PICREF-2

Intelligent Battery Charger Reference Design

INTRODUCTION

Typically, simple battery chargers do not provide the intelligence to charge different battery technologies or batteries 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.

Microcontroller Benefits

- Flexibility to handle different technologies, voltages and capacities.
- Variable Voltage Generation Control
- Charge/Discharge Multiple Battery Packs
- "Windowed" A/D for High Resolution

PICREF-2 OVERVIEW

The Microchip Technology PICREF-2 Intelligent Battery Charger (IBC) Reference Design offers a ready-made battery charger solution. This Reference Design is targeted to battery charger applications such as camcorders, portable audio equipment, portable phones, and portable power tools.

With the PICREF-2 Reference Design, the user will be able to simply pick their complete battery charging system by completing the steps listed:

1. Pick the required battery management features from the modular source code provided.
2. Pick the critical battery pack parameters and modify the global constants to those specifications.

The hardware design contains the necessary circuitry to support charging and discharging algorithms, charge termination methods, and RS-232 communications.

The modular source code is written in C and consists of the charge termination algorithms, discharge algorithm, interdevice communications, and RS-232 communications modules.

The PC based software provides a means for requesting and displaying battery status information.

PICREF-2 Key Features

- Compatibility Across Battery Technologies
- Low Cost
- Flexible Development Environment
- Fast Charge Rate
- High Charge Current Capability
- High Discharge Current Capability for Conditioning
- Real-Time Debug
- Data Logging
- User Selectable Embedded Charge Termination Algorithms

PICREF-2

TABLE OF CONTENTS

TRADEMARKS

System Overview

The PICREF-2 system block diagram is shown in Figure 1. This reference design can charge or discharge single or dual batteries of the same type.

The PIC16C7XX microcontroller contains the embedded charging algorithm and controls the external charging components and buck, or step-down, converter. To develop the charging algorithms, the PICREF-2 has a development mode. Once the algorithm has been developed, the PICREF-2 may be placed in stand-alone mode.

The voltage for battery charging is generated through a buck converter, which is controlled by the PIC16C7XX's Hardware PWM.

The PIC16C7XX controls battery charging and discharging through the Battery Charge Select and Battery Discharge Select lines. Battery Temperature and Battery Voltage lines provide information for charge termination algorithm calculation and status. The Current Sense line monitors the current being delivered to the battery during charge for status information.

The A/D functions are implemented using the on-board A/D converter of the PIC16C7XX.

The electrical specifications for the system are listed in Appendix A.

Development Mode

In order to develop the firmware for the PICREF-2 system, a development mode has been included.

This mode supports an RS-232 serial link to a PC for battery status communication. The PIC16C73A also contains the embedded charging algorithm and controls the external charging components and buck converter.

Development mode offers real-time debug of charge termination algorithms. In this mode, charging parameters can be changed on the fly via the microcontroller software and battery data can be logged.

Stand-Alone Mode

Once the correct charging algorithm has been developed and charge parameters have been determined, the global constants can to be set for stand-alone mode. There is no RS-232 communication or discharge capacity in this mode.

FIGURE 1: PICREF-2 INTELLIGENT BATTERY CHARGER (IBC) BLOCK DIAGRAM
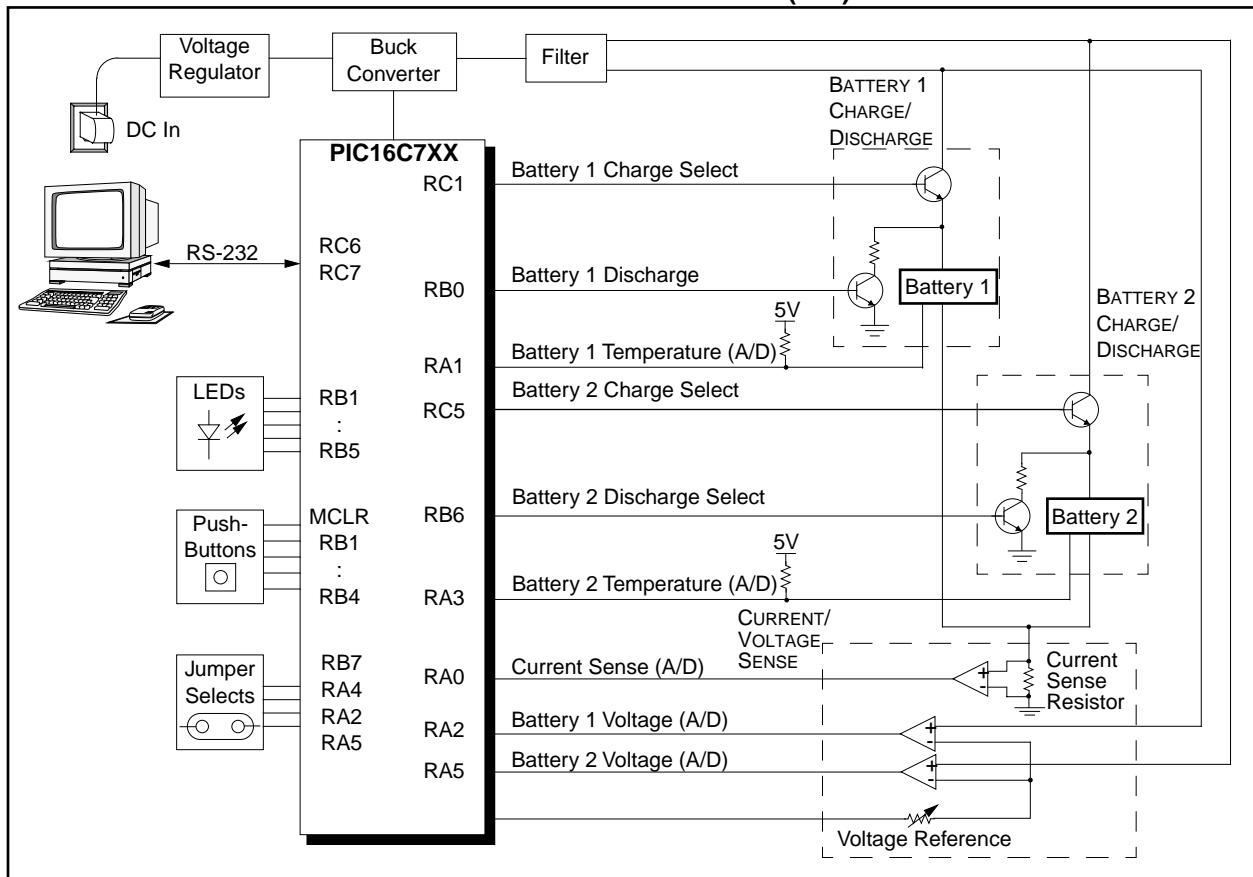
PICREF-2

Hardware Overview

This section describes the PICREF-2 hardware and how it functions in the Intelligent Battery Charger (IBC) system. Hardware detail (schematics) may be found in Appendix C.

Microcontroller

The PIC16C7XX microcontroller gives the PICREF-2 reference design flexibility. Changes can be made using software instead of hardware, and charging algorithms can be easily customized to accommodate the user's specific battery packs.

The ability to charge and discharge either a single battery or two batteries of the same type means greater flexibility.

PWM control of voltage generation (via the buck converter) and A/D monitoring of the voltage means precise control over the voltage used for charging batteries.

Development mode uses the PIC16C73A microcontroller (Figure 2), which provides more memory and a USART (RS-232) communications port for development of firmware. Stand-alone mode uses the PIC16C72 (Figure 3). The PIC16C72 or the PIC16C73A can be inserted in either 28-pin socket (U17 or U19).

FIGURE 2: PIC16C73A PINOUT
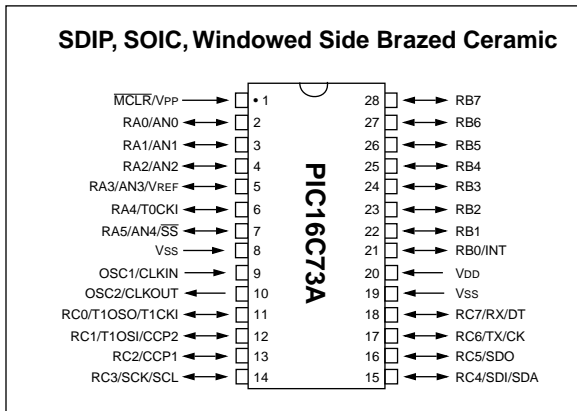
FIGURE 3: PIC16C72 PINOUT
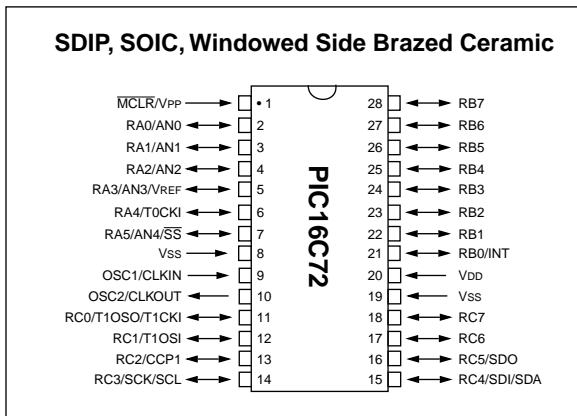
Voltage Regulator

The input voltage (+V_FUSED) is used by the voltage regulator to generate the +5 VDC needed by the board. The voltage regulator LT1118CS8-5 (U10) may be replaced by U14 (NJM7805).

> **Note:** U10 and U14 are +5V regulators. U14 may be populated in place of U10 at the designer's option.

Buck (Step-Down) Converter

The most critical parameter in charging batteries is the control of the power source. Whether current or voltage charging is being used (PICREF-2 uses a constant current method), control of the power source is imperative to proper battery charging.

The power source for this design is a buck converter. A buck converter was chosen because of its simplicity, efficiency and low heat dissipation. A simplified diagram of the converter circuit is shown in Figure 4.

FIGURE 4: SIMPLIFIED BUCK CONVERTER

Where:
PWM = Input PWM from microcontroller
V_i = Input voltage
V_o = Output voltage
D = Schottky Diode
C_o = Output capacitor
L = Inductor
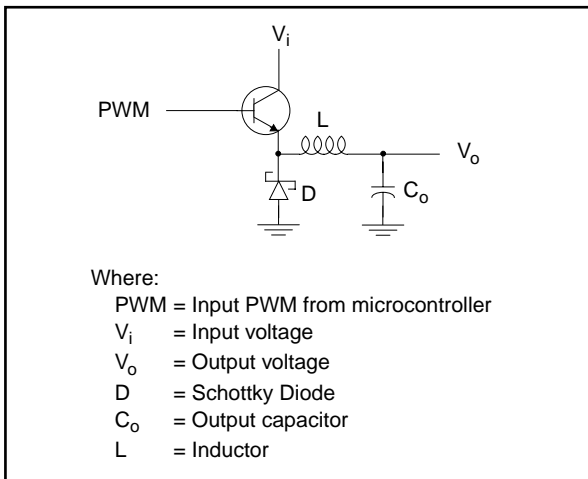
Buck Converter Basics

The PIC16C7XX microcontroller controls the buck converter through the use of a hardware PWM module and an external current sense resistor. The hardware PWM and current sense resistor feedback are significant in providing an accurate and repeatable charge methodology.

The buck converter operates as follows. When the PWM output is high, the current passes through the transistor and inductor to the battery. During this state, the inductor is energized and the capacitor is charged. When the PWM output is low, the inductor voltage reverses, and the current is provided through the diode. The inductor and capacitor act as a filter for the output voltage and current.

There are two modes in which a buck converter can operate: (1) continuous, where the current is flowing continuously, or (2) discontinuous, where the current drops to zero for a period of time. For heavy current loads, the converter would be in continuous mode. Under light load conditions, however, the buck converter current may fall to zero for a period of time.

The converter in this reference design is controlled such that it always operates in continuous mode. Thus, it produces the sawtooth waveform shown in Figure 5.

FIGURE 5:   BUCK CONVERTER OUTPUT CURRENT
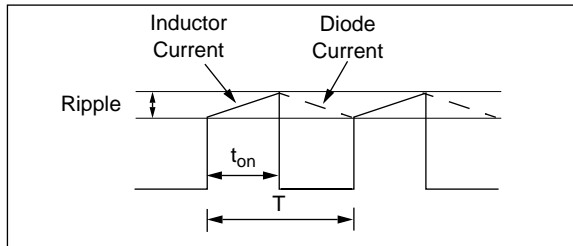
For a given input voltage and output voltage, the peak-to-peak amplitude of this inductor current waveform remains constant. As the load current rises or falls, the entire sawtooth current waveform also rises or falls. The average DC value of this waveform is equal to the DC load current.

Buck Converter Detail

The microcontroller PWM output will look like Figure 6.

FIGURE 6:   PWM OUTPUT
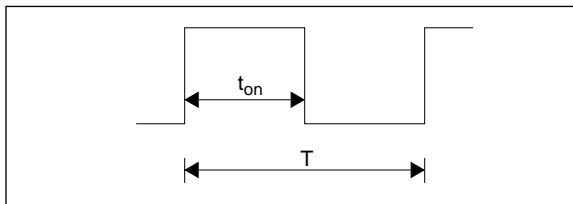
The relationship between PWM output and the output voltage is:

$$t_{on}/T = (V_o + V_D) / (V_i - V_{sat} + V_D) \qquad (1)$$

where:

t_{on}	= "On time" of PWM
T	= PWM period
V_i	= Input voltage
V_o	= Output voltage
V_{sat}	= Saturation voltage of transistor
V_D	= Diode forward-bias voltage drop

This equation is valid for $0 < t_{on} < T$. Since the equation was derived assuming current flow in the inductor, the special cases of $t_{on} = 0$ (transistor switch off for T) and $t_{on} = T$ (transistor switch on for T) are not valid for this equation.

For V_D, V_i, V_{sat}, and T constant, increasing or decreasing t_{on} will increase or decrease the output voltage, V_o. Therefore, for different battery technologies requiring different charging voltages, V_o may be varied by varying t_{on}.

The use of a fast recovery or Schottky diode is recommended for diode D. Either diode provides the necessary forward voltage and switching speed required. A fast recovery diode is used in the PICREF-2. A Schottky may be used if lower forward voltage is required.

The output capacitance is chosen such that:

$$C_o \geq I_{pk}T / 8V_{ripple} \qquad (2)$$

where:

I_{pk}	= 2 I_{oMAX}
I_{oMAX}	= Maximum output current
T	= PWM period
V_{ripple}	= Output voltage ripple

To minimize ripple, choose a large value, low ESR (equivalent series resistance) capacitor for C_o.

The buck converter inductor value is determined by:

$$L = (V_i - V_{sat} - V_o)t_{on} / I_{pk} \qquad (3)$$

where:

V_i	= Input voltage
V_o	= Output voltage
V_{sat}	= Saturation voltage of transistor
I_{pk}	= 2 I_{oMAX}
I_{oMAX}	= Maximum output current
t_{on}	= "On time" of PWM

From this equation, a relationship between PWM (t_{on}) and inductor value (L) can be seen. A minimum inductor value (L_{MIN}) may be calculated from t_{onMAX}. The disadvantage of this is that the PWM resolution is reduced as the frequency is increased. However, reducing the inductor size reduces the overall buck converter size and price.

EXAMPLE 1: CALCULATING THE INDUCTOR VALUE

Using Equation (3), calculate the inductor (L) value for:

V_i = 13.6V V_{sat} = 0.2V

V_o = 7.2V I_{pk} = 2A

PWM "on time" (t_{on}), is calculated as:

Processor clock (f_{osc}) = 4 MHz

Duty Cycle = 50%

PWM Resolution = full 8 bits

So; $T = T_{osc} * 255 = 63.75$ μs

And; $t_{on} = 31.87$ 5μs

Finally; L = 98.8 μH

If a 7 bit resolution PWM is acceptable, then:

T   = Tosc * 127 = 31.75 μs

t_{on} = 15.875 μs

L   = 49.2 μH

> **Note:** U1, U2, and U3 are p-channel FETs for the buck converter. U1 or U3 may be populated in place of U2 at the designer's option. L2 may be populated in place of L1 at the designer's option.

Filter - Optional

The filter circuit is intended to provide additional ripple suppression at the buck converter output stage (Figure 7).

The filtering circuit is bypassed by connecting JMPR1-1 to JMPR1-2 (see *JUMPERS*). To enable the filter circuit, connect JMPR2-1 to JMPR2-2 and JMPR3-1 to JMPR3-2.

> **Note:** L3, C3, and C4 provide additional ripple filtering on the output of the buck converter. They may be populated at the designer's option.

FIGURE 7: FILTER
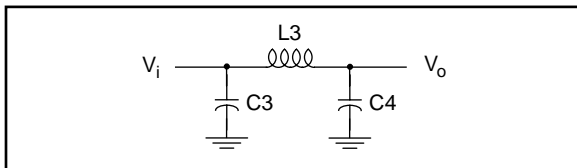
Battery 1 and Battery 2 Charge/Discharge

The PIC16C7XX microcontroller Battery Select I/O line uses a transistor to select a battery for charging. The Discharge Battery Select I/O line drives a transistor to ground to fully discharge the battery. This feature can erase the voltage depression or "memory effect" (see *Design Background*).

The PIC16C7XX powers up in an idle state. If a battery discharge is requested, a discharge cycle is started followed by a complete charging cycle.

The microcontroller also monitors the current source (when charging through an I/O line) and a current sense resistor to provide constant current to the battery.

The microcontroller displays the status of the battery on the LEDs (see *LEDs*). The LEDs display the charging status (CHRG or DISCHRG) and faulty cell detection (ERROR). These LEDs are driven directly from the microcontroller I/O lines. For more information on the LEDs.

> **Note:** U4, U6, U7, and U8 are p-channel FETs used to select the battery to be charged. U4 and U8 may be populated at the designer's option.

Voltage Sense

The PIC16C7XX performs battery voltage readings during the rest period of the charge cycle. This is accomplished by reading the battery voltage when the PWM is low. Reading the battery voltage during the active period of the charge cycle (PWM is high) will result in erroneous operation.

The A/D converter uses a "windowing" technique to determine the charge termination values. The "windowing" feature gives you higher resolution over the standard 0V to 5.0V A/D converter range.

For example, the cell voltage for a NiCd battery typically ranges from 0.8V to 1.6V per cell. If you were monitoring a four-cell pack, the voltage range for the pack could be 3.2V to 6.4V. This would exceed the 5V limit on the A/D converter. If you divide the voltage before the A/D converter input, you would actually lose resolution.

The "windowing" feature subtracts an offset from the battery voltage and amplifies the difference to actually give higher resolution. The difference voltage is gained by a factor of 3.33 so that the voltage range decreases by this factor (and the resolution increases by this factor). The standard 5V A/D range gives a resolution of (5.0V/ 256) = 19.5 mV/bit. With the gain factor of 3.33, the 5.0V range decreases to (5.0/3.33) = 1.50V (i.e., a 1.5V difference will be amplified to 5.0V at the A/D converter input). Therefore the resolution becomes (1.50 V/ 256) = 5.86 mV/bit.

FIGURE 8: A/D - WINDOWED
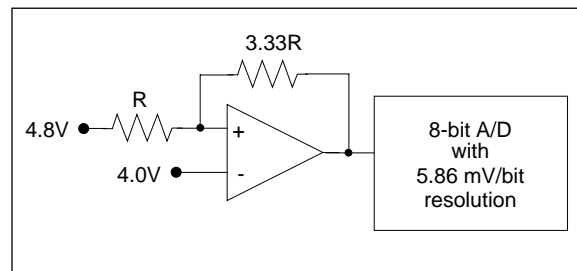
The offset can be adjusted by writing to the digital potentiometer so the microcontroller can "seek out" any battery voltage ranging from 0V to 15.0V. The jumper settings for operation in "windowed" mode are:

JMPR9-1 to JMPR10-1 (Battery 1)
JMPR7-1 to JMPR8-1 (Battery 1)
JMPR11-1 to JMPR12-1 (Battery 2)
JMPR13-1 to JMPR14-1 (Battery 2)

If the battery voltage is known, the digital potentiometer can be replaced by a fixed voltage reference and still maintain the 5.86 mV/bit resolution. The jumper settings for operation in "fixed" mode are:

JMPR8-1 to JMPR8-2 (Battery 1)
JMPR9-1 to JMPR10-1 (Battery 1)
JMPR12-1 to JMPR12-2 (Battery 2)
JMPR13-1 to JMPR14-1 (Battery 2)

In addition, the "windowing" and "fixed" circuit can be bypassed and the direct battery voltage can be read if lower resolution is needed. The jumper settings for "direct" mode are:

JMPR10-1 to JMPR10-2 (Battery 1)
JMPR14-1 to JMPR14-2 (Battery 2)

> **Note:** D3, D4, R17, and R24 provide the voltage reference for "fixed" mode. In this mode, U13 may be removed.

> **Note:** The battery voltage is divided by resistors R5, R9, R10, and R14. If a smaller dynamic range that 0V to 15V is required, these resistor values can be changed to increase "direct" mode resolution.

Current Sense

The PIC16C7XX performs battery current readings during the rest period of the charge cycle. This is accomplished by reading the battery current when the PWM is low. Reading the battery current during the active period of the charge cycle (PWM is high) will result in erroneous operation.

The current sense circuitry works by amplifying and converting the current through a 0.05 ohm resistor into a voltage. The maximum current reading with a 0.05 ohm resistor and an amplifier gain of 40 is 2.5A (2.5A x 40 x 0.05 ohms = 5.00V). This translates into a 9.77 mA/bit resolution (2.5A / 256 bits). The current sense resistor is user replaceable.

> **Note:** The current sense resistor in H2 may be replaced at the designer's option to give either more range or more resolution.

Temperature Sense

The temperature sense is accomplished through a 10k pull-up resistor ( ). The voltage read corresponds to the thermistor's value in relation to its 25°C value. This means that at 25°C the converted voltage would be 2.5V. The converted voltage decreases as the temperature increases and the thermistor value decreases.

FIGURE 9: TEMPERATURE SENSE CIRCUIT
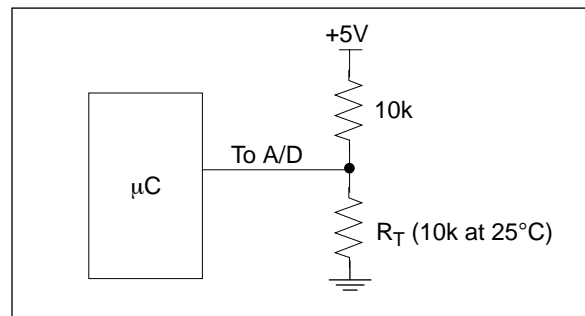
A simple lookup table in the software provides the corresponding temperature for the converted voltage. The temperature sense resistors are selectable.

