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RFID Tag + Reader

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Abstract

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This thesis focuses on the development of a prototype RFID system project using 13.56MHz frequency band and a passive RFID system. This RFID thesis aims to give an understanding of the operation about the RFID technology communication system and all the processes involved. The prototype project includes the designing of RFID system, and the results are as expected and in line with what the available theory shows.

The first part of this RFID Project Prototype report describes the basic physical concepts governing the overall functioning of RFID identification system especially inductive coupling, which defines the communication between RFID Tag and Reader. The second part of the report details the various RFID system application areas starting from the basic functions to different important industries. Many countries in the world are implementing the above functions of RFID identification. In the third part of the report, the RFID Prototype Project was developed using MFRC-522 13.56 MHz RFID reader and a photon programmed with a code. This RFID Project Prototype has achieved its goals when the developed Prototype showed a green LED light for allowed Smart Cards and red LED light for non-permitted Smart Cards. The Project read the RFID tag ID and display it on a computer screen, check the white list and give or deny Access to the tag requesting access.

This project was developed as an access control system Guest Houses in Addis Ababa, Ethiopia.

It is possible to develop the RFID Prototype Project to an even advanced level by incorporating various simulation schemes and software, which can ease the building of a prototype RFID system. The use of control points and computer monitor can improve the observation of results. The future RFID research students can use more resourceful techniques in the making of the prototype and they can gather more optional resources to practice as many designs as possible available in the electronics industry.

Keywords: Mutual Inductance, Inductive Coupling, RFID

Contents

List of Abbreviations

RFID: Radio frequency identification.

EPC: Electronic Product Code.

ISO: International Standard Organization.

NFC: Near Field communication.

1 Introduction

RFID stands for frequency Identification. The RFID system is a near field identification via alternating magnetic fields to track and communicate different objects with passive or active nature tags attached. It contains an info carrier, referred to as the electrical device (card, tag or paper label), and a reader/writer (RFID reader). Once the electrical device is close to the (near) field of a reader, they will communicate with one another.

It is possible to track an object can very quickly with both bar code technology and RFID system, but it is possible to track several objects at a time with RFID system that is impossible using barcode technology because of the need of direct line of sight with the object. [1.]

RFID is the technology that allow the Near Field Communication (NFC) in World War II. In 1940, the idea of using RFID for the first time to spot an aircraft in the World War II has assisted the identification of allied planes. [2.]

In 1945, the Soviet Union Young Pioneer Organization presented a hand-carved USA seal to the USA ambassador, Harriman. The seal was a spy equipment as it has an antenna buried inside where the Soviets generated radio waves from and tracked the Seal. The Soviets have spied the ambassador for seven years recording the ambassador’s sensitive private phone conversations that gave a high political advantage.
In the 1970s, RFID tags were the main security system for railways. Later in 1990, RFID various part of the world has normalized technology by permitting it configured with different systems. [1.]

Starting from 2005 RFID, technologies are being widely employed in most industrial sectors (aeronautics, automotive, logistics, transportation, health, and daily life). The ISO (International Standard Organization) has for the most part

contributed to the implementation of many standards (both technical and applied) to realize a degree of ability. [2.]

Today many big stores and supermarket chains throughout the world use RFID tags: to administer their property management, to trace their products in different level of their supply chain, their customer satisfaction survey and their quality control programs. [1.]

RFID is the best identification system for its many comparative advantages over other identification systems. A large number of data carriers (transponders) may be browsed at the same time by using RFID system, it is a Secure technology with nearly no risk of remote spying. A better security result when used with contactless smartcards, it is easy to put in and integrate, no special optics is required for the electrical device, Passive transponders do not need electric battery and Transponders are compact and costs little.

RFID systems is prone to materials and environmental factors that can cause diminished scan ranges and deter overall system accuracy. Metal and liquids are the most typical sources of interference for RFID applications, but the right RFID tags, equipment, and designing can offset their impacts.

This thesis work describes the RFID identification system nature and working principle as well as building a simplified prototype RFID system based on other previous prototype design ideas and practices. The primary purpose of building a prototype design of the RFID identification system is to design a 13.56 MHz high frequency band RFID identification with a passive Tag and a Reader having reading range of up to 30 centimetres.

The designed prototype RFID system addressed the simple way of designing and building Passive RFID system in a small budget. This Project opens a door to many small-scale entrepreneurs who wants to start a business by building a simple RFID system for future sale of a business to homeowners and thereby to small-scale real estate companies operating in different European countries.

2 Impact of RFID System on Our Health

There overall nature of RFID system is still a myth as there are many unanswered questions about it and many technology companies do not want customers to turn toward the use of the cheaper identification system of RFID.

RFID radiation impact on human health includes:

The constant exposure to a tag even for a much-extended period does not result in any health impact. The safe nature of RFID technology is another reason of its high quality over other identification systems.

It is possible to detect a wide range of RFID tags showing a detailed personal information on a reader screen with just a near touch. There is no need of manual record keeping when using RFID system and Electronic Signing is possible using this technology.

3 Components of RFID (Radio Frequency Identification)

An RFID tag in its most simple kind has two components –the antenna the part for transmitting and receiving signals, plus RFID chip (or computer circuit, IC) which stores the tag's ID and alternative info. RFID tags connected to things to track them with RFID reader and antenna (Figure1.):

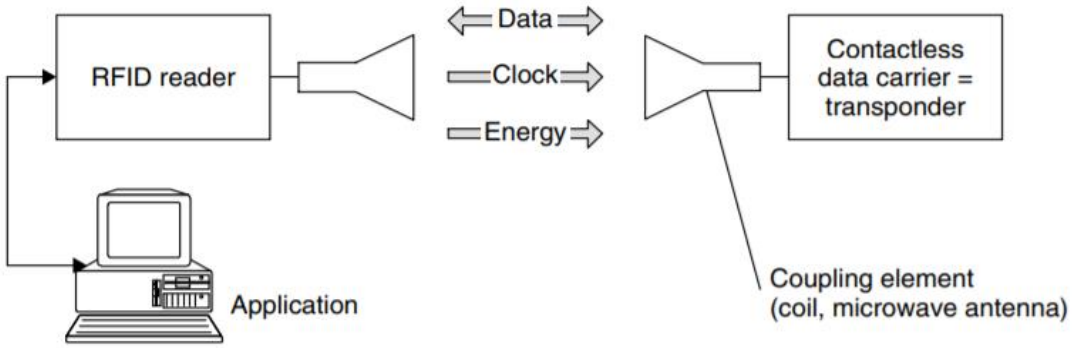


Figure 1. The Reader and the Tag (transponder) of RFID system. [4]

3.1 Tag

A tag is the part located on the object to be identified which is a source of signal in the RFID system and is made of a silicon microchip containing antenna placed on a substrate covered by a plastic or a glass material with a different sizes and shapes (Figure 2.):

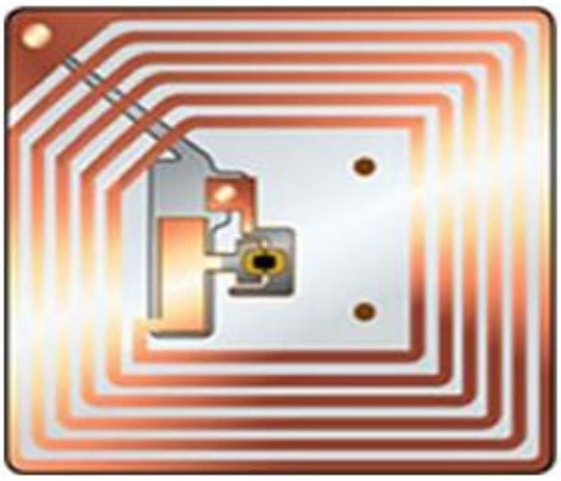


Figure 2. RFID Tags. [3]

RFID tags transmit information regarding an item through radio waves to the antenna/reader combination. RFID tags usually do not contain a battery (unless nominative as Active or bread tags); instead, they receive energy from the radio waves generated by the reader. Once the tag receives the transmission from the reader/antenna, the energy runs through the interior antenna to the tag's chip. The energy activates the chip that modulates the energy with the specified info, and so transmits a signal back toward the antenna/reader.

There are hundreds of completely different RFID tags on the market in several shapes and sizes with features and choices specific to environments, surface materials, and applications.

3.1.1 Types of Tags

Because there is such wide selection of RFID applications, it is also possible to categorise them. One way to categorize them is as Active, which have their own power source, and Passive tags that do not have their own power source. A typical group to divide tags into varieties is inlays vs. hard tags where are Inlays cheaper in their price. [7.]

3.1.2 TAG Pricing

Tag pricing depends on the type of tag and the quantity of production. Inlays typically are cheaper than hard tags. The higher the level of customization or the more specialized the tag, the more expensive it will be in comparison to typical off-the shelf tags.

3.1.3 TAG Selection Criteria

The sort of surface to tag, the reading range for the reader, size limitations, method of attachment and excessive environmental conditions considerations decides the selection criteria. Tag layers with moisture will end up broken on use, weak connection of the antenna to its chip will break the tag in case of vibration and capsule are necessary to protect the tag from corrosive chemicals.
The cost of applying the tag to the object should allow the justification behind the necessity of the specific tag selected. Tag's manufacture following different ISO and proprietary standards are high quality, because they fit in many products from various parts of the world. [6.]

3.2 Reader

The brain of the RFID system is the reader and is critical for the whole system to function. Readers technically are interrogators, devices that transmit and absorb radio waves to understand with RFID tags. Manufacturing of RFID readers has two distinct forms – mounted RFID Readers and Mobile RFID Readers.

