DESIGN AND DEVELOPMENT OF AN INTELLIGENT BATTERY CHARGER STATION

TEOH WEE WEE

UNIVERSITI SAINS MALAYSIA

2009

DESIGN AND DEVELOPMENT OF AN INTELLIGENT BATTERY CHARGER STATION

by

TEOH WEE WEE

Thesis submitted in fulfillment of the requirements
for the degree of
BEng. (Electrical Engineering)

March 2009

ACKNOWLEDGEMENTS

Throughout the whole final year's project during my final year, I have learned a lot and at the same time enriched my knowledge. The most proud thing is that I had applied the theoretical knowledge that I gained into practical use. I am grateful that I was able to do my project in the final semester before I begin my working life. For that, I would like to take this opportunity to express my deepest appreciation to the School of Electrical and Electronic, University of Sains Malaysia for providing me this project. I would also sincerely thank my supervisor, Dr. Dahaman Ishak for his invaluable ideas and advices, particularly provided the necessary assistance whenever I faced a problem. I really appreciate all the guidance, advices and support given by Dr. Dahaman Ishak throughout this project.

Besides, I would also like to thank the technical staff in the school lab for their guidance and help in using the lab tools. My friends help who offered assistance in many and varied ways in order to complete this project was greatly appreciated too.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

ADC	Analog-to-digital converter
BJT	Bipolar junction transistor
FCP	Fast charge process
IBC	Intelligent battery charger
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
PCB	Printed circuit board
PWM	Pulse width modulation

ABSTRAK

Thesis ini mempersembahkan rekabentuk pengecas bateri pintar yang boleh mengecas empat NiMH bateri serentak. Ia direkabentuk untuk memenuhi keperluan aplikasi arus tinggi dan pemberian cas yang cepat seperti kereta elektrik yang menggunakan bateri sebagai punca tenaga. Tujuan rekabentuk ini ialah untuk menghasilkan kaedah pemberian cas yang cekap dengan menggunakan mikropengawal PIC16F877 untuk melindungi bateri daripada pemberian cas yang berlebihan dan juga megurangkan masa mengecas. Rekabentuk ini mempunyai kelebihan untuk tujuan menyahcas. Kawalan dan penyeliaan untuk seluruh process dikawal oleh mikropengawal, ia ada kebolehan untuk mengenalpasti voltan awalan bateri , mengambil langkah untuk mengecas bateri dan mengenalpastikan bila proses mengecas berhenti. Rekabentuk ini membekalkan beberapa pilihan arus untuk mengecas dengan cara memilih kadar mengecas yang sesuai untuk bateri. Kaedah megecas diprogramkan ke dalam mikropengawal dengan menggunakan PIC Basic Pro. Rekabentuk ini menggunakan empat kaedah biasa iaitu lambat (10%C) , lembut (20%C), cepat (55%C) dan perlahan(4%C). Keputusan eksperimen menyatakan bahawa pengecas bateri ini beroperasi seperti program yang dinyatakan dalam mikropengawal. Regulasi arus berjaya dikawal dengan menggunakan kawalan PWM. Ketepatan menghentikan kitaran pengecasan cepat mempersembahkan kebolehharapan rekabentuk ini. Graf mengecas dan menyahcas yang didapati adalah hampir sama seperti yang dinyatakan dalam teori. Masa mengecas bateri dari kosong kepada penuh adalah hampir dua jam. Voltan bateri pada kitaran akhir mengecas adalah 1.38V/bateri. Kitaran mengecas cepat mengecas bateri kepada hampir 90% bateri penuh. Pembinaan rekabentuk ini memenuhi kehendak objektif dan ia disokong oleh keputusan eksperimen.

ABSTRACT

This thesis presents the design and development of an intelligent battery charger for simultaneous charging of four NiMH batteries. It is designed to satisfy the demands of high current and fast charge applications such as electrical vehicles which use batteries as the electrical source energy. The purpose of this design is to provide an efficient charging algorithm using a microcontroller PIC16F877 in order to protect against overcharging and reduce the recharging time. This design includes the discharging function. In this design, the control and supervision of the whole charging process is entrusted to a microcontroller, which able to find out the initial battery state , decide the fit way to charge the battery (in order to ensure a long cycle-life) and determine when the charge process must be finished. The proposed design provides multiple charging current options with automated selection of optimum charging rate for the battery being charged. The charging algorithm is programmed in the PIC16F877 by using PIC Basic Pro. There are four basic charging algorithm used in this charger: slow (10%C), soft (20%C), fast (55%C) and trickle (4%C). The experimental results obtained show that the charger is functioning properly with the state defined in the microcontroller. The current regulation is successfully done by using PWM control. The accurate termination of fast charging cycle and safe charging of batteries demonstrate the reliable functioning of the proposed design. The charging and discharging curve obtained is almost the same as stated in the theoretical characteristic. The charging time to charge the battery from empty to full is almost two hours. The battery voltage at the end of charging cycle obtained is around 1.38V/battery. The fast charge cycle bring the battery to approximately 90% of the full charge condition. The implementation of design’s objective is fulfilled and is supported by experimental results.

CHAPTER ONE

INTRODUCTION

1.1 Overview

The rapid progress of battery charger in many areas of applications leads to designs of battery chargers to provide high performance and high power demands while meeting low cost requirements. A battery is an electrochemical device that converts chemical energy containing in its active materials directly into electric energy through electrochemical oxidation-reduction reactions. The secondary or rechargeable batteries can be returned to their fully charged state after once discharged. These batteries can be recharged after being exhausted by passing current through them in the opposite direction to that of discharge current. The widely used secondary batteries are Nickel Cadmium (Ni-Cd), Nickel Metal Hydride (Ni-MH) and Lithium Ion (Li-Ion) (Panom Petchjatuporn et. al., 2005).

