Timing System and Injection Control in the SRRC

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Abstract

The accelerator system of SRRC has been operational for nearly five years. There are good as well as bad features the present timing system. The timing system upgrade project was started recently to improve its performance and to satisfy new requirements. The SRRC consists of three accelerators. The timing system provides trigger signal to synchronize the injection sequence of a 50 MeV electron linear accelerator, 1.3 GeV booster synchrotron and the 1.3-1.5 GeV storage ring. The timing system also provides trigger signals for diagnostics devices on the accelerator system. Trigger signal with picosecond jitter is also available for streak camera trigger. Low phase noise reference signal that phase locked with the RF clock is also provided for mode-locked laser system synchronization. The system will be used for the synchrotron radiation-laser hybrid experiments in the near future. Bunch synchrotron signal for time-resolved experiments is also provided. Several injection control applications are available for the machine operation. Details of the timing system are described below.

1 Introduction

There are three accelerators at SRRC, one is a 50 MeV linac, one 1.3 GeV synchrotron booster, and one 1.3-1.5 GeV storage ring. The booster and the storage ring use 500 Mhz Rf system. Harmonic number of booster is 120 and the storage ring is 200. Timing system has been working well during the last five years. However, some stringent requirements still cannot be achieved before the upgrade of the system. The upgrade started in August 1997 and is expected to finish on March 1998. Timing system update work includes two parts. First, to find the source of imperfection and to eliminate the problem. Second, improper timing system hardware and software will be replaced by new design. Commercialy available timing related module will be used for this upgrade.

2 Timing scheme of the SRRC accelerator complex

The major functional block of the timing system and the signal distribution is shown in Figure 1 [1]. A Rhode&Schwarz SMG signal generator is used as master oscillator. The timing sequence for the klystron modulator, the gun and the pulses magnets is shown in Figure 2. Clock generator produces revolution frequency of the accelerator system and the 0.833 MHz synchronization signal which is the coincident frequency of the storage ring and the booster. Phase of the 0.833 Mhz system is used to control the bucket position during injection.

Bucket addressing is done by shifting the phase of the synchronization signal. A programmable delay generator with a resolution of RF period exactly (2 ns), developed in-house, is used for this purpose. The timing system of the injector consists of a slow timing and fast timing system. The slow timing system handles the phasing of the dipole/quadrupole power supplies and provides the trigger signal for septums and bumpers. The fast timing system generates the necessity signal for the klystron modulator, the kickers and the gun trigger. Trigger signals for the injection pulse magnets of the storage ring are also provided by the slow and fast timing systems. Triggers of injection septum of the storage ring are derived from the slow timing system. Triggers for the storage ring injection kickers are produces by the fast timing system. A multi-channel digital delay generator is used to adjust the trigger timing of the storage ring injection kicker.

3 Timing modules implementation

The timing system of SRRC uses three kinds of modules of the existing system. One is the in-house development module which is in C-size VME/VXI form-factor for design. The other is the timing module that was originate from the vendor of the injector. The last category is commercial digital delay generator. There are a lot of similar designs at other facilities [2,3,4,5,6].

The in-house development timing module includes clock generator unit (CGU) to generate the storage ring clock, booster clock, and synchronization clock. It also includes Bucket addressing unit (BAU), injection control unit (ICU), clock distribution fanout ...etc. Old version is implementd in Eurocard format. New revised modules have been change into C-size VME/VXI format. The VME crates are compliant with CERN spec. V431 which provides necessary power for ECLinPS logic. LEMO connector was used for the front panel signal connection. VMEbus interface on timing module permit setting various timing patterns by the control system. All trigger fanout stages are implemented by monolithic 50 ohm pin-driver. Figure 3 shows the CGU of new timing system.

The fast timing and slow timing delay module were original from the vendor of the injector. All modules are in Eurocard format and installed on a customized crate. Fast timing module are implemented by MECL logic and AD9500 analog delay generator. Slow timing logic was implement by TTL logic. Timing resolution of fast timing system is 100 ps and the slow timing system is 100 ns. The control Bitbus interface is installed inside the crates.

