PORTABLE TOUCH ‘N GO CARD READER

MUHAMMAD SYAFIEQ BIN ABD RAZAK

UNIVERSITI SAINS MALAYSIA

2019
PORTABLE TOUCH ‘N GO CARD READER

by

MUHAMMAD SYAFIEQ BIN ABD RAZAK

Thesis submitted in partial fulfilment of the requirements for the degree of Bachelor of Engineering (Mechatronic Engineering)

JUNE 2019
ACKNOWLEDGEMENT

Through the way to complete this final year project, I have received a lot of support and contribution from many people. First, I would like to present my greatest gratitude to my supervisor, Assoc. Prof. Ir. Dr. Rosmiwati Mohd Mokhtar for all the guidance and advice in completing this project. Her words kept me in the right path towards objective of this project. I am very honoured to have her as my supervisor for my final year project.

My thankful and grateful also goes to the technical staff of my proud School of Electrical and Electronic (PPKEE) for the resourceful and handy guidance to me. I learnt valuable lessons from them especially in handling the lab equipment.

Applauds and appreciation towards my fellow friends for the time to listen, exchanging opinions, advices, and leisure treatments all the way towards the submission of this writing. Last but not least, for my beloved family, my father and mother for everything I could not wish for as well as the heart-warming encouragement that they had unleashed upon me since my first day as an undergraduate student at the Universiti Sains Malaysia. Finally, to all who had been involved in this project, thank you so much.
# TABLE OF CONTENTS

Acknowledgement ...................................................... ii  
Table of Contents .................................................... iii  
List of Tables .......................................................... v  
List of Figures .......................................................... vi  
List of Abbreviations ................................................ viii  
Abstrak ................................................................. ix  
Abstract ................................................................. x  

## Chapter 1: Introduction ........................................... 1  
1.1 Overview ....................................................... 1  
1.2 Problem Statements .......................................... 5  
1.3 Objectives of Research ........................................ 5  
1.4 Scope of Research .............................................. 6  
1.5 Thesis Outline .................................................. 7  

## Chapter 2: Literature Review .................................... 8  
2.1 Introduction ................................................... 8  
2.2 E-TAG Infrared On-Board Unit 530 .......................... 8  
2.3 Proximity (contactless) Card Technology .................. 9  
2.4 Touch ‘n Go Cards Origin ..................................... 10  
2.5 Lithium-based Battery Charger Module .................... 12  
2.6 Arduino Nano Microcontroller ............................... 15  
2.7 Summary ......................................................... 16
Chapter 3: Research Methodology

3.1 Introduction 17
3.2 Project Implementation Flow 17
3.3 Project Requirement 19
    3.3.1 Hardware System 19
    3.3.2 Software Program 21
3.4 Operating System Development 21
3.5 Battery Charger and Boost Converter Development 23
3.6 PCB Layout Design 26
3.7 Mechanical Design 26
3.8 Overall System Testing 27
3.9 Summary 28

Chapter 4: Result And Discussion

4.1 Introduction 29
4.2 Operating System Development Results 29
4.3 Battery Charger and Boost Converter Results 31
4.4 Overall Discussion 36

Chapter 5: Conclusion

5.1 Introduction 37
5.2 Project Conclusion 37
5.3 Further Recommendation 38

References 39

Appendices 42
LIST OF TABLES

Table 2.1: Rprog current setting [22] 14
Table 2.2: Technical specification of Arduino Nano [25] 16

Table 3.1: Hardware and software used in this project 19
Table 3.2: Battery voltage mapping. 22
Table 3.3: Selected ICs for battery charger and switching circuit. 23
Table 3.4: Bill of materials. 25

Table 4.1: Measured battery voltage with 5 minutes interval. 34
# LIST OF FIGURES

| Figure 1.1 | Max Tag with a TnG card slotted displaying the balance of the card. | 2 |
| Figure 1.2 | Cropped print screen of TnG portal. | 3 |
| Figure 1.3 | Screenshot of TnG eWallet application. | 3 |
| Figure 1.4 | TnG reload receipt [4]. | 4 |
| Figure 1.5 | A toll fare display [5]. | 4 |
| Figure 2.1 | Technical specifications of E-TAG Infrared OBU 530 [6]. | 9 |
| Figure 2.2 | Generic RF smart card [8]. | 9 |
| Figure 2.3 | MIFARE RFID-RC522 kit [12]. | 10 |
| Figure 2.4 | Contactless MIFARE system [16]. | 11 |
| Figure 2.5 | Block diagram of MF1S70yyX/V1 [16]. | 11 |
| Figure 2.6 | TP4056 lithium battery charger and protection module [21]. | 12 |
| Figure 2.7 | Power supply options [24]. | 13 |
| Figure 2.8 | Indicator LEDs and configuration resistor [24]. | 14 |
| Figure 2.9 | Arduino Nano mounted on a breadboard [28]. | 15 |
| Figure 3.1 | Project implementation flow. | 18 |
| Figure 3.2 | Block diagram of hardware system. | 19 |
| Figure 3.3 | Portable card reader topology. | 20 |
Figure 4.1: MFRC522 write program result.

Figure 4.2: Sector 0 of MF1S50yyX/V1 EEPROM memory organization.

Figure 4.3: MFRC522 read program result.

Figure 4.4: MFRC522 read program output displayed on LCD.

Figure 4.5 Top layer (left) and bottom layer (right) of the fabricated PCB.

Figure 4.6: Unsoldered battery charger and boost converter region at top layer of the PCB.

Figure 4.7: Soldered battery charger and boost converter region at top layer of the PCB.

Figure 4.8: Red LED lit up indicates battery being charged.

Figure 4.9: Battery voltage against time curve.

Figure 4.10: Blue LED lit up indicates battery fully charged.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>DSRC</td>
<td>Dedicated Short Range Communication</td>
</tr>
<tr>
<td>EEPROM</td>
<td>Electrically Erasable Programmable Read-Only Memory</td>
</tr>
<tr>
<td>ETC</td>
<td>Electronic Toll Collection</td>
</tr>
<tr>
<td>IC</td>
<td>Integrated Circuit</td>
</tr>
<tr>
<td>IDE</td>
<td>Integrated Development Environment</td>
</tr>
<tr>
<td>IoT</td>
<td>Internet of Things</td>
</tr>
<tr>
<td>LCD</td>
<td>Liquid Crystal Display</td>
</tr>
<tr>
<td>LED</td>
<td>Light Emitting Diode</td>
</tr>
<tr>
<td>Li-Po</td>
<td>Lithium-Polymer</td>
</tr>
<tr>
<td>MOSFET</td>
<td>Metal Oxide Semiconductor Field Effect Transistor</td>
</tr>
<tr>
<td>NFC</td>
<td>Near Field Communication</td>
</tr>
<tr>
<td>OBU</td>
<td>On-Board Unit</td>
</tr>
<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
</tr>
<tr>
<td>PCD</td>
<td>Proximity Coupling Device</td>
</tr>
<tr>
<td>PICC</td>
<td>Proximity Integrated Circuit Card</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio Frequency Identification</td>
</tr>
<tr>
<td>RGB</td>
<td>Red, Blue and Green</td>
</tr>
<tr>
<td>TnG</td>
<td>Touch ‘n Go</td>
</tr>
<tr>
<td>USB</td>
<td>Universal Serial Bus</td>
</tr>
</tbody>
</table>
PEMBACA KAD “TOUCH ‘N GO” MUDAH ALIH