> **Note:** The temperature sense resistors in H1 may be replaced at the designer's option based on the designer's battery pack thermistor value.

The temperature reading is done during the OFF period of the buck converter.

Battery Pack

The battery pack provided is comprised of the KR-1100AEL NiCd Fast Charge Battery Cell. It can be standard-charged at a 110 mA rate or fast-charged at up to a 1600 mA rate. The temperature range for charging (either standard or fast) is 0°C to 45°C. For discharge, the temperature range is -20°C to 60°C.

> **Note:** Refer to the manufacturer's specifications before charging any battery pack.

> **Note:** Improper disposal of NiCd batteries poses an environmental hazard. Contact a local battery collection center for recycling information.

LEDs

LEDs are provided to indicate the status of the IBC (Table 1). LED locations on the PICREF-2 are shown in Figure 11 (D5 through D10).

TABLE 1: LED INDICATORS

LED	Steady On	Flashing
BATTERY 1 CHRG (D5)	Battery 1 charging	trickle charge
BATTERY 1 DISCHRG (D6)	Battery 1 discharging	N/A
BATTERY 2 CHRG (D7)	Battery 2 charging	trickle charge
BATTERY 2 DISCHRG (D8)	Battery 2 discharging	N/A
ERROR (D9)	Battery error detected	N/A
POWER (D10)	Power on	N/A

PICREF-2

Pushbuttons

Pushbutton switches may be used to select different PICREF-2 modes (Table 2). Pushbutton locations on the PICREF-2 are shown in Figure 11 (SW1 through SW5).

TABLE 2: PUSHBUTTON SELECTS

PushButton	Function
SW1	Reset
SW2	Battery 1 Charge
SW3	Battery 1 Discharge
SW4	Battery 2 Charge
SW5	Battery 2 Discharge

Jumpers

Jumpers may be used to select different options for PICREF-2 operation (Table 3). Jumper connection conditions are shown in Figure 10. Jumper locations on the PICREF-2 are shown in Figure 11 (JMPR1 through JMPR14).

FIGURE 10: JUMPER CONNECTION CONDITIONS
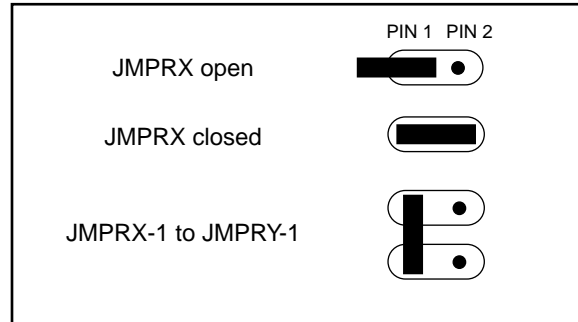
TABLE 3: JUMPER SELECTS

Function	Jumpers
Bypass of filter after buck converter (default)	JMPR1 closed JMPR2 and JUMPR3 open
Add filter after buck converter	JMPR1 open JMPR2 and JMPR3 closed
Access to Ground (GND)	JMPR4
Stand-Alone Mode	JMPR5 closed JMPR6 open
Development Mode (Handshake)	JMPR5 open JMPR6 open
Voltage Sense – Windowed Mode	JMPR7-1 to JMPR8-1 (Battery 1) JMPR9-1 to JMPR10-1 (Battery 1) JMPR11-1 to JMPR12-1 (Battery 2) JMPR13-1 to JMPR14-1 (Battery 2)
Voltage Sense – Fixed Mode	JMPR8-1 to JMPR8-2 (Battery 1) JMPR9-1 to JMPR10-1 (Battery 1) JMPR12-1 to JMPR12-2 (Battery 2) JMPR13-1 to JMPR14-1 (Battery 2)
Voltage Sense – Direct Mode	JMPR10-1 to JMPR10-2 (Battery 1) JMPR14-1 to JMPR14-2 (Battery 2)

FIGURE 11: LED, PUSHBUTTON AND JUMPER LOCATIONS
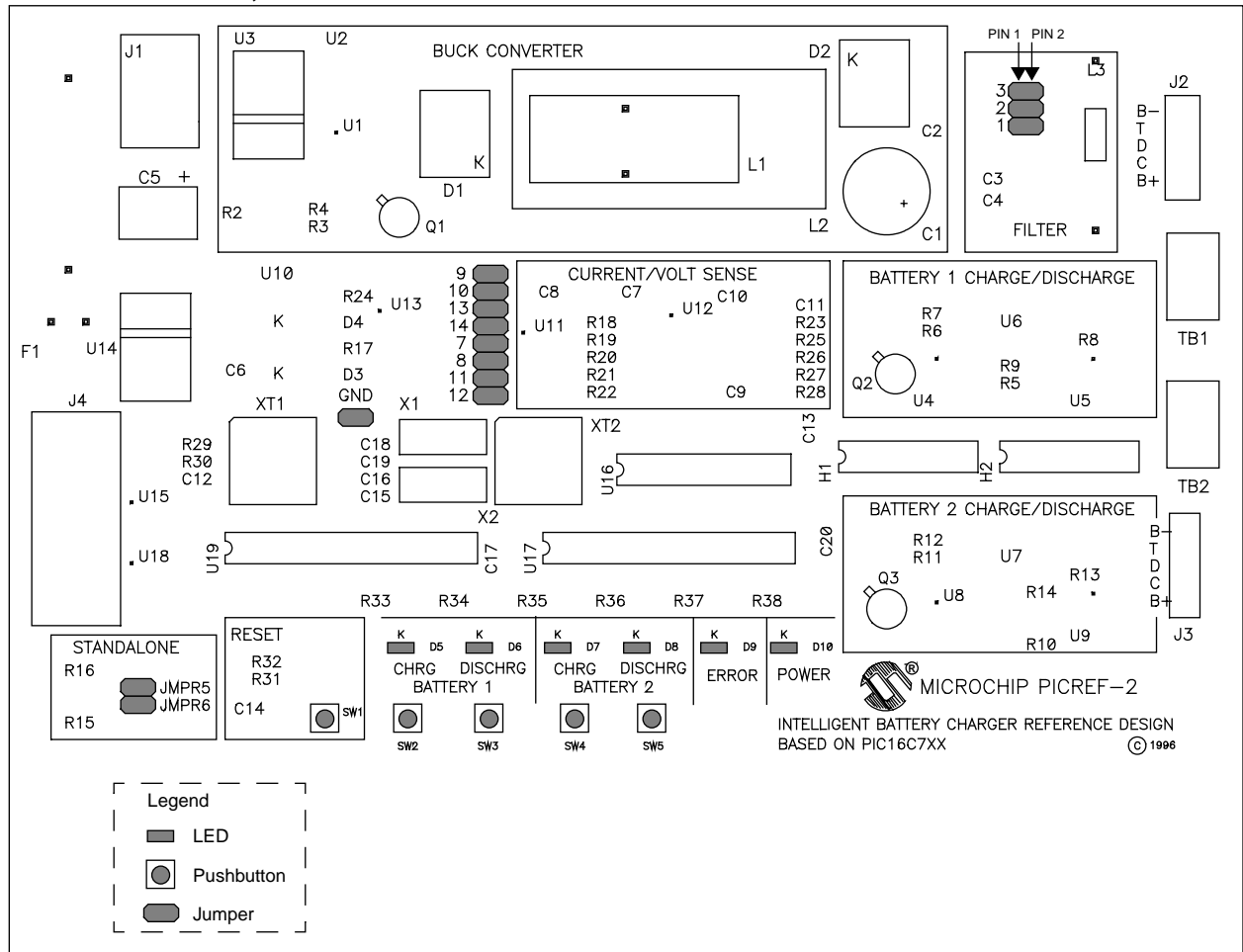
PICREF-2

Firmware Overview

The source code for the PICREF-2 microcontroller was designed to be modular.

In general, the PICREF-2 software has the following features:

- Algorithms to support NiCd battery technology
  - Negative Delta V (-ΔV) Charge Termination
  - Zero Delta V (Zero ΔV) Charge Termination
  - Absolute Voltage Termination
  - Delta T / Delta t (ΔT/Δt) Charge Termination
- PWM-Controlled Discharge Profile

The current charge termination flow diagram is shown in Figure 12.

A discussion of charge termination types and the battery technologies that use them may be found in the section *Design Background*.

Future revisions of this reference design will include:

- Add Li-Ion
- Additional Charge Termination Algorithms

Algorithms

The equations in Table 4 were used to translate battery physical quantities into data.

TABLE 4: EQUATIONS USED FOR CHARGE TERMINATION CALCULATION

Equations	Fast Charge Term.				Fail-Safe Charge Term.			
	-ΔV	Zero ΔV	Abs V	$\frac{\Delta T}{\Delta t}$	timed	↑↓ temp	↑↓ V	trickle
Battery Voltage in volts = Battery Voltage * Scale Factor			x					
Battery Temperature in ˚C = Battery Temperature (signed, 1˚C/bit)						x		
Battery Charge Current in x10 mA = Battery Charge Current								x
Battery Scale Factor = Battery Scale Factor	x	x	x	x				
Max Battery Voltage in volts = Max Battery Voltage * Scale Factor							x	
Min Battery Voltage in volts = Min Battery Voltage * Scale Factor							x	
Measured -ΔV in mV per minute = Measured -ΔV * Scale Factor (signed)	x	x						
Measured ΔT/Δt rate in ˚C per minute = Measured ΔT/Δt * Scale Factor (unsigned)				x				
Measured Time per second = [MSB * 256] + LSB					x			

FIGURE 12: CHARGE TERMINATION FLOW DIAGRAM

```
                          ┌─────────────────────┐
                          │   Start Fast Charge │
                          └──────────┬──────────┘
                                     │
                                     ▼
                          ╱─────────────────────╲
                         ╱   Cell Voltage Within  ╲      No
                         ╲   Charging Limits?     ╱─────────────┐
                          ╲─────────────────────╱               │
                                     │ Yes                      │
                                     ▼                          │
                          ╱─────────────────────╲               │
                         ╱   Cell Temperature     ╲      No      │
                         ╲   Within Charging      ╱─────────────┤
                         ╱   Limits?              ╲              │
                          ╲─────────────────────╱               │
                                     │ Yes                      │
                          ┌─────────────────────┐               │
                          │ Settling Time Charge│               │
                          └──────────┬──────────┘               │
                                     ▼                          │
                          ╱─────────────────────╲               │
                         ╱   Cell Voltage Within  ╲     No       │
                         ╲   Charging Limits?     ╱─────────────┤
                          ╲─────────────────────╱               │
                                     │ Yes                      │
                                     ▼                          │
                          ╱─────────────────────╲      Yes      │
                         ╱   Cell Voltage Error?  ╲─────────────┤
                          ╲─────────────────────╱               │
                                     │ No                       │
                   ┌────────┐        ▼                          │
                   │ Charge │ ╱─────────────────────╲    Yes    │
                   └────────┘ ╲   Cell Temperature   ╱─────────┤
                              ╲   Error?            ╱           │
                               ╲─────────────────╱             │
                                     │ No                       │
                                     ▼                          │
                          ╱─────────────────────╲      Yes      │
                         ╱   Time-Out Error?      ╲─────────────┤
                          ╲─────────────────────╱               │
                                     │ No                       │
                                     ▼                          │
                  No      ╱─────────────────────╲               │
              ┌─────────── ╲   Charge Complete?   ╱              │
              │           ╲─────────────────────╱               │
              │                  │ Yes                          │
              │       ┌─────────────────────┐     ┌─────────────────────┐
              │       │   End Fast Charge   │     │ Terminate Charge Error│
                      └─────────────────────┘     └─────────────────────┘
```
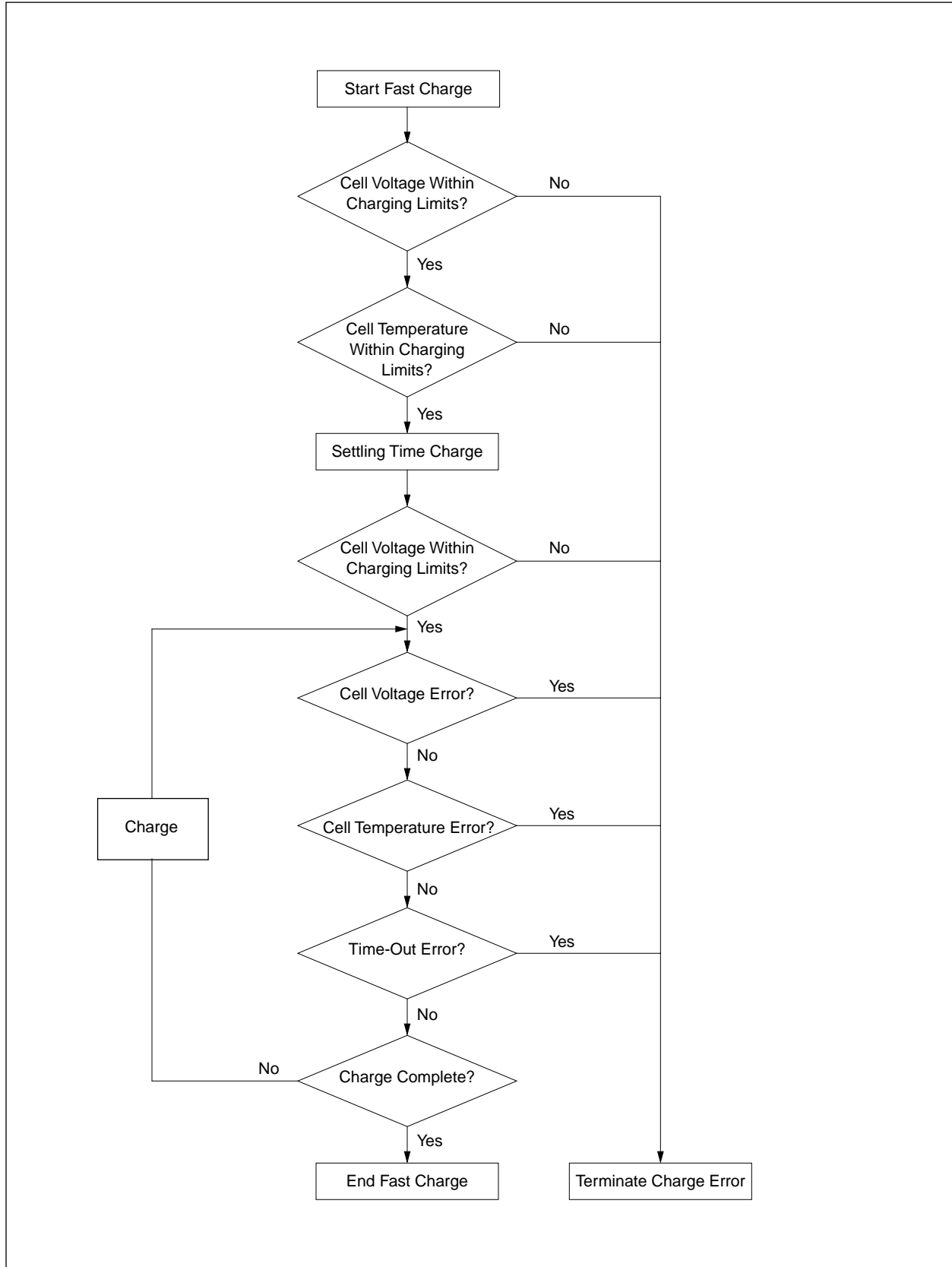
PICREF-2

Program Flow

The flow of `MAIN.C` is shown in Figure 13. The main program starts by initializing the hardware for battery charger operation. The program then performs an endless loop of checking for communications, sensing battery parameters, performing control functions, and checking for the TIC counter.

The flow of `INIT.C` is shown in Figure 14. The function initializes peripheral features and RAM variables. The following peripherals are initialized: Timer1, CCP1 (PWM), and A/D converter.

Timer1 is used for the TIC counter. It is initialized so that an interrupt is generated every 0.1 seconds. This is used as the frame clock for the battery charger algorithms.

The PWM function is initialized for 25 kHz operation. The peripheral is enabled and set for 0% duty cycle.

The A/D converter is initialized for conversion clock frequency and is enabled for operation.

In addition to peripherals, the I/O ports are configured for pushbutton, LED, and serial communications. The RAM locations are cleared and initialized to support charger operation. If DEVELOPMENT mode is selected, I^{2}C and RS-232 communications are initialized.

The flow of `COMMAND.C` is shown in Figure 15. In STAND_ALONE mode the switch inputs are read and debounced on the TIC count (0.1 seconds). If SW2 is detected as being pressed, the battery 1 charge state is selected. If SW4 is detected as being pressed, battery 2 charge state is selected. If both switches were detected, battery 1 will charge completely, then battery 2 will charge. After charge completion for both batteries, both batteries will be simultaneously trickle charged.

In DEVELOPMENT mode, the data received from the PC is interpreted and converted to battery control states. This enables the selected feature to be executed. The received character is echoed back to the PC for verification by the PC-based software.

The flow of `SENSE.C` is shown in Figure 16. If the TIC counter has counted to 1.0 seconds, then the sense features are executed. When the PWM goes LOW it is disabled, and the current, voltage, and temperature are monitored (Figure 17). The PWM is then re-enabled. The TIC counter and PWM control counter are updated. If the initialization time has completed, the termination check is done based on the selected charge termination algorithm. Also, if the initialization stage is complete, the fail safe limits are checked (Figure 18). If any fail safe limit has been exceeded, then all charging is terminated. If the PWM control is activated and the initialization is done, then the charge algorithm is performed. The charge algorithm can be either the fast charge algorithm or the trickle charge algorithm. If the

battery is in trickle charge state and both batteries are selected, then the trickle charging is swapped every loop execution.

The flow of `CONTROL.C` is shown in Figure 19. If a new command has been received, then the appropriate states are set. The states are executed in the following sequence:

1. Discharge Battery 1
   (DEVELOPMENT mode only)
2. Discharge Battery 2
   (DEVELOPMENT mode only)
3. Fast Charge Battery 1
4. Fast Charge Battery 2
5. Trickle Charge Battery 1
6. Trickle Charge Battery 2
7. Repeat Selected States
8. Idle

If a state is not selected then its operation is not executed and the function advances to the next state. Each state must complete execution before the next state commences.

FIGURE 13: **MAIN.C**

```
                    ┌──────────────┐
                    │    Start     │
                    └──────┬───────┘
                           │
                           ▼
                    ┌──────────────┐
                    │  Initialize  │
                    └──────┬───────┘
                           │
                           ▼
           ┌──────────────────────────┐
           │       Communicate        │◄──────┐
           └──────────┬───────────────┘       │
                      │                        │
                      ▼                        │
                ┌──────────────┐               │
                │    Sense     │               │
                └──────┬───────┘               │
                       │                        │
                       ▼                        │
                ┌──────────────┐                │
                │   Control    │                │
                └──────┬───────┘                │
                       │                        │
                       ▼                        │
                  ╱──────────╲         No       │
                 ╱  Timer1     ╲────────────────┤
                 ╲  Overflow?  ╱                │
                  ╲──────────╱                  │
                       │                        │
                      Yes                       │
                       │                        │
                       ▼                        │
           ┌──────────────────────────┐         │
           │       Reset Timer1       │─────────┘
           └──────────────────────────┘
```

PICREF-2

FIGURE 14:   INIT.C

```
                        ┌──────────────┐
                        │    Start     │
                        └──────────────┘
                               │
                               ▼
                    ┌────────────────────┐
                    │    Init Timer1     │
                    │   (TIC Counter)    │
                    └────────────────────┘
                               │
                               ▼
                    ┌────────────────────┐
                    │     Init PWM       │
                    │  (Buck Converter)  │
                    └────────────────────┘
                               │
                               ▼
                    ┌────────────────────┐
                    │   Init I/O Ports   │
                    └────────────────────┘
                               │
                               ▼
                    ┌────────────────────┐
                    │     Init A/D       │
                    │     Converter      │
                    └────────────────────┘
                               │
                               ▼
                    ┌────────────────────┐
                    │     Clear RAM      │
                    └────────────────────┘
                               │
                               ▼
                    ┌────────────────────┐
                    │   Init Variables   │
                    └────────────────────┘
                               │
                               ▼
                        ┌──────────────┐
                        │    Return    │
                        └──────────────┘
```

FIGURE 15: COMMAND.C

```
                        ┌─────────────┐
                        │    Start    │
                        └─────────────┘
                               │
                               ▼
                        ┌─────────────────┐
                        │ Read Switch Input│
                        └─────────────────┘
                               │
                               ▼
                             ◇ SW2
                               Pressed          No
                             (B1 Charge) ──────────────┐
                               │                        │
                              Yes                       │
                               ▼                        │
                        ┌─────────────────┐             │
                        │ Enable B1 Charge │             │
                        └─────────────────┘             │
                               │                        │
                               ▼                        │
            No               ◇ SW4 ◀───────────────────┘
         ┌───────────────────  Pressed
         │                   (B2 Charge)
         │                     │
         │                    Yes
         │                     ▼
         │              ┌─────────────────┐
         │              │ Enable B2 Charge │
         │              └─────────────────┘
         │                     │
         │                     ▼
         │              ┌─────────────┐
         └─────────────▶│   Return    │
                        └─────────────┘
```

PICREF-2

```
                          ┌──────────────┐
                          │    Start     │
                          └──────────────┘
                                 │
                                 ▼
                            ╱─────────╲                          ┌──────────────┐
                          ╱  TIC Counter = ╲     No              │    Return    │
                          ╲   1.0 sec?    ╱  ─────────────────▶  └──────────────┘
                            ╲─────────╱
                                 │ Yes
                                 ▼
                          ┌──────────────┐
                          │  IVT_SENSE   │
                          └──────────────┘
                                 │
                                 ▼
                            ╱─────────╲          No
                          ╱ Terminate Flag = TRUE? ╲──────────────┐
                          ╲─────────────────────╱                 │
                                 │ Yes                            │
                                 ▼                                │
                          ┌──────────────┐                        │
                          │Terminate Charge│                      │
                          └──────────────┘                        │
                                 │                                │
                                 ▼                                │
                No        ╱─────────────╲                         │
         ┌──────────────╱ Sensor Initialization ╲◀───────────────┘
         │              ╲    Complete?    ╱
         │                ╲─────────────╱
         │                       │ Yes
         │                       ▼
         │                ┌──────────────┐
         │                │  FAIL_SAFE   │
         │                └──────────────┘
         │                       │
         │                       ▼
         │                ┌──────────────┐
         └───────────────▶│  Continued   │
                          └──────────────┘
```

