DUAL POWER ACTIVE RFID TAG

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Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
June 2010

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.

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(MOHAMMAD FIRDAUS BIN HARIS)

ABSTRACT

Radio Frequency Identification (RFID) has been around since a few decades. The concept of using Radio Frequency to identify objects dates back to World War II when the RF was used to distinguish between returning English airplanes and the German ones [19]. RFID tags are increasingly being used in many diverse applications in industries nowadays. The capabilities of these tags span from very dumb passive tags to smart active tags, with the cost of these tags correspondingly ranging from a few pennies to many dollars. The application of RFID varies from inventory control, manufacturing lines, pharmaceutical and much more. In this report, a project is developed to improve the lifetime of batteries used in active RFID tag. The improvisation is from 3V lithium ion battery that is currently used to dual power system, that is solar and battery. The project "Dual Power Active RFID Tag" will comprise the knowledge of microelectronics, communication system and also power and energy. The usage of solar power makes it more efficient as to replace the current system of power for active RFID tag. The abundance of solar radiation in Malaysia makes this project feasible. The implementation of the system is discussed, involving the identification of its hardware and the circuit of microelectronics. Improvements on the hardware are also discussed to gain an efficient working system.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

Radio Frequency Identification (RFID) is classified as one of the automatic identification data collection (AIDC). Barcodes, card technologies, magnetic cards, smart cards and optical cards are other technologies that are classified in AIDC [2]. RFID is growing rapidly in today's world and are being implemented in industries such as race timing, passports, transportation payments, product tracking, transportation and logistics, inventory systems and many more [3].

As the name itself, RFID technology works by identifying people and objects by using radio frequency. It is basically divided into two types, passive RFID and active RFID. The difference is that active RFID requires battery while passive RFID doesn't. RFID main components are RFID reader (transceiver), RFID tags (transponder) and its data processing subsystem [4]. Active RFID allows very low-level signals to be received by the tag (because the reader does not need to power the tag), and the tag can generate high-level signals back to the reader, driven from its internal power source. Additionally, the Active RFID tag is continuously powered, whether in the reader field or not. It can be read at distances of one hundred feet or more, greatly improving the utility of the device [3].

Malaysia is a country blessed with abundant of solar energy. Since Malaysia is situated in the equatorial region with an average radiation of 4,500 KWh per square meter, it is an ideal location for large scale solar power installations. Considering that Malaysia gets on an average 4.5 hours to 8 hours of free and bountiful sunshine every day, the potential for solar power generation is very high.

However, at present, Solar Photovoltaic (PV) applications in Malaysia are restricted to rural electrification, street and garden lighting, and telecommunications, while solar water heaters are basically used for heating purposes in hotels, the food and beverage industry, and upper-class urban homes [5]. This PV technology uses semiconductor material to convert sunlight directly into electricity.

The advantages of a photovoltaic (PV) system are numerous: it's non-polluting, there are no moving parts, and it operates silently and requires little maintenance. Photovoltaic power can also be stored in deep-cycle batteries for evening or back-up use [6]. It is estimated that 6,500 MW power can be generated by using only 40% of nation's house-roof tops (2.5 million houses) and 5% of commercial buildings alone. The cost of solar PV system is continuing to decrease and solar energy experts have forecasted that grid parity is expected to be reached by 2015, which means the cost of electricity generated by solar PV is competitive with the cost of electricity generated from conventional energy resources such as gas, coal, oil and nuclear [7].

1.2 Problem Statement

As mentioned earlier, the current active RFID is using battery as its internal power source. This system has its drawbacks such as:

- Lifetime of the battery is short, due to sensors use (consume too much power), e.g. temperature and noise sensor.
- The long-term maintenance costs for an active RFID tag is very expensive and not cost-effective because of expensive battery.
- Battery outages in an active tag can result in expensive misreads.
- Battery outages also may result in security issues due to interruption in monitoring

1.3 Objectives

The objectives of the project are:

- To improve the power system of active RFID tag, making it dual power (solar and battery).
- To induce cost-effective tags, suitable for any application (shorten the battery usage by more than half)
- To improve the reliability of active tag, in terms of effectiveness, longevity and the distance covered by the tag
- To improve the circuit, from using 6V battery to 3V battery and further to 1.5V (if possible)

1.4 Scope of Study

The scope of study will comprise first, communication system. This is to understand more on the characteristics of radio frequency, and the interference that involved with the system. Secondly, microelectronics is involved in order to study on the circuit and configurations of the RFID hardware such as readers, field generators and tags. The circuit of RFID tag and solar system will also be studied. Lastly, the scope will be on power and energy. This is to study on the solar power, its radiation and also the photovoltaic cell (PV). All the characteristics will be investigated. The development of the tag and the system testing can be done within the time frame allocated, as long as each task is done according to plan.

CHAPTER 2
LITERATURE REVIEW

2.1 RFID

Radio frequency identification (RFID) is a common term that is used to describe a system that transmits the identity (in the form of a unique serial number) of an object or person wirelessly, using radio waves. A RFID system consists of two separate components: a tag and a reader. Tags are similar to barcode labels, and come in different shapes and sizes. The tag contains an antenna connected to a small microchip containing up to two kilobytes of data. The reader, or scanner, functions similarly to a barcode scanner; however, a barcode scanner uses a laser beam to scan the barcode, and RFID scanner uses electromagnetic waves. To transmit these waves, the scanner uses an antenna that transmits a signal, communicating with the tags antenna. The tags antenna receives data from the scanner and transmits its particular chip information to the scanner [8].

In length, the data on the chip is usually stored in one of two types of memory. The most common is Read-Only Memory (ROM); as its name suggests, read-only memory cannot be altered once programmed onto the chip during the manufacturing process. The second type of memory is Read/Write Memory; though it is also programmed during the manufacturing process, it can later be altered by certain devices. RFID tags and readers have to be tuned to the same frequency in order to communicate [9].

2.1.1 RFID General Operation Principle

RFID communication involves a two way radio frequency communication process between transceiver (reader) and transponder (tags) via wireless air interface. The principles of RFID operation can be classified into two forms which are reactive / inductive coupling and coupling by propagation of electromagnetic waves [10].

2.1.2 Inductive Coupling and Load Modulation

In general, *Inductive Coupling* is the transfer of energy from one circuit to another through a shared magnetic field. An electrical current passing through the coil of a primary conductor creates a magnetic field that induces an electrical current in the coil of a secondary conductor exposed to the magnetic field. The coupling between the reader and tags is inductive for low and high frequencies (typically 13.56 Mhz) [11]. In inductive coupling, predominantly data in the communication of tags and readers is carried by magnetic field causing coupling to occurs (between primary and secondary coils) in an air-cored transformer.

Electric current is induced in the tag's antenna, which is used to power the integrated circuit and obtain the ID. The data transfer operation between transponder and reader is operated using load modulation. In load modulation, the carrier signal is modulated by switching impedance from a matched condition to an unmatched condition to alter the reflection coefficient. Inductive coupling is usually applied in near field communication system [12].

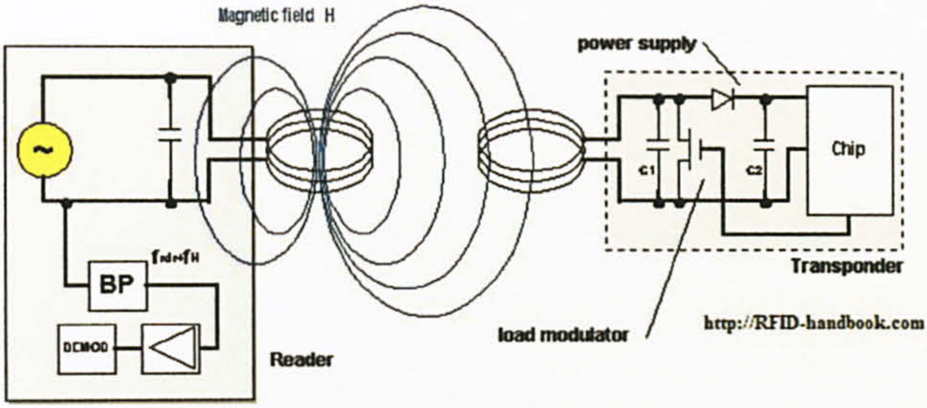


Figure 1: Load modulation circuitry

2.1.3 Propagation Coupling and Backscatter Modulation

Propagation coupling involves ultra-high frequency (UHF). Using electromagnetic field to read and interrogate tags, these system field components dissociates from their source in the reader and propagates into free space [11]. Backscatter modulation is a form of communication method used by transponder to transmit data to transceiver. In other terms, backscattering is also defined as reflected power. This is because, the incident wave radiates by transceiver will be absorbed (part of it), then the rest will be reradiated as a backscatter wave [13]. Propagation modulation and backscatter is usually used in far field communication system.

