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ON THE ACCURACY OF PC-BASED MEASURING SYSTEMS

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1. INTRODUCTION

Over the last few years, many acoustical measurement systems have emerged, which are based on computer architectures, rather than being dedicated instruments. Although the benefits of this approach are normally to be found in the user interface and extensions to other office software programs, the use of the PC architecture, and in particular the Windows® interface, has offered several advantages in measurement flexibility.

The performance of measurement instruments, in particular sound level meters, has been tightly specified in standards such as IEC 651 for sound level meters, and IEC 804 for integrating sound level meters. These standards were conceived with dedicated instruments in mind, but they still apply when developing instruments using more generic architectures.

This paper examines some typical PC architectures, in relation to sound & vibration measurement, and describes a procedure by which such software instruments have been tested for conformance with national requirements, as well as manufacturer's specifications.

2. THE VIRTUAL INSTRUMENT

The concept of the 'virtual instrument' is not new, and it owes its definition to work done during the standardisation of an automated test equipment (ATE) specification which later became the VXI specification (VMEbus eXtensions for Instrumentation) [1].

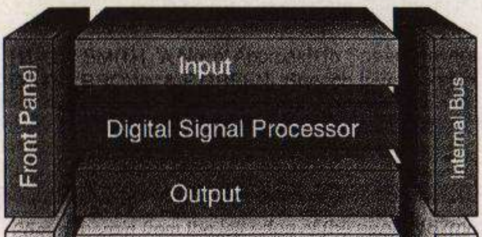


Figure 1 : The basic building blocks

Loosely described as a *'combination of software and hardware resources to achieve measurement functionality'*, the virtual instrument has taken many forms, some less efficient and successful than others.

To understand the concept, it is necessary to examine each function within the measurement instrument, and then establish the benefits or otherwise of implementing these functions in software, possibly running on a general computer platform, rather than dedicated instrument hardware.

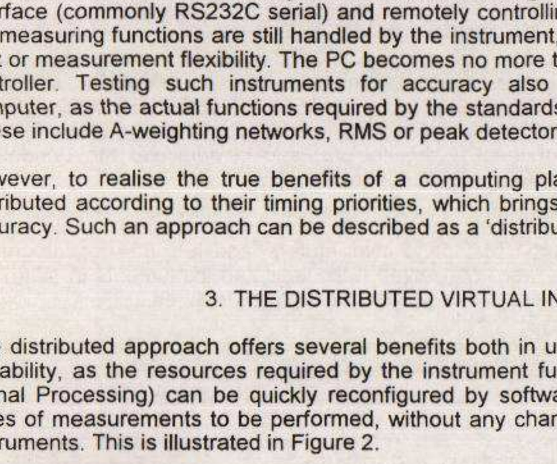
Figure 1 shows how a traditional measurement instrument may be built up from generic building blocks. The main instrumentation functions are found in the input, output and signal processing stages, and all other functions can be regarded as 'services' which manage these resources to yield the measurement result.

In its simplest form, a virtual instrument can simply replace the user interface on the measuring instrument by lifting off the front panel and graphical display, and using the host computer for these functions. This has benefits in terms of display resolution, colour and control interface, but in practice this is no more complicated than connecting a PC to a sound level meter via an interface (commonly RS232C serial) and remotely controlling it from a software package. All of the measuring functions are still handled by the instrument, and there is little benefit in terms of cost or measurement flexibility. The PC becomes no more than a storage device and instrument controller. Testing such instruments for accuracy also places little demand on the host computer, as the actual functions required by the standards are realised in hard- and firm-ware. These include A-weighting networks, RMS or peak detectors, gain etc.

However, to realise the true benefits of a computing platform, instrument functions can be distributed according to their timing priorities, which brings with it implications in measurement accuracy. Such an approach can be described as a 'distributed virtual instrument' [2], [3].

3. THE DISTRIBUTED VIRTUAL INSTRUMENT

The distributed approach offers several benefits both in user interface and also measurement capability, as the resources required by the instrument function (i.e. Input, Output and Digital Signal Processing) can be quickly reconfigured by software. This then allows many different types of measurements to be performed, without any change in hardware, or use of additional instruments. This is illustrated in Figure 2.



