7.0 NiCd and NiMH Battery Pack Design Overview

NiCd and NiMH fall into a different design category than Lithium based batteries. This section is about Nickel based packs. Battery pack describes any grouping of individual cells physically connected to one another to achieve the dimensional and electrical characteristics desired. Many of today's NiMH battery packs are assembled as "drop-in" replacements for NiCd's, but many custom batteries are being developed as new portable products are introduced. A Nickel battery pack can be designed to fit into most compartments, cases and enclosures, as long as the physical dimensions match that of electrical requirements. For all new product designs battery packs should be designed before the area in which it will be enclosed. This will ensure all aspects of the battery pack have been established before costly tooling is made for the battery enclosure.

Before a battery pack can be designed and assembled, both electrical requirements and physical parameters need to be determined. The following sections identify key factors in designing a battery pack best suiting the requirements of a given application and ensuring cost effective reproducibility.

7.1 Electrical Requirements

Typically, the electrical requirements needed to run a device or application are already known when the battery pack is to be designed. The primary elements regarding battery pack design are:

- Pack voltage
  - Nominal
  - Maximum
  - Minimum
- Capacity (or runtime)
  - Maximum Current
  - Average Current
  - Temperature
- Charging
  - Required Charge Time
  - Temperature during charge and ability to dissipate heat

As previously discussed in previous sections, both the voltage and capacity of a battery pack are dependent on the conditions in which the battery is discharged and charged. Therefore, the discharge and charge requirements of a device need to be identified.

7.1.1 Discharge Requirements

- Nominal Voltage
  The pack voltage is based on the number of cells in the battery pack. The industry standard for the rated voltage of Nickel based cells are 1.2V. Thus, five cells of 1.2V each connected together in series would result in a battery pack with a pack voltage of 6.0 Volts.

- Maximum Voltage
  It is important to know the discharge rate in order to design a battery pack with the appropriate voltage, capacity and electrical components. For all sizes of Nickel based batteries, there is no significant effect on voltage and capacity for discharge rates below 1C. A reduction in the nominal voltage occurs for discharge rates between 1C and 3C for most Nickel based batteries.

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- Minimum Voltage
  Equally important is the identification of the voltage cutoff or discharge termination to protect against damage occurring to the battery pack at the end of discharge.

- Temperature
  At high discharge rates the over heating of the battery could cause derating of the capacity. The pack should be designed to dissipate heat if high current draw is required.

7.1.2 Capacity (or Runtime)

The amount of capacity, or runtime, that a battery pack will have is dependent on many factors.

- Cell size
  Determines the amount of capacity a battery pack will have, and is directly associated to the amount of room there is in the battery compartment/enclosure (See www.hardingenergy.com for Cell Specification Data Sheets for capacity and dimensional information).

- Discharge rate
  Has an influence on the amount of capacity/runtime that a battery pack will deliver (see Section 3.7. NiMH Discharge Characteristics and 4.7 NiCd Discharge Characteristics).

- Charge method
  See Section 3.8 NiMH Charge Characteristics Overview and 4.8 NiCd Charge Characteristics Overview.

- Environment
  The environment in which the battery pack is used, and the electrical configuration (series/parallel) of the battery pack will also have some affect on the capacity of a battery.

To determine the runtime for a battery in an application, divide the battery's rated capacity, C, by the discharge rate for the application. For example, a battery with a capacity of 1500 mAh discharged at 750 mAmps (with proper discharge termination) would have a runtime of 2 hours.

7.1.3 Charge Requirements

The charging of a battery pack will have some influence on performance, but does not need to be in place at the time that a battery pack is first designed. Yet, consideration of the basic methods of charging NiMH batteries needs to be done to ensure the designed battery pack and battery enclosure will be compatible with the charge method(s) that may be desired (see Section 3.8 & 4.8 Charge Characteristics). This includes the dissipation of the heat generated by the battery when charged. This is especially true just before and during the event of the battery being overcharge. In addition, it is critical not to place batteries in close proximity to other sources of heat or in compartments with limited cooling or ventilation.

