Pharmacology Biochemistry & Behavior, Vol. 3, pp. 1133–1135.

BRIEF COMMUNICATION

Amplitude Modulator-Demodulator System for Recording Electroencephalographic Signals with a Standard ¼ Inch Magnetic Tape Deck

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(Received 28 February 1975)

LUTTGES, M. W., R. A. GERREN, D. E. GROSWALD AND W. BANK. *Amplitude modulator-demodulator system for recording electroencephalographic signals with a standard 1/4 inch magnetic tape deck.* PHARMAC. BIOCHEM. BEHAV. 3(6) 1133–1135, 1975. – Circuit diagrams and sample oscilloscopic tracings are provided for a simple modulator-demodulator system which permits the recording of low frequency bioelectric phenomena with an entertainment type tape recorder. The system is economical and easy to use. Several of the systems have been used successfully in routine laboratory applications for more than a year.

Low frequency responses   Magnetic tape   Amplitude modulation   Bioelectric recordings   Instrumentation

THE recording of electroencephalographic (EEG) signals or other low frequency bioelectric phenomena necessitates instrumentation capable of amplifying and storing low frequencies without introducing distortion. Most laboratories are readily equipped with the necessary instrumentation at nominal cost. A major exception is the availability of magnetic tape recording devices which can faithfully record and reproduce low frequency EEG signals. Frequency modulated tape recording devices are costly and difficult to maintain. Alternatives are scarce and can be almost as expensive. Accordingly, we have developed an inexpensive amplitude modulator-demodulator system which can be used with any reasonable quality 1/4 in. magnetic tape recording device. The performance of this modulator-demodulator is not dependent upon any assumptions about the linearity of frequency responses inherent to different tape decks.

The modulator-demodulator unit makes it possible to record relatively low frequency (0.2–100 Hz) signals. The unit can be used without critical calibration equipment. The requisite minor adjustments necessary for effective signal modulation are made while monitoring the output of the unit by oscilloscope. The amplitude of a 3 KHz carrier signal is modulated by frequency and amplitude variations in the EEG signals. The resulting 3 KHz envelope carrying the superimposed EEG signal is recorded on a standard entertainment type tape deck. During data retrieval the demodulator uses a synchronous detector to remove the 3 KHz carrier signal and to recreate the original EEG signal.

A major advantage of the amplitude modulation device is that, unlike frequency modulated devices, nontechnical personnel can adjust the input and use the device following simple instructions. The modulated signal can be observed or continuously monitored and compared directly to the unmodulated signal. Proper operation is insured because the envelope of the modulated signal can be compared directly with EEG input on any dual-trace oscilloscope. Over or under modulation is readily noted by observing whether the modulation envelope is too shallow (too little modulation signal) or too deep (too much modulation signal). An input attenuator can be adjusted to achieve optimal levels of modulation. Such convenient monitoring of signal modulation is not possible, of course, with frequency modulated devices.

CIRCUIT DESCRIPTION

A circuit diagram is provided in Fig. 1. The T05 type 741 operational amplifiers (A_n) are used throughout. A_3 amplifies the EEG input and establishes a positive 1 VDC for the current source to A_4 which, in turn, serves Q_1 and Q_2, the carrier signal modulator (Fig. 1a). The positive 1 VDC is produced by connecting either Pin 1 or 5 to negative 15 VDC. R_1 balances the modulated signal and A_2 is the differential output stage. A_1 is the Wien bridge oscillator which provides the 3 KHz carrier signal. The amplitude of the output is adjusted to approximately 2 volts peak to peak at A_2. Any conventional ± 15 VDC power supply can be used for both the modulator and demodulator. Also a multiplier may be used for signal modulation but the present design employs a modulation system which simultaneously provides needed amounts of signal amplification.