FIGURE 16:   SENSE.C (CON'T)

```
                        ┌──────────────────┐
                        │    Continued     │
                        └──────────────────┘
                                 │
                                 ▼
                              ╱─────╲
                           ╱           ╲                    No
                        ╱  Sensor Init    ╲
                       ╱   Complete          ╲──────────────────────┐
                        ╲  and PWM Control = ╱                       │
                           ╲   TRUE?       ╱                         │
                              ╲─────╱                                │
                                 │ Yes                              │
                                 ▼                                  │
                              ╱─────╲                               │
                           ╱           ╲           No              │
                        ╱    Charge       ╲───────────────────┐    │
                       ╱      State          ╲                │    │
                        ╲    Active?        ╱                 │    │
                           ╲             ╱                    │    │
                              ╲─────╱                         │    │
                                 │ Yes                        │    │
                                 ▼                            │    │
                        ┌──────────────────┐                  │    │
                        │  Perform Charge  │                  │    │
                        └──────────────────┘                  │    │
                                 │                            │    │
                                 ▼                            │    │
            No                ╱─────╲                         │    │
    ┌─────────────────────  ╱           ╲  ◄──────────────────┘◄───┘
    │                     ╱  Trickle Charge ╲
    │                    ╱   State Selected?  ╲
    │                     ╲                  ╱
    │                        ╲             ╱
    │                           ╲─────╱
    │                              │ Yes
    │                              ▼
    │                     ┌──────────────────┐
    │                     │  Swap Batteries  │
    │                     └──────────────────┘
    │                              │
    │                              ▼
    │                     ┌──────────────────┐
    └────────────────────►│      Return      │
                          └──────────────────┘
```

PICREF-2

FIGURE 17:   INT_SENSE

```
                    ┌──────────────┐
                    │    Start     │
                    └──────┬───────┘
                           │    ◄─────────────────────┐
                           ▼                          │
                         ╱────╲              No        │
                       ╱        ╲  ──────────────────►─┘
                      ◄ PWM = LOW? ►
                       ╲        ╱
                         ╲────╱
                           │
                           ▼ Yes
                    ┌──────────────┐
                    │  Disable PWM │
                    └──────┬───────┘
                           │
                           ▼
                    ┌────────────────────┐
                    │ Read Battery I,V, and T │
                    └──────┬─────────────┘
                           │
                           ▼
                    ┌────────────────────┐
                    │ Update TIC Counter │
                    └──────┬─────────────┘
                           │
                           ▼
                    ┌────────────────────┐
                    │    Update PWM      │
                    │  Control Counter   │
                    └──────┬─────────────┘
                           │
                           ▼
                    ┌──────────────┐
                    │    Return    │
                    └──────────────┘
```

FIGURE 18: FAIL_SAFE

```
                              ┌──────────┐
                              │  Start   │
                              └────┬─────┘
                                   │
                                   ▼                     No
                              ◇ Fast Charge? ◇──────────────┐
                                   │                         │
                                   │ Yes                     │
                                   ▼                         │
                 No          ◇ I,V,T Error? ◇                │
            ┌─────────────────    │                         │
            │                     │ Yes                     │
            │                     ▼                         │
            │          ┌──────────────────────┐            │
            │          │  Terminate to Idle and│           │
            │          │   Reset Variables     │           │
            │          └──────────┬────────────┘           │
            │                     │                         │
            │                     │                         │
            │         No          ▼                         │
            ├──────────────  ◇ Trickle Charge? ◇◀───────────┘
            │                     │
            │                     │ Yes
            │                     ▼
            │        No      ◇ I,V Error? ◇
            │    ┌───────────     │
            │    │               │ Yes
            │    │               ▼
            │    │    ┌──────────────────────┐
            │    │    │ Disable Trickle Charge│
            │    │    │    (Can Recover)      │
            │    │    └──────────┬───────────┘
            │    │               │
            │    └───────┐       ▼
            └──────────────▶┌──────────┐
                            │  Return  │
                            └──────────┘
```

PICREF-2

New Command?

No

Yes

Set States

State Selected?

No

Yes

State Enabled?

Yes

No

Enable State

State Complete?

No

Yes

Advance State

Return

User Customization

In order to select between DEVELOPMENT mode and STAND_ALONE mode, the following modifications must be made:

- Development Mode
- Stand-alone Mode

Development Mode

DEVELOPMENT Mode uses the PIC16C73A in conjunction with the PC-Based Development software for selecting battery charge/discharge parameters. The description below defines how DEVELOPMENT mode is enabled and may be customized by the user.

1) MAIN.C

Comment out the "#define STAND_ALONE" line in MAIN.C. This define is used by BATTERY.H to include the appropriate files, functions and variables.

Example:

```
//#define STAND_ALONE
```

2) BATTERY.H

No changes are needed. Based on DEVELOPMENT mode being defined, the battery parameters are placed in RAM so that they may be modified by the PC-based software. Also, RAM variables for serial communications are defined in this mode.

The duty cycle of the PWM is limited by the constant FST_CHARGER_MAX to 85%. If a higher duty cycle is needed, this constant may be modified.

3) INIT.C

No changes are needed.

4) COMMAND.C

No changes are needed. Based on DEVELOPMENT mode being defined, the new commands are received via the RS-232 serial link, parsed, and executed.

5) SENSE.C

No changes are needed.

6) CONTROL.C

No changes are needed.

7) LIBRARY.C

The user must update TERMINATE() Delta V to match their Zero ΔV time-out and voltage drop threshold. The algorithm times out if a voltage change is not detected within 255 seconds when Zero ΔV is selected. Also, if the voltage drop during Zero ΔV is greater than 47 mV, then the algorithm terminates.

The user must update FAST_CHARGE(). The charge current is limited to 1100 mA in DEVELOPMENT mode. If a higher charge rate is desired, this limitation can be removed.

The user must update the check_temp() lookup table to match their thermistor's Resistance-Temperature (RT) tables.

The V_SENSE() algorithm performs differently from STAND_ALONE mode although the resolution is the same. The "windowing" feature is used in DEVELOPMENT mode which gives 5.85 mV/bit resolution. Therefore a 16-bit variable is used for the voltage readings in DEVELOPMENT mode. This is converted to the 58.5 mV/bit resolution variable used for charge monitoring and termination decisions. So the decision tree is the same for both modes.

If the system frequency is changed, the serial communications must be updated appropriately.

Stand-Alone Mode

STAND_ALONE Mode uses the PIC16C72 in conjunction with the defined battery parameters to charge the selected battery packs. The description below defines how STAND_ALONE mode is enabled and may be customized by the user.

1) MAIN.C

Do not comment out the "#define STAND_ALONE" line in MAIN.C. This define is used by BATTERY.H to include the appropriate files, functions, and variables.

Example:

```
#define STAND_ALONE
```

2) BATTERY.H

The battery definition must be modified for the user's battery pack. The parameters that are used in RAM in DEVELOPMENT mode are moved to ROM for STAND_ALONE mode. So, the algorithm performs charge termination based on these definitions. The code example (Example 1) is an excerpt from the BATTERY.H file and includes the battery definition for a Sanyo KR1100-AEL NiCd 4-cell battery.

The duty cycle of the PWM is limited by the constant FST_CHARGER_MAX to 85%. If a higher duty cycle is needed, this constant may be modified.

3) INIT.C

No changes are needed.

4) COMMAND.C

No changes are needed. Based on STAND_ALONE mode being defined, the switch inputs for charge are read and executed. Only battery charge features are supported. If both switches are pressed, then charging is done on both batteries as defined by the state machine (CONTROL.C). The switch inputs are debounced on the TIC clock (0.1 seconds).

5) SENSE.C

No changes are needed.

6) CONTROL.C

No changes are needed. Discharge features are disabled in STAND_ALONE mode.

7)   LIBRARY.C

The user must update `TERMINATE() Delta V` to match their Zero ΔV time-out and voltage drop threshold. The algorithm times out if a voltage change is not detected within 255 seconds when Zero ΔV is selected. Also, if the voltage drop during Zero ΔV is greater than 47 mV, then the algorithm terminates.

The user must update the `check_temp()` lookup table to match their thermistor's Resistance-Temperature (RT) tables.

The `V_SENSE()` algorithm performs differently from DEVELOPMENT mode although the resolution is the same. The "direct sense" feature is used in STAND_ALONE mode which gives 58.5 mV/bit resolution. This resolution can be increased through hardware modifications. Therefore, an 8-bit variable is used for the voltage readings in STAND_ALONE mode. However, the decision tree is the same for both modes.

EXAMPLE 1: STAND-ALONE BATTERY DEFINITIONS

```
/***********************************************************************

          BATTERY DEFINITION FOR STANDALONE MODE

***********************************************************************/
//  The following are the definitions for the supplied NiCd battery
//  pack.
//
//  Battery Charge Temperature 0 to 45 deg C
//  Battery Charge Hi Voltage (1.63V per cell) = 6.52V
//  Battery Charge Lo Voltage (0.90V per cell) = 3.60V
//  Battery Charge Time Limit 60 minutes = 3600 sec
//  Battery Fast Charge Rate 1.10A
//  Battery Trickle Charge Rate 0.01A
//  Battery -dV/dt Threshold (0.03V per cell) = 0.12V
//  Battery  dT/dt Threshold (2 deg C per minute)
//  Battery Discharge Voltage (1.0V per cell) = 4.00V

#define B1_SYSTEM_STATUS 0x60
// Battery 1 Setup: Charge Once, NiCD

#define B2_SYSTEM_STATUS 0xA0
// Battery 2 Setup: Charge Once, NiCD

//#define B1_CHARGE_STATUS 0x70
// Battery 1 Setup: Fast Charge, Abs Voltage Termination

//#define B1_CHARGE_STATUS 0x60
// Battery 1 Setup: Fast Charge, Delta T/Delta t Termination

#define B1_CHARGE_STATUS 0x50
// Battery 1 Setup: Fast Charge, Delta V Termination

//#define B2_CHARGE_STATUS 0x70
// Battery 2 Setup: Fast Charge, Abs Voltage Termination

//#define B2_CHARGE_STATUS 0x60
// Battery 2 Setup: Fast Charge, Delta T/Delta t Termination

#define B2_CHARGE_STATUS 0x50
// Battery 2 Setup: Fast Charge, Delta V Termination

#define FAIL_SAFE_FC_TEMP_LO 0x00
// STAND_ALONE MODE: 8-bit signed, 0.5 C per bit

#define FAIL_SAFE_FC_TEMP_HI 0x5A
// STAND_ALONE MODE: 8-bit signed, 0.5 C per bit

#define FAIL_SAFE_FC_VOLT_HI 0x70
// STAND_ALONE MODE: 8-bit unsigned, 58.5 mV/bit

#define FAIL_SAFE_FC_VOLT_LO 0x3D
```

```
// STAND_ALONE MODE: 8-bit unsigned, 58.5 mV/bit

#define FAIL_SAFE_TC_TEMP_LO 0x00
// STAND_ALONE MODE: 8-bit signed, 0.5 C/bit

#define FAIL_SAFE_TC_TEMP_HI 0x5A
// STAND_ALONE MODE: 8-bit signed, 0.5 C/bit

#define TERMINATE_ABS_VOLT_HI 0x70
// STAND_ALONE MODE: 8-bit unsigned, 58.5 mV/bit

#define FAIL_SAFE_FC_TIME_OUT 0x0E10
// STAND_ALONE MODE: 16-bit unsigned, 1 second/bit

#define FAIL_SAFE_FC_AMP_HI 0x6E
// STAND_ALONE MODE: 8-bit unsigned, 10 mA/bit

#define FAIL_SAFE_TC_AMP_HI 0x01
// STAND_ALONE MODE: 8-bit unsigned, 10 mA/bit

#define FAIL_SAFE_DC_VOLT_LO 0x44
// STAND_ALONE MODE: 8-bit unsigned, 58.5 mV/bit

#define TERMINATE_DV_THRESHOLD 0x9C
// STAND_ALONE MODE: 8-bit unsigned, 5.85 mV/bit

#define TERMINATE_DT_THRESHOLD 0x02
// STAND_ALONE MODE: 8-bit unsigned, 0.5 C/minute
```

PICREF-2

Test Results - NiCd

Six (6) battery packs of the four-cell Sanyo KR1100-AEL battery packs were tested for changes in battery pack capacity for the charge termination algorithms listed in Table 5 and Table 6. The results show that there was a very high degree of correlation based on the charge termination algorithm chosen (i.e., the behavior of battery packs for Negative Delta Voltage terminations was nearly identical).

The batteries were cycled through harsh usage conditions of consecutive 1C charge and 0.8C discharge terminations (For a definition of C, see *Design Background - Battery Packs - Charge Rate*). After this, the battery was fully recharged, and the battery capacity was measured using a constant 0.8C load. The discharge was terminated after the reaching the "knee" of the battery voltage curve (approximately 1.0 volt per cell). The capacity measurement was determined by multiplying the load current by the amount of time before reaching the battery voltage curve "knee" (Figure 20).

As seen in the tables, after 200 cycles, the tested battery packs maintained over 90% capacity. The manufacturer's test data was under less strenuous conditions (0.1C charge and 0.7C discharge) and showed battery capacity of > 90% through 200 cycles of testing.

This data is for informational reference only. Differences in battery pack construction, battery cells, thermistor characteristics, thermistor placement, battery usage, and ambient conditions all affect battery performance.

TABLE 5: NEGATIVE DELTA VOLTAGE TERMINATION (100 mV)

Charge/Discharge Cycles	Original Capacity	Final Measured Capacity	Percent of Original Capacity
200	1100 mAh	1070 mAh	97%

TABLE 6: DELTA T / DELTA t TERMINATION (1 DEG C/MIN)

Charge/Discharge Cycles	Original Capacity	Final Measured Capacity	Percent of Original Capacity
200	1100 mAh	1020 mAh	93%

FIGURE 20: BATTERY CHARGING GRAPH
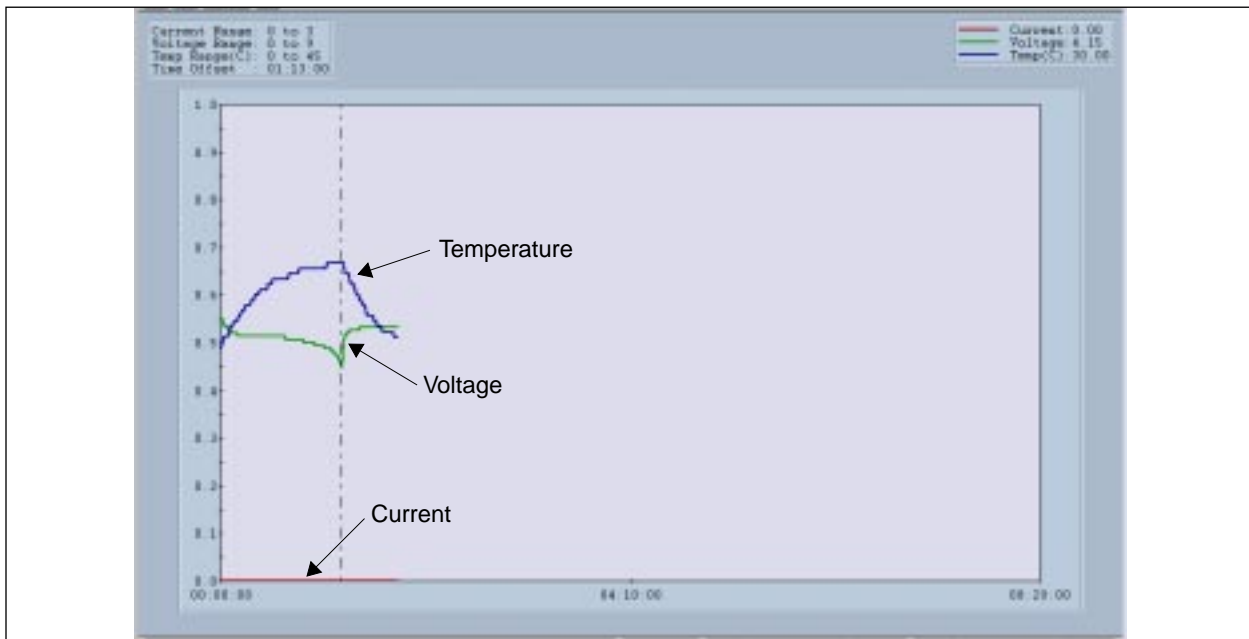
Test Results - NiMH

Two Duracell® battery packs (DR-15 and DR-35) were tested for changes in battery pack capacity for the -ΔV charge algorithm. The results show that there was a very high degree of correlation based on this charge termination method.

The DR-15 was cycled through consecutive 0.8C charge and 0.6C discharge terminations. After which, the battery was fully recharged and the battery capacity was measured using a constant 0.5C load. The discharge was terminated after the reaching the "knee" of the battery voltage curve (approximately 1.0 volt per cell). The capacity measurement was determined by multiplying the load current by the amount of time before reaching the battery voltage curve "knee."

As seen in Table 7 and Table 8, after 100 cycles, the tested battery packs maintained over 92% capacity.

This data is for informational reference only. Differences in battery pack construction, battery cells, thermistor characteristics, thermistor placement, battery usage, and ambient conditions all affect battery performance.

TABLE 7: DR-15 NEGATIVE DELTA VOLTAGE TERMINATION (100 mV)

Charge/Discharge Cycles	Original Capacity	Final Measured Capacity	Percent of Original Capacity
100	1420 mAh	1340 mAh	94%

TABLE 8: DR-35 NEGATIVE DELTA VOLTAGE TERMINATION (100 mV)

Charge/Discharge Cycles	Original Capacity	Final Measured Capacity	Percent of Original Capacity
100	2200 mAh	2020 mAh	92%

FIGURE 21:   BATTERY CHARGING GRAPH
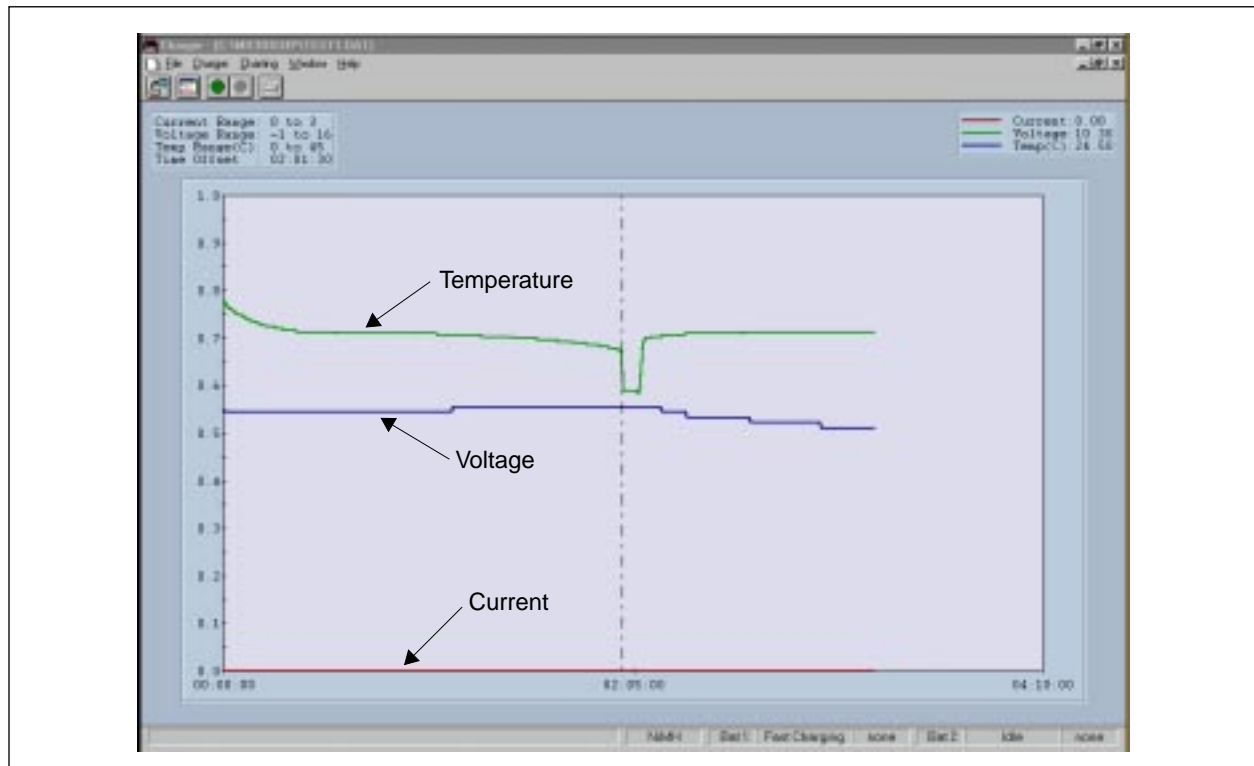
PICREF-2

PICREF-2 to PC Software Overview

Development mode provides a means for the PICREF-2 to talk to the PC via RS-232 communications. This provides for real-time battery monitoring and battery data logging.

The PICREF-2 to PC software is a Windows™-based application called Charger that allows for easy programming of the PIC16C73A microcontroller and monitoring of the IBC operation.

System Requirements

To use the Charger application, you will need:

- A PC with a 386 processor (or higher) running in 386 enhanced mode
- A hard disk with 4 Mbyte of free space
- A mouse or other pointing device
- An EGA, VGA or other compatible display
- 8 Mbyte RAM
- One free serial (COM) port
- Microsoft® Windows 3.1 (or higher)

System Setup

Connect power to the PICREF-2. Then, connect the PICREF-2 to the free COM port on the PC, with a serial cable. The firmware in the PIC16C73 microcontroller will automatically establish communications with the PC.

Installing Charger

To install the application:

- Start Windows
- Insert the Charger disk in a 3 1/2" disk drive (ex: A).
- In the Windows 3.1 Program Manager, choose Run from the File menu. In Windows 95, click on the Start Button and select Run from the drop-down menu.
- Type a:\setup in the Command Line box (Where a: is the disk drive letter).
- Choose OK.
- Follow the setup instructions.

When the setup is complete, you should have a Charger program group as shown in Figure 22.

FIGURE 22: CHARGER ICONS

Starting Charger

To start the Charger application for Windows 3.1, simply double click on the application icon in the Charger program group. For Windows 95, click on the Start button, select Programs, then the Charger program group, and finally the Charger application (charger.exe). The Charger window is shown in Figure 23.

