APLIS: AN AUDIO PEAK LEVEL MONITORING SYSTEM FOR BLIND SOUND RECORDISTS

James A S Angus Nicholas J Malyon

Signal Processing Group, Department of Electronics, University of York, York YO1 5DD

INTRODUCTION

A large number of visually impaired people require a system which will indicate audio levels in a form which is suitable for them. Currently many can not use their cassette decks and mixers to their full as these indicate their manual audio levels in a visual form.

Sighted people are informed of audio levels via either bargraph or moving-coil-type meters. These visual means of indicating audio levels obviously hinder visually impaired people who use cassette decks, reel to reels, mixers, DAT recorders and so on which have manually controlled levels.

There are audio units which use an automatic level control (ALC) circuit to automatically set and alter the recording levels. These give a lower performance than systems with manual control due to the extra hiss added in quiet sections and the sudden 'pop' as the system tries to quieten a peak. The automatic system is changing the signal - far from the aim of hi-fi recorders, and unacceptable in professional situations. Also an automatic system is not available on all types of equipment (especially audio mixers). Visually impaired people, despite many clever ways of setting levels (eg by remembering the volume of a 1kHz test signal the level of which was calibrated by using a sized block of wood at the top of a mixer fader) are currently excluded from using audio equipment to its full.

At present, the visually impaired people that wish to make high quality, manual level, recordings are forced to 'guess' the audio level. The guesswork is helped by what is often a very high working knowledge of the equipment and by monitoring the recording. The monitoring volume is set as a constant level so that when the recording volume is altered the level heard (either from speakers or headphones) will be proportional to the level of the recording. This requires that the sound level when a peak occurs is remembered - this is difficult to do especially during a long recording session where there is a tendency to become used to the higher sound level and so accept greater audio peaks. This method is inaccurate and so, due to either under-using a tape's capacity (which will increase the noise relative to the audio signal) or over-loading the tape causing saturation and distortion, the quality of the audio recording will be reduced.

The rest of this paper will describe a device which allows the blind to monitor their recording levels. It will first discuss the specifications and then outline some of the design considerations. Finally it will describe the system and some of its features and possible extensions.

APLIS: AN AUDIO PEAK LEVEL MONITORING SYSTEM

SPECIFICATION

From the above considerations, and on the basis of consultation with visually impaired people, we arrived at the following specification.

* The unit must be simple and inexpensive (cost must be less than £35).
* The unit must be capable of portable operation.
* The unit must be easily integrated into typical recording set-ups.
* The unit should be capable of being connected, set up and used by a visually impaired person without needing assistance from a sighted person.
* The unit should not degrade the audio signal being monitored.
* The unit should produce an output which is useful to the visually impaired user.
* The unit must be suitable for portable use.

DESIGN CONSIDERATIONS

In order to meet these requirements we have to consider

a) The position of the device in the system.
b) The means of setting up and using the unit.
c) The means of indicating an overload.

The position of the device in the system

The audio level peak indication system (APLIS) could be connected to many points within an audio system. The audio level should be controllable at this point for there to be any need for an APLIS.

To analyse whether the unit would be compatible with a large range of audio systems, the structure of these sytems needs to be examined.

Figures 1 to 3 represent simplified (in terms of numbers of audio imputs and not structure) audio systems. In the diagrams a dashed line represents an uncontrolled level; a solid line represents a controlled audio level. As the function of the APLIS is to control audio levels, it is sensible only to connect the unit to controlled (solid) audio lines. These are typical set-ups for domestic (separates) hi-fi (Figure 1), amateur/professional recording (Figure 2) and portable recording (Figure 3).

The one option common to these three situations is the connection of the APLIS at the line out of the recorder. Ideally, especially for the professional system, it should be possible to connect the APLIS elsewhere into the system (eg mixer output).

The portable system does not have access to an external amplifier - other types of set up may, or may not. The APLIS, then, should be capable of 'stand alone' indication as well as indication, possibly, via an amplifier after it in the audio chain.

APLIS: AN AUDIO PEAK LEVEL MONITORING SYSTEM

With the APLIS connected to the output of the recorder it is in the **monitor** path of the system. Any degradation that the APLIS may make on the audio signal will not be recorded. However this degradation should be limited, as far as possible, as the quality of the monitoring is clearly important to the quality of the final recording or mix.

