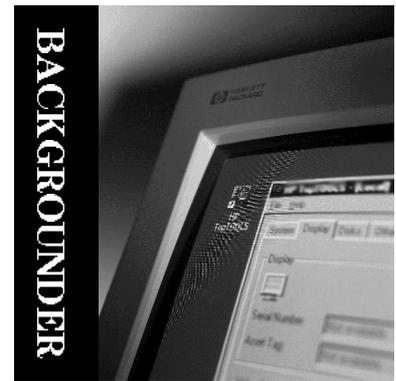

HP PCs and Acoustic Noise



Background information on PC noise, and its effect and measurement

Noise pollution is a growing problem in our society today. In everyday life we have to tolerate high levels of noise, such as that of traffic, factory workplaces, and busy shopping centers. To concentrate, however, we need a quiet work environment. Personal computers in the office do create noise and can be distracting.

In this white paper, we outline the basics of acoustic noise: what it is, how it is perceived, and how it is measured. We then explain why it is important to look carefully at the type of sound measures stated in a PC's specifications sheet, and finally we talk about what Hewlett-Packard is doing to minimize noise disturbance from PCs.

What is acoustic noise?

Acoustic noise is nothing other than pressure waves produced by a 'vibrating' source. These pressure waves are detected and translated into electrical signals by the human ear that are then decoded by the brain.

Usually a sinusoidal wave is referred to as a *tone*, a combination of several tones is called a *sound*, and an irregular vibration is referred to as *noise*.

The frequency of a sound is expressed in Hertz (Hz). 1 Hz equals 1 cycle, or one vibration, per second. The human ear can perceive frequencies between 20 Hz and 20 000 Hz.

How is noise measured?

Sound is a form of energy. Any sound is generated by a *source*. There are two forms of sound measures: acoustic *power*, and acoustic *pressure*.

Acoustic power is the total amount of sound energy radiated by a sound source over a given period of time and is usually expressed in Watts.

Acoustic pressure is the pressure generated by the sound waves at a given point in space and is usually expressed in microbars or in Pa.

It is important to distinguish acoustic power from acoustic pressure.

To illustrate the difference between acoustic power and acoustic pressure, imagine a person sitting in front of a fire. The acoustic power can be likened to the amount of heat generated by the fire, and the acoustic pressure can be likened to the temperature felt by the person.

Acoustic power and acoustic pressure are absolute sound level measures. They vary over a wide range and are not handy to use. Therefore, sound levels are usually expressed relative to an agreed reference level. For acoustic power, the reference level is 1 picowatt. For acoustic pressure, the reference is the hearing threshold of the human ear which is taken as 0.0002 microbar or 20 microPa.

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 *logarithmic* values which are better suited to represent a wide range of measurements than *linear* values.

Relative acoustic power (measured at the source) is represented by the symbol **L_w**. Relative acoustic pressure (measured at the receiving end) is represented by the symbol **L_p**.

Remember, acoustic power and acoustic pressure are two related but very different measures. However, both are expressed in dB, and can therefore be easily confused.

How is noise perceived?

The human ear is not a reliable instrument with which to measure sound levels because its sensitivity varies with the frequency of a sound. The human ear is very insensitive to low frequencies, reaching maximum sensitivity between 700 and 5000 Hz, and becoming less sensitive again at higher frequencies.

The perceived loudness of, for example, a 40 Hz tone is much lower than the perceived loudness of a 1000 Hz tone of equal intensity.

Fletcher and Munson have plotted a sensitivity curve that indicates which *linear* acoustic pressure levels are needed at different frequencies to produce the same subjective impression of loudness for the average person.

Sound Pressure Levels (SPLs) are expressed either in linear decibels (dB(Lin)) or in *weighted* decibels (usually dB(A)). The latter are calculated taking the Fletcher-Munson sensitivity curve of the ear into account, and therefore best reflect the subjective impression of loudness that we have.

The difference in value for a sound expressed in dB(Lin) and the same sound expressed in dB(A) can be very large. For example, 60 dB(Lin) is perceived as being quiet at 50 Hz, and as being loud at 1 kHz; whereas 60 dB(A) is perceived as being the same loudness at both 50 Hz and at 1 kHz.

