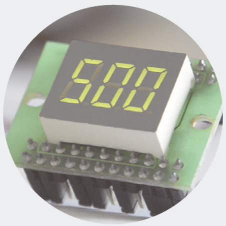
INSTITUTO SUPERIOR DE ENGENHARIA DO PORTO

MESTRADO EM ENGENHARIA ELECTROTÉCNICA - SISTEMAS ELÉCTRICOS DE ENERGIA



HARDWARE MODULE DEVELOPMENT FOR RFID DRONE

MUTHUKKUMAR ARUNACHALAM

novembro de 2017

POLITÉCNICO
DO PORTO

INSTITUTO SUPERIOR DE ENGENHARIA DO PORTO
MESTRADO EM ENGENHARIA ELECTROTÉCNICA - SISTEMAS ELÉCTRICOS DE ENERGIA

isep

HARDWARE MODULE DEVELOPMENT FOR RFID DRONE

MUTHUKKUMAR ARUNACHALAM

Outubro de 2017

POLITÉCNICO
DO PORTO

HARDWARE MODULE DEVELOPMENT FOR RFID DRONE

MUTHUKKUMAR ARUNACHALAM

Instituto Superior de Engenharia do Porto

Department of Electrical Engineering

Masters in Electrical Engineering – Power Systems

2017

Report prepared for the partial satisfaction of the requirements of DSEE Unit Course – Dissertation of the Masters in Electrical Engineering – Power Systems

Muthukkumar Arunachalam, Nº 1150254, 1150254@isep.ipp.pt

Professor. Rui Chibante, rmc@isep.ipp.pt

Company: Creative Systems,C.A, São João da Madeira, Portugal

Supervisor: Mr. João Sousa, jsousa@tycoint.com

Instituto Superior de Engenharia do Porto

Department of Electrical Engineering

Masters in Electrical Engineering – Power Systems

2017

ACKNOWLEDGMENT

At the end, the last stage of many successful stages over the course of my academic career comes to an end and it is pride and pleasure that I completed it. During the development of this thesis work, the support and encouragement of several people were fundamental. So, I would like to thank all those who have left their footprints in my way.

This journey would not have been possible without the support of my professors, supervisors and mentors, family and friends. To my family thank you for encouraging me in all of my pursuits and inspiring me to follow my dreams. I am especially grateful to my family and friends who supported me emotionally and financially. I always knew that you believed in me and wanted the best for me. Thank you for teaching me that my job in life was to learn, to be happy, and understand myself; only then could I know and understand others.

I would like to express my sincere gratitude to Instituto Superior de Engenharia do Porto and for the continuous support and encouragement. I express my sincere and special thanks to Prof. Teresa Alexandra Nogueira, Course Director and Mr. João Sousa, Head of Software Development departments and Prof. Rui Filipe Marques Chibante, Thesis Supervisor, Creative Systems, São João da Madeira for giving me an opportunity to use the facilities in College and Company premises to complete the Masters Thesis.

I also extend my gratitude to Prof. Rui Filipe Marques Chibante Thesis Supervisor in ISEP and Mr. João Oliveira Team Leader and Software Developer, Creative Systems, São João da Madeira for their guidance and sincere co-operation. With great pleasure my profound sense of gratitude to R&D , Other department Engineers, and Co-workers of Creative Systems, São João da Madeira, for their valuable support and encouragement to do this Master's Thesis. Thank you very much to everyone!

ABSTRACT

Nowadays most of the industry or stores uses RFID (Radio Frequency Identification) technology to monitor the state of the product. But, sometimes there is a difference between registered and the real value. In big stores manual inventory is very hard, expensive and time consuming process. In the present decades many researches are going on to avoid the above problem and one of the solutions is to use drones for RFID inventory.

This project is focused on designing and developing hardware for RFID drone to aid RFID inventory and development of a software module capable for reading of tags data.

The project presents analysis of the hardware devices such as Passive UHF (Ultra High) RFID Reader, Antenna, CPU (Central Processing Unit), PSU (Power Supply Module) and other interfacing components. Selection of the devices is based on criteria such as size and weight, market options and the components which is going to be used for RFID drone. Finally, software coding to read the RFID tags.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS & ACRONYMS

AC - Alternative Current

AIDC - Automatic Identification & Data Capture

API - Application Programmable Interface

ASK - Amplitude Shift Keying

CC - Constant Current

CPU - Central Processing Unit

CS - Creative Systems

CV - Constant Voltage

DC - Direct Current

DSB-ASK - Double Side Band-Amplitude Shift Keying

EPC - Electronics Product Code

GPIO - General Purpose Input Output

HF - High Frequency

IC - Integrated Circuit

ID - Identification

IPS - Indoor Positioning System

ISEP - Instituto Superior Engenhario de Porto

ITF - Integrator Talk First

LF - Low Frequency

LIPO - Lithium Ion Polymer

LOS - Lion of Straight

OCP - Over Current Protection

OS - Operating System

OVP - Over Voltage Protection

PC - Personal Computer

PIE - Pulse Interval Encoding

POS - Point of Scales

PSU - Power Supply Unit

R&D - Research & Development

RF - Radio Frequency

RFID - Radio Frequency Identification

RHCP - Right Hand Circular Polarization

SCP - Short Circuit Protection

SDK - Software Development Kit

SMA - SubMiniature version A

SSB - ASK - Single Side Band-Amplitude Shift Keying

TARI - Type A Reference Interval

TTL - Transistor Transistor Logic

UHF - Ultra High Frequency

UI - User Interface

USB - Universal Serial Bus

UVP - Under Voltage Protection

VSWR - Voltage Stand Wave Ratio

1 INTRODUCTION

The present dissertation was elaborated within the scope of the Masters in Electrical Engineering in Power Systems. The project was developed in an industrial environment. In the company of Creative Systems, São João da Madeira, Portugal.

The present dissertation was developed in the Department of R&D (Research and Development) of Creative Systems, São João da Madeira, Portugal and Special Electrical Machines Laboratory of ISEP to develop the hardware module and test the hardware devices.

1.1 Presentation of the Company

The Creative Systems is in Portugal since 2000. Creative system has two branches in São João de Madeira and Braga.

The main branch is in São João de Madeira, dealing about RFID solutions for data flow automation and optimization in retail supply management, RFID inventory and related software development. In Braga branch they are mainly dealing about creating of mobile application for RFID solutions.

The Creative Systems, São João da Madeira branch has mainly three departments Software development, Hardware development and Finance & Administration department.

Creative Systems develops integrated solutions for data flow automation and optimization, supported by expert consulting in innovation, operational management and interactive experiences.

A pioneer in the implementation of RFID technology, Creative Systems creates and implements advanced solutions for automatic identification and traceability that cover the entire project's life cycle (design, hardware, software, services, support), with special emphasis in retail, logistics, and manufacturing, where the company holds deep knowledge and experience.

Creative Systems works with project management best practices in order to ensure project success at all phases from consulting to design, development, implementation and maintenance. Creative System is a port of Tyco Internationals. Tyco has more than 65 000 employees in 1 000 locations in nearly 50 countries, and is dedicated to advancing safety and security in the world's most demanding environments and across diverse industries and business activities. Tyco products and solutions help protect more than three million commercial, government and residential customers around the globe.

1.2 Objectives of the Dissertation

This section explains about the main goals, scope of the project and structure of the dissertation.

1.2.1 Main Goals:

- Study and analysis of hardware devices such as Passive UHF RFID reader, Antenna, CPU, PSU and Other interfacing components.
- Analysis of criteria for the hardware devices.
- Selection of hardware devices for RFID drone.
- Development of software code for reading tags and storing.

1.2.2 Scope of the Project

- Selection of RFID hardware devices and assembling of hardware module.
- Develop the software module for reader to read the tags.

1.3 Structure of the Dissertation

- The dissertation has six main chapters. The literature review (Chapter 2) covers the EPC RFID Generation2 protocol and analysis study of devices used in the proposed system hardware module.
- Chapter 3 explains, Existing inventory processes and about RFID components.
- Market analysis and Hardware selection for RFID drone hardware module is explained in Chapter 4.
- Hardware development for RFID drone and Software coding for configuration of RFID reader module explained in Chapter 5.
- Chapter 6 describes a reflection on the proposed project and the difficulties encountered throughout it. In this same Chapter, steps for improving the proposed hardware module in the future are presented.

2 LITERATURE REVIEW

2.1 Introduction

This chapter is mainly divided into two sub chapters such as “Standard protocol” used in the proposed system, and “Study of references books and publications”. Standard protocol section explains about the protocol EPC UHF RFID Generation-2 Protocol, the existing system is designed based on this protocol. The Study of references books and publications section explains about the publication and reference papers, which are used to analyse the RFID devices in the proposed system.

2.2 Standard Protocol

This section describes about the protocol EPC UHF RFID Generation-2 protocol and its requirement.

2.2.1 EPC UHF RFID Generation-2 Protocol

The proposed RFID inventory system is based on the RFID Class 2 GEN protocol. The RFID components such as UHF passive RFID reader, Reader antenna and tags are working based on this protocol.

2.2.1.1 Overview of EPC RFID Class 2

This protocol specifies the physical and logical requirements for a passive-backscatter, ITF (Integrator Talk First), RFID system operating in the 860 MHz – 960 MHz frequency range, physical interaction between reader and tags, logical working principle and commands between readers and tags.

2.2.1.1.1 General conformance requirements

A. Interrogators

To conform to this protocol an interrogator shall:

- Meet the requirements of this protocol.
- Implement the mandatory commands defined in this protocol (Ex. Operating frequency, integrator to tag communication. etc.).
- Modulate and receive a sufficient set of the electrical signals defined in this protocol to communicate with conformant tags,

- Conform to all local radio regulations.

To conform to this protocol an interrogator may:

- Implement any subset of the optional commands defined in this protocol.
- Implement any proprietary and/or custom commands in conformance with this protocol.

To conform to this protocol an interrogator shall not:

- Implement any command that conflicts with this protocol.
- Require using an optional, proprietary, or custom command to meet the requirements of this protocol.

B. **Tags**

To conform to this protocol, a tag shall:

- Meet the requirements of this protocol.
- Implement the mandatory commands defined in this protocol.
- Modulate a backscatter signal only after receiving the requisite command from an Interrogator.
- Conform to all local radio regulations.

To conform to this protocol a Tag may:

- Implement any subset of the optional commands defined in this protocol.

To conform to this protocol, a tag shall not:

- Implement any command that conflicts with this protocol.
- Require using an optional, proprietary, or custom command to meet the requirements of this Protocol.

2.2.1.2 Protocol Requirements

This section explains about the physical layer requirement of this protocol.

2.2.1.2.1 Physical layer

An interrogator sends modulated RF signals to one or more tags using Double-Sideband Amplitude Shift Keying (DSB-ASK), Single-Sideband Amplitude Shift Keying (SSB-ASK), or Phase-Reversal Amplitude Shift Keying (PR-ASK) using a Pulse-Interval Encoding (PIE) format. Tags receive their operating energy from this same modulated RF carrier.

An interrogator receives unmodulated RF signal from a tag and listening for a backscattered reply. Tags communicate information by backscatter modulating the amplitude and/or phase of the RF carrier. The encoding format, selected in response to interrogator commands, is either FM0 or Miller-modulated subcarrier. The communications link between interrogators and tags is half-duplex, meaning that tags shall not be required to demodulate interrogator commands while backscattering. A tag shall not respond to a mandatory or optional command using full-duplex communications [10].

2.2.1.2.2 Tag-identification layer

An interrogator manages tag populations using three basic operations:

a) Select

Choosing a tag from tag population. An interrogator uses a select command to select one or more tags based on a value in tag memory, and also uses a challenge command to challenge one or more tags based on tag support for the desired cryptographic suite and authentication type. An interrogator may subsequently inventory and access the chosen tag(s).

b) Inventory

Identifying individual tags. An interrogator begins an inventory round by transmitting a Query command in one of four sessions. One or more tags may reply. The interrogator detects a single tag re-ply and requests the tag's EPC. Inventory comprises multiple commands. An inventory round operates in one and only one session at a time.

c) Access

Communicating with an identified tag. The interrogator may perform a core operation such as reading, writing, locking the tag; a security-related operation such as authenticating the tag; or a file-related operation such as opening a file in the user memory of the tag. Access comprises multiple commands. An interrogator may only access a uniquely identified tag.

2.2.1.3 Physical Interface Requirement

The physical interface between an interrogator and a tag viewed in a layered network communication system. The signaling interface defines frequencies, modulation and other parameters required for RF communications.

a) Operational frequencies

Tags receive power from and communicate with interrogators within the frequency range from 860 – 960 MHz, inclusive. An interrogator's choice of operational frequency will be determined by local radio regulations and by the local radio-frequency environment.

b) Interrogator-to-Tag (R=>T) communications

An interrogator communicates with by modulating an RF carrier using DSB-ASK, SSB-ASK, or PR-ASK with PIE encoding. Interrogators shall use a fixed modulation format. The interrogator sets the data rate by means of the preamble that initiates the inventory round.

c) Interrogator frequency accuracy

Interrogators certified for operation in single- or multiple-Interrogator environments shall have a frequency accuracy that meets local regulations. Interrogators rated by the manufacturer to have a temperature range wider than nominal but different from extended shall have a frequency accuracy of +/– 10 ppm over the nominal temperature range and +/– 20 ppm to the extent of their rated range. If local regulations specify tighter frequency accuracy, then the Interrogator shall meet the local regulations [7].

d) Modulation

Interrogators shall communicate using DSB-ASK, SSB-ASK, or PR-ASK modulation, shall demodulate all three modulation types.

e) Tari values

TARI (Type A Reference Interval) is the duration of a pulse of energy sent to UHF EPC Gen 2 tags to indicate a 0 in binary code. EPC Gen 2-compliant readers use pulse interval encoding (PIE) to code binary data. A binary '0' is indicated by a short, high-level pulse, followed by a low pulse of equal length. The length of a Tari can vary from 6.25 μs to 25 μs. Interrogators communicate using Tari values in the range of 6.25 μs to 25 μs. Interrogator compliance shall be evaluated using at least one Tari value between 6.25 μs and 25 μs with at least one value of the parameter *x* [10]. The tolerance on all parameters specified in units of Tari shall be +/–1%. The choice of Tari value and *x* shall be in accordance with local radio regulations.

f) Interrogator power-up waveform

The interrogator power-up RF envelope shall comply with Figure 2 and Table 2. Once the carrier level has risen above the 10% level, the power-up envelope shall rise monotonically until at least the ripple limit Ml. The RF envelope shall not fall below the 90% point in Figure 1 during interval Ts. interrogators shall not issue commands before the end of the maximum settling-time interval in Table1 (i.e. before the end of Ts).

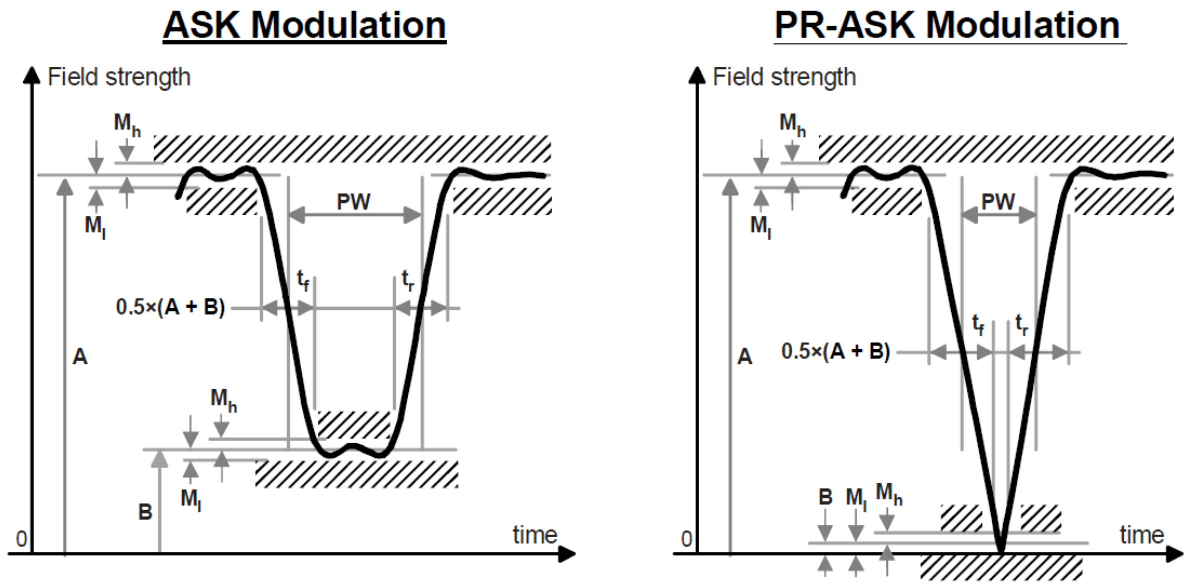


Figure 1 - Integrator-to-Tag-RF-Envelope.

