HIGH-POWER PIEZOELECTRIC TUNER DRIVER FOR LORENTZ FORCE COMPENSATION

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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.

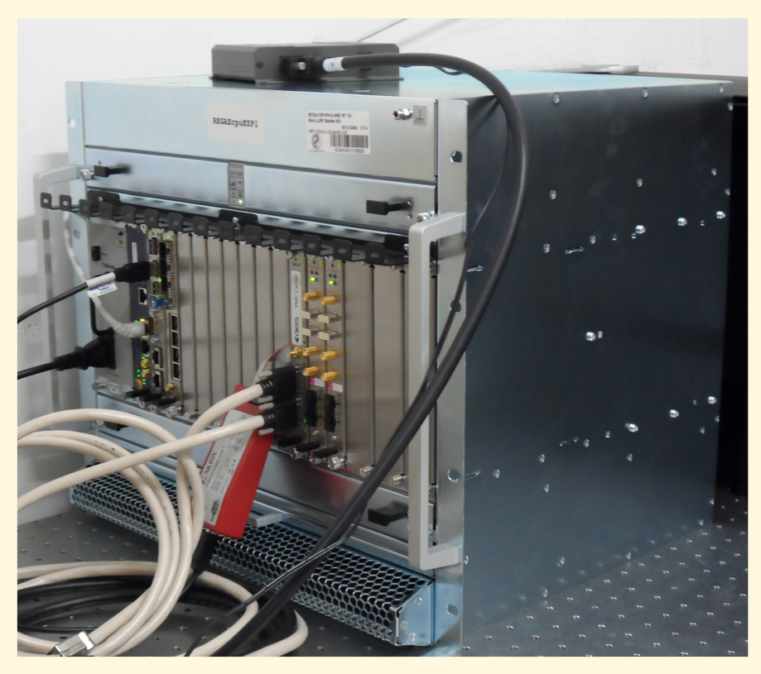
MicroTCA.4 standard was developed to accommodate control and data acquisition electronic systems of large-scale physics applications. The poster presents the design of a high-power amplifier implemented using the MicroTCA.4 technology. The design of the driver was optimized for driving large-capacitance 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 2011 is based on the original PCI Industrial Computer Manufacturers Group (PICMG) 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 nontrivial task.

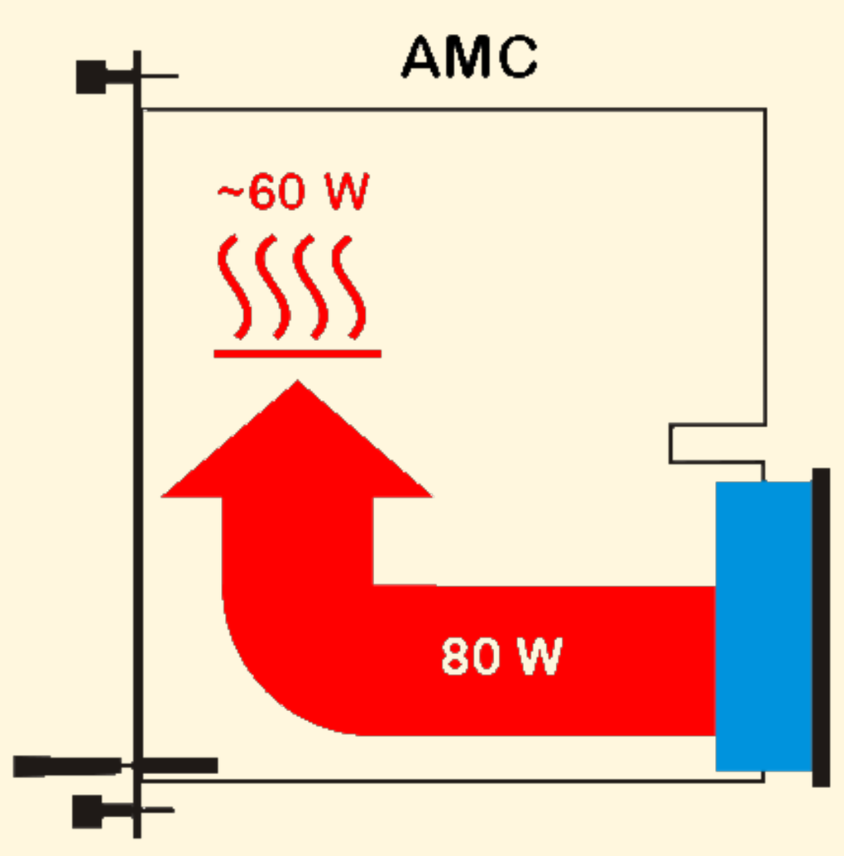
Specification

- 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 IPMI standards
- Provide health monitoring and diagnostics
- Assure safe operation of piezo actuator