Among the available choice of portable energy sources, batteries have been the most popular choice of energy source for electrical vehicles since the beginning of research and development programs in these vehicles. The electrical vehicles and hybrid electrical vehicles commercially available today use batteries as the electrical energy source. The types of rechargeable batteries can be considered for electrical vehicles and hybrid electrical vehicles applications are: NiCd (Nickel-Cadmium) and NiMH (Nickel-Metal-Hydride) (Iqbal Husain, 2003). Hence, an intelligent battery charger is suitable to be used in charging station.

Charging battery may seem like an easy and simple task; however it could involve complicated control algorithm. The control algorithm must be able to provide the means to protect the battery from over-charging, which leads to the destruction of the battery. Moreover, a fast-charger is very interested in order to reduce battery recharging-time to a very short period. In recent years, fast-charging has received considerable attention and many techniques have been proposed accordingly. In the fast-charging algorithm proposed with the relation of voltage and temperature at battery (Panom Petchjatuporn et. al., 2005).

Typically, simple battery chargers do not provide the intelligence to charge different battery technologies or battery with the same technology but different voltages and capacities. At best, this may leave the battery improperly charged. At worst, it can pose a serious safety hazard. A microcontroller can provide the intelligence to overcome these problems.

In addition to intelligent control, the microcontroller can provide a low-cost, flexible solution for charging batteries. Complete battery charging applications may be developed quickly using a microcontroller. Add to this the serial communication capability of the microcontroller, real-time data logging and monitoring is possible. Simple battery chargers use all analog components to accomplish their function. However, by using a microcontroller, a battery charger can be made intelligent (Intelligent Battery Charger Reference Design, 2006).

1.2 Objective

The objective of this project is to design and developed an intelligent battery charger using a microcontroller, PIC 16F877. Action plan for this project is as follow:-

1. To develop a charger using intelligent charging algorithm
2. To design a charger with reliable protection against overcharging
3. To design a charger with a short period of recharging time

1.3 Problem Statement

The battery technology is improving at a fairly rapid pace, and the consumers are expected to be able to upgrade and replace the cells every one to three years. The chargers, on the other hand, are a longer-term investment, and charger performance is said to have a significant impact on battery performance. Many battery chargers available in the market today do not provide efficient and reliable charging cycles. This means that the charger may leave the battery improperly charged, which can reduce the battery's life and possibly damage the battery.

Overcharging of the battery is the most common cause of battery failure in a battery charger. The simple charger does not alter its output based on time or the charge on the battery. This simplicity means that a simple charger is inexpensive, but there is a tradeoff in quality. Typically, a simple charger takes longer to charge a battery to prevent severe over-charging. Even so, a battery left in a simple charger for too long will be weakened or destroyed. It does not provide reliable protection against overcharging. Moreover, if a battery left in the battery charger too long, it's lifespan will be reduced.

There is a timer-based charger in the market which is available in the market in order to overcome this problem. Often a timer charger and set of batteries could be bought as a bundle and the charger time was set to suit those batteries. If batteries of lower capacity were charged then they would be overcharged, and if batteries of higher capacity were charged they would be only partly charged. With the trend for battery technology to increase capacity year on year, an old timer charger would only partly charge the newer batteries. Timer based chargers also had the drawback that charging batteries that were not fully discharged, even if those batteries were of the correct capacity for the particular timed charger, would result in over-charging.

The design of a better battery charger would require the charger to sense the condition of cells and charge accordingly. Hence, to perform this task we need a device that can measures, remembers and controls which state the charge should be in. After coupled with some complex characteristics that rechargeable batteries can exhibit, it seemed that logic control circuitry was required. Hence an intelligent battery charger can be designed to overcome this problem. An intelligent charger may monitor the battery's voltage or temperature to determine the optimum charge current at that instant. Charging is terminated when the voltage indicates that the battery is fully charged.

All in all, an intelligent type battery charger is suitable to be used in a charging station since the electrical vehicles and hybrid electrical vehicles commercially available today use batteries as the electrical energy source. It can help to prolong the lifespan of the rechargeable batteries used.

1.4 Methodology

In order to achieve the objectives, the following methodology had been set up.

1. Research on Intelligent Battery Charger is done through book, journal and also online.
2. An intelligent battery charger is designed with the help of the research on this topic.
3. An assembly program is written using PIC basic pro to operate the microcontroller.
4. The hardware is first developed on the breadboard using appropriate component and tested.
5. The layout of the circuit is drawn using ORcad Layout Plus and then is implemented on the Printed Circuit Board (PCB).
6. The circuit is tested again. If the result obtained is not appropriate, then the PCB board should be check. Correction is made until a desired result is obtained.
7. The design of the Intelligent Battery Charger is then presented in the full report.

A flow diagram of this project methodology was drawn and shown in Figure 1.1.

