# DEVELOPING OF THE PULSE MOTOR CONTROLLER ELECTRONICS FOR RUNNING UNDER WEAK RADIATION ENVIRONMENT

Miyuki Ishizuka*, Hiroaki Kashima, Hiroyuki Mukai and Natsuji Araki
Hitachi Zosen Corp., Japan

## Abstract

Hitachi Zosen Corporation (called "Hitz") has developed new pulse motor controller. The pulse motor controller operates two axes per one controller, and implements high performance processor, pulse control device and peripheral interface. This controller has simple extensibility and various interfaces, and realizes low price. We are able to operate the controller through Ethernet TCP/IP(or FLnet). In addition, the controller has functions of operating max 16 axes. We discuss drive the motor controller in optics hatch filled with weak radiation. If we can put the controller in optics hatch, wiring will become simple because of closed wiring in optics hatch. Therefore, we have evaluated controller electronics running under weak radiation. We performed on the controller board γ-ray and X-ray irradiation test. The results of irradiation of approximately 200Gy integrate dose, we guarantee that the controller board to work without problems.

## INTRODUCTION

This paper reports the performance and specification of pulse motor controller developed Hitz for accelerator equipment drive control. Moreover, this reports the motive, evaluation, test and result of use in accelerator facilities under weak radiation environment, for example inside of accelerator chamber and experiment hatch.

The equipment drivers are used for beam observational equipment, scraper and extraction electrode. The motor driver mechanism is seen in various places of accelerator. Especially, pulse motor has high accuracy of position and high control reproducibility.

However, these equipment driver need to set in radiation environment. Generally, high density PCB is weak against radiation. The motor controller boards have high accumulation LSI, for example motor control chip, FPGA and processor.

The ways of attenuate radiation are distance and shield A controller is put on the position separated enough from radiation sources, for example a main part of an accelerator. Or it has to be used shield materials. In the former case, to take a lot of distance from a motor, it is necessary to prepare the cable of sufficient length. Furthermore, control wires, such as a limit switch, also need to prepare the same length. In the latter case, if shield wall etc. are installed, the cost will start.

If the controllers can be located near the motor, they can be connected with upper layer system by only 100BASE-T/Ethernet cable. To locate the controller near the motor is more reasonable than usual composition.

*miyuki_ishizuka@hitachizosen.co.jp

## PRODUCTS CHARACTERISTICS

### Concepts

The drive mechanism used in an accelerator, differs the number of axes driven by the roles of various equipment. This equipment fills the following demands.

- Realization of one axis – multiple axis control (a maximum of 16 axes in combination is possible)
- Easy customization by modularization
- Having an Ethernet/USB interface.
- Performance on-site operation which became independent of upper layer system control.

### Specification

These devices are composed of "controller module" and "driver module". Figure 1 shows the exterior of equipments.

#### Controller Module

This controller is an implementation of SH-2 CPU, PCL6123 pulse controller, the resolver/encoder and LAN controller on the substrate 3U Euro size(single height). This controller has serial connection interface with LAN to upper layer system. Essentially the user can remotely control motor by connection program of TCP/IP.

This controller can control two axes (rotation angle monitor) in one board and maximum 16 axes by local bus (RS-485A) connect between modules. The board required as master is only connected to upper layer system.
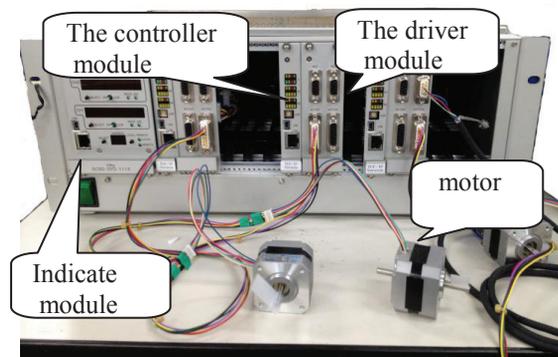


Figure 1: The exterior of equipments.

