DEVELOPMENT OF THE DEFENDER NOISE LIMITER FOR USE IN CALL CENTRES

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1 INTRODUCTION

This document describes an analogue companding device that has been developed by BTexact. It provides protection against noise interference signals for call centre personnel who, in order to carry out their work, are required to wear a headset.
It has long been a concern that operators, who are required to wear a headset to answer calls over extended periods of time, are not exposed to excessively high acoustic signal levels. In the past, BS standards ensured that the send and receive levels were within fixed limits. This is no longer mandatory and CE standards only cover safety and EMC. Headset manufacturers, however, have continued to ensure that acoustic protection is built into the headset.

Whilst it is relatively straightforward to provide protection circuitry that ensures that a particular maximum sound pressure level (SPL) is never exceeded, this in itself is not the complete answer. Sudden noises and long periods of exposure to high sound levels must also be considered if the operator is to have a safe working environment. Even with a maximum signal limiter, an operator can be exposed to high levels of sound close to this maximum, and may still exceed the recommended noise dose by virtue of exposure to the cumulative effect of these high levels. Also, it is not always signal levels close to the absolute maximum that may be harmful. Using a headset while listening to ‘normal’ signal levels, a sudden and extraneous stimulus that causes the overall level to rise in a very short time period may result in temporary hearing loss, giddiness and nausea. A good example is an operator call from a payphone located adjacent to a set of road works when suddenly a pneumatic drill starts up. Such an occurrence can be likened to a ‘startle effect’ for both the payphone user and the operator and is both very disturbing and potentially can cause hearing damage due to the sudden change in acoustic levels.

For these reasons various solutions have been suggested that provide additional signal conditioning rather than simply limiting the maximum level in an attempt to provide improved comfort for personnel using headsets for extended periods. Most of the solutions available in the market use digital techniques to provide the additional signal processing. Whilst at first this appears to be an attractive solution to the problem by virtue of the flexibility that a digital signal processor (DSP) offers, in practice it is difficult to reach a solution that achieves all the original design aims (quality, sidetone etc) without significant cost penalties due to the processing speeds required. This is because a DSP requires a finite amount of time to carry out the required signal processing in order to detect and manage the sound events that exceed certain limits. Even a few milliseconds of delay in the speech/receive path is sufficient to cause an echo or the receive signal to sound ‘hollow’ which the operator may find objectionable. The ideal, of course, is a noise attenuator device that has little or no effect on the standard noise performance of the operator’s workstation and only becomes effective when required to reduce an increasing sound level.

In a normal home or work environment the use of a corded or cordless handset allows the user to move a source of noise rapidly away from the ear. In the call centre workplace the vast majority of people use headsets and it takes appreciably longer to remove the source away from the ear. This significantly increases the risk that the user could be subject to levels of sound that could cause hearing problems.

Research by the Auditory Laboratory, Physiology, University of Australia has shown evidence that an effect known as the 'startle effect' can contribute to the cases of hearing damage among operators. A sudden and unexpected noise can cause temporary damage to the inner ear mechanism caused by excessive middle-ear muscle contractions. The levels of these sounds may be well below the acoustic shock threshold and it is proposed that the suddenness or speed of the noise event is the contributing factor. It is generally agreed that to reduce this effect the noise limiter has to react faster than the inner ear and less than 50ms.

High acoustic signal levels and noise incidents can result in a number of symptoms, such as headaches, nausea, tenseness, and hypersensitivity to loud sounds. The amount of exposure time and the volume of sound have a bearing on the level of the symptoms. Typical causes of noise incidents are 'Static' noise, FAX machines, DTMF tones and noise deliberately produced by the customer, oscillation feedback and signalling tones on the line.

For these reasons, a new approach was taken to solve this long running problem using a simple and cost effective design that makes use of analogue signal envelope techniques to ensure virtually instantaneous response times whilst providing a subtle decay time to ensure the gain restores to normal levels in a manner which is acceptable to the user. This new operator's Headset Envelope Level/logger Protection device, the "Defender", is described in more detail in the next section.

2 COMPATIBILITY WITH EXISTING BT CALL CENTRES

The main requirements of a noise interference suppressor must be that of compatibility with existing equipment. Pre 999 call alert tones must not be suppressed, the send, receive quality and level of sidetone must be maintained or even improved. It is critical on calls such as emergency calls, where the caller may be in a noisy or difficult environment, that the operator clearly hears the caller and can assist. Also transmitted speech from the operator to the caller should be totally unaffected.

