

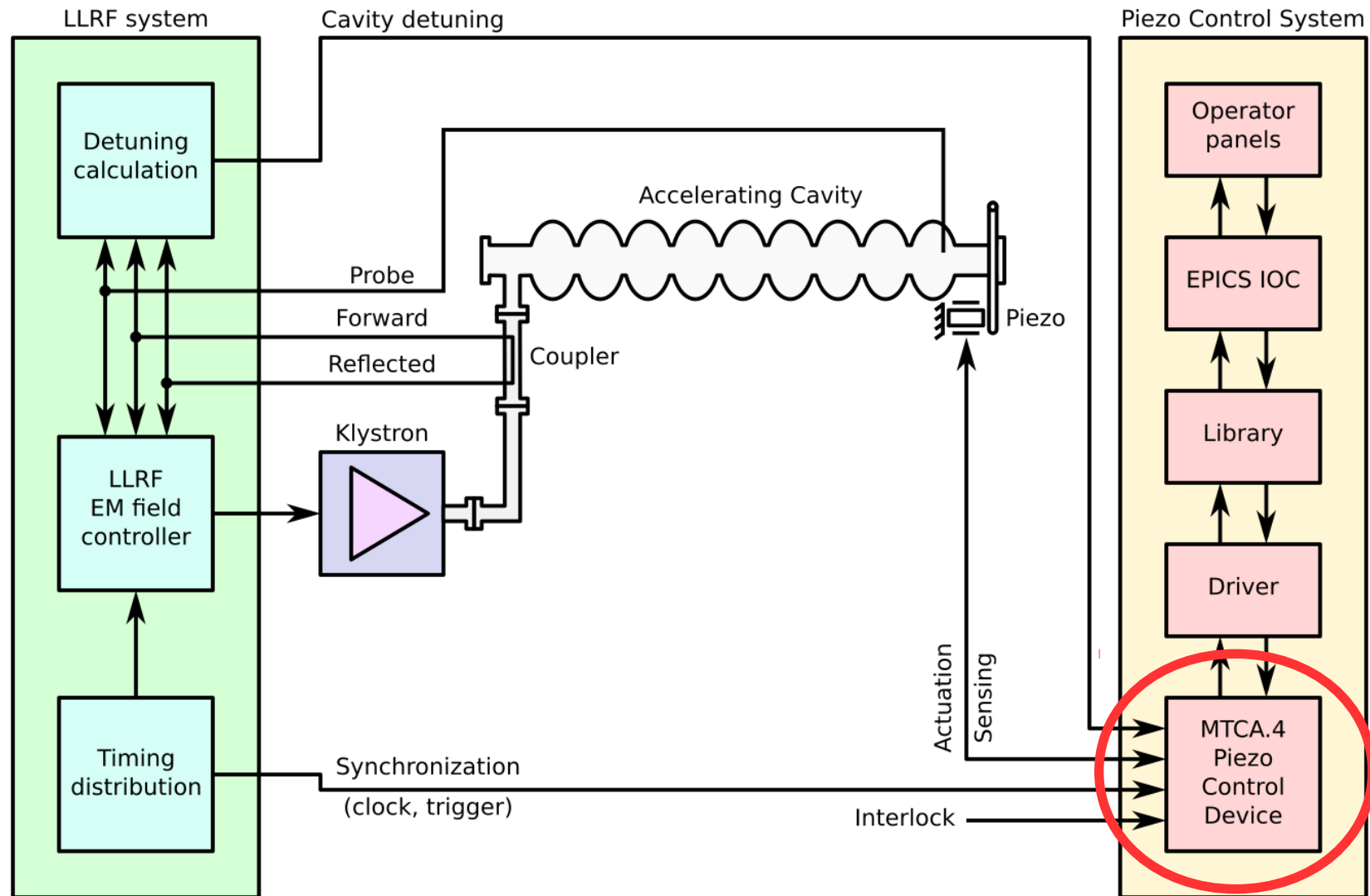
Extension of MMC for Diagnostics and Management of High Power Piezo Driver

Dariusz Makowski
dariusz.makowski@p.lodz.pl

Polish In-Kind for European Spallation Source in Lund, Sweden

- ◆ Responsible for MicroTCA.4 LLRF system for medium- and high-beta cavities
- ◆ TUL-DMCS provides hardware and software for Piezo Control System
- ◆ High Power Piezo Driver - Short Specification
 - ◆ Provide a control signal for piezo actuators of medium-, high-beta and spoke cavities of ESS accelerator operating in cryogenic temperatures
 - ◆ Measure cavity deformation using piezo device as sensor element
 - ◆ Support two independent channels with configurable mode of operation:
 - Piezo actuator and/or
 - Piezo sensor
 - ◆ **Compatible with MicroTCA.4 and MicroTCA.4.1 standards**
 - ◆ Provide health monitoring and diagnostics
 - ◆ Assure safe operation of piezo actuator

