biofeedback — instant yoga?

Using electronic biofeedback techniques you can monitor the internal operation of your body. But that's not all - knowing what's going on enables you to control usefully some of the processes, helping you to relieve tension and the disorders resulting from it. Collyn Rivers explains.

AN ESSENTIAL PART OF MOST control processes is some form of feedback information which enables the system to maintain a controlled equilibrium.

A room thermostat, for example, senses room temperature and regulates heat output accordingly — an indication of the heater's operation is 'fed back' to enable temperature to be automatically controlled.

When you learn the piano you see or sense where the keys are, and how hard you are striking them. The piano makes corresponding sounds which are fed back to your ear. Your brain now compares what you've got with what you hoped you had. This process of feeding back information about what you are achieving so you can compare it with what you are *trying* to achieve enables you to make appropriate corrections. In this example the acoustic feedback is vital.

A similar process is involved when you learn to ride a bicycle — the feedback process is so effective that balancing eventually becomes automatic.

Feedback is used when you first drive a strange car. The first time you brake you know only within wide limits the relationship between pedal pressure and deceleration. It may be as low as 5 kg or as high as 25 kg for (say) 0.4 G. But the very first time you press that pedal several feedback loops come into operation. Your stomach is sensitive to rate of change of velocity and it sends signals to your brain — your eyes sense the rate of change also — this data too is sent to your brain. If the tyres are squealing then there's an acoustic loop as well.

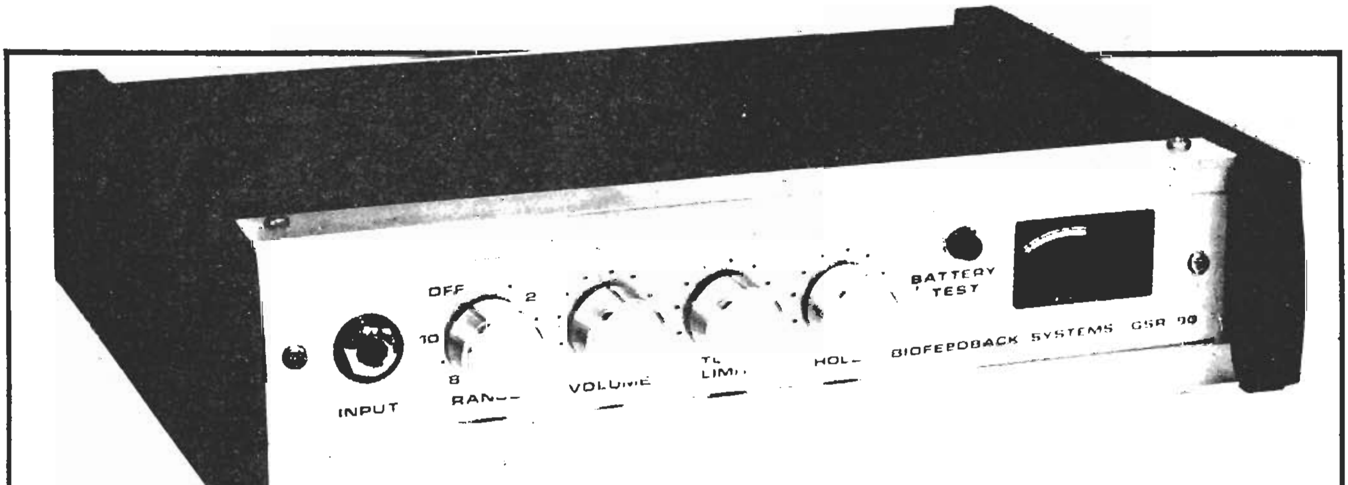
These and innumerable other physiological mechanisms collectively tell you whether you're pressing that pedal too hard or not hard enough, and you make a series of appropriate corrections — virtually instantaneously. Once you've done this a few times the response becomes automatic. You've used feedback to learn, and subsequently reinforce, a new skill.

THE AUTOMATIC NERVOUS SYSTEM

So far we've described what are primarily external feedback loops. But the body has a vast number of internal automatic mechanisms — what medics call the autonomic nervous system. These are internal feedback loops and whilst they're working correctly all one normally perceives is the end result. If the body is too hot it perspires — if you run for a bus your respiratory rate increases, if you walk from a light area to a dark area your pupils expand accordingly. And all these mechanisms work in very much the same way as their technological equivalents.

Until recently it has been taken totally for granted that man had no control over the autonomic nervous system. We could learn to control at least some of our external bits — but not our internal systems. We knew we could learn to use our hands — or even wiggle our ears — but to control body temperature or heart rate was something else again.

And until very recently Western science believed this implicitly — despite ever-increasing evidence to the contrary. Yogis have long maintained that *they* have some measure of control over their autonomic systems, but the evidence was always anecdotal rather than scientific. (It is only in the last decade that their performances have been monitored and scientifically authenticated.)



Galvanic skin response meter from Biofeedback Systems. A large external meter may be added to this unit.

biofeedback —

Then ten or so years ago the scene suddenly changed. It was caused by a now classical experiment involving the study of part of the brain's electrical activity. Researchers were studying a subject's alpha rhythms (a low amplitude 10 Hz generated when the subject is relaxed). It was found that if the subject could *perceive* a signal corresponding to his alpha activity he could learn to generate more or less of it at will. Even more excitingly, it was found that almost all subjects could do the same.

CONTROLLING YOUR INSIDES

For the first time it was proved scientifically that humans could control some internal processes once a visual or aural feedback loop was established. Yet the tremendous significance of this discovery was not at first appreciated by the medical profession, but rather by engineers and physicists who were of course more familiar with the use of feedback in control systems.

Subsequent experiments have shown that a very large number of internal functions can be controlled in the same fashion — and even more importantly that many partially mal-functioning mechanisms can be 're-programmed' so that newly-learnt patterns can become automatic.

One of the most important of these is conscious control of tension and anxiety, for this implies that it is possible to control tension-related conditions such as migraine, colitis, asthma etc.

Other work has shown that it is possible to control hypertension (high blood pressure), heart rate, muscular tension, body temperature — and of course to generate, or at least partially control, alpha, beta and theta brainwaves. It is in fact now commonly believed that it may eventually be possible to bring under some degree of voluntary control *any* physiological process that can be continuously monitored, amplified and displayed

GALVANIC SKIN RESPONSE

The skin is an extraordinarily sensitive and rapid indicator of stress. Some people know this only too well – they literally develop nervous rashes.

When you become tense a number of readily measurable changes take place. A major change is the massive shift in electrical resistance of the dermis (the layer beneath the skin's outside surface). This shift is not only large but also very swift and the reaction happens regardless of where the centre of stress happens to be. A minor change in tension of a stomach muscle will cause just as large a change as clenching your fingers.

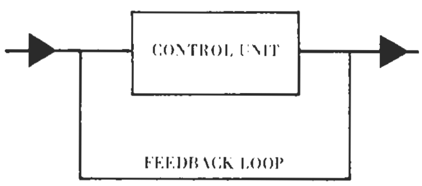
Galvanic skin response monitors (or GSR machines as they're generally called) monitor the resistance between two adjacent fingers of one hand. They translate and present this data as a meter indication or as a tone of related pitch (i.e. as tension decreases, pitch falls, and vice versa).

GSR machines are quite easy to build: they can be simply expanded-scale ohmeters covering the range 5000–100 000 ohms. A sensitivity control is essential, as is a readily adjustable method of switching resistance ranges.

Readout may be a simple analogue meter (digital tends to be harder to read in this application) or preferably a corresponding audio tone in which the pitch decreases as tension falls. Surprisingly perhaps GSR resistance *increases* as tension falls.

Electrodes may be made from any flexible conductive material — like steel wool, soft metal mesh etc — held firmly against the fleshy part of your finger tips by a velcro strap or something similar.

GSR machines are very easy to use. In fact one of the best ways is simply to switch on and try to cause the meter reading to fall — or the tone to drop in pitch. Usually you will find out how to do this within a few minutes.

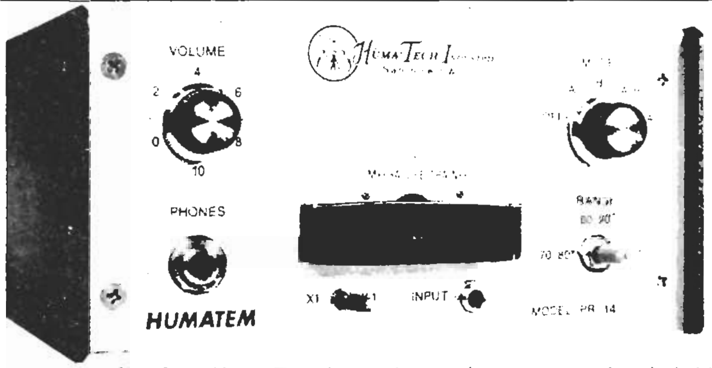


The basic feedback loop.

GSR machines make you *aware* of tension — and then enable you to *control* that tension. Eventually — after ten or so half-hour sessions the conscious control that you have learned becomes an automatic response. From then on the GSR machine is no longer required. In fact it becomes a handicap to further progress just like retaining 'training wheels' on a kid's bicycle.

Biofeedback thus operates in the opposite way to drugs. You can use sedatives to control tension if you wish. But if you do you've then got *two* problems. You still have the underlying tension — which will become only too apparent when you run out of sedatives. And you've become a drug addict as well.

To fully appreciate the efficacy of GSR machines in tension reduction it should be understood that there is an almost one-for-one relationship between mind and body. If you reduce muscular tension you will automatically reduce mental tension which in turn will reduce muscular tension yet further — and so on.



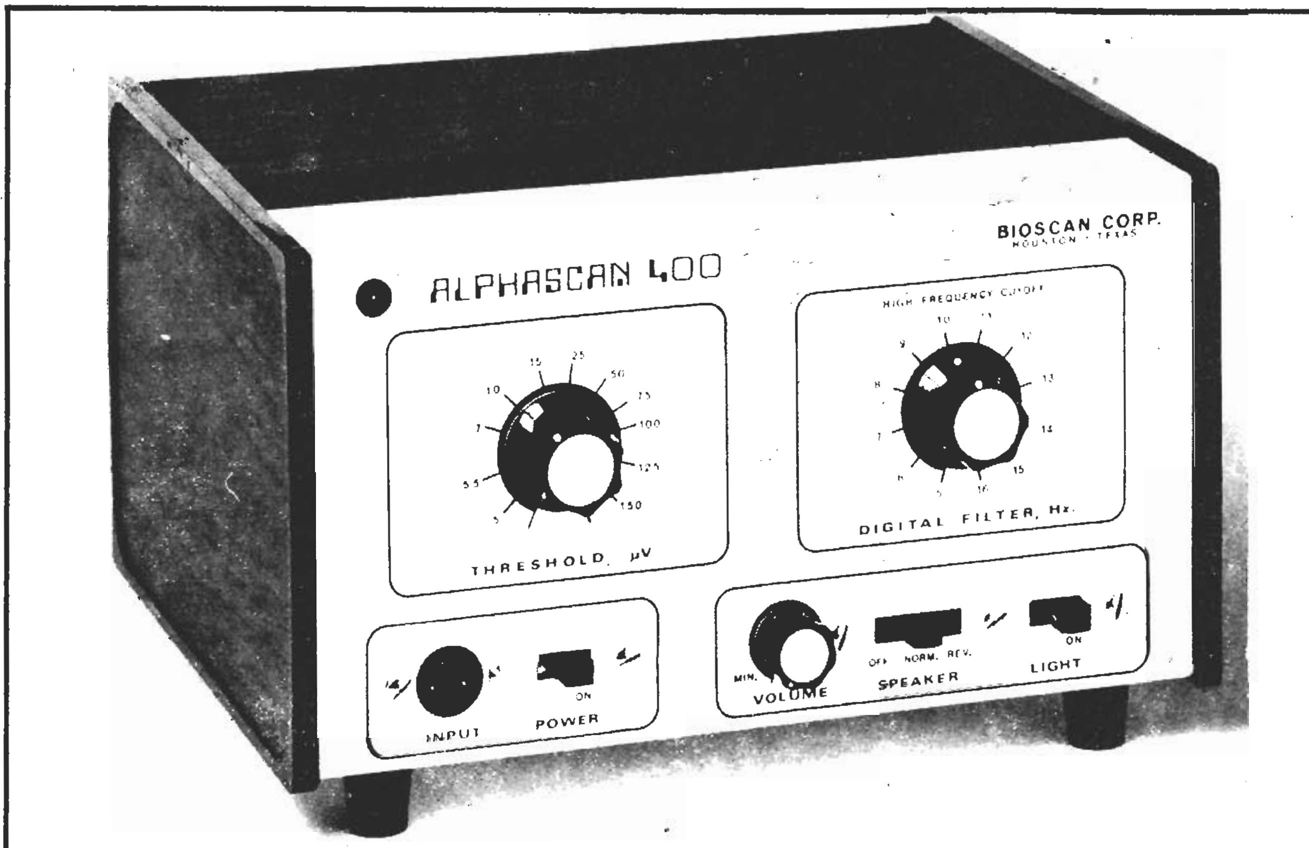
Temperature trainer from Huma-Tech Industries has three ranges each switchable to provide 0-10° or 0-1° fsd.

TEMPERATURE MONITORING

Tension is also reflected in skin temperature — particularly in the hands. A considerable amount of work in this field has been performed by Green and Green of the USA's Menninger Foundation research dept, who use this technique extensively in the control of migraine.

As with GSR, the technique and equipment is remarkably simple. Subjects are simply taught to raise their hand temperature — meanwhile monitoring the effect on an expanded-scale temperature meter. A small thermistor is taped to a finger tip to monitor changes and the output from this is backed off against a second thermistor within the instrument to compensate for ambient temperature changes.

instant yoga?



Advanced alpha/theta instrument from Bioscan uses digital filtering and threshold adjustment to eliminate interference from spurious phenomena.

At a recent demonstration (attended by the writer) some fifty subjects with no previous experience of temperature training all succeeded in varying their hand temperature (in some cases by as much as 5°C within a single twenty minute session).

If you're contemplating building your own temperature monitor choose thermistors with a two to three second response time. Build the thermometer so that ambient temperature can be backed off, thus enabling the meter to give a centre zero indication at the beginning of the experiment. The instrument should have two switchable ranges — ±2.5°F and ±7.5°F.

As with GSR machines the readout may be either a tone of varying pitch and/or a meter reading.

People teach themselves to use these devices very quickly — usually within ten to fifteen minutes. However, whilst almost everyone can effect a change of temperature, about 50% will find the change to be in the opposite direction to that intended! Nevertheless the correct technique is quickly acquired after a few more minutes.

ELECTROMYOGRAPHS

Feedback electromyographs (EMGs) provide information about muscular tension by visually and aurally displaying neuron firings caused by muscular activity. They are commonly used in both clinical and research applications for the observation and reduction of stress and anxiety, tension and migraine headaches, tension backaches, muscle spasms and tics, essential hypertension etc.

Unlike the far simpler GSR and temperature indicators, myographs necessarily need sophisticated electronic circuitry in order to monitor the very low level activity of neuron firings.

The actual signals are picked off by silver, silver-chloride or gold electrodes placed on the surface of the skin directly across the muscle concerned. In some cases the signal may be obtained via implanted electrodes.

Signal level is very low — often as small as 0.1 microvolts, so noise rejection must be high. A typical unit will have common mode rejection of better than 100 dB. A bandpass filter is usually incorporated. This typically rolls off at 18 dB/octave beyond 100–500 Hz. The output signal is generally averaged over an adjustable 0.5 to 5 second period.

This type of instrument is not really suitable for home designing or building.

HEART RATE

The heart is simply a four-chambered pump. It receives circulating blood, causes the blood to be pushed into the lungs where it picks up oxygen, then causes this blood to be returned to the heart and finally and very powerfully this re-oxygenated blood is forced through the body.

The rate at which the heart beats appears to be directly related to the metabolic requirements of the body, but the way in which this is done is not currently understood. However virtually every part of the brain yet examined appears to play some part in the determining and controlling heart rate.

Short of simply feeling one's pulse and timing it with a stopwatch, the next simplest method is to monitor fluctuations in blood density as the pulse occurs. This may be done opto-electronically using a simple light source and photocell attached across an ear-lobe or finger tip.

There is growing evidence that the ability to control heart rate via a biofeedback process would be of value in protecting it from undue stress. As with most biofeedback activities it is very easy to do this given the correct apparatus. Yogis have, of course, gained such

biofeedback

control *without* apparatus. Nevertheless it should be emphasised that less appears to be known about heartrate control than galvanic skin response or myography.

BRAINWAVE MONITORS

The brain produces four major electrical rhythms, classified by frequency. These rhythms may be monitored by an electroencephalograph (EEG) which detects, amplifies and displays them electrically.

The major rhythms are —

Beta: 13-30 Hz — associated with attention, anxiety.

Alpha: 8-12 Hz — associated with relaxation, well being.

Theta: 4-8 Hz — associated with imagery, meditation.

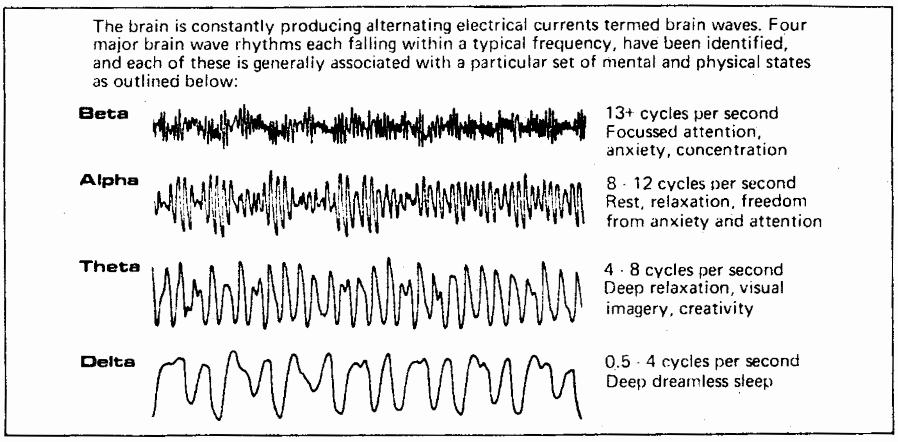
Delta: 0.5-4 Hz — associated with dreamless sleep.

Generally the rhythms are produced in short bursts — often of 10—25 cycles — and generally non-overlapping.

The signals may all be monitored via one set of electrodes placed at the front and rear of the skull — a third electrode is also used to provide a 'reference'.

All four rhythms have very low amplitude — about a microvolt or two — so that good noise performance is essential if the equipment is to function correctly.

Very good filtering is also required to eliminate interference from stray 50 Hz signals and also to prevent interference from artifacts (spuria generated by muscular activity). Analogue filters having the required characteristics can be produced but digital filters should preferably be used. If an analogue filter is used, a good one is a three-pole Butterworth with 18 dB/octave rolloff.



It is almost essential to use a differential input amplifier using low noise devices. Input cables must be shielded. Common mode rejection should be about 120 dB at 10 Hz and if possible at least 150 dB at 50 Hz. Input impedance should be no less than one megohm. The output indication should be aural. Most people prefer to have their eyes closed when trying to generate alpha rhythms.

Alpha training has become somewhat of a cult — particularly in the USA where a large industry exists simply to supply alpha monitors (of varying efficacy!)

Most people can learn to generate alpha rhythms at will and there is a great deal of evidence that a state of well-being and deep relaxation is associated with alpha production.

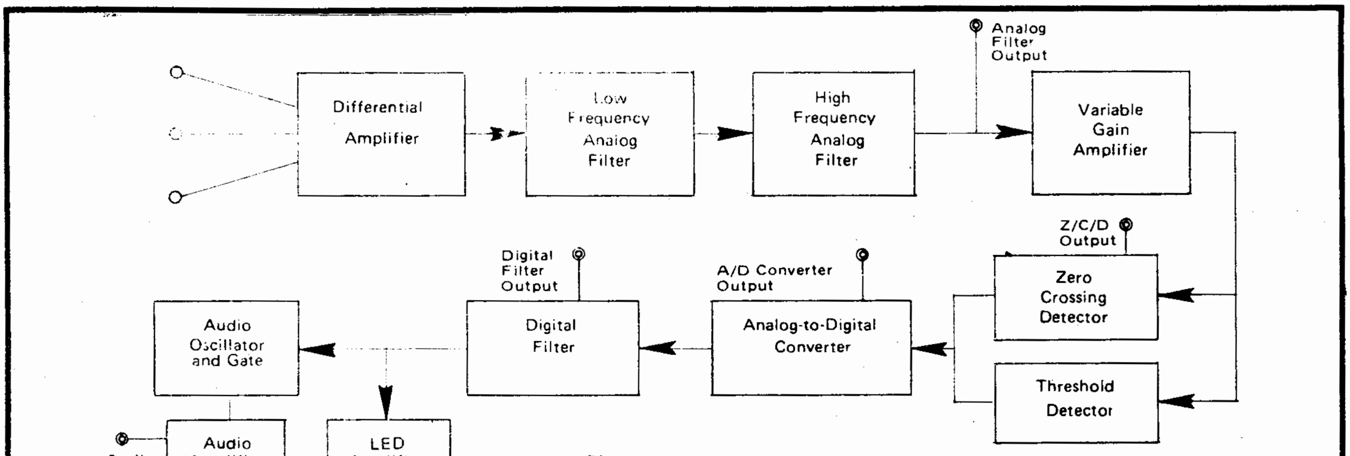
Alpha training is also used by clinical psychologists and psychiatrists particularly in attitude change and re-inforcement.

Theta waves are also controllable. This type of waveform appears to be in some way associated with creativity. It may well be that creativity can be enhanced by learning to control a theta state: we understand that some researchers are investigating this at present.

Biofeedback is still very much an infant and largely orphan science and at present it is difficult to forecast just what impact it will have on mankind.

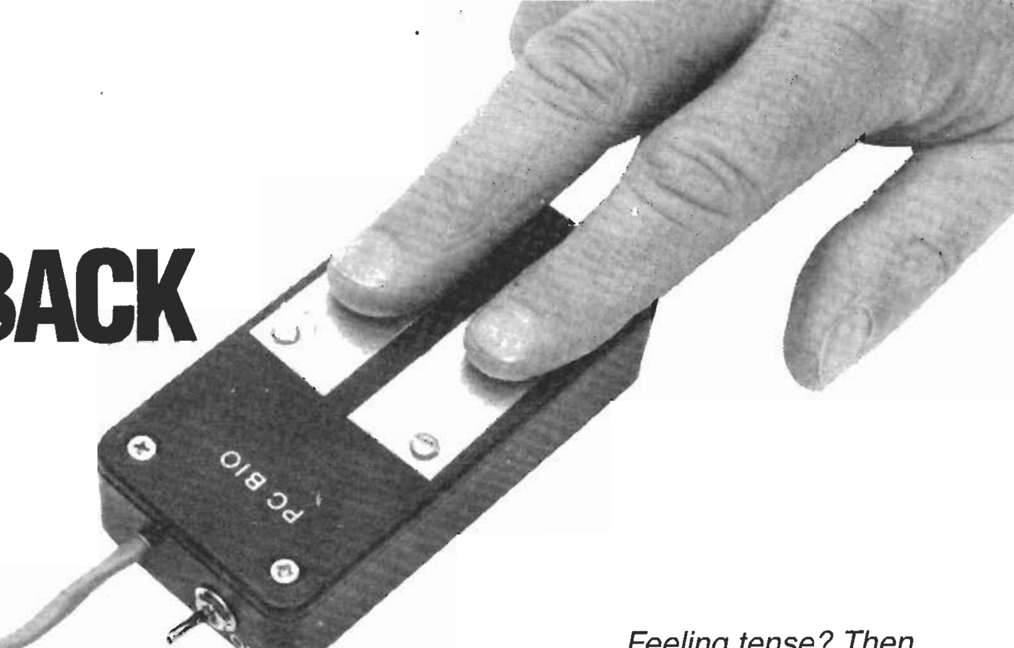
There is ample evidence that by using biofeedback the average subject can in minutes learn to vary his state of tension, body temperature, heart rate, brainwave generation etc — techniques which have taken gurus a lifetime to master.

Many autonomic nervous functions clearly *can* be willfully controlled and there is growing evidence that many tension-related illnesses (and about 90% of illnesses are currently believed to be so related) can be alleviated or cured by biofeedback techniques. ●



Bioscan alpha/theta instrument — block schematic

BUILD A BIOFEEDBACK MONITOR



JIM BARBARELLO

Feeling tense? Then let your computer calm you down.

Although most persons think of the IBM PC primarily as a business computer that grinds its way from 9 to 5 through spreadsheets, databases, and documents, it can also be made to serve other, quite-different roles. One such application is as a computer-assisted biofeedback monitor.

Biofeedback is the process of monitoring a biological function that indicates your level of tenseness, and then feeding back that information to you in real time. By allowing you to see what happens when you try to relax, biofeedback lets you discover the techniques that work best for you. You can then practice those techniques to gain more control over daily tension and stress.

One biological function that indicates tenseness is your galvanic skin response, usually called simply GSR, which in non-medical terms simply means the resistance of your skin. As you become more tense, your rate of perspiration increases, thereby lowering the resistance of your skin. As you become less tense—as you "calm down"—the perspiration rate slows and your skin's resistance increases. A variation from your normal or average GSR is therefore an accurate biofeedback indicator of how tense or calm you are at a given instant in time. If you then use a computer to store a record of how tense or calm you were over a period of time, the same computer can provide you with a listing or a graphic display of the effectiveness of your efforts at reaching mental nirvana.

Measuring GSR

The easiest, and certainly the most simple way to measure GSR would be with an analog resistance-measuring device such as an ohmmeter. Unfortunately, analog measurements are not well-suited to digital computers. There is, however, a surprisingly simple alternative. By using a circuit that generates a digital pulse whose duration is proportional to a resistance, we can use a computer to measure the length of the pulse and then interpolate the pulse-length into a resistance value. That approach forms the basis for a biofeedback monitor for IBM PC-type computers. The monitor's schematic is shown in Fig. 1.

Integrated circuit IC1 is a 555 timer that is configured as a simple pulse generator. The width of its output pulse is the product of capacitance C1, resistance R1, and the skin resistance present between probes A and B. Since C1 and R1 are constant, any change in the pulse width is the direct result of a change in the resistance between probes A and B. Now all we need to do is to trigger IC1 to force its ouput, output pin 3, high, and measure the period of time until the output on pin 3 goes low (returns to ground—the end of the pulse).

The printer port

It may seem strange, but the computer's LPT1 parallel-printer port is the ideal way of interconnecting the biofeedback monitor to the computer. The PC's printer port has a number of input and output lines that are normally used to do things like initialize the printer and check for a busy status. Connector PL1 attaches to the PC's printer port. Pin 16 of the connector, the INIT line, connects to IC1's trigger input, pin 2. Sending out a short INIT pulse from the computer triggers IC1 and causes IC1's output, pin 3, to go high. Pin 3 goes low at the end of the pulse.

Pin 11 of PL1 is the computer's BUSY line. If we have the computer check for a low on pin 11, it will know when IC1's pulse has ended.

The common ground between the computer and the biofeedback monitor is through PL1 pin 20. Switch S1 applies power to the circuit through series-connected

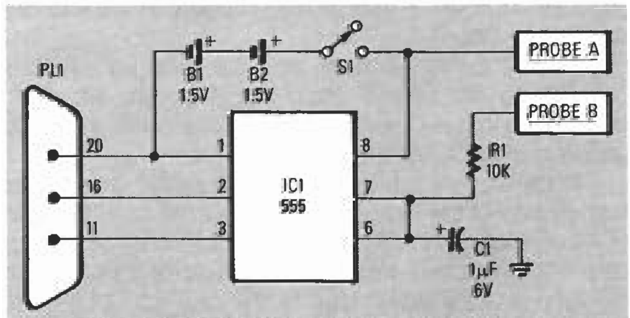


FIG. 1—THE PROBES ARE ACTUALLY FOIL STRIPS cemented to the top of the plastic case that houses the circuit. Because absolute stability is needed, batteries B1 and B2 should be secured by a holder, rather than be simply soldered into the circuit.

batteries B1 and B2. The batteries provide only 3 volts, so the output of IC1 will also be about 3 volts instead of the more usual 5 volts. Although 3 volts is much less than 5 volts, it is high enough to be sensed by the computer's printer port.

The software

The simplicity of the hardware is made possible by the fact that the software does most of the work in creating a screen display of your GSR. Let's look at some of the more important aspects of the program, called *PCBIO*, that is shown in Listing 1 and available on the REBBS (516-293-2283).

Line 30 looks to see if a printer port is installed and determines its address. Line 50 uses that information to set the addresses for the trigger input (T) and output (G) to the circuit. Line 190 begins the process of initialization. Since each person's GSR is different, the program takes five initial samples and averages them to determine a mid-range value (Y in line 220). Line 220 also calculates an increment value (INC) used to determine the range from full calm to full tense. Those range values are stored in array L in line 230.

The actual monitoring process begins in line 250. A call to the subroutine at line 320 gets a sample from the hardware as a count stored in variable X. Lines 280 and 290 determine where the tenseness indicator should be and places it there. The monitoring session ends when either full calm is reached (L>22 in line 280) or when you press the ESC key during monitoring (C = 27 in line 260).

The subroutine at line 320 interfaces with the hardware. Line 330 generates a short negative-going pulse to trigger IC1. Line 340 begins counting the time by incrementing variable X and checks to see if IC1's output has returned to zero (INP(G) = 127). When it does, line 350 checks to see if another sample should be taken (Z<XF). Variable XF is a scaling factor used to ensure that the count returned in variable X will always be above 100 (lower counts make the gauge displayed on the screen respond too quickly, and are distracting during the monitoring session). The commands LOCATE 1,60:PRINT X;: in line 350 display the actual count number just past the title on the screen display. The number may be removed.

Construction

The circuit can be assembled on a small scrap of perforated wiring board, which is installed along with a battery holder in a Radio Shack *270-220*, or similar, plastic case. Simply pass the components' leads through the appropriate holes and solder them together on the underside of the board.

Glue the battery holder into the case, as close as possible to one end. If you'd like to secure the circuit board, it, too, can be glued to the case with a drop of silicon rubber (RTV) adhesive or caulk.

The probes are simply two aluminum foil strips glued to the cover of the case; they are connected to the circuit by wires that run inside the case. Cut two strips of ordinary household aluminum foil to a size of 2 × ¾-inch. Apply a drop of white glue to the dull side of the foil. Then, as shown in Fig. 2, place the foil (glue side down) on the cover of the case, smoothing out the foil and removing any excess glue that squeezes out with a damp cloth. Let the glue dry for at least one hour and then drill

LISTING 1

```
1 REM**          PC Biofeedback Monitor Program
2 REM**          NAME: PCBIO
3 REM**          c 1987, JJ Barbarello, Manalapan, NJ 07726
4 REM**          V870911
10 CLEAR:DEFINT G,X:G=0:X=0:DEFSTR A,B:A=CHR$(232):B=SPACE$(2)
20 COLOR 0,6,6:CLS:KEY OFF:WIDTH 80:DIM L(22)
30 DEF SEG=64:PA=PEEK(8)+256*(PEEK(9))
40 IF PA=0 THEN COLOR 7,0,0:CLS:GOTO 430
50 A=CHR$(232):B=SPACE$(2):G=PA+1:L=13:T=PA+2:LOCATE 1,23,0
60 PRINT STRING$(5,16);" P.C. BIOFEEDBACK MONITOR ";STRING$(5,17)
70 LOCATE 2,37:PRINT CHR$(201);STRING$(5,205);CHR$(187)
80 FOR I=3 TO 22:LOCATE I,37:PRINT CHR$(204);B;A;B;CHR$(185):NEXT
90 LOCATE 23,37:PRINT CHR$(200);STRING$(5,205);CHR$(188)
100 LOCATE 3,31:PRINT"TENSE ";CHR$(206)
110 LOCATE 13,29:PRINT"AVERAGE ";CHR$(206)
120 LOCATE 22,32:PRINT"CALM ";CHR$(206):PLAY "L64"
130 FOR I=3 TO 22:LOCATE I,40:PRINT" ":P$="N"+STR$(60-I*2):PLAY P$:NEXT I
140 FOR I=22 TO 13 STEP -1:LOCATE I,40:PRINT A:P$="N"+STR$(60-I*2)
150 PLAY P$:LOCATE I,40:PRINT" ":NEXT I:LOCATE 13,40:PRINT A
160 LOCATE 24,22,1:PRINT"Press <ENTER> to begin, or <ESC> to end...";
170 AA=INPUT$(1):C=ASC(AA):IF C=27 THEN 400 ELSE IF C<>13 THEN 170
180 LOCATE 24,22,0:PRINT SPACE$(42);
190 LOCATE 24,34:PRINT"INITIALIZING...";:Y=0:PLAY"L64":XF=1
200 GOSUB 320:IF X<100 THEN XF=XF+1:PLAY "L64;N32":GOTO 200
210 FOR I=1 TO 5:GOSUB 320:PLAY "L64;N34":Y=Y+X:NEXT I
220 Y=Y/5:INC=Y/100:LOCATE 24,28:PRINT"Press <ESC> to End Trial.";
230 PLAY"L32":LOW=Y-10*INC:FOR I=3 TO 22:L(I)=LOW+(I-2)*INC:NEXT
240 REM** MONITORING
250 P$="N"+STR$(60-(L*2)):PLAY P$:IF X=0 THEN 360
260 AA=INKEY$:IF AA<>"" THEN C=ASC(AA):IF C=27 THEN 370
270 GOSUB 320
280 IF X>L(L) THEN LOCATE L,40:PRINT" ":L=L+1:IF L>22 THEN 370 ELSE LOCATE
    L,40:PRINT A
290 IF X<L(L) THEN L=L-1:IF L<3 THEN L=3 ELSE LOCATE L+1,40:PRINT " ":LOCATE
    L,40:PRINT A
300 GOTO 250
310 REM**  SAMPLING SUBROUTINE
320 X=0:Z=0
330 OUT T,0:OUT T,4
340 X=X+1:IF (INP(G) AND 128)=0 THEN 340
350 Z=Z+1:IF Z<XF THEN 330 ELSE LOCATE 1,60:PRINT X;:RETURN
360 REM** TRIAL END
370 LOCATE 13,8,1
380 PRINT"TRIAL COMPLETED.  Press <ENTER> to try again, or <ESC> to end...";
390 AA=INPUT$(1):C=ASC(AA):IF C=13 THEN CLS:GOTO 50 ELSE IF C<>27 THEN 390
400 COLOR 7,0,0:CLS:LOCATE 10,28,1:PRINT"MONITORING SESSION OVER"
410 LOCATE 13,1:END
420 REM** CAN'T FIND STANDARD PRINTER PORT
430 LOCATE 10,27,1 PRINT"PRINTER PORT 1 NOT AVAILABLE":PRINT:PRINT:END
```

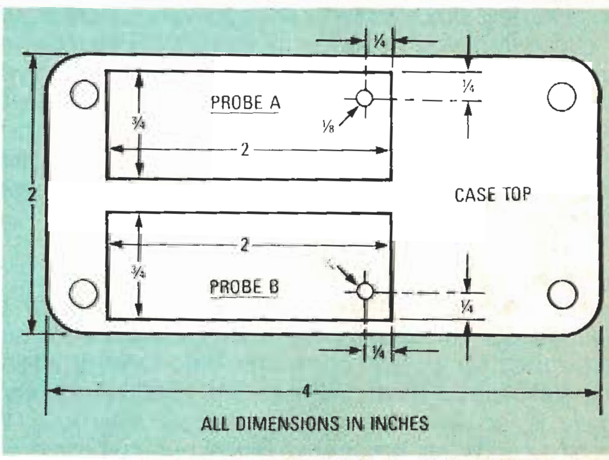


FIG. 2—IT'S NOT ALL THAT CRITICAL, but this kind of installation for the foil strips on the cover of the specified case will prove the most convenient for all sizes of hands and fingers.

two ⅛-inch diameter holes at the locations shown in Fig. 2. Place two 4-40 × ¼-inch machine screws through the holes and loosely screw a 4-40 nut onto each screw. Wrap the bare end of either of the wires from the circuit board around either of the screws and tighten the nut. Repeat the procedure for the remaining wire and screw. Figure 3 shows how the prototype was assembled.

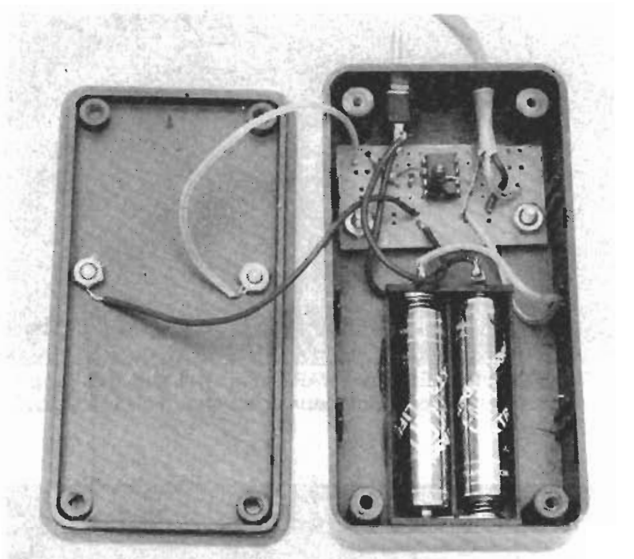


FIG. 3—THE COMPLETED PROTOTYPE. Notice how the wires to the foil strips simply connect to the screws that pass through the cover.

PARTS LIST

- IC1—555 timer
- R1—10,000 ohms, ¼-watt, 10% resistor
- C1—1 µF, 6-volt, Tantalum capacitor
- B1, B2—1.5 volt, AAA battery
- PL1—25 pin D-connector
- S1—SPST switch
- Miscellaneous—Plastic case, battery holder, perforated wiring board, wire, solder, machine screws, etc.
- Note: A compiled, enhanced version of the *PCBIO* program is available on 5¼-inch diskette from JJ Barbarello, RD #3, Box 241 H, Tennent Road, Manalapan, NJ 07726. Price of $7 includes postage and handling. NJ residents must add appropriate sales tax. If known, indicate the type of computer and its clock speed.

Using the monitor

Connect PL1 to your computer's parallel printer port, apply power to the monitor by closing S1, then load BASIC and the PCBIO program in your computer. When you run the program, the computer will create the screen shown in Fig. 4. In the center is a tenseness gauge resembling a thermometer. The top of the gauge is maximum tenseness, the bottom of the gauge is maximum calm, and the center of the gauge (where you begin) is average. The message on the bottom of the screen asks you to press ENTER to begin monitoring, or ESC to end the session.

The room you're in should be comfortable (about 70°F). Sit in a chair that provides good support and loosen any tight clothing. Place the biofeedback monitor unit next to you on a table or stand that can support the unit and your forearm. Make sure your fingers are free of oil or excess perspiration. Rest your forearm on the stand in front of the unit, place your first (index) finger on one probe and your second finger on the other probe. It is

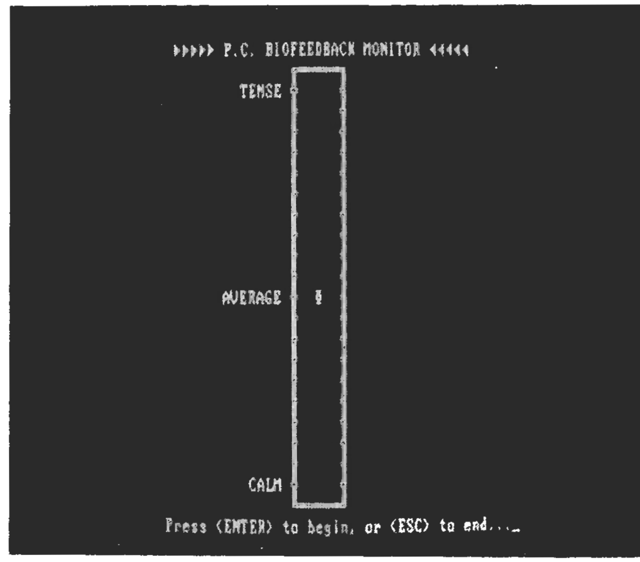


FIG. 4—THE OPENING SCREEN shows a thermometer-type device that ranges from calm to tense.

very important that you do not move your fingers or change the pressure on the probes during the monitoring session, as that will change the resistance between the probes and give a false reading.

