Alternative Power Generator Design for Active RFID Tag

by

Nur Barieah binti Muhammad Noor
14605

Dissertation submitted in partial fulfillment of
The requirements for the
Bachelor of Engineering (Hons)
(Electrical and Electronics)

SEPT 2014

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Alternative Power Generator Design for Active RFID Tag

By

Nur Barieah binti Muhammad Noor

14605

A project dissertation submitted to the

Electrical and Electronic Engineering Programme

Universiti Teknologi PETRONAS

In partial fulfilment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

(ELECTRICAL AND ELECTRONIC)

Approved by,

____

(Assoc. Prof. Ir. Dr. Nursyarizal Mohd Nor)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

September 2014

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 reference and acknowledgements, and the original work contained herein have not been undertaken or done by unspecified sourced or persons.

NUR BARIEAH BINTI MUHAMMAD NOOR

ABSTRACT

Radio Frequency Identification (RFID) is used for identification of object since World War II, when English airplanes are distinguished with Germans' by using the technology. Presently, RFID application is used widely in control inventory, pharmaceutical, medical field and manufacturing lines. The capability of RFID has evolved from passive to active tags. Active RFID tag is powered by a rechargeable battery which is not efficient since the battery need to be frequently charge and replace. This report proposed an alternative power generator charger for the tag to increase the battery efficiency. Photovoltaic cell is used as energy harvester to absorb ambient light energy and convert it to electrical energy. The power generated is directly use to charge a battery continuously under ambient light. LTC3105 DC/DC and LT1073 Step up converter is experimented to boost the voltage and current from battery cell in order to produce an output of 3.3V 40mA as minimum requirement to power RFID Tag. The charging battery is capable to power RFID tag without being charge frequently. This project comprises the theory of power and energy, communication system and microelectronics. Mono-crystalline type of PV cell are used as the cell have high efficiency. Risk and contingency while doing this project is discussed and recommendation is made to counter the problem.

ACKNOWLEDGEMENT

Firstly, I would like to express my highest gratitude to the Almighty for blessing me with the chance to undergo my degree in Universiti Teknologi PETRONAS. I would like to convey my inmost appreciation to my supervisor, Assoc. Prof. Ir. Dr. Nursyarizal Mohd Nor for his guidance, advice, and supervision for the completion of this final year project. Without his encouragement and support, I could not harvest knowledge and experiences as much as I wanted.

There were also many individuals and parties that helped facilitate my work. These parties helped instruct, shared ideas, teach and supervise me in my works and projects. They have contributed immeasurably. The amount of help, support, advice, guidance, and motivation they give to me for the completion of this project is greatly appreciated. I would like to convey my utmost gratitude and appreciation to all of them for their assistance and commitment in helping to complete this final year project.

I would like to express my highest gratitude to:

- Dr. Hanita binti Daud – Co-supervisor
- Mr. Mohd Zuraimi bin Rahman
- Mr. Adz Jamros bin Jamali
- Pn. Nurul Fauzana binti Imran Gulcharan
- Mr. Sayyid Haziq bin Hassmoro

Special thanks also go to all my friends and family who has been helping and supporting me throughout the completion of this project. Finally, thanks to others whose name was not mentioned, all your guidance, support and cooperation are very important in completing my final year project.

CONTENT

CERTIFICATION OF APPROVAL i
CERTIFICATION OF ORIGINALITY ii
ABSTRACT iii
ACKNOWLEDGEMENT iv
LIST OF FIGURES vii
LIST OF TABLES viii
ABBREVIATIONS AND NOMENCLATURES viii
INTRODUCTION 1
1.1 Background of Study 1
1.2 Problem Statement 2
1.3 Objectives 3
1.4 Scope of Study 3
CHAPTER 2 4
LITERATURE REVIEW 4
2.1 RFID 4
2.2 Energy Harvesting 9
2.3 Solar Energy Harvesting 10
2.4 Step-Up Converter 14
CHAPTER 3 15
METHODOLOGY 15
3.1 Project Workflow 16
3.2 Tools and Components 17
3.3 Study Plan 22
3.4 Gantt Chart and Key Milestone 23
CHAPTER 4 24
RESULT AND DISCUSSION 24
4.1 System Block Diagram 24
4.2 Solar Panel No Load Test 25
4.3 DC/DC Step-Up Converter Simulation Test 26

4.4 DC/DC Step-Up Converter Comparison..30
4.5 Solar Charger System 31
4.6 Tag Design..34
CHAPTER 5..36
CONCLUSIONS AND RECOMMENDATIONS 36
REFERENCES.. ix
APPENDICES.. xi

LIST OF FIGURES

Figure 1: RFID System 4
Figure 2: Optimal Protocol State Diagram 7
Figure 3: Solar Cell I-V Curve 11
Figure 4: Basic solar system 12
Figure 5: Project Flow Chart 16
Figure 6: Mono-crystalline PV Cell 17
Figure 7: Schematic Diagram of LTC3105 19
Figure 8: Schematic Diagram of LT1073 19
Figure 9: Study Plan 22
Figure 10: Overall System Block Diagram 24
Figure 11: Testing a Solar Cell 25
Figure 12: LTC3105 Simulation Circuit 26
Figure 13: LTC3105 Simulation Result 28
Figure 14: LT1073 Simulation Circuit 29
Figure 15: LT1073 Simulation Result 29
Figure 16: Testing LTC3105 30
Figure 17: Testing LT1073 30
Figure 18: Solar Charger Experiment 31
Figure 19: Graph of Battery and Solar Cell Voltage with Time 32
Figure 20: Graph of Battery and Solar Cell Current with Time 33
Figure 21: Plan and Side View of Tag Design 34
Figure 22: Tag Design in 3D 34
Figure 23: Tag Design - Testing 35
Figure 24: Tag Design - Top View 35
Figure 25: Tag Design - Inside Box 35

LIST OF TABLES

Table 1: Types of RFID Tags 6
Table 2: Nominal Power from Energy Harvesting 9
Table 3: Efficiency of Solar Cell based on type 17
Table 4: Specification of Solar cell.. 18
Table 5: Type of Rechargeable Battery Comparison... 20
Table 6: Components and Software 21
Table 7: Gantt Chart.. 23
Table 8: Power Generated from a Solar Cell 25
Table 9: Justification of components used... 27
Table 10: Output of DC/DC Converter... 30

ABBREVIATIONS AND NOMENCLATURES

PV	Photovoltaic
RFID	Radio Frequency Identification
ROM	Read-Only Memory
RF	Radio Frequency
UTP	Universiti Teknologi PETRONAS

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Monitoring and tracking human, equipment, animals and objects require reliable and continuous monitoring system. The system shall be able to be used at any circumstances without any disturbance. Critical data collection such as patient temperature, blood pressure and heart rate in the hospital are currently being done manually which requires physical logging. This practice is less efficient since the users have to be closed to the data source. In order to enhance the efficiency, vast research on application of Radio Frequency Identification (RFID) in patient monitoring, tracking and identification is being done [1].

RFID device will be worn by patients and it shall monitor the patient temperature, blood pressure, and heart rate at regular intervals and the signals will be transmitted to a host computer. When the measured reading exceeds the predefined limit, alert will be generated by the host computer and the nurses or doctors on duty will get a notify SMS. This device shall also track the exact place of patients and staff whereabouts and alarms will be triggered when they approach undesignated areas inside the hospital.

Apparently, the current RFID tags is powered by normal battery or lithium ion battery to operate the device. However, these batteries have to be frequently charge as it does not last long. In medical field, using a normal battery for power source is not practical since there is a need for a continuous power supply. Therefore, this research work is proposing a solution in order to address this power supply issue for RFID tag to efficiently monitor the temperature, blood pressure and heart rate as well as patients tracking in real time remote or automatic in the hospital.

Energy harvesting device such as solar photovoltaic, thermoelectric and piezoelectric have potential to be incorporated with active RFID monitoring system to prolong the battery life. This device capture unused ambient energy and convert it into electrical energy. This method may reduce the dependency on battery power whilst correspond with the government's approach to introduce 'Green Technology' applications by utilizing natural energy source for daily usage.

This project is incorporating means of power supply generated from solar powered rechargeable battery into active RFID monitoring devices which makes our invention unique and different from what is available in the market. The solar powered rechargeable battery is capable of converting the light or photon from the sun and surroundings to generate power. The excessive power then will be stored within battery installed in the device for the use during night or dark condition. From this method, we could obtain continuous and uninterruptable power supply day and night.

1.2 Problem Statement

Active RFID tag is currently using battery as its internal power source. This system has its drawbacks as follow:

- The battery lifetime is brief since the sensors integrated in the RFID device such as temperature and noise sensor consumed high power.
- The maintenance cost for an active RFID tag in a long term is very expensive because the battery need to be recharged and replaced frequently.
- Battery outages in active RFID tag may result in security issue due to interruption in monitoring especially in medical field.
- Battery outages also cause misreads and confusion and the cost for reconstruction is high.

1.3 Objectives

The objectives of this project are:

- To design and develop an alternative power generator charger using photovoltaic cell which can charge a battery indoor.
- To design a booster with a minimum output voltage of 3.3V and minimum output current of 40mA to power up an active RFID tag.
- To minimize the battery usage by more than half which shall induce cost effective tags, suitable for any application.
- To improve the reliability of an active RFID tag battery, in term of its effectiveness, safety, and longevity.

1.4 Scope of Study

The scope of study shall comprise:

- Communication system

  Study on communication system can help to understand the characteristics of radio frequency, and the interference that involves within active RFID system.
- Microelectronics

  Microelectronics involve in study of the circuit, configurations and specifications of the active RFID hardware such as field generators, reader and tags. Also, the circuit of active RFID tag and solar system will be studied.
- Power and energy

  The study on power and energy shall help to understand the characteristic of solar power and PV cell as well as its configuration in order to integrate the circuit designed with an active RFID tag as an alternative power source.

CHAPTER 2

LITERATURE REVIEW

2.1 RFID

System that wirelessly transmits identity of an element in a unique serial number pattern using radio waves is called RFID. It consists of two separate components which is a tag as transponder and a reader as a transceiver. The tag is similar to a barcode label. It contains an antenna connected to a small microchip. The reader in other hand functions similarly to a barcode scanner but to scan, RFID scanner use electromagnetic waves while barcode scanner uses laser beam. Data transmission occur when the scanner antenna transmits a signal to communicate with the tags antenna. The tags antenna then transmits the specific chip information to the scanner [2].

