FROM MAHOGANY TO COMPUTER

Alan D. Wallis

Cirrus Research plc Hunmanby, United Kingdom.

1.OVERVIEW

Since modern acoustics started as a science and certainly since Internoise and the International Congress on Acoustics became the world acoustic forums, there have been several thousand technical papers relating to the description of noise, sound, wave propagation and allied subjects. In 1992 alone, over 2000 technical papers will be published in several languages, many describing how a noise problem has been solved or how a new method of describing the effects of sound on man can be used.

If technical papers presented by engineers from instrument manufacturers are set aside, almost none of these papers acknowledges the great strides that have been made in instrumentation since the only instruments were made only of glass, metal and mahogany. This review sets out to pay tribute to the designers and engineers, many unknown and unsung, who make all these papers possible.

It is axiomatic that to describe a phenomenon, you have to be able to measure it and this principle is even more important in acoustics where we cannot touch sound, we cannot see it, all we can do is to use the two poor acoustic instruments at each side of our head to recognise pitch and level. Work on loudness by many people has shown that these two instruments are very inferior indeed when it comes to making level judgements, particularly where combinations of level and frequency are involved.

Any paper on instrumentation must include, among the descriptive parameters the cost, the ease of use and other design criteria. Price, cost or any other mention of commercial matters is usually frowned on by conference papers committees as 'beyond the pale', but in this paper, commercial matters play a big part in the measuring equation. The criteria for an academic or a government servant is clearly different from that of an instrument designer. Success to an instrument designer can only be measured by how many people part with money to buy your design. The clear implication of this criteria is that usually, but not universally, successful designers work for growing and profitable companies; it is the designs which make this so.

It has been put to me many times, by some academics and standards bodies, that sheer excellence is all that matters.

I reject this argument and choose to use the example of motor cars. I think that nobody here would suggest that the Rolls Royce was not one of the best cars in the world and very few would claim that the General Motors Cavalier, while an excellent design, could rival it in that claim. However, the Cavalier meets the need of a salesmen, or at least the company that employs him, rather better than does a Rolls Royce. Compare the sales of Rolls Royce and General Motors!

In the same way, there is no point in equipping everybody in, for example, the worker protection field with Type 1 precision sound level meters. The acoustic climate in the average factory is such as to largely negate the accuracy difference between a precision unit and a general purpose one, especially in the hands of an untrained user. If this lesson was learnt by some emerging countries, for a given budget, the amount of instrumentation and thus the number of measurements could increase dramatically. One would hope that more measurements would lead to more understanding of noise and its problems.

2. ACKNOWLEDGEMENTS

It is usual to end a paper with any acknowledgment, but in the field of acoustic instrumentation, I feel it is necessary to start with one. While in the near 3 decades that I have been involved with acoustic instrument design, there have been around 100 companies in the field. Of these, one stands out from all the others; I speak obviously of Bruel and Kjaer. Started in 1942 by Per Bruel and Viggo Kjaer, their efforts for 30 years, gave all professional acousticians a measuring excellence that would be hard to improve. The troubles of the company, leading to its sale this year have been well publicised and have largely truthfully been an 'own goal'. However for over 30 years the company was so far ahead of most of its rivals that until computers came along and changed the face of acoustics, Bruel and Kjaer were synonymous with acoustic instrumentation.

Of course, the success of the company was not due just to the efforts of two men, although it was personal leadership which gave the climate of excellence. Many papers have been published by engineers from B & K, for example Gunnar Rasmussen with the 2203 dating from about 1960 and 2209 (1971) also Peter Hedegaard with 2230 (1983) and 2231 (1985) are among the people to whom all acousticians owe a real debt of gratitude from the instruments they and their teams designed. I will not further note B & K 'firsts' in this paper, rather I will bring to your notice other, less well known engineers.

3. THE BEGINNINGS

I have tried to find the first references to noise level and attempt to use this as the start point of instrumentation. I am sure that some Latin or Greek scholar will find earlier ones, but Pliny the elder seems to be the earliest documented source I can find; he made comparisons about city noise levels about 20 centuries ago. He had nothing except his two sound level indicators to measure it by and his data store could not remember levels very well, so his comparisons of the level at a particular time and the level two weeks before must be suspect. In addition, his two indicators were very unreliable. They suffered from wax deposition changing the weighting curve, they seemed less sensitive after refuelling with the local wine and for some reason, some noises were always louder at night. Unfortunately, his indicator had no means of computing L90, so he was not aware the background levels had changed.

