Description:	This document provides all the items required for CDR for Piezo Control Device and Power Supply Module
Title:	Piezo Control Device and Power Supply Module - Critical Design Review for the LLRF submodules
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REVISION TABLE:

Revision	Date	Modification
0.1	2018-04-06	Initial version for CDR
0.2	2018-04-09	Added chapters 1, 2
0.3	2018-04-10	Added chapter 3
0.4	2018-04-11	Added chapters 4
0.5	2018-04-12	Added chapter 5
0.6	2018-04-19	Added chapters 6, 7
0.7	2018-04-21	Added chapters 8-10
0.8	2018-04-22	Added chapters 10-16
0.9	2018-04-23	Added requirements for Power Supply module
1.0	2018-04-23	Updates and final corrections
1.1		

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1 FOREWORD

The European Spallation Source (ESS) accelerator operates in a pulsed mode with a repetition rate of 14 Hz. The Piezo Compensation System (PCS) is required for compensation of detuning of superconducting cavities caused by a Lorentz Force and microphonics. Piezo actuators are commonly used both for applying force to the cavity (actuator mode) and measuring its mechanical stress (sensor mode).

There were no commercially available piezo controller solutions matching PCS system requirements, therefore a custom controller was designed. The PCD is composed of FPGA-based real-time controller, actuator module and high voltage power supply. The FPGA firmware, Linux driver, device library and EPICS support are required to configure control and maintain the PCS. The contribution from PEG includes design, construction, testing and commissioning of the Piezo Control Device hardware. All software components of the system including: FPGA firmware, Linux driver, device library and EPICS support will be provided by ESS.

2 PIEZO CONTROL DEVICE REQUIREMENTS

The PCD hardware should be designed using the state-of-the-art MicroTCA.4 technology. The PCD device, composed of control and driver modules will be installed in the MicroTCA.4 chassis of the LLRF control system. PCD will share several common MicroTCA.4 components (CPU, MCH, PSM).

The Piezo Control Device should fulfil the following functional specification:

- Provide a control signal for piezo actuators used for Lorentz Force detuning of Medium and High Beta accelerator cavities.
- Measure cavity deformation using piezo device as sensor element.
- Two independent channels with configurable mode of operation: piezo actuator or sensor.
- Single LLRF synchronization input.
- Single interlock input.
- Digital control and diagnostic interface.
- Compatible with MicroTCA.4 standard.
- Health monitoring and diagnostics.
- Provides firmware upgrade for all programmable devices.
- Allows to disable external Piezo Power Supply Module.

The detailed specification is available in [1] document.

The electrical parameters of PCD are presented in Table 1. The parameters of piezo actuators that have to be supported are presented in Table 2 and Table 3. The piezo actuators for Spoke cavities will be supported by assembly variant of the PCD (modified the output L-C-L-C filter).

Table 1. Electrical specification of PCD

Parameter	Value	Comments
Supported standards	MTCA.0, MTCA.4, AMC.0, AMC.2, IPMI 2.0	
Number of channels	2 bipolar channels with actuator/sensor mode	NOLIAC piezo, see Table 2
Repetition Rate	14 Hz	pulse duration: max. 3.5 ms
Piezo capacitance	6.6 – 11 µF (room temperature)	2.2 – 3.6 µF (cryo-temperature)
Piezo supply voltage	-80 V – +80 V (160 Vpp)	
Maximum actuator power	35 W per channel	
Controller Bandwidth	DC – 1 kHz	
Actuator excitation signal	Arbitrary waveform generation Sampling frequency: 1 MHz Number of samples: 30000 Resolution: 16-bits Output voltage range: ±80 V	
Piezo sensor	Sampling frequency: 1 MHz	

	Number of samples: 30000 Resolution: 16-bits Input voltage range: ±1 V Input impedance: 10 kΩ	
Protection	Overcurrent Overvoltage Thermal protection of the driver Maximal control power of piezo	
Maximum cable length for piezo connection	min. 30 m long, max. 45 m long min. 5 Ω (total in both directions)	Agreed cable: Lapp 0030924

Table 2. Supported piezo stacks

Cavity type	Piezo actuator type
Medium Beta cavities	Noliac NAC 2022 H30
High Beta cavities	Noliac NAC 2022 H30
Spoke cavities	Piezo #1: Noliac NAC2022-H90-A01 Piezo #2: PI PICMA P-888.91/51

Table 3. Piezo stacks specification

Piezo type	Noliac NAC 2022 H30
Dimensions	10 x 10 x 30 mm
Cell material	NCE51F
Number of cells	15
Total capacitance	6.6 µF
Max. free stroke	49.5 µm
Blocking stroke in cryo temp.	3 µm
Blocking force	4200 N
Max. operating voltage	200 V
Max. operating temperature	200°C

3 Piezo Control Device Interfaces

The piezo elements are expected to be directly connected to the DBPC 102 A053-130 Fischer sockets of the RTM board, without any patch-panel[1]. The piezo connector pinout for both piezo elements is specified in Table 4. The "Plug ID" pin is used for determining the type of a connected load. For the nominal operation, it shall be connected to the GND pin with a resistor of 4.7 kΩ.

Table 4. Piezo element connector pinout

Connector pin	Description	Electrical Specification	Direction
1	Driver output -	Max. 200 VDC, 1 A	Out
2	Driver output +	Max. 200 VDC, 1 A	Out
3	GND	Ground, 1 A	
4	Plug ID	LVTTL 3.3 V	In

The pin definition for the high-voltage input connector of the RTM board is presented in Table 5. It utilizes DBPC 103 A058-130 connector, capable of providing up to 1 A of electrical current per terminal. The power supply contains simple 1-wire temperature monitors, supplied by the "Management Power" pin and accessible through the "Data" pin.

Table 5. RTM board high-voltage input connector pinout

Connector pin	Description	Electrical Specification	Direction
1	GND	Ground, 1 A	GND
2	GND	Ground, 1 A	GND
3	High voltage -	Max. 60 VDC, 1 A	In
4	High voltage -	Max. 60 VDC, 1 A	In
5	Management Power	3.3 VDC, 0.01 A	Out
6	Data	LVTTL 3.3 V	In-Out, open drain
7	High voltage +	Max. 60 VDC, 1 A	In
8	High voltage +	Max. 60 VDC, 1 A	In

All Zone 3 connectivity is implemented using LVDS and LVCMOS (2.5 V) signalling standards. The RTM module is fitted only with J30 connector featuring 13 differential pairs and 16 single-ended signals. The Zone 3 pinout is specified in Table 6.

Table 6. Zone 3 connector specification

Connector pin	Description	Electrical Specification	Direction
1A, 1B	+12V	RTM payload power	In
2A, 2B	+12V	RTM payload power	In
3A, 3B	Not used	Terminated with 100R	In
4A, 4B	Not used	Terminated with 100R	In

[1] The piezo patch-panel was never included in the costs of the piezo driver module.

