White Paper

Intelligent Battery Charger Design for Power Tools using RL78/G12 MCU

May 2019

Introduction

Power tools can be classified as traditional (AC powered) and rechargeable (cordless) depending on their different power sources. Amongst them, cordless power tools were introduced relatively late, with nickel-cadmium batteries initially dominating the market however, due to their obvious environmental and performance shortcomings, they were destined to be replaced. Lithium batteries are considered the best alternative to nickel-cadmium batteries. In addition to being more environmentally friendly, power tools using lithium batteries are lighter, and will gradually decrease in price with the increased use of lithium battery materials. The application of lithium batteries in power tools will become increasingly prevalent. To this end, it is particularly important to develop a power tool (lithium battery) charger that is stable, safe, reliable, and economical.

In consideration of battery charging safety and costs, this application includes a switched-mode power supply lithium battery charger based on RL78/G12 single-chip PWM control, which effectively overcomes general charger issues such as overcharge, undercharge, and inefficiency. The MCU is used to intelligently manage the entire lithium battery charging process. Charge current, voltage, and temperature information are collected in real time during the charging process, and the charge current is dynamically adjusted. The system provides desired results through a variety of functions such as smart alerts, real-time monitoring, and charge protection. The solution is designed to meet the needs of various forms of lithium battery charging. The RL78/G12 integrated flash memory also makes it easy to debug and upgrade software.

Lithium Battery Charge Characteristics

Lithium battery charging requires control of voltage and limiting current. This is done in three steps:

Step 1: When voltage is < 3V, the charging process begins at a very low frequency (0.05C);

Step 2: When the voltage is 3V - 4.2V, the charging process proceeds at a constant rate of 0.2C - 1.0C;

Step 3: When the voltage is > 4.2V, the charging process will retain its current voltage until charging is complete. During this process, current will drop while voltage remains the same.

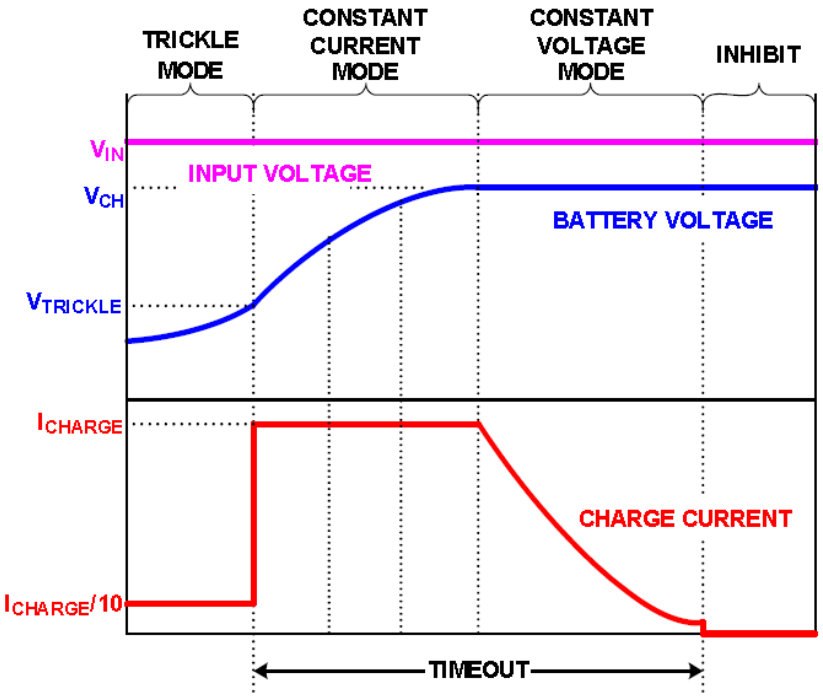

Figure 1. A typical charging curve for a lithium battery.

Note: The charge and discharge currents are generally referred to as C. C is a value corresponding to battery capacity. Battery capacity is generally expressed in Ah and mAh, such as an M8 battery capacity of 1200mAh, with the corresponding C being 1200mA. 0.2C is equal to 240mA.

For power tools, we have 3 lithium batteries (e.g. the 12V/3Ah series).

If the battery voltage is lower than the trickle charge threshold, the charger enters trickle charge mode, at which point the charge current is 10% (0.05C) of the constant charge current. If the battery voltage gets higher than the trickle charge threshold, the charger enters constant current charging mode. When battery voltage continues to rise close to the constant charging voltage, the charger enters constant voltage charge mode and the current gradually decreases. When the charge current is reduced to 10% of the constant charge current, the charge is completed. After charging is completed, if the input power is disconnected and then re-connected, a new charging cycle will begin. If the battery voltage drops to the recharge threshold, then a new charge cycle will also automatically begin.

