

Experimental Analysis on Liquid-cooled Minichannel Heatsink for Personal Computers.

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Abstract – In the present experiment, the liquid cooling in minichannel heat sink for processors of personal computers is studied. A minichannel heat sink is designed, analyzed and fabricated from copper with the length, width and base with thickness, of 30, 31 and 6mm respectively with 15 channels, for a pre-chosen test CPU, with TDP of 95 watts and maximum surface temperature of 71°C. Distilled water is used as coolant. The liquid cooling in minichannel heat sink is compared with the factory air cooled aluminium heat sink setup. Experiments are performed at full load conditions for 60 minutes at various operating speeds for both setup and temperatures of the CPU are logged. The objective of this study is to determine the effectiveness of liquid cooled minichannel heat sink.

Key Words: Liquid Cooling, Minichannel, Heat Sink.

1. INTRODUCTION

The heat flux generated in the processor chip is rising day by day at a very fast rate with development, because of reduction in CPU sizes and large amount of heat load generated at the chip. Consequently, it is becoming a challenging task for researchers to handle such enormous amounts of heat fluxes. The high heat generation inside the CPU may result in slowing down the computation speed, failure of the processor chip, gate oxide breakdown, effect on screen resolution and many more electrical failures as well as mechanical failures. Presently, in CPU very complicated designs of air-cooled heat sinks are used which dissipates heat to the surroundings by flowing large volumes of air. These heat sinks have two major shortcomings. Due to space constraints air should be thrown at very high velocities and to maintain such velocities big size fan has to be used. In addition, the air flowing at high velocities creates a lot of noise. Moreover, in air-cooled units there is no active cooling device so we cannot go below the ambient temperature. As a result, working at high speeds in the hot ambient conditions had become extremely difficult.[1]

Chuan-Fu Chien, [2] has invented a high performance CPU Cooling system that effectively carries heat away from the CPU. According to the invention, a CPU cooling system comprises of a water-cooling type CPU heat dissipating unit, water cooling radiator, a pump and a reservoir. Kunal Pardeshi et. al. [3] explains the need of cooling system for electronics and how liquid cooling can enhance the performance of the system. It also lists the advantages and the disadvantages of liquid cooling. X. L. Xie et. al. [4]

explains the heat transfer characteristics in a water-cooled mini channel heatsink. Satish G. Kandlikar [5] explains mechanism of heat transfer and fluid flow in minichannel and microchannel and numerical study of liquid cooled minichannel heatsink.

2. EXPERIMENTAL SETUP

A water cooling loop follows the same principle an air cooler does, it takes heat from a hardware (e.g., a CPU die) and dissipates it into the air. A schematic diagram of a water cooling loop is shown in Fig. 1. Any loop consists of the following nodes:

- pump- pushes the liquid through your loop.
- reservoir- stores excessive liquid and feeds the pump with it.
- waterblock for CPU - uses a cold plate to make a direct contact with a hot hardware, transferring heat from this hardware to a heat spreader inside the block's body.
- coolant- a liquid that flows through a waterblock's heat spreader and captures its heat.
- radiator - cools the liquid down by forcing it to flow through narrow pipes with fins attached to them: fins create a huge dissipation surface area which ensures the liquid heat is rapidly taken away into the atmosphere.
- tubing- rigid or flexible tubing that connects all these parts into a single loop;
- fittings- connect tubing with other loop nodes and ensure the loop is sealed.