ABSTRAK

Tesis ini membincangkan tentang kaedah-kaedah membaca baki kad Touch ‘N Go (TnG) yang terdapat masa kini dan menganalisa kecekapan dan kebolehpercayaan kaedah-kaedah tersebut untuk para pengguna TnG. Projek ini bertujuan untuk menyelesaikan permasalahan baki kad TnG yang tidak mencukupi tanpa disedari oleh pengguna dengan menyediakan pembaca kad pintar mudah alih sebagai kaedah alternatif kepada pengguna TnG untuk memeriksa baki kad TnG dengan mudah. Pembinaan prototaip kad pintar mudah alih melibatkan manipulasi pengaturcaraan sistem pengenalan frekuensi radio (RFID) dalam Arduino IDE dengan modul RFID MFRC522 di mana organisasi EEPROM kad pintar tanpa sentuh ditulis dengan nilai samaran untuk dibaca oleh prototaip dan diinterpretasikan sebagai wang digital dengan mata wang Malaysia. Sistem simpanan tenaga dibangunkan berdasarkan skematik aplikasi tipikal litar terkamir (IC) pengecas bateri berasaskan litium TP4056 yang didatangkan bersama IC perlindungan bateri FS312F-G. Voltan bateri kemudian diubah menjadi tahap voltan arus terus (DC) yang lebih tinggi oleh litar bersepadu pengubah galakan DC-DC MT3608 bagi memenuhi keperluan voltan input Arduino Nano. Semua komponen disepadukan di atas papan litar tercetak yang susun aturnya diubah suai menggunakan perisian dalam talian secara percuma yang dikenali sebagai EasyEDA. Pada akhir projek ini, sistem dapat membaca dan memaparkan maklumat yang disimpan dalam kad pintar dengan jayanya. Sementara itu, pengecas bateri berjaya mengecas bateri litium-polimer sel tunggal berkapasiti 1500mAh sehingga 4.205V selama 190 minit.
PORTABLE TOUCH ‘N GO CARD READER

ABSTRACT

This thesis discussed the methods to read the balance of Touch ‘N Go (TnG) card that currently available and analyse its efficiency and reliability for TnG users. This project intended to resolve the user’s unexpected insufficient TnG card balance by providing a portable smart card reader as an alternative method for TnG users to check TnG card balance conveniently. The development of the portable smart card prototype involves manipulation of Radio Frequency Identification (RFID) system programming in Arduino IDE with MFRC522 RFID module whereby the EEPROM (Electrically Erasable Programmable Read-Only Memory) organization of contactless smart card is written with ambiguous values to be read by the prototype and interpreted as digital money with Malaysian currency. The energy storage system is developed based on utilization of typical application schematic of TP4056 lithium-based battery charger integrated circuit (IC) alongside FS312F-G battery protection IC. The battery voltage is then converted into a higher direct current (DC) voltage level by MT3608 DC-DC boost converter IC to fulfil Arduino Nano input voltage requirements. All hardware components are integrated on a printed circuit board where its layout design was made using free online software called EasyEDA. At the end of this project, the system was able to read and display the information stored in the smart card successfully. Meanwhile, battery charger had successfully charged a single cell lithium-polymer battery with capacity of 1500mAh up to 4.205V for 190 minutes.
CHAPTER 1

INTRODUCTION

1.1 Overview

The Touch ‘n Go (TnG) card is synonymous with the contemporary Malaysian drivers’ smart card when it comes to electronic toll collection (ETC) in Western Malaysia highways. The TnG cards were initially intended to be used at toll plazas along Malaysian highways when it first launched at Kuala Lumpur – Seremban Highway (formerly known as Metramac Highway) and Projek Lebuhraya Utara Selatan (PLUS) Expressways in 1997 [1]. Nowadays, TnG cards are used extensively for electronic payment in expressways, public transit, theme parks, parking bays, and purchasing goods in selected retail outlets. According to Touch ‘n Go Sdn. Bhd. (TNGSB) in their official website, there are a growing figure of 6 million TnG cardholders with more than 3 million transaction a day [2]. These could include every Malaysian identification card – also known as MyKad – that have TnG logo at the back of the card. The TnG card stores discrete value of electronic money to perform cashless transactions if the smart card were reloaded by its user. It had been a concern of many TnG card users on the degree of efficiency regarding currently available methods to check balance of the smart card.

One method to check the balance of the Touch ‘n Go card is by using an infrared On Board Unit (OBU) with contactless chip card interface, famously known as Smart Tag. The OBU features an 8 segment LCD display to indicates battery life and displays the balance of the Touch ‘n Go card if the smart card is inserted on the designated tray of the OBU. It also allows fast toll transactions with drive-through convenient by means of infrared...
communications. Figure 1.1 shows EFKON’s latest OBU 530 known as E-Tag (Max Tag) with a TnG card slotted in, displaying the balance of the card (highlighted inside the red box).

Figure 1.1: Max Tag with a TnG card slotted displaying the balance of the card

Another method is via Internet of Things (IoT) platforms that require an internet connection to check the balance of the TnG card. Such IoT platforms are the Touch ‘n Go portal and the Touch ‘n Go eWallet application that is available on Android and IOS devices. TnG portal only displays the details of registered TnG cards by its user. Notice in Figure 1.2, there are two cards associated to a single registered user – one being the “USM Golden Jubilee” card and another one is the Malaysian IC (MyKad). The TnG card is recognised by the system via the 10-digit serial number which can be found on the bottom left on the back of the TnG card or on the receipt of the TnG card reload or as stated in the TnG portal. By having the serial number, user can add up to three TnG cards or MyKad to the TnG eWallet mobile application to view balance of each cards as shown in Figure 1.3. TnG eWallet is an all in one e-wallet service covering all existing and future Touch ‘n Go products & services [3].
Figure 1.2: Cropped print screen of TnG portal

Figure 1.3: Screenshot of TnG eWallet application
There are traditional ways to check the balance of the TnG card. As shown in Figure 1.4 and Figure 1.5, TnG user able to read out the balance from Touch ‘n Go reload receipt or from the toll fare display while driving out of a toll lane.

Figure 1.4: TnG reload receipt [4]

Figure 1.5: A toll fare display [5]
1.2 Problem Statements

The issue of unnoticed low TnG card balance due to battery drainage is common among its users. TnG users are advised to check their TnG card balance in advance to avoid unexpected complications such as traffic congestion at toll plaza due the issue mentioned earlier. Despite all the methods to check the balance of the TnG card available today, there are limitations need to overcome.

The older version of Smart Tag OBU and its improved version called the Max Tag uses a standard 9 V alkaline battery block that is exchangeable by the user. The battery is expected to operate the new OBU up to 2 – 3 years of daily usage ensured by low power mode with patented wake-up on coded infrared signal [6]. However, previous users’ experience of the older version OBU has it display to be faulty after a year of usage and requires its user to prepare spare batteries to avoid unexpected battery drainage after long term usage. In the other hand, the IoT platforms are basically unavailable without a working internet connection. Meanwhile, all traditional methods have locality issue for instance user can only know the TnG card balance from reload receipt before using the TnG card and from the toll fare display at toll plaza.

1.3 Objectives of Research

This project aims to resolve the limitations of TnG balance checking methods that are available today as discussed earlier by achieving the following objectives:

1. To develop a portable device that able to read and display balance from TnG card.

2. To integrate the portable device with rechargeable energy storage system.
1.4 **Scope of Research**

This final year project focuses on developing portable device that able to read MIFARE Classic EV1 contactless smart card content by utilizing the MFRC522 RFID module. The portable device will have its own rechargeable energy storage system that should be a reliable new feature introduced to the existing TnG card readers.

The development of reading a contactless smart card will focuses on programming the RFID system. Meanwhile, the battery charging system focuses on utilizing electronic components related to battery charger and converting the battery voltage to a higher voltage level. All hardware components are integrated in a single fabricated PCB.
1.5 Thesis Outline

This “Portable Touch ‘n Go Card Reader” project will be explained in all five chapters starting from introduction until conclusion.

Chapter one describes the overview of the project, problem statements, research objectives, project scope and this progress report outline sub-topic.

Chapter two is the summarization of the information collected from the literature review on relevant previous research that related to RFID systems technology, battery charger and microcontroller application.

