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Double Protection Charger for Li-Ion Battery

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Abstract

A low cost battery charger is introduced in this paper. The charging feature meets the requirement of a Li-Ion rechargeable cell designed for electric vehicles and manufactured by E company. The charger is capable of constant current/constant voltage charging strategy, double over current/voltage protection and automatically offloaded with a sound alarm when the charging current is smaller than about 40mA. A detail circuit diagram and its operation principle are proposed and some experimental results are also given. All devices used in the charger circuit are very common and easily purchased. Because of its simple structure only a few modifications are needed to make one's own specific charger.

Keywords: battery charger, lithium ion, battery

1. Introduction

Lithium-Ion (Li-Ion) batteries are characterized by the greatest capacity/volume ratio and can be found in notebooks, pocket PCs, cell phones, electric vehicles and other newer-technology consumer applications. The Li-Ion charger design is known for its simplicity, low cost, and small size, and there are highly-integrated charger ICs offered by various vendors in the market [1-5]. The particular charging algorithm, charging protection, board space, and complexity are the decisive factors governing Li-Ion battery charger design [6-8]. This paper provides another solution to make a single cell Li-Ion charger and describes how to use double over current/voltage protection strategies in the charger on an example of an IHR18650A battery [9].

The IHR18650A cylindrical cell consists of a lithium Nickel-Manganese-Cobalt oxide positive electrode and a graphitic carbon negative electrode providing 3.6 volts and 1950 mAh. The double protection battery charger completely meets the charging characteristics of IHR18650A in two charging phases: fast-charge/constant current and constant voltage.

2. Circuit Design

Parts specifications of IHR18650A are listed in Table 1. Detailed cell specifications can be found in [9]. Based on the cell specifications, we design the double protection battery charger for the two charging phases: constant current and constant voltage. All techniques used in the circuit can be found in textbooks as in [10-11]. To describe the circuit in detail, we divide it into 3 parts as in Figure 1.

2.1 CC Charging and OV Protection Circuit

Figure 2 shows the schematic of the constant current charging and over voltage protection circuit. Constant current control circuit consists of zener diode ZD1, resister R5, R2, R4, R6, capacitor C2, potentiometer R3, transistor Q1 and operational amplifier U1. Diode D1, D2, and indicator LED1, LED2 form a switch circuit. D1 and LED2 will be turned on (D2 and LED1 be turned off) while the voltage of the battery BTR1 is lower than 4.2V and the constant current control circuit is activated. The current through R2 is

$$I_{R2} = \frac{V_{TP1} - V_{TP6}}{R2} . \quad (1)$$

Table 1: Parts specifications of IHR18650A.

Typical Capacity		1950 mAh
Minimum Capacity		1850 mAh
Nominal Voltage		3.6 V
Charge Voltage		4.2 V ± 0.05 V
Charge Current		Less than 2.0 A
Charge Time		3.0 hrs
Discharging Current (Max.)		4.0 A
Discharging Cutoff Voltage		3.0 V
Temperature	Charge	0°C to 45°C
	Discharge	-20°C to 60°C
	Storage	< 35°C

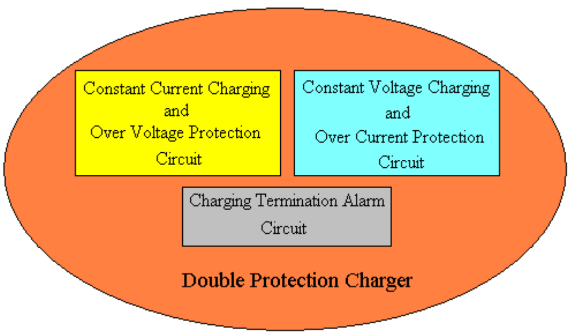

Figure 1: circuit structure of the double protection charger.

