# Reducing acoustical noise in personal workstations by increasing cooling efficiency

The HP xw9400 Workstation employs an innovative liquid cooling technology that reduces noise while maintaining high levels of performance.

# Introduction

Personal workstations have provided users with substantial increases in processing power over the past decade. Increases in memory size, increased graphics capability and hard drive capacity, and much higher processor performance have all contributed to creating much more powerful desktop and deskside systems.

However, the beneficial increases in capabilities have also increased power requirements, with a corresponding increase in generated heat. To combat the increased heat, cooling systems (mostly fans) have been added to dissipate the internal heat to the environment outside of the cabinet. The addition of fans generates acoustical noise—noise that can be irritating and uncomfortable to users, reducing productivity or even causing illness.

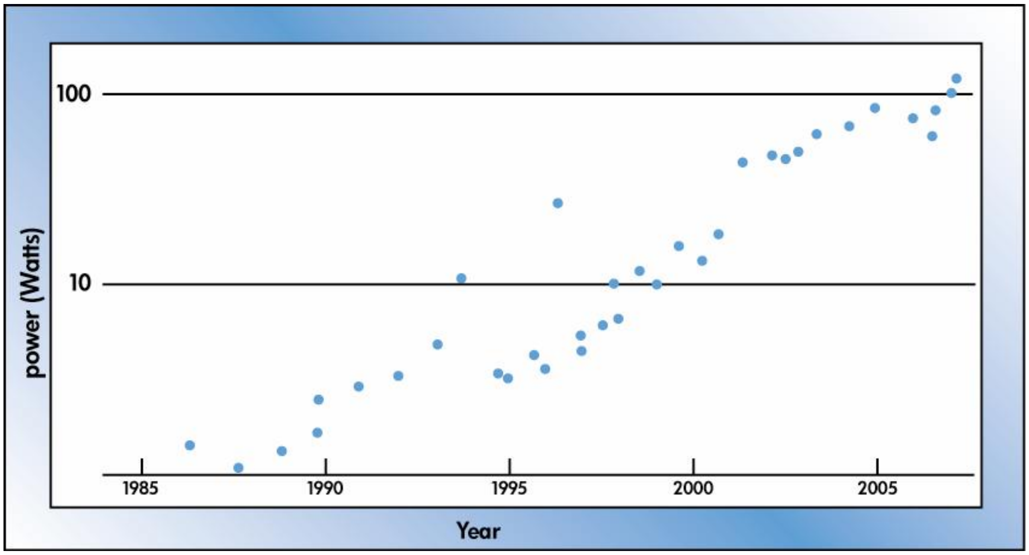
Hewlett-Packard places great emphasis on employing the latest technology in personal workstations, and noise reduction is no exception. HP employs innovative technology to reduce noise levels in its high-end xw9400 workstations, ensuring high levels of performance while still maintaining low acoustic noise emissions. This paper will examine this technology and discuss the acoustical benefits of a quieter and more efficient cooling system.

# Power and noise in workstations

In a typical personal workstation, processors are one of the biggest factors in increased system heat[1]. Early desktop systems were based on a single processor that had a few thousand transistors and generated less than ten watts of heat (Figure 1). Such systems required little or no electromechanical cooling; natural convection of ambient air was sufficient to keep components within operating range.

Current processors are composed of hundreds of millions of transistors, and can generate 120 watts or more of heat. The situation is compounded by today's compact systems that have multiple processors, multiple hard drives, I/O and graphics cards, and multiple gigabytes of memory. The result is an environment that requires a high volume of moving air to cool—and moving air creates noise.

