



Low-Cost NiMH Battery Charger Using the Z8F0830

AN025902-0208

Abstract

This application note presents a concept for a simple, low-cost nickel-metal hydride (NiMH) battery charger using the Zilog's 20-pin Z8 Encore!® F0830 series microcontroller.

The battery charger design uses the 5.5296 MHz internal clock. An internal reference voltage of 2 V is applied to the on-chip analog-to-digital converter (ADC), which is used to monitor battery voltage, current, and temperature.

► **Note:** *The source code associated with this application note is available under Z8 Encore! Applications Code Library in Application Sample Libraries on www.zilog.com.*

Features

The key features of the battery charger design include:

- Minimal hardware required
- Constant current charging using the Z8 Encore! F0830 pulse-width modulation (PWM)
- Fast charge = 0.25 C (500 mA) for 2000 mAh battery
- Ability to charge three serially connected 1.2 V AAA batteries at up to 500 mA
- In-circuit programming simplifies firmware upgrades and evaluation
- Battery voltage and current monitoring using Z8 Encore! F0830 10-bit ADC
- Three methods for ending the charge cycle are:
 - Detecting negative dv/dt

- Setting maximum charging time between 4 hrs and 4.5 hrs (charging at C/4 of 2000 mAh)
- Over-voltage termination
- Bad battery detection using battery voltage/current measurement
- LED indication for battery charging and charge completion

Discussion

NiMH batteries are an excellent choice for powering high-drain devices such as digital cameras. They last longer than alkaline batteries, and are less expensive.

The challenge with recharging NiMH batteries is 'overcharging'. Overcharging an NiMH battery significantly reduces its operating life. With traditional overnight chargers, they are left un-plugged. These low-cost chargers seldom have a 'charge complete indicator,' so that they are too easy to neglect.

A slow charge is technically more efficient than a fast charge. The workaround is, create a low-cost charger design that charges batteries with a maximum 4 hrs to 4.5 hrs charging cycle.

The circuit is designed to stop the charging cycle when it detects negative dv/dt . The circuit continuously monitors battery voltage and current.

The advantage of this proposed design is its simplicity—fewer components reduce the cost of the circuit, and implementation is fast and easy.

Hardware Architecture

The hardware circuit is designed using the 20-pin Z8 Encore!® F0830 microcontroller. The design speci-

fies generally available components, and is simple to build and test.

The following Z8 Encore! F0830 microcontroller features are used in the design:

- Internal precision oscillator (5.5296 MHz) used to set the system clock.
- Internal PWM frequency for charging set to 10 kHz.

The design uses a 7.5 V_{DC} regulated external power supply to provide 3.3 V_{DD} for the Z8 Encore! F0830 MCU.

For details on hardware connections, see [Appendix A—Schematics](#) on page 4.

Software Implementation

The software design consists of the following modules:

- [ADC](#)
- [Timer](#)
- [Feedback](#)
- [Charging](#)

For information on each module, see [Appendix B—Flowchart](#) on page 5.

ADC

The Z8 Encore!® F0830 MCU provides eight ADC channels. Three channels are used to read the battery voltage, current, and temperature using an internal voltage reference of 2 V. A set of readings is obtained from each of the channels and stored in an array which is later used for calculating the average voltage and average current. The ADC values are read with respect to timed intervals. The initialization routines are available in `adc.c` file.

Timer

The Z8 Encore!® F0830 MCU provides two timers, Timer0 and Timer1. Timer0 is initialized to generate the PWM output at a frequency of 10 kHz. Timer1 generates regular 50 μs interrupts, during which Flags are set or reset depending on the task to be completed. The initialization routines are available in `timer.c` file.

Feedback

The feedback module provides the logic for calculating average voltage and current from the values captured by the ADC. The routines are available in `feedback.c` file.

Charging

After calculating the average battery voltage and battery current, the loop parameter is calculated using the proportional and integral (PI) loop. The routine returns an error percentage with respect to its previous value. The error percentage is used to stabilize the current flowing into the battery. The Ki and Kp variables of the PI loop can be changed if required. The routine is available in `charger.c` file.

Once the charging current is stabilized, the battery is in the charging state. The charging routine is designed to prevent overcharging and overheating. The charge cycle is ended when any one of the following occur:

- Negative dv/dt is detected.
- Maximum charge time as set in the charging routine elapses.
- Maximum battery voltage is detected.
- A bad battery is detected.