Piezo Compensation System



Piezo Actuators Selected for ESS

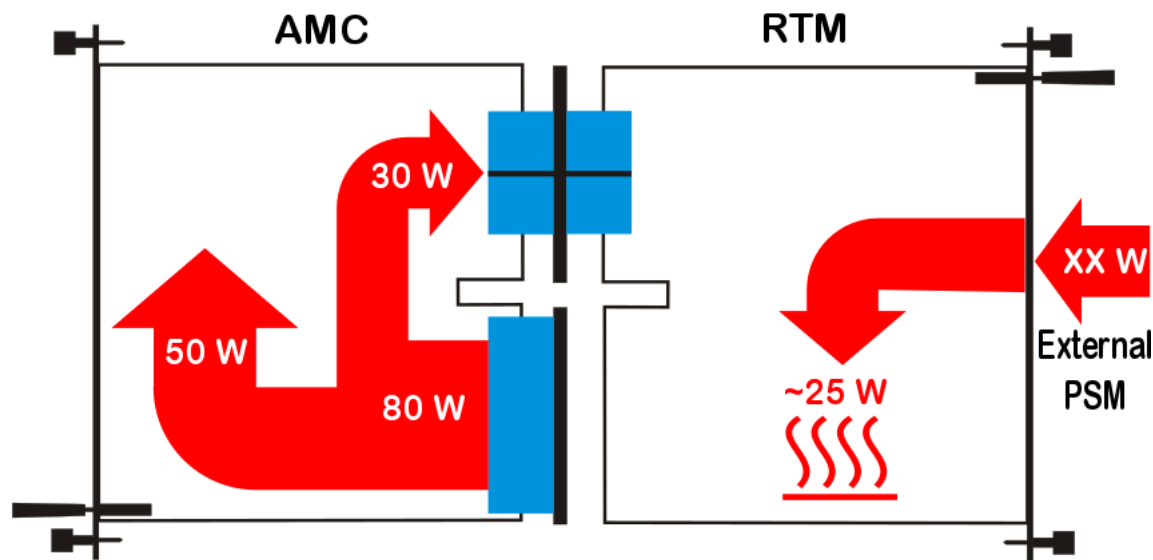
Cavity type	Piezo actuator type
Medium Beta cavities	Noliac NAC 2022 H30
High Beta cavities	Noliac NAC 2022 H30
Spoke cavities	Piezo #1: Noliac NAC2022-H90-A01 Piezo #2: PI PICMA P-888.91/51

Piezo type	Noliac NAC 2022 H30	Noliac NAC 2022 H90	PI Stack 2x P-888.90 + 1x P-888.50
Dimensions	10 x 10 x 30 mm	10 x 10 x 90 mm	10 x 10 x 90 mm
Cell material	NCE51F	NCE51F	PIC252
Number of cells	15	45	
Total capacitance (room temp.)	6.6 μF $\pm 15\%$	17.4 μF $\pm 15\%$	32 μF $\pm 20\%$
Total capacitance (cryo, 20 K)	~2.2 μF	~5.8 μF	~9.8 μF
Max. free stroke	46.2 μm	145.2 μm	94 μm
Blocking force	4200 N	4200 N	3600 N
Max. operating voltage	200 V (± 100 V)	200 V (± 100 V)	-20 to 120 V
Max. operating temperature	200°C	200°C	150°C

Possible Solutions of Piezo Driver MicroTCA.4 Implementation #3

III. AMC + RTM card + External PSM

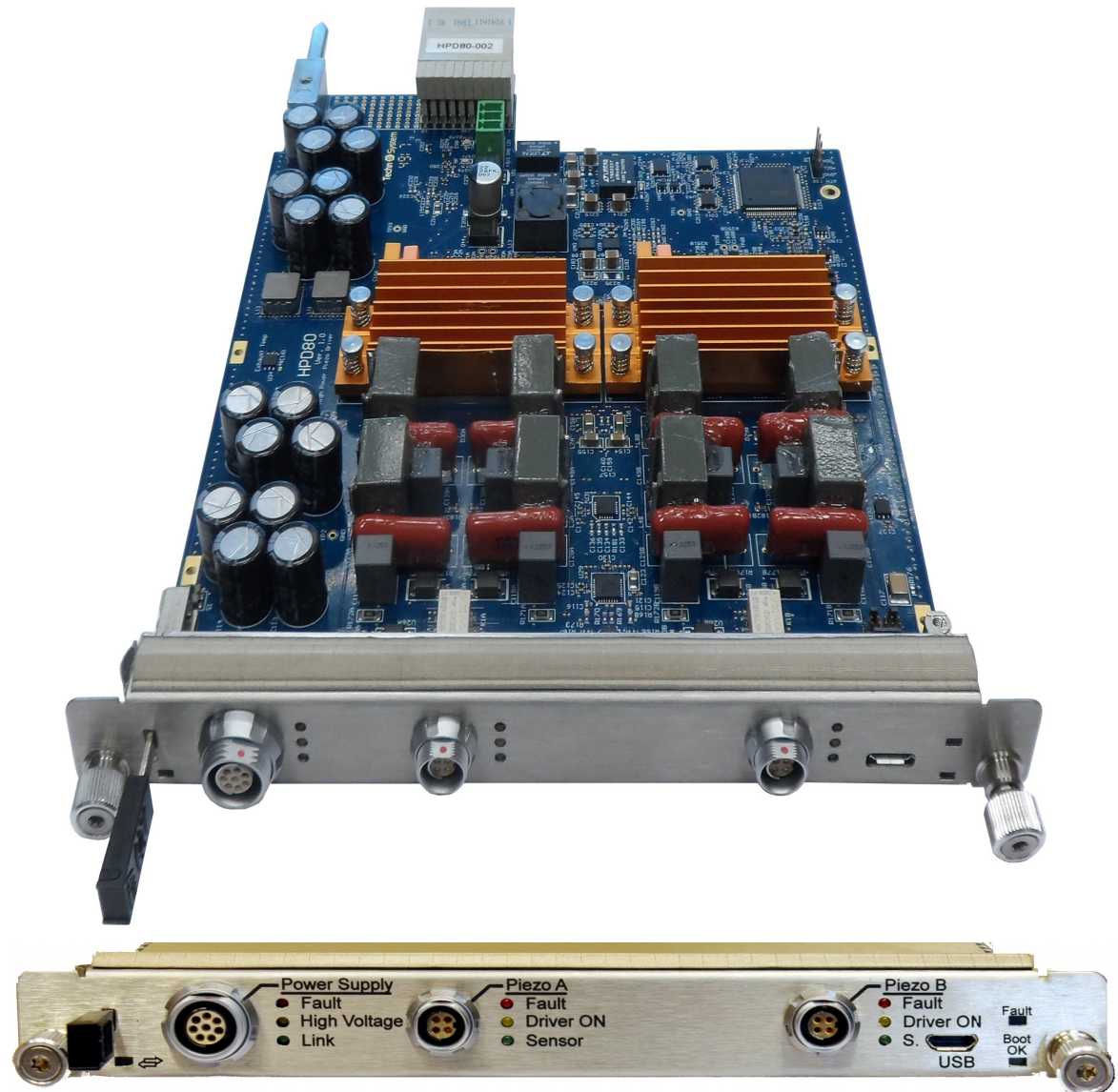
1. 5-10 Watts for Payload (from AMC)
2. Untimed power for Piezo Driver from external power supply
3. Limited piezo power by cooling capability to ~20-25 Watts