Chapter three will thoroughly discuss the method used to fulfil the objectives of the project. It will explain the theory used in to achieve the portability of the card reader powered by a battery as the primary power source of the system.

Chapter four discusses on the results obtained from the tests conducted. This chapter also describes how does the tests conducted could led to achieve the objective of this project.

Chapter five concludes the overall project starting from the beginning of the project development until the stage of suggesting further recommendations.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The previous research and past work related to this project is synthesized and summarized to provide relevant fundamentals and understanding of this project. This chapter discusses the information based on literature reviews that are related to the studies of the portable TnG card reader project.

2.2 E-TAG Infrared On-Board Unit 530

The E-TAG Infrared OBU 530 is a newer and improved version of SmartTAG OBU portable device. The intellectual property right for both E-TAG and SmartTAG OBUs belongs to EFKON GmbH – an Austrian ETC technology provider. The OBU featured a contactless communication interface based on ISO 14443 that allows plausible usage of the OBU as a direct debit medium for fully anonymous toll payments, parking charges and other kinds of transactions for vehicles. It allows a broad range of different chip card types that can be used for storing, charging and debiting real money through the OBU and secured with state-of-the-art encryption mechanisms [6].

The combination of DSRC (dedicated short-range communication) designed for high-speed vehicle communication in an interrogation zone about 5–15 metres and MIFARE/NFC communication designed for secure communication in a zone of about 0–2 centimetres. Figure 2.1 shows the technical specifications of E-TAG Infrared OBU 530.
Figure 2.1: Technical specifications of E-TAG Infrared OBU 530 [6].

2.3 Proximity (contactless) Card Technology

A proximity (contactless) cards do not necessarily need to touch the card reader as the cards are typically short-range integrated card identification (IC ID) systems. An inductive coil in the proximity coupling devices (PCDs) or a card reader is used in these systems to generate radio frequency (RF) magnetic field that couples to another inductive coil that is embedded inside the card [7]. A depiction of a generic RF smart card having the physical appearance as a standard credit card that consists of a microchip and the inductive coil made up of several wires serve as antenna for communication and power as shown in Figure 2.2.

Figure 2.2: Generic RF smart card [8]
The standard for contactless smart card communications is ISO/IEC 14443 that allows for communication at a close distance [9, 10]. RFID-RC522 of MFRC522 is a popular RFID MIFARE cards and tags reader/writer. The MFRC522 supports MIFARE series of high-speed non-contact communications, rapid CRYPTO1 encryption algorithm and other validation terminologies of MIFARE products [11, 12]. Figure 2.3 shows the MIFARE RFID-RC522 kit consists of the RFID board, a RFID card, a RFID tag and header pins.

![MIFARE RFID-RC522 kit](image)

Figure 2.3: MIFARE RFID-RC522 kit [12]

### 2.4 Touch ‘n Go Cards Origin

The TnG card is a standard credit card-sized or according to the definition of the physical characteristics of proximity cards (PICCs) which is fully standard ISO/IEC 14443 Type A 1-3 compliance [13]. The card is made up of plastic embedded with NXP Semiconductors’ MIFARE Classic EV1 4K MF1S70yyX/V1 IC microchip technology which operates in the 13.56 MHz frequency range with read/write capability [14, 15]. Figure 2.4 shows the relation of a smart card to its PCD. Note that energy is pointed towards the card from the PCD signifying that the smart card being energized by the PCD. When the card is energized, data can be transferred between them in a proximity.
Figure 2.4: Contactless MIFARE system [16]

Figure 2.5 shows the general idea of communication between the MIFARE card PCD and the PICC. The MF1S70yyX/V1 is designed for simple integration and user convenience to allow a complete transaction to be handled in less than 100 ms [11, 12]. Figure 2.5 shows the block diagram of the MF1S70yyX/V1 microchip.

Figure 2.5: Block diagram of MF1S70yyX/V1 [16]
2.5 Lithium-based Battery Charger Module

It is essential to have a portable energy storage system embedded on a portable device. Rechargeable batteries, for instance, are among currently available battery technologies. Lithium-based batteries, such as Li-ion batteries, are considered the most promising ones because of their relatively higher energy density. In the past recent years, all-solid-state Li batteries had progressed significantly by experimentally developing and optimizing solid electrolytes, which would, features better performance [17]. These rechargeable batteries are coupled with a charging controller module with battery protection to provide a rechargeable portable energy storage system. The TP4056 lithium battery charger module, shown in Figure 2.6, had been used extensively in many portable devices and implemented in various projects [18-20].

Figure 2.6: TP4056 lithium battery charger and protection module [21]

It is a constant-current or constant-voltage linear charger for single cell lithium batteries. This charger module uses the TP4056 lithium charge controller and the DW01A lithium-ion battery protection integrated circuit [22]. The combination of the two ICs provides
protection for the battery against over-discharge, overcharge and overcurrent as well as to ensure soft-start protection limits in rush current and battery reconditioning [23].

It can be powered (for charging), from a micro USB cable or the positive and negative terminals as shown in Figure 2.7. At least 1A from the power source is needed to be able to correctly charge a connected battery. The charge current can be configured externally with programmable resistor (Rprog). Table 2.1 shows the Rprog resistor values to configure with its corresponding charge current values. Figure 2.8 shows the position of the Rprog resistor on the charging module.

Figure 2.7: Power supply options [24]
Figure 2.8: Indicator LEDs and configuration resistor [24]

Table 2.1: Rprog current setting [22]

<table>
<thead>
<tr>
<th>Rprog (kΩ)</th>
<th>I_{BAT} (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>130</td>
</tr>
<tr>
<td>5</td>
<td>250</td>
</tr>
<tr>
<td>4</td>
<td>300</td>
</tr>
<tr>
<td>3</td>
<td>400</td>
</tr>
<tr>
<td>2</td>
<td>580</td>
</tr>
<tr>
<td>1.66</td>
<td>690</td>
</tr>
<tr>
<td>1.5</td>
<td>780</td>
</tr>
<tr>
<td>1.33</td>
<td>900</td>
</tr>
<tr>
<td>1.2</td>
<td>1000</td>
</tr>
</tbody>
</table>
2.6 Arduino Nano Microcontroller

Arduino Nano is a small and breadboard-friendly microcontroller board based on the ATmega328P. The small-sized Arduino Nano microcontroller as shown in Figure 2.9 is the main reason to use it in this project. It can be powered via the Mini-B USB connection. Besides that, Arduino Nano can also be powered with 6-20V unregulated external power supply at pin 30 or 5V regulated external power supply at pin 27. Arduino Nano will automatically select the highest voltage source in case of multiple input power source present at a time [25]. Table 2.2 shows the technical specifications of Arduino Nano.

Figure 2.9: Arduino Nano mounted on a breadboard
Table 2.2: Technical specification of Arduino Nano [25]

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcontroller</td>
<td>ATmega328</td>
</tr>
<tr>
<td>Architecture</td>
<td>AVR</td>
</tr>
<tr>
<td>Operating Voltage</td>
<td>5 V</td>
</tr>
<tr>
<td>Flash Memory</td>
<td>32 KB of which 2 KB used by bootloader</td>
</tr>
<tr>
<td>SRAM</td>
<td>2 KB</td>
</tr>
<tr>
<td>Clock Speed</td>
<td>16 MHz</td>
</tr>
<tr>
<td>Analog IN Pins</td>
<td>8</td>
</tr>
<tr>
<td>EEPROM</td>
<td>1 KB</td>
</tr>
<tr>
<td>DC Current per I/O Pins</td>
<td>40 mA (I/O Pins)</td>
</tr>
<tr>
<td>Input Voltage</td>
<td>7-12 V</td>
</tr>
<tr>
<td>Digital I/O Pins</td>
<td>22 (6 of which are PWM)</td>
</tr>
<tr>
<td>PWM Output</td>
<td>6</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>19 mA</td>
</tr>
<tr>
<td>PCB Size</td>
<td>18 x 45 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>7 g</td>
</tr>
<tr>
<td>Product Code</td>
<td>A000005</td>
</tr>
</tbody>
</table>

2.7 Summary

To summarize this chapter, the subject matters on the E-TAG OBU have become main interest for developing the project prototype with the intention to provide new features to improve the existing product. In order to conduct this project, the basic of RFID system and the contactless smart card technology are necessary. Next, it is possible replicate the battery charger circuit by understanding the particulars of existing battery charger module. Understandably, Arduino Nano is the most suitable microcontroller to be used in this project based on the information obtained in this chapter.
CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter will discuss in detail regarding the methods and procedures to design the portable TnG card reader step by step and every interaction between the hardware and software part of the system to achieve the desired results in design specification.

