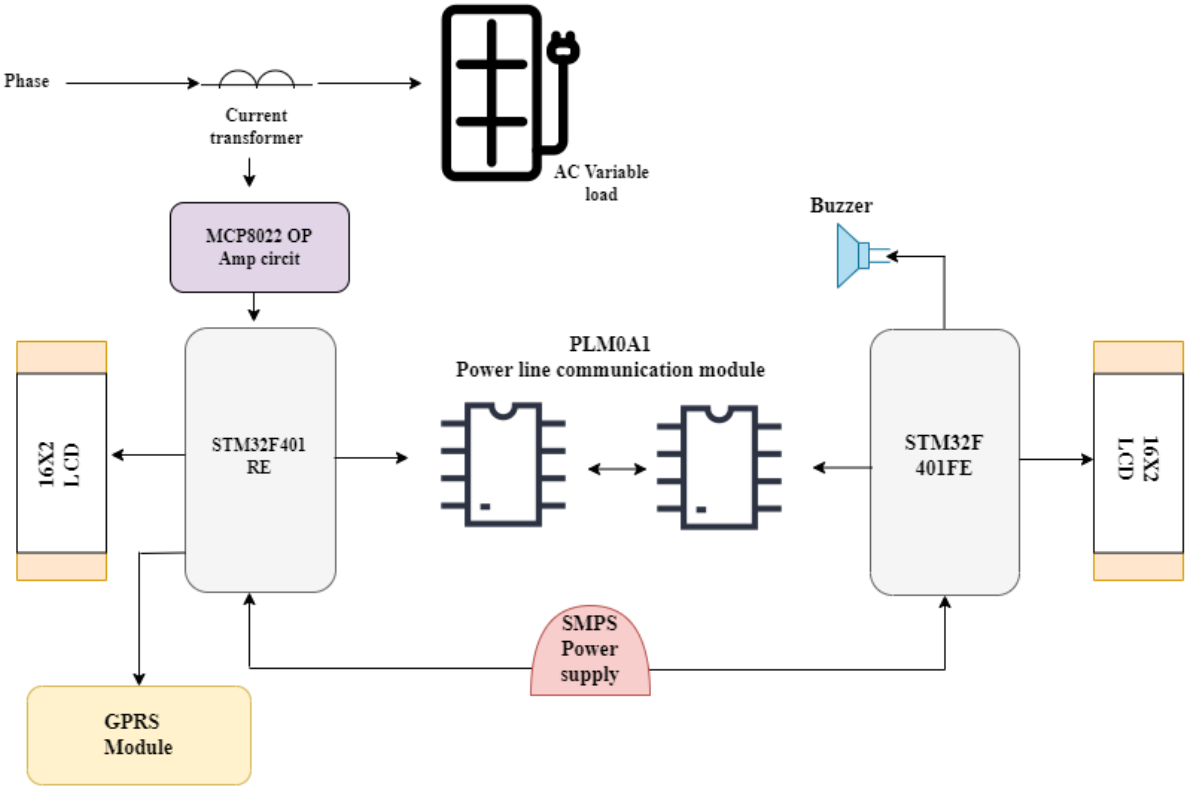


Fig 4.1: Block Diagram

4.2 Embedded system

4.2.1 Introduction

An embedded system is a special-purpose computer system, which is completely encapsulated by the device it controls. An embedded system has11 specific requirements and performs predefined tasks, unlike a general-purpose personal computer. An embedded system is a programmed

hardware device. A programmable hardware chip is the 'raw material' and it is programmed with particular applications. This is to be understood in comparison to older systems with full functional hardware or systems with general purpose hardware and externally loaded software. Embedded systems are a combination of hardware and software which facilitates mass production and variety of applications. A combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a dedicated function.

4.2.2 Features

- Reactive: computations must occur in response to external events
- Correctness is partially a function of time Small Size, Low Weight
- Hand- held electronics and Transportation applications - weight costs money Low Power.
- Battery power for 8+ hours (laptops often last only 2 hours) Harsh environment
- Heat, vibration, shock, power fluctuations, RF interference, lightning, corrosion Safety- critical operation
- Must function correctly and must not function correctly.

4.3 Microcontroller

4.3.1 Introduction

A Micro controller consists of a powerful CPU tightly coupled with memory RAM, ROM or EEPROM, various I / O features such as Serial ports, Parallel Ports,Timer/Counters, Interrupt Controller, Data Acquisition interface Analog to Digital Converter (ADC), Digital to Analog Converter (ADC), everything integrated onto a single Silicon Chip. It does not mean that any micro controller should have all the above said features on chip, depending on the need and area of application for which it is designed, the on-chip features present in it may or may not include all the individual section said above. Any microcomputer system requires memory to store a sequence of instructions making up a program, parallel port or serial port for communicating with an external system, timer / counter for control purposes like generating time delays, Baud rate for the serial port, apart from the controlling unit called the Central Processing Unit.

4.3.2 Application

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. In the context of the internet of things, microcontrollers are an economical and popular means of data collection, sensing and actuating the physical world as edge devices.

4.4 Microcontroller STM32 NUCLEO-F401RE

4.4.1 Description

The STM32 Nucleo-64 board provides an affordable and flexible way for users to try out new concepts and build prototypes by choosing from the various combinations of performance and power consumption features, provided by the STM32 microcontroller. For the compatible boards, the external SMPS significantly reduces power consumption in Run mode. The ARDUINO® Uno V3 connectivity support and the ST morpho headers allow the easy expansion of the functionality of the STM32 Nucleo open development platform with a wide choice of specialized shields. The STM32 Nucleo-64 board does not require any separate probe as it integrates the ST-LINK debugger/programmer. The STM32 Nucleo-64 board comes with the STM32 comprehensive free software libraries and examples available with the STM32Cube MCU Package.

4.4.2 Description

- STM32 microcontroller in LQFP64 or LQFP48 package
- 1 user LED shared with ARDUINO
- 1 user and 1 reset push-buttons
- 32.768 kHz crystal oscillator
- Board connectors
- ARDUINO Uno V3 expansion connector
- ST morpho extension pin headers for full access to all STM32 I/Os
- Flexible power-supply options: ST-LINK USB VBUS or external sources
- On-board ST-LINK debugger/programmer with USB re-enumeration capability: mass storage, Virtual COM port, and debug port
- Comprehensive free software libraries and examples available with the STM32Cube MCU Package
- Support of a wide choice of Integrated Development Environments (IDEs) including IAR Embedded Workbench, MDK-ARM, and STM32Cube IDE

- Board-specific features
- External SMPS to generate Vcore logic supply
- 24 MHz or 48 MHz HSE
- Board connectors:
- External SMPS experimentation dedicated connector
- Micro-B or Mini-B USB connector for the ST-LINK
- MIPI debug connector

4.4.3 STM32F401RE-Microcontroller Pin Mapping

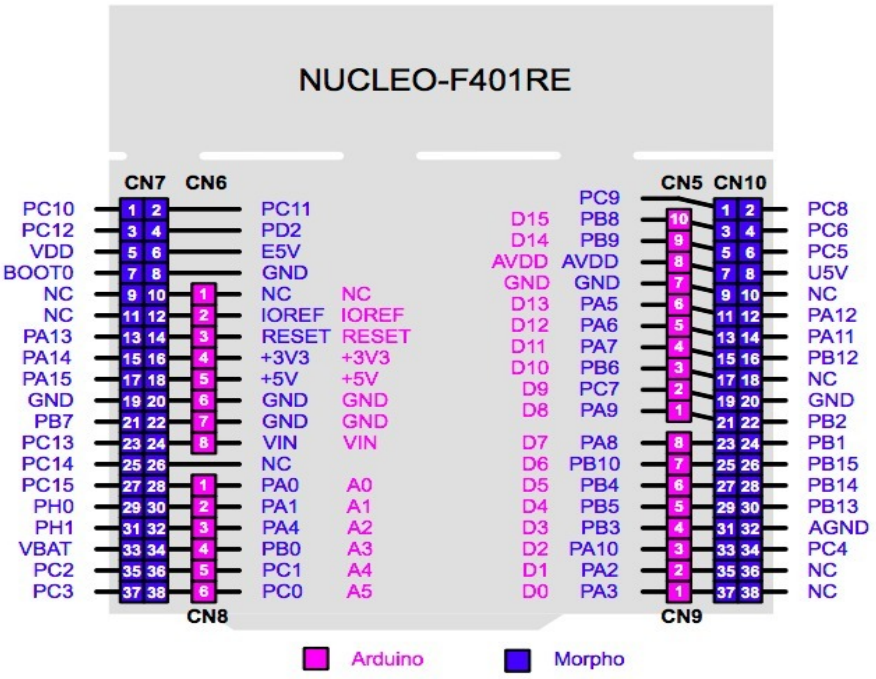


Fig 4.2: STM32f401re Nucleo board

The STM32 Nucleo boards are the official Development Boards from STMicroelectronics. It features the ARM Cortex M4 32-bit STM32F401RET6 microcontroller which is in the LQFP64 package. The Boards pinout is similar to Arduino UNO and has many other additional pins to expand performance. This board also comes with an integrated ST-LINK/V2-1 programmer and debugger; hence it is very easy to get started with this board.

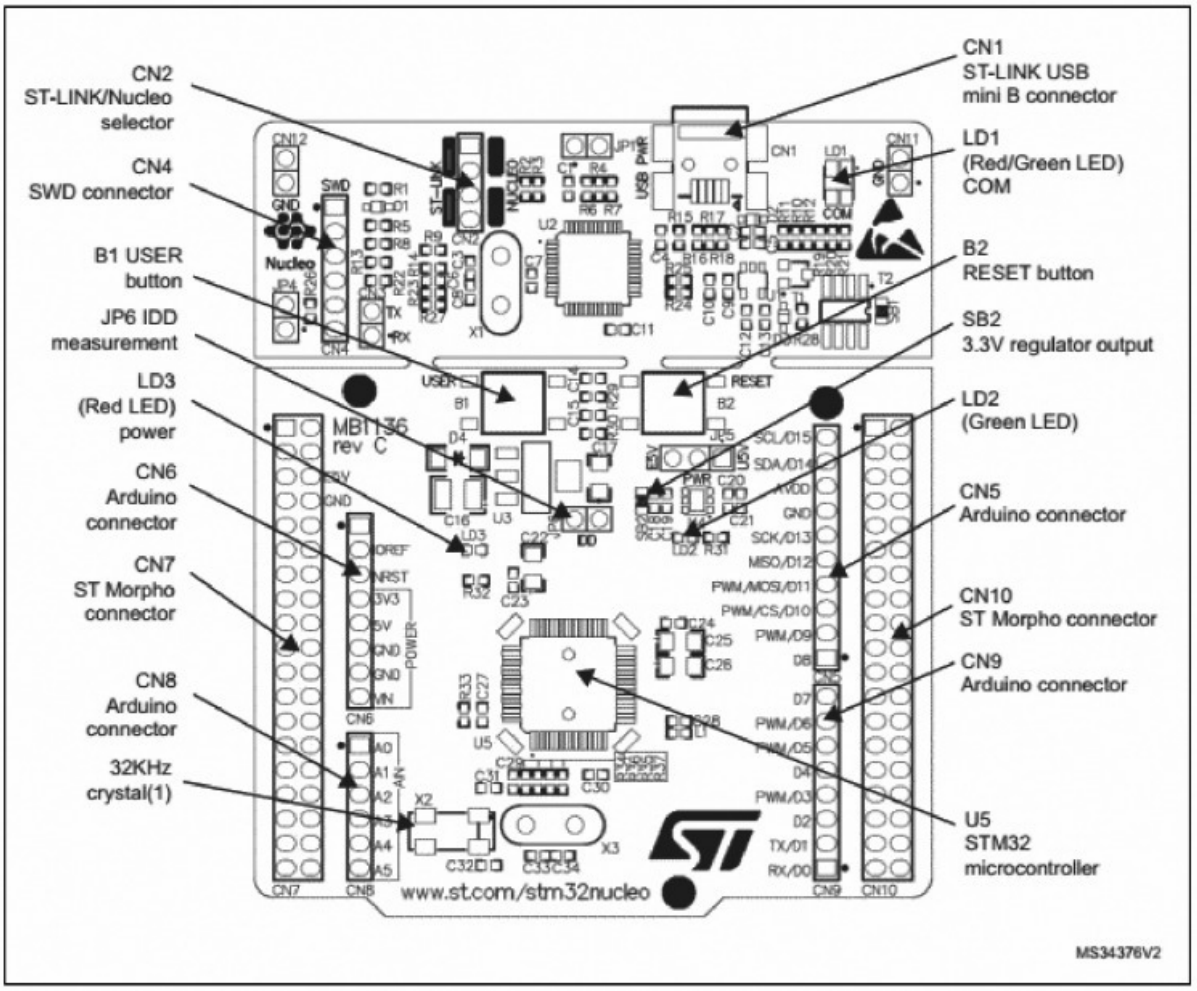


Fig 4.3: Nucleo-F401RE

4.4.4 Nucleo-F401RE Pinout Configuration

The **STM32 Nucleo board pinout** is shown above. As you can see, there are two sets of pins. The pin one resembles the Arduino UNO and the blue one is the STM32 style (**Morpho**). The arduino like pins are female connector pins which exactly match the order and position of Arduino UNO pins and hence any Arduino shield can be used with these development boards.