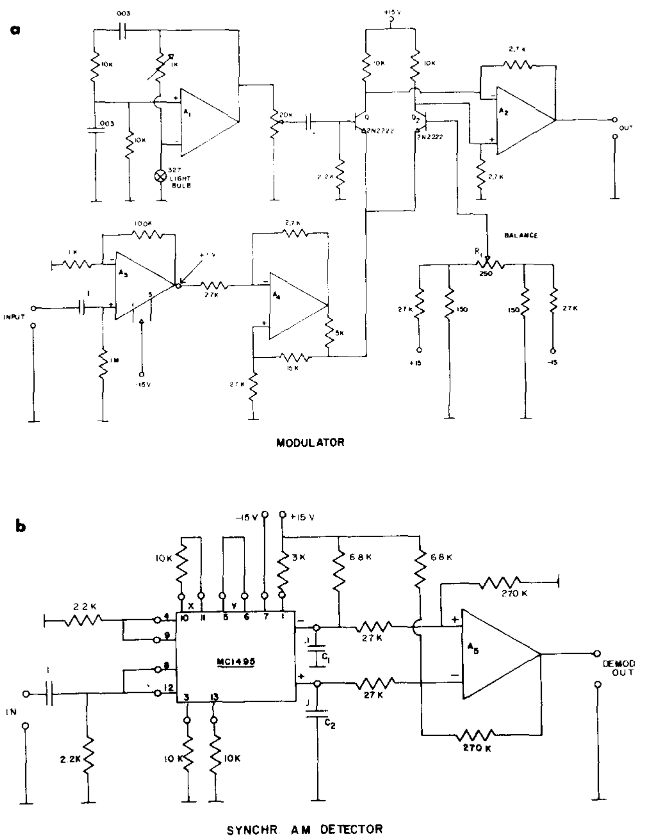

FIG. 1. (a) Schematic for amplitude modulator. A_n represents T05 741 operational amplifiers. Any ± 15 VDC power supply may be used. (b) Schematic for amplitude demodulator. The MC1495 unit multiplier can be replaced by any of a number of similar devices. Some multiplier packages obviate the need for A_5.

The demodulator consists of a MC1495 [1,2] type multiplier (Fig. 1b). Both X and Y inputs (Pins 4 and 9) are grounded. The modulated signal is fed to Pins 8 and 12 (X and Y common). The Y gain settings on Pins 5 and 6 are shorted. A_5 serves as the differential to single-ended stage. C_1 and C_2 filter out the carrier signal. Many alternative demodulation schemes are possible, including a diode detection system coupled with appropriate filtering. Synchronous detection with a multiplier, however, provides good signal to carrier frequency resolution and low impedance output in one package.

USE

In normal practice the modulator usually receives 0.5–2.0 V peak to peak signals. The attenuator at the input can usually bring EEG signals within this range. Considerably smaller (> 50 mV) signals can also be accommodated without serious distortions or signal losses. Input frequencies are commonly limited to 100 Hz or less, although somewhat higher frequency signals are not severely distorted until they approach a substantial frequency compared to the 3 KHz carrier signal. Such higher frequencies are recorded on 1/4 in. tape readily without the need for a modulator. The inputs to both the modulator and demodulator circuits can be protected by diodes and the outputs, by series resistance.

The oscilloscope tracings of Fig. 2 demonstrate the operation of the modulator during the recording of EEG signals from a chronically-implanted electrode array attached to a freely moving mouse. Throughout the EEG records, the mouse exhibited large amounts of low-frequency (6–9 Hz) theta activity. Such activity is recorded and stored on magnetic tape quite easily using the modulator-demodulator system.

The optimal adjustments necessary for modulator use also are demonstrated in Fig. 2. In the C tracing the input has been adjusted properly. The EEG input (C1) produces a graded envelope (C2) of moderate deformations in the 3 KHz carrier signal. In the A and B tracings the input amplitude is too low. As a result the 3 KHz envelopes (A2, B2) are hardly perturbed and relatively little EEG information (A1, B1) is superimposed on the carrier signal. In the bottom tracings (D,E) the input amplitude is too high. Consequently, the 3 KHz envelopes (D2,E2) are often overmodulated and high amplitude EEG signals are lost. The appearance of a virtually straight, thin tracing on the modulator trace of the dual-trace oscilloscope is clear evidence of input amplitudes which are too high. Any of the above difficulties are readily recognized and remedied by inexperienced, nontechnical users. Any known amplitude, low frequency input can be used for EEG signal calibration purposes so a continuous range of input adjustments is possible.

The demodulator requires little adjustment. At times it may be necessary to reduce demodulator input when using different types of magnetic tape decks but in practice such adjustments are rarely required. On occasion it may be desirable to increase the values of C_1 and C_2 to eliminate some residual carrier frequency ripple from the demodulated EEG signal. Again, this alteration is rarely necessary.

The modulator-demodulator systems have been routinely employed in our laboratory. The modulated-demodulated signals have been used for a wide range of purposes including the preparation of photographic reproductions, analog power spectra and digital computer analyses. The system uses a carrier which is faithfully reproduced at even very slow tape transport speeds, thus requiring minimal amounts of inexpensive 1/4 in. magnetic tape. In addition, the device is inexpensive and simple enough to be used in undergraduate teaching laboratories.

