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NiMH Battery Charger Reference Design

Designer Reference Manual

M68HC08 Microcontrollers

DRM051/D
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NiMH Battery Charger Reference Design Designer Reference Manual — Rev 1

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The following revision history table summarizes changes contained in this document.

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Revision History

Section	Page	Description of Change
2	12	Figure 2-1: Minor changes to ADC channels for consistency

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Section 1. System Overview

1.1 Introduction

This manual describes a reference design for a NiMH battery charger that uses the Motorola MC68H(R)C908JK3E MCU. For full specification of MC68H(R)C908JK3E, please refer to the data sheet, Motorola order number *MC68HC908JL3/D*.

RD68CH908NBCSW contains software files for this design and is available from the motorola website: http://motorola.com/sps.

1.2 Overview

MC68H(R)C908JK3E is a member of Motorola HC08 Family of microcontrollers (MCUs). The MC68H(R)C908JK3E includes a 10-channel Analog-to-Digital Converter (ADC) and a 2-channel Timer Module which can be programmed to generate PWM signals. This feature makes this MCU suitable for applications such as a NiMH or NiCd battery charger. The MC68H(R)C908JK3E is available in several packages. In this reference design, the low-cost NiMH battery charger demonstrated uses the 20-pin SOIC package. The main features of this low-cost NiMH battery charger reference design include:

- Capable of fast charging two in-series NiMH batteries with charging current approximately 1 A
- Implements fast, trickle, and maintenance charging modes
- Safety protection terminates charging when:
  - Battery is fully charged by -ve dV, zero dV/dt and dT/dt.
  - Maximum charging-time is achieved
  - Battery's temperature, voltage, or current is out of range
- Auto detection of battery insertion
- Supports in-circuit programming

1.3 MC68HRC908JK3E Features

MC68HRC908JK3E is a 20-pin MCU which has 4096 bytes of user FLASH memory. The FLASH memory can be on-chip, in-application programmed without special programming voltage. By use of the internal charge pump of the MCU, the FLASH memory can be read, programmed, and erased from a single external supply. MC68HRC908JK3E has128 bytes RAM, a 10-channel, 8-bit ADC. The RC oscillator helps to reduce the system cost of the application by eliminating the expensive external crystal oscillation circuit. It has one 16-bit timer module with two timer channels which can be configured to generate PWM signals. Most of the I/O pins are multiplex together with the ADC channels, KBI, and TIM. This gives users great flexibility for their application. All of these features make MC68HRC908JK3E suitable for small applications like a battery charger.

1.4 Charging Characteristic of NiMH Battery Cell

Figure 1-1 illustrates the charging characteristic of a NiMH cell with charging current applied. When charging a NiMH battery, the battery's cell voltage will rise rapidly to reach 1.3 V or 1.4 V depending on the charging current. So for a NiMH battery, if the battery voltage is below 1.0 V before charging, we should apply a small charging current for a few minutes to test whether the battery is good or faulty. This is for safety purposes only. If the battery is good, then we can start fast charging process. When the battery is fully charged, the battery voltage will stop rising and it may level off or drop slightly. In this case, we can apply the –ve dv or zero dv method to check and cut off the charging power when the battery is fully charged. During charging, the NiMH battery cell will start getting warm. Continuing to charge the battery when it is near fully charged will make its temperature rise much quicker. We can also make use of this characteristic to tell that the battery is fully charged.

