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BEAM GATE CONTROL SYSTEM FOR THE PROTON INJECTOR AND BEAMLINES ON KOMAC*

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Abstract

The Korea Multi-purpose Accelerator Complex (KOMAC) 100 MeV proton linear accelerator operates with the programmable timing system to change real-time timing parameters for low and high-flux proton beam utilization. The main requirements are to synchronize the operation of the facility including accelerator, target, and instruments, to provide the base frequency of up to 60 Hz on a variable beam repetition rate, and to support post-mortem analysis when a beam trip occurs. The MRF event timing system, which consists of one event generator and eleven event receivers, is configured to control the beam gate and beam distribution to transmit the proton beam to the target beam line. The timing events are distributed from the event generator to local event receivers. Local subsystem specific timing can be adjusted locally from beam monitoring and RF modulators. Corresponding to user's demands, beam gate should be automatically controlled, and the beam distribution must be precisely synchronized with the main reference signal for beam gate and accelerator operation. The timing system is configured with sequence logic for beam gate control, and the timing events can trigger the software to perform actions including beam on or off, post-mortem data acquisition, and beam distribution on the beam lines. The results of the timing control system for the beam gate and beam distribution are presented.

INTRODUCTION

The KOMAC linac and multi-beam lines were designed to provide users with a proton beam under various beam operation conditions. Representative specifications of the linac are maximum beam energy of 100 MeV, and peak beam current of 20 mA, and the adjustable repetition rate is up to 120 Hz. The specifications of the KOMAC 100 MeV linac are summarized in Table 1. The KOMAC has four beam extraction points at 20 and 10 MeV for proton beam utilization [1, 2].

The proton accelerators are capable of accelerating the beam under stable operating conditions of various components. The accelerator operating conditions must be kept constant. This can be achieved by changing the beam pulse width and repetition rate for beam service conditions while the accelerator conditioning is stable. To change the beam repetition rate, it is limited to the high frequency repetition rate fixed in the accelerator operating condition. As the number of beam user increases, various beam conditions are required. In order to satisfy this problem, the beam extraction repetition rate can be changed regardless of the high frequency operation repetition rate.

Table 1: The Summarized Specifications of KOMAC 100 MeV Proton Linac

Parameters	20	100
Extraction energy (MeV)	1 ~20	20 ~ 100
Beam current (mA, peak)	20	20
Beam duty (%)	24	8
Beam current (mA, average)	4.8	1.6
Pulse length (µS)	2,000	1,333
Repetition rate (Hz)	120	60
Beam power (kW, average)	96	160

The KOMAC timing system is an MRF event timing system. Event Generator (EVG) is responsible of creating and sending out timing events to an array of Event Receiver (EVR) [3]. Event sequences provide a method of transmitting sequences of events stored in random access memory with defined timing. Using the event sequence, the beam pulse is synchronized with the operation of high frequency and the beam pulse repetition rate can be used without limitation.

KOMAC TIMING SYSTEM

The timing system was fabricated using a versa module eurocard (VME) system composed of an event generator (EVG-230) and event receiver (EVR-230RF) based on EPICS software [4, 5]. The EVG is responsible for generating and sending out event codes over 2-Gbits/s fiber optic links to an array of EVR, which is programmed to decode specific event codes. The EVR generates trigger pulses for the linac components, such as the beam diagnostics, high-power RF system, and high-voltage power supply through the fan-out board. One EVG and one fanout are installed in the control server room, and 12 EVRs are installed in the klystron gallery and beam experiment hall. Figure 1 shows a schematic layout of the timing system with a 300-MHz external reference signal.

For beam extraction, timing was added to the beam injector with a BNC565 delay generator. The delay generator receives a 20 MHz clock and trigger signal from the EVR. The trigger signal determines the repetition rate for the beam service request, and the delay generator operates in burst mode to synchronize the external clock and the trigger and generate the trigger as requested pulses. The beam trigger is limited to a divisor of the rf repetition rate.

