Post Office Box 96
Albion, California 95410
U.S.A.

the ALPHAPHONE*

Brainwave analyzer

Instruction manual

*Trademark of Aquarius Electronics

AQUARIAN* ALPHAPHONE* headset
AQUARIAN* ALPHAPHONE* brainwave analyzer
AQUARIAN* ALPHAPHONE* basic e.e.p.
ALPHAPHONE* headset
ALPHAPHONE* brainwave analyzer
ALPHAPHONE* basic e.e.p.
AQUARIAN* photon coupler

NOTE

We recommend that persons with a history of epilepsy, other convulsive disorders, or serious personality defects consult their physician prior to using the ALPHAPHONE headset or brainwave analyzer. Although we do not know of any ill effects resulting from the use of these instruments, we want to emphasize that they are research instruments intended for use in an area that science is still exploring. We have heard rumors that feeding back brainwaves at about 14Hz can trigger convulsive seizures in those subject to them, although we haven't found documented cases of this. As we are neither licensed nor inclined to practice medicine, we must advise that anyone who suspects a possible difficulty should consult his physician.

The ALPHAPHONE headset and brainwave analyzer are brainwave feedback instruments. They are neither intended nor designed for use in other bio-feedback or bio-monitor modes (e.g., heart rate, respiration, blood pressure, etc.). Each of these functions requires a different type of instrument. We feel that many biological functions are best left under the control of the autonomic nervous system. BFT experiments with these functions should be undertaken only under professional supervision. We feel that brainwave feedback has proven safe enough to be excluded from this class.

Aquarius Electronics is a manufacturing company located in Mendocino, California. We are not doctors, neurophysiologists, psychologists or otherwise credentialed professionals and have no intention of pretending to be. While we have attempted to document our references to formal research, and to keep our speculations within the realm of plausibility, we claim no professional authority and acknowledge the hypothetical nature of much of the contents of this manual.

Aquarius Electronics assumes no responsibility for any damage, real or imagined, resulting from the use of this instrument.

CONTENTS

Sections A B and C of this manual introduce the historical, physiological and psychological aspects of EEG, and suggest an approach to the practice of brainwave feedback. Those with a thorough grounding in these areas should proceed directly to section D.

The ALPHAPHONE brainwave analyzer will give many years of reliable service if it is treated with the same care that one would use in handling any fine instrument. The following will help in this regard.

DO

— Clean the electrodes after every use.
— Turn the VOLUME knob to OFF when not in use.
— Remove the batteries if the brainwave analyzer is not used for extended periods (more than a month).
— Read the operating instructions and the warranty before beginning to use the brainwave analyzer.

DON'T

— Store the brainwave analyzer in extremely hot or cold places.
— Leave a dead battery in battery compartment.
— Allow dust or moisture to reach the speaker.
— Drop the instrument.
— Connect the brainwave analyzer to AC powered equipment without using AQUARIAN photon coupler or similar optical isolation.
— Remove the front panel (such removal could damage the instrument and voids the warranty).

HISTORY

Altered states of consciousness, once an area of taboo reserved for witches, cultists, monks and "fanatics," is now a fertile field of research. Since the turn of the century, our cultural attitudes toward these mental variations have changed markedly.

In 1902, William James wrote that "our normal waking consciousness. . . is but one special type of consciousness, whilst all about it, parted from it by the filmiest of screens, there lie potential forms of consciousness entirely different. . . No account of the universe in its totality can be final which leaves these other forms of consciousness quite disregarded."

Increasingly, this century has been one of a new discovery, perhaps a rediscovery, of the many potentials of the mind. Old techniques of expanding consciousness have been revived and re-examined. New techniques, suited to the pace of our age, have been developed to facilitate our effort to know ourselves.

New tools are available which can serve us in this effort. Late last century, it was discovered that the brain generates electric current. As early as 1874, it was reported by Caton in the British Medical Journal that the brains of monkeys and rabbits exhibit electric currents that vary with arousal from sleep, exposure to light flashes, death, and other changes. These first experiments were made with a sensitive (for the time) galvanometer and electronic sensors (electrodes), the latter being placed directly on the surfaces of the animals' brains.

In the ensuing years, other work of this type was performed on animals. In 1929, Hans Berger published work in which the electroencephalogram (EEG) of man had been monitored from outside the head by placing electrodes on the scalp. He observed that these currents varied in frequency and amplitude and bore some relation to the changes in consciousness.

Berger is credited with discovering the alpha and beta rhythms and relating them to mental states. He worked with a wide variety of patients--schizophrenics, manics, epileptics, drug users -- and with "normal" people. While much of his work was in the vein of imaginative speculation, it has largely been borne out by subsequent research. His primary interest was not so much in pathology as in demonstrating the "psycho-physical" (mind-body) non-duality of man. In 1938, Hans Berger was abruptly "retired" by the Nazis.

Since that time, interest and research in brainwaves have been gaining momentum. Until the last decade, this interest was primarily in the realm of pathology. That is, EEG was used mainly to identify brain tumors, epilepsy, and other such disorders. Recently, scientists have been at work studying the apparent correlation between states of consciousness and brainwave activity.

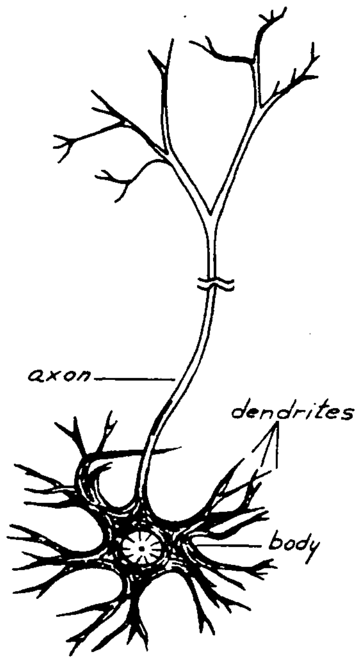
During the 1960's, work in "bio-feedback" developed. Bio-feedback, using electronic tools, is an extension of the same sort of mechanism as speaking (the ears pick up sound from the voice, relay it to the brain as an electrical signal, whereupon the brain uses the information to manipulate the voice. The loop thus being closed, speaking is accomplished.

There are many forms of bio-feedback training (BFT), which allow for the control over the heartbeat, perspiration, skin temperature and the like. Brainwave feedback is a form of BFT in which one learns to control his cerebral electricity, and thus, (to some degree), his state of consciousness.

PHYSIOLOGY AND ELECTRODE PLACEMENT

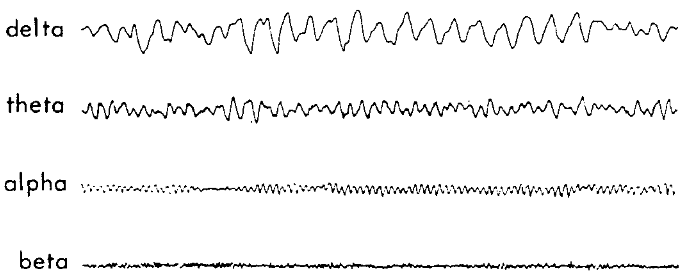
It is common to think of the brain as a single unit, and of alpha as a gear into which this unit occasionally shifts. Perhaps these illusions would be easier to dismiss if we were to refer to it as "the brains," for the organ is composed of many parts, and of millions of cells within those parts. We would like, in this section, to present a model of the parts and their functions and correlate the information to states of consciousness and the use of the ALPHAPHONE headset as a mental discipline. It must be remembered that all models lose their accuracy where they gain simplicity. Like a toy airplane, our model of the brain only conveys an approximation of the structure of the real article.

The cells that compose the brain are known as "neurons." They resemble an uprooted sapling tree--a bulbous body with a rootlike structure surrounding it, and a thin trunk dividing into branches toward the end. While a neuron in the brain of man might be a few thousandths of an inch, end to end, one carrying information from the extremities of his body to the brain might be two or three feet in length (though the body would be less than 1/100 of an inch across.) The axon (trunk) receives an electrical pulse through the tips of its branches and transfers this pulse to the body of the neuron. The body fires a new pulse which travels out the dendrites to the entwined axon tips of other neurons. This electrical contact between neurons is called a "synapse."



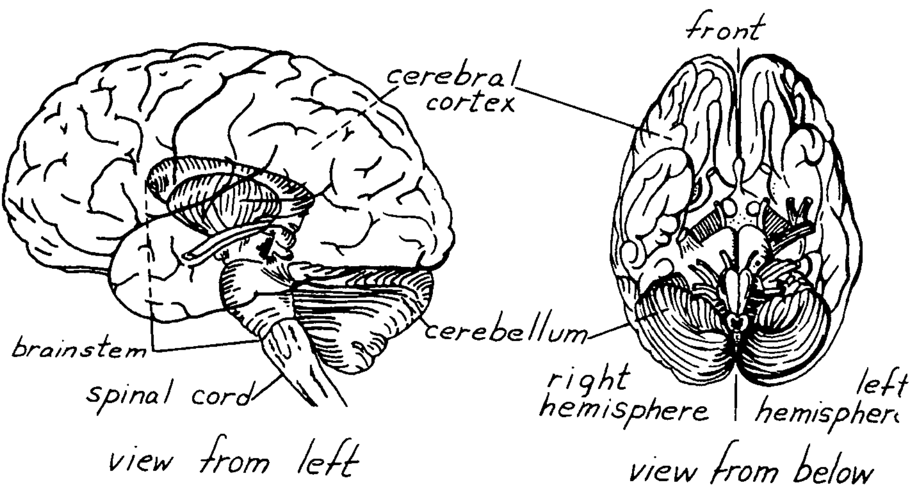
The brain and nervous system are composed of millions of interwoven and intricately connected neurons, relaying electrical pulses along complex circuits. It was thought for some time that the actual firing of pulses by the millions of neurons in the brain was the source material for what we know as EEG. Later writing has it that it is the general flow of current passing through the dendrites which is sensed by the electrodes. While this model is currently popular, it is not firmly established in the research community.

In any case, the neurons act as on-off switches relaying pulses of current (as opposed to waves). The apparent variation in the frequency of brainwaves seems to relate to the synchronicity of the firing of these pulses. That is, as the pulses (or surges of energy through the dendrites) become synchronous with each other, the EEG registers a lower vibrational rate and a higher amplitude. The pulses in one area of the brain might be synchronous (alpha EEG), while those of another are non-synchronous (beta EEG). Those of yet another might be still more synchronous than the first (theta or delta EEG). It appears to be a constantly changing array of patterns reflecting the activity and responses of the different areas in the brain.



Brainwaves have been sorted into four fundamental frequency ranges (illustrated above), using the Greek letters, 'beta,' 'alpha,' 'theta' and 'delta' for denotation. The term 'Hertz' (Hz) is used in describing frequencies (cycles or beats per second). Beta waves have frequencies of more than 13 Hz. The alpha range is from 8 to 13 Hz, theta from 4 to less than 8 Hz, and delta, less than 4 Hz. In addition to these basic four, there are waves of about 14 Hz (occurring in sleep) which are known as "spindles," and "alphoid" waves which are 1 or 2 Hz slower than one's normal alpha frequency. EEG chart recordings, such as those above, vary widely from person to person, and from one state of consciousness to another. The basic frequency ranges, although in common use among researchers, are broad categories that include a great variety of complex wave forms.

At this point, understanding a little basic cerebral geography would help. The brain consists primarily of three main parts: the brainstem, the cerebellum and the cerebral cortex. The brainstem and cerebellum are "white matter" areas, while the cerebral cortex is mainly composed of "gray matter." This derives from the grayness of the neuron bodies and the whiteness of their axons. The spinal cord, brainstem and cerebellum are composed of neurons that have comparatively large and long axons, their small grayish bodies tending toward the surfaces of the organs. White matter areas are primarily relay facilities, some carrying sensory information to, and others carrying motor information from, the gray cerebral cortex.



The cerebral cortex consists of two physically separate halves, called "hemispheres," connected at the base by white matter. Primary sensory and motor functions occur in strictly assigned areas in these two cortices, and generally there is a reversal, right to left, for these functions. For example, the feeling and moving of the right hand is accomplished by specific areas in the left hemisphere. In the case of sight, impulses from the eyes are channeled through a mixing box called the "optic chiasma," so that both of the optic centers in the cerebral cortex process vision from both eyes.

In higher functions, such as speech, logical processes, and the like, there is often redundancy and plasticity. That is, an area that handles such a higher function is often duplicated by another area, the latter being held in reserve. Should damage occur to the prime area, the function can (in time) move to another area so the lost faculty returns. No such movement is possible for sensory and motor work.

