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Hansueli Meyer

ETH Zurich, Institute of Astronomy (IfA), CH-8092 Zurich, Switzerland

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Abstract. We report a possible design of an external liquid cooling system for a FPGA chip. The FPGA chip operates in an AC240 sampler card manufactured and sold by Acqiris company, Geneva. An incoming sampled data stream running at 2 GS/s is real time processed in a FPGA Xilinx chip. The FPGA chip calculates an FFT with 16384 channels within a bandwidth of 1 GHz. In full speed mode and without cooling the operating temperature can reach more then 64 degrees Celsius. To prevent damaging of the sampler card an additional metallic cooling plate was designed and mounted on the sampler card to cool and thermally stabilize the chip.

Key words. Liquid cooling system, AC240, sampler card, high altitude.

1. Introduction

Several FFT spectrometers containing one or two AC240 sampler cards were used and tested at different altitudes in Switzerland (Diavolezza 3100 a.s.l. and Gornergrat 3200 a.s.l.) and in Chile (Pampa la Bola 4850 a.s.l). The FPGA chips on the AC240 board have two built in temperature sensors which can be read out by software. In addition the FPGA itself internally checks temperature periodically. As soon as the temperature exceeds $65°C$, the system is switched off automatically to prevent damage of the sampler card. This automatic switch off never occurred below 3200 a.s.l. because the internal cabinet ventilator was sufficient. But, in Chile at an altitude of 5000 a.s.l the cooling air stream was not sufficient, the hardware overheated and switched off. The spectrometer could not be used in this standard configuration. An alternative cooling method had to be evaluated. Two solutions passive an active will be described in this paper. First tests at Gornergrat (3200 a.s.l.) showed positive results.

2. The Cooling Plate

A commercial available metallic cooling plate was mounted on the sampler card (AC240). The plate was directly mounted on the sampler card using three 2.5 mm bolts. A heat-conductive paste between the AC240 and the cooling plate served as heat transfer layer. The size of the plate is 80x80x10 mm with two inlet pipes to connect the external cooling system (Fig. 1).

Send offprint requests to: Hansueli Meyer, e-mail: `meyerh@astro.phys.ethz.ch`

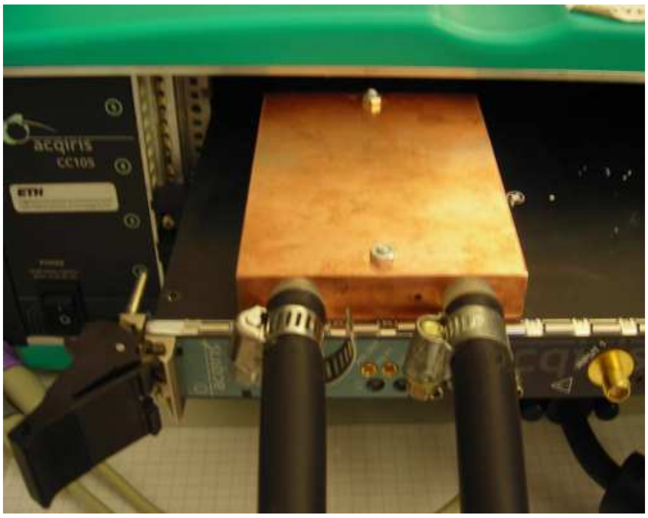

Fig. 1. Commercial metallic cooling plate mounted on the AC 240 sampler card.

Active cooling system	
Julabo F-240	Technical datas
Operating temperature	-10...40$°C$
Refrigerating capacity	240 W at 25$°C$
Liquid water capacity	3 liters
Weight	21 kg

Table 1. Technical details of the cooling system Julabo F-240.

3. Setup external liquid cooling system

Two different systems an active and a passive cooling system were tested. A so called Julabo F240 (Tab. 1) heat exchanger was used to test the temperature behavior of one AC240 card.

Fig. 2. Eight slot crate sold by Acqiris company, Geneva. The crate holds two AC240 sampler cards, an I/O interface card and a slot PC.

Passive cooling system	
Julabo EH-5	Technical data
Operating temperature	20...150°C
Heating capacity	2000 W
Liquid water capacity	4.5 liters
Weight	7 kg

Table 2. Technical details of the cooling system Julabo EH-5.

This test was done at the Institute of Astronomy laboratory, Zurich (450 a.s.l.). The Julabo F240 was adjusted to an operating temperature of 25°C. The Julabo is able to regulate to this adjusted temperature range.
In addition a passive cooling system Julabo EH-5 (Tab. 2) was tried out also. In this case all temperature tests were done for two AC240 cards at an altitude of 3200 a.s.l.. Both measurement setups were tested in a eight slot crate (CC108) from Acqiris company. Four in built cabinet ventilators generate a continuous air stream through the crate. Another additional ventilator to cool the power supply is used. The slots of the crate include the following devices (slots numbering top-down): blanking cover with cooling plate 1, AC240 sampler card with FPGA 1, blanking cover with cooling plate 2, AC240 sampler card with FPGA 2, blanking cover, I/O interface, blanking cover and the internal slot pc (Fig. 2). The cooling plate was in both cases connected via a 1.5 meter long flexible tube with the Julabo's. As cooling liquid water with antifreezer was used.

4. Results Active Cooling System

A Julabo F240 was adjusted to 25°C operating temperature. Fig. 3 shows the result of the cooling process. For the first 50 minutes the cooling machine was switched on and a FPGA temperature of 42°C could be achieved. The Julabo was then switched off after 50 minutes of operation.