5A, 5B	ADC data, channel #3	LVDS	Out
6A, 6B	ADC data, channel #1	LVDS	Out
7A	DAC1 chip select	LVCMOS, 2.5 V	In
7B	DAC1 output clear	LVCMOS, 2.5 V	In
8A	DAC2 chip select	LVCMOS, 2.5 V	In
8B	DAC2 output clear	LVCMOS, 2.5 V	In
9A, 9B, 10A, 10B	Four GPIO signals to diagnostic processor	LVCMOS, 2.5 V	In/Out
1C	RTM presence	Tied to ground	Out
1D, 2D	RTM I^2C bus, according to MTCA.4 spec.	I^2C bus, referenced to management power 3.3 V	In/Out
2C	Management power	RTM management power	In
3C, 3D	Not used	Terminated with 100R	In
4C, 4D	ADC conversion trigger	LVDS	In
5C, 5D	ADC data, channel #4	LVDS	Out
6C, 6D	ADC data, channel #2	LVDS	Out
7C, 7D	DAC1 clock signal	LVDS	In
8C, 8D	DAC2 clock signal	LVDS	In
9C, 9D, 10C, 10D	Four GPIO signals to diagnostic processor	LVCMOS, 2.5 V	In/Out
1E, 1F, 2E, 2F	JTAG interface, according to MTCA.4 spec.	Unused connection, TDI connected to TDO	In/Out
3E, 3F	Input channel gain selection	LVCMOS, 2.5 V	In
4E, 4F	Input channel bandwidth selection	LVCMOS, 2.5 V	In
5E, 5F	ADC interface clock	LVDS	In
6E, 6F	ADC returned clock	LVDS	Out
7E, 7F	DAC1 data signal	LVDS	In
8E, 8F	DAC2 data signal	LVDS	In
9E, 9F	Serial data from diagnostic processor	LVDS	Out
10E, 10F	Serial data to diagnostic processor	LVDS	In

4 FUNCTIONAL BLOCK DIAGRAM

The PCD system will be designed using the state-of-the-art MicroTCA.4 technology. The PCD is designed as MicroTCA.4 module. It is connected to piezo-elements operating as sensors or actuators. The block diagram of the PCS is presented in Figure 1

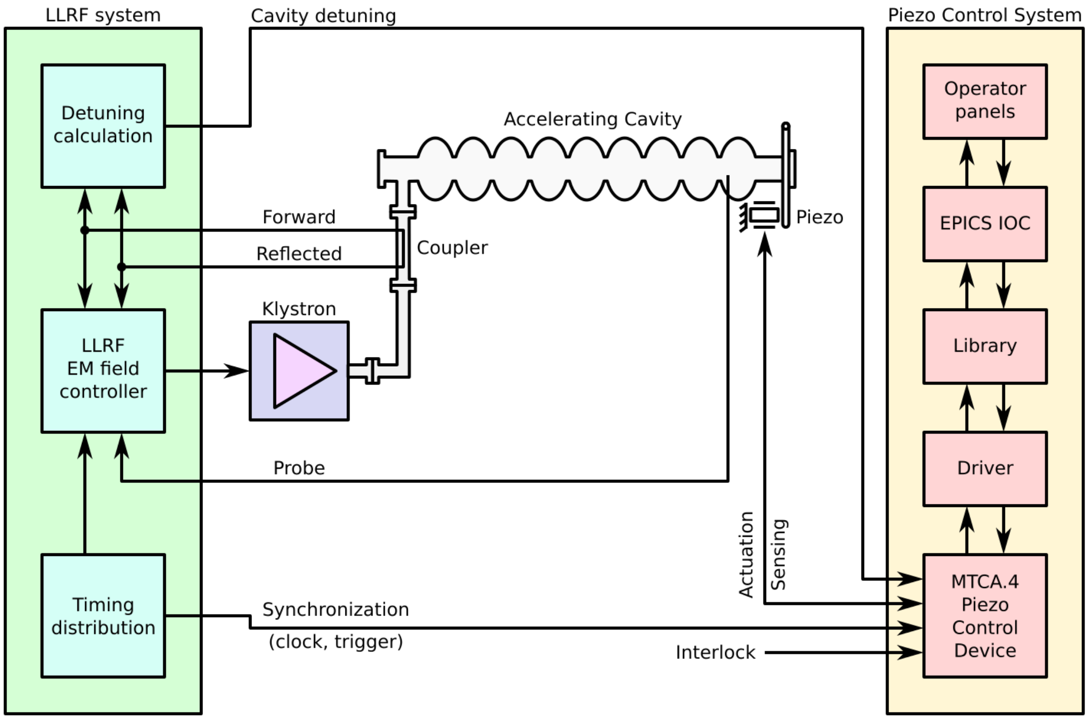

Figure 1. The Piezo Compensation System of ESS Accelerator

The PCD generates an arbitrary signal that is used to excite the piezo actuator. A cavity detuning signal is provided by LLRF controller module using MicroTCA.4 backplane. The PCS controller executes the feed-forward algorithms required for piezo control. The calculated excitation signal is amplified and then delivered to piezo actuator. The device monitors the amplifier temperature as well as the output voltage, current and power in order to assure a proper driving signal and therefore ensure long piezo lifetime. The PCD also allows reading a signal from redundant piezo-element operating as a vibration sensor recording the spectrum of mechanical resonances. Each channel of PCD can be switched between actuator and sensor mode.

The PCS should be synchronized with LLRF control system. It should provide exception handling (interlock system) and piezo protection circuits.

The PCS system is connected to CPU via PCIe interface provided by MicroTCA.4 backplane. All parameters can be modified using EPICS panels.

The piezo control system consists of the CPU connected via PCIe interface to the piezo actuator controller. The block diagram of the piezo actuator device connected to CPU is shown in Figure 2.

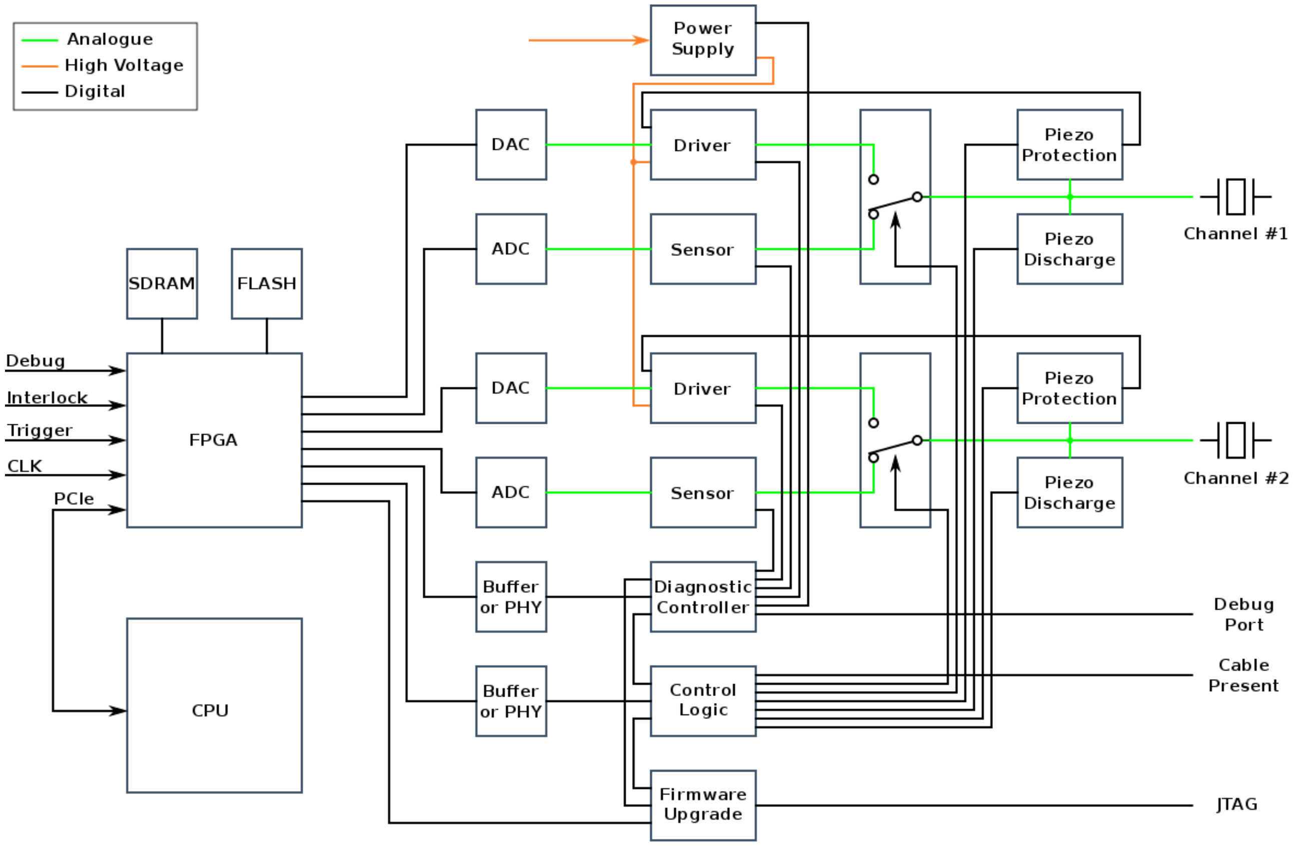

Figure 2. Architecture neutral block diagram of piezo control system.