Readers with fixed nature are those that stays on walls, desks, doors, top of an entrance or any kind of fixed locations through the ports attached on the antenna, which makes the antenna an essential part of the fixed reader. The Fixed readers stay at the specific place to identify different objects with tags continuously for a certain period. A common example of mounted or fixed readers are Integrated Readers.

Fixed readers allow accurately moving a large volume of objects very fast saving logistics time in big companies. They are the best fit in high traffic production facilities and in identifying RF-challenging objects. [6.]

Mobile or Handheld Readers are a hand carried readers designed for use in small objects and a less special environment. They can read a large number of items when directed at many objects with one scan. Many businesses use mobile readers to keep track of the level of stock to avoid running out of stock in the store. [7.]

RFID reader contains an implanted antenna that with another extra antenna port available to configure the chip with an external antenna. Integrated readers look very attractive with give elegant design when used indoor and less traffic identification purposes. The beautiful design of the integrated readers is business-minded approach by manufacturers for high customer satisfaction.

The high frequency RFID reader operates at 13.56 MHz manufactured in different sizes and shapes (Figure 3.). When the tag approaches the magnetic field of the reader’s antenna, the transponder draws energy from the magnetic field and power itself to complete the identification process. This type of passive tag operation alleviates the need of external power device or a battery, which increase overall cost by a certain amount.

Figure 3. Fixed RFID Reader (left) or Mobile RFID Reader (right). [3]

4 Types of RFID Systems

4.1 Low frequency, High Frequency and Ultra-High Frequency RFID System

Based on the Electromagnetic spectrum there are three types of RFID systems with varying reading range of the reader from the Tag. The three main frequency ranges used for RFID transmissions include Low Frequency, High Frequency, and Ultra-High Frequency. [4.]

4.1.1 Low Frequency RFID System

The low frequency RFID system operating under a frequency band of 30 KHz up to 300 KHz and a reading range of 1 to 10 centimetres. Commonly used in Access control applications, Animal tagging, health care, Car key fob, laundry and other applications with objects under high volume of liquid and metal environments. They are preferred because they have a large wavelength unit that allow penetration through metal sheets and through liquid, but they are not favoured

due to their limited quantity of memory, their low data transmission rate, they are expensive to produce and have very short reading range. [4.]

4.1.2 High Frequency RFID System

The High frequency RFID works in a primary frequency range of 13.56MHz, which is the frequency range focused on this project. It reads the signal generated by the tag at a reading range of 30 centimetres and they are widely used in Library books, personal ID cards and poker game chips. They fulfil the Near Field Communication protocols as well as various global standards and manufactured with larger memory options. [4.]

4.1.3 Ultra- High Frequency RFID Systems

These are RFID systems with a general frequency band of 300 to 3000 MHz and a primary frequency range of 433MHz up to 960MHz and a reading range of up to 12 meters. They have a faster data transfer rate than both Low and High frequency RFID, are the most sensitive readers to interference, are the cheapest of all the three types, and have a high-performance rate designed to operate at difficult environment. [4.]

4.2 Active and Passive RFID Systems

4.2.1 Active Systems

In active RFID systems, tags have their own transmitter and power supply. Usually, the power supply could be a battery. Active tags broadcast their own signal to transmit the data available on their microchips. Active RFID systems usually operate within the ultra-high frequency (UHF) band and supply about 100-meter ranges. Generally, they are found on big objects, like rail cars, huge reusable containers, and alternative assets that require being caterpillar-tracked over long distances.

There are two varieties of active tags: transponders and beacons. Transponders are “woken up” after they receive a radio wave from a reader, so power on and respond by transmitting a signal back. Active RFID tags do not radiate radio waves until they receive a reader signal that help them to conserve the battery life. [4.]

4.2.2 Passive RFID Systems

A Tag mounted on an object with large amount of data stays dormant before it gets a signal from a reader that make it passive. In Passive RFID systems, the reader and reader antenna send a radio emission to the tag and the RFID tag then uses the transmitted signal to power on, and mirror energy back to the reader. [8.]

Passive RFID systems will operate within the low frequency (LF), high frequency (HF) or ultra-high frequency (UHF) radio bands. They usually operate within 10-meter distance or less. The ability of the tag’s reflection (the radio wave mirrored from the tag back to the reader) restricts the Passive RFID system ranges to a shorter distance. Passive tags do not need any source supply or transmitter that make it possible to manufacture at a less cost and so they are cheaper, smaller, and easier to use than active tags. [4.]

Passive tags are often pre-packaged in many various ways in which, counting on the RFID application necessities. It is possible to mount them on a substrate enclosed in a plastic pack together with an antenna, or to put in between an adhesive layer and a paper label giving an easy-to-understand mark and explanation by the users. Passive tags can withstand different harsh chemicals and high temperature due to the quality of their packages and enclosures. [8.]

5 RFID as an Alternative to Barcodes

RFID is a very good technology as an alternative to Barcode technology for many good reasons. Both technologies are available in the world and are useful identification systems, but they operate in different ways (Table1.).

Table 1. RFID vs Barcode Technology.

RFID Technology	Barcode Technology
There is no need to have a direct line of sight between the reader and the tag to operate.	The barcode should be in a direct line of sight with the reader to operate.
Proximity is not necessary for reading because the reader can track from inches to feet away.	The barcode needs to be very closer to the barcode reader when compared to RFID tags.
Includes an antenna and a sensor planted inside the system.	Printed on the external body of the abject.
Can withstand various environmental factors.	Easy to be crashed or wear out.
Relatively expensive.	Cheaper than RFID system.
Object data update in real time.	Object contain read only data on the Barcode and no room for updates.
The Tag has to absorb power from the reader, or it needs own power source otherwise.	The Barcode does not require a power to operate.

6 RFID Application Areas

6.1 Device Tracking

RFID is the main technology for tracking parts and workflows in the day-to-day operations of many big companies and the internal operation of big manufacturing companies. By tagging objects in the overall operation system, companies can reduce the loss of assets due to flawed manufactured products, facilitate the mobilization of the products at different levels and able to manage the production of different versions of the same product. Device tracking is the main application are of RFID technology.

6.2 RFID Toll

A toll is a charge payable to use a bridge or the lane of a road controlling traffic by permitting those drivers that paid toll charge to drive over the lane or the bridge (Figure 4.).

The toll machine calculates the toll amount for each driver passing the bridge or the road electronically by using the RFID tag planted on the windshield of the passing car. RFID tolls avoid the delays on road tolls at high traffic roads especially at rush hours because they do not have to stop and wait for a manual payment system, which waste time. Once the RFID toll system reads and charges the amount to the individual car account it will open the automatic tollgate automatically, the system also blocks the gate or sends a picture of the car registration number to the authority, to the drivers whom their account is not charged. [9.]

Figure 4. Talking a Toll. [9]

6.3 Pharma Industry

The regulation of operation of drug manufacturers, hospitals and medical suppliers, the quality of the medical products and their circulation to the population is the main factor promoting the use of RFID Technology in Pharma industry. RFID implemented pharma industry generally provides a more effective identification of the drugs in the world market. [9.]

6.4 Supply Chain Management

A successful supply chain requires good information sharing between the parties involved at each stage of the supply chain, especially in today's world where goods travel to far destinations. Suppliers, whole sellers and transportation companies need a real time and detailed communication about the business dealing for the shipment of goods.

RFID allows the shipment of goods from the supplier warehouse and the wholesaler will track the arrival of the goods to their corresponding warehouse and inform the supplier. The supply chain then becomes a smooth operation and accountability for the whole process can be clear and the overall supply chain goes successfully.

6.5 Animal Tagging

Animal Tagging with RFID is a using RFID tag implanted on animals' body and keep track of their detail information regarding their health status, their origin, and their behaviour and food preference in real time with the help of the reader.
The veterinary doctors record the animal's medical history and update their information on the RFID tag and the owner of the animal can have access to the stored data at any time necessary. Due to the relatively large number of animals owned by farmers the use of RFID is very important to the overall safety of the animals and thereby the farming industry in general.

6.6 Surgeries

RFID technology in hospitals has several uses from helping track of the doctors, nurses, security officers, human resource staff, supervisors, patients, and the tools they are using. The surgical operation in hospitals is the most sensitive section whereby the life of patients depends on, and its smooth operation decides the continuation of the whole system of the building.

RFID tagged medical tools are tracked in real time to facilitate the smooth running of surgical operation. Medical staffs avoid medical errors and forgetting medical gauzes, scissors, and other small devices in the patient's body, with the help of the RFID tags on each of the medical tools or their packages. The system tracks which medical tool the staff has taken from the store and to the surgical room to allow them to remember the exact count of the returned item. [9.]

6.7 Access Control

The RFID access management systems work to spot the information about who is coming into a building or a space. The RFID system supply necessary data regarding the people in a building in normal workday, especial events, sport competition or art exhibition and allow access to them or deny access depending on the necessary decision.

Employees shifts are scheduled easily using the updated information stored, sick leaves are administered, absence of individuals can be traced and updated to the desk of supervisors for the necessary decision making. The RFID system implementation in a company help to restrict entry to sensitive rooms or sections except designated staffs. [7.]

6.8 Passports

Biometric passports and digital passports contain embedded microchip that store the personal information of the passport holder. The data uploaded on digital-passports are a digital photograph name, date of birth, nationality, and gender. Biometric passports include that information included in the digital plus the biometrics of individual faces, the pupils' size, and shape pf their eyes and the fingerprints.