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7.2 Battery Pack Construction

After the electrical requirements have been determined, the designing of the battery pack can begin. The areas that need to be considered in battery pack design include:

1. Battery Pack Configuration
2. Protective Devices
3. Connectors
4. Packaging
5. Labeling

With the rising demand for portable battery packs, the materials and technologies for battery pack assembly have become more advanced and refined. The basic materials used in the construction of a battery pack can be seen in battery pack assemblies from around the world. The following three figures illustrate the basic construction materials and components as well as some of the specialized devices of a battery pack assembly to be discussed.

Figure 7.2.1 Basic Battery Pack Components

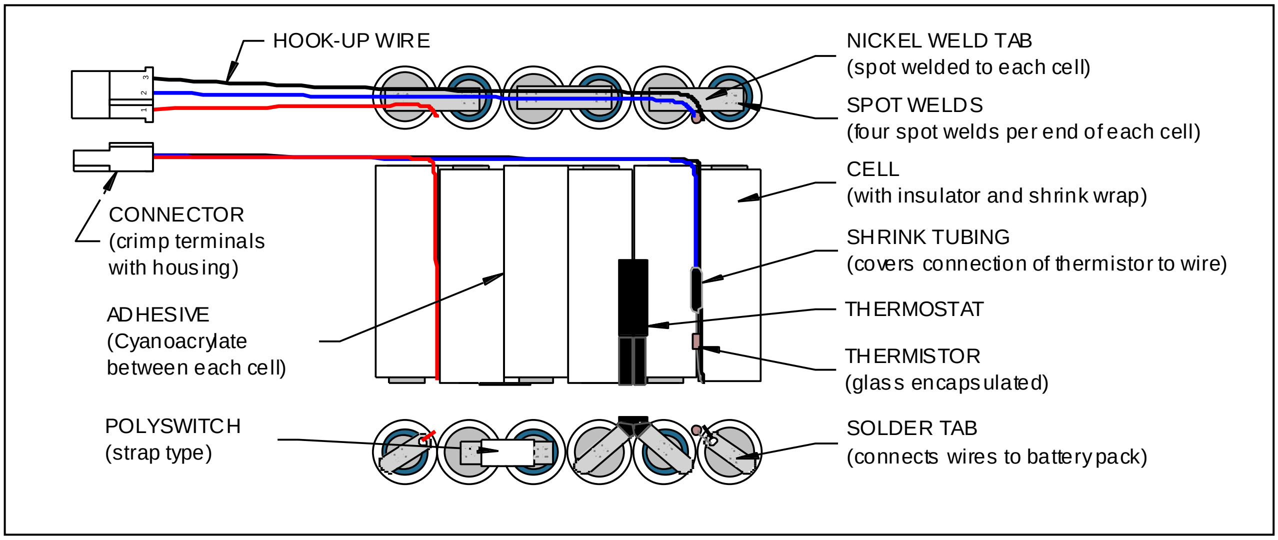

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Figure 7.2.2 Insulative Battery Materials