The block diagram of the Piezo Control Device power supply is presented in Figure 3.

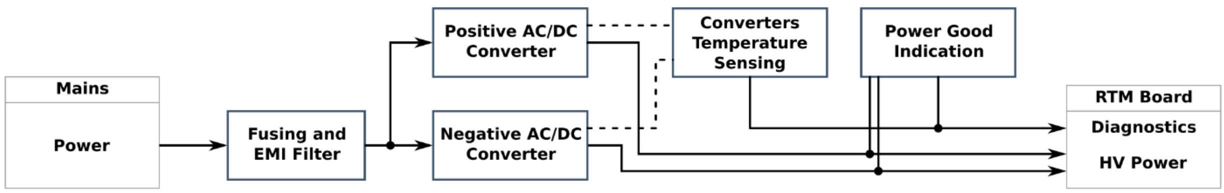

Figure 3. The piezo power supply block diagram.

5 SYSTEM DESIGN DESCRIPTION

The piezo actuator controller will be implemented as a set of three separate devices:

- an Advanced Mezzanine Card – providing the FPGA device with appropriate memories and capability to support an RTM module, so called “RTM Carrier”,
- a Rear Transition Module – providing digital-to-analogue conversion, power amplifier stage and diagnostic circuits
- an 1U 19” rack module – providing the positive and negative 50 V power supply.

The digital controller is based on Field Programmable Gate Array (FPGA) device and provide the resources required to implement a digital controller for piezo actuator. The module is equipped with data memory (SDRAM), FPGA bitstream memory (FLASH) and PCIe interface. The digital controller generates the arbitrary digital signal synchronized with LLRF controller that is used to excite the piezo actuator. The module realizes the following operations:

- Transmits the waveform from memory to DACs,
- Records the piezo sensor voltage and stores it to the memory,
- Monitors the piezo actuator voltage and current, performs calculations of piezo capacitance,
- Waits for a selected trigger,
- Provides communication channel to diagnostic controller,
- Can receive additional interlock signal (exception generated by the other module in critical situations, e.g. importer temperature of cryogenic system).

The digital controller provides the control signal for DAC device that converts the piezo actuation waveform into analogue signal connected to the driver module. The driver module consists of power amplifier and amplifier protection circuits. The power amplifier uses high voltage (±80 V) provided by the power supply module (DC/DC step-up converter) to generate a suitable control signal for piezo actuator. A high efficiency switching amplifier is planned to be used in order to limit the generated heat and power consumption.

The high amplitude driving signal is connected to piezo actuator via a switch and piezo protection systems. The piezo protection is an independent digital device that constantly monitors piezo supply voltage, current and power in order to detect conditions that could damage piezo actuator (e.g. too high voltage, current or energy transferred to piezo). Piezo protection circuit should fulfil the following requirements:

- Monitors the piezo voltage and current, calculates the dissipated power,
- Disables the driver, in order to prevent piezo from overheating,
- Disables the driver, in case of presence of excessive currents or voltages,
- Disables the driver in case of abnormal FPGA circuit operation,
- Once activated, has to be restarted by the FPGA.

The piezo device could operate in two modes: piezo-actuator and piezo-sensor. The mode of operation could be changed for both channels in order to enhance the blocking force, decrease driving signal amplitude and enhance the piezo lifetime. The piezo signal is digitized and recorded in case of piezo-sensor mode.

The piezo discharge module removes the charge from piezo element once the channel becomes disabled.

The control logic module provides a basic configuration and protection of the piezo controller. It is responsible for:

- Selection the operation mode of the piezo channels
- Implements the interlock function in a fast and reliable way
- Monitors the piezo presence
- Enables the discharge circuit

The device will be implemented using a simple programmable logic with build in FLASH memory (CPLD) in order to assure high reliability.

The diagnostic controller allows for basic diagnostics and management of the piezo actuator device:

- Monitors the board voltages, currents and temperatures on critical components,
- Controls the power supplies,
- Orchestrates the firmware upgrade process,
- Provides early warnings on the module health problems.

The firmware upgrade component provides is-system firmware upgrade of all programmable devices (microcontrollers, CPLD, FPGA) of the diagnostic controller:

The buffer/PHY module provides level translation between the controller module and actuator subsystem.

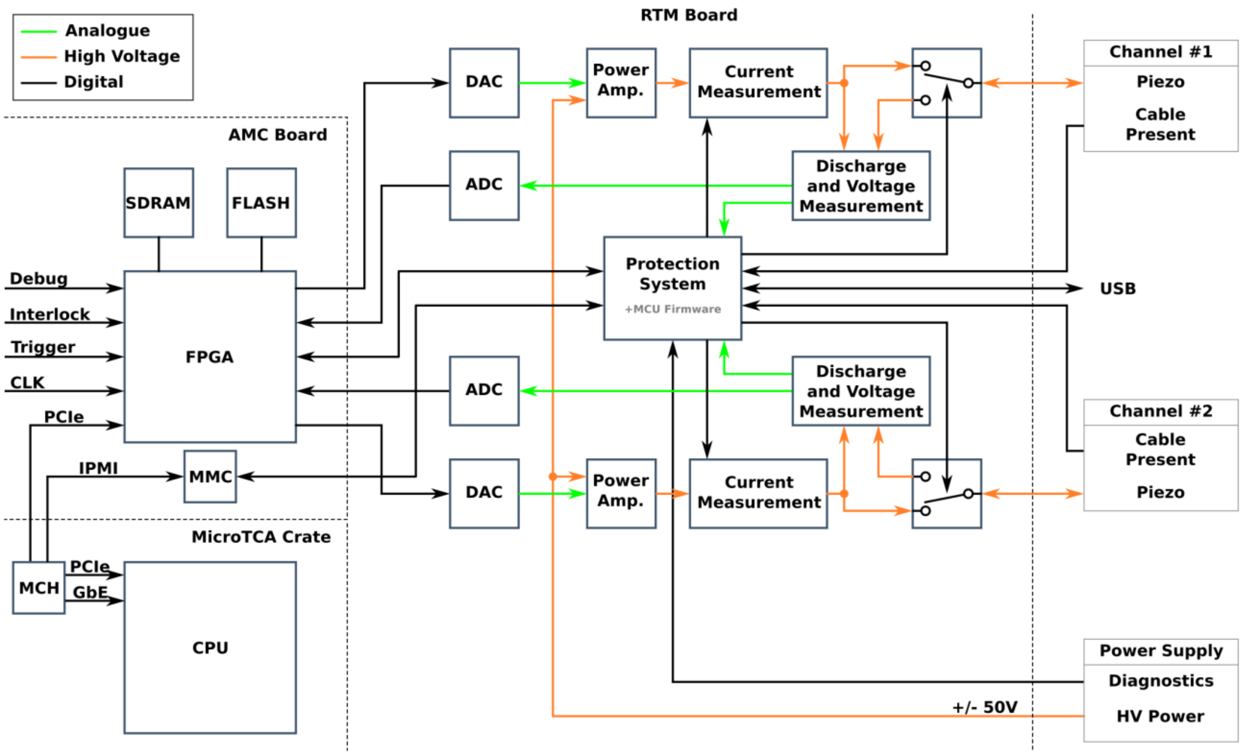

Figure 4. Block diagram of piezo control device implemented as AMC, RTM and external power supply

The AMC module provides FPGA processing power, communication interfaces, interlock and trigger signals that are connected to MicroTCA.4 infrastructure and external devices. The RTM device includes all components required for piezo operation (ADC, DAC, piezo driver, piezo sensor, piezo protection, switch module) and diagnostic circuits. The high voltage power supply is provided from external power supply realised as a standard 19” unit. The power supply module provides the main +/- 50 V power supply and basic diagnostics (e.g. temperature). The block diagram of the solution is presented in Figure 4.

