zilog

Application Note

Z8 Encore!® Based AA Type NiMH and NiCd Battery Charger Reference Design

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Abstract

This application note demonstrates AA type NiMH and NiCd battery charger application using 28-pin Z8 Encore!® 8K Series MCU. The battery charger uses 18.432 MHz external clock. An internal reference voltage of 2 V is applied to the Analog-to-Digital Converter (ADC) peripheral for monitoring the battery voltage, battery current, and charger voltage. The battery temperature is monitored using an external I^2C temperature sensor. The battery status information and battery type selection are controlled by the push button switches and monitored using an LCD display.

The battery charger is a stand-alone product. It requires 9 V external power supply for charging the 1.2 V AA type NiMH and NiCd battery.

Features

Key features of the battery charger used here include:

- The battery type is AA and voltage rating is 1.2 Volts.
- The charger can charge upto 1 to 4 batteries at a time.
- The combination of three switches perform the function of selecting thebattery type and viewing the charging status. The battery charger has following press button type function keys:
  - **Battery type selection key** — Used to select the type of battery to be charged.
  - **Display info selection key** — Used to select the status (battery type, battery, voltage, battery current, battery temperature and charger voltage) of the battery to be displayed.
  - **Enter key** — Used to enter the selection type and status for battery .
  - **Reset key** — Used to reset the system.
- Monitoring the battery status using LCD display.
- Charging and full charge indication using LED.
- The temperature sensor measures the temperature of each battery separately. The temperature is read continuously using I^2C bus.
- A dynamic PWM is used for controlling the battery charging.
- For termination of charging at the appropriate time, the battery charging algorithm continuously monitors the battery voltage.
- For NiMH and NiCd battery types, the charging is done in the constant current mode with the maximum charging current equal to 500 mA. The charging is terminated when the battery voltage exhibits no increase in the terminal voltage (zero Δ termination) or negative termination voltage.

Display Features

The display function performs the following:

- Display the battery parameters (battery type, battery voltage, battery current, battery temperature and charger voltage) during the charging process.
- The LCD display is used for viewing the battery charging status and battery type.

- Display the full battery status.
- Four LEDs display the following status: power on, battery charging, charger on, and battery full.
- The buzzer beeps and LED ON indicates the full charge status of the battery.

Buzzer indicator

The buzzer indicator indicates the full charging status of the battery by beeping sound.

Other Features

The other features of the battery charger used in this reference design include:

- In-circuit programming for upgrading firmware.
- Adjusting the battery charging using online PWM.

Hardware Details

The hardware of the battery charger (see Appendix B—Photograph on page 8), is built and tested with commonly available components. The main component of the hardware is Z8 Encore!® 8K Series 28-pin microcontroller. Figure 1 displays the block diagram of the battery charger. See Figure 3 of Appendix C—Schematics on page 9 for the schematic diagram of battery charger demo board.

The demo board uses 9 V dc regulated external input power supply to drive the 5 V and 3.3 V internal supply.

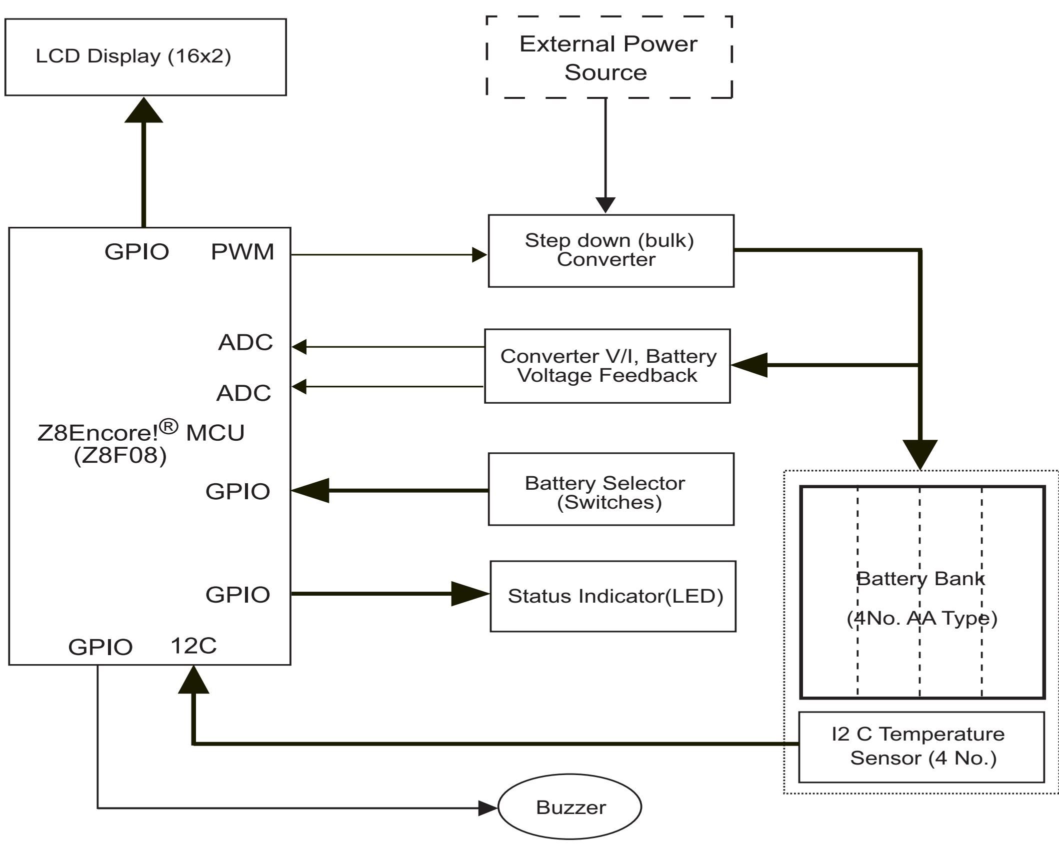


Figure 1. Block diagram of the Battery Charger

The hardware consists of the following modules:

DC- DC Step down converter (DC-DC converter)

The PWM is an input to the DC-DC converter, which is controlled by the MCU. Depending on the charging speed, the output of the converter usually ranges from 1.2 V to 3.6 V. This voltage is supplied to the battery. See Figure 4 of Appendix C—Schematics on page 10 for the schematic diagram of DC-DC converter.

Feedback Module

The feedback module provides the battery voltage, battery current, and converter output using three channels of the operational amplifier. The I^2C temperature sensor is used for reading the temperature of the battery. These readings are used for checking the safety of the battery, terminating the charging and keeping the current constant using a variable PWM. The feedback is obtained using an ADC. See Figure 5 of Appendix C—Schematics on page 11 for the schematic diagram of the feedback converter.

Switch Selection and LED Indication

Select the battery type using SW2 (B-TYPE) and the status of the battery using the switch SW3 and press SW4 (ENTER). The LED indicators D4 and D5 indicate the full charge and battery charging status, respectively. The LED D1 indicates the DC-DC converter output status.

Display Module

The 16x2 character LCD displays the battery information. The potentiometer RV1 controls the intensity of character and potentiometer RV2 controls the backlight of the LCD. See Figure 3 of Appendix C—Schematics on page 9 for the schematic diagram of the hardware interface of the display module.

Software Details

The software provided with this application note is developed and tested on the hardware as per the schematics provided in Appendix C—Schematics on page 9. This section provides the functionality of different software blocks used for battery charging.

The following are the different functional blocks:

- Battery charging algorithm
- Battery safety and termination
- Display and Control of Battery Charger
- Initializing the Z8 Encore!® Peripheral

Battery charging algorithm

The battery charging algorithm is a close loop constant current algorithm. The DC-DC converter current is controlled by the PWM duty cycle based on the battery current feedback. The input PWM frequency of the DC-DC converter is 50 kHz. If the battery is not completely charged, then the duty cycle required for maintaining the set points at the converter output is calculated by the control algorithm. The control algorithm implements proportional plus integral (PI) control to derive the PWM output based on the following equation:

$$u(t) = k1*e(t) + k2*\int e(t)dt$$

The Interrupt Service Routine (ISR) timer is invoked every 5 ms. The PWM value computed by the control algorithm is loaded into the PWM generators to be sent out via the output pin. The 16-bit timer PWM mode offers a programmable switching frequency based on the reload value. This flexibility allows you to trade-off between accuracy and frequency of the PWM switching signal.

The higher the frequency, lesser the reload value and lower the resolution in the pulse width variation and vice versa.

Battery safety and termination

The safety and termination threshold calculations are based on the battery parameters.

Follow the steps below to check for battery safety and termination:

- The set points for the DC-DC step-down (buck) converter voltage, the current, and the current limit are calculated. Once the one-time calculations are complete, the charger software enters into an infinite loop, which is broken only by a successful charge completion or a safety error.
- Inside the infinite loop, the ADC reads the actual values of the converter output voltage, the battery voltage, the current, and the temperature (temperature is measured only if the battery features a temperature sensor).
- The ADC measures the output voltage and the output current of the DC–DC converter as a feedback to the controller.
- The ADC measures the voltage at the battery terminals as an input to determine the charging termination. Measurement of the output voltage, the output current, and the battery voltage are the basic measurements. For the charge termination, the current across the battery terminals must be same as the measured converter output current .
- For batteries featuring externally provided temperature sensors, the charger reads the battery temperature also in addition to the basic measurements. The temperature measurement is significant for safety measures. After the actual values (VOUT, VBATT, and IBATT) are known, they are checked for safety limit compliance.

The safety routine is responsible for the overall safety features associated with the battery charger. The charger ensures safety by comparing the actual converter voltage, the battery voltage, and the battery temperature with the calculated thresholds. Crossing these thresholds switches off the PWM output, which turns off the converter output and terminates charging functions. Such termination protects the batteries in case of a device failure. If all the actual values are within limits, the battery is tested for full charge. For NiMH batteries, the battery is considered to be completely charged if the measured battery voltage stops increasing (zero ΔV termination).

The timer ISR also updates the charge termination variables every 10 seconds.

Display and Control of Battery Charger

Display functionality is achieved using the 16x2 character LCD display. Display information is provided below:

- Displays the battery type. The battery type is user-selectable using a press switch.
- Displays the battery status (battery charging status, battery voltage, battery current, and battery temperature).
- Battery status display is user selectable and can be changed at any point of time.
- Displays the battery temperature of individual AA type batteries. It is user-selectable.
- By default displays the battery type (NiCd) and battery voltage.
- Displays the battery full indication status, once the charging is complete.

