ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-WEPAL036

IMPLEMENTATION OF CSNS RCS BEAM INJECTION AND EXTRACTION MODES IN TIMING SYSTEM

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Abstract

Based on the physical design of the accelerator and the demand of the beam research, we designed four RCS beam injection modes and two RCS beam extraction modes, each of which corresponds to a series of specific timing for the accelerator. RCS beam injection and extraction modes are implemented on "VME + customized boards" hardware platform. In this paper, we will introduce the design and implementation of RCS beam injection and extraction modes as well as the RCS timing requirements and implementation in detail.

INTRODUCTION

The China Spallation Neutron Source (CSNS) consists of an 80MeV H^- LINAC accelerator, a 1.6GeV Rapid Cycling Synchrotron (RCS), a solid tungsten target station, and some instruments for neutron applications [1]. The RCS accelerates the 80MeV injected beam to the designed energy of 1.6GeV and extracts the high energy beam to the target. The design goal of beam power for CSNS is 100 kW and can be upgraded to 500 kW [2].

The repetition frequency of LINAC and RCS is 25Hz, LINAC RF is 324MHz, when the peak current intensity is designed value 15mA, the beam pulse length is 391us, the chopping rate is 50%, bunch and gap length are 489ns. Each bunch consists of 159 micro-pulses with a period of 3.09ns (corresponding to the 324 MHz frequency of the LINAC RF) [3]. The timing of the RCS beam is shown in Figure 1.

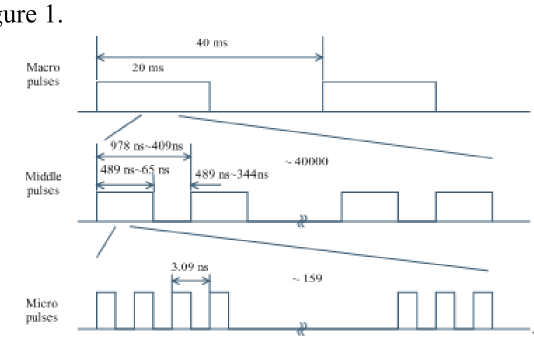

Figure 1: Time structure of the RCS beam pulse.

The CSNS timing system is based on an event distribution system that broadcasts the timing information to all the components to be synchronized. The event system is used to generate and distribute the sequence of events to all the relevant components. Practically the whole operation cycle is generated within the Event Generator (EVG). At each destination there is an Event Receiver (EVR) that decodes the received event codes and performs the appropriate actions that are programmed for each event of interest to the controlled device. The timing system scheme is shown in Fig. 2.

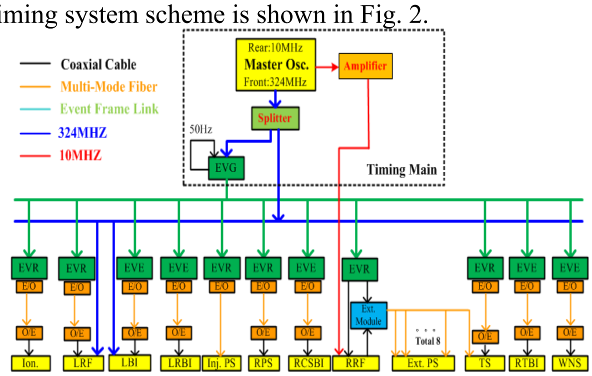

Figure 2: Scheme of the timing system.

In order to obtain more methods and techniques in the beam commissioning, RCS beam injection and extraction mode needs to be done. Four RCS beam injection modes and two RCS beam extraction modes have been designed and implemented. RCS beam injection modes: Normal, Single Turn, Single Bunch and 1~32 Turn, meanwhile, to achieve beam extraction at different time, 20ms and 1~N Turn modes have been designed and implemented.

DESIGN OF VME + CUSTOMIZED BOARDS

The RCS beam injection and extraction mode are implemented using "VME + customized boards" hardware platform, which uses FPGA for signal processing and VME interface for data reading, especially, the customized boards can delay with the step of 250ps, which is very important to adjust fine-tuning, which is very important for beam commissioning.

