LLRF systems for ESS elliptical cavities - DMCS-LUT contribution status

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Abstract

European Spallation Source is currently in the middle of construction/installation phase. Department of Microelectronics and Computer Science - Lodz University of Technology have been involved in elliptical cavities LLRF systems preparation and installation as a part of Polish Electronic Group (PEG). Current contribution summarizes DMCS work towards LLRF reference system preparation, control systems integration and performance studies with dedicated hardware cavity simulator and design and evaluation of piezo driver to be used for fine cavities tuning.

LLRF system for ESS elliptical cavities

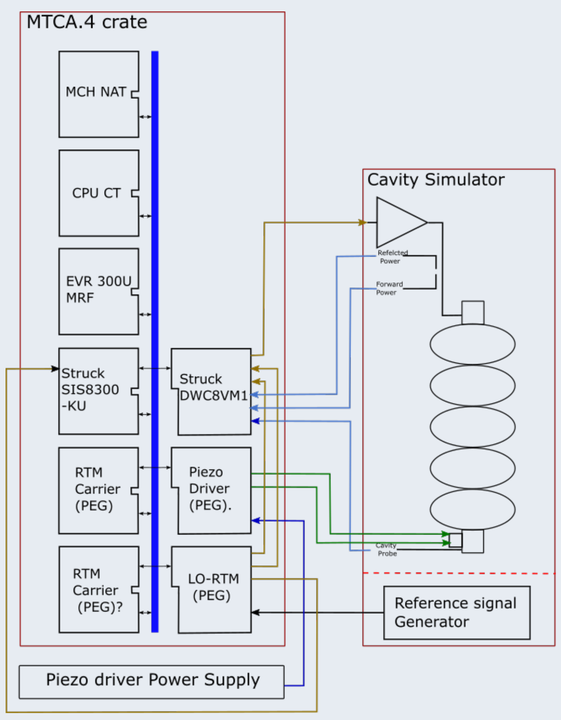


Figure 1: LLRF system overview

According to Lund University and ESS design the LLRF system for all ESS accelerating structures will be build using MTCA.4 standard hardware components.
Following components have been chosen as COTS modules:

- CPU,
- digitizer module,
- down-converter & vector-modulator module,
- timing receiver module

Other modules are being delivered by PEG:

- AMC module - RTM carrier NCNR Swierk,
- Local Oscillator RTM module WUT-ISE,
- Piezo driver RTM module LUT-DMCS,
- Piezo driver external power supply LUT-DMCS.

Additionally hardware cavity simulator (of M-Beta and H-Beta resonators) and various firmware components are PEG responsibility. Finally this in-kind effort includes also LLRF systems integration, testing and installation.

DMCS responsibilities

- RTM (MTCA.4) piezo driver and power supply for elliptical cavities LLRF systems,
- Reference LLRF system integration and evaluation,
- Support in hardware cavity simulator (delivered by WUT-ISE) design and evaluation,
- Cooperation in LLRF systems integration and installation in the ESS,
- Chosen low level software components preparation (firmware for piezo driver, software for developed board MMC),
- Support in systems integration, testing and installation.

Piezo driver status and evaluation

Main goal: To provide piezo elements controller with independent 2 channels operation. Driver have to provide enough power and operation flexibility to compensate Lorentz force detuning (LFD) (and possibly static detunig) of M-Beta and H-Beta (and spoke) cavities during the proton linac operation. This compensation is crucial due to the limited RF power budget available for some elliptical resonators.

Status

1. First prototype (AMC version - fig. 2) delivered and tested in the lab environment and with first spoke prototypes,
2. Second prototype (RTM version with external power supply - 19" box, see fig. 3) delivered and tested in the lab and with H-beta prototype (at FREIA),
3. Pre-series production of the M-Beta driver version produced in summer 2019 and tested.
4. Series production paused due to the modification of the driver specification (eq. extending piezo operation voltage and change in piezo operation polarity requirements),
5. Remote operation of the system successfully tested (during spoke cavity testing)

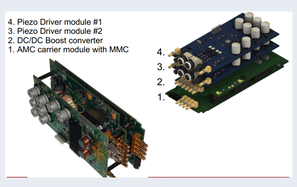
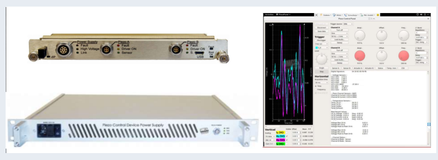


Figure 2: First piezo driver prototype (AMC type)

Figure 3: Second (M-Beta) prototype



System test stand preparation

Reference system preparation goal
Provide LLRF system that integrates all the HW and SW components according to the system specification. System can/should be used for LLRF integration study and design confirmation before mass production, integration and deployment.