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

Figure 2 : The distributed virtual instrument

In practice, this involves a further transfer of responsibility to the host computer, where calculations of e.g. $L_{Aeq,T}$ are made in software, rather than instrument firmware. In fact, an instrument can be achieved with the hardware performing little more than analogue-to-digital conversion, before the software takes over.

The implication of this is that the hardware itself is no longer a measuring instrument, but simply a resource component of a measuring system. The PC becomes an integral part of the process, and therefore any measurements of instrument accuracy or calibration must include the software element.

To illustrate which elements in the measuring chain are best handled by dedicated hardware, and which parts are best suited to interrupt-driven computing, the data handling process is shown in Figure 3.

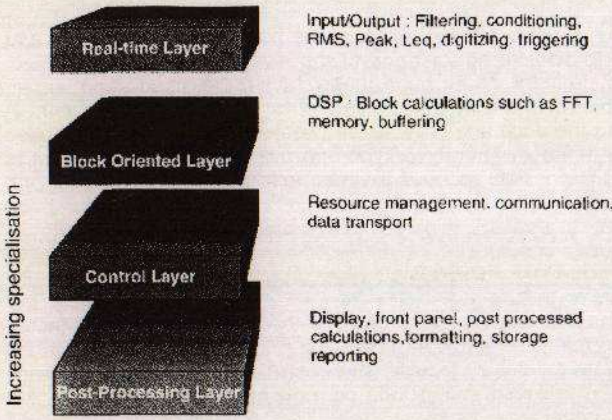


Figure 3 : Processing Layers

At the physical interface, e.g. acoustic pressure, all processes need to occur in real-time, in other words, a process must be dedicated to a particular function at all times. Such processes include A/D conversion, filtering, etc.

Data acquired from this interface can then be treated in a block-oriented fashion, assuming it is buffered to avoid loss of data. Calculations such as Fast Fourier Transformation are examples of block-oriented processing.

The results of these calculations can then be passed on to a display processor to yield the results to the user, and further post-processing calculations may be made, for example, sound power levels may be calculated from sound pressure measurements, after spatial averaging.

In a dedicated measurement instrument, certainly no more than 10 years ago, all of this functionality would be achieved in hardware and firmware, with computers performing no more than archiving of results output from these instruments.

With today's commodity computing power, and by selecting a sensible distributed architecture, the PC will take care of certainly the second two stages in the chain, and in many cases, the block oriented layer. It is now possible to calculate an FFT using floating point arithmetic on a Pentium processor faster than some dedicated DSP chips. However, the designer must consider how much extra work the processor is being asked to do, such as display, peripheral management, etc.

In practice, then, the real-time layer still requires dedicated hardware in many cases, and the nature and size of the sound & vibration market will still dictate specialised functions not addressed, or even acknowledged, by the PC development departments.

4. ACCURACY

Although the benefits of the use of computers are now accepted for many functions, there is no sense in creating such a virtual instrument unless it can achieve accuracy as good as or better than a dedicated instrument. Unfortunately, early exponents of the virtual instrument, in their rush to use the technology, overlooked some of the stringent requirements of sound and vibration measurements.

The nature of sound pressure measurements is such that a very high dynamic range is required, along with excellent frequency response and linearity, with relatively high insensitivity to meteorological effects such as humidity and temperature, over time.

Fortunately, the instrument standards provide tolerances for these parameters, and more, and any instrument developer will strive to achieve at least one of the levels of accuracy specified. The development of the virtual instrument must bear these factors in mind, and earlier realisations faltered as a result of one or more of the requirements. This has led to a certain mistrust in the marketplace regarding the accuracy of PC-based systems, a fact not overlooked by instrument manufacturers on the defence. Therefore, type-approval has become, at least, a marketing necessity to prove that it is possible to build a virtual instrument, which meets and often exceeds specifications for Type 1 accuracy.