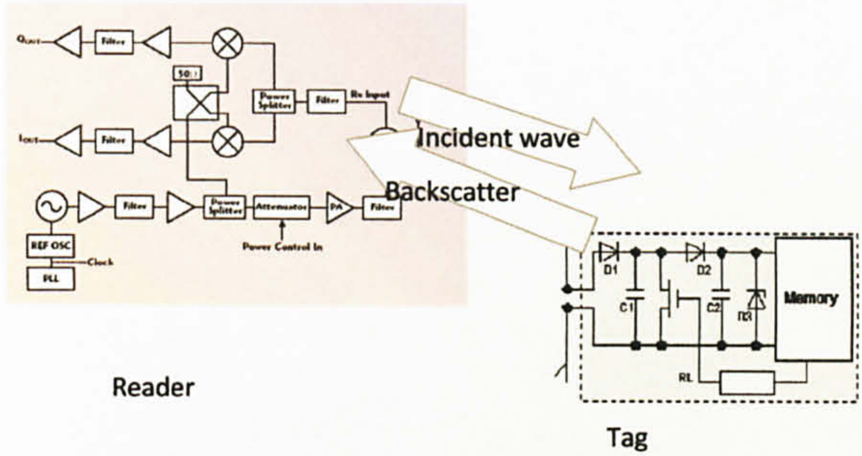


Figure 2: Backscatter modulation circuitry

2.2 RFID Tags

There are two main components present in the RFID tag. Firstly, a small silicon chip or integrated circuit which contains a *unique* identification number (ID) and secondly, an antenna that can send and receive radio waves. These two components can be tiny: the antenna consists of a flat, metallic conductive coil rather than a protruding FM-style aerial and the chip is potentially less than half a millimeter. These two components are usually attached to a flat plastic tag that can be fixed to a physical item. These tags can be quite small, thin and, increasingly, easily embedded within packaging, plastic cards, tickets, clothing labels, pallets and books [14].

There are generally three types of RFID tags: active RFID tags, which contain a battery and can transmit signals autonomously, passive RFID tags, which have no battery and require an external source to provoke signal transmission, and battery assisted passive (BAP) which require an external source to wake up but have significant higher forward link capability providing great read range [3]. This report will be focusing on the passive and active tags only.

2.2.1 *Active Tags*

Active tags have an onboard power supply, which is used to amplify signal from the reader and then transmitting data back to the reader. Because of this, it has longer reading range (up to 100 feet) and doesn't need the RF carrier signal to energize the data processing section [15]. Active tags can hold more data and have the ability to store data from the reader. The data processing and protocols is controlled by microprocessors. For low power consumptions and longer life, sleep mode is introduced. The tag that doesn't go through interrogation mode will stay in sleep mode, thus reserving power. Active tags come in bigger size than the passive one and more expensive. The main advantage is that active tags can be programmed, thus can be used on various items repetitively. It is usually applied to tag variable movement assets, more sophisticated security and sensing.

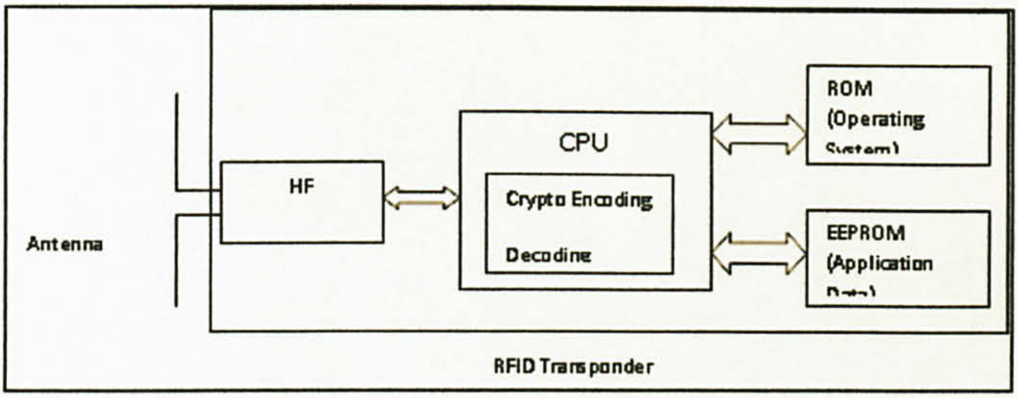


Figure 3: Block Diagram of an Active RFID Tag

Sleep mode is introduced in order to optimize the energy usage for active RFID. In the optimal protocol there would be no energy loss for the tag to detect an RFID-reader and wake up from sleep-mode. The only energy that this optimized tag uses is when transmitting information to the RFID-reader and receiving a confirmation that the RFID-reader has successfully retrieved the tag information. After the received acknowledge message the tag enters deep sleep- mode. The tag stays in this mode for a predetermined time, specified in the acknowledge message from the RFID-reader. The flow chart below shows the typical state operation for a tag executing the optimal protocol. The power consumption in deep-sleep- and sleep-mode for all described protocols is much less than in the wake-modes where the tag is receiving and transmitting [16].

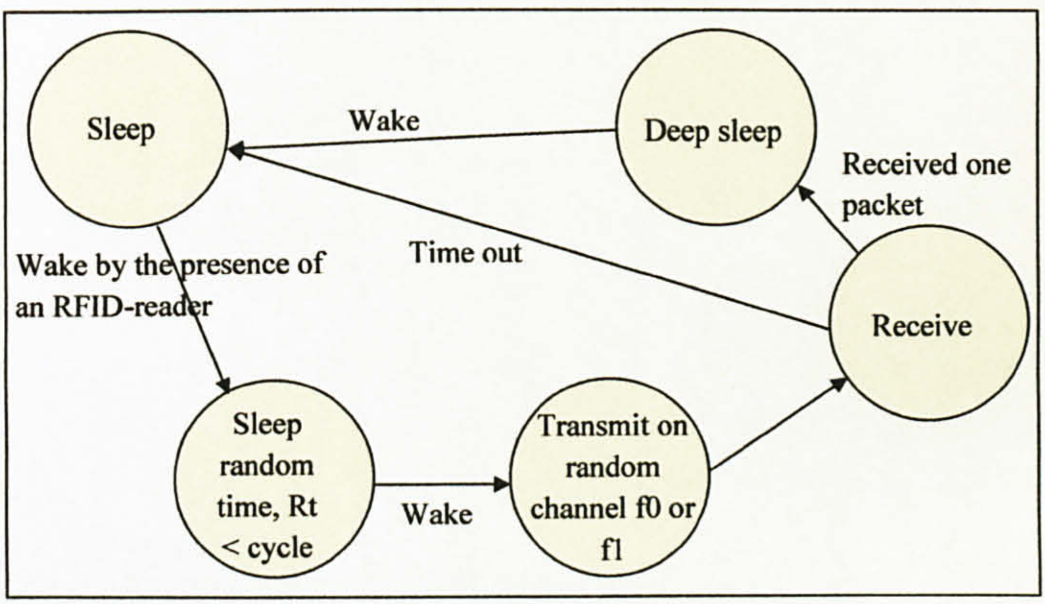


Figure 4: State Diagram of a Tag Executing the Optimal Protocol

2.2.2 Existing Integration of RFID and Solar

Currently, there has been integration made between solar and RFID. A company in US, Savi Technology taps solar energy into readers. Savi Technology, a Lockheed Martin company, has recently begun deploying solar-powered radio frequency identification (RFID) readers and signposts, enabling customers in the defense and commercial sectors to conserve energy and reduce costs while tracking supplies in real-time. Solar energy provides an energy efficient and environmentally friendly power source for users' RFID hardware and also eliminates the need to install electrical infrastructure in remote areas where there is no fixed reader infrastructure [17].

Savi engineers mounted solar panels and RFID signposts on poles located at a major U.S. Army supply facility in Kuwait. The solar-powered signposts activate RFID tags attached to vehicles or pieces of equipment. The tags then report the assets' positions to nearby RFID readers, which relay the information to Savi Site Manager software that automatically updates the assets' latest location. These tools enable the facility to track more than 25,000 tags per day [17].

Savi Networks also operates an RFID-based network in Colombia that also uses solar energy to power Savi RFID signposts and readers that track the status and security of containerized cargo shipments managed by Emprevi Ltda., a Colombia-based provider of logistics and security services for major importers and exporters. Savi Networks, a joint venture in which Savi Technology holds a majority interest, installed solar-powered panels at strategic supply chain checkpoints, including source factories and port facilities, to monitor in-transit goods manufactured in and exported from Colombia [17].