Let us go forward in time to one of the first great acoustics measurements, when the speed of sound was established by Marsenne in about 1660. Frequency measurement was established by Savart in 1830, using Hookes wheel described in 1868. However, probably the greatest of early acousticians, was J. W. Strutt, although when he was working, the word 'acoustician' had not been invented.

Despite the fact that at Cirrus, we use computers for everything, one of the books most often used by me is the two volume work 'The theory of sound' by Strutt, better known as Lord Rayleigh,[1] published in 1877. In his time instrumentation was obviously non electronic, indeed it was mostly non-electrical and all the experimental and comparative work had to be done with water, brass, glass and mahogany. Indeed, many of the methods I have often used to illustrate, for example, the difference between Leq and SEL are taken from Lord Rayleigh's experiments. However, do not think that electricity was not used. In one experiment Rayleigh writes 'Observations upon the swellings and contractions of a regularly resolved jet may be made stroboscopically, one view corresponding to each complete period of the vibrator; or photographs may be taken by the instantaneous illumination furnished by a powerful electric spark'.

In fact, using mirrors and smoked glass plates, he measured the frequency, amplitude and phase of various sound signals, confirming the work of Helmholtz and others. One piece of apparatus in use today is his Rayleigh disk used to measure the particle velocity.

Sound recording was invented in the last century which led to the first method of 'outbox processing' where data, in the from of a recording, was taken on site and brought back to the laboratory for analysis, a method still used today, usually by workers who have not yet come to terms with the computer.

4. MODERN TIMES

Electronics, or rather the word electronics, was a product of world war two. Well before 1930 the thermionic valve or vacuum tube was, if not commonplace, an available device. For the first time, electrical signals could be amplified using easily available, low cost parts. Naturally, one of the first popular applications was to amplify the sound of the human voice and play it back through loudspeakers. Now, we had the technology to amplify sound but also to measure it. The first sound level meter, although it was not called that, was described by Pierce [2] in 1908, using a step up transformer to produce an adequate level for the crude rectifier. One should note he misnamed sound pressure as sound intensity. Soon there were units consisting of simple microphones, with a triode valve amplifier followed by a moving coil or moving iron meter. The one valve sufficed to amplify the signals from the carbon microphones which were very sensitive compared with today's devices. At the time, almost no papers were published suggesting that measuring the simple pressure was not the ideal route, simply to be able to measure something, indeed anything, seems to have taken the imagination of the scientific community.

One of the more interesting side issues, is that while the air condenser microphone was invented by Wente in 1921, and while always difficult to manufacture, still today remains much as he described it, the cornerstone of acoustic measurements. It was however nearly 30 years before it was fitted to a commercial sound level meter.

At the end of the world war two, when the electronic dust had settled, we were able to manufacture portable sound level meters using deaf-aid valves which had a power consumption of about 150 milli-Watt per valve, about 10% of what was possible before the war. The publication by MIT of their 'Radiation Laboratory Series' in 1948 [3] gave all the information to make quite sophisticated instruments, based as it was on wartime radar work.

) first commercial sound level meters became available in the 1950's with two batteries. A 1,5 ıt battery for the valve heaters or filaments and a higher voltage battery for the anode current supply. The first devices had a performance which was less than sparkling, but 4 hours operating was possible. None of these devices met a standard, although it was in 1953, the year of the first ICA that IEC Technical committee 29 met in the Hague to start the long and tortuous process not completed until 1961, when IEC 123 was published. IEC 179, the precision grade specification was also eventually published in 1962, only 9 years after it was started.

On the computer front, in 1945 ENIAC one of the world's first electronic computers was in operation at the Aberdeen proving ground in Maryland, where it was used to compute firing tables. With about 20,000 thermionic valves and consuming 80 kilowatt of heater power and with a clock speed of 100kHz, it was hardly a speed hog, but it would often operate for a whole day without breaking down.

The next stage in computing, at least in the USA was the EDVAC, which made use of a acoustic delay line as its storage media. The first meeting between computers and acoustics?

5. POST VALVES

In 1948 the transistor was invented and at last, the 20 kilowatts of power simply to run valve heaters in the computer could be a thing of the past. However, some time passed between the invention of the device and its coming into common use as a readily available part. Indeed the first transistorised sound level meters did not appear until the very late 1950's and as late as 1966, a British manufacturer, Dawe Instruments, thought they were sufficiently radical to call their meters 'transistorised sound level meters'; as though by this time there were any others. By the late 1950's, GEC in the UK had finally removed the last valves from its computer where they were used to drive the core store memory.

