

- [54] **ELECTROENCEPHALOPHONE AND  
FEEDBACK SYSTEM**
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- [22] Filed: **Jan. 18, 1971**
- [21] Appl. No.: **107,215**
- [52] U.S. Cl. .... **128/2.1 B, 128/1 C**
- [51] Int. Cl. .... **A61b 5/05**
- [58] Field of Search .... **128/2.1 A, 2.1 B,**  
**128/2.1 R, 2.06 R, 1 C, 422**

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[57] **ABSTRACT**

An electroencephalophone which is battery operated and completely self-contained in a headset to be worn by the user and having a plurality of scalp electrodes carried on flexible leads permitting placement of the electrodes on the user's head when the headset is mounted thereon and having an electronic circuit and transducer for converting brain wave signals picked up by the electrodes into recognizable audio tones enabling the user to listen to his own brain wave generation. The scalp electrode signals are amplified and chopped by an audible oscillator signal the frequency of which is controlled by the scalp electrode signals. The resulting combined amplitude and frequency modulation of the audible generator tone provides a distinctive sound for brain wave recognition.

**19 Claims, 7 Drawing Figures**

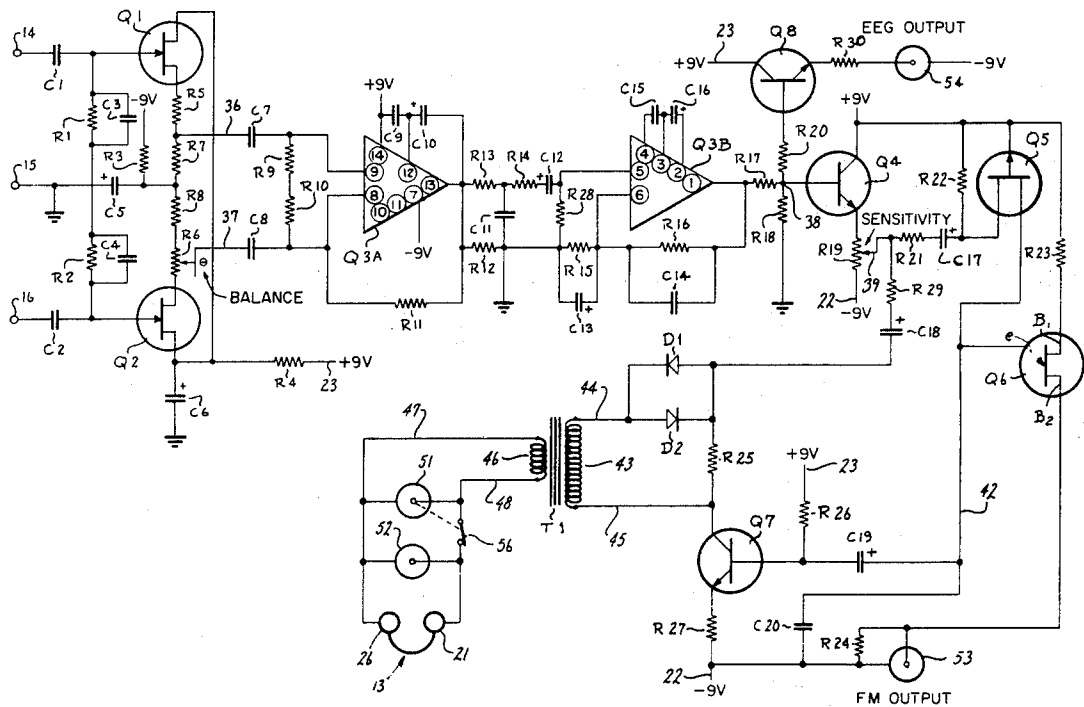


Fig. 1

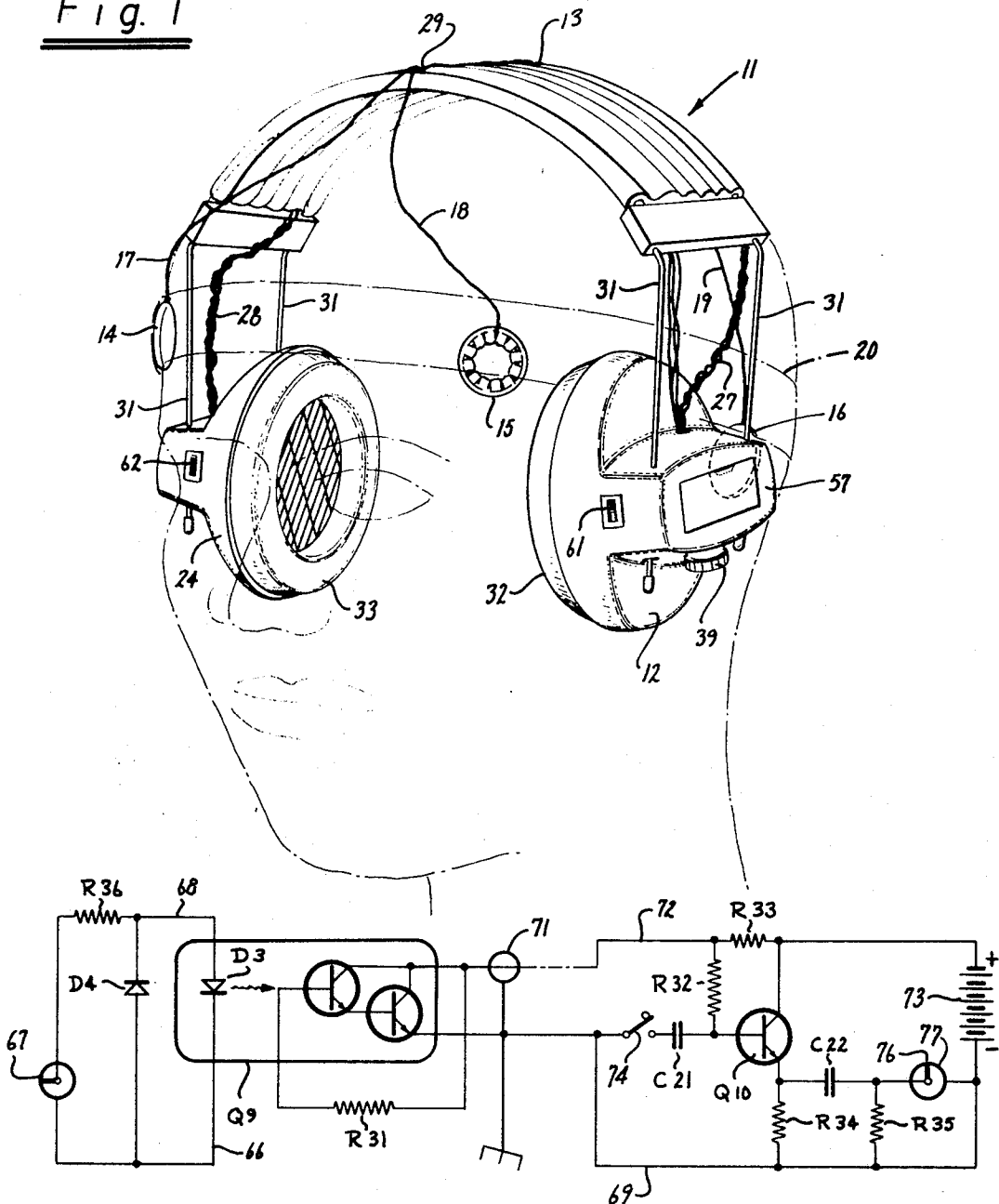


Fig. 7

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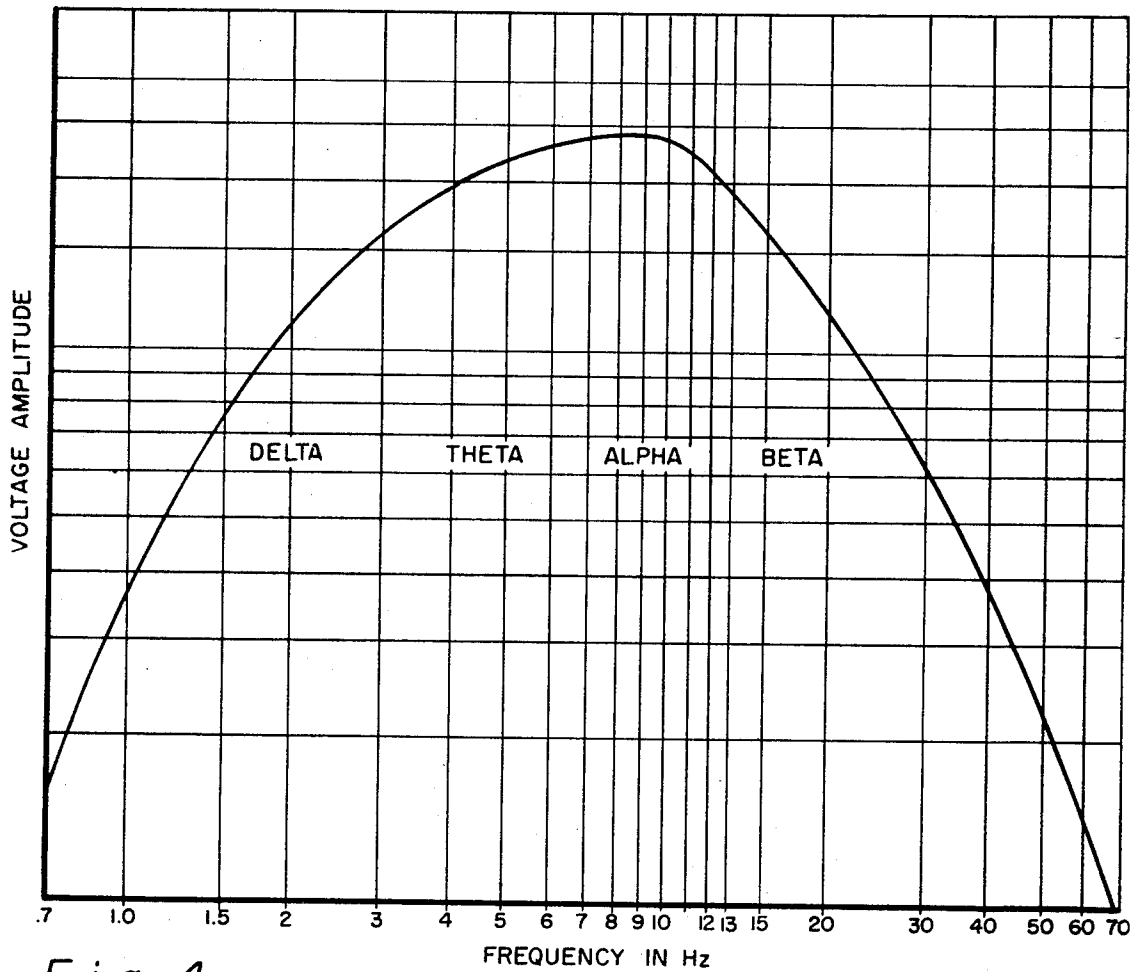