3.2 Project Implementation Flow

The following flow chart in Figure 3.1 is the overall process of conducting this project. The project implementation flow begins with researching the necessary knowledge specifically on RFID tags and its reader and how to program them, the background of Li-Po battery charger circuit and the basics of PCB layout design and fabrication. Then, required hardware components and suitable software programs were selected based on understanding of the subject matters studied during research. The flow continues with operating system development and followed by battery charger and boost converter development which will be further discussed in subchapters 3.4 and 3.5 respectively.

Afterwards, this project involves technical and physical development. PCB layout design are based on typical application schematics of selected solid-state electronics and hardware components. Upon completion, overall system testing will take place. If problem persisted, error checking plan will feedback into the flow chart from operating system.
development until problem are solved as it goes down the flow chart. Hence, the results will be analysed and recoded for comprehension in Chapter 4.

Figure 3.1: Project implementation flow.
3.3 Project Requirement

As discussed in previous subchapter 3.2, the hardware and software integration have been considered. Table 3.1 shows selected hardware and software required to achieve the project objectives.

Table 3.1: Hardware and software used in this project

<table>
<thead>
<tr>
<th>Hardware Component</th>
<th>Software Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>• RFID MFRC522 Reader Module</td>
<td>• Arduino IDE</td>
</tr>
<tr>
<td>• ATmega328P-PU</td>
<td>• EasyEDA</td>
</tr>
<tr>
<td>• Liquid Crystal Display (LCD)</td>
<td>• SolidWorks</td>
</tr>
<tr>
<td>• Passive RFID Tags</td>
<td></td>
</tr>
<tr>
<td>• Battery charger and switching circuit</td>
<td></td>
</tr>
</tbody>
</table>

3.3.1 Hardware System

The block diagram of the hardware system overview is shown in Figure 3.2. It depicts the relationship of the hardware components with each other with the microcontroller Arduino Nano which is powered primarily by 3.7V lithium polymer rechargeable battery or secondary external 5V power supply.

![Figure 3.2: Block diagram of hardware system](image-url)
Figure 3.3 shows the topology of the hardware system for the portable card reader. The lines connecting the hardware component blocks are describing a simple representation of wires connecting them in actual prototype. The blue dashed-line surrounds the hardware components represents the prototype case or containment. The Arduino Nano, MFRC522 reader and the Li-Po battery are dubbed as internal components because those components are placed inside a containment. Whereas the push button, LCD display, the LED panel and TP4056 battery charger are dubbed as the peripheral components because some portion of the components are exposed to the external environment for power switch and system display. Orange lines near MFRC522 card reader symbolizes electromagnetic field as it communicates with the TnG card.

Figure 3.3: Portable card reader topology.
3.3.2 Software Program

Software programs are used in designing the portable card reader with aid of computer. The Arduino software is called as the Arduino integrated development environment (Arduino IDE). Arduino IDE shall be used to write paragraphs of programming codes to the Arduino Nano. Meanwhile, circuit and PCB design are done by EasyEDA software. As for mechanical design of the prototype casing are done by using SolidWorks. Arduino Nano will control all the task assigned through a program written in Arduino IDE.

3.4 Firmware Development

Paragraphs of instruction codes written in Arduino IDE will become the operating system for the portable card reader. There are two main parts of the OS program which is the battery monitor program and MFRC522 program.

Battery monitor program checks the battery voltage level by reading the battery analogue voltage value within the range from the minimum boost converter input voltage up to 4.4 volts. This is done by having a switching circuit to indirectly feeding positive terminal of battery to pin A0 of Arduino Nano. The range of the required battery voltage are divided into three levels to indicates the health of the battery. The program shall compare the voltage value to instructs three different digital pins to have a high or low signal. The following Table 3.2 shows the mapping of different voltages to designated levels indicated by colours of an RGB LED.
Table 3.2: Battery voltage mapping.

<table>
<thead>
<tr>
<th>Voltage reading at pin A0</th>
<th>Level</th>
<th>Digital pin</th>
<th>LED colour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>D2</td>
<td>D3</td>
</tr>
<tr>
<td>4.4V – 4.0V</td>
<td>4</td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td>3.9V – 3.5 V</td>
<td>3</td>
<td>HIGH</td>
<td>LOW</td>
</tr>
<tr>
<td>3.4V – 3.00V</td>
<td>2</td>
<td>LOW</td>
<td>HIGH</td>
</tr>
</tbody>
</table>

MFRC522 program includes writing values to the EEPROM of RFID tags and read the value being stored in the EEPROM of RFID tags or precisely to the MF1S50yyX/V1 chip of MIFARE Classic 1K contactless smart card. In this project, several smart cards are to be written so that it contains certain values to be read by the portable card reader.

According to MIFARE Classic EV1 datasheet in Appendix C.1, the MF1S50yyX/V1 chip has 1 kB of EEPROM memory organized in 16 sectors of 4 blocks with each block consists of 16 bytes. Each sector has a block called “trailer” located at the end of a sector, which contains two secret keys and programmable access condition for each block in a sector. Every MF1S50yyX/V1 chip has a manufacture block which is the first block (block 0) of the first sector (sector 0). The manufacture block contains the IC manufacturer data. The block cannot be rewritten as it is programmed and write protected. Therefore, each sector has 2 value blocks reserved to perform electronic purse functions.

This project shall utilize block 1 of sector 0 of the 1k EEPROM for write and read value operations. The program is written in Arduino IDE with MFRC522 library and header files being installed to the programming software and included in the program. SPI library should also be included in the program for communication between Arduino Nano and RFID MFRC522 card reader module.
3.5 Battery Charger and Boost Converter Development

The idea of implementing battery charger and boost converter is to power the Arduino Nano as the microcontroller and the rest of the system with a lightweight and small-sized lithium polymer (Li-Po) rechargeable battery as the main power source. However, the nominal voltage of the Li-Po battery for about 3.7V is not enough to power the system. Therefore, the system needs a circuit that can boost the battery voltage up to 6V. Table 3.3 tabulates four ICs that being selected for battery charger and switching circuit. Each of the ICs are chosen based from its electrical characteristics as stated in their respective datasheets.

Table 3.3: Selected ICs for battery charger and switching circuit.

<table>
<thead>
<tr>
<th>Manufacture Part Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP4056</td>
<td>PMIC - Battery Management SOP-8_EP_150mil RoHS</td>
</tr>
<tr>
<td>FS312F-G</td>
<td>Battery Protection ICs SOT-23-6 RoHS</td>
</tr>
<tr>
<td>FS8205</td>
<td>MOSFET 2 N-Channel (Dual) 20V 6A 1.2V @ 250μA 28 mΩ @ 4A, 4.5V SOT-23-6 RoHS</td>
</tr>
<tr>
<td>MT3608</td>
<td>DC-DC Converters Step-Up Adjustable 1 2V 24V 28V SOT-23-6 RoHS</td>
</tr>
</tbody>
</table>

According to TP4056 datasheet included in Appendix C.2, it is a constant current/constant voltage, single cell lithium ion charge IC which would also applicable with a Li-Po cell. At the end of the datasheet, there is a typical application schematic which needs to be rebuild within the EasyEDA software by utilizing the passive components as shown in the schematic. Next, a micro USB port is added to supply an external 5V power input. A 1.2kΩ resistor is used as the programmable resistor to set the charge current to 1 ampere.

