MRF timing system design at SARAF

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MRF TIMING SYSTEM DESIGN AT SARAF

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Abstract

CEA Saclay Irfu is in charge of an important part of the control system of the SARAF LINAC accelerator based in Tel-Aviv. It's including among other the control of the timing system (synchronization and timestamping). CEA has already installed and used successfully timing distribution with MRF on test bench for ESS or IPHI, so it has been decided to use the same technologies. The reference frequency will be distributed along the accelerator by a Rhode & Schwartz oscillator and the UTC time will be based on a Meridian II GPS, these 2 devices, to synchronize MRF cards, will be connected to the Event Master (EVM) card which is the main element of the timing system architecture.

The MRF timing system [1] thanks to an optical fiber network allows to distribute downstream and upstream events with a µs propagation time. Currently we are working on development to also use it for the machine protection system of the accelerator.

In this paper I will present the hardware used, timing architecture, developments and tests we have performed.

INTRODUCTION

SNRC and CEA collaborate to the upgrade of the SARAF accelerator to 5 mA CW 40 MeV deuteron and proton beams (Phase 2) at 176MHz. The timing system is a key part of the accelerator as the machine protection system. The CEA control team is in charge of them and we have selected the MRF products to provide an integrated solution.

TIMING SYSTEM ARCHITECTURE

Overview

The SARAF timing system main functionality is to distribute:

- Trigger events
- Timestamping
- Reference frequency

The main EVM is in charge of distributing these 3 above topics. This EVM generates the trigger events from sequencers, multiplexed counters or external inputs. The timestamping will be defined by the Meridian 2 GPS [2] that distributes the UTC time by NTP and the Pulse Per Second signal (PPS). The PPS consists of a signal sent to the EVM to increment the second of the timestamp with an accuracy of 10ns. The GPS also distributes a 10MHz with ultra-low phase noise to the master oscillator that distributes itself the reference frequency (176MHz) of the accelerator to the EVM and to the RF devices.

Propagation Time

For machine protection system or PostMortem analysis, we use the upstream propagation of events. For machine protection system, the event propagation time associated to a machine issue is an important point to be able to ensure that the system performance is suitable to the requirements. To test this feature, we built a test bench to measure the propagation of an event. The principle of the test is generating a signal on one input of an EVR, and measuring the time for the system to generate an output signal on any other EVR of the bench (see Fig. 1). On this test bench, the propagation time is about 700µs for each additional floor of EVM fan-out.

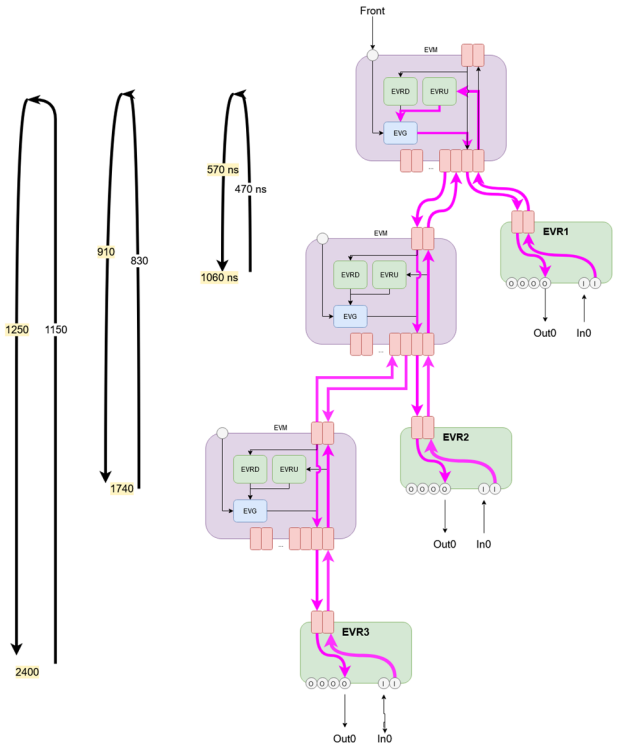

Figure 1: Test bench and result of event propagation.