The **STM32 Nucleo boards** are the official Development Boards from STMicroelectronics. It features the **ARM Cortex M4** 32-bit **STM32F401RET6 microcontroller** which is in LQFP64 package. The Boards pinout is similar to Arduino UNO and has many other additional pins to expand performance. This board also comes with an integrated ST-LINK/V2-1

programmer and debugger; hence it is very easy to get started with this board. There are three LEDs, where LD1 is for indicating USB communication, LD2 is a programmable LED, and LD3 indicates power. Similarly, there are two push buttons where one is user programmable, and the other is to reset the microcontroller. The Board operates with 3.3V supply but a wide voltage range of 7-12V can be provided to the VIN pin since it has an onboard voltage regulator.

Pin category	Pin type	Pin name	Description
CN6	Power	IOREF	3.3V Reference voltage pin
RESET	Resets the microcontroller		
+3.3V	Provides 3.3V as output can also be used to power the MCU		
+5V	5V output only pin		
GND	Ground pins		
CN8	Analog pins and I2C	A0-A1	Used to measure analog voltage
A4 & A5	These pins also be used for I2C Communication A4 is SDA and A5 is SCL		
CN5	Digital pins and SPI	D8-D15	Digital GPIO pins

AVDD	Can be used to provide analog reference voltage		
GND	Ground pins		
D13,D12,D11 and D10	Acts as SCK,MISO,MOSI and CS pins respectively for SPI communication		
CN9	Digital pins and USART	D0 to D7	Digital GPIO pins
D0 and D1	Acts as Rx and Tx pins respectively for USART communication		

Table 4.1: STM32 Nucleo F401RE I/O and Power

Apart from the Arduino pins, the board also has 76 (38+38) GPIO pins as male headers on either side of the board as shown above. These pins are classified into CN7 and CN10 with each having 38 Pins. They comprise of GPIO pins, Analog Pins, Timer Pins, and Power pins. The name of the pins can be found in the image above

They are also categorized with the table below:

Pin category	Pin type	Pin name	Description
CN7	Port pins	PC0, PC1, PC2, PC3, PC10, PC11, PC12, PC13, PC14, PC15	Port C digital I/O pins
PD2	Port D I/O pin		
PA0, PA1, PA4, PA13, PA14, PA15	Port A I/O pins		
PB7, PB8 and PB9	Port B I/O pin		
PH0 and PH1	Port H I/O pins		
Power	VBAT	Can be used to power them module from battery	

+3.3V	Provides 3.3V as output can also be used to power the MCU		
+5V	5V output only pin		
VIN	Unregulated input power pin		
RESET	Resets the MCU		
IOREF	Reference Voltage Pin	PC4, PC5, PC6, PC7, PC8, PC9	Port C I/O Pins
PA2, PA3, PA4, PA6, PA7, PA10, PA11 and PA12	Port A I/O Pins		
PB1, PB2, PB3, PB4, PB5, PB6, PB8, PB9, PB10, PB12,	Port B I/O Pins		

PB14, PB15			
Power	U5V	5V Power Pin	
GND	System Ground of the MCU		
AGND	Analog Ground Pin		

Table 4.2: STM32 Nucleo F401RE Pinout

4.5 X-NUCLEO-PLM01A1

Power line communication expansion board based on ST7580 for STM32 Nucleo PSK multi-mode power line networking system-on-chip.

4.5.1 Introduction

Power Line Communication implemented using the support of ST Microelectronics ST7580 module. Which has all the industrial PLC compatibility.

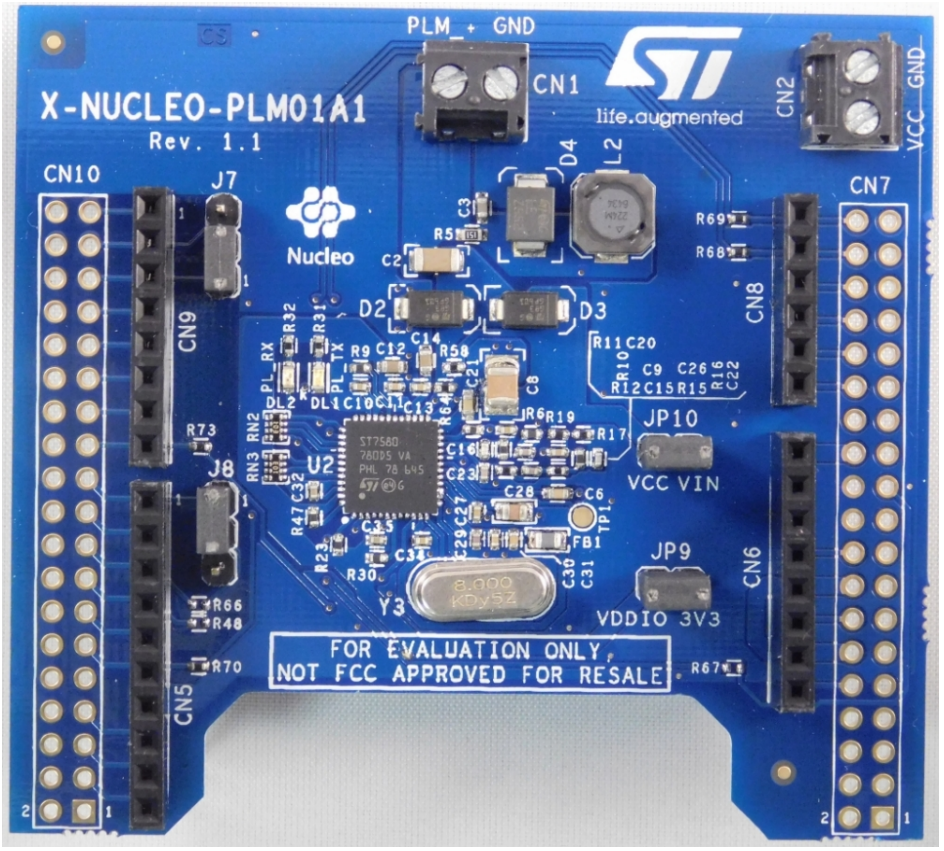


Fig 4.4: Power line communication module X-NUCLEO-PLM01A1

4.5.2 Description

The X-NUCLEO-PLM01A1 expansion board for STM32 Nucleo is based on the ST7580 FSK, PSK multi-mode power line networking system-on-chip. It provides an affordable and easy-to-use solution for the development of connectivity applications based on power line communication. It lets you easily evaluate the communication features of the ST7580 based on a DC two-wire

link between two boards. X-NUCLEO-PLM01A1.

You can also perform evaluation on an AC power line by connecting the X-NUCLEO-PLM01A1 to an STEVAL-XPLM01CPL board providing effective AC coupling and isolation. The X-NUCLEO-PLM01A1 is interfaced with the STM32 controller via UART and GPIO pins and is compatible with the Arduino UNO R3 (default configuration) and ST morpho (optional, not mounted) connectors.

4.5.3 Features

- PLC hardware Implementation is achievable with high accuracy.
- STM 32 X-Nucleo BSP libraries makes the software much more efficient and simple.
- API level programming.
- Data reliability.
- STM32 Nucleo expansion board based on the ST7580 power line networking system-on-chip
- ST7580 main characteristics:
- FSK, PSK modem for robust wireline communication up to 28.8 kbps
- 8-18 V analog supply voltage
- 3.3 V digital supply
- Output transmitted signal capability up to 14 Vp-p, 1 Arms
- Frequency range 9-250 kHz
- TX and RX filters on board optimized for the CENELEC B (95-125 kHz) frequency band, suitable for IoT / Smart Home / Smart City applications
- Compatible with STM32 Nucleo boards
- Equipped with Arduino UNO R3 connectors

- Example firmware available for point-to-point communication, compatible with STM32Cube firmware
- RoHS compliant

4.5.4 Applications

Hardware setup The following hardware components are needed:

- Two STM32 Nucleo development platforms (suggested order code: NUCLEO-F401RE or NUCLEO-L053R8)
- Two power line expansion boards (X-NUCLEO-PLM01A1)
- Two USB type A to Mini-B USB cables to connect the two STM32 Nucleo boards to the PC One lab DC power supply to provide 12V Four wires for power supply (2 per board)
- Two wires for PLM connection The following picture shows the environment detailed above.

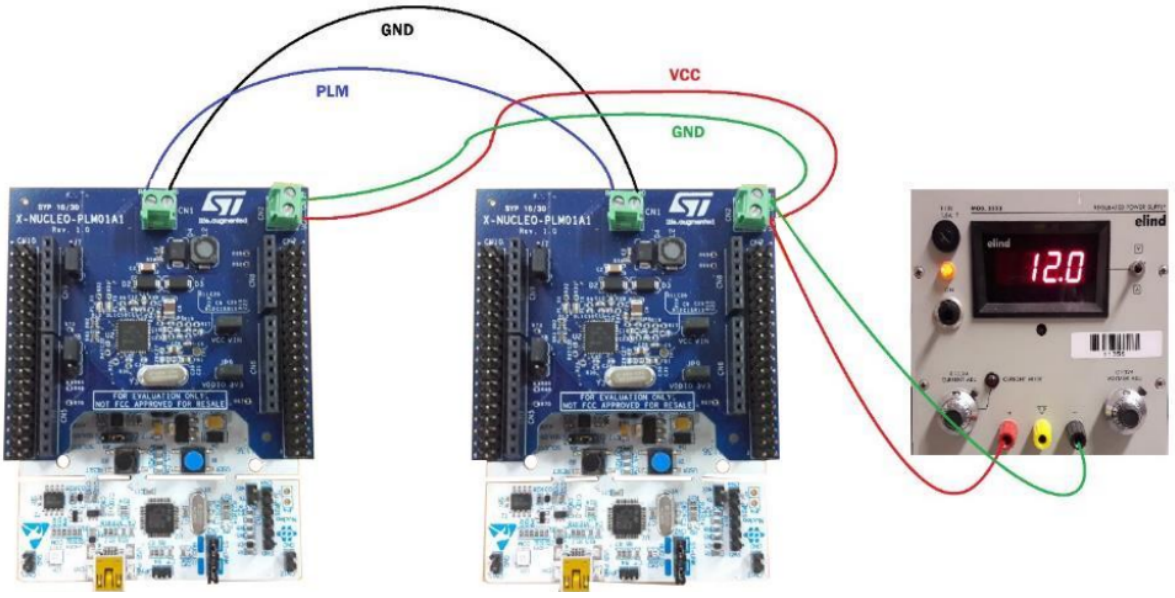


Fig 4.5: Power line communication environment

A sample application using the X-NUCLEO-PLM01A1 expansion board with the NUCLEO F401RE or NUCLEO-L053R8 board is provided in the "Projects" directory. Ready-to-use projects are available for multiple IDEs.The sample application contains a simple point-to-point communication between two nodes equipped with an STM32 Nucleo board and an X-NUCLEO-PLM01A1 expansion board.

To create a demo (using a PC to monitor the activity on the power line), the developer has to use the STM32 Nucleo LEDs and/or buttons. He can assign each node a role as master or slave by pushing the STM32 Nucleo USER button at boot time: USER button pressed = master USER button released = slave These options allow having only a single precompiled binary for both roles. After the role assignment, in an endless loop, the master board sends a TRIGGER frame to the power line (toggling the X-NUCLEO-PLM01A1 green LED) that the slave will receive and recognize (toggling the X-NUCLEO-PLM01A1 red LED). The slave will send back an ACK frame as a confirmation (toggling the X-NUCLEO PLM01A1 green LED). The master node will recognize the ACK frame (toggling the X-NUCLEO-PLM01A1 red LED). If the two nodes are connected through USB cables, they print power line status messages on a debug serial port (e.g. message sent, message received, etc). The following figure shows the master and slave routine described above.