Press the ENTER key with your free hand. The message on the bottom of the screen will change to "INITIALIZING" and you will hear a series of beeps as the system measures your initial level of tenseness. After a short time, the message on the bottom of the screen will change to "Press C to End Trial"; you are now monitoring your changing level of tenseness. That's indicated by the moving cursor in the middle of the gauge, and a beep with a changing tone. As you become more tense, the beep's frequency and the indicator ascend, as shown in Fig. 5. When you calm down, the beep's frequency and the indicator descend, as shown in Fig. 6. The session will end when you either press the ESC key or reach maximum calm (nirvana?). The message "TRIAL COMPLETED. Press Enter to try again, or Escape to end" will appear in the middle of the screen. When you end the session, the

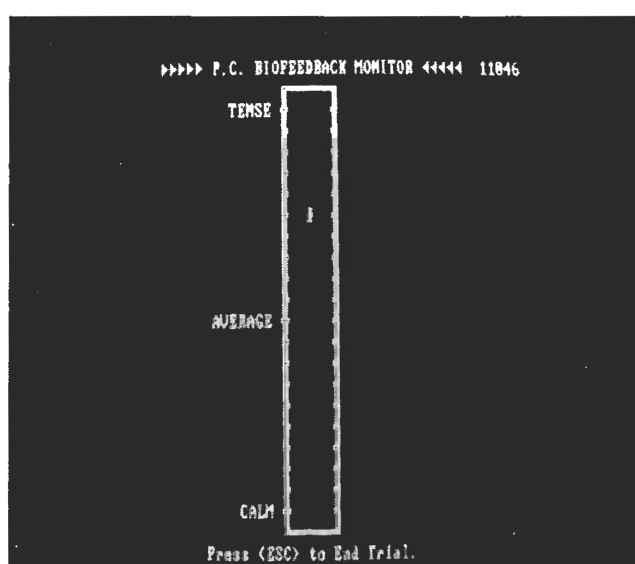


FIG. 5—IF YOU'RE TENSE, the indicator will slide up the thermometer and tone from the computer's speaker will rise in pitch.

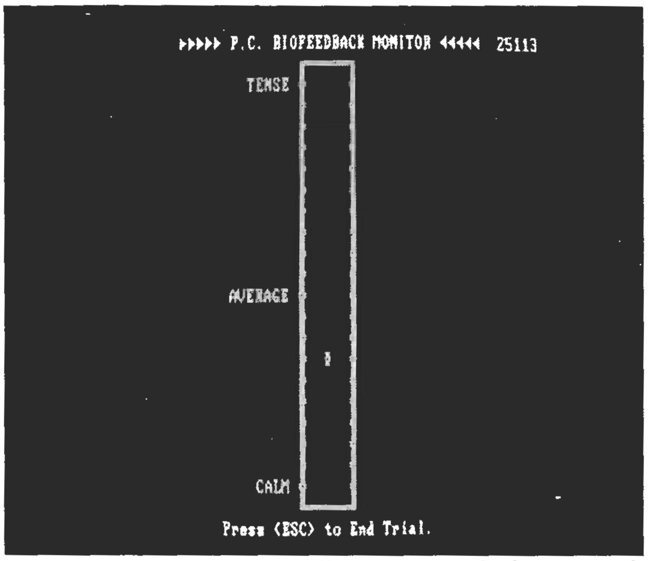


FIG. 6—THE CALMER YOU GET the lower the indicator's position, and the lower the tone heard from the speaker.

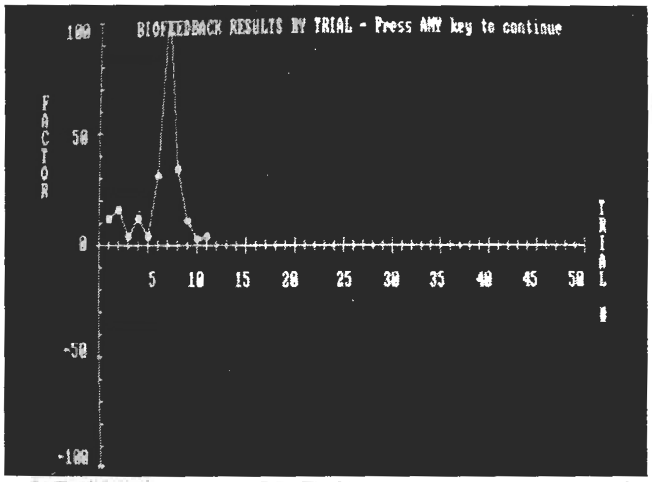


FIG. 7—THE COMPILED SOFTWARE will store and then graphically plot the results of a biofeedback session. This is the standard display.

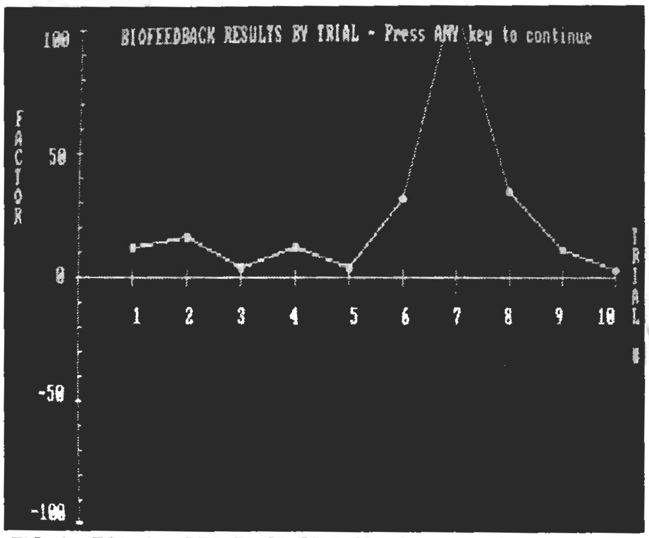


FIG. 8—FOR A MORE PRECISE EXAMINATION of your session, the plot can be expanded.

screen will clear except for the message "MONITORING SESSION OVER."

To test the unit, begin monitoring. Press down hard with your two fingers to simulate increased perspiration (tenseness). The indicator should begin to rise. Release the pressure and note that the indicator begins to fall. Press ESC to end the trial. When you are sure that the unit is working properly, you can begin actual monitoring.

You should now try to concentrate on different images or thoughts and note the results on the gauge. At first it may seem that trying to calm down actually increases tension. That is normal because the untrained mind tends to race through both conscious and unconscious thoughts. Through practice you will learn how to focus on the images and thoughts that actually decrease tension—disregarding everything else, and use them to assist you in your calming process.

Tweaking

The software monitoring subroutine is sensitive to the speed of your computer. The program listing contains the factor "IF X <100" in line 200 to adjust it for use on a standard 4.77-MHz computer. Computers operating at 8 MHz, or AT systems, will respond more quickly and produce a higher count for the same amount of time and seem to be racing along. To compensate for racing, simply change the "100" in line 200 to a higher number (try 300 as a starting value, and adjust it until you are comfortable with the speed).

Enhanced software

The program may have some difficulty with some versions of BASIC on floppy-disk-only systems. If that is the case, you will notice the indicator move very slowly when you initially run the program (normally the indicator zips down the gauge and then back up to "AVERAGE"). If you experience the problem, a compiled version of the program is available from the source given in the parts list. It is an executable program that runs in DOS and, thus, does not require the use of BASIC. The compiled program has also been enhanced to include storage and analysis of results: both lists and graphic plots. Figure 7 shows a standard plot display of a monitoring session. Figure 8 shows the same session using the program's expanded plot feature.

Closing thoughts

The biofeedback monitor is basically just a self-learning type of device, that also happens to be a lot of fun. It is not meant to take the place of any necessary medical treatment or equipment. However, with practice, the device can help you learn how to reduce everyday stress and tension. Sooner or later you'll find that you do have the ability to mentally calm and relax yourself. It's just a matter of finding the technique that's right for you.

Another interesting point is that GSR is one measure that is used by polygraphs (lie-detector) to determine whether or not someone is lying. For that reason, the device can be used as a rudimentary "lie detector" for general entertainment at parties and gatherings. We're sure that you'll find many other interesting uses for the biofeedback monitor—perhaps you can even modify it so that you can monitor other bodily functions. If you do, why don't you drop us a note and let us know about." R-E

LISTING 1

```
1 REM**         PC Biofeedback Monitor Program
2 REM**         NAME: PCBIO
3 REM**         c 1987, JJ Barbarello, Manalapan, NJ 07726
4 REM**         V870911
10 CLEAR:DEFINT G,X:G=0:X=0:DEFSTR A,B:A=CHR$(232):B=SPACE$(2)
20 COLOR 0,6,6:CLS:KEY OFF:WIDTH 80:DIM L(22)
30 DEF SEG=64:PA=PEEK(8)+256*(PEEK(9))
40 IF PA=0 THEN COLOR 7,0,0:CLS:GOTO 430
50 A=CHR$(232):B=SPACE$(2):G=PA+1:L=13:T=PA+2:LOCATE 1,23,0
60 PRINT STRING$(5,16);" P.C. BIOFEEDBACK MONITOR ";STRING$(5,17)
70 LOCATE 2,37:PRINT CHR$(201);STRING$(5,205);CHR$(187)
80 FOR I=3 TO 22:LOCATE I,37:PRINT CHR$(204);B;A;B;CHR$(185):NEXT
90 LOCATE 23,37:PRINT CHR$(200);STRING$(5,205);CHR$(188)
100 LOCATE 3,31:PRINT"TENSE ";CHR$(206)
110 LOCATE 13,29:PRINT"AVERAGE ";CHR$(206)
120 LOCATE 22,32:PRINT"CALM ";CHR$(206):PLAY "L64"
130 FOR I=3 TO 22:LOCATE I,40:PRINT" ":P$="N"+STR$(60-I*2):PLAY P$:NEXT I
140 FOR I=22 TO 13 STEP -1:LOCATE I,40:PRINT A:P$="N"+STR$(60-I*2)
150 PLAY P$:LOCATE I,40:PRINT" ":NEXT I:LOCATE 13,40:PRINT A
160 LOCATE 24,22,1:PRINT"Press <ENTER> to begin, or <ESC> to end...";
170 AA=INPUT$(1):C=ASC(AA):IF C=27 THEN 400 ELSE IF C<>13 THEN 170
180 LOCATE 24,22,0:PRINT SPACE$(42);
190 LOCATE 24,34:PRINT"INITIALIZING...";:Y=0:PLAY"L64":XF=1
200 GOSUB 320:IF X<100 THEN XF=XF+1:PLAY "l64;N32":GOTO 200
210 FOR I=1 TO 5:GOSUB 320:PLAY "L64;N34":Y=Y+X:NEXT I
220 Y=Y/5:INC=Y/100:LOCATE 24,28:PRINT"Press <ESC> to End Trial.";
230 PLAY"L32":LOW=Y-10*INC:FOR I=3 TO 22:L(I)=LOW+(I-2)*INC:NEXT
240 REM** MONITORING
250 P$="N"+STR$(60-(L*2)):PLAY P$:IF X=0 THEN 360
260 AA=INKEY$:IF AA<>"" THEN C=ASC(AA):IF C=27 THEN 370
270 GOSUB 320
280 IF X>L(L) THEN LOCATE L,40:PRINT" ":L=L+1:IF L>22 THEN 370 ELSE LOCATE
    L,40:PRINT A
290 IF X<L(L) THEN L=L-1:IF L<3 THEN L=3 ELSE LOCATE L+1,40:PRINT " ":LOCATE
    L,40:PRINT A
300 GOTO 250
310 REM**  SAMPLING SUBROUTINE
320 X=0:Z=0
330 OUT T,0:OUT T,4
340 X=X+1:IF (INP(G) AND 128)=0 THEN 340
350 Z=Z+1:IF Z<XF THEN 330 ELSE LOCATE 1,60:PRINT X;:RETURN
360 REM** TRIAL END
370 LOCATE 13,8,1
380 PRINT"TRIAL COMPLETED.  Press <ENTER> to try again, or <ESC> to end...";
390 AA=INPUT$(1):C=ASC(AA):IF C=13 THEN CLS:GOTO 50 ELSE IF C<>27 THEN 390
400 COLOR 7,0,0:CLS:LOCATE 10,28,1:PRINT"MONITORING SESSION OVER"
410 LOCATE 13,1:END
420 REM** CAN'T FIND STANDARD PRINTER PORT
430 LOCATE 10,27,1 PRINT"PRINTER PORT 1 NOT AVAILABLE":PRINT:PRINT:END
```

GRAPHIC BIOFEEDBACK MONITOR

Here's a simple and interesting experiment...

Ronald A. Peterson

■Biofeedback is a fascinating area of exploration in that it allows you to mechanically produce a physical reaction that is associated with a change in your thoughts. Perhaps some of the fascination comes from the possibility that with a subtle enough device one could draw a line on a computer screen or direct a robot to move an object. Such an advance would give us the ultimate in remote control and would provide an end to many excuses for not doing things, since the thought would be sufficient to trigger the action.

This article describes the interfacing of a simple biofeedback device to a Commodore 64 computer to provide a graphic display of your state of mental relaxation. The most easily measured property of your body which can be linked to changes in state of mind

```
1 REM---BIOFEEDBACK ROUTINES
2 REM---RE DECEMBER 5,1985
3 REM--- RONALD PETERSON
10 REM---LOAD MACHINE ROUTINES
20 FOR I=4096 TO 4165
30 READ A:POKEI,A:CK=CK+A
40 NEXT I
50 FOR I=12288 TO 12386
60 READ A:POKEI,A:CK=CK+A
70 NEXT I
80 FOR I=12544 TO 12557
90 READ A:POKEI,A:CK=CK+A
100 NEXT I
110 IF CK=22442 THEN 120
115 PRINT"ERROR IN DATA STATEMENTS"
116 STOP
120 REM---SET FREQUENCY
130 SYS4096
140 PRINTPEEK(8192)+256*PEEK(8193)
150 FORI=1TO100:NEXT
160 PRINT "□SET TO 50-->";
170 GETA$:IFA$<>"" THEN 200
180 GOTO130
190 REM---CLEAR SCREEN
200 POKE53280,0:POKE53281,0
210 FOR I=1024 TO 2023
215 POKEI,160:NEXT I
220 FOR I=55296 TO 56295
225 POKEI,0:NEXT I
230 REM---UPDATE GRAPHICS
240 SYS4096
250 Q=PEEK(8192)+256*PEEK(8193)
260 CL=CL+1:CL=CLAND15:POKE12434,CL
270 FOR J=1 TO 3*Q:NEXT
280 SYS12288
290 GOTO 240
295 REM---READ JOYSTICK PORT
300 DATA  120 , 169 , 0 , 141
310 DATA  0 , 32 , 141 , 1
320 DATA  32 , 173 , 0 , 220
330 DATA  41 , 1 , 240 , 249
340 DATA  173 , 0 , 220 , 41
350 DATA  1 , 208 , 249 , 32
360 DATA  64 , 16 , 173 , 0
370 DATA  220 , 41 , 1 , 240
380 DATA  246 , 32 , 64 , 16
390 DATA  173 , 0 , 220 , 41
400 DATA  1 , 208 , 246 , 88
410 DATA  96 , 173 , 0 , 32
420 DATA  24 , 105 , 1 , 141
430 DATA  0 , 32 , 173 , 1
440 DATA  32 , 105 , 0 , 141
450 DATA  1 , 32 , 173 , 0
460 DATA  220 , 41 , 1 , 240
470 DATA  232 , 96
480 REM---DISPLAY ROUTINES
490 DATA  169 , 0 , 133 , 251
500 DATA  169 , 216 , 133 , 252
510 DATA  169 , 0 , 141 , 144
520 DATA  48 , 169 , 40 , 141
530 DATA  145 , 48 , 162 , 12
540 DATA  173 , 146 , 48 , 172
550 DATA  144 , 48 , 234 , 234
560 DATA  145 , 251 , 234 , 200
570 DATA  204 , 145 , 48 , 208
580 DATA  247 , 32 , 0 , 49
590 DATA  238 , 146 , 48 , 238
600 DATA  144 , 48 , 206 , 145
610 DATA  48 , 202 , 16 , 224
620 DATA  234 , 234 , 234 , 206
630 DATA  144 , 48 , 206 , 144
640 DATA  48 , 238 , 145 , 48
650 DATA  238 , 145 , 48 , 162
660 DATA  12 , 173 , 146 , 48
670 DATA  172 , 144 , 48 , 145
680 DATA  251 , 200 , 204 , 145
690 DATA  48 , 208 , 248 , 32
700 DATA  0 , 49 , 238 , 146
710 DATA  48 , 206 , 144 , 48
720 DATA  238 , 145 , 48 , 202
730 DATA  16 , 227 , 96
740 REM---SUBROUTINE
750 DATA  165 , 251 , 24 , 105
760 DATA  40 , 133 , 251 , 165
770 DATA  252 , 105 , 0 , 133
780 DATA  252 , 96
```

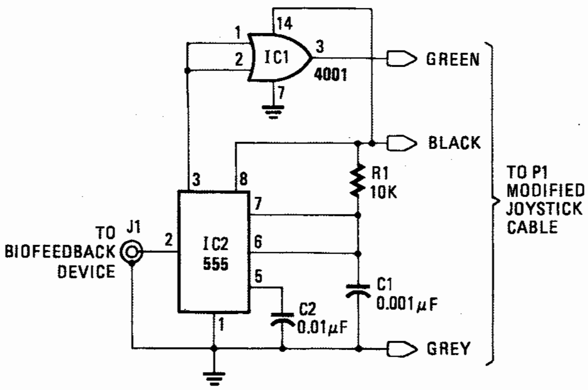
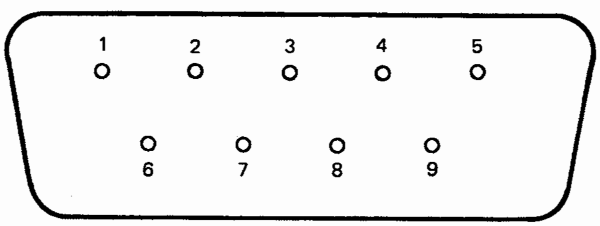


Fig. 1—SCHEMATIC DIAGRAM of interface device between joystick port and the biofeedback monitoring device.

is the resistance of your skin. To measure skin resistance we will use a biofeedback device made by Radio Shack (catalog #63-675, $12.95) The output of this device will be connected through a simple interface circuit to the joystick port on the computer and used to control the speed at which a graphic pattern changes.

To begin, build the circuit shown in figure 1. Since circuit speed is not a problem and there are no dangerous voltages, the construction technique is not critical. Building the circuit on perfboard or an experimenters socket is fine. A 1/8-inch miniature phone plug is used to connect the earplug output from the biofeedback device to the circuit. A joystick extension cable is modified by cutting off the end that goes to the joystick in order to connect the circuit to the computer's joystick port. Pay attention to the color coding of the modified cable. (See figure 2.) Improper wiring could short out the five volt power supply in your computer, destroying it!

Next type the program into the computer and Save It BEFORE running it. Since the program uses machine code routines, any error in typing it in could cause the computer to hang up, thus making it necessary to type the program in again. When you run the program the machine code will be loaded into memory and



Pin	Color	Type
1	Green	Joy Up
2	Yellow	Joy Down
3	Orange	Joy Left
4	Red	Joy Right
5	Brown	Pot DY
6	Blue	Fire Button
7	Black	+5Vdc
8	Grey	Ground
9	White	Pot AX

Fig. 2—JOYSTICK PORT pinout diagram for the Commodore. Refer to the text for further clarification.

automatically checked. Examine the DATA statements if an error occurs when it is run. The program can be tested by connecting a joystick to port 2 and running the program while moving the joystick up and down. A message will appear with a number next to it while you move the joystick. Keep moving the stick and hit the space bar on the computer. After a few moments the screen will clear and a graphic pattern will appear. If you do not get the pattern then something is wrong and you should check the program for typing errors.

To make it all work together, first load the program and run it. Then plug the biofeedback device into the circuit and connect the circuit to joystick port 2 on the computer. Next you need to set the frequency of the oscillator in the biofeedback device. It will not oscillate unless it is connected to something so attach it to your fingers and then turn it on and adjust its pitch control until the number next to the message on the computer screen begins to change. When you have a reading in the 50 to 200 range, hold down the space bar to activate the display. The screen will clear and a moving pattern will appear. Then sit back and relax! The speed with which the pattern changes should now alter depending on how relaxed you are. Since the device is sensitive to changes in skin resistance be careful not to move the hand with the electrodes attached to it or you will alter the pattern speed.

How it works

When you are relaxed your breathing slows, your heart slows down and your muscles loosen up. In this state your body doesn't need to burn as much fuel to keep going, and so with the furnaces damped down there is less oil, water and other wastes expelled through your skin. This causes a change in the resistance of your skin and it is this change that can be measured and fed back to your senses with the proper device.

Radio Shack's biofeedback device is essentially a variable frequency pulse generator where the frequency is controlled by resistance. A small current is fed through your skin, amplified, and then used to control the oscillator. The pulse output from the oscillator is fairly sloppy however so it has to be cleaned up before being sent to the computer. The 555 timer is configured as a monostable multivibrator (one-shot flip-flop) to extend the duration of the pulses which are then fed to an inverter made from a NOR gate to further square them up. Power for the circuit is provided by a +5Vdc line from the joystick port. The output of the inverter is fed to a pin on this port which is usually connected to the UP switch on a joystick. Thus each pulse from the biofeedback device is made to look to the computer like a joystick switch opening and closing.

The software contains three fundamental parts. The first is a BASIC routine which provides master control. The second is a machine language subroutine that reads the joystick port and counts the time between pulses. Lines 140 and 250 in the BASIC program read this count from where it is stored in RAM. The third is another machine language routine that draws the colored pattern on the screen. Line 260 in the BASIC program sets the starting color for the pattern every time it is redrawn. Machine language is used here for speed. The pulses from the biofeedback device are at audio frequencies and BASIC is far too slow to count the length of time between pulses. Changing all the colored bars on the screen would also be too slow in BASIC as shown by how fast the screen is cleared initially.

PARTS LIST
Semiconductors
IC1—4001 quad NOR gate
IC2—555 timer
Resistor
R1—10,000 ohms, ¼ watt, 5%
Capacitors
C1—.001μF., ceramic
C2—.01μF., ceramic
Miscellaneous
J1—Miniature phone plug
P1—Modified joystick extension cable (see text)
BF1—Biofeedback monitor (Radio Shack #63-675)
Wire, perfboard, solder, etc.

The software and hardware described here can be used for a variety of other purposes with little or no modification. The duration of events lasting less than a few seconds can be measured by connecting a switch to the joystick port in place of the circuit. A crude audio frequency meter could be built by using the machine code routine to measure the duration of one cycle. (A comparator and amplifier will probably be needed to square up and increase gain of the signal.) The code could also be modified to read the other joystick switch connections in order to sense several events simultaneously. (The lowest four bits at memory location 56320 represent the four joystick positions. The fifth bit is the fire button.) Experiment with it! Maybe you'll be the first to build a thought-controlled robot! ◀CD▶

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-Cl 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

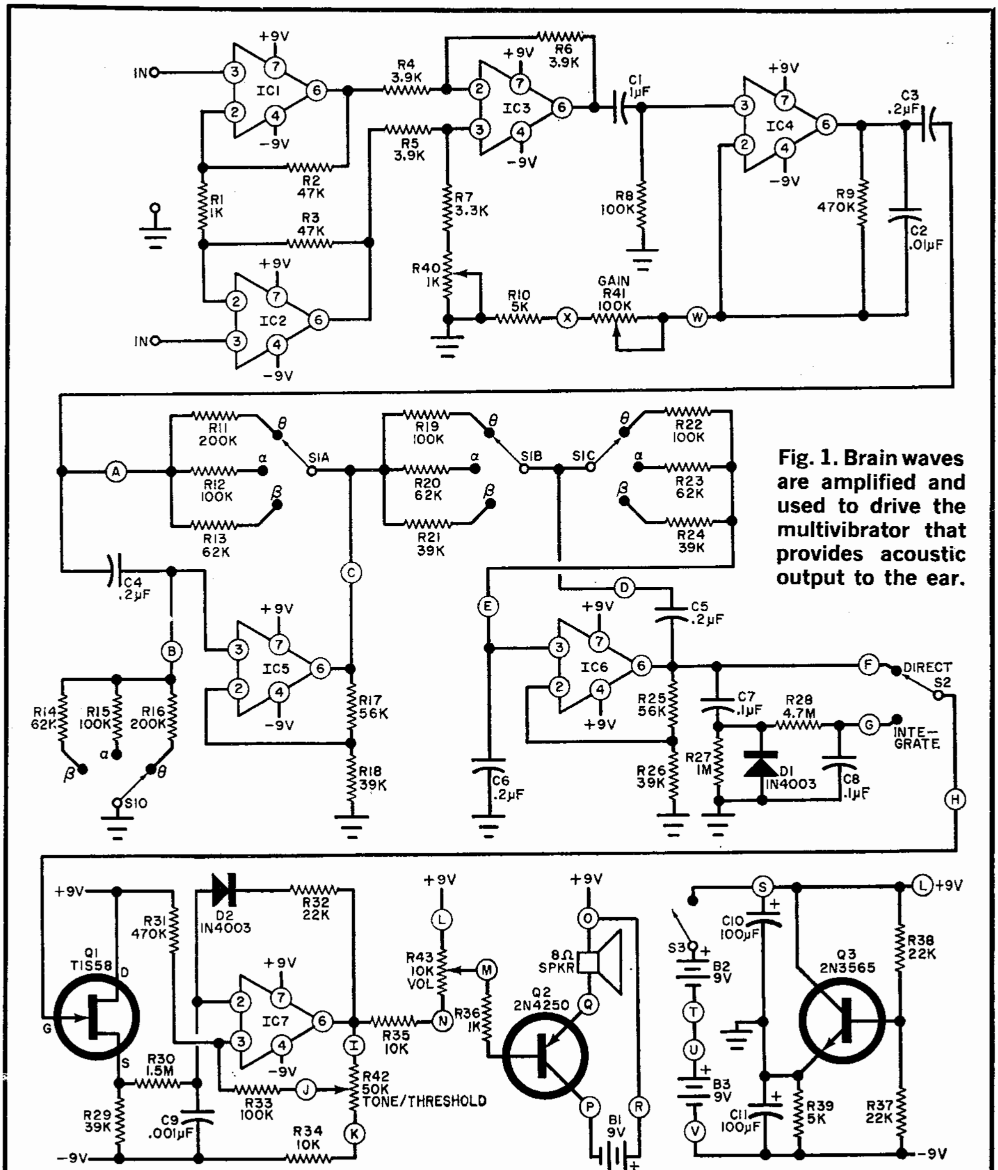
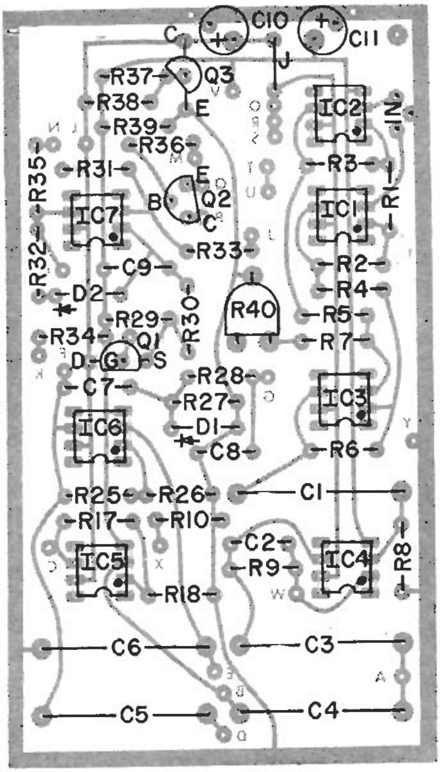


Fig. 1. Brain waves are amplified and used to drive the multivibrator that provides acoustic output to the ear.

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



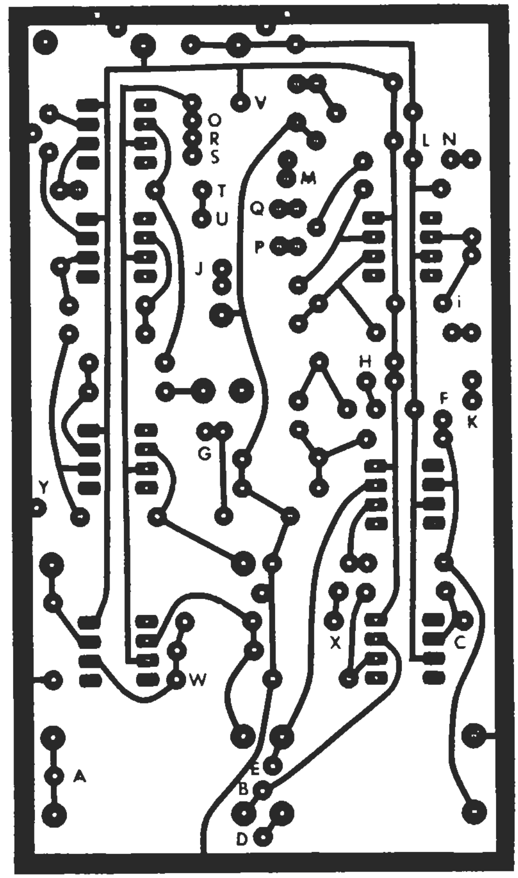


Fig. 2. Actual size foil pattern is at right with component layout above.

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.

cording," June 1972.

CORRECTION—*In the November 1972 "Letters" column, under "Wants Solid-State Circuits Book," we incorrectly stated the title of the recommended John Markus book; the correct title is "Electronic Circuits Manual" (McGraw-Hill Book Co. No. 07-04044-5). Our apologies for any inconvenience.*

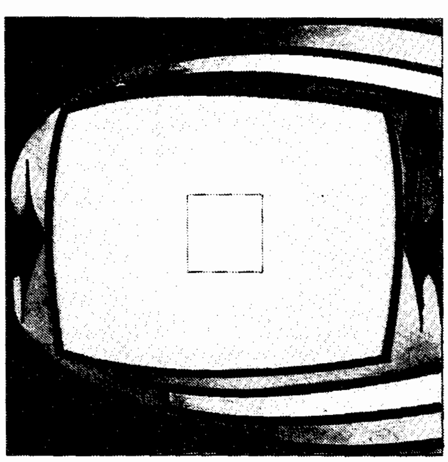
In "Build an Alpha Brain-Wave Feedback Monitor," (January 1973) on page 42, the voltage rating of C10 and C11 should have been 15 or 25 volts, not 2 volts.

video biofeedback

In recent years the use of biofeedback techniques to achieve conscious control of brain activity has become extremely popular. Of particular interest is 'alpha feedback' which, by stimulating the production of alpha-waves, promotes relaxation. Many designs for alpha monitors have been published, but most of these have provided an audible output. As the brain is better equipped to respond to visual stimuli, the design presented here provides a visual output on a TV screen.

Anybody who is interested in electronics will have at least a fair idea of what 'feedback' is. Speaking very broadly, it can be described as 'feeding (information from) the output of a system back to its input, often with the objective of reducing errors and increasing performance'. In essence, in other words, the system either 'knows' or 'is told' what it should be doing; the feedback information 'tells it' what it is actually doing; by comparing the two, it can attempt to make its actual performance conform more closely to the ideal.
This description is intentionally broad, so that it can also be applied to other systems as well as electronic circuits. In its application to living organisms, and in particular human beings, the concept has become known as 'biofeedback'.
Biofeedback consists of the monitoring of various physiological functions and presenting the results to the subject being monitored. This is obviously not an end in itself; the object is to achieve regulation on these functions by conscious control. Many functions can be regulated, including those which, until recently, it was thought were wholly under the control of the autonomic nervous system and thus not subject to conscious regulation. Such functions include pulse rate, blood pressure, body temperature and, of course, brain activity.
The achievement of conscious control of physiological processes is known as autogenic training. Although the application of electronic biofeedback techniques to autogenic training is relatively new, autogenic training has been practised in the East for thousands of years (Yoga).
In the West interest in autogenic training began at the turn of the century. The neurologist Oskar Vogt discovered that some patients who had participated in sessions of hypnosis were able to put themselves into a trance, and after repeating this several times experienced a sense of increased physical well-being with a disappearance of symptoms of nervous tension and stress.
The technique of autohypnosis was further developed by J.H. Schulze, who devised a training programme to enable patients to improve their state of health, and the term 'autogenic training' was coined to describe Schulze's method.
Advocates of autogenic traning maintain that the following aims can be achieved:
- Muscular relaxation
- Control of pulse rate
- Control of body temperature
- Control of brain activity

all of which combat stress and nervous tension and promote more rapid and refreshing sleep.



Brain rhythms

Schulze discovered that patients who had progressed sufficiently in his autogenic training program could reach an even deeper state of trance by means of 'meditation'. This would hardly come as a surprise to many Orientals . . .
One good way of reaching this state was found to be initiated by turning the eyes up and 'within'. This is also clearly reminiscent of certain Yoga techniques! Much later it was discovered that this technique is one of the ways of stimulating the brain to produce so-called alpha-waves. The implications of this discovery are perhaps not earth-shaking, but it helped to forge a link between Oriental meditation and Western technology. It is known that the brain generates regular electrical impulses in four principal patterns that are associated with different modes of brain activity.

- Alpha waves have a frequency between 8 Hz and 12 Hz and are associated with physical relaxation in the waking state.
- Beta waves have a frequency between 13 Hz and 30 Hz, and are associated with a high level of audio-visual stimulation and a state of tension or excitement.
- Delta waves, which have a frequency between 0.5 Hz and 3 Hz, are the predominant rhythm during sleep.
- Theta waves occur during activities of a creative nature, and have a frequency between 4 Hz and 7 Hz.

In normal cases, closing eyes and relaxing should cause the brain to slowly shift from beta-activity to alpha. Some people have extreme difficulty in

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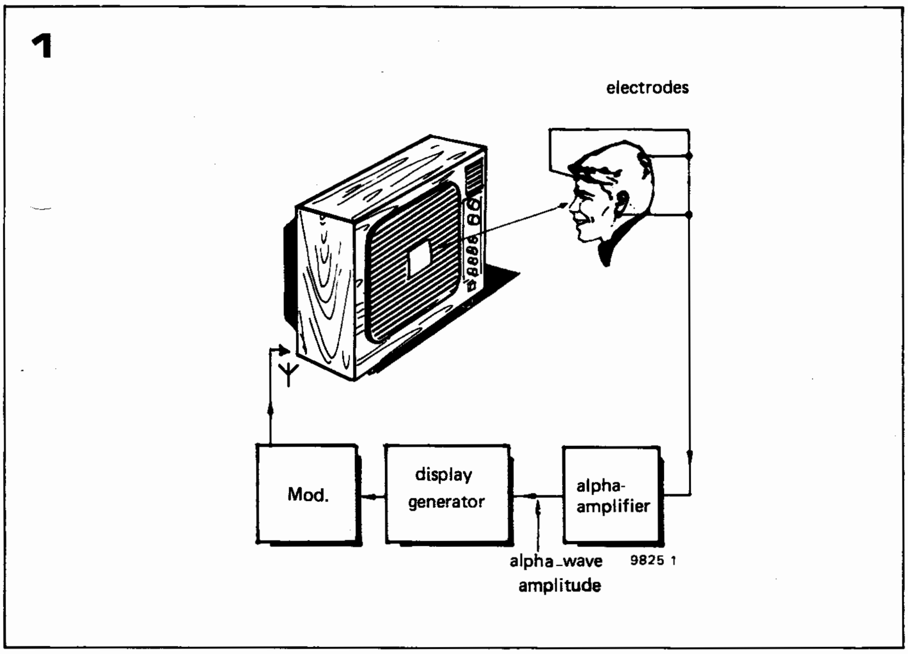

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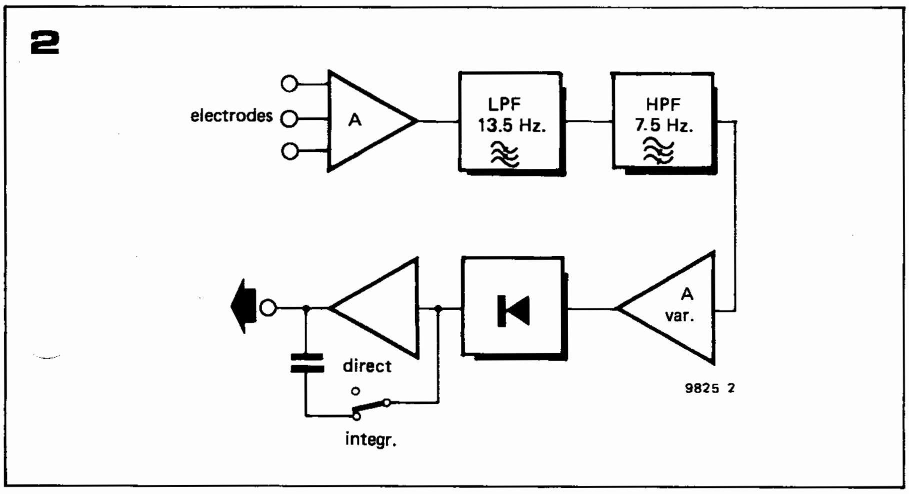

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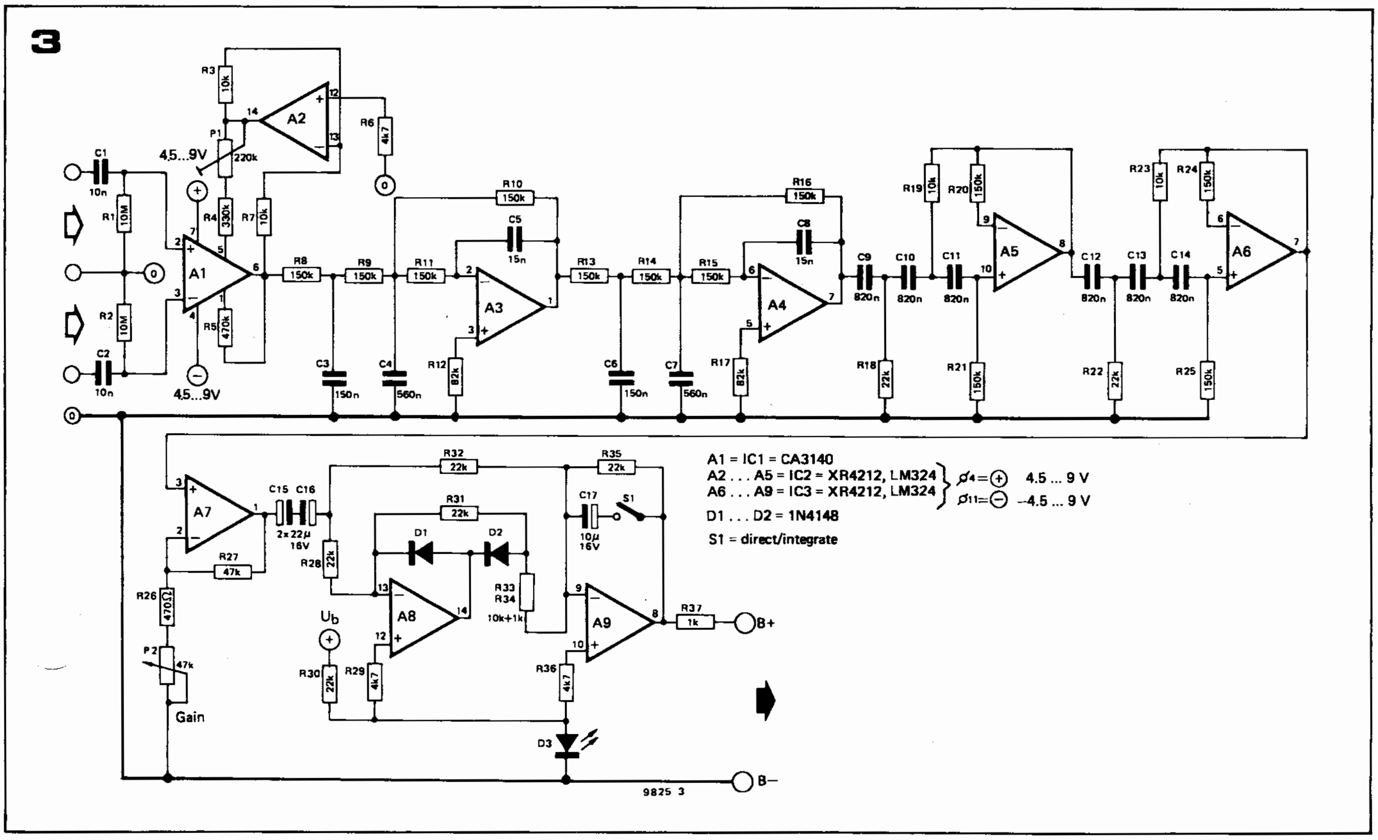

Figure 1. Block diagram of the video-biofeedback system. The alpha amplifier filters and amplifies alpha waves from the brain, and the output of the alpha amplifier drives a display generator which produces, on a TV screen, a rectangle whose size is proportional to the alpha amplitude.

