APPLICATION NOTE

A COST EFFECTIVE ULTRA FAST Ni-Cd BATTERY CHARGER

by L. Wuidart, J.M. Ravon

ABSTRACT

Cordless and portable battery powered equipment are proliferating thanks to the increasing capacity of rechargeable Ni-Cd batteries. A useful feature in applications where the battery is rapidly discharged, such as power tools, is ultra fast charging in under an hour. The solution described in this paper is an efficient 100kHz converter charging a Ni-Cd battery in half an hour. The battery charge is monitored by a low cost microcontroller (ST6210) enabling battery voltage identification, temperature monitoring and charge control.

1. INTRODUCTION

Today, many types of cordless and portable equipment are supplied by a Ni-Cd battery. Ultra fast charging in under one hour is a very attractive service for users. Such a short charging time requires a charge control circuit that is more complex than for standard chargers.

The power converter presented in this paper is able to fully charge a common Ni-Cd battery pack of 7.2V/1.2Ah in 30 minutes. It has a corresponding output power capability of roughly 35W and operates as a current source providing a constant 3.5A current to the battery while charging.

The battery charger is controlled by a low cost microcontroller, the ST6210. This control is compatible with the charge of Ni-Cd battery packs from 2 to 6 cells (2.4V to 7.2V). The microcontroller IC is supplied from an auxiliary winding of the power transformer.

2. THE POWER CONVERTER

2.1 Circuit description

The asymmetrical half-bridge is considered today as one of the most attractive topologies for the primary side of a 220V ac off-line Switch Mode Power Supply, SMPS, see figure 1.

Contrary to single switch structures, the leakage inductance of the power transformer is much less critical. The two demagnetisation diodes, BYT01/400 provide a simple non-dissipative way to systematically clamp the voltage across the switches to the input DC voltage, V_{in}. This allows the use of standard 500V Power MOSFETs such as the isolated ISOWATT220 packaged IRF820FI.

The power converter is totally controlled from the primary side with a standard PWM control IC, the UC3845, regulating in current mode. A single optocoupler controls how the SMPS functions, either in battery charge mode or in burst mode standby current charge. The charger is controlled from the secondary side of the SMPS by the microcontroller via this optocoupler.

The switching frequency has been fixed at 100kHz, in order to keep the magnetic part to a reasonable manufacturing cost level. The power transformer and the output inductor can be integrated on a single ferrite core [1][2]. Well optimised, this integrated magnetic technique can bring significant shrinking of the power converter size.

2.2 "Transformerless" driver

In an asymmetrical half bridge, the high side Power MOSFET requires a floating level shifter circuit in order to be driven properly. Usually, this level shifter function is realised with a pulse transformer.

In this application, the level shifter is simply an auxiliary winding of the power transformer plus a few discrete small signal devices (see figure 1).

The high side Power MOSFET is turned on as soon as the transformer primary inductance is completely demagnetised.