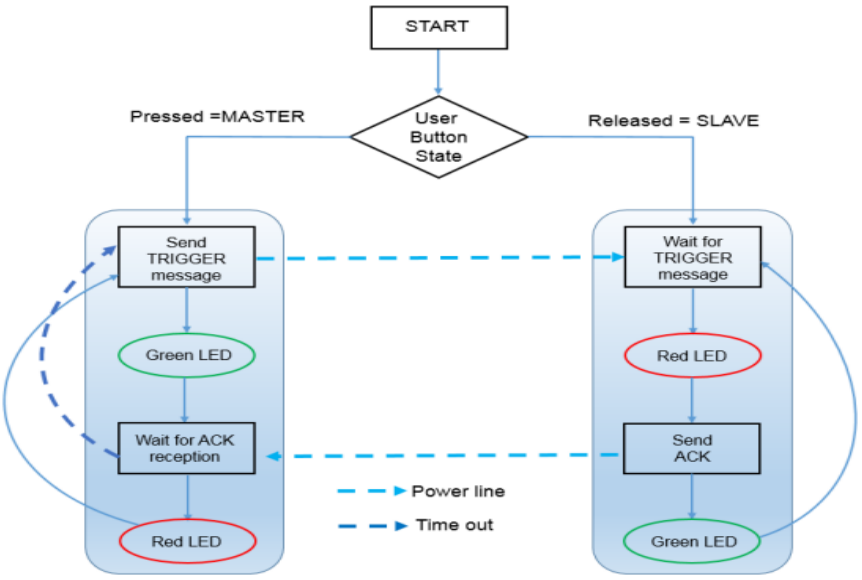


Fig 4.6: X-NUCLEO-PLM01A1 and STM32 Nucleo

4.6 Current Transformer

4.6.1 Introduction

A current transformer is a device that is used for the transformation of current from a higher value into a proportionate current to a lower value. It transforms the high voltage current into the low voltage current due to which the heavy current flows through the transmission lines is safely monitored by the ammeter.

4.6.2 Description

The ratio of the primary current and the secondary current is known as a current transformer ratio of the circuit. The current ratio of the transformer is usually high. The secondary current ratings are of the order of 5A, 1A and 0.1A. The current primary ratings vary from 10A to 3000A or more. The symbolic representation of the current transformer

4.6.3 Instructions

The Current Transformer (**C.T**), is a type of "**instrument transformer**" that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary. Current transformers reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. The principal of operation of a basic current transformer is slightly different from that of an ordinary voltage transformer.

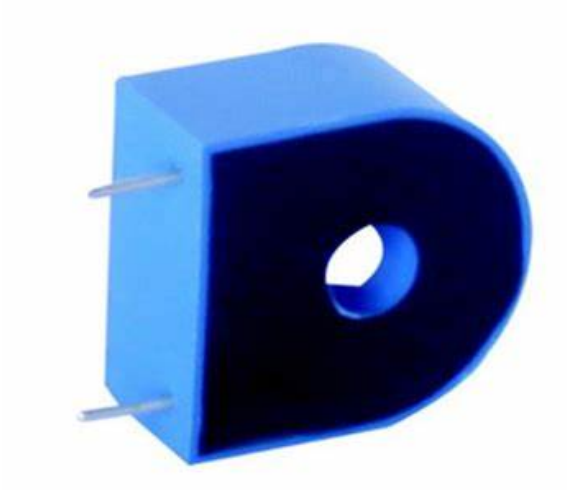


Fig 4.7: TA21B11 Toroidal Current Transformer

4.6.4 Application

- CT name (as noted): TA21B11
- Primary rated current: 20 A
- Secondary rated current: 10 mA
- Turns ratio: 20/0.01 = 2000
- Max burden resistance (sampling resistance): 100 Ohm

The wire that feeds the load passes through the hole of the current transformer. Note that only 1 wire of a single phase load has to be used to measure the AC current, the CT will read 0A if the two wires (phase and natural) are used because the sum of the magnetic field produced by the 2 wires is 0.Other types of current transformers may be used such as 1000/1 but its ratio needs to be modified in the Arduino code.

The secondary of the current transformer is connected to resistor with resistance of 20 Ohm (R8), other resistance values may be used (up to 100 Ohm).

With R8 = 20 Ohm and at rated primary current of 20A, the voltage drop across R8 is:

V = 20 x 10mA = 200mV AC.

4.7 MCP6022 OP-Amp

4.7.1 Introduction

The microcontroller ADC can't read voltages lower than 0 (negative voltages) and we need to shift the AC signal to the positive side, this can be done by adding a DC offset to the AC signal.

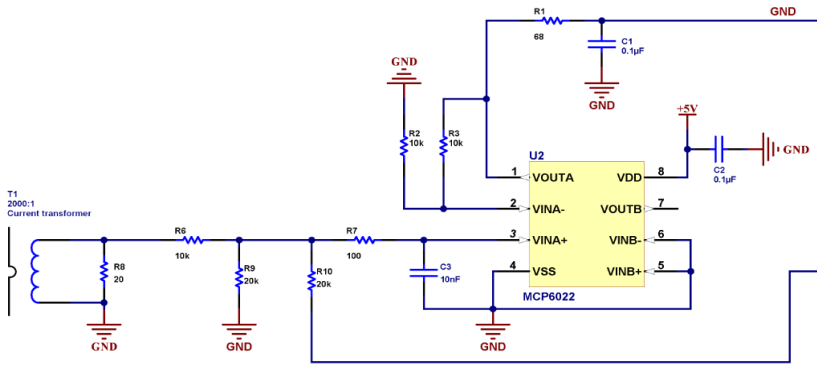


Fig 4.7: MCP6022

For that I used an amplifier circuit which firstly filters the signal and secondly adds a dc offset of 0.512V. The main component is MCP6022 (U2) where just 1 op amp is used. It is supplied with 5V from the Arduino board (pin 8 of U2 is connected to Arduino 5V pin, and pin 4 of U2 is connected to any of Arduino GND pins).This circuit has a gain of 1 and dc offset of 0.512V.For the U2 IC and instead of MCP6022, other op amp ICs may be used such as MCP6062 (or MCP6061).

Before the AC signal goes to Arduino analog channel 0 (A0) it passes through an RC low pass filter which comprised of R1 and C1. The frequency of this filter can be simply calculated using the equation below:

$f = 1/(2 \times \pi \times R \times C) = 23.4kHz$

An Operational Amplifier, or op-amp for short, is fundamentally a voltage amplifying device designed to be used with external feedback components such as resistors and capacitors between its output and input terminals. These feedback components determine the resulting function or "operation" of the

amplifier and by virtue of the different feedback configurations whether resistive, capacitive or both, the amplifier can perform a variety of different operations, giving rise to its name of “Operational Amplifier”.

An *Operational Amplifier* is basically a three-terminal device which consists of two high impedance inputs. One of the inputs is called the Inverting Input, marked with a negative or “minus” sign, (–). The other input is called the Non-inverting Input, marked with a positive or “plus” sign (+).

A third terminal represents the operational amplifiers output port which can both sink and source either a voltage or a current. In a linear operational amplifier, the output signal is the amplification factor, known as the amplifiers gain (A) multiplied by the value of the input signal and depending on the nature of these input and output signals, there can be four different classifications of operational amplifier gain.

Voltage – Voltage “in” and Voltage “out”
Current – Current “in” and Current “out”
Transconductance – Voltage “in” and Current “out”
Transresistance – Current “in” and Voltage “out”

Since most of the circuits dealing with operational amplifiers are voltage amplifiers, we will limit the tutorials in this section to voltage amplifiers only, (Vin and Vout).

The output voltage signal from an Operational Amplifier is the difference between the signals being applied to its two individual inputs. In other words, an op-amps output signal is the difference between the two input signals as the input stage of an Operational Amplifier is in fact a differential amplifier as shown below.

4.7.2 Differential Amplifier

The circuit below shows a generalized form of a differential amplifier with two inputs marked V1 and V2. The two identical transistors TR1 and TR2 are both biased at the same operating point with their emitters connected together and returned to the common rail, -Vee by way of resistor Re.

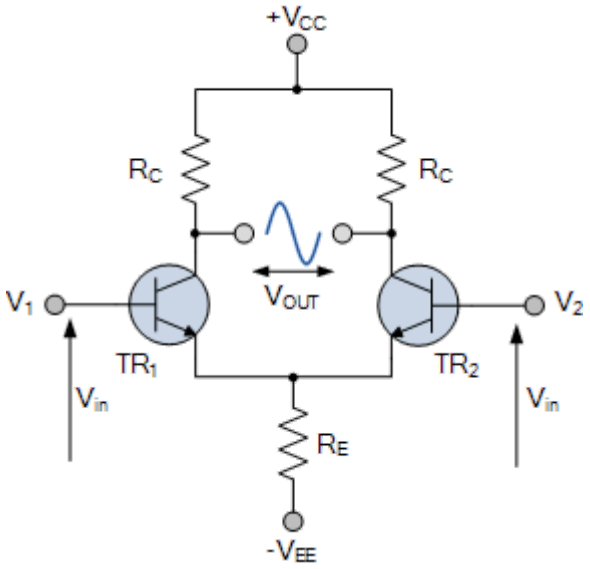


Fig 4.8: Differential Amplifier

The circuit operates from a dual supply +Vcc and -Vee which ensures a constant supply. The voltage that appears at the output, Vout of the amplifier is the difference between the two input signals as the two base inputs are in *antiphase* with each other.

So as the forward bias of transistor, TR1 is increased, the forward bias of transistor TR2 is reduced and vice versa. Then if the two transistors are perfectly matched, the current flowing through the common emitter resistor, Re will remain constant.

Like the input signal, the output signal is also balanced and since the collector voltages either swing in opposite directions (anti-phase) or in the same direction (in-phase) the output voltage signal, taken from between the two collectors is, assuming a perfectly balanced circuit the zero difference between the two collector voltages.

This is known as the *Common Mode of Operation* with the common mode

gain of the amplifier being the output gain when the input is zero.

Operational Amplifiers also have one output (although there are ones with an additional differential output) of low impedance that is referenced to a common ground terminal and it should ignore any common mode signals that is, if an identical signal is applied to both the inverting and non-inverting inputs there should no change to the output.However, in real amplifiers there is always some variation and the ratio of the change to the output voltage with regards to the change in the common mode input voltage is called the Common Mode Rejection Ratio or CMRR for short.

Operational Amplifiers on their own have a very high open loop DC gain and by applying some form of Negative Feedback we can produce an operational amplifier circuit that has a very precise gain characteristic that is dependant only on the feedback used. Note that the term "open loop" means that there are no feedback components used around the amplifier so the feedback path or loop is open.

An operational amplifier only responds to the difference between the voltages on its two input terminals, known commonly as the "*Differential Input Voltage*" and not to their common potential. Then if the same voltage potential is applied to both terminals the resultant output will be zero. An Operational Amplifiers gain is commonly known as the Open Loop Differential Gain, and is given the symbol (Ao).

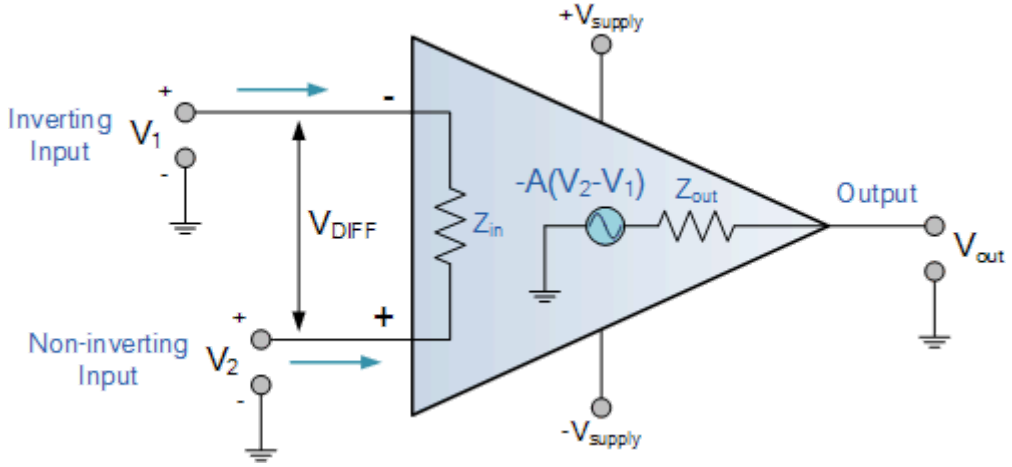


Fig 18:Equivalent Circuit of an Ideal Operational Amplifier

4.7.3 Description

The MCP6021, MCP6022, MCP6023 and MCP6024 from Microchip Technology Inc. are rail-to-rail input and output op amps with high performance. Key specifications include: wide bandwidth (10 MHz), low noise (8.7 nV/√Hz), low input offset voltage and low distortion (0.00053% THD+N). These features make these op amps well suited for applications requiring high performance and bandwidth. The MCP6023 also offers a chip select pin (CS) that gives power savings when the part is not in use.

4.7.4 Features

• Rail-to-Rail Input/Output
• Wide Bandwidth: 10 MHz (typ.)
• Low Noise: 8.7 nV/√Hz, at 10 kHz (typ.)
• Low Offset Voltage:
- Industrial Temperature: ±500 µV (max.)
- Extended Temperature: ±250 µV (max.)
• Mid-Supply VREF: MCP6021 and MCP6023
• Low Supply Current: 1 mA (typ.)
• Total Harmonic Distortion: 0.00053% (typ., G = 1)
• Unity Gain Stable
• Power Supply Range: 2.5V to 5.5V

4.8 SIMCOM GSM/Voice Modem

4.8.1 Introduction

This GSM Modem can work with any GSM network operator SIM card just like a mobile phone with its own unique phone number. Advantage of using this modem will be that its RS232 port can be used to communicate and develop embedded applications. Applications like SMS Control, data transfer, remote control and logging can be developed easily using this. The modem can either be connected to PC serial port directly or to any microcontroller through MAX232. It can be used to send/receive SMS and make/receive voice calls. It can also be used in GPRS mode to connect to internet and run many applications for data logging and control. In GPRS mode you can also connect

to any remote FTP server and upload files for data logging.