The charging current is controlled by increasing or decreasing the PWM duty cycle. This process is adapted with respect to the error percentage returned by the PI loop, thus stabilizing the charging current. The routines for the above tasks are available in `charger.c` file.



Overcharging Protection

Three additional charge termination checks are considered in our design. Therefore, if negative dv/dt is not detected for any reason, then the application terminates charging based on over-voltage or timeout to prevent overcharging.

You can set over-voltage (`MAX_BATT_VOLT`), current set limit (`CURRENT_MAMP`), maximum count of negative slope (`MAX_SLOP_COUNT`), and maximum charging time (`BATTERY_TIMEOUT`) to the desired values in `charger.h` file and `timer.h` file.

Example: Maximum timeout calculation; if battery rating is 400 mAh and charging current is 200 mA.

Maximum Time (Hour) = Rated battery current / charging current = $400/200 = 2$ hrs

Set the macro in `timer.h` file for 2 hrs:

```
# BATTERY_TIMEOUT 2 /* maximum
battery charging time */
```

Results

The batteries are charged in CONSTANT-CURRENT mode up to 500 mA. Charging is terminated when negative dv/dt is detected, maximum battery voltage is detected, or the maximum charge time elapses.

Summary

This application note describes a low-cost NiMH battery charger implementation using the Z8 Encore!® F0830 MCU. The MCU's internal 10-bit ADC makes accurate recharging possible, and the overall design ensure that the NiMH batteries are never overcharged.

The design also makes use of PWM to provide an accurate DC-DC converter (buck) implementation, so that the hardware cost is low.

References

The documents associated with Z8 Encore! F0830 available on www.zilog.com are provided below:

- Z8 Encore!® F0830 Series with Extended Peripherals Product Brief (PB0161).
- Z8 Encore!® F0830 Series Product Specification (PS0251).
- Z8 Encore!® F083x Series Programming Specification (PRS0010).
- Z8 Encore!® Based AA type NiMH and NiCD Battery Charger Reference Design (AN0229).
- Z8 Encore!®-Based SLA Battery Charger Application Note (AN0223).
- Z8 Encore!®-Based NiMH Battery Charger Application Note (AN0222).
- Z8 Encore!®-Based NiCD Battery Charger Application Note (AN0221).
- Z8 Encore! XP®-Based Lithium Ion Battery Charger (AN0218).
- Z8 Encore!®-Based Battery Charger (AN0137)
- eZ8 CPU Core User Manual (UM0128).

Appendix A—Schematics

Appendix A displays the schematics of Low-Cost NiMH Battery Charger (Figure 1).

