DEVELOPMENT OF REAL-TIME CHARGE INTEGRATOR FOR THE IRRADIATION DOSE MEASUREMENT

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Abstract

KOMAC (Korea Multi-purpose Accelerator Complex, Gyeongju, Korea) has several kinds of facilities using proton beam or ion beam. The KOMAC has provided beam service to user group since 2013. For effective beam service, it is important that irradiation dose at a target should be supplied as much as user requires.

To control the irradiation dose of target, a multi-channels charge integrator, Faraday cups, and a beam shutter are used. The amount of irradiation dose is calculated in real time by accumulative charge, which is represented to integration of induced current at each Faraday cup for the target. If the measurements reach to the set value (desired dose), the beam is automatically blocked by beam shutter. Thus, precise measurement of accumulative charge is required.

For our purpose, two kinds of real-time charge integrators were implemented with different measuring ranges. In order to verify performance of the integrators, each device's linearity was evaluated after measuring accumulative charge corresponding to dc current. And their measurable range was determined.

INTRODUCTION

Since the KOMAC started proton or ion beam services in 2013, users in various fields are increasing every year. For effective the beam services, the beam characteristics such as irradiation dose, beam uniformity, beam size, energy, etc. should be controlled appropriately to meet user requirements.

To control the irradiation dose, we have been used Faraday cup (or ionization chamber) very close to the target, electric charge measuring device, and a beam shutter (or gate valve). As soon as the measured total charge at target position reaches the desired amount, the shutter was automatically operated to block the beam. As shown in Fig. 1, the irradiation dose [particles/area] of target can be estimated indirectly from the total charge of Faraday cup measured by a charge integrator. Therefore, the charge should be accurately measured in real time. In the paper, two types of charge integrators with different measuring ranges were designed.

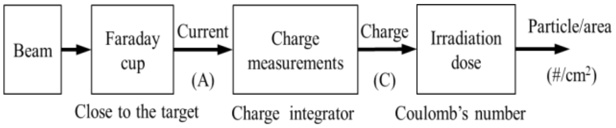

Figure 1: Estimation of the irradiation dose using the Faraday cup and the charge integration.

REAL-TIME CHARGE INTEGRATOR

Charge Integrator with Operational Amplifier

To calculate the irradiation dose in real time, the charge integrators were implemented using an operational amplifier. Fig. 2 shows the simple structure of charge integrator. The charge integrator receives the Faraday cup's output current *i(t)*, and the integrator's output is expressed as a voltage *v(t)*, by the transfer function of the operational amplifier as shown in Eq. 1[1]. Then, constant c is capacitance of the capacitor. The integrator's output is converted from analog to digital.

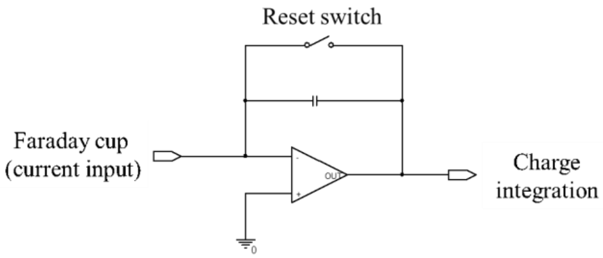

Figure 2: Schematic of the charge integrator using an operational amplifier, a capacitor, and a reset switch.

$$v(t) = -\frac{1}{c}\int i(t)dt. \quad (1)$$

By repeatedly opening and closing the reset switch, the accumulated charge can be measured infinitely. However, the reset switch must be opened in order to discharge the capacitor before the capacitor is saturated (full-charged). In other words, the maximum input current is limited by the capacitance. Because of this reason, two kinds of charge integrators with different maximum inputs were implemented.

Implementation & Specifications

The proposed charge integrators were implemented using a commercial IC for x-ray detector (AFE0064, Texas Instruments) including 64 operational amplifiers [2] and an A/D converter with 12-bit resolution (AD9222, Analog Devices) [3]. In case of single input, because the capacitance connected to the operational amplifier is limited as 9.6 pC during 28.32 µsec, the maximum input current is about 340 nA. Thus, the input current range was expanded by paralleling the inputs of the operational amplifiers. Finally, two kinds of devices were used in

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combination of 16 or 64 inputs. Fig. 3 and Table 1 show these device and their specifications, respectively. The charge integrator is consists of a LCD for display and setting of the desired value, control buttons (start/stop/reset), and Ethernet communication.

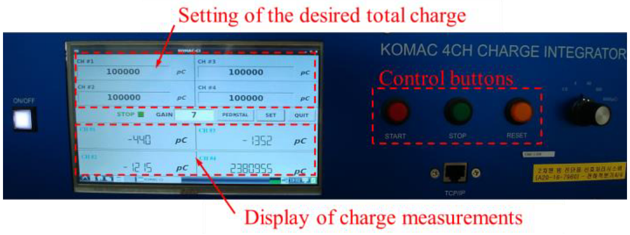

Figure 3: The implemented charge integrator.

