DECUS

PROGRAM LIBRARY

DECUS NO.	12-35
TITLE	BIOELECTRIC SIGNAL SORTER (JULIA)
AUTHOR	Vratislav J. Prochazka
COMPANY	University of Ulm Ulm, West Germany
DATE	October 11, 1971
SOURCE LANGUAGE	LAP6

BIOELECTRIC SIGNAL SORTER
(JULIA)

DECUS Program Library Write-up DECUS NO. 12-35

BINARY NAME: JULIA

1. ABSTRACT

This program provides a means for the automatic sorting and time analysis of biological action potentials. The basis for automatic unit selection by shape is a continuous mean-square-error comparison between the incoming displayed signal and previous "template" unit selections. Interference potentials caused by simultaneously-firing units are sorted using a semi-automatic subtraction procedure. Three types of histograms are available for each sorted unit:

(a) Simple interval versus time
(b) Interval occurrence probability
(c) Joint interval

2. MINIMUM HARDWARE

(a) PDP-12 with A-D, VR12 Display, basic LINCtape system and 8K Extended Memory
(b) ASR-33 teletype
(c) KW12 real-time clock
(d) KE12 extended arithmetic element

3. LOADING PROCEDURES

Place a LAP6-DIAL system tape containing JULIA on tape unit 0 (in REMOTE with WRITE ENABLED). Place a scratch tape on tape unit 1 (in REMOTE with WRITE ENABLED). The binary is loaded using the DIAL loader by the command:

→ LO JULIA,0↓

Signal display should appear on successful loading.

4. OPERATIONAL PROCEDURE

Analog data is sampled at 125 Hz at analog input channel 10. The analog signal must therefore be fed in at an appropriately reduced speed (e.g. for normal EMG, 1/32nd of real time speed).

Analog channel 7 provides an amplitude pedestal. Using this potentiometer, the zero level of the displayed signal must now be matched to the zero point displayed on screen. Best results are achieved if the input signal is of the order of ±0.5V. The amplitude trigger point on the left of the screen is adjustable by analog channel potentiometer 0.

5. UNIT SELECTIONS

5.1 Phase 1

Up to 4 differently-shaped units may be keyboard-selected for analysis. When the first example of a desired unit appears on screen, one of the digits 1, 2, 3 or 4 is typed. As soon as the level criterion at the amplitude trigger point is met, (the unit having traversed to the left side of the screen) it will be automatically transferred into the stored and displayed "template" bin corresponding to the digit typed.

Each subsequent incoming unit which surmounts the trigger is automatically compared with each of the template units and according to an internal recognition system, is treated in either of two ways:

(a) If it is similar enough to one of the template units, it is automatically selected. The template is automatically updated by the new unit and the time of occurrence is stored.

