TIMING SYSTEM AT MAX IV

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Abstract

The MAX IV Laboratory is the successor of the MAX-lab national laboratory in Sweden. The facility is being constructed at Brunnshög in the North Eastern part of Lund and will contain one long linac 3GeV (full energy injector), two storage rings (SR 1.5GeV and SR 3GeV) and a short pulse facility (SPF). This paper describes the design status of the timing system in 2013.

INTRODUCTION

The purpose of the timing system is to allow synchronization of various machine components. Moreover, the timing signal distribution has to be provided around a machine.

A proposal for an event based timing system for MAX IV was investigated. The basic event topology can be viewed in Figure 1 (one event generator - EVG, plus many event receivers - EVRs/nodes). The network cabling between all the components will consist of optical fibres.

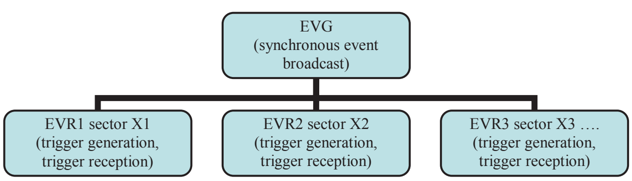

Figure 1: Timing system - event based.

MAX IV MACHINE

An overview of the facility is shown in Figure 2.

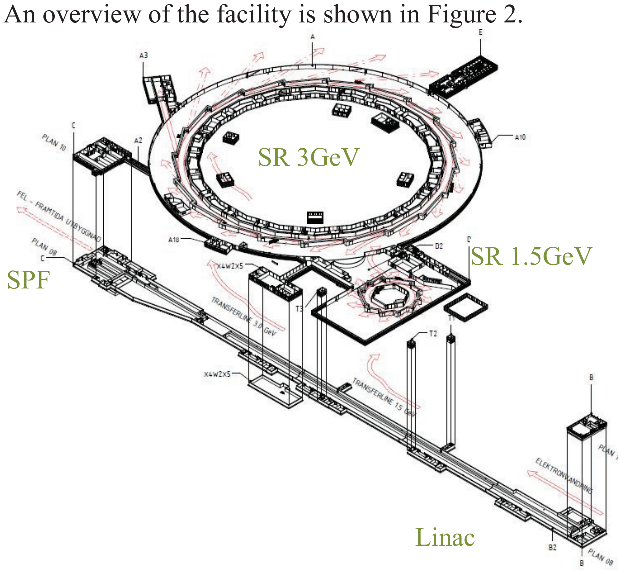

Figure 2: MAX IV layout.

Linac

The MAX IV linac [1] has following parameters: maximum energy: 3GeV, number of accelerating structures: 39, overall length: ~300 m, bunch structures: 1 x 100pC at 100Hz, 10 x 3 x 100pC at 10Hz (see Figure 3), bunch lengths: 100fs - 5ps.

The linac will be working in 3 main modes:

- SPF injection (RF1, Figure 3A).
- SR 1.5GeV injection (RF2, Figure 3B).
- SR 3GeV injection (RF3, Figure 3B).

Storage Rings

The generic parameters for both SRs are presented in Table 1.

Table 1: SRs Parameters

	SR 1.5GeV	SR 3GeV
Circumference	96m	528m
Nr of straight sections	12	20
Injection	Full energy, top-up	Full energy, top-up
Stored current (max)	500mA	500mA

RADIO FREQUENCIES

An injection into the different accelerator parts requires synchronization between the following frequencies:

- RF1 ≈ 80MHz for the laser of the photocathode gun driving the SPF (timing 1 – TIM1).
- RF2 ≈ 100MHz for SR 1.5GeV (timing 2 – TIM2).
- RF3 ≈ 100MHz for SR 3GeV, where RF3≠RF2 (timing 3 – TIM3).

The reason that those two 100MHz frequencies are different is related to parameters derived from the exact circumference and temperature of the rings after construction. The bunch patterns of the linac electron beam are presented in Figure 3.

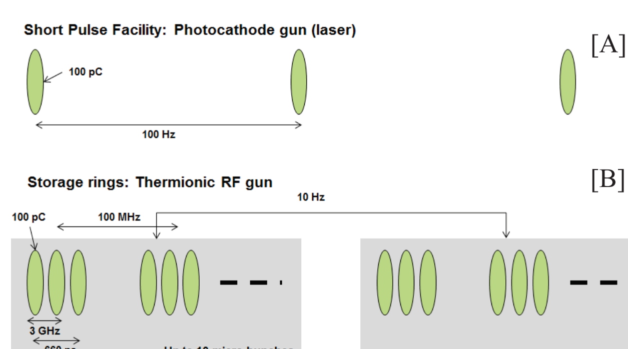

Figure 3: Linac electron beam structure for injection into the SPF [A] and any one of the storage rings [B].