5. TYPE APPROVAL

Although, sadly, not a requirement in the UK, type approval has become an important factor, controlling the performance of sound measurement instruments. In principle, a set of measuring instruments of a particular type will be subjected to extensive tests, to establish conformance with the instrumentation standards. These tests will include not only metrological performance, but also resistance to environmental effect.

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin

Zulassungsschein
Innerstaatliche Bauartzulassung
Nr 1.52-16/93

Auf Grund des § 9 des Eichgesetzes vom 11. Juli 1969 (BGBl. I S. 759) in Verbindung mit § 26 des Eichgesetzes in der Fassung vom 23. März 1992 (BGBl. I S. 711) sowie den §§ 16 Abs. 1-3 und 17 Abs. 1 der Eichordnung vom 12. August 1988 (BGBl. I S 1657) in ihren derzeit gültigen Fassungen wird der Firma:

01 dB Acoustique Informatique
111 rue du 1er Mars
69100 Villeurbanne - FRANKREICH
folgende Bauart zur innerstaatlichen Eichung zugelassen:

ARIA Acoustic Measuring System - als integrierender Schallpegelmesser

mit
Vorverstärker Typ Pre 12S und Kabel (ca. 10 m)
und/oder
Vorverstärker Typ MV 181 A und Kabel 10 m mit Batteriekasten und Kabel Cannon/BNC (1m)
und
Mikrofon Typ (MK) 224 [illegible] mit Windkappe
und/oder
Mikrofon Typ RION UC-53 wahlweise mit Windkappe
und
Schallkalibrator [illegible] Typ 5117

Die Bauart erhält folgendes Zulassungszeichen:

21.21
93.68

Die wesentlichen Merkmale und gegebenenfalls die Zulassungsauflagen, Befristungen und Bedingungen sowie inhaltlichen Beschränkungen sind in der Anlage festgelegt. Sie ist Bestandteil der Zulassung und umfaßt 4 Seite(n).

Physikalisch-Technische Bundesanstalt — Braunschweig, 03.05.1993

Im Auftrag — Dienststempel

Dr.-Ing. Hans-O. Finke

- Hinweise und Rechtsbehelfsbelehrung auf der Rückseite -

Figure 4 : An early type approval of Aria

When conformance is demonstrated, the instrument will be type-approved to a given accuracy, sometimes with exemptions, such as limited temperature range, and the manufacturer may then claim this accuracy on promotional literature. In some countries, notably Germany, it is not possible to claim compliance to a particular standard without the type approval being given.

Type approval will be given for a particular combination of instrumentation, which for a sound level meter will be the instrument type, including the type of microphone and accessories. This can present a particular problem with a virtual instrument, as the host computer should be considered as part of the instrument function, and therefore approval will only be issued for a particular brand and model of PC.

An example of this can be found in the original type-approval for the Aria measurement system from *01dB*, where the certificate referred to a particular type of computer (Figure 4). In principle, this implies that the customer may not use another type, for risk of stepping outside the accuracy constraints.

Although the performance of the computer may well have been critical some years ago, modern PCs are many times more powerful and compatible than earlier machines, and to constrain the virtual instrument to a particular type would cause obsolescence within months, as manufacturers update their PC product range.

Figure 5 : The Concerto virtual instrument

Improvements in not only PC hardware, but also software operating system design, in particular the Microsoft Windows® user interface, has meant that the performance of the measuring instrument is largely, and demonstrably, independent of the computing platform. This is demonstrated in a type approval for a recent configuration of the **Concerto** system from *01dB* (Figure 5) [4], where the approval certificate refers only to a requirement for minimum processor speed and memory configuration. This ensures that as long as the host computer conforms to the minimum specification, the choice of manufacturer and other peripherals will not affect the measurement performance.

Interestingly, this approval also allows the choice of a variety of microphones with the system, whilst retaining stated accuracy, giving even more flexibility to the customer.