Many countries demand the most basic information of individuals to be stored in those digital passports that helps them easily track the movement of people especially during traveling out of a country. At time of accidents, the police department can easily access very crucial information of individuals from their digital passports or their biometric passports that play key part of possible crime investigations.

6.9 Supermarket of the Future

Supermarkets are key part of the daily life of the overall population and their smooth operation plays a vital role in the overall economy of a country. At rush hours, customers have to wait a long queue at the checkout point even in supermarkets with a number of payment desks.

RFID technology implemented supermarkets register its customers on the on the database and customers can easily pay for their purchases at the checkout and it also upload unrecorded customers by using their smart cards to the system to charge their account very easily that saves a lot of time for the overall transaction.

The system also keeps track of the level of stock, update all the time and the stores can be replenished quickly and the supermarket will avoid running out of supplies.

6.10 Timing of Sport Events

In several gymnastic competition, international or domestic sport races demand the punctuality of the participants the participants, referees, assistant officers and other necessary competition tools.
RFID systems help to see the overall presence of all the stakeholders on time before hand assist the necessary measures to fix the aroused problems and let the event continue smoothly. [7.]

6.11 Inventories and Warehouses

The main objective to use RFID is to extend the potency of warehouses by reducing work and supplying prices. Likewise, to induce instantly associate correct inventory of products with all quite details, like size, quality, country, and so on. Physical inventory counts cots big-ticket and inaccurate do not seem to be necessary any longer and this will save us cash and time. [7.]

7 RFID Industry

7.1 RFID in Finland and Globally

Globally RFID technology deployment is the highest in North America and Europe (Figure 5).The distinction in deployments of RFID technology between the above areas lies in scale; whereby North America region especially USA has a relatively large-scale deployments of the RFID technology, Europe leads the world in pilot deployments and new studies in Universities and Colleges.
Next to Europe and North America, South America has the foremost future growth potential due to their proximity to the USA, whereas Asia Pacific continue to have the best growth rates in the RFID system compared with the rest of Asia. China is becoming the new hub for RFID technology investments and production facilities with the rather large population size together with India. Not surprisingly, Africa has the bottom level of RFID penetration due to the general low level of advanced technology facilities. [5.]

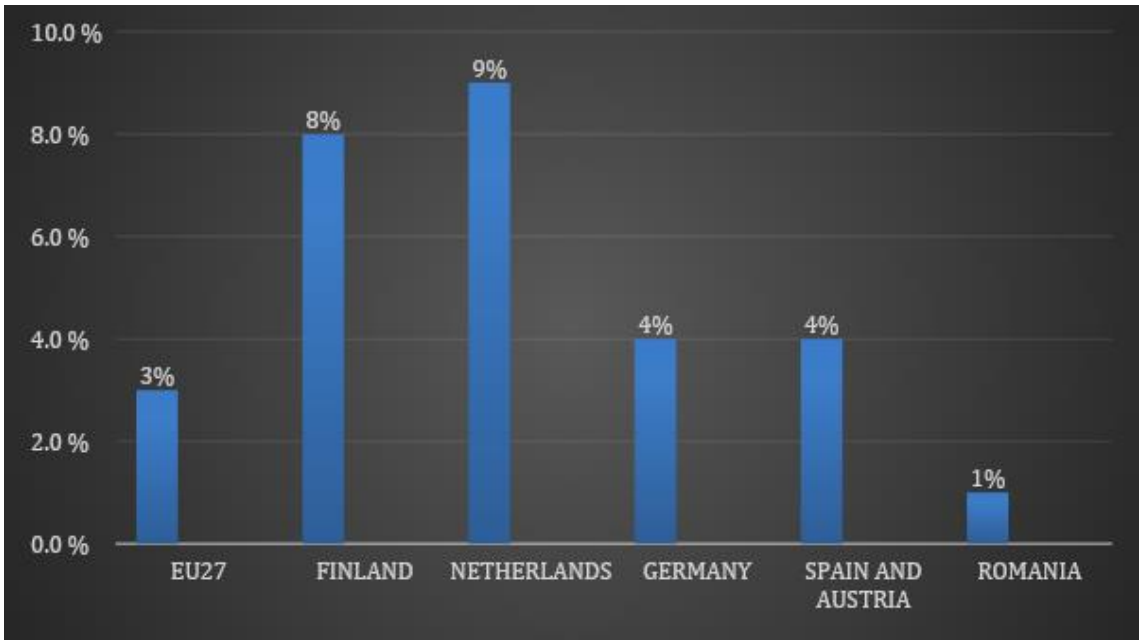


Figure 5 Percentage of Enterprises using RFID. [5]

The Commission to the ECU Parliament, the Council, the EU Economic and Social Committee, the Committee of the Regions on frequency Identification (RFID) in Europe framed a policy back in the year 2007. The published opinion by the EU commission laid out a comprehensive initiative that promotes the increased use of RFID identification system on consumer gods circulating inside the EU territory. The general framework aimed at promoting the growth in implantation of RFID chips in consumer goods that guarantee the data protection and address the risks that poses a risk to the market. [10.]

European technology investors, governmental infrastructure and capacity building institutes organizations, research centres and educational institutes have enhanced Europe standout from the growing global RFID competition. From barcode technology to RFID tag implementation, the European technology stakeholders are leading the world in general and in the area of special label-making machinery, they are among the market leaders. Germany leads the EU market followed by France and the UK, Italy, the Netherlands, and the Nordic countries; Switzerland and Austria have a comparatively greater potential in general.

However, the U.S.A. dominates the market, with large-scale capital projects, first rank companies and R&D programmes, and a robust position quality setting and patents associated with these settings.

In Asia, Japan, Korean Peninsula and Taiwan are highly competitive followed by China presently because of the massive domestic demand driven by the largest population in the world. [10.]

7.1.1 RFID Microchip Implant in Sweden

The most cutting age technology in Sweden is not the smart phone on people’s hand, but it is the microchip imbedded on their hand under their skin. Sweden is the country leading the world in the transformation to a cashless society as well card free society because the microchip implanted under their skin substituted all

the information to be carried separately in various cards, access control ID cards and cash. Employees can enter a security check point of big factory buildings, can log in their work hours and employers can identify their whereabouts by simply going through the control system to track the microchip logged at that same specific time. [11.]

7.2 Covid-19 and the Global RFID Industry

The COVID-19 pandemic in 2020 has negatively affected the RFID sector largely. RFID producing firms and suppliers spread in many countries across, Europe, Asia-Pacific, America, and many others. The RFID products are important in many industries for various applications and the decreased level of business operations due to the COVID-19 has directly affected day-to-day activities of the RFID suppliers, retailors, partners and distributors.

The lockdown measures disrupt the worldwide supply chain and demand. Many expensive retail products and have slowed down the RFID market growth largely. Even if governments of developing countries mandated the RFID tagging on vehicles for tolling, the delay in travel has restricted the manufacturing of the RFID tags. As the lockdown measures continue to loosen in various countries, production facilities are re-opened as well.

The increased security measures and package protection is anticipated to extend the growth of the RFID tags market trends. The penetration of those RFID solutions will increase the expansion of the RFID market as well as it helps to identify if many individuals gathered at a certain place.

8 Future of RFID Application

8.1 Results of Innovative Manufacturing

Due to the increased investment trend towards new technologies throughout the world, the future of RFID technology is growing and expanding very rapidly. Many economic development studies show that the passive RFID tag market alone will grow to 7 million tags by the end of the 2021 as a result many big stores implementation of the UHF RFID tags to keep track and update their daily stocks level.

The technological advancements in printed board electronics have initiated the rapid increase in the production of very thin and flexible tags that combined with thin-film photovoltaic cells, printed sensors, printed batteries and other electronics. Thanks to the new conductive ink technologies and the new electronic circuit board design systems, many companies could now print a chip less RFID tag on site.

The key to smart tag performance is the effective performance of the antenna design incorporated in the RFID system. The antenna is crucial to the possible way a tag may be used, and the extent of its effective performance life. Because of increase in the competition for RFID antenna style, the world market in next few years will bring about several new antennas and inlays.

RFID technology development goes together with the latest digital technology applications within the retail, healthcare, manufacturing and alternative sectors, however the difficulty in the administration of the data flowing in from a large number of tags. With cloud-based applications advancing the purpose of IT support far from the role of record keeping, many companies are now applying centralised provisions of solutions.

8.2 General RFID Trends

Currently the RFID business is an interesting field during which increased adoption can offer the means for advanced technology suppliers to focus on an attractive innovation.
Nano technology is the new advanced technology that serves as a replacement of many manufacturing operations to practice the better use of RFID to help increase in productivity. For effective deployment of RFID system, cooperation with Nano technology in the administration of manufactured goods in production facilities is very important. Rather than a tag hooked up to a garment, for instance, RFID tag device may be printed directly or in the packaging using perishable semiconducting inks.

8.3 Threats to RFID System

The future of RFID is under a threat because the Next Generation Asset Tracking technology has the best possibility to replace RFID technology. Bluetooth low energy technology is becoming more efficient nowadays and many companies are heading to invest more on it instead of sticking to RFID technology.
The future has to prove the success of the Next Generation Asset tracking (the Bluetooth low energy technology) after the investment in technology reaches a high level.

9 Physical Principles of RFID Systems

9.1 Magnetic Field

The flow of current produces a magnetic field. The magnetic field intensity is the force acting on a magnetic needle that arises from an external current and not caused by the conductor itself (Figure 6).