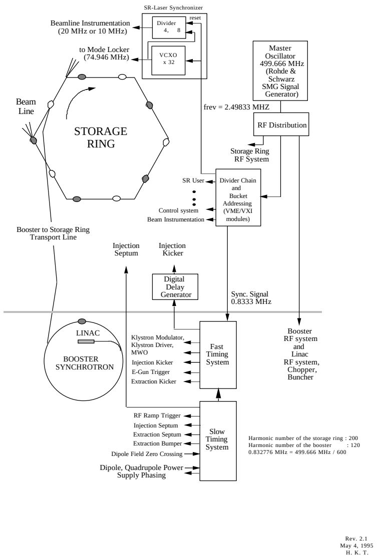

Figure 1. Timing system block diagram

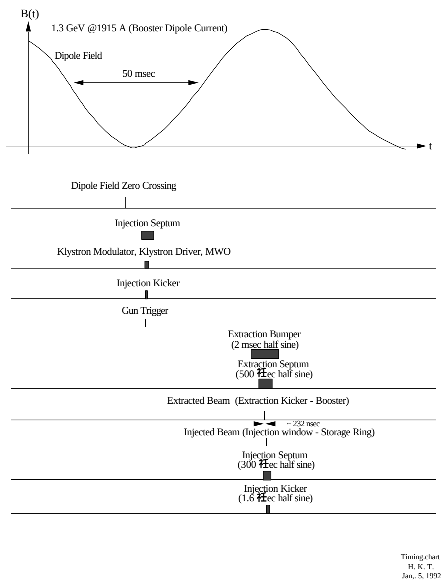

Figure 2. Timing sequence of the injection process

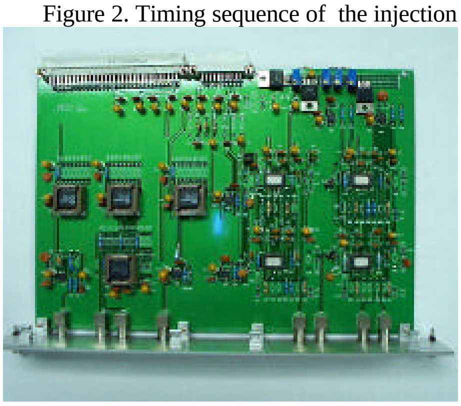

Figure 3. Clock generator unit

The jitter introduced by the fast timing modules areslightly large. The reason for large jitter is that slow rising edge devices are used at input and output stages.

We also use commercial IEEE-488 based digital delay generator (DDG) for various purposes. These DDG have been used for injection kicker trigger. The new system will replace IEEE-488 based DDG by VME form-factor DDG. VME timing module has fast control response, it is promising for some special applications.

To improve system performance, the timing module and signal distribution is now being revised. New system will replace old MECL logic by ECLinPS logic and VME DDG.

4 Trigger and clock distribution

Major timing system modules are distribute in several areas. The RF distribution is done by 1/2 inch phase stabilized coaxial cable (Andrew LDF4-50A). The trigger connects to the high voltage desk for gun electronics via fiber. The other signal is done by high quality coaxial cable. The RF reference sent to the injector system are interferenced by the modulator noise. A high Q cavity filter is used to reduce the effect of interference.

5 Trigger for various subsystems

Many systems and devices need trigger signals that are related to the timing system directly. Examples are describe below:

5.1 Trigger for diagnostics

There are many diagnostics devices that operate with the cycle of the injector at the booster-to-storage ring transport line and the storage ring. These devices include BPM, charge monitor, radiation monitors and the turn-by-turn BPM on the storage ring. The timing accuracy in nsec is enough.

5.2 Streak camera trigger

A dual-sweep Hamamatsu C5680 streak camera has been installed on the synchrotron radiation diagnostics ports to measure bunch length and to study longitudinal dynamics in near future. The streak camera system needs low jitter RF clock for operation. The RF clock is sent to the streak camera through a high Q cavity bandpass filter and a DC-block. The injection 10n Hz are also provided for synchronization. The jitter of the RF clock is less than 2 psec in rms.

