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NEW MICROTCA PIEZO DRIVER (PZT4)

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Abstract

In the paper we would like to present a new Micro Telecommunication Computing Architecture (MicroTCA) piezo driver (PZT4). The piezo driver module is capable of driving of 4 piezo actuators with high voltages up to 160 V_{pp}. It is also possible to measure cavity mechanical vibrations using 4 analog to digital converters (ADCs) ported to the driver electronics. The new piezo driver can be supplied using internal 12 V payload power provided by the MicroTCA generation 4 (MTCA.4) standard. For the applications that need more than 30 W of the input power, the external power supply module can be provided. In order to protect the piezo driver electronics against output short condition a dedicated supervision circuit is designed. The piezo driver module has been setup at Cryo Module Test Bench (CMTB) facility in Deutsches Elektronen-Synchrotron (DESY) as a part of the single cavity low-level radio frequny (LLRF) controls. The LLRF control system has been used to demonstrate the radio frequency (RF) field stabilization and cavity tuning capabilities for continuous wave (CW) and pulse modes of operation of 1.3 GHz superconducting RF (SCRF) cavity. The preliminary results are demonstrated and briefly discussed.

INTRODUCTION

The 4-channel piezo driver has been designed by DESY as a rear transition module (DRTM-PZT4). The DRTM-PZT4 is compliant to MTCA.4 standard. The possible applications include not only piezo tuners control of the SCRF cavity but also precision object positioning, laser mirror steering, synchronization of the pulsed lasers and an active fiber link stabilization. It is equipped with an internal high voltage power supply, four power amplifiers, digital to analog converters (DACs) and monitoring ADCs. The piezo driver module simultaneously supports driving and sensing four piezo actuators and four piezo sensors. Actuator and sensor functionality can be selected on the fly using on-board switches. The dedicated inhibit switches are provided in order to allow outputs connection and disconnection from the load. The 4-channel power amplifiers can be supplied using internal high voltage power modules (<30W) or using external power supply source (>30W). The drivers have been designed in a way to allow flexible operation of any kind of piezo elements (unipolar, bipolar, at room and cryogenic temperatures). The RTM can be operated with an advanced mezzanine card (AMC) support or as a stand-alone card (on-the-table operation). The piezo driving signals can be generated by the FPGA on the AMC side using RTM DACs or any other kind of external drive source connected to the front panel input connectors. The on-board ADCs allow monitoring all crucial parameters such piezo current, voltage, power amplifier voltage and high voltage power supply rails. The piezo driver unit has been equipped with a dedicated metal shielding. The special housing allows not only user protection against touching of the high voltages but also providing enough heat dissipation for both internal and external power supply variants. The driver electronics also supports interlock functionality. The RTM management is compliant to the latest recommendation module management controller (MMC) version 1.0. The Zone 3 pin-out of the RTM is compatible to the DESY digital classes D1.0, D1.1 and D1.2 recommendations. In addition, the inside electronics have been carefully studied and designed to be robust against any kind of shorts, over-voltage or over-current conditions. The inside electronics safety analyzes allow industrialization as well as Conformité Européenne (CE) certification of the module. In the paper we present functional as well as destructive tests of the module performed in the laboratory conditions. We also demonstrate an application of the module usage for the 1.3 GHz SCRF cavity tuning using mechanical frequency tuners based on redundant piezo elements.

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LABORATORY TESTS

The RTM has been inserted to the MTCA.4 crate (12 Slot Schroff) with cooling units setup to 50% of the speed. The internal power test has been performed using 100 nF capacitance load connected to all four piezo driver output channels. The driver outputs have been connected to the load with inhibit relay switches and driven 160 V_{pp} each. The frequency of the excitation for each of the channel has been fixed to 1.25 kHz. Measured current consumption by the RTM was 2.4 A at 12 V which gives a power dissipation close to the RTM shutdown threshold of 30 W. During the test the RTM temperature has been recorded using on-board temperature sensors. The test has been carried out at the room temperature of 19 degrees Celsius. The results are shown in Fig. 1. Next the single channel of the piezo driver has been connected to the dummy short with inhibit relay switch and driven 0.1 V (initial offset by the power amplifier electronics). The DC bias voltage has been increased with a small steps (100 counts of the DAC code). The output current as well as high voltage positive rail for each step have been recorded as it is shown in Fig. 2. During the measurements the high voltage power supply drop (from 100 V to 61 V) has been noticed for the DAC input value reached 4000 counts. Unexpected level of several volts drop occurred again with strong oscillation on the output current (internal DC/DC converter tried to recover from an exception condition) for the DAC code of 8000 counts. Due to the fact the power

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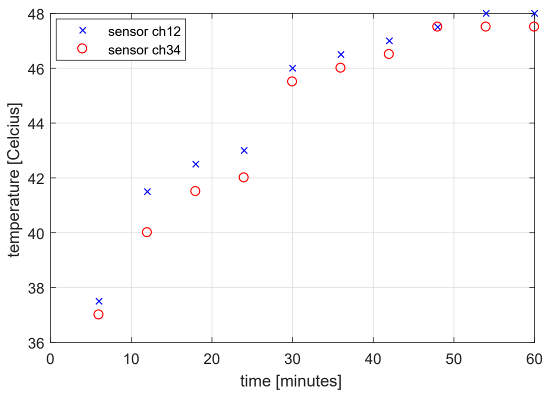

Figure 1: Temperature measurement versus time for the full scale drive of all piezo driver outputs connected to the dummy load.

