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MULTICHANNEL ANALYZER CLASSIFYING CIRCUIT FOR THE DETERMINATION OF ACTION POTENTIAL INTERVALS AND DURATIONS

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Activity patterns of spontaneous active (pacemaker) nerve cells are frequently different, and the individual patterns are closely related to the nerve cell functions. Spike generation frequency and duration of the single spikes are both different (BULLOCK and HORRIDGE, 1965). Even a single cell may show different activity patterns during operation as a result of an afferent input (S.-RÓZSA and SALÁNKI, 1973), and the operating frequency of stimulated cells is highly dependent on the temperature, ion content etc. of the physiological solution surrounding the cell (CARPENTER, 1967). These parameters which are primarily of external origin will have an effect not only on the operating frequency of the cell but also on the duration of the action potentials. Investigations classifying cell responses on external parameter changes are extremely useful.

The above considerations led to experiments in our Institute concerning the operation of Br type cells of *Helix pomatia* L. as a function of temperature. (SALÁNKI et al., 1973). This cell will show at normal room temperature (22 deg C) a specific activity pattern *(Fig. 1b)*. Increasing or decreasing the temperature of the physiological solution surrounding the cell will change the activity pattern, i.e. the length of the intervals and the duration of the action potentials *(Figs. 1a* and *1c)*. For detailed investigation of this phenomenon, pulse trains pertaining to different temperatures are needed, and these can only be evaluated economically by electronic methods.

To solve the above problem, the 1024-channel analyzer type NTA-512B, developed by the Central Research Institute for Physics "KFKI", Budapest, has been applied. Suitable additional circuits and modifications have been used in order to realize the high precision and rapid data analysis needed.

The principle of data analysis is shown by the block diagram of *Fig. 2*. In order to achieve off-line type data analysis, the action potentials are amplified by a FET input preamplifier (VÉRÓ, 1971) and are stored on an FM type analog magnetic data recorder. From the recorder, data are transferred through a FET input amplifier on an operational amplifier which will limit the signals at a hight corresponding to half of the action potentials. The next circuit is a squarer which generates square pulses having widths equal to the action potential duration. Finally, short pulses coinciding with the leading

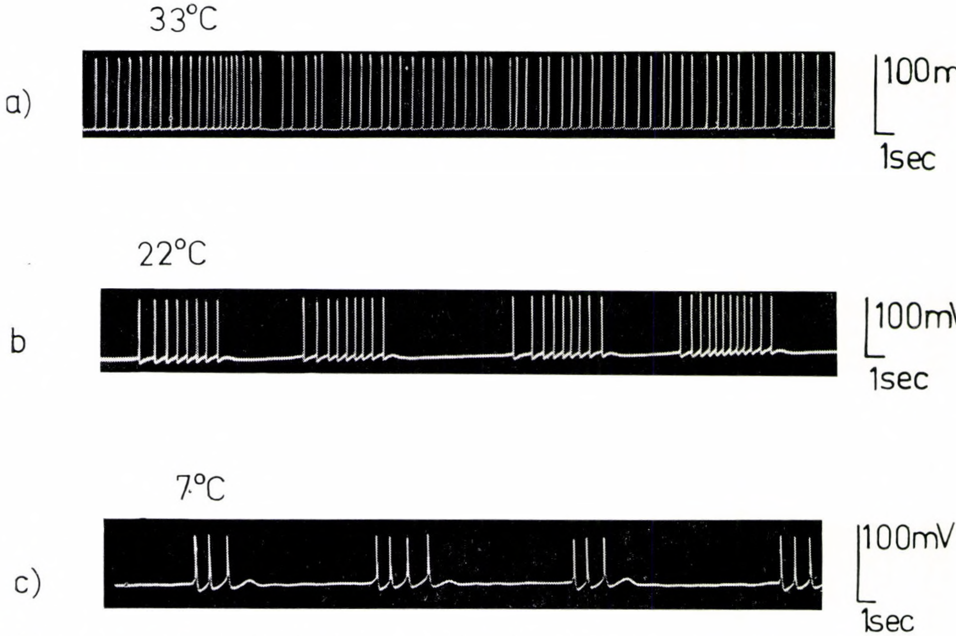

Fig. 1. Activity pattern of a Br type cell of *Helix pomatia* L. at different temperatures

