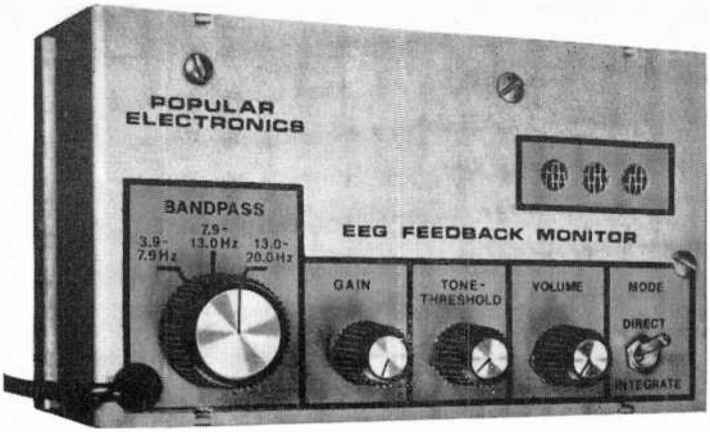


Build an

ALPHA BRAIN WAVE FEEDBACK MONITOR

You may be able to learn how to relax through electronics

BY MITCHELL WAITE

THERE is nothing quite so pleasant as being able to relax completely whenever you want to. Unfortunately, today's quick pace rarely leaves us the time to truly relax.

Perhaps for that reason, scientists have come up with an electronic approach to relaxation that might revolutionize the art of "calming down." Drawing on knowledge of general psychology, eastern meditation techniques, and, in particular, clinical electroencephalography, researchers in the field of alpha-wave feedback have progressed rapidly in the last few years and made many significant gains.

Unlike the older forms of meditation, alpha-wave feedback requires neither an avatar or guru. Researchers have found that the minute brain-wave frequency band between 7.5 and 13 Hz is continuously produced in meditative stages of Yoga and Zen. This is called the "alpha state." The assumption is that the length and intensity of alpha-wave production is an impartial measurement of the ability to reach a special state of "relaxed awareness," found in certain types of meditation.

People who produce continuous alpha seem to experience a generally heightened sense of well-being, with a parallel increase in clarity. Thus, alpha feedback allows one to prepare for demanding mental tasks by previously clearing the mind of distracting thoughts and ideas. It is precisely for this reason that some businesses are investigating alpha feedback. Researchers are also suggesting that the "pain" of education can be lessened if these procedures are used in attention control. There is the possibility, they say, that recall can be improved and mental blocks avoided during examinations, by the use of alpha feedback.

Basic Approach. In alpha feedback, high-gain, low-noise amplifiers detect the microvolt signals of the brain and use them to modulate a sound or other stimulus. The person training for increased alpha completes the feedback loop by listening to the rise and fall of a tone as the brain waves come and go. Thus, by learning to produce just the elusive 7.5-to-13-Hz modulation, a person can experience the alpha state.

Actually, all brain waves have characteristic mental correlates. For example, deep sleep produces the long slow waves between 2 and 4 Hz; problem solving and daydreaming give rise to the theta rhythms (3.5 to 7.5 Hz); while tension, worry, or surprise produce the beta frequencies (13 to 28 Hz). There is also evidence that creative and spontaneous moods occur most often when the frequencies between alpha and theta are active. This has led some researchers to speculate that creativity and insight might be facilitated by learning how to increase frequencies.

The important thing is to find out more of all this for yourself. With the circuit described, you may be able to influence and enjoy all of the brain-wave states. In addition, the project can be used to listen to such body signals as scalp tension and heart rate.

About the Circuit. Because of the rapid increase in the popularity of biofeedback, a large selection of feedback monitors have appeared on the market. Their complexity ranges from a device for alpha feedback using only one IC to research laboratory equipment costing thousands of dollars. The latter include such features as strip chart recorders, multi-channel amplifiers, highly controllable filters, percent time indicators, etc.

