ASTRON
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Liquid Cooling UniBoard

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1 Introduction

1.1 Scope

In this document the first steps of liquid cooling UniBoard are described. The measurements are done to gain knowledge of liquid cooling and see how suitable it is for UniBoard^2. Part of the measurement is to verify that a more efficient heat transfer can be achieved with liquid cooling. In this document both a description and the measurements are described.

2 System Setup

The block diagram of the cooling system is shown in Figure 1.

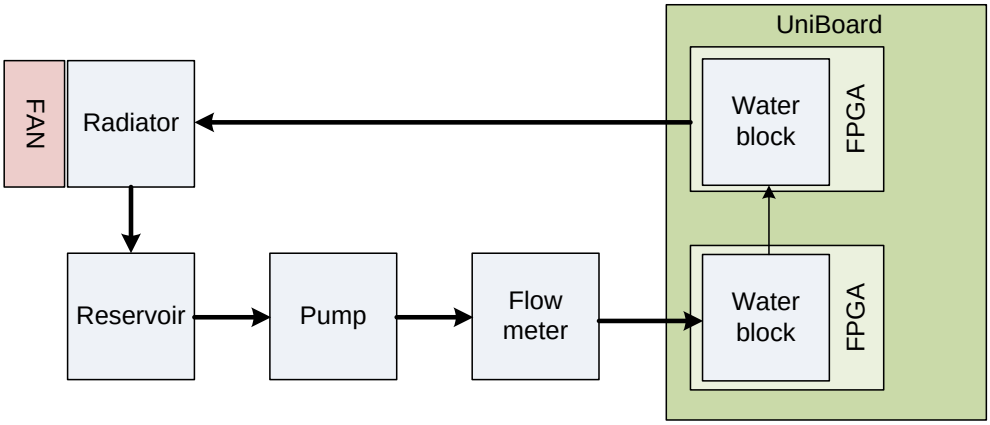

Figure 1 Block diagram liquid cooling

A pump is used to pump the liquid from the reservoir to the water blocks. The heated liquid from the FPGA is cooled down in the radiator. The radiator is cooled by fans mounted on the radiator. The setup is shown in Figure 2.

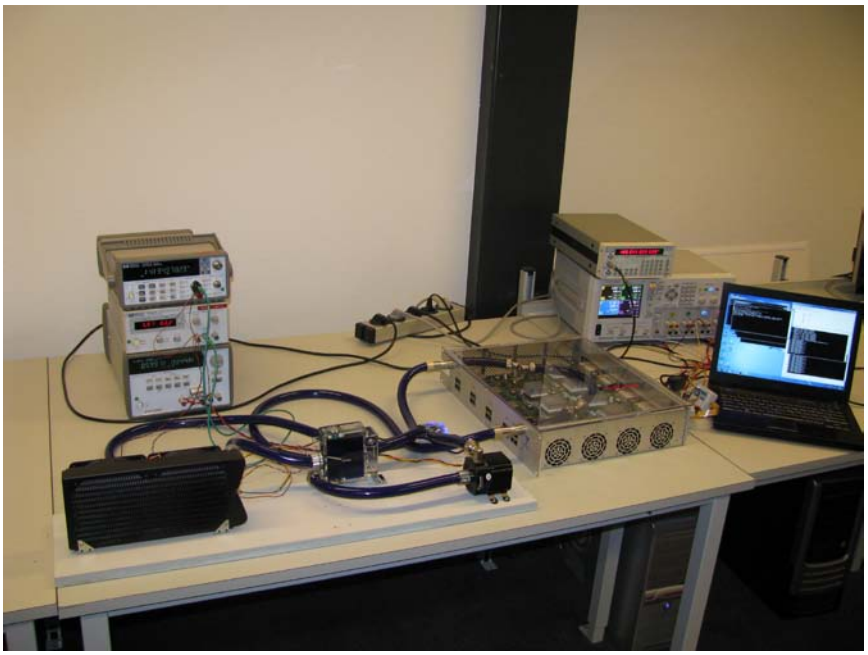

Figure 2 Picture of the measurement setup

2.1 Reservoir

The Swiftech MCRES-Micro Rev2 Reservoir is used to buffer the liquid in the system.

Figure 3 Reservoir

2.2 Pump

A Koolance PMP500 pump is used, see Figure 4. In Figure 5 the characteristics of the pump are shown.