The battery protection IC, FS312F-G offers a high over-discharge detection voltage of 2.90 volts which is suitable for Li-Po batteries. The datasheet of the FS312F-G which can be
referred in Appendix C.3 also includes a typical application schematic that can connects to previously modified schematics of TP4056.

However, the FS312F-G needs two MOSFETs in its typical application schematic. Therefore, a dual n-channel MOSFET IC, FS8205 is applied in the circuit design. According to its datasheet in Appendix C.4, it can withstand high drain-source voltage of 20 volts, 6 amperes of continuous drain current at room temperature and has a low minimum gate threshold voltage of 0.45 volts.

A boost converter is needed to provide enough energy to the system. Therefore, MT3608 DC-DC boost converter are chosen. According to its datasheet as provided in Appendix C.5, it has a suitable low minimum input voltage of 2V and the output voltage is adjustable up to 28V. There is also a typical application schematic but without parameters of the passive and active components. The output voltage is set to 6.6V by utilizing the formula in Equation 3.1 with \( R_1 = 10 \text{k ohms} \) and \( R_2 = 1 \text{K ohms} \). Note that the value 0.6 in Equation 3.1 is given in the datasheet as the typical internal reference voltage.

\[
V_{out} = 0.6 \times (1 + \frac{R_1}{R_2}) \tag{3.1}
\]

Next, the datasheet recommends input and output ceramic capacitors of 22\( \mu \)F while highest recommended values for inductor of 22\( \mu \)H are chosen. A Schottky diode is included in the circuit, all of course according to the datasheet. A toggle switch shall be added between the positive battery terminal and the input supply pin to turn on and off the boost function.

All four ICs discussed in this subchapter would likely to be functioned as Li-Po battery charger with 6.6V boost converter to power the rest of the hardware components discussed in subchapter 3.3. The full schematic is built in EasyEDA software with solder pad symbols added to the schematic for the Li-Po battery terminals and for measurement purposes. The schematic
of the whole system is included in Appendix B.1. The following Table 3.4 tabulates the bill of materials utilized including their respective schematic designator values and PCB footprint names.

Table 3.4: Bill of materials.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Designator</th>
<th>Footprint</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TP4056</td>
<td>U1</td>
<td>SOP-8_EP_150MIL</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Micro USB Female</td>
<td>USB1</td>
<td>MICRO-USB-1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>2kΩ Chip Resistor</td>
<td>RPROG, R5</td>
<td>0603</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>BAT+ Terminal</td>
<td>BAT+</td>
<td>HDR-1X1/2.54</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>100Ω Chip Resistor</td>
<td>R4</td>
<td>0603</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>FS312F-G</td>
<td>U2</td>
<td>SOT23-6</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>FS8205</td>
<td>Q1</td>
<td>SOT-23-6</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>BAT- Terminal</td>
<td>BAT-</td>
<td>HDR-1X1/2.54</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>EG2208 DPDT Switch</td>
<td>SW1</td>
<td>EG2208</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>MT3608</td>
<td>U3</td>
<td>SOT-23-6</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>22uF Ceramic Capacitor</td>
<td>C3, C4</td>
<td>1812</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>10K Chip Resistor</td>
<td>R6</td>
<td>0603</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>22uH Power Inductor</td>
<td>L1, L2</td>
<td>7<em>7</em>4</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>SS34 Schottky Diode</td>
<td>D3</td>
<td>SMA(DO-214AC)</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>5V Terminal</td>
<td>OUT+</td>
<td>HDR-1X1/2.54</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>Ground Terminal</td>
<td>OUT-</td>
<td>HDR-1X1/2.54</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>Arduino Nano</td>
<td>U5</td>
<td>ARDUINO_NANO1</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>10uF Ceramic Capacitor</td>
<td>C1</td>
<td>1812</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>Jumper pin 1</td>
<td>P3</td>
<td>HDR-1X1/2.54</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>Jumper pin 2</td>
<td>P4</td>
<td>HDR-1X1/2.54</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>1kΩ Chip Resistor</td>
<td>R1, R2, R3, R7, R8, R9</td>
<td>0603</td>
<td>6</td>
</tr>
<tr>
<td>22</td>
<td>RBG LED</td>
<td>RGB1</td>
<td>LED-4-Pins</td>
<td>1</td>
</tr>
<tr>
<td>23</td>
<td>LCD I2C</td>
<td>LCD1</td>
<td>LCD I2C</td>
<td>1</td>
</tr>
<tr>
<td>24</td>
<td>RFID-RC522</td>
<td>RFID2</td>
<td>RFID RC522</td>
<td>1</td>
</tr>
<tr>
<td>25</td>
<td>Blue LED</td>
<td>LED1</td>
<td>LED-0603</td>
<td>1</td>
</tr>
<tr>
<td>26</td>
<td>Red LED</td>
<td>LED2</td>
<td>LED-0603</td>
<td>1</td>
</tr>
<tr>
<td>27</td>
<td>100nF Ceramic Capacitor</td>
<td>C2</td>
<td>1812</td>
<td>1</td>
</tr>
</tbody>
</table>
3.6 PCB Layout Design

The PCB of the portable smart card reader will integrate all the hardware components as well as the battery charger and boost converter circuit into a double-layer PCB. The layout design of the PCB and trace is built using EasyEDA by referring to the full schematic in Appendix B.1.

Current flowing through micro USB terminal from the external power source may vary depending on the ratings of power adapter used. The EasyEDA software has a tool called Solid Region that can be used to draw ambiguous shapes. This tool can be taken as an advantage to overcome damaging excessive heat on the trace. Last but not least, all ground terminal connections are made into a single continuous block of copper called as the ground plane which applies to both layers of the PCB. A full PCB layout design is included in Appendix B.2 of this thesis.

3.7 Mechanical Design

The prototype needs to be in a containment or case to protect the hardware components. To maximize the effectiveness of the prototype, the prototype assembly is done properly by placing each hardware component at a designated space inside the case. The case also features fastening for secured environment inside the containment. The wall thickness of case next to the reader MFRC522 is set to 30 mm to allow effective communication between the card and the reader.

The dimension of the containment is suitable for portable application – a compact size similar to the surface area of the TnG card. The containment has a designated area for USB
slot, LCD display, extended push button and LEDs to indicate battery health. Therefore, the dimension of all hardware components is measured to design the case by using SolidWorks.

3.8 Overall System Testing

Overall system testing is covered on the operating system development and the battery charging circuit development. The tests are conducted as a requirement of achieving the objectives of this final year project.

Firstly, the operating system of the portable TnG card reader were to be tested. Ambiguous values are to be written into several different contactless smart cards via MFRC522 write program. Then, the system should be able read back by the system and displayed on the LCD display together with the serial number of the card via MFRC522 read program.

Next, data collected from the battery charger function test will validate the reliability of the design as suggested in the datasheets of utilized ICs. Theoretically, the boost converter function should convert the battery nominal DC voltage to steady 6.6V DC hence, the overall portable TnG card reader system should function as intended.
3.9 Summary

The research methodology discussed in this chapter are based on from research of the references related to the development of portable TnG card reader. The Arduino Nano microcontroller will run the operating system of the successfully with enough voltage input delivered by Li-Po battery via voltage amplification done by the boost converter. The battery can be recharged whenever the prototype is running on a low battery health. The expectation for both operating system development and the battery charger and boost converter development could be determined by conducting tests as suggested in in this chapter. The test result shall be recorded and further discussed in Chapter 4.
CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

Observations and results from the overall system testing conducted are presented and discussed in this chapter. The results from operating system development test are focused on the MFRC programs as an indicator for the first objective of research achievement. Meanwhile, the battery charger and boost converter development test results will be made as the indicator for the second objective of research achievement.