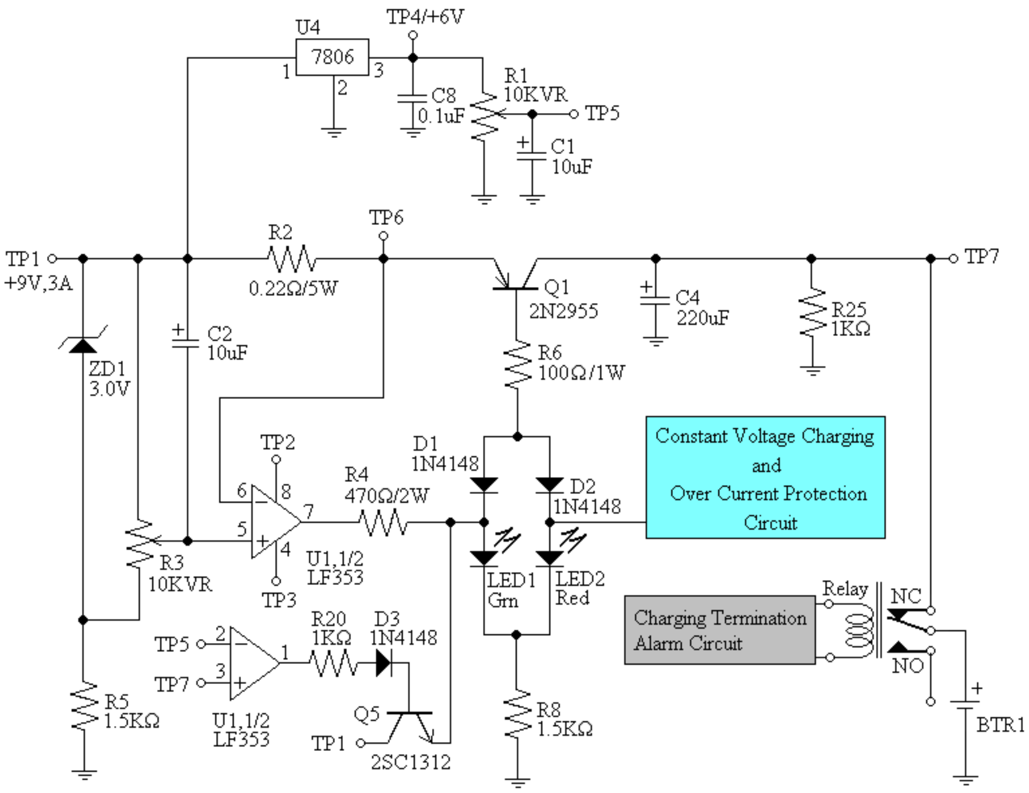

Figure 2: schematic of constant current charging and over voltage protection circuit.

Because the virtual connect function at pin #5 and #6 for U1 operating on linear condition, the current through R2 can be reformed as

$$I_{R2} \cong \frac{V_{TP1} - V_{U1\#5}}{R2}, \qquad (2)$$

where $V_{U1\#5}$ is the voltage at pin #5 of U1. One should carefully adjust R3 to obtain an intended charging current for BTR1. The ZD1, R5, and C2 are used for stabilizing the voltage difference between TP1 and U1#5 and avoiding loading effect on voltage variation at TP1. Over voltage protection mechanism is achieved by using U4, C8, R1, C1, U1, R20, D3, and Q5. One should carefully adjust R1 and let V_{TP5} approach 4.2V. When V_{TP7} is greater than V_{TP5}, Q5, LED1 and D2 are turned on and constant voltage charging circuit is activated.