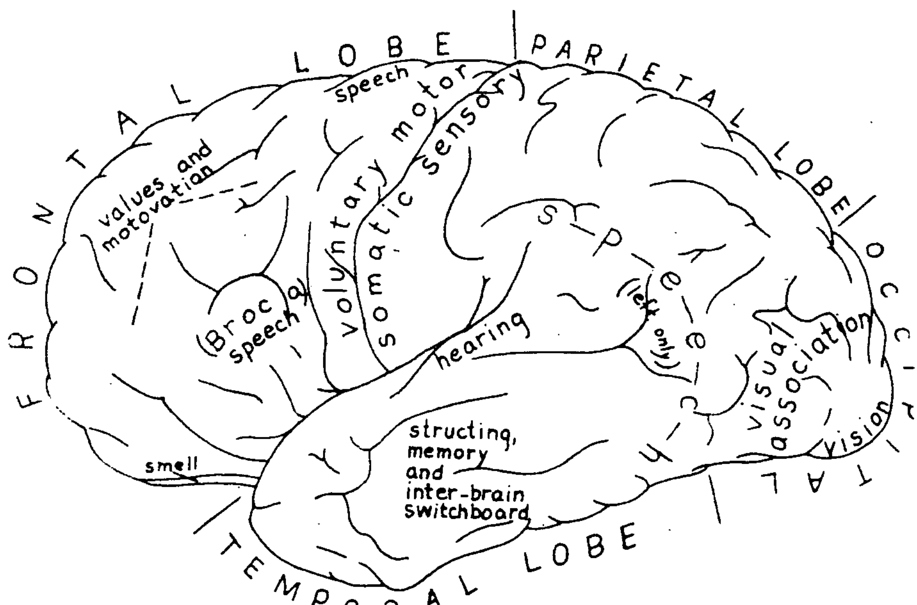
There also appear to be qualitative differences between the operations of the left and right hemispheres. Paul Bakan (Psychology Today, April 1971) offers the following comparison:

left hemisphere	right hemisphere
verbal	pre-verbal
analytic	synthetic
abstract	concrete
rational	emotional
temporal	spatial
digital	analogic
objective	subjective
active	passive
tense	relaxed
euphoric	depressed
sympathetic	parasympathetic
propositional	appositional

When a person would be better described by one set of adjectives than the other, it is likely that the corresponding hemisphere is the dominant one. This works out to be true more often for men than for women (who have a more even balance between hemispheres).

Bakan's method of testing for hemisphere dominance is to note the movement of eyes when the Subject is asked a question that requires some thought. The conjugate lateral eye movements (CLEMS) of a Subject with right hemisphere dominance will be upward and to the left. The eyes of a more analytical, verbal person will be upward and to the right. He notes that people with right hemisphere dominance tend to produce alpha waves more easily.

As the following drawing indicates, each hemisphere of the cerebral cortex has been subdivided into four major areas, called "lobes." The division is on the basis of physical configuration and function, primarily the latter. After studying the results of localized brain damage, neurophysiologists were able to form an idea as to the division of labor within the brain. Lately, scientists have been using the application of current with a thin wire electrode, insulated except for the tip, to selectively trigger brain functions. Aided by this later research, a rather detailed model of the functions of the brain is being formed. The drawing below, while incomplete and approximate, gives a rough idea as to these functions.



VIEW FROM LEFT

When damage is suffered in the primary visual area of the occipital lobes, loss of sight ensues. When the damage is in the visual interpretive area, there is usually enough plasticity and redundancy to duplicate the lost faculty. Damage to the frontal lobes yields a different result nearly every time. Often there is a lack of motivation, and some primary qualitative dualities are lost (e.g., frontal lobotomy has been used to relieve intractable pain; after the operation, there is still intense pain, but the patients don't care much one way or the other about it). Damage in the temporal region often leads to hallucinations, loss of speech faculties, and (if the damage is deep within the lobe) occasionally confusion or loss of memory. The results of parietal damage are less well defined. As well as their function of primary body sense, they appear to act as an auxillary visual interpretive area, perhaps in correlating vision and touch.

It has become popular to speak of a person as being "in alpha" or being "in beta" as though to imply that the brain generates but one frequency of brainwave at a time. In fact, however, the brain generates different frequencies in different areas. The more accurate the measurement, the more divergent the readings. When fine wire probes are implanted within the cortex, they indicate frequency and amplitude differences from areas only a few millimeters apart. The form of electrodes used with the ALPHAPHONE headset and ALPHAPHONE brainwave analyzer naturally do not allow for such fine measurement, but they do display marked differences in brainwave patterns when they are moved around the surface of the head.

The average person most easily generates alpha (synchronizes his neuronal flashes) in the visual area of the brain. It appears that alpha in the occipital lobes signifies a disuse of the faculty of seeing and visualizing, and a general relaxation. In the study of Zen monks by Akira Kasamatsu and Tomio Hirai (Folia Psychiatlica et Neurologica Japonica, 1966), strong alpha signals were observed in all lobes of the brain. It would seem, then, that these Zen men had control over not only visual attention, but memory, valuing, body sense, verbalization, and other such functions as well.

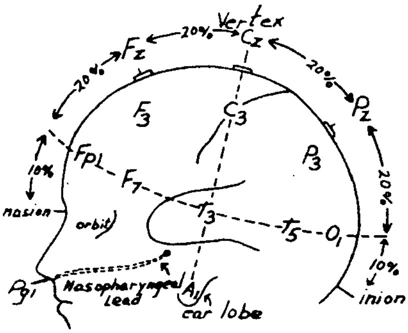
As we are inferring from the model of the brain, alpha in one lobe (or area within a lobe) might signify one thing, while alpha in another lobe might signify quite another. The practice we are proposing is to selectively place the electrodes (within the limitation of their somewhat diffuse reading) over the area of the brain whose function one wishes to bring under control. By moving from easy areas to more difficult ones, and by varying the sensitivity of the instrument, one can follow his own pattern to overall selective control.

For the average person, this will mean learning to generate alpha consistently and loudly in the occipital lobes first, then extending the practice to more difficult areas, such as the frontal lobes. Differences in brainwave generation between individuals are far too great for us to propose any method that will be universal. There is a vast middle ground of people who generate a mixture of alpha and beta in their normal waking state. There are also, however, people who generate alpha nearly all the time, and those who generate nearly no alpha at all. By varying the sensitivity of the ALPHAPHONE headset or brainwave analyzer, many of these people can effectively be brought into the middle ground. Those who generate a lot of alpha could benefit from learning to suppress alpha, or from seeking an area where alpha generation is more difficult. Those who generate little should turn the sensitivity up, and if alpha is still difficult to produce, find a quiet place to "work," away from distractions.

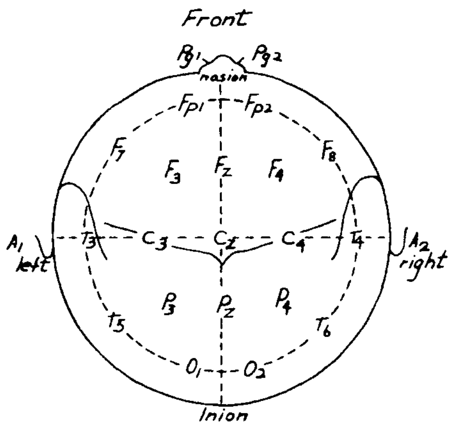
The object of the game (one possible object, at least), is to generate a loud, even alpha pattern with few or no lapses into beta, and then to suppress alpha as completely as possible. This "shifting gears" from one state to the other is very useful for both learning to relax deeply and to focus attention strongly. We are often in situations where attention must be focussed quickly, or where rest must be taken in a short time. It is easy to see how cortical gear changes can help these transitions become smoother.

We are speculating (perhaps wildly in this case) that the activities of one part of the brain might inhibit or enhance the activities of another part. It might be that one could relax the functions of valuation and motivation (from the frontal lobes), and structuring, classification and memory (from the temporal lobes), in order to "see" an object without its being unduly colored by these functions. To do this, one might learn to generate low frequency brainwaves in the frontal and temporal lobes, while generating high frequency brainwaves in the occipital lobes. Similarly, it might be that the activities of one's dominant hemisphere could be slowed, and those of the passive hemisphere increased, the individual thus achieving a better verbal/emotional balance.

Below is illustrated a standard map of electrode placement. In beginning use of the ALPHAPHONE headset or brainwave analyzer, the red electrodes should be placed at Fp_1 & O_1 to monitor the left hemisphere (mainly providing a monitor of the left occipital lobe), or at Fp_2 & O_2 to monitor the right hemisphere. Placing the red electrodes at O_1 & O_2 will provide a monitor of both occipital lobes; Fp_1 & Fp_2 will provide a monitor of only the frontal lobes, etc. The black electrode is a ground, and may be placed anywhere that a good contact with the scalp may be obtained (the forehead is best).



Left side of head



top of head

It is very difficult to write a set of instructions for the generation of a particular brainwave. One of the primary values of biofeedback is that no such instructions are actually needed. If there is difficulty in learning rudimentary control, some hints could help. For increasing beta generation: focus outwardly, work a mathematical puzzle, stare at the "phosphenes" (spots seen with eyes closed), or simply look around. For increasing alpha generation: relax, close the eyes (in a darkened room, if necessary), concentrate on feeling your heart or abdomen. Classically, Zen meditators focus attention (not visual) on the "Hara"--a spot below the navel and within the body; Yoga meditators often chant "Om," saying "Ah" aloud and feeling the sound vibrate in the abdomen, then "Oh," feeling the sound vibrate in the chest, then "Mm," feeling the vibration move to the head.

When rudimentary control has been established, the sensitivity is gradually diminished, the electrodes are moved to more difficult areas, and control is learned under more difficult conditions and in less comfortable settings. A further extension of brainwave control is to learn to generate theta activity in the various regions of the head, the practice proceeding as with learning to control alpha.

CORRELATION AND PRACTICE

Most of the early interest in brainwaves was in the area of pathology. Brainwaves were used to identify brain tumors, epilepsy, and similar disorders. Although Berger himself appeared to have an interest in the study of ordinary and naturally altered consciousness, the general pathological orientation--the use of EEG to study diseases--persisted until the late 1950s. Researchers in the Orient, using EEG examination techniques developed in the West, discovered that their traditional religious practices had demonstrable physiological correlates. This has led to an interest in the study of states of consciousness among both Eastern and Western researchers.

Dr. Stanley Krippner has identified nineteen states of consciousness besides the "normal" waking state (Krippner, J. Amer. Soc. Psycho. Dent. & Med., 1969). They are: dreaming, sleeping, hypnagogic, hypnopompic, hyperalert, lethargic, rapture, hysteria, fragmentation, regressive, meditative, trance, hypnotic dream, daydreaming, internal scanning, stupor, coma, stored memory, and "expanded consciousness." He points out that while it was first thought that EEG would serve as an accurate measure of these states, it is now apparent that the relation is rather tenuous and complicated.

A few states of consciousness seem to produce, or at least coincide with, a particular type (or combination of types) of brainwave. In cases where this coincidence has been repeatedly demonstrated, the state is said to have a "brainwave correlate." Many states are decidedly not correlated with brainwave patterns. Other states may have some degree of brainwave correlation, but research is as yet too incomplete to confirm it.

Perhaps it is safest to say that brainwaves relate to the relative degree of cortical excitation (brain activity). States which share the same degree of brain activity often share similar brainwave frequencies, although they may be subjectively quite different. In this way, anger, creativity and deep meditation are often reflected in theta activity; meditation (other than very deep), inattention and drowsiness share alpha activity. Differences are often drawn along graphic lines: although of the same fundamental frequency, the waves of one state might be spiked in a certain way while those of another are even and rolling. In this section, we would like to explore several modes of consciousness which appear to have some relation to EEG study, which are related (often mistakenly) to each other, and which serve to better define the limits of EEG research and brainwave-feedback training. They are sleep, meditation, hypnosis, ESP, imagery and attention.

SLEEP

To study the various levels of sleep, researchers employed the combination of EEG and EOG (electro-oculogram, a bio-monitor of eye movements). The tracings of the EOG are categorized as REM (rapid eye movements), SEM (slow eye movements), and NREM (no rapid eye movements). The method used to determine the qualitative nature of the different levels of sleep is the comparison of subjective reports upon awakening with EEG/EOG data. When the EEG/EOG data indicates a given level of sleep, the Subject is awakened and asked to reveal his dreams, thoughts, etc. By repeating this method of inquiry with scores of subjects, a rough picture of the different kinds of mentation that occur in sleep is being formed (Dement and Kleitman, 1957; Foulkes, 1964 in Tart (ed.) 1969; Tart, 1965 in Tart (ed.) 1969; Bertini, Lewis and Witkin, 1964 in Tart (ed.) 1969; Vogel, Foulkes and Trosman, 1966 in Tart (ed.) 1969; etc.).

As one passes from wakefulness to sleep, he enters a transitional phase known as the "hypnagogic state." This is a semiconscious, drowsy realm in which the ego (self) of the waking state becomes completely destructured, and the ego of the dream state takes its place. The degree of structuring, as defined, is based on two things: 1) contact with the external world--whether the Subject knows where he is; and 2) regressive content--whether any visual display or other mentation is plausible and coherent relative to waking standards. Often one ego function will be operating without the other (Vogel, Foulkes and Trosman, 1966; Bertini, Lewis and Witkin, 1964).

The first phase of the hypnagogic state is typified by alpha rhythms and REM. The waking ego is still intact. The second phase still exhibits alpha activity; but the eye movements are slower (SEM), and the ego has become somewhat destructured. The third phase, with less well-defined brainwave activity and SEM, is referred to as "descending stage 1." The ego is completely destructured (usually in both senses) at this point. The witness of whatever visual display is present (it couldn't be called "dreaming" exactly) often sees bizarre, unconnected images, perhaps more like still pictures than a movie. Usually these scenes are just witnessed, with no particular sense of self or role, as in a dream. The fourth stage, called "descending stage 2," exhibits almost no eye movements (NREM). The ego has completely restructured (with respect to non-regressive content) but has lost sensory contact with the physical environment.

The hypnopompic state is much like the hypnagogic state, but it is the transitional ascension from sleep to wakefulness. With respect to EEG/EOG data, the two are quite similar. Perhaps our more bizarre and otherworldly dreams are a result of being in a dream and nearly waking--that is, rising into the hypnopompic state.

Dr. Charles Tart suggests that the hypnagogic state has been left too much alone by scientists. He notes that "certain occult magical procedures" use conscious control of the hypnagogic state as an introductory discipline (Ophiel, 1961; Carrington, 1958). In these cases, the state was used as a doorway, not into sleep and unconsciousness, but into "another world of experience" (Tart, 1969).