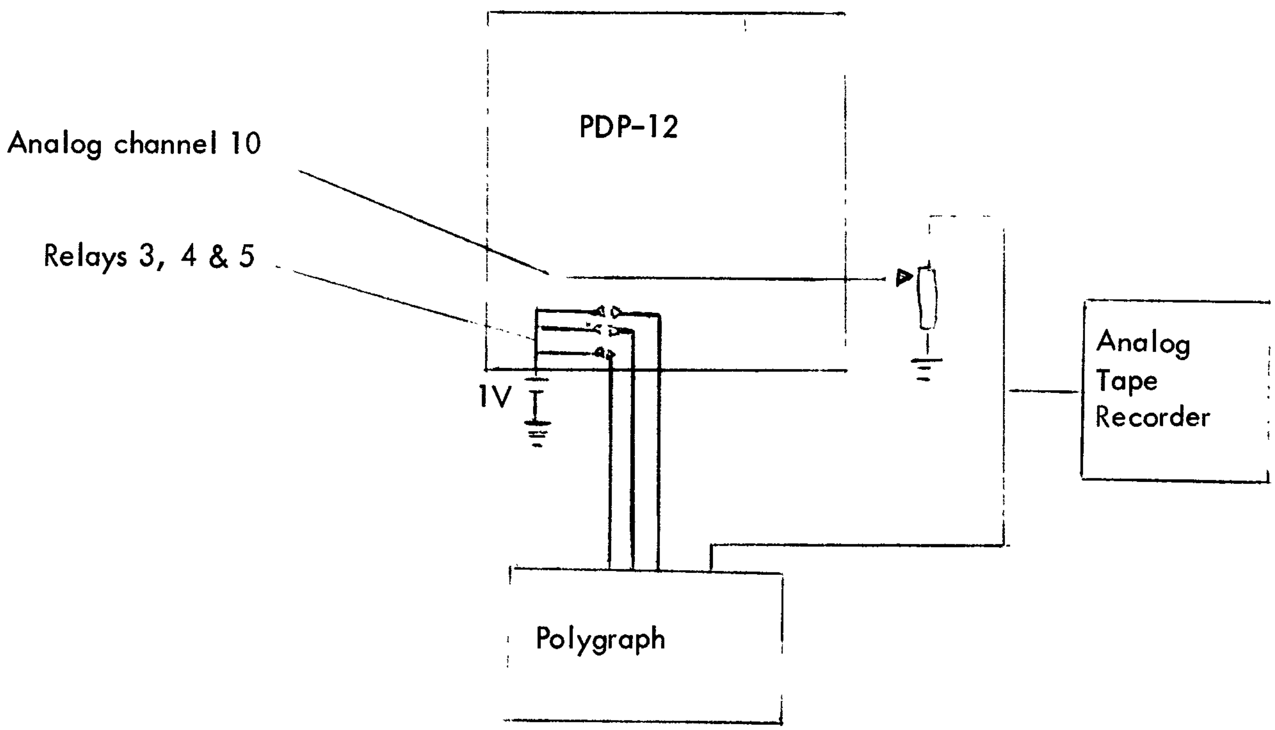
(b) The unit is dissimilar to all the templates. A buffered NO-PAUSE LINCtape storage occurs whereby the unit is saved together with its occurrence time and the contemporary template units. Such non-conforming units (usually interference potentials) are specially treated in phase 2.

Operator interaction in Phase 1 may be limited to the initial 4 selections and controlling the trigger point level. Any incoming unit may, however, be keyboard-selected at any time, if this is desired.

Impulses in DPDT relays 3, 4 & 5 provide binary coding of the selections. The following table shows the code used:

DPDT relay			Selection
3	4	5	
0	0	1	Unit 1
0	1	0	Unit 2
0	1	1	Unit 3
1	0	0	Unit 4
1	1	1	Special unit

These outputs may be used if a simultaneous control tracing is made:



A control tracing is often of assistance in the semi-automatic sorting of special units in Phase 2.

Phase 1 is terminated when enough units have been analyzed by setting the RIGHT SWITCHES to zero.

5.2 Phase 2

A printout of the selections now automatically commences. On encountering a special unit, (5.1 (b)) the processor recalls the appropriate signal epoch from LINCtape. This appears stationary on screen together with its contemporary templates. The operator can now select any one of the templates by sense switch (1, 2, 3 or 4) and subtract it from the special unit, the result appearing in the additionally displayed upper trace. Horizontal reference is manually set by Analog Channel 0.

Interference units formed by the summation of two simultaneously-firing units represented among the templates may thus be resolved into their component units.

Sometimes the units are not well-enough defined for a reliable decision on this basis. A control tracing (5.1) often greatly facilitates this procedure. The operator types in any of the digits 1 to 4 corresponding to the units he has decided are components of the special unit and then types /.

E.g. in the following printout, two special units have been decided by the operator. The component units in the first case were 1, 3 and 4. In the second case the special unit was one which had not been selected for analysis. The operator has therefore rejected this unit entirely.

12341
32413
42(134/23 ⟵ case 1
$41\overline{234}$
12(/34 ⟵ case 2
$13\overline{241}$

The whole of Phase 2 can be restarted by typing ↓ while the printout is taking place.

6. RESULTS

6.1 Interval Statistics Available

When the selections printout is complete, any of three displays may be chosen for each unit: an interval-time plot, a joint-interval histogram and an interval distribution histogram.

(a) Interval-time plot: type xT where x=1, 2, 3 or 4. The vertical scale may be varied by analog channel 4. The horizontal scale may be varied by analog channel 0.

