DELL H_2C TECHNOLOGY: HYBRID COOLING FOR OVERCLOCKED CPUs

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Dell recently introduced a hybrid cooling system in new high-end Dell™ XPS™ 710 gaming systems. H_2Ceramic (H_2C™) cooling is a patent-pending technology that supports CPU overclocking.[1] It uses a unique two-stage cooling process that combines a high-performance liquid-to-air heat exchanger, thermoelectric fluid chiller, and control circuitry to optimize CPU cooling with minimal power.

H_2Ceramic cooling is designed for PC enthusiasts and high-end gamers who overclock their CPUs to get top performance. These systems need extra cooling to help avoid failures caused by overheating.

Figure 1. Dell XPS 710 H_2C Edition

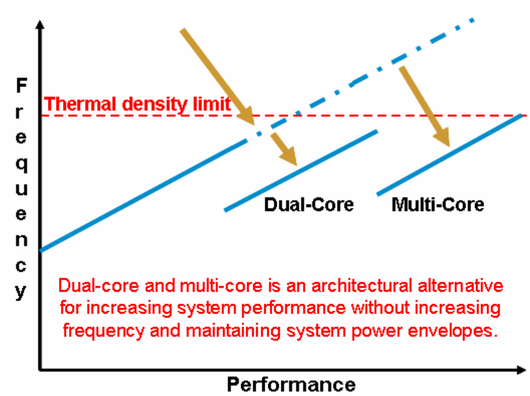
H_2C extends CPU cooling capacity beyond what is possible with heat sinks and forced-air convection or more conventional liquid cooling systems. H_2C uses thermal sensors, electronic controls, and active management of fan speeds and thermoelectric cooling (TEC) voltage to keep CPU temperature slightly above ambient room temperature, which prevents the formation of humidity condensation or frost.

TEC modules at the center of the heat exchanger rely on the same Peltier effect[2] that is used to counter the effect of direct sunlight on only one side of a satellite or spacecraft. The Peltier effect dissipates the heat over the cold shaded side, and from there into deep space.

The Need for Advanced CPU Cooling

CPU cooling has become more of an issue in recent years, as the industry moved to higher-frequency processors. The Intel® 8088 processor used in the original IBM personal computer ran at only 4.77 MHz and did not require a heat sink. However, CPU clock rates have risen sharply since then, producing much more heat, and most systems now ship with large heat sinks and fans to cool the processor.

Dual-core and multi-core processor architectures help to moderate thermal issues by increasing system performance without increasing frequency. Future performance gains will rely less on frequency increases and more on increasing the number of cores and cache sizes, and other architecture enhancements.



Note: For more information, see "Intel® Multi-Core Processors: Making the Move to Quad-Core and Beyond," http://www.intel.com/technology/architecture/downloads/quad-core-06.pdf

Figure 2. Thermal Density Limits Frequency

1. For more information on overclocking, see "What Is Overclocking?" in the appendix of this paper. Dell warrants the full functionality of your system at factory overclocked settings. Overclocking beyond factory settings may cause system instability and reduce the operating life of your system components. Dell does not provide technical support for any hardware or software issues arising from any third party application, such as NVIDIA® nTune 5.0, used to enable overclocking.

2. For more information on TEC, see http://en.wikipedia.org/wiki/Thermoelectric_Cooling.

Despite these improvements, more advanced cooling is often required when a CPU is overclocked in a high-end gaming system. CPU heat output tends to rise exponentially during overclocking. Liquid-cooling solutions exist, but overclocking can require the additional cooling provided by the H_2C technology.

As implemented in the XPS 710, H_2C does not address the cooling requirements of advanced graphics accelerators, which continue to drive improved performance through faster clock rates and higher wattage. Still, H_2C helps improve overall thermal capacity by efficiently removing CPU heat from the cabinet. This allows fans on the graphics cards to cool more efficiently, extending the system's operation at maximum performance.

Cooling Alternatives

Figure 3 shows various cooling technologies, with natural convection cooling through a simple heat sink at the top of the list, and liquid nitrogen at the bottom. The target cooling level for H_2C is just above ambient room temperature because colder temperatures can cause condensation or frost that damage the system. Because thermoelectric cooling can cool below ambient room temperature, H_2C includes sensors and control logic to keep recirculating fluid temperature from falling below the ambient temperature.