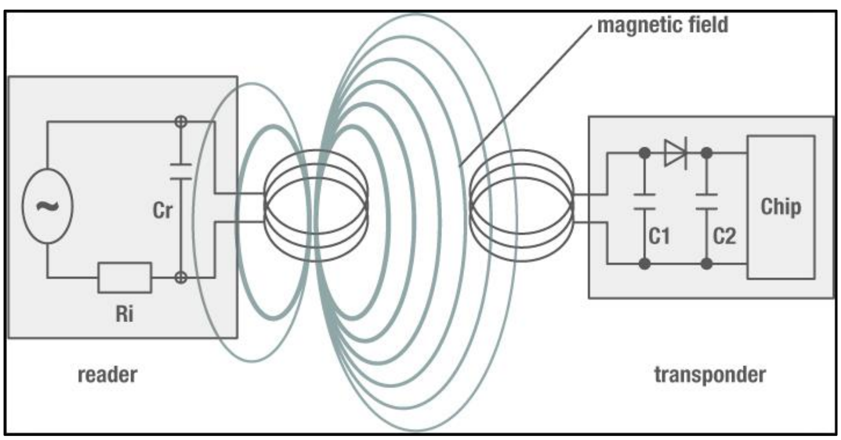


Figure 1: RFID System

Concurrently, there are two types of memory used to store data in the chip which are Read-Only Memory (ROM) and Read/Write Memory. ROM is the most common memory used. As its name suggest, the memory or data can only be programmed onto the chip during manufacturing process. In contrary, Read/Write Memory can be later altered after programmed during manufacturing by using certain device. RFID communication involve two way radio frequency communication process between the transceiver and transponder via wireless air interface. Both of them need to be turned to the same frequency in order for the device to communicate [3].

2.1.1 RFID Tags

RFID tags composed of two main components which is a micro silicon chip which is an integrated circuit that have identification number and an antenna that able to transmit and receive radio waves. Both of these components can be in a small size: The chip can be less than half millimeter and the antenna is made of a flat, metallic conductive coil. Usually, both components are attached to a tag made of plastic that can be mounted to a physical item. The tag can be small, thin, and it is increasingly easy to be embedded within practical devices [4].

Generally, there are three types of RFID tags which are active, passive and battery assisted passive RFID tags. Table 1 shows the difference of these three types of tags [5].

Table 1: Types of RFID Tags

Type of RFID Tags	**Difference**
Active	- Powered by a battery - Able to transmit signals autonomously.
Passive	- Does not powered by battery - Transmission of signal need to be provoked by external source.
Battery assisted passive	- Transmission of signal need to be provoked by external source but forward link capability is still significant which can provide a great read range.

This project will be focusing on active RFID tags only.

Active RFID tags is powered by a portable power supply which enable it to amplify signal from the reader and transmitting data autonomously. It has a longer reading range, up to 100 feet and does not require the data processing section to be energize by RF carrier signal [6]. Active tags is able to hold more data and have the can store data from the reader. Microprocessors controls the data processing and protocols. Active tags is expensive compared to a passive one and it only come in bigger size. However, the ability of an active tags which can be programmed and used repetitively make it the researcher preference for future innovations.

In order to optimize the energy usage of an active RFID tag, sleep mode is introduced. Referring to the optimal protocol, no energy loss will be experienced if this mode is to be apply by RFID tag. The energy is only optimized when the tag is transmitting and receiving information to and from the RFID reader respectively. The tag shall enters deep-deep sleep mode for a predetermined time when it received an acknowledgement message from RFID reader. Figure 2 shows the basic state operation for an RFID tag executing the optimal protocol. Based on the figure, the power consumption for all described protocols is less during deep-sleep and sleep mode compared to the wake mode; when the tags is receiving and transmitting [7].

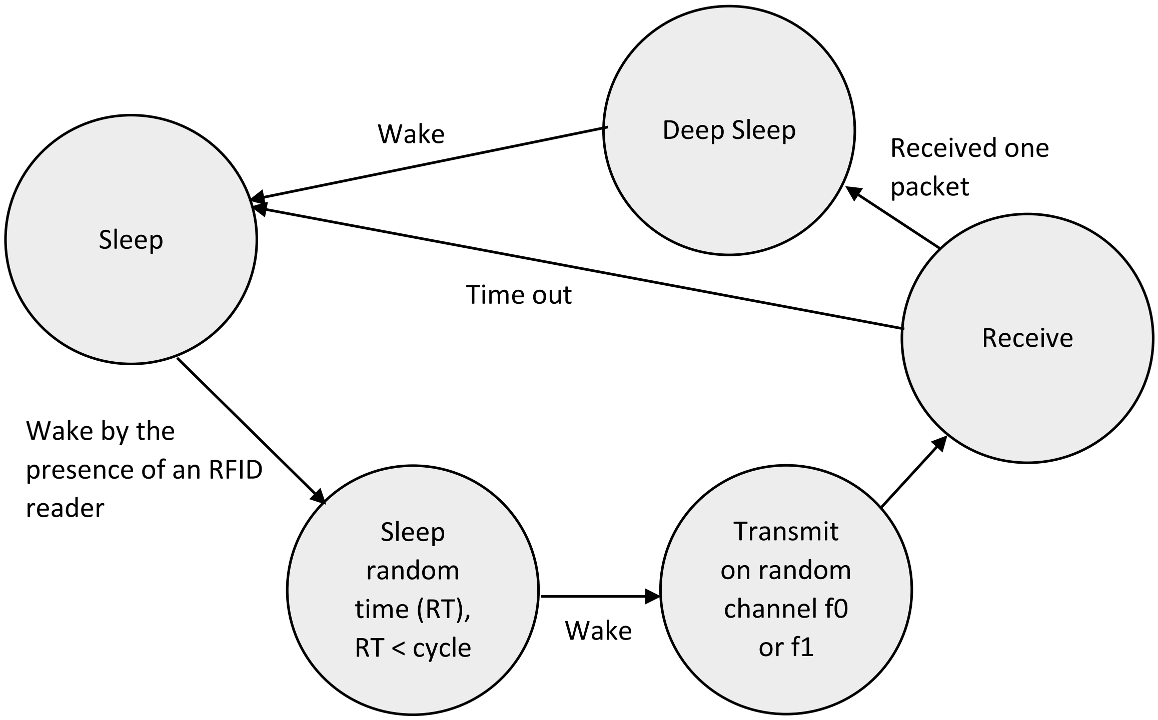


Figure 2: Optimal Protocol State Diagram

2.1.2 RFID Systems in Medical Field

Prior to RFID systems, barcodes have been used in health care successfully. In 2006, approximately 70 percent containers used for medication was installed with barcodes [8]. Also, barcodes is used for identifying patients and staff. Still, barcodes system require a line-of-sight scanning and real time tracking cannot be used. Tearing, wrinkling and wetting of barcodes shall also decrease the level of the codes readability. The advancement of technology have introduced RFID system which is believed can replace the barcodes system especially in critical sectors such as hospital since it does not need line- of-sight scanning, resistant to moisture and tearing and make real time tracking possible.

A pilot program was held at Harvard Medical School on a barcode and RFID hybrid system which is known as Harvard hybrid system [1]. The findings of this pilot program showed that active RFID tags can be used for real time tracking of patients, staff and equipment. In other hand, passive RFID tags is useful to identify patients especially during night when the patient is sleeping since scanning can be done without interrupting them compared to the previous patients identified using barcodes wristbands.

Other research and innovation include an application named Galway RFID which was developed in Ireland at University College Hospital Galway [1]. This application uses RFID, IEEE 802.11b wireless networks, and handheld devices aims to speeds up and eases the access to patient data. Furthermore, a collaboration between Intel, Cisco Systems, Autentica and Hospital of San Raffaele in Milan conducted a pilot system which aim to enhance blood transfusion safety by using RFID. Every year, more than 15000 blood transfusions delivered and the safety of the process was enhance by using the system. Patients and staff worn a secure RFID badges or wristbands that installed with their encrypted data to be identified.

2.2 Energy Harvesting

Energy harvesting is the act of harnessing ambient energy from surrounding environment and convert it to electrical energy for any useful applications. This action is possible by referring to the theorem of energy conservation, which states that in any isolated system, the total energy will not change but it shall conserved over time. There are abundant of free energy that are being wasted every single day. They exist in many forms such as wind energy, solar energy, kinetic energy, hydropower, thermal energy and radio-frequency (RF) energy.

New technology breakthrough have come out with more efficient methods to convert these free energy into useful electrical power. Each source of energy need a specialized technology for the conversion to take place efficiently. Some energy sources are able to harness huge amount of power (kW to MW) while some can only harvest small amount of power (µW to mW). These techniques are called macro-energy harvesting and micro-energy harvesting respectively. Macro-energy harvesting have advantage in generating large amount of power but they are large, expensive and hard to handle. In contrary, micro-energy harvesting is small, inexpensive and lightweight make it easily handle by user. Table 2 shows the categorize energy harvesting sources as discussed above.

Table 2: Nominal Power from Energy Harvesting

Type of Energy Harvesting	Source	Nominal Power Generated
Macro-energy	Hydropower	10 kW/cm^2
	Wind	7.5 kW/cm^2
	Solar	7.4 kW/cm^2
Micro-energy	Solar	10 mW/cm^2
	Thermal	5 mW/cm^2
	Kinetic	10 µW/cm^2
	Radio Frequency	0.1 µW/cm^2

Based on Table 2, solar has the capability to be used as energy source for both types of energy; it depends on the type and size of solar panel used. Under modern technique of micro-energy harvesting, automatic power system design is made feasible. The system is designed to be independent to any external influence which work great for a sustainable power system. Back in a few decades, sustainable power system were infeasible. The amount of generated power need to be greater than amount of consumed power. In order to overcome the barriers, power management circuit was introduced to increase the system output power.

2.3 Solar Energy Harvesting

Solar energy is free and abundant in almost all parts of the world. The earth received 1.8×10^{11} MW from the sun which is higher than current commercial energy sources available in the world. A solar powered system comprises of the four main components. They are external surroundings, solar panel or collector, energy storage and the load system. The solar collector collect solar energy from surrounding and convert it to electrical energy. The energy storage which is connected to the load is used as an intermediary to vary energy income. However, the methods these modules are connected and implemented depend on the application which they can vary tremendously.

For macro-energy generation, large solar panels is used. 100-mm photovoltaic (PV) cell can harvest approximately 1 mW power. Typical efficiency is 10% and the capacity factor of PV sources is roughly 15% to 20%. For micro-energy generation, maximum power point tracking (MPPT) technique is used to absorb or collect maximum power from a single solar module. MPPT is the most important part of solar energy harvesting. It took DC input from PV cell, convert it to AC and change it back to a DC voltage and current which will then match the PV module to the battery.

Maximum power point (MPP) is an important specification of a PV module. It is the voltage when PV module generate maximum power. The main objective of having MPPT is to ensure the solar cell operate at it most efficient voltage. However, MPP varies with surrounding temperature, solar radiation and solar panel temperature. Figure 3 illustrates a solar cell I-V curve. MPP line intersects the knee of the curves. At that point, slope of the line is equal to the I/V ratio and dP/dV = 0 , where dP/dV is the change in power with respect to voltage of the solar cell.