The circuit shown in Fig. 1 incorporates functions usually found only in more sophisticated equipment. For example: because the different brain waves are very close in frequency, a switchable 4-pole bandpass filter is used. Each filter is tuned to the center frequency of the theta, alpha, and beta bands. These filters obviously make recognition of a particular brain wave much easier and faster.

Another critical parameter of a feedback machine is its ability to reject strong common-mode interference—such as 60-Hz hum or erroneous signals from electrode movement—while presenting a high input impedance. An inexpensive solution to this problem is to use a single low-noise op amp in the differential mode. This solution is not completely satisfactory because of the inevitable tradeoff between input impedance, balance, and common mode rejection. Here we use an instrumentation amplifier for the front end, with two low-bias op amps (*IC1* and *IC2*) providing an almost infinite input impedance and excellent common mode rejection.

Electrodes, which couple the microvolt signals to the amplifier, are critical in two respects. They should not generate short-term voltages (tiny noise spikes) or long-term voltages (offset or drift). A number of low-cost commercial machines use an inert material such as stainless steel for electrodes. The difficulty with these electrodes is that they produce some noise spikes and (more seriously) generate a slow voltage offset, which (if the input stage is direct coupled) can eventually saturate the output. A better approach is found in laboratory applications where silver electrodes coated with a layer of chloride are used. Though these electrodes are free of noise and have no long-term voltage drifts, the chloride surface must eventually be replaced so the electrodes are disposable types. However, with proper cleaning, they will last for some time. The least troublesome approach is to use pellet-type Ag/Ag-C1 electrodes which, due to their special construction, last indefinitely.

Another more general consideration in designing an EEG monitor is the type of modulation used to produce the audio feedback. Most models use the amplified, filtered brain wave either to amplitude- or frequency-modulate a fixed tone. In the monitor described here, a unique combination tone-threshold control can be adjusted to produce either AM, FM, or a combination of the two.

It is also necessary to determine what aspects of the brain-wave envelope shall vary the tone. The two most common methods use either a direct or integrated waveform to modulate the audio. With the mode selector switch, S2, in the DIRECT position, the instantaneous waveform passing through the filter frequency modulates an adjustable tone. This mode creates an effect in which one seems to be tuning directly to the thought of the brain. If the continuous tone is objectionable, the oscillator can be set just below its threshold point so that only the peaks of the filtered waveform trigger the tone. The latter method integrates the filtered waveform over a fixed period of time.

In this monitor, depending on the setting of the threshold control (*R42*), the tone can be made absent when no signal is present. When the threshold is exceeded, the frequency of the tone is proportional to the envelope of the signals. This mode is better for biofeedback training since the