Beneath the hypnagogic state is sleep, which consists of the following four states. Stage 1 is an irregular mixture of theta waves, occasional alpha waves, alphoid waves (1 or 2 Hz slower than normal waking alpha), and REM. Stage 2 consists of the above, with the addition of sleep's characteristic "spindle" activity (bursts of 14 Hz waves), and with the absence of REM. Stages 3 and 4, also without REM, maintain the spindle pattern, but replace alphoid, alpha and theta waves with delta waves. Stages 2, 3 and 4 are a continuum of slower and slower waves. The deepest sleep is characterized by delta waves to the exclusion of other patterns. Stage 1 is distinct from the other three by absence of spindle waves and by REM. The distinctions between the other three stages, which are arbitrary, are based on the percentage of delta waves (Dement and Kleitman, 1957a, 1957b; Tart, 1965; Foulkes, 1964).

Stage 1 sleep, which is sometimes referred to as REM sleep, is where we dream. In the three stages of NREM sleep beneath it, the mentation is much more like everyday thinking than inside movies. It appears that both are needed to process and adapt to the involvements of our waking activity. In the course of a normal night's sleep, there is a vacillation between REM and NREM sleep, with occasional emergences into hypnopompic (with REM) dreaming. One passes first through the hypnagogic state and brief REM sleep into NREM sleep. This restful period lasts for about an hour to an hour and a half. The first dream period lasts for about ten minutes, to be followed by another deep sleep cycle, somewhat shorter than the first. The ensuing sleep periods are shorter, and the dream periods become longer. Toward morning, the dreams are quite long with only very short sleep periods intervening (Krippner and Hughes, 1970; Dement and Kleitman, 1957; Ephron and Carrington, 1969; Foulkes, 1964; Ullman, 1969; Tart, 1965).

ESP

Research at the Menninger Dream Laboratory in Brooklyn, New York, headed by Dr. Stanley Krippner, points to associations between dreams, EEG and ESP. In these studies "target pictures" are focussed upon by "agents." Subjects who are awakened from various stages of sleep (usually REM dreaming) report their dream images, and judges screen the reports for hints of the target pictures (Krippner, S. and Ullman, M., 1969). Preliminary results have demonstrated an increase in paranormal sensitivity resulting from feedback and intense sensory overload experiences.

MEDITATION

One of the more interesting things unearthed by EEG research is the correlation between brainwave changes and traditional meditation as practiced in the Orient. A variety of studies conducted in both the East and the West has yielded a wealth of information regarding this correlation (Anand, Chhina and Baldev Sing, 1961; Bagchi and Wegner, 1957; Hirai, 1960; Hirai, Izawa and Koga, 1959; Kasamatsu and Hirai, 1966; Kasamatsu, Okeima, Takenaka, et al., 1957; Kasamatsu and Hirai, 1963; Kasamatsu, Hirai and Ando, 1962; Okeima, Koga, Ikeda and Sugiyama, 1957; Wallace, 1970).

Of these studies, perhaps the most complete and detailed is Kasamatsu and Hirai, 1966. In this study, the EEG, pulse rate, respiration, and galvanic skin response of priests and disciples of both Soto and Rinzai sects of Zen Buddhism were recorded. The recordings were made before, during and after Zen meditation (Zazen). The

Subjects covered a range of 24 to 72 years in age and 1 to more than 20 years in Zen experience. There were control Subjects representing the same range of ages but without any experience in Zen.

Before meditation, the EEG illustrated the normal "activating" pattern (beta waves). Within moments of commencing meditation, the Subjects would slip into alpha activity. The "roshi" (master, abbot) and the older disciples exhibited alpha that was higher in amplitude and more even (smoothly contoured waves as opposed to jagged ones, although of the same dominant frequency) than the younger monks. The high amplitude alpha appeared in all regions of the head, including the occipital lobes (despite the fact that Zazen is conducted with open eyes).

The EEG of one Zen master was reported in detail. Within a minute of the beginning of meditation, strong (40-50 microvolts), evenly contoured alpha waves appeared. Eight or nine minutes into the session, the amplitude of the alpha rhythm reached 60-70 microvolts, being strongest in the frontal and central areas. In the beginning of meditation, alpha and beta alternated, but as the session progressed, the percent time of alpha increased to the point that its presence was nearly continuous. After 27 minutes and 10 seconds, alpha/theta waves of 7-8 Hz appeared briefly (2 seconds), and 20 seconds later theta waves of 6-7 Hz appeared. The theta rhythms, which last just a few minutes, do not always occur, even in the master. Common to most of the Subjects was a trend toward decreased alpha frequency and increased alpha amplitude. The theta waves appeared only in the roshis and the highest of their disciples.

One of the methods used in EEG research of this type is the introduction of an interruptive stimulus, such as a click, clap, flash of light, etc. The alpha of relaxation in the ordinary man will be blocked (stopped) by the stimulus, usually to return after a few minutes (or less). The second time the stimulus is triggered, the blocking time will decrease until there is no blocking whatever. This adaptation to interruptive stimuli is referred to as "habituation."

In the case of the Zen men, the alpha blocking reaction time would begin and remain at just a few seconds. That is, the alpha would consistently be blocked and spontaneously reappear moments later. This indicates that the stimulus (a click) was heard, was responded to, and was immediately dismissed. If the sound were bothersome, the alpha would not return so quickly. If the sound were shut out from the consciousness (not responded to), there would be no alpha blocking at all.

This method was used to compare the theta of a sleepy monk with the theta of the roshi. When the disciple exhibited sleep-associated theta (which is graphically different than meditation-associated theta when drawn with EEG pen writer), he was presented with the click stimulus. The result was a resumption of the alpha pattern: he woke up and resumed meditation. When the roshi was presented with the click, the theta pattern was momentarily blocked, but spontaneously resumed in the same manner as the reappearance of alpha in earlier stages of meditation. Although generating a slow wave pattern often associated with light sleep, the response to repeated clicks shows the old Zen man never became unconscious.

This method also points to differences between Zen and Yoga meditations. The Raj Yogis in the Anand, Chhina and Baldev Singh (1961) study exhibited non-habituated alpha blocking when presented with a variety of interruptive stimuli (light, sound, touch) prior to meditation. When in meditation, however, they exhibited no response at all, habituated or otherwise. Further, one was observed to generate continuous alpha even though his hand was immersed in ice cold water. No changes were observed in the parietal area corresponding to the feeling of that hand.

The Yogis in this study meditate with eyes closed and with attention apparently turned completely away from the physical senses. In Zazen, on the other hand, meditation is done with eyes open and with simultaneous internal/external orientation. The Transcendental Meditators in the Wallace (1970) study showed alpha blocking with no habituation although they also meditate with eyes closed. (Transcendental Meditation is a form of mantra Yoga taught by the Maharishi Mahesh Yogi).

In all cases, the meditation is characterized by alpha waves which increase in amplitude and regularity during the course of the meditative session. Also, in all (reported) cases, there is no habituation to interruptive stimuli. But there are differences. It appears from the above that attention to "external reality" is optional; that is, one may carry out his meditation with or without the outside world.

Kamiya (1969) pioneered the synthesis of Western science and Eastern "religious" discipline in suggesting that bio-feedback may be useful in making the samadhi/satori state accessible to modern, urban man. To this end, he began training Subjects (paid) in alpha control. They found the experiences so enjoyable that he now has a long waiting list of Subjects (free), eager to learn to control their minds through this technique. The responses of people who had had some prior exposure to meditation were usually that it wasn't just like their form of meditation, but that it was a very calming, pleasant and sometimes "high" experience.

HYPNOSIS

Hypnosis is a state that eludes definition by EEG. The majority of research findings indicate that the EEG of hypnosis is not significantly different from that of the normal waking state (Fujisawa, 1960; Chertok and Kramarz, 1959; Diamant, Dufek, Hoskovec, et al., 1960; Dynes, 1947; Loomis, Harvey and Hobart, 1936).

Drawing on the work of Fujisawa (1960), Kasamatsu and Hirai (1966), note that the EEG of hypnotic trance is quite different from meditation (with which it is often confused). Trance (Sanran) is suppressed in Zen meditation, and is one of the principal reasons why Zazen is done with eyes open: it is felt that with them closed, trance states are more tempting. While hypnosis is a very important, useful, and often spectacular altered state of consciousness, it is experientally and encephalographically different from meditation and sleep.

Deikman (1963) observes that there is a superficial (and therefore misleading) similarity between the methods used to induce trance and meditation. As a main point of contrast in methodology, he notes that "the surrender of will power, which is the cardinal feature of the hypnotic state, is encountered in meditation only insofar as S renounces his normal intellectual activities." As a further distinction, he notes that in meditation one can bring himself "back" at any time he wishes; however, in trance the fluctuations of depth are involuntary. He states that, more important than differences in methodology or encephalography, there is a profound difference between the subjective experiences of trance and meditation. The classic mystic experience, which is the aim of meditation, has an "ineffable, profound, uplifting" quality that hypnosis lacks.

While it has been demonstrated that there is not a correlation between alpha waves and hypnosis, it appears that learning to increase alpha production through brainwave feedback training increases one's susceptibility to hypnosis (Engstrom, London and Hart, 1970; Galbraith, London, Leibovitz, Cooper and Hart, 1970; London, Hart, Leibovitz, 1968).

Interested by these studies, Dr. Charles Tart investigated the possibilities of increasing hypnotic susceptibility through EEG feedback. His method was to condition occipital alpha in an ordinary manner and test for susceptibility. The results were negative: he found no significant increases, although a number of Subjects were tested.

He mentioned this at the Bio-Feedback Research Society Meeting in 1969. Hart responded that it is only through greatly increasing (quadrupling) frontal alpha that significant changes in hypnotic susceptibility were gained--mere conditioning of occipital alpha has no effect on this. The method used was a rather extreme one--strobe light feedback with frontal electrode position. Subjects for this type of training are carefully screened as there is a remote possibility of triggering an epileptic seizure in those who are prone to them. We do not recommend that individuals undertake this type of training except with professional supervision.

IMAGERY

Most EEG research has been carried out in studies of the occipital-parietal area of the brain. One such study, conducted by K. Slatter (1960) in England, suggests that occipital EEG can be used to determine the capacity of a person for visual imagery. He found that people who are "visualisers" (i.e., who think in pictures) tend to generate less occipital alpha than people who are "verbalisers." Apart from active vision, non-visual people have some difficulty attenuating alpha.

Most of the people in the Slatter study represented a cross between visualizer and verbalizer types. When given a problem to ponder that required thought in verbal terms, alpha would not be blocked. When asked to recall an image or perform some task of thought that required visualization, the alpha would give way to beta. This suggests a possible correlation to the yogic practice of mantra meditation--the repetition of a word or phrase to occupy the mind and hold off visual or other thought.

Slatter noted that mental imagery did not attenuate alpha to the degree that visual attention to an external object did, except in a few cases of extreme visual imagination. Also, visual imagination appears to have its own particular frequency of brainwave (Slatter, 1960; Shipton and Grey Walter, 1957). When subjects are engaged in visual imagination or recall, 12 Hz alpha/beta waves appear in the EEG. This suggests the possibility of cultivating creative visualization through the use of a narrow band filter which gives feedback only for the 12 Hz frequency (our speculation). Slatter noted that anxiety (more than sometimes caused by Subjects' uneasiness in laboratory situations) can block alpha generation and confuse statistical results.

ATTENTION

The concept of attention is one of the most controversial issues in circles of EEG research today. The term has been in general use with little semantic doubt cast upon it; but lately neurophysiologists are attempting to define it by its physiological correlates and asking themselves, "just what do we mean when we say 'attention'." To treat a complex subject briefly, attention (particularly visual) blocks alpha production. If a person is relaxed, alert, but paying no attention to anything in particular, the chances are high that he will be generating alpha, at least occipitally. If he is presented with a visual display and responds to it, if his attention is caught by it, his brain will shift into beta (Evans, Mulholland (eds.), 1969).

There have been several studies at the UCLA Brain Research Institute which have dealt with the ability of monkeys to solve game problems under conditions of simulated space flight. In one case reported in the popular media, the simian astronauts were taught to play "tic-tac-toe" (Newsweek, June 21, 1971). When the deeply planted electrodes indicated fast, low amplitude activity, the monkeys performed well. As the brainwaves shifted to alpha, they would make errors. On the basis of EEG, the researchers were able to predict with very high accuracy the likelyhood of mistakes.

In another study the monkeys were taught to match a button with a light of the same geometric shape; e.g., when the triangular light would flash, pushing the triangular button would yield a food reward (Berkhout, Adey and Campeau, 1968). Slow wave activity accompanied error, while fast wave activity tended to accompany correct choices. The monkeys could respond to light as a nondescript stimulus without emerging from the slow wave pattern; but in order to perceive it as a specific form and respond correctly, fast waves were needed.

Work is being done in the encephalographic study of attention by Dr. T. B. Mulholland (Mulholland and Runnels, 1963). He has assembled an attention correlated slide projection system based on a brainwave filter-computer. In one mode of operation, this device projects an image on the screen when alpha is attenuated, the attention thus being focussed. If the Subject slips back into alpha, the image disappears.

He suggests that this may be used as a trainer to increase the attention span of Subjects (by learning to hold an image on the screen for long periods and perhaps by learning to generate higher amplitude beta waves). Also, it may be used to test the applicability of images for use in teaching situations' images held longer would be the more attracting and involving.

He notes, however, a number of limitations on this general theory. The most prominent is the fact that in some people, oculomotor activity--the movement of the eyes--can cause EEG changes which are not always related to the focussing of attention. For instance, if the eyes are turned upward as far as possible, alpha generation is increased (reliably in those for whom this trick works). This suggests the Yogic practice of looking upward at the "ajana" (a' juh nuh), or "third eye."