Figure 4 Pump PMP-500

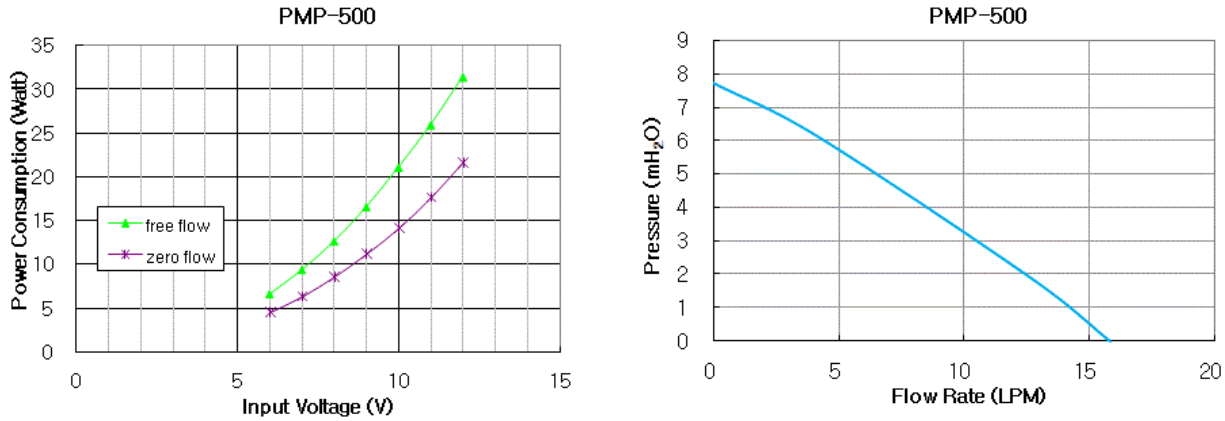

Figure 5 Pump characteristics

The characteristics are display in mH_2O, most pressure drop figures are in psi therefore: 1 mH_2O = 1.42 psi.

2.3 Flow Meter

To gain knowledge about the flow in the system a flow meter (Koolance INS-FM16) is placed in the loop. The characteristics are shown in Figure 6.

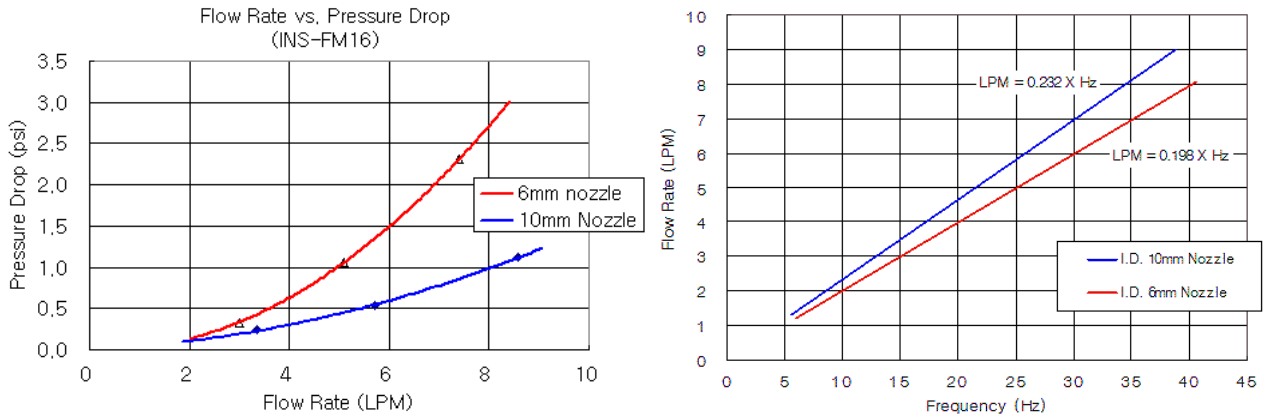

Figure 6 Koolance INS-FM16 flow meter characteristics

2.4 Water Block

The water block, used to transfer the heat of the FPGA to the water, is shown in Figure 7.

Figure 7 Water block

The characteristics are shown in Figure 8. From the left image it can be seen that the thermal resistance is flat (<25%) between 2 and 7LPM.