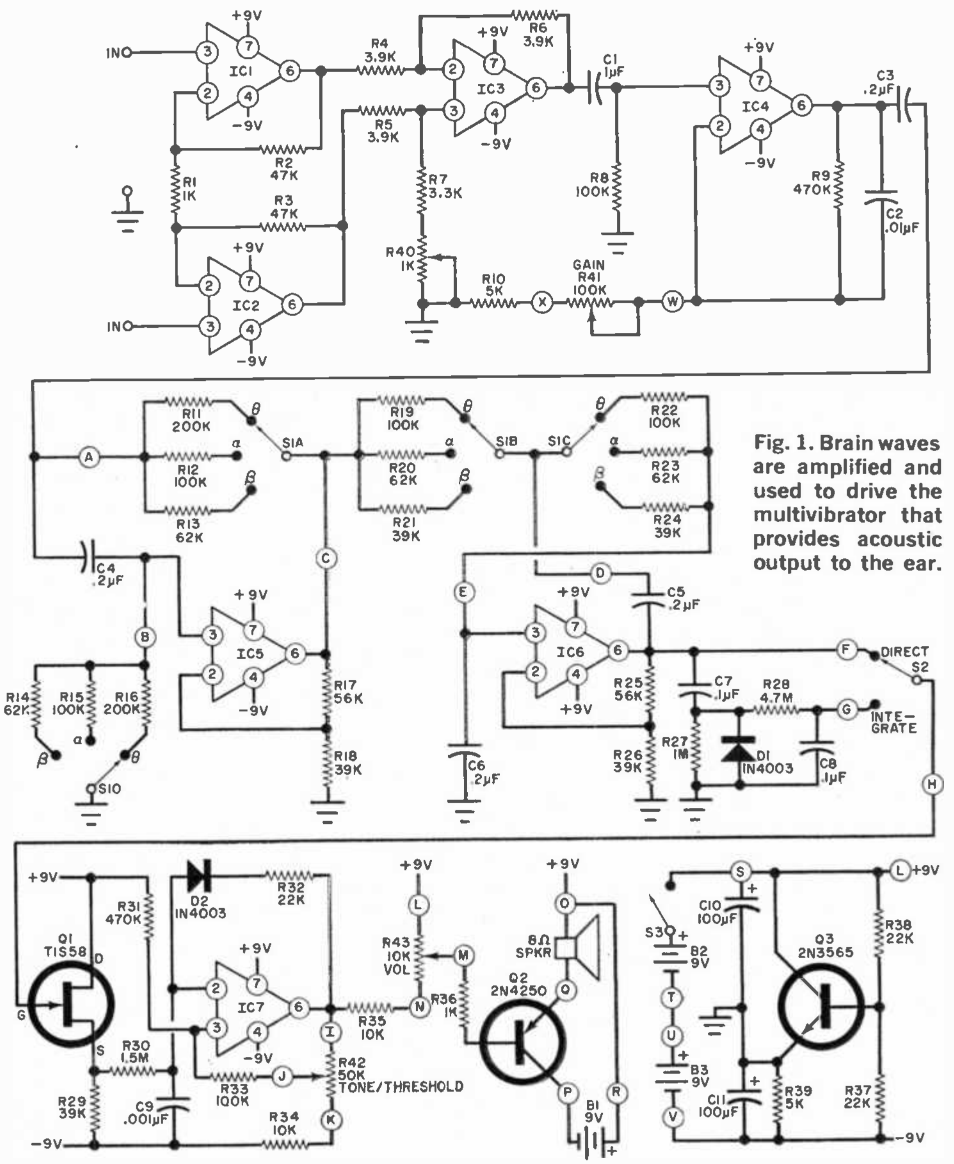
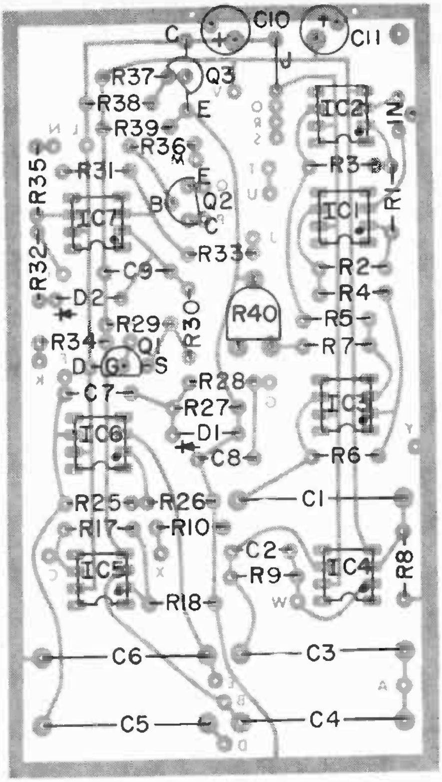


Fig. 1. Brain waves are amplified and used to drive the multivibrator that provides acoustic output to the ear.

