# A New Timing System for NSRL

Pengjie Zhang Qi An Shubin Liu Yanfang Wang
Fast Electronics Lab, Modern Physics Dept. University of Science and Technology of China
(Mailbox 4, HeFei, AnHui, 230027 , P. R. China)

**Abstract**

The timing system is an important part of the NSRL control system. Its main function is to provide synchronization trigger signals for the LINAC (which includes the Electron-Gun, the Microwave Excitor and six Modulators), the Switch Magnet, the Septum, the Kicker and the beam diagnosis system. The former Timing System[1] only allowed injection in full bunch mode, the new Timing systems provide more precise and stable trigger signals, it will allow injection in both full bunch mode and single bunch mode.

The New Timing System consists of two parts: Fast Timing System and Slow Timing System. The Fast Timing System provides trigger signals for the Electron-Gun and the Kicker, the jitters of these trigger signals are measured to be less than 100pS (Sigma < 30pS) [2] with respect to the storage ring RF. The time delays of these signals can be programmed with a step of 50pS. The fast Timing System also provides period pre-trigger signal for LINAC and injection. The Slow Timing System provides trigger signals for other devices The timing delay of each trigger signal can be adjusted in the full range of its period.

## 1 Introduction

The NSRL synchrotron radiation facility has two main components: an 800MeV storage ring and a 200MeV linear accelerator (LINAC). The LINAC and injection devices are operated in pulsed mode. The maximum repetition rate of the LINAC is 100Hz, and minimum injection period is 1s. The LINAC and injection system are composed of various transient devices, such as the Electron Gun, Modulators and Kickers, etc. At the end of the LINAC, a switch magnet is installed. In each injection cycle, the magnet delivers one beam bunch to the injection system and several bunches to beam analyzer for energy measurement purpose. Injection into the storage ring is accomplished via a septum magnet and three fast Kickers. The function of the Timing System is to provide synchronization trigger signals for the LINAC, the switch magnet and the injection system, so that a bunch will be fully accelerated in the LINAC, transported to the injection point at the right time and injected into the storage properly.

In full bunches injection mode, the pulse width of the LINAC output beam is 0.2-1.0μS, after fully accelerated in LINAC, it is transported to the injection point, and is injected into the ring sequentially. The bunches in the storage ring have a revolution period of 0.22μS, if the pulse width is 1.0μS, one ″Multi-Turn Injection″ will contain about four turns. The Electrons will be distributed into 45 buckets. In single bunch injection mode, the LINAC output beam duration is about 2 - 3nS. The successive injection beams will be filled in the same bucket, so the trigger signals of the electron gun and kickers must be synchronized to the Radio Frequency (RF) of the storage ring, and the injection period must be integral times of the revolution period of the electron in the Storage Ring. In single bunch injection mode, the timing system must use the RF signal as the time reference (Clock). While in the full bunch mode, it is not a necessary. In the full bunches mode, the electron beam is much longer than single bunch mode, so the timing requirements are much lower than in single bunch mode. The new Timing system will provide more precision and stable trigger signals, and will allow the facility to inject both full bunches mode and single bunch mode.

## 2 Timing requirements

Table 1 shows the timing specification of the trigger signals in the New Timing System.

According to the timing resolution, the trigger signals can be classified into three catalogs. The trigger signals for E-GUN(I) and the Kicker are in the first catalog, and their resolutions are less than 1nS. We call them ″Fast Timing Signals″. The second catalog includes the trigger signals for E-GUN(II), six Modulator, Micro-Wave Excitor and Switch Magnet synchronization. The resolution of these signals should be less than 0.1μS, and their repetition rate equal to the LINAC's. The rest trigger signals are concerned with injection, their timing resolution should be less than 1.0μS, and their period is the same as the injection cycle. Trigger signals in the second and the third catalogs are entitled ″Slow Timing Signals.″

E-GUN(I) and E-GUN(II) are the trigger signals of the electron gun, E-GUN(I) is used in the single bunch injection mode, while E-GUN(II) in the full bunch mode. In the full bunch mode, the beam duration is the same as the width of the trigger signal, so the pulse width of the E-GUN(II) can be adjusted from 0.1μS to 10 μS with a step of 0.1μS. In the single bunch mode, the jitters of the E-GUN(I) and kicker should be less than 500pS with respect to the storage ring RF, otherwise the electron from the LINAC may enter the buckets adjacent to the ″main bunch″, and form ″Satellite bunches″.