Since, the Class-D amplifier has a high efficiency (80–90%) it should be possible to implement the piezo driver module as RTM device. It is assumed that a single RTM slot could dissipate maximum 30 Watts. Further, assuming that single piezo driver channel will provide maximum 50 Watts and the amplifier efficiency is 80%, the maximum generated power is estimated to 10 Watts for a single channel. The additional 10 Watts should be enough to realize the diagnostic and protections devices.

The proposed block diagram of 2-channel PCD mapped to RTM card is presented in Figure 5

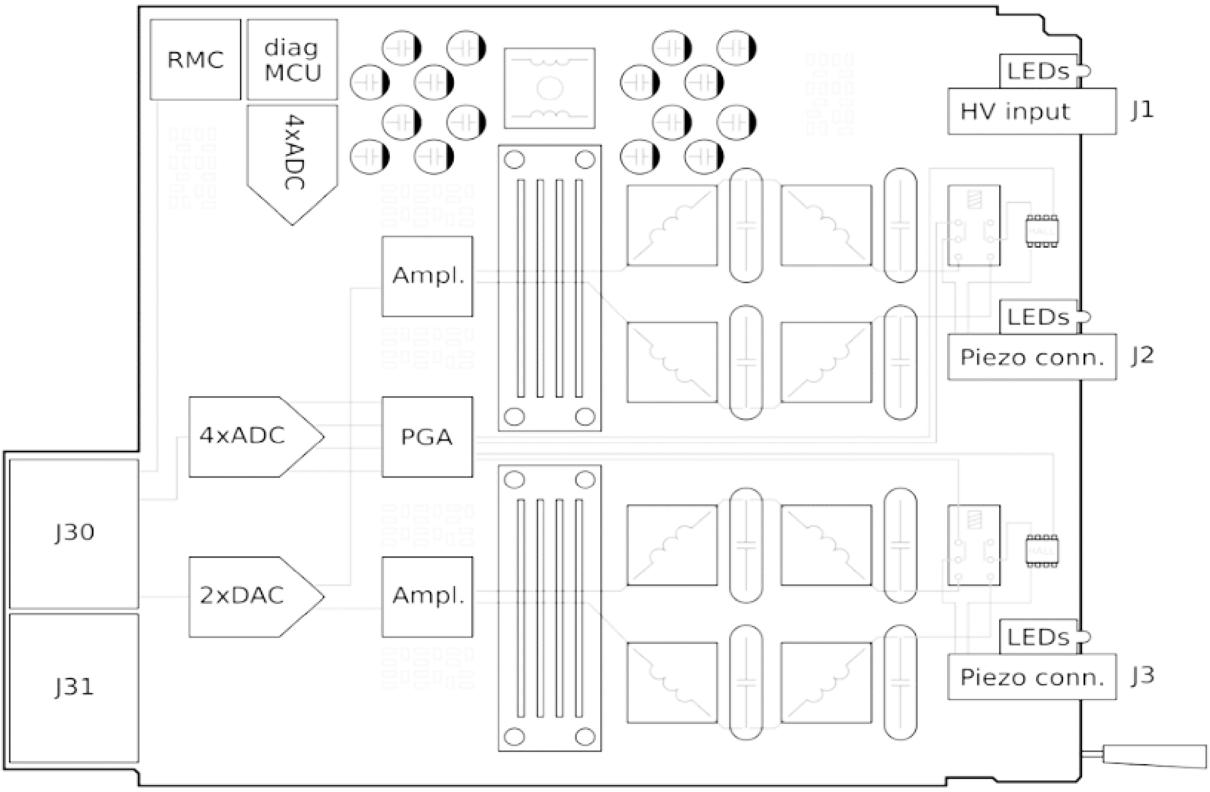

Figure 5. 2-channel Piezo Control Device designed as RTM component.

6 PIEZO CONTROL DEVICE – POWER SUPPLY MODULE

The power supply for the Piezo Control Device is provided by a separate dedicated 19” power supply unit.

The Piezo Power Supply Module should fulfil the following functional specification:

- Provide high-voltage power supply for PCD.
- Provide power good indicators.
- Provide AC power supply indicator.
- Provide EMI filtering.
- Compatible with 19” standard.
- Provide basic health monitoring and diagnostics.
- Allow for power control from RTM-piezo card.

The main ratings and parameters are presented in Table 7.

Table 7. Electrical specification of PPSM

Parameter	Value	Comments
Supported standards	1 U, 19” custom	
Output voltage	+50 V ±5%, -50 V ±5%	
Output current	1 A per channels in CW	Suitable for pulse operation
Output current protection	2 A per channels in CW	
Over voltage protection	for +50 V max. 55 V, for -50 V max. -55 V	
Output power	Min. 50 Watts per channel	
Input voltage range	Vin = 100 – 240 VAC, f = 50 – 60 Hz	
Main fuse	6 A slow-blow or time-lung fuse	
Reliability	Expected lifetime: min. 10 years at 30 °C ambient temperature	
Protection	Overcurrent Overvoltage Thermal protection of the power supply	
Diagnostics	Power good indicator for +50 V and -50 V, Temperature of both PPSM via one wire interface Ambient temperature Digital signature	
Control	Power supply (+50 V and -50 V) disable via digital interface between RTM-piezo and PPSM	

Non-functional requirements	Passively cooled – without fans Suitable for long-time continuous operation and pulsed load, High reliability and availability of power supply Low EMI emission Controlled inrush current	

The detailed specification is available in [2] document.

The PSM will use two connectors:

- The 230 V mains AC connector.
- The high-voltage piezo power supply connector.

The computer-rendered visualization of the completed power supply is shown in Figure 6.

Figure 6. PCD Power Supply visualization

The power supply module is powered from 230 V AC mains using regular C14 connector according to IEC 60320 standard. The connector block is integrated with power switch and fuse. The power supply provides output voltages using DBPC 103 A058-130 round connector. The central part of the front panel is milled to enable the front-to-back air flow through the chassis. The complete design of the device's front panel is presented in Figure 7.

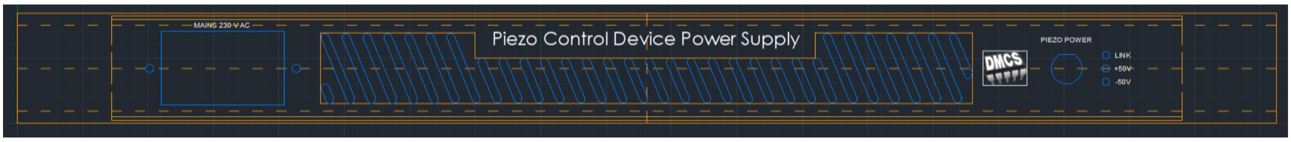

Figure 7. Design of the PCD Power Supply front panel

The piezo power connector pinout is presented Table 8. It is compatible to the one of the RTM card. The power supply device is directly connected to piezo driver module. The length of connection between the piezo driver RTM board and the power supply is limited by the cable and connectors resistance and cannot exceed 1 m.

