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TIMING SYSTEM AT THE CANADIAN LIGHT SOURCE

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Abstract

The Canadian Light Source (CLS) is a third generation 2.9 GeV synchrotron comprised of a 250 MeV linear accelerator (LINAC), a full energy booster, and a storage ring with 13 insertion devices and 22 operational beamlines. The synchronization required to produce, transport, accelerate and inject electrons into the storage ring is achieved using a timing system that was designed and built by the CLS. This paper provides a detailed overview of the history of this system and its operational performance.

OVERVIEW

The timing system, shown in Fig. 1 [1], is crucial as it supplies the trigger signals necessary to synchronize operation of all components required to inject current into the storage ring. These operations include firing the electron source, accelerating the electrons, injecting into the booster, ramping the booster, extraction from the booster and injection into the storage ring. Signals from the timing system are also used to synchronize data collection from diagnostic and experimental equipment.

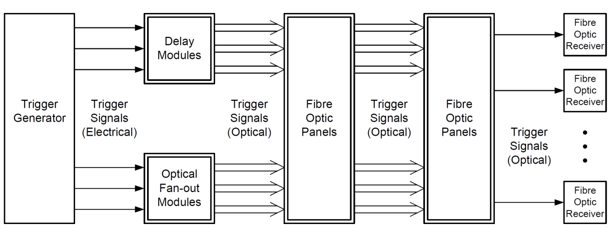

Figure 1: Simplified timing system block diagram.

HARDWARE

Trigger Generator

At the core of the timing system is the trigger generator which produces all of the trigger signals necessary to support operation and monitors the 500 MHz master oscillator and the timing system for interlock conditions.

The first trigger generator was called the Trigger Generator Module (TGM). The TGM, described in Fig. 2 [2] was a double width VXI module that was controlled using an on-board 8051 microprocessor via RS-232 which went into operation in 2001.

The second version of the trigger generator, called the Trigger Generator Unit (TGU), was introduced to deal with component obsolescence. The TGU, described in Fig. 3 [3], went into operation in 2012, and is currently being controlled using a GE Fanuc VMIVME2536 digital I/O VME module [4].

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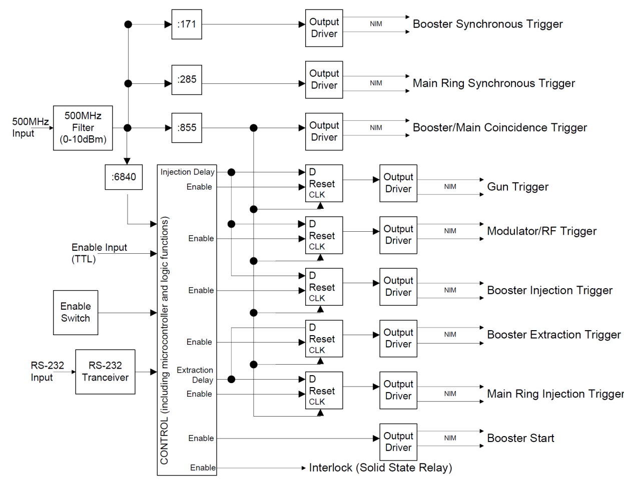

Figure 2: Trigger Generator Module schematic.

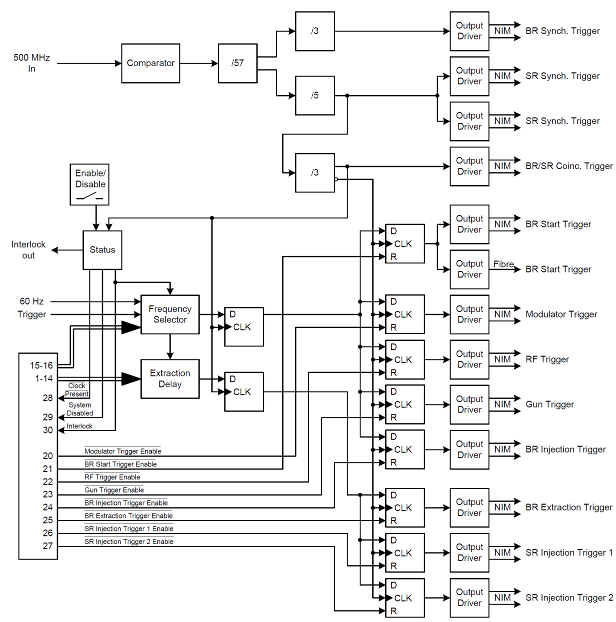

Figure 3: Trigger Generator Unit schematic.