By 1960, computers had improved by leaps and bounds as there was clearly a market for these devices, but the coming together of the two fields was not until 1962 when the first significant paper on computerised acoustics I have seen was published as an invited paper at ICA in Copenhagen [4]. In this paper E. E. David clearly felt that the computer was not well understood as a whole page of the paper was devoted to explaining what a computer did and what a program was. Today, perhaps the most interesting part of his paper says:-

"However, it is true that computers will not do things that cannot be done in principle by other equipment. —— The automobile is much more than a super horse. Yet given enough time and horses, a person can do just about anything an automobile can." We will return to the subject of horses, or rather the stagecoach they used to pull, later in the paper.

Thus by 1962, the way was clear, we had a precision sound level meter standard, practical digital computers and readily available transistors and the 2203 was in production. However, there were no commercial companies who were prepared to hear David's words and take note. Thirty years later, when computers in acoustics are commonplace, these words spoken in Copenhagen were the true death knell of mahogany boxes. To put my personal experience here; at the time, I was a junior engineer at Advance Components where we were working on a precision sound level meter under licence from Pekel in Holland.

Who has heard of that instrument now? Even I cannot even remember its type number.

6. THE COMMERCIAL FIELD

Until about 1969, there were four main companies making sound level meters. The market leader then, as now, was Bruel and Kjaer, closely followed in the USA by General Radio and in the Communist block by RFT. Europe had other players, indeed a major player in Dawe Instruments, with France having LEA (Laboratoire Electro-Acoustique).

However, the world was about to change. In the USA the Walsh-Healey act was published, demanding that no worker should be exposed to more than 90 dB for 8 hours with a 5dB doubling or exchange rate after this. However, the act did not clearly explain the 5dB doubling rule, but it gave the following table of levels and times.

Exposure dB	Maximum time
90	8 Hr
95	4 Hr
100	2 Hr
105	1 Hr
110	30 min
115	15 min

Accordingly instruments were manufactured with 6 counters, each one being activated when the appropriate level was passed, the final 'dose' total being found by adding together the numbers in the counters. Sullivan et al in the USA commissioned such a device and the first unit went into production in 1969, to the eternal shame of the specifiers.

Today it seems unbelievable that anyone could read the act in that way, but at the time, nobody really believed that there was anything wrong with this interpretation. The blame for this must lie clearly at the door of academics and the drafters of the act, rather than the derided instrument designers who simply did what was specified. In 1988, little had changed and the EC directive 86/188/EEC is another typical example of poorly, indeed foolishly, drafted legislation. This demands that the peak level should be measured 'unweighted' in frequency. Do we assume that they want all frequencies measured from dc to light?

At about the same time, a very competent American Consultancy produced a report which they offered for sale, calculating the number of noise level measuring devices that would be needed in the USA by 1975.

They estimated that around 100,000 sound level meters and dosimeters would be needed, based on the number of noisy industries in the USA. Many people generated similar figures and in 1969 and 1970, about 15 companies were set up each intending to take 20% of this huge market. Apart from the fact that there are not fifteen 20%'s in 100 %, the initial figures were over-estimated by about ten times.

Thus, these new start-up companies or divisions of older companies were doomed before they started. Not only was the market not there, but the two 'giants', B & K and General Radio also expected a significant share of the market, and indeed they achieved it. It is interesting that not a single one of these 15 American companies is in existence in the same form today, although two of them Quest Electronics and Pulsar Instruments still exist and make sound level meters. Quest were bought by Labelle Industries although one of the founders Bob Wurm is still managing the company and Pulsar Instruments was moved to the UK in 1980 and is now part of the Cirrus group. Even the mighty General Radio, now called GENRAD, has sold its acoustic instrument division and Bruel and Kjaer has been sold outright. Another USA start-up company, Metrosonics, founded a little later by Al Stolberg is still operating successfully, largely in the same form.