2.2.3 *Active RFID Applications*

Although active RFID are more costly than the passive one, it has its own unique applications in industries which passive RFID can't handle. Some of active RFID applications are:

1. Asset tracking and management
   - Mobile computers, with integrated RFID readers, can deliver a complete set of tools that eliminate paperwork, give positive proof of identification and prove attendance.
   - Web based management tools allow organizations to monitor their assets and make management decisions from anywhere in the world, giving real time information of their valuable assets [18].
2. Headcount system (Internship experience)
   - An emergency headcount system to track and identify missing individuals during emergencies in plants. Applied in PASB, Kerteh.
   - Improve old headcount system in many ways, thus reducing casualties and loss of lives.
3. Inventory control and monitoring
   - Whenever the total inventory at a warehouse or distribution centre drops below a certain level, the RFID enabled system could place an automatic order.
   - RFID-tagged products will allow stores to track the location and count of inventories in real time. This will better monitor demand for certain products and place orders to prevent an out-of-stock situation [3].
4. Airline Baggage
   - RFID tags put at the baggage that travelling around the world, so that it can be tracked.
   - Make airline baggage mishandling a thing of the past [3].

5. Access Control
    - Provides a hands-free access control solution with many advantages over traditional access control badges and systems.
    - Eliminates the need to handle the badge or walk very close to the reader [3].

2.3 Photovoltaic Cell (PV)

When sunlight strikes a PV cell, the photons of the absorbed sunlight dislodge the electrons from the atoms of the cell. The free electrons then move through the cell, creating and filling in holes in the cell. It is movement of electrons and holes that generates electricity. The physical process in which a PV cell converts sunlight into electricity is known as the photovoltaic effect. Normally, a single PV cell can produce up to 2 watts of power, too small for powering calculators or other equipments. In order to increase the power output, PV cells are connected together to form modules, which are further assembled into larger units called arrays. This modular nature of PV has enables designers to build PV systems with various power output for different types of applications [19]. In general, the larger the area of a module or array, the more electricity will be produced. Photovoltaic modules and arrays produce direct-current (dc) electricity. They can be connected in both series and parallel electrical arrangements to produce the required voltage and current combination.

Direct conversion of solar radiation into electricity is one of the advantages of PV cells. Therefore, no mechanical moving parts and high temperature procedures take place for the electrical generation. Besides that, PV will offer zero pollution and the energy source from the sun is free and is available every day. PV has a very long lifetime and provides a very flexible energy source, its power ranging from microwatts to megawatts [19].

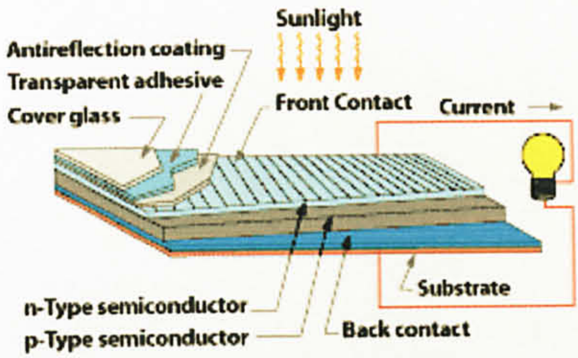


Figure 5: A Typical Solar Cell System

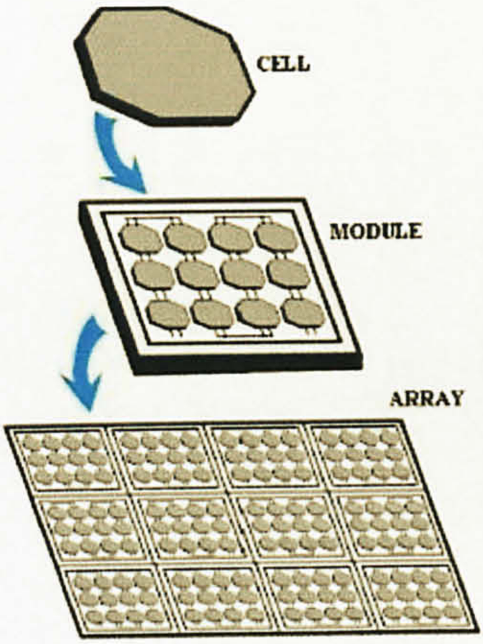


Figure 6: Combination of cells and module to produce array

2.3.1 Types of PV

PV cells are connected electrically in series and/or parallel circuits to generate higher voltages, currents and power levels. PV modules made up of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of PV systems. PV panels include one or more PV modules assembled as a pre-wired, field-installable unit. A PV array is the complete power-generating unit, consisting of any number of PV modules and panels [20].

There are several types of PV modules available in markets which are monocrystalline, polycrystalline, amorphous silicon and thin films.

- Monocrystalline Silicon Cells

  These cells are made from very pure monocrystalline silicon. The silicon has a single and continuous crystal lattice structure with almost no defects or impurities. The principle advantage of monocrystalline cells are their high efficiencies, typically around 15%, although the manufacturing process required to produce monocrystalline silicon is complicated, resulting in slightly higher costs than other technologies [21].

- Multicrystalline Silicon Cells

  Multicrystalline cells are produced using numerous grains of monocrystalline silicon. Multicrystalline cells are cheaper to produce than monocrystalline ones, due to the simpler manufacturing process. However, they tend to be slightly less efficient, with average efficiencies of around 12% [21].

- Amorphous Silicon

  Amorphous silicon cells are composed of silicon atoms in a thin homogenous layer rather than a crystal structure. Amorphous silicon absorbs light more effectively than crystalline silicon, so the cells can be thinner. Amorphous cells are, however, less efficient than crystalline based cells, with typical efficiencies of around 6%, but they are easier and therefore cheaper to produce. Their low cost makes it ideally suited for many applications where high efficiency is not required and low cost is important [21].

- Other Thin Films

A number of other promising materials such as cadmium telluride (CdTe) and copper indium diselenide (CIS) are now being used for PV modules. The attraction of these technologies is that they can be manufactured by relatively inexpensive industrial processes, certainly in comparison to crystalline silicon technologies, yet they typically offer higher module efficiencies than amorphous silicon [21].

2.3.2 *Applications of PV cell*

1. Power Stations
   - A lot of countries have been venturing into solar power stations. This is to replace the source of power from hydro, natural gas, etc. to solar [22].
2. In buildings and housing areas
   - Houses use the solar panel as their source of energy for electrical applications in the house. Installation of the solar panel is expensive and the solar panel itself very costly. Not many people use solar panel as their source of energy [22].
3. Calculators, watches and flashlights
   - For these applications, small PV cells are used. This is because the current that needs to be generated is not too high, compared to other applications [22].

2.4 Inductor

The key factor of completing the circuits is by using inductor. For this particular project, a center-tapped inductor is needed to help the transistor in the boost converter to oscillate; this is with the help of resistor. An inductor works by storing energy in the form of a magnetic field. When current flows through an inductor, it causes a magnetic field in the core and in the case of a rod shaped core, in the surrounding space. When the source of current is removed, the energy stored in the magnetic field rushes back into the inductor as the magnetic field collapses, causing current to flow in the other direction. This effect, something like an electrical equivalent of a spring, is used in many ways [23]. In the case of this particular inductor, when the field collapses, it makes a voltage higher than the voltage that created the field (the amount of voltage is a function of how fast the field collapses) and this makes enough voltage to light the LED even though the LED voltage is higher than the battery voltage.

2.5 Trickle Charge

Trickle charge is associated with the charging of a battery. More often than not, people are considering that charging needs to come along with charge controller to avoid overcharging. Unless a very large solar cell or a very small rechargeable battery is used, there will not be enough current to worry about. In this particular project, charge controller is not needed. Most rechargeable batteries can take a trickle charge of 1/10 their amp-hour capacity for a very long time. Trickle charge is charge at a low rate, balancing through self-discharge losses, to maintain a cell or battery in a fully charged condition [24].

Trickle charging, or float charging, means charging a battery at a similar rate as its self-discharging rate, thus maintaining a full capacity battery. Most rechargeable batteries, particularly nickel-cadmium batteries or nickel metal hydride batteries have a moderate rate of self-discharge, meaning they gradually lose their charge even if they are not used in a device [25].