The field strength expresses the magnetic field magnitude, measured in units of amperes per meter and its value along a closed curve is equal to the sum of the individual current strengths of the current in it. [4]

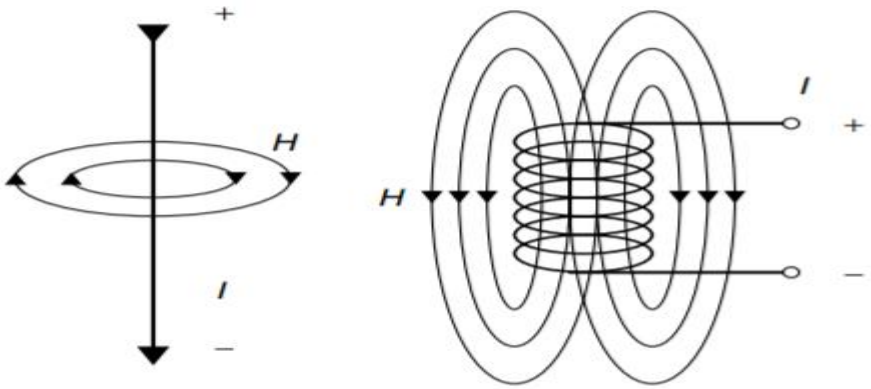


Figure 6. Magnetic field lines around a current-carrying conductor Coil. [4]

To calculate the path of the magnetic field traveling along the x-axis of a round coil implanted in the reader antennas of inductively coupled RFID systems it is possible to use the equation below (Formula 1.):

$$M_{21} = \frac{(I.N.R^2)}{2\sqrt{(R^2+x^2)^3}} \quad (1)$$

Looking at the above equation, N is the number of Turns, R is radius of the coil and x is the distance from the centre of the coil in the x direction. The Figure below (Figure 7.) helps to understand the above equation (Equation 1.).

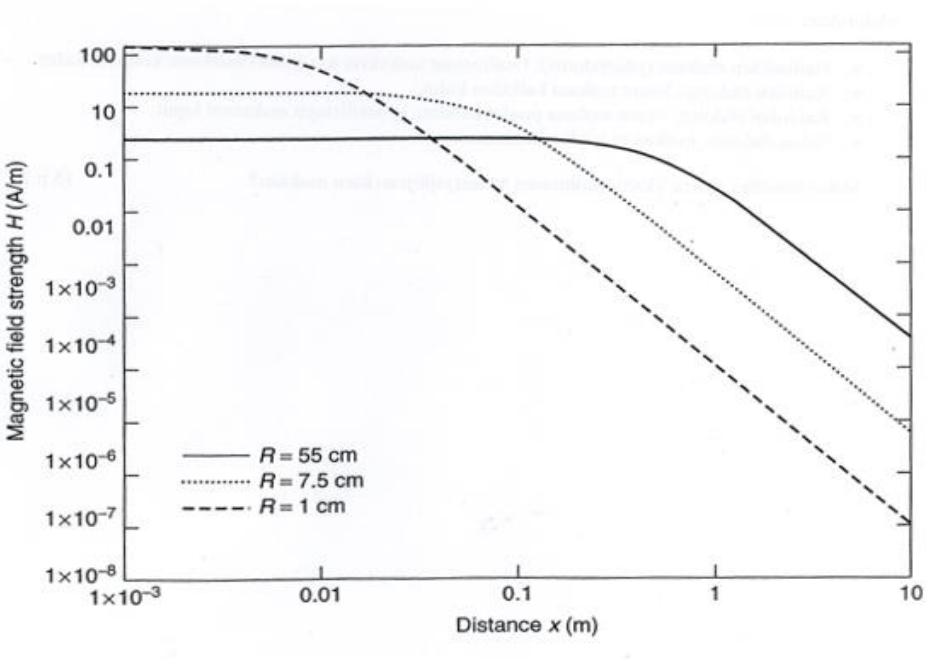


Figure 7. Graph of magnetic field strength of a coil. [4]

9.2 Magnetic Flux and Flux density

Magnetic flux (φ) is the number of magnetic flux lines that pass through the inside of a cylindrical coil. Magnetic flux density B is a further variable related to area A (Formula 2.) of the magnetic field around the coil.

$$\varphi = B.A \tag{2}$$

9.3 Inductance L

A current passing through a loop will generate a relatively strong magnetic field than a current carrying wire that will again generate a stronger magnetic flux(φ). The increase in the number of turns of the coil will increase the amount of the

magnetic flux proportionally and the total flux ψ is the result of all the loops contributing to its strength that give us the formula below showing this relationship (Formula 3.).

$$\psi = \varphi . N \tag{3}$$

One of the characteristics variables of a conductor coil is its Inductance (L). The inductance of a conductor coil depends on the permeability of the space in which the magnetic flux flows through and its geometrical shape.

9.4 Mutual Inductance M (Inductive Coupling)

When a conductor coil (2) with area (A_2) gets near another current carrying conductor coil (1) with an areaA_1, it experiences a proportion of the total magnet flux passing through (A_1). This partial flux called coupling flux (ψ_{21}) connects the two circuits together and the corresponding value of this coupling flux ψ_{21} depends on the physical dimensions of the two conductor loops (coils).

The mutual inductance M_{21} (Equation 6) of the conductor loop (2) in relation to conductor loop 1 is the ratio of the partial flux (ψ_{21}) surrounded by coil (2), to the current (I_1) passing through coil (1) and the formula below shows the above relationship (Formula 4.):

$$M_{21} = \frac{\psi_{21} . (I_2)}{I_1} \tag{4}$$

The current I_2 circulating around coil 2 determining the other coupling flux ψ_{12} created in coil (1) defines the other mutual inductance M_{12} created on coil (1) in relation to loop (2).

Because of the homogenous nature of the flux between the two current flows of the coils, the values of these two mutual inductances are equal in magnitude, as shown on the formula below (Formula 5.):

$$M = M_{21} = M_{12} \tag{5}$$

Mutual inductance is the coupling of two circuits through a magnetic field created (Figure 8). The presence of two electric circuits next to one another always creates a magnetic field, which develops a Mutual inductance between them.

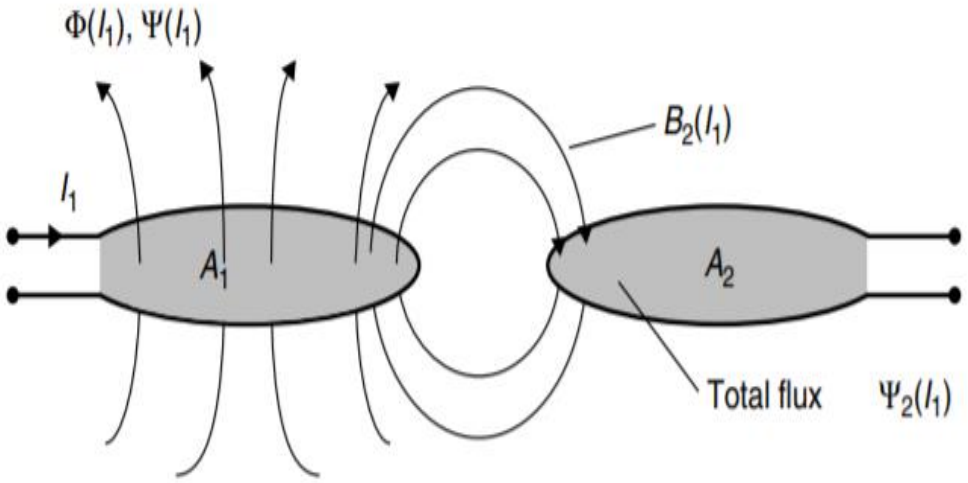


Figure 8. Mutual inductance created by the coupling of two coils. [4]

The physical principle governing the operation of two inductively coupled RFID systems is the coupling of two electric current carrying coils inside a magnetic field. The inductive coupling is related to the area of the conductor (A), number of turns N, magnetic field strength permeability constant μ_o and the current I with the equation below (Formula 6.):

$$M_{21} = \frac{(\mu_o).(H)(I_1).(N_2).(A_2)}{I_1} \tag{6}$$

A mutual inductance graph (Figure 9) below corresponds with a strong similarity with the magnetic field strength graph (Figure 7).