To give an idea of the scale of the problem. Pulsar Instruments was formed in 1969, by three academics from Stamford university who had brilliant circuit ideas. To meet the new market, they purchased in 1970, an optimistic one years worth of plastic instrument bodies, 7000 in total. Today, in 1992, they still have not completely used that first batch of cases and yet Pulsar was one of the survivors of these 15 companies. Just imagine the problems for the losers. One company at least, buried several hundred finished acoustic instruments as they could not be sold. To give another example, one of own staff bought a sound level meter at a 'flea market' in California for $50. This unit had been produced by B & K for another company under their brand name; as they could not be sold, they were sent to a scrap merchant at 5% of the true price. The result of this market disaster was that small American companies did not have the income to support new work and thus most of them stopped all development and the field stagnated for a decade. To make matters worse, many companies dumped perfectly good sound level meters at any price from their huge stocks. The result was, that actual production effectively stopped in small companies. In Europe, small companies were more fortunate and had generally not expected such a huge market.

Some designers learnt several lessons from this fiasco and we at Cirrus produced two 'Company laws'.

1. Unless you are involved with the standards bodies and law makers, you are unlikely to make an instrument which truly meets the specification and market requirement.

2. Put not your trust in salesmen or market reports, they are both broken reeds.

What relevance does this have to professional acoustics? The answer is a great deal of relevance.

Many of these smaller companies have produced the truly great instrument ideas over the last 20 years, but went bankrupt before they could obtain market acceptance. There is no doubt in my mind that this slowed down the technology, or at least directed it into a particular path. Let us look at each part of a sound level meter and see what technology has given us.

6. THE MICROPHONE

The first obvious part is the microphone, which is today probably an electret air condenser unit. While the exact invention of this is not totally clear, Sessler and West at Bell Labs [5] were certainly among the motivators for its current performance.

FROM MAHOGANY TO COMPUTER

Until the charge could be put onto the backplate allowing the use of metal membranes instead of plastic, this type of microphone was never going to replace the classic device invented by Wente and superbly engineered by B & K staff. In 1977 General Radio presented a paper on their electret microphone and were howled down when they suggested that it would one day overtake the classic air condenser unit. Today, at Cirrus 98% of all sound level meters are fitted with electret microphones as are most other manufacturers. A good unit will have the stability of a 200 volt unit without the dreadful humidity problems associated with early 200 volt capsules. Can we remember the 'good old days' when we had three microphones; two drying in the pockets while the third one was already failing on the instrument?

There were many companies in the early 1970's who were trying to produce microphones with better weather protection, but the financial losses they all suffered, forced most of them to give up the work. In addition, the volume of piezo-electric microphones was so low, that no third party supplier was prepared to invest in improving that device, as there was, and is, no theoretical reason why a relatively low cost piezo-electric device should not meet Type 1. Thus, everyone had to pay very high prices for air condenser units. I do not suggest that a piezo-electic device can be as good as a 200 volt air condenser unit; that is not the point. Meeting a standard is rather like pregnancy. You cannot 'nearly' meet a standard, just as you cannot be 'nearly pregnant'. If a piezo unit met Type 1 that would have been all that most practical users required.

7. THE AMPLIFIER AND WEIGHTING

This is probably the least 'different' part. In 1970, most sound level meters did not use integrated circuits for their amplifiers as they took too much current and had too poor a noise performance. The basic circuit used by most companies was possibly first described by the late C. Cieplak of Dawe Instruments and is still today superior in its current/gain bandwidth performance to all but the most modern integrated circuits. As developed by several people, Cieplak's circuit gave gains of 50dB at 100kHz bandwidth with equivalent noise levels below 5dB(A).

Variants of the circuit can be found in instruments from most manufacturers in the 70's and 80's. Many of these like the Open University sound level indicator managed to use the circuit to produce weighting and gain in two simple stages and thus bring down the circuit cost significantly. Before this unit, in 1969, the lowest cost instrument on the market was just under 50 pounds. After this unit, the 'street price' halved overnight; a simple 6dB reduction.

7. THE RECTIFIER

Initially, many of the first units had mean or average rectifiers, but with the publication of IEC 123, manufacturers realised that rms rectification was needed for acoustic measurement. At the time, this was really very difficult to do and two main approaches were used. The first was to ignore the requirements and to develop a circuit which met the test for rms as specified in the standard, but did not actually measure rms. This 'trick' did not work well for an Impulse sound level meter and Kundert of General Radio discussed the implications of an Impulse meter in 1974 [III]. The second was to develop a circuit that would perform the rms function but was so power hungry that it was not suitable for a portable unit. Devices such as the hot wire rectifier, or vacuum thermocouple, being obvious methods.

