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Power Management of Switching Mode Power Supplies

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Abstract

Yutaka Electric MFG. Co., Ltd. develops, manufactures and sells devices for switching power supply (AC-DC, DC-DC) and uninterruptible power supply (UPS). As mobile facilities and the UPS became widely used, demands are increasing for DC-DC converters, battery chargers and switching power supplies. The power supply circuits described herein are designed to work with the techniques such as variable output voltage based on signals from CPU and control of remaining battery power using a bus for an entire system, which techniques are becoming standards for these circuits.

1. Introduction

Recently, the application of power management to electronic facilities widely used in offices and homes has expanded remarkably. Power management is a power saving measure by meticulously controlling power consumption in the whole system. This paper describes some recent topics of switching power supply devices such as DC-DC converters, battery chargers, etc. in relation to the power management, and describes the activities of Yutaka Electric Manufacturing Co., Ltd. (hereinafter YEC) in the field of technology.

2. DC-DC Converters for Notebook PCs

A power providing system of a notebook size personal computer (notebook PC) receives a DC input of about 20 V from an AC adapter fed by a common commercial power source (AC 100 V) and another DC input of 7 to 15 V from an internal backup battery pack, as shown in **Fig. 1**. The system converts the input power in the above voltages by a DC-DC converter and outputs DC power in a CPU core voltage and 12 V, 5 V, 3.3 V, etc. required by different internal circuits.

The power supply circuits of a notebook PC has to perform the power conversion within a limited space, which also means a very difficult heat dissipation condition. A high power conversion efficiency not to waste power for anything useless is required of the power supply circuits, since the longest possible operating time is required, especially when the PC is powered by a battery pack. Presently, a method called the synchronous rectifying method is generally used to meet the requirement. The synchronous rectifying method is a method where a flywheel diode used in a rectification section of a conventional step-down switching regulator system is substituted with a low on-resistance value switching element (MOS-FET) having equivalent performance, as seen in **Fig. 2**. Use of the synchro-

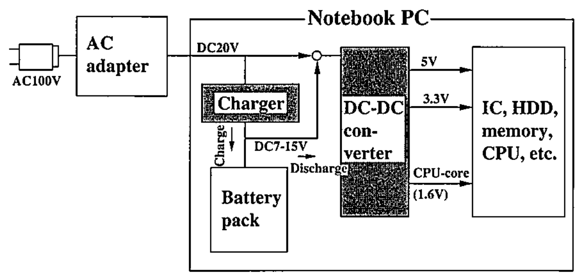

Fig. 1 Power supply system of notebook PC

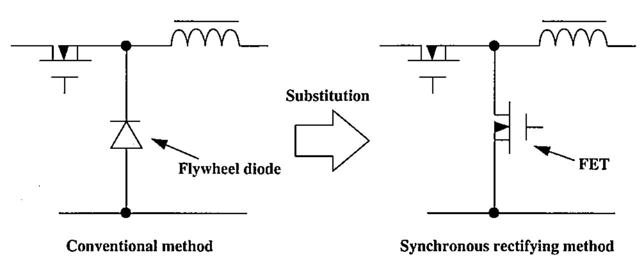

Fig. 2 Synchronous rectifying method

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nous rectifying method has raised the conversion efficiency from 85% or so of conventional methods to 90% or higher. The synchronous rectifying method efficiency is higher at lower output voltages and higher output currents.

The CPU core voltage has been decreasing year by year: it was generally 3.3 V a few years ago, but energy saving efforts have brought it down to the present 1.3 V. On the other hand, power consumption of CPU has increased owing to enhanced performance of CPU cores. In this background, reduction of power conversion loss has become a significant requirement and, therefore, the synchronous rectifying method is now an indispensable technology in the DC-DC converters for notebook PCs.