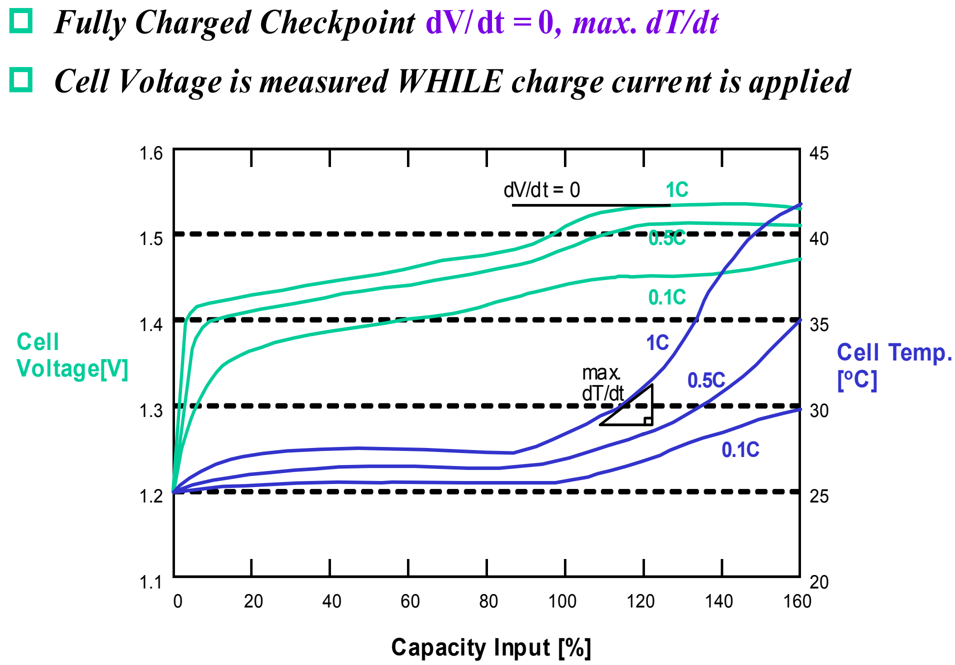

Figure 1-1. Charging Characteristics of NiMH Cell

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Section 2. Hardware and Firmware

2.1 Hardware Descriptions

Please refer to the detailed schematics at **3.3.3 Schematics**.

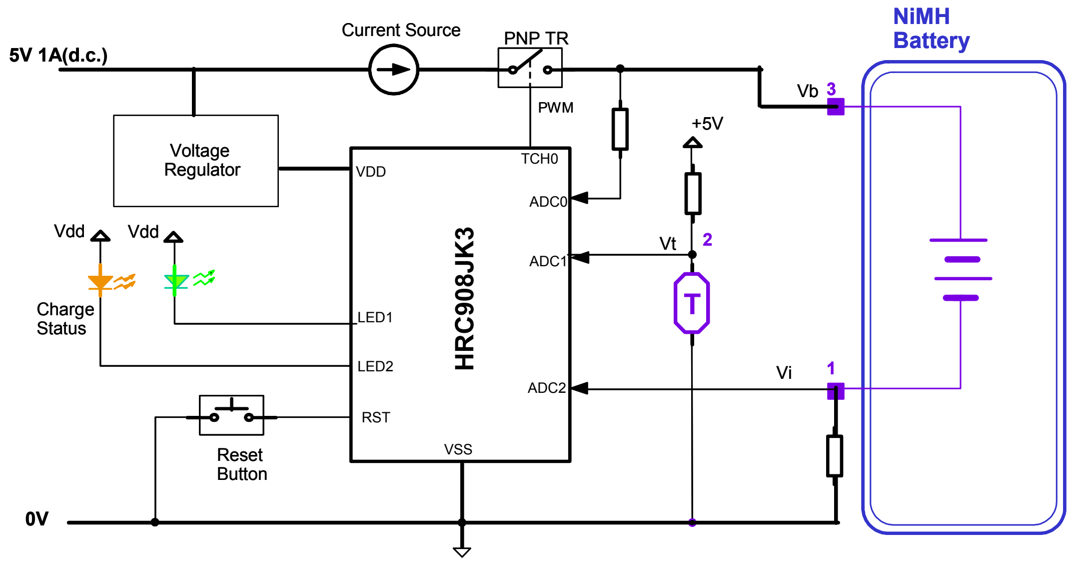

Figure 2-1. NiMH Battery Charger Block Diagram

2.1.1 Power Supply to the MCU

The power supply input to the charger is a regulated 5 V, 1 A at P1. TL431 is used in this reference design to act as a voltage regulator. It serves two purposes:

- to provide accurate power to the microcontroller with Vdd = 4 V
- to provide reference voltage for the ADC module with 1% in accuracy

2.1.2 Charging Control

Pin 19 of the MCU is the TCH0 which is configured as a PWM output. The PWM output signal will control the on/off of charging power to the battery, and thus controls the charging current and voltage. Q2, D1, L1, and C8 form the bulk regulator, which provides a smoother charging power source to the battery being charged.