Because of the non-uniform transmission delay and internal delay of the each device, the trigger signal should have sufficient range and resolution to satisfy different cases.

## 3 System description

The new timing system consists of two parts: fast timing system and slow timing system. Figure 1 is the schematic Diagram of the new timing system.

Table 1  Timing specifications

| Device | Period | Range | Resolution | Rise time | Jitters | Pulse Width |
|---|---|---|---|---|---|---|
| E-GUN(I) | 2/1/0.2… 0.02 /0.01S | 100mS | 100pS / 5ns | < 500pS | < 500pS | 2uS |
| Kicker | 200mS~2S | 2S | 100pS / 5nS | < 500pS | < 500pS | 4uS |
| Septum | 200mS~2S | 2S | < 1.0uS | 50nS | 5nS | 4uS |
| S.M. RESET | 200mS~2S | 2S | < 1.0uS | 50nS | 5nS | 0.5S |
| Beam Analyzer | 200mS~2S | 2S | < 1.0uS | 50nS | 5nS | 4uS |
| E-GUN(II) | 10~100mS | 100mS | < 0.1uS | 50nS | 5nS | 0.1~10uS |
| Modulator(6) Micro Wave S.M. SYN | 10~100mS | 100mS | < 0.1uS | 50nS | 5nS | 4uS |

*3.1 Fast timing system*

The fast timing system provides the trigger signal for electron gun (single bunch mode: E_GUN(I)) and the kicker, it also generates the pre-trigger signal for LINAC(L-S) and repeats signal for injection(K-S). The fast timing system consists of Clock Driver, Repeat Signals and low frequency Clock Generator and three ″Fast Timing Signals″ generators.

Figure 2 is the schematic layout of the ″Repeat Signals & Clock Generator″. Repeat signals are the pre-trigger for the LINAC(L-S) and the injection(K-S).

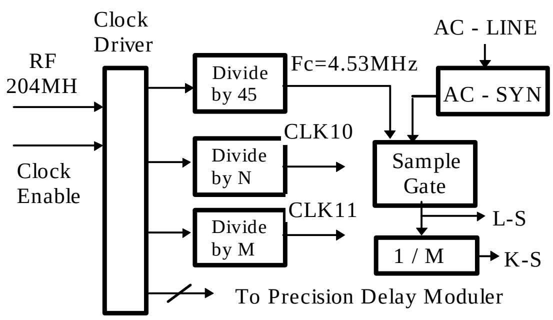


Figure2: schematic of the ″Repeat Signal & Clock Gen.″

First, the revolution clock is obtained by dividing the ring RF by the ring harmonics (45), then the revolution clock samples the AC-SYN, and get the LINAC pre-trigger signal L-S. The injection repetition period is M times of the LINAC period. Pick one L-S pulse every M cycle of L-S will get K-S. The low frequency clocks (Clk10, Clk11), which will be used in the ″Slow Timing system″, are also generated by dividing the ring RF.

The ″Precision delay module″ generates the ″Fast timing signal″. It has a very fast binary counter, whose frequency is 204MHz (Ring RF), and a programmable delay generator with a resolution of 50pS. There are three Fast Timing Signals, one for kicker and one for E-GUN(I), the other one is spare. They are transmitted by optic fiber.

The fast timing system is designed with ECL (orECLinPS) family devices.

*3.2 Slow timing system*

Slow Timing System generate all the ″Slow timing signals″. It has two parts: LINAC Timing Subsystem and Injection Timing Subsystem. LINAC Timing Subsystem is installed in the LINAC control room, as shown in figure 1 (which is in the dotted line rectangle). It provides trigger signal for electron gun (E-GUN(II)), six modulators, micro wave excitor, and one spare signal. The Injection Timing Subsystem and the fast Timing System are installed in the central control room. The clock (CLK10) and the LINAC repeat signal(L-S) are transmitted differentially from central control room to LINAC control room with twisted pairs. There is a local OSC in the LINAC Timing Subsystem, which make it possible to run LINAC separately.