The APLIS, both when it is operated in its normal monitoring path position and when it is in the recording path, should have a structure which will allow the visually impaired user to install (ie set up and calibrate) the unit.

Setting up the Unit

The specification states that the APLIS should be designed so that it is possible for a visually handicapped person to set up the unit. The setting up of the unit is done in two stages: the APLIS is connected into the user's audio system with cables and the unit is calibrated. Most visually impaired users will be able to connect the unit when a description of the connections required is given.

The unit will need to be calibrated ie set so that when the source produces a certain voltage the unit will indicate a peak. The voltage at which the peak should be indicated will vary depending on the source. This calibration should be a one-time only operation for each unit with each recorder. However it should be possible to repeat this calibration if the user then wishes to use the APLIS with another recorder/mixer.

Most potential customers will use cassette-based systems so priority was given to designing a system to allow them to set up their unit. The instructions for setting up will be supplied on an audio cassette tape, therefore this cassette could also contain a tone to allow the unit to be calibrated.

If a tone was recorded on to the tape at 0dB then this should appear as a 0dB tone on any cassette deck which it is played back on. The voltage, at the line out socket (or a speaker or headphone socket if the volume level is at a set, calibrated, position), will be at a level when the 0dB tone is sounding which will vary from deck to deck. The user can calibrate the unit by adjusting it (eg adjusting a multi-turn preset) unit the switching point of the indication is found - thus the 0dB point is referenced.

Furthermore if the unit contained a switch which provided a variety of reference levels relative to 0dB then the user could easily set other peak levels without having to recalibrate the unit.

People who are using a recording medium other than cassette, or who are using a mixer, will need a calibration tone on that media (eg a 0dB tone on reel to reel tape which is commercially available) or a sighted person for a few minutes to inform them when the levels are at a certain point (eg 0dB).

The APLIS could also be calibrated by comparing the peaks that it indicates with the visual peak indicated by the existing meters. This would cost nothing but it cannot be done by visually handicapped people so, due to the clause in the specification, must be rejected.

APLIS: AN AUDIO PEAK LEVEL MONITORING SYSTEM

Output Form

There are a number of ways in which the APLIS can indicate to a visually impaired person that a peak has occurred in the audio signal which is being monitored.

For the body to detect that an event has occurred one of the five senses must be stimulated, either:

* Touch
* Taste
* Sight
* Smell
* Hearing

The olfactory and taste senses can be dismissed as the time delay between the stimulus and its detection will be too large.

The remaining tactile, visual and audible senses are all suitable in some form/s for visually handicapped people. However, the use of an audible tone seemed to provide the most suitable output.

Audible Output

An audible indication of a recording or mixing peak is possible in a number of forms. First, a bell "like a telephone" could ring in the room where the visually handicapped operator is sitting, however, this has the following problems:

* if the recording was using microphones and the microphones were, as is likely, nearby, then the bell would appear on the recording.

* the volume of the bell is fixed - the monitoring volume is variable. Thus in some conditions the bell will 'drown' the monitored recording and in others the bell itself could be inaudible.

Once again, this form of output, could be connected to a control output system provided by the APLIS.

Secondly, instead of using an electro-mechanical bell, with all the problems of cost and power consumption this implies, an electronically generated tone could be used. This tone could be added to the audio signal which the visually impaired user will hear (either via speakers or headphones) and should not, itself, be recorded. This has the following advantages:

* The volume of this tone, if it is passed through the audio systems own amplifier, will be proportional to the monitoring level. This prevents the tone being 'drowned' or the tone being too loud.

APLIS: AN AUDIO PEAK LEVEL MONITORING SYSTEM

* The problem of the tone affecting the recording via microphones is also removed - an operator could monitor the recording by using headphones. It is likely that headphones would already be used in this situation to prevent acoustic feedback.

If the operator was recording their own voice they may, initially, find the tone distracting. However the user is likely to soon become accustomed to the tone.

The type of tone needed to be chosen. Careful attention was paid to the tone's spectral frequency components. The frequency, or frequencies, were selected so that

* they are not masked by the audio signal that they are being added to
* the tone is of a frequency which can be detected well.

The sound which a person can detect will change, for a fixed sound pressure level, with

* frequency
* age of the listener.

For a single, pure, tone the threshold at which a young and trained listener can detect a tone at a certain sound pressure level is given in Figure 4 (Van Cott et al, [2]).

