A DATA ACQUISITION AND CONDITIONING SYSTEM FOR ANALYSIS OF FAST TRANSIENTS IN SEMICONDUCTORS

by

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FOREWORD

The software discussed in this thesis was developed exclusively for the Solid State Electronics Laboratory in the Department of Electrical Engineering at Texas Tech University. All of the programs except one were written by the author. The single exception was the program controlling the communications between the laboratory's HP-85 Desktop Computer and Nicolet 2090-III Digital Oscilloscope. This program was initially developed by Software Consulting Group of Santa Clara, CA.

In order to integrate this program into the system under development, extensive modifications were necessary. The necessary modifications were performed by the author. As a result, the present software represents the efforts of the author and the software engineers of Software Consulting Group. Their efforts and assistance are greatly appreciated and duly recognized.

ACKNOWLEDGEMENTS

I owe my sincerest gratitude to the many individuals without whose contributions this work would not have been possible. Space does not permit me to note all of these individuals and their efforts, but several deserve special attention. Chief among those are members of my committee who have acted as supporters and advisors throughout my graduate career: Dr. W. M. Portnoy, graduate advisor and committee chairman, whose direction and support provided me the opportunity to undertake and complete my graduate studies; Dr. D. L. Gustafson, primary thesis advisor, whose efforts brought this text from dissociated documentation to completed thesis; Dr. W. T. Ford, minor advisor, whose instruction bridged the often disparate paths between mathematical theory and practice, and; Dr. R. H. Seacat, Jr., whose support, guidance, and counsel throughout my educational career, both graduate and undergraduate, have molded my perspectives on science, engineering, and education, and our responsibility as individuals to that society which educated us.

To Mark S. Bavousett, I owe my eternal thanks for his energy and diligence in serving initially as proofreader and eventually as emissary to the university following my departure from the Lubbock area. Without his aid and support, all of my labors would have been for naught.

Lastly, I owe the greatest debt of gratitude to a couple whose patience, encouragement, and financial support over the years have made all things possible--Coolidge and Nola Graves, my parents.

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ABSTRACT

This thesis discusses the development of a data acquisition and conditioning system including the definition of laboratory needs, subsystem and system development phases, system tutorial, and error analysis of the completed system. Three (3) realized system goals are: (1) relative ease of use; (2) use of a variety of data acquisition hardware, and; (3) timely data reduction.

The design used an HP-85 computer as the controller for digitizing hardware which included: an HP 9111A Graphics Tablet, a Tektronix 7612D Programmable Digitizer, a Nicolet 2090-III Digital Oscilloscope, and an Hewlett-Packard 3437A System Voltmeter. These components allow the system to digitize data over the range from 10 picoseconds per sample to 27.775 minutes per sample.

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VOLUME I

CHAPTER 1

INTRODUCTION

Computers have been a key to the advance of science and engineering since their inception. The computer has managed to enhance this progress by allowing scientists and engineers to carry out computations that would have been measured in man-months rather than in milliseconds. This revolution has not been utilized solely by the theoreticians. As technology has advanced, computers have become a mainstay in the laboratory. There they have proven of inestimable value.

Though initially devised to aid in calculation, the computer has come to be a very powerful controller. As a controller, the computer has become a centerpiece in the experimental laboratory. Using the technology available at the present time, experimentalists can use the computer to control measurements which would have been impossible otherwise.

At present, a growing impetus exists to supplant former measurement techniques and equipment with more sophisticated, computer-aided techniques and computer-controlled hardware. This is due to the fact that when properly programmed, a computer can remove a great deal of the problems associated with laboratory work. Some of the problems associated with experimental laboratory work are: (1) experiments which require long observation times; (2) short period events which are aperiodic; (3) analog-to-digital conversions to make possible calculations, and; (4) simple human error.

Of the problems noted, the final problem is the most prevalent. Human error arises in many cases where laboratory conditions similar to problem areas (1), (2), and (3), exist. In these cases, the accuracy and attentiveness of a computer are needed. Where computers are utilized in the experimental process to replace the human element, they can all but eliminate the first three (3) problem areas. After all, with proper ventilation and with well-conditioned power (no large power transients and adequate capacity), a computer can run for an indefinite time. The same cannot be said of humans. Besides, with the aid of the computer in the laboratory, a human can focus on other areas of interest.

Based on the premise of removing as much human error as possible while addressing the needs to acquire and to store data as effectively as possible, the Solid State Electronics Laboratory in the Department of Electrical Engineering at Texas Tech University under the direction of Dr. W. M. Portnoy chose to develop such a data acquisition and conditioning system. In addition to the broader problems noted previously, the graduate students in the laboratory, especially in the study of second-breakdown characteristics of semiconductors, found the volumes of data generated in the experiments difficult to process.

In the experiments, measurements of voltage and current were taken. From these measurements, the values for power and energy were calculated. Without the aid of a computer, the students were faced with the arduous task of reducing the data by hand. At best, the graphical analysis techniques were inaccurate and time-consuming. Thus, large amounts of data could be taken and stockpiled though little could be reduced to useful data--never in a timely manner.

Therefore, the work to be discussed in this thesis was undertaken to develop a centralized data acquisition and conditioning system (DACS). This DACS was to answer three (3) objectives:

(1) develop a system which was easy to use by an operator who has minimal exposure to a computer;

(2) develop a system which can utilize effectively several pieces of data acquisition hardware;

(3) develop a system which can carry out calculations based on measurements in a timely manner.

In the following pages, these three (3) objectives will be discussed and the system developed to implement them will be considered.

Chapter 2 examines more closely the needs of the laboratory, and defines specific components to answer these needs. This will include a discussion of the critical areas of interest present and future.

Chapter 3 examines the interactive subsystems developed using the specific components designated in Chapter 2. The discussion will develop a more complete analysis of the needs of laboratory at the subsystem level of interaction.

Chapter 4 provides the reader with a tutorial of each of the subsystems. In so doing, the reader is taken through each of the processes that are available at the present time. The endeavor of this portion of the thesis is to illustrate to the reader the step-by-step processes of the system, and thereby, provide a working framework for any measurements which the reader may desire to make.

Chapter 5 provides the results of several tests undertaken after the final assembly of the system. These tests were performed to establish effective benchmarks of the effectiveness and accuracy of the data acquisition and conditioning system.

Chapter 6 provides a final summary analysis of the system. In the final chapter, the author provides a comparison between the system capabilities and the objectives set forth in this chapter. In addition, the author develops a framework for developing the next generation of data acquisition system for this laboratory. In so doing, the author defines the areas where the system can be improved to provide a more substantial aid to the graduate students carrying out work within the laboratory. Areas of expansion ranging from enhanced graphics to artificial intelligence are discussed.

In addition, the reader is provided with several appendices to further document the work that was done. Appendix A of the thesis is a fully commented listing for each of the software programs within the system. Prior to each of these program listings is an abstract describing the function of the specific software program.

Appendix B is a description of the program protection system. In this appendix to the thesis, the reader is provided with a description of the program protection codes. This is done to provide the reader with the information necessary to edit any of the software programs on the system. Undoubtedly, occasions will arise where the needs of the laboratory will exceed the limitations of the present system. Therefore, a reader will find the necessity to edit programs in the system, or write new pieces of software. However, the author admonishes the reader to carefully document any changes to the software for the user that will follow.

Appendix C is a user's manual developed as a separate document for working with the system. This appendix includes a description of each of the programs used by the system. These descriptions are detailed analyses of the workings of each of the software programs which the system accesses. Also, the data storage file format is discussed in detail to provide the reader with the knowledge necessary to develop software which can be used in conjunction with the data files which are created by the system.

The reader also will find a number of appendices attached to the user's manual. These appendices include a flow chart for startup of the system, a table of the present equipment addresses, a listing of the error codes which can be generated by the system, and a detailed set of flow charts documenting the logical flow of the system.

CHAPTER 2

SYSTEM COMPONENTS

2.1 Introduction

In developing an adequate data acquisition and conditioning system for the Solid State Electronics Laboratory, the scope of work carried out at the lab was examined. From this examination, the needs for data acquisition, storage, and manipulation, were defined, and solutions instrumented.

The Solid State Electronics Laboratory has carried out work in a number of areas in recent years. These activities range from fabrication to characterization to reliability studies. Some process times were on the order of weeks; while other measurements involved characteristics on the order of a few nanoseconds. Thus, a flexible system was necessary which could acquire data from a few nanoseconds to a few weeks. This involved the development of a system incorporating a number of data acquisition units with a wide range of capabilities.

In addition, the system needed to have the capability to store the data acquired on permanent media. In this manner, a record was preserved of all measurements. Therefore, old measurements and data could be recalled and reprinted at any future time. The work was no longer dependent only upon a single hardcopy result. Also, data storage facilitated calculations based on the data.

The system also was designed to support some limited data conditioning activities. At the time of this work, software was developed for calculating products and time integrals of products from the data.

A final requirement of the system was the entry of data taken prior to the development of the data acquisition system, data external to the Solid State Electronics Laboratory, and data acquisition beyond the time resolution capabilities of the equipment on the system. This was to facilitate entry of any data which was of importance to a program.

Thus, the system needed to have access to old data, publications and outside work, and very fast transient data.

The system was designed to address the needs outlined previously, as well as, the three (3) objectives outlined in Chapter 1. The following text examines in detail the specific needs of the laboratory and the system components which address these needs. The discussion is broken into sections concerning: 1) data acquisition capabilities; 2) data storage capabilities; 3) hardcopy output capabilities; 4) data conditioning capabilities.

2.2 Data Acquisition Capabilities

As noted earlier, the laboratory needed a system capable of making measurements with characteristic times of nanoseconds to weeks. In order to do this, several different data acquisition units were used. The needs for the data acquisition equipment were broken into four (4) time regimes.

The first time regime is defined as slow measurements. These measurements involve data taken at intervals of minutes over a period of up to several weeks. This type of data acquisition is necessary for the reliability studies described previously where sample component characteristics, e.g., current and voltage, are monitored over several days. The slow measurements are useful in experiments where component characteristics, such as capacitance, change over several seconds and are monitored at intervals of a few milliseconds. This type of data acquisition is needed in studying trapping levels and recombination times in discrete devices.

A second time regime is defined as intermediate measurements. These measurements involve data taken at intervals of milliseconds down to hundreds of nanoseconds. This type of data acquisition is necessary for any characteristic with a risetime of 1 microsecond or greater. One piece of work which needed this data acquisition was a study on the switching characteristics of thyristors.

A third time regime is defined as fast measurements. These measurements involve data taken at intervals down to 5 nanoseconds. This sampling time allows resolution of phenomena with risetimes on the order of 50 nanoseconds. This type of data acquisition was used in the study of second-breakdown characteristics in semiconductors.

The final time regime is defined as very fast measurements. These measurements involve data taken at intervals of less than 5 nanoseconds. In the previous three (3) time regimes, digital data acquisition equipment with the capabilities noted did exist. However, sample rates of greater than 200 megasamples per second are not financially attractive. Instead, a data entry device was chosen to enter other data by hand. This allows analog data, such as photographs, with very fast risetimes to be digitized. Thus, this data acquisition process allows entry of very fast data, as well as, data acquired prior to the development of the system and data acquired outside the laboratory. This data acquisition process was needed in the study of the switching characteristics of avalanche transistors. There, the risetimes were on the order of 1 nanosecond.

2.2.1 Slow Measurement Capabilities

The units chosen for the slow measurements were the HP3497A Data Acquisition/Control Unit (DACU) and the HP3437A Digital Voltmeter (DVM). The DACU has a variety of modules which can be plugged into the unit. The modules include both digital and analog capabilities for controlling, and monitoring, inputs and outputs. The module used for this work was an analog module.

The module has three (3) analog inputs which can be selected individually. The selected channel is transferred to the DVM. The DVM then measures the voltage on the line and outputs the value to the computer.

The DVM has an accuracy of 3 1/2 digits with voltage ranges of 10 V, 1V, and .1 V. Thus, the DVM can measure quantities down to several millivolts. However, in order to measure a large voltage, e.g., 150 V, some type of attenuation is necessary.

The DACU is used primarily as a timer to switch to channels in its analog module. While the DACU can switch once every 100 milliseconds, the analog line has a finite settling time. Experimentation showed that approximately .5 second was necessary from the time a channel was output to the DVM to the time when the DVM was triggered. This insured that the measurement was reliable. Thus, there is a finite delay due to the equipment. This delay is programmed into the software discussed later.

2.2.2 Intermediate Measurement Capabilities

The unit chosen for the intermediate measurements was the Nicolet 2090-III Digital Oscilloscope (referred to as the Nicolet). The Nicolet was designed as a digital storage oscilloscope. In the version purchased by the Solid State Electronics Laboratory, the Nicolet has an on-board floppy disk for permanent storage.

The Nicolet can store up to eight (8) 512-sample traces in volatile memory. These sample times are selectable down to 500 nanoseconds. In addition, the Nicolet allows traces to be stored which are a sum or a difference of the two (2) inputs.

Although the Nicolet can save eight (8) traces, this work only used two (2) of the traces. The software controlling the transfer of data from the Nicolet to the computer was purchased from Software Consulting Group of Santa Clara, California. This software then was modified extensively to facilitate its use by the laboratory.

In addition to its use as a controlled data acquisition unit, the Nicolet can be used as a free running oscilloscope. The machine was designed to function as a normal oscilloscope with its enhanced storage capabilities. Thus, the Nicolet can be used freely off-line from the system for any number of experiments.

2.2.3 Fast Measurement Capabilities

The unit chosen for the fast measurements was the Tektronix 7612D Programmable Digitizer (referred to as the 7612D). The 7612D was designed as a single-shot storage device. The unit purchased for the laboratory had two (2) programmable dual channel plug-ins.

The 7612D has two (2) programmable time bases with sampling times which range down to 5 nanoseconds. The time bases also feature the ability to store sixteen (16) programmable points (called breakpoints) where the sample times can be changed. If, for example, a 1-millisecond square wave is to be characterized very closely, the 7612D can be programmed to take data at 5-nanosecond intervals for the first 256 points, at 10-microsecond intervals for the subsequent 96 points, and at 5-nanosecond intervals for the remaining points. Thus, the risetime and fall time of the square wave can be measured very accurately without the need for an extraordinarily large memory capacity.

The 7612D can store two (2) traces. Each trace has a programmable number of data points: 256, 512, 1024, or 2048. Using this large memory capacity with the previously described breakpoints, a very flexible measurement system was developed.

In addition, the 7612D has one (1) programmable trigger and one (1) plug-in for each time base. Thus, two (2) traces can be taken simultaneously which have very different time characteristics. The possibility also exists to use all 4096 points in a single sweep by triggering time base B at the end of the time base A sweep. This capability, however, is not utilized on the system.

Although the 7612D can store two (2) 2048-point traces, only 1024 points per curve are transferred to the computer. This is due to the limited memory space on the computer. The capabilities of the system software will be more closely examined in Chapter 3.

2.2.4 Very Fast Measurement Capabilities (Hand Entry)

As mentioned in section 2.2, this process is not truly a measurement. Instead, the HP 9111A Graphics Tablet was chosen to carry out the hand-entered process. Thus, the time resolution was no longer restricted to the capabilities of a digital data acquisition unit. Analog data acquisition methods could be capitalized upon by allowing hand entry of data. Thus, the data which could be accessed by the system was essentially unlimited.

However, since the data entered was digitized by hand, the problem of human error arose. This seemed an acceptable trade-off for the data obtainable. Besides allowing entry of very fast transient data, the operator could enter data taken prior to development of the system, and data acquired outside of the laboratory.

The tablet has two (2) active areas for digitization. The first is bounded by a grey line on the board. This area is referred to as the active platen. When the point of the pen is depressed within this area, the tablet outputs the coordinates associated with the pen's location.

The second area at the top of the tablet is subdivided into a set of sixteen (16) smaller areas. Each of these areas are referred to as softkeys. When the point of the pen is depressed within these areas, the tablet outputs the softkey associated with the pen's location. These areas are programmed to indicate menu selections in the operation of the system. All digitized data are transferred to the computer. The assignment of the softkeys, and the storage of the digitized points, is under software control.

The one disadvantage of the tablet may be its mode of operation. The tablet uses field strength to approximate the pen's location. If the pen is depressed over a conductive material, e.g., pencil lead, the field is distorted. Thus, the tablet could take an inaccurate measurement. Investigation of this effect showed that the tablet interpreted the center of the conductive area to be the pen's location. Thus, if a 1" x 1" piece of conductive material was placed on the tablet, digitizing almost any location on that area produced the same result--coordinates associated with the center. Care is required, therefore, not to use conductive materials on the tablet.

2.3 Data Storage Capabilities

In addition to the data acquisition capabilities described, a data acquisition system needed mass storage capabilities. The computer chosen for the central processor of the system was an HP85 desktop computer. This decision was based upon availability of the machine and ease of programming. In addition, the computer had a built-in mass storage unit--a magnetic tape drive.

However, storage and access of data using a magnetic tape tended to be rather time-consuming. Therefore, an additional mass storage unit was chosen, the HP9895A Flexible Disk Drive. This unit has two (2) disk drives which are accessible to the computer. Each flexible disk can hold over 1.18 megabytes of information. This compares to the 210 kilobyte capacity of a magnetic tape.

Aside from data storage, the disk drives are used to store the programs controlling each of the operations performed by the system. Due to the limited memory of the computer, the software was configured into a set of stand-alone programs. Each program controls a particular operation; for example, there is a program for controlling the Tektronix 7612D.

Since the software was developed as a set of programs, the time advantage of the disk drive again became apparent. Programs stored on a floppy disk can be loaded and run much faster. The disk drives can transfer data at an average rate of 23 kilobytes per second. In comparison, the tape drive can transfer data at a mere 650 bytes per second. Thus, the disk drive proved to be indispensable in the function of the system. Since the disk drive has two (2) units, one is designated as the program drive and the other is designated as the data drive.

2.4 Hardcopy Output Capabilities

A necessary support component for the data acquisition and storage capabilities was the HP7470A Plotter. This plotter was chosen for its speed and accuracy. The plotter served to complement the hardcopy capabilities of the computer.

The computer has an on-board thermal printer/plotter. This printer/plotter is used primarily for its print capabilities. In several of the software packages, the printer is used to create hardcopy output for the operator. In addition, the graphic display can be dumped to the printer/plotter.

However, the graphic display performs a direct dump to the printer/plotter. Therefore, the resulting plot was limited to the resolution obtainable on the computer's small screen.

In contrast, the plots which can be generated on the HP7470A Plotter are high resolution. Therefore, all hardcopy plots are created using the plotter. Also, the plotter is used as a slow printer. The software to be discussed later uses the plotter in a print mode to list second-breakdown characteristics based upon the processed data files.

A further preference for the plotter arose from the printer/plotter paper lifetime. Any hardcopy saved on the thermal paper used by the computer was found to fade over time. This fading did not require extended exposure to light, but appeared to require only time. Thus, hardcopies made with the plotter on normal typing paper have a longer lifetime; while hardcopies made on the thermal printer/plotter paper disappear after several months.

2.5 System Computational Capabilities

A final requirement of the system was the development of software to carry out limited calculations. The software which carried out these operations is described in detail in Chapter 3. In brief, the software was developed to compute instantaneous power given a current curve and a voltage curve. The software then calculates the time integral of the power curve. Then, these curves--current, voltage, power, and energy--are stored on the selected media.

2.6 Summary

The Solid State Electronics Laboratory had specific needs for a data acquisition system. This system needed to answer three (3) co-equal goals. The system needed to be: 1) user friendly; 2) flexible, and; 3) efficient and timely.

To obtain these goals, the specific requirements for past, present, and future work were examined. In so doing, the author defined the basic capabilities required of an effective data acquisition and conditioning system. These capabilities were: 1) data acquisition capabilities; 2) data storage capabilities; 3) hardcopy output capabilities; 4) limited computational capabilities.

The topic of data acquisition capabilities was further defined by examining various time regime requirements. These time regimes were classified as: 1) slow measurements--100 milliseconds per sample and greater; 2) intermediate measurements--500 nanoseconds to 100 milliseconds per sample; 3) fast measurements--5 nanoseconds to 500 nanoseconds per sample; 4) very fast measurements--less than 5 nanoseconds per sample.

Based upon the classifications and requirements noted, a set of equipment was gathered to accomplish the system goals. These units were chosen specifically for their capabilities and the manner in which their capabilities fulfilled system requirements. In Chapter 3, the software controlling these components will be examined and their interactivity will be documented.

CHAPTER 3

SYSTEM INTERACTION

3.1 Introduction

In Chapter 2, the author examined the needs of the Solid State Electronics Laboratory. In so doing, the task of developing a data acquisition and conditioning system was broken into a discrete number of subtasks. These subtasks describe the principal functions to be carried out by the system. In turn, individual pieces of equipment were identified to support these functions. In the following chapter, the software developed to support and control the prescribed equipment will be examined.

Selected components were chosen to support various data acquisition, data storage, data output, and data conditioning activities. However, these components cannot carry out the described activities without interaction with other components. Thus, within the framework of the system, several subsystems exist. These subsystems are grouped according to the needs of the particular tasks. The subsystem tasks are quite similar to those outlined in Chapter 2. There exist three (3) basic areas of activity: 1) data acquisition; 2) data output; 3) data conditioning. Data storage is not a separate function in and of itself. This is due to the fact that data storage is an integral portion of all activities.

Within the area of data acquisition, there are four (4) separate areas of interest. These areas are based upon the time regimes described in Chapter 2. Separated by time regime, again, are the data acquisition areas: 1) slow measurements; 2) intermediate measurements; 3) fast measurements; 4) very fast measurements and other hand entries. Each of these areas are covered by a subsystem configured around the equipment described in Chapter 2.

In addition to the requirements described in Chapter 2, a desire was expressed to monitor slowly changing phenomena during tests using the fast and intermediate measurement subsystems. As will be pointed out in the following sections, the fast and intermediate measurements take a relatively short time for acquisition and transfer. However, the data storage process, transfer from computer to data storage media, takes a great deal longer. During this time, slowly changing phenomena such as temperature, can be monitored using the slow measurement system. In the following text, each of the subsystems will be examined in detail.

3.2 Data Acquisition Subsystems

As described in Chapter 2, there were four (4) separate time regimes which were needed for the complete development of this data acquisition and conditioning system. Discrete subsystems were designed for each of these time regimes. These subsystems are composed of: 1) the system component(s) described in the appropriate section in Chapter 2, e.g., slow measurement system components are the HP3497A Data Acquisition/ Control Unit and the HP3437A System Voltmeter, which perform data acquisition; 2) the HP85 Desktop Computer which performs control and processing; 3) the HP9895A Flexible Disk Drive which serves as data storage.

Therefore, within the system, there exist four (4) different data acquisition subsystems--one for each time regime. In addition, the intermediate and fast measurement subsystems were designed to use the slow measurement data acquisition elements. This was to answer the request for additional monitoring of slowly changing phenomena, such as temperature or humidity.

3.2.1 Slow Measurement Subsystem

The slow measurement subsystem was developed using the HP85 Desktop Computer, the HP9895A Flexible Disk, the HP3497A Data Acquisition/ Control Unit (DACU), and the HP3437A System Voltmeter (DVM). These units are tied together using the software package named HP-DAS. Figure 3.1 shows the block diagram of the slow measurement subsystem.

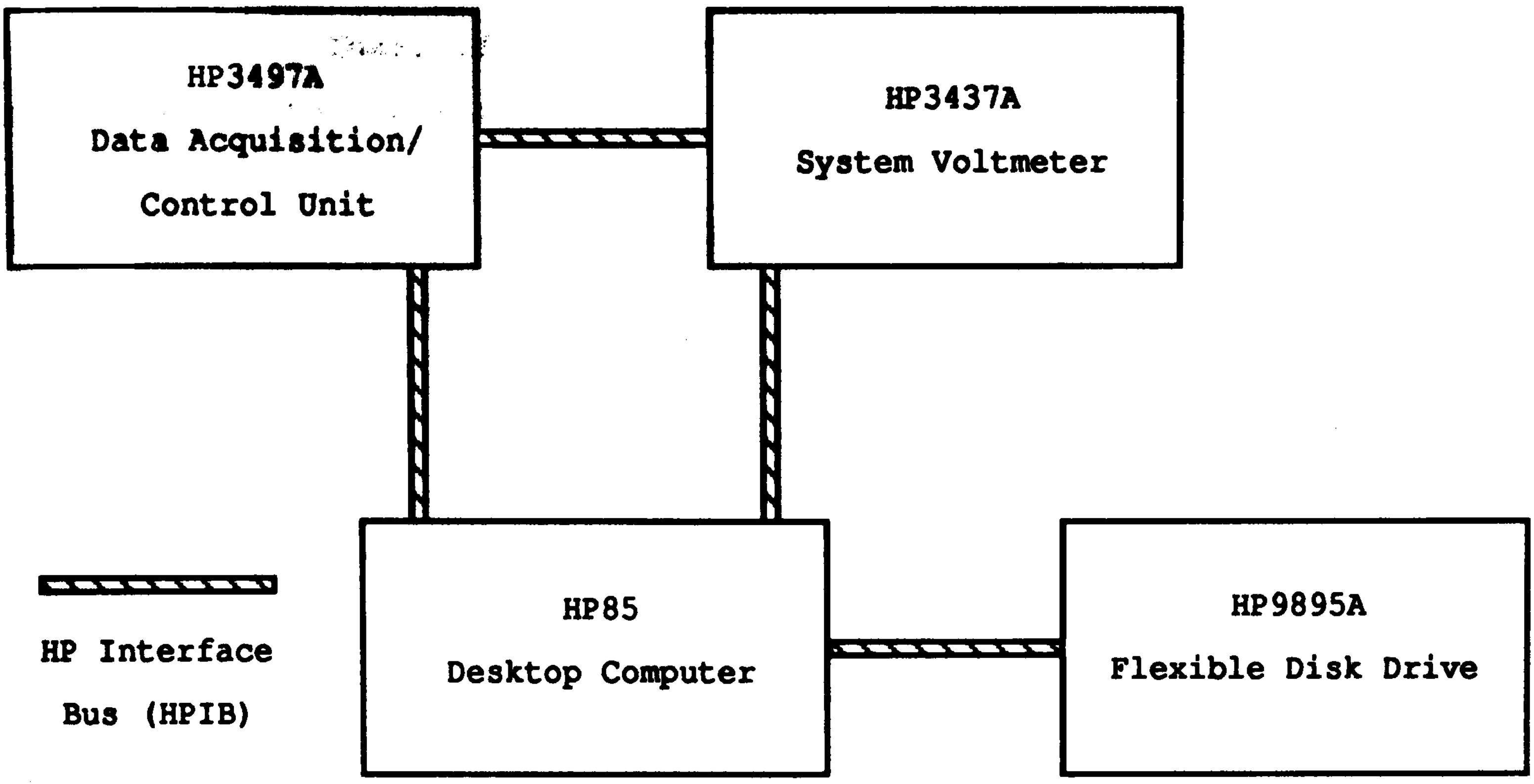

Figure 3.1. Slow Measurement Subsystem

The software was developed to take four (4) curves with 256 points per curve. The software was designed to select a channel on the DACU. This channel is transferred to the DVM. Then, the computer triggers the DVM, and inputs the measurement.

This process is carried out at operator selected intervals. The operator chooses a sampling interval from 2 seconds to 27.775 minutes. The maximum delay is limited by the DACU; while the minimum delay is limited by the DVM.

As pointed out in section 2.2.1, the DACU can sample as quickly as once every 100 milliseconds. However, the software was designed with the premise that more than one (1) channel would be monitored. Since approximately .5 second is needed for a voltage to settle once channels are changed, the software was written with a .5-second delay between readings. This practice is to insure an accurate reading for each sample.

The data acquisition proceeds for a period selected by the operator. For example, the operator can take measurements every 5 seconds over a period of 3 minutes; 36 samples will be taken. Since the program can store 256 points, the operator has a limit on the size of period for the measurements. Thus, if the operator chooses a 5-second sample time, the operator can continue the process a maximum of 21 minutes, 20 seconds.

The data acquired by the computer is a voltage. Thus, when the data acquisition is completed, the computer will ask for any conversion factors in the process. This is to allow the operator to condition the data to reflect the measurement of interest, e.g., current, prior to storage. After the conversion factor is entered, the computer stores the conditioned data in the chosen mass storage media.

If more than two (2) channels are monitored, the computer will request the operator to input pairs of curves. This is done because the mathematical processing program can only process a file with two (2) input curves.

This data acquisition process is described in more detail in Chapter 4. In section 4.2.1, a sample experiment is performed with the human/ machine interaction documented. This example was designed as a tutorial for use of this program, HP-DAS, including computer prompts and operator responses.

For further details regarding this program, refer to: 1) Appendix A, Program Listings, "HP-DAS," and; 2) Appendix C, User's Manual, Chapter 9, "System Multiplexer and Voltmeter Control Package."

3.2.2 Intermediate Measurement Subsystem

The intermediate measurement subsystem was developed using the HP85 Desktop Computer, the HP9895A Flexible Disk, the Nicolet 2090-III Digital Oscilloscope (Nicolet). These units are tied together using the software package named NIC-85. In addition, the intermediate measurement subsystem was developed with an option to use the slow measurement subsystem described in section 3.2.1. Figure 3.2 shows the block diagram of the intermediate measurement subsystem.

The software is groomed to accept four (4) curves with 1024 point per curve. The software is a highly modified version of a program purchased from Software Consulting Group, as noted in section 2.2.2. This program was primarily fashioned to function as a transfer network. The operator sets the time base, channels, trigger functions, etc., at the front panel of the Nicolet. Once the settings are completed, the operator takes a measurement.

