ANOPS-101

SIGNAL AVERAGING AND HISTOGRAM ANALYZER

OPERATING INSTRUCTION

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

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C O N T E N T S

section 1

APPLICATION OF ANOPS 101

In order to test and verify hypothesis the biomedical sciences rely on experiments carried out on living organisms.
The effectiveness of the research work depends greatly on a number of experiments that are to be carried out in order to verify a given hypothesis.
The need for multiple experiments results of a natural scatter of results existing in the population of the phenomena under unvestigation. The scatter is due to the complexity of the organism's functions, which are never entirely under out control, as well as it is due to the inaccuracy of the instruments applied in the experiments and the inaccuracy of the research methods themselves. All factors mentioned above lead to the application of statistical techniques in the evaluation of the results, which calls for multiple measurements.
On the other hand, the effectiveness of the research work calls for the decrease in the number of experiments.
The immediate evaluation of results, leading to the adjustment of the measurement range or factors influencing a process under investigation, permits the aptimization of experiments. What is more interesting, such methods facilitate observation of new, unexpected phenomena, which are often a valuable source of information on the functions under test. The instantaneous assessment of the processes occuring in an organism if of prime importance in the clinical practice.
Nowadays, the number and variety of information being gathered during experiments constantly increases as a result of quick development in the research techniques. This calls for the digital on-line processing. As the result, specialized computers are being designed for the application in biomedical research.
They are capable of performing some simple analysis on-line with measurement realization; for instance they produce different kinds of histograms of pulses as well as the averages of the voltage waveforms. If the need for more complicated analysis arises the specialized computers can be treated as the preliminary data processing devices for larger, more powerfull, general-purpose computers.
The specialized computers can be also used as the means of the off-line processing with the information being fed via magnetic tapes recorded at the process site. The latter mode of work becomes a common practice as it greatly facilitates the data acquisition processes and makes possible handling experiments with rapidly changing parameters to be controled, which could not be handled with the use of previously existing methods.
The work on design and application of the systems of the mentioned kind has been carried

out with the help of biologists and doctors at the Research Division of Computer Department at Warsaw Institute of Technology on the span of the last few years.
ANOPS is the result of this cooperation. The successive, improved version of this system have been applied and are being constantly used in many research centers at home and abroad.
ANOPS is an analogue-digital analyzer designed for measurement and statistical processing of an input information in the form of continuous or pulse type voltage waveforms.
ANOPS has been designed so that it can work in the systems combined of stimulators, encephalographs, electromyographs, electrocardiographs, as well as XY plotters, paper tape punches and magnetic tape units.
ANOPS finds the clinical applications in electromyography, electroencephalography, cardiology and audiology as well as in numerous experiments in the field of medicine and biology.
ANOPS performs following operations:

1. AV - picking signals out of noise by averaging the waveform for example the examination of the evoked cortex cerebri potentials and the examination of the evoked potentials ogriginating in muscles and nerves, measured through skin as the response to stimuli.
2. PSH - post-stimulus histograms (sequential) - registration of pulse distribution as a function of time, e.g. to evaluate the response of a single nerve element to stimuli.
3. IH - interval histograms (S - sequential, N - non-sequential) e.g. examination of the distribution of intervals in a series of a single nerve cell's discharges in preset conditions without recurring stimulus.
4. LH - latency histograms (S - sequential, N - non-sequential) - examination of pulse delay distribution in response to stimuli.
5. EH - electromyographical unit histograms (non-sequential) - examination of the statistical distribution of motor unit duration number of phases, amplitudes and density parameters - used in quantitative EMG practice.
6. Arithmetic operations - addition, subtraction and restoring contents of given memory locations in new locations.
7. Possibility to easily connect additional peripheral devices, such as plotters, paper tape punches or magnetic tape units.

As ANOPS is a digital analyzer its input signals are being transformed into digitals by means of pulse forming (e.g. IH function) or through analogue-to-digital conversion for continuous waveforms inputs (e.g. AV). The operation of the system can be treated as two distinctive functions - measurement of input data and then performing calculations in accordance with a preselected routine.
Results are being stored in a memory and displayed on a CRT screen.
They can be also obtained in a from of a hard copy.

section 2

TECHNICAL DATA

PROGRAM	1. AV - averaging, 2. PSH - post-stimulus histograms, 3. EH - electromyographical unit histograms, 4. IH - interval histograms, sequential and non-sequential, 5. LH - latency histograms, sequential and non-sequential, 6. AR - arithmetic operations, 7. IN - input operations, 8. OUT - output operations.
NUMBERS OF CHANNELS	4 for averaging and histograms, 2 for myographic histograms.
INPUT VOLTAGE	
for averaging AV	±4 V
frequency band	0 to 20 kHz
input resistance	2 MΩ
Input voltage for histograms (PSH, IH, LH, EH)	adjustable with triggering level of ±5 V
frequency band	5 Hz to 100 kHz
Sampling intervals T_i and accuracy of time measurement for histograms	0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1, 2, 5, 10 msec and external
FACTOR k	1, 10^3
Delay T_d between a stimulus and the beginning of sampling $T_D = T_d \times m \times k$	0, 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1, 2, 5, sec and external
FACTOR m	m = 0.1, 0.2, 0.5, 1, 2
SWEEP TIME T_a in sec $T_A = T_a \times m \times k$	0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1, 2, 5, 10 and external
Number of sweeps	1, 2, 4, 8, 16, ... 512, N
STORE - number of memory	1 x 1000 x P

locations storing the measurement	or 2 x 500 x P
results	or 4 x 250 x P
where	p = 0.1, 0.2, 0.5, 1, 2
Memory cycle	2 μsec
Number of bits	16
Numerals' range	$-32768 < x < +32768$

A/D CONVERTER

input voltage	±4 V
sampling intervals	10 μsec
number of states	256

ARITHMETIC OPERATIONS

1. ADDITION AND SUBSTRACTION
   $A \pm B \rightarrow A$
2. RESTORING
   $B \rightarrow A$

TRIGGERING

Internal - synchronizing output pulses	+14 V, 120 μsec
External - synchronizing input pulses	Voltage = ±5 V (as for IH)
	Intervals $T \geq T_D + T_A$

ANALOGUE OUTPUT

1. Built in CRT screen 8 cm x 10 cm
   a. amplification 1, 2, 4, 8, 16 or 32 times,
   b. can be used as a monitor.
2. Possibility to connect a X, Y or X, t plotter
   time of output transmission onto the plotter adjustable within the range of 30 to 300 sec.
3. An information of nine bits length from any of the channels can be obtained through a linear DA converter
   The nine bits to be sent out are being selected with a switch or automatically.

DA converter out voltage	circa 8 V
Linear DA converter sensibility	1024 states

DIGITAL OUTPUT

Paper tape punch

16 bits of each memory location of a selected channel are being divided into 4 tetrads. The transmission starts with the least significant and ends with the most significant tetrad.
Output of data in mode 16 bits.

A magnetic tape unit can also be connected as an input device.

CIRCUITRY	Integrated circuits
POWER SUPPLY	220 V 50 Hz ± 10% 100 VA or 110 V 60 Hz ±10% 150 VA
OVERALL DIMENSIONS	470 x 220 x 470 mm
WEIGHT	35 kg

section 3

PANELS

Controls and push-buttons of the front panel are depicted on figure 3-1, rear panel controls, input and output sockets are detailed on figure 3-2.
1 to 9, 33 and 34 controls enable continuous adjustment of CRT parameters, while 11, 13 and 16 control switches enable stepwise regulation of the SWEEP time and the number of SWEEPS.
The 10, 12, 14, 18, 23, 26, 29 and 31 push-buttons and 30, 35 to 38, 40 and 42 controls are provided for the mode of work selection.
Auxilary functions are being selected with the help of 15th, 22nd, 24th and 28th push-buttons.
For the convenience of a user a group of control lights has been designed and situated in the right top corner of the front panel.
These lights provide the information on the present state of the Scan Number Counter (holding the number of scane N carried out up to the present moment) - which can be read of by adding the values corresponding to each of the lamps set on at the moment.

FRONT PANEL CONTROLS AND PUSH-BUTTONS

1. INTENSITY - a control enabling brightness of an CRT image adjustment.
2. FOCUS - used for image sharpness adjustment.
3. ASTIGMATISM - enable adjustment of the CRT screen astigmatism.
4. SCALE - used for the scale illumination.
5. Y SENSITIVITY - a switch for a stepwise regulation of the amplitude of vertical amplifier's output for CRT.
6. CHANNEL IV - vertical shift on the screen of an information from channel no. IV (operates if the selector switch no. 30 is in the "I-IV" position).
7. CHANNEL III - vertical shift of an image from channel III (opera-

tes if the selector switch no. 30 is in the "I-IV" position).

8. CHANNEL II - vertical shift of an image from channel II (operates if the selector switch no. 30 is in "I-IV" position).

9. CHANNEL I - vertical shift of an image from channel I (operates with the selector switch no. 30 in any of its positions).

10. - push-buttons: 0.1, 0.2, 0.5, 1 and 2 enable selection of a multiplier m for the sweep time as well as the regulation of sweep duration by the way of using correspondingly 100, 200, 500, 1000 or 2000 memory location (which is equal to the number of sampling points and to the number of points displayed on the CRT screen).

11. DELAY BEFORE - a selector switch for setting the delay T_D between a stimulus accurrance and the beginning of sampling. $T_D = T_d \times m \times k$, where m-one of the push-buttons (no. 10) pressed in, K-te push-buttons (no. 12), T_d - a selected position of the delay switch.
Example: with $T_d = 0.5$ sec, $m = 0.2$ $K = 1$ we have $T_D = 0.5 \times 0.2 \times 1 = 1$ sec.

12. - a push-button designed for setting for a factor for the sampling intervals, and delay and duration of scan process regulation.
$K = 1$ when the button is pressed out and $K = 10^3$ when it is in.

13. SWEEP TIME. SAMPLING INTERVALS - a selector switch enabling adjustment of sweep time T_A and of the lenght of sampling intervals T_i (an actual sampling for AV function descreeting process for PSH, EH, LH, IH
$T_A = T_a \times m \times K$, $T_i = t_i \times K$, where T_a - selected position of the switch in sec, t_i - the same position but in msec, a and K as described above.

14. A, +B, -B - a set of push buttons used in arithmetic operations of addition, subtraction and restoring of channel contents.

15. RESET, SET - RESET push-button resets the Number of Sweep Counter, the memory contents being left unchanged. SET - sets the Number of Sweep Counter in accordance with the position of the selector switch no. 16.

16. SWEEPS - a selector switch enabling setting the value of the Number of Sweeps Counter (SC). The position N of

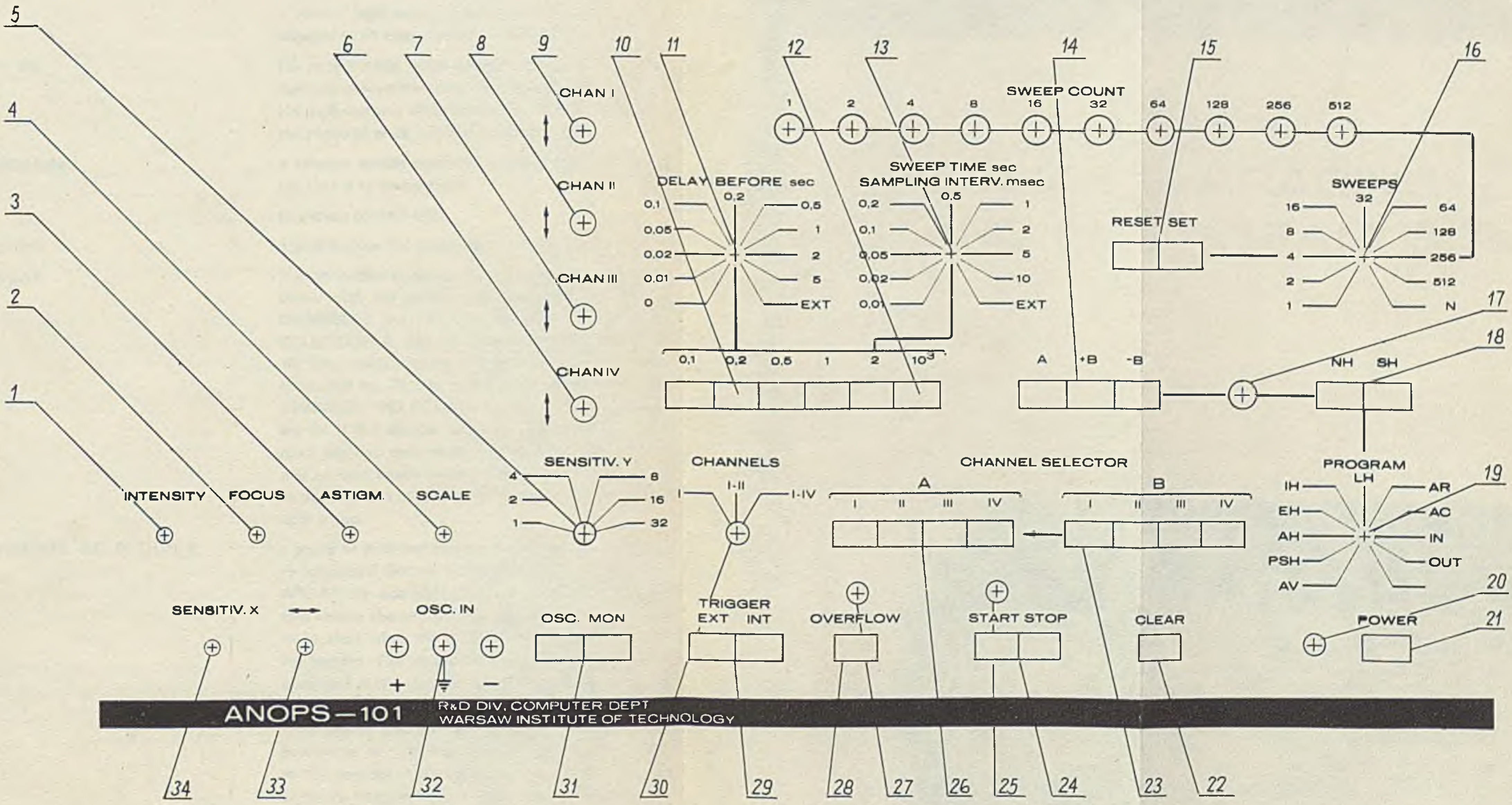

SWEEP COUNT
1 2 4 8 16 32 64 128 256 512
CHAN I
CHAN II
CHAN III
CHAN IV
DELAY BEFORE sec
0,1 0,05 0,02 0,01 0 0,2 0,5 1 2 5 EXT
SWEEP TIME sec
SAMPLING INTERV. msec
0,2 0,1 0,05 0,02 0,01 0,5 1 2 5 10 EXT
0,1 0,2 0,5 1 2 10³
RESET SET
SWEEPS
16 8 4 2 1 32 64 128 256 512 N
A +B -B
NH SH
SENSITIV. Y
4 2 1 8 16 32
CHANNELS
I I-II I-IV
CHANNEL SELECTOR
A B
I II III IV
PROGRAM
LH
IH EH AH PSH AV AR AC IN OUT
INTENSITY
FOCUS
ASTIGM.
SCALE
SENSITIV. X
OSC. IN
+ −
OSC. MON
TRIGGER
EXT INT
OVERFLOW
START STOP
CLEAR
POWER
ANOPS—101
R&D DIV. COMPUTER DEPT
WARSAW INSTITUTE OF TECHNOLOGY
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34

Fig. 3 - 1

the Sweeps switch enables continuous process. Notice: the state of the SC means either the number of completed sweeps (for AV and PSH function or, after being multiplied by the value selected with the selector switch no. 42, the global amount of pulses tested so far (for EH, LH and IH functions).

17. - a control light being on whenever the analyzer is engaged in an execution of a selected routine.

18. HN, HS - HN push-button, when pressed in, selects the non-sequential characteristics of the histogram functions. HS push-button, when pressed in, selects the sequential mode of work for the histograms functions.

19. PROGRAM - a selector switch enabling selecting one of the routines that is to be executed.

20. - power-on control light.

21. POWER - a push-button for switching the mains on.

22. CLEAR - a push-button enabling memory resetting in accordance with the positions of the selector switch CHANNELS (no. 30) the push-buttons CHANNEL SELECTION B (no. 23) and the push-buttons no. 10. The entire memory is being reset when the selector switch no. 30 is in its left-most position and the CHANNEL SELECTION B push-button I is pressed in. If the selector switch no. 30 is in the right-most position only those channels (part of memory) will be reset which numbers are indicated by pressed in push-button of the CHANNEL SELECTION B (23) group.

23. CHANNEL SELECTION B - a group of push-buttons for selecting parts of memory (channels) that are to be used during execution of AR, AC, IN, and OUT functions. The push-buttons also enable the selections of memory parts that are to be reset when the RESET button (no. 22) is being toggled. The push-button I enables access to the channel I if the selector switch CHANNELS no. 30 is in any of its positions. When the push-button II is pressed in and the selector switch is in its central position or its right-most position the access is open to the channel II. The push-buttons III and IV give access to the channels III and IV only if the selector switch CHANNELS (no. 30) is in its right-most position.

24. START, STOP - a push-button START starts the execution of a selected routine, while the push-button STOP stops

sweeps regardless to the selector switch Sweeps (no. 16) position.

25. - a control light being switched on whenever the push-button START is pressed in.

26. CHANNEL SELECTION A - the push-buttons enabling selection of a channel to be used in AV, PSH, EH, IH, LH, AR or AC routines. The I push-button enables access to the channel I regardless of the position of the selector switch CHANNELS (no. 30). All the remaining push-buttons give access to the channels II, III and IV whenever the conditions similar to those described in the CHANNEL SELECTION B operation are satisfied.

27. OVERFLOW - a control light being switched on whenever the number range in any of the memory locations is exceeded, or if the input voltage for AV function exceeds ±4 V.

28. OVERFLOW - a push-button resetting the OVERFLOW light (no. 27).

29. TRIGGER - a push-buttons for the selection of the release mode and the mode of work of the devices responsible for the stimulus generation.

30. CHANNELS - a selector switch enabling the number of channel selection.

31. MON. OSC. - with the MON push-button pressed in the contents of the ANOPS memory are being displayed on the CRT screen. If the OSC push-button is pressed in the signals occuring at the OSC IN socket (no. 32) are being monitored with the time base equal this of the ANOPS analyzer .