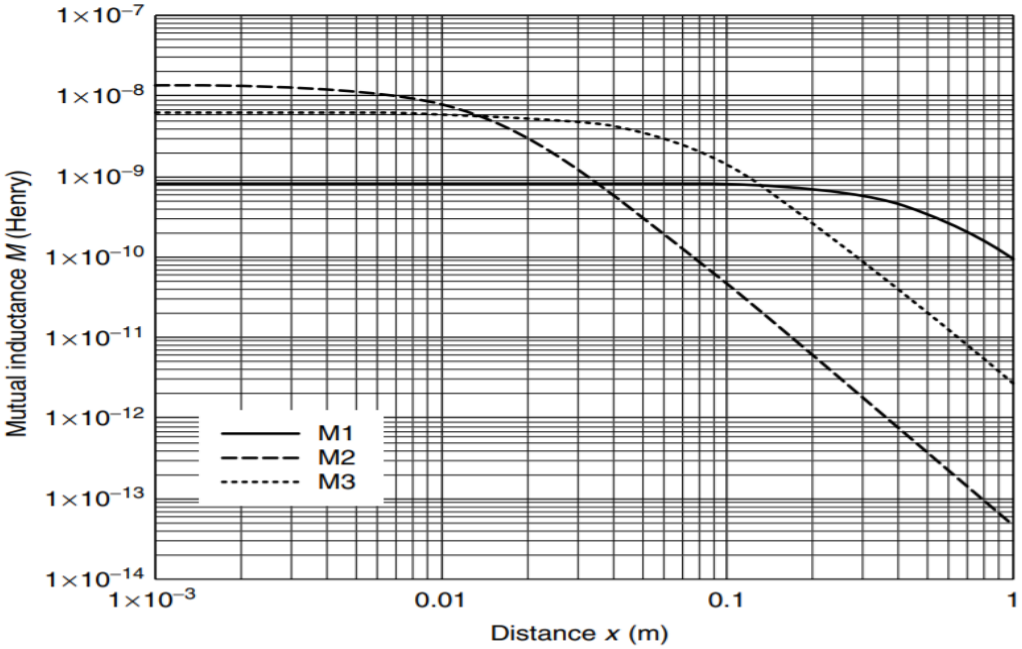


Figure 9. Mutual inductance Graph of RFID Tag and Reader. [4]

9.5 Coupling coefficient K

The coupling coefficient K is a simple physical quantity coefficient necessary for a qualitative prediction of the coupling of the coils irrespective of their physical measurements. The formula for coupling coefficient is directly proportional to mutual inductance and reversely related to the individual inductances (Formula 7.).

$$K = \frac{M}{\sqrt{L1.L2}} \tag{7}$$

9.5.1 Full Coupling and Decoupling

The value of a coupling coefficient K varies between two extremes $0 \leq k \leq 1$ and has different meaning in each of those values. When K=0 it shows Full decoupling because of magnetic shielding due to longer distance between the two coils and they no longer have a mutual magnetic flux φ. The value of K= (1) means there is a full coupling because the two coils are subject to the same magnetic flux(φ). [4.]

When the RFID tag and reader are inside the reading range the value of K is between zero and one whereby a certain amount of coupling exists, and when they are out of the reading range the coefficient of coupling K is almost zero and the reader does not read the tag at all. The graph below (Figure10) explains the coefficient of coupling K in detail:

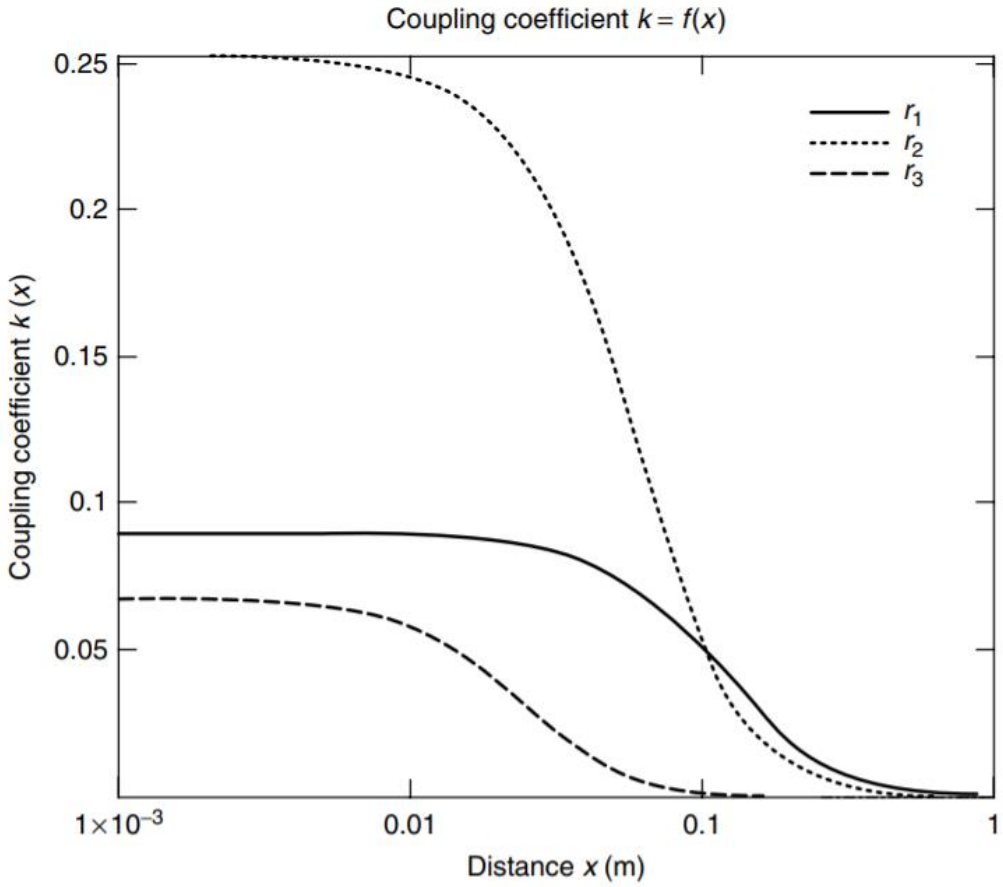


Figure 10. Graph of coupling coefficient of different size coils. [4]

10 Scope of the RFID Prototype Project Study

10.1 Requirements and Design Level

This prototype RFID Tag + Reader identifies concepts of the working principle of the system that enhances the building process of RFID system for different level of use. Furthermore, this study is to explore physical principles of the radio frequency technology, the framework of the RFID system design guidelines, present the components of the system and relate the theoretical presentation with actual laboratory experimentation. The system is analysed using the available physical resources on the Finnish electronics market as well as the theoretical resources on internet.

This study covers only designs related to RFID Reader and its Tag. Electronic components currently available at the Metropolia University of applied Sciences electronics laboratory measure the reading range; defines the magnetic flux, the consumed volts, and the inductance were done using.

The frequency band was 13.56MHz; Raspberry pi reader is the reader hardware together with the tag components. To design the prototype a photon and an LCD screen combined, which are not part of the original study plan. The photon included a program code to connect the whole system to a computer network and the LCD screen monitor the signal level during the tag and reader interaction.

10.2 Old vs New RFID Prototype Projects

There were Many RFID Prototype Projects in the past. Most of the projects focus on specific purpose RFID system, for instance RFID based attendance system, RFID technology for device control and authentication industries, RFID for book tracking in Libraries and many other tasks specific prototype.
Use of RFID chips is one sector, and the level of complexity has never been as the high level the world have now.

In today's level of technological advancement RFID, technology prototype is a growing research idea. Furthermore, as the nature of human need is growing towards smart technology related styles, the new RFID prototypes will continue to vary in type, importance, and application in a greater level of advancement. The complexity and the decrease in their physical sizes is what makes the new prototype research.

11 Hardware Components of the Prototype

11.1 Raspberry Pi MFRC-522 13.56 MHz Reader

The RFID Reader acts as the master and the tag acts as a slave, and we start setting up the design starting with the reader. The MFRC-522 Reader (Figure 11) has a frequency of 13.56MHz, a magnetic field strength of 55,58dBμA/m with -29,19Dbm, RFID protocol Mi. fare, DC 3.3 volts power input span.

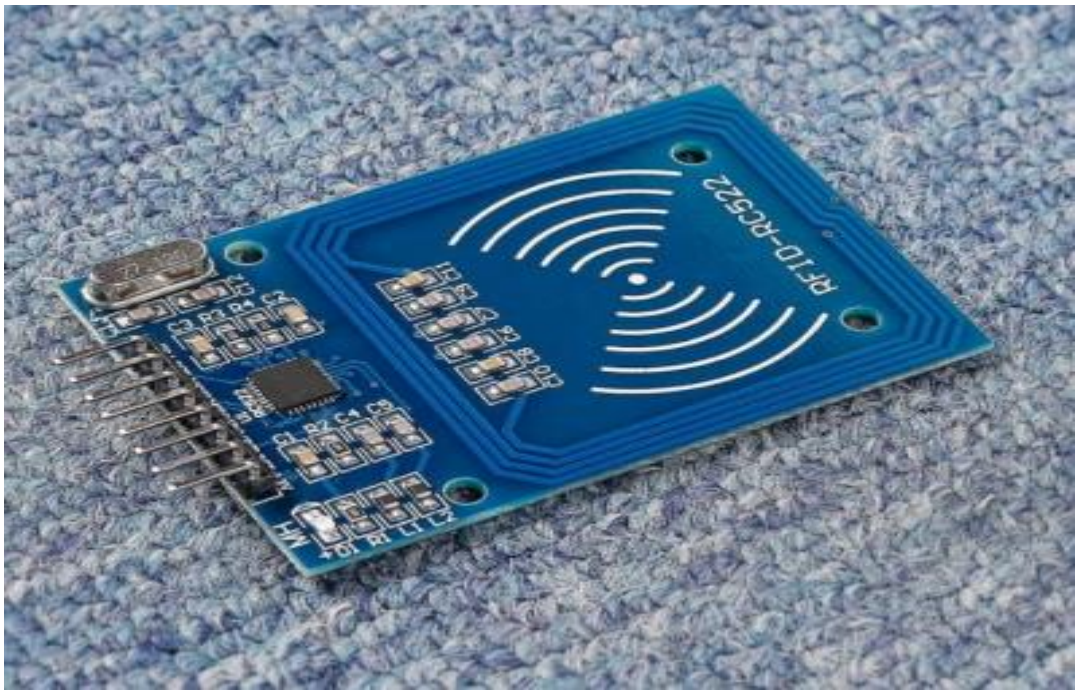


Figure 11. MFRC-522 Reader.

11.1.1 MFRC-522 Set up Design

The PIN label 1 takes the VCC of about 3.3 volts, PIN label 3 to ground (GND), the figure below (Figure 12) shows all the above PIN connection, and the rest 8 PIN labels are connected to the breadboard of our circuit accordingly. We chose this Item because it easy to set up gives our desired result and is the best 13.56 MHz Reader available.