Fig. 4

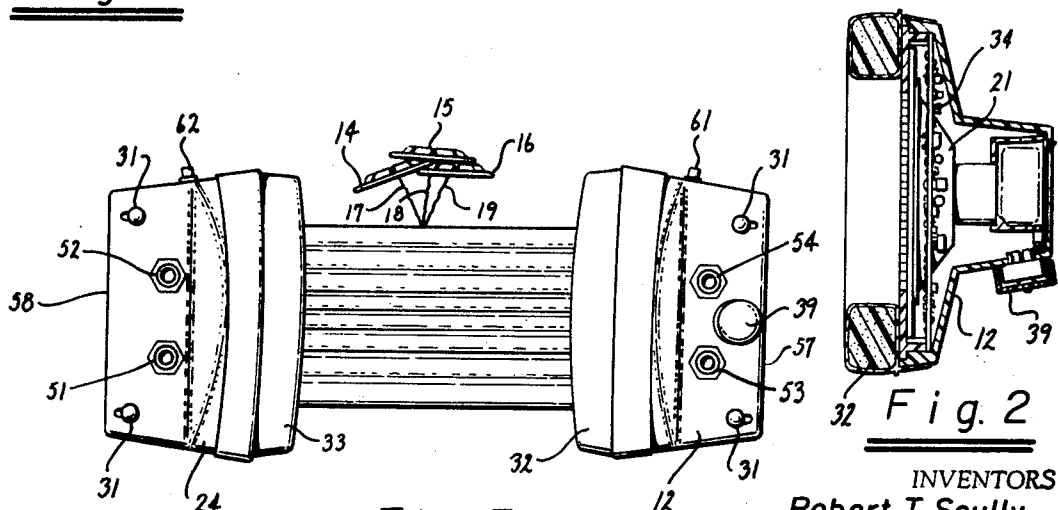


Fig. 3

Fig. 2

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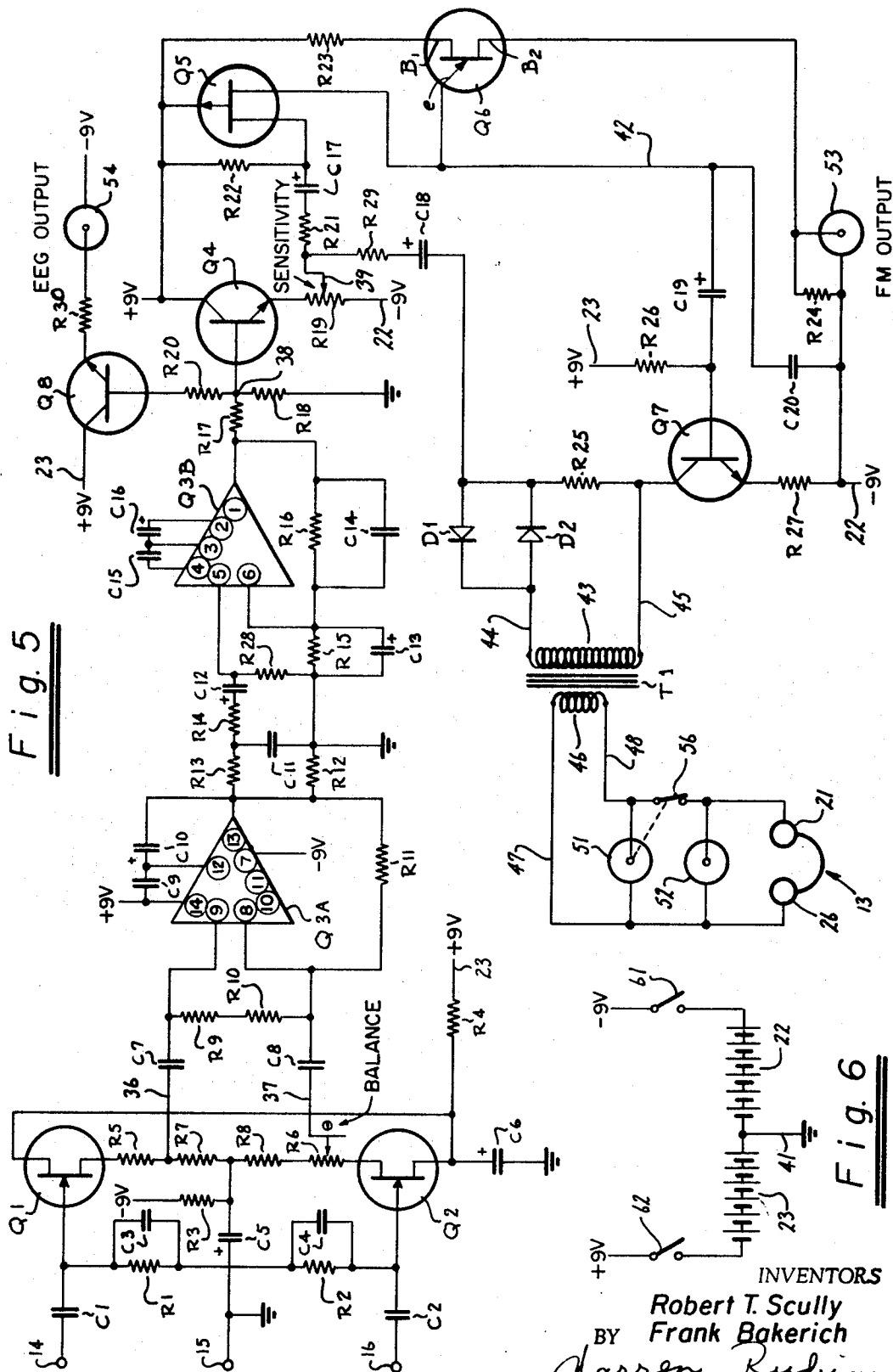


Fig. 5

Fig. 6

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## ELECTROENCEPHALOPHONE AND FEEDBACK SYSTEM

The invention relates to electroencephalographs in which the EEG output is converted into an audio signal enabling audio study and analysis of the type and character of brain waves being generated.

Researchers and investigators have found that there is a relationship between subjective states of mind and observable brain wave activity as seen with the aid of an electroencephalograph (EEG). Anxiety, focused attention, relaxed inattention, the various stages of sleep, and meditation appear to have correlating brain wave patterns. Anxiety, focused attention and active thought tend to produce beta waves considered as those having a frequency greater than about 13 Hz. Relaxed, alert inattention, with the eyes closed or at least defocused with no patterned visual input, will tend to produce alpha waves considered as those having frequencies from about 8 Hz to about 13 Hz. Deeper states of relaxation, meditation, sleep will involve lower frequencies in the theta and delta ranges considered as between about 4 Hz to about 8 Hz, and below 4 Hz respectively. The electroencephalograph thus provides an important research, educational, and training tool to aid doctors, investigators and patients in better understanding and achieving various states of mind. For example, there has been a continuing search for a means of achieving a peaceful state of mind. Various meditative techniques, some very ancient and some quite new, have been and are being used. However, these techniques have a common drawback in that they do not provide an immediate feedback as to the progress that the individual is making. It is known that a peaceful, meditative state of mind is accompanied by the production of alpha waves and experimental studies have shown that a person, given appropriate feedback information as to the brain waves he is generating, can learn to turn on the alpha rhythm at will.