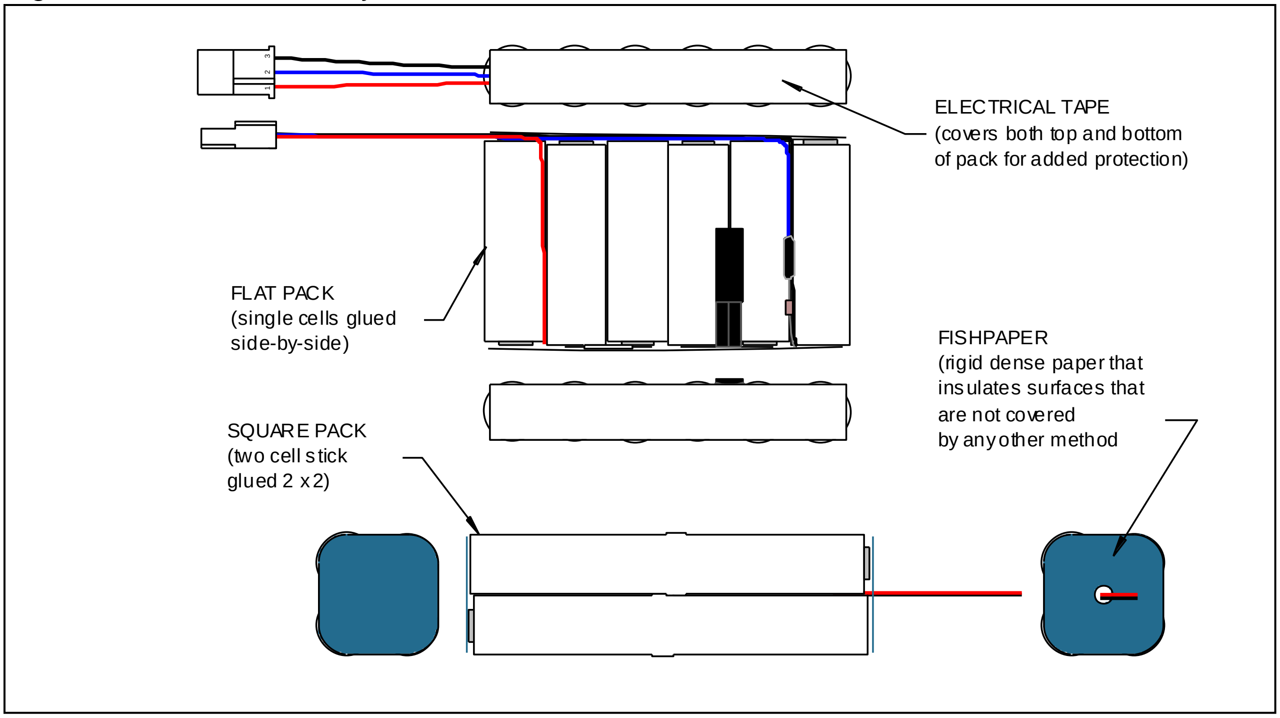
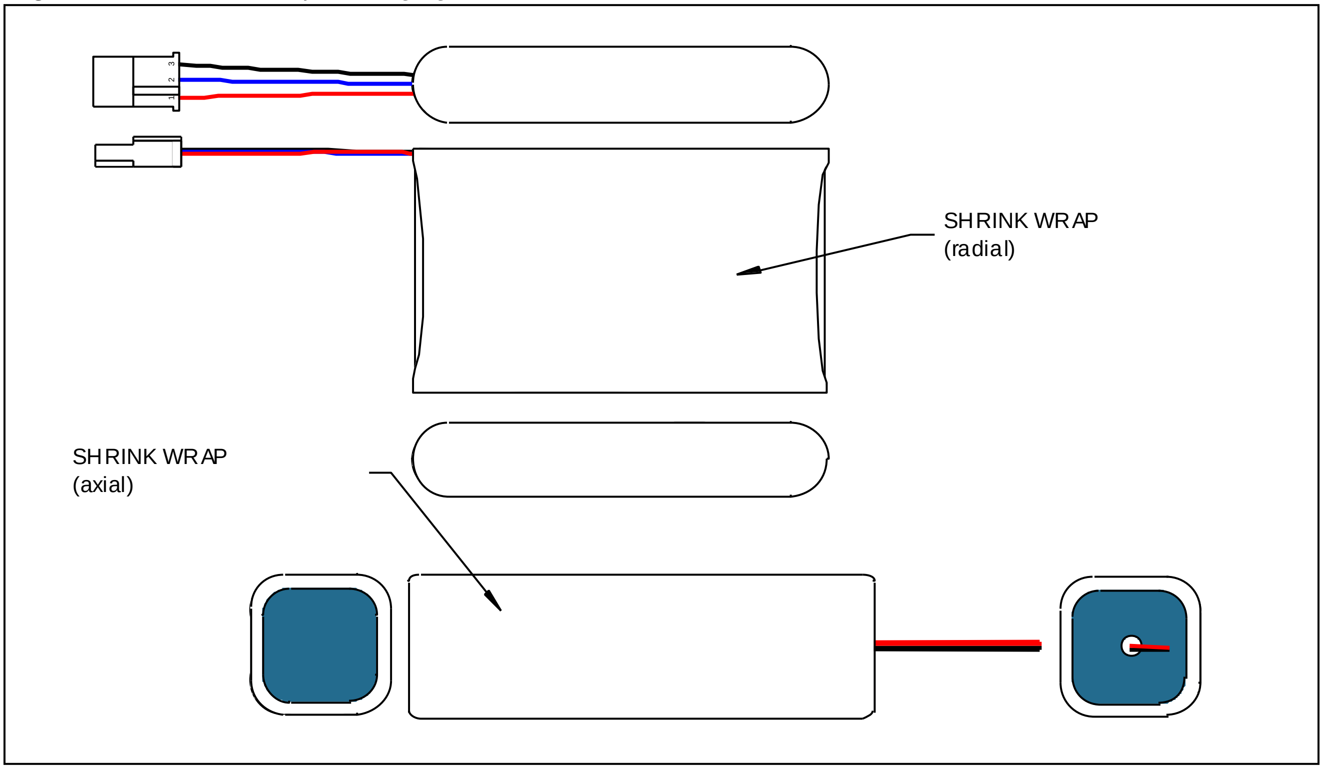