Battery keys

- **Battery type selection key —** It is a press button type of key, used to select the type of battery to charge.

- **Battery status selection key** — It is a press button type of key, used to select the type of status to monitor.
- **Enter key** — It is used for entering the selection type for battery or battery status along with the selection switch.
- **Reset key** — It is used to reset the system.

LED indicators

Four different LEDs display the various functionalities of the charger:

- Power-on indication LED
- DC-DC converter output indication LED
- Battery charging indication LED
- Charging complete indication

Initializing the Z8 Encore!® Peripheral

All Z8 Encore! peripherals are initialized from their power-on state to the required mode of operation.

Port A pin 0, 1, 2 and Port C pin 2, 3, 4, 5 are initialized as General-Purpose Input/Output (GPIO) ports. These pins are used to communicate with LCD display.

Port A pin 3, 4, 5 are initialized as GPIO input ports to read the status of control switches.

Port A pin 6, 7 are initialized in alternate function mode (I^2C) to communicate with the temperature sensor device.

Port C pin 1 works in alternate function mode and supplies the PWM output for DC-DC converter.

Port C pin 0 is initialized as GPIO output port to control the buzzer function.

Port B pins 0, 1, 2 are initialized in alternate function mode (ADC) to read feedback values for battery voltage, converter voltage, and charging current.

Port B pins 3, 4 are initialized as GPIO output ports to indicate the status of charger on LEDs.

Initialize the battery parameters stored in the variables. These battery parameters are defined in the `charger.h` header file.

Testing the Application

This section describes the setup, equipment, and procedure to test the Z8 Encore! based NiMH, NiCd battery charger. The test setup consists of a Z8 Encore! battery charger board (see Appendix B—Photograph on page 8) NiMH or NiCd batteries that are to be charged and a 9 V Vdc power supply.

Procedure

Follow the steps below to test the Z8 Encore! based NiMH and NiCd battery charger:

- Launch ZDS II for Z8 Encore!.
- Load the NiMH or NiCd batteries to the battery charger board.
- Connect the batteries to be charged across the provided battery terminals (see Appendix C—Schematics on page 9).
- Ensure that jumper JP5 is connected 1-2 position for supplying the 9 V for DC - DC converter. Power up the battery charger board with the 9 V DC supply.
- Download the code to the Z8 Encore! Flash Memory using the debug connector (JP3) with the help of ZDS II-IDE, if required. The code is shipped along with the board.
- Press reset key to execute the battery charger code.
- Select battery type by pressing switch SW2 and press SW4 for entering the selected type (default type is NiCd).

- Select battery voltage by pressing switch SW3 and press SW4 for entering the selected type.
- Observe the gradual increase in battery voltage on LCD display.
- When the battery is fully charged under normal circumstances, the buzzer will beep and "*Battery charging complete*" is displayed on the LCD display.
- If the temperature is above 40° C, charging of the batteries will be terminated.

Results

Figure 2 displays the test results for the Z8 Encore!® based NiCd battery charger. These readings are obtained using single NiCd AA-type battery (700 mAh) at 300 mA charging rate.

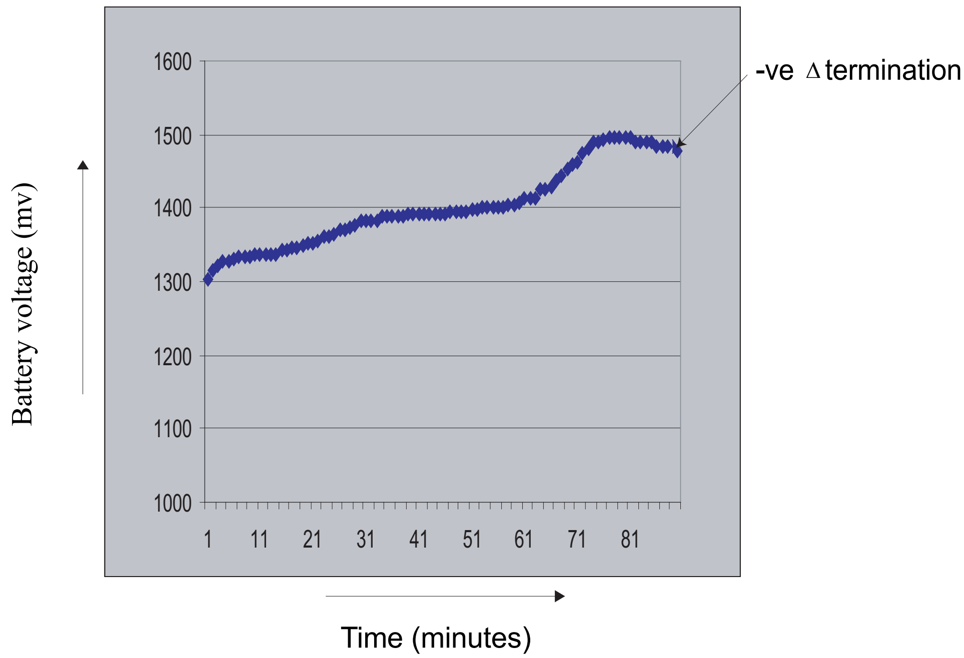


Figure 2. NiCd Battery Charging Characteristics

Summary

This application note discusses NiCd and NiMH battery charger implementation using Z8 Encore! F08 MCU. The battery charger software accompanying this reference design provides fast charging algorithm. Fast recharge is possible due to the monitoring of charging parameters rendered by the 10-bit accuracy of the ADC. This charging mechanism facilitates the accurate termination of charging. Therefore, over-charging is prevented, resulting in a longer battery life.