4.8.2 Description

This GSM Modem can accept any GSM network act as SIM card and just like a mobile phone with its own unique phone number. Advantage of using this modem will be that you can use its RS232 port to communicate and develop embedded applications. The SIM800C is a complete Dual-band GSM/GPRS solution in a SMT module featuring an industry-standard interface, the SIM800CS is a quad- band GSM/GPRS module that works on frequencies GSM850MHz, delivers performance for voice, SMS, Data, and Fax in a small form factor and with low power consumption.

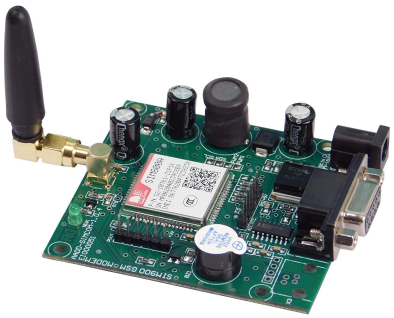


Fig.19: GSM module

4.8.3 Features

- High Quality Product
- RS232 interface @ RMC Connector for direct
- MCU kit Configurable baud rate
- SMA connector with GSM Antenna.
- SIM Card holder.
- Built in Network Status LED
- Inbuilt Powerful TCP/IP protocol stack for internet data transfer.
- Audio interface Connector

- Normal operating temperature: -20 °C to +55 °C
- Input Voltage: 4.5V-12V DC

4.8.4 Application

- short message service(SMS) incoming/outgoing voice calls
- internet
- SMS based Remote Control and Alerts
- Security Applications
- Sensor Monitoring

4.9 16X2 LCD Display

4.9.1 Introduction

LCD stands for liquid crystal display. They come in many sizes 8x1 , 8x2 , 10x2 , 16x1 , 16x2 , 16x4 , 20x2 , 20x4 ,24x2 , 30x2 , 32x2 , 40x2 etc . Many Multinational companies like Philips Hitachi Panasonic make their own special kind of LCD'S to be used in their products. All the LCD'S performs the same functions (display characters numbers special characters ASCII characters etc).Their programming is also same and they all have same 14 pins (0-13) or 16 pins (0 to 15). Alphanumeric displays are used in a wide range of applications, including palmtop computers, word processors, photocopiers, point of sale terminals, medical instruments, cellular phones, etc.

4.9.2 Description

This is an LCD Display designed for E-blocks. It is a 16 character, 2-line alphanumeric LCD display connected to a single 9-way D-type connector. This allows the device to be connected to most E-Block I/O ports. The LCD display requires data in a serial format, which is detailed in the user guide below. The display also requires a 5V power supply. Please take care not to exceed 5V, as this will cause damage to the device. The 5V is best generated from the E-blocks Multi programmer or a 5V fixed regulated power supply. The 16 x 2 intelligent alphanumeric dot matrix displays is capable of displaying 224 different characters and symbols. A full list of the characters and symbols is printed on pages 7/8 (note these symbols can vary between brand of LCD used). This booklet provides all the technical specifications for connecting the unit, which requires a single power supply (+5V).

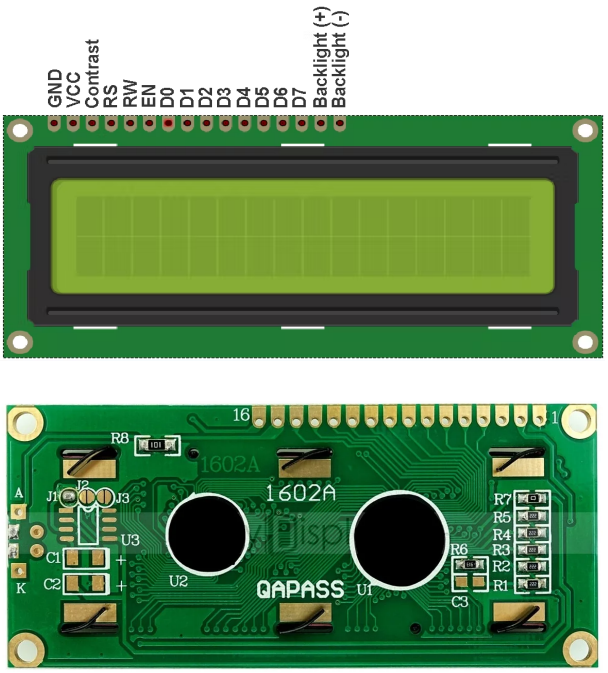


Fig20: 16X2 LCD

4.9.3 Features

- Input voltage: 5v
- E-blocks compatible
- Low cost
- Compatible with most I/O ports in the E-Block range
- Ease to develop programming code using Flow code icons

4.9.4 Application

- Monitoring
- Output display
- Program status indication
- Debugging.

4.10 Power Supply

4.10.1 Introduction

Power supply is the backbone of any electric system. The power supply takes AC from the wall outlet, converts it to unregulated DC, and reduces the voltage using and input power transformer, typically stepping it down to the voltage required by the load.

4.10.2 Transformer

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. Electromagnetic induction produces an electromotive force within a conductor which is exposed to time varying magnetic fields. Transformers are used to increase or decrease the alternating voltages in electric power applications. It is a step down transformer in which the secondary winding is more than primary winding. Due to this windings it can able to step down the voltage. A Transformer changes electricity from high to low voltage or low to high voltage using two properties of electricity.It is a general purpose chassis mounting mains transformer. Transformer has 240V primary windings and centre tapped secondary winding. The transformer has flying coloured insulated connecting leads (Approx 100 mm long).The transformer act as step down transformer reducing AC - 240V to AC - 12V. Power supplies for all kinds of project & circuit boards. Step down 230 V AC to 12V with a maximum of 1 Amp current. In AC circuits, AC voltage, current and waveform can be transformed with the help of Transformers. Transformer plays an important role in electronic equipment. AC and DC voltage in Power supply equipment are almost achieved by transformer's transformation and commutation

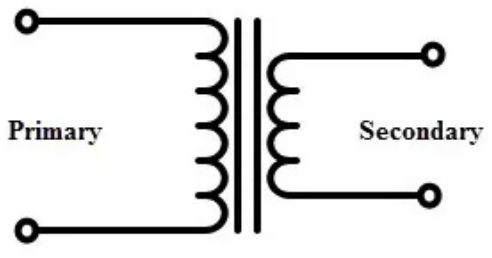


Fig.21: Step-down Transformer

4.10.3 Features

- Output current:1A
- Supply voltage: 220-230VAC
- Output voltage: 12VAC
- Soft Iron Core
- Amp Current Drain

4.10.4 Application

- DIY projects Requiring In-Application High current drain.
- On chassis AC/AC converter.
- Designing a battery Charger.
- Electronic applications.
- Step down applications (Power transmission)

4.10.5 Rectifier

A rectifier is a device that converts an oscillating two-directional alternating current (AC) into a single-directional direct current (DC).

There are mainly three types of rectifiers:-

1.Half-wave rectifier

2.Full-wave rectifier

3.Bridge rectifier

The most important component of a rectifier is diode. In this project we used full wave bridge rectifier in power supply part. The bridge rectifier is one

of the capable forms of full wave rectifier that uses four diodes in a bridge topology.

The 120V AC supply is converted in to 12V DC supply by the step-down transformer and Full wave Bridge rectifier. The diagram of a full-wave bridge rectifier is given below,

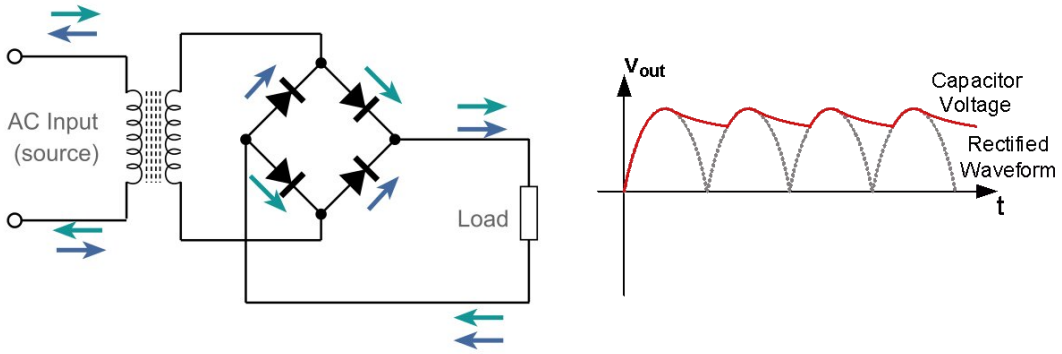


Fig.22: Bridge Rectifier

The four diodes labelled D0 to D3 are arranged in series pairs with only two diodes Conducting current during each half cycle .During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodes D0 and D3 are reverse biased and current flows through the load RL.During the negative half cycle of the supply, diodes D0 and D3 conduct in series, but the diodes D1 and D2 switch OFF as they are now reverse biased. The current flowing through the load is same direction as before.

4.11 Voltage Regulator (7805 IC)

4.11.1 Introduction

A regulated power supply is very much essential for several electronic devices due to the semiconductor material employed in them have a fixed rate of current as well as voltage. The device may get damaged if there is any deviation from the fixed rate. The AC power supply gets converted into constant DC by this circuit. By the help of a voltage regulator DC, unregulated output will be fixed to a constant voltage. The circuit is made up of linear voltage regulator 7805 along with capacitors and resistors with bridge rectifier made up from diodes. From giving an unchanging voltage supply to building confident that output reaches uninterrupted to the appliance, the diodes along with capacitors handle elevated efficient signal conveyal.

4.11.2 Description

As we have previously talked about that regulated power supply is a device that mechanized on DC voltages and also it can uphold its output accurately at a fixed voltage all the time although if there is a significant alteration in the DC input voltage. ICs regulator is mainly used in the circuit to maintain the exact voltage which is followed by the power supply. A regulator is mainly employed with the capacitor connected in parallel to the input terminal and the output terminal of the IC regulator. For the checking of gigantic alterations in the input as well as in the output filter, capacitors are used. While the bypass capacitors are used to check the small period spikes on the input and output level. Bypass capacitors are mainly of small values that are used to bypass the small period pulses straightly into the Earth.

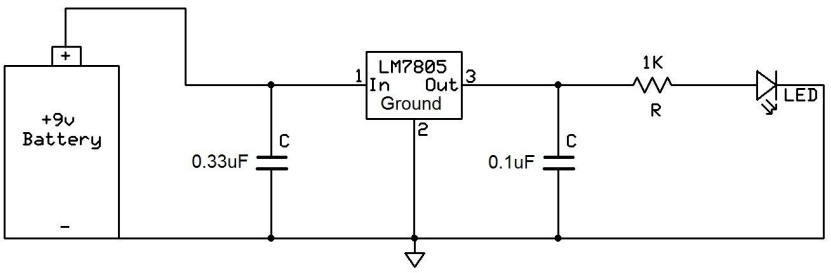


Fig.23: Regulated Power Supply Circuit

Component	Function
C1	This capacitor is known as bypass capacitor and is employed to bypass extremely tiny duration spikes to the ground with no distress the other components.
C2	C2 is the filter capacitor employed to steady the slow changes in the voltage applied at the input of the circuit. Escalating the value of the capacitor amplify the stabilization as well as the declining value of the capacitor reduces the stabilization. Moreover this capacitor is not alone capable to ensure very constricted period spikes emerge at the input.
C3	C3 is known as a filter capacitor employed in the circuit to steady the slow alterations in the output voltage. Raising the value of the capacitor enlarges the stabilization furthermore declining the value of the capacitor declined the stabilization. Moreover this capacitor is not alone capable to ensure very fine duration spikes happen at the output.
C4	C4 is known as bypass capacitor and worked to bypass very small period spikes to the earth with no influence the other components.
U1	U1 is the IC with positive DC and it upholds the output voltage steady exactly at a constant value even although there are major deviation in the input voltage.

Table.4.3: Working of the Components

IC 7805 is a DC regulated IC of 5V. This IC is very flexible and is widely employed in all types of circuit like a voltage regulator. It is a three terminal device and mainly called input , output and ground. Pin diagram of the IC 7805 is shown in the diagram below.