Figure 7.2.3 Shrink Wrap Packaging Material



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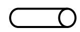
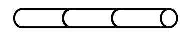
7.2.1 Nickel Battery Pack Configuration

Based on the electrical requirements and size (dimensional) restrictions, the actual physical construction or battery configuration can be determined.

Figure 7.2.1.1

Single Cell	2 Cell Stick	3 Cell Stick
		

Cell Type (Size)

The type, or size, of the cells to be used in the battery pack is determined once the pack voltage, capacity, and dimensional requirements have been identified. The list of cell sizes and designs is continually growing as the market for NiMH batteries becomes more diverse (see www.hardingenergy.com for Quest® NiMH cell sizes available).

Cell Configuration

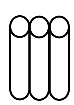
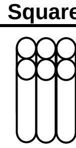
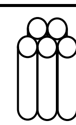
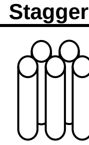
The cell configuration refers to the way an individual cell is assembled into a battery pack. The common cell configurations are either a “single” individual cell or an assembled “stick” of two, three, or more cells welded together end-to-end as shown in Figure 7.2.1.1

The “single cell” or “cell sticks” are then assembled into the desired battery pack configuration. (Note: the “cell stick” configurations are sometimes considered as a finished battery pack)

Pack Configuration

The battery pack configuration is the way the cell configurations are assembled together. Typical pack configurations are shown in Figure 7.2.1.2. Packs can be assembled in configurations listed in Figure 7.2.1.2 using cells configured in the “single” or “stick” configurations listed in Figure 7.2.1.1.

Figure 7.2.1.2

Flat	Square	Nested	Staggered
			

The “flat” battery pack configuration is the most common because of its ease of assembly. Next are the “square” and then the “nested” battery pack configurations. The “staggered” configurations are not common and more difficult to assemble, but will sometimes work for battery packs with restrictions in depth.

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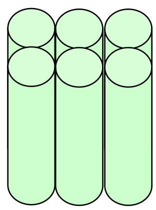
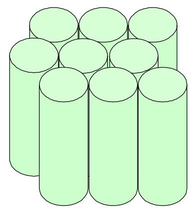
The configuration of a battery pack is almost limitless, yet designing a battery pack that is considered "non-typical" is usually not as cost effective. A "non-typical" battery pack often incorporates a mixture of cell configurations as well as locating cells at various directions to one another that would inhibit the ease of assembly. To ensure the efficient reproduction of a battery pack, the above cell and pack configurations are recommended.

