DESIGN AND IMPLEMENTATION OF EXTERNAL POWERING SOURCE FOR AN ACTIVE RFID TAG

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Dr. Mohd Yunus Bin Nayan
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Muhammad Zulfadhli Bin Abdul Rahman

ABSTRACT

The work is about developing an external powering source of an active RFID tag. The objective of the project is to design and implement the external power source to the active RFID tag that will be embedded with heartbeat, temperature and blood pressure sensors individually. This tag will be attached to the patient so that it can send the information of each sensor to the reader that is connected to the computer. In order to extend the lifetime of the tag, author decided to use a rechargeable Lithium battery to replace the conventional method which was using a normal battery that can only stand for a few hours. This method was done by designing a prototype that consists of a circuit using voltage comparator and voltage regulator. A few types of batteries were selected and their performance was observed. The observation is based on the application, cost and flexibility. The developed prototype was tested and verified to ensure its smoothness operation and compatible with its application. Lastly, the result of the project will be analysed based on the efficiency and lifetime of the tag and to be compared with the present technology used on RFID tag.

ACKNOWLEDGEMENTS

Alhamdulillah and praised to God to give me a chance to finish my final dissertation in conjunction to complete my final year project in Universiti Teknologi PETRONAS. Without His bless this project will not be success.

First and foremost, I would like to express my greatest appreciation to my supervisor, Dr. Mohd Yunus Bin Nayan for his time and warm advices during the completion of this project. I also want to thanks my co-supervisors, Dr. Hanita Binti Daud and Ir. Dr. Nursyarizal Bin Mohd Nor. Without their guidance and ideas, this project will be completely hard for me. Next, I would like express my gratitude to Nurul Fauzana Binti Imran Gulcharan, one of the postgraduate students who help me in most of the testing process. I believed the ideas and knowledge from these people contributed to vital success of this project. I am very lucky to have people around me to give me constant support until the end of this project. Their contribution is highly appreciated.

Lastly, I would like to thanks my beloved family and friends who always being supportive and encourage me during my hard days. The whole process of finishing this project really teaches me the value of love, friendship and respect to each other.

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CHAPTER 1
INTRODUCTION

In this chapter, RFID technology and its main concern and problems are discussed. This continues with the explanations on the problem statement, objective, and scope of study of this project.

1.1 Background of study

One of the wireless data transmissions is called Radio Frequency Identification (RFID). It transmits data from a tag to the reader through radio frequency electromagnetic field [1]. RFID tags can be divided into three groups which are passive (battery-less), semi active, and active (battery powered). Normally, passive RFID tags are the main choice for tagging of items due to the tag cost. However, in different situation where the need of the RFID performance is to read long range information, the battery powered RFID tag is preferred [2]. Examples include tagging shipping containers, freight packages, valuable assets, or applications requiring sensors, such as cold-chain shipping, and asset tracking [3]. The increasing usage of active RFID tags nowadays is due to the expanding of inexpensive CMOS radio frequency integrated circuit (RFIC) and microcontrollers that can produce low cost tags. Moreover, the cost of the battery also one of the reason active RFID tags becomes so much popular nowadays. The cost is dropping and a new type of thin-film battery also can be available at low cost. So the battery power tags can be manufactured in a form of thin card or can be called Smart Active Label [4].

The active RFID tag that was invented actually will be worn by the patient in the hospital. This tag will be equipped with sensors such as heart beat, blood pressure and heat sensors. In order to make sure the tag working efficiently, the battery inside the tag must continuously power up the tag to avoid data interruption. Typically, a new 3 volts coin battery only can stand up to 4 hours after connected to an RFID tag. In this project, the normal RFID tag's lifetime is to be improved by introducing a new power management for the RFID tag. The idea is to place a Lithium rechargeable battery inside the tag together with the charging circuit. The usage of lithium battery is due to its advantages overtakes the normal alkaline battery. A charging circuit will be built inside the tag so that it can easily charge the battery using any external sources such as AC power supply, power bank, or from any USB output.

Figure 1: Active RFID Tag

1.2 Problem Statements

The main part inside the active RFID tag is the battery itself. In order to maintain the data transmission and storage, there are some aspects need to be take care of:

- The power consumption of the circuit inside the tag is inefficient for the battery to last long – internal circuit consume too much power.
- The decreasing range of the data transmission due to low battery power.
- High cost in order to change the battery frequently.

1.3 Objectives and Scope of Study

1.3.1 Objective

- To design and analyse the condition of proposed designated circuit of a battery charger
- To integrate the developed battery charger to active RFID tag.

1.3.2 Scope of study

This project is focusing on the production of the prototype. The working rechargeable battery charger is to proof that the battery will regain its power when the charger is connected to the tag. The circuit will be analysed to improve the efficiency of the charger. Lastly, the prototype produced will generate a compatible power output to the tag in order to maximize its efficiency and working life span

1.4 Project Feasibility

This project is considered feasible to the author since University Teknologi PETRONAS have a high grade facilities for students to do the research and experiments. Especially in electrical and electronics department, students are given the permission to use the laboratory to do their research. Electrical component store also give the service for the student to seek and borrow the electrical components. The project is believed to be completed within the timeframe due to the planned Gantt Chart and methodology.

CHAPTER 2
LITERATURE REVIEW

In this chapter, the previous projects and research papers that have been invented by other people that are related to the objectives of this research are to be discussed. The selection of the references is based on the active RFID tag projects and the projects related to lithium ion battery. This chapter also describes the different types of battery that will be used in this project.

2.1 Lithium Ion Battery

Lithium ion battery has been widely used in practical devices such as cell phones, cameras, and laptop computers. In this project, lithium ion rechargeable battery is selected to be used as the internal battery for the active RFID tag due to common used in consumer electronics. Some aspects need to take into consideration about this type of battery to retain its safety, battery life and durability.

From [5], in his research paper "Li-ion battery Aging, Degradation and Failure" discussed the properties of lithium battery is dependable on the chemical nature of the electrode material. During charging and discharging the battery, the lithium which is originally present in the electrolyte and at the positive electrode, they chemically react to one or other electrode, inserting and intercalating into the bulk material. When the process occurs, it actually changes the chemical identity of the electrode.

