

SMART CHARGER / BATTERY FOR ELECTRIC VEHICLE

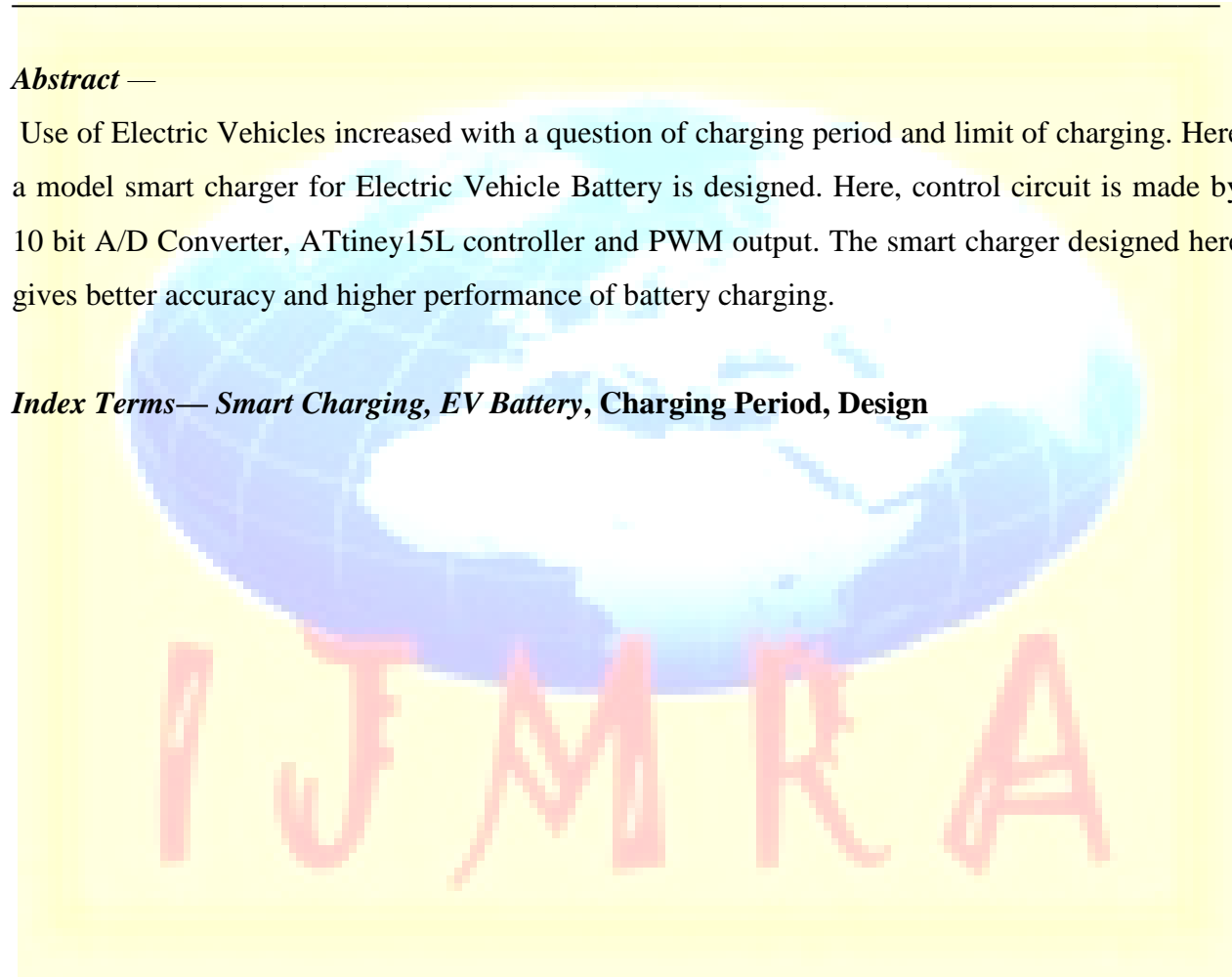
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Abstract —

Use of Electric Vehicles increased with a question of charging period and limit of charging. Here a model smart charger for Electric Vehicle Battery is designed. Here, control circuit is made by 10 bit A/D Converter, ATtiny15L controller and PWM output. The smart charger designed here gives better accuracy and higher performance of battery charging.

Index Terms— Smart Charging, EV Battery, Charging Period, Design



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I. INTRODUCTION

The traditional simple charger charges only specific battery that is manufactured by same methods and that with same capacity and voltage. The traditional charger if used for different capacity and voltage batteries manufactured using different technique, it results in improper charge, even a series of hazardous and problems are created. To solve these problems, Micro-Controller should be used in the charger. Micro-Controller applied in battery charger not only realizes intelligent control, but also is with the advantages of low cost, efficient charging, long life of battery and many more. The application of micro-controller makes that develop a smart charger that can be widely applied in different situations and with perfect function in a very short time. Moreover, real-time data logging and monitoring becomes easy [1]. The hardware structure of smart battery charger based on micro-controller is given in the paper, and intelligent control is achieved in software by modularization programming method.