Figure 2. Block diagram of the alpha amplifier, which consists of a high impedance amplifier, low- and highpass filters, a variable gain amplifier and a rectifier stage. A switchable integrator provides the option of fast or slow response to changes in alpha amplitude.

Figure 3. Complete circuit of the alpha amplifier.

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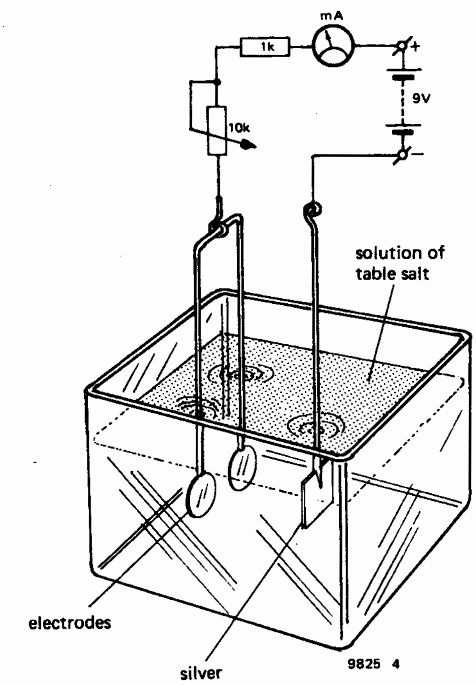

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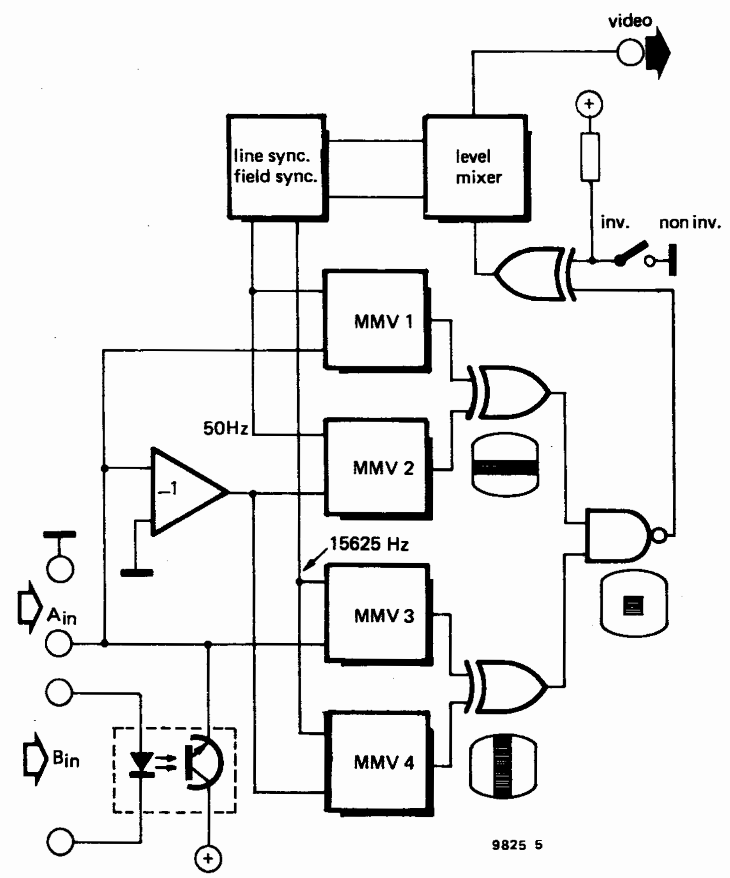

achieving this, however: they remain in a state of tension. The Oriental solution to this problem is meditation exercises; the best-known Western solution is the sleeping-pill.
Recently, it has been discovered that biofeedback training can be use[d t]o produce similar results: the [subject] 'learns' to produce alpha-waves with their associated sensation of relaxation and well-being.

Alpha feedback

The amplitude of the different brain rhythms increases with the intensity of the particular mental state associated with the rhythm. Thus, in the case of alpha waves the alpha amplitude is at a maximum when a person is most relaxed.
In order to practise alpha feedback training to achieve relaxation and tranquillity it is necessary to monitor the alpha amplitude and present this information to the subject. In essence then, an alpha monitor must consist of an 8 to 13 Hz selective filter-amplifier that will pass only alpha rhythms, and some form of display to indicate the alpha amplitude.
In the present design a TV screen is used as the display medium (figure 1). A rectangle is generated in the middle of the screen. The size is proportional to the alpha amplitude and hence to the degree of relaxation of the subject. The objective of the alpha feedback training is therefore to attempt to [rela]x in order to make the rectangle expand until it fills the whole of the screen.
Although alpha rhythms are easier to generate with the eyes closed, and initially it may be difficult to produce them with the eyes open, this small disadvantage is offset by the improved response which visual feedback provides.

Alpha detection

Figure 2 shows a block diagram of the alpha amplifier, which produces a DC output voltage proportional to the alpha amplitude. Electrical impulses from the brain are picked up by electrodes attached to the scalp and are amplified before being fed to a lowpass filter, which removes frequencies above 13.5 Hz and a highpass filter, which removes frequencies below 7.5 Hz. The resulting signal, which is now predominantly alpha waves, is then fed to a variable gain amplifier, the output of which is rectified to provide a DC voltage proportional to the alpha amplitude. If desired the DC voltage can be fed direct to the display to provide a rapid response to changes in alpha amplitude, or via an integrator to provide a [slow]er response.
Figure 3 shows the complete circuit of the alpha amplifier. It consists of a high impedance differential amplifier (A1) feeding a lowpass filter comprising two third order filter sections (A3 and A4), which in turn feeds a highpass filter

comprising two third order sections (A5 and A6).
Since it was felt that the high cost of a fixed gain, high input impedance, instrumentation amplifier for A1 was not justified, some method had to be found of defining the closed-loop gain of an inexpensive op-amp, without compromising the input impedance. It was not possible to achieve the high input impedance required if normal feedback to the input were used, since this would demand impossibly high feedback resistors. The solution chosen here was to use a relatively inexpensive CA3140 FET op-amp and to provide negative feedback to the offset inputs via A2. The input resistance is now determined solely by R1 and R2.
The output of the final highpass filter stage, A6, feeds the variable gain amplifier A7. Potentiometer P2 varies the gain of A7, and thus the sensitivity of the amplifier, so that signal levels from about 6 μV to 600 μV can be processed.
The final stage of the alpha amplifiers consists of an active rectifier constructed around A8, to convert the alpha waves to a D.C. signal, followed by a buffer A9, which provides the option of a direct or integrated signal. The integrated signal is preferable for the TV display since it provides a more stable picture.
For safety reasons the alpha amplifier is coupled to the display generator via an opto isolator, so that there is no danger of electric shock in the event of an insulation breakdown between the TV set and the display generator, or in the display generator itself. Since the opto-isolator will only function if the voltage applied to it is above the knee voltage of its LED, it must be provided with a forward bias even in the absence of an input signal. To this end LED D3 is included in the circuit to provide a permanent positive offset at the output of A9.

Electrodes

The alpha amplifier input is provided by three electrodes, one of which is attached to the forehead, another to the back of the head, and the third (earth) electrode to one of the earlobes. To avoid electrolytic voltages being produced, all three electrodes should be of the same material. Stainless steel will give acceptable results, but the best material is silver or silver-plated copper.
Since such electrodes are not readily available commercially, the best plan is to have a jeweller or silversmith make several small discs of approximately 8 mm diameter. The two input electrodes can be soldered onto leads and can be secured to the head using a headband of insulating material. Note that the electrode at the back of the head should make good contact with the scalp! The earth electrode can be made by soldering two of the silver plates to a small crocodile clip which can be clipped onto the earlobe.

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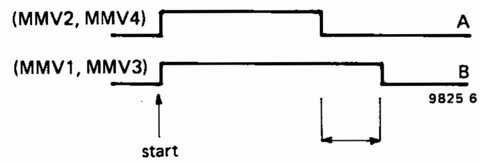

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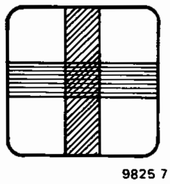

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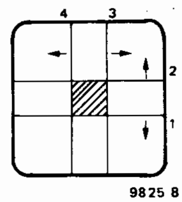

Figure 4. The silver electrodes are coated with silver chloride using this setup, to provide an electrolytically inactive layer between the electrodes and the skin.

Figure 5. Block diagram of the video display generator. To avoid the danger of electrical shock in the event of a malfunction, there is no direct electrical connection between the alpha amplfier (which is battery powered) and the display generator. The signal is transferred using an opto-isolator.

Figure 6. The pulse length of MMV1 is always longer than that of MMV2, so when the two pulses are combined in an EXOR gate the output is high when the MMV2 pulse has finished but the MMV1 pulse is still high. The same applies to MMV3 and MMV4.

Figure 7. The rectangular display is obtained by combining the horizontal and vertical bars in a NAND gate.

Figure 8. MMV1 (P6) controls the lower edge of the rectangle, MMV2 (P5) controls the upper boundary, etc.

Despite the use of silver electrodes it is still possible for voltages to be generated electrolytically due to differences in chemical conditions on the skin in the contact areas. It is therefore necessary to coat the electrodes with an electrolytically 'neutral' layer of silver chloride. The setup to carry out this operation is shown in figure 4. A solution is made consisting of 0.9% by weight pure sodium chloride (refined table salt is suitable) dissolved in 99.1% by weight distilled water. The electrodes are then immersed in this solution together with another silver plate to act as the cathode and plated at a current density of 1 mA/sq. cm. for about one hour, after which time they should be coated with a dark deposit of silver chloride. In the example shown using 8 mm diameter discs, the area of each disc is about 0.5 cm^2 per side, so the total area of the two discs is 2 cm^2, and the pot. should thus be adjusted to give a current of 2 mA.
In order to reduce contact resistance to an absolute minimum, the electrodes should ideally be coated in a special conductive paste before connection to the skin. However, this is again not readily obtainable, and a heavily salted starch paste will prove adequate for the present application.
After use the electrodes should be carefully washed with distilled water to avoid deterioration of the chloride layer. Should this layer become damaged for any reason it must be restored by repeating the chloration procedure.

Display generator

A block diagram of the display generator is given in figure 5. At the top left of the diagram are line and field sync oscillators, which produce 15625 Hz and 50 Hz waveforms to synchronise the TV raster.

The output of the field sync oscillator also triggers two voltage-controlled monostable multivibrators MMV1 and MMV2. The pulse duration of MMV2 is always less than that of MMV1 (see figure 6). The outputs of MMV1 and MMV2 are fed to an exclusive OR gate, the output of which will go high only when the two inputs are different, which in this case means when the output pulse of MMV2 has terminated but that of MMV1 is still high. The result is that the output of the EXOR gate is high for a certain time in the middle of a field scan, and this would produce a horizontal bar across the screen. However a pair of monostables MMV3 and MMV4 are triggered by the line sync output and their outputs combined in an EXOR gate to produce a vertical bar display.
The required display is a rectangle which occupies the area where the two bars overlap (figures 7 and 8), and this is achieved by combining the two EXOR outputs in a NAND gate. The output of the NAND gate, together with line and field sync pulses, is fed to a video mixer to produce a composite video signal.
An EXOR gate and switch provide the option of normal or inverted video signal i.e. a white rectangle on a black background or a black rectangle on a white background.
MMV1 is controlled directly by the output of the opto-isolator, so that as the output of the alpha amplifier increases the pulse length of MMV1 increases. MMV2 is connected to the output via an inverting amplifier, so that as the alpha output increases the MMV2 output pulse length decreases. The same is true of MMV3 and MMV4, and the effect is that as the alpha amplitude increases the rectangular display increases in size.

Display generator circuit

Figure 9 is the complete circuit of the display generator. The line and field sync generators, IC1 and IC2, are 555 times connected as astable multivibrators. The line and field sync frequencies may be adjusted by means of P1 and P2; the adjustment ranges are sufficient to allow for both the originally intended 625 line/50 Hz and the alternative 525 line 60 Hz systems. For the 625 line system, the required period times are shown in figure 10.
The internal block diagram of a 555 is shown in figure 11. Its output is high during the charging time of the capacitor, $t_1 = 0.7 \cdot (R_a + R_b) \cdot C$; it is low for the discharge time $t_2 = 0.7 \cdot R_b \cdot C$. For both AMVs, t_2 is the duration of the corresponding sync pulse as specified in figure 10. The total period time $t_1 + t_2$ is more critical, however; for this reason R_a is replaced by a preset potentiometer in series with a fixed resistor in the final circuit. These presets are simply adjusted until a stable picture is obtained.

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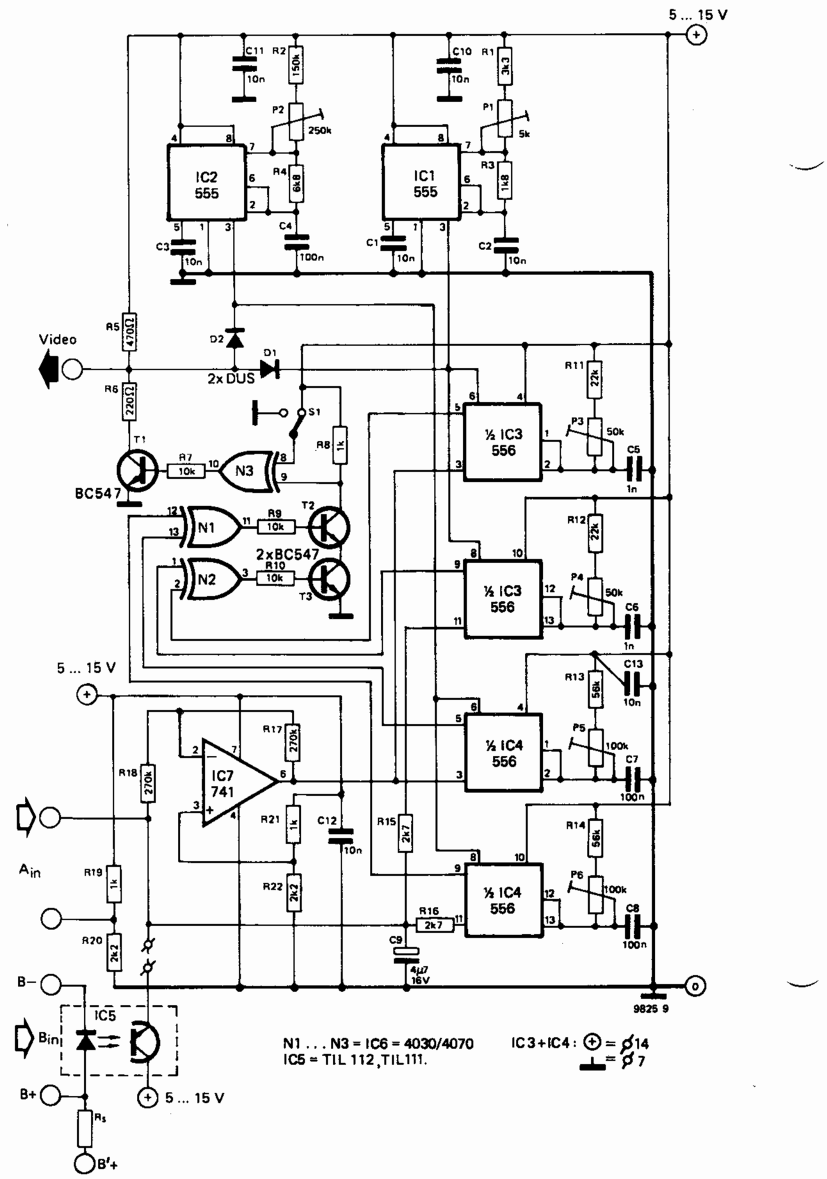

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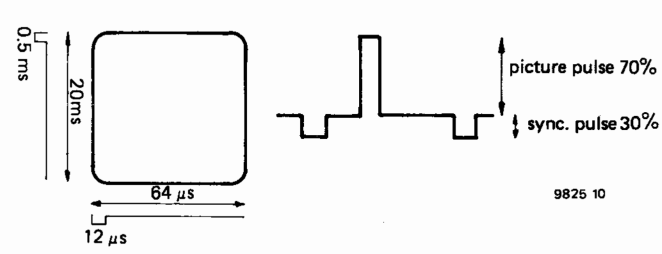

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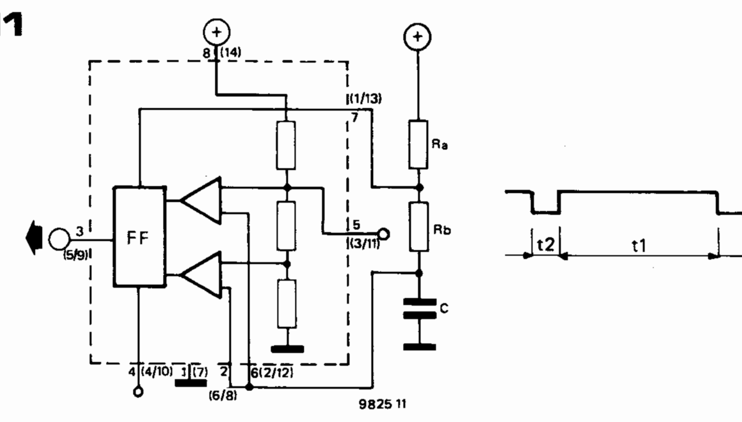

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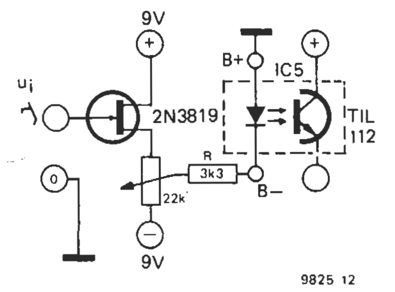

Figure 9. Complete circuit of the display generator.

Figure 10. The amplitude of the video waveform varies between about 30 and 100% supply voltage during a line period, but during line or field blanking intervals it is clamped to about 0.6 V.

Figure 11. Showing the internal circuit of a 555 (or ½ 556) timer, and how it is connected as an astable multivibrator. The pinning shown in brackets refers to the (two halves of a) 556 timer.

Figure 12. This high-impedance front-end can be used for testing the display generator. It can also prove useful if the generator is to be driven from a high-impedance source.

Figure 13. Printed circuit board and component layout for the alpha amplifier shown in figure 3 (EPS 9825-2).

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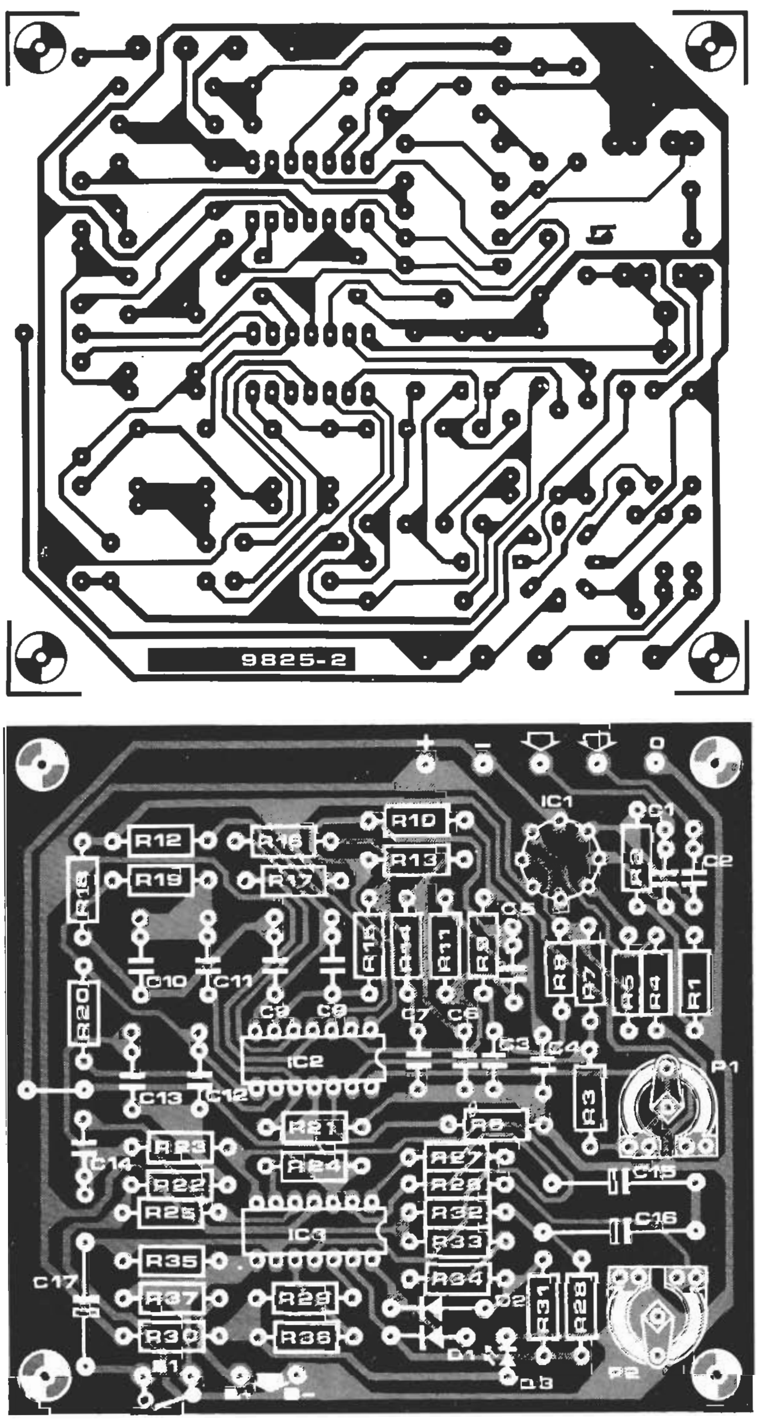

Parts list to figures 3 and 13.

Resistors:
R1,R2 = 10 M
R3,R7,R19,R23 = 10 k
R4 = 330 k
R5 = 470 k
R6,R29,R36 = 4k7
R8,R9,R10,R11,R13,R14,R15,
R16,R20,R21,R24,R25 = 150 k
R12,R17 = 82 k
R18,R22,R28,R30,R31,
R32,R35 = 22 k
R26 = 470 Ω
R27 = 47 k
R33,R34 = 11 k (10 k + 1 k)
R37 = 1 k

Capacitors:
C1,C2 = 10 n
C3,C6 = 150 n
C4,C7 = 560 n
C5,C8 = 15 n
C9 . . . C14 = 820 n
C15,C16 = 22 μ/16 V
C17 = 10 μ/16 V

Semiconductors:
A1 (IC1) = CA 3140
A2 . . . A5 (IC2) = XR 4212 or LM 324
A6 . . . A9 (IC3) = XR 4212 or LM 324
D1,D2 = 1N4148
D3 = LED

Miscellaneous:
P1 = preset 220 k
P2 = preset 47 k lin.
S1 = switch SPST

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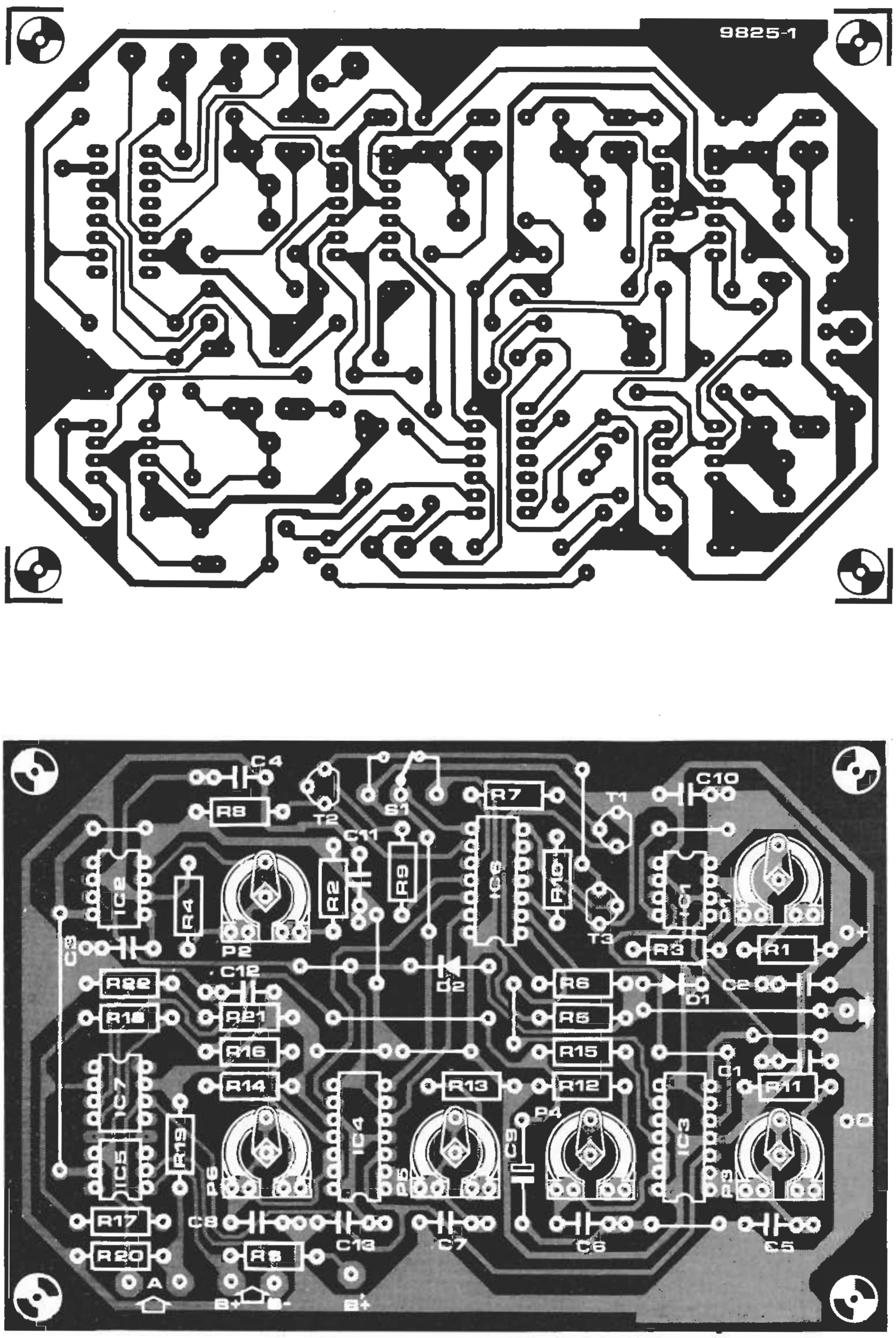


Parts list to figures 9 and 14.

Resistors:
R1 = 3k3
R2 = 150 k
R3 = 1k8
R4 = 6k8
R5 = 470 Ω
R6 = 220 Ω
R7,R9,R10 = 10 k
R8,R19,R21 = 1 k
R11,R12 = 22 k
R13,R14 = 56 k
R15,R16 = 2k7*
R17,R18 = 270 k
R19,R21 = 1 k
R20,R22 = 2k2

* Nominal value. Depending on IC tolerances, optimally smooth control of boundaries 1 and 3 may be obtained with slightly different values for these resistors.

Capacitors:
C1,C2,C3,C10,C11,C12,
C13 = 10 n
C4,C7,C8 = 100 n
C5,C6 = 1 n
C9 = 4µ7/16 V

Semiconductors:
IC1,IC2 = 555
IC3,IC4 = 556
IC5 = TIL 111 or TIL 112
IC6 = 4030 or 4070
IC7 = 741
T1,T2,T3 = BC 547
D1,D2 = DUS

Miscellaneous:
P1 = preset 5 k
P2 = preset 250 k
P3,P4 = preset 50 k
P5,P6 = preset 100 k
S1 = switch SPDT

The field sync oscillator triggers two monostables corresponding to MMV1 and MMV2 in the block diagram, which are built around a 556 dual timer IC4. Similarly, the line sync oscillator triggers two monstables built around IC3, and corresponding to MMV3 and MMV4 in figure 5.
The two EXOR gates connected to the MMV outputs are N1 and N2, while the NAND gate is made up from two discrete transistors T2 and T3. This is to avoid the necessity for an extra NAND gate IC. The EXOR gate that provides for selection of normal or inverted display is N3, and this drives T1, which forms part of the video mixer. During the field and line blanking intervals, the outputs of IC1 or IC2 go low, pulling down the video output to about 0.6 V via D1 or D2. At all other timers however, the outputs of IC1 and IC2 are high; D1 and D2 are reverse-biased and T1 is free to switch the video output between 30% supply voltage and full supply voltage (figure 10). The video output must be fed to the aerial input of the TV via a video modulator such as that described in the Elektor TV Tennis article (Nov. '75).
The inverting amplifier of the block diagram is a 741 op-amp IC7, and the opto-isolator is at the bottom left of the circuit. In the absence of an input signal the output of IC7 is biased to about two-thirds supply voltage by R21 and R22. As the output of the alpha amplifier increases, then the input

voltage of the op-amp will rise as the opto-isolator transistor draws more current, and the output voltage of the op-amp will fall. As described earlier the input and (inverted) output voltages of IC7 are used to control the monostable pulse lengths and hence the size of the displayed rectangle.

A test input A is provided, which may be fed with a DC voltage or from a pot connected between point A and the positive supply rail, to check the functioning of the display generator. The operation of the display generator via the opto-isolator may be checked using the test circuit of figure 12, where a test signal is fed to the opto-isolator via a FET source-follower rather than from the output of the alpha amplifier. This circuit can also prove useful if it is desired to use the display generator for other applications than biofeedback. The 22 k potentiometer should be adjusted so that the voltage U_R across the 3k3 resistor is 1.5 V when the input of the circuit is shorted. Table 1 show the sort of results to be expected with this circuit.

For completeness' sake, a third input option is provided: B'+. This input can be used if the display generator is to be driven from some other source than the alpha amplifier. Provision is made on the p.c. board for including a resistor R_S in series with the LED in the opto-coupler. The value of R_S will of course depend on the input level to be applied to this input.

Construction

A printed circuit board and component layout for the alpha amplifier are given in figure 13, and for the display generator in figure 14. The following safety points should be noted:

1. The power supply to the alpha amplifier must be a 9 V battery, which must be connected only to the + and 0 terminals of the alpha amplifier.
2. The only connections between the alpha amplifier and display generator should be the B+ and B– leads that join the output of the alpha amplifier to the opto-isolator input. There must be no connection between any part of the alpha amplifier circuit and the display circuit other than these connections.
3. The supply to the display generator may be stabilised mains power supply between 5 V and 15 V, or a separate 9 V battery may be used. DO NOT USE A COMMON POWER SUPPLY FOR THE ALPHA AMPLIFIER AND DISPLAY GENERATOR.
4. Care should be taken in the construction to ensure that no part of the display generator circuit or its power supply can contact any part of the alpha amplifier circuit, even in the event of a wire breaking. The simplest way to achieve this is to partition the box in which the unit is mounted, and place the alpha amplifier in one half and the display generator in the other half.

Figure 14. Printed circuit board and component layout for the display generator shown in figure 9 (EPS 9825-1).

Table 1. Measurement values for the video-feedback display with the add-on input circuit of figure 12.

Table 1

U_i peak-peak (mV)	U_R peak-peak (mV)	horizontal picture width at 1 Hz
200	170	very small
300	240	
400	340	2...3% screen width
500	400	
600	480	
800	640	
1000	800	
1200	960	
1500	1200	20% screen width
2000	1700	
2500	2100	
3000	2400	
4000	3200	½ screen width
5000	4200	
6000	4400	¾ screen width
7000	4700	
8000	5000	almost full screen
9000	5400	
10000	5600	out of screen

WARNING: As already pointed out in the text, it is essential that complete isolation is maintained between the alpha amplifier and the display generator. To this end the following points should be observed:

- The alpha amplifier must be battery-powered. It is potentially lethal to connect it to a mains power supply.
- The '0' of the alpha amplifier should not be connected to the '0' of the display generator. The only connection between these two units should be the opto-coupler.
- Contrary to what one might expect, the '0' of the alpha amplifier should not be 'earthed' either! To put it plainly, the only connections between the alpha amplifier and the 'outside world' are the electrodes at one end and the opto-coupler at the other.
- Although provision is made for mounting the opto-coupler on the p.c. board, extreme care should be taken at this point. Ideally, there should be absolutely no possibility of a leakage path between its input and output. To play it completely safe, the input pins can be bent up from the board and the input connections soldered direct to these pins; or, better still, the unit can be mounted 'off-board' between the alpha amplifier and display generator.

Adjustment procedure

1. First adjust P1 on the alpha amplifier board until the output of A1 is at half supply voltage (4.5 V). Close S1.
2. Adjust potentiometer P1 and P2 on the display board until a stable picture is obtained.
3. With the input electrode grounded, adjust potentiometer P3 to P6 until a rectangle is obtained in the centre of the screen. It is important at this stage to ensure that the pulse lengths of the monostables are in the correct sense, otherwise the rectangle will decrease in size when an input is applied. The following points should thus be checked:

a. P3 sets the left boundary of the rectangle.
b. P4 sets the right boundary of the rectangle.
c. P5 sets the upper boundary of the rectangle.
d. P6 sets the lower boundary of the rectangle.

If the control of any of these pairs of boundaries is interchanged (e.g. P3 sets right and P4 left) then the corresponding pots must be readjusted until they are correct. The presets must then be adjusted until an extremely small rectangle is obtained.

The alpha amplifier can now be given a quick check by using it, not to pick up alpha rhythms, but heart activity. Holding an electrode in each hand a large rectangle should be obtained on the screen, whose size varies with the heartbeat.

The electrodes can now be connected to the head and attempts made to produce alpha rhythms, adjusting the sensitivity of the alpha amplifier as necessary by means of P2. ◀

Have you got three hands?
If so, the circuit on the inside of this month's mailing wrapper will be of little interest to you.

Build this $35 Brainwave Monitor

Build this brainwave monitor for Alpha waves. You can use it to learn how to control your Alpha waves and gain from the benefit of the relaxation that comes with it.

by MARK EHREN*

PROBABLY ONE OF THE MOST FASCInating and intriguing elements within the human body are the constant and cryptic signals that originate within the depths of the brain.

Until a few years ago, these signals were considered to be only messages transmitted from the brain to the various organs and muscles, much like the signals within a telephone exchange. However, recent electronic developments have shown that these miniscule electrical signals are more than just muscle acitvators, but can be "demodulated" to determine the state of the emotions of the person being measured.

Where do these tiny, but important signals originate? Called bio-potentials, these tiny voltages exist in all living organisms, originate deep within the cellular structure, and can usually be detected in the local skin areas.

A visit to a doctor for a checkup will illustrate the uses of some of these bio-potentials. You will note that the doctor attaches electrodes to certain areas of the chest to record what is called an EKG, or electrocardiagram. The wiggly lines produced on his recorder indicate the state of the heart by amplifying, detecting and further amplifying these tiny voltages to operate the pens in the recorder. With some electrodes attached to certain areas of the skull, the doctor can also perform an EEG—an electro-encephalogram in which certain brain waves are analyzed for the detection of some disorders. In other areas, there is the electromyogram—(EMG), or the measurement of the activity of the muscles that also generate minute voltages as they are flexed. All of these signals are tiny, and range from a few microvolts to as many as 100 microvolts.

Other signals, generated deep within the brain, have not yet been fully explained, but do have a lot to do with the state of the emotions (whether you are calm or irritated, awake or asleep, etc.).

Most of these signals have been identified, and some numbers have been attached to them. The following list illustrates the presently known brain waves, and their associated mental states:

Alpha: frequency is approximately 8 to 12 Hz, and the associated mental state is relaxation, heightened awareness, elation, and in some cases, dreamlike.

Beta: frequency is approximately 13 to 28 Hz, and the associated mental state is irritation, anger, jitters, frustration, worry, tension, etc.

Delta: frequency is approximately .2 to 3.5 Hz, and the associated mental state is usually a deep sleep, or a trance-like state.

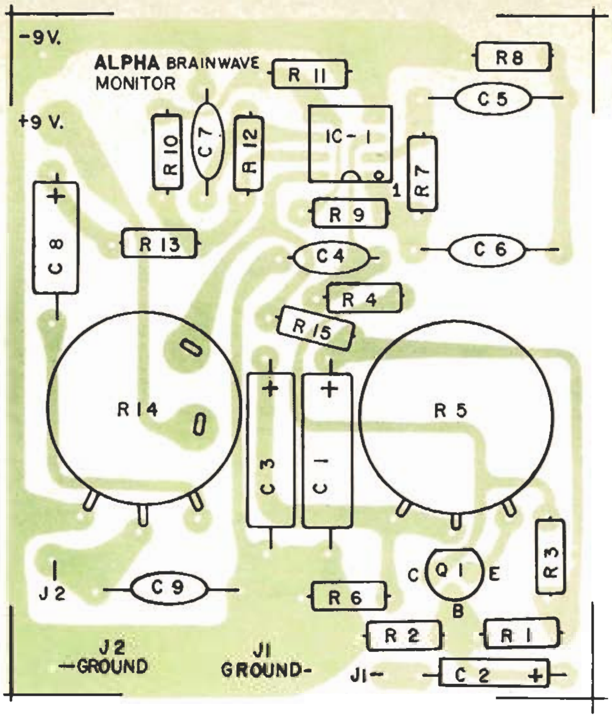
Theta: frequency is approximately 3.5 to 7.5 Hz and the associated mental state is fuzzy, unreal, uncertainty, daydreaming, ambiguity.

The various areas and their associated frequencies are not sharply defined and there is some overlap between alpha and beta, beta and theta, and theta and alpha.

Probably the most discussed brain wave is *alpha*, with its connotations of Eastern meditation, Zen, Yoga, etc. First noted by Hans/Berger (Germany) and E. D. Adrian and B. H. C. Mathews (England) in the early '30's during a study of EEG waves, they noted that the alpha seemed to disappear when the subject's eyes were open, or if the subject engaged in mental activity while he was wired to the EEG device. In the years since, many researchers have attempted to discover whether alpha is associated with mental effort, or from a relief from mental effort. Many brain researchers are still unsure. You can still get many arguments as to whether the eyes should be open or closed during an alpha experiment. Many experimenters close their eye lids but unconsciously turn their eyes upward when they do this. Therefore, in many instances the alpha that does appear at this time is a direct function of what their eye muscles are doing.

Then there are many varieties of

*Marketing Director, EICO, Electronic Instrument Co.