Oculomotor changes, such as focussing or moving the eyes, may themselves be correlated with, or at least coincidental with, changes in attention. As well as the EEG/attention work of Dr. Mulholland and others, there is Paul Bakan's suggestion that the conjugate latteral eye movements (CLEMS) of a Subject indicate which hemisphere is being used for thought (Psychology Today, April, 1971). Dr. Mulholland points out, however, that the correlation is weaker in some people than in others, such as those who produce nearly no alpha at all (to Rosenberg, 1969).

In recent studies of the nature of attention at the Langley Porter Neuropsychiatric Institute in San Francisco, Kamiya and others have examined the responses of Subjects to different images using a projection system similar to Mulholland's. In one instance, an image of a nude held the Subject in beta, while flowers precipitated a shift into alpha.

Perhaps the concept of attention would be easier understood as a facet of the broader category of "attachment"--a term frequently used by people in traditional Oriental meditation. In this usage, anxiety, (occipital) visual thought processes, (temporal) classifying and verbalizing, (frontal) caring and valuing, (parietal) somatic discrimination, and general "attention" to structured, named and formalized external reality would all be forms of attachment. Interestingly enough, all tend to be associated (albeit loosely) with beta waves in their respective cerebral quarters.

Maurice Merleau-Ponty (1960), the French phenomenologist, suggested that attention was really "intention." That is, by paying attention to a structured object, by naming it, we give it its structure; we cause its manifestation by recognizing its manifestation. This statement is highly speculative in Western circles, where reality has long been held to have its own concreteness quite apart from our attachment to it. To Zen people, Yogins, Taoists and others of similar Oriental leanings, the idea is nothing new. "The named is the mother of all things," begins the Tao Te Ching (Lao Tzu, Tao Te Ching).

Berkhout, Adey and Campeau (1968) noted that monkeys could respond to unstructured stimuli without shifting into beta, but to see a square as a square (not just as "that") required the faster pattern. In circles of Eastern "religion," non-attachment is held as an ideal. Kasamatsu and Hirai (1966) pointed out that the Zen men in their study maintained a steady responsiveness to stimuli with no habituation. They generated loud, evenly contoured alpha rhythms in spite of the fact that their eyes were held open. This would perhaps indicate that they see their world only as "that," not as this and this and this.

Mulholland (to Rosenberg, 1969) has suggested that brainwave feedback could be used to develop one's "attention span." Learning to suppress alpha waves at will and for long periods, learning to produce a more intense and longer lasting beta signal, may be the key to performing tasks of concentration with greater ease. The results of these studies suggest that it would also be possible to cut down on mistyped words, hammered thumbs, and other botching.

PRACTICE

One of the most important keys to establishing an individual program of brainwave feedback training is finding a useable level of difficulty. Kamiya noted that when he used Zen monks as Subjects for experimental alpha training, they did exceptionally well--but "so what?" The experiment was for them no particular challenge, and they shifted into alpha easily. The experiment did not precipitate any startling changes in consciousness.

In using brainwave feedback to enhance an internal state that could loosely be called a "high," it is desirable that there be some alpha in one's natural brainwave pattern, but not too much. If there is some alpha, the individual can culture and favor it, bringing it up in volume and down in frequency. If there is no detectable alpha present, as appears to be the case with about 8% of the population (Rosenberg, 1969), learning to generate it only by feedback is naturally difficult. If there is too much alpha, its production is no challenge. This suggests the old movie image of a plane throwing baggage out to clear a frosted mountain pass. First, the plane has to get off the ground. If it is already higher than the pass, it doesn't need to discard any baggage. If it is in the air but lower than the pass, the experience will certainly be a cathartic one.

In the cases of people experiencing altered states of consciousness through brainwave feedback training, it is difficult to know what is the operative factor. It appears to have some relation to this "baggage throwing." It has been found that brainwave activity relates rather closely to the degree of adeptness of Zen meditators (Kasamatsu and Hirai, 1966). We have also observed that in using brainwave feedback to alter consciousness, a shift into alpha accompanies the internal, motionless exhilaration we choose to refer to as "high."

Still, there is room to suspect that it is not the objective shift in frequencies that is the source of the unique sensations brought about through brainwave feedback, but rather the inward-looking that the practice facilitates. In more direct terms, this looking inside to see just what is going on, this strongly deliberate sensing of internal states to see what changes the tone, could as easily be the source of these sensations as the presence of a given brainwave. In Sanskrit (the classical language of India) this inward looking is called "avritti chakshus." Ramana Maharshi (1968) suggests that all meditative forms--breath control, mantra (chanting), mouna (not speaking), etc.--are methods of developing this internal orientation. In chanting and breath control, the attention is drawn to the diaphragm area by the vibration of the voice and the passage of air. In brainwave feedback the attention is turned downward because it accompanies a shift into alpha.

In order to use the ALPHAPHONE headset, ALPHAPHONE brainwave analyzer or ALPHAPHONE basic e.e.p. to best advantage, people who find they generate too much or too little alpha should make efforts to get into the middle category of normal difficulty. Often, the right hemisphere tends to produce more alpha than the left; people with some difficulty generating alpha might first try the right hemisphere electrode position. Another approach would be to place both red electrodes at the back of the head to pick up alpha from both occipital lobes. Those whose thinking is very visual may experience some difficulty getting into alpha at first, but tend to get higher when it is finally accomplished (as verbal people would get by letting go of words).

There are control adjustments on the various instruments which are intended to allow for differences in brainwave intensity. On the ALPHAPHONE headset and the ALPHAPHONE basic e.e.p., there is a sensitivity control which varies the instruments' responses to different brainwave intensities. Turning it up makes it respond to weaker alpha; turning it down does the reverse. It should be left so that whatever alpha is present is just barely audible--this way increases in amplitude are easily heard. If there is little alpha present, the sensitivity should be turned up so that weak alpha will register. On the ALPHAPHONE brainwave analyzer, there is both an ANALOG SENSITIVITY control (only operative in "ANALOG" function), which is the same as the sensitivity control on the headset and basic e.e.p., and a NOISE THRESHOLD. The latter sets the minimum amplitude that a signal has to have to not be considered noise. As with the sensitivity control, it is adjusted according to the strength of one's brainwave signal.

If no manipulation of the controls or movement of the electrodes produces a detectable alpha signal, try other environments and other times of day (or night). Having people about wondering when/if you are going to produce some alpha doesn't help at all. Patience is an extremely useful talent in this regard, as alpha isn't always immediately heard even in those with some adeptness at brainwave control. People who have difficulty generating alpha might try sitting still and erect in a dim and quiet place, breathing very slowly through the nose and directing attention to the breath, feeling it fill the lungs. People who produce lots of occipital alpha, even with the sensitivity down, might try proceeding directly to frontal and temporal alpha control.

As a first principle in learning brainwave control, we might suggest that you make yourself comfortable. Concern over supporting the body may tend to hamper the focus on internal states necessary to this training. Oriental disciplines, whatever their differences in dogma and practice, often recommend that the meditator sit in what is commonly called the "lotus posture." Basically, this is a way of sitting (with the legs fully crossed, with or without a pillow) so that the spine is straight and erect, the body balanced and the muscles relaxed. In this posture, turning the attention away from the body won't cause it to topple over. If the lotus posture is grossly uncomfortable (as it is for most Westerners), the purpose is defeated, and another suitable position should be found. Sitting in a straight back chair, such as a dining chair, works quite well. In any case, the body should be comfortable, uncramped and fully supported by whatever position the Subject should choose.

It must be re-emphasized that the use of an encephalophone for brainwave-feedback training is a practice. That is, while the method is comparatively fast, the results are not often instantaneous. As with other mental practices, it will usually be found that depth will increase with the frequency and the duration of the meditative sessions.

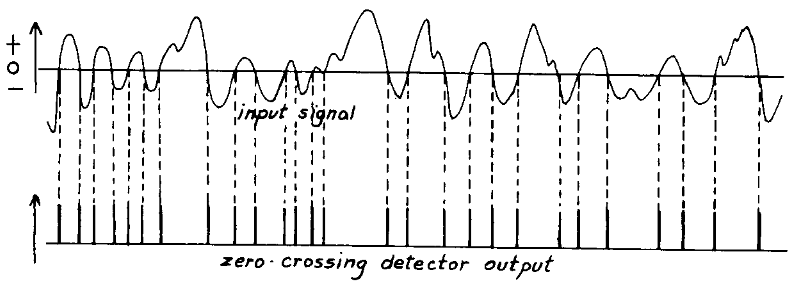
CIRCUIT DESCRIPTION

There are three main techniques available for frequency analysis of brainwave signals: analog filters, digital filters, and fast fourier analysis. There are advantages and disadvantages to each.

Fast fourier analysis, using an expensive digital computer, is the most complete and accurate in the information it yields. It gives very exact frequency, amplitude, and phase information, but is quite costly.

Analog (bandpass) filters are another means of getting both frequency and amplitude information (power spectrum). However, they have marked limitations. Very sharp cut-off filters tend to be rather expensive, due to the large number of stages needed. They are also subject to ringing if excited by a fast rising wave form (such as some artefacts) -- thus giving rise to false brainwave signals. Another problem is their slow rise time: it may take several cycles of a repetitive wave form to excite the filter to accurate output levels. Of course, these drawbacks may be avoided by not using sharp cut-off filters, but this leads to a gross loss of frequency accuracy.

For most types of analysis, a digital filter system provides a workable solution. Digital filters are circuits which can determine the dominant frequency of a wave form quite accurately and inexpensively. They do not yield any information on amplitudes or power spectra. Their basic building block is a zero-crossing detector, which produces a pulse every time its input wave form passes through zero potential (see diagram below). The balance of the circuitry simply measures the interval between pulses, thus measuring the period (and the dominant frequency) of the input signal. As can be seen from the diagram, the other frequency components of the wave form are ignored by this circuit, which is its major drawback.



A digital filter alone provides frequency information only. It is very easy to build digital "bandpass" filters with ± 5% cut-off frequencies (e.g., 8Hz ± 0.4Hz to 13Hz ± 0.65Hz)--a performance that is costly with analog filters. On the other hand, a digital filter presents much less information: it merely indicates whether the dominant frequency component of the zero-crossing was inside or outside the chosen frequency limits. The corresponding analog filter would pass all of the signals within its passband (preserving amplitude information within the limits of its tendency to ring and/or rise slowly) while rejecting all but the strongest signals outside its passband.

The information yielded by a digital filter may be usefully supplemented by the use of amplitude measuring circuits of the threshold detector type. Thus, a circuit may be added which will insist that the input signal exceed a minimum level at some point between each pair of zero-crossings in order for it to be sorted into one of the frequency categories. Another circuit may be added which insists that the input not exceed a preset **maximum** level in order for it to be sorted into one of the frequency categories. This is the ALPHAPHONE brainwave analyzer: a digital filter sorting circuit with high and low amplitude limits.

The ALPHAPHONE brainwave analyzer is a system designed to perform basic brainwave frequency and amplitude analysis on a real time basis, thus making it a very useful and flexible bio-feedback system. The incoming EEG signal is sorted into one of six categories once each cycle (every other zero-crossing). The brainwave analyzer will indicate, during any given cycle, the category into which the previous cycle was sorted, thus providing extremely short latency.

The six categories are: ARTEFACT (above the preset maximum amplitude level), NOISE (below the adjustable minimum amplitude level), BETA (above 13Hz), ALPHA (8Hz to less than 13Hz), THETA (4Hz to less than 8Hz), and DELTA (less than 4Hz). Toggle switches enable the user to disable either (or both) of the amplitude limitations.

The ALPHAPHONE brainwave analyzer contains internal provisions for auditory and visual feedback. A three position FUNCTION SWITCH allows the user to select one of three types of feedback: ANALOG, DIGITAL- or DIGITAL+. In the ANALOG position, one hears the same warbling AM-FM sound heard in the ALPHAPHONE headset. The selection of this function does not disable the digital filter circuit.

In the DIGITAL- position, the user hears a tone which becomes silent only if the EEG signal falls into the selected frequency category. In the DIGITAL+ position, the user hears a tone only if the EEG signal is of the correct frequency.

A four position FREQUENCY SWITCH allows the user to select the frequency range desired (e.g., ALPHA, BETA, etc.). An INTEGRATED PERCENT TIME METER indicates the percentage of time one spends in the selected frequency range. Six light emitting diodes are mounted on the ALPHAPHONE brainwave analyzer's front panel, one for each of the six categories into which an EEG signal may be sorted.

Eight "banana" jacks are mounted on the ALPHAPHONE brainwave analyzer's panel, adjacent to the light emitting diodes. Six of them are for the six categories, one is common ground and the last is a clock pulse output. The CLOCK output provides a 10 volt positive pulse (200 microseconds long) once each cycle of the EEG signal. The six category outputs provide logic signals suitable for driving accessory equipment. The outputs are "high" (more than 3.0 volts), except when the EEG signal is sorted into the chosen category. In that case, the output becomes "low" (less than 0.5 volt). The current drawn by these outputs shouldn't exceed 1 milliamp.

OPERATING INSTRUCTIONS

Before operating the ALPHAPHONE brainwave analyzer, please read these instructions carefully.

BATTERIES

The brainwave analyzer is shipped without batteries. This is done for two reasons: The batteries are more expensive to ship than they are to buy locally, and the added weight of the batteries inside the analyzer would make it more subject to shipping damage from rough handling. If you have occasion to ship your analyzer, it is best to remove the batteries first.

The analyzer uses 6-volt lantern cell batteries. They usually can be found in hardware stores. Lantern batteries come in two main types: Those with screw terminals and those with spring terminals. Although the analyzer is designed to use the screw terminal lantern cell (such as Burgess F4BP), the spring terminal type can be used in a pinch.