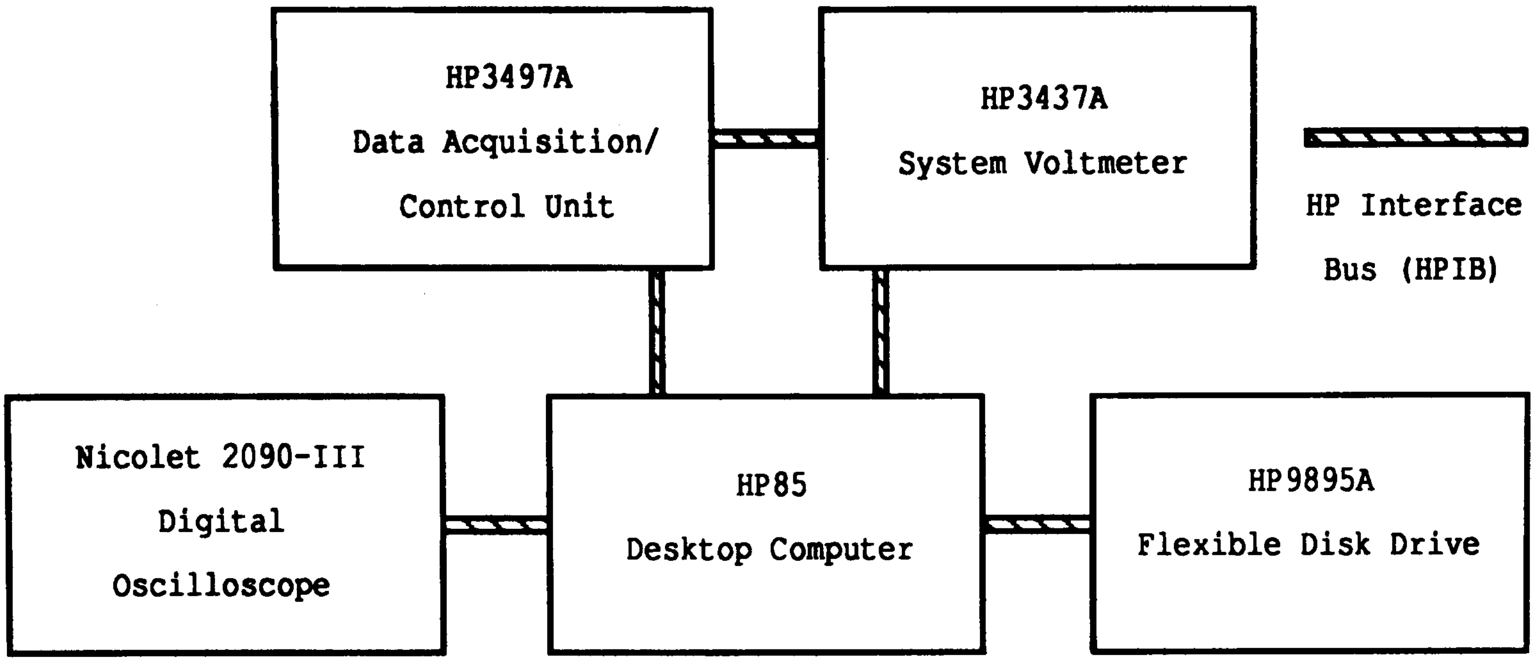

Figure 3.2. Intermediate Measurement Subsystem

Once the operator has obtained a trace worthy of storage, the operator notifies the computer to transfer the data. The Nicolet has a total memory capacity of 4096 points. This capacity is divided equally between the traces. If one (1) trace is taken, all 4096 points are used by that trace; if four (4) traces are taken, 1024 points are used by each curve. The Nicolet can be set to take 1, 2, 4, or 8 traces.

The software was designed to enter a representative group of points from the trace. This was done using a sequential skip. If there are 1024 points in a curve, all points are entered and zero (0) points are skipped; if there are 4096 points in a curve, 1/4 of the points are entered and 3 of every 4 points are skipped--every fourth point is entered.

The data acquired by the computer is a voltage. Thus, when the data acquisition is completed, the computer asks for any conversion factors in the process. This is to allow the operator to condition the data to reflect the measurement of interest, e.g., current, prior to storage. After the conversion factor is entered, the computer stores the conditioned data in the chosen mass storage media.

If more than two (2) channels are monitored, the computer requests the operator to input pairs of curves. This is done because the mathematical processing program can only process a file with two (2) input curves.

As mentioned earlier, the slow measurement subsystem is also available for use. If the slow measurement subsystem is desired, it is used during the storage phase of the intermediate measurement process. As the data is being stored, the software takes a measurement from the voltmeter. This is done once every 256 storage cycles.

The interval of once every 256 storage cycles was arrived at because the program size allowed room for only 64 data points to be taken. Thus, under the greatest load on the system, there are two (2) curves to be stored with 1024 points each. Each point has an x-coordinate and a y-coordinate. Therefore, there are 4096 storage operations.

With a maximum auxiliary storage capacity of 64 points, and a desire to monitor four (4) channels, the software was left with 16 monitoring times. Subdividing 4096 storage operations into 16 equal portions left a sample interval of once every 256 storage cycles. This provides a sampling rate with approximately equivalent time steps throughout the sweep.

Also, the limited available space made necessary the development of an auxiliary processing program, VMAUX. This program takes care of the processing and storage of the auxiliary voltage measurements. VMAUX loads automatically and runs if the slow measurement options are exercised.

This data acquisition process is described in more detail in Chapter 4. In section 4.2.2, a sample experiment is performed with the human/ machine interaction documented. This example was designed as a tutorial for use of this program, NIC-85, including computer prompts and operator responses.

For further details regarding this program, refer to: 1) Appendix A, Program Listings, "NIC-85," and; 2) Appendix C, User's Manual, Chapter 8, "Nicolet Digital Oscilloscope Control Package."

3.2.3 Fast Measurement Subsystem

The fast measurement subsystem was developed using the HP85 Desktop Computer, the HP9895A Flexible Disk, the Tektronix 7612D Programmable Digitizer (7612D). These units are tied together using the software package named 7612D. In addition, the fast measurement subsystem was developed with an option to use the slow measurement subsystem described in section 3.2.1. Figure 3.3 shows the block diagram of the fast measurement subsystem.

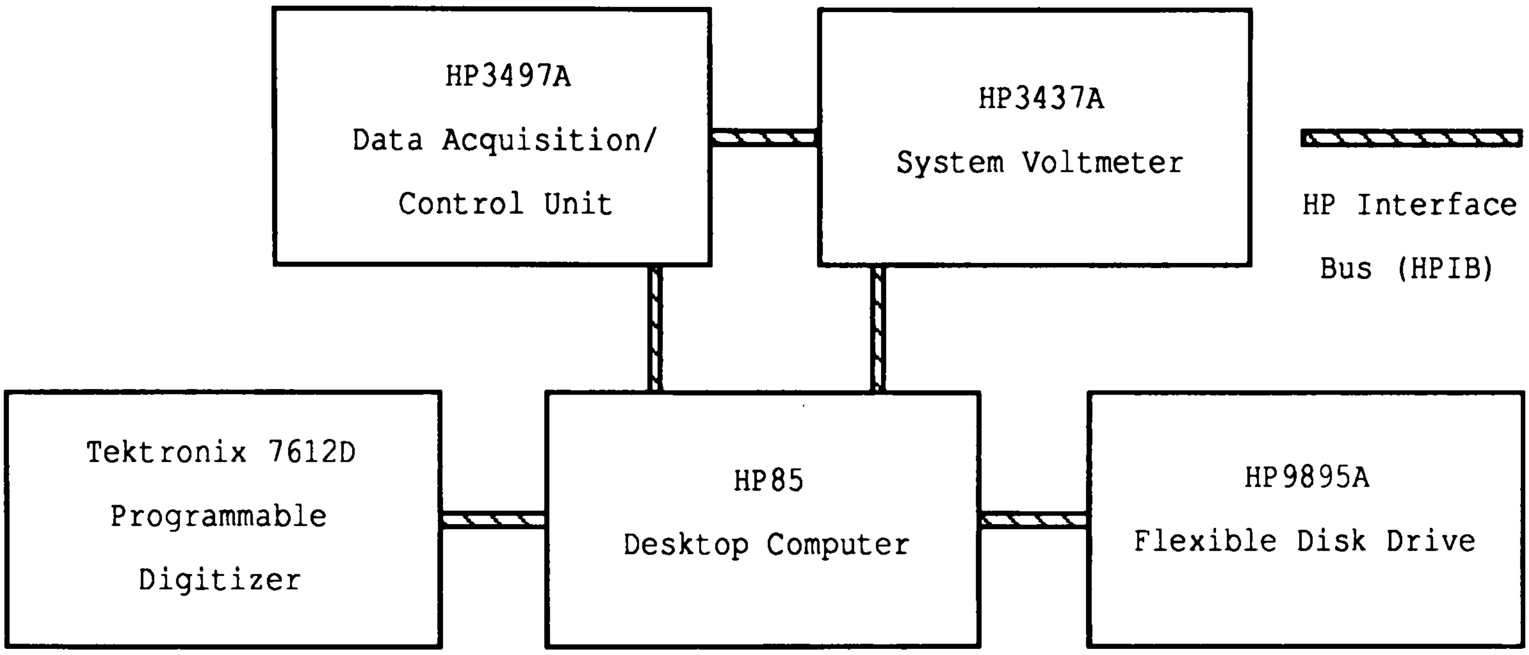

Figure 3.3. Fast Measurement Subsystem

The software was designed to accept two (2) curves with 1024 points per curve. Much like the intermediate measurement subsystem, the fast measurement subsystem functions as a transfer network. Again, the operator enters the settings on the front panel of the 7612D.

Unlike the intermediate measurement subsystem, however, once the 7612D is set up, the operator notifies the computer to take control. From that point forward, the computer controls the process. The computer arms the 7612D and awaits a sweep. Once a sweep is acquired, the computer asks if the sweep is to be stored. If not, the computer returns control to the operator and waits for the operator to acquire a good sweep.

The data acquired by the computer is a voltage. Thus, when the data acquisition is completed, the computer asks for any conversion factors in the process. This is to allow the operator to condition the data to reflect the measurement of interest, e.g., current, prior to storage. After the conversion factor is entered, the computer stores the conditioned data in the chosen mass storage media.

As mentioned earlier, the slow measurement subsystem is also available for use. If the slow measurement subsystem is desired, it is used during the storage phase of the fast measurement process. As the data is being stored, the software takes a measurement from the voltmeter. This is done once every 256 storage cycles. This cycle is based upon the same considerations as noted in section 3.3.2.

This data acquisition process is described in more detail in Chapter 4. In section 4.2.3, a sample experiment is performed with the human/machine interaction documented. This example was designed as a tutorial for use of this program, 7612D, including computer prompts and operator responses.

For further details regarding this program, refer to: 1) Appendix A, Program Listings, "7612D," and; 2) Appendix C, User's Manual, Chapter 7, "Using Tektronix 7612D As A Single-shot O-scope."

3.2.4 Very Fast Measurement Subsystem (Hand Entry)

The very fast measurement subsystem was developed using the HP85 Desktop Computer, the HP9895A Flexible Disk, and the HP9111A Graphics Tablet. These units are tied together using the software package named TABLET. Figure 3.4 shows the block diagram of the very fast measurement subsystem.

Unlike the preceding three (3) subsystems, this data acquisition subsystem was not designed to control a real-time data taker. Instead, this subsystem is centered around a hand-entry digitizer.

The software was developed to input two (2) curves with 512 points per curve. The operator attachs a piece of data to the graphics tablet. The operator then is prompted to enter the four (4) corners of the graph. These allow the software to correct the input data for rotational and translational offsets.

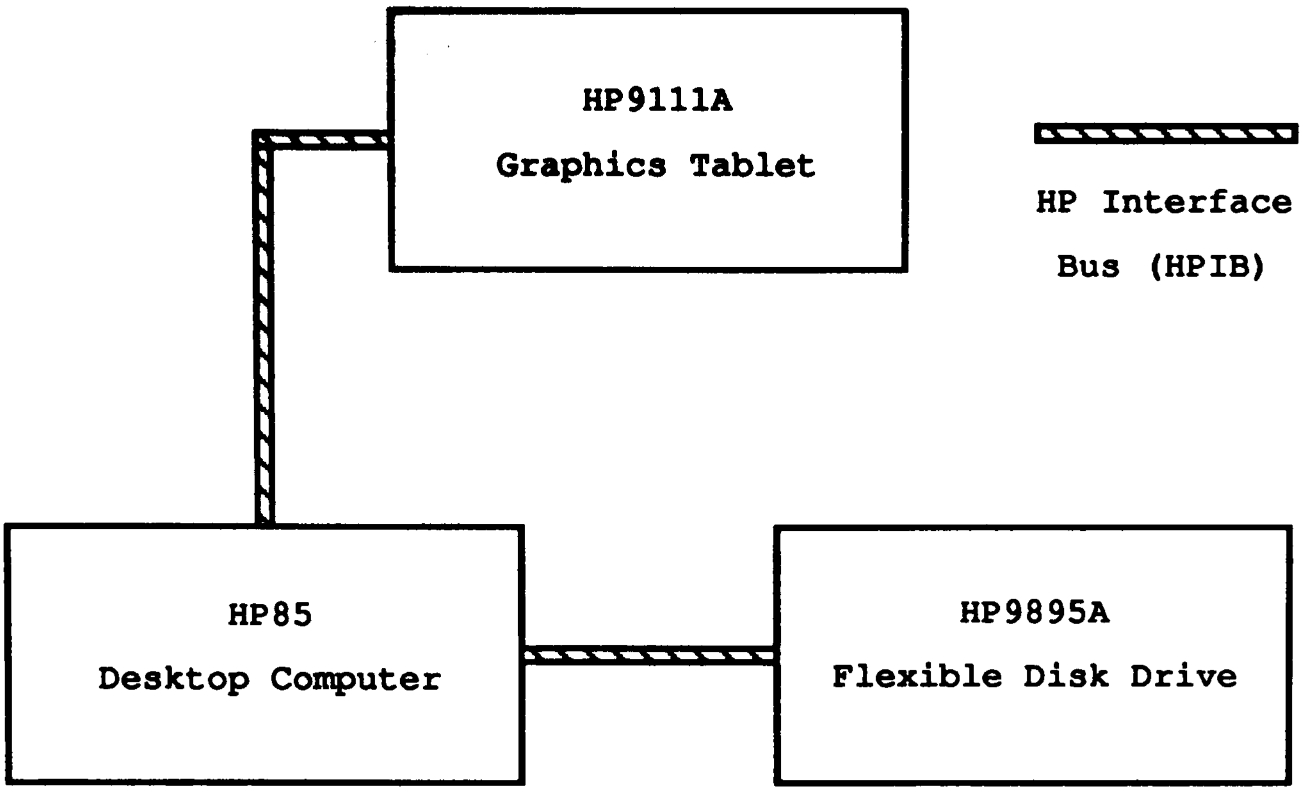

Figure 3.4. Very Fast Measurement Subsystem (Hand Entry)

These offsets occur because a plot placed anywhere in the active platen has a non-zero coordinate associated with it. Also, placing a plot so that its boundaries are exactly parallel to the coordinate axis of the graphics tablet is almost impossible. Therefore, the software was developed to correct for these errors.

After entering the curve(s), the operator notifies the computer to store the data. The software also allows the operator to enter data pertinent to the experiment. The inputs were designed to accept data related to a test device undergoing second-breakdown testing. However, the device data could be used in other ways. At any rate, these inputs are printed out on the thermal printer as a record of the experiment. The computer requests: 1) manufacturer; 2) device type; 3) mask type; 4) device number; 5) temperature; 6) second-breakdown type; 7) forward base current; 8) reverse base current, and; 9) additional comments.

This data acquisition process is described in more detail in Chapter 4. In section 4.2.4, a sample experiment is performed with the human/ machine interaction documented. This example was designed as a tutorial for use of this program, TABLET, including computer prompts and operator responses.

For further details regarding this program, refer to: 1) Appendix A, Program Listings, "TABLET," and; 2) Appendix A, User's Manual, Chapter 10, "Graphics Tablet Control Package."

3.3 Hardcopy Output Subsystem

The hardcopy output subsystem was developed using the HP85 Desktop Computer, the HP9895A Flexible Disk, and the HP7470A Plotter. These units are tied together using the software packages named PLOT and I-V. Figure 3.5 shows the block diagram of the hardcopy output subsystem.

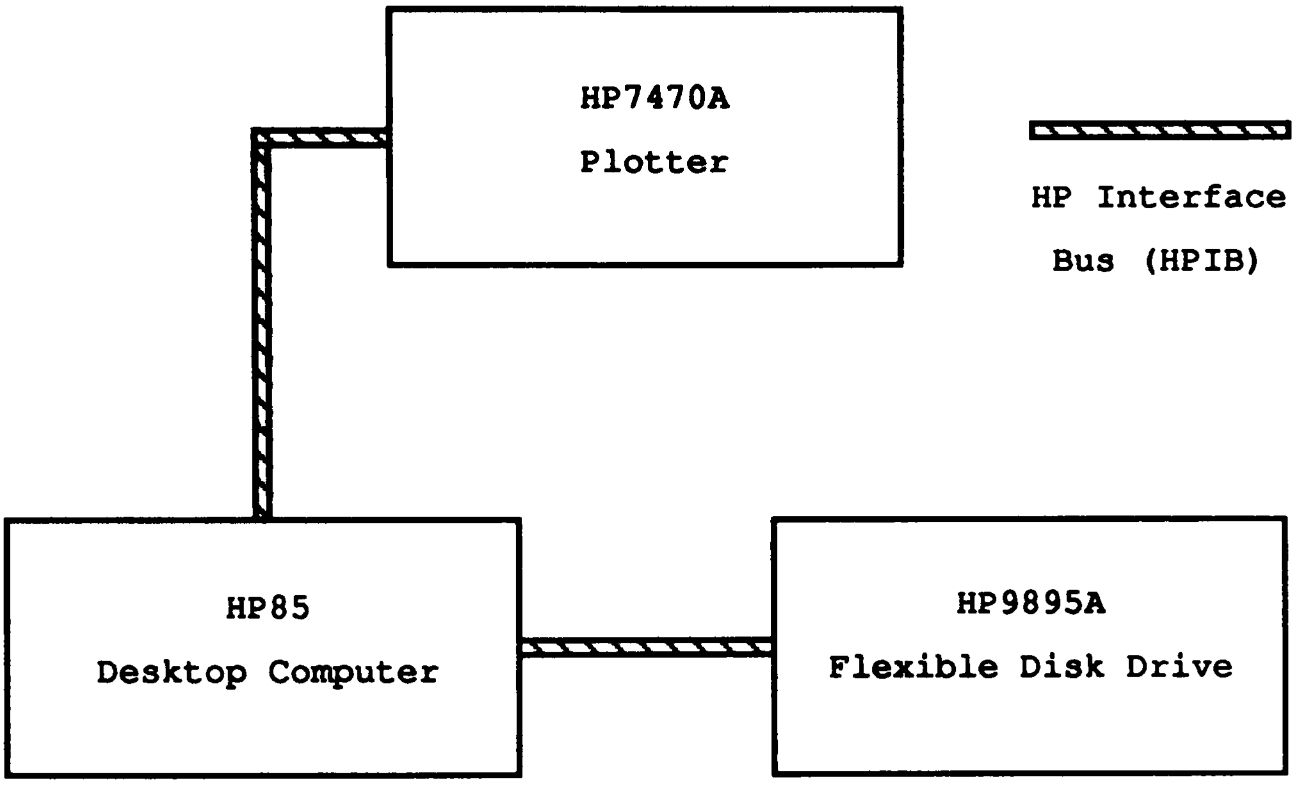

Figure 3.5. Hardcopy Output Subsystem

This software was designed to: 1) plot one (1) of four (4) curves; 2) scale the size of the output; 3) either plot all four (4) plots on a single page or plot each curve on a separate page; 4) generate a set of second-breakdown characteristics for a processed set of curves. The operator chooses the name of a data file. The software then allows the operator to choose from among the noted options.

The first option allows the operator to choose one (1) of four (4) curves to be plotted. The plots this software package generates are: 1) current; 2) voltage; 3) power; 4) energy. The latter two (2) curves exist only for the processed data files. Therefore, the software was developed with provisions that distinguish processed files from unprocessed files. Since the processed and unprocessed data files are stored in slightly different formats (described in detail in Appendix C), the program has to know how to read the data, and which data to read. Once the computer receives an input for a valid curve, the software enters that storage file. The program was developed to accept one (1) curve with a maximum size of 2048 points.

The program then requests the operator for the axis titles, the graph title, and the location for the graph title. With this information, the software generates a plot on the plotter in the chosen format. The operator has the option to choose between a format of all plots on a single sheet of paper or a single plot per sheet of paper. In addition, the size of these plots can be changed by the operator at the keyboard.

In support of the second-breakdown (SB) characteristic studies, the program was developed with the ability to generate a printout of the SB characteristics. This printout is generated on the plotter by placing the plotter in a print mode and outputting as though it were a printer. The software finds or calculates values for: 1) voltage at second-breakdown; 2) current at second-breakdown; 3) power at second-breakdown; 4) energy at second-breakdown; 5) time at second-breakdown; 6) time, T_O, when voltage represents 10% of second-breakdown voltage; 7) voltage at T_O; 8) current at T_O; 9) power at T_O; 10) energy at T_O; 11) time from T_O to second-breakdown, and; 12) change in energy from T_O to second-breakdown.

The hardcopy options outlined are contained in the program called PLOT. However, the system has a second program called I-V. This program was designed from the PLOT program. I-V was generated to provide the ability to plot a curve of the current versus voltage. This capability was not included in PLOT because the memory capacity of the computer was restricted to 24 kilobytes. When PLOT is loaded, there is insufficient room for the portion of the software which generates the current versus voltage curve.

This hardcopy output process is described in more detail in Chapter 4. In section 4.3, a sample experiment is performed with the human/

machine interaction documented. This example was designed as a tutorial for use of this program, PLOT, including computer prompts and operator responses.

For further details regarding these programs, consult the following references: 1) Appendix A, Program Listings, "PLOT"; 2) Appendix C, User's Manual, Chapter 4, "Plotting Package"; 3) Appendix A, Program Listings, "I-V," and; 4) Appendix C, User's Manual, Chapter 5, "I vs. V Plotting Package."

3.4 Mathematical Conditioning Subsystem

As was pointed out in section 2.5, the system required a limited capability for computation. This computational subsystem is composed of the HP85 Desk top Computer and the HP9895A Flexible Disk Drive. Figure 3.6 shows the block diagram of the computational subsystem. This software computes a power curve and an energy curve given a current curve and a voltage curve. These computations are carried out in two (2) steps.

First, the current curve and the voltage curve are interpolated. This is done by comparing the two (2) sets of time data to define a common time frame for the two (2) measurements. Any readings outside this time frame are thrown out. All of the time values within the time frame are combined into a final time set. Both curves are then interpolated linearly and evaluated for all times in the final time set.

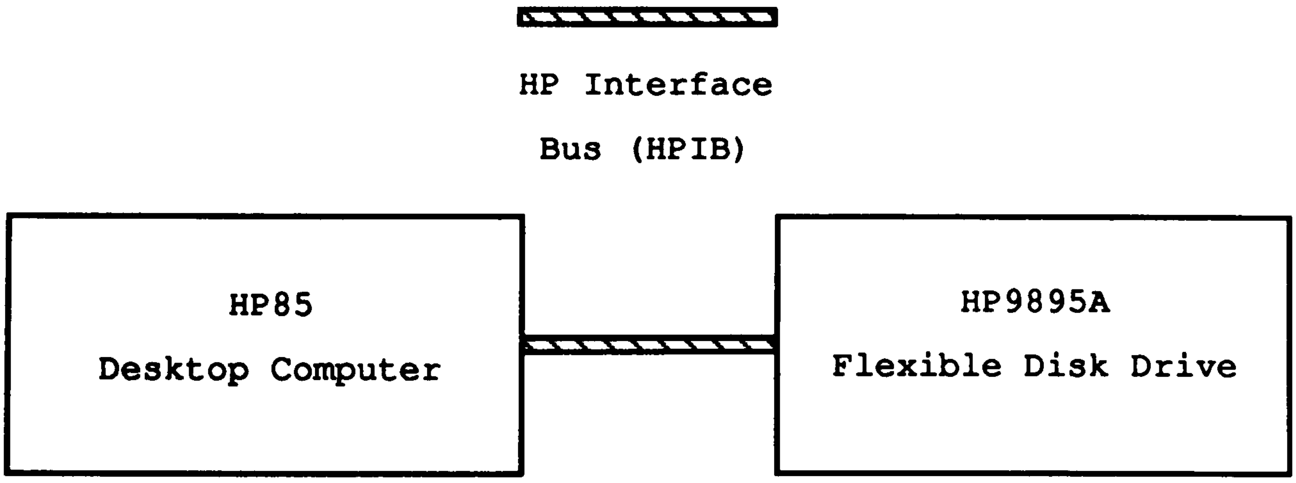

Figure 3.6. Data Conditioning Subsystem

Next, the power curve and the energy curve are calculated using the interpolated current and voltage curves. The power curve is calculated by taking a product of the current and the voltage at each of the times. The energy curve is calculated by taking the time integral of the power curve. The integral is calculated using a trapezoidal approximation. As can be seen in Figure 3.7, the area associated with a trapezoid is

$$A = .5(X_{i+1} - X_i)(Y_{i+1} + Y_i)$$

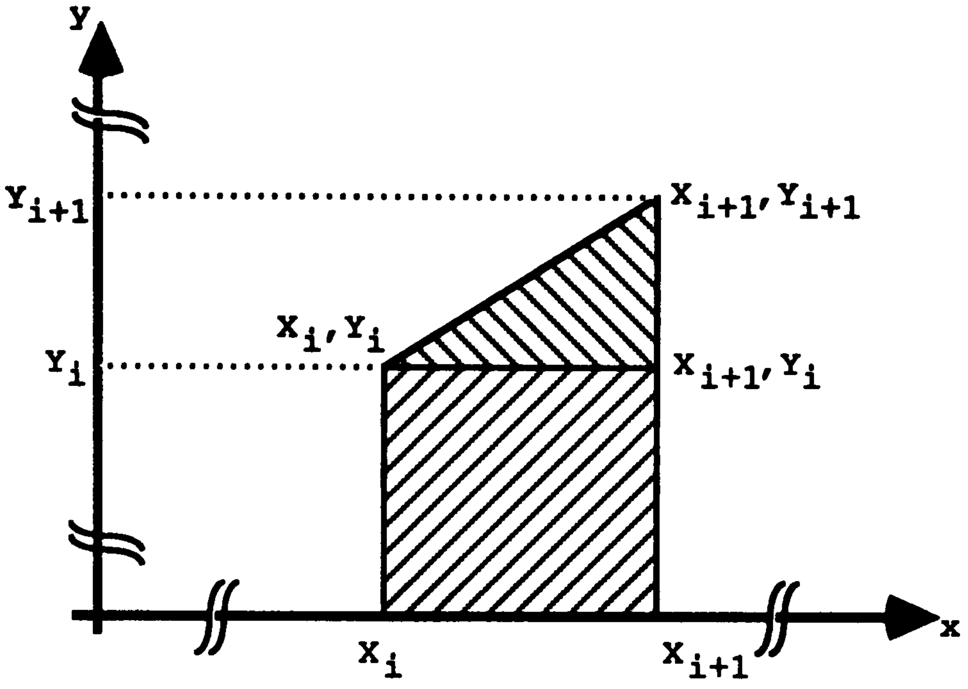

Figure 3.7. Trapezoidal Approximation

Once the calculations are completed, the computer stores the processed data file on the mass storage media for later recall. Due to the restricted memory space, the program was developed so that all of the x data (2048 points--1024 points per curve) is loaded and evaluated while the y data is loaded, evaluated, and stored, 256 points at a time.

This computational process is described in more detail in Chapter 4. In section 4.4, a sample experiment is performed with the human/machine interaction documented. This example was designed as a tutorial for use of this program, MATH, including computer prompts and operator responses.

For further details regarding this program, refer to: 1) Appendix A, Program Listings, "MATH," and; 2) Appendix C, User's Manual, Chapter 3, "Mathematical Processing Package."

3.5 Summary

The operation of the system has now been defined at the component level and at the subsystem level. In Chapter 2, the needs of the laboratory were examined to develop an effective data acquisition system. At the most basic level, functional system elements, and system components, were defined to answer those needs. In this chapter, those functional elements were networked together to define subsystems to carry out the tasks noted earlier.

These subsystems were examined operation by operation. In so doing, the author has defined the capabilities of the subsystems in contrast to the capabilities of the individual system components. Table 3.1 gives an overview of the comparison between the system component capabilities and subsystem capabilities.

In Chapter 4, the operations of each subsystem will be examined more closely by offering examples to provide as tutorials. These tutorials will include computer prompts and correct operator responses.

Table 3.1. Comparison of Component and Subsystem Capabilities

Component Name	Number of Records		Record Length		Minimum Sample Time	
	A[1]	B[1]	A[1]	B[1]	A[1]	B[1]
HP 3537A	1	2[2]	1	256	1E-1	2E+0
Nicolet 2090	8	2[2]	4096[3]	1024	5E-7	5E-7
Tek 7612D	2	2	2048	1024	5E-9	5E-9
HP 9111A	1	2	1	512	1E-4[4]	1E-4[4]

[1] A represents component capabilities; B subsystem capabilities.

[2] Software allows 4 curves to be acquired but storage is in pairs.

[3] Total storage of 4096 points is equally divided among traces.

[4] Measurements are in meters rather than seconds. See section 5.3.1.

CHAPTER 4

SYSTEM TUTORIAL

4.1 Introduction

In the previous chapters, the functional structure of the data acquisition system was analyzed. In Chapter 2, the system was examined at the component level by matching individual pieces of equipment to the laboratory needs. In Chapter 3, the system was examined at the subsystem level and the interactive capabilities were defined. To supplement the subsystem level discussion, this chapter was written to provide a tutorial on the subsystem activities. For ease of interpretation, except where specifically noted, the **computer requests** and the ***operator input*** use these indicated fonts.

First, however, the point should be made that there is a single program which takes care of interconnecting the subsystems. This program, Autost, allows the operator to choose from all of the system capabilities. When the operator powers up the system, Autost is automatically loaded and run. From this program, the operator chooses the subsystem to be used. When the program begins, the following appears on the screen:

Enter the data in a MMDD format.
For example, March 5 is entered
0305.

After the operator enters the correct date,

0803

the computer will display:

Enter the time in an HHMMSS
format.
For example, 3 a.m. is entered
030000.

The operator enters an accurate time of day,

022828

and the software sets the time and date of the computer. The computer has then been initialized for operations. Initializing the computer time and date is important because these values are stored with the data that is taken. This serves to document exactly when the measurements were taken.

Now, the operator is allowed to choose the operation to be implemented. The computer displays the message:

Press key for desired function.

K1 = Choose among data-takers.

K2 = Process data.

K3 = Plot curves.

K4 = Plot I-V curve only.

K5 = Use graphics capabilities.

The operator chooses from among these options. Based upon the option chosen by the operator, the computer proceeds to poll the equipment on the network to make sure the subsystem elements are available.

If the operator chooses to take data, the computer produces the following list of equipment available for measurement:

Press key for desired equipment.

