



Libera LLRF and Trigger

Synchronization System

for VEGA Linac







Our experience with the system testing and operation. Current status and plans for future upgrade.

Libera LLRF and Trigger Synchronization System for VEGA Linac (and Storage Ring):

- 1. Reference Master Oscillator (Libera RMO)
- 2. Reference Master Oscillator Distribution Amplifier (Libera RMO-DA)
- 3. Low-Jitter Continuous Wave Reference Clock Transfer System (Libera Sync)
- 4. LLRF System (Libera LLRF): analog front-end (TSRF) and digital processor (LLRF)
- 5. Multichannel Trigger Synchronization and Distribution System (Libera TSU)

October 2023 - Contract sign

September 2024 - SAT / commissioning







Linac Module – feedback signals

for stable high-power RF pulse that feeds RF cavities at VEGA Linac (Gun SW cavity, SW cavity, 20x TW cavities).





Location of racks in technical rooms









FAT: Dec. 2023 and April 2024



Libera RMO and RF Distribution - Home Tests



Spectrum Analyzer N9324C

(RMO)





Single side-band:





Libera RMO and RF Distribution

Home Tests

frequency counter 53230A







Libera RMO-DA



Libera LLRF: analog front-end (TSRF) and digital processor (LLRF)

First Home Tests Oscilloscope DPO70604C



6 μs pulse with phase flipping at 4 μs

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Libera Trigger Synchronization and Distribution System

Front Panel



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Trig IN A: 13x input channels (LEMO) 26x
Trig IN B: 13x input channels (LEMO) trigger inputs
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REF IN: SMA for Reference Master Clock input.
Trig OUT C (idle): 13x output channels (LEMO)
Trig OUT D (beam): 13x output channels (LEMO)
Trig OUT E (MDR): BNC to connect RF modulators

3x9 - trigger outputs

Inputs from Group A are sent to outputs from Group C (e.g. $A5 \Rightarrow C5$); Inputs from Group B are sent to outputs from Group D (e.g. $B8 \Rightarrow D8$) There is no functional difference between the 26 input/outputs channels.

There is a set of E outputs (to trigger modulators), which are generated by applying a logical OR function to the synchronized triggers from Groups A and B. (for example, E9 is triggered if there is an active signal at C9 or D9)

MDR outputs: since there are 6 modulators at VEGA linac, 7 of 5V TTL channels can be used for future Linac upgrade. 26 of 3.3 LVTTL output channels: there are 6 Libera LLRF modules / klystrons in use, 20 of LVTTL channels remain free. Because each LLRF module is typically paired with a modulator, up to 7 additional LLRF modules can be added (for example to Group C). Then, the Group D cannot be used to control additional LLRF modules.



Libera Trigger Synchronization and Distribution System

Each output trigger signal can be individually:

- enabled or disabled,
- delayed,
- controlled in polarity,
- controlled in pulse duration,
- controlled in pulse repetition rate (max. 50 Hz), (global not 'individual')
- user can select the trigger source (internal or external or hybrid).

enable parameter: the settings are either "true" or "false".

inverse polarity: the settings are either "false" or "true".

trigger source: the settings are either "Internal" or "ExtTrig".



one clock cycle (period) = 1/71.4 MHz $\approx 1.4006 \cdot 10^{-8}$ s *Example: delay* => 4.2 µs integer delay = $4.2 \cdot 10^{-6}/1.4006 \cdot 10^{-8} \approx 300$



5.5.2 The delay parameter Extract from "TSU User Manual and Specifications" The delay parameter enables a further offset of individual trigger outputs with respect to the time when the fulses are sampled (at the end of the window time frame). This parameter is defined as a positive integer in the range [0,4095]. This timing parameter defines the integer number of clock periods in Table 7. $z \approx 1.4006 \cdot 10^{-8} s$

2 5.00 V

3 5.00 V

(20.0µs **m→**▼0.000000 s 50.0MS/s 10k points 2 / 3.20 V 10 Apr 2025 12:12:56

Libera Trigger Synchronization and Distribution System

5.5.5 The duration parameter

This parameter controls the output pulse width. This parameter is defined as a positive integer in the range [0,1048575]. This timing parameter defines the integer number of clock periods in Table 7.

one clock cycle (period) = 1/71.4 MHz $\approx 1.4006 \cdot 10^{-8}$ s

maximal pulse duration: $1.4006 \cdot 10^{-8} \text{ s} \cdot 1048575 \approx 14.7 \text{ ms}$



p11





Future Upgrade

• Five Linac Modules will be upgraded with additional modulator each => one S-band LLRF system will be added for each new modulator.









• Two new linac modules will be added => corresponding S-band LLRF systems will be added.

ADC 1 ADC 2

 2x
 AccStr1
 AccStr2

 New Linac Modules
 LLRF TSRF

Courtesy of i-Tech



THANK YOU !