Various forms of feedback information have been proposed. It has been found that the sense of hearing is far superior to the sense of sight as a harmonic analyzer, and is therefore more adept at detecting and analyzing patterns of activity. Stewart, Belcher and Morris, *Auditory Analysis of Electroencephalogram: Electroencephalophony, Encephalography and Clinical Neurophysiology*, Volume II, pages 161-164 (May, 1959 ed.). The practical difficulty with listening to brain wave patterns directly is that the clinically interesting frequencies are in the sub-audible range. The brain's electrical output must therefore be transformed before the analytical merits of the human auditory system can be utilized. The mentioned publication describes several methods by which this can be accomplished and suggests a combined amplitude and frequency modulation of an audio carrier by the brain waves as providing a highly satisfactory method.

One of the disadvantages of EEG equipment heretofore available for research, study and training has been the high cost of such equipment and accordingly the investigations have so far been conducted in the research settings of major medical laboratories. Circuitry and components heretofore developed and used have been complex and relatively large and cumbersome. An object of the present invention is to provide an electroencephalograph feedback system of the character described in which the very best of earlier techniques

are used, e.g., amplitude and frequency modulation, while at the same time circuitry and components have been modified and evolved to provide a small inexpensive yet completely effective instrument.

Another object of the present invention is to provide an electroencephalophone of the character described which is battery operated and completely self-contained whereby all of the apparatus is exclusively and comfortably worn on the head of the user without any trailing wires and thus affording the user mobility, convenience and safety from electric shock.

A further object of the present invention is to provide an electroencephalophone of the character above which may be mounted on the head of the user with ease and facility, is easy to operate, and in which the desired brain waves are amplified and raised in pitch to a pleasant comfortable audio frequency, substantially free of background noise.

Still another object of the present invention is to provide an extremely small, battery operated EEG circuit combined with an electroencephalophone and output circuit providing FM telemetry data and a direct EEG signal, the total system being sufficiently small and light in weight to be comfortably worn on the head of the user.

Still a further object of the present invention is to provide an electroencephalophone of the character above which will provide dependable substantially carefree service over a long period of use.

The invention possesses other objects and features of advantage, some of which of the foregoing will be set forth in the following description of the preferred form of the invention which is illustrated in the drawings accompanying and forming part of this specification. It is to be understood, however, that variations in the showing made by the said drawings and description may be adopted within the scope of the invention as set forth in the claims.

Referring to said drawings:

FIG. 1 is a perspective view of an electroencephalophone constructed in accordance with the present invention.

FIG. 2 is a cross sectional view of a portion of the electroencephalophone.

FIG. 3 is a bottom view of the electroencephalophone.

FIG. 4 is a graph of the electronic amplifier output.

FIG. 5 is a schematic wiring diagram of the electronic circuit.

FIG. 6 is a schematic wiring diagram of the battery circuit.

FIG. 7 is a schematic wiring diagram of a photo coupler used in connection with the present system.

The electroencephalophone of the present invention has as one of its principal features the fact that it is entirely self-contained in association with a headset 11 having at least one earphone housing 12 and a headband 13 connected thereto for mounting on the head of the user; a plurality of scalp electrodes 14, 15 and 16 adapted for mounting on the user's head to provide an electric signal pickup of brain waves; electronic circuit means, see FIGS. 5 and 6, for converting brain wave signals into an audio output signal and being mounted in housing 12; flexible leads 17, 18 and 19 carried by the headset and connected to electrodes 14, 15 and 16 permitting placement of the latter on the user's head when the headset is mounted in place and connecting

the electrodes to the input of the electronic circuit means; a transducer 21 in housing 12 connected to the output of the electronic circuit means; and a battery 22 mounted in housing 12 for powering the electronic circuit.

Preferably a binaural headset is used having a pair of earphone housings 12 and 24 each fitted with a transducer 21 and 26 (see FIG. 5); and advantage is here taken of the second earphone housing 24 to include therein a second battery 23 connected in the circuit as seen in FIG. 6. Electric cables 27 and 28 extend between the housings 12 and 24 through a conduit provided in the headband 13; and leads 17, 18 and 19 are here conveniently mounted through an opening 29 in the headband conduit. Housings 12 and 24 are here mounted for reciprocation on headband rods 31 for adjusting the headset to the user's head; and the housings 12 and 24 are preferably provided with the usual ear pads 32 and 33. The electronic circuit as seen in FIGS. 5 and 6 is miniaturized and constructed on a circuit board 34 in housing 12.

With reference to FIGS. 5 and 6, the electroencephalograph feedback system of the present invention comprises briefly a balanced, differential input, high impedance amplifier which accomplishes the task of initially picking up the weak brain wave signals at electrodes 14, 15 and 16 and amplifying these signals to a relatively high voltage which can be used to drive the amplitude and frequency modulation portions of the circuit. The amplifier is here composed of a pair of source follower field effect transistors Q1 and Q2 connected to a pair of operational amplifiers Q3A and Q3B. Q1 and Q2 comprise a preamplifier whose purpose is to provide high input impedance. Field effect transistors offer the advantages of lower equivalent input noise and lower costs. Electrode 14 is here connected through capacitor C1 to the gate of transistor Q1; electrode 15 is connected to ground and through capacitor C5 to the midpoint of voltage divider made up of R5, R7, R8 and R6 connected in series between the drain and source of Q1 and Q2. Electrode 16 is connected to the gate of Q2 through capacitor C2. Similar input RC impedance networks R1, C3 and R2, C4 are connected in the input circuits to Q1 and Q2.

