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PCs and Instruments - The Great Divide?

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Introduction

During the last decade, there has been much written and said about the use of personal computers in acoustics and vibrations, both for measurement and results processing. The advances in PCs have been nothing short of phenomenal, driven by the fast moving requirements of information technology in the office environment, and these benefits has filtered into our world of acoustics, in the form of more flexible measurement tools.

The pure technologists amongst us plunged headlong into building an instrument on a PC, and the resulting system offers clear benefits to the user. It is now accepted as a true alternative to more dedicated instrumentation.

This article explores the issues instrument developers faced, and shows how the computer architecture generates truly accurate and flexible measurement tools for noise and vibration measurements.

Some history

A simple instrument such as a sound level meter has a long pedigree stretching over decades, starting with heavyweight analogue designs, with the noise readings being displayed on a moving coil meter display.

In principle, these instruments have changed little, except that functions that were performed in analogue circuitry are now found in digital calculations, using firmware, rather than hardware. However, to achieve the large dynamic range and frequency range required for acoustic measurements, careful design is still necessary and often based on years of experience.

A sound level meter can be broken down into its constituent building blocks, as shown in Figure 1. The acoustic pressure is converted into an electrical analogue signal by a precision condenser microphone, and the impedance converter gives a signal that is easily handled by the following amplifiers. Filters may be used to provide an estimate of human response to the sound (e.g. A-weighting) or for analysing the signal in more detail. The resulting conditioned signal is then 'detected', either using a root-mean-square (RMS) detector, to give an estimate of the energy in the signal, or by using a Peak detector, to give a measure of the raw acoustic over- or under-pressure. The output of these detectors is then fed to a metering device, and to ensure the meter can be read by eye, various time constants (e.g. F, S, I) have evolved to provide a degree of damping, or simulation of human response.

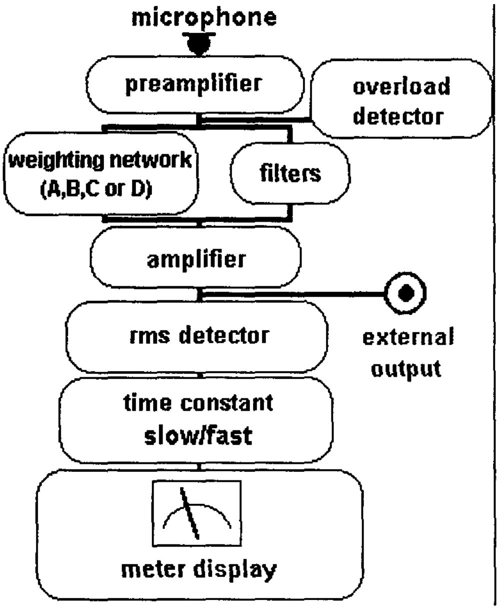


Figure 1: Sound level meter

The first changes into the digital world came when moving coil meters were replaced by digital displays (some still bemoan this fact), which suddenly appeared to give us hitherto unheard of accuracy of tenths of a decibel! Of course the accuracy was exactly the same, but we could now improve the precision of the result. At about the same time, a new measurement parameter emerged, the equivalent continuous sound pressure level, or Leq, and some would argue that this was invented just to make the digital displays readable!

Slowly, the digital calculations replaced the measurement functions, firstly by sampling the output of the analogue detectors, often at slow rates using 8-bit A/D conversion, and then later by replacing the detector itself, calculating the RMS and Peak values from data digitised at high speed from the input amplifiers. Some of the current instruments now sample the signal from the microphone preamplifier directly, and the rest of the chain is achieved using digital signal processing only.

The use of digital circuitry has allowed digital communication with other devices, such as printers and computers, where, before, a pen recorder or X-Y plotter may have been the only hard copy output from a sound level meter.

The Great Divide

This is where one of the traditional divides has emerged between instruments and PCs. The dedicated instrument has always been used to provide the measurements, and the computer has been used simply as a storage device for archiving and displaying results, with simple post-processing functions. The interface between the two has either been in the form of a simple RS-232C serial communication, or via manual entry of results from a paper printout. This latter in particular has been responsible for many errors, with the tedium of copying numbers into a spreadsheet, for example, from a long roll of silver paper!

