UNIVERSITY OF COLOMBO

BSc. in Electronics and Automation Technologies: Level III

SAR BEACON

An IoT-based Search and rescue Device

PROJECT REPORT

EA3160

22SEA028 - KANISHKA ISURU GANGULAL

1 Declaration

I certify that this dissertation does not incorporate without acknowledgement, any material previously submitted for a degree or Diploma in any university and to the best of my knowledge and belief it does not contain any material previously published or written or oral communicated by other person except where due reference is made in the text.

....

D.P.L.K.I. Gangulal

2 Acknowledgment

I have taken great efforts in this project; however, it would not have been possible without the kind support and help of numerous individuals and organizations. I would like to extend my heartfelt gratitude to all who contributed to the successful completion of this endeavour.

I am deeply indebted to Dr. Hiran Jayaweera, Mr. Deshitha Wickramarathna, and Mr. Gayan Akmeemana for their invaluable guidance, constant supervision, and expert insights. Their encouragement and support throughout this project have been instrumental in its successful completion. I am sincerely grateful for the knowledge and direction they provided during every stage of the development.

I would like to express my deepest gratitude to my parents and family members for their unwavering support, encouragement, and cooperation. Their belief in my abilities and motivation has been a driving force in completing this project.

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Finally, my sincere thanks and appreciation go to my colleagues, whose collaboration and shared efforts have been crucial in bringing this project to fruition. I am also thankful to everyone who willingly extended their help and abilities to support the successful completion of this project.

3 Abstract

The IoT-Based SAR Beacon with GPS, Health Monitoring, LoRa Communication, SMS Alerts, and Firebase Integration for Trekkers' Safety is an innovative technology designed to enhance the safety of outdoor enthusiasts, particularly trekkers and adventurers, in remote environments. By leveraging the Internet of Things (IoT), this system enables real-time health monitoring, precise location tracking, and reliable communication, which are critical during search and rescue (SAR) operations. The integration of these features allows for timely responses to emergencies, making it a notable advancement in the field of personal safety devices.

The significance of this technology lies in its comprehensive approach to safety and emergency management. Traditional SAR methods often struggle with communication breakdowns and delayed response times, particularly in remote areas lacking cellular infrastructure. The IoT-based beacon addresses these issues by utilizing LoRa (Long Range) communication for long-distance connectivity and providing health monitoring capabilities to assess trekkers' conditions in real-time. These functionalities not only empower individuals to seek help quickly but also enhance the efficiency of rescue teams by providing them with critical information about the individual's health and location.[1][2].

Prominent features of the IoT-based SAR beacon include continuous monitoring of vital health metrics through integrated sensors, GPS for accurate location tracking, and the ability to send SMS alerts in emergencies. Additionally, the system's compatibility with cloud-based platforms, such as Firebase, facilitates real-time data management and remote access for healthcare professionals and rescue teams.[3][4]. While the technology shows great promise in improving safety for trekkers, it also faces challenges, including infrastructure limitations in remote areas, potential cybersecurity vulnerabilities, and the need for user training to effectively utilize the system in emergency situations.[5][6].

As outdoor activities continue to grow in popularity, the development of such advanced safety solutions is increasingly critical. The IoT-Based SAR Beacon exemplifies the intersection of technology and safety, setting a precedent for future innovations in emergency response and personal safety devices in outdoor recreation.[7][8].

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6 Introduction

6.1 Background

Outdoor recreational activities such as trekking and mountaineering have gained significant popularity over the years. However, the inherent risks of these activities including unpredictable weather, rough terrain, and limited connectivity pose serious safety challenges for trekkers and adventurers. Search and rescue (SAR) operations in such environments often rely on traditional tools like radio communication, handheld GPS devices, and visual searches, which can be time-consuming and ineffective in emergencies.

Technological advancements on the Internet of Things (IoT) and wireless communication have opened new opportunities to enhance SAR systems. IoT-based devices, equipped with GPS tracking, health monitoring sensors, and long-range communication technologies, provide critical real-time information to rescuers, improving the effectiveness of rescue operations. This project introduces the **SAR Beacon**, an IoT-based solution that combines GPS tracking, health monitoring, LoRa communication, and SMS alert systems to address the challenges of modern search and rescue operations.

6.2 Objectives

This project aims to:

- Develop a robust system capable of real-time GPS tracking and health monitoring for trekkers.
- Integrate long-range, low-power LoRa communication to transmit data effectively over extended distances.
- Incorporate an SMS alert mechanism using the SIM7600 GSM module for emergency notifications in low-connectivity areas.
- Store and visualize real-time data on Firebase for accessibility by rescue teams.
- Design a portable, user-friendly, and energy-efficient solution for SAR applications.

6.3 Scope

The SAR Beacon integrates advanced IoT components into a single system capable of operating in remote environments. Its transmitter unit collects data from sensors and transmits it using LoRa, while the receiver relays the data to Firebase for real-time access by rescue teams.

7 Literature Review

7.1 IoT in Emergency Management

IoT has significantly transformed emergency management systems by enabling the collection, processing, and transmission of real-time data. IoT devices, equipped with sensors and communication modules, facilitate faster decision-making and improve the efficiency of SAR operations. According to IIETA's study on IoT-based smart health monitoring systems [1], IoT technologies allow for seamless integration of health data and location tracking, which is crucial in life-saving situations. Emerging solutions, such as IoT-enabled drones and wearables, have further improved SAR operations by enhancing the speed and accuracy of rescue missions [5][21].

7.2 LoRa Communication

LoRa (Long Range) communication has emerged as a preferred choice for IoT applications due to its low power consumption and extended range. Studies have shown that LoRa can achieve reliable communication over several kilometres, even in challenging terrains like mountains and forests [16]. LoRa operates on unlicensed radio frequency bands, making it an affordable and scalable solution for SAR systems [18]. For instance, a LoRa-based emergency assistance system was successfully implemented to provide safety in remote areas, demonstrating its potential for enhancing SAR technologies [15][16].

7.3 GPS Technology

GPS technology plays a critical role in modern SAR operations by providing accurate and real-time location data. GPS-enabled IoT devices allow rescuers to locate individuals quickly, reducing response times and increasing the chances of survival. A survey by TrackoBit highlighted how IoT is improving GPS tracking and location-based services [3]. In addition, advancements in satellite communication have enhanced GPS accuracy in remote and obstructed environments [23]. Research from Sartech also emphasizes the importance of personal locator beacons in improving SAR effectiveness [4]. The integration of GPS with health monitoring systems ensures a holistic approach to SAR operations, as both location and medical conditions are considered during rescue missions [5][6].

7.4 Health Monitoring Sensors

Health monitoring sensors, such as pulse oximeters and heart rate sensors, have become increasingly popular in IoT-based healthcare and safety systems. The MAX30100 sensor, used in this project, is a widely adopted solution for non-invasive health monitoring. Studies have demonstrated the accuracy and reliability of such sensors in tracking vital signs, making them suitable for emergency response systems [10][11]. Additionally, iSmarch's LoRa GPS smartwatches have highlighted the potential of integrating real-time health monitoring with SAR technologies [17]. Integrating health data with location tracking allows rescue teams to assess the condition of individuals in real-time, enabling them to prioritize critical cases [8][9].

7.5 SMS Alerts in IoT Systems

In SAR operations, reliable communication is critical. While internet-based platforms provide robust solutions for data visualization, areas with limited connectivity require alternative methods such as SMS alerts. GSM modules, like the SIM7600, enable devices to send text messages over cellular networks, ensuring that emergency notifications reach rescuers even in remote locations [12][13]. This feature has proven invaluable in SAR systems, where quick communication can mean the difference between life and death [22][24].

8 Theory

8.1 LoRa Communication Principles

LoRa (Long Range) communication is a wireless data transmission technology designed specifically for low-power, long-distance communication in IoT applications. It operates on unlicensed radio frequency bands, such as 868 MHz in Europe and 915 MHz in North America, allowing it to function without regulatory licensing costs. LoRa employs **Chirp Spread Spectrum (CSS)** modulation, which spreads data over a wide frequency range, making it highly resistant to interference and noise.

The key advantage of LoRa lies in its ability to achieve communication over several kilometres while maintaining low power consumption. Its robust signal propagation enables reliable performance even in obstructed environments, such as dense forests or mountainous regions, where traditional communication methods fail. This makes LoRa ideal for SAR systems that require reliable connectivity in remote, infrastructure-limited areas. Moreover, LoRa supports bi-directional communication, ensuring that both data transmission and acknowledgment are possible, improving reliability in critical operations [15][16][18].