2.6 Blocking Oscillator

As mentioned before, oscillation is the key in operating the circuits. In this case, blocking oscillation is used to successfully execute the desired operation. A blocking oscillator is the minimal configuration of discrete electronic components which can produce a free-running signal, requiring only a capacitor, transformer, and one amplifying component. The name is derived from the fact that the transistor (or tube) is cut-off or "blocked" for most of the duty-cycle, producing periodic pulses. The non-sinusoidal output is not suitable for use as a radio-frequency local oscillator, but it can serve to flash lights or LEDs, and the simple tones are sufficient for applications such as alarms or a Morse-code practice device. Some cameras use a blocking oscillator to strobe the flash prior to a shot to reduce the red-eye effect [26].

The circuit works because of how capacitors and transistors combine to create an oscillating switch (turns on and off repeatedly). As the current enters the capacitor, it quickly charges it. This creates a tiny delay before the transistor spikes with current at a certain threshold. As the spike of current is transformed into alternating current by the transformer and flows through the speakers, the capacitor recharges, continuing the cycle. Adding a resistor in parallel with the capacitor will control the frequency of the final output. This is caused by the introduction of a new route for electricity to flow, causing some electrons to skip the capacitor and go straight to the base of the transistor, subsequently increasing the time for it to charge enough to switch the transistor, while (because of its parallel positioning) not decreasing the final amplitude (volume) significantly or at all [26].

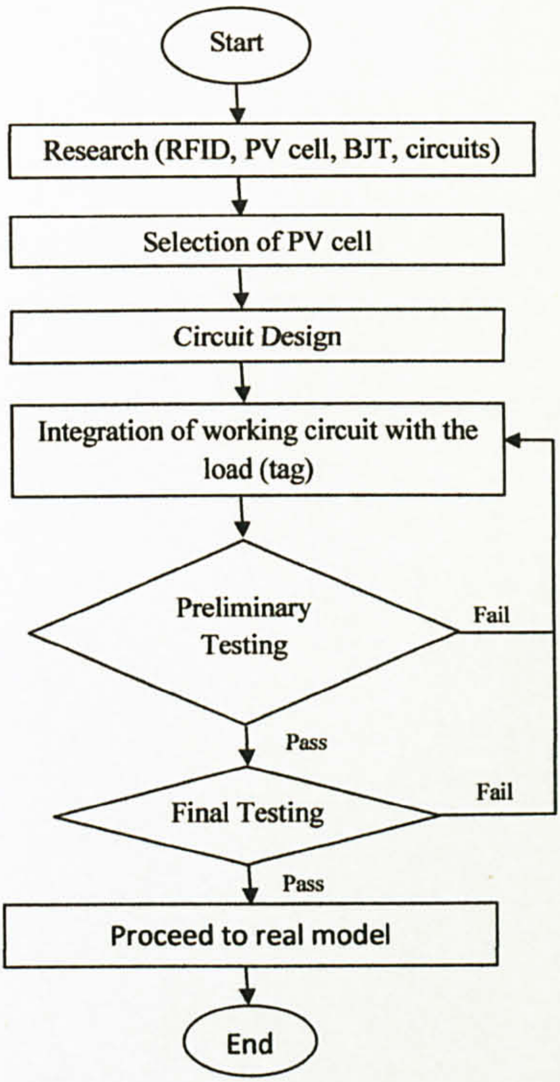
2.7 BJT as a Switch

Another property that is utilized for the circuit operation is by using bipolar junction transistor (BJT) as a switch. Switching is really important, since the circuit is concentrating in the switching task, from solar to battery and vice versa. The bipolar transistor, whether NPN or PNP, may be used as a switch. Recall that the bipolar transistor has three regions of operation: the cut-off region, the linear or active region, and the saturation region. When used as a switch, the bipolar transistor is operated in the cut-off region (the region wherein the transistor is not conducting, and therefore makes the circuit 'open') and saturation region (the region wherein the transistor is in full conduction, thereby closing the circuit) [27].

The bipolar transistor is a good switch because of its large trans conductance G_m, with $G_m = \frac{I_c}{V_{be}}$ where I_c is the collector-to-emitter (output) current and V_{be} is the base-emitter (input) voltage. Its high G_m allows large collector-to-emitter currents to be easily achieved if sufficient excitation is applied at the base [27].

CHAPTER 3
METHODOLOGY

3.1 Procedure Identification



- First of all, all beneficial information and data are collected from sources in order to help understanding more on RFID and photovoltaic cell.
- Design and simulate the circuit for the solar power system, taking into account all the hardware needed.
- Build the working circuit using the components bought.
- The circuit then integrated into the active RFID tag, replacing the lithium battery.
- Repetitive testing is made on the tag that has been equipped with the solar panel and solar circuit.
- The testing is done by calling the tags using the reader

Figure 7: Flow Chart of the Project

3.2 Tools and Equipment Used

Table 1: Hardware and Software Used

Hardware	Software
RFID tag	HOMER
Electrical Tools	PASCO
Solar Cells	DataStudio
	PSpice Schematics

3.3 System Illustration

Basically, all the designed systems are based on this operation. When there is enough sunlight, it generates power more than 30mW, the tag will operate purely on solar power. When there is not enough sunlight, means that the power generated from the sunlight is less than 30mW, the tag will operate on battery power.

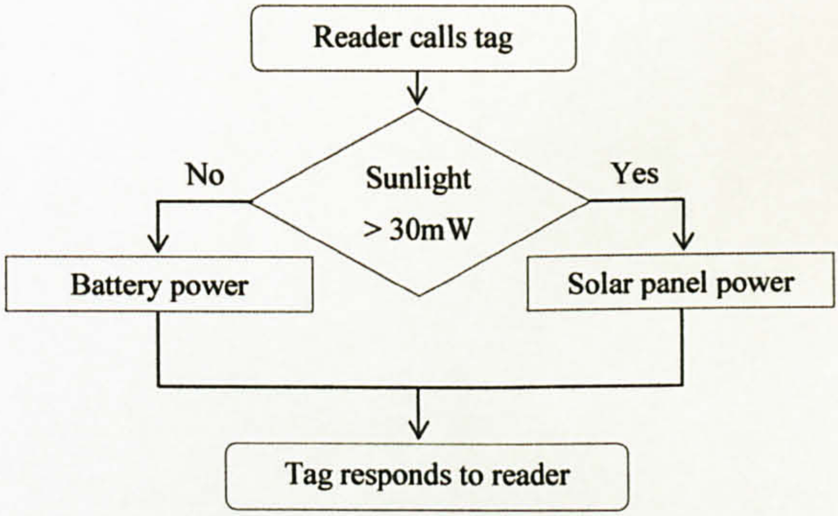


Figure 8: System illustration of the project

3.4 Systems Design

Overall, there are 3 systems that have been invented:

1) 6V circuit – the circuit operates on 6V battery, dual power. When there is enough sunlight, it will operate on sunlight, otherwise will get power from 6V battery.
2) 3V circuit – the circuit operates on 3V battery, dual power, utilizing boost converter, the circuit is more complex than the 6V circuit. Same operation as 6V circuit, except that it uses 3V battery.
3) 3V rechargeable circuit – the circuit operates on 3V rechargeable battery, and uses 2 solar panels. One solar panel is used to power up the tag during daylight, and the other to charge the battery. The operation is as mentioned above. The circuit is more complex than the 3V circuit.
4) 1.5V circuit – the circuit operates on 1.5V battery. The making of this circuit is still on-going, since there are problems on getting it to work.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Findings on PV cells

Firstly, investigation is made on photovoltaic (PV) cell to determine whether this project is feasible, in other words, can the solar panel be small enough so that it can be mounted on top of an active tag. A lot of findings has been discovered on the photovoltaic (PV) cell. At the early stage, research was conducted using PV cells from previous FYP project. The size of the solar panel is quite big, with rated voltage of 7.8V. Tests have been conducted by with utilizing the multimeter and also using PASCO software.

A small size PV cell of similar rated voltage was purchased. This PV cell is more effective, and better in size. Up until now, for this project, 3 types of solar panel have been used, each with different sizes and effectiveness. Measurement of solar radiation was made by using multimeter, under two conditions, direct sunlight and shaded area. Figure 9 and Figure 10 show measurement method and radiation results.

