A Project Report on

Development of A Container GPS Tracking System To Enhance Supply Chain Security

Submitted in partial fulfilment of the requirement of the degree of

Bachelor of Engineering

by

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Certificate

This is to certify that the project entitled **"Development of A Container GPS Tracking System To Enhance Supply Chain Security "** is a bonafide work of

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Project Report Approval for B.E.

This project report entitled **"Development of A Container GPS Tracking System To Enhance Supply Chain Security "** by **Russel Dmello, Sakshi Kaveri, Sanskar Kumar, Shreyas Nanaware** is approved for the degree of **Bachelor of Engineering** in **Electronics** & **Telecommunication Engineering**.

Internal Examiner

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Date:
Place: Mumbai

Declaration

I declare that this written submission represents my ideas in my own words and where othersâ ideas or words have been included, I have adequately cited and referenced the sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented, fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources that have thus not been properly cited or from whom proper permission has not been taken when needed.

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Place: Mumbai

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Submitted with regards,

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List of Abbreviations

GSM	Global System For Mobile Communications
GPS	Global Positioning System
GPRS	General Packet Radio Service
STM	STMicroelectronics
IDE	Integrated Development Environment
UART	Universal Asynchronous Receiver-Transmitter
AT	Attention
NMEA	National Marine Electronics Association
GGA	Global Positioning System Fix Data
RMC	Recommended Minimum Navigation Information
PCB	Printed Circuit Board

Abstract

This project intends to provide an innovative GPS tracking and anti-theft system for container shipments, addressing the growing concern about theft and smuggling. The suggested system uses GSM, GPS modules, and an STM32F302R8 microcontroller for better durability and cost effectiveness compared to existing alternatives. A simple current break sensor detects theft attempts, triggering alerts sent to the server via the GSM module. Real-time location monitoring is enabled through NMEA message format packets broadcast from the GPS module to the server, facilitating swift intervention to prevent theft. The system ensures accurate tracking and effective theft prevention. This approach has the potential to greatly improve security in shipping operations, providing concrete benefits to society by protecting valuable cargo from unlawful activity.

Chapter 1

Introduction

In the span of 2021 to 2022, supply networks in North America had a 13% increase in cargo theft volume, with a 16% increase in value, a trend that has persisted into 2023. While electronic products remain extremely susceptible, thieves are increasingly targeting domestic items and food and beverages, showing that increased pressures are driving shifts in criminal behavior. The below Figure 1.1 shows the statistics of cargo thefts in year 2023.

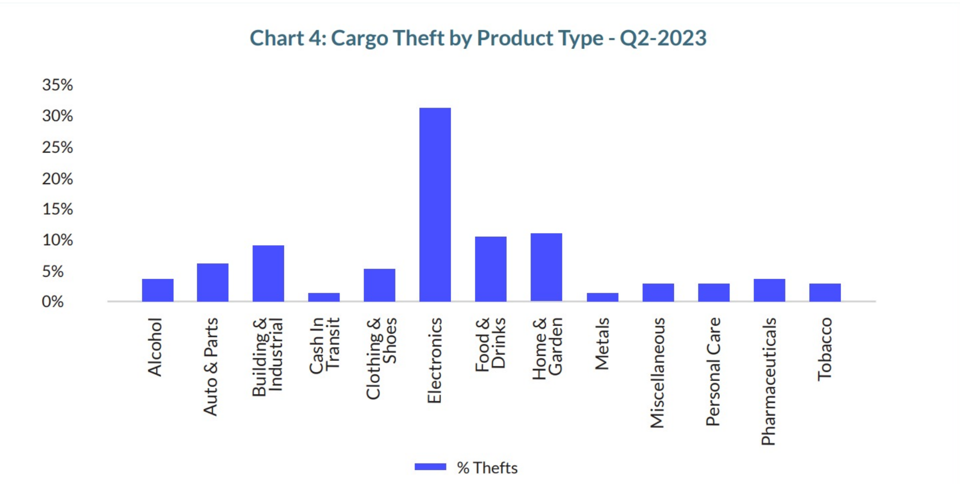

Figure 1.1: Cargo Theft Statistics

With a stolen product value of $107 million in 2022, a considerable rise from the $68 million recorded in 2020, cargo theft is definitely a concern that requires increased monitoring. Allianz Commercial, a worldwide maritime insurance, has observed an increase in cargo theft cases in recent years, notably in transportation and logistics. [1]

Cargo theft cases increased more than 57% in 2023 compared to the previous year, according to CargoNet, a Verisk firm. According to CargoNet, about $130 million in products were stolen in 2023, but because reporting cargo theft is not mandated, the figure is likely to be greater. Cargo theft refers to the theft of products at any step during the shipping process, and instances have reached record proportions. [2]

The major aim is to keep the containers and their contents safe throughout travel. The items will be transported safely, and the tracking technology will help to track the position in real-time. If the customers know the precise locations of their containers, there will definitely be a trust factor from the client side due to the reliable mode of business.

The goal of the proposed project is to create a GPS tracking system for containers that will enhance supply chain security and aid in preventing theft. Companies will be able to monitor the whereabouts of their containers in real time and receive notifications in the event that any unwanted activity is discovered thanks to the system's usage of GPS technology.

This project addresses various aspects given as follows :

- Integrity : To ensure that the shipments are undamaged and unchanged during the transportation process. This includes ensuring that no illegal changes or tampering occur, and that the items remain in their original condition and quality.
- Trust : Building confidence and reliability in the shipping process.
- Safety of Equipment : Ensuring that all equipment involved in the transportation process, such as vehicles, containers, and handling machinery, is well-maintained and operates safely.
- Social Reference : Businesses can build confidence with their partners and consumers by setting up methods to ensure the security and accuracy of shipments. This can strengthen relationships and encourage repeat business.

By implementing this system, businesses can safeguard their precious shipments, ensure seamless logistics, and elevate overall customer satisfaction.

1.1 Motivation

During the Covid-19 pandemic, when most modes of transportation were severely limited due to lockdowns and safety precautions, the movement of products grew more reliant on shipping containers, particularly for critical things like medical supplies, food, and other emergency goods. Shipping containers are really important for global trade, worth about $10 billion in 2024. But there are some significant challenges. One is ensuring that these containers are safe and secure. Imagine if someone stole or tampered with what's inside; that could be a major issue.

So we're particularly working on keeping these containers safe and secure.That includes employing lock systems and technologies to ensure that everything stays where it is supposed to and is not tampered with.

1.2 Problem Statement

We developed and set up a low-power container GSM, GPS monitoring system that monitors and tracks container locations while avoiding theft, hence improving supply chain security and assuring safe movement of commodities. This system runs effectively, saving battery power to allow for longer durations of operation without rapidly consuming resources. Using GSM technology, it enables remote contact with the tracking system, allowing for smooth data transmission and reception via cellular networks even during container movement. Integrated GPS technology gives real-time coordinates, allowing for exact position monitoring. In addition a sensing system provides instant alert at door breach hence ensuring safe movement of the cargo. Businesses may use this service to monitor their containers in real time, trace their progress through the supply chain, and proactively enhance security measures depending on the specific container position.

1.3 Scope and Objective of the Project

The project's goal is to develop a complete system capable of tracking several containers simultaneously and individually. To achieve this, several key outcomes have been proposed.

- The project will include incorporating GPS devices into the tracking system.
  These devices will be mounted on each shipping container and will constantly collect location information. The acquired data will include latitude and longitude coordinates, allowing for accurate real-time information on the container's current location. This connection will allow logistics managers and other stakeholders to monitor container movement throughout the shipping process, from origin to destination.
- GSM modules will add to GPS systems by allowing remote communication and data transmission over cellular networks.These modules will allow two-way communication between the tracking system and a central server or control center. They will allow the system to send alerts, receive commands, and transmit data, such as location updates and sensor readings, using standard mobile network infrastructure. This feature increases the system's versatility and allows for seamless connectivity, even in remote or inaccessible regions.
- In addition to GPS and GSM technology, the tracking system will incorporate sensor systems to enhance security and monitoring capabilities. The system includes a closed loop circuit system. It will continuously monitor the container's environment and detect any irregularities or unauthorized access attempts. When such events are detected, the system triggers an alert and notify specified persons or authorities, allowing for immediate response and intervention. By combining sensor systems, the tracking system improves theft prevention and cargo security while in transit.
- To ensure reliable and continuous functioning, the project intends on optimizing battery usage inside the tracking system. This optimization involves carrying out careful calculations to determine the power requirements of numerous components, such as GPS devices, GSM modules, microcontrollers. The sleep and wake cycles of the GSM module, and power-saving features of other components will be considered in battery optimization strategies.
- The tracking system will be connected to a database so we can see where something is going and check if someone tries to steal it.

The ultimate objective is to develop a viable GPS and GSM tracking system for shipping containers that provides
continuous location visibility.

Chapter 2

Literature Survey

The primary aim of this comprehensive literature survey is to meticulously evaluate the current landscape of solutions available, scrutinizing them through the lens of diverse parameters. By discerning the existing gaps within these solutions, we endeavor to formulate robust strategies for overcoming these limitations effectively.

Table 2.1: **Conducting literature review by analyzing research papers, comparing across parameters, and identifying gaps in current solutions.**

Research Paper	**Year**	**Component Specifications**	**Parameters focused**	**How is our work going to fill the gap identified in existing systems?**
Paper 1 [3]	2023	SIM800L GSM/GPRS module, SM5100B GPS module, Arduino UNO, RFID	Crash detection tracking system. Developed an algorithm that can tell if the vehicle is driving or parked. This helps prevent false alarms.	Modules used in this paper are comparatively expensive and consume more power. No sensing system present.
Paper 2 [4]	2023	GPS NEO-6 , Automatic Vehicle Location System (AVLS) tracker, Arduino UNO , RFID	Anti-theft system by creating a verification step and also setting up the system to send coordinates in case of intrusion	This paper uses RFID for identification of the vehicle , no other layer of security making it vulnerable to attackers.
Paper 3 [5]	2017	GSM, GPS, STM32	Anti-theft system for motorcycles. Immobilizer relay can shut the engine off, Ignition and fuel level monitoring	Not live location monitoring.

Paper 4 [6]	2023	GSM , STM32	Prevent Vehicle hijacking	Making use of vehicle battery , thus draining it rapidly, no use of GPS thus no tracking at all, only focus is to prevent vehicle hijacking.
Paper 5 [7]	2023	GPS module GY-NEO6MV2, GSM module SIM 900A, Arduino UNO	Vehicle location display on demand	Both the modules require 9V, thus requiring larger battery life. No real-time tracking or alert is given.
Paper 6 [8]	2023	NEO-6 GPS Module, Arduino Nano, sim800l GSM module	Anti-theft application	Requires larger battery, no real time tracking.
Paper 7 [9]	2021	A6 GPRS Pro Serial GPRS GSM Module, a ATK1218- BD GPS Beidou dual positioning module, an HC-SR501 PIR infrared sensor module, an ultrasonic distance detection module and an OLED display module , STM32 microcontroller	Vehicle security	Uses an infrared sensor to monitor strangers around the vehicle and accordingly sends the message to the owner. No real-time tracking.
Paper 8 [10]	2019	NEO 6M module, GSM SIM 900 module , Arduino UNO	Vehicle tracking system	No real-time tracking, works on user demand.
Paper 9 [11]	2018	AT89S52 uC, GPS module LR9540, GSM SIM 900 module	Anti-theft tracking system	High power consumption and low storage available in uC.

- Paper 1: The 2023 publication lacks details regarding the parts that make up its anti-theft mechanism. Although it is devoid of real-time tracking, which is a feature that most modern systems have, it does have an undefined "demand" function that may be useful. This "demand" might be something like location retrieval upon request or remote engine immobilization.[3]
- Paper 2 : Like the first publication, this one withholds the precise parts of its system from public view. It was published in 2023 and mentions a 20 watt power utilization, suggesting that the focus is on reducing power consumption. Additionally, a Model 900

component is mentioned; this may refer to a particular part with special capabilities, but the table doesn't provide any clarification.[4]

- Paper 3: Preventing unauthorized ignition and turning off the engine in the event of theft are given top priority in this paper's approach. Engine immobilization: As the table makes clear, this is primarily concerned with avoiding unapproved ignition. This implies that the study explores ways to disable the engine or stop it from starting at all. This could entail employing a kill switch or breaking the circuit of electricity. Engine Shutdown: The system's ability to turn off the engine in the event of theft is mentioned in the table. This suggests that the article will cover ways to remotely disable a stolen car, maybe via communication modules or relays.[5]

- Paper 4: There appear to be two publication dates for this research, 2011 and 2023, which could point to a system update in 2023. The exact parts utilized are not listed in the table. Although STMI's system communicates via outdated GSM/GPRS technology, it also provides SMS alerts, a rudimentary alerting system. It's unclear from the data which capabilities cause these notifications, though. In comparison to other contemporary notification techniques, SMS notifications itself may be sluggish and inaccurate.[6]

- Paper 5 : (2023) talks about an anti-theft system. It has two main parts: GY-NEO6MV2 GPS module and SIM900A GSM module. These modules both need 9V power supply, indicating the possibility of a high battery usage system. The table shows that users can request to see their vehicle location; however, no information is available about continuous tracking or notifications in real time.[7]

- Paper 6: The sixth paper released in 2023 introduces an anti-theft system that comprises multiple parts. At its heart lies a NEO-6 GPS module and an Arduino Nano microcontroller, complemented by a SIM8001 GSM module (used for communication) and an A6 GPRS Pro Serial module (presumably for cellular data connectivity). Moreover, the ATK1218-BD GPS Beidou dual positioning module is included to indicate improved geolocation accuracy. In addition, the system features an HC-SR501 PIR infrared sensor module which detects movement surrounding the vehicle along with an ultrasonic distance detection module used for proximity sensing. The focus seems to be on anti-theft through motion detection and possibly scaring away potential thieves with an alarm or notification, as the table mentions an infrared sensor to monitor strangers but no real-time tracking. The use of multiple sensors and a display suggests a more comprehensive system design, but the table doesn't mention how these components work together.[8]

- Paper 7 (2021):

  An anti-theft system outlined in Paper 7, which was released in the year 2021, comprises a GPS GSM module, an infrared sensor module, an ultrasonic distance detection module and an OLED display module. Although the exact details are not provided, it can be inferred that the system makes use of GPS technology for tracking the location; an infrared sensor for detecting movement in the vehicleâs proximity; an ultrasonic sensor for identifying obstacles in close range; and an OLED display for presenting information. While the table indicates that the system deploys the infrared sensor to survey strangers around the vehicle and enable message transmission to the ownerâ it does not confirm whether real-time tracking is a feature.[9]

- Paper 8 : A system was detailed in Paper 8 (2019) to curb theft with a few parts. It comprises a NEO 6M GPS module, a GSM SIM 900 module, and an Arduino UNO microcontroller. The former is presumed to offer GPS features while the latter enables cellular communicationâ and finally, the brain of the system would be the Arduino UNO microcontroller. On the other hand, real-time tracking capabilities are not mentioned in the table. The system seems to operate depending on user demand, which may imply that human participation is necessary to initiate alerts or do other activities, even though the functionality isn't stated.[10]
- Paper 9 (2018): An anti-theft system based on an AT89S52 microcontroller, an LR9540 GPS module, and a GSM SIM 900 module is described in Paper 9, which was published in 2018. The system is probably managed by the AT89S52 microprocessor, while the LR9540 module handles GPS and the GSM SIM 900 module facilitates cellular communication. The microcontroller's low storage capacity and high power consumption are mentioned as constraints in the table. It also makes no mention of the ability to track in real time.[11]

Chapter 3

Methodology

3.1 Methodology of the project

The system begins by initializing the GPS module, which is necessary for the device to detect its accurate position. The initialization involves configuring the hardware connections and software settings to ensure proper operation. In addition, UART connection is established between the GPS module and the STM32 Microcontroller. UART is a common serial communication protocol used for transmitting data between devices.

After establishing connectivity, the GPS module starts transmitting location data in NMEA. This data contains critical information such as latitude, longitude, altitude, time, and satellite status. The STM32 microcontroller then conducts the parsing process, carefully examining the NMEA words to extract relevant information, such as latitude and longitude coordinates.

In addition, AT instructions are used to activate the GSM module. AT commands are standardized instructions for controlling and communicating with modems and other devices. Similar to the GPS setup, UART connection is established between the GSM module and the STM32 microcontroller. This allows data flow between the microcontroller and the GSM module.