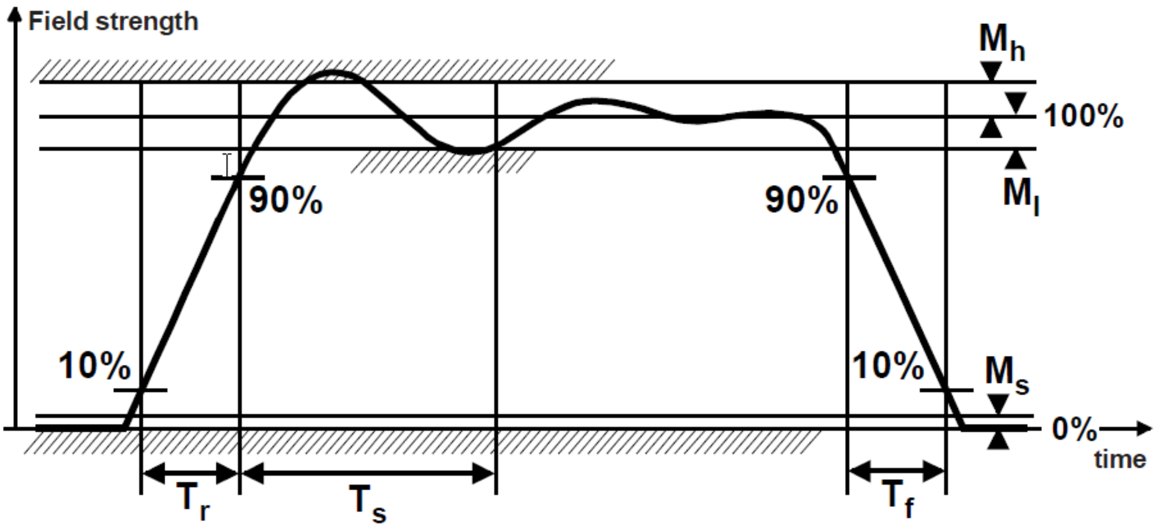


Figure 2 - Interrogator Power-up and Power-Down RF Envelope.

Table 1 - RF Envelope Parameters

Tari	Parameter	Symbol	Minimum	Normal	Maximum	Units
6.25 µs to 25 µs	Modulation Depth	(A–B)/A	80	90	100	%
	Modulation Depth	Mh = Ml	0	-	MAX (0.265 Tari, 2)	V/m or A/m
	Modulation Depth	tr,10–90%	0	-	0.33 Tari	µs
	Modulation Depth	tf,10–90%	0	-	0.33 Tari	µs
	Modulation Depth	PW	MAX (0.265 Tari, 2)	-	0.525 Tari	µs

Table 2 - Interrogator Power-up Waveform Parameter

Parameter	Definition	Minimum	Normal	Maximum	Units
T_r	Rise time	1	-	500	µs
T_s	Setting time	-	-	1500	µs
M_s	Signal level when OFF	-	-	1	% full scale
M_i	Undershoot	-	-	5	% full scale
Mr	Overshoot	-	-	5	% full scale

Table 3 - Interrogator Power-down Waveform Parameters

Parameter	Definition	Minimum	Normal	Maximum	Units
T_r	Fall time	1	-	500	µs
M_s	Signal level when OFF	-	-	1	% full scale
M_i	Undershoot	-	-	5	% full scale
Mr	Overshoot	-	-	5	% full scale

g) Interrogator power-down waveform

The interrogator power-down RF envelope comply with Figure 2 and Table 3. Once the carrier level has fallen below the 90% level, the power-down envelope shall fall monotonically until the power-off limit Ms. Once powered off, an interrogator shall remain powered off for a least 1ms before powering up again.

h) R=>T preamble and frame-synchronization

An interrogator begins all R=>T signaling with either a preamble or a frame-synchronization. A preamble shall precede a *query* command and denotes the start of an inventory round. All other signaling shall begin with a frame-synchronization. The tolerance on all parameters shall be +/–1%. A preamble shall comprise a fixed-length start delimiter, a data-0 symbol, an R=>T calibration (RTcal) symbol, and a T=>R calibration (TRcal) symbol.

2.3 Study of Reference Books and Publications:

1. **Analysis of Passive Tag RFID Readers**

This section discusses about the RFID reader and RFID reader antenna performance parameters and gives idea to choose the better RFID reader for the proposed system.

A. RFID Reader Performance Parameter Analysis

I. **RF Power Output -** The RF power output level of the reader is an important parameter to determine the distance at which tags can be powered up called as read rang of the reader.

II. **DC Power Consumption -** If the application is an AC-powered reader, the DC power consumption of the module will be of little concern, but many RFID reader modules are used in battery-powered readers their key features are Power consumed while transmitting at maximum RF output power levels and ability to save power by transmitting at less than the maximum RF power level. The battery power supplied reader is used in the proposed system model.

III. **Dimension of the Module and Weight -** For the RFID drone application size and dimension are important parameters to consider. For the less size and weight will increase the battery autonomy of the drone, which the run flying time of the drone. As RFID is considered for a greater number of products and solutions, the size of the RFID module becomes a more important factor. Solution developers may benefit from working with a vendor that offers several modules of differing sizes and capabilities, allowing for the development of highly complementary connected enterprise applications. Some applications require modules to have a maximum size, usually if the reader needs to have a small form factor or if UHF RFID is being added to a reader that was not originally designed to support this technology and limited space is available to accommodate the module. Module size, however, should also be viewed within the context of performance. Sacrificing performance for size typically does not pay off.

IV. **Antenna Ports -** One RF port is sufficient for many applications, but there are many applications where more than one port is required. In gate tunnel application the reader connected to the more the one antenna to cover the gat space and to avoid the error.

V. **RF, Power and Control Physical Interfaces -** Module RF interfaces are of three types:

• SMA – This interface allows the module port to be pushed through a hole in the enclosure and used directly [19].

• MMCX – It is small edge connector that can be disconnected and connected repeatedly, but needs a cable to connect it to the readers bulkhead connector or to an internal antenna.

• U.FL – This is small connector that can be anywhere on the module and unique because it protrudes vertically from the board; It cannot be repeatedly re-connected and supports only a small RF cable, so the bulkhead connector or antenna must be located fairly near to the module Power/data connectors come in four types

• Common external connector: Ex. Micro USB connector, which could be accessed through a hole in the reader enclosure.

• Multi-pin cable connector: It provides the most flexibility for locating the motherboard connector relative to the module's connector.

• Ribbon-cable connector: This type of connector does not require a mating connector – the connector has a locking mechanism so a ribbon cable with exposed contacts on both ends is used between the module and motherboard; For best results, the motherboard connector must be aligned with the module connector (although ribbon cables can be folded to accommodate an offset [19].

• Board-to-board connector: The connector on the module plugs directly into the connector on the motherboard without an interconnecting cable; this is often used to achieve the lowest profile, but can make heat sinking difficult as it is difficult to mount the module on a heat sink and to the motherboard simultaneously [9].

VI. **Heat Dissipation -** UHF RFID readers dissipate heat when transmitting RF power. The maximum amount of time the reader can transmit is often related to the maximum ambient temperature inside the reader and the ability of the module to dissipate its heat to the reader's enclosure. A heat sink of some sort will be needed to conduct the heat from the components on the board to the enclosure [1].

VII. **Support for Optional, and Custom, Gen2 Commands -** Nowadays most of the tags are designed based on Gen2 protocol. To work with new version tags the reader module should be flexible for firmware update the newer version.

VIII. **Availability of an API That Supports Planned Host Applications -** The programs that control the reader can interface with the modules at a program level and do not have to explicitly deal with low-level tasks such as:

- Establishing and tearing down communication channels to the module.
- Assembling command packets, which often involve calculating interpreting responses and error messages.

IX. **Global (or multi-regional) Compliance -** Certifying an RFID reader for global or multi-regional operation requires strict and ongoing compliance. By using an RFID module that has been certified, could be easy for solution developers are starting with a product that has been designed to meet future needs and that has been fully tested and approved for regional use [4].

B. RFID Reader-Antenna Performance Parameter Analysis:

FREQUENCY RANGE: Each country has regulations that specify the frequency ranges for UHF RFID transmissions within that country. The three most prevalent frequency ranges for UHF RFID antennas and also for the readers. But almost all the reader is for global application. The range of the regions are listed below:

- 902-928 MHz (US/FCC)
- 865-868 MHz (EU/ETSI)
- 860-960 MHz (Global)

When choosing an RFID antenna, be sure to select the frequency range that is right for your region. For example, an antenna tuned to the 865-868 MHz range and used in the United States would violate the regulations that govern the use of RFID equipment in the United States.

- **Beam Width/ Gain of the antenna**: Gain and beam width are grouped together because they are both electrical components of an antenna and are distinctly related. The higher the gain, the narrower (or smaller) the beam width. Higher gain creates a narrower area of coverage, but the beam will travel a longer distance. Beam width and gain are analogous to the beam of a flashlight [3].

- **Read range and size** – smaller antennas within the same frequency will have shorter read range and vice versa. The antennas with the shortest read range for UHF technology will be Near Field Antennas, which utilize near field as opposed to far field as regular UHF antennas. These are often used for item tracking and where short ranges are required for security purposes.
- **Polarization** – We can select between circular and linear polarization. Circularly polarized antennas will have shorter read range but will be less orientation sensitive. We can select between right hand circularly polarized antennas (RHCP) or left hand circularly polarized antenna (LHCP). Sometimes there are antenna like dual circularly polarized antennas that have both left hand and right hand polarization. Linearly polarized antennas will provide longer read range and more focused beam but will read only tags that have antennas parallel to the plane of wave. If the tag orientation is not fixed, especially when using single dipole tag antennas (which are most common), we should select a circularly polarized antenna. For RFID inventory application Circular polarization could be the best chose. Because, we don't know the exact orientation of the tags in the ware house [6].
- **VSWR** – Voltage standing wave ratio or also called return loss - Due to mismatches in impedance within the connector, some of the signal is reflected. The ratio of the input to the reflected signal is called the Voltage Standing Wave Ratio (VSWR). This ratio can also be measured in dB, and expressed as Return Loss. The VSWR signifies antenna design efficiency and the lower the VSWR the smaller the return loss and the better the antenna (ideal VSWR is 1:1). But, in market the typical value is 1:1.5 [2].
- **Axial Ratio** - The axial ratio is the ratio of orthogonal components of an E-field. A circularly polarized field is made up of two orthogonal E-field components of equal amplitude, which are 90° out of phase. Because these components are of equal magnitude, the axial ratio is 1 or 0 dB. Axial ratios are often specified for circularly polarized antennas. The axial ratio tends to degrade away from the main beam of an antenna, therefore, in the spec sheet for an antenna. For Ex."Axial Ratio: <3 dB for +-30 degrees from the main beam". This indicates that the deviation from circular polarization is less than 3 dB over the specified angular range.
- **Beam Width** – select elevation beam width (vertical, up and down) and azimuth beam width (horizontal, left to right) based on the desired coverage of an interrogation zone.

Wider beam width antennas will provide wider coverage without the need for additional antennas, however, the read range may be shorter (which is often desired as not to read tags outside the portal or door).

- **Front to Back Ratio** – This ratio indicates the ratio of forward and backward signal transmission. Most if not all antennas radiate also to the back of the main beam, which is often due to the signal bending from the main beam. We want this ratio to be as large as possible unless you plan to utilize also the back beam (this is not usual) [5].
- **Environmental Protection and Ruggedness** – select an antenna with a suitable IP rating and made of materials that will survive the environment it will be installed in. Most antennas are enclosed in hard plastic, but there are also all metal antennas (suitable for very harsh environments or where they will suffer impact) or antennas encased in rubber (for mounting on the ground).

2. Analysis of Lithium-ion Battery

The above paper was used to study and analysis the characteristics and performance of LIPO batteries.

- **Chemical Structure of LIPO -** Li-Ion cell has a tree layer structure. A positive electrode plate (made with Lithium Cobalt oxide - cathode), a negative electrode plate (made with specialty carbon - anode) and a separator layer. Inside the battery also exists an electrolyte which is a lithium salt in an organic solvent. Li-Ion is also equipped with a variety of safety measures and protective electronics and/or fuses to prevent reverse polarity, over voltage and overheating and also have a pressure release valve and a safety vent to prevent battery from burst [18].
- **Charging Performance of LIPO -** Charging method that is commonly used for charging of Lithium-Ion cells is constant current - constant voltage (CV-CC). This means charging with constant current until the 4.2 V are reached by the cell (or 4.2 V x the number of cells connected in series) and continuing with constant voltage until the current drops to zero. The charge time depends on the charge level of the battery and varies from 2-4 hours for full charge [15]. Also, Li-Ion cannot fast charge as this will increase their temperature above limits. Charging time increases at lower temperatures.

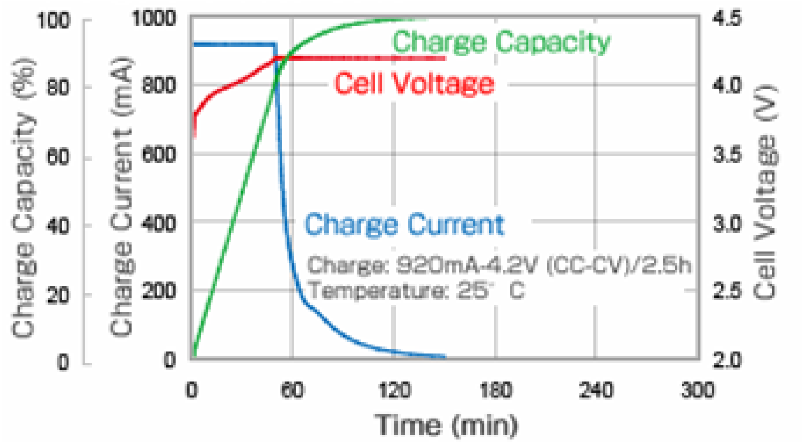


Figure 3 - Charge Load Characteristics of LIPO Batteries.

Charge voltage – the maximum voltage is 4.2 V multiplied to the number of cells connected in pack charge Current – recommended 0.7 mA, when voltage per cell should be 2.9 V or less and charge current of 0.1 mA or less. Charge Temperature – range of battery charging temperature should be between 0 °C to 45 °C Polarity Charging – it is recommended to verify the polarity of the batteries before charging, due to Lithium-Ion batteries are never charged with the reversed polarity.

- **DISCHARGING OF LITHIUM-ION CELLS**

Discharge Termination voltage – It is strongly recommended to avoid discharging at voltage less than 3.0 V per cell. Due to overcharging can damage the performance of the Lithium-Ion battery. The recommendation is to use discharge equipment with overcharge prevent mechanism. Discharge Current – the current should be maintained at 1.0 mA or less [16].

Discharge Temperature – The recommendations for discharging of batteries are temperature range between -10 °C to +60 °C.

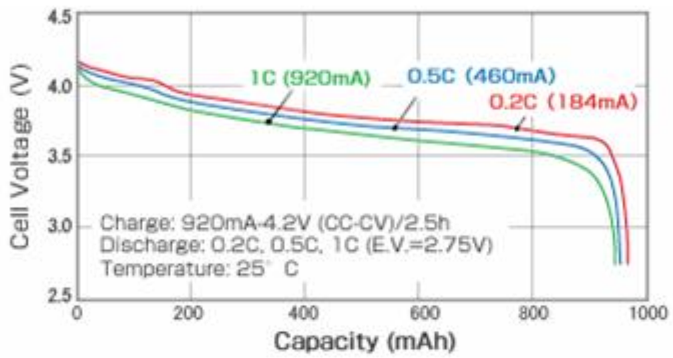


Figure 4 - Discharge Load Characteristics of LIPO Batteries

- **Low Self-Discharge** – When not in use, batteries can slowly discharge. LiPo batteries have a low self-discharge rate of approximately 5% per month. In contrast nickel metal hydride (ni-mh) cells typically see 30% per month and 10% for nickel cadmium (ni-cd) batteries. This of course varies depending on the storage temperature and the brand of the cells, but in general Lithium batteries are good at retaining their charge [17].
- **Improved Chemistry** – The Lithium-ion battery's improve chemistry allows for greater energy density, it allows for high open voltage potential (3.6 V to 3.7 V per cell), and it allow for very high discharge currents (good for motors and high power applications).
- **Higher Energy Density** – Lithium Polymer batteries have over 20% higher energy density than Lithium-ions.
- **Reduced Weight** – LiPo batteries are physically different in that are packaged in a flexible foil-like package instead of rigid metal cases. This greatly reduces the weight and still allows for a variety of different form factors.

3 EXISTING INVENTORY SYSTEMS

3.1 Intorduction:

RFID is a technology which can be used in a wide variety of businesses and industries. In the present decades, the RFID technology has been widely used for more functions in different areas including; air industry, military, library services, health services, sports, security and many fields. A prominent use of this technology is inventory management in supply chain of the product (logistics). But applications are widespread and growing in healthcare, security, and agriculture etc., RFID systems are also used to prevent theft in the retail stores.