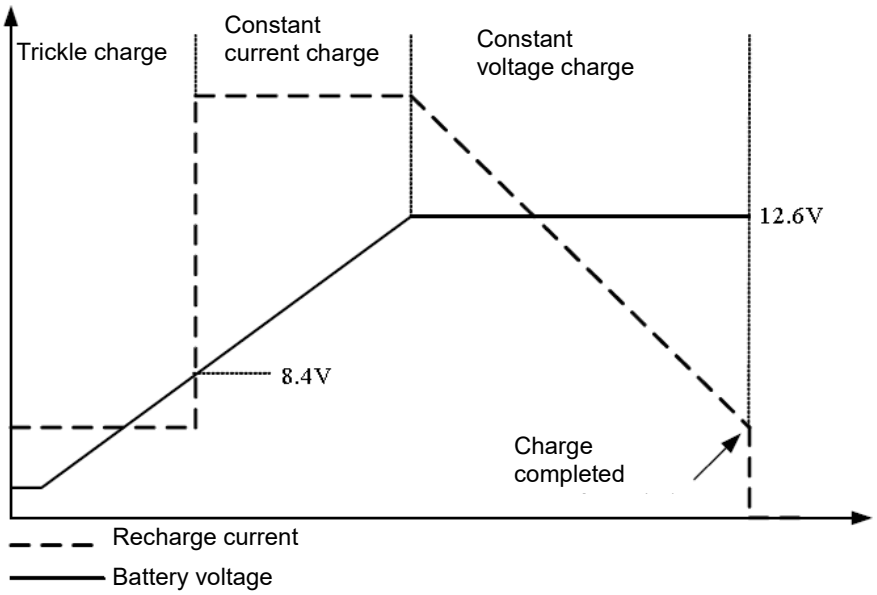

Figure 2. Charge current and voltage.

In addition, the lithium battery protection board acts as charge and discharge protection for the lithium battery pack. When fully charged, it can ensure that the voltage difference between the individual cells is less than the set value (generally ±20mV), which ensures equalization between each cell of the battery pack. At the same time, it detects over-voltage, under-voltage, over-current, short circuiting, and over-temperature in each of the battery pack's cells to protect and extend battery life. Undervoltage protection prevents any single cell from being damaged due to over-discharge.

RL78/G12 Features

The RL78/G12 microcontroller series is a high performance balanced product with the lowest current consumption (CPU: 63µA/MHz, standby (STOP): 230nA) and 32.4 DMIPS (24 MHz). It contains an internal oscillator, data flash, A/D converter, and several other notable attributes. Its built-in safety function (detecting invalid hardware operations) complies with the household appliance safety standard (IEC/UL 60730) and uses a compact 20 to 30-pin package.

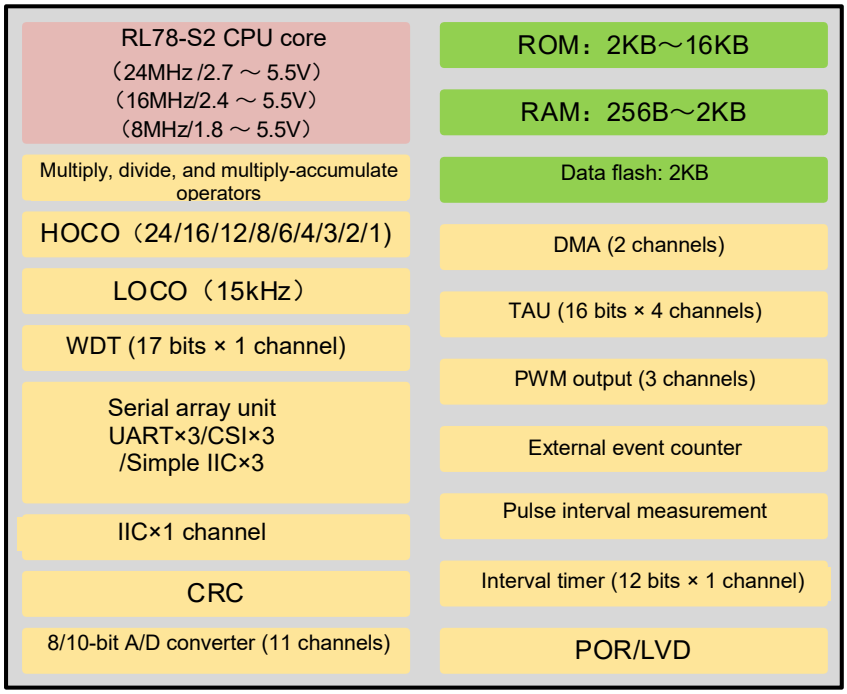

Figure 3. The outline of the RL78/G12 microcontroller.