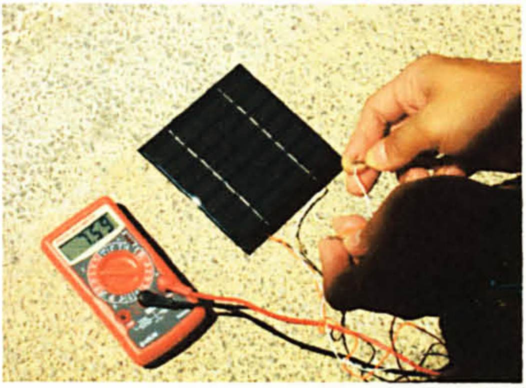


Figure 9: Voltage measured (7.59V)

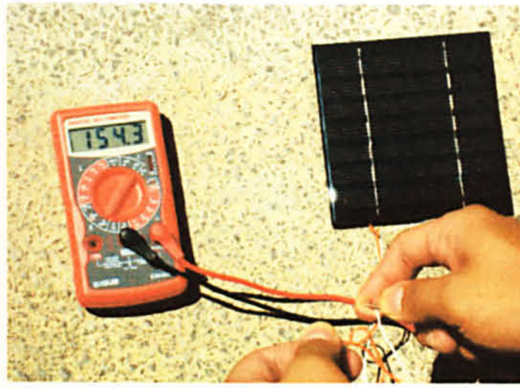


Figure 10: Current measured (154.3mA)


Figure 11: Voltage measured (4.33V)


Figure 12: Current measured (48.5mA)


Figure 13: Voltage measured (4.21V)


Figure 14: Current measured (0.94mA)

For the radiation under shaded area, only current was measured. The amount of current generated was around 7mA for the bigger PV cell and 3mA for the medium size PV cell respectively. The current from the smallest PV cell was 0.98mA which was very low. Therefore, the small PV cell cannot produce enough current to operate an active RFID tag.

From the values that were measured above, we shall observe that the voltage generated from medium size and the small size PV cells were almost the same. The current on the other hand had shown huge differences. Current produced from the medium sized PV cell was enough to power up an active RFID tag. For the purpose of building the prototype, the medium-size PV cell shall be used, due to the voltage and the current that was generated, and its smaller size.

In summary, the power that was generated from the sunlight listed below:

Table 2: Voltage, Current and Power from PV cell

Voltage (V)	Current (A)	Power (mW)
7.59	154.3m	1171.13
4.33	48.5m	210.005
4.21	0.94m	3.9574

4.2 Designed Circuits

For the purpose of testing the prototype, LED is used instead of the tag. This is to minimize the risk of damaging the tag which will be costly. The LED is chosen because it has same voltage and current rating with the standard RFID tag.

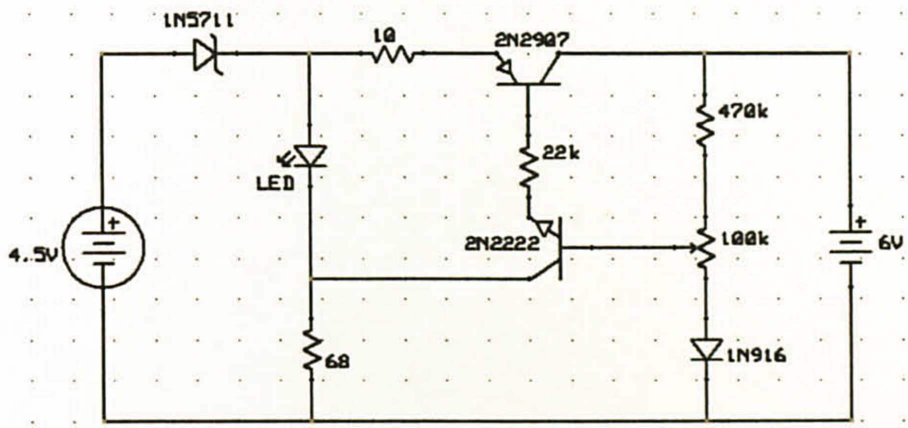


Figure 15: 6V circuit

Figure 15 is the preliminary testing circuit of the tag. It is used to test whether the tag can operate by using outside circuit, instead of its usual batteries. The circuit is using 6V battery, compared to the current system which is using 3V battery. It operates the tag perfectly; it shows that it is possible to operate the circuit with an external circuit of supply.

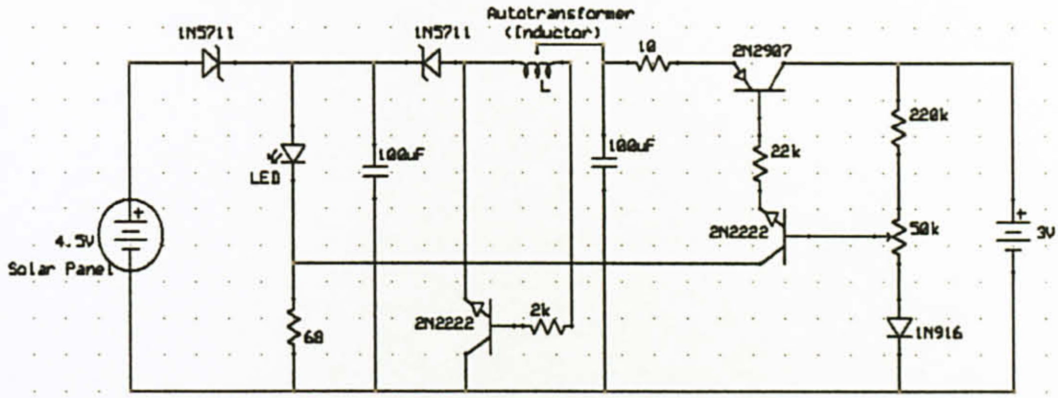


Figure 16: 3V circuit with boost converter

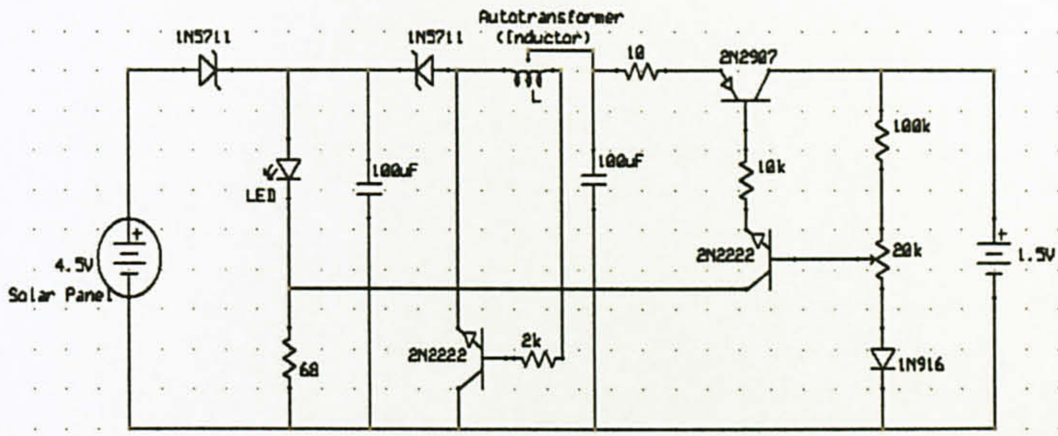


Figure 17: 1.5V circuit with boost converter

Circuits above are designed with boost converter. Boost converter is used to step up the input voltage, from the battery into the load, which is the LED. Even though the battery that is used is 3V, and the LED needs 3V, the batteries' power still needs to be stepped up, due to the dissipation of power in both of the circuits. The power that is dissipating will be compensated by the power stepped up by the boost converter. Theoretically, 1.5V battery can also be used for the circuit, by changing the value of the components, but the reliability is still yet to be determined.