In addition, for making the battery life longer, a system has been worked out recently to minimize power consumption by using different CPU clock frequencies during the AC adapter-powered operation and the battery-powered operation and making the supply voltage for the CPU core as low as possible. This requires the DC-DC converter to change its output voltage in response to a demand signal from a power saving function of the main CPU. Latest specifications require that voltage can be changed at an interval of 50 mV in the range from 1.3 to 2.0 V in response to a 4-bit coded signal as shown in **Table 1**. Further, it will be required in the near future to set voltage at an interval of 25 mV in a voltage range expanded to below 1.3 V against a 5-bit coded signal. A method generally used to meet the above requirement is the one shown in **Fig. 3**, wherein, for feeding back the output voltage, a digital-analogue converter (D/A converter) is used as a reference voltage source and the output voltage is set exactly at a value required by the main system.

YEC have manufactured and marketed module-structured DC-DC converters for use as the power supply units of notebook PCs. The units are designed to include, in modules, a power supply section for the CPU core and a battery charger to suit the system configuration, in addition to 5 and 3.3 V outputs catering for large power consumption. Examples of the DC-DC converters for notebook PCs YEC developed are shown in **Photos 1 and 2**. The one in Photo 1 is a two-output type module-structured power supply unit for 5 and 3.3 V. Use of the synchronous rectifying method provides output currents up to 5 - 6 A at both the voltages in high efficiency. Since the

Table 1 Codes for output voltages for CPU core

Input code	Output voltage (median) (V)
0000	2.00
0001	1.95
0010	1.90
0011	1.85
0100	1.80
0101	1.75
0110	1.70
0111	1.65
1000	1.60
1001	1.55
1010	1.50
1011	1.45
1100	1.40
1101	1.35
1110	1.30
1111	Shutdown