2.1.3 Sensing Circuit

Three ADC channels (ADC0, ADC1, and ADC2) of the MCU are used in this reference design for checking the battery's voltage, current, and temperature.

Charging current is determined at the B- of J1 by AD2. When the battery is being charged, charging current will flow through the detection resistors R18 and R29. A voltage drop will appear on the resistors R18 and R29. R18 and R29 are 1 Ω, 1% resistors. They are in parallel and give an equivalent value of 0.5 Ω. With a charge current of 1 A, the voltage at B- will be 500 mV.

The voltage of the battery can be determined directly at the B+ terminal of J1. When the battery is being charging, current will flow through the R18 and R19. Therefore it is required to subtract the voltage across on these two resistors. That is, subtract the voltage at B- to obtain the actual battery voltage at its terminals.

An NTC is connected between terminals T of J1 and ground. The battery's temperature can be determined by detecting the voltage at the terminal T of J1 with the help of the NTC.

2.1.4 Charging Status

PTD2 and PTD3 are used to control the on/off of the two LEDs which indicate the status of the charger during charging. (Please refer to **Table 2-1**). Both of them are set as output port. When output high, it will turn off the LED. When output low, it will turn on the LED.

Table 2-1. Charging Status

	Red LED	Green LED
Charge in Progress	On	Off
Battery is Fully Charged	Off	On
Battery is Not Connected	Off	Off
Fault Condition Occurred	Flashing	Flashing

2.1.5 In-Circuit Programming

J3 contains the signals for the MCU 68HRC908JK3E to enter monitor mode for ICP. The ICP requires connecting J3 to the MON08 cable of Cyclone programmer (see **Figure 2-2**). The signals from the J3 are Vdd, Vss, Vtst and OSC1, and PA0. Entering monitor mode also requires that PTB1 is pulled low, and PTB2 and PTB3 must be pulled up. This requirement is fulfilled with the carefully designed charger hardware. When in-circuit programming, the jumper J4 must be opened to disconnect the filter cap, 0.1 μF at PTB0/AD0 to avoid distortion of the data signal caused by the capacitor's loading.

The programming software is PROG08SZ.exe from P&E. Select Class V for Target Hardware Type. Select baud rate 9600 bps. The ICP supports erasing, programming, and verifying the firmware in the MCU.

Figure 2-2. In-Circuit-Programming of the JK3E Charger

2.2 Firmware Description

2.2.1 Battery Inserted Detection

When the charger is powered up, the charger-control software will enable the PWM output, and it will gradually charge up the cap E8. Before any battery is inserted, the B+ voltage read by the AD0 will be near or equal to its full scale. Whenever a battery is inserted, the B+ voltage will fall immediately to the value equal to the battery's voltage. Therefore, the battery insertion or removal can be checked by the microcontroller by sensing the variation of B+ points' voltage of the battery. (Please refer to **3.3.3 Schematics**).

When battery insertion is detected, the firmware will go on to check the inserted battery's terminal voltage and temperature. If they fall in the valid range, then proceed to charging mode. Table 2-2 compares the battery voltage to the charger status.

Table 2-2. Battery Voltage and Charger Status

Battery Voltage	Charger Status
V_{bat} < 1.0 V	Not charging, bad battery, flashing LEDs
V_{bat} > 2.8 V	Battery full, no charging, green LED on
1.0 V < V_{bat} < 2.0 V	Trickle charge, red LED on
2.0 V <V_{bat} < 2.8 V	Fast charge, red LED on
Vtemp < 0 °C	Not charging, flashing LEDs
Vtemp > 45 °C	Not charging, flashing LEDs
I_charge > 1.5 A	Over current, stop charging, flashing LEDs

2.2.2 Trickle Charge

If the battery voltage is <2.0 V but >1.0 V, then go to trickle charge. The current for the trickle charge is set to 0.1C which equals to the 10% of the battery's rate capacity.

The maximum charge time is 10 minutes. If within 10 minutes time, the battery voltage can be charged above 2.0 V, then the battery is good and the charger can be switched to fast charging mode. If the voltage does not rise up to 2.0 V after 10 minutes trickling charge, the charger will signify that the battery is bad and stop the charging process.