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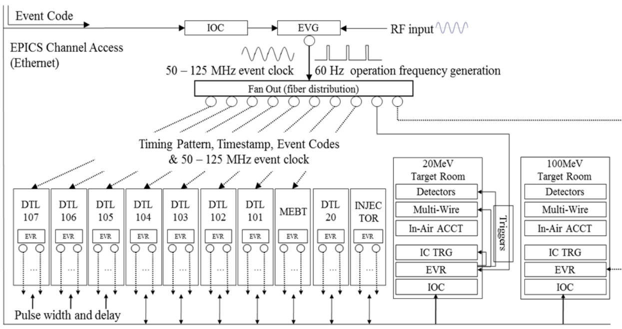

Figure 1: Schematic layout of the event timing system in the klystron galley and beam experiment hall.

BEAM GATE

In order to handle pulse repetition rate limitation and beam pulse termination after providing the requested beam pulse, the sequence random access memory of the EVG is used, and the beam pulse control is implemented in State Notation Lange and Sequencer.

The beam pulse width accelerated in the RFQ is determined by the rf pulse width of the RFQ. To distribute the signal of the beam pulse, the beam pulse width of the beam injector and the RFQ rf pulse width can be found at the intersection point. The burst mode of a delay generator is used to provide beams according to beam requirement, and a delay generator is additionally used for beam pulse distribution. Using a sequencer replaces the delay generator's burst mode, eliminating the need for additional delay generators.

Switching Beam Sequence

Event sequencers provide a method of transmitting sequences of events stored in random access memory with defined timing. The 8-bit event codes are stored in a RAM table each attached with a 32-bit timestamp relative to the start of sequence. For example, if the accelerator rf is driven at 10Hz, the beam period is 1, 2, 5, 10, which is a divisor of 10, depending on the rf operation period. The event sequence can be used to accelerate the beam from 1Hz to 10Hz, although it is an irregular period but synchronized with rf operation. It is important to use the beam repetition rate without limitation to meet the beam condition. When the operation period of the rf is determined in advance. We prepare the event list and timestamp of various beam periods in advance and pass them to the event sequence.

This method is constructed using a transferArray recode [6]. The transferArray record manages elements of waveform record. This record copies arbitrary part of waveform elements and pastes them into another waveform. Figure 2 describes schematic view of transferArray record. Ten sequences are prepared in the waveform records for Event code and Timestamp and one of them are selected and set into EVG with the processes of transferArray records.

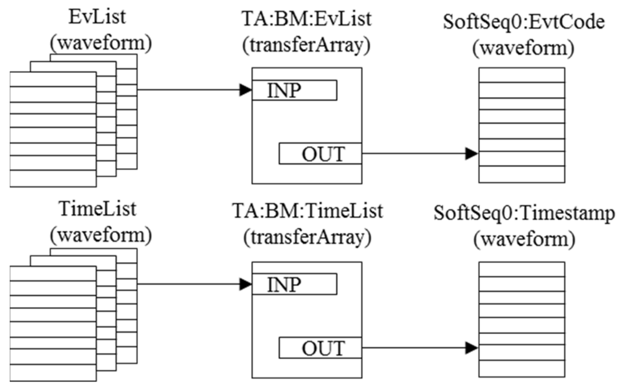

Figure 2: Copies event cord and timestamp waveform elements and pasts those in to waveform record of EVG sequencer random access memory.

Beam Gate Control

The EVG generates and sends out event clock signals and codes to an EVR array through a fan-out board. The high configurability makes possible the building of an entire timing system with a single EVG without external counters. Events are sent out by the EVG as event frames that consist of an 8- bit event code and an 8-bit distributed bus data byte. The-100 MHz event transfer rate is derived from an external 300-MHz RF clock. The optical event stream transmitted by the EVG is phase locked to the reference clock.