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The figure also shows that two guns are used as an electron source:

- The photocathode gun driven by RF1.
- The thermionic gun driven by RF2 (injection to SR 1.5GeV) or RF3 (injection to SR 3GeV).

The 3GHz structure corresponds to a frequency of the master oscillator (MOSC). It is a frequency of the accelerating field. The beam structure (Figure 3B) for the storage ring injection is produced by a chopper.

The Figure 3 frequencies give an idea that linac timing components have to be aligned to both patterns (100Hz and 10Hz), although in the future, other patterns might be considered.

The simplified idea and basic overview of the RF/Timing sections in MAX IV are presented in Figure 4.

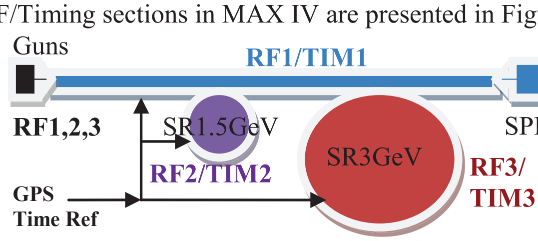

Figure 4: MAX IV RF/timing coverage.

A GPS time reference is presented in details in section “Timestamp”. Figure 4 gives a base of what is presented in more detail in other sections of this paper.

LINAC TIMING

The timing for linac (TIM1, see Figure 3 and Figure 4) was splitted to two systems:

- “TIM1a” – a digital system based on delay generators and a main trig line (MTL) which distributes synchronous signals along the linac.
- “TIM1b” – a future event based system which will be an extension to TIM1a.

Synchronization (TIM1a)

MOSC is connected to a low level drive line (LLDL) which provides 3GHz to the first three sections of the linac. Those sections are synchronized with digital delay generators triggering RF pulses. In the 3rd section, a portion of the amplified RF pulse is coupled out into a main drive line (MDL) which distributes the pulse as input to the remaining 15 linac sections. Each section has the following components: one attenuator, phase shifter, drive amplifier and a klystron, feeding two linac structures via a SLED cavity.

The synchronization has to be adjusted to 100Hz or 10Hz (see Figure 3) depending on the gun drive pattern. In parallel to the MDL, a main trig line (MTL) was implemented. The line distributes signals along the MDL, synchronising devices. The input signal to the line is provided by the 3rd section delay generator which allows adjustment of the MTL synchronisation. Capacitive couplers pick up the signal from the MTL and the signal is then split and forwarded to components along the linac sections. The trigger splitter device has been developed in-house and splits the trigger signal to multiple outputs. A 3D model of the splitter is shown in Figure 5. The device besides splitting can add some delays independently to any channel (e.g. to tune modulators, to consume less power and work more optimal).

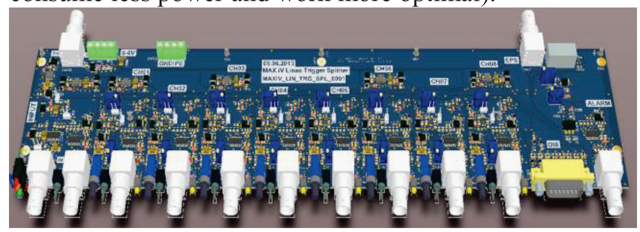

Figure 5: In-house trigger splitter.

The TIM1a solution allows synchronization of linac components for any RF pulse repetition frequency, so custom tests (e.g. synchronous from 1Hz up to 120Hz) of the linac can be done, without any loss in diagnostics and functionality. The first run of the linac will be based on this synchronization solution (simple timing mode).

The components which will be synchronized to RF pulses are: BPMs, digital cameras, oscilloscopes, modulators - everything distributed along all linac sections and some diagnostic oscilloscopes in SPF.

Extended Timing - Synchronization to ≈80MHz Laser Oscillator (TIM1b)

RF1 will be used to synchronize the photocathode gun and diagnostics in SPF but also to provide timestamp functionality to BPMs distributed along the linac, plus for a fast interlock system (see “Fast Interlock System (FIS)” section).

Extended Timing – Topology

An event generator (EVG1) will be placed next to the RF1 source*, and one associated even receiver (EVR) will be in the first linac section and one EVR in the last one (SPF), moreover all the BPMs will be connected to the same network.

The topology of the timing system will allow global access to timing signals, taking into account future extensions to the implementation anywhere in the linac. The tree topology is presented in Figure 6, every arrow presents a branch (it means that the layer 3 has the highest amount of nodes).

