BEPC-II TIMING SYSTEM

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Abstract

BEPC-II is the upgrade project of Beijing Electron Position Collider and its timing system has been contructed based on EVG and EVRs. Details of the BEPCII timing system will be discussed in this paper, focusing on the realization of the fast bucket selection timing in 50Hz.

INTRODUCTION

BEPCII continues to serve the purposes of both high energy physics experiments and synchrontron radiation applications[1]. The accelerator consists of a 200 meter long linac, two transport lines for electron and position respectively, and two storage rings for colliding mode. These two rings are named as BER and BPR. Besides, a by-pass beamline is constructed at the north interaction region, to connect the two outer half rings of BER and BPR, to form the ring for synchrotron radiation, which is named as BSR. So altogether there are three storage rings to be commissioned Table 1 shows the timing related parameters of BEPC-II.

Table 1: Timing Related Parameters of BEPC-II

	Colliding mode	SR mode
Circumference	237.531m	241.129m
Energy	1.89GeV	2.5GeV
RF frequency	499.8MHz	
Harmonic number	396	402
Revolutions frequency	1.262MHz	1.243MHz
Linac RF frequency	2856MHz	
Linac repetition rate	5/3, 5, 12.5, 25, 50 (Hz)	

The timing system of BEPCII performs the following tasks:

- To ensure the electrons and positrons to be accelerated to the designed energy and injected into the storage rings, triggers in linac repetition rate should be generated for the following equipments: the electron gun, solid state amplifier and PSK, positron source, 16 sets of modulators of klystrons, and injection kickers. These equipments must work at the designed and very accurate timing sequence. Usually the repetition rate of BEPCII linac is set to 50Hz, 25Hz or 12.5Hz during three commissioning stages [1]. However, 5Hz and 5/3Hz have also been applied for special purpose of radiation background control.
- To ensure beam monitor equipments acquisite beam signals at the right time and right rate, triggers in linac repetition rate should be provided to beam position monitors in linac, transport lines and the Libera BPMs in storage rings.
- Providing revolution clocks to spectrometer (BESIII), synchrotron radiation experimental stations, transverse and longitudinal feedback BPMs and trun-by-turn BPMs in storage rings.
- Providing special synchronizing clocks for beam instrumentation, such as the 9.996MHz to linac BPM controllers and 99.96MHz to beam length measurement equipments.
- Top-off injection control, which tells weather to inject or not, to keep the beam current in the storage ring between high and low limits.
- Fast bucket selection in repetition rate, which tells which bucket should be injected. This task has been accomplished half by beam instrumentation system and half by timing system.
- Some interlocks among equipments.

Table 2: Timing Related Parameters of BEPC-II

	Delay resolution	RMS jitter to ring RF clock
Injection kickers	2ns	<100ps
e-Gun	10ps	<35ps
Other triggers	10ns	<200ps
Clocks		<100ps

Table 2 shows the requirements on timing system performance.

TIMING SYSTEM ARCHITECTURE

BEPCII timing system has been constructed based on the Event Generator (EVG) and Event Receivers (EVR), which are products of Micro Research Finland Oy.

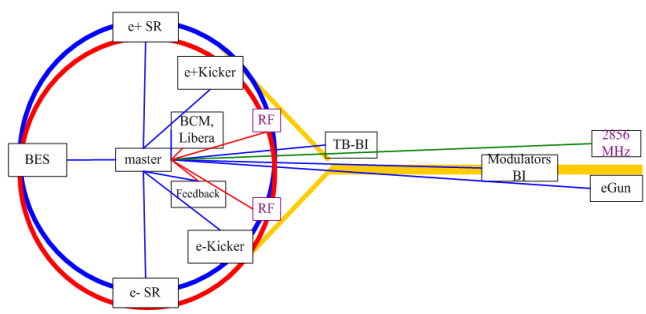

Figure 1: Layout of BEPC-II timing system stations.

The EVG creates and sends out timing events and clocks to an array of EVRs, and all operations on the EVG are synchronised to the event clock which is derived from an externally provided RF clock [2]. The EVRs

recover the clock signal from EVG and generate an event clock that is phase locked to the EVG event clock and thus to the RF reference. EVRs also convers event codes to hardware outputs [3].