In the design, a general timing processing board was developed using Xilinx's Spart3 FPGA, including normal e/o signal input/output, VME interface and fine delay module, and so on. Figure 3 is the board physical diagram.

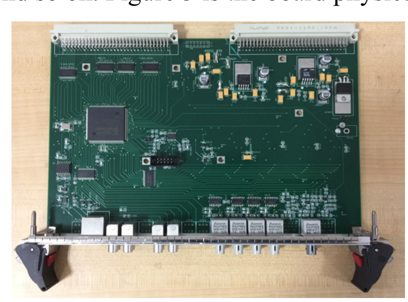

Figure 3: Physical diagram.

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According to the analysis and research, the Dallas company 8-bit single-channel programmable delay chip DS1023S-25/50/100/200/500 has 31 delay units and a 3-bit Sub DAC, the delay accuracy is 0.25ns. The 1ns-step delay is shown in Fig. 4.

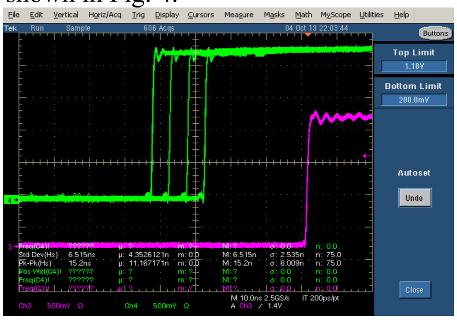

Figure 4: 1ns-step delay test.

The VME bus interface logic in the FPGA is mainly VME read/write registers module. Practical experience of more than one year proves that this interface has advantages of strong compatibility, high reliability.

IMPLEMENTATION OF RCS BEAM INJECTION MODES

The CSNS LINAC accelerator consists of a 50keV H- Penning surface plasma ion source, a low energy beam transport line, a 3.5MeV RFQ accelerator, a medium energy beam transport line, an 81MeV Drift Tube LINAC accelerator and a high energy beam transport line [4]. The CSNS LINAC scheme is shown in Fig. 6.

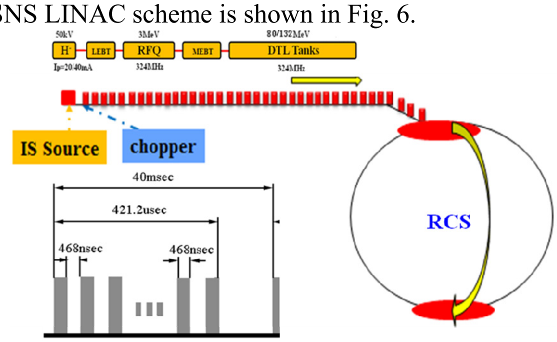

Figure 6: Scheme of the CSNS LINAC.

In the LINAC accelerator design, an H- ion beam with a peak current of 20mA and a pulse width of 500us is accelerated up to 81MeV, and then injected into the RCS at a repetition rate of 25Hz [5]. In order to capture and accelerate beam effectively, a chopper is designed in the LINAC low-energy line to cut the pulse beam from IS. The LINAC chopper operates by two triggers: one signal (frequency: 25Hz, pulse width: 100us~500us, the time information of the beam macro pulse for H- ion) and another signal (902kHz~1.024MHz, adjustable duty ratio, the time information of the RCS RF) [6]. Through the sequential processing of the two signals, the LINAC chopper can operates in different working modes: Normal, Single Turn, Single Bunch and 1~32 Turn, each mode corresponds to a specific timing for the LINAC chopper, then the micro-pulse time structure is formed after beam cutting, achieving the beam injection mode required for physical beam commissioning [7]. The CSNS RCS injection mode- Single Turn scheme is shown in Fig. 7.