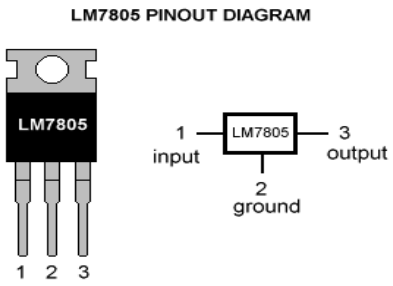


Fig.24: Pin Diagram of IC

PIN NO	PIN	DESCRIPTION
1	INPUT	In this pin of the IC positive unregulated voltage is given in regulation
2	GROUND	In this pin where the ground is given. This pin is neutral for equally the input and output
3	OUTPUT	The output of the regulated 5V volt is taken out at this pin of the IC regulator

Table 4.4: Pin explanation of IC 7805

4.11.3 Application

- To provide constant power supply to the device.

4.12Relay

4.12.1 Introduction

A Relay is an electrical operated switch. It consists of a set of input terminals for a single or multiple control signal, and a set of operating contact terminal. In this project we using 5V 5-pin relay as electromagnetic switch.

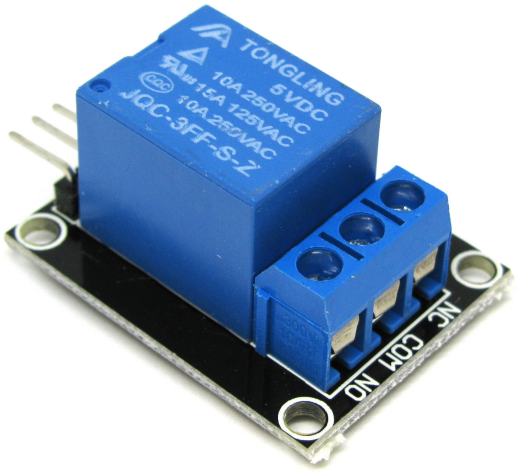


Fig 25: 5V-5 Pin Relay

Pin number	Pin name	Description
1	Coil End 1	Used to trigger(On/Off) the Relay, Normally one end is connected to 5V and the other end to ground
2	Coil end 2	Used to trigger (on/off) the Relay, normally one end is connected to 5V and other end to ground.

3	Common (COM)	Common is connected to one end of the load that is to be controlled.
4	Normally Close (NC)	The other end of the load is either connected to NO or NC. If connected to NC the load remains connected before trigger.
5	Normally Open (NO)	The other end of the load is either connected to NO or NC. If connected to NO the load remains disconnected before trigger.

Table 4.5 : Relay Pin Configuration

4.12.2 Features

- Trigger Voltage (Voltage across coil) : 5V DC
- Trigger Current (Nominal Current) : 70mA
- Maximum AC load Current : 10A @250/125V AC
- Maximum DC load Current : 10A@30/28V DC
- Compact 5-Pin Configuration with Plastic moulding
- Operating Time : 10ms Release Time : 5ms
- Maximum Switching : 300 operating/min (Mechanically)

4.12.3 Applications

- Commonly used in switching circuits
- For Home Automation projects to switch AC loads
- To Control (On/Off) heavy loads at a predetermined time/condition
- Used in safety circuits to disconnect the load from supply in event of failure
- Used in Automobiles electronics for controlling indicators glass motors e.t.c

4.13 STM32Cube IDE

4.13.1 Introduction

STM32Cube IDE is an all-in-one multi-OS development tool, which is part of the STM32Cube software ecosystem. STM32Cube wIDE is an advanced C/C++ development platform with peripheral configuration, code generation, code compilation, and debug features for STM32 microcontrollers and microprocessors.It is based on the Eclipse/CDT framework and GCC toolchain for the development, and GDB for the debugging. It allows the integration of the hundreds of existing plugins that complete the features of the Eclipse IDE.

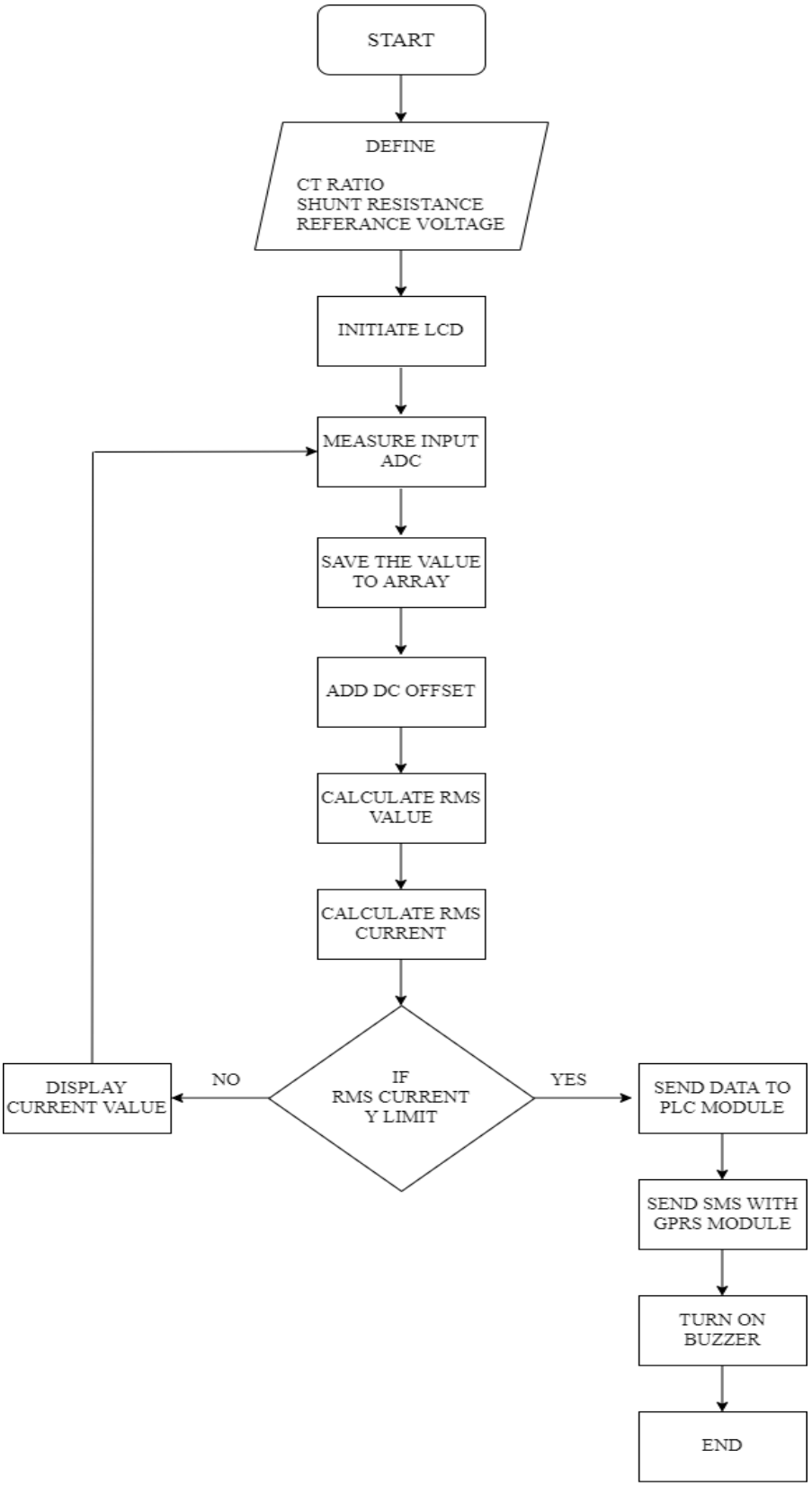
STM32CubeIDE integrates STM32 configuration and project creation functionalities from STM32CubeMX to offer all-in-one tool experience and save installation and development time. After the selection of an empty STM32 MCU or MPU, or pre configured microcontroller or microprocessor from the selection of a board or the selection of an example, the project is created and initialization code generated. At any time during the development, the user can return to the initialization and configuration of the peripherals or middleware and regenerate the initialization code with no impact on the user code.

STM32Cube sIDE includes build and stack analyzers that provide the user with useful information about project status and memory requirements. STM32Cube sIDE also includes standard and advanced debugging features including views of CPU core registers, memories, and peripheral registers, as well as live variable watch, Serial Wire Viewer interface, or fault analyzer.

4.13.2 Features

- Integration of services from STM32CubeMX:STM32 microcontroller, microprocessor, development platform and example project selection Pinout, clock, peripheral, and middleware configuration Project creation and generation of the initialization code Software and middleware completed with enhanced STM32Cube Expansion Packages
- Based on Eclipse/CDT, with support for Eclipse add-ons, GNU C/C++ for Arm toolchain and GDB debugger
- STM32MP1 Series:Support for OpenSTLinux projects: Linux Support for Linux
- Additional advanced debug features including:CPU core, peripheral register, and memory views Live variable watch view System analysis and real-time tracing (SWV)CPU fault analysis tool RTOS-aware debug support including Azure
- Support for ST-LINK (STMicroelectronics) and J-Link (SEGGER) debug probes
- Import project from Atollic TrueSTUDIO and AC6 System Workbench for STM32 (SW4STM32)
- Multi-OS support: Windows, Linux, and macOS, 64-bit versions only

ALGORITHM


START
DEFINE
CT RATIO
SHUNT RESISTANCE
REFERANCE VOLTAGE
INITIATE LCD
MEASURE INPUT ADC
SAVE THE VALUE TO ARRAY
ADD DC OFFSET
CALCULATE RMS VALUE
CALCULATE RMS CURRENT
IF RMS CURRENT Y LIMIT
NO
YES
DISPLAY CURRENT VALUE
SEND DATA TO PLC MODULE
SEND SMS WITH GPRS MODULE
TURN ON BUZZER
END

CHAPTER 6
RESULT AND CONCLUSION

In our proposed system the fault detected when the current cross the limit and the information is transferred to the receiver microcontroller via PLC module. The system can also notify the authorities through GSM module as a secondary communication method.

The proposed system hardware setup is given in the figure below,

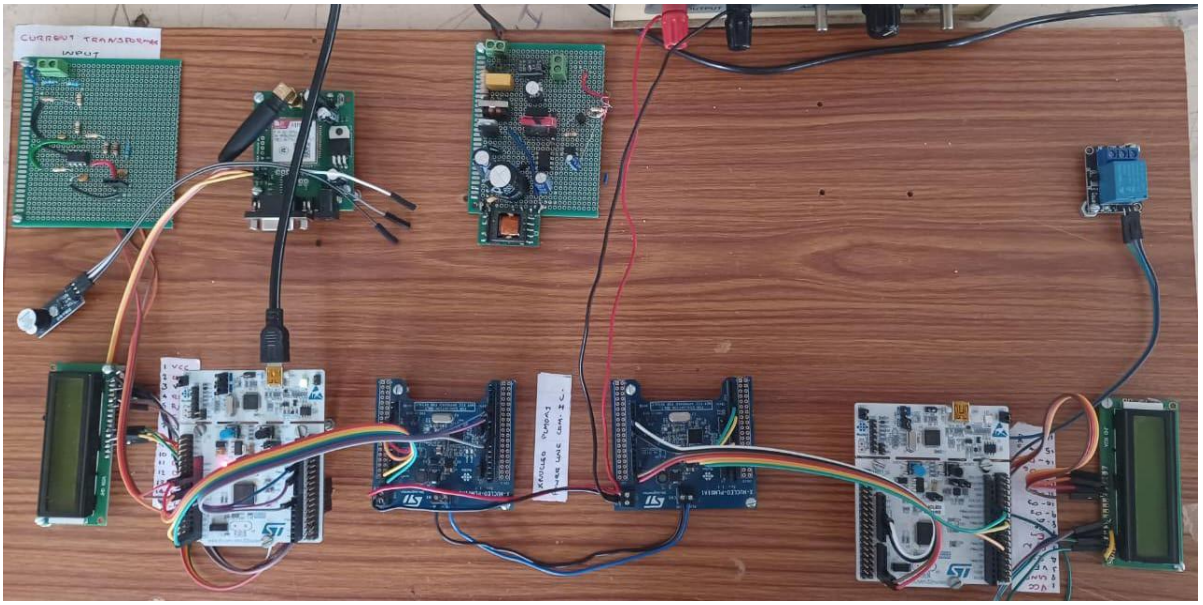


Fig.6.1 Proposed System Hardware Setup

The hardware setup include,

- Transmitter PLC module
- Transmitter STM32
- 16x2 LCD
- OP-Amp circuit
- Reciever STM32
- Reciever PLC module
- Relay