Figure 1. Increasing power requirements for off-the-shelf microprocessors over time[2]




[1]For example—a system with two 120-watt processors consumes 240 watts; dual high-powered graphics cards are the only component that can surpass this figure.
2 Sources: http://www.amd.com/us-en/Processors/TechnicalResources/0,,30_182_739_1102,00.html; http://www.intel.com/support/product.htm

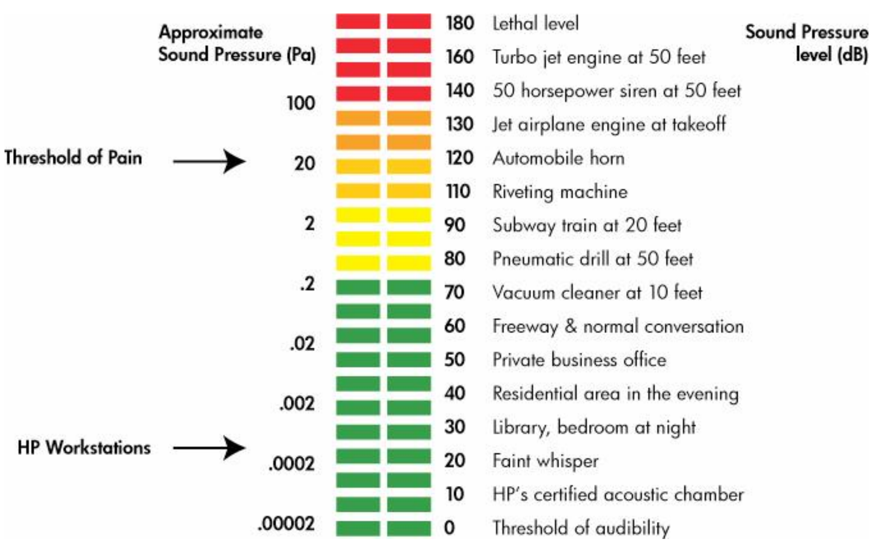
## What is acoustic noise?

Acoustic noise is pressure waves produced by a vibrating source. The pressure waves are detected and translated into electrical signals by the human ear. *Noise* is generally regarded as an irregular vibration, as opposed to a *tone* (which is a sinusoidal wave) or a *sound* (which is a combination of several tones).

There are two ways to measure the "loudness" of a sound: acoustic *power* and acoustic *pressure*. Acoustic power is the total amount of sound energy radiated by a sound source over a specific period and is usually expressed in watts. Acoustic pressure is the pressure generated by sound waves at a given point in space and is usually specified in microbars or Pascals (Pa). Both measurements are useful, although they are typically expressed relative to an agreed reference level (as opposed to absolute levels). The unit of measure used to express these relative sound levels is the Bel or decibel (1 Bel equals ten decibels). The Bel and decibel are both *logarithmic* values. Both acoustic power and acoustic pressure are expressed in dB. For the rest of this paper we will use sound pressure as the measurement of "loudness," as it is the more commonly cited measure. Pressure is more commonly used because humans directly perceive sound pressure; sound power is more of an engineering-oriented measurement.

An increase of 3 decibels in sound pressure is roughly a doubling of pressure; an increase of 10 decibels is 10 times the sound pressure. However, humans perceive the pressure increase differently than the absolute increase—an increase of 3 decibels is perceived as roughly a 20% increase and an increase of 10 decibels as roughly a doubling (Figure 2).

Figure 2. A popular scale of sound pressure levels[3].




The human perception of sound is quite complex, combining both amplitude and tonal aspects (frequency, type of waveform and perturbations) into the total perceived loudness. Ultimately, a reduction of perceived loudness requires a reduction in the amplitude and changes to the tonal aspects of the resulting sound.

