British Patent No. 530,506 the invention provides 'a wide angle eyepiece; in which the available image field has in the front focal plane of the eyepiece a diameter that is as great as the focal length of the eyepiece; whose distortion is eliminated, in which the difference between the enlargements of the colours red and blue is removed without use being made of more than one lens of flint glass; in which the astigmatism is reduced at the margin of the image field to such an extent that it has only such a value as results from the Petzval image curvature; in which the deviation of the locus of the eye is eliminated or even assumes a value reverse to the ordinary one, so that the shadow phenomenon in the field of view is reduced; and in which the brilliancy is increased by approximately 12 % by reducing the free lens groups.' For this eyepiece the focal lengths of the two components are 3·15 and 1·42. Σ= +0·74 and E.C.=66 % (Fig. 26). The glasses used are B.S.C. and E.D.F.

(27) The second is by Messrs Barr and Stroud Ltd. and describes a 3-1 combination of the orthoscopic type in which the simple eye lens is bounded by an aspherical surface on the side remote from the eye. No such claims are made as characterize the preceding example but an apparent field of 64° is implied. The focal lengths of the two components are 3·91 and 1·19. Σ= +0·78 and E.C.=91 % (Fig. 27). The glasses used are B.S.C. and E.D.F.

For convenience, particulars of all the above eyepieces have been tabulated. It would be a matter of some interest to evaluate the residual aberrations in every case, but the exigencies of war do not permit this. It will be seen, however, that the compact form of eyepiece favours the Petzval sum and that the simple eye lens favours the eye clearance. It will be
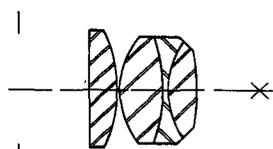

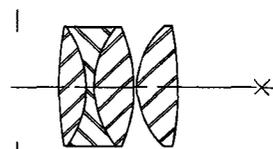Fig. 26. Zeiss eyepiece (type 1-3)

Fig. 27. Barr and Stroud eyepiece (type 3-1)

seen also that a good eyepiece is required simultaneously to form two images under different conditions of ray vergency, namely to project a good virtual image of the image formed by the objective and also to form a good real image of the objective aperture to form the exit pupil.

It will also be noted that many of the newer types of optical glass, particularly the Dense Barium Crowns and Double Extra Dense Flints, have found a place in the modern inverting eyepiece.

Particulars of inverting eyepieces

Fig.	Type of eyepiece		Focal length	Focal lengths of components				Approx. field	Petzval sum Σ	% eye clearance	Patent no.
				1	2	3	4				
1	Monocentric	1	1·0	1·0	—	—	—	30°	+0·74	85	—
2	Huyghenian	1-1	1·0	1·75	0·70	—	—	50°	+1·33	30	—
3	Compensating	2-2	1·0	1·33	0·76	—	—	40°	+1·27	25	—
4	Ramsden	1-1	1·0	1·0	1·0	—	—	40°	+1·33	—	—
5	Ramsden	1-1	1·0	1·25	1·25	—	—	40°	+1·07	25	—
6	Kellner	1-2	1·0	1·78	0·81	—	—	40°	+0·91	45	—
7	Cooke	1-3	1·0	1·64	1·01	—	—	50°	+1·03	45	125,430
8	Zeiss	1-1-2	1·0	1·97	1·36	−4·94	—	50°	+0·82	34	188,200 (German)
9	Cooke	1-3-2	1·0	7·86	2·33	1·80	—	60°	+0·86	69	126,837
10	Dial sight	2-2	1·0	1·76	1·76	—	—	40°	+0·82	77	—
11	Zeiss	2-2	1·0	2·20	1·78	—	—	?	+0·67	64	509,585
12	Zeiss	1-2-2	1·0	1·70	1·25	1·25	—	70°	+1·44	32	144,321
13	Orthoscopic	3-1	1·0	2·64	1·48	—	—	40°	+0·78	80	—
14	Zeiss orthoscopic	3-1	1·0	2·77	1·51	—	—	70°	+0·64	82	509,585
15	Berthele	1-1-2	1·0	2·62	2·29	2·96	—	?	+0·55	80	233,308
16	Zeiss	1-2-1	1·0	2·31	6·08	1·96	—	?	+0·77	67	509,990
17	Kapella	1-2-2	1·0	2·96	2·83	2·77	—	70°	+0·69	68	409,464
18	Goerz	1-3-1	1·0	3·56	3·67	1·63	—	?	+0·75	59	215,337
19	Zeiss	2-1-1	1·0	6·75	2·60	2·43	—	?	+0·66	92	509,990
20	Zeiss	2-1-2	1·0	4·31	2·79	4·49	—	70°	+0·64	60	145,503
21	Zeiss	2-2-1	1·0	2·05	3·44	1·86	—	70°	+0·96	56	175,966
22	Unknown	2-2-2	1·0	6·60	3·42	1·90	—	60°	+0·65	72	—
23	Goerz	2-3-2	1·0	2·42	2·95	2·79	—	?	+0·79	46	215,337
24	Zeiss	3-2-1	1·0	3·71	2·82	2·21	—	?	+0·77	69	509,990
25	Unknown	2-3-1-1	1·0	4·76	3·76	2·54	3·18	63°	+0·82	70	—
26	Zeiss	1-3	1·0	3·15	1·42	—	—	?	+0·74	66	399,452
27	Barr and Stroud	3-1	1·0	3·91	1·19	—	—	?	+0·78	91	530,506