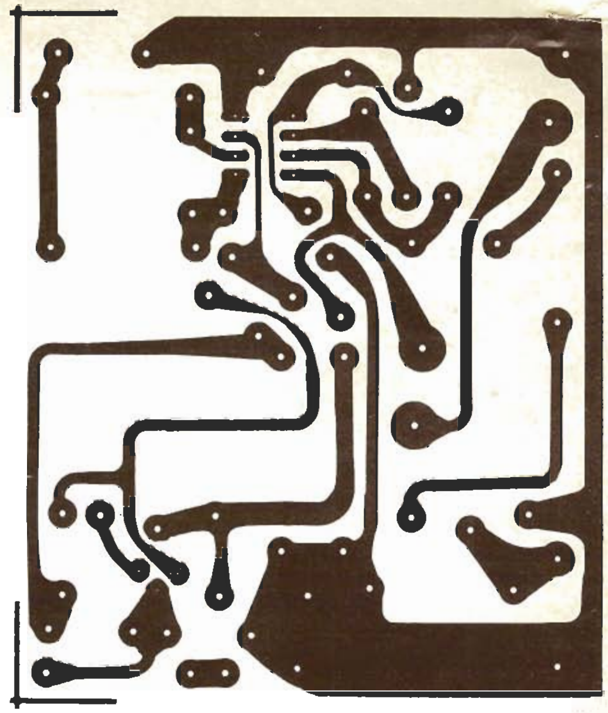


FIG. 1 (right)—SCHEMATIC DIAGRAM of the Alpha Brainwave Monitor. FIG. 2 (above)—FOIL PATTERN of circuit board shown actual size. FIG. 3 (left)—COMPONENT LAYOUT of the circuit board.

alpha. Low-level signals can mean a different set of behavioral and personality characteristics than do a high-level set of signals. Whether the alpha occurs at the lower or higher frequency end of the zone also means different things for different people. Then there is the area of the head that produces the most easily detected alpha. In fact, within the same person, each different aspect of form or location has many different meanings to the trained operator.

To conclude anything about alpha is perilous. The 20-billion cells within the brain runs the mind and body. We cannot learn all the secrets merely by examining some local electrical topography.

The amount of alpha usually increases with practice. Many subjects can double the amount of alpha after a couple of hours of biofeedback practice, and after another session, increase it even further.

Now, how does one detect the existence of alpha and learn to control it to gain benefit from the relaxation that comes with it? Obviously, several years of Yoga or Zen training will come in handy. But, with advances in the state of electronics, it is possible to use a relatively simple electronic device to short-cut those long years of training. This device *will not* give the same results as those attained in the years of study, but will give you some of them, particularly in the area of relaxation, something that we all have a need for in our busy and complex lives.

CIRCUIT BOARD of the Alpha Brainwave Monitor with all the components installed.

Basic alpha detector

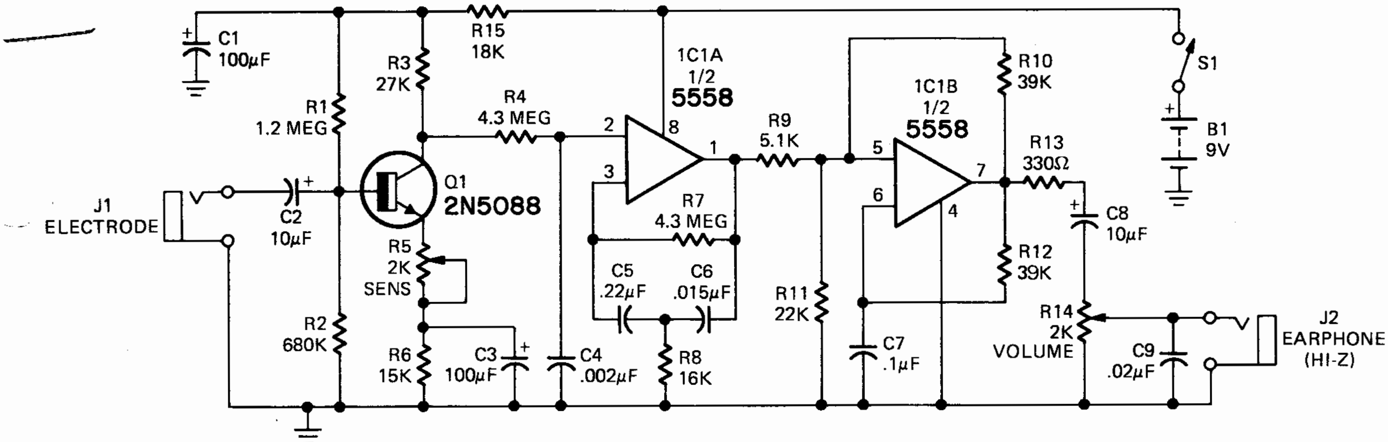
Because of the very low levels of signal involved (only a handful of microvolts), a high-gain low-noise preamplifier must be used. Some form of bandpass filter must be used to pass only the 8 to 12 Hz of the desired alpha and remove any other signal, and any noise. The filtered alpha frequencies can then be used to control a low-level audio oscillator whose tone signal then indicates the presence of alpha. This is the purpose of the device whose schematic is shown in Fig. 1.

The basic alpha wave is initially detected by a pair of electrodes that make electrical contact with the scalp. Two types of electrodes are used: an earlobe clip that forms the "ground" (or reference) contact, and a nickel-plated electrode that is coupled to the posterior (occipital) region of the scalp via some conductive electrode paste. A headband using a Velcro closure keeps the head electrode in place during the tests.

The minute voltages picked up enters the circuit via J1 and fed to a low-noise, high-gain amplifier Q1, whose gain is established by the setting of front panel "Sensitivity" control R5. The amplified output signal at the collector of Q1 consists of a broad spectrum of signals (and noise) including the 8- to 12-Hz alpha we are seeking.

ICI-a (part of a 5558 dual op-amp) is connected as a narrow-band active filter whose components are selected to form a filter having a center frequency of about 10 Hz (center of alpha) ± 2 Hz so as to encompass the entire known alpha frequency span. All frequencies other than the desired alpha are greatly attenuated. Incidentally, other alpha devices that do not incorporate such active filters allow all frequencies to pass, thus unnecessarily complicating the detection of the desired alpha.

The sharply filtered alpha signals are then passed to ICI-b (the second half of the 5558 dual op-amp). This stage forms an almost-square wave generator (actually a rectangular wave having a 20% duty cycle) that is continuously in operation. Other alpha devices that use the alpha signal to *start* an audio oscillator is considered by some researchers to work against the user as the sudden "turn on" of the tone can startle the use, thus affecting the generation of alpha. Research has also shown that a single, low-level tone that is continuously on, and *frequency modulated* by the users alpha is more conducive to alpha



Parts List

B1—9-volt battery (NEDA1604, Mercury 146X, or similar)
C1, C3—100-µF 15-volt electrolytic
C2, C8—10-µF, 15-volt electrolytic
C4—.002-µF
C5—.22-µF Mylar ±10%
C6—.015-µF Mylar ±10%
C7—.1-µF
C9—.02-µF
1C1—5558 dual op-amp
J1, J2—miniature earphone jack
Q1—2N5089
All resistors ½ watt, 10%, unless noted
R1—1.2 megohm, ½ watt
R2—680,000 ohms
R3—27,000 ohms
R4, R7—4.3 megohms
R5, R13—potentiometer, 2000 ohms
R6—15,000 ohms
R7—16,000 ohms
R8—5100 ohms
R9, R11—39,000 ohms
R10—22,000 ohms
R12—330 ohms
R14—18,000 ohms
S1—spst switch

Misc.—PC board, suitable enclosure, knobs (2), battery holder, battery connector, electrodes, interconnecting cable, high-impedance light-weight earphones, electrode paste, headband with Velcro closure, mounting hardware.

The following items are available from Dean Adv. Inc., 283 Malta St., Brooklyn, N.Y. 11207.

Printed circuit board (etched, drilled & screened). $4.00 postpaid.

Electrode-headband kit including headband with electrodes, electrode cream, high-impedance light-weight earphones. $6.00 postpaid.

Complete Alpha Brainwave Monitor Kit including all parts with case and knobs. $34.50 postpaid.

"learning". The voltage-to-frequency generator used here (ICI-b) emits a low-level (approximately 700 Hz) pleasant tone and when alpha occurs, this tone will shift in frequency. The amount of frequency shift is proportional to the amplitude (intensity) of the alpha and the number of frequency shifts per second is directly related to the brainwave frequency—alpha causes a 10-Hz shift, while theta produces a 5-Hz shift. This sounds something like the "vibrato" on an electric organ.

The output of ICI-b is then coupled to front-panel volume control R14 and fed to lightweight stethoscopic-type high-impedance earphones whose light weight insures maximum comfort even after long hours of use.

How to build it

Although any type of short-lead clean construction may be used, the PC board shown actual size in Fig. 2 is the best approach. The component installation is shown in Fig. 3. **In the interest of safety, the device must be powered by an internal battery. Do not connect the alpha device to any external system using an ac power supply as any leakage, however slight, can be lethal across the skull electrodes.**

Select an enclosure that can accommodate the PC board, the 9-volt battery and holder, and whose front panel can accommodate volume control R14, and associated on/off switch S1, sensitivity control R5, input jack J1, and output jack J2. Use some form of press-on lettering to identify the front-panel elements, and the various "level" settings of the two potentiometers as shown in the front-view photograph.

Using the detector

Apply a small amount of electrode paste to the earclip electrode, and then clip this electrode to either the right or left earlobe. Coat the front-surface of the other electrode, and parting the hair at the rear of the skull, press this electrode close to the skin. Use the headband to secure this electrode in place, and the Velcro end to secure it tight. Plug the end of the electrode cable into J1.

Place the earphones comfortably on the ears and position them for maximum comfort. Plug its jack into J2.

Sit in a comfortable chair, located in a quiet place, place the feet flat on the floor. Turn off any radios, hi-fi's, etc., to reduce external influences, turn down the lights, and relax.

Turn on the power, via volume control R14, adjust R14 for a pleasing listening level, turn up the sensitivity. After several seconds with the eyes closed, and as relaxed as possible, the tone will stabilize. You will soon note the slight "warble" or "waa-waa" and this indicates the presence of alpha. Do not try to produce this rhythm—let the mind go and just listen for it. If you fail to attain the tone variation, check the electrode connections and the presence of the electrode paste. In some cases, alpha is more easily detected by placing the large electrode (suitably paste covered) over one eyebrow. In some cases, alpha production increases in the frontal areas of the brain.

It is difficult to describe how alpha "sounds". You have to close the eyes, clear the mind of any visual imagery, don't "try" to produce alpha, and physically relax. Opening and closing the eyes will produce some sort of tone reaction, and what you are searching for is the 10Hz warble of the 700 Hz tone. If you have access to an electronic organ, play F5 note without "vibrato' or "tremolo" and listen for the steady tone. Switch on the "vibrato" or "tremolo" and note the modulation of the tone. This, in essence, is what the alpha sounds like. Alpha monitoring is essentially an indication of the degree of relaxation, therefore almost any relaxation technique you may know (non-alcohol and non-drug) will facilitate alpha production.

Alpha sessions usually last for 10 to 15 minutes per day, and if you stick to it, you will note a general relaxation and a feeling of well being after each alpha session. Do not keep it up for more than 15-minutes a day at first, as fatigue rapidly sets in, nullifying any extra time. The two key words here must be relaxation and patience.

After each session, carefully wipe each electrode clean with alcohol, as skin oils; dirt, and other deposits may accumulate to destroy the good electrical contact, thus degrading performance. **R-E**

ELECTRONIC DEVICES FOR SELF-IMPROVEMENT

State-of-the-art electronics combined with recent medical discoveries can help you master your mind and body's "involuntary" actions.

DAVID R. WHEELER

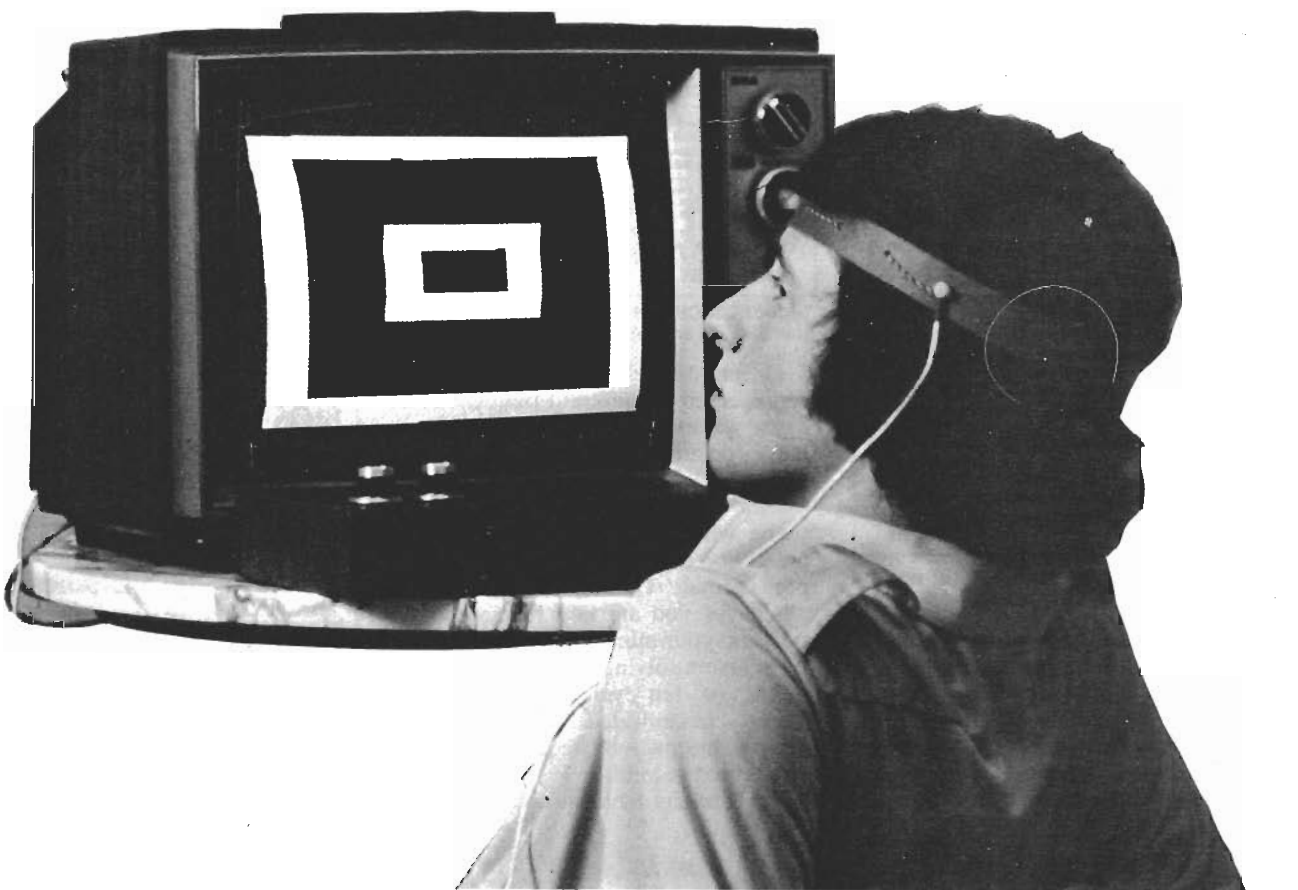
"EVERY DAY, IN EVERY WAY, I AM GETTING better and better."

Emile Couê had the idea that telling yourself you were improving was enough. That was in the 1920's and before the miracle of electronics made it possible to have total control over one's body and mind.

To change your behavior, your habits, and/or to improve yourself, two conditions—call them principles of behavioral technology—must be present and used. They are something which can be observed and measured, and feedback of the observed "something" has to occur. To improve at bowling, golfing, pool, or handball, you have to know where the ball went after being hit. Improvement comes about as adjustments are made from feedback. Knowledge of the results is of critical importance if you are to learn.

Electric devices have been used since the beginning of this century as crude, and sometimes dangerous, apparatus for curing diseases. Electrical current was sent through the human body to purge the system of "malevolent and evil spirits." Many of the mail-order catalogs at the time contained advertisements for the miracle "cure in electricity." Today, medical researchers are experimenting with low-voltage currents as a means of stimulating bone repair in patients with broken bones. That is not self-improvement, but medical treatment.

Behavior modification—the technology of altering and controlling thought and action—rests soundly on the prin-

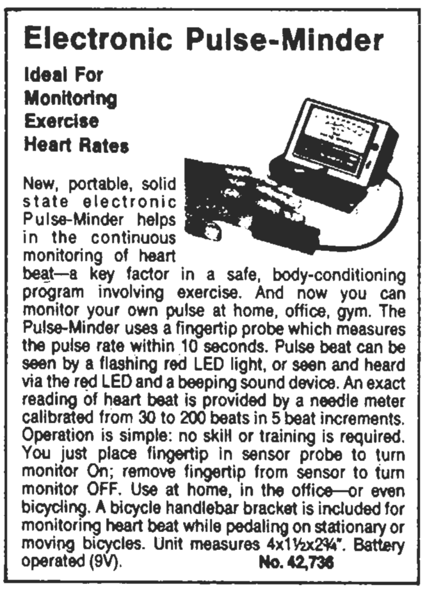


ciples of recognition and feedback. One of the earliest applications of that idea is shown in a patent for an alarm that would awaken sleepers to the fact that they have just begun to wet their beds; that is recognition and feedback.

The relationship between thought and muscle reaction was demonstrated in a now-classic study by Dr. E. Jacobson, described in the 1932 article for *The American Journal of Psychology*, entitled "Electrophysiology of Mental Activities." He measured the electric currents in resting muscles and then he suggested to his subjects: "Imagine that you are lifting a heavy suitcase in your right hand." He discovered that electric activity in the muscle resulted from the mental activity.

Behavioral electronics

By the 1960's, it was generally recognized that the brain and nervous system were similar to solid-state electronic devices. Electronic principles could be coupled with behavioral principles. The resulting "Behavioral Electronics" could be used to modify, improve, and control human behavior—including the autonomic nervous system's activities of regulating the beating of the heart, and pupil dilation and constriction. Using the behavioral technology (recognition and feedback) with the aid of electronics to amplify minute electrical signals, researchers were able to train individuals to alter blood pressure, the temperature of hands and fingers, and even to control the rhythms of the human brain.



ELECTRONIC PULSE COUNTER derives and displays pulse rate within ten seconds.

Electronic instruments now make it possible to observe routinely what was once difficult, if not impossible. Production costs have lowered to the point that the prices on many instruments for reading blood pressure, heart beats, and body temperature are within the reach of consumers for home use.

Behavior-modification programs have been bought by businesses to reduce employee stress and improve productivity. Control Data has bought an electronic feedback structure from Kiel and Associates of Minneapolis. It will be used as relaxation therapy for employee stress and anxiety. Ford Motor Company has used feedback in its stress program to help calm potential heart attack victims. McDonald's (fast food franchise company) has used biofeedback devices to enhance executive decision-making and improve creative thinking. First International Bank of Houston has run a series of advertisements relating to cases in which behavior modification has been used to reduce executive stress.

SIMPLE BIOFEEDBACK MONITOR based on galvanic skin response and skin temperature.

Biofeedback phenomenon

"Probably no discovery in medicine or psychology compares in breadth of application or in scope of implications to the biofeedback phenomenon," wrote Dr. Barbara Brown, who is a renowned psychologist.

BIOFEEDBACK MONITORS USING (a) alpha and theta waves and (b) galvanic skin response.

Different levels of consciousness are represented by different frequencies of brain waves. In very deep sleep brain waves occur, on the average, every two seconds, which has been labeled the "delta" stage. The theta stage, thought to be where insight is developed and creativity occurs, averages six cycles per second. The alpha stage occurs whenever you are in a relaxed condition and your mind is not concentrating on problem solving; that stage has a frequency of ten cycles per second. An alert, concentrated problem solver shows brainwave frequencies of 18 cycles per second.

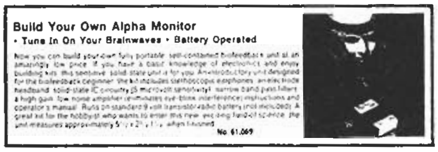
Researchers have shown that individuals who can control the electrical rhythms of their brains can enter the alpha state and experience the most "profound type of relaxation." Thinking heightens neuronal activity over much of the cortex and that disrupts the alpha state, leading, it is thought, to inferior decisions, anxiety, tensions, and ultimately, to high blood pressure and heart attacks. Learning to relax has been shown many times to be good for one's health. With the aid of electronic technology—called electroencephalographs—viewing the electrical patterns of the brain, those patterns can be monitored; with the use of behavior modification, they can be controlled.

"Alpha Machines," brain-wave biofeedback devices, EEG recorders, or thought detectors are now available in kit form for as little as $37.50, or $49.95 ready made.

ELECTRONIC BLOOD PRESSURE TESTER automatically takes systolic and diastolic readings.

ALPHA/THETA WAVE MONITOR permits audio and visual indications of brain activity.

During the last few years, the public has become very disillusioned with the so-called alpha machines. The devices just did not seem to achieve their advertised potentials. The major reason for the disparity between actual performance and advertised claims was the quality of the electronic products made for professional use and those offered to the American consumer. Medical equipment consists of multi-channel electroencephalograph amplifiers and multi-faceted recorders. Those sold through the mails omitted much of the costly electronics and left just barely enough for feedback of only the largest-amplitude brain signals. Those signals may or may not be alpha, or theta, or any other frequency. While it is true



ALPHA WAVE MONITOR KIT offers inexpensive means of measuring basic brain activities.

that one *can* use electronic equipment for monitoring the rhythms of the brain, not every electronic device offered to the public had the power to do what was claimed for it.

Given the proper equipment, listening to one's brain rhythms can be a relaxing experience. At the Langley Porter Neuropsychiatric Institute, University of California at San Francisco, medical psychologist, Joe Kamiya, found that increasing alpha waves in his patients reduced their anxiety. Kamiya wrote: "People can be trained to achieve a kind of mental relaxation or reduction in tension. Biofeedback involves providing the subject with some measure of body function, the kind of measurement that can be followed."

Digital thermometers & stress

Our emotions and the temperature of our skin are interconnected by way of the sympathetic nervous system which is controlled by the hypothalamus of the brain. It can be activated by physical conditions (a hot or cold environment) or by psychological factors (worry or stress). Regardless of the cause, the end results are sweating, changes in blood pressure, and a lower heart rate.

In 1939, scientists B. Mittelmann and H. G. Wolff found that material laden with emotional associations could lower the temperature of the hands.

In later studies (1976) researchers at Duke University found that anxiety, stress, and excitement caused the blood vessels in the hands and feet to constrict, educing the flow of blood and decreasing the temperature of the extremities. Those researchers used thermometers with electronic circuits accurate to the hundredths of a degree and with digital readouts. Accurate digital thermometers are available today for prices as low as $49.95.

Scientists at the Menninger Foundation in Topeka, Kansas, have trained patients to alter finger temperature by concentrating on a digital readout. No one is sure how thinking about "warmer" or "colder" hands actually causes a temperature change, but everyone can learn to do it in 15 minutes. The Menninger patients were able to stop their migraine headaches by regulating their own finger temperatures.

Raynaud's disease syndrome (reduced blood flow in hands and feet) has been treated with the biofeedback approach. They are told to "imagine your hands and feet getting warmer and warmer." They watch the meter and concentrate on "warmer."

One of greatest fears (phobias) for Americans is public speaking. Telling yourself not to be afraid, preparing in great detail what your going to say, having several drinks, and praying hard have not always reduced the anxiety and stress many people have when they know they have to make a speech.

DIGITAL THERMOMETER gives constant indication of changes in skin temperature.

The anxiety preceding a speech can be reduced by concentrating on making one's hands warmer and colder. There is a woman who takes a battery-powered digital thermometer with her as she travels around the nation delivering several speeches a month. Just before going on stage she sits down and thinks her fingers warmer by five degrees and lower by ten. It reduces her stage fright.

AN INEXPENSIVE means for detecting differences in body temperature.

Another method of achieving relaxation is by learning to control sweating. Since the circuitry is so inexpensive

GALVANIC SKIN RESPONSE meter provides audible indication of amount of stress.

and the results so clearly demonstrated, many manufacturers and marketers have entered the market with "galvanic skin response" machines—devices which measure resistance across the skin. The more nervous a person is, the more anxious, the more stress that is felt, the more the individual perspires and the easier it is for an electric current to flow across the skin.

Lie detectors

Polygraphs measure respiration, heart beat, and changes in galvanic skin response. Lying causes a change in the sympathetic nervous system, leading to physiological changes which can be detected by the electronic instruments. A lie will usually be indicated by a galvanic skin response, a lowering of skin resistance occurring from one to four seconds after the false answer has been given.

Lie-detector examinations are a big business—a million or more exams given a year—and the consequences are enormous, with future employment or freedom being the outcome. But the results are less than precise. People show great variation in their responses. Some are able to tell simple lies without emotional reaction, others have learned to lie convincingly with practice involving some form of biofeedback.

Some years ago, a book called the *Organization Man* (1956) by William H. Whyte, Jr., contained an appendix which detailed how to cheat on personality tests. At the time, many firms were using clinical tests such as the MMPI (*M*innesota *M*ultiphasic *P*ersonality *I*nventory). That test originally was developed to help diagnose severe psychological problems, not to determine whether someone would show the makings of a good salesperson, etc., on their job applications. The Federal government has ruled that personality tests cannot be given unless there is a direct bearing on the specific job. But polygraph tests can be legally given to anyone applying for a job.

Researchers at Lackland Air Force Base in Texas have taught people to use biofeedback to beat the polygraph[1].

In Miami, police are using biofeedback kits containing small electronic instruments with fluorescent digital dials —the more they relaxed and lower their galvanic skin response, the higher the numbers on the dial. Twenty-five percent of police have alcohol problems, 60 percent are divorced, and there are high suicide rates. Three-fourths of the heart attacks suffered by police officers are directly related to stress on the job. Learning to reduce stress by learning to relax seems to be one way of counter acting the serious problem. Biofeedback is effective in reducing stress.

Noise can sicken you. It reduces the ability to concentrate. Students nearer distracting noises (freeway traffic) did less well in their grades then students farther from the noise. Noise leads to stress, tension, nervousness, heart disease, high blood pressure, chronic headache, and stomach ulcers. It affects one's mental health. Sudden noise stops food digestion.

Pink noise generators

Psychologists have found that electronic sound conditioners can change the impact of noises on the human system. Those devices can mask or reduce the noise's impact. One of the most inexpensive devices for generating a white-noise masking effect is the electric fan. Most of the devices for sale today are pink-noise generators. White noise has equal distribution of sounds throughout the frequencies; on the other hand, pink noise is a distribution weighted toward the audio spectrum.

Some years ago dentists experimented with the use of pink noise instead of anesthetics. It worked for some patients, but not all.

NOISE GENERATORS mask external distractions and reduce their effects.

There are several sources of pink-noise generators; some are in kit form, others ready-to-use. One electronic masking device is made by Control Electronics Company (139 Florida Street, Farmingdale, New York 11735). The device is suspended over a noise source and tuned to mask a specific sound with another, almost subliminal sound. A six-and-one-half inch diameter cylinder is $98. Those devices allow privacy in meeting rooms.

Marpac Corporation manufactures sound-conditioning devices. James Buckwalter, president of Marpac has said: "Users of the electromechanical devices got 50 percent more delta—deep sleep—than those who did not use it."

Those electronic devices seem to reduce stress and anxiety by helping people produce more alpha rhythms. Dr. Lou Gerstman, psychologist in City University of New York, has suggested why the electronic sound devices help us to concentrate. The left side of the brain deals with structured thought–reading, problem solving—while the right side deals with abstract thought, imagination, and subjective feelings. Dr. Gerstman believes that the noise generators interfere with the functioning of the left side, freeing the right to function in artistic and creative areas.

Ions, health, & the unknown

The mixture of negative to positive ions in the air around us influence the way we think, our emotional attitudes, and subjective feelings. Restlessness and anxiety are modified by the electrostatic field in which we are exposed.

In Israel, civil order is disrupted by the dry, positive ion-rich winds that blow across the country. Scientists have developed the Ionotron (at the Hebrew University) to enrich the air with negative ions. Throughout the world, the winds alter the composition of ions in living space. When that happens people begin suffering from thyroid conditions and breathing problems—particularly asthma; auto accidents increase, and crime can jump by 20 percent.

In the Middle East, the winds are called the khamsin which blow in from across the deserts of the Sahara. Italians suffer physiological and psychological disruptions from the winds calls the sirocco. France has the mistral. The Alpine regions have the foehn. The Rocky Mountain area in the United States has winds called chinook. California has the Santa Ana winds. Regardless of their names, the results are the same. People absorb the positive ions; they develop migraine headaches, nausea, and have an inability to relax and concentrate.

Electronic air cleaners do remove particles and clean the air, but they also produce ozone, which is much more toxic than carbon monoxide. (One-tenth of a part per million causes eye trouble and throat irritation.)

Breathing positive ions reduces reaction time. With negative ion environments, old rats learned mazes faster than control groups in normal air. A researcher at the University of Pennsylvania found that negative ions in the air promote feelings of exhilaration and well-being. The growth of house plants was better in negative ions than in positive ions. Many firms now have started to market devices which generate negative ions. They use modern microelectronics to produce ionized ions.*

Athletes, joggers & electronics

The development of products using electronics to use in self-development programs for athletic and exercise activities has mushroomed in the last couple of years. There is a device that gives the user a LED display of jogging performance while the person jogs in place in the home. (Beacon Scientific). Dynavit digitally displays heart rate, oxygen pulse, watts workload, and caloric expenditure. The Amerec Exercise Rate Monitor electronically watches human physiology and warns the user if he is about to reach his limit. Tredex has developed the experience in fitness. It gives a LED display of exercise performance. Then there are the smaller, less expensive electronic units —pacesetters to help a jogger adjust his pace, electronic stopwatches (Texas Instruments has a light-weight one that retails for less than $20), and light-weight transistor radios that strap to a jogger's chest. Also, a relatively new addition appears to combine the best of then electronics element (precise observation of an event) with the principles of behavior modification (feedback)—the unit is a puttermeter.

For those wanting to improve themselves in terms of weight, there are now electronic scales. What makes those units better than regular household scales is the read-out mechanisms—they are LED digitals. To improve oneself, a objective measure of changes is needed. See the precise number "187" is better feedback than having to guess at what the hand is pointing at with conventional scales.

Electronics has given those desiring ways of improving themselves precise and objective methods. The marriage of electronics with behavioral technology allows people to design their own self-improvement programs that work better than any other method. The subject designs the program, administers the rewards for sequential completion, and he or she is the person in charge, not someone else.

Every day, in every way, electronics and behavior modification are helping people master themselves. **R-E**

[1] J.F.T. Corcoran (chief and staff psychologist Department of Mental Health, Lackland AFB), M.D. Lewis, and R.B. Garver, "Biofeedback-Conditioned Galvanic Skin Response and Hypnotic Suppression of Arousal," *Journal of Forensic Sciences*, Vol. 23, No. 1, pages 155 to 161.

*One potential problem with those negative ion devices is a lack of a meter, dial, or some other indicator of ion concentration. Since we can neither see nor feel directly the influence of negative ions, there may be a tendency to doubt the output. Several years ago a manufacturer developed a super-quiet vacuum cleaner. It did not sell because no one believed that a quiet cleaner was working.

ELECTRONICS TODAY

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JULY 1977

35p

NERVOUS TENSION?

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LEARN TO REDUCE TENSION WITH ETI's

GSR MONITOR

This galvanic skin response monitor provides a means of measuring the minute variations in skin resistance which research has linked to the emotional state of a person

THE BEST WAY to start experimenting with biofeedback is to use a galvanic skin response monitor, a device which measures changes in skin resistance. In March 1977,we published an article which covered the background and theory of biofeedback and we discussed the various types of biofeedback instruments which are available. The GSR monitor is the most simple to use, the electrodes can be simply attached to the fingers with straps and the technique of using the machine can be quickly learned.

Skin resistance changes with changes of emotional state. When tension increases, the skin resistance falls — when tension decreases there is an increase in skin resistance. (Some biofeedback instruction manuals speak in terms of conductivity rather than resistance and state measurements in mhos, and the meter we use gives a positive deflection for decreasing resistance.)

The connection between skin resistance and tension is not fully understood. Tension affects sweat glands and with the changes in the sweat glands there is a change in the membrane permeability of the skin and this change in permeability is the major cause of changes in electrical activity.

Almost a century ago, a scientist named M. Ch. Fere discovered the resistance of the skin to a small electric current changed in response to aroused emotions. This information has since been used in various ways; one obvious example is the polygraph, or lie detector, which responds to the tension generated when a person is lying.

It was not until 1961 that Dr. J. Kamiya, whilst conducting a series of

GSR MONITOR

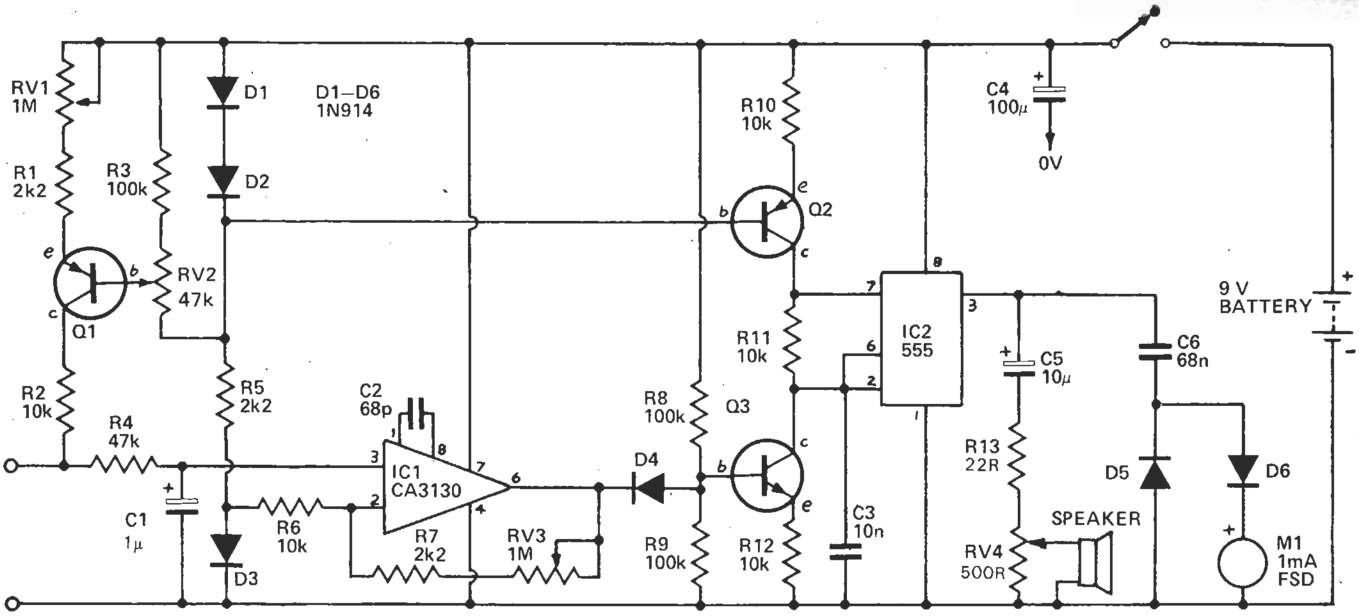
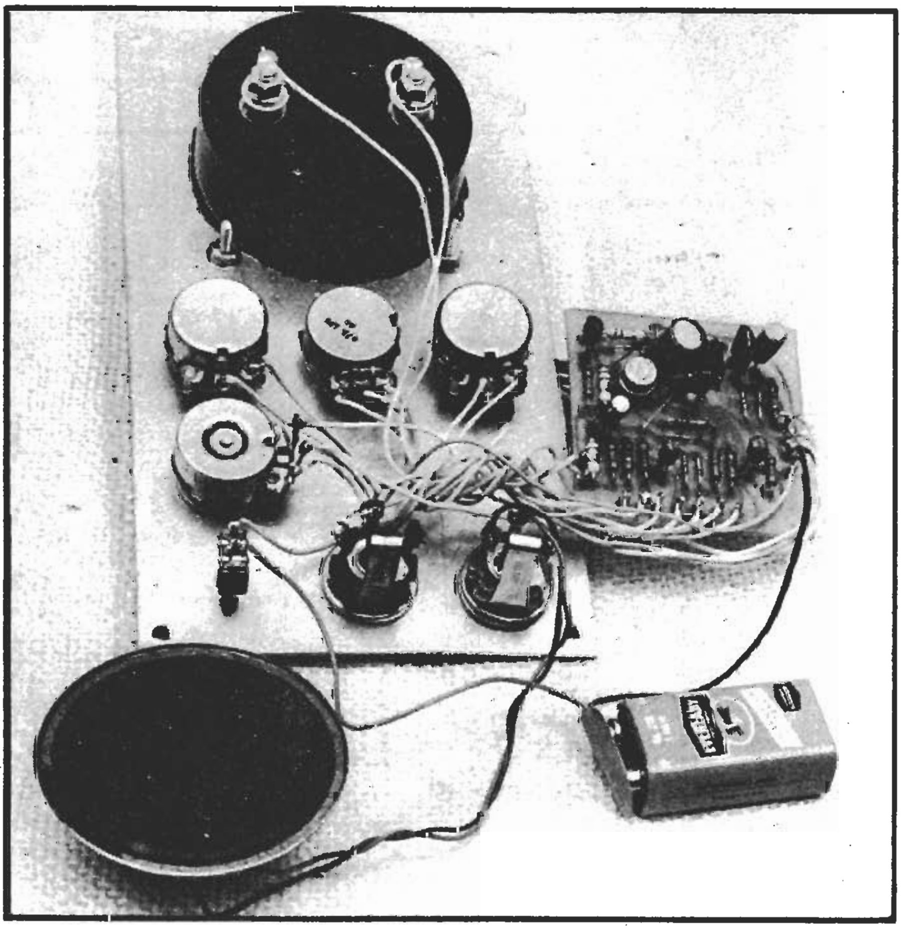


Fig. 1. Circuit diagram of the GSR monitor.

WARNING: THE GSR MONITOR SHOULD NOT BE USED WITH A MAINS POWER SUPPLY.



The picture above shows the internal layout of the GSR monitor. The wiring from the PCB to the front panel, loudspeaker and meter is clearly shown.

HOW IT WORKS

Transistor Q1 acts as a constant current source - the actual value can be varied over a large range by RV1 and over a limited range by RV2. These act as the coarse and fine level controls. This current is passed via R2 to the probes. The voltage developed across the probes is proportional to the skin resistance and is fed to the input of IC1. This amplifies the signal with reference to 0.6 V (drop across D3) and the gain is variable by RV3.

The second IC is an NE555 oscillator where Q2 provides a constant current (about 60 uA) to the capacitor C3. When the voltage on C3 reaches 6 V the IC detects this and shorts pin 7 to ground, discharging C3 via R11. This continues until the voltage reaches 3 V at which point the short on pin 7 is released, allowing C3 to recharge. The output of the oscillator is connected to a speaker via the volume potentiometer RV4 and the meter via C6 and the diodes D5 - 6. The meter operates in reverse sense to usual, a low resistance gives full scale (or high tone) and high resistance gives zero (or low tone).

We vary the frequency of the oscillator and the meter reading by robbing some of the current supplied by Q2 into Q3. In this way the frequency can be lowered and actually stopped. Transistor Q3 is controlled by IC1 completing the connection between the probes and the output.

Getting hold of components
Nothing here to trouble the constructor

Cost of construction
Should be about £5.00 excluding boxing and meter.

experiments with brain waves, found that with feedback his subjects developed the ability to produce 'Alpha waves' at will.

Dr. Kamiya's experiments created considerable interest and started investigations into whether other bodily functions could be brought under conscious control. Since that time it has been demonstrated that with feedback it is possible for people to control heart beat, blood pressure and temperature — all previously considered to be automatic bodily functions mostly beyond conscious control.

Of course it should be stated that various mystics and yogis have previously demonstrated this type of ability but the fascination of biofeedback is the speed and ease with which this type of control can be learned.

Biofeedback has exciting medical possibilities. GSR machines are being used by therapists for the treatment of many disorders related to tension. The average person will find a GSR machine mainly useful for relaxation training. With the GSR machine it is possible to recognise tension and learn how to decrease tension levels. This type of training is so effective that the machine quickly becomes unnecessary.

However not everyone suffers from tension. The biofeedback machine can be a fascinating toy to play with. Discovering that you can bring an internal bodily function under conscious control with the same ease that you can twitch your nose is most interesting. And of course you can then perfect this ability just as you perfect your ability at a game like tennis. For many people this is reason enough to build this machine.