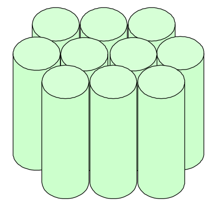
The size of a flat pack is D x nD x H where D is the diameter of the cell, n is the number of cells, and H is the height of the cells.

Square

There are two ways to start assembling them. One could be called the square, and the other nested.







nD x mD x H	L = (m +½)D W = [0.86(n-1)+1] D	L = mD W = [0.86(n-1)+1] D

Where D is the cell diameter, m is the number of cells in the longest layer, and n is the number of layers.

7.3 Protective Devices

Electrical components of a battery pack refer to the devices incorporated into the battery pack to increase functionality. These components protect a battery pack from damage that may otherwise occur if they are not used.

This first group of protective devices includes a variety of ways to sense and protect a battery pack from damage. The following list describes most of the commonly used protective devices.

7.3.1 Thermistor

Used primarily with the more sophisticated methods of charging NiMH batteries, this device senses temperature throughout the charging of the battery, which is then analyzed by the charging circuitry. Thermistors are thermally sensitive resistors that exhibit a large, predictable and precise change in electrical resistance when subjected to a corresponding change in temperature. The thermistors typically used in battery packs are negative temperature coefficient (NTC) thermistors. This means that they exhibit a decrease in electrical resistance when subjected to an increase in temperature.

Thermistors come in various types, but the most commonly used and the preferred type is a 10K 1% glass encapsulated with axial leads. Other thermistors used are the epoxy bead type thermistors, but are less desired due to the increased difficulty to assemble into the battery packs.

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7.3.2 PTC Resettable Fuse

The most commonly used component in the assembly of battery packs is the strap-type polymeric positive temperature coefficient (PTC) device. Strap-type polymeric PTC resettable fuses are easily installed in series with the cells inside the battery pack with only a small addition (~1 mm) to the overall dimensions of the battery pack. PTC resettable fuses limit the flow of dangerously high current during fault conditions, which includes accidental, short-circuits of battery. Providing over-current protection as well as over-temperature protection, the polymeric makeup of the PTC resettable fuse latches into a high-resistance state when a fault occurs. While only allowing a small amount of current through the battery, this high-resistance state will remain until the fault is removed. Once the fault and power to the circuit are removed, the PTC resettable fuse will then automatically reset, ready for normal operation. See section 7.6 for Harding's standard components.

7.3.3 Thermostat

The other commonly used circuit protection device used is the bi-metallic thermostat or circuit breaker. This type of resettable fuse also protects against short-circuit but using an entirely different technology than the PTC resettable fuse.

Thermostats use a bi-metal disc that senses both heat and current from the battery pack. When the temperature reaches a predetermined temperature, the disc snaps open the contacts, thus completely breaking the path of the current. When the battery returns to normal operating temperature, the thermostat resets. See section 7.6 for Harding's standard components.

7.3.4 Thermal Fuse

The one-time use thermal fuse is less common. These fuses open at elevated temperatures caused by run-away current. They are a fail-safe measure since the battery will become inoperative once the fuse has opened. These fuses are recommended, if absolute termination of current is needed for safety concerns only.

7.4 Gas Gauge

Obvious advantage is available with the use of a gauge to inform the user on the available capacity of the battery. Voltage sensing is not accurate for nickel based batteries. There are several variables to take into consideration in determining the state of charge of a pack (SOC). These variables include environmental temperature, discharge rate, self-discharge, and time. The electronics that must be installed on the pack also require the use of the battery so if the pack is stored on the shelf for an extended period of time, the gas gauge losses its memory or pulls the pack down below the recommended storage level.

Harding does carry standard gas gauge boards and has capabilities to meet most custom requirements. However, the standard gas gauge boards must be configured for each specific pack.

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7.5 Connectors

This diverse group of components provides an easy and efficient means of connecting the battery pack to device. The most commonly used methods are described in the following:

7.5.1 Crimp Terminal and Crimp Terminal Housing

This connector system uses a terminal that is crimped onto the stripped ends of each wire leading from the battery pack. The crimp terminals are then inserted into the crimp terminal housing. These connectors can be used to connect battery lead wires to wires leading to the device, or to the printed circuit board of the device.