The input amplifier Q1 and Q2 functions to provide a high input impedance for the electrodes 14-16 so as to make less critical the quality of the contact of the electrodes with the scalp. Preferably R6 is made adjustable and may be set to a balanced condition at the factory. With such an input amplifier, the electrodes 14-16 see a very high impedance, as compared to the input of operational amplifier Q3A. Input condenser C1 is connected to the base of Q1. The addition of C3 in the input impedance provides protection against radio frequency noise. Q1 and Q2 may be either N or P channel. Components R3 and R4, C5 and C6 form a decoupling network for transistors Q1 and Q2. The output leads 36 and 37 of the input amplifier Q1 and Q2 are connected through C7 and C8 across an output impedance composed of R9 and R10, and to input pins 8 and 9 of operational amplifier Q3A. The input impedance of the present circuit is about 1 million ohms which is many times larger than the scalp contact resistance of the electrodes and which accordingly minimizes the generation of artifactual signals.

Q3A and Q3B here comprises a dual externally frequency compensated operational amplifier such as

Fairchild Semiconductor Model  $\mu$  A739C dual integrated operational amplifier. The pin marking on the drawing corresponds with the pin identification on the Fairchild amplifier. Q3A is an operational amplifier so constructed as to eliminate common mode signals, such as power line noise, radio frequency pickup, etc., thus presenting at its output only clear brain wave signals.

The band width as well as gain of amplifier Q3A is closely controlled by components C9, C10, R9, R10, R11, R12 as well as C7, C8, C1, C2, C3 and C4.

C1 and C2 isolate dc potentials developed by contact between the electrodes and skin, while allowing low frequency brain wave signals to be conducted to transistors Q1 and Q2.

C3 and C4 provide a low impedance path for short circuiting all radio signals to ground thereby eliminating annoying radio station interference.

C7 and C8 also provide increasingly better conduction for high frequencies between Q1 and Q2 and Q3A. This effect is compensated for by C9 and C10 both of which tend to reduce the gain of amplifier 3A for high frequencies.

R9 and R10 serve the function of controlling the gain and dc stability of the operational amplifiers.

R13, R14 and C11 form a high frequency filter, and C12 forms an additional low frequency filter to drive operational amplifier Q3B. The latter's response is further modified by C15, C16, C14 and C18. C14, C15 and C16 all tend to reduce the amplifier high frequency response while C13 tends to set the low frequency response roll off point. The result of the combination of all of these frequency response determining elements is a relatively sharp band pass amplifier whose output is delivered through R17 to an output circuit point 38.

The dc stability of operational amplifier Q3B is maintained by components R15, R16, R28, R17 and R18. The amplified EEG signal at point 38 is applied to the base of bi-polar transistor Q4 which is here connected as an emitter follower so that it has only unity voltage gain and much lower output impedance than input impedance. The output of amplifier Q4 is connected to one end of potentiometer R19, the moving contact 39 of which here functions as a sensitivity control. A manually engagable knob, here identified by the same numeral 39, may be seen on housing 12 for use by the operator in adjusting the sensitivity of the apparatus.

The effect of the frequency response determining elements above described is to produce a narrow band amplifier having an output substantially as shown in FIG. 4 where the voltage amplitude is plotted as the ordinate against frequency in Hz as the abscissa. It will be noted that the amplifier has a peak sensitivity in the range of about 4-13 cycles per second and a sharp roll off outside of this range. As hereinabove noted the apparatus is particularly designed for enabling the user to sense alpha wave generation and it will be noted that the amplifier peaks out in the alpha range of 8-12 cycles per second. As training progresses, and alpha generation becomes easier, the user may begin to listen for the deeper rhythmic theta train leading to a deeper meditative state. It will be noted that the amplifier output is still high in the theta range of about 4-8 cycles per second. On the other hand the amplifier output falls off sharply in the beta range of frequencies greater than 13 Hz.

As hereinabove noted the practical difficulty with listening to brain wave patterns directly is that the clinical

cally interesting frequencies as herein noted are in the sub-audible range. Accordingly the balance of the electronic circuit converts the low frequency brain wave signal into a clearly recognizable audio signal by using the low frequency signal to modulate an oscillator operating in the audio range whereby a combination amplitude and frequency modulation is obtained. The balance of the electronic circuit for accomplishing this result comprises briefly a relaxation oscillator Q6 having a timing capacitor C20 and C19; means, Q5, connected to output 39 and the timing capacitor, C20-C19, for charging the capacitor at a rate dependent upon the potential at 39; an output circuit including a voltage actuated chopper device, Q7, and a series load impedance R25 connected to output 39 and being connected to oscillator Q6 for controlling the operation of the chopper device and current flow in the load impedance 25 synchronously with the operation of the oscillator; and an electronic audio read-out device, transducers 21 and 26, connected to load impedance 25.

As a feature of the present construction, oscillator Q6 comprises a uni-junction transistor having its bases B1 and B2 connected to supply voltage, battery 23, and common (ground) 41 through battery 22, R23 and R24 so as to fire when its emitter *e* is raised to a predetermined voltage, here about 4 to 8 volts. Emitter *e* is connected via conductor 42 to capacitors C19 and C20. C20 is connected to common through battery 22 and C19 is connected to common through battery 22 through the base and emitter of transistor Q7 and resistor 27.

As a further feature of the present construction, the means for controlling the charging rate of capacitors C19 and C20 as a function of EEG potential at output 39 here comprises a field effect transistor Q5 having its drain terminal connected to output 39 through capacitor C17 and resistor R21, its gate terminal connected to supply voltage 23 and its source terminal connected via conductor 42 to the emitter of Q6 and capacitors C19 and C20. The relaxation oscillator thus provided furnishes a pleasing triangular shaped output tone having a frequency of about 1,000 Hz. Capacitor C19 couples the oscillator signal to Q7 thus turning the chopper on and off with the oscillations from Q6. Additionally, resistor R26 acts to provide dc bias for transistor Q7.