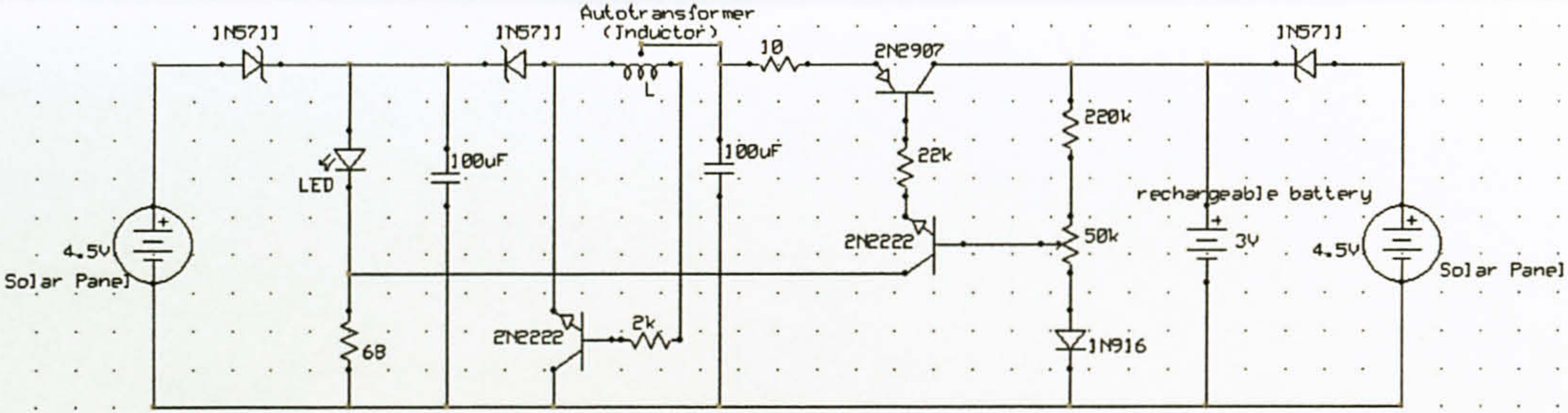


Figure 18: 3V rechargeable batteries with boost converter

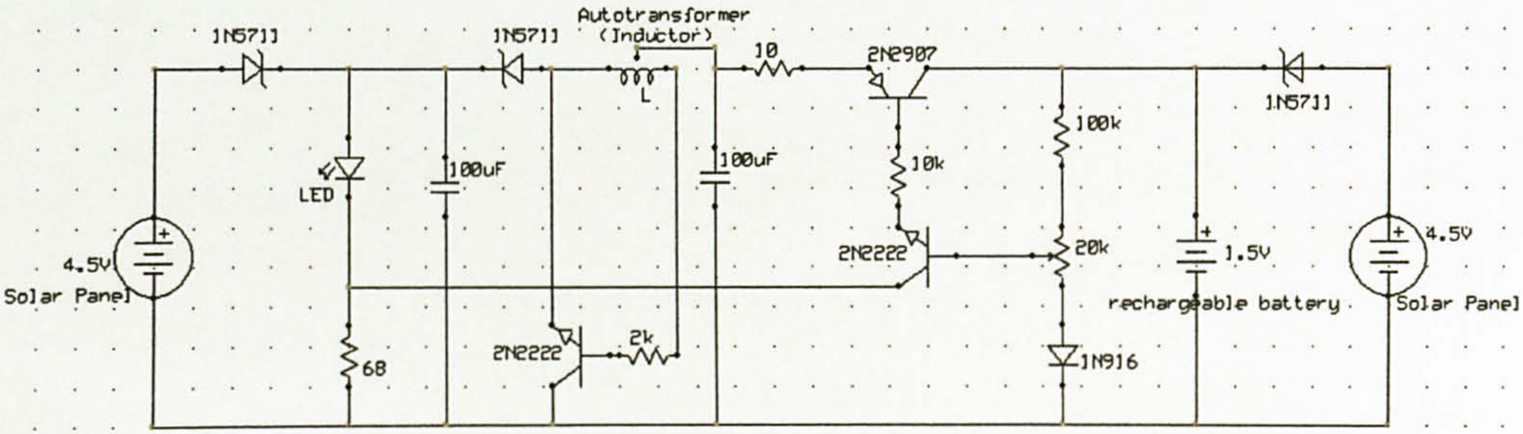


Figure 19: 1.5V rechargeable batteries with boost converter

Basically, there are two parts of circuits in these circuits. One part is the solar panel circuit and the other part is the regulator. The solar panel circuit is simple, with only a Schottky Diode, 1N5711 connected to it. This is a switching diode and is chosen because of its high rate of efficiency, compared to other types of diodes.

The other part of the circuit is regulator. This part is the most crucial, as it plays an important role in determining the success of this project. This part consists of capacitor, inductor, transistor and potentiometer. The vital component in the switching of the circuit, from solar to battery is the potentiometer. The purpose of potentiometer is to set the circuit and to start providing current from the battery, when the current from the solar cell drops below some predefined point. It is adjusted so that the current to start up the regulator is just a little less that the current provided by the solar cell.

Both the circuits in Figure 18 and Figure 19 represent voltage supply circuits using rechargeable batteries. The regulator part of the circuit is added with another solar panel. For the purpose of maintaining the reliability of charging the rechargeable batteries, another solar panel is used. This solar panel will only charge the batteries at daylight, and not supplying current to the circuit. The circuits in Figure 18 and Figure 19 are utilizing the same operation with the circuits of Figure 16 and Figure 17. The only difference is the regulator part. For the regulator part, Figure 18 and 19 is added with the circuit of another solar panel. This part of circuit is used to charge the rechargeable batteries to its capacity.

4.3 Voltage generated from medium-size PV cells

Using Science Workshop 750 Interface from PASCO, voltage that produced from solar radiation is as below:

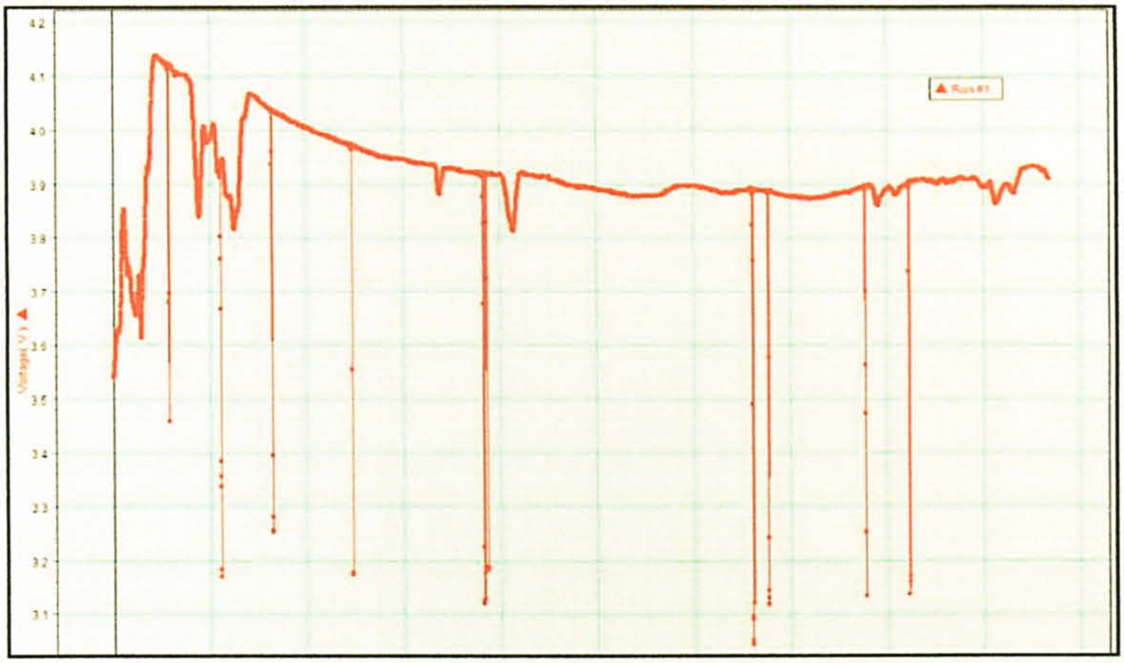


Figure 20: Output voltage of PV cell under direct sunlight

The measurement was made under direct sunlight for 30 minutes. As we can see, the maximum voltage that was generated was around 4.13V. This shows that the PV cell is good enough to operate the RFID tag. The dips in the graph were due to the blockage of PV cell from sunlight. The experiment was done at pathway, where people were walking.

4.4 Boost Converter

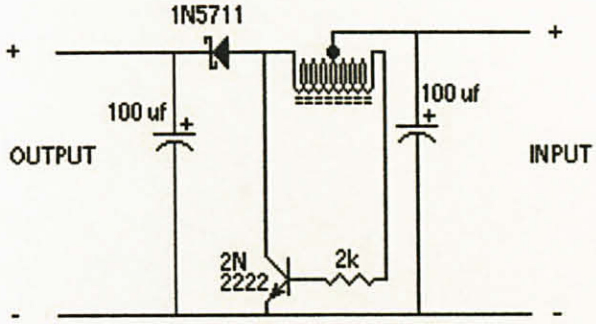


Figure 21: Circuit for boost converter only

The boost converter is drawn backward with respect to the conventional way of drawing schematics diagram, with the output on the left and input on the right, because it makes a neater schematic circuit. The 2N2222 in the boost converter oscillates with the help of the tapped inductor and the 2k resistor. Whenever the 2N2222 turns off, the magnetic field around the inductor collapses, which both helps speed up the turn-off of the 2N2222 and creates a large positive voltage on the collector of the 2N2222. The voltage peak is detected by the 1N5711 and the 100 uF capacitor on the output of the boost converter, and the voltage is effectively limited by the LED.

4.5 Inductor

In the boost converter above, there is a component that is called inductor. The inductor has a tapped connection and it is called autotransformer in some application. The black circle on top of it is the tap connection. The inductor is hand-made, as it is not available in lab or store. A lot of experimentations have been done in designing the right inductor. It is made of a core, which in this case is ferrite and copper wire to wound the core. The tap is the most important part as it is the one that makes this inductor differ than any other inductor.