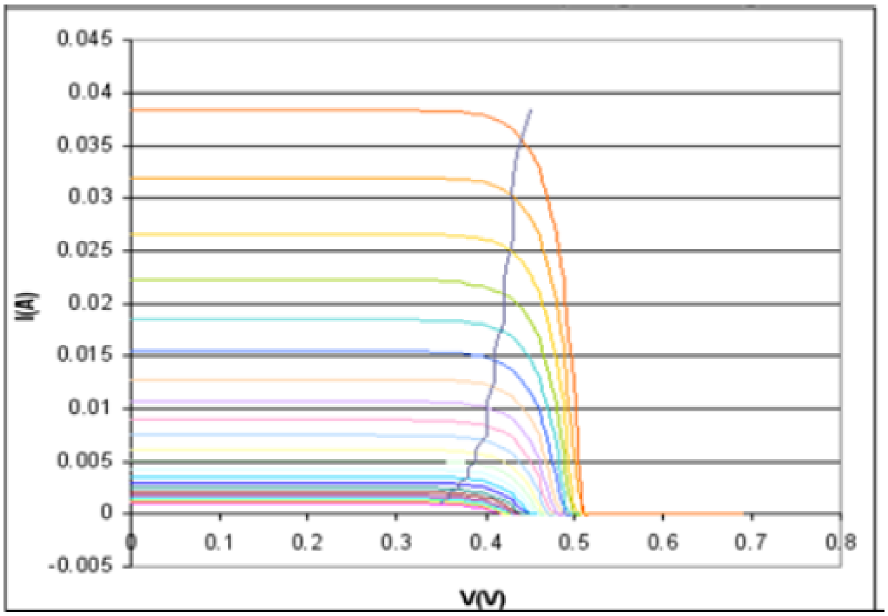


Figure 3: Solar Cell I-V Curve

2.3.1 Photovoltaic Cell (PV)

When a PV cell strikes by sunlight, electrons will be released from the photons of the sunlight absorbed by the cells. The free electrons will then spread through the cell, filling the cell with holes. The electricity is generated by the movement of the free electrons and holes. The process in which sunlight is converted into electricity by a PV cell is called photovoltaic effect. A single PV cell normally can generate maximum power of 2 watts which is even not enough to power a calculator. PV cells are therefore connected together either in series or parallel to form a larger modules called arrays to increase the output power. The method of modular nature of PV has turned various applications powered by a solar system into realization [9]. In whole, when the area of PV module or array is increased, the electricity generated will also increase.

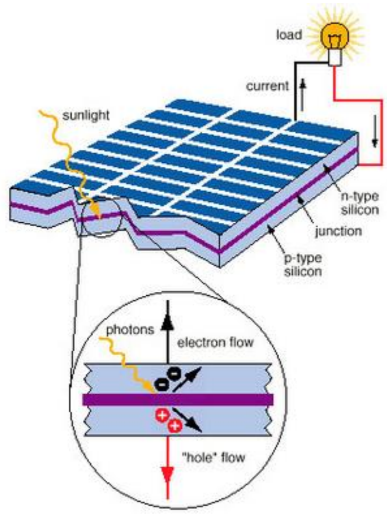


Figure 4: Basic solar system

Major advantage of PV cells is that they can directly convert solar radiation into electricity. Thus, no mechanical movement of any parts and extreme procedure shall take place in the electrical generation process. Other advantages of using PV are it offer zero pollution since the energy source comes from the sun which is natural, always free and available every day. The power generated by PV modules varies from microwatts to megawatts [10]. PV produces a flexible energy source and also, its lifetime period is long.

2.3.2 Existing Integration of RFID and Solar

Currently, there has been integration made between solar and RFID. A Lockheed Martin company named Savi Technology has begun deploying solar powered onto the company products: RFID reader and signposts [11]. These new technology helps customers especially in defense and commercial sectors to reduce cost by conversing natural energy, and at the same time supplies can be tracked in real time. The utilization of solar energy increase the energy efficiency and it is environmental friendly besides help to reduce the need to build electrical infrastructure in isolated and remote areas. This technology basically use large PV panels to generate electricity thus the energy generated is sufficient to power the RFID in whole. In contrary, integration of solar with an active RFID tag require a small PV panels which shall be a challenge since the power generated might be insufficient.

Research also being done by former UTP student on dual powered active RFID tags by using solar. Experiment was done on three different size of PV cells to measure the output voltage and current produced [12]. The result show that the current produced by small PV cell is insufficient to power up an active RFID tag. Though the output current of medium sized PV cell is enough, the size of the panel is considered not applicable to be mounted on the RFID tag. Thus research will be done in this project to encounter the stated problem.

2.4 Step-Up Converter

Energy harvester such as photovoltaic cell, thermoelectric generator and piezoelectric can produce a minimum energy which is absorbed from ambient surrounding. This energy need to be stepped up by using a suitable step-up converter to produce a desired voltage. Step-up converter is a DC-DC switching converter which comprise of switches, inductor and rectifier[13]. It convert low input voltage to greater output voltage. When PV cell is used with DC/DC step-up converter, the maximum achievable power form the cell is extracted to utilize its power rate[14].

The basic principle of a step-up converter is the propensity of an inductor to create and eradicate magnetic field to refrain from current changes. The output voltage is controlled by regulation in which a lot of IC is designed for this function. The typical step-up converter is LM27313 manufactured by Texas Instrument. The IC is suitable to be used with low power application such as autonomous device, mobile phones, cameras and PDAs.

The rapid evolution of technology has resulted with a more compatible step-up converter such as LTC3105 and LTC3108 manufactured by Linear Technology. Mihail et. Al in their research used LTC3105 to harvest energy form thermoelectric generator to charge a Lithium ion battery [15]. LTC3105 requires a low input voltage ranging from 0.2V to 5V and able to produce voltage of 5.25V with output current of 100mA. This IC is suitable to use with any energy harvester which produce very low voltage and current to power up a low power autonomous device.

CHAPTER 3

METHODOLOGY

Research has been done through journal, internet and books to achieve the objectives of this project. There are three major steps or works done during FYP which are defining problem, research and analysis and come out with results. The explanation of stated works are as below:

- Defining problem

  Critical data collection such as in medical field need to be accessed at any circumstances and time without any disturbance. Active RFID Tag powered by a rechargeable battery is currently being experimented to be used in this field. However, it is not efficient since the tag need to be charged frequently and disturbed the monitoring system. Thus, this project will use solar cell to continuously charging the battery indoor which shall help to avoid system disturbance and at the same time initiate the usage of green energy.

- Research and analysis

  The type of solar cell to be used is crucial as each type of solar cell will give different power efficiency. Research and experiment have been done to choose the best type. Furthermore, the criteria and specifications of other materials for prototype building are considered based on their performance, size and quality to support the production of green energy charger.

- Results

  Designed prototype is experimented to test the solar cell performance in order to charge a rechargeable battery. The result shall indicate if the objective is achieved.

3.1 Project Workflow

Figure 5 shows the overall project flow chart which start from collecting data until final model fabrication. After analyzing the data, circuit is design and simulate by using suitable simulator. Component shall be assembled and tested and if the designed circuit fail to produce desired output, the circuit will be redesigned. Below is the detailed procedure.

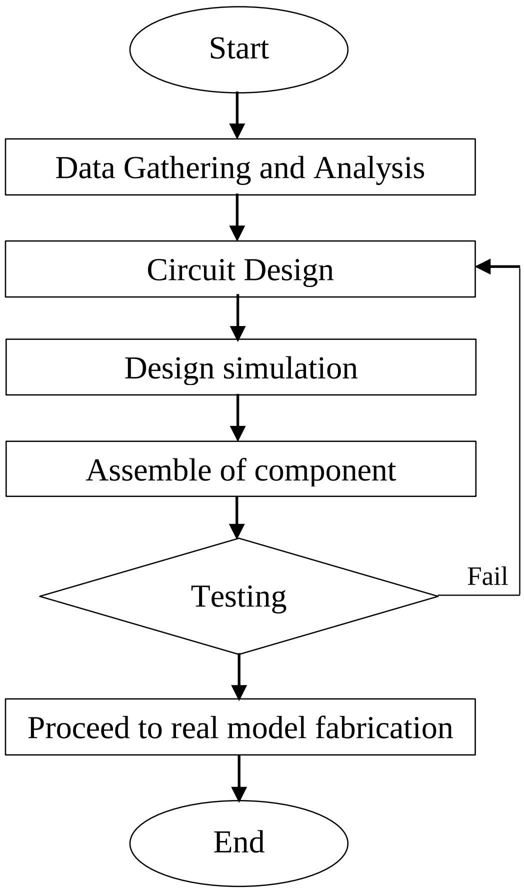


Figure 5: Project Flow Chart

1. All beneficial information and data are collected from sources such as technical paper, research paper, and component data sheet in order to understand theory and specification.
2. Design and simulate the booster circuit using LTSpice simulator, in order to produce output of 3.3V 40mA.
3. Assemble all components and start with testing phase.
4. Conduct a test on the designed circuit continuously and repeat step 2 to 5 until the desired result is gained.
5. Integrate the circuit with an active RFID tag.

3.2 Tools and Components

3.2.1 Solar cell

The solar cell must properly choose to achieve the highest output efficiency. Mono-crystalline solar cell is chose as it has the highest output efficiency compared to other types of solar cell. Research on the efficiency of solar cell based on type is done and the result are based on Table 4.

Table 3: Efficiency of Solar Cell based on type

Type of Cell	Efficiency (%)
Mono-crystalline	12-15
Polycrystalline	11-14
Amorphous Silicon	6-8

Figure 6: Mono-crystalline PV Cell

This solar cell was built from highest quality materials. Table 5 shows the specifications of this cell.

Table 4: Specification of Solar cell

Type	Mono-crystalline Silicone
Peak power (P_{max})	3.5W
Weight	50g
Measurement	80mm x 40mm
Maximum open circuit voltage (V_{oc})	7V
Maximum short circuit current (I_{sc})	0.50 A

3.2.2 DC/DC Step-Up Converter

Two types of step-up converter are experimented and the converter that give the best efficiency is to be used in this project. They are LTC3105 and LT1073 Step-Up DC/DC Converter. Both of them is a versatile micro power DC/DC converter which can be used as a buck or boost converter. Both converters are used to step up the voltage from 1.2V rechargeable battery to produce output of 3.3V 40mA. LTC3105 is an adjustable converter. It can operate under 0°C up until 85°C and over temperature protection is included to protect the device in overload condition. In other hand, LT1073 is a fixed value DC/DC converter which can deliver 5V 40mA from input as low as 1.25V. Figure 7 and Figure 8 shows the schematic diagram of the LTC3105 and LT1073 respectively.