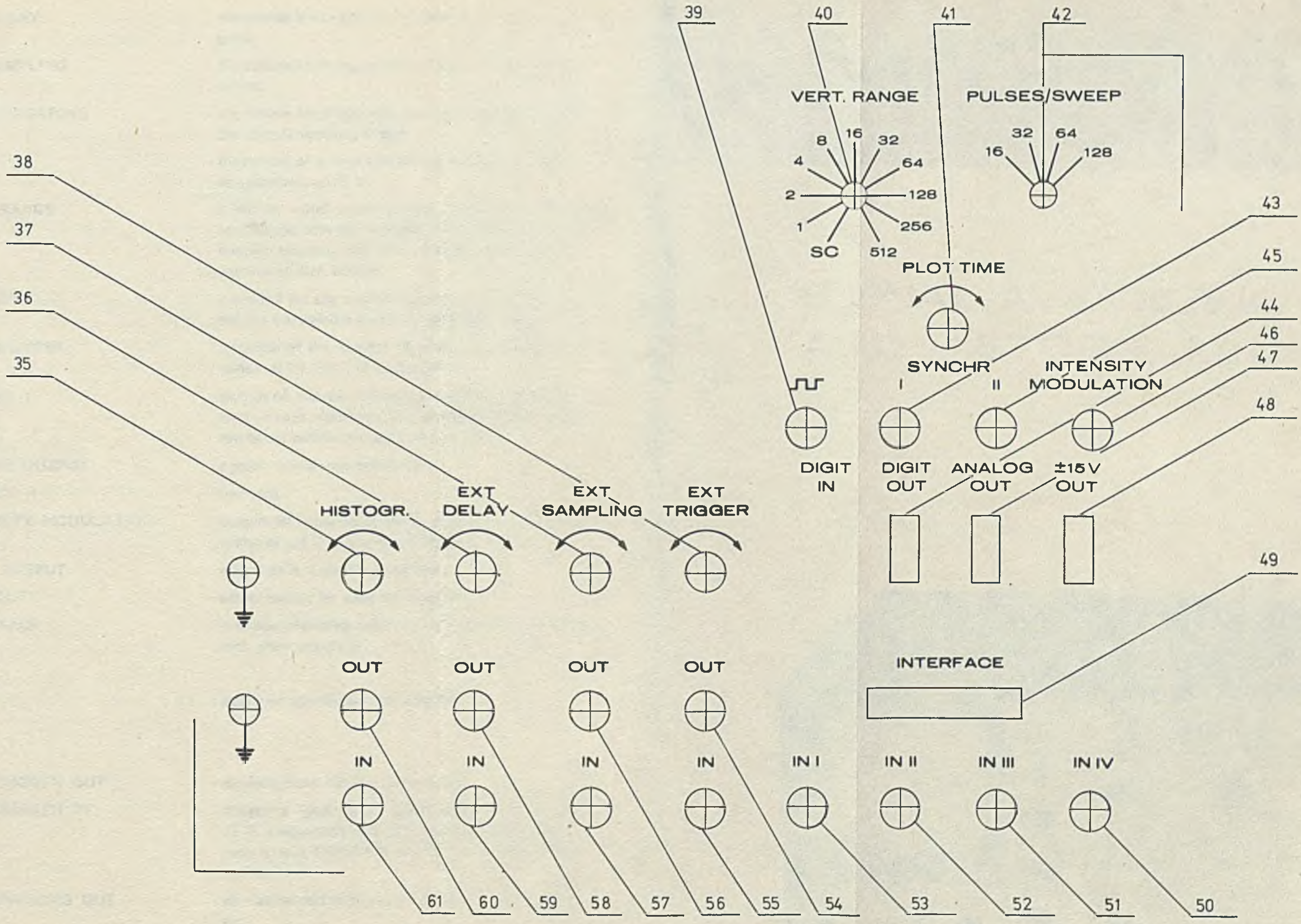
32. OSC IN - an input socket (symmetrical) of the CRT used as a monitor - with the OSC push-button pressed in.

33. - horizontal shift.

34. X'SENSITIVITY - is designed for the CRT's time base broadening. The intervals between light points being always equal to the sampling intervals set with the SAMPLING INTERVALS selector switch.

REAR PANEL CONTROLS AND SOCKETS

35. HISTOGR. - the release level regulation for the counting circuit used in the histogram functions.



VERT. RANGE
1
2
4
8
16
32
64
128
256
512
SC
PULSES/SWEEP
16
32
64
128
PLOT TIME
SYNCHR
I
II
INTENSITY MODULATION
DIGIT IN
DIGIT OUT
ANALOG OUT
±15 V OUT
HISTOGR.
EXT DELAY
EXT SAMPLING
EXT TRIGGER
OUT
OUT
OUT
OUT
IN
IN
IN
IN
IN I
IN II
IN III
IN IV
INTERFACE
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61

Fig. 3 - 2

36. EXT. DELAY - the release level regulation for the external delay circuits.

37. EXT. SAMPLING - the release level regulation for the external analysis circuit.

38. EXT. TRIGGERING - the release level regulation for the circuit producing the start of scanning trigger.

39.  - the output of a circuit forming a rectangular wave of an amplitude of ±5 V.

40. VERT RANGE - a selector switch enabling either display of results in accordance with the Number of Sweeps Counter content (position SC) of the display chosen part of content of each address.

41. PLOTTER - a control for the continuous regulation of the information transmition speed for the plotter output.

42. PULSES/SWEEP - selection of the number of pulses per sweep in execution of IH, EH, LH histograms.

43. SYNCHR. I - output of a circuit forming the pulses at the beginning of each repetition, the amplitude of the pulses can be set within the range of 0 to +15 V.

44. DIGITAL OUTPUT - a paper tape punch connector.

45. SYNCHR. II - not used.

46. INTENSITY MODULATION - output for blanking off beam of external CRT scope (pulse of -24 V to 0 V every 20 µsec).

47. ANAL. OUTPUT - a X, Y or X, t plotter connector.

48. ±15 V OUT - power supply for external amplifiers.

49. INTERFACE - a socket providing possibility of connecting ANOPS with other computer.

50. IN IV

51. IN III - inputs of signals analysed with AV, EH.

52. IN II

53. IN I

54. EXT. TRIGGER OUT - releasing pulse observation output.

55. EXT. TRIGGER IN - triggering signal input. Input voltage in the range of ±5 V is adjustable with the control no. 38 (with the push-button TRIGGER, no. 19, in the EXTERNAL position).

56. EXT. SAMPLING OUT - an observation output for a pulse of external analysis.

57. EXT. SAMPLING IN - input for an external analysis pulse. Input voltage

range ±5 V is adjustable with the control no. 37 with the SWEEP TIME switch (no. 13) in EXTERNAL position.

58. EXT. DELAY OUT - observation output for the pulse of an external delay.

59. EXT. DELAY IN - input for the external delay signal. Input voltage range ±5 V is adjustable with the help of the no. 36 control with the DELAY switch (no. 11) in EXTERNAL position.

60. HISTOGR. OUT - observation output for the pulse used in the PSH, IH, and LH functions.

61. HISTOGR. IN - input for the signals used in the PSH, IH, and LH functions. Input voltage range of ±5 V is adjustable with no. 35 control.

section 4

ASSEMBLY

ANOPS-101 is shipped in a wooden container. After unpacking unscrew the upper lid and remove insorted foam. Check that all the boards are well insorted in the slots; check that high voltage supply cable is connected and CRT socket is in place. Replace upper lid.
Remove the bottom lid and check visually wire connections on the motherboard. Replace the lid.

Line voltage selection

This instrument operates from either a 115 volt or a 220 volt nominal line voltage source, 48 to 62 hertz.
To convert from one nominal voltage range to the other insert 6 amperes fuse for the 115 voltage range or 3 amperes fuse for the 220 voltage range into the appropriate fuse holder.

Caution

1. ANOPS-101 may be operated only from three-wire line supply socket with earth connection.
2. If it is necessary to remove (or insert) any plug-in module, FIRT SWITCH OFF POWER SUPPLY - to avoid possible electrical damage.

section 5

OPERATION CHECK

Before switching the power on preset the following front panel controls:

1. SENSITIVITY	(no. 5) in position 1
2. CHANNELS	(no. 30) in position I
3. DELAY BEFORE	(no. 11) in position 0
4. SWEEP TIME	(no. 13) in position 0.5
5. SWEEPS	(no. 16) in position 256
6. PROGRAM	(no. 19) in position AV
Press PUSH BUTTON	(no. 10) into position 2000
Release PUSH BUTTON	(no. 12) in position 10^3
Push CHANNEL SELECTOR A	(no. 26) in position I
Push CHANNEL SELECTOR B	(no. 22) in position I
Press button MON	(no. 31)

Set the rear panel control VERTICAL RANGE (no. 40) into position SC.

On the rear panel connect socket BNC designed INI (no. 53) and socket (no. 39) with a suitable cable.

Instrument is now ready for the operation check.

Switch POWER on, lamp no. 20 should be on, allow several minutes for instrument warm up.

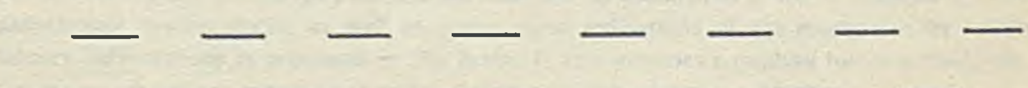
Press buttons CLEAR (no. 22), RESET (no. 15) and OVERFLOW (no. 28) to set initial conditions and clear memory.

Turn the SENSITIVITY control fully counterclockwise, control no. 33 in the midrange and INTENSITY control (no. 1) fully clockwise.

Turning the control CHANNEL I (no. 9) find the trace on the CRT screen.

Adjust intensity, focus and astigmatism with the controls no. 1, no. 2 and no. 3.

Push button START (no. 24). Lamps START (no. 25), ANALYSE (no. 17) and OVERFLOW (no. 27) should be on. There should be a one division squarewave on the CRT screen (see figure below).



SWEEP COUNT lamps alternately turn on and off. Lamp no. 1 turns on and off every second. After 256 seconds time lamps START (no. 25) and ANALYSE (no. 17) turn off. Lamps no. 256 in SWEEP COUNT and OVERFLOW remain on. Repeat operation check using another number of sweeps.
When the number of sweeps is smaller than 256 the one division squarewave on the CRT screen remains stable. When the number of sweeps is greater than 256 the amplitude and phase of squarewave on the CRT screen may change due to memory overflow.
Waveform on the CRT screen do not depend on setting of DELAY (no. 11) and SWEEP TIME (no. 13) switches.
When the SWEEP TIME (no. 13) switch is one of the positions 0.01; 0.02 waveform on the CRT screen may be different; example is shown below.

Caution

Do not change any ANOPS setting during analysis - when the lamp START is on.
When the operation check does not work exactly as described, contact the manufacturer.

section 6

SIGNAL AVERAGING

Signals averagers are used to improve the signal-to-noise ratio of biological responses which are either evoked by stimuli or which follow well defined events or potentials changes.
The total period of time during which analysis takes place after each trigger pulse is referred to as the sweep duration.
Each sweep is divided into 2000 smaller time intervals, colloquially termed "points". During each of these intervals the voltage of the signal and noise is measured and the value is stored. The values measured for one sweep are added to the values previously measured for corresponding points of the preceding signals and displayed on the oscilloscope.
The degree of improvement in signal-to-noise rationobtained by averaging depends on a number of factors.
With unlimited bandwidth the reduction of noise by averaging is proportional to $\sqrt{N}$, where N is the number of sweeps.
The signal has been assumed to be of constant amplitude but this is not rarely true in electrophysiology in which the amplitude of the evoked potential can vary considerably from trial to trial. In addition to the amplitude variability there may be variability in the latency of the components of the evoked responses because of the variable time delays in the peripheral sense organs, transmission times and processing in the cortex.
The average evoked potential will have a latency that is approximately the mean of the individual latences of the trials; but it will be impossible to determine from the average whether it is composed of variable - latency responses, or stable - latency responses.
In some of the examination amplitude calibration is an essential part of any study of evoked responses.
The most satisfactory method is to include in each trial a calibration waveform which occurs at constant time with respect to the stimulus.
The resolution of digital averages is dependent on the number of sample points on the sweep. Since this is fixed, the resolution is inversely proportional to the sweep duration, that is the longer the sweep duration the lower the maximum frequency that can be faithfully recorded.
The average evoked responses has been proved as noninvasise electrodiagnosis in: Audiology, Audiometry, Neurology, Neurosurgery in Cardiology and Rehabilitation Medicine.
Evoked from the brain cortex potential are now well established as a tool in diagnosing some pathological disease states, as well as giving some indications of the mechanism by which sensory informations is processed in the brain. It also provides a method for objectively testing sensory functions especially in young children or uncooperative subjects.

For example:

Visual evoked potential elicted by checkerboard which reverses colors of squares. The brain perception of a changing pattern results in a large evoked response. It is thought that on of the reasons for shifts in the latency of visual response is the incidence of multiple sclerosis.

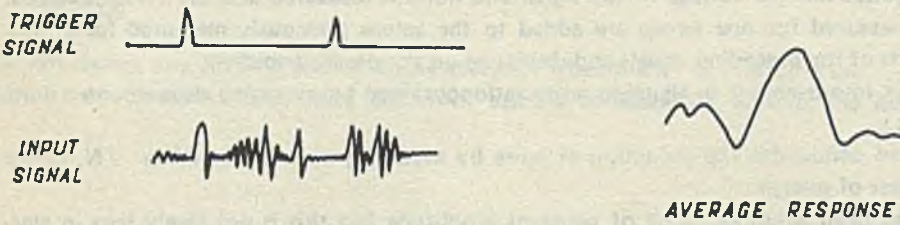
Electrical stimuli to a peripheral nerve evoked the potential in the scalp in corresponding projection. The latency and the amplitude provide information about the functional integrity of anatomical pathways in the peripheral nerve in spinal cord and cortex.

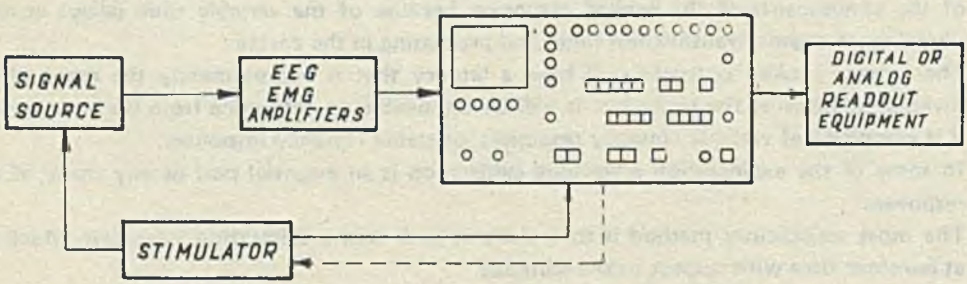
Click-sound stimulus is used to record electrical events generated along the auditory pathway, through the brainstem, on its way to the cortex. The recorded waveform consists of a series of seven waves from the auditory nerve activity and the inferior colliculus of the brainstem.

Auditory evoked potential to a gated tone stimulus provide an objective measurement of hearing loss.

Electrocochleography is used to detect hearing problems by measuring the electrical impulses of the cochlea and the auditory nerve.

In electromyography evoked potential are used for sensory nerve conduction velocity measurements, and for averaging single motor units potential selected by means of delay line.





PREPARATORY OPERATIONS

After switching on the mains with the no. 21 switch a control light (no. 20) should go on.

With all four push-buttons CHANNEL SELECTION B (no. 23) pressed in press buttons CLEAR (no. 22) and RESET (no. 15) for resetting the Number of Sweeps Counter. This should cause display a horizontal line on the CRT's screen.