II. STRUCTURE ANALYSIS OF SMART CHARGER

Smart Charger is suitable to charge nickel-chromium, nickel hydrogen and lithium-ion batteries, etc. It has problems that how to adapt to different types of batteries, constant current and voltage of output signal should be taken into account in the design. The structure is adopted as shown in Fig.1, when constant current and voltage of output signal comparison and output that Phase-Locked Loop (PLL) are involved and the function that output in step with input.

Phase-lock achieved by Micro-Controller in this paper. An 8-bit square wave is output within the allowed precision range. By amending the comparison value to change the duty cycle of square wave, and then use the square wave to modulate the output current and voltage, to output a constant value.

As the monopoly of EV manufacturers is not there, the customer may replace its original battery with any other battery. To adapt problems of different batteries, manual customer-selection is adopted in the paper. Customers select the type of battery that need to charge after plugged in and the battery is rightly placed, micro-controller initializes the charge parameters in accordance with the appropriate type [2]. Continued charge power-off is in the design thought of charger, it means that after choosing the type of battery, micro-controller records the choice immediately and clear the record at the end of normal charge, if the charge is abnormally interrupted by external power supply interruption, the record (SOC) remain stored in the memory unit, when you start charging

again, micro-controller finds this record, to make charging continue.

According to the current direction during charging, the charger circuit is divided into a few important modules as follows: power supply module (including the chip power, charging power and reference voltage), voltage and current modulation module, voltage measurement module, current measurement module, temperature measurement module, charge module, discharge module, battery selection module, display module and alarm module.

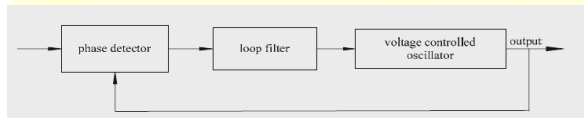


Figure 1. Phase-Locked Loop

III. Concept of Smart Battery

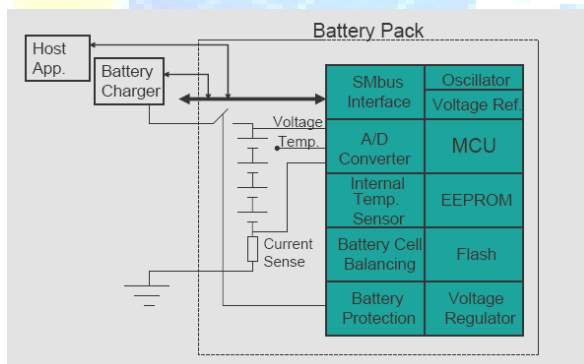


Figure 2. Smart Battery Pack

ATMEL has given the declaration of Smart Battery (SB) as shown in figure 2. It is a battery with a degree of logic. It performs various tasks logically,

- (a) **ID Recognition** : The application prompt the SB for an identification string and rejects the operation if the SB doesn't reply with the correct identifier.
- (b) **Reporting Battery Voltage**: SB measures its own battery voltage and report it to the application, which acts accordingly.
- (c) **Report Charge / Discharge Current**: SB monitors the charge / discharge current and reports to the main application.
- (d) **Intervene in Hazardous Situations**: SB itself reacts if a dangerous situation occurs. It

includes blocking the charge / discharge of the battery if either current is too high, and completely shut down the discharging of the battery if a certain level is achieved. [5]

III. HARDWARE CIRCUIT

According to the above analysis, the circuit of designed charger is shown in Figure 4.

Many components parameters are involved in the circuit design, which ensure the circuit work proper, more important is to ensure safe and quick charging.

According to the direction of charger current, a few parameters like reference voltage, key element modulation circuit, measurement range of voltage and current, the distance, measuring accuracy and time/count of Micro-Controller needs to be fixed [3].

The reference voltage of circuit is provided by TL431, A_{ref} set by proportional resistance. The ideal value can be obtained from equation (1).

$$A_{ref} = V_{ref} (1 + R_1/R_2) = 3.67 \quad (1)$$

Where 3.67 V is a middle value between high degree of accuracy (which is a little lower) and high signal-to-noise (which is a little higher), the proportional resistance of R_1 is 4.7 k Ω , R_2 is 10 k Ω .