On the Measurement of Small and Slow Potential Variations by Means of Frequency Modulation

By C. A. BEEVERS, D.Sc., F.Inst.P., and R. FÜRTH, D.Phil., F.InstP., University of Edinburgh

ABSTRACT. An improved design of apparatus is described in which a small potential difference is amplified and caused to alter the frequencies of two high frequency oscillator circuits by means of frequency modulation. The change of pitch of the beat note is made audible and is taken as a measure of the original potential difference. The design is symmetrical throughout and is capable of measuring potential changes in the order of $1\,\mu$V in time intervals of the order of 1 sec. There are possible applications of the device to the measurement of small and slow fluctuations of pressure, light intensity, and temperature.

Some time ago the present authors[1, 2] published the description of a new instrument, the 'Encephalophone', to be used as an acoustical method for the investigation of the rhythmic potential changes produced on the scalp by the activity of the nerve cells of the brain. The order of magnitude

of these potential changes is between 1 and 100 μV, and that of the frequency between 1 and 10 c/s. This method has some advantages over the standard method of oscillographic recording; on the one hand the apparatus required is cheap and easily transportable; on the other hand, it makes use of the extreme sensitivity of the human ear for the detection of small changes in pitch and for estimating musical intervals. Finally, it does not interfere with other visual observations the observer might have to perform simultaneously. For similar reasons acoustical methods are used extensively in physics and physical chemistry, e.g. bridge methods where telephones are used instead of galvanometers.

In the meantime the authors have tried to improve the performance of the device in several respects, and have succeeded in constructing a compact instrument which is working very satisfactorily. As it seems that this instrument could be also used for other investigations in the field of physics, physical chemistry, and physiology where very small and slow potential variations occur, a brief description of it is given in the following.

Fig. 1 shows the circuit diagram. The instrument consists of two separate parts, each mounted separately on an aluminium chassis and carefully shielded against external disturbances. Both parts are fastened together so that they can be carried about. The whole instrument is seen in Fig. 2. Its dimensions are about 12 in. × 12 in. × 14 in., and its weight, without batteries, about 12 lb.

The amplifier part is seen in the upper half of Fig. 1. It consists of a six-valve symmetrical amplifier with resistance-capacity coupling, especially designed for linear amplification
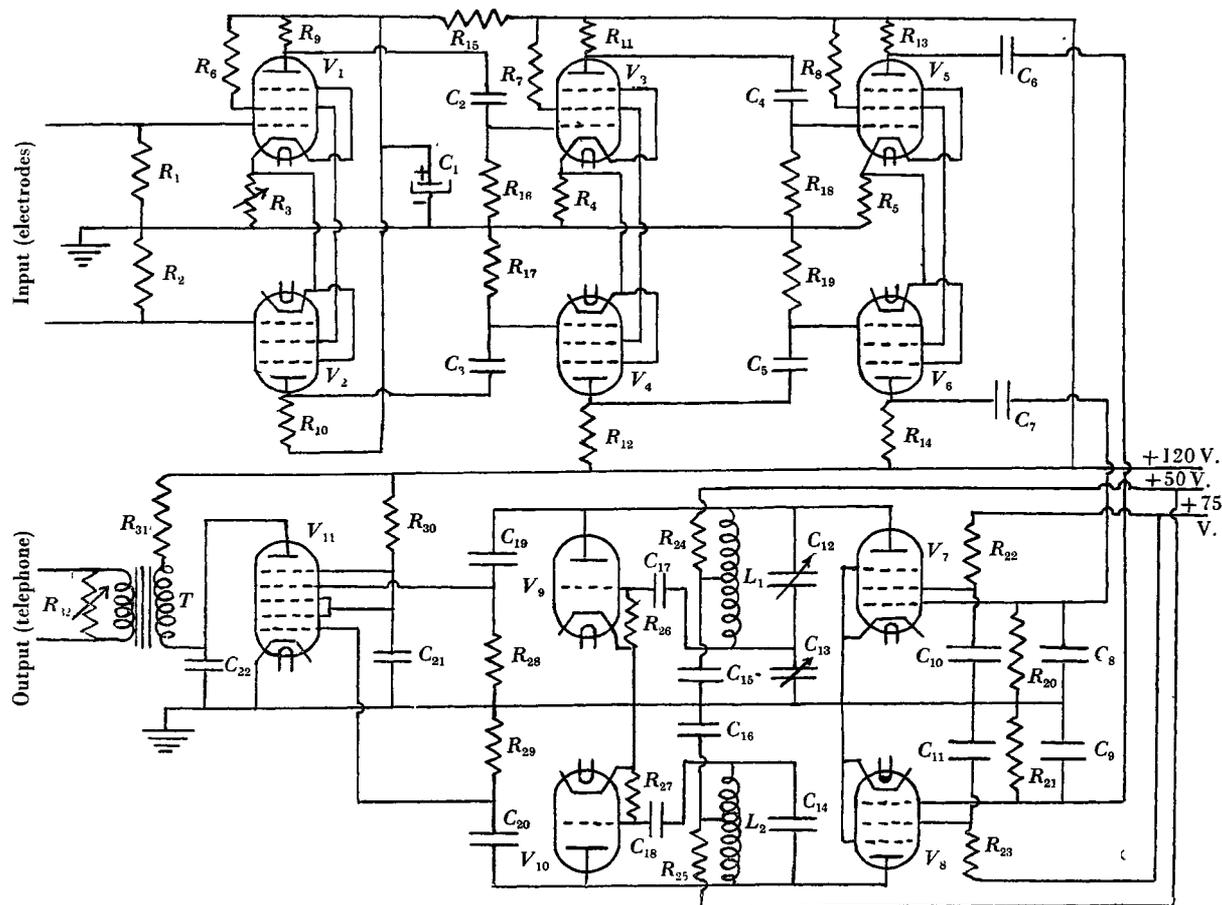

