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APPLICATION OF COMMERCIAL MICROPROCESSOR TECHNOLOGY TO ACOUSTIC INSTRUMENTATION

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At first sight the measurement of sound may not appear too great a problem but closer inspection shows that it is a complex quantity varying simultaneously in intensity and frequency with respect to time, over a great range when compared with more familiar parameters such as temperature. The demands for simple field instrumentation for industrial and environmental applications, and capable of handling this time varying signal conspired to produce design difficulties which have only satisfactorily been solved with the latest generation of microprocessor based instrument systems. Because of the very variable nature of the input signal it is often inappropriate to display the signal continously and statistical reduction and integration techniques are used to simplify the description of the signal. It is in this area that microprocessors have made considerable impact.

The CEL-393 Precision Computing Sound Level Meter fulfils all the requirements of the International Standards for sound level meters in the Type 1 Precision Standards for sound level meters in the Type 1 Precision category whilst at the same time using a low power consumption microprocessor to sample the sound level output to provide a variety of acoustic parameters in four alternative operating modes. All answers are stored in memory for subsequent read-out via an internal LCD display, or printed out via the serial data interface.

An interesting alternative to the dedicated microprocessor-based instrument is the application of a suitable desk top microcomputer to the measurements outlined above. Two characteristics of the system stand-out,

i) a good visual display of the frequency spectrum
ii) automated control and data manipulation routines

The CEL approach has been to take a CBM 8032SK microcomputer and build separately and third-octave band frequency analyser with digital interface compatible with the CBM computer. High level software controlling rapid data transfer, screen display and data manipulation has been written in such a way that user customisation can be easily achieved. The frequency analysis is implemented to International Standard Type 1 Precision accuracy and multiple input multiplexing and excitation signal sources are optionally available in the CEL-8000 System. This approach has halved the cost of the traditional measurement hardware whilst offering vastly improved data manipulation routines and a desk top microcomputer which can be used for a wide variety of other applications.

Another use to which microprocessors have successfully been deployed in CEL instruments has been in providing a breakthrough in chart recording. Traditionally pen recorders have been limited in acoustic applications due to the inherent poor response in following dynamic signals. Different applications have also required the use of appropriate different pre-printed charts. An interesting use of the microprocessor has been to control an electrical discharge writing system with a resulting dramatic improvement in dynamic response. In addition by storing in memory a number of chart configurations for different applications, only one paper stock is required and the appropriate graticule is printed at the command of the user. Seven entirely different recording modes can be implemented with appropriate ROMS in a compact battery powered instrument.

Acoustic measurements are notoriously difficult to achieve with high accuracy due to the very many factors influencing the acoustic environment. Consequently, many measurements rely upon 'averaging' to overcome random influences and measurement routines can be tiresomely tedious. An interesting application of the benefits of microprocessor power is illustrated by the graphic recorder measurement of RT60.

Graphic Recorder

The heart of the system is the CEL-160 Graphic Recorder which combines in one battery powered unit a precision grade sound level meter with DC RMS output, analogue to digital converter, Intersil 6100 12-bit microprocessor controller and high speed electrodischarge print system.

Each of the building blocks outlined above plays some part in enabling the system to operate. When measuring reverberation time the provision of a log RMS DC output signal has the advantage of converting the exponential sound energy decay encountered by the microphone into a "straight-line" output signal which is linear in decibels. However within the RMS detector of a sound level meter there is an averaging time constant which is typically 125msecs for FAST response and 1 sec for SLOW response. The effect of the time constant is to control the decay of the signal so that it falls at a rate of 3dB every /2 x time constant, which results in 60dB decay taking up to 1.8secs with FAST response and over 10 secs with SLOW response. In order to measure a RT60 of less than 500 msecs then the time constant must be less than 35msecs for decaying signals. A further advantage of using a fast decay log RMS signal is that it also offers some smoothing i.e. averaging of the inevitable signal "flutter". Consequently the rate of decay should not be so fast that unnecessary signal variations are introduced into the signal and trial and error has shown that an averaging "time constant" of 10msec is well suited to this application.

The speed and resolution of the A/D convertor is also critical in ensuring a valid answer can be calculated. The output of the sound level meter stage is accurate over a 50dB range which is adequate for reverberation time measurements and this output is digitised to 10 bit resolution at 2msec intervals with 30microsec conversion time. With the 10msec time constant selected the time taken to decay from full scale deflection to minimum scale deflection is 120 msecs and will result in 60 samples of the RMS output of the sound level meter output with each sample having a resolution of 1/16dB. For a typical RT60 of 500msecs then over 200 samples of the decay would be taken between full scale and minimum scale. Since it is normal practice to perform the measurement over a smaller decay range than the full 60dB, usually 20dB or 30dB, then it follows that in the typical RT60 of 500msecs at least 60 samples of the signal would lie within the 20dB range from which the RT60 value is calculated.