K1 = Tektronix 7612D Digitizer

K2 = Nicolet Digital O-scope

K3 = HP Multiplexer & Voltmeter

K4 = HP Graphics Tablet

The computer then branches to the proper portion of the program to check the availability of the subsystem. If the Tektronix 7612D is chosen, the operator is asked:

Do you want to use the 7612D as
a normal O-scope or a one-shot
storage scope? (NORM/SINGLE)

The computer first polls the network to see if the Tektronix 7612D Programmable Digitizer and the HP9895A Flexible Disk Drive are on-line. Then, if the operator has chosen to use the 7612D as a single-shot storage scope, the computer asks:

Do you want to use the system
voltmeter to make additional
readings? (Y/N)

If the operator chooses to use the system voltmeter, the software polls the network to see if the HP3497A Data Acquisition/Control Unit and the HP3437A System Voltmeter are available, as well.

Once all of the components are found to be available, the software loads and runs the desired program. If the 7612D is used as single-shot storage scope, the program, 7612D (discussed in Appendix C, Chapter 7), is loaded and run; otherwise, the program, NORML (discussed in Appendix C, Chapter 6), is loaded and run.

If the Nicolet Digital Oscilloscope is chosen, the program polls the network to see if the Nicolet 2090-III Digital Oscilloscope and the HP9895A Flexible Disk Drive are available. Then, the program asks:

Do you want to use the system
voltmeter to make additional
readings? (Y/N)

If so, the program polls the network to ascertain the availability of the HP3497A Data Acquisition/Control Unit and the HP3437A System Voltmeter. The program then loads and runs the program, NIC-85 (discussed in Appendix C, Chapter 8).

If the operator chooses to make use of the system multiplexer and system voltmeter, the program polls the system to see if the HP9895A Flexible Disk Drive, the HP3497A Data Acquisition/Control Unit, and the HP3437A System Voltmeter are available. Then, the program loads and runs the program, HP-DAS (discussed in Appendix C, Chapter 9).

If the operator chooses to use the graphics tablet, the program checks the network for the availability of the HP9895A Flexible Disk Drive and the HP9111A Graphics Tablet. Then, the software loads and runs the program, TABLET (discussed in Appendix C, Chapter 10).

If the operator chooses to process a set of curves, then the software polls the network for the availability of the HP9895A Flexible Disk Drive. Then, the software loads and runs the program, MATH.

If the operator chooses to plot a set of curves, then the software polls the network for the availability of the HP9895A Flexible Disk

Drive and the HP7470A Plotter. Then, the software loads and runs the appropriate program--I-V for current versus voltage plots; PLOT for the remainder of the plots.

All of the previously mentioned options are available to the operator, however, the graphics subroutine is not operational. Therefore, if the operator chooses to use the graphics capabilities, the message appears:

This program is not operational.

Please choose another function.

In the following sections, the software controlling each of the subsystems is described in a tutorial setting. This is provided to allow the operator a closer look at the interaction between human and software.

4.2 Slow Measurement Subsystem Tutorial

When the operator chooses to use the slow measurement subsystem, the program, HP-DAS, is loaded and run. First, the program displays the message:

Initializing ,

then proceeds to set the default values for variables in the program and initializes the data registers. Then, the software asks:

How many channels are to be

monitored by voltmeter? (4 max.)

The operator enters the number of channels to be monitored,

2 .

The operator then responds to the request

Enter the channel number and the

voltage range.

(.1V = 1, 1V = 2, 10V = 3)

by entering the value

1 .

This is then followed by a request for the time sample information:

Enter the time between samples.

(There will automatically be a

2-second delay between groups

of measurements. M=minutes,
S=seconds. Separate number from
unit with a comma. [Ex. 30,S]

This is responded to with the value

45,S

which sets the sample rate to once every 45 seconds. The software then requests the operator to choose a time frame to sample over:

Enter the total time over which
to take samples. (Max. 192 s)
(Separate number from unit with
a comma.)

The operator chooses to sample over the maximum sample period and enters

192,S .

Given this information, the software calculates the number of samples to be taken. Then, the software notifies the operator that the operation has begun. The measurement is taken in two (2) pieces. First, the software takes a measurement. Then, the computer awaits the designated sample time before taking another measurement. Thus, the following messages are repeated until the operation is completed:

Taking data ,

and

Waiting .

When the software has completed the data acquisition, it sets off a two-tone alarm which sounds until the operator responds to the following prompt:

The data is stored.
Press K1 to continue program .

When the operator presses the K1 key, the alarm halts and the program proceeds to the data storage phase. First, the program asks:

Where do you want to store these
curves? (DISK00/DISK01/TAPE)

This is responded to with

DISK00 .

The disk is preferred since it is much quicker than the tape drive on the HP85. The computer then begins the storage process. This is done by notifying the operator that:

There are 2 curves.

and then requesting the operator to:

Enter the name for curve 1.

This is entered as:

DASTST .

The software then proceeds with the actual storage cycle. The program first creates a file on the disk, and then stores the data. During the storage cycle, the software displays:

Storing data in DASTST.

After completing the storage process, the software queries:

Do you want to take another set
of data? (Y/N)

If the operator wishes to take another set of measurements, then the entry is made:

Y ,

and the software displays the message:

Re-initializing .

The software then resets the default values, re-initializes the data registers, and returns to the segment of the program described in the beginning of this section where the operator was asked to enter the number of channels to be monitored.

If the operator does not wish to take another set of curves, then the entry is made:

N ,

and the program displays the message:

MISSION CONTROL
will now resume control.

At this point, the software loads and runs the program, Autost (described in the previous section).

4.3 Intermediate Measurement Subsystem Tutorial

When the operator chooses to use the intermediate measurement subsystem, the program, NIC-85, is loaded and run. First, the program displays the message:

Initializing ,

then proceeds to set the default values for variables in the program and to initialize the data registers. Since the intermediate measurement subsystem was designed to make auxiliary voltage measurements, if desired, the software asks:

Do you want to use the system
voltmeter to make additional
measurements? (Y/N)

If the operator chooses to use the auxiliary system, then the entry is made:

Y ,

which brings about the following interchange:

How many channels are to be
monitored by voltmeter? (4 max.)
2 ;
Enter the channel number and the
voltage range.
00,2 ;
Enter the channel number and the
voltage range.
01,2 .

When the operator responds:

N

to the prompt for the system voltmeter, or the entries for use of the system voltmeter are completed, the program prompts:

Set up Nicolet and take
measurement.
When you have the curve you
wish to store, press CONTINUE.

After the operator acquires a desirable curve, the computer is notified. The program then warns the operator of the restrictions associated with this software:

The processing package can
handle no more than 1024 data

```
        per curve.  Therefore, only 1024
        of the data will be used by the
        processing program.  This is
        equivalent to using Q1 to Q4.
        To view what will be processed,
        turn the MEMORY switch to Q3.
        To resume:  restore MEMORY to ALL
        and press CONTINUE.
```

When the computer is notified that a good measurement had been taken, the software proceeds to load the normalization factors and the curve data from the Nicolet. Then, the software displays the available options:

```
        K1 = Store all data.
        K2 = Process new set.
        K3 = Finished.
```

If the operator first seeks to store the data acquired, the software prompts the operator for the name and storage location for the file:

```
        What name do you want for the
        storage file?
            NICTST                                  ;
        Where do you want the curves
        stored?  (DISK00/DISK01/TAPE)
            DISK00                                  .
```

In order to display the capabilities of the system, four (4) curves are acquired before notifying the computer that the transfer is ready. Since there were more than two (2) curves to be transferred, the software notifies the operator:

```
        There are 4 curves but
        the processing package can only
        handle two curves per run,
        unless both curves are the same
        type, i.e. both current.  In that
        case, only 1 curve per file.
        Which two curves do you want
        paired together?  (1-4)
```

(Separate curves by a comma: 1,4)
(To store single curves, enter
number twice: 1,1)

The curves that are acquired reflect two (2) pairs of readings. Thus, the operator enters the first pair:

1,2 ,

for the first storage cycle. The software displays the message:

Storing data in NICTST .

At that time, the software creates space for the file and stores the data. Since there are more than one (1) pair of readings the computer asks:

Do you want to store another
set of these curves? (Y/N) .

Again, the set of four (4) curves are taken to reflect two (2) distinct pairs of readings. Therefore, the operator enters:

Y .

At that point, the software again asks for a pair to be stored together. To this request, the operator responds:

3,4 .

Whereupon, the computer proceeds to store the other pair of curves. After completing the storage process, since the auxiliary voltage system has been used, the software asks:

What name do you want for the
auxiliary file?

The operator responds to this query:

NICAUX .

The computer then begins storing the auxiliary data:

Storing data in NICAUX .

This storage process is not in a standard format. This difference was pointed out in the previous chapters. Therefore, once the rest of the operations are completed, the software loads and runs the program, VMAUX. After completing this storage process, the software asks:

Have you stored the present set
of curves? (Y/N)

Of course, the curves **have been** stored. Thus, the operator enters:

Y .

Having completed the storage process, the computer asks for further data:

Do you wish to digitize another
set of curves? (Y/N)

If the operator chooses to take another set of curves, then the entry is made:

Y .

Whereupon, the software returns to the acquisition beginning with the initialization.

If, on the other hand, the operator is finished with the acquisition process, then the entry is made:

N .

At that point, the software will load and run one of two programs. For the case of no auxiliary voltage measurements, the software loads and runs the program, Autost. In that case, the software displays:

MISSION CONTROL
will now resume control.

For the case where auxiliary measurements are taken, the software loads and runs the program, VMAUX. This program is designed to reformat the auxiliary file data into a form consistent with the rest of the files. After loading VMAUX, the program proceeds by displaying:

Initializing .

The program first asks for the name of the auxiliary voltage file and its storage location:

What is name of the auxiliary
voltage file associated with
NICTST?

NICAUX ;

Where is NICAUX stored?

DISK00 .

With this information, the program then begins reading in the file. The software then asks for the name for the auxiliary files--one at a time:

```
        Reading
        There are 2 curves.
        Enter the name for curve 1.
            AUXFN1                                          ;
        Enter the name for curve 2.
            AUXFN2                                          .
```

The program then stores each of the curves in a separate file under the name given above. However, before storing the files, the software asks for the conversion processes associated with each curve. If, for example, there is only one conversion process (the first curve). The interaction is:

```
        Storing AUXFIN
        Is an attenuator, current
        transformer, thermocouple, etc.,
        being used?  (Y/N)
            Y                                               ;
        What is the conversion process?
        (For example, a 6dB attenuator
        converts a 2-volt input at the
        source to a 1-volt input at the
        scope.  So conversion is 2V to
        1V - entered 2V, 1V.  Enter
        using scientific notation and
        include units - A, V, K, etc.)
            2A,1V                                           .
```

As the curves are stored, their data is scaled to reflect the conversion process. Thus, the stored data reflects the quantity of interest. After reformatting the data files and storing them, the software then asks if there are more curves which were stored during the measurement process:

```
        Did you store any curves other
        than TRNTST?  (Y/N)
```

If more curves were stored, then the program will return to the initialization process in <u>VMAUX</u>. Otherwise, the software will notify the operator that Autost is being loaded and run:

MISSION CONTROL
will now resume control.

4.4 Fast Measurement Subsystem Tutorial

When the operator chooses to use the intermediate measurement subsystem, the program, 7612D, is loaded and run. First, the program displays the message:

Initializing

then proceeds to set the default values for variables in the program and initializes the data registers. The program then asks for the number of curves to be digitized:

How many curves will be
digitized and stored? (1-2)

For this tutorial, two (2) curves are chosen for digitizing. Thus, the entry is made:

2 .

The program next asks if there will be a repetitive set of measurements. This program was designed for measurements that will all be made with exactly the same instrument settings. For this case, only one set of measurements is taken:

Will this be a repetitive set
of measurements at the same
settings? (Y/N)

N .

Since the fast measurement subsystem was designed to make auxiliary voltage measurements, if desired, the software asks:

Do you want to use the system
voltmeter to make additional
measurements? (Y/N)

If the operator chooses to use the auxiliary system, then the entry is made:

Y ,

which brings about the following exchange:

```
        How many channels are to be
        monitored by voltmeter?  (4 max.)
            2                                                   ;
        Enter the channel number and the
        voltage range.
        (.1V = 1, 1V = 2, 10V = 3)
            00,2                                                ;
        Enter the channel number and the
        voltage range.
        (.1V = 1, 1V = 2, 10V = 3)
            01,2                                                .
```

When the operator responds:

```
            N
```

to the prompt for the system voltmeter, or the entries for use of the system voltmeter are completed, the program prompts:

```
        Adjust the POSITION knob on
        plug-in A to set zero line.
        Adjust the POSITION knob on
        plug-in B to set zero line.
```

This prompt is to get the operator to adjust the baseline on the individual plug-ins so that the sweeps appear in the correct position on the screen. After the baseline is established for the plug-ins, the program prompts:

```
        Enter the measurement settings
        on the front panel of the 7612D.
        When entry is complete, press
        the REMOTE button on the front
        panel (lower center).
```

This program was developed to allow the operator to adjust instrument settings at the front panel. This reduces the setup time, and makes the entry easier. After the operator is finished with the measurement setup, the computer is notified that the system is prepared, and the computer loads all of the measurement settings and reprints them on the screen:

```
For the mainframe:
    CLK INT
    BTA OFF
    WRI OFF
    RQS ON
    REM OFF
For time base A:
    REC 1,1024
    SBPT 0,1E-6
    MODE PRE,104
    LTC LEFT
    SRC INT
    SLO POS
    HFR OFF
    CPL AC
    LEV 0
For time base B:
    REC 1,1024
    SBPT 0,1E-6
    MODE PRE,104
    LTC LEFT
    SRC INT
    SLO POS
    HFR OFF
    CPL AC
    LEV 0
```

Once the software has completed displaying the settings, the operator is asked:

```
Are all of the settings correct?
(Y/N)
```

If the settings are incorrect, the operator enters:

N

and the program returns to the setup routine above. Otherwise, the program proceeds to ask if there are any conversion processes:

```
Is an attenuator, current
transformer, or current-sensing
resistor being used?  (Y/N)
(Do not consider x10 probes.)
   Y                                                     ;
Which of the plug-ins uses one
of these devices?  (A/B/C)
(C is equivalent to A and B.)
   A                                                     ;
What is the conversion process
for plug-in A?
   2A,1V                                                 .
```

These values are used to calculate the true units from the voltages which appear at the scope. After the conversion factors are entered, the program proceeds with the data acquisition process by arming the time bases. If only one (1) curve is being taken, the program asks:

```
Which time base is to be armed?
(A/B)
   A                                                     .
```

The program then arms the designated time base, and awaits the acquisition of a good measurement. The program then notifies the operator to take a measurement:

```
Time base A armed.
Now, simply take measurement.
When the curve appears on the
monitor, press CONTINUE.
```

Once the computer finds an acquisition has been made, it queries the operator:

```
Do you wish to keep this data?
(Y/N)
```

If the operator decides not to keep the data, the computer will prompt:

```
Do you wish to change the
settings?  (Y/N)
```

If the settings need to be changed, the program will return to the settings area described earlier in this section. Otherwise, the program will keep the same settings and attempt to take another sweep by arming the time base(s) again. Once the program is notified that the operator wishes the curve to be stored, the software will ask where to store the file and under what name:

```
Where do you want the curves
stored?  (DISK00/DISK01/TAPE)
    DISK00                                            ;
What name do you want for the
storage file?
    TRNTST                                            .
```

Once the program has a file name and storage location, the program will proceed to store the data. Until the data storage cycle is completed, the software will display the message:

```
Storing data in TRNTST                                .
```

Once the program has completed storing the normal curve data, the program will prompt for the name of the auxiliary voltage data:

```
What name do you want for the
auxiliary file?
    TRNAUX                                            .
```

This is stored temporarily in the same way as the auxiliary voltage measurements from the intermediate measurement subsystem. Thus, VMAUX will be called later. Once the program has a name for the auxiliary file, the software proceeds to store:

```
Storing data in TRNAUX
Data is stored.
```

After completing the auxiliary storage cycle, the program will ask:

```
Do you want to take another
set of data?  (Y/N)
```

If the operator chooses to take another set of curves, then the entry is made:

```
    Y                                                 .
```

Whereupon, the software returns to the acquisition beginning with the initialization. If, on the other hand, the operator is finished with the acquisition process, then the entry is:

N .

At that point, the software will load and run one of two programs. For the case of no auxiliary voltage measurements, the software will load and run the program, Autost. In that case, the software displays:

MISSION CONTROL

will now resume control.

For the case where auxiliary measurements are taken, the software loads and runs the program, VMAUX. This program was designed to reformat the auxiliary file data into a form consistent with the rest of the files. After loading VMAUX, the program proceeds by displaying:

Initializing .

The program first asks for the name of the auxiliary voltage file and its storage location:

What is name of the auxiliary
voltage file associated with
TRNTST?

TRNAUX ;

Where is TRNAUX stored?

DISK00 .

With this information, the program then begins reading the file. The software then asks for the name for the auxiliary files--one at a time:

Reading

There are 2 curves.

Enter the name for curve 1.

AUXFNA ;

Enter the name for curve 2.

AUXFNB .

The program then stores each of the curves in a separate file under the name given above. However, before storing the files the software asks for the conversion processes associated with each curve. In this case, there is only one conversion process, that being for the first curve. The interaction is:

Storing AUXFNA

Is an attenuator, current

transformer, thermocouple, etc.,
being used? (Y/N)
Y ;

What is the conversion process?
(For example, a 6dB attenuator
converts a 2-volt input at the
source to a 1-volt input at the
scope. So conversion is 2V to
1V - entered 2V, 1V. Enter
using scientific notation and
include units - A, V, K, etc.)
2A, 1V .

As the curves are stored, their data is scaled to reflect the conversion process. Thus, the stored data reflects the quantity of interest. After reformatting the data files and storing them, the software then asks if there are more curves which were stored during the measurement process:

Did you store any curves other
than TRNTST? (Y/N)

If there are more curves stored, then the program returns to the initialization process in VMAUX. Otherwise, the software notifies the operator that Autost is being loaded and run:

MISSION CONTROL
will now resume control.

4.5 Very Fast Measurement Subsystem Tutorial (Hand Entry)

When the operator chooses to use the very fast measurement subsystem, the program, TABLET, is loaded and run. First, the program displays the message:

Initializing ,

then proceeds to set the default values for variables in the program and initializes the data registers. The program then makes a hardcopy on the printer of the functions assigned to the softkeys on the graphics tablet:

Softkey Assignments

1 END

End of curve. Digitize to start next curve.

2 STORE

Transfer curves to tape or disk.

3 NEW SET

Reinitialize and process new set of curves.

4 FINISHED

Finished with this program.

5 DEVICE DATA

Print out device data.

6-16 Not used.

After notifying the operator of the options available on the graphics tablet, the software then proceeds with the digitization process by requesting:

How many curves will be entered? (1/2)

To this the operator responds:

1

The program then prepares to carry out the digitization process. First, the boundaries of the trace to be entered have to be defined. As pointed out in previous chapters, this is done to allow the software to compensate the data for rotational and translational offsets. The software requests the boundary inputs:

Please digitize the corners of the graph grid in the following order: upper left, upper right, lower left, and lower right.

From this information, the software calculates the compensating constants for rerotating the plot. Next, the software asks for the information necessary to scale the newly defined active area to give true units rather than the xy information which the computer actually receives from the graphics tablet:

```
        How many horizontal divisions
        are there?
            10                                          ;
        How many vertical divisions
        are there?
            8                                           ;
        What is the value per horizontal
        division for curve 1?
        (Enter value and unit, for
        example 5ms = 5E-3,s.)
            10,ms                                       ;
        What is the value per vertical
        division for curve 1?
        (Enter value and unit, for
        example, 5A = 5,A.)
            10,V                                        .
```

From these inputs, the software calculates the values that correspond to the xy positions being digitized. These values, however, will all be positive. The values cannot reflect a negative value, however, without establishing a zero reference. Therefore, the program asks for that zero reference level:

```
        For curve 1:
        on a scale of 0 to 8, what is
        the y-coordinate for the origin?
        (0 = lower left corner,
         4 = left center, and
         8 = upper left corner.)
```

After entering the relative position of the zero reference for curve 1:

```
            4                                           ,
```

the software notifies the operator to begin entering the curve:

```
        Digitize curve 1.
```

The program then displays the options which can be selected by pressing the available keys:

```
        K1 = End of curve.
```

K2 = Store all data.

K3 = Process new set.

K4 = Finished.

K5 = Print device data.

These are in addition to the softkey assignments printed earlier. This is done so that the operator can select functions from either the graphics tablet or the computer keyboard. After the operator has entered the curves, the computer displays:

Digitization process is
complete. Please press key or
digitize softkey to continue.

From this point, the operator first chooses to store the data. First, the software asks:

What name do you want for the
storage file?

To this, the operator responds:

TABTST .

Next, the software asks for the desired storage location:

Where do you want the curves
stored? (DISK00/DISK01/TAPE)

Again, the operator chooses the disk because of its storage speed:

DISK00 .

The program then proceeds to store the data and notifies the operator:

Storing data in TABTST
Data is stored.

When the program finishes storing the data, the operator is asked whether or not another set of curves will be digitized. First, however, the program checks to see if the operator has stored the present curves:

Have you stored the present set
of curves? (Y/N)

Then, the program asks if another set of curves will be digitized:

Do you wish to digitize another
set of curves? (Y/N)

If the operator chooses to digitize another set of curves, the reply is entered:

Y ,

and the program returns to the initialization process mentioned at the beginning of this section. Otherwise, the program proceeds to load and run the program, Autost. In that case, the software displays:

MISSION CONTROL

will now resume control.

On the other hand, if the operator chooses to print the device data, then the program proceeds to enter and print the device data. For the device data discussion only, the **computer requests** and the ***hardcopy output*** sent to the thermal printer use the indicated fonts:

Enter manufacturer.

Manufacturer - UNITRODE

Enter device type.

Device type - BUX98

Enter mask type or other
applicable data.

Mask type or other applicable
data - NH LOT 5

Enter device number.

Device number - 037

Enter temperature (RT or
degrees C)

Temperature - RT C

Enter SB type (N, A, B, or C.)

SB type - C

Enter forward base current.

Forward base current - .20 A

Enter nominal reverse base
current.

Reverse base current:
Nominal - 1 A

Enter reverse base current
at SB.

Actual at SB - 1 A

Enter any additional comments.

Comments:

After producing the printout of the device data, the software returns to its former operation. Thus, if the device data is produced during digitization, then the software returns to the digitization process. If, however, the operator digitizes a softkey which is not defined (6 through 16), then the program displays:

This softkey performs no
function. Please choose
another.

4.6 Hardcopy Output Subsystem Tutorial

When the operator chooses to get a hardcopy output of the curves which have been acquired, the program, PLOT, is loaded and run. First, the program displays the message:

Initializing .

Unless PLOT is the first program to be called after applying power to the system, the name of the last file to be processed is passed to the program. Therefore, the software asks first:

Where is TABTST stored?
(TAPE/DISK00/DISK01)

To this the operator responds:

DISK00 .

The program then displays the available options. The program is written so that first the operator chooses the desired plot; then, the software loads the proper plot, if it exists:

```
Currently operating on TABTST
Plot V      Plot I      Plot P      Plot U
Scale       New Set    Finished
```

Based upon the operation chosen, the software loads the proper curve. For any of the plot routines, the software asks:

Do you want this plot by itself?
(Y/N)

If the operator wants a plot of the curve by itself, then the reply is entered:

Y ,

and the software sets up the plot so that only one (1) plot is placed on a sheet of paper. Otherwise, the operator enters:

N ,

and the software uses the default configuration which plots the curves so that all four (4) can be plotted on a single piece of paper. The software then proceeds to ask for the axis titles which the operator desires:

What title do you want for the
time axis of this
current vs. time curve?

TIME ;

What title do you want for the
current axis of this
current vs. time curve?

Ic .

The program also has the ability to plot the curve on either a grid or an open graph. Thus, the software queries the operator as to a preference for grid or graph:

Do you want a grid or graph?

To this, the operator responds:

GRID .

The program then is ready to plot the curve. Thus, the software notifies the operator:

Load plotter and press CONTINUE.

Once the plotter is loaded, the operator presses CONTINUE and the program carries out the plotting. In so doing, the software scans the data file for maximum and minimum values to automatically scale the size of the axis, and read the data into memory 1024 points at a time:

Scanning
Reading 1 of 1 .

The program then plots the curve. After completing the plot, the software asks the operator for the final quantities to complete the plot:

Enter the y-coordinate for the
date and time.

8 ;

Enter the year - 1985

1985 ;

Enter the label for this graph.
(Maximum length of 40 char.)

Collector Current ;

Enter the y-coordinate for the
label of this graph.

7 .

After completing a plot on a processed data file, the software asks:

Do you want a copy of the
second-breakdown statistics?

If the operator does not wish to obtain a copy of the second-breakdown characteristics, then the reply is entered:

N ,

and the program returns to the available options indicated earlier. Otherwise, the operator enters the response:

Y ,

and the software displays:

Load plotter and press CONTINUE.

After the operator loads the plotter and presses CONTINUE, the software proceeds to calculate the second-breakdown statistics. This is done by examining the voltage curve to find the time at which second-breakdown began. The values of each of the quantities are printed which correspond to that time with the following statements:

The value for instantaneous
voltage at 2nd-breakdown is
765 V

The value for instantaneous
current at 2nd-breakdown is
3.38 A

```
The value for instantaneous
power at 2nd-breakdown is
  2580 W
The value for instantaneous
energy at 2nd-breakdown is
  166 uJ
2nd-breakdown occurs at
  .722 us
```

The program then finds the time which corresponds to the voltage which most closely approximates 10% of the second-breakdown voltage. This time is defined to be t_o. Then, the values which corresponded to t_o are printed for each of the quantities:

```
To is the time at 10% of the
2nd-breakdown voltage.
The value for instantaneous
voltage at To is 76.5V.
The value for instantaneous
current at To is 5.06 A.
The value for instantaneous
power at To is 387 W.
The value for instantaneous
energy at To is 33 uJ.
```

Next, the software calculates the time from t_o to second-breakdown, and the change in energy from t_o to second-breakdown:

```
The time from To to
2nd-breakdown is .0839 us.
The change in energy from To
to 2nd-breakdown is 133 uJ.
```

After completing the printout of the second-breakdown characteristics, the software then returns to the available options noted earlier.

If the operator chooses to do so, the software changes the scale of the plots. In so doing, the operator is allowed to control the size of the plot:

```
Enter the scale factor for
plotting (less than 2.25.)
```

Once the operator is prepared to proceed to another set of curves, the software prompts:

What is the new file name?

To this the operator responds:

TRNTST ,

and the software begins the operations again at the initialization process outlined in the beginning of this section.

When the operator is finished, the software loads and runs the program, Autost:

MISSION CONTROL

will now resume control.

The software package, PLOT, was developed to generate plots of current, voltage, power, and energy. Another useful plot is one of the current versus the voltage. Unfortunately, due to the limited memory capacity of the HP85, this option could not be included in the program, PLOT. Instead, a second program, I-V, was developed.

The program, I-V, was developed specifically for plotting the current versus voltage curve. The program operates in much the same way as the program, PLOT. First, the program displays the message:

Initializing .

Unless I-V is the first program to be called after applying power to the system, the name of the last file to be processed is passed to the program. Therefore, the software asks first:

Where is TABTST stored?

(TAPE/DISK00/DISK01)

To this the operator responds:

DISK00 .

The program then displays the available options:

Currently operating on TABTST

I-V Scale New Set Finished

The software then proceeds to ask for the axis titles which the operator desires:

What title do you want for the

voltage axis of this

current vs. voltage curve?

Vce ;

What title do you want for the
current axis of this
current vs. voltage curve?

Ic .

The program also has the ability to plot the curve on either a grid or an open graph. Thus, the software queries the operator for a preference of grid or graph:

Do you want a grid or graph?

To this, the operator responds:

GRID .

The program then is ready to plot the curve. Thus, the software notifies the operator:

Load plotter and press CONTINUE.

Once the plotter is loaded, the operator presses CONTINUE and the program carries out the plotting. In so doing, the software scans the data file for maximum and minimum values in both plots to automatically scale the size of the axes, and read the data into memory 1024 points at a time:

Scanning A
Scanning B
Reading 1 of 1 .

If the operator chooses to do so, the software will change the scale of the plots. In so doing, the operator is allowed to control the size of the plot:

Enter the scale factor for
plotting (less than 2.25.)

Once the operator is prepared to proceed to another set of curves, the software prompts:

What is the new file name?

To this the operator responds:

TRNTST ,

and the software begins operations again at the initialization process outlined in the beginning of this section.

When the operator is finished, the software loads and runs the program, Autost:

MISSION CONTROL

will now resume control.

4.7 Mathematical Processing Subsystem Tutorial

When the operator chooses to process data acquired in the earlier processes, the program, MATH, is loaded and run. First, the program displays the message:

Initializing .

Unless MATH is the first program to be called after applying power to the system, the name of the last file to be processed is passed to the program. Therefore, the software asks first:

Where is TABTST stored?

(TAPE/DISK00/DISK01)

To this the operator responds:

DISK00 .

The program then reads in the maximum and minimum time for each of the curves to be processed. These values are used to define the time frame over which the power (product) and energy (product time-integral) will be evaluated. This is denoted by the message:

Sorting .

Having calculated the time frame over which the curves will be evaluated, the program proceeds to read the applicable time values. These time values are then sorted together to produce a set of common times. This portion of the program is announced by the display:

Initial read and sort .

Having developed a full set of time values by sorting together all the available times and discarding any redundant times, the program then creates a file of sufficient size to store the file which is to be processed. The software displays:

Creating file space .

The program then carries out the processing. The first step in the processing is the interpolation of the curves. Each curve is composed of a finite number of samples. The equations for each of these lines are calculated. These lines are then evaluated for each of the time values. This is performed in a three-part process of reading, evaluating, and storing. During the interpolation of the voltage curve, the computer displays:

```
        Process 1 of 4
        Reading 1 of 1
        Process 1 of 4
        Working 1 of 1
        Process 1 of 4
        Storing 1 of 1                                          .
```

Next, the current curve is interpolated, evaluated, and stored. During this process, the computer displays:

```
        Process 2 of 4
        Reading 1 of 1
        Process 2 of 4
        Working 1 of 1
        Process 2 of 4
        Storing 1 of 1                                          .
```

After finishing the interpolations, a power curve is calculated. This is done by performing a point-by-point multiplication of the voltage and the current curves. During this process, the computer displays:

```
        Process 3 of 4
        Reading 1 of 1
        Process 3 of 4
        Working 1 of 1
        Process 3 of 4
        Storing 1 of 1                                          .
```

After completing the power curve, the software evaluates the energy curve. This is done by performing a time integral of the power (product) curve. This is evaluated using a trapezoidal approximation discussed in the previous chapter. During this process, the computer displays:

```
        Process 4 of 4
        Reading 1 of 1
        Process 4 of 4
```

```
Working 1 of 1
Process 4 of 4
Storing 1 of 1
```

After the processing is completed, the software asks for a processed data file name. This allows the operator to keep both an unprocessed and a processed data file. Should the operator choose to store under the same name, then the program will take care of purging the old file. In order to store the processed data file, the program asks:

```
What name do you want for the
processed data file?
```

After the processing is completed, and the processed file has been stored, the computer displays:

```
The processing is finished.
```

Then, the program is ready to process another file. The program displays:

```
Would you like to process
another set of curves?  (Y/N)
```

If the operator chooses to process another set of curves, then the operator replies:

```
  Y
```

Then, the software returns to the initialization described at the beginning of this section. Otherwise, the software loads and runs the program, Autost:

```
     MISSION CONTROL
will now resume control.
```

4.8 Summary

Each of these tutorials was developed as an example of correct system operation. They do not reflect, however, the extensive error handling capabilities of the system software. Instead, the operator is presented with the prompts generated by the computer and realistic operator responses.