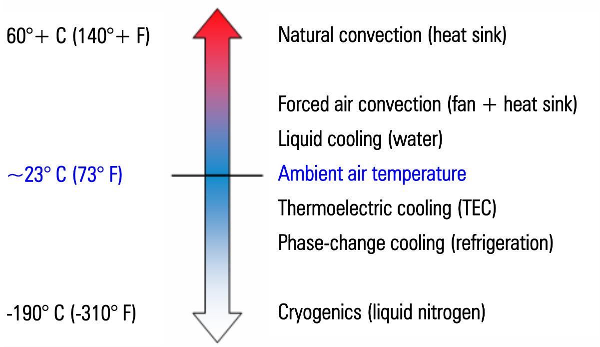


Figure 3. Typical Full-Load Temperatures

H_2C Cooling Benefits

H_2C technology helps to extend CPU life and reduce overclocking risks from heat build-up. In Dell performance tests using an Intel Core™ 2 Extreme QX6700 quad-core processor, H_2C was found to be up to 6° C cooler than the XPS 710 air cooling solution at 2.66 GHz, up to 5° C cooler when overclocked to 2.93 GHz, and up to 9° C cooler when overclocked to 3.2 GHz. This performance is achieved with a lower fan speed than that achieved when cooling with the standard heat sink.[3]

The XPS 710 H_2C Edition is designed for years of maintenance-free operation, where system cooling increases automatically during peak loads. For user convenience, the system ships with overclocking enabled as the factory default. Users can adjust overclocking, H_2C cooling, and other system settings through system BIOS.

Thermoelectric Cooling (TEC) and Peltier Effect

A key component of the H_2C technology is the TEC heat exchanger. At the heart of this heat exchanger are two thermoelectric modules that use the Peltier effect to pump heat from one ceramic face to the other ceramic face when a DC current is applied. Conceptually, it is similar to a refrigerator that uses a refrigerant to move heat out into the environment, but the TEC uses electrons instead of refrigerant.

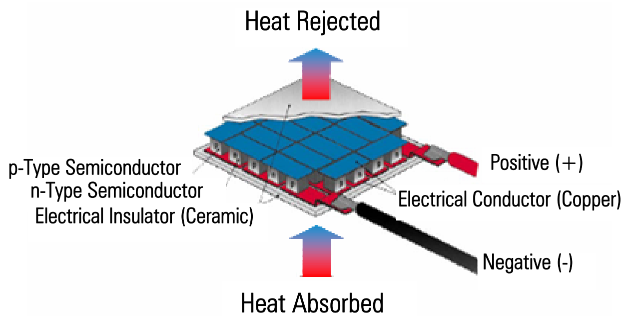


Figure 4. Thermoelectric Module

When the current is applied, one side of the TEC module (or heat pump) is cold, and the other is hot. Reversing the polarity causes heat to flow in the opposite direction. Varying the current allows for tight temperature controls. For more detail on thermoelectric cooling, see www.melcor.com/pdf/Thermoelectric%20Handbook.pdf.

Figure 5 shows the location of the TEC modules and internal fin structure. Thermal grease is used on both

3. Based on testing using a standard maximum-power utility benchmark by Dell performance labs in October 2006 on a pre-production XPS 710 with processor as specified. The system was also equipped with 256 megabytes of dual-channel DDR2 533-MHz 4x memory, dual NVIDIA 7950 GX2 graphics card, and 4x 40-gigabyte hard-disk drive formatted with Raid 0. Actual performance will vary based on configuration, usage, and manufacturing variability.

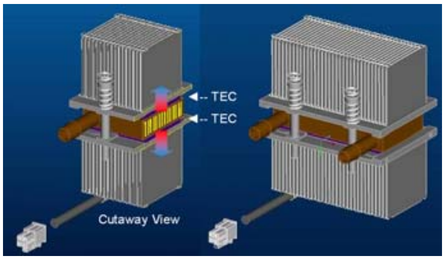


Figure 5. Cut-Away View of Heat Exchanger

sides of the TEC devices to reduce thermal resistance, and coil springs maintain compressive force between the TEC devices and heat sinks. Hoses are attached to the fluid heat exchanger with hose barb fittings. Fluid passing through the heat exchanger is cooled by the TEC Peltier effect and exits at nearly ambient air temperature.

H_2C Thermal Flow Detail

Figure 6 shows the components of the H_2C technology.