The attractiveness of a microprocessor based measuring system lies in its ability to undertake a wide variety of routines limited only by the extent of its support program. This inherent versatility is further enhanced in a measurement routine which by its nature is repetitive. The measurement of RT60 exemplifies both of these attributes.

The Program

The program functions in three parts:

(1) User selectable measurment parameters.

(2) Data acquisition and calculation.

(3) Presentation of results.

Selectable Parameters

The following functions can be operator selected, entered via the keypad.

i. Impulsive or continous noise source
ii. RT20 or RT30 measured on decay
iii. Single RT or automatic sweep through a band of filters

If filter sweep selected then:-

iiiA Type of filter unit connected
iiiB Starting frequency band (by number)
iiiC Finishing frequency band (by number)
iiiD Number of times each band is repeated, x1, x2, x4 or x8
iv. Duration of RT sampling period 0.4, 0.8, 1.6, 3.2, 6.4 or 12.8secs

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Default Conditions

When the RT60 program is selected it is necessary to select impulsive or continuous, otherwise the program will not proceed. The recorder then assumes that RT30 (ie from -5 to -35 dB SPL) will be measured for a single RT with no filter set connected for a duration of 0.8secs.

Impulse Noise Source

As no reference level can easily be established prior to the noise being produced the program undertakes the necessary preparation internally and then indicates that it is ready for the noise event. If this is triggered automatically from the recorder this will proceed immediatly, otherwise the programe will halt and wait for the event, sampling the sound pressure level (SPL) every 2msecs. When it detects an increase of at least 30dB between two successive samples an event is detected and the SPL is then logged for the required period. The RT can then be calculated by noting the maximum SPL after the detection of an event and a delay of 8msec to allow for the shock wave to pass, and counting the number of samples that fall between -5dB or this level and the lower selected measurement level. The RT60 can be computed.

Continuous Noise Source

If this mode is selected, then the program detects when the SPL is at a fairly constant level. A 2.24secs average value of SPL is used as the reference level and the source is automatically turned off. The decay calculation is then performed in the same way as for impulsive noise.

Sequence Of Measurements

After receiving the start keystroke, a short pause allows for filter settling and then readings of the SPL are taken on a 4msec sample basis for the next 152msec. These are average to produce a value for the averaged background SPL and this is stored in memory. In impulse mode the ready signal halts any further events until the SPL increase between samples is 30dB (the ready signal will trigger the event source externally if this is possible but the RT start will still be on a detected SPL increase). In continuous mode the ready signal turns on the sound source.

In the impulse mode, once an event is detected, SPL measurements are sampled every 2 msec. The largest sample is used as the 0dB reference point and -5dB on this value is calculated. The number of samples that give an SPL between the -5dB point and the -25 or -35dB point (whichever has been selected) is counted in total and logged. In addition, 204 samples of SPL per period are put into memory to form the graphical display of the RT curve. On the fastest sampling period, this will store every sample, on longer periods only samples every 8, 16, 32 or 64msecs will be remembered, but will not affect the calculation accuracy of the RT Calculation.

When the last sample has been taken, a check is made to see if either the SPL is less than the background level of the CEL-160 or whether the SPL is less than the background level (measured at the beginning of the RT routine) +6dB. If either or both of these conditions are met the measurement stops otherwise the measuring continues until one or other occurs which will immediately cease the measurement. In the event of neither occurring, the measurement will cease when the memory space in the CEL-160 is filled. A calculation based on the dynamic range and the number of samples counted, produces the RT60 which is printed, together with the RT trace, immediately the measurement is completed.

In continuous mode, the sound source is left switched on for 2.24secs to establish a fairly constant SPL in the building. During this time, the SPL is sampled and an average value computed at the end of the period and this value is used as the 0dB point for calculations of the RT. The sound source will then be switched off by the 160 and the decay measured, recorded and computed in exactly the same way as for impulse, except that the last 32 values of SPL measured, during the initial 2.24 secs will be stored in memory and printed along with the decay that follows in the graphical presentation.

Display Of Results

When the RT decay has fallen to the prescribed level, the memory will have a store of SPL's representing the decay and a value calculated to produce the RT60. The printer is energised at 30mm/sec paper speed and will print its own X and Y axes. On 50dB dynamic range intervals of 2.5dB are drawn, and the lines for 0, 25 and 50dB annotated. On the X axis time markers are drawn at 1/8sec intervals on the 0.8sec range and at 1/4, 1/2, 1 and 2sec intervals on the higher ranges respectively. The graph of the SPL is arranged to lie with its 0dB value positioned at -5dB with respect to the top of the chart and the value of the RT and the frequency band associated with it is printed above the RT decay and in the same direction as the graph. Each RT is stored in memory if an automatic sequence is taking place and where repeats of each frequency have been performed each one will be displayed as above, but additionally after the last run, a tabular print-out with no decay graph prints the arithmetic average of the number of RT's taken at each frequency.

Error Messages

Error messages appear for the following conditions:

RANGE - Insufficient dynamic range to enable RT measurement.
TIME - Memory full before stop condition arrived at.
OVER - Initial SPL too high (max at -5dB c.f. 160 max input signal).