The controller circuit shown in Figure 4 is designed and implemented with ATMEL Processor. The design components parameters of modulation circuit, F_{osc} of oscillator frequency, V_{sat} of saturation voltage, V_i of input voltage is 12 V, V_o of output voltage is 1.5 V, I_{omax} of maximum output current is 1.5 A, the period of 8-bit PWM in μs , on state time is also in μs of the half of the period when duty cycle is 50%.

Inductance can be calculated by (2) according to above parameters:

$$L = (V_i - V_{sat} - V_o) T_{on} / 2I_{omax} \quad (2)$$

Since all results are 10-bit, measuring accuracy should be calculated by the equation of (3).

$$3.67/1024 = 3.58 \text{ mV/step} \quad (3)$$

According to equation 1, the measurement voltage of ADC (Analog-Digital Converter) ranges from 0 to 3.67 V. From equation 4, The output voltage of voltage divider:

$$V_{\text{ADC}} = (R_1/R_1+R_2) (V_b) \quad (4)$$

Where V_{ADC} is the output voltage of voltage divider, also the analog input of Micro-Controller, V_b is the voltage across the battery. R_1 and R_2 are proportional resistances dividing the voltage across the battery, assume R_1 is 3.7 k Ω and R_2 is 2.2 k Ω , we got 9.8 V of V_b from equation 4.

From the circuit, the charging current is generated by acting reference voltage across 0.25 Ω sensing resistance, voltage on the resistance need to be amplified “K” times, to improve the conversion accuracy, and A/D conversion. Assume V_{ibat} as analog input voltage of A/D converter, I_r as the current across 0.25 Ω of Sensitive resistance R_m , R_1 and R_2 are proportional resistance dividing the voltage across 0.25 Ω of resistance, in order to unify the proportion, recognize $R_1 = 3.7 \text{ k } \Omega$, $R_2 = 2.2 \text{ K}\Omega$. Analog input voltage is given by (5).

$$V_{\text{ibat}} = K (R_2/R_2+R_1)*I_r*R_m \quad (5)$$

The maximum charge current is measured and calculated – 1.9 mA, approximately.

The workflow of charger from the overall function, as per flow chart shown in Figure 3.

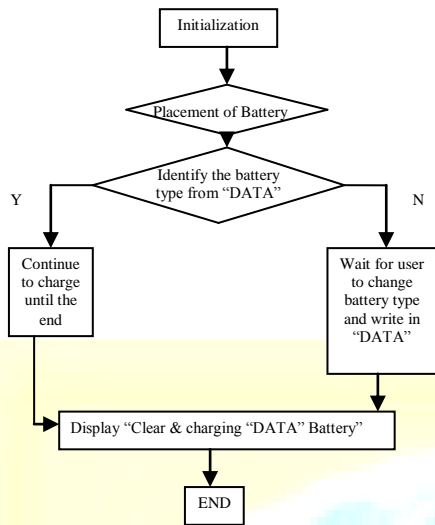


Figure 3. Flow chart

From the workflow diagram, we need to check the placement of battery and identify the battery type before charging.

Measure the voltage across the battery through A/D convert and check battery if properly placed or not, normally it would not be 0 or negative. If the measurement results less than or equal to 0, it means there is fault, thus implement this cycle continuously and give the tips.

To identify the battery type, from the hardware circuit we know that port PB0, PB1 and PB2 of ATMEL processor are connected with the switch respectively and the switch connected with analog ground. If the switch corresponding to port PB0 is pressed, the pin of port PB0 must be at low level, thus 1111110 is read in, automatic pulsing 1, the result is 11111111, the initial value of R16 is 11111111, result of the two values subtracted from each other is 0, one type is chosen. If the switch corresponding to port PB1 is pressed, the pin of port PB1 must be at low level, thus 1111101 is read in, twice automatic pulsing 1, the result is 11111111, the result is 0 to both, achieved the identification of battery type, and begin to charge according to selected type. [4].