Pulse width modulation technique facilitates an accurate DC-DC converter (buck) implementation with excellent line/load regulation.

References

The document associated with Z8 Encore! battery charger include Z8 Encore! XP® F0822 Series Product Specification (PS0225).

Appendix A—Glossary

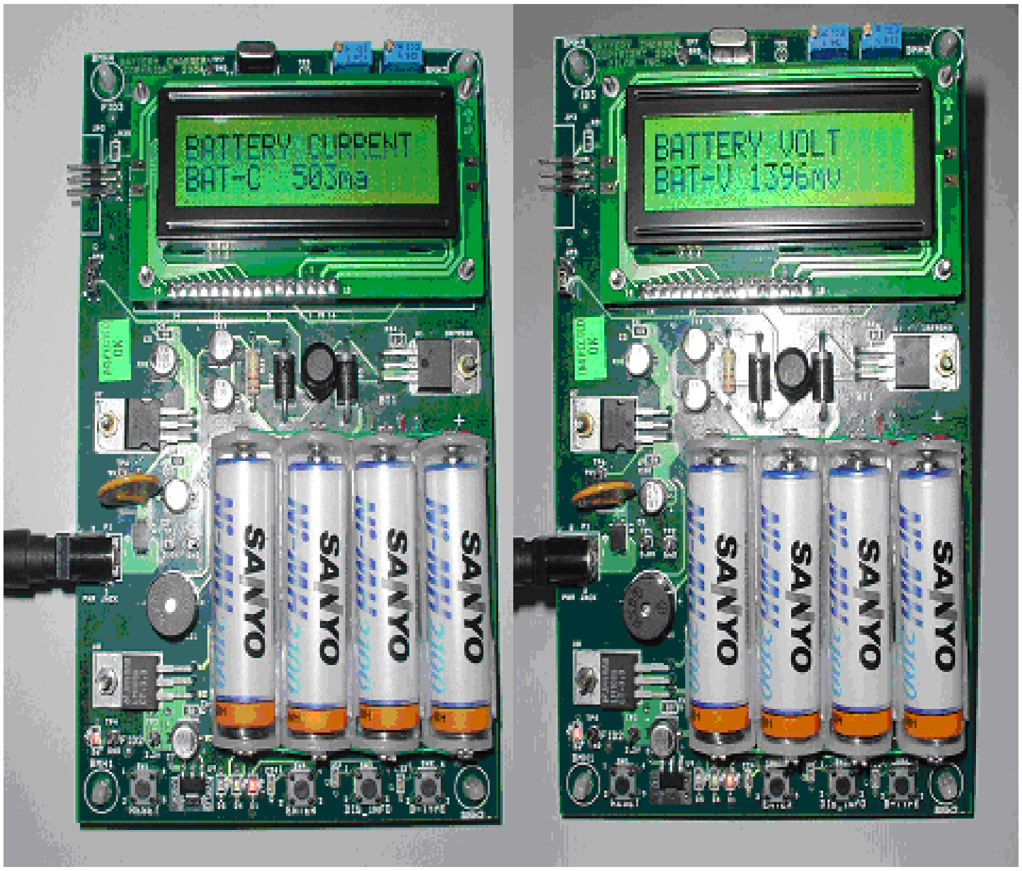
Table 1 lists the terms and abbreviations used in this Application Note.

Table 1. Glossary

Term/Abbreviation	Definition
ADC	Analog-to-Digital Converter
ISR	Interrupt Service Routine
NiCd	Nickel cadmium
NiMH	Nickel Metal Hydride
MAh	milli-Ampere-hour : The unit of battery capacity
PI	Proportional plus Integral
PWM	Pulse Width Modulation

Appendix B—Photograph

Appendix B provides the photograph of the NiMH and NiCd battery charger hardware.



Appendix C—Schematics

Appendix C provides the schematic diagrams for NiMH and NiCd battery charger.