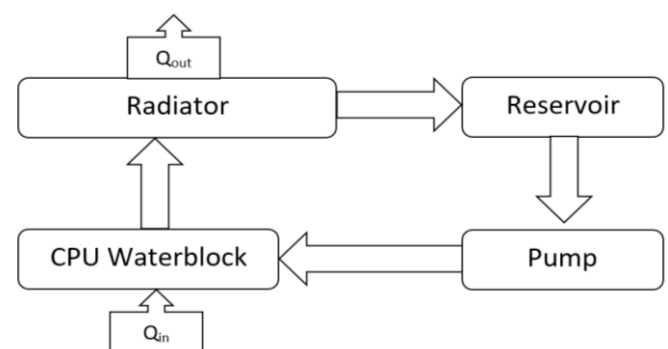


Fig -1: Water Cooling Loop

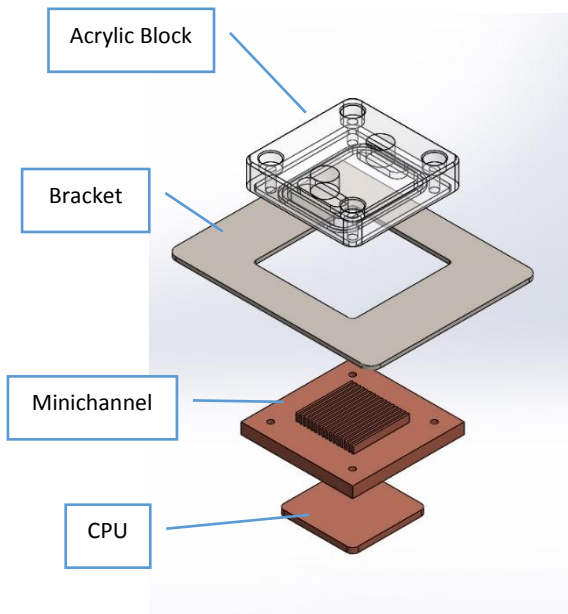


Fig -2: Exploded View of Water Block

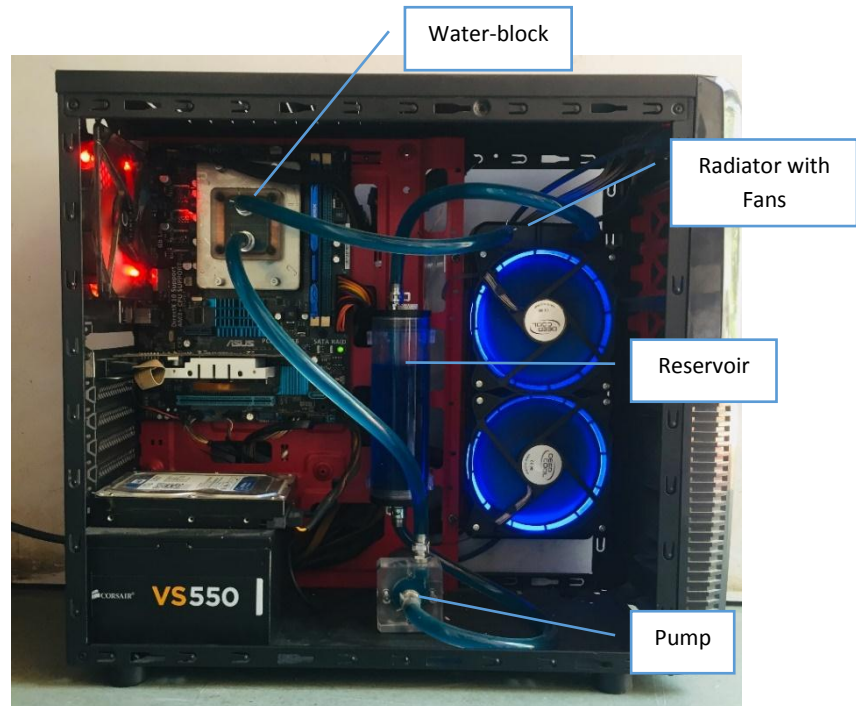


Fig -3: Experimental Setup

The Following components for the testing computer are selected:

Table -1: Components of Test Computer

Component Type	Product Name
CPU	AMD FX 4300 @3.8 Ghz
Motherboard	Asus M5A78L - M LX3
Power Supply	Corsair VS 550 Watt PSU
Hard disk drive	Western Digital 1 TB 7200 rpm Drive
RAM memory	Kingston Hyper-x 8 GB Module
Operating system	Windows 10 Professional 64 bit

To maximize the CPU power output, the software package AIDA64 is used. Temperature measurement is logged from the CPUs integrated sensors using Openhardwaremonitor. These logs are then processed with Google sheets, generating graphs.

