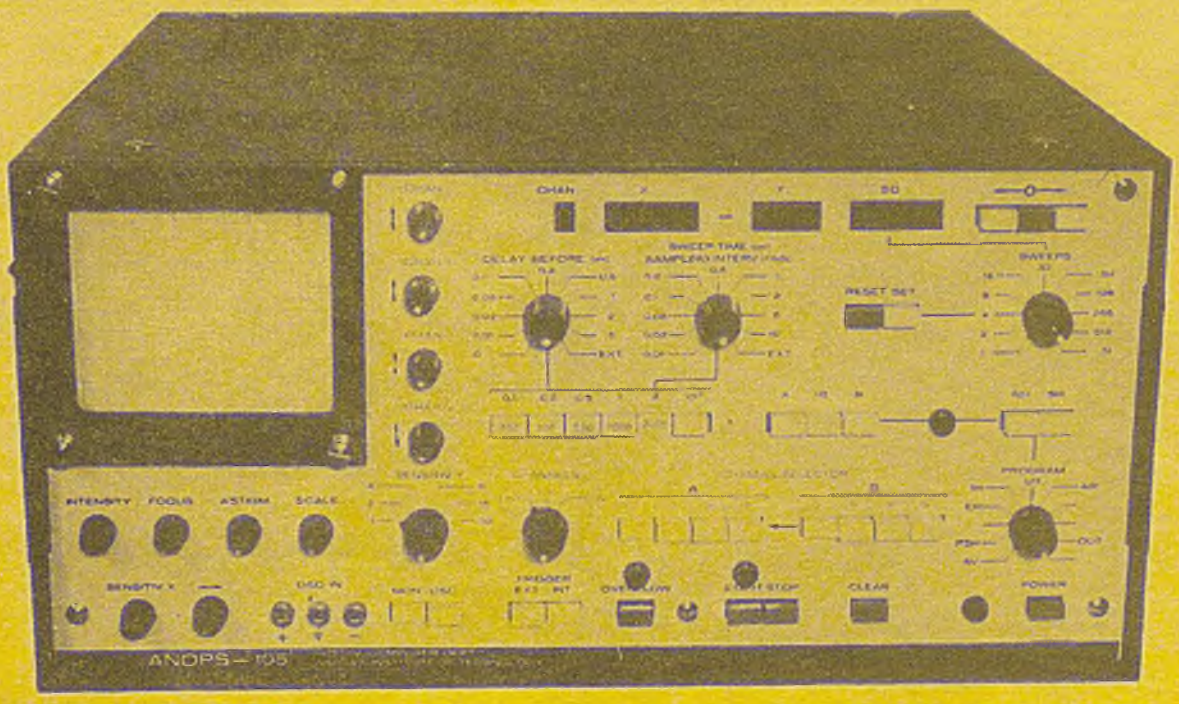
ANOPS-105

SIGNAL AVERAGING AND HISTOGRAM COMPUTER



WARSAW INSTITUTE OF TECHNOLOGY
RESEARCH DIVISION OF COMPUTER DEPARTMENT
00-665 Warszawa ul. Nowowiejska 15/19

ANOPS—105

SIGNAL AVERAGING AND HISTOGRAM COMPUTER

WARSAW INSTITUTE OF TECHNOLOGY
RESEARCH DIVISION OF COMPUTER DEPARTMENT
00-665 Warszawa ul. Nowowiejska 15/19

Druk wykonano w ITR.Nr zam. 153/82. Nakład 100 egz.

INTRODUCTION

ANOPS -105 is a modern, specialized, digital computer designed for application in medical and biological research. Its design is a result of close co-operation of engineers, doctors and biologists. ANOPS - 105 is an invaluable tool in acquisition and data processing in neurophysiological, biological and pharmacological research.

ANOPS - 105 finds the clinical application in electroencephalography, electromyography, retinography, cardiology and audiology as well as in numerous experiments in the fields of medicine and biology.

ANOPS - 105 provides a unique, developed in the Polish medical center, programme for automatic analysis of electromyographic record. The programme is based on the classical quantitative electromyography criteria, where during weak valuntary effort parameters of single motor unit potentials have been defined, such as the duration, number of phases and amplitude. The amplitude and record's density are computed during analysis in the case of the maximal muscle contraction. In each of the histograms the automatically computed mean values of the distribution are indicated on the display and constitute the basic parameters for the diagnostic evaluation of an EMG record.

ANOPS - 105 finds application in all the cases where the small signals are to be extracted from noise of relatively higher amplitude level. By means of repetitive averaging of the input signal the signal/noise ratio can be increased in proportion to the square root of the number of averaging process repetitions. The ANOPS - 101 computer provides the user with programmes for computing the PSH, IH and LH histograms, which permits the automatic calculation of the statistical fluctuation of the input data.

ANOPS - 105 features the possibility of co-operation with stimulators, electroencephalographs, electromyographs, while the results of the measurement and calculations can be sent to the following output devices: magnetic tape units, paper tape punches, XY plotters and other devices. The on-line observation of the experiment's results is made possible owing to the built-in CRT display unit.

PROGRAMMES AND APPLICATIONS

AUTOMATIC ANALYSIS OF ELECTROMYOGRAPHIC RECORDS IN THE FORM OF EH HISTOGRAMS.

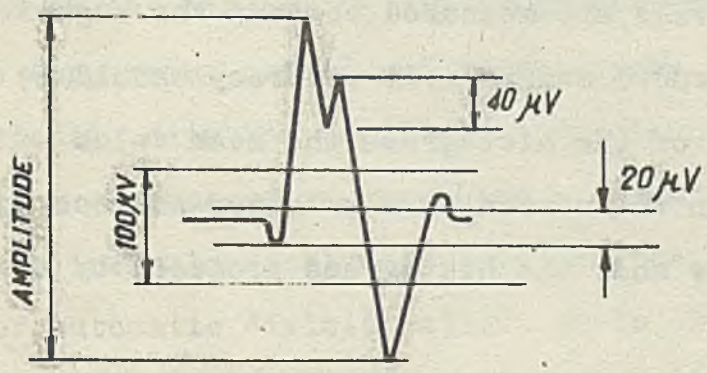
1. Histograms of motor units duration and the number of phases.

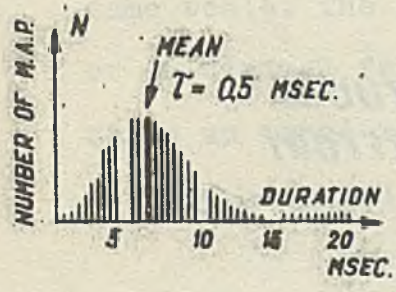
Automatic analysis consists of the definition of the spectrum distribution of duration, number of phases and amplitudes in the motor unit potentials measured during weak voluntary effort. The measurements are carried out with observance of the following criteria.

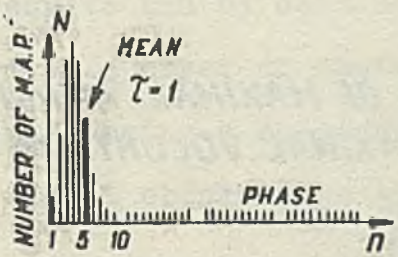
A motor unit is being registered if its absolute amplitude exceeds the value of 100 uV and its duration is being measured at the 20 uV level. A phase in a motor unit is being registered whenever the amplitude of a turn between a positive and a negative slope is greater than 40 uV. ANOPS's input is connected directly to the electromyograph's output, which should be capable of producing the output signals of the 2 V/cm deflection of EMG oscilloscope's beam. The ANOPS - 105 computer produces the mentioned above parameters' distribution histograms and computes the mean values of the parameters, which are indicated on the screen as brighter bars. Recommended measurement accuracy should be equal to 0.5 ms per address τ (it depends on the sampling interval value) in the case of duration measurement and it is equal one phase per address τ in the case of the number of phases measure-

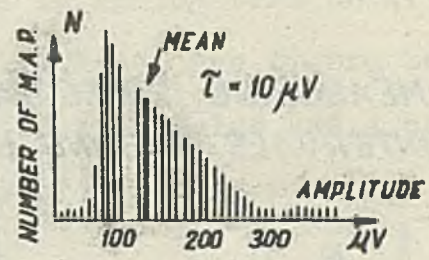
rement. The amplitude is measured of 1 mm of EMG osoillosoop's beam deflection per address (which depends upon the EMG sensitivity). The histograms obtained from the ANOPS - 105 computer are presented below.