As another feature of the present circuit, the chopper device here comprises a bipolar transistor Q7 having its emitter connected through R27 to supply voltage 22, its base connected through capacitor C19 to the emitter of oscillator Q6, and its collector connected through load impedance R25, capacitor C18 and resistor R29 to output 39. The primary 43 of output transformer T1 is connected by conductors 44 and 45 across impedance R25; and the secondary winding 46 of transformer T1 is connected by conductors 47 and 48 to transducers 21 and 26. The result of the foregoing is that the current passing through the earphones becomes a replica of the brain wave signal chopped by the oscillator signal produced by oscillator Q6 and thus comprises an amplitude and frequency modulated presentation of the brain waves.

The use of the field effect transistor Q5, and more particularly its connections in the present circuit, are unorthodox in that the normal connections for the FET in a voltage dependent resistor mode are to connect its drain to the supply voltage and its gate to the control voltage. The reversal of these two connections in the

present case enables a substantial simplification in the circuitry. The relaxation oscillator circuit Q6 differs from other relaxation oscillators in that its frequency is adjusted by changing the rate of charging of its timing capacitance rather than shifting the firing voltage of the triggering device.

To summarize, the voltage fluctuation at C19 due to firing of Q6 turns on and off chopper Q7. Accordingly, brain wave signals at R25 are chopped to ground by Q7 at the running frequency of oscillator Q6. When the EEG voltage at point 39 goes positive, the running frequency of oscillator Q6 will rise due to decreasing resistance of FET Q5 causing more rapid charging of C19 and C20. At the same time that the frequency increases, voltage at output 39 is going up, increasing current flow through R29, C18, R25, Q7 and R27 to ground. As a result the voltage drop across R25 increases thereby providing amplitude modulation of the signal. On decreasing voltage at point 39, the reverse effect takes place, e.g., reduction in frequency of the oscillator, the chopping action of Q7 and amplitude drop across R25. The overall variation in frequency may be in the order of about 500 Hz to about 2,000 Hz. The combination of these two actions, viz, frequency and amplitude modulation, provide a most distinctive sound for brain wave recognition which is at the same time most pleasant to listen to for long periods of time. When the user is not producing a desired brain wave pattern, the output at the transducer is as close to silence as possible. The sound produced by alpha wave generation is similar to the vibrato of an organ at about middle C13 the frequency of the vibrato being in the range of about 8-10 cycles per second.

Three electrodes are preferably used although it would be possible to have a balanced input with only two electrodes. The third electrode, usually black, shown as electrode 15, is desired to provide an actual ground or electrical midpoint connection between the other two electrodes 14 and 16, commonly red electrodes. A wide variety of electrode placements may be used on the head depending on the part of the brain to be monitored. It is usually desirable to employ a minimum amount of electrode paste on the electrodes and particularly in the hair, and accordingly, a common placement of the electrodes is to locate the black electrode on the skin of the forehead over one eye, one red electrode on the skin of the forehead over the other eye, and the other red electrode at the back of the head generally behind the first electrode. These may be held conveniently in place by an elastic headband 20.

Another important feature of the present invention is the incorporation of a squelch circuit which eliminates output signals below a predetermined level. This circuit here comprises a pair of reversely connected germanium diodes D1 and D2 which are connected in series with load impedance R25 and the primary 23 of transformer T1. Reversely connected diodes D1 and D2 connected in this manner are effective in eliminating annoying background noise and cooperate with variable resistor R19 for adjusting not only the magnitude and frequency of the output signal but also the threshold of squelch action. Signals not of interest are suppressed by the diodes by reason of the fact that when point 39 is at a relatively constant voltage, almost no output will appear at transformer T1 due to the fact that capacitor C18 conducts almost no current down through R25 and this small current produces a voltage

across R25 insufficient to cause the diodes to conduct. On the other hand, a significant signal at 39 will be emphasized not only in the amplitude of output at T1, but also by shift in frequency of the oscillator. Thus the combination of the sensitivity control R19, the squelch circuit, frequency and amplitude modulation cooperate to emphasize as much as possible the signals which are of interest and to de-emphasize as much as possible background noise which is not of interest. Also placing the squelch circuit at the "back end" of the circuit has the very significant advantage of applying the squelch only where it is needed—thus not affecting the FM or EEG output signals which may be taken from the circuit ahead of the squelch circuit. Also, by reason of the placement of the squelch circuit, the signal level is such that no biasing is needed to set the proper squelch level. The threshold level depends upon the component values in the output circuit. These are chosen to eliminate signals below a minimum value. The squelch circuit is thus automatically set to eliminate all audible signals of less than the preset level which is the threshold of comfortable listening. The sensitivity control R19 also adjusts the squelch level since it changes the peak-to-peak signal voltage across R25 as well as adjusting the FM deviation by changing the amount of EEG signal fed to Q5 through R21 and C17. It will also be noted that the present circuit is limited in low frequency response in that it is AC coupled by capacitor C18. The presence of capacitor C18 ensures that there will be no carrier audible unless there is a brain wave signal present above a minimum frequency and amplitude, the circuit thus serving to achieve carrier suppression.

Other features of advantage of the present circuit is the provision for use of auxiliary equipment. As will be seen from FIG. 3, four output jacks 51, 52, 53 and 54 are provided on the headset housings 12 and 24 for monitoring the operation of the unit by a user, and obtaining an FM output and an EEG output therefrom. Jack 51 is connected across transducers 21 and 26 and is coupled to a normally closed switch 56. An observer may plug in a headphone into jack 51 and listen to the feedback signal generated by the patient or user while cutting off the feedback to the patient. Jack 52 is similarly connected across transducers 21 and 26 but without a switch incorporated therewith so that the observer plugging his headset into jack 52 will listen to the feedback along with the patient.