In addition to the tutorials presented in this chapter, the operator may refer to Appendix C for a complete user's manual. Also, there are program listings contained in Appendix A if the reader is interested in the exact manner in which the operations are performed.

CHAPTER 5

SYSTEM ACCURACY

5.1 Introduction

In the previous chapters, the development of a data acquisition and conditioning system was discussed from conceptualization to implementation. The discussion of the system would not be complete, however, without a discussion of system accuracy. System accuracy will be considered in two (2) distinct areas: 1) data acquisition, and 2) data conditioning.

For the data acquisition discussion, system accuracy is considered to be the difference between the bit accuracy claimed by the manufacturer and the bit accuracy observed during measurements made with the component. To support this line of investigation, the various errors associated with analog to digital conversion were identified and their respective effects on the data analyzed.

For the data conditioning discussion, system accuracy is considered to be the errors associated with the data processing. This processing includes both binary to decimal code conversions and multiplicative scalar corrections. In support of this investigation, the separate numerical algorithms were analyzed.

5.2 Analysis of Acquisition System Accuracy

To ascertain the accuracy of the system components, the inherent errors associated with analog to digital (A/D) conversion were defined. Each type of A/D conversion then was examined to identify the conversion errors which were unique to a given form of A/D conversion. After identifying the pertinent errors for each type of A/D conversion, each subsystem was examined to identify the respective conversion type, thereby identifying the pertinent A/D errors. Finally, measurements were defined and performed to ascertain the system component accuracy.

5.2.1 Definitions of A/D Conversion Accuracy

Each of the subsystems has a component which carries out some A/D conversion. Several different types of errors are associated with any A/D conversion. A/D conversion errors include quantizing error, gain error, offset (zero) error, hysteresis error, non-linearity, and differential non-linearity. These errors are inherent in the A/D conversions carried out by the HP System Voltmeter and the Nicolet Digital Oscilloscope.

Quantizing error is the uncertainty associated with each digital step. All analog values within a given range are represented by the same digital code. Therefore, there is a limited accuracy in the value of the measurement. In most cases, the code is equivalent to the midrange value so that the uncertainty is ±1/2 the least significant bit (LSB).

Gain error is the difference between the actual input voltage and the theoretical input voltage for a full-scale output code. This phenomena can be attributed to errors in reference voltage, ladder resistance values, or amplifier gain. Under these circumstances, some bit(s) in an A/D converter (ADC) would require a larger or smaller step to set the bit(s). Thus, the value associated with the output code is not uniformly weighted.

Offset (zero) error is the required mean value of input voltage to set the output code to zero (0). This error corresponds to some DC offset in the measurement which is due not to the desired channel; rather, the output code reflects an artifact of the measurement setup. This error, however, is removed using software. Under software control, a measurement is taken with the input grounded. This provides a non-zero trace which corresponds to the offset error. The offset error is averaged and removed from the actual measurement by numerical means.

Hysteresis error causes the voltage at which a code transition occurs to be dependent upon the direction from which the transition is approached. Thus, the thresholds associated with each range boundary are dependent upon the direction from which the range is entered. For example, if the range to produce code 1011_2 is from .01 to .02 mV, one would expect the code to change from 1010_2 to 1011_2 at .01 mV for an increasing function and from 1011_2 to 1010_2 at .01 mV for a decreasing function. If the code changed from 1010_2 to 1011_2 at .015 mV for an increasing function and from 1011_2 to 1010_2 at .005 mV for a decreasing function, then one would know that there is a hysteresis error.

Non-linearity describes the deviation of the analog values from a straight line in a plot of the measured conversion relationship. This can be expressed by either of two (2) quantities: 1) integral non-linearity, and 2) differential non-linearity. The integral non-linearity is the overall deviation from a straight line transfer function. This will be referred to simply as non-linearity.

Differential non-linearity is any deviation of the measured "step" from the ideal width. Thus, the differential non-linearity is a measure of the performance at the bit level while integral non-linearity describes the overall behavior of the ADC.

Both types of non-linearity are used to qualify the quantity of monotonicity. Monotonicity insures that an ADC will provide no decreasing output code for an increasing input voltage.

In addition, to the errors associated with standard ADCs, there is also the error associated with stuck bits. This occurs when a bit is in a particular state (1 or 0) and remains in that state despite the change in input voltage. Stuck bits are of particular interest in the Tektronix Programmable Digitizer since it uses a different type of A/D conversion process. Where the HP System Voltmeter and Nicolet Digital Oscilloscope use a successive approximation method for A/D conversion, the Tektronix Programmable Digitizer (7612D) sweeps an electron beam across a semiconductor target.

In this manner, the 7612D directly converts the position of the beam on the target into a digital code. This digital value is then clocked into memory. As such, the errors mentioned earlier do not pose a problem to the 7612D. Only the problem of stuck bits is significant.

5.2.2 Errors in Successive-Approximation A/D Conversion

As noted earlier, the HP System Voltmeter and the Nicolet Digital Oscilloscope are susceptible to several types of error. Of the errors mentioned in section 5.2.1, however, two (2) error types are not significant: 1) quantizing error, and 2) offset (zero) error. The quantizing error is not significant because it is intrinsic to all A/D conversions. This uncertainty is equal to one (1) part in 2^n over the full-scale reading value. For example, an 8-bit ADC with a full-scale reading of 10 volts will have a quantizing error of 39.06 mV. This corresponds to 1/256th of the 10 V full-scale reading.

The offset error is also ignored in the following discussion because the offset error is calibrated out of the measurement by taking a baseline reading prior to the first measurement. This data is then used to evaluate an offset value which is removed from the actual data. This conditioning removes the offset error numerically to allow for both the offset error in the ADC, and the thermal drift and DC offset associated with the plug-in(s).

Thus, there remain five (5) possible errors which can impact the accuracy of the measurement: 1) gain error, 2) hysteresis error, 3) non-linearity, 4) differential non-linearity, and 5) stuck bits. In order to evaluate the possible effect of these errors, a slow triangular waveform was measured using each of the two (2) components. From the resulting data file, each of the errors was examined.

If there is a gain error, then a constant-slope waveform (such as a triangular or saw-tooth wave) will develop a recurring pattern in the individual changes from point to point. For example, instead of having a pattern of 2, 2, 2, 2, 2, 2 there will be a pattern of 2, 4, 3, 2, 4, 3. The latter pattern indicates the bits are not equally weighted.

If there is a hysteresis error, then a constant-slope, symmetrical waveform will not transition from value to value in an equivalent manner on opposite sides of the waveform. This is consistent with the description for hysteresis error given in section 5.2.1.

If there is a problem with non-linearity, the montonicity of the signal will be destroyed. As noted in section 5.2.1, a monotonic ADC will never give decreasing values for an increasing voltage input. By examining the values measured for a triangular or saw-tooth wave, one can find if the curve is truly monotonic. If so, the linearity of the component is within the bounds of 1 1/2 least significant bit (LSB).

Finally, if there are stuck bits, again the monotonicity of the waveform will be destroyed. However, stuck bits will effect the monotonicity of the curve in a manner different from the non-linearity errors. Stuck bits can be characterized in one (1) of two (2) possible patterns: 1) sporadic, and 2) continuous.

A sporadically stuck bit will be seen as isolated points where the waveform is no longer monotonic. This will be easily detectable since the values will not necessarily be consistent. In fact, the error associated with a sporadically stuck bit could also be explained as unwanted noise on the signal channel. However, if this noise does not occur in all of the measurements, one could argue that the error is due to the digitizer rather than the source.

Each continuously stuck bit will prevent one (1) in every 2^n codes from being written for an n-bit ADC. For d stuck bits, an n-bit ADC will be able to generate $2^{(n-d)}$ unique codes. Thus, an 8-bit ADC will be able to develop 128 possible codes instead of 256 codes if there is one (1) stuck bit.

5.2.3 Errors in Direct Conversion A/D Processes

As noted at the end of section 5.2.1, the manner in which the Tektronix Programmable Digitizer (7612D) acquires digital information removes the susceptability of the device to many of the errors mentioned in section 5.2.1. As such, the only anticipated error arises from a problem with stuck bits. (Again, quantizing error and offset error are either insignificant or correctable and are not discussed in the following text.)

Examining the monotonicity of the acquired waveform will provide the information necessary to decide whether or not the device has stuck bits. As noted earlier, this could be a problem of a continuously stuck bit or a sporadically stuck bit. However, due to the fact that the 7612D does not have an intrinsic problem with differential non-linearity, the determination as to whether or not there were stuck bits proved rather simple.

One (1) last error which may occur in data acquisition with the 7612D is the possibility of non-linearity in the sweep circuit. This will cause the beam to sweep across one (1) portion of the target more quickly than another. This will not effect monotonicity. However, it will appear as a non-linear error comparable to that noted for gain error. This non-linear sweep will manifest itself as a repetitive pattern equivalent to that noted for gain error.

5.2.4 HP System Voltmeter Measurements

In accordance with the rationale set forth in section 5.2.2, a triangular waveform was measured using the HP System Voltmeter. The waveform was a 4-volt triangular wave with a frequency of approximately 2 mHz (millihertz). The waveform was digitized approximately once every 3.168 s. This data was then examined for any indications of the errors set forth in section 5.2.2.

First, the data was examined for evidence of gain error. This type of error can be identified by a repetitive unequal bit pattern with a length greater than two (2) bits. This type of pattern was not observed. Therefore, the HP System Voltmeter is presumed to have no appreciable gain error. Next, the monotonicity of the data was examined. Again, there was no indication of error. Since the data was monotonic, it can be inferred that linearity is within the constraints of 1 1/2 least significant bit, and that there were no stuck bits during the measurement.

Finally, the symmetry of the data was examined. If a hysteresis error existed, the symmetry of the data would be perturbed. Again, there was no indication of an error.

Therefore, the errors associated with the A/D conversion of the HP System Voltmeter are within theoretical limits. This indicates that the HP System Voltmeter was operating at the accuracy claimed by the manufacturer. The 3 1/2 digit accuracy of the HP System Voltmeter corresponds to a 12-bit accuracy.

5.2.5 Nicolet Digital Oscilloscope Measurements

Next, a triangular waveform was measured using the Nicolet Digital Oscilloscope. This measurement was patterned after the one performed using the HP System Voltmeter. In this case, the waveform was a 4-volt triangular wave with a frequency of approximately 800 Hz. This waveform was digitized approximately once every .25 µs. This data was then examined for any indications of the errors set forth in section 5.2.2.

First, the data was examined for evidence of gain error. This type of error can be identified by a repetitive unequal bit pattern with a length greater than two bits. This type of pattern was not observed. Therefore, the Nicolet Digital Oscilloscope is presumed to have no appreciable gain error.

Next, the monotonicity of the data was examined. Again, there was no indication of error. Since the data was monotonic, it can be inferred that linearity is within the constraints of 1 1/2 least significant bit, and that there were no stuck bits during the measurement.

Finally, the symmetry of the data was examined. If a hysteresis error existed, the symmetry of the data would be perturbed. Again, there was no indication of an error.

Therefore, the errors associated with the A/D conversion of the Nicolet Digital Oscilloscope are within theoretical limits. This indicates that the Nicolet Digital Oscilloscope was operating at the accuracy claimed by the manufacturer. The accuracy claimed by Nicolet for this particular scope and plug-ins is 12 bits.

5.2.6 Tektronix Programmable Digitizer Measurements

Finally, a triangular waveform was measured using the Tektronix Programmable Digitizer. This measurement was patterned after the previously described measurements. In this case, the waveform was a 4-volt triangular wave with a frequency of approximately 80 kHz. This waveform was digitized approximately once every 50 ns. This data was then examined for the errors described in section 5.2.3.

Unlike the previous tests, there are only two (2) anticipated error types: 1) stuck bits, and 2) non-linear beam sweep. These two (2) errors will be indicated by a lack of monotonicity and a repetitive unequal bit pattern, respectively. The non-linear beam sweep, should it occur, would be comparable in appearance to the gain error mentioned in the previous sections.

First, the monotonicity of the waveform was examined. For a 256-point measurement, there were four (4) points where the waveform was non-monotonic. Two (2) of those four (4) points were measured in the same neighborhood (approximately the same value). An error rate of four (4) in 256 samples is equivalent to one (1) in 64. Thus, for one (1) in every 64 points, the accuracy is reduced to seven (7) bits. For the remaining 63 of every 64 points, the accuracy is eight (8) bits. This represents an average value of slightly less than eight (8) bits. Therefore, the accuracy of the Tektronix Programmable Digitizer will be taken to be seven (7) bits for worst case considerations.

Finally, the data was examined for evidence of a non-linear beam sweep. There was no indication of a repetitive unequal bit pattern such as that described for a gain error in the standard A/D conversions.

Therefore, when the Tektronix Programmable Digitizer is operated at a sampling time of approximately 50 ns, the user can anticipate that the accuracy of the instrument will be seven (7) bits.

5.2.7 HP Graphics Tablet Measurements

In the previous sections, the errors associated with the operation of the HP Graphics Tablet have been ignored. This is due to the fact that establishing a benchmark for a hand-operated digitization device is difficult. The HP Graphics Tablet has an elemental grid whose dimensions are 12032 by 8710 units on a matrix which is 301 mm by 218 mm. This grid structure corresponds to a placement of one (1) element every .025 mm. The manufacturer claims this grid can resolve pen placement to .1 mm. The principle difficulty in validating the resolution of the HP Graphics Tablet is that the resolution is greater than that obtainable by a human. Therefore, the accuracy of the HP Graphics Tablet is presumed to be that given by the manufacturer. For the described grid, one (1) part in 12032 is slightly less than 14-bit accuracy so that 13-bit accuracy will be used for the HP Graphics Tablet.

However, there is a difficulty associated with the operation of the HP Graphics Tablet. This difficulty is inherent to the physics of the digitization process. The location of the pen on the platen is evaluated using the gradient of the electric field. As such, the process is very sensitive to any conductive materials on the platen. Therefore, the user is warned to take care not to use any materials which are electically conductive. This includes graphite pencil leads, some eraseable pen inks, and films using a conductive emulsion. Any of these materials will degrade the resolution of the HP Graphics Tablet significantly by interfering with the mechanism used in digitization. Further discussion of this matter is contained in Appendix C.

5.3 Analysis of Data Conditioning Accuracy

In addition to errors associated with the acquisition process, the data stored by this system has uncertainties associated with data processing. These uncertainties can be described in terms of accuracy. Accuracy is considered to be the difference between the actual value and the estimated value, and is expressed either as a magnitude (e.g., ±1 V) or as a fraction of the full-scale magnitude (e.g., .01 V_{fs}).

The quantities evaluated during the processing are voltage, current, power, and energy. The accuracies for voltage and current are set by the system components used during the data acquisition phase. The bit accuracies for the system components were derived in previous sections. The accuracy associated with power is derived from the individual accuracies for voltage and current. The accuracy associated with the energy calculation is derived from the accuracy of the power calculation and the time resolution capabilities of the particular system component.

In addition to the evaluation of the mentioned quantities, the data processing selects the values at second-breakdown for voltage, current, power, and energy. These values are then rounded to three (3) significant figures. To completely describe the accuracy of the system, the system component time resolutions, computational algorithms, and value selection algorithms are investigated.

5.3.1 System Time Resolution

Time resolution reflects the system's ability to resolve between two (2) adjacent points in time. The closer in time the points are; the greater the resolution of the system. This resolution is set by the digitizing rate of the selected device. The maximum resolution is equivalent to the minimum sample period. The minimum sample period varies from device to device. For the components of this system the minimum sampling periods are: 1) 100 ms for the HP Data Acquisition/Control Unit; 2) 500 ns for the Nicolet Digital Oscilloscope; 3) 5 ns for the Tektronix Programmable Digitizer, and; 4) .1 mm for the HP Graphics Tablet.

Of course, the resolution of the HP Graphics Tablet is given in millimeters rather than some derivative of seconds since it is an x-y format device. This length resolution can be related to an equivalent maximum time resolution in the following manner.

For a standard oscilloscope, the grid format is 10 mm per division. Most modern oscilloscope cameras produce a 1:1 reproduction of the oscilloscope trace. Thus, the resolution of the HP Graphics Tablet corresponds to .01 division. For data stored at 1 ns/division, the HP Graphics Tablet resolution is 10 ps. For example, data quoted in Chapter 4 was digitized using the HP Graphics Tablet. Hence, the resolution of the time data being used for example material is approximately 10 ps.

In general, the time resolution of any system component is equal to the sample period, t_s, with an associated error term of Δt. The time resolution associated with the HP System Voltmeter is set by the timing of the HP-85 Computer. The computer timing command, WAIT, has a resolution of 1 ms. This yields a worst case resolution for the computer of 1 ms. In addition, the algorithm controlling the HP System Voltmeter includes a wait state of .5 s to allow the voltage being measured to settle. This yields a worst case error term of 1 ms in .5 s which corresponds to one (1) part in 500. For the more general case, there will be a programmed delay chosen by the user which will add to the .5 s. Therefore, the error term is one (1) part in ($500 + t_s$) where t_s is expressed in milliseconds.

According to the manufacturer, the error term associated with the Nicolet Digital Oscilloscope is .01% of the sample period. This yields an error term of one (1) part in 10000 of t_s.

According to the manufacturer, the error term associated with the Tektronix Programmable Digitizer is .0035% of the time base frequency, 200 MHz. This yields an error term of .175 ps. This error term is the same for all sample period settings because they are all based on the same single frequency clock.

The time resolution associated with the HP Graphics Tablet is in terms of the total time; however, the total time is dependent upon the physical size of the data being digitized. Since the digitized time data is not necessarily evenly spaced as in the other devices, the HP Graphics Tablet's time resolution can be expressed in terms of the accuracy associated with the physical digitization process. The HP Graphics Tablet has error terms of one (1) part in 12032 and one (1) part in 8710 for a digitizing area that is 301 mm by 218 mm, respectively. The associated error terms are subsets of this digitizing area. Thus, for an oscilloscope trace captured on film with a standard format of ten (10) divisions by eight (8) divisions with 1 cm per division, the error terms are approximately one (1) part in 4000 of the full-scale magnitude in the x direction and one (1) part in 3200 of the full-scale magnitude in the y direction. In conventional use, the time data corresponds to the x direction. Therefore, the error term is one (1) part in 4000 of the total time for a standard oscilloscope trace. In general, the error term is given by

$$\Delta t = t_{tot}(12032\ X_{tot}\ /\ 301)^{-1}$$

where t_{tot} is the total time and X_{tot} is the total length of the data set along its x axis in millimeters.

5.3.2 Computational Accuracy

The steps involved in converting raw voltage and current data to completely processed energy data are: 1) scalar multiplication for conversion from binary format to decimal format; 2) multiplication of voltage and current to calculate instantaneous power, and; 3) time integration of instantaneous power curve to generate energy data.

The voltage and current data can be defined in the following manner:

$$V_{mb} = V_b \pm 1$$

and

$$I_{mb} = I_b \pm 1.$$

V_{mb} and I_{mb} represent the estimated data values. V_b and I_b represent the actual data values.

To produce a decimal value for each of these quantities, the binary numbers are multiplied by appropriate scalar values such that

$$\begin{aligned} V_m &= \Delta V(V_b \pm 1) \\ &= V \pm \Delta V \end{aligned}$$

and

$$\begin{aligned} I_m &= \Delta I(I_b \pm 1) \\ &= I \pm \Delta I \end{aligned}$$

where

$$\Delta V = V_{fs}\ (2^{-n}),$$
$$\Delta I = I_{fs}\ (2^{-m}).$$

V_m and I_m represent the estimated data values. V and I represent the actual data values. ΔV and ΔI represent the estimated accuracies of the data values. V_{fs} and I_{fs} are the respective full-scale values which can be measured by the system components. In general, n and m represent bit accuracies of the respective system components. However, for this system, the two (2) bit accuracies are equivalent, i.e., $m = n$, since the system is designed to take two (2) simultaneous measurements using a single system component.

For this data acquisition system, the values for voltage and current have errors of: 1) one (1) part in 4096 of the full-scale magnitude using the HP System Voltmeter; 2) one (1) part in 4096 of the full-scale magnitude using the Nicolet Digital Oscilloscope, and; 3) one (1) part in 128 of the full-scale magnitude using the Tektronix Programmable Digitizer.

The error term associated with the HP Graphics Tablet is also in terms of the full-scale magnitude; however, the full-scale is dependent upon the data being digitized. The HP Graphics Tablet has error terms of one (1) part in 12032 and one (1) part in 8710 for data that is 301 mm by 218 mm, respectively. The associated error terms are subsets of this active digitizing area. Thus, for an oscilloscope trace captured on film with a standard format of ten (10) divisions by eight (8) divisions with 1 cm per division, the error terms are approximately one (1) part in 4000 of the full-scale magnitude in the x direction (total time in most cases) and one (1) part in 3200 of the full-scale magnitude in the y direction.

The instantaneous power is calculated by multiplying the voltage and current waveforms and can be described as

$$\begin{aligned} P_m &= P + \Delta P \\ &= V_m\, I_m \\ &= (V \pm \Delta V)(I \pm \Delta I) \\ &= VI \pm V\Delta I \pm I\Delta V \pm \Delta V \Delta I. \end{aligned}$$

Substituting in the values for ΔV and ΔI,

$$P_m = VI \pm V(I_{fs}\ 2^{-n}) \pm I(V_{fs}\ 2^{-n}) \pm (V_{fs}\ 2^{-n})(I_{fs}\ 2^{-n}).$$

Thus, the error term for the instantaneous power can be described as

$$\Delta P = V(I_{fs}\ 2^{-n}) + I(V_{fs}\ 2^{-n}) + (V_{fs}\ 2^{-n})(I_{fs}\ 2^{-n}).$$

The worst case error occurs for $V = V_{fs}$ and $I = I_{fs}$. This yields a worse case error of

$$\begin{aligned} \Delta P &= V_{fs}(I_{fs}\ 2^{-n}) + I_{fs}(V_{fs}\ 2^{-n}) + (V_{fs}\ 2^{-n})(I_{fs}\ 2^{-n}) \\ &= V_{fs}\ I_{fs}(2^{-n} + 2^{-n} + 2^{-2n}) \\ &= V_{fs}\ I_{fs}(2^{1-n} + 2^{-2n}). \end{aligned}$$

Since the second term is approximately the square of the first term, the second term in this equation is considered to be insignificant so that the error term becomes

$$\begin{aligned} \Delta P &= V_{fs}\ I_{fs}\ (2^{1-n}) \\ &= P_{max}\ (2^{1-n}). \end{aligned}$$

where P_{max} is the maximum power.

For this data acquisition system, the values for power have errors of: 1) one (1) part in 2048 of P_{max} using the HP System Voltmeter; 2) one (1) part in 2048 of P_{max} using the Nicolet Digital Oscilloscope, and; 3) one (1) part in 64 of P_{max} using the Tektronix Programmable Digitizer. These error terms represent twice that of their respective voltage and current error terms. The corresponding error term for the HP Graphics Tablet is one (1) part in 1600 of P_{max}.

The energy is calculated by summing over the areas described by the equation

$$A = .5(X_{i+1} - X_i)(Y_{i+1} + Y_i)$$

which was derived in section 3.4. For data taken using the HP Graphics Tablet, the area is given as

$$\begin{aligned} A_{mi+1} &= A_{i+1} \pm \Delta A_{i+1} \\ &= .5(t_{i+1} \pm \Delta t - t_i \pm \Delta t)(P_{i+1} \pm \Delta P - P_i \pm \Delta P) \\ &= .5(t_{i+1} - t_i \pm 2\Delta t)(P_{i+1} - P_i \pm 2\Delta P) \\ &= .5(t_{i+1} - t_i)(P_{i+1} - P_i) \pm \Delta t(P_{i+1} - P_i) \pm \\ &\qquad \Delta P(t_{i+1} - t_i) \pm 2\Delta t\Delta P. \end{aligned}$$

As was noted earlier, the term $2\Delta t\Delta P$ represents a second-order error and can be disregarded. Thus, the equation becomes

$$\begin{aligned} A_{mi+1} &= .5(t_{i+1} - t_i)(P_{i+1} - P_i) \pm \Delta t(P_{i+1} - P_i) \\ &\qquad \pm \Delta P(t_{i+1} - t_i). \end{aligned}$$

The energy is a sum over this equation for all i. So the energy is represented as

$$\begin{aligned} E_m &= E \pm \Delta E \\ &= \Sigma(.5(t_{i+1} - t_i)(P_{i+1} - P_i) \pm \Delta t(P_{i+1} - P_i) \pm \Delta P(t_{i+1} - t_i)) \\ &= \Sigma(.5(t_{i+1} - t_i)(P_{i+1} - P_i)) \pm \\ &\qquad \Sigma(\Delta t(P_{i+1} - P_i) + \Delta P(t_{i+1} - t_i)) \end{aligned}$$

so that

$$\Delta E = \Sigma(\Delta t(P_{i+1} - P_i) + \Delta P(t_{i+1} - t_i)).$$

This can be represented as two (2) separate sums

$$\Delta E = \Sigma(\Delta t(P_{i+1} - P_i)) + \Sigma(\Delta P(t_{i+1} - t_i)).$$

Since Δt and ΔP are constants, the expression can be rewritten

$$\Delta E = \Delta t\Sigma(P_{i+1} - P_i) + \Delta P\Sigma(t_{i+1} - t_i).$$

The first sum reduces to $P_m - P_1$, and the second sum reduces to $t_m - t_1$. The initial values for time and power, t_1 and P_1, respectively, are zero (0). Therefore, the error for the energy calculation reduces to

$$\Delta E = t_m\Delta P + P_m\Delta t.$$

The worst case error occurs for $P_m = P_{max}$. (t_m is the total time represented earlier as t_{tot}.) This yields a worse case error term

$$\Delta E = t_{tot}\Delta P + P_{max}\Delta t.$$

Substituting in values for ΔP,

$$\Delta E = t_{tot}P_{max}\ (2^{1-n}) + P_{max}\Delta t.$$

The error term for time, Δt, can be represented in terms of the total time, t_{tot}, as kt_{tot}. Thus, the equation becomes

$$\Delta E = t_{tot}P_{max}\ (2^{1-n}) + P_{max}kt_{tot}$$

$$= t_{tot}P_{max}(2^{1-n} + k)$$
$$= E_{max}(2^{1-n} + k).$$

The error terms for time are: 1) one (1) part in $(500 + t_s)$ in ms using the HP System Voltmeter; 2) one (1) part in 10000 of t_s using the Nicolet Digital Oscilloscope; 3) .175 ps using the Tektronix Programmable Digitizer, and; 4) one (1) part in 4000 of t_{tot} for a standard oscilloscope trace using the HP Graphics Tablet. Expressing these values in terms of the total time, t_{tot}, the error terms for time are: 1) one (1) part in $(500 + t_s)m$ of t_{tot} using the HP System Voltmeter; 2) one (1) part in 10000m of t_{tot} using the Nicolet Digital Oscilloscope; 3) one (1) part in 28571m of t_{tot} using the Tektronix Programmable Digitizer, and; 4) one (1) part in 4000 of t_{tot} for a standard oscilloscope trace using the HP Graphics Tablet for m samples. The largest error terms occur for the smallest sample sets.

For the HP System Voltmeter, the user can select the number of samples, m. Typically, more than 100 measurements will be taken. Using this to bound the equation, the worst case error term occurs when the sample period, t_s, is chosen as zero (0). For $t_s = 0$, the error term is one (1) part in 50000 of t_{tot}.

However, for considerations of energy, a useful quantity is the minimum m which produces a negligible value for k. Presuming that k is negligible for any $2^{1-n} \geq 10k$, k is insignificant any time more than 40 samples are acquired using the HP System Voltmeter. Therefore, the user needs to take a minimum of 40 samples when using the HP System Voltmeter. This yields an error term for time of one (1) part in 20000 of t_{tot}.

For the Nicolet Digital Oscilloscope and the Tektronix Programmable Digitizer, the minimum sample sets are 2048 data and 512 data, respectively. The error terms for time are: 1) one (1) part in 20.5 million of t_{tot} using the Nicolet Digital Oscilloscope, and; 2) one (1) part in 14.6 million of t_{tot} using the Tektronix Programmable Digitizer.

The error terms for power are: 1) one (1) part in 2048 of P_{max} using the HP System Voltmeter; 2) one (1) part in 2048 of P_{max} using the Nicolet Digital Oscilloscope; 3) one (1) part in 64 of P_{max} using the Tektronix Programmable Digitizer, and; 4) one (1) part in 1600 of P_{max}

for the HP Graphics Tablet. Comparing the relative magnitudes of the error terms, k is insignificant for the HP System Voltmeter, the Nicolet Digital Oscilloscope, and the Tektronix Programmable Digitizer while k and 2^{1-n} are comparable for the HP Graphics Tablet.

Therefore, the error terms for energy are: 1) one (1) part in 2048 of E_{max} using the HP System Voltmeter within the constraints outlined in the previous paragraph; 2) one (1) part in 2048 of E_{max} using the Nicolet Digital Oscilloscope; 3) one (1) part in 64 of E_{max} using the Tektronix Programmable Digitizer, and; 4) one (1) part in 1143 of E_{max} for the HP Graphics Tablet.

5.3.3 Value Selection Accuracy

An additional function of the data processing is to select specific values for voltage, current, power, and energy. These values are evaluated at second-breakdown and at 10% of second-breakdown. These values are then rounded to three (3) significant figures. In order to be confident in these values, the data must be accurate to one (1) part in 1000. In Table 5.1, the accuracies for each system component are summarized according to the data type, e.g., voltage or current.