[3] Based on http://www.osha.gov/dts/osta/otm/noise/health_effects/soundpropagation.html

## Acoustic noise in personal workstations

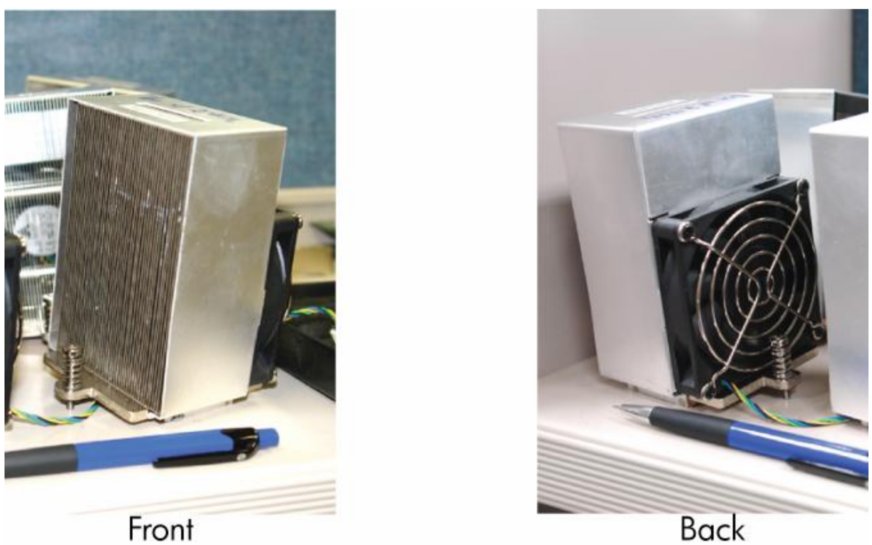
There are multiple sources of noise in personal workstations, including (in order of "loudness"):

- Fans
- Hard Disk Drives (HDDs)
- Optical disk drives
- Other noises (e.g., transformers, keyboards, etc.)

Fans are by far the strongest source of acoustical noise in a workstation[4]. Workstations generally contain multiple fans—fans to cool the interior of the box, fans on graphics cards, and often fans on the processors themselves. To improve cooling efficiency, processors generally have heat sinks on them. Heat sinks increase the surface area over which cooler air flows to dissipate the heat of the component (Figure 3). By their very nature, heat sinks create a great deal of turbulence as forced air flows over and through them; this turbulence generates considerable acoustical noise.

Fans cause further noise as the forced air hits other components within the workstation cabinet, as well as turbulence generated by exiting the cabinet itself.

Figure 3. A typical heat sink and associated fan for a ~100-watt processor.




To reduce fan-generated acoustical noise emitted from a workstation, then, involves either reducing the amount of generated heat (and thus reducing the amount of airflow required), or making the cooling mechanisms more efficient. Reducing the generated heat, while possible, is unacceptable—reducing heat by lowering the processor frequency results in lower performance, and workstation users want the highest absolute performance attainable with a given technology. Put another way, users are often willing to trade performance for acoustic output (up to a point), and that generally means pushing the limits on power consumption. On the other hand, increasing the efficiency of the cooling—reducing the number of fans, removing airflow restrictions, or moving air a shorter distance—is an addressable challenge.

[4] In a "typical" configuration reasonably balanced between memory, graphics (and other I/O), and processors.