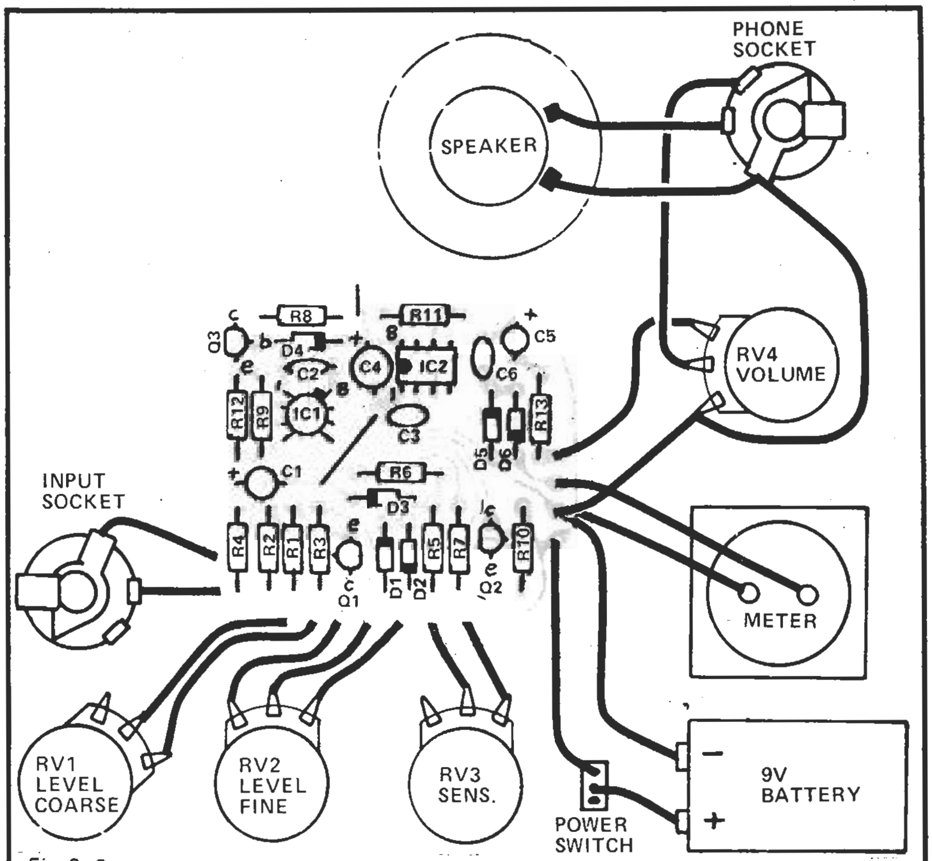


Fig. 2. Component overlay and interconnection diagram.

PARTS LIST

RESISTORS (all ½ W 5%)		C3	10 n polyester
R1	2k2	C4	100 u 16 V electrolytic
R2	10 k	C5	10 u 16 V electrolytic
R3	100 k	C6	68 n polyester
R4	47 k		
R5	2k2	SEMICONDUCTORS	
R6	10 k	D1-6	1N914
R7	2k2	Q1,2	BC559 or BC179
R8,9	100 k	Q3	BC549 or BC109
R10-12	10 k	IC1	CA3130
R13	22 R	IC2	NE555
POTENTIOMETERS		MISCELLANEOUS	
RV1	1 M log	PC board ETI 546	
RV2	47 k lin	Meter 1 mA FSD	
RV3	1 M log	Box 196 x 113 x 60 mm	
RV4	500 R lin	Two phone jacks	
		Four knobs	
CAPACITORS		Small speaker	
C1	1 u 16 V electrolytic	PP3 or 9 V battery + holder	
C2	68 p ceramic	Pickup probes	

What you do with it once you have built it

The ETI GSR monitor has an on/off switch, a sensitivity control and fine and coarse level controls. The machine also has a connection for headphones.

To start relaxation training, you'll need a comfortable chair, low lighting and no distractions. Taking any type of drug can interfere with your ability to relax. This applies to alcohol and cigarettes. Attach the electrodes to the fleshy part of the first two fingers on one hand — firm but not too tight (the non-dominant hand is recommended). Set the sensitivity control to minimum and the 'fine' level control to mid-range. Turn the volume control to minimum. Now you have to set the level with the 'coarse' level control (when the sensitivity is set low the 'fine' level control need not be used). Start with the 'coarse' control at full anticlockwise and turn it up until the meter needle starts to move. Carefully set the needle to mid-range. Now the instrument is set-up in its minimum sensitivity position.

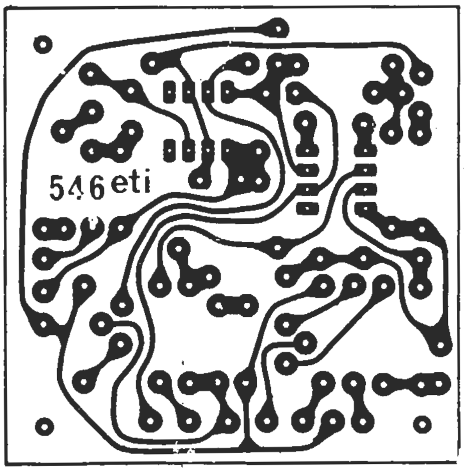
Having mastered setting up with minimum sensitivity try to set the GSR monitor with the sensitivity set half-way. It will require delicate adjustment of the 'coarse' level control. Now the effect of the 'fine' level control can be seen. This control enables you to set the level on a high sensitivity setting.

GSR MONITOR

Although the GSR machine measures minute changes in skin resistance, the level of skin resistance varies considerably from person to person so a wide range of settings is provided.

Now turn up the volume and observe that the meter reading is accompanied by a medium pitched tone. (A convention has developed to link high-pitched tone with tension increase and low pitched tone with a decrease in tension.) Now you relax and bring the tone down and the needle back to zero.

How? Basically you are supposed to find this out for yourself. After watching the needle for some time you will notice it move up or down. Something has happened to cause a change in your skin resistance. You would be barely aware of what had caused the change but aware enough to try to reproduce the effect. Eventually your awareness grows and so does your ability to control your tension. Many people find that relaxation of the stomach muscles makes the difference. It varies from person to person.



There are several relaxation techniques which work very well. One method is to tense all the muscles of the body as hard as possible, hold them tense for several seconds then very deliberately relax all muscles. There are several books and cassettes available which describe relaxation techniques. The techniques work. The biofeedback machine makes it possible to monitor progress.

As you relax, the needle on the meter and the audible tone will decrease. When the needle reaches zero, reset it again towards the fsd end of the scale and repeat the procedure.

Twenty minutes is the recommended time for a training session. After about one or two weeks of daily relaxation training, it should be possible to produce the same level of relaxation without using the machine and the machine can simply be used occasionally as a reference.

Construction

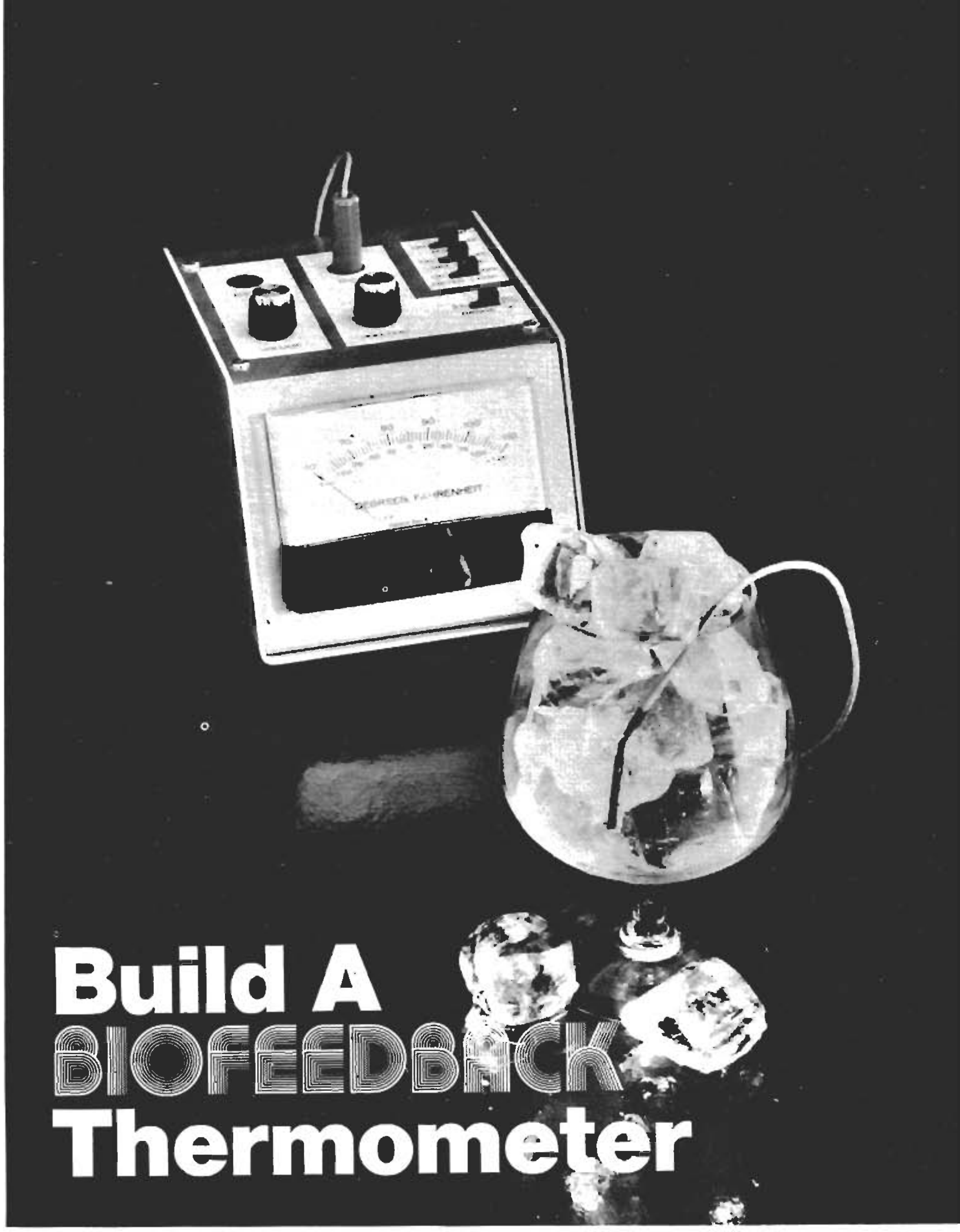
Construction is not critical although we recommend you use the pc board as it makes things easier. Before soldering the components made sure they are orientated correctly. External wiring can be done with the aid of the overlay-wiring diagram.

Probes

Probe construction and electrical contact is not nearly as critical as with most other biofeedback machines.

Commercial GSR machines use a pad of soft steel wool which is held firmly onto the finger by a short length of Velcro strap (Band-Aids work fine!). However, any method ensuring a firm contact between probe leads and the fleshy part of the finger will do. One method which works very well is to bind tinned copper wire around a guitar finger pick (or solder to a steel pick). Two probe connections are of course required — one for each of the first two fingers. ●

Build this biofeedback thermometer and learn how to control your body temperature and gain from the benefit of the relaxation and pain reduction that comes with it.



Build A BIOFEEDBACK Thermometer

by MITCHELL WAITE
and LARRY BROWN

STAYING WARM IS SOMETHING THAT CONCERNS everyone. The most natural way to keep warm is to wear lots of clothes and build fires. But what if, rather than fighting the cold, you learn to adapt to it? Animals adapt by regulating their body temperatures until the minimum possible amount of body heat is radiated. People are now learning to regulate their body temperatures in yet another application of biofeedback—a painless technique that demands neither sacrifice nor discomfort.

Using sensitive electronic temperature sensors, scientists and biofeedback researchers are showing that people can learn to "turn off" many types of ailments by following a simple learning routine.

One group of reports explains that the old saying of "cold hands means cold heart" may in fact have much truth to it. Individuals have actually been taught to increase the temperature in their hands by ten degrees! This temperature change resulted in improved circulation and helped reduce the pain of migraine headaches. (**Warning:** *This feedback thermometer is intended for experimentation and entertainment only. It is not to be used as a substitute for professional clinical therapy. Persons with any tension-related illness should consult a physician. The device is* not *to be considered a home remedy for any illness.—Ed.*)

How do you take advantage of this? The electronic temperature sensor described in this article monitors body temperature. Through mental concentration, you attempt to vary your body temperature. Eventually you obtain some minor control. With additional practice, the control will increase somewhat. Once control is mastered, only occasional retraining is necessary. This technique of learning to control body temperature is called temperature biofeedback.

Another intriguing application of temperature biofeedback is teaching people how to relax. The stabilization of body temperature seems to have a calming effect on the entire nervous system. The highest success rate has been in the treatment of psychosomatic illnesses. The requirements on biofeedback devices are critical to this technique. Because the actual temperature changes are quite small, the temperature monitor must have a high degree of amplification along with stable response.

The Biofeedback Thermometer described in this article covers from 60° to 110° Fahrenheit while maintaining an accuracy of ±2%. The circuit is especially designed for biofeedback training and can detect temperature variations of as little as .05 degree Fahrenheit. A large 4½-inch front-panel meter is calibrated in °F. The meter displays the absolute body temperature with a resolution of 1 degree-per-division.

The Biofeedback Thermometer can also be used in an expanded-scale mode. In this mode, the meter has a resolution of 1/20 degree-per-division but only covers a 2.5°F range (±1.25°F). A front panel NULL control is used to center the meter when the thermometer is in this mode.

SPECIFICATIONS

Temperature Span:	
Metered, ±2%	60—100° F (15—45° C)
Rear panel jack, ±2%	15—45° C (60—115° F)
Rear panel, 10%	0—90° C (32—194° F)
Resolution:	
Normal range (60—110° F)	1° F/division
Expanded (2.5° F)	1/20° F/division
Rear-Panel Voltage Sensitivity:	
100 mV/°C	
Battery Life:	
Two Neda 910 or Eveready 276 @ 2 hours/day	715 hours
VCO Range:	
Linear from 12 clicks/minute (one every five seconds) to a 100-Hz tone. Increasing temperature causes decreasing frequency.	
Response Time:	
Less than one second for a 1-degree change in temperature.	

Both modes are used with the front-panel meter for "eyes-open" monitoring. For eyes-closed monitoring, the output of a voltage-controlled oscillator (VCO) is modulated by the temperature variations. The VCO audio signal drops from a steady tone to a slow click as body temperature increases. The VCO output is used with headphones.

A jack on the rear panel allows the thermometer to measure temperature in degrees centigrade and over a wider range than is possible with the front-panel meter. This jack provides a linear 100 mV-per-degree-centigrade voltage over a range of 0°C to 90°C with an accuracy of ±10%. Within a narrower range (15°C to 44°C), the accuracy is within ±2%. Any 0 to 10-volt full-scale voltmeter connected to the jack on the rear panel will provide a direct

PARTS LIST

All resistors are ¼-watt, 5%, unless noted.

R1, R4, R34—1000 ohms
R2—3300 ohms
R3—2000 ohm, ⅛-watt, horizontal-mount trimmer
R5, R6—62,000 ohms
R7—470,000 ohms
R8—158,000 ohms, 1%
R9—100,000-ohm *Uni-Curve*® thermistor
R10, R12, R16—47,000 ohms
R11—1 megohm
R13—360 ohms
R14, R30—5000 ohm, linear taper, potentiometer
R15—1600 ohms
R17—129,000 ohms
R18, R25—100,000 ohm, ⅛-watt, horizontal-mount trimmer
R19, R28—20,000 ohms
R20, R26—27,000 ohms
R21—200,000 ohms
R22—51 ohms
R23—5600 ohms
R24, R29, R32—4700 ohms
R27—10,000 ohms
R31—2700 ohms
R33—470 ohms
C1, C2—0.1-μF, 100V, 10%, Mylar
C3—0.47-μF, 100V, 10%, Mylar
C4—10-μF, 25V, electrolytic
IC1—Quad 741 op-amp (Raytheon RC4136DB)
Q1—2N3565 transistor
D1—5.6 volt, 200 mW, Zener diode (1N752 or equal)
M1—100-μA, 4½-inch meter*
S1-S4—SPDT slide switch, PC mount
S5—DPDT slide switch, PC mount
J1, J2—¼-inch phone jack
Misc.—8-ohm headphones, battery snaps, shielded 2-conductor cable, hardware, etc.

The following parts are available from Cal Kit, PO Box 877, Sebastopol, CA 95472:
#FT-1. Drilled and solder-plated PC board, $8.50.
#FT-2. 100,000-ohm *Uni-Curve*® thermistor, $14.50.
#FT-3. Complete kit including drilled and screened cabinet, PC board, thermistor probe, meter, and all components except headphones, $99.00.
#FT-4. RC4136 quad op-amp, $4.00.

***Following parts are available from Mouser Corp., 11511 Woodside Ave., Lakeside, CA 92040:**
100-μA, 4½-inch meter—order stock no. 39LK417—$10.90.
Meter illumination kit—order stock no. 39LK900—$1.50.

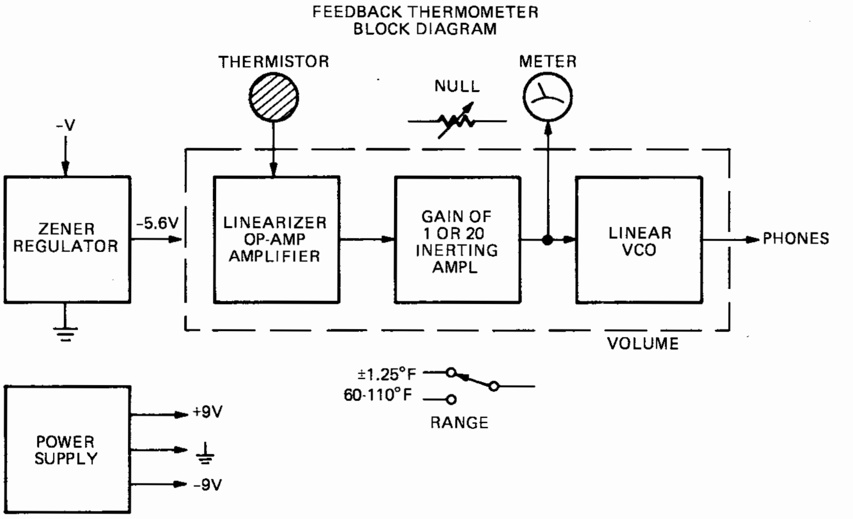


FIG. 1—BIOFEEDBACK THERMOMETER consists of a linearizer, inverting amplifier and a linear VCO.

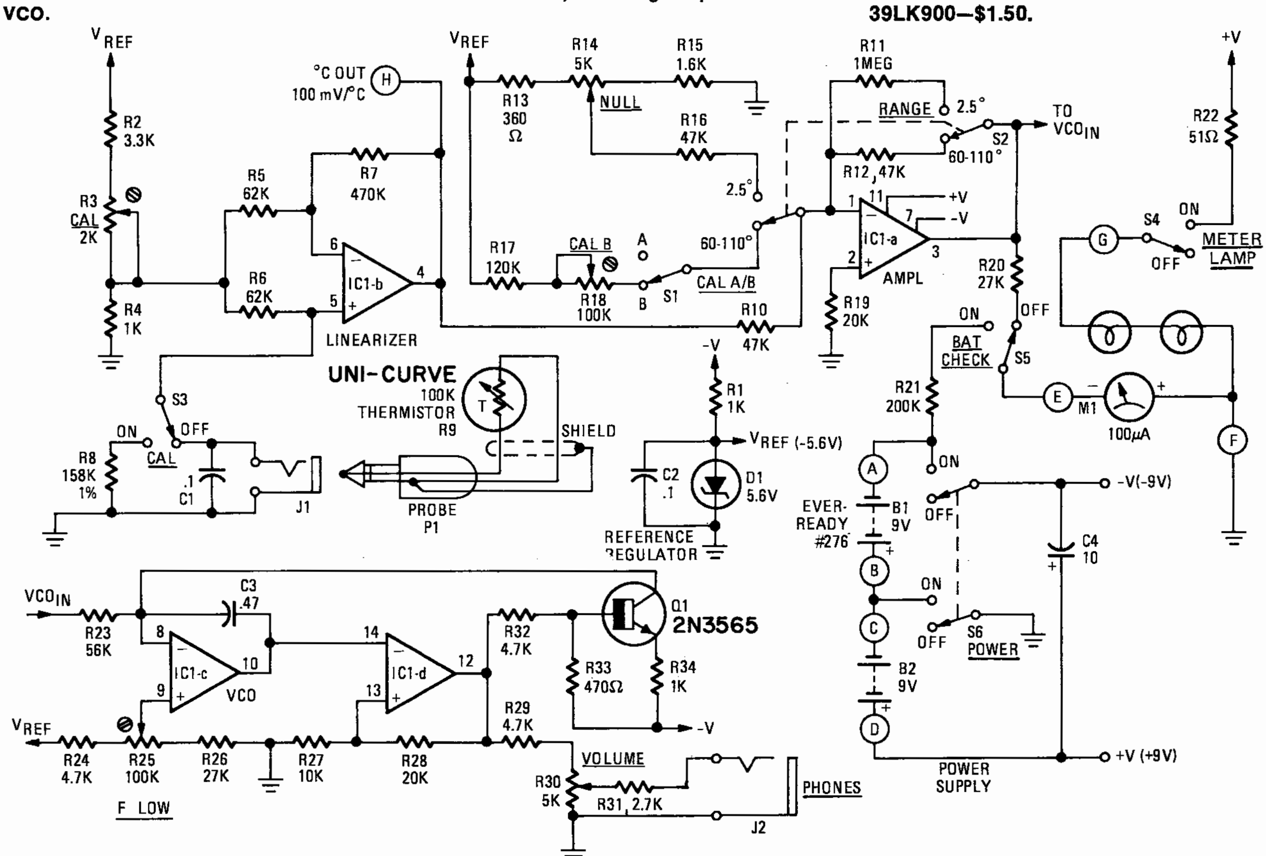


FIG. 2—CIRCUIT is built around a single IC.

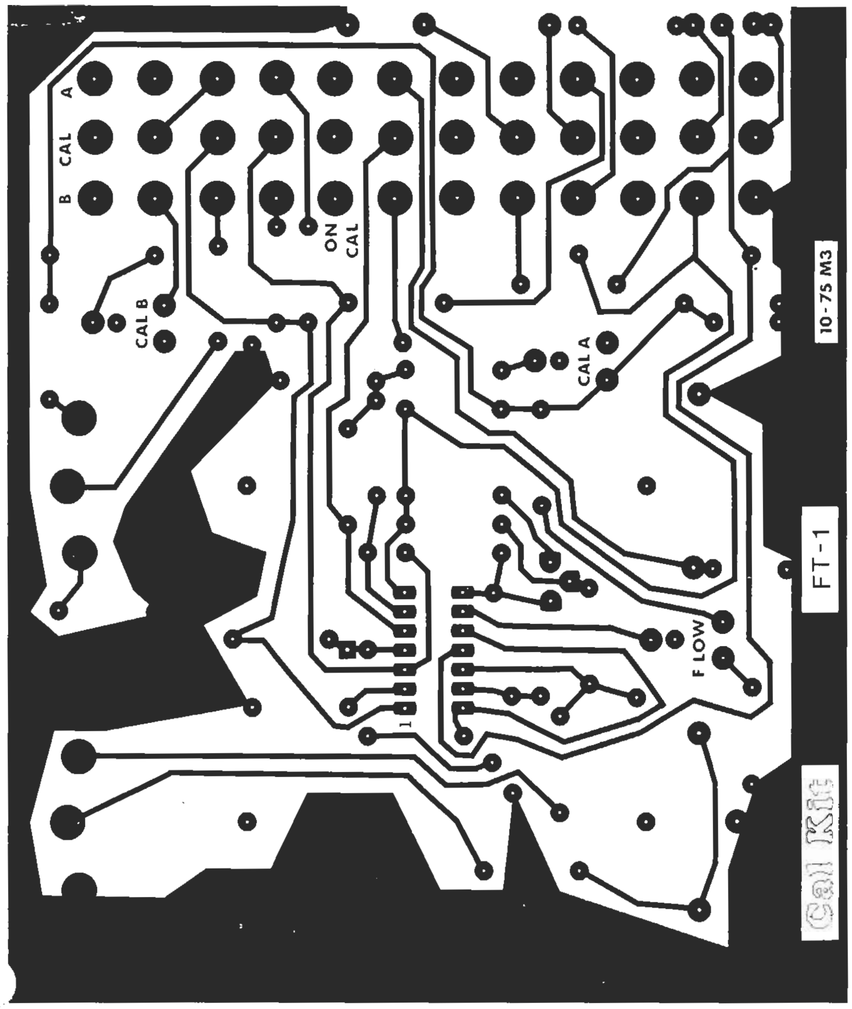


FIG. 3—FOIL PATTERN shown full-size.

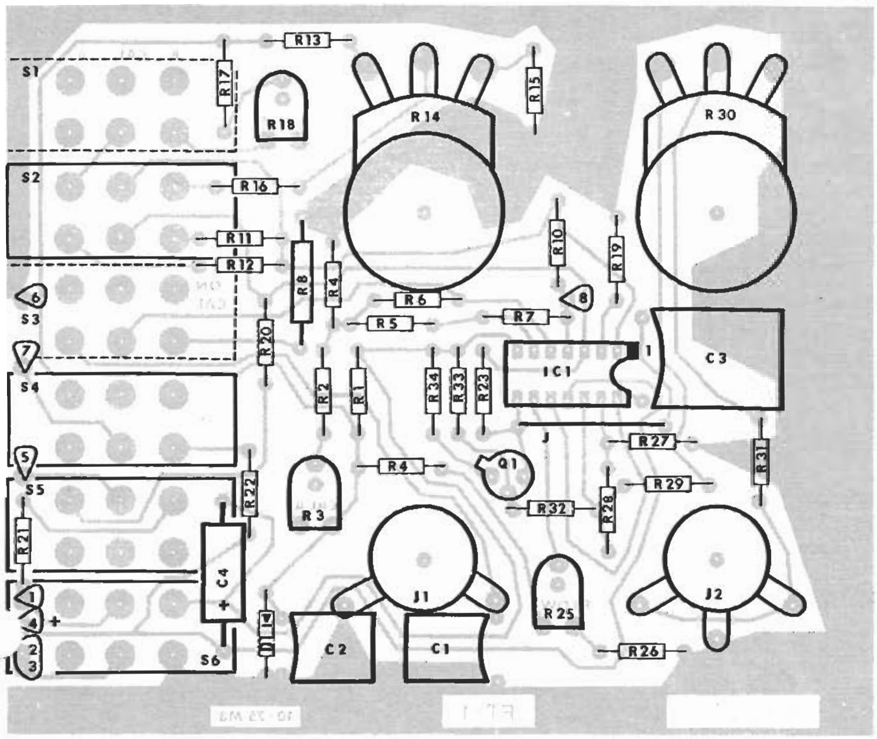


FIG. 4—COMPONENT PLACEMENT diagram.

readout of temperature in degrees centigrade. For example, a reading of 2.5 volts is equal to 25°C, 5 volts equal 50°C, and so on.

About the circuit

The Biofeedback Thermometer circuitry consists of a linearizer/amplifier, a second switchable amplifier with a gain of 1 or 20, and a linear audio voltage-controlled oscillator (see Fig. 1). All these circuits are contained in a single-quad op-amp integrated circuit (IC1). A lost-cost thermistor plugs into the linearizer circuit and produces a voltage proportional to the temperature of the thermistor probe. The second amplifier drives the meter and VCO and amplifies the signal for the expanded-scale mode

The linearizer circuit is used to convert the exponential resistance changes from the thermistor to linear voltage changes for the VCO and meter. Without the linearizer circuit, a non-linear voltage would be sensed, and the meter and VCO would have a highly asymetrical response. The linearizer circuit can be made from a single op-amp and is quite a useful general-purpose circuit.

From the linearizer circuit the signal passes to an inverting amplifier with two possible gain settings, 1 or 20. In both cases, the amplifier inverts the thermistor signal. This results in an inverted frequency-temperature relationship in the VCO—as the temperature at the probe increases, the frequency of the VCO decreases. The gain-of-one stage also has a trimmer that cancels any offset errors in the op-amp and zeros the meter.

In the gain-of-20 setting, the additional amplification enables the thermometer to resolve down to 1/20 degree. When in this setting, the meter covers a range of 2.5°F (±1.25°F) and a front-panel NULL control is used to adjust the offset to the op-amp. This allows nulling the meter as the absolute temperature changes.

The output of the switchable gain amplifier drives a 100-μA meter and a VCO. The VCO is the classical two op-amp one-transistor type and produces both sawtooth and pulse outputs. Two 9-volt batteries form a hefty supply for the circuit.

How it works

The thermistor (R9) used in this circuit is a special interchangeable low-cost minature type. This tiny device has a well-controlled accuracy of ±0.2 degree centigrade over a 0- to 70-degree range. Its small size allows it to respond to temperature changes rapidly. Different replacement thermistors of the same type can be placed in the circuit and no calibration is required.

The resistance of the thermistor increases as the temperature decreases. This changing resistance is coupled to the non-inverting input of IC1-b (see Fig. 2). Switch S3 connects a 1% resistor in place of the thermistor for calibration. The linearizer circuit (IC1-b) is also fed a constant voltage reference of —5.6 volts. The linearizer works on the principle that if the sensor response is truly exponential (follows the equation $A\varepsilon^{-bT}$), then there is a certain range (of bT) for which the circuit produces a linear voltage response. The re-

(continued on page 96)

BIOFEEDBACK THERMOMETER

(continued from page 35)

sponse depends on the input and feedback resistors. Trimmers R3 is used to adjust the gain of the linearizer to approximately five for calibration.

The output of the linearizer is coupled to IC1-a, the inverting op-amp. In normal operation, the signal is inverted and applied to meter M1 through resistor R20. The negative terminal of M1 receives the active signal, while the positive terminal is grounded. As the output of IC1-a becomes more negative, the meter reads up-scale. In the gain-of-20 setting of the op-amp, a larger feed-resistor (R11) is used along with a different offset network. The network allows varying the offset so the voltage coming out of this stage can be adjusted for a center reading on the meter.

The output of the linearizer is also coupled to the VCO. The VCO circuit consists of an integrator (IC1-c) and a comparator (IC1-d). Transistor Q1 is used to reset the oscillator once every cycle by discharging the timing capacitor C3 through R34. C3 charges through R23. The ratio of R23 to R34 is about 56 to 1, which results in a fairly narrow output pulse. Trimmer R25 subtracts a current from C3, allowing the VCO low-frequency point to be adjusted.

A Zener diode regulator (D1) provides –5.6-volt reference voltage. Capacitor C2 removes any noise in the reference voltage. The battery condition is checked by a circuit that uses S5 to disconnect the meter from the amplifier and to reconnect it through Resistor R21 to the negative terminal of the battery. With the POWER switch off, current flows from the negative terminal of B1, through R21, the meter, ground, then to the positive terminal of battery B2 and finally back to B1. A mark on the meter shows

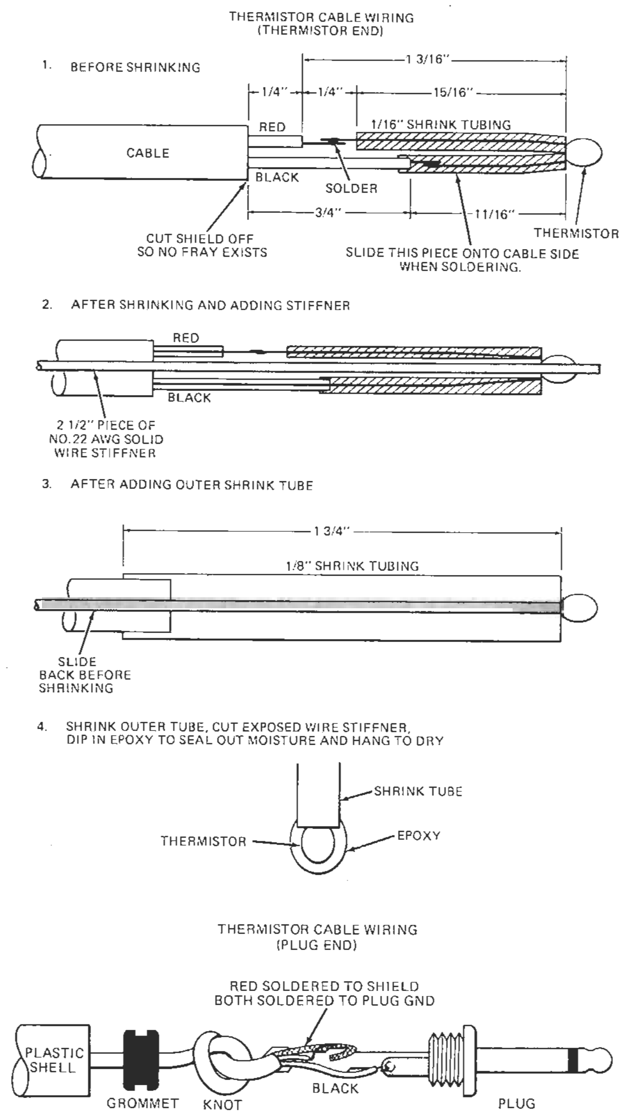


FIG. 5—CONSTRUCTION OF THERMISTOR PROBE. The steps for constructing the thermistor-end and the plug-end of the cable.

when the batteries have reached the point where the Zener stops regulating.

Switch S4 is used to turn on the two small incandescent lamps used for meter illumination. R22 limits the current to these lamps to under 50-mA.

Resistor R8 is a 1% resistor that allows calibrating the circuit to a known standard. Its value, 158,000 ohms, is the same as that of the thermistor at 25 degrees centigrade. Capacitor C1 bypasses any 60-Hz signal on the thermistor probe and C4 decouples the circuit from instability in the op-amps.

Construction

The easiest way to build the Biofeedback Thermometer is to use printed circuit board. The foil pattern of the PC board is shown in Fig. 3 and the component placement diagram is shown in Fig. 4. The board is designed to accept plug-in switches and pots; this reduces construction time. (A pre-drilled solder-plated board is available from the supplier indicated in the parts list.)

The actual wiring is not complex and almost any technique will suffice. Start by installing and soldering all the resistors, capacitors, and semiconductors. Next install and solder the one jumper, followed by the slide switches, potentiometers and jacks. When you install the potentiometers, bend their lugs down so they touch the pads on the board and then solder them. Solder the two large 9-volt battery clips, and wire in the meter, illumination lamps and rear panel jack.

Construct the probe using the drawings (Fig. 5) as a guide. Heat-shrink tubing works well in sealing the thermistor from the outside world and insulating its leads. Use a shielded cable with the shield grounded at the chassis side and floating at the thermistor side (the cable should be twin-conductor). The plug of the cable should be strain-relieved with a knot and grommet.

Check-out and calibration

Attach the two 9-volt batteries using the large battery clips. Plug in the thermistor probe. Set the RANGE switch to 60 to 110 degrees, METER LAMP to OFF, BAT. CHECK to OFF, and S3 (the calibration on/off switch) to ON. Switch S1 (the CAL A/B switch) to CAL B. Zero the meter by adjusting the CAL B trimmer (R18). Now switch S1 to CAL A and adjust the CAL A trimmer (R3) until the meter reads exactly 88 degrees or 56 microamps if a 100-microamp scale is used). Switch back and forth between CAL A and CAL B until no improvement can be made in the adjustments. The accuracy of the gains should be within 2%. Set switch S3 to OFF and S1 back to CAL B. Hold the probe in your hand. The meter should start moving up-scale and settle around body surface temperature, 85 to 90 degrees.

Next adjust the F LOW trimmer (R25) so that when the meter is registering about 85 degrees, the VCO produces a slow click. The circuit is designed so that, according to the setting of R25, the frequency can be either increasing or decreasing as temperature increases. However, the decreasing direction will give better results for biofeedback. Adjust R25 for the lowest possible click at the desired temperature. **R-E**

CHECK THOSE PIX-TUBE VOLTAGES!

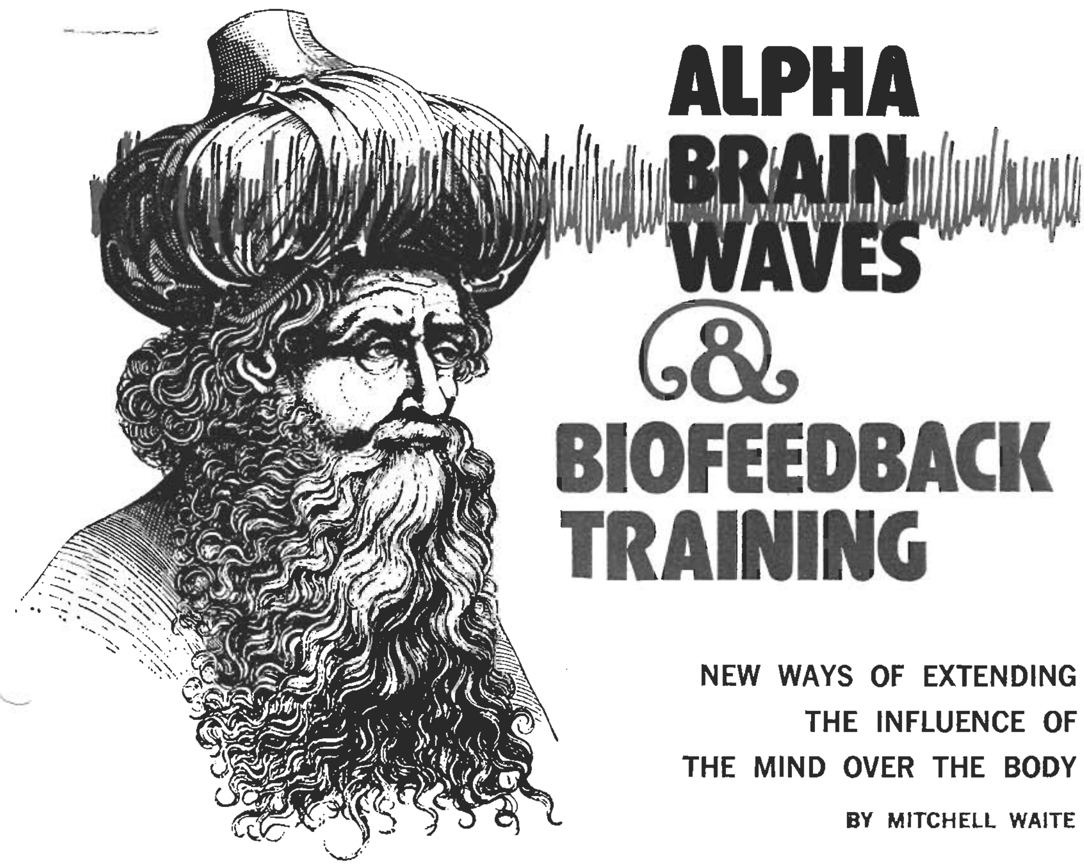
In September, 1975, I asked you for help in finding a no-raster problem in a Philco 3CY80. You suggested checking the DC voltages on the picture tube. The problem turned out to be a 15¢ resistor! 330K, in series with the +290 volt supply to the three picture tube screen controls. It was completely open. Thanks for the help!—W.L., Cincinnati, OH.

REPLACEMENT TRANSISTORS

Can you tell me what transistors will replace types D325E and B511E in a Dokorder stereo amplifier?—P.R., Barbados.

I can give you an educated (?) guess. This is an import, and not listed in Sams. In many Far Eastern countries, they use JEIA transistor numbering, "2SC—". In quite a few cases, the first two digits left off!

Here's the guess: for a 2SD325E, RCA SK-3054. For ²B511E, SK-3084. Actually I'd rather use an SK-3083 the last one since it has a high collector-breakdown ·e, matching the voltage of the SK-3054. Both substi- nsistors have the same cases as the originals.



ALPHA BRAIN WAVES & BIOFEEDBACK TRAINING

NEW WAYS OF EXTENDING THE INFLUENCE OF THE MIND OVER THE BODY

BY MITCHELL WAITE

HIGH in the Himalayas, the monks of Tibet have practiced a remarkable initiation ritual for thousands of years. On the coldest days of winter, candidates go to spend the night by frozen lakes clad only in their thin orange robes. Symbolic white robes are dipped into the icy water and draped around their naked bodies. The number of robes a candidate can melt in a single night symbolizes the level of his spiritual achievement.

Eastern mystical teachings have a formula that anyone can follow to achieve such spectacular body control: years devoted to meditation, complex visualizations, and sexual continence.