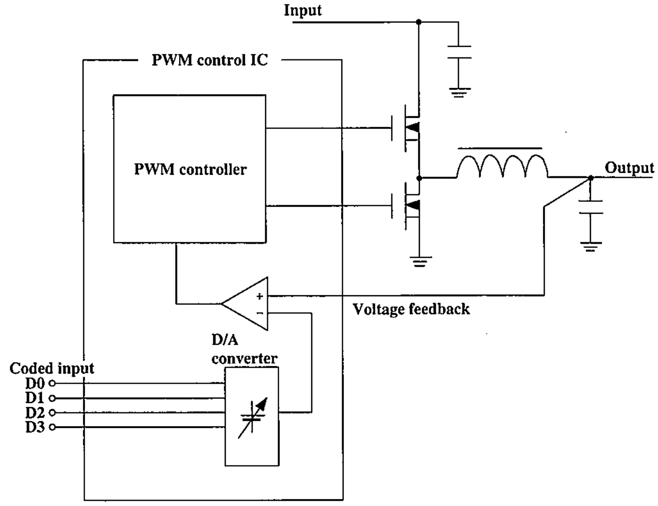

Fig. 3 Outline of control IC for CPU power supply

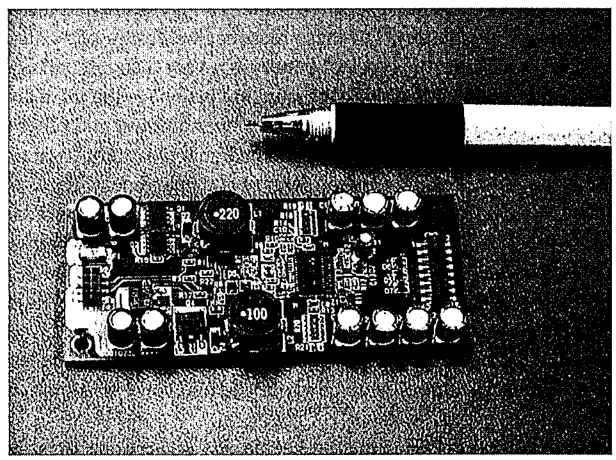

Photo 1 Example 1 of DC-DC converter for notebook PC

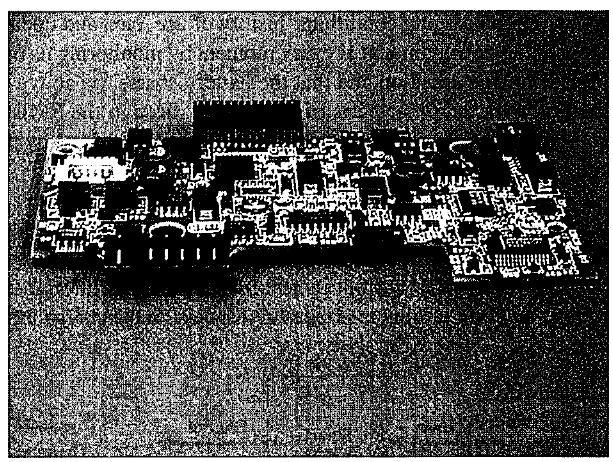

Photo 2 Example 2 of DC-DC converter for notebook PC

height of this converter is rather large, the components rising to 8 mm above its printed circuit board, it is used for notebook PCs having comparatively thick enclosures.

The one in Photo 2 was developed for B5 size (182 mm x 257 mm) thin notebook PCs. It is structured to output three voltages including a CPU core voltage, besides the one for a battery charger. Demands for this type of DC-DC converters especially for thin notebook PCs are rapidly increasing lately. A total thickness of 6 mm inclusive of the printed circuit board has been realized through revision of capacitors, choke coils, connectors and other components and their rated capacities.

3. Smart Battery Charger

Nickel-Hydride (Ni-MH) batteries or Lithium Ion batteries (including Lithium Ion polymer batteries) are used as internal rechargeable batteries of notebook PCs, and a rechargeable battery requires a charger to refill it with power as shown in Fig. 1.

Since the single-cell voltage is different in these two types of rechargeable batteries, the different methods of charging have to be used for the two. Besides, attained voltage at full charge is different in different varieties of the Lithium Ion battery. Circuits of a charger, therefore, have to be designed in accordance with the characteristics of the battery used in the PC. Even when the battery type and its characteristics are given, however, charging patterns may be significantly different depending on environment temperature and the history of use of the battery. For these reasons, the design of a charger to charge more than one types of battery is a very difficult endeavor.

A recent trend under the above situation is to have the main computer system monitor exact remaining power amount and other information about the condition of the rechargeable battery from time to time and utilize the information for power management. The Smart Battery System Forum (SBS) has been promoting work to standardize this function. SBS is a standard proposed by Intel and Duracell in 1994 for a battery management system that uses a System Management Bus (SMBus). The standard was last revised in 1998 into Version 1.1 and, on that occasion, standards of Packet Error Codes (PEC) and Smart Battery System Manager (SBSM) for simultaneous charge/discharge control were newly added and some terminologies were changed.

Many notebook PCs in the market already incorporate smart batteries completely or partially conforming to the standard. The SMS is characterized in that a battery keeps the information of its own type, optimum charging conditions, history of use, etc., and updates the remaining power amount at every moment by monitoring its own charge/discharge situation and that the battery shares the above information with the other parts of the system through the SMBus. The problems of the charger described above can be solved by this standard.

A charger conforming to the SBS (hereinafter smart charger) receives via the SMBus the information of optimum charging voltage and current the smart battery keeps, and charges the battery by supplying the voltage and current in accordance with the information (See **Fig. 4**). The charging is stopped also based on the charge information from the smart battery. The voltage control action of the charger is performed in the same manner as the variable output voltage control of the DC-DC converter for the CPU core described before.

The smart charger is advantageous in that it can charge a rechargeable battery of whatever variety as far as it is a smart battery, because the charger responds to instructions of the battery about optimum charging voltage and current, the battery pack absorbing the difference of characteristics within itself. Thus, a computer system is given a wider choice of rechargeable battery types and the smart charger is expected to accommodate new types of rechargeable battery that may appear in the future without modification.

The SBS allows active data access not only to the system proper (host) but also to a smart charger and a smart battery. Therefore, the charger can be provided with additional functions as required such as: multiple protections in the full charge detection; direct display of remaining power amount, deterioration of battery capacity by aging and other information; and priority control in charging more than one batteries based on their remaining power amounts.