Apart from the frequency, the type of waveform and its repetition rate also have a considerable impact on the human perception of sound. A 2 kHz sine wave at 45 dB will be perceived as very unpleasant, whereas a one-third octave band of pink noise at the same frequency and with the same SPL will not create much disturbance. So it's not only

the average loudness level that's important, but also the type of noise. For instance, prominent and monotonous tones can be disturbing.

A last point regarding the perception of sound level differences: most people cannot hear a difference in sound level of 1 dB; most people can hear a difference of 2 dB; 3 dB corresponds to a clearly noticeable difference between two sound levels; a difference of 10 dB would be perceived by most people as relating to twice the previous volume.

How to compare noise levels between PCs

Many PC brochures, data sheets, and advertisements happily mix up all sorts of noise related 'measures'.

The only sure way to make a proper comparison is to compare acoustic power with acoustic power, acoustic pressure with acoustic pressure, dB(A) with dB(A), dB(Lin) with dB(Lin), and to compare only data measured by a certified test lab with an acoustic measurement room with a background level at least 10 dB below the lowest measurement to be made (background typically below 18 dB(Lin)). Note that even measurements made by such a certified lab can still show variances of up to 2 dB!

The two most interesting measures for PCs are:

- the (relative) acoustic power in dB(A) - LwA - which is the most reliable measure since it does not depend on distance or position
- the (relative) acoustic pressure in dB(A) - LpA - which is the most commonly quoted figure. However, the value obtained depends on the distance and position relative to the source from which the measurement is taken.

Both acoustic power and acoustic pressure should be measured according to a standardized measurement method such as ISO 7779/EN27779. When acoustic pressure is measured, it makes most sense to measure it in 'operator position'. This corresponds to measuring noise at the level of the ears of a PC user. Some manufacturers measure acoustic pressure from a distance of 1 meter (in 'bystander position'). We believe this makes no sense for PCs since no user works on his/her PC from 1 meter away.

It is an absolute must to quote the measurement method and distance for acoustic pressure, because it will be clear that, for example, a pressure measurement at 1 meter will yield results which look more favorable than a pressure measurement at 0.5 meters.

A statement such as this PC only produces 38 dB" without further information doesn't mean anything.

Unless specified otherwise, Hewlett-Packard quotes the acoustic power (Lw), measured according to ISO 7779/EN27779. Remember, the acoustic power value is always higher than the acoustic pressure value and looks less favorable.

For example, an HP Vectra VE Series 3 PC, measured according to ISO 7779, has a acoustic power level of 37.2 dB(A), and a acoustic pressure level of only 31.1 dB(A). So the same product could be advertised 6.5 dB more favorably by using pressure specifications in operator position, and about 10 dB more favorably by quoting the pressure value at a distance of 1 meter! HP will continue to publish acoustic power values, and may add pressure values in the future to facilitate comparisons.

To allow reliable noise comparisons between different PCs, Hewlett-Packard hopes other manufacturers will also start to publish acoustic power values according to ISO 7779.

Indicative values of acoustic power and pressure for HP PCs (measured according to EN27779 at 20°C in the Laboratoire National des Essais in Paris)		
Model	Acoustic Power - LwA in dB (Ref. = 1 pW)	Acoustic Pressure - LpA in dB (in operator position) (Ref. = 20µPa)
HP Vectra VE Series 3	37,2	31,1
HP Vectra VL Series 5/166	39,5	33,7
HP Vectra VA 6/200 MT	38,9	34,7
HP Vectra XA 5/200	37,5	32,4
HP Vectra XA 6/200	40	34,4
HP Vectra XU 6/200	42,7	39,3

What are the limits, standards and regulations for noise?

The threshold of hearing (lowest audible noise level) is approximately 20 microPa. This level corresponds by convention to an SPL (Sound Pressure Level) of 0 dB.

The background noise level in a quiet library is about 30 dB(A), while in a typical living room it is at about 40 dB(A). A typical conversation heard from a distance of 1 meter will be 60-70 dB(A) and city traffic is about 80 dB(A).