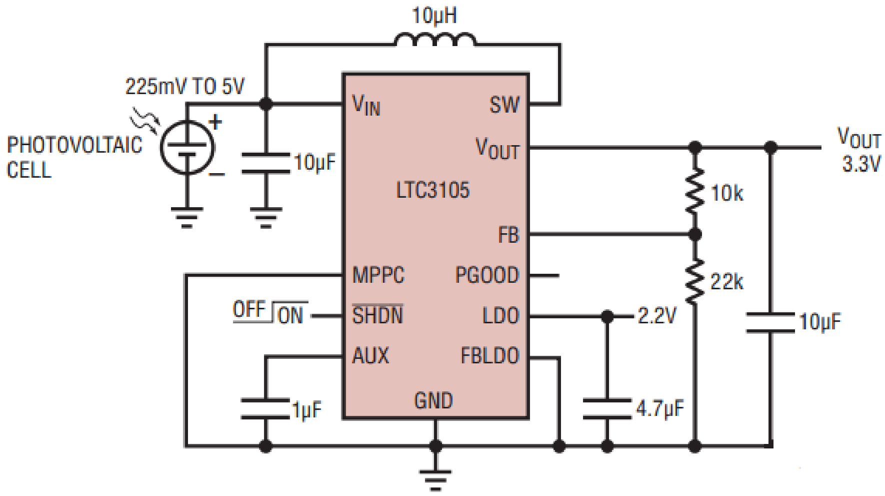


Figure 7: Schematic Diagram of LTC3105

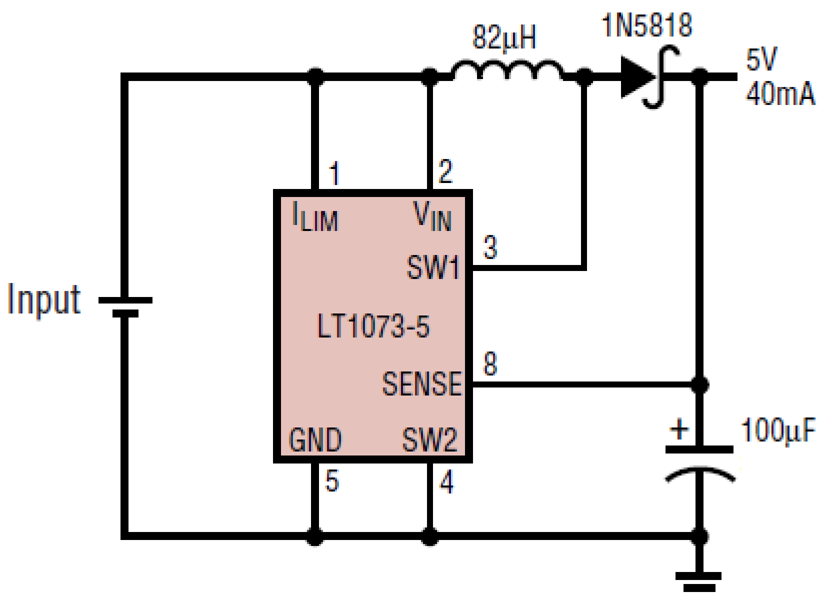


Figure 8: Schematic Diagram of LT1073

3.2.3 Rechargeable battery

Like the selection of solar cell, the type of rechargeable battery used also crucial to the overall system designed. In this project, Nickel-Metal Hydride (NiMH) rechargeable battery is chose. This type of battery is the most reliable for continuous low power charging. In addition, NiMH battery is cheap, environmentally friendly and can be recycle. Table 5 below shows the comparison of three types of potential rechargeable battery.

Table 5: Type of Rechargeable Battery Comparison

Parameter	**NiMH**	**NiCd**	**Li-Ion**
Capacity	1.25	1.25	3.6
Memory effect	Little effect	Noticeable effect	Little effect
Cycle life	300+	500+	300+
Overcharge tolerance	high	moderate	Very low
Self-discharge	30%	20%	10%
Battery cost	Low	Low	High
Environmental friendly	Yes	No	Yes
Recyclable	Yes	Yes	No

1.2V NiMH 2650mAh rechargeable battery shall be connected in series with booster circuit to produce output voltage of 3.7V. 2650mAh battery shall deliver current of 2650mA in an hour and generate power of 3.18Wh. When the tag operates at 3.3V 40mA, it needs 132mW and assume the step up converter is 50% efficient, it will need 264mW to operate. By doing this estimation, the battery can power up the tag for 12 hours. The calculation is shown below.

2650mAh deliver 2650mA in an hour

Power generated per hour = $1.2V \times 2650mAh = 3.18Wh$

Power consumed by tag = $40mA \times 3.3V = 132mW$

Assume step-up converter is 50% efficient:

Power consumed by the converter = $2 \times 132mW = 264mW$

If the battery can deliver 3.18W per hour, the tag can be powered for:

$3.18Wh \div 264mW = 12\ hours$

Other electrical component include resistors, capacitors and inductors, to complete the circuit, Multimeter to read the reading of voltage and current and Arduino to analyze the output. CadSoft EAGLE is used to design Printed Circuit Board (PCB) and LTSpice to do circuit simulation. The components and software used are listed in Table 6.

Table 6: Components and Software

Components	Software
Resistor	LTSpice Simulator
Capacitor	Arduino
Inductor	Inventor
Multimeter	CadSoft EAGLE

3.3 Study Plan

Figure 9 shows the study plan for the two semesters which include Final Year Project 1 and Final Year Project 2. The blue section is the data gathering and analysis while the red section is the design phase, proof of concept, testing and fabrication.

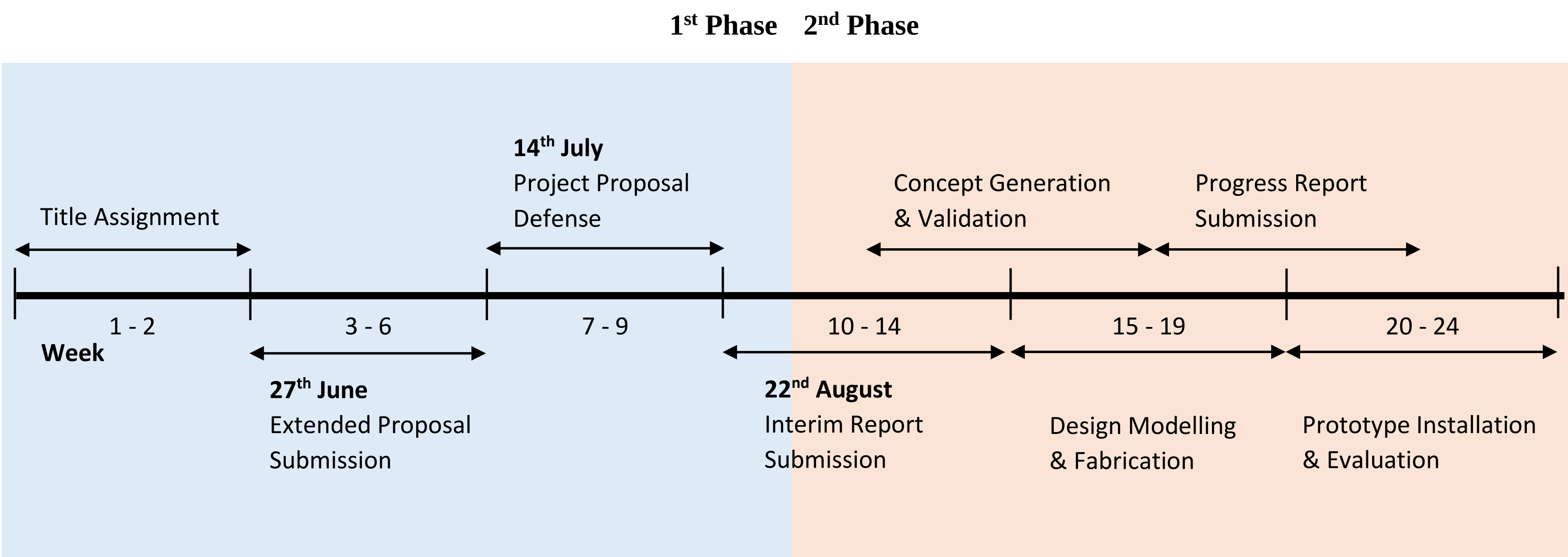


Figure 9: Study Plan

3.4 Gantt Chart and Key Milestone

Table 7: Gantt Chart

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Task																								
Project title assignment																								
Research and acquire project detail																								
Extended Proposal																								
Data gathering and analysis																								
Circuit Design																								
Interim Report																								
Assemble of component and testing phase																								
Integration of circuit with active RFID tag																								
Progress Report																								
Prototype fabrication																								
Prototype evaluation and data gathering																								
Documentation Report																								

Project Milestone

CHAPTER 4

RESULT AND DISCUSSION

Several experiment was conducted to test and verity the operational ability of the solar charger system. In this project, Mono-crystalline solar cell is used to charge a 1.2V NiMH battery. LTC3105 converter step-up the battery voltage from 1.2V to 3.7V and directly power an active RFID tag. In the beginning, LED is used as load to test the overall system reliability.

4.1 System Block Diagram

Figure 10 shows the overall system block diagram of this project. PV cell will harvest ambient light energy and convert it to electrical energy. In this project, we use 7V 50mA PV cell as the size is suitable to be mounted on top of RFID Tag. Harvested power is used to charge a rechargeable battery continuously. Power from rechargeable battery is stepped-up by booster circuit from 1.2V to 3.7V and directly power an active RFID tag. Note that the system is to be used indoor, thus the PV cell is not capable to directly power the RFID tag.

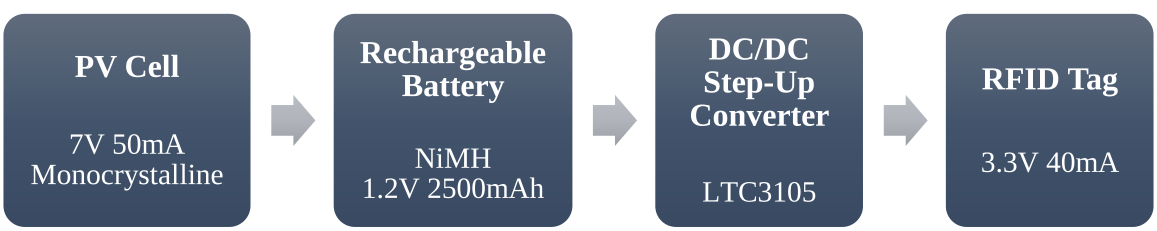


Figure 10: Overall System Block Diagram

4.2 Solar Panel No Load Test

Solar cell is tested in several different condition to figure out how much power can be generated as in Figure 11. Based on the testing done, the solar cell is not able to directly power the RFID Tag because the current generated is very low. However, the voltage of the solar panel is enough to charge a 1.2V NiMH rechargeable battery. Only one solar cell is needed charge the battery during night time. Table 6 is the summary of the data taken.

Figure 11: Testing a Solar Cell

Table 8: Power Generated from a Solar Cell

	Voltage	**Current**	**Power**
Day Time			
Bright light	5.81V	11.9mA	69.1mW
Dim light	4.01V	7.5mA	30.1mW
Night Time			
Bright light	2.45V	41.5µA	0.1mW
Dim light	2.02V	30.4µA	61.4µW

4.3 DC/DC Step-Up Converter Simulation Test

4.3.1 LTC3105 Step-Up DC/DC Converter

Figure 12 shows the schematic diagram of the designed circuit. Based on the diagram, the output current from 1.2V battery cell is connected to V_{in} of LTC3105. The converter shall start- up by using the energy from the input capacitor, C_1. V_{out} from LTC3105 is connected to FB pins through a resistor divider. C_4 is the feedforward capacitor which can improve load transient response and minimize output ripple. RFID tag is to be connected to V_{out} for direct supply.