5.3 Laser system synchronization

A mode-locked Ti-Sapphire laser system with repetitive rate 79.946 Mhz was installed. The system will be used for time resolved and two-color chemical dynamics experiments. Pulse length of the laser system is adjustable form 2 psec to 60 psec. The harmonic number of the storage ring is 200, repetitive frequency of the laser system is chooses as 32nd harmonics of the revolution frequency. The storage ring can be operated in 1, 2, 4, 8 bunches and kept fully synchronized with the laser pulse. A 79.946 Mhz oven stabilized voltage control crystal oscillator (VCXO) is used to generate 79.9642 Mhz and phase locked to ring clock. The tuning range of about +/- 800 Hz can satisfy the RF tuning range from 499.659 Mhz to 499.668 Mhz at current user shift operation. The jitter can be controlled within a few pico-second.

6 System performance

6.1 Single bunch operation

Single bunch electron beam is produced by a step recovery diode (SRD) type pulser with about 1 ns in FWHM. Single bunch impurity can be controlled to less than 0.001 compared with the main bunch easily after proper setting of timing parameters, pulser amplitude and gun bias. The beam pulse is about 2 ns in length totally. There is subharmonic buncher installed between gun and the linac. Hence, the linac will produce about five to six 3 Ghz bunches. Only one or two of these bunches can be captured by the booster. The allowed timing jitter of gun trigger with respect to the ring RF is one linac rf cycle 330 ps for a single bunch operation. Revised timing system has less than 100 psec (rms) jitter, more reduction is still planned.

6.2 Multibunch operation

Gun electronics operates in start and stop manner when working in multibunch mode. The timing system provides a start signal and stop signal to gate the gun electronics. Produced beam length is the difference of the time of both pulse. The gun electronics can produce a beam with about 10 ns to 2 usec pulse length. However, since the revolution period of the booster is 240 ns, beam length larger than 200 ns is useless. Length of the bunch train has about 10 ns jittering in length, more improvement is necessary.

6.3 Mixed mode operation

The machine can operate in mixed mode and fill a single bunch in multibunch mode. Since TLS only 200 buckets, mixed mode operation cannot have many varieties. Special timing is not needed for this operation mode. After routine multibunch fill, we can fill one single bunch between the gap of multibunch.

7 Injection control and related applications

There are several control applications to aides the routine operation. Current operation mode is mainly in multibunch mode. Multibunch operation control interface accepts input parameters including start bucket address and number of the step to fill, current per bucket, and bucket advanced during injection. Current injection bucket address is changed progressively, a trapezoid shape filling pattern is obtainable. Single bunch injection has been used for machine study up to now. However, We expect to have single bunch users in coming year. A simple application supports random fill bunches of the storage ring for exotic machine study. Mixed mode is also tested. Preliminary topping-up mode injection is also tested. All of these operation modes reveal several shortcomings of the current system.

8 Problems of the existing timing system

There are several issues of the current timing system and related injection problem. Problems that are caused by timing jitter are one issue. Separate control for various timing system settings causing the operational inconvenience is another issue. Timing jitter is slightly large. The jitter will degrade performance of many applications and also increases difficulty of the machine operation. Separate control system of the storage ring and injector is not good from technical and operation point of view. Injection process automation is not easy for current system. Integration of the injector control system has been launched recently. Timing system control related problem can be solved in the near future.

9 Timing system improvement update

Efforts to reduce timing jitter is the highest priority. The goal expected to achieve is less than 100 ps (rms) timing jitter from ring RF to the beam pulse that are generated by the gun. For minimum jitter, the trigger should have a high amplitude, high slew rate, and minimum noise. Note that both high-frequency noise (arcs, thrytron impulses, nearby RF equipment) and low-frequency noise (unstablesource amplitude, 60 Hz ground loops) can dither the trigger threshold and induce jitter. Every crucial timing module as well as signal distribution will be evaluated intensively to minimize added jitter.

The project of control integration of injector is under way. Most of the timing system modules will be revised and will use new implementation to achieve desire performance.

Improper timing distribution can possibly introduce jitter on the system. Improved timing signal distribution system is also important for timing system upgrade.

10 Discussions and conclusions

The timing system update plan has been started recently to improve its performance and to satisfy new requirements. Problems of the existing system are under systematic investigation. All imperfection will be addressed in the new system. The new timing system not only solve the timing problem of the accelerator system but also will satisfy new requirement. The new timing system will provide trigger signal for diagnostics devices, streak camera trigger, and low phase noise reference signal for mode-locked laser synchronization. Bunch synchrotron signal for time-resolved experiments is also provided. Several injection control applications are available for the machine operation. Injection related control applications will be update also.

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