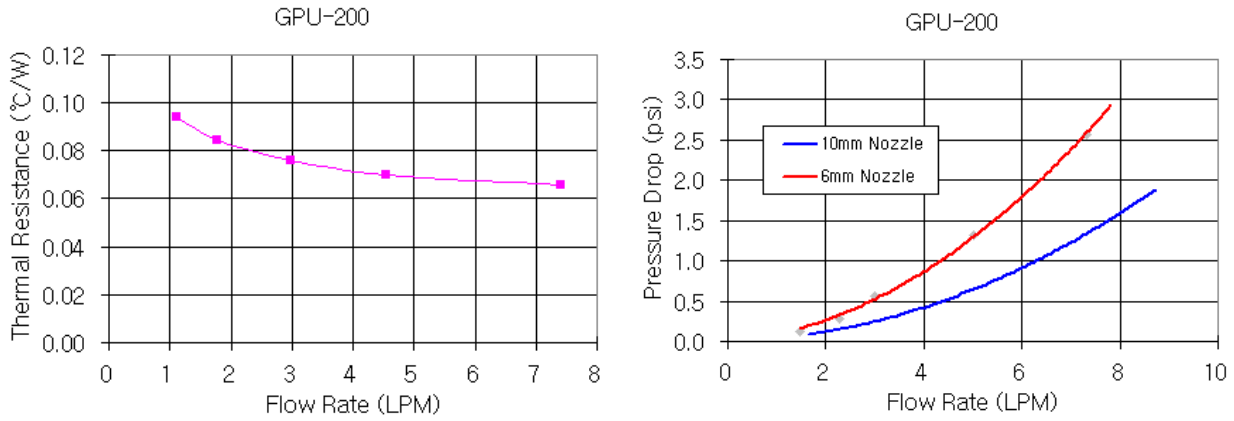

Figure 8 Water block characteristics

2.5 Radiator

The radiator used in the system is the Swiftech MCR220-QP-K 240 Radiator, see Figure 9. On this fan two 95x95mm fan's are be mounted.

Figure 9 Radiator

The characteristics are shown in Figure 10.

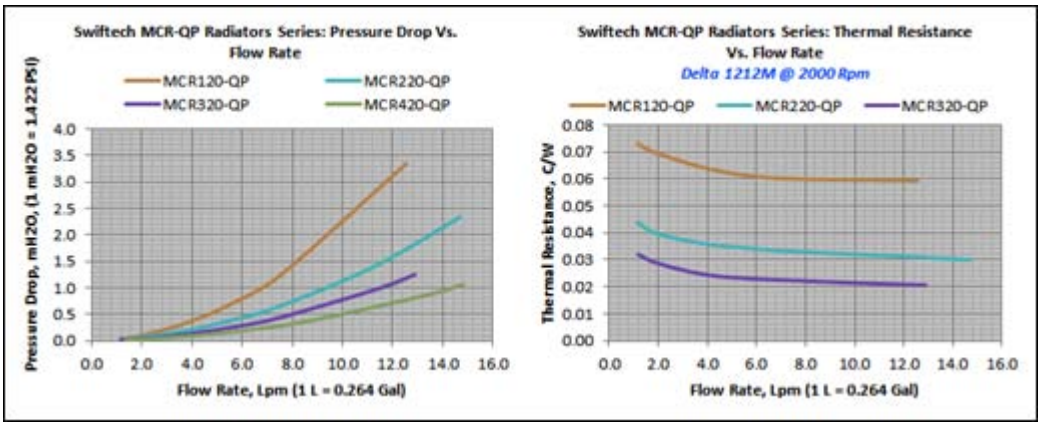

Figure 10 Radiator characteristics pressure drop (left) and thermal resistance (right)

2.6 Tubes

For the tubing between the parts the Freser 13mm internal diameter tubes are used, see Figure 11. This PVC hose is flexible with smooth surfaces at the in- and outside.

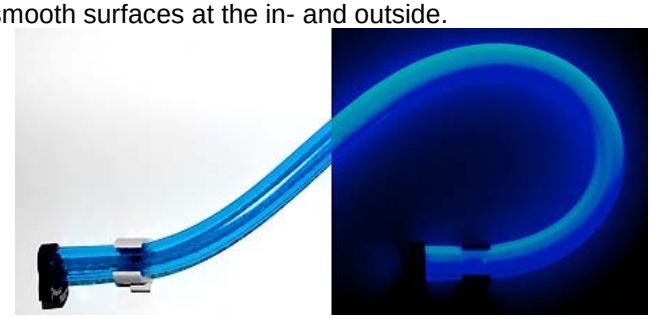

Figure 11 13mm (1/2") tubes

2.7 Liquid

For the liquid in the cooling system Feser One Cooling Fluid is used. This liquid has the following features:

- Non Conductive / Conductivity < 10 µS/cm (20°C)
- Corrosion protection for copper, brass,aluminum and nickel
- Prevents algae growth within your water cooling system
- UV Reactive properties (help finding leaks)

2.8 Fittings

Examples of the fittings are shown in Figure 12. Compressions fittings are used in this test setup.