8.2 GPS and Health Monitoring Integration

The integration of GPS technology and health monitoring systems forms the backbone of the SAR Beacon's functionality. The GPS module (such as Neo-6M) determines the precise location of the user by calculating signals received from multiple satellites. This process, known as **trilateration**, ensures accurate latitude, longitude, and altitude data, which is critical for rescuers to pinpoint the trekker's location in real time.

Health monitoring is achieved through the MAX30100 sensor, which measures **heart rate** and **blood oxygen levels (SpO2)** using photoplethysmography (PPG). The sensor emits infrared and red light into the skin and measures the reflected light to calculate blood flow and oxygen saturation. Combining this health data with GPS coordinates provides a holistic overview of the trekker's condition, enabling rescuers to prioritize responses based on both location and medical emergencies.

The seamless integration of GPS and health sensors is managed by the microcontroller (ESP32), which processes the data and transmits it over LoRa to the receiver. This integration ensures real-time tracking and health analysis, enhancing the efficiency and effectiveness of search and rescue operations [3][6][8].

8.3 SMS Alert Mechanism

The SIM7600 module facilitates the transmission of SMS alerts, ensuring that critical emergency notifications are delivered even in areas with limited or no internet connectivity. The module operates on Global System for Mobile Communications (GSM) networks, enabling text-based communication over cellular infrastructure. In the SAR Beacon, the SIM7600 is programmed to trigger an SMS alert when predefined emergency conditions are met, such as abnormal heart rate readings, low SpO2 levels, or a distress signal from the user.

The SMS alert contains vital information, including:

- GPS coordinates (latitude and longitude) for precise location tracking.
- Health data (heart rate and SpO2 levels) to assess the user's condition.
- A predefined emergency message indicating the need for immediate assistance.

This mechanism ensures that rescuers or emergency contacts receive critical information in a timely manner, enabling quick decision-making and response. The reliability of GSM networks, combined with the simplicity of SMS, makes this feature invaluable in remote environments where alternative communication systems may be unavailable or unreliable [12][13][22].

9 Materials and Methods

9.1 System Components

The SAR Beacon system comprises hardware and software components that work together to collect, transmit, and visualize data in real time.

Transmitter Unit:

- **ESP32**: Serves as the central microcontroller, managing data collection and communication.
- **Neo-6M GPS Module**: Provides precise latitude and longitude for location tracking.
- **LoRa RA-02 Module**: Enables low-power, long-range communication between the transmitter and receiver.
- **MAX30100 Sensor**: Measures heart rate and SpO2 to monitor user health.
- **LiPo Battery**: Powers the transmitter unit, ensuring portability and extended operation.

Figure 9-1 - Transmitter Device

Receiver Unit:

- **ESP32**: Receives data transmitted via LoRa and processes it for storage or alerts.
- **SIM7600 GSM Module**: Sends data to my website via google firebase and sends SMS alerts to pre-defined contacts during emergencies.
- **Firebase & Website**: A cloud-based platform for storing and GPS and health data. WordPress website hosted in server for visualising above data.

Figure 9-2 - Receiver Device

9.2 Workflow

The operation of the SAR Beacon system follows these key steps:

1. **Data Acquisition**: Sensors collect health (SpO2, heart rate) and GPS location data.
2. **Data Transmission**: The transmitter sends collected data via LoRa to the receiver unit.
3. **Cloud Integration**: The receiver processes and uploads the data to website through Google Firebase for real-time monitoring.
4. **SMS Alerts**: The SIM7600 module triggers SMS alerts when abnormal conditions are detected.

9.3 Visualization: "sarbeacon.infinityfreeapp.com" platform displays data for rescuers to analyse.

9.4 Hardware Design

The hardware design prioritizes **portability, power efficiency, and durability**. Compact PCBs, low-power modules, and a LiPo battery ensure prolonged operation in remote areas. The modular design allows for easy maintenance and upgrades [11][14].

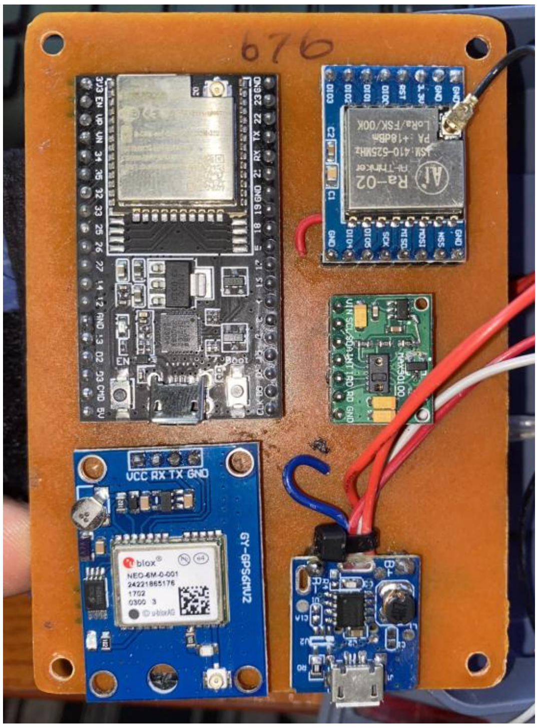


Figure 9-4 - Transmitter PCB Top Layer

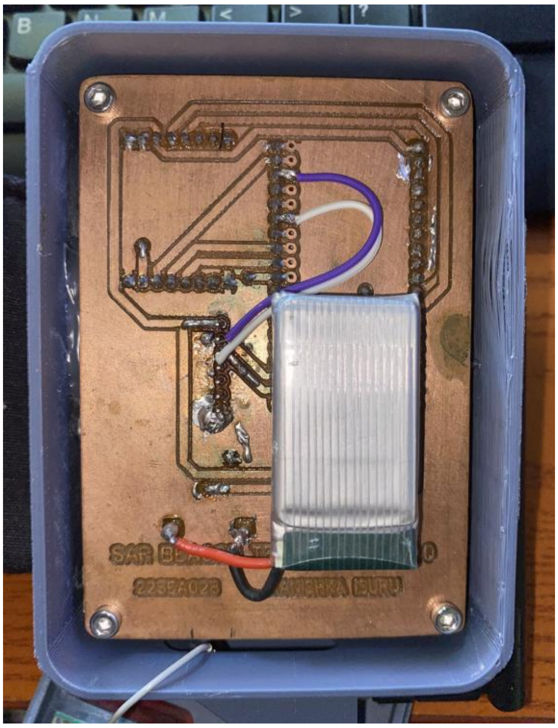


Figure 9-3 - Transmitter PCB Bottom Layer

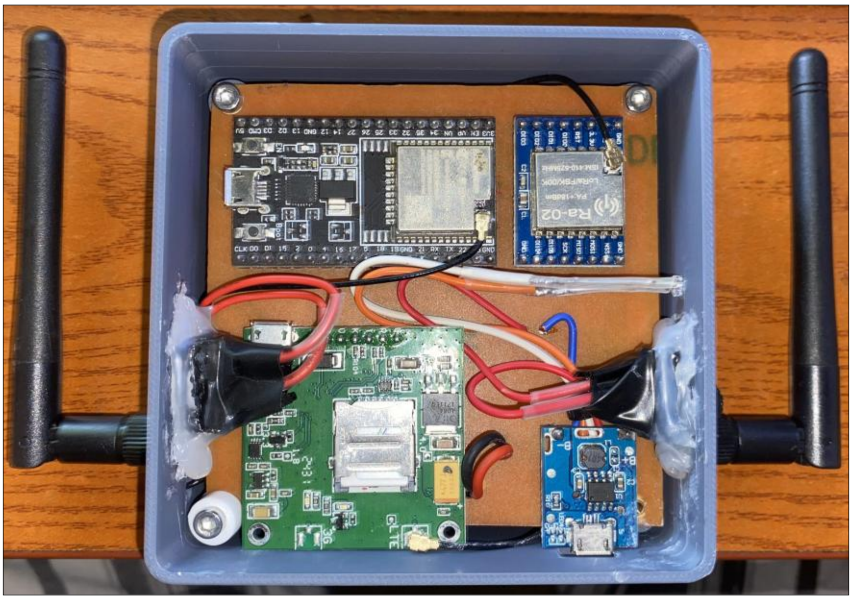


Figure 9-5 - Receiver PCB Top Layer

10 Results and Evaluation

10.1 System Performance

1. **LoRa Range**: Field tests demonstrated reliable communication up to 3 kilometres in open areas, with performance dropping slightly in obstructed terrains.
2. **Sensor Accuracy**: The MAX30100 sensor reported heart rate and SpO2 values with an accuracy margin of ±2% compared to standard medical devices.
3. **Battery Efficiency**: The system achieved over 12 hours of continuous operation on a single LiPo charge.