Table 1: The Design Specifications of Charge Integrators

	Type I	Type II
Outputs	4 channels	
The coupled inputs of charge integrator	16	64
Maximum input current	10 μA	40 μA
Measuring interval	about 460 μsec	
Data Display	Every 1 sec in real-time	
Communication	Ethernet	

EXPERIMENTS AND RESULTS

To verify the performance of charge integrator, linearity and background noise of two devices were measured using dc current source which was calibrated. Based on the results, we were can be able to determine the input range of each device.

Experimental Setup

As shown Fig. 4, an experiments setup for performance test was set up. After supplying dc current of the calibrated power source (Soucemeter 2400, Keithley) to type I or type II charge integrators, the accumulative charge is displayed on LCD panel and the software in real time. Then, the input current range is set from 10 nA to 40 μA. All data was acquired during 10 seconds every set current. And raw data file for time was saved through Ethernet communication. Finally, in case of zero current input, noise charge was measured.

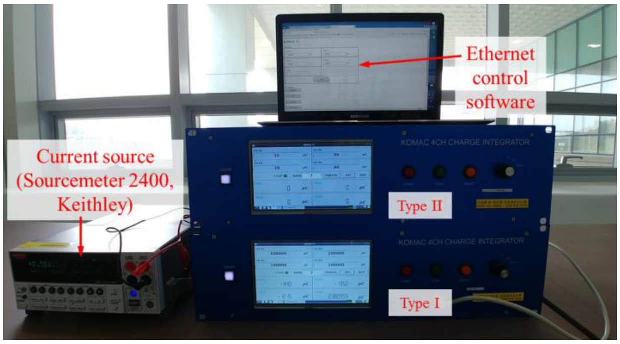

Figure 4: Experimental setup for the performance test.

Linearity & Background Noise

Using the raw data, averages of rate of accumulative charge and measurement deviation according to input current were calculated during the time of 1024 data measurements (about 470 msec). Fig. 5 and Fig. 6 show the results about the type I and the type II integrators, respectively.

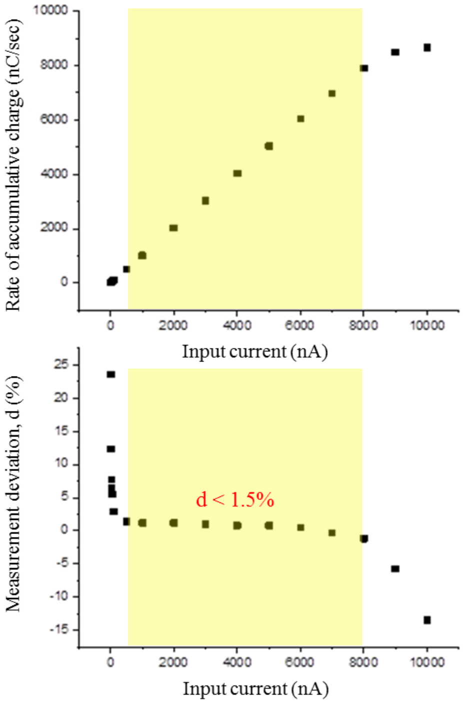

Figure 5: The experimental results of type I integrator.

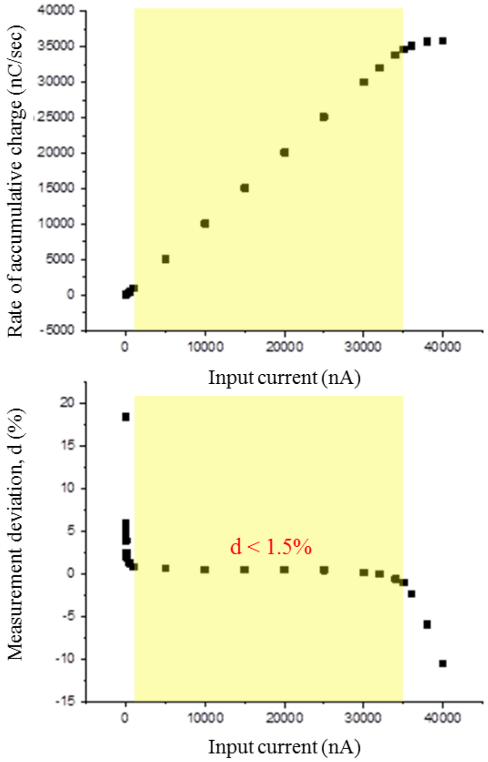

Figure 6: The experimental results of type II integrator.

It was considered to be linear if the measurement deviation is kept below 1.5 %. In the figures, the linear section is marked in yellow. It was confirmed that linearity of the each integrator was maintained from 500 nA to 8 μA (type I) and from 500 nA to 35 μA (type II). On the other hand, the measured charge due to background noise are -0.32 nC/sec (type I) and -3.21 nC/sec (type II), respectively. Therefore, it's judged that the characteristics of integrator are lower than the design specifications due to the noise.

CONCLUSION

In the paper, two kinds of real-time charge integrators were implemented to estimate the irradiation dose of target. To verify the performance of devices, the linearity and the background noise were checked using the calibrated current source. In the results, it is confirmed that each device's reasonable measuring range is from 500 nA to 8 μA (type I) and from 500 nA to 35 μA (type II). Therefore, the irradiation dose on target can be precisely controlled by these real-time integrators and the beam shutter.

ACKNOWLEDGEMENT

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