The purpose of the tap is to make the signal on the base of the transistor the opposite polarity of the signal on the collector. In this circuit, a NPN transistor is used, so when the collector of the transistor turns on, it pushes the base more positive, making the transistor turn on harder, until for some reason, the transistor cannot continue to increase it collector current, at which time, the magnetic field collapses, driving the base of the transistor negative, which turns it over all the faster, resulting in energy being transferred from the magnetic field to the LED.

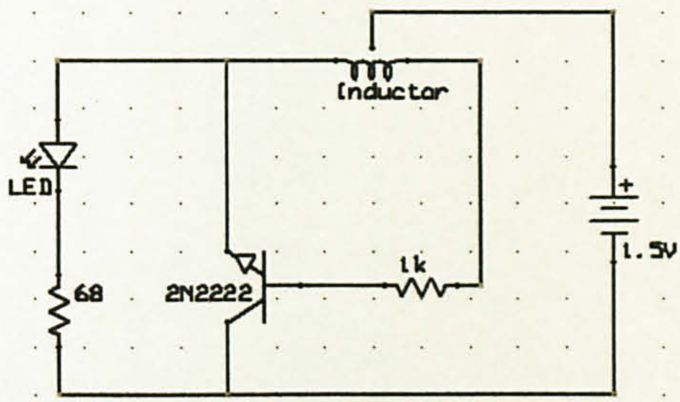


Figure 22: Simplest circuit to test the inductor

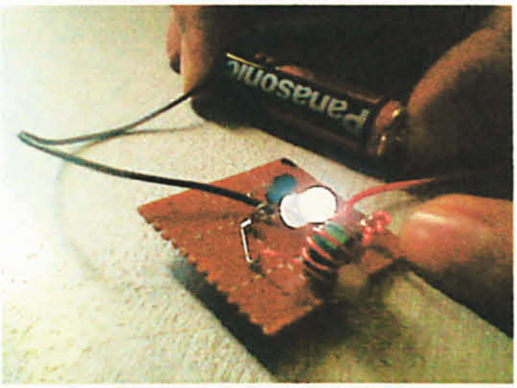


Figure 23: Testing of the inductor

4.6 Rechargeable Battery for Solar Panel

For this project, 1300mAh rechargeable batteries are used. They are connected in series to get the 3V and are used to get the 1.5V, for the circuit in Figure 18 and 19.

Calculations have been done in determining the rationality of the battery, in terms of its rating and capacity.

1300 mAh = deliver 1300mA in 1 hour.
For this particular cell, 1.2V, 1300mAh = 1.56 Watt-hours.
Assume the tag to operate at 20mA, it needs 20mA x 3V = 60mW
The step-up circuit will lose some of its power, let's assume 50%.
If the step-up circuit is 50% efficient, the power that is needed into the step-up circuit = 2 x 60mW = 120mW.
If the cell can deliver 1.5 Watt-hours, then it could power the tag for:
1.5 Watt-hours / 120mW = 12.5 hours.

But it is not that simple. The circuit might become much more inefficient as the battery runs down, so it would not last long.

4.7 Test Run of the Final System

After building and completing the final circuit, tests have been conducted, to determine that the readability of system. The circuit was brought to a place where the sunlight was quite bright, and the power generated at that time was around 40mW.

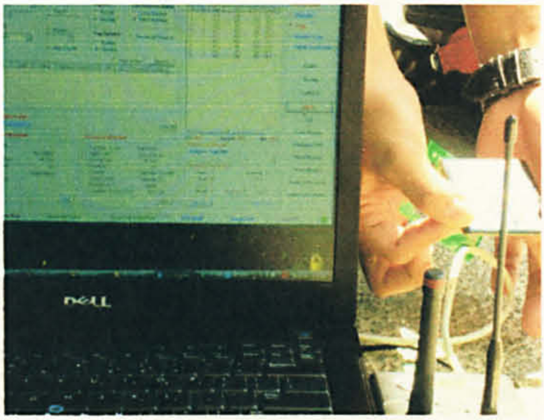


Figure 24: Test run of the final system

From the test, the tag was called and responded to the reader perfectly, without any failure.

4.8 Comparison of Systems

All the system designed has their pros and cons. These systems invented to provide choice for company that will undertake this project. Comparisons are made between them to get clearer picture of which system to choose.

Table 3: Comparison of Systems

Criteria	6V	3V	3V rechargeable
Lifetime	3 days	2.5 days	More than 1 week
Cost (RM)	15	12	20
Reliability	Yes	Yes	Yes
Maintenance	Needed	Needed	Not needed

There are a few criteria to compare. They are lifetime, cost, reliability and maintenance. These criteria are considered as the deciding factor to determine which system is to be implemented. For 6V, the lifetime is 3 days, but still double of the current system. The cost for this system is RM15, for the components and the solar panel. There are not many electronic components used in this circuit. It still needs maintenance because the battery still needs to be changed when it worn out.

For the 3V circuit, the lifetime is two and a half days, less than the 6V but still double as compared to the current system. The cost is cheaper than 6V circuit that is RM12 because it uses 3V battery, but more electronic components as the complexity increases. It also needs maintenance because the battery will need to be changed once it worn out. For the 3V rechargeable circuit, the lifetime is more than a week, and can be considered infinity. This is because the battery will not wear out. Solar panel keeps on charging the battery as needed. One solar panel is used to power up the tag and one other solar panel is used to charge the battery. It is more expensive than the previous circuits because of the two solar panels that are being used. It does not need maintenance because the batteries need not to be changed. Therefore, it can be safely concluded that the 3V rechargeable is the best circuit to be implemented even though the price is higher.

4.9 Prototype

Prototype has been built for all the systems. These prototypes illustrate how the real model would be made, along with the solar panel. Solar panel being used is big, because of its low rate of efficiency. These prototypes are for 6V, 3V and 3V rechargeable. Prototype for 1.5V circuit is still yet to be finalized. Circuit of 1.5V is not stable and up until now it cannot produce enough power to operate the tag. But research is still on-going. Below are the figures of these prototypes.

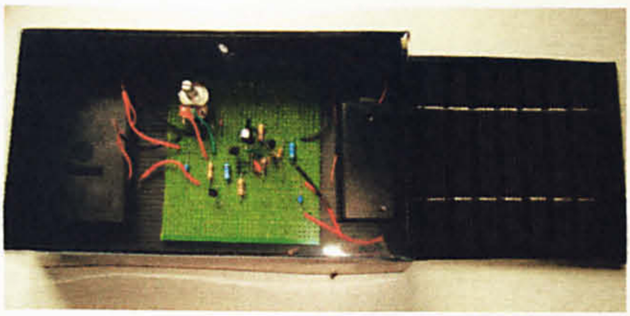


Figure 25: Top view of the 3V rechargeable circuit

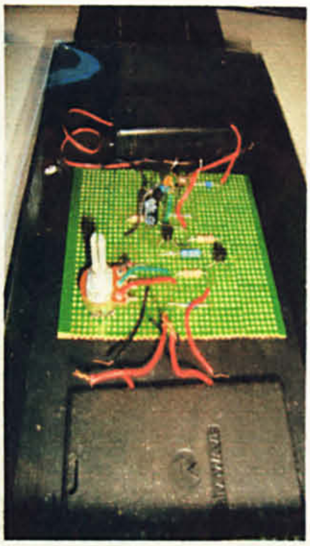


Figure 26: 6V circuit

Figure 25 is showing the prototype of 3V rechargeable circuit, while Figure 26 is showing the 6V circuit. In both prototypes, the circuit is connected to the battery and the tag in the transparent box. The solar panel is also connected to the circuit, illustrating how it is going to be made for real implementation. Figure 27 is showing all the prototypes arranged side by side, that is the 6V circuit (right), 3V circuit (left) and also 3V rechargeable circuit (centre).