Once both the GPS and GSM modules are initialized and communication channels are established, the location data is transmitted to a mobile phone via the GSM module. This enables real-time tracking of the device's position. To ensure continuous and automated updates, the system is designed to repeat the data retrieval and transmission process hourly. This periodic procedure takes advantage of both GPS and GSM technologies to deliver efficient and dependable tracking functionality.

3.2 Circuit Schematics

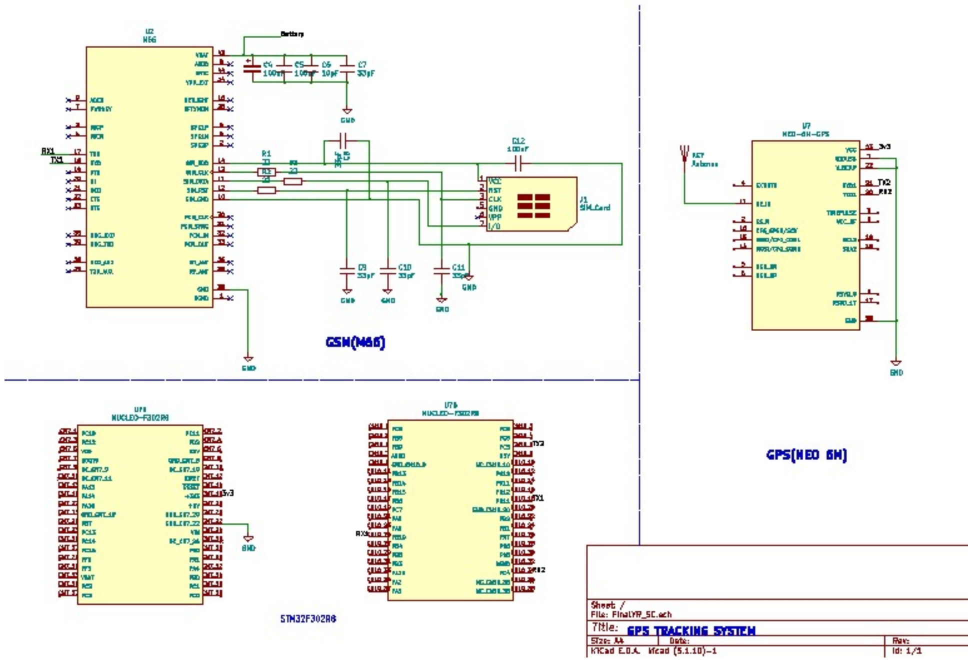

Figure 3.1: Schematics

The Figure 3.1 represents the schematics of our system. The circuit schematic represented above shows the modules GPS and the GSM module respectively. The schematics are made in an open source free software named KiCad. Based on datasheets and as per required application, the required connections are made in the circuit. Each and every value of every component has been verified by going through the data sheet thus ensuring proper calibration of the circuit.

3.3 Block Diagram

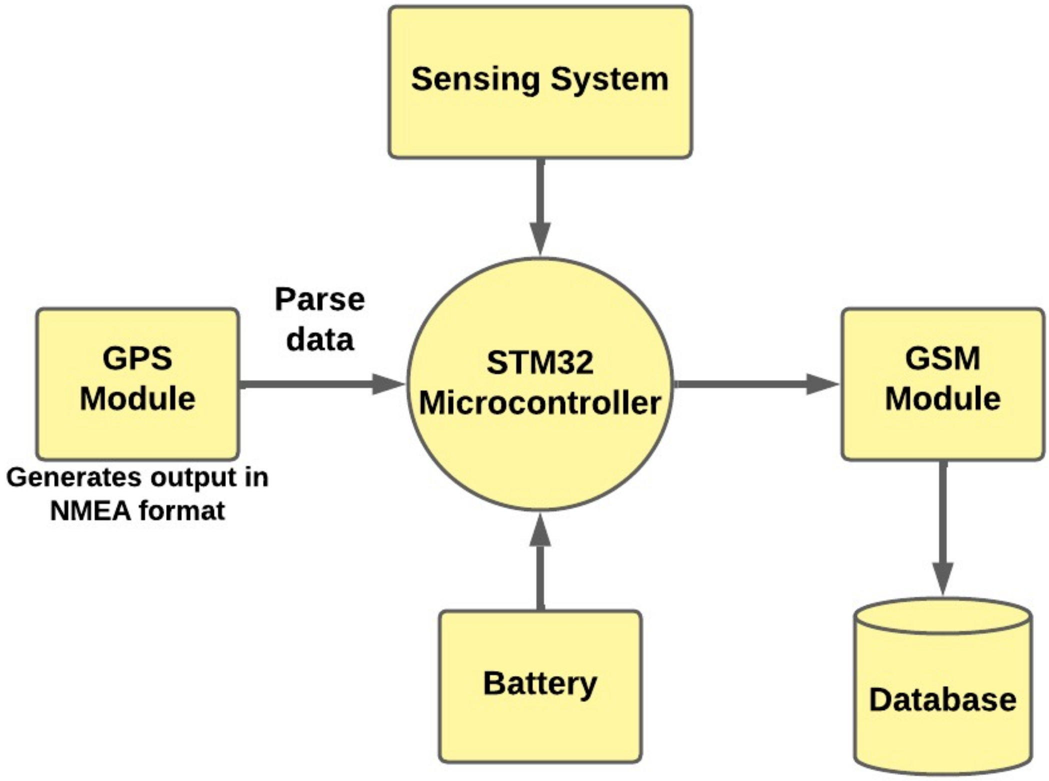

Figure 3.2: Block Diagram

The above Figure 3.2 represents the block diagram of our system.

The first step in the process is initializing the GPS module, which entails turning it on and going through the setup procedures needed to get it ready to receive satellite signals. Next, the GPS module and the STM32 microcontroller establish UART communication. This arrangement is essential because it guarantees that the microcontroller, with communication characteristics like data rate and protocol appropriately adjusted to match those of the GPS module, can receive data supplied by the GPS module reliably.

The system constantly receives data supplied from the GPS module after the communication connection has been established. This data is usually provided in NMEA phrases, which are then parsed to extract crucial position information including latitude, longitude, and time stamps.

Using AT instructions, the GSM module is simultaneously enabled, setting up network connectivity and getting ready to transmit data over the cellular network. The GSM module and the STM32 microcontroller are also connected via UART. Once the location data is prepared and structured, it is transmitted to a designated mobile device and server over the GSM module.

After then, the location data is received and processed by the server, which can enable real-time tracking on a user interface. Through the combined use of GPS for location data acquisition and GSM for data communication, the system is set up to automatically repeat the process of reading, processing, and sending updated location data every hour, ensuring continuous tracking and timely updates.

Chapter 4

Implementation and Troubleshooting

4.1 Implementation of the system

To begin implementation, we initially tested the Quectel M66 GSM module, by linking its TX, RX, VCC i.e anywhere from 3.7 - 4.5V, and GND pins to a USB to TTL converter and then to the docklight. By adjusting the baud rate at 115200, selecting the suitable COM port and using AT commands, the GSM functionality was verified by acquiring the âOKâ response in return and also its operational integrity.

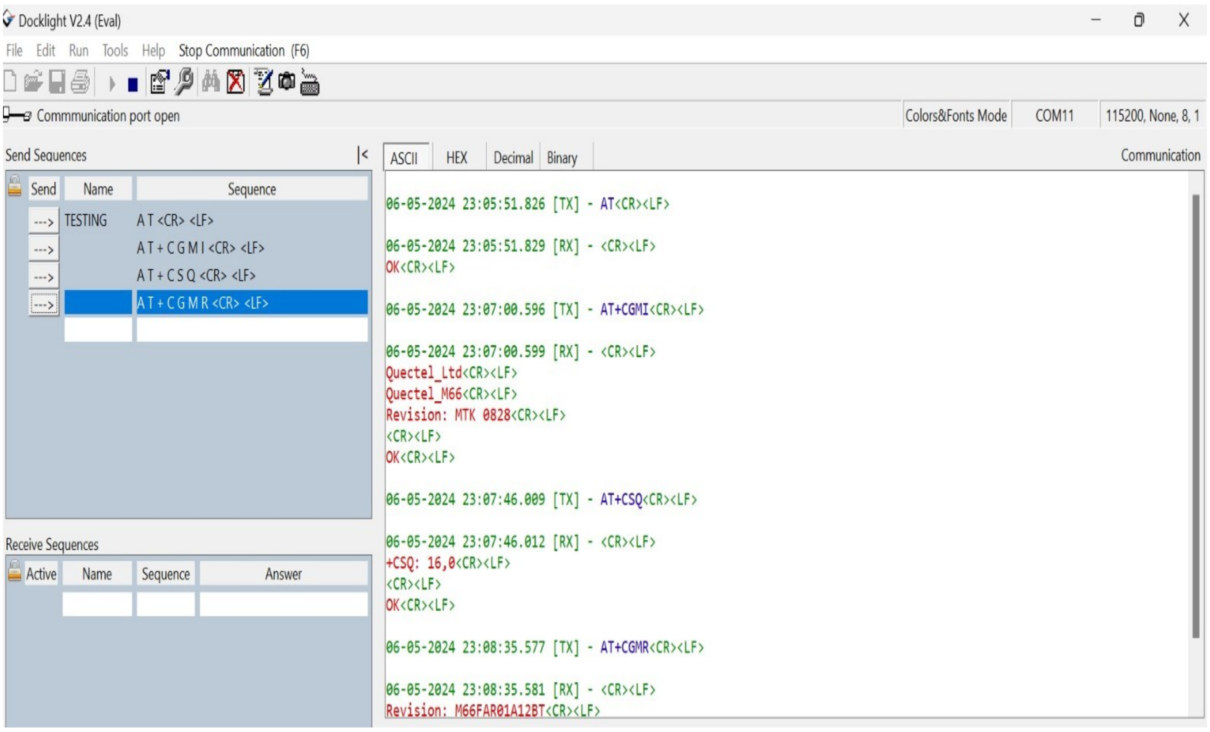

Figure 4.1: AT commands response on Docklight

Further, the GPS module was tested by linking its TX, RX, VCC i.e 3.3V, and GND pins to a USB to TTL converter, then to the docklight. By adjusting the baud rate at 9600 and selecting the suitable COM port, we observed NMEA sentences displayed on the docklight as illustrated below.

```
$GPGGA,065729.00,1900.93039,N,07305.79090,E,1,04,3.84,19.4,M,-66.1,M,,*46<CR><LF>
$GPGSA,A,3,22,05,20,24,,,,,,,,,4.99,3.84,3.19*03<CR><LF>
$GPGSV,3,1,09,05,38,176,19,11,61,002,08,12,50,332,06,13,02,172,*7F<CR><LF>
$GPGSV,3,2,09,19,19,065,08,20,64,136,29,22,21,132,23,24,31,232,32*71<CR><LF>
$GPGSV,3,3,09,25,21,322,*47<CR><LF>
$GPGLL,1900.93039,N,07305.79090,E,065729.00,A,A*68<CR><LF>
$GPRMC,065730.00,A,1900.93227,N,07305.79083,E,3.175,24.70,040524,,,A*5E<CR><LF>
$GPVTG,24.70,T,,M,3.175,N,5.880,K,A*09<CR><LF>
$GPGGA,065730.00,1900.93227,N,07305.79083,E,1,04,3.84,18.8,M,-66.1,M,,*4C<CR><LF>
$GPGSA,A,3,22,05,20,24,,,,,,,,,4.99,3.84,3.19*03<CR><LF>
$GPGSV,3,1,09,05,38,176,16,11,61,002,08,12,50,332,06,13,02,172,*70<CR><LF>
$GPGSV,3,2,09,19,19,065,08,20,64,136,29,22,21,132,24,24,31,232,33*77<CR><LF>
$GPGSV,3,3,09,25,21,322,*47<CR><LF>
$GPGLL,1900.93227,N,07305.79083,E,065730.00,A,A*6F<CR><LF>
$GPRMC,065731.00,A,1900.93327,N,07305.79080,E,3.441,7.73,040524,,,A*6D<CR><LF>
```

Figure 4.2: NMEA sentences recorded on Docklight

Example of GPGGA GPS sentence:-
$GPGGA, 161229.487, 3723.2475, N, 12158.3416, W, 1, 07, 1.0, 9.0, M, , , , 0000*18

161229.487: Time of the fix in UTC.
3723.2475, N: Latitude of the fix (in degrees and minutes, with N indicating North).
12158.3416, W: Longitude of the fix (in degrees and minutes, with W indicating West).
1: Quality of the fix (1 = GPS fix).
07: Number of satellites being tracked.
1.0: Horizontal Dilution of Precision (HDOP).
9.0: Altitude of the fix in meters.
M: Units of altitude (meters).
(Empty fields): Additional information (may be empty).
0000: Differential GPS data age.
*18: Checksum for data integrity.

Example of GPRMC GPS sentence:-
$GPRMC, 161229.487, A, 3723.2475, N, 12158.3416, W, 0.13, 309.62, 120598, , *10

161229.487: Time of fix in UTC hours, minutes, and seconds.
A: Status A = active or V = void. This tells if the GPS has a valid fix at the moment.
3723.2475, N: Latitude 37 degrees 23.2475 minutes North.
12158.3416, W: Longitude 121 degrees 58.3416 minutes West.
0.13: Speed over the ground in knots.
309.62: Course over ground in degrees true.
120598: Date - 12th May 1998.
,: Magnetic variation direction (not provided in this sentence).
10: Checksum, used for error checking the data.

A ring buffer maintains continuous data flow by storing elements in a fixed-size buffer and overwriting the oldest ones when the buffer is full. Thus, the ring buffer was developed to verify UART communication, guaranteeing alignment between transmitted and received data. This establishes a groundwork for incorporating GPS functionality using this dependable communication method.

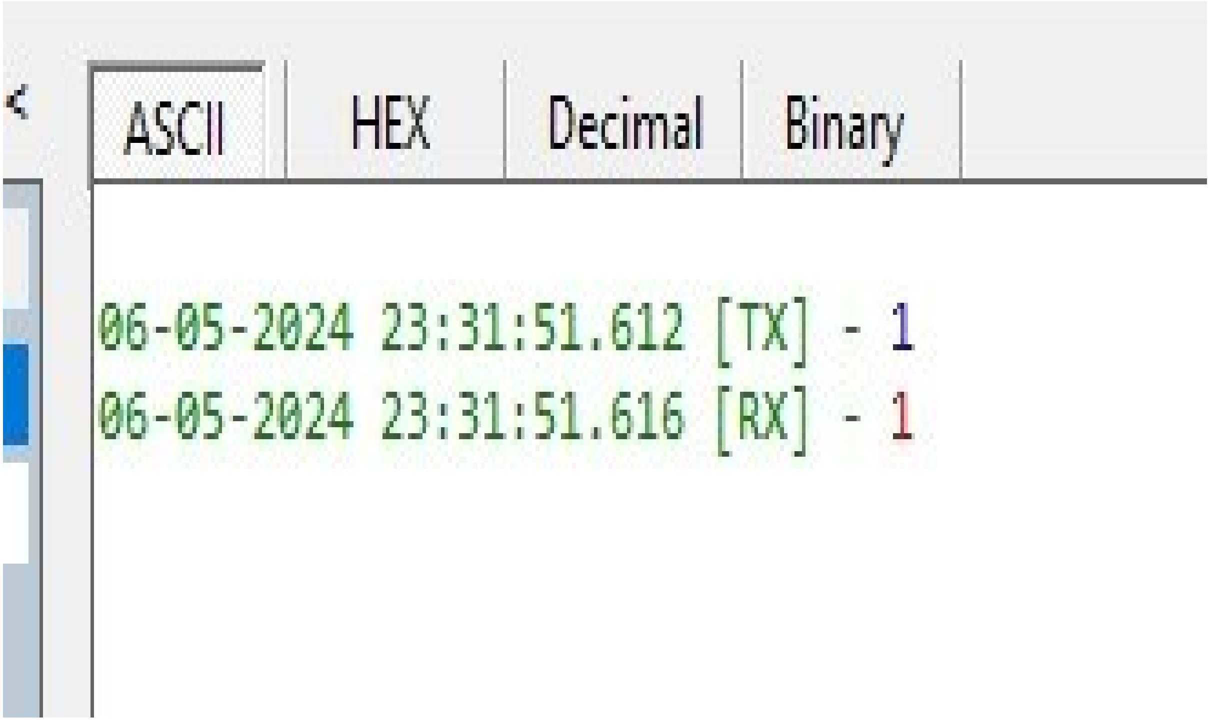

Figure 4.3: Verifying UART establishment on Docklight

Sensing System : The STM32 board was utilized to generate an alert that displayed a message in response to a voltage drop at the RX pin. To demonstrate a prototype in which if no value is present at a pin, an alert message should be presented on the console at that time. The two pins were connected using jumper wires wherein one pin was providing the power supply to the next pin. As in when the connection of jumper wires was removed the output was displayed on the console. To use this sensing system prototype, the merging with the GSM module was done so that when the closed loop circuit used for sensing breaks the alert message will be received on the specified mobile phone whose number will be put in the program.