200 W Piezo Power Supply Module

Piezo Driver RTM Module – the final Device

- ◆ 2 channels of high power piezo driver
 - ◆ 2x 35 Watts (MTCA.4 power supply)
 - ◆ 2x 100 Watts (external power supply)
- ◆ Piezo driver and piezo sensor mode
- ◆ Build-in diagnostics (advanced implementation of RMC)
- ◆ Various protection mechanisms for both Piezo channels to protect driver itself and piezo actuator
- ◆ Working on a new digital high-voltage class D1.2-HV (± 50 V) on Zone 3 (MTCA.4 power supply)



More about High Power Piezo Driver

High-power Piezoelectric Tuner Driver for Lorentz Force Compensation

12 Jun 2018, 14:40

1h 30m

Woodlands Conference Center

Speaker

Dr Dariusz Makowski (Lodz University of Te...)

Poster presentation

New Standards

Poster 1

HIGH-POWER PIEZOELECTRIC TUNER DRIVER FOR LORENTZ FORCE COMPENSATION

D. MAKOWSKI, A. MIELCZAREK, P. PEREK, A. SZUBERT, P. PLEWIŃSKI, G. JABŁOŃSKI, W. CICHALEWSKI, A. NAPIERALSKI

LODZ UNIVERSITY OF TECHNOLOGY, DEPT. OF MICROELECTRONICS AND COMPUTER SCIENCE

Introduction

Superconducting Radio Frequency (SRF) cavities are used in modern accelerators to efficiently accelerate particles. When cavity is supplied with pulsed RF field it undergoes a mechanical strain due to the Lorentz force. The resulting deformation causes dynamic detuning of which magnitude depends on mechanical properties of the cavity, RF pulse rate and their profile. This effect causes considerable loss of acceleration performance. Therefore, it is usually actively compensated, most commonly with fast piezoelectric actuators.

MicroTCA.4 standard was developed to accommodate control and data acquisition electronic systems of large-scale physics applications. The poster presents the design of a high-power amplifier implemented using the MicroTCA.4 technology. The design of the driver was optimized for driving large-capacitance piezo actuators. Several possible architectures of the driver are presented and compared, taking into consideration the power and cooling limitations of MicroTCA.4. The design of a two-channel piezo driver and its initial laboratory test results are also discussed.

MicroTCA.4

The MicroTCA.4 standard, developed in 2003 is based on the original PG Industrial Computer Manufacturers Group (PGMG) MicroTCA.0 specification and therefore inherits the main limitations of the base standard concerning power consumption and heat generation in a single slot. The hard limits of MicroTCA.4 technology make designing a high-power piezo driver a non-trivial task.

Specification

- Provide a control signal for piezo actuators operating with power of 100 W for each channel
- Measure cavity deformation with piezo sensor
- Support two independent channels with configurable mode: Piezo actuator and/or sensor
- Compatible with MicroTCA.4 and PMM standards
- Provide health monitoring and diagnostics
- Assure safe operation of piezo actuator

Possible Scenarios

The MicroTCA.4 and MicroTCA.4 standards allow dissipating up to 80 W in a single AMC slot. The Piezo Driver could be designed as AMC device dissipating up to 80 W for AMC and 30 W for RTM. The control division on RTM consumes ca. 10 W. Only 20 W is available for the high-power driver. Therefore a design of a two-channel piezo driver is not possible in this configuration.

When the Rear Transition Module (RTM) is used the power provided by the MicroTCA.4 power supply system is shared between the AMC (50 W) and the RTM device (30 W). In such situation the cooling capabilities are limited to 80 W for AMC and 30 W for RTM. The control division on RTM consumes ca. 10 W. Only 20 W is available for the high-power driver. Therefore a design of a two-channel piezo driver is not possible in this configuration.

The architecture involving an external power supply was selected. The external power supply can provide much more power than available from MicroTCA.4 internal power supply. However, the cooling is still limited to 30 W on the RTM side. Therefore, the design of a large-power piezo driver suitable for accelerators operating with long RF pulses, such as the ESS machine built in Sweden, requires a high-efficiency amplifier designed as an RTM.

Implementation

In order to overcome the 30 W cooling limits on RTM a high-efficiency power amplifier is needed. A typical linear class-AB amplifier is clearly not suitable for such applications, due to its poor energy efficiency limited to 50%. A 300-W class-AB amplifier dissipates at least 60 W. Therefore, a high-efficiency class-D amplifier based on a PrimeMOS[®] MOSFET technology from International Rectifier was applied.