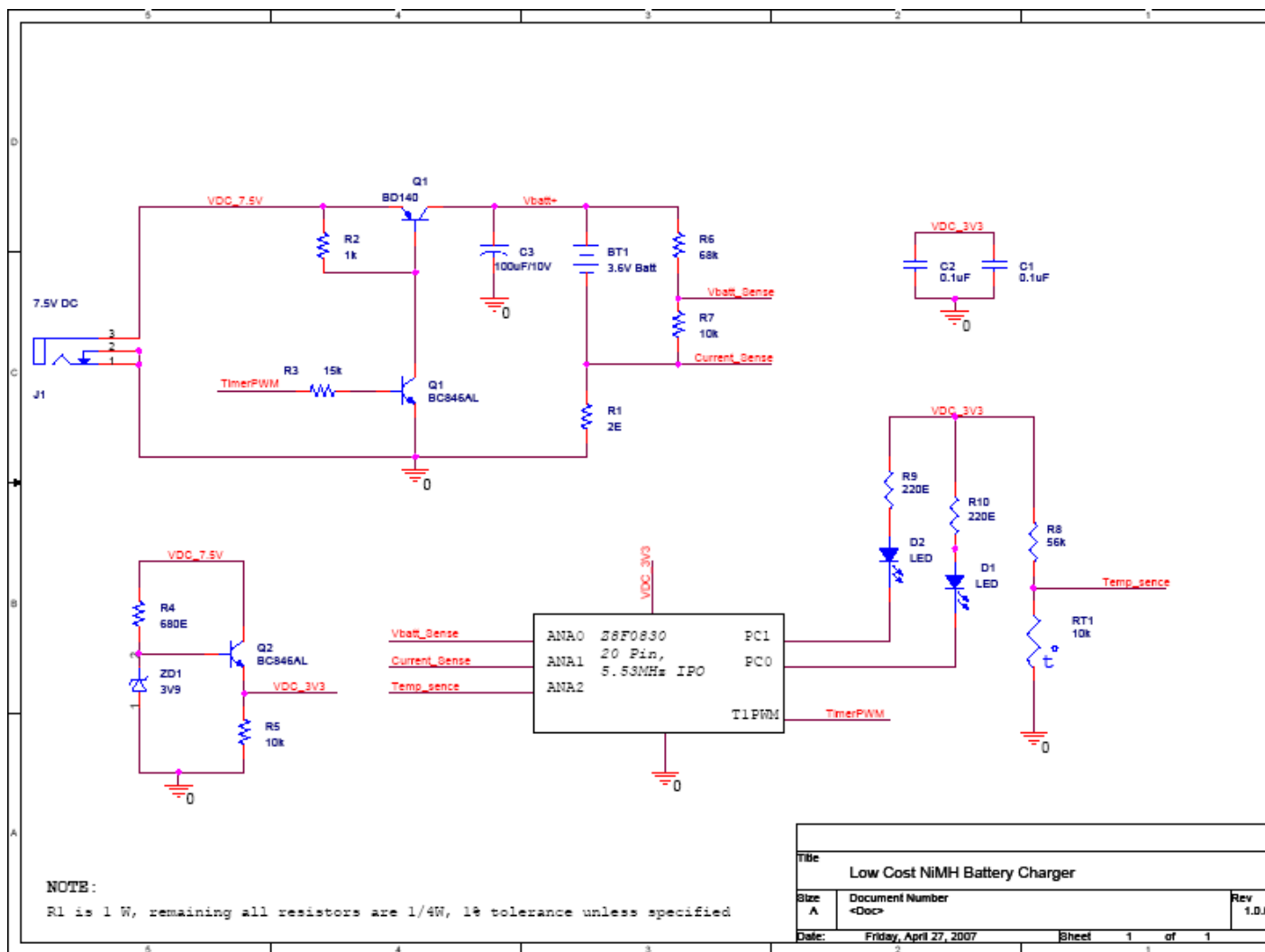


Figure 1. Low-Cost NiMH Battery Charger Schematic



Appendix B—Flowchart

This Appendix displays the flowchart for the Low-Cost NiMH Battery Charger (Figure 2).

