SYNCHRONIZATION SYSTEM OF SYNCHROTRON SOLEIL

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Abstract

This document presents the synchronization system deployed at the SOLEIL synchrotron facility. It explains the main technical choices and the results.

INTRODUCTION

The SOLEIL synchrotron is a 2.75 GeV third-generation light source under commissioning near Paris, France, which will serve the international community in many fields of science. The project was launched in January 2002 and construction started in August 2003. Today, the 100 MeV LINAC injector and the BOOSTER have been fully commissioned, and the STORAGE RING is being optimized. Around 10 beam lines have already received light, and the first users are expected by the end of 2007.

To bring electrons from the LINAC to the storage ring, many instruments must be triggered synchronously to the electron beam. The synchronization system (timing system) provides the time base needed for this purpose. More than a simple clock distribution system, it is a real network, broadcasting clocks and data throughout SOLEIL.

REQUIREMENTS

There are different types of requirements for the synchronization of the synchrotron light sources. The main task is to manage the various timings in the injection process from the LINAC gun to the STORAGE RING via the BOOSTER. All signals triggering the pulsed magnets must be synchronized to electron pulses. This is why the clocks derive from the RF (352MHz). Beside this injection process, synchronization must also trigger various diagnostics, such as Beam Position Monitors (BPMs) and current transformers following the electron pulses throughout all the machines. The timing resolution must be one (or a few) RF bucket duration(s) (2.8 ns at SOLEIL).

Other requirements that require less timing precision are related to triggering of the ramped components, such as the BOOSTER power supplies and the BOOSTER RF. These injection triggers must be recurrent at 3Hz. Furthermore, some instruments, such as the pulsed elements and the LINAC, must be synchronized to the mains at 50 Hz, for better reproducibility.

The synchronization system must be able to deliver the machine clocks (one turn frequency) for the BOOSTER and the STORAGE RING, in order to trigger the BPMs [1] in their turn-by-turn mode. These clocks are also needed for bunch-to-bunch current monitoring, single bunch purity measurements, and single bunch tracking for specific experiments.

The synchronization system must be able to schedule certain specific actions, for instance, sequences for various STORAGE RING filling modes .

HARDWARE ARCHITECTURE

The architecture of the synchronization system is depicted in figure 1. The main components are a CENTRAL system and cPCI LOCAL boards. The CENTRAL system is connected to LOCAL boards through an optical network . They are also connected to the ethernet network for TANGO [2][3][4] supervision.

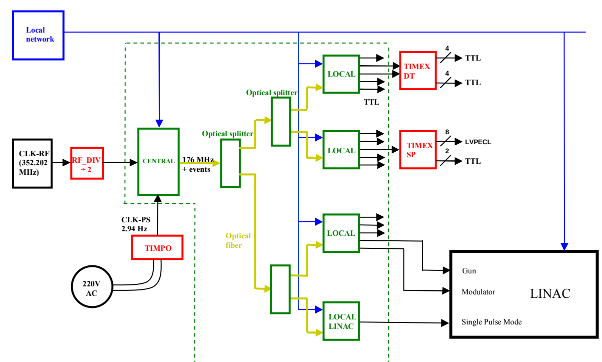

Figure 1: SOLEIL synchronization system architecture.

The CENTRAL system is synchronized to the RF and to the injection / extraction frequency (3Hz). It generates frames containing the BOOSTER clock, the STORAGE RING clock, and events [5][6]. Up to 255 events may be defined by the user. Event 2 is used to trigger equipment (LINAC, kickers ...), which injects electrons into the BOOSTER. Event 3 is used to trigger equipment which extracts electrons from the BOOSTER and sends them into the STORAGE RING. The delay between event 2 and event 3 may be adjusted inside the CENTRAL, thus allowing control of the energy of extracted electrons and their insertion into the STORAGE RING bunch train.

The LOCAL boards receive the optical frames. Each of the 8 outputs of a LOCAL board is configured to trigger upon a given event. After a delay, an electrical TTL pulse is generated, which triggers the instrument. These delays are used to compensate offsets due to distances between instruments and their latencies. Events and delays are user-configurable for each output. Furthermore, LOCAL boards deliver two clocks: one is the BOOSTER revolution frequency and the other is the STORAGE RING revolution frequency.

A special LOCAL board has been developed for the LINAC. It is more accurate (80ps resolution, jitter < 100ps rms), thus allowing triggering of the LINAC single-pulse mode for reaching an RF bucket.

To satisfy all the requirements of SOLEIL, we use duplication boards (TIMEX_DT) and electrical conversion boards (TIMEX_SP), especially for Beam Position Monitors (BPMs). A TIMPO board uses 50Hz from the mains to generate the injection / extraction frequency (50/17 Hz).

This system was fully specified by SOLEIL. The CENTRAL and LOCAL boards were designed by Greenfield Technology [7]. TIMEX_DT, and the TIMEX_SP and TIMPO boards were designed by SOLEIL.