FROM MAHOGANY TO COMPUTER

The IEC test consists of adding two equal level non-harmonically related pure tones, which should increase the level by 3dB. If your circuit could do this, within the stated tolerances, it was reading rms. Initially, a four diode shaper was used with copper oxide rectifiers, then a multi-transistor circuit, but once again, the Open University meter with its low cost could not use either of these methods, so Wallis described a simple two diode circuit shown in figure 1, using gold bonded devices, which gave a reasonable approximation to rms, even to IEC 179 standards, over the very low dynamic span of meters at the time.

By the early 70's, the implicit function rms generator had been invented, probably by Hanley of the US navy, but put onto a single chip by Gilbert of Analogue Devices. This took the true analogue root mean square of the ac signal by using log and antilog amplifiers. At last there was a circuit which could meet the design objectives of the standard and not just the tests as shown in figure 2. The complexity increase needs no comment.

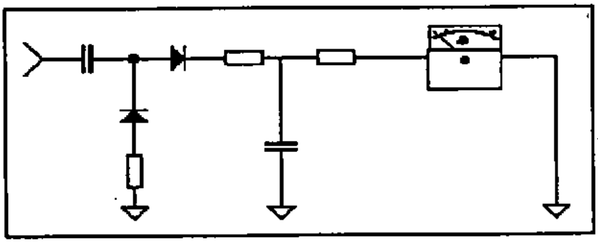

Figure 1 A two diode rms circuit

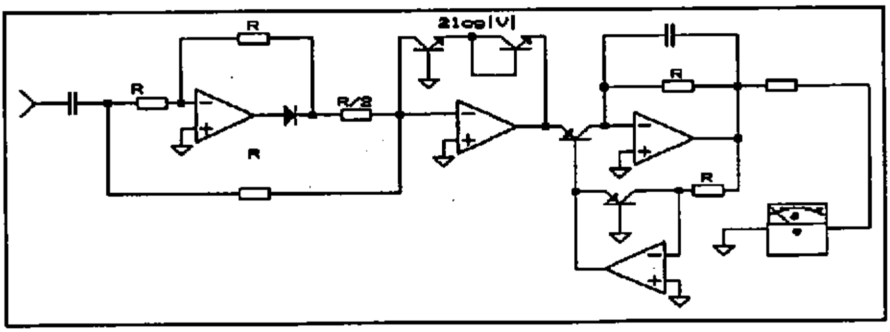

Figure 2 An implicit rms circuit

The implicit rms function generator uses the logarithmic current voltage relationship of a semi-conductor junction to generate antilog 2log v or v^2. It soon became clear that the same logarithmic circuits could be used to make sound level meters where the scale was linear in decibels and not as hitherto linear in volts. Among the first sound level meters using this were shown at ICA 1974 in London by General Radio and Castle, although Pulsar had shown a linear scaled prototype in 1972, albeit with a rectifier that did not meet the rms test and with very poor temperature performance. The penalties of this new technique were a general increase in the temperature drift of the sound level meter as well as a much higher initial cost, but now the scale of the sound level meter could be 50dB long instead of the 15 to 20dB of earlier instruments.

This gave a significant improvement in practical measuring accuracy, in that the user did not have to constantly change range to capture a signal coming out of a background.

8. THE DISPLAY

Now that the meter scale could be linear in decibels, it was possible to replace the moving coil meter with a digital voltmeter, to make a digital sound level meter. The first well known, all digital, sound level meter was designed by Hardenburg of Digital Acoustics and was shown in 1977. At a stroke we were free from all the inaccuracies of analogue instruments and could now have 0,1dB resolution right throughout the huge measuring range. In fact it was not so simple.

Firstly, the early logarithmic amplifiers had severe temperature drift and non-linearities problems and the amplifiers, filters and weighting networks simply had not traditionally been designed with sufficient dynamic span to take advantage of a unlimited digital range. The result was that designers started to fit auto-ranging circuits to their instruments driven by market demand.

One of the first major companies to do so was General Radio and while they had an excellent design, their auto-range circuit could not manage to cope with very rapidly changing sound levels. In their defence, it must be said that a decade later, no-one else had really solved the problem.