4. Examples of Smart Battery Charger

A smart charger YEC developed in compliance with the Smart Battery Standard is shown in **Photo 3** and **Fig.5**. The charger can select any charging voltage within a range from about 10 to 20 V at a 40-mV step in accordance with requests from battery packs. This is a level 3 smart charger equipped with a CPU, and it actively accesses smart batteries for data to obtain not only the full charge information but also the remaining power amount and other information for multiple overcharge protection. This smart charger is provided with a selector function to choose one of two batteries given in

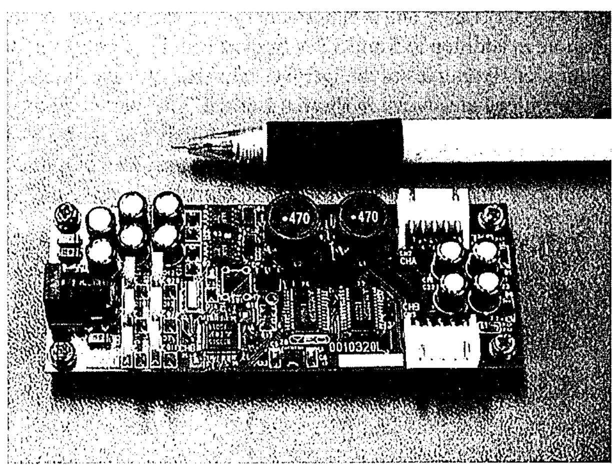

Photo 3 2-channel smart charger

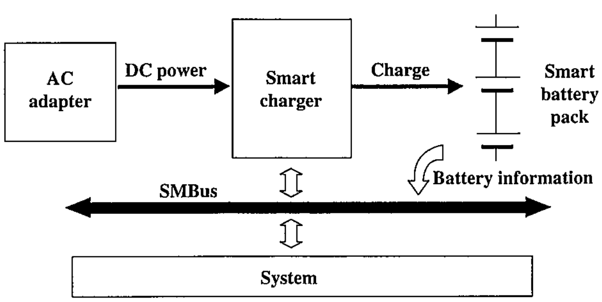

Fig. 4 Outline of smart charger

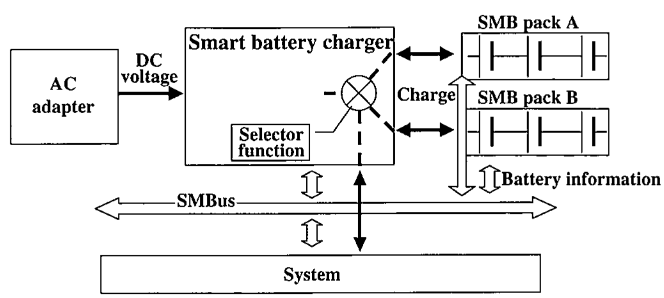

Fig. 5 Outline of YEC's smart charger

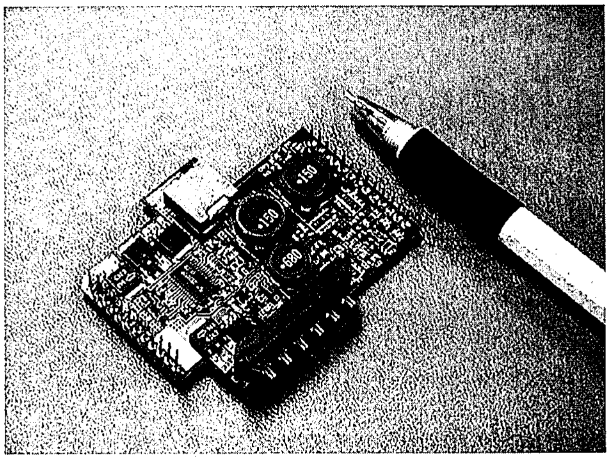

Photo 4 Smart charger integrating DC-DC converter

a PC depending on the situation, in addition to the basic specifications of the smart charger shown in Fig. 4. This enables the charger to charge two smart batteries simultaneously or sequentially, as the situation requires.