(b) Joint-interval histogram: type xJ where x=1, 2, 3 or 4. Both vertical and horizontal scales may be varied by analog channel 0.

(For consecutive intervals I_n and I_{n+1} the coordinates (I_{n+1}, I_n) define the corresponding point on the joint histogram.)

Average scaled consecutive interval difference (ASCID) coefficient. This decimal value is superimposed on the joint histogram if both display channels are selected. It provides a measure of the regularity of an interval train independent of slow trends.

(For n consecutive intervals $I_1 \ldots . I_i \ldots . I_n$ the ASCID coefficient is defined as:

$$K \sum_{i=2}^{n} \frac{I_i - I_{i-1}}{I_i + I_{i-1}}$$

The factor K is arbitrary and has been chosen as 1024(10) for computational convenience.)

(c) Interval distribution histogram: type xA where x=1, 2, 3 or 4. The distribution density may be varied by analog channel 0.

6.2 Plotting

Any of these displays may be plotted using an X-Y plotter connected to the X, Y and Ground pins (8, 11 & 9 resp.) of the 24-contact Blue Ribbon connector on the Data Terminal Panel. The plotter may be externally advanced by pulses from the Intensified Pulse pin (4).

(The processor cycling time must be slowed down by using the Auto Restart facility with single step switch activated.) Zero points are obtained by depressing sense swigches 0 and 5. These freeze the display at x=0,y=0 and x=0777,y=0 respectively.

6.3 Data Storage

All of the interval data from a given run may be stored on LINCtape as follows:

Set the right switches to a desired tape block number from 0 to 0777.

Type ↑ ↑ ↑

The data will be written into the subsequent 16(10) tape blocks. A maximum of 32(10) runs may therefore be stored on one reel.

6.4 Data Retrieval

All of the interval data from a given run may be loaded into core from LINCtape as follows:

Set the right switches to the first tape block number of the stored data segment desired.

Type +++

Any of the displays (6.1) may now be selected.

6.5 Calibration Facility

The interval axes of a given display may be calibrated with respect to the contents of a stored set of calibration intervals. (These may be obtained by analyzing a train of calibration spikes included on the original analog tape recording and storing the results on LINCtape (6.3).)

Retrieve the calibration segment from LINCtape (6.4).

Type xC where x=1, 2, 3 or 4 and corresponds to the unit field in which the calibration intervals were stored - usually 1).

Retrieve the record to be calibrated. The interval axis of any histogram will now be calibrated (display channel 2).

6.6 Editing Facility

This enables the erasing of erroneous data points in a given set of intervals. (This is necessary for correct ASCID coefficients.)

Type xE where x=1, 2, 3 or 4.

The interval-time display corresponding to x will appear.

Analog channel 1 controls the horizontal position of the projected pointer.

Select the data point to be erased. Type RUBOUT. To exit from this routine, type RETURN.

7. RESTARTING JULIA WITHOUT RELOADING

Toggle STOP. Set left switches to 0200. Set mode switch to PMODE. Press I/O PRESET and START LS.

8. NEGATIVE TRIGGERING

If it is desired that the signal trigger be activated by a negative-going signal, the following changes are to be made:

The contents of absolute address 0257 should be changed to 1620.

The contents of absolute address 0610 should be changed to 7700.