In any case, the batteries are mounted in the bottom compartment of the brainwave analyzer. To open the battery compartment, unscrew the four screws holding the rubber feet on the bottom panel and unscrew the two plain screws in between the rubber feet (a total of six screws). Then lift the bottom panel out of the analyzer's box. Because the bottom panel is recessed, you may have to pry it up by poking a screwdriver into one of the screw holes.

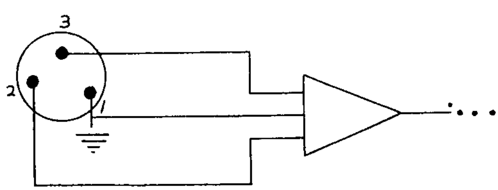
When the bottom cover plate comes off, you'll find that it is still attached to the analyzer by a cable. This is the cable attached to the NORMAL/SWITCHED ANALOG and BATTERY TEST switches. The cable is long enough for you to set the bottom cover next to the brainwave analyzer. If you look inside the battery compartment, you will find a diagram showing the proper battery connection scheme.

First of all, put the four batteries inside the battery compartment, being careful not to pinch the cable between the batteries and the compartment wall (the cable belongs in its slot), and being careful to align the battery terminals as shown in the battery connection diagram. The positive, or corner, terminals should face up and to your right.

Once the batteries are properly in place, connect the battery wires as shown in the diagram. If you have screw terminal batteries, just slip the spade lugs under the screw caps and tighten them. If you had to substitute spring terminal batteries, bend the springs to pinch the spade lugs between the bottommost coils of the springs. Two short green jumper wires are supplied to connect the batteries into two separate 12-volt pairs. Please note that the four batteries are NOT all connected together in series. If you connect the batteries exactly as shown in the diagram, you can't go wrong.

Once the batteries are connected and before you replace the cover plate, tip the analyzer on its side and turn it ON. Then operate the BATTERY TEST switch by sliding it to one of its extreme positions. The front panel meter should indicate well over 60%. Then push the BATTERY TEST switch to its other extreme position. The meter should read well over 60% again. The two meter readings probably won't be equal. If both pairs of batteries check out OK in this test, turn the analyzer off, tip it back over and carefully replace the bottom cover plate. Be careful to stuff the excess cable into the empty space next to the battery compartment, and don't pinch it between the batteries. Tighten all six screws.

Once you have a set of batteries installed, all the analyzer lacks is electrodes. Most brainwave analyzers are shipped with a standard bipolar electrode set with a four-foot cable. A bipolar electrode set has three electrodes: Two red "hot" electrodes and one black "ground" electrode.



INPUT JACK WIRING

The bipolar hookup is the most popular one because its three electrodes enable it to take advantage of the brainwave analyzer's differential preamplifier. The major source of interference in measuring brainwaves is 60 Hz powerline hum. In most houses and laboratories, the hum field caused by the powerline wiring is hundreds, or even thousands, of times as strong as the brainwaves you are trying to measure. A differential preamplifier uses something called common mode rejection to cancel out the 60 Hz hum while picking up the brainwave signals. To do this, it needs two input electrodes and a ground electrode.

In experiments which can be run outdoors away from powerlines, and in laboratories where a shielded room is available, the monopolar or two-electrode hookup often is used. Aquarius sells a monopolar electrode set for the brainwave analyzer (catalog No. CN7, $10).

You will probably notice that the brainwave analyzer picks up signals when nothing is connected to its electrodes and even when no electrodes are plugged into its input jack. This is normal and does not indicate any malfunction of the instrument.

The analyzer's preamplifier (which is connected to the input jack) is a very powerful and sensitive amplifier which is capable of amplifying the very weak brainwave signals to usable amplitudes. It is more sensitive than the average radio receiver's amplifier, and, like a radio, it will pick up signals broadcast from its surroundings.

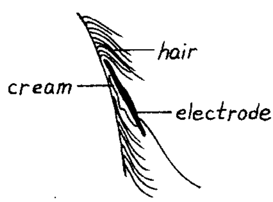
The preamp has very high impedence. This impedence normally is terminated by the comparatively low impedence of the electrode connections to the scalp, and in that condition it does not pick up broadcast interference from powerline wiring, etc. When the electrodes aren't connected, they will act as antennas and will pick up random signals from the air. These account for the weak signals the analyzer will display when the instrument is connected to nothing.

In most experiments, the electrodes are held in place with an elastic headband. The headband supplied with your analyzer can be made smaller with a Velcro closure. It should be adjusted tightly enough to hold the electrodes firmly in contact with the skin, while leaving the headband loose enough to avoid discomfort, especially in long sessions with the analyzer.

The electrode hookup we suggest for primary alpha training is: One red electrode at Fp1, another at O1 and the black ground electrode at Fp2. These placement designations are explained on Page B8 of this manual. The reason for this electrode placement is simple: It puts two electrodes on the forehead, away from hair, and it will pick up occipital alpha (the most commonly produced).

A good contact between the electrodes and the skin is absolutely essential to proper operation of the brainwave analyzer. The skin in the area where the electrodes are to be applied should be clean and free of dead skin. It is a good idea to scrub if possible, though it is not absolutely necessary. Electrode cream is used between the electrode and the skin to ensure good contact. Although any commercial EEG contact cream will work well with the brainwave analyzer, we have found that a commercial hairdressing, GROOM AND CLEAN, also works well and it is obviously much more compatable with the hair.

The two electrodes to be placed on the forehead will need only small dabs of GROOM AND CLEAN to assure good contact. Of course, the electrode cream goes on the silver side of the electrode and that is the surface which touches the skin. The electrode placed



at O1 will require more electrode cream. As in any placement of an electrode in an area where there is hair, be careful to part the hair (it isn't necessary to shave any hair off the head), to expose bare skin before applying the electrode. It is very important that the silver electrode surface actually is in contact with bare skin. The electrode will feel cold on the back of the head when it is properly in place.

For people with very thick, curly hair, such as a "natural," special measures sometimes are needed to assure a good electrode contact. A cotton pad soaked in electrode cream or in salt solution can be placed between the electrode and the scalp to make good contact despite the thick hair. In this case, the silver electrode does not have to touch the scalp. Contact is made through the electrically conductive cotton pad.

Once the electrodes are properly in place, the electrode cable can be plugged into the INPUT connector on the brainwave analyzer. Then the analyzer should be adjusted to produce the same AM-FM representation of the brainwave signal as the ALPHAPHONE headset. This is called the ANALOG sound, and it provides the best means of checking the electrode contacts, the operation of the brainwave analyzer and the subject's state of relaxation. Very tense scalp and eyelid muscles will produce artefacts which block brainwave measurement. This check, using ANALOG sound, should be done every time you hook up the analyzer.

To listen to the ANALOG sound, adjust the analyzer's controls as follows:

ANALOG SENSITIVITY: Full clockwise (CW)
TONE: Full CW
FREQUENCY SELECTOR SWITCH: Any position
FUNCTION SELECTOR SWITCH: ANALOG
ON/OFF VOLUME CONTROL: Full CW
NOISE THRESHOLD: Any position
ARTEFACT THRESHOLD: Either position) These are the four toggle
NOISE SUPPRESSION: Either position (switches, three along the
ARTEFACT SUPPRESSION: Either position (upper right edge of the pa-
TIME CONSTANT: Either position) nel, one next to the meter.
NORMAL/SWITCHED ANALOG SWITCH: Either position
BATTERY TEST SWITCH: Center position.

The sound you should hear with the controls set as listed above are recorded on the ALPHAPHONE headset instruction record, a copy of which is included with your brainwave analyzer. In this test you should first check to be sure the brainwave sounds don't have the rasping quality which the pickup of 60 Hz powerline hum produces. Such rasping is an indication of either a poor electrode contact or, much less likely, an unusually high level of electrical interference from fluorescent lights, electric motors, etc. Check your electrode contacts and, if necessary, move away from any source of strong electrical interference. With a bipolar electrode hookup, a few feet is far enough away from any noise source to keep hum to a minimum.

Once you are sure the electrode contacts are good, as evidenced by a clear warbling tone from the analyzer, next listen for eyeblink and muscle twitch artefacts. Examples of these also are recorded on the ALPHAPHONE headset instruction record. If you hear many artefacts, tell the subject to relax and point out to him the sounds produced by muscle tension and eyeblinks. People often are tense when first hooked up to a brainwave analyzer; a few minutes of familiarization should cure this tenseness.

Once you hear a clear and resonably artefact-free brainwave signal, you are ready to make use of the analyzer's automatic brainwave analyzing circuitry.

To make good use of the automatic analyzing circuits, you should understand what they do. First of all, it is important that you understand that each cycle of the brainwave signal is measured individually. The peak amplitude of each cycle is measured by the analyzer. Unless you have deliberately disabled the ARTEFACT SUPPRESSION circuit, any extremely high amplitude cycles will be rejected on the assumption they probably are not brainwave signals but rather eyeblinks and/or muscle twitches. In other words, the ARTEFACT SUPPRESSION circuit sets a maximum amplitude level above which the brainwave signal cannot cross and still be measured.

Unless you have deliberately disabled the NOISE SUPPRESSION circuit, there is also a minimum amplitude against which each cycle of the brainwave signal is compared. If the brainwave signal falls below the minimum amplitude limit, the analyzer considers it too weak to measure accurately, and it will be sorted into the NOISE category. The NOISE category is really a "below minimum amplitude" category. We chose to call it NOISE so the lettering would fit easily on the analyzer's front panel.

If a cycle of the brainwave signal falls between the two amplitude limits, then its period will be measured and it will be sorted into a frequency category. In the case of the standard brainwave analyzer, this means that:

Frequency over 13 Hz is BETA
Frequency between 8 and 13 Hz is ALPHA
Frequency between 4 and 8 Hz is THETA
Frequency less than 4 Hz is DELTA.

You will find that most people's brainwaves are a mixture of several brainwave types. A common mixture is about 15% theta, 30% alpha and 50% beta; this mixture of brainwaves might be measured from someone whose eyes are open but who is relaxed. The brainwave analyzer's six category lights are turned on only one at a time, but because of the mixture of brainwaves most people make, two or three of the lights may appear to flicker on and off at the same time.

To make best use of the automatic analyzing circuitry of the brainwave analyzer, it is necessary to adjust the front panel controls properly. There are many possible sets of control adjustments. We will detail only a few here.

The analyzer's various controls can be grouped together, for purposes of discussion, by their related functions. For example, the three toggle switches on the upper right edge of the front panel are all adjustments which affect the analyzer's amplitude limits. The first switch is the ARTEFACT THRESHOLD. It sets the maximum brainwave amplitude.

If the brainwave analyzer didn't have artefact suppression, it would often be fooled into believing that signals like eyeblinks and muscle twitches were brainwaves. This would lead to inaccurate measurements.

The more relaxed someone is, the fewer eyeblink and muscle twitch artefacts he will produce. In some experiments, so few artefacts are seen that it may be possible to do away with the artefact suppression altogether by flipping the ARTEFACT SUPPRESSION switch to its DISABLE position. Otherwise, in normal circumstances, you'll want the artefact suppression working for you to eliminate as many as possible of the electrical signals that don't originate in the brain.

The analyzer detects artefacts because they are unusually high in amplitude. The ARTEFACT THRESHOLD determines just how high in amplitude a signal must be before the analyzer discards it as an artefact. You will want to set this threshold as low as you can without discarding real brainwave signals. For an average person you can set the threshold on LOW. Some people have high enough amplitude brainwaves to exceed the LOW setting. For them you'll want to use the HIGH setting. In any case, the idea is to set the control as low as possible without losing any valid brainwaves. That way you'll reject as many artefacts as possible.

If you find yourself measuring the brainwaves of someone like a Zen monk, then you may have to disable the artefact suppression completely, because his brainwaves are so intense they cross even the high threshold.

As with any other function of the analyzer, the best check of how you've set this control is to listen to the analog sound: See if the signals you recognize as eyeblinks are being properly designated as artefacts and if the signals you recognize as real brainwaves are being recognized as such by the brainwave analyzer.