10.2 Data Visualization

Real-time data was visualized seamlessly on my website, with minimal latency and accurate GPS coordinates. Graphs showing health trends were easily accessible to rescuers.

10.3 Challenges Addressed

1. **Signal Interference**: Adjustments to LoRa parameters improved signal resilience.
2. **Power Consumption**: Implementing sleep modes for ESP32 extended battery life.

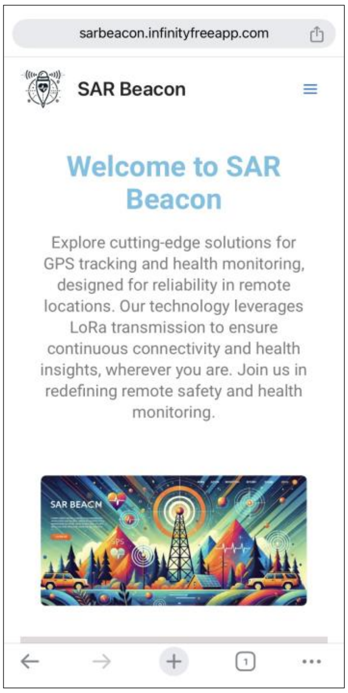


Figure 10-1 - Home page 1

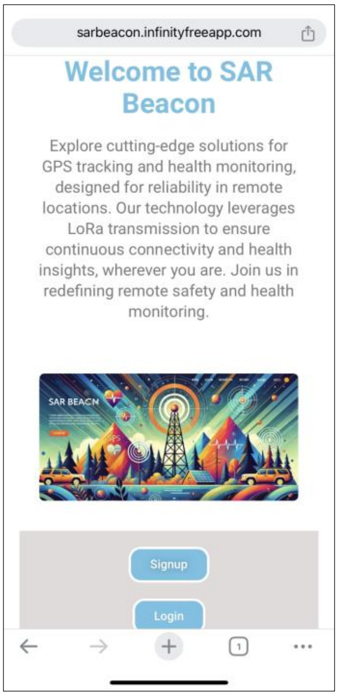


Figure 10-2 - Home page 2

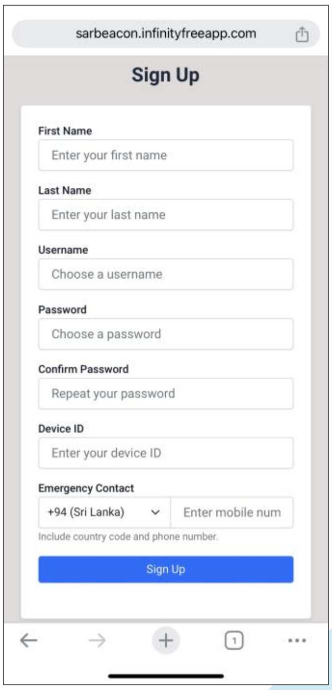


Figure 10-3 - Signup page

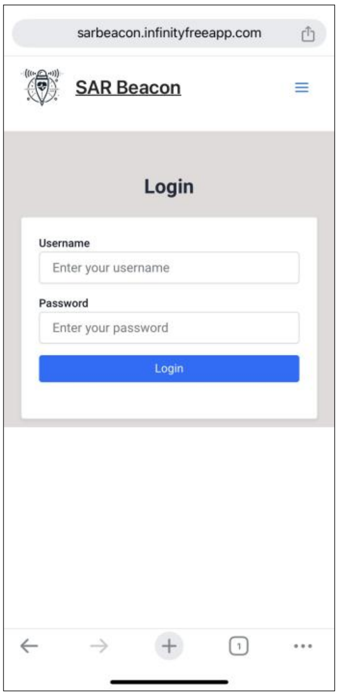


Figure 10-4 - Login page

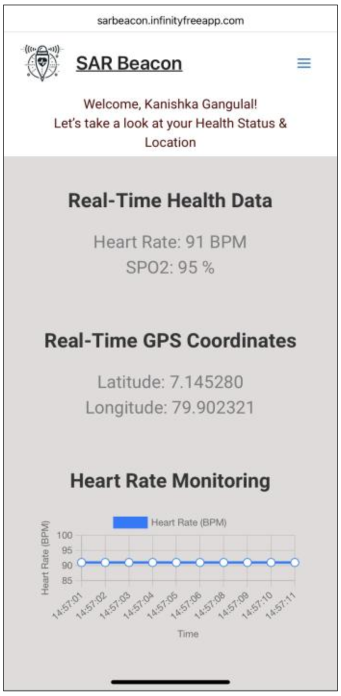


Figure 10-5 - Device data 1

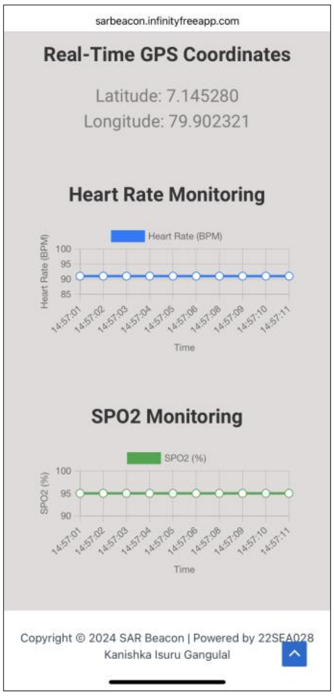


Figure 10-6 - Device data 2

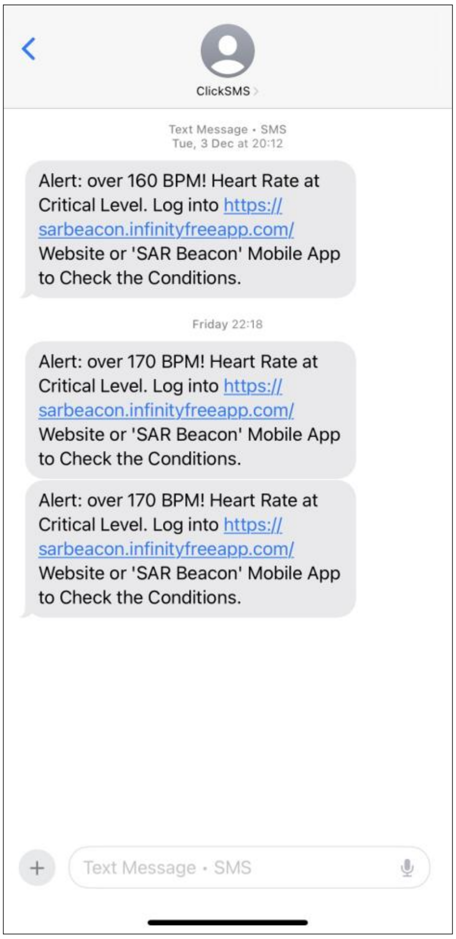


Figure 10-7 - SMS Alert

11 Discussion

The SAR Beacon system offers significant advantages for trekkers and rescuers alike. By integrating GPS, health monitoring, LoRa communication, and SMS alerts, the system provides a reliable and comprehensive safety solution. **Real-time data availability** allows rescuers to act quickly, while SMS alerts ensure critical information is delivered even without internet access.

Challenges faced during implementation included optimizing LoRa range in obstructed environments and reducing power consumption. These were mitigated through hardware adjustments and sleep-mode configurations. Future improvements may include integrating **AI for anomaly detection**, satellite-based communication for greater range, and wearable form factors for enhanced usability.

12 Conclusion

The SAR Beacon is an innovative IoT-based system designed to enhance safety for trekkers in remote regions. By combining GPS location tracking, health monitoring, long-range communication, and emergency alerts, it addresses critical challenges faced in search and rescue operations. The system's real-time monitoring capabilities, efficient power management, and modular design demonstrate its viability as a reliable safety solution. Future developments can focus on expanding its range, improving user experience, and leveraging advanced technologies for predictive analytics.

13 References

[1] O. N. B. S. M. Robertas Damaševičius, "From Sensors to Safety: Internet of Emergency Services (IoES) for Emergency Response and Disaster Management," 16 May 2023. [Online]. Available: https://www.mdpi.com/2224-2708/12/3/41.

[2] K. T. H. O. A. A. F. A. Abdikarim Abi Hassan, "IoT-Based Smart Health Monitoring System: Investigating the Role of Temperature, Blood Pressure and Sleep Data in Chronic Disease Management," 27 December 2023. [Online]. Available: https://iieta.org/journals/i2m/paper/10.18280/i2m.220602.