Table 5.1. Summary of Processing Accuracies[1]

Component	Time[2]	Voltage[3]	Power	Energy
HP 3437A	1:20000	1:4096	1:2048	1:2048
Nicolet 2090	1:20.5M	1:4096	1:2048	1:2048
Tek 7612D	1:14.6M	1:128	1:64	1:64
HP 9111A	1:4000	1:3200	1:1600	1:1143

[1] All of the values are with respect to their maximum magnitude.

[2] M represents millions, i.e., 14.6M is 14.6 million.

[3] Voltage accuracies also apply to any signal quantities, e.g., current.

A cursory examination of the summary shows that all values for the HP System Voltmeter, the Nicolet Digital Oscilloscope, and the HP Graphics Tablet are accurate to at least one (1) part in 1000. In addition, the time associated with the Tektronix Programmable Digitizer is accurate to one (1) part in 14.6 million--far greater than one (1) part in 1000. Thus, the user can be confident that a representation of three (3) significant digits is accurate for these quantities.

However, the accuracies associated with the Tektronix Programmable Digitizer are one (1) part in 128 for voltage and current, and one (1) part in 64 for power and energy. For voltage and current, the values should be represented with two (2) significant digits; for the power and energy, the values should be represented with one (1) significant digit. At present, the algorithms in the program controlling the Tektronix Programmable Digitizer do not reflect this inadequacy. To account for this, the user should reduce the values produced to the noted number of significant digits.

5.4 Summary

In conclusion, every type of analog-to-digital conversion has associated uncertainties and errors. These errors are dependent upon the type of A/D conversion which is carried out. By examining the particular type of A/D conversion, one can identify the pertinent errors for a given system component. Thereby, one can define a measurement which will quantify the associated errors.

In this manner, the accuracy of each of the system components was identified and quantified. The HP System Voltmeter, the Nicolet Digital Oscilloscope, and the HP Graphics Tablet perform with accuracies equivalent to the manufacturers' specifications: 1) 12 bits for the HP System Voltmeter and the Nicolet Digital Oscilloscope, and; 2) .1 mm for the HP Graphics Tablet. The Tektronix Programmable Digitzer, however, is susceptible to error. These errors occur at a rate of approximately one (1) in every 64 operations. This reduces the accuracy of the Tektronix Programmable Digitizer to seven (7) bits for a sampling period of 50 ns.

In addition to the errors associated with data acquisition, data processing produces errors. Many of these errors are exagerations of the data acquisition errors. The particular algorithms were analyzed and the error terms were calculated. In this manner, the final accuracy of the system was analyzed according to the quantity of interest and the system component.

This analysis showed that the values for second-breakdown processing are accurate as represented for the HP System Voltmeter, the Nicolet Digital Oscilloscope, and the HP Graphics Tablet. However, the analysis also showed that the representations produced using the Tektronix Programmable Digitizer are less accurate and the lesser accuracies should be noted carefully when using the component.

CHAPTER 6

SUMMARY AND CONCLUSIONS

In Chapter 1, the need for a data acquisition and conditioning system was identified at the Solid State Electronics Laboratory in the Department of Electrical Engineering at Texas Tech University. This need was based upon the history of work carried out by the laboratory. In developing the framework for a system to answer this need, goals were established. The three (3) co-equal goals were to: 1) develop a system which was easy to use by an operator with minimal exposure to a computer; 2) develop a system which could be used on a variety of experiments of interest to the laboratory, and; 3) develop a system which could carry out data acquisition, manipulation, and storage in a timely manner.

To achieve these goals, specific system requirements were defined based upon both on-going research work and anticipated projects. In Chapter 2, these specific requirements were examined, and specific components chosen. These components were selected based upon system requirements, availability, and financial attractiveness. The system requirements were organized by function: 1) data acquisition; 2) data storage; 3) data manipulation, and; 4) data hardcopy output.

Within the category of data acquisition, further categorization occurred based upon time sampling requirements: 1) slow measurements; 2) intermediate measurements; 3) fast measurements, and; 4) very fast measurements (hand entry).

Specific system components were selected to accomplish the duties defined by these requirements. The system components which were defined to fulfill the system requirements were: 1) data acquisition: a) slow measurements: HP3497A Data Acquisition/Control Unit and HP3437A System Voltmeter; b) intermediate measurements: Nicolet 2090-III Digital Oscilloscope; c) fast measurements: Tektronix 7612D Programmable Digitizer, and; d) very fast measurements: HP9111A Graphics Tablet;

2) data storage: HP9895A Flexible Disk Drive; 3) data manipulation: HP85 Desktop Computer, and; 4) data hardcopy output: HP7470A Plotter.

In Chapter 3, these system components were grouped together to develop individual subsystems. In the sections of Chapter 3, these subsystems were examined in detail. Again, these subsystems were to fulfill the system requirements at a subsystem level of organization.

In Chapter 4, the system organization and control was examined. To foster a more complete understanding of the system capabilities, tutorials were formulated which led the reader through the specific operations of the system. Of course, a more thorough explanation of the operations is contained in Appendix C, User's Manual.

Finally, in Chapter 5, the system was used to perform a series of benchmarking tests and the results were analyzed. The accuracy for each operational subsystem was developed.

At this point, a discussion of the effectiveness of the system seems appropriate. In this case, effectiveness would be judged by answering some simple questions: 1) Did the system fulfill the goals set out in Chapter 1? a) Is the system flexible? b) Is the system user-friendly? c) Is the system efficient and timely? 2) How can the system be improved?

In order to answer the initial question, the second, third, and fourth must be answered first. Yes, the system is flexible. As shown clearly in Chapter 4, the system can acquire data from a plethora of digital data takers. The system controls data takers which are capable of sampling from once every 27.775 minutes to once every 5 nanoseconds. These measurements are taken directly. In addition, the system has the capability to enter data by hand. The resolution of this method is limited only by the technology available at the time.

Also, the system can store any data entered. The data then can be retrieved at any future time. The system includes programs to perform preliminary data reduction and conditioning, and to generate hardcopy plots of the data. Therefore, the system seems to be quite flexible.

Yes, the system is user-friendly. The system software was developed so that the interaction between the operator and the computer is clearly defined. The programs include thorough error handling structure. This prevents the system from halting in the middle of an operation due to simple human error. In addition, many of the operations which the system carries out are restricted to menu selections. By using menus and restricting interactive decisions to yes/no selections, much of the human error was effectively negated. Also, the choices posed to the operator were carefully phrased for clarity.

Yes, the system is efficient and timely. When compared with the analysis which was carried on prior to the development of the system, the present situation is far preferable. As was noted in Chapter 1, the old analysis involved graphical analysis by hand. Again, graphic analysis by hand is an extremely tedious and time-consuming task. This discussion, of course, is restricted to computational concerns. Any analysis that requires a human eye cannot be replace by this system -- although this system makes analysis somewhat easier.

Based upon these observations, the conclusion would be made that the system goals were indeed achieved. Since each of the goals was achieved individually, yes, the system goals were achieved. In fact, based upon the error handling capabilities, the point could be made that the system exceeds the goals. A user-friendly system is one which makes operation by a novice easy; this system accomplishes that and, in many cases, notifies the user when an error has occurred, and suggests a corrective course of action.

As far as improvement of the system, there is always room for improvement. There are many areas where the system can be enhanced, among them: 1) enhanced graphics capabilities; 2) increased computational facilities, and; 3) advanced analysis tools including artificial intelligence.

Both the graphics enhancements and the increased computational power are available by interfacing between the present system and a second system within the laboratory. The second system includes an HP2105MX Minicomputer, a Tektronix 4010-I Graphics Terminal, and a Versatek Matrix 1110A Printer/Plotter. By interfacing the two (2) systems, data acquired by the HP85-based system can be processed off-line using the HP2105. Thereby, reducing the work load on the HP85 and accomplishing many of the calculations more quickly. The increased speed is a product of the power of the minicomputer and the fact that it could be used as a dedicated computational device.

In the area of enhanced graphics, at present, the graphics are restricted to the small screen on the HP85 and the plotter. The former gives low resolution but quick access; the latter gives high resolution but is slow. By using the graphics terminal, the operator has the opportunity to have both high resolution and speedy access to data representations. In addition, the printer/plotter gives a middle ground between the high speed, low resolution of the thermal printer and the low speed, high resolution of the plotter.

In the area of advanced analysis tools, two (2) options exist. Initially, interfacing the second system allows the operator the use of the minicomputer as a dedicated computational machine. A second option is to simply develop more analysis tools for the HP85. In either case, development of more advanced analysis software is necessary. The advantage of the minicomputer option, however, is that off-line computational analysis is feasible without tying up the HP85.

In conclusion, at the time of this system's development, the Solid State Electronics Laboratory had the most comprehensive and flexible data acquisition in the Department of Electrical Engineering. This system will prove to be of great value to the graduate students in their work. However, this system is not without flaw. The system has room for improvement, and the opportunities for improvement should be pursued as vigorously as possible.

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APPENDIX A

PROGRAM LISTINGS

INDEX

Autost

The HP85 Desktop Computer has limited memory space. Therefore, to develop an effective data acquisition system the software was divided into several smaller packages. These packages are controlled and accessed by Autost.

The Autost program serves as the central program control for the system. The program controls initialization of the system clock and calendar and functional program branching.

The Autost program allows the operator to select from the functions: (1) data acquisition, (2) data processing, (3) data plotting. Based upon the selections made by the operator, the program ascertains whether the devices necessary to carry out the desired function is online, and runs the program which performs the desired function. After completion, each of the programs return to Autost.

```
10 REM *
20 REM *
30 REM *  MISSION CONTROL
40 REM *    MAIN PROGRAM
50 REM *
60 REM *Copyright:  1/18/85
70 REM * gandalf software, inc.
80 REM * Chuck Graves, wizard
90 REM *
100 REM *
110 COM X$[10]                                 ! Make file name common
120 GOSUB 400                                  ! Initialize registers
130 CLEAR @ BEEP
140 DISP "Press key for desired function."
150 DISP @ DISP "K1 = Choose among data-takers"
160 DISP "K2 = Process data "                  ! Display program options
170 DISP "K3 = Plot curves"
180 DISP "K4 = Plot I-V curve only"
190 DISP "K5 = Use graphics capabilities"
200 ON KEY# 1,"  Data" GOTO 270                ! Acquisition option
210 ON KEY# 2," Process" GOTO 1690             ! Processing option
220 ON KEY# 3,"  Plot" GOTO 1970               ! Plotting option
230 ON KEY# 4,"I-V only" GOTO 1990             ! I-V plot option
240 ON KEY# 5,"Graphics....." GOTO 2230        ! Graphics option
250 KEY LABEL
260 GOTO 260                                   ! Loop until choice
270 CLEAR @ BEEP @ OFF KEY# 5
280 DISP "Press key for desired equipment."
290 DISP @ DISP "K1 = Tektronix 7612D Digitizer"
300 DISP "K2 = Nicolet Digital O-scope"        ! Display data
310 DISP "K3 = HP Multiplexer & Voltmeter"     ! acquisition options
320 DISP "K4 = HP Graphics Tablet"
330 ON KEY# 1," 7612D" GOTO 540                ! Tek 7612D option
340 ON KEY# 2,"Nicolet" GOTO 910               ! Nicolet option
350 ON KEY# 3," HP Mux" GOTO 1200              ! HP DACU/VM option
```

```
360 ON KEY# 4," Tablet" GOTO 1410                ! HP Graph Tablet option
370 KEY LABEL
380 GOTO 380                                     ! Loop until choice
390 END
400 REM *
410 REM *
420 REM *  INITIALIZATION
430 REM *    SUBROUTINE
440 REM *
450 REM *
460 SET TIMEOUT 7;10000                          ! Set HPIB timeout
470 ON ERROR GOSUB 510                           ! Trap disk errors
480 IF X$="NULL" THEN RETURN
490 IF DATE<101 OR DATE>1231 THEN GOSUB 2660     ! Time/date invalid?
500 RETURN
510 IF ERRN=7 THEN X$="NULL"                     ! Set default name
520 OFF ERROR
530 RETURN
540 REM *
550 REM *
560 REM *  7612D SYSTEM
570 REM *    SUBROUTINE
580 REM *
590 REM *
600 ON ERROR GOSUB 890                           ! Trap timeout error
610 CLEAR @ BEEP
620 DISP "Do you want to use the 7612D as"
630 DISP "a normal O-scope or a one-shot"
640 DISP "storage scope? (NORM/SINGLE)"
650 INPUT Q$                                     ! Normal or single-shot?
660 A=700 @ A$="disk drive"                      ! Set values for disk
670 GOSUB 740                                    ! Check for device
680 A=702 @ A$="digitizer"                       ! Set values for 7612D
690 GOSUB 740                                    ! Check for device
700 IF Q$="SINGLE" THEN GOSUB 2340               ! Aux measurements?
```

```
710 OFF ERROR
720 IF Q$="SINGLE" THEN CHAIN "7612D:D700"      ! Load single-shot prog
730 CHAIN "NORML:D700"                          ! Load normal prog
740 ON TIMEOUT 7 GOTO 840                       ! Set timeout branch
750 IF A≠700 THEN 790                           ! Not disk drive
760 ASSIGN# 1 TO "LAMB:D700"                    ! Open dummy file
770 ASSIGN# 1 TO *                              ! Close dummy file
780 RETURN
790 SEND 7 ; UNL MTA LISTEN 2 SCG 0             ! 7612D Listener
800 OUTPUT 7 ;"ID?"                             ! Get 7612D ID
810 SEND 7 ; UNT MLA TALK 2 SCG 0               ! 7612D Talker
820 ENTER 7 USING "K" ; B$                      ! Accept 7612D response
830 RETURN
840 DISP "The ";A$;" is OFF. Turn"              ! Notify user of
850 DISP "ON the ";A$;" and press"              ! timeout and ask for
860 DISP "CONTINUE."                            ! corrective actions
870 RESET 7 @ PAUSE                             ! Reset HPIB
880 GOTO 610                                    ! Retry to find subsystem
890 IF ERRN=131 THEN 840                        ! Timeout error
900 RETURN
910 REM *
920 REM *
930 REM *  NICOLET SYSTEM
940 REM *     SUBROUTINE
950 REM *
960 REM *
970 ON ERROR GOSUB 1180                         ! Trap timeout error
980 CLEAR @ BEEP
990 A=700 @ A$="disk drive" @ B=1               ! Set values for disk
1000 GOSUB 1050                                 ! Check for device
1010 A=714 @ A$="Nicolet o-scope" @ B=2         ! Set values for Nicolet
1020 GOSUB 1050                                 ! Check for device
1030 GOSUB 2340                                 ! Chk aux measurements
1040 OFF ERROR @ CHAIN "NIC85:D700"             ! Load Nicolet prog
1050 ON TIMEOUT 7 GOTO 1130                     ! Set timeout branch
```

```
1060 IF A≠700 THEN 1100                    ! Not disk drive
1070 ASSIGN# 1 TO "LAMB:D700"              ! Open dummy file
1080 ASSIGN# 1 TO *                        ! Close dummy file
1090 RETURN
1100 OUTPUT A+1 ;"D4"                      ! Address Nicolet
1110 ENTER A USING "K" ; C1,C2             ! Accept Nicolet response
1120 RETURN
1130 DISP "The ";A$;" is OFF. Turn"        ! Notify user of
1140 DISP "ON the ";A$;" and press"        ! timeout and ask for
1150 DISP "CONTINUE."                      ! corrective actions
1160 RESET 7 @ PAUSE                       ! Reset HPIB
1170 GOTO 980                              ! Retry to find subsystem
1180 IF ERRN=131 THEN 1130                 ! Timeout error
1190 RETURN
1200 REM *
1210 REM *
1220 REM *  HP3497A SYSTEM
1230 REM *    SUBROUTINE
1240 REM *
1250 REM *
1260 ON ERROR GOSUB 1390                   ! Trap timeout error
1270 CLEAR @ BEEP
1280 A=700 @ A$="disk drive"               ! Set values for disk
1290 ON TIMEOUT 7 GOTO 1340                ! Set timeout branch
1300 ASSIGN# 1 TO "LAMB:D700"              ! Open dummy file
1310 ASSIGN# 1 TO *                        ! Close dummy file
1320 GOSUB 2470                            ! Chk aux measurements
1330 OFF ERROR @ CHAIN "HP-DAS:D700"       ! Load DACU/VM prog
1340 DISP "The ";A$;" is OFF. Turn"        ! Notify user of
1350 DISP "ON the ";A$;" and press"        ! timeout and ask for
1360 DISP "CONTINUE."                      ! corrective actions
1370 PAUSE
1380 RESET 7 @ GOTO 1270                   ! Reset HPIB & retry
1390 IF ERRN=131 THEN 1340                 ! Timeout error
1400 RETURN
```

```
1410 REM *
1420 REM *
1430 REM *  HP9111A SYSTEM
1440 REM *    SUBROUTINE
1450 REM *
1460 REM *
1470 ON ERROR GOSUB 1670                    ! Trap timeout error
1480 CLEAR @ BEEP
1490 A=700 @ A$="disk drive"                ! Set values for disk
1500 GOSUB 1540                             ! Check for device
1510 A=706 @ A$="HP graphics tablet"        ! Set values for tablet
1520 GOSUB 1540                             ! Check for device
1530 OFF ERROR @ CHAIN "TABLET:D700"        ! Load Tablet prog
1540 ON TIMEOUT 7 GOTO 1620                 ! Set timeout branch
1550 IF A≠700 THEN 1590                     ! Not disk drive
1560 ASSIGN# 1 TO "LAMB:D700"               ! Open dummy file
1570 ASSIGN# 1 TO *                         ! Close dummy file
1580 RETURN
1590 OUTPUT A ;"OI"                         ! Address graphics tablet
1600 ENTER A USING "K" ; B$                 ! Accept tablet response
1610 RETURN
1620 DISP "The ";A$;" is OFF. Turn"         ! Notify user of
1630 DISP "ON the ";A$;" and press"         ! timeout and ask for
1640 DISP "CONTINUE."                       ! corrective actions
1650 RESET 7 @ PAUSE                        ! Reset HPIB
1660 GOTO 1480                              ! Retry to find subsystem
1670 IF ERRN=131 THEN 1620                  ! Timeout error
1680 RETURN
1690 REM *
1700 REM *
1710 REM *  PROCESSING SYSTEM
1720 REM *    SUBROUTINE
1730 REM *
1740 REM *
1750 ON ERROR GOSUB 1890                    ! Trap timeout error
```

```
1760 CLEAR @ BEEP
1770 A=700 @ A$="disk drive"                  ! Set values for disk
1780 GOSUB 1800                               ! Check for device
1790 OFF ERROR @ CHAIN "MATH:D700"            ! Load processing
1800 ON TIMEOUT 7 GOTO 1840                   ! Set timeout branch
1810 ASSIGN# 1 TO "LAMB:D700"                 ! Open dummy file
1820 ASSIGN# 1 TO *                           ! Close dummy file
1830 RETURN
1840 DISP "The ";A$;" is OFF. Turn"           ! Notify user of
1850 DISP "ON the ";A$;" and press"           ! timeout and ask for
1860 DISP "CONTINUE."                         ! corrective actions
1870 RESET 7 @ PAUSE                          ! Reset HPIB
1880 GOTO 1760                                ! Retry to find subsystem
1890 IF ERRN=131 THEN 1840                    ! Timeout error
1900 RETURN
1910 REM *
1920 REM *
1930 REM *  PLOTTING SYSTEM
1940 REM *    SUBROUTINE
1950 REM *
1960 REM *
1970 B=3
    ! Set for plot option
1980 GOTO 2000
1990 B=4
    ! Set for I-V option
2000 ON ERROR GOSUB 2210                      ! Trap timeout error
2010 CLEAR @ BEEP
2020 A=700 @ A$="disk drive"                  ! Set values for disk
2030 GOSUB 2080                               ! Check for device
2040 A=705 @ A$="plotter"                     ! Set values for plotter
2050 GOSUB 2080                               ! Check for device
2060 IF B=3 THEN CHAIN "PLOT:D700"            ! Load Plot prog
2070 OFF ERROR @ CHAIN "I-V:D700"             ! Load I-V prog
2080 ON TIMEOUT 7 GOTO 2160                   ! Set timeout branch
```

```
2090 IF A≠700 THEN 2130                        ! Not disk drive
2100 ASSIGN# 1 TO "LAMB:D700"                  ! Open dummy file
2110 ASSIGN# 1 TO *                            ! Close dummy file
2120 RETURN
2130 OUTPUT A ;"OI"                            ! Address plotter
2140 ENTER A USING "K" ; B$                    ! Accept plotter response
2150 RETURN
2160 DISP "The ";A$;" is OFF. Turn"            ! Notify user of
2170 DISP "ON the ";A$;" and press"            ! timeout and ask for
2180 DISP "CONTINUE."                          ! corrective actions
2190 RESET 7 @ PAUSE                           ! Reset HPIB
2200 GOTO 2000                                 ! Retry to find subsystem
2210 IF ERRN=131 THEN 2160                     ! Timeout error
2220 RETURN
2230 REM *
2240 REM *
2250 REM *  GRAPHICS SYSTEM
2260 REM *    SUBROUTINE
2270 REM *
2280 REM *
2290 CLEAR @ BEEP
2300 DISP "This program is not operational."   ! Notify user that
2310 DISP "Please choose another function."    ! graphics not
2320 WAIT 4500                                 ! functional
2330 GOTO 130                                  ! Return to main prog
2340 REM *
2350 REM *
2360 REM *  AUXILIARY VOLTAGE
2370 REM *    SUBSYSTEM
2380 REM *
2390 REM *
2400 CLEAR @ BEEP
2410 DISP "Do you want to use the system"
2420 DISP "voltmeter to make additional"
2430 DISP "readings?  (Y/N)"
```

```
2440 INPUT V$
2450 IF V$="Y" THEN 2470                      ! Aux measurements?
2460 RETURN                                   ! No, return
2470 ON ERROR GOSUB 2640                      ! Yes, trap timeout error
2480 A=709 @ A$="HP control unit" @ B$="TD"   ! Set values for DACU
2490 GOSUB 2530                               ! Check for device
2500 A=724 @ A$="HP voltmeter" @ B$="R1"      ! Set values for DVM
2510 GOSUB 2530                               ! Check for device
2520 RETURN
2530 ON TIMEOUT 7 GOTO 2580                   ! Set timeout branch
2540 CLEAR A @ OUTPUT A ;B$                   ! Clear & Send setting
2550 IF A=724 THEN TRIGGER A                  ! Trigger if DVM
2560 ENTER A ; B$                             ! Accept response
2570 RETURN
2580 CLEAR @ BEEP
2590 DISP "The ";A$;" is OFF. Turn"           ! Notify user of
2600 DISP "ON the ";A$;" and press"           ! timeout and ask for
2610 DISP "CONTINUE."                         ! corrective actions
2620 PAUSE
2630 RESET 7 @ GOTO 2480                      ! Reset HPIB & retry
2640 IF ERRN=131 THEN 2580                    ! Timeout error
2650 RETURN
2660 REM *
2670 REM *
2680 REM *  TIME AND DATE
2690 REM *    SUBROUTINE
2700 REM *
2710 REM *
2720 CLEAR @ BEEP
2730 DISP "Enter the date in a MMDD format."
2740 DISP @ DISP "For example, March 5 is entered"
2750 DISP "0305."
2760 INPUT A$                                 ! Input date string
2770 A=VAL(A$[1,2])                           ! Month = A
2780 IF A>12 THEN 2840                        ! Month invalid; retry
```

```
2790 IF A>7 THEN A=A-7                        ! Identify 31-day months
2800 B=VAL(A$[3,4])                           ! Day = B
2810 IF FP(A/2)≠0 AND B<32 THEN 2890          ! 31-day month valid
2820 IF VAL(A$[1,2])=2 AND B<30 THEN 2890     ! February valid
2830 IF FP(A/2)=0 AND B<31 THEN 2890          ! 30-day month valid
2840 CLEAR @ BEEP
2850 DISP "The date you entered cannot be"
2860 DISP "correct.  Please re-enter."
2870 WAIT 4500
2880 GOTO 2720                                ! Re-enter date
2890 CLEAR @ BEEP
2900 DISP "Enter the time in an HHMMSS"
2910 DISP "format."
2920 DISP @ DISP "For example, 3 a.m. is entered"
2930 DISP "030000."
2940 INPUT B$                                 ! Input time string
2950 A=VAL(B$[1,2])                           ! Hours = A
2960 B=VAL(B$[3,4])                           ! Minutes = B
2970 C=VAL(B$[5,6])                           ! Seconds = C
2980 IF A<24 AND B<60 AND C<60 THEN 3040      ! Time valid
2990 CLEAR @ BEEP
3000 DISP "The time you entered cannot be"
3010 DISP "correct.  Please re-enter."
3020 WAIT 4500
3030 GOTO 2890                                ! Re-enter time
3040 SETTIME A*3600+B*60+C,VAL(A$)            ! Set time/date
3050 RETURN
```

