AUDIOMETRY...

ASSESSMENT OF HEARING IMPAIRMENTS **By S. A. HARDY**

ELECTRONICS plays a very large part in providing diagnostic and remedial equipment for the hard of hearing. The hearing aid is widely publicised and advertisements for these devices appear regularly in the daily press. However, little mention is made of the diagnostic facilities available, for example, local medical centres and education authorities. Also it is seldom pointed out that a hearing aid should *only* be used if prescribed by an otologist (ear specialist) as in some cases a hearing aid would serve no useful purpose, or may be a source of great discomfort to the user even to the point of accelerating the degeneration of a hearing impairment.

AUDIOMETER

The measurement of the sensitivity of a patient's hearing under set conditions is of prime importance to the otologist who is making a diagnosis of a hearing impairment.

A simplified block diagram of an audiometer is shown in Fig. 1. The audio sine wave generator may be of the continuously variable tuning type, or it may have preselected fixed frequencies which are based on the physical scale of C = 256Hz and not the British standard concert pitch based on A = 440Hz—where C would be 261·6Hz. The output from the oscillator is fed into an attenuator which is calibrated in decibels against laboratory standards. All extraneous equipment, such as the headset and bone conduction transducer, are included in the calibration process.

Signals are passed from the attenuator into a linear frequency response amplifier which drives either the headset or a bone conduction transducer, probably of the type shown in Fig. 2. The headsets used are of the type which exclude external noise, also the earpieces may be independently selected so that whilst one ear is being tested the other can be fed from a masking (white) noise generator at a preset level. This avoids the possibility of erroneous results due to the tone being fed to the ear under investigation being heard by the other through bone conduction.

The basis of the audiometric tests is to select at random certain frequencies and moving the attenuator from maximum attenuation to minimum. The patient presses a switch, illuminating a lamp on the audiometer, as soon as the sound becomes audible. The audiometrician, not necessarily an otologist, then prepares a graph called an audiogram which in this particular case would show the patient's threshold to hearing.

AUDIOMETRIC TESTS

A few audiometric tests used in determination of hearing malfunctions, other than the threshold test mentioned in the previous paragraph, are outlined below to demonstrate the usage of the different transducers:

(a) The *Rinne* test is conducted by placing a bone conduction transducer on the mastoid bone just behind the ear under test—the patient then indicates when a tone is no longer audible at a particular level. The tone is then fed directly to the ear at the same level and should be perfectly audible in the case of the healthy ear. The use of masking noise for the ear not under investigation is necessary to avoid ambiguous results.

(b) The *Weber* test is conducted with both of the patient's ears occluded to external noise and tones are fed to a bone conduction transducer placed on the centre line of the forehead. The patient then indicates the ear in which the tones appear. This test is used to prove the binaural function of the ears.

A range of early horn hearing aids

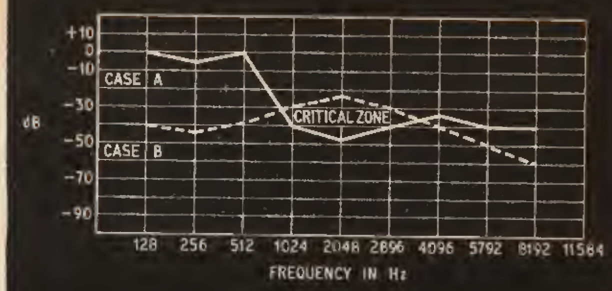


Fig. 3. Audiogram showing the critical area of hearing impairment

(c) The *Gelle* test is carried out by slightly increasing the air pressure in the external auditory meatus and simultaneously introducing a tone via an earpiece. In a normal ear the threshold of hearing slightly increases at frequencies below 1kHz as the pressure is increased. This test is used to show seizure of the stapes.

(d) The *Bing* test is used to demonstrate malfunctions of the middle ear mechanism. This test is carried out by placing a bone conduction transducer against the mastoid bone adjacent to the ear under investigation and the tone level is then turned down until inaudible, then the ear canal is closed off. The tone then becomes audible again in the case of normal ear.