PARTS LIST

B1,B2,B3,—9-volt battery
C1—1-µF, 10% Mylar capacitor
C2—0.01-µF disc capacitor
C3-C6—0.2-µF, 10% Mylar capacitor
C7,C8—0.1-µF, 10% Mylar capacitor
C9—0.001-µF, 10% Mylar capacitor
C10,C11—100-µF, 2-volt electrolytic capacitor
D1,D2—1N4003 silicon diode
IC1,IC2—N5556 op amp (Signetics, do not substitute)
IC3-IC7—741 op amp
Q1—TIS58 field effect transistor
Q2—2N4250 transistor
Q3—2N3565 transistor
R1,R36—1000-ohm, ¼-watt, 5% resistor
R2,R3—47,000-ohm, ¼-watt, 5% resistor
R4-R6—3900-ohm, ¼-watt, 5% resistor
R7—3300-ohm, ¼-watt, 5% resistor
R8,R12,R15,R19,R22,R33—100,000-ohm, ¼-watt 5% resistor
R9,R31—470,000-ohm, ¼-watt, 5% resistor
R10,R39—5000-ohm, ¼-watt, 5% resistor
R11,R16—200,000-ohm, ¼-watt, 5% resistor
R13,R14,R20,R23—62,000-ohm, ¼-watt, 5% resistor
R17,R25—56,000-ohm, ¼-watt, 5% resistor
R18,R21,R24,R26,R29—39,000-ohm, ¼-watt, 5% resistor
R27—1-megohm, ¼-watt, 5% resistor
R28—4.7-megohm, ¼-watt, 5% resistor
R30—1.5-megohm, ¼-watt, 5% resistor



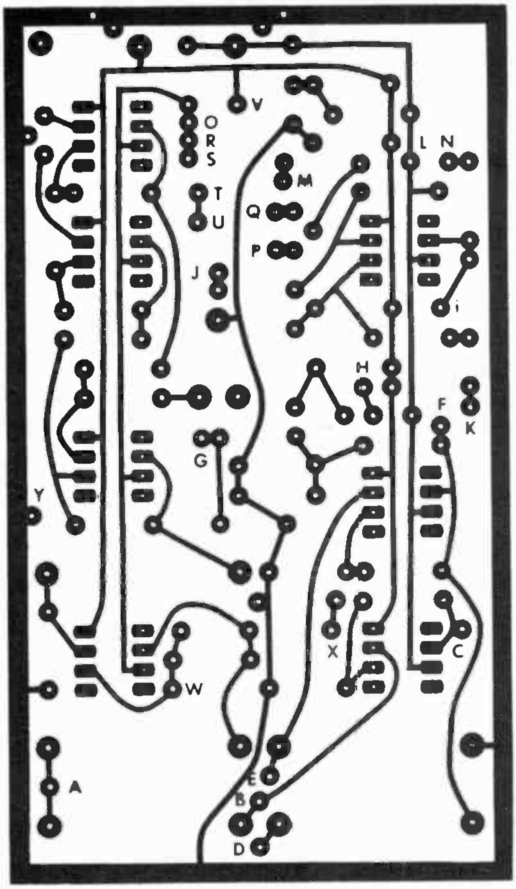


Fig. 2. Actual size foil pattern is at right with component layout above.

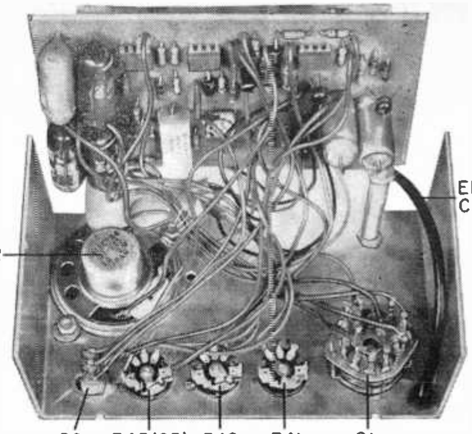
tone gives a direct indication of the desired result.

This monitor also has an audio amplifier with speaker and volume control (*R43*), so that a group can listen or the volume can be reduced to a quiet level.

How It Works. Integrated circuit *IC1* and *IC2* amplify the differential signal between the two input leads while providing unity gain for the common mode signal. The residual common mode signal is removed by *IC3* and can be nulled to zero by trimmer *R40*. The signal is then coupled through *C1* to *IC4* and further amplified. The gain of this stage can be varied from about 5 to 95 by the setting of *R41*.