Table 8. Power supply high-voltage output connector pinout

Connector pin	Description	Electrical Specification	Direction
1	GND	Ground, 1 A	GND
2	GND	Ground, 1 A	GND
3	High voltage -	Max. 60 VDC, 1 A	In
4	High voltage -	Max. 60 VDC, 1 A	In
5	Management Power	3.3 VDC, 0.01 A	Out
6	Data	LVTTL 3.3 V	In/Out, open drain
7	High voltage +	Max. 60 VDC, 1 A	In
8	High voltage +	Max. 60 VDC, 1 A	In

The power supply module is also equipped with a set of three optical indicators, as presented in Table 9.

Table 9. Power supply indicators

Indicator	Description
1	Connection to piezo module
2	Positive high voltage presence
3	Negative high voltage presence

7 PIEZO CONTROL DEVICE – LABORATORY MEASUREMENTS

The PCD was tested at TUL-DMCS Control and Data Acquisition (CADAQ) laboratory. The hardware used during testing is presented in Figure 8. The commercially available AMC module with Zone D1.2 connector was applied as the front module. The firmware and developed software allow to generate various test signals with variable frequency and amplitude in continuous and pulsed modes. The PCD was loaded with foil capacitors (2.2, 5, 10, 20, 40 uF) and the safe operation area characteristics were measured in both continuous and pulsed modes (n=10 pulses, repetition frequency 14 Hz). The PCD was first supplied from laboratory +/- 50 V power supply with current limiter.

Next, the module was supplied from the designed PPSM, as presented in Figure 8 and the characteristics were measured. The results from measurements are presented in Figure 9 and Figure 10. Both PCD channels were tested with the load connected using cable with 5 Ohm and 7 Ohm resistance. The load current and voltage was measured using a dedicated current and high-voltage probes.

The measured characteristics in pulsed and continuous modes prove that the device fulfil the required specification defined in Table 1 and Table 7.

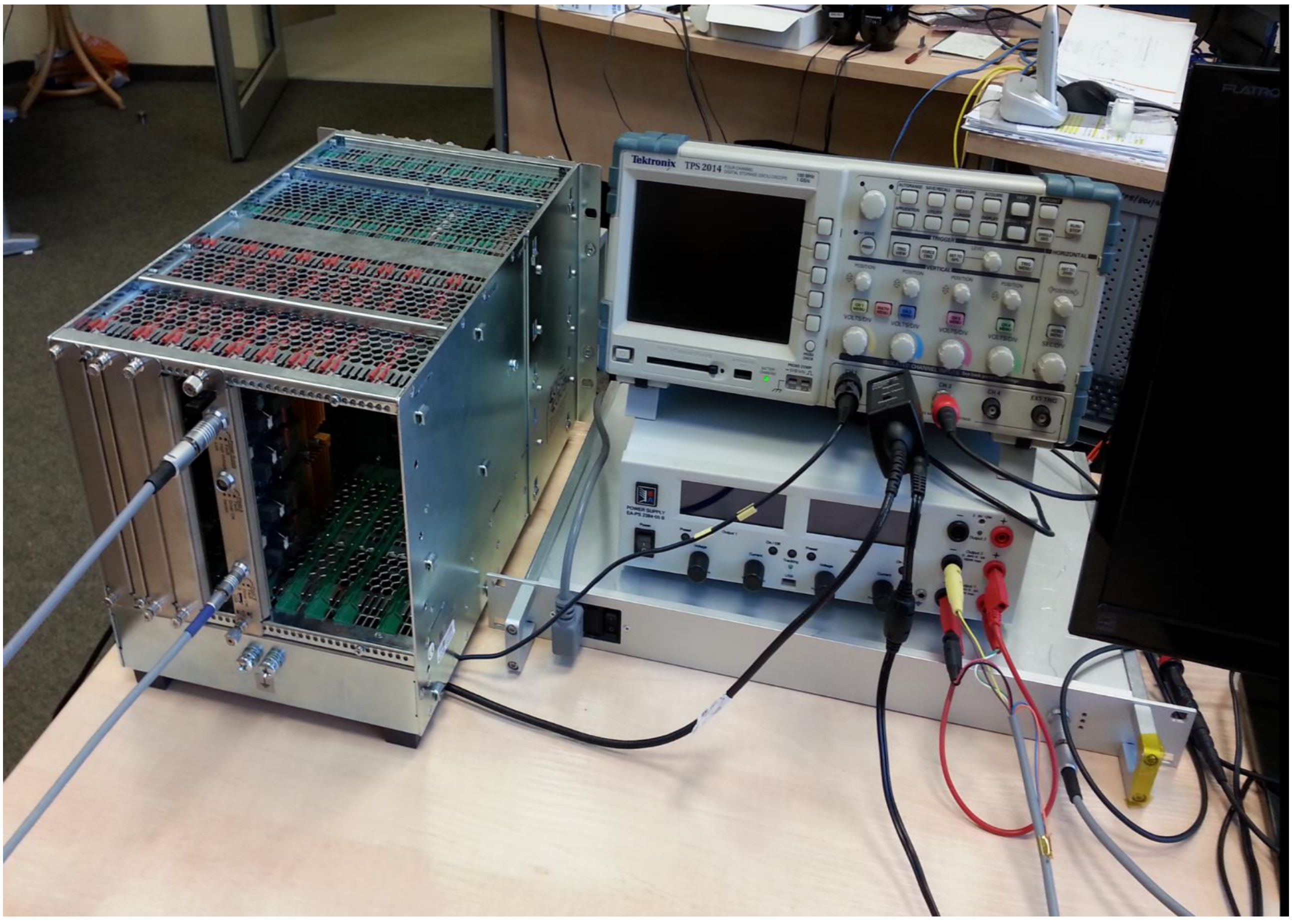

Figure 8 Test stand used for testing and measurements of PCD and PPSM at TUL-DMCS premises.

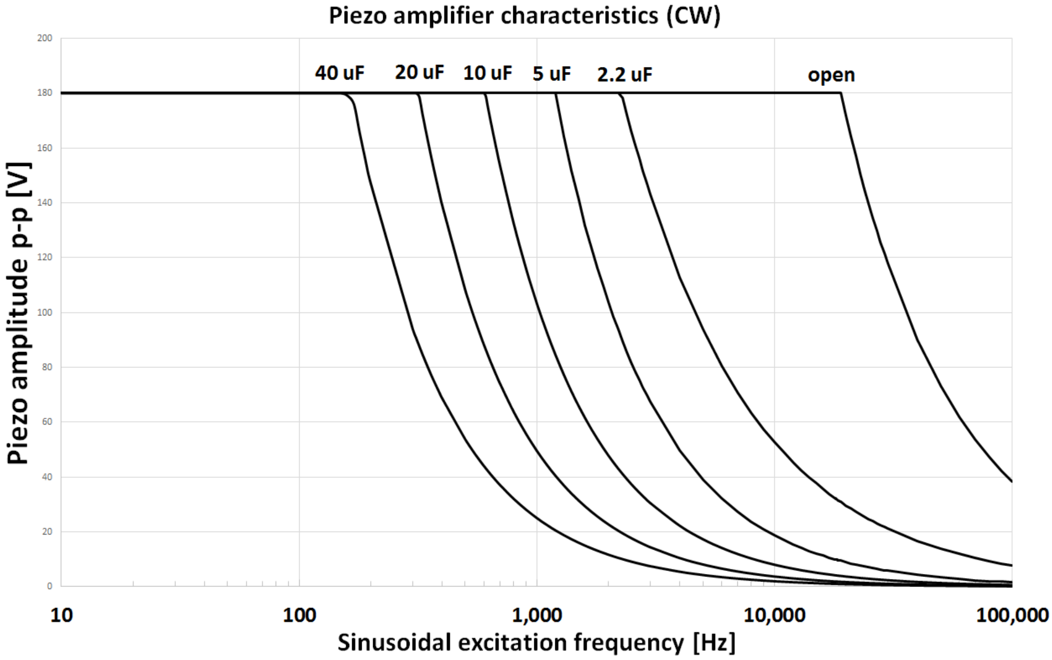

Figure 9 Safe operation area characteristics measured for various capacitive loads in continuous mode.