Reference system status

- Integrates all HW components (since Feb. 2019) including prototypes of piezo driver, LO RTM module and RTM Carrier module,
- Connected to cavity simulator in order to perform functional testing and identify missing firmware and software components,
- Equipped with additional VNA, RSA and scope devices for additional testing and evaluation
- Used as a base for system tests procedure development and evaluation.

Figure 4: Reference system setup (front view)

Figure 5: Reference system setup (rear view)

System evaluation with real cavities

- Important for real evaluation of delivered HW/SW components - piezo driver prototypes tested with spoke and H-beta resonators,
- Crucial for appropriate cavity simulator configuration,
- Fully integrated system tests to be conducted next months (TestStand2-ESS, HNOSS-FREIA).

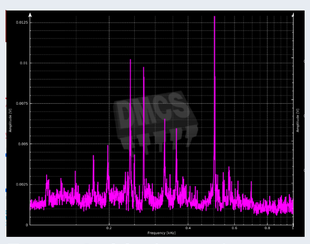


Figure 6: Mechanical excitation scan

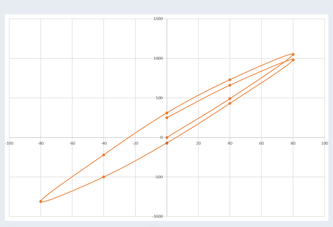


Figure 7: Piezo regulation range scan (spoke)

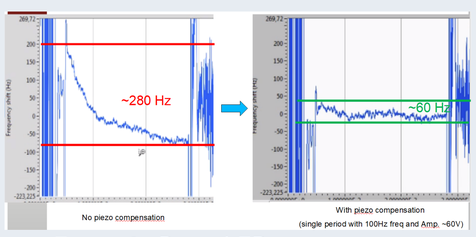


Figure 8: Piezo LFD compensation

Tests procedures

- Tests procedures are being developed for integrated systems check and evaluation before shipment to ESS.
- Final testing after systems installation (with resonators or simulator connected - dependent on availability)

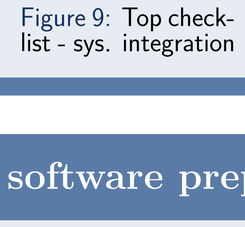


Figure 9: Top checklist - sys. integration

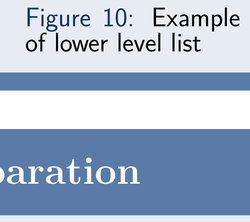


Figure 10: Example of lower level list

Cavity simulator management software preparation

Main goal
Cavity simulator configuration and management by means of easy to use user interface.

Main features
Software allows for:

- Configuration of the CS input/outputs and model parameters (modes freq., Ql, detuning),
- Monitoring of CS parameters (eq. temperatures),
- Executing CS functionalities (eq. channels calibration).

Implementation

- standalone Python based application,
- in the form of IOC (compliant with ESS E3 framework).

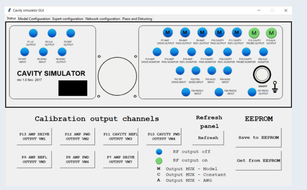


Figure 11: GUI screen

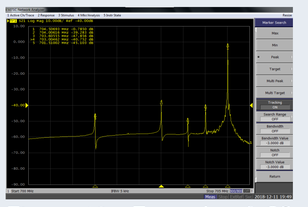


Figure 12: Example of CS configuration (M-Beta)

Summary and Future Plans

- Hardware prototypes designed and evaluated - piezo driver proved its performance during laboratory and cavity tests,
- Prototyping of new driver to be started as soon as new specification will be accepted,
- Reference system is being tested (with cavity simulator) to provide feedback for FW/SW development and testing procedure preparation,
- FW/SW components are under development by PEG(DMCS) and ESS (RF & ICS groups)

Acknowledgment

This work has been supported by the Polish Ministry of Science and Higher Education, decision number DIR/WK/2016/2017/03-1