4.2 Firmware Development Results

As discussed in Chapter 3, the MFRC522 program requires to write and read the MF1S50yyX/V1 EEPROM memory organization. There were three cards being written with different values during the write operation beforehand. As a result, the script in the serial monitor as shown in Figure 4.1 is the MFRC522 write program output where the value “1.20” was written to one of the contactless smart cards. Hence, the card stores balance of RM1.20.

![Figure 4.1: MFRC522 write program result.](image-url)
For further discussion, Figure 4.2 shows the sector 0 of MF1S50yyX/V1 memory structure which had obtained from an example Arduino code of MFRC522 program called “DumpInfo”. The value “1.20” written to the card is in ASCII character encoding standard which equals to the first four bytes of hexadecimal values stored in block 1 of sector 0 of the EEPROM as highlighted in yellow shown in Figure 4.2. The following hexadecimal value $20_{16}$ in block 1 of sector zero is equivalent to “space” symbol had filled the remaining unattended 12 bytes of storage in the block. Meanwhile, the hexadecimal values highlighted in green is converted to decimal numbers hence, four bytes serial number of the written card had obtained as $11792163217$ ($117_{10}$, $92_{10}$, $163_{10}$, and $217_{10}$).

![Figure 4.2: Sector 0 of MF1S50yyX/V1 EEPROM memory organization.](image)

During read operation, each card was scanned by MFRC522 module one after another. The information of the cards read by the program was printed to the serial monitor shown in Figure 4.3. Photographs in Figure 4.4 shows the serial number and card balance for each written card that had successfully read by the program and displayed on LCD.

![Figure 4.3: MFRC522 read program result.](image)
4.3 Battery Charger and Boost Converter Results

Results for the battery charger and boost converter are highly depended on PCB layout design and its fabrication outcome as it is difficult to test the SMD circuitry without risking the limited SMD components at hand. Hence, the SMD components were soldered cautiously onto the PCB. But before soldering take place, the PCB traces connectivity were tested first. Figure 4.5 shows photographs of both top and bottom layer of the fabricated PCB.

Figure 4.5 Top layer (left) and bottom layer (right) of the fabricated PCB.
The PCB traces were tested and there was no shortage between different individual traces found except for interconnected solder pads. The top layer traces and bottom layer traces are well connected regardless of perturbing narrow vias connecting the traces for both layers. All ground solder pads connection possessed no issue as they are secured to ground plane for both layers despite of the fact that PCB needs a large number of ground vias for keeping the ground voltage at the same level throughout the board. Figure 4.6 shows a close-up photograph of unsoldered battery charger and boost converter circuit at top layer of the PCB. After the required SMD components were soldered as shown in Figure 4.7, the circuit had been tested and there were no shortage issues found. Thus, functionality of the battery charger and boost converter circuit can be tested. Note that the DPDT switch is marked with position 0 and 1 to turn off or on the boost converter function respectively.

Figure 4.6: Unsoldered battery charger and boost converter region at top layer of the PCB.
First, the battery charger had been tested by plugged in a mini USB cable to USB port. A Li-Po battery with capacity of 1500mAh was connected to the battery terminals on the PCB. The DPDT switch lever should be at position 0, shown in Figure 4.7 to avoid activation of the boost converter function. When an external 5V power source being supplied to the circuit, red LED on the other layer lit up as shown in Figure 4.8. This indicates that the battery is being charged.

While the battery was charging, voltage across the battery terminals was measured at interval of 5 minutes. The data was tabulated in Table 4.1. Figure 4.9 shows the battery voltage against time curve represented the data collected. By referring to TP4056 datasheet, the
generated curve has few similarities to the complete charge cycle curve for 1000mAh battery. The difference between the curves are observed and can be deduced that 1500mAh battery may take longer time to achieve steady charge voltage level compared to 1000mAh battery. At around 190th minutes, the blue LED lit up and the red LED turned off indicating that the charge cycle had been terminated at 4.205V. Therefore, the battery charger test was a success.

Table 4.1: Measured battery voltage with 5 minutes interval.

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Battery Voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3.381</td>
</tr>
<tr>
<td>5</td>
<td>3.514</td>
</tr>
<tr>
<td>10</td>
<td>3.682</td>
</tr>
<tr>
<td>15</td>
<td>3.792</td>
</tr>
<tr>
<td>20</td>
<td>3.856</td>
</tr>
<tr>
<td>25</td>
<td>3.913</td>
</tr>
<tr>
<td>30</td>
<td>3.975</td>
</tr>
<tr>
<td>35</td>
<td>4.036</td>
</tr>
<tr>
<td>40</td>
<td>4.072</td>
</tr>
<tr>
<td>45</td>
<td>4.087</td>
</tr>
<tr>
<td>50</td>
<td>4.091</td>
</tr>
<tr>
<td>55</td>
<td>4.097</td>
</tr>
<tr>
<td>60</td>
<td>4.101</td>
</tr>
<tr>
<td>65</td>
<td>4.109</td>
</tr>
<tr>
<td>70</td>
<td>4.113</td>
</tr>
<tr>
<td>75</td>
<td>4.117</td>
</tr>
<tr>
<td>80</td>
<td>4.120</td>
</tr>
<tr>
<td>85</td>
<td>4.125</td>
</tr>
<tr>
<td>90</td>
<td>4.139</td>
</tr>
<tr>
<td>95</td>
<td>4.147</td>
</tr>
<tr>
<td>100</td>
<td>4.153</td>
</tr>
<tr>
<td>105</td>
<td>4.159</td>
</tr>
<tr>
<td>110</td>
<td>4.164</td>
</tr>
<tr>
<td>115</td>
<td>4.172</td>
</tr>
<tr>
<td>120</td>
<td>4.177</td>
</tr>
<tr>
<td>125</td>
<td>4.186</td>
</tr>
<tr>
<td>130</td>
<td>4.193</td>
</tr>
<tr>
<td>135</td>
<td>4.194</td>
</tr>
<tr>
<td>140</td>
<td>4.195</td>
</tr>
<tr>
<td>145</td>
<td>4.196</td>
</tr>
<tr>
<td>150</td>
<td>4.197</td>
</tr>
<tr>
<td>Time (minutes)</td>
<td>Battery Voltage (V)</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>155</td>
<td>4.198</td>
</tr>
<tr>
<td>160</td>
<td>4.199</td>
</tr>
<tr>
<td>165</td>
<td>4.200</td>
</tr>
<tr>
<td>170</td>
<td>4.201</td>
</tr>
<tr>
<td>175</td>
<td>4.202</td>
</tr>
<tr>
<td>180</td>
<td>4.203</td>
</tr>
<tr>
<td>185</td>
<td>4.204</td>
</tr>
<tr>
<td>190</td>
<td>4.205</td>
</tr>
<tr>
<td>195</td>
<td>4.205</td>
</tr>
<tr>
<td>200</td>
<td>4.205</td>
</tr>
</tbody>
</table>

Figure 4.9: Battery voltage against time curve.

Figure 4.10: Blue LED lit up indicates battery fully charged.
Next, the boost converter test was conducted. While the battery is still connected to the PCB and the DPDT switch remain at position 0, the voltage difference between OUT+ and OUT- terminal was measured as 100mV while the circuit was still being powered externally. Then the DPDT switch was toggled to position 1 however the boost converter output voltage was measured as 3.92V which is lower than the battery voltage. Next, USB cable was unplugged from the PCB and the voltage was measured as 3mV and 24mV when the boost converter was turned off and on respectively.

4.4 Overall Discussion

The portable TnG card reader was intended to able to read and display an actual TnG card. However, the TnG card are substituted with MIFARE Classic contactless smart card for prototyping purpose and there is a need for a permission from TnG authorities to read the actual TnG card legally. Since the operating system test was successful, the first objective of research is achieved.