2.2.3 Fast Charge

In fast charging mode, a constant current of 1 A is applied to the battery. A maximum charging time is set for the fast charging mode to prevent over charging.

Fast charging mode is actually a constant current charging mode and the charger system is in closed-loop control. The firmware continuously checks the charging current by sensing the voltage at the current-determining resistors (R13, R14) and adjusts the duty of PWM output from the MCU accordingly. The battery's voltage is checked frequently during the charging process. Whenever the zero dV or –ve dV condition is detected, the battery is announced fully charged. In the meantime, if the MCU determined that the battery's temperature gradient is becoming steep and the battery's voltage is over 1.4 V, the battery is also announced fully charged.

Since the charging current and the battery's terminal voltage must be measured with the charging current applied, the transistors Q1 and Q2 (which are controlled by the PWM output pin of the MCU) must be turned on when the measurement takes place. This can be implemented by the firmware described below.

The timer overflow interrupt is enabled for the MCU and a flag will be set to indicate the timer overflow has occurred. This flag will be cleared after the ADC conversion. The PWM output is a part of the mechanism of the timer overflow. Immediately after the timer overflow, the PWM is output high to turn on Q1. Then Q2 turns on to charge the battery.

When a measurement is required, the firmware will enable the corresponding ADC channel, clear this flag, and then wait until the flag is set again. After the flag is set, the MCU will start the ADC conversion to get the conversion data. This conversion data, either voltage or current, is the data with the charging current applied. It is required to determine whether the battery is fully charged. The flag will be cleared after the ADC conversion.

Charging Current Table; Rsense = 0.5 Ohm, VrefH = 4.0V.						
I (mA)	1200	1000	800	500	200	100
Isense (mV)	600	500	400	250	100	50
Hex	$26	$20	$19	$10	$06	$03

Battery Voltage Table; refH = 4.0V										
Bat Voltage (V)	1	1.8	2	2.4	2.6	2.8	3	3.2	3.4	3.6
Hex	$40	$73	$80	$99	$A6	$B3	$C0	$CC	$D9	E6

Battery Temperature Table; refH = 4.0V, R pull-up =10K (1%)							
T (degC)	50	45	40	25	10	0	-5
R NTC (K)	3.63	4.4	5.356	10	19/85	32.33	42.81
Tsense (V)	1.17	1.34	1.53	2.2	2.92	3.36	3.57
Tsense(Hex)	$4A	$55	$61	$8C	$BA	$D6	$E3

2.2.4 Maintenance Charge

When the battery is fully charged and not removed, the maintenance charge mode is applied. Maintenance charge will applied a 0.01C charging current to the battery continuously until the battery is removed or the battery voltage is low enough for a fast charge to take place.

2.2.5 Safety Protection

During charging (either trickle or fast charge mode), anytime the battery's voltage, current, or temperature is determined to be out of range, the charger will shut off the charging power.

2.3 Firmware Files

Firmware is complied under CASM08Z.EXE ver 3.16 from P&E Microcomputer System, Inc.

Table 2-3 summarizes the functions of each firmware files:

Table 2-3. Files Functions

Files	Functions
JK3ECHGRDEMO.asm	Charger main program
MC68HC908JL3.equ	Registers and memory definitions file
JK3ECHGR_INC.asm	Subroutines file

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Section 3. Solution

3.1 Test Description

The solution was tested with two 1.2 V NiMH battery cells using a +5 V power supply (HP6236B).

3.2 Extra Features

There is a useful subroutine included in the file JK3ECHGR_INC.asm. It is DSRL_OUT which is a serial RS-232 data transmit routine. It uses PTB7 as the data line to serial out the data. The baud rate is 19200 bps when the RC oscillation frequency is trimmed at bus frequency of 2.4576 MHz. The data line is output to a standard RS-232 interface circuit that connected to the COM port of a PC. This routine is helpful in project development because the developer can monitor the battery charging status and has the charging parameters such as voltage, temperature, and current for analysis. Since RC oscillation is used, some fine tuning might need on the bit delay routines if the bus frequency cannot be tuned to exactly to 2.4576 MHz bus frequency. When calling this routine, the interrupt mask bit is set to avoid interrupt, and the mask interrupt bit will be clear before leave this subroutine. When software development is completed, calling this sub-routine is not necessary, and it should be removed from the main program.

