Control and Timing of the 250kA Pulsed Magnetic Horn

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Abstract

This paper reports on an interface used in a pulsed magnetic-horn system which generates a 250 kA 3 msec magnetic field to enhance the neutrino beam, synchronized to the 12-GeV KEK proton synchrotron. The interface is imbedded in the system, and offers the capability to communicate with an upper-level computer through the GPIB and LAN. The functions of the interface are not only to operate the system, but also to control and check the timing, and to return messages to help the supporting staff.

Before completion of the whole physics experimental arrangement of the neutrino beam line and its control system, this magnetic-horn system is capable of operating effectively to check its function, and to test the reliability of the horn magnet with a PC in local-area in a short time. This interface design has been shown to save time in the construction of a large physics experiment arrangement.

1 Introduction

In a large physics-experiment facility, there are many components in a wide area. Some problems are raised due to the scale, which is larger than a small one. One of the problems is how to control the many components at minimum cost. The next is how to maintain those components for long-term physics experiments. The first is a problem of choice. However, when we obtain an adequate answer from two, the choice is more limited, especially in the recent engineering environment using a PC or WS and LAN. Those tools are a great help with both control and maintenance work by reporting on the conditions instantly of many components over a wide area.

Presently, at KEK a neutrino beam line has been constructed. One of the components, a 250-kA magnetic horn and a pulsed power supply is under testing. Also an interface for controlling the pulsed power supply has been designed and is now under testing. The interface must have the remote-control function of a normal magnet power supply, and additionally to have the function of timing control of the charging unit and the trigger gate of the high-voltage thyristor switch, and monitoring its synchronizing condition with the fast-extracted beam from the 12-GeV proton synchrotron(PS). As an answer to the above mentioned demands, a microprocessor and some circuit boards have been selected and embedded in the pulsed power supply: the STD-bus cards and an 8-bit microprocessor.

2 Hardware for control

The main parts of the hardware for controlling the pulsed power supply, and its functions are as follows:

Z80: ROM-based 8-bit microprocessor performs the function of a pulsed power supply;
TMS-9914: Provides a GPIB connection;
CTC: Counter/timer circuits to control and measure the time of the operation of the pulse power supply;
PIO: A programmable input/output circuit to control the trigger gate of the high-voltage thyristor switch;
DAC1: DAC701KH controls the charging voltage of the capacitor;
DAC2: AD7546KN (dac with external reference) modulates the output voltage of DAC1 to generate a ramp voltage;
Some other IO boards: Operate the pulse power supply and monitor the status;
LAN adapter: LAN/HP-IB gateway connects with GPIB and LAN.

3 Operation of the pulse power supply

Fig. 1 shows the pulse power supply. It consists of a charging unit, a capacitor bank, a thyristor switch, and a pulse transformer. The charging-unit rating is 8.5kV dc at the maximum voltage. The capacitor bank has 12 capacitors of 500 micro-farad, and totally 6 milli-farad. The thyristor switch is a stack of three thyristors of TOSHIBA-SF3000GXs. The I^2t is 18E6(A^2s). The turn ratio of the pulse transformer is 10 (20:2). The dimensions are 1530mm wide, 1070mm high, 1430mm deep. The weight is about 11 tons. The operation of the charging unit is performed by a microprocessor-based circuit with a 2-second repeated cycle, which starts to charge the capacitors synchronously with the PS. Fig.2 shows the capacitor voltage and time. A charging process is started after a triggering signal (TS) is received. The charging unit has a variable-value control. The reference voltage of the capacitors is generated from a ramp voltage by a circuit of serial connections with DAC1 and DAC2. The output voltage of DAC2 is (DAC1)x(DAC2 set value/ 2048). The value is counted up by a Z80 every 994 micro-second periodic interrupt of a timer of the CTC. Since the full count-up value is 2048, the DAC2 outputs the same voltage as that received from the DAC1. DAC1 constantly outputs a voltage, the value of which is received from the GPIB controller. In Fig. 3, the period of DAC1 to be set a value is when the charging unit is cutoff. When the capacitors have charged up, the charging unit is cut off from the capacitors, and the gate of the thyristor switch is opened by a signal from the PS to trigger the thyristor switch. When the thyristor is triggered and turned on, the circuit of the capacitors and the reactance of the load make a simple oscillation circuit. A 25kA pulse current as a single half sine wave is obtained. The negative part is