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Interpretation of Results

The correct interpretation of RT decays is ultimately a subjective assessment by a responsible acoustician. Graphical decay presentation clearly enables multiple decays to be eliminated, and the acceptance of digitally computed RT values can only arrive with confidence in the coincidence of subjective and objective results. The method chosen for calculation ensures that all acoustic energy in the decay ranges elected is taken into account and this will also be the case where there is "flutter" above and below the lower cut off level. This will move the slope of the RT calculation away from the slope of the early decay but in many cases this would follow the reaction of a subjective assessment and is believed to be acceptable.

Since the level recorder may also control both noise generator and frequency filter, source spectra and transmitted spectra may also be measured. The results of RT and spectra can then be entered into a suitably programmed personal computer or programmable calculator and appropriate sound reduction values calculated.

The Future

The examples which have been given illustrate two important characteristics

i) the importance of the information display
ii) both battery-powered and mains-powered use of microprocessors have a place in instrument development

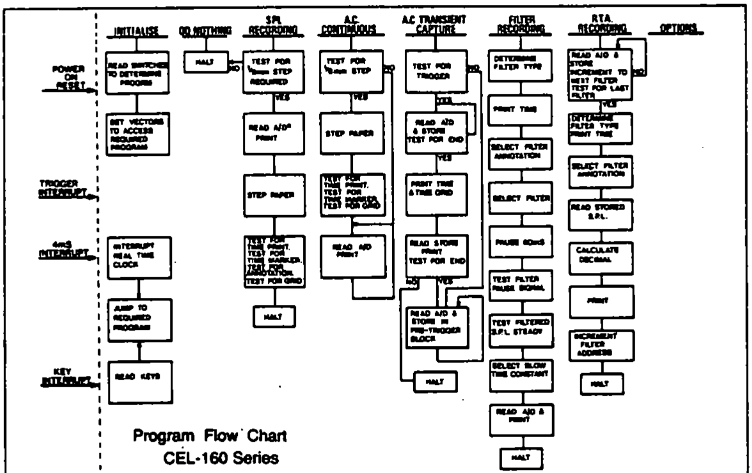
Familiarity with the microcomputer has increased dramatically during the last five years, and many users singing, all-dancing, go anywhere matchbox sized black box. The CEL-393 in the field of acoustic instrumentation represents a major step forward but could not have succeeded without several practical limitations being overcome.

A consequence of increased instrument flexibility is the risk of switch proliferation and subsequent user confusion. The number of switches which can be used is limited by the size switch which is in turn limited by the size of the human finger; and the available space in which to mount them, which in turn limits the compactness of design. The alternative to switch profusion is to use a keyboard but here the danger is that multiple keystrokes will be required without satisfactory mode information. This has been overcome in the CEL-393 with the use of a dedicated LCD display which displays a wide range of information in addition to the answer.

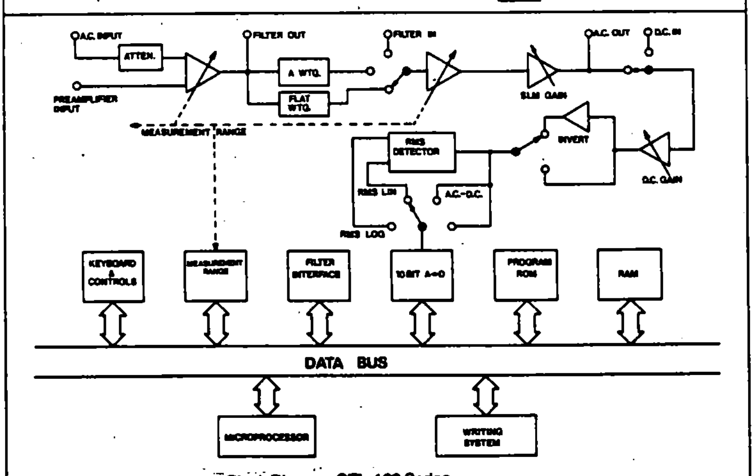
Another potential limitation to the compactness of design is the available operating time from one set of batteries. A reasonable design objective is a minimum of eight hours continuous operation. Reduction of the CEL-393 quiescent power consumption to 12mA enables the use of compact readily available batteries and a reasonable compromise is achieved between instrument size and operating life.

However, it is not always essential to look to the future development exclusively being battery powered designs. The CEL-8000 Computing Signal Analysis System shows that many applications will remain essentially laboratory based and can be accommodated using mains powered systems.

The way ahead therefore will be secure for both types of microprocessor application depending upon use. Difficulties which are as yet unanswered surround the fact that component hardware development is taking place at a rate which software development cannot keep pace! Manufacturers run the risk that individual processors may rapidly become unsupported and an expensive development could become marooned as a result. Irrespective of this danger so far as the user is concerned the cost of achieving a particular measurement objective will continue to fall dramatically.



Program Flow Chart
CEL-160 Series



Block Diagram CEL-160 Series