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The Open Electrical & Electronic Engineering Journal, 2014, *8*, 229-233

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A Kind of Intelligent Fast Charger of the Lead Acid Battery Based on MCU

Lun-qiong Chen*, Bei Li and Lin Yu

School of Electronic Information and Electrical Engineering, Changzhou Institute of Technology, Changzhou, 213002, China

Abstract: Based on pulse fast charge of the lead acid battery, this paper designed a kind of intelligent battery charger, including mainly a minimum system of 16 bit MCU as intelligent center, the constant resistance discharge unit to complete SOC prediction and duty cycle of the pulse charging waveform, the voltage-current-temperature measurement unit, pulse charging control unit. The duty cycle of this charger agreed with SOC of the battery, then using short floating charge in the later stage, thus greatly optimizing the pulse charging mode. Finally, compared with the conventional constant voltage and constant current charging, the charger greatly reduced the charging time.

Keywords: Duty cycle, microcontroller unit(MCU), pulse fast charge, state of charge (SOC), the constant resistance discharge.

1. INTRODUCTION

As a stable power supply and the main DC power supply, lead acid battery is widely applied in automobiles, motorcycles, electronic bicycles, Telecom, telecommunications, banks, shopping malls, broadcasting, and other industries, due to its superior technical specifications and economical prices. However, the greatest impact on the duration of the battery is its charge mode [1]. Currently the more popular charge mode is pulse fast charge, including positive and negative pulse fast charge [2], Reflex fast charge, alternating current fast charge [3], alternating voltage fast charge, and intermittent alternating current-voltage positive-negative pulse fast charge [4] etc. Based on research of the characteristics of a variety of pulse fast charge, This paper designed a new intelligent charging method and charger, namely, it mainly used pulse charging mode, predicting SOC in early stage and duty cycle, adding a short float charging unit in later stage.

2. RESEARCH DESIGN

Before the charge, constant load method was applied to detect state of charge(SOC) of the battery. Setting a constant resistance discharge circuit in the charger, when using the charger for the first time to discharge completely, the discharge curves $i = f(t)$ for three times are shown in Fig. (**1**), which showed that the three curves were very close.

Based on this curve of Fig. (**1**), there was a sharp drop at 90% discharge time, as expected inflection point, recording time being t_z and the voltage value being $U_d[t_z]$. Total discharge time was denoted as N. Recording start voltage value being $U_d[0]$, recording time X and the voltage $U_d[X]$ per minute during discharge. Finally getting the formula 1 as the basis for making the SOC-Ud table 1, In other words, the SOC was determined by testing the fixed voltage U_d values.

$$SOC = \frac{(U_d[X] + U_d[t_z])(0.9 * N - X)}{(U_d[0] + U_d[t_z]) * N} \quad (1)$$

Secondly, duty cycle and SOC was obtained through selective experiments of pulse fast charge and constant voltage charging time, as shown in Table **1**.

Finally, the charge was realized according to the scheduled duty cycle. For example: when the remaining capacity is 10%, use 9:1 as the duty cycle of charge-stop, that is, after charging for 4 hours and floating charge for about 3 minutes (constant voltage and small current), the charging amount paralleled that of charging for 6-7 hours with constant flow and constant voltage (0.3C constant flow -2.4V constant voltage).

3. SYSTEM IMPLEMENTING SCHEME

Charger system included the smallest system which consists of 16-bit single chip microcomputer system circuit, voltage-current-temperature measurement circuit, discharge control circuit, charge control circuits, and keyboard and communication circuits.

3.1. The Minimum System Circuit

The minimum system circuit was shown in Fig. (**2**). MC9SXS128MAE is a 16-bit CPU produced by Freescale Company, which is characterized by integrated 128K Flash program, 8K RAM, 8K data Flash, dual-channel, 8-channel