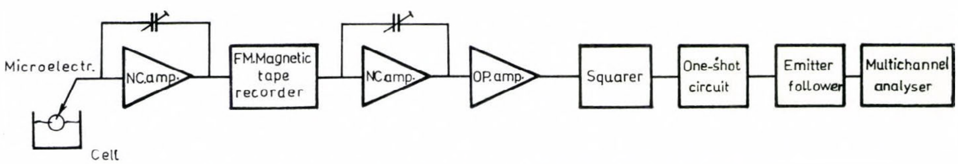

Fig. 2. Block diagram of the data evaluation system

and trailing edges of the square pulses are generated, thus producing trigger signals to be analyzed by the analyzer (D'ALTON and RYAN, 1972).

The special classifying task has necessitated the modification of some of the analyzer circuits as given in the original Instructions Manual for the NTA-512B Multichannel Analyzer System, prepared by the Central Research Institute for Physics. First, the address increase function by the internal clock generator had to be substituted by an address increase by the pulses generated from the action potentials. Charging of the channels is given by the clock generator which is not used for address increase any more, and this will satisfy the accuracy requirements, as the counting time can be adjusted in the range of 20 μsec to 10^3 sec. The block diagram of the analyzer thus modified is shown in *Fig. 3*.

The circuit for generating the analyzer trigger from the recorded analog signal is shown in *Fig. 4*. The action potential is routed through a FET input preamplifier to the inverting input of an operational amplifier. This amplifies the signal and introduces squaring at a definite level (STARR, 1953). Two methods may be used for exact adjustment of squaring level. Either the

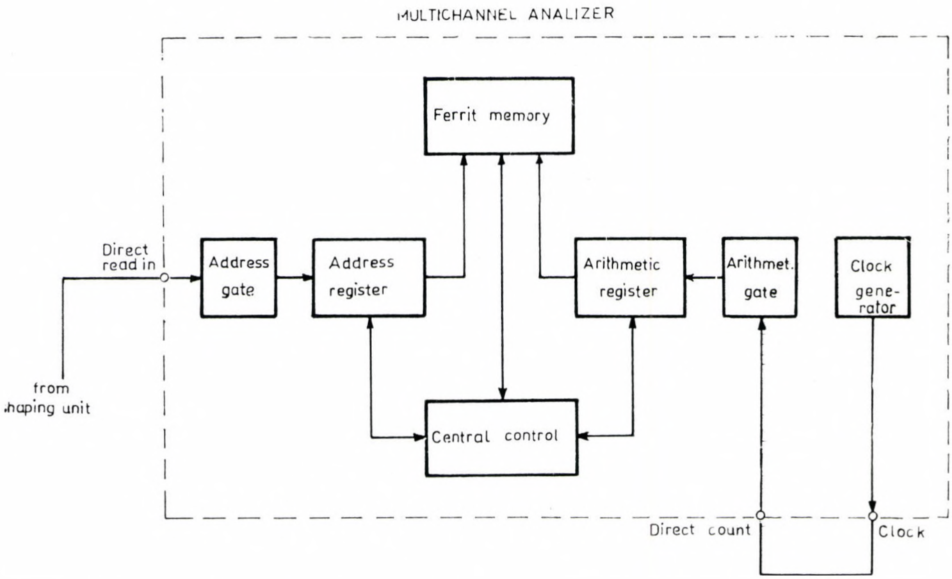

Fig. 3. Block diagram of the modified analyzer read-in operating mode

amplification of the operational amplifier or the amplification of the FET input preamplifier may be adjusted according to the square level required. The squared signal at the operational amplifier output is given to the base of the OC 1070 transistor operating in the switching mode. Thus the collector signal will have leading and trailing edges coinciding with the instants when the input signal passes through the squaring level. The leading edge of this signal will trigger the base of the emitter coupled one-shot multivibrator which has a flip-flop time of 0.2 msec. This mode of operation is used for measuring the interval T_s between action potentials.