Users also found out that digital instruments were not quite as useful as their supporters claimed. In the real-non laboratory- world, the new digital devices tended to give a blur of numbers with little meaningful information as to the variations of the level. No longer could you see L_{min} and L_{max} by looking at the meter. Initially users bought the new devices as they were 'modern', but, today, many professional users have gone back to analogue instruments. The same thing happened with many digital devices, such as the digital watch and the digital speedometer. When digital watches first appeared, nearly all engineers bought them and at a conference in 1982 probably over half the audience wore them. Today, a decade later, I would suggest that less than 20% of people here have all digital watches on their wrist.

There is no doubt whatever, that in the laboratory, digital instruments are a scale order better than the older analogue devices. However, in the practical world of sound level as opposed to L_{eq}, the analogue meter is far from dead.

Today of course, we can have the best of both worlds, with fully addressed computer graphics, using LCD technology, which can simulate any display you like. No commercial company has yet produced a fully addressed display on a production sound level meter, but new instruments from Yamaguchi at Ono Sokki, first shown at Internoise 1990, have displays which show the way forward.

9. INTEGRATING METERS

In a technical paper, the correct title of integrating averaging sound level meters should be used at least once, although most real people call them L_{eq} meters. The concept of integrating the energy is as old as acoustics itself, but L_{Aeq} as we know it today is a product of the 1960's.

FROM MAHOGANY TO COMPUTER

Again, the first practical, production instruments were from a small company, being designed by Reg Norgan of Computer Engineering Ltd, now Lucas-CEL. He produced the 112 noise integrator in 1972, the 122 noise dosimeter in 1974 and a second generation unit, a true Leq meter type CEL-175 in 1977. Of course, there were 5dB exchange rate dosimeters in the USA before the first CEL L_{eq} meter, from Dupont and Quest among others, but these were not true energy integrators.

There are many claims from engineers as to who made the first 'true' Leq meter, but apart from Norgan, Weissing at RFT and Haig-Arbib at HSE lead teams who produced very good prototypes. In 1977, B & K showed their new 2218 very much in the mould of earlier instruments such as the 2209.

Among 1980's instruments, the 110 acoustic analyser from Norsonics designed by Ole-Herman Bjor in 1988 stands out as an excellent example of putting a computer chip inside the meter as well as sending data out to be re-processed as does the CRL 703 from Bob Krug.

Some of the first integrating instruments designers either did not understand true integration or were confused and tried to integrate the output of the rms rectifier leading to 'Fast', 'Slow' and even 'Impulse' L_{eq}. Others, mainly in France, designed units where the pulse range, that is the range over which the unit would integrate short pulses, was less than the linear operating range. France even produced a national standard with the quaint designation Class 1P (pulse) for units which measured true L_{eq} to IEC 804 and Class 1N (normal) for those which did not. Such nonsense is still to be seen as some developing countries use out of date specifications for new instrument tenders. Cynics have said that the annotations should really be class 1N (normal) and class 1M.

The purpose of an L_{eq} meter is to correctly integrate all the weighted signals from the microphone and this requires acquisition ranges of about 120 dB which leads to problems. Some manufacturers, particularly in the United States claim dynamic spans as high as 100 decibels for their meters. However, if the range where the unit meets the IEC standard is counted, today, the greatest single span possible is of the order of 70dB. To obtain more than this, some companies have two Leq meters operating in parallel 40 dB apart and an internal computer decides every few milliseconds which one is in its linear range. One limit of the dynamic span is the ratio between the leakage current of the integrator and the maximum current available and since the first Cirrus L_{eq} meter, the CRD 125, designed in 1979, over 16 dB of improvement has been possible due to improved operational amplifiers.

The first proposed International standard for L_{eq} meters was developed at HSE in the UK, but by the time various national and commercial interests had worked on it, we had IEC 804, which is truly a mongrel standard. Currently, working group 4 of IEC technical committee 29 is working on a sound level meter standard to include integrating and non-integrating instruments. Not before time one might think.

10. THE COMPUTER

All through the 1970's computers became more and more important. However, they were still not tools for field use. In the early 1980's the Apple 2 in the USA and the Acorn BBC in the UK changed that. Now, we had a desktop computer we could program in BASIC which could carry out computations in any form you wanted.

At last this meant that statistical noise data could be produced without resorting to large unwieldy level recorders and mechanical statistical analysers.
Not only that, but if you could store your raw data, it could be re-analysed in a different way for different purposes. As far as is known, the late Simon Alport was the first to use such a system in the field, when a BBC computer connected to a sound level meter was used to control the noise level at a Status Quo 'final' concert in 1984.