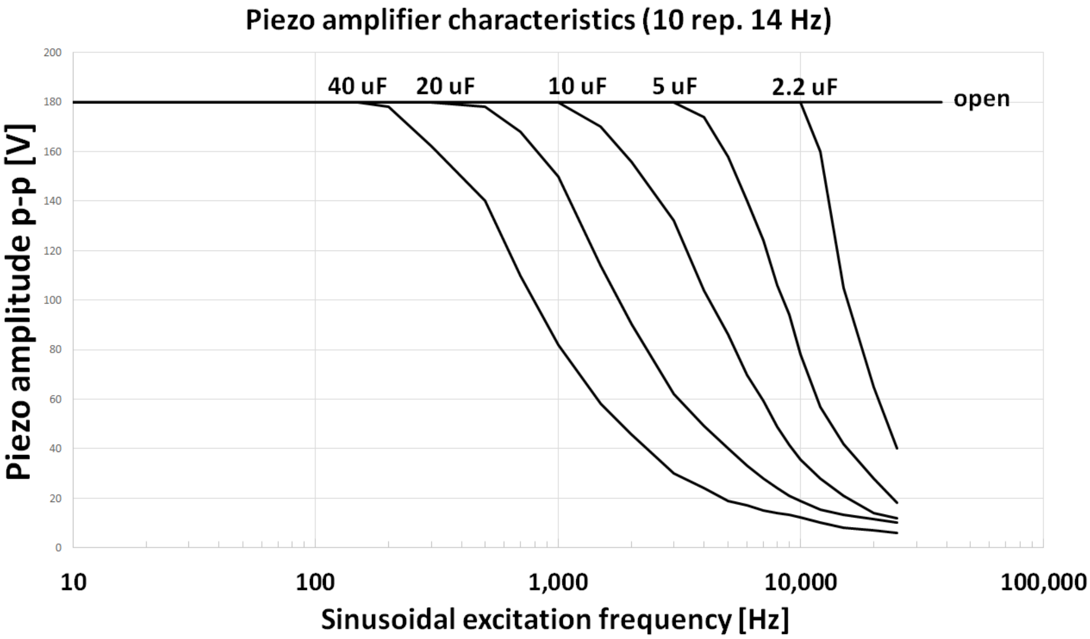

Figure 10 Safe operation area characteristics measured for various capacitive loads in pulsed mode.

During the test, the temperature of critical components was verified using thermometers assembled in the module, thermocouple sensors and thermal camera. The measurements presenting device during the operation is presented in Figure 11 (CW mode with 10 uF load, f=1 kHz, V=100 Vpp). The hottest components are the first stage L-C filter coils and heat-sink. The temperature reached 80 C.

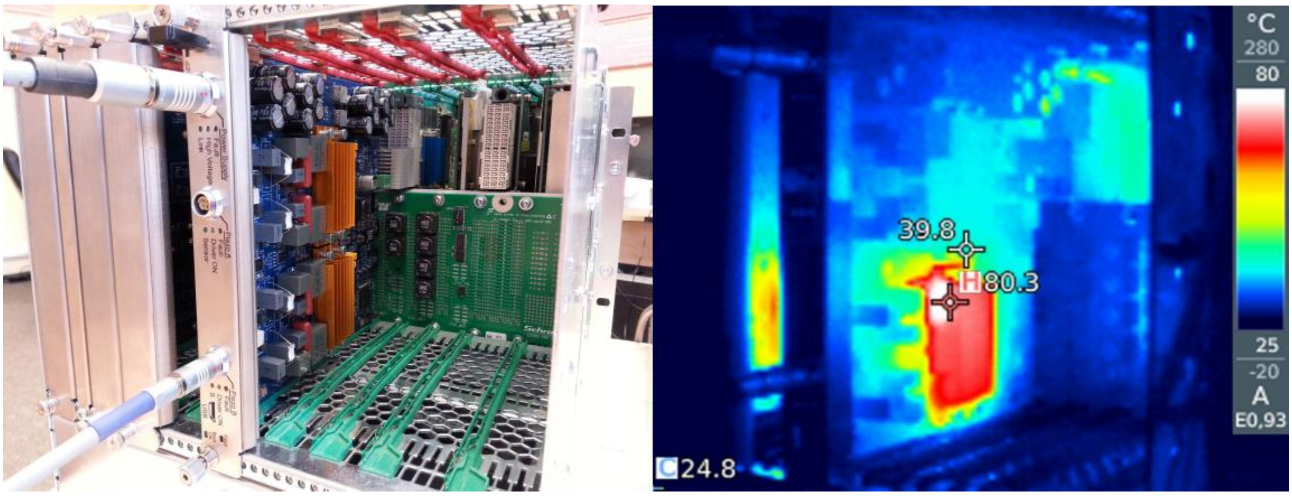

Figure 11 The thermal measurements during piezo operation (single channels active).

The developed PCD prototype was tested for 4 days using the setup present in Figure 12. During 96 hours the device operated without any problems. The device was loaded with two 2.2 uF capacitors connected via two 5 Ohm cables. The PCD was supplied with sinusoidal CW signal (f=1 kHz and 160 Vpp amplitude).

The device has various protection mechanisms including temperature monitoring in critical places, RMS current, maximum current and energy monitoring in series resistances and coils, as well as piezo protection algorithms. All protection mechanisms except piezo protection were successfully tested.

Further long-term tests are strongly recommended to verify the operation of the devices for longer time (> 30 days). Finally, all the measurements will be collected in final report for PCD and PPSM.

Figure 12 The MicroTCA.4 chassis used for long-term tests.

The L-C-L-C filter was optimised for 2.2 uF load and min. 5 Ohm cable resistance to avoid parasitic resonances and flat response to input signal up to 180 Vpp driving signal. Using larges capacitances (> 10 uF) may require further tuning and optimisation.

8 PIEZO CONTROL DEVICE INSTALLATION AND OPERATION

The PCD can only be used in certified MicroTCA.4 crate with the dedicated RTM carrier board and a dedicated external Piezo Power Supply Module. The PZD PCB is presented in the Figure 13.

