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A COMPUTER-CONTROLLED AUDIOMETRY SYSTEM

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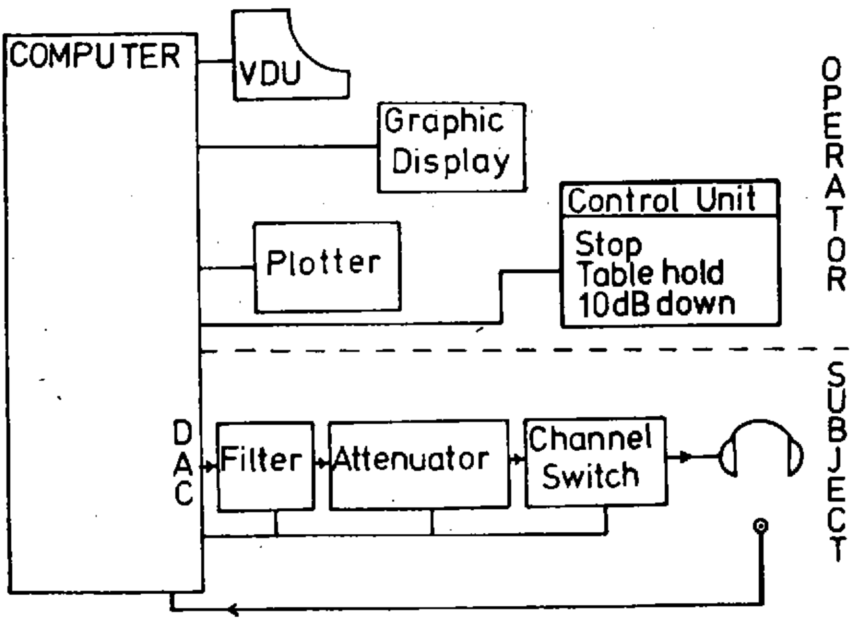
Introduction

A number of accounts have been published of the application of computer technology to the determination of hearing thresholds[1]. These generally refer to attempts to bring traditional manual procedures under computer control. The objective of the work described in this paper was to produce a system complying in essential respects with the proposed international equipment standards [2,3] and capable of performing fixed frequency self recording audiometry.

System Hardware

Figure 1 shows a simplified block diagram of the equipment used.



A COMPUTER-CONTROLLED AUDIOMETRY SYSTEM

The heart of the system is a PRIME 300 minicomputer. The operator controls the test from a visual display unit (VDU) and a control unit in which 3 switches (STOP, TABLE HOLD, and 10 dB DOWN) are connected to the minicomputer digital input system. Results of audiometric tests are displayed on a digital plotter (Tektronix 4662) or graphic display (Tektronix 4051) and on the VDU.

Pulsed, pure tone signals are generated by the computer loading the series of numbers representing the successive samples of the signal into the digital to analogue converter (DAC), triggered by a 20 kHz pulse generator. A single pulse of each frequency used, at maximum amplitude, is kept in disc store and transferred into core store as required. The pulse parameters are in accordance with the proposed IEC equipment standard[2]. The chosen pulse rate (2 per second) is controlled by the computer's real time clock. Signal level variation is achieved by scaling, within the processor, of the maximum amplitude stored signal, over a range of 40 dB, and by computer control of an attenuator (Farnell PA122).

The signals are presented to the subject via earphone (Telephonics TDH-39 with MX-41/AR cushions) or, in the case of bone conduction tests, via a bone vibrator (Radioear B71). In such tests masking noise, generated from a Brüel and Kjaer Type 1402 Noise Generator is passed via a ⅓-octave band filter and attenuator (both computer-controlled) to a similar TDH-39 earphone. The subject's handswitch is connected to the computer digital input system.

Testing procedure

The test begins with the operator calling up the operating programme from the VDU and typing in the subject's name, date of test, etc. Then, in a typical six frequency air conduction test the left ear is tested beginning at a frequency of 500 Hz.

At this first frequency a hearing level of 10 dB is set up by controlling the attenuator. The plotter is directed to the appropriate point and the first pulse is generated. Pulse level is then increased by 2.5 dB by scaling of the sample values as they are transferred from the processor to the DAC. The programme causes the plotter to chart the changes in signal level. When the first change in the subject's switch is detected, i.e. the subject begins to press indicating audibility of the test sound, the attenuator is set to a value such that the 40 dB dynamic range of the DAC is available to vary the signal level during the tracking from 15 dB above to 25 dB below the level at the first inversion. The initial inversion level is stored in a data array and the signal level progressively reduced (2.5 dB per pulse, 5 dB per second). After each pulse the state of the subject switch is monitored until the next inversion occurs. The level is again stored and the signal is caused to increase by 2.5 dB per pulse. The tracking process continues for 60 pulses corresponding to a total time of 30 seconds for a single frequency.

At this time, and before the test proceeds to the next frequency the stored values of the signal levels at the inversions are processed by the threshold calculation algorithm described in DP 6189 (3). This discounts the first inversion and checks for various error conditions, before calculating the mean of the average peak and average valley. This quantity, expressed as hearing threshold level is written by the plotter onto the audiometric recording. The result also appears on the VDU screen, together with any error codes generated by the algorithm. In addition this information, along with the unprocessed inversion data,is stored on disc.

The test then proceeds to the next frequency. When both ears have been tested the left ear test is repeated. The operator can then, if required, repeat the test at up to six selected frequencies. The cycle can also be terminated at any point within the repeat test of the left ear if desired. After a complete test all results can be printed on a line printer.

Calibration

The calibration process is similar to that used on conventional audiometers, the transducer (earphone or vibrator) being attached to an appropriate coupler. Measurement of the sound pressure or vibration level is not automated. A calibration programme is run which generates continuous tones at the test frequencies at a hearing level of 60 dB (re ISO 389)[4]. Adjustments are effected by changing the values of a set of calibration constants used by the main operating programme.

Applications

The first application of the system will be in a study designed to acquire normative data on the air conduction/bone conduction threshold gap in a group of normal subjects who have recently been tested by air conduction with the Laboratory's conventional self recording audiometers[5].

Advantage will be taken of the ability of the system to provide numerical threshold data in "real-time". Thus, for each ear, the air conduction thresholds will be determined. The results will then be used by the computer programme to calculate the amount of masking noise required, and hence the appropriate settings of the computer-controlled attenuator, for the bone conduction tests.

References

(1) See for example, T. HASHIMOTO et al, 1977. J. Auditory Res., 17, 59-76. Computer-aided group audiometry (and references contained therein).

(2) International Electrotechnical Commission, 1978. IEC/29C (Central Office) 3 Audiometers.

(3) International Organization for Standardization, 1977. ISO Draft Proposal DP 6189. Pure Tone Air Conduction Threshold Audiometry for Hearing Conservation Purposes.

(4) International Organization for Standardization. 1975. ISO 389. Standard Reference Zero for the Calibration of Pure Tone Audiometers.

(5) D.W. ROBINSON, M.S. SHIPTON and R. HINCHCLIFFE. 1979. NPL Acoustics Report Ac 89. Normal hearing threshold and its dependence on clinical rejection criteria (in preparation).