6.1. SOFTWARE OUTPUT

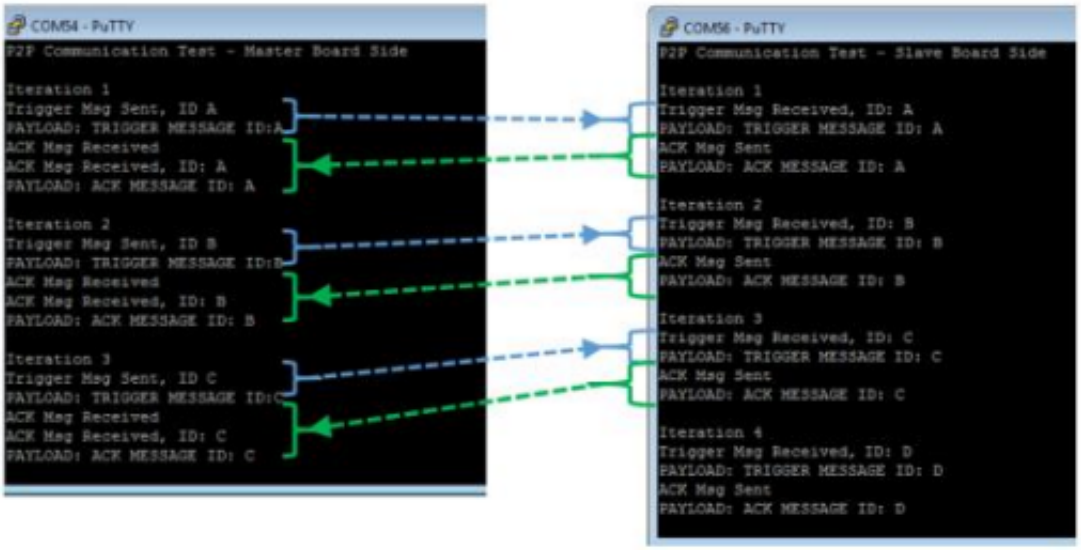


Fig.6.2 PLC Reciever and Transmitter Putty Output

6.2 Hardware Output

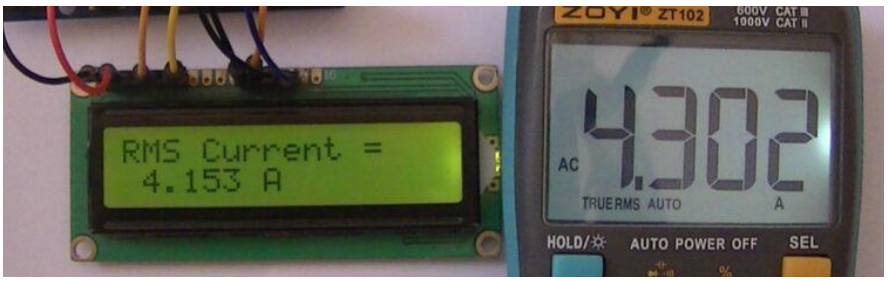


Fig.6.3 RMS Current LCD output

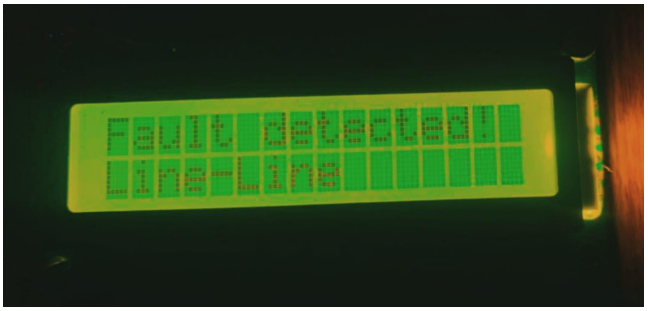


Fig. No 6.4 Fault detected LCD output

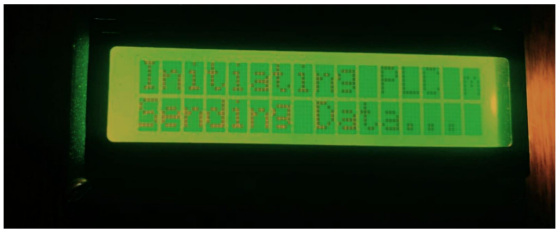


Fig. No 6.5 Sending Data Through PLC LCD O/P

Fig. No 6.6 Receive data through PLC LCD output

CHAPTER 7

FUTURE SCOPE

Future Scope

- Power line communication is challenging under high noise produced by power grid equipments
- By utilizing proper noise suppression and attenuation we can reduce communication errors upto a good extend
- By using the support of mapping and telemetry services the fault locations/AB switch branch can be navigated easily
- AI and neural network technology fed with fault data, such as:

1. Fault current
2. Relay status
3. Delay of tripping
4. AB switch status
5. Surge current

From these detailing AI can arrive at approximate fault distance from AB switch to fault location.

- Power line communication channel through H.V line can be utilized for internet access, intra substation communication etc…
- Established power line communication channel equipped FPD enabled smart AMR technology eases the billing and services automatically.
- Private power grids, industrial power supplies can also be monitored by PLC FPD's
- As the home automation advances the PLC technology will get more eyeballs since the wireless network have significant limitation in large buildings to reach each equipments
- Since the power line spreads into every electrical / electronic gadgets PLC technology opens the best communication channel for IoT equipment

ANNEXURE

POWER LINE COMMUNICATION FAULT PASSAGE DETECTOR FOR HV LINES

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Abstract— India has one of the largest power grids and greater numbers in power usage. Unfortunately, our power grid faces faults, insulator punctures, and theft for decades. Finding the fault and rectification of power lines are tedious and time-consuming procedures that involve manual labor costs and time. Locating line faults with the help of faulted circuit indicators(using powerline communication) will be a great cost-effective solution instead of draining human resources.

To monitor faults we are using power-line-communication enabled FPDs (Fault Passage Indicator Device) with locating methods. An FPD measures the current flow in a transmission line by measuring and calibrating the strength of the EM field around transmission lines. If this value crosses the present value, the FPD analyses the type of fault and pulls the data into the power line communication interface.

The line current will be monitored using the current transformer method to detect fault current in the event of line-to-line or line-to-earth scenarios. The fault current data and other resources are collected and transmitted through Power Line Communication Module PLM0A1 to the receiver module. This information is collected and analyzed to decide the exact fault location and AB switch branch.

I. INTRODUCTION

GENERAL

India has one of the largest power grids as well as greater numbers in usage. Unfortunately, our power grid sustains from faults, insulator punctures, and theft for decades. Locating and rectification of power line faults are a tedious time-consuming procedure burning a large chunk of the maintenance budget. Rapid locating and proper maintenance of line faults will be a great cost-effective solution instead of discharging precious energy and draining human resources

CURRENT SCENARIO

Faults can occur due to various reasons. Broadly we can categorize faults into two,

a. Line-Earth Faults:

High volt electricity leaking to earth due to insulator punctures, broken lines, or nearby trees and buildings. As the metallic body of any electrical equipment or device is connected to the earth. So if the live or phase wire touch to the body of the electrical equipment then a huge current will flow through the phase and earth conductor Which is known as Line to Earth Fault.When the line to earth fault occurs, a huge amount of current flows so there will be a large voltage drop.

Effects of Earth Faults

When Earth faults occur a huge amount of current flow through the phase and earthing conductor and a large voltage drop occurs. So this will affect the other loads and it may cause the burning of phase or line conductor. Earth fault causes huge sparking, Heat, fire, etc.

b. Line-Line faults:

Short circuit in between the lines due to various environmental or manmade causes. A line-to-line fault or unsymmetrical fault occurs when two conductors are short circuited. In the figure shown below shows a three phase system with a line-to-line fault phases b and c. The fault impedance is assumed to be Zf. The LL fault is placed between lines b and c so that the fault be symmetrical with respect to the reference phase a which is in-faulted.

Transmission Line Insulator puncture

A puncture is a breakdown and conduction of the material of the insulator, causing an electric arc through the interior of the insulator. Simply, it means electrical discharge occurs from conductor to pin through the body of the insulator.Generally, the pin insulator is designed with a factor of safety. Safety factor of an insulator is the ratio of puncture voltage to flash voltage. Due to this factor of safety, the flash-over takes place before the insulator gets punctured and by that it protects from complete damage. Basically, insulator puncture will occur due to switching over voltage and lightning. In the rainy season lightning is one major cause of failures of insulators.

2.a Power Line Fault Rectification Procedure

In practical electricity, people use the trial and error method to detect the fault location (Line to line fault / line to ground fault) of a transmission line. They feed supply at the single end at a time by dividing that transmission line into two parts and check the fault up to that section. These processes go on until they find the fault area. After checking if they found anything, then it is ok to go forward.This process is done from both ends and they sort out the exact location. For finding out the fault phase, they use megger (check the value of resistance between the line to ground and Line to Line for each phase). These technologies take more human effort and consume more time.

Faults in the power distribution lines are the major challenge faced by the over head indian power lines which not only increases the maintenance budget but also cause long power outages in industrial areas and hospital zones affecting overall economy. Locating the faults in overhead lines instantly is the solution to reduce the damage.

In this project, we are introducing a method to locate and identify the fault type to transmit the information at the power line communication without a service provider expenses.

II. EXISTING SYSTEM

There Fault Passage Indicator available in foreign markets. These types of equipment are meant to indicate (By blinking indicator lights at the bottom) the occurred fault by measuring the line current. The fault area can be located by patrolling the transmission branches.

Products available in the market

FPD (Fault Passage Detectors) are available widely at high costs in the market. These are some of the online available FPDs.

A.Pressure Spring Type led indicator fault passage indicator

B.Pole-mounted or clipped on the MV overhead lines from Schneider Electric SE

Flite 110-SA: ammetric FPI clipped on the MV line for resistive or solidly earthed neutral.

Flite 3xx: directional FPI pole-mounted for compensated or isolated neutral.

Disadvantages of existing products

- Unaffordable price for Indian power sector.
- Data transmission is not available. Manual patrolling is required to find the FPD with fault.
- FPDs integrated with GSM come at higher cost and service maintenance charges.

A Microcontroller consists of a powerful CPU tightly coupled with memory RAM, ROM or EEPROM, various I / O features such as Serial ports, Parallel Ports, Timer/Counters, Interrupt Controller, Data Acquisition interface Analog to Digital Converter (ADC), Digital to Analog Converter (ADC), everything integrated onto a single Silicon Chip. It does not mean that any microcontroller should have all the above-said features on-chip, depending on the need and area of application for which it is designed, the on-chip features present in it may or may not include all the individual sections said above. Any microcomputer system requires memory to store a sequence of instructions making up a program, a parallel port or serial port for communicating with an external system, a timer/counter for control purposes like generating time delays, Baud rate for the serial port, apart from the controlling unit called the Central Processing Unit.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys, and other embedded systems. In the context of the internet of things, microcontrollers are an economical and popular means of data collection, sensing, and actuating the physical world as edge devices.

The STM32 Nucleo-64 board provides an affordable and flexible way for users to try out new concepts and build prototypes by choosing from the various combinations of performance and power consumption features, provided by the STM32 microcontroller. For the compatible boards, the external SMPS significantly reduces power consumption in Run mode. The ARDUINO® Uno V3 connectivity support and the ST morpho headers allow the easy expansion of the functionality of the STM32 Nucleo open development platform with a wide choice of specialized shields. The STM32 Nucleo-64 board does not require any separate probe as it integrates the ST-LINK debugger/programmer. The STM32 Nucleo-64 board comes with the STM32 comprehensive free software libraries and examples available with the STM32Cube MCU Package.

The STM32 Nucleo boards are the official Development Boards from STMicroelectronics. It features the ARM Cortex M4 32-bit STM32F401RET6 microcontroller which is in the LQFP64 package. The Boards pinout is similar to Arduino UNO and has many other additional pins to expand performance. This board also comes with an integrated ST-LINK/V2-1 programmer and debugger; hence it is very easy to get started with this board.

The STM32 Nucleo board pinout is shown above. As you can see, there are two sets of pins. The pin one resembles the Arduino UNO and the blue one is the STM32 style (Morpho). The Arduino like pins are female connector pins that exactly match the order and position of Arduino UNO pins and hence any Arduino shield can be used with these development boards.

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The X-NUCLEO-PLM01A1 expansion board for STM32 Nucleo is based on the ST7580 FSK, PSK multi-mode power line networking system on-chip. It provides an affordable and easy-to-use solution for the development of connectivity applications based on power line communication. It lets you easily evaluate the communication features of the ST7580 based on a DC two-wire link between two boards. X-NUCLEO-PLM01A1.

You can also perform the evaluation on an AC power line by connecting the X-NUCLEO-PLM01A1 to a STEVAL-XPLM01CPL board providing effective AC coupling and isolation. The X-NUCLEO-PLM01A1 is interfaced with the STM32 controller via UART and GPIO pins and is compatible with the Arduino UNO R3 (default configuration) and ST morpho (optional, not mounted) connectors.

A sample application using the X-NUCLEO-PLM01A1 expansion board with the NUCLEO F401RE or NUCLEO-L053R8 board is provided in the "Projects" directory. Ready-to-use projects are available for multiple IDEs.
The sample application contains a simple point-to-point communication between two nodes equipped with an STM32 Nucleo board and an X-NUCLEO-PLM01A1 expansion board.