The Defender will allow the pre 999 call alert tones to pass through to the output unimpaired except that they will not exceed the average maximum acoustic limit of 95dBSPL. The pre999call alert tones are generated within the workstation (PC) on receipt of a flag that indicates that the next call is a request for one of the emergency services. The tones occur as two separate bursts with less than a second between. A single burst alerts the operator that the next call is a return call from the emergency service and not a new customer request for service. These pre 999 alert bursts of sound must not be impaired in quality but will be reduced in level to 95dBSPL.

3 DEVELOPMENT OF THE OPERATOR'S HEADSET LEVEL & LOGGING PROTECTION UNIT – THE DEFENDER

Figure 1 shows a block diagram of the Defender. The main functional units are shown in the diagram with the event-logging block shown within the dotted rectangular box. Each of these functional blocks are described in turn in the following sections.

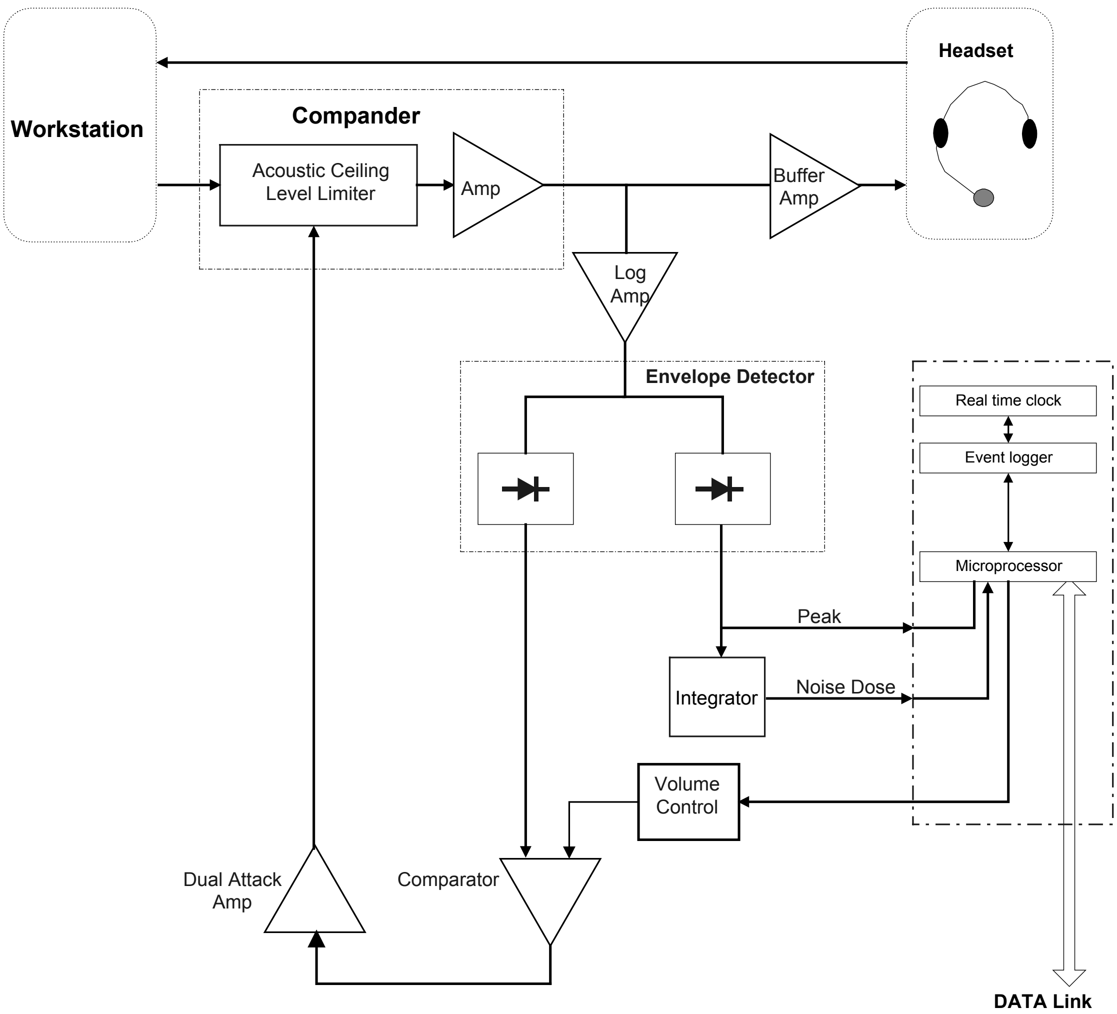

Fig. 1 Block diagram of the Headset Envelope Level & Logging Protection device.