About rotation angle detecting, there are two type of pulse counting, absolute type and relative type. This controller has a function which records the present discreate value on the Non-volatile Memory inside FPGA so that both can respond. Furthermore, it monitors the power automatically in the FPGA.

If it detects the instantaneous stop, it stores automatically absolute coordinate position in the memory.

This controller module has master/slave mode. Master mode has an interface function to upper layer systems (PC, PLC, etc.), and operates a motor according to those command. Simultaneously with making the motor controlled by itself drive, the controller module in master mode operates the module in a slave mode.

The instructions from upper layer system perform control of the pulse output to a motor driver, stop/start operation and brake control. On the other hand, in an upper layer system, there are information of pulse value, the operation of a limit switch, and the existence of high-speed stopping operation for urgent trouble, etc.

We describe to hardware specification below.(Table 1)

Table 1: Specification of Hardware

| Item | Specification |
|---|---|
| CPU | SH-2(Type: R5F70855AN80FPV) |
| | We used Serial SCI-1 as USB serial. Embedded memory: RAM 32KB, ROM 512KB |
| LAN Controller | Type: AX88796B(ASIX) |
| | Data transport:10/100Base-T |
| Memory | SRAM:8Mbit, SROM:8Kbit 2 |
| Motor Cntroller | Type:PCL6123(two axis) |
| | Pulse output: one pulse/two pulse method Rotation angle detection:resolver/encoder Sensor input:4 point(CW, CCW, ORG, emergency stop) |
| Local Bus | Connection level:RS-485A |
| | Protocol: asynchronous communication method(half-duplex communication) Connection speed:1,228,800bps |
| Resolver Interface | 6802N1 |
| Encoder Interface | Incremental encoder of A-phase, B-phase, Z-phase and power 5V |
| Configure SW | Address SW:0~F(Master/Slave1~7) |

**Driver Module**

This motor controller can be connected any manufacturer's driver module whatever signal specification suits. However, we prepared to driver module, too. Specification of our driver module is as follows.(Table 2)

Table 2: Specification of Driver Module

| Item | Specification |
|---|---|
| Type | TD-5D14C |
| Power supply | DC24V±20%  3A Max. (from power supply) |
| Output currency | 0.75A-1.5A/phase(L-magnetization), 0.3A～0.75A/phase(H-magnetization) |
| Method of operation | Pentagon five wire connection, bipolar, chopper constant current |
| Step angle | full/half(0.72° /0.36° ) |
| The highest speed of response | 100Kpulse/sec |

**Indicate Module**

The pulse motor control can realize by operation of upper layer system. In case of constructed large control system, if we want to test of operation in local area, we must specially request to operator of upper layer system. For example, when users perform positioning of drive mechanism in local area, transmitting a command from upper layer system at every time requires time and effort.

From this reason, the indicate module which can perform minimum operation in the spot and a position monitor is required.

The module also has the specification of the master mode of a controller module. However, a motor is not operated by the module itself.

## IRRADIATION TEST

*Motivation*

The large synchrotron radiation facilities, SPring-8, makes various experiment by using synchrotron radiation. Now about stepping motor used in there, a motor driver and controller are placed the inside of optics hatch. A motor driver is connected with wire for each drive-pulse signal, contact signal (e.g. limit switch, emergency stop switch), position monitor signal and braking control signal, and they are connected to pulse motor and the peripheral devices.

If the pulse motor system will be located in optics hatch, wiring cost can be lower than other location. Because the wiring between inside and outside of hatch is only Ethernet cable for interface to upper layer system.

However, we need to check whether the pulse motor controller have a resistance to radiation in hatch. If the pulse motor controller has resistance to radiation, we can realize as above idea. Therefore, we should evaluate whether the pulse motor controller shielded with radiation shield can be equal to practical use enough.

## A Conduct of Electronics Device under the Radiation Environment

There are two effects of radiation for electronics devices. One is single event upset effect, the other is total dose effect.