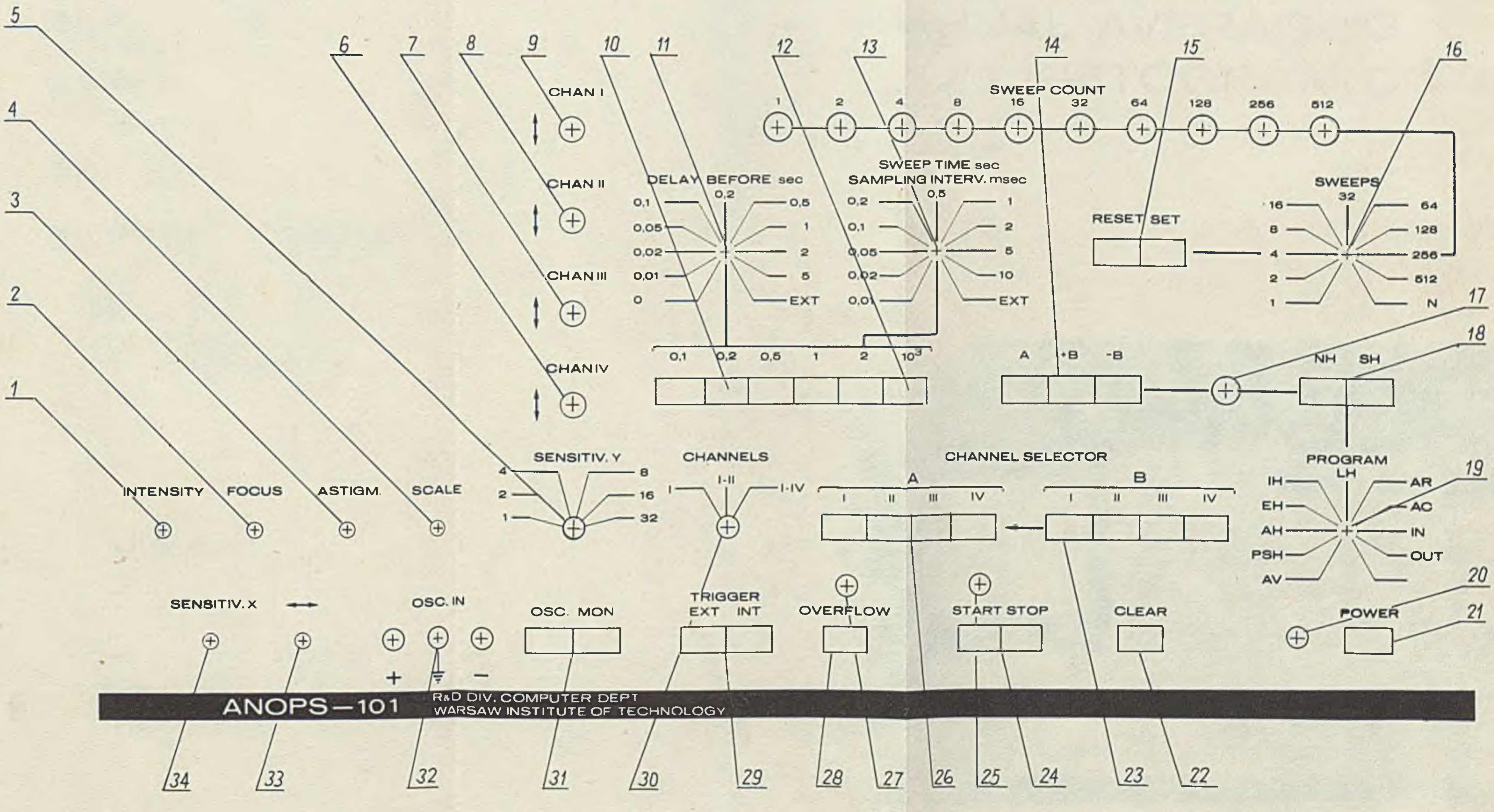
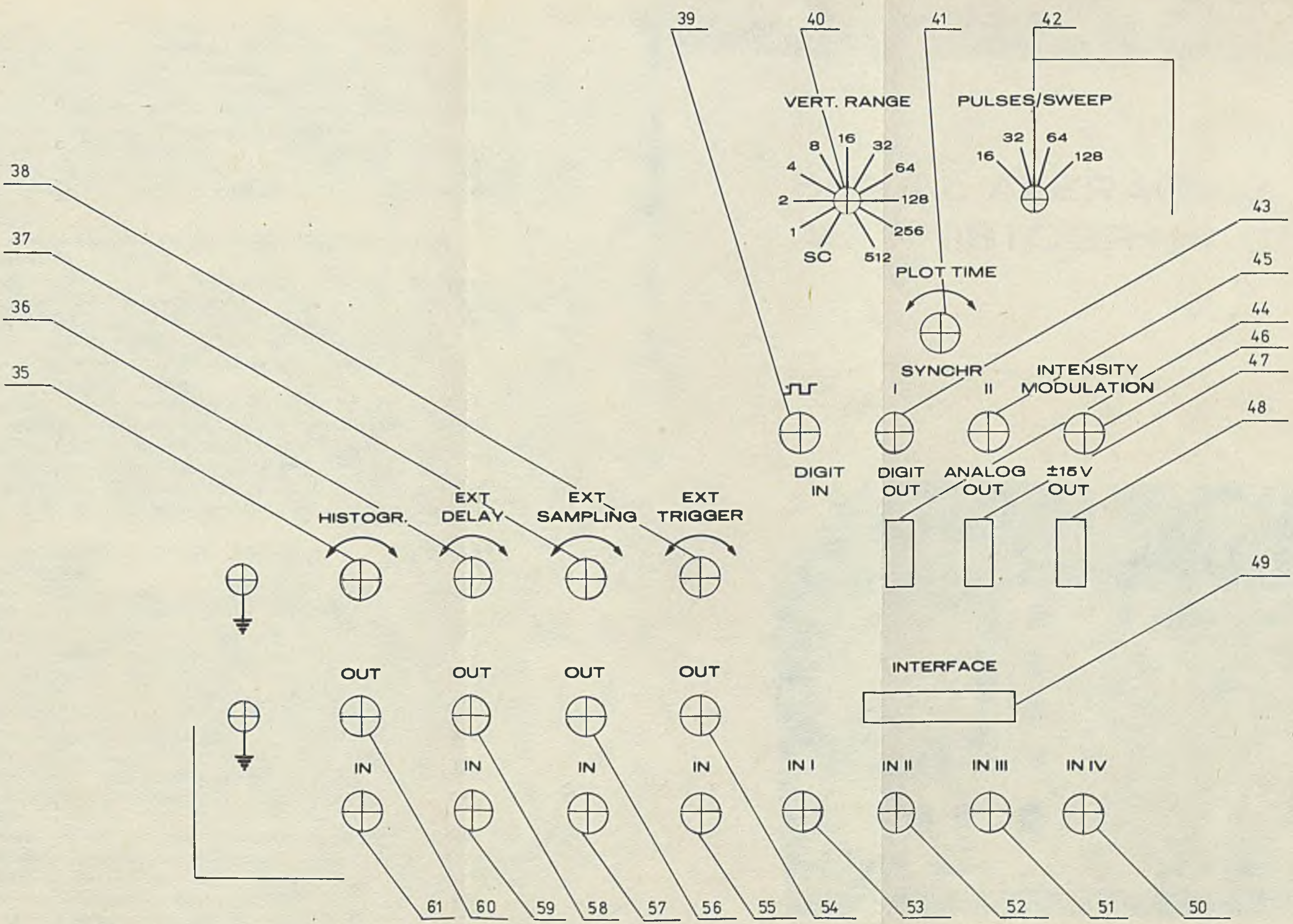

CHAN I
CHAN II
CHAN III
CHAN IV
SWEEP COUNT
1 2 4 8 16 32 64 128 256 512
DELAY BEFORE sec
0,1 0,05 0,02 0,01 0 0,2 0,5 1 2 5 EXT
SWEEP TIME sec
SAMPLING INTERV. msec
0,2 0,1 0,05 0,02 0,01 0,5 1 2 5 10 EXT
0,1 0,2 0,5 1 2 10³
RESET SET
SWEEPS
16 8 4 2 1 32 64 128 256 512 N
A +B -B
NH SH
INTENSITY
FOCUS
ASTIGM.
SCALE
SENSITIV. Y
4 2 1 8 16 32
CHANNELS
I I-II I-IV
CHANNEL SELECTOR
A
I II III IV
B
I II III IV
PROGRAM
LH
IH EH AH PSH AV AR AC IN OUT
SENSITIV. X
OSC. IN
+ −
OSC. MON
TRIGGER
EXT INT
OVERFLOW
START STOP
CLEAR
POWER
ANOPS—101
R&D DIV. COMPUTER DEPT
WARSAW INSTITUTE OF TECHNOLOGY
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
22 23 24 25 26 27 28 29 30 31 32 33 34

Fig. 6 - 1



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VERT. RANGE
PULSES/SWEEP
8
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64
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PLOT TIME
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HISTOGR.
EXT
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SAMPLING
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TRIGGER
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INTERFACE
OUT
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IN I
IN II
IN III
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Fig. 6 - 2

A routine selected with the PROGRAM (no. 19) switch is being executed as soon as the push-button START (no. 24) is pressed in and the first of the release signals appears: either external, if the TRIGGER (no. 29) push-button is in the EXTERNAL position, or internal, if it is in its INTERNAL position. A control light no. 25 is set on when the push-button START (no. 24) is pressed in and it is switched off automaticall with the completion of a routine or when the push-button STOP (no. 24) is pressed in.
When a selected routine is being run the no. 17 lamp is switched on. This light is switched off with the completion of the routine execution or with the completion of a part of a routine (for example: the end of the scan repetition for AV function), if the push-button STOP (no. 24) was pressed in.

Set the no. 19 selector switch in the "AV" position - the push-buttons HN, HS (no. 18) and +B, -B (no. 14) should be pressed out.
The selector switch DELAY (no. 11), SWEEP TIME (no. 13), one of the push-buttons no. 10, the no. 12 push-button and the selector switch SWEEPS (no. 16) should be set in accordance with the process requirements. If the sweep time is to be externally controlled the selector switch SWEEP TIME (no. 13) should be set in its EXTERNAL position. The timing pulses should be connected to the IN (no. 57) input and the amplitude of releasing signals set with the EXTER. SAMPLING (no. 37) knob.
In the case of the externally controlled delay set the selector switch DELAY (no. 11) in its EXTERNAL position, connect the delay pulses to the IN (no. 59) input and adjust their amplitude with the help of the EXTER. DELAY (no. 36) knob. The rectangular pulses, formed at the treshold level, can be examined at the no. 56 and no. 58 socket.
Set the CHANNELS (no. 30) selector switch and the push-buttons CHANNEL SELECTION A and B (no. 26 and 23) in accordance with the number of channels that are to be used in the routine.
Press one of the release buttons (no. 29) - EXTERNAL or INTERNAL - according to the required mode of release.
In the case of the external release - the EXTERNAL (no. 19) push-button pressed in - the triggering pulses are to be connected to the IN (no. 55) input and their amplitude readjusted with the help of the TRIGGER (no. 38) knob. The selector switch Y SENSITIVITY (no. 5) should be in its "1" position and the push-button MON (no.31) pressed in.
The SELECTOR Switch VERT. RANGE (no. 40) should be set in accordance with the process requirements. If it is in its SC position - automatical division in accordance with the Number of Sweeps Counter value - the mean value of the signal appearing at the ANOPS input per each scan process is being displayed. If this switch is in any other of its positions the global sum of an input signal is being displayed for each scan process.
The waveforms that are to be averaged should be connected to the IN I, IN II, IN III or IN IV inputs (no. 53, 52, 51 or 50) in accordance with the number of channels that are to be used in the analysis.
The press button START (no. 24) and follow the display of results which will complete whent the number of completed scan processes will be equal to the value set with the selector switch SWEEPS (no. 16) or it may complete if the push-button STOP (no. 24) was pressed in during the routine execution. If during examination the range of input voltage ±4 V exceeded in and of the channels or if the number range in any of the memory locations was exceeded the control light OVERFLOW (no. 27) will be set on and the display of results on the CRT's screen will be incorrect. For the AV function the overflow informing that the numeral range

was exceeded occurs when the A-D converter's input signal is of the highest possible amplitude ±4 V and the number of repetitions equals 256.

If an overflow occurred the test should be carried out again. To do this press the STOP (no. 24) button, reset store with the help of the CLEAR (no. 22) button, reset the Number of Sweeps Counter with the RESET (no. 15) button and switch off the OVERFLOW (no. 27) control light with the OVERFLOW (no. 28) push-button.

The resetting of the results can be done in any of the channels separately or in all the memory simultaneously, depending on which of the CHANNEL SELECTION B (no. 23) push-buttons are being pressed in.

READING OF RESULTS

On the CRT's screen the Y axis corresponds to the signal value in Volts, and the X axis to the time variable. The time base in equal the sampling time selected with the help of the following control switches: the SWEEP TIME (no. 13) selector switch, the no. 10 and no. 12 push--buttons.

The intervals between the consecutive analysis points (in the horizontal axis direction) depend on the CHANNELS (no. 30) selector switch position. If only one of the channels is being used these intervals are equal to the SWEEP TIME INTERVALS (no. 13) - 0.01 msec, 0.02 msec, 0.05 msec, ..., 10 msec - position multiplied by the m and K factors' value.

If the selector switch no. 13 is in its EXTERNAL position the intervals between two consecutive analysis points depend on the external source.

If two of the channels are being used the intervals between two consecutive analysis points are twice the one-channel mode of work intervals: 0.02 msec, 0.04 msec, 0.1 msec,..., 20 msec multiplied by m and K values.

With all four channels used, the intervals are four times greater: 0.04 msec, 0.08 msec, 0.2 msec,..., 40 msec multiplied by m and K values.

Signals' amplitude, along the Y axis, is being read with the help of the Table 6-1.

Table 6-1

Y SENSITIVITY switch position	1	2	4	8	16	32	Number of sweeps SC
Amplitude in V/cm	8	4	2	1	0,5	0,25	SC = 256
	4	2	1	0,5	0,25	0,125	SC = 512
	2	1	0,5	0,25	0,125	0,62	SC = 1024
	1	0,5	0,25	0,125	0,062	0,031	SC = 2048

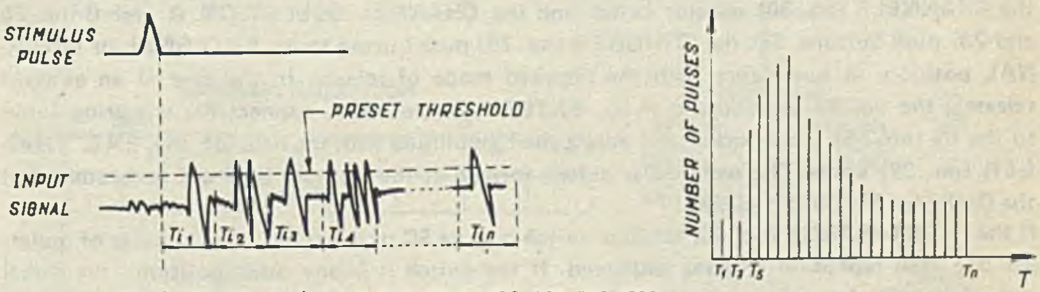
section 7

POST-STIMULUS HISTOGRAMS - PSH

The programme consists of counting 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.

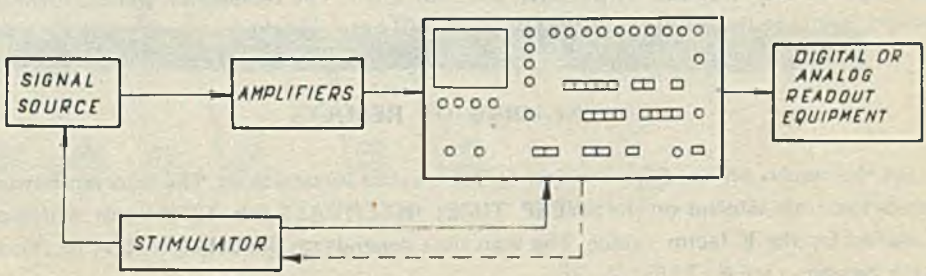
They are applied in analyzing the experiment's records such as: nervous cell pulse potentials, standard behaviour actions, heart rhythm.

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 analyzer) are counted; the corresponding histograms obtained on the ANOPS's CRT screen is also shown.



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

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

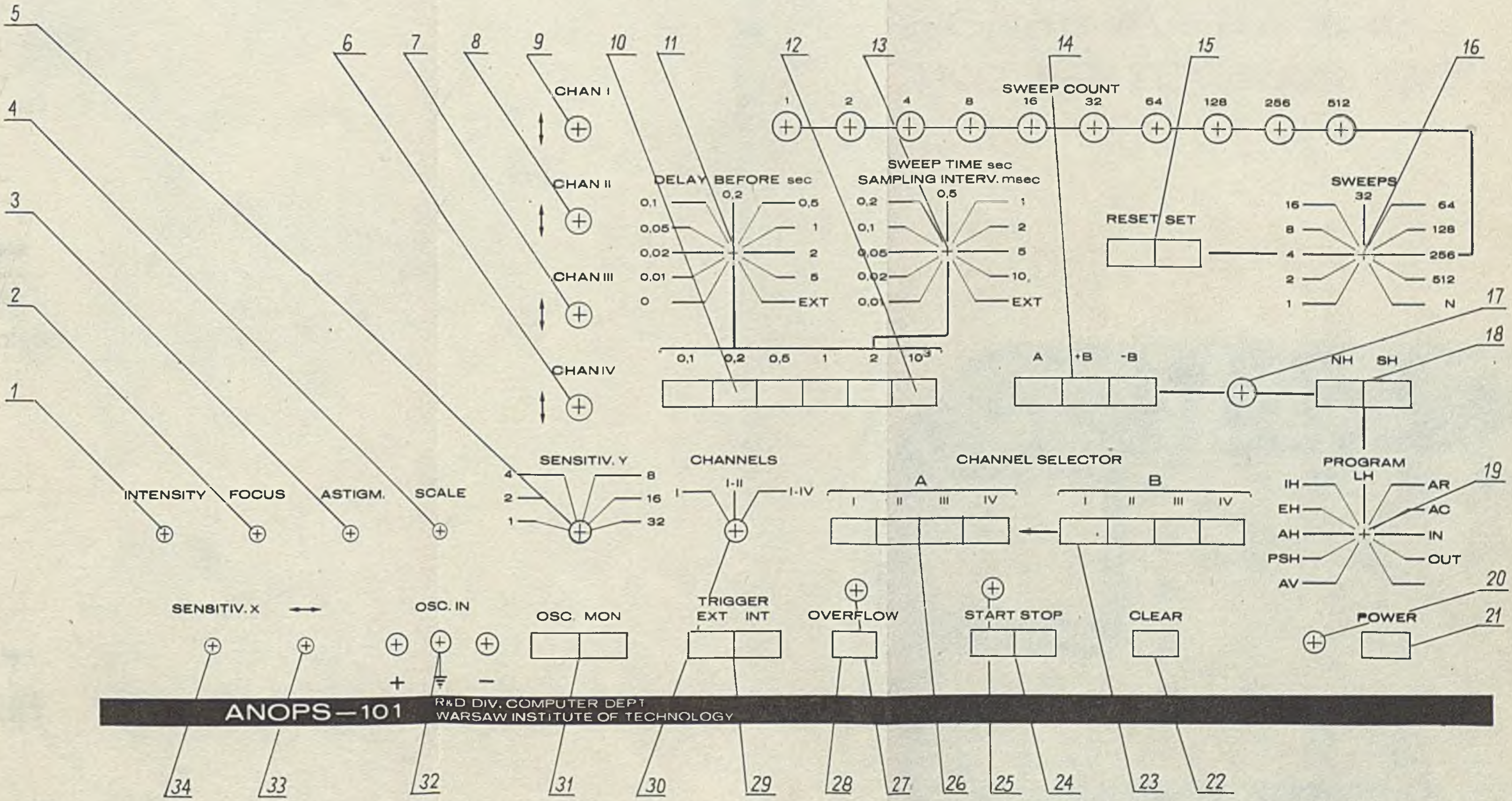


PREPARATORY OPERATIONS

After switching on the mains with the no. 21 switch a control light (no. 20) should go on. With all four push-buttons CHANNEL SELECTION B (no. 23) pressed in press buttons CLEAR (no. 22) and RESET (no. 15) for resetting the Number of Sweeps Counter. This should cause display of a horizontal line on the CRT's screen.
A routine selected with the PROGRAM (no. 19) switch is being executed as soon as the push-button START (no. 24) is pressed in and the first of the release signals appears: either external, if the TRIGGER (no. 29) push-button is in the EXTERNAL position, or internal, if it is in its INTERNAL position. A control light no. 25 is set on then the push-button START (no. 24) is pressed in and it is switched off automatically with the completion of a routine or when the push-button STOP (no. 24) is pressed in. When a selected routine is being run the no. 17 lamp is switched on. This light is switched off with the completion of the routine execution or with the completion of a part of a routine (for example: the end of the scan repetition for AV function), if the push-button STOP (no. 24) was pressed in.
Set the PROGRAM (no. 19) selector switch into the PSH position and press in the HN (no. 28) push-button.
The selector switches DELAY (no. 11), SWEEP TIME (no. 13), one of the no. 10 push-buttons, the no. 12 push-button and the selector switch SWEEPS should be set in accordance with the process under examination requirements. In the case of the scan time being externally controlled set the SWEEP TIME (no. 13) selector switch into its EXTERNAL, connect the timing pulses to the IN (no. 57) input socket and adjust their amplitude with the EXTER. SAMPLING (no. 37) knob. In the case of externally controlled delay set the DELAY (no. 11) selector switch in its EXTERNAL position, connect the delay pulses to the IN (no. 59) input socket and adjust their amplitude with the EXTER. DELAY (no. 36) knob. Set appropriately the CHANNELS (no. 30) selector switch and the CHANNEL SELECTION A and B (no. 26 and 23) push-buttons. Set the TRIGGER (no. 29) push-button to its EXTERNAL or INTERNAL position, in accordance with the required mode of release. In the case of an external release - the no. 29 push-button in its EXTERNAL position - connect the triggering pulses to the IN (no. 55) input socket and adjust their amplitude with the help of the EXT. TRIGGER (no. 38) knob. The rectangular pulses, formed at the treshold level can be examined at the OUT (no. 54) output socket.
If the VERT RANGE (no. 40) selector switch is in its SC position the mean number of pulses per one scan repetition is being displayed. If the switch is in any other position - the global sum of input pulses is being displayed for each of the repetitions. The number of encountored pulses can be read in accordance with the Table no. 7 - 1.
Connect the signal, that is to be examined, to the IN (no. 61) input socket and adjust the counting treshold with the HISTOGR. (no. 35) knob. The rectangular pulses, formed at the treshold level can be examined at the OUT (no. 60) output socket.