Figure 12 13mm fittings

For the connection to and from UniBox quick connections from Koolance are used, see Figure 13. This enable disconnection a UniBox without draining the water system, only a small drip is spilled.

Figure 13 Quick Disconnection No-Spill Couplings

3 Cooling Capacity

The flow in the system determined the cooling capacity of the water blocks (take up heat) and the radiator (emit heat). As shown for the pump characteristics in Figure 5 the flow is depended on the pressure build up. This pressure build-up is again depended on the flow.

For the start the flow is taken at halfway the pump capacity, 7 LPM, this results in a pressure drop of: 2x1.3psi (water block) + 1x0.75psi (radiator) + 1x0.75 (flow meter) = 4.1psi ~3mH_2O resulting in a flow at the output of the pump of 6.7LPM.

With 7LPM the thermal resistance of the water blocks are 0.065°C/W. The thermal resistance from the die to case is 0.2 °C/W (Altera website) and from the case and the water block (thermal conductive foil) is approximately 0.2°C/W (3.1/16) resulting in 0.465°C/W from the die to the water. The thermal resistance of the radiator at 7LPM is 0.033°C/W resulting in a total thermal resistance of 0.489 With an ambient temperature of 22°C and a power consumption of 20W the die temperature will be 31.8 °C.

From Figure 10 and 7LPM the capacity of the radiator can be seen as ~300W with 10°C temperature increase, to cool 16 FPGAs of 20W the temperature increase will be 11°C.

4 Measurement results

4.1 Used Equipment

The equipment used for the measurements are shown in Table 1.

Table 1 Used Equipment

Equipment	Type	Manufacturer	ZWO number
Temperature Meter			
Power supply	E3610A	HP	ZWO1811
Power supply	E3634A	Agilent Technologies	ZWO2060
Power supply	N6705B	Agilent Technologies	ZWO2104
Clock Source	CG635	SRS	ZWO2083
Universal Counter	53131A	Agilent Technologies	ZWO53131A
IR camera	T335	FLIR	ZWO2102

4.2 Flow

The flow is measured just after the pump. The result is shown in Table 2.

Table 2 Flow at different pump power supply setting

Power Supply	Frequency	Flow
6V	14 Hz	3.25 LPM
9V	20.5 Hz	4.5 LPM
12V	25.8 Hz	6 LPM

The flow of 6LPM at 12V close to the expected 6.7LPM.

4.3 FPGA temperature

The temperatures of the FPGA are measured with the test image. After the testing is completed the temperatures of the FPGA are measured every second.

Table 3 FPGA temperatures

Power Supply	Liquid input	Liquid out	FN0	FN3
6V	FN3	FN0	42°C	35°C
9V	FN3	FN0	44°C	34°C
12V	FN3	FN0	43°C	36°C
6V	FN0	FN3	40°C	36°C
12°C	FN0	FN3	39°C	35°C
6V alternative mounting	FN0	FN3	30°C	27°C
6V alternative mounting	FN3	FN0	30°C	27°C

Power consumption of the complete board is 4*48V=192W. The estimated FPGA power is 20W.
With and environmental temperature of 22°C the thermal resistance is 0.6°C/W. The mounting of water block on FN0 was not optimal, therefore the temperature of FN3 are taken in the calculations. With 20W dissipation in the FPGA and a temperature difference between the die and the ambient of 13°C (35-22°C) the thermal resistance results at 0.65°C/W. This is more than the expected 0.49°C/W for the thermal resistance between the die and the water.

The die temperatures are decreased with an alternative mounting where the water blocks are mounted with thermal transfer compound (thermal paste) instead of tape. From this measurement it can be seen that the thermal resistance is decreased to 0.35°C/W, the expected thermal resistance with compound is approximately 0.29°C/W.

4.4 Power consumption

The power consumption is shown in Table 4.

Table 4 Power consumption

Power Supply	FAN's	Pump	Total	Power consumption
6V	0.22 A	0.95 A	1.2 A	7.2W
9V	0.33 A	1.6 A	1.9 A	17.1W
12V	0.5 A	2.2 A	2.6 A	31.2W

For comparison the four fan's for a UniBox consume 17W.