3.1 Acoustic Ceiling Level Limiter

This module controls the incoming receive signal and ensures that the maximum output rms sound pressure level of 95 dBSPL is never exceeded. Since this is essentially an analogue attenuator, it is able to act fast enough given an appropriate control signal level but not too fast as to distort the signal during attenuation. The secret to the Defender is in the manner that this control signal, which 'turns-on' the limiter, is derived.

3.2 Audio Amplifier

To ensure a comfortable listening level regardless of the incoming signal level, a small amount of positive gain can be inserted. The amplification ensures that very low receive signal levels that are perceived as quiet are brought up to a more acceptable listening level. On the current version the maximum gain is 10dB and there is the potential of making the gain user-adjustable to allow for personal customisation. Conversely, very high signal levels arriving at the Defender are reduced by the initial level limiter and pass through the amplifier in much the same way as the lower levels. The gain at low receive levels and reduction of high receive levels provides a companding feature to the Defender.

3.3 Logarithmic Amplifier

A logarithmic amplifier in the feedback loop has been incorporated to increase the sensitivity of the measurement of the low signal levels. Although this has little benefit to the control of large sound levels, it enables a more accurate measurement of the noise dose to be made.

3.4 Full-wave Rectifier

The full-wave rectifier, shown by the diode symbol, takes the logarithmic amplified signal, and provides the AC to DC conversion as part of the signal level detection.

3.5 Envelope Detection

Having converted the AC signal to a varying DC level, it is necessary to smooth the DC level so that the actual instantaneous signal level can be derived. This takes place in the envelope detector.
There are two parts to the envelope detection.

The first envelope detector has a slow response time, smoothing the signal before integrating and deriving a signal suitable from which the microprocessor can calculate the noise dose. The signal prior to the integrator is connected to the microprocessor to enable it to measure the peak signal level.

The second envelope detector has a faster response time to ensure that large amplitude signal levels which last greater than 25ms are correctly processed. A comparator circuit looks at the signal, compares it with the volume control signal set by the microprocessor and the resulting output is sent to the dual-stage attack/decay circuit. This ensures that large signals, greater than the level threshold set to give 95dBSPL at the output and longer then than 25ms duration, are reduced in level. The circuit also incorporates a pre-programmed timeout that ensures the audio signal is gradually returned back to its nominal level once the extraneous signal has passed. This ensures that the shock or 'startle effect' is removed but on-going protection continues as the signal dissipates and the level reduction is not heard as an objectionable 'clicking' as the unit operates.

In practice it was found that the speed of response should not be faster than 25ms (which has an equivalent modulation frequency of 10Hz). Conversely reaction times within 2.5ms (which have an equivalent modulation frequency of 100Hz) is too close to the audio frequency band and in practice can be heard as a click.

The peaks of the speech signal, which may also exceed the level threshold, pass through unhindered. The speech signal will be reduced to 95dBSPL if the average rms speech signal level exceeds the level threshold for longer than 25ms duration. The signal is controlled by reducing the input signal using an opto-isolated variable potentiometer.

3.6 Software control of the noise interference signal

Reducing the input signal to 95dBSPL may not be sufficient. The software monitors the signal and applies a further reduction in level (10dB approx) during the disturbance should it detect a disturbance lasting greater than 25ms.

3.7 Noise Interference Event Logging

The Defender can also provide an audit trail of noise interference event logging and noise dose measurement. These features have been added to help call centre management better understand when the events occur and also what level of noise dose their personnel are being subjected to. The previous section describes how these signals are physically derived and the processing and logging is performed by the microprocessor in software. Simple ‘threshold’ type events can be logged. These are where the unit records the time and date when the input signal passes the acoustic threshold. This is a similar concept to traffic monitoring and gives a better understanding of the proportion of calls that are high or very high in level and gives insight into the duration of these occurrences . Such information could prove important to a call centre managers to ensure operators are not unduly exposed for long periods to excessive levels of noise dose.

3.8 Noise Dose Measurement

Noise dose measurement is carried out in software by the microprocessor. Noise dose indication is provided by way of a tri-coloured Light Emitting Diode to allow the user to know when their noise dose is reaching the mandatory level. Green indicates a dose level below 80dB changing to amber at 80dB and red at 85dB.

3.9 Self calibration

The software also enables self calibration of the Defender. An internally generated tone can be injected at the input and the signal at the output measured. The digital acoustic ceiling volume control can be adjusted while the output is monitored and the final value stored. Any variation in the component tolerances, mainly that of the opto-isolator over time, are removed from the circuit. The Defender will indicate whether it has passed or failed via the LED on the unit.

3.10 Self test

The output is continually monitored to ensure that the level does not exceed the required preset value. An internally generated 1kHz tone can be injected at the input, triggered by an event (the operator logging on or a request from the operator’s terminal) and the output monitored for the preset output value. A message will indicate that the Defender has passed or failed.

3.11 Control of the Defender

The Defender has a data socket and using this the threshold value, headset type etc can be loaded and the information captured by the Defender downloaded. This can be performed either by a laptop PC , from the operator’s local PC or by the centre manager polling all workstations. Software has been written to perform this function from the operator’s PC with password protected access for certain preset functions and values. Future developments are planned on the user interface and the look and feel of this information. For example the noise dose could appear as a small ‘thermometer’ icon in the PC system tray changing to red when the noise dose level was reached.

3.12 CPU and Memory

The Defender is controlled by a 8Kbyte RISC central processing unit running at 4MHz. The memory size is 32Kbytes and allocating 8bytes per record results in a maximum number of records of 4096. This felt to be adequate for the unit given that these records can be uploaded to a central PC and stored. A SuperCap maintains the clock when disconnected although a battery has been allowed for in the case design to enable the Defender to operate for a short period of time if power fails.

3.13 Logging all the call centre positions

Further enhancements are planned to the logging functionality that will allow the centre manager to collate these statistics automatically onto a spreadsheet application as shown below.

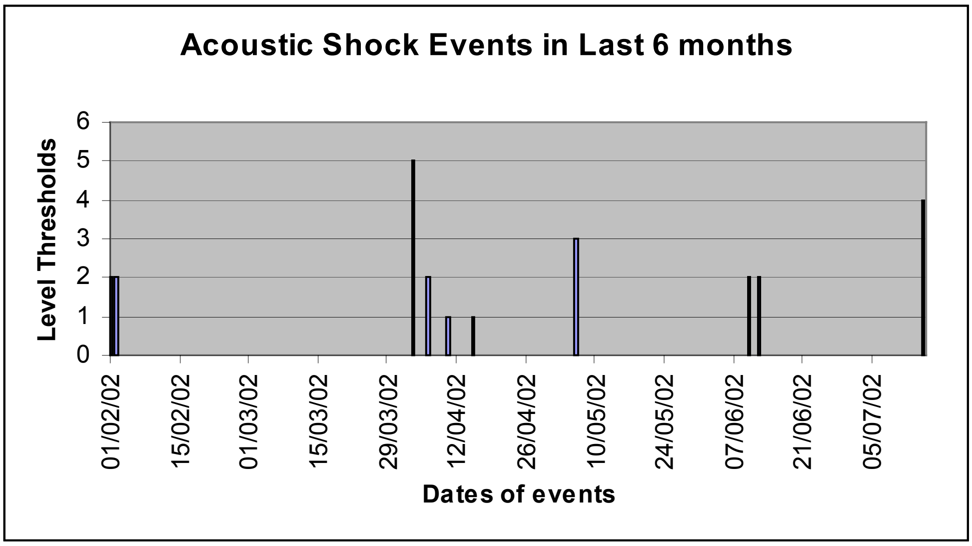

Fig. 2. An example report produced from logging event data downloaded from the Defender.

3.14 Power supply

The Defender operates from a standard small 9V plug-top power supply and consumes less than one watt. The serial interface is used for data collection using a terminal software package.
Battery backup is also an option from an optional pp3 battery located in the unit.

3.15 Size

The unit is very small (14cm x 9cm x 4cm approx.) and is supplied with appropriate RJ-22 plugs and sockets so that it can be inserted between the current operator's headset and workstation.