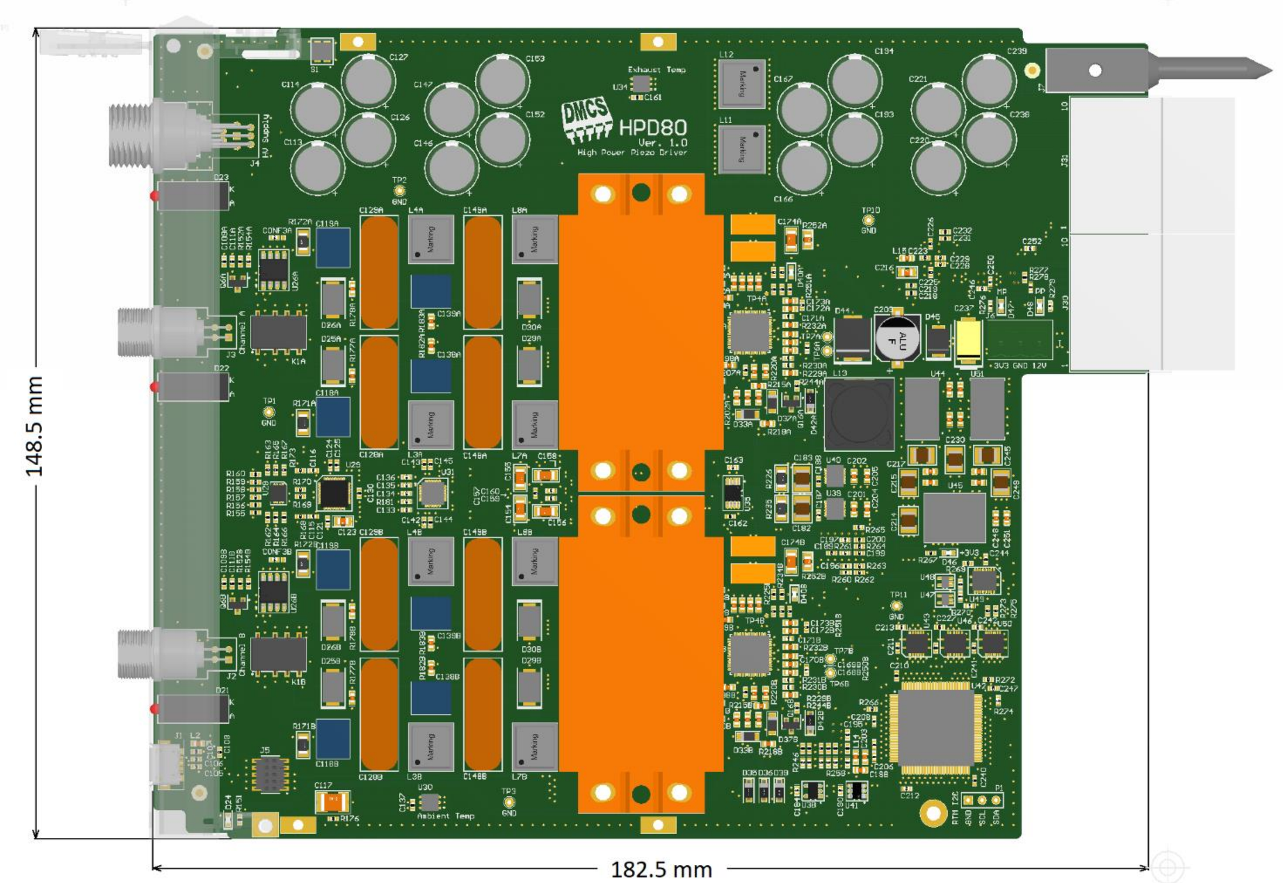

Figure 13 Piezo Control Device - Top-view.

The dedicated Piezo Power Supply Module should be connected to Piezo Control Device using a dedicated cables with maximum length of 2 m. The PPSM device is connected using 8-pin DBPC 103 A058-130 Fisher connector. Two piezo actuators (Channel A and Channel B) are connected using 4-pin DBPC 102 A053-130 Fisher connectors. The fisher connector requires suitable ID coding resistors as described in in details in Chapter 0. The front-panel connectors are presented in Figure 14.

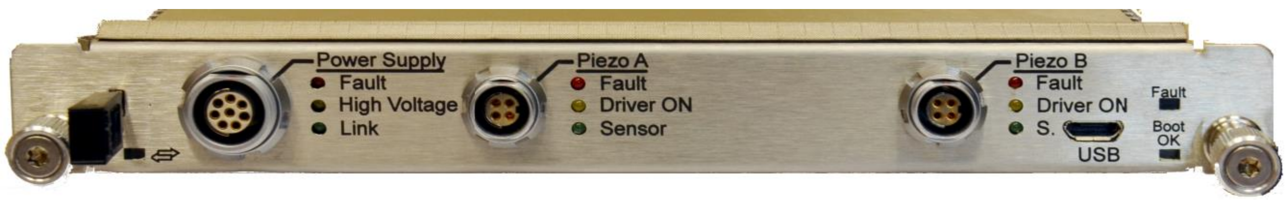

Figure 14 Connectors on the front-panel of Piezo Control Device.

Before performing any operation on PCS cabling the power supply shall be turned off and the RTM module shall be deactivated.

Installation procedure:

- Make sure:
  - The power supply mains switch is in the off position.
  - The AMC handle of the RTM module is open.
  - The RTM carrier module is properly installed in the MicroTCA.4 chassis.
  - There is no risk to any persons and equipment due to powering the piezo elements.
- Mount the 19” power supply unit in the same cubicle as the MTCA.4 crate in which the PCD will operate. Keep in mind the maximum length of the power cable between the PCD with its power supply. The power supply relies on the externally induced airflow. Make sure the air is pushed through the device front-to-back.
- Insert the PCD module in the rear slot of an MTCA.4 crate corresponding to the RTM carrier module. Do not close its handle yet. If the crate is operational, the PCD module should get the Management Power and it shall turn on the blue IPMI LED.
- Connect the power cable between J1 connector PCD (see Figure 14) and its PPSM. Avoid exerting excessive mechanical stress on the cable.
- Connect the piezo elements to the PCD connectors labelled “Piezo A” and/or “Piezo B”. Avoid contact with the terminals as there is a risk of them carrying a considerable electrical charge (e.g. due to a mechanical stress to the piezo stack), see Figure 14.
- Connect the mains power cord to the power supply and power it on.

Power on procedure:

- Turn on the power supply with the switch located on its front panel. At this time no LED on the power supply shall be lit.
- Turn on the MTCA.4 chassis and close the PZD hot-plug handler to activate the module. The Blue IPMI LED should start blinking and turn off after dozen of seconds. The properly activated module should turn on the Green IPMI LED. The link between the PZD module and external PPSM should be established, blinking ‘Link’ LED close to Power Supply connector. The ‘High Voltage’ LED is enable when PPSM provides high voltage supplying piezo driver. All the three LEDs of the power supply shall turn on.

Power off procedure:

- Open the AMC handle of the PCD. The board shall deactivate (blue LED on) and disable the power supply high-voltage (all LEDs off on the power supply and the ‘High Voltage’ LED on PZD should be off). The piezoelectric elements will be discharged.
- Turn off the PPSM using the switch located on its front panel.

Emergency power off procedure:

- In case of:
    - Being unable to deactivate the RTM.
    - Necessity of quickly disabling the piezo power.
- Turn off the power supply using the switch located on its front panel. The piezo actuators will be disabled and discharged automatically. The procedure is safe, however a fault will be reported by the PCD module.

9 Piezo Control Device Maintenance and Servicing

General Safety Instructions:

To avoid potential hazards, use this product only as specified. Do Not Operate in Wet/Damp Conditions. Comply with local and national safety codes. If you suspect there is damage to this product, have it inspected by qualified service personnel.

Air Flow and Cooling:

To ensure proper cooling, keep the front and rear of the instrument clear of obstructions. Slots and openings are provided for ventilation and should never be covered or otherwise obstructed. Do not push objects into any of the openings. To prevent product overheating, provide proper ventilation.

Servicing:

The power supply contains user serviceable power line fuse, which shall only be replaced by a fuse of identical type. If the fuse is repeatable getting broken the device shall be sent for repair. Other PCD components are not user serviceable. Only qualified personnel should perform the service procedures. Do not operate this product with covers or panels removed.

Critical Components:

These products are not authorised for use as critical components in nuclear control systems, life support systems or equipment for use in hazardous environments.

Product Usage:

The PCD and its power supply are designed for use within a host equipment, which restricts access to authorised competent personnel. It is not intended for sale to end users. The PCD RTM is a component and does not fall within the scope of the EMC directive. Compliance with the EMC directive must be considered in the final installation.

End of Life Disposal:

The unit contains components that require special disposal. Make sure that the unit is properly disposed of at the end of its service life and in accordance with local regulations.