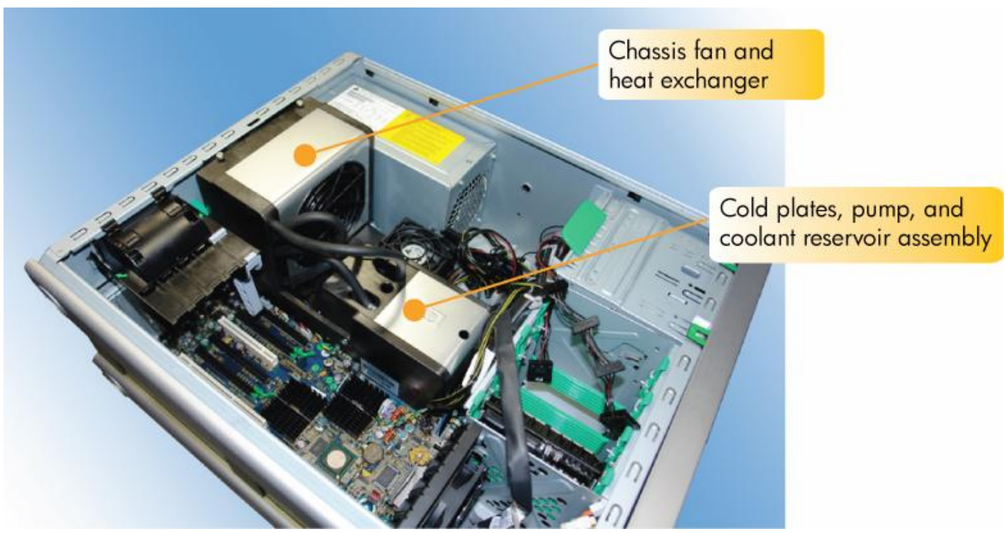
# HP acoustic reduction technology

The high-end HP workstation, the HP xw9400 workstation, is geared toward high-end users that need the highest performance possible—given space, power, and noise constraints. The xw9400 gives these users what they need—it employs one or two AMD® Opteron™ processors (each consuming up to 120 watts), one or more high-end graphics cards, and can house up to 32 GB of SDRAM and up to five internal 3.5-inch hard disk drives. Powering all of this equipment is a massive 800-watt power supply. It takes an innovative approach to cooling to dissipate that much heat while still maintaining office-environment acoustics.

## Liquid cooling assembly

Leveraging years of experience in developing workstations, and some recently developed liquid cooling technology, HP has reduced the acoustics of the xw9400 over its non-liquid cooled counterpart. The reduction in noise is accomplished through the use of a liquid cooling assembly that quickly moves heat away from the processors to a heat exchanger, located near the outside back wall of the enclosure, improving cooling efficiency and reducing airflow requirements and associated airflow turbulence (Figure 4).

Figure 4. The xw9400 workstation chassis with liquid cooling technology




The large air-cooled heatsinks connected to each processor in the non-liquid cooled xw9400 configuration are replaced by two cold-plates that are firmly attached to the top of the processors. The cold plates, pump, and liquid coolant are connected to the heat exchanger with proprietary rubber tubing, designed for high temperatures and long life. All of the liquid cooling components are housed within a small plastic frame, which allows for quick installation and/or processor upgrades.

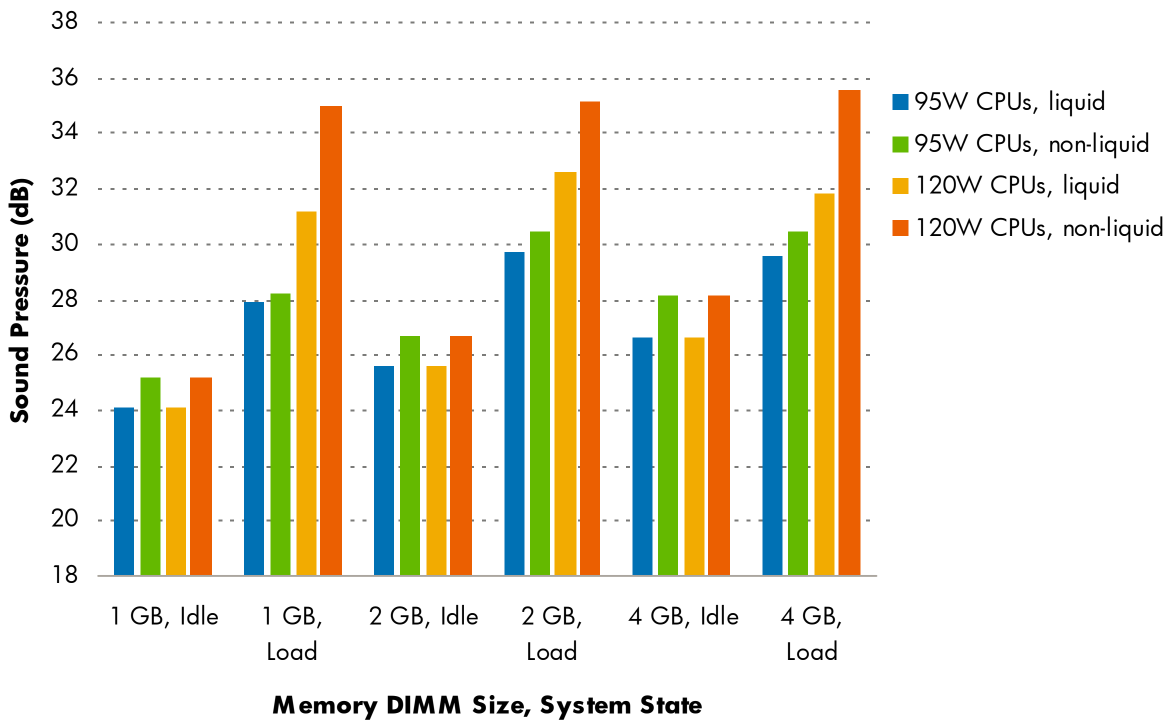
The heat generated by the CPUs is transferred to the liquid as it passes through the cold-plates. The heat is transferred again when the liquid passes through the heat exchanger, which is attached to the back panel of the chassis and cooled by the rear chassis fan. This means that up to 240 watts of CPU power directly exits the rear of the box, reducing interior airflow and nearly eliminating the inefficient recirculation of air inside the chassis.