(The titles for the above list are of American origin.)

HEARING AID REQUIREMENTS

Most of the consonants in human speech have frequency products which lie in the range of 1kHz to 4kHz and an impairment of hearing in this frequency range renders speech unintelligible, especially in the presence of background noises. The audiogram (Fig. 3) shows the critical area below which a hearing aid becomes a necessity. For instance case A would find a hearing aid a necessity, even though the low frequency response of the ear is satisfactory. Whereas case B could get by without an aid because the impairment is over the whole frequency spectrum, but there is an improvement over the critical area of the audiogram.

HEARING AIDS

There are many types of hearing aid available from reputable manufacturers. However, the circuits given in Figs. 4 and 5 are Mullard experimental circuits and the design considerations discussed are the same for both aids. Both circuits have TR1 (input) and TR2 (driver) collector currents of approximately 250 microamperes, this being the lowest practicable value consistent with low noise level without signal clipping. Transistor TR3 in both circuits are class A power amplifiers and have standing collector currents of roughly 2·5mA to give outputs of about 0·5mW.

The circuit in Fig. 4, though having more components, is able to cope with large variations in ambient temperature and by siting the volume control between the input and driver stages contact noise generated by the microphone is reduced. If a mercury cell (such as the Mallory RM625) is used; the decoupling components R3 and C3 may be omitted and the cell life is about 100 hours. This circuit gives an output of 0·4mW for 5 per cent total harmonic distortion with an

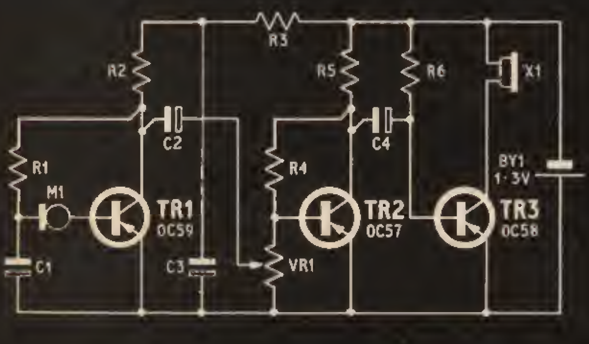


Fig. 4. Hearing aid circuit by Mullard

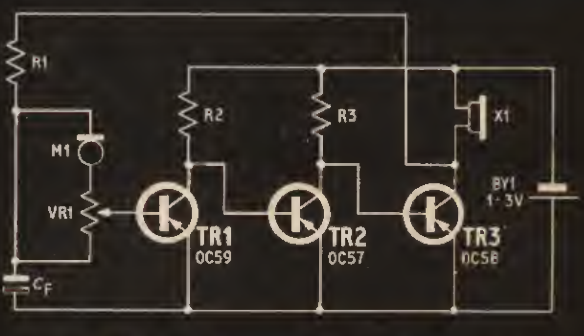


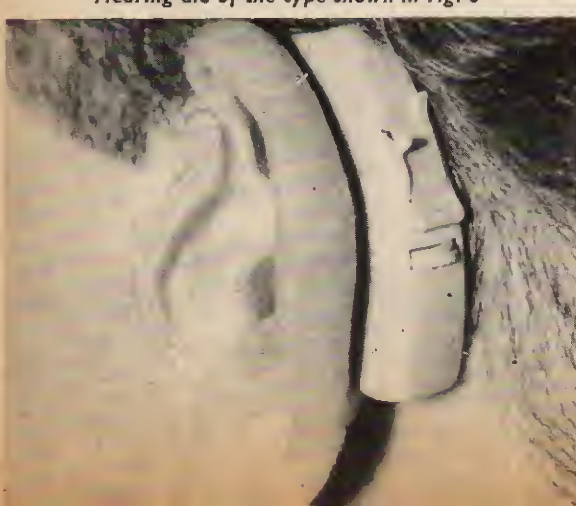
Fig. 5. Mullard hearing aid circuit using a d.c. amplifier

The Audiorama headrest type hearing aid

electrical frequency response that is flat to within 0·25dB between 100Hz and 4kHz.