2.2 CV Charging and OC Protection Circuit

Figure 3 shows the schematic of the constant voltage charging and over current protection circuit. Constant voltage control circuit consists of resister R6, R7, R16, R17, R18, R19, capacitor C3, potentiometer R15, transistor Q1, Q2 and operational amplifier U2. R17, R18, C3 and part of U2 form an inverse integration amplifier. The inverse integration amplifier provides negative feedback gain for the constant voltage control loop. One should carefully adjust the potentiometer R15 to obtain an intended charging voltage. Over current protection mechanism is achieved by using R2, R9, R10, R11, R13, R14, potentiometer R12, and transistor Q3, Q4. If output charging current is over a specified limit,

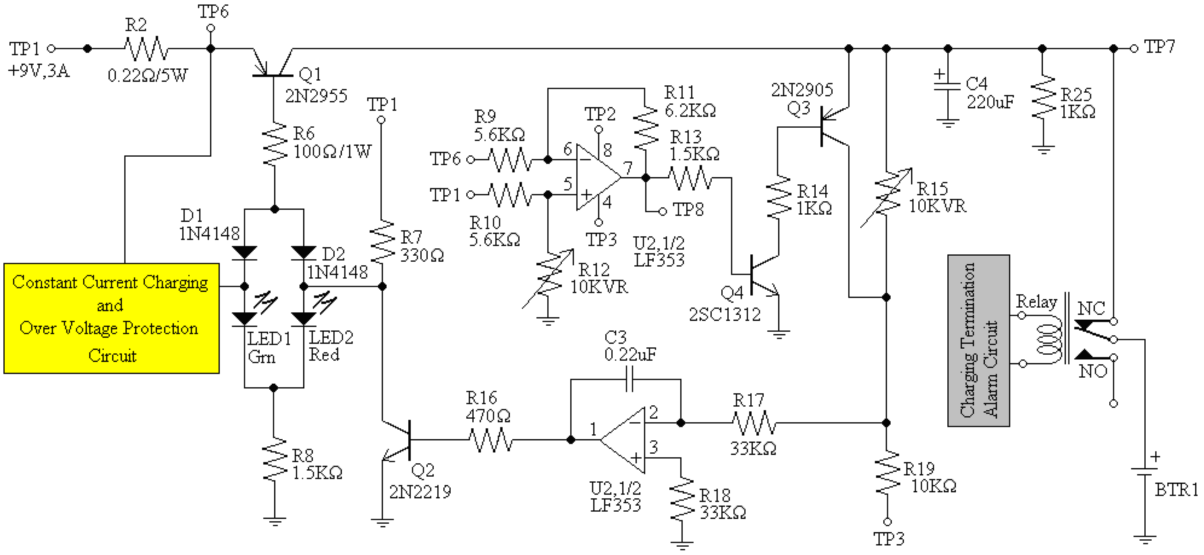

Figure 3: schematic of constant voltage charging and over current protection circuit.