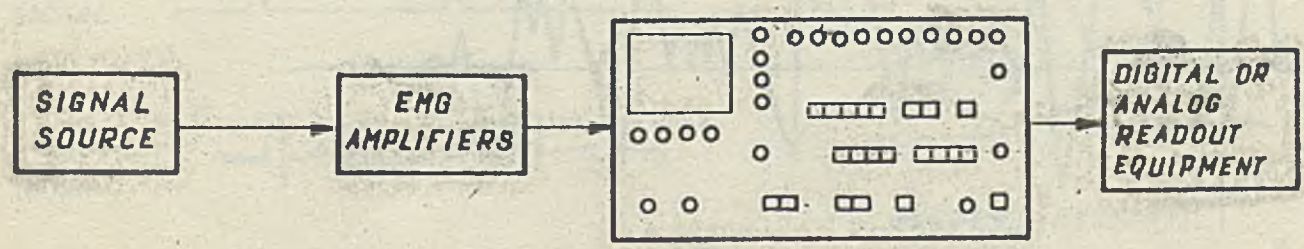
THE MEASURING CRITERIA OF SINGLE MUSCLE ACTION POTENTIAL





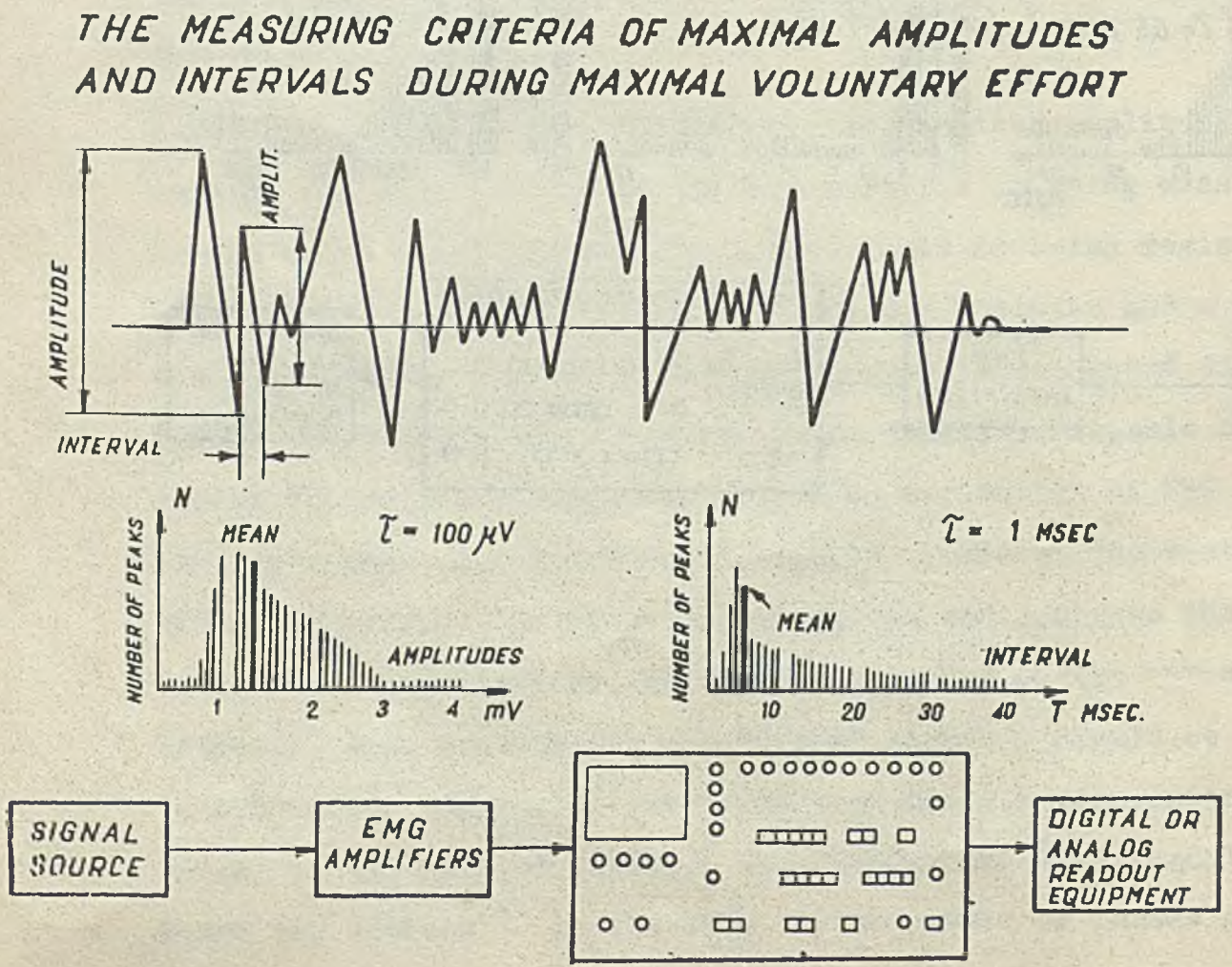






2. Amplitude and interval histograms.

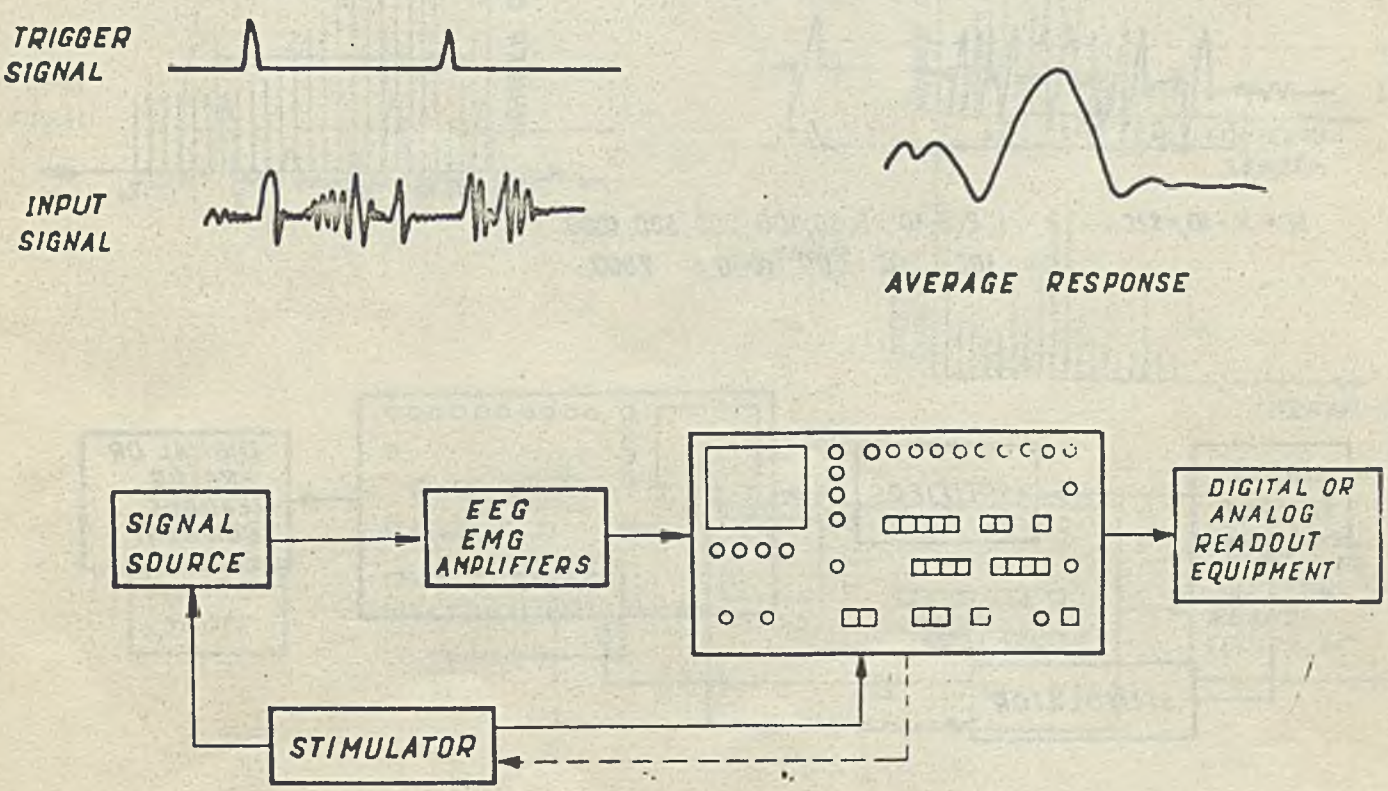
Both of these histograms are obtained while measuring the signals originating in a muscle during maximal voluntary effort. The amplitude histogram presents the distribution of amplitudes measured between a positive and a negative peaks with the accuracy of 1mm of EMG oscilloscope deflection per an address. The interval histogram presents the record's density in the maximal effort of a muscle; the intervals are measured between the negative peaks of the signal. Recommended measurement accuracy should be 1ms per an address. In each of the histograms the mean value of the parameter is indicated on the screen by a brighter address bar. The figures presented below show the histograms produced by the computer.