Fig. 1. Circuit diagram

T	Output transformer	R_{13}, R_{14}, R_{15}	50,000 Ω carbon resistors
$V_1, V_2, V_3, V_4, V_5, V_6$	High-frequency pentode valves EF 36 (Mullard)	$R_{16}, R_{17}, R_{18}, R_{19}, R_{20}, R_{21}$	2 MΩ carbon resistors
V_7, V_8	'Variable mu' pentode valves AC/VP 1 (Mazda)	$R_{22}, R_{23}, R_{24}, R_{25}$	5000 Ω carbon resistors
		$R_{26}, R_{27}, R_{28}, R_{29}$	50,000 Ω carbon resistors
V_9, V_{10}	Triode valves AC/HL (Mazda)	R_{30}, R_{31}	5000 Ω carbon resistors
V_{11}	Octode frequency changer FC 4 (Mullard)	R_{32}	10,000 Ω potentiometer
		C_1	30 μF electrolytic condenser
R_1, R_2	2 MΩ carbon resistors	$C_2, C_3, C_4, C_5, C_6, C_7$	1 μF paper condensers
R_3	1000 Ω variable resistor	C_8, C_9, C_{10}, C_{11}	50,000 $\mu\mu$F paper condensers
R_4	800 Ω carbon resistor	C_{12}	Variable 200 $\mu\mu$F condenser
R_5	300 Ω carbon resistor	C_{13}	Variable 50 $\mu\mu$F condenser
R_6, R_7, R_8	150,000 Ω carbon resistors	C_{14}	100 $\mu\mu$F paper condenser
R_9, R_{10}	50,000 Ω carbon resistors	C_{15}, C_{16}	50,000 $\mu\mu$F paper condensers
R_{11}, R_{12}	80,000 Ω carbon resistors	C_{17}, C_{18}	100 $\mu\mu$F paper condensers
		$C_{19}, C_{20}, C_{21}, C_{22}$	50,000 $\mu\mu$F paper condensers

in the frequency region mentioned above. Its amplification is about 500,000-fold under normal conditions, but is reduced in the present instrument to about 100,000-fold by using lower heater current and anode voltage. This amplification is sufficient to make potential changes in the mentioned order of magnitude clearly audible, whereas the simple two-stage amplifier, described in the former publications was not sufficient in itself. The new amplifier is also, because of its symmetrical design, less affected by external disturbances and almost free of the 'blocking' effects encountered before and caused by sudden and accidental large potential changes between the electrodes.
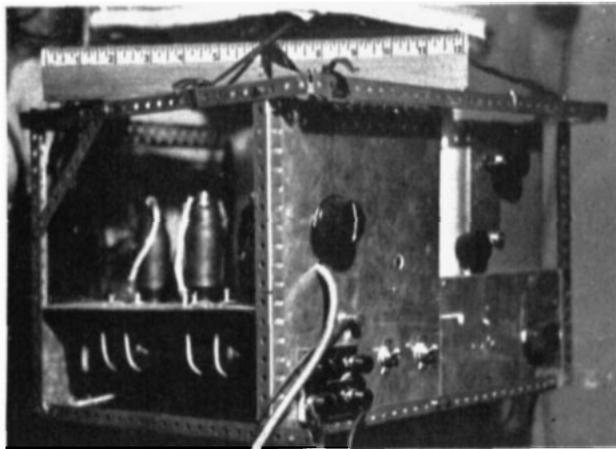