The RFID technologies gives many options to systematically technologies provide many and diverse options to systematically control, monitor efficient organize production and logistics processes. They guarantee maximum transparency by:

- Clear identification of items throughout the entire transport.
- Continuous tracking of flows of goods in the entire supply chain.
- Central and distribution data acquisition for quality assurance [7].

Figure 5 - RFID Applications

3.2 Working Principle in Inventory Management:

Radio Frequency Identification or RFID is a non-contact, non-line-of-sight (LOS) type Automatic Identification & Data Capture (AIDC) technology, which uses radio frequency to establish communication and data transfer between a RFID transponder, a microchip fitted inside the RFID Tag and RF antenna.

The RFID tag is placed at the point of manufacture (Production tagging) and RFID readers (handheld or fixed depends) fixed at the each point of the supply chain from manufacturing company till the POT (Point Of Scale). In all the points, the inventory is done by RFID system. The RFID system consists of RFID reader and RFID antenna. And the inventory will be stored in the system database via inventory software [5].

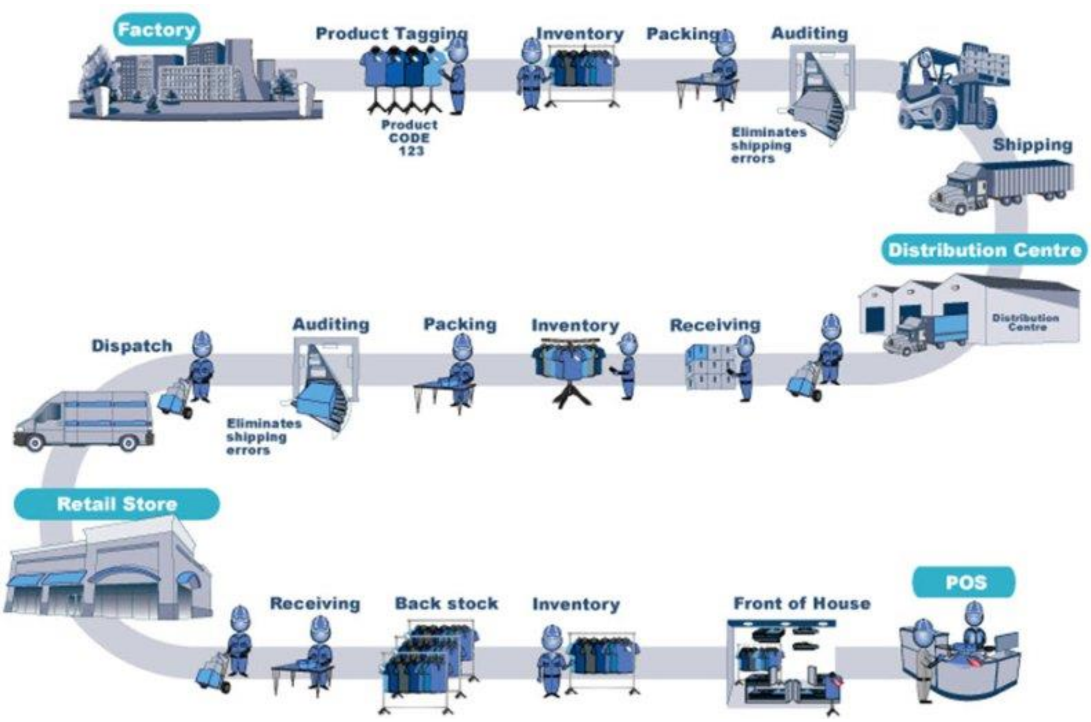


Figure 6 - Working Principle of RFID Inventory System.

3.3 Working Principle of RFID System:

The RFID reader transmits information to a tag by modulating an RF signal in the 860 MHz – 960 MHz frequency range. The tag receives both information and operating energy from this RF signal. Tags are passive, meaning that they receive all of their operating energy from the Interrogator's RF signal. Tag responds by modulating the reflection coefficient of its antenna, thereby backscattering an information signal to the interrogator. Tag modulates its antenna reflection coefficient with an information signal only after being directed to do so by an Interrogator.

An interrogator receives information from a tag by transmitting in the form of CW (continuous-wave) RF signal from the tag. Reader of interrogator and tags are not required to talk simultaneously; rather, communications are half-duplex, meaning that interrogators talk and tags listen, or vice versa.

Figure 7- Working of RFID System.

3.3.1 RFID systems are distinguished mainly by their frequency ranges.

i. Low-frequency

LF (Low Frequency) systems have short reading ranges and lower system costs. The frequency range of the system starts from 30 kHz to 300 kHz. The read range of this system is very low about 10cm. They are most commonly used in security access, asset tracking and animal identification applications.

ii. **High frequency**

The HF band ranges from 3 to 30 MHz. Most HF RFID systems operate at 13.56 MHz with read ranges between 10 cm and 1 m. HF (High Frequency)systems, offer higher read ranges as compared to LF systems and better reading speeds, and are used for such applications as railroad car tracking and automated toll collection.

iii. **UHF system (850 MHz to 950 MHz)**

The UHF frequency band covers the range from 300 MHz to 3 GHz. RFID systems comply with the UHF Gen2 standard and use the 860 to 960 MHz band. The read range of passive UHF systems can be as long as 12 m, and UHF RFID has a faster data transfer rate than LF or HF. This UHF system is mostly used for supply chain management [4].

3.3.2 Basic Components in the RFID System:

- RFID Tags
- RFID Reader
- RFID Antenna
- Computer software

I. **RFID Tags**

The RFID tag has an electronic chip or silicon that works with RF (Radio Frequency) to provide wireless tracking capability. Each chip contains a unique ID (Identification) number. Data can be stored in the chip as well. These electronic chips are in the form of sticker labels, than the RFID tag labels are stick on each product or item, which should be tracked by the RFID system.

RFID tags come in three general varieties: passive, active (also called as battery -activated) and semi-passive Passive tags require no internal power source (they are only active when a reader is nearby to power them), whereas semi-passive and active tags require a power source, usually a small battery.

Passive-tags

These type of tags don't have the internal power supply. The minute the external current induced in the antenna by RF signals coming from the RFID reader, provides enough power for the metal oxide semi-conductor IC in the tags to power up the IC in the tags.

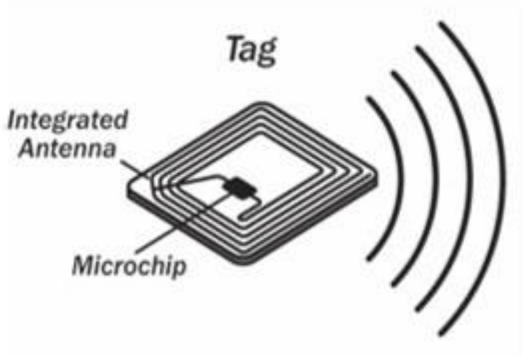


Figure 8 - RFID Passive Tags.

The tags are using this power to response for the RFID readers. Most passive tags signal by backscattering the carrier wave from the reader. So, the antenna of the tag should be designed both to collect power from the incoming signal and also to transmit the outbound backscatter signal. The main application of these tags is ware house inventory management.

Active Tags

The active RFID tags have their own internal power source, which is used to power the integrated circuits and to broadcast the response signal to the reader. Communications from active tags to readers is typically much more reliable than from passive tags.

Active RFID tag or transponder can be fixed to any asset (laptops or notebooks, computers, peripherals, electronic equipment, pallets, inventory items, etc.) for the long range asset protection and monitoring throughout the enterprise or supply chain.

Signal transmissions penetrate walls and obstructions, such as warehouses and computer rooms. Simultaneous Multiple tags read also possible. So, in that both the asset and its carrier can be identified in an automatic, hands-free manner. This also allows the asset to communicate with one or more owners, providing maximum security with greater freedom of movement [8].

Figure 9 - RFID Active Tags. Semi-passive RFID

Semi-passive tags are similar to active tags. But, one of the major differences is that a battery is used to run the microchip's circuitry but not to communicate with the reader. Some semi-passive tags sleep until they are woken up by a signal from the reader, which increase battery life [7].

Electronic Product Code (EPC)

The electronic product code (EPC) is stored in the tag chip's memory. It contains 96-bit string data written to the tag and typically. The first eight bits are a header which identifies the version of the protocol. The next 28 bits identify the organization that manages the data for this tag. The next 24 bits are an object class, identifying the kind of product; the last 38 bits are a unique serial number for a particular tag. These last two fields are set by the organization that issued the tag. The total electronic product code number can be used as a key into a global database to uniquely identify that particular product.

II. RFID Reader:

An RFID reader is an electronics device that is used to interrogate with an RFID tag. The reader has an antenna that emits RF waves and the tag responds by sending back its data. The antenna is a conductive element that permits the tag to exchange data with the reader. Passive RFID tags make use of a coiled antenna that can create a magnetic field. Using the energy provided by the reader's carrier signal. The reader comes up with application software which can be synchronised with the application software to maintain the master database.

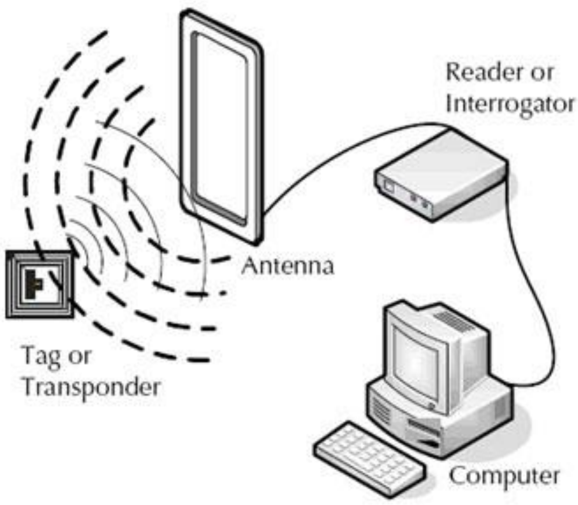


Figure 10 - RFID Reading System.

III. Reader Antennas

RFID readers and reader antennas work together to read tags. Reader antennas convert electrical current into electromagnetic waves that are then radiated into space where they can be received by a tag antenna and converted back to electrical current. Just like tag antennas, there is a large variety of reader antennas and optimal antenna selection varies per the solution's specific application and environment. The two most common antenna types are linear- and circular-polarized antennas. Antennas that radiate linear electric fields have long ranges and prominent levels of power that enable their signals to penetrate through different materials to read tags. Linear antennas are sensitive to tag orientation; depending on the tag angle or placement, linear antennas can have a challenging time reading tags.

Choice of antenna is also determined by the distance between the RFID reader and the tags that it needs to read. This distance is called read range. Reader antennas operate in either a "near-field" (short range) or "far-field" (long range). In near-field applications, the read range is less than 30 cm and the antenna uses magnetic coupling so the reader and tag can transfer power. In near-field systems, the readability of the tags is not affected by the presence of dielectrics, such as water or metal, in the field.

IV. Computer Software:

Computer software is used to manage the inventory data reed by RFID reader. The retail shop or organization which is handling the large inventory data will use the different software based on their requirement and their ease of use.

This software mainly used to get the tag ID from the RFID reader. Also, to store in the database and to manipulate the data. (Ex. Searching the particular tag, finding the location of tag., etc)

3.4 Inventory Methods:

- RFID inventory using Hand held reader.
- RFID Inventory Using Gateway tunnels.

3.4.1 RFID inventory using Hand held reader:

In a retail shop the employers use a hand-held reader mainly for the inventory management, theft avoidance and shrinkage management.

Figure 11- RFID Inventory in Retail Shops.

In a retail shops the small chip attached to all the merchandise things. The chip contains store data such as a serial number, price or purchase record. The tag can be fixed to all things. Then, an electronic scanner can use radio signals to read or track the ID tag.

Radio Frequency Identification is often used in clothing and other merchandise stores. The shop owners put tags on each item before it is arranged on shelves. When a customer buys an item, the clerk removes or disables the RFID tag. If an active tag passes by the exit of the shop, the alarm rings and the shop owners can detect attempted shoplifting. At the same time, RFID tags can help identify and inventory delivered goods from suppliers. The tags don't cost much, but they are extremely helpful in managing and safeguarding retail goods.

3.4.2 RFID Inventory Using Gateway tunnels

This system is mainly used in the large ware house management system. The tunnel RFID arrangement is placed on the entry point of the ware house. The tunnel consists of passive RFID reader and sufficient number of one or more RFID reader antenna. The antennas are arranged to cover the entire space of the gate tunnel.

The storage item will pass via in that tunnel so, that the reader can read all the tag items and sends to the database via ethernet or wireless technology depending on the system and user requirement.

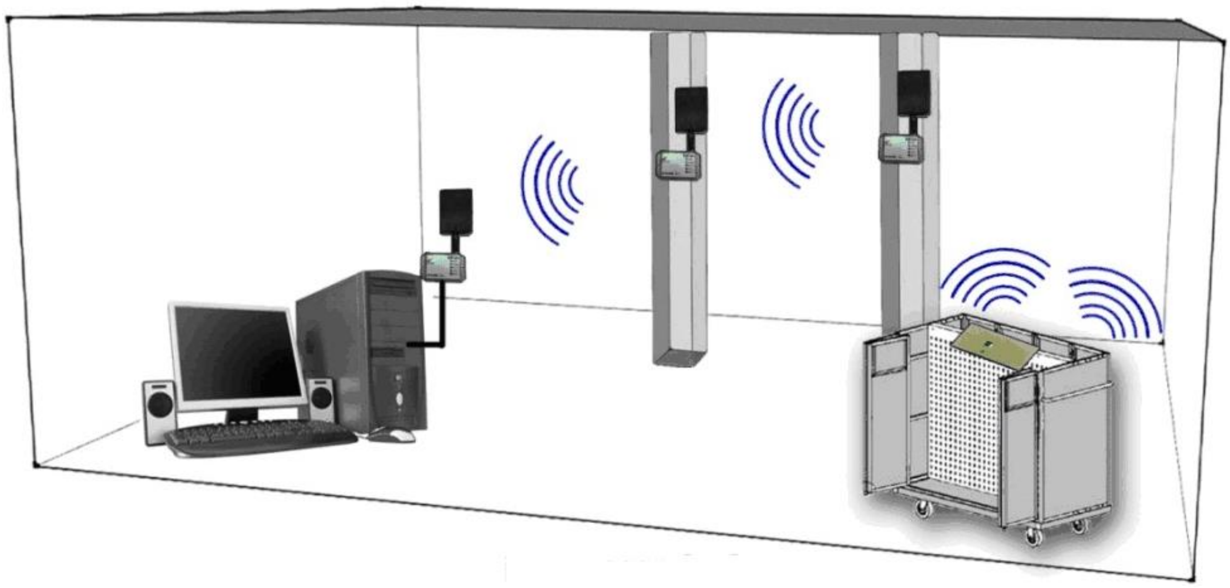


Figure 12 - RFID Tunnel Based Inventory System

3.5 Advantages and Disadvantages of the Existing System:

Advantages

- Less manual work.
- Less costs.
- Improved visibility.
- Improved planning.

Disadvantages

- The existing reduces the, but still the system require a human interaction for the inventory.
- There is some chance for the occurrence of error such as missing to read some tags.
- Not much cost-effective compare with the proposed system.

4 PROPOSED INVENTORY METHODOLOGY – HARDWARE SELECTION

This chapter explains about the hardware module development of proposed RFID inventory system using drones. The hardware module consists of:

- UHF RFID reader and antenna to read the tags.
- CPU (Central Processing Unit) to configure and command the reader to read tags and store.
- PSU (Power Supply Unit) with LiPo (Lithium Ion Polymer) battery and voltage regulator.