6. TESTING PROCEDURES

As well as measurement for type approval, manufacturers may also need to have access to fast test procedures for quality assurance and final certification purposes. With older analogue instruments, this was a very time consuming task, with each function being selected manual. The advent of computer interfaces on simple measurement instruments has greatly aided this process, and now it is possible to test a complex measurement instrument completely in a matter of minutes rather than hours, with automatic printing of the report.

With a virtual instrument, it may seem obvious to perform these tests in the same way, especially as the instrument is already part of the computer. However, as mentioned before, the hardware is only part of the instrument, and to tests a computer-based instrument using a computer raises some interesting questions.

Firstly, as with a dedicated instrument, an interface must be set up between the test program and the instrument. In practice, this means talking to one piece of software from another piece of software, which in turn is handling hardware resources.

In the Windows 'operating system', communication between software routines is achieved using Dynamic Data Exchange (DDE) where control commands can be made and data shared. This interface was developed with office software in mind, where data on a spreadsheet may be linked to a word-processor, essentially two different software routines running in memory.

For such communication to succeed, each software must fulfil requirements of the environment, to avoid any application requesting resources needed by the other. Windows achieves this by using 'co-operative multi-tasking' and switching between software, rather than running both at the same time. This can have implications for measurement integrity, as a measurement task must continue unabated, whilst a word-processor is being called up for example.

7. MEASURING THE dBTRIG APPLICATION

The **dBTRIG** application is essentially a virtual sound level meter, which has been type approved for measurements to Type 1 accuracy, on the Concerto platform, for example. This virtual instrument has some functionality distributed in hardware, and some in software. For example, the Concerto data acquisition unit performs high-pass filtering, anti-aliasing, A/D conversion and real-time operations such as weighting and detection. The **dBTRIG** software takes over and calculates any desired sound level measurement parameter, and stores both noise level data, as well as raw digitised audio data for later processing (Figure 6).

Figure 6 : The dBTRIG sound level meter application

The software extensively uses the Windows multimedia interface, to ensure data compatibility with other applications, and to achieve a high level of multi-tasking.

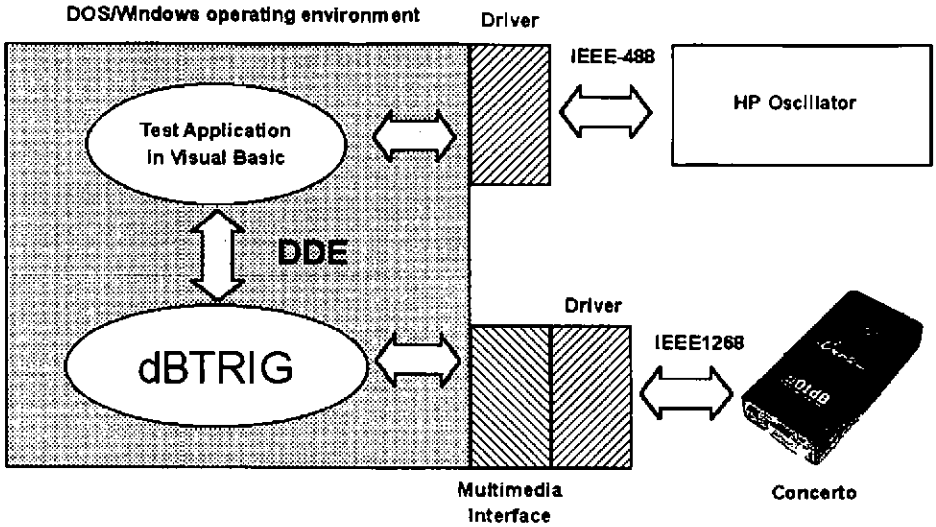


Figure 7 : Test layout using DDE communication to dBTRIG

A DDE interface has been written to allow communication with the measurement software, during measurement, and this has led to many additional applications being possible, such as remote control by modem, addition of meteorological data, and triggering/synchronisation with external processes. This is shown in simplified form in Figure 7.

A by-product of this interface is that it can also be used for testing the application itself, and this has led to an automated test program, for quality checking before systems leave the factory.