FIGURE 23: CHARGER WINDOW
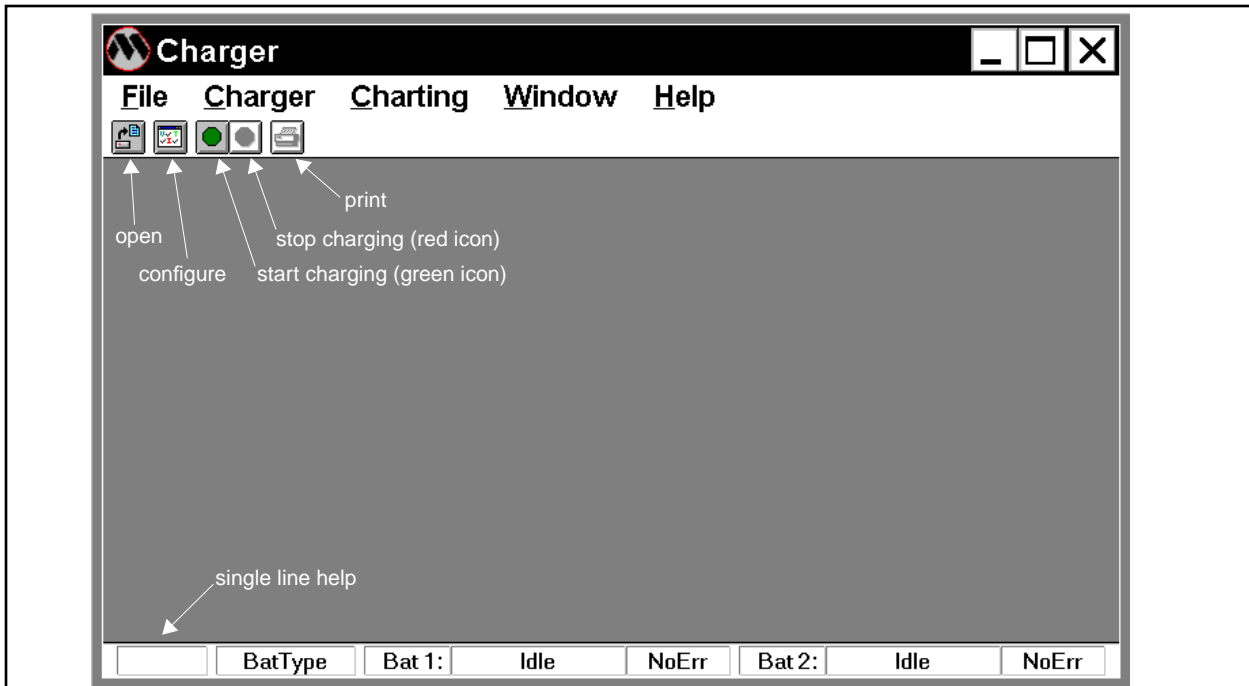
Setting up Charger

To set up the Charger application, select the Options command under the File menu to open the Battery Charger Setup Options window, as in Figure 24.

FIGURE 24:   BATTERY CHARGER SETUP OPTIONS
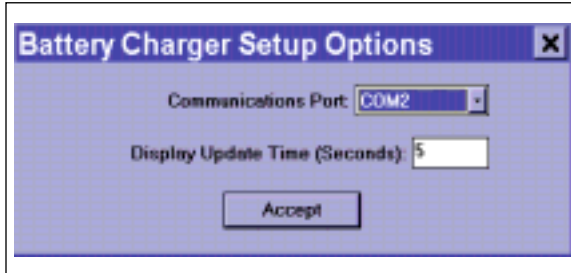
A communications port is chosen and displayed (ex: COM2). If you want to use a different com port, select one from the pull-down menu.

If the PC is not connected properly to the PICREF-2, an error message will appear. Exit from the Charger application and check the PC to PICREF-2 connections and power to PICREF-2. Then restart the Charger and attempt to set the Communications Port again.

Display Update Time (in seconds) is the rate at which battery charging data will be displayed when graphed to the screen. A default time will be entered. This time may

be changed by deleting the default value and entering a value from 1 second to 60,000 seconds (1000 minutes or almost 17 hrs).

When the charger is set up, accept all input by clicking on the Accept button.

Charger Configuration

When the charger is setup for the first time, it will automatically start the Battery Configuration window (Figure 25) after setup. To open this window at another time, select the Charger Configure... command from the Charger menu or click on the configure button.

Battery configuration parameters and their value ranges are as follows.

Fail Safe Limits

*   Charge Voltage Limit (V):
    Maximum values: 0V to 15V,
    Minimum values: 0V to 15V.
*   Fast Charge Temp Limit (C):
    Maximum values: 0˚C to 60˚C,
    Minimum values: -20˚C to 0˚C.
*   Trickle Charge Temp Limit (C):
    Maximum values: 0˚C to 60˚C,
    Minimum values: -20˚C to 0˚C.
*   Charge Time-out (Min):
    Values: 0 minutes to 541 minutes (over 9 hrs).

FIGURE 25:   BATTERY CONFIGURATION
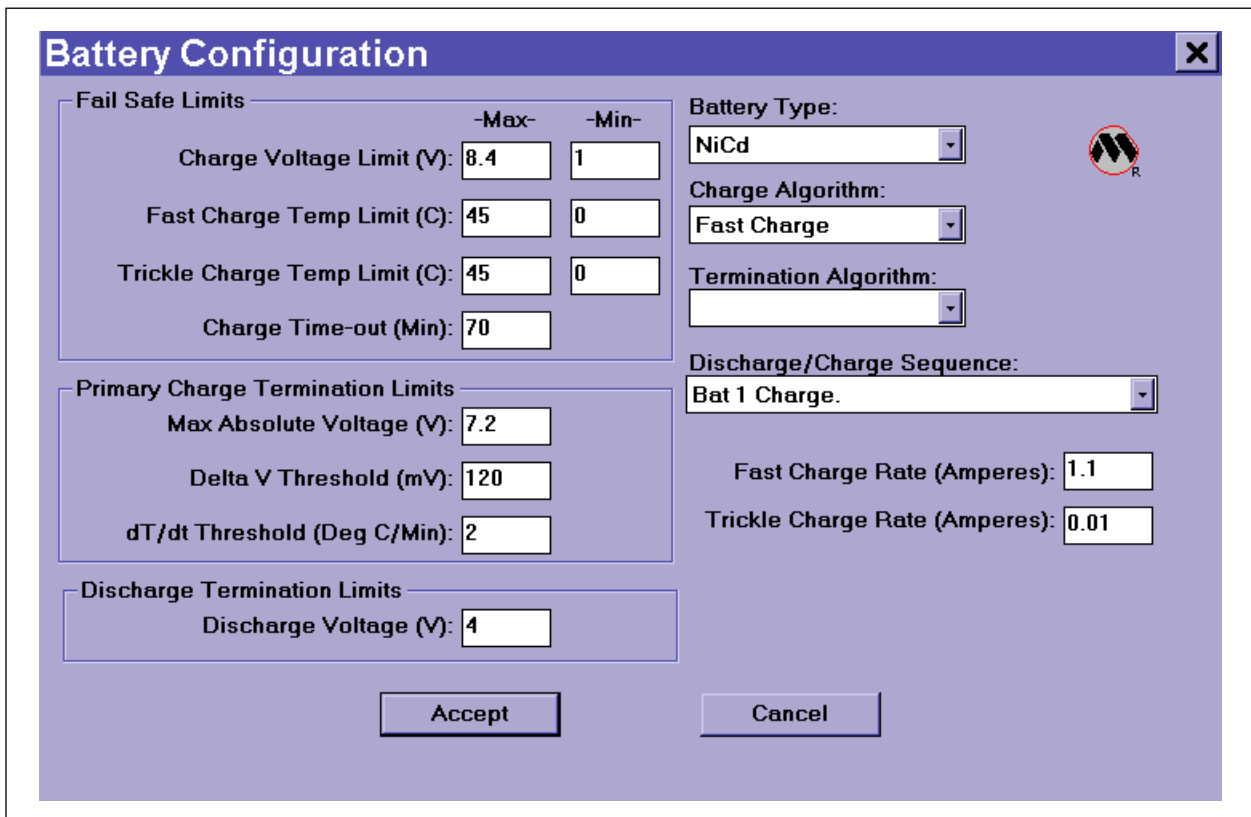
PICREF-2

Primary Charge Termination Limits

- Max Absolute Voltage (V):
  Values: 0V to 15V.
- ΔV (Negative or Zero) Threshold (mV):
  Values: 0 mV to 1500 mV.
- $\Delta T/\Delta t$ Threshold (Deg C/Min):
  Values: 0˚C/Min to 5°C/Min.

Discharge Termination Limits

- Discharge Voltage (V):
  Values: 0V to 15V.

Battery Type

- Pb-Acid with Temp
- Pb-Acid without Temp
- NiCd
- NiMH
- Li-Ion (not available)

Charge Algorithm

- Fast Charge
- Trickle Charge

Termination Algorithm

- ΔV (Negative or Zero)
- $\Delta T/\Delta t$
- Absolute Voltage

Discharge/Charge Sequence

- Battery 1 and 2 Discharge/Charge Once
- Battery 1 and 2 Discharge/Charge Repeatedly
- Battery 1 Discharge, Battery 2 Charge
- Battery 1 Charge, Battery 2 Discharge
- Battery 1 Discharge
- Battery 1 Charge
- Battery 1 Discharge/Charge Once
- Battery 1 Discharge/Charge Repeatedly
- Battery 2 Discharge
- Battery 2 Charge
- Battery 2 Discharge/Charge Once

Fast Charge Rate (Amperes)

- Fast Charge Rate (Amperes):
  Values: 0A to 2.55A.

Trickle Charge Rate (Amperes)

- Trickle Charge Rate (Amperes):
  Values: 0A to 0.3A.

If you are not familiar with the different battery technologies and the charge algorithms used with them, please refer to the section *Design Background*.

Running Charger

Once the Charger application is set up and configured, battery charging is started by selecting Start Charging from the Charger menu, or by clicking on the Start Charging button. Also, charging is halted by selecting Stop Charging from the Charger menu or by clicking on the Stop Charging button.

Charger Menus

The charger application has 5 menus: File, Charger, Charting, Window, and Help.

File Menu

The File Menu contains the following list of commands:

Open	Opens an existing data file to graph
Print...	Print this document
Print Setup...	Setup this document's print characteristics
Window Color	Change background color of edit window
Window Font	Change the font of edit window
Exit (Alt-F4)	Quit the Charger application

Charger Menu

The Charger Menu contains the following list of commands:

Stop Charging	Stop charging batteries
Start Charging	Start charging batteries
Charger Configure...	Configure battery charger parameters
Options...	Set communications and graphing options

Charting Menu

The Charting Menu contains the following list of commands:

Center On Marker	Zoom full in centered on the marker position
Max Zoom In	Display one data point per graph point
Max Zoom Out	Fit all available data points on the graph
Zoom In	Increase data point resolution
Zoom Out	Decrease data point resolution
Display Configuration	Display configuration and graphing parameters for data file chart

Windows Menu

The Windows Menu contains the following list of commands:

Cascade	Cascade open windows
Tile	Tile open windows vertically
Arrange Icons	Arrange icons on the desktop
Close All	Close all open windows

Help Menu

At this time, there is no on-line help.

Charger Example 1: NiCd using Delta V

To use PICREF-2 to charge a Sanyo NiCd battery pack using the Delta V termination algorithm, configure the charger as shown in Figure 26.

Charging can commence once PICREF-2 is configured. Clicking on the Start Charging button will bring up the Select Battery Save File window. Determine a name (ex: battery1.dat) and directory for the charging information to be stored in, and then click OK.

Charging will commence with the display of the charging graph (Figure 27). End charging by clicking on the Stop Charging Button.

Clicking on the completed graph at any point will place a marker there. Current, voltage and temperature information will be displayed (in the top right-hand data box) for the time offset (in the top left-hand data box) represented by the marker.

FIGURE 26:   NICD BATTERY CONFIGURATION FOR DELTA V (NEGATIVE OR ZERO)
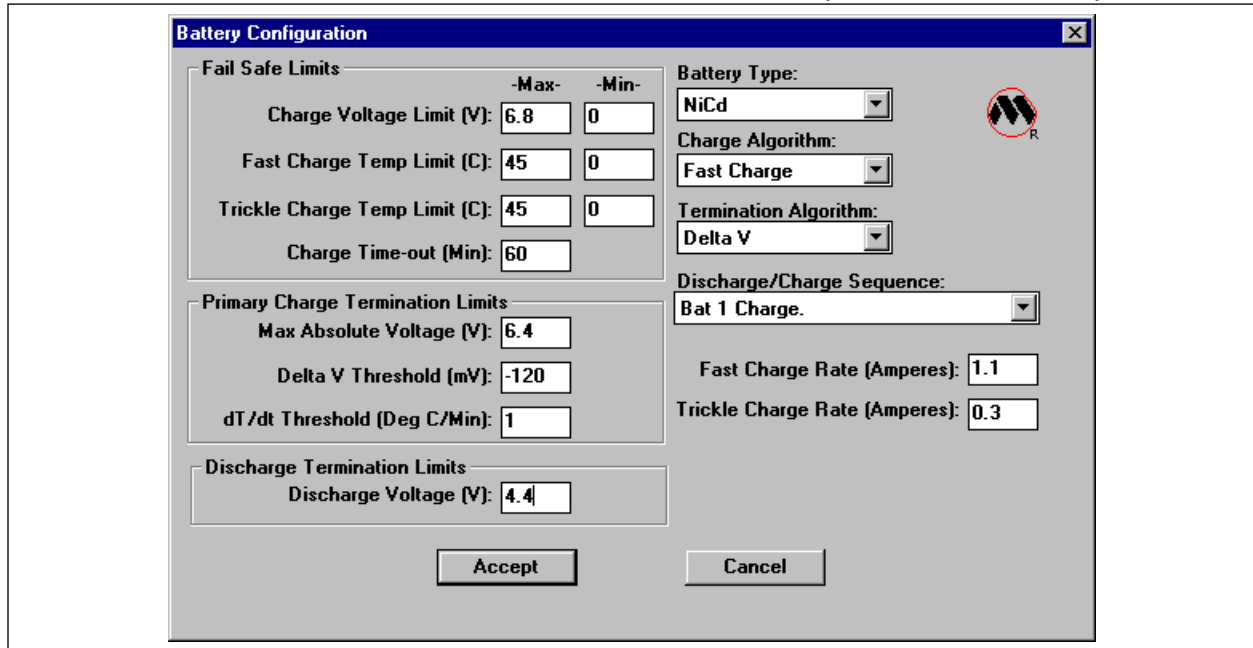
FIGURE 27:   NICD CHARGING GRAPH FOR DELTA V (NEGATIVE OR ZERO)
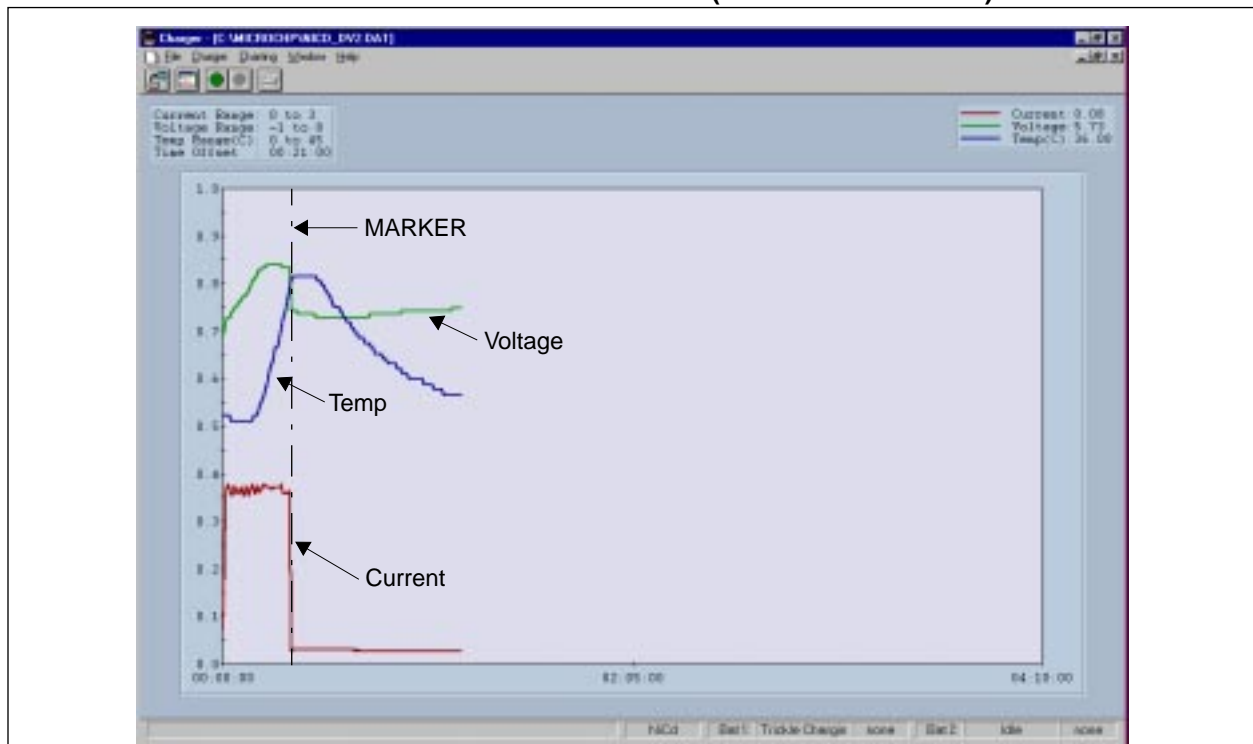
Charger Example 2: NiCd using DeltaT/Deltat

To use PICREF-2 to charge a Sanyo NiCd battery pack using the DeltaT / Deltat (dT / dt) termination algorithm, configure the charger as shown in Figure 28.

Charging can commence once PICREF-2 is configured. Clicking on the Start Charging button will bring up the Select Battery Save File window. Determine a name (ex: battery2.dat) and directory for the charging information to be stored in, and then click OK.

Charging will commence with the display of the charging graph (Figure 29). End charging by clicking on the Stop Charging Button.

Clicking on the completed graph at any point will place a marker there. Current, voltage, and temperature information will be displayed (in the top right-hand data box) for the time offset (in the top left-hand data box) represented by the marker.

FIGURE 28:   NICD BATTERY CONFIGURATION FOR DELTAT / DELTAt
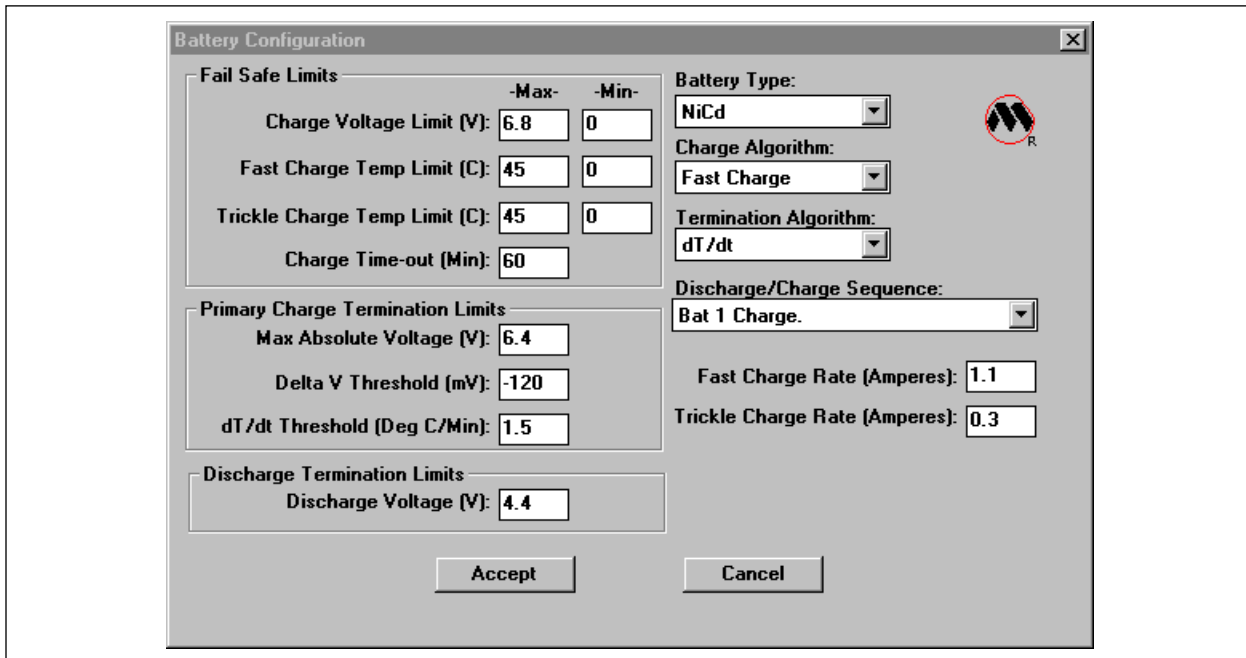
FIGURE 29:   NICD CHARGING GRAPH FOR DELTAT / DELTAt
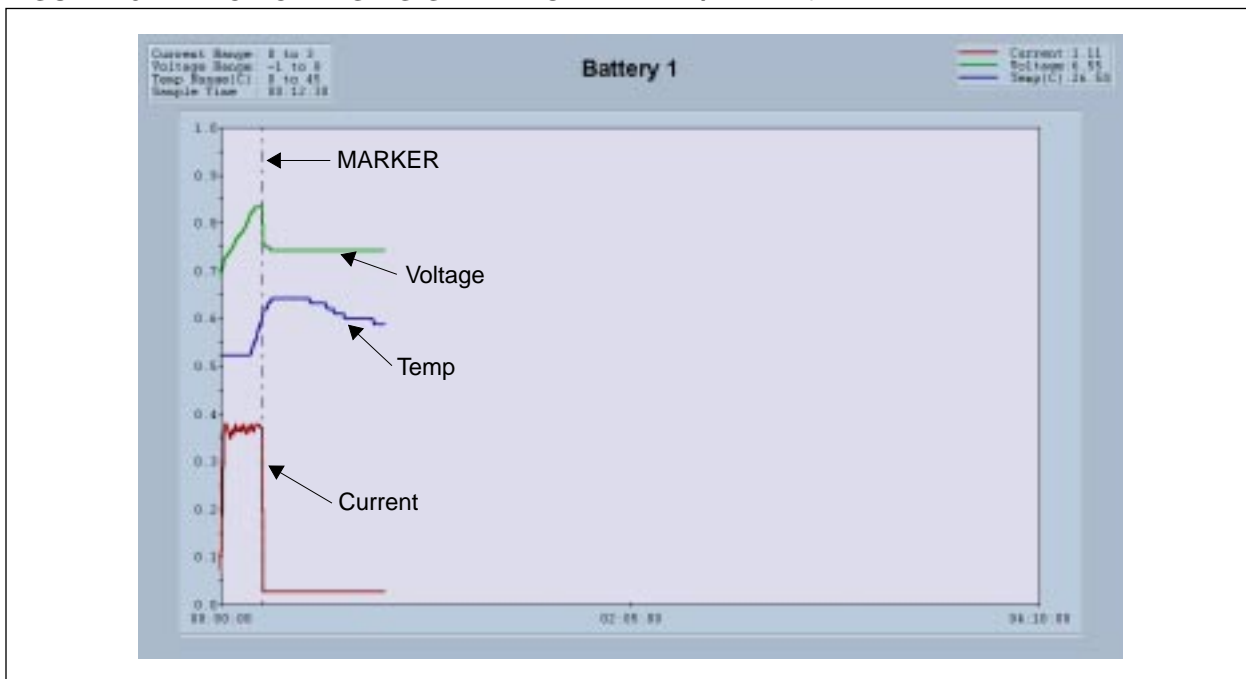
Charger Example 3: NiMH using Delta V

To use PICREF-2 to charge a NiMH battery pack using the Delta V termination algorithm, configure the charger as shown in Figure 30.