Based on the result obtained from the battery charger test, the fabricated PCB can be used to charge a single cell Li-Po battery. The battery voltage needs to be converted into a higher voltage level with a minimum of 6V input voltage for the microcontroller to run the operating system. However, the boost converter test had returned unfavourable results hence overall energy power delivery from the battery to the microcontroller is interrupted. Nonetheless, the second objective of research is achieved since rechargeable energy storage system feature are present on the prototype.
CHAPTER 5

CONCLUSION

5.1 Introduction

The whole project achievement is concluded in this chapter. Also, future recommendations for this project to improve the portable TNG card reader are suggested in this chapter.

5.2 Project Conclusion

This project aims to resolve currently limitations of checking the TnG cards even though there are existing products being widely used today. The ability to read an actual TnG cards legally is solely on card readers approved by Touch ‘n Go Sdn Bhd. However, this final year project proves that the development of portable TnG card reader had enabled user to read a mock-up TnG card which is the MIFARE Classic 1k contactless smart card embedded with MF1S50yyX/V1 microchip. The Li-Po battery powered portable TnG card reader prototype had successfully displayed serial number of the card and pre-programmed values in Ringgit Malaysia currency on a 16x2 LCD display.

By integrating TP4056 lithium-ion battery charger IC and accurately configured MT3608 DC-DC boost converter in a single PCB, a new feature had successfully introduced to existing TnG card reader. Therefore, the portable device can be charged using micro USB for user convenience.
In a nutshell, the objectives of this final year project are achieved and the portable TnG card reader had been successfully developed. Lessons and experience gained throughout this project shall be guidance for numerous future projects especially further development of portable devices concerning TnG card balance checking.

5.3 Further Recommendation

Many different adaptations, tests, and experiments have been forsaken in order to successfully completes this final year project within the timeframe given. Future works and further recommendations concern deeper analysis of design, microcontroller stability, better component selections, and the application of IoT. Perhaps, there are no limitation to improvements and further developments could be made to the existing prototype.

There are many ways that the developed portable TnG card reader can be further improved. One of the ways is that to consider the utilization of ATmega328 microchip which is certainly allows the portable device to have much design.

Despite of using USB cable, the portable TnG card reader could be a potential platform for application of solar charger technology. With contemporary knowledge and numerous previous works on the technology, a simple device like the portable TnG card reader can embrace wireless charging by harvesting energy from the ultimate source of energy.

It would also be interesting to consider IoT implementation for a better battery management system. IoT could provide real-time battery level monitoring. Users can be alerted if their portable TnG card reader is running on low battery on their smartphones. This feature is believed to improve user assistance experience.
REFERENCES


22. Nanjing Top Power ASIC Corp., *1A Standalone Linear Li-Ion Battery Charger with Thermal Regulation in SOP-8*. Addicore.


APPENDICES

Appendix A

A.1 MFRC Write Program Source Code

```c
#include <SPI.h>
#include <MFRC522.h>

#define RST_PIN 9
#define SS_PIN 10

MFRC522 mfrc522(SS_PIN, RST_PIN); // Create MFRC522 instance

void setup() {
  Serial.begin(9600); // Initialize serial communications with the PC
  SPI.begin(); // Init SPI bus
  mfrc522.PCD_Init(); // Init MFRC522 card
  Serial.println("Place a tag on the scanner.");
}

void loop() {
  // Prepare key - all keys are set to 1FFFFFFFFF at chip delivery from the factory.
  MFRC522::MIFARE_Key key;
  for (byte i = 0; i < 6; i++) key.keyByte[i] = 0xff;

  // Look for new cards
  if (! mfrc522.PICC_IsNewCardPresent()) {
    return;
  }

  // Select one of the cards
  if (! mfrc522.PICC_ReadCardSerial()) {
    return;
  }

  Serial.println("Card detected!");
  Serial.println({"Card S/N:"); // Dump UID
  for (byte i = 0; i < mfrc522.uid.size; i++) {
    //Serial.println(mfrc522.uid.uidByte[i] < 0x10 ? " 0" : " ");
    Serial.println(mfrc522.uid.uidByte[i], DEC);
  }

  byte buffer[16];
  byte Block;
  MFRC522::StatusCode status;
  byte len;

  Serial.setTimeout(2000000); // wait until 20 seconds for input from serial
  // Input balance
  Serial.println(" ");
  Serial.println("Input balance, ending with ")
  len = Serial.readBytesUntilGGG, (char *) buffer, 30); // read balance from serial
  for (byte i = len; i < 30; i++) buffer[i] = ' '; // pad with spaces
```
block - 1;
//Serial.println(F("Authenticating using key A..."));
status = mfrc522.PCD_Authenticate(MFRC522::PICO_CMD_MF_AUTH_B, block, 0x01, &mfrc522.uid);
if (status != MFRC522::STATUS_OK) {
    Serial.print(F("PCD_Authenticate() failed. "));
    Serial.println(mfrc522.GetStatusCodeName(status));
    Serial.println(" ");
    Serial.println("-----------------------------");
    return;
} //else Serial.println(F("PCD_Authenticate() success! "));
else Serial.println(F("..."));

// Write block
status = mfrc522.MIFARE_Write(block, buffer, 16);
if (status != MFRC522::STATUS_OK) {
    Serial.print(F("MIFARE_Write() failed. "));
    Serial.println(mfrc522.GetStatusCodeName(status));
    Serial.println(" ");
    Serial.println("-----------------------------");
    return;
} //else Serial.println(F("MIFARE_Write() success! "));
else Serial.println(F("Card successfully written."));

Serial.print("Balance: ");
//PRINT CARD BALANCE

for (byte i = 0; i < 16; i++) {

    Serial.write(buffer[i]);
}
Serial.println(" ");
Serial.println("-----------------------------");

Serial.println(" ");
mfrc522.PCD_StopCrypto1(); // Stop PCD
A.2 MFRC Read Program Source Code

```c
#include <SPI.h>
#include <MFRC522.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

#define SS_PIN 10
#define RST_PIN 9

MFRC522 mfrc522(SS_PIN, RST_PIN); // Create MFRC522 instance.
LiquidCrystal_I2C lcd(0x027, 2, 1, 0, 4, 5, 6, 7, 3, POSITIVE);

void setup() {
  Serial.begin(9600); // Initiate a serial communication
  SPI.begin(); // Initiate SPI bus
  mfrc522.PCD_Init(); // Initiate MFRC522
  lcd.begin(16, 2);
  lcd.clear();
  Serial.println("Display card balance.");
}

void loop() {
  lcd.home();
  lcd.print("S/N: ");
  lcd.setCursor(0, 1);
  lcd.print("Bus1:RM");

  // Prepare key - all keys are set to FFFFFFFFFFFfh at chip delivery from the factory.
  MFRC522::MIFARE_Key key;
  for (byte i = 0; i < 6; i++) key.keyByte[i] = 0xFF;

  // Some variables we need
  byte block;
  byte len;
  MFRC522::StatusCodes status;

  // Look for new cards
  if ( ! mfrc522.PICC_IsNewCardPresent() )
    return;

  // Select one of the cards
  if ( ! mfrc522.PICC_ReadCardSerial() )
    return;

  Serial.print("Serial number: ");
  // Show UID on serial monitor
  for (byte i = 0; i < mfrc522.uid.size; i++)
    Serial.print(mfrc522.uid.uidByte[i], DEC);
  Serial.println();
```