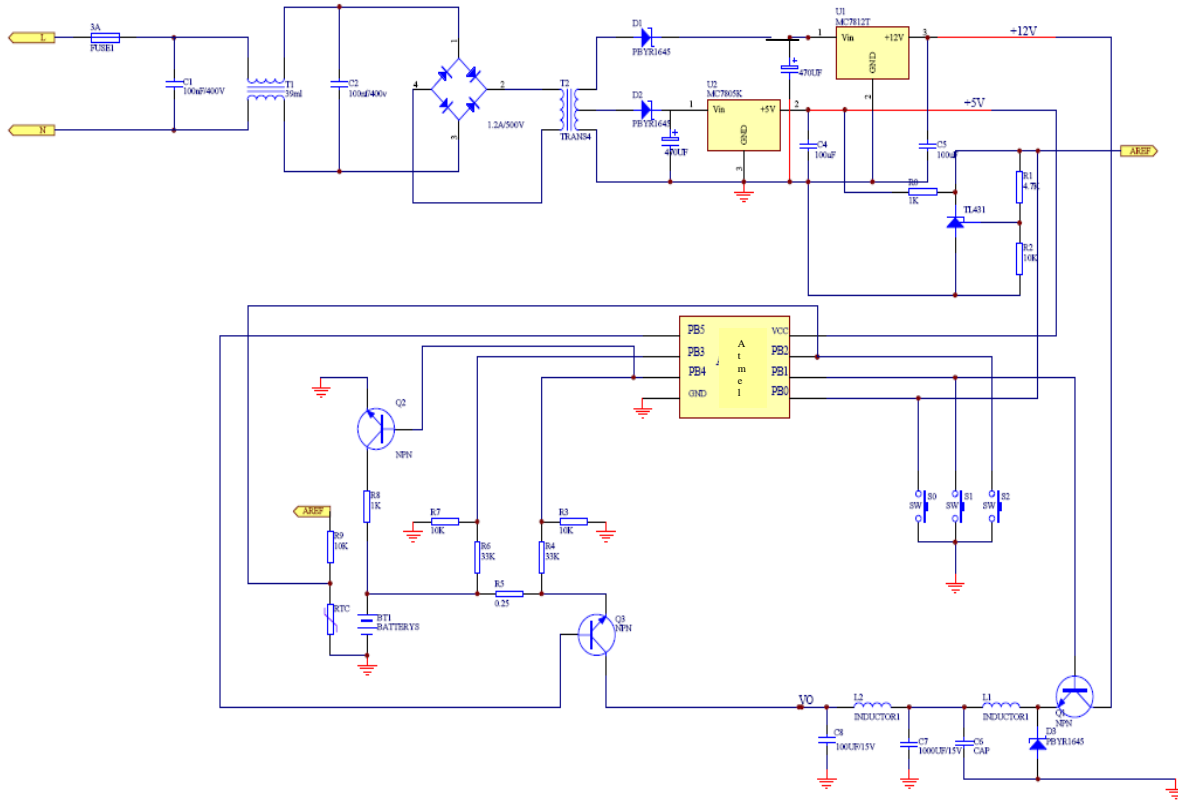


Fig. 4 Charger and Controller Circuit.

IV. OPTIONAL INTERACTIVE CHARGING STRATEGY

The interactive charging strategy is realized by sophisticated algorithm. Its function is to optimize charging schedule in Electric Vehicles to minimize cost, enhance grid stability. This charging strategy includes six charging modes as follows:

1) Charging immediately: Charging instantaneously when the electrical vehicles plugged in. The mode is the most common charging way. The EV battery is a high power electrical load while it's charging, and such large number of charging of EV increase the difficulty of peak shaving Grid.

2) Timed Charging: Start charging at the given moment that can be set by the owners. This method takes the effect of EV charging at the Grid peaking into consideration and realizes stagger peak charging by controlling the start charging time.

3) Price-Based Charging: Optimal-cost start/stop time for charging based on time-of-use, critical peak pricing, and real-time pricing. The mode makes the EV start charging flexibly at a lower price, and brings the economic benefits to the owners. The time-of-use pricing from electricity power companies is needed to realize this mode.

4) Charging response to DSM (Demand Side Management) : A real-time technology that detects grid stress and adjusts charging time. It can control the charging time dynamically according to the grid load.

The realization of the method needs two steps: first of all, monitoring the real-time AC frequency and AC voltage, and getting the value of grid frequency and voltage. The next step is to adjust charging time according to the standard. The EV keeps charging except that the frequency is not lower than 49.8Hz and the voltage is not lower than ninety-three percent of 220V.

5) Battery-responded charging: Charging is controlled by the battery information. The charging state is adjusted according to the charging information that is coming from BMS (Battery Management System).

6) V1G (Vehicles Plug-in with Logic/Control Regulated Charge): Charging status is controlled by commands from the grid. The two-way wireless communication is necessary to realize this mode. V1G mode can optimize charging schedule and improve power grid efficiency. [5]

The interactive charging strategy combines the six methods, adjusts control of electric vehicle charging operation automatically and ensures the charging orderly electric car.

V. CONCLUSIONS

The smart charger which adopts micro-controller as the core of control circuit, can choose the battery types, adjust control parameters and diagnose fault itself according to the charging process, unattended operation during charging, and prolong the battery life. The design process (peripheral circuit) is simple, with the advantages of small, light, programmable charging sessions, also with reliable performance and fine applicability. The technology occupies a certain market share if promoted in the market, thus achieve pretty good social and economic benefits. The Smart Battery Pack will make the Battery itself intelligent using ATMEL processors.

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