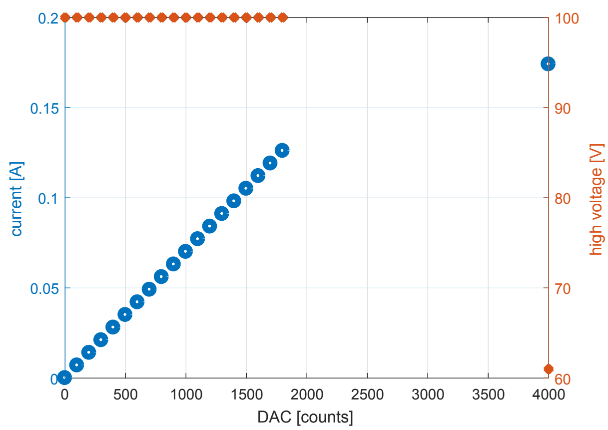

Figure 2: The single channel current consumption versus DAC counts under short output condition.

consumption is linearly scaled one can estimate that when X channels operated the maximum power per channel will be 120 mA divided by the number of used channels. During the next test the DRTM-PZT4 has been configured for the operation with an external high voltage power supply. The laboratory power supply of +/-85V and 1.94A has been used to power the piezo driver board with high voltages. The test has been performed using 150 nF dummy load connected to all four piezo driver outputs. The outputs have been connected one by one to the load with inhibit relay switches and driven 140 V_{pp} at fixed frequency of 4.5 kHz each. The output current measurement is presented in Fig. 3. For the first hour of the measurement only first channel of the driver was active. After one hour other channels have been switched on with a time shift of 20 minutes each. The temperature arise during this process is depicted in Fig. 4. Finally, the piezo driver output protections have been tested. The principle of the over-current protection is to measure the output current, integrate it over time and compare with user defined threshold. When the threshold level is reached the alarm is triggered as it is shown in Fig. 5. There are two possible scenarios implemented on the board. The first

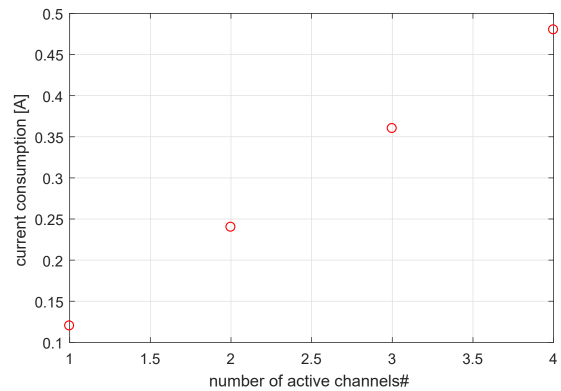

Figure 3: The current consumption of all piezo driver outputs drive at full scale and powered by an external high voltage supply unit.

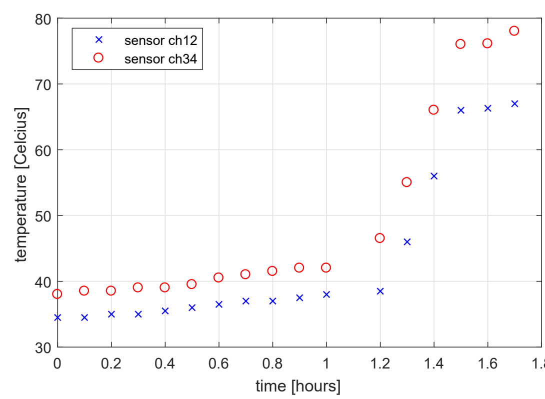

Figure 4: The piezo driver temperature versus time for different number of active channels supplied from external high voltage source.

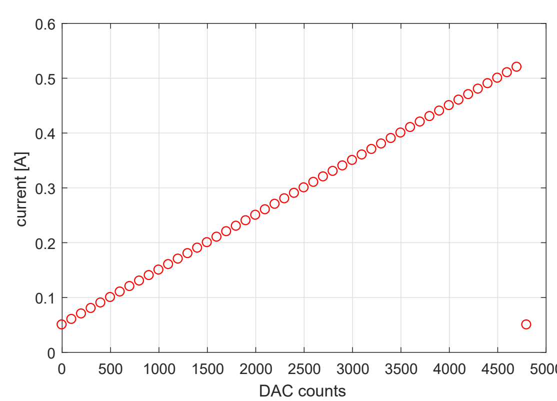

Figure 5: The over-current event triggered on the chosen output channel with short applied.

scenario is to disconnect the channel that triggers alarm from the load while keeping the other channels active (local protection). The second option is to switch off high voltage power supply (global protection). The user can decide which protection option to use for a specific application needs.