Integrated circuit *IC5* forms a two-pole

R32,R37,R38—22,000-ohm, ¼-watt, 5% resistor
R34,R35—10,000-ohm, ¼-watt, 5% resistor
R40—1000-ohm trimmer potentiometer (PC type)
R41—100,000-ohm miniature potentiometer
R42—50,000-ohm miniature potentiometer
R43—10,000-ohm miniature potentiometer with attached switch for S3
S1—4-pole, 3-position shorting rotary switch
S2—Spdt switch
S3—Spst switch on R43
SPKR—Miniature 8-ohm speaker
Misc.—Four feet of 2-conductor shielded flexible cable, metal enclosure, battery connectors (3), knobs (4), rubber grommet, headband, electrode cream, electrodes, earclip, mounting hardware.
Note—The following are available (postpaid, but insurance extra) from Extended Digital Concepts, Box 9161, Berkeley, CA 94709: #PE2, etched and drilled PC board at $4.49; #PE3, IC1 and IC2 at $6.49; #PE4, set of stainless steel electrodes at $1.49; set of disposable Ag/Ag-Cl electrodes at $3.49; #PE6, set of reusable Ag/Ag-Cl electrodes at $14.95; #PE1, complete kit of parts including sets of disposable and stainless steel electrodes, drilled and etched board, drilled and painted enclosure, elastic headband, electrode cream, and earclip at $58.95. California residents, add 5% sales tax.



Photograph of prototype shows how components were assembled in box.

active filter which rejects signals lower than the frequency determined by capacitors *C3* and *C4* and *R11* through *R16*. Conversely, *IC6* removes signals higher than its selected frequency. The net effect is a filter which passes only a narrow band of low frequencies.

With *D1* as a shunt rectifier and *C8* and *R28* as a smoothing filter, the signal is passed to *Q1*, a FET operating as a source follower with unity gain. Integrated circuit *IC7* is connected in a multivibrator circuit and is normally saturated with the output voltage near the positive supply voltage. When *C9* charges through *R30* to a voltage higher than the level provided by the voltage divider made up of *R31, R33, R42,* and *R34*, *IC7* saturates due to positive feedback. Capacitor *C9* then discharges through *D2* until *IC7* flips back to its previous state. The signal from *Q1* varies the charge on *C9* and thus modulates the tone.

Transistor *Q2* is a source follower which provides a low impedance to drive the speaker without overloading the multivibrator. A separate battery (*B1*) is used for the speaker to avoid feedback.

Transistor *Q3* is a source follower which creates a low-impedance ground about half way between the plus and minus supply voltages. This also permits the use of a single-pole switch (*S3*) to turn the monitor on and off. It is not necessary to disconnect *B1* because its drain is negligible with *S3* open.

Construction. The use of a PC board (foil pattern shown in Fig. 2) makes construction easy. Mount the components as shown, observing the notch and dot code of the IC's. Also make sure that the two diodes and three transistors are properly installed. The lettered terminals correspond to those on the schematic. The resistors associated with *S1* are connected directly to the terminals on the switch. Use fine solder and a low-power soldering iron.

The circuit board and batteries can be installed in any small enclosure. The three potentiometers (*R41, R42,* and *R43*) and the two switches (*S1* and *S2*) should be mounted on the front panel, with a small grommeted hole also on the front panel for the shielded cable. The speaker is cemented to the front panel with a few holes drilled in the panel for the sound to come through.

Prepare the electrode cable by removing about 12" of the outer insulation from the cable. Unwind the shield and twist it into cable form. Solder this shield lead to the earclip. Remove about ½" of insulation from the two insulated leads and carefully solder them to the electrodes. When soldering to stainless steel, first lightly sand the metal surface with fine sandpaper.

Testing. Install fresh batteries, turn the circuit on, and adjust the tone/threshold control (*R42*) until a tone is heard in the speaker. Set the bandpass switch (*S1*) to its lowest range (3.9-7.9 Hz) and the mode control (*S2*) to direct. Using a small amount of electrode cream, clip the ground lead to an earlobe. Saturate the electrodes with cream, and steadily hold one electrode in each hand. The circuit should pick up your heartbeat, amplify it, and send it through the speaker. This is a noticeable beep, about one a second. The pulse signal is about 1 millivolt (10 times greater than alpha-wave level) so turn the gain control down. If you cannot hear your pulse, check the wiring.