Charging can commence once PICREF-2 is configured. Clicking on the Start Charging button will bring up the Select Battery Save File window. Determine a name (ex: battery3.dat) and directory for the charging information to be stored in, and then click OK.

Charging will commence with the display of the charging graph (Figure 31). End charging by clicking on the Stop Charging Button.

Clicking on the completed graph at any point will place a marker there. Current, voltage, and temperature information will be displayed (in the top right-hand data box) for the time offset (in the top left-hand data box) represented by the marker.

FIGURE 30: NIMH BATTERY CONFIGURATION FOR DELTA V (NEGATIVE OR ZERO)
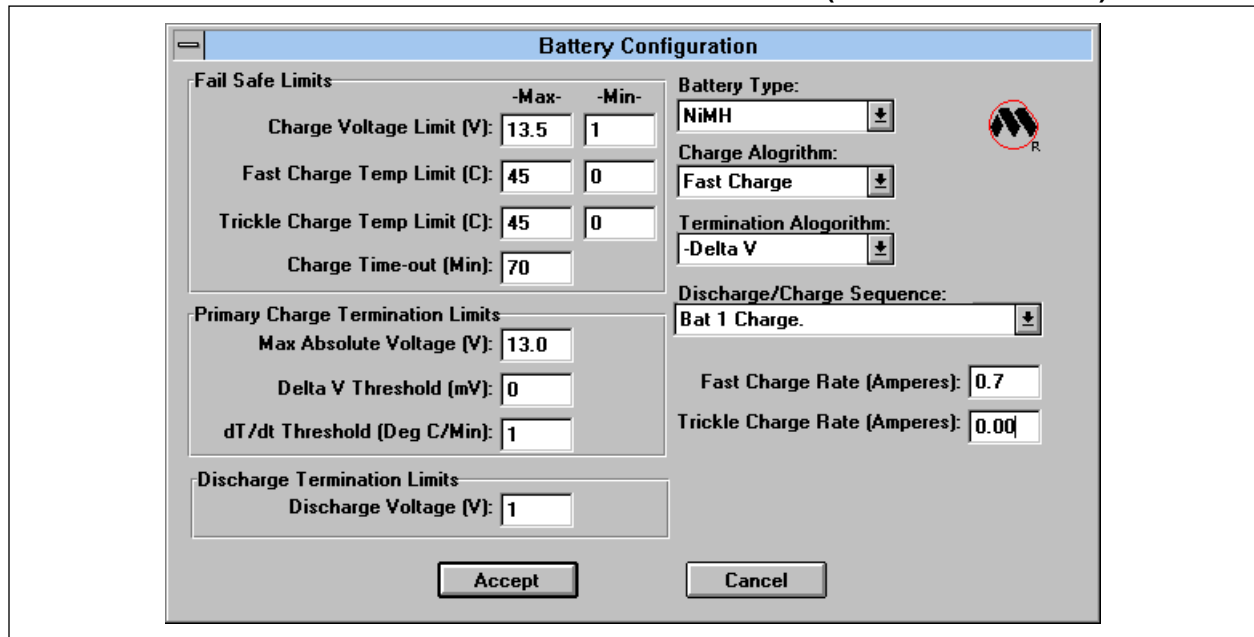
FIGURE 31: NIMH CHARGING GRAPH FOR DELTA V (NEGATIVE OR ZERO)
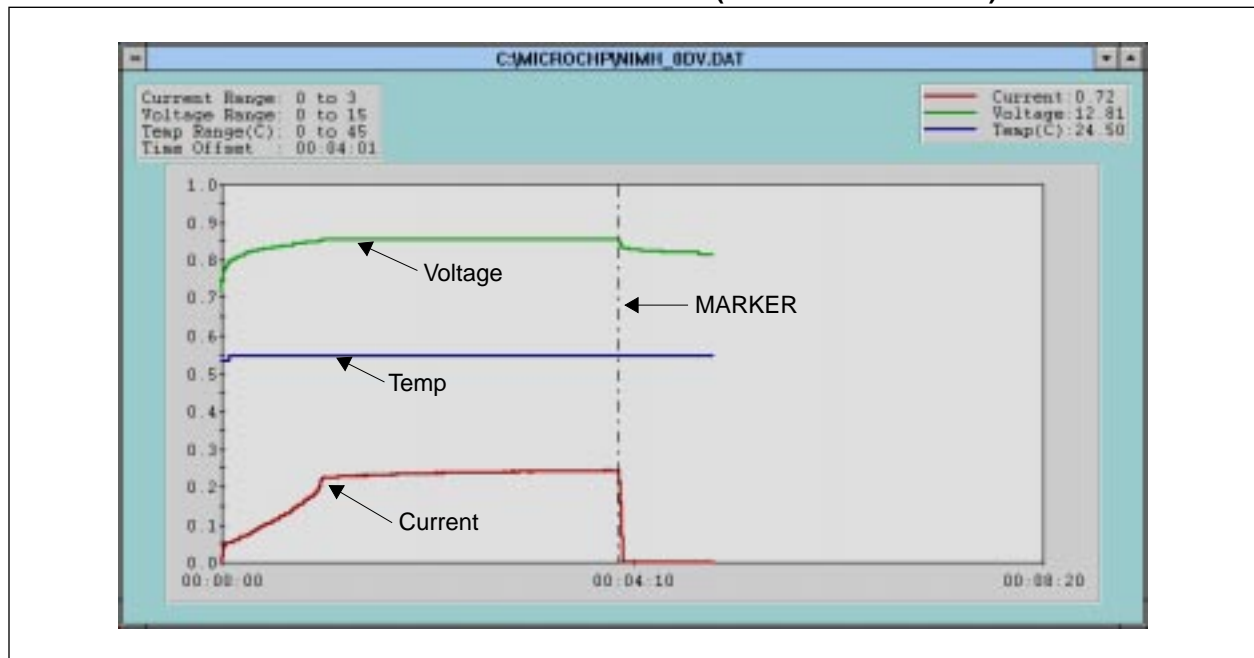
PICREF-2

Design Background

An example of how to implement a battery charger using microcontrollers has been described in the previous sections. However, if a customer wishes to change part or all of this design, then an understanding of why the design was developed as it was, i.e., an understanding of batteries, battery technology, and charging methods, is essential.

Battery Technologies

A list of available battery technologies, along with manufacturers and battery specifications, are shown in Table 9.

TABLE 9: BATTERY SPECIFICATIONS

Battery Technology	Manufacturer	Specifications
NiCd	Sanyo	4.8V to 12.0V at 1.1Ah to 1.7Ah Capacity
NiMH	Duracell®	DR-XX: 4.8V to 12.0V at 1.2Ah to 2.8Ah Capacity
Lead Acid	Yuasa™	NPX: 4.0V to 12.0V at 2.0Ah to 7.0Ah Capacity
Li-Ion	GS Batteries	LP9: 3.6V at 0.8Ah Capacity (Gaphite Electrode)

Battery Packs

The battery pack will consist of the following connections:

- Battery V+
- Battery V-
- Thermistor Interface

Battery Pack Capacity

The capacity of the battery pack is a function of the individual cells used. The cells can be standard, rapid-charge, high-temperature, high-capacity, or super high-capacity. Rapid charge cells have increased negative plate gas absorption characteristics which allow charging in < 1 hour. High-temperature cells contain a separator (typically polypropylene), which allow operating temperatures to exceed 65°C. High-capacity cells have both a high-capacity density positive plate and a high-density paste negative plate which provides 30%+ additional capacity over a standard cell. Super high-capacity cells contain enhanced positive and negative plate densities which provides 80%+ additional capacity over a standard cell.

Low capacity battery pack application requirements are in the 1200 mAh range, while high capacity battery pack application requirements are in the 3000 mAh range. The PICREF-2 will support both battery pack application requirements, though hardware must be changed to support 3000 mAh.

Charge Rate

The charge rate of a battery is defined in terms of the capacity C. For a battery capacity of 3000 mAh, a 1C charge rate would correspond to a charge current of 3.0 amps.

Maximum Discharge Rate

Floating loads are used in applications such as emergency devices, alarm systems, or memory back-up. These applications continually charge the battery so that the battery provides power when primary power is removed. Battery life is typically measured in years.

Cyclic loads are in applications such as camcorders, portable audio equipment, portable phones, and portable power tools. These applications use the battery as the primary power source. The battery is depleted and recharged repeatedly. Battery life is typically measured in terms of cycles.

Charging Considerations

Excess Gas & Thermal Runaway

Recharging must be controlled so that the gasses produced do not built up to dangerous levels. Manufacturers typically compensate for this by oversizing the negative plate. Also, heat can cause deterioration of the separator plate which will weaken it.

As a battery cell charges, gas bubbles are released and accumulate on the plates. This reduces the effective area of the plate and increases cell impedance. When the cell approaches full charge, the rate of gas generation and thermal energy increase. This causes the cell impedance to increase, which in turn produces more gas. This condition is called thermal runaway.

To charge lead acid, provide a charge current that is below the gassing voltage.

Memory Effect

Memory effect is the formation of crystals. Periodic full (deep) discharge is sufficient to reduce memory effect. Therefore, it is not necessary to fully discharge a NiCd battery each time.

Voltage Depression

A reversible drop in voltage and capacity may occur when a sealed NiMH battery is partially discharged and then recharged. This results in voltage depression or the "memory effect." The loss in voltage or capacity occurs because only a portion of the active materials is discharged and recharged during shallow or partial charging. The active materials that have not been cycled change in physical characteristics and increase in resistance. The active materials can be restored to their original state by subsequent full discharging-charging cycles.

Overdischarge

When a multi-cell series-connected battery is discharged, the lowest capacity cell will reach the point of full discharge before the other cells. If discharge is con-

tinued, the lower capacity cell can be driven into an overdischarge condition through 0.0V. This will cause its polarity to reverse.

This is caused by the positive electrode being discharged and producing hydrogen gas. The gas may be absorbed by the negative electrode with the remainder building up in the cell. If discharge continues, active material has been depleted and oxygen is produced on the negative electrode.

To minimize the possibility of polarity reversal, cells should be "matched" to within 5% capacities.

Self Discharge

Self discharge is caused by the reaction of residual hydrogen in the cell with the positive electrode along with the slow decomposition of both electrodes (the decomposition is reversed on subsequent charging). The self discharge rate increases with temperature (Table 10).

TABLE 10:SELF DISCHARGE OVER A 30-DAY PERIOD

Battery Technology	Temperature (degrees C)	Residual Capacity
NiCd	0	90%
	20	80%
	45	30%
NiMH	0	90%
	20	80%
	40	40%

Charge Termination Types

The controller specifies the primary and "fail-safe" charge termination algorithms for NiMH, NiCd, Li-Ion, and Lead Acid. Two modes of charging are implemented: a high current fast charge mode and a low current trickle charge mode. Several "fail-safe" backup mechanisms are provided to ensure that the fast charge mode is not allowed to continue indefinitely. Fail-safe mechanisms for trickle charge mode are also included to allow termination of all charging if the battery voltage or temperature is out of range.

Fast charging will continue until the programmed limit for the selected principal fast charge method is reached or exceeded. Fast charging can also terminate if any one of the fast charge "fail-safe" limits are exceeded. Trickle charge mode will always be entered after the fast charge mode terminates, if normal termination occurs. (Fail safe termination stops all charging.)

TABLE 11:FAST CHARGE NOMENCLATURE

Text	Symbolic	Formula
Negative Delta V	$-\Delta V$	$-dV/dt$
Zero Delta V	Zero ΔV	$dV/dt = 0$
Delta T / Delta t	$\Delta T/\Delta t$	dT/dt

TABLE 12:FAST CHARGE TERMINATION ALGORITHMS.

Fast Charge Termination Method	Li-Ion	NiMH	NiCd	Lead Acid
$-\Delta V$			X	
Zero ΔV		X		
$\Delta T/\Delta t$		X	X	
Absolute Voltage	X			X

TABLE 13:FAIL-SAFE CHARGE TERMINATION ALGORITHMS

"Fail-Safe" Termination Method	Li-Ion	NiMH	NiCd	Lead Acid
Timed Charge	X	X	X	X
Over/Under Temperature	X	X	X	X
Over/Under Voltage	X	X	X	X

The basic flow diagram for the charge termination algorithms is shown in Figure 12. The cell voltage and temperature is monitored until it is within safe charging limits. The battery is then charged for an initial settling period so that proper cell operation is ensured and false termination signals are filtered out. Fast charge continues until the primary charge termination method has been satisfied or a fail-safe termination condition is met.

Fast Charge Terminations

The fast charge mode is designed to allow rapid, high-current charging of a battery pack. Although there are many techniques available, the techniques used in this reference design are:

• Negative Delta V $(-\Delta V)$ Charge Termination
• Zero Delta V (Zero ΔV) Charge Termination
• Delta T / Delta t $(\Delta T/\Delta t)$ Charge Termination
• Absolute Voltage Charge Termination

$-\Delta V$ / Zero ΔV Charge Termination

When a NiCd battery reaches full charge, its voltage decreases. The $-\Delta V$ method makes use of this property by terminating fast charge mode when the voltage slope becomes negative. This method is widely used for NiCd. However, the voltage drop for NiMH is not as great; therefore the Zero ΔV method is used for NiMH. When a NiMH battery reaches full charge, its voltage plateaus. The Zero ΔV method makes use of this property by terminating fast charge mode when the voltage slope reaches this plateau. Figure 32 shows these characteristics.

FIGURE 32: BATTERY VOLTAGE VS. TIME (NICD/NIMH)
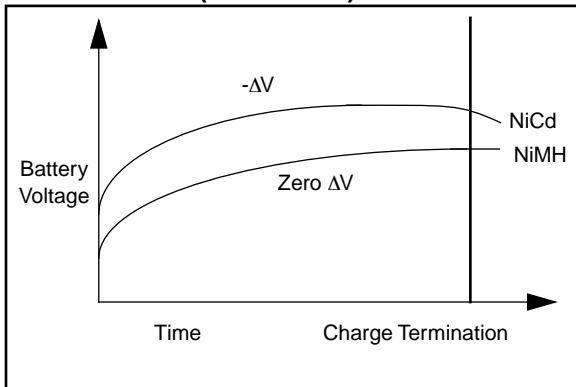
ΔT/Δt Charge Termination

When a NiCd or NiMH battery reaches full charge, the battery pack will experience a rapid rise in temperature. This is due to an increase in the conversion of charging energy into thermal energy. The ΔT/Δt method makes use of this property by using an internal thermistor to detect the rise in temperature. The controller measures the battery temperature and calculates the temperature rise rate with respect to time. It then compares this value to the stored threshold. The controller will terminate fast-charge mode, if the measured ΔT/Δt rate meets or exceeds and the stored ΔT/Δt rate threshold. Figure 33 shows this characteristic.

FIGURE 33: BATTERY TEMPERATURE VS. TIME (NICD/NIMH)
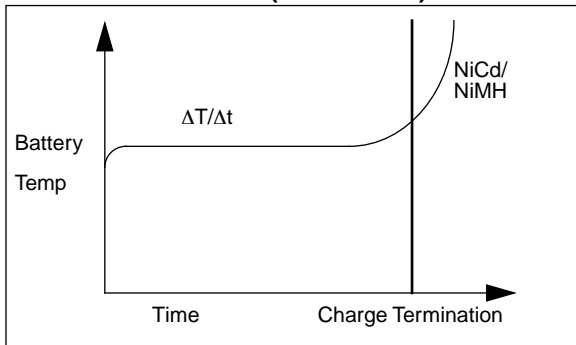
Absolute Voltage Charge Termination

When a Li-Ion or Lead Acid battery approaches full charge, the battery pack voltage reaches its predefined limit based on the technology of the cell. The absolute voltage method makes use of this property by terminating charging when the battery voltage meets or exceeds its limit. This should not be confused with the fail-safe over-voltage mechanism that will terminate charging, if a maximum voltage limit is exceeded. The over-voltage limit is a backup mechanism for fast-charge termination and is always enabled. The predefined voltage limit is a primary charge termination limit and is only active when absolute voltage charge termination is enabled. Figure 34 shows this characteristic.

FIGURE 34: BATTERY VOLTAGE VS. TIME (LI-ION/LEAD ACID)
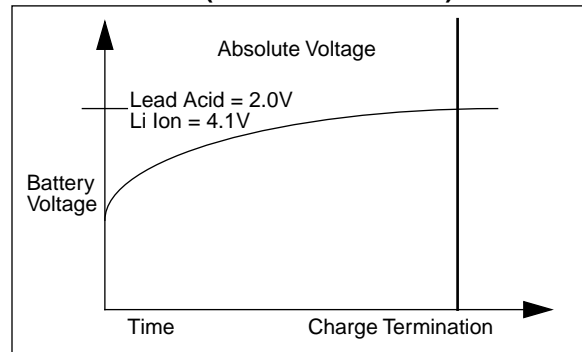
Fail-Safe Charge Terminations

The fail-safe charge termination methods are:

• Timed Charge Termination
• Over/Under Temperature Charge Termination
• Over/Under Voltage Charge Termination
• Trickle Charge Mode

Timed Charge Termination

The timed charge termination is 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.

Over/Under Temperature Charge Termination

The over/under temperature charge termination is a fail-safe method for terminating any charging algorithm. Temperature limits for both over-temperature and under-temperature are monitored. Fast charging will not be allowed if the battery temperature exceeds the over-temperature limit or is less than the under-temperature limit. Fast charging will begin or resume when the temperature falls within these limits.

Over/Under Voltage Charge Termination

The over/under voltage charge termination is a fail-safe method for terminating any charging algorithm. Voltage limits for both over-voltage and under-voltage are monitored. Fast charging will not be allowed if the battery voltage exceeds the over-voltage limit or is less than the under-voltage limit. Fast charging will begin or resume when the voltage falls within these limits.

Trickle Charge Mode

The trickle charge mode allows the battery to continue charging and remain at or near a 100% state of charge during periods of charge/discharge inactivity. The amount of current provided to the battery is determined by the duty cycle of the PWM-driven current source. Fail-safe limits for battery over-temperature, under-temperature, over-voltage, and under-voltage can all suspend trickle mode charging.

PICREF-2

Reference Material

For additional battery information, please refer to the following books:

- "Handbook of Batteries" 2nd Edition, McGraw-Hill, David Linden, 1995
- "Rechargeable Batteries Applications Handbook," Butterworth-Heinemann, 1992

Design Modifications

This reference design is for guidance only, and it is anticipated that customers will make modifications. With this in mind, this section suggests modifications that the customer may wish to make to the design.

- This design may be modified to create a single battery charger using a PIC16C711 microcontroller (Figure 35 and Figure 36). The hardware for this modification is supported, but the firmware has not yet been developed.
- Several circuits are optional and may be used or not used at the user's discretion. The trade-offs are reduced cost (by using fewer circuits/components) vs. necessary performance.

FIGURE 35: PIC16C711 PINOUT
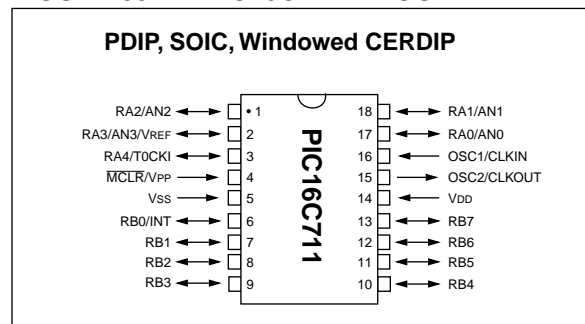
FIGURE 36: PICREF-2 INTELLIGENT BATTERY CHARGER - SINGLE BATTERY SYSTEM
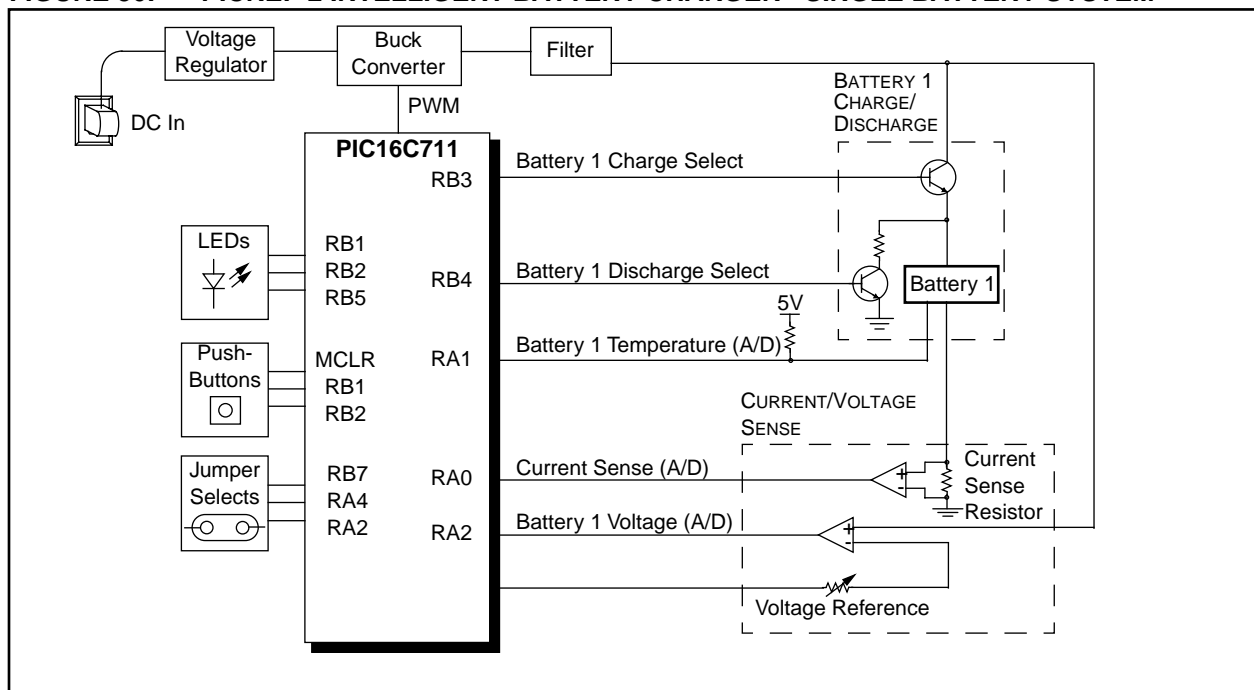
NOTES:

APPENDIX A: SYSTEM SPECIFICATIONS

Voltage Range: 7V to 24V DC, based on battery pack

Maximum Battery Pack Capacity: 3000 mAh @ 25°C

Maximum Charge Current: 2.0A   (L2 w/o L3)

1.3A   (L2 with L3)

Operating Temperature: -20°C to 60°C

A.1 Minimum Charger System

The schematic for a minimum charger system is shown in Appendix B. This system will only charge batteries (no discharge). The PIC16C72 microcontroller is used in this system, which means it functions in stand-alone mode only. Also, voltage regulator U10 is used, and there is no input filter.