The lithium is more stable at the positive electrode. So, power supply need to detach the lithium from the positive electrode to form the Li+ ion and push them to the negative electrode for charging. The only process that must occur at the mesoscale (smaller than an electrode, larger than a molecule) is transport of lithium ions through the electrolyte and in the active particles, with the reversible reaction of the lithium at appropriate location within the electrode. So any unwanted mechanism occurs there will results in battery inefficiency and failure.

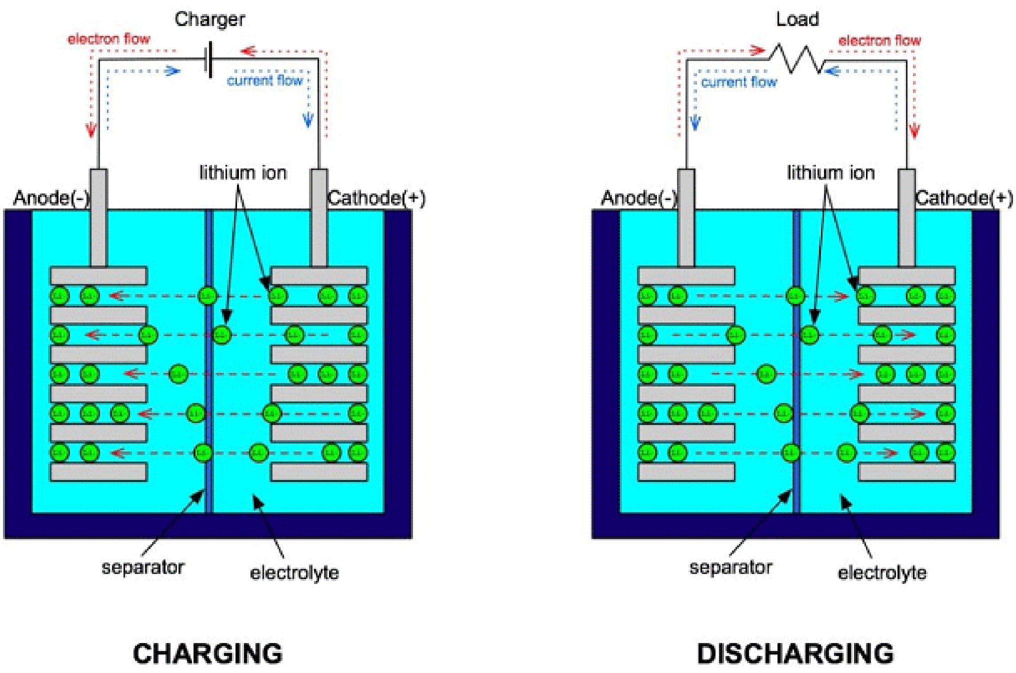

Figure 2: Lithium Battery Charging and Discharging [5]

2.2 Lithium Ion Battery Charger

As this project is using Li-ion rechargeable battery, charging circuit for lithium battery is important to maintain the voltage of the internal battery in the active RFID tag. The design of the charging circuit will determine the battery life time because lithium ion battery is sensitive and need a proper charger that can control the current flows when the battery is fully charged [6].

From [7], in his paper "Designing Low-Cost Single/Multi-Cell Li-ION Battery Chargers" said that in designing of a battery charger, safety is the main focus.

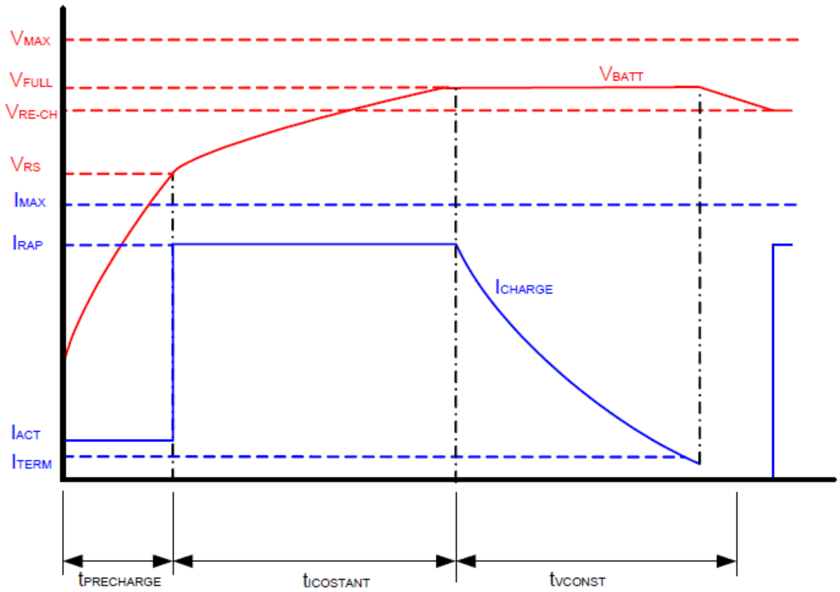

Figure 3: Charging Phase. Precharge, Fast-charge/Constant Current and Constant Voltage

For the purpose of getting the constant current and voltage charging stage must be protected by the time out, which is usually implemented by a timer charging IC. He suggested that to simplify charger design is to use a single cell charger that can easily adapt to multi-cell.

From [8], entitled "Power Management - Low-Cost, Two-Cell Li-Ion/Li-Pol Battery Charger with Cell-Balancing Support", a charger was created that can be used either as a standalone application to charge a battery pack with two serial connected li-ion batteries embedded with residential, office and industrial application. The cell must be at the same level of voltage during charging and discharging. If not, they are considered as not balanced and in effect can reduce their cell life.

2.3 VL-3032 Rechargeable Coin Battery

The first battery that is chosen was Panasonic VL-3032 rechargeable coin battery. Based on the datasheet, the battery has nominal voltage of 3V and capacity of 100mAh. For 3V coin battery, this type of battery has the highest energy density compared to other type of batteries such as NiCd and NiMh. So the lifetime of the battery is longer. The battery using technology of Lithium Vanadium Pent-oxide and weight about 6.2g [9]. In details, the positive electrode of the battery contain 5~21wt% of Vanadium pent-oxide and the negative electrode contain 0.2~2wt% of Lithium alloy [10]. The dimension of the battery is same as shown in figure 4 below.