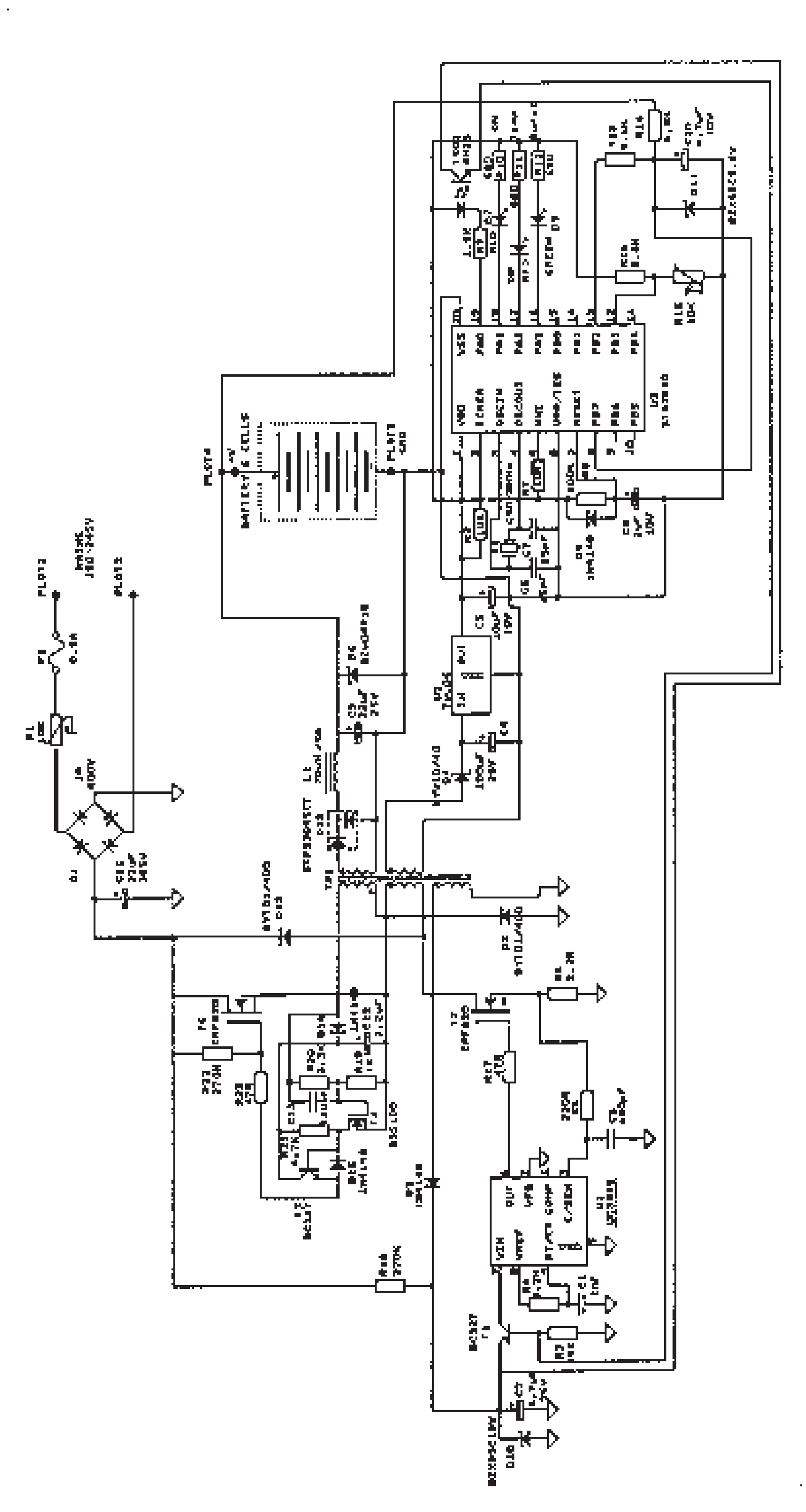
At turn off, the high side Power MOSFET is synchronised with the low side device by the voltage polarity inversion across the auxiliary winding.

2.3 Current mode forward

A Ni-Cd battery requires charging with a constant current. A current mode control is the recommended way to realise such a charge characteristic. In a Forward converter, the primary peak current gives an image of the current flowing in the output choke.

An output current ripple of 25% instead of the typical

Figure 1. Ultra fast Ni-Cd battery charger schematic



10% encountered in conventional forward SMPSs, is quite acceptable for correct charge of Ni-Cd batteries. A larger output current ripple also gives a steeper primary current ramp (see figure 2).

This way, the current spike due to rectifier recovery, typically occurring on the leading edge of the waveform, does not stop the pulse prematurely.

The current mode control can be easily realised with a sufficient noise immunity from the primary side by using a simple current sense resistor (see figure 1).

Constant DC output current is regulated by limiting the primary peak current to a fixed value.

This type of current mode control provides a natural pulse-by-pulse short-circuit protection. Moreover, this current mode control supplies the battery with a constant current of 3.5A whatever the input line voltage variations (from 245V DC to 375V DC).

A low cost PWM current mode IC such as UC3845 is well suited to regulate the complete power converter efficiently.

3. BATTERY CHARGE CONTROL

3.1 Ultra fast charge control method

For ultra fast charge systems - under half an hour - the majority of battery manufacturers recommend the negative delta voltage method (-ΔV) otherwise called negative slope cut-off circuit [3] [4].

When a Ni-Cd battery reaches full charge, its voltage decreases slightly (see figure 3).

The negative delta voltage method (-ΔV) consists of stopping the charge as soon as the voltage characteristic slope becomes negative. This

Figure 2. Using a steeper primary current ramp to cancel effect of diode recovery current spike