Simple Block Diagram:

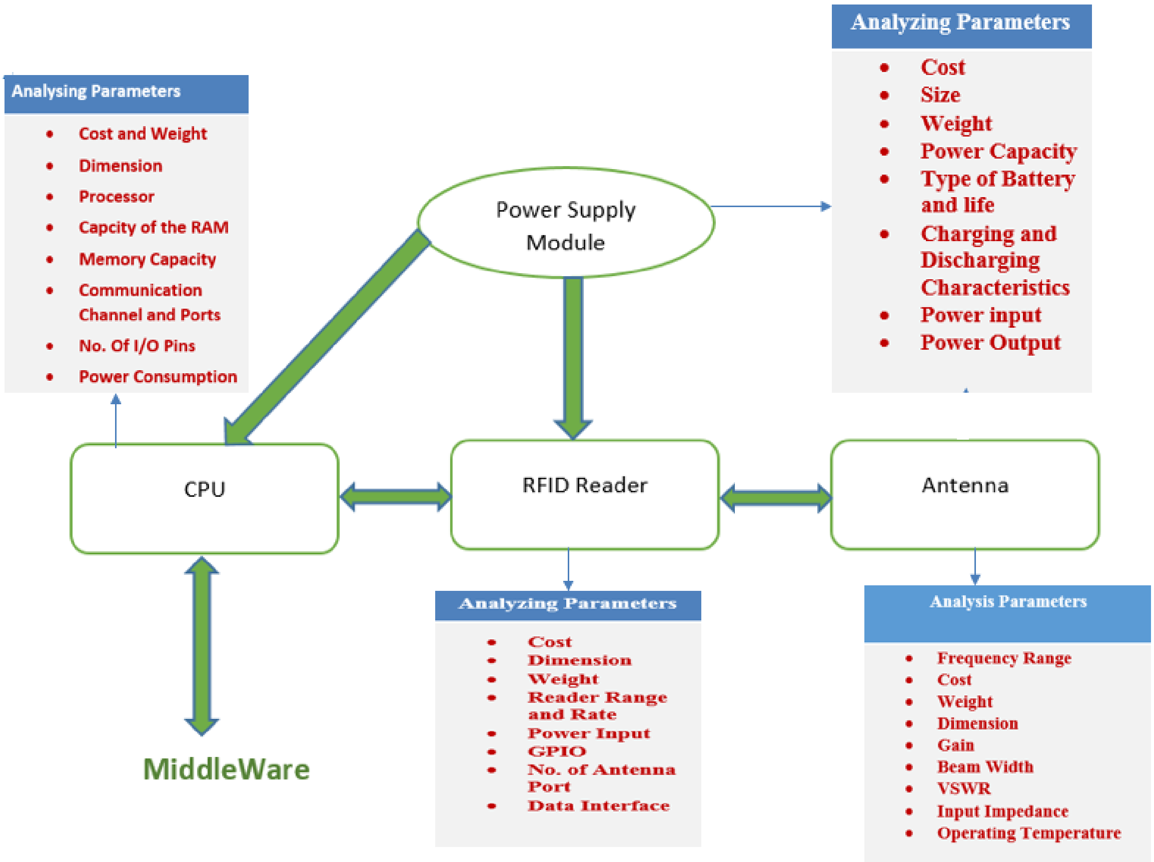


Figure 13 - Simple Block Diagram of the Hardware Module

4.1 UHF RFID Reader Analysis and Selection

This section explains about the market analysis of different reader for the hardware module and the selection of the reader.

4.1.1 RFID Reader

RFID reader consist of RF module, which is used for both receive and transmit the RF signal. The RFID module consists of oscillator, modulator, amplifier in the transmit side and a demodulator, receiver amplifier in the receiver side. The transmitter oscillator generates carrier signal frequency, the modulator modulate the carrier signal depends upon the data then, which is amplifying enough to wake the tag using booster or amplifier. The receiver has demodulator to retrieve the signal from the tag. The amplifier employs to strengthen the signal for further processing. The microcontroller control unit uses the OS to filter and save the data. Finally the data is ready to transmit to the network.

The interaction between the RFID reader and the tags relationship are like master-slave or otherwise RFID reader itself a slave for the host system, means the reader and the transponder are activated based on the command from the host. The host may be micro controller or PC.

4.1.2 Required Reader Performances

- Less weight, size and cost.
- Best read rate and read range.
- Best performance chip.
- No. of Antenna port and GPIO.
- Less power consumption and RF power output.
- Easy data interface options.
- Good thermal characteristics.

4.1.3 Market Analysis of the Reader

The Market analysis of the UHF RFID reader is done based on the above-mentioned performance requirements.

Table 4 - RFID Readers in the Market

Brand of the Reader	Reader Link for Reference	Disadvantages
Rodin Bell	http://www.rodinbell.com/cpzxIS/info_55.aspx?itemid=20&CategoryID=17&Cid=20	- (Selected one)
Winned	http://www.winnix.net/product2.asp?ClassCode=0004	Low read rate
Alien	http://www.alientechnology.com/products/readers/	Large size, Heavy weight
Impinj	https://www.atlasrfidstore.com/impinj-rfid-readers/	Large size, Heavy weight
TSL and Other hand held readers	https://www.tsl.com/rfid-products/	High cost
GAO	http://gaorfid.com/product/reader-long-rs485-wiegand-gpio-uhf-4-port-rfid/	Heavy weight and large size

Based on the above analysis of the RFID reader the RodinBell reader matches the selection criteria of our project.

Table 5 - Specifications of Rodin Bell Readers

Specification/Module Type	R2800	R2900
Image		
Cost (USD)	225	335
Dimension (mm)	67.5 X 51 X 5.2	63.6 X 91 X4.3

Weight-Module + Evaluation kit (g)	40 + 595	90 + 630
Read Rate (Tags/s)	Greater then 700	Greater then 700
Read Range (m)	10	10
GPIO	2 input and 2 output	2 input and 2 output
No. Antenna Port	4	8
Data Interface	UART and USB	UART and USB
Read Write Level (m)	10	10
Temperature Range (°C)	20 to +55	20 to +55
RF Power Output(dBm)	0-33	0-33
Max. Power Consumption(W)	7	7
Power Input(V)	5	5

The M2800 module is chosen based on the antenna ports. For RFID drone application 4 ports are much enough.

4.1.4 Analysis of M2800

Figure 14 - M2800 UHF RFID Reader Module

Features and Specification

- Based on Indy R2000 chip, which is used to increase the performance of anti-collision.
- Less Cost, Best dimension and weight which helps to reduce the place constrain for our project.
- Greater read rate, read range which helps to increase the performance of the RFID system.
- Read 216 bytes in one time takes less than 500 ms.
- Write 216 bytes in one time takes less than 3.5 s.
- Can also read/write data with various lengths.
- Extremely stable (approximate 100% success rate).
- Less power consumption which reduce the capacity of the Power Supply Module.
- Low-power Mode, few tags only 600 mA +/-10%(5 V Input).
- Maximum out power only 1.2 A +/-10% (5 V Input).
- Dual CPU architecture:
    - Main CPU is responsible for tag inventory, assistant CPU is responsible for data management.
    - Inventory and data transfer are parallel and simultaneous. This feature improves the total performance significantly.
    - Assistant CPU is responsible for generating real random number.
    - Assistant CPU is responsible for system operating surveillance
- Two Inventory modes
    - Buffer mode and real time mode.
    - In buffer mode, inventoried tag will be stored in buffer. This mode improves the efficiency of multi tag inventory.

Electrical Characteristics

- **Operating Voltage** 3.7 V to 5 V.
- **Standby Mode Current** <50 mA (EN high level).
- **Sleep Mode Current** <100 uA (EN low level).
- **Operating Current** 1.2A +/-10%, 600 mA +/-10%(Low-power Mode, few tags).
- **Operating Temperature** - 20 °C to + 55 °C
- **Storage Temperature** - 20 °C to + 85 °C

- **Humidity** < 95% (+ 25 °C)
- **Air Interface Protocol**
    - EPC global UHF Class 1 Gen 2 / ISO 18000-6C
    - ISO 18000-6B
- **Spectrum Range** 860 MHz to 960 MHz
- **Output Power** 0 to 33 dBm
- **Output Power Precision** +/- 1 dB
- **Peak Inventory Speed** > 700 tags/s
- **Tag Buffer Capacity** 1000 tags @ 96 bit EPC
- **Host Communication** TTL Uart port
- **GPIO** 2 inputs optical coupling 2 outputs optical coupling
- **Max Baud Rate** 115 200 b/s

Table 6 - Pin Description of M2800

Pin	**Interface**	**Description**
1	GND	Grounding
2	GND	
3	3.7 V to 5 V	Power input
4	3.7 V to 5 V	
5	GPIO 3	Output
6	GPIO 4	
7	GPIO 1	Input
8	Beeper	Has driven with > 50 mAh output current
9	UART_RXD	TTL level
10	UART_TXD	
11	USB_DM	For testing
12	USB_DP	
13	GPIO 2	Input
14	EN	High level enable
15	GPIO 5	RS-485 direction control

Advantages:

- Indy R2000 chip.
- Required performance for our project.
- Best price.

4.2 UHF RFID Antenna Market Analysis and Selection

This section says about the market analysis of the difference antenna and the selection of the antenna for the RFID drone hardware module.

4.2.1 RFID Antennas

An antenna is connected to a reader depends upon the reader specification we can connect one or more antennas. These antennas send reader's signals. The reader sends the antenna how to generate the RF signal based on the host command. The antennas send the RF field based on the gain. By using that RF fields the tags get waked up and respond. And the reader receives the tags data using the same antenna.

Our Performance Requirements

- Best beam - width in order cover the entire height of the selves at once.
- Less weight, dimension and cost.
- Gain - To achieve the read range of the reader, because the distance between the drone and shaves are not much.
- Less VSWR - To avoid the dBi losses at the output terminal of the antenna.

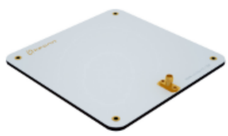
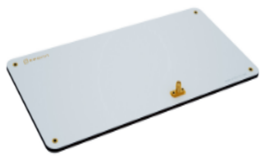
4.2.2 Market Analysis of UHF RFID Antenna

Table 7 - Market Study of UHF RFID Antennas.

Name of the Brand	Antenna Reference Link	**Disadvantages**
AXEM Technology	http://www.axemtec.com/fr/produit/antennes-uhf-oem-patch-ceramique/	**Very low gain**
Zebra RFID Antennas	https://www.zebra.com/us/en/products/spec-sheets-latest/rfid-rfidantenna-spec-sheet-en.html	**Large size, heavy weight**

Sensormatic	https://www.sensormatic.com/products/inventory-intelligence/rfid-antennas-readers/rfid-work-surface-rp-tnc/	**Low gain and beam width**
Alien Antennas	https://www.barcodesinc.com/cats/rfid-antennas/?nav=hdr	**Heavy and Large**
Impinj Antennas	http://www.impinj.com/products/readers/speedway-antennas/	**Heavy and Large**
Invengo Antennas	http://www.invengo.com/rfid-product-line/readers-antennas/rain-rfid-uhf-antennas/	**Heavy and Large**
Kathrein Antennas	https://www.atlasrfidstore.com/kathrein-wide-range-70-rfid-krai-antenna-fcc-etsi/	**Heavy and Large**

Table 8 - Specifications of Keonn Antennas

Specification/Model	**Advantenna p-11**	**Advantenna p -12**
Image		
Frequency Range (MHz)	865 - 868	865 - 868
Cost (USD)	100	135
Weight (g)	115	230
Dimension (mm)	137 X 137 X 3	227 X 227 X 3
Beam width (°)	100	60
VSWR	1.5:1	1.5:1
Impedance (Ω)	50	50
Peak Gain (dBi)	3.2	5.3
Polarization	Circular	Circular

The Keonn Advantenna p-11 is chosen based on the less weigh, polarization and beam width.

Advantages Kennon Advantenna p-11:

- Best beam width and less weight.
- Less price and small dimension.

Disadvantages:

- Less gain.

4.3 CPU Analysis and Selection

This section describes the analysis and selection of the CPU module for the RFID drone application.

4.3.1 CPU

CPU is the heart of the hardware module, which commands and controls the all of the devices in the hardware module. In our module CPU has responsibilities to configure the reader and the antenna configuration parameter. It runs the code continuously to get the tag information from the reader and stores into the database.

Requirements

- Best Processor and Good processor.
- High Communication interface speed.
- More options for future development.

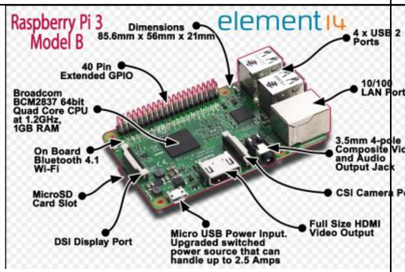
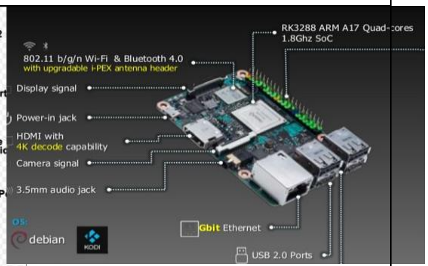
Software Modules

The below mentioned list is the responsibilities of the CPU in the RFID drone. In that application of flight control and SDK for bacons are used for autonomous and IPS (Indoor Positioning System) respectively. SQLite database used to store the inventory information during drone is flying or drone is taking inventory. At the end of the each inventory the inventory database will be send to the middle ware for the further data processing.

- Application for flight control.
- SDK for beacons.
- SQLite database for to store the inventory data.

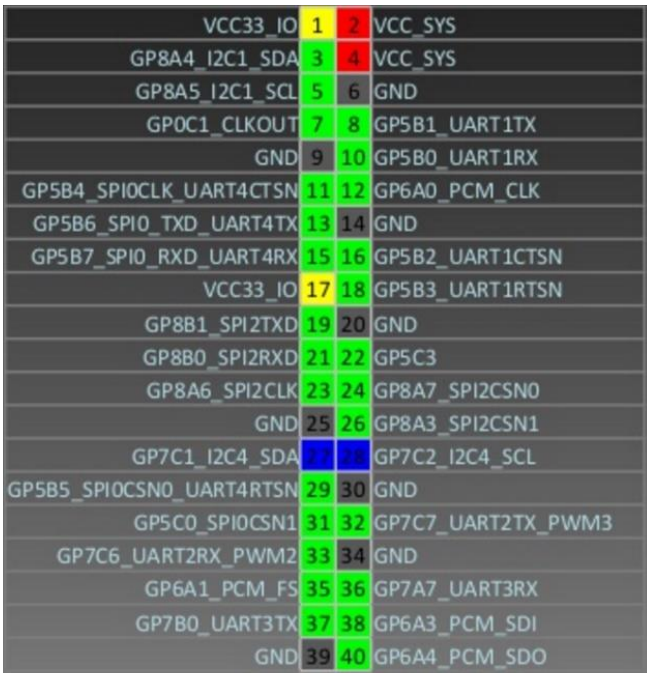
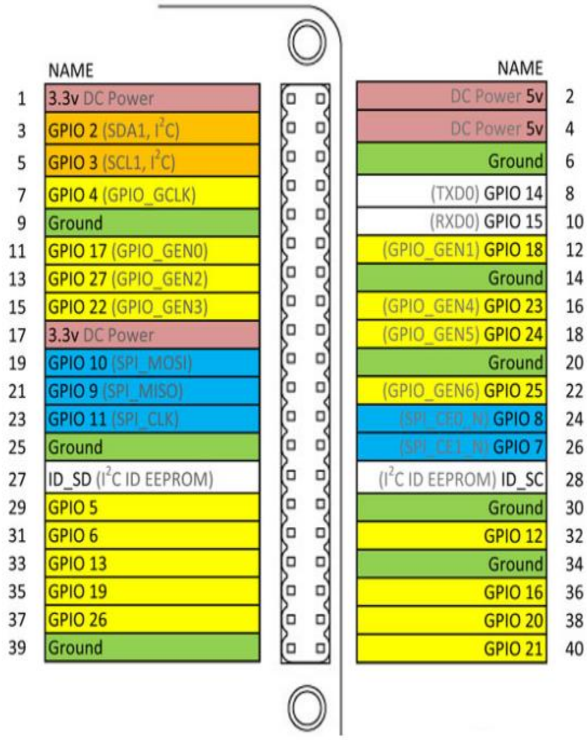
4.3.2 Market Analysis of the CPU Modules

Table 9 - Comparison Between Asus Thinker Board and Raspberry PI3

Specifications/Modules	**Asus Thinker Board**	**Raspberry PI 3**
Image		
CPU	Quad core 1.8 GHz ARM Cortex-A17	Quad core 1.2 GHz ARM Cortex-A53
RAM	2GB LPDDR3	1GB LPDDR3
Storage	MicroSD slot with UHS-I support	MicroSD
Display	Output HDMI 2.0 port to support H.264 4K resolution	HDMI, supports HD resolution
Audio	Supports up to 192 k/24 bit sample rate Supports up to 48 K/16 bit sample rate	Same
GPIO	40-pin Internal header with 28 GPIO pins	40-pin header, populated
Connectiviy	Gigabit LAN and Bluetooth 4.0 + EDR connectivity Gigabit Ethernet port via PCI, 802.11 b/g/n Wi-Fi - 3.5mm audio jack	Bluetooth: Bluetooth 4.1 Classic, Bluetooth Low Energy 10/100 Ethernet, 2.4 GHz 802.11n wireless 3.5 mm analogue audio-video jack
Ports	Four (4) USB 2.0 ports HDMI 2.0 with 4K support MIPI-CSI camera port MIPI-DSI with HD support	Four (4) USB 2.0 HDMI Port Camera Serial Interface (CSI) Display Serial Interface (DSI)
Power	Micro-USB (5 V/2 A)	Micro-USB (5 V/2.5 A)

OS support	Linux-Debian,KODI	Linux-Debian,KODI
Price(USD)	49	40

Table 10 - Pin Diagram of Asus Thinker Board and Raspberry PI3

Asus Thinker Board	**Raspberry PI3**	
		

Advantages of Asus Thinker Board

- Advanced Processor Compared with RPI3.
- Double time faster than RPI3.
- Baud rate of the communication interface is higher compared with RPI3.