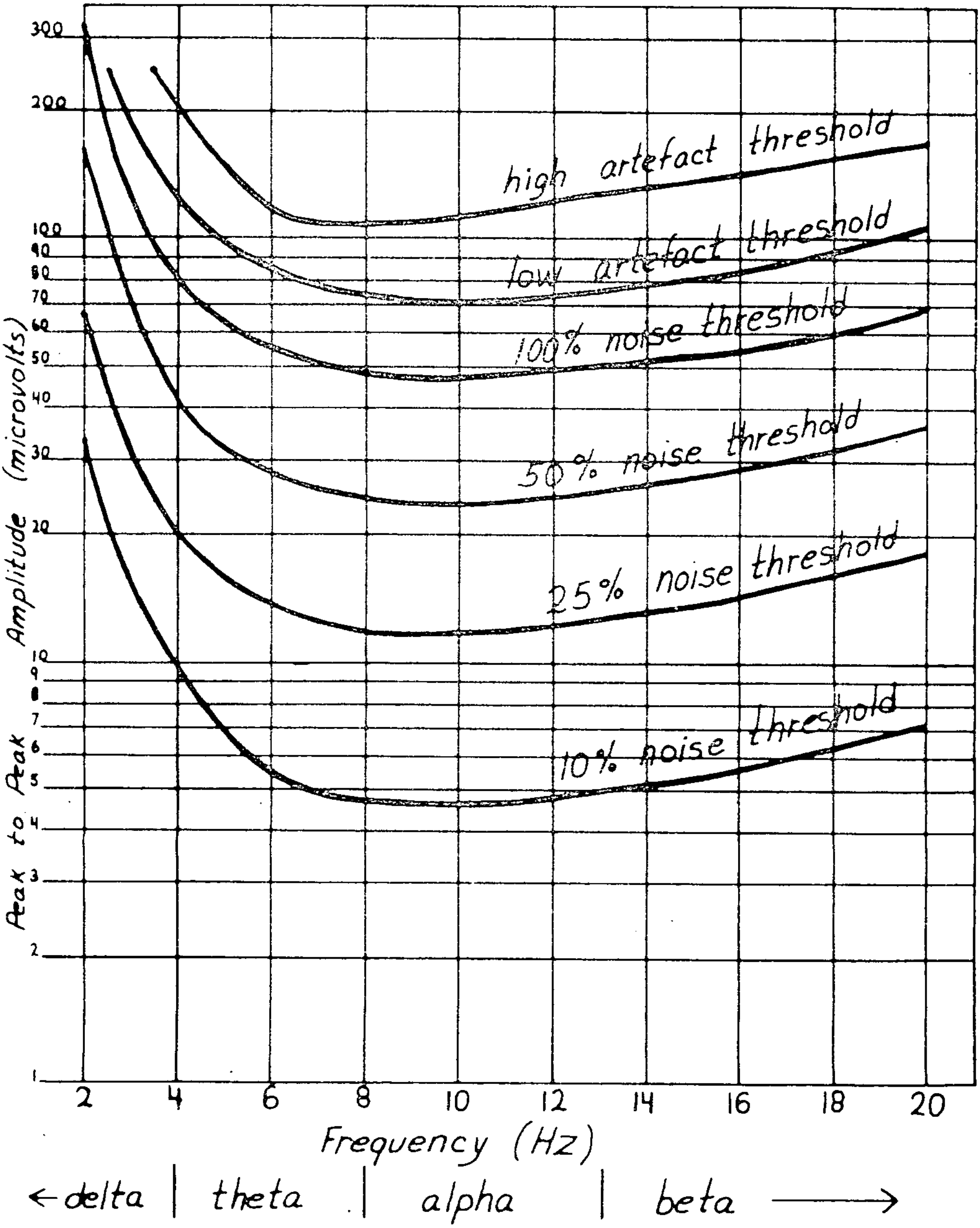
The NOISE THRESHOLD adjustment is located to the left of the loudspeaker. In normal use, this knob is set to about 20%. That sets a minimum amplitude threshold of about 10 microvolts. Brainwaves weaker than 10 microvolts will be considered to be "noise" by the analyzer, while any stronger than 10 microvolts will be measured as brainwaves (provided they aren't so strong as to exceed the artefact threshold).

If you are practicing beta feedback, you may want either to reduce the NOISE THRESHOLD setting, or perhaps completely disable it with the toggle switch provided for that purpose. This is because beta is very weak in amplitude and might not exceed the 10-microvolt noise threshold setting usually used for alpha or theta feedback.

The NOISE THRESHOLD control can be used to measure the amplitude of your brainwaves. If you just keep raising its level until the brainwave type you are measuring no longer registers, then you will have reached the setting corresponding to its maximum amplitude. The calibration curve below will show you the amplitude corresponding to any setting of the NOISE THRESHOLD for a particular frequency range.

Turning the NOISE THRESHOLD up beyond 20% is also a way to cultivate higher amplitude brainwaves. By raising the "noise threshold," you are insisting that you make stronger brainwaves before the analyzer will reward you with the feedback signals.

Typical Calibration Curves



CALIBRATION CURVES

You will note from the chart on the opposite side of this page that the numbers on the NOISE THRESHOLD dial are arbitrary. The actual cutoff point varies with frequency. In other words, when it is set at 25%, a 13 microvolt brainwave at 10 Hz probably would be sorted into the ALPHA category, but a 13 microvolt wave at 5 Hz or 18 Hz probably would be treated as noise.

When training for alpha, a subject usually starts with the NOISE THRESHOLD at about 20% and increases the setting as training progresses, but for beta training, where the brainwaves normally are low amplitude, you might want to start with NOISE THRESHOLD at 0%.

Even at 100%, the NOISE THRESHOLD control never cuts out all brainwaves. In fact, it does not overlap the low ARTEFACT THRESHOLD. There still is a narrow window for detection, but if training for high-amplitude alpha, for instance, it probably would be wise to set the ARTEFACT THRESHOLD to high or to disable it entirely.

The curves on the chart are typical, but they will differ slightly with each instrument. Researchers probably will find it usefulto have their own sets of curves that are specific to a particular machine's NOISE and ARTEFACT THRESHOLDS.

To calibrate your own curves, you must use a signal generator which will supply synthetic signals of known amplitude and frequency.

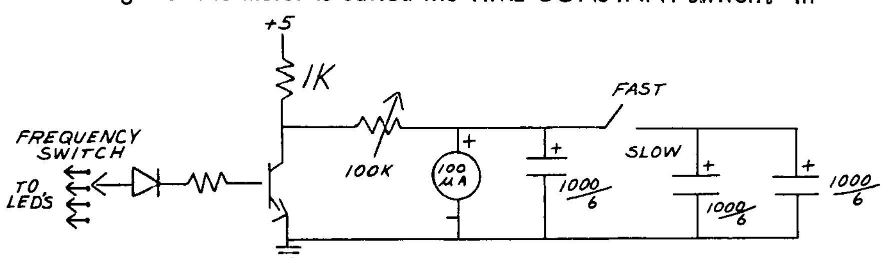
To summarize, for normal use you will set the controls as follows:

NOISE THRESHOLD: 20%
ARTEFACT THRESHOLD: Low) This means all three toggle
NOISE SUPPRESSION: Enable) switches will have their handles
ARTEFACT SUPPRESSION: Enable) in the "down" position.

Although the brainwave analyzer filters for all four types (beta, alpha, theta and delta) of brainwaves at once, only one brainwave type is selected to control the analyzer's feedback sound and the PERCENT TIME meter. This selection is make with the FREQUENCY switch, which is just to the left of the NOISE THRESHOLD control.

If you are training for alpha production, for example, you will set the FREQUENCY switch to alpha. This will cause the analyzer to display on the PERCENT TIME meter the fraction of time you spend in alpha (within the amplitude limits you have chosen with the noise and artefact thresholds). If you are making a mixture of half alpha and half beta, the PERCENT TIME meter will indicate 50% alpha.

The meter's readings are an average of your brainwave production taken over a period of time. The toggle switch located just to the right of the meter is called the TIME CONSTANT switch. In



the FAST position, the meter averages over a period of about 2 seconds, while in the SLOW position, it averages over about 5.5 seconds. Most people usually use the slow position because the longer time constant lets them work on a brainwave control task with eyes closed for awhile, and then open the eyes for a peek at the meter reading before it begins to change (due to the change in brainwaves caused by opening the eyes). The fast position is handy for measuring rapid fluctuations of brainwaves.

In many experiments it is desirable to keep track of percent time spent in each of the brainwave types. The Model 1502 percent time chart recorder does this. Its four pens record independently the fraction of time spent in each of four brainwave states. Since it is recording percent time instead of the EEG signal itself, very little chart paper is consumed, even in fairly lengthy experiments. This feature makes the 1502 one of the more popular brainwave analyzer accessories.

Once you've chosen the frequency range you wish to train for or measure, the only remaining decision is the choice of feedback sound. Much brainwave feedback training is done with the eyes closed, especially elementary alpha training, so the feedback sound is quite important.

The analyzer offers a choice of seven different feedback sounds. You will need to experiment to find which sound works best for a particular training session. The table below shows how to adjust the controls for each of the seven possible feedback sounds. For the purpose of this example, we are assuming that you are training for alpha. The same settings apply for beta or theta training, only the FREQUENCY switch setting will be different.

The switched analog feedback tones are especially useful for training subjects to recognize the various sounds different brainwave types produce in an AM/FM eep, such as the ALPHAPHONE headset or basic eep. There is one factor to watch for when using the switched analog feature: Short (one- or two-cycle) bursts of a particular brainwave type will not sound as you might expect because the switched analog audio gate opens to let you hear the cycle after the one which fell into the desired category. For long bursts of the desired brainwave type this introduces negligible error, but for short bursts the error is large. The solution to this problem is to ignore short bursts and pay attention to the long ones. Of course, this applies only to using the switched analog feature as a training method for basic eep and headset users.

For feedback training in alpha as an aid to meditation, many

FEEDBACK SOUND TYPE	ANALOG SENSITIVITY	FUNCTION SWITCH	NORMAL/SWITCHED ANALOG SWITCH	EXT AUDIO INPUT
flat tone for alpha, silence otherwise	full CCW	digital +	normal	none
AM/FM tone for alpha, silence otherwise	full CW	digital +	switched analog	none
external audio for alpha, silence otherwise	any position	digital +	normal	yes
AM/FM tone for all brainwaves	full CW	analog	either position	none
silence for alpha, flat tone otherwise	full CCW	digital-	normal	none
silence for alpha, AM/FM tone otherwise	full CW	digital-	switched analog	none
silence for alpha, external audio otherwise	any position	digital-	normal	yes

NOTE: CW means clockwise, CCW means counter-clockwise.

people find the silent feedback for alpha with a tone otherwise is the easiest to work with.

It is possible to control the analyzer's feedback sounds and the percent time meter from more than one brainwave category at a time. For example, many people find it desirable to turn on a feedback tone whenever they are making either alpha or theta. To do this, set the analyzer's controls for alpha feedback and connect a jumper cable between the ALPHA and THETA category output banana jacks. A jumper cable is just a piece of wire with a banana jack at each end.

EXPERIMENTS WITH MOVING SUBJECTS

The ALPHAPHONE brainwave analyzer (or any other research quality EEG instrument) is sensitive enough that simply moving its electrode wires through the earth's magnetic field will generate electrical signals large enough in amplitude to mimic brainwaves. For this reason, the subject should be very still whenever possible. Otherwise, precautions should be taken so that movement artefacts will not produce inaccurate measurements.

If all of the electrode wires move together through the earth's magnetic field, the induced electrical currents will cancel each other out and no artefact will result. Thus, movement of the shielded large diameter black cable will not cause problems. But at its end the shielded cable ends and three unshielded wires continue for a foot or so to the site of the electrode on the subject's head. It is movement of these three wires relative to each other that can cause problems.

If your subject is going to be stationary, it is all right to let the heavy black electrode cable just dangle wherever it may. But if your subject will be moving at all, it is important to clip or fasten the end of the shielded cable to his clothing so it will not tug or jiggle the three smaller wires leading from its end to the electrodes. A clothespin clipping the cable to a shirt collar works pretty well. Another possibility is to run the shielded cable up under the headband so it is held firmly in place.

If you want to test to see if the movements your subject will be making will produce too many artefacts, one experiment you can run is to clip the electrode cable in place as you will in the actual experiment, then fasten the three electrodes firmly together with tape so that their silver surfaces are in contact. Slip the three electrodes under the headband to simulate their position on the scalp and have your subject move as in the planned experiment. Any increase of the usual small amount of internally generated noise from the brainwave analyzer due to movement artefacts will be immediately apparent.

ON INPUT AND OUTPUT JACKS

Their uses and misuses

> WARNING!! Do not connect any input/output to power line operated equipment without providing proper isolation. Failure to do so will not only introduce large amounts of power frequency noise (60 cycle hum) into the system, but may also lead to electrocution of the Subject (if the power line operated equipment used is improperly grounded or if it fails). See AQUARIAN* photon coupler data sheet.

The ALPHAPHONE brainwave analyzer has many accessory input and output jacks. It isn't necessary to use them, but they provide endless possibilities for expanding the analyzer into a sophisticated research system.

Care should be exercised in using the ALPHAPHONE brainwave analyzer's input and output connectors. They do not all share the same common lead. The seven banana jack outputs all have the eighth banana jack (GROUND) as common. This is the same ground which is common for the EXT AUDIO INPUT, EXT EEG INPUT and the main EEG INPUT connector. The FM OUTPUT, the EEG OUTPUT and the EXT PHONES OUTPUT all have -5 volts as common. Clearly the -5 volt common should not be shorted to the grounded common.

The mini-phone jacks provided for EEG INPUT and EXT AUDIO INPUT are of the switching type. This means that only the proper size mini-phone plug should be inserted into the jack. Using an improper size plug may deform the jack so much that the "normally closed" switch contact may remain always open, thus disabling a part of the circuitry of the analyzer. The phone jack provided for EXT PHONES is also of the switching type, and it should be used only with the proper size two-circuit (mono) phone plug.

EXT EEG IN

By using the EXT EEG IN jack, it is possible to use the analyzer's circuitry to measure and display brainwave signals from an external preamplifier. A hospital-type EEG machine may be hooked into the brainwave analyzer, for example. Or a special preamplifier with broader frequency response and/or lower noise may be used.

Other sources of EXT EEG inputs include recorded brainwave signals (either from an instrumentation tape deck or from demodulated recordings of the FM output).

Because the analyzer's accuracy depends on its zero crossing detector, it is very important that any EXT EEG INPUT be exactly referenced to ground. In other words, when there is exactly zero brainwave voltage, there should be exactly zero volts of EXT EEG INPUT.

If you decide to use an ALPHAPHONE headset as an EXT EEG INPUT, then the Model 502 photon coupler will provide the proper interface. It will isolate the signal, filter it for 60 Hz hum, amplify it and restore the zero DC level properly.

If you are using a laboratory EEG amplifier or some other source not built by Aquarius Electronics, be careful to observe the following:

1. The EXT EEG INPUT should never exceed 10 volts peak to peak at any time.

2. The best amplitude for matching the analyzer's input is 35 millivolts per microvolt of brainwave signal.

3. The EXT EEG INPUT's input impedence is 4,700 ohms bypassed by 0.2 microfarads. Your accessory preamp should be capable of driving such a load.