3. TESTING PROCEDURE

Before the testing of the water-cooling setup, test is performed on the factory air-cooled setup at various speeds recommended by the manufacturer for comparison purpose. Later the factory heat sink is removed. Before installing the water-block to the IHS of the processor, both the IHS and the water-block are cleaned with alcohol to remove any dust particles. After installation of the water-block, the computer is booted and all diagnostic software are started. Other processes and background processes are kept minimum as to not interfere with the testing. All tests are conducted with room temperature between 30° - 35°C

4. PERFORMANCE

Chart-1 (a), is generated for stock air-cooled setup running at 3.8 Ghz, 4.0 Ghz, 4.2 Ghz. For air cooled setup, the maximum stable speed achieved is 4.2 Ghz while further increasing the speed causes shutdown of the computer due to temperature limit. Chart - 1 (b), for water cooled setup is generated at speeds, 3.8 Ghz, 4.0 Ghz, 4.2 Ghz, 4.4 Ghz, 4.6 Ghz, which is the maximum speed achieved by the processor in this setup due to motherboard's power constraints.

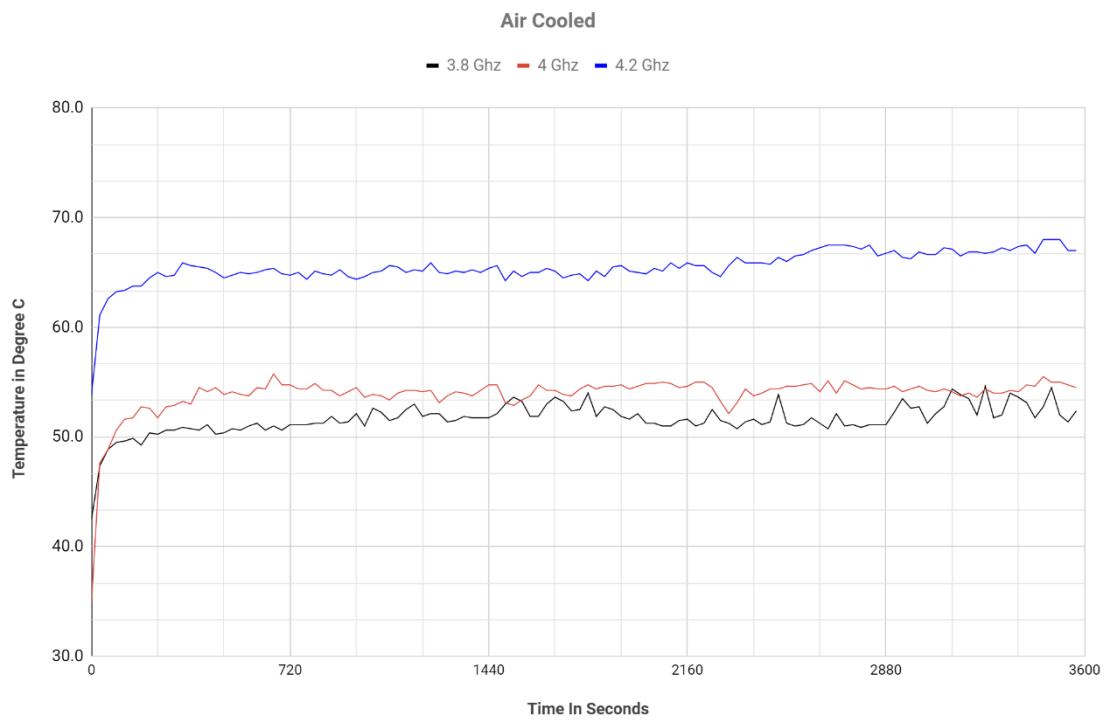


Chart - 1 (a): Time vs. Temperature plot for Air Cooled Setup at Various Operating Speeds.