Topology

The main topology is represented in Figure 2. Due to the propagation time described in the previous paragraph, we need to have as less as possible floors of EVM fan-outs. Therefore the distribution has been divided into 3 distinct parts: Injector, MEBT and SCL.

The Injector EVR has a direct link to the main EVM because it has an important role in protection and has to receive trigger events as soon as possible.

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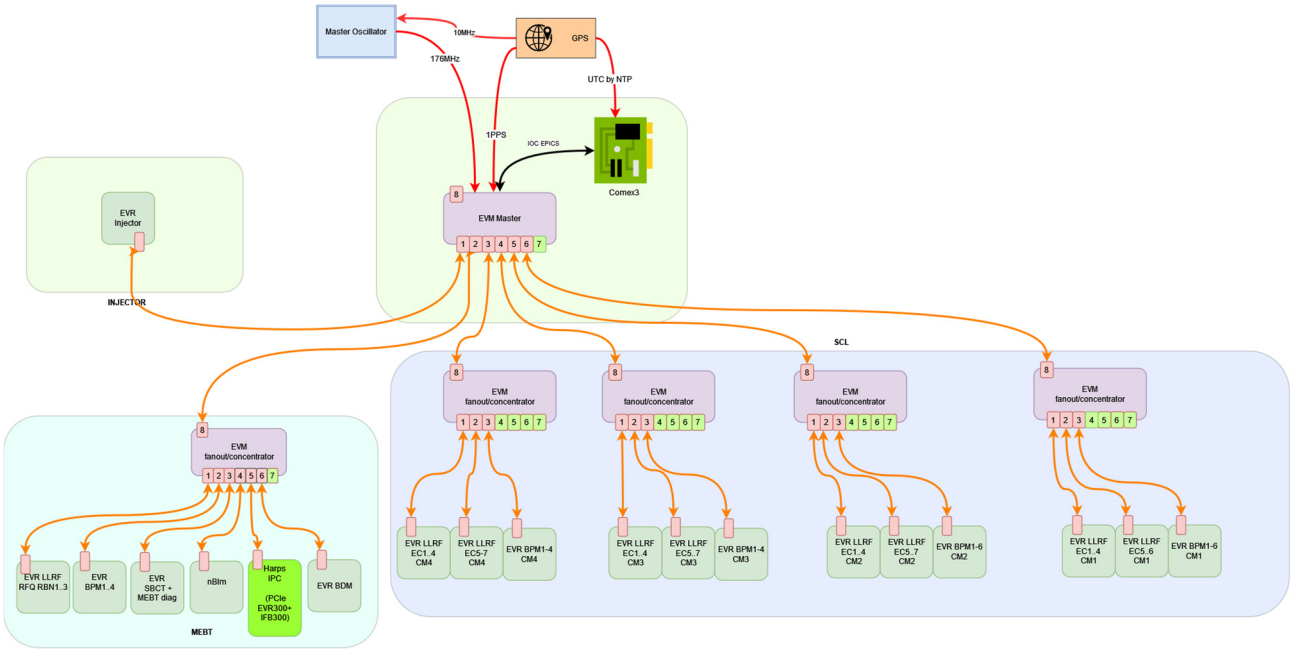

Figure 2: SARAF LINAC MRF Timing topology.

The MEBT (Medium Energy Beam Transport) part is controlled essentially by one EVM fan-out that will only be used as fan-out during beam operation. However for RF conditioning, it will produce events for RF to let cavities as independent as possible.

For the same reason in the SCL (Super Conducting Linac) part, each cryomodule will have a devoted EVM fan-out.

HARDWARE PLATFORM

SARAF that mainly rely on MTCA.4 platform with NAT R2 crate, NAT-MCH-PHYS80 and NAT-MCH-RTM-COMex-E3 [3], uses for the timing system the MTCA-EVM-300 and the MTCA-EVR-300U provided by Micro-Research Finland (MRF), which are already being deployed for the injector part. When an Industrial PC runs EPICS IOCS, the PCIe-EVR-300DC can be used. This EVR has a PCI express interface and can be plugged easily in a lot of computers. This EVR also has a micro SCPI interface to connect it on the IFB300 device offering up to 8 universal modules proposed by MRF to produce the synchronization trigger. Figure 3 shows an overview of the hardware.