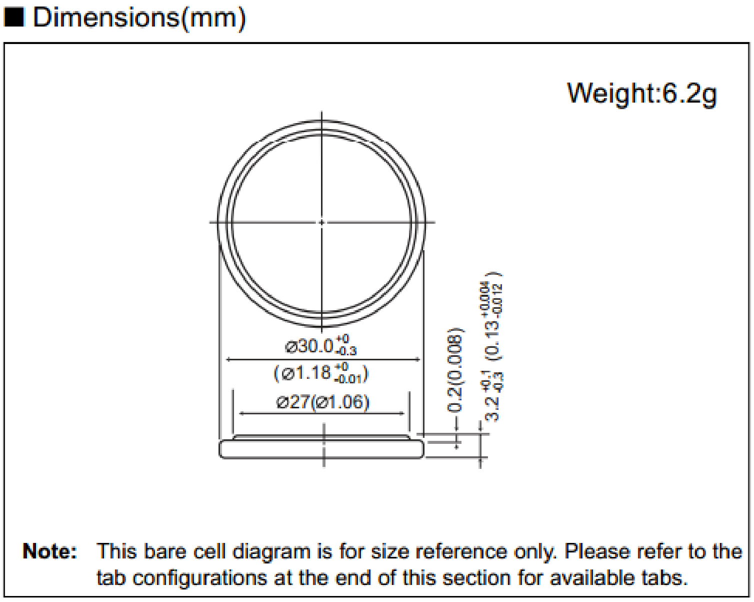

Figure 4: Dimension of Panasonic VL-3032 Rechargeable Coin Battery [9]

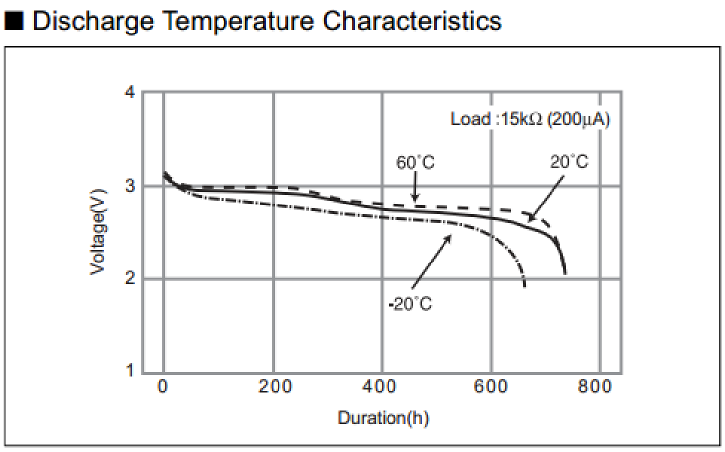

Figure 5: Discharge Temperature Characteristic [9]

2.4 Nokia BL – 5B/5C

Another type of battery that was chosen was Nokia BL-5B. This type of battery is used normally for Nokia brand cellphones. Based on its datasheet, this type of battery has nominal voltage of 3.7V and capacity of 890mAh. It has maximum charged voltage of 4.2V and weight only 20g. The dimension of the battery is same as shown in figure below.

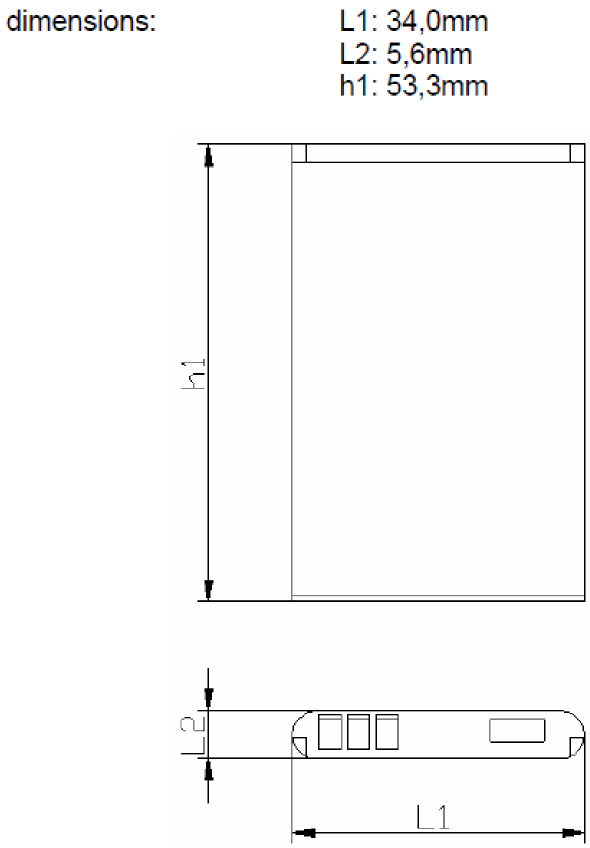

Figure 6: Dimension of BL-5C/5B [Refer to Appendix B]

2.5 Lithium Polymer Battery

The final choice is Lithium-polymer (LiPo) battery. Lithium-polymer battery is an advanced version of Lithium-ion battery. It is differs from the other type of battery due to the type electrolyte used. The electrolyte is bonded to a solid thin layer of polymer, which is placed between positive and negative electrode materials and high conducting current collector as shown in figure below [11].

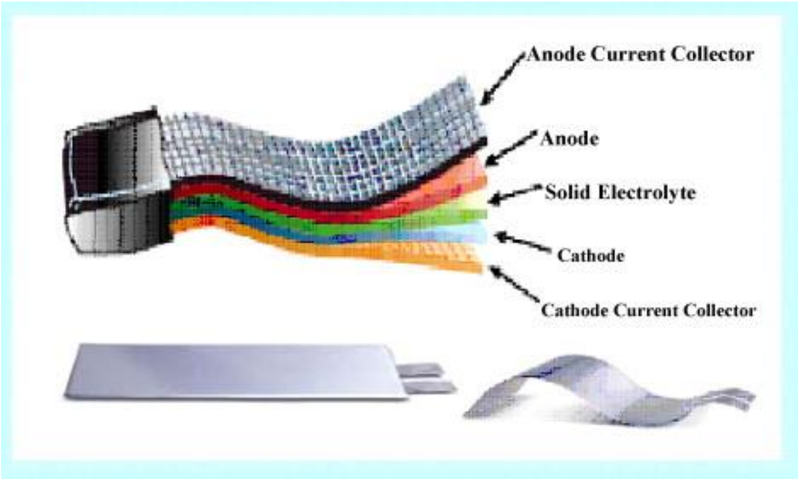

Figure 7: Lithium-Polymer Cell [11]

Due to its internal design, this type is can be designed in any shape without casing. Usually the size of a Lithium-polymer battery is smaller than Lithium-ion battery which has the same capacity. The battery that is used for this work has nominal voltage of 3.7V and capacity of 180mAh. The dimension of the battery is 2.5cm X 2cm X 0.5cm and the picture of the battery is shown below.