The beam pulse depends on the beam fluence in the beam target room, and the beam pulse should be stopped after the beam satisfying the accumulated fluence is provided. The sequencer was used to control the pulser using an event code PV in the EVR that could count the number of beam pulses. The sequencer was installed in mrfioc2 to distribute beam pulses, and enable/disable pulsers of EVR that handles output pulses. The beam pulse allows one event code to be used. The sequencer in the main EVR controls the pulser of the EVR using beam pulses compared to the number of beam pulses that require PV of the event code counter.

```
record (bo, "$(SYS){$(D)}BGEna-Sel") {
  field (OUT, "BGFout")
  field (ZNAM, "Disabled")
  field (ONAM, "Enabled")
}
record (dfanout, "$(SYS){$(D)}BGFout") {
  field (DESC, "Beam Gate Output On Off ")
  field (OUTA, "$(SYS){$(D)-Out:FP0}Ena-SP CA")
  field (OUTB, "$(SYS){$(D)-Out:FP1}Ena-SP CA")
  field (SCAN, "Passive")
  field (PINI, "YES")
  field (SELM, "All")
  field (DOL, "$(SYS){$(D)}BGEna-Sel")
  field (OMSL, "closed_loop")
}
```

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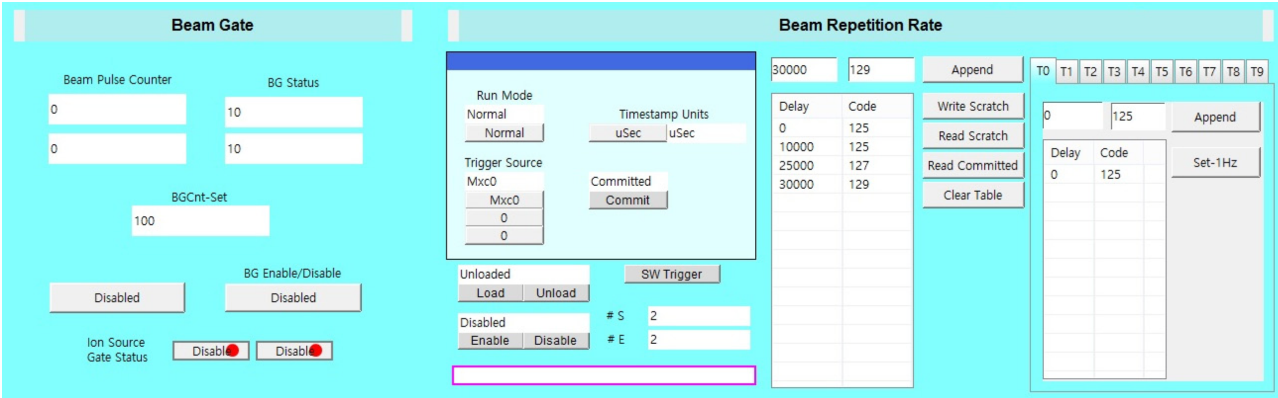

Figure 3: User interface to control beam gate and switch from EvCode and Timestamp to EVG sequencer.

Figure 3 shows a user interface for beam gate and event sequence control the EVR sequencer. EVR database includes an analog out BGCnt-Set record for number of beam pulse set value, fanout BGFout record for enable/disable control for output pulse. The following describes some of the beam gate record defined in the EVR database.

CONCLUSION

In order to handle pulse repetition rate limitation and beam pulse termination after providing the requested beam pulse, the sequence random access memory of the EVG is used, and the beam pulse control is implemented in State Notation Lange and Sequencer. When the operation period of the rf is determined in advance. We prepare the event list and timestamp of various beam periods in advance and pass them to the event sequence. This method is constructed using a transferArray recode. The beam pulse depends on the beam condition of the user, and the beam pulse should be stopped after the beam satisfying the condition is provided. The beam pulse, which was limited to high frequency operation, can be used without restriction, and the burst mode of the beam pulse can be used where a beam pulse is needed without a belay generator.

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