• Single event upset effect

This effect changes circuit action by radiation attack to device. It causes ionization to semiconductor (e.g. transistors, diodes), positive hole and electron arise.
Then the noise generated by this situation may cause failure or system down. And high density charge is caused along the range, a part of this is collected to electrode. It causes failure of circuit by transient current. However the failure is local and temporary. When a memory device is irradiated, memory status inverts by the transient current. This situation is caused by high LET radiation, such as proton beam, heavy ion beam.

• Total dose effect

This effect may cause performance degradation of analogue circuit by noise, although malfunction or the system failure is not confirmed. It is caused by low LET radiation, such as X-ray, γ-ray and electron beam.

The weak devices in radiation are as follows:
  • memory
  • transmitter
  • optical device for communication
  • capacitor

On the other hand, the strong devices are as follows:
  • resister
  • connector
  • wire
  • pattern of PCB

## Determination of Irradiation Parameter

In this test, we assumed the users use the motor controller in optics hatch under γ–ray and X-ray environment. Experimentally γ-ray limit dose of PCB is 200Gy integrated dose. We assumed that this equipment is used under 80% of operation rate for three years. In that case, dose rate is 35mSv/h. Then we decided to the value as a standard, and irradiated approximately 40Gy/h for five hours.

## Preparing

We located motor controller module, driver module and case in irradiation chamber. LAN cable was laid irradiation chamber to outside. We operated to the controller module from outside.
We put lead sheet on only LSI. The thickness of lead is 1mm(the surface) and 2mm(the back). Figure 2 and Figure 3 show the shield of controller module. Moreover we used silicon glue and insulator polyimide tape. Figure 4 shows the inside of radiation chamber.
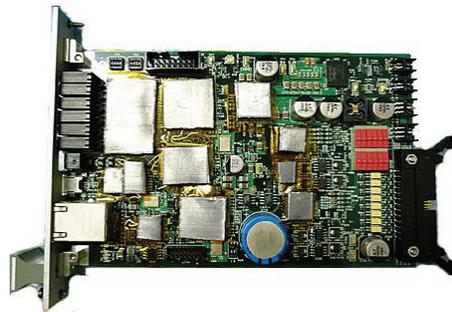
Figure 2: The shield of controller module(the surface).
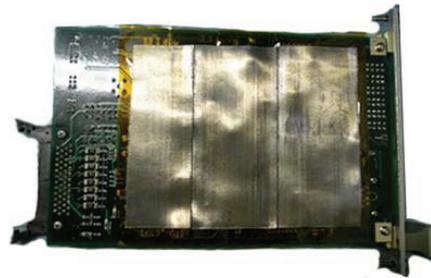
Figure 3: The shield of controller module(the back).

The setup in an irradiation facility is shown below (Figure 4).

The motor

The controller
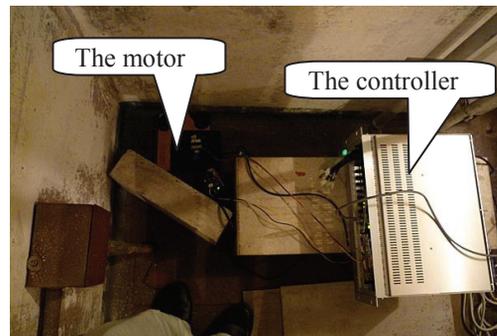
Figure 4: The setup of equipment in irradiation chamber.

The distance between a case and a wall was 80 cm in the farthest place, 40cm in the nearest place. In addition, the distance from radiation source was about 2.5-3m. There were steel plates between the pulse motor controller and radiation source for making radiation weak.
Figure 5 shows the inside of case.
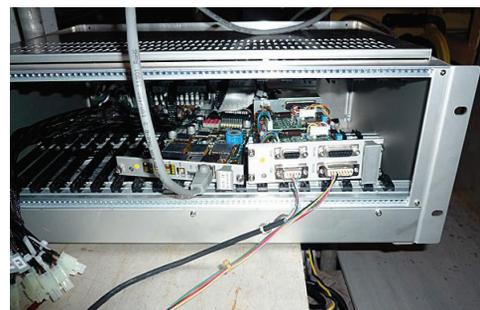
Figure 5: The inside of case. The left: motor controller, The right: driver module.