To create a demo (using a PC to monitor the activity on the power line), the developer has to use the STM32 Nucleo LEDs and/or buttons. He can assign each node a role as master or slave by pushing the STM32 Nucleo USER button at boot time: USER button pressed = master USER button released = slave These options allow having only a single precompiled binary for both roles. After the role assignment, in an endless loop, the master board sends a TRIGGER frame to the power line (toggling the X-NUCLEO-PLM01A1 green LED) that the slave will receive and recognize (toggling the X-NUCLEO-PLM01A1 red LED). The slave will send back an ACK frame as a confirmation (toggling the X-NUCLEO PLM01A1 green LED). The master node will recognize the ACK frame (toggling the X-NUCLEO-PLM01A1 red LED). If the two nodes are connected through USB cables, they print power line status messages on a debug serial port (e.g. message sent, message received, etc). The following figure shows the master and slave routine described above.

The Current Transformer (C.T), is a type of “instrument transformer” that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary. Current transformers reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. The principal of operation of a basic current transformer is slightly different from that of an ordinary voltage transformer magnetic field, which is detected up by the fault indicator causing a state change on the mechanical target flag, LED, or remote indication device.

III. PROPOSED SYSTEM

India has one of the largest power grids as well as greater numbers in usage. Unfortunately, our power grid sustains from faults, insulator punctures, and theft for decades. Locating and rectification of power line faults are a tedious time-consuming procedure burning a large chunk of the maintenance budget. Rapid locating and proper maintenance of line faults will be a great cost-effective solution instead of discharging precious energy and draining human resources

An embedded system is a special-purpose computer system, which is completely encapsulated by the device it controls. An embedded system has11 specific requirements and performs predefined tasks, unlike a general-purpose personal computer. An embedded system is a programmed hardware device. A programmable hardware chip is the 'raw material' and it is programmed with particular applications. This is to be understood in comparison to older

Microcontroller

A Microcontroller consists of a powerful CPU tightly coupled with memory RAM, ROM or EEPROM, various I / O features such as Serial ports, Parallel Ports, Timer/Counters, Interrupt Controller, Data Acquisition interface Analog to Digital Converter (ADC), Digital to Analog Converter (ADC), everything integrated onto a single Silicon Chip. It does not mean that any microcontroller should have all the above-said features on-chip, depending on the need and area of application for which it is designed, the on-chip features present in it may or may not include all the individual sections said above. Any microcomputer system requires memory to store a sequence of instructions making up a program, a parallel port or serial port for communicating with an external system, a timer/counter for control purposes like generating time delays, Baud rate for the serial port, apart from the controlling unit called the Central Processing Unit.

A microcontroller (MCU for microcontroller unit) is a small computer on a single metal-oxide-semiconductor (MOS) VLSI integrated circuit (IC) chip. A microcontroller contains one or more CPUs (processor cores) along with memory and programmable input/output peripherals. Program memory in the form of ferroelectric RAM, NOR flash or OTP ROM is also often included on chip, as well as a small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications consisting of various discrete chips

Application

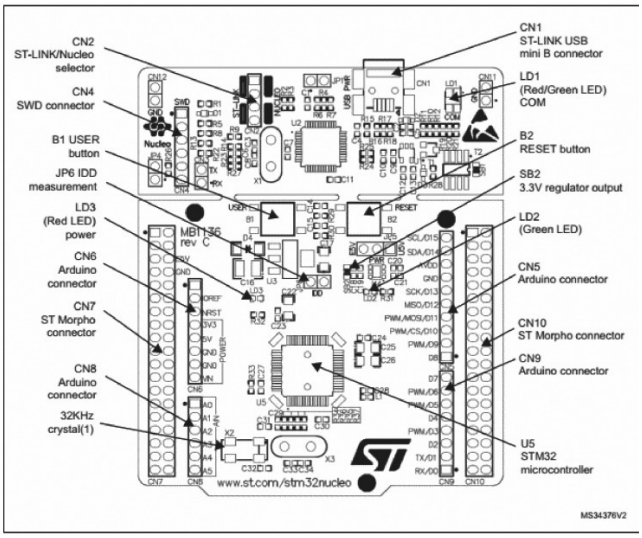
Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys, and other embedded systems. In the context of the internet of things, microcontrollers are an economical and popular means of data collection, sensing, and actuating the physical world as edge devices.

Microcontroller STM32 NUCLEO-F401RE

The STM32 Nucleo-64 board provides an affordable and flexible way for users to try out new concepts and build

prototypes by choosing from the various combinations of performance and power consumption features, provided by the STM32 microcontroller. For the compatible boards, the external SMPS significantly reduces power consumption in Run mode. The ARDUINO® Uno V3 connectivity support and the ST morpho headers allow the easy expansion of the functionality of the STM32 Nucleo open development platform with a wide choice of specialized shields. The STM32 Nucleo-64 board does not require any separate probe as it integrates the ST-LINK debugger/programmer. The STM32 Nucleo-64 board comes with the STM32 comprehensive free software libraries and examples available with the STM32Cube MCU Package.

The STM32 Nucleo boards are the official Development Boards from STMicroelectronics. It features the ARM Cortex M4 32-bit STM32F401RET6 microcontroller which is in the LQFP64 package. The Boards pinout is similar to Arduino UNO and has many other additional pins to expand performance. This board also comes with an integrated ST-LINK/V2-1 programmer and debugger; hence it is very easy to get started with this board.



Nucleo-F401RE Pinout Configuration

The STM32 Nucleo board pinout is shown above. As you can see, there are two sets of pins. The pin one resembles the Arduino UNO and the blue one is the STM32 style (Morpho). The Arduino like pins are female connector pins that exactly match the order and position of Arduino UNO pins and hence any Arduino shield can be used with these development boards.

STM32 Nucleo F401RE Development Board

The STM32 Nucleo boards are the official Development Boards from STMicroelectronics. It features the ARM Cortex M4 32-bit STM32F401RET6 microcontroller which is in the LQFP64 package. The Boards pinout is similar to Arduino UNO and has many other additional pins to expand performance. This board also comes with an integrated ST-LINK/V2-1 programmer and debugger; hence it is very easy to get started with this board. There are three LEDs, where LD1 is for indicating USB communication, LD2 is a programmable LED, and LD3 indicates power. Similarly, there are two push buttons where one is user programmable, and the other is to reset the microcontroller. The Board operates with 3.3V supply but a wide voltage range of 7-12V can be provided to the VIN pin since it has an onboard voltage regulator.

Apart from the Arduino pins, the board also has 76 (38+38) GPIO pins as male headers on either side of the board as shown above. These pins are classified into CN7 and CN10 with each having 38 Pins. They comprise of GPIO pins, Analog Pins, Timer Pins, and Power pins. The name of the pins can be found.

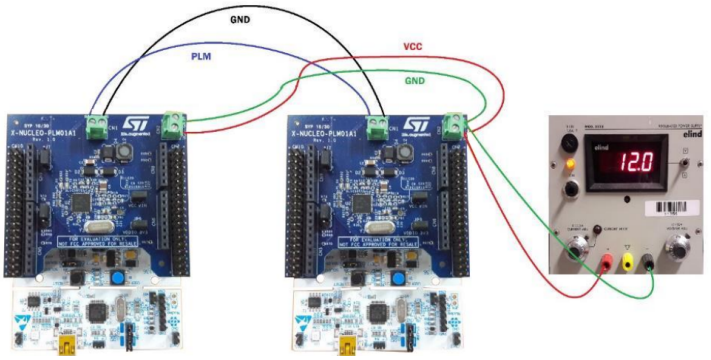
X-NUCLEO-PLM01A1

Power line communication expansion board based on ST7580 for STM32 Nucleo PSK multi-mode power line networking system-on-chip.

Power Line Communication implemented using the support of ST Microelectronics ST7580 module. Which has all the industrial PLC compatibility.

The X-NUCLEO-PLM01A1 expansion board for STM32 Nucleo is based on the ST7580 FSK, PSK multi-mode power line networking system on-chip. It provides an affordable and easy-to-use solution for the development of connectivity applications based on power line communication. It lets you easily evaluate the communication features of the ST7580 based on a DC two-wire link between two boards. X-NUCLEO-PLM01A1.

You can also perform the evaluation on an AC power line by connecting the X-NUCLEO-PLM01A1 to a STEVAL-XPLM01CPL board providing effective AC coupling and isolation. The X-NUCLEO-PLM01A1 is interfaced with the STM32 controller via UART and GPIO pins and is compatible with the Arduino UNO R3 (default configuration) and ST morpho (optional, not mounted) connectors.



Hardware setup The following hardware components are needed:

-Two STM32 Nucleo development platforms (suggested order code: NUCLEO-F401RE or NUCLEO-L053R8)

Two power line expansion boards (X-NUCLEO-PLM01A1)

Two USB type A to Mini-B USB cables to connect the two STM32 Nucleo boards to the PC One lab DC power supply to provide 12V Four wires for power supply (2 per board)

Two wires for PLM connection The following picture shows

the environment detailed above.

Current Transformer

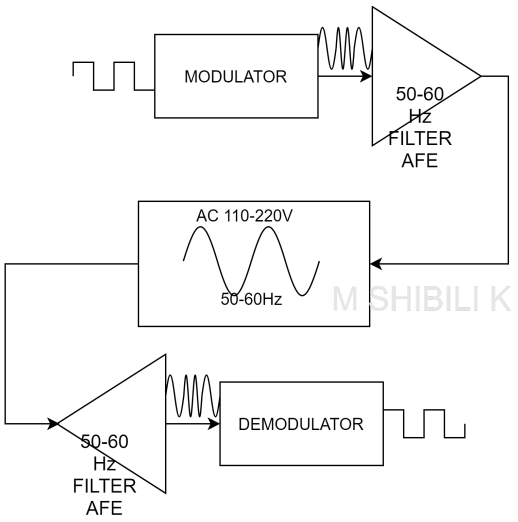
A current transformer is a device that is used for the transformation of current from a higher value into a proportionate current to a lower value. It transforms the high voltage current into the low voltage current due to which the heavy current flows through the transmission lines is safely monitored by the ammeter.

The ratio of the primary current and the secondary current is known as a current transformer ratio of the circuit. The current ratio of the transformer is usually high. The secondary current ratings are of the order of 5A, 1A and 0.1A. The current primary ratings vary from 10A to 3000A or more. The symbolic representation of the current transformer

What is Power Line Communication?

Powerline communication (PLC) is a technique in which existing electricity supply networks are re-used for communication. The primary benefit of PLC is the reduction of costs in the realization of new communication networks [4]. That is the AC electric power conductor is also used simultaneously for the transmission of data. The existing public and private wirings can be efficiently reused to transmit data regarding power usage and device status. The power line media is free of cost than Narrow Band (single fixed radio frequency) GSM and less attenuated than wide Wi-Fi networks. Soon PLC will have more adaptation for applications like lighting applications (for traffic light control, LED dimming, etc.), industrial applications (for irrigation control, etc.), and machine-to-machine applications (like as vending machines or a hotel's reception-to-room communication).

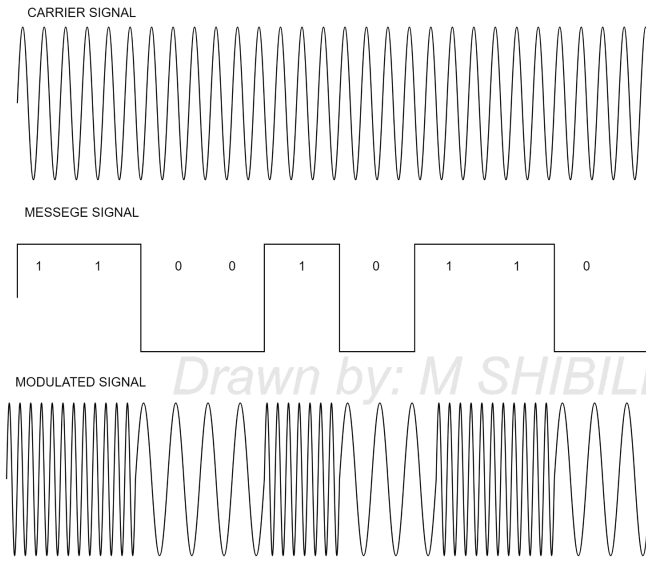
The data transmission in the power line can be done through various methods and protocols. The signal to be transmitted is modulated to FM analog signal. The digital one value is represented by the high-frequency components and the digital low value is converted to low-frequency components. Both frequencies are at the range of Kilo Hz (varying for protocols and methods from 10KHz to 130 kHz).



The frequency switching technique is also called FSK (Frequency shift keying) since the digital signal is transmitted through the discrete of the carrier signal. The frequency changed modulated signal then coupled with the AC power line via 'High pass filters' which reject the low frequency 50Hz AC signal and make the wire available for the transmission of data. When multiple devices are interconnected in the PLC network, we use the multiplexing technic called FDM. FDM (Frequency Division Multiplexing) is an encoding method of digital data on multiple carrier frequencies. This method allows simultaneous data transfer on the available frequency range. FDM assigns frequency divisions for each device to enable multiplexing.