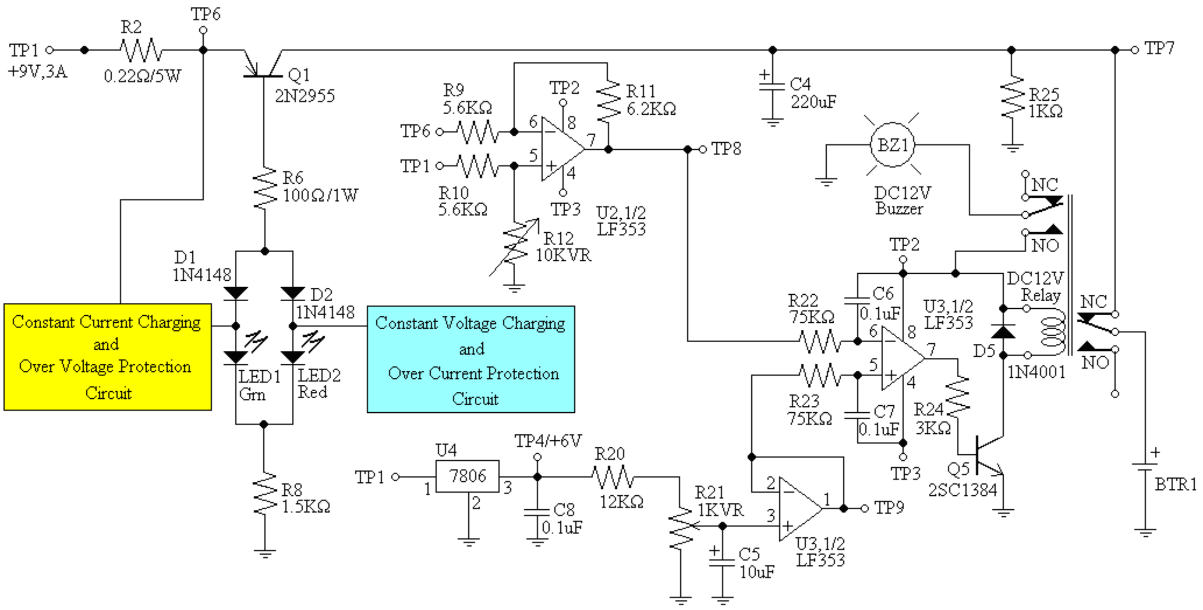

Figure 4: schematic of charging termination alarm circuit.

Q3 and Q4 will be turned on and the constant voltage charging circuit will be shutdown. One should carefully adjust the potentiometer R12 to obtain an intended current limit.

2.3 Charging Termination Alarm Circuit

Figure 4 shows the schematic of the charging termination alarm circuit. The circuit consists of resister R20, R22, R23, R24, potentiometer R21, capacitor C5, C6, C7, diode D5, transistor Q5, operational amplifier U3, buzzer BZ1, and a 12-V DPDT relay. The upper part of U3 acts as a voltage comparator. The lower part of U3, a voltage follower, provides a terminated threshold voltage V_{TP9}. When the charging current is less than a specified limit, at this point V_{TP8} should

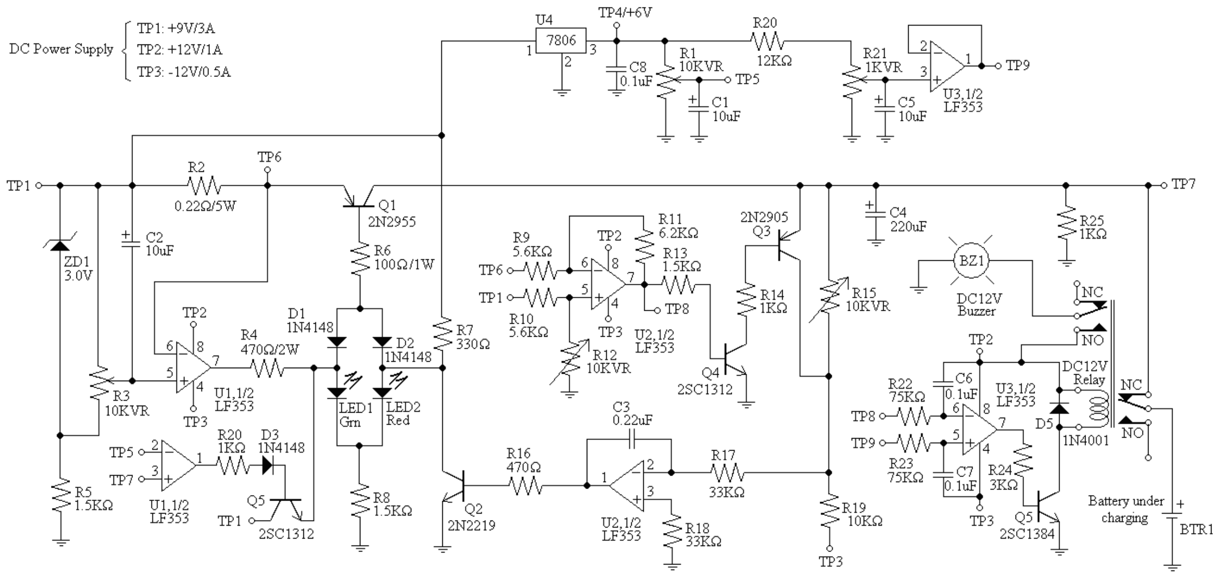

Figure 5: schematic of complete circuit.

less than the threshold voltage V_{TP9}, Q5 turns on, relay is activated, so is BZ1, BTR1 is isolated, and charging process is terminated. One should carefully adjust the potentiometer R21 to obtain an intended termination current limit.