AVERAGING

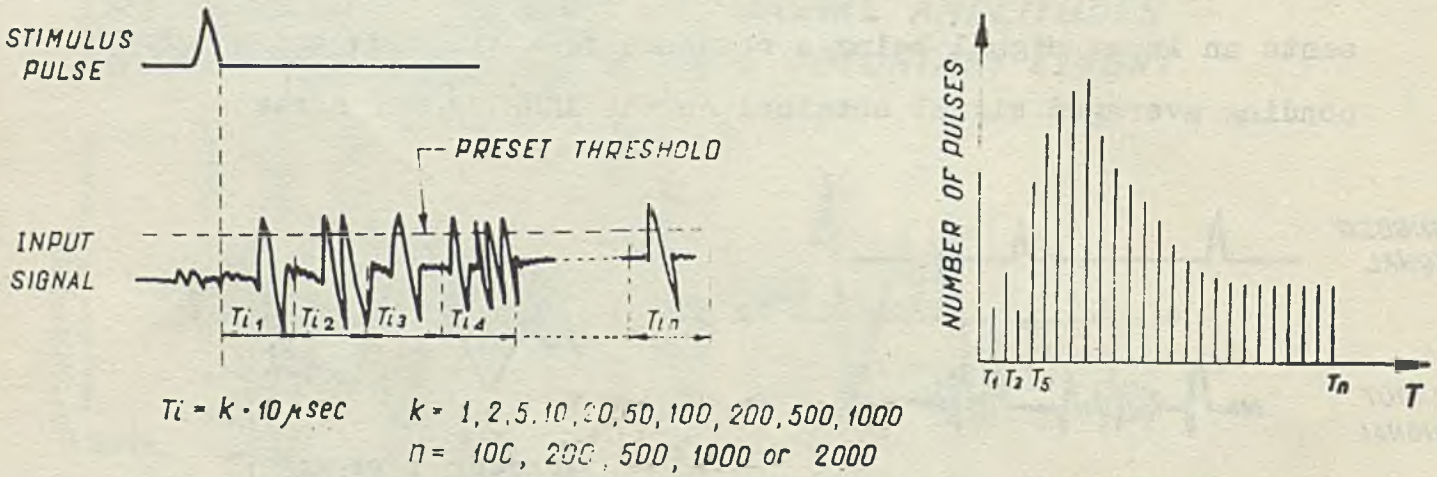
The averaging is applied in the case of experiments based on measurement of the potentials evoked by the different kind of shock. The electromyography, electroencephalography, electrocardiology and the measurement of the evoked potentials in electrophysiological research can be used as examples.

These potentials have random amplitude changes and the frequency band from zero to a few kHz. Frequently the response to stimulus is being lost in the biological noise (spontaneous activity), electrical noise (apparatus noise) and in artefacts. In order to extract out the signal, with the amplitude lower than the noise, the method of averaging of successive responses has been applied. The averaged results are instantaneously displayed on the ANOPS's CRT screen and the use of automatic division allows us to obtain the results in the same scale. The results can be obtained in analog form on XY plotter or in digital form on a paper or magnetic tape. The figure below presents an input signal being a response to a stimulus and a corresponding averaged signal obtained on the ANOPS's CRT screen.



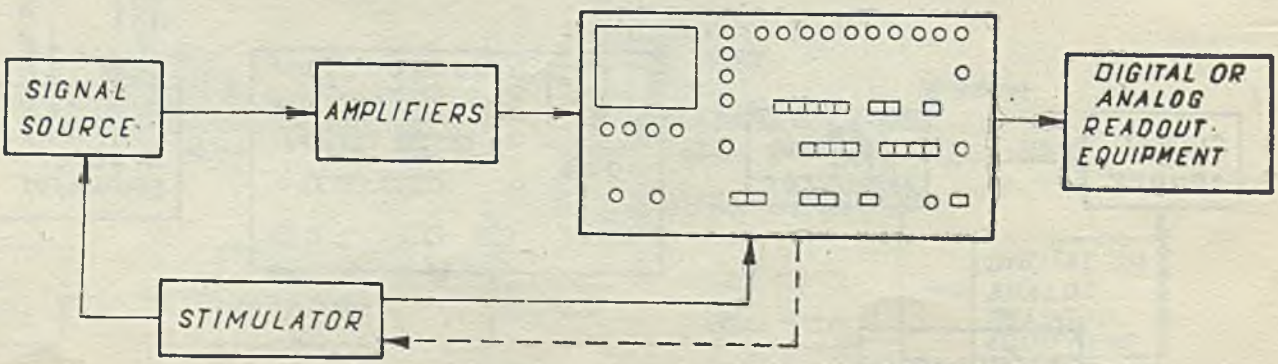
POST-STIMULUS HISTOGRAMS - PSH

The programme consists of couting the pulses occuring in defined time intervals. These histograms are commonly used in the observation of the influence of a stimulus on the series of pulse waves. They are applied in analyzing the experiment's records such as: nervous cell pulse potentials, standard behaviour actions, heart rhythm. On the figure below a response to a stimulus is presented, where in time intervals T_i the pulses which exceeded a certain triggering level (adjustable in the ANOPS computer) are counted; the corresponding histogram obtained on the ANOPS's CRT screen is also shown.



$Ti = k \cdot 10\,\mu sec$ $\quad k = 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000$