The control architecture and a number of components were changed between the TGM and the TGU. The operational theory and the supported functionality remains the same, with the exception of some minor improvements that were derived from operational experience. The trigger generator produces three different subsets of signals; clock signals and injection and extraction triggers.

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The clock signals are generated using the 500 MHz master oscillator input and the revolution frequency of both the booster ring (BR) and the storage ring (SR). The harmonic numbers are 171 and 285, respectively for the booster ring and the storage ring. The harmonic number is the ratio of the radio-frequency (RF) accelerating frequency to the particle's revolution frequency, and defines how many times the RF system completes a cycle for each revolution of a particle. The greatest common factor between the harmonic number for the BR and the SR is 57. Therefore the 500.04 MHz clock signal is divided by 57 to get 8.7719 MHz [5]. The clock signals are then derived as follows:

$$\text{BR Synchronous Trigger} = \frac{8.7719\ MHz}{3} = 2.9239\ \text{MHz}$$

$$\text{SR Synchronous Trigger} = \frac{8.7719\ MHz}{5} = 1.7544\ \text{MHz}$$

$$\text{BR/SR Coincidence Trigger} = \frac{SR\ Synchronous\ Trigger}{3}$$

$$= 584.80\ \text{kHz}.$$

In order to inject into specific buckets in the storage ring, all injection and extraction trigger signals are synchronized with the BR/SR coincidence trigger using D-flip flops, to eliminate delay and timing jitter experienced with slower components.

In order to provide sufficient time to ramp the booster a delay is applied to the extraction triggers. This delay can be set in steps of 50 µs and can vary in length by up to 500 ns [3].

The triggers are active when the 500 MHz clock is present and when each individual trigger has not been inhibited. The injection trigger signals include the BR Start, Modulator, RF, Gun and BR Injection triggers. The extraction trigger signals include the BR extraction and the SR injection triggers [5]. The names assigned to each of these triggers describes the intended use.

The trigger signals are distributed via a fiber optic network that consists of delay generator and optical fan-out modules, distribution panels and fiber optic repeaters and receivers.

Delay Modules

Delay modules support adjustment of trigger timing relative to a specific trigger signal. The original timing system made use of Highland Technology V951 VXI delay modules [6] which have both electrical and optical outputs. Many of these modules are still in use today.

Optical Fan-Out Modules

Optical fan-out modules support expansion of the system without adding more complex programmable hardware. The optical fan-out NIM modules [7] designed and built at the CLS are used to split a single NIM electrical signal into four optical outputs.

Fiber Optic Repeaters and Receivers

A fibre optic cable network is used to distribute the optical trigger signals around the facility using 62.5/125 µm multi-mode fibre. Various fiber panels and fibre optic repeaters and receivers are used to transmit the signals. The fiber optic repeaters and receivers are used to convert optical signals to the appropriate electrical signal (NIM, TTL, LVTTL, ECL, PECL) based on the requirements of the equipment being triggered. Some of the receivers are incorporated into devices, such as power supplies, but the majority of these components are stand alone units. All of the fiber optic repeaters and receivers used at the CLS were designed and built on site.

SOFTWARE

The control software for the timing system enables communication with the trigger generator unit and the delay modules. Operators can remotely inhibit a trigger being produced by the trigger generator, disable the output of a delay module, and configure unique delays for each delay module output.

This software has evolved over the years to include group delays that isolate the timing associated with the linac, booster and storage ring. The timing system software supports a variety of features, including configuring timing rows to dictate the length of the bunch train and which storage ring buckets will be filled with each shot. The timing system software also incorporates injection efficiency and top up logic.

PLANNED HARDWARE ENHANCMENTS

Although the GE Fanuc VMIVME2536 digital I/O and the Highland Technology V951 delay modules have served this system well over the years, they have reached end of life and the manufacturers are no longer willing to service or repair these modules. The CLS has been migrating away from VME and VXI so we are actively working to replace the existing VXI delay modules with Stanford digital delay generator [8] units. The new delay generator units are being deployed with new electronics designed and built at the CLS that converts the signal from the new digital delay generator units to optical and NIM outputs. We also intend to incorporate a stand alone CLS designed digital I/O unit which will use a PoLabs single board controller (SBC) [9] to support communication with the trigger generator.

CONCLUSION

The CLS timing system has been in operation since 2001 and it has proven itself to be stable and robust. This system has withstood the test of time with flexibility that has allowed growth and enhancement where required based on operational requirements. The hardware enhancements currently being undertaken will ensure that we are able to maintain the CLS timing system and enjoy many more years of operation.

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