Disadvantages of Asus Thinker Board

- Costly compared with RPI3.

4.4 Interface Modules

In this section explains the interface module used to connect the RFID reader with the CPU module.

4.4.1 Interface between M2800 and Thinker Board(PL2303HX)

This module is used to convert the serial information (TTL) from the reader to USB which in the thinker board (CPU) or to PC during testing.

Image:

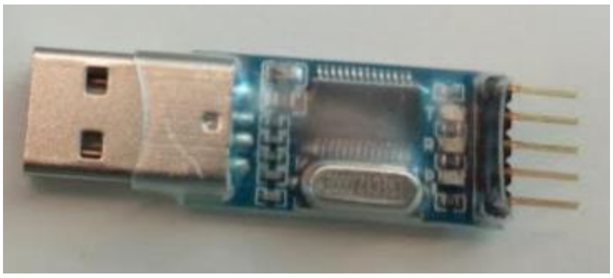


Figure 15 - Image of PL2303HX TTL to USB Module

Features and Specification

- Fully Compliant with USB Specification v2.0 (Full-Speed)
- On Chip USB 1.1 transceiver, 5 V to 3.3 V regulator
- On-chip 96 MHz clock generator
- Supports RS-422/RS-485 like serial interface (TXD, DTR_N, and RTS_N pins should be externally pulled-up to 5 V)
- Supports RS232-like Serial Interface (PL-2303HX USB to Serial Bridge Controller Product Datasheet., 2017)

4.5 Power Supply Module

The Power Supply Module is used to supply up the reader and the CPU in the hardware module. It has LiPo batteries and voltage regulators to give a constant voltage for different load current. Because the reader and the CPU which we are using the hardware module will make the overheating if we supplied in variable voltage.

4.5.1 Block Diagram of the PSU

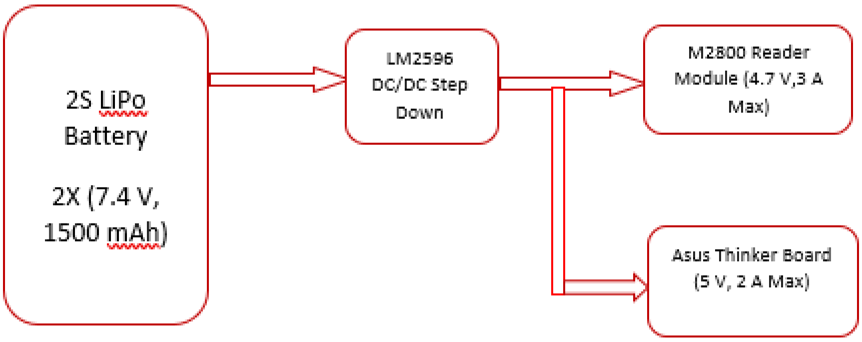


Figure 16- Simple Block Diagram of the PSU module

The PSU consists of 2*2S, 1500 mAh Lipo and the LM 2596 Dc/Dc Stepdown adjustable voltage regulator to step down from 7.4 V DC to constant 5 V DC.

4.5.2 LiPo Batteries

Figure 17 - 3.7 V, 1500 mAh LiPo Battery

The battery unit is made up or 4 single 3.7 V, 1500 mAh batteries. They are connected in the manner that 2 unit of 2S batteries. So, we obtain the 7.4 V, 3000 mAh.

Specifications

- Length: 70 ± 0.4 mm.
- Width: 40 ± 0.4 mm.
- Thickness: 5.8 0.2 mm.
- Cable: 150 ± 3.0 mm (26AWG UL 1007).
- Weight: approximately 30.0 g.

Electrical Specifications

- Rated capacity: 1480 mAh min, 1500 mAh typ.
- Nominal voltage: 3.7 V.
- Max. operating voltage range: 3.0V to 4.2 V.
- Charge voltage: 4.2 ± 50 mV.
- Initial charge current: Standard charge: 750 mA.
- Rapid charge: 1500 mA.
- Charging cut-off (A or B).
- A) By time: Standard charge: 7 h.
- Rapid charge: 4 h.
- B) By min. current: 30.0 mA.
- Max continuous discharge current: 1500 mA.
- Internal impedance (1kHz): approximately 43 mΩ.
- Exp. cycle life: >500 cycles >70% of initial cap. (0.5 C/0.5 C).

4.5.3 LiPo Charger Module

The Lipo battery charger based on MCP73833 regulator IC, used to charge the battery. One end is connected to the power supply and another end of the module is connected to the input of the battery. It has LEDs to show the current condition of the charging.

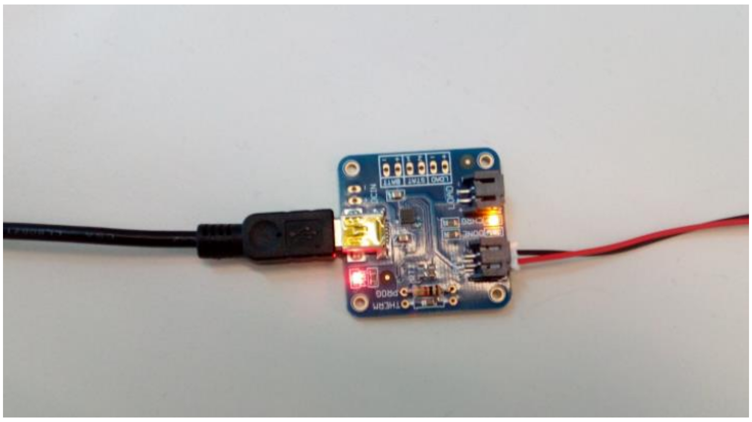


Figure 18 - Lipo Battery Charger Module

Specifications:

- 5 V input via mini-B USB connector.
- For charging single Lithium Ion/Lithium Polymer 3.7 V/4.2 V batteries (not for older 3.6 V/4.1 V cells).

- ➢ 500mA charge current, adjustable from 100 mA to 1000 mA by soldering in a resistor
- ➢ Separate JST connectors for battery and load system so batteries don't have to be removed for charging.
- ➢ Chip supports a 10K NTC thermistor which we have stuffed as a plain 10K. For people who require temperature monitors (using high charge rates), remove the 10K and solder in the thermistor in its place.

4.5.4 LM2596 DC to DC Step Down Converter-Voltage Regulator

Figure 19 - LM2596 DC/ DC Adjustable Step-Down Module

The output from the battery is 7.4 V. LM2596 voltage DC/ DC step down voltage regulator used to reduce the voltage in to 4.7 V for RFID reader and 5 V for the Asus Thinker board [12].

Specifications

- ➢ Input voltage: 4.5 to 60 V.
- ➢ Output voltage: adjustable 3-35 V (default delivery voltage 5 V).
- ➢ Output current: rated current 2.5 A input, maximum 3 A.
- ➢ Output power: maximum 15 W.
- ➢ Conversion efficiency: up to 92%.
- ➢ Static power consumption is only about 6 mA.
- ➢ Working temperature: industrial grade (- 40 ℃ to + 85 ℃).

- Input mode: IN+ (input positive), IN - (input negative).
- Output mode: OUT+ (output positive), OUT- (output negative).
- Size: 45 * 22 * 13.5 mm (incudes potentiometer).
- Load regulation: ±1%.
- Voltage regulation: ±0.5% (in order to reach the point at which the no-load output voltage will be higher, but as long as there is with 1 mA load, the output voltage is normal, and will not affect the function, please be assured about that when use it.).
- Short circuit protection: current limiting, overheating protection, but since the recovery.

5 HARDWARE ASSEMBLY

5.1 Reader Configuration

The reader is connected to the computer using TTL to USB converter. The configuration is done step by step as per explained in the user manual.

5.1.1 Hardware Configuration

Step 1: Powering the reader:

The reader is powered up using the PSU module as per the below Figure 21.

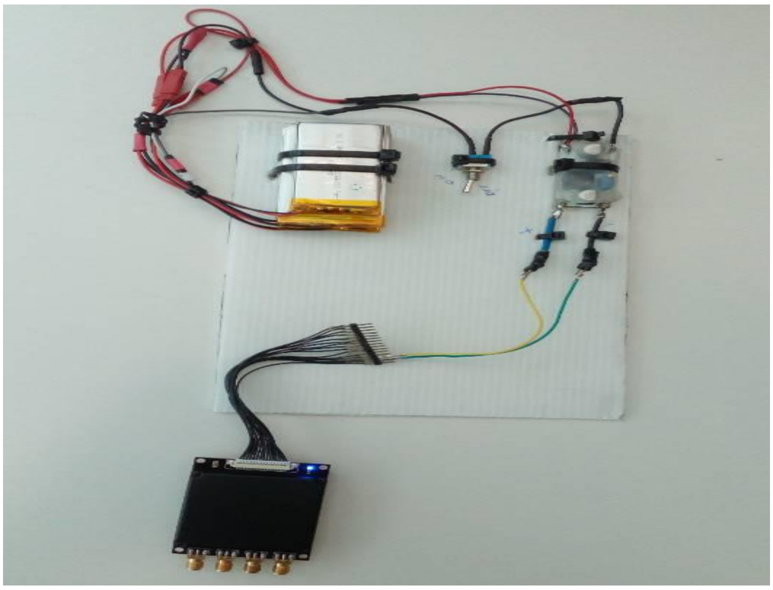


Figure 20 - Powering up of Reader

Step 2: Connecting the antenna port:

The antenna is connected to the port 1fo the reader as shown in the Figure 22.

Figure 21 - Antenna connection with Reader

Step 3: Connecting data link to the reader:

The reader is connected to the PC using PL2303HX TTL to USB module. The pin number nine (Rx) of the reader is connected to the Tx pin of the PL module, pin number ten (Tx) of the reader is connected to the Rx of the PL module and the GND pin of the both is connected.

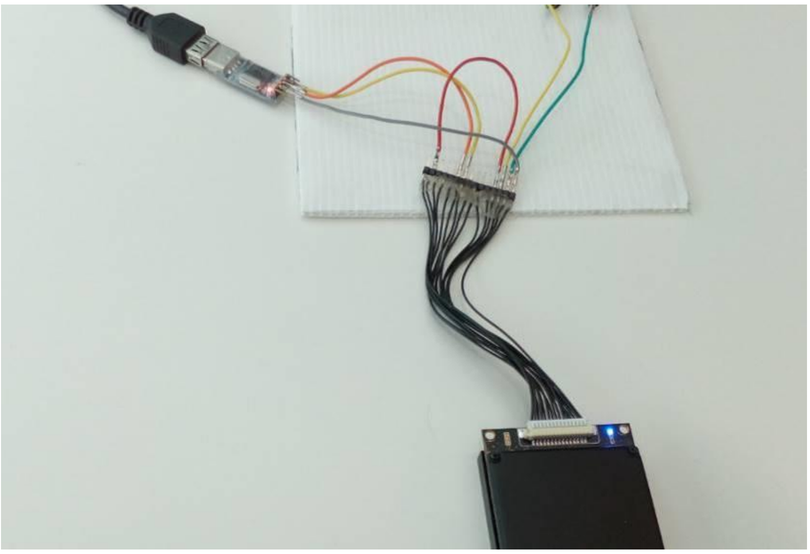


Figure 22 - Establishing the Datalink for Reader

5.1.2 Operating the Reader Via Demo SDK

Step1: Choosing the Communication Link

After running the SDK (C# form application), the application will provide the UI (User Interface) to do a reader configuration. In the menu Basic Setup, the communication type RS232, port of communication and baud rate are entered finally connect button clicked as shown in the below image.

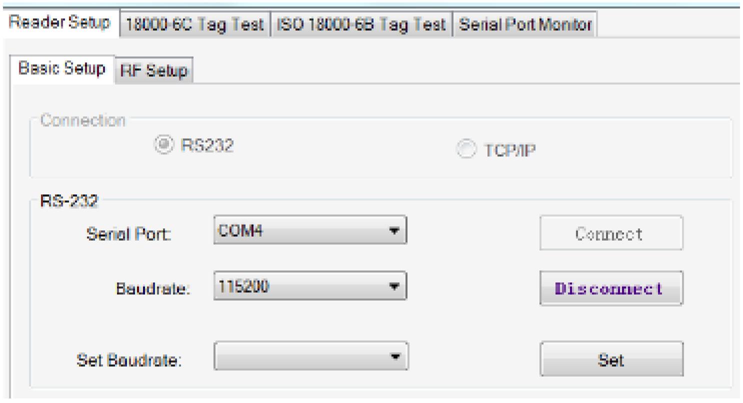


Figure 23- Setting Communication Link

Step 2: Setting Reader Identifier

Follow by the reader address, reader identifier and firmware version of the reader are chosen as mentioned in the instruction manual. So, these are all about in the Basic Setup. For each updating the below display will show the notification of the connection or error message.

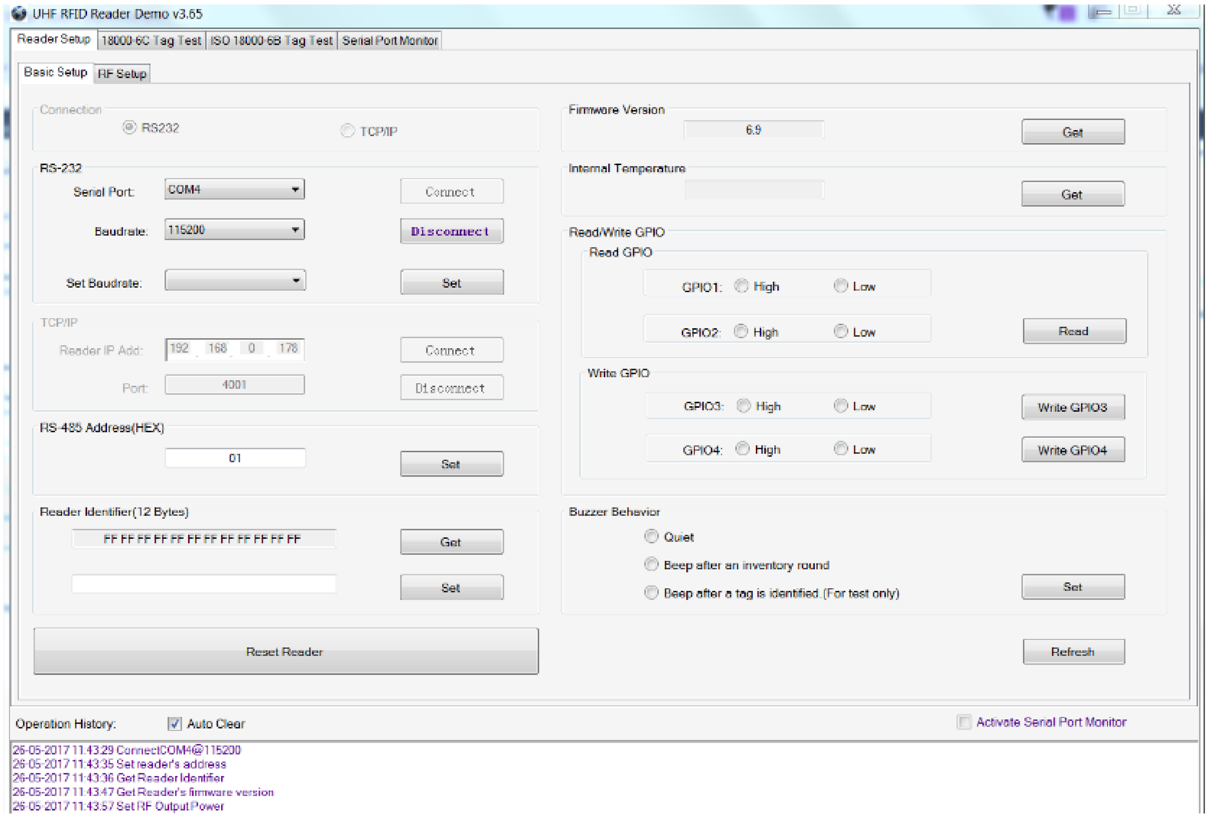


Figure 24 - Setting Basic Setup of the Reader

Step 3: Setting RF Parameters:

- In the menu RF Set up the RF output power of the reader is chosen, which should be between (0 – 33) dBm. 30 dBm is the optimal value for the better performance of the reader. Once if set the RF output power which will be store in the reader it won't lost after the cut off power.

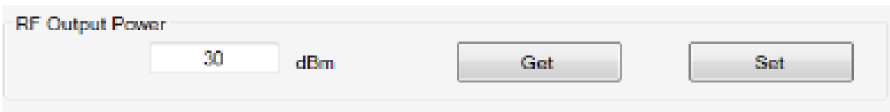


Figure 25 - Setting RF Output Power of the Reader

- Followed by the RF Return Loss, this value is based on the operating carrier frequency of the spectrum. Then RL Threshold value, this value is used to check whether the antenna is connected in the port or not. For the larger value the impedance matching between the antenna and port could be best. For the better operation 4 is the optimal value.