Figure 8: Picture of LiPo Battery

CHAPTER 3
METHODOLOGY

In this chapter, the procedures to conduct this research work are to be discussed. The steps of each procedure are then elaborated and the Gant Chart was created to make sure the project run in the right track.

3.1 Procedure Identification

The methodology of conducting this project is the waterfall/hierarchy method. This method is step by step approach to the project management. By using this method, the project is well planned from one phase to another phase with distinct goal. The picture illustrate below is the model of each phase defined from starting until the end point of the project.

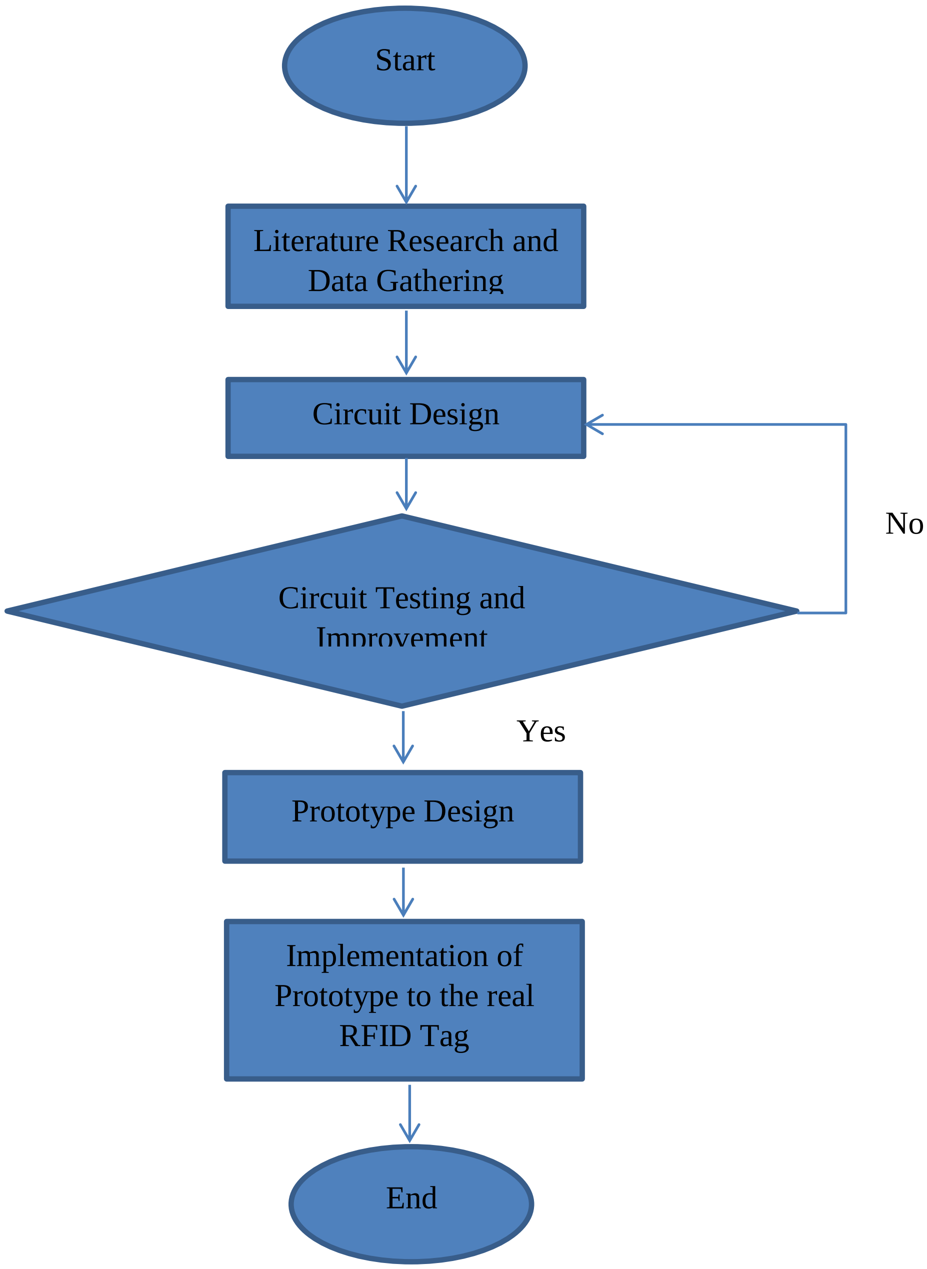

Figure 9: Research Methodology

3.2 Descriptions of the Methodology

3.2.1 Literature Research and Data Gathering

All other projects and research papers that are related to the author's project from books, websites and lecturers are gathered to benchmark and guide this research work. This will improve the author understanding of the project and to ensure no duplication of work.

3.2.2 Circuit Design

After the data are collected, the designation of the circuits was conducted. The designated circuit will consist of voltage comparators and voltage regulator.

3.2.3 Circuit Testing and Improvement

For initial testing, the circuit was simulated using Multisim 11 software. After the circuit is believed to work, the design is then transferred onto a breadboard. If the simulated circuit is not working, the process of the circuit design is to be repeated.

3.2.4 Prototype Design

When all the designated circuit was completed and finalized, the process of designing the prototype is to be conducted. The circuits will be mounted to the PCB board and the casing for the circuit will be made. At this stage, the Eagle Cad software was used to design the PCB layout.

3.2.5 Implementation of Prototype to the real RFID Tag

After all the process is done, the prototype is then can be implement to the real active RFID tag. During this phase, the prototype that will be integrated with RFID tag will undergo several tests to make sure the prototype can actually power up the RFID tag and can increase the lifetime of the tag or not.

3.3 Tools

In this project, tools that will be used can be divided into two groups; hardware and software.