System Design

The RL78/G12 gathers current, voltage and temperature information in real time during the charge process and dynamically adjusts the current. It also has many functions such as smart alerts, automatic temperature adjustment, real-time monitoring and charge protection.

System Requirements:

- Lithium battery pack voltage specifications: Three-cell lithium battery (10.8V ~ 12.6V/3Ah).
- Battery overtemperature protection (recoverable): 60°C
- Combined battery overcurrent protection (10ms): 30 ~ 35A (according to motor design of the customer's power tool)
- Charge mode: Constant current and pressure
- Single-section overcharge protection voltage: 4.25V
- Single-section overdischarge protection voltage: 2.70V

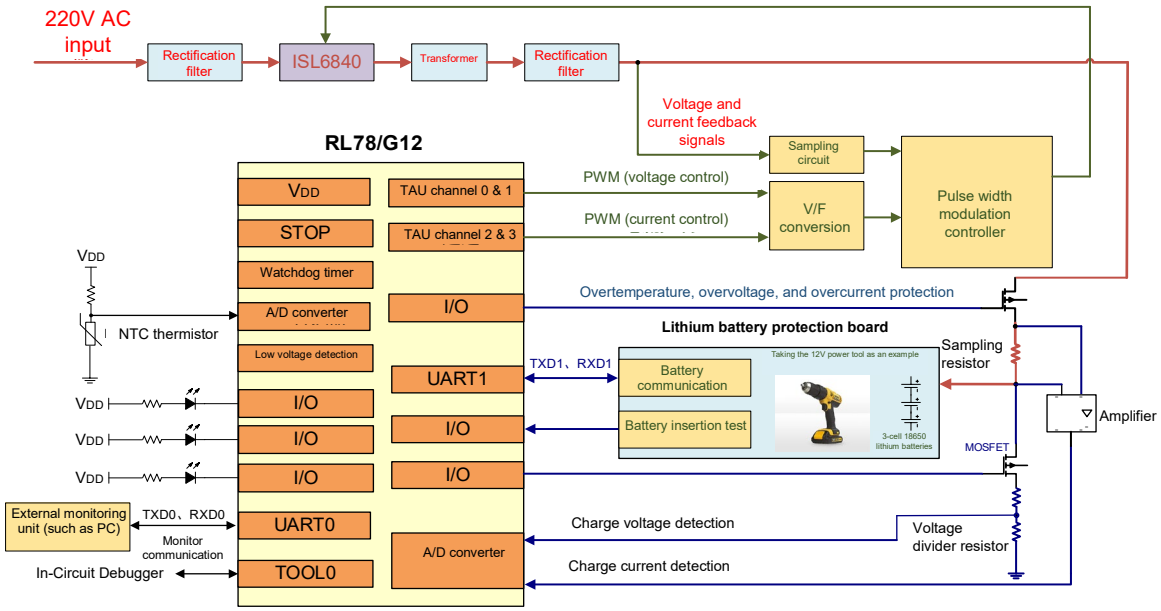

Figure 4. System block diagram

Peripheral function	Purpose
Timer array unit channel 0 and channel 1	Output PWM for current control
Timer array unit channel 2 and channel 3	Output PWM for voltage control
A/D converter	Detection of charge current, charge voltage and temperature
Serial array unit channel 0 and channel 1	UART0： Communication within lithium batteries
Serial array unit channel 2 and channel 3	UART1： Perform monitor communication with an external monitoring unit such as a PC
I/O port	LED indication control (3 ports) Check if a battery is inserted Control charge current/voltage cutoff by MOSFET (occurrence of overtemperature, overcurrent, and overvoltage) Charge voltage control detection

Table 1. Peripheral functions used by RL78/G12.

Pin name	Input / Output	Summary
P16/TO01	Output	Output PWM control charge current
P31/TO03	Output	Output PWM control charge voltage
P20/ANI0	Output	Charge current detection
P21/ANI1	Output	Charge voltage detection
P22/ANI2	Output	Temperature detection
P12/TxD0, P11/RxD0	Input / Output	Communication within lithium batteries
P00/TxD1, P01/RxD1	Input / Output	Perform monitor communication with an external monitoring unit such as a PC
P13, P14, P15	Output	LED indication control (3 ports)
P30	Output	Check if a battery is inserted
P51	Output	Control charging current/voltage through MOSFET (abnormal processing)
P10	Output	Charge voltage control detection
P40/TOOL0	Input / Output	On-chip debugging
RESET	Output	Hardware reset

Table 2. Used pin.