A.2 Full Charger System

The schematics for the full charger system is shown in Appendix C. This system includes circuits that may be replaced by others at the designer's option.

The PIC16C73A microcontroller is shown in the main schematic. However, a PIC16C72 may be used (for STAND-ALONE mode only) or a PIC16C711 (for STAND-ALONE mode, single battery).

A 10 MHz crystal oscillator is shown with the PIC16C73A in the main schematic. This may be replaced with the XT1 (CTX163). If the PIC16C72 microcontroller is used, crystal oscillator X1 or XT2 (CTX163) may be used.

PICREF-2

APPENDIX B: MINIMUM CHARGER SCHEMATIC

This schematic may be obtained electronically on the Microchip BBS and WWW sites (OrCAD, DOS v4.40).

### B.1   PICREF-2 Minimum Charger Schematic - 1 of 1

© 1997 Microchip Technology Inc.
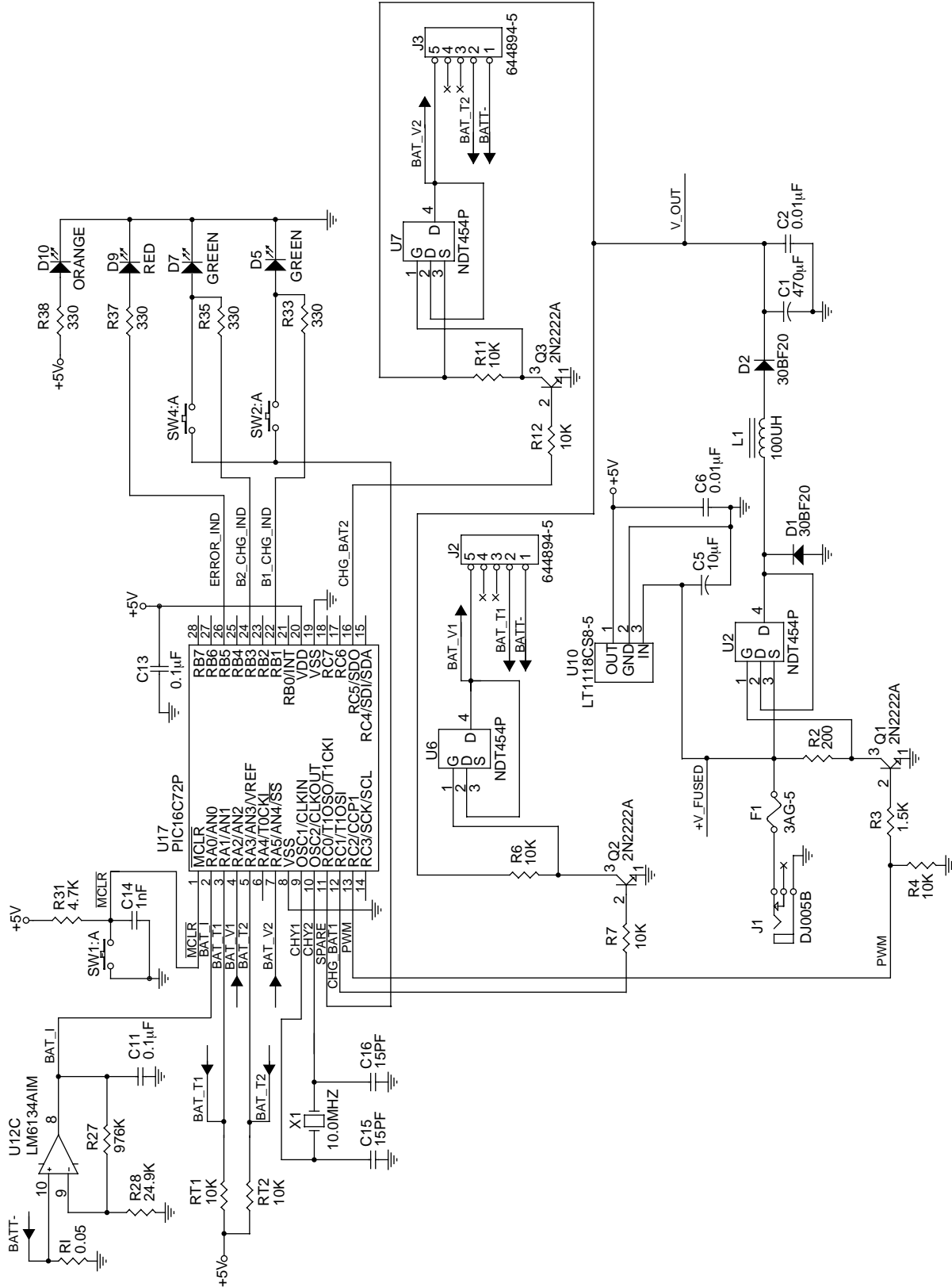
APPENDIX C: FULL CHARGER SCHEMATIC

This schematic may be obtained electronically on the Microchip BBS and WWW site (OrCAD, DOS v4.40).

C.1   PICREF-2 Full Charger Schematic - 1 of 3

H2   BATT-   pp 2

0.05

U12C
LM6134AIM
BAT_I

R27
976K
C11
0.1µF

R28
24.9K

HANDSHAKE   R15   +5V   R16   STANDALONE
10K   10K
JMPR6   JMPR5

JMPR4

+5V
R31
4.7K
SW1:A   MCLR
C14
1nF

C20   +5V
0.1µF

H1   +5V
10k

10k

BAT_T1   pp 2

BAT_T2   pp 2

pp 2

pp 2   pp 2

U19
PIC16C73P

MCLR	1	MCLR/VPP
BAT_I	2	RA0/AN0
BAT_T1	3	RA1/AN1
BAT_V1	4	RA2/AN2
BAT_T2	5	RA3/AN3/VREF
HANDSHAKE	6	RA4/T0CKI
BAT_V2	7	RA5/SS/AN4
	8	Vss
CHY1_73	9	OSC1/CLKIN
CHY2_73	10	OSC2/CLKOUT
SPARE	11	RC0/T1OSO/T1CKI
CHG_BAT1	12	RC1/T1OSI/CCP2
PWM	13	RC2/CCP1
SCK	14	RC3/SCK/SCL

RB7   28   STANDALONE
RB6   27   DIS_BAT2   pp 3
RB5   26   ERROR_IND   pp 3
RB4   25   B2_DIS_IND   pp 3
RB3   24   B2_CHG_IND   pp 3
RB2   23   B1_DIS_IND   pp 3
RB1   22   B1_CHG_IND   pp 3
RB0/INT   21   DIS_BAT1   pp 2
VDD   20
Vss   19
RC7/RX/DT   18   RECV
RC6/TX/CK   17   XMIT
RC5/SDO   16   CHG_BAT2   pp 2
RC4/SDI/SDA   15   SDA   pp 2

X2
10.0MHZ

C18   C19
15pF   15pF

pp 3   pp 2

pp 2

+5V
XT1
4   5V   OSC   3   CHY1_73
2   GND   NC   1
CTX163

Optional Oscillator Circuit

+5V
RECV   1   DOUT   VCC   8
XMIT   2   VDRV   RXIN   6
3   DIN   NC
4   GND   TXOUT   5
U18
DS1275S

J4
1
6
2
7
3
8
4
9
5
DB9F

Optional
Voltage
Regulator

U14
VIN   1
VOUT   2
GND   3
NJM7805

U10
OUT   1
GND   2
IN   3
LT1118CS8-5

+5V

C5   C6
10µF   0.01µF

+V_FUSED

J1   F1
3AG-5
DJ005B

R2
200

PWM   R3
1.5K

R4
10K

Q1
2N2222A

U1
NC   D   8
S   D   7
G   D   6
D   5
IRF7406

U2
G   1
D   2
S   3   D   4
NDT454P

U3
IRF9540

D1
30BF20

L1
100uH

D2
30BF20

C1   C2
470µF   0.01µF

pp 2   V_OUT

JMPR1

JMPR2   L3   JMPR3
27uH

C3   C4
0.47µF   0.47µF

Optional Input Filter

PICREF-2

C.2   PICREF-2 Full Charger Schematic - 2 of 3
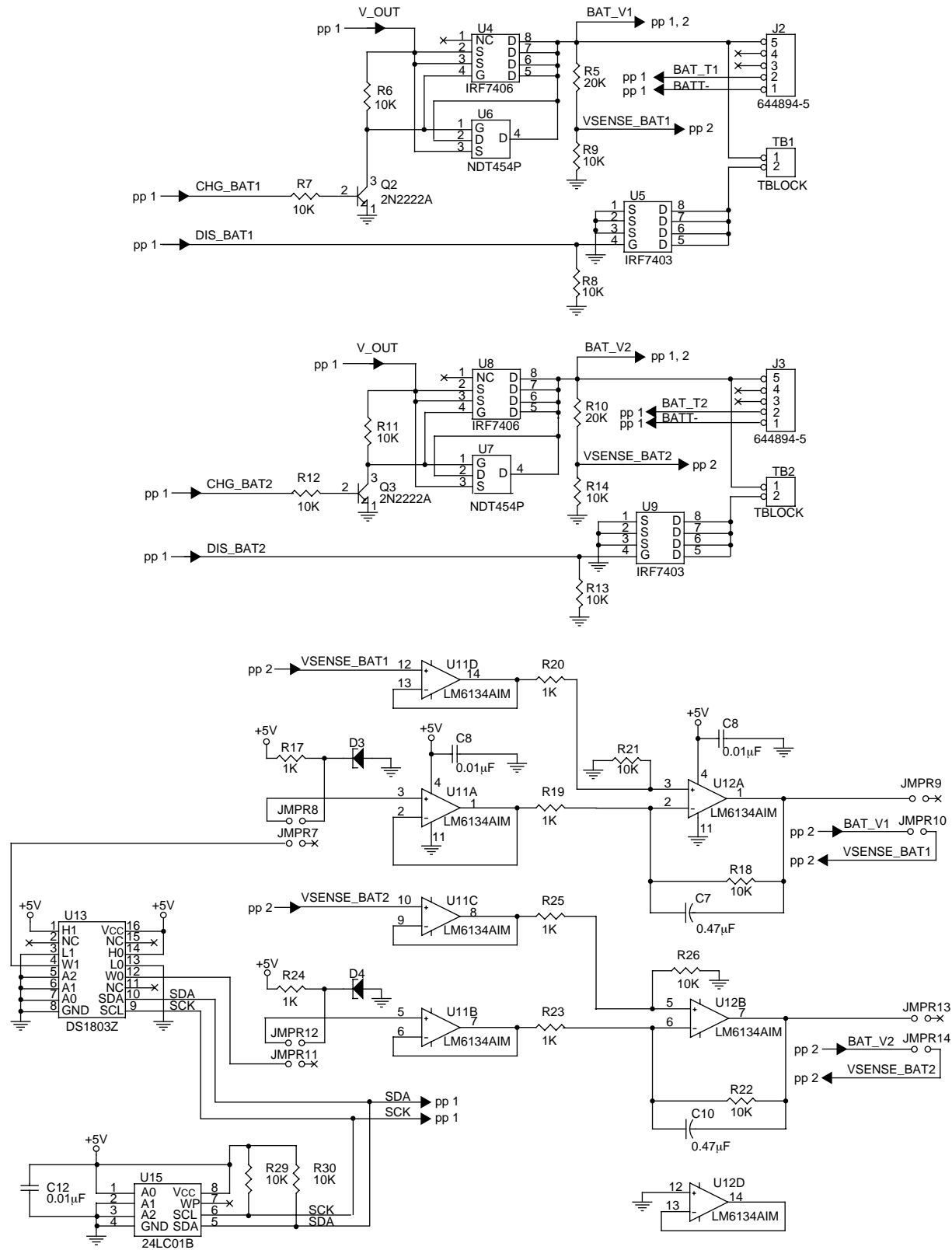
C.3   PICREF-2 Full Charger Schematic - 3 of 3
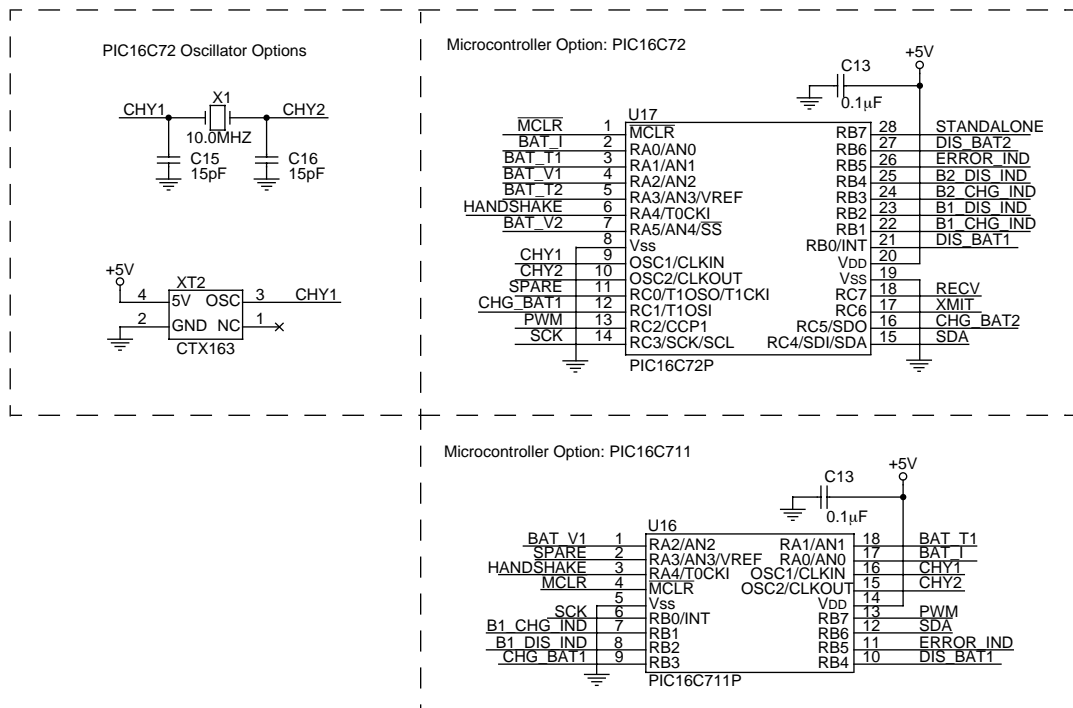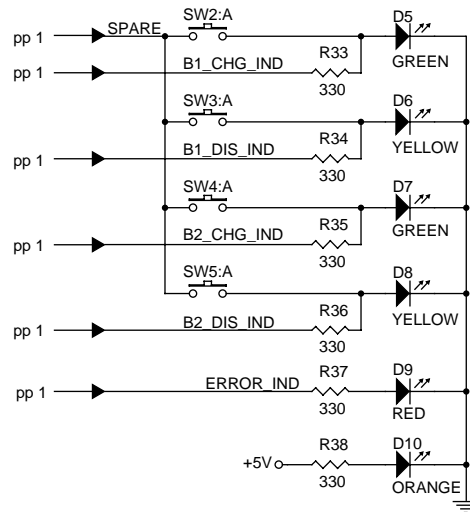
APPENDIX D: FIRMWARE LISTING

PIC16C7X firmware source code listings may be obtained electronically on the Microchip BBS and WWW site. Source code is written is C and may be compiled using MPLAB-C.

Source code files:

- battery.h
- control.c
- command.c
- init.c
- library.c
- sense.c
- main.c

APPENDIX E: PICREF-2 TO PC PROTOCOL

This section describes the communications protocol used between the PICREF-2 Intelligent Battery Charger (IBC) and a Host PC. The physical and data link layers of this interface are provided by an RS-232 serial link. This protocol forms the transport layer; i.e., provides the mechanism for transporting control and data between the PICREF-2 and the Host PC.

The protocol consists of a message format, a set of commands, and data field definitions for each command. It is a master-slave protocol, meaning that the Host PC controls the flow of information between the two units (i.e., the PICREF-2 only sends data in response to a request from the Host PC). The Host PC can send commands or configuration data to the PICREF-2 or it can ask for status to be sent back to the Host PC by the PICREF-2. All communications over the RS-232 link are done at a 9600 baud rate, eight bits, one stop bit, no parity, using binary data (vs. ASCII-based text data).

E.1 Message Format

The message format for communications from the PC to the PICREF-2 is defined as follows:

<command> <data1> <data2> … <dataN> <checksum>

where <command> represents a command byte, <data#> represents one or more data bytes associated with the command byte, and <checksum> represents an 8-bit checksum. The checksum is determined by summing all bytes of the message (command and all data bytes), truncating all but the lower eight bits of the summation, and then inverting (one's complement) the byte.

Data sent from the PICREF-2 to the PC follows the same format as shown above, with the exception that there is no command byte at the start of the message. There is only one data set definition for the PICREF-2, so a header byte is not needed to distinguish between data sets.

E.2 Handshaking

To prevent from having to use interrupts on the PICREF-2, a handshake is built into the protocol by having each byte received by the PICREF-2 from the Host PC being echoed back to the Host PC after reception. The Host PC has an eventual (one second) time-out, after which time it assumes the last character sent was not received. In this case, the character will be resent. The character will also be resent if the echoed character does not match the character sent by the Host PC. Note that the Host PC does NOT echo received characters back to the PICREF-2; i.e., the handshake is only one-way.

PICREF-2

E.3 Command & Data Field Definitions

The commands defined for communication from the Host PC to the PICREF-2 are as follows:

- System enable
- Configure
- Send data
- Send configuration

E.3.1 SYSTEM ENABLE COMMAND (04h)

This command sends the System (byte 1) and Charge Enable (byte 2) bytes, respectively, which override the current settings and initiate an action (e.g., charge or discharge). This command also has the effect of resetting the battery error byte and the battery charging algorithm. Data field definitions are shown as follows:

Message Format

PC Host:

04h	System Enable Byte	Charge Enable Byte	Checksum

Byte 1: System Enable Byte (charge/discharge sequence)

Battery Charge/Discharge Mode		Battery Chemistry	

bit7   bit0

bit 7-4: Battery Charge/Discharge Mode
- 0000 = Idle Mode
- 0001 = Special Mode - Discharge B1/Charge B2 (not supported in prototype)
- 0010 = Special Mode - Charge B1/Discharge B2 (not supported in prototype)
- 0011 = Battery 1 & 2 Discharge/Charge ONCE Mode
- 0100 = Reserved
- 0101 = Battery 1 Discharge Mode
- 0110 = Battery 1 Charge Mode
- 0111 = Battery 1 Discharge/Charge Mode
- 1000 = Reserved
- 1001 = Battery 2 Discharge Mode
- 1010 = Battery 2 Charge Mode
- 1011 = Battery 2 Discharge/Charge Mode
- 1100 = Reserved
- 1101 = Battery 1 & 2 Discharge Mode
- 1110 = Battery 1 & 2 Charge Mode
- 1111 = Battery 1 & 2 Discharge/Charge REPEAT Mode

bit 3: Reserved

bit 2-1: Battery Chemistry (assumes battery 1 and 2 are of the same type)
- 00 = NiCd enabled
- 01 = NiMH enabled
- 10 = Lead Acid enabled
- 11 = Li-Ion enabled (Provisional)

bit 0: Reserved

Byte 2: Charge Enable Byte

Charge Algorithm	Charge Term. Algorithm				
bit7					bit0

bit 7-6:   Charge Algorithm
  00 = Reserved
  01 = Fast Charge Algorithm
  10 = Trickle Charge Algorithm
  11 = TBD

bit 5-4:   Charge Termination Algorithm
  00 = None Enabled (except Fail Safe is always enabled)
  01 = Delta-V (Zero Delta-V or Negative Delta-V)
  10 = Delta-T/Delta-t
  11 = Absolute Voltage

bit 3-0:   Reserved

PICREF-2

E.3.2   CONFIGURE COMMAND (2Ah)

This command sends configuration data to the PICREF-2. This command is used to pass device-specific parameterization input from the PC to the PICREF-2. This information will overwrite previous settings, but this command does not initiate any new activity. If a charge or discharge is in progress when a Configure command is received, the current activity will be stopped (i.e., device parameters should not be changed mid-way through a charge or discharge).

Data field definitions are defined as follows: (Note: If two batteries are present, it is assumed that both are started at the same time and use the same parameters).

Message Format

PC Host:

2Ah	Temp_Lo	Temp_Hi	Max_Voltage	Max_Voltage	• • •	Checksum

Byte 1: TEMP_LO

Minimum low temperature in degrees C for Fast Charge/discharge mode, represented as an 8-bit signed binary value with 0.5 degrees C/bit (range: -64°C [80h] to +63.5°C [7Fh]).

Byte 2: TEMP_HI

Maximum high temperature in degrees C for Fast Charge/discharge mode, represented as an 8-bit signed binary value with 0.5 degrees C/bit (range: -64°C [80h] to +63.5°C [7Fh]).

Byte 3: MAX_VOLTAGE

Overall maximum voltage in any charge mode (for Fail-Safe termination) for all battery cells, represented as an 8-bit unsigned binary value with each bit representing 58.5mV (range: 0 to 14.91V).