Crimp terminal connectors may have a number of positions from 2 to over 20 depending on the connector style chosen. Also, these types of connectors have many optional features that aid in the connection of a battery to a device. In addition, a wide range of wire sizes (28 AWG to 12 AWG) can be used, as well as a wide range of connector sizes and styles.

7.5.2 Quick Connect/Fast-on Connectors

This connector style uses a tab-to-tab type connection with the female tab having rolled edges that receives the flat tab of the male connector. This type of connector is also a crimp type connection to each wire lead of the battery, but is only a single position connector with an optional protective cover or housing.

7.5.3 Contacts

Some battery pack assemblies have been designed without the use of wires and connectors. As an alternative they use metal contacts designed within the battery pack to mate directly with the device and charger. The contacts are typically heavy gauge nickel tabs placed on and/or around the battery pack that line-up with corresponding springs or tabs in the battery compartment of the device and charger. This method of connection can be effective depending on the location of the contacts and overall design of the battery pack. If the contact connection method is preferred, it is recommended to make the contacts on or near the positive and negative ends of the battery pack for ease of assembly.

7.5.4 Other Connector Types

- Molded cable assemblies
- Insulation displacement termination (IDT)
- Mass termination assemblies (MTA)
- Low voltage DC assemblies
- 9V snap-on connectors
- Watertight connection systems.

Many of these connection methods (e.g. molded cable assemblies, 9V snap-on, and watertight) are more expensive and complex to assemble. With this in mind these connector types are not the most cost effective battery pack assemblies.

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7.5.4 Harding Preferred Connectors

Not all connectors are created equal. Many require special tools. We can supply any connector you choose but some may add additional costs. Since it is impossible for us to carry every tool and every connector, we are better able to serve you if you choose one of our standard connectors. Section 7.6 lists a representative sample. For a more complete list please see our website.

7.6 Harding Preferred Components

Connectors

SMALL (26-22 AWG. WIRE)
HOUSING: MOLEX TERMINAL: MOLEX #08-50-0114
2 PIN: #22-01-3027
3 PIN: #22-01-3037
4 PIN: #22-01-3047
MATING PARTS: MOLEX KK 2.54mm PITCH HEADERS AND 0.04mm PINS

MEDIUM (22-18 AWG. WIRE)
HOUSING: MOLEX TERMINAL: MOLEX #02-06-2103
2 PIN: #03-06-2023
3 PIN: #03-06-2032
4 PIN: #03-06-2042
MATING PARTS: MOLEX SERIES #1625R

LARGE (18-16 AWG. WIRE)
HOUSING: MOLEX
2 PIN: #03-12-2026
3 PIN: #03-12-2036
4 PIN: #03-12-2046
TERMINAL: MOLEX #18-12-2222
MATING PARTS: MOLEX SERIES #42179R

Thermostat

AA & AAA Diameter Cells
Klixon #6MM70A-06

A & Larger Diameter Cells
Klixon #4MM70A-06.

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Positive Temperature Coefficient (PTC) Device

Harding Standard PTCs (Others are available)

PTC Part Number	I (Hold)*	V (Max)	Reference @20C Min. Ω	Resistance Max. Ω
Raychem SRP 120	1.2	15	0.085	0.160
Raychem SRP 175	1.75	15	0.050	0.090
Raychem LTP 180	1.8	24	0.040	0.068
Raychem SRP 200	2.0	30	0.030	0.060
Raychem SRP 350	3.5	30	0.017	0.031
Raychem VTP 210	2.1	16	0.018	0.030
Raychem LR4 450	4.5	20	0.011	0.020

* At room temperature the device must be de rated for expected operating temperature

Thermistor

10K 1% glass encapsulated with axial leads with a beta of –3965.

10K 1% Glass Encapsulated
Therm-O-disk #1H10305T
Axial Leads
Beta: -3965

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