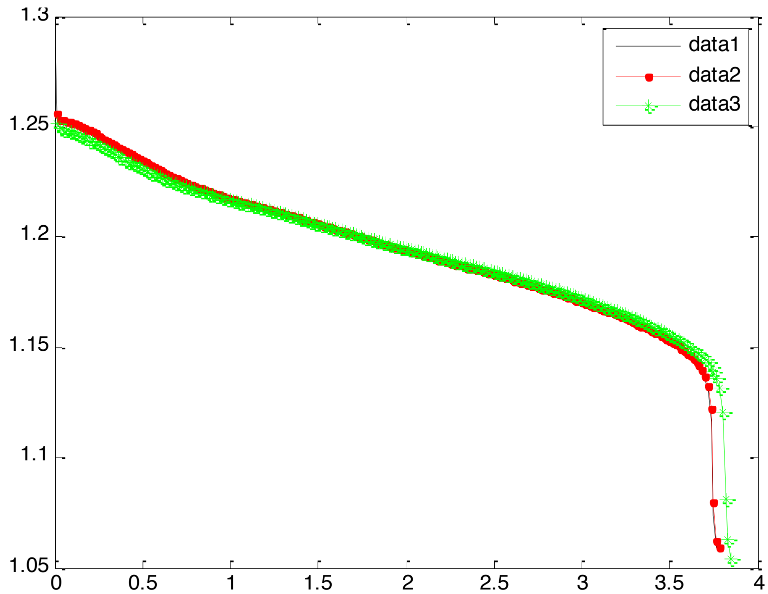

Fig. (1). Discharge Curve of constant resistance discharges.

Table 1. SOC-DC table.

SOC	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
DR	90%	90%	80%	70%	60%	50%	40%	40%

12-bit A/D, 8-channel TIM, 8-channel 8-bit or 4-channel 14-bit PWM, 1 channel SPI and 1 channel CAN.

3.2. Voltage-Current-Temperature Measurement Circuit

Fig. (**3**) showed the voltage-current-temperature measurement circuit. VBAT was the positive side of the battery, whose voltage was partitioned through resistance R18 and potentiometer VR4, R12 and C9 being filter circuit, Vout being battery voltage measurement terminal.

Isensoro was the output for current sampled, R11 and C8 being filter circuit, amplifier U6A and resistance R19 and variable resistance VR being proportional amplifier, which amplifying voltage to get Iout(charge current measurement terminal).

V2.5 was precise voltage regulator, VR3 and R10 being divider circuit, Rt1 being the NTC temperature sensor, which constitutes the proportional amplifier circuit with amplifier U6B and R9. After the R16 and C14 filter, the output voltage gets Tout (battery temperature measurement terminal).

3.3. Discharge Control Circuit

Fig. (**4**) showed the constant resistance discharge circuit. U3 was the optical coupling circuit, MCU pin PP0 exporting signals to control Q5 by U3, Q5 driving relay RELAY1. R22 was the discharge resistor. When relay RELAY1 being on, the positive side of the battery discharged through resistors R22. Analysing VBAT voltage and discharge time by the computer program to calculate SOC of the battery.

3.4. Charge Control Circuit

Fig. (**5**) showed the charge control circuits. U2 was the optical coupling circuit. MCU pin PP7 outputted PWM pin signal, via U2 optical isolation, controlling the push-pull circuit by Q2 and Q3, to realize constant voltage or constant current control. R3 was a protection resistor. R7 was a current-sampling resistor. VBAT was voltage measurement terminal. Isensor was current measurement terminal.

3.5. Other Circuit Function

LCD display: display battery voltage, current, temperature, SOC, time and other information in real-time.

Parameter settings: parameters could be set or selected in the control process as needed. Parameters were stored in MCU Flash.

Communication functions: MCU serial port 0 levels via MAX232, could be used with PC connections, transmit measurement of voltages, currents, temperatures, PWM and other information in real-time.

4. SYSTEM SOFTWARE SCHEME

Preparation before making the Charger: communicating with the customer before making the charger, so that the currents and voltages limits and the protection values could be preset in the storage. Besides, the value of constant resistance could be determined according to the battery capacity, SOC and the duty cycle table stored into Dflash, and SOC-Ud table methods stored into Dflash.