HP-DAS

The HP-DAS program controls the HP3497A Data Acquisition/Control Unit (DACU) and HP3437A Digital Voltmeter (DVM). These instruments are used to make up to four (4) 256-point measurements. The operator selects the input channel(s), voltage range(s), sampling time, and test period. The program uses these quantities to acquire data. After completion, the program generates an alarm to notify the operator. The program, then, stores the curves in pairs. These pairs are selected by the operator.

```
10 REM *
20 REM *
30 REM *  3497A CONTROLLER
40 REM *    MAIN PROGRAM
50 REM *
60 REM *Copyright:  6/6/85
70 REM * gandalf software, inc.
80 REM * Chuck Graves, wizard
90 REM *
100 REM *
110 COM X$[10]                                ! Make file name common
120 DIM X(4,256),Y(4,256),P(4,5,C(2,4),T(2)
130 CLEAR @ BEEP
140 DISP "Initializing"
150 GOSUB 1390                                ! Initialize registers
160 CLEAR @ BEEP
170 DISP "How many channels are to be"
180 DISP "monitored by voltmeter? (4 max.)"
190 INPUT P1                                  ! Input # channels
200 P1=IP(P1)                                 ! Make integer #
210 IF P1>0 AND P1<5 THEN 260                 ! # channels valid?
220 CLEAR @ BEEP                              ! No, notify user
230 DISP "Please choose a number from 1 "
240 DISP "to 4."
250 WAIT 4500 @ GOTO 160                      ! Re-enter # channels
260 FOR I=1 TO P1                             ! Yes, cont
270 CLEAR @ BEEP
280 DISP "Enter the channel number and the"
290 DISP "voltage range."
300 DISP @ DISP "(.1V = 1,1V = 2, and 10V = 3)"
310 INPUT A,B                                 ! Channel, voltage rng
320 A=IP(A) @ B=IP(B)                         ! Make integers
330 IF A>-1 AND A<1000 THEN 370               ! Channel valid?
340 CLEAR @ BEEP                              ! No, notify user
350 DISP "Please enter a number 0-999."
```

```
360 WAIT 4500 @ GOTO 270                   ! Re-enter chan, rng
370 IF B>0 AND B<4 THEN 410                ! Yes; voltage rng valid?
380 CLEAR @ BEEP                           ! No, notify user
390 DISP "Please enter a number 1-3."
400 WAIT 4500 @ GOTO 270                   ! Re-enter chan, rng
410 FOR J=1 TO I                           ! Yes, chk entries
420 IF C(1,J)≠A THEN 470                   ! Entered previously?
430 CLEAR @ BEEP                           ! Yes, notify user
440 DISP "You have already chosen that"
450 DISP "channel. Please enter another."
460 WAIT 4500 @ GOTO 270                   ! Re-enter chan, rng
470 NEXT J
480 C(1,I)=A @ C(2,I)=B                    ! No, store values
490 NEXT I
500 CLEAR @ BEEP
510 DISP "Enter the time between samples."
520 DISP @ DISP "(There will automatically be a "
530 DISP "2-second delay between groups"
540 DISP "of measurements. M=minutes,"
550 DISP "S=seconds. Seperate number from"
560 DISP "unit with a comma. [Ex. 30,S])"
570 INPUT A,A$                             ! Input delay time
580 IF A$="M" OR A$="S" THEN 620           ! Units valid?
590 CLEAR @ BEEP                           ! No, notify user
600 DISP "Re-enter with correct units."
610 WAIT 4500 @ GOTO 500                   ! Re-enter delay time
620 T1=A*1000                              ! Yes, convert s to ms
630 IF A$="M" THEN T1=T1*60                ! Finish for m to ms
640 IF T1<=1666650 THEN 690                ! Is delay too long?
650 CLEAR @ BEEP                           ! Yes, notify user
660 DISP "Maximum delay of 27.775 minutes."
670 DISP "Re-enter with a smaller number."
680 WAIT 4500 @ GOTO 500                   ! Re-enter delay time
690 CLEAR @ BEEP
700 DISP "Enter the total time over which"
```

```
710 DISP "to take samples. (Max. ";VAL$(256*A);A$;")"
720 DISP @ DISP "(Seperate number from unit with"
730 DISP "a comma.)"
740 INPUT B,B$                                 ! Input sample time
750 IF B$="M" OR B$="S" THEN 790               ! Units valid?
760 CLEAR @ BEEP                               ! No, notify user
770 DISP "Re-enter with correct units."
780 WAIT 4500 @ GOTO 690                       ! Re-enter sample time
790 T2=B*1000                                  ! Convert s to ms
800 IF B$="M" THEN T2=T2*60                    ! Finish for m to ms
810 IF T2/T1<=256 THEN 860                     ! Enough room?
820 CLEAR @ BEEP                               ! No, notify user.
830 DISP "Not enough room. Enter smaller"
840 DISP "number."
850 WAIT 4500 @ GOTO 690                       ! Re-enter sample time
860 T2=IP(T2/T1)                               ! Yes, make integer
870 CLEAR 709 @ CLEAR 724                      ! Clear DACU & DVM
880 OUTPUT 709 ;"AF0AL999AC0"                  ! Select 0 of 0-999
890 OUTPUT 724 ;"T3R3D.1S"                     ! Man trg;10V rng;.1s dly
900 T(1)=DATE @ T(2)=TIME                      ! Set start time/date
910 FOR I=1 TO T2
920 CLEAR @ BEEP
930 DISP "Taking data."
940 GOSUB 1630                                 ! Get data
950 CLEAR @ BEEP
960 DISP "Waiting."
970 WAIT T1                                    ! Wait for next meas
980 NEXT I
990 CLEAR @ BEEP
1000 DISP "The data is stored."
1010 DISP @ DISP "Press K1 to continue program."
1020 ON KEY# 1,"CONT" GOTO 1050                ! Set cont branch
1030 KEY LABEL
1040 BEEP 10,700 @ BEEP 9,700 @ GOTO 1040      ! Sound alarm
1050 OFF KEY# 1
```

```
1060 GOSUB 1780                                ! Assign mass storage
1070 CLEAR @ BEEP
1080 DISP "There are ";P1;" curves."
1090 FOR I=1 TO P1                             ! Store single curves
1100 DISP "Enter the name for curve ";VAL$(I);"."
1110 INPUT X$                                  ! Enter file name
1120 P(I,4)=T2                                 ! Set # data pts
1130 IF LEN(X$)>0 AND LEN(X$)<11 THEN 1190     ! Name too large?
1140 CLEAR @ BEEP                              ! Yes, notify user
1150 DISP "Name is too large. Pick a name"
1160 DISP "with less than 11 letters."
1170 WAIT 4500 @ CLEAR
1180 BEEP @ GOTO 1100                          ! Re-enter file name
1190 CLEAR @ BEEP                              ! No, cont
1200 DISP "Storing data in ";X$
1210 GOSUB 1920                                ! Store data
1220 CLEAR @ BEEP
1230 NEXT I
1240 DISP "Do you want to take another set"
1250 DISP "of data? (Y/N)"
1260 INPUT Q$                                  ! More data?
1270 IF Q$≠"Y" THEN 1310
1280 CLEAR @ BEEP                              ! Yes, re-initialize
1290 DISP "Re-initializing"
1300 GOTO 150                                  ! Repeat process
1310 CLEAR @ BEEP                              ! No, return to Autost
1320 DISP "    MISSION CONTROL"
1330 DISP "will now resume control."
1340 FOR I=1 TO 65
1350 BEEP 65-I,20
1360 NEXT I
1370 CHAIN "Autost:D700"                       ! Load Autost prog
1380 END
1390 REM *
1400 REM *
```

```
1410 REM *  INITIALIZATION
1420 REM *    SUBROUTINE
1430 REM *
1440 REM *
1450 FOR I=1 TO 4
1460 FOR J=1 TO 256
1470 X(I,J)=0                                 ! Initialize time
1480 Y(I,J)=0                                 ! Initialize voltage
1490 NEXT J
1500 FOR J=1 TO 5
1510 P(I,J)=0                                 ! Initialize cntl reg
1520 NEXT J
1530 P(I,5)=86                                ! Set units to "V"
1540 NEXT I
1550 FOR I=1 TO 2
1560 FOR J=1 TO 4
1570 C(I,J)=1000                              ! Init chan/rng reg
1580 NEXT J
1590 NEXT I
1600 T(1)=0 @ T(2)=0
1610 R$=":D700"                               ! Default mass storage
1620 RETURN
1630 REM *
1640 REM *
1650 REM *  DATA ACQUISITION
1660 REM *    SUBROUTINE
1670 REM *
1680 REM *
1690 FOR J=1 TO P1
1700 OUTPUT 709 ;"AC"&VAL$(C(1,J))            ! Close chan on DACU
1710 OUTPUT 724 ;"R"&VAL$(C(2,J))             ! Set rng on DVM
1720 WAIT 500                                 ! Let voltage settle
1730 TRIGGER 724                              ! Trigger DVM
1740 ENTER 724 ; Y(J,I)                       ! Store DVM voltage
1750 X(J,I)=TIME-T(2)                         ! Store time
```

```
1760 NEXT J
1770 RETURN
1780 REM *
1790 REM *
1800 REM *  MASS STORAGE
1810 REM *     SUBROUTINE
1820 REM *
1830 REM *
1840 CLEAR @ BEEP
1850 DISP "Where do you want to store these"
1860 DISP "curves? (DISK00/DISK01/TAPE)"
1870 INPUT Q$                                   ! Input destination
1880 IF Q$="DISK01" THEN R$=":D701"
1890 IF Q$="TAPE" THEN R$=":T"
1900 MASS STORAGE IS R$                         ! Set mass storage unit
1910 RETURN
1920 REM *
1930 REM *
1940 REM *  STORE SUBROUTINE
1950 REM *     1) CREATE FILE
1960 REM *     2) STORE CURVE
1970 REM *
1980 REM *
1990 ON ERROR GOTO 2220                         ! Trap file create error
2000 CREATE X$,10+2*P(I,4),8                    ! Create file space
2010 OFF ERROR
2020 ASSIGN# 1 TO X$                            ! Open file
2030 PRINT# 1,1 ; 1                             ! # of curves in file
2040 PRINT# 1,2 ; 10                            ! # of horiz divisions
2050 PRINT# 1,3 ; 8                             ! # of vert divisions
2060 PRINT# 1,4 ; T(1)                          ! start time for meas
2070 PRINT# 1,5 ; T(2)                          ! date of measurement
2080 GOSUB 2380                                 ! Get channel conversion
2090 GOSUB 2690                                 ! Calculate cntl values
2100 K=6
```

```
2110 FOR J=1 TO 5
2120 PRINT# 1,K ; P(I,J)                      ! Store cntl values
2130 K=K+1
2140 NEXT J
2150 FOR J=1 TO P(I,4)
2160 PRINT# 1,K ; X(I,J)                      ! Store time values
2170 PRINT# 1,K+P(I,4) ; Y(I,J)*M             ! Store magnitude values
2180 K=K+1                                    ! (Stored time array,
2190 NEXT J                                   !    then magn array)
2200 ASSIGN# 1 TO *                           ! Close file
2210 RETURN
2220 OFF ERROR
2230 IF ERRN≠63 THEN 2330                     ! File already exist?
2240 CLEAR @ BEEP                             ! Yes, notify user
2250 DISP "File already exists. Do you want"
2260 DISP "to purge? (Y/N)"
2270 INPUT Q$                                 ! Purge existing file?
2280 IF Q$="Y" THEN PURGE X$ @ GOTO 2000      ! Yes, purge & cont
2290 CLEAR @ BEEP                             ! No, enter new name
2300 DISP "Enter another name."
2310 INPUT X$
2320 GOTO 1990                                ! Retry storage
2330 IF ERRN≠130 THEN 2000                    ! Disk error; no, retry
2340 CLEAR @ BEEP                             ! Yes, notify user
2350 DISP "Disk error. Re-enter storage."
2360 WAIT 4500
2370 GOTO 1060                                ! Re-assign mass storage
2380 REM *
2390 REM *
2400 REM * CONVERSION SUBROUTINE
2410 REM *   1) SCALE INPUT
2420 REM *
2430 REM *
2440 CLEAR @ BEEP @ M=1
2450 DISP "Is an attenuator, current"
```

```
2460 DISP "transformer, thermocouple, etc.,"
2470 DISP "being used? (Y/N)"
2480 INPUT Q$                                ! Meas reflect voltage?
2490 IF Q$≠"Y" THEN RETURN                   ! Yes, return
2500 CLEAR @ BEEP                            ! No, enter conversion
2510 DISP "What is the conversion process?"
2520 DISP @ DISP "(For example, a 6-dB atttenuator"
2530 DISP "converts a 2-volt input at the"
2540 DISP "source to a 1-volt input at the"
2550 DISP "scope. So conversion is 2V to"
2560 DISP "1V - entered 2V, 1V. Enter using"
2570 DISP "scientific notation and proper"
2580 DISP "units - A, V, K, etc.)"
2590 INPUT W$,Q$                             ! Input conversion string
2600 P(I,5)=NUM(W$[LEN(W$),LEN(W$)])         ! Assign cntl reg units
2610 IF NUM(Q$[LEN(Q$),LEN(Q$)])=86 THEN 2670 ! RH entry voltage?
2620 CLEAR @ BEEP                            ! No, notify user
2630 DISP "Incorrect entry. The voltage "
2640 DISP "entry should be on the right."
2650 DISP "Re-enter."
2660 WAIT 4500 @ GOTO 2500                   ! Re-enter conversion
2670 M=VAL(W$)/VAL(Q$)                       ! Calculate scale factor
2680 RETURN
2690 REM *
2700 REM *
2710 REM *  SORT SUBROUTINE
2720 REM *     1) FIND UNIT/DIV
2730 REM *
2740 REM *
2750 G=Y(I,1)                                ! Set default minimum
2760 H=Y(I,1)                                ! Set default maximum
2770 FOR J=2 TO P(I,4)
2780 IF Y(I,J)<G THEN G=Y(I,J)               ! Set new minimum
2790 IF Y(I,J)>H THEN H=Y(I,J)               ! Set new maximum
2800 NEXT J
```

```
2810 P(I,1)=X(I,P(I,4))/10                        ! Set time per division
2820 P(I,2)=(H-G)/8                               ! Set magnitude per div
2830 IF H-G<H THEN P(I,2)=H/8                     ! If max & min > 0, set
2840 RETURN                                       ! mag/div so min = 0
```

NIC85

The NIC85 program is a highly modified version of a software package purchased from Software Consulting Group of Santa Clara, California. The program controls the Nicolet 2090-III Digital Oscilloscope and, if desired, the HP3497A Data Acquisition/Control Unit (DACU) and HP3437A Digital Voltmeter (DVM).

The oscilloscope is used to make up to four (4) 1024-point measurements. The operator takes the measurements using the oscilloscope. Once a good measurement is acquired, the program stores the curves in pairs. These pairs are selected by the operator.

The DACU and DVM are used to take measurements of slower phenomena. They are used to make up to four (4) 16-point measurements. These instruments are used during the storage cycle of the program. This data is stored by the program, and, later, processed using the VMAUX program.

```
10 REM *
20 REM *
30 REM *  NICOLET-85
40 REM *    MAIN PROGRAM
50 REM *
60 REM *Copyright:  7/8/85
70 REM * gandalf software, inc.
80 REM * Chuck Graves, wizard
90 REM *
100 REM *
110 COM X$[10]                                  ! Make file name common
120 DIM D$[8200],H$[29]
130 SHORT P(3,5),T(2,69),A(7),B(7),C(7),D(7),Z(7)
140 CLEAR @ BEEP
150 DISP @ DISP "Initializing"
160 GOSUB 1050                                  ! Initialize registers
170 CLEAR @ BEEP
180 DISP "Do you want to use the system"
190 DISP "voltmeter to make additional"
200 DISP "measurements? (Y/N)"
210 INPUT V$                                    ! Make aux measurements?
220 IF V$="Y" THEN GOSUB 1360                   ! Yes, setup aux meas
230 CLEAR @ BEEP
240 DISP "Set-up Nicolet and take "
250 DISP "measurement."
260 DISP @ DISP "When you have the curve you"
270 DISP "wish to store, press CONTINUE."
280 PAUSE
290 OUTPUT 715 ;"N1"                            ! Ask for norm factors
300 GOSUB 1780                                  ! Get norms for curve 1
310 FOR I=1 TO 7
320 A(I)=Z(I)                                   ! Store norms for curve 1
330 NEXT I
340 P1=A(3)                                     ! Set number of curves
350 IF P1>=4 THEN 480                           ! Too many curves?
```

```
360 CLEAR @ BEEP                               ! No, cont
370 DISP "The processing package can"
380 DISP "handle no more than 1024 data"
390 DISP "per curve. Therefore, only 1024"
400 DISP "of the data will be used by the"
410 DISP "processing program. This is"
420 DISP "equivalent to using Q1 to Q4."
430 DISP "To view what will be processed,"
440 DISP "turn the MEMORY switch to Q3."
450 DISP @ DISP "To resume: restore MEMORY to ALL"
460 DISP "and press CONTINUE."
470 PAUSE
480 IF P1≠8 THEN 540
490 CLEAR @ BEEP                               ! Yes, notify user
500 DISP "This program can handle only 4"
510 DISP "curves per run. Please do over."
520 WAIT 4500 @ GOSUB 1300                     ! Re-initialize cntl reg
530 GOTO 230                                   ! Start over
540 IF P1=1 THEN 680                           ! No more curves
550 GOSUB 1780                                 ! Get norms for curve 2
560 FOR I=1 TO 7
570 B(I)=Z(I)                                  ! Store norms for curve 2
580 NEXT I
590 IF P1=2 THEN 680                           ! No more curves
600 GOSUB 1780                                 ! Get norms for curve 3
610 FOR I=1 TO 7
620 C(I)=Z(I)                                  ! Store norms for curve 3
630 NEXT I
640 GOSUB 1780                                 ! Get norms for curve 4
650 FOR I=1 TO 7
660 D(I)=Z(I)                                  ! Store norms for curve 4
670 NEXT I
680 CLEAR 7                                    ! Clear HPIB
690 S1=4096/P1                                 ! Set skip count
700 P(1,3)=DATE @ P(2,3)=TIME                  ! Store start date/time
```

```
710 IOBUFFER D$                              ! Declare I/O buffer
720 OUTPUT 715 ;"D3D2"                       !
730 TRANSFER 714 TO D$ FHS ; EOI             ! Fast transfer data
740 CLEAR @ BEEP                             ! Disp program options
750 DISP "K1 = Store all data."
760 DISP "K2 = Process new set."
770 DISP "K3 = Finished."
780 ON KEY# 1," STORE" GOTO 1940             ! Store option
790 ON KEY# 2,"NEW SET" GOTO 830             ! New data option
800 ON KEY# 3," FINIS" GOTO 840              ! Finished option
810 KEY LABEL
820 GOTO 820                                 ! Loop until choice
830 N$="Y"                                   ! Set new data flag
840 IF S$="Y" THEN 900                       ! Data stored flag?
850 CLEAR @ BEEP                             ! No, ask user
860 DISP "Have you stored the present set"
870 DISP "of curves? (Y/N)"
880 INPUT S$                                 ! Data stored?
890 IF S$≠"Y" THEN 1940                      ! No, store data
900 IF N$="Y" THEN 140
   ! Yes, restart process if new data flag is set
910 CLEAR @ BEEP
920 DISP "Do you wish to digitize another"
930 DISP "set of curves? (Y/N)"
940 INPUT N$                                 ! Digitize more data?
950 IF N$="Y" THEN 140                       ! Yes, repeat process
960 IF V$="Y" THEN CHAIN "VMAUX:D700"
   ! No, load auxiliary processing if auxiliary data was taken
970 CLEAR @ BEEP                             ! Return to Autost
980 DISP "    MISSION CONTROL"
990 DISP "will now resume control."
1000 FOR I=1 TO 65
1010 BEEP 65-I,20
1020 NEXT I
1030 CHAIN "Autost:D700"                     ! Load Autost
```

```
1040 END
1050 REM *
1060 REM *
1070 REM *   INITIALIZATION
1080 REM *     SUBROUTINE
1090 REM *
1100 REM *
1110 FOR I=1 TO 3
1120 FOR J=1 TO 5
1130 P(I,J)=0                                   ! Initialize cntl reg
1140 NEXT J
1150 NEXT I
1160 P(1,3)=DATE                                ! Store date
1170 P(1,4)=1024 @ P(2,4)=1024                  ! Default pts per curve
1180 P(1,5)=86 @ P(2,5)=86                      ! Default units
1190 P(3,1)=10 @ P(3,2)=8                       ! Dflt horiz & vert div
1200 R$=":D700" @ S$="N"
   ! Default mass storage and data storage flag
1210 N$="N"                                     ! Default new data flag
1220 F=1 @ G=2
1230 M=1 @ N=1                                  ! Default scale factors
1240 FOR I=1 TO 2
1250 FOR J=1 TO 69
1260 T(I,J)=9999                                ! Initialize aux reg
1270 NEXT J
1280 NEXT I
1290 R=1
1300 FOR I=1 TO 7
1310 A(I)=0 @ B(I)=0                            ! Initialize norms 1 & 2
1320 C(I)=0 @ D(I)=0                            ! Initialize norms 3 & 4
1330 Z(I)=0                                     ! Initialize norms
1340 NEXT I
1350 RETURN
1360 REM *
1370 REM *
```

```
1380 REM *    AUXILIARY VOLTAGE
1390 REM *       SUBROUTINE
1400 REM *
1410 REM *
1420 CLEAR @ BEEP
1430 DISP "How many channels are to be"
1440 DISP "monitored by voltmeter? (4 max.)"
1450 INPUT T1                             ! Input # of chan
1460 T1=IP(T1)                            ! Make integer
1470 IF T1>0 AND T1<5 THEN 1520           ! Chan # valid?
1480 CLEAR @ BEEP                         ! No, notify user
1490 DISP "Please choose a number from 1"
1500 DISP "to 4."
1510 WAIT 4500 @ GOTO 1420                ! Re-enter # of chan
1520 FOR I=69 TO 70-T1 STEP -1            ! Yes, cont
1530 CLEAR @ BEEP
1540 DISP "Enter the channel number and the"
1550 DISP "voltage range."
1560 DISP @ DISP "(.1V = 1, 1V = 2, 10V = 3)"
1570 INPUT U,V                            ! Channel, voltage rng
1580 U=IP(U) @ V=IP(V)                    ! Make integers
1590 IF U>-1 AND U<1000 THEN 1630         ! Channel valid?
1600 CLEAR @ BEEP                         ! No, notify user
1610 DISP "Please enter a number 0-999."
1620 WAIT 4500 @ GOTO 1530                ! Re-enter chan, rng
1630 IF V>0 AND V<4 THEN 1670             ! Yes; voltage rng valid?
1640 CLEAR @ BEEP                         ! No, notify user
1650 DISP "Please enter a number 1-3."
1660 WAIT 4500 @ GOTO 1530                ! Re-enter chan, rng
1670 FOR J=69 TO I STEP -1                ! Yes, chk entries
1680 IF T(1,J)≠U THEN 1730                ! Entered previously?
1690 CLEAR @ BEEP                         ! Yes, notify user
1700 DISP "You have already chosen that"
1710 DISP "channel. Please enter another."
1720 WAIT 4500 @ GOTO 1530                ! Re-enter chan, rng
```

```
1730 NEXT J
1740 T(1,I)=U @ T(2,I)=V                    ! No, store values
1750 NEXT I
1760 T2=1
1770 RETURN
1780 REM *
1790 REM *
1800 REM * NORMALIZATION FACTOR
1810 REM *      SUBROUTINE
1820 REM *
1830 REM *
1840 ENTER 714 ; H$
1850 H$=UPC$(H$)
1860 Z(1)=VAL(H$[1,1])
1870 Z(2)=VAL(H$[2,2])
1880 Z(3)=VAL(H$[3,3])
1890 Z(4)=VAL(H$[4,8])
1900 Z(5)=VAL(H$[9,13])
1910 Z(6)=VAL(H$[14,20])
1920 Z(7)=VAL(H$[21,27])
1930 RETURN
1940 REM *
1950 REM *
1960 REM *   STORAGE SUBROUTINE
1970 REM *     A) CONVERT DATA
1980 REM *     B) STORE DATA
1990 REM *
2000 REM *
2010 CLEAR @ BEEP
2020 DISP "What name do you want for the"
2030 DISP "storage file?"
2040 INPUT X$                               ! Input file name
2050 IF LEN(X$)<=10 THEN 2110               ! Name too long?
2060 CLEAR @ BEEP                           ! Yes, notify user
2070 DISP "Name is too large. Please enter"
```

```
2080 DISP "a name with less than 11 "
2090 DISP "letters."
2100 WAIT 4500 @ GOTO 2010                     ! Re-enter name
2110 CLEAR @ BEEP
2120 DISP "Where do you want the curves"
2130 DISP "stored? (DISK00/DISK01/TAPE)"
2140 INPUT Q$                                  ! Enter data destination
2150 IF Q$="TAPE" THEN R$=":T"
2160 IF Q$="DISK01" THEN R$=":D701"
2170 MASS STORAGE IS R$                        ! Set mass storage unit
2180 IF P1<3 THEN 2400                         ! More than a pair?
2190 CLEAR @ BEEP                              ! Yes, notify user
2200 DISP "There are ";VAL$(P1);" curves but"
2210 DISP "the processing package can only"
2220 DISP "handle two curves per run, "
2230 DISP "unless both curves are the same"
2240 DISP "type, i.e. both current. In that"
2250 DISP "case, only 1 curve per file."
2260 DISP "Which two curves do you want "
2270 DISP "paired together? (1-4)"
2280 DISP @ DISP "(Seperate curves by a comma:1,4)"
2290 DISP @ DISP "(To store single curves, enter"
2300 DISP "number twice: 1,1)"
2310 INPUT F,G                                 ! Input curve pair
2320 F=IP(F) @ G=IP(G)                         ! Make integers
2330 IF F>0 AND F<5 THEN 2400                  ! Valid curve F?
2340 IF G>0 AND G<5 THEN 2400                  ! Valid curve G?
2350 CLEAR @ BEEP                              ! No, on either
2360 DISP "Both numbers must be on the"        !   notify user
2370 DISP "range 1 to 4. Please enter a"
2380 DISP "proper pair."
2390 WAIT 4500 @ GOTO 2190                     ! Re-enter curve pair
2400 I=2 @ E=F
2410 GOSUB 3800                                ! Conversion routine
```

```
2420 IF P(1,5)=P(2,5) AND F≠G THEN 2190
    ! If same type curves, then re-enter curve pair
2430 CLEAR @ BEEP
2440 DISP @ DISP @ DISP
2450 DISP "Storing data in ";X$
2460 IF F=G THEN I=1                       ! Set value for sngl crv
2470 H=5+2053*I                            ! Calculate data space
2480 ON ERROR GOTO 3050                    ! Trap data create error
2490 CREATE X$,H,8                         ! Create file space
2500 OFF ERROR
2510 ASSIGN# 1 TO X$                       ! Open file
2520 PRINT# 1,1 ; I                        ! Store # of curves
2530 PRINT# 1,2 ; P(3,1)                   ! Store horiz divisions
2540 PRINT# 1,3 ; P(3,2)                   ! Store vert divisions
2550 PRINT# 1,4 ; P(1,3)                   ! Store date
2560 PRINT# 1,5 ; P(2,3)                   ! Store start time
2570 K=6
2580 H=F
2590 IF H>2 THEN H=1
2600 FOR J=1 TO 5
2610 PRINT# 1,K ; P(H,J)                   ! Store cntl reg
2620 K=K+1
2630 NEXT J
2640 IF F≠G THEN F=G @ H=2 @ GOTO 2600
    ! If another curve, then set values and store other cntl reg
2650 T(2,65)=TIME @ F=E                    ! Store aux start time
2660 IF F=1 THEN H=A(7)                    ! Use time norm 1
2670 IF F=2 THEN H=B(7)                    ! Use time norm 2
2680 IF F=3 THEN H=C(7)                    ! Use time norm 3
2690 IF F=4 THEN H=D(7)                    ! Use time norm 4
2700 IF P1=1 THEN R=4                      ! If 1 curve, every 4th
2710 IF P1=2 THEN R=2                      ! If 2 curves, every 2nd
2720 FOR I=F TO R*1024 STEP R
2730 X=H*IP((I-F)/R)                       ! Calculate time
2740 PRINT# 1,K ; X                        ! Store time
```

```
2750 K=K+1
2760 IF FP(IP((I-F)/R)/256)=0 AND V$="Y" THEN GOSUB 3200
    ! Take desired auxiliary data if n*256th operation
2770 NEXT I
2780 IF E=F THEN PRINT# 1,6 ; X/10          ! Store time/div curve 1
2790 IF E≠F THEN PRINT# 1,11 ; X/10         ! Store time/div curve 2
2800 IF F≠G THEN F=G @ GOTO 2660
    ! If another curve, set values and repeat process
2810 F=E
2820 IF F=1 THEN H=A(6)                     ! Use voltage norm 1
2830 IF F=2 THEN H=B(6)                     ! Use voltage norm 2
2840 IF F=3 THEN H=C(6)                     ! Use voltage norm 3
2850 IF F=4 THEN H=D(6)                     ! Use voltage norm 4
2860 FOR I=2*F-1 TO R*2048 STEP 2*R
2870 Y=(256*NUM(D$[I,I])+NUM(D$[I+1,I+1]))*H*M
    ! Calculate voltage: D$[I,I] = upper byte (8-bit ASCII)
    ! D$[I+1,I+1] = lower byte (8-bit ASCII)
    ! H = normalization factor
    ! M = scale factor
2880 IF BIT(NUM(D$[I,I]),7) THEN Y=Y-256^2*H*M
    ! Convert number for negative value
2890 PRINT# 1,K ; Y                         ! Store voltage
2900 K=K+1
2910 IF FP(IP((I-F)/(2*R))/256)=0 AND V$="Y" THEN GOSUB 3200
    ! Take desired auxiliary data if n*256th operation
2920 NEXT I
2930 IF E=F THEN PRINT# 1,7 ; 500*H*M       ! Store volt/div curve 1
2940 IF E≠F THEN PRINT# 1,12 ; 500*H*M      ! Store volt/div curve 2
2950 IF F≠G THEN F=G @ M=N @ GOTO 2820
    ! If another curve, set values and repeat process
2960 F=E @ S$="Y"                           ! Set store flag
2970 ASSIGN# 1 TO *                         ! Close file
2980 CLEAR @ BEEP
2990 DISP "Do you want to store another"
3000 DISP "set of these curves?(Y/N)"
```

```
3010 INPUT Q$                                 ! Store another pair?
3020 IF Q$="Y" THEN 2010                      ! Yes, repeat process
3030 IF V$="Y" THEN GOSUB 3390
   ! No. If auxiliary data was taken, auxiliary storage routine
3040 GOTO 840                                 ! Return to main prog
3050 OFF ERROR
3060 IF ERRN≠63 THEN 3160                     ! File already exist?
3070 CLEAR @ BEEP                             ! Yes, notify user
3080 DISP "File already exists. Do you want"
3090 DISP "to purge? (Y/N)"
3100 INPUT Q$                                 !   Purge file?
3110 IF Q$="Y" THEN PURGE X$ @ GOTO 2490      !   Yes, purge & cont
3120 CLEAR @ BEEP                             !   No, enter new name
3130 DISP "Enter another name."
3140 INPUT X$
3150 GOTO 2050                                !   Retry storage
3160 IF ERRN≠130 THEN 2490                    ! Disk error; no, retry
3170 CLEAR @ BEEP                             ! Yes, notify user
3180 DISP "Disk error. Re-enter storage."
3190 WAIT 4500 @ GOTO 2110                    ! Re-assign mass storage
3200 REM *
3210 REM *
3220 REM *    AUXILIARY VOLTAGE
3230 REM *      ACQUISITION
3240 REM *
3250 REM *
3260 CLEAR 709 @ CLEAR 724                    ! Clear DACU & DVM
3270 OUTPUT 709 ;"AF0AL999AC0"                ! Select 0 of 0-999
3280 OUTPUT 724 ;"T3R3D.1S"                   ! Man trg;10V rng;.1s dly
3290 FOR I1=69 TO 70-T1 STEP -1
3300 OUTPUT 709 ;"AC"&VAL$(T(1,I1))           ! Close chan on DACU
3310 OUTPUT 724 ;"R"&VAL$(T(1,I1-T1))         ! Set rng on DVM
3320 WAIT 500                                 ! Let voltage settle
3330 TRIGGER 724                              ! Trigger DVM
3340 ENTER 724 ; T(1,T2)                      ! Store DVM voltage
```

```
3350 T(2,T2)=TIME-T(2,65)                    ! Store time
3360 T2=T2+1                                 ! Increment time index
3370 NEXT I1
3380 RETURN
3390 REM *
3400 REM *
3410 REM *   AUXILIARY VOLTAGE
3420 REM *      STORAGE
3430 REM *
3440 REM *
3450 CLEAR @ BEEP
3460 DISP "What name do you want for the"
3470 DISP "auxiliary file?"
3480 INPUT Y$                                ! Input aux file name
3490 IF LEN(Y$)<=10 THEN 3550                ! Name too long?
3500 CLEAR @ BEEP                            ! Yes, notify user
3510 DISP "Name is too large. Please choose"
3520 DISP "a name with less than 11"
3530 DISP "letters."
3540 WAIT 4500 @ GOTO 3450                   ! Re-enter name
3550 CLEAR @ BEEP                            ! No, store aux data
3560 DISP @ DISP @ DISP
3570 DISP "Storing data in ";Y$
3580 ON ERROR GOTO 3690                      ! Trap file create error
3590 CREATE Y$,138,8                         ! Create file space
3600 OFF ERROR
3610 ASSIGN# 1 TO Y$                         ! Open file
3620 FOR I=1 TO 2
3630 FOR J=1 TO 69
3640 PRINT# 1,69*(I-1)+J ; T(I,J)            ! Store aux array
3650 NEXT J
3660 NEXT I
3670 ASSIGN# 1 TO *                          ! Close file
3680 RETURN
3690 OFF ERROR
```

```
3700 IF ERRN≠63 THEN 3590                     ! File already exist?
3710 CLEAR @ BEEP                             ! Yes, notify user
3720 DISP "File already exists. Do you want"
3730 DISP "to purge? (Y/N)"
3740 INPUT Q$                                 ! Purge file?
3750 IF Q$="Y" THEN PURGE Y$ @ GOTO 3590      ! Yes, purge & cont
3760 CLEAR @ BEEP                             ! No, enter new name
3770 DISP "Enter another name."
3780 INPUT Y$
3790 GOTO 3490                                ! Retry storage
3800 REM *
3810 REM *
3820 REM * SCALING SUBROUTINE
3830 REM *   A) SCALE INPUT FOR
3840 REM *      TRANSFORMER,ETC
3850 REM *
3860 REM *
3870 CLEAR @ BEEP
3880 DISP "Is an attenuator, current"
3890 DISP "transformer, current-sensing"
3900 DISP "resistor, or multiplying probe"
3910 DISP "being used? (Y/N)"
3920 INPUT Q$                                 ! Conversion?
3930 IF Q$≠"Y" THEN RETURN                    ! No, return
3940 CLEAR @ BEEP                             ! Yes, cont
3950 DISP "Which of the curves uses one"
3960 DISP "of the devices? (";VAL$(F);"/";VAL$(G);"/";VAL$(F+G);")"
3970 DISP @ DISP "(";VAL$(F+G);" is equivalent to both.)"
3980 INPUT Q
3990 IF Q=F+G THEN E=Q @ Q=F
   ! If both curves, set values to enter first
4000 CLEAR @ BEEP
4010 DISP "What is the conversion process"
4020 DISP "for curve ";VAL$(Q);"?"
4030 DISP
```

```
4040 DISP "(For example, a 6 dB attenuator"
4050 DISP "converts a 2-volt input at the"
4060 DISP "source to a 1-volt input at the"
4070 DISP "scope. So conversion is 2V to"
4080 DISP "1V - entered 2V,1V. Enter"
4090 DISP "using scientific notation and"
4100 DISP "include units - A or V.)"
4110 INPUT W1$,Q1$                             ! Input conversion
4120 I=POS(W1$,"A")                            ! Posn for current
4130 IF I=0 THEN I=POS(W1$,"V")                !   or posn for voltage
4140 IF I≠0 THEN 4190                          ! I or V?
4150 CLEAR @ BEEP                              ! No, notify user
4160 DISP "Please redo and include the"
4170 DISP "appropriate units - A or V."
4180 WAIT 4500 @ GOTO 4000
4190 J=POS(Q1$,"V")                            ! Posn for voltage
4200 IF J≠0 THEN 4250                          ! Voltage?
4210 CLEAR @ BEEP                              ! No, notify user
4220 DISP "The right-hand term should be"
4230 DISP "a voltage term."
4240 WAIT 4500 @ GOTO 4000                     ! Re-enter conversion
4250 IF Q=F THEN M=VAL(W1$)/VAL(Q1$) @ P(1,5)=NUM(W1$[LEN(W1$),
     LEN(W1$)])                                ! Set curve 1 conversions
4260 IF Q=G THEN N=VAL(W1$)/VAL(Q1$) @ P(2,5)=NUM(W1$[LEN(W1$),
     LEN(W1$)])                                ! Set curve 2 conversions
4270 IF E=F+G THEN Q=G @ GOTO 4000             ! Repeat for 2nd conver
4280 RETURN
```

7612D

The 7612D program controls the Tektronix 7612D Programmable Digitizer and, if desired, the HP3497A Data Acquisition/Control Unit (DACU) and HP3437A Digital Voltmeter (DVM).