[3] D. Bhandari, "How IoT is Improving GPS Tracking and Location-based Service," 4 July 2023. [Online]. Available: https://trackobit.com/blog/iot-improving-gps-tracking-and-location-based-service.

[4] "Which Emergency Beacon?," [Online]. Available: https://sartech.com/which-emergency-beacon/.

[5] "A Look at Drones in Search and Rescue: Finding Hope from Above," 18 July 2024. [Online]. Available: https://www.thedroneu.com/blog/drones-in-search-and-rescue/.

[6] M. A. R. A. S. A. U. K. A. T. A. H. T. S. A. B. Md Munirul Hasan, "Search and rescue operation in flooded areas: A survey on emerging sensor networking-enabled IoT-oriented technologies and applications," June 2021. [Online]. Available: https://research.monash.edu/en/publications/search-and-rescue-operation-in-flooded-areas-a-survey-on-emerging.

[7] K. Murphy, "NASA Search and Rescue Technologies Saved Hundreds in 2020," 26 January 2021. [Online]. Available: https://esc.gsfc.nasa.gov/news/NASA_Search_and_Rescue_Technologies_Saves_Hundreds_in_2020.

[8] "Improved Search and Rescue with wrist-worn Personal Locator Beacons," 31 January 2018. [Online]. Available: https://cordis.europa.eu/article/id/231914-improved-search-and-rescue-with-wristworn-personal-locator-beacons.

[9] "How IoT in Healthcare is Transforming Patient Monitoring Systems," 16 October 2024. [Online]. Available: https://www.smartdatainc.com/knowledge-hub/how-iot-in-healthcare-is-transforming-patient-monitoring-systems/.

[10] M. M. I. M. R. I. M. S. S. S. N. Ashikur Rahaman, "Developing IoT Based Smart Health Monitoring Systems: A Review," 30 December 2019. [Online]. Available: https://iieta.org/journals/ria/paper/10.18280/ria.330605.

[11] S. D. S. F. I. d. l. T. D. ,. J. B. J. C. M. E. Imran Shafi, "Design and development of patient health tracking, monitoring and big data storage using Internet of Things and real time cloud computing," 11 March 2024. [Online]. Available: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0298582.

[12] "Iot based health monitoring system," 30 April 2020. [Online]. Available: https://www.slideshare.net/slideshow/iot-based-health-monitoring-system/232909585.

[13] L. C. N. C. A. R. J. B. A. P. Daniel Fuentes, "SAR.IoT: Secured Augmented Reality for IoT Devices Management," 07 September 2021. [Online]. Available: https://www.mdpi.com/1424-8220/21/18/6001.

[14] K. I. K. G. A. V. Andreas Soularidis, "Real-Time Semantic Data Integration and Reasoning in Life- and Time-Critical Decision Support Systems," 28 January 2024. [Online]. Available: https://www.mdpi.com/2079-9292/13/3/526.

[15] R. R. R. T. C. D. R. Deeksha Rai Sharma, "LoRa-Based IoT System for Emergency Assistance and Safety in Mountaineering," 30 July 2023. [Online]. Available: https://iieta.org/journals/ijsse/paper/10.18280/ijsse.130311.

[16] G. M. Bianco, "Radio wave propagation of LoRa systems in mountains for Search and Rescue operations," 2020. [Online]. Available: https://www.academia.edu/71045126/Radio_wave_propagation_of_LoRa_systems_in_mountains_for_Search_and_Rescue_operations.

[17] "Transforming Healthcare with Cutting-Edge Lora and GPS-Enabled Smartwatches," [Online]. Available: https://ismarch.com/lora-smartwatch-for-healthcare/.

[18] "What Is LoRaWAN? A Complete Guide For Businesses & LoT Solutions," 25 October 2024. [Online]. Available: https://www.minew.com/what-is-lorawan/.

[19] B. L. G. P. J. Y. N. P. Akash Sunar, "Trek Monitoring System: Enhancing Safety and Adventure in the Outdoors using Arduino UNO and NodeMCU," September 2023. [Online]. Available: https://irojournals.com/iroei/article/view/5/3/1.

[20] G. R. S. Silvia Liberata Ullo, "Advances in Smart Environment Monitoring Systems Using IoT and Sensors," 31 May 2020. [Online]. Available: https://www.mdpi.com/1424-8220/20/11/3113.

[21] Z. Dukowitz, "Search and Rescue Drones: A Guide to How SAR Teams Use Drones in Their Work," 14 June 2024. [Online]. Available: https://uavcoach.com/search-and-rescue-drones/.

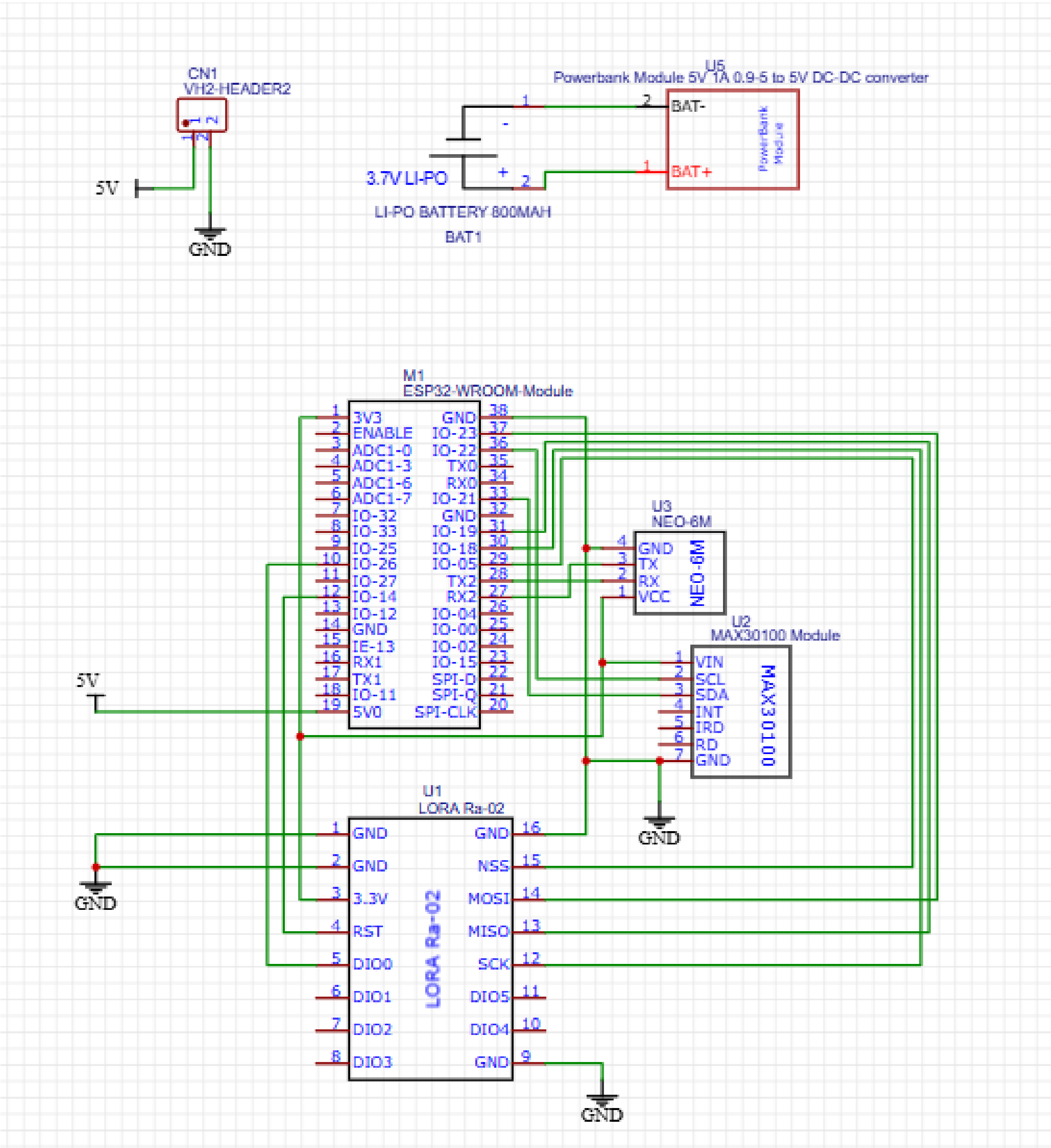
[22] A. A. G. T. N. M. Leonardo Militano, "The Cloud-to-Edge-to-IoT Continuum as an Enabler for Search and Rescue Operations," 30 January 2023. [Online]. Available: https://www.mdpi.com/1999-5903/15/2/55.