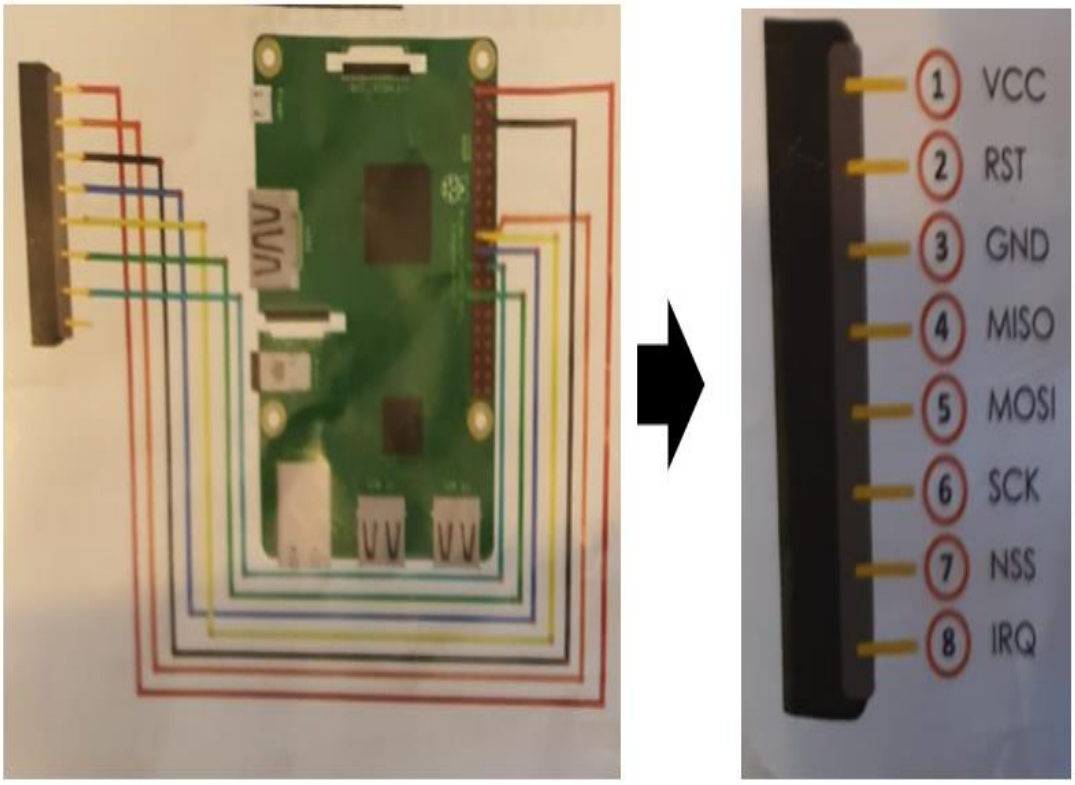
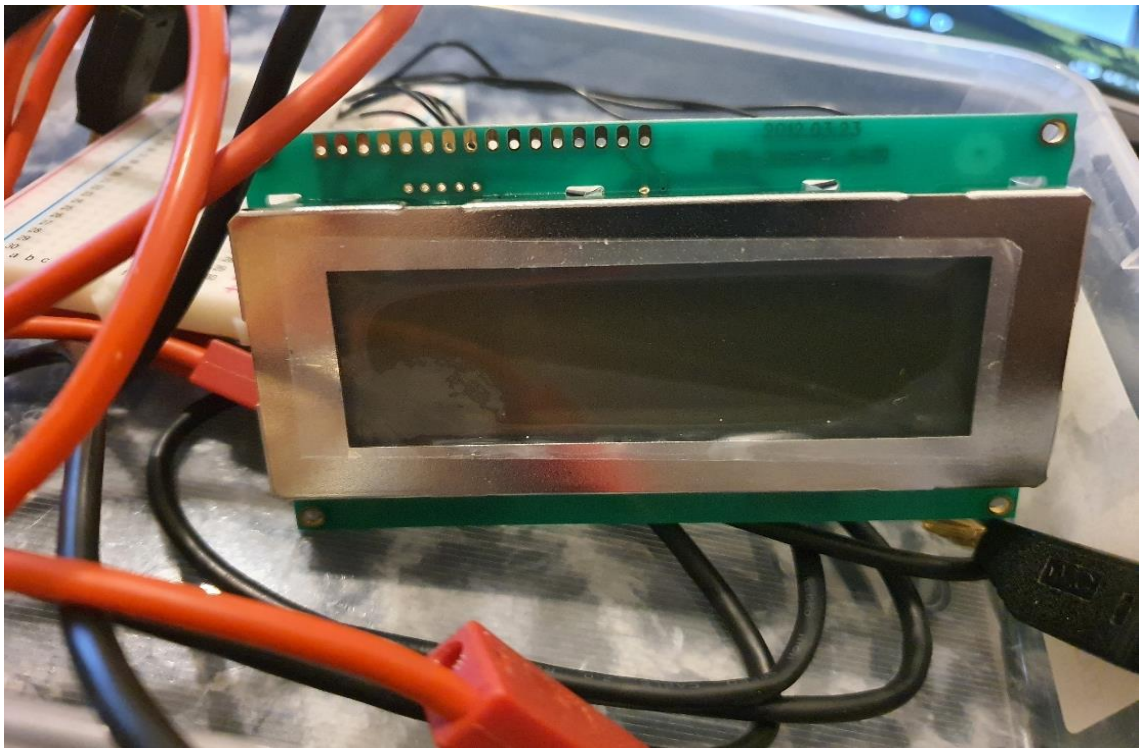


Figure 12. RFID Module MFRC-522 Schematic.

11.2 Alphanumeric LCD Screen

The Alphanumeric LCD shows the RFID tag number on the LCD screen. When the Tag enters in the magnetic flux of the reader located within the reading range the LCD screen shows the RFID Tag ID, serving as the monitor in the RFID system (Figure 11.). It has a logic voltage of 5Volts, with a size of 98mm x 60mm, and an operating temperature of 50 degree Celsius.

The main reasons to choose this LCD are that the school lab has the necessary power supply, it shows a clear tag ID, and it is available in the electronics shops shelf in Finland that minimized the delivery time to our school Electronics lab.



11.3 LCD Interface Signal

The LCD contains 16 PINs and 20 characters (5 x 8 dots) x 4 lines, a white Transflective LCD character module, 6 O'clock viewing direction, a driving duty of 1/16 duty by 1/5 bias. This LCD Screen has a data sheet that clearly puts the connection guide, and it fits the MFRC-522 Reader design.

11.4 Breadboard (Generic)

A solderless Breadboard is a construction base for prototyping of electronics. It has two sets of very long power rails with a green and red colour, and the large middle section that full of 5-holes-long terminal strips.

11.5 Resistors

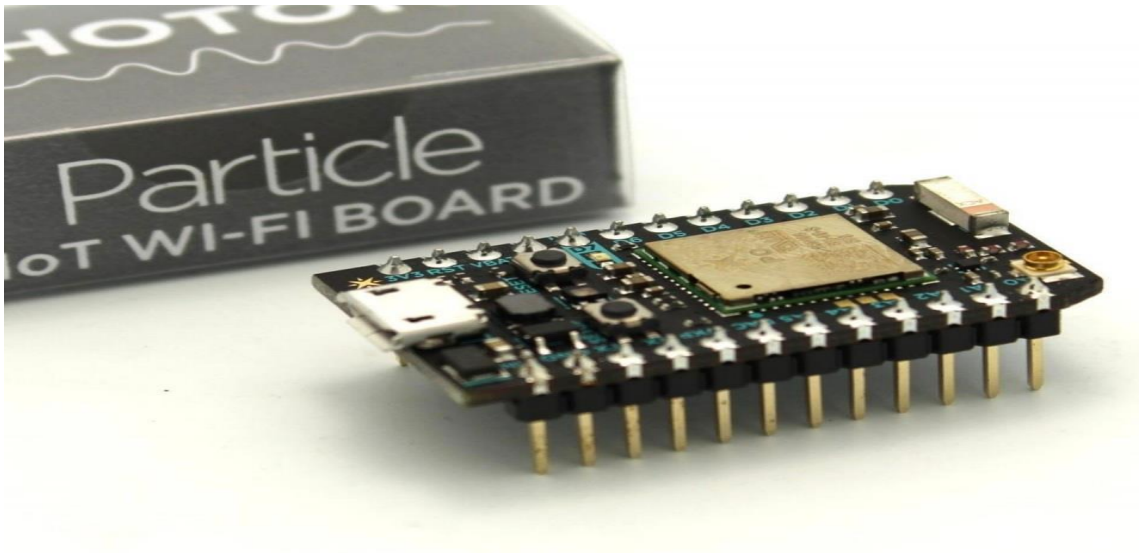
The design has two serially connected Resistors with a value of 10 K ohms between the LCD and the Photon.

11.6 Jumper Wires

Jumper Wires provide the connection between the various hardware components together on the breadboard and then connect to draw power from the supply.

11.7 Photon

Photon is the hardware used to address the programming of the identification system to connect the RFID components to a computer through an internet by using a programming code.



12 Prototype Testing

12.1 Prototype Creation

This prototype report is designed RFID system for a bachelor thesis level and is aimed at getting a basic experience of studying, designing, and testing theoretical identification techniques in practical laboratories.
This study report considered addressing many possibilities when the rules set up on testing the RFID identification. Mainly the testing goals are the base for setting testing scenarios, expanding the level of the system reliability on using the ideal RFID framework.