9. ADDITIONAL INFORMATION

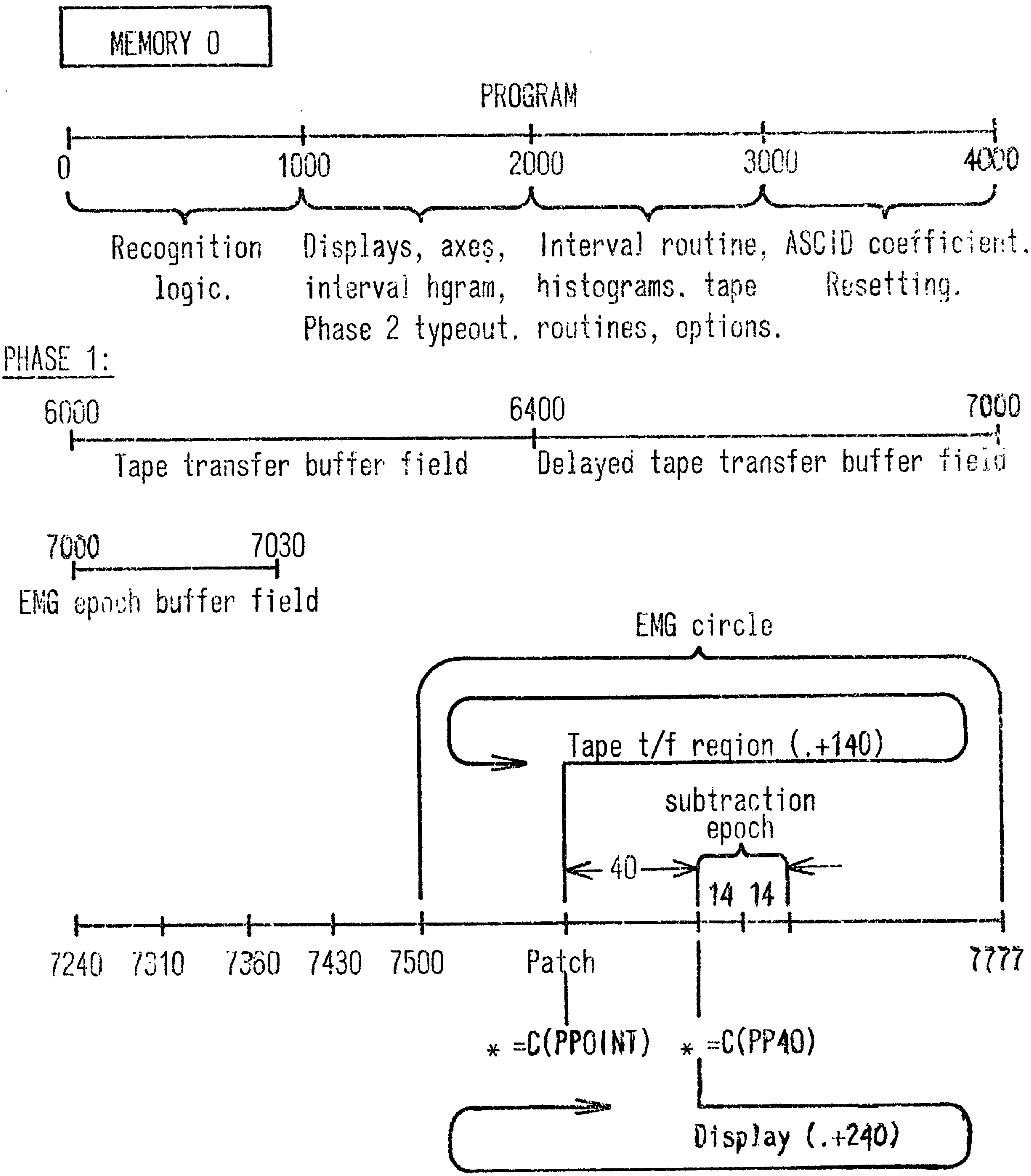
The sampling period in phase 1 can be increased by changing the constant PERIOD (absolute address 0172). This constant is loaded into the clock counter after each cycle and must therefore be the complement of the desired sampling period (clock counter rate 10 KHz).

REFERENCES

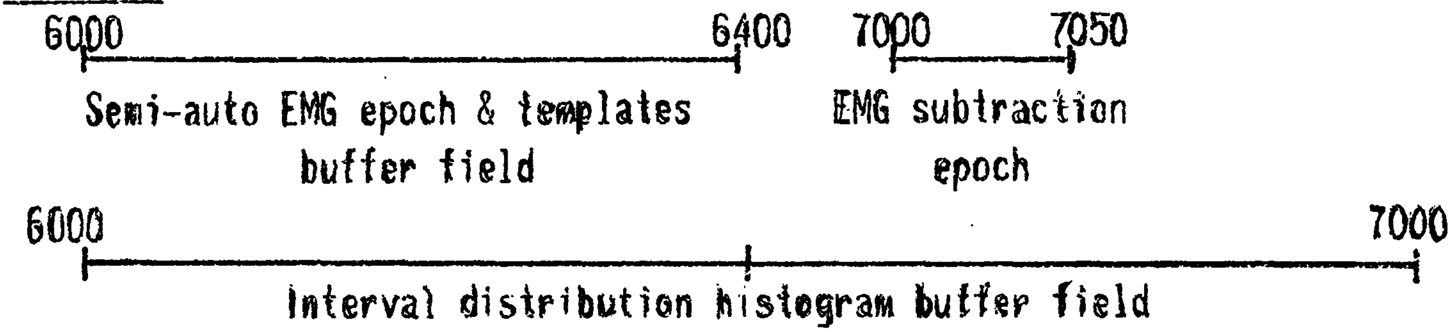
Friedmann, D. H. Detection of Signals by Template Matching. John Hopkins Press, Baltimore, 1968, 62p