3.3 Further Information

3.3.1 Related Documents

MC68HRC908JK3E Technical Data

3.3.2 Notes on Schematic and Layout

The current schematic and layout show an identical set of charging paths for another set of NiMH batteries. This is for user reference if implementing a charger that can charge four NiMH cells (i.e. 2 x 2 x1.2V).

3.3.3 Schematics

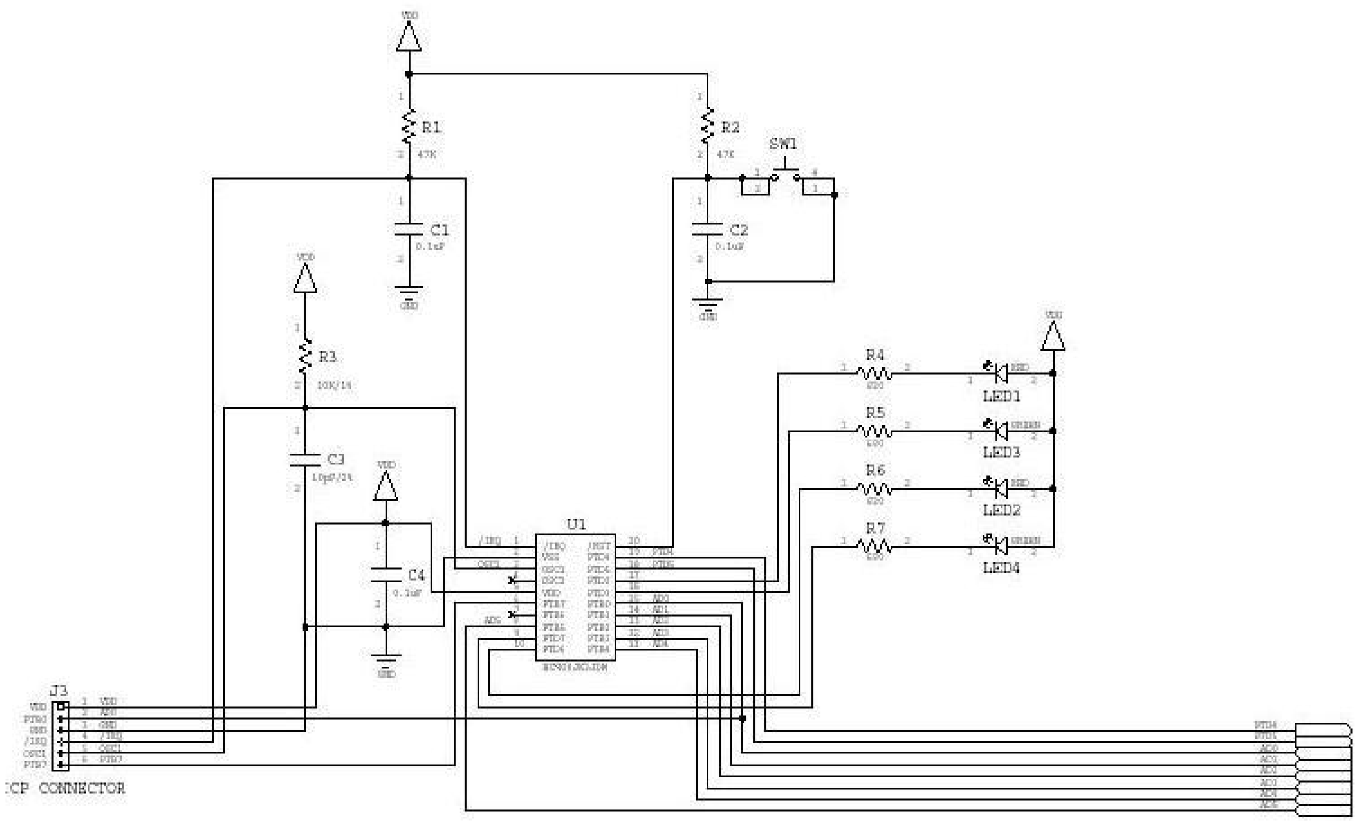

Figure 3-1. JK3 NiMH Battery Charger — MCU Section

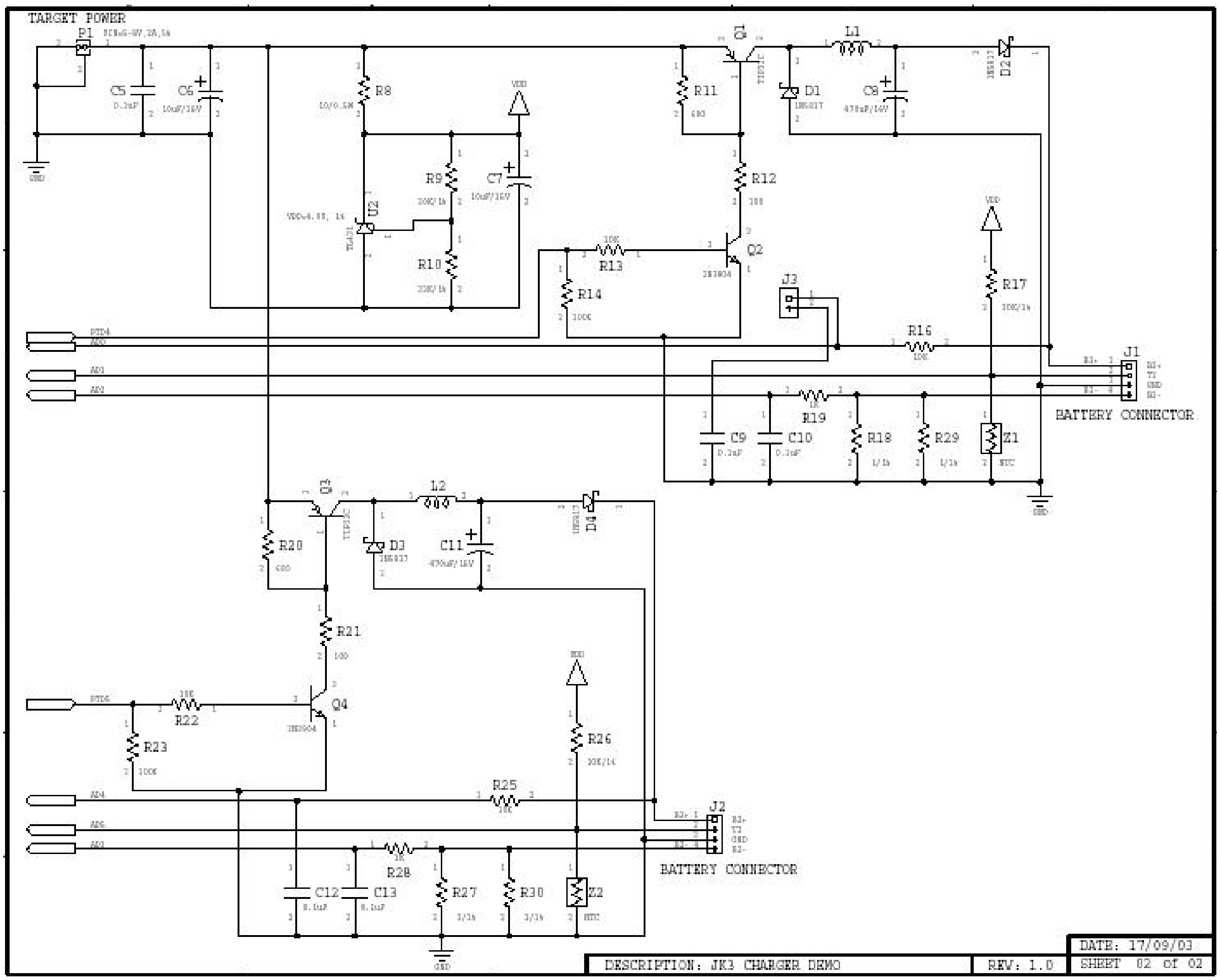

Figure 3-2. JK3 Battery Charger — Control Section

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