Development of High Performance Magnet Power Supply

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Abstract

It is always necessary to high performance power supplies for the magnet system in the accelerator, especially when the number of power supplies are large. We have developed the compact power supply using switching technology instead of SCR phase control. We adopt the pulse width modulation (PWM) method with a half bridge DC/DC converter. In this way, we can make a compact system with light weight and small volume. Actual system we developed 1.2 kW, 35V/35A bipolar DC power supply into the current precision of +/- 0.02%. It is possible to mount 10 units in conventional 19″ rack. The built-in controller has an RS422 protocol to drive 10 unit by one serial port up to 1.2 km distance. If we adopt RS485 protocol, one serial port can control 32 power supplies. In the paper, we report the design and performance of the prototype power supply.

1 INTRODUCTION

Recently, there are increasing demand on advanced DC power sources for various applications including communication devices, control system, measurement devices in basic science field. Typical requirements for these power supplies are usually high-accuracy, high-efficient, small-sized, light-weighted, high-power capacity and multi-function. Especially in the accelerator physical field, high-accuracy a large number of DC current sources with various capabilities for the magnet system are used. Normally they are adopting the SCR phase control technique, so power supplies are also bulky and heavy because of input transformers, inductors and output filters. We have developed the DC power supply improving such problems. Also, this new power supply integrates useful remote control capabilities. The main power conversion technology for newly developed DC power supply is a half-bridge, push-pull duty-ratio control DC-DC converter. This power supply has a capability of 0 - +/- 35ADC output with +/- 0.02% precision of output current and has built-in remote controller. This power supply is able to communicate various serial communication (RS232C/RS422/RS485) with a remote host computer. This paper describes the electric characteristics, remote controls and test results of the prototype DC power supply.

2 Half Bridge, Push-Pull Duty Ratio control DC/DC Converter

Fig. 1 is the main concept of power conversion. Under the steady-state condition, capacitors Ci1 and Ci2 are charged the half of rectified DC input voltage.

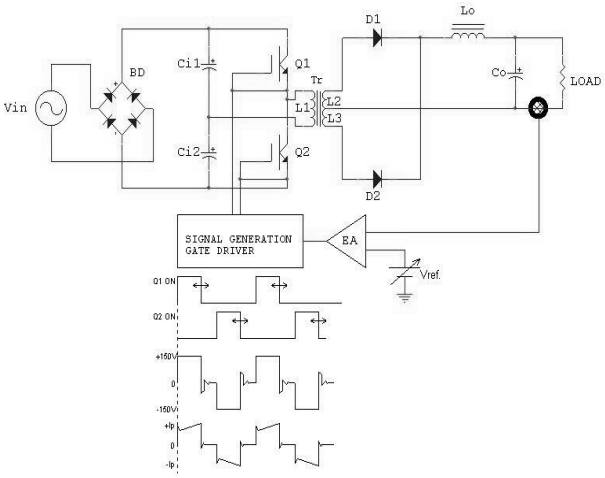


Figure 1. Main Circuit Concept

When Q1 turns on (Q2 turns off), a half of the input voltage will be applied to the primary winding L1. A reflected load current and the magnetization current will now build up at L1 and Q1. After a time interval defined by the control circuit, Q1 will be turned off. Now, as a result of the primary and leakage inductance, the current will continue to flow onto of the primary winding. After a period defined by the control circuit, Q2 will be turned on (Q1 turned off), making the direction of the primary winding negative. Load and magnetizing current will now flow at Q2 and into the primary winding opposite direction so that the former process will repeat. When Q1 is on state (Q2 is off state), the start of all secondary windings (L2, L3) will go positive, and diode D1 will conduct. The secondary current will flow in Lo, load and capacitor Co. When Q2 is on state (Q1 is off state), the voltage on all transformer winding will fall toward zero, but current will continue to flow in secondary diode as a result of the forcing action of Lo. The diode D1 and D2 will share the inductor current nearly equally, acting as flywheel diodes and clamping the secondary voltage zero. Neglecting losses, the output voltage and current are given by the following equations.

$$* \text{ Vout} = (\text{Vcc} \times D)/n \quad (1)$$

$$* \text{ Iout} = \text{Vout}/R_L \quad (2)$$

Vcc : primary voltage
N : turn ratio(Np/Ns)

Np : primary turns
Ns : secondary turns
ton : on time
toff : off time
D : duty ratio(ton/(ton+toff))
R_L : load impedance