GSM+STM32 : Initially, the STM32F302R8 board was selected using STM32CubeIDE. Following the micrcontroller parameters were configured and it starts with establishing clock settings and GPIO pins, which sets up the hardware environment.The baud rate for GSM is 115200. The USART3 peripheral is initialized to allow UART connectivity, which is required for dealing with external modules such as GSM devices. Before entering the main loop, the system sends a sequence of AT instructions over UART to set up the GSM module for SMS transmission. These instructions contain fundamental AT commands for setup and configuration, like “AT” for checking if the GSM module responds, `"AT+CREG?"`- provides information about the registration status and access technology of the serving cell, and `"AT+CMGF=1"`- this command sets the GSM modem in SMS Text Mode.

After startup, the system constantly checks the status of a jumper pin attached to a GPIO pin (PA1). If the jumper pin is identified in a low condition (indicating a door breach), the system generates an SMS message notifying a breach attempt. The `alertMsg[]` array stores the message “Alert: Door breach detected”. To send the SMS message, the system first creates the `"AT+CMGS"` (the command sends an SMS message to a GSM phone) command and specifies the recipient's phone number. This command is formatted as a string and sent to the GSM module over UART. The system then waits for the ">" prompt, which indicates that the GSM module is prepared to accept the SMS message payload. Once the ">" prompt is received, the system sends the message content contained in the `alertMsg[]` array. Finally, the system transmits the CTRL-Z character (ASCII code 0x1A) to mark the conclusion of the message. Delays are introduced throughout the process to guarantee correct timing for command execution and message transmission.

GPS+STM32: For this process also the initialization was done for a system based on a micro-controller, most likely an STM32F3xx series device by setting up the required configurations in the STM32Cube IDE. The baud rate for GPS is 9600. Specifically, it sets up the USART1 peripheral for UART connection with the GPS module. The system then enters an indefinite loop, always waiting for and processing GPS data.

Within the loop, the system uses custom methods to handle GPS data receiving and decoding. It uses the `Wait_for` function to wait for certain GPS data phrases, such as "`GGA`" and "`RMC`". When the system detects these phrases, it replicates the incoming data into the "`GGA`" and "`RMC`" character arrays. These words usually include important GPS information like position, time, and velocity. The line `Copy_upto("*", RMC/GGA);` likely invokes a custom function called `Copy_upto` with two arguments: a character pointer "" and a destination character array. The purpose of this function call appears to be to copy characters from a source buffer up to a specified delimiter (in this case, the asterisk character) into the destination array.

Once the data has been received and copied, the system will decode it using specialized decoding routines such as `decodeGGA` and `decodeRMC`. These routines parse GPS data from character arrays and extract important information into a structured manner that is saved in the `gpsData` structure. The `decodeGGA` function retrieves GPS fix information from a `GGA` phrase, such as latitude, longitude, altitude, fix quality, time, and number of satellites. Similarly, the `decodeRMC` function pulls date, speed, course data, and RMC data validity from the `RMC` statement.

After getting the coordinates from the GPS module the parsing was done and extraction of only certain sections of the NMEA format was carried out .The retrieved data must then be transferred to the GSM module for transmission.This ring buffer was created using a UART1 connection within the STM32Cube IDE environment. The ring buffer stores the coordinates received from the GPS module via Docklight-Testing, analysis and simulation tool for serial communication protocols.The algorithm for reading GPS data and writing it to the buffer was included into the loop structure, guaranteeing that it runs continuously as long as fresh data is recognized.As data comes, it is stored in the buffer before being passed to the next level of processing.

4.2 Troubleshooting

The project encountered its first obstacle when the UART Tx and Rx pins of the STM32 controller malfunctioned, necessitating a switch to a different UART port due to the multiple UARTs available on the controller. Moreover, upon each restart, the GSM module defaulted back to its default baud rate of 9600, despite being previously configured to a different rate. Indoors, the GPS module struggled to obtain a fix on the antenna, requiring placement in an open area. Additionally, there was a challenge in converting the latitude and longitude coordinates obtained from the GPS module. Compatibility issues arose between the GSM module and the high-frequency clock of the STM32 microcontroller. Despite the GPS module's slightly inaccurate location data, which deviated slightly from the actual location but still met project requirements, a USB to TTL converter was employed to troubleshoot communication errors, with analysis performed using Docklight software.

Chapter 5

Results

5.1 Mapping the Co-ordinates

In this segment, a collection of locations were gathered, tracing out an entire route. This journey encompassed various testing parameters, including traversing restricted areas, passing through an international airport, crossing a river, and navigating heavy traffic and congested roads. The tracing data extended for approximately an hour, yielding 42 to 43 coordinates at one-minute intervals.
Following are the extracted coordinates :

Table 5.1: Latitudes and Longitudes

Latitude	**Longitude**
19.082709	72.8853531
19.084328	72.8847555
19.082890	72.8824158
19.079544	72.8810425
19.079861	72.8802795
19.079101	72.8802668
19.079101	72.8802541
19.079105	72.8802542
19.079105	72.8802542
19.079110	72.8802795
19.079110	72.8802795
19.079123	72.8802795
19.0791136	72.8802795
19.0790976	72.8802541
19.0791105	72.8802975
19.0789546	72.8798096
19.0784761	72.8773295
19.079825	72.8743413
19.081380	72.8710222
19.082489	72.8686575
19.083017	72.8686575
19.084234	72.8622233
19.084044	72.8622233

19.080258	72.8592605
19.077784	72.8592605
19.077616	72.864550
19.080045	72.8685175
19.0813261	72.871960
19.0798798	72.873731
19.078818	72.8764266
19.0788533	72.8764266
19.0787958	72.8764393
19.0788021	72.8764266
19.0787958	72.8764266
19.0787958	72.8764266
19.0787958	72.8764521
19.078036	72.878969
19.0800578	72.8805975
19.0835958	72.882811
19.0842921	72.884984
19.082779	72.885391
19.0815518	72.8873621

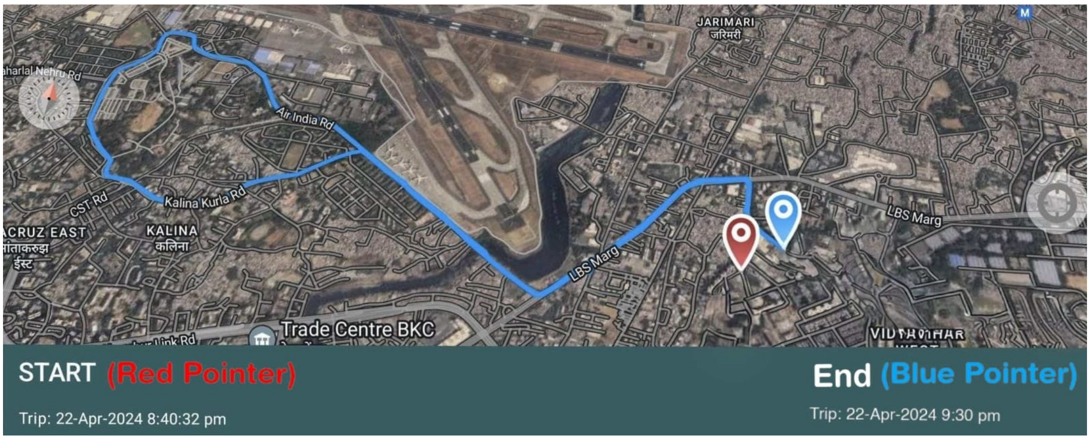

Figure 5.1: Route

In Figure 5.1, Google Earth was used to map out the entire route, allowing for subsequent verification of the GPS coordinates' accuracy. The testing began at Holy Cross Church, highlighted in red, and concluded at the same endpoint, now marked in blue. The route included passing through the LBS area which is a high traffic zone, crossing the Mithi River to assess GPS reliability, and traveling alongside restricted zones such as Mumbai International Airport and Kalina Military Camp. Upon returning, the journey also takes place through Kalina's urban and residential areas, following the same route, crossing the Mithi River again, and navigating the congested LBS area.

The table contains extracted co-ordinates from the real-time data received from the GPS module for kurla-Kalina region.

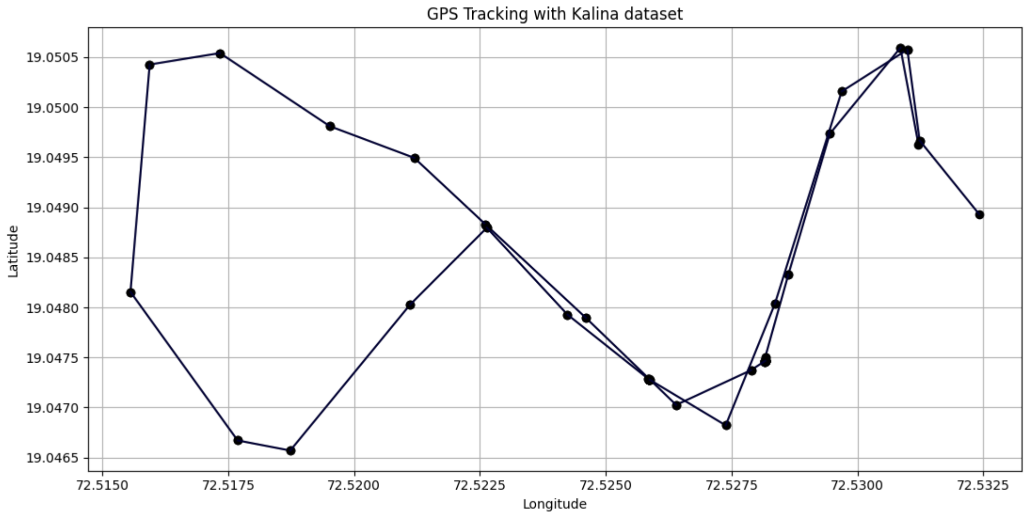

Figure 5.2: Graph

Figure 5.2 Plotting those coordinates in Google Colab using Python and the Matplotlib module, a graph was obtained, mirroring their route, confirming GPS accuracy. Comparing their tracked path to Google Maps, a high level of consistency was found, validating the system's accuracy in tracing their journey from point A to point B.

5.2 Accuracy measurement

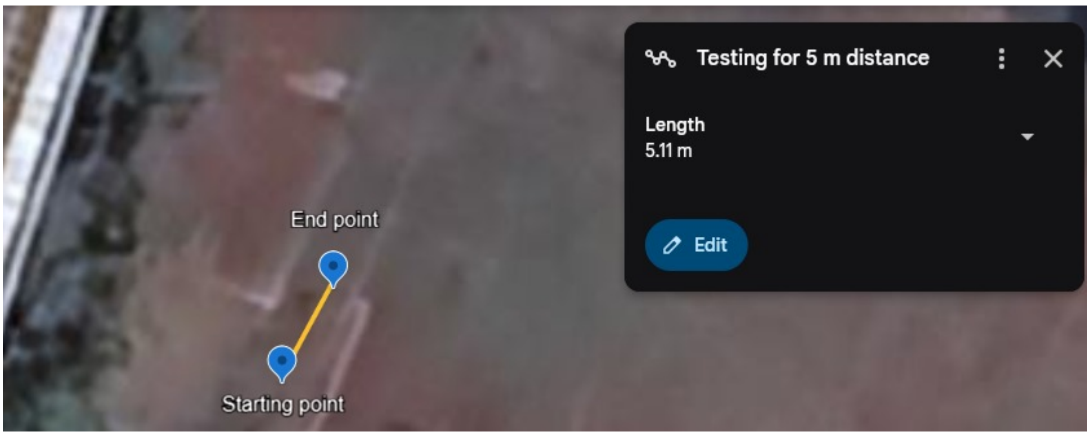

Figure 5.3: Accuracy Measurement of 5 meter path

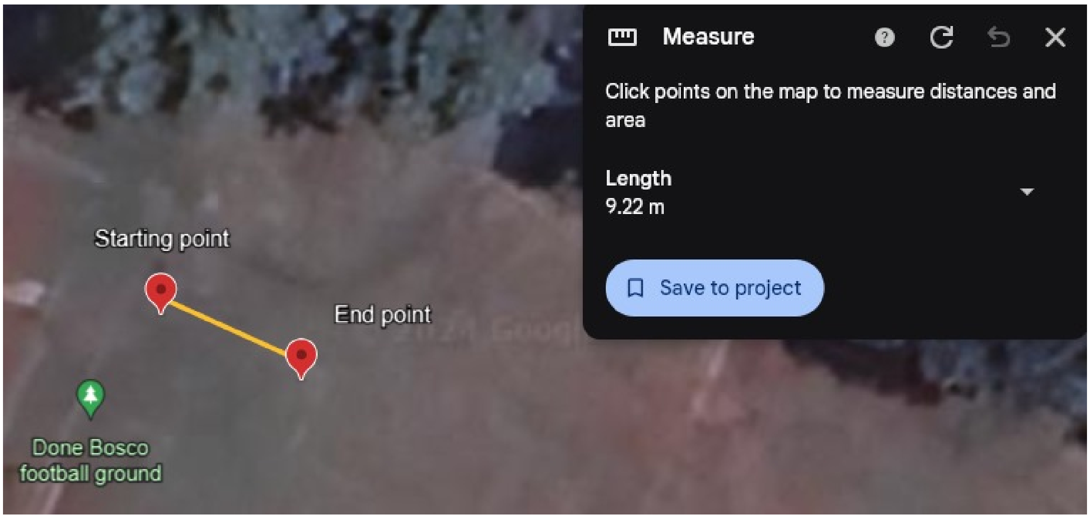

Figure 5.4: Accuracy Measurement of 10 meter path

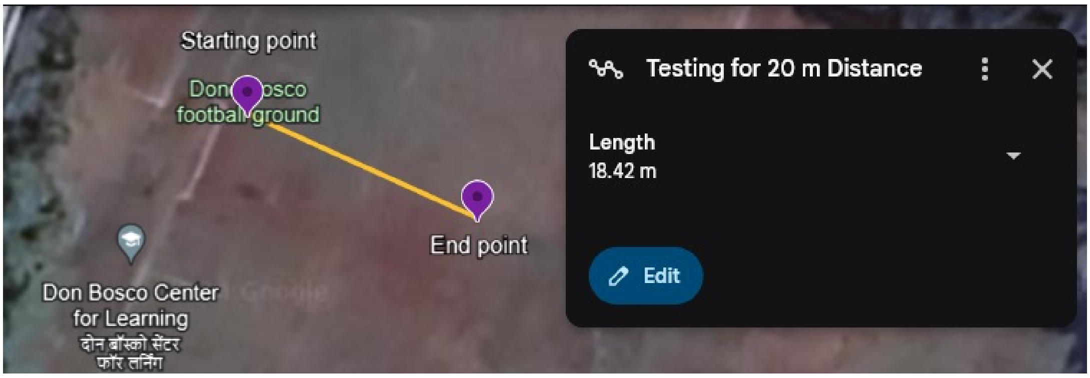

Figure 5.5: Accuracy Measurement of 20 meter path

Figures 5.3 , 5.4 , 5.5 shows the accuracy of the GPS module.

In the precision test of the GPS module at Don Bosco College Playground, a 5-meter path, 10 meter path, 20 meter path was chosen for measurement using Google Earth. Walking these path with the GPS module produced latitude-longitude coordinates, which when analyzed on Google Earth, showed a traveled distance of exactly 5.11 meters for 5 meter distance travelled , 9.22 meters for 10 meter distance travelled , and 18.42 meters for 20 meter distance travelled respectively. Despite this divergence, the GPS module consistently generated distinct coordinates for some points along the path.

Further, our tracking system is incorporated with an alert sensing mechanism to promptly alert us of any intrusion during container tracking. Upon detection, the system sends real-time alert messages containing latitude and longitude coordinates to the vehicle's driver for immediate response, while simultaneously logging this information in the database so that the company which owns the cargo can conduct further inspection and take necessaryÂ actions. The above Figure 5.6 represents the alert SMS.