ACKNOWLEDGMENTS

The authors wish to thank T. Bank for schematic drawings and J. Button for help in manuscript preparation. The work was supported, in part, by the University of Colorado Graduate School, CRCW.

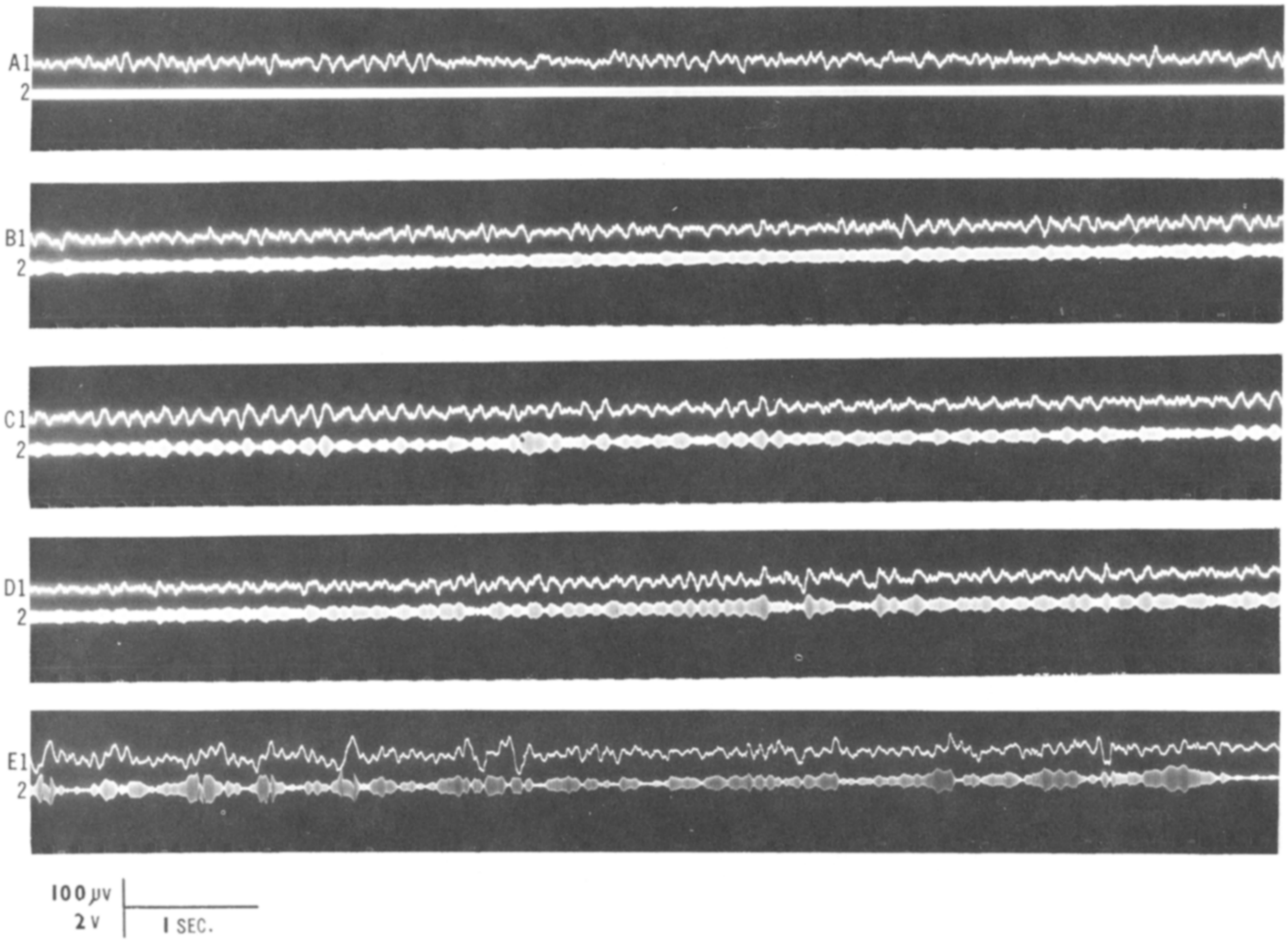

FIG. 2. Adjustments for optimal signal modulation are demonstrated in these dual-trace oscilloscopic tracings. The electroencephalographic signals were obtained from a chronically-implanted mouse. Top (1) traces of actual signals can be compared to the 100 μv calibration at the lower left and bottom (2) traces of modulated signals can be compared to the 2 V calibration.

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