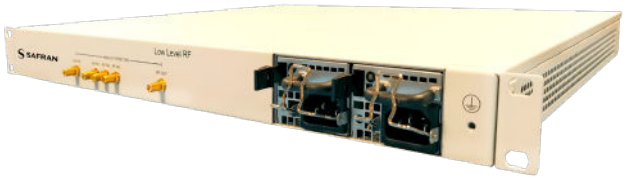
UTCA/STAND-ALONE DIGITAL LOW LEVEL RADIO FREQUENCY

Accurate control of the electromagnetic field inside accelerating cavities.



The digital RF stabilization system is available on the uTCA or stand-alone form-factors for best in-class LLRF solutions.

They are our industry leading fully digital RF systems designed to offer an accurate control of electromagnetic field inside any accelerating cavities and playing a key role in the overall performance of any particle accelerator. Our solution is tailored on customer needs and take full advantage of our previous expertise on PCIe-S LLRF equipment, now working with the most advanced crate technologies.

- Continuous and pulsed amplitude and phase or amplitude and frequency cavity field control.
- Real-time monitoring of RF signals (Incident, reflected, cavity field ...).
- Two cavities control in one uTCA based LLRF system.
- Post interlock/alarm analysis capabilities.
- EPICS control system support and easy user interface.
- Compatible with White-Rabbit and IEEE-1588 protocols. Seamless integration into the Timing system for triggering and timestamping control operations.
- Great performance:
  -Amplitude precision: 0.03% Vpp
  -Phase precision: 0.03 degree
  -Output jitter 182 fs RMS
  -Total group delay < 1us

Safran Electronics & Defense is with you every step of the way, building in the intelligence that gives you a critical advantage in observation, decision-making and guidance.

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Frequency range of operation

The system can be customized to generate RF signal up to 500MHz

Continuous and pulsed mode

Amplitude and phase or amplitude and frequency cavity field control y continuous wave or pulsed wave.

Open loop mode

Amplitude and phase control in open loop mode for cavity conditioning.

Close loop mode

Amplitude and phase regulation, based on proportional-integral (PI) control loop, to stabilize the cavity field to the required values.

Feedforward

Feedforward control to apply an opposite signal of pulse beam to the cavity field to compensate the beam loading effect.

Pulse shaping

Pulse edges smoothing capability to avoid abrupt voltage transitions.

VSWR

VSWR (arcing/reflection) detection and handling events. Configurable signal power thresholds and off RF time after event detection.

Cavity tuning

Keeps RF cavity at resonance by monitoring the phase of forward and reflected signals. The LLRF can communicate with tuners like step motors which modifies the geometry of the cavity to adjust the resonant frequency.

Frequency shift

The nominal RF frequency can be shifted +/-1MHz in open loop to adjust the RF signal to the resonant frequency of the cavity. This is of special interest during conditioning tasks.

Digital PLL

The frequency of the RF signal can be maintained at the resonant frequency of the cavities by means of the digital PLL feature. Monitoring the phase of the forward and cavity signals, the system can adjust the frequency of the RF signal generated in open loop. This feature is of special interest for the commissioning of superconducting cavities.

Machine diagnostics

The system stores the digitized signals for real time monitoring and for a postmortem analysis allowing the user to know at every moment the state of the system and the causes of an event.
The triggers to generate postmortem files are configurable, as well as the capture rate, depth, and pre-trigger capture time.

White Rabbit compatible

Compatible with White-Rabbit and IEEE-1588 protocols. Seamless integration into the Timing system for triggering and timestamping control operations.

Fast interlocks

Fast input interlock control to shut down the RF generation for protecting the machine.
Fast output interlock generation to communicate the alarm to other systems.

EPICS based

EPICS control system support and intuitive graphic user interface (GUI) to configure and monitor the operation of the system.