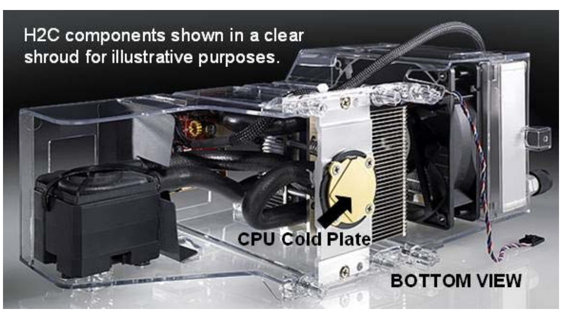
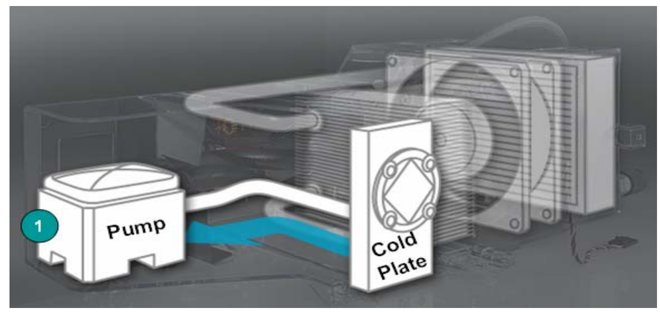


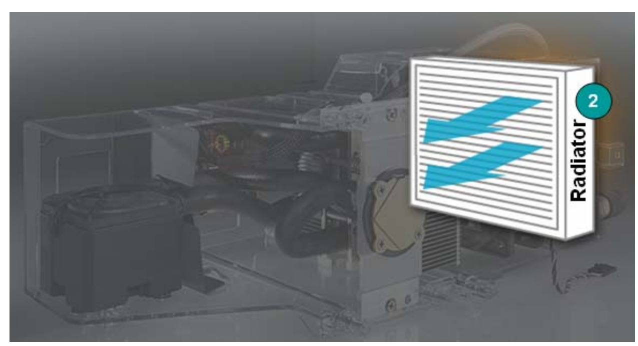
Figure 6. HPC Components

What happens to the heat as it moves from the CPU and exits at the back of the system into the room? To understand this process, it is helpful to look at the fluid flow through the H_2C components shown in the following series of illustrations.

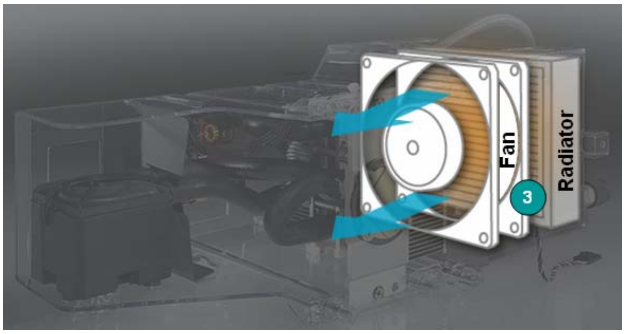
1 *Heat dissipated by the CPU is transferred to a CPU cold plate that is attached with thermal grease and approximately 45 pounds of force. The cold plate has a very fine fin structure inside to enhance heat transfer to the fluid. A high reliability pump circulates fluid through the system, drawing in heat from the cold plate. The pump includes a reservoir and volume compensator that can hold up to 20 cc of fluid to compensate for permeation loss over life. An integrated tachometer provides feedback to the system controller about the pump's speed.*



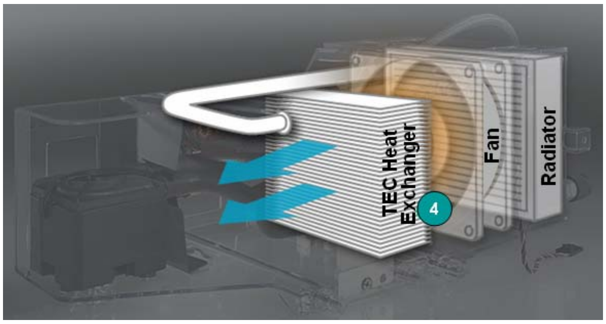
2 *Cool air is pulled through an efficient fluid-to-air heat exchanger that works much like a car's radiator to remove most of the heat in this first stage of cooling. The heat exchanger is custom-designed and built by Delphi for Dell.*



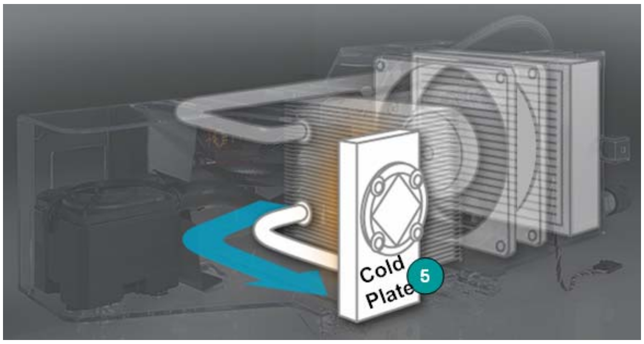
3 *The 120-mm-diameter fan used in the H_2C system is also used in many other Dell systems in conjunction with more common heat sinks. Enclosed in a shroud to amplify the wind tunnel effect, it pulls ambient room air into the front of the systems unit and through the fluid-to-air heat exchanger before pushing it through additional heat sinks on the TEC fluid chiller and out the back. Fan speed is controlled by a pulse width modulation signal from the controller.*