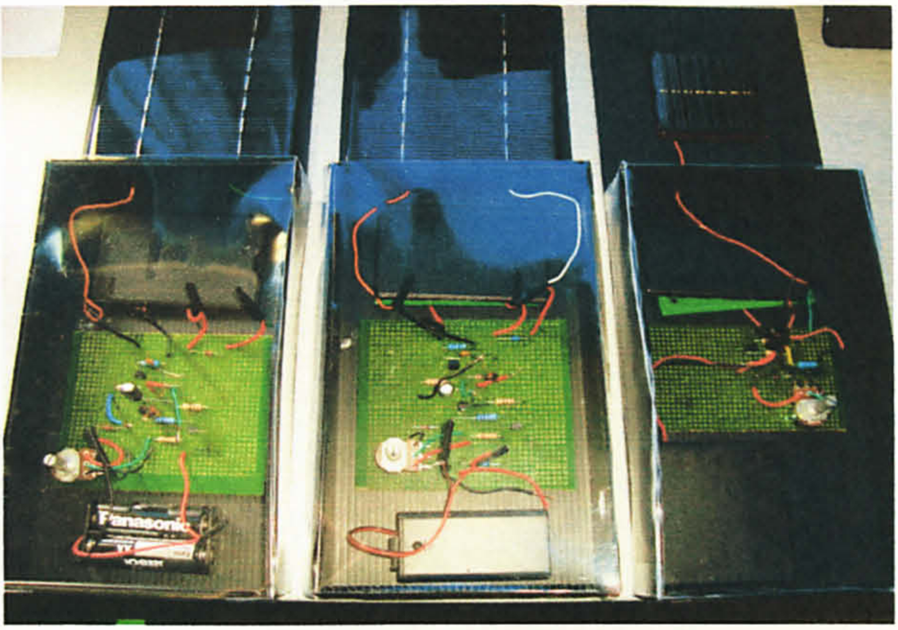


Figure 27: Circuit of all the systems

4.10 Letter of Intent

This project has been recognized by Consurv Technic Sdn. Bhd, Solartif Sdn Bhd and also ActiveWave Inc. Consurv Technic (M) Sdn Bhd is an established company, providing services and supplies to a multitude of industries with special focus on Oil & Gas. Consurv Technic (M) Sdn Bhd specializes in Radio Frequency Identification (RFiD) solutions, providing clients with state of the art technology in meeting their needs in assets and people tracking. Solartif, a solar company based in Terengganu, is willing to collaborate in research and development (R&D), and has been supplying solar panels that are needed for the project. ActiveWave Inc. on the other hand is a RFID manufacturer from US, and they have agreed to collaborate in commercializing the end product should it works and meet its standard and specialization. Consurv Technic has given Letter of Intent to show their intention in commercializing this project, as shown in Appendix A.

4.11 Actual Implementation

4.11.1 Printed Circuit Board (PCB)

The circuits were built in the earlier stage of this project are mounted on breadboard. The purpose of using breadboard is for many testing that need to be done first, to before proceeding to the next step. After the circuits being tested and indicating good results, then we proceeded to assembling the circuit on Vero board. Tests also were conducted to determine whether the circuits built on these Vero board was working perfectly.

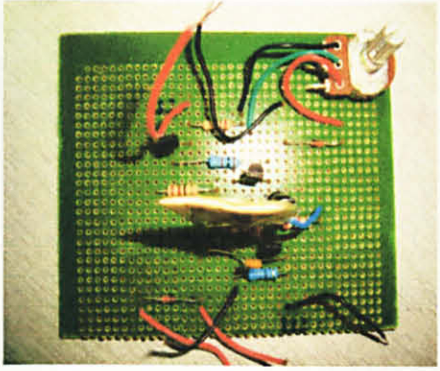


Figure 28: 3V circuit on Vero board

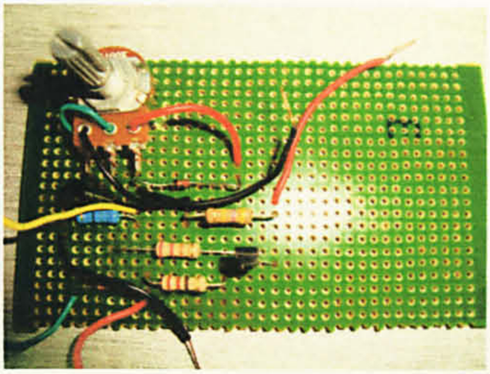


Figure 29: 6V circuit on Vero board

Finally, all these circuits will be fabricated on printed circuit board (PCB). ActiveWave Inc. has agreed to fabricate this PCB once it is tested good and up to the standard. Figure 28 and 29 show that the sizes of these circuits are big. So, once it is mounted on PCB, it shall be small enough to be fit on top of tag casing.

4.11.2 Solar Panel

From Figure 27, it can be seen that the circuit is using a big solar panel. For commercialization purposes later, small size solar panels will be used, small enough to be nicely mounted on top of the tag. These small solar panels will be supplied by Solartif Sdn Bhd, the company that is collaborating with Consurv Technic Sdn Bhd.

Solartif will be assisting in providing PV cell, for the purpose of testing. Up to now, the discussion is on the type of solar panel to be used because the chosen one was polycrystalline silicon, which is not suitable for this application due to its very small size. A proposal was sent to the company requesting for other types of solar panel, which can be less-effective than the polycrystalline but the size is a little bit bigger and easy to handle. Below is the suggested size of the PV cell if polycrystalline silicon were to be used in the model.

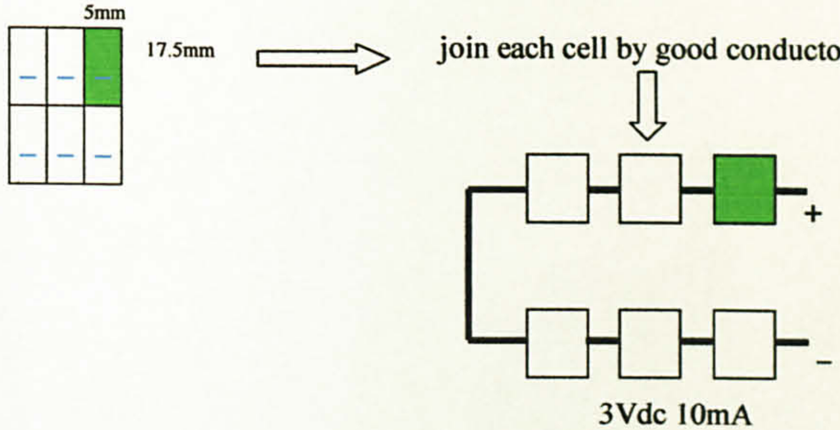


Figure 30: PV cell cutting to fit the rating

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

In a nutshell, this project has a bright future because of the integration that has never been made. There is integration between solar and RFID reader so this integration should be the complement to it. By using solar power as an alternative of power source, it will reduce the cost of maintenance of the RFID system. Users do not need to send their tags to specialists or factory so that the battery can be changed frequently. They also will not need to buy new tags, which will be very costly. They may use the developed active tag powered by solar which will have longer life cycle and more efficient. This project has also awarded silver medal in EDX 25th held on 21-22 April 2010.

5.2 RECOMMENDATIONS

Up until now, the 1.5V circuit it still does not produce the desired output power. 1.5V circuit is the best circuit to be implemented, because the cost would be much lesser than the 3V circuit. Therefore, continue researching and improving the 1.5V circuit is the best thing to do. Another recommendation is, to use better electronic components for the circuits. For example, diode 1N5711 can be used instead of 1N916 and 1N914. This will improve the switching work, hence improve the efficiency of the circuit.

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APPENDICES

APPENDIX A
LETTER OF INTENT

Consurv TECH

Consurv Technic Sdn Bhd
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LETTER OF INTENT

11th January 2010

Dear Sir,

Letter of Intent to Collaborate and Commercialize End Product of Final Year Project (FYP)

We take this opportunity to declare our intention to collaborate and commercialize the end product of a Final Year Project made by Mohammad Firdaus bin Haris (ID 8083), **'Dual Power Active RFID Tag'**. This project is under supervision of Puan Hanita bt Daud, lecturer from the Faculty of Fundamental and Applied Sciences of UTP. Consurv Technic (M) Sdn Bhd is an established company, providing services and supplies to a multitude of industries with special focus in Oil & Gas. Consurv Technic (M) Sdn Bhd specializes in Radio Frequency Identification (RFID) solutions, providing clients with state of the art technology in meeting their needs in asset and people tracking.

In view of the above, we, Consurv Technic (M) Sdn Bhd hereby confirm with full responsibility that we are willing and able to assist the student in completing the project, and proceed to the real model which will be made for the purpose of commercialization. Consurv Technic (M) Sdn Bhd is a strategic partner with ActiveWave Inc., a company based in US, and one of the market leaders in RFID R&D and manufacturing. We also currently are collaborating with a solar company, Solartif Sdn Bhd in doing Research and Development (R&D). Should the end product successfully developed, we will work closely with ActiveWave and Solartif in finalizing it and proceed to the commercialization of the real model.

We understand that this letter of intent is a starting point for further negotiations and operates as a framework under which the joint development can proceed.

We look forward to working with UTP on this important business proposal.

Thanking you, we wish to remain.

Sincerely,

(Faiz H. Hussin)
Managing Director