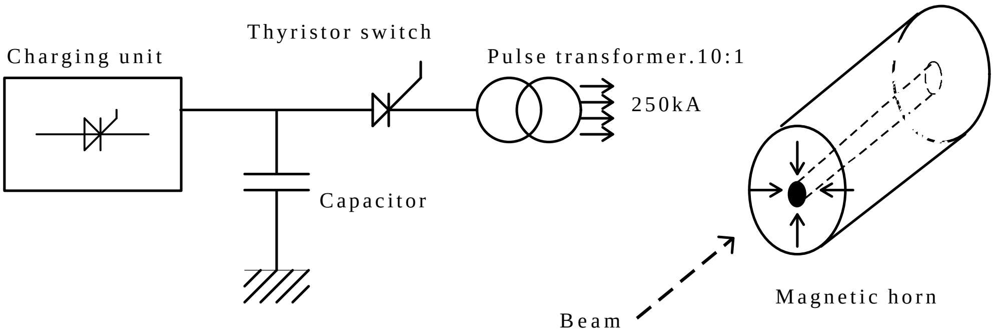
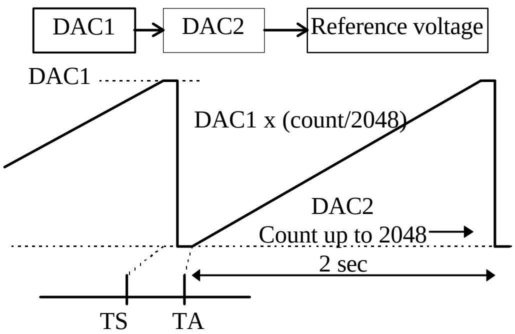


Fig. 1 Pulse power supply and magnetic horn

dumped in the resistors through diodes. Then, the gate of the switch is closed, and the charging unit starts again to charge the capacitors.



TS: Trigger of charging capacitors
TA: Trigger of 250kA pulse current

Fig. 2 Capacitor voltage and time

4 Timing

The timing signal used to trigger the thyristor switch comes from the PS, and is supplied to a delay circuit, as shown in Fig.4. The triggering time is controlled by the delay circuit to meet the time of fast-extracted beam pass through the Horn. The circuit consists of three timer/counter circuits (CTC0, CTC1, CTC2). Those are operated with a 4-MHz clock, and are set to below the characteristics.

CTC0: programmable timer of 4 to 996 microseconds; operation is started by an external signal;

CTC1: 1 millisecond timer. Start of operation is triggered by the CTC0;

CTC2: programmable counter. Preset value is 1 to 255.

The circuit has totally a delay range of 4 microseconds to 255.996 milliseconds with a 4 microsecond programming resolution. The delay value is controlled through the GPIB and LAN communication path.

5 Monitoring of timing

Monitoring of the timing is performed by the processor to read out a time counter CTC3, shown in Fig. 4. The time counter is started when a signal triggers the thyristor switch. The timer counts up time with a 4-microsecond step resolution. When a beam signal is received from a beam monitor (CT), an interrupt occurs for the microprocessor to read the time counter, and check the time value. If the value is out of a range, a SRQ signal is sent out through the GPIB and LAN to the controller.