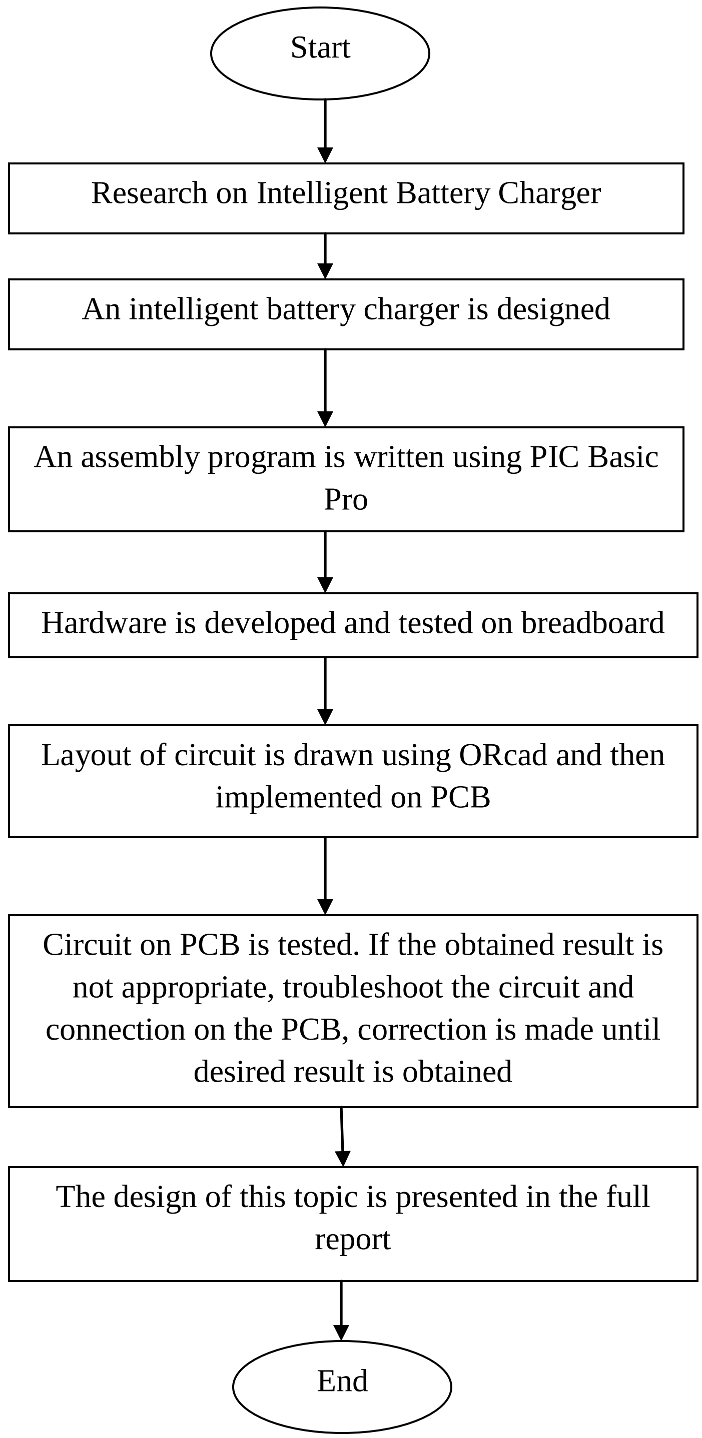

Figure 1.1: Methodology Flow Chart

1.5 Contribution of This Project

The outcome of this project is important in providing a battery charger with intelligent control and shortening the recharging time of the batteries without damaging the batteries. The batteries will have longer life-span due to reliable protection against overcharging. The rapidly expanding feature sets on today's portable electronics products are placing a rising premium on the capabilities of the battery charger function. Consumer will benefit from this device since the ability of the system power source to deliver as much power as possible for as long as possible and recharge as quickly as possible. This becomes all the more important to users (Charles Cole et. al., 2008).

1.6 Outline of Report

- **Chapter 1**
  - This chapter gives a brief introduction on the background and the objective of this project. The problem statement is also included in this topic to give a brief statement of the objective of design and development of an intelligent battery charger station.
- **Chapter 2**
  - This chapter gives a brief theory on the charging and discharging characteristic of the battery, several charging algorithm to provide an intelligent charging, previous work, and some basic theory of operation.
- **Chapter 3**
  - This chapter gives a brief explanation on the proposed designed and the detail on the hardware and software design.

- **Chapter 4**
    - This chapter presents the development of the hardware, results and also discussions on the results obtained.
- **Chapter 5**
    - This chapter shows the conclusions of this project.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

The charging of a battery is made possible by a reversible chemical reaction that restores energy in a chemical system. Depending on the chemicals used, the battery will have certain characteristics. When designing a charger, a detailed knowledge of these characteristics is required to avoid damage inflicted by overcharging (Charging Nickel-Metal Hydride Batteries with ATAVRBC100, 2007).

A battery charger is expected to charge batteries at an optimized charging rate and terminate the charging procedure when the battery is fully charged. The charger design thus strongly relies on a reliable charge termination method adopted. Each battery cell has its own composition and therefore charging curve/characteristics. The battery charger should be knowledgeable enough to comply with such battery specific requirements (Tanvir Singh Mundra, et. al. 2007).

2.2 Charging and Discharging Characteristic of NiCd Battery

2.2.1 Charging Characteristic

The charge characteristics of NiCd batteries are affected by the current, time, temperature and other factors. Increasing the charge current and lowering the charge temperature causes the battery voltage to rise. Charge efficiency will also vary according to the current, time, and temperature. For rapid charge, a charge control system is required. Figure 2.1 below shows the charge characteristic of NiCd battery (Rechargeable Ni-Cd Batteries, 2005).