Byte 4: MIN_VOLTAGE

Overall minimum voltage in any discharge mode (for Fail Safe termination) for all battery cells, represented as an 8-bit unsigned binary value with each bit representing 58.5mV (range: 0 to 14.91V).

Byte 5: TRICKLE_TEMP_LO

Minimum low temperature in degrees C for maintenance charge mode, represented as an 8-bit signed binary value with 0.5 degrees C/bit (range: -64°C [80h] to +63.5°C [7Fh]).

Byte 6: TRICKLE_TEMP_HI

Maximum high temperature in degrees C for maintenance charge mode, represented as an 8-bit signed binary value with 0.5 degrees C/bit (range: -64°C [80h] to +63.5°C [7Fh]).

Byte 7: ABS_VOLT_HIGH

Lead acid maximum voltage in charge mode, represented as an 8-bit unsigned binary value with each bit representing 58.5mV (range: 0 to 14.91V).

Byte 8: MAX_TIME_LIMIT_LB

Low byte of maximum allowable time, in seconds, during any charge mode for Fail-Safe charge termination, represented as a 16-bit unsigned binary value (range: 0 to 65,536 seconds, or about 18.2 hours).

Byte 9: MAX_TIME_LIMIT_HB

High byte of maximum allowable time, in seconds, during any charge mode for Fail-Safe charge termination, represented as a 16-bit unsigned binary value (range: 0 to 65,536 seconds, or about 18.2 hours).

Byte 10: FAST_CHARGE_RATE

The current, in mA, at which the battery can be charged in Fast Charge mode. Expressed as an 8-bit unsigned binary value with each bit representing 10 mA (range: 0 to 2.55A).

Byte 11: TRICKLE_CHARGE_RATE

The current, in mA, at which the battery can be charged in Trickle Charge mode. Expressed as an 8-bit unsigned binary value with each bit representing 10 mA (range: 0 to 2.55A).

Byte 12: SPARE

Reserved.

Byte 13: DISCHARGE_VOLTAGE

The voltage, in V, at which the discharge of the battery will stop, represented as an 8-bit unsigned binary value with each bit representing 58.5mV (range: 0 to 14.91V).

Byte 14: DELTAV_THRESH_SIGNED

The -ΔV charge termination threshold, in Volts, used for the battery to be charged. Expressed as an 8-bit signed binary value, with each bit representing 5.85mV (range: -750 to +744 mV).

Byte 15: DELTAT_DELTAt_THRESH

The ΔT/Δt charge termination threshold, in degrees C per minute. Expressed as an 8-bit signed binary value, with each bit representing 0.5 degrees C/min (range: 0 to 127.5 °C/min).

PICREF-2

E.3.3   SEND DATA COMMAND (15h)

This command requests the PICREF-2 to send the real-time data set, which are typically requested at a periodic rate of 1 second to update the Host PC's screen. This command consists of only the 15h command byte and the checksum (EAh). The data which is returned to the PC from the PICREF-2 in response to a Send Data command is defined as follows:

Message Format

PC Host:

15h	EAh

PICREF-2 Response:

B1_Volts	B1_Temp	B1_Current	B2_Volts	• • •	Checksum

Byte 1: B1_Volts

Battery 1 Voltage, represented as an 8-bit unsigned binary value with each bit representing 58.5 mV (
range: 0V to 14.91V).

Byte 2: B1_Temp

Battery 1 Temperature in degrees C, an 8-bit signed binary value with 0.5 degrees C/bit
(range: -64°C [80h] to +63.5°C [7Fh]).

Byte 3: B1_Current

Measured Battery 1 Charge Current, in mA, an 8-bit unsigned binary value with each bit representing 10 mA
(range: 0V to 2.55A).

Byte 4: B2_Volts

Battery 2 Voltage, represented as an 8-bit unsigned binary value with each bit representing 58.5 mV
(range: 0V to 14.91V).

Byte 5: B2_Temp

Battery 2 Temperature in degrees C, an 8-bit signed binary value with 0.5 degrees C
(range: -64°C [80h] to +63.5°C [7Fh]).

Byte 6: B2_Current

Measured Battery 2 Charge Current, in mA, an 8-bit unsigned binary value with each bit representing 10 mA
(range: 0A to 2.55A).

Byte 7: System Status

Battery Charge/Discharge Mode		Battery Chemistry	
bit7			bit0

bit 7-4:   Battery Charge/Discharge Mode
          0000 = Idle Mode
          0001 = Reserved
          0010 = Reserved
          0011 = Battery 1 & 2 Discharge/Charge ONCE Mode
          0100 = Reserved
          0101 = Battery 1 Discharge Mode
          0110 = Battery 1 Charge Mode
          0111 = Battery 1 Discharge/Charge Mode
          1000 = Battery 1 Discharge/Charge REPEAT Mode
          1001 = Battery 2 Discharge Mode
          1010 = Battery 2 Charge Mode
          1011 = Battery 2 Discharge/Charge Mode
          1100 = Battery 2 Discharge/Charge REPEAT Mode
          1101 = Battery 1 & 2 Discharge Mode
          1110 = Battery 1 & 2 Charge Mode
          1111 = Battery 1 & 2 Discharge/Charge REPEAT Mode

bit 3:   Reserved

bit 2-1:   Battery Chemistry (assumes battery 1 and 2 are of the same type)
          00 = NiCd enabled
          01 = NiMH enabled
          10 = Lead Acid enabled
          11 = Li-Ion enabled (Provisional)

bit 0:   Reserved

Byte 8: Charge Status

Charge Algorithm	Charge Term. Algorithm	Battery 2 Charge Status	Battery 1 Charge Status
bit7			bit0

bit 7-6:   Charge Algorithm
          00 = Reserved
          01 = Fast Charge Algorithm
          10 = Trickle Charge
          11 = TBD

bit 5-4:   Charge Termination Algorithm
          00 = None Enabled (except Fail Safe is always enabled)
          01 = Delta V (Zero Delta V or Negative Delta V)
          10 = Delta T/Delta t
          11 = Absolute Voltage

bit 3-2:   Battery 2 Present Charge Status
          00 = Idle
          01 = Fast Charging
          10 = Trickle Charging
          11 = Discharging

bit 1-0:   Battery 1 Present Charge Status
          00 = Idle
          01 = Fast Charging
          10 = Trickle Charging
          11 = Discharging

PICREF-2

Byte 9: Battery 1 Error Status

OVE	UVE	OTE	UTE	TOE	CKE	SE	NB

bit7   bit0

bit 7:   Overvoltage Error
       1 = Error
       0 = No error

> **Note:** This field is cleared by either a CONFIGURE or a SYSTEM ENABLE command.

bit 6:   Undervoltage Error
       1 = Error
       0 = No error

bit 5:   Overtemperature Error
       1 = Error
       0 = No error

bit 4:   Undertemperature Error
       1 = Error
       0 = No error

bit 3:   Time-out Error
       1 = Error
       0 = No error

bit 2:   Checksum Error
       1 = Error
       0 = No error

bit 1:   Selftest Error
       1 = Error
       0 = No error

bit 0:   No Battery Detected
       1 = No battery detected
       0 = Battery detected

Byte 10: Battery 2 Error Status

OVE	UVE	OTE	UTE	TOE	CKE	SE	NB

bit7   bit0

bit 7:   Overvoltage Error
         1 = Error
         0 = No error

> **Note:** This field is cleared by either a CONFIGURE or a SYSTEM ENABLE command.

bit 6:   Undervoltage Error
         1 = Error
         0 = No error

bit 5:   Overtemperature Error
         1 = Error
         0 = No error

bit 4:   Undertemperature Error
         1 = Error
         0 = No error

bit 3:   Time-out Error
         1 = Error
         0 = No error

bit 2:   Checksum Error
         1 = Error
         0 = No error

bit 1:   Selftest Error
         1 = Error
         0 = No error

bit 0:   No Battery Detected
         1 = No battery detected
         0 = Battery detected

Byte 11: Battery 1 Measured ΔV Signed

Battery 1 measured ΔV, in Volts, a running average of the voltage difference between the present and last sample. Expressed as an 8-bit signed binary value, with each bit representing 5.85 mV (range: -750 mV to +744 mV).

Byte 12: Battery 1 Measured ΔT/Δt Rate

Battery 1 measured Delta T/Delta t rate, in degrees C per minute, a running average of the change in temperature over time, with each bit representing 0.5° C/min (range: 0° C/min to 127.5° C/min).

Byte 13: Battery 2 Measured ΔV Signed

Battery 2 measured -ΔV, in Volts, a running average of the voltage difference between the present and last sample. Expressed as an 8-bit signed binary value, with each bit representing 5.85 mV (range: -750 mV to +744 mV).

Byte 14: Battery 2 Measured ΔT/Δt Rate

Battery 2 measured ΔT/Δt rate, in degrees C per minute, a running average of the change in temperature over time, with each bit representing 0.5° C/min (range: 0° C/min to 127.5° C/min).

PICREF-2

E.3.4   SEND CONFIGURATION COMMAND (3Ch)

This command requests the PICREF-2 to send the configuration data set to the Host PC. These are the same configuration fields sent via the Configure Command. Data field definitions are defined to be the same as for the Configure Command.

Message Format

PC Host:

3Ch	C3h

PICREF-2 Response:

Temp_Lo	Temp_Hi	Max_Voltage	Max_Voltage	• • •	Checksum

E.3.5   RESET COMMAND (55h)

This command causes a software reset of the processor controlling the charging and discharging of the battery, known as the Battery Controller. This command will stop any ongoing activity in terms of charge/discharge.

Message Format

PC Host:

55h	AAh

E.4   PC DATA FILE FORMAT

The structures in Example E-1 define how the battery charger data is organized. The data resolution is called out in the preceding documentation as well as the firmware.

The data file saved during a charge session is a binary file which is a dump of the charge information and data received for a charge session for a single battery.

The order of the information is as follows:

a) sizeof(int) – Battery number that was charged (1 or 2).

b) sizeof(gOptionSettings) – The option settings for the session.

c) sizeof(gConfigSettings) – The configuration settings for the session.

d) sizeof(TBatFileDataStruct) – Each sample taken.

Once the configuration is read to determine the attributes to apply to the TBatFileDataStruct, (i.e., need to know sample frequency form gOptionSeettings). Each data point can be successively read from the file (TBatFileDataStruct).

EXAMPLE E-1: CODE STRUCTURE

```
// This structure contains one data interval saved to disk.
struct TBatFileDataStruct
{
  uint8  ui8Voltage;
  int8   i8Temperature;
  uint8  ui8MeasuredChargeCurrent;
  uint8  ui8SystemStatus;
  uint8  ui8ChargeStatus;
  uint8  ui8ErrorStatus;
  int8   i8DeltaV;
  int8   i8DeltaT;
};
// This class contains the option settings chosen for the charge session. These determine
// the graphing characteristics and graphing support routines.
class TOptionSettings
{
  public:
  char szComPort[10];
  int  iDisplayUpdateFrequency;
  int  iMaxGraphCurrentRange;
  int  iMaxGraphVoltageRange;
  int  iMaxGraphTempRange;
  int  iMinGraphCurrentRange;
  int  iMinGraphVoltageRange;
  int  iMinGraphTempRange;
  int  iTimeDisplayed;
  int  iMaxY;
  int  iMinY;

  inline float NormalizeCurrent(float fCurrent);
  inline float NormalizeVoltage(float fVoltage);
  inline float NormalizeTemp(float fTemp);
  inline float UnNormalizeCurrent(float fCurrent);
  inline float UnNormalizeVoltage(float fVoltage);
  inline float UnNormalizeTemp(float fTemp);

};

// This stucture contains the configuration settings chosen for the charge session.
struct TConfigSettings
{
  int iChargeAlgorithm;
  int iChargeDischargeSequence;
  int iTerminationAlgorithm;
  int iChemistry;

  float  fChargeVoltageMax;
  float  fChargeVoltageMin;
  int    iFastChargeTempMax;
  int    iFastChargeTempMin;
  int    iTrickleTempMax;
  int    iTrickleTempMin;
  uint16 ui16MaxChargeTime;
  float  fMaxVoltage;
  float  fDischargeRate;
  float  fDischargeVoltage;
  float  fDTDtThreshold;
  int    iDvThreshold;
  float  fFastChargeAmps;
  int    iSpare;
  float  fTrickleChargeAmps;
  float  fReserved;
};
```

NOTES:

APPENDIX F: PCB LAYOUT & FAB DRAWING

The top silk screen drawing for the battery charger is shown below. The board dimensions listed are, with respect to the orientation of this page, horizontal dimension x vertical dimension.

FIGURE F-1:   INTELLIGENT BATTERY CHARGER LAYOUT
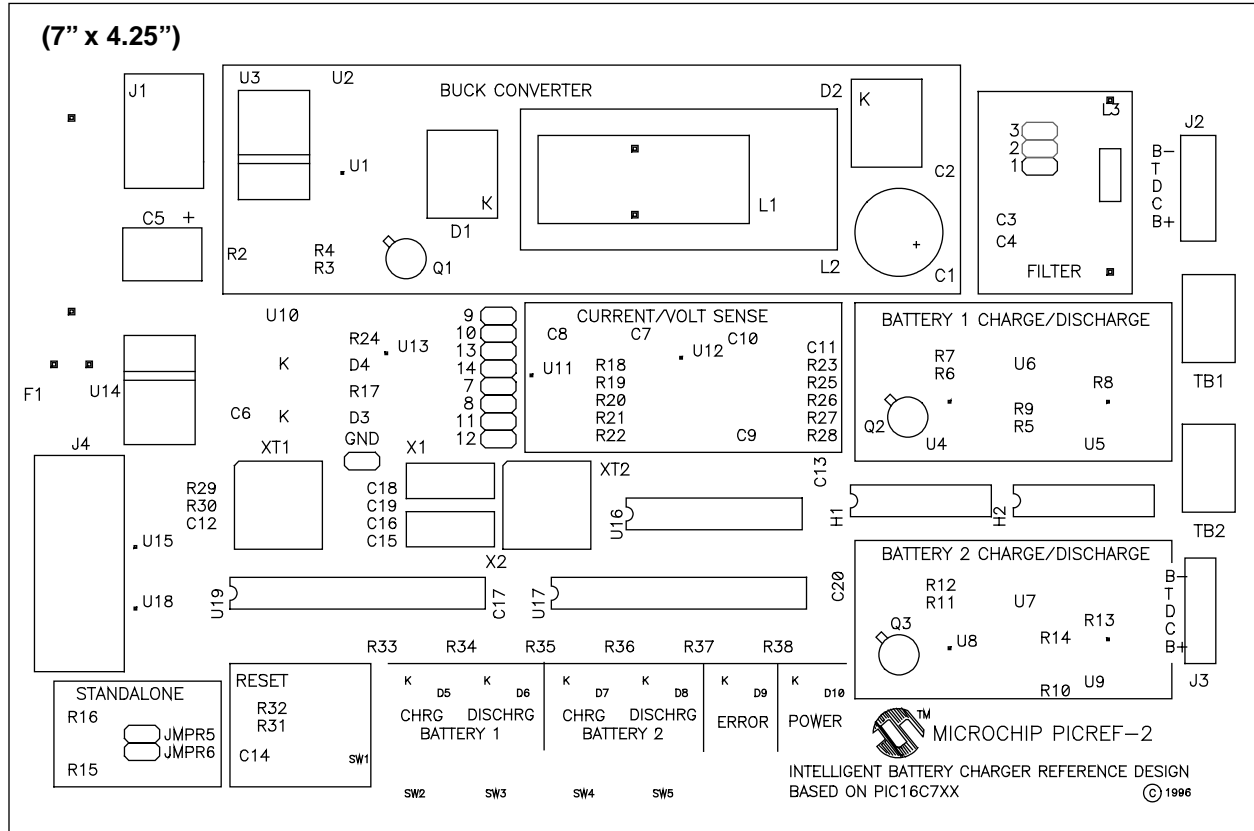
PICREF-2

APPENDIX G: BILL OF MATERIALS (BOM)

TABLE G-1:   BOM FOR PICREF-2

Line #	Qty	Part #	Part Description	Manufacturer	Vendor	Vendor Part #	Reference Designator
1	1	03-01422	SCHEMATIC, BCC CARD	N/A	N/A	N/A	N/A
2	1	04-01422	PCB FABRICATION, BCC CARD	N/A	N/A	DM003002	N/A
3	1	DJ005B	CONN, POWER	LZR (301) 921-4600	JIT	RL30B	J1
4	2	644894-5	CONNECTOR, 5PIN, BATTERY	AMP (717) 564-0100 (800) 522-6752*	NEWARK	644894-5	J2,J3
5	1	DE9S-FRS	CONN, PCB, RT ANGL, 9 CONTACT SOCKET	SPC TECH (773) 907-5193	NEWARK	89N1583	J4
6	5	B3S-1002	SWITCH, MOMENT, SMT	OMRON (847) 843-7900 (800) 55OMRON*	DIGIKEY	SW416-ND	SW1,SW2,SW3, SW4,SW5
7	2	99426	TBLOCK	JAMECO (415) 592-8097 (800) 831-4242*	NEWARK	99426	TB1,TB2
8	2	37330	HEADER, 16 PIN DIP	JAMECO (415) 592-8097 (800) 831-4242*	NEWARK	37330	H1,H2
9	2	PZC36SAFN	HEADER, 0.025	SULLINS (619) 744-0125	DIGIKEY	S1061-36-ND	JMPR HEADERS
10	14	SULLINS	JUMPER	SULLINS (619) 744-0125	DIGIKEY	S9002-ND	JMPR1-14
11	1	ECA-1HFQ471	CAP, 470UF, ALUM ELEC, RADIAL	PANASONIC (714) 373-7366	DIGIKEY	P5772-ND	C1
12	5	ECU-V1H103KBM	CAP, 0.01UF, SMT, 1206	PANASONIC (714) 373-7366	DIGIKEY	PCC103BCT-ND	C2,C6,C8,C9,C12
13	1	195D106X9035D2T	CAP, TANT CHIP, 10UF, 35V	SPRAGUE (516) 334-8700	NEWARK	95F9802	C5
14	2	87222	CAP, 0.47UF, SMT, 1206	JAMECO (415) 592-8097 (800) 831-4242*	NEWARK	87222	C7,C10
15	1	ECU-V1H102JCH	CAP, 1000PF, SMT, 1206	PANASONIC (714) 373-7366	DIGIKEY	PCC102CCT-ND	C14
16	4	ECU-V1H150JCM	CAP, 15PF, SMT, 1206	PANASONIC (714) 373-7366	DIGIKEY	PCC150CCT-ND	C15,C16,C18,C19
17	4	ECU-V1H104KBW	CAP, 0.1UF, SMT, 1206	PANASONIC (714) 373-7366	DIGIKEY	PCC104BCT-ND	C11,C13,C17,C20
18	1	WK0003-ND	FUSE, 3AG-5	WICKMAN (404) 699-7820 (800) 553-7894*	DIGIKEY	WK0003-ND	F1
19	1	RC-10	ROD CORE, HI CUR, 100 UH	MAGNETEK (219) 297-3111	DIGIKEY	10606-ND	L1
20	2	30BF20	DIODE, FAST RECOVERY 200V	INTL RECT (310) 322-3331	FAI	30BF20	D1,D2
21	2	LT1120CT-ND	LED, SMT, GREEN	LITE-ON (408) 946-4873	DIGIKEY	LT1120CT-ND	D5,D7
22	2	LT1122CT-ND	LED, SMT, YELLOW	LITE-ON (408) 946-4873	DIGIKEY	LT1122CT-ND	D6,D8
23	1	LT1123CT-ND	LED, SMT, RED	LITE-ON (408) 946-4873	DIGIKEY	LT1123CT-ND	D9
24	1	LT1119CT-ND	LED, SMT, ORANGE	LITE-ON (408) 946-4873	DIGIKEY	LT1119CT-ND	D10

* 800 numbers are valid in the USA only.

TABLE G-1: BOM FOR PICREF-2 (CONTINUED)

Line #	Qty	Part #	Part Description	Manufacturer	Vendor	Vendor Part #	Reference Designator
25	1	ERJ-1WYI201	RES, 200, SMT, 2512	PANASONIC (714) 373-7366	DIGIKEY	P200XCT-ND	R2
26	6	ERJ-8ENF1.00K	RES, 1K, SMT, 1206	PANASONIC (714) 373-7366	DIGIKEY	P1.00KFCT-ND	R19,R20,R23
27	1	ERJ-8ENF1.50K	RES, 1.5K, SMT, 1206	PANASONIC (714) 373-7366	DIGIKEY	P1.50KFCT-ND	R3
28	17	ERJ-8ENF10.0K	RES, 10K, SMT, 1206	PANASONIC (714) 373-7366	DIGIKEY	P10.0KFCT-ND	R4,R6,R7,R8,R9,R11, R12,R13,R14,R15, R16,R1,R21,R22, R26,R29,R30
29	2	ERJ-8ENF20.0K	RES, 20K, SMT, 1206	PANASONIC (714) 373-7366	DIGIKEY	P20.0KFCT-ND	R5,R10
30	1	ERJ-8ENF976K	RES, 976K, SMT, 1206	PANASONIC (714) 373-7366	DIGIKEY	P976KFCT-ND	R27
31	1	ERJ-8ENF24.9K	RES, 24.9K, SMT, 1206	PANASONIC (714) 373-7366	DIGIKEY	P24.9KFCT-ND	R28
32	1	ERJ-8ENF4.75K	RES, 4.75K, SMT, 1206	PANASONIC (714) 373-7366	DIGIKEY	P4.75KFCT-ND	R31
33	6	ERJ-8ENF332	RES, 332, SMT, 1206	PANASONIC (714) 373-7366	DIGIKEY	P332FCT-ND	R33,R34,R35,R36, R37,R38
34	1	SFB270	INDUCTOR, 27UH	WILCO (317) 293-9300 (800) 611-2343*	WILCO	SFB270	L3 (PROVISIONAL)
35	3	IRF7406	SO-8	INTL RECT (310) 322-3331	NEWARK	IRF7406	U1,U4,U8 (PROVISIONAL)
36	3	NDT456P	MOSFET, P CHAN, SOT-223	NAT SEMI (408) 712-5800 (800) 272-9959*	DIGIKEY	NDT456PCT-ND	U2,U6,U7
37	1	IRF9540	HEXFET, P-CH, TO-220AB	INTL RECT (301) 322-3331	FAI	IRF9540	U3 (PROVISIONAL)
38	2	IRF7403	SO-8	INTL RECT (301) 322-3331	NEWARK	IRF7403	U5,U9
39	1	LT1118CST-5	IC, 5V REG, 800MA, SOT-223	LINEAR TECH (408) 432-1900	DIGIKEY	LT1118CST-5-ND	U10
40	2	LM6134AIM	QUAD OP AMP, SO-14	NAT SEMI (408) 712-5800 (800) 272-9959*	DIGIKEY	LM6134AIM-ND	U11,U12
41	1	DS1803Z-100K	IC, DUAL EEPROM POT, SO-16	DALLAS (214) 450-0400	NEWARK	DS1803Z-100K/10K	U13
42	1	NJM7805	IC, 5V RES	NJR CORP. (415) 961-3901	DIGIKEY	NJM78MOSFA-MD	U14
43	1	24LC65	IC, SERIAL EEPROM, SO-8	MICROCHIP (602) 786-7200	MICROCHIP	24LC65/SO	U15
44	1	PIC16C711	IC, MICROCONTROLLER, 18 PIN	MICROCHIP (602) 786-7200	MICROCHIP	PIC16C711-20	U16 (PROVISIONAL)
45	1	110-99-318-41-001	SOCKET, 18 PIN	MILL-MAX (516) 922-6000 (888) 922-6544	DIGIKEY	ED3118-ND	U16a
46	1	PIC16C72	IC, MICROCONTROLLER, 28 PIN	MICROCHIP (602) 786-7200	MICROCHIP	PIC16C72-20	U17
47	2	110-99-328-41-001	SOCKET, 28 PIN	MILL-MAX (516) 922-6000 (888) 922-6544	DIGIKEY	ED3128-ND	U17a, U19a

* 800 numbers are valid in the USA only.