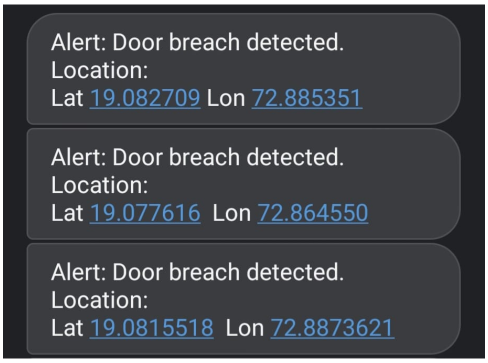

Figure 5.6: Alert SMS

5.3 Web-based visualization

Figure 5.7 demonstrates the tracked points shown in color red for the respective latitudes and longitudes provided via packets. The arrows show the path traced along.

The tracking system sends real-time latitude and longitude data to a specified server endpoint using Postman. It is a Graphic User Interface for sending and viewing HTTPS requests. The primary or most commonly-used HTTP methods are POST, GET, PUT, PATCH, and DELETE. For sending the data to the server in our system "`POST`" request is used.

POST request sends the packet to the URL of the server. By putting the current date and time in UTC format and providing real time latitudes and longitudes continually, the points are plotted represented by arrows. Information about the point can also be obtained by clicking on the specified arrow. It shows information regarding UNIT-ID, location, longitude, time at which packet is transmitted.

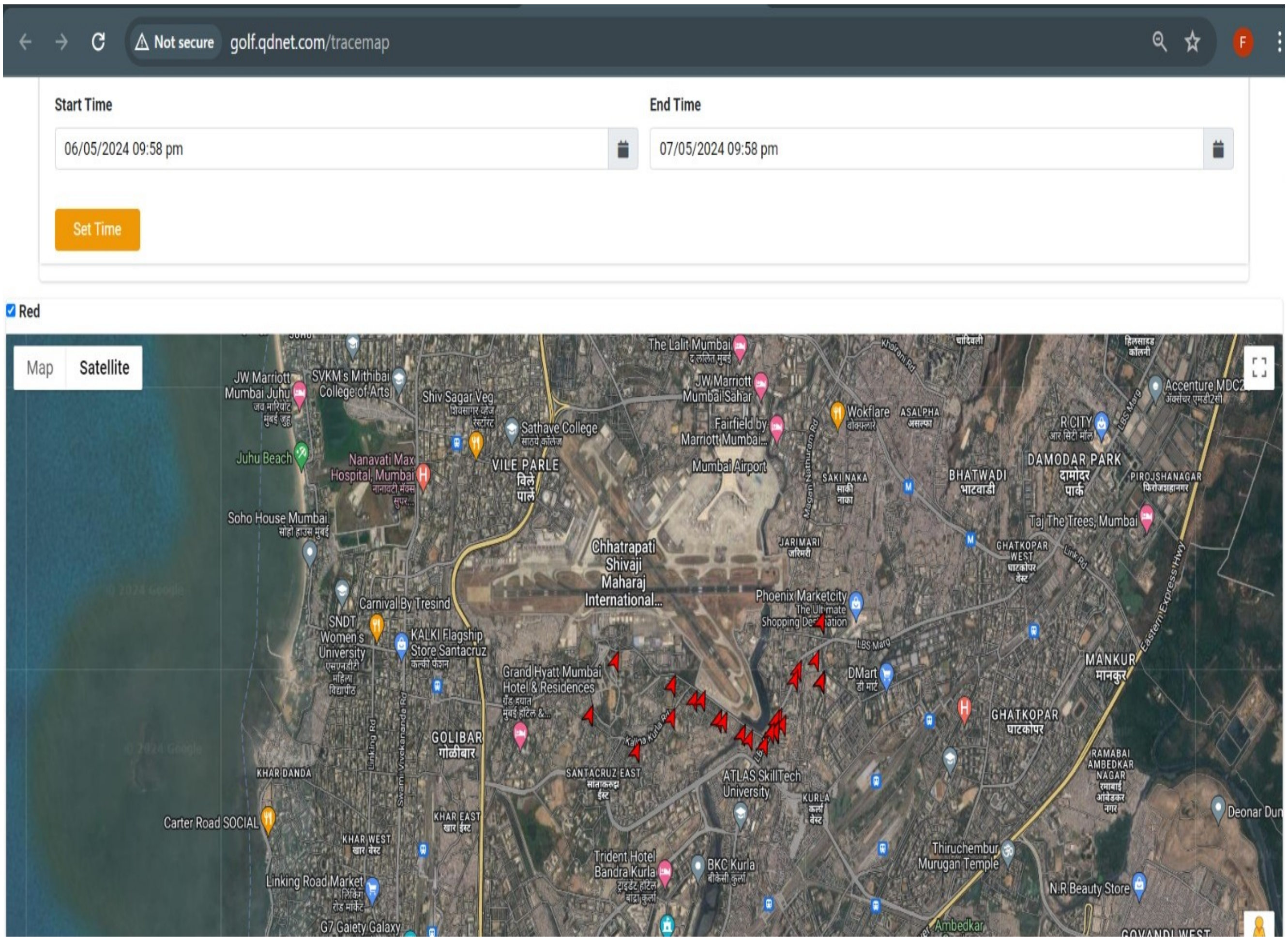

Figure 5.7: Dashboard for real-time monitoring

Chapter 6

Conclusion & Future Scope

Overall, the project resulted in the development of a GPS tracking system employing GPS and GSM modules in conjunction with an STM32 microcontroller, was successfully accomplished. This system offers real-time tracking and monitoring with approximate GPS data. This system is also integrated with an sensing system which alerts us with a message from GSM in case of detection of any suspicious activities resulting from deviations in the predefined route. Adding the STM32 microcontroller to the system improves its capacity and control. The combination of GPS and GSM technologies along with an STM32 microcontroller to create a system that can track and monitor objects in real-time. GPS provides accurate location data, while GSM transmits it to the database. The STM32 microcontroller acts as the system's control center, ensuring smooth operation and enhanced capabilities. In essence, this project resulted in a system which provides precise tracking and communication functionalities through the integration of GPS, GSM, and the STM32 microcontroller. In summary, the future of this project lies in continual innovation and adaptation to emerging technologies and market demands. The advancements in IoT can be leveraged by using more IoT sensors the system can handle more sensitive cargo and also the battery can be optimized. Further, the utilization of contact sensors can be done instead of closed loop sensing system.

Appendix

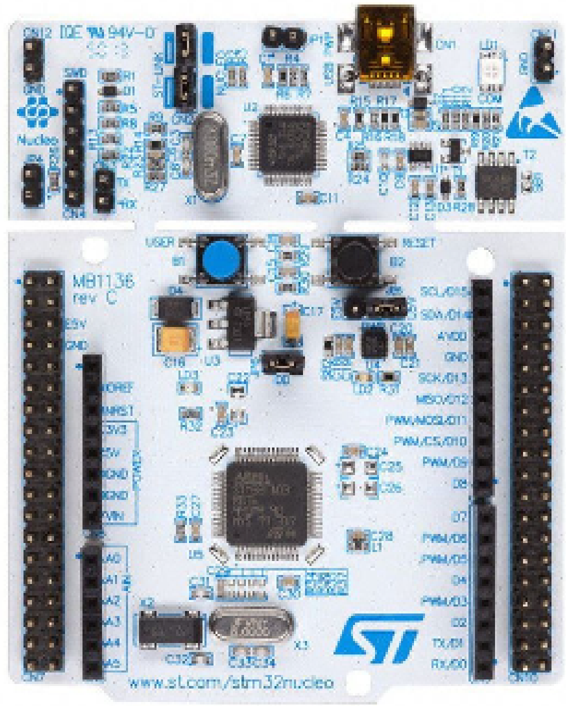

Figure 6.1: STM32F302R8 Microcontroller

STM32 microcontrollers is known for playing an important role in various sectors across various industries. Some of the areas it is used in are engine control, safety systems, etc. In our proposed system we are using STM32F302R8 as our microcontroller which will be responsible for taking the data sent by the GPS module and making it in suitable format before storing it in the buffer memory so that it can be sent to the GSM module which will further pass it on to the dedicated database and server created which will hold all the data for displaying it to the user at all times.

Figure 6.2: TTL Converter

Transistor-Transistor Logic, or TTL, is a type of serial communication that is frequently used in modern microcontrollers using the UART (universally asynchronous receiver/transmitter) transmission technique. In order to receive data on your PC, it converts a serial protocol, such as UART, to USB protocol. It resembles something like a microcontroller that has been configured to convert data from USB to UART and vice versa based on the flow of the data.

Figure 6.3: Quectel M66 GSM module

The M66 is a quad-band GSM/GPRS 2G module with LCC castellation packaging that measures 17.7mm 15.8mm 2.3mm. It is developed for low-power IoT use cases that run in challenging environments and is based on the most recent 2G chipset. It is optimized for data, SMS, and voice transmission. The M66 employs surface mounted technology, which makes it perfect for large-scale manufacturing, which can have stringent cost and efficiency requirements. The M66's ultra-compact profile makes it particularly suitable for applications that have a strict requirement for size, and the module can be used in a variety of settings, including wearable technology, automobiles, PDAs, asset tracking, point-of-sale systems, smart meters, and telematics. The GSM module will take the data sorted out by the STM32 micrcontroller that it received from the GPS module and the sensing system and GSM module is thus responsible for sending this data to the database for storing purposes.

Figure 6.4: Neo 6M GPS Module

The Neo 6M GPS module is a compact, high-performance Global Positioning System (GPS) receiver widely used in various applications, from navigation systems to IoT devices. It features a small form factor and low power consumption, making it suitable for integration into portable and battery-powered devices. The module utilizes the MediaTek MT3339 chipset, which provides fast and accurate positioning information with support for multiple satellite systems including GPS, GLONASS, and BeiDou. With its UART interface and simple command structure, the Neo 6M is easy to interface with microcontrollers and other embedded systems, making it a popular choice for projects requiring precise location tracking and navigation capabilities.

Here is the list of softwares that have been utilized until this point of time :

1) STM32 Cube IDE : Designed for programming and developing applications for STM32 microcontrollers

2) Docklight : Docklight is a testing, analysis and simulation tool for serial communication protocols

3) KiCad : KiCad is an open-source electronic design automation (EDA) software suite for creating schematics and printed circuit boards (PCBs)

4) Putty : Putty is a free and open-source terminal emulator, serial console, and network file transfer application. It supports various network protocols like SSH, Telnet, rlogin, and raw socket connections.

5) Google Earth : Google Earth is a virtual globe, map, and geographical information program that allows users to explore the Earth's surface and view satellite imagery, maps, terrain, and 3D buildings. It enables users to navigate to different locations, view geographical features, landmarks, and even explore outer space. Google Earth is available as a web-based application, desktop software, and mobile app, providing an immersive and interactive way to discover and learn about our planet.

An important point to be noted is that all the above softwares used are open source and free of cost which means anyone can install it on their systems and work on it to develop applications free of cost.