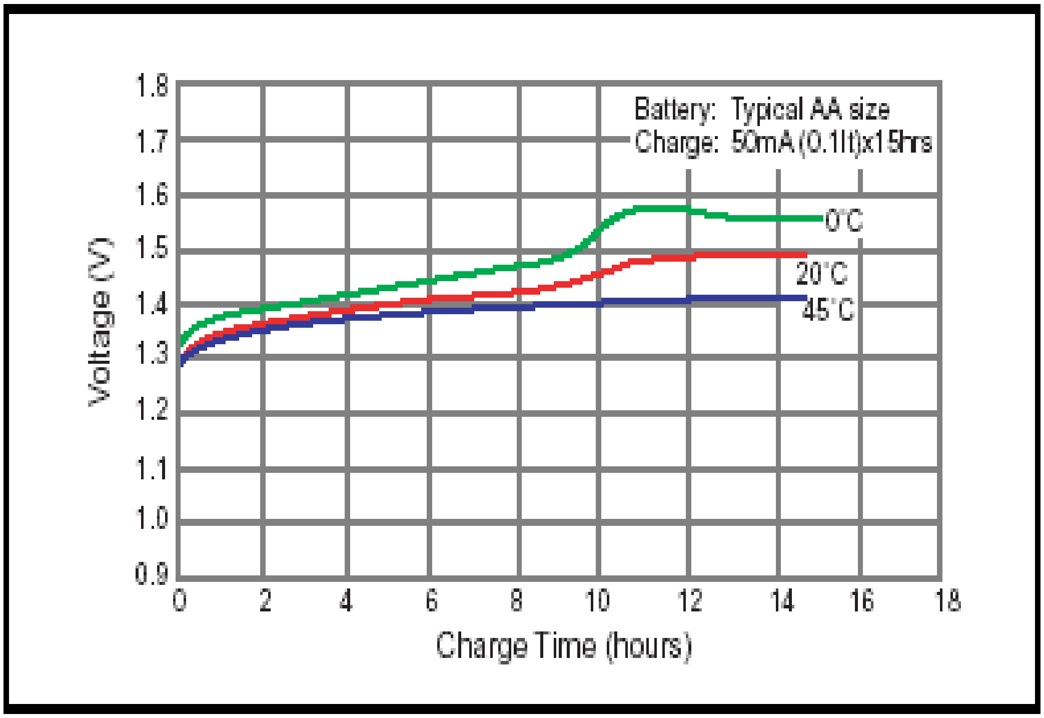

Figure 2.1: Typical charge characteristics of NiCd

2.2.2 Discharging Characteristic

The discharge characteristics of NiCd batteries will vary according to the current, temperature, and other factors. Generally, in comparison with dry-cell batteries, there is less voltage fluctuation during discharge, and even if the discharge current is high, there is very little drop in capacity. Among the various types of NiCd batteries, there are specifically designed to meet the need for high current discharge, such as for power tools, and there are also model such as the Rapid Charge type which are designed to meet the need for high capacity, such as for high-tech devices. Figure 2.2 and Figure 2.3 show the typical self discharge characteristics and typical discharge characteristic of NiCd battery (Rechargeable Ni-Cd Batteries, 2005).