TABLE G-1:   BOM FOR PICREF-2 (CONTINUED)

Line #	Qty	Part #	Part Description	Manufacturer	Vendor	Vendor Part #	Reference Designator
48	1	PIC16C73	IC, MICROCONTROLLER, 28 PIN	MICROCHIP (602) 786-7200	MICROCHIP	PIC16C73-20	U19
49	1	DS275S	IC, RS232 TRANS, SO-8	DALLAS (214) 450-0400	NEWARK	DS275S	U18
50	2	ECS-100-S-4	10.0MHz QUARTZ CRYSTAL	ECS (913) 782-7787 (800) 237-1041*	DIGIKEY	X422-ND	X1,X2
51	3	2N2222A	TRANS, NPN, T0-18	NAT SEMI (408) 712-5800 (800) 272-9959*	DIGIKEY	2N2222A-ND	Q1,Q2,Q3
* 800 numbers are valid in the USA only.							

APPENDIX H: BATTERY CHARGER DEMONSTRATION UNIT

A limited number of battery charger demonstration units are available for customer evaluation. To obtain a demonstration unit, contact any Microchip sales office.

For a more detailed description of the demonstration circuits, see *Hardware Overview*.

Microcontrollers

A PIC16C72 or a PIC16C73A can be inserted in either 28-pin socket (U17 or U19).

Voltage Regulator

The +5 Vdc voltage regulator LT1118CS8-5 (U10) may be replaced by U14 (NJM7805).

Note:	U10 and U14 are +5V regulators. U14 may be populated in place of U10 at the designer's option.

Buck Converter

The PWM output from the microcontroller drives an NPN transistor (Q1) which biases the P-channel FET (U2). So when the PWM output is high, Q1 conducts, providing the gate-source voltage to turn on the P-channel FET. This allows current to flow through to inductor L1. Diode D2 is used to isolate the buck converter output from the battery voltage. Capacitor C1 is used in conjunction with L1 as a filter for the output of the buck converter and capacitor C2 is used to filter high frequency.

Note:	U1, U2, and U3 are p-channel FETs for the buck converter. U1 or U3 may be populated in place of U2 at the designer's option. L2 may be populated in place of L1 at the designer's option.

Filter

The filter circuit is intended to provide additional ripple suppression at the buck converter output stage.

Note:	L3, C3, and C4 provide additional ripple filtering on the output of the buck converter. They may be populated at the designer's option.

Battery 1 & Battery 2 Charge/Discharge

The PIC16C7X controls the charge and discharge of both battery 1 and battery 2 through the I/O lines.

For charge mode, the I/O line drives an NPN transistor to bias a P-Channel FET in the same fashion that the PWM drives the buck converter.

Note:	U4, U6, U7, and U8 are p-channel FETs used to select the battery to be charged. U4 and U8 may be populated at the designer's option.

For discharge mode, the I/O drives an N-channel FET, connecting the load at TB1/TB2 to ground. This line is set in software to be either ON or OFF, but the end user may pulse the line to simulate various discharge modes.

Voltage Sense

Voltage Sense has 3 modes: windowed, fixed, and direct, which may be selected by jumpers (see *Hardware Overview - Jumpers*).

Note:	D3, D4, R17, and R24 provide the voltage reference for "fixed" mode. In this mode, U13 may be removed.

Note:	The battery voltage is divided by resistors R5, R9, R10 and R14. If a smaller dynamic range than 0V to 15V is required, these resistor values can be changed to increase "direct" mode resolution.

Current Sense

The current sense circuitry works by amplifying and converting the current through a 0.05 ohm resistor into a voltage.

Note:	The current sense resistor in H2 may be replaced at the designer's option to give either more range or more resolution.

Temperature Sense

The temperature sense is accomplished through a simple 10K pull-up resistor.

Note:	The temperature sense resistors in H1 may be replaced at the designer's option based on the designer's battery pack thermistor value.

Battery Pack

The KR-1100AEL is a Fast Charge Battery Cell that can be charged at up to a 1600 mA rate in less than 1 hour. It can be discharged at up to an 8C rate in < 6 minutes (1C discharge takes 60 minutes).

Note:	Refer to the manufacturer's specifications before charging any battery pack.

Note:	Improper disposal of NiCd batteries poses an environmental hazard. Contact a local battery collection center for recycling information.

LED's, Pushbuttons, and Jumpers

LED's (D5-D10) are provided are indicator lights. Pushbuttons (SW1-SW5) and Jumpers (JMPR1-JMPR14) are provided for charger control. For more detailed functional descriptions, see the respective sections under *Hardware Overview*.

PICREF-2

H.1   Demonstration Specifications

Maximum Charge Current:

The maximum charging current is limited by the following components:

L3   1.3A (Provisional)

L1   2.0A

D1,D2   3.0A

L3 may be bypassed to increase the charging current to 2.0A. Also, L1 may be replaced by a higher current inductor to increase the charging current to 3.0A.

Maximum Input Voltage: 24 Volts DC

Supported Battery Technologies: NiCd,
                                 NiMH,
                                 Lead Acid
                                 Li-Ion

H.2   Demonstration Unit Assembly

A PICREF-2 Intelligent Battery Charger demonstration board photo is shown in Figure H-1.

The demonstration board comes as part of a kit that includes two disks (PIC16C7X source code and PC development software), a power supply and a sample battery pack (Figure H-2).

FIGURE H-1:   PICREF-2 DEMONSTRATION BOARD
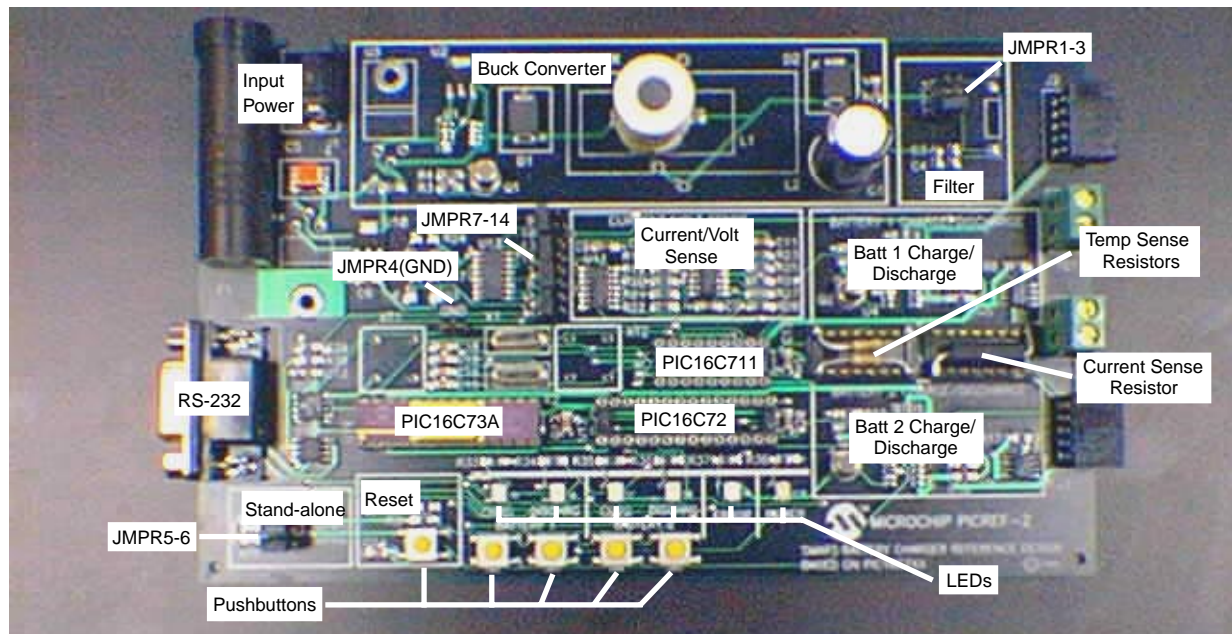
FIGURE H-2:   PICREF-2 DEMONSTRATION KIT
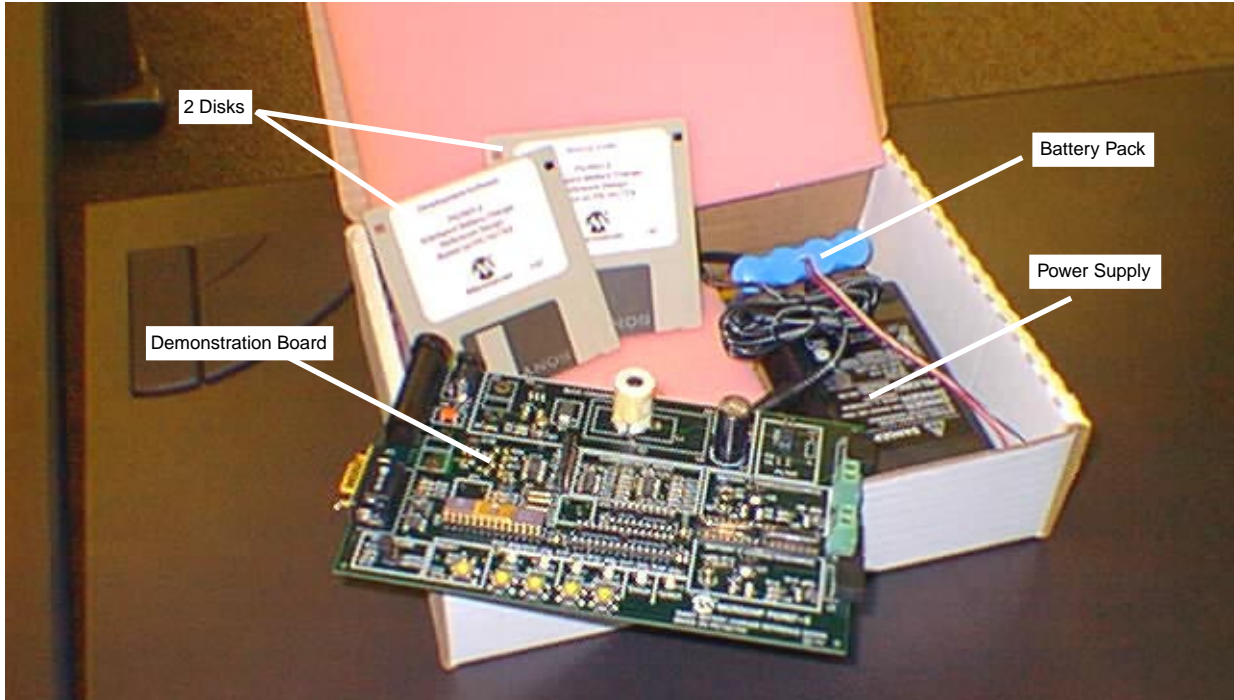
H.3   How to Demonstrate the PICREF-2 in Development Mode

The demonstration board should be hooked up as shown in Figure H-3.

- Plug in power supply (13.6V, 1.9A)
- Plug in battery pack
- Connect demonstration board to PC (RS-232)
- Run PC Software (See *PICREF-2 to PC Software Overview*)
- Run simple charge/discharge cycle

FIGURE H-3:   PICREF-2 SETUP - DEVELOPMENT MODE
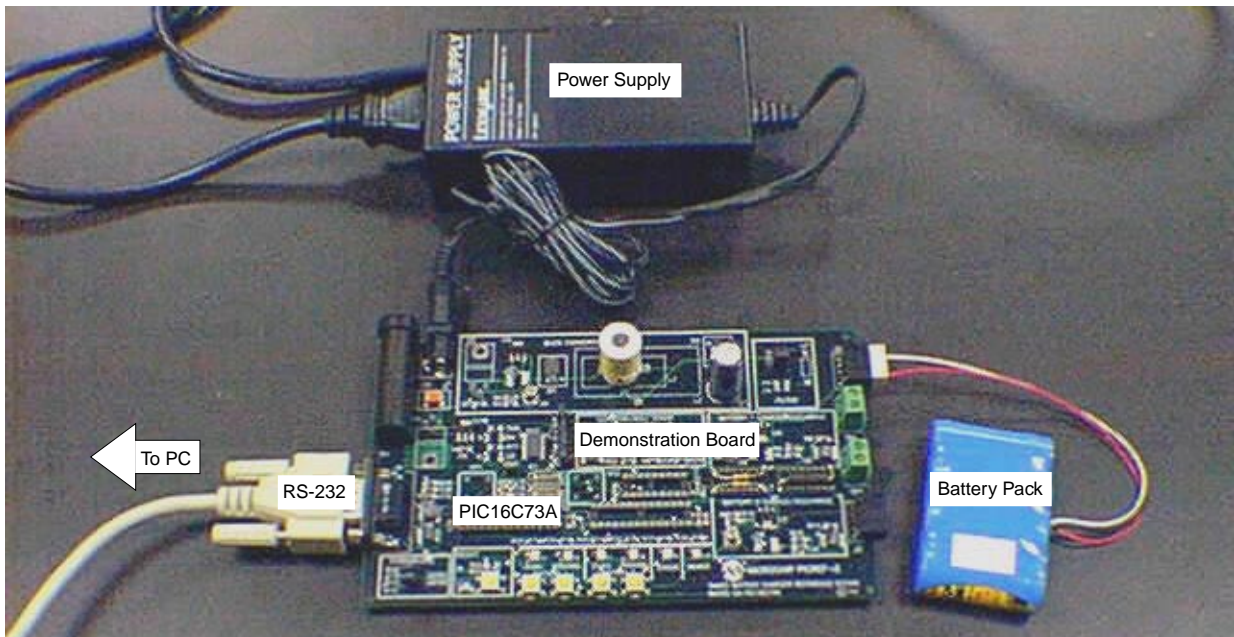
PICREF-2

H.4   How to Demonstrate the PICREF-2 in Stand-Alone Mode

The demonstration board should be hooked up as shown in Figure H-4.

- Plug in power supply (13.6V, 1.9A)
- Plug in battery pack
- Use pushbuttons to charge/discharge (See *Hardware Overview - Pushbuttons*)

FIGURE H-4:   PICREF-2 SETUP - STAND-ALONE MODE

© 1997 Microchip Technology Inc.
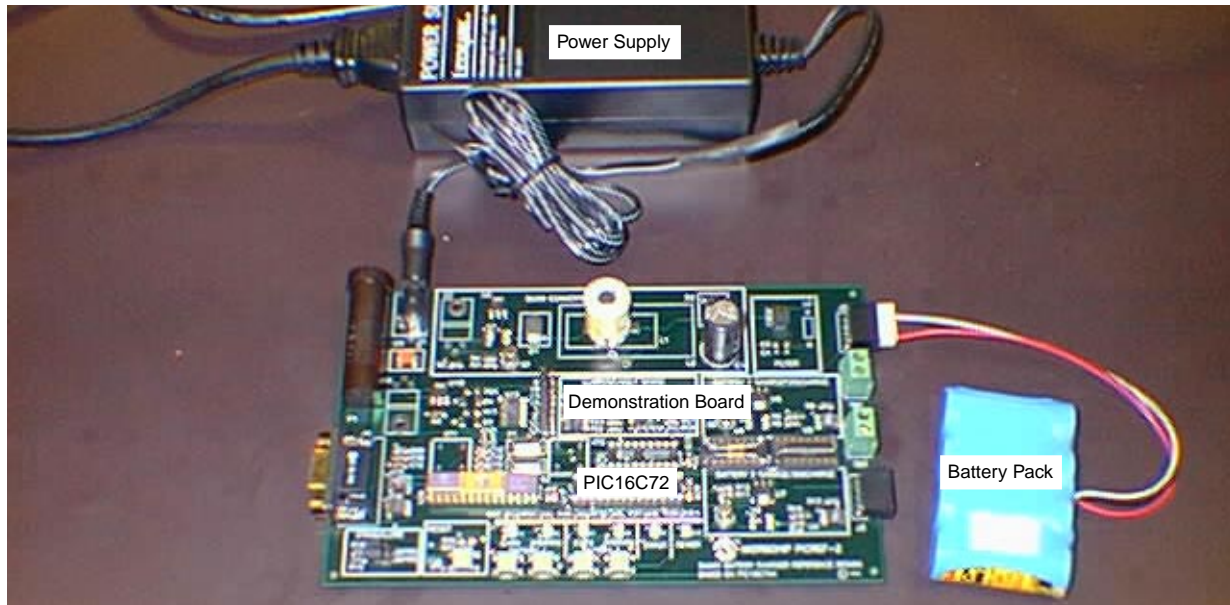
NOTES:

WORLDWIDE SALES AND SERVICE

AMERICAS

Corporate Office
Microchip Technology Inc.
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 602-786-7200 Fax: 602-786-7277
Technical Support: 602 786-7627
Web: http://www.microchip.com

Atlanta
Microchip Technology Inc.
500 Sugar Mill Road, Suite 200B
Atlanta, GA 30350
Tel: 770-640-0034 Fax: 770-640-0307

Boston
Microchip Technology Inc.
5 Mount Royal Avenue
Marlborough, MA 01752
Tel: 508-480-9990 Fax: 508-480-8575

Chicago
Microchip Technology Inc.
333 Pierce Road, Suite 180
Itasca, IL 60143
Tel: 630-285-0071 Fax: 630-285-0075

Dallas
Microchip Technology Inc.
14651 Dallas Parkway, Suite 816
Dallas, TX 75240-8809
Tel: 972-991-7177 Fax: 972-991-8588

Dayton
Microchip Technology Inc.
Two Prestige Place, Suite 150
Miamisburg, OH 45342
Tel: 937-291-1654 Fax: 937-291-9175

Detroit
Microchip Technology Inc.
42705 Grand River, Suite 201
Novi, MI 48375-1727
Tel: 248-374-1888 Fax: 248-374-2874

Los Angeles
Microchip Technology Inc.
18201 Von Karman, Suite 1090
Irvine, CA 92612
Tel: 714-263-1888 Fax: 714-263-1338

New York
Microchip Technology Inc.
150 Motor Parkway, Suite 202
Hauppauge, NY 11788
Tel: 516-273-5305 Fax: 516-273-5335

San Jose
Microchip Technology Inc.
2107 North First Street, Suite 590
San Jose, CA 95131
Tel: 408-436-7950 Fax: 408-436-7955

AMERICAS (continued)

Toronto
Microchip Technology Inc.
5925 Airport Road, Suite 200
Mississauga, Ontario L4V 1W1, Canada
Tel: 905-405-6279 Fax: 905-405-6253

ASIA/PACIFIC

Hong Kong
Microchip Asia Pacific
RM 3801B, Tower Two
Metroplaza
223 Hing Fong Road
Kwai Fong, N.T., Hong Kong
Tel: 852-2-401-1200 Fax: 852-2-401-3431

India
Microchip Technology Inc.
India Liaison Office
No. 6, Legacy, Convent Road
Bangalore 560 025, India
Tel: 91-80-229-0061 Fax: 91-80-229-0062

Japan
Microchip Technology Intl. Inc.
Benex S-1 6F
3-18-20, Shinyokohama
Kohoku-Ku, Yokohama-shi
Kanagawa 222-0033 Japan
Tel: 81-45-471- 6166 Fax: 81-45-471-6122

Korea
Microchip Technology Korea
168-1, Youngbo Bldg. 3 Floor
Samsung-Dong, Kangnam-Ku
Seoul, Korea
Tel: 82-2-554-7200 Fax: 82-2-558-5934

Shanghai
Microchip Technology
RM 406 Shanghai Golden Bridge Bldg.
2077 Yan'an Road West, Hong Qiao District
Shanghai, PRC 200335
Tel: 86-21-6275-5700 Fax: 86 21-6275-5060

ASIA/PACIFIC (continued)

Singapore
Microchip Technology Singapore Pte Ltd.
200 Middle Road
#07-02 Prime Centre
Singapore 188980
Tel: 65-334-8870 Fax: 65-334-8850

Taiwan, R.O.C
Microchip Technology Taiwan
10F-1C 207
Tung Hua North Road
Taipei, Taiwan, ROC
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

EUROPE

United Kingdom
Arizona Microchip Technology Ltd.
505 Eskdale Road
Winnersh Triangle
Wokingham
Berkshire, England RG41 5TU
Tel: 44-1189-21-5858 Fax: 44-1189-21-5835

France
Arizona Microchip Technology SARL
Zone Industrielle de la Bonde
2 Rue du Buisson aux Fraises
91300 Massy, France
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

Germany
Arizona Microchip Technology GmbH
Gustav-Heinemann-Ring 125
D-81739 Müchen, Germany
Tel: 49-89-627-144 0 Fax: 49-89-627-144-44

Italy
Arizona Microchip Technology SRL
Centro Direzionale Colleoni
Palazzo Taurus 1 V. Le Colleoni 1
20041 Agrate Brianza
Milan, Italy
Tel: 39-39-6899939 Fax: 39-39-6899883

7/7/98

Microchip received ISO 9001 Quality System certification for its worldwide headquarters, design, and wafer fabrication facilities in January, 1997. Our field-programmable PICmicro™ 8-bit MCUs, Serial EEPROMs, related specialty memory products and development systems conform to the stringent quality standards of the International Standard Organization (ISO).