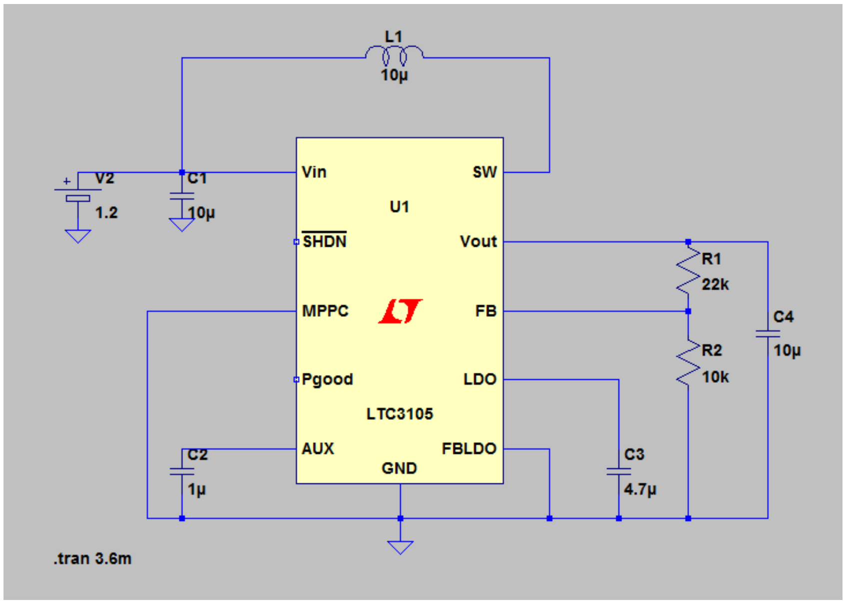


Figure 12: LTC3105 Simulation Circuit

Table 9 shows the details of the component used together with description and justification.

Table 9: Justification of components used

Component	Value	Justification
I_1	10µH	I_1 is low DCR power inductor. It is suitable for value between 4.7µH and 30µH. A larger value of I_1 can provide better efficiency when the input voltage is low.
C_1	10µF	C_1 is input capacitor which energy stored in the capacitor is used during the converter start-up mode.
C_2	1µF	C_2 is connected between AUX pin and Ground. Small value of the capacitor is used to reduce start-up time.
C_3	10µF	C_3 is a feedforward capacitor which is used to minimize output ripple and enhance load transient response.
R_2	22kΩ	R_2 and R_3 is the resistor divider. The value of those resistors can be varies to control the value of output voltage, V_{out}. The values of R_2 and R_3 is determined by using equation: $V_{out} = 1.004\left(\frac{R_2}{R_3} + 1\right)$ Using the values of 22kΩ and 10kΩ for R_2 and R_3 respectively, the value of V_{out} is 3.3V.
R_3	10kΩ	

Figure 13 shows the circuit simulation. Based on the graph, the blue line indicate the input voltage while the black line indicate the output voltage. It is clearly shown that the converter shall take less than 1ms before start up. This is the time when the capacitor C_1 is charged. However, the duration is negotiable. This simulation also proved that the converter is able to boost the input voltage from 1.2V to approximately 3.3V which is enough to power an active RFID tag.

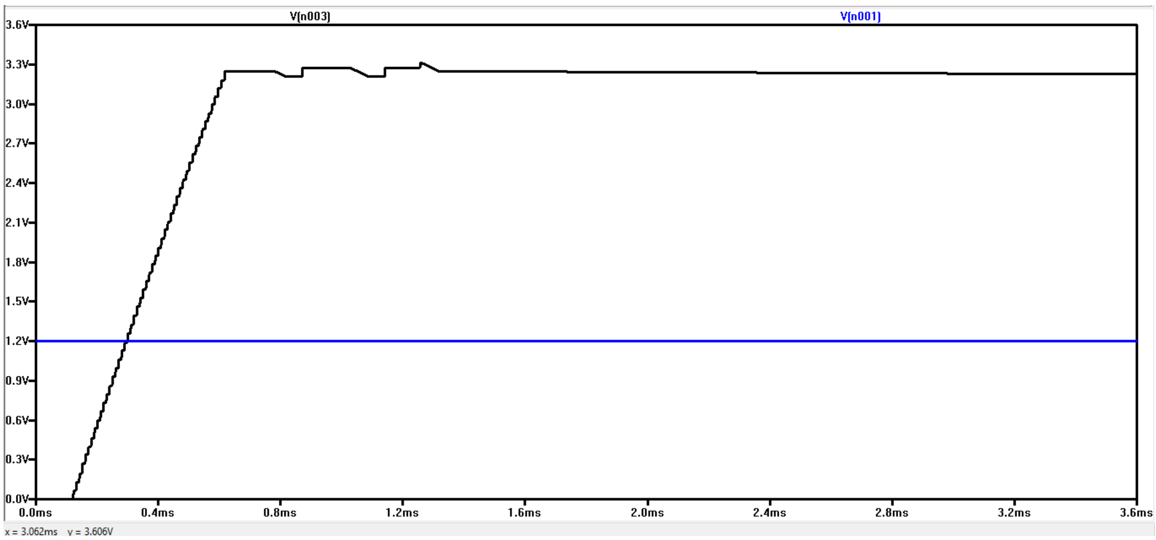


Figure 13: LTC3105 Simulation Result

4.3.2 LT1073 Fixed 5V DC/DC Converter

Figure 14 shows the schematic diagram of designed circuit. Input from 1.2V battery cell as low shall enter pin 1 of the converter. Diode 1N5818 serve as a Shottky diode is the most efficient diode to be used with this converter. The combination of its 500mV forward drop at 1A current, fast turn-on and turn-off time and 4µA to 10µA leakage current fit nicely with LT1073.

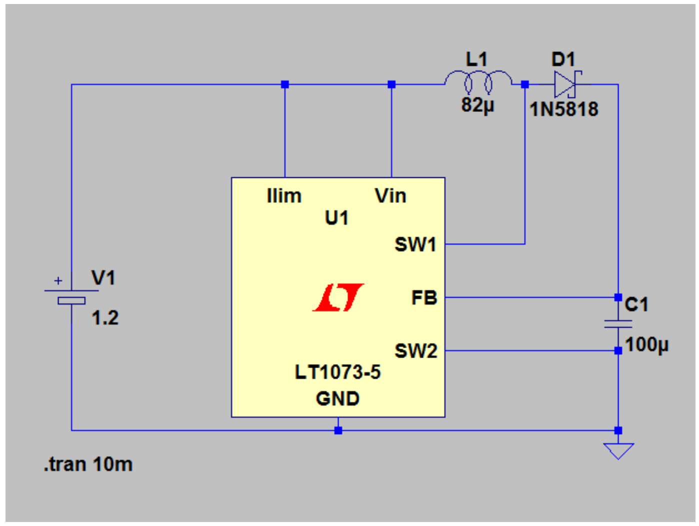


Figure 14: LT1073 Simulation Circuit

Figure 15 shows the circuit simulation of LT1073-5 step-up converter. Based on the graph, the blue line indicate the input voltage and the black line indicate the output voltage. It is clearly shown in this graph that the converter shall take almost 5.5ms before start up. The duration also known as dead time is longer compared to LTC3105. This simulation also proved that the converter is able to boost the input voltage from 1.2V to fixed value 5V.

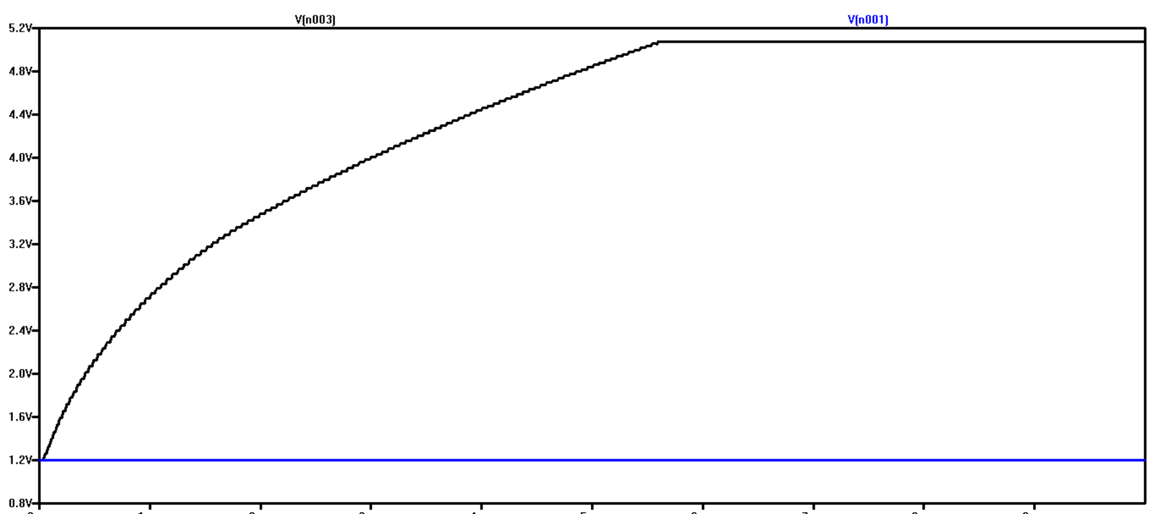


Figure 15: LT1073 Simulation Result

4.4 DC/DC Step-Up Converter Comparison

Figure 16 and Figure 17 show the experiment done to test the performance of LT1073 and LTC3015 respectively. The objective of the experiment is to compare the output of each booster and its reliability to be used in the system. This experiment was done in room temperature. The booster circuit was tested using a laboratory power supply before using battery cell as input. From the experiment, it is shown that LTC3105 is more reliable compared to LT1073 because it need lower voltage start-up compared to LT1073 which are 0.9V and 1.0V respectively. Besides, the output of LTC3105 is adjustable and LT1073 is fixed 5V. The theory of power in is equal to power out is applicable in this experiment. Since the voltage of LT1073 is high, the current produce will be low. Thus it is not able to power up the RFID tag. In other hand, the output voltage of LTC3105 can be adjust to the minimum in order to maximize the output current. The result of experiment is tabulated in Table 10.