2.4 Complete Circuit

Figure 5 shows the schematic of the complete circuit. Figure 6 is a photo of the circuit. Once upon the circuit is assembled correctly, adjustments should follow the numbered steps as below.

1. Adjust R3 to obtain a specified constant charging current.
2. Adjust R1 to obtain an over voltage protection threshold limit.
3. Adjust R15 to obtain a specified constant charging voltage.
4. Adjust R12 to obtain an over current protection threshold limit.
5. Adjust R21 to obtain a specified termination charging current limit.

3. Experimental Results

Figure 7 shows experimental results of an IHR18650A battery charging with constant current = 2.0A and constant voltage = 4.2V. The charging characteristics of the charger meet the specifications in [9]. In the experiment, some specified data are listed as following.

- V_{TP5} = 4.15V.
- Termination charging current = 40 mA.

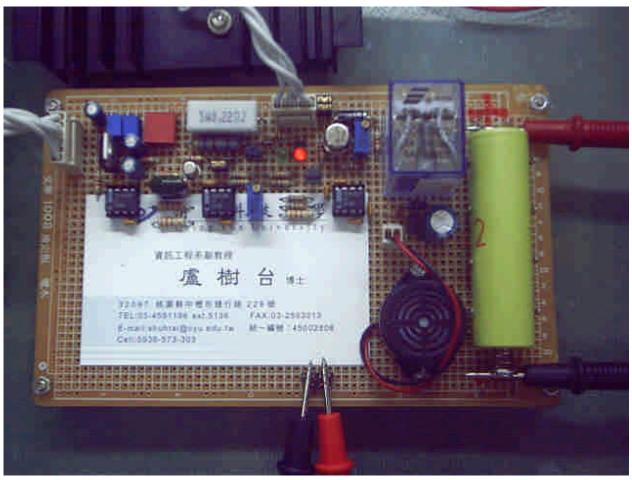

Figure 6: photo of the double protection charger.