If you have a signal generator and scope, the circuit may be further analyzed by clipping one input and the ground lead to the signal generator ground and feeding an attenuated signal into the other input lead.

The dc output of all op amps should be near zero.

Balancing the Amplifier. Potentiometer *R40* is used to trim the gain of one side of the differential amplifier to make both gains exactly the same. When they are equal, common mode rejection is maximum. The best procedure is to feed a common mode signal of 3 to 4 volts into both inputs tied together, across a 10,000-ohm resistor. Put a scope or ac VTVM on the output of *IC4* and adjust *R40* for the smallest signal. If you do not have a scope or signal generator, hook the electrodes through the 10,000-ohm resistor to ground and touch the common leads. You will hear 60-Hz noise from your body. Adjust *R40* for minimum noise or the clearest tone.

Use of the Monitor. First, a note of caution. The monitor, like most commercial machines of this type, is battery operated. This is to prevent a shock in the rare event that the 60-Hz power line shorts to the inputs. Therefore, for complete safety, avoid hooking the monitor to any ac-operated equipment such as scopes, battery eliminators, etc. When ac devices are hooked up to an EEG monitor in a laboratory, light coupling devices or fused fail-safe systems are used.

If you are sure the monitor is picking up EKG and properly balanced, you are ready to try EEG feedback. Place a small bit of electrode cream on the earclip and attach it to either earlobe. Wrap an elastic or soft cloth band around the head, aligned so that it is over the eyebrows and at the widest part at the back of the head. Pin the cloth to hold it on. Put a small amount of cream on each electrode and place one under the band just above the left or right eyebrow. Place the other in line with the first at the rear of the head. Spread the hair apart and add a little more cream. The electrodes will function best when they float above the scalp with electrode cream bridging the gap. With the electrodes placed in this manner, you should be picking up mostly what is called occipital alpha. In more advanced stages of meditation, alpha production increases in the frontal areas of the brain. You can experiment with this by placing both leads on the forehead.

Sit or lie down in a quiet, comfortable place. Turn the monitor on, place the bandpass switch in the alpha range (7.9-13.0 Hz), with mode in DIRECT, turn the gain all the way down, and adjust the tone and volume to a pleasing level. Blink your eyes and listen for a beep. Slowly turn the gain up. If the electrodes are correctly placed, no hum will be heard. Now, with the eyes open and focused on an object, adjust the gain for a fairly steady tone. Because you are producing mostly beta and the bandpass is on alpha, you should not hear the beta frequencies. Now close the eyes and listen for a rhythmic modulation of the tone. Do not *try* to produce this rhythm; let the mind go and just listen for it. The occasional fluttering of the tone will be the alpha waves.

Notice the types of thoughts that block the alpha. After you are sure you are producing alpha, switch S2 to INTEGRATE and adjust the threshold/tone control so that, when the eyes are open, there is no tone. Shut the eyes and practice increasing the number of times the tone is on (percent time training). Later try increasing the frequency of the tone (amplitude training).

In laboratory training, a usual alpha session lasts 10 to 15 minutes a day for about two weeks. If you stick to it, you may eventually notice a feeling of well-being and relaxation after each session. To experiment with the other brain-wave bands, simply repeat the procedure with the filter switched to the desired band. Try lowering the dominant alpha frequency toward theta in the direct mode and notice if spontaneous thoughts or ideas come more easily.

When you have finished using the monitor, carefully wipe the cream off the electrodes. If you are using stainless steel electrodes, sand them lightly and clean them with alcohol.

One final note: alpha-wave feedback has produced results similar to meditation, but it works much faster. It is still, however, a subtle effect and requires diligence and experimentation to obtain worthwhile results. ◈

Editor's Note: This article, which follows last month's story on principles of biofeedback training, describes an easily constructed project for experimentation. There have been many claims made for brain-wave monitors —some highly exaggerated. We make no such claims, other than that the circuit operates properly.