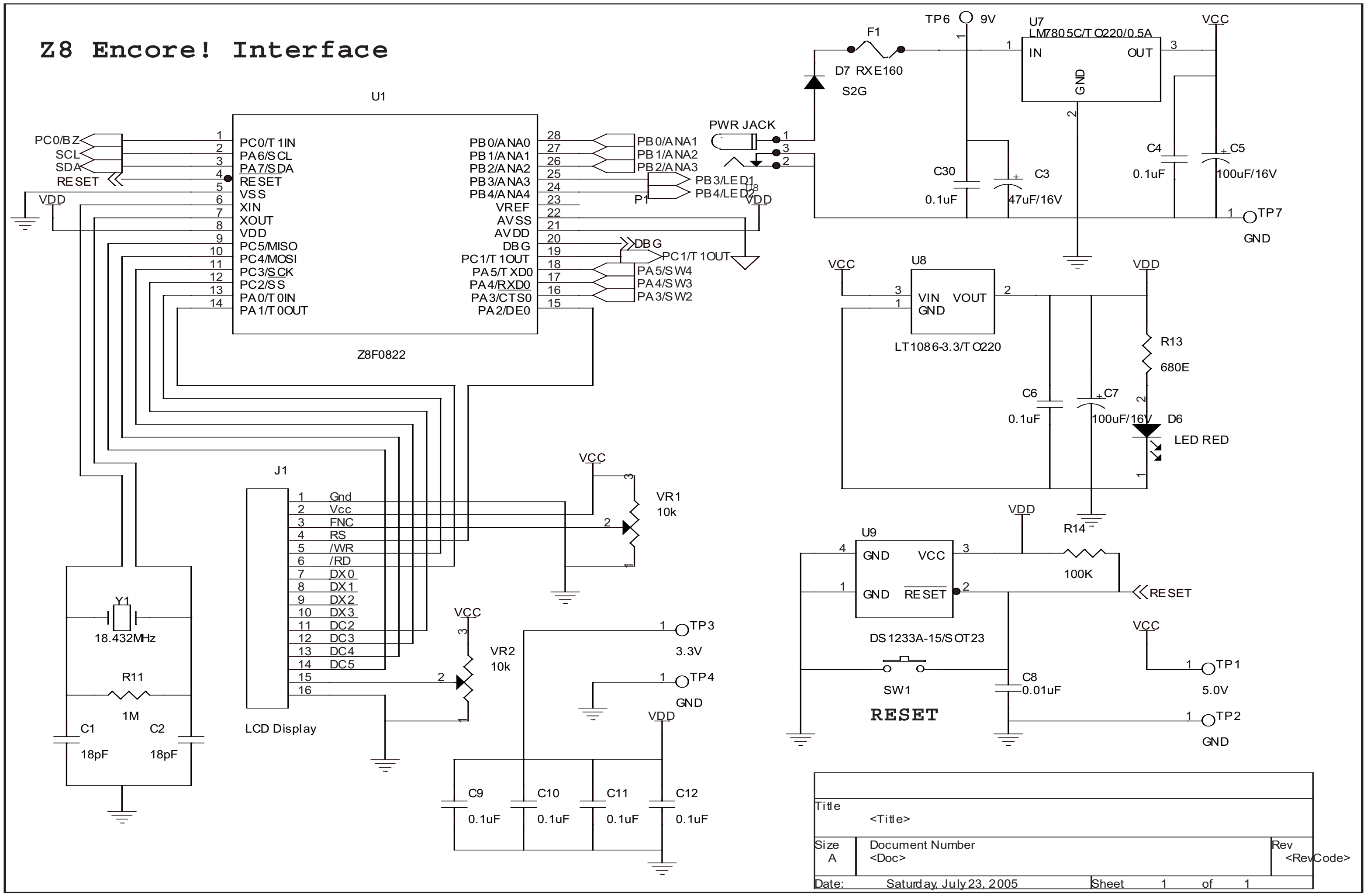


Figure 3. Schematic diagram of Z8 Encore!® Interface

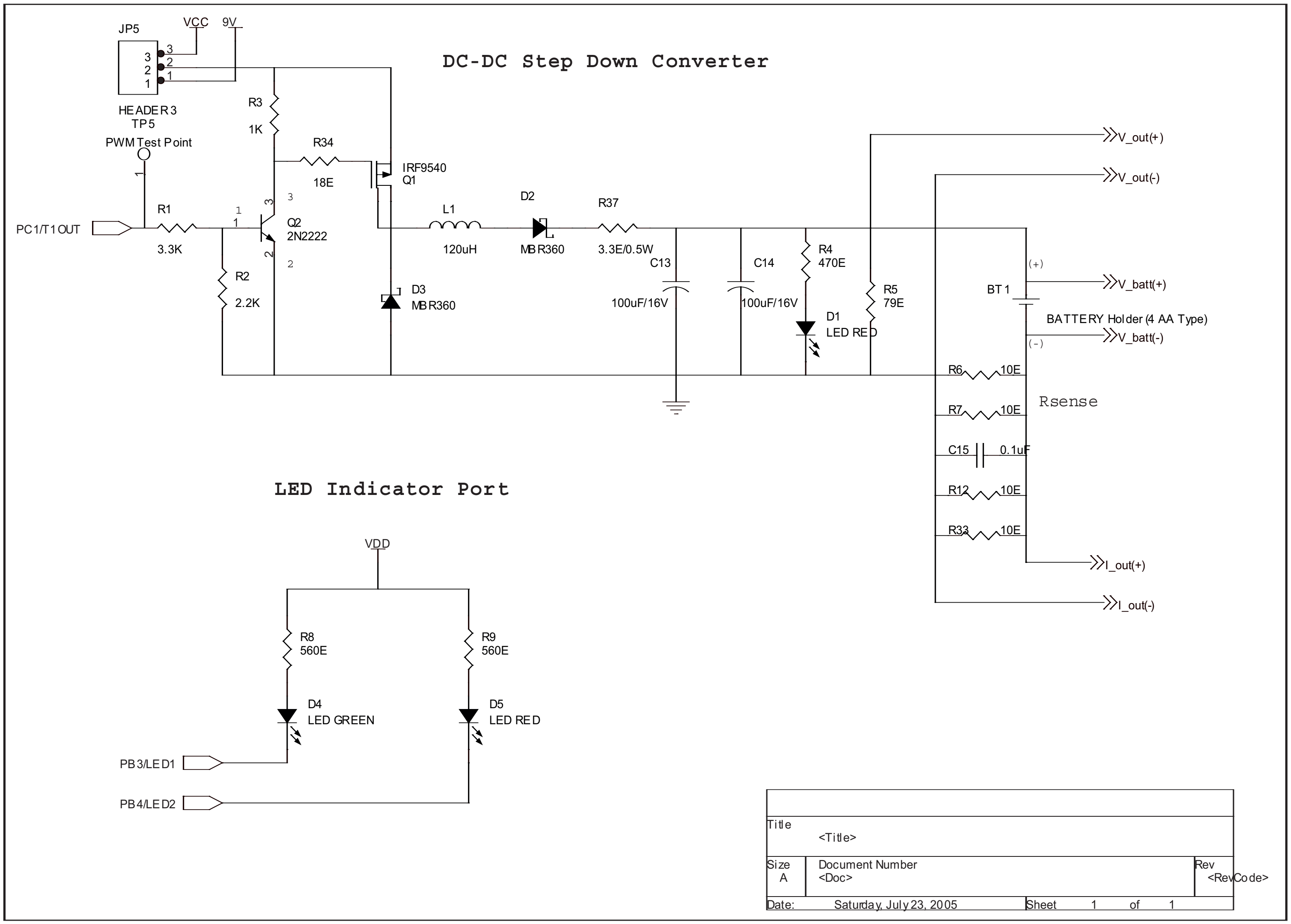