3 The Main Circuit of Prototype MPS

Fig. 2 is show the main circuit of the prototype MPS using principle of Fig. 1 circuit. Rectified input voltage is 310V, IGBTs (2MBI50L) are used as switching devices, switching transformer made using litz wire (type5, 600 wire/5.766 MILSQ, 100 kHz, DC 20A) and Mn-Zn core (BM-2n, μiac = 2400, Bms = 5100 Gauss, Brms = 1500 Gauss, cms(a/m) = 0.16, ten = 0.1δ/μiac(x 0.1), 500 ρ(Ω-m)). The primary inductance (L1) is 2.91 mH, the secondary inductances(L2, L3) of switching transformer are 0.36 mH, and as rectifier diode of secondary circuit, FRD100BA60s are used. When turning on, inrush current is limited by RCC circuit. Output current is sensed by DCCT (LA-50-S). Output polarity change charged is by SCR circuit in output part.

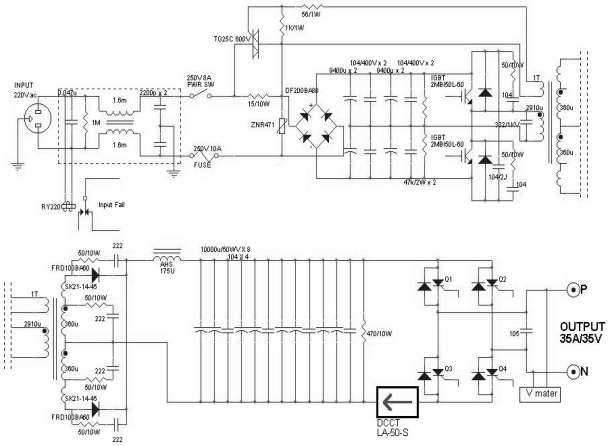
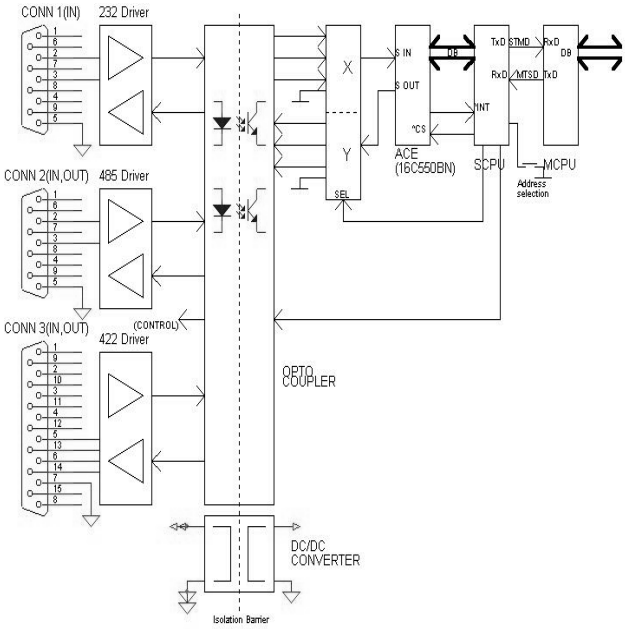


Figure 2. Main Circuit of Developed Prototype MPS

4 REMOTE CONTROL

A remote controller of the MPS is built in power supply. This remote controller can control various serial communication (RS232C/RS422/RS485) with remote host computer and it is convenient to use this MPS in large scale facility. SCPU of controller takes charge of the serial I/O link and MCPU takes charge of all functions except the serial I/O link. For The isolation of communication data photo couplers are used. The connection for communication with host computer is followings. RS232C can be used for only one to one



connection by one driver method. By half-duplex method, RS485 can be used for one to thirty two connection at the maximum. By full-duplex method, RS422 can be used for one to ten connection at the maximum. In case of RS485 or RS422, address of each MPS is inputted in MCPU by key pad of front panel.

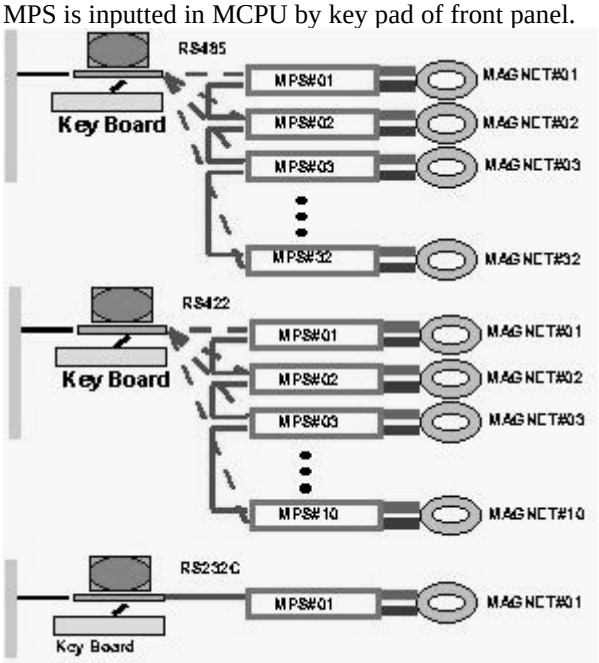
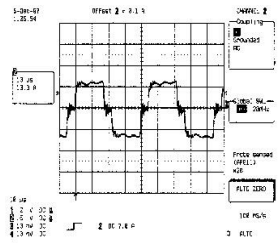