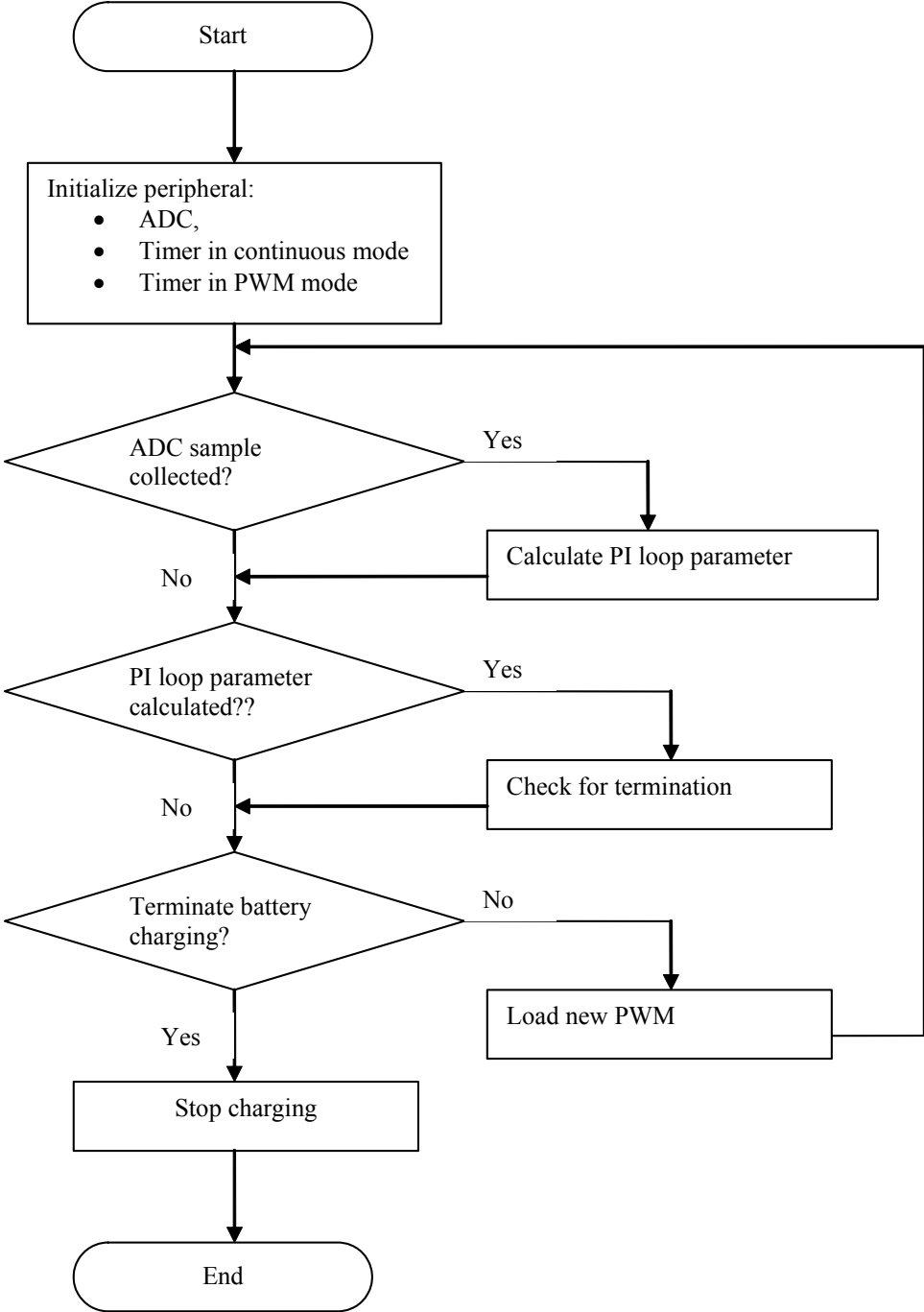


Figure 2. Flowchart for NiMH Battery Charger

Appendix C—Battery Technology

The four mainstream battery chemistries (NiCd, NiMH, SLA, Li-Ion) have different charging and discharging characteristics. Long-term battery life and performance is critically dependent on how the battery is charged. It is therefore critical to charge the respective batteries with the mechanism they require.

It is also important to know when to terminate charging. Battery overcharging causes in poor performance and can damage the battery in extreme cases. Different battery types behave differently in full charge condition and thus require specific charge termination techniques.

Charging a Nickel-Metal Hydride (NiMH) Battery

NiMH batteries exhibit higher power density compared to their NiCd counterparts. The per-cell voltage of the NiMH battery type is 1.2 V, similar to NiCd batteries.

NiMH batteries must be charged via the constant current charging method. While charging, as the voltage crosses the full charge point, the voltage drop is not as low as it is in NiCd batteries. Consequently, negative dv/dt charge termination is usually not recommended for these batteries.

Instead of the drop in cell voltage, the battery tends to plateau after a small drop. This flat region is the preferred indication for full battery charging, rather than the drop. Consequently, this termination mechanism is called zero dv/dt termination.

NiMH batteries do not suffer from memory effect as do NiCd batteries. As a result, they replace NiCd battery types in applications such as cell phones because the increase in price is justified by the reduction in weight and absence of memory effect.



Warning: DO NOT USE IN LIFE SUPPORT

LIFE SUPPORT POLICY

ZILOG'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF ZILOG CORPORATION.

As used herein

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

Document Disclaimer

©2008 by Zilog, Inc. All rights reserved. Information in this publication concerning the devices, applications, or technology described is intended to suggest possible uses and may be superseded. ZILOG, INC. DOES NOT ASSUME LIABILITY FOR OR PROVIDE A REPRESENTATION OF ACCURACY OF THE INFORMATION, DEVICES, OR TECHNOLOGY DESCRIBED IN THIS DOCUMENT. ZILOG ALSO DOES NOT ASSUME LIABILITY FOR INTELLECTUAL PROPERTY INFRINGEMENT RELATED IN ANY MANNER TO USE OF INFORMATION, DEVICES, OR TECHNOLOGY DESCRIBED HEREIN OR OTHERWISE. The information contained within this document has been verified according to the general principles of electrical and mechanical engineering.

Z8, Z8 Encore!, and Z8 Encore! XP are registered trademarks of Zilog, Inc. All other product or service names are the property of their respective owners.