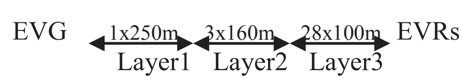

Figure 6: Draft of the optical installation for the linac – tree topology.*

STORAGE RINGS

The electron source for both storage rings [1] is a thermionic gun placed in the first section of the linac. The implication is to use two EVRs in an OR configuration, each synchronized with the RF of the corresponding ring

*It is not the final solution and changes may be applied in the future

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(RF2/RF3), so belonging to the relevant timing system (TIM2/TIM3).

The timing system for storage rings will provide complete synchronous signal coverage for each ring (see Figure 4), so that any future extensions will be easy to implement. Beam position monitors (BPMs) are the most common diagnostic devices in both SRs and they are synchronized to respective machine clocks. Other extra features can be provided with a post mortem signal (to make a deterministic log etc.). Each BPM electronics unit can also report a fast interlock if a beam problem occurs (more info in “Fast Interlock System (FIS)” section). The log of interlocks will be fully deterministic (time stamped) and presenting beam related issues.

The primary components for both SRs for which the precise timing is required are listed in Table 2.

Table 2: SRs Components That Require Synchronization

	SR 1.5GeV	SR 3GeV
Electron source	Thermionic gun	Thermionic gun
BPM crates	12	60
RF plants	1	3
Pulsed dipole magnet	1x horizontal, 1x vertical	1x horizontal, 1x vertical
Pulsed multipole magnet	1	1
Diagnostic beamline	1	1

Synchronization

The RF2 and RF3 frequencies will be provided to an EVG2 and EVG3 (the timing system TIM2 and TIM3) probably placed next to the control room* and the synchronized event stream will be distributed to SR components. It involves making a fiber optical network routed 500m* to the thermionic gun at the beginning of the linac and:

- 2-layer network for SR 1.5GeV, presented in Figure 7.

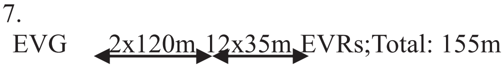

Figure 7 SR 1.5GeV timing tree topology*

- 3-layer network for SR 3GeV and its beamlines, presented in Figure 8.

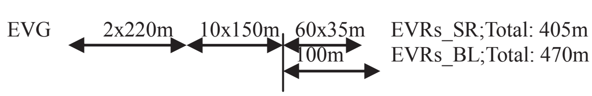

Figure 8: SR 3GeV timing tree topology*

The solution shown in Figure 8 also involves some misalignments in time between the storage ring and its beamlines because of the different cable lengths on the last layer, of about 300ns. So, if a very accurate timestamp is required, a calibration for equivalent beamline will be performed.

TIMESTAMP

All the EVGs will be synchronized to one GPS Lantime server which will provide one exact time scale for the timing system. In the future, probably other systems (network, PCs etc.) will use the same time reference too. It would make data, signals and history of all MAX IV machine components referred to one time origin. The timestamp accuracy is targeted to be around 12.5ns for TIM1 and 10ns for TIM2/TIM3.

FAST INTERLOCK SYSTEM (FIS)

The FIS [2] is an option which might be implemented in the future. This interlock system would have the ability to react to any signal/interlock in the MAX IV accelerators and take appropriate action in less than 10µs. All the interlocks would be logged to allow a reproduction of the machine status and history with all the data distributed in the same time scale provided by the GPS Lantime server. The signals which should trigger a FIS are still under investigation. Calculations to distinguish which failures could damage the machine and in which timespan are under investigation. This would separate the machine protection system (MPS) to a fast one (FIS) or slow one (based on programmable logic controllers - PLCs). For example, If the timespan is long (vacuum loss etc.) probably a protection system based on PLCs could be used as responses in tens of milliseconds range are sufficient. In other cases which would require a faster response, FIS could be needed to protect the machine. Besides, both, the PLCs and FIS could be interconnected to allow redundancy and an exchange of state information.

SOFTWARE

CentOS ("Community Enterprise Operating System") Linux was selected as a system hosting control for all the timing components. It is a Linux distribution based on a rebuild of the freely available sources from Red Hat Enterprise Linux.

A probable software solution would be based on: Pythonized API for EVG, EVR and fanout, Tango device servers written in Python (using the PyTango binding) for controlling all the hardware, Tango device servers for globally managing/monitoring the system (more information is presented in [3]).

CONCLUSIONS

The details of the final design are ongoing. The paper describes an outline of the timing system for the MAX IV facility that will meet our initial requirements and can be expanded in the future, if new needs arise.

REFERENCES

[1] J. Lidon-Simon et at., “Status of the MAX IV Laboratory Control System”, MOPPC109, ICALEPS’13.

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[3] J. Moldes et at., “The MRF timing System. The complete control software integration in Tango”, MOPMU023, ICALEPCS’11.

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