It is only relatively recently that computers have moved *into the measurement* arena, supported by the massive increase in available processing power. But to build a sensible instrument using a PC, we need to consider which processes are better handled by dedicated hardware, and what can be transferred to the PC environment.

Building the virtual instrument

To visualise how we might build a computer-based instrument, we can look at the basic building blocks used in a traditional stand-alone instrument. Figure 2 gives a generic approach, which could be found in any instrument, be it a sound level meter, tape recorder or multi-channel FFT analyser.

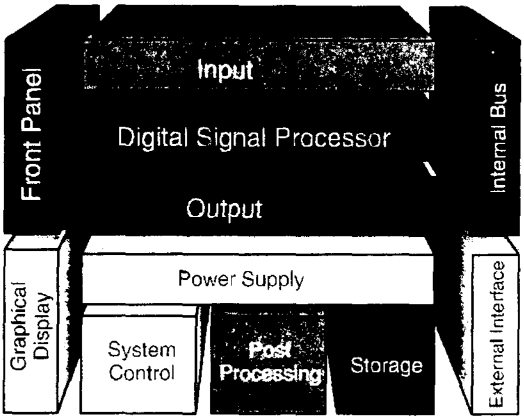


Figure 2: Basic building block

Any digital system will have an input and/or output section, the contact with the physical world, with some dedicated DSP function performing the actual measurements. A system controller, using a proprietary internal system bus, all supported by a power supply, controls the whole. To control the instrument, a front panel is required, and perhaps the results, such as a spectrum or time history graph, may be presented on a graphical display. Simple post-processing may be provided in the form of, for example, building acoustics calculations, and data may be stored in some sort of storage medium. This can be considered as generalised storage, and may consist of a spectrum memory, or a set of Ln measurements or even raw audio data, in the case of a DAT recorder.

Finally, the instrument may have an interface to, say, a computer for further analysis and reporting.

A host of such instruments are available, which are commonly used with a computer, but when such a combination is made, the duplication of function quickly becomes apparent. Many of the internal functions can be handled just as efficiently by a computer, for example, both the front panel and graphical display might be realised in a high-resolution colour display, with Windows™. The storage can be looked after by the computer hard disk, devices which appear to be doubling in capacity and halving in price every year or so. The computer can do even the system control, and it is ironic that some analysers in particular actually feature an internal Pentium (or worse x86) processor as the system controller!

In principle, the remaining functions could also be lifted, but perhaps this approach is too simplistic. To make sensible decisions about which functions should be handled by a standard PC, another dimension should be considered.

As well as looking at physical building blocks, the actual *processes* in the measurement chain should also be reviewed. These are illustrated as the four main layers in Figure 3.

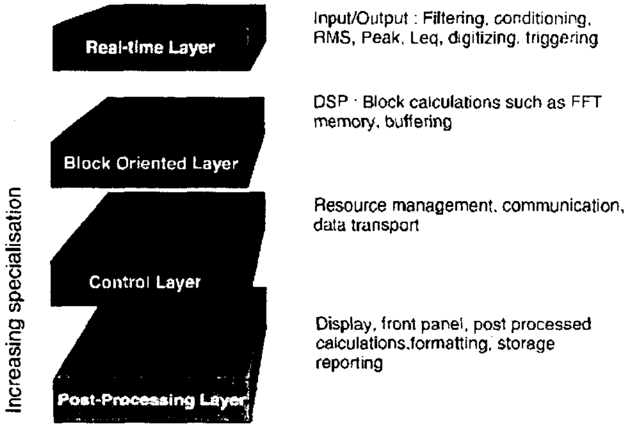


Figure 3: Processing Layers

At the top of the chain is the *real-time layer* where processes are handled in real-time, with no loss of data, with resources dedicated to particular functions 100% of the time. Examples are A/D conversion and basic filtering, such as anti-aliasing and weighting functions.

The next layer is *block-oriented*, where data from the real-time layer is handed over, and fast calculations are performed, but not necessarily in real-time, although buffering can protect against data loss. A very good example is Fast Fourier Transformation (FFT), where complete blocks of time samples are transformed into the frequency domain for frequency analysis.

The *control layer* holds all these processes together, and handles both data transport and system requests, which will be interrupt driven. In other words, resources are made available when requested, and are often used for many other tasks.