## Parameters

- Date: September 3, 2013 10:00am-5:00pm
- Place RIC-1 irradiation chamber, at RADIA INDUSTRY co.,ltd
- Source: $^{60}$Co γ-ray
- Irradiation rate: 40Gy/h
- Time: 5 h
- Integrated dose: 200Gy

## The Software for Examination

There are two rotate velocity – linear pattern and S curve pattern. The software drives pulse motor between CW and CCW, alternately. The software checks the soundness of the system by obtaining the information from a rotary encoder. If these values which are the difference between set pulse value and rotary encoder value exceed the threshold, it is assumed as error. The threshold was set to 100.

Moreover, the periodical command for a system check is sent as heartbeats. The software can check the system breakdown. Then we can know the error by watching screen of computer.

## Result

The actual parameters are as follows.

- Dose rate: 38.26 Gy/h
- Irradiation time: 5.23h
- Integrated dose: 200.0998Gy

The result of number of sending command, received command times, driving times and error times are shown Table 3.

Table 3: The Result of Motor Operation

|  | Number of times |
| --- | --- |
| sending command | 205703 |
| received command | 205703 |
| driving times | 320 |
| error times | 154 |
| error times(S) | 151 |

In the number of driving times, the phenomenon occurred at the rate of one time about twice. According to the log data, it is considered that the motor moved only CW direction. Therefore, The CCW driving rarely carried out. Also, it became in the CW direction.

On the other hand, motor was good operation till the end of test except for above problems. And the communication error didn't occur. In addition, motor did not rise temperature during test.

## Consideration

The $^{60}$Co emits γ -ray 1.17MeV and 1.33MeV. Because of lead mass attenuation ratio, mostly Compton scattering went on under this experiment. Then scattering X-ray affects to PCB. In addition, irradiation chamber wall that made by cement, emits X-ray too.

According to a report about radiation test to transistor, transistor's threshold voltage dropped to a lower value after irradiation by TOTAL DOSE EFFECT. [1][2] After that, the voltage went back a little. However, the value became lower than before. However this result was caused more than 2kGy dose case which is 10 times dose of our test. If we want to observe degradation of transistor or LSI directly, we need to irradiate higher dose. We will study such test to observe degradation process.

About CCW direction error, we assume that the error judging was caused by setting error of a driver module. Therefore, even if the commands reached a controller, a motor didn't move. About CW direction error, we could reproduce the test under same condition. Therefore, we assume that the error in the test is not caused by radiation.

The motor was driving continually without the abnormalities in communication during the test. Accordingly, it seems that the radiation resistance of the pulse motor controller to 200Gy doses was collateralized by the PCB.

## CONCLUSION

We did experiment in pulse motor controller to irradiate 200Gy dose. It is expected to use in optics hatch. As a result, we checked that the pulse motor controller ran without any incident up to this value nearly. The value was expected from dose 35mGy/h in hatch. However, there are places having higher dose in hatch, actually.

The purpose of this test is not to make an electronic device with high radiation resistance, but to clarify the scope of available under radiation environment by the minimum shielded processing. If a pulse motor controller is installed in a hatch, it needs to be installed in the low place of dose distribution.

## REFERENCES

[1] C. Fukunaga, Tokyo Metropolitan. Univ,1998;http://www.comp.tmu.ac.jp/morbier/public_html/stdydocm2000.html

[2] Y. Takahashi, Nihon Univ., "A basic study on semiconductor devices for space application", 2009; http://www.cst.nihon-u.ac.jp/research/gakujutu/53/pdf/S4-17.pdf