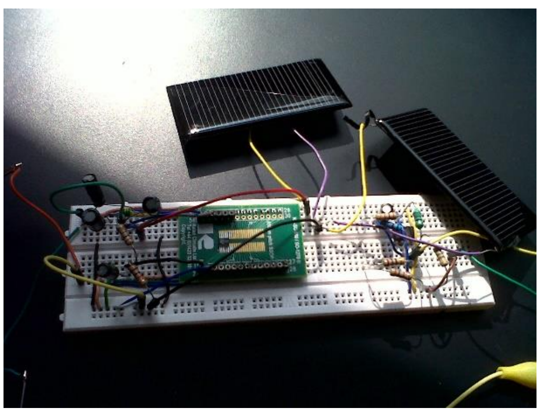


Figure 16: Testing LTC3105

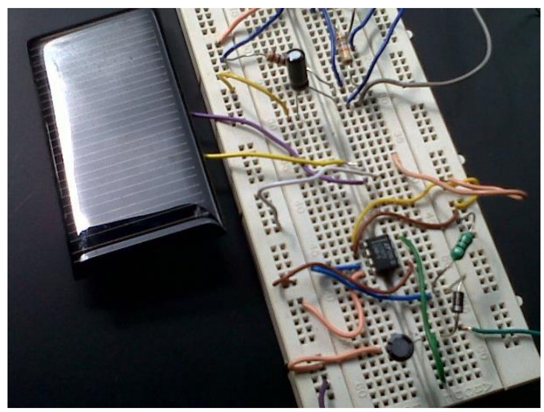


Figure 17: Testing LT1073

Table 10: Output of DC/DC Converter

	LTC3105	**LT1073**
Minimum Input Voltage	0.9 V	1.0 V
Minimum Input Current	10 mA	20 mA
Output Voltage	3.3 V - adjustable	5 V - fixed
Output Current	65.4 mA	0.02 mA

4.5 Solar Charger System

Experiment was conducted to test the ability of solar cell to charge a 1.2V battery in various position and condition including vertical, horizontal and slanted. This experiment was done in room condition for 3 consecutive days and the average value is calculated for result. Figure 18 shows the setup of experiment conducted with the solar panel was vertically, horizontally and slant positioned respectively. Solar cell is connected in parallel with the battery and Shottky diode 1N5107 is connected in series with solar panel to avoid current backflow. The result of experiment is displayed in Figure 19 and Figure 20.

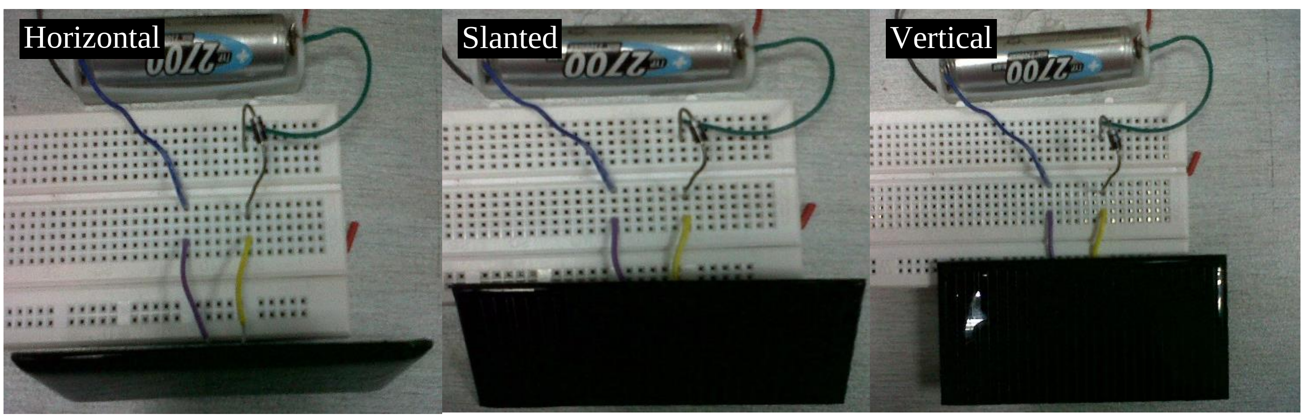


Figure 18: Solar Charger Experiment

Figure 19 shows the graph of battery and solar cell voltage with time. Based on the graph, the peak hours for solar cell to harvest light energy are at 12 noon and 3pm. The voltage of solar cell without load connected start to decrease at 4pm and at its minimum starting from 9pm. Note that the time for this experiment is between 8am and 9pm. It is assumed that there is no light source beyond this period. From the graph, the battery cell need approximately 5 hours to be fully charged during the day. At night, battery voltage will only be charge to compensate the power loss by the device itself.

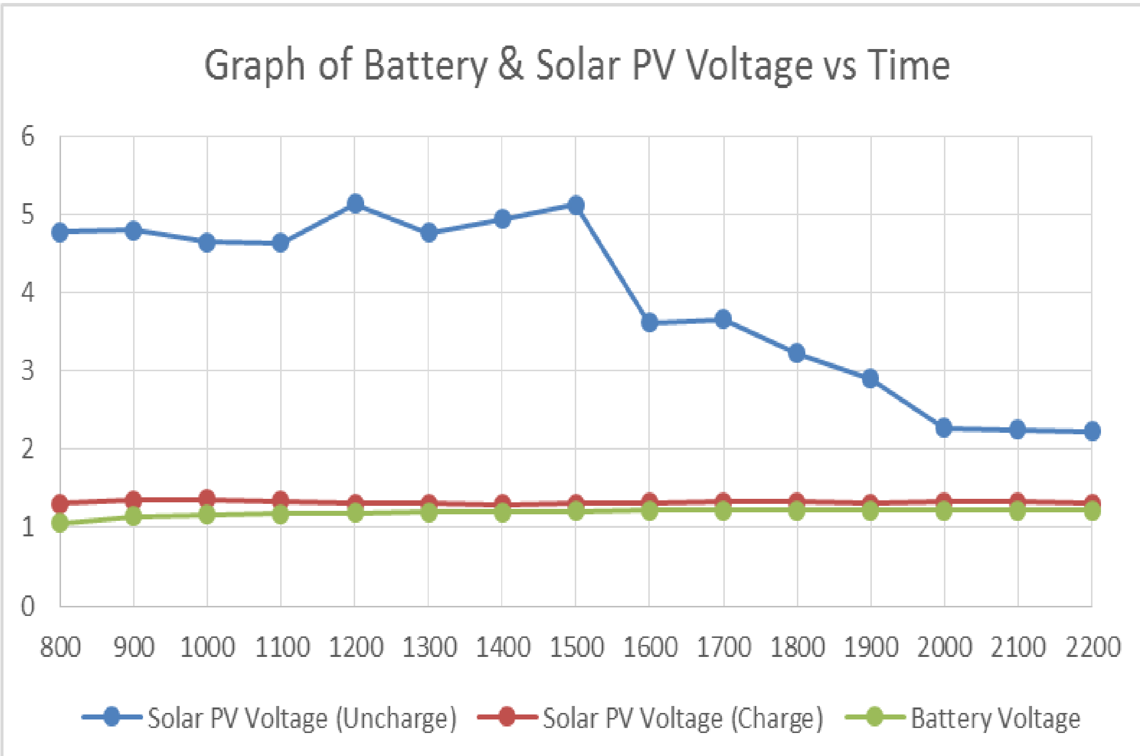


Figure 19: Graph of Battery and Solar Cell Voltage with Time

Figure 20 shows the graph of battery and solar cell current with time. The current for solar cell, diode and battery is the same since they are connected in series. Based on the graph, the maximum current is produce at 9am and the current start to decrease at 4pm. During this period, the battery is actively charged to compensate power usage during no light source.

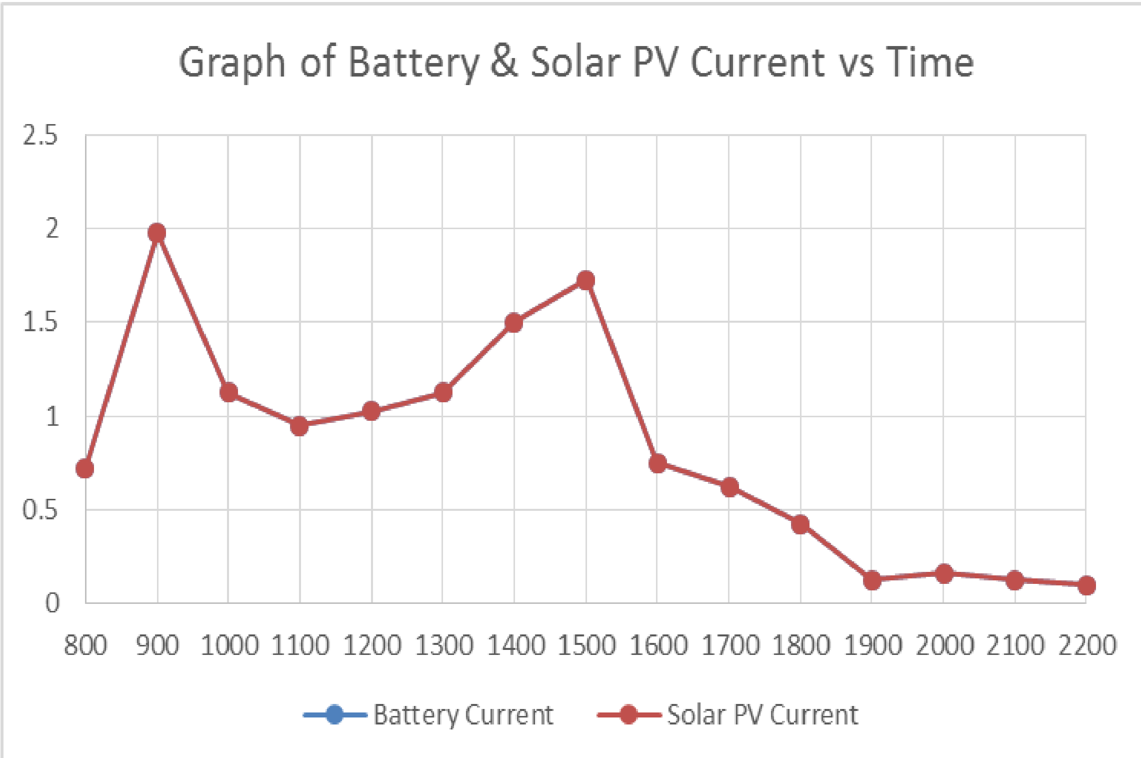


Figure 20: Graph of Battery and Solar Cell Current with Time

By referring to the data provided, analysis has been done to see the efficiency of this solar charger system when it is integrated with an active RFID tag. A typical 1.25V AA battery connected in series to produce output of 3V can last for approximately 3 days if it is actively used. Thus a single 1.2V battery can last for 29 hours. By using this solar charger system, the battery only take 5 hours to be fully charge. Thus it is proven that this solar power charger is capable to avoid monitoring disturbance since the battery will always be charging.

4.6 Tag Design

Figure 21 shows the 3D view and Figure 22 shows the plan view and side view of the tag design. The strap shall be made from bendable material and comfortable to use by patient. Velcro is use so that the tag can be removed easily during emergency and easier to be adjusted. PV cell is to be mounted on top of the box to allow for maximum light intensity. The box will store the active RFID Tag and circuitry together with rechargeable battery. All materials are to be made from lightweight material and water resistance to avoid short circuit and at the same time provide comfort to users. Figure 23, 24, and 25 is the fabricated tag design.