12.2 Testing Goals

This RFID Prototype Project test aimed at:

Validating theoretical concept of RFID system with the aim of verifying if users of this research work can easily figure out what they are reading and looking at. This test is commonly performed for use in basic own RFID system building rather than building a solution on this identification system.

Readers of this report can understand the functionality flow. The quality of this prototype depends on the steps followed in designing the RFID system smoothly and getting a certain level of understanding of the nature of RFID system.

12.3 Test Scenarios

The usability testing of this research is giving users a specific direction towards performing their need related to RFID identification system. The research designed to resemble a realistic approach of the identification system.

12.3.1 Test Successful with LCD

The first trial of the design using LCD effectively read the tag Ids of different Smart Cards and show it on the LCD Screen.

12.3.2 New set up with a Computer Screen

Changing the code to program needed and the reader reads tag Ids of different Smart Cards, show it in a computer screen, and give access to the preferred group while denying it to other Smart Cards.

13 Research Findings

13.1 Findings using the LCD

The actual design connects the designated PINS on the Raspberry Pi MFRC-522 13.56 MHz Reader with the breadboard scanner including the LCD.

By using the overall framework set up in the research beginning resulted a Reader connected with the Tag, a photon, and an LCD screen. Beginning with finding out the coil size necessary for the Reader, flow chart presented below (Figure 16) shows the designed prototype briefly.

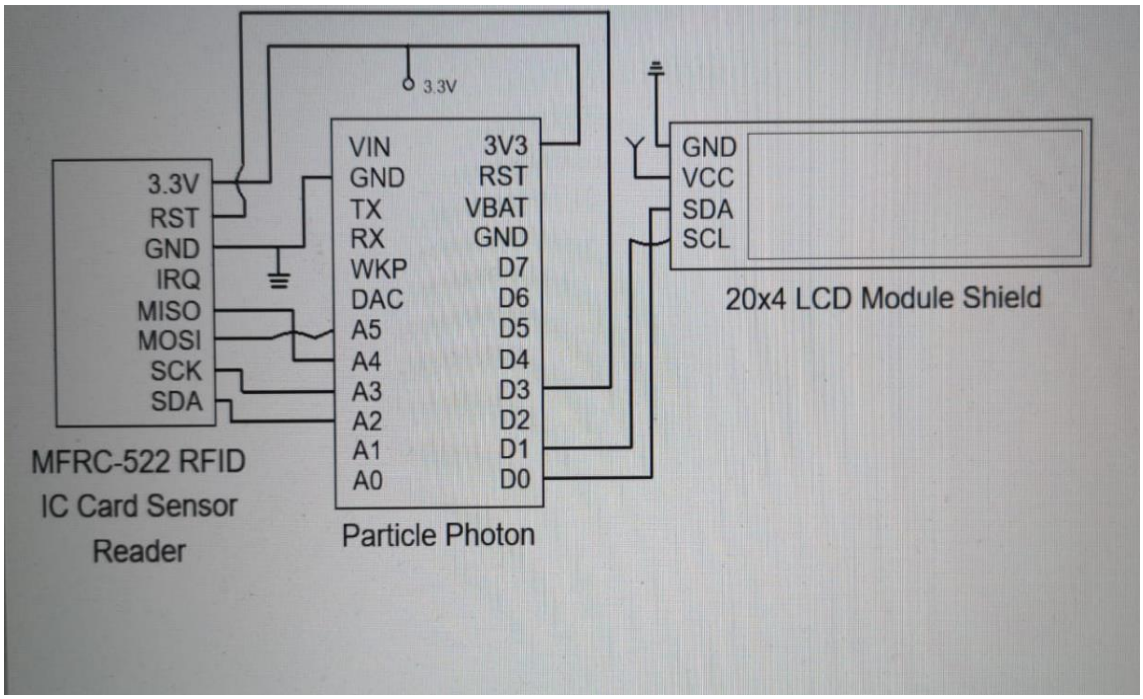


Figure 16. Flow chart of RFID Prototype Design.

As can be seen from the figure above (Figure16) the integrated circuit card reader has seven PINS connected to the Photon. The photon programmed and displayed on the LCD screen should take the programming role and display it on the screen.

The reader took 3.3 Volts of source from the lab; GND goes to both ends so the circuit is complete.

Whenever the current starts to flow through the coil created the magnetic field in the Reader that was allowing the Tag to draw energy once it enters the reading range. This stage of the study tested the passive RFID system working principle of using inductive coupling to power the TAG.

The connection between the PIN numbers were correct, but the LCD did not display the Smart Cards ID as expected. The design did not result in a successful completion to identify the Smart Cards and the design failed to achieve the desired result.

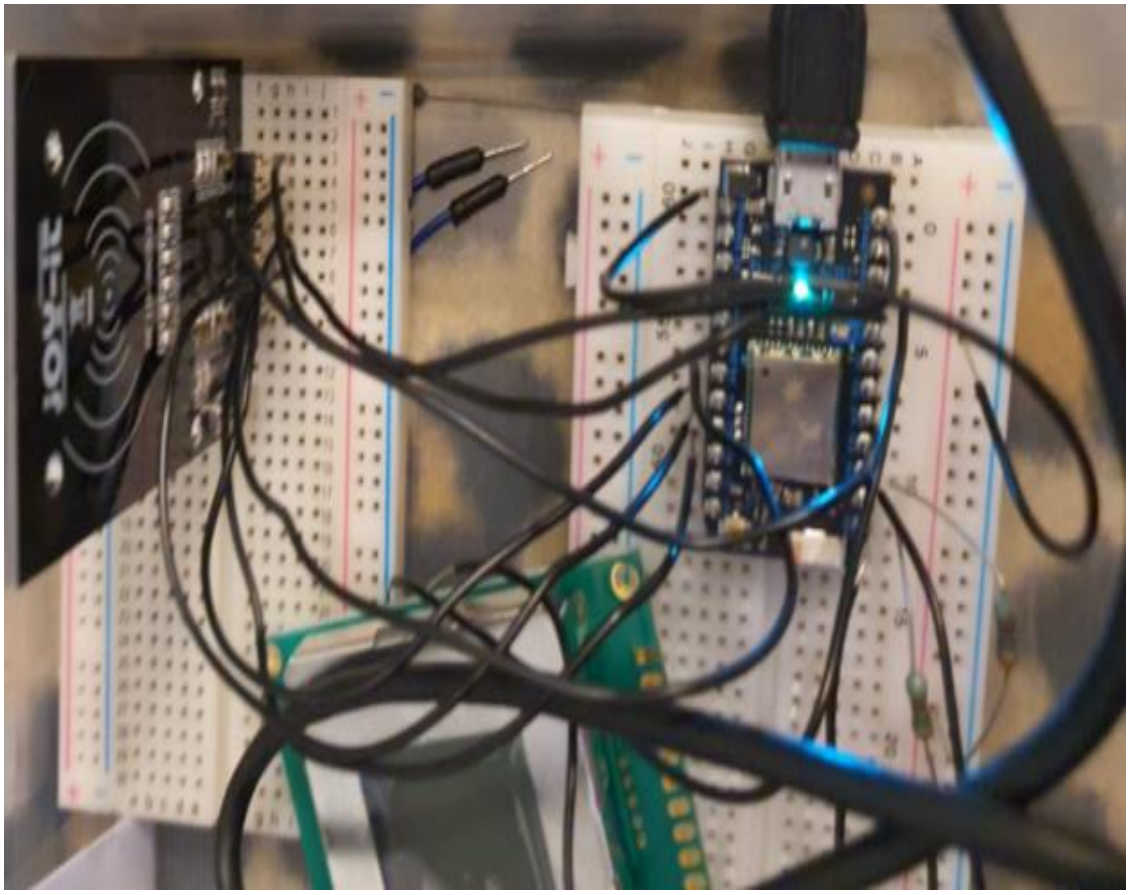


Figure 17. Designed RFID system using LCD.

13.2 Findings using a Computer Screen

The tag was giving feedback to the reader and the reader recognized the different Smart Cards tag Ids, which completes the total system. The tag was able to get energy from the reader when it enters the reading range.

The Circuit built on a breadboard allows easy flow and it reached to the intended level of identifying the Tag in a range of 1cm, 5cm and 10cm. The new design uses two LEDs with a green and a red colour lights to show at different readings.

The RFID reader identify and light a green LED light for the preferred blue Smart Card, the Blue Master Card in the following figure (Figure 18) giving access to this card.