Evaluation

The output of the driver was first evaluated with various film capacitors ranging from 2.2 μ F up to 300 μ F. Next, the driver was applied to excite two NAC 2022 H33 piezo actuators/hensors installed in machine vics.

Piezo actuator is considered for ESS Lorentz force detuning

Piezo sensor and actuator in machine vics

Experimental results in continuous Mode

Experimental results in pulsed Mode

Conclusion

We developed the first high-power piezo driver for MicroTCA.4-based systems that can control the largest piezoelectric actuators with the capacitances up to 300 μ F. The driver fulfills all the MicroTCA.4 requirements, in particular the RTM dissipated power limited to 30 W.

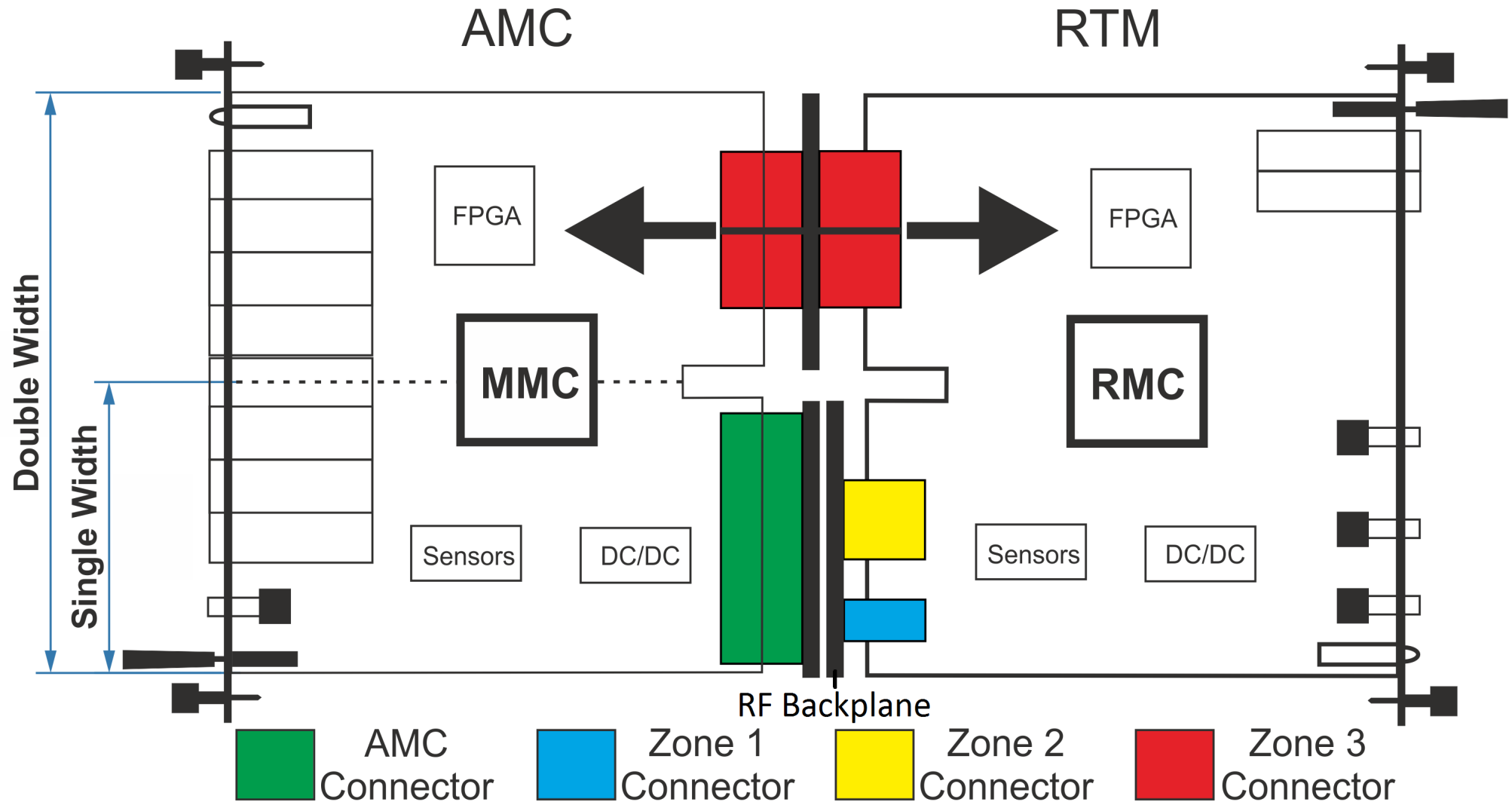
The initial tests have shown, that the RTM can interoperate with the AMC module and can drive loads up to 300 μ F. We are planning further tests in cavity assemblies in cryostats and accelerators.

The current high-power version of the driver requires an external power supply. However, if the driver requirements were relaxed, it would also be possible to build a version supplied solely from an AMC module.