ISL6840 Features

The ISL6840 is a low-power and pulse-width modulated (PWM) current mode controller with adjustable frequency designed for a variety of power conversion applications, including boost, flyback, and isolated output configurations. Peak current mode control effectively handles power transients and provides overcurrent protection.

This advanced BiCMOS design is pin-compatible with the industry standard 384x series of controllers and offers significantly improved performance. Its features include a low operating current, a 60µA startup current, adjustable operating frequency to 2MHz, and high peak current drive capability with 20ns rise/fall times.

Operations Summary

The ISL6840 controls voltage and current with the RL78/G12 microcontroller. When a battery is detected, it checks the voltage of the battery to be charged. If the voltage is < 9V, trickle charging is performed and the charge current is set to 1/10 of the set current, usually around 0.05C. The standard charging process will commence once voltage rises to 9V. The standard charging process is as follows: Constant current charge is performed with the set current. When the battery voltage rises to 12.6V, it is changed to constant voltage charge with a voltage of 12.6V. The charge current then gradually decreases and drops to 1/10 of the set charge current which signals that charging has been completed. Charging stops when battery removal is detected. In addition, the charging process is suspended if overtemperature, overvoltage, or overcurrent is detected.

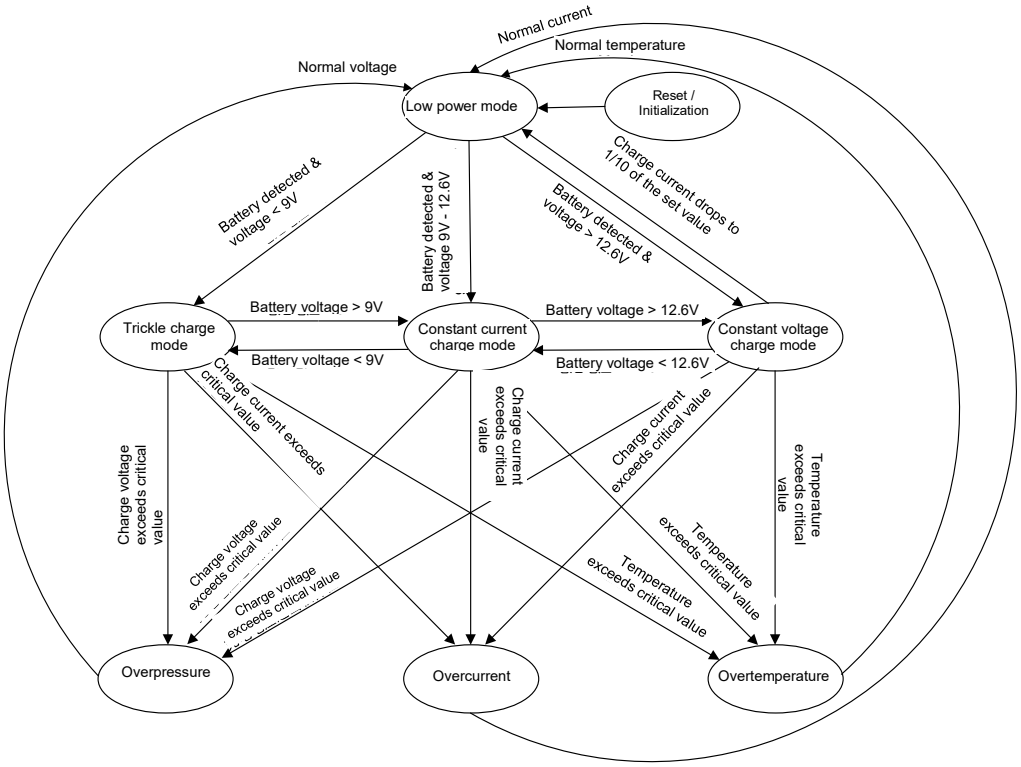

Figure 5. The state transition.

Conclusion

RL78/G12's excellent price-performance ratio has enhanced the intelligence and applicability of the product, and reduced development time and cost. In addition, leveraging on existing system functionality, the RL78/G12's on-chip resources and external components can be fully utilized. The lithium battery charger can be easily upgraded to a smart power management system through its UART communication functionality.