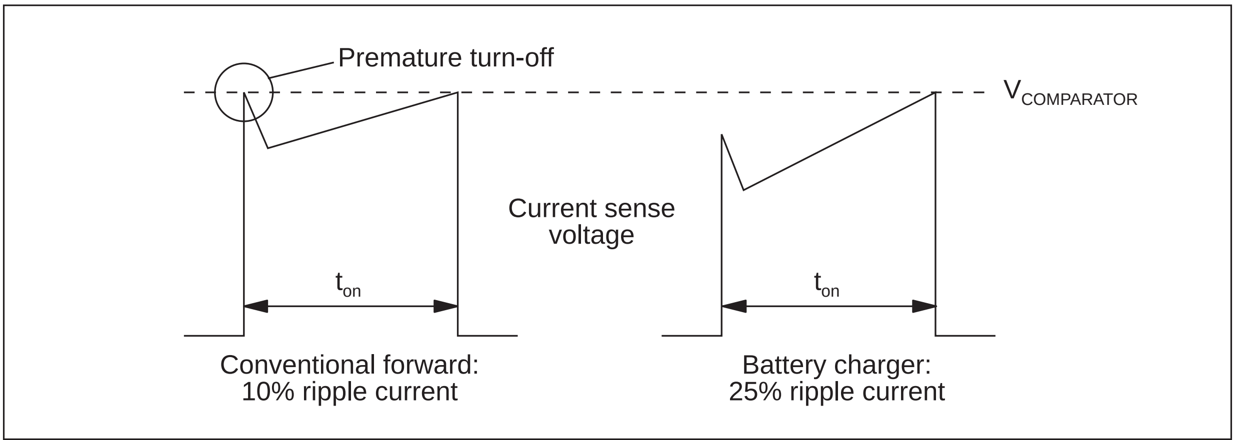
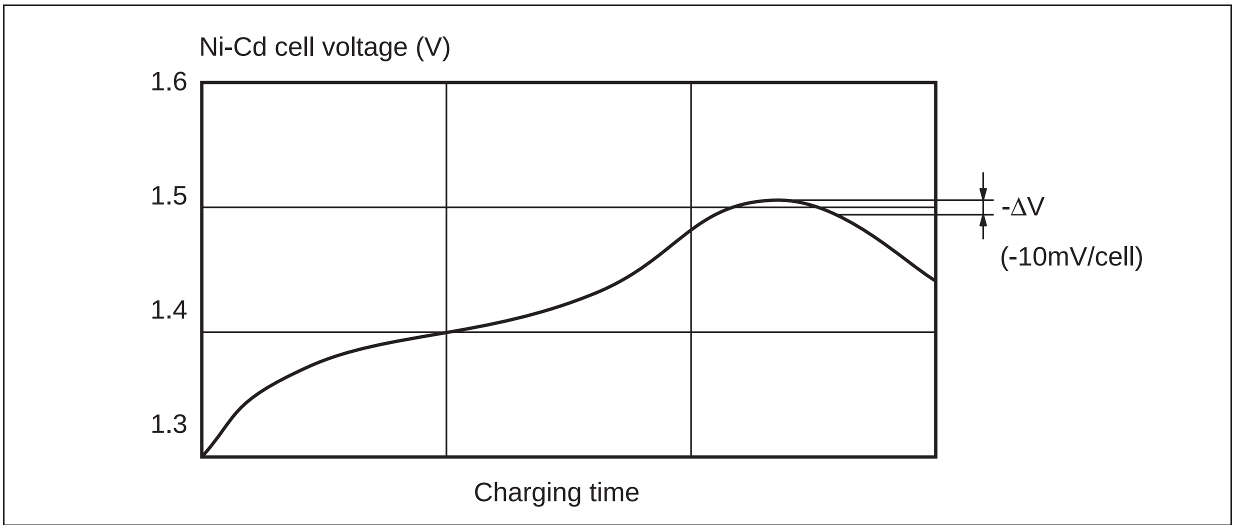


Figure 3. Charging characteristics of a single Ni-Cd cell



technique allows the very rapid charge of a Ni-Cd battery, near to its full capacity. Moreover, no compensation for the age of the battery is required because only relative voltages are measured.

In this application, the battery voltage is sensed by a ST6210 micro-controller housed in 20 pin dual in line package. The integrated analogue to digital (A/D) converter of this microcontroller is able to detect a typical voltage drop of -10mV/cell. The overall system is reset after each new mains connection. The ST6210 can automatically identify the battery voltage from 2 to 6 cells (2.4V to 7.2V).

3.2 Monitoring functions

The battery charge is totally monitored by an 8-bit HCMOS micro-controller (in PDIP or PSO 20 pin package), the ST6210 [5]. By using this microcontroller, additional monitoring functions can be easily added to the ultra fast charge control program.

3.2.1 Stand-by current charge: Burst mode

Once the negative voltage drop has been detected by the microcontroller, the ultra fast charging is stopped and the power converter supplies the battery with a stand-by current of around 100mA. This stand-by charge is provided by burst mode current control.