Figure 4. Schematic diagram of DC-DC Step Down Converter

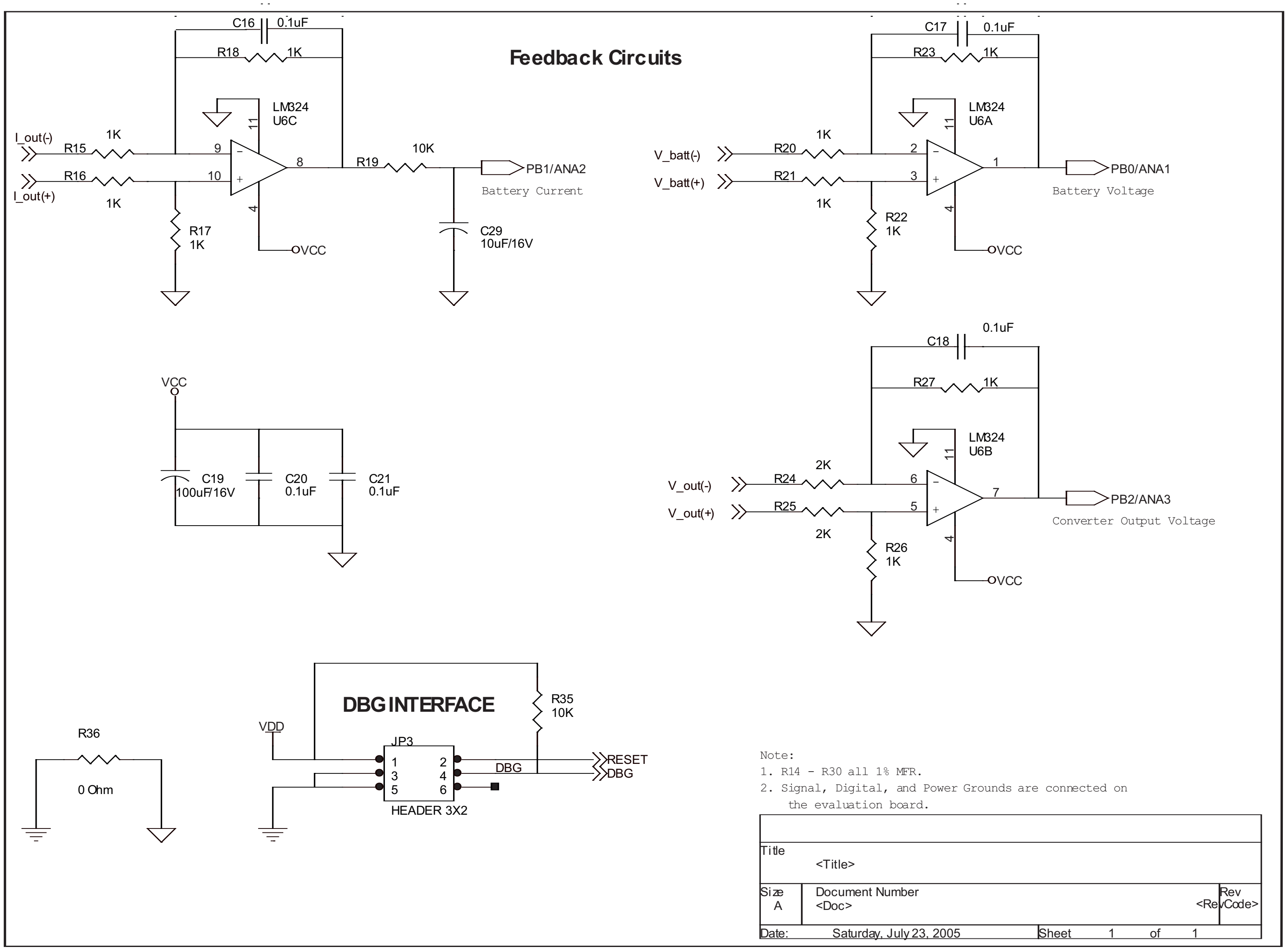


Figure 5. Schematic Diagram of Feedback Converter