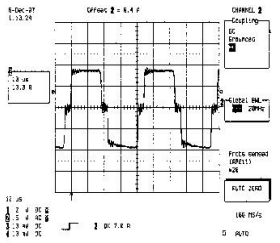
Figure 3. Block Diagram of Remote Controller Serial Communication

Figure 4. Computer Communication Concept for Control & Monitor

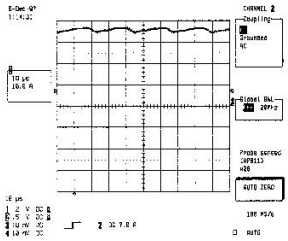
5 Experimental Results



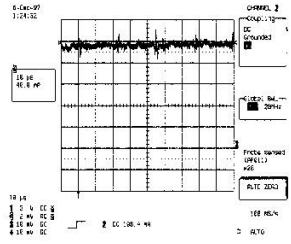
Trans. 1st Current



Trans. 2nd Current



Inductor Lo Current



Output Current Ripple

Figure 5. Experiment Waveforms(at 35A output)

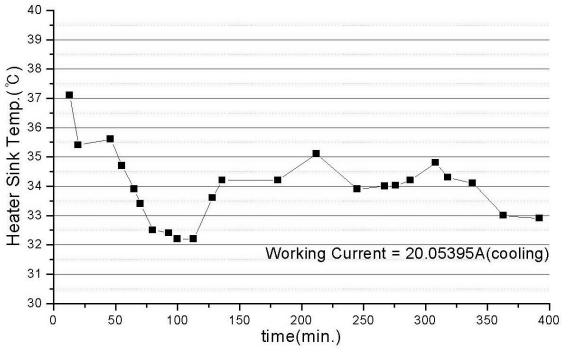


Figure 6. Heating Temperature of Prototype MPS

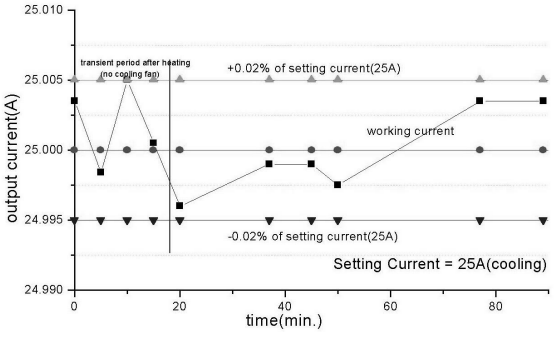


Figure 7. Output Current Stability of Prototype MPS

6 The Specifications of Developed Prototype MPS

Input	AC 220V, 60 Hz
Output	Output Power: Max. 1.2 kW Constant Current Control 1. local manual/key 2. remote computer Output Current Range: 0 – 35A, 0 – 35V Bipolar Accuracy: +/- 0.02 % (of output current)
Load	Magnet, $Z_L = 1\Omega$
Efficiency	80%(at $R_L = 1\Omega$, Iout = 35A)
Protection	Over Current (>35A) Over Voltage (>35V) PS Over Temp. (>85°C) Load Over Temp (settable) External (Normal Close)
Size	Volume: 485(19″) x 133.4(3U) x 450 Weight: 14.98 kg
Remote Controller	Built-in MPS 8data bit, 1 stop bit, no parity Speed: 1200 BPS – 1 MBPS(select) Connection with host computer 1. RS232C: 1:1 connection 2. RS422: 1:1 or 1:10 connection 3. RS485: 1:1 or 1:32 connection

Table 1. The Specifications of Prototype MPS

Figure 8. The Developed Prototype MPS

7 SUMMARY

We developed high performance magnet power supply using half bridge, push-pull duty-ratio control DC/DC converter technologies. This power supply is small-sized, light-weighted and has various functions including remote control so that it is vary useful in large scale science facility such as accelerator machine.

8 ACKNOWLEDGMENTS

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9 REFERENCES

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