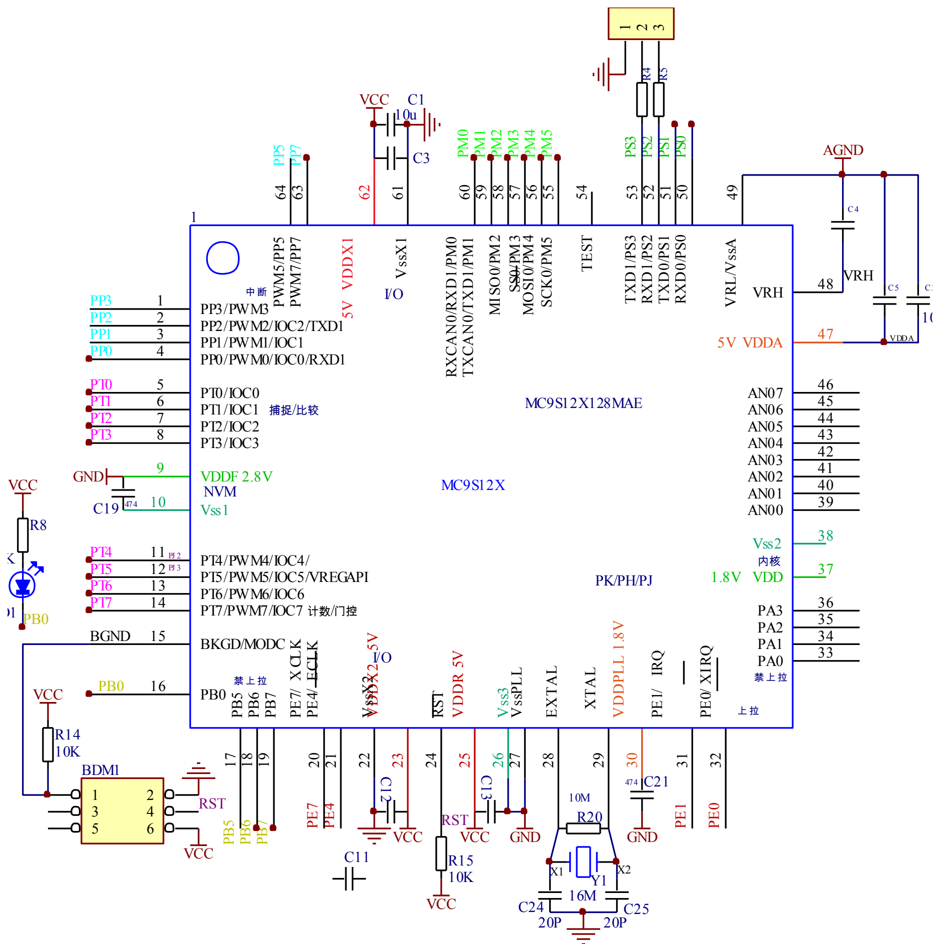

Fig. (2). The smallest system electrical circuit.

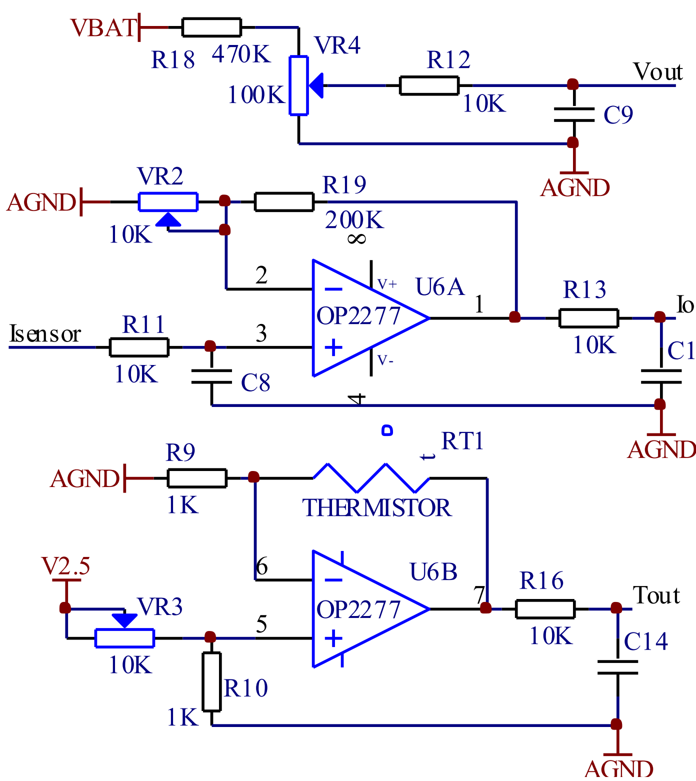

Fig. (3). Voltage-current-temperature measurement circuit.