## Advantages

The primary advantage of the liquid cooling system is to provide a higher-performing processor set to users of a personal workstation, without increasing acoustic noise. In fact, in a laboratory comparison of results between the liquid cooled and non-liquid cooled systems, the reduction in acoustic noise was measured at 1.5 dB idle, and 3.7 dB running the CPU-intensive benchmark Thermnow![5] (Figure 5). The reduced noise levels can make users more comfortable and productive, without sacrificing application performance.

As can be seen, the reduction in acoustic noise is substantial. Recall that dB is sound pressure measured at a specific point, and is expressed by a logarithmic scale—3dB represents a one-half reduction of the sound pressure.

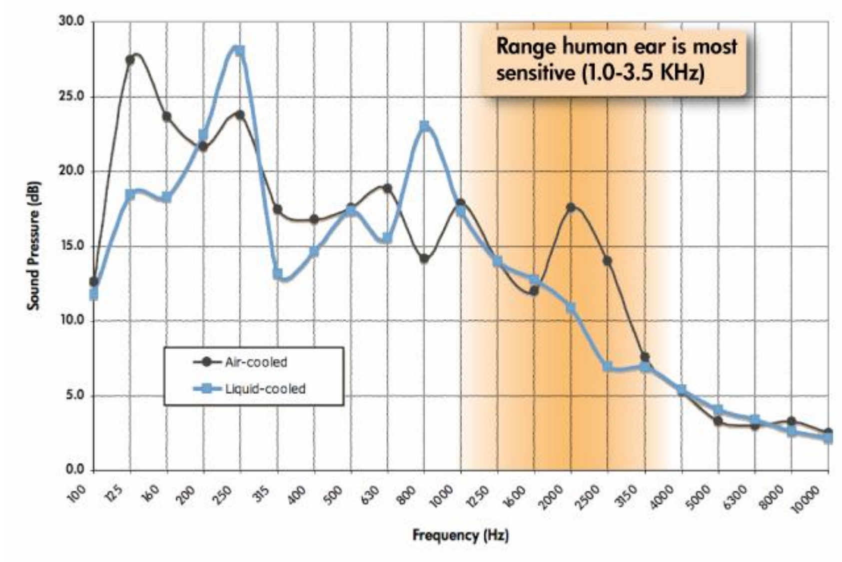
Figure 5. Laboratory comparison of results between non- and liquid cooled systems[6].