[23] D. B. Madison Olson, "NASA Develops Second-Generation Search and Rescue Beacon Technology," 02 December 2019. [Online]. Available: https://www.nasa.gov/missions/artemis/nasa-develops-second-generation-search-and-rescue-beacon-technology/.

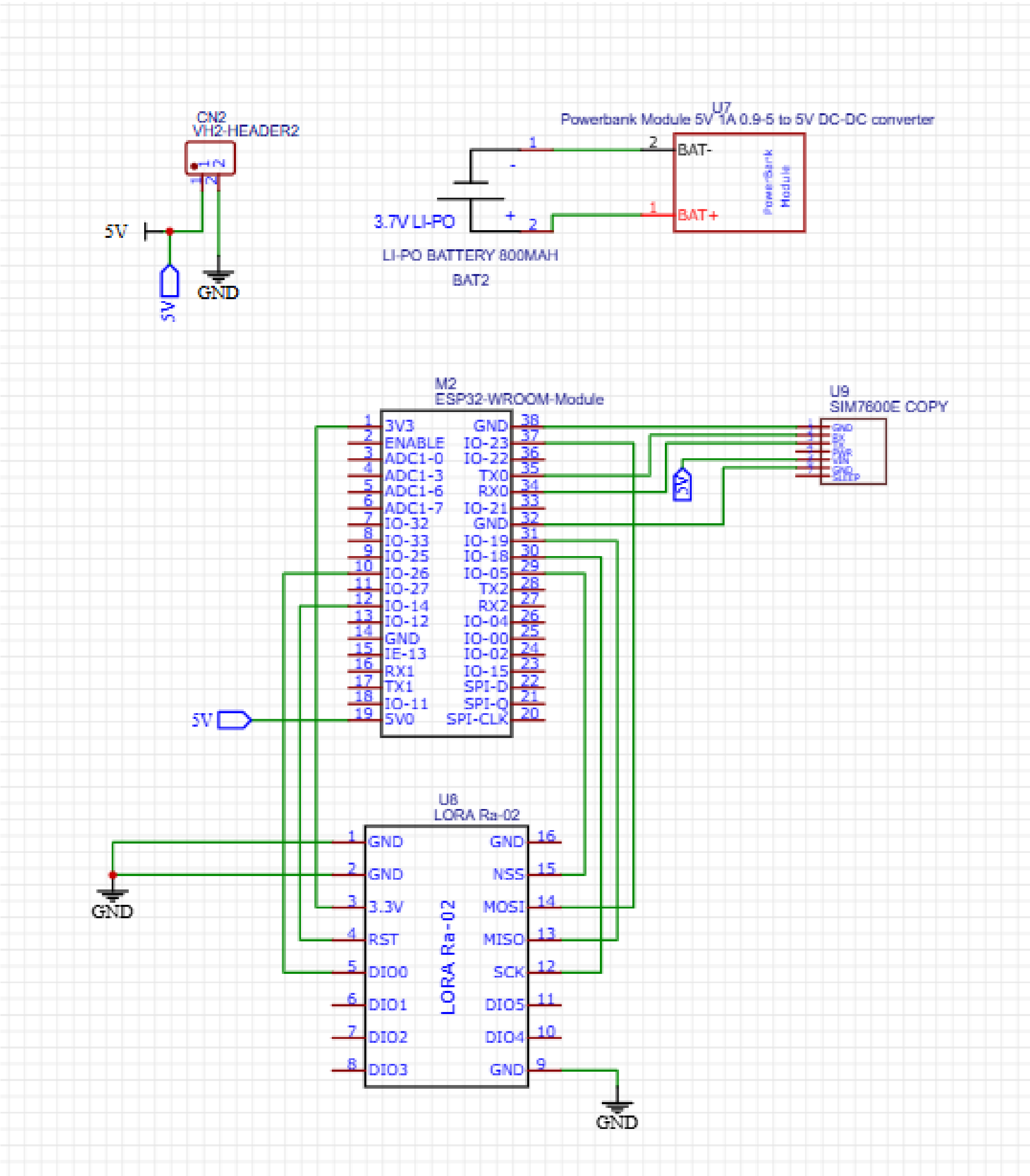
[24] "Have beacons taken the 'search' out of land-based search and rescue?," 27 November 2024. [Online]. Available: https://nzsar.govt.nz/news/have-beacons-taken-the-search-out-of-land-based-search-and-rescue.

14 Appendices

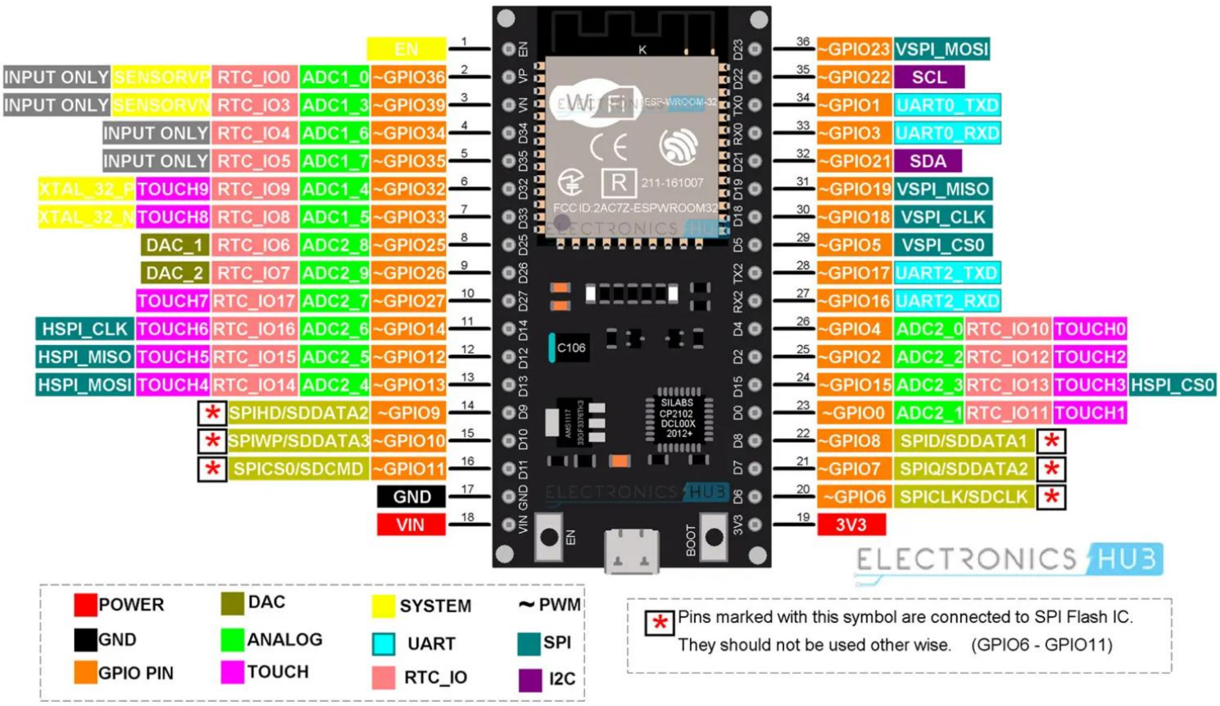
14.1 Appendix A: Transmitter Schematic Diagram