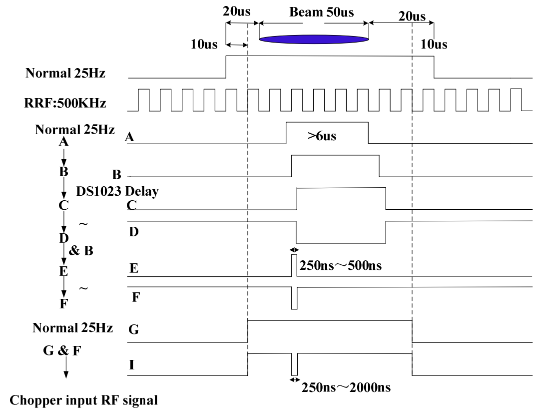

Figure 7: Injection mode-Single Turn scheme.

For ease of operation, we use a popular tool BOY in CSS to develop remote interface. BOY is an OPI development and real-time operating environment, providing a rich graphical interface, support for multiple platforms, and even mobile phones. In order to be consistent with the CSNS control system, select the version of EPICS base-3.14.12; select BOY in CSS 3.1.4 to develop the interface. The CSNS injection modes OPI in central control room is shown in Fig. 8. From top to bottom in order, it shows: standard 25Hz signal parameter settings and readback; beam injection mode setting and readback; Single Turn mode, beam flow Width setting and readback.

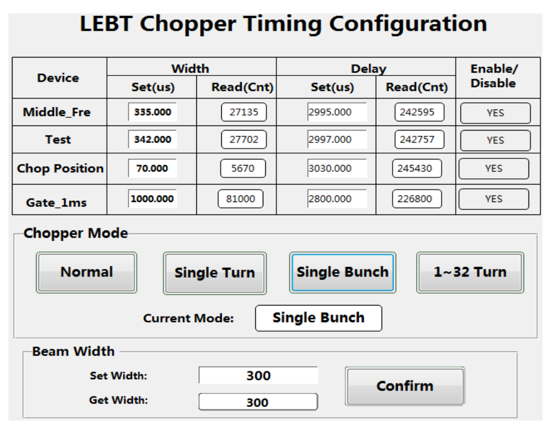

Figure 8: CSNS injection modes OPI.

IMPLEMENTATION OF RCS BEAM EXTRACTION MODES

In order to extract the beam from RCS to RTBT, the eight kickers have different kinds of magnetic field strengths combinations and their magnetizing relationship need to be obtained. Therefore, to achieve beam extraction at different time, 20ms and 1~N Turn modes have been designed and implemented, each mode corresponds to eight kickers timing. The CSNS extraction scheme is shown in Fig. 9.

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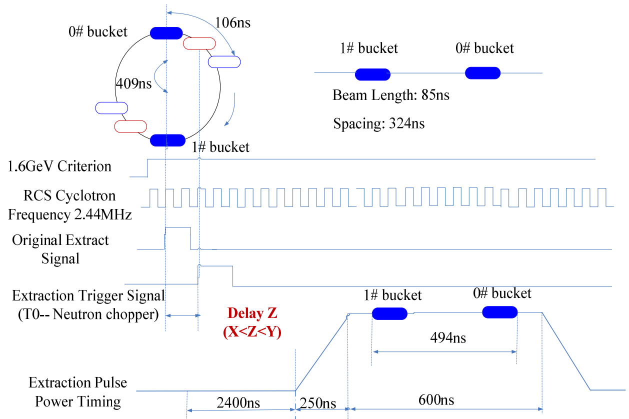


Figure 9: RCS extraction scheme.

The CSNS RCS employs multiple rings of smear injection, with beams in the first 20ms. In the double bucket mode, two beam buckets are extracted in one RCS RF cycle; which is the same as the single bucket mode. The eight kickers use the synchronization timing, phase-locked with the RCS RF. The CSNS extraction kicker timing scheme is shown in Fig. 10.