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Appendix A

Code for the implemented system

Tracking System Code in C language

```
/* USER CODE BEGIN Header */
/**
  ******************************************************************************
  * @file           : main.c
  * @brief          : Main program body
  ******************************************************************************
  * @attention
  *
  * Copyright (c) 2024 STMicroelectronics.
  * All rights reserved.
  *
  * This software is licensed under terms that can be found in the LICENSE file
  * in the root directory of this software component.
  * If no LICENSE file comes with this software, it is provided AS-IS.
  *
  ******************************************************************************
  */
/* USER CODE END Header */
/* Includes ------------------------------------------------------------------*/
#include "main.h"

/* Private includes ----------------------------------------------------------*/
/* USER CODE BEGIN Includes */
#include "stm32f3xx_hal.h"
#include "stdio.h"
#include "string.h"
#include "UartRingbuffer.h"
#include "NMEA.h"

/* USER CODE END Includes */

/* Private typedef -----------------------------------------------------------*/
/* USER CODE BEGIN PTD */
GPIO_TypeDef* JUMPER_PORT = GPIOA;
#define JUMPER_PIN_1 GPIO_PIN_1
#define CTRL_Z 0x1A   // ASCII code for CTRL-Z
//char alertMsg[] = "Alert: Door breach detected";
char smsBuffer[160];
```

```
/* USER CODE END PTD */

/* Private define
   ------------------------------------------------------------*/
/* USER CODE BEGIN PD */

/* USER CODE END PD */

/* Private macro
   -------------------------------------------------------------*/
/* USER CODE BEGIN PM */

/* USER CODE END PM */

/* Private variables
   ---------------------------------------------------------*/
extern UART_HandleTypeDef huart1;
UART_HandleTypeDef huart3;

/* USER CODE BEGIN PV */
uint8_t tx1data[10] = "AT\r\n";
uint8_t tx2data[10] = "AT+CREG?\r\n";
uint8_t tx3data[11] = "AT+CMGF=1\r\n";
 // Buffer to hold the SMS message including GPS coordinates
/* USER CODE END PV */

/* Private function prototypes
   -----------------------------------------------*/
void SystemClock_Config(void);
static void MX_GPIO_Init(void);
static void MX_USART1_UART_Init(void);
static void MX_USART3_UART_Init(void);
/* USER CODE BEGIN PFP */

/* USER CODE END PFP */

/* Private user code
   ---------------------------------------------------------*/
/* USER CODE BEGIN 0 */
char GGA[100];
char RMC[100];

GPSSTRUCT gpsData;

int _write(int file, char *ptr, int len) {
    int i = 0;
    for (i = 0; i < len; i++)
        ITM_SendChar((*ptr++));
    return len;
}
uint8_t count = 0;
/* USER CODE END 0 */

/**
  * @brief  The application entry point.
  * @retval int
  */
int main(void)
{

  /* USER CODE BEGIN 1 */
```

```
float value = 3.14159;
printf("Value: %.2f\n", value);
/* USER CODE END 1 */

/* MCU Configuration
    -------------------------------------------------------*/

/* Reset of all peripherals, Initializes the Flash interface and the
    Systick. */
HAL_Init();

/* USER CODE BEGIN Init */

/* USER CODE END Init */

/* Configure the system clock */
SystemClock_Config();

/* USER CODE BEGIN SysInit */

/* USER CODE END SysInit */

/* Initialize all configured peripherals */
MX_GPIO_Init();
MX_USART1_UART_Init();
MX_USART3_UART_Init();
/* USER CODE BEGIN 2 */
Ringbuf_init();
HAL_Delay (500);

HAL_UART_Transmit(&huart3, tx1data, sizeof(tx1data), 1000);
HAL_Delay(1000);
HAL_UART_Transmit(&huart3, tx2data, sizeof(tx2data), 1000);
HAL_Delay(1000);
HAL_UART_Transmit(&huart3, tx3data, sizeof(tx3data), 1000);
HAL_Delay(1000);
/* USER CODE END 2 */

/* Infinite loop */
/* USER CODE BEGIN WHILE */
while (1)
 {

   /* USER CODE END WHILE */

   /* USER CODE BEGIN 3 */

   if (Wait_for("GGA") == 1)
   {
      Copy_upto("*", GGA);
      decodeGGA(GGA, &gpsData.ggastruct);
         }
   if (Wait_for("RMC") == 1)
         {
            Copy_upto("*", RMC);
            decodeRMC(RMC, &gpsData.rmcstruct);
              }
  if(HAL_GPIO_ReadPin(JUMPER_PORT,JUMPER_PIN_1) == GPIO_PIN_RESET){
   snprintf(smsBuffer, sizeof(smsBuffer), "Alert: Door breach detected.
       Location: Lat %f Lon %f",
              gpsData.ggastruct.lcation.latitude, gpsData.ggastruct.lcation.
```

```
                longitude);
            // Sending the AT+CMGS command
            char cmgsCommand[30];
            snprintf(cmgsCommand, sizeof(cmgsCommand), "AT+CMGS
                =\"+918169181670\"\r\n");
            HAL_UART_Transmit(&huart3, (uint8_t*)cmgsCommand, strlen(
                cmgsCommand), 1000);
            HAL_Delay(1000); // Wait for the ">" prompt

            // Sending the actual message
            HAL_UART_Transmit(&huart3, smsBuffer, sizeof(smsBuffer), 1000);

            // Sending the CTRL-Z character to end the message
            uint8_t ctrlZ = CTRL_Z;
            HAL_UART_Transmit(&huart3, &ctrlZ, 1, 1000);

            HAL_Delay(1000); // Give some time for the message to be sent
        }
    }
  /* USER CODE END 3 */
}

/**
  * @brief System Clock Configuration
  * @retval None
  */
void SystemClock_Config(void)
{
  RCC_OscInitTypeDef RCC_OscInitStruct = {0};
  RCC_ClkInitTypeDef RCC_ClkInitStruct = {0};
  RCC_PeriphCLKInitTypeDef PeriphClkInit = {0};

  /** Initializes the RCC Oscillators according to the specified parameters
  * in the RCC_OscInitTypeDef structure.
  */
  RCC_OscInitStruct.OscillatorType = RCC_OSCILLATORTYPE_HSI;
  RCC_OscInitStruct.HSIState = RCC_HSI_ON;
  RCC_OscInitStruct.HSICalibrationValue = RCC_HSICALIBRATION_DEFAULT;
  RCC_OscInitStruct.PLL.PLLState = RCC_PLL_NONE;
  if (HAL_RCC_OscConfig(&RCC_OscInitStruct) != HAL_OK)
  {
    Error_Handler();
  }

  /** Initializes the CPU, AHB and APB buses clocks
  */
  RCC_ClkInitStruct.ClockType = RCC_CLOCKTYPE_HCLK|RCC_CLOCKTYPE_SYSCLK
                              |RCC_CLOCKTYPE_PCLK1|RCC_CLOCKTYPE_PCLK2;
  RCC_ClkInitStruct.SYSCLKSource = RCC_SYSCLKSOURCE_HSI;
  RCC_ClkInitStruct.AHBCLKDivider = RCC_SYSCLK_DIV1;
  RCC_ClkInitStruct.APB1CLKDivider = RCC_HCLK_DIV1;
  RCC_ClkInitStruct.APB2CLKDivider = RCC_HCLK_DIV1;

  if (HAL_RCC_ClockConfig(&RCC_ClkInitStruct, FLASH_LATENCY_0) != HAL_OK)
  {
    Error_Handler();
  }
  PeriphClkInit.PeriphClockSelection = RCC_PERIPHCLK_USART1;
  PeriphClkInit.Usart1ClockSelection = RCC_USART1CLKSOURCE_PCLK1;
  if (HAL_RCCEx_PeriphCLKConfig(&PeriphClkInit) != HAL_OK)
  {
```

```
    Error_Handler();
  }
}

/**
  * @brief USART1 Initialization Function
  * @param None
  * @retval None
  */
static void MX_USART1_UART_Init(void)
{

  /* USER CODE BEGIN USART1_Init 0 */

  /* USER CODE END USART1_Init 0 */

  /* USER CODE BEGIN USART1_Init 1 */

  /* USER CODE END USART1_Init 1 */
  huart1.Instance = USART1;
  huart1.Init.BaudRate = 9600;
  huart1.Init.WordLength = UART_WORDLENGTH_8B;
  huart1.Init.StopBits = UART_STOPBITS_1;
  huart1.Init.Parity = UART_PARITY_NONE;
  huart1.Init.Mode = UART_MODE_TX_RX;
  huart1.Init.HwFlowCtl = UART_HWCONTROL_NONE;
  huart1.Init.OverSampling = UART_OVERSAMPLING_16;
  huart1.Init.OneBitSampling = UART_ONE_BIT_SAMPLE_DISABLE;
  huart1.AdvancedInit.AdvFeatureInit = UART_ADVFEATURE_NO_INIT;
  if (HAL_UART_Init(&huart1) != HAL_OK)
  {
    Error_Handler();
  }
  /* USER CODE BEGIN USART1_Init 2 */

  /* USER CODE END USART1_Init 2 */

}

/**
  * @brief USART3 Initialization Function
  * @param None
  * @retval None
  */
static void MX_USART3_UART_Init(void)
{

  /* USER CODE BEGIN USART3_Init 0 */

  /* USER CODE END USART3_Init 0 */

  /* USER CODE BEGIN USART3_Init 1 */

  /* USER CODE END USART3_Init 1 */
  huart3.Instance = USART3;
  huart3.Init.BaudRate = 115200;
  huart3.Init.WordLength = UART_WORDLENGTH_8B;
  huart3.Init.StopBits = UART_STOPBITS_1;
  huart3.Init.Parity = UART_PARITY_NONE;
  huart3.Init.Mode = UART_MODE_TX_RX;
  huart3.Init.HwFlowCtl = UART_HWCONTROL_NONE;
```

```
  huart3.Init.OverSampling = UART_OVERSAMPLING_16;
  huart3.Init.OneBitSampling = UART_ONE_BIT_SAMPLE_DISABLE;
  huart3.AdvancedInit.AdvFeatureInit = UART_ADVFEATURE_NO_INIT;
  if (HAL_UART_Init(&huart3) != HAL_OK)
  {
    Error_Handler();
  }
  /* USER CODE BEGIN USART3_Init 2 */

  /* USER CODE END USART3_Init 2 */

}

/**
  * @brief GPIO Initialization Function
  * @param None
  * @retval None
  */
static void MX_GPIO_Init(void)
{
  GPIO_InitTypeDef GPIO_InitStruct = {0};
/* USER CODE BEGIN MX_GPIO_Init_1 */
/* USER CODE END MX_GPIO_Init_1 */

  /* GPIO Ports Clock Enable */
  __HAL_RCC_GPIOF_CLK_ENABLE();
  __HAL_RCC_GPIOA_CLK_ENABLE();
  __HAL_RCC_GPIOC_CLK_ENABLE();
  __HAL_RCC_GPIOB_CLK_ENABLE();

  /*Configure GPIO pin : PA1 */
  GPIO_InitStruct.Pin = GPIO_PIN_1;
  GPIO_InitStruct.Mode = GPIO_MODE_INPUT;
  GPIO_InitStruct.Pull = GPIO_NOPULL;
  HAL_GPIO_Init(GPIOA, &GPIO_InitStruct);

/* USER CODE BEGIN MX_GPIO_Init_2 */
/* USER CODE END MX_GPIO_Init_2 */
}

/* USER CODE BEGIN 4 */

/* USER CODE END 4 */

/**
  * @brief  This function is executed in case of error occurrence.
  * @retval None
  */
void Error_Handler(void)
{
  /* USER CODE BEGIN Error_Handler_Debug */
  /* User can add his own implementation to report the HAL error return
     state */
  __disable_irq();
  while (1)
  {
  }
  /* USER CODE END Error_Handler_Debug */
}

#ifdef  USE_FULL_ASSERT
```

```
/**
  * @brief  Reports the name of the source file and the source line number
  *         where the assert_param error has occurred.
  * @param  file: pointer to the source file name
  * @param  line: assert_param error line source number
  * @retval None
  */
void assert_failed(uint8_t *file, uint32_t line)
{
  /* USER CODE BEGIN 6 */
  /* User can add his own implementation to report the file name and line
     number,
     ex: printf("Wrong parameters value: file %s on line %d\r\n", file,
         line) */
  /* USER CODE END 6 */
}
#endif /* USE_FULL_ASSERT */
```

Appendix B

Datasheet of STM32F302R8 Microcontroller

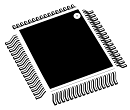
STM32F302x6 STM32F302x8

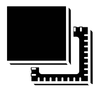
Arm® Cortex®-M4 32-bit MCU+FPU, up to 64 KB Flash, 16 KB SRAM, ADC, DAC, USB, CAN, COMP, Op-Amp, 2.0 - 3.6 V

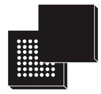
Datasheet - production data

Features

- Core: Arm® 32-bit Cortex®-M4 CPU with FPU (72 MHz max.), single-cycle multiplication and HW division, DSP instruction
- Memories
  - 32 to 64 Kbytes of Flash memory
  - 16 Kbytes of SRAM on data bus
- CRC calculation unit
- Reset and power management
  - V_{DD}, V_{DDA} voltage range: 2.0 to 3.6 V
  - Power-on/Power down reset (POR/PDR)
  - Programmable voltage detector (PVD)
  - Low-power: Sleep, Stop, and Standby
  - V_{BAT} supply for RTC and backup registers
- Clock management
  - 4 to 32 MHz crystal oscillator
  - 32 kHz oscillator for RTC with calibration
  - Internal 8 MHz RC with x 16 PLL option
  - Internal 40 kHz oscillator
- Up to 51 fast I/O ports, all mappable on external interrupt vectors, several 5 V-tolerant
- Interconnect matrix
- 7-channel DMA controller supporting timers, ADCs, SPIs, I^2Cs, USARTs and DAC
- 1 × ADC 0.20 µs (up to 15 channels) with selectable resolution of 12/10/8/6 bits, 0 to 3.6 V conversion range, single ended/differential mode, separate analog supply from 2.0 to 3.6 V
- Temperature sensor
- 1 x 12-bit DAC channel with analog supply from 2.4 to 3.6 V
- Three fast rail-to-rail analog comparators with analog supply from 2.0 to 3.6 V
- 1 x operational amplifier that can be used in PGA mode, all terminal accessible with analog supply from 2.4 to 3.6 V


LQFP48 (7x7 mm)
LQFP64 (10x10 mm)


UFQFPN32
(5x5 mm)


WLCSP49
(3.417x3.151 mm)

- Up to 18 capacitive sensing channels supporting touchkey, linear and rotary sensors
- Up to 9 timers
  - One 32-bit timer with up to 4 IC/OC/PWM or pulse counter and quadrature (incremental) encoder input
  - One 16-bit 6-channel advanced-control timer, with up to 6 PWM channels, deadtime generation and emergency stop
  - Three 16-bit timers with IC/OC/OCN or PWM, deadtime gen. and emergency stop
  - One 16-bit basic timer to drive the DAC
  - 2 watchdog timers (independent, window)
  - SysTick timer: 24-bit downcounter
- Calendar RTC with alarm, periodic wakeup from Stop/Standby
- Communication interfaces
  - Three I2Cs with 20 mA current sink to support Fast mode plus
  - Up to 3 USARTs, 1 with ISO 7816 I/F, auto baudrate detect and Dual clock domain
  - Up to two SPIs with multiplexed full duplex I2S
  - USB 2.0 full-speed interface
  - 1 x CAN interface (2.0B Active)
  - Infrared transmitter
- Serial wire debug (SWD), JTAG
- 96-bit unique ID

Table 1. Device summary

Reference	Part number
STM32F302x6	STM32F302R6, STM32F302C6, STM32F302K6
STM32F302x8	STM32F302R8, STM32F302C8, STM32F302K8

2 Description

The STM32F302x6/8 family is based on the high-performance Arm® Cortex®-M4 32-bit RISC core operating at a frequency of up to 72 MHz and embedding a floating point unit (FPU). The family incorporates high-speed embedded memories (up to 64 Kbytes of Flash memory, 16 Kbytes of SRAM), and an extensive range of enhanced I/Os and peripherals connected to two APB buses.

The devices offer a fast 12-bit ADC (5 Msps), three comparators, an operational amplifier, up to 18 capacitive sensing channels, one DAC channel, a low-power RTC, one general-purpose 32-bit timer, one timer dedicated to motor control, and up to three general-purpose 16-bit timers, and one timer to drive the DAC. They also feature standard and advanced communication interfaces: three I^{2}Cs, up to three USARTs, up to two SPIs with multiplexed full-duplex I2S, a USB FS device, a CAN, and an infrared transmitter.

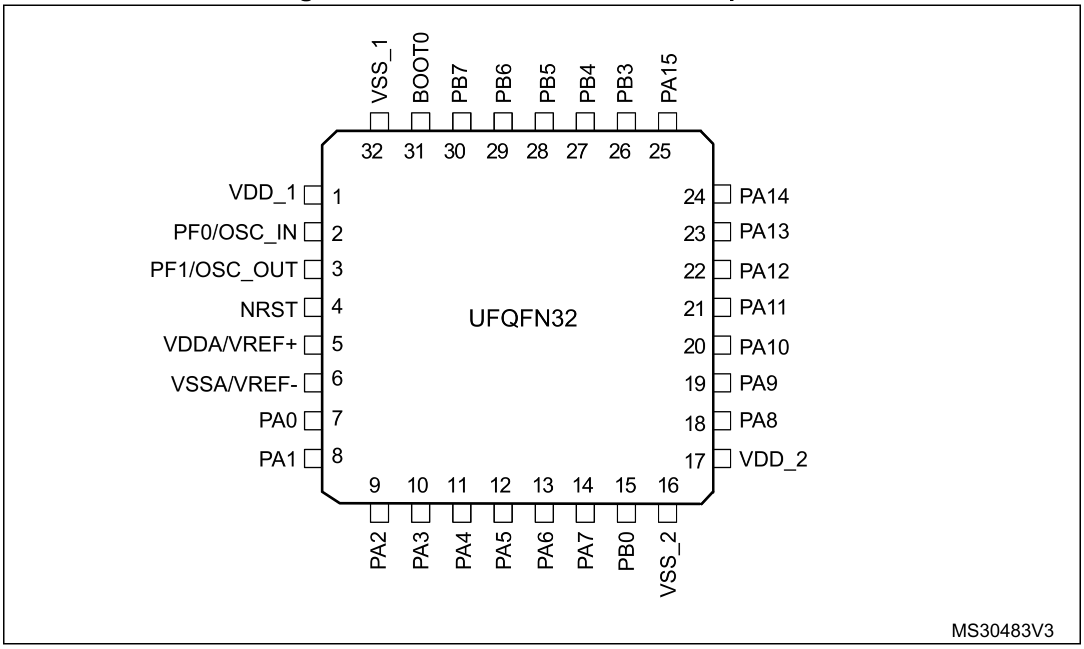
The STM32F302x6/8 family operates in the –40 to +85°C and –40 to +105°C temperature ranges from at a 2.0 to 3.6 V power supply. A comprehensive set of power-saving mode allows the design of low-power applications.

The STM32F302x6/8 family offers devices in 32-, 48-, 49- and 64-pin packages.

The set of included peripherals changes with the device chosen.