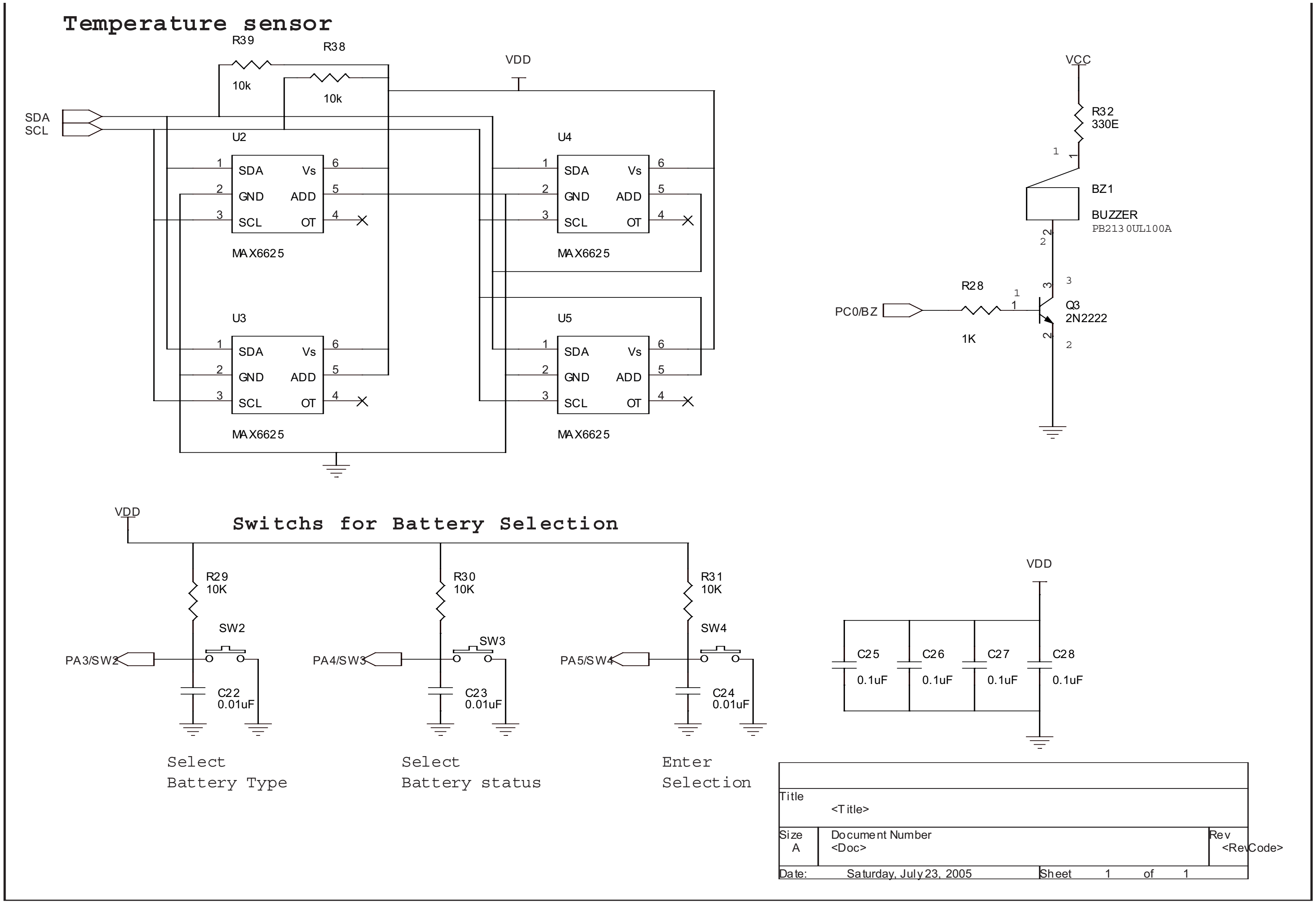


Figure 6. Schematic Diagram of Temperature Sensor

Appendix D—Flowcharts

Figure 7 displays the main battery-charging routine.