Technical Specifications

System on Chip	
SoC	Xilinx Zynq Ultrascale+ series
CPU	Quad ARM® Cortex™-A53 1.5GHz
Memory	8GB DDR4 16 GB SD card

Front End board

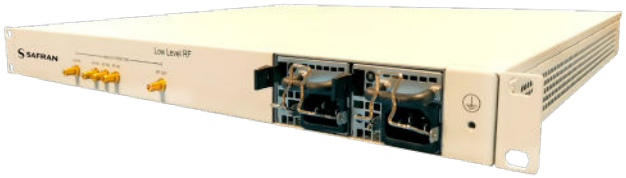
- RTM with double height and mid-size form factor uTCA.4
- 1 x RF MO Ref.: sine wave for LLRF reference.
- 7 x RF inputs to monitor up to two cavities.
- 2 x RF outputs to drive up to two cavities.
- Direct sampling architecture.
- RF input power dynamic range: [-60, +10] dBm.
- Maximum RF output power: +10dBm.
- Fail-safe for overheating mode.
- EEPROM memory.

Digitizer board

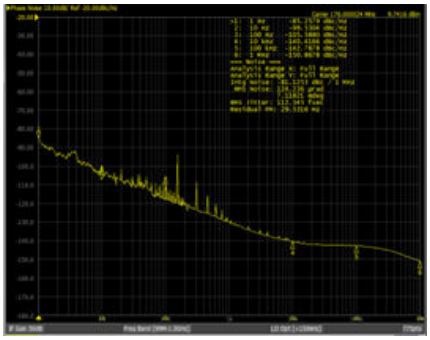
- 8 x ADC channels.
- 2 x DAC channels.
- 16 bits, 250MSPS ADCs - QDR LVDS interface.
- 16 bits, 1.5 GSPS DACs – DDR LVDS interface.
- 7 x configurable input/output TTL connectors.
- Zynq UltraScale+ FPGA from Xilinx.
- PLL for low phase noise distribution clocks.
- 8GB DDR4 for processor and data storage (postmortem analysis).
- ETH & SFP port (White Rabbit compatible).
- uTCA MMC controller.
- Fail-safe for overheating mode.
- uSD socket, uUSB port.

Management	
OS	Linux (Kernel v4.14 & buildroot)
Control	EPICS/TANGO
Monitoring	CSS/GUI & Taurus

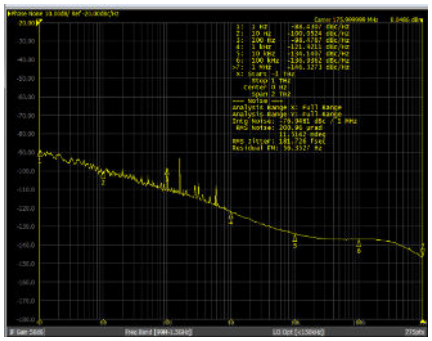
Performance	
Amplitude precision	< 0.03% (0dBm)
Phase precision	< 0.03° (0dBm)
Amplitude stability	< 0.3% (0dBm)
Phase stability	< 0.3° (0dBm)
Loop delay	< 1 us
Added jitter	142 fs (1Hz-1MHz)



Added Jitter

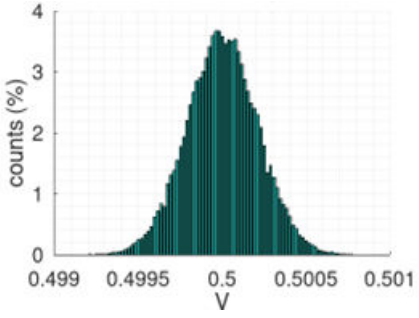


Master Oscillator jitter = 112 fs (176MHz)

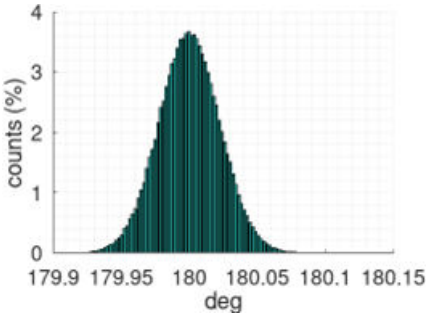


LLRF output jitter = 182 fs (176MHz)

Stability



Amplitude stability in closed loop (175MHz)
σ = 0.042 %



Phase stability in closed loop (175MHz)
σ = 0.022

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