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Strobe trigger, compound alpha filter, and phase coherence detector for EEG biofeedback

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Circuit diagrams and theoretical perspective are given for phase-locked strobe light, compound alpha spindle, and phase coherence EEG for biofeedback.

Since Shipton's (1949) original article, several important studies have reported using modifications of the Shipton trigger, which was designed to pulse a strobe light in phase with the EEG recorded from the human scalp. Bechtereva and Zontov (1962) varied the phase relation between the strobe flash and the alpha rhythm (8-13 Hz) and found that triggering on the positive going baseline crossing produces more alpha most of the time. Dustman and Back (1965) later reported that a cortical excitability cycle covaried with the alpha rhythm and peaked with negative slopes of this signal. They argued that afferent signals triggered near the maximum positive slope of the alpha rhythm would activate reticular discharge to the cortex during the negative going phase of the alpha rhythm.

More recently, Engstrom, London, and Hart (1970) reported using a phase-locked strobe light to facilitate EEG alpha biofeedback training. These and other developments demonstrate the importance of such a circuit. Figure 1 shows an improved trigger implimented with inexpensive 741 operational amplifiers (DigiKey, P.O. Box 126, Theif River Falls, Montana 56701). The bandpassed EEG enters the input comparator, which can be gated on-off by the field-effect transistor (FET) e.g., to place frequency and/or amplitude requirements on the strobe output. The 5-megohm feedback resistor is adjusted to just eliminate noise. The square-wave output is then differentiated, and the resultant spikes pulse a relay driver directly or through an additional one-shot for variable delay. The linked toggle switches make this choice, plus that of baseline-crossing polarity (e.g., negative spikes representing the maximum negative slope of the alpha rhythm). The relay gates a 320-V pulse to the strobe light and introduces a 16-msec delay; reed relays will not handle the voltage. The bandpass filter feeding the input comparator also introduces a significant delay proportional to its Q and a phase shift related to frequency and Q. If the delay one shot is used, an additional phase limitation is added, i.e., phase varies with frequency in the same direction as that produced by the bandpass filter. Frequencies slower than center lead in phase after a time lag; frequencies faster than center lag. All such factors should be accounted for when calibrating the circuit with a variable bandpass filter, EEG amplifier, photocell, and dual trace oscilloscope.

Some work has been done on biofeedback of compound alpha spindles, the simultaneous occurrence of alpha at more than one electrode (Rouse, 1972). Such activity is thought to involve the action of integrating neural structures in the thalamus (Andersen & Andersson, 1968). Recently, compound alpha spindling has been linked to certain meditational practices (Banquet, 1973). A circuit designed to indicate the presence of such activity in effect increases the sampling area over that of a single electrode, but without the phase interaction introduced by the skull and scalp.

The top section of Fig. 2 shows one channel of a 4-channel filter network designed to activate a tone when alpha occurs at 1, 2, 3, or 4 electrodes within .25 sec of each other. The first section is an active bandpass filter with independent Q and center frequency adjustments. The output of this circuit is converted by a full-wave rectifier and integrator to a varying voltage that indicates the average amplitude of alpha within the bandpass of interest. When this voltage exceeds that applied to the noninverting input of the comparator, a Logic 1 (+1.5 V) appears at one of four inputs of a summer-comparator operational amplifier AND gate, whose other three inputs are driven by identical parallel circuits connected to separate amplifiers recording the EEG from separate electrodes. The reference voltage at the noninverting input of the AND gate determines the number of channels necessary at Logic 1 to drive the output of the AND gate negative and turn on the analog gate controlling the feedback tone to the S.

With added expense, a hybrid alpha filter with step-function cutoff points can be substituted for the straight analog filter mentioned above (Paskewitz, 1971; Rouse, 1974). This approach provides better frequency resolution and reduces the phase and time lag errors of a high Q analog bandpass filter.

Phase coherence between compound alpha spindles is another important phenomenon (Darrow et al, 1956) and has also been studied in the biofeedback loop (Fehmi, 1971). The bottom section of Fig. 2 shows a