The slow trigger signals are transmitted by twisted pairs. At the end of each transmission line, an optic isolator is installed to protect the timing system from EM influence. The slow timing system is designed mainly with Field Programmable Gate Array (FPGA).

*3.3 Control of timing system*

Two PCs have been introduced to control the Timing System. One is installed in the central control room, the other in the LINAC control room. They are connected through a serial link. The operator in the central control room can control the whole Timing System. The Timing System can link to the real-time net when upgrading the NSRL Control System. Software is designed with LabVIEW for Windows, and it has a friendly interface. All the timing parameters can be set and recorded. The timing system is packed in three cases, one case is installed in the LINAC control room and the other two in central control room. A PC-ISA bus interface card is plug in the one of the ISA-bus slots, and it is connected to the timing circuit with a ribbon cable. The ribbon cable is shield with copper net to protest EM noise.

## 4 System performance

After the New Timing System was set up, performance had been tested. The jitters of ″Fast Trigger Signal″ are measured to be less than 100pS (and RMS < 30pS) with respect to the storage ring RF, and its resolution is 50pS, much better than the requirements (shown in table 1). The jitters of the ″Slow Trigger Signal″ are less than 1nS with respect to Electron-Gun trigger.

**Acknowledgments**

We would like to thank Prof. G.C Wang, Prof. Y.J. Pei and Prof. S.Q. Liu for their help.

**Reference**

[1] C.Y Yao et al., Proc. Intl. Conf. Synchrotron Radiation Applications, Hefei, China, 1989. P241

[2] P.J Zhang, ″New Timing System Test Report″, Modern Physics Dept. Univ. of Sci. & Tech. of China, 1997.

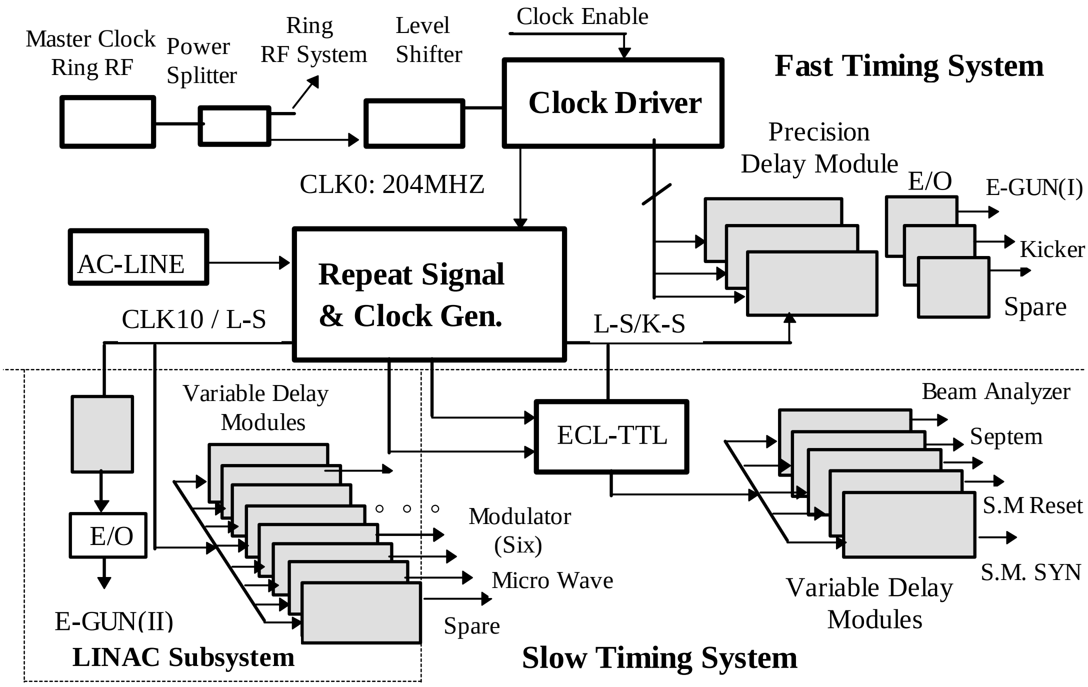


Figure 1: Schematic Diagram of the New Timing System