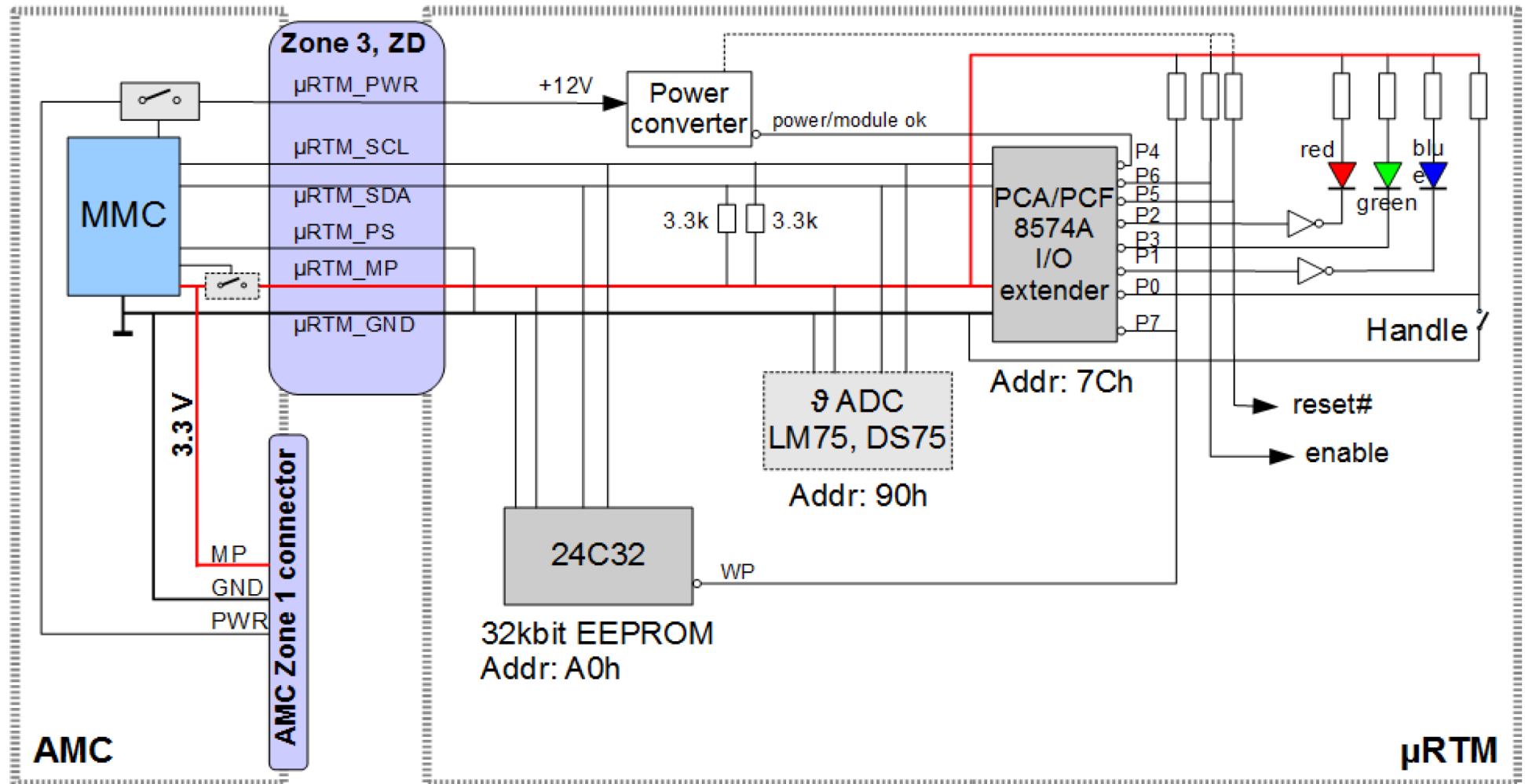
External Power Supply Health

- ◆ Condition of external PSM need to be monitored to assure high reliability (MTBF)
 - ◆ Avoid active cooling if possible (in other case monitor fan RPMs)
 - ◆ Monitor temperature of critical components (active components in AC/DC converters)
 - -50 V and +50 V
 - ◆ Monitor voltages:
 - -50 V and +50 V
- ◆ ID signature of PSM
- ◆ Communication with PSM
- ◆ Control External PSM
 - ◆ Disable in critical situation
 - ◆ Disable when cable disconnected
 - ◆ Provide power sequencer for high-voltage management

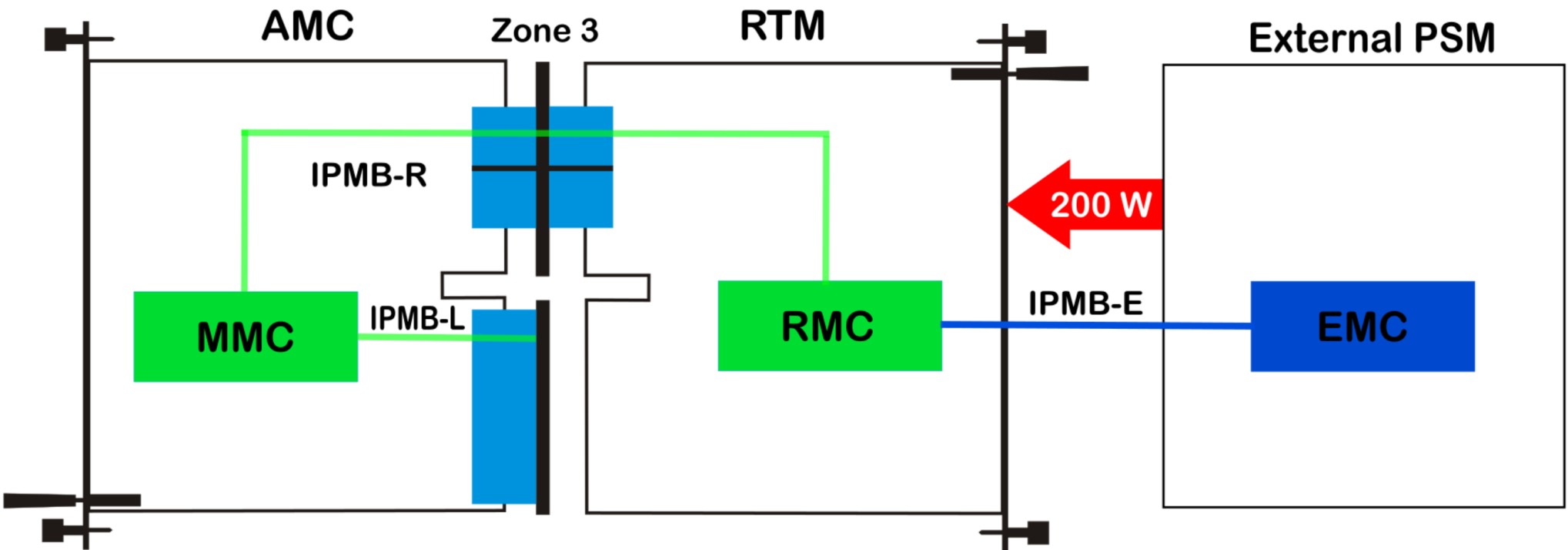
MicroTCA.4 – Intelligent Platform Management Interface