Characteristically, however, Western technology is encroaching on this formerly Eastern monopoly with electronic devices that demand neither sacrifice nor discomfort.

Elmer Green at the Menninger Foundation in Topeka, Kansas, has taught subjects to lower the temperature of their hands ten degrees by using a simple device which indicates body temperature increases by movement of a meter. Subjects were told to move the indicator up-scale and hold it there. Most subjects could, in a small amount of time, learn to influence the temperature of different parts of their bodies by using the information transmitted by the electronic measurement circuit.

Similar to the monks, his subjects were using their minds to generate heat energy at a particular area of their body. Ten degrees is a long way from melting frozen robes but scientists are finding that people can influence all kinds of body processes, hitherto believed beyond the range of conscious control.

Closing the Loop. Traditionally, Western medicine considered certain regulatory func-

Editor's Note: In response to many requests from readers for articles on alpha brain waves, we are presenting two stories. This month, we cover the general principles of biofeedback training as well as the various types of waveforms generated by the brain. Next month, we will have an alpha-wave monitor construction project for those who want to do some experimenting.

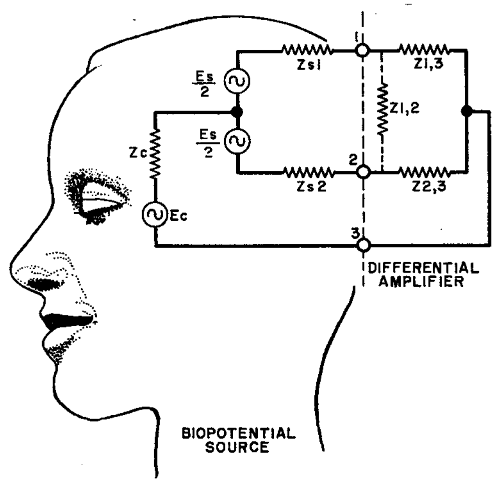
tions of the body such as skin temperature and heart rate as outside the domain of willful control. This assumption seems to have helped shape the self-concept most of us have of being at the mercy of our involuntary nervous system. The self-regulating nervous system is, of course, a necessity, for imagine the effort of controlling all the specialized muscles involved in breathing or digesting. We could, you might say, speed up our heart rate by physical exertion such as fast breathing, but this is not direct control of the autonomic nervous system.

Certain recent experiments have now caused scientists to take a new look at this old assumption. Some visceral organs, it was discovered, could be eventually controlled by the mind if special conditions were first set up. What was needed was a special signal or stimulus, such as sound or light, which would follow the activity of the body function to be controlled. By observing the "feedback" signal, people could actually interact with a particular body function through the monitor. The monitor or biofeedback mechanism serves in a sense as an interpreter between the mind and the so-called "automatic" mind.

The principle is similar to the way you learn to throw a ball. You feel your arm move, see where the ball went and correct your arm movement the next time. In a similar way, an electronic instrument can detect small internal changes in such processes as blood flow or brain-wave patterns of which you may not be consciously aware. By showing you these changes, the device can help you to recognize the cues and learn control. What is even better is that with practice, control can be developed so that the instrument is no longer needed.

The Body Electronic. To understand fully the range of the feedback principle, it is helpful to examine the source of the feedback signal.

Bio-potentials, tiny voltages present in all living organisms, are caused in man by the activity of nervous system sensors, muscles, or nerves. All bio-potentials originate at the cellular level, but the measurement of any one signal is related to a specific physiological subsystem. Thus, the electrocardiogram (EKG) is a recording of the electrical activity of the heart, the electroencephalogram (EEG) of the voltages in the brain, the electromyogram (EMG) of the activity of the muscles.



Z1,2=COMMON MODE INPUT IMPEDANCE
Ec=COMMON MODE SIGNAL GENERATOR
Zs1,Zs2=IMPEDANCE BETWEEN ELECTRODE AND BRAIN
$\frac{Zs1}{Zs2}$ CAN VARY FROM ONE TO OVER ONE HUNDRED

Fig. 1. Schematic of brain shows how unbalancing of source impedances (Zs1 and Zs2) can affect the common mode rejection of differential circuit. Common mode generator includes all unwanted signals such as electrode potentials, power line interference, noise from extraneous body signals, etc. Unfortunately, these signals are not always common mode and show up at differential amplifier output, distorting the real brain-wave signal. Ignoring the loading effect of Z1,2, and if Z1,3 equals Z2,3, and both Zs1 and Zs2 are much less the Z1,3 and Z2,3, the CMR limit (greatest reduction to a common mode signal) is 20 times the log to base 10 of Z1,3 divided by the difference between Zs1 and Zs2. Thus, if Z1,3 is 100,000 ohms and electrode impedance ratio is 100, the CMR limit is 60 dB. Source and input impedance of circuit determine actual rejection. A circuit with these values produces 1 mV of common mode output noise for every 1 volt on the input.

Detecting the brain-wave biopotentials is greatly complicated by the minute signal voltages, high level of external interference (noise and hum) and high impedance values of the body. For example, the magnitudes of the signals measured on the scalp typically vary from ten to a hundred millionths of a volt (10-100 microvolts) peak-to-peak. To top it off, in residential areas, stray 60-cycle fields from power lines surround the body. Such fields may reach values of 10 volts, or a million times stronger than the brain-wave signal! It is this interference problem which has been a stumbling block of experimentalists for so long.

Recent advances in semiconductor technology have allowed the construction of miniature feedback devices which overcome these basic problems. The large fields can be screened out by a differential amplifier, which rejects any extraneous voltage *common to two inputs* while boosting the small difference signal *between the two inputs.* (See Fig. 1.)

Because of the typically high impedance levels of the head (1,000 to 10,000 ohms) the differential amplifier cannot load the signal source and therefore requires a very high input impedance, typically 0.1 to 100 million ohms. The amplifier also must not, while amplifying, contribute any spurious signals to the original biopotential. All these factors add up to a high-gain, low-noise, high-input-impedance differential amplifier commonly referred to in electronics as an instrumentation amplifier. Medical equipment reflects this high quality with typical prices for a multi-channel EEG amplifier and recorder of $1000 to $10,000. Less expensive devices sacrifice the unnecessary electronics involved in medical equipment while retaining just enough information for feedback recognition.

The second step in a biofeedback system is utilization of the amplified biopotential signal. Optimally, a second signal source which falls into the range of one of the five senses is varied (modulated) by the amplified biopotential signal. For example, a tone which is easily sensed by the ears is made to vary in volume by the amplified biopotentials of the brain. The user of the feedback device makes a mental effort to alter the intensity of the sound. (See Fig. 2.)

This last step, altering the sound, completes the biofeedback loop. With routine practice a user develops control over the sound pattern and thus is actually altering an organ's functioning. It is still however, a subtle effect, difficult to describe to other people, and some never completely master it.

Although biofeedback training has similarities to conditioning, it does not offer an explicit reward for the correct response. The only reward is what comes from eventual mastering of the process.

Clinical Research. Currently, biofeedback research is being carried on by over 150 different laboratories. A Biofeedback Society has been formed which brings together experimental research and integrates it with current psychological knowledge. The mainstream of activity covers five basic areas of body control: (1) muscle tension (EMG), (2) blood flow and blood pressure, (3) heart rate (EKG), (4) body temperature, and (5) brain waves (EEG).

For example, psychologists at the University of Colorado Medical Center in Denver have employed feedback therapy to cure patients who have suffered from muscle tension headaches for an average of nine years.

Patients lie down in a comfortable position with small surface electrodes taped to their foreheads. They then listen to a tone from a pair of headphones. As the muscle contraction of the forehead increases (increased muscle tension) the pitch of the tone goes higher. The people are told to try to lower the tone. Within twenty minutes the tone drops and they have halved the original muscle tension!

What are these people doing that they hadn't already tried? Most found that any direct effort to relax resulted in a higher pitch tone (increased muscle tension). Only by "letting go" could they relax the forehead muscles. It appears that by not concentrating on the headache, other processes of the brain come into play, processes that are unfamiliar and difficult to explain.

At the Menninger Foundation in Topeka, Kansas, researchers have helped patients to stop their migraine headaches by monitoring the blood flow as it went up the main artery to the face. They trained these people to reduce the arterial swelling by reducing the blood flow through it. Rather than trying directly to stop the headache, they learned, through biofeedback, to steer around it much as a pilot does when he is flying blind.

But even more incredible is the new information coming from heart rate control research. At the University of Wisconsin in Madison, subjects were taught to "drive" their own hearts much like the driving skill booths at penny arcades. Subjects would watch a light which moved left or right as the time between heartbeats changed. Trained subjects could eventually keep the light in the middle and thus keep the time between heartbeats a constant 10%. This didn't mean necessarily that they were directing the autonomic nervous system. As mentioned earlier, the heart can be influenced by the breathing process. However, this was later ruled out when subjects showed they could learn to control breathing and heart rate independently.

At the Gerontology Research Center in Baltimore, Dr. Bernard T. Engel and his colleagues have trained eight persons to control potentially lethal irregularities in heart rhythm. The subjects were trained to slow their heartbeats by concentrating intensely when a red light appeared and to speed up the heart rate in the presence of a green light. Ultimately, they learned to maintain a safe mid-pace indicated by a steady yellow light. Eventually, three of the patients acquired the ability to stabilize their rhythms at the first sign of an oncoming attach of arrhythmia with their own feedback cues.

Map of Consciousness. Perhaps the most exciting aspect of biofeedback is its contribution to mapping altered states of consciousness.

Dr. Joe Kamiya at the Langley Porter Neuropsychiatric Institute in San Francisco has spent a decade studying the effect of *alpha* brain-wave training. He was particularly interested in whether normal subjects could discriminate alpha from non-alpha. Dr. Kamiya used a feedback program which produced a score every time the person indicated verbally which state he was in; alpha or non-alpha. After two weeks of training, 70 percent of the subjects could differentiate alpha and non-alpha. What was the alpha experience of Dr. Kamiya's subjects?

The replies were mostly diverse and inarticulate. This is almost to be expected—the English language has few words to describe different conscious states. Alpha has been described as "a range of mildly pleasurable reveries and body feelings often called relaxed awareness."

As for the other brain-wave states, each frequency band has associated with it certain behavior traits. (See Table.) The theta band (3.5 to 7.5 Hz) occurs during uncertainty, day dreaming, and problem solving. Worry, anger, fear, and tension are characteristic of the beta band, 13 to 28 Hz. Between theta and beta lie the alpha rhythms. These frequencies, 7.5 to 13 Hz, have drawn special attention since they are most often produced during states of meditation and relaxation.

Alpha is difficult to describe. It is a non-thinking and non-emotional condition; a detachment from the usual reality. There is an opening of awareness and an enhanced ability to be still. Researchers call it a mode of de-automization, a reduction in the cortical activity of the brain.

This partly explains why alpha-wave feedback is being so widely discussed. It is because the alpha wave and its positive mental character can be turned on and sustained by using a biofeedback device.

TYPICAL BRAIN-WAVE DETAILS

Name of Brain Wave	Magnitude ($V \times 10^{-6}$)	Frequency (Hz)	Associated Mental State*	Percent Produced Per Day
Alpha	10 to 100	7.5 to 13	Tranquility, relaxation, heightened awareness.	10
Theta	50 to 200	3.5 to 7.5	Uncertainty, problem solving, future planning, switching thoughts, day dreaming.	25
Delta	10 to 50	0.2 to 3.5	Deep sleep, trance state, non-REM type of sleep.	10
Beta	10 to 50	13 to 28	Worry, anger, fear, attention, tension, hunger, surprise.	35
?	0.01 to 0.1	Vhf to Uhf	**	?

*These descriptors are from a Clyde Mood Adjective checklist following one 60-minute feedback session with the eyes open.
**This last band is a recent Russian discovery. It could be revolutionary in the brain-wave field. In terms of just information content, these signals could contain over a billion times more data than the slower brain waves produce.

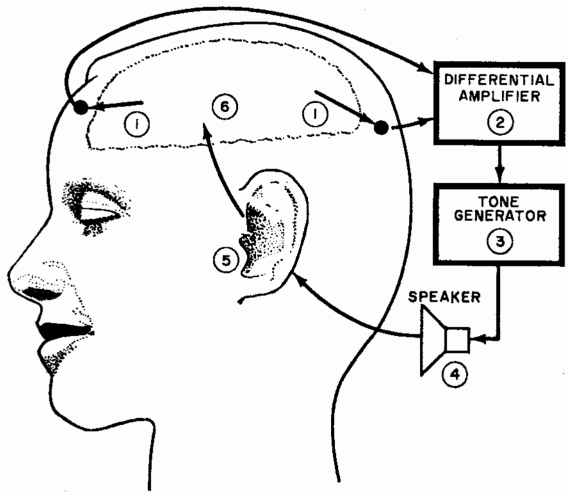


Fig. 2. Brain-wave signals originating in the brain (1) pass through cerebral fluids and reach the surface electrodes. Electrode cream is used on electrodes to help lower resistance to the scalp. From electrodes, the signals flow into the special differential amplifier where interference is reduced and signal level is raised. The amplified signal is used to control (turn on and off) a tone (3) which drives a speaker (4). Sounds leaving the speaker are following the brain-wave signal (the brain-wave frequency is well below the threshold of human hearing) so a sound is perceived each time the brain-wave signal reaches a peak. These peaks occur at a smooth staccato rate which the hearing integrates as the alpha wave if it is a 10-Hz rate or the theta wave if it is 4 Hz. Signals from speaker return to the ear (5) and then back to brain (6).

Kamiya and researchers like him seem to feel that this is one way of reducing tension and increasing awareness by dealing with it in an internal and self-motivated way. It may be possible, says Kamiya, to use the descriptors of biopotential signals (frequency, magnitude, direction, origin) to discover how to reproduce altered states of awareness.

Already various groups are following brain-wave biofeedback research and presenting it to the public in more palatable form. Some of the interest is in providing verbal instruction and exercises in producing the desired brain-wave states. There is some skepticism voiced that these different groups have over-inflated claims and they are using mass suggestion. However, no one has tested the brain waves of these people or how they control them so it is still to be proved. The brain waves of people with ESP powers have been studied and they show a definite abundance of the alpha wave just prior to the ESP experience.

Some companies are producing brain-wave monitors which allow anyone to safely experiment in feedback training. The Xerox Corporation is exploring the feasibility of brain-wave training in helping employees relax and get their strength back after hard business meetings.

Besides mapping consciousness, brain-wave research is giving science more insight into different philosophies and their objective biophysical correlations.

The classical experiments that started this exploration were set up to record the brain waves of both students and masters of Yoga and Zen. Kasamatsu and Hirai in 1966 found a highly positive correlation between the EEG pattern and the number of years of Zen meditation. They reported as the years of study of Zen increased: (1) the brain-wave rhythm which was predominately alpha lowered in frequency toward theta by up to three hertz; (2) the percentage of alpha in the occipital areas (back of the head) decreased while alpha activity in the frontal (front of the head) increased; (3) there was an increase in average brain-wave amplitude; (4) there was alpha activity with the eyes open (something that is particularly rare in most people's EEG's); and (5) when an external stimulus (such as a loud click) was delivered, the alpha activity of the Zen student was blocked for constant 2-to-3-second periods. Normal subjects, that is those with non-Eastern type philosophies, block alpha but the blocking interval decreases as the external stimulus occurs more often.

When Anand, et al., studied the brain waves of Yoga masters, they found "increased alpha activity (magnitude and percent occurance) and absolutely *no* blocking on an external stimulus"!

How can the difference in alpha blocking between the Zen, Yoga, and non-meditator be explained? In the case of the normal subjects (non-meditators) the more the stimulus occurs, the less interference there is in alpha production. The subject adapts to the stimulus and eventually does not hear it. On the other hand, the Yoga student (no alpha blocking) apparently is totally screening out stimuli from the outside world while the Zen meditator (constant alpha blocking interval) is reacting to every stimuli in an equal manner.

For psychology and philosophy, these results help to organize a division between subjective reporting of conscious states according to a particular world view and their measureable physiological correlates. The follower of Buddhism (who uses Yoga as an exercise) believes the sensory world to be illusory and attempts to withdraw from it. The practicer of Zen, however, believes the world is not illusion and tries to remain awake and fully sensitive to it. From the point of view of the average subjects, the world is simply related to him in a self-centered manner. He explores the stimulus with a "What's in it for me" attitude and, if satisfied it offers nothing, stops paying attention to it.

Biofeedback in the Future. Interpreting brain-wave patterns is helping scientists understand the general activity level of moods, feelings and mental attitudes. To understand the actual mechanisms of thinking and reasoning a closer look at the brain is needed. However the countless chemical reactions of the brain occur at such high speeds and low magnitudes that direct observation reveals little.

Nevertheless, Derek Fender, professor of biology and applied science, and his graduate assistant Robert Kavanagh, have found some beginning answers to how the brain works. They have constructed a machine which records brain waves from many areas of the scalp and sends them into a specially programmed computer. From there the brain waves are analyzed and displayed on a cathode ray tube. The result is a picture of the brain waves—a contour map of the peaks and troughs of electrical activity as "seen" through the top of the subject's head.

Each picture is photographed and used to make a movie. Two movies have been made, each a minute long, representing the brain-wave activity in a quarter of a second—but slowed down 250 times.

By studying various subjects, Fender and Kavanagh have discovered a simultaneous sound and light-flash stimulus causes activity in three distinct locations of the brain. One area analyzes visual images, the second sound patterns, and the third seems to decide if the sound and light come from the same place. They have discovered these locations by increasing the number of electrode positions to 49 and plotting the locus of the neuron emissions with the powerful computer program. The computer gives an accurate reading of exact positions of the brain-wave sources rather than just the frequency and magnitude. By studying these brain-wave movies, scientists are bridging the gap between single neuron firing and the functioning of groups of neurons working together.

During this project Fender discovered that the best subjects for his brain-wave studies were waitresses. Most people either produced fast surface level beta waves or just went to sleep. Waitresses however were just right. They were quick-minded so they didn't fall asleep and industrious enough to concentrate on the light-flash stimulus. And they weren't too nosy about what was going on or too preoccupied with some other problem.

As computers become more powerful with faster and larger memories, Fender's programs might reveal creative brain-wave patterns and possibly provide a means of utilizing biofeedback to stimulate these types of thinking.

As biofeedback techniques become more effective, we might begin to see their use in therapeutic techniques. Ancient teachings have constantly pointed to using the mind to prevent disease and eliminate infection. We may one day see doctors prescribing biofeedback methods instead of pills. ◈

MIND POWER: ALPHA

Build this biofeedback device that displays the presence of alpha waves on a TV screen. You can use it to learn how to control your alpha waves and gain from the benefit of the relaxation that comes with it

DEVISED BY SCIENTISTS, RATHER THAN YOGIS, ALPHA-WAVE biofeedback is a technique of *mental training*, through which the brain and the body are made to link-up more closely, so that the physiologic sources of stress come under the control of the mind.

If that seems a bit too much to grasp on the first pass, consider this: Since birth, your mind has gradually "learned" to control many of your body's important functions. Most have come naturally, like learning to stand erect, to walk, to throw a ball, ride a bicycle, to speak, to type, and countless others. Yet, there are several functions in which the body apparently acts *independently* of the mind. The heartbeat, respiration, digestion and certain glandular functions are representative of these *autonomous functions*. So, too, are the reactions of small muscle masses surrounding the tiny blood vessels of the body. When these tense under stress, blood pressure goes up.

What has this to do with alpha wave biofeedback? Well, research over the past two decades has suggested that if we can get the brain to downshift from its usual *high-gear state*, to the "idling" state, in which a recording of brain wave activity shows a predominance of *alpha waves*, a host of beneficial physiologic changes take place. A feeling of well-being and general comfort spreads throughout the body as muscles slacken, heart-rate and respiration slow down, body temperature eases and the body enters into a longed-for state of relaxation. The body is essentially responding to a *mental state* of relaxation. Obviously, therefore, a feedback link *does* exist between the brain and "involuntary" body functions. To strengthen that link, an outside training instrument is needed. Using it, the mind can be made aware of its success in achieving the alpha state, and, the accompanying beneficial physiologic responses serve as a "reward" to the mind, thus inspiring the continuation of the alpha state.

Such an instrument is *Mindpower: Alpha*. It is a *true* alpha-wave biofeedback instrument that incorporates an electroencephalographic "front-end," designed to amplify and selectively process the tiny potential indicative of the brain's "idling" state, as picked up by headband electrodes. It also includes the circuitry for converting these potentials into signals, that exert control over *both auditory* and *visual* stimulus devices. In the auditory sense, *Mindpower: Alpha* provides an audible tone indication when the user's mind is generating alpha waves. However, *Mindpower: Alpha* also includes the circuitry to convert alpha waves into *signals that control a video display on a television screen!*

Why? Well, if it is possible to train the mind to generate the waves of relaxation in quiet meditation, with eyes closed, does it not make sense that the mind can be trained to the extent that the waves of relaxation can be generated with *eyes open*? After all, the things that cause *stress* and *anxiety* to arise in our minds are largely *visual* in nature. We *see* emotion-charged situations that cause our bodies to tense-up. We *read* words that produce anxiety. We respond to television news programs, in which the visual input sometimes elicits responses from us which can only be classed as preparation for *fight* or *flight*.

And so, it is only natural that the brain should "communicate" with and train itself, through our powerful visual sensors: the eyes. But, to do so, an external instrument is needed to "close the loop." That instrument is the combination of *Mindpower: Alpha* and your television set.

NOTE

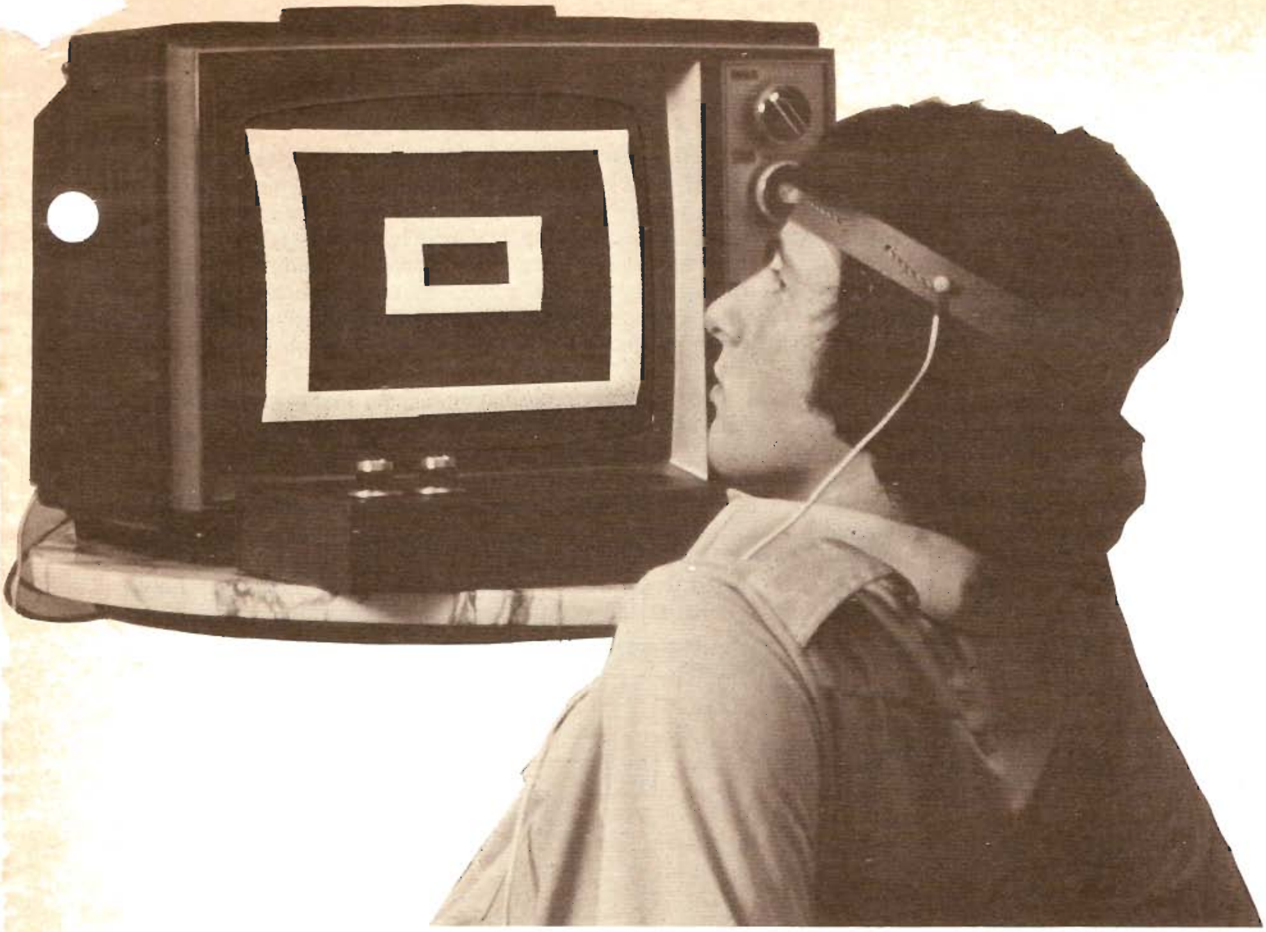
Mindpower: Alpha is an intriguing device for entertainment and experimentation in video biofeedback. It is not a therapeutic instrument, neither is it suggested as a cure for individuals suffering from psychological or physiological disorders.

The Mindpower: Alpha biofeedback loop

The brain is totally dependent upon its sensors for information. The eyes, ears, nose, mouth, skin, and the proprioceptors within the body's muscles supply the basic data inputs through which the brain is informed, educated, and on which it bases its executive functions. But, our sensors are mostly directed to the external world, rather than to our internal environment. We have no built-in means to see or hear what is happening within our bodies. Without a mirror, we cannot even look into our own eyes!

Yes, once information about what is going on inside the body or mind can be brought outside ourselves, where our sensors can detect it, a main-line path is opened to the information-hungry brain. With that link established, the executive power of the mind can begin to go to work on itself.

Mindpower: Alpha is designed to detect and amplify the tiny bioelectric signals produced by your brain's activity. From the full spectrum of the brain waves, it filters-out everything but the alpha waves (slow 8 to 13-Hz variations) and converts these into signals that control an audio "beeper" *and* a video display created by a symbol generator. (The symbol is a white rectangle on a black field.) The beeper sounds each time a significant amount of alpha appears in your brain-wave spectrum, thus feeding back to your brain via the ears.



Part of the price we pay for the comfort and convenience of living in an advanced, industrialized society is the acceptance of a high degree of *anxiety* and *stress*. Sociologists, psychiatrists, and medical investigators agree that the forces of our complex, technologic, and ever-changing society hammer away incessantly on the individual. Shock waves of change and new crisis wash over us so rapidly that, scarcely have we prepared ourselves to deal with a problem, when suddenly, it mutates or disappears, leaving us confronted by a new threat. In rapid succession, we find ourselves buffeted by an Energy Crisis, Inflation, Recession, Shortages, Lay-offs, Corruption in High Government, and the countless smaller forces in our daily lives which keep us constantly "on-edge" and defensively anxious.

This anxiety and the stress of being always ready to ward off the blow of some new crises can have fearfully great effects upon our health *and* our ability to lead a "normal" life. Extreme, prolonged stress is believed to be linked to high blood pressure, increased incidence of heart attacks and strokes, and serious deterioration of important organs of the body. What's more, constant stress and anxiety exert a debilitating effect on the *mind* as well as the body. That "always tired" feeling—the inability to hold a problem in focus and think through a solution—both may have the same malevolent origin: *constant stress!*

Small wonder that Transcendental Meditation (TM) has found so many new converts in our overwrought society. Combining the mysticism of the East with varied exercises in meditation, TM seems to have proven helpful to many people in the relief of stress. Unfortunately, the technique is long in learning for many people and requires a daily regimen of meditation which some busy people find as hard to swallow as their dentist's demand for thrice-daily brushing!

However, there is another approach to stress—relief, relaxation, and the rejection of anxiety. This article will show you how to build an Alpha-Wave trainer to help you learn how to control these stresses with your own MINDPOWER.

Meanwhile, the alpha has a *direct visual impact* on the video display. In Mode 1, where the rectangle is normally stationary, when alpha occurs, the rectangle shrinks. Steady alpha will reduce it to a small dot at the screen center. When alpha stops, the rectangle grows again, until it fills the screen, or until reappearance of alpha reverses the process.

In Mode 2, the rectangle is always moving, originating as a dot at the screen center and automatically growing outward until it passes beyond the extreme edges of the screen, only to reappear at the screen center and start travelling outward again. In this mode, the occurrence of alpha slows or stops the rectangle's inexorable travel. Prolonged alpha will even back it down to a dot and hold it there!

The implications of this instrument are apparent. By feeding back success at alpha generation to the brain which is producing it, more and stronger alpha should be produced. With time and practice, it should be possible to extend the periods of alpha and, it may ultimately be possible for the user to generate the waves of relaxation *at will*! In effect, here is the prospect for developing a new retaliatory response to everyday stress, and to increasing the power of the mind to overcome anxiety.

Understanding your brain waves

More properly called the EEG (electroencephalogram), brain waves are neither incomprehensibly medical nor mystical. However, to properly understand the workings of *Mindpower: Alpha*, you must have a fair grasp of these simple facts.

The adult human brain contains some 12 billion neurons—specialized nerve cells that are densely packed to form an organ that weighs scarcely more than three pounds and fits easily into the limited space within the human skull. All of the brain's neurons exhibit *bioelectrical* activity: the production of small varying potentials associated with their functioning. Such a dense population of active neurons might be compared to a crowd of noisy spectators in a football stadium, and the shouts of individual spectators likened to the changing potentials of individual neurons. Just as it would be hard to single-out a conversation within the noisy environment of the crowd, it is also practically impossible to single-out the electrical activity of just a few neurons in their "noisy" environment.

But just as the overall noise of the crowd is audible outside the stadium, so also are the gross changes of the bioelectric potentials detectable outside the brain, on the surface of the forehead and scalp. And, just as you, standing outside, might easily detect rhythmic chants of the crowd in the stadium without knowing specifically what is being said, so also can we detect rhythmic variations in the gross bioelectric activity of large neural masses of the brain by strategically placing electrodes on the forehead and scalp.

Early in this century, medical researchers discovered that the brain generates a broad spectrum of rhythmically varying electrical waves. Though very low in amplitude (on the order of 10 microvolts in averaging amplitude), these potentials are detectable at the skin surface of the forehead and scalp. At first, the waves appeared to be completely random—rather like the noise of the football stadium crowd. But, through patient research, investigators were able to separate the dominant bands of brain-wave rhythms into these four:

delta (δ): 1— 3 Hz
theta (Θ): 4— 7 Hz
alpha (α): 8—13 Hz
beta (β): 13—30 Hz

Further research has shown that psychological and pyhsiological states affect the frequency content of the brain waves. Thus, when we are in deep sleep, the brain generates delta waves. Day-dreaming and problem solving brings up the theta waves. Fear, anger and intense concentration increase the beta waves. But a state of relaxation and tranquility bring up the alpha waves. A graphic recording of the brain waves produces a chart that is called an electroencephalogram. (EEG, for short).

The waves are recorded by placing electrodes on the forehead and scalp, and by measuring the instantaneous *potential difference* between selected pairs of electrodes. Thus, for example, the potential detected at the right frontal lobe of the brain may be differentially measured with respect to the potential present at the rear of the skull, opposite the left occipital lobe of the brain. The two electrodes, connected to a carefully designed high-gain differential amplifier that rejects common-mode voltages (60-Hz pickup, im-

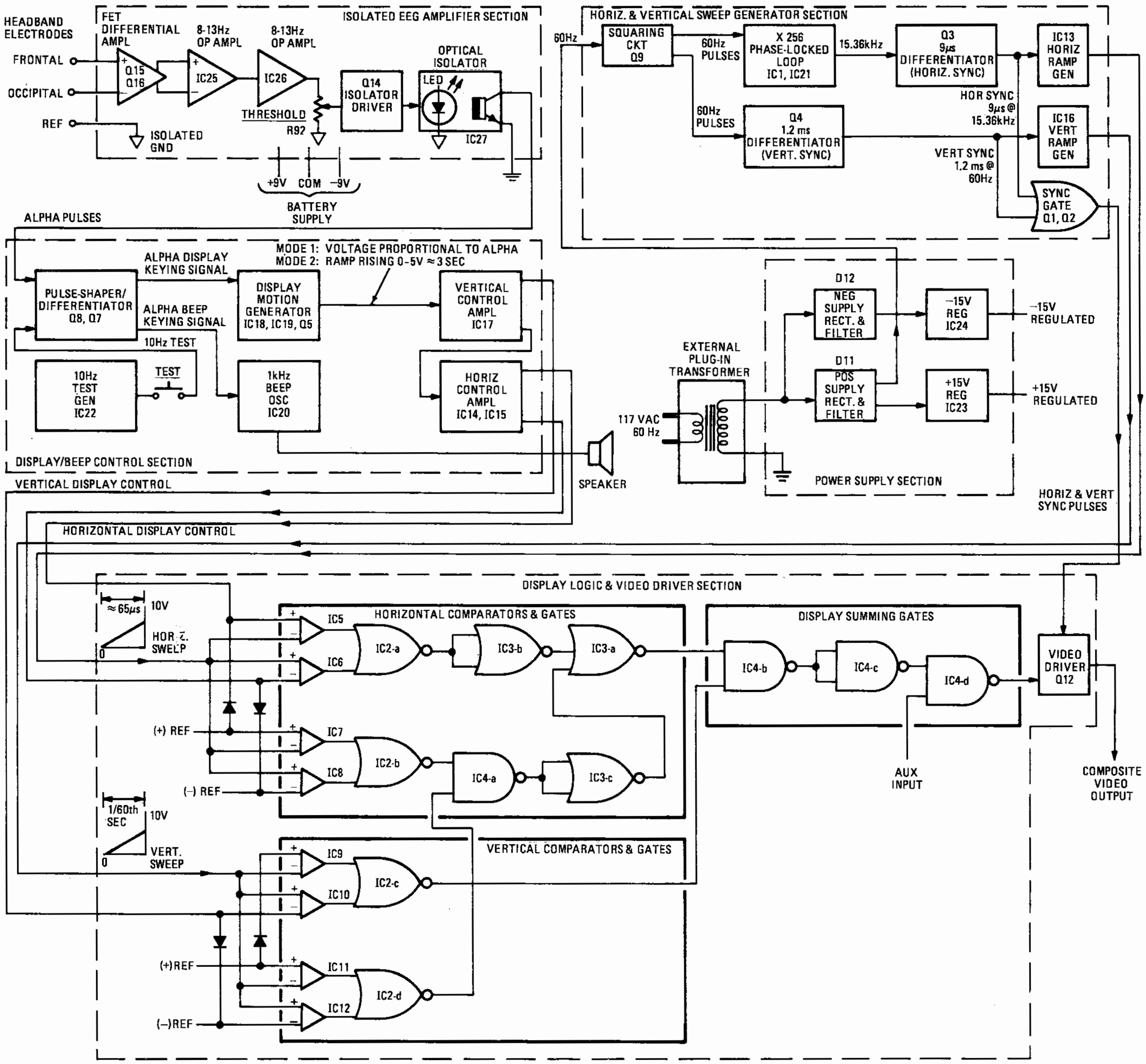


FIG. 1—MINDPOWER: ALPHA, block diagram. The device displays a pattern on a TV screen in accordance with the amount of alpha waves detected.

PARTS LIST

All resistors ¼-watt 10% unless noted
R1, R2, R14, R16, R20, R28, R32, R45, R46, R64—10,000 ohms
R3, R4, R41, R42, R47, R68, R72, R73—10,000 ohms, 5%
R5, R31—2700 ohms
R6—27,000 ohms
R7, R8, R48—30,000 ohms, 5%
R9, R10, R12, R13—3 megohms, 5%
R11—3900 ohms
R15, R53, R63, R65, R74, R75, R77, R78, R79, R80, R88—4700 ohms
R17—820,000 ohms
R18—22 ohms
R19, R36, R52—56,000 ohms
R21, R39, R44, R59, R76, R91—15,000 ohms
R22, R34, R51—100,000 ohms
R23, R25, R26, R33, R81, R82, R83, R84, R86—22,000 ohms
R24—47,000 ohms
R27—3300 ohms
R29—10 megohms
R30—1.5 megohms
R35—750,000 ohms
R37—20,000 ohms, 5%
R38—4700 ohms, 5%
R40, R89—1000 ohms
R43—15,000 ohms, 5%
R49—120,000 ohms
R50—39,000 ohms
R54, R57, R58, R60, R61—5600 ohms
R55, R62—33,000 ohms
R56—220,000 ohms, 5%
R66, R71—13,000 ohms, 5%
R67—220,000 ohms
R69—12,000 ohms, 5%
R70—7500 ohms, 5%
R85—12,000 ohms
R87—240 ohms
R90—200 ohms
R92—10,000 ohms, linear potentiometer

All capacitors 25V or more unless noted
C1, C2—0.47 μF, 100 V, 10%
C3, C4, C5, C6—.0033 μF, disc, 10%
C7, C8, C20—5 μF, electrolytic
C9, C15, C29, C30—10 μF, 25V, electrolytic
C10, C12, C14, C19—1 μF, 100V, 20%
C11, C23—0.1 μF, 100V, 10%
C13, C26, C27—0.01 μF, disc
C16—(see text)
C17, C18—2000 μF, 50V, electrolytic
C21—.0082 μF, disc, 10%
C22—.033 μF, 100V, 10%
C24—.0015 μF, disc, 10%
C25—.0068 μF, disc, 10%
C28—150 pF, disc
C29, C30—10 μF, 25V, electrolytic
*C31, C32—10 μF, 25V, electrolytic
*If required (see text)

Transistors*
Q1, Q2, Q3, Q4, Q5, Q7, Q8, Q9, Q10, Q11, Q12, Q13—2N4401
Q6—2N4403
Q14—2N5524
Q15—SE4021

Diodes*
D1 through D19—1N3064
D20—1N5240, 10V, 10% Zener

Integrated Circuits*
IC1—CD4046AE (CMOS)
IC2, IC3—CD4001AE (CMOS)
IC4—CD4011AE (CMOS)
IC5, IC6, IC7, IC8, IC9, IC10, IC11, IC12—LM311N (voltage comparator)
IC13—LM318N (op amp)
IC14, IC15, IC16, IC17, IC18, IC19, IC25, IC26—LM307N (op amp)
IC20, IC22—NE555 (programable timer)
IC21—CD4040AE (CMOS)
IC23—MC7815 (+15V regulator)
IC24—MC7915 (−15V regulator)
IC27—MCT-2 photocoupler

Miscellaneous
Printed circuit board (2 sided, plated through holes)
Plastic case
Miniature speaker, 8-ohms
Headband assembly
Battery clips
Battery connectors
BATT1, BATT2—9-volt alkaline batteries
Transformer
S1—3-pole, double throw slide
S2—N.O. single pole pushbutton (or slide)
S3—dpst slide
S4—spst slide
IC sockets
Misc hardware

***Do not substitute**

The following items are available from National Mentor Corp., Box 53, Wykagyl Station, New Rochelle, NY 10804

Circuit board. 2-sided, plated through holes. Order part number NM-P108: $34.50

Transformer. Order part number NM-T6: $17.50

Headband. Order part number NM-HA39: $9.50

Case, punched and drilled. Order part number NM-C56: $14.75

Set of all semiconductors including 27 IC's and 35 transistors and diodes. Order part number NM—Semis 1: $99.50

Complete set of all parts needed to build Brainwave: Alpha: $265.00.

All prices include postage and insurance in the continental United States.

pinging noise voltages, etc.) produce a signal that shows the predominant make-up of the brain waves across the greatest mass of the brain, traversing the frontal, temporal, parietal, and occipital lobes. In effect, such a signal describes the principal state of the brain's major, distinguishable lobes, thus providing a useful index of brain-wide mental state.

How it works

A simplified functional block diagram of *Mindpower: Alpha* is shown in Figure 1. There are five principal sections, enclosed by dashed lines. These are: the horizontal and vertical sweep generators, the display logic and video driver, the isolated EEG amplifier, the display beep control section, and the power supply.