The computer predicted the L_{eq} over the next 15 minute period and told the mixing desk operator what level he could use to stay within the GLC guidelines for level.

It was at Internoise 1981 that perhaps the greatest revolution occurred. Komorn [7] presented publicly a method of storing data and using a computer to replay this; the technique he and Luquet called 'L_{eq} Courte' [8] or Short L_{eq} in English. This work was the result of an EEC grant in 1979 following similar work which had been done by Commins & Sirieys[9] on aircraft noise for the French Ministry of the Environment. The method basically involved taking very short integrals of noise and using these to describe the acoustic climate. The first meter to go into commercial production using this technique was described at Internoise 1984 by Wallis and Holding [10]. Today, as is well known, Cirrus Research in the UK and 01dB in France have taken the short Leq technique to a position where data can be stored with resolutions as fine as 5 milliseconds or with storage times well over 1 year. In the field of airport noise monitoring, short L_{eq} is now effectively the standard method of transferring data from the field terminal to the host computer and in some countries it is the method of choice for environmental measurements. At one end of the scale, it gives an alternative to the level recorder, while at the other it allows the most sophisticated statistical analysis.

Figure 3 shows one of the earliest coded 'level recorder' traces, still extant, taken at a training course on the technique in 1986.

11. THE PC

Another new event in 1981 was the introduction of the IBM PC in the USA, coming to Europe a year later. With its 'huge' memory of 64k and floppy disks, it was a revolution, particularly when married to an updated version of CP/M. Called initially 86-DOS by its author Tim Paterson of Seattle Computer Products when written in 1980, it was bought by Microsoft and renamed MS-DOS, or when sold by IBM, PC-DOS. Despite the best efforts of IBM to brain damage the PC by using an 8 bit bus on a 16 bit chip, the 8088 and despite a limited address and maximum disk space, it became the true standard for desktop computers.

Clearly there are rivals, such as the Macintosh, with significant technical advantages, but in reality, apart from a following among academics, the MS-DOS family of computers have become the de-facto standard for everybody, with an installed base of many millions. Today, even notebook computers can have the 32 bit 80486 chip with effective 50MHz clock rates, 200 megabyte hard disks and 32 megabytes of memory, all operating from a small battery.

In fact, today a 80386 notebook computer plus a data storing dosimeter, from at least three small companies, is less than the volume and weight of a B & K 2203, perhaps the most famous, and certainly the best for its time, of all sound level meters. 30 years has indeed seen progress.

The installed base of MS-DOS computers and intense competition, ensures that the technology will not stand still. To develop a new complex sound level meter will take about 6 man years of effort and when the task is complete, the performance will come nowhere near matching that of a very low cost computer. The maximum quantity of a new complex sound level meter that is likely to be sold is typically less than 750 units. For a new design of computer, some companies can look forward to 50,000 models being made, with an investment of perhaps 12 man years. The implications for cost are obvious.