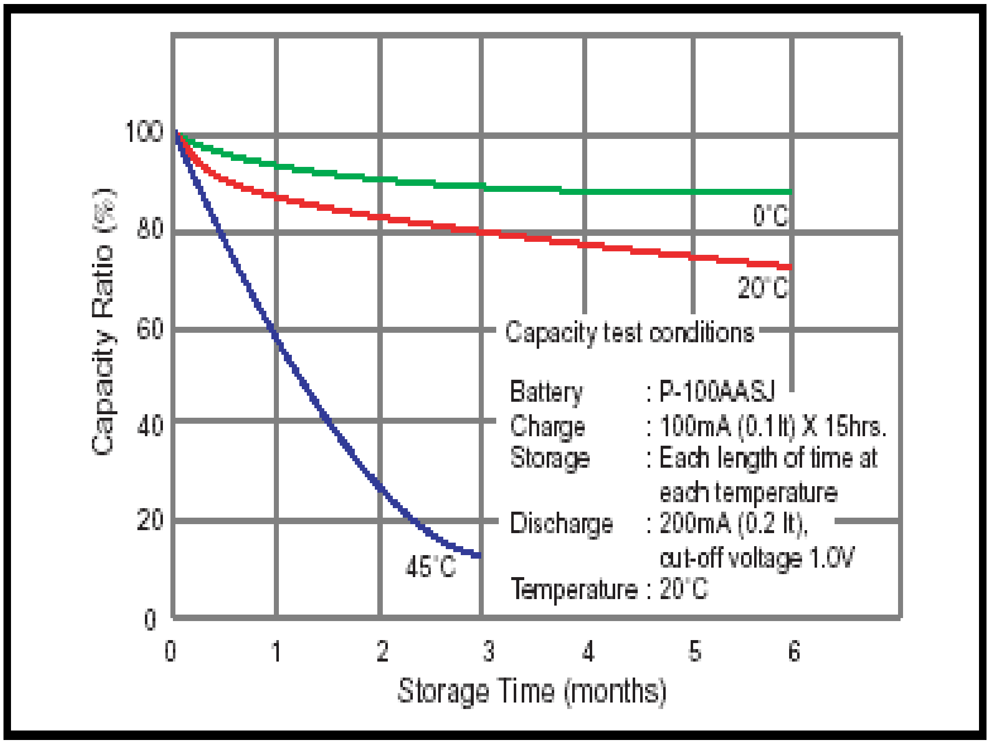

Figure 2.2: Typical self discharge characteristics of NiCd during storage

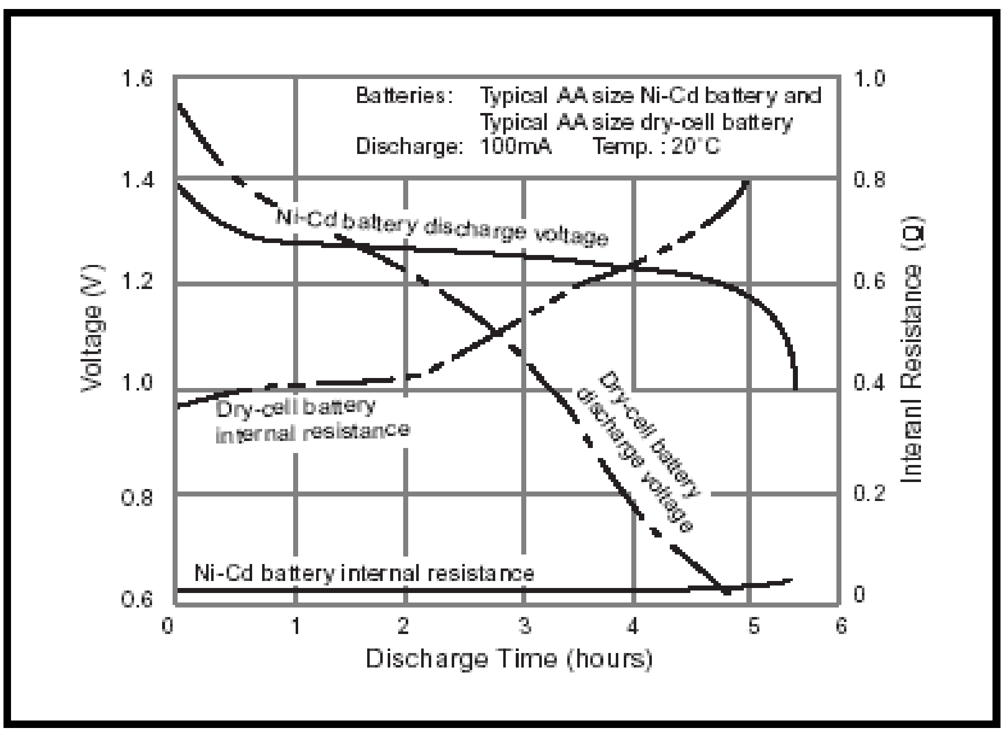

Figure 2.3: Typical discharge characteristics of NICd battery and dry-cell

2.3 Charging and Discharging Characteristic of NiMH Battery

2.3.1 Charging Characteristic

Like NiCd batteries, the charge characteristics of NiMH batteries are affected by current, time and temperature. The battery voltage rises when the charge current is increased or when the temperature is low. The charge efficiency differs depending on the current, time, temperature and other factors. Repeated charge at high or low temperature causes the battery performance to deteriorate. Furthermore, repeated overcharge should be avoided since it will downgrade the battery performance. The charge characteristics of NiMH battery are shown in Figure 2.4 below (Nickel Metal Hydride Batteries, 2005).

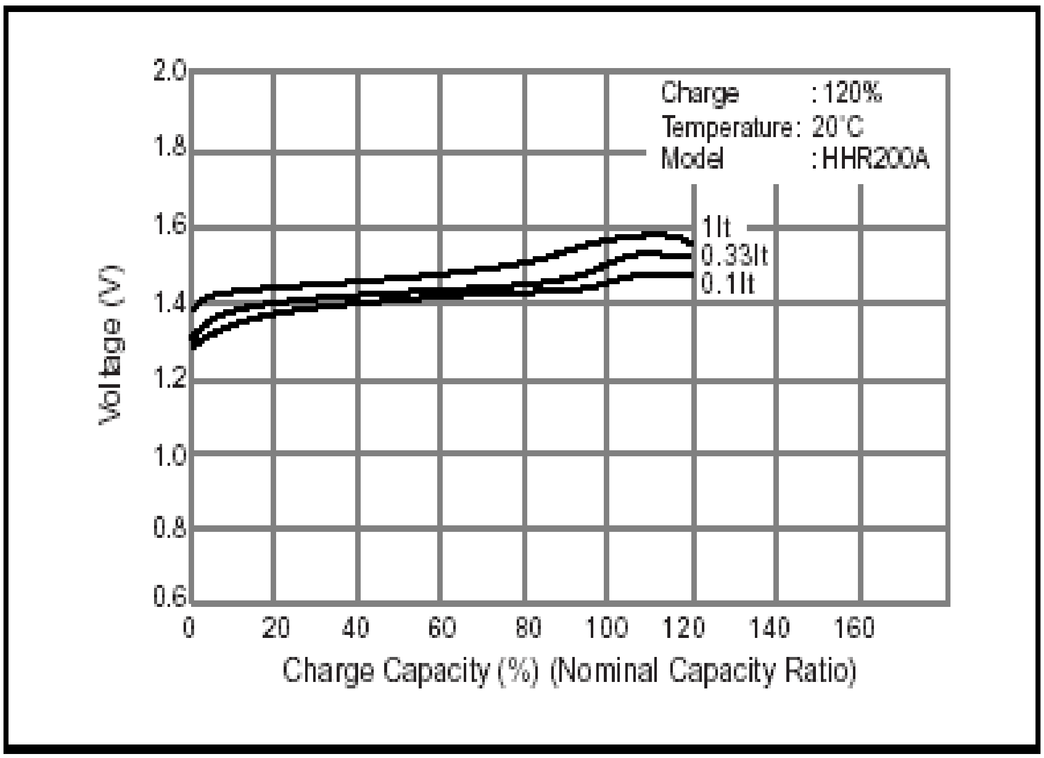

Figure 2.4: Charge characteristics of NiMH

2.3.2 Discharging Characteristic

The discharge characteristics of NiMH batteries are affected by current, temperature, etc., and the discharge voltage characteristics are flat at 1.2V, which is almost the same for NiCd batteries. The discharge voltage and discharge efficiency decrease in proportion as the current rises or the temperature drops. Compared with NiCd batteries, NiMH batteries have inferior high rate discharge characteristics, making them less suitable for use in applications requiring high current discharge. Figure 2.5 shows the discharge characteristics of NiMH batteries (Nickel Metal Hydride Batteries, 2005).