Because *Mindpower: Alpha* creates a video display that is then acted upon by control signals developed from an alpha wave input, the most logical starting point is the horizontal and vertical sweep generators section.

To establish a field for producing a display on a TV screen, it is necessary to sweep the CRT electron beam both horizontally and vertically on the screen face. The horizontal sweep must produce 256 left-to-right lines (one-half frame), moving vertically from top to bottom of the screen within 1/60th of a second. Each line must be written within 65 microseconds. The flyback time between lines must thus be less than nine microseconds. To develop this basic field, the horizontal and vertical sweep generators receive a 60-Hz AC input signal from the AC power supply. This signal is squared by transistor Q9. This stage provides 60-Hz pulse outputs to the two sweep generators. Horizontal sweep is obtained with a X 256 phase-locked loop (IC1, IC21), that multiplies the input to an output of 15.36 KHz. This output is differentiated by Q3, and is applied to the horizontal ramp generator, IC13. This stage produces a ramp voltage rising from 0 to 10 volts in 65 microseconds. Its output is applied to the horizontal comparators and gates of the display logic and video driver section.

Since the vertical sweep rate is synonymous with the line frequency, the pulse output of Q9 is simply differentiated to produce pulses which control the vertical ramp generator, IC16. The output of this stage is a ramp voltage rising from 0 to 10 volts in 1/60th of a second (16.7 milliseconds), and is applied to the vertical comparators and gates of the display logic and video driver section. Sync pulses to determine field timing are provided by sync driver Q1, Q2 to video driver Q12.

The two ramp voltages provided from these earlier stages are used to produce a rectangular display by comparing their instantaneous voltage levels against reference voltage levels in horizontal comparators IC5 through IC8 and vertical comparators IC9 through IC12. These develop beam control signals which determine the point on each line where the CRT electron beam will be turned-on and shut-off. However, since it is desired to produce a rectangle display rather than a cross-hatch, we must use logic to eliminate those line segments which lie *outside* the rectangle's confines. This function is performed by gates IC2, 3, and 4. The result is a white rectangle on a dark field, sized (in Mode 1) to fill about 75% of the screen's usable area. This video signal is applied to the television set by video driver Q12.

Having established the basic display, all we now need is a way to vary the *size* of the display. This is done by the display/beep control section. Vertical control amplifier IC17

(continued on page 91)

BRAINWAVE: ALPHA
(continued from page 39)

and horizontal control amplifier IC14, IC15, provide control voltages to the horizontal and vertical comparators that can vary the "detect" points of the stages with respect to the horizontal and vertical ramp inputs. Since this determines the coordinates at which the electron beam will turn-on and shut-off, the apparent size of the rectangle is determined by the respective levels of the display control signals.

As we have now established the method for producing and sizing the on-screen display, let us now examine the method by which the minute alpha wave potentials produced by the brain achieve control of the display.

The *Mindpower: Alpha* user wears an elastic headband that places three electrodes against the skin of the forehead and scalp. Two of these lie opposite the brain's right frontal lobe and left occipital lobe, thus establishing differential signal-measuring points that traverse most of the brain's neural mass. These two electrodes provide the differential input to an FET differential amplifier, comprising Q15 and Q16. The third electrode connects to the isolated ground of the EEG amplifier, establishing a neutral reference on the skin of the skull that aids in the elimination of stray signal pickup. The FET-input stage provides extremely high common-mode rejection and a high input impedance, thus making it a most efficient processor of the very low-level brain wave signals obtainable at the cranial skin surface and picked up by the head-band electrodes.

All front-end stages of the unit are operated from a dual 9-volt battery power supply for user safety, and the amplified output of the EEG amplifier is safely isolated from the remaining stages by means of a photo-isolator (IC27). This ensures complete user safety.

The amplified neurological potentials of the FET input stage are applied to cascaded operational amplifier stages IC25 and IC26, that are optimized for response to signals in the 8- to 13-Hz alpha wave frequency range. Overall gain of the amplifier is approximately 100,000 and output appears across threshold control R92. This control can be set so that amplified alpha waves of increasing level are required to achieve audible or visual response. The selected alpha voltage is applied to isolator driver Q14. It drives the light-emitting diode section of optical isolator IC27. Hence, as alpha wave bursts are detected and amplified, IC27 converts these to light pulses which are transmitted across a space to a phototransistor. This, in turn, provides the alpha pulse to pulse shaper/differentiator Q8, Q7, in the display/beep control section (that is transformer-powered from the AC line).

The output signal of the isolated EEG amplifier section, for a given signal input, is a train of about-equal amplitude pulses, which are differentiated and applied to both 1-KHz beep oscillator IC20, and display motion generator IC18, IC19, Q5. The differentiated pulses key IC20 on and off so that an audible indication of alpha occurrence is provided to the user by the speaker. (This can be silenced by opening a switch.) The pulses also control the display motion generator's response in either of two ways, depending upon the units selected mode.

In Mode 1 (fixed display), incoming alpha pulses subtract from a fixed reference voltage, so that the display motion generator produces an output causing the display rectangle to shrink in size in proportion to the alpha produced. Return to normal size is automatic, if alpha is not sustained. In Mode 2 (moving display), the generator produces a rising ramp voltage which can be reduced by the arrival of an alpha wavetrain. This makes it possible for the user to hold the display "in check" on screen, or to move it down to maller size by sustained alpha. Failure to sustain alpha auses the display to grow in size. **R-E**

MIND POWER: ALPHA

Part II. Build this biofeedback device that displays the presence of alpha waves on a TV screen. You can use it to learn how to control your alpha waves and gain from the benefit of the relaxation that comes with it

THANKS TO MODERN ELECTRONIC TECHnology, the idea that your brainwaves can control a video display on a TV screen is no longer in the realm of science fiction. Mindpower: Alpha makes use of state-of-the-art techniques and components to make that dream of science-fiction writers into concrete *fact!* Whether you build it just to find out if you have the *mindpower* to control the display on your TV set screen, or because you have a serious interest in experimenting with altered states of consciousness and the alluring prospects of achieving more complete control of the brain-body matrix, you'll find Mindpower: Alpha a fascinating instrument unlike any other you've ever seen!

NOTE

Mindpower: Alpha is an intriguing device for entertainment and experimentation in video biofeedback. It is not a therapeutic instrument, neither is it suggested as a cure for individuals suffering from psychological or physiological disorders.

How the circuit works

Figure 1 shows the complete schematic diagram of the Mindpower: Alpha circuit. The sweep voltages required to control the picture tube's electron-beam position are derived from the 60-Hz AC line. The 60-Hz sinusoidal voltage appearing across the secondary of transformer T1 is applied to the base-emitter junction of Q9, driving this stage into saturation on each peak of the sinewave. The square-wave output of Q9 provides the input signal to the CMOS phase-locked loop (IC1) and to Q4.

IC1 consists of a phase comparator and a voltage-controlled oscillator (VCO) connected through a low-pass filter (R49, C19, R50, C20) to form a closed-loop frequency feedback system. The center frequency of the VCO is nominally 15.36 kilohertz and is determined by the value of C21, R47 and R48. The output of the VCO is applied to a CMOS ripple counter/divider (IC21) that divides the VCO center-frequency to 60 Hz. The output of IC21 is connected to one input of the phase comparator; the squared 60 Hz input from Q9 is the other input. So long as the two inputs are exactly the same, the phase comparator output is zero, signifying that the 15.36 kHz oscillator is precisely on-frequency. If the VCO tends to drift, the comparator develops a proportional error voltage output that precisely corrects the VCO frequency. In this way, the horizontal sweep-frequency is maintained in a phase-locked relationship to the 60 Hz line frequency.

The 15.36 kHz output of IC1 is differentiated by C24 and R63, and is applied to Q3 to generate 9-μs horizontal-sync pulses. These pulses are summed by Q1 and Q2, and applied to the video driver Q12. Meanwhile, the output pulses of Q3 are also applied as control pulses to horizontal discharge switch Q10 to determine the flyback interval of the horizontal ramp generator IC13. The ramp generator is a linear integrator whose period is determined by C25 and R66. The output of IC13 rises linearly from 0 to 10 volts in a period of approximately 65 μs. Each horizontal scan line is written on the picture tube during one such period. At the end of this period, the sync pulse input from Q3 turns on Q10 for a period of approximately 9 μs., discharging C25 and instantaneously resetting the integrator to zero. (During this brief period, the spot flies-back to the left of the screen to commence a new line.) The horizontal ramp output of IC13 thus consists of an endless series of linear sawtooth waves of 65 μs duration, separated by 9-μs flyback periods during which the output is 0 volts. These are applied to the inputs of horizontal comparators IC5 and IC8.

The vertical sweep is considerably simpler than the horizontal sweep because the vertical sweep frequency is synonymous with the 60 Hz AC power line frequency. Thus, the squared output of Q9 is simply differentiated by C22, R51 and R52, and is applied to Q4. Transistor Q4 produces a pulse of approximately 1.2 ms duration every 16.7 ms. These vertical sync pulses are summed with the horizontal sync pulses by Q1 and Q2.

The vertical sync pulses also control the period of the vertical ramp generator IC16 by causing Q11 to discharge C23 every 16.7 ms. Operation of IC16 as a linear integrator is identical to that described for IC13. Thus, IC16 produces an endless series of linear sawtooth waves of 1/60th second duration, separated by 1.2 ms periods during which the output is zero volts. Thes are applied to the inputs of horizontal comparators IC9 and IC12.

Display logic and video driver

The function of the display logic is to detect the points on each line written on the picture-tube face where the electron beam is to be turned-on and turned-off, so as to create the white rectangle (beam on), on the dark field (beam off). This requires four detect-points for the horizontal and four detect-points for the vertical. Also, because the size of the rectangle must be controllable, the detect-points of all comparators must be proportionally variable. However, the detect-points must remain in-ratio with one another so as not to distort the rectangle as its size changes.

For simplicity, we will first look at the vertical comparators, IC9 and IC12. These are LM311-types that feature very closely controlled characteristics making them well-suited to this application. The waveforms associated with the comparators is shown in Fig. 2.

The vertical ramp output of IC16 is applied to the inverting inputs of IC9 and IC11, and to the non-inverting inputs of IC10 and IC12. The non-inverting input of IC11 is biased from the positive 15-volt supply through R76, and the non-inverting input of IC9 is biased a constant 0.6 volts less positive, by the forward voltage drop across D9. Also, the inverting input of IC12 is biased from the negative 15-volt supply through R44, and the inverting input of IC10 is biased a constant 0.6 volts less negative by the forward voltage drop across D10.

The comparators receive two vertical display control inputs, consisting of the voltage output of IC18 (which is a fixed voltage in mode 1, under quiescent conditions; or, a 0–5 volt ramp voltage in mode 2), and an inverted form of the IC18 output, obtained from IC17. These two vertical control inputs are respectively applied to the non-inverting input of IC9 and to the inverting input of IC10.

Looking now at the states of the vertical comparators, as the vertical sweep ramp starts to rise from zero, IC9 and IC11 outputs are at a logic 1 level. The output of IC10 and IC12 are at logic 0 level. As the sweep ramp rises (assuming that the circuit is operating in mode 1, where the vertical display control signals

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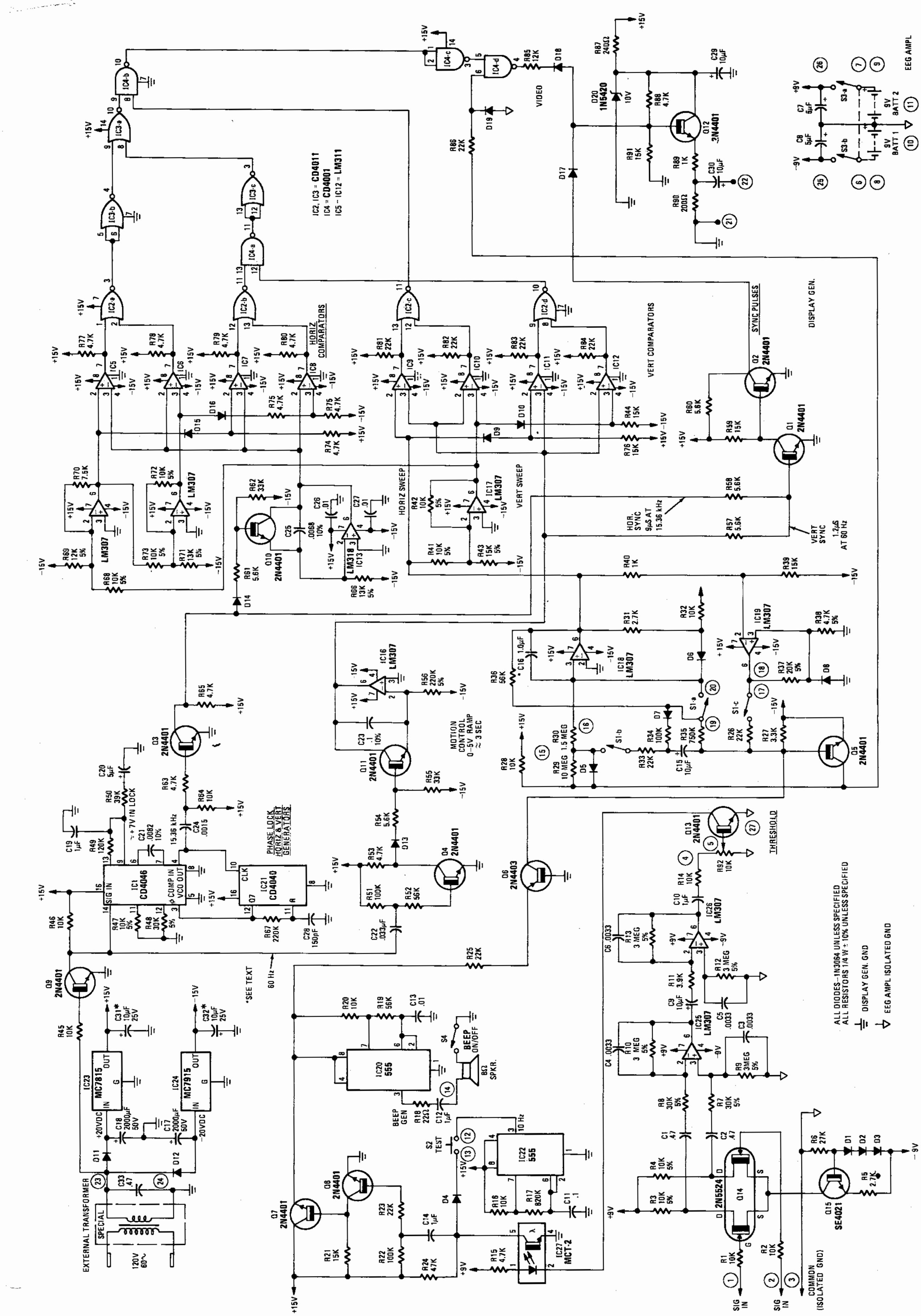


FIG. 1—COMPLETE SCHEMATIC DIAGRAM OF MINDPOWER: ALPHA. The EEG amplifier in the front-end is battery powered and optically isolated. Thus, the user is safely isolated from the AC power line.

Part of the price we pay for the comfort and convenience of living in an advanced, industrialized society is the acceptance of a high degree of *anxiety* and *stress*. Sociologists, psychiatrists, and medical investigators agree that the forces of our complex, technologic, and ever-changing society hammer away incessantly on the individual. Shock waves of change and new crisis wash over us so rapidly that, scarcely have we prepared ourselves to deal with a problem, when suddenly, it mutates or disappears, leaving us confronted by a new threat. In rapid succession, we find ourselves buffeted by an Energy Crisis, Inflation, Recession, Shortages, Lay-offs, Corruption in High Government, and the countless smaller forces in our daily lives which keep us constantly "on-edge" and defensively anxious.

This anxiety and the stress of being always ready to ward off the blow of some new crises can have fearfully great effects upon our health *and* our ability to lead a "normal" life. Extreme, prolonged stress is believed to be linked to high blood pressure, increased incidence of heart attacks and strokes, and serious deterioration of important organs of the body. What's more, constant stress and anxiety exert a debilitating effect on the *mind* as well as the body. That "always tired" feeling—the inability to hold a problem in focus and think through a solution—both may originate from *constant stress!*

Small wonder that Transcendental Meditation (TM) has found so many new converts in our overwrought society. Combining the mysticism of the East with varied exercises in meditation, TM seems to have proven helpful to many people in the relief of stress. Unfortunately, the technique is long in learning for many people and requires a daily regimen of meditation which some busy people find as hard to swallow as their dentist's demand for thrice-daily brushing!

However, there is another approach to stress—relief, relaxation, and the rejection of anxiety. Here's how to build an Alpha-Wave trainer to help you learn how to control these stresses.

are fixed positive and negative voltages), IC9 reaches its threshold point and its output falls to a logic 0 level. IC11 remains at a logic 1 level because of the 0.6-volt drop across diode D9, until the ramp has reached a higher level corresponding to its threshold point, after which it switches to a logic 0 level. As the ramp rises higher, the outputs of all the vertical comparators are a logic 0 level, until the threshold level of IC12 is reached, causing its output to go to logic 1. A further increase in the ramp voltage accounts for the constant drop across D10, and IC10 switches to a logic 1.

In effect, comparators IC9 through IC12 have now determined the "top" and "bottom" bar segments of the rectangle, and D9 and D10 have set the thickness of these segments. The apparent size of these elements is a function of the display control voltages supplied by IC18 and IC17. Thus, if that voltage is not fixed, but is a ramp, the threshold points along the vertical sweep ramp can be smoothly varied to create the illusion of expanding display

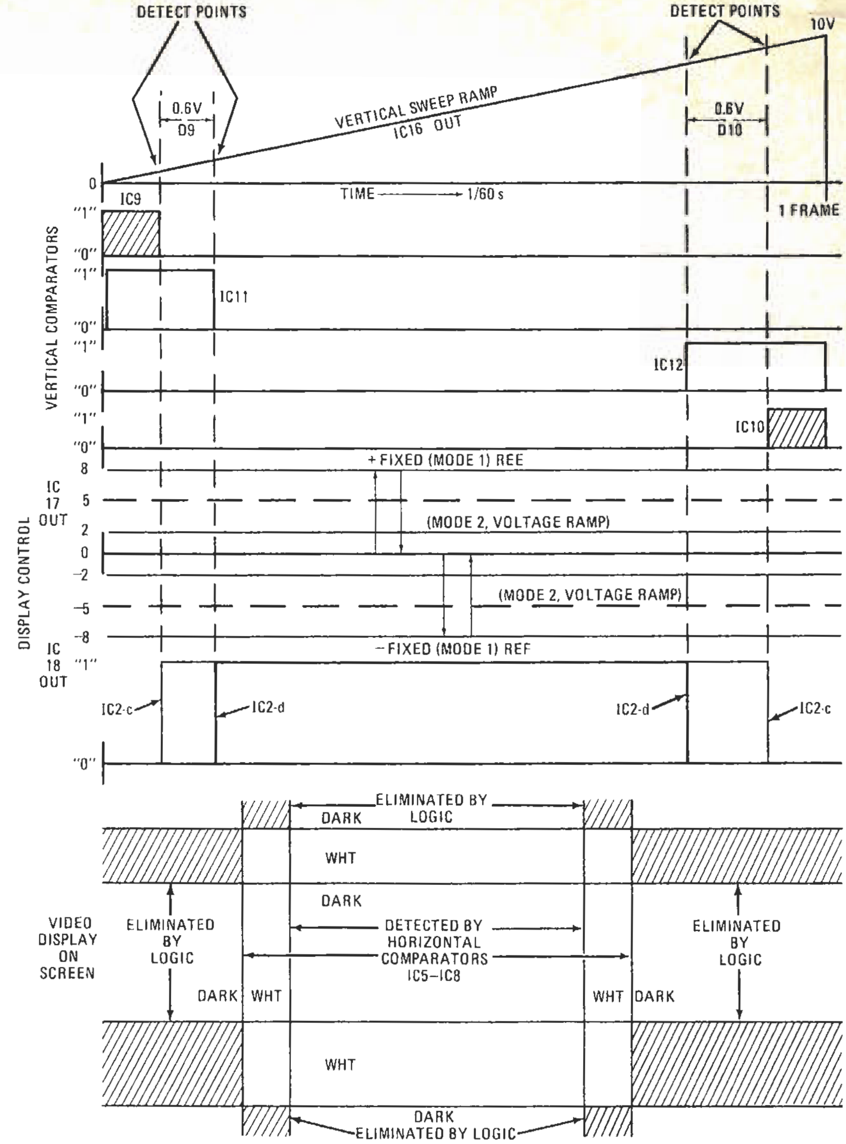


FIG. 2—TIMING WAVEFORMS associated with the comparators in the display logic and vic driver section. Generation of the video display on the picture tube is also shown.

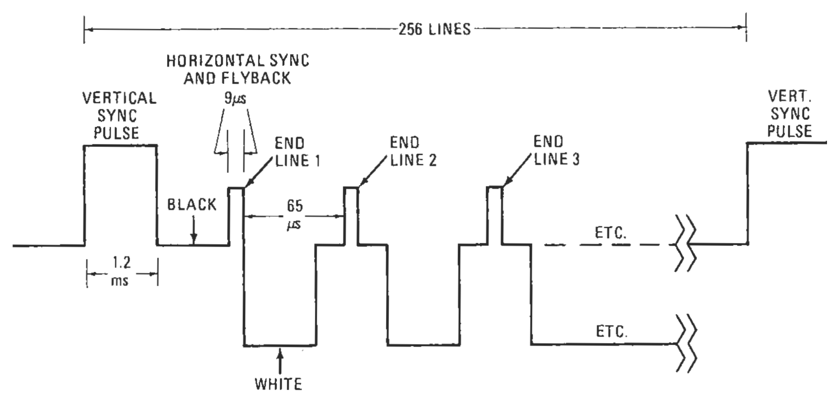


FIG. 3—COMPOSITE VIDEO SIGNAL produced from Mindpower: Alpha.

segments. Also, if the display control voltages are changed sharply, in response to a proportional level of alpha activity, these segments will abruptly "shrink" as the threshold-points are shifted.

The horizontal comparators IC5 through IC8 are identical in function to the vertical comparators, and are controlled from the output of IC17 through IC14 and IC15.

Having now established two pairs of controllable bars, overlying each other horizontally and vertically to for crosshatch (rather like a tic-tac-toe tern, we still have to eliminate those segments that lie outside the rectangl fined by the intersections of the ver and horizontal bars. This is achieve comparing the logic states of the hor tal and vertical comparators, and ap priately gating video output.

In order to gate the video bean (that is, to write a white segment).

(continued on page

MINDPOWER: ALPHA

continued from page 52

FRONT PANEL of the assembled Mindpower: Alpha unit.

output of NAND gate IC4-d must be at logic 0. Beam off (black) is obtained with a logic 1. Looking backwards to the vertical comparators, NOR gate IC2-c, and NOR gate IC2-d respectively gate the outputs of the two comparators that define the beginning and end of a bar segment. Thus, if either comparator output is at logic 1, the NOR gates will be at logic 0. If both comparators are at logic 0, the output of the NOR gates will be logic 1. In the horizontal section, NOR gates IC2-a and IC2-b perform the same function.

The output of NOR gate IC2-a is inverted by IC3-b and applied to NOR gate IC3-a. Meanwhile, the output of NOR gate IC2-b is applied to NAND gate, IC4-a, along with the output of NOR gate IC2-d. The output of IC4-a is inverted by IC3-c, supplying the second input to IC3-a. The outputs of IC3-a and IC2-c are then gated by IC4-b. At this point, if *either* input is a logic 0, the output of IC4-b will be a logic 1. If both inputs are at logic 1, the output will be logic 0. This is inverted by IC4-c and supplies the video input to NAND gate IC4-d, which gates it with the output of Q5 in the display motion generator section. In effect, any of the comparator outputs representing bar segments that occur when there are no coincident outputs from the comparators controlling bar segments in the other display axis, will result in a logic 1 output from IC4-d—corresponding to blanking of the electron beam. Where the display logic does detect the required coincidence, the output of IC4-d goes to logic 0, providing a beam-on video signal to write a white-bar segment. The result is a white, open-center rectangle, appearing on a dark field.

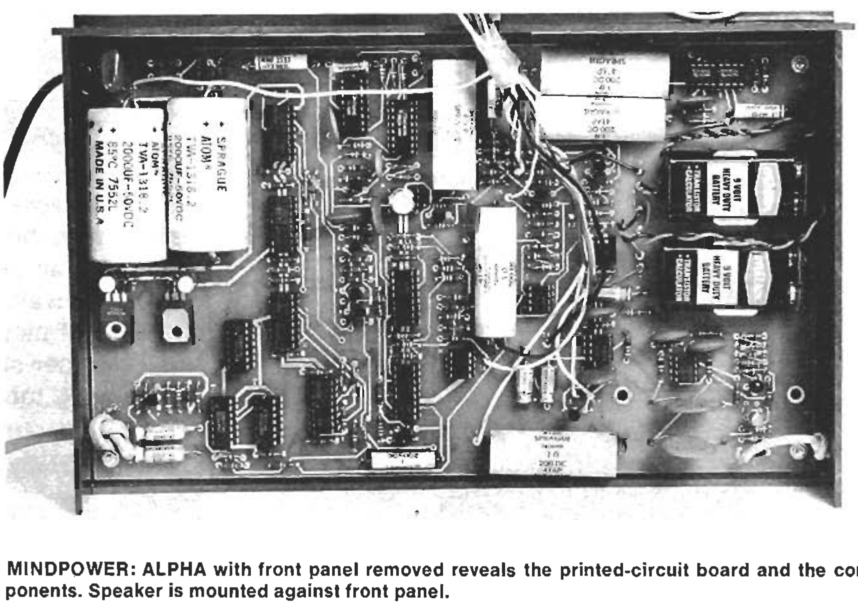
The video signal thus created is applied through diode D18 to video driver Q12, an emitter follower that supplies the signal to the TV set. Horizontal and vertical sync pulses from Q1 and Q2 are supplied to the base of Q12 through diode D17. A representative illustration of the composite video signal appearing at Q12's output is shown in Fig. 3.

Isolated EEG amplifier

The very low amplitude of brainwave signals at the skin surface of the head necessitates use of a differential input amplifier that possesses a high common-mode rejection-ratio (CMRR) and an input impedance that is very high with respect to the equivalent impedance measurable between the electrodes.

The optimum choice for an EEG amplifier subjected to these wide extremes is a matched—FET input amplifier (Q14 in Fig. 1). The 2N5524 FET features very high input impedance, by virtue of the "floating gate" configuration used. Resistors R1 and R2 provide current-limiting in the input circuit to limit the effect of static potentials applied to the electrodes. Gate-source protection is provided by diode junctions within the 2N5524 structure, which prevent the gate potentials from rising to a level that might damage the FET structure. The excellent CMRR of the dual FET input stage is maintained by use of a constant-current source, consisting of bipolar stage Q15. Fixed bias for this stage is obtained by diodes D1, D2, D3. Noise potentials common to both electrodes are applied to the base of Q15 from the common isolated ground electrode. These potentials are inverted by Q15 and thus, cancel the common mode noise potentials appearing at the gates of the dual FET. The gain of the Q14 stage is about 4.

The outputs of Q14 are coupled to the non-inverting and inverting inputs of IC25, a differential amplifier. The values of C1 and C2 limit the low frequency re-



MINDPOWER: ALPHA with front panel removed reveals the printed-circuit board and the components. Speaker is mounted against front panel.

sponse of IC25 to about 8 Hz. Feedback provided by C4, R10, C3 and R9 sets the upper frequency response limit of IC25 to about 13 Hz. Within the bandpass of the amplifier, a gain of approximately 300 is provided. The single-ended output of IC25 thus represents the amplified alpha wave content of brain wave potentials picked up by the active headband electrodes. The alpha signal is further amplified by IC26.

The alpha wave output of IC26 is coupled by C10 and R14 to the THRESHOLD control R92. Here, the amplified alpha signals are picked-off and applied to Q13, which converts the alpha impulses into keying signals for the light-emitting diode (LED) half of optical isolator IC27.

The optical isolator consists of an LED and a photo-transistor, separated by an air gap of about 10 mm. Each time Q13 conducts in response to alpha, the LED is turned-on, illuminating the photo-transistor and causing it to switch from the off-state to the on-state. Thus, the alpha waves are converted to square waves of equal amplitude, whose width depends upon the duration of the alpha input. Importantly, the alpha signal conversion is accompanied by the fact that the signal transmission occurs over an *optically coupled path*. This path offers no electrically conductive pathway between the isolated circuitry driving the LED and the transformer-powered circuitry that receives its signal input from the excited phototransistor.

The isolated EEG amplifier is powered by a dual 9-volt battery supply, B1, B2. Power input is controlled by switch S3-a, S3-b, and decoupling is provided by capacitors C7 and C8.

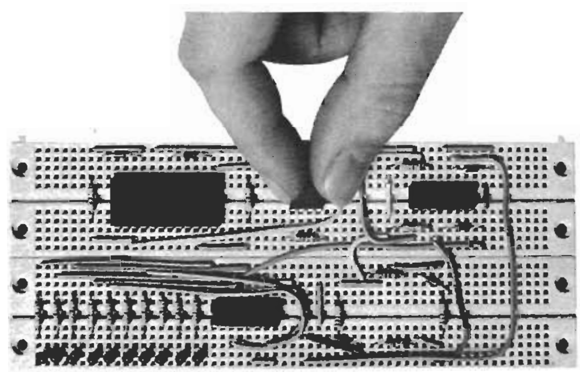
Audio control section

The optically coupled alpha signal (now uniform squarewave pulses) from IC27 is applied to pulse shaper/differentiator Q8, Q7, that provides a switched keying signal to IC20—a type 555 connected as an audio oscillator. IC20 provides an audio output to the loudspeaker through C12 and R18. The speaker can be silenced by opening switch S4. Assuming, however, that S4 is closed, an alpha-burst keys on Q7 so that IC20 receives power for the duration of the burst, thus issuing a "beep" for that period.

The output of transistor Q7 is applied through Q6 to the display motion generator, Q5, IC18, IC19. Transistor Q6 is connected in a noise-immunizing configuration, so that a definite switching input is required from Q7 before a signal is passed. In this way, noise is prevented from securing control of the video display's size.

Transistor Q5 is connected as a switch, capable of pulling-down the input voltage to IC18 each time an alpha burst occurs. IC18 has two modes (Mode 1 and Mode 2), determined by the position of switch S1. In Mode 1 (S1-a open, S1-b open, S1-c closed), IC18 receives a bias voltage through R28, R29, and R30. (The value of R30 determines the rate of response of the stage to an alpha burst. For a quicker response, values down to 330K can be used.) This causes a fixed voltage to appear at output pin 6, thus providing a fixed reference to the vertical and horizontal

continued on page 72



MINDPOWER: ALPHA

(continued from page 67)

comparators through IC14, IC15 and IC17. As a result, the video display on the TV set screen is a stationery rectangle in this mode. However, when an alpha burst is applied to Q5, it switches on, instantly pulling-down the bias to IC18 through diode D5. This reduces the output of IC18 and shrinks the size of the rectangle on the screen. To speed up the process, IC19 is regeneratively connected from the output of IC18 to the base of Q5. The added gain of IC19 significantly reduces the on-screen size of the rectangle, overcoming the integrating effect of C16. When the alpha burst ceases, Q5 switches off and IC18 receives normal DC bias. As C16 recharges, the rectangle on the TV screen grows back to its normal, quiescent, size.

Assuming now that switch S1 is in the Mode 2 position (S1-a closed, S1-b closed, S1-c open), IC18 now functions as an active integrator. The input bias to the stage now is applied to C15 through the resistive ladder of R28, R29, and R33. An exponential voltage is applied to the IC18 input, resulting in a ramp output of 0–5 volts. This slowly increases the size of the rectangle display on the TV screen from a small size at screen center to a larger rectangle that disappears at the screen edges, bringing on the next cycle. An alpha burst switches on Q5, partially discharging C15. The output of IC18 falls, thus causing the rectangle to shrink. If the alpha burst has ceased, C15 recharges and the rectangle resumes its growth/reappearance/growth cycle.

Power supply

Other than the isolated EEG amplifier, all stages of Mindpower: Alpha are powered from the AC line through external plug-in transformer T1.

The input from the transformer is rectified by diodes D11 and D12, each of which is filtered by a 2,000 μF capacitor (C18, C17). In order to provide "stiff" supply voltages under load, the filtered outputs are applied to integrated voltage regulators IC23 and IC24. As a result, the +15 and −15-volt DC power supplies that serve the non-isolated circuitry of Mindpower: Alpha are maintained constant under varying load conditions.

Because the power supply is an integral part of the many circuits, it is essential that the supply impedance be as low as possible to minimize the possibility of circuit interaction through the supply impedance. For this reason, the regulator outputs are bypassed by 10 μF decoupling capacitors, soldered to the parts side of the board. Also, to prevent the horizontal or vertical sync stages from responding to noise (transients) coupled through the inter-winding capacitance of transformer T1, a 0.47 μF bypass capacitor is connected across the line input terminals (23 and 24) of the printed-circuit board. **R-E**

PARTS LIST

All resistors ¼-watt 10% unless noted

R1, R2, R14, R16, R20, R28, R32, R45, R46, R64—10,000 ohms
R3, R4, R41, R42, R47, R68, R72, R73—10,000 ohms, 5%
R5, R31—2700 ohms
R6—27,000 ohms
R7, R8, R48—30,000 ohms, 5%
R9, R10, R12, R13—3 megohms, 5%
R11—3900 ohms
R15, R53, R63, R65, R74, R75, R77, R78, R79, R80, R88—4700 ohms
R17—820,000 ohms
R18—22 ohms
R19, R36, R52—56,000 ohms
R21, R39, R44, R59, R76, R91—15,000 ohms
R22, R34, R51—100,000 ohms
R23, R25, R26, R33, R81, R82, R83, R84, R86—22,000 ohms
R24—47,000 ohms
R27—3300 ohms
R29—10 megohms
R30—1.5 megohms
R35—750,000 ohms
R37—20,000 ohms, 5%
R38—4700 ohms, 5%
R40, R89—1000 ohms
R43—15,000 ohms, 5%
R49—120,000 ohms
R50—39,000 ohms
R54, R57, R58, R60, R61—5600 ohms
R55, R62—33,000 ohms
R56—220,000 ohms, 5%
R66, R71—13,000 ohms, 5%
R67—220,000 ohms
R69—12,000 ohms, 5%
R70—7500 ohms, 5%
R85—12,000 ohms
R87—240 ohms
R90—200 ohms
R92—10,000 ohms, linear potentiometer

All capacitors 25V or more unless noted
C1, C2—0.47 µF, 100 V, 10%
C3, C4, C5, C6—.0033 µF, disc, 10%
C7, C8, C20—5 µF, electrolytic
C9, C15, C29, C30—10 µF, 25V, electrolytic
C10, C12, C14, C19—1 µF, 100V, 20%
C11, C23—0.1 µF, 100V, 10%
C13, C26, C27—0.01 µF, disc
C16—(see text)
C17, C18—2000 µF, 50V, electrolytic
C21—.0082 µF, disc, 10%
C22—.033 µF, 100V, 10%
C24—.0015 µF, disc, 10%
C25—.0068 µF, disc, 10%
C28—150 pF, disc
C29, C30—10 µF, 25V, electrolytic
C31, C32—10 µF, 25V, electrolytic

Transistors*
Q1, Q2, Q3, Q4, Q5, Q7, Q8, Q9, Q10, Q11, Q12, Q13—2N4401
Q6—2N4403
Q14—2N5524
Q15—SE4021

Diodes*
D1 through D19—1N3064
D20—1N5240, 10V, 10% Zener

Integrated Circuits*
IC1—CD4046AE (CMOS)
IC2, IC3—CD4001AE (CMOS)
IC4—CD4011AE (CMOS)
IC5, IC6, IC7, IC8, IC9, IC10, IC11, IC12—LM311N (voltage comparator)
IC13—LM318N (op amp)
IC14, IC15, IC16, IC17, IC18, IC19, IC25, IC26—LM307N (op amp)
IC20, IC22—NE555 (programable timer)
IC21—CD4040AE (CMOS)
IC23—MC7815 (+15V regulator)
IC24—MC7915 (−15V regulator)
IC27—MCT-2 photocoupler

Miscellaneous
Printed circuit board (2 sided, plated through holes)
Plastic case
Miniature speaker, 8-ohms
Headband assembly
Battery clips
Battery connectors
BATT1, BATT2—9-volt alkaline batteries
Transformer
S1—3-pole, double throw slide
S2—N.O. single pole pushbutton (or slide)
S3—dpst slide
S4—spst slide
IC sockets
Misc hardware

***Do not substitute**

The following items are available from National Mentor Corp., Box 53, Wykagyl Station, New Rochelle, NY 10804

Circuit board. 2-sided, plated through holes. Order part number NM-P108: $34.50

Transformer. Order part number NM-T6: $17.50

Headband. Order part number NM-HA39: $9.50

Case, punched and drilled. Order part number NM-C56: $14.75

Set of all semiconductors including 27 IC's and 35 transistors and diodes. Order part number NM—Semis 1: $99.50

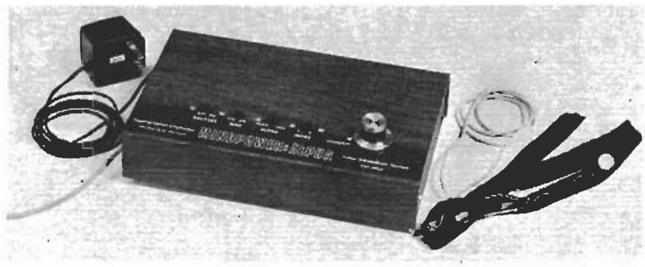
Complete set of all parts needed to build Mindpower: Alpha: $265.00.

All prices include postage and insurance in the continental United States.

MINDPOWER: ALPHA

Part III. Build this biofeedback device that displays the presence of alpha waves on a TV screen. You can use it to learn and gain from the benefit of the relaxation that comes with it

> **NOTE**
>
> **Mindpower: Alpha is an intriguing device for entertainment and experimentation in video biofeedback. It is not a therapeutic instrument, neither is it suggested as a cure for individuals suffering from psychological or physiological disorders.**



THE POWERS OF THE HUMAN MIND RANK AT THE very top of the list of unknowns being studied by scientists throughout the world today. In no small way, this activity has resulted from the discovery that the powers and capabilities of the brain are chiefly limited by the amount and quality of information that reaches it through our senses. With the discovery of *biofeedback*, it has become possible for us to use an instrument to detect the brain's activity, and to feed this information back to the brain through the senses. This fascinating discovery has opened great new possibilities for expanding the powers of the mind through biofeedback training.

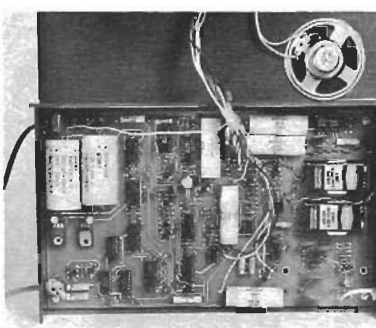
Mindpower: Alpha is an entirely new type of biofeedback instrument. It is designed to serve as a link between your *mind* and *a visible, controllable display on your television set's screen.* Its purpose is to aid you in training your mind to "downshift" from the high-tension state of anxiety and stress, to the state of relaxation in which the brain produces a dominant alphawave rhythm. This state, the subject of intense interest among meditators, yogis, mind control groups, and researchers, is believed to be both beneficial to the body and an important step in expanding the creative consciousness. Once you have achieved it, you will find it a fascinating state, in which you are free to experiment with the powers of your own mind!

In the July and August issues of **Radio-Electronics,** we described how Mindpower: Alpha works. This month we will discuss the assembly details.

Assembly

The two-sided printed-circuit board (see parts list) speeds up assembly and ensures freedom from poor joints and stray coupling. The foil patterns of the PC board is shown in Figs. 1 and 2.

Begin construction by installing IC sockets on the board. To save space, 16-pin sockets are used to hold pairs of closely related 8-pin IC's in several instances. Figure 3 shows the parts layout of the board.



MINDPOWER: ALPHA printed-circuit board mounted in metal case.