4 *The second stage of the cooling process is performed by a Dell custom-designed thermoelectric fluid chiller, which uses an internal fin structure to transfer heat to a TEC device. For this component, Dell went to CoolIT Systems, a company with experience manufacturing similar fluid chillers for PC cooling applications.*



5 *The combination of system-level firmware and controller circuitry manages the delivery of power to the TEC devices and regulates the speed of the fan and pump. This combination cools the CPU as much as possible during normal and overclocked operation.*



H_2C Testing

When looking for a cooling system for PC enthusiasts, Dell evaluated the leading liquid-cooling solutions before choosing to develop a custom two-stage liquid/TEC solution for better performance. In testing against the best custom solutions available, H_2C was proven to be cooler in overclocked mode and potentially quieter in normal operating mode as shown in Figure 7.

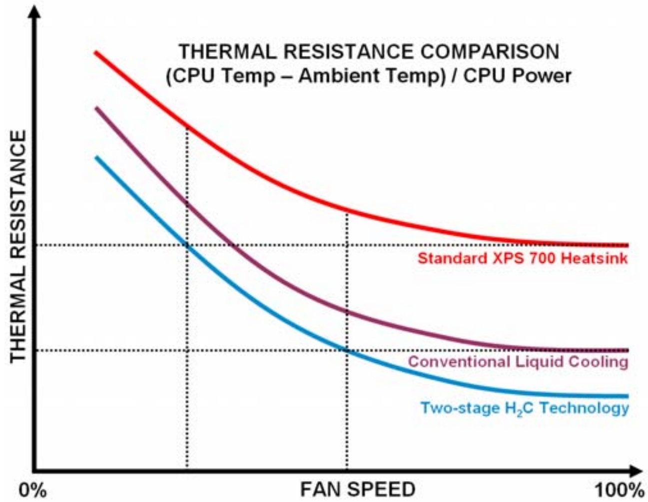


Figure 7. Fan Speed vs. CPU Case-to-Ambient Resistance

In Figure 7, the vertical reference lines show how H_2C can keep CPU temperature lower than alternative cooling systems at any given fan speed. Horizontal lines suggest that H_2C needs lower fan speeds to achieve the same amount of cooling.

Conclusion

In addition to the advanced cooling offered in the H_2C Edition of the XPS 710 systems, all Dell Dimension™ and XPS systems feature the QuietCase™ design and Balanced Technology eXtended (BTX) form factor that have been recognized for cool and quiet operation. For more information on H_2C and Dell gaming systems, see www.dell.com/h2c.

APPENDIX: WHAT IS OVERCLOCKING?

Overclocking is the process of forcing a computer component to run faster than designed or designated by the component manufacturer. The PC enthusiasts who choose to overclock their components usually focus their efforts on processors, graphics cards, motherboard chip sets, and memory, but expansion buses can also be overclocked.

Overclocking allows one to boost a computer system's performance by increasing clock frequencies. There are several methods of overclocking, and no two components will overclock by exactly the same amount.

Considerations before Overclocking

1. Cooling—Due to the excessive heat produced by overclocked components, an effective cooling system is critical to avoid damaging the hardware. Because most stock cooling systems are designed for the amount of heat produced during non-overclocked use, a more effective cooling solution, often employing heavy-duty heat sinks and more powerful fans is usually required. Liquid cooling is often used as well and, when properly implemented, provides much more effective cooling than heat sink and fan combinations. Dell's H_2C cooling technology goes even further to keep overclocked CPUs cool under pressure. H_2C is smarter and more effective than other Dell-tested liquid cooling systems.
2. Stability and functionality—An overclocked component is by definition operating outside of the manufacturer's recommended operating conditions, which may lead to system instability. An unstable overclocked system, while fast, can be frustrating to use. Testing the system is required to determine whether or not it is stable.
3. Measuring effects of overclocking—Measuring the actual improvement from overclocking may be problematic. Even if statistics for the clocks demonstrate an increase, the actual perceptible improvements may not be visible.

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