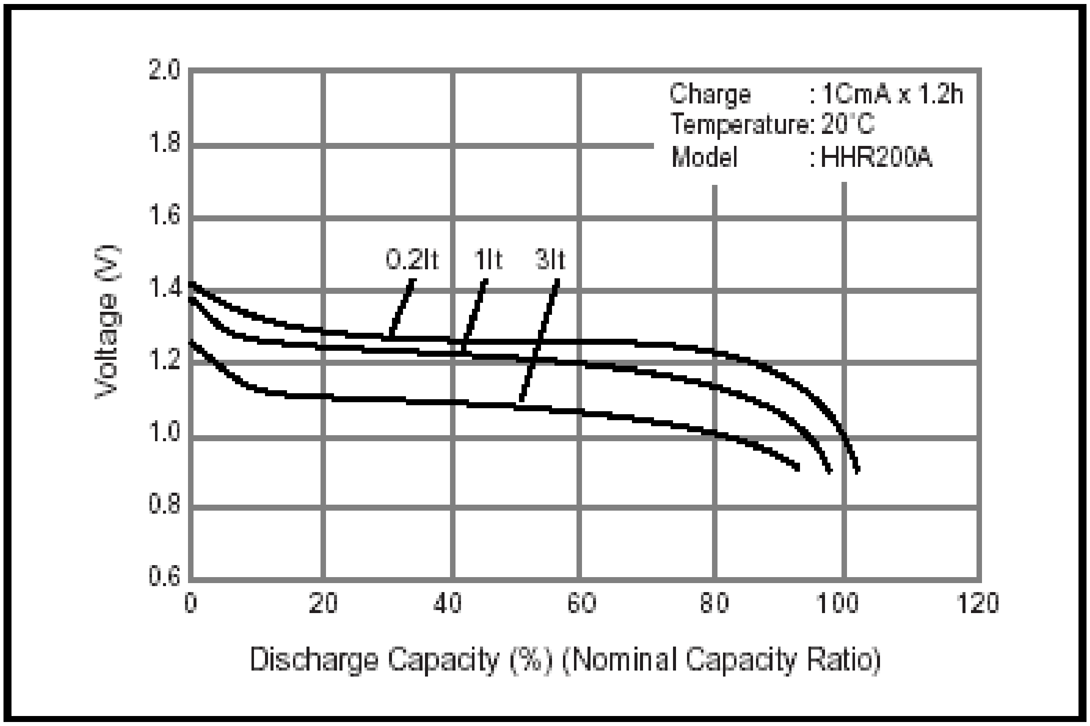

Figure 2.5: Discharge characteristics of NiMH battery

2.4 NiCd Battery Charging Algorithm

NiCd batteries are typically charged with constant current. Most of them can be safely charged at rates up to C/3 (where C is the charge potential) without electronic control, but electronic control helps ensure reliability and efficiency. Charging at high rates up to 2C requires electronic monitoring of battery parameters to detect when the charge cycle is complete (Smart NiCd/NiMH Battery Charger Using MC68HC908QY4, 2004).

2.4.1 Charging Termination Method

- Standard Charging (Overnight)

Charging at rates C/10 and lower takes approximately 15 hours to fully charge the cell or battery. A limited amount of overcharging is acceptable, so it is not necessary to have an accurate end-of-charge detector. However, prolonged overcharging can damage the battery packs. The limitation of this method is the slow recharging time.

- Controlled Charging Time

The charging current is terminated at specific time. This requires knowing the initial amount of charge in the battery, which is simple if the battery is discharged completely. The battery capacity must be known and set by the user. For this method, the battery pack capacity must be specified, but the capacity value is difficult to specify because it changes with age and other conditions. This method is commonly used as a fail-safe method for terminating any charging algorithm. If the charging algorithm does not complete within the predefined amount of time, the charge will terminate.

- Temperature Detection

When the battery reaches full charge, the battery pack will experience a quick rise in temperature. This is due to an increase in the conversion of charging energy into thermal energy. The method uses a sensor to measure the battery temperature. The microcontroller unit will terminate the charge if the measured rate meets or exceeds the stored rate threshold. This method can be adversely affected by ambient temperature and may result in under charge conditions when charged in high ambient temperature environments, or overcharge in low ambient temperature environments.

- Negative Delta V Cut-off Charge System

Batteries are charged at constant current of between 0.5 and 1.0 C rate. The battery voltage rises as charging progresses to a peak when fully charged then subsequently falls. This voltage drop, -delta V, is due to polarization or oxygen build up inside the cell which starts to occur once the cell is fully charged. At this point the cell enters the overcharge danger zone and the temperature begins to rise rapidly since the chemical changes are complete and the excess electrical energy is converted into heat. The voltage drop occurs regardless of the discharge level or ambient temperature and it can therefore be detected and used to identify the peak and hence to cut off the charger when the battery has reached its full charge or switch to trickle charge.

- Trickle Charge

A very small amount of current is applied to the battery. This technique is used when a battery is continuously connected to the charger or as a supplementary charge at the end of a fast charge cycle to replace charge loss due to self-discharge. The recommended rate for trickle charging in most NiCd battery packs is between 0.03C to 0.05C. This method serves to maintain a 100% charged battery when it is left in the charger for some time. There is generally no limit for tickle charging, so it can continue for an indefinite amount of time.

The typical NiCd battery pack voltage and temperature during charge was shown in Figure 2.6 (Smart NiCd/NiMH Battery Charger Using MC68HC908QY4, 2004).

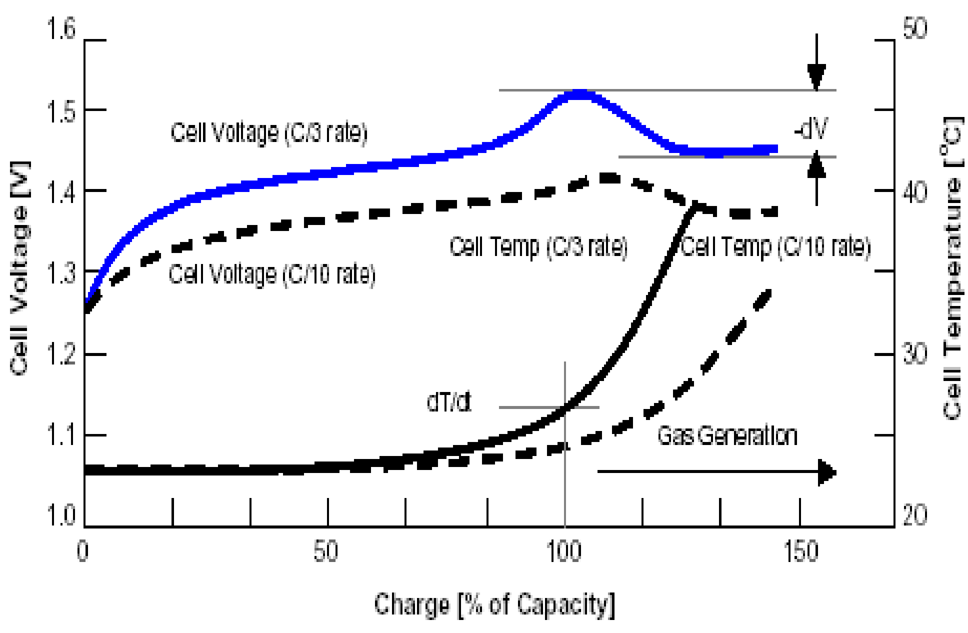

Figure 2.6: Typical NiCd battery pack voltage and temperature during charge

2.5 NiMH Battery Charging Algorithm

NiMH batteries are charged using techniques similar to NiCd batteries. However, NiMH requires more monitoring due to its greater sensitivity to overcharging. A NiMH battery is often charged with a constant current with the current limited to approximately C/2 rate to avoid excessive temperature rise [9]. The charging characteristics of NiCd and NiMH battery packs are similar, but NiMH generates more heat during charge and peak voltage is less noticeable (Smart NiCd/NiMH Battery Charger Using MC68HC908QY4, 2004).