We use the sequence RAM of EVG to send out events which are taken by the EVRs to generate repetition triggers. The distributed Buses of EVG are used to generate synchronizing clocks to BPMs, etc.

The event clock rate of BEPC-II timing system is selected as 99.96MHz, i.e. ring RF clock divided by 5. Therefore, timing resolution of EVRs is 10 nano-seconds. Gun-TX module is used on gun triggering to get a resolution of 10 pico-seconds on delay adjustment, and TD4Vs are used on Injection Kickers to get a resolution of 2ns.

The klystron timing station and the e-Gun timing station have been working since Feb. 2006 to support the commissioning of linac. Other 9 timing stations have been settled down before the storage ring commissioning in Nov. 2006. In 2007 and 2008, two more stations have been added, and there are altogether 2 EVG-200 and 18 EVR-200 operating on-line. In this summer, two more stations, longitudinal feedback timing station and SR experiments timing station, are under construction.

Figure 2 shows the logic connections of BEPC-II timing system

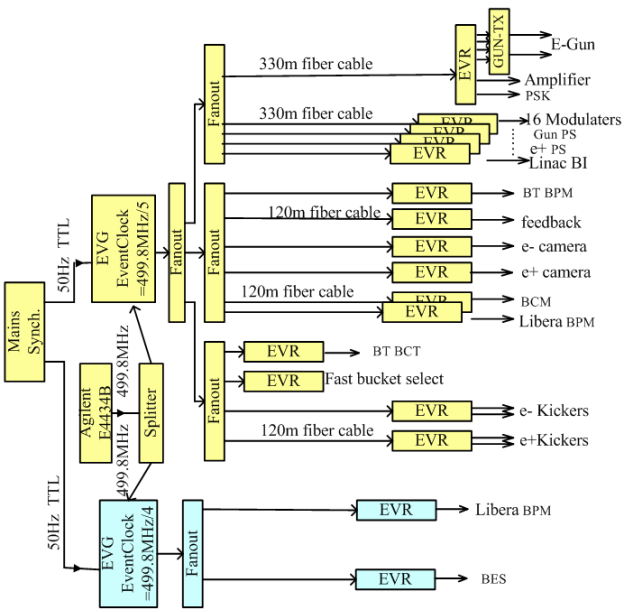

Figure 2: Logic connections of BEPC-II timing system.

Special Hardware

Special OTB modules had been made in 2005 for transporting trigger signals in the 200 meter long gallery of linac klystrons. Modifications to GUN-RC had been done to generate NIM level outputs and give better cooling effect.

We have had a special module made for generating revolution frequency. This module takes 499.8MHz as input, and uses CPLD to generate 1.262MHz for colliding mode and 1.243MHz for SR mode. This module has been applied to 4 timing stations.

Applications

An application using LabView and shared memory of EPICS has been developed to control and monitor the storage ring RF signal generator. Some station notation language programs have been developed for providing real-time data, such as injection patterns and operating mode needed by the programs of other groups.

OPIs using MEDM and EDM have been created for linac klystron timing, e-Gun timing, injection kicker timing, liberal BPM timing.

The most frequently used application of timing system is the top-off injection control program.

A special record support has been designed and realized for fast bucket selection.

BUCKET SELECTION

The BEPCII has 396 buckets in electron and positron storage rings (BER and BPR) for colliding mode, and 402 buckets in outer ring (BSR) for SR mode. Any bucket is required to be selectable. In this section, we describe the bucket selection method only for colliding mode which has 396 bucket in the ring. For SR mode, the method is similar.

Event Clock

The event clock is the basic clock working both on EVG and EVR. All operations on the EVG and EVR are synchronized to the event clock which is derived from an externally provided clock reference [2], which is the storage ring RF clock in our case.

In EVG the input RF clock can be divided by 4, 5, 6, 8, 10 or 12, to generate the event clock. We select 5 as the divider for our timing system, i.e. the event clock is 99.96MHz.

Any Bucket Selectable from Event Sequencer

The event sequence is one of the event sources of EVG. In the EVGs there are two event sequencers, which are Random Access Memory. The 8-bit event codes are stored in the RAM table. We set the sequencer clock register as 7, which means the sequencer clock is 499.8MHz/5/7.