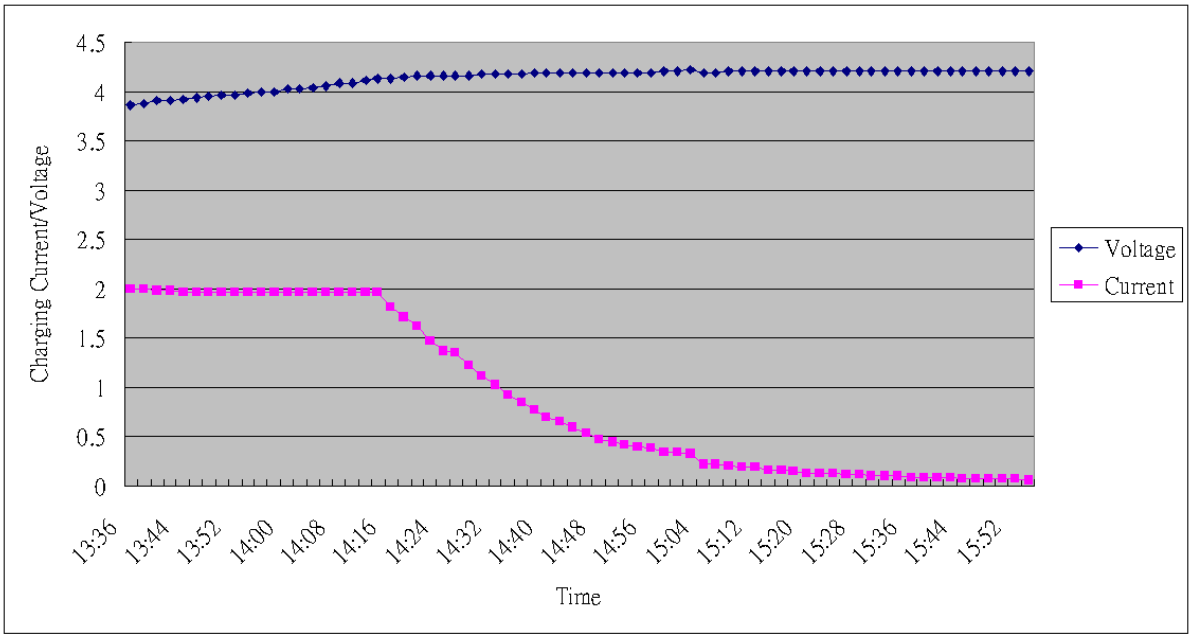

Figure 7: experimental results.

4. Conclusion

A double protection charger for single cell Li-Ion battery is introduced in this paper. The charger is capable of constant current and constant voltage charging capabilities. There is an over voltage protection mechanism in the constant current charging phase. An over current protection mechanism is also provided in the constant voltage charging phase. For describing the circuit clearly, the charger circuit is divided into three parts and depicted one by one. The steps of adjustment are also introduced. If adjustments are not correct, charging from constant current switches to constant voltage will not be smooth. Though the charger is designed for single cell, one can modify the circuit easily to make one's own charger.

Acknowledgments

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References

[1] Svyatoslav Paliy, *Power Management – Single Cell Li-Ion Battery Charger*, Cypress Application Note AN2267 (http://www.cypress.com/?rID=2657, visited on 2010/7/23).

[2] Meng He, *Designing Low-Cost Single/Multi-Cell Li-ION Battery Charges*, Cypress Document (http://www.cypress.com/?docID=21355, visited on 2010/7/23).

[3] Oleksandr Karpin, *Li-Ion/Li-Polymer Battery Charger with Fuel Gauge Function*, Cypress Application Note AN2294 (http://www.cypress.com/?rID=2698, visited on 2010/7/23).

[4] Oleksandr Karpin, *Power Management – Battery Charger with Cell-Balancing and Fuel Gauge*

Function Support, Cypress Application Note AN2344 (http://www.cypress.com/?rID=2736, visited on 2010/7/23).

[5] ADP2291: *Compact, 1.5 A Linear Charger for Single-Cell Li+ Battery*, Analog Devices Corp. (http://www.analog.com/en/power-management/battery-management/adp2291/products/product.html, visited on 2010/7/29).

[6] M.Chen, G.A.Rincon-Mora, *Accurate, Compact, and Power-Efficient Li-Ion Battery Charger Circuit*, IEEE Transactions on Circuits and Systems-II: Express Briefs, Vol. 53, No. 11 (2006), p. 1180-1184.

[7] J.Buxton, *Li-Ion battery charging requires accurate voltage sensing*, Anal. Devices Anal. Dialog., Vol. 31, No. 2, 1997.

[8] S.Dearborn, *Charging Li-ion batteries for maximum run times*, Power Electron. Technol. Mag., Apr. 2005, p. 40-49.

[9] IHR18650A Data Sheet, E-ONE Moli Energy Corp. (http://www.molicel.com/hq/product/DM_IHR18650A.pdf, visited on 2010/7/23).

[10] Sedra A.S., Smith K.C., *Microelectronic Circuits*, Oxford University Press, ISBN:0195116909, 1998.

[11] Frank R. Dungan, *Op Amps & Linear Integrated Circuits for Technicians*, 2nd Edition, Delmar Publishers Inc., ISBN:0827350864, 1991.

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