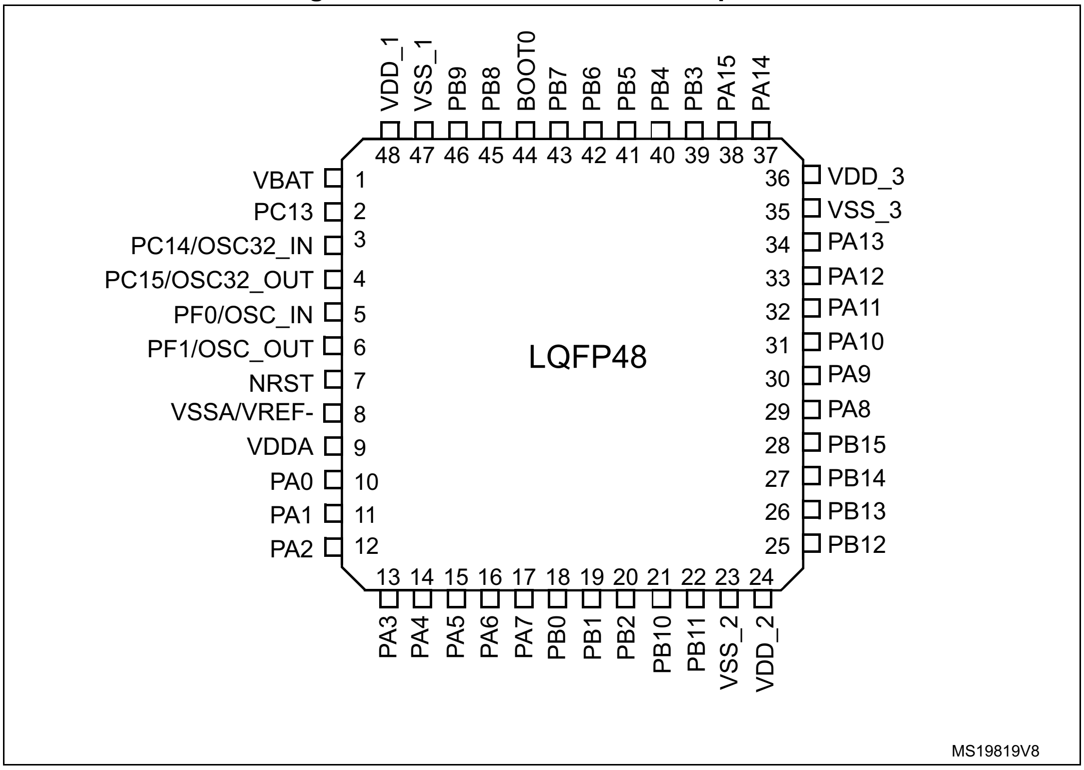
4 Pinouts and pin description

Figure 4. STM32F302x6/8 UFQFN32 pinout



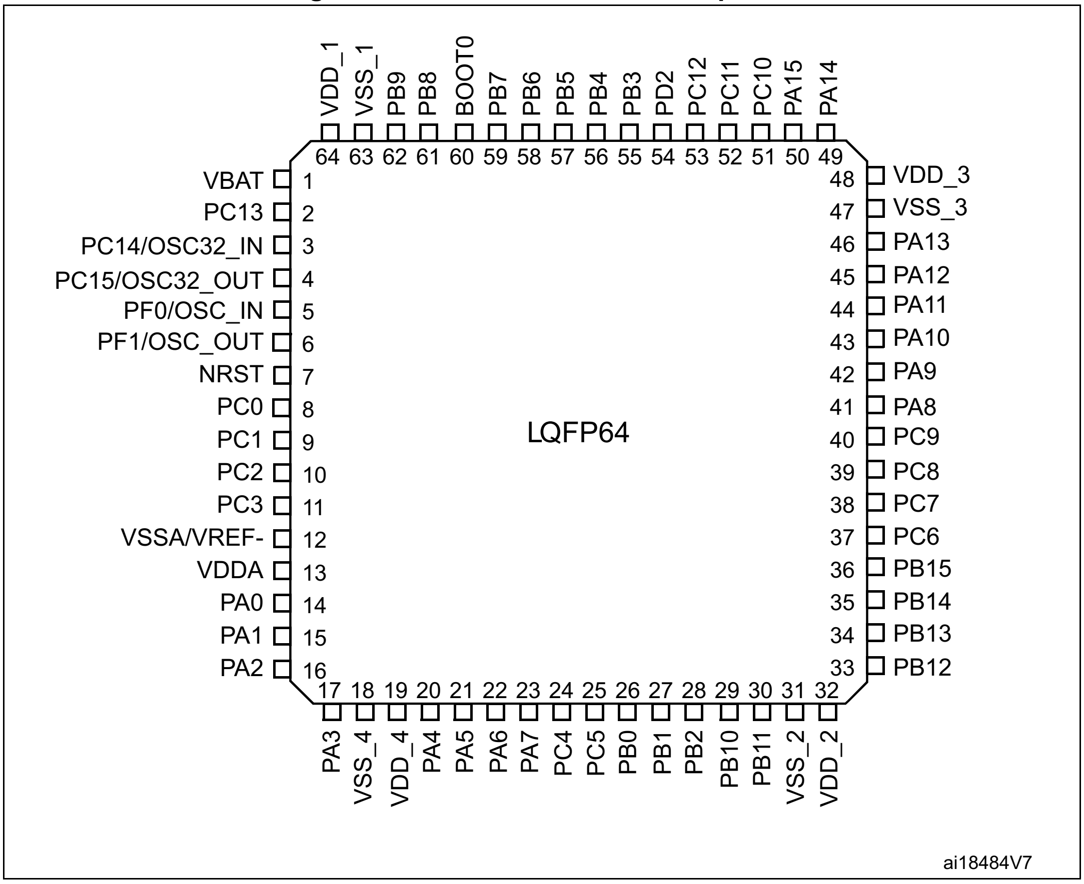
1. The above figure shows the package top view.

Figure 5. STM32F302x6/8 LQFP48 pinout



1. The above figure shows the package top view.

Figure 6. STM32F302x6/8 LQFP64 pinout



1. The above figure shows the package top view.

6.2 Absolute maximum ratings

Stresses above the absolute maximum ratings listed in *Table 20: Voltage characteristics*, *Table 21: Current characteristics*, and *Table 22: Thermal characteristics* may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these conditions is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

Table 20. Voltage characteristics(1)

Symbol	Ratings	Min	Max	Unit
$V_{DD}–V_{SS}$	External main supply voltage (including $V_{DDA,}$ V_{BAT} and V_{DD})	-0.3	4.0	V
$V_{DD}–V_{DDA}$	Allowed voltage difference for $V_{DD} > V_{DDA}$	-	0.4	V
V_{IN}(2)	Input voltage on FT and FTf pins	$V_{SS} – 0.3$	$V_{DD} + 4.0$	V
	Input voltage on TTa and TT pins	$V_{SS} – 0.3$	4.0	
	Input voltage on any other pin	$V_{SS} – 0.3$	4.0	
	Input voltage on Boot0 pin	0	9	
$\|\Delta V_{DDx}\|$	Variations between different V_{DD} power pins	-	50	mV
$\|V_{SSX} – V_{SS}\|$	Variations between all the different ground pins(3)	-	50	
$V_{ESD(HBM)}$	Electrostatic discharge voltage (human body model)	see *Section 6.3.12: Electrical sensitivity characteristics*		V

1. All main power (V_{DD}, V_{DDA}) and ground (V_{SS}, V_{SSA}) pins must always be connected to the external power supply, in the permitted range. The following relationship must be respected between V_{DDA} and V_{DD}:
V_{DDA} must power on before or at the same time as V_{DD} in the power up sequence.
V_{DDA} must be greater than or equal to V_{DD}.
2. V_{IN} maximum must always be respected. Refer to *Table 21: Current characteristics* for the maximum allowed injected current values.
3. Include V_{REF-} pin.

Table 21. Current characteristics

Symbol	Ratings	Max.	Unit
ΣI_{VDD}	Total current into sum of all VDD_x power lines (source)	130	mA
ΣI_{VSS}	Total current out of sum of all VSS_x ground lines (sink)	-130	
I_{VDD}	Maximum current into each V_{DD_x} power line (source)(1)	100	
I_{VSS}	Maximum current out of each V_{SS_x} ground line (sink)(1)	-100	
$I_{IO(PIN)}$	Output current sunk by any I/O and control pin	25	
	Output current sourced by any I/O and control pin	-25	
$\Sigma I_{IO(PIN)}$	Total output current sunk by sum of all IOs and control pins(2)	80	
	Total output current sourced by sum of all IOs and control pins(2)	-80	
$I_{INJ(PIN)}$	Injected current on TT, FT, FTf and B pins(3)	-5/+0	
	Injected current on TC and RST pin(4)	+/-5	
	Injected current on TTa pins(5)	+/-5	
$\Sigma I_{INJ(PIN)}$	Total injected current (sum of all I/O and control pins)(6)	+/-25	

1. All main power (V_{DD}, V_{DDA}) and ground (V_{SS} and V_{SSA}) pins must always be connected to the external power supply, in the permitted range.
2. This current consumption must be correctly distributed over all I/Os and control pins.The total output current must not be sunk/sourced between two consecutive power supply pins referring to high pin count LQFP packages.
3. Positive injection is not possible on these I/Os and does not occur for input voltages lower than the specified maximum value.
4. A positive injection is induced by $V_{IN} > V_{DD}$ while a negative injection is induced by $V_{IN} < V_{SS}$. $I_{INJ(PIN)}$ must never be exceeded. Refer to *Table 20: Voltage characteristics* for the maximum allowed input voltage values.
5. A positive injection is induced by $V_{IN} > V_{DDA}$ while a negative injection is induced by $V_{IN} < V_{SS}$. I_{INJ}(PIN) must never be exceeded. Refer also to *Table 20: Voltage characteristics* for the maximum allowed input voltage values. Negative injection disturbs the analog performance of the device. See note (2) below *Table 68*.
6. When several inputs are submitted to a current injection, the maximum $\Sigma I_{INJ(PIN)}$ is the absolute sum of the positive and negative injected currents (instantaneous values).

Table 22. Thermal characteristics

Symbol	Ratings	Value	Unit
T_{STG}	Storage temperature range	–65 to +150	°C
T_J	Maximum junction temperature	150	°C

6.3 Operating conditions

6.3.1 General operating conditions

Table 23. General operating conditions

Symbol	Parameter	Conditions	Min	Max	Unit
f_{HCLK}	Internal AHB clock frequency	-	0	72	MHz
f_{PCLK1}	Internal APB1 clock frequency	-	0	36	
f_{PCLK2}	Internal APB2 clock frequency	-	0	72	
V_{DD}	Standard operating voltage	-	2	3.6	V
V_{DDA}	Analog operating voltage (OPAMP and DAC not used)	Must have a potential equal to or higher than V_{DD}	2	3.6	V
	Analog operating voltage (OPAMP and DAC used)		2.4	3.6	
V_{BAT}	Backup operating voltage	-	1.65	3.6	V
V_{IN}	I/O input voltage	TC I/O	–0.3	V_{DD}+0.3	V
		TT I/O(1)	-0.3	3.6	
		TTa I/O pins	–0.3	V_{DDA}+0.3	
		FT and FTf I/O(1)	–0.3	5.5	
		BOOT0	0	5.5	
P_D	Power dissipation at T_A = 85 °C for suffix 6 or T_A = 105 °C for suffix 7(2)	LQFP64	-	444	mW
		LQFP48	-	364	
		WLCSP49	-	408	
		UFQFPN32	-	540	
TA	Ambient temperature for 6 suffix version	Maximum power dissipation	–40	85	°C
		Low power dissipation(3)	–40	105	
	Ambient temperature for 7 suffix version	Maximum power dissipation	–40	105	°C
		Low power dissipation(3)	–40	125	
TJ	Junction temperature range	6 suffix version	–40	105	°C
		7 suffix version	–40	125	

1. To sustain a voltage higher than V_{DD}+0.3 V, the internal pull-up/pull-down resistors must be disabled.
2. If T_A is lower, higher P_D values are allowed as long as T_J does not exceed T_{Jmax}. See *Table 82: Package thermal characteristics*.
3. In low power dissipation state, T_A can be extended to this range as long as T_J does not exceed T_{Jmax}. See *Table 82: Package thermal characteristics*.

Appendix C

Datasheet of NEO 6M GPS Module

GPS

NEO-6

u-blox 6 GPS Modules

Data Sheet

locate, communicate, accelerate

Abstract

Technical data sheet describing the cost effective, high-performance u-blox 6 based NEO-6 series of GPS modules, that brings the high performance of the u-blox 6 positioning engine to the miniature NEO form factor.
These receivers combine a high level of integration capability with flexible connectivity options in a small package. This makes them perfectly suited for mass-market end products with strict size and cost requirements.

16.0 x 12.2 x 2.4 mm

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Document Information	
Title	NEO-6
Subtitle	u-blox 6 GPS Modules
Document type	Data Sheet
Document number	GPS.G6-HW-09005-E
Document status	

Document status information	
Objective Specification	This document contains target values. Revised and supplementary data will be published later.
Advance Information	This document contains data based on early testing. Revised and supplementary data will be published later.
Preliminary	This document contains data from product verification. Revised and supplementary data may be published later.
Released	This document contains the final product specification.

This document applies to the following products:

Name	Type number	ROM/FLASH version	PCN reference
NEO-6G	NEO-6G-0-001	ROM7.03	UBX-TN-11047-1
NEO-6Q	NEO-6Q-0-001	ROM7.03	UBX-TN-11047-1
NEO-6M	NEO-6M-0-001	ROM7.03	UBX-TN-11047-1
NEO-6P	NEO-6P-0-000	ROM6.02	N/A
NEO-6V	NEO-6V-0-000	ROM7.03	N/A
NEO-6T	NEO-6T-0-000	ROM7.03	N/A

1.3 GPS performance

Parameter	Specification			
Receiver type	50 Channels GPS L1 frequency, C/A Code SBAS: WAAS, EGNOS, MSAS			
Time-To-First-Fix[1]		NEO-6G/Q/T	NEO-6M/V	NEO-6P
	Cold Start[2]	26 s	27 s	32 s
	Warm Start[2]	26 s	27 s	32 s
	Hot Start[2]	1 s	1 s	1 s
	Aided Starts[3]	1 s	<3 s	<3 s
Sensitivity[4]		NEO-6G/Q/T	NEO-6M/V	NEO-6P
	Tracking & Navigation	-162 dBm	-161 dBm	-160 dBm
	Reacquisition[5]	-160 dBm	-160 dBm	-160 dBm
	Cold Start (without aiding)	-148 dBm	-147 dBm	-146 dBm
	Hot Start	-157 dBm	-156 dBm	-155 dBm
Maximum Navigation update rate		NEO-6G/Q/M/T	NEO-6P/V	
		5Hz	1 Hz	
Horizontal position accuracy[6]	GPS	2.5 m		
	SBAS	2.0 m		
	SBAS + PPP[7]	< 1 m (2D, R50)[8]		
	SBAS + PPP[7]	< 2 m (3D, R50)[8]		
Configurable Timepulse frequency range		NEO-6G/Q/M/P/V	NEO-6T	
		0.25 Hz to 1 kHz	0.25 Hz to 10 MHz	
Accuracy for Timepulse signal	RMS	30 ns		
	99%	<60 ns		
	Granularity	21 ns		
	Compensated[9]	15 ns		
Velocity accuracy[6]		0.1m/s		
Heading accuracy[6]		0.5 degrees		
Operational Limits	Dynamics	≤ 4 g		
	Altitude[10]	50,000 m		
	Velocity[10]	500 m/s		

Table 2: NEO-6 GPS performance

---

[1] All satellites at -130 dBm
[2] Without aiding
[3] Dependent on aiding data connection speed and latency
[4] Demonstrated with a good active antenna
[5] For an outage duration ≤10s
[6] CEP, 50%, 24 hours static, -130dBm, SEP: <3.5m
[7] NEO-6P only
[8] Demonstrated under following conditions: 24 hours, stationary, first 600 seconds of data discarded. HDOP < 1.5 during measurement period, strong signals. Continuous availability of valid SBAS correction data during full test period.
[9] Quantization error information can be used with NEO-6T to compensate the granularity related error of the timepulse signal
[10] Assuming Airborne <4g platform

1.4 Block diagram

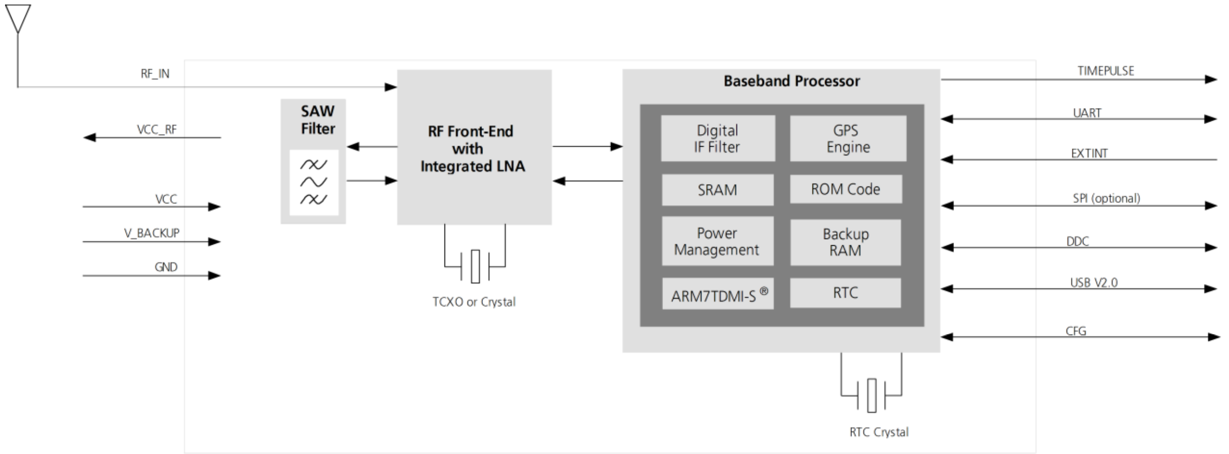

Figure 1: Block diagram (For available options refer to the product features table in section 1.2).

1.5 Assisted GPS (A-GPS)

Supply of aiding information like ephemeris, almanac, rough last position and time and satellite status and an optional time synchronization signal will reduce time to first fix significantly and improve the acquisition sensitivity. All NEO-6 modules support the u-blox AssistNow Online and AssistNow Offline A-GPS services[11] and are OMA SUPL compliant.

1.6 AssistNow Autonomous

AssistNow Autonomous provides functionality similar to Assisted-GPS without the need for a host or external network connection. Based on previously broadcast satellite ephemeris data downloaded to and stored by the GPS receiver, AssistNow Autonomous automatically generates accurate satellite orbital data (“AssistNow Autonomous data”) that is usable for future GPS position fixes. AssistNow Autonomous data is reliable for up to 3 days after initial capture.

u-blox’ AssistNow Autonomous benefits are:

- Faster position fix
- No connectivity required
- Complementary with AssistNow Online and Offline services
- No integration effort, calculations are done in the background

☞ For more details see the u-blox 6 Receiver Description including Protocol Specification [2].

[11] AssistNow Offline requires external memory.