Finally, the *post-processing* layer has no urgency, and results can be processed at any time, often days after the initial measurements are made.

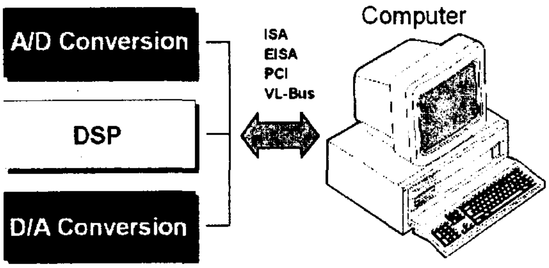
Computers have been used for the post-processing layer for some time, and already instrument systems are being devised where the computer also provides the control layer. However, because of the tight requirements on timing and real-time considerations, the first two layers tend to be handled by specialised hardware and firmware.

This combination of hardware and software to create an instrument has been termed the *Virtual Instrument* in the sense that the measurement functionality does not exist until the combination is brought together. The term VI is often misunderstood as simply a hardware box controlled by a computer, with the measurement functionality still contained purely in dedicated circuitry.

Distributing the Virtual Instrument

A much more flexible approach is the *Distributed Virtual Instrument* where the only dedicated *resources* are Input, Output and DSP functions.

This is illustrated in Figure 4, where the only remaining blocks are the A/D & D/A conversion, and a DSP resource. The system control is performed entirely by the computer, and the software is also performing extensive measurement calculations, and programming the DSP on the fly, only for floating-point calculations where real-time capabilities may be required, with high dynamic range.



Examples:- Generator = DSP + D/A
Analyzer = A/D + DSP + D/A
Sound Level Meter = A/D (+DSP)

Figure 4: The Distributed Virtual Instrument

Graphics, user interface, storage and post-processing are also all handled by the PC platform, and the DVI is defined simply by the software running on the computer, which sends calls to the hardware resources as necessary.

This type of approach puts a premium on both computing power as well as the type of bus structure used to co-ordinate the resources. In traditional instruments, this bus has been proprietary and unseen by the user, but in the DVI concept, standardised interfaces can be used, such as *ISA*, *PCI*, *SCSI*, *USB*, etc. In the larger world of Test & Measurement, automated test systems are using high speed buses such as *VXI*, from which the original DVI concepts emerged at the beginning of the nineties [1], [2], [3], [4].

The best examples of the DVI are the **Symphonie** (2-channel) and **Harmonie** (4 channel) systems (Figure 5) developed by 01dB-Stell in France [5], the first company in the world to design a type 1 approved PC-Based sound level meter in the late eighties.

In this two DVI, a small, lightweight, and battery-free external unit, containing the distributed resources, is connected to a notebook PC via PC-card (earlier known as PCMCIA). The advantage of this interface is that it consumes much less power; it can directly power the external unit, and is therefore well suited to highly portable instrumentation.

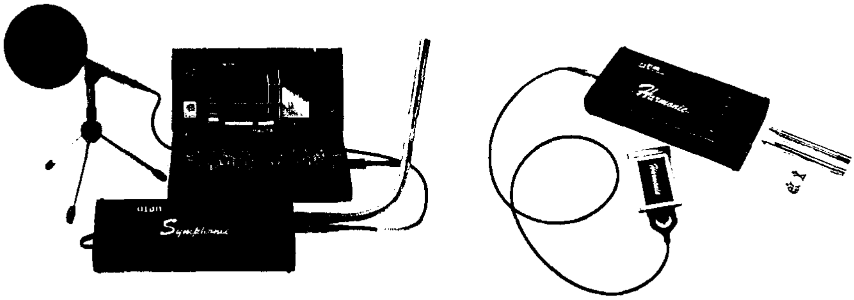


Figure 5: Symphonie (2-channel) and Harmonie (4-channel) systems

The software runs under Windows™ 95, 98 or Me, and defines whether the instrument is an environmental noise real time analyser, a building acoustics real time analyser or a real time signal/frequency analyser. To change the instrument, the user simply calls up different software 'module'.

Windows on acoustics

In parallel with the development of PC computing power, Windows™ appeared. Originally conceived as a way of making computers more accessible to users, hence avoiding command-line interfaces, Windows™ became the standard in the office environment. In addition to an easy user interface, however, the operating systems have also laid down some very strict rules regarding interconnection of hardware as well as data transport. These are manifested in phrases like 'multimedia' and 'plug and play'.