SOFTWARE ARCHITECTURE

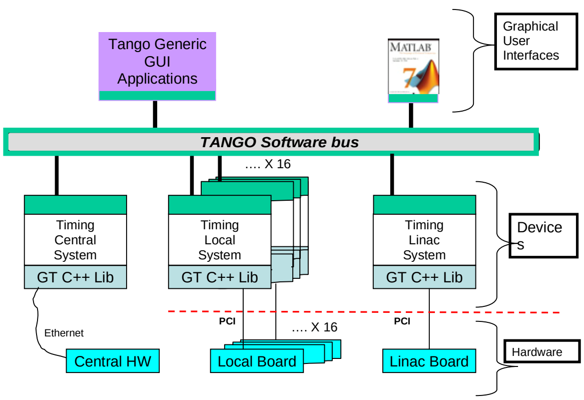

Figure 2: Software architecture.

Control of the SOLEIL synchronization system is based on the Tango Framework. Three Tango devices were developed: TimingCENTRALSystem, for controlling the CENTRAL; TimingLOCALSystem, for the LOCAL boards; and the TimingLinacSystem, for the special LOCAL board used on the LINAC. There are 16 instances of the TimingLOCALSystem, as many as there are LOCAL boards.

The CENTRAL is accessed through the ethernet network, whereas the LOCAL boards are inside a CompactPCI crate and use a PCI driver. The three devices use a C++ library from Greenfield Technology.

With these three Tango devices, one can access all the functionalities of the synchronisation system, i.e. setting delays in the CENTRAL and LOCAL boards and setting the event to subscribe on the LOCAL boards. A Matlab [8] application was written by the beam dynamics team to facilitate and automate the injection / extraction process. This application "talks" to the Tango devices.

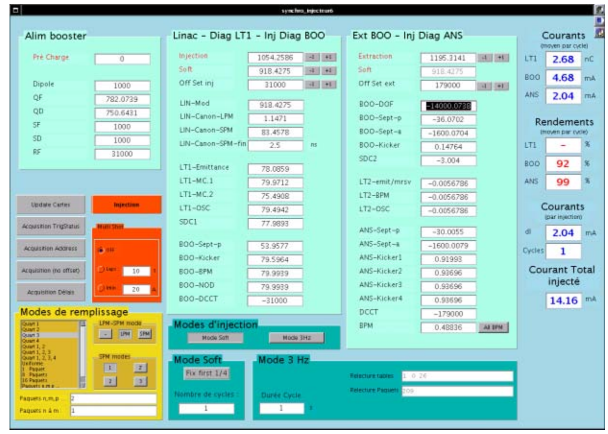

Figure 3: Matlab timing manager.

RESULTS

Today, a CENTRAL system, 16 LOCAL boards, 1 LOCAL LINAC board, 22 TIMEX_DT, and 80 TIMEX_SP are used, allowing the triggering of a few hundred instruments. Triggers are configured in steps of 5.64ns and jitter is less than 100ps rms. In single-bunch operation, every STORAGE RING bunch is individually targeted. In the long-pulse mode (104 bunches), every quarter of the STORAGE RING is successfully filled.

The synchronization system allows the machine to work routinely in several filling patterns: multibunch (usually three-quarters of the ring), single bunch, and eight-bunch mode.

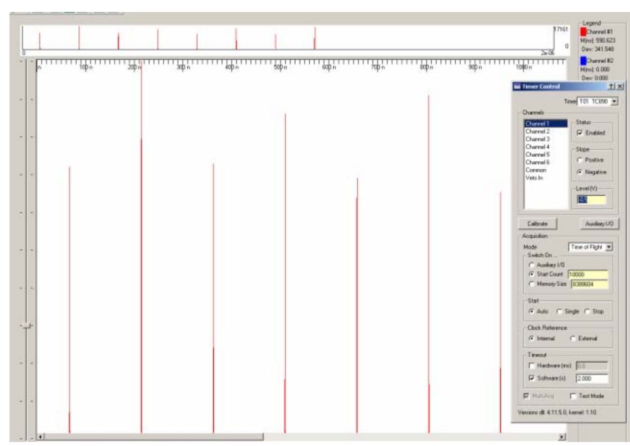

Figure 4: Purity measurements, 8-bunch mode.

CONCLUSION

SOLEIL's synchronization system has been running for more than a year with no major difficulty. Upon completion of an update now in progress, this system should be ready to provide additional functionalities needed for the top-up injection. The next challenge will be synchronization of beam lines to the electron bunch inside the STORAGE RING. An extension of the current system and some specific developments are under study in order to achieve this goal in 2008.

REFERENCES

[1] N. Hubert and al, Synchrotron Soleil, "The Soleil BPM and orbit Feedback Systems", DIPAC42007.
[2] The TANGO framework, http://www.esrf.fr/Infrastructure/Computing/tango/
[3] A. Buteau, P. Betinelli-Deck, Synchrotron Soleil, "Status of the SOLEIL Control System", ICALEPS'05.
[4] A. Buteau, N. Leclercq, Synchrotron Soleil, "Status of the SOLEIL Control System", ICALEPS'07.
[5] Franck, R. Lenkszus and Robert Laird, "Advanced Photon Source Injection Timing system", ICALEPCS'95.
[6] T. Korhonen, PSI, "Review of Accelerator Timing System", ICALEPCS'99.
[7] http://www.greenfieldtechnology.com/
[8] Matlab, http://www.mathworks.com/