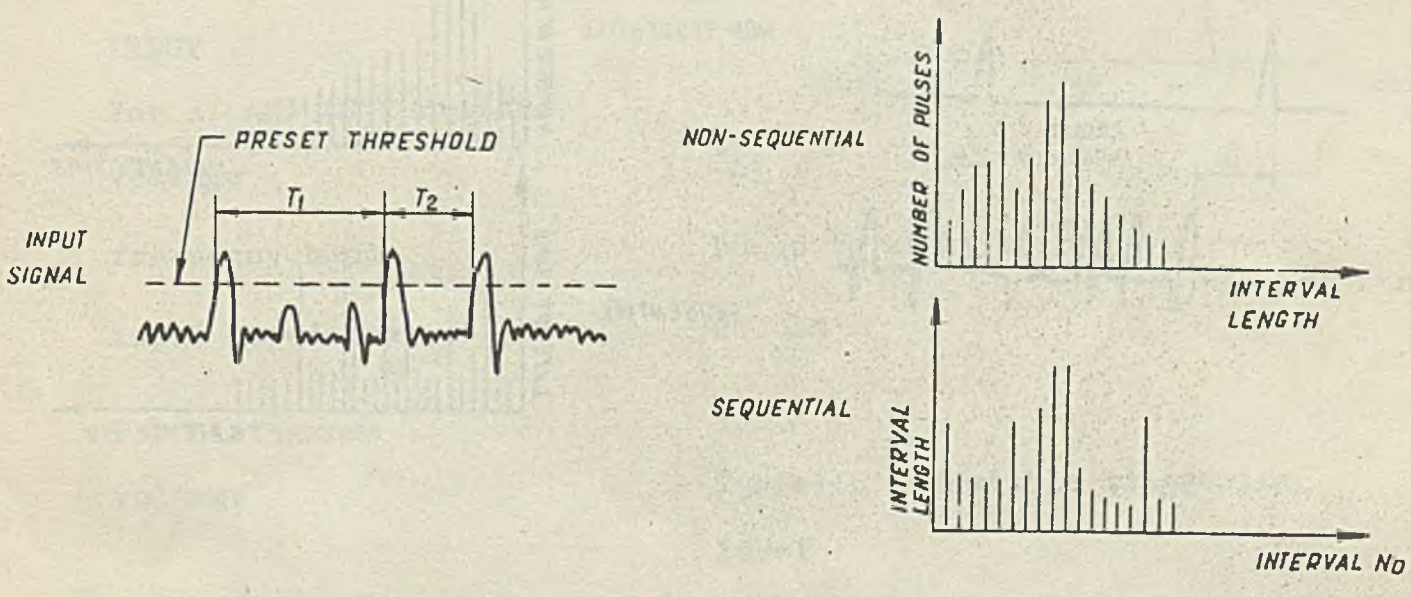
$n = 100, 200, 500, 1000$ or 2000

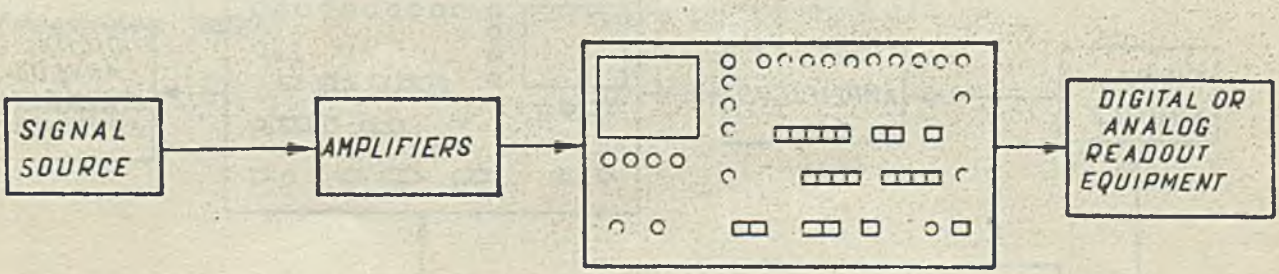


INTERVAL HISTOGRAMS - IH - SEQUENTIAL AND NON-SEQUENTIAL

These histograms find application in the research of the neuron adaptation states when it is exposed to different stimuli, in the research of the functional potentials generation in a cell or in the testing the heart arrhythmia.

The non-sequential histograms consist of producing the statistical distribution of distances between the consecutive pulses in a train while the sequential histograms consist of the measurement of intervals between the consecutive pulses in a pulse train. The latter programme allows registering of a sequence of biological occurences characterized with the great variance of the intervals between pulses. The figure belowe presents the signal under investigation, in which the intervals between pulses, which exceeded the triggering level, are measured. The picture obtained on the CRT's screen is also presented.





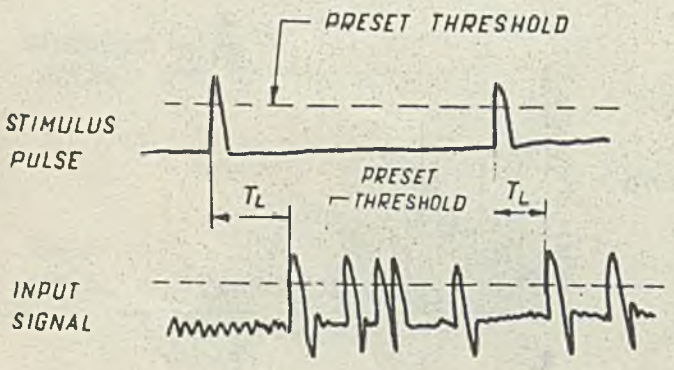
LATENCY HISTOGRAMS LH - SEQUENTIAL AND NON-SEQUENTIAL

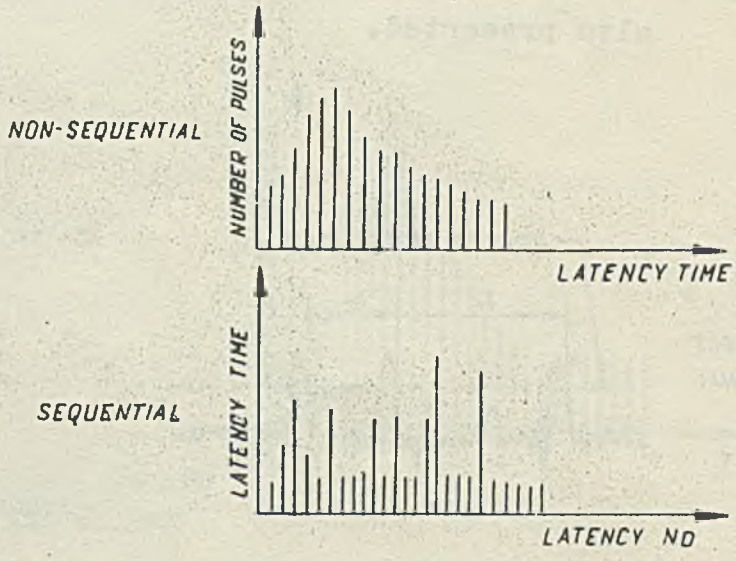
These histograms are of interest in the reserach of the reaction time and of the conduction time of an isolated nervous fibre, as well as in research of latency of muscle contraction when the nerve is exposed to some kind of stimulation.

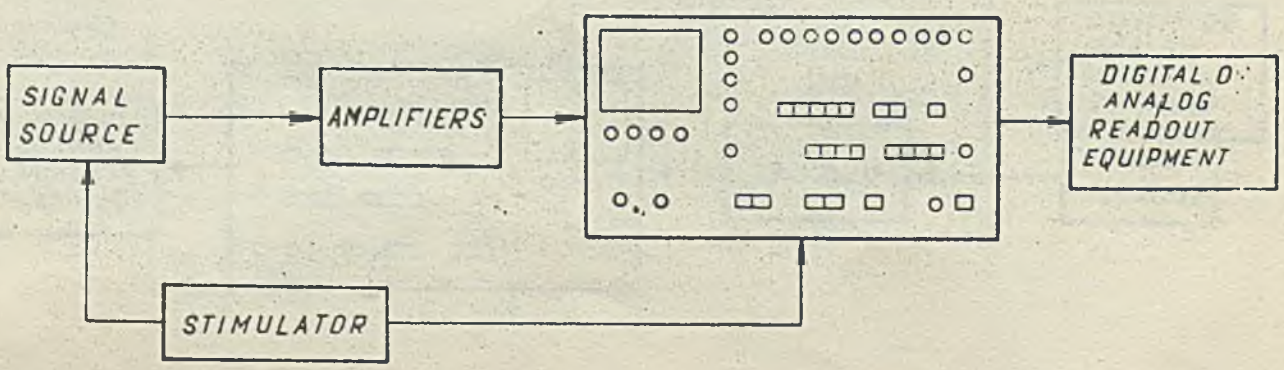
The non-sequential histograms consist of producing a statistical distribution of time T_L which elapses between a stimulus occurance and the occurance of the first pulse of the response.

The sequential histograms consist of the measurement of successive latency times between the stimulus and the first pulse of the response.

The figure below presents a series of stimuli and a series of responses, as well as the picture obtained on the ANOPS's CRT screen.