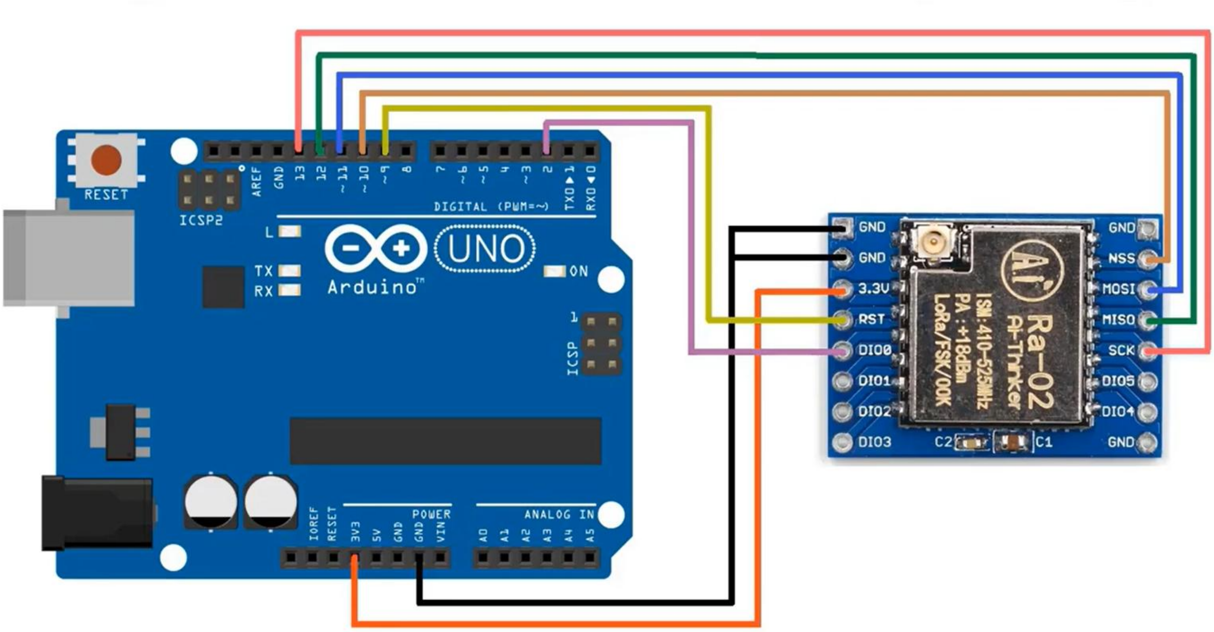
14.2 Appendix B: Receiver Schematic Diagram



14.3 Appendix C: ESP32 WROOM 32U Pinout



14.4 Appendix D: LoRa wiring Connection

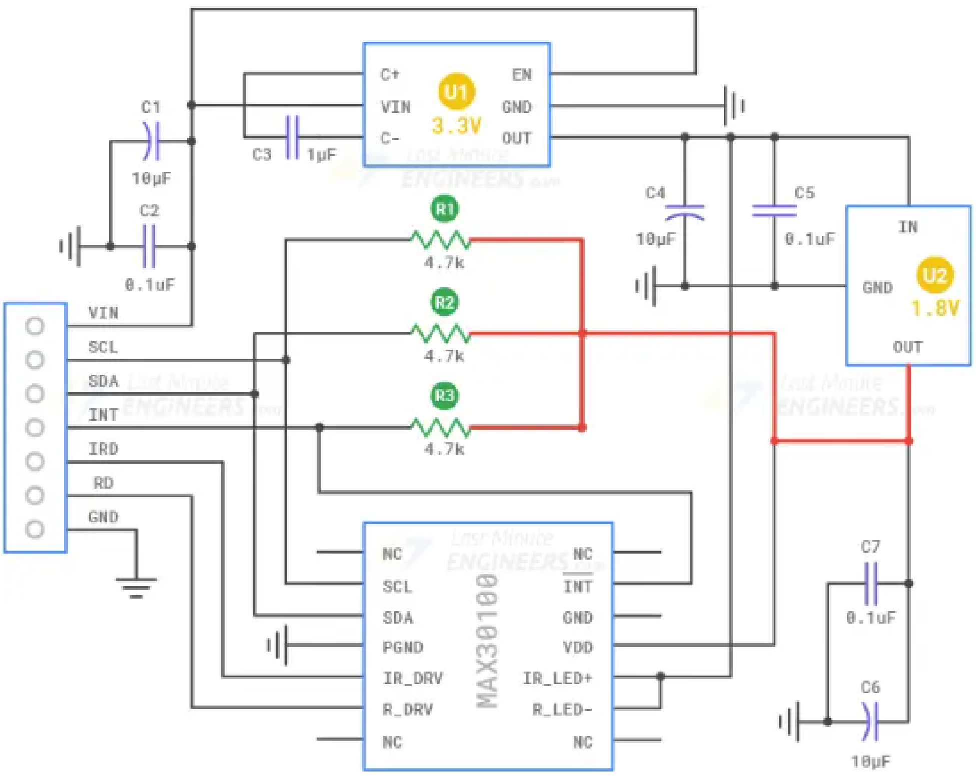


14.5 Appendix E: Solution for MAX30100 not working

The Problem

The MAX30100 chip requires two different supply voltages: 1.8V for the IC and 3.3V for the RED and IR LEDs. So the module comes with two linear voltage regulators – U1 and U2. The first generates 5V to 3.3V. The second regulator is connected to the output of the first and generates 1.8V.

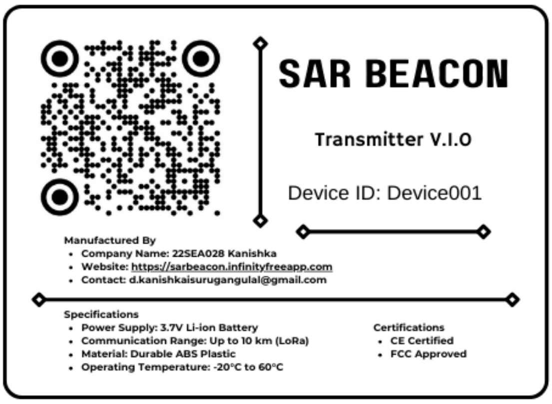
Now take a closer look at the 4.7kΩ pull-up resistors (R1, R2 and R3) for the SCL, SDA and INT signal lines. They are connected to the 1.8V supply (highlighted with a thick red line)!



The two regulators U1, U2 and the trace that connects the 4.7kΩ pull-up resistors to the 1.8V supply are highlighted on the module as well.

14.6 Appendix F: QR Code for Website

14.7 Appendix G: Transparent Sticker



14.8 Appendix H: Pin Connection Chart

Pin Connection Chart - Transmitter Device

Component	Pin Name	Pin Name (ESP32)	Pin Number (ESP32)
MAX30100	SCL	SCL	GPIO 22
	SDA	SDA	GPIO 21
	INT	Any digital pin	
	VDD	VCC	3V3
	GND	GND	
NEO 6M GPS	TX	SoftwareSerial RX	GPIO 16
	RX	SoftwareSerial TX	GPIO 17
	VCC	VCC	5V
	GND	GND	
Ra-02 LoRa	NSS	CS0	GPIO 05
	MOSI	MOSI	GPIO 23
	MISO	MISO	GPIO 19
	SCK	SCK	GPIO 18
	RESET	Any digital pin	GPIO 14
	DIO0	Any digital pin	GPIO 26
	3.3V	3V3	
	GND	GND	

Pin Connection Chart - Receiver Device

Component	Pin Name	Pin Name (ESP32)	Pin Number (ESP32)
SIM7600	TX	SoftwareSerial RX	GPIO 16
	RX	SoftwareSerial TX	GPIO 17
	VCC	VCC	Battery +
	GND	GND	Battery -
Ra-02 LoRa	NSS	CS0	GPIO 05
	MOSI	MOSI	GPIO 23
	MISO	MISO	GPIO 19
	SCK	SCK	GPIO 18
	RESET	Any digital pin	GPIO 14
	DIO0	Any digital pin	GPIO 26
	3.3V	3V3	
	GND	GND	

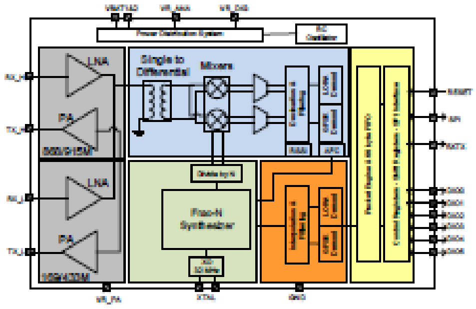
14.9 Appendix I: LoRa Ra-02 Data sheet

SEMTECH **SX1276/77/78**

WIRELESS & SENSING

SX1276/77/78 - 137-1050 MHz Ultra Low Power Long Range Transceiver

LoRa



GENERAL DESCRIPTION

Semtech's SX1276/77/78 family provides ultra long range while maintaining low current consumption, making it optimal for numerous applications.

With Semtech's patented modulation technique the device can achieve sensitivity of over -140 dBm using a low cost crystal and bill of materials. The high sensitivity combined with the integrated +20 dBm power amplifier creates the highest link budget making it optimal for any application requiring range. This modulation technique also provides significant advantages in blocking and selectivity over FSK.

The devices also support high performance (G)FSK for WMBus, FCC Part 90, 15.4g, and other legacy modes. Semtech's technology overcomes a typical trade-off of performance versus current consumption. The devices deliver exceptional phase noise, selectivity, receiver linearity, and IIP3 for significantly lower current consumption than competing devices.