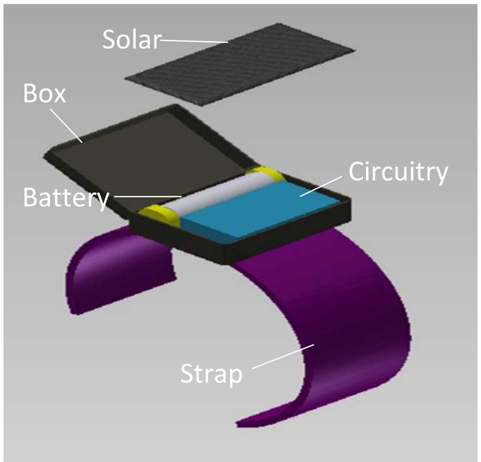


Figure 22: Tag Design in 3D

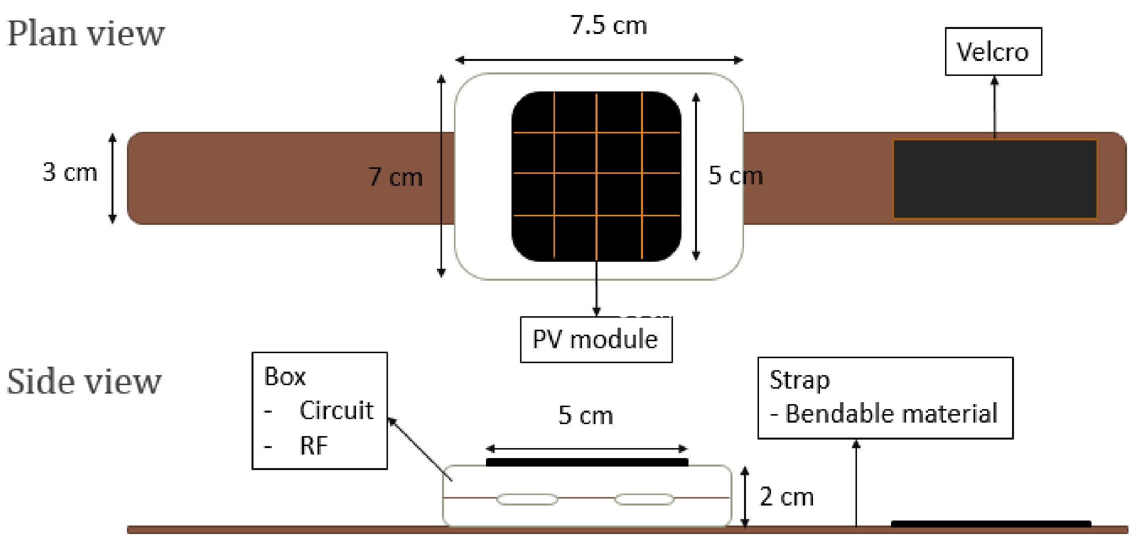


Figure 21: Plan and Side View of Tag Design

Figure 23: Tag Design - Testing

Figure 24: Tag Design - Top View

Figure 25: Tag Design - Inside Box

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Active RFID tags is one of the best device that can monitor patients in hospital. It is durable, operates autonomously and make real time tracking possible. However, the current battery used by the tags limit its performance since it need to be charged frequently. This battery problem can be altered by energy harvesting device which convert ambient energy to electrical energy. Not only this method or device is free, it is also environmental friendly as the energy comes from natural source. For this project, the source of ambient temperature shall focus on solar energy harvested by solar PV.

Concurrently, integration of RFID has been made but in a large scale. This project is therefore aim to integrate small solar module with active RFID tag making it dual powered. The maintenance cost of RFID tag can be reduced when solar is used as an alternative source of power. Users might not need to frequently change or even charge their RFID device since it is being charge constantly using solar energy making the lifetime period longer. In future, more device and application which need a small energy like RFID tag can use the proposed method and design made in this project.

Although this project is successfully done, there are still room for improvement in order to increase its efficiency and reliability. Firstly, based on datasheet attached in Appendix A, the LTC3105 step up converter is capable to boost voltage as low as 250mV. However, in this project it can only boost from minimum voltage of 0.9V. In future, this converter can be further experimented since it has potential to be use with other low power energy harvester system such as thermoelectric and piezoelectric.

Secondly, hybrid power generator system can be experimented by integrating solar with thermoelectric or other capable energy harvester so that the RFID tag can be powered directly by the system. The ability of thermoelectric generator to produce current and solar to produce voltage should be fully utilize in order to support green technology.

In conclusion, after several months of determination and hard work, all objectives of this project is achieved which is to design, testing and integrate an alternative power generator charger for an active RFID tag using a solar cell. This system can also be used by many other low power autonomous device especially in indoor condition.

REFERENCES

[1] H. Al Nahas and J. S. Deogun, "Radio Frequency Identification Applications in Smart Hospitals," in *Computer-Based Medical Systems, 2007. CBMS '07. Twentieth IEEE International Symposium on*, 2007, pp. 337-342.

[2] S. Garfinkel and B. Rosenberg, *Rfid: Applications, Security, And Privacy*: Pearson Education, 2006.

[3] I. J. Forster, "RFID communication systems and methods," ed: Google Patents, 2007.

[4] K. Domdouzis, B. Kumar, and C. Anumba, "Radio-Frequency Identification (RFID) applications: A brief introduction," *Advanced Engineering Informatics*, vol. 21, pp. 350-355, 2007.

[5] R. Weinstein, "RFID: a technical overview and its application to the enterprise," *IT Professional*, vol. 7, pp. 27-33, 2005.

[6] J. S. Kim, "Active RFID tag," ed: Google Patents, 2009.

[7] L. Zhang and Z. Wang, "Integration of RFID into wireless sensor networks: Architectures, opportunities and challenging problems," in *Grid and Cooperative Computing Workshops, 2006. GCCW'06. Fifth International Conference on*, 2006, pp. 463-469.

[8] J. D. Halamka, K. D. Mandl, and P. C. Tang, "Early experiences with personal health records," *Journal of the American Medical Informatics Association*, vol. 15, pp. 1-7, 2008.

[9] T. B. Johansson and L. Burnham, *Renewable energy: sources for fuels and electricity*: Island Press, 1993.

[10] R. Pitz-Paal, "Chapter 19 - Solar Energy – Concentrating Solar Power," in *Future Energy (Second Edition)*, T. M. Letcher, Ed., ed Boston: Elsevier, 2014, pp. 405-431.

[11] R. R. Rotzoll, "Wake up device for a communications system," ed: Google Patents, 1998.

[12] M. F. b. Haris, "Dual Power Active RFID Tag," Universiti Teknologi PETRONAS, MalaysiaJune 2010.

[13] T. Ishii, M. Motomori, J. Morita, T. Ryu, M. Koto, M. Ishimaru*, et al.*, "Step-up converter," ed: Google Patents, 2010.

[14] F. M. Savio, R. H. Kumar, and M. Sasikumar, "Power Optimisation and Performance Evolution of High Step-Up Solar PV System For Dc Drives‖," *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (IJAREEIE)*, vol. 2, 2013.

[15] M. O. Cernaianu, C. Cirstea, and A. Gontean, "Thermoelectrical energy harvesting system: Modelling, simulation and implementation," in *Electronics*

and Telecommunications (ISETC), 2012 10th International Symposium on, 2012, pp. 67-70.

APPENDICES

APPENDIX I

LTC3105

400mA Step-Up DC/DC Converter with Maximum Power Point Control and 250mV Start-Up

FEATURES

- **Low Start-Up Voltage: 250mV**
- **Maximum Power Point Control**
- **Wide V_{IN} Range: 225mV to 5V**
- **Auxiliary 6mA LDO Regulator**
- **Burst Mode® Operation: I_Q = 24µA**
- Output Disconnect and Inrush Current Limiting
- $V_{IN} > V_{OUT}$ Operation
- Antiringing Control
- Soft Start
- Automatic Power Adjust
- Power Good Indicator
- 10-Lead 3mm × 3mm × 0.75mm DFN and 12-Lead MSOP Packages

APPLICATIONS

- Solar Powered Battery/Supercapacitor Chargers
- Energy Harvesting
- Remote Industrial Sensors
- Low Power Wireless Transmitters
- Cell Phone, MP3, PMP and GPS Accessory Chargers

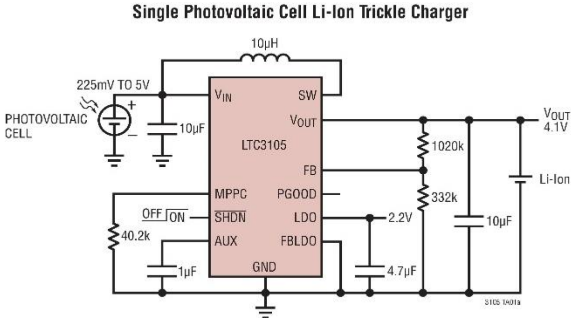
DESCRIPTION

The LTC®3105 is a high efficiency step-up DC/DC converter that can operate from input voltages as low as 225mV. A 250mV start-up capability and integrated maximum power point controller (MPPC) enable operation directly from low voltage, high impedance alternative power sources such as photovoltaic cells, TEGs (thermoelectric generators) and fuel cells. A user programmable MPPC set point maximizes the energy that can be extracted from any power source. Burst Mode operation, with a proprietary self adjusting peak current, optimizes converter efficiency and output voltage ripple over all operating conditions.

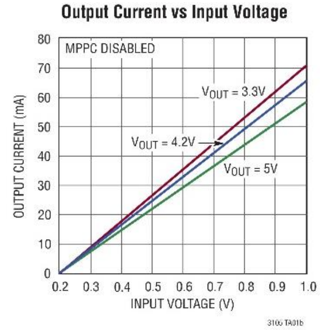
The AUX powered 6mA LDO provides a regulated rail for external microcontrollers and sensors while the main output is charging. In shutdown, I_Q is reduced to 10µA and integrated thermal shutdown offers protection from overtemperature faults. The LTC3105 is offered in 10-lead 3mm × 3mm × 0.75mm DFN and 12-lead MSOP packages.

TYPICAL APPLICATION

Single Photovoltaic Cell Li-Ion Trickle Charger



Output Current vs Input Voltage

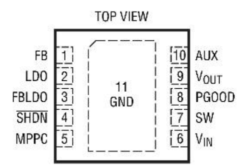


ABSOLUTE MAXIMUM RATINGS (Note 1)

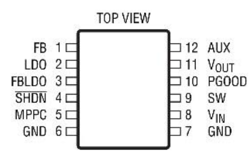
SW Voltage
- DC .... –0.3V to 6V
- Pulsed (<100ns) .... –1V to 7V

Voltage, All Other Pins .... –0.3V to 6V
Operating Junction Temperature
Range (Note 2) .... –40°C to 85°C
Maximum Junction Temperature (Note 4) .... 125°C
Storage Temperature .... –65°C to 150°C
Lead Temperature (Soldering, 10 sec.)
- MS Package .... 300°C

PIN CONFIGURATION



DD PACKAGE
10-LEAD (3mm × 3mm) PLASTIC DFN
T_{JMAX} = 125°C, θ_{JA} = 43°C/W, θ_{JC} = 3°C/W
EXPOSED PAD (PIN 11) IS GND, MUST BE SOLDERED TO PCB



MS PACKAGE
12-LEAD PLASTIC MSOP
T_{JMAX} = 125°C, θ_{JA} = 130°C/W, θ_{JC} = 21°C/W

ORDER INFORMATION

LEAD FREE FINISH	TAPE AND REEL	PART MARKING	PACKAGE DESCRIPTION	TEMPERATURE RANGE
LTC3105EDD#PBF	LTC3105EDD#TRPBF	LFQC	10-Lead (3mm × 3mm) Plastic DFN	–40°C to 85°C
LTC3105EMS#PBF	LTC3105EMS#TRPBF	3105	12-Lead Plastic MSOP	–40°C to 85°C

Consult LTC Marketing for parts specified with wider operating temperature ranges.
Consult LTC Marketing for information on non-standard lead based finish parts.