EXT AUDIO IN

The EXTERNAL AUDIO INPUT allows you to use the brainwave analyzer's digital circuitry to turn on and off any feedback sound you desire. As with all input and output jacks, any input to this jack must be isolated properly if it is from a powerline operated source. Such precautions are unnecessary if you use a battery operated source such as a battery operated casette tape recorder.

Plugging any audio signal into the EXT AUDIO INPUT will disconnect the internally generated tone from the analyzer's digital switching circuitry and substitute the new signal. The EXT AUDIO INPUT should be less than 12 volts peak to peak in amplitude. The output from most battery operated tape recorders is perfect.

The EXTERNAL AUDIO INPUT will be displayed by the brainwave analyzer only when the switched analog/normal switch is in the normal position.

INPUT

Although the INPUT jack isn't really an accessory input, it does deserve a bit more discussion. The electrode cable supplied with your brainwave analyzer plugs into the input jack. The standard cable is four feet long and has three silver disc electrodes at its end.

You can order other electrode cables from Aquarius, or you can make them up yourself. The four-foot cable can be extended by using shielded three-wire microphone cable; with some care in cable routing, the analyzer can be located 50 feet or more from the subject without excessive hum pickup. This can be very useful in laboratories where the subject and the experimenter aren't in the same room.

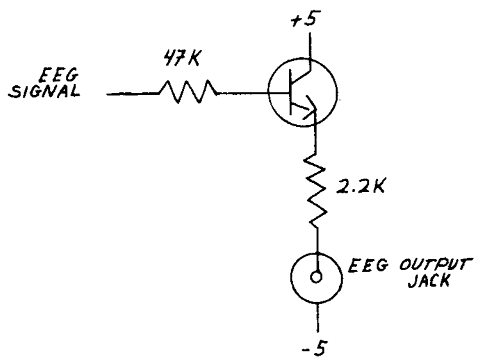
The alternate electrode cables available from Aquarius are described in our catalog. They include monopolar assemblies (two-electrode sets), assemblies with earclip grounds and extension cables.

The diagram on Page K2 shows how the input jack is wired. A switchcraft A3F is the matching connector which attaches to the cable.

EXT PHONES OUTPUT

Plugging a pair of earphones into the EXT PHONES OUT will cut off the sound from the analyzer's built-in loudspeaker and will supply the same sound to the earphones. This can be useful for feedback training in noisy locations, where earphones help block out background noise. In laboratories where the subject and experimenter aren't in the same room, the EXT PHONES OUT can be used to supply feedback signals to the subject via a long cable and a pair or earphones (or an efficient extension speaker).

The EXT PHONES OUT is a low impedence output. 8- or 16-ohm earphones will work best with it. For more volume, a battery powered amplifier may be used.



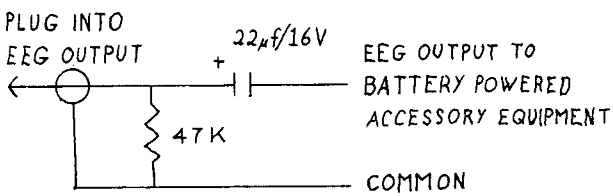
EEG OUTPUT

The EEG OUTPUT jack supplies the amplified brainwave signal without any feedback tone or other modifications. It is a current output designed specifically to drive the AQUARIAN photon coupler (Model 501A or 502). With the isolation provided by a photon coupler, this EEG signal may be displayed on an oscilloscope, chart recorder or other accessory.

The EEG OUTPUT jack is a mini-phone jack. It is a current output, as can be seen by the following diagram. It is intended to drive the AQUARIAN photon coupler accessory. The photon coupler provides the necessary isolation to safely use the EEG signal to drive powerline operated (AC) equipment.

The EEG signal may be used in a wide variety of applications. It can serve as input for a chart recorder or oscilloscope, allowing for visual analysis of brainwaves. It could be used as an integral part of a light show, or could control or modulate musical sounds.

Although the EEG OUTPUT is designed primarily to drive a photon coupler because most accessories are powerline operated, it is possible to adapt this output for use with battery powered accessories without the expense of the photon coupler. To do this, it is necessary to provide a large emitter resistor for the emitter follower output of the EEG OUTPUT jack. The diagram above shows the internal wiring of the analyzer. The diagram below shows the adaptation needed to make the EEG signal available for use with battery powered equipment.



FM OUTPUT

The FM OUTPUT jack is a mini-phone jack. It provides positive pulses about 5 volts in amplitude and about 200 microseconds in duration. Its output impedence is 100 ohms. The common side of the jack is -5 volts. The period between pulses is modulated by the EEG signal.

The FM signal is not as clearly intelligible to the human ear as the AM-FM signal presented by the ALPHAPHONEheadset or by the

ALPHAPHONE brainwave analyzer in its ANALOG position, but it is valuable for recording and telemetry in situations where any appreciable amount of amplitude modulation is undesirable. The recorded or transmitted FM signal is made usable by demodulation by the Model 620 demodulator, which converts the FM signal back into an EEG signal. The recovered EEG signal may then be used to drive chart recorders, oscilloscopes and other experimental tools.

The FM signal may be recorded directly using an inexpensive battery operated tape recorder. The purpose of recording the FM signal is simply to preserve the brainwave signal, as inexpensively as possible, in a form suitable for later analysis. Thus, the FM OUTPUT provides a means whereby, in a lengthy experiment, only the segments which actually turn out to be of interest would be demodulated and transferred to chart paper.

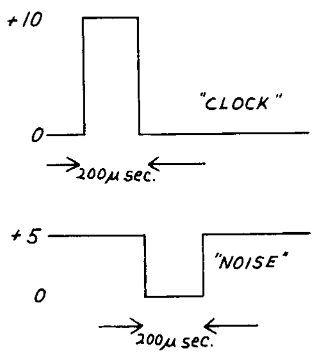
Most researchers using the FM OUTPUT will want to use a calibration oscillator, such as the Model 610, to calibrate the FM signal-tape recorder-chart recorder (or oscilloscope) system for sensitivity. The deviation of the FM OUTPUT will vary with different ANALOG SENSITIVITY settings.

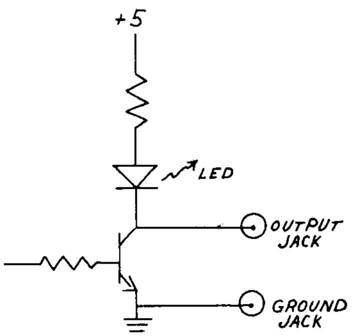
The AQUARIAN photon coupler, Model 501A or 502, which provides isolation for using AC powered equipment with the ALPHAPHONE brainwave analyzer, allows for recording on stereo or multichannel tape recorders. Thus spoken commentary, the AM-FM ANALOG signal, either of the DIGITAL signals and/or a timing signal can be recorded synchronously with the FM data.

BANANA JACK OUTPUTS

The ALPHAPHONE brainwave analyzer has eight banana jack outputs which may be used (with suitable isolation when AC equipment is employed) to drive an event recorder, accessory analysis equipment, other types of feedback, etc. There is a jack for each of the six catagories into which the signals can be sorted, plus CLOCK and GROUND. The six category jacks are connected to the light-emitting diodes used to indicate (instantaneously) the brainwave state. They provide TTL logic level signals with negative logic.

In the case of the four frequency categories, (BETA, ALPHA, THETA and DELTA), the outputs are normally "high" (more than 3.0 volts). The jack corresponding to the brainwave frequency of the last pair of zero crossings will be "low" (less than 0.5 volt). The ARTEFACT output is also normally high. It will drop to low if the brainwave signal exceeds the preset maximum amplitude. The NOISE output is normally high. In cases where the brainwave signal fails to exceed the preset noise threshold, the NOISE output will be briefly (about 200 microseconds) low at the end of the CLOCK pulse. All voltages are referred to the GROUND jack, which is common to the other seven banana jack outputs.



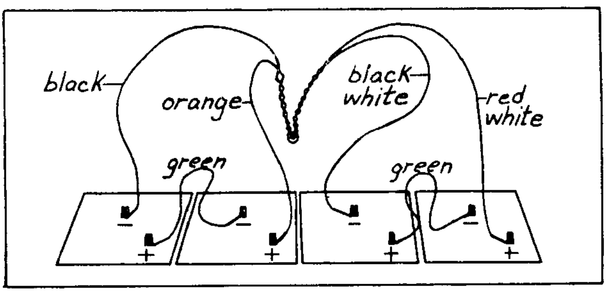


The CLOCK output provides a 10-volt positive pulse, about 200 microseconds long, at every other zero crossing of the brainwave signal. It may be used in conjunction with other outputs to count the number of cycles of each type of brainwave, to trigger a synchronous strobe, or for digital period measurements. If two ALPHAPHONE brainwave analyzers are used in conjunction, the CLOCK outputs may be used to provide phase comparison information.

The NOISE light is dim compared to the other five lights. The reason is simple: It is tumed on for only a very brief (200 microsecond) period of time during each cycle of "noise." If the noise is low frequency (less than 10 Hz), you can see an individual flash once for each cycle. If none of the six lights seems to be on, the signal is probably in the noise catagory between zero crossings.

BATTERIES

The ALPHAPHONE brainwave analyzer is battery operated. It uses four screw terminal 6-volt lantern batteries (such as the Burgess F4BP). A set of batteries should last for about 200 hours of use. The four batteries are connected as two series pairs of 12 volts each (see diagram below). Each 12-volt battery pair supplies power to a voltage regulator: One for the brainwave analyzer's -5-volt supply, the other for its +5-volt supply. The regulators cease to work reliably when their supply voltage drops below 9 volts (loaded). This corresponds to a 60% reading on the meter when the BATTERY TEST switch is operated.



MAINTENANCE

The ALPHAPHONE brainwave analyzer will give many years of reliable service if it is treated with normal care. The wooden cabinet is waxed at the factory, and periodic waxing will preserve the instrument's appearance. The front panel can be polished with a soft cloth. It may be cleaned with rubbing alcohol, but avoid getting alcohol on the wooden cabinet.

TUNABLE ANALYZER

The Model 1001DT tunable analyzer has adjustable frequency limits in contrast to the Model 1001A analyzer's fixed frequency limits of 4, 8 and 13 Hz. These limits are adjusted by three rotary switches, each of which adjusts one of the three frequency limits in 1-Hz incremental steps.

The four frequency categories which the Model 1001DT sorts brainwaves into are named CATEGORY 1, 2, 3 and 4 instead of beta, alpha, theta and delta. This is because the frequency limits may be set outside the traditional brainwave boundaries.

The Model 1001DT creates its four frequency categories by comparing the frequency period of each cycle to the three switch-selected frequency limits. Any cycles whose frequency is higher than the uppermost frequency boundary will be sorted into CATEGORY 1. The switch located at the upper right corner of the Model 1001DT's control panel selects the lower frequency boundary of category 1. If this switch is set at 12 Hz, any cycles of the brainwave signal above 12 Hz in frequency will be sorted into category 1. Since the brainwave analyzer really measures period instead of frequency, this means that any cycles whose period is shorter than 83 milliseconds will be sorted into category 1.

The middle knob on the right edge of the 1001DT's panel sets the lower frequency boundary of category 2. This switch MUST BE SET TO A FREQUENCY LOWER THAN THE SWITCH ABOVE IT (the lower limit for category 1 and the upper limit for category 2). Category 2 will then be all the brainwaves in between this frequency and the setting chosen for the topmost frequency limit. For example, if we set the middle switch at 9 Hz, and we still have the top switch set at 12 Hz, the category 2 will be all the cycles whose frequency falls between 9 and 12 Hz. The diagram below will make this clearer.

The bottom knob also sets the upper limit for category 4. With the setting of 5 Hz described above, category 4 consists of all brainwave cycles below 5 Hz. Of course, the bottom knob MUST BE SET TO A FREQUENCY LOWER THAN THE SETTING OF THE MIDDLE KNOB (the lower limit for category 2 and the high limit for category 3).

low frequencies						high frequencies
	5 Hz		9 Hz		12 Hz	
category 4	/	category 3	/	category 2	/	category 1
	low limit category 3, high limit category 4		low limit category 2, high limit category 3		low limit category 1, high limit category 2	

CONTINUOUSLY TUNABLE ANALYZER

The Model 1001CT tunable brainwave analyzer is exactly like the Model 1001DT except that the frequency limits can be adjusted smoothly over a range of frequencies, rather than being adjusted in incremental steps of one Hz at a time. Therefore, for instance, it is possible to set a frequency boundary at 3.2 Hz.

The frequency limits are set by three 10-turn helipots. Each helipot has a 10-turn, turns-counting duo-dial which allows the operator to select 1,000 different settings.

These are the knobs near the right edge of the instrument. The center knob is marked into 100 segments. Each time the dial swings past zero, the little number in the inset at the edge flips up or down a digit. To set the dial at 476, the little number should be at 4, and the dial pointer should be at 76. At the edge of the dial is a black lever. When the lever is pushed clockwise, the knob is locked in position so that the analyzer won't be knocked out of adjustment accidentally during use.

The added resolution of the Model 1001CT does have its cost: The frequency limits are complicated to adjust. If this instruction manual is accompanying a Model 1001CT, it includes a calibration table which has been calculated for that particular instrument. Each dial has been calibrated separately. To set a particular frequency, the operator looks up the dial setting which corresponds to the chosen frequency in the table and sets it accordingly. Each dial has its own set of numbers. On the top dial, 24 Hz may be dial setting 955, but on the middle dial, it might be 947, while 986 might be right for the bottom dial.