TECHNICAL DATA

PROGRAMS	EH - electromyographic histograms
	AV - averaging
	PSH - post-stimulus histograms
	IH - interval histograms, sequential and non-sequential
	LH - latency histograms, sequential and non-sequential
	AR - arithmetic operations - addition, subtraction and transmission of parts of memory
	AC - auto and cross-correlation functions - option
	OUT - output of information - option
NUMBER OF CHANNELS	4
INPUT	
For AV and AC functions	
voltage	$\pm$4V
frequency band	DC up to 20 kc/s
input impedance	2M ohm
For histograms	
voltage	$\pm$5V with adjustable triggering level
frequency band	5c/s up to 100kc/s
impedance	10 k ohm

TIME CYCLES

Sampling intervals or time measurement accuracy for histograms	from 0.01 to 10ms or from 0.01 to 10s in the sequence 1-2-5
Delay between a stimulus and the start of sweep	0 or from 0.01 to 5s, or from 10 to 5 10^3s, in the sequence 1-2-5 multiplied by the memory factor m
Sweep time	from 0.01 up to 10s of from 10 up to 10^4s, multiplied by the memory factor m

MEMORY

Number of addresses	2000
Numbers of bits in an address	16
Memory cycle	2 us
Effective memory	100, 200, 500, 1000 or 2000 addresses
Memory factor m	0.1, 0.2, 0.5, 1 or 2 for correspondingly 100, 200, 500, 1000 or 2000 of effective memory addresses
Effective memory is divided:	into 4 parts, when four channels are used, into two parts when two channels are used

NUMBER OF SWEEPS	1, 2, 4, 8, 16,..., 512, N
A/D CONVERTER	
Input voltage	±4V
Sampling intervals	10 usec
Number of states	256
TRIGGERING	
external	±5V with adjustable triggering level
SYNCHRONIZING OUTPUT	±14V, 120 usec
ANALOG OUTPUT	
Cathode ray tube	
screen dimenssions	8 x 10cm
amplification	1, 2, 4, 8, 16, 32
XY plotter	
plotting time	from 30 to 300sec
output voltage	±4V
DIGITAL OUTPUT	
16 bits of any of the memory addresses can be sent out in the form of	4 tetrads 4 bits each, or 2 bytes 8 bits each, or a single 16 bit word
CIRCUITRY	TTL integrated circuits
POWER SUPPLY	150VA, 115 or 220V ± 10%
OVERALL DIMENSIONS	470 x 220 x 470 mm
WEIGHT	35 kg

Practical application of quantitative analyses EMG recording by means of ANOPS computer. This is supplement for manual instruction of ANOPS.

PROGRAMES AND APPLICATIONS

THE USE OF COMPUTER TO ANALYZE ELECTROMYOGRAM PARAMETERS.

INTRODUCTION.

Clasical clinical electromyography using needle electrodes provides information about the parameters of individual motor unit potential /MUP/, about rate of firing during increasing muscle contraction. In pathological condition the MUP may be changed. If there is a reduction in the number of fibres per motor unit like e.g in various structural myopathic, a needle electrode will record a less integrated MUP. The average amplitude will be lower than normal, similary the duration of MUP is usually reduced.

In neurogenic atrophies secondary to peripheral neuron lesion, the motor units may have more than average number of muscle fibres, the innervation ratio usually is increased. As the results in widening of the innervation zone, the temporal dispersion of motor unit is increased which leads to the polyphasic and or prolongated MUP. Severs abnormalities of the EMG in primary muscle disease and in neurogenic lesions are easily recognized by observing the cathode ray tube and listening to the loudspeaker.

In the assestment of mild changes, quantitative methods are required to provide a statistical basis for sampling of muscle during voluntary effort. There is no doubt that only the quantitative electromyography can give basis of clinical

diagnosis. 3 parameters of individual MUP due to Buchthal work are measurable and in laboratories applying quantitative method are statistically evaluated. The maximal effort pattern evaluation even in Buchthal's method is descriptive and has no quantitative expression. Quantitative electromyography is commonly highly appreciated but surprising enough is very seldom applyied. The most important if not the only reason for it is fact, that this method is very time consuming specially that in a good centers everybody is aware of necessity to examine as many muscle as possible if the diagnosis has to be reliable. ANOPS is equipped with special program for automatic EMG analysis. It makes possible to use the quantitative electromyography to common clinical practice by making it less time-consuming.

METHOD.

On Fig.1. is shown the basic block diagram of the input system ANOPS computer. Minicomputer ANOPS works on-line and has to be connected to the output of the electromyograph. Due to build in hybrid circuits it records the selected MUP on the C.R.T. screen, in the form of ready histograms. The number of MUP to be recorded and the measuring accuracy there of, my be arbitrary chosen by means of suitable controls. The MUP coming from the electromyograph are fed to the input system where they are converted into corresponding pulse sequences. Thus, the input system provides ready impulses, being then only counted and classified in the computer. The input system is provided with a number of outputs of its channels, which decide about the parameters of the EMG record to be measured.

During a weak contraction two parameters are simultaneously measured, namely the duration and the number of phases of single MUP. During maximum muscle contraction two others parameter are measured: amplitudes and density of interference pattern. The specified device is aimed at plotting the statistical distribution of pulses generated in the input system. The content of each store address is simultaneously automatically displayed. The horizontal co-ordinate of each line corresponds to the duration of MUP, to the number of phases, and to the amplitude or interval between the potential peaks. The height of each line /bar/ expresses the number of units being measured. In each histogram, mean value of measured parameter are calculated and additionally lighted on the screen.

The measuring criteria.

During weak effort 3 parameters of single MUP are measured. On Fig.2. are shown the measuring criteria of single MUP.

Duration. For practical reason we sugest to take 64 MUP for analysis in each of 8 or 16 sites in the examined muscle, yielding a total 512 or 1024 MUP. Constant sensitivity of 100 uV/div. has to be used. Thus, only potentials exceding 100 uV /decision level/ are accepted for measurment. The duration of those potentials are measured at the 20 uV level /measuring level/. The accuracy of 0,5 ms is recomended.

Phases. The same 512 or 1024 MUP are simultaneously examined for complexity. A phase is recognized and counted each time as potential changed its polarity by more than 50 uV.

Amplitude. The amplitude of MUP is measured in the same program as for maximal effort, thus in fact we are measure of every phase from its negative to positive peak. The amplitudes are measured at different sensitivity just to get whole amplitude of MUP in the range of 3-4 div. On the histogram the amplitude is expressed as uV per address /each address corresponds to 1 mm of the EMG record/. During maximal effort two parameters of interference pattern are measured. On Fig.3. are shown the measuring criteria of interference pattern.

Amplitudes. In the amplitude program amplitudes of interference pattern are measured at correspondingly to the preset sensitivity of electromyograph amplifiers expressed in uV per div. The maximum amplitudes are measured between their negative and positive peaks and in the computer the amplitude is expressed as uV per address.

Density. The density of interference pattern is measured with an accuracy of 1 ms, in terms of the intervals between successive negative peaks.

NEEDLE ELECTRODE STUDIES /ELECTROMYOGRAPHY/.

There is no fixed procedure in the plan of an electromyographical investigation; its form, unlike some other electrophysiological investigations, depends not only upon the clinical problem under consideration but also upon information gained in the course of it, and a knowlage of peripheral anatomy, especially of innervation, is indispensable.
The investigation should be performed in a comfortably warm room se that the patient may be undressed without shivering a source of artefact. An examination couch is necessary so that

the patient can lie, usually on his back, in as relaxed a position as possible. Each investigation demands a sharp needle sterilised, according to type by autoclave or immersion in formaldehyde vapour. If the doctor performing the investigation has not already examined the patient clinically he must do so before embarking upon electromyography. In particular, he must test the power of muscles he intends to sample before inserting the needle as pain may then discourage a maximal effort. The patient can then be shown how he will be required to contract the muscle concerned after the needle has been inserted. The entry of the needle will be heard rather than seen any insertion activity will last little longer than the movement of the needle; the presence of insertion activity indicates that the tip of the needle has entered the muscle proper. The loudspeaker should have been switched on before insertion of the needle so that no early potentials of any kind are missed. Then with the muscle completely relaxed, the investigator watches and listens for spontaneous activity. So - called endplate noise can be distinguished from short duration potentials of pathological significance by its form and by the ease with which readjustment of the needle position will abolish it. When a healthy muscle is relaxed no action potentials should be registered, but this is not the case with extra-ocular muscles, which always show some basic continuous activity /stabilisation of the eye/. Having ascertained that there is no spontaneus activity, the patient is now asked to activite the muscle; one can start with maximal effort, but it is more usual to ask for the weakest possible contraction in order to study individual motor

unit action potentials. Recruitment of further potentials and increase in discharge frequency can then be achieved by asking the patient to progressively increase his effort; this results eventually in the interference pattern.