This is an added bonus to the DVI builder, as it allows many types of data to be handled safely, using complex buffering and communications, as well as easy integration into mainstream software.

For example, our DVI might be measuring sound pressure levels over time, and when a level is exceeded, audio data can be streamed to a storage medium (e.g. hard disk), so the user can later listen to the noise that caused the exceedance. This powerful feature is taken care of by the *media control interface* (MCI), conveniently built-in to Windows™ environments, ensuring that audio data does not collide with noise data and so on.

Once collected and processed, data can also be transferred to the office spreadsheet for further processing or word processing to make reports, simply by using cut-and-paste, a powerful method of communication between software programs.
The current DVI can even automatically create reports according to the ISO standars, simply by clicking on an icon!

Advanced users can remotely control the DVI by using *Dynamic Data Exchange* (DDE) to control the system by telephone modem from a remote site, or to integrate the DVI in a process line control system (for example on-line quality control)

Alternatively, you may wish to illustrate to a colleague anywhere in the world what the new concert hall acoustics sound like. Simply embed an audio file in a document and send it via e-mail. Your colleague can then click on the document to play back the sound.

The benefits in the user interface are obvious; no more tiny monochrome displays, but instead a high resolution colour TFT display, with mouse control, simple menu structures, toolbars and shortcuts for regularly used functions, such as calibration, audio recording...
Measurement results are clearly presented, and with today's huge hard disks, the data storage is almost limitless. An environmental noise analyser on a notebook can run for years (if anyone needs the data) before needing more storage space.

Last, but not least, the last versions of Windows proved to be much more stable than the earliest ones. The robustness and reliability of the system is not any more a concern, even if developers still uses to say that they correct the bugs of Windows™ in order to develop highly reliable DVI, like the 01dB-Stell ones!

What about accuracy?

All this sounded like science fiction only a few years ago, but it is available and happening now.

However, the technology may be in danger of taking control, and we could end up forgetting what we set out to achieve; that is, some benefit over the traditional approach to measuring noise and vibration.

No technology is of any use if it cannot measure things as accurately as we expect. With the development of sound level meters, several standards have emerged which lay down minimum expectations for instrument accuracy, for given grades of instrument. IEC651, IEC804 and more recently IEC1260 and their national equivalents, lay down the law in this respect, with minimum requirements for dynamic range, linearity, frequency response and indications. There is no sense in developing a measuring system if it cannot meet these requirements.

So what is the measuring system? Well, in the case of a DVI, it is the complete set of hardware resources, software modules and host computer, which must be subjected to the same approval tests as a standard instrument. Of course, many of the requirements of the standards reflect the use of dedicated instruments, but until they are revised, the new instruments must still comply.

It is reassuring to note, then, that the new instrument systems (particularly **Symphonie & Harmonie**) have now received type-approval in several countries to Type 1 accuracy, interestingly, using generic computing hardware (Figure 6). In other words, it does not matter which brand of computer is used, as long as it meets minimum requirements relating to clock speed, memory and floating point availability [6].

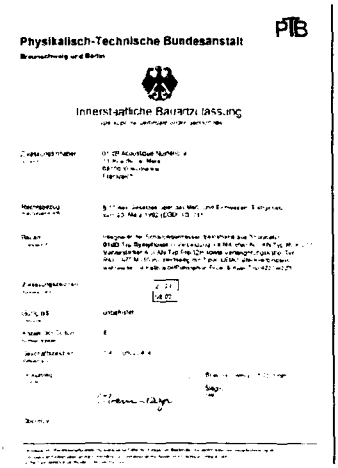


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Figure 6: PTB certification

This allows the user to have a very flexible choice for her/his measuring system, some choosing the last Pentium 4 processors, others selecting huge hard disks for installing other applications such as modelling software, others choosing very small touch screen laptop and so on. It makes much more sense now to use a computer as a sound level meter, rather than the other way round!

The sound level meter is dead. Long live the sound level meter!

After reading this, you may be forgiven for thinking that the traditional instruments should be consigned to the cupboard.