The circuit of Fig. 5 is intended for use in spectacle frames, hence the requirement of the minimum number of components. However, the d.c. coupled amplifier of this type relies on the feedback loop to govern the d.c. stabilisation of the transistors and their temperature dependent characteristics. Thus the choice of R1 and C_f are critical, as R1 sets TR3 collector standing current and C_f affects the working frequency range of the circuit. A loss of 6dB at 1kHz is considered permissible and a time constant of one second ($R1 \times C_f$) is required. The predicted electrical frequency response of this circuit is within 1·5dB of the response level at 1kHz over the range of 300Hz to 5kHz. However, the battery drain is slightly higher and the circuit has an ambient temperature limitation of 0 to 39 degrees C, the ideal working point being set at 25 degrees C.

Hearing aid of the type shown in Fig. 6



Both circuits have an approximate acoustic gain of 50dB allowing for an overall air to air loss in the microphone and earpiece of 35dB.

TRANSDUCERS

Both circuits (Figs. 4 and 5) use electromagnetic devices for the microphones and earpieces. Two advantages of the electromagnetic device are that it is not affected by high humidity levels and it is less sensitive to contact noise than the higher gain crystal counterpart. Most hearing aids are designed to drive electromagnetic earpieces or bone conduction transducers which are sometimes used for certain types of deafness.

Some aids, such as the spectacle frame or behind the ear device, have the transducer mounted in the body of the aid with a small bore ($\frac{1}{8}$in internal diameter) flexible polythene acoustic coupling tube which terminates in a special acrylic perspex ear insert as shown in Fig. 6. Also the type of transducer that is fitted directly into the outer ear canal, though similar to the earpiece supplied with some transistor radios, has the ear insert moulded to fit the individual's ear for maximum efficiency and comfort.

When a hearing aid is prescribed utilising either of the above inserts, casts are made by the consultant from which the insert is manufactured. This is done by filling the contours of the part of the ear where the insert is to be situated with a special compound. The compound consists of two chemical components which,

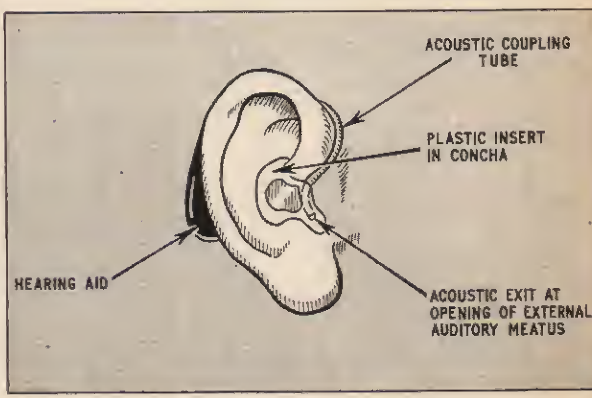


Fig. 6. A hearing aid using an acoustic coupling from the transducer in the aid to the outer ear canal

on mixing, are semi fluid but rapidly harden after a short period of time though retaining a certain amount of flexibility. This impression is then used to form the casting mould for the plastic insert. The process is much the same for the manufacture of dentures.

It is not usually convenient to use a hearing aid all the time and some people do have hearing impairments that do not require the use of an aid. For this reason Audiorama (a member of the Plessey group of companies) manufacture a headrest for domestic usage in conjunction with television, radio, tape and disc replay equipment. The headrest (Fig. 7) also provides protection from the hazard of equipment using the live chassis a.c./d.c. technique.

Future trends with the advent of integrated circuits should result in even smaller hearing aids with much improved frequency responses and power gains allowing for the limitations of acoustic feedback. ★