Jack 53 is here connected across resistor R24 in the oscillator circuit and will accordingly provide a low impedance positive pulse signal of several volts amplitude corresponding in frequency to the oscillator formed by Q6, R25, R24 and C20. Since the signal derived is pure FM, it is possible to obtain a highly satisfactory recording qualitywise using even an inexpensive consumer-type audio tape recorder. The signals can later be demodulated by a simple diode pump circuit to recover the original brain wave signal. An interesting and important advantage is obtained in using a stereo cassette recorder having one channel connected to the headset and the other channel connected to a microphone so that as significant brain wave patterns are experienced by the subject he may make an appropriate note of them on the second channel of the recorder. Thus after a relatively long session the particularly significant portions of the recording may be quickly isolated from the balance of the tape. This output may also be used to

drive an FM radio transmitter thus providing FM-FM telemetry data.

Jack 54 provides an EEG output and is connected at the output of a network formed by R30, transistor Q8, and resistor R20, the latter being connected to point 38 in the circuit. More specifically, Q8 has its base connected to R20, its collector connected to battery 23, and its emitter connected through R30 to jack 54. This network provides a high current output EEG signal in amplified form but without audible tone. This signal may be fed to chart recorders, oscilloscopes, or tuned-computer systems which will sort out particular spectra or groups of brain waves. In all instances where auxiliary equipment is power line operated, it is mandatory that the auxiliary equipment positively prevent an accidental feedback of high voltage to the headset. One means of accomplishing this safety feature is to use the signal to drive a gallium arsenide photo diode to provide a light signal replica of the EEG signal. This light signal may be picked up and detected by a Darlington photo transistor thus providing a means of extracting the brain wave signal from the present battery operated electroencephalophone and making it available for use with power line operated equipment without electrical shock hazard to the user, the connection between the power line operated equipment and the present headset being light transmission. The circuit formed by resistor R20, transistor Q8, and resistor R30 draws no current from the battery unless and until the gallium arsenide photo diode is plugged into the EEG output jack.

Earphone housings 12 and 24 are provided with demountable end covers 57 and 58 which are removed to open the interior battery compartments for insertion and removal of batteries 22 and 23. The present circuit is designed for use with, and the compartments are dimensioned to receive, standard size 9 volt transistor radio batteries. Manually operable switches 61 and 62 are carried by the earphone housings and are connected to the batteries as shown in FIG. 6. The dual operational amplifier, relaxation oscillator and chopper circuit are preferably microminiaturized by means of hybrid integration techniques for compact mounting on circuit board 34 in headset housing 12.

The light emitting portion of the photon coupler is a gallium arsenide light emitting diode D3 (see FIG. 7) whose anode is connected by conductor 66 to the common side of plug 67 adapted for connection to output jack 54. The cathode of the diode is connected by conductor 68 through a current limiting resistor R36 to the center pin of plug 67. An ordinary silicon diode D4 is reverse connected across the photon coupler's light emitting diode D3 to protect it from excessive reverse transients.

The phototransistor Q9 portion here shown is a Darlington phototransistor. A feedback resistor R31 is connected between its base and collector to provide dc stability. The emitter is "grounded," that is, it is connected to the negative power supply lead 69 which is also the shield 71 of the cable conductor 72 leading to the photon coupler. The light emitting diode-phototransistor combination, together with D4, R36, and R31 are all mounted as close as possible to the plug 67 which is used to connect the photon coupler to the EEG output jack 54. The output from this assembly is a shielded cable whose shield is connected to the emitter of Q9 and whose center conductor 72 is connected to the collector of Q9. The remainder of the circuitry



may be mounted fairly remotely (several yards) from this assembly.

The collector of Q9 is connected via the cable through a load resistor R33 to the plus supply of battery 73. The EEG signal appears at this point. From the collector the signal is conducted by way of a current limiting resistor R32 to the base of transistor Q10, an emitter follower. The base of Q10 is also connected to one side of a switch 74 through filter condenser C21, the opposite side of the switch being connected to common. This switch allows a filter capacitor C21 to be inserted or removed from base to ground. This filter capacitor is inserted when the photon coupler is used with the EEG output to filter out high frequency oscillator noise which may be present in the output from the headset. When the photon coupler is used with the FM output, this switch is opened to allow the higher frequency FM signal to be amplified.

The output of the emitter follower Q10 is coupled by a dc blocking capacitor C22 to the center pin 76 of output jack 77 having its outside contact connected to common 69. Q10's emitter load resistor R34 and output dc restoring resistor R35 are connected on opposite sides of capacitor C22 to common. This signal taken from jack 77 and appearing across resistor R35 may be used to drive chart recorders, oscilloscopes, and other power line operated equipment without electrical shock hazard to the subject wearing the headset.

The following is a schedule of suggested component values:

C1	1mf/35v	R10	470 K ohms
C2	1mf/35v	R11	10 meg ohms
C3	0.001mf	R12	150 K ohms
C4	0.001mf	R13	470 K ohms
C5	1000mf/6v	R14	470 K ohms
C6	1000mf/6v	R15	270 K ohms
C7	10mf/35v	R16	1 meg ohm
C8	10mf/35v	R17	4.7 K ohms
C9	0.001mf	R18	47 K ohms
C10	0.33mf/35v	R19	5 K ohms
C11	0.2mf/20v	R20	47 K ohms
C12	1mf/35v	R21	8.2 K ohms
C13	10mf/35v	R22	4.7 K ohms
C14	0.01mf/20v	R23	100 ohms
C15	0.47mf/3v	R24	100 ohms
C16	0.22mf/35v	R25	4.7 K ohms
C17	22mf/16v	R26	100 K ohms
C18	22mf/16v	R27	100 ohms — 1 K ohm
C19	0.47mf/35v	R28	150 K ohms
C20	0.05mf/20v	R29	1 K — 100 ohms
C21	.22mf/35v		
C22	250mf/12v		
R1	1meg ohm	R30	2.2 K ohms
R2	1 meg ohm	R31	22 meg ohms
R3	10 K ohms	R32	100 K ohms
R4	10 K ohms	R33	2.2 K ohms
R5	100 ohms	R34	4.7 K ohms
R6	200 ohms	R35	10 K ohms
R7	22 K ohms	R36	220 ohms
R8	22 K ohms	C21	0.02 mf
R9	470 K ohms	C22	250 mf/10v
D1, D2	Transition S3443G germanium signal diodes		
D3, Q9	Commercially available in a combined package as a General Electric PC4-73 photon coupler		
D4	Silicon signal diode		
Q1, Q2	Fairchild Semiconductor S34134, N-channel field effect transistor		
Q3	Fairchild Semiconductor $\mu$ MA739C dual integrated operational amplifier		
Q4, Q7, Q8	General Electric 2N5825 transistor (NPN silicon)		
Q5	Fairchild Semiconductor 2N4360, P-channel field effect transistor		
Q6	Motorola Semiconductor 2N4871 uni-junction transistor		
Q9	Monsanto MCT-2		
Q10	Fairchild S34134		
T1	5,000 ohms to 16 ohms output		

transformer

All capacitors are  $\mu$  f/dc working volts.