READING OF RESULTS

We get the results on the CRT's screen in the form of vertical lines. The intervals between two consecutive lines depend on the SWEEP TIME, INTERVALS (no. 13) selector switch position multiplied by the K factor's value. The scan time depends on the CHANNELS (no. 30) selector switch position - see 6 - 7 (Fig. 7 - 3).



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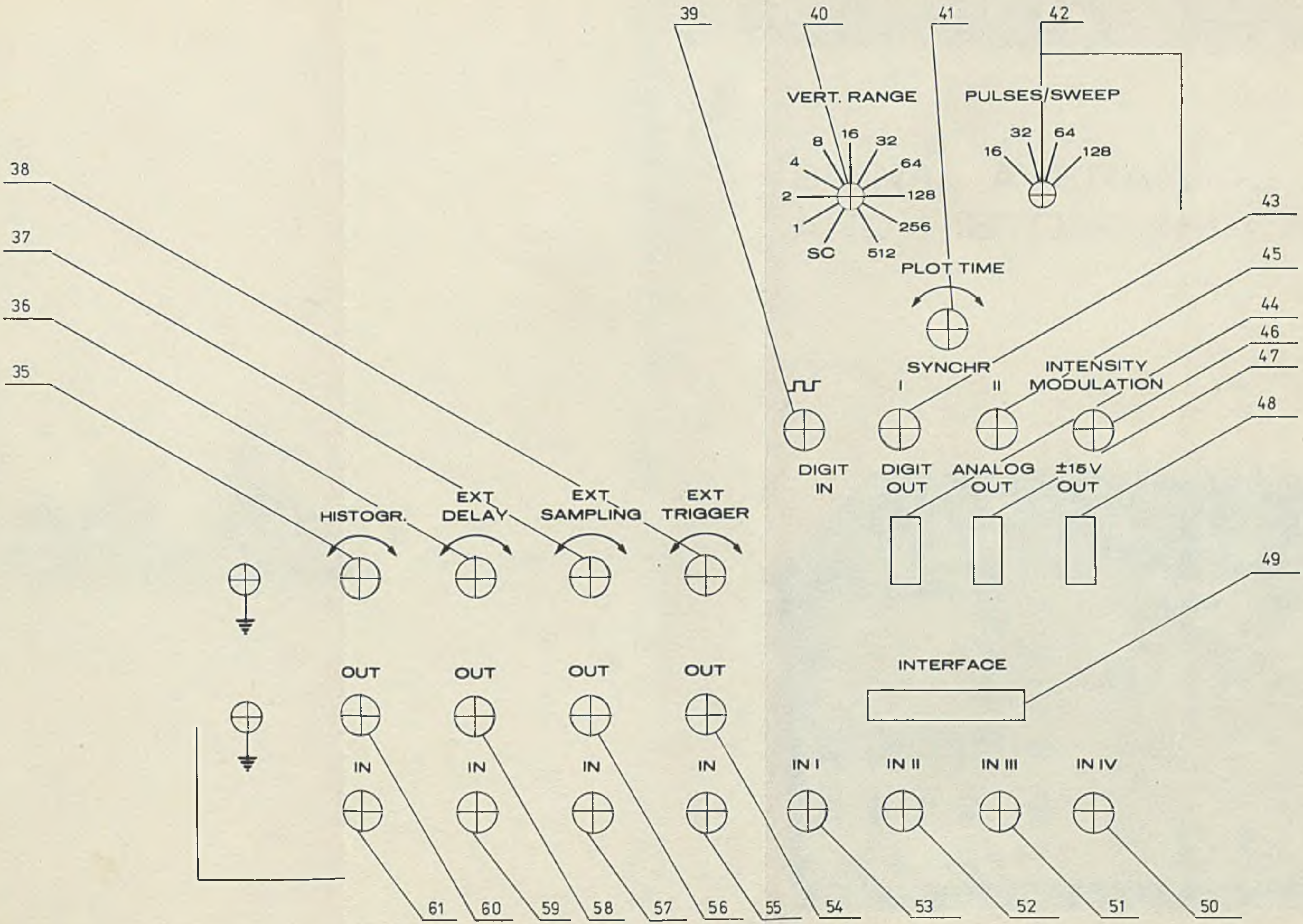
33
34
CHAN I
CHAN II
CHAN III
CHAN IV
SWEEP COUNT
1 2 4 8 16 32 64 128 256 512
DELAY BEFORE sec
0,1 0,05 0,02 0,01 0
0,2 0,5 1 2 5 EXT
SWEEP TIME sec
SAMPLING INTERV. msec
0,2 0,1 0,05 0,02 0,01
0,5 1 2 5 10, EXT
0,1 0,2 0,5 1 2 10³
RESET SET
SWEEPS
16 8 4 2 1
32 64 128 256 512 N
A +B -B
NH SH
INTENSITY
FOCUS
ASTIGM.
SCALE
SENSITIV. Y
4 2 1
8 16 32
CHANNELS
I I-II I-IV
CHANNEL SELECTOR
A
I II III IV
B
I II III IV
PROGRAM
LH
IH EH AH PSH AV
AR AC IN OUT
SENSITIV. X
OSC. IN
+ −
OSC. MON
TRIGGER
EXT INT
OVERFLOW
START STOP
CLEAR
POWER
ANOPS—101
R&D DIV. COMPUTER DEPT
WARSAW INSTITUTE OF TECHNOLOGY

Fig. 7 - 1



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VERT. RANGE
PULSES/SWEEP
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PLOT TIME
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SYNCHR
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Fig. 7 - 2

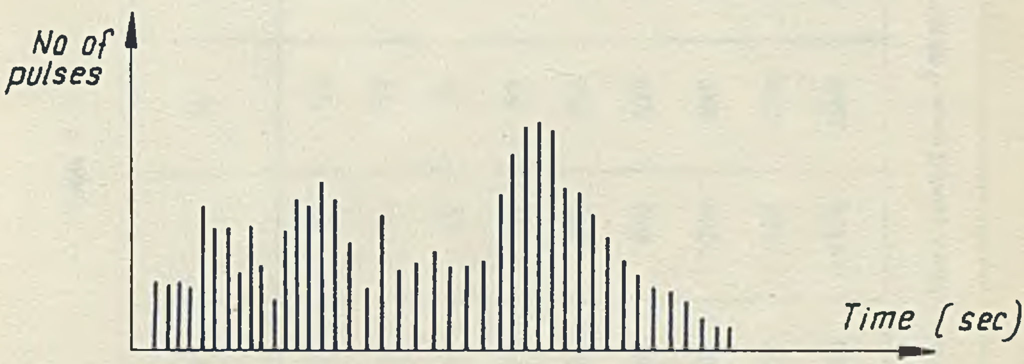


Fig. 7 - 3

Table 7 - 1

SENSITIVITY Y selector (5) positions:	1	2	4	8	16	32	VERT. RANGE switch (40) position (with SWEEPS selector (16) set to Sweep Counter position)
NUMBER OF PULSES PER CM	160	80	40	20	10	5	1
	320	160	80	40	20	10	2
	640	320	160	80	40	20	4
	1280	640	320	160	80	40	8
	2560	1280	640	320	160	80	16
	5120	2560	1280	640	320	160	32
	10240	5120	2560	1280	640	320	64
	20480	10240	5120	2560	1280	640	128
	40960	20480	10240	5120	2560	1280	256 or 512

NOTE: The maximum number of pulses recorded in one address cannot exceed 65455.

section 8

ELECTROMYOGRAPHY HISTOGRAMS

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 assessment 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 applied. 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. 8-1 is shown the basic block diagram of the input system ANOPS analyzer. Minicomputer ANOPS works on-line and has to be connected to the output of the electromyograph. Due to build in hybrid circui it records the selected MUP on the CRT screen, in the form of

ready histograms. The number of MUP to be recorded and the measuring accuracy thereof, may be arbitrary chosen by means of suitable controls. The MUP coming from the electromyography 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 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. 8-2 are shown the measuring criteria of single MUP.

Duration

For practical reason we suggest 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 µV/div. has to be used.
Thus, only potentials exceeding 100 µV/decision level are accepted for measurement. The duration of those potentials are measured at the 20 µV level (measuring level).
The accuracy of 0.5 ms is recommended.

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 µV.

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

BLOCK DIAGRAM OF ANOPS

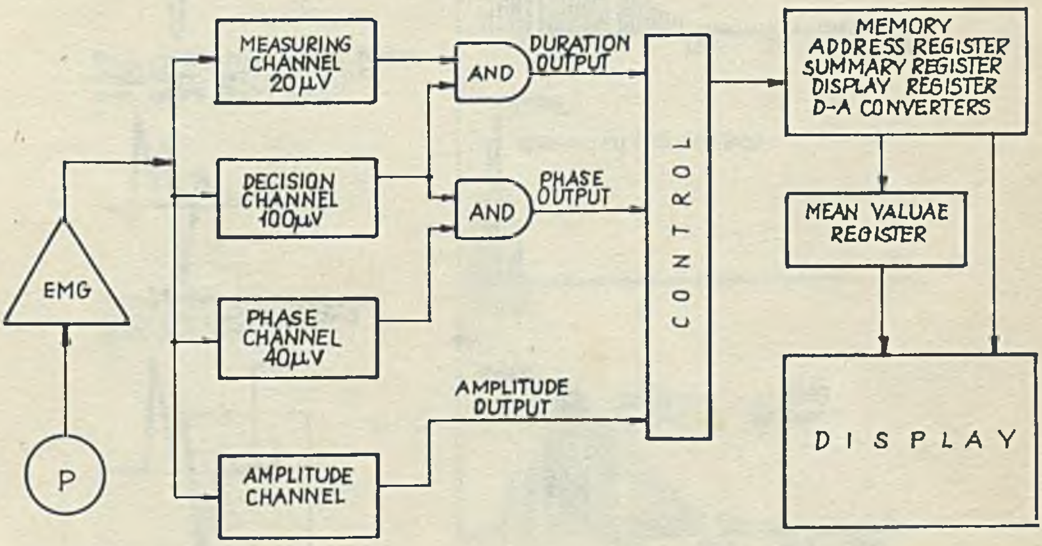


Fig. 8 - 1

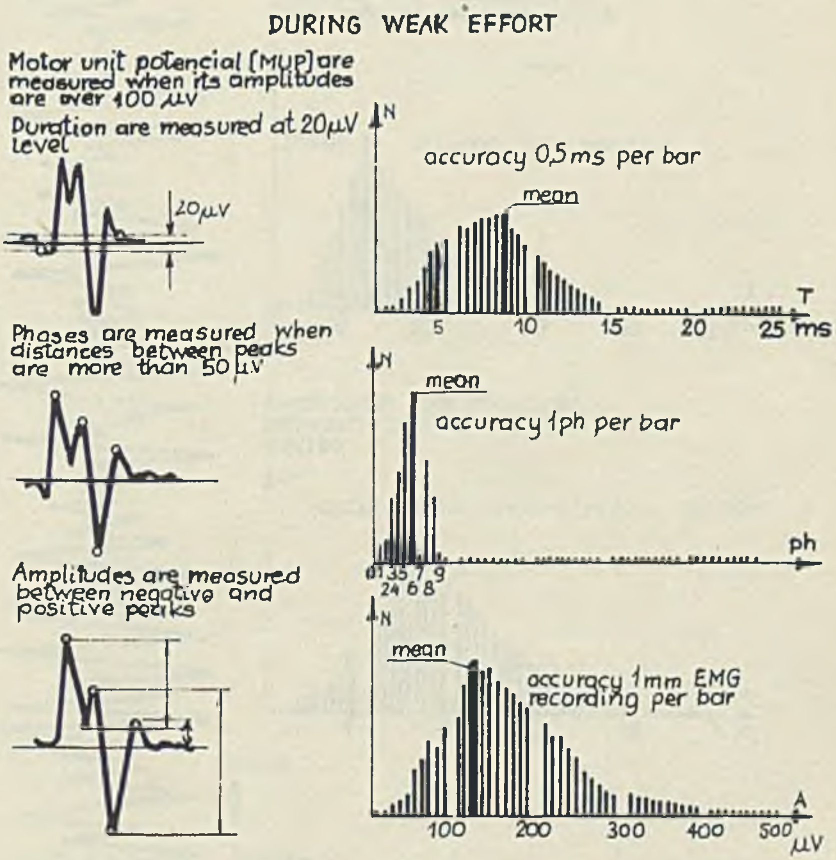

DURING WEAK EFFORT
Motor unit potencial (MUP) are measured when its amplitudes are over 100 µV
Duration are measured at 20µV level
20µV
Phases are measured when distances between peaks are more than 50 µV
Amplitudes are measured between negative and positive peaks
N
accuracy 0,5 ms per bar
mean
T
5 10 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. 8 - 2

DURING MAXIMAL EFFORT

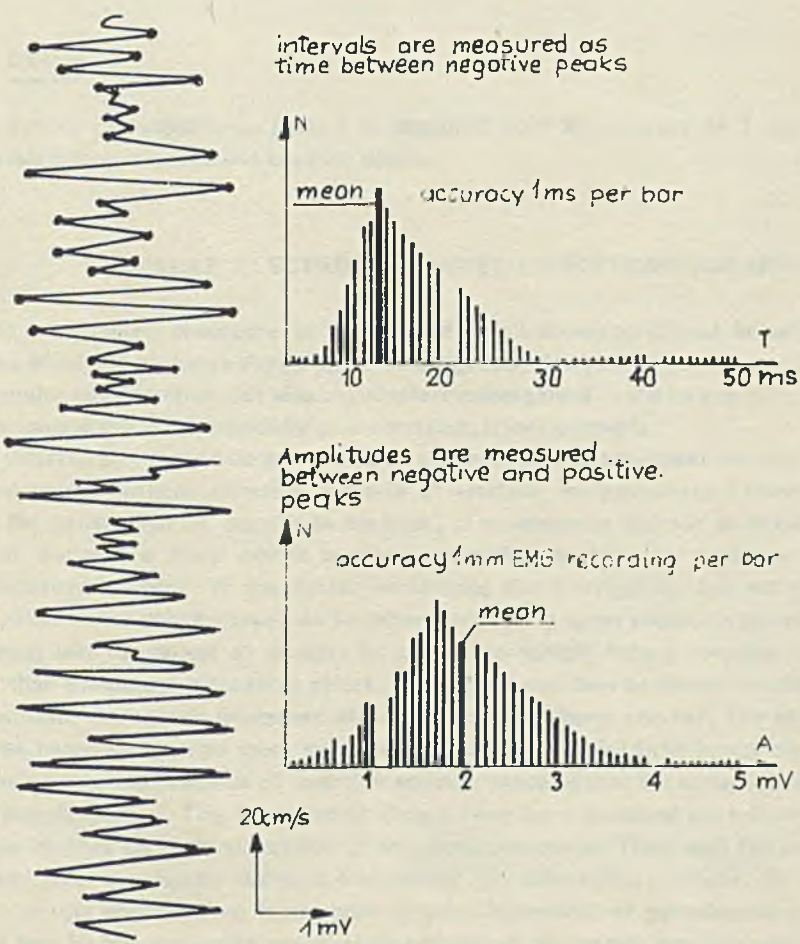


Fig. 8 - 3

histogram the amplitude is expressed as µV address (each address corresponds to 1 mm of the EMG record). During maximal effort two parameters of interference pattern are measured. On Fig. 8-3 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 µV per div.
The maximum amplitudes are measured between their negative and positive peaks and in the computer the amplitude is expressed as µV 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 investigation, depends not only upon the clinical problem under consideration but also upon information gained in the course of it, and a knowledge of peripheral anatomy, especially of innervation, is indispensable.
The investigation should be performed in a comfortably warm room see 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 spontaneous activity, the patient is now asked to activite the muscle; one can start with maximal effort, but it is mor 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 known fact that duration of single MUP is very much depended from the used electrode (its picking up area). Therefore it is essential that the normal values can be only used for given type of electrods. Connection between output of any standard Electromyograph and the ANOPS should be made by concentric cable with BNC plugs to input socket marked IN I (no. 53).