The recording procedure.

The recording procedure will be the same for each type of electrode. It is very well know fact that duration of single MUP is very much depende from the used electrod /its picking up area/. Therefore it is essential that the normal values can be only used for given type of electrods. There is a big difference in values obtained by two different types of concentric needle electrodes /DISA 13K57 and TECA Cf25M/, for single MUP duration. phase and amplitude. Output from the electrode is amplified by standard DISA Electromyograph or TECA. Conection between output of any standard Electromyograph and the ANOPS should be made by concentric cable with BNC plugs to input socet marked IN I /no 52/.

Than following procedure should be applied:

1. Turn on the machine and minicomputer and check the dial, and knob settings. On the EMG, vertical position of the trace focus, trace intensity, sweep speed. Sweed speed of the oscilloscope should be at 10 ms. per grid division, potentials may appear double or triple due to rapid trace sweep making them difficult to interpret.

2. Place the ground electrode on patient, prefarably near the muscle to be tested. Select an EMG needle, using a 1 1/2 in, needle for obese individuals or when deep muscules are to be examined, and a 3/4 in, needle for children. If monopolar needle is being used, place the indifferent electrode on the skin in proximy to the needle. Plug the cable form needle into the machine outlet on the flexible arm. Select the muscle to be tested and cleanse the skin with alcohol in preparation for insertion of the needle. Obtain muscle relaxion and be prepared to listen to the sound of insertion activity. Let the patient know that the needle is about to be insert. Insert the needle in a swift, smooth movement into the muscle and listen to the insertion potential and any potentials that follow. Normally there will be a brief burst of insertion activity and looklisten for any abnormal potentials such as spontaneus fibrilations or fasciculations. Do this for 30 to 60 records. If no abnormalities are noted, investigate the area further. If fasciculations are present, allow the needle to remain in place and note the approximate number per unit time.

   If fibrilation are noted to occur after insertion activity, then record how long they persist, together with size and frequency. If fibrilations occur spontaneously, see if they can be increased in number by tapping the muscle near the needle. Before the quantitative measurment has to be done check the controls on ANOPS for duration and phase histograms.

3. Set the PROGRAM selecter /no 19/ into EH position the HN /no 18/, HS /no 18/, A, +B /no 14/ push-buttons should be pressed out. Press the TRIGGER /no 29/ INTERNAL push-button. Set the DELAY /no 11/ selector switch into its 0 position. The SAMPLING INTERVAL /no 13/ set to 0.5 ms /this is your accuracy measurment/. The SWEEP setting depends on the desired sample size. /Number of MUP to be calculated in the histogram/.

$$\text{Sweep Setting} = \frac{\text{Desired sample size}}{4 \text{ /Number of sample points/}}$$

If desired sample size is 512 MUP, and you will sample from 4 points in the muscle:

$$\text{Sweep Setting} = \frac{512}{4 \times 4} = 32$$

Set a multipler selector push-button on 0.5 getting 500 memory addresses for two histograms.
Press in the CHANNEL SELECTOR A /no 26/ I and II push-buttons and the CHANNEL SELECTOR B /no23/ I and II push-buttons.
Select two channels only by means of the CHANNELS switch /no 30/. Than the PULSES /SWEEP/ no 42/ selector switch should be set to its "16" position and the VERT RANGE /no 40/ switch in its "4" position. Now you are ready to make muscle examination asking patient to contract the muscle as little as possible to study the individual MUP.

As it was already stressed the sensitivity of the EMG should be constant at 100 uV/div. The number of units observed may be increased by moving the needle vertically and thus using auditory information to determin optimal position /sharp and biggest amplitudes of MUP/.

4. Having a needle in striated muscle picks up potentials from 4-6 motor units pressing the push-button START /no 24/. On the screen you will see how two histograms /duration and number of phases/ is complited. The preselect number of MUP will be calculated and automatically stop /the proper number will be seen on given lamp - SWEEP COUNT/. Then sample predetermined number areas of the muscle using the "quadrant" technique, using the same procedure for every insertion. Fig.4. Shows histograms from biceps muscle in normal subject. The upper histogram represents duration of single MUP.
Each bar corresponds to the selected sampling interval = = 0,5 ms. The mean duration is shown in 16 th bar = 8 ms. The lower part of histogram represents the same number of MUP with their phases distribution. Each bar corresponds to one phase, with the first bar indicating 0 phases.
In this example the mean number of phases is 2.
During the same procedure we recomend also to measure amplitudes of single MUP which gives very sensitive factor for distinguishing peripheral neuropathy from anterior horn cell disease. Withe the same setting turn to amplitude programm pressing the push-button NH /no 18/. Now it would be necessary to change sensitivity of the EMG to get single MUP in the range of 3 division on the EMG screen.

Fig.5. Shows the amplitude histogram of single MUP. In this case we disregarde the upper histogram and observe only lower - amplitudes. Each bar on the histograms corresponds to 0,1 x gain setting on the electromyograph /in fact one bar corresponds 1 mm of EMG amplitude/. In this example the sensitivity setting was still 100 uV/div. The mean amplitude is 130 uV/13-th address/ and the maximum 340 uV. The gain set, se that the amplitude should exceed four division on the EMG.

The interference activity.

The interference activity is measured with the accuracy of 1 ms by changing SAMPLING INTERVAL /13/ to 1 ms. To get 512 or 1024 number of peaks from one point of a muscle it is necessary to change SWEEPS control /16/ to 128 or 256 position.

5. Turn the gain down do get maximal amplitudes in the range of 3-4 division on the EMG screen and the sweep speed at 50 ms per grid division. Have the patient contract the muscle maximally press the push botton START. Fig.6. Shows an example of maximal effort recording from the same muscle and patient.
The upper histograms represents density of interference pattern. Each bar corresponds to the sampling interval setting. In this example the mean interval = 7 ms /143 Hz/ and the maximum 21 ms /48 Hz/. The lower histogram represents amplitudes distribution. Each bar on the histogram corresponds to 0,1 gain setting on the electromyograph. In this example the gain setting was 1000 uV/div. the mean

amplitude is 1200 uV, and the maximum 3400 uV. The gain is set so that the amplitude does not exceed four division on the electromyograph.

After recording all five parameter of quantitative electromyography than proceed to the next muscle to be tested. It is very important that during a time patient is making maximal contraction, the measurment should be complieted in the first 3-5 seconds. If the histogram was not completed to 512 or 1024 peaks it is necessary to begin the next measurment after 20-30 seconds rest.

The ANOPS computer proved easy to use and the EMG examination of a muscle is usually compled is less than 5 minutes, including the time required for making report of all parameters.

As an example the means values for the four muscle action potential parameters obtained by concentric DISA electrode in 21 controls with the ages from 15 to 58 years are given below.