Table 1: Tools

Hardware	Software
Soldering kit	**Multisim 11**
Digital Multimeter	**Eagle Cad 5.7.0**
Breadboard	
Electronics Component	

3.4 Gant Chart

Table 2 : Gant Chart FYP 1

Activities	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
Project title selection and briefing with supervisor	■	■												
Research on literature review		■	■	■	■									
Extended proposal submission						■								
Proposal defend viva									■					
Testing and development of prototype							■	■	■	■	■	■	■	■
Progress Report Writing											■	■	■	
Interim draft report submission													■	
Interim final report submission														■

Table 3: Gant Chart FYP 2

Activities	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
Methodology Re-evaluation	■	■												
Methodology Optimization		■	■	■										
Material Purchase	■	■	■	■	■	■								
Model Development	■	■	■	■	■	■	■							
Model Testing and Improvement						■	■	■	■	■	■			
Progress Report Writing						■	■	■						
Final Report and Technical Paper Writing								■	■	■	■	■	■	■

CHAPTER 4
DESIGN AND RESULT

In this chapter, the result and discussion of this project is to be discussed. For the early stage, the experimentation on the charging circuit was done to prove the concept of battery charging. After come out with the initial results, the design was finalized and the PCB circuit of the charger was created and tested. The battery that will be used was also selected. The chosen prototype is then implemented to the real tag.

4.1 Proposed Charging Circuit Design

As stated earlier in previous chapter, a charging circuit for the lithium battery inside the tag is to be implemented. A USB hub will be mounted as the input of the circuit. So, it easier for user to connect any source of supply such as from AC power supplies using DC adaptor or any USB supply. The designated charging circuit for lithium battery is shown in figure 10.

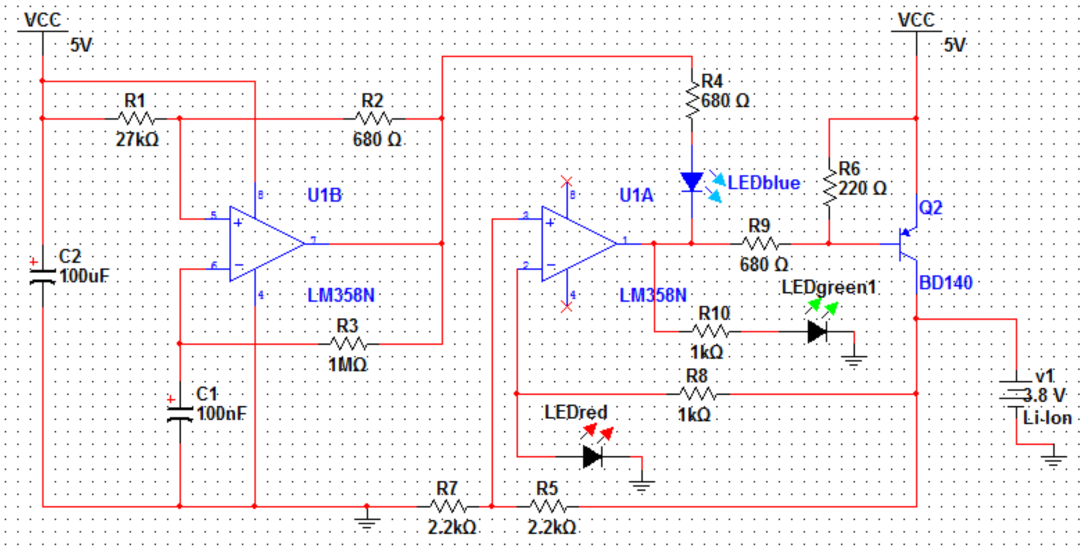

Figure 10: Charging Circuit Design

For proposed design of the charging circuit, the operational amplifiers are used as voltage comparator. As we all know, an operational amplifier have two incoming input which is v+ and v- where v+ is the input of non-inverting input and v- is the inverting input. An ideal op-amp amplifies the input voltage by the equation below.

$$V_{\text{out}} = A_{OL}\,(V_+ - V_-)$$

The voltage of the connected battery will be reduced before entering the op-amp by the voltage divider set by the resistors. When the input voltage is low, the output voltage of the op-amp will be low causing the forward bias of blue led is positive value hence current will flow through it.

The transistor BD140 is used as a switch to limit the current and voltage fed into the battery. When the base voltage less than 1V, the transistor will turn off. The base voltage of the transistor is depending on the voltage output of the op-amp and voltage from the Vcc. When the battery voltage is at 3.8V (full charged), the transistor will turn off and the circuit will stop feeding the current and voltage into the battery.

4.2 Block Diagram

To understand more on the designated charging circuit, the working principle of the circuit can be explained by creating a block diagram. The block diagram for working principle of the charging circuit is shown in figure 11.

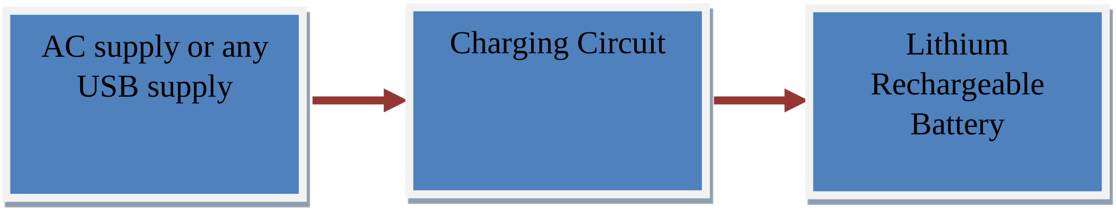

Figure 11: Charging Circuit Working Principle Diagram

Input of 5 Volts DC voltage is injected into the charging circuit. If the voltage of connected rechargeable lithium battery is lower than 3.8 Volts, the charging circuit will feed the voltage and current into the battery. But if the charging circuit detect that the voltage of the battery is at 3.8 Volts or higher, no voltage and current will be supply to the battery.

4.3 PCB Layout Design

After the finalized circuit was tested on the breadboard, all the electronic components will be mounted on the printed circuit board (PCB). The advantages of using PCB board are the layout is fixed and the design can be printed in mass amount. Compared by using veroboard, the layout of the circuit is not fixed and designer need to re-design the layout each time during the manufacturing of the charging circuit. For the PCB layout design, author used Eagle Cad 5.7.0 software. Initially, author created a two sided board as shown in figure 12. Then, after consulting with the lab technicians, the design was suggested to be improved by creating a single sided board compared to initial design. Single sided board is more efficient to use in this project because the circuit design is not too complex and the board is cheaper than double sided design. The actual board must be small so that we can minimize the size of the RFID tag. After the fabrication, the actual size of the board is 6.5x5cm. The final design of PCB layout and board was shown in figure 13 and figure 14.