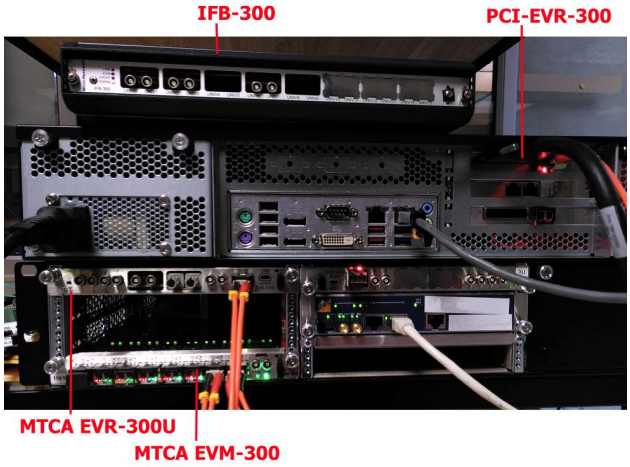

Figure 3: MRF hardware used in SARAF.

An EVM can be connected up to 7 MRF devices through optical fiber thanks to SFP connector. The 8th connector can only be used to get signals from an upstream EVM. This card can be used as the master, or as fan-out.

MTCA-EVR-300U has 4 LVTTL outputs, 2 TTL inputs and 2 slots to plug universal modules. Thanks to MTCA.4 this EVR can also use backplane lines of the MTCA.4 bus from the line 17 to 20 (see Fig. 4), meaning 8 channels can be configured as outputs or inputs.

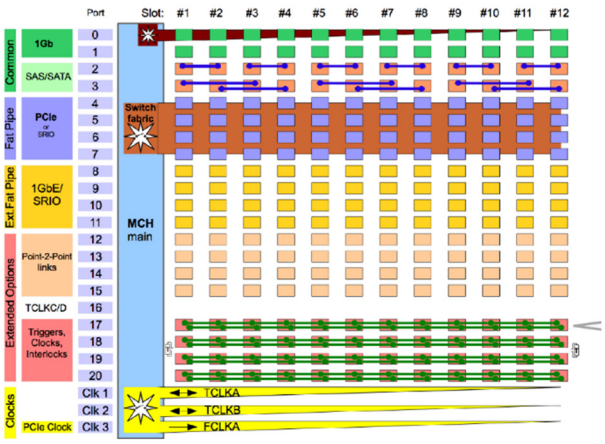

Figure 4: MTCA.4: MLVDS Bus.

Those backplane lines have been standardized for all the crates of the accelerator [4].

The Figure 5 shows the EVR design and its interface to the LLRF developed by Seven Solutions [5].

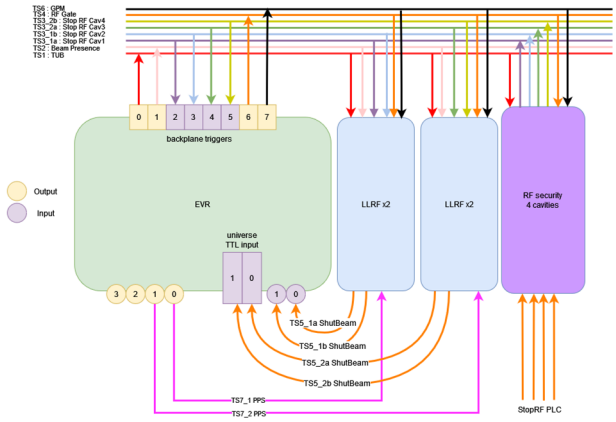

Figure 5: Distribution of signals on LLRF EVR.

OPERATION MODE

Beam Operation

Beam operation is in charge of authorized or not the operator to perform actions on the accelerator like starting the source.

For beam operation, we will use one of the sequencers of the EVM. The sequencer will trig events corresponding to the RF Gate, the chopper and the beam presence as shown in Figure 6.