The converter is successively turned on and off at 50Hz with a small duty cycle of 0.03. The microcontroller manages this burst mode from the secondary side via an optocoupler, to the auxiliary supply of the PWM control IC (UC 3845).

Thanks to the low current consumption of this HCMOS micro-controller, a small 100µF reservoir capacitor (see figure 1) is sufficient to keep the ST6210 properly powered during the off periods of the burst mode.

3.2.2 Battery temperature protection

A Temperature protection is simply realised by using an NTC resistor placed on the battery pack. This NTC is directly connected to another input of the A/D converter of the ST6210. When the battery temperature reaches 40°C during an Ultra Fast charge phase, the micro-controller turns the converter into burst mode to protect the battery.

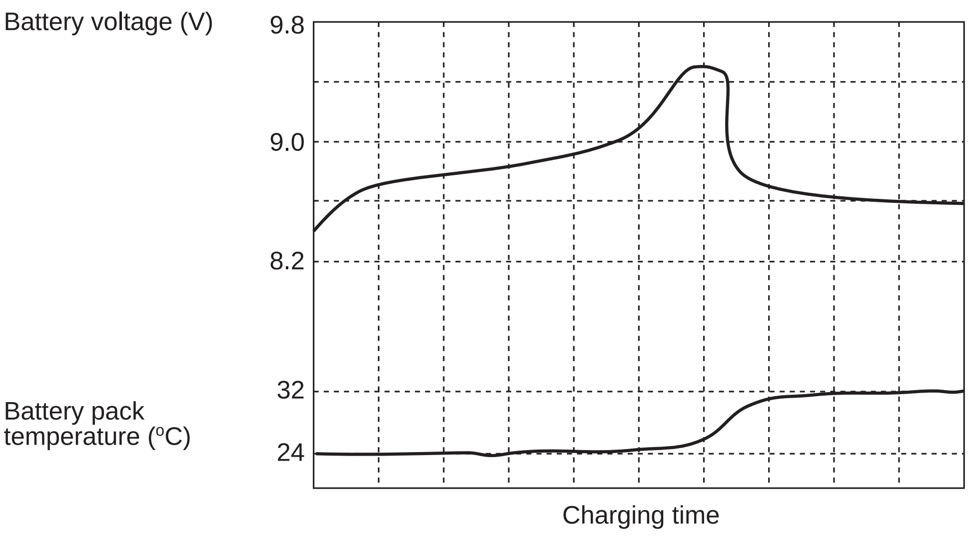
3.2.3 Battery presence

The micro-controller detects whether the battery pack is connected or not. When the battery is not connected, the microcontroller turns the converter into burst mode. The resulting stand-by current (100mA) flows into the output Transil diode (BZW04P15, see figure 1).

4. PRACTICAL RESULTS

The battery voltage and pack temperature versus charging time are shown in figure 4. These recordings have been made with a popular 1.2Ah/7.2V Ni-Cd battery pack for cordless drills. The temperature of the battery pack does not exceed 32°C for an ambient temperature of 23.6°C.

Figure 4. Battery voltage and pack temperature versus charging time



5. CONCLUSION

Charging a Ni-Cd battery in half an hour can save battery packs and time. It can expand the use of battery powered equipment, especially for professional applications. Such an ultra fast charge has to be carefully monitored to maximise the life time of the battery and the charge safety. Moreover, this improvement should be achieved with compact equipment including a minimum of components.

The forward half-bridge circuit for this battery charger has been realised without any pulse transformer.

The paper shows that an ultra fast charge can be totally monitored by a single 20 pin HCMOS microcontroller, the ST6210. The actual software includes a stand-by charge, temperature protection, battery presence detection and battery voltage rating identification.

Other specific requirements can be implemented inside the existing microcontroller program.

REFERENCES

[1] Core selection for Integrated-magnetic power converters.
G.E. Bloom, Powertechnics Magazine - June 1990.

[2] Ultra fast Ni-Cd battery charger with integrated magnetic.
L. Wuidart, PClM - June 1991 - Nürnberg

[3] Fast-charge batteries
A. Watson-Swager, EDN, Dec. 7,1989.

[4] Focus on rechargeable batteries: economic portable power.
M. Grossman, Electronic Design, March 3 1988.

[5] Ultra fast Ni-Cd battery charging using ST6210 micro-controller.
L. Wuidart, P. Richter, ST6 APPLICATION MANUAL, AN433.

Littlediode supplies new, hard to find or obsolete electronic components and semiconductors all over the world.

With over two million different components listed you are sure to find the part you need.

Feel free to visit us today at our online store:

LittleDiode.com

Looking forward to providing you with the best possible service.