Prochazka, V. J., Conrad, B. and Sindermann, F A Neuroelectric Signal Recognition System. Electroenceph. Clin. Neuro-physiol, 1972, 32 (In press).

ORGANIZATION OF JULIA

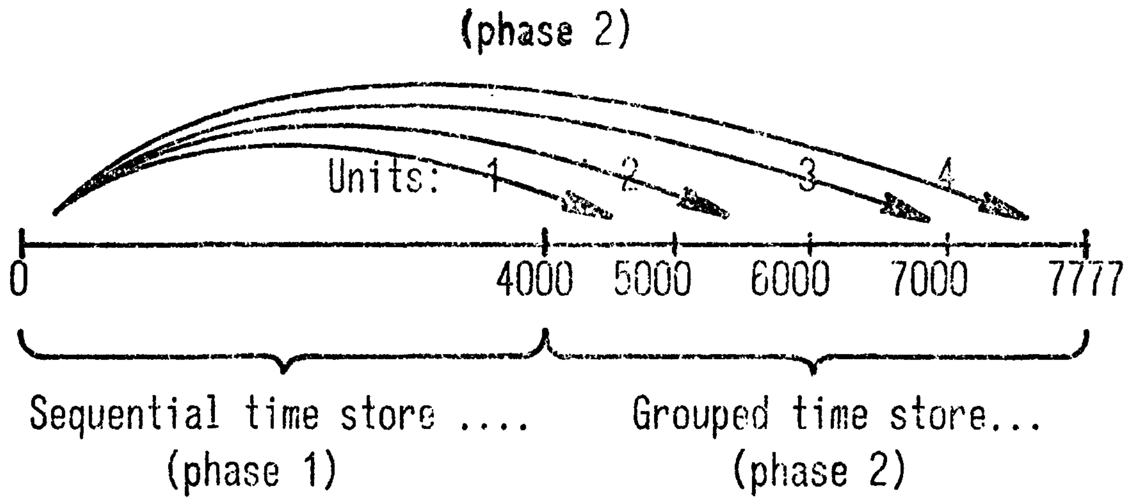


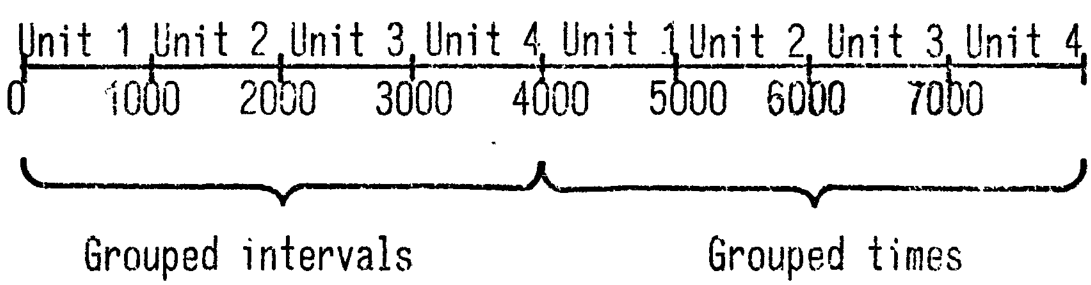
PHASE 2:


6000
6400
7000
7050
Semi-auto EMG epoch & templates buffer field
EMG subtraction epoch
6000
7000
Interval distribution histogram buffer field

ORGANIZATION OF JULIA

MEMORY 1





V.J.Prochazka,
4 10 71