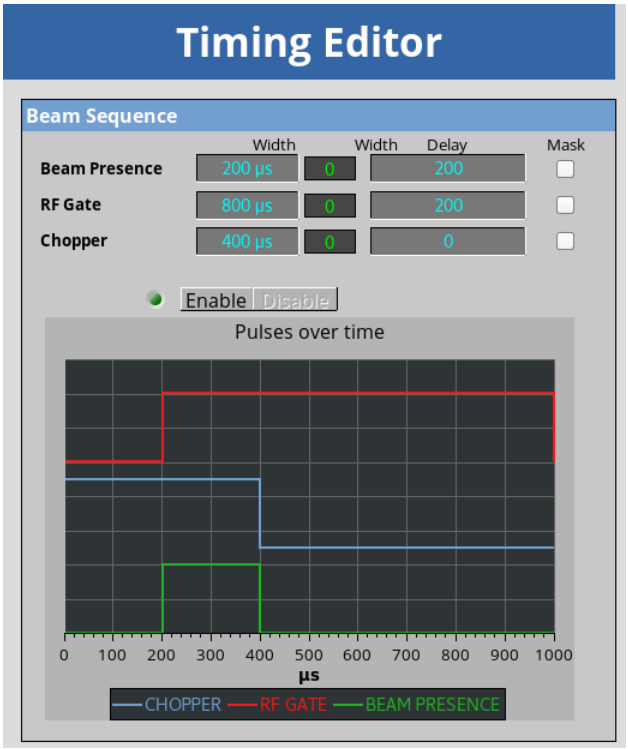

Figure 6: Graphical interface on CSS for the control of the sequencer.

We have different states during this operation:

- Pilot Beam: if the injection of beam is possible, the sequence is enabled and can send 3 different event triggers to manage the beam.
- Stop Beam: the sequence status is still on, but using the mechanism of mask of MRF, we mask the chopper event and then magnetron and RFQ are still on but the beam is not produced. It happens when we want to change the destination of the beam.
- Start Beam: the sequence status is still on and we unmask the chopper event trigger to generate the beam, it happens when the destination of the beam has been changed.
- Reset Beam: the sequence is stopped and no beam is produced.

RF Conditioning Operation

The sequence of the RF conditioning is handled by another EPICS application, but it uses the timing EPICS application to apply a new width to the RF Gate and to change the frequency period. As seen in Figure 7 in RF conditioning mode, the main EVM will not produce the trigger events, it's each sub EVM fan-out that will manage the RF trigger events for the conditioning of cavities. Meaning that each EVM will provide the same RF Gate for its cavities:

- EVM MEBT : RFQ and 3 rebunchers
- EVM CM1: 6 equipped cavities
- EVM CM2: 7 equipped cavities
- EVM CM3: 7 equipped cavities
- EVM CM4: 7 equipped cavities

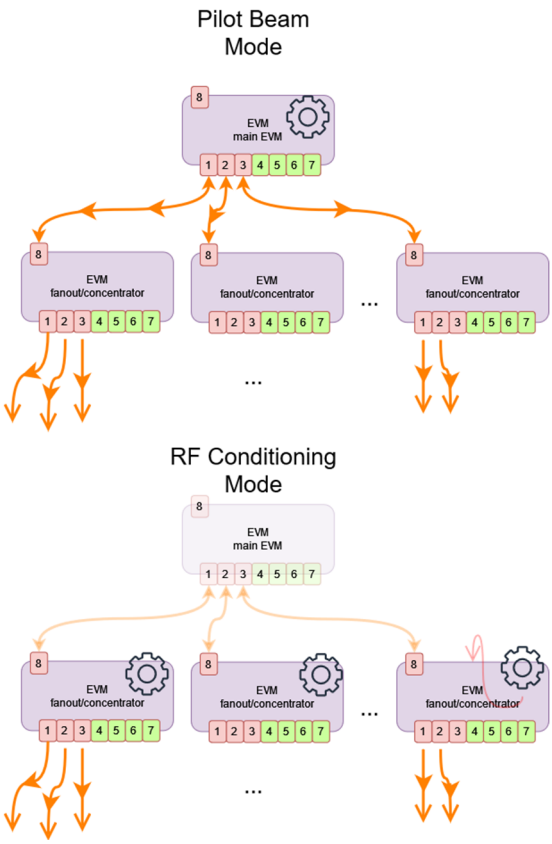

Figure 7: Timing distribution modes.