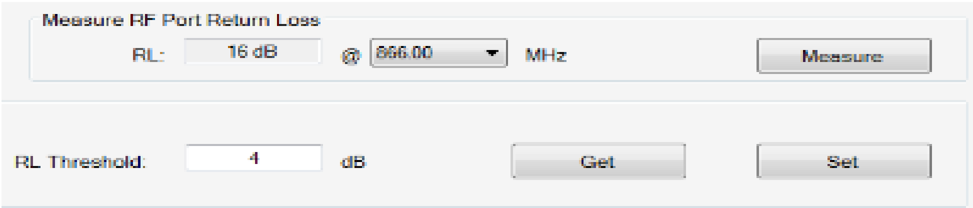


Figure 26 - Setting RF Port Return Loss

- The frequency spectrum of the reader is depends upon the operating region of the reader. For Europe the UHF spectrum ranges from 865 MHz to 856 MHz.

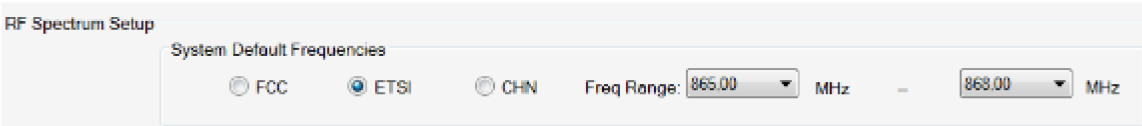


Figure 27 - Setting Frequency Spectrum

Step 4: Setting Inventory Mode:

In the 18000-6C Tag Test menu provide two inventory modes real time mode and buffer mode. In the read time mode the tag information will be provided in the below list and in the buffer which will be stored in the buffer we take whenever we want. We tested the reader in real time mode.

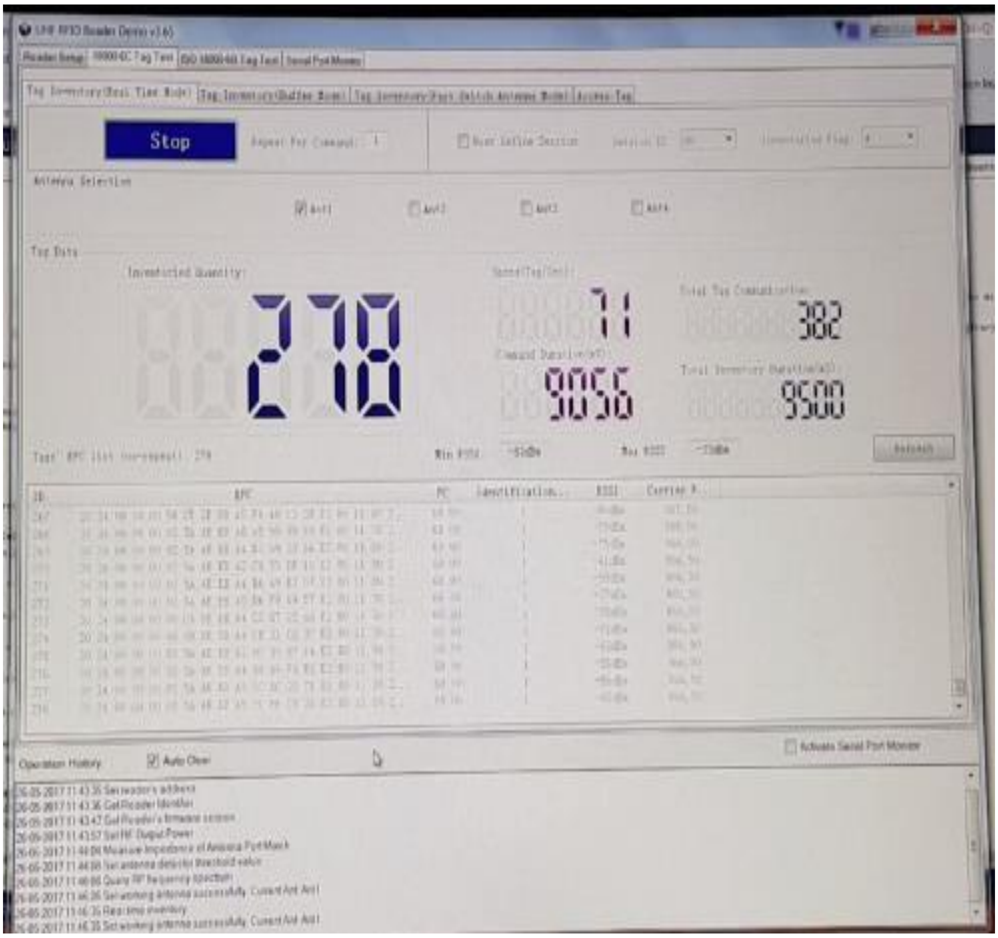


Figure 28 - Real Time Mode Inventory

Finally, the performance of the reader is good for the above configure parameter.

5.2 Integration of the Hardware Module:

The devices are connected in the hardware module as per the below diagram:

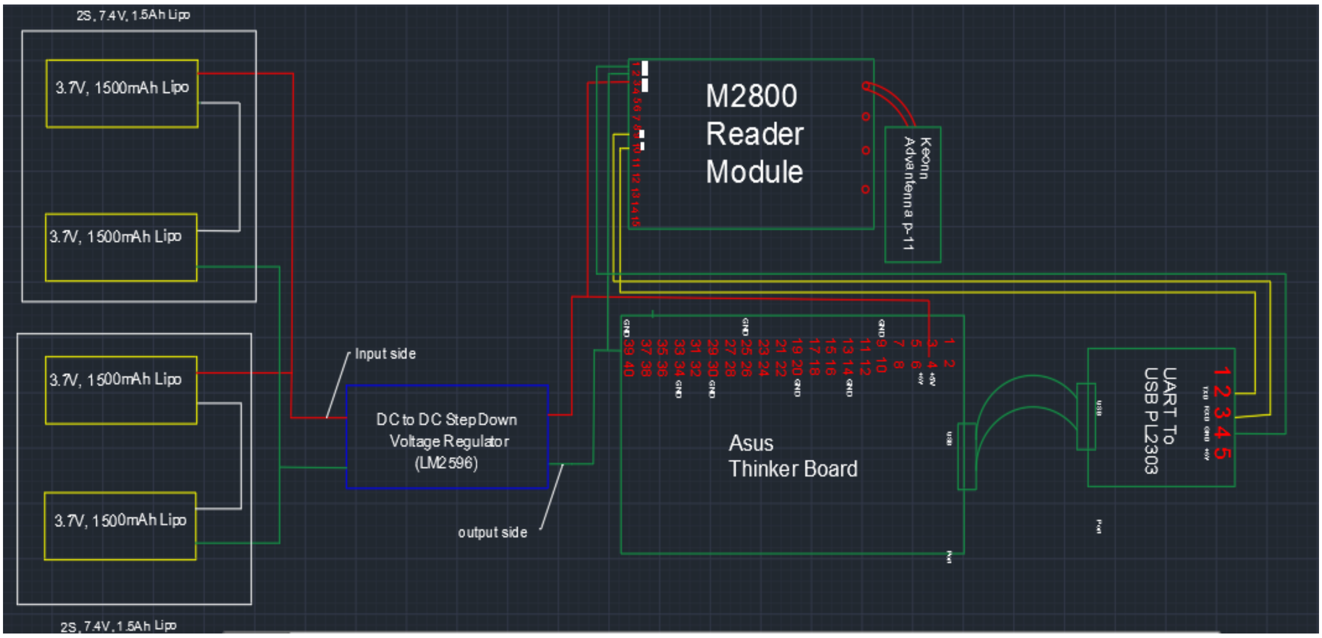


Figure 29 - Hardware Module Devices Connection Diagram

The image shows the integration of devices in the hardware module

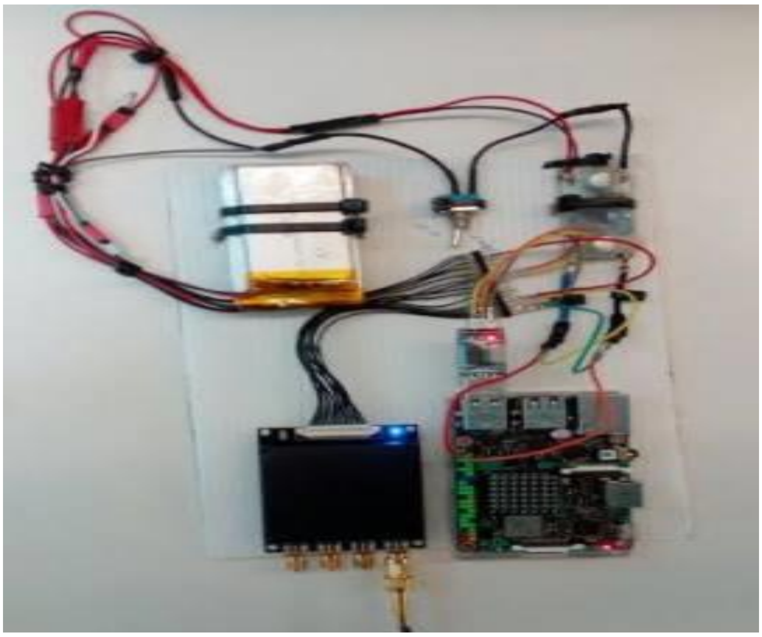


Figure 30 - Image of Hardware Module

5.3 Testing of Voltage Regulator Devices

In The LM2596 DC to DC step down voltage regulator module is used to step down the 7.4 V DC from the Battery unit to 5 V DC for reader and the CPU. The below section will explain about testing of the regulator module and the performance under different load current conditions.

5.3.1 Connection Diagram for the Testing

The regulator is connected as per the below shown diagram. The FLUKE oscilloscope provide two ports to see both input parameter (V_{in} and I_{in}) as well as the output parameters (V_{out} and I_{out}) at the same time by selecting the two port options in the oscilloscope [11] [14].

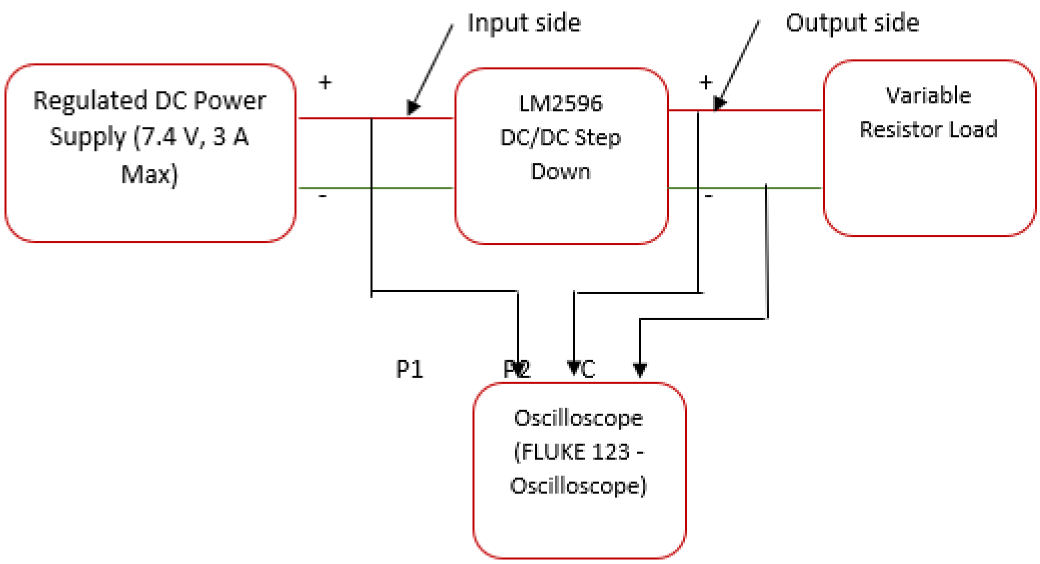


Figure 31 - Testing Connection Diagram for LM2596 Module.

Where P1 = Port one of the oscilloscope,

P2 = Port two of the oscilloscope,

C = Common port.

5.3.2 Testing Procedure

Step 1: Connections are made as per the above connection diagram.

Step 2: The RPS (Regulated Power Supply) is turned ON and the out put voltage is set as 7.4 V (same as like output voltage of the battery unit). And current is set as 2.5 A Max. Because the continuous maximum input current of the regulator module is 2.5 A.

Step 3: For the various value of load resistance the input and output V&I are noted in the below table. The resistance values are varying from maximum to minimum [13].

Table 11 - Performance of LM2596 for different Load Current.

Serial No	V_{in} (V)	I_{in} (A)	P_{in} (W)	V_{out} (V)	I_{out} (A)	P_{out} (W)	R_{load} (Ω)	Efficiency (%)
1	7.40	0.40	2.96	5.09	0.45	2.29	11.00	77.38
2	7.40	0.63	4.66	5.09	0.76	3.86	6.60	82.97
3	7.40	0.78	5.83	5.06	0.95	4.80	5.00	82.43
4	7.40	1.19	8.85	5.05	1.46	7.37	3.30	83.30
5	7.40	1.43	10.58	5.04	1.78	8.97	2.70	84.77
6	7.40	1.57	11.64	5.03	1.99	10.00	2.50	85.93
7	7.40	2.14	15.83	5.02	2.65	13.30	1.79	84.00
8	7.40	2.36	17.46	5.01	2.90	14.52	1.60	83.19
9	7.39	2.43	18.00	5.01	2.94	14.72	1.56	81.82
10	7.39	2.58	19.06	4.99	3.02	15.06	1.50	79.03
11	7.39	2.67	19.73	4.98	3.05	15.18	1.45	76.97

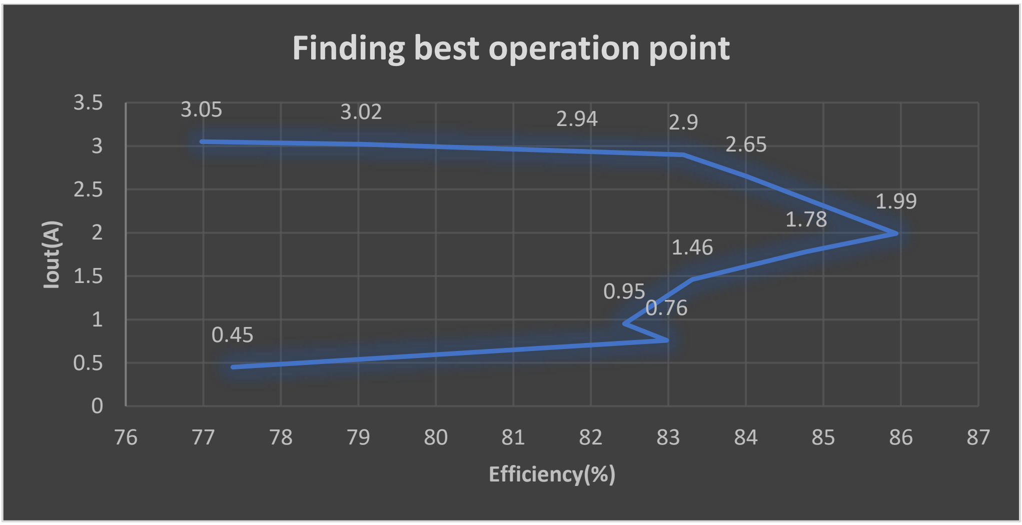


Figure 32 - Performance Graph for LM2596 Module

The above test will give the best high efficiency operating region of the LM2596 step down voltage module lies between the load current of 1 A until 2 A. The efficiency is around 86%.

5.4 Calculation of Minimum Ah for the Battery Unit

Required power for the UHF RFID reader = V * I = 5*1.2 = 6 W.

Energy consumed by the reader for an hour = P * t = 6 Wh.

Required Power for the thinker board = 5 * 2 = 10 W.

Energy consumed by the thinker board for an hour = 10 Wh.

Where, V = Required input (V).

I = Input current (A).

P = Power in (W).

Considering 88% LM2596 efficiency, the power required from the battery is:

(10+6)/0.86 = 18.6 Wh

So, the required battery is

= Total power required for Hardware module / Nominal voltage of the battery.

= 18.6/ 7.4 = 2.51Ah

Note: The above calculations are done by considering the maximum load current of the devices in the hardware module such as reader and CPU.

Calculation of Battery Capacity

The Battery unit consist of four 1 S, 1500 mAh batteries, which are connected in the way that each 2 batteries are connected to make 2 * 2 S battery of 7.4 V, 1500mAh. Then those 2 * 2S batteries are connected in parallel to achieve 7.4 V and 3000 mAh.

Capacity of the battery for one hour = 3 Ah.

The power delivered = 7.4 * 3 = 22.2 W.

Energy delivered by the battery for one hour = 22.2 Wh.

The capacity of the battery is 1C, so it will discharge the energy of 1 h.

So, the battery unit has capability to supply the hardware module = Capacity of the battery / Capacity required for hardware unit.

= 3/2.4 = 1.19 h.

= 1h and 11 min.