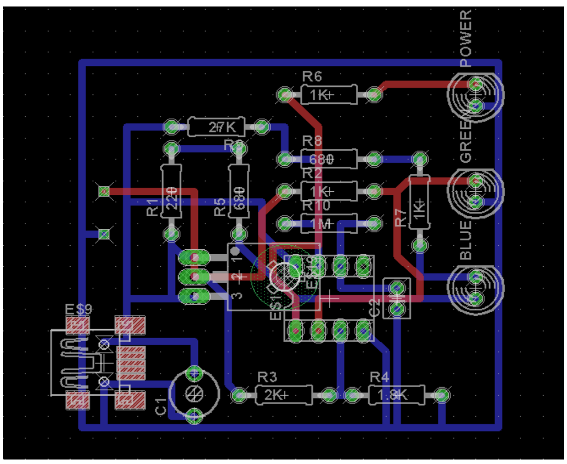

Figure 12: Preliminary Design of PCB Layout

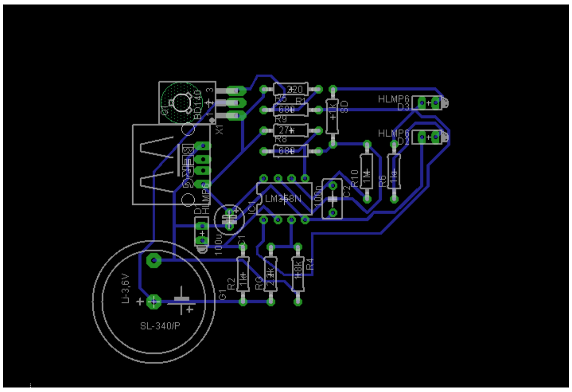

Figure 13: Final Design of PCB Layout

Figure 14: Manufactured PCB Board

4.4 Results & Discussion

Initially, test have been done for the three types of batteries which were VL 3032 rechargeable coin battery, Li-ion Nokia BL-5B and 3.7V Lithium-polymer battery. The test that has been made includes the integration of the battery with the RFID tag to observe the discharging time of the battery. Next is to connect the discharged battery to the charging circuit to observe their charging time. All the result will be discussed later. For the circuit testing, some modification from the designated charging circuit has been made especially for the color of the led. The orange led is to be replaced with the green led to indicate the charging status and yellow led is to be replaced with the blue led to indicate the full charge status.

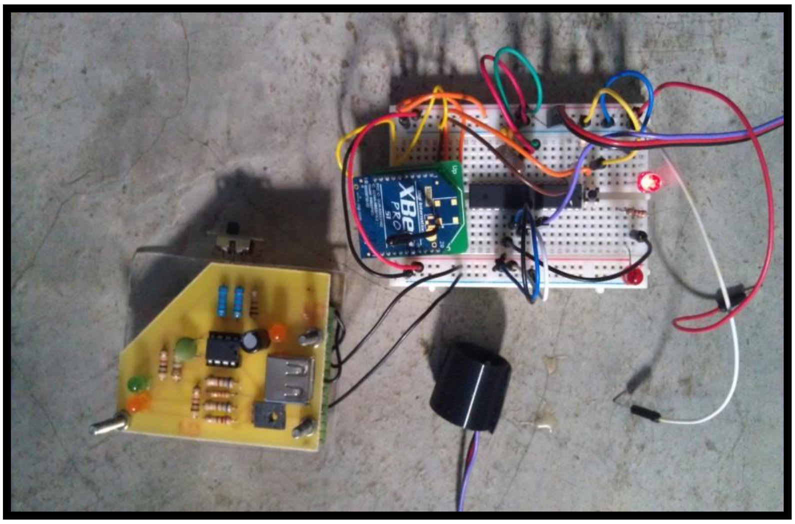

Figure 15: Battery Testing During Integration with Tag

When the circuit connected to power source, the red led will always light up indicating the circuit is connected to power supply. When the circuit is charging the battery, the orange and red led will flash as in Figure 16. Meanwhile, when the battery is fully charged, the orange led will turn off and the yellow led will flash as in Figure 17.

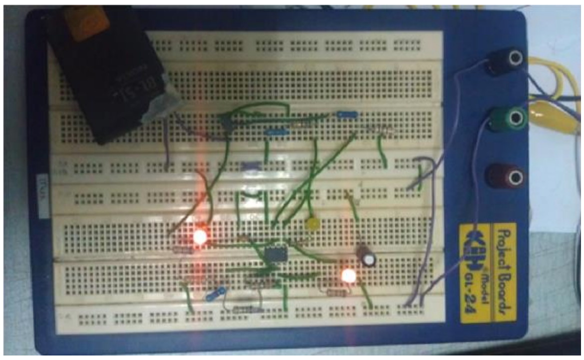

Figure 16: Indication of LED during Charging

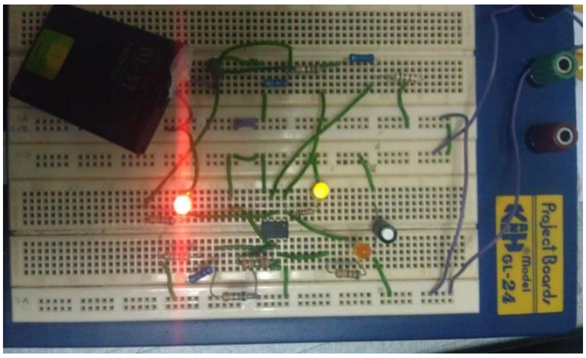

Figure 17: Indication of LED during Full Charged

4.4.1 Test for VL 3032 Rechargeable Coin Battery

Initially, a charging circuit consists of voltage comparator for lithium battery for 3.7V battery was created. Since VL3032 coin battery has nominal voltage of 3V, the circuit need to be modified by varying the resistors so that the fully charge voltage of the circuit was set to 3.2V. Eventually, when the battery was integrated with the real tag, it fails to work. It seems like the current draw for the battery is too low. Minimum current consumption of the tag is 70mA but the battery was failed to power up the tag.

4.4.2 Test for Nokia BL-5B Battery

Since the nominal voltage is 3.7V, it will work perfectly with the original circuit design. Even though the maximum charging voltage of the battery is 4.2V, author already set the maximum voltage of the charging circuit to 3.9V to suit with the tag maximum voltage. The maximum voltage of the tag is +-3.3V. From the output of the battery, the voltage of the battery was regulated to 3.3V so that the battery is applicable to the tag. A few tests have been done using this battery and implemented to the tag. The result was tabulated in the graph below.

