PHYSICS

A Simple Low-Noise Low-Frequency Transistor Amplifier

The properties of the amplifier to be described are entirely due to the type of transistor used, and the purpose of this communication is to report on its suitability for the amplification of electro-physiological wave-forms, particularly those originating in the brain. Of the commonly recorded physiological potentials, the electroencephalogram (EEG) presents the most difficulties because of the low voltage (10–1,000 μV.) and low frequency (1–50 c./s.) of its components. Recordings are usually obtained from electrodes on the scalp which give an output impedance of the order of 10,000 ohms. Hitherto, transistors have been unsuitable for amplifying these potentials direct because their intrinsic noise at low frequencies was too high and because the input impedance of the simpler circuit configurations was too low—about 1,000 ohms in the common emitter mode.

However, a new type of planar silicon transistor (Texas Instruments Inc., Type No. 2*N*929), designed to have low noise, has recently become available. Furthermore, because of the low currents at which it can be operated, it has a high input impedance when used in the common emitter mode. The circuit of Fig. 1 probably does not represent the best that can be devised for this transistor, but it gives a useful performance as an amplifier, providing a gain of about 30 and presenting an input impedance of about 200,000 ohms for a transistor power consumption of 10 μamp. at 3 volts.

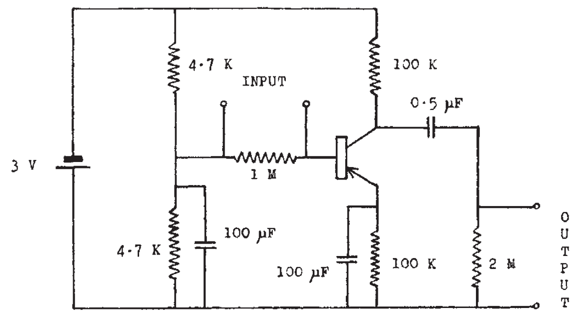

Fig. 1

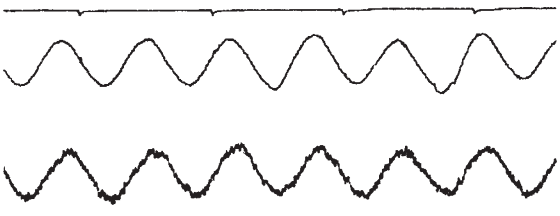

Fig. 2. Upper trace, 1-sec. time marker; middle trace, 5-μV. peak-to-peak input at 1·5 c./s. from a source impedance of 100 ohms, via transistor amplifier; lower trace, same input via EEG amplifier

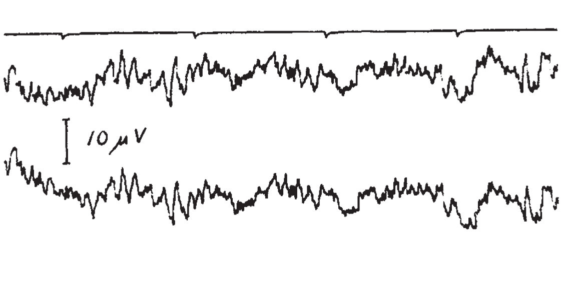

Fig. 3. Upper trace, 1-sec. time marker; middle trace, EEG signal via transistor amplifier; lower trace, same signal via standard EEG amplifier

The noise-level is illustrated in Fig. 2. The middle trace shows the output from the transistor amplifier (further amplified by a conventional EEG channel working at low gain) for an input of 5 μV. peak-to-peak at 1½ c./s. derived from a source impedance of about 100 ohms. The lower trace shows the same signal amplified by another channel of the same EEG machine. The transistor amplifier has a noise-level of appreciably less than 1 μV. referred to the input. This is better than that obtained by an average EEG amplifier of which the lower trace is a typical example. Fig. 3 shows a low-voltage EEG signal derived from a pair of standard padded electrodes on the scalp and recorded by both methods at a sensitivity of 10 μV./cm. These traces suggest that the noise-level of the transistor amplifier is not sensibly worsened by the higher output impedance of ordinary EEG electrodes—about 8,000 ohms in this case.

A floating single-ended amplifier stage of this kind, with one side of the power supply earthed, has an in-phase rejection ratio of zero. However, the low-power requirements of these devices, which make it possible to use power supplies completely isolated from earth, open up new possibilities for the attainment of very high in-phase rejection ratios. Work is in hand to devise practical arrangements.

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X-Ray Yields from Elements in the Range Beryllium to Aluminium

Absolute measurements have been made, it is believed for the first time, of the *K* X-ray quantum yields resulting from electron bombardment of solid targets containing the elements beryllium, boron, oxygen and fluorine. For beryllium and boron 99 per cent pure targets were used while beryllium oxide and lithium fluoride were used for the oxygen and fluorine yields; corrections were applied for electron and X-ray absorption in the beryllium and lithium respectively. The yields from carbon (graphite) and aluminium targets have also been measured.

The X-ray count-rate was determined by pulse height analysis of the output from a gas-flow proportional counter filled with argon plus 2·5 per cent carbon dioxide. An essential feature of this counter was the provision of a very thin nitrocellulose entrance window capable of withstanding a pressure difference of one atmosphere: for the beryllium measurements this was only about 1000 Å. thick. After subtraction of the continuous radiation from the pulse height distribution, the measured *K* radiation count-rate was corrected for instrumental effects, such as the variation of counter efficiency with X-ray wave-length. A range of incident electron energies between 500 and 30,000 eV. was used on each target; the current was independently controlled and was varied between 5×10^{-10} and