5.5 Software Module Development

This chapter explains about the program control flow chart for the reader program and software. C# coding for the reader to read the tags.

5.5.1 Program Procedure

Step 1: Start the Program.

Step 2: Initialize the RFID reader configuration variables.

Step 3: Check the reader connection.

Step 4: If the reader is connected to the system, the program move to next step. If not, it will show the error ("Check the reader connection") message.

Step 5: Configure the reader basic setup values and check the limits of the values.

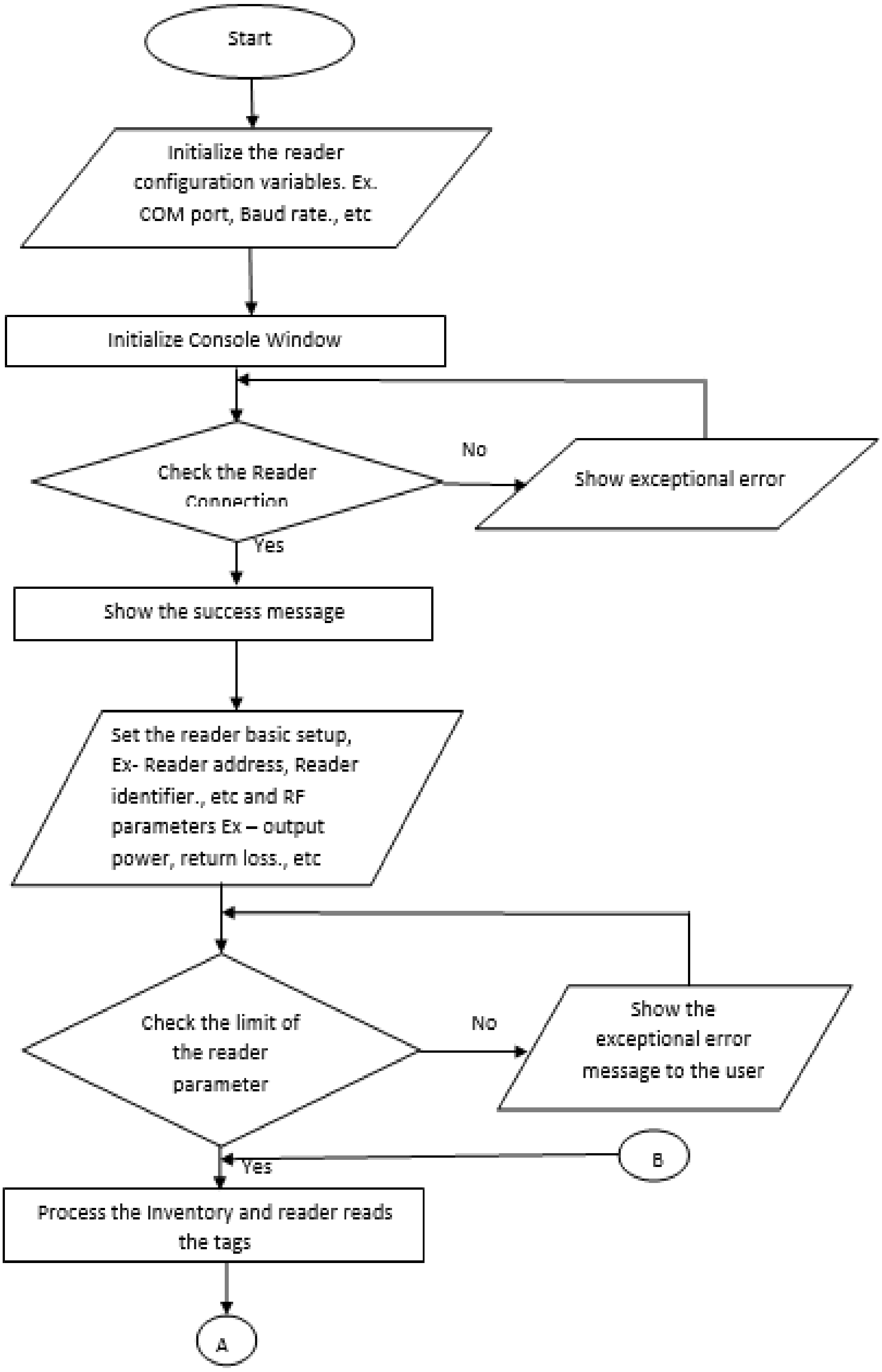
Step 6: If the ranges are under limit move to next step. If not show the error message based on the value to the user.

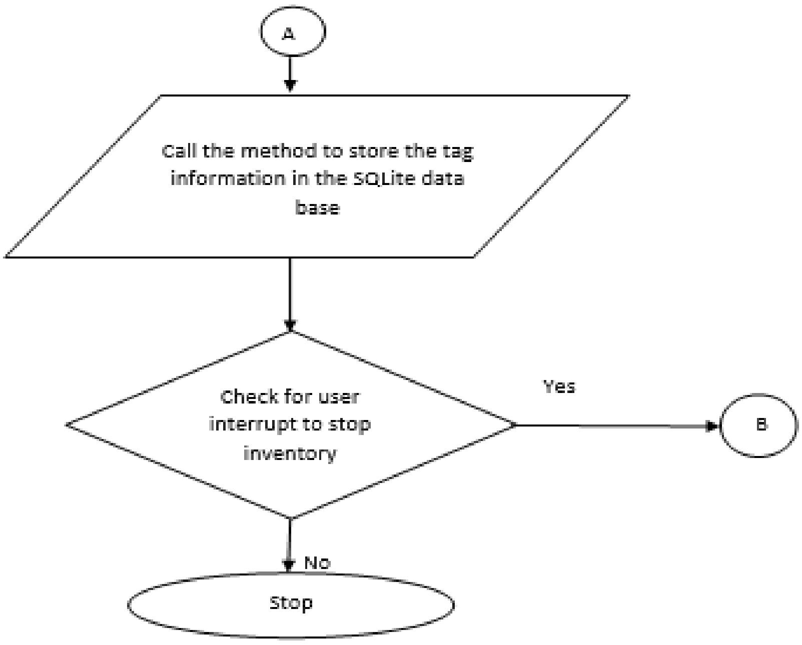
Step 7: Start the inventory and read the passive RFID tags.

Step 8: Continuously check for the user interrupt.

Step 9: If the user send the stop message, stop the reading process and update the inventory database.

5.5.2 Program Control Flow Chart:




A
Call the method to store the tag information in the SQLite data base
Check for user interrupt to stop inventory
Yes
B
No
Stop

6 CONCLUSION AND FUTURE WORK

This chapter will discuss about the limitation of the proposed system and suggestion for the future work.

6.1 Limitation of the Proposed System

At the beginning level (demonstration) of the development the proposed system works well. But, in future when it will work as a product, the number of antenna connected to the reader will increase (max. of 4) and also, we have possible to connect the devices in to the Asus thinker board. In that case the RFID reader and thinker board may consume more current. So, in order to avoid the heating problem in the regulator circuit and to increase the efficiency, the better and much efficient regulator for each device will be good.

6.2 Future Work

The suggestion for the future work in the proposed system, voltage regulator circuit in PSU will be designed using MP3423. Because, the efficiency and the load current of the MP3423 high compared with LM2596. In future, If we connect more antennas with the reader module and also, if we connect more devices with the Asus thinker board the current consumption will increase. So, in that case the MP2323 will provide good efficiency.

6.2.1 Designing of Regulator Circuit using MP 3423

The MP3423 is a high-efficiency, synchronous, current-mode, step-up converter with output disconnect. The MP3423 starts up from an input voltage as low as 1.9V, while providing inrush current limiting and output short-circuit protection. The integrated P-channel synchronous rectifier improves efficiency and eliminates the need for an external Schottky diode. This P-channel disconnects the output from the input during shutdown [12] [13].

The 600 kHz switching frequency allows small external components, while the internal compensation and soft-start minimize external component count. The MP3423 provides a compact solution for a 5 V output, 3.1 A load requirement, using a supply voltage down to 2.8 V.

6.2.1.1 Features of MP3423

- Up to 98% Efficiency.
- 1.9 V to 5.5 V Input Range.
- 2.5 V to 5.5 V Output Range.
- Internal Synchronous Rectifier.
- 600 kHz Fixed Switching Frequency.
- 9 A Typical Switch Current Limit.
- 43 µA Quiescent Current.
- High Efficiency over Full Load Range.
- Internal Soft-start and Compensation.
- True Output Load Disconnect from Input.
- OCP, SCP, OVP and OTP Protection.
- Small 2 mm x 2 mm QFN14 Package.

6.2.1.2 Efficiency Curve for Different Input Voltage

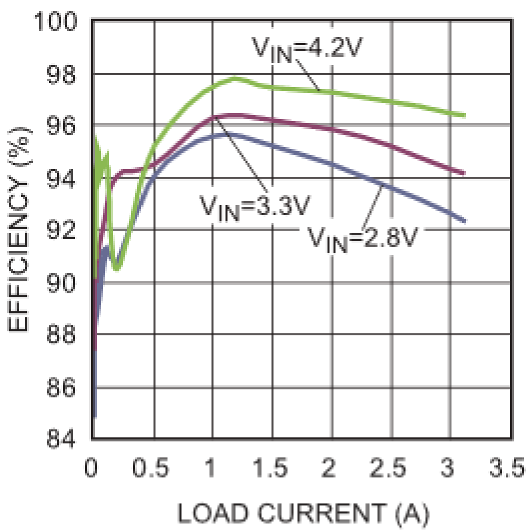


Figure 33 - Efficiency Curve

6.2.1.3 Block Diagram of the Proposed System Using MP3423

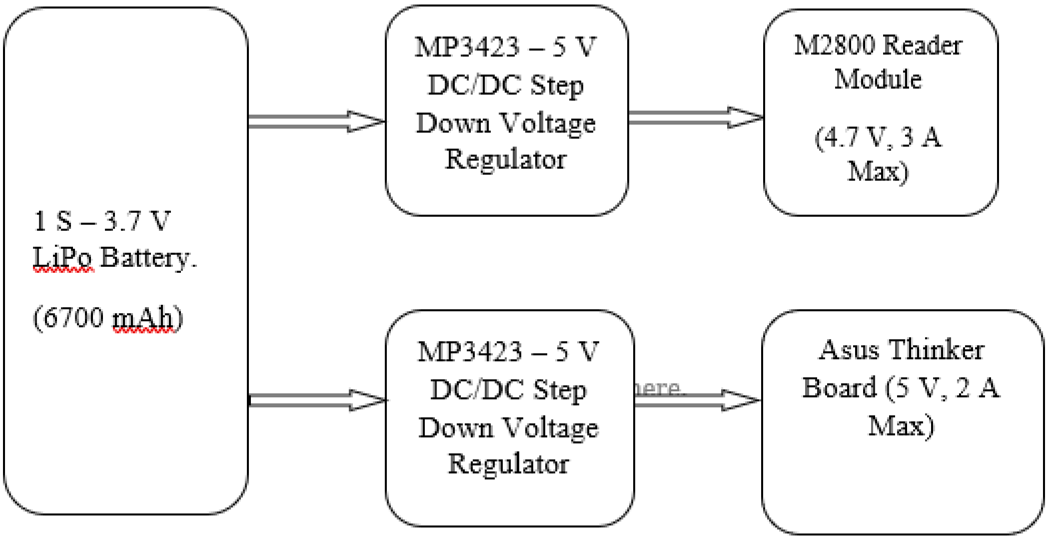


Figure 34 - Block Diagram Using MP3423

6.2.1.4 General Circuit Diagram of MP3423 Regulator

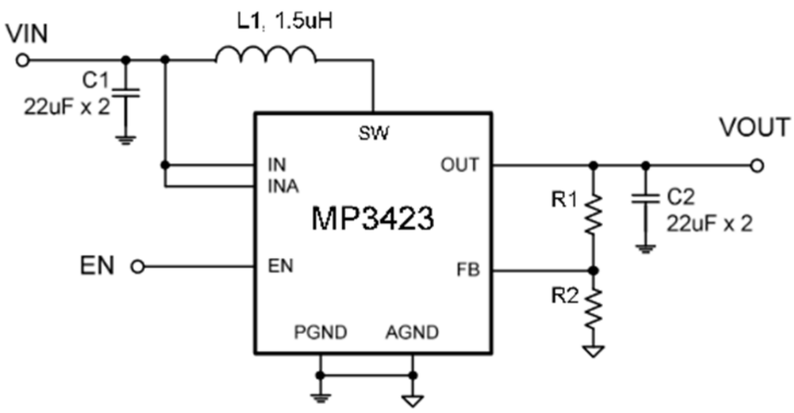


Figure 35 - Circuit Diagram of MP3423.

6.2.1.5 General Equation to Find the R1 and R2 values

$V_{out} = 0.807V_{in} * (1 + \frac{R1}{R2})$ [R2=150 KΩ]……………..(1)

Where, V_{in} = Input voltage of the voltage regulator circuit in V.

V_{out} = Output voltage of the regulator circuit in V.

R1 and R2 = Voltage divider resistance in Ω.

Value of R1 for 4.7V output voltage:

- V_{in} = 3.7 V (Lipo Battery output).
- V_{out}= 4.7 V(To RFID reader).
- R2 = 150 KΩ.

Substitute in equ. (1).

$$4.7 = 0.807 * 3.7 * (1 + \frac{R1}{150K})$$

R1= 86.10 kΩ.

Value of R1 for 5V output voltage:

- V_{in} = 3.7 V (Lipo Battery output).
- V_{out}= 5 V (To RFID reader).
- R2 = 150 kΩ.

Substitute in equ. (1).

$$5 = 0.807 * 3.7 * (1 + \frac{R1}{150K})$$

R1= 101 kΩ.

7 RERERENCES

[1] Pui Yi Lau; Chu Qingix; Wu Yueshan, “A New Generation of Smart UHF RFID Reader”, 2017 International Workshop of on Electromagnetics: Application & Student Innovation Competition, pp:50-52, 2017.

[2] Clarie Swedberg, “Mark & Spencer Experts to Achieve 100 Percent RFID Tagging by 2017”, www.rfidjornal.com/articalviews?, May10,2017.

[3] Pavel V. Nikitin; K.V.S Rao, Antenna & “Propogation in UHF RFID System 2008”, IEEE International Conferences on RFID 2008, pp:277-288.

[4] W. C. Brown, “The history of power transmission by radio waves”, IEEE Transactions on Microwave Theory and Techniques, vol. 32, no. 9, Sep. 1984, pp. 1230 – 1242.

[5] D. Dobkin, T. Wandinger, “A radio-oriented introduction to RFID“, High Frequency Electronics, pp. 46-54 (June 2005 issue), pp. 32-46 (August 2005 issue).

[6] M. A. Jensen and J. W. Wallace, “A review of antennas and propagation for MIMO wireless communications”, IEEE Transactions on Antennas and Propagation, vol. 52, no. 11, Nov. 2004, pp. 2810 – 2824.

[7] P. H. Cole and D. M. Hall , “Fundamental constraints on RFID tagging systems”, research paper, available at http://autoidlabs.eleceng.adelaide.edu.au/researchpapers.htm.

[8] Andrey Larionov, Roman Ivanov, and Vladimir Vishnevsky, “UHF RFID in Automatic Vehicle Identification: Analysis and Simulation”, IEEE Jornal of Radio Frequency Identification, pp:1-1, 2008.

[9] D. M. Dobkin, “The RF in RFID: Passive UHF RFID in Practice” Elsevier Inc,.pp:10-25, 2008.

[10] M. Mohaisen, H. Yoon, and K. Chang, “Radio transmission performance of EPCglobal Gen-2 RFID system,” CoRR , vol. abs/0911.0542, 2009.

[11] Xiaojing; Zhaolong Zhang, “Study on the Output controllability of Buck-Boost Converter”, IEEE International Conference on Mechatronics &% Automation, pp: 107-112, 2017.

[12] Liberzon, A S Morse, “Basic problems in stability and design of switched systems,” IEEE Control Systems Magazine, Vol.19, No.5, pp.59-70,1999.

[13] Li Xiao-jing, WU Ai-guo. Output controllability of buck converter in DCM [J]. Electrotechnical Application, 2015,34(3):27-31.

[14] Xie Guangming, Wang Long, “Output controllability of switched linear systems,” IEEE International Symposium on Intelligent Control- Proceedings, Houston,Texas,USA, pp.134-139, Oct.2003.
[15] J. Cao and A. Emadi "Batteries need electronics", IEEE Ind. Electron. Mag., vol. 5, no. 1, pp.27 -35 2011.
[16] S.H. Wen, "Cell balancing buys extra run time and battery life", Analog Application Journal, pp.14-18, 2009 .
[17] N. S. Jian Cao and A. Emadi, "Battery balancing methods: A comprehensive review", Proc. IEEE VPPC, pp.1 -6 2008.
[18] MaurizonPaschero; Vito Di Giacomo, “Parameter Identification of an Equivalent Circuit Model for Lithium-Ion Batteries” IEEE Conference Publication, pp:1-6, 2010.
[19] Miodrag Bolic, David Simplotl, Ivan Stojmenovic , “The RF in RFID: Passive UHF RFID in Practice”**,** Vol.19, No.5, pp.59-70.
[20] Clarie Swedberg, “Glossary of RFID Terms” http://www.rfidjournal.com/glossary/?T , May 20, 2017.