Than following procedure should be applied:

1. Turn on the machine and analyzer and check the dial, and knob setting.
2. Place the ground electrode on patient, preferably near the muscle to be tested. Select an EMG needle, using a 1 1/2 in, needle for obese individuals or when deep muscles are to be examined, and a 3/4 in, needle for children.

   Before the quantitative measurement has to be done check the controls on ANOPS for duration and phase histograms.
3. Set the PROGRAM selector (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 measurement). The SWEEP setting depends on the desired sample size. (Number of MUP to be calculated in the histogram).

   $$\text{Sweep Setting} = \frac{\text{Desired sample size}}{4 \times (\text{number of sample points})}$$

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

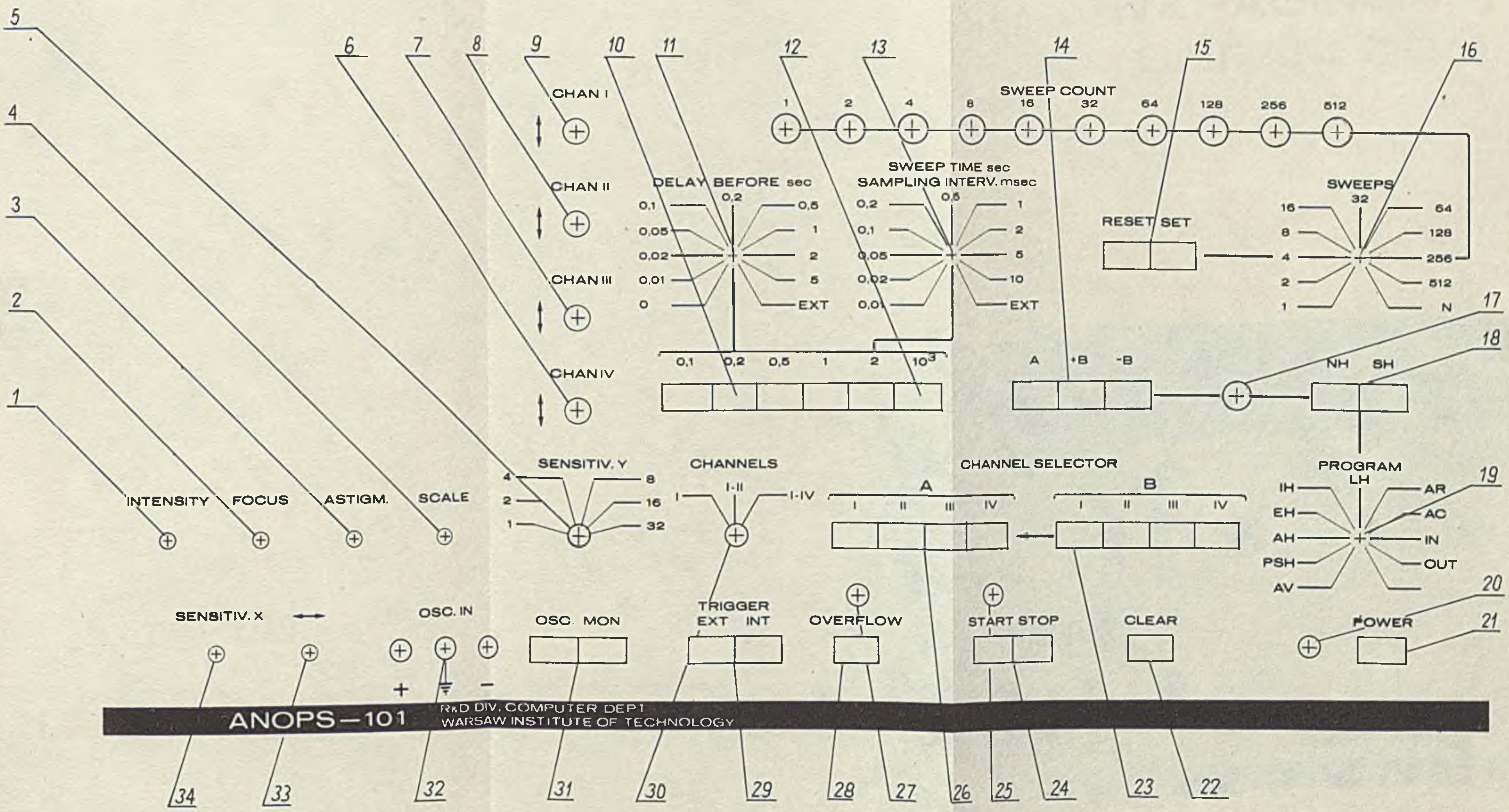
   $$\text{Sweep Setting} = \frac{512}{4 \times 4} = 32$$

   Set a multiplier 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 (no. 23) 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.
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 completed. The preselect number of MUP will be calculated and automatically stopped (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. 8 - 6 shows histograms for biceps muscle in normal subject. The upper histograms represents duration of single MUP.

   Each bar corresponds to the selected sampling interval = 0.5 ms. The mean duration is shown in 16th bar = 8 ms.



CHAN I
CHAN II
CHAN III
CHAN IV
DELAY BEFORE sec
SWEEP TIME sec
SAMPLING INTERV. msec
SWEEP COUNT
SWEEPS
RESET SET
PROGRAM
NH SH
SENSITIV. Y
CHANNELS
CHANNEL SELECTOR
INTENSITY
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ASTIGM.
SCALE
SENSITIV. X
OSC. IN
OSC. MON
TRIGGER
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START STOP
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ANOPS—101
R&D DIV. COMPUTER DEPT
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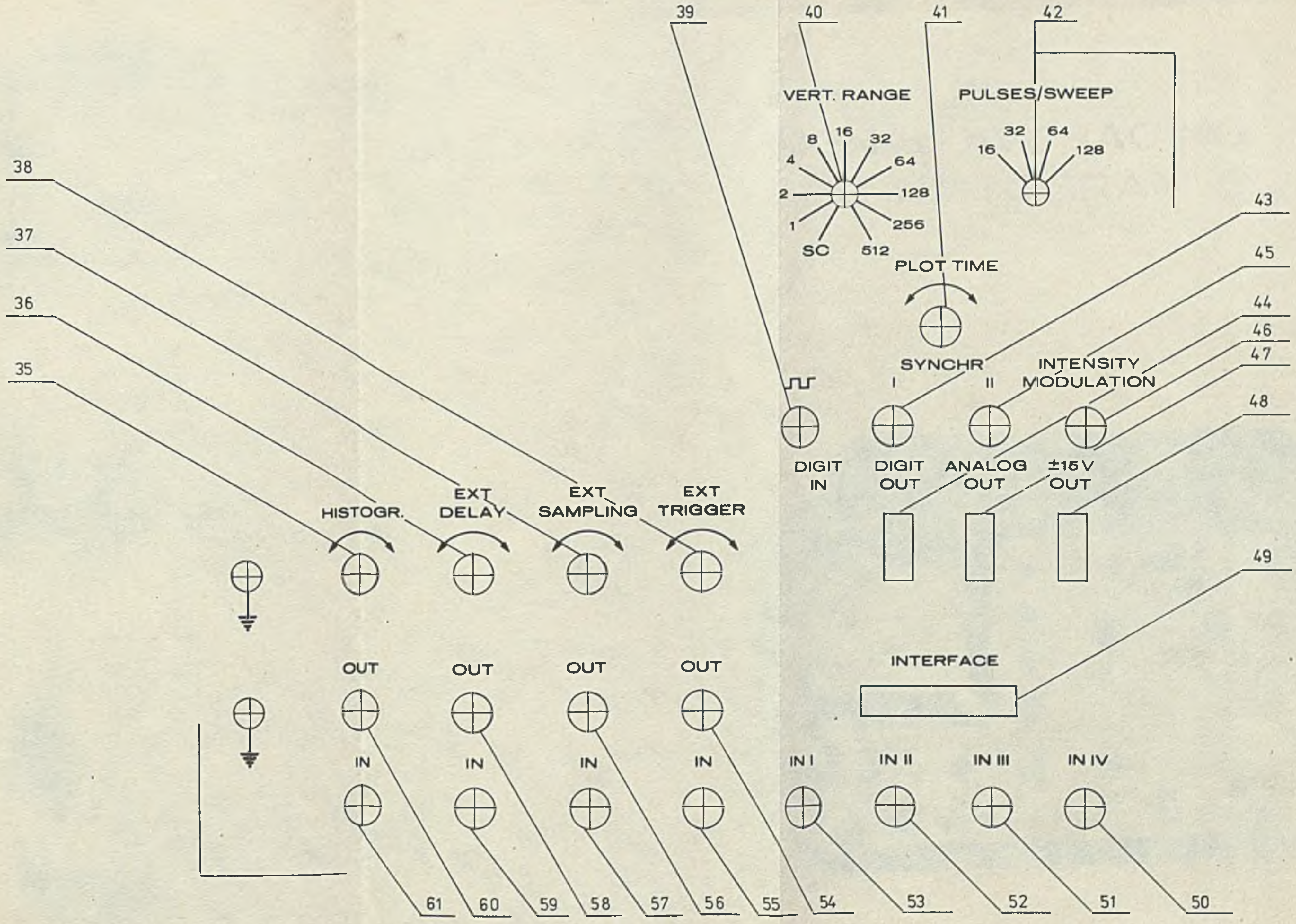
Fig. 8 - 4



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VERT. RANGE
PULSES/SWEEP
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PLOT TIME
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TRIGGER
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50

Fig. 8 - 5

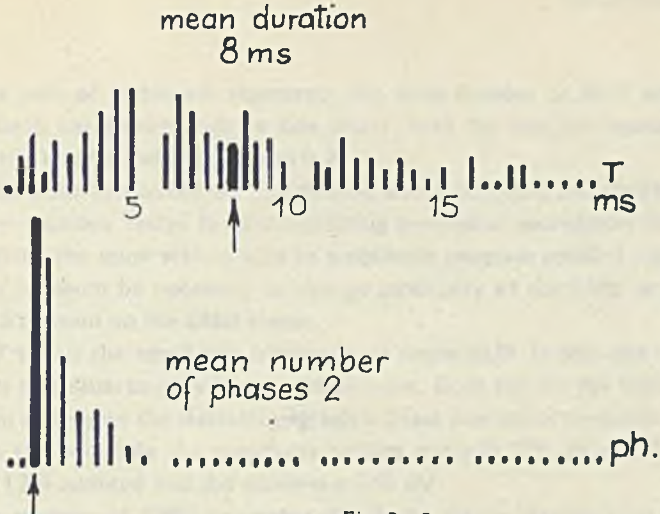


Fig. 8 - 6

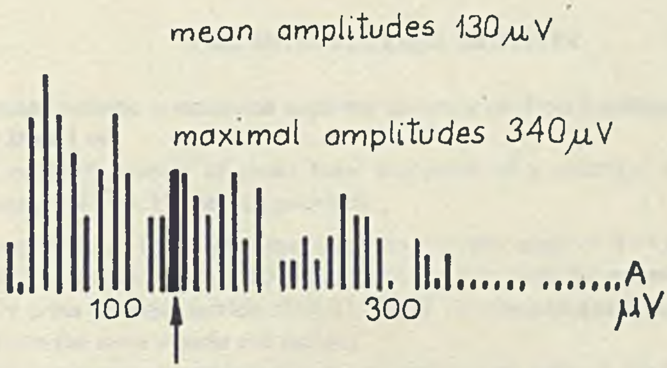


Fig. 8 - 7

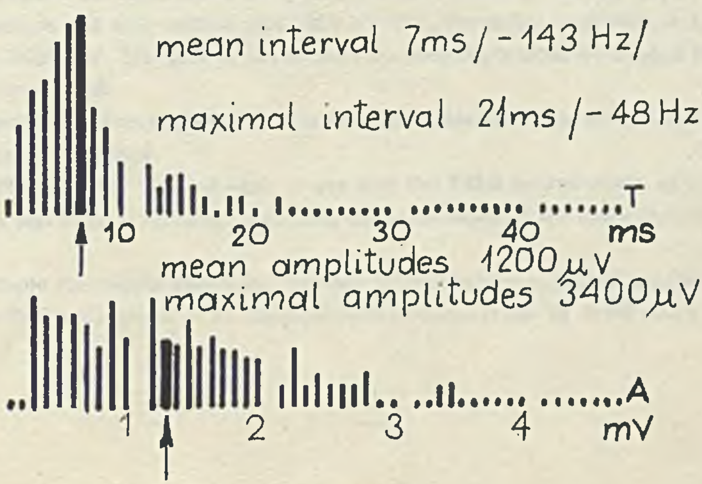


Fig. 8 - 8

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 recommend also to measure amplitudes of single MUP which gives very sensitive factor for distinguishing peripheral neuropathy from anterior horn cell disease. With the same setting turn to amplitude program pressing the push-button HN (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. 8 - 7 shows the amplitude histogram of single MUP. In this case we disregard 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 μV/div. The mean amplitude is 130 μV (13th address) and the maximum 340 μV.

The gain selector of EMG apparatus should be set on the position that the amplitude of EMG signal should not exceed four divisions of CRT screen.

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 to 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-button START. Fig. 8 - 8 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 intervals 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 μV/div., the mean amplitude is 1200 μV, and the maximum 3400 μV. The gain is set so that the amplitude does no exceed four division on the electromyograph.

   After recording all five parameters of quantitative electromyography than proceed to the next muscle to be tested.

   The ANOPS analyzer 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 X	± SD	M. interroseus dorsalis X	± SD	M. quadriceps femoris X	± SD	M. tibialis anterior 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
Amplitude MUP (μV)	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
	min.	46.0	12.2	47.2	16.1	38.6	10	40.4	8
Amplitudes (μV)	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

Table 8 - 1

SENSITIVITY Y SELECTOR (5) positions:	1	2	4	8	16	32	VERT. RANGE switch (40) position (with SWEEPS selector (16) set to Sweep Counter position)
NUMBER OF PULSES PER CM	160	80	40	20	10	5	1
	320	160	80	40	20	10	2
	640	320	160	80	40	20	4
	1280	640	320	160	80	40	8
	2560	1280	640	320	160	80	16
	5120	2560	1280	640	320	160	32
	10240	5120	2560	1280	640	320	64
	20480	10240	5120	2560	1280	640	128
	40960	20480	10240	5120	2560	1280	256 or 512

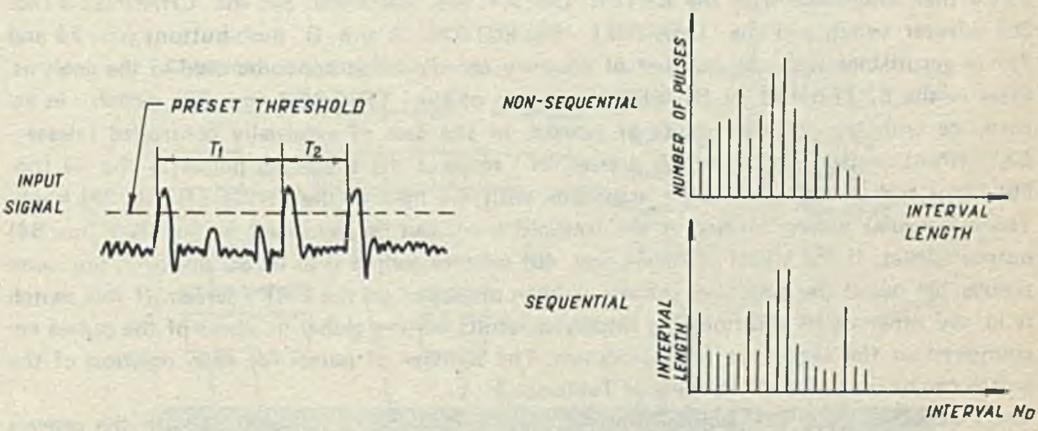
NOTE: The maximum number of pulses recorded in one address cannot exceed 65455.

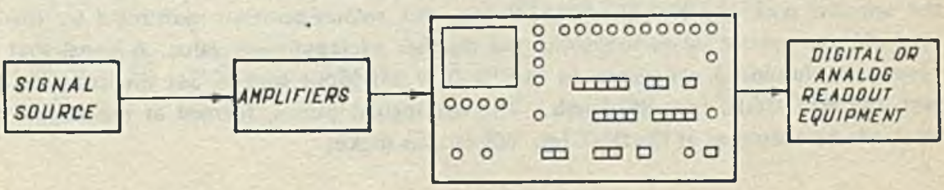
section 9

INTERVAL HISTOGRAMS 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.