The test program has been developed in Visual Basic®, under Windows, to act as a controller for the dBTRIG application, and acquire measurement results, in the same way as if it were a dedicated stand-alone instrument [5]. In order to apply test signals at varying frequency and amplitude, the program also controls externally a digital generator via another interface IEEE-488, but this time a hard-wired instrument.

The performance of dBTRIG is thus measured and documented, with a simple user interface being presented to the operator, whilst dBTRIG runs in the background. Results include measurements of frequency response, linearity, weighting curves and detector response, generating a measurement report at the end of the process (Figure 8). This report is then supplied as part of the installation process at the customer, to ensure compliance with in-house quality standards. This in itself does not necessarily constitute a calibration, although traceable instruments are used, but it does provide reassurance that the performance of the system meets the published specifications.

RAPPORT D' ESSAI

NOM DU CLIENT:	RG		
DATE DU TEST :	02-06-1995		
Type:	Concerto 4 broches	N° série :	4409
Sensibilité:	0.048 mV/Pa		
Type du pré-ampli:		N° série :	
Type du micro:	Cirrus 45mV/Pa	N° série :	xxxxxxxx

TEST	dB LIN	dB A
Linéarité	Hors norme	Hors norme
Pondération fréquentielle	OK	OK
Sélecteur de gammes	OK	OK

SELECTEUR DE GAMMES

Gamme	Valeur attendue	Valeur mesurée		Valeur attendue	Valeur mesurée	
		dB LIN	dB A		dB LIN	dB A
64-129 dB	64			94	94	94
54-119 dB	64	63.8	63.7	94	94.1	94.1
44-109 dB	64	63.7	63.9	94	94.1	94.1
34-99 dB	64	64	64	94	94.1	94.1
24-89 dB	64	63.8	63.9	94		
14-79 dB	64	64	64	94		

Test de pondération fréquentielle

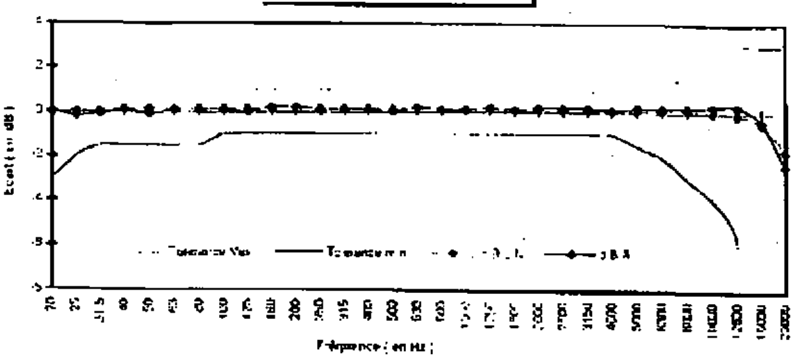


Figure 8 : Typical test report from automatic test program

dBTRIG is one software measurement application of a suite, but the principle can be applied for other applications, giving added confidence to the end-user that his measurement results are at least as good as those achieved on a dedicated instrument system.

8. CONCLUSIONS

The distributed virtual instrument architecture has been described and issues relating to its measurement accuracy discussed. This approach to developing measurement systems brings its own set of problems, relating to test procedures, which have been addressed by the development of a DDE interface to the instrument for testing and other purposes.

A test program has been described which allows the documentation of virtual instrument performance, for the purposes of quality control and installation.

9. REFERENCES

1. VXI Consortium, "VMEbus eXtensions for Instrumentation, IEEE standard No 1155

2. SHELTON, J, "Distributed virtual instruments and layered software architectures", Proc. Elektronik 93, Stockholm, (May 1993)

3. SHELTON, J, "Building on the multimedia PC architecture, to provide noise & vibration measurement systems, based on virtual instruments", Proc. IOA, Vol 17 : Part 4, pp 311-316, (1995)

4. ROUFFET, J-M, "Concerto, acoustic measurement on a notebook", Proc. Euronoise 95, Lyon (March 1995)

5. BERETTI, Françoise, Final Year Report, I U T de St Etienne, Département Mesures Physiques, (June 1995)