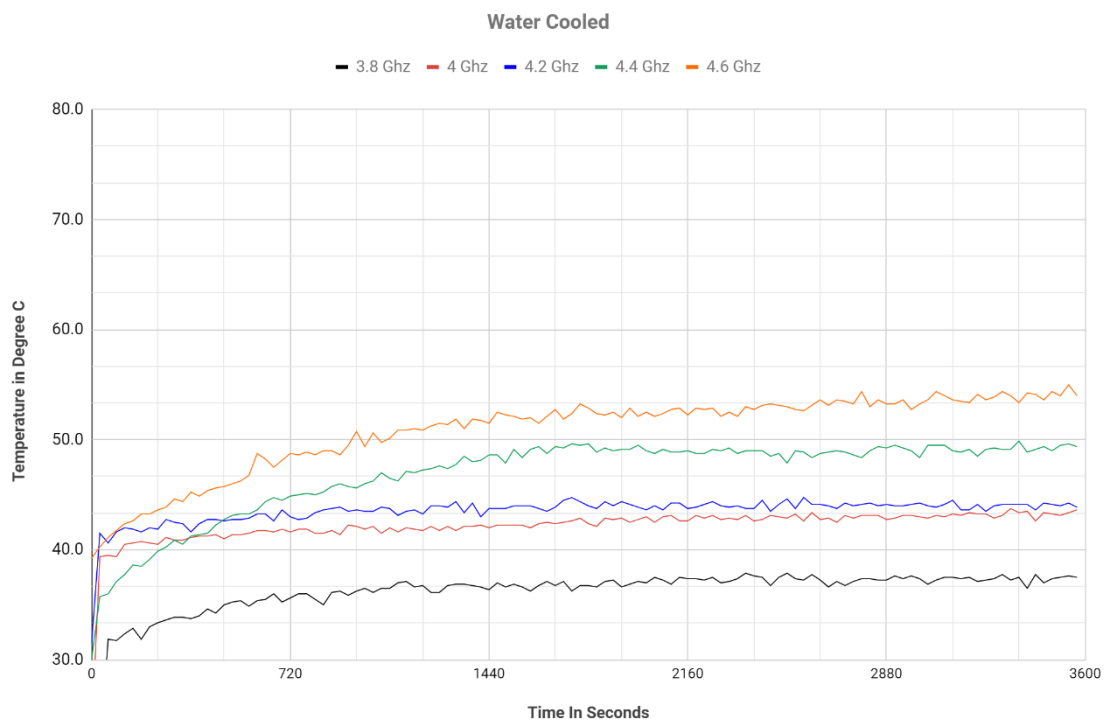


Chart - 1 (b): Time vs. Temperature plot for Water Cooled Setup at Various Operating Speeds.

5. RESULTS

Table – 2 represents the maximum and average temperature reached by the processor at various speed on both air-cooled as well as water-cooled setup.

Table -2: Maximum and Average Temperature for Air Cooled and Water Cooled Setup

Speed (Ghz)		Max. Temperature (°C)	Avg. Temperature (°C)
Air-cooled	3.8	54.6	51.6
	4.0	55.8	53.9
	4.2	68	65.5
Water-cooled	3.8	37.9	36.2
	4.0	43.8	42.1
	4.2	44.8	43.4
	4.4	49.9	46.7
	4.6	54.4	50.7

Chart -2 (a), (b), (c) shows the temperature difference between air cooled and water cooled setup at 3.8 Ghz, 4.0 Ghz, 4.2 Ghz respectively.

(a) The average temperature difference between the air cooled and water cooled setup running at 3.8 Ghz is given as,

$$\Delta T_{avg} = 15.4 \text{ }^\circ\text{C}$$

3.8 Ghz

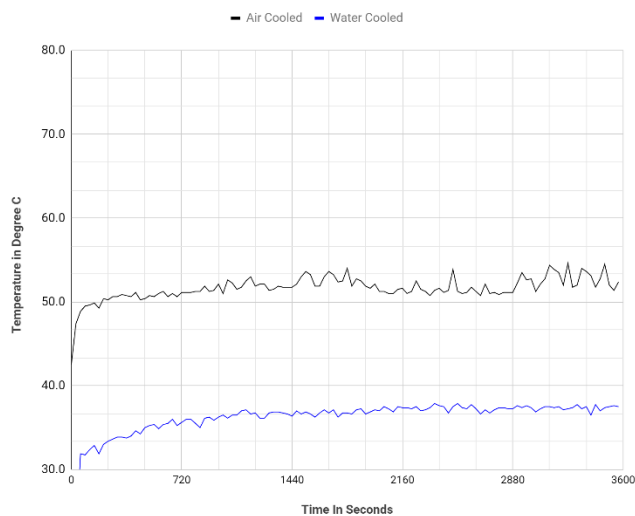


Chart -2 (a) Air Cooled and Water Cooled comparison @3.8 Ghz.