The digitizer is used to make up to two (2) 1024-point measurements. The operator enters the measurement settings on the front panel of the digitizer. The program loads these settings and asks the operator for verification. Then, the program arms the digitizer for a measurement. Once a good measurement is acquired, the program stores the data.

The DACU and DVM are used to take measurements of slower phenomena. They are used to make up to four (4) 16-point measurements. These instruments are used during the storage cycle of the program. This data is stored by the program, and, later, processed using the VMAUX program.

```
10 REM *
20 REM *
30 REM *     PROGRAMMABLE
40 REM *     DIGITIZER CONTROL
50 REM *     MAIN PROGRAM
60 REM *
70 REM *Copyright:  8/13/84
80 REM * gandalf software, inc.
90 REM * Chuck Graves, Wizard
100 REM *
110 REM *
120 COM X$[10]                              ! Make file name common
130 OPTION BASE 1 @ CLEAR
140 DIM P(2,5),C(2,15),D(2,15),A3$[128],B3$[128],W1$[200],W2$[200],
    T(2,69)
150 DIM S$[512],D$[2100],A$[256],B$[256],A2$[128],B2$[128],W$[200],
    D1$[2100],D2$[2100]
160 BEEP @ BEEP
170 DISP @ DISP "Initializing"
180 GOSUB 3220                              ! Initialize registers
190 CLEAR @ BEEP
200 DISP "How many curves will be"
210 DISP "digitized and stored?(1-2)"
220 INPUT P1 @ P1=IP(P1)                    ! Input integer # curves
230 IF P1=1 OR P1=2 THEN 270                ! Too many curves?
240 CLEAR @ BEEP                            ! Yes, notify user
250 DISP "Please choose 1 or 2."
260 WAIT 4500 @ GOTO 190                    ! Re-enter # curves
270 W$="A"
280 CLEAR @ BEEP                            ! No, cont
290 DISP "Will this be a repetitive set"
300 DISP "of measurements at the same"
310 DISP "settings? (Y/N)"
320 INPUT K$                                ! Set repetitive flag
330 GOSUB 5450                              ! Aux meas routine
```

```
340 REMOTE 7 @ LOCAL LOCKOUT 7                ! Take control HPIB
350 IF W$="A" THEN SEND 7 ; UNL MTA LISTEN 2 SCG 1  ! Listen left plug
360 IF W$="B" THEN SEND 7 ; UNL MTA LISTEN 2 SCG 2  ! Listen rt plug
370 OUTPUT 7 ;"CPL GND;"                      ! Ground input
380 ON KEY# 1," CONT" GOTO 490                ! Set cont branch
390 CLEAR @ BEEP                              ! Set zero references
400 DISP "Adjust the POSITION knob on "
410 DISP "plug-in ";W$;" to set zero line."
420 KEY LABEL
430 REMOTE 7 @ LOCAL LOCKOUT 7                ! Take control HPIB
440 SEND 7 ; UNL MTA LISTEN 2 SCG 0           ! Listener 7612D
450 OUTPUT 7 ;"ARM "&W$&";"                   ! Arm timebase
460 LOCAL 7 @ WAIT 50                         ! Go local for 50 ms
470 OUTPUT 7 ;"MTRIG;"                        ! Trigger timebase
480 GOTO 430                                  ! Repeat
490 IF P1=1 OR W$="B" THEN 520                ! Another curve?
500 W$="B"                                    ! Yes, set other timebase
510 GOTO 340                                  ! Repeat procedure
520 LOCAL 7 @ REMOTE 7                        ! No, take control HPIB
530 SEND 7 ; CMD "SPE" UNT MLA TALK 2 SCG 0   ! Config 7612D for poll
540 Q=SPOLL(7)                                ! Serial poll 7612D
550 Q1$=W$
560 IF P1=2 THEN Q1$="C"
570 CLEAR @ BEEP                              ! Set 7612D front panel
580 DISP "Enter the measurement settings"
590 DISP "on the front panel of the 7612D."
600 DISP "When entry is complete, press"
610 DISP "the REMOTE button on the front"
620 DISP "panel (lower center)."
630 GOSUB 1520                                ! Settings routine
640 W$=Q1$
650 IF Q$≠"Y" THEN 570                        ! Set bad, rst frt panel
660 P(1,2)=A2                                 ! Volts/div for crv 1
670 P(2,2)=B2                                 ! Volts/div for crv 2
680 IF A3=1 AND B3=1 THEN 760                 ! Single records?
```

```
690 CLEAR @ BEEP                              ! No, notify user
700 DISP "This program is developed for"
710 DISP "single-record usage only. Please"
720 DISP "reset the number of records to"
730 DISP "1 and adjust the record length,"
740 DISP "if necessary."
750 WAIT 4500 @ GOTO 570                      ! Reset front panel
760 IF A4<=1024 AND B4<=1024 THEN 840         ! Yes; file too long?
770 CLEAR @ BEEP                              ! Yes, notify user
780 DISP "The processing program can only"
790 DISP "handle a record less than or "
800 DISP "equal to 1024 points. Please "
810 DISP "choose a record length of less "
820 DISP "than or equal to 1024 points."
830 WAIT 4500 @ GOTO 570                      ! Reset front panel
840 P(1,4)=A4                                 ! Set # pts in crv 1
850 P(2,4)=B4                                 ! Set # pts in crv 2
860 CLEAR @ BEEP
870 GOSUB 3490                                ! Conversion routine
880 CLEAR @ BEEP
890 Q$="s A and B are " @ W$="C"
900 IF P1>1 THEN 990                          ! Arm both timebases
910 DISP "Which time base is to be armed?"
920 DISP "(A/B)"
930 INPUT W$                                  ! Input timebase
940 IF W$="A" OR W$="B" THEN 980              ! Timebase valid?
950 CLEAR @ BEEP                              ! No, notify user
960 DISP "Please choose A or B."
970 WAIT 4500 @ GOTO 880                      ! Re-enter timebase
980 Q$=" "&W$&" is "                          ! Yes, cont
990 GOSUB 2870                                ! Arm & read routine
1000 IF Q$="Y" THEN 1080                      ! Keep data?
1010 DISP "Do you wish to change the "        ! No,
1020 DISP "settings? (Y/N)"                   !   then
1030 INPUT Q$                                 !   change settings?
```

```
1040 IF Q$="Y" THEN 570                    !   Yes, reset frt panel
1050 Q$="s A and B are "
1060 IF W$="A" OR W$="B" THEN 980
1070 GOTO 990                              !   No, re-arm and reread
1080 CLEAR @ BEEP                          ! Yes, store data
1090 DISP "Where do you want the curves"
1100 DISP "stored? (DISK00/DISK01/TAPE)"
1110 INPUT Q$                              ! Input data destination
1120 IF Q$="TAPE" THEN R$=":T"
1130 IF Q$="DISK01" THEN R$=":D701"
1140 MASS STORAGE IS R$                    ! Set mass storage unit
1150 CLEAR @ BEEP
1160 DISP "What name do you want for the"
1170 DISP "storage file?"
1180 INPUT X$                              ! Input file name
1190 IF LEN(X$)<=10 THEN 1250              ! Name too long?
1200 CLEAR @ BEEP                          ! Yes, notify user
1210 DISP "Name is too large. Please enter"
1220 DISP "a name with less than 11 "
1230 DISP "letters."
1240 WAIT 4500 @ GOTO 1150                 ! Re-enter file name
1250 IF P(1,5)=P(2,5) AND C1=0 AND P1>1 THEN GOSUB 6490
   ! Same type curve routine. C$ is separate curve storage.
1260 IF C$="N" THEN 860                    ! Return to conversion
1270 CLEAR @ BEEP
1280 DISP @ DISP @ DISP
1290 DISP "Storing data in ";X$
1300 GOSUB 4110                            ! Store data
1310 IF P(1,5)=P(2,5) AND C1=1 AND W$="A" THEN W$="B" @ GOTO 1150
   ! Store next curve separately
1320 CLEAR @ BEEP
1330 DISP "Data is stored."
1340 DISP @ DISP "Do you want to take another "
1350 DISP "set of data? (Y/N)"
1360 INPUT Q$
```

```
1370 IF Q$≠"Y" THEN 1430                     ! Take more data?
1380 IF K$="Y" THEN GOSUB 3450 @ GOTO 880    ! Yes, repetitive meas
1390 CLEAR @ BEEP
1400 DISP @ DISP @ DISP
1410 DISP "Re-initializing"
1420 GOTO 180                                ! or reset non-repetitive
1430 CLEAR @ BEEP                            ! No, return to Autost
1440 IF V$="Y" THEN CHAIN "VMAUX:D700"       ! Process aux meas first
1450 DISP "     MISSION CONTROL"
1460 DISP "will now resume control."
1470 FOR I=1 TO 65
1480 BEEP 65-I,20
1490 NEXT I
1500 CHAIN "Autost:D700"                     ! Load Autost
1510 END
1520 REM *
1530 REM *
1540 REM *     SETTINGS SUBROUTINE
1550 REM *       1) INPUT TIME
1560 REM *          BASE SETTINGS
1570 REM *       2) INPUT PLUG-IN
1580 REM *          SETTINGS
1590 REM *
1600 REM *
1610 SEND 7 ; UNL MTA LISTEN 2 SCG 0         ! Listener 7612D
1620 OUTPUT 7 ;"REM ON"                      ! Set Remote SRQ
1630 LOCAL 7                                 ! Give 7612D local cntl
1640 SEND 7 ; CMD "SPE" UNT MLA TALK 2 SCG 0 ! Config 7612D for poll
1650 Q=SPOLL(7)                              ! Serial poll 7612D
1660 IF NOT BIT(Q,7) THEN 1680               ! SRQ asserted?
1670 GOTO 1640                               ! No, repeat poll
1680 REMOTE 7                                ! Yes, take control
1690 SEND 7 ; UNL MTA LISTEN 2 SCG 0         ! Listener 7612D
1700 OUTPUT 7 ;"REM OFF;SET?;TMBS A;NBPT?"   ! Ask settings, A brkpts
1710 SEND 7 ; UNT MLA TALK 2 SCG 0           ! Talker 7612D
```

```
1720 ENTER 7 USING "K" ; S$,A1$             ! Enter settings, A bkpts
1730 SEND 7 ; UNL MTA LISTEN 2 SCG 1        ! Listener left plugin
1740 OUTPUT 7 ;"INP?;BW?;CPL?;RN?;VAR?;V/D?;POL?;POS?;PRB?;"
   ! Ask for input, bandwidth, coupling, term imp, variable gain,
   ! volt/div, polarity, position, probe multiplier for left plugin
1750 SEND 7 ; UNT MLA TALK 2 SCG 1          ! Talker left plugin
1760 ENTER 7 USING "K" ; A2$                ! Enter left plugin set
1770 SEND 7 ; UNL MTA LISTEN 2 SCG 2        ! Listener rt plugin
1780 OUTPUT 7 ;"INP?;BW?;CPL?;RIN?;VAR?;V/D?;POL?;POS?;PRB?;"
   ! Ask for input, bandwidth, coupling, term imp, variable gain,
   ! volt/div, polarity, position, probe multiplier for right plugin
1790 SEND 7 ; UNT MLA TALK 2 SCG 2          ! Talker rt plugin
1800 ENTER 7 USING "K" ; B2$                ! Enter rt plugin set
1810 SEND 7 ; UNL MTA LISTEN 2 SCG 0        ! Listener 7612D
1820 OUTPUT 7 ;"TMBS B;NBPT?"               ! Ask B breakpoints
1830 SEND 7 ; UNT MLA TALK 2 SCG 0          ! Talker 7612D
1840 ENTER 7 USING "K" ; B1$                ! Enter B breakpoints
1850 A=POS(S$,"TMBS A")                     ! Begin timebase A set
1860 B=POS(S$,"TMBS B")                     ! Being timebase B set
1870 A$=S$[A+7,B-1]                         ! Timebase A string
1880 B$=S$[B+7,LEN(S$)]                     ! Timebase B string
1890 A1=VAL(A1$[5,LEN(A1$)-1])              ! # timebase A bkpts
1900 B1=VAL(B1$[5,LEN(B1$)-1])              ! # timebase B bkpts
1910 A=POS(A2$,"V/D")                       ! Posn left volt/div str
1920 B=POS(B2$,"V/D")                       ! Posn rt volt/div str
1930 A2=VAL(A2$[A+4,A+9])                   ! Left plugin volt/div
1940 B2=VAL(B2$[B+4,B+9])                   ! Rt plugin volt/div
1950 A=POS(A$,",")                          ! Posn record #  A
1960 B=POS(A$,";")                          ! Posn record length A
1970 A3=VAL(A$[A-1,A-1])                    ! Timebase A record #
1980 A4=VAL(A$[A+1,B-1])                    ! Timebase A rec length
1990 A=POS(B$,",")                          ! Posn record # B
2000 B=POS(B$,";")                          ! Posn record length B
2010 B3=VAL(B$[A-1,A-1])                    ! Timebase B record #
2020 B4=VAL(B$[A+1,B-1])                    ! Timebase B rec length
```

```
2030 A=POS(A$,"SBPT")                    ! Posn bkpt settings A
2040 B=POS(A$,"MODE")                    ! Posn of trig mode A
2050 A3$=A$[A+4,B-2]                     ! Timebase A bkpts
2060 A=POS(B$,"SBPT")                    ! Posn bkpt settings B
2070 B=POS(B$,"MODE")                    ! Posn of trig mode B
2080 B3$=B$[A+4,B-2]                     ! Timebase B bkpts
2090 W$=A3$ @ A=A1 @ N=1
2100 FOR I=1 TO A                        ! Get breakpoints
2110 B=POS(W$,",")                       ! Posn of bkpt
2120 IF N=1 THEN C(1,I)=VAL(W$[1,B-1])   ! Store bkpt count A
2130 D(1,I)=VAL(W$[1,B-1])               ! Store bkpt count B
2140 W$=W$[B+1,LEN(W$)]                  ! Shorten string
2150 B=POS(W$,",")                       ! Posn new sampling
2160 IF B=0 THEN 2210                    ! Last bkpt?
2170 IF N=1 THEN C(2,I)=VAL(W$[1,B-1])   ! No, store new smpl tm A
2180 D(2,I)=VAL(W$[1,B-1])               ! Store new smpl time B
2190 W$=W$[B+1,LEN(W$)]                  ! Shorten string
2200 NEXT I
2210 IF N=1 THEN C(2,I)=VAL(W$)          ! Yes, store smpl time A
2220 D(2,I)=VAL(W$)                      ! Store last smpl time B
2230 IF N≠1 THEN 2260                    ! Another curve?
2240 W$=B3$ @ A=B1 @ N=2                 ! Yes, assign values
2250 GOTO 2100                           ! Repeat process
2260 A=5 @ W$=S$[1,LEN(S$)-LEN(A$)-LEN(B$)-14] @ N=0
   ! Find 5 substrings, workspace is mainframe info
2270 CLEAR @ BEEP                        ! No, cont
2280 DISP "For the mainframe:"
2290 GOSUB 2460                          ! Decomposition routine
2300 WAIT 4500
2310 A=9 @ W$=A$ @ N=A1 @ Q$="A"
   ! Find 9 substrings, workspace is timebase A info
2320 CLEAR @ BEEP
2330 DISP "For time base "&Q$&":"
2340 GOSUB 2460                          ! Decomposition routine
2350 WAIT 4500
```

```
2360 IF Q$="B" THEN 2390                     ! Another timebase?
2370 A=9 @ W$=B$ @ N=B1 @ Q$="B"
   ! Find 9 substrings, workspace is timebase B info
2380 GOTO 2320                               ! Repeat process
2390 CLEAR @ BEEP
2400 DISP "Are all of the settings correct?"
2410 DISP "(Y/N)"
2420 INPUT Q$                                ! Settings correct?
2430 C(1,A1+1)=A4 @ D(1,B1+1)=B4             ! Last bkpt = file size
2440 GOSUB 5060                              ! Zeroline correction
2450 RETURN
2460 REM *
2470 REM *
2480 REM *     DECOMPOSITION SUBROUTINE
2490 REM *       1) DECOMPOSE STRING
2500 REM *          AS A CHECK
2510 REM *
2520 REM *
2530 L=1
2540 FOR I=1 TO A                            ! Find A substrings
2550 B=POS(W$,";")                           ! Posn substring
2560 W1$=W$[1,B-1]                           ! Assign substring
2570 W$=W$[B+1,LEN(W$)]                      ! Shorten workspace
2580 IF I≠2 OR LEN(W1$)<=12 THEN 2820        ! Entry multiple bkpts?
2590 B=POS(W1$,",")                          ! Yes, posn 1st bkpt
2600 W2$=W1$[1,B]                            ! Assign substring
2610 W1$=W1$[B+1,LEN(W1$)]                   ! Shorten workspace
2620 B0=POS(W1$,",")                         ! Posn 1st bkpt smpl time
2630 W2$=W2$&W1$[1,B0-1]                     ! Concat substrings
2640 W1$=W1$[B0+1,LEN(W1$)]                  ! Shorten workspace
2650 DISP "    "&W2$                         ! Disp 1st bkpt, smpl tm
2660 FOR J=1 TO N-1
2670 B=POS(W1$,",")                          ! Posn next bkpt
2680 W2$=W1$[1,B]                            ! Assign substring
2690 W1$=W1$[B+1,LEN(W1$)]                   ! Shorten workspace
```

```
2700 B0=POS(W1$,",")                            ! Posn next bkpt smpl tm
2710 IF B0=0 THEN W2$=W2$&W1$ @ GOTO 2730       !   Last bkpt?
2720 W2$=W2$&W1$[1,B0-1]                        !   No, concat substrings
2730 W1$=W1$[B0+1,LEN(W1$)]                     ! Shorten workspace
2740 FOR K=1 TO 10-B                            ! Right justify
2750 DISP " ";
2760 NEXT K
2770 DISP W2$                                   ! Disp substring
2780 L=L+1                                      ! Increment disp count
2790 IF L>13 THEN L=L-13 @ WAIT 4500            ! Screen full wait 4.5s
2800 NEXT J
2810 GOTO 2850                                  ! Next substring
2820 DISP "   "&W1$                             ! No, display substring
2830 L=L+1                                      ! Increment disp count
2840 IF L>13 THEN L=L-13 @ WAIT 4500            ! Screen full wait 4.5s
2850 NEXT I                                     ! Next substring
2860 RETURN
2870 REM *
2880 REM *
2890 REM *     ACTIVE SUBROUTINE
2900 REM *       1) ARM TIME BASE
2910 REM *       2) READ DATA
2920 REM *
2930 REM *
2940 IF W$="A" THEN W1$="ARM A;" @ A=1          ! For timebase A only
2950 IF W$="B" THEN W1$="ARM B;" @ A=1          ! For timebase B only
2960 IF W$="C" THEN W1$="ARM A,B;" @ A=2 @ W$="A" ! For both timebases
2970 SEND 7 ; UNL MTA LISTEN 2 SCG 0            ! Listener 7612D
2980 OUTPUT 7 ;W1$                              ! Arm timebase(s)
2990 P(1,3)=DATE                                ! Store date
3000 P(2,3)=TIME                                ! Store start time
3010 CLEAR @ BEEP
3020 DISP "Time base";Q$;"armed."
3030 DISP @ DISP "Now, simply take measurement."
3040 DISP "When the curve appears on the "
```

```
3050 DISP "monitor, press CONTINUE. " @ PAUSE
3060 CLEAR @ BEEP
3070 DISP "Do you wish to keep this data?"
3080 DISP "(Y/N)"
3090 INPUT Q$                                   ! Keep data?
3100 IF Q$="N" THEN RETURN                      ! No, return to main prog
3110 SEND 7 ; UNL MTA LISTEN 2 SCG 0            ! Yes, Listener 7612D
3120 OUTPUT 7 ;"READ "&W$                       ! Ask for curve data
3130 SEND 7 ; UNT MLA TALK 2 SCG 0              ! Talker 7612D
3140 TRANSFER 7 TO D$ FHS ; EOI                 ! Fast transfer of data
3150 IF W$="A" THEN D1$=D$                      ! Store timebase A data
3160 D2$=D$                                     ! Store timebase B data
3170 IF W$="A" AND A=2 THEN W$="B" @ D$=" " @ GOTO 3110
    ! If another curve, set values and repeat data transfer process
3180 IF A=2 OR W$="A" THEN D1$=D1$[5,LEN(D1$)-1] @ P(1,1)=1
    ! Get rid of leading info (not data) for timebase A
3190 IF A=2 OR W$="B" THEN D2$=D2$[5,LEN(D2$)-1] @ P(2,1)=1
    ! Get rid of leading info (not data) for timebase B
3200 IF A=2 THEN W$="C"
3210 RETURN
3220 REM *
3230 REM *
3240 REM *     INITIALIZATION
3250 REM *     SUBROUTINE
3260 REM *
3270 REM *
3280 P1=1
3290 SEND 7 ; CMD "SPE" UNT MLA TALK 2 SCG 0   ! Config 7612D for poll
3300 Q=SPOLL(7)                                 ! Serial poll 7612D
3310 FOR I=1 TO 2
3320 FOR J=1 TO 5
3330 P(I,J)=0                                   ! Initialize cntl reg
3340 NEXT J
3350 FOR J=1 TO 15
3360 C(I,J)=2048                                ! Initialize A bkpt reg
```

```
3370 D(I,J)=2048                              ! Initialize B bkpt reg
3380 NEXT J
3390 NEXT I
3400 FOR I=1 TO 69
3410 T(1,I)=9999 @ T(2,I)=9999                ! Initialize aux reg
3420 NEXT I
3430 IOBUFFER D$                              ! Initialize I/O buffer
3440 L=1 @ M=1 @ N=1 @ O=1
   ! Default disp count, A scale, B scale, time scale
3450 R$=":D700"                               ! Default mass storage
3460 A=1 @ B=1 @ P(1,5)=86 @ P(2,5)=86
   ! Default positions (A & B) and default units - V
3470 C$="Y" @ C1=0
   ! C$ - store identical curve types separately
   ! C1 - curves are not identical type
3480 RETURN
3490 REM *
3500 REM *
3510 REM *    SCALING SUBROUTINE
3520 REM *      1) SCALE INPUT FOR
3530 REM *         TRANSFORMERS OR
3540 REM *         ATTENUATORS
3550 REM *
3560 REM *
3570 M=1 @ N=1                                ! Default scale factors
3580 DISP "Is an attenuator, current"
3590 DISP "transformer, or current-sensing"
3600 DISP "resistor being used?(Y/N)"
3610 DISP @ DISP "(Do not consider x10 probes.)"
3620 INPUT Q$
3630 IF Q$≠"Y" THEN 4010                      ! Conversion? No, return
3640 IF W$≠"C" THEN Q$=W$ @ A=1 @ GOTO 3720
   ! Yes; if only taking one curve, then input that conversion
3650 CLEAR @ BEEP
   !  Otherwise, ask which curve
```

```
3660 DISP "Which of the plug-ins uses one"
3670 DISP "of these devices? (A/B/C)"
3680 DISP @ DISP "(C is equivalent to A and B.)"
3690 INPUT Q$
3700 IF Q$≠"C" THEN A=1                         ! Conversion on one
3710 IF Q$="C" THEN A=2 @ Q$="A"                ! Conversion on both
3720 CLEAR @ BEEP
3730 DISP "What is the coversion process"
3740 DISP "for time base ";Q$;"?"
3750 DISP
3760 DISP "(For example, a 6 dB attenuator"
3770 DISP "converts a 2-volt input at the"
3780 DISP "source to a 1-volt input at the"
3790 DISP "scope. So conversion is 2V to "
3800 DISP "1V - entered 2V, 1V. Enter"
3810 DISP "using scientific notation and "
3820 DISP "include units - A or V.)"
3830 INPUT W1$,Q1$                              ! Input conversion
3840 I=POS(W1$,"A")                             ! Posn for current
3850 IF I=0 THEN I=POS(W1$,"V")                 !   or posn for voltage
3860 IF I≠0 THEN 3910                           ! Current or voltage?
3870 CLEAR @ BEEP                               ! No, notify user
3880 DISP "Please redo and include the "
3890 DISP "appropriate units - A or V."
3900 WAIT 4500 @ GOTO 3720                      !   Re-enter conversion
3910 J=POS(Q1$,"A")                             ! Yes, posn for current
3920 IF J=0 THEN J=POS(Q1$,"V")                 !   or posn for voltage
3930 IF J=0 THEN 3870                           ! I or V? No, notify user
3940 IF Q$="A" THEN P(1,5)=NUM(W1$[I,I])        ! Yes, store A units
3950 IF Q$="B" THEN P(2,5)=NUM(W1$[I,I])        ! Store B units
3960 IF Q$="A" THEN M=VAL(W1$[1,I-1])/VAL(Q1$[1,J-1]) ! Store A scale
3970 IF Q$="B" THEN N=VAL(W1$[1,I-1])/VAL(Q1$[1,J-1]) ! Store B scale
3980 IF A=1 OR Q$="B" THEN 4010                 ! Another conversion?
3990 Q$="B"                                     ! Yes, set values
4000 GOTO 3720                                  !   Repeat process
```

```
4010 GOTO 4030
4020 GOTO 4030
4030 IF S$[5,7]="INT" THEN 4100               ! No; internal clk?
4040 CLEAR @ BEEP                             ! No, input clock freq
4050 DISP "Enter the frequency of the"
4060 DISP "external clock using scientific"
4070 DISP "notation. For example, if the"
4080 DISP "frequency is 5 MHz, enter 5E 6."
4090 INPUT A @ O=O/A                          ! Set time scale
4100 RETURN
4110 REM *
4120 REM *
4130 REM *     STORAGE SUBROUTINE
4140 REM *       1) CONVERTS DATA
4150 REM *       2) STORES DATA ON
4160 REM *          TAPE OR DISK
4170 REM *
4180 REM *
4190 REM *
4200 A=0
4210 IF P(1,5)=P(2,5) AND C1=1 THEN W$="A"    ! Set to store A sep
4220 IF W$="A" THEN A=P(1,4)                  ! Set to store A
4230 IF W$="B" THEN A=P(2,4)                  ! Set to store B
4240 IF W$="C" THEN A=P(1,4)+P(2,4)           ! Set to store both
4250 B=2*A+5*P1+5                             ! Calculate file space
4260 ON ERROR GOTO 4910                       ! Trap file create error
4270 CREATE X$,B,8                            ! Create file space
4280 OFF ERROR
4290 ASSIGN# 1 TO X$                          ! Open file
4300 I=10 @ J=8
4310 PRINT# 1,1 ; P1                          ! Store # curves
4320 PRINT# 1,2 ; I                           ! Store # time div
4330 PRINT# 1,3 ; J                           ! Store # voltage div
4340 PRINT# 1,4 ; P(1,3)                      ! Store date
4350 PRINT# 1,5 ; P(2,3)                      ! Store start time
```

```
4360 P(1,2)=P(1,2)*M @ P(2,2)=P(2,2)*N
4370 K=6
4380 FOR I=1 TO 2
4390 IF P(I,1)=0 THEN 4440                ! Control reg used
4400 FOR J=1 TO 5                         ! Yes, store cntl reg
4410 PRINT# 1,K ; P(I,J)
4420 K=K+1
4430 NEXT J
4440 NEXT I                               ! No, next cntl reg
4450 T(2,65)=TIME                         ! Set aux start time
4460 IF W$="B" THEN 4600                  ! Store time A?
4470 A=1 @ B=0                            ! Yes.
4480 FOR I=1 TO A1
4490 FOR J=A TO C(1,I+1)                  ! Store to next bkpt
4500 X=(J-A+1)*C(2,I)*O+B
   ! Calculate time: A = beginning index for present sampling time
   ! B = time at end of last sample time period (offset time)
   ! C(2,I)  = present sampling time for timebase A
4510 PRINT# 1,K ; X                       ! Store time A
4520 K=K+1
4530 IF FP((J-1)/256)=0 AND V$="Y" THEN GOSUB 5930
   ! Take desire auxiliary measurement if n*256th operation
4540 NEXT J
4550 A=C(1,I+1)+1                         ! Set new start index
4560 B=X                                  ! Set new offset time
4570 NEXT I
4580 PRINT# 1,6 ; X/10                    ! Store time/div A
4590 IF W$="A" THEN 4740                  ! Store time B?
4600 A=1 @ B=0                            ! Yes
4610 FOR I=1 TO B1
4620 FOR J=A TO D(1,I+1)                  ! Store to next bkpt
4630 X=(J-A+1)*D(2,I)*O+B
   ! Calculate time: A = beginning index for present sampling time
   ! B = time at end of last sample time period (offset time)
   ! D(2,I)  = present sampling time for timebase B
```

```
4640 PRINT# 1,K ; X                       ! Store time B
4650 K=K+1
4660 IF FP((J-1)/256)=0 AND V$="Y" THEN GOSUB 5930
   ! Take desired auxiliary measurement if n*256th operation
4670 NEXT J
4680 A=D(1,I+1)+1                         ! Set new start index
4690 B=X                                  ! Set new offset time
4700 NEXT I
4710 IF W$="B" THEN PRINT# 1,6 ; X/10
   ! Store time per division for timebase B in single operation
4720 IF W$="C" THEN PRINT# 1,11 ; X/10
   ! Store time per division for timebase B in dual operation
4730 IF W$="B" THEN 4810                  ! Store voltage A?
4740 FOR I=1 TO LEN(D1$)-3                ! Yes
4750 Y=(NUM(D1$[I,I])-Z0)*P(1,2)*8/255
   ! Convert 8-bit ASCII characters into voltage values
   ! D1$[I,I] = ASCII character from curve A
   ! Z0 = zeroline offset error for curve A
   ! P(1,2) = timebase A voltage per division
   ! Values in D1$[] vary from 0 to 255
4760 PRINT# 1,K ; Y                       ! Store voltage A
4770 K=K+1
4780 IF FP((I-1)/256)=0 AND V$="Y" THEN GOSUB 5930
   ! Take desired auxiliary measurement if n*256th operation
4790 NEXT I
4800 IF W$="A" THEN 4870                  ! Store voltage B?
4810 FOR I=1 TO LEN(D2$)-3                ! Yes
4820 Y=(NUM(D2$[I,I])-Z1)*P(2,2)*8/255
   ! Convert 8-bit ASCII characters into voltage values
   ! D2$[I,I] = ASCII character from curve B
   ! Z1 = zeroline offset error for curve B
   ! P(2,2) = timebase B voltage per division
   ! Values in D2$[] vary from 0 to 255
4830 PRINT# 1,K ; Y                       ! Store voltage B
4840 K=K+1
```

```
4850 IF FP((I-1)/256)=0 AND V$="Y" THEN GOSUB 5930
   ! Take desired auxiliary measurement if n*256th operation
4860 NEXT I
4870 ASSIGN# 1 TO *                        ! Close file
4880 IF P(1,5)=P(2,5) AND C1=1 AND W$="A" THEN W$="B"
   ! If storing a second curve separately, set value for next pass
4890 IF V$="Y" THEN GOSUB 6120             ! Store aux data
4900 RETURN
4910 OFF ERROR
4920 IF ERRN≠63 THEN 5020                  ! File already exist?
4930 CLEAR @ BEEP                          ! Yes, notify user
4940 DISP "File already exists. Do you want"
4950 DISP "to purge? (Y/N)"
4960 INPUT Q$                              ! Purge existing file?
4970 IF Q$="Y" THEN PURGE X$ @ GOTO 4270   ! Yes, purge & cont
4980 CLEAR @ BEEP                          ! No, enter new name
4990 DISP "Enter another name."
5000 INPUT X$
5010 GOTO 4260                             ! Retry storage
5020 IF ERRN≠130 THEN 4270                 ! Disk error; no, retry
5030 CLEAR @ BEEP                          ! Yes, notify user
5040 DISP "Disk error. Re-enter storage."
5050 WAIT 4500 @ GOTO 1080                 ! Re-assign mass storage
5060 REM *
5070 REM *
5080 REM *  ZERO COMPENSATION
5090 REM *    SUBROUTINE
5100 REM *    1) COMPENSATE FOR
5110 REM *       ZERO ERROR
5120 REM *
5130 REM *
5140 IF Q1$="A" OR Q1$="B" THEN A=1        ! Set for single curve
5150 IF Q1$="C" THEN A=2 @ Q1$="A"         ! Set for both curves
5160 SEND 7 ; UNL MTA LISTEN 2 SCG 1       ! Listener left plugin
5170 OUTPUT 7 ;A2$[1,6]&"V/D "&VAL$(A2)&";CPL GND" ! Gnd left plugin
```

```
5180 SEND 7 ; UNL MTA LISTEN 2 SCG 2          ! Listener rt plugin
5190 OUTPUT 7 ;B2$[1,6]&"V/D "&VAL$(B2)&";CPL GND" ! Gnd rt plugin
5200 SEND 7 ; UNL MTA LISTEN 2 SCG 0          ! Listener 7612D
5210 OUTPUT 7 ;"ARM "&Q1$&";MTRIG;READ "&Q1$  ! Arm & trigger curve
5220 SEND 7 ; UNT MLA TALK 2 SCG 0            ! Talker 7612D
5230 TRANSFER 7 TO D$ FHS ; EOI               ! Fast transfer data
5240 IF Q1$="A" THEN D1$=D$                   ! Store curve A data
5250 D2$=D$                                   ! Store curve B data
5260 IF Q1$="A" AND A=2 THEN Q1$="B" @ D$=" " @ GOTO 5200
   ! If both channels, reset values and repeat process
5270 Z0=0 @ Z1=0                              ! Default zeroline errors
5280 IF A=2 OR Q1$="A" THEN D1$=D1$[4,LEN(D1$)-1] @ Z0=1
   ! Remove unnecessary string information from curve A
5290 IF A=2 OR Q1$="B" THEN D2$=D2$[5,LEN(D2$)-1] @ Z1=1
   ! Remove unnecessary string information from curve B
5300 B=0 @ C=0
5310 FOR I=1 TO 10                            ! Average 1st 10 samples
5320 IF Q1$="B" AND A=1 THEN 5340             ! Curve B only?
5330 B=B+NUM(D1$[I,I])                        ! No, add next A value
5340 C=C+NUM(D2$[I,I])                        ! Add next B value
5350 NEXT I
5360 Z0=IP(Z0*B/(I-1)+.5)                     ! Zeroline error A
5370 Z1=IP(Z1*C/(I-1)+.5)                     ! Zeroline error B
5380 SEND 7 ; UNL MTA LISTEN 2 SCG 1          ! Listener left plugin
5390 OUTPUT 7 ;A2$                            ! Set to orig state
5400 SEND 7 ; UNL MTA LISTEN 2 SCG 2          ! Listener rt plugin
5410 OUTPUT 7 ;B2$                            ! Set to orig state
5420 IF A=2 THEN Q1$="C"                      ! Set for both curves
5430 D$=" " @ D1$=" " @ D2$=" "               ! Re-initialize buffers
5440 RETURN
5450 REM *
5460 REM *
5470 REM *  AUXILIARY VOLTAGE
5480 REM *    SUBROUTINE
5490 REM *
```

```
5500 REM *
5510 CLEAR @ BEEP
5520 DISP "Do you want to use the system"
5530 DISP "voltmeter to make additional"
5540 DISP "measurements? (Y/N)"
5550 INPUT V$
5560 IF V$≠"Y" THEN RETURN
5570 CLEAR @ BEEP
5580 DISP "How many channels are to be"
5590 DISP "monitored by voltmeter? (4 max.)"
5600 INPUT T1                              ! Input # of chan
5610 T1=IP(T1)                             ! Make integer
5620 IF T1>0 AND T1<5 THEN 5670            ! # of channels valid?
5630 CLEAR @ BEEP                          ! No, notify user
5640 DISP "Please choose a number from 1 "
5650 DISP "to 4."
5660 WAIT 4500 @ GOTO 5570                 ! Re-enter # of channels
5670 FOR I=69 TO 70-T1 STEP -1             ! Yes, enter chan, rng
5680 CLEAR @ BEEP                          !   store at top of reg
5690 DISP "Enter the channel number and the"
5700 DISP "voltage range."
5710 DISP @ DISP "(.1V = 1, 1V = 2, and 10V = 3)"
5720 INPUT A,B                             ! Channel, voltage rng
5730 A=IP(A) @ B=IP(B)                     ! Make integers
5740 IF A>-1 AND A<1000 THEN 5780          ! Channel valid?
5750 CLEAR @ BEEP                          ! No, notify user
5760 DISP "Please enter a number 0-999."
5770 WAIT 4500 @ GOTO 5680                 ! Re-enter chan, rng
5780 IF B>0 AND B<4 THEN 5820              ! Voltage rng valid?
5790 CLEAR @ BEEP                          ! No, notify user
5800 DISP "Please enter a number 1-3."
5810 WAIT 4500 @ GOTO 5680                 ! Re-enter chan, rng
5820 FOR J=69 TO I STEP -1                 ! Yes, check entries
5830 IF T(1,J)≠A THEN 5880                 ! Entered previously?
5840 CLEAR @ BEEP                          ! Yes, notify user
```

```
5850 DISP "You have already chosen that"
5860 DISP "channel. Please enter another."
5870 WAIT 4500 @ GOTO 5680                 ! Re-enter chan, rng
5880 NEXT J
5890 T(1,I)=A @ T(2,I)=B                   ! No, store values
5900 NEXT I
5910 T2=1                                  ! Set time index
5920 RETURN
5930 REM *
5940 REM *
5950 REM *  AUXILIARY VOLTAGE
5960 REM *    ACQUISITION
5970 REM *
5980 REM *
5990 CLEAR 709 @ CLEAR 724                 ! Clear DACU & DVM
6000 OUTPUT 709 ;"AF0AL999AC0"             ! Select 0 of 0-999
6010 OUTPUT 724 ;"T3R3D.1S"                ! Man trg;10V rng;.1s dly
6020 FOR I1=69 TO 70-T1 STEP -1
6030 OUTPUT 709 ;"AC"&VAL$(T(1,I1))        ! Close chan on DACU
6040 OUTPUT 724 ;"R"&VAL$(T(1,I1-T1))      ! Set rng on DVM
6050 WAIT 500                              ! Let voltage settle
6060 TRIGGER 724                           ! Trigger DVM
6070 ENTER 724 ; T(1,T2)                   ! Store DVM voltage
6080 T(2,T2)=TIME-T(2,65)                  ! Store time
6090 T2=T2+1                               ! Increment time index
6100 NEXT I1
6110 RETURN
6120 REM *
6130 REM *
6140 REM *  AUXILIARY VOLTAGE
6150 REM *    STORAGE
6160 REM *
6170 REM *
6180 CLEAR @ BEEP
6190 DISP "What name do you want for the"
```

```
6200 DISP "auxiliary file?"
6210 INPUT Y$                              ! Input aux file name
6220 IF LEN(Y$)<=10 THEN 6280              ! Name too long?
6230 CLEAR @ BEEP                          ! Yes, notify user
6240 DISP "Name is too large. Please choose"
6250 DISP "a name with less than 11 "
6260 DISP "letters."
6270 WAIT 4500 @ GOTO 6180                 ! Re-enter name
6280 CLEAR @ BEEP                          ! No, store aux data
6290 DISP @ DISP @ DISP
6300 DISP "Storing data in ";Y$
6310 ON ERROR GOTO 6380                    ! Trap file create error
6320 CREATE Y$,138,8                       ! Create file space
6330 OFF ERROR
6340 ASSIGN# 1 TO Y$                       ! Open file
6350 PRINT# 1 ; T(,)                       ! Print aux array
6360 ASSIGN# 1 TO *                        ! Close file
6370 RETURN
6380 OFF ERROR
6390 IF ERRN≠63 THEN 6320                  ! File already exist?
6400 CLEAR @ BEEP                          ! Yes, notify user
6410 DISP "File already exists. Do you want"
6420 DISP "to purge? (Y/N)"
6430 INPUT Q$                              ! Purge file?
6440 IF Q$="Y" THEN PURGE X$ @ GOTO 6320   ! Yes, purge & cont
6450 CLEAR @ BEEP                          ! No, enter new name
6460 DISP "Enter another name."
6470 INPUT Y$
6480 GOTO 6310                             ! Retry storage
6490 REM *
6500 REM *
6510 REM *   DUPLICATE CURVE
6520 REM *      SUBROUTINE
6530 REM *
6540 REM *
```

```
6550 CLEAR @ BEEP
6560 DISP "The processing package cannot"
6570 DISP "handle 2 curves of the same "
6580 DISP "type, i.e. both current. Do "
6590 DISP "you want the curves stored"
6600 DISP "separately? (Y/N)"
6610 INPUT C$                          ! Store curves separately
6620 IF C$="N" THEN RETURN             ! No, return
6630 C$="Y" @ C1=1                     ! Yes, set flags
6640 CLEAR @ BEEP
6650 DISP "The curve from plug-in A will"
6660 DISP "be stored first."
6670 WAIT 4500 @ RETURN
```