The IC sockets are inserted, pressed in, then sparingly soldered to the foil side of the board. (Use a 25-watt iron with a small, conical tip and do not dwell on a pad for more than a few seconds, otherwise you will cause foils to delaminate.) Next, install transistors Q1-Q15 being careful to orient them correctly. Diodes are installed next and the same care should be exercised.

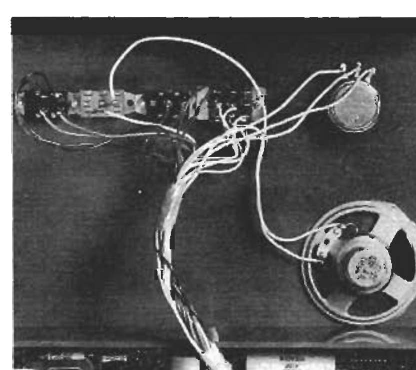
Resistors are installed next, and here it is worthwhile to remember that ¼-watt composition resistors are fairly fragile. Form their leads before inserting and don't be too vigorous in pressing them into place. A cracked resistor can be next to impossible to find by usual troubleshooting methods. There are 91 resistors to be installed on the board. Check values carefully against the parts list and Figure 3 before installing each resistor. Also, check again after all resistors have been installed. A wrong resistor value in a wrong location can be tedious to find later.

Next, install capacitors. Electrolytic capacitor polarity is indicated by a (+) mark on the board opposite the hole that accepts the positive lead of the capacitor. Disc and the non-polar tubular capacitors are installed, as shown, without regard for polarity. Note that 10 μF electrolytic capacitors C31 and C32 do not have pad holes on the board. These capacitors are soldered directly to the foils on the parts side of the board. The positive side of C31 connects to the +15 volt output of the regulated supply, and the negative side goes to the ground foil. Conversely, the minus side of C32 connects to the −15 volt output of the regulated supply, and the positive side goes to the ground foil. Capacitor C33 is soldered to the transformer wires that connect to points 23 and 24 after those wires are soldered to the board.

The +15 and −15 volt regulators, IC23 and IC24, are soldered to the board in the plated-through holes. The −15 volt regulator (an MC 7815) is installed with its brass-colored heat-sink up.

The two battery clips for installation of BATT1 and BATT2 are each secured to the board by short No. 4-40 screws and nuts. Screw heads are on the bracket side of the board and nuts are tightened from the foil side. When this stage of assembly has been reached, set the partially completed board aside and install parts on the case top.

Four slide switches S1-S4, control R92, and a miniature 8-ohm speaker are installed on the case top-half. The BATTERY switch S3 installs in the left-most punched rectangular hole in the case top. Next comes BEEP switch



REAR VIEW of the front panel

S4, followed by ALPHA test switch S2, and finally, MODE switch S1. THRESHOLD control R92 mounts in the round hole with its mounting hardware. The miniature speaker is glued to the inner vinyl surface of the case

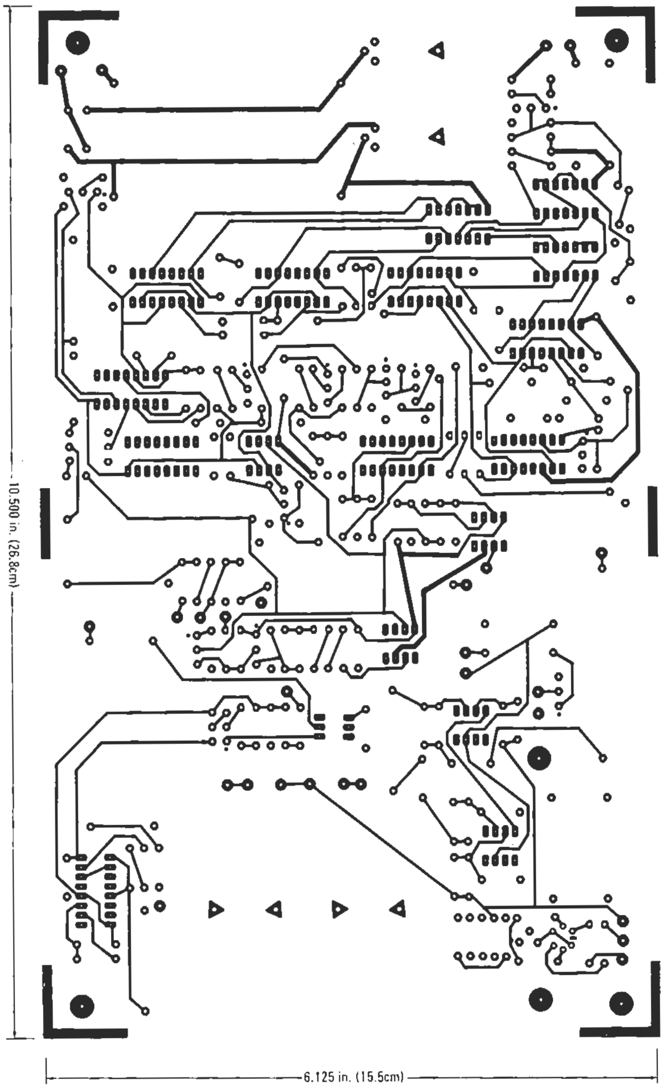


FIG. 1—MINDPOWER: ALPHA PRINTED-CIRCUIT BOARD foil pattern of the bottom of the double-sided board shown half-size.

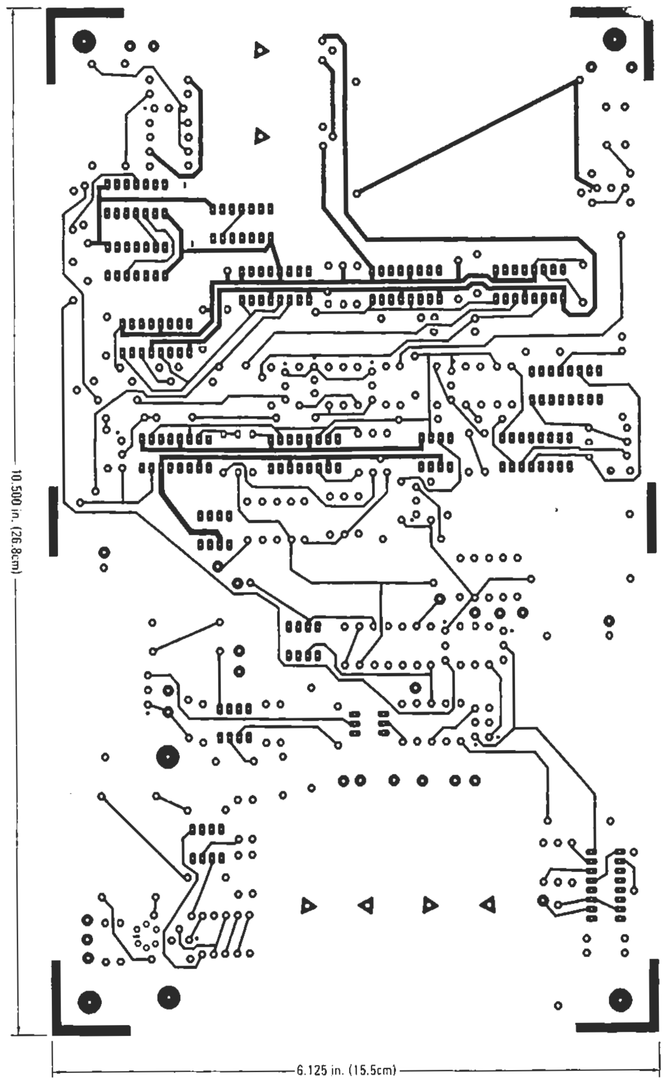


FIG. 2—PRINTED-CIRCUIT BOARD foil pattern of the component side of the double-sided board shown half-size.

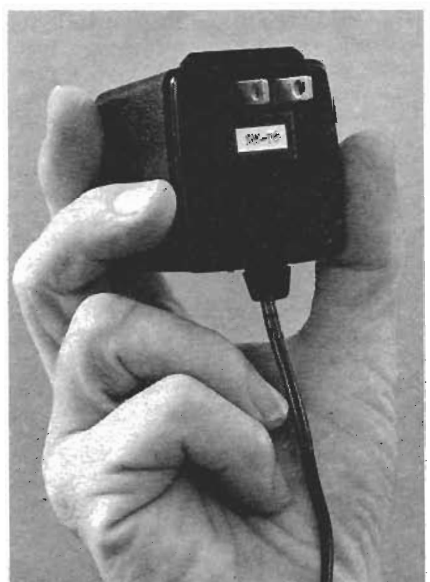
top beneath the drilled speaker opening. Apply contact cement sparingly to the outer rim (not the paper cone) of the speaker and press into place. Allow to dry before proceeding.

To interconnect the parts mounted on the case top, with the board, a simple wiring harness is needed. Each attachment point on the board bears a number (also shown on the schematic) and its destination is illustrated in Fig. 4. To ensure just the right wire length, lay the board next to the case top and lay out enough wire to reach from a numbered board point to the attachment point on the case-top. Now, add a few inches so that there's enough slack to bundle the wires at about the middle of the case top. You should be able to wire-up the parts, but still neatly gather and tape the wires into a harness bundle. Using this method, you'll be able to open up your unit without having wires in your way.

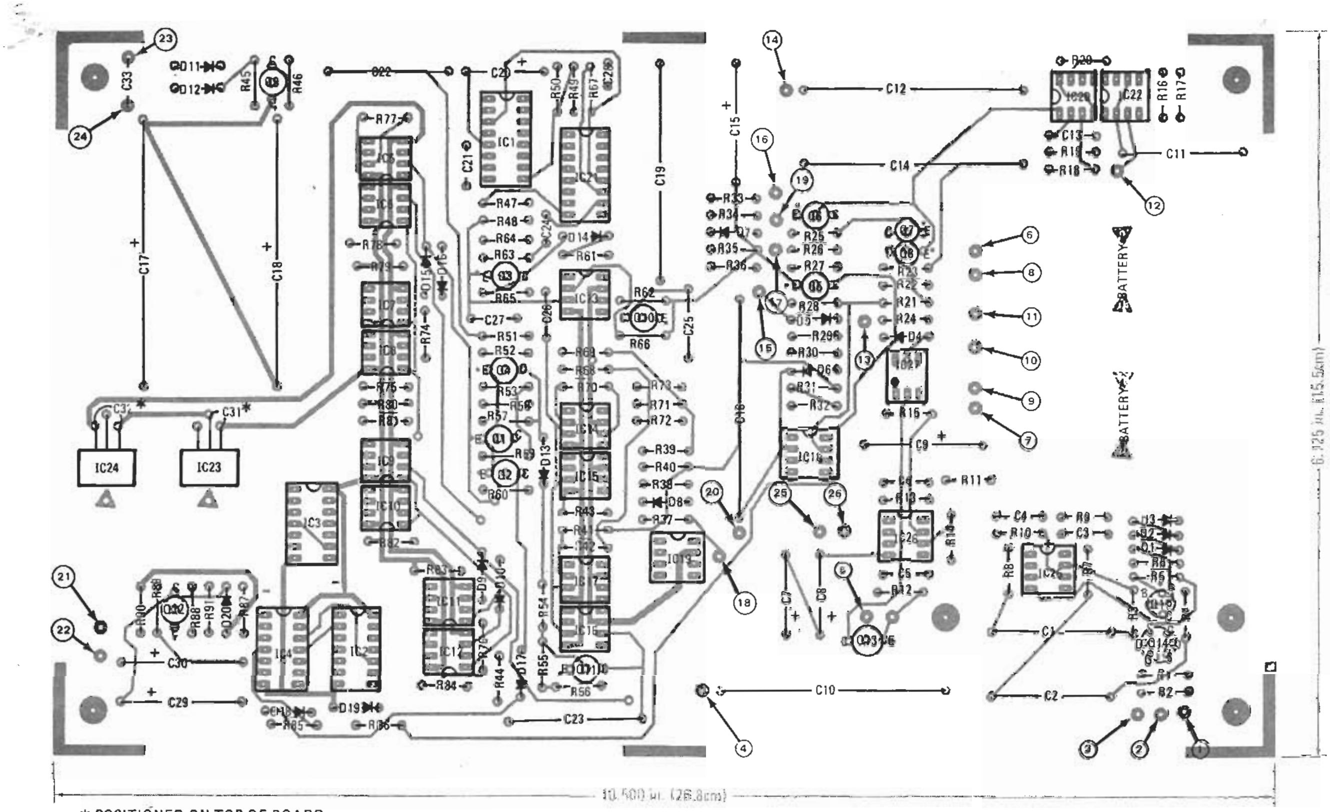
Attach battery terminal wires to the designated board points and dress the wires between the battery clips. Next, pass the wires of the external power transformer, the video output cable and the headband electrode cable, through the holes in the sides of the case bottom. Tie a knot in each entering cable for strain-relief. Leave about 2 inches of free wire end on each. Now, pull through the wires and cables, strip the wire ends and solder them to the proper points on the board, as shown in Figure 4. After connecting transformer secondary wires to points 23 and 24, be sure to solder bypass capacitor C33 across these two points. The finished, interconnected board can then be drawn back into the case by taking up the slack on the wires. To mount the board, push through screws from the outside of the case bottom, install ¼-inch spacers, and fasten with four nuts from the parts side of the board.

Finally, the IC's are installed. Great care is required in handling IC's, especially IC1–IC4, and IC21, all of which are CMOS types susceptible to damage from static discharges. The other IC's, though not as static-sensitive as the CMOS types, still require a gentle hand in inserting them into their respective sockets. Pay particular attention to correctly orienting the IC's when inserting them. (Note: In the accompanying photos, IC13 is shown as a TO-5 metal can package, with leads formed to fit the IC socket. In actuality, this IC is supplied in the parts kit as an 8-pin DIP, similar to the other IC's. For this reason, it is shown as a DIP in Fig. 3.

Upon completion, spend some time checking your work. Be critical and don't close your eyes to small defects like excessive rosin, solder flakes or loose foils. Every minute you



POWER comes from an external transformer.



* POSITIONED ON TOP OF BOARD. SOLDERED DIRECTLY TO FOIL.

FIG. 3—COMPONENT PLACEMENT diagram. Circled numbers are interconnect points to external components.

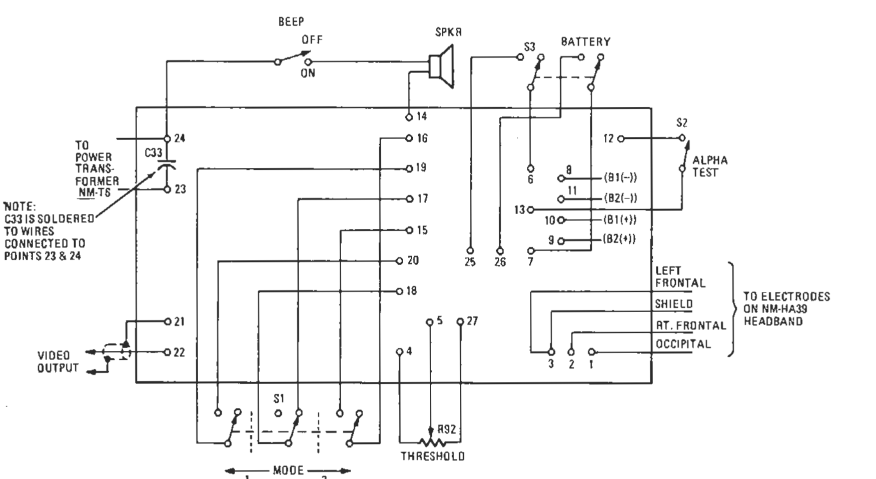


FIG. 4—INTERCONNECT DIAGRAM showing connection of external components to printed-circuit board.

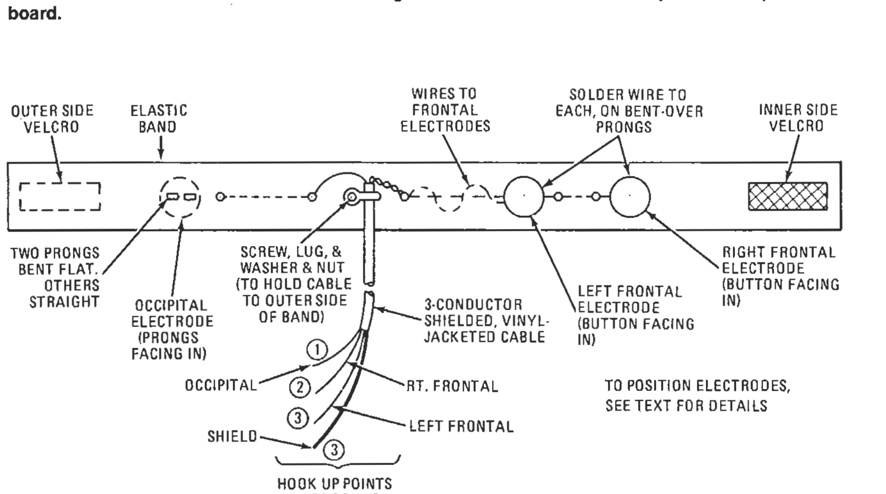


FIG. 5—HEADBAND ASSEMBLY details. View is from inside surface of headband.

invest in checking now could save you troubleshooting time later. Once you are satisfied that everything is correct, set aside the assembled unit and start fabricating the headband electrode assembly.

Headband assembly

The elastic headband assembly that holds the three EEG electrodes against the skin surface of your head is assembled from parts contained in the Headband Electrode Kit (NM-HA39) (see parts list). Assembly of these parts deserves care and attention, for it is through these electrodes that the tiny potentials of your brainwaves enter the Mindpower: Alpha circuitry.

Figure 5 is an assembly plan of the headband. The elastic band comes with pre-attached Velcro fasteners, located to permit snug attachment of the band to any size scalp. Four metal electrode buttons are provided, although only three of these will be used. Note that one of the four buttons has extra-long prongs. This is an occipital (back of the head) electrode, intended for use by people who have a substantial amount of hair covering the skin at the back of the head. The long prongs are intended to face inward and to comb-through the hair to touch the skin below at several points, thus providing a low-impedance contact. For those blessed with a lesser covering of hair at the back of the head, a better choice for the occipital electrode will be one of the buttons having shorter prongs. Plainly, where the hair is thin, there is less cushioning and the button with shorter prongs will be more comfortable in combing through a sparse hair covering.

To begin assembly of the headband, first mark the positions of the electrodes. Wrap the band about your head so that the closing ends overlap just above your right ear. Pull the band snugly, but comfortably tight, and mesh the Velcro ends. Now, standing before a mirror, place a mark on the band directly above the center of each eye using a piece of chalk. This will establish the positions of the right frontal lobe active electrode and the left

HEADBAND ASSEMBLY of Mindpower: Alpha.

frontal reference electrode. Now, place the base of your left hand's index finger against the top of your left ear, and extend your finger tip to the band at the back of the head. Place the chalk on the band against your finger tip, and you will establish the position for the occipital electrode.

Remove the band and lay it flat. Position it with the two frontal electrode marks to the right and facing down. Place the prongs of an electrode button on the band behind the rightmost mark and press the prongs through the band's fabric. Now, repeat the process to mount the left frontal electrode. Crimp all of the prongs over on the outside of the band to hold the two frontal button electrodes in place. (The smooth button side is the inside surface.)

Now, mount the occipital electrode, working from the outside *in*. Place the selected occipital electrode directly *over* the chalk mark and press its prongs through the fabric. Crimp *only two* of its prongs flat against the band leaving the remaining prongs protruding. This means that you will now have one electrode at the left, formed by prongs and two smooth button electrodes at the right of the band.

TABLE I—CHECK-OUT PROCEDURE

FROM	TO	USING	RESULT
IC23 out	Point 24 (gnd)	VOM	+15 VDC
IC24 out	Point 25 (gnd)	VOM	−15 VDC
Point 25	Point 10	VOM	−9 V (S3 ON)
Point 26	Point 11	VOM	+9 V (S3 ON)
IC1 (pin 9)	Point 24 (gnd)	Scope	Approx. 7V in-lock

Standing before the mirror again, fit the band to your head with the two frontal electrodes on the forehead above your eye centers. The prongs of the rear occipital electrode should now comb through your hair to contact the skin surface at the back left of your head.

Once the electrodes have been assembled to the band, you are ready to attach their lead wires. Begin by removing about 12 inches of the electrode cable's outer sheath and shield braid. This will reveal the three insulated wires of the cable. Crimp a solder lug around the outer sheath of the cable just below the point where the wires exit. This will be used as a strain-relief. Simply punch a tiny hole through the elastic band about 5″ to the right of the occipital electrode. Now, insert a ¼″ No. 4-40 screw (with washer on) through the band from the inside, slip on the lug from the outside, and secure in place with a No. 4-40 nut. Twist together the two insulated wires leading to points 2 and 3 on the PC board. Punch two small holes in the electrode band between the cable attachment point and the first electrode to the right. Thread the twisted wires through these holes. The first electrode is the left frontal (isolated ground) electrode. Cut to length the wire leading from PC board point 3, strip its end and solder it to the crimped prongs of that electrode. Punch two more holes in the band between the first and second electrodes and thread through the wire from PC board point 2. This wire should then be stripped and soldered to the crimped prongs of the right frontal electrode.

To complete assembly, punch two more tiny holes between the cable attachment point and thread the remaining wire leading from PC board point 1, through both, and solder it to one of the crimped-down prongs of the occipital electrode. This completes assembly.

Check-out

After a final check of all wiring and connections, you should make a few voltage checks to ensure that all is functioning correctly. Install 9-volt batteries BATT1 and BATT2, and insert the prongs of the power transformer assembly into an AC wall outlet. Table 1 lists the measurements that should be made during the check-out procedure.

When these checks have proven satisfactory, set the BEEP switch S4 to ON and move ALPHA switch S2 to the TEST position. You should hear a rapid succession of 1-kHz "beeps" from the speaker signifying that the alpha test oscillator is keying the speaker, as would amplified alpha. To check the input amplifier, run the THRESHOLD control up and down. At maximum, you will hear some 60-Hz modulation of the alpha test beeps. At minimum, the tones will be crisp and clean. (The 60 Hz modulation results from stray pickup by the "open" electrode circuit. When electrodes are placed on the head, the electrode circuit is "closed" and 60 Hz pickup is minimal because of the differential input circuit.)

When you have reached this stage, you are ready to connect your Mindpower: Alpha to the TV set for some fascinating experiments in video biofeedback.

HORIZONTAL SYNC

This one is beginning to get to me! Wards Airline GHI-4836. The problem is very bad horizontal sync. You can set it up and it works for a moment, then jumps out of sync. Moving the horizontal hold control will make it lock, then it goes out again. I've checked everything I can think of. I note that touching the horizontal oscillator plate with a scope probe makes it go out of sync. When I take the probe off, it comes back temporarily. Should I take this down to the creek and make a fish-trap out of it or what?—C.S., Vergennes, IL.

Probably wouldn't make a very good fish-trap; let's fix it. This sounds very much like a thermal. Something is changing in value as it warms up. Try heating and cooling various parts. The oscillator plate should *not* be that sensitive. Sounds very much like a resistor increasing in value to me. (Feedback: Right! 18K resistor across horizontal oscillator plate coil read anywhere from 100K to 200K, out of the circuit on the bench! Thanks!)

"ADD-ON" AUTOMATIC FREQUENCY CONTROL?

Is it possible to install an automatic frequency control in an old Zenith model FM radio? This is a model G-725.—O.B., Monett, MO.

Frankly, it would be pretty hairy to add something like this to an existing design, even in a tube chassis like this. Suggestion; if you are having oscillator drift problems in this chassis, check that little ceramic capacitor across the oscillator coil. This is a negative-temperature-coefficient type, and was used to correct drift. We replaced several of these when these sets were new! Aerovox part number for this capacitor is CN22JN080 and it's a 22-pF unit.

WHITE COMPRESSION

The picture looks odd on this Philco 7L40. It looks something like white compression. The brightness control has no effect. All of the DC voltages on the picture tube read about +300 volts! No; the cathode is about normal. The grid resistance to ground is too low. 1.0 megohm normal. What is this?—J.D., Mena, AR.

You have a shorted blanking coupling capacitor, C46, the .0022 μF from the vertical output transformer to the picture tube grid.

WIDTH COIL

I have an old Capehart CT-125 TV that I'm working over. I need a width coil for it. It works fine but I have no AGC and sync.—V.M., Mission, TX.

Tight! This is one of the old dual-winding types—you get the AGC and sync keying pulses from the secondary of the width coil. You can get a Triad WLC-29 that is listed as a replacement for the original part number that I'm not going to copy since it's so long! Thordarson WC-26 is also a sub.

MIND POWER: ALPHA

Part IV. Build this biofeedback device that displays the presence of alpha waves on a TV screen. You can use it to learn how to control your alpha waves, and gain from the benefit of the relaxation that comes with it

BIOFEEDBACK IS ONE OF THE IMPORTANT METHODS THAT SCIENCE has unearthed to help us relax. The principle is simple: provide a way for the brain to sense that it is successfully gaining control over sources of stress, and control will become a new, normal function. Thus, just as your brain can learn to read, understand a foreign language, play a chess game, etc., so too can it learn to reduce tension and stress.

During the state of relaxation and tranquility, brainwaves show a dominant *alphawave rhythm.* To detect these alphawaves, an outside instrument is needed. That instrument is Mindpower: Alpha.

Mindpower: Alpha is a unique new biofeedback instrument that serves as a link between your mind and a visible, controllable display on your television set's screen. It aids you to train your mind to come down from a high-tension state of anxiety and stress, to a state of relaxation and stress-relief. This *alpha* state—the subject of intense interest among physicians, meditators, yogis, mind control groups and scientific researchers—has been shown to be beneficial to the body as well as to the mind.

In the preceding three parts of this article, the design, components, and assembly of Mindpower: Alpha have been described in detail. This month's concluding part of the article will describe how to connect Mindpower: Alpha to your television set, the initial set-up procedures and how to use Mindpower: Alpha to gain control over your alphawaves.

Hookup

The composite video output signal from the Mindpower: Alpha video-driver can enter the TV set by either of two ways: *direct connection* to the video amplifier stage of the TV set; or, injection via a modulated RF-oscillator connected between the video output of Mindpower: Alpha and the antenna input terminals of your TV set. The modulated RF-oscillator is the type commonly used and sold to connect a television camera to a TV set for closed-circuit use. Such an oscillator generates a very low-power TV signal on a selected TV-channel that is then tuned-in as a broadcast TV signal would be.

Although not offered for sale by National Mentor Corporation, a modulated RF-oscillator that is compatible with Mindpower: Alpha's video levels is the *Pixie-Verter*, model PXV-2A, available in kit form at $8.50 postpaid from ATV Research, 13th and Broadway, Dakota City, NE 68731. Instructions for assembly and use accompany the *Pixie-Verter.*

Note: The combination of Mindpower: Alpha and any modulated RF-oscillator may be construed to be a *Class-I Video Device,* within the meaning of Part 15 of FCC Rules and Regulations. The FCC may require certification of such a combination and can impose penalties for willful, malicious or harmful interference. Moreover, it is against FCC regulations to sell such a combination unless properly certified. Users of such combinations are advised to familiarize themselves with the relevant portions of Part 15 so as to ensure compliance with present standards and requirements.

NOTE

Mindpower: Alpha is an intriguing device for entertainment and experimentation in video biofeedback. It is not a therapeutic instrument, neither is it suggested as a cure for individuals suffering from psychological or physiological disorders.

Direct Connection

If you choose, instead, to connect your Mindpower: Alpha directly to your TV set's video amplifier, be sure to take safety into consideration. First, determine what kind of power supply your TV operates from. If it is an AC-DC set, it lacks a power transformer. This means that one side of the power line connects directly to the chassis of the TV set, making it "hot" with respect to ground. **Connection to a set of this type is hazardous and is not recommended.** The danger, here, is that the shield of the video cable may bring the "hot" chassis potential of the TV set out to the otherwise safe, transformer-operated section of the Mindpower: Alpha printed-circuit board. Your TV set should have a power transformer-isolated power supply for complete safety in operation. If it does not, locate one that does or purchase an external isolation transformer and use it to operate your TV set.

Second, be aware that hazardous-level voltages are present inside any TV set. It is possible to receive a severe shock from the circuitry, even with power-off due to storage of potentials in power supply capacitors and the second-anode capacitance of the picture tube. If you are unfamiliar with the locations of hazardous voltages within your set, have a qualified TV service technician make the connection for you.

Third, locate the input to the video amplifier section of your TV set. To do this, you should have the schematic diagram of your TV set. As an aid in locating the correct connection point, Figs. 1 and 2 show typical vacuum tube and transistor-type video amplifier stages used in most TV sets. Yours will probably be a variation of either circuit. The connection point will be the input to the video amplifier where the video detector connects.

While the video output level of Mindpower: Alpha is just right for most TV sets, it may be too high for some. If necessary, you can reduce the video output to a lower level by

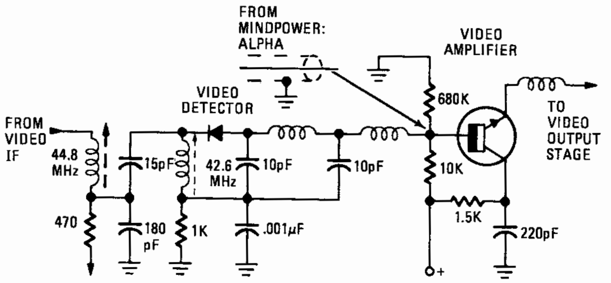


FIG. 1—TYPICAL TRANSISTOR VIDEO AMPLIFIER stage showing the connection point of Mindpower: Alpha.

use of a simple resistive divider. (The resistor values to be used depend upon the circuit values in the video amplifier of your TV set.)

Final check

With the TV set on, plug in Mindpower: Alpha and set its MODE switch to the 1 position. (Turn off the BATTERY switch to prevent stray pickup from the electrode circuit from affecting the display.) At this point, you *may* see the display on the screen, although you probably will have to adjust the horizontal hold control of your TV set slightly to account for the 390-Hz difference between Mindpower: Alpha's horizontal frequency (15.36 kHz) and the 15.75 kHz horizontal frequency of a standard U.S. television broadcast signal. When this simple adjustment has been made, the image should stabilize and the TV screen should now be displaying a stationary white "hollow" rectangle against a dark field. Turn down the TV's brightness control to darken the field. Turn up the contrast control to increase the "whiteness" of the rectangle while improving the "blackness" of the field. Avoid excess contrast that makes the display seem harsh. Find a combination of settings at which the display seems visually comfortable to you.

Next, set the ALPHA switch to the TEST position. Note that the display shrinks to the center of the screen and blinks at the alpha test oscillator's rate. If you'd like to hear this, set the BEEP switch to the ON position.

If you don't obtain the results specified, re-check your connections and be sure that you've properly chosen the video amplifier connection point in your set. If the display won't stay in sync, or tears, you are probably overloading the video amplifier with signal, and a resistive divider will be needed to reduce the signal level. (Alternatively, you may wish to reduce the value of resistor R91 to lower the video signal output of driver Q12.)

Using Mindpower: Alpha

Note: Mindpower: Alpha is intended for use by normal individuals, as a device for entertainment and experimentation in video biofeedback. Persons suffering from epilepsy, or mental or physical disorders of any kind, should use Mindpower: Alpha only under the supervision of a physician. No therapeutic claims are made for this device, nor that each and every individual who uses the device will benefit from such use. National Mentor Corporation assumes no liability whatsoever with respect to the assembly, installation, use or misuse of this device.

To apply the electrodes, hold the headband so that the two frontal electrode-buttons are closest to your right hand; the buttons should be facing toward you. Place the buttons against your forehead (comb back your hair first so that no hair gets trapped between button and skin to cause erratic contact), then wrap the band around your head about as snugly as you can comfortably stand. The prongs of the occipital electrode should comb through the hair at the back of the skull, and you should feel them contact the skin, below. If there is any sensation of discomfort, at first, it will pass within a minute or so as your skin sensors become accustomed to the headband and electrodes.

Turn on the TV and plug in the Mindpower: Alpha power transformer. Now, turn on the EEG front-end by setting the BATTERY and BEEP switches to the ON positions. With electrodes positioned as described above, gradually turn the THRESHOLD control clockwise. If you've barely turned it and hear a raspy, buzzing note from the speaker, plus a display that shrinks to nothing or even vanishes from the screen, you're not seeing alpha but you are seeing stray 60-Hz pickup caused by poor electrode contact. Check that there is no hair interfering between the electrodes and skin. Also, that there is no skin lotion, cream or make-up on the skin where electrodes are contacting. Wash the skin and clean the electrodes, if necessary, and try again.

Assuming, however, that you *don't* have a problem, advance the THRESHOLD control about a third of its rotation and blink your eyes. At some point, you will hear a "beep" and see the display shrink slightly in response to your eye blink. The blink response shows that gain is close to the

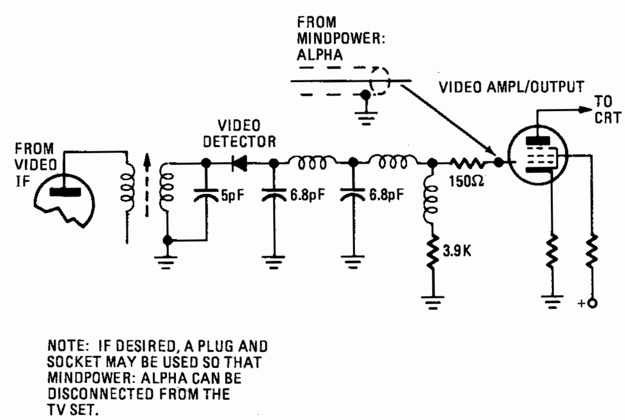


FIG. 2—TYPICAL TUBE-TYPE VIDEO AMPLIFIER STAGE. Mindpower: Alpha is connected between video amplifier and video detector.

correct setting. You are now picking up bioelectric signals from the occipital region of the brain, where visual signals are "projected" on the surface of the brain's cortex. Advance the THRESHOLD control a bit further and you may notice occasional beeps and response of the video image. You are now catching occasional alpha bursts that may be originating in any region of the brain between the right frontal electrode and the left occipital electrode. Advancing the control further, you may start to pick up 60-Hz interference, and you should now back off slightly on the control until the device responds only occasionally to bursts and is otherwise quiet. Note the setting of the THRESHOLD control for future reference.

To give yourself with a reference as to what strong, sustained alpha looks and sounds like, move the ALPHA switch to TEST. You should hear a rhythmic beeping and observe that the display shrinks to screen center and flickers at the beep rate. Slide the ALPHA switch back to NORM and you're ready to begin experimenting.

Progressive stages of training

Despite the temptation you may feel to rush ahead *now* and try controlling the TV display with your brainwaves, you may be in for a disappointment if you do. As in all learning processes, the power to learn increases with each thing we learn. And so, Mindpower: Alpha is designed to help you progress through five learning stages; each strengthening your capacity to handle the next stage.

First, turn off the TV set and the BATTERY switch on Mindpower: Alpha. If possible, darken the room you're in to dimly lit state. Choose a comfortable chair to rest in and place a stool or hassock beneath your legs so that you can relax your leg muscles. Leave the headband electrodes on so that you will remain accustomed to the gentle pressure of the band. Settle back in your chair, trying to make yourself as comfortable as possible. You may want to place a cushion or pillow behind your shoulders and neck so that you don't press the occipital electrode uncomfortably against the head. Loosen or remove any tight articles of clothing that make their presence felt. As much as you can, try to eliminate distracting sensations. Now, commence this simple relaxation exercise.

HEADBAND shown properly positioned on users head.

Think of the word RELAX. It has five letters. Breathe in deeply and think of the letter R. Now, exhale slowly visualizing the letter R in your mind. Repeat the sound of the letter R to yourself three times, silently. Remain quiet and breathe regularly. Now, breathe in deeply and think of the letter E, and exhale slowly visualizing the letter E in your mind. Repeat the sound of the letter E to yourself three times, silently. Remain quiet and breathe regularly. Repeat this procedure for the letters L, A and X.

Your body and your mind should now be relaxed and alert, ready to try the first of the five learning stages.

Stage 1. Set the BATTERY switch to ON and note the beeper's response to your present comfortable state of mind and body. Settle back with your eyes closed and recall the pleasant relaxation sensations of a few minutes earlier. Let your mind drift, daydream if you wish. It doesn't matter about what, so long as you don't focus intently on some detail or problem. (Doing so will immediately shift your mind into beta, causing cessation of alpha.) As you mentally drift you will hear the beeper occasionally, signifying alpha occurrence in bursts. As time passes, the bursts will grow longer and more frequent. (This may happen within the first session, or, it may take several hours, spread over many twenty-minute sessions.) When alpha is occurring, try opening your eyes and note if the beeper's response stops abruptly or diminishes to random bursts. In most cases, opening the eyes will cause cessation of alpha. Close your eyes again and try to regain the alpha state. When it occurs note the mental state and physical sensations you feel when the beeper sounds. With practice you should be able to learn the mental and physical states that bring on the greatest alpha response. When you have achieved this, you're ready for Stage 2.

Stage 2. The setup is the same as for Stage 1. With your eyes closed, try to recall the mental and physical sensations that brought on the greatest alpha response in Stage 1. If you have difficulty in achieving alpha, try the R-E-L-A-X method to help you settle down. When alpha is occurring, reinforce yourself by noting your mental and physical state. Settle down again into alpha, and now try opening your eyes. If alpha ceases, try regaining it with your eyes open by recalling the mental and physical states that brought greatest response in Stage 1. (Generally, keep your eyes fixed on a point, while letting your attention drift.) With practice, you should be able to generate alpha with your eyes open, and you should be able to associate your mental and physical states with prolonged alpha generation. The time required to reach this state will vary. But, when you've obtained alpha with your eyes open, you are ready for Stage 3.

Stage 3. The setup is much the same as for Stages 1 and 2, except that the TV set is now on and the Mindpower: Alpha unit's MODE switch is set to 1. Begin with your eyes closed, working with the beeper to get into sustained alpha. Open your eyes and try to regain the eyes-open alpha you learned in Stage 2. Now, commence watching the Mode 1 video display on the TV screen. Slide into alpha again, noting what happens when the display shrinks in reaction to your alpha. If the shrink reaction causes cessation of alpha, try to regain the mental and physical sensations you learned in Stages 1 and 2. This should restore alpha each time it is "blocked" by the display's movement. With time and practice, the "blocking" reaction should be extinguished. Gradually, your alpha should become sustained and you will find the rectangle shrinking to a smaller and smaller size and remaining so for longer periods. When you've reached this point, move on to Stage 4.

Stage 4. You are now ready to make the transition from audio feedback to video feedback. Set the BEEP switch to OFF and use Mode 1 video alone. Using the methods described earlier, get into a relaxed state and now attempt to recall the sensations that produced the greatest alpha response. As you now see the alpha response by the video display, you will realize that what your brain has previously learned through aural sensation has now been carried over into the *visual* sensory pathway. To increase the strength of your alpha, try reducing the THRESHOLD setting slightly so that it will be necessary to generate alpha waves of higher amplitude to secure response. With time and practice, you should see this increase occur. You are then ready to move on to Stage 5.

Stage 5. In this stage, we add the dimension of *movement* to the video display. We live in a world of moving visual-stimulus, and so it is another training step toward relaxing in the real world to learn how to generate alpha when confronted by a dynamic visual sensation. Commencing as before, enter the alpha state. Now, set the MODE switch to 2 and let your eyes follow the periodic expanding display on the TV set screen. Recall the physical and mental states that yield peak alpha and observe how each burst arrests the rectangle's outward expansion. Your goal is simple: overcome the display's motion and hold the rectangle at a fixed size on the screen. Beyond this, you can try to *back it down* to a minimum size at screen center, completely preventing its outward motion. Both of these tasks are difficult because they require sustained high-amplitude alpha. It should be expected that considerable time may be required to master this stage. Once you have done so, however, you will have reached a new plateau of control over the brain-body matrix.

Perhaps the most fascinating results of your experience with Mindpower: Alpha will come from your day-to-day experiences in real-world situations. Your mind and body have now been trained to some extent to relate to one another in a new way. In the presence of a stressful situation, attempt to recall the mental and physical sensations associated with peak alpha. By doing so, you should be able to bring on a state of stress-reduction. The degree of success you experience in doing this will determine whether or not you need additional training in the earlier stages to achieve stronger results. **R-E**