2 Pin Definition

2.1 Pin assignment

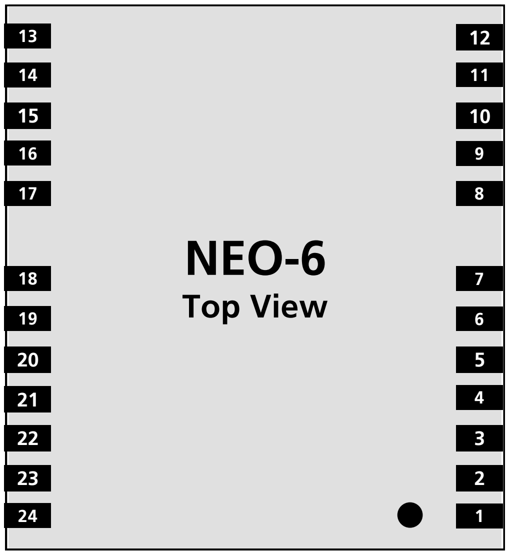

Figure 2 Pin Assignment

No	Module	Name	I/O	Description
1	All	Reserved	I	Reserved
2	All	SS_N	I	SPI Slave Select
3	All	TIMEPULSE	O	Timepulse (1PPS)
4	All	EXTINT0	I	External Interrupt Pin
5	All	USB_DM	I/O	USB Data
6	All	USB_DP	I/O	USB Data
7	All	VDDUSB	I	USB Supply
8	All	Reserved		See Hardware Integration Manual Pin 8 and 9 must be connected together.
9	All	VCC_RF	O	Output Voltage RF section Pin 8 and 9 must be connected together.
10	All	GND	I	Ground
11	All	RF_IN	I	GPS signal input
12	All	GND	I	Ground
13	All	GND	I	Ground
14	All	MOSI/CFG_COM0	O/I	SPI MOSI / Configuration Pin. Leave open if not used.
15	All	MISO/CFG_COM1	I	SPI MISO / Configuration Pin. Leave open if not used.
16	All	CFG_GPS0/SCK	I	Power Mode Configuration Pin / SPI Clock. Leave open if not used.
17	All	Reserved	I	Reserved
18	All	SDA2	I/O	DDC Data
19	All	SCL2	I/O	DDC Clock
20	All	TxD1	O	Serial Port 1
21	All	RxD1	I	Serial Port 1

No	Module	Name	I/O	Description
22	All	V_BCKP	I	Backup voltage supply
23	All	VCC	I	Supply voltage
24	All	GND	I	Ground

Table 8: Pinout

☞ Pins designated Reserved should not be used. For more information about Pinouts see the LEA-6/NEO-6/MAX-6 Hardware Integration Manual [1].

3 Electrical specifications

3.1 Absolute maximum ratings

Parameter	Symbol	Module	Min	Max	Units	Condition
Power supply voltage	VCC	NEO-6G	-0.5	2.0	V	
		NEO-6Q, 6M, 6P, 6V, 6T	-0.5	3.6	V	
Backup battery voltage	V_BCKP	All	-0.5	3.6	V	
USB supply voltage	VDDUSB	All	-0.5	3.6	V	
Input pin voltage	Vin	All	-0.5	3.6	V	
	Vin_usb	All	-0.5	VDDUSB	V	
DC current trough any digital I/O pin (except supplies)	Ipin			10	mA	
VCC_RF output current	ICC_RF	All		100	mA	
Input power at RF_IN	Prfin	NEO-6Q, 6M, 6G, 6V, 6T		15	dBm	source impedance = 50Ω, continuous wave
		NEO-6P		-5	dBm	
Storage temperature	Tstg	All	-40	85	°C	

Table 9: Absolute maximum ratings

GPS receivers are Electrostatic Sensitive Devices (ESD) and require special precautions when handling. For more information see chapter 6.4.

Stressing the device beyond the "Absolute Maximum Ratings" may cause permanent damage. These are stress ratings only. The product is not protected against overvoltage or reversed voltages. If necessary, voltage spikes exceeding the power supply voltage specification, given in table above, must be limited to values within the specified boundaries by using appropriate protection diodes. For more information see the *LEA-6/NEO-6/MAX-6 Hardware Integration Manual* [1].

3.2 Operating conditions

All specifications are at an ambient temperature of 25°C.

Parameter	Symbol	Module	Min	Typ	Max	Units	Condition
Power supply voltage	VCC	NEO-6G	1.75	1.8	1.95	V	
		NEO-6Q/M NEO-6P/V/T	2.7	3.0	3.6	V	
Supply voltage USB	VDDUSB	All	3.0	3.3	3.6	V	
Backup battery voltage	V_BCKP	All	1.4		3.6	V	
Backup battery current	I_BCKP	All		22		µA	V_BCKP = 1.8 V, VCC = 0V
Input pin voltage range	Vin	All	0		VCC	V	
Digital IO Pin Low level input voltage	Vil	All	0		0.2*VCC	V	
Digital IO Pin High level input voltage	Vih	All	0.7*VCC		VCC	V	
Digital IO Pin Low level output voltage	Vol	All			0.4	V	Iol=4mA
Digital IO Pin High level output voltage	Voh	All	VCC -0.4			V	Ioh=4mA
USB_DM, USB_DP	VinU	All	Compatible with USB with 22 Ohms series resistance				
VCC_RF voltage	VCC_RF	All		VCC-0.1		V	
VCC_RF output current	ICC_RF	All			50	mA	
Antenna gain	Gant	All			50	dB	
Receiver Chain Noise Figure	NFtot	All		3.0		dB	
Operating temperature	Topr	All	-40		85	°C	

Table 10: Operating conditions

Operation beyond the specified operating conditions can affect device reliability.

3.3 Indicative power requirements

Table 11 lists examples of the total system supply current for a possible application.

Parameter	Symbol	Module	Min	Typ	Max	Units	Condition
Max. supply current [15]	Iccp	All			67	mA	VCC = 3.6 V[16] / 1.95 V[17]
Average supply current[18]	Icc Acquisition	All		47[19]		mA	VCC = 3.0 V[16] / 1.8 V[17]
	Icc Tracking (Max Performance mode)	NEO-6G/Q/T		40[20]		mA	
		NEO-6M/P/V		39[20]		mA	
	Icc Tracking (Eco mode)	NEO-6G/Q/T		38[20]		mA	
		NEO-6M/P/V		37[20]		mA	
	Icc Tracking (Power Save mode / 1 Hz)	NEO-6G/Q		12[20]		mA	
		NEO-6M		11[20]		mA	

Table 11: Indicative power requirements

Values in Table 11 are provided for customer information only as an example of typical power requirements. Values are characterized on samples, actual power requirements can vary depending on FW version used, external circuitry, number of SVs tracked, signal strength, type of start as well as time, duration and conditions of test.

[15] Use this figure to dimension maximum current capability of power supply. Measurement of this parameter with 1 Hz bandwidth.
[16] NEO-6Q, NEO-6M, NEO-6P, NEO-6V, NEO-6T
[17] NEO-6G
[18] Use this figure to determine required battery capacity.
[19] >8 SVs in view, CNo >40 dBHz, current average of 30 sec after cold start.
[20] With strong signals, all orbits available. For Cold Starts typical 12 min after first fix. For Hot Starts typical 15 s after first fix.

7 Default settings

Interface	Settings
Serial Port 1 Output	9600 Baud, 8 bits, no parity bit, 1 stop bit Configured to transmit both NMEA and UBX protocols, but only following NMEA and no UBX messages have been activated at start-up: **GGA, GLL, GSA, GSV, RMC, VTG, TXT** (In addition to the 6 standard NMEA messages the NEO-6T includes **ZDA**).
USB Output	Configured to transmit both NMEA and UBX protocols, but only following NMEA and no UBX messages have been activated at start-up: **GGA, GLL, GSA, GSV, RMC, VTG, TXT** (In addition to the 6 standard NMEA messages the NEO-6T includes **ZDA**). USB Power Mode: Bus-Powered
Serial Port 1 Input	9600 Baud, 8 bits, no parity bit, 1 stop bit Automatically accepts following protocols without need of explicit configuration: **UBX, NMEA** The GPS receiver supports interleaved UBX and NMEA messages.
USB Input	Automatically accepts following protocols without need of explicit configuration: **UBX, NMEA** The GPS receiver supports interleaved UBX and NMEA messages. USB Power Mode: Bus-Powered
TIMEPULSE (1Hz Nav)	1 pulse per second, synchronized at rising edge, pulse length 100ms
Power Mode	Maximum Performance mode
AssistNow Autonomous	Disabled.

Table 15: Default settings

Refer to the u-blox 6 Receiver Description including Protocol Specification [2] for information about further settings.

Appendix D

Datasheet of Quectel M66 GSM Module

Wireless Module Expert

M66 Hardware Design

GSM/GPRS Module Series

Rev. M66_Hardware_Design_V1.1

Date: 2014-11-24

www.quectel.com

2.2. Key Features

The following table describes the detailed features of M66 module.

Table 1: Module Key Features

Feature	Implementation
Power Supply	Single supply voltage: 3.3V ~ 4.6V Typical supply voltage: 4V
Power Saving	Typical power consumption in SLEEP mode: 1.3 mA @DRX=5 1.2 mA @DRX=9
Frequency Bands	● Quad-band: GSM850, EGSM900, DCS1800, PCS1900. ● The module can search these frequency bands automatically ● The frequency bands can be set by AT command ● Compliant to GSM Phase 2/2+
GSM Class	Small MS
Transmitting Power	● Class 4 (2W) at GSM850 and EGSM900 ● Class 1 (1W) at DCS1800 and PCS1900
GPRS Connectivity	● GPRS multi-slot class 12 (default) ● GPRS multi-slot class 1~12 (configurable) ● GPRS mobile station class B
DATA GPRS	● GPRS data downlink transfer: max. 85.6kbps ● GPRS data uplink transfer: max. 85.6kbps ● Coding scheme: CS-1, CS-2, CS-3 and CS-4 ● Support the protocols PAP (Password Authentication Protocol) usually used for PPP connections ● Internet service protocols TCP/UDP, FTP, PPP, HTTP, NTP, PING ● Support Packet Broadcast Control Channel (PBCCH) ● Support Unstructured Supplementary Service Data (USSD)
Temperature Range	● Normal operation: -35°C ~ +80°C ● Restricted operation: -40°C ~ -35°C and +80°C ~ +85°C [1)] ● Storage temperature: -45°C ~ +90°C
Bluetooth	● Support Bluetooth specification 3.0 ● Output Power: Class 1 (Typical 7.5dBm)
SMS	● Text and PDU mode ● SMS storage: SIM card
SIM Interface	Support SIM card: 1.8V, 3.0V
Audio Features	Speech codec modes: ● Half Rate (ETS 06.20) ● Full Rate (ETS 06.10)

	● Enhanced Full Rate (ETS 06.50/06.60/06.80) ● Adaptive Multi-Rate (AMR) ● Echo Suppression ● Noise Reduction
UART Interfaces	UART Port: ● Seven lines on UART port interface ● Used for AT command, GPRS data ● Multiplexing function ● Support autobauding from 4800bps to 115200bps Debug Port: ● Two lines on debug port interface DBG_TXD and DBG_RXD ● Debug Port only used for firmware debugging Auxiliary Port: ● Used for AT command
Phonebook Management	Support phonebook types: SM, ME, ON, MC, RC, DC, LD, LA
SIM Application Toolkit	Support SAT class 3, GSM 11.14 Release 99
Real Time Clock	Supported
Physical Characteristics	Size: 15.8±0.15 × 17.7±0.15 × 2.3±0.2mm Weight: Approx. 1.3g
Firmware Upgrade	Firmware upgrade via UART Port
Antenna Interface	Connected to antenna pad with 50 Ohm impedance control

NOTE

[1)] When the module works within this temperature range, the deviations from the GSM specification may occur. For example, the frequency error or the phase error will be increased.

Table 2: Coding Schemes and Maximum Net Data Rates over Air Interface

Coding Scheme	1 Timeslot	2 Timeslot	4 Timeslot
CS-1	9.05kbps	18.1kbps	36.2kbps
CS-2	13.4kbps	26.8kbps	53.6kbps
CS-3	15.6kbps	31.2kbps	62.4kbps
CS-4	21.4kbps	42.8kbps	85.6kbps

2.3. Functional Diagram

The following figure shows a block diagram of M66 and illustrates the major functional parts.

- Radio frequency part
- Power management
- The peripheral interface
  —Power supply
  —Turn-on/off interface
  —UART interface
  —Audio interface
  —PCM interface
  —SIM interface
  —ADC interface
  —RF interface
  —BT interface

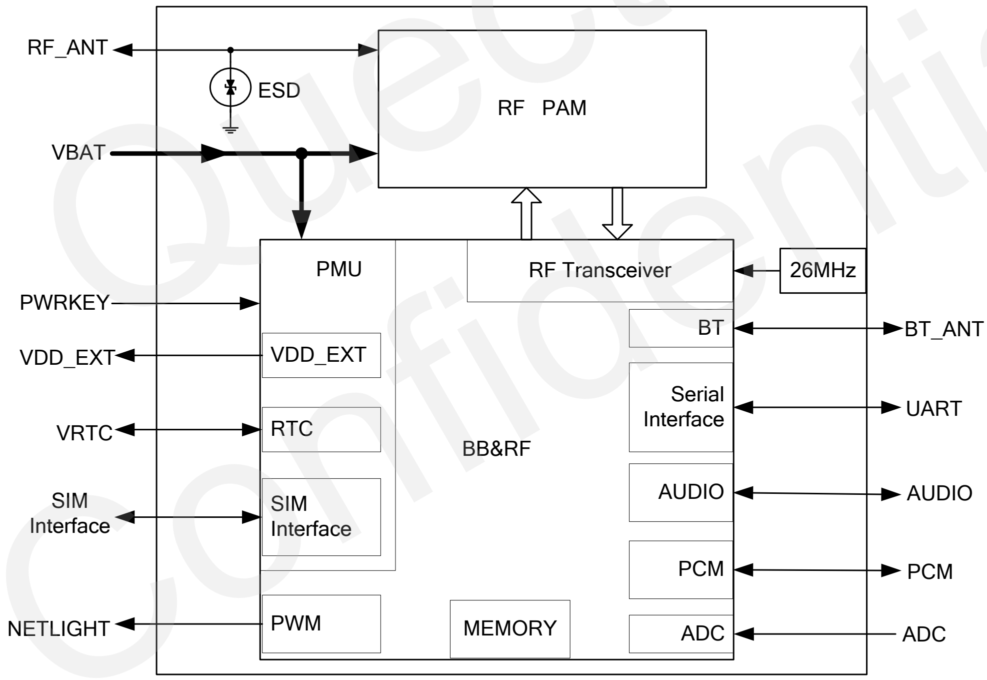

Figure 1: Module Functional Diagram

2.4. Evaluation Board

In order to help you to develop applications with M66, Quectel supplies an evaluation board (EVB), RS-232 to USB cable, power adapter, earphone, antenna and other peripherals to control or test the module. For details, please refer to the ***document [11]***.

3.1. Pin of Module

3.1.1. Pin Assignment

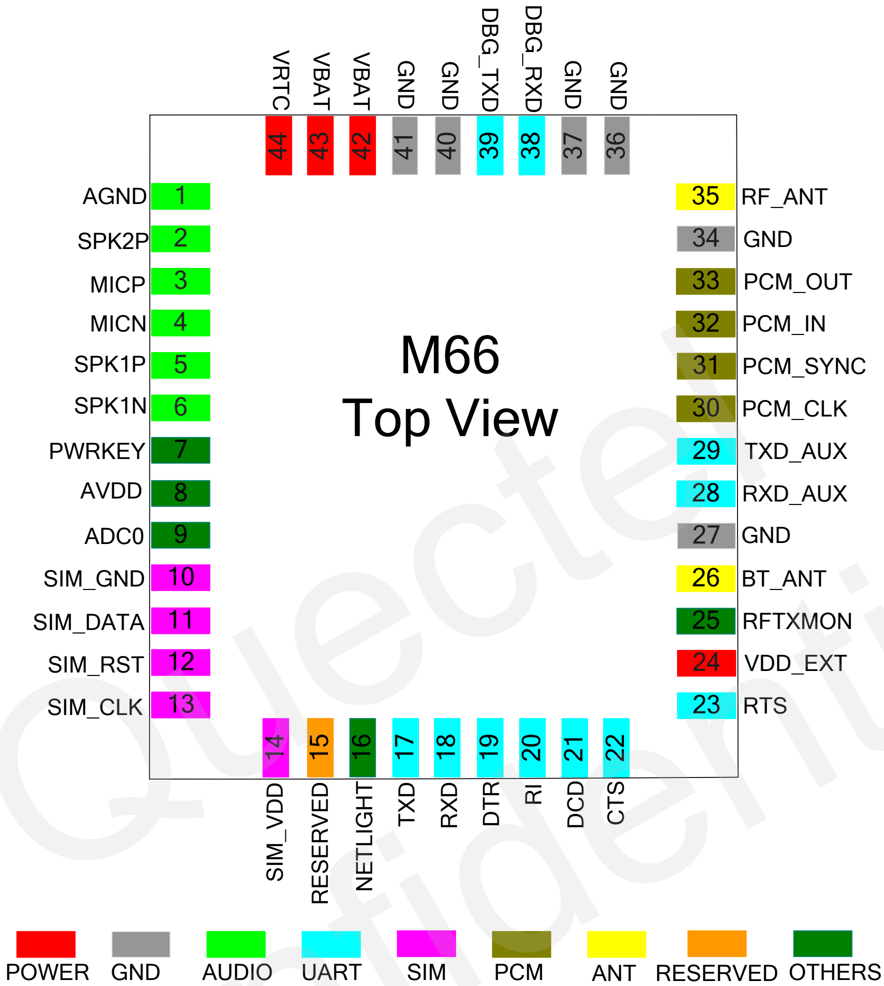

Figure 2: Pin Assignment

NOTE

Keep all reserved pins open.