The perceived difference is actually much greater because of the improvement in tonal qualities using the liquid cooling system. As shown in Figure 6, the frequencies emitted from a typical high-end configuration show greatly reduced sound pressure in the 1.0-3.5 KHz range—almost exactly the range that is most sensitive to human hearing[7]. This is true for configurations with 16 GB of total memory or less.

[5]Thermnow! is an AMD-proprietary CPU load program specifically for testing thermal characteristics.
[6] For hardware configuration: NVIDIA FX3500 graphics card and SAS HDD. "Load" is running memory, CPU, and graphics tests simultaneously.
[7] http://en.wikipedia.org/wiki/Sound

Figure 6. Comparison of frequencies generated from air-cooled (STD) and liquid-cooled (LQ) configurations[8].




In addition, studies have also shown that certain kinds of acoustic noise are more distracting than others, especially higher frequencies and irregular modulations[9]. The liquid cooling assembly removes the large heat sinks directly connected to the processors, and eliminates a high-pitched "sirening" that can be caused by airflow through the heatsink fins.

## System requirements

As we have seen, a substantial reduction in acoustic noise may be realized by employing liquid cooling technology in the HP xw9400 workstation. **However, some configurations may not benefit from liquid cooling**. Some notes on the system requirements using the liquid cooling implementation in the xw9400:

- The liquid cooling adds a small amount of cost to the system. Therefore, the consumer may see a higher price in return for lower noise levels and/or higher performance.
- Liquid cooling provides a distinct acoustic advantage in systems configured such that processor cooling is the dominant noise source. For system configurations where other components, such as memory fans or hard drives, are the dominant noise source, liquid cooling will provide little or no advantage over air cooling. These configurations are:
  - 3 or more SAS hard disk drives
  - 95W CPUs and more than 16 GB of memory total

It is expected as performance (and power) of processors and other components increases, liquid cooling will become more prevalent in the industry.

# Conclusion

Reinforcing its technology leadership position, HP is adopting an innovative technology to improve the experience of its end users. As workstation power consumption continues to increase, the demand for liquid cooling may well extend beyond CPUs to other components in the system. HP is using its experience in thermal management and workstation engineering to develop high-performance, quiet systems for today, and provide a foundation for tomorrow's more powerful systems. These systems will employ a variety of technologies to both increase performance and lower system noise levels.

[8] For identical hardware configurations: NVIDIA FX3500 graphics card, SAS HDD, 120W processors and 2 GB DIMM memory or less.
[9] http://www.osha.gov/dts/osta/otm/noise/health_effects/index.html

# For more information

## Useful URLs

Information about HP personal workstations:
www.hp.com/go/workstations

Specification for HP's xw9400 entry workstation
http://h10010.www1.hp.com/wwpc/us/en/sm/WF25a/12454-296719-296721-307907-296721-3211286.html

A useful resource for explaining sound measurements
http://en.wikipedia.org/wiki/Sound

## HP offices and contact information

For the HP sales office nearest you, please refer to your local phone directory, or call the HP regional office listed below.

Corporate and North American Headquarters

Hewlett-Packard
3000 Hanover Street
Palo Alto, CA 94304-1185
Phone: (650) 857-1501
Fax: (650) 857-5518

Regional Headquarters

Latin America
Hewlett-Packard
Waterford Building, 9th Floor
5200 Blue Lagoon Drive
Miami, Florida 33126 USA
Phone: (305) 267-4220

Europe, Africa, Middle East
Hewlett-Packard
Route du Nant-d'Avril 150
CH-1217 Meyrin 2
Geneva, Switzerland
Phone: (41 22) 780-8111

Asia Pacific
Hewlett Packard Asia Pacific Pte. Ltd.
138, Depot Road 5th floor
Singapore 109683
Phone: +65 62753888



4AA1-0390ENW, 06/2007