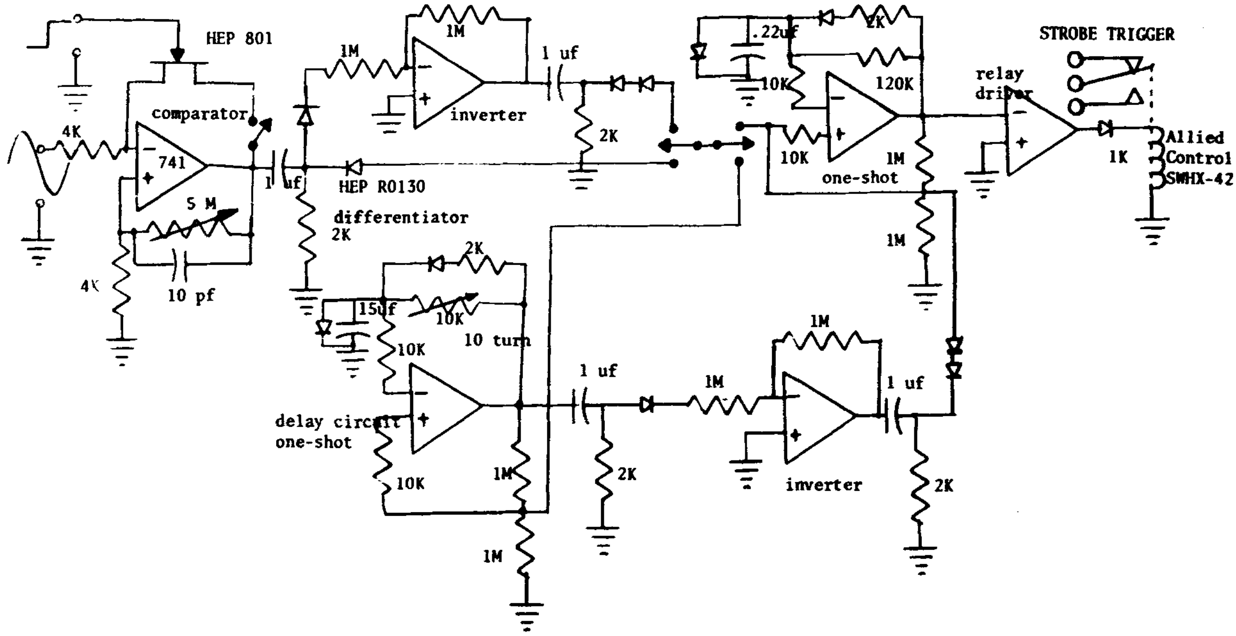

Fig. 1. Strobe light trigger.