Far from it. Manufacturers will continue to produce such instruments according to demand, but they will become more dedicated and 'commodity' in nature. For industrial noise, where a limited set of parameters is required, such instruments will always be cheaper and easier to use than any computer system, but for the manufacturers, the margins will become smaller. Parallels to this trend can be seen in other markets, e.g. most people have a digital voltmeter to hand, but when more serious electronic circuit analysis is required, the technician turns to the computer.

Moreover, advanced sound level meters can know be used either as dedicated instruments but also as DVI by simply connecting it to a PC through RS232 and using a Windows^{TM} based software as the controller (e.g. the SIP95 from 01dB-Stell).

It is in the area where the acoustician is looking for flexibility, and additional performance, that the computer based instruments are now succeeding. As measurement procedures become more complex (witness the measurement of sound power according to ISO9614-1 using intensity!), and as users demand clearer user interfaces and automated measurements, it makes logical sense to incorporate a computer into the process, and where better than into the measurement process itself.

As manufacturers cram more functions into the dedicated instruments, the user interface suffers in proportion, with complex nested menus and special functions.

Windows™, specifically developed to make computers easy, overcomes these problems, with common look-and-feel to software, and use of colour graphics.

Where will it all end?

There is no doubt that PC based instruments will continue to eat into the traditional instrument market, and already, most FFT analysers sold worldwide are based more or less on PC architectures, either as specialised PCs in boxes or as expansion cards.

The steady increase in performance of PCs, with corresponding improvements in user interfaces and also portability, is still a serious issue. When climbing up a cooling tower to measure plant noise, it is a lot easier to pull out a hand-held sound level meter than a notebook computer. But today, with touch pad computers, it is already easy to handle (Figure 7). In two years, this could just as easily be a *Personal Digital Assistant* (PDA) with the same power as today's notebooks.

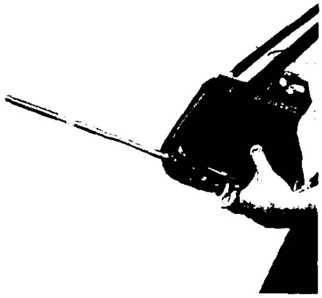

Figure 7: DVI (Symphonie) used with touchpad computer

Developments in the PC industry have repeatedly confounded the prophets, with considerable computing power sitting on most laptops today, which would have been unthinkable ten years ago.

One interesting development in the context of this article is the use of *native* digital signal processing. Although we have traditionally used dedicated gate arrays for this difficult function, for real-time digital filtering for example, it is now possible to perform real-time FFT analysis on a Pentium processor, using data from a simple multimedia card. This exercise shows what is now possible, where the PC takes over another bastion of dedicated instrument function, the DSP.

The last 01dB-Stell DVI, **Melodie** (Figure 8) use the PC processor to do all the real time calculation (FFT, 1/3 octave...) previously made in the DSP. The block-oriented layer (Figure 3) shifted from the DSP to the PC!

With a very common Pentium 3 700 MHz, it can handle a FFT real time on 14 channels simultaneously with a bandwidth of 10kHz on each channel!

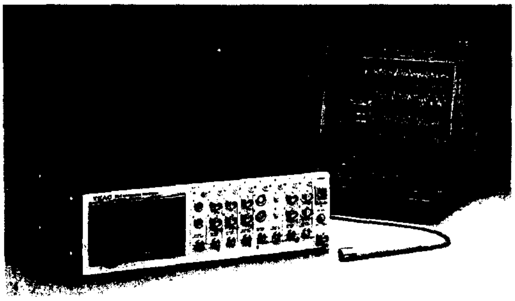

Figure 8: Melodie, 16-channel DVI

Conclusions

Within the context of traditional instrument architectures, an optimum PC-based measurement system has been described, which is already in use for many acoustics applications. Using the benefits of developments in consumer and office computing, measurement applications increasingly find a place on the virtual instrument, in preference to dedicated instrumentation.

Although there will always be a demand for specific, particularly hand-held, instruments, accurate PC-based instruments rapidly become the norm for noise and vibration measurements, rather than exotic toys for technologists.

So what of the Great Divide? Clearly, in a PC based instrument, the divide is no longer physically there, as data is by definition within the PC during measurement, and any transfer to other software is done via a software interface, removing potential errors. The only divide which remains is more to do with historical prejudices and misgivings about using a PC for measurement, which gradually breaks down as more systems become available.

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