2.5.1 Charging Termination Method

- Controlled Charging Time

This technique is the same as for NiCd type battery packs and is typically used only as a way to complete the charge after using some other charge technique.

- Absolute Temperature Detection

This method uses a sensor to detect when the battery pack temperature reaches an absolute specified value. At that time, the charge is terminated. This method can be adversely affected by ambient temperature and may result in under charge conditions when charged in high ambient temperature environments, or overcharge in low ambient temperature environments.

- Temperature Detection

This is the preferred method of detecting end of charge for NiMH because it provides a long cycle life for the battery. When the battery reaches full charge, the battery pack will experience a quick rise in temperature. This is due to an increase in the conversion of charging energy into thermal energy. The method uses a sensor to measure the battery temperature. The microcontroller will terminate the charge if the measured rate meets or exceeds the stored rate threshold. This method can be adversely affected by ambient temperature and may result in under charge conditions when charged in high ambient temperature environments, or overcharge in low ambient temperature environments.

- Negative Delta V Cut-off Charge System

This method is less suitable for NiMH batteries because the drop in voltage at the end of the charging is significantly lower. A voltage drop of 10mV per cell is recommended to set off the trigger in the case of NiMH batteries. The allowed drop in voltage should not be too small, as this would make the trigger sensitive to noise. On the other hand, a too large value will lead to detrimental overcharging. This is especially true at lower currents and elevated ambient temperatures, because then the battery voltage drop will be lower and it will take longer for the trigger to be set off. This end-of-charge trigger is usually used to terminate fast charging.

- Zero Delta Voltage

This technique is similar to the controlled charge voltage method except that the zero delta voltage circuitry detects when the slope of the battery voltage curve (during the charge process) becomes zero. Consequently, the risk of battery overcharge is small and trickle charge can be applied to complete a full charge operation.

- Trickle Charge

A relatively small trickle or maintenance charge rate of 0.03C to 0.05C is applied to the battery to compensate for self-discharge. Trickle charging serves to maintain a 100% charged battery when it is left in the charger for some time. Trickle charging begins directly after fast charging has ended when no top-off charging is applied. Alternatively, it can also start directly after quick or top-off charging has ended, when applicable. There is generally no time limit for trickle charging, so it can continue for an indefinite amount of time.

The typical NiMH battery pack voltage and temperature during charge was shown in Figure 2.7 (Smart NiCd/NiMH Battery Charger Using MC68HC908QY4, 2004).

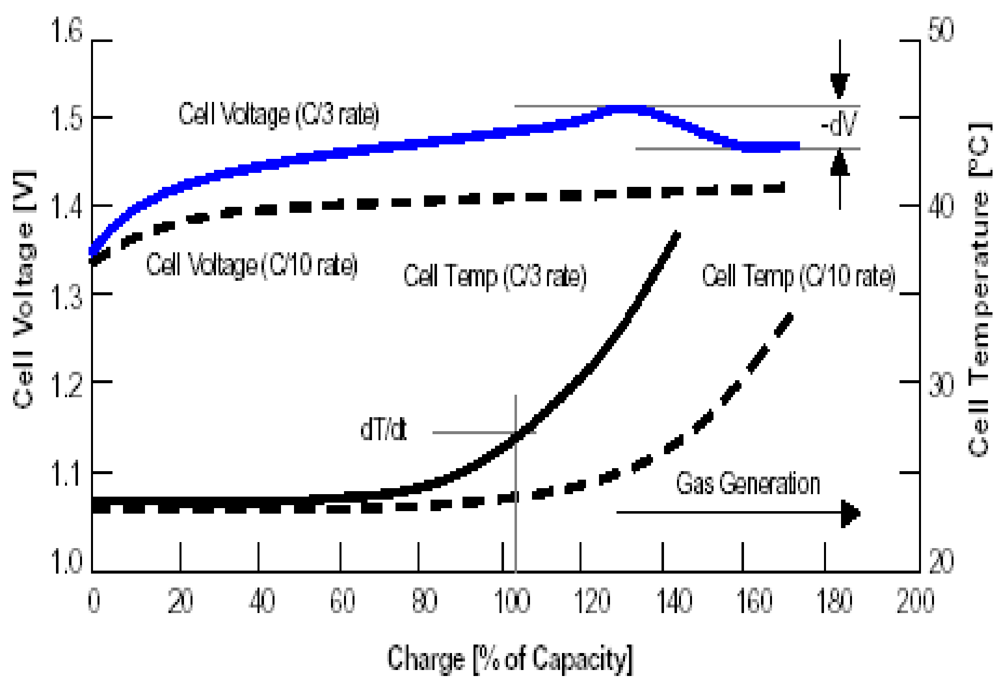

Figure 2.7: Typical NiMH battery pack voltage and temperature during charge

2.6 NiCd/NiMH Cell Characteristics

NiCd/NiMH cells are rated at 1.2V for design purposes although they normally develop about 1.25V. Under full charge they require about 1.5V to 1.6V. They can supply very large amounts of current and display a remarkably flat discharge characteristic, maintaining a consistent 1.2V throughout discharge. The voltage then drops quite suddenly, and they are almost completely flat at 0.8V. This is called the "knee" characteristic because of the shape of the graph of voltage against time.

Rechargeable battery capacity is rated in mAH (milliampere-hours). The total capacity of a battery is defined as "C", that is it can supply C mA for 1 hour, or 2C for 30 minutes etc. Charge rates can vary from trickle charges to keep the battery 'topped up' of 3.3% of C to 5% of C, a slow current charge of 10% of C to 20% of C or a fast charge of 50% of C to 100% of C.