MACHINE PROTECTION SYSTEM

The machine protection system is the system that will shut down the beam and protect the accelerator from material damages. Based on ALBA accelerator experience [6], we've decided to delegate a part of the MPS to the MRF system. Thanks to the EVM-300, it's now easier to have an upstream configuration. Indeed, the EVM integrates 2 internal EVRs (see Fig. 8) that can handle upstream events and associate the reaction of the EVM.

As seen in Figure 8, a signal detected on the input of an EVR can upstream to the EVM and be submitted to the EVRU (for EVR Upstream). From there, like any other EVR, the EVRU can be configured to act on the reception of an event and trig the event in the integrated EVG of the EVM and then redistribute events to the whole EVRs of the accelerator. We use among others this method to propagate a "shut beam" event to the whole accelerator when a critical default is detected by a device.

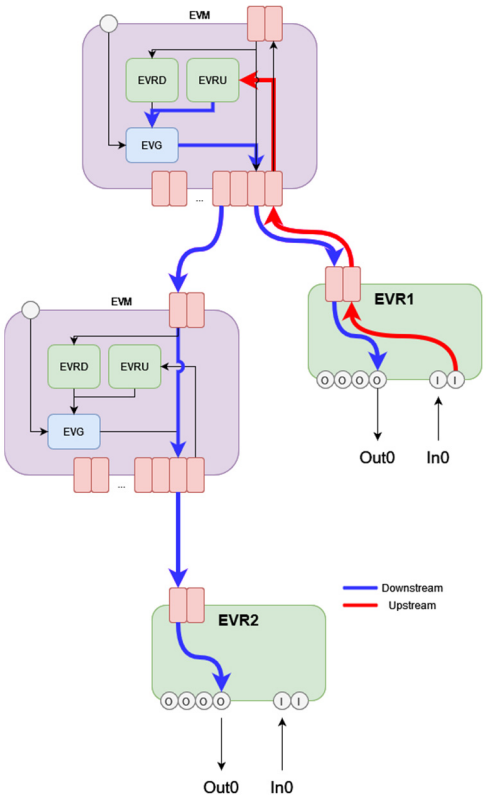

Figure 8: Upstream and propagation of an event to the whole MRF tree architecture.

EPICS APPLICATION

The EPICS timing application is based on mrfioc2 driver developed by Michael Davidsaver and a fork developed by ESS ICS [7]. We have modified the ESS driver to add mask functionalities of the sequencer [8]. We use the Irfu EPICS Environment (IEE) for EPICS development and deployment [9].

An SNL sequencer is implemented to handle the different Operation mode described earlier. Each EVR and EVM configuration will have an interface in order to operate simply the timing but an expert interface is also proposed for MRF developers. In the simplified interface (see Fig. 9), the user can modify the width and the delay of pulses produced by the EVR and have an overview of the status of pulses.

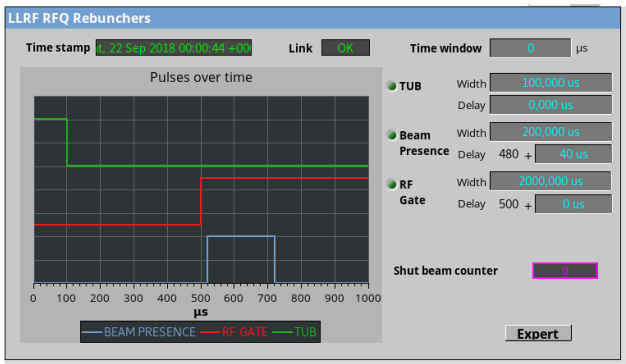

Figure 9: Example of simple interface for EVR LLRF.

CONCLUSION

We have completed the test of the MRF solution for the Timing and Machine Protection Systems at CEA Saclay in 2021. Due to the fact that those functionalities are transversal, they have been progressively installed at SOREQ this year.

ACKNOWLEDGEMENTS

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