An other mode of operation is used for measuring the duration of action potentials. In this mode, the trailing edges of the square pulses at the OC 1070 output will again operate the one-shot multivibrator on the collector. Thus, the assessment of the action potential duration is simplified to the measurement of time-durations between two 0.2 msec pulses. The pulses appearing at the one-shot multivibrator collector are used to drive an emitter follower which supplies an output signal corresponding to the analyzer logic level at the low impedance required (MALVINO and LEACH, 1967; DAKIN and COOKE, 1968). The trigger signals are given on the address gate system input (DIRECT READ IN on the analyzer type used).

Analog presentation of the analyzed data in the activity pattern shown in *Fig. 1b* is given in *Fig. 5b*. The address numbers along the horizontal axis correspond to the successive action potentials. The address content, i.e. the time duration pertaining to the addresses are plotted along the vertical axis. In *Fig. 5b*, evaluation of the interval times T is shown, whereas in *Fig. 6b*, the action potential durations τ' and the $\tau'' = T_s - \tau'$ values are shown together. Thus, the interval times $T_s = \tau' + \tau''$ and $T_b = T_b' + \tau'$ can be calculated by simple addition from *Fig. 6b*.

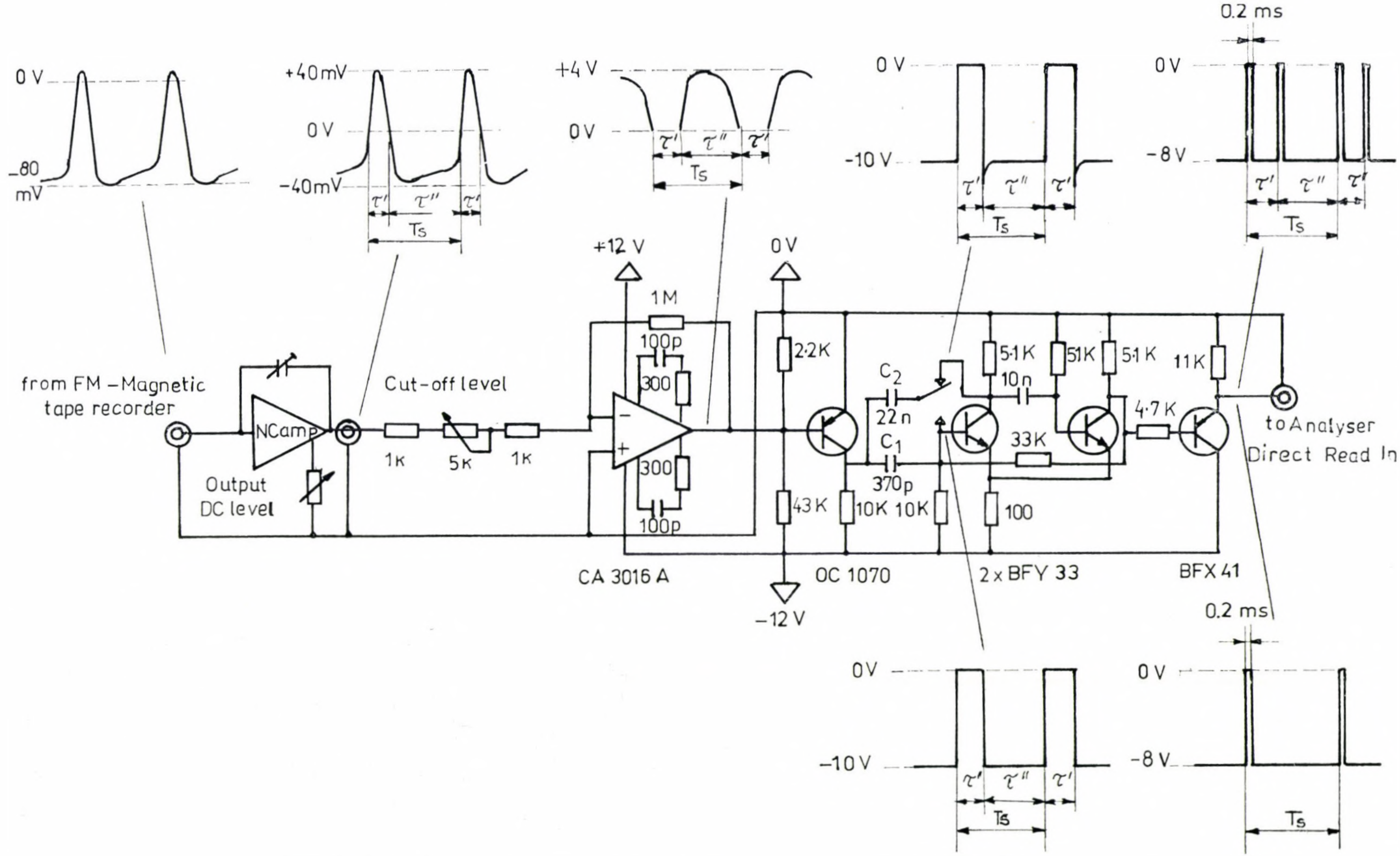

Fig. 4. Circuit and relevant waveforms of the analyzer trigger signal arrangement

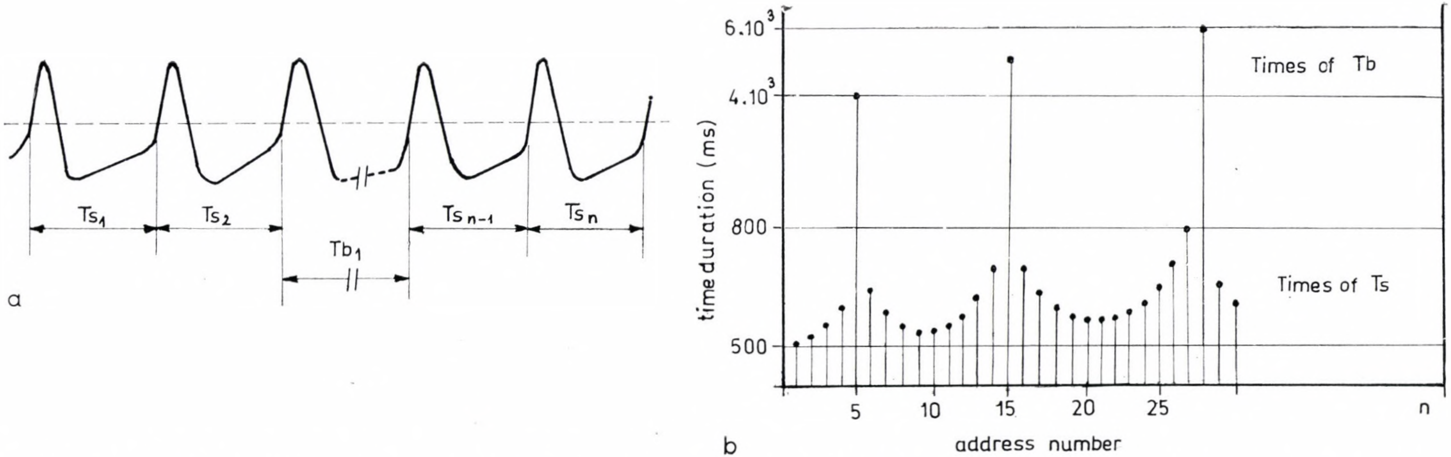

Fig. 5. a) Enlarged waveform of the action potential shown in *Fig. 1b; b)* Interval evaluation and the results presented by the analyzer. T_s — interspike interval, T_b — interburst interval