Slow charges are not meant to be continually applied, and since NiCd/NiMH batteries are about 66% efficient, they normally last about 8-15 hours. Fast charges such as 100% of C should be terminated after about 1.5 hours, providing the battery is flat to begin with. Once a battery is fully charged, the battery produces gas creating a high internal pressure, and a sudden rise in temperature. The charge should be switched to a trickle charge at this point or the battery will begin to vent and release its electrolyte.

It may be able to discharge individual cells to 0V, it is certainly not recommended to discharge an entire battery of cells. The reason is simple. When the battery is discharged below 0.8V per cell, one of the cells is inevitably weaker than the others, and goes to zero first. If the battery is further flattened this battery becomes charged in reverse, which again makes it still weaker. This creates a more common but less commonly known effect called "voltage depression". Eventually the battery's performance drops off quite suddenly which ironically is the very thing that the user is trying to prevent. Most users know where the battery's "knee" occurs; it is when the original equipment first starts to show signs that the battery performance (and hence voltage) is suddenly dropping, and it is a good idea to place it straight on charge at this point. Usually there is less than 5% of C remaining anyway.

One other thing, batteries don't like getting too hot or cold; they do not take a full charge and they actually discharge (even under no load) much faster when over 40 degrees or below 0 degrees. They can build up internal heat when working and this can cause temperatures inside to increase also. Particularly avoid leaving cordless tools inside a hot car for this reason. They also should be left to cool down for a while after discharge before placing them on charge. NiCd/NiMH batteries do self-discharge too, as a rule of thumb a battery will hold a full charge (with no load) for about a month or two, although when they get old or hot, they might only last a day (Peter Hayles, 2006).

2.7 Charging Rate and Charge Termination

2.7.1 Battery Charging Rate

The NiMH and NiCd batteries are high density batteries and can be rapidly charged in 1 to 2 hours with the usage of proper charging method. However, it is necessary to closely monitor the allowed operating conditions so that they are not violated. Generally two types of charging techniques are followed and used.

Trickle Charging **–** A fixed charging current at 0.1C (where C represents the rated battery capacity) is applied to the battery. This charges the battery in typically 16 to 18 hours. However, charging beyond this limit can damage the battery. NiMH cells are more vulnerable to damage than NiCd cells and they get damaged when subjected to extended trickle charging at rate greater than 0.1C. The trickle charging current for NiMH batteries should thus be limited to between 0.033C to 0.05C to avoid damage to the battery with an upper time limit of 18 – 20 hours.

Boost Charging **–** (i) A fixed charging current at 0.3C or 0.5C is applied and the charging time is typically 3 to 4 hours. On completion of the boost charge cycle the charger steps down to a trickle charge to top up the battery. (ii) The charger applies a fixed charging current of 1C or 1.5C and the charging time is typically 1 to 2 hours followed by top up at low current. This procedure of charging requires continuous monitoring of battery temperature to avoid any damage due to overcharging (Tanvir Singh Mundra et. al., 2007).

2.7.2 Determination of End of Charge Condition

As the charging rate increases, possibility of battery damage due to overcharging increases. Therefore, it is important to accurately terminate the fast charging of the battery when it is fully charged. The most reliable parameters for terminating the battery charging are the rate of change of battery temperature (dT/dt) and the battery voltage (dV/dt) with time.

Detecting the –dV/dt Point: NiMH batteries have charging characteristic that shows small fall in voltage towards the end of the boost charging cycle. This is designated as dV/dt (also called -ΔV) point. At this point the charger is shifted from boost charging to trickle charging. This phenomenon is more pronounced with NiCd batteries. With NiMH battery the voltage drop at end of charge is small and is usually difficult to detect. It is noted that for a NiMH battery a voltage drop of 5-10 mV/cell (and 10-20 mV/cell for NiCd batteries) from peak is observed at the end of charge condition.

Detecting the dT/dt Point: As the battery reaches towards the completion of charge, the battery produces gas creating a high internal pressure, and a sudden rise in temperature. The temperature rise is considerable reaching a peak of 50°C to 60°C in NiMH batteries. This sudden increase in the temperature can be used to terminate the charging. Since - Δ V is not always easy to detect, overcharging can happen. Thus dT/dt termination (also called ΔT) has to be followed. NiMH/NiCd batteries can be charged at higher rates, 1C to 1.5C and a rise in temperature of 1°C/minute to 2°C/minute is commonly observed at end of charge condition. The rise in temperature is more abrupt in case of NiMH batteries as compared to NiCd (Tanvir Singh Mundra et. al., 2007).

2.8 Previous Work

The development of battery charger has invited considerable attention and the efforts have been detailed in the previous posted journal. In S. T. Hung et. al. (1993) and A.E. Demian et. al. (2004) journal stated an intelligent charger design goes a long way to extend the battery life by preventing its damage due to destructive over charging. Microcontrollers are being used to control the battery charging and to detect the full charge condition for fast charge termination. Papers by J. A. Martin et. al. (1998), J. Diaz et. al.(2004), N. A. Rahim et. al.(2006), M. A.S. Masoum et. al.(2004), A.E. Demian et. al. (2004), T.H. Liu et. al. (2000) presents the design around a processor based system. The charging process is modified and adjusted depending on the battery charge state (A.E. Demian et. al., 2004), (T.H. Liu et. al., 2000). A reliable solar battery charger design is proposed in M. A.S. Masoum et. al. (2004) journal and in J. A. Martin et. al. (1998), J. Diaz et. al. (2004), and M. González et. al. (1996) journal details the design of a NiMH/NiCd battery charger for portable telecommunication applications. F. Lima et. al. (2003), M. González et. al. (1997) reports the design of a novel CMOS IC to monitor and control the charging process in NiMH/NiCd batteries. The devices proposed employ few external components to supervise and control the charge management of batteries. In papers of J. A. Martin et. al. (1998), M. González et. al. (1997), the initial battery state is determined by measuring the battery voltage to decide the charging algorithm and fast charge termination is decided by measuring the time required for a fixed increase in per cell battery voltage. However, in F. Lima et. al. (2003) paper, the end of charge detection is through an ADC that detects the peak voltage followed by voltage drop. A low cost