(b) The average temperature difference between the air cooled and water cooled setup running at 4.0 Ghz is given as,

$$\Delta T_{avg} = 11.8 \text{ }^\circ\text{C}$$

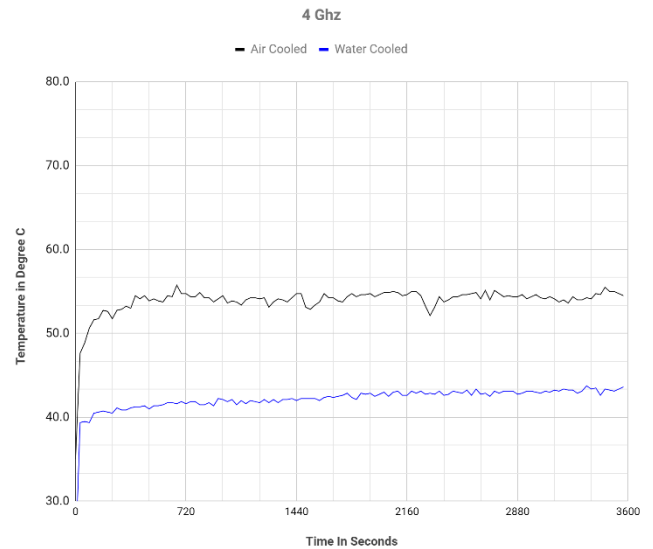


Chart -2 (b) Air Cooled and Water Cooled comparison @4.0 Ghz.

(c) The average temperature difference between the air cooled and water cooled setup running at 4.2 Ghz is given as,

$$\Delta T_{avg} @4.2 \text{ Ghz} = 22.1 \text{ }^\circ\text{C}$$

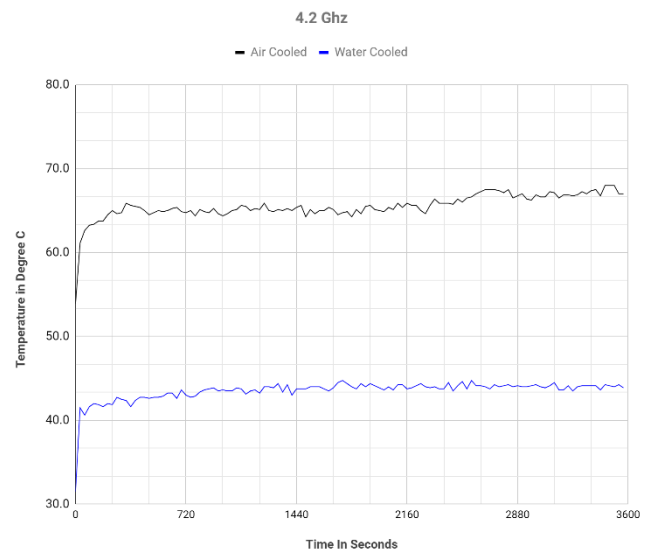


Chart -2 (c) Air Cooled and Water Cooled comparison @4.2 Ghz.

6. CONCLUSIONS

As the power dissipation by the processor in high performance personal computers continues to increase, closed loop liquid cooling systems offer an excellent means to provide efficient reliable cooling with high cooling capacity and low noise. The wetted component of the cooling system is made from copper and copper alloys, which provide very good reliability with aqueous coolants in single-phase liquid cooling systems. Aluminium plate fins is used on the airside of the heat exchanger.

The performance of the liquid cooling system in the computer was in accord with predictions. The observed performance increase was around 21% gain in computational speed and maintaining low CPU temperatures, which increases the life expectancy of the processor and other components.

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