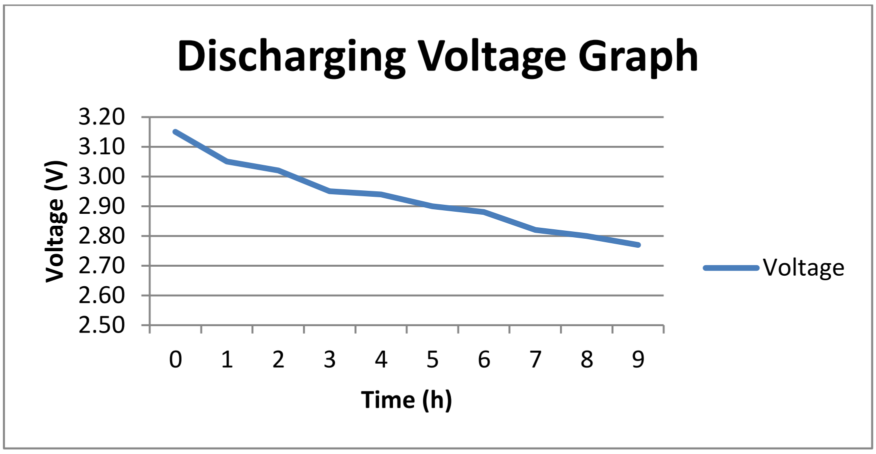

Figure 18: Battery Discharging Time

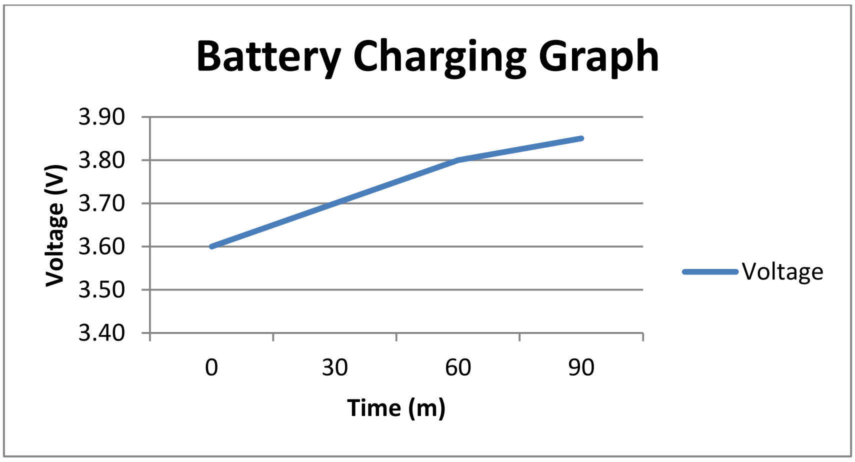

Figure 19: Battery Charging Time

During the implementation of the battery to the tag, the voltage was at 3.15V and the voltage of the battery was taken for each hours. After 8 hours of continuous transmission of data, the voltage of the battery was at 2.8V which was at the tag's minimum voltage. It can be observed that the tag still continuously transmitting the data without any problem. So as the result, the battery was recommended to use up 8 hours for continuous data transmission.

4.4.3 Test for 3.7V Lithium Polymer Battery

Lastly for 3.7V Lithium polymer battery, the nominal voltage is ideal for the design of the charging circuit. So the charging process was done without any problem at all. Same as previous type of battery, the output voltage of this battery was regulated before connected to the tag to suits the tag’s power consumption. The result of the test was recorded in the graph below.

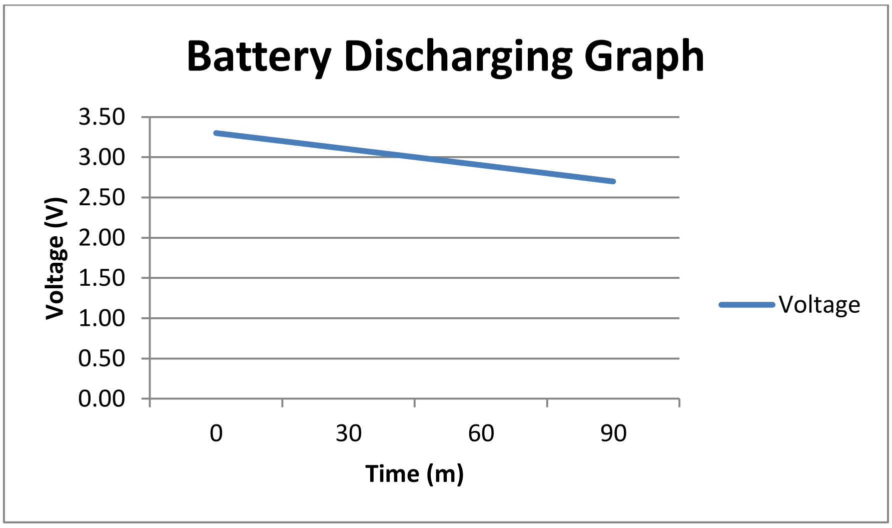

Figure 20: Battery Discharging Time

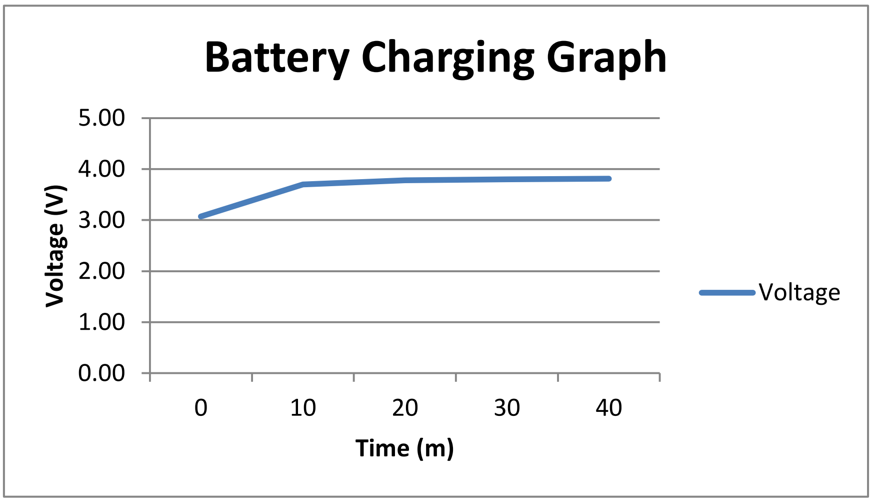

Figure 21: Battery Charging Time

For Lithium polymer battery, the voltage of the battery was taken in every 10 minutes. After 2 hours, the tag cannot transmit any data to the receiver. As the result, the battery only can stand up to one hour and half.