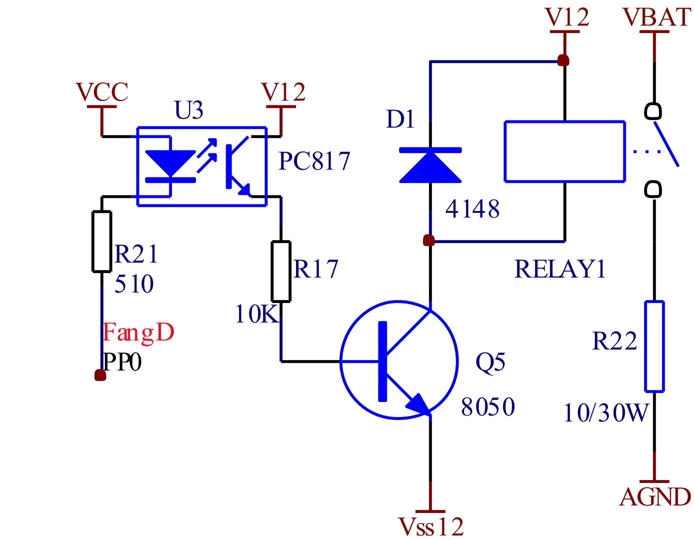

Fig. (4). Constant resistance discharge circuit.

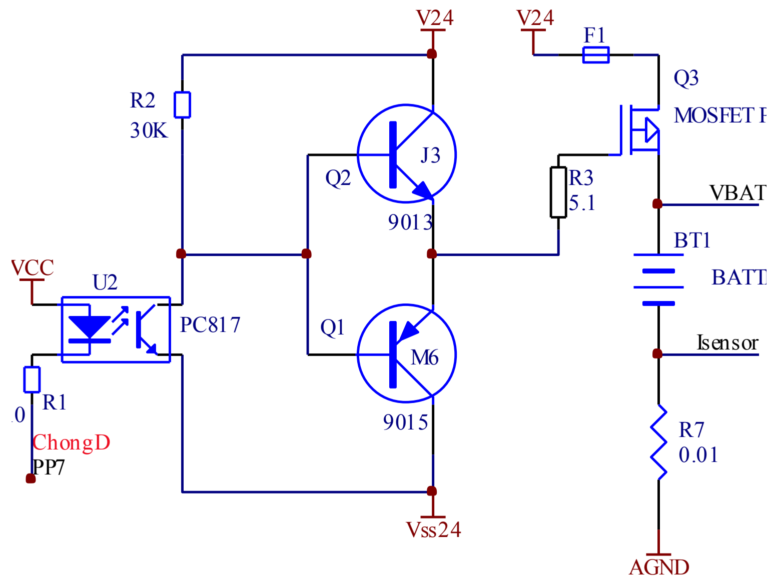

Fig. (5). Charge control circuit.

Software scheme: first, by constant resistance discharge, detecting SOC of the battery. Secondly, on the basis of SOC, finding the stored data in MCU memory to determine duty cycle. Moreover, setting the charge time. Finally, beginning pulse charging according to the duty cycle, at the end of pulse charge, pausing 3 minutes to floating charge.

CONCLUSION

The charger, with the 16-bit intelligent MCU as the core, realized the measurement of voltage, current and temperature, and taked advantage of the constant resistance circuit and its associated data setting a reasonable duty cycle of pulse charging, which made the duty cycle of the pulse and the battery status consistent, while maintaining the battery performance, shortening charge time, and also adding short floating in the later stage. This charger with the traditional one, found that could greatly save time, taking 7AH lead-acid battery for example, the charging time can be reduced by more than 40%, in other words, previously 7 hours are needed to get charged, and now only 4 hours are needed. The practice has proved that this charger is of great practical value.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

This work was financially supported by Science and technology support program of Changzhou (Program No. CE20130084, 2013-2015) and the program of Changzhou Institute of Technology (Program No.YN1108, 2011-2014 and YN1315,2013-2015)

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Received: October 29, 2014 Revised: December 02, 2014 Accepted: December 11, 2014