The charger is also equipped with functions to display the remaining power amounts of the two batteries using LEDs and to react to error correction codes of the SMBus by incorporating the PEC. Another advantage of the charger is that it can easily accommodate minor changes and addition of new functions in accordance with the system configuration thanks to the CPU provided in it. The smart charger underwent a series of connection tests (Plug Festa) with various batteries of different manufacturers at the SBS Forum in Tokyo in 1999, and satisfactory charging performance was confirmed with every kind of smart battery tested therein.

Besides the above, YEC is designing other smart chargers using special ICs (level 2) having specific functions according to specifications. As an example, a power supply module combining a smart charger with a DC-DC converter for notebook PCs is shown in **Photo 4**. Although the SBS was originally developed mainly for the application to notebook PCs, the technology to utilize the information held by a rechargeable battery will be applied also to other kinds of facilities powered by batteries. YEC intends to cultivate yet wider fields of application of the technology.

5. Switching Power Supply

Some switching AC-DC conversion power supplies with buck-up function for general use are equipped with rechargeable batteries such as Ni-MH batteries. In normal conditions, they are powered by the AC 100 V commercial power source and supply the power for their own battery charge circuits and for facilities inside themselves, and the batteries will act as back-up to protect the whole system against power interruption at a failure of the commercial power supply.

It is applicable mainly to the systems requiring an uninterrupted power supply function such as automatic teller machines (ATMs), measuring instruments (data loggers), etc.

By using SBS technology, YEC developed new power supplies with buck-up function. **Photo 5** shows a switching power supply unit capable of backup in DC and **Photo 6** another unit capable of backup in AC.

These new power supplies have a battery pack consisting of 10 units of serially-connected 1.2 V, 2.9 Ah nickel hydride batteries built in, and accommodate the information of charge control, capacity monitoring, temperature measurement, etc. of the battery pack via the SMBus. Furthermore, power management of the whole system includes the battery pack, charge circuits and other facilities are controlled under CPU using the information.

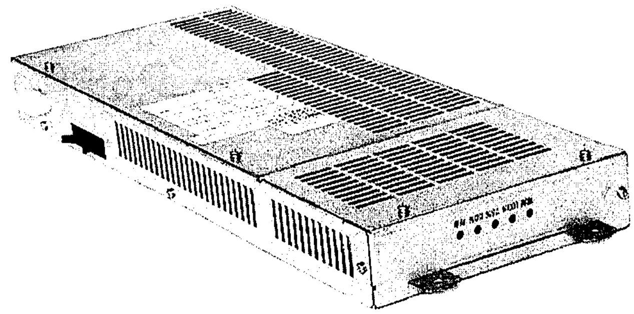

Photo 5 DC backup type switching power supply unit

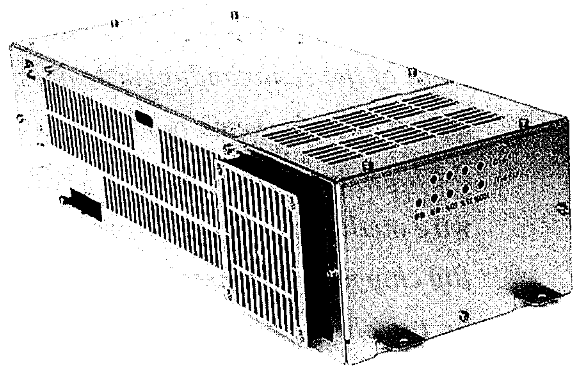

Photo 6 AC backup type switching power supply unit

Former power supply can supply a DC 150 V, 1 A output for 8 to 10 min, and for usage of an AC power, latter power supply can supply an AC 100 V, 1 A output for several minutes using an internal DC-AC inverter.

6. Closing

Besides the on/off control of power output in response to requests from the main computer, new control functions will be required for power management. Such new control functions include change of output voltage, load connections, etc. in accordance with the situation changing from time to time. The demands for these functions will grow in the devices and functions such as DC-DC converters for notebook PCs and other mobile facilities, the chargers for the rechargeable batteries, and the uninterrupted power supply function for the switching power supply units. YEC is determined to actively address these requirements.

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