

# A Program for Acquisition of Primary and Ancillary Neurophysiological Data

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## 1 INTRODUCTION

The computer has long been a valuable tool in the neurophysiology laboratory. Its use permits large parametric studies of single nerve cells. The usual paradigm is to systematically vary the stimulus and record the associated neural response. The quantity of data generated in these experiments often becomes quite formidable. Fortunately, the computer can also be utilized to render large data bases manageable.

This article describes an interactive assembly language program that controls stimulus presentations, data collection and storage, and performs considerable on-line analysis of the data. A unique file format was designed and implemented that facilitates management of large data base neurophysiological experiments. Within a single file, primary data (single-cell activity) is stored in blocks of variable length while accessory data (information usually kept in experimental protocol books) is stored in fixed length blocks. The program and its file format relieve the experimenter of unnecessary bookkeeping, yet provides easy software access to the data for post-experimental analysis.

The specific application for this program is in extracellular, single-unit studies of the central auditory system. The computer system is built around a Digital Equipment Corporation LAB11/40. The operating system used is RT-11. Some features of this program have been previously described (2, 3).

## 2 DATA ACQUISITION PROGRAM

Data are collected when the acquisition program, dubbed **AQUIRE**, is in one of two modes. Probe mode is used to search for stimuli which cause a neural response. No data are stored in Probe mode. Data are automatically collected and stored for subsequent analysis when **AQUIRE** is in Map mode. **AQUIRE** determines the sequence of stimulus presentations in map mode after the response boundaries of a single cell have been determined in Probe mode. The program completes the response map of a single cell by filling in a preselected frequency-intensity matrix of stimulus presentations. Alternatively, interaural

time or intensity differences may be varied. Data for any one of the several types of Maps are collected automatically until either the series is complete, or the operator intervenes. Points in the Map presentation matrix may be deleted or repeated through light pen interactions while the map is in progress.

User interaction with **AQUIRE** is achieved through Decwriter commands, light pen interaction, and a joystick console. The light pen controls program display functions, permitting the selection of one of several histograms (post-stimulus time, interspike interval, latency or phase) generated on-line. The joystick console is used while in Probe mode to permit user control over stimuli. Choice of pure tone, white noises or clicks is provided by a three position switch. Frequency of sound is varied by joystick movement along the y-axis. When binaural clicks are being presented, interaural time differences are represented along the x-axis.

## 3 FILE FORMAT

Primary Data. A Schmitt trigger is used to convert action potentials recorded from single neurons into TTL pulses. The interval of time between successive pulses is then measured and fed to the computer. A pulse interval timer (PIT) (1, 2) was designed and built to facilitate data collection. The device has a resolution of two microseconds and allows up to six simultaneous inputs. Intervals of time are formatted as two 16 bit words. The first word contains an END bit, signalling the last interval of an epoch, six event bits (one for each channel of the PIT), an overflow bit (set when the timer overflows 24 bits), and timer bits 23 through 16. The second word contains timer bits 15 through 00. In our experiments, one channel of the PIT is used to time action potentials. The start and stop of a stimulus presentation, and the time of zero phase crossings of the stimulus tone are measured on three other channels. Two channels remain for future development.

Accessory Data. Accessory data include the physiological state of the preparation, the electrode condition and depth, the general characteristics of a unit being studied, information pertaining to the overall protocol of the experiment, and stimulus and recording parameters for each interval data epoch. The operator may request to enter specific types of accessory data, and the program will ask the necessary questions to fill the block. Since the computer is accepting and checking the accessory data, the information is assured of being collected and of being accurate.

Accessory data are recorded serially in the file with the primary data (intervals), and are grouped into blocks composed of a header block followed by the specific data. Header blocks are common to all accessory data blocks. The first word of the header block contains the identifying code of the accessory data, and the length of the accessory block in words, since the length is held in only the lower eight bits of the header word, the length of an accessory block is limited to 255 words. Header words also have bit 15 set (=1) to distinguish them from interval data. The precedence of the type and length in the first word of the header permits programs not required to process a specific block type to skip over it. This enables new block types to be added to the data acquisition program without necessitating modifications of previously written analysis programs.

The remainder of the header block contains the date and time, held in the standard operating system format, and a unique integer tag. The tag number is automatically incremented by the data acquisition program for each accessory block. The tags allow the investigator to refer to specific data blocks of a given experiment uniquely during the analysis, and also provide redundancy for error checking.

Data Representation. Eight data field types are employed in this file format, and for the most part these are standard fields used throughout the operating system (RT-11) and the computer line (PDP-11). Non-fractional numbers are held as one word integers. Numbers requiring fractional representation or a large dynamic range are stored in a two word floating point format. No other number formats are used. In some cases, these formats require more space than other compressed formats, but software maintainability and documentation would suffer if compressed formats were employed. In addition, the use of standard formats permits easy access to the data by analysis programs written in different languages (i.e., FORTRAN or MACRO assembler).