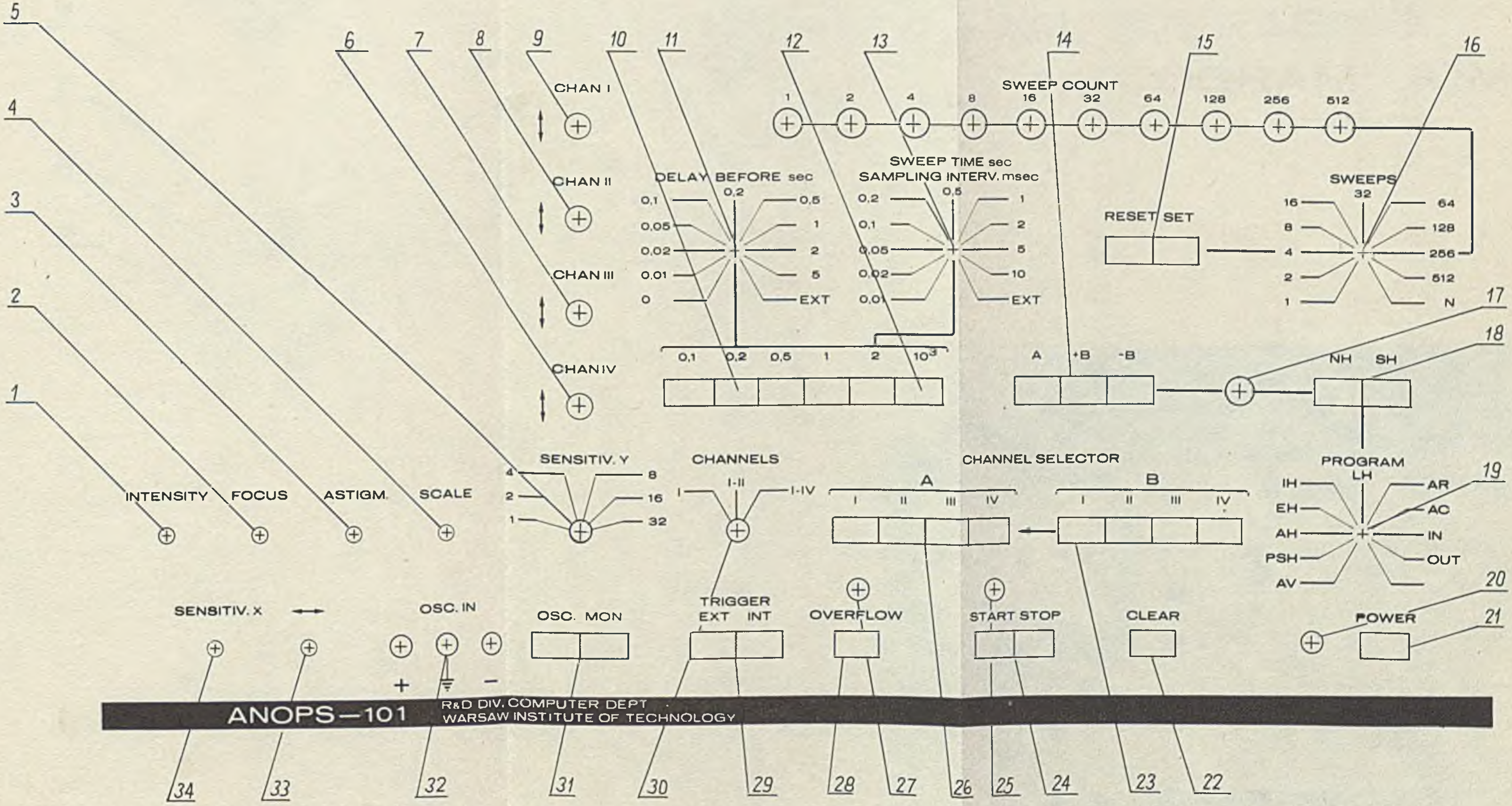
The non-sequential histograms consist of producing the statistical distribution of distances between the consecutive pulses in a train while the sequential histograms consist of the measurement of intervals between the consecutive pulses in a pulse train. The latter programme allows registering of a sequence of biological occurences characterized with the great variance of the intervals between pulses. The figure below 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.





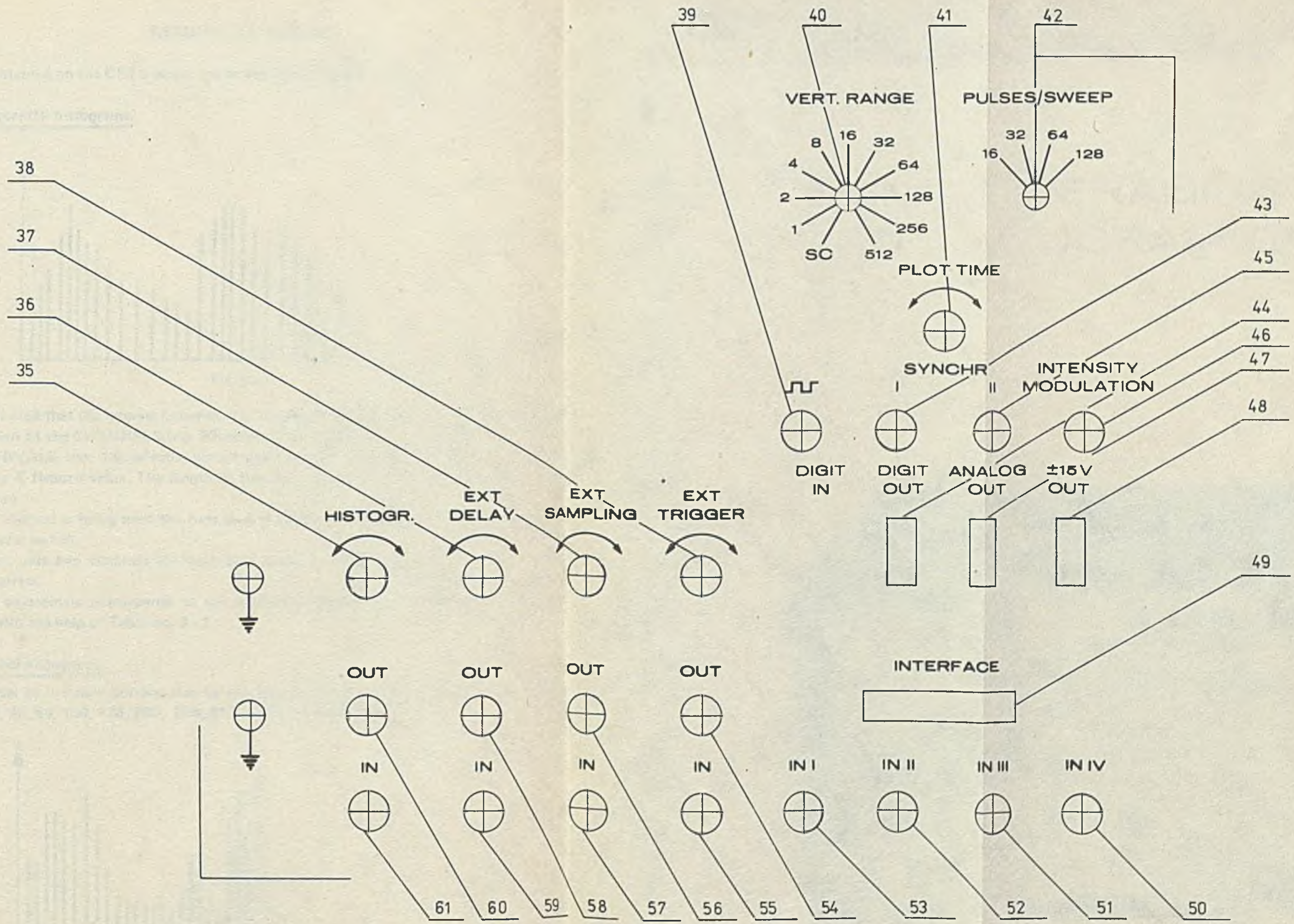
PREPARATORY OPERATIONS

After switching on the mains with the no. 21 switch a control light (no. 20) should go on. With all four push-buttons CHANNEL SELECTION B (no. 23) pressed in press buttons CLEAR (no. 22) and RESET (no. 15) for resetting the Number of Sweeps Counter. This should cause display of a horizontal line on the CRT's screen.
A routine selected with the PROGRAM (no. 19) switch is being executed as soon as the push-button START (no. 24) is pressed in and the first of the release signals appears: either external, if the TRIGGER (no. 29) push-button is in the EXTERNAL position, or internal, if it is in its INTERNAL position. A control light no. 25 is set on when the push-button START (no. 24) is pressed in and it is switched off automatically with the completion of a routine or when the push-button STOP (no. 24) is pressed in. When a selected routine is being run the no. 17 lamp is switched on. This light is switched off with the completion of the routine execution or with the completion of a part of a routine (for example: the end of the scan repetition for AV function), if the push-button STOP (no. 24) was pressed in. Set the PROGRAM (no. 19) selector switch into its IH position, press HN (no. 18) push-button for the non-sequential histograms, or HS (no. 18) push-button for sequential histograms, the +B, -B (no. 14) and IN, OUT (no. 18) push-buttons should be pressed out. The DELAY (no. 11), SWEEP TIME (no. 13) selector switches, one of the no. 10, no. 12 push-buttons and the SWEEPS (no. 16) selector switch should be set in accordance with the process requirements. In the case of the scan time being externally controlled set the SWEEP TIME (no. 13) selector switch into its EXTERNAL position, connect the timing pulses to the IN (no. 57) input socket and adjust their amplitude with the EXTER. SAMPLING (no. 37) knob. In the case of externally controlled delay set the DELAY (no. 11) selector switch into its EXTERNAL position, connect the delay pulses to the IN (no. 59) input socket and adjust their amplitude with the EXTER. DELAY (no. 36) knob. Set the CHANNELS (no. 30) selector switch and the CHANNEL SELECTION A and B push-buttons (no. 26 and 23) in accordance with the number of memory channels that are to be used in the analysis. Press in the EXTERNAL or INTERNAL button of the TRIGGER (no. 29) switch - in accordance with the required mode of release. In the case of externally controlled release - EXTERNAL button of the switch pressed in - connect the triggering pulses to the IN (no. 55) input socket and adjust their amplitude with the help of the TRIGGER (no. 38) knob. The rectangular pulses, formed at the treshold level, can be examined at the OUT (no. 54) output socket. If the VERT. RANGE (no. 40) selector switch is in its SC position, the mean number of pulses per one scan process is been displayed on the CRT's screen. If this switch is in any other of its positions the displayed results are the global numbers of the pulses encountered in the successive scan processes. The number of pulses for each position of the switch can be read off with the help of Table no. 9 - 1.
The PULSES/SWEEP (no. 42) selector switch should be set in accordance with the process requirements. The global number of pulses registered during the test is equal the value of the selected with the PULSES/SWEEP (no. 42) switch position multiplied by the number read off the control lights indicating the number of repetitions value. A signal that is to be examined, should be connected to the IN (no. 61) input socket. Set the counting treshold with the HISTOGR. (no. 35) knob. The rectangular pulses, formed at the release treshold level, can be examined at the OUT (no. 60) output socket.



CHAN I
CHAN II
CHAN III
CHAN IV
SWEEP COUNT
1 2 4 8 16 32 64 128 256 512
DELAY BEFORE sec
0,1 0,05 0,02 0,01 0 0,2 0,5 1 2 5 EXT
SWEEP TIME sec
SAMPLING INTERV. msec
0,2 0,1 0,05 0,02 0,01 0,5 1 2 5 10 EXT
RESET SET
SWEEPS
16 8 4 2 1 32 64 128 256 512 N
0,1 0,2 0,5 1 2 10³
A +B -B
NH SH
SENSITIV. Y
4 2 1 8 16 32
CHANNELS
I I-II I-IV
CHANNEL SELECTOR
A
B
I II III IV
PROGRAM
LH
IH EH AH PSH AV AR AC IN OUT
INTENSITY
FOCUS
ASTIGM.
SCALE
SENSITIV. X
OSC. IN
+ −
OSC. MON
TRIGGER
EXT INT
OVERFLOW
START STOP
CLEAR
POWER
ANOPS—101
R&D DIV. COMPUTER DEPT
WARSAW INSTITUTE OF TECHNOLOGY
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34

Fig. 9 - 1



39
40
41
42
VERT. RANGE
PULSES/SWEEP
16
8
32
4
64
2
128
1
256
SC
512
32
64
16
128
38
43
37
PLOT TIME
45
36
44
46
35
SYNCHR
INTENSITY
MODULATION
47
I
II
48
DIGIT
IN
DIGIT
OUT
ANALOG
OUT
±15 V
OUT
EXT
DELAY
EXT
SAMPLING
EXT
TRIGGER
HISTOGR.
49
INTERFACE
OUT
OUT
OUT
OUT
IN
IN
IN
IN
IN I
IN II
IN III
IN IV
61
60
59
58
57
56
55
54
53
52
51
50

Fig. 9 - 2

READING OF RESULTS

The results obtained on the CRT's screen are in the form of the vertical lines.

Non-sequential histograms.

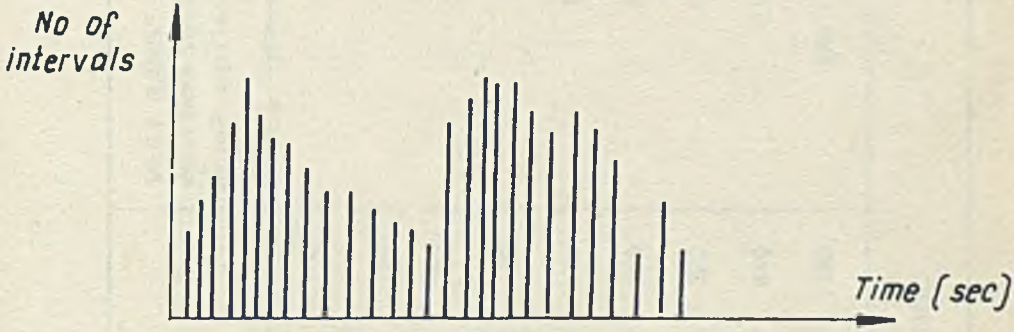


Fig. 9 - 3

It should be noted that the interval between two successive lines of the display does not depend on the position of the CHANNELS (no. 30) selector switch position. It depends on the SWEEP TIME, INTERVALS (no. 13) selector switch position and is equal the value of this position multiplied by K factor's value. The length of time base depends on the CHANNELS (no. 13) switch position.

If only one channel is being used the time base is equal value chosen with the SWEEP TIME (no. 13) selector switch.

If the routine uses two channels the time base is twice lesser, with four channels used it is four times shorter.

The vertical co-ordinate corresponds to the number of encountered pulses and its value can be read off with the help of Table no. 9 - 1.

Sequential histograms.

The horizontal co-ordinate corresponds to the number of intervals of a given length and can be equal: 16, 32, 64, 100, 128, 200, 256, 512, 1000, 1024 or 2000.

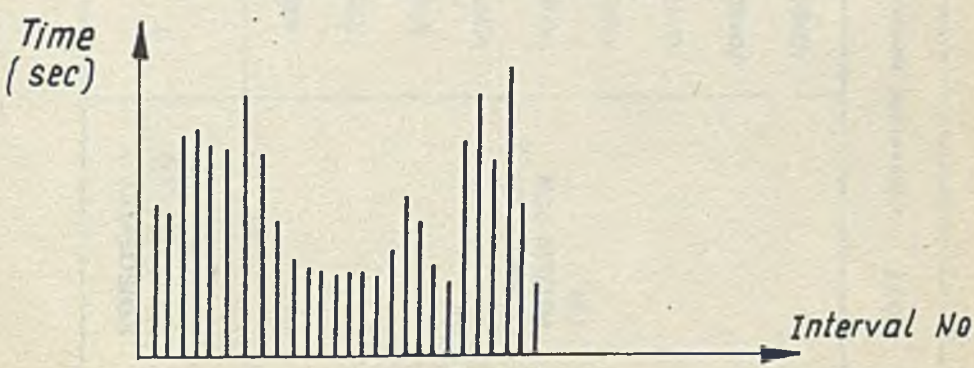


Fig. 9 - 4

The vertical co-ordinate of each display line corresponds to the pulse duration.
The sensitivity of the interval measurement is equal the value of the position selected with the INTERVALS (no. 13) switch multiplied by the K factor's value. The duration of each interval is equal the accuracy multiplied by the number of pulses read off with the help of Table no. 9 - 1.

Table 9 - 1

SENSITIVITY Y SELECTOR (5) positions:	1	2	4	8	16	32	VERT. RANGE switch (40) position (with SWEEPS selector (16) set to Sweep Counter position)
NUMBER OF PULSES PER CM	160	80	40	20	10	5	1
	320	160	80	40	20	10	2
	640	320	160	80	40	20	4
	1280	640	320	160	80	40	8
	2560	1280	640	320	160	80	16
	5120	2560	1280	640	320	160	32
	10240	5120	2560	1280	640	320	64
	20480	10240	5120	2560	1280	640	128
	40960	20480	10240	5120	2560	1280	256 or 512

NOTE: The maximum number of pulses recorded in one address cannot exceed 65455.

section 10

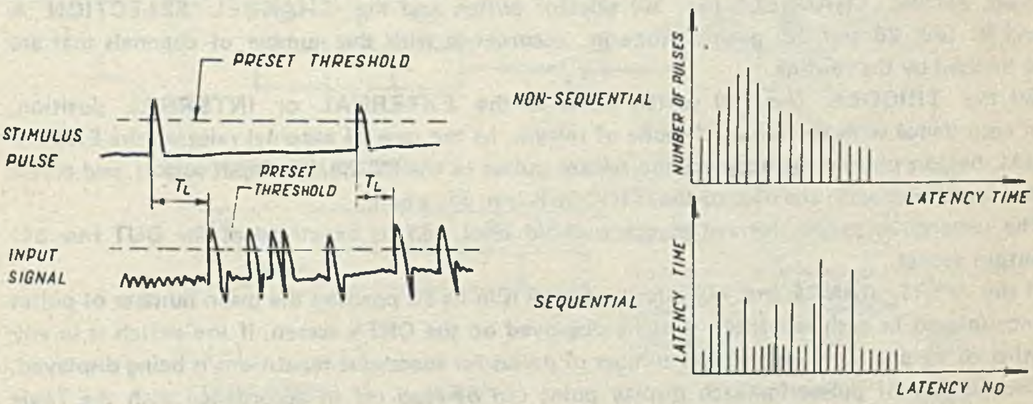
LATENCY HISTOGRAMS SEQUENTIAL AND NON-SEQUENTIAL

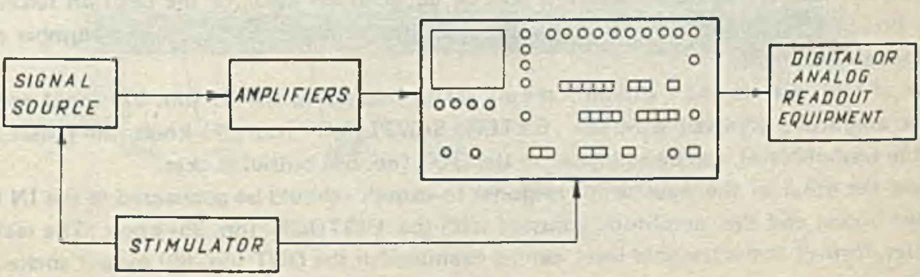
These histograms are of interest in the research of the reaction time and of the conduction time of an isolated nervous fibre, as well as in research of latency of muscle contraction when the nerve is exposed to some kind of stimulation.

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.