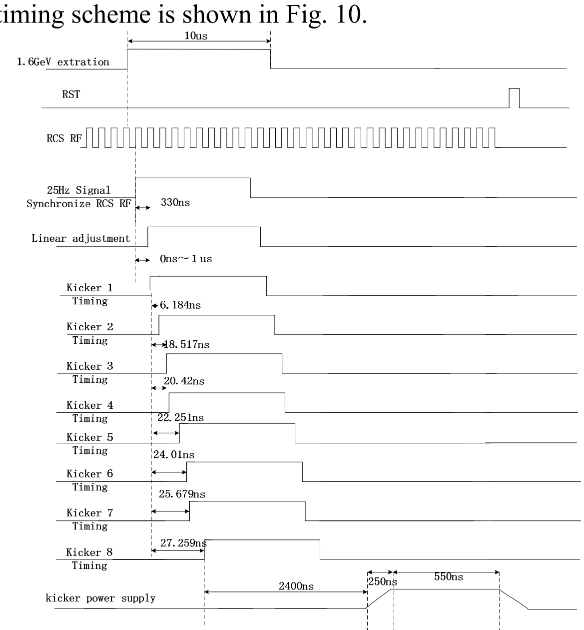
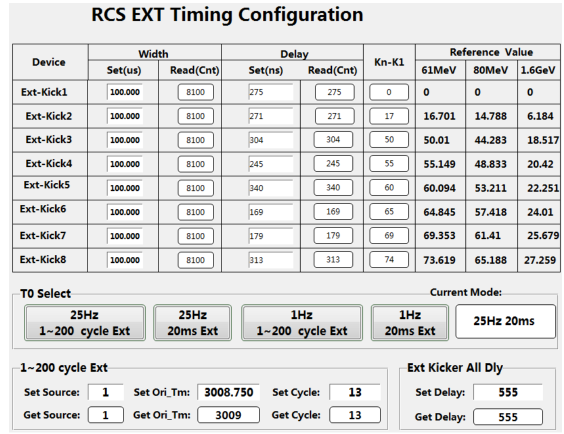


Figure 10: The CSNS extraction kicker timing scheme.

Through the design of the working and relative time sequence, eight kickers can be used to switch the beam working time, thus forming different extraction modes. The CSNS extraction modes OPI in central control room is shown in Fig. 11. The RCS beam drawing mode operation interface is composed of four parts. As shown in Fig. 11, from top to bottom, (1) the kickers timing setting and readback; (2) the beam extraction mode setting and readback; (3) the number setting for 1~N Turn mode; (4) the beam extraction position setting for 20ms mode. (5) the number of turns for beam;


RCS EXT Timing Configuration

Device	Width		Delay		Kn-K1	Reference Value		
	Set(us)	Read(Cnt)	Set(ns)	Read(Cnt)		61MeV	80MeV	1.6GeV
Ext-Kick1	100.000	8100	275	275	0	0	0	0
Ext-Kick2	100.000	8100	271	271	17	16.701	14.788	6.184
Ext-Kick3	100.000	8100	304	304	50	50.01	44.283	18.517
Ext-Kick4	100.000	8100	245	245	55	55.149	48.833	20.42
Ext-Kick5	100.000	8100	340	340	60	60.094	53.211	22.251
Ext-Kick6	100.000	8100	169	169	65	64.845	57.418	24.01
Ext-Kick7	100.000	8100	179	179	69	69.353	61.41	25.679
Ext-Kick8	100.000	8100	313	313	74	73.619	65.188	27.259

Figure 11: The CSNS extraction modes OPI.

During the beam commissioning, if the magnetic field strengths combination of the eight kickers is suitable, the beam can be extracted from RCS to RTBT accurately.

CONCLUSIONS

In this paper, the timing of CSNS, LINAC chopper and eight kickers are introduced firstly, then the key hardware and VME interface design are also introduced. The injection mode and the extraction mode can be freely used to complete related physical beam commissioning, machine performance studies and further improvement of beam conditioning efficiency.

ACKNOWLENDGMENTS

The authors want to thank other CSNS colleagues for the discussions and consultations.

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