Certain field types encode a choice made from a fixed set of alternatives, such as Left, Right, Ipsi, or Contra (i.e., stimulus ear). These fields are represented as a single ASCII character (L, R, I, C) stored in one word. Whole words are employed to preserve the word boundaries required by other field types.

Comment fields may contain information not strictly specified by the program. These items are held as packed ASCII character strings, with up to 32 characters permitted for each field. All printable characters, space, and tab are allowed, but control characters are eliminated. Comment fields are padded with null bytes if they are not entirely filled with text.

Examples of three types of accessory data blocks are presented below, to illustrate the organization and implementation of the file scheme described above.

Unit Block. The unit block signifies that a unit has been isolated and has been subject to a preliminary investigation. The information contained in the unit block is primarily related to data obtained while collecting intervals in Probe mode, although some of this information is internal to the program (constants), or may be read from instruments. All interval data between one unit block and the following unit block may be considered as having been recorded from one cell. The information in each unit block includes the action potential amplitude, the polarity of the spike used for triggering, the background noise amplitude, the presence or absence of spontaneous activity, the laterality of excitation and inhibition converging on the unit, the best frequency, the threshold of excitation at best frequency, the response latency, and click response characteristics. Other information held in the unit block includes the unit identification, a comment field, the side (L, R) of the electrode puncture, and the electrode depth. The program also adds information about the PIT channels for data and stimulus markers that are currently being employed, and the timing interval resolution.

Analog Data Block. Analog data blocks may include any analog information such as EEG, EKG, local evoked potentials, or blood Pressure. Although the length of the data record for analog information is known in advance of collecting the data, and therefore does not present the same problem as the unit data, it is likely that the information will be longer than the 255 words permitted by the file format. Therefore, a separate scheme involving a header block followed by a variable length data segment has been devised. Immediately following the header block is a word containing the length of the rest of the data block. In this way, analog data blocks may be up to 65,000 words long. Other information following the length of the block would include the type of data, recording conditions, number of points recorded, and, if the data is averaged, the number of samples included in the average. Stimulus parameters might also be included, if appropriate.

Map Blocks. Map blocks contain information about the stimulus and recording parameters of interval data that are automatically collected. There are three block types associated with the stimulus response maps. The map start block contains the type of stimulus, the stimulus parameters used to generate the map (from which the individual points in the map may be reconstructed), and the timing of the

stimuli. This block appears at the start of each matrix of stimulus presentations. The map presentation block is associated with interval data collected with a single set of stimulus conditions. It contains information about the stimulus parameters employed in the collection of interval data (frequency, interaural time differences, and intensity). The map presentation block is usually followed immediately by the interval data associated with it. In our current program, the map presentation block is always followed by interval data, and interval data is always preceded by a presentation block although this close association is not required by the file format or the analysis programs. The final map block type is the map end block, which merely signifies the end of the map, and is composed of only a header block. The map end block is important for determining when a map has been aborted before the entire stimulus series has been presented. The map end block is usually preceded by interval data.

## 4 SUMMARY

The data acquisition program just described is being used to collect auditory neurophysiology data. Its general features and particularly its file format should be useful for other neurophysiological experiments. A probe stimulus is almost always used in such experiments and the accessory data derived from its use must be manually entered into a protocol book. The file format used in **AQUIRE** greatly reduces operator dependency on a protocol book and simplifies bookkeeping. Block length for primary data epochs is typically unknown at the start of collection. This is true whether the primary information is intervals or behavioral responses.

The format simplifies the problem of file management for experiments since many data epochs are combined into one file. This means that far fewer files are required to hold the data of an experiment so they are easier to keep track of and there is less file management overhead during the experiment.

The file format lends itself well to the solution of off-line data analysis problems. Every interval is saved, so that it is always possible to reconstruct the various histograms post-experimentally with appropriate parameters. Calculations and high level statistical analysis may be made on the raw data. The format permits analysis programs to skip data that are not of immediate concern. The tag numbers provide an easy way for analysis programs to sort through the data, and to build libraries composed of specific data files.

## 5 REFERENCES

- (1) Brown, P. B., Duffy, D. J., and McIntyre, T. W., (1976), Three computer interfaces for neurophysiologists, in P. B. Brown, ed., *Computer Technology in Neuroscience, Hemisphere, Washington, D. C.*, 569-590.
- (2) Duffy, D. J., (1977), A pulse interval timer for neurophysiology experiments with the PDP11, *proceedings of DECUS*, 31379-1382.
- (3) Duffy, D. J., and Brownell, W. E., (1977), File format for neurophysiology data collection, *Proceedings of DECUS*, 3: 1209-1212.

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