All electrolytics have polarity indicated.

We claim:

1. An electroencephalophone feedback system comprising:

scalp electrodes;

an amplifier having an input connected to said electrodes and having an output;

an output circuit connected to said amplifier output and including a voltage actuated chopper device and a series load impedance connected thereto;

a transducer connected to said load impedance;

a relaxation oscillator generating an audible frequency connected to and driving said chopper device, said oscillator having a timing capacitor controlling its said frequency; and

means connected to said amplifier output and capacitor for charging said capacitor at a rate dependent upon the potential at said amplifier output.

2. A system as defined in claim 1:

a voltage supply and common;

said oscillator comprising a uni-junction transistor having its emitter connected to said capacitor and its bases connected to said voltage supply and common to fire when its emitter is raised to a predetermined voltage, said means being connected to said emitter to periodically raise the voltage thereat to said predetermined value.

3. A system as defined in claim 2, said means comprising a field effect transistor connected to said output, emitter, capacitor and voltage supply.

4. A system as defined in claim 3, said field effect transistor having its drain terminal connected to said output, its gate terminal connected to said voltage supply and its source terminal connected to said emitter and capacitor.

5. A system as defined in claim 2;

an impedance connected in series in the connection between common and said uni-junction base connected to common; and

output terminals connected to said impedance for providing a frequency modulated brain wave signal.

6. A system as defined in claim 1 and having a common, and said chopper device comprising a bipolar transistor having its emitter connected to said common, its base connected to said oscillator, and its collector connected through said load impedance to said output.

7. A system as defined in claim 1 wherein said transducer is connected across said load impedance; and a pair of parallel reversely connected diodes connected in series with said transducer and impedance.

8. A system as defined in claim 1, and manually controlled means for adjusting the magnitude of said output potential thereby setting the range of amplitude and frequency modulation.

9. A system as defined in claim 8 said transducer being connected across said load impedance; and a pair of parallel reversely connected diodes connected in series with said transducer and impedance providing a squelch action below a predetermined signal level, said signal level being controlled by said manually controlled means.

10. A system as defined in claim 1, said amplifier comprising a narrow band-pass amplifier having peak

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sensitivity in the range of about 4 to 13 cycles per second and a sharp roll-off outside of said range.

11. A system as defined in claim 10, said amplifier comprising a dual operational amplifier.

12. A system as defined in claim 1, said amplifier having an input impedance substantially higher than the scalp contact resistance of said electrodes to minimize generation of artifactual signals.

13. A system as defined in claim 12 wherein said amplifier comprises a pair of source follower field effect transistor pre-amplifiers connected to said electrodes; and

a dual operational amplifier having a balanced input connected to the outputs of said pre-amplifiers.

14. A system as defined in claim 13 wherein said operational amplifier has common mode rejection thereby eliminating common mode noise originating at said electrodes and the requirement for system operation in a shielded room.

15. A self-contained electroencephalophone comprising:

a headset having an earphone housing and a headband connected thereto for mounting on the head of a user;

a plurality of scalp electrodes adapted for mounting on the user's head to provide an electric signal pickup of brain waves;

flexible leads carried by said housing and connected to said electrodes for permitting placement of the latter on the user's head when the housing is mounted thereon; and

an electronic circuit carried by said housing and comprising an amplifier having an input connected to said electrodes and having an output; an output circuit connected to said amplifier output and including a voltage actuated chopper device and a series load impedance connected thereto; an oscillator generating an audible frequency connected to and driving said chopper device; and means connected to said amplifier output and said oscillator for controlling said oscillator frequency as a func-

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tion of the potential at said amplifier output; and a transducer carried by said housing and connected to said load impedance.

16. An electroencephalophone as defined in claim 15, carried by said housing said electronic circuit including a voltage supply and common;

said oscillator having a timing capacitor controlling its frequency and comprising a uni-junction transistor having its emitter connected to said capacitor and its bases connected to said voltage supply and common to fire when its emitter is raised to a predetermined voltage; and

said means comprising a field effect transistor having its drain terminal connected to said amplifier output, its gate terminal connected to said voltage supply and its source terminal connected to said emitter and capacitor.

17. An electroencephalophone as defined in claim 16:

said chopper device comprising a bipolar transistor having its emitter connected to said common, its base connected to said oscillator, and its collector connected through said load impedance to said output.

18. An electroencephalophone as defined in claim 17, and a pair of parallel reversely connected diodes carried by said housing connected in series with said transducer and impedance.

19. An electroencephalophone as defined in claim 15;

a resistor connected to said output;

an EEG output terminal;

a voltage supply carried by said housing;

a transistor having its base connected to said resistor, its collector connected to said voltage supply, and its emitter connected to said terminal;

a light source connected to said terminal; and

a light detector electrically insulated from said headset and optically coupled to said light source for providing an electrical brain wave signal.

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UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,753,433 Dated August 21, 1973

Inventor(s) FRANK BAKERICH and ROBERT T. SCULLY

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 53, "utilzed" is corrected to --utilized.--.

Column 6, line 32, "Cl3" is corrected to -- C-- -- .

Column 7, line 60, "heatset" is corrected to --headset--.

Signed and sealed this 8th day of October 1974.

(SEAL)  
Attest:

McCOY M. GIBSON JR.  
Attesting Officer

C. MARSHALL DANN  
Commissioner of Patents