The devices cover the major ISM bands from 137 MHz to 1050 MHz. For ease of matching, low BOM cost, and higher performance the SX1276/77/78 family offers separate high band and low band support for applications wanting to cover dual bands for world-wide operation, dual band support, or security against future band allocation changes.

KEY PRODUCT FEATURES

- 168 dB maximum link budget
- +20 dBm - 100 mW constant RF output vs. V supply
- +14 dBm high efficiency PA
- Programmable bit rate up to 300 kbps
- High sensitivity: down to -146.5 dBm
- Bullet-proof front end: IIP3 = -12 dBm
- 100 dB blocking immunity
- Low RX current of 10 mA, 200 nA register retention
- Fully integrated synthesizer with a resolution of 61 Hz
- FSK, GFSK, MSK, GMSK, LORA and OOK modulations
- Built-in bit synchronizer for clock recovery
- Sync word recognition
- Preamble detection
- 115 dB+ Dynamic Range RSSI
- Automatic RF Sense with ultra-fast AFC
- Packet engine up to 64 bytes with CRC
- Built-in temperature sensor and Low Battery indicator

APPLICATIONS

- Automated Meter Reading
- Wireless Sensor Networks
- Home and Building Automation
- Wireless Alarm and Security Systems
- Industrial Monitoring and Control

ORDERING INFORMATION

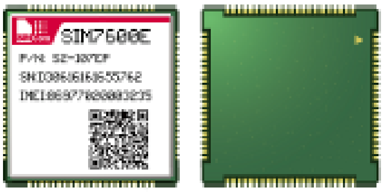
Part Number	Delivery	MOQ / Multiple
SX1276	T&R	3000 pieces
SX1277	T&R	3000 pieces
SX1278	T&R	3000 pieces

14.10 Appendix J: SIM7600E Data sheet

Version: 1001

SIMCom

SIM7600X



SIM7600X is a complete multi-band LTE-FDD/LTE-TDD/HSPA+/UMTS/EDGE/GPRS/GSM module solution in LCC type which supports LTE CAT1 up to 10Mbps for downlink and 5Mbps for uplink data transfer. Designed in the compact and unified form factor, SIM7600X is compatible with SIMCom HSPA+ SIM5360 module/LTE CAT3 SIM7100 and LTE CAT4 SIM7600X-H module, which allows customer to design their application once for different technology and benefit from great development time-saving.

Smart Machine Smart Decision

Variant for EMEA/Korea/Thailand
SIM7600E:
•LTE-TDD B38/B40/B41
•LTE-FDD B1/B3/B5/B7/B8/B20
•UMTS/HSPA+ B1/B5/B8
•GSM/GPRS/EDGE B3/B8
Variant for North America
SIM7600A:
•LTE-FDD B2/B4/B12
•UMTS/HSPA+ B2/B5
Variant for Australia/New Zealand/South America
SIM7600SA:
•LTE-TDD B40
•LTE-FDD B1/B2/B3/B4/B5/B7/B8/B28
•UMTS/HSPA+ B1/B2/B5/B8
•GSM/GPRS/EDGE 850/900/1800/1900MHz

General features
•LCC Package
•Control Via AT Commands
•Supply voltage range: 3.4V~ 4.2V, 3.8V Typical
•Operation temperature: -40℃ to +85℃
•Dimension: 30*30*2.9mm
•Weight: 5.7g
•Bandwidth: 1.4/3/5/10/15/20MHz
•3GPP E-UTRA Release 11

Specifications for Data transfer
•LTE CAT1
- Uplink up to 5Mbps
- Downlink up to 10Mbps
•HSPA+
- Uplink up to 5.76 Mbps
- Downlink up to 42 Mbps
•UMTS
- Uplink/Downlink up to 384Kbps
•EDGE
- Uplink/Downlink up to 236.8Kbps
•GPRS
- Uplink/Downlink up to 85.6Kbps

Other features
•USB Driver for Microsoft Windows 2000/XP/Vista/Win7/Win8/Win10
•USB Driver for Linux /Android
•RIL supporting for Android 2.4/4.0/5.0/6.0/7.0
•MBIM to Win8
•Firmware update via USB
•TCP/IP/IPV4/IPV6/Multi-PDP/FTP/FTPS /HTTP/HTTPS/DNS
•SSL3.0/TLS1.0/TLS1.2
•DTMF (Sending and Receiving)
•Audio Playing
•USB Audio and VoLTE
•FOTA

Interfaces
•USB2.0 with High speed up to 480Mbps
•UART
•GPIO
•Antenna: Solder pads for Primary, Rx-diversity and GNSS antennas
•(U)SIM card (1.8V/3.0V)
•Digital Audio through PCM
•MMC/SD
•ADC
•GNSS: GPS/GLONASS/Beidou/Galileo*

Approvals
•RoHS Compliant
•CE(SIM7600E/SIM7600SA*)
•FCC/PTCRB/AT&T* (SIM7600A)
•ACMA* (SIM7600SA)

*Under Development/Testing

More about SIMCom SIM7600X
Please contact:
Tel: 86-21-32523300
Fax: 86-21-32523301
Email: simcom@sim.com
Website: www.simcomm2m.com

14.11 Appendix K: MAX30100 Data sheet

EVALUATION KIT AVAILABLE

MAX30100 — Pulse Oximeter and Heart-Rate Sensor IC for Wearable Health

General Description

The MAX30100 is an integrated pulse oximetry and heart-rate monitor sensor solution. It combines two LEDs, a photodetector, optimized optics, and low-noise analog signal processing to detect pulse oximetry and heart-rate signals.

The MAX30100 operates from 1.8V and 3.3V power supplies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times.

Applications

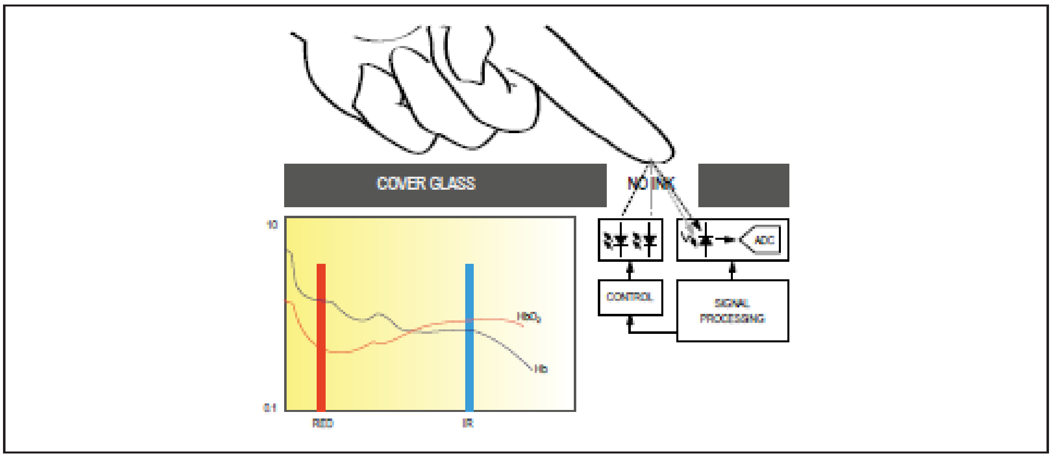
- Wearable Devices
- Fitness Assistant Devices
- Medical Monitoring Devices

Benefits and Features

- Complete Pulse Oximeter and Heart-Rate Sensor Solution Simplifies Design
    - Integrated LEDs, Photo Sensor, and High-Performance Analog Front -End
    - Tiny 5.6mm x 2.8mm x 1.2mm 14-Pin Optically Enhanced System-in-Package
- Ultra-Low-Power Operation Increases Battery Life for Wearable Devices
    - Programmable Sample Rate and LED Current for Power Savings
    - Ultra-Low Shutdown Current (0.7µA, typ)
- Advanced Functionality Improves Measurement Performance
    - High SNR Provides Robust Motion Artifact Resilience
    - Integrated Ambient Light Cancellation
    - High Sample Rate Capability
    - Fast Data Output Capability

Ordering Information appears at end of data sheet.