MTCA.4.1 – Basic RTM Management



Extended IPMI Diagnostics #1

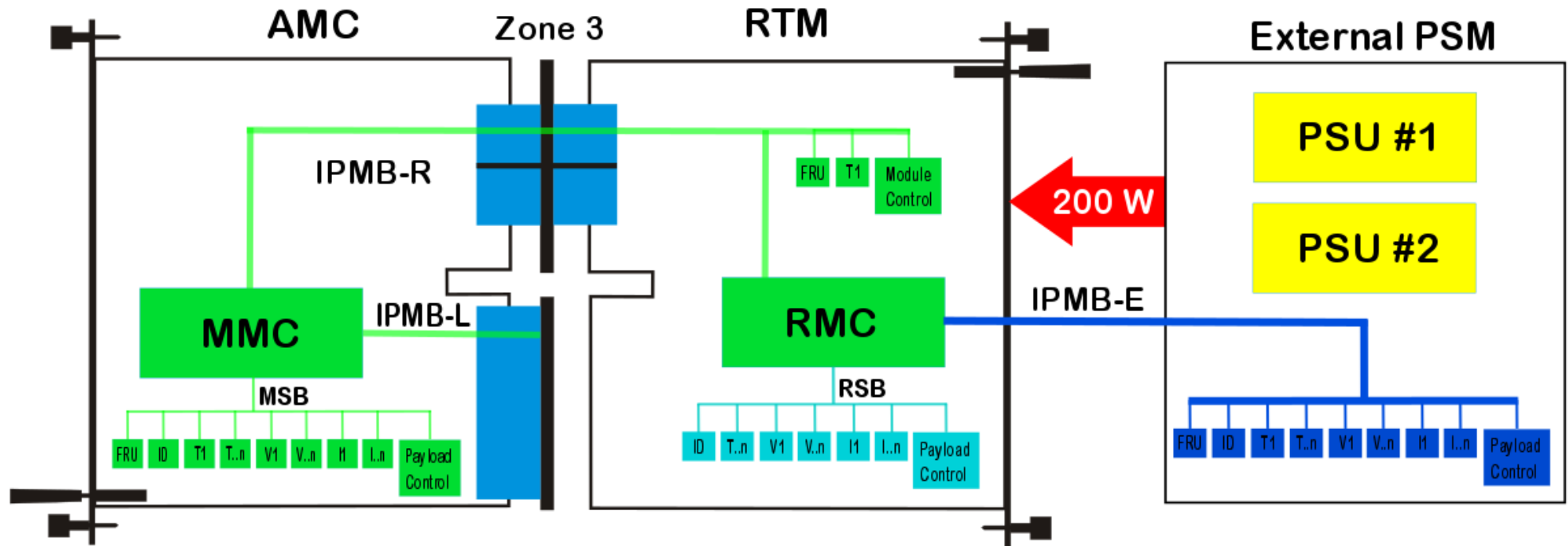


Based on MTCA.0, MTCA.4 and MTCA.4.1 PICMG standards

- MMC – Module Management Controller
- RMC – RTM Management Controller
- EMC – External Management Controller