Digital data consist of start code, letter code, and number code. The start code will poke the receiver and make it ready to read the data. The letter code consist of transmitting device address and number code enclose the data. Further for more application parameters, the data sequence can be extended. Here we use the following data sequence for efficient AMR and power theft detection.

- Start Code = 4 bits
- House code = 4 bits
- Extended code 1 = 5 bits (01111)
- Unit code (device code) = 4 bits
- Data = 8 bits
- Command = 8 bits



From right to left, data to be transmitted are first modulated (digital bits are converted to analog frequency/sine wave e.g. bit 1 is converted to a sine wave of 20Khz bit 0 is converted to the sine wave of 10Khz). To "clear" the Mains frequency and make the wire available for the transmission of data the 50/60Hz signal is filtered. This filter clears any signal of 50Hz to 60Hz. The transmitted data then are free to travel over the Mains. When they find their destination another 50 to 60Hz filter is involved. After the filter pass, the remaining signal is the modulated transmitted data. This signal is then demodulated and converted to digital bits at the receiver side.

Advantages of power line communication

- **Low Implementation Cost**: It is the major advantage PLC, it does not require any installation of new wires which as a result, would significantly reduce the deployment costs.
- **Large Reach:** It delivers data where ever the power reaches. PLC can access communication with hard to reach nodes where the RF wireless signal suffers from high levels of attenuation like in the concrete buildings or underground structures, or places like hospitals where the wireless signal is undesirable due to the EMI issues.
- **Lower Running Cost:** PLC provides a low-cost solution compared to the other existing technologies such as Wi-Fi or Narrow Band (single fixed radio frequency) GSM

The Current Transformer (C.T), is a type of "instrument transformer" that is designed to produce an alternating current in its secondary winding which is proportional to primary. Current transformers reduce high currents to a value and convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. The principle of operation of a basic current transformer is slightly different from that of an ordinary voltage transformer.

CT FAULT DETECTION STAGE

MCP6022 OP-Amp

The microcontroller ADC can't read voltages lower than 0 (negative voltages) and we need to shift the AC signal to the positive side, this can be done by adding a DC offset to the AC signal.
For that, I used an amplifier circuit that firstly filters the signal and secondly adds a dc offset of 0.512V. The main component is MCP6022 (U2) where just 1 op-amp is used. It is supplied with 5V from the Arduino board (pin 8 of U2 is connected to the Arduino 5V pin, and pin 4 of U2 is connected to any of the Arduino GND pins).
This circuit has a gain of 1 and a dc offset of 0.512V.
For the U2 IC and instead of MCP6022, other op-amp ICs may be used such as MCP6062 (or MCP6061).

Before the AC signal goes to Arduino analog channel 0 (A0) it passes through an RC low pass filter which is comprised of R1 and C1. The frequency of this filter can be simply calculated using the equation below:
$f = 1/(2 \times \pi \times R \times C) = 23.4kHz$
An Operational Amplifier, or op-amp for short, is fundamentally a voltage amplifying device designed to be used with external feedback components such as resistors and capacitors between its output and input terminals. These feedback components determine the resulting function or "operation" of the amplifier and by virtue of the different feedback configurations whether resistive, capacitive, or both, the amplifier can perform a variety of different operations, giving rise to its name of "Operational Amplifier".
An Operational Amplifier is basically a three-terminal device that consists of two high impedance inputs. One of the inputs is called the Inverting Input, marked with a negative or "minus" sign, (–). The other input is called the Non-inverting Input, marked with a positive or "plus" sign (+).
A third terminal represents the operational amplifier's output port which can both sink and source either a

voltage or a current. In a linear operational amplifier, the output signal is the amplification factor, known as the gain of the amplifier (A) multiplied by the value of the input signal, and depending on the nature of these input and output signals, there can be four different classifications of operational amplifier gain.

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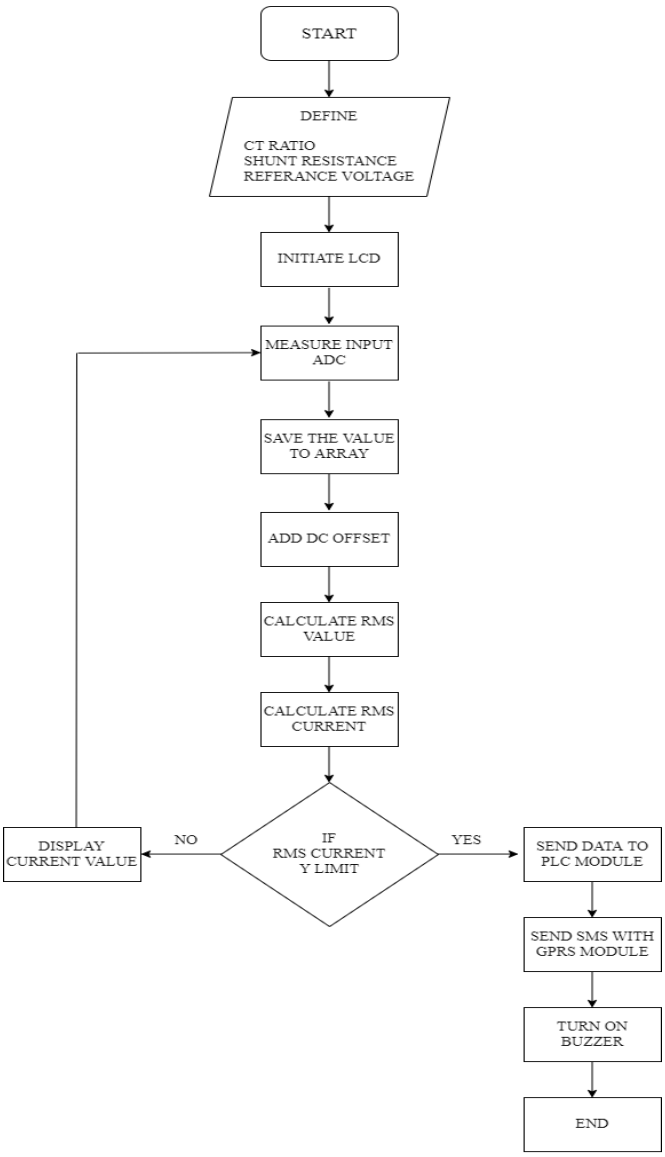
STM32Cube IDE

STM32Cube IDE is an all-in-one multi-OS development tool, which is part of the STM32Cube software ecosystem. STM32Cube wIDE is an advanced C/C++ development platform with peripheral configuration, code generation, code compilation, and debug features for STM32 microcontrollers and microprocessors.It is based on the Eclipse/CDT framework and GCC toolchain for the development, and GDB for the debugging. It allows the integration of the hundreds of existing plugins that complete the features of the Eclipse IDE.

STM32CubeIDE integrates STM32 configuration and project creation functionalities from STM32CubeMX to offer all-in-one tool experience and save installation and development time. After the selection of an empty STM32 MCU or MPU, or pre configured microcontroller or microprocessor from the selection of a board or the selection of an example, the project is created and initialization code generated. At any time during the development, the user can return to the initialization and configuration of the peripherals or middleware and regenerate the initialization code with no impact on the user code.

STM32Cube sIDE includes build and stack analyzers that provide the user with useful information about project status and memory requirements. STM32Cube sIDE also includes standard and advanced debugging features including views of CPU core registers, memories, and peripheral registers, as well as live variable watch, Serial Wire Viewer interface, or fault

FLOWCHART



Result

Line current is monitored using CT ratio calculation and thus the fault data collected and transmitted through power line communication using PLM0A1 and STM32F401RE.

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Certificates

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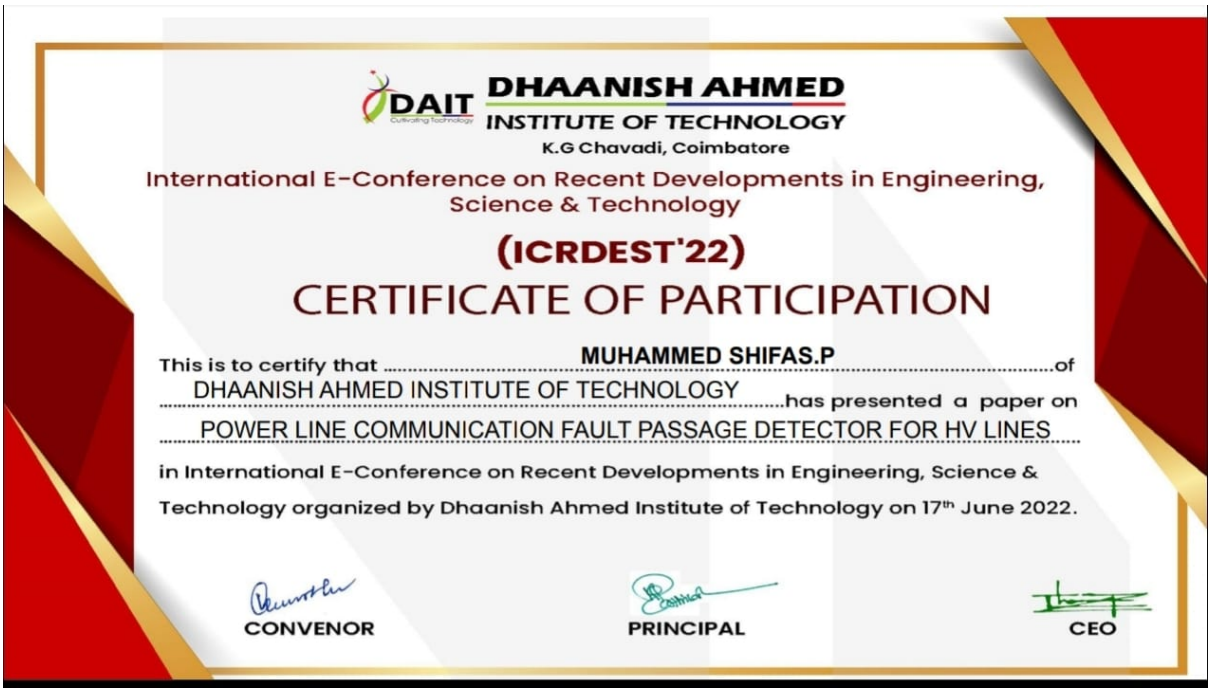

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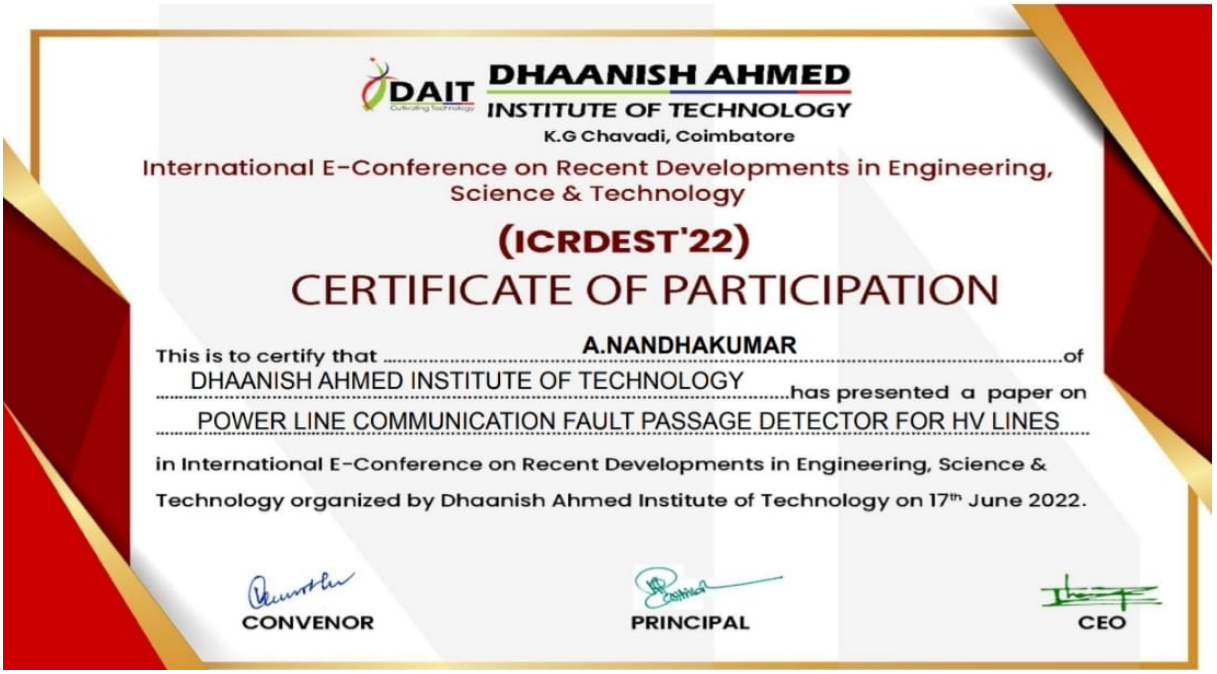

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