Fig. 2. Apparatus for measurement of small and slow potential variations by means of frequency modulation

The second part of the instrument, shown in the lower half of Fig. 1, is a device for transforming potential changes into changes of pitch of a musical note produced by the instrument. It consists of two high-frequency oscillators (triode valves in connection with Hartley oscillating circuits), each of which is connected in parallel to a frequency modulator valve (variable-mu pentode), and a mixer valve (frequency changer) which produces an alternating current of a frequency equal to the difference between the frequencies of the oscillators. This alternating current is fed into a telephone through an output transformer. This arrangement is practically the same as that described before, except that the former one contained only one frequency modulator as compared with the new completely symmetrical arrangement, which apart from the fact that it doubles the sensitivity, also makes the instrument independent of the earthing conditions of the object to be investigated.

The order of magnitude of the high frequencies is 5 Mc/s. By adjusting the frequency of one of the oscillators by means of the variable condensers C_{12} and C_{13} the difference between them can be easily set to any convenient value in the acoustical range, say e.g. 500 c/s, which will be heard in the telephone as a musical note of this pitch. The tone, once set, keeps its pitch with remarkable constancy. A small change in the potential difference between the control grids of the modulator valves results in a small change of frequency of the corre-

sponding oscillators, and hence in a relatively large change of pitch of the telephone tone, proportional to the mentioned variation of potential difference. In the present instrument a potential change of 0·1 V produces an alteration of pitch of about a whole tone which is easily heard by anybody. The function of the amplifier is to enlarge the original potential changes sufficiently before they are applied to the modulator grids. With an amplifier giving a 100,000-fold amplification a change of pitch of one whole tone corresponds to approximately 1 μV, and a potential variation of 10 μV thus produces a change of pitch of about one octave.

All the valves used in the present set are indirectly heated (the heater circuit not being shown in the diagram). The heater current of about 5 A is provided by two accumulator cells. If it is desired to reduce the capacity of the heater cells in order to reduce the weight of the whole apparatus the valves can, of course, be replaced by directly heated ones. A high-tension dry battery of 120 V (with tapping holes) is sufficient for all the anode and grid voltages. No special shielding of the batteries is necessary, but no leads carrying alternating current should be near the instrument unless shielded by earthed metal tubing.

The original purpose of the instrument was, as mentioned before, to provide a simple method for the investigation of a special kind of electro-physiological phenomenon; although this method does not give as complete a knowledge about the details of the process as the encephalographic recording instruments, it was found to be quite sufficient for the detection of deviations from the normal. It also proved to be a useful means for demonstrating the phenomenon to a large audience which is hardly possible with other existing methods. It is obvious that the method might also be used for the investigation of other electro-physiological phenomena.

A further field for the application of the method is the investigation of piezo-electric phenomena where it could be used for routine testing of piezo quartzes and other crystals (3). A change of sign of the piezo-electric effect, for example, would be immediately made obvious. Indirectly the connexion of the encephalophone with a piezo quartz provides an extremely sensitive device for detecting and estimating the magnitude of very small and slow mechanical oscillations and waves. Similarly, investigations on light intensity variations could be carried out by a combination of the encephalophone with a photocell, and on temperature variations by the combination with a thermocouple or thermopile. Also in this way such phenomena can be readily demonstrated to a large audience.

We wish to thank Mr T. Sheddan for his valuable help in building up a part of the instrument and Mr A. W. Russell of Mullards Wireless for letting us have the diagram of the amplifier used in some of their instruments and also for providing us with some components.

REFERENCES

(1) FÜRTH, R. and BEEVERS, C. A. Nature, 151, p. 111 (1934).
(2) BEEVERS, C. A. and FÜRTH, R. Electronic Engineering (March 1943).
(3) VIGOUREUX, P. Quartz Resonators and Oscillators (London: H.M. Stationery Office, 1931).

Slow-Time Sweeps for a High-Speed Cathode-Ray Oscillograph

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ABSTRACT. Occasions arise when it is desirable to use a longer sweep on a high-speed cathode-ray oscillograph than that obtainable from normal-sweep circuits. The paper describes a circuit which employs the voltage change on a condenser during charging via a high resistance from the cathode voltage supply of the high-speed cathode-ray oscillograph. Practical circuit details and performance are discussed and examples of the results obtained with it are given.