System Block Diagram



19-7065; Rev 0; 9/14

Absolute Maximum Ratings

V_{DD} to GND ....-0.3V to +2.2V
GND to PGND ....-0.3V to +0.3V
x_DRV, x_LED+ to PGND ....-0.3V to +6.0V
All Other Pins to GND ....-0.3V to +6.0V
Output Short-Circuit Current Duration .... Continuous
Continuous Input Current into Any Terminal ....±20mA
Continuous Power Dissipation (T_A = +70°C)
OESIP (derate 5.8mW/°C above +70°C) 464mW
Operating Temperature Range.................... -40°C to +85°C
Soldering Temperature (reflow)....................+260°C
Storage Temperature Range.................... -40°C to +105°C

Package Thermal Characteristics (Note 1)

OESIP
Junction-to-Ambient Thermal Resistance (θ_{JA}) ....150°C/W
Junction-to-Case Thermal Resistance (θ_{JC})............170°C/W

Note 1: Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to www.maximintegrated.com/thermal-tutorial.

Electrical Characteristics

(V_{DD} = 1.8V, V_{IR_LED+} = V_{R_LED+} = 3.3V, T_A = +25°C, min/max are from T_A = -40°C to +85°C, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
POWER SUPPLY							
Power-Supply Voltage	V_{DD}	Guaranteed by RED and IR count tolerance		1.7	1.8	2.0	V
LED Supply Voltage (R_LED+ or IR_LED+ to PGND)	V_{LED+}	Guaranteed by PSRR of LED Driver		3.1	3.3	5.0	V
Supply Current	I_{DD}	SpO_2 and heart rate modes, PW = 200µs, 50sps			600	1200	µA
		Heart rate only mode, PW = 200µs, 50sps			600	1200	
Supply Current in Shutdown	I_{SHDN}	T_A = +25°C, MODE = 0x80			0.7	10	µA
SENSOR CHARACTERISTICS							
ADC Resolution					14		bits
Red ADC Count (Note 3)	RED_C	Propriety ATE setup RED_PA = 0x05, LED_PW = 0x00, SPO2_SR = 0x07, T_A = +25°C		23,000	26,000	29,000	Counts
IR ADC Count (Note 3)	IR_C	Propriety ATE setup IR_PA = 0x09, LED_PW = 0x00, SPO2_SR = 0x07, T_A = +25°C		23,000	26,000	29,000	Counts
Dark Current Count	DC_C	RED_PA = IR_PA = 0x00, LED_PW = 0x03, SPO2_SR = 0x01			0	3	Counts
DC Ambient Light Rejection (Note 4)	ALR	Number of ADC counts with finger on sensor under direct sunlight (100K lux) LED_PW = 0x03, SPO2_SR = 0x01	RED LED		0		Counts
			IR LED		0		

Electrical Characteristics (continued)

(V_{DD} = 1.8V, V_{IR_LED+} = V_{R_LED+} = 3.3V, T_A = +25°C, min/max are from T_A = -40°C to +85°C, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
IR ADC Count—PSRR (V_{DD})	$PSRR_{VDD}$	Propriety ATE setup 1.7V < V_{DD} < 2.0V, LED_PW = 0x03, SPO2_SR = 0x01, IR_PA = 0x09, IR_PA = 0x05, T_A = +25°C		0.25	2	%
		Frequency = DC to 100kHz, 100mV_{P-P}		10		LSB
RED/IR ADC Count—PSRR (X_LED+)	$PSRR_{LED}$	Propriety ATE setup 3.1V < X_LED+ < 5V, LED_PW = 0x03, SPO2_SR = 0x01, IR_PA = 0x09, IR_PA = 0x05, T_A = +25°C		0.05	2	%
		Frequency = DC to 100kHz, 100mV_{P-P}		10		LSB
ADC Integration Time	INT	LED_PW = 0x00		200		µs
		LED_PW = 0x03		1600		µs
IR LED CHARACTERISTICS (Note 4)						
LED Peak Wavelength	λ_P	I_{LED} = 20mA, T_A = +25°C	870	880	900	nm
Full Width at Half Max	$\Delta\lambda$	I_{LED} = 20mA, T_A = +25°C		30		nm
Forward Voltage	V_F	I_{LED} = 20mA, T_A = +25°C		1.4		V
Radiant Power	P_O	I_{LED} = 20mA, T_A = +25°C		6.5		mW
RED LED CHARACTERISTICS (Note 4)						
LED Peak Wavelength	λ_P	I_{LED} = 20mA, T_A = +25°C	650	660	670	nm
Full Width at Half Max	$\Delta\lambda$	I_{LED} = 20mA, T_A = +25°C		20		nm
Forward Voltage	V_F	I_{LED} = 20mA, T_A = +25°C		2.1		V
Radiant Power	P_O	I_{LED} = 20mA, T_A = +25°C		9.8		mW
TEMPERATURE SENSOR						
Temperature ADC Acquisition Time	T_T	T_A = +25°C		29		ms
Temperature Sensor Accuracy	T_A	T_A = +25°C		±1		°C
Temperature Sensor Minimum Range	T_{MIN}			-40		°C
Temperature Sensor Maximum Range	T_{MAX}			85		°C

Electrical Characteristics (continued)

(V_{DD} = 1.8V, V_{IR_LED+} = V_{R_LED+} = 3.3V, T_A = +25°C, min/max are from T_A = -40°C to +85°C, unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DIGITAL CHARACTERISTICS (SDA, SDA, $\overline{INT}$)						
Output Low Voltage SDA, $\overline{INT}$	V_{OL}	I_{SINK} = 6mA			0.4	V
I²C Input Voltage Low	V_{IL_I2C}	SDA, SCL			0.4	V
I²C Input Voltage High	V_{IH_I2C}	SDA, SCL	1.4			V
Input Hysteresis	V_{HYS}	SDA, SCL		200		mV
Input Capacitance	C_{IN}	SDA, SCL		10		pF
Input Leakage Current	I_{IN}	V_{IN} = 0V, T_A = +25°C (SDA, SCL, INT)		0.01	1	µA
		V_{IN} = 5.5V, T_A = +25°C (SDA, SCL, INT)		0.01	1	µA
I²C TIMING CHARACTERISTICS (SDA, SDA, $\overline{INT}$)						
I²C Write Address				AE		Hex
I²C Read Address				AF		Hex
Serial Clock Frequency	f_{SCL}		0		400	kHz
Bus Free Time Between STOP and START Conditions	t_{BUF}		1.3			µs
Hold Time (Repeated) START Condition	$t_{HD,START}$		0.6			µs
SCL Pulse-Width Low	t_{LOW}		1.3			µs
SCL Pulse-Width High	t_{HIGH}		0.6			µs
Setup Time for a Repeated START Condition	$t_{SU,START}$		0.6			µs
Data Hold Time	$t_{HD,DAT}$		0		900	ns
Data Setup Time	$t_{SU,DAT}$		100			ns
Setup Time for STOP Condition	$t_{SU,STOP}$		0.6			µs
Pulse Width of Suppressed Spike	t_{SP}		0		50	ns
Bus Capacitance	C_B				400	pF
SDA and SCL Receiving Rise Time	t_R		20 + 0.1C_B		300	ns
SDA and SCL Receiving Fall Time	t_{RF}		20 + 0.1C_B		300	ns
SDA Transmitting Fall Time	t_{TF}		20 + 0.1C_B		300	ns

Note 2: All devices are 100% production tested at T_A = +25°C. Specifications over temperature limits are guaranteed by Maxim Integrated's bench or proprietary automated test equipment (ATE) characterization.
Note 3: Specifications are guaranteed by Maxim Integrated's bench characterization and by 100% production test using proprietary ATE setup and conditions.
Note 4: For design guidance only. Not production tested.

14.12 Appendix L: NEO 6M GPS Data sheet

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

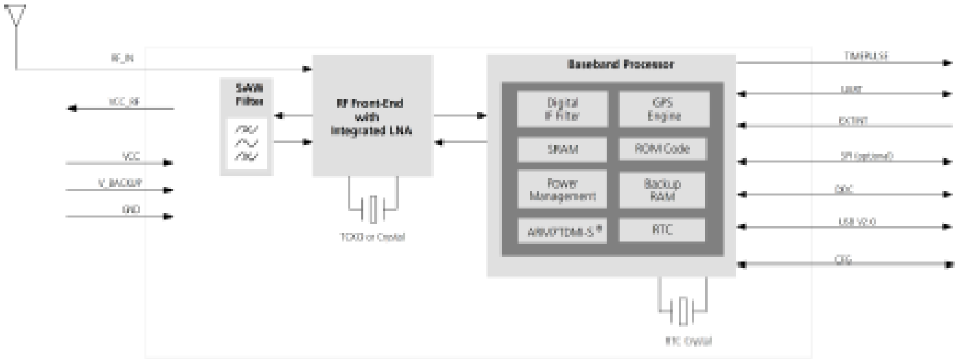


Figure 1: Block diagram (For available options refer to the product features table in section 1.2).

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.

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].