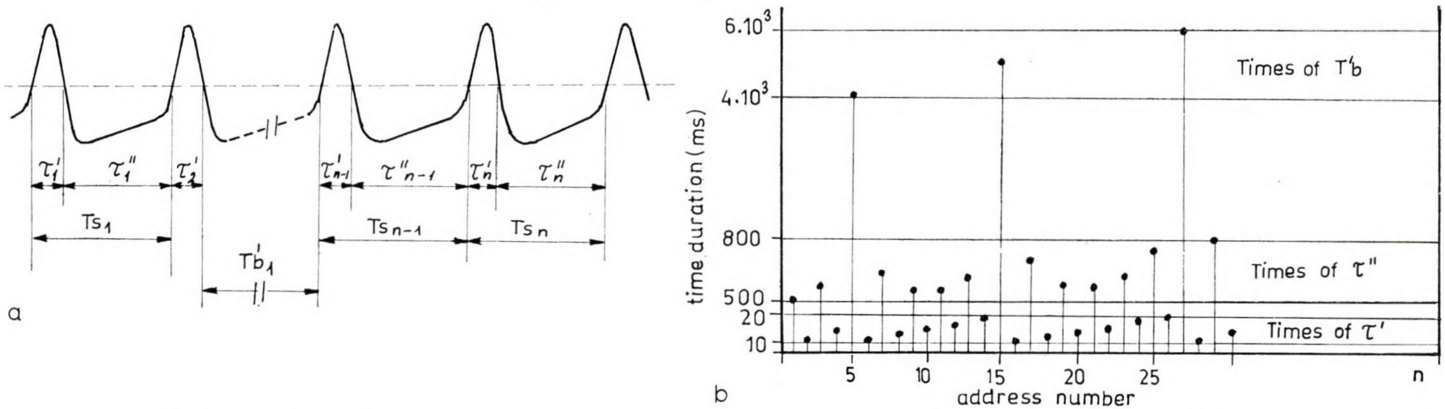

Fig. 6. a) Enlarged waveform of the action potential shown in *Fig. 1b; b)* Pulse width and interval evaluation, and the results presented by the analyzer. τ = pulse width, $\tau''_n = T_{sn} - \tau'_n$, T_s = interspike interval ($T_{sn} = \tau'_n + \tau''_n$), T_b = interburst interval ($T_{bn} = T'_{bn} + \tau'_{n-1}$)

Summary

A multichannel analyzer classifying circuit suitable for rapid and accurate assessment of intervals between action potentials and durations of the individual potentials is presented. A detailed description of the circuit used for generating the analyzer trigger signal from the analog signal and the modifications carried out on the applied 1024-channel analyzer type NTA-512B are given. A display is presented showing the interval and width evaluation of a nerve cell activity sample.

REFERENCES

Bullock, T. H., Horridge, G. A. (1965): Structure and function in the nervous systems of invertebrates. — *Vol.* **1**,, W. H. Freeman and Co., *San Francisco, California.*

Carpenter, D. O. (1967): Temperature effects on pacemaker generation, membrane potential and critical firing threshold in *Aplysia* neurons. — *J. Gen. Physiol.* **50,** 1469—1484.

Dakin, C. J., Cooke, C. E. G. (1968): Circuits for digital equipment. — *Illife Books Ltd., London* 66—77.

D'Alton, L. G., Ryan, P. J. (1972): Practical technic for measuring probability density. — *El. Eng.* **44,** 54—56.

Malvino, A. P., Leach, D. P. (1967): Digital principles and applications. — *McGraw-Hill Book Co., New York,* 11—20.

NTA-512B Multichannel Analyzer System. — *Instruction Manual, Central Res. Inst. for Physics, Budapest.*

S.-Rózsa, K., Salánki, J. (1973): Single neurone responses to tactile stimulation of the heart in the snail, *Helix pomatia* L. — *J. Comp. Physiol.* (in press)

Starr, A. T. (1953): Radio and Radar Technique. — *Pitman, London,* 544—548.

Salánki, J., Vadász, I., Véró, M. (1973): Temperature dependence of the activity pattern in the Br-type cell of the snail *Helix pomatia* L. — *Acta phys. Acad. Sci. hung.* (in press)

Véró, M. (1971): Negative capacitance amplifier for microelectrode investigations. — *Annal. Biol. Tihany* **38,** 107—115.

ÁRAMKÖR SOKCSATORNÁS ANALIZÁTORHOZ AKCIÓSPOTENCIÁLOK INTERVALLUMAINAK ÉS SZÉLESSÉGEINEK ÉRTÉKELÉSÉRE

Véró Mihály

Összefoglalás

A szerző idegsejtek aktivitás mintáinak analizátoros feldolgozásához alkalmas áramkört ismertet, amely lehetővé teszi az elvezetett akciópotenciálok közötti intervallumok, és az egyes potenciálok szélességének pontos és gyors kiértékelését. A cikk részletesen ismerteti azt az áramköri megoldást, amely az analóg jelből az analizátor indításához szükséges jelet előállítja, és ugyancsak ismerteti az alkalmazott NTA-512B típusú 1024 csatornás analizátor szükséges módosításait. Végezetül példa szemlélteti, a kiértékelésnél kapott eredmények analóg display-en történő adatábrázolását.