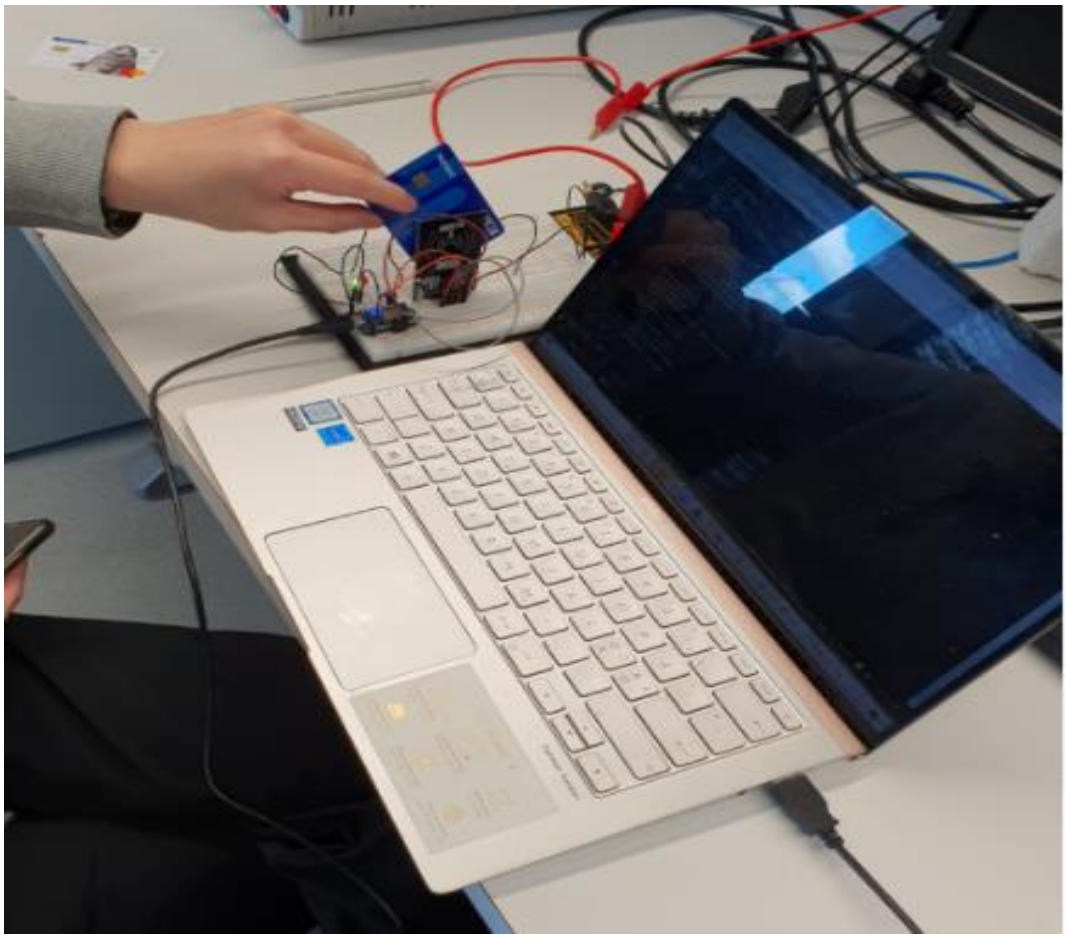


Figure 18. Preferred Smart Card given Access.

The RFID reader identify on the second test whereby another Smart Card got closer to the reader. The Reader then read the tag ID of the disallowed Smart Card, white Master Card, and light a red LED light on the circuit to deny access of entry. (Figure 19)

The testing of the system with many Smart Cards gives the same result. In all tests, the reading works perfectly giving different IDs for the different Tags check the white list and give or deny access depending on whether the Smart Card are on the white list (allowed) or black list (disallowed).

The Test was successful, and this RFID Project Prototype study reached its intended target of Access control using Smart Cards with different tag Ids.

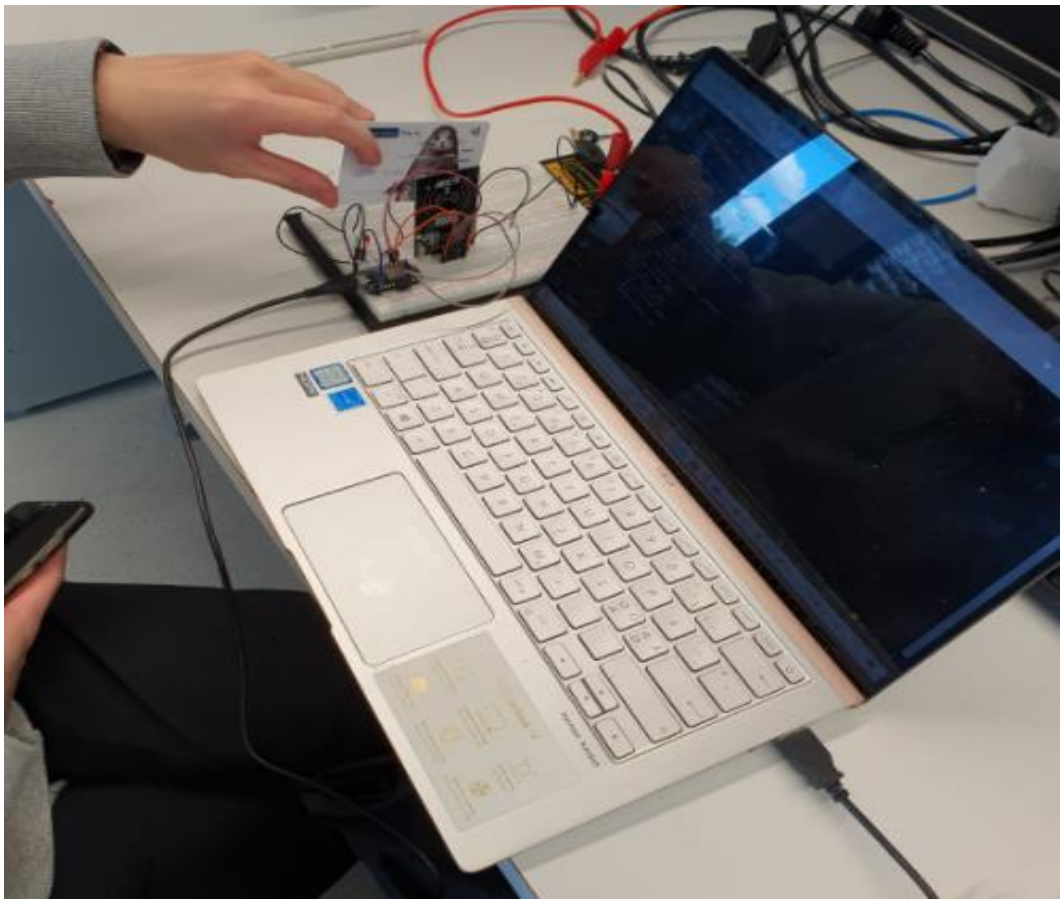


Figure 19. Disallowed Smart Card denied Access.

There is a better way to do the RFID Prototype Project design to operate as an even better RFID system in the future using the basic idea in this research with LCD Screen. However, the designed prototype has reached it objective at an acceptable level.

14 Applying the RFID Project Prototype to Guest Houses in Addis Ababa, Ethiopia

Many Guest Houses in Addis Ababa, Ethiopia do not have a proper Access Control system. This RFID identification system will improve the services of the Guest Houses by saving time, by simplifying the tracking of individuals and their movement in the building, by allowing to keep a real time data and by advancing the access control system in the building in general.

A visitor coming to the Guest House can easily get access to the rooms according to his wishes once he communicates with the secretary administering guests. The secretary by the INFO desk will read the tag ID from the Visitor's Smart Card and issue the paid amount access to the customer. After recording the tag ID, the Guest House can track the overall movement of the individual and update his status in real time to make changes if necessary.

The RFID identification system will improve the general service and at time of crimes or any accidents, the Guest Houses can access the record and report the police or take the necessary action using the data recorded during the guest's visit.

15 Conclusion

The basic objective of this study was to design a prototype RFID system that identifies Smart Cards, tracks, and controls access to enter a certain section, to discover improvements in practices that will enable planning and conducting a more detailed and improved RFID Tag and Reader system research in the future.

After successfully completing the RFID Prototype Project the study showed that, the RFID reader using 13.56MHz identified the tag ID, display it and perform Access Control function to match the developed design with the Inductive-coupling concept of the RFID Identification.

The study achieved less than its intended first test goal scenario using LCD screen, but in the future this RFID Project Prototype can be fully functional by better designing a code that run the LCD on the system and much can be done using this topic as a future research topic.

However, it has fully reached its intended test goal of Accesses control RFID Project Prototype system using a code that allows the MFRC-522 13.56 MHz reader to track, control Smart Cards and show their Ids on a computer screen.

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Programming Code used on the Photon

```
 #include <MFRC522.h>
#include "MFRC522/MFRC522.h"
#define SS_PIN D1
#define RST_PIN D2
const pin_t LEDG = D7;
const pin_t LEDR = D5;
MFRC522 mfrc522(SS_PIN, RST_PIN);
void setup() {
  pinMode(LEDG, OUTPUT);
  pinMode(LEDR, OUTPUT);
  Serial.begin(9600);
  mfrc522.setSPIConfig();
  mfrc522.PCD_Init();
  RGB.control(true);
}

void blink() {
  RGB.color(0, 0, 255);
  delay(150);
  RGB.color(0, 0, 0);
  delay(100);
  RGB.color(0, 0, 255);
  delay(150);
  RGB.color(0, 0, 0);
}
void loop() {
  if ( mfrc522.PICC_IsNewCardPresent()) {
    if ( mfrc522.PICC_ReadCardSerial()) {
      String UID = "";
      for (byte i = 0; i < mfrc522.uid.size; i++) {
        UID += String(mfrc522.uid.uidByte[i] < 0x10 ? "0" : "");
        UID += String(mfrc522.uid.uidByte[i], HEX);
      }

      mfrc522.PICC_HaltA();
      Serial.print("UID: ");
      Serial.println(UID);
      Particle.publish("rfid-read", UID, 5, PRIVATE);
      blink();
      if ( UID == "b72b6ff2") {
        digitalWrite(LEDG, HIGH);
```

```
      delay(2000);
      digitalWrite(LEDG, LOW);
    }
    else {
        digitalWrite(LEDR, HIGH);
        delay(2000);
        digitalWrite(LEDR, LOW);


    }
  }
}
```