- IPMB-L – IPMI Local Bus
- IPMB-R – IPMI RTM Bus
- IPMB-E – External IPMI Bus

Extended IPMI Diagnostics #2

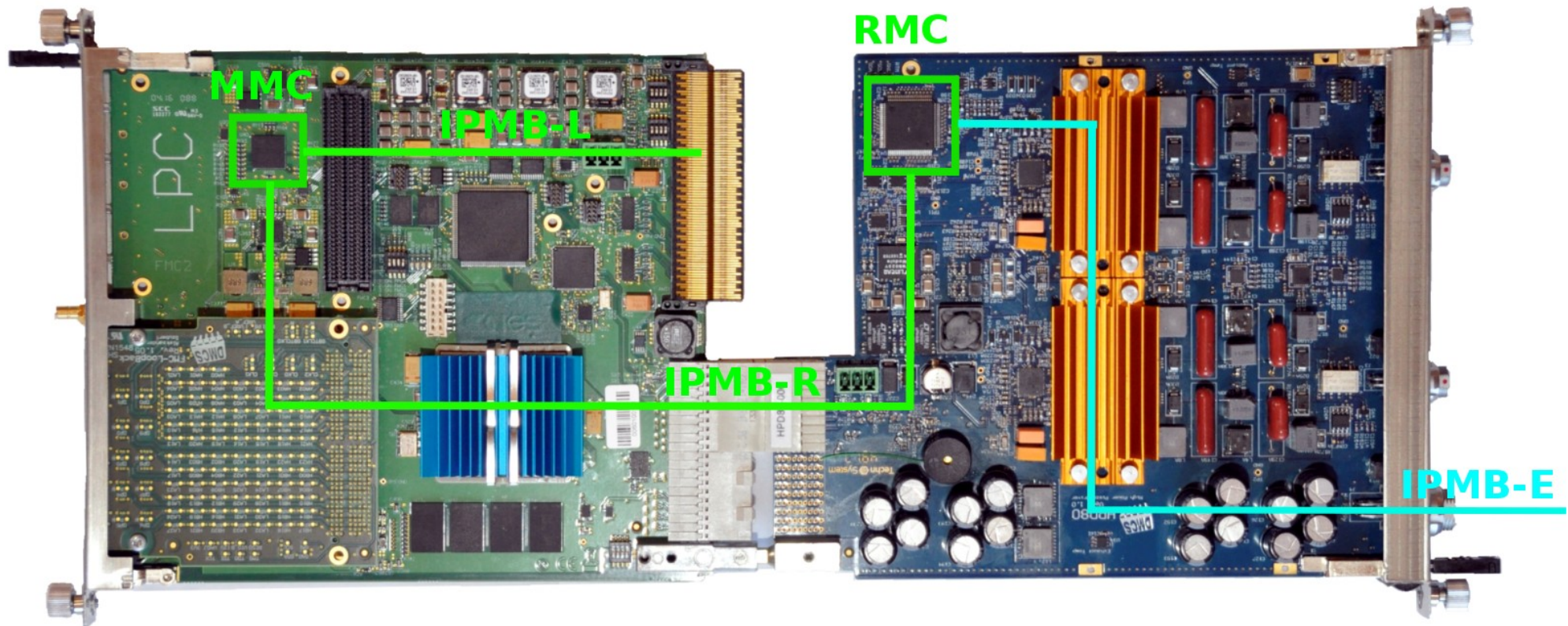


New architecture proposed for Extended IPMI Diagnostics

- MSB – MMC Sensors Bus
- RSB – RTM Sensors Bus

Hardware Setup for Extended IPMI Diagnostics Development

- ◆ Module Management Controller (MMC) designed by TUL-DMCS based on our 15-years experience in xTCA developments and standards (e.g. DESY MMC1.0).
- ◆ New project: Extended with RTM Module Management Controller (RMC)



AMC module with MMC

High-power Piezo Driver RTM
with RMC

High-Power Piezo Driver – IPMI Sensor Devices

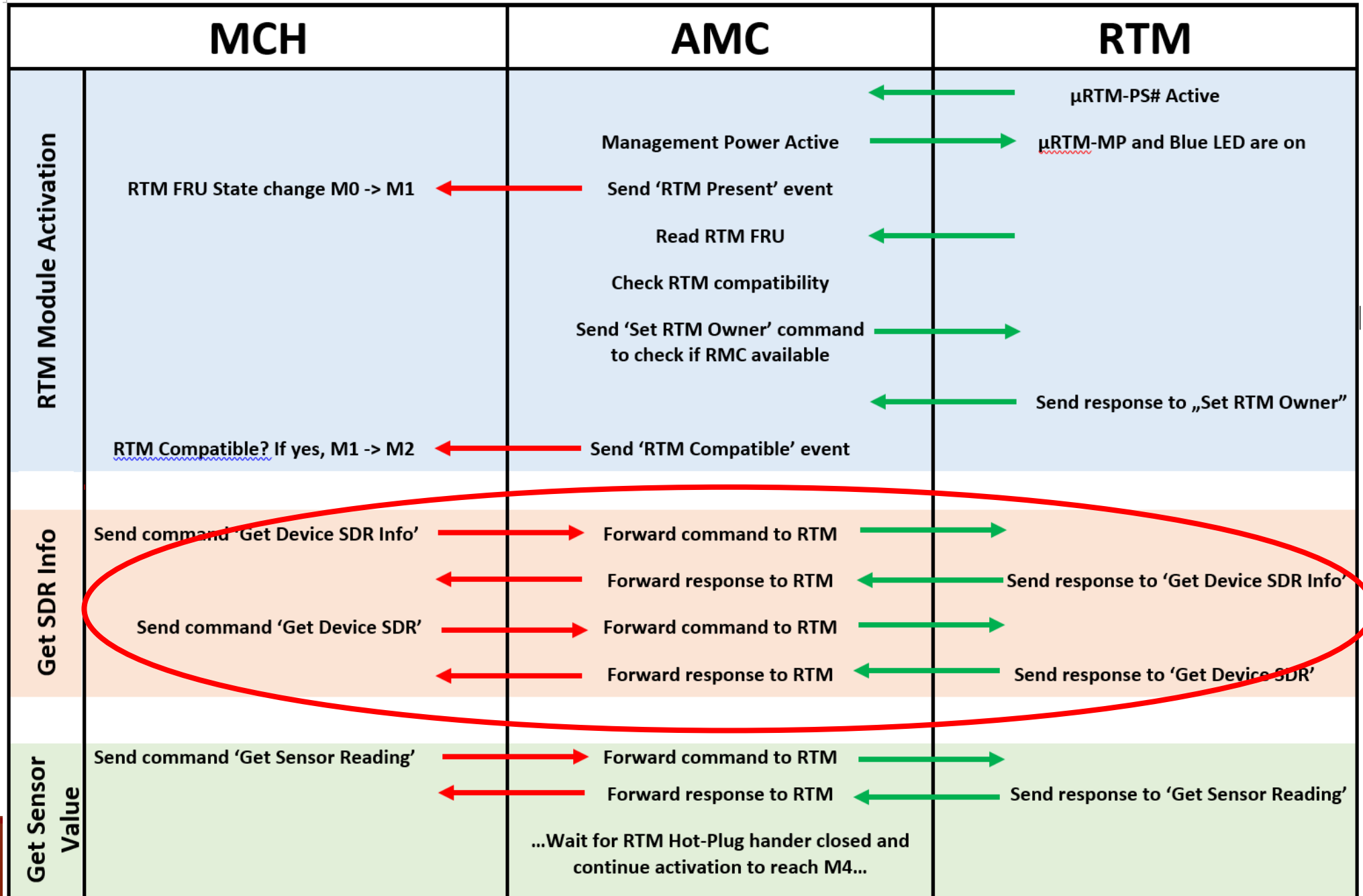
◆ Static IPMI Sensors:

- ◆ Module Hot Swap
- ◆ Temperature

◆ Dynamic IPMI Sensors:

- ◆ Temperature
 - Piezo Driver (Channel 1 and 2)
 - Inlet and Outlet
- ◆ Voltage
 - High Voltage +/-50 V
 - Analogue and Digital supply (6 voltages)
- ◆ Piezo Protection Circuit
 - Peak and Averaged Power (Channel 1 and 2)
- ◆ Piezo Channel Status
 - Mode of operation: Driver or Sensor (Channel 1 and 2)
 - Piezo presence and ID signature (Channel 1 and 2)
- ◆ External power supply
 - Device Presence (communication)
 - Temperature (ambient, negative and positive power supply)
 - Power Good signals (negative and positive power supply)
 - Device State

IPMI Protocol – Dynamic Sensors



Get Device SDR Info Command

Table 35-, Get Device SDR Info Command

Request Data	(1)	<p>Operation (optional)</p> <p>[7:1] - reserved</p> <p>[0] - 1b = Get SDR count. This returns the total number of SDRs in the device.</p> <p>0b = Get Sensor count. This returns the number of sensors implemented on LUN this command was addressed to.</p>
Response Data	1	Completion Code
	2	<p>For Operation = "Get Sensor Count" (or if byte 1 not present in request): Number of sensors in device for LUN this command was addressed to.</p> <p>For Operation = "Get SDR Count": Total Number of SDRs in the device.</p>
	3	<p>Flags:</p> <p><u>Dynamic population</u></p> <p>[7] - 0b = static sensor population. The number of sensors handled by this device is fixed, and a query shall return records for all sensors.</p> <p>1b = dynamic sensor population. This device may have its sensor population vary during 'run time' (defined as any time other than when an install operation is in progress).</p> <p><u>Reserved</u></p> <p>[6:4] - reserved</p> <p><u>Device LUNs</u></p> <p>[3] - 1b = LUN 3 has sensors</p> <p>[2] - 1b = LUN 2 has sensors</p> <p>[1] - 1b = LUN 1 has sensors</p> <p>[0] - 1b = LUN 0 has sensors</p>
	4:7	<p>Sensor Population Change Indicator. LS byte first.</p> <p>Four byte timestamp, or counter. Updated or incremented each time the sensor population changes. This field is not provided if the flags indicate a static sensor population.</p>

HPD80 RTM – Dynamic Sensors

show_sensorinfo 93

Sensor Information for FRU 93 / RTM4

=====							
#	SDRType	Sensor Entity	Inst	Value	State	Name	

128	FDevLoc		0xc0	0x64		DMCS-HDP80 RTM	
32	Full	0xf2	0xc0	0x64	0xa1	RTM Hot Swap	
33	Compact	0x0b	0xc0	0x64	0x00	0x00 001EC0FEA37D	
34	Full	Temp	0xc0	0x64	27.3 C	ok	TEMP_CH_A
35	Full	Temp	0xc0	0x64	49.2 C	ok	TEMP_CH_B
36	Full	Temp	0xc0	0x64	25.7 C	ok	TEMP_INTAKE
37	Full	Temp	0xc0	0x64	34.2 C	ok	TEMP_EXHAUST
38	Full	Voltage	0xc1	0x64	49.88 V	ok	VCC+50V_IN
39	Full	Voltage	0xc1	0x64	-49.98 V	ok	VCC-50V_IN
40	Full	Voltage	0xc1	0x64	5.050 V	ok	VCC+5V0A
41	Full	Voltage	0xc1	0x64	-5.025 V	ok	VCC-5V0A
46	Compact	0x0b	0xc1	0x67	0x01	0x00 RES_ID_CH_A	
47	Compact	0x0b	0xc1	0x67	0x00	0x00 RES_ID_CH_B	
48	Compact	0x0b	0xc1	0x67	0x01	0x00 CH_A_STATE	
49	Compact	0x0b	0xc1	0x67	0x0	0x00 CH B STATE	

Summary

- ▶ 200 W Piezo Driver was designed as MicroTCA.4 RTM
- ▶ External Power Supply Module is required for high-power driver operation
- ▶ MicroTCA.4 and MicroTCA.4 RTM has a limited diagnostic capabilities
- ▶ We proposed an extended diagnostics based on IPMI Dynamic Sensor Devices
 - ▶ Real-time diagnostics of RTM Piezo Driver is possible (ca. 20 sensors)
 - ▶ Real-time diagnostics and basic control over external Power Supply (6 sensors)
- ▶ In case of questions or suggestions you can contact with me via email:
dariusz.makowski@p.lodz.pl.

Thank you for your attention