The means for four muscles:

		M.biceps brachi $\bar{X}$	± SD	M.intermoseus dorsalis $\bar{X}$	± SD	M.quadriceps femoris $\bar{X}$	± SD	M.tibialis anterior $\bar{X}$	± SD
Duration MUP /ms/	Mean	9,9	1,4	9,5	1,5	10,9	1,1	11,3	2,1
	modal	4,1	1,6	5,7	1,5	5,4	2,3	5,4	2,1
Phase MUP	mean	3,7	1,9	3,6	1,7	3,6	2,2	3,8	1,8
	modal	1,1	0,5	2,0	0,3	1,1	0,4	1,4	0,7
Amplitud MUP /uV/	mean	205	80,5	290	129	289	131	337	129
	modal	118	62,5	140	90	137	59,8	182	77
Density of interference pattern /Hz/	mean	113,7	32,3	132,5	50,8	97,8	31,2	115	43
	modal	211,8	94,7	243	82,6	184	67,5	225,4	86
	minim.	46,0	12,2	47,2	16,1	38,6	10	40,4	8
Amplitudes /uV/	mean	1155	537	1467	546	962	309	1020	418
	modal	605	285	855	483	640	276	632	278
	max.	2996	1566	3693	1372	2447	900	2530	1056

BLOCK DIAGRAM OF ANOPS

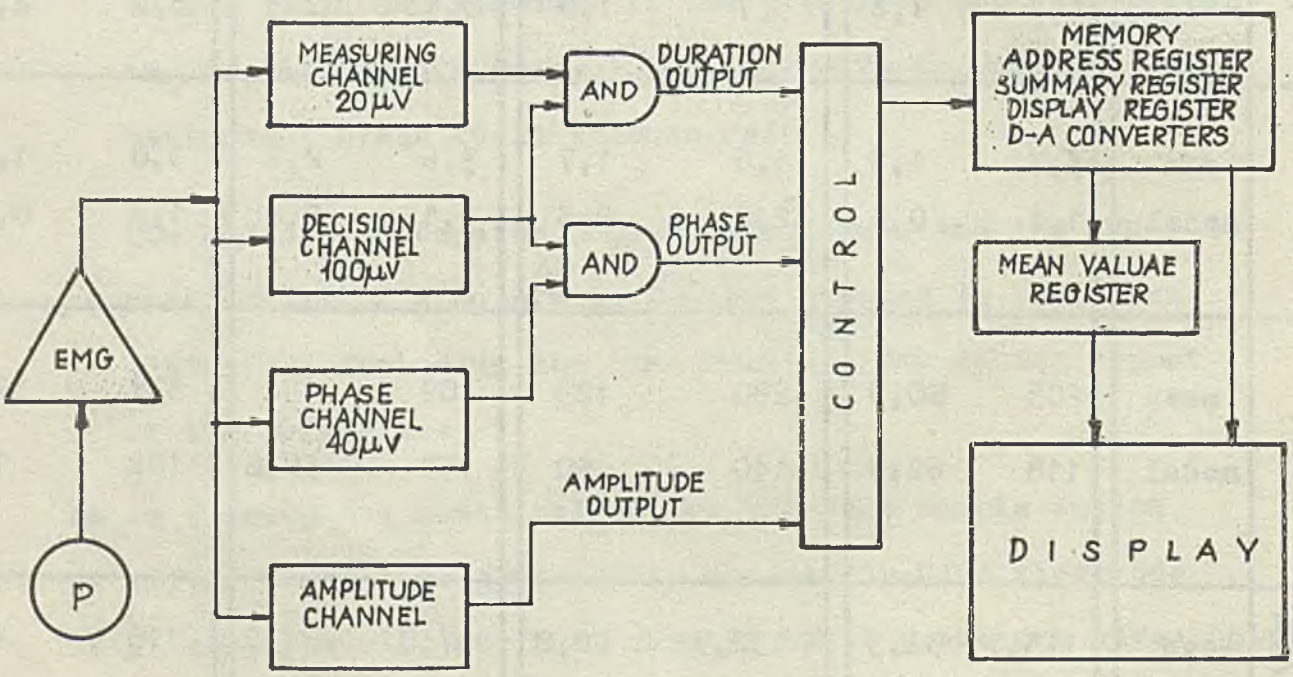


Fig. 1

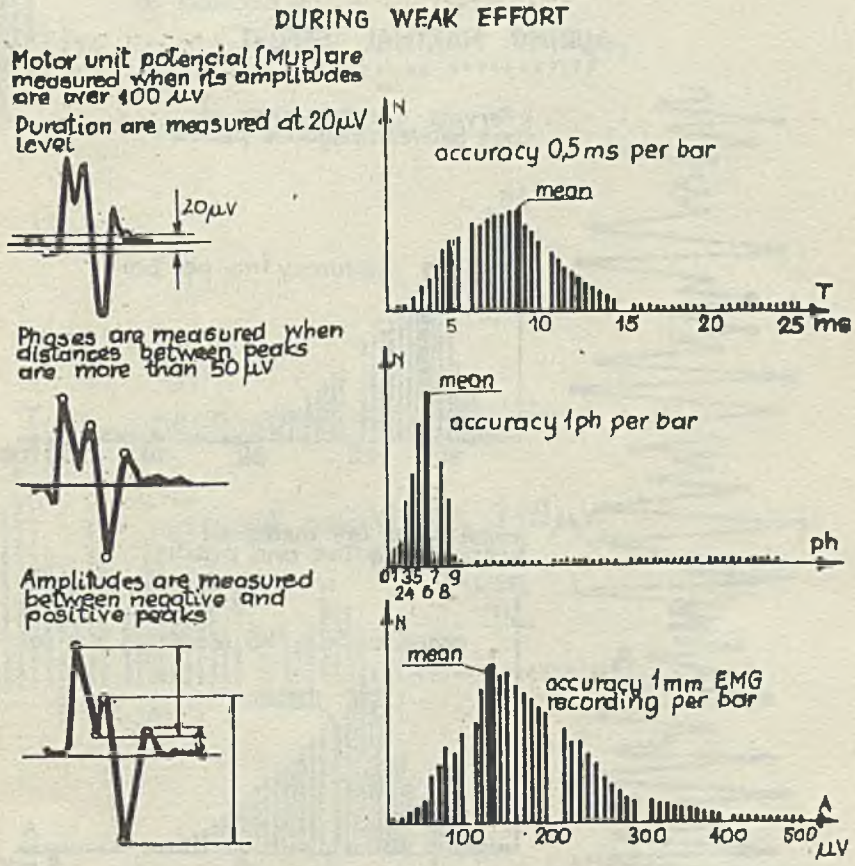

DURING WEAK EFFORT
Motor unit potencial [MUP] are measured when its amplitudes are over 100 µV
Duration are measured at 20µV level
20µV
Phases are measured when distances between peaks are more than 50 µV
Amplitudes are measured between negative and positive peaks
N
accuracy 0,5 ms per bar
mean
T
5
10
15
20
25 ms
N
mean
accuracy 1ph per bar
ph
0 1 3 5 7 9
2 4 6 8
N
mean
accuracy 1mm EMG recording per bar
A
100
200
300
400
500
µV