For more information on lead free part marking, go to: http://www.linear.com/leadfree/
For more information on tape and reel specifications, go to: http://www.linear.com/tapeandreel/

APPENDIX II

LT1073

Micropower DC/DC Converter Adjustable and Fixed 5V, 12V

FEATURES

- No Design Required
- Operates at Supply Voltages from 1V to 30V
- Consumes Only 95μA Supply Current
- Works in Step-Up or Step-Down Mode
- Only Three External Off-the-Shelf Components Required
- Low-Battery Detector Comparator On-Chip
- User-Adjustable Current Limit
- Internal 1A Power Switch
- Fixed or Adjustable Output Voltage Versions
- Space-Saving 8-Pin PDIP or SO-8 Package

APPLICATIONS

- Pagers
- Cameras
- Single-Cell to 5V Converters
- Battery Backup Supplies
- Laptop and Palmtop Computers
- Cellular Telephones
- Portable Instruments
- 4mA to 20mA Loop Powered Instruments
- Hand-Held Inventory Computers
- Battery-Powered α, β, and γ Particle Detectors

DESCRIPTION

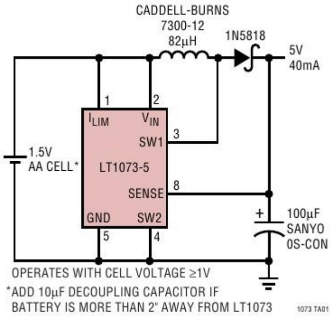
The LT®1073 is a versatile micropower DC/DC converter. The device requires only three external components to deliver a fixed output of 5V or 12V. The very low minimum supply voltage of 1V allows the use of the LT1073 in applications where the primary power source is a single cell. An on-chip auxiliary gain block can function as a low-battery detector or linear post-regulator.

Average current drain of the LT1073-5 used as shown in the Typical Application circuit below is just 135μA unloaded, making it ideal for applications where long battery life is important. The circuit shown can deliver 5V at 40mA from an input as low as 1.25V and 5V at 10mA from a 1V input.

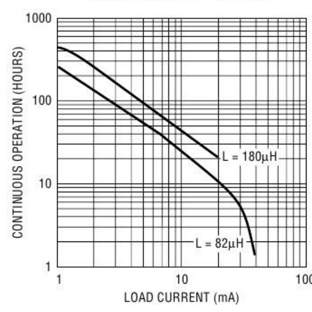
The device can easily be configured as a step-up or step-down converter, although for most step-down applications or input sources greater than 3V, the LT1173 is recommended. Switch current limiting is user-adjustable by adding a single external resistor. Unique reverse-battery protection circuitry limits reverse current to safe, nondestructive levels at reverse supply voltages up to 1.6V.

TYPICAL APPLICATION

Single-Cell to 5V Converter



Single Alkaline "AA" Cell Operating Hours vs DC Load Current

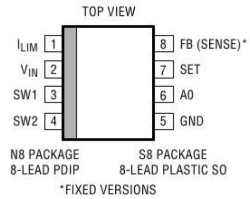


ABSOLUTE MAXIMUM RATINGS

(Note 1)

Supply Voltage, Step-Up Mode 15V
Supply Voltage, Step-Down Mode 36V
SW1 Pin Voltage 50V
SW2 Pin Voltage .... –0.4 to V_{IN}
Feedback Pin Voltage (LT1073) 5V
Switch Current 1.5A
Maximum Power Dissipation 500mW
Operating Temperature Range .... 0°C to 70°C
Storage Temperature Range .... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) .... 300°C

PACKAGE/ORDER INFORMATION



T_{JMAX} = 125°C, θ_{JA} = 100°C/W (N8)
T_{JMAX} = 125°C, θ_{JA} = 120°C/W (S8)

ORDER PART NUMBER
LT1073CN8
LT1073CN8-5
LT1073CN8-12
LT1073CS8
LT1073CS8-5
LT1073CS8-12
S8 PART MARKING
1073
10735
107312

Consult factory for parts specified with wider operating temperature ranges.

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = 1.5V unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS			MIN	TYP	MAX	UNITS
I_Q	Quiescent Current	Switch Off		●		95	130	µA
I_Q	Quiescent Current, Step-Up Mode Configuration	No Load	LT1073-5 LT1073-12			135 250		µA µA
V_{IN}	Input Voltage	Step-Up Mode		●	1.15 1.0		12.6 12.6	V V
		Step-Down Mode		●			30	V
	Comparator Trip Point Voltage	LT1073 (Note 2)		●	202	212	222	mV
V_{OUT}	Output Sense Voltage	LT1073-5 (Note 3) LT1073-12 (Note 3)		● ●	4.75 11.4	5 12	5.25 12.6	V V
	Comparator Hysteresis	LT1073		●		5	10	mV
	Output Hysteresis	LT1073-5 LT1073-12		● ●		125 300	250 600	mV mV
f_{OSC}	Oscillator Frequency			●	15	19	23	kHz
DC	Duty Cycle	Full Load (V_{FB} = V_{REF})		●	65	72	80	%
t_{ON}	Switch ON Time			●	30	38	50	µs
I_{FB}	Feedback Pin Bias Current	LT1073, V_{FB} = 0V		●		10	50	nA
I_{SET}	Set Pin Bias Current	V_{SET} = V_{REF}		●		60	120	nA
V_{AO}	AO Output Low	I_{AO} = –100µA		●		0.15	0.4	V
	Reference Line Regulation	$1V \le V_{IN} \le 1.5V$ $1.5V \le V_{IN} \le 12V$		● ●		0.35 0.05	1.0 0.1	%/V %/V
V_{CESAT}	Switch Saturation Voltage Set-Up Mode	V_{IN} = 1.5V, I_{SW} = 400mA		 ●		300	400 600	mV mV
		V_{IN} = 1.5V, I_{SW} = 500mA		 ●		400	550 750	mV mV
		V_{IN} = 5V, I_{SW} = 1A		 ●		700	1000 1500	mV mV
A_V	A2 Error Amp Gain	R_L = 100kΩ (Note 4)		●	400	1000		V/V

APPENDIX III

Bulletin PD-20590 rev. B 11/04

International
IOR Rectifier

1N5818
1N5819

SCHOTTKY RECTIFIER

1.0 Amp

Major Ratings and Characteristics

Characteristics	Values	Units
$I_{F(AV)}$ Rectangular waveform	1.0	A
V_{RRM}	30/40	V
I_{FSM} @ tp = 5 μs sine	225	A
V_F @ 1 Apk, T_J = 25°C	0.55	V
T_J range	- 40 to 150	°C

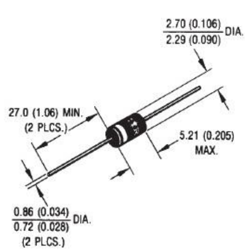
Description/Features

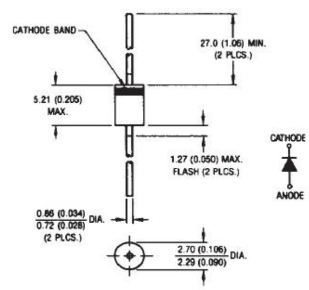
The 1N5818/ 1N5819 axial leaded Schottky rectifier has been optimized for very low forward voltage drop, with moderate leakage. Typical applications are in switching power supplies, converters, free-wheeling diodes, and reverse battery protection.

- Low profile, axial leaded outline
- High purity, high temperature epoxy encapsulation for enhanced mechanical strength and moisture resistance
- Very low forward voltage drop
- High frequency operation
- Guard ring for enhanced ruggedness and long term reliability
- Lead-Free plating

CASE STYLE AND DIMENSIONS

Device Marking: 1N581X





Conform to JEDEC Outline DO-204AL (DO-41)

Dimensions in millimeters and inches

www.irf.com 1

Voltage Ratings

	Part number	1N5818	1N5819
V_R	Max. DC Reverse Voltage (V)	30	40
V_{RWM}	Max. Working Peak Reverse Voltage (V)		

Absolute Maximum Ratings

	Parameters	Value	Units	Conditions	
$I_{F(AV)}$	Max. Average Forward Current * See Fig. 4	1.0	A	50% duty cycle @ T_L =90 °C, rectangular wave form	
I_{FSM}	Max. Peak One Cycle Non-Repetitive	225	A	5µs Sine or 3µs Rect. pulse	Following any rated load condition and with rated V_{RRM} applied
	Surge Current * See Fig. 6	35		10ms Sine or 6ms Rect. pulse	

Electrical Specifications

	Parameters	1N5818	1N5819	Units	Conditions	
V_{FM}	Max. Forward Voltage Drop	0.55	0.6	V	@ 1A	T_J = 25 °C
	* See Fig. 1 (1)	0.71	0.73	V	@ 2A	
		0.875	0.9	V	@ 3A	
		0.5	0.55	V	@ 1A	T_J = 125 °C
		0.61	0.63	V	@ 2A	
		0.77	0.79	V	@ 3A	
I_{RM}	Max. Reverse Leakage Current	1.0		mA	T_J = 25°C	V_R = rated V_R
	* See Fig. 2 (1)	6.0		mA	T_J = 100°C	
		12		mA	T_J = 125°C	
C_T	Max. Junction Capacitance	60		pF	V_R = 5V_{DC} (test signal range 100 to 1Mhz) 25°C	
L_S	Typical Series Inductance	8.0		nH	Measured lead to lead 5mm from pack. body	
dv/dt	Max. Voltage Rate of Change (Rated V_R)	10000		V/µs		

(1) Pulse Width < 300µs, Duty Cycle < 2%

Thermal-Mechanical Specifications

	Parameters	Value	Units	Conditions
T_J	Max. Junction Temperature Range	-40 to 150	°C	
T_{stg}	Max. Storage Temperature Range	-40 to 150	°C	
R_{thJL}	Max. Thermal Resistance Junction to Lead (2)	80	°C/W	DC operation (* See Fig. 4)
wt	Approximate Weight	0.33(0.012)	g (oz.)	
	Case Style	DO-204AL(DO-41)		

(2) Mounted 1 inch square PCB, thermal probe connected to lead 2mm from package