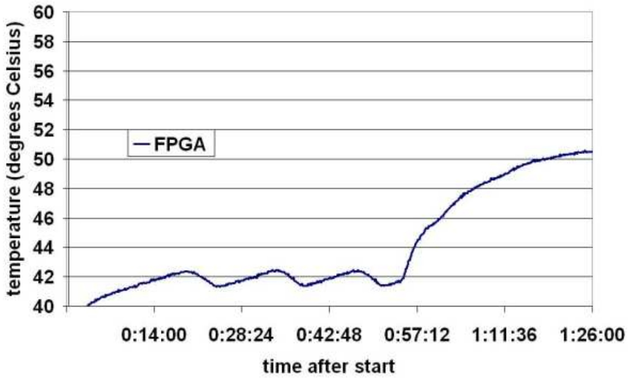

Fig. 3. Eight slot crate sold by acqiris company, Geneva.

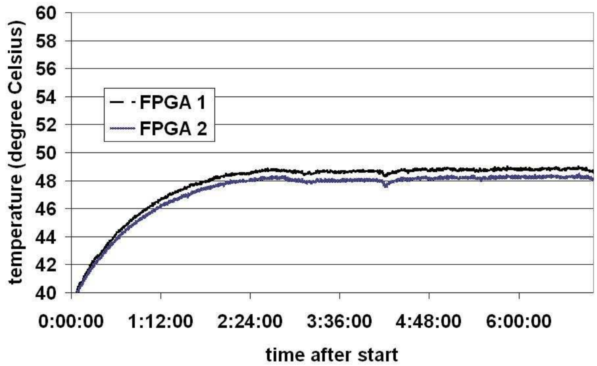

Fig. 4. An external Julabo cooling system was used to temperature stabilize two sampler cards.

Active cooling system, Julabo at 25°C	
Which temperature	°C
Environmental	22
FPGA 1, cooling on	42±0.5
FPGA 1, cooling off	53±0.5

Table 3. All temperatures are steady state results.

It is clearly visible that the FPGA temperature is increasing with time to a constant temperature of 53°C. The environmental temperature was measured to 22°C (Tab. 3). All measurements were done at the IfA laboratory at ETH Zurich.

5. Results Passive Cooling System

All passive cooling measurements tests were done at the Gornergrat Observatory, Switzerland. The Gornergrat observatory is 3200 above sea level. Thus the air pressure is reduced. An reduced air pressure decreases the cooling power of the built in ventilators. If two sampler cards are installed in the crate and no external thermal stabilization is done, AC240 reaches a steady state temperature of 57°C (Fig. 5). The FPGA temperature of 57°C at 3200 a.s.l. is already quite high. The environmental temperature was in this case 22°C. After that, an external Julabo

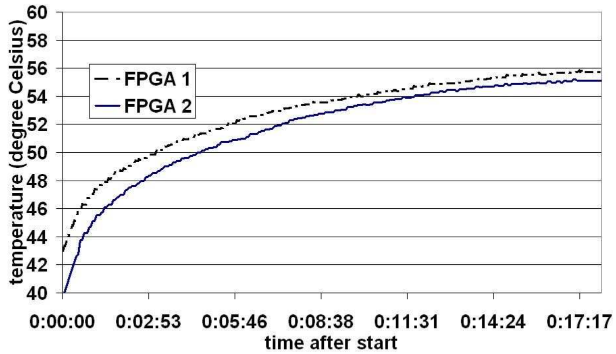

Fig. 5. Temperature characteristics of the AC240 FPGA chips, if no external cooling system at all was used.

Passive cooling system, Julabo at $20°C$	
Which temperature	$°C$
Environmental	25
Water Julabo device	35
FPGA 1	49±0.5
FPGA 2	48±0.5

Table 4. All temperatures are steady state results.

EH-5 was set to $20°C$. The Julabo can not cool but pumps the liquid through the cooling plate of the sampler card. The sampler card heat dissipates to the room temperature through the liquid medium of the Julabo. At a environmental temperature of $25°C$ a FPGA temperature of less than $49°C$ can be reached (Fig. 4).

The FPGA 1 has a slightly higher temperature then the FPGA 2 because the heat from FPGA 2 flows up (Tab. 4) to FPGA 1. At an environmental temperature of $16°C$ a FPGA 1 temperature of $34°C$ and FPGA 2 of $32°C$ was measured. This kind of thermal stabilization system depends on the environmental temperature but one can expect that in most cases the spectrometer operates in a air conditioned environment. It is possible to calibrate the ADC of the AC240 sampler card via a software command to adapt to different operating temperatures. The calibration of the ADC should be repeated if the environmental temperature fluctuations are very high ($\pm 2°C$). If no cooling system is used the steady state temperature is reached after 15 minutes. On the other hand for the passive cooling system a steady state temperature of the whole system is reached not until 2.5 hours (Fig. 4) after power on.

6. Conclusions

The external cooling system in active or passive mode can be used to thermal stabilize and prevent the FPGA chip for overheating. At 3200 a.s.l. a maximum FPGA temperature of $49°C$ was measured with an external passive cooling system (environmental temperature $25°C$). Both cooling system the passive and active are suitable to cool the FPGA chip and temperature stabilize the AC240 card even at high altitudes (Pampa la Bola 4850 a.s.l.). It is also very important to close all noon-used slots of the crate tightly.

7. Relevant internet addresses

7.1. Acqiris Company, Geneva

`http://http://www.acqiris.com/`

7.2. Institute of Astronomy, FFT related links

`http://www.astro.phys.ethz.ch/instrument/argos/argos_nf.html`

7.3. University of Cologne, Germany

`http://www.ph1.uni-koeln.de/`

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