NORML

The Tektronix 7612D Programmable Digitizer was developed as a single-shot transient digitizer. Therefore, the NORML program was written to simulate a normal oscilloscope.

The NORML program continuously arms and triggers the Tektronix 7612D Programmable Digitizer to simulate a free-running state. To change settings on the digitizer, the operator pauses the program, makes the desired changes, and continues the program.

```
10 REM *
20 REM *
30 REM * NORMAL O-SCOPE - 7612D
40 REM *    MAIN PROGRAM
50 REM *
60 REM *Copyright:  6/10/85
70 REM * gandalf software, inc.
80 REM * Chuck Graves, wizard
90 REM *
100 REM *
110 COM X$[10]                          ! Make file name common
120 REMOTE 7                            ! Control HPIB
130 SEND 7 ; UNL MTA LISTEN 2 SCG 0     ! Listener 7612D
140 OUTPUT 7 ;"WRI ON"                  ! Set 7612D data rdy SRQ
150 CLEAR @ BEEP                        ! Display program options
160 DISP "Press when necessary."
170 DISP @ DISP "K1 = Pause to adjust settings."
180 DISP "K2 = Finished"
190 ON KEY# 1,"  PAUSE" GOTO 260        ! Change settings option
200 ON KEY# 2," FINIS" GOTO 300         ! Finished option
210 KEY LABEL
220 SEND 7 ; UNL MTA LISTEN 2 SCG 0     ! Listener 7612D
230 OUTPUT 7 ;"ARM A,B;MTRIG"           ! Arm traces & trigger
240 WAIT 90                             ! Wait 90 ms
250 GOTO 220                            ! Repeat
260 CLEAR @ BEEP
270 DISP "Adjust settings and press CONT."
280 LOCAL 7 @ PAUSE                     ! Give 7612D local cntl
290 REMOTE 7 @ GOTO 150                 ! Take cntl and cycle
300 CLEAR @ BEEP                        ! Return to Autost
310 DISP "    MISSION CONTROL"
320 DISP "will now resume control."
330 FOR I=1 TO 65
340 BEEP 65-I,20
```

```
350 NEXT I
360 CHAIN "Autost:D700"                      ! Load Autost prog
370 END
```

TABLET

The TABLET program controls the HP9111A Graphics Tablet. The tablet is used to digitize up to two (2) 1024-point curves by hand.

The operator enters the corners of the graph, the number of x divisions, value per x division (time), the number of y divisions, value per y divisions (e.g. voltage), and the location of the zero line. The program uses these values to correct the data for rotational and translational digitizing errors, and scales the data to represent the curves digitized, i.e. converts xy coordinates to voltage vs. time data. This converted data is stored.

The TABLET program also allows the operator to generate a hardcopy of device data. The program will list manufacturer, device type, mask type, device number, temperature, second-breakdown type, forward base current, nominal reverse base current, reverse base current at second-breakdown, and comments. These device data are not stored, however.

```
10 REM *
20 REM *
30 REM *    TABLET MAIN
40 REM *      PROGRAM
50 REM *
60 REM *Copyright:  7/6/85
70 REM * gandalf software, inc.
80 REM * Chuck Graves, wizard
90 REM *
100 REM *
110 COM X$[10]                                 ! Make file name common
120 INTEGER X(2,512),Y(2,512),U(4),V(4),T(3)
130 SHORT P(3,5),M(2),N(2)
140 DIM P$[25],D$[25]
150 DEG
160 CLEAR @ BEEP
170 DISP "Initializing"
180 GOSUB 980                                  ! Initialization routine
190 GOSUB 1270                                 ! Visual aid routine
200 CLEAR @ BEEP
210 DISP "How many curves will be entered?"
220 DISP "(1/2)"
230 INPUT Q                                    ! Input # of curves
240 IF Q=1 OR Q=2 THEN 280                     ! # of curves valid?
250 CLEAR @ BEEP                               ! No, notify user
260 DISP "Please choose 1 or 2."
270 WAIT 4500 @ GOTO 200                       ! Re-enter # of curves
280 CLEAR @ BEEP                               ! Yes, cont
290 OUTPUT 706 ;"BP42,125,5"                   ! Generate tone
300 DISP "Please digitize the corners of"
310 DISP "the graph grid in the following"
320 DISP "order:  upper left, upper right,"
330 DISP "lower left, and lower right."
340 FOR I=1 TO 4
350 GOSUB 1540                                 ! Digitization routine
```

```
360 IF NOT S OR B=7 THEN 350
   ! If no digitization or softkey digitized, then repeat process
370 U(I)=T(1)                             ! Store x value
380 V(I)=T(2)                             ! Store y value
390 NEXT I
400 GOSUB 1880                            ! Correction routine
410 FOR I=1 TO Q
420 P1=I
430 CLEAR @ BEEP                          ! Display prog options
440 DISP "Digitize curve ";VAL$(I);"."
450 DISP @ DISP "K1 = End of curve."
460 DISP "K2 = Store all data."
470 DISP "K3 = Process new set."
480 DISP "K4 = Finished."
490 DISP "K5 = Print device data."
500 ON KEY# 1,"  END" GOTO 670            ! End of curve option
510 ON KEY# 2," STORE" GOTO 2610          ! Storage option
520 ON KEY# 3,"NEW SET" GOTO 790          ! New data set option
530 ON KEY# 4," FINIS" GOTO 790           ! Finished option
540 ON KEY# 5," SPECS" GOSUB 3420         ! Device specs option
550 KEY LABEL
560 FOR J=1 TO 512
570 GOSUB 2330                            ! Active tablet routine
580 IF B=7 AND T(1)=5 THEN GOSUB 3420 @ GOTO 570
   ! If softkey 5 digitized, device spec routine & return to act tab
590 IF B=7 AND T(1)>5 THEN GOSUB 3970 @ GOTO 570
   ! If softkey > 5 digitized, unused softkey routine
600 IF B=7 THEN 2470                      ! Other softkey branch
610 NEXT J
620 CLEAR @ BEEP
630 DISP "Storage file is full. Do you "
640 DISP "wish to re-enter data? (Y/N)"
650 INPUT Q$                              ! Re-enter data?
660 IF Q$="Y" THEN 160                    ! Yes, start over
670 P(I,4)=J-1                            ! Store # of pts in crv
```

```
680 NEXT I
690 CLEAR @ BEEP
700 DISP "Digitization process is"
710 DISP "complete. Please press key or"
720 DISP "digitize softkey to continue."
730 KEY LABEL
740 GOSUB 2330                          ! Active tablet routine
750 IF B≠7 THEN 750                     ! Loop until softkey
760 IF T(1)=5 THEN GOSUB 3420 @ GOTO 690
   ! If softkey 5 digitized, device spec routine & return to act tab
770 IF T(1)>5 THEN GOSUB 3970 @ GOTO 690
   ! If softkey > 5 digitized, unused softkey routine
780 GOTO 2470                           ! Other softkey branch
790 P(I,4)=J-1                          ! Store # of pts in crv
800 CLEAR @ BEEP
810 DISP "Have you stored the present set"
820 DISP "of curves? (Y/N)"
830 INPUT Q$                            ! Data stored?
840 IF Q$≠"Y" THEN 2610                 ! No, storage routine
850 CLEAR @ BEEP                        ! Yes, cont
860 DISP "Do you wish to digitize another"
870 DISP "set of curves? (Y/N)"
880 INPUT Q$                            ! New data set?
890 IF Q$="Y" THEN 160                  ! Yes, start over
900 CLEAR @ BEEP                        ! No, return to Autost
910 DISP "    MISSION CONTROL"
920 DISP "will now resume control."
930 FOR I=1 TO 65
940 BEEP 65-I,20
950 NEXT I
960 CHAIN "Autost:D700"                 ! Load Autost
970 END
980 REM *
990 REM *
1000 REM *  INITIALIZATION
```

```
1010 REM *    SUBROUTINE
1020 REM *
1030 REM *
1040 OUTPUT 706 ;"IN"                       ! Initialize tablet
1050 FOR I=1 TO 2
1060 FOR J=1 TO 512
1070 X(I,J)=0                               ! Initialize x reg
1080 Y(I,J)=0                               ! Initialize y reg
1090 NEXT J
1100 FOR J=1 TO 5
1110 P(I,J)=0 @ P(3,J)=0                    ! Initialize cntl reg
1120 NEXT J
1130 M(I)=0 @ N(I)=0                        ! Initialize scale factor
1140 NEXT I
1150 L=0
1160 FOR I=1 TO 4
1170 U(I)=0                                 ! Initialize corner x reg
1180 V(I)=0                                 ! Initialize corner y reg
1190 NEXT I
1200 FOR I=1 TO 3
1210 T(I)=0                                 ! Initialize temp reg
1220 NEXT I
1230 P(1,5)=86 @ P(2,5)=86                  ! Default units = V
1240 R$=":D700" @ F=1                       ! Default mass storage
1250 C$="Y" @ C1=0
    ! C$ = store identical curves separately
    ! C1 = stores are not identical in type
1260 RETURN
1270 REM *
1280 REM *
1290 REM *   VISUAL AID
1300 REM *    SUBROUTINE
1310 REM *
1320 REM *
1330 PRINTER IS 2                           ! Use thermal printer
```

```
1340 PRINT "Softkey Assignments"
1350 PRINT @ PRINT
1360 PRINT "1  END"
1370 PRINT "   End of curve. Digitize to"
1380 PRINT "   start next curve."
1390 PRINT @ PRINT "2  STORE"
1400 PRINT "   Transfer curves to tape or"
1410 PRINT "   disk."
1420 PRINT @ PRINT "3  NEW SET"
1430 PRINT "   Reinitialize and process new"
1440 PRINT "   set of curves."
1450 PRINT @ PRINT "4  FINISHED"
1460 PRINT "   Finished with this program."
1470 PRINT @ PRINT "5  DEVICE DATA"
1480 PRINT "   Print out device data."
1490 PRINT @ PRINT "6-16  Not used."
1500 FOR I=1 TO 5
1510 PRINT @ PRINT
1520 NEXT I
1530 RETURN
1540 REM *
1550 REM *
1560 REM *  DIGITIZER SUBROUTINE
1570 REM *     A) CHECK STATUS
1580 REM *     B) GET DATA
1590 REM *
1600 REM *
1610 OUTPUT 706 ;"SG;DP"                     ! Set for digitization
1620 B=7 @ B$="RS" @ B1=1
    ! Check softkey bit (7), read softkey, store 1 input value
1630 P$="BP24,125,5;BP36,125,5"              ! Set softkey tones
1640 GOSUB 1700                              ! Digitizing routine
1650 IF S THEN 1690
    ! If status bit set, then return
```

```
1660 B=2 @ B$="OD" @ B1=3
    ! Check digitized point bit (2), output point, store 3 input values
1670 P$="BP36,125,5"                            ! Set point tone
1680 GOSUB 1700                                 ! Digitizing routine
1690 RETURN
1700 REM *
1710 REM *
1720 REM *  STATUS SUBROUTINE
1730 REM *    A) CHECK SOFTKEY
1740 REM *    B) CHECK POINT
1750 REM *
1760 REM *
1770 OUTPUT 706 ;"OS"                           ! Ask for status byte
1780 ENTER 706 ; S                              ! Accept response
1790 S=BIT(S,B)                                 ! Check bit in status
1800 IF NOT S THEN 1870
    ! If desired bit is not set, then return
1810 OUTPUT 706 ;B$
    ! If desired bit is set, then ask for data
1820 IF B1=3 THEN 1850                          ! Point?
1830 ENTER 706 ; T(1)                           ! No, get softkey
1840 GOTO 1860
1850 ENTER 706 ; T(1),T(2),T(3)                 ! Yes, get point
1860 OUTPUT 706 ;P$                             ! Send tone(s)
1870 RETURN
1880 REM *
1890 REM *
1900 REM * SET-UP SUBROUTINE
1910 REM *   A) ROTATION FACTORS
1920 REM *   B) GRID FACTORS
1930 REM *
1940 REM *
1950 V1=SQR((U(3)-U(4))^2+(V(3)-V(4))^2)        ! Lower boundary length
1960 U1=ATN((V(4)-V(3))/(U(4)-U(3)))            ! Rotation wrt tablet
1970 U(4)=U(3)+IP(V1+.5)                        ! Correct x lower RH
```

```
1980 V(4)=V(3)                                ! Correct y lower RH
1990 V1=SQR((U(1)-U(3))^2+(V(1)-V(3))^2)      ! Left boundary length
2000 U(1)=U(3)                                ! Correct x upper LH
2010 V(1)=V(3)+IP(V1+.5)                      ! Correct y upper LH
2020 U(2)=U(4)                                ! Correct x upper RH
2030 V(2)=V(1)                                ! Correct y upper RH
2040 CLEAR @ BEEP
2050 DISP "How many horizontal divisions"
2060 DISP "are there?"
2070 INPUT P(3,1)                             ! Input # of x divisions
2080 CLEAR @ BEEP
2090 DISP "How many vertical divisions"
2100 DISP "are there?"
2110 INPUT P(3,2)                             ! Input # of y divisions
2120 P(1,3)=DATE                              ! Store date
2130 P(2,3)=TIME                              ! Store time
2140 FOR I=1 TO Q
2150 CLEAR @ BEEP
2160 DISP "What is the value per horizontal"
2170 DISP "division for curve ";VAL$(I);"?"
2180 DISP @ DISP "(Enter value and unit, for"
2190 DISP "example 5ms = 5E-3,s)"
2200 INPUT P(I,1),A$                          ! Input x/division
2210 CLEAR @ BEEP
2220 DISP "What is the value per vertical"
2230 DISP "division for curve ";VAL$(I);"?"
2240 DISP @ DISP "(Enter value and unit, for"
2250 DISP "example, 5A = 5,A.)"
2260 INPUT P(I,2),A$                          ! Input y/division
2270 P(I,5)=NUM(A$)                           ! Store units in cntl reg
2280 M(I)=P(3,1)*P(I,1)/(U(4)-U(3))           ! Calculate x scaling
2290 N(I)=P(3,2)*P(I,2)/(V(1)-V(3))           ! Calculate y scaling
2300 GOSUB 4170                               ! Zeroline routine
2310 NEXT I
```

```
2320 RETURN
2330 REM *
2340 REM *
2350 REM *  ACTIVE SUBROUTINE
2360 REM *    A) GET DATA
2370 REM *    B) CONTROL BRANCH
2380 REM *
2390 REM *
2400 GOSUB 1540                               ! Digitization routine
2410 IF NOT S THEN 2400
   ! If not digitization, then repeat process
2420 IF B=7 THEN RETURN                       ! If softkey, return
2430 GOSUB 2480                               ! Pt correction routine
2440 X(I,J)=T(1)                              ! Store x value
2450 Y(I,J)=T(2)                              ! Store y value
2460 RETURN
2470 ON T(1) GOTO 670,2610,790,790
   ! Softkey branches: end of curve, storage, new set, finished
2480 REM *
2490 REM *
2500 REM * SKEW SUBROUTINE
2510 REM *   A) ADJUST ROTATION
2520 REM *
2530 REM *
2540 V1=SQR((U(3)-T(1))^2+(V(3)-T(2))^2)      ! Lower LH to point
2550 IF T(1)-U(3)=0 THEN U2=90 @ GOTO 2580
   ! If point is over lower LH, then angle = 90°
2560 U2=ATN((T(2)-V(3))/(T(1)-U(3)))          ! Else calculate angle
2570 IF U2<0 AND T(2)-V(3)>0 THEN U2=U2+180   ! 2nd quadrant correction
2580 T(1)=IP(V1*COS(U2-U1)+.5)                ! Corrected x value
2590 T(2)=IP(V1*SIN(U2-U1)+.5)                ! Corrected y value
2600 RETURN
2610 REM *
2620 REM *
```

```
2630 REM *  STORAGE SUBROUTINE
2640 REM *
2650 REM *
2660 P(I,4)=J-1                          ! Set # of pts in curve
2670 G=P1                                ! Set # of curves
2680 CLEAR @ BEEP
2690 DISP "What name do you want for the"
2700 DISP "storage file?"
2710 INPUT X$                            ! Input file name
2720 IF LEN(X$)<=10 THEN 2780            ! Name too long?
2730 CLEAR @ BEEP                        ! Yes, notify user
2740 DISP "Name is too large. Please enter"
2750 DISP "a name with less than 11"
2760 DISP "letters."
2770 WAIT 4500 @ GOTO 2680               ! Re-enter file name
2780 IF C1=1 THEN 2860                   ! No; Same type?
2790 CLEAR @ BEEP                        ! No, cont
2800 DISP "Where do you want the curves"
2810 DISP "stored? (DISK00/DISK01/TAPE)"
2820 INPUT Q$                            ! Set data destination
2830 IF Q$="TAPE" THEN R$=":T"
2840 IF Q$="DISK01" THEN R$=":D701"
2850 MASS STORAGE IS R$                  ! Set mass storage unit
2860 IF P(1,5)=P(2,5) AND P1=2 THEN GOSUB 4380
   ! Yes. If both curves are same type, then duplicate file routine
2870 IF C$="N" THEN GOSUB 2140 @ GOTO 410
   ! If don't want to separate, re-enter y/division & redigitize
2880 CLEAR @ BEEP
2890 DISP @ DISP @ DISP
2900 DISP "Storing data in ";X$
2910 A=P(1,4)+P(2,4)
2920 IF P1=1 THEN A=P(1,4)
2930 IF F=2 THEN A=P(2,4)
2940 B=2*A+5*P1+5                        ! Calculate file space
```

```
2950 ON ERROR GOTO 3270                     ! Trap file create error
2960 CREATE X$,B,8                          ! Create file space
2970 OFF ERROR
2980 ASSIGN# 1 TO X$                        ! Open file
2990 PRINT# 1,1 ; P1                        ! Store # of curves
3000 PRINT# 1,2 ; P(3,1)                    ! Store # of x divisions
3010 PRINT# 1,3 ; P(3,2)                    ! Store # of y divisions
3020 PRINT# 1,4 ; P(1,3)                    ! Store date
3030 PRINT# 1,5 ; P(2,3)                    ! Store time
3040 K=6
3050 FOR I=F TO G
3060 FOR J=1 TO 5
3070 PRINT# 1,K ; P(I,J)                    ! Store control registers
3080 K=K+1
3090 NEXT J
3100 NEXT I
3110 FOR I=F TO G
3120 FOR J=1 TO P(I,4)
3130 PRINT# 1,K ; X(I,J)*M(I)               ! Store x data
3140 K=K+1
3150 NEXT J
3160 NEXT I
3170 FOR I=F TO G
3180 FOR J=1 TO P(I,4)
3190 PRINT# 1,K ; Y(I,J)*N(I)-Z(I)          ! Store y data
3200 K=K+1
3210 NEXT J
3220 NEXT I
3230 IF C1=1 AND F=1 THEN F=2 @ G=2 @ GOTO 2680
   ! If storing curves separately, store second curve
3240 CLEAR @ BEEP
3250 DISP "Data is stored." @ DISP
3260 GOTO 860                               ! Return to main prog
3270 