Suppose the calibration table for the top dial shows the proper settings to be 935 for 22 Hz, 955 for 24 Hz and 971 for 26 Hz. Suppose the operator wants to set for 23.5 Hz. The simplest way to find the proper setting is to do a straight line interpolation. 23.5 is three-quarters of the way from 22 to 24. Three-fourths of the way from 935 to 955 is 950, so that would be the setting.

In general, to interpolate, follow this procedure, using the worksheet on the last page of this section:

Write down the frequency you want to use as a boundary between categories. Call that number F.

Look at the calibration chart. Write down the frequency on the chart which is closest to, but just higher than, the desired frequency. Call that number H. Write down the frequency on the chart which is closest to, but just lower than, the desired frequency. Call that number L.

Subtract L from H. Call the result B.

Subtract L from F. Call the result A. Divide A by B. The result should be a fraction smaller than one. Call that number D.

Write down the dial setting for the proper dial corresponding to the H frequency. Call that number X.

Write down the dial setting for the proper dial corresponding to the L frequency. Call that number Y.

Subtract Y from X. The result, which should be a positive number, can be called C. Multiply C times D. Call the result E. Add E to Y. That's your proper dial setting.

In general, the above procedure will be adequate for accuracy. However, for very low frequencies, the curve does not really follow a straight line. For more accuracy, it is possible to do a curved line interpolation by adding two more calculations to the above procedure:

After computing E, divide H by F. Call the result Q. Multiply E times Q. Call the result R. Add R to Y. That's your more accurate dial setting.

As with the 1001DT, the four frequency categories into which the Model 1001CT divides brainwaves are named CATEGORY 1, 2, 3 and 4 instead of beta, alpha, theta and delta, because the frequency limits may be set outside the traditional brainwave boundaries.

The knob at the upper right corner of the control panel selects the lower frequency boundary of category 1. If this knob is set at 12.3 Hz, which, perhaps, might be a dial setting of 764, any cycles of the brainwave signal above 12.3 Hz in frequency will be sorted into category 1.

The middle knob on the right edge of the 1001CT panel sets the lower frequency boundary for category 2. This knob MUST BE SET TO A FREQUENCY LOWER THAN THE KNOB ABOVE IT (the lower limit for category 1 and the upper limit for category 2). Remember, it is the frequency that must be lower. It is possible, sometimes, that the middle dial will have a lower dial setting than the upper dial, but still be set at a higher frequency. The frequencies must be computed for each dial.

If the middle dial is set correctly, category 2 will then be all the brainwaves in between this frequency and the setting chosen for the topmost frequency limit. For example, if we set the middle knob at 8.7 Hz and keep the top knob at 12.3 Hz, category 2 will be all cycles whose frequency falls between 8.7 and 12.3 Hz.

The bottom knob sets the lower limit of category 3, which is the upper limit of category 4. Of course, the bottom knob MUST BE SET TO A FREQUENCY LOWER THAN THE SETTING OF THE MIDDLE KNOB (the lower limit for category 2 and the high limit for category 3).

ACCURACY

The higher the amplitude of the brainwave being detected by the brainwave analyzer, up to the artefact threshold, the sharper the boundaries between categories will be. For very low amplitude brainwaves, the noise always present in the circuitry will partly mask the waves and make the zero level, where the zero crossings are detected, wander up and down in voltage a greater percentage of the total wave than in high amplitude waves. That is, the noise is about the same in all cases, but with low amplitude waves, it is a greater percentage of the total wave being measured.

This problem is characteristic of any EEG measuring device. The accuracy limit probably will make itself felt when measuring beta waves more than any other, because they ordinarily are low amplitude waves.

Therefore, on the Model 1001CT, for instance, it probably will not help to calculate the frequencies out to two decimal places in the higher frequencies, or in the extremely low frequencies below 4 Hz.

INTERPOLATION WORKSHEET

Desired Frequency F ____

Low Frequency L ____

Difference A ____

High Frequency H	____	Comparable Dial Setting X	____
Low Frequency L	____	Comparable Dial Setting Y	____
Difference B	____	Difference C	____

STRAIGHT LINE

A ÷ B ____ Ratio D

C x D ____ Product E

E + Y ____ Proper Dial Setting

CURVED LINE

A ÷ B ____ Ratio D

C x D ____ Product E

H ÷ F ____ Quotient Q

E x Q ____ Product R

R + Y ____ Proper Dial Setting

APPENDIX

ARTEFACTS

Signals picked up by the circuitry of the ALPHAPHONE headset or brainwave analyzer from sources other than the brain are known as "artefacts." There are external artefacts, such as interference from electric clocks, lamps, wiring, etc., and bio-electric artefacts, such as eye blinks and muscle twitches. In general, artefacts are easily identified. The signal from a blinking eye sounds much louder than brainwave signals ("boing. . .boing. . .boing"). Electrical noise produces a readily recognizable buzz, and can usually be attenuated by moving a few feet from the source. The only artefacts which can cause confusion in practice are the rather subtle ones, such as lightly fluttering eyelids, a tense and slightly vibrating neck or throat, gritting teeth, etc.

In order to be sure that what is heard reflects true brainwave activity; the entire face, neck and shoulders of the Subject should be relaxed. Some individuals have difficulty at first in relaxing the eyelids. One way to avert this problem is to hold the fingers over them until they come to rest. (The fingers can feel the eyelid flutter and the brain uses the information to stop the flutter--another form of biofeedback.) Another way to solve the problem is to practice in a dark room, as the flutter seems to be a response to light. In any case, one should be careful not to cultivate such a flutter, thinking it is alpha. This would only be possible with the ALPHAPHONE headset as the brainwave analyzer usually rejects these signals.

Identifying blinks and twitches as artefacts is a relative matter. If one were interested in using bio-feedback specifically to control them, they would be the primary signal. One Yogi advised us in a conversation that excessive eye blinks are an indication of a noisy mind, and that our units are useful for learning to control them.

ACCESSORIES FOR THE ALPHAPHONE brainwave analyzer

Aquarius Electronics will quote on request price and delivery for accessories to the ALPHAPHONE brainwave analyzer. An example of such is an 8 channel event recorder (one channel for each of the six categories, one for the clock pulse and one for external input). Another example is a four channel percent time chart recorder to record on chart paper the percentage of the time spent in each of the four frequency channels. Both of these recorder systems include the necessary optical isolating circuits essential for the safe use of power line operated accessories with the ALPHAPHONE brainwave analyzer.

IN CASE OF DIFFICULTY

If the ALPHAPHONE brainwave analyzer begins to operate in an erratic manner, either low batteries or a poor electrode connection are likely causes. Each of the two twelve volt batteries (made up of two six volt lantern cells in series) must put out at least 9 volts under load for the instrument to operate properly. All of the binding post terminals should be tightly screwed onto the spade lug terminals attached to the battery leads.

Another possible cause of erratic operation is artefactual electrical interference. This can easily be heard with the FUNCTION SWITCH in the ANALOG position, the ANALOG SENSITIVITY at maximum (full CW), and the VOLUME turned up (CW). Power line noise will be apparent as a rasping buzz. Noise from electric motors, etc., may sound like static. In any case, the best solution is to move around until an electrically "quiet" spot is found. Always be sure the electrodes are in good contact with the scalp; a poor connection will greatly increase the instrument's susceptibility to external electrical noise.

If the digital filter portion of the ALPHAPHONE brainwave analyzer fails to operate properly, even though the ANALOG portion seems to be working, check to be sure you haven't plugged something into the EXT EEG INPUT jack. The act of plugging into this jack disconnects the digital filter circuit from the analog circuit and preamplifier. If the NOISE THRESHOLD is inadvertently set at its maximum, only very high amplitude brainwave signals will activate the digital filter.

In general, if you experience difficulty in operating the analyzer, first check all control knob settings and input/output jack connections. Then check electrode connections. If the trouble still is elusive, check batteries. Then check for outside interference.

If all else fails, call us at 707-937-0064 or write to:

Aquarius Electronics
Post Office Box 627
Mendocino, California
95460

We are always happy to provide applications assistance. If you have a specialized application for the ALPHAPHONE brainwave analyzer and need advice on how to accomplish the desired result, write or call us.

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Copyright laws prevent us from publishing reprints or articles without specific written permission. Therefore, we are unable to supply reprints to our customers. Most of these articles are available in medical libraries. Those who care to visit the Aquarius Electronics factory are welcome to examine copies we have in our file. As an introduction to brainwaves, we recommend that you investigate Tart, Altered States of Consciousness, Wooldridge, The Machinery of the Brain, and Cooper, Osselton & Shaw, EEG Technology.

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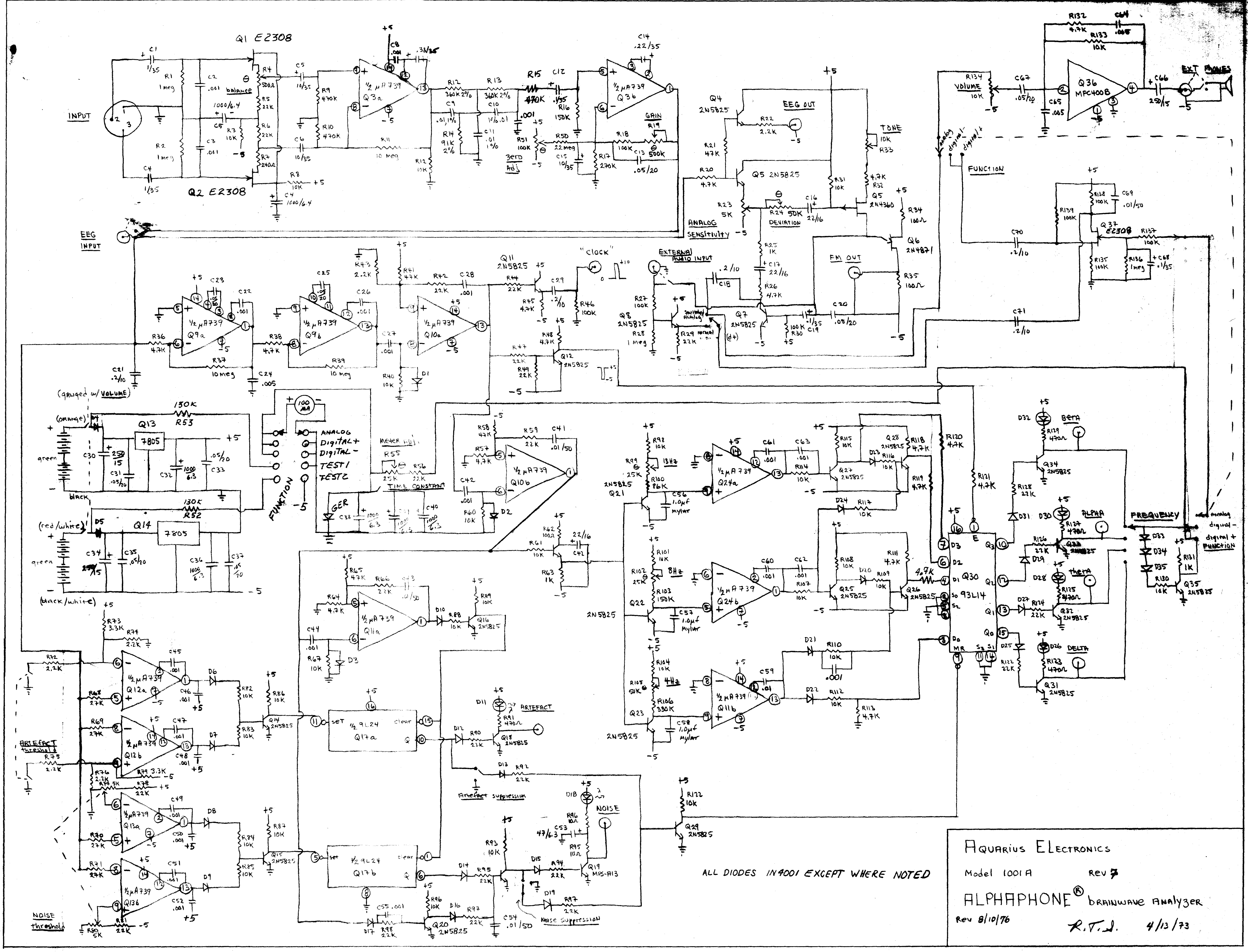

INPUT
Q1 E2308
Q2 E2308
balance
Q3a
Q3b
3erd Adj
GAIN
EEG OUT
TONE
ANALOG SENSITIVITY
DEVIATION
EXTERNAL AUDIO INPUT
FM OUT
VOLUME
Q36 MFC4008
EXT PHONES
FUNCTION
Q37 E2308
EEG INPUT
"Clock"
Q9a
Q9b
Q10a
Q10b
Q11 2N5825
Q12 2N5825
(ganged w/ VOLUME)
Q13 7805
Q14 7805
ANALOG
DIGITAL+
DIGITAL-
TEST1
TEST2
FUNCTION
Meter adj.
TIME CONSTANT
GER
13Hz
8Hz
4Hz
Q24a
Q24b
Q11b
Q30 93L14
BETA
ALPHA
theta
DELTA
FREQUENCY
analog
digital-
digital+
FUNCTION
Q12a
Q12b
Q13a
Q13b
ARTEFACT threshold
NOISE threshold
1/2 9L24 Q17a
1/2 9L24 Q17b
ARTEFACT
Artefact suppression
NOISE
Noise suppression
ALL DIODES IN4001 EXCEPT WHERE NOTED
Aquarius Electronics
Model 1001A
Rev 7
ALPHAPHONE® brainwave Analyzer
Rev 8/10/76
R.T.J.
4/13/73