Table 4: Overall Test Result

Type of Battery	VL-3032 Coin Battery	Nokia BL-5B	3V Lithium Polymer Battery
Voltage (V)	**3**	**3.7**	**3.7**
Capacity (mAh)	**110**	**890**	**180**
Size	**Small**	**Big**	**Medium**
RFID Data Transmission	**Fail**	**Success**	**Success**
Stand-up Time (m)	**-**	**480**	**90**
Charging Time (m)	**-**	**90**	**40**

As for the result, a few considerations must be take care before the type of the battery that will be used in this project is finalized. Based on the stand up time, Nokia BL-5B has the longer stand up time compared to the other batteries. The disadvantage is that the size of the battery is big and not suitable to power up the RFID tag for medical purposes. The ideal choice of the battery is the 3.7 Volts Lithium Polymer Battery. The size is suitable to be implemented with the RFID tag. Even though the stand-up time is short, but higher capacity battery from this type of battery is available in market. So the stand-up time of the tag will be longer if the battery from this tag is selected. Final result is tabulated in the table 4.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In conclusion, the conventional power management for the active RFID tag can be change with this approach by replacing the current battery to new rechargeable lithium battery and introduce a suitable charging circuit together is believed to increase the lifetime of the tag due to its re-charging concept and cost effective because of the maintenance free. The suitability of the approach also can be used in other application that uses normal battery. This approach will reduce the cost of the battery's maintenance besides increase the lifetime of the item.

5.2 Recommendations

The external powering source for active RFID is to ensure continuity of power supply for the tag. The efficiency of the charging circuit plays important role to maintain the lifetime of the battery inside it. There are a few ways to improve the efficiency of the circuits; one of them is to re-create the circuit using battery management IC. By using this IC, the charging current and the charging voltage was ideally set inside the IC. So that the protection measure was already build inside the IC. Moreover, the circuit will be less complex compare to the circuit using operational amplifier. But before the author replace the usage of operational amplifier with the battery management IC, of course some experimentation must be done and data from each circuit will be collected to prove whether this new approach is applicable or not.

The size of the circuit also play the important role in this project because at last, the circuits designed will be integrate with the real RFID tag which is small in size. The author will replace the original operational amplifier with the SMD operational amplifier. A few changes in the designated circuit will be made to replace this new chip inside the original circuit. As the results, the size of the circuit will be smaller than the original.

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APPENDICES

APPENDIX A

PNP TRANSISTOR DATASHEET

PNP Epitaxial Silicon Transistor

Absolute Maximum Ratings T_C=25°C unless otherwise noted

Symbol	Parameter		Value	Units
V_{CBO}	Collector-Base Voltage	: BD136 : BD138 : BD140	- 45 - 60 - 80	V V V
V_{CEO}	Collector-Emitter Voltage	: BD136 : BD138 : BD140	- 45 - 60 - 80	V V V
V_{EBO}	Emitter-Base Voltage		- 5	V
I_C	Collector Current (DC)		- 1.5	A
I_{CP}	Collector Current (Pulse)		- 3.0	A
I_B	Base Current		- 0.5	A
P_C	Collector Dissipation (T_C=25°C)		12.5	W
P_C	Collector Dissipation (T_a=25°C)		1.25	W
T_J	Junction Temperature		150	°C
T_{STG}	Storage Temperature		- 55 ~ 150	°C

Electrical Characteristics T_C=25°C unless otherwise noted

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Units
V_{CEO}(sus)	* Collector-Emitter Sustaining Voltage : BD136 : BD138 : BD140	I_C = - 30mA, I_B = 0	- 45 - 60 - 80			V V V
I_{CBO}	Collector Cut-off Current	V_{CB} = - 30V, I_E = 0			- 0.1	μA
I_{EBO}	Emitter Cut-off Current	V_{EB} = - 5V, I_C = 0			- 10	μA
h_{FE1} h_{FE2} h_{FE3}	* DC Current Gain	V_{CE} = - 2V, I_C = - 5mA V_{CE} = - 2V, I_C = - 0.5A V_{CE} = - 2V, I_C = - 150mA	25 25 40		 250	
V_{CE}(sat)	* Collector-Emitter Saturation Voltage	I_C = - 500mA, I_B = - 50mA			- 0.5	V
V_{BE}(on)	* Base-Emitter ON Voltage	V_{CE} = - 2V, I_C = - 0.5A			- 1	V

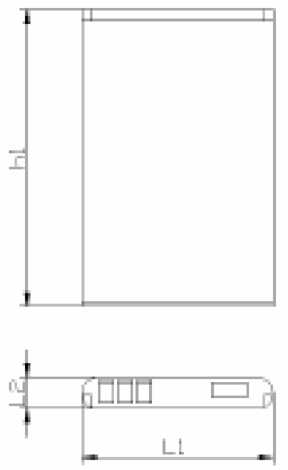
* Pulse Test: PW=350μs, duty Cycle=2% Pulsed

APPENDIX B

LITHIUM ION DATASHEET

data sheet

system:	Lithium-Ion-Battery
nominal voltage:	3,7V
end charge voltage:	4,2V
max. charge current:	600mA
charge conditions	
standard charge:	300mA for 3,5h min.
fast charge:	600mA for 2,5h min.
charging method:	CC-CV (constant current and constant voltage)
capacity	after standard charge
nominal:	600mAh at 0,2C discharge to 2,75V
minimal:	540mAh at 0,2C discharge
	480mAh at 1C discharge
max. discharge current:	600mA
life time expectancy:	> 300 cycles
ambient temperature range	
charge:	0…45°C
discharge:	-20…60°C
long term storage:	-20…35°C (less than 1 year)
weight:	20g
dimensions:	L1: 34,0mm
	L2: 5,6mm
	h1: 53,3mm



ANSMANN energy	specifications for model/type:	A – Nok2 (Nokia BL-5C)
	Ansmann drawing number / part number:	5060053
	drawn by / date:	Gremlich / 28.07.2005