PREPARATORY OPERATIONS

After switching on the mains with the no. 21 switch a control light (no. 20) should go on. With all four push-buttons CHANNEL SELECTION B (no. 23) pressed in press buttons CLEAR (no. 22) and RESET (no. 15) for resetting the Number of Sweeps Counter. This should cause display of a horizontal line on the CRT's screen.
A routing selected with the PROGRAM (no. 19) switch is being executed as soon as the push-button START (no. 24) is pressed in and the first of the release signals appears: either external, if the TRIGGER (no. 29) push-button is in the EXTERNAL position, or internal, if it is in its INTERNAL position. A control light no. 25 is set on when the push-button START (no. 24) is pressed in and it is switched off automatically with the completion of a routine or when the push-button STOP (no. 24) is pressed in. When a selected routine is being run the no. 17 lamp is switched on. This light is switched off with the completion of the routine execution or with the completion of a part of a routine (for example: the end of the scan repetition for AV function), if the push-button STOP (no. 24) was pressed in.
Set the PROGRAM (no. 19) selector switch into its LH position, press in the HN (no. 18) push-button for non-sequential histograms, or the HS (no. 18) button for sequential mode of work, the +B, -B (no. 14) push-buttons should be pressed in.
The DELAY (no. 11) SWEEP TIME (no. 13) selector switches, the no. 10 and the no. 12 push-buttons and the SWEEPS (no. 16) switch should be set in accordance with the process requirements. In the case of externally controlled delay the DELAY (no. 11) selector switch should be set in its EXTERNAL position, the delay pulses should be connected to the IN (no. 59) input socket and their amplitude adjusted with the EXTER. DELAY (no. 36) knob. Set the CHANNELS (no. 30) selector switch and the CHANNEL SELECTION A and B (no. 26 and 23) push-buttons in accordance with the number of channels that are to be used by the routine.
Set the TRIGGER (no. 29) switch either to the EXTERNAL or INTERNAL position, in accordance with the required mode of release. In the case of external release - the EXTERNAL button pressed in - connect the release pulses to the IN (no. 55) input socket, and adjust their amplitude with the help of the TRIGGER (no. 38) knob.
The rectangular pulses, formed at the treshold level, can be examined at the OUT (no. 54) output socket.
If the VERT RANGE (no. 40) selector switch is in its SC position the mean number of pulses encountered in each repetition is being displayed on the CRT's screen, if the switch is in any other of its positions - the global number of pulses for successive repetitions is being displayed. The number of pulses for each display point can be read off in accordance with the Table no. 10 - 1.
Set the PULSES/SWEEP (no. 42) switch in accordance with the process requirements. The global number of registered intervals will be equal to the value of the position selected with the PULSES/SWEEP (no. 42) switch multiplied by the number read off the Number of Repetitions control lights.
One of the waveforms - stimuli - should be connected to the IN (no. 57) input socket and their amplitude adjusted with the EXTER. SAMPLING (no. 37) knob, the pulses, formed at the treshold level, can be examined at the OUT (no. 56) output socket.
While the other of the waveform - response to stimuli - should be connected to the IN (no. 61) input socket and the amplitude adjusted with the HISTOGR. (no. 35) knob. The rectangular pulses, formed at the treshold level, can be examined at the OUT (no. 60) output socket.

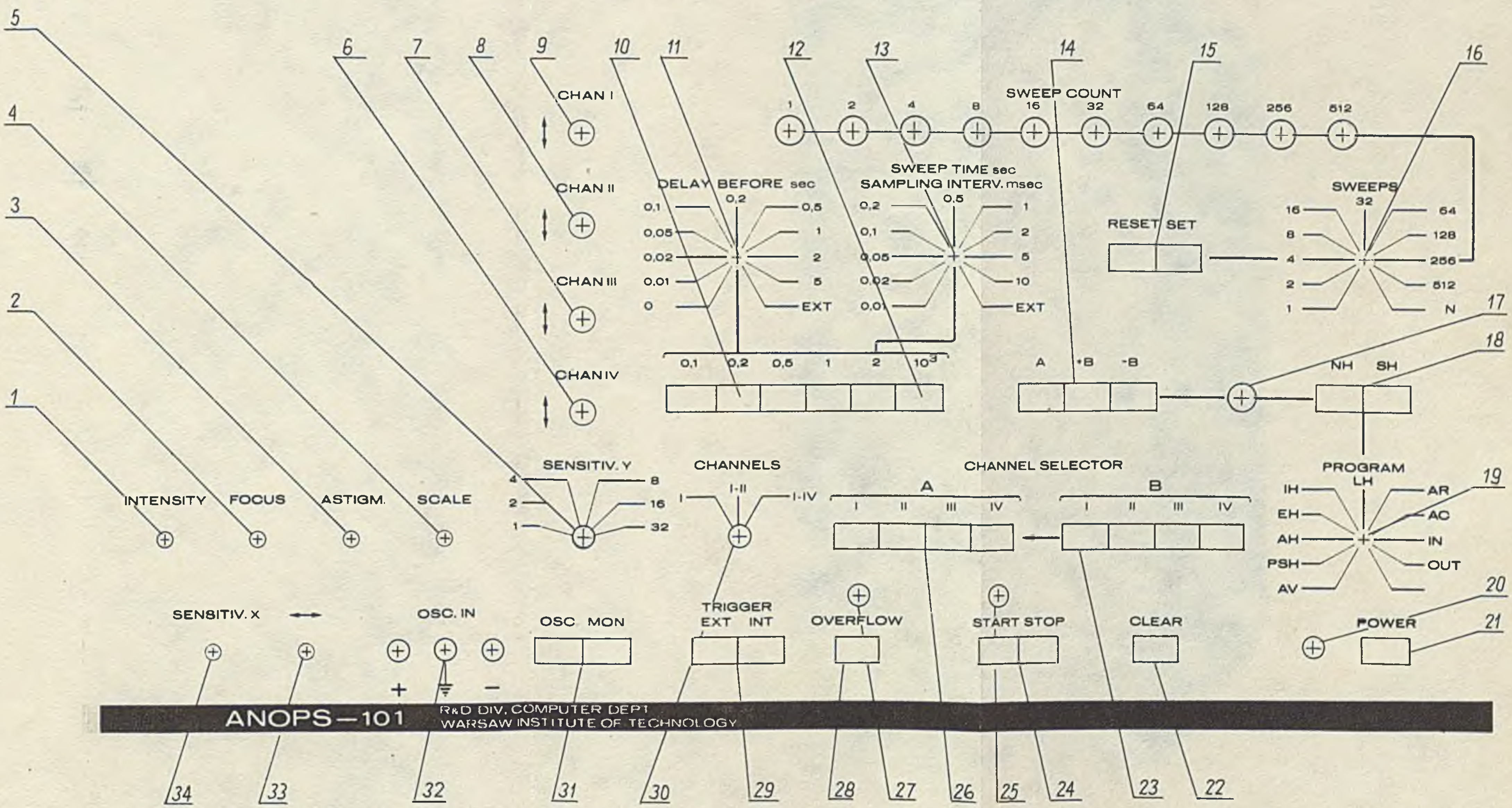
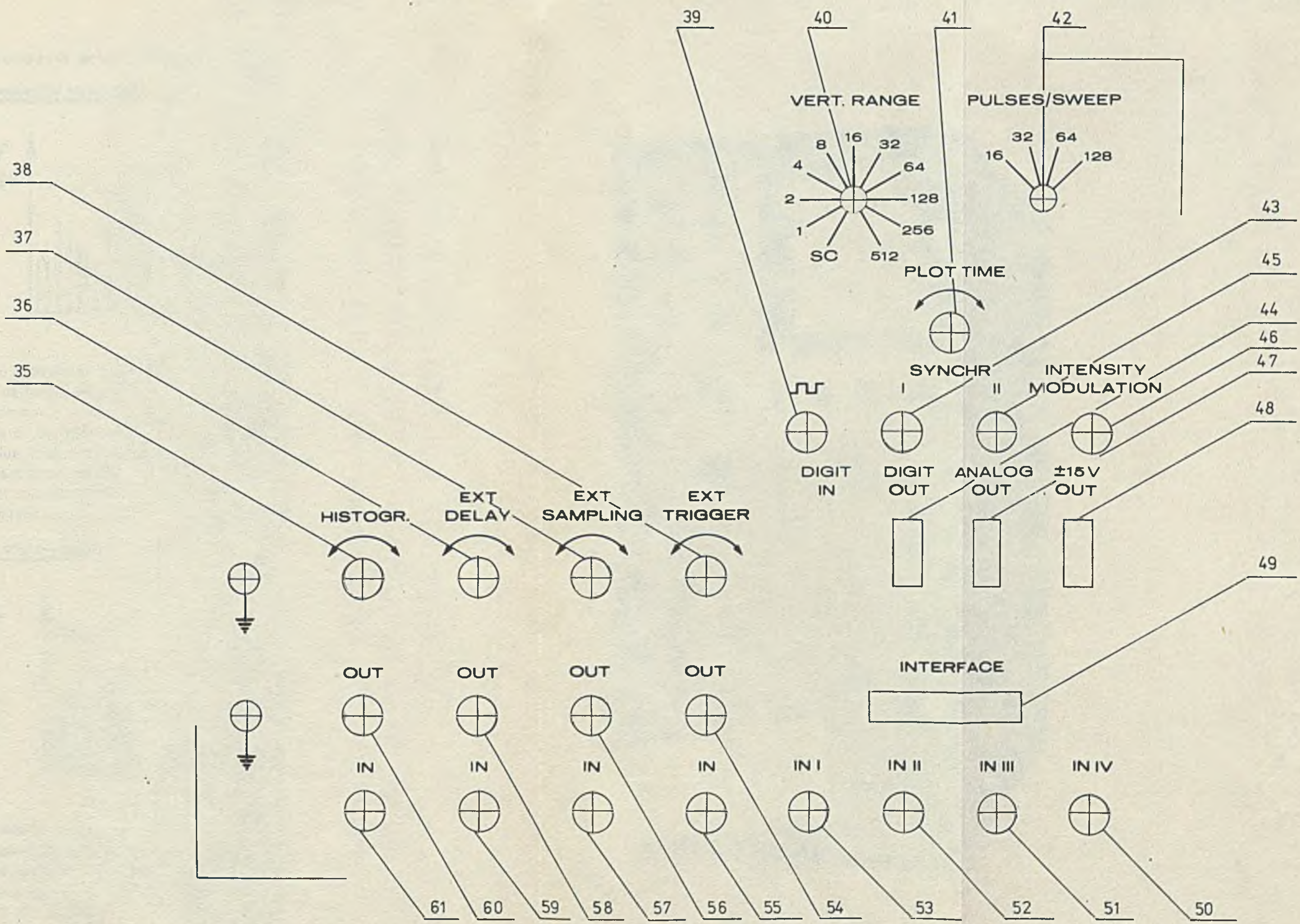

CHAN I
CHAN II
CHAN III
CHAN IV
SWEEP COUNT
DELAY BEFORE sec
SWEEP TIME sec
SAMPLING INTERV. msec
SWEEPS
RESET SET
A +B -B
NH SH
SENSITIV. Y
CHANNELS
CHANNEL SELECTOR
PROGRAM
INTENSITY
FOCUS
ASTIGM.
SCALE
SENSITIV. X
OSC. IN
OSC MON
TRIGGER
EXT INT
OVERFLOW
START STOP
CLEAR
POWER
ANOPS—101
R&D DIV. COMPUTER DEPT
WARSAW INSTITUTE OF TECHNOLOGY

Fig. 10 - 1



VERT. RANGE
PULSES/SWEEP
PLOT TIME
SYNCHR
INTENSITY MODULATION
DIGIT IN
DIGIT OUT
ANALOG OUT
±15V OUT
HISTOGR.
EXT DELAY
EXT SAMPLING
EXT TRIGGER
OUT
IN
IN I
IN II
IN III
IN IV
INTERFACE

Fig. 10 - 2

READING OF RESULTS

The results displayed on the CRT's screen are in the form of the vertical lines.

Non-sequential histograms.

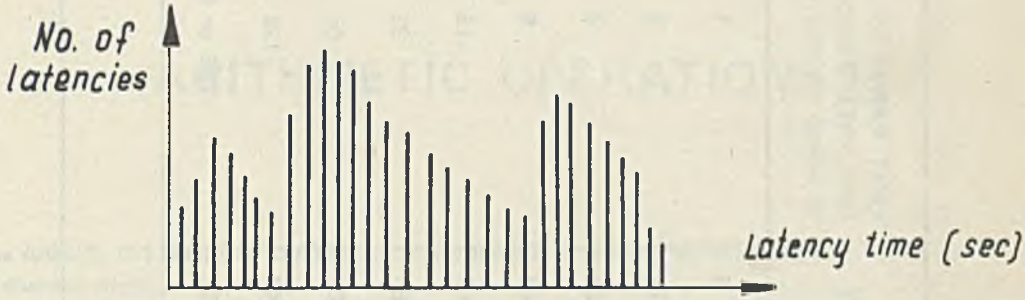


Fig. 10 - 3

The interval between two successive line does not depend on the CHANNELS (no. 30) switch position. The length of the time base does, however, depend on the CHANNELS (no. 30) switch position.

If only one of the channels is selected the time base is equal the SWEEP TIME (no. 13) switch's value. With two channels selected the time base is two times shorter, with four channels - it is four times shorter.

The vertical co-ordinate of each of the lines corresponds to the number of intervals (latency) and is being read off with the help of Table no. 10 - 1.

Sequential histograms.

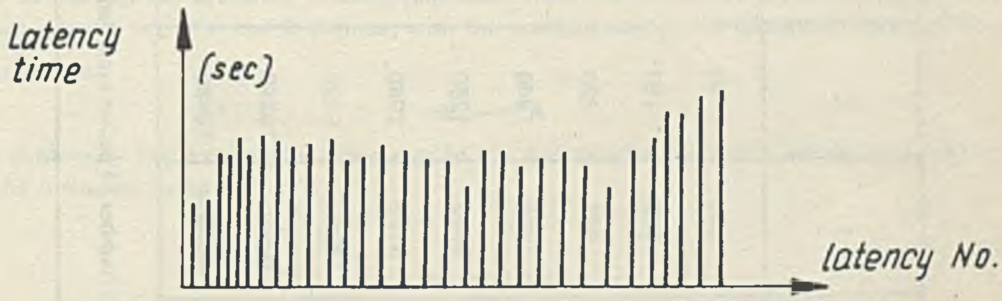


Fig. 10 - 4

The horizontal co-ordinate of each of the display lines corresponds to the successive interval (latency) value, which can be equal 16, 32, 64, 100, 128, 256, 500, 512, 1000, 1024 and 2000. The vertical co-ordinate of each of the lines corresponds to the latency duration. The accuracy of the latency measurement is equal the INTERVALS (no. 13) switch position multiplied by the m and K factor's value.

The duration of latency is equal the accuracy of measurement multiplied by the number of intervals value read off with the help of Table no. 10 - 1 for each latency value.

Table 10 - 1

SENSITIVITY Y SELECTOR (5) positions:	1	2	4	8	16	32	VERT. RANGE (40) position (with SWEEPS selector (16) set to Sweep Counter position)
NUMBER OF PULSES PER CM	160	80	40	20	10	5	1
	320	160	80	40	20	10	2
	640	320	160	80	40	20	4
	1280	640	320	160	80	40	8
	2560	1280	640	320	160	80	16
	5120	2560	1280	640	320	160	32
	10240	5120	2560	1280	640	320	64
	20480	10240	5120	2560	1280	640	128
	40960	20480	10240	5120	2560	1280	256 or 512

NOTE: The maximum number of pulses recorded in one address cannot exceed 65455.

section 11

ARITHMETIC OPERATIONS

The ANOPS 101 analyzer can execute the following arithmetic operations:
1) channel addition
2) channel subtraction
3) channel transmission

On the front panel of the ANOPS analyzer there are two sets of push-buttons CHANNEL SELECTION A (no. 26) and CHANNEL SELECTION B (no. 23).

The addition is being performed in the following manner:

$$A + B \longrightarrow A$$

which means that the contents of the B channel is being added to the contents of the A channel and the result is being stored in the A channel, the previous A channel data being lost.

Subtraction:

$$A - B \longrightarrow A$$

The content of the B channel is being subtracted from the content of the A channel and the result is being stored in the A channel, with the previous content of the A channel being lost.

Transmission:

$$\pm B \longrightarrow A$$

the content of the B channel is being sent to the A channel, the previous information existing in the A channel being lost.

ADDITION

Set the PROGRAM (no. 19) selector switch into its AR position, press in the A and +B (no. 14) push-buttons, press out the HN and HS (no. 13) push-buttons. Set the CHANNELS (no. 30) switch into "I - II" or "I - IV" position, in accordance with the channels' numbers that are to take part in the addition operation

$$A + B \longrightarrow A$$

Press in the appropriate CHANNEL SELECTION A (no. 26) and CHANNEL SELECTION B (no. 23) push-buttons. Press the START (no. 24) button.

SUBTRACTION

Set the PROGRAM (no. 19) selector switch into its AR position, press in the A and -B (no. 14) push-buttons, press out the HN and HS (no. 18) buttons.
The CHANNELS (no. 30) switch should be set in "I - II" or "I - IV" position, in accordance with the numbers of the channels that are to take part in the subtraction operation

$$A - B \longrightarrow A$$

Press in the appropriate CHANNEL SELECTION A (no. 26) and CHANNEL SELECTION B (no. 23) buttons and press the START (no. 24) button.

TRANSMISSION

Set the PROGRAM (no. 19) switch into its AR position and press in the +B or -B (no. 14) button, whether the execution of the

$$+B \longrightarrow A$$

or the operation is required

$$-B \longrightarrow A$$

Check that the A (no. 14) and HN, HS (no. 18) push-buttons are pressed out. Set the CHANNELS (no. 30) switch into "I - II" or "I - IV" position in accordance with the channels' numbers that will take part in the transmission. Press in the appropriate CHANNEL SELECTION A (no. 26) and CHANNEL SELECTION B (no. 23) buttons and press the START button.

section 12

OUTPUT OF INFORMATION

PAPER TAPE PUNCH

The paper tape punch is to be connected to DIGIT. OUT (no. 44) out socket.
Set the PROGRAM (no. 19) selector switch into its OUT position. The HN, HS (no. 18) and A, +B, -B (no. 14) push-buttons should be pressed out.
The output information originates in any of the channels selected with the CHANNELS (no. 30) switch and with the CHANNEL SELECTION B (no. 23) push-buttons. The output of the information begins when the START (no. 24) button is pressed and it terminates when the memory address, selected with the no. 10 push-buttons, are exhausted or when the STOP (no. 24) button is pressed.
The information on the paper tape is coded or in binary code for positive numbers or in two's complement code for negative numbers.
Each item of information contents four rows on the tape.
The succession of the bits is shown on Fig. 12 - 3, where bit no. 15 - sign bit.