Appendix

C# Reader Coding

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using Reader;
namespace CS_ConsoleApp
{
    class Program
    {
        private static ReaderMethod reader;
        private static string strComPort = "COM4";
        private static int nBaudrate = 115200;
        private static int m_nReceiveFlag = 0;
        private static string btReaderIdentifier = String.Empty;
        private static bool InvokeRequired = false;

        //Temp
        private static byte btReadId = 0xFF;
        private static byte btOutputPower = 0xFF;
        private static byte btAntDetector = 0x00;
        private static byte btRegion = 0x02;
        private static byte btMajor = 0x00;
        private static byte btMinor = 0x00;
        private static byte btAntImpedance = 0x00;
        private static byte nStartFrequency = Convert.ToByte(0);
        private static byte nEndFrequency = Convert.ToByte(6);
        public static byte btSession;
        public static byte btTarget;
        public static List<byte> lAntenna = new List<byte>() { 0x00, 0x01 };
```

```
private static bool m_bDisplayLog = false;
private static bool bLoopInventoryReal = false;
private static int nCommond = 0;
private static bool m_bInventory = false;
private static DateTime dtEndInventory;
static void Main(string[] args)
{
    InitializeConsoleWindow();
    reader = new ReaderMethod();
    //Callback function
    reader.AnalyCallback = AnalyData;
    reader.ReceiveCallback = ReceiveData;
    reader.SendCallback = SendData;
    try
    {
        //Connect the reader
        String strException = String.Empty;
         int nRet = reader.OpenCom(strComPort, nBaudrate, out strException);
        if (nRet != 0){
            Console.WriteLine(strException);
            ErrorMessage("ERROR :" + strException);
            return;
        } else {
            SucessMessage("Connect sucessly");
        }
        //SET RS-485 Address(HEX)
        reader.SetReaderAddress(btReadId, Convert.ToByte("01", 16));
        btReadId = Convert.ToByte("01", 16);
        System.Threading.Thread.Sleep(1000);
        //GET reader Identifier
        var xpto = reader.GetReaderIdentifier(btReadId);
        if (xpto != 0) {
            ErrorMessage("Error on \'Get reader Odentifier\'");
        }
```

```
            WarnMessage("Get FirmareVersion");
            System.Threading.Thread.Sleep(1000);
            //GET FirmareVersion
            var FV = reader.GetFirmwareVersion(btReadId);

            //--------
            //RF Setup
            //--------
            //RF Output Power
            reader.SetOutputPower(btReadId, Convert.ToByte("30"));
             btOutputPower = Convert.ToByte("30");
            //RF Port Return Loss
            reader.MeasureReturnLoss(btReadId, Convert.ToByte(2));
            System.Threading.Thread.Sleep(1000);
            //RL Threshold
            reader.SetAntDetector(btReadId, Convert.ToByte("4"));
            btAntDetector = Convert.ToByte("4");
            System.Threading.Thread.Sleep(1000);
            WarnMessage("set region");
            //RegionEtsi
            reader.SetFrequencyRegion(btReadId,          btRegion,          nStartFrequency,
nEndFrequency);
            System.Threading.Thread.Sleep(1000);
            bLoopInventoryReal = true;
            m_bInventory = false;
            // btRepeat = Convert.ToByte(textRealRound.Text);
            byte btWorkAntenna = lAntenna[0];
            reader.SetWorkAntenna(btReadId, btWorkAntenna);

            Console.WriteLine("on Work...");
            Console.ReadKey();
          } catch (Exception ex){
            Console.WriteLine(ex.Message);
            Console.ReadKey();
```

```
    }
}
#region Reader events
private static void AnalyData(MessageTran msgTran) {
    m_nReceiveFlag = 0;
    switch (msgTran.Cmd)
    {
        case 0x71:
            ProcessSetUartBaudrate(msgTran);
            break;
        case 0x72:
            ProcessGetFirmwareVersion(msgTran);
            break;
        case 0x73:
            ProcessSetReadAddress(msgTran);
            break;
        case 0x74:
            ProcessSetWorkAntenna(msgTran);
            break;
         case 0x76:
            ProcessSetOutputPower(msgTran);
            break;
        case 0x78:
            ProcessSetFrequencyRegion(msgTran);
            break;

        case 0x7E:
            ProcessGetImpedanceMatch(msgTran);
            break;
        case 0x62:
            ProcessSetAntDetector(msgTran);
            break;
        case 0x68:
            ProcessGetReaderIdentifier(msgTran);
```

```
                break;
                        case 0x89:
            case 0x8B:
                ProcessInventoryReal(msgTran);
                break;
        }
    }
    private static void ReceiveData(byte[] btAryReceiveData){
        if (m_bDisplayLog){
            //    string  strLog  =  CCommondMethod.ByteArrayToString(btArySendData,  0, btArySendData.Length);
            //(  WriteLog(lrtxtDataTran, strLog, 0);
            //LOG4NET
        }
    }
    private static void SendData(byte[] btArySendData){
        if (m_bDisplayLog){
         //      string  strLog  =  CCommondMethod.ByteArrayToString(btArySendData,  0, btArySendData.Length);
          //(  WriteLog(lrtxtDataTran, strLog, 0);
        //LOG4NET
        }
    }

    private delegate void RefreshOpTagUnsafe(byte btCmd);
    private void RefreshOpTag(byte btCmd)
    {
    }
    private delegate void RefreshInventoryRealUnsafe(byte btCmd);
    private void RefreshInventoryReal(byte btCmd)
    {
    }
    private void ProcessInventory(Reader.MessageTran msgTran)
    {
```

```
    string strCmd = "Inventory";
    string strErrorCode = string.Empty;
    Console.WriteLine("ProcessInventory");
}
private static void ProcessInventoryReal(MessageTran msgTran)
{
    var a = "";
}
private delegate void RunLoopInventoryUnsafe();
private static void RunLoopInventroy()
{
    var a = "";
}
private delegate void RunLoopFastSwitchUnsafe();
private void RunLoopFastSwitch()
{
    var a = "";
}
private delegate void RefreshISO18000Unsafe(byte btCmd);
private void RefreshISO18000(byte btCmd)
{
    var a = "";
}
private delegate void RunLoopISO18000Unsafe(int nLength);
private void RunLoopISO18000(int nLength)
{
    var a = "";
}
private delegate void RefreshInventoryUnsafe(byte btCmd);
private void RefreshInventory(byte btCmd)
{
    Console.WriteLine("RefreshInventory");
}
#endregion
```

```
#region Configure Reader
private static void ProcessSetUartBaudrate(MessageTran msgTran){
    string strCmd = "Set Baudrate";
    string strErrorCode = string.Empty;
    if (msgTran.AryData.Length == 1){
        if (msgTran.AryData[0] == 0x10){
            btReadId = msgTran.ReadId;
        } else {
            //  strErrorCode = CCommondMethod.FormatErrorCode(msgTran.AryData[0]);
            ErrorMessage("ERROR : ProcessSetUartBaudrate");
        }
    }else {
        strErrorCode = "Unknown Error";
    }

    string strLog = strCmd + "Failure, failure cause: " + strErrorCode;

    //WRITE TO CONSOLE ERROR
    ErrorMessage("ERROR :" + strLog);
}

private static void ProcessSetReadAddress(MessageTran msgTran)
{
    string strCmd = "Set reader's address";
    string strErrorCode = string.Empty;

    if (msgTran.AryData.Length == 1){
        if (msgTran.AryData[0] == 0x10){
            btReadId = msgTran.ReadId;
            //WriteLog(lrtxtLog, strCmd, 0);
            return;
        }else{
            //strErrorCode = CCommondMethod.FormatErrorCode(msgTran.AryData[0]);
            ErrorMessage("ERROR : ProcessSetReadAddress");
```

```
            }
        }else{
            strErrorCode = "Unknown Error";
        }

        string strLog = strCmd + "Failure, failure cause: " + strErrorCode;
        //WRITE TO CONSOLE ERROR
        ErrorMessage("ERROR :" + strLog);
    }
    private static void ProcessGetReaderIdentifier(Reader.MessageTran msgTran)
    {
        string strCmd = "Get Reader Identifier";
        string strErrorCode = string.Empty;
        short i;
        string readerIdentifier = "";

        if (msgTran.AryData.Length == 12)
        {
            btReadId = msgTran.ReadId;
            for (i = 0; i < 12; i++){
                readerIdentifier = readerIdentifier + string.Format("{0:X2}",
msgTran.AryData[i]) + " ";
            }
            btReaderIdentifier = readerIdentifier;
            RefreshReadSetting(0x68);
         //  WriteLog(lrtxtLog, strCmd, 0);
            return;
        }
        else
        {
            strErrorCode = "Unknown Error";
            ErrorMessage("ERROR : ?????");
        }
        string strLog = strCmd + "Failure, failure cause: " + strErrorCode;
```

```
    //  WriteLog(lrtxtLog, strLog, 1);
    //WRITE TO CONSOLE ERROR
    ErrorMessage("ERROR :" + strLog);
}
private delegate void RefreshReadSettingUnsafe(byte btCmd);
private static void RefreshReadSetting(byte btCmd)
{
 /*   try {
        if (this.InvokeRequired)
        {
            RefreshReadSettingUnsafe InvokeRefresh = new RefreshReadSettingUnsafe(RefreshReadSetting);
            //this.Invoke(InvokeRefresh, new object[] { btCmd });
        }
        else
        {
            //ErrorMessage("ERROR : RefreshReadSetting");
            switch (btCmd)
            {

            }
        }

    } catch (Exception ex) {
    }*/
}

private static void ProcessGetFirmwareVersion(Reader.MessageTran msgTran)
{
    string strCmd = "Get Reader's firmware version";
    string strErrorCode = string.Empty;
    if (msgTran.AryData.Length == 2){
        btMajor = msgTran.AryData[0];
        btMinor = msgTran.AryData[1];
```

```
            btReadId = msgTran.ReadId;
            RefreshReadSetting(msgTran.Cmd);
           // WriteLog(lrtxtLog, strCmd, 0);
            return;
        }
        else if (msgTran.AryData.Length == 1){
            //  strErrorCode = CCommondMethod.FormatErrorCode(msgTran.AryData[0]);
            ErrorMessage("ERROR : RefreshReadSetting");
        }
        else{
            strErrorCode = "Unknown Error";
        }
        string strLog = strCmd + "Failure, failure cause: " + strErrorCode;
        //WriteLog(lrtxtLog, strLog, 1);
        //WRITE TO CONSOLE ERROR
        ErrorMessage("ERROR :" + strLog);
    }
    private static void ProcessSetOutputPower(Reader.MessageTran msgTran)
    {
        string strCmd = "Set RF Output Power";
        string strErrorCode = string.Empty;
        if (msgTran.AryData.Length == 1)
        {
            if (msgTran.AryData[0] == 0x10){
                btReadId = msgTran.ReadId;
               // WriteLog(lrtxtLog, strCmd, 0);
                return;
            }
            else{
                // strErrorCode = CCommondMethod.FormatErrorCode(msgTran.AryData[0]);
                ErrorMessage("ERROR : ProcessSetOutputPower");
            }
        }else{
            strErrorCode = "Unknown Error";
```

```
    }
    string strLog = strCmd + "Failure, failure cause: " + strErrorCode;
    //WriteLog(lrtxtLog, strLog, 1);
    //WRITE TO CONSOLE ERROR
    ErrorMessage("ERROR :" + strLog);
}

private static void ProcessGetImpedanceMatch(Reader.MessageTran msgTran)
{
    string strCmd = "Measure Impedance of Antenna Port Match";
    string strErrorCode = string.Empty;
    if (msgTran.AryData.Length == 1)
    {
        btReadId = msgTran.ReadId;
        btAntImpedance = msgTran.AryData[0];
        RefreshReadSetting(0x7E);
      //  WriteLog(lrtxtLog, strCmd, 0);
        return;
    }else{
        strErrorCode = "Unknown Error";
        ErrorMessage("ERROR : ProcessGetImpedanceMatch");
    }
    string strLog = strCmd + "Failure, failure cause: " + strErrorCode;
    //   WriteLog(lrtxtLog, strLog, 1);
    //WRITE TO CONSOLE ERROR
    ErrorMessage("ERROR :" + strLog);
}
private static void ProcessSetFrequencyRegion(Reader.MessageTran msgTran)
{
    string strCmd = "Set RF frequency spectrum";
    string strErrorCode = string.Empty;
    if (msgTran.AryData.Length == 1){
        if (msgTran.AryData[0] == 0x10){
            btReadId = msgTran.ReadId;
```

```
        // WriteLog(lrtxtLog, strCmd, 0);
        return;
    }else{
        // strErrorCode = CCommondMethod.FormatErrorCode(msgTran.AryData[0]);
        ErrorMessage("ERROR : ProcessSetFrequencyRegion");
    }
  }else{
    strErrorCode = "Unknown Error";
  }
  string strLog = strCmd + "Failure, failure cause: " + strErrorCode;
  // WriteLog(lrtxtLog, strLog, 1);
  //WRITE TO CONSOLE ERROR
  ErrorMessage("ERROR :" + strLog);
}
private static void ProcessSetAntDetector(Reader.MessageTran msgTran)
{
  string strCmd = "Set antenna detector threshold value";
  string strErrorCode = string.Empty;

  if (msgTran.AryData.Length == 1){
    if (msgTran.AryData[0] == 0x10){
        btReadId = msgTran.ReadId;
      //  WriteLog(lrtxtLog, strCmd, 0);
        return;
    }
    else{
      // strErrorCode = CCommondMethod.FormatErrorCode(msgTran.AryData[0]);
        ErrorMessage("ERROR : ProcessSetAntDetector");
    }
  }else{
    strErrorCode = "Unknown Error";
  }

  string strLog = strCmd + "Failure, failure cause: " + strErrorCode;
```

```
    //   WriteLog(lrtxtLog, strLog, 1);
    //WRITE TO CONSOLE ERROR
    ErrorMessage("ERROR :" + strLog);
}
public static byte btWorkAntenna;
private static void ProcessSetWorkAntenna(Reader.MessageTran msgTran)
{
    int intCurrentAnt = 0;
    intCurrentAnt = btWorkAntenna + 1;
    string strCmd = "Set working antenna successfully, Current Ant: Ant" +
intCurrentAnt.ToString();
    string strErrorCode = string.Empty;
    if (msgTran.AryData.Length == 1)
    {
        if (msgTran.AryData[0] == 0x10)
        {
            btReadId = msgTran.ReadId;
            //WriteLog(lrtxtLog, strCmd, 0);
            //Verify inventory operations
            if (m_bInventory)
            {
                RunLoopInventroy();
            }
            return;
        }
        else
        {
            //strErrorCode = CCommondMethod.FormatErrorCode(msgTran.AryData[0]);
            ErrorMessage("Error : ProcessSerWorkAntenna");
        }
    }
    else
    {
        strErrorCode = "Unknown Error";
```

```
    }
    string strLog = strCmd + "Failure, failure cause: " + strErrorCode;
    //WriteLog(lrtxtLog, strLog, 1);
    if (m_bInventory)
    {
        nCommond = 1;
        dtEndInventory = DateTime.Now;
        RunLoopInventroy();
    }
}

#endregion
#region properties console
#region Fonte Colors
private static void ColorSucess()
{
    Console.ForegroundColor = ConsoleColor.Green;
}
private static void ColorError()
{
    Console.ForegroundColor = ConsoleColor.Red;
}
private static void ColorDefault()
{
    Console.ForegroundColor = ConsoleColor.White;
}
private static void ColorWarn()
{
    Console.ForegroundColor = ConsoleColor.Yellow;
}
#endregion
private static void InitializeConsoleWindow()
{
    Console.Clear();
```

```
            Console.Title = "Creative Systems - SensorMatic Example";
            Console.WriteLine("|------------------------------------|");
            Console.WriteLine("|          CREATIVE SYSTEMS          |");
            Console.WriteLine("|------------------------------------|");
            Console.SetWindowSize(150, 50);
            Console.BufferHeight = 1000;
            Console.TreatControlCAsInput = true;
        }
        #endregion
        #region commom
        public static void WarnMessage(string message)
        {
            ColorWarn();
            Console.WriteLine("warn: " + message);
            ColorDefault();
        }
        public static void ErrorMessage(string message)
        {
            ColorError();
            Console.WriteLine("Error: " + message);
            ColorDefault();
            Console.WriteLine("Press <Enter> to Exit!");
            Console.ReadLine();
            return;
        }

        public static void SucessMessage(string message)
        {
            ColorSucess();
            Console.WriteLine(message);
            ColorDefault();
        }
        #endregion
    }
```

}