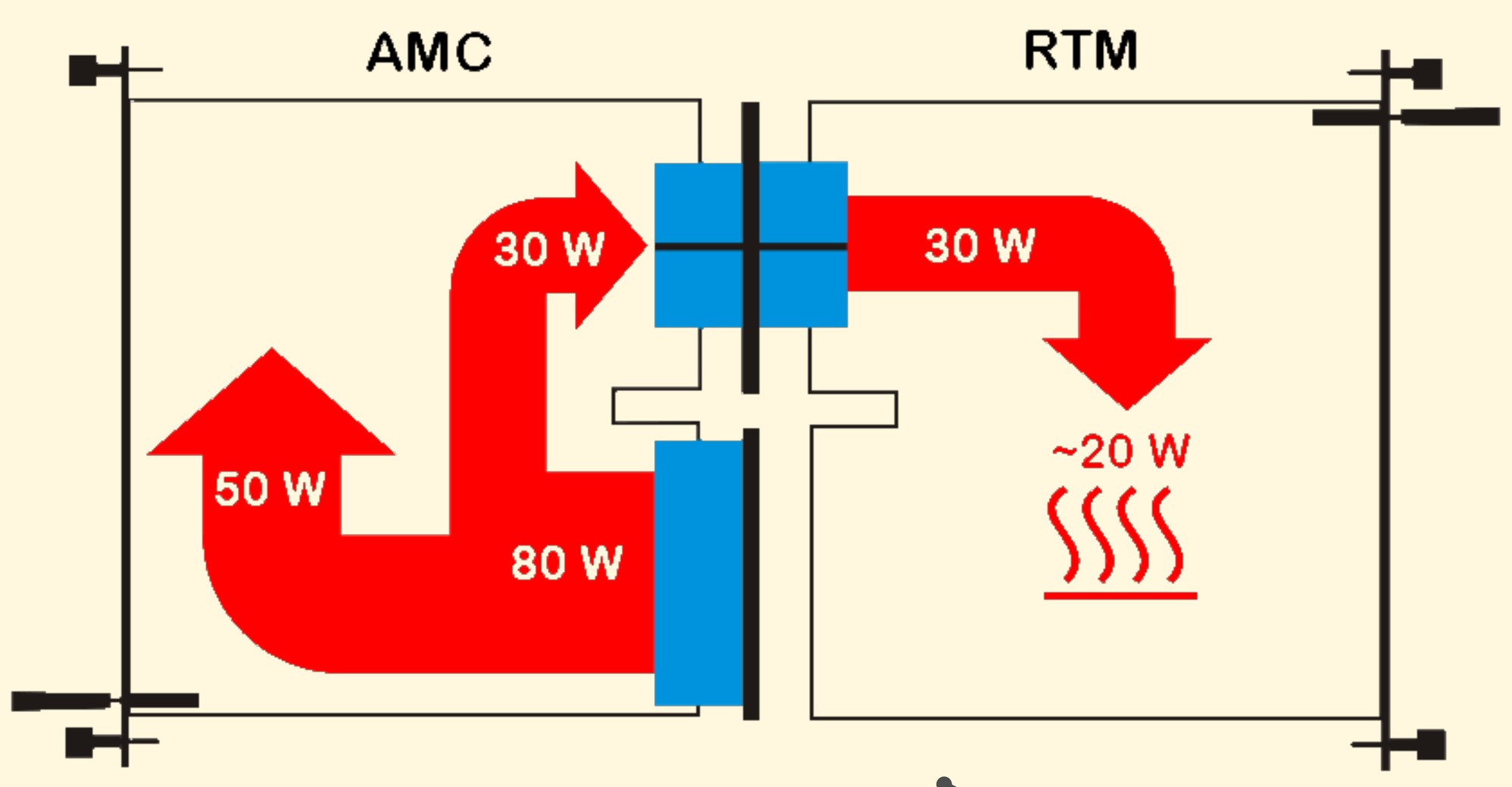


Possible Scenarios

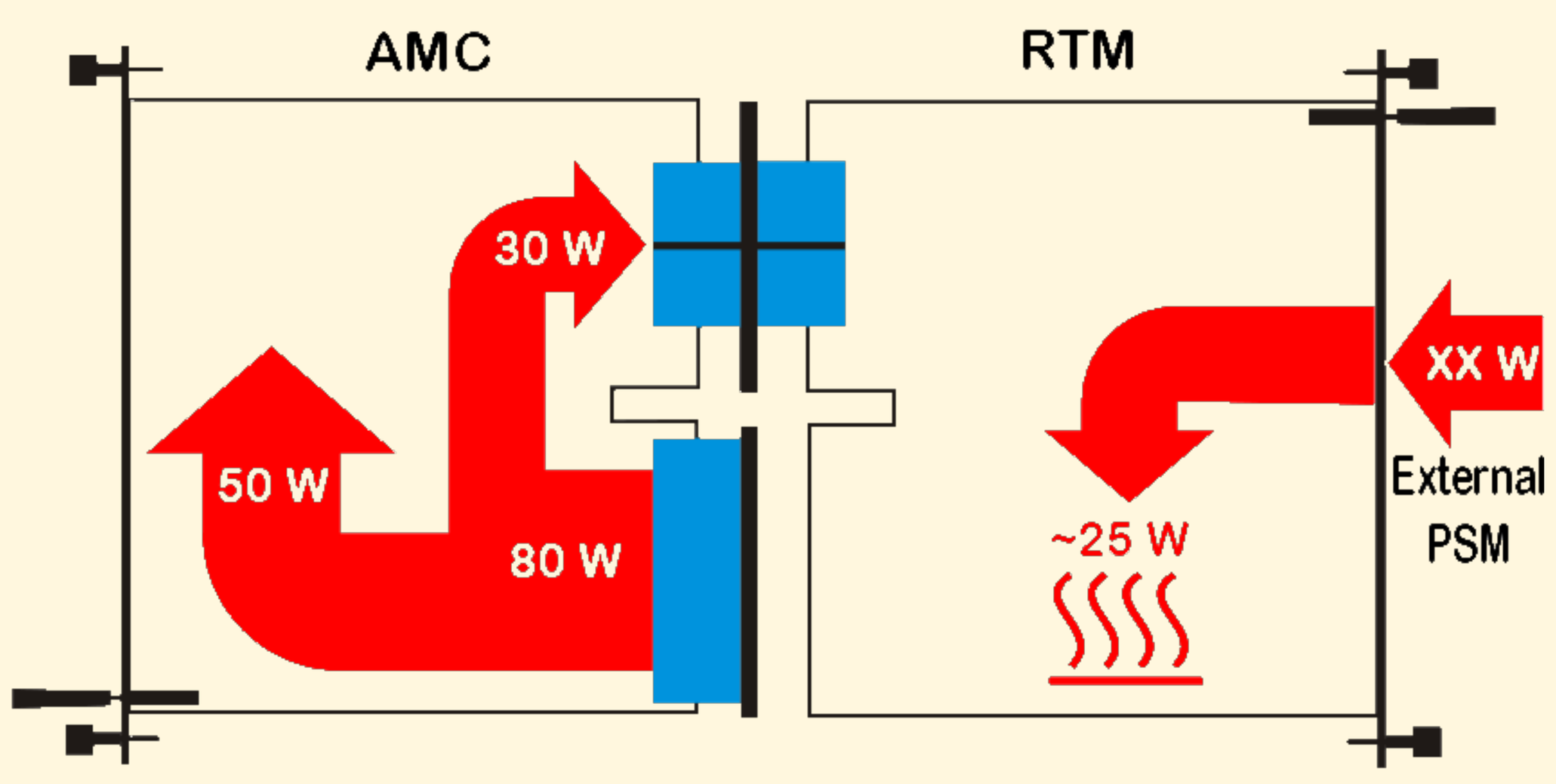
The MicroTCA.0 and MicroTCA.4 standards allow dissipating up to 80 W in a single AMC slot. The Piezo Driver could be designed as AMC device supplied from 12 V available on AMC module. The maximum power will be limited to 80 W.



When the Rear Transition Module (RTM) is used the power provided by the MicroTCA 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 devices on RTM consumes ca. 10 W. Only 20 W is available for the high-power driver. Therefore a design of a few hundreds Watts piezo driver is not possible in this configuration.

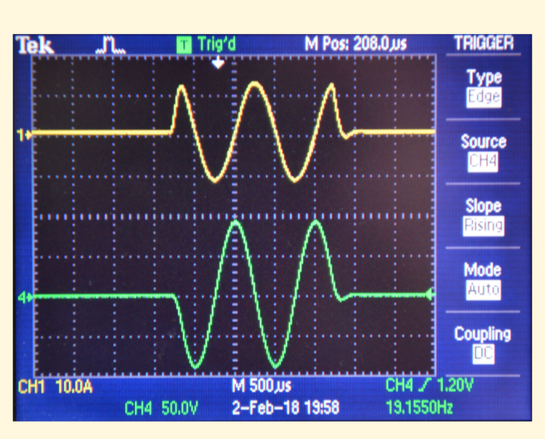


The architecture involving an external power supply was selected. The external power supply can provide much more power than available from MicroTCA internal power supply. However, the cooling is still limited to 30 W on the RTM side. Therefore, the design of a large-power piezo driver suitable for accelerators 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 100 W class-AB amplifier dissipates at least 50 W. Therefore, a high-efficiency class-D amplifier based on a Pulse-Width Modulation controller from International Rectifier was applied.