PLOTTER

The plotter is to be connected to the ANAL OUT (no. 47) output socket.
Set the PROGRAM (no. 19) switch into its OUT position. Select the right channel with the help of the CHANNELS (no. 30) switch and with the CHANNEL SELECTION B (no. 26) push-buttons.
The HN, HS (no. 18) and A, +B, -B (no. 14) buttons should be pressed out.
The output of the information begins when the START (no. 24) button is pressed and it terminates when the memory addresses, selected with the no. 10 push-buttons, are exhausted or when the STOP (no. 24) button is pressed.

OUTPUT OF DATA IN MODE 16 BITS

INTERFACE JACK is to be connected to the INTERFACE SOCKET (49).
Set the PROGRAM (19) selector switch into its OUT position. Output of data from ANOPS 101 can begin when signal PEN LIFT (pin 39) is in low level. The PEN LIFT signal is in low level if and only if

a. connector INTERFACE is plug in

b. button START is pushed (START light is on).

PLOT COMPLETE (pin 37) is a signal coming to ANOPS 101 from another equipment and means a request of data transfer (the equipment is ready to accept data from ANOPS).

When PEN LIFT signal is in low level, when high level of PLOT COMPLETE results in a high level of a SEEK NULL signal (pin 38) a high level of the SEEK NULL enable the transfer of data IBO-IB 15 (pin 1 - 16 of the connector INTERFACE) to the equipment connected to ANOPS through connector INTERFACE.

The time interval of the high level of the SEEK NULL signal can be modified using capacitor C1 or resistor R11 connected to the circuit M16 (SN 74123). This circuit can be found on printed board 02 PER localized in place 15.

A change from a high to a low level of the SEEK NULL signal results a preparation of a data to be out from the next address of memory of ANOPS 101.

Next signal PLOT COMPLETE repeat the cycle. The end of output of data from ANOPS take place when the PEN LIFT signal come back to the high level, that is when data from all addresses of a selected channel of the memory were transfered or a button STOP is being pushed.

Timing diagram is shown on Fig. 12 - 4.

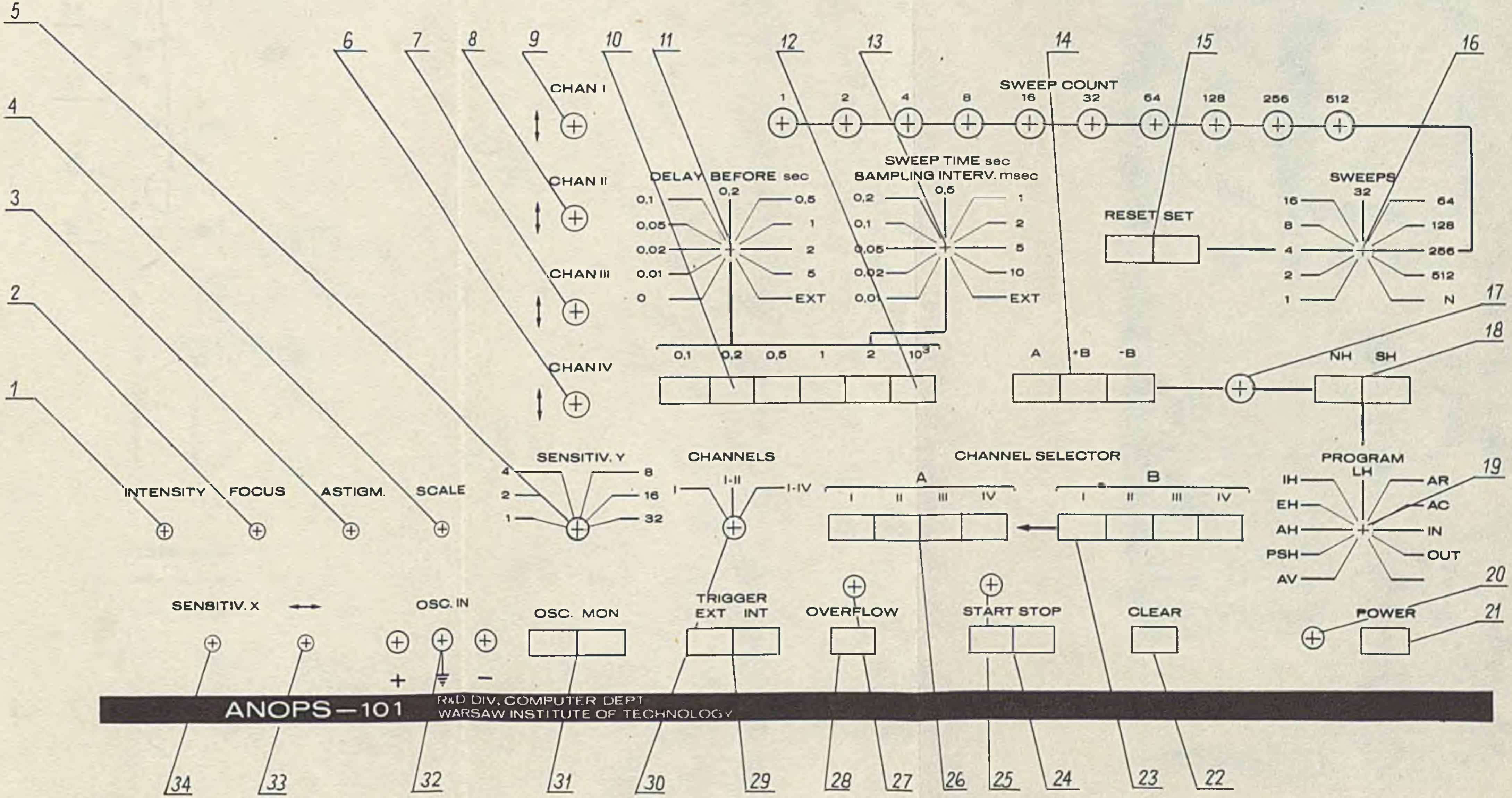
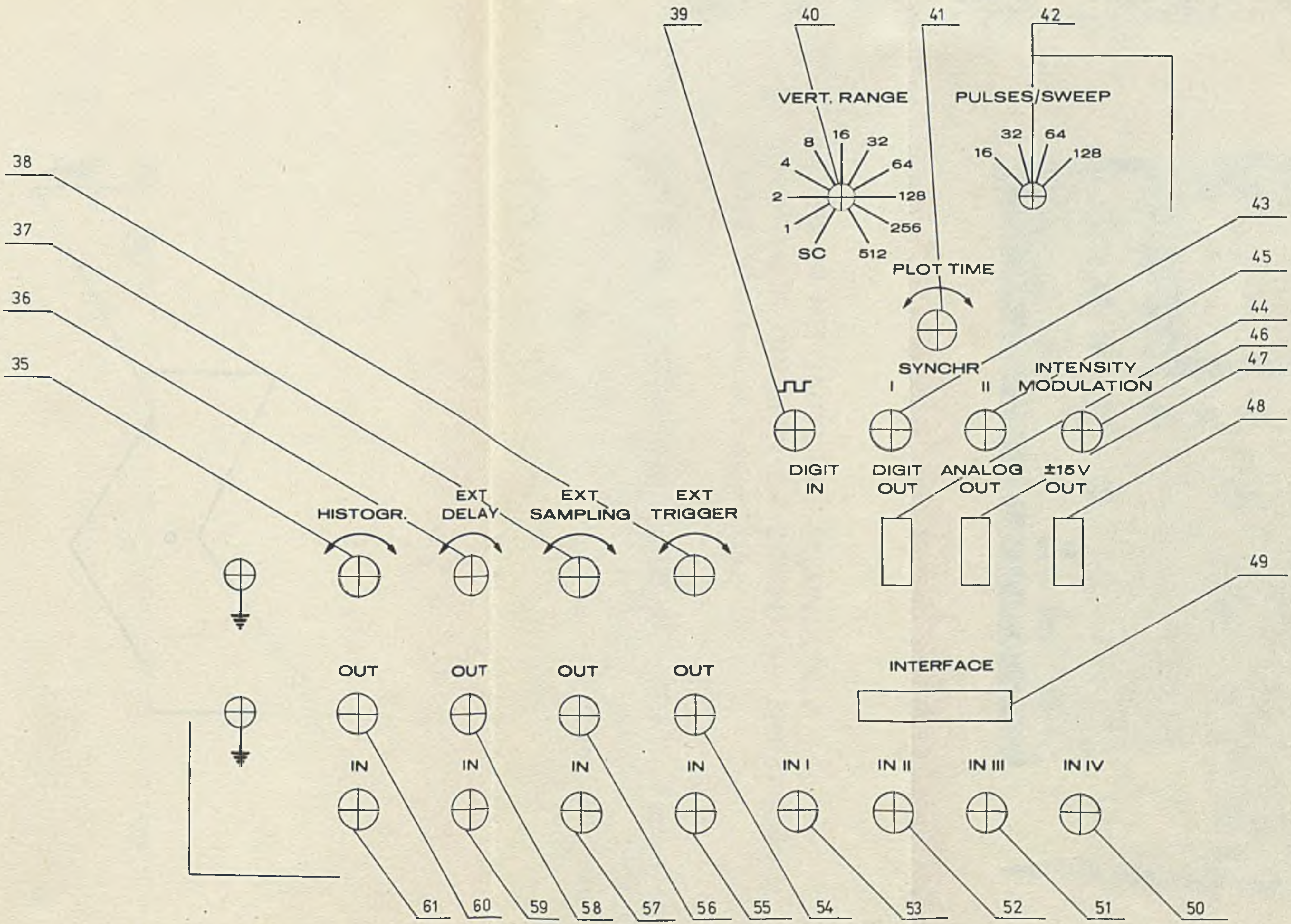

CHAN I
CHAN II
CHAN III
CHAN IV
SWEEP COUNT
1 2 4 8 16 32 64 128 256 512
DELAY BEFORE sec
SWEEP TIME sec
SAMPLING INTERV. msec
RESET SET
SWEEPS
A +B -B
NH SH
SENSITIV. Y
CHANNELS
CHANNEL SELECTOR
PROGRAM
LH
IH EH AH PSH AV
AR AC IN OUT
INTENSITY
FOCUS
ASTIGM.
SCALE
SENSITIV. X
OSC. IN
OSC. MON
TRIGGER
EXT INT
OVERFLOW
START STOP
CLEAR
POWER
ANOPS—101
R&D DIV. COMPUTER DEPT
WARSAW INSTITUTE OF TECHNOLOGY

Fig. 12 - 1



39
40
41
42
VERT. RANGE
PULSES/SWEEP
16
8
32
4
64
2
128
1
256
SC
512
32
64
16
128
38
37
36
35
43
45
44
46
47
48
PLOT TIME
SYNCHR
I
II
INTENSITY
MODULATION
DIGIT
IN
DIGIT
OUT
ANALOG
OUT
±15 V
OUT
HISTOGR.
EXT
DELAY
EXT
SAMPLING
EXT
TRIGGER
49
INTERFACE
OUT
OUT
OUT
OUT
IN
IN
IN
IN
IN I
IN II
IN III
IN IV
61
60
59
58
57
56
55
54
53
52
51
50

Fig. 12 - 2

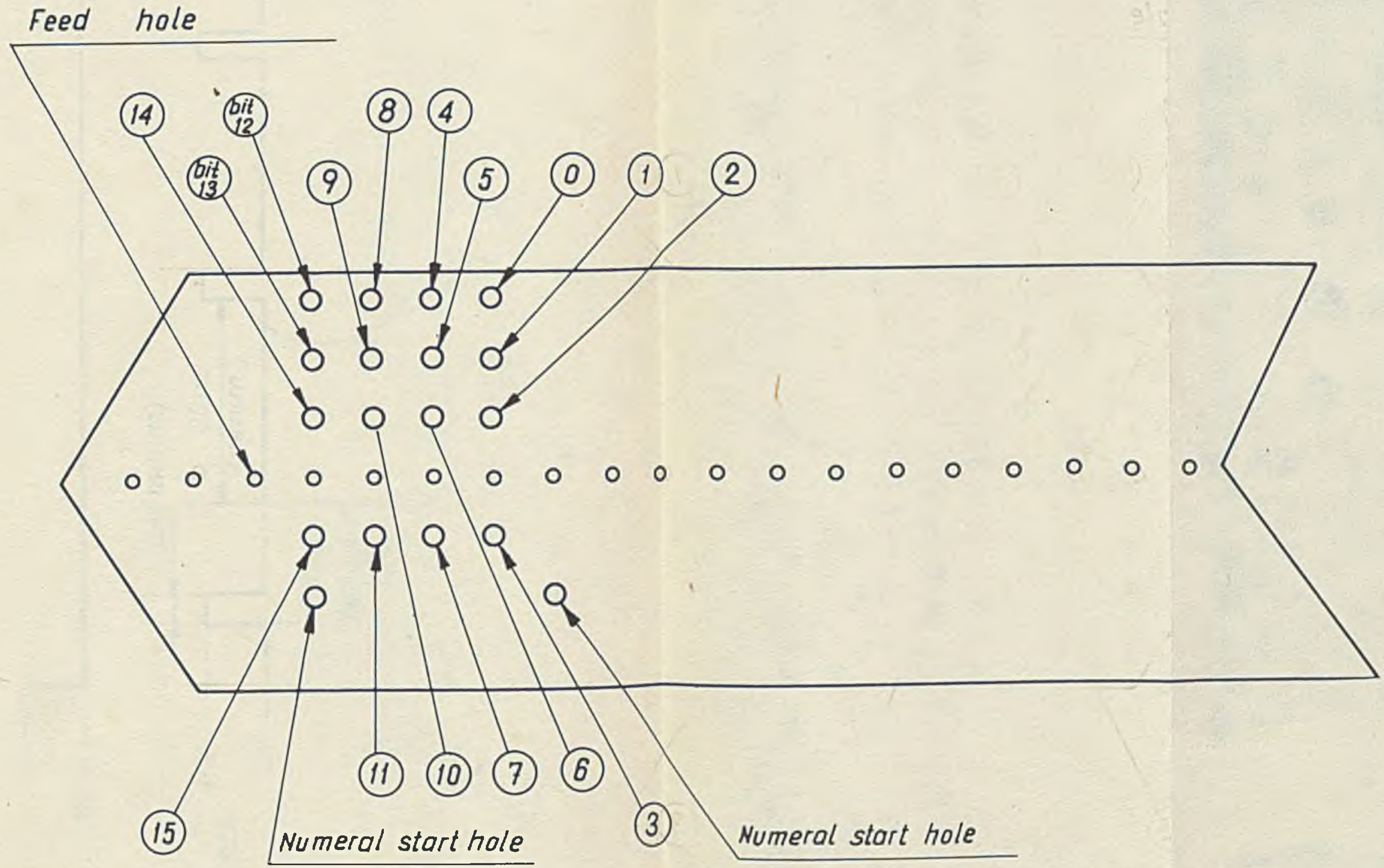

Feed hole
14
bit 12
8
4
bit 13
9
5
0
1
2
11
10
7
6
15
3
Numeral start hole
Numeral start hole

Fig. 12 - 3

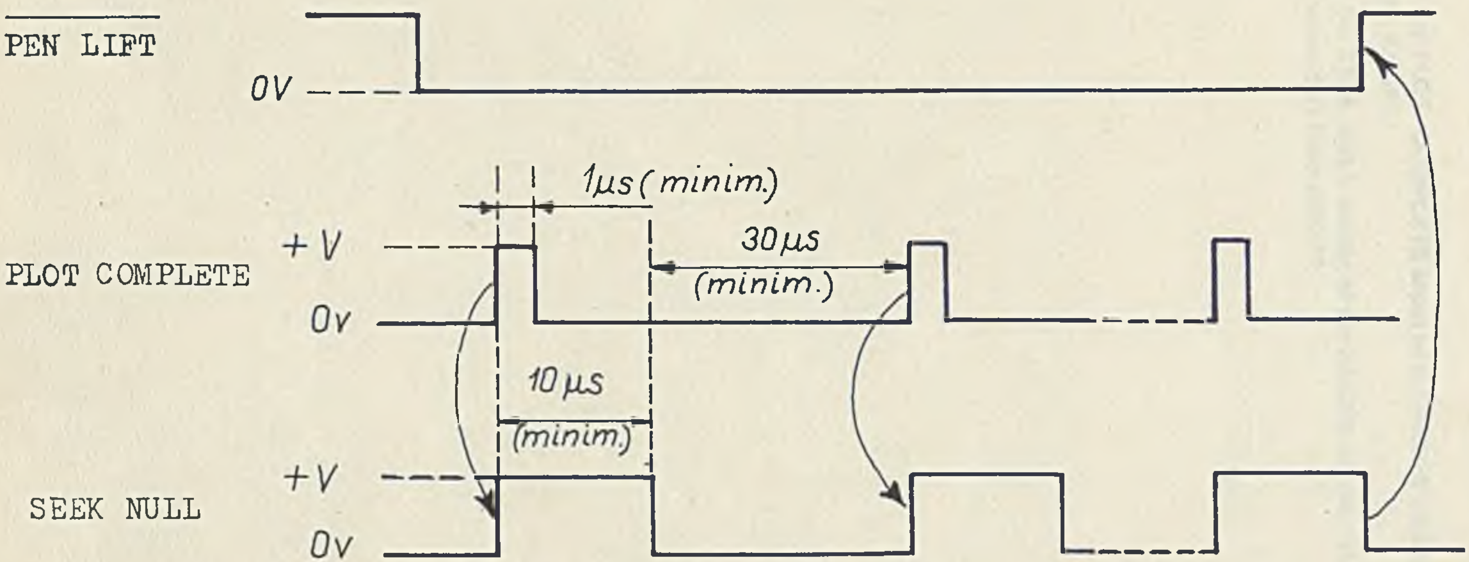

PEN LIFT
0V
1µs (minim.)
+V
PLOT COMPLETE
0v
30µs
(minim.)
10µs
(minim.)
+V
SEEK NULL
0v

Fig. 12 · 4

1. Low level on the PEN LIFT output of the ANOPS indicates that ANOPS is ready to send the data.
2. High level on the PLOT COMPLETE input of the ANOPS indicates that output device requests data from ANOPS.
3. High level on the SEEK NULL output of the ANOPS indicates that data is available (on the INTERFACE connector) from ANOPS.

section 13

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