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The module has been also equipped with outputs protection. The high voltages generation is only possible when all four outputs of the driver are closed with a safety chain switches. The safety chain switches must be closed outside the module (e.g. on the load side). If not all the outputs are needed for the application the unconnected ones have to be installed with a dummy safety plugs. For the RTM module industrialization and CE certification processes the piezo driver module has been applied for destructive tests. The test results are shortly summarized with Table 1. Some tests were not required due to the fact the fully isolated DC/DC converter was used in the safety chain.

Table 1: Destructive Tests Matrix for Internal and External High Voltage (HV) Power Source Assembly Variants

Test / HV Variant	Int. HV	Ext. HV
Short HV Capacitor	n/a	passed
Short Feedback Capacitor	n/a	passed
Short Sensor-Actuator	passed	passed
Short HV to 12V PP	n/a	n/a

CAVITY TUNER CONTROLS

The DRTM-PZT4 has been installed as a part of a single cavity LLRF controls at CMTB in DESY. The accelerating module composed of 8 SCRF 1.3 GHz cavities has been connected to 120 kW inductive output tube (IOT). Each of the cavities has been equipped with a mechanical tuner, consisting of a stepper motor for the coarse and a piezo for the fine regulation. The accelerating module has been conditioned to high external quality factor (Q_L) operation of order of 6e7. The LLRF control system has been setup with the 8-channel downconverter and 1-channel vector modulator (DRTM-DWC8VM1) and the AMC digitizer (SIS8300L2V2) cards. The DRTM-DWC8VM1 card has been used to sense RF signals of the chosen cavity and drive the pre-amplifier of the IOT. The DRTM-PZT4 has been equipped with DAMC-FMC25 digital processing unit and applied for driving the piezo actuator and sensing cavity mechanical vibrations [1]. The example result of cavity tuning process applied for a long pulse (LP) operation is presented in Fig. 6. The RF field LLRF controller drive has been changed from LP to CW after tuning of the 1.3 GHz SCRF cavity. The active noise cancellation (ANC) feedback controller has been activated in order to compensate for the dominated 50 Hz microphonics as shown in Fig. 7 [2]. Finally, the RF field inside CW cavity has been ramp up to 25 MV operation and regulated using both LLRF and piezo controls as depicted in Fig. 8.

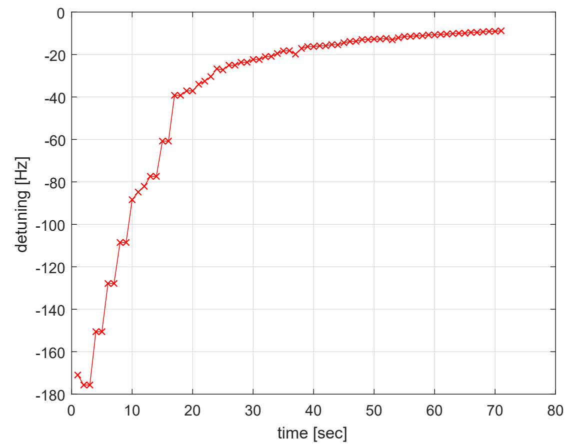

Figure 6: The 1.3 GHz SCRF cavity tuning using piezos for LP mode of operation. The adaptive feedforward controller takes into account cavity detuning calculated for the previous RF pulse and calculates piezo voltage correction for the next RF pulse.

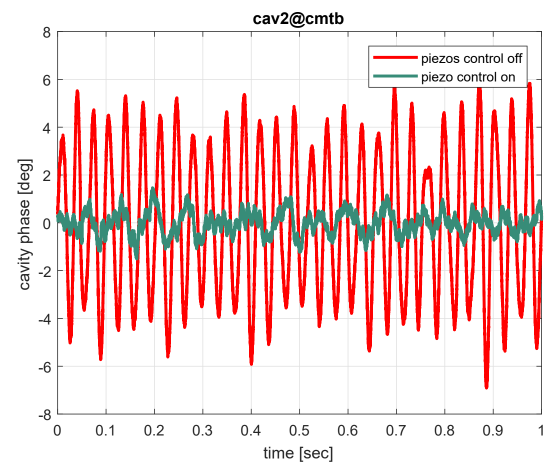

Figure 7: The microphonics compensation of the 1.3 GHz cavity operating in CW mode .

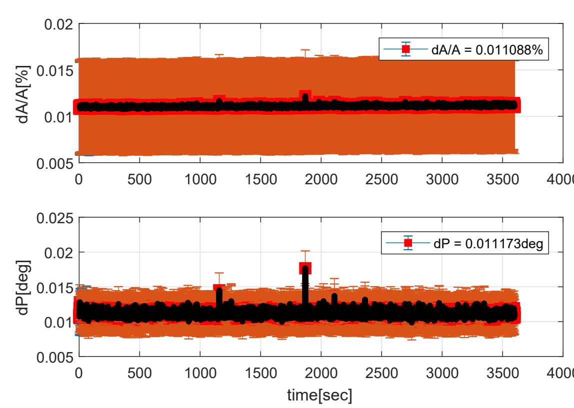

Figure 8: The long term RF amplitude and phase stability measurement for the 1.3 GHz cavity at Q_L of 6e7 in CW mode.

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