Fig. 2

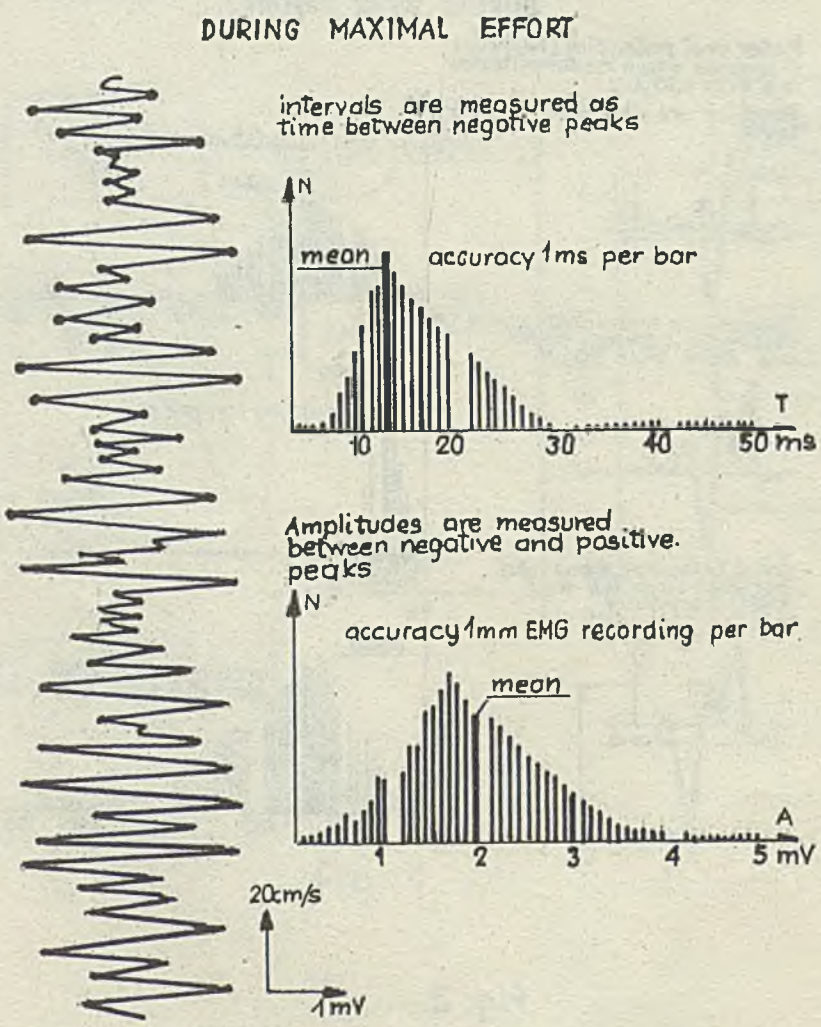

DURING MAXIMAL EFFORT
intervals are measured as time between negative peaks
N
mean
accuracy 1ms per bar
T
10
20
30
40
50 ms
Amplitudes are measured between negative and positive peaks
N
accuracy 1mm EMG recording per bar
mean
A
1
2
3
4
5 mV
20cm/s
1mV

Fig. 3

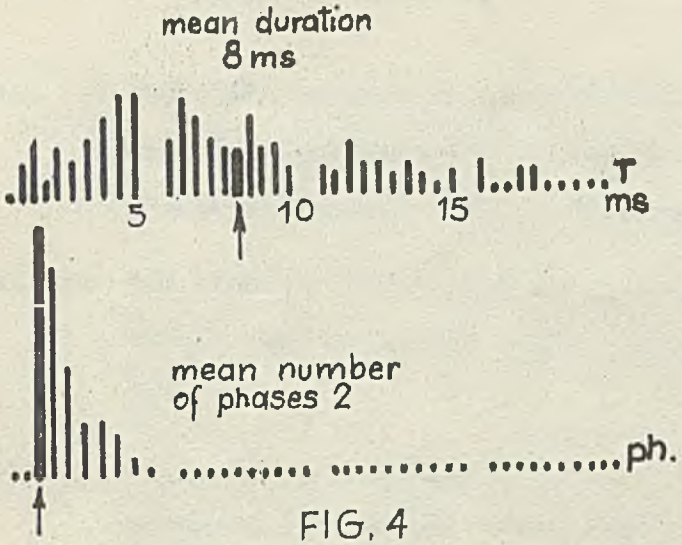


FIG. 4

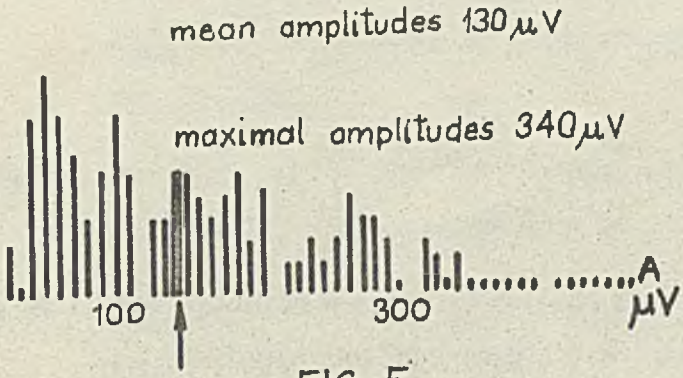


FIG. 5

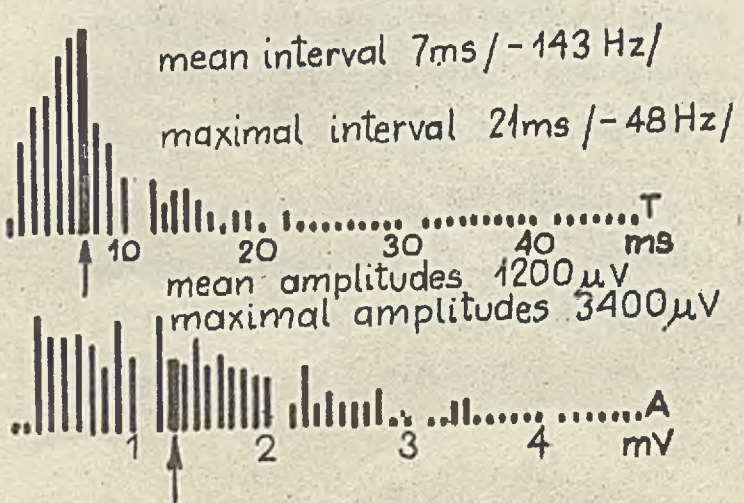


FIG. 6

REFERENCES

1. Bergmans, J.: Computer-assisted on line measurement of motor unit potential parameters in human electromyography. Electromyography, 1971, 2, 161-181.

2. Buchthal, F., and Pinelli, P.: Action potentials in muscular atrophy of neurogenic orgin, Neurology, 1953, 3, 591-603.

3. Buchthal, F., Guld, Chr., and Rosenfalck, P.: Action potential parameters in normal human muscle and their dependence on physical variables. Acta physiol, scand, 1954, 32, 200-218.

4. Buchthal, F., Pinelli, R., and Rosenfalck, P.: Action potential parameters in normal human muscle and their physiological determinations. Acta physiol. scand. 1954, 32, 219-229.

5. Buchthal, F.: An introduction to Electromyography. Scandinavian University Books, Copenhagen 1957.

6. Hayward, M.: The recognition of partial denervation by automatic analysis of the EMG, Abst. 9 th Internal. Congr. Electromyography, Brussels 1971, pp. 64-65.

7. Kopeć, J., Hausmanowa-Petrusewicz, I., Rawski, M., Wołyński, M.: Automatic Analysis in Electromyography, New developments in Electromyography and Clinical Neurophysiology. Karger, Basel 1973, 447-481.

8. Kopeć, J., Hausmanowa-Petrusewicz, I., Rawski, M., Wołyński, M.: Automatic Recording of EMG Parameters in the form of Histograms by an ANOPS computer in Hausmanowa-Petrusewicz, I., Jędrzejewska, M. /eds./ Structure

a function of normal a diseased muscle a nerve. PZWL., Warszawa, 1974a, 375-381.

9. Kopeć, J., Hausmanowa-Petrusewicz, I.: Application of automatic analysis of electromyography in clinical diagnosis. Electroenceph. Clin. Neurophysiol, 1974b, 14, 2, 303.

10. Kopeć, J., Hausmanowa-Petrusewicz, I.: Automatic analysis of electromyograms by means of ANOPS computer. Excerpta Medica Proceeding of III rd International Congress on Muscle Diseases. 1974c, abstr. 314.

11. Lang, A.N., and Vaahtoranta, K.M.: The baseline, the time characteristics and the slow alterwaves of the motor unit potential. Electroenceph, clin. Neurophys, 1973, 35, 387-394.

12. Lee, R.G., and White, D.G.: Computer analysis of motor unit action potentials in routine clinical electromyography. New Developments in Electromyography and Clinical Neurophysiology. Karger, Basel 1973, 454-461.

13. Pinelli P., and Buchthal, F.: Muscle action potentials in myopathies with special regard to progressive muscular dystrophy. Neurology 1953, 3, 347-359.

14. Willison, R.G.: Analysis of electric activity in health and dystrophic muscle in man. J. Neurol. Neurosurg. Psychiat. 1964, 27, 386-394.

15. Kopeć, J., Hausmanowa-Petrusewicz, I.: On-line computer application in clinical Quantitative Electromyography. Electromyogr. Clin.Neurophysiol. 1976,16, 49-64.

FOREIGN

TRADE ENTERPRISE

METRONEX

OF THE UNION OF AUTOMATION AND MEASURING

INSTRUMENTS INDUSTRY "MERA"

Al. Jerozolimskie, 00-950 Warszawa, POLAND

P.O. BOX: 198, TELEX: 81 44 71

PHONE: 26-22-21, 26-74-41