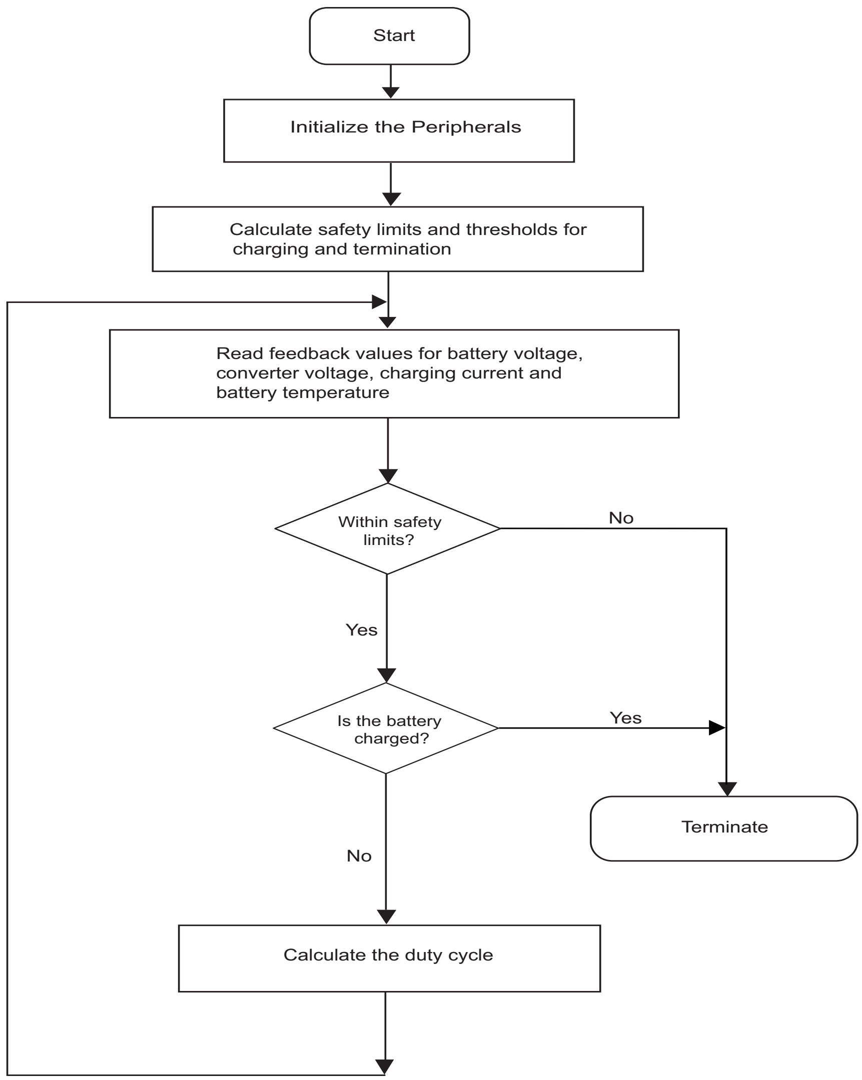


Figure 7. Main Routine

Figure 8 displays the ISR Routine of the battery charger.

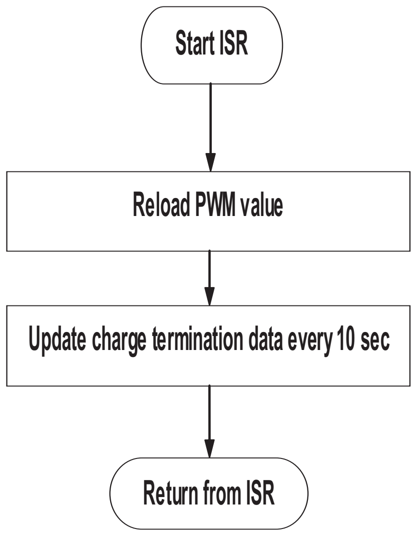


Figure 8. ISR Routine

Appendix E—Battery Technology

Battery Technology

The four popular battery types (NiCd, NiMH, SLA, Li-Ion) possess different charging and discharging characteristics. The battery life and performance critically depends upon the battery charging mechanism. Therefore, batteries must be charged in a proper mechanism. The charging must terminate at the appropriate time as overcharging of the battery invariably results in poor performance and can also damage the battery.

Different batteries require different charge termination techniques as they behave differently while approaching the full charge state. While charging, batteries exhibit the marked rise in voltage above the rated battery voltage.The NiCd and NiMH rechargeable battery types are briefly discussed below.

Nickel Cadmium (NiCd)

NiCd batteries are used in camcorders, walkman and in other consumer portable equipments. The single-cell voltage for NiCd batteries is 1.2 V. These batteries are charged using the constant current charging method. While charging, as the voltage crosses the full charge point, the current gradually drops.This current drop is approximately 15 mV per cell in the battery. This current drop is recognized as full charge condition resulting in the termination of the charge. This termination mechanism is known as -ΔV termination). The battery voltage rises to 1.65 V per cell during charging. The main disadvantage of the NiCd battery is that it must be discharged periodically to protect the performance. This phenomenon is known as *memory effect.*

Nickel Metal Hydride (NiMH)

NiMH batteries exhibit high power density compared to the NiCd batteries.The per cell voltage of the NiMH battery type is 1.2 V which is similar to NiCd batteries. NiMH batteries are charged with constant current charging method. While charging, the voltage drop is not as low as compared to NiCd batteries. Therefore, - ΔV charge termination is not recommended. Instead of the drop in cell voltage, the battery tends to stabilize after a small drop.This flat region is the indication for full battery charging. This termination mechanism is known as zero ΔV termination.

NiMH batteries do not suffer with memory effect as compared to NiCd batteries. As a result, they replace NiCd batteries in devices such as cell phones. The increase in price is justified by the reduction in weight and absence of memory effect.

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