6 Control of the pulsed power supply

The total operation, including the timing control of the pulsed power supply, is performed by the same processor as the timing control. The commands for operation are received through the GPIB and LAN. For example, when the "V 5000" command is received, the processor does as follows:

1. check status;
2. turns on the main contactor of the charging unit;
3. sets DAC1 to output 5000 volts;
4. enables an interrupt of the charging unit to start.

Synchronization of the charging and the generation of a pulsed current are controlled and checked by the processor. When an error or a problem is detected, a message is sent out for help from a maintenance staff to fix it within a short time. The functions of the other commands are to read-out the status, including the load horn, and the conditions of the internal low-voltage power supplies. Those also greatly help to care for the system remotely through the GP-IB and LAN.

7 Conclusion

The design of the control is message-based, and distributed. The complicated operation process, which is depend on the device, is performed internally by its microprocessor through a single interface. The remote-control message becomes simple, and easily passes over

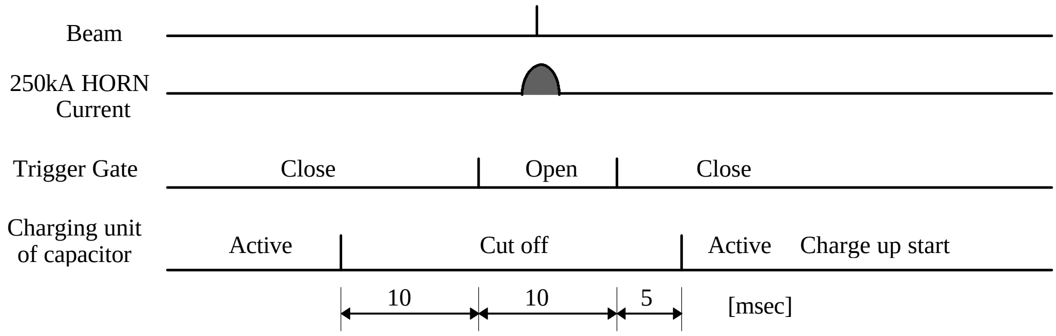


Fig. 3 Timing of the charging unit and trigger gate

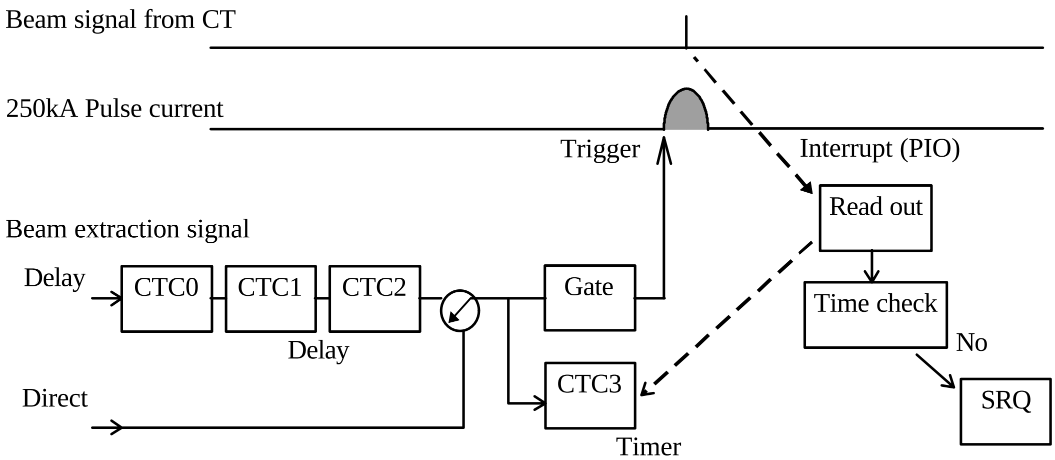


Fig. 4 Control and monitor of timing

the LAN, and helps the maintenance staff to correct the condition.

The pulsed power supply has been under test in a local experimental house, and is expected to be installed in the neutrino beam line one year later. The installation is expected to be easier than that for a device with an interface requiring much wiring.

Acknowledgments

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