Noise levels above 80 dB(A) over a long period of time degrade hearing and noise levels of 120 dB(A) and above are perceived as painful.

Laws concerning acoustic noise

There are very few laws that apply to acoustic noise. What follows are the laws or regulations that do exist.

The European Union Directive 86/188/CEE requires employers to provide ear protection to workers who are exposed to noise in excess of 85 dB(A) for prolonged periods of time.

In Germany, the law obliges manufacturers or importers of equipment to specify the exact sound level produced by the equipment when it produces a sound level of more than 70 dB(A) (Lp) measured according to the ISO 7779 standard.

The Swedish Statskontoret specifies an upper value for computers of 68 dB(A) (Lw) measured according to the same standard.

No single PC on the market produces noise levels exceeding the limits outlined in any of the three previously mentioned laws.

To our knowledge, there are no laws relative to noise levels in offices, but the European Union has issued some official recommendations. European Norm EN31690:1992 (ISO/DIS 11690) gives guidelines for the design of low-noise workplaces. It recommends a noise exposure limit of 55 dB(A) (Lp) for normal office work, and 45 dB(A) for conference rooms and mental work. The Swiss Caisse Nationale d'Assurance

recommends the same value of maximum 55 dB(A) as EN31690.

The Swedish Labor Union TCO also recommended a maximum of 55 dB(A) up to a few years ago, but has recently changed its target value to less than 45 dB(A).

Of more importance than regulations is the manner in which a PC user perceives noise. The noise level which a user will accept from his or her PC depends on many factors including the following:

- work in an open plan office or in a closed single room office
- PC installed against a reflective wall or not
- carpet on the floor and walls, as opposed to reflective tiles and painting
- PC used occasionally or continually
- noise of the PC masked by other noise (e.g. air conditioning) or not
- special attention paid to noise or not
- cultural differences.

Note that a very low noise level in the office also creates problems: any 'normal' noise will create such a large difference compared to the very low ambient noise that it will be perceived as excessively loud. For example, if you use a '40 dB PC' in a '30 dB office' there is a very noticeable difference of 10 dB. Use the same PC in a '45 dB' office and you won't hear it anymore. Both EN31690 and the Swiss Caisse Nationale d'Assurance, therefore, recommend a background noise level (generated by air-conditioning, external noise, etc.) of 35 to 45 dB(A) for open plan offices, and 30 to 40 dB(A) for single room offices.

What makes PCs so noisy?

What follows are details (in decreasing order of importance) of the elements that contribute to PC noise:

SPU (System Processing Unit)

The system processing unit is the main 'box' of the PC that contains the processor, disk drives, and accessory cards. Within an SPU, the key sources of noise are (also in decreasing order of importance):

- **Fans** are required for cooling the processor and the power supply. The more powerful a PC is, and the higher its maximum allowed operating temperature, the more cooling it requires. Note that HP PCs are designed for operation up to 40°C, even with a fully-loaded configuration, which is more than most other PCs. It is an absolute must to provide sufficient cooling, otherwise the reliability of the PC will suffer, and it may even break down altogether. The fan provides a 'continuous' type of noise, although some low-quality fans also provide a fluctuating noise spectrum.
- **Disks** provide both a 'continuous' type of noise due to the rotation of the drive, and an 'impulse' type of noise created by data accesses.
- As **CD-ROMs** become faster and faster, their contribution to the noise created by the SPU also grows. For example a 16x CD-ROM drive is considerably noisier than a 4x CD-ROM drive.
- **Transformers** can produce mechanical vibrations. With switching power supplies these vibrations are lower in amplitude, and usually higher in frequency, than with conventional power supplies.

Most people, when talking about PC noise, are referring to the noise produced by the SPU. However, other elements also play a contributory role:

Keyboard

Keyboards produce noise, but it is not constant and usually not disturbing. A little bit of acoustic feedback is even desirable to confirm that a key has been pressed. Modern, good-quality keyboards are, in general, better damped than old keyboards, and therefore produce less noise.