44
Serial.print("UID: ");
//Show UID on serial monitor
for (byte i = 0; i < mfrc522.uid.size; i++)
{
    Serial.print(mfrc522.uid.uidByte[i], HEX);
}
Serial.println();

byte buffer[16];
block = 1;
status = mfrc522.PCD_Authenticate(MFRC522::PIOC_CMD_READKEY_B, 1, skey, i(mfrc522.uid)); //line 834
if (status != MFRC522::STATUS_OK) {
    Serial.print(F("Authentication failed: "));
    Serial.println(mfrc522.GetStatusCodeName(status));
    return;
}
status = mfrc522.MIFARE_Read(block, buffer, clen);
if (status != MFRC522::STATUS_OK) {
    Serial.print(F("Reading failed: "));
    Serial.println(mfrc522.GetStatusCodeName(status));
    return;
}
Serial.print("Card Balance: ");
//PRINT CARD BALANCE
for (byte i = 0; i < 16; i++) {
    Serial.write(buffer[i]); //Print on serial monitor in ASCII characters.
}
Serial.println(F(""n"End Reading""n"));
delay(10);  //change value if you want to read cards faster

lcd.clear();
lcd.setCursor(4, 0);
for (byte i = 0; i < 4; i++)
{
    lcd.print(mfrc522.uid.uidByte[i], DEC);
}
lcd.setCursor(6, 1);
for (byte i = 0; i < 10; i++)
{
    lcd.write(buffer[i]);
}
mfrc522.PICC_HaltA();
mfrc522.PCD_StopCrypto1();
}
Appendix B

B.1 Portable TnG Card Reader Schematic
B.2  Portable TnG Card Reader PCB Layout
Appendix C

C.1 MF1S50yyX/V1 Datasheet

8.4 Three pass authentication sequence

1. The reader specifies the sector to be accessed and chooses key A or B.
2. The card reads the secret key and the access conditions from the sector trailer. Then the card sends a number as the challenge to the reader (pass one).
3. The reader calculates the response using the secret key and additional input. The response, together with the random challenge from the reader, is then transmitted to the card (pass two).
4. The card verifies the response of the reader by comparing it with its own challenge and then it calculates the response to the challenge and transmits it (pass three).
5. The reader verifies the response of the card by comparing it to its own challenge. After transmission of the first random challenge the communication between card and reader is encrypted.

8.5 RF interface

The RF-interface is according to the standard for contactless smart cards ISO/IEC 14443A.

For operation, the carrier field from the reader always needs to be present (with short pauses when transmitting), as it is used for the power supply of the card.

For both directions of data communication there is only one start bit at the beginning of each frame. Each byte is transmitted with a parity bit (odd parity) at the end. The LSB of the byte with the lowest address of the selected block is transmitted first. The maximum frame length is 153 bits (15 data bytes + 2 CRC bytes + 10 x 3 = 2 x 5 + 1 start bit).

8.6 Memory organization

The 1024 x 8 bit EEPROM memory is organized in 16 sectors of 4 blocks. One block contains 16 bytes.
C.2 TP4056 Datasheet

<table>
<thead>
<tr>
<th>Indicator light state</th>
<th>Charge state</th>
<th>Red LED</th>
<th>Greed LED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>charging</td>
<td>bright</td>
<td>extinguish</td>
</tr>
<tr>
<td>Charge Termination</td>
<td>extinguish</td>
<td></td>
<td>bright</td>
</tr>
<tr>
<td>Vin too low; Temperature of battery too low or too high; no battery</td>
<td>extinguish</td>
<td>extinguish</td>
<td></td>
</tr>
</tbody>
</table>

| BAT PIN Connect 10u Capacitance; No battery | Red LED bright, Red LED Coruscate T=1-4 S |

<table>
<thead>
<tr>
<th>Rprog Current Setting</th>
<th>Iprog (k)</th>
<th>Ibat (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>580</td>
<td></td>
</tr>
<tr>
<td>1.66</td>
<td>690</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>780</td>
<td></td>
</tr>
<tr>
<td>1.33</td>
<td>900</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>

TYPICAL APPLICATIONS

[Diagram of TP4056 application circuit]
C.3 FS312F-G Datasheet

7. Functional Block Diagram

8. Typical Application Circuit
1. Features
1.1 Low on-resistance
1.1.1 \( R_{\text{on(I)}} = 28 \, \text{m}\Omega \) MAX. \( V_{\text{DD}} = 4.5\, \text{V}, I_{\text{D}} = 4\, \text{A} \)
1.1.2 \( R_{\text{on(I)}} = 37 \, \text{m}\Omega \) MAX. \( V_{\text{DD}} = 2.5\, \text{V}, I_{\text{D}} = 3\, \text{A} \)

2. Applications
- Li-ion battery management applications

3. Ordering Information

<table>
<thead>
<tr>
<th>Product Number</th>
<th>Description</th>
<th>Package Type</th>
<th>Quantity/Reel</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS8205</td>
<td>SOT23-6 package version</td>
<td>SOT23-6</td>
<td>6,000</td>
</tr>
</tbody>
</table>

4. Pin Assignment

SOT23-6
Top View

```
S1  1  6  G1
D12 2  5  D12
S2  3  4  G2
```

5. Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Rating</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDS</td>
<td>Drain-Source Voltage</td>
<td>20</td>
<td>V</td>
</tr>
<tr>
<td>VGS</td>
<td>Gate-Source Voltage</td>
<td>±12</td>
<td>V</td>
</tr>
<tr>
<td>ID @ TA = 25°C</td>
<td>Continuous Drain Current</td>
<td>6</td>
<td>A</td>
</tr>
<tr>
<td>ID @ TA = 70°C</td>
<td>Continuous Drain Current</td>
<td>5</td>
<td>A</td>
</tr>
<tr>
<td>IDM</td>
<td>Pulsed Drain Current</td>
<td>25</td>
<td>A</td>
</tr>
<tr>
<td>PD @ 25°C</td>
<td>Total Power Dissipation</td>
<td>1</td>
<td>W</td>
</tr>
<tr>
<td>Rthermal</td>
<td>Linear Derating Factor</td>
<td>0.008</td>
<td>W/°C</td>
</tr>
<tr>
<td>TSTG</td>
<td>Storage Temperature Range</td>
<td>-55 to 150</td>
<td>°C</td>
</tr>
<tr>
<td>TJ</td>
<td>Operating Junction Temperature Range</td>
<td>-55 to 150</td>
<td>°C</td>
</tr>
</tbody>
</table>

6. Thermal Data

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>RthJA</td>
<td>Thermal Resistance Junction-ambient</td>
<td>Max. 125</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

7. Electrical Characteristics

Electrical Characteristics \( T_J = 25°C \) (unless otherwise specified)
C.5  MT3608 Datasheet

**FEATURES**
- Integrated 80mΩ Power MOSFET
- 2V to 24V Input Voltage
- 1.2MHz Fixed Switching Frequency
- Internal 4A Switch Current Limit
- Adjustable Output Voltage
- Internal Compensation
- Up to 28V Output Voltage
- Automatic Pulse Frequency Modulation Mode at Light Loads
- up to 97% Efficiency
- Available in a 6-Pin SOT23-6 Package

**GENERAL DESCRIPTION**
The MT3608 is a constant frequency, 6-pin SOT23 current mode step-up converter intended for small, low power applications. The MT3608 switches at 1.2MHz and allows the use of tiny, low cost capacitors and inductors 2mm or less in height. Internal soft-start results in small inrush current and extends battery life.
The MT3608 features automatic shifting to pulse frequency modulation mode at light loads. The MT3608 includes undervoltage lockout, current limiting, and thermal overload protection to prevent damage in the event of an output overload. The MT3608 is available in a small 6-pin SOT-23 package.

**APPLICATIONS**
- Battery-Powered Equipment
- Set-Top Boxed
- LCD Bias Supply
- DSL and Cable Modems and Routers
- Networking cards powered from PCI or PCI express slots

**TYPICAL APPLICATION**

![Image of Basic Application Circuit]

**Figure 1. Basic Application Circuit**

![Image of Efficiency Curve]

**Figure 2. Efficiency Curve**

Aerosemi Technology Co., Ltd