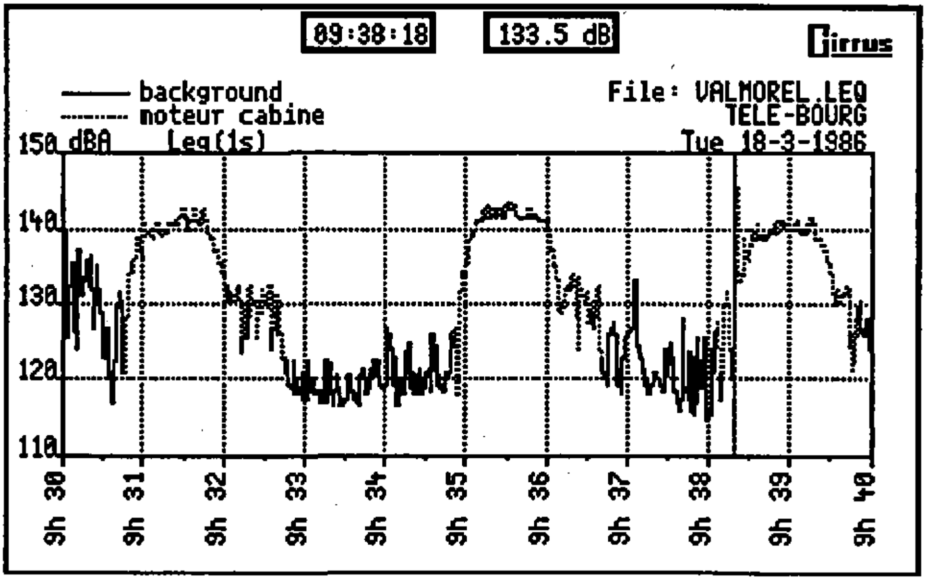

Figure 3 Level Recorder simulation with coding

The computer will have to carry 0.06 man days of development overhead whereas the sound level meter will have 2 man days cost on every model. If the sound level meter sold about 75 total, which is still more than many precision models do annually, 20 man days of overhead will be included in the manufacturing price. The obvious result is that as more and more people use computerised systems, the price of complex sound level meters will rise to a point where they will no longer become viable, even for the most die-hard users. This decision becomes more stark when the public price of some lap-top computers is already much less than 20 man days of work. Even the most desperately poor university lecturer, only needs to work for 5 days to buy a good MS-DOS computer.

Obviously, smaller companies with lower sales realised this first, while the largest companies, with their bigger investment in existing product, took much longer.

It was similar to the problem of the world's best stage coach makers a century ago, when faced with the automobile. The business solution when a stage coach has to compete with an automobile is not to improve the stage coach, it is to get rid of the horse and put in an engine. E. E. David's words of 1962 were not heeded and fitting more sophisticated accessories and adding more cost to the stage coach is not an solution.

Taking this argument to its logical conclusion, the more complex the acoustic instrument and the longer it takes to develop, the more likely it is that it will be replaced by a computer system of some sort. The only real question is only where the computer takes over from the instrument.

The first significant description of the route forward was given I feel by Patrick Luquet and Adam Rozwadowski at Internoise 1988 [11], which effectively foretold the end of much dedicated instrumentation. "The exponential expansion of computer technology means that programmable and evolutive systems supersede fixed electronic equipment." We, the instrument designers, ignore this message at our peril!

12. THE FUTURE

Initially, the computer only worked on data stored by a stand alone sound level meter, true outbox processing. Today, on a system such as the 01dB ARIA system, the only external acoustic 'parts' are the microphone and its pre-amplifier. In other units such as the Quest M28 designed by Bob Krug and some Larson Davis units from the team led by Larry Davis, the sound level meter can not only pre-process the raw data, but formats it ready to send straight to a printer.

In the Cirrus 700 series also designed by Krug, both pre-formatted data and raw short L[illegible] data are stored as is done in the B & K and Cirrus airport noise monitors. There are also systems just about to be announced where full spectrum analysers have built-in software as well as external processing.

In other words, the line between outbox and inbox processors is already becoming blurred. Today, it is still not possible to have a *multi-purpose* system like ARIA running from batteries of a sensible size, and this is probably the greatest drawback of the concept today. However, it is certain that the speed of development will soon change this and that tomorrow designers will put yesterdays 'transit van' laboratory into a space less than an attache case. Today, almost all serious designs have a digital interface to allow the acoustic instrument to talk to an external computer and many can be remote controlled, remotely configured and have some limited 'intelligence'. We have at last moved from mahogany to computers.

13. REFERENCES:-

1. 'The theory of sound' J.W.S. Rayleigh Macmillan & Co. 1877

2. 'A simple method of measuring the intensity of sound' G.W. Pierce Proc AAA&S 1908

3. The radiation laboratory series L. N. Ridenour (Ed) Massachusetts Institute of Technology & McGraw Hill 1948

4. 'Computer-Catalyzed Speech Research' E. E. David. Proc ICA Copenhagen 1962 pp 69 -88

5. G.M. Sessler & J. E West IEEE Trans. Audio Electro-Acoustic AU-19, 19 1971.

6. The Impulse sound level meter -What's it all about" W. Kundert Sound & Vibration 8 NO.3 50-53 (1974)

7. 'Description objective d'un environment acoustique' A. Komorn Proc Internoise 1981.

8. 'Methode de description objective d'un environnement acoustique' A. Komorn & P. Luquet LNE report to EEC April 1979

9. "Niveau equivalents et bruit d'avions" D. Commins & J-P Sirieys. Ministere De l'Environnement, Paris France June 1978

10. 'A method of generating Short Leq' A.D. Wallis & J. M. Holding Proc Internoise 1984 Hawaii pp 1039-1042

11. 'PC Based Integrated Acquisition & Data Processing System' P. Luquet & A. Rozwadowski Proc Internoise. Avignon 1988