7 is the common factor of BEPC-II linac RF frequency and storage ring RF frequency. And 5, value of the divider, is a prime number, and is the only prime number among the possible values for divider in EVG-200.

Bn = MOD (Rn * 35, 396)

Where Rn is the sequencer unit number, and Bn is the bucket number. Using this formula, any unit from 0 to 395 in the sequencer can be mapped to one and only one bucket in the storage ring.

The above formula can generate a table from sequencer unit to bucket number. It is transformed to a table mapping bucket number to sequencer unit, and this table is used in the bucket selection record support which was developed specially in BEPC-II.

Therefore every bucket can be selected by EVG.

Fast Bucket Selection

The Beam Instrumentation Group developed bunch current monitor (BCM) systems for electron ring and position ring. The BCM system includes FADC and reflective memory. One of the reflective memory is used in bucket selection timing station, alone with an EVR, to do the fast bucket selection.

A new record support, named bkt has been developed. More than 30 new fields have been created for this record support.

TOP-OFF INJECTION CONTROL

The top-off injection control is developed using SAD, which is a script language developed by KEK.

The top-off injection control application has the following features:

- applying top-off injection control loop or one-run injection control logic.
- Set the bucket selection algorithm in IOC: the smallest the first, or to inject if the bucket is less than the limit by the sequence defined in the injection pattern files.
- Load injection pattern files and set parameters of the special record for bucket selection
- Some interlock logics, etc.

The OPI of BEPC-II top-off control is shown in Figure 3.

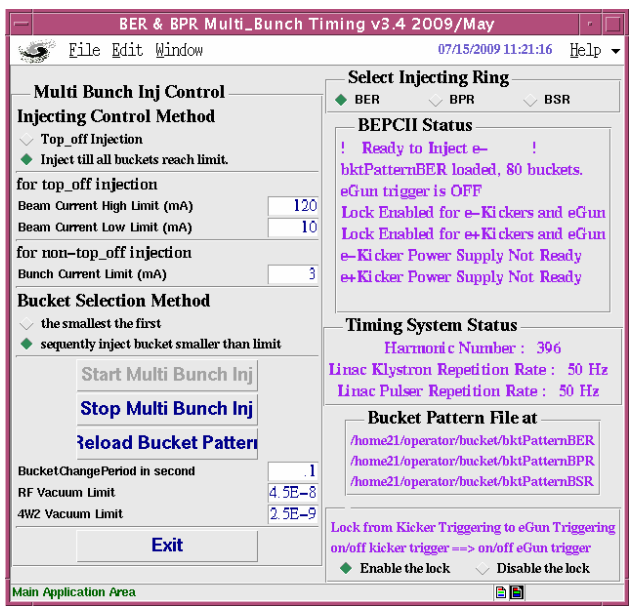

Figure 3: Top-off injection control OPI.

PERFORMANCE

Performance has been monitored at test bend, linac and storage ring. Figure 4 shows the measurement result taken in April 2007, in which the purple signal is from ring RF signal generator, the green signal is from BCT of the electron transport line. The StdDev value is around 15 pico seconds and it includes the jitter of the whole timing system from EVG to EVR until GUN-TX and GUN-RC.

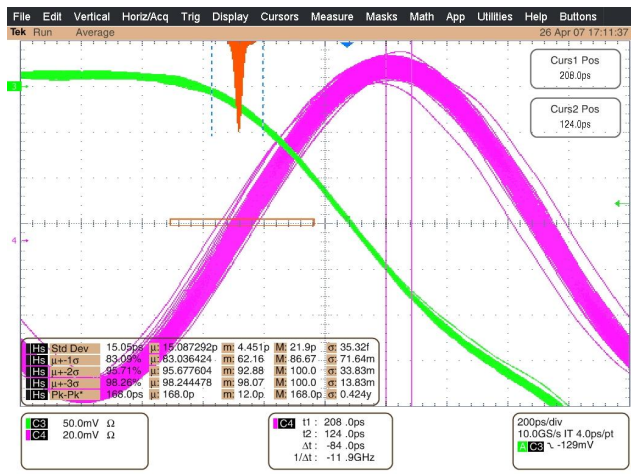

Figure 4: Jitter measurement.

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