4.5 IR image

With the Infrared camera an image is taken to analyse the temperature of the UniBoard

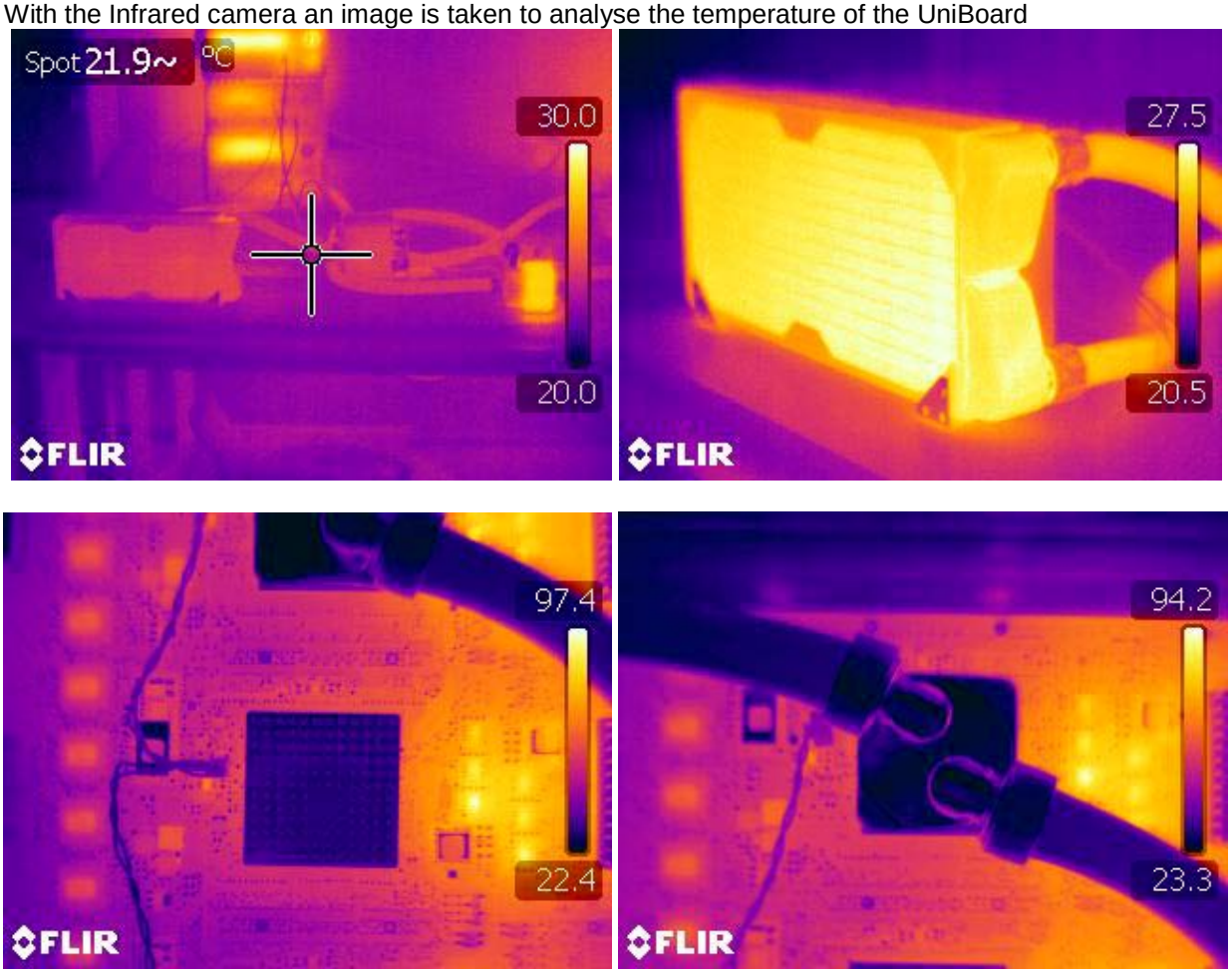

Figure 14 FPGA temperature with normal heat sink (left) and water (right)

From these images it can be seen the maximal temperature in the cooling system is the pump (consuming 26W). From the images of the board it can be seen that the maximal temperature of the board (the heat sinks and water blocks reflect the IR radiation of the room temperature) is somewhat reduced with the water cooling.

5 Web links

Dutch supplier:
http://www.highflow.nl

Manufactures:
http://koolance.com/
http://www.swiftech.com/
http://www.tfc-us.com/