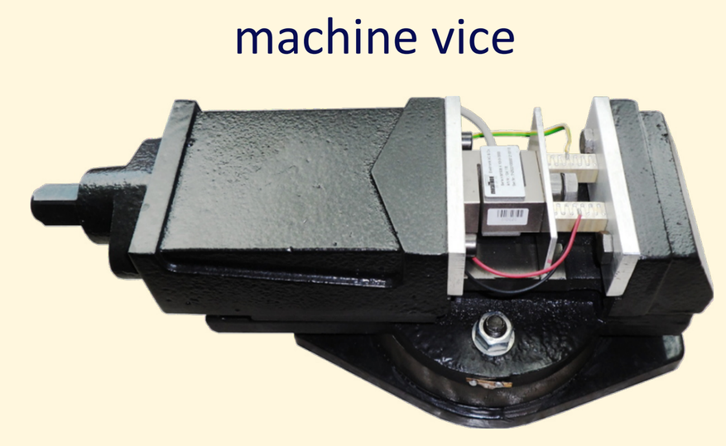
Evaluation

The output of the driver was first evaluated with various film capacitors ranging from 2.2 μF up to 100 μF.
Next, the driver was applied to excite two Noliac NAC 2022 H30 piezo actuators/sensors installed in machine vice.

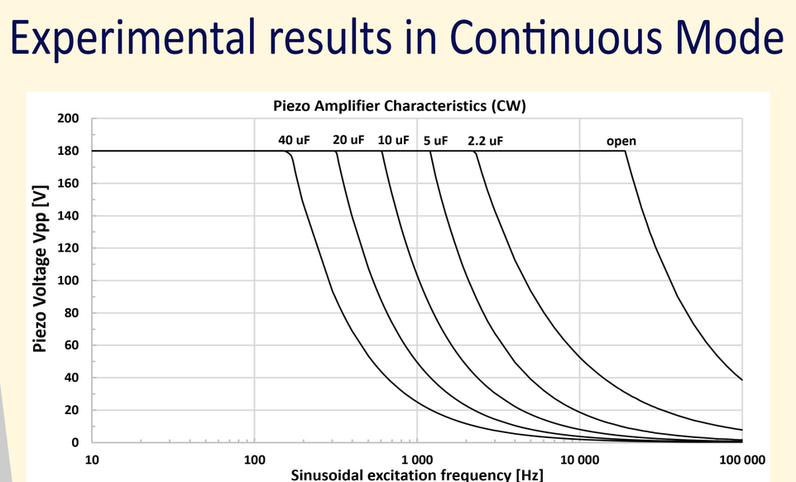
Piezo actuators considered for ESS Lorentz force detuning

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 ±15%	17.4 μF ±15%	32 μF ±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

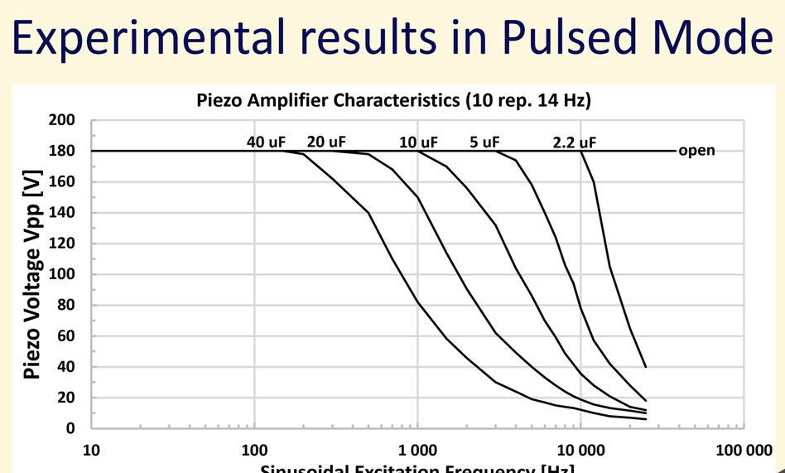
Piezo sensor and actuator in machine vice



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 100 μF. The driver fulfills all the MicroTCA 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 100 μF. 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 drive requirements were relaxed, it would also be possible to build a version supplied solely from an AMC module.