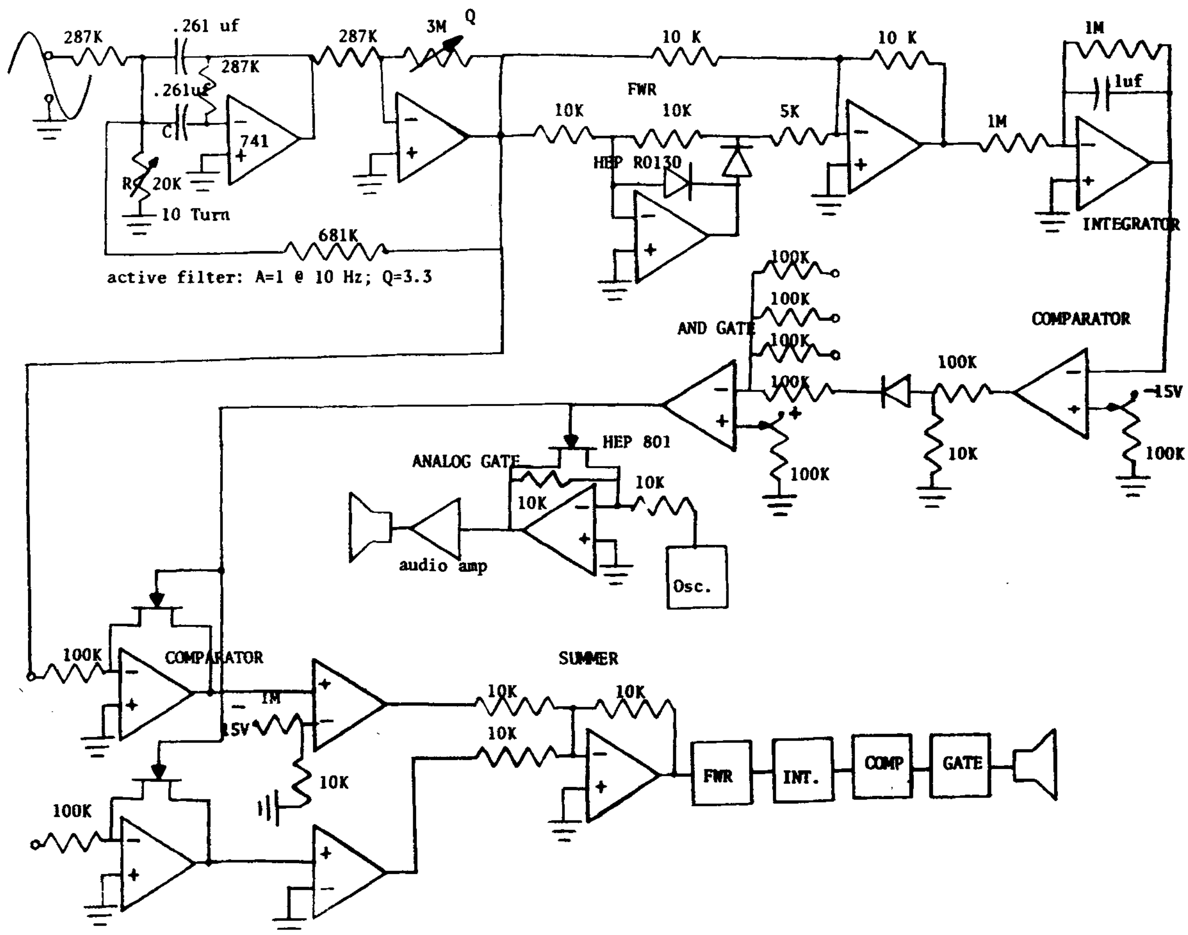

Fig. 2. Compound alpha filter and phase coherence detector.

simple phase coherence detector adapted from Burch (1958). One of the two input comparators is shown connected to the output of the active filter. The input comparators feed through error suppressing circuitry to a summing op-amp whose rectified and integrated output varies with the phase angle between the two

Table 1
Parts List

741 op amp		42
HEP R0130 Diode		15
HEP 801 FET		5
12-V Relay (Allied Control SWHX-42)		1
	4K	2
	5K	2
	2K	6
	1M	11
Resistors	10K	15
	120K	1
	287K	3
	681K	1
	100K	7
	5M	1
	10K (10 Turn)	1
Potentiometers	20K (10 Turn)	1
	3M	1
	100K	2
	10 pf	1
	1 uf	4
Capacitors	.22 uf	1
	15 uf	1
	.261	2
	.1	1

applied signals, and is indifferent to phase polarity. The two FETs are turned off by the AND circuit discussed above and prevent a single signal from operating the circuit. The two open loop op-amps after the input comparator stage cancel each other out when both signals are absent simultaneously, preventing a false phase indication. Another circuit provides polarity as well as phase degree information (Hamaoui, 1973). In addition, the phase detector of a 565 phase-locked loop integrated circuit could be adapted (Signetics, Sunnyvale, California 94086).

These circuits were designed with information obtained from Graeme, Tobey, and Heulsman (1971), Malmstadt and Enke (1969), and Brophy (1972), and are used in conjunction with a hybrid alpha filter and multichannel analyzer used to period analyze the EEG (Rouse, 1974). Cost of the circuits alone is approximately $50. A parts list is provided in Table 1.

REFERENCES

Andersen, P., & Andersson, S. *Physiological basis of the alpha rhythm*. New York: Appleton-Century-Crofts, 1968.

Banquet, J. P. Spectral analysis of the EEG in meditation. EEG Journal, 1973, 35, 143-151.

Bechtereva, N. P., & Zontov, V. V. The relationship between certain forms of potentials and the variation in brain excitability (based on EEG recorded during photic stimuli triggered by rhythmic brain potentials). EEG Journal, 1962, 14, 320-330.

Brophy, J. J. *Basic electronics for scientists*. New York: McGraw-Hill, 1972.

Burch, N. R. Automatic analysis of the electroencephalogram: A review and classification of systems. EEG Journal, 1958, 11, 827-834.

Darrow, C. W., Wilcott, R. L., Siegel, A., Strobe, M., & Aarons, I. Instrumentation and evaluation of EEG phase relationships. EEG Journal, 1956, 8, 333-336.

Dustman, R. E., & Beck, E. C. Phase of alpha brainwaves, reaction time and visually evoked potentials. EEG Journal, 1965, 18, 433-440.

Engstrom, D. R., London, P., & Hart, J. T. Hypnotic susceptibility increased by EEG alpha training. Nature, 1970, 222, 1261-1262.

Fehmi, L. G. Biofeedback of EEG parameters and related states of consiousness. Paper presented at the Annual American Psychological Association Convention, Washington, D.C. 1971.

Graeme, J., Tobey, G., & Heulsman, L. *Operational amplifiers: Design and applications*. New York: McGraw-Hill, 1971.

Hamaoui, M. Voltage comparator applications using the μA 734. Applications Note 323, Fairchild, Mountain View, California, August 1973.

Malmstadt, H., & Enke, C. G. *Digital electronics for scientists*. New York: Benjamin, 1969.

Paskewitz, D. A. A hybrid circuit to indicate the presence of alpha activity. Psychophysiology, 1971, 8, 107-112.

Rouse, L. O. Panel discussion: Clinical applications of EMG and EEG training-current status. Biofeedback Research Society Annual Meeting, Boston, 1972.

Rouse, L. O. On-line period analysis of EEG by time-to-amplitude conversion (TAC). Psychophysiology, 1974, in press.

Shipton, W. H. An electronic trigger circuit as an aid to neurophysiological research. Journal of the British Institute of Radio Engineers, 1949, 9, 1-10.

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