Monitor

Monitors produce much less noise than SPUs. The yoke, transformer, and some other components such as capacitors, may produce some mechanical vibration. Apart from mains frequency noise, some high-pitched line frequency noise may also be produced. In the past, this line frequency noise occurred around 16 kHz, and could sometimes be heard by young people. On modern high-quality monitors, these high-pitched noises have been attenuated and shifted to well above 20 kHz. As a result their impact to PC users has become negligible.

What can be done to reduce PC noise?

The greatest amount of noise from PCs is generated by cooling fans and by the disk drives.

Reducing cooling fan noise

PC users have two contradictory demands of a PC: they want it to be powerful and to be quiet. However, greater power usually means more heat, and more heat means better cooling is required, which usually means a more powerful (and noisier) fan is needed.

Eliminate the fan: the ideal solution would be to eliminate the cooling fan altogether. However, recent more powerful PCs generate more heat and require more cooling.

Reduce power consumption: as a long term goal, Hewlett-Packard are working towards producing PCs that consume less power, and are optimizing the thermal design of their PCs. Meanwhile, most PCs still require a cooling fan.

Use low noise fans: another solution is to use low-noise fans and fan speed control circuits that reduces the rotational speed of the fans when the ambient temperature is low or when the PC is not loaded with accessories. Most HP Vectra PCs have a fan speed control circuits. However, there are limits as to how much fans can be slowed down before affecting their reliability.

About 'noise-killer' circuits: care should be taken with retrofitting so-called noise-killer circuits into existing products. These circuits, which control fan speed as a function of temperature, must be mounted in such a way that critical components remain below their specified temperature limits. This requires an exact knowledge of the different components, and of how to measure temperatures at different points within the SPU. Very few people have this knowledge.

Installing an add-on noise-killer does not always bring an improvement. This is the case when the PC already has a built-in fan speed control circuit, or when the fan already runs at its lowest recommended operating speed. In certain cases, installing a noise-

killer circuit may jeopardize the product safety.

For all these reasons, installation of add-on noise-killer circuits should only be considered and executed by authorized HP service personnel in accordance with the HP factory guidelines. Unauthorized installation of noise-killer circuits in HP PCs will void the PC's warranty.

Other cooling techniques: alternate cooling techniques include, for example, natural convection, heat ducts, and directed air flow.

Natural convection allows air to circulate through holes in the PC cover. This is currently a viable solution only for low-power, entry-level PCs which represent only a very small portion of the professional PC market.

Heat ducts, or heat pipes, soak away heat from a particular component, such as the processor, to a radiator on the back of the PC.

Directed air flow cools heat generating components, such as the processor, more than other cooler components in the SPU.

All these cooling techniques allow a substantial reduction in noise.

Reducing hard disk drive noise

The hard disk is, in general, less audible than the fan, but the noise it produces is not negligible. Two solutions are possible:

- selecting an intrinsically low-noise disk drive (but again, higher performance drives usually produce more noise)
- damping the noise by means of damping trays or encapsulation.

Hewlett-Packard is working on new products which combine both these solutions.

Hints on how to reduce the noise from your PC

Proper installation of the PC will also improve the user's comfort without any modifications to the PC itself. Here are a few hints on how to minimize the noise generated by your PC:

- If possible, put the PC under the desk: it is further away from the ear, and the desk top will cut direct sound radiation to the ear. This makes a difference of at least three decibels.
- If you do place the PC on a desktop, a desk with a heavy, non-resonant top is best. Installing the PC on a desk with a lightweight top can amplify vibrations produced by the PC.
- Don't put the PC with its back (that's usually where the fan is) close to a reflective wall. Install it so that the fan can blow freely away from the user. If this is not possible, installing a sound-absorbing panel behind the PC will help. Just make sure there is at least 10 cm free space behind the fan in order to allow proper ventilation.

Conclusions

Noise can be distracting in an office environment. For this reason, Hewlett-Packard takes noise reduction in its PCs very seriously.

There are a number of ways of measuring acoustic noise. The two most common are acoustic power (L_w) and acoustic pressure (L_p). Acoustic pressure values are always lower than acoustic power values for the same level of perceived noise.

HP will continue to optimize the combination of processing power, reliability, and acoustic noise.

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