High Voltage Warning:

Dangerous voltages are present within both the power supply and the PCD. None of the PCS cables should be connected or disconnected during operation. In case of spurious disconnection of the piezoelectric element a high voltage can be present on its terminals for a long time.

10 PIEZO CONTROL DEVICE VERIFICATION PLAN

Each manufactured RTM Piezo Control Device should be tested at manufactured site (Factory Acceptance Test) and ESS site (Site Acceptance Tests). The device test plan will provide detailed information concerning test environment and list of test that should verify the proper operation of PCD module.

In the first step, a visual inspection will be performed to find out assembly problems.

In the further steps, a dedicated test stand will be applied for automated testing of PCD and PPSM components. The test stand will take advantage of IPMI sensors for automated parameters measurements and verification, including voltages, currents, and temperatures.

The PDC will be loaded with reference capacitance (C=2.2 uF) and it driven by reference pulsed sinusoidal signal (f= 1kHz, n=10 pulses). The voltage and load current will be recorded for maximum output amplitude 160 Vpp to verify the device fulfils the electrical requirements specified in Table 1 and Table 7.

A detailed test report, similar to report presented in Figure 15, will be delivered for each tested PCD and PPSM components.

Report on uTCK7-16.0021

Report information

Table 1: Report properties

Parameter name	Value
Date	2015-10-26 21:31:04
DESY inventory number	uTCK7-16.0021
Place	DMCS, Łódź
Digital ID	001EC0DE7D7A
Tester	Dariusz Makowski

FRU Information Readout

Table 2: FRU Info

Parameter name	Value
Product Version	2.1
Product Manufacturer	Vadatech
Product Name	DAMC-TCK7

Test result PASS

Preliminary board information

Table 3: Evaluation results

Question	Status
Is the board free of scratches?	PASS
Are all the elements fitted?	PASS
Is the board in good mechanical condition?	PASS
Remarks	Repeated test, because of problems with Zone 3 communication with VM. Tested with VM: uVM-19.0065.

Test result PASS

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Figure 15 Example test report generated by automated test stand.

The final Piezo Control Device test plan will be proposed when the final tests of PCD with the final RTM-carrier module will be finished.

11 PIEZO CONTROL DEVICE MANUFACTURE DOCUMENTATION

The set of documentation for the final Piezo Control Device will be provided when the final, tested device will be available.

12 PIEZO CONTROL DEVICE PROJECT SCHEDULE

The initial plan for development and production schedule for PZD and PPSM is presented in Figure 16.

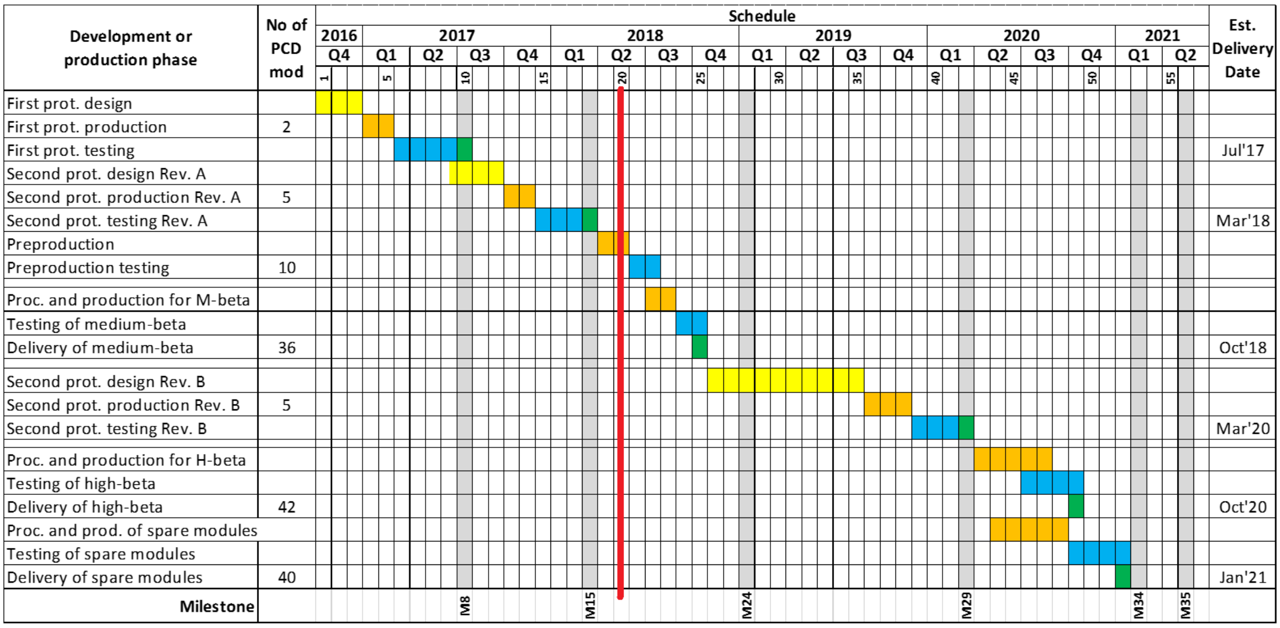

Figure 16 The development and production schedule for PZD and PPSM.

Before the preproduction we be started the following tests need to be finished:

- Long-term reliability tests (min. 30 days).
- Corner thermal tests in climatic test chamber.
- EMC/ESD tests for PZD and PPSM, certification for PPSM.
- Tests with the final RTM-Carrier module.
- Test with real cavity and Lorentz force detuning algorithms.

At this stage, we are not ready for the final production. We plan the preproduction of next 4 PZD modules as soon as tests above will be succeeded.

The proposed schedule need to be updated according to the main schedule agreed with PEG consortium.

13 Piezo Control Device - Procurement, Production and delivery planning

The design of the PCD need to be redesigned because of the modifications of output resistance, output L-C-L-C filter components and specification concerning HV power supply control of the external PPSM.

Therefore, the production of 4 corrected modules is planned when the tests mentioned in Chapter 12 will be succeeded. Next, the preproduction will be triggers (10 devices) and the final production (36 devices), see Figure 16.

Some of components for PCD and PPSM could have a long delivery time reaching 16 weeks. The identified components are:

- J1 Fisher HV power supply connector and length of the cable between PCD and PPSM.
- J2 and J3 connectors and cable connecting PCD and piezo actuators installed in cryo-module.
- TDK Lambda power supply modules.

The procurement need to be carefully scheduled to avoid potential delays.

It is important to agree and fix the interfaces and connectors between PCD, PPSM and other component of the accelerator.

14 Piezo Control Device – RAMI Report

The RAMI Report will be covered by PEG presentation.

15 Piezo Control Device – Hazard Analysis Report

The Hazard Analysis Report will be covered by PEG presentation.

16 PIEZO CONTROL DEVICE – PROJECT QUALITY PLAN

The project Quality Plan will be covered by PEG presentation.

17 Piezo Control Device – Risk register

The Risk Register is managed by PEG consortium and it will be covered by PEG presentation. The main risk were identified and they are available in the currently available Risk Register [3].

In addition, the following additional risks were identified for PCD and PPSM:

- Lack of long term reliability tests (min. 30 days).
- Lack of corner thermal tests in climatic test chamber.
- Lack of EMC/ESD tests and certification.
- Lack of tests with final RTM-Carrier module.
- Missing specification for piezo control signal.
- Missing load specification, including piezo and cables.
- Lack of test with real cavity and Lorentz force detuning algorithms.
- Long-delivery time or unavailability of components required to manufacture PCD or PPSM.

18 References

[1] D. Makowski, A. Mielczarek: “Piezo Control Device - specification and conceptual design document”

[2] D. Makowski, A. Mielczarek: “Piezo Power Supply Module - specification and conceptual design document”

[3] PEG: “Risk Register for Polish IKC delivery”