3.1.2. Pin Description

Table 3: IO Parameters Definition

Type	Description
IO	Bidirectional input/output
DI	Digital input
DO	Digital output
PI	Power input
PO	Power output
AI	Analog input
AO	Analog output

Table 4: Pin Description

Power Supply					
PIN Name	**PIN No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
VBAT	42,43	PI	Main power supply of module: VBAT=3.3V~4.6V	$V_I$max=4.6V $V_I$min=3.3V $V_I$norm=4.0V	Make sure that supply sufficient current in a transmitting burst typically rises to 1.6A.
VRTC	44	IO	Power supply for RTC when VBAT is not supplied for the system. Charging for backup battery or golden capacitor when the VBAT is applied.	$V_I$max=3.3V $V_I$min=1.5V $V_I$norm=2.8V $V_O$max=3V $V_O$min=2V $V_O$norm=2.8V $I_O$max=2mA Iin≈10uA	If unused, keep this pin open.
VDD_EXT	24	PO	Supply 2.8V voltage for external circuit.	$V_O$max=2.9V $V_O$min=2.7V $V_O$norm=2.8V $I_O$max=20mA	1. If unused, keep this pin open. 2. Recommend to add a

					2.2~4.7uF bypass capacitor, when using this pin for power supply.
GND	27,34 36,37 40,41		Ground		
Turn on/off					
PIN Name	**PIN No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
PWRKEY	7	DI	Power on/off key. PWRKEY should be pulled down for a moment to turn on or turn off the system.	V_{IL}max= 0.1×VBAT V_{IH}min= 0.6×VBAT V_{IH}max=3.1V	
Audio Interface					
PIN Name	**PIN No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
MICP MICN	3, 4	AI	Positive and negative voice input		If unused, keep these pins open.
SPK1P SPK1N	5, 6	AO	Channel 1 positive and negative voice output		If unused, keep these pins open.
SPK2P	2	AO	Channel 2 voice output	Refer to Section 3.8	Support both voice and ringtone output.
AGND	1		Analog ground. Separate ground connection for external audio circuits.		If unused, keep this pin open.
Network Status Indicator					
PIN Name	**PIN No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
NETLIGHT	16	DO	Network status indication	V_{OH}min= 0.85×VDD_EXT V_{OL}max= 0.15×VDD_EXT	If unused, keep this pin open.
UART Port					
PIN Name	**PIN No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**

TXD	17	DO	Transmit data	V_{IL}min=0V V_{IL}max= 0.25×VDD_EXT V_{IH}min= 0.75×VDD_EXT V_{IH}max= VDD_EXT+0.2 V_{OH}min= 0.85×VDD_EXT V_{OL}max= 0.15×VDD_EXT	If only use TXD, RXD and GND to communicate, recommended to keep other pins open.
RXD	18	DI	Receive data		
DTR	19	DI	Data terminal ready		
RI	20	DO	Ring indication		
DCD	21	DO	Data carrier detection		
CTS	22	DO	Clear to send		
RTS	23	DI	Request to send		
Debug Port					
PIN Name	**PIN No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
DBG_ TXD	39	DO	Transmit data	Same as above	If unused, keep these pins open.
DBG_ RXD	38	DI	Receive data		
Auxiliary Port					
PIN Name	**PIN No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
TXD_ AUX	29	DO	Transmit data	Same as above	If unused, keep these pins open.
RXD_ AUX	28	DI	Receive data		
SIM Interface					
PIN Name	**PIN No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
SIM_ VDD	14	PO	Power supply for SIM card	The voltage can be selected by software automatically. Either 1.8V or 3.0V.	All signals of SIM interface should be protected against ESD with a TVS diode array. Maximum trace length is 200mm from the module pad to SIM card holder.
SIM_ CLK	13	DO	SIM clock	V_{OL}max= 0.15×SIM_VDD V_{OH}min= 0.85×SIM_VDD	
SIM_ DATA	11	IO	SIM data	V_{IL}max= 0.25×SIM_VDD V_{IH}min= 0.75×SIM_VDD V_{OL}max= 0.15×SIM_VDD V_{OH}min= 0.85×SIM_VDD	

SIM_ RST	12	DO	SIM reset	V_{OL}max= 0.15×SIM_VDD V_{OH}min= 0.85×SIM_VDD	
SIM_ GND	10		SIM ground		
ADC					
PIN Name	**PIN No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
AVDD	8	PO	Reference voltage of ADC circuit	$V_O$max=2.9V $V_O$min=2.7V $V_O$norm=2.8V	If unused, keep this pin open.
ADC0	9	AI	General purpose analog to digital converter.	Voltage range: 0V to 2.8V	If unused, keep this pin open.
PCM					
PIN Name	**PIN No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
PCM_ CLK	30	DO	PCM clock	V_{IL}min= 0V V_{IL}max= 0.25×VDD_EXT V_{IH}min= 0.75×VDD_EXT V_{IH}max= VDD_EXT+0.2 V_{OH}min= 0.85×VDD_EXT V_{OL}max= 0.15×VDD_EXT	If unused, keep this pin open.
PCM_ SYNC	31	DO	PCM frame synchronization		
PCM_ IN	32	DI	PCM data input		
PCM_ OUT	33	DO	PCM data output		
Antenna Interface					
PIN Name	**PIN No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
RF_ ANT	35	IO	GSM antenna pad	Impedance of 50Ω	
BT_ ANT	26	IO	BT antenna pad	Impedance of 50Ω	If unused, keep this pin open.
Transmitting Signal Indication					
PIN Name	**PIN No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
RFTXMON	25	DO	Transmission signal indication	V_{OH}min= 0.85×VDD_EXT V_{OL}max=	If unused, keep this pin open.

				0.15×VDD_EXT	
Other Interface					
PIN Name	**PIN No.**	**I/O**	**Description**	**DC Characteristics**	**Comment**
RESERVED	15				Keep these pins open.

3.2. Operating Modes

The table below briefly summarizes the various operating modes in the following chapters.

Table 5: Overview of Operating Modes

Mode	Function	
Normal Operation	GSM/GPRS Sleep	After enabling sleep mode by **AT+QSCLK=1**, the module will automatically enter into Sleep Mode if DTR is set to high level and there is no interrupt (such as GPIO interrupt or data on UART port). In this case, the current consumption of module will reduce to the minimal level. During Sleep Mode, the module can still receive paging message and SMS from the system normally.
	GSM IDLE	Software is active. The module has registered to the GSM network, and the module is ready to send and receive GSM data.
	GSM TALK	GSM connection is ongoing. In this mode, the power consumption is decided by the configuration of Power Control Level (PCL), dynamic DTX control and the working RF band.
	GPRS IDLE	The module is not registered to GPRS network. The module is not reachable through GPRS channel.
	GPRS STANDBY	The module is registered to GPRS network, but no GPRS PDP context is active. The SGSN knows the Routing Area where the module is located at.
	GPRS READY	The PDP context is active, but no data transfer is ongoing. The module is ready to receive or send GPRS data. The SGSN knows the cell where the module is located at.
	GPRS DATA	There is GPRS data in transfer. In this mode, power consumption is decided by the PCL, working RF band and GPRS multi-slot configuration.

POWER DOWN	Normal shutdown by sending the **AT+QPOWD=1** command or using the PWRKEY pin. The power management ASIC disconnects the power supply from the base band part of the module, and only the power supply for the RTC is remained. Software is not active. The UART interfaces are not accessible. Operating voltage (connected to VBAT) remains applied.
Minimum Functionality Mode (without removing power supply)	**AT+CFUN** command can set the module to a minimum functionality mode without removing the power supply. In this case, the RF part of the module will not work or the SIM card will not be accessible, or both RF part and SIM card will be disabled, but the UART port is still accessible. The power consumption in this case is very low.

3.3. Power Supply

3.3.1. Power Features of Module

The power supply is one of the key issues in designing GSM terminals. Because of the 577us radio burst in GSM every 4.615ms, power supply must be able to deliver high current peaks in a burst period. During these peaks, drops on the supply voltage must not exceed minimum working voltage of module.

For the M66 module, the max current consumption could reach to 1.6A during a burst transmission. It will cause a large voltage drop on the VBAT. In order to ensure stable operation of the module, it is recommended that the max voltage drop during the burst transmission does not exceed 400mV.

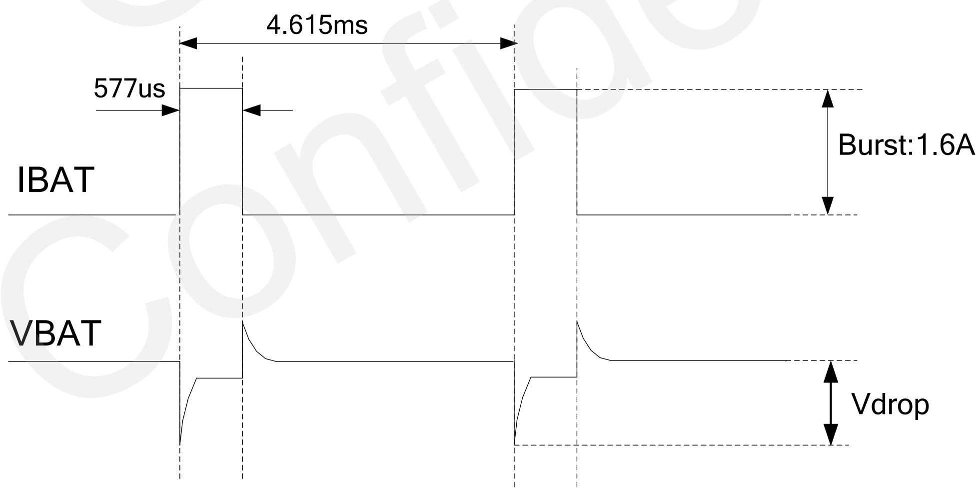

Figure 3: Voltage Ripple during Transmitting

5 Electrical, Reliability and Radio Characteristics

5.1. Absolute Maximum Ratings

Absolute maximum ratings for power supply and voltage on digital and analog pins of module are listed in the following table:

Table 29: Absolute Maximum Ratings

Parameter	Min.	Max.	Unit
VBAT	-0.3	+4.73	V
Peak Current of Power Supply	0	2	A
RMS Current of Power Supply (during one TDMA- frame)	0	0.7	A
Voltage at Digital Pins	-0.3	3.08	V
Voltage at Analog Pins	-0.3	3.08	V
Voltage at Digital/analog Pins in Power Down Mode	-0.25	0.25	V

5.2. Operating Temperature

The operating temperature is listed in the following table:

Table 30: Operating Temperature

Parameter	Min.	Typ.	Max.	Unit
Normal Temperature	-35	+25	+80	℃

7.3.1. Tape and Reel Packaging

The reel is 330mm in diameter and each reel contains 250 modules.

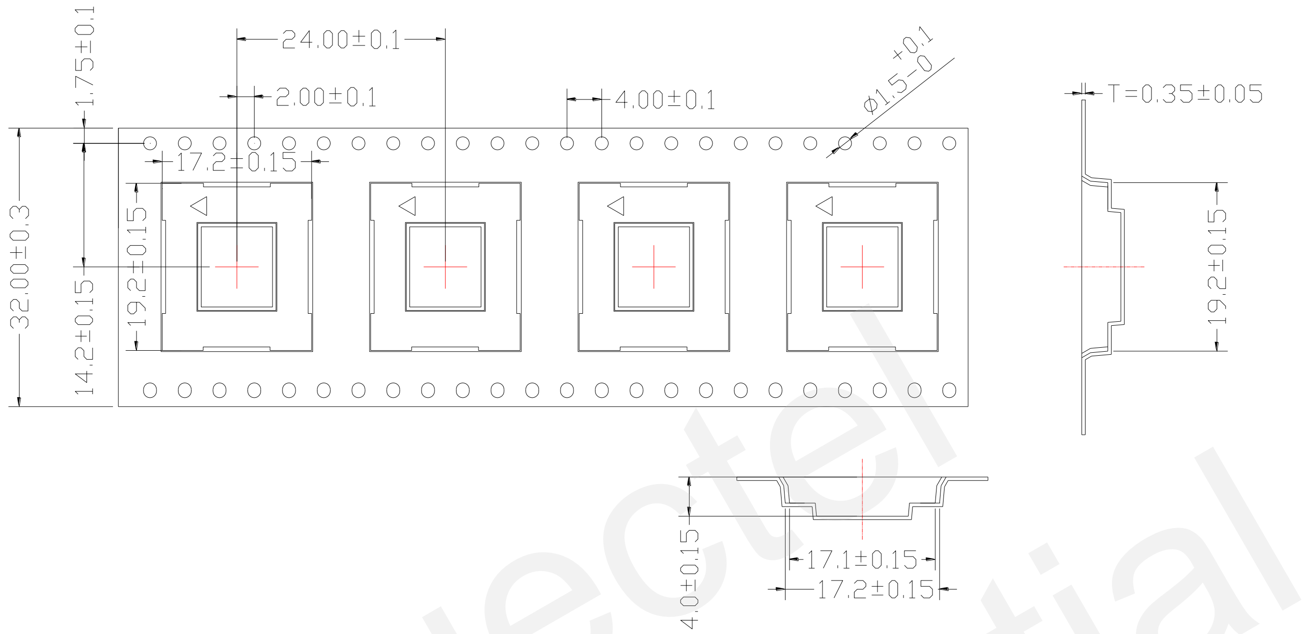

Figure 49: Tape and Reel Specification

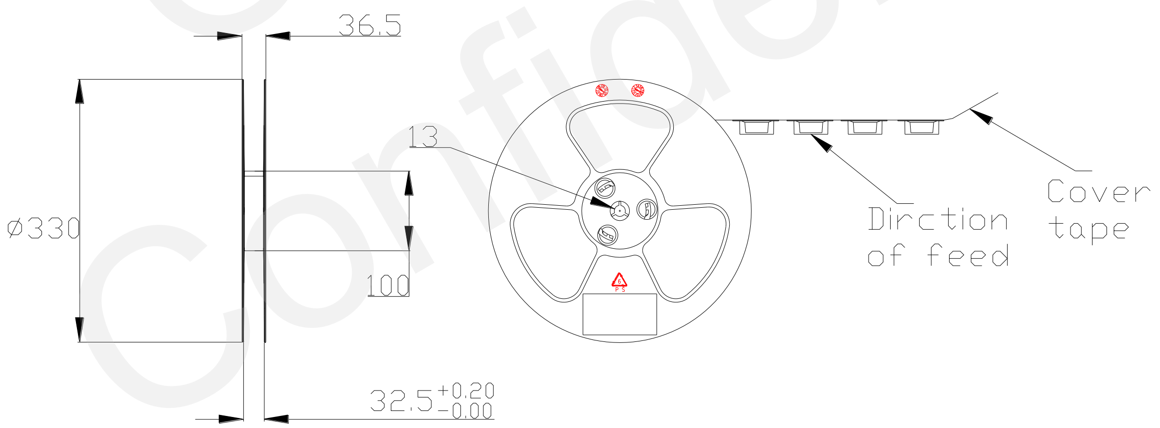

Figure 50: Dimensions of Reel