The conclusion can be drawn that, for a young trained listener, human auditory perception reaches a sensitivity peak between approximately 2kHz and 4kHz. This suggests that it would be sensible to generate the tone within this range as it should be easiest to detect.

However, the sensitivity of hearing at high frequency, tends to decrease with age. As Figure 5 (American Standards Association, [3]) shows this is particularly true for men.

From the sensitivity graphs it is clear that the tone, which is in the young persons' peak range, and which will suffer the lowest age loss is 2kHz. For men, on average, their sensitivity to a tone at this frequency will fall by over 20dB from their teenage to pensionable years. This makes a high frequency tone unsuitable for older people.

If a dual tone was used - one at a lower frequency which is affected little by ageing (say 500Hz) and another in the peak sensitivity band (say 2kHz) then the output will be suitable for all age groups. If, further, these tones are made inharmonic, then the chances of the tone being masked by the audio signal are reduced.

The audible tone seems to solve the problem of finding the output form which is suitable for visually impaired people in the most universally acceptable way. However users may require other output forms, thus some control output is necessary.

An output needs to be provided from the APLIS which will allow the tone to be heard without an external amplifier (eg for portable use). If this output produced the tone only (ie without adding it to the audio signal) then the tone output could, with some simple external circuitry, also be used as the control output. This will remove the need for a separate control output and so reduce the unit's cost.

THE STRUCTURE OF APLIS

From the above considerations we arrived at the structure shown in Figure 6.

From this we see that APLIS is a device which takes a stereo audio input and inserts a tone on its outputs. This tone is either available separately or added to the audio signal whose level is being monitored.

A more detailed block diagram is shown in Figure 7.

The device consists of four basic elements.

1. Threshold Detector
   This compares the incoming signal on both channels with a reference voltage to detect the presence of a peak.

2. Voltage Reference
   This provides the necessary voltage reference for the threshold detector. It is variable, via a rotary switch, so that different signal levels can be detected. The unit has four possible levels each separated by 3dB, thus one may have reference levels of 0dB + 3dB + 6dB + 9dB or any other set with 3dB spacing.

3. Monostable
   This circuit stretches the overload sensing indication so that a short overload is clearly audible.

4. Tone generation and addition
   This circuit generates the inharmonic warning tone which was described earlier and also adds it to the signal being monitored to provide a monitor output with the warning tone inserted.

The design of the tone addition stage warrants careful consideration and this is covered in the next section.

Tone Insertion Techniques

The APLIS, when it is connected in line with the audio signal, needs to allow an audio signal to pass through it and, when a peak is detected, add a tone to this audio signal. The audio signal, which passes through the APLIS, should not suffer degradation, that is, the unit should appear as transparent as possible because the operator will be using this signal to monitor the quality of the recording.

There are two techniques which can be used to add the tone to the audio signal when a peak is detected. Active components, such as an op-amp could be used to sum the audio signal and the tone (if it is sounding) as the audio signal passes through the unit. Passive components, such as resistors, could also be used to add the tone to the audio signal.

An active summing method would induce noise into the audio signal. The distortion of the audio signal could be minimised by suing a high quality audio pre-amplifier. However these are expensive and to work well need a good, steady, power supply.

If the tone is added to the audio signal using passive components then the signal degradation is minimised but the tone can pass 'backwards', through the passive coupling components, to the input. This passive method should be cheaper to produce and give better audio signal quality. However, the design of a passive network is more complex than a basic active one and is discussed in the next section.

3.1.1 Passive Tone Addition

The final APLIS added the tone in a simple passive way, and its basic structure is shown in Figure 8. To prevent self-retriggering and to give an acceptable tone level at the input R_C has to be large. However R_C will act as a potential divider with the input impedance of the following audio component and so cause attenuation - a greater value of R_C will cause more attenuation.

A way of preventing most of the output tone from passing from the output to the input which did not require an unacceptably large value of R_C had to be found

* an active component could replace R_C which would prevent the tone passing from the audio output to the audio input. But this would degrade the audio quality of the signal.
* an out-of-phase tone could be added to cancel, or significantly reduce, the tone voltage at the input. However, the circuit will face a range of input and output impedances due to the variety of equipment that it is connected to. The network would have to account for this.

Tone Addition With Phase Cancellation

When a peak is detected in the audio signal which the APLIS is monitoring, it will indicate this by producing a tone. This tone is added to the audio signal at the output of the APLIS. A signal, which is out of phase with the tone, is added at the input to cancel much of the tone at the input.

The out of phase component was added by using a network of resistors and an antiphase output from the tone generator.

The values for the resistors were obtained by modelling the audio network using a spreadsheet. This allowed a very large number of situations to be modelled with various input and output impedances. The audio attenuation, tone level at the input and output and the APLIS's input impedance were, among others, considered. The model used is shown in Figure 9 R_3 and R_4 were included to test whether adding a series resistor would increase performance under certain conditions (such as an output short circuit). Their benefits were not outweighed by their cost so they were not used to the final network.

Many plots were made to discover the optimum values for the resistors. Part of the calculation for the value of R_C is shown below as an example of the method used. The components were set the values shown in Table 1. R_C was varied and the graph shown in Figure 10 was produced.

This led to the setting of R_C as 10 k. The value was chosen due to the good compromise between the audio and tone levels. Also a 10k resistor was used elsewhere in the circuit. This audio/tone compromise occurred at the 'convenient' point because R_1 was varied until such a point was found (R_2 was fixed at 47k as this value had already been used for R_b).

The network was tested under various input and output situations. An example of part of this testing is shown in Table 2.

From these results we can see that the phase cancellation system, in conjunction with R_C set to 10k ohms provides a reverse attenuation of the tone of 40dB and a forward attenuation of the audio signal of 2.4dB.

This was the value of R_C chosen for the final version. The specifications of the system are shown in Figure 11 and the unit can be retailed at a price of approximately £35. It has been tested by a few visually impaired users who have found it satisfactory.

APLIS AND MULTICHANNEL MONITORING

APLIS could be extended to multichannel monitoring. The main requirement would be to provide tones that identified which channel peaked over the threshold. There are several ways of doing this but the two most straightforward ones would be as follows:

a) use different combinations of high and low frequency tones in the same manner as dual tone multifrequency dialling (DTMF) systems. For example, a set of eight high and eight low frequencies give a set of 64 distinct tones.

b) Use a stereo tone buss to pan the overload tone for each channel to a different stereo location. This could be fixed, which would be quite simple to implement. However if one was willing to modify the pan-pots in the mixer to add an extra wafer, or use the signals currently available from an extra wafer, then one could pan the overload tone to the same position as the signal being monitored.

One would not want to have a separate threshold switch for each channel. However one could distribute the reference voltage selected by the threshold switch to a multiplicity of detectors. Thus, for example, one might only have three to four threshold switches which set thresholds for channel, group out, tape return, main mix.

There are other issues such as how to handle solo/PFL and monitoring effects and foldback levels which would also need to be addressed. However, it is eminently feasible to integrate

APLIS: AN AUDIO PEAK LEVEL MONITORING SYSTEM

APLIS into a modern mixing desk for a small and economic cost.

CONCLUSION

We have described an audio level monitoring system (APLIS) for visually impaired users.

The design of the APLIS was complex due to the problems of meeting the wishes of the visually impaired people that were questioned. The major difficulty was to provide a unit which would perform the technical functions required in a way that was simple to use and possible for a visually handicapped person to install, but as a price that potential customers would be willing to pay.

The circuit produced does appear to be very 'simple' with only a few types of component. This 'simple' form was designed to reduce the costs of production. The design of the circuit was far from trivial: many different circuits were designed and redesigned before the final circuit was produced.

The low cost was partly achieved by not over-specifying the system's functions. Circuit modules were also designed to allow the use of cheaper, low tolerance, components. The complete circuit was designed to be produced quickly by using PCB mounted components on an inexpensive, low tolerance, single-sided PCB. This technical design will allow the unit to be produced at the price levels demanded by potential users.

The cost of the unit depends on the number of APLIS's which are demanded (sold) which in turn depends on the price of the unit. If a pessimistic sales total of five hundred units is taken then the APLIS would cost £14 at the 'factory gate' (excluding VAT). This price would rise to around £30 to £35 at a conventional retail outlet (when VAT, advertising and retail profit are added).

This paper has considered the design of an audio peak level indication system for visually impaired people. The research, both technical and with visually impaired people, led to a specification which produced a unit which is acceptable both in technical and commercial terms. The unit, perhaps with a small amount of additional work, *could* be manufactured. Indeed it *should* be manufactured to aid the thousands of visually impaired people who currently guess their audio recording and mixing levels.

REFERENCES

[1] Broadcasting Support Services; 'The "In Touch" 1990 handbook', BBC, 1990.

[2] H P Van Cott, and R G Kinkade, 1972 'Human Engineering guide to equipment design', McGraw-Hill, 1972.

APLIS: AN AUDIO PEAK LEVEL MONITORING SYSTEM

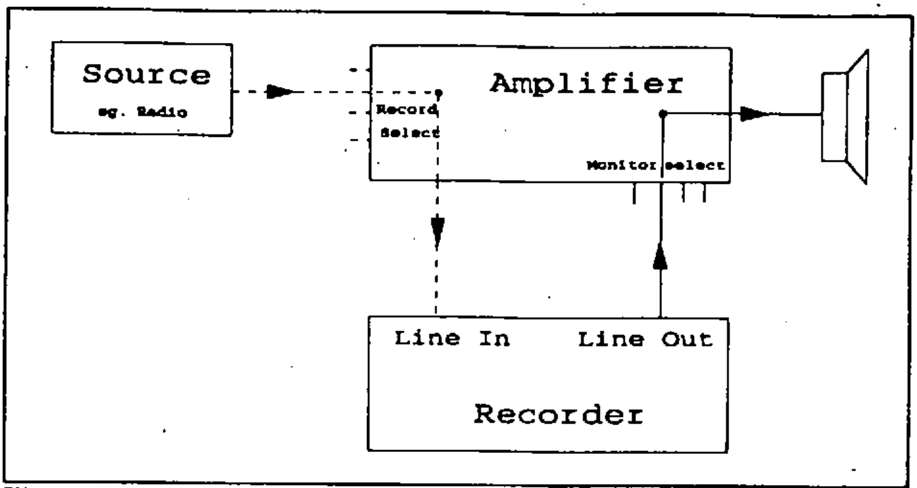

Figure 1 Domestic Hi-fi set-up.
Note: Some, less expensive, amplifiers do not provide a monitor select function - the amplifier just uses the record select. It is still possible to monitor the levels at the recorder's 'Line Out' socket.

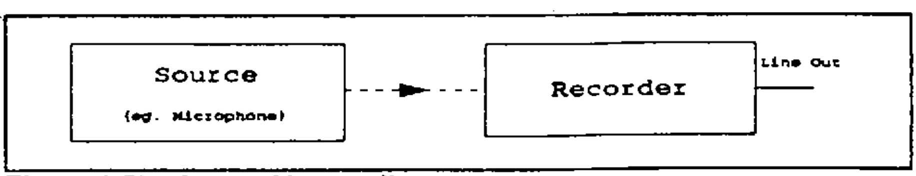

Figure 3 Simple portable recording system.

APLIS: AN AUDIO PEAK LEVEL MONITORING SYSTEM

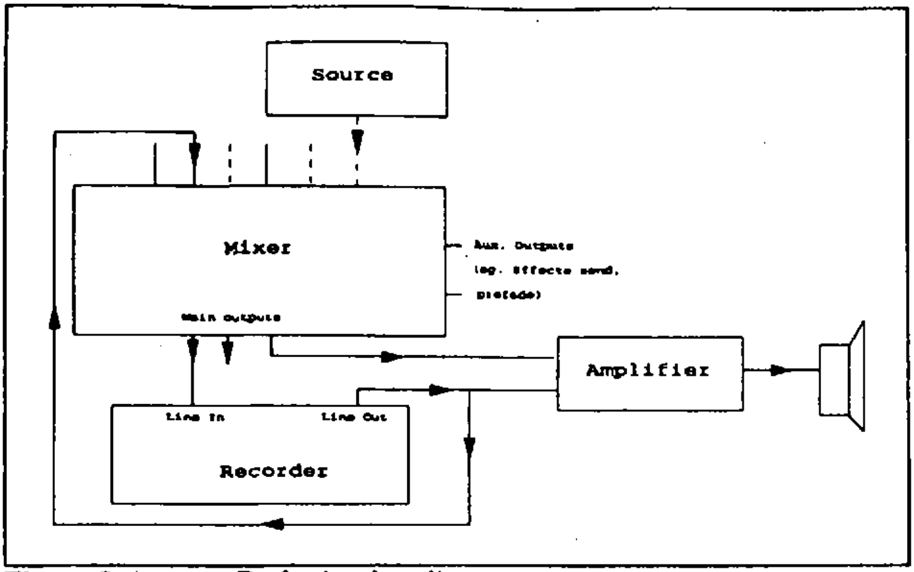

Figure 2: Amateur/Professional studio arrangement.
Note: Virtually all the connections are controlled (either by the mixer or the recorder) so there are many connection points for the APLIS.

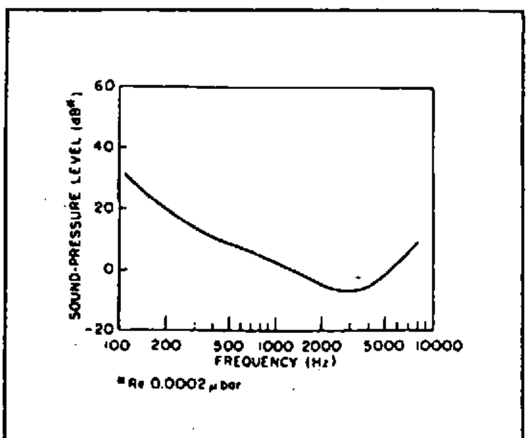

Figure 4 Minimum audible field threshold curve for pure tones.

APLIS: AN AUDIO PEAK LEVEL MONITORING SYSTEM

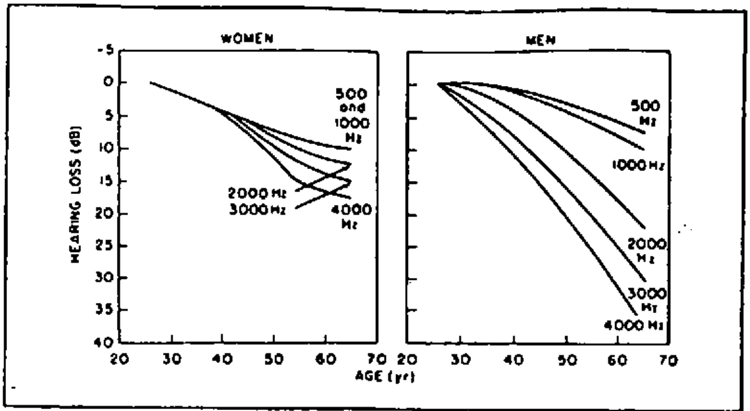

Figure 5 Sensitivity of human hearing at various frequencies with age.

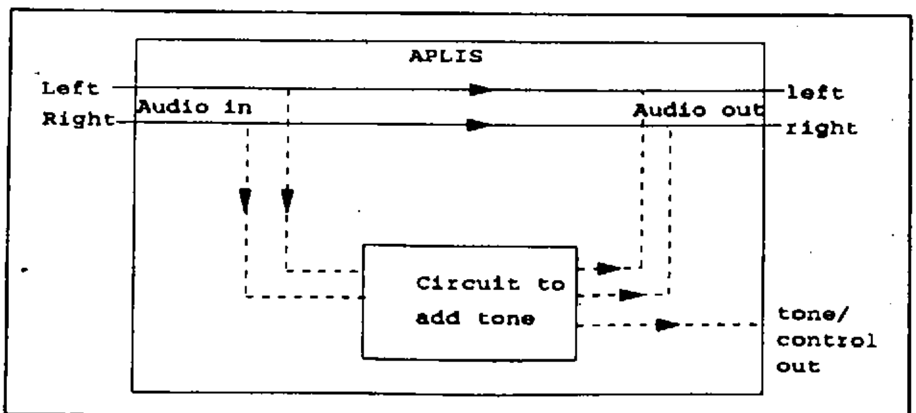

Figure 6 Basic electronic structure

APLIS: AN AUDIO PEAK LEVEL MONITORING SYSTEM

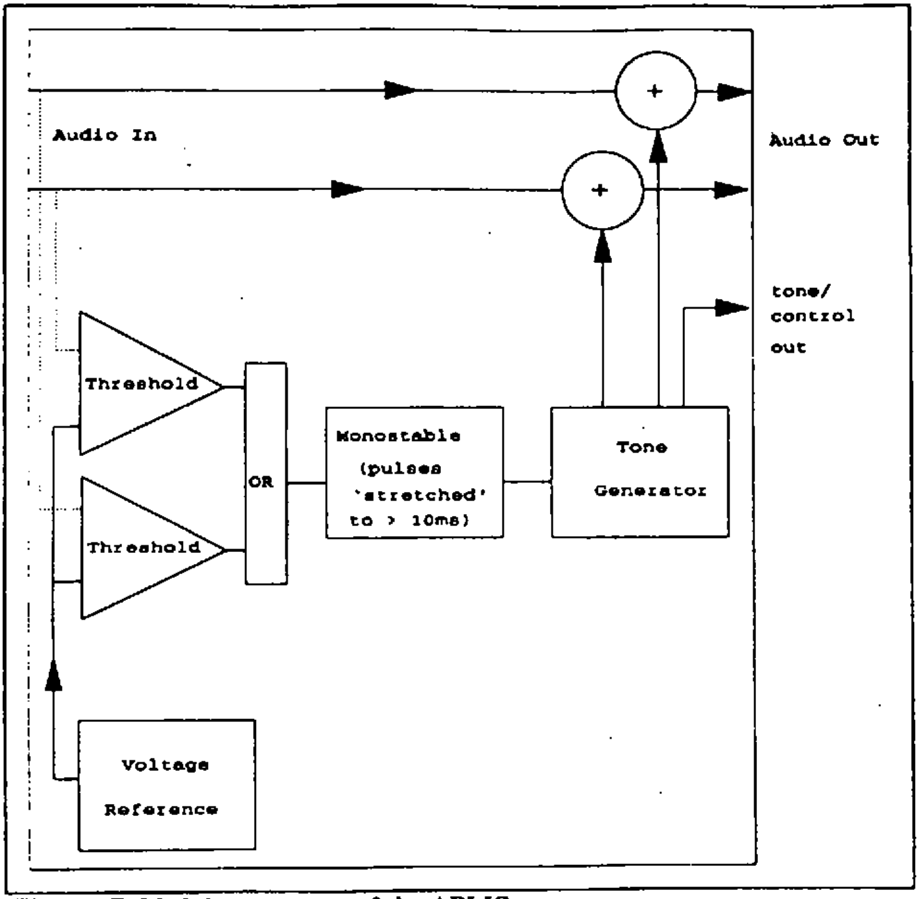

Figure 7 Modular structure of the APLIS.

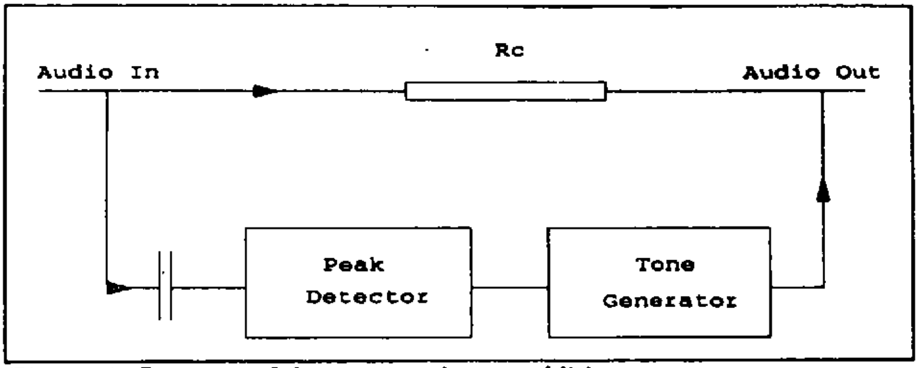

Figure 8 Structure of the prototype's tone addition

APLIS: AN AUDIO PEAK LEVEL MONITORING SYSTEM

All resistor values in kohms.	
Voltages are peak to peak.	
R1	56
R2	47
R3	0
R4	0
Rc	Varied
Rs	1
Rbias	47
Rload	100
Vs	1
Vgate	5

Table 1 Components used in the model to find R_C.

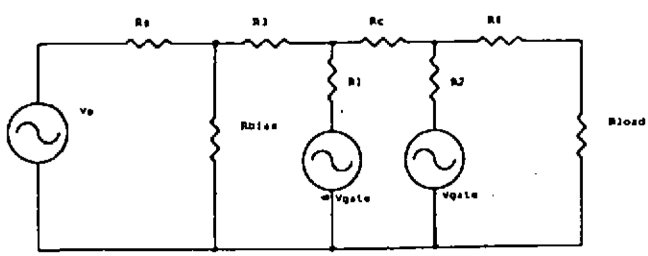

Figure 9 Audio/tone resistor network

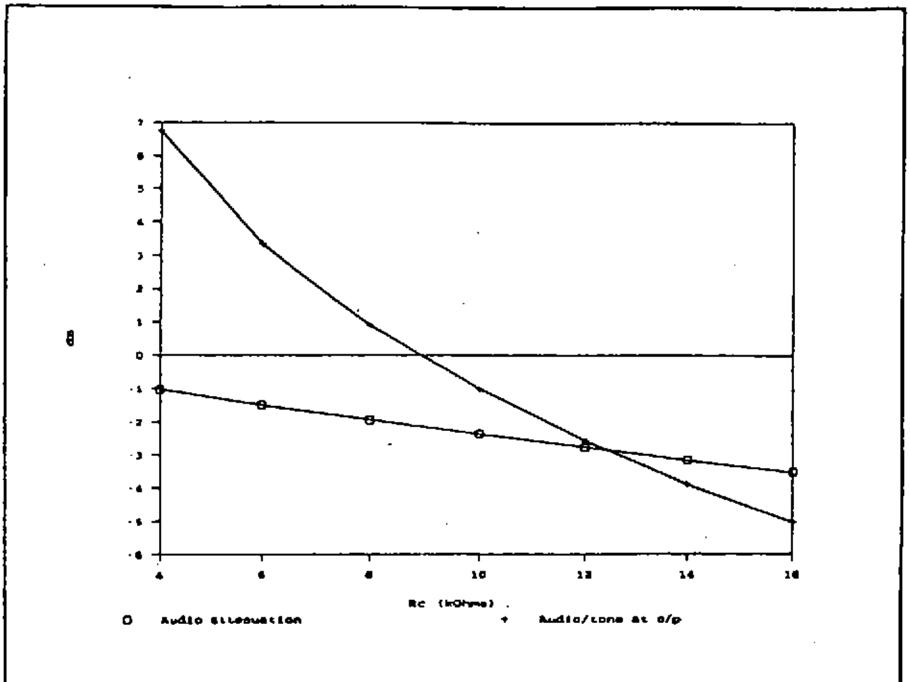

Figure 10 One of the plots used to determine the value of R_c.

All resistor values are in kohms. Voltages are peak to peak.				
R1=56, R2=47, R3=R4=0, Rc=10, Rbias=47, Vs=1V, Vgate=5V.				
	'Normal' Conditions	Low impedance source	High impedance source	Short circuit at output
Rs	1	0.1	10	1
Rload	100	100	100	0
Audio attenuation (dB)	-2.36375	-2.36375	-2.36375	ERR
Tone attenuation (dB)	40.313	59.89408	23.66439	ERR
At INPUT:				
Audio Voltage	0.94077	0.993744	0.613652	0.87786
Tone Voltage	-0.00776	-0.00082	-0.05062	-0.07838
Audio/Tone (dB)	41.67257	61.67257	21.67257	20.98436
Rin	15.88343	15.88343	15.88343	7.187329
At OUTPUT:				
Audio voltage	0.716632	0.756985	0.46745	0
Tone voltage	0.804462	0.809748	0.771815	ERR
Audio/Tone (dB)	-1.00418	-0.58526	-4.35557	ERR

Table 2 The function of the APLIS modelled under typical operating conditions

APLIS: AN AUDIO PEAK LEVEL MONITORING SYSTEM

Voltage Supply range

Recommended 6V[1] to 24V

Absolute Max. 30.6V

Current Required 1.5 mA

(approximately the same whether sounding or not)

Input Voltage Range

0.1V to 3.0V on 0dB setting (peak to peak).[1]

0.2V to 6.0V on +6dB setting (peak to peak)

Tone output frequencies

Primarily at 550Hz and 2475 Hz. (nominal at 9V)

Audio Attenuation

Approximately 2dB (depending on input and output impedances).

Input Impedance

Approximately 15kΩ (depending on input and output impedances).

[1] Note: the 0dB setting is the second most sensitive setting. The user can scale the settings as required when they are calibrating the unit. Throughout this report the levels of -3, 0 , +3 and +6dB have been used - any four levels could be used that are 3dB apart (eg. 0, +3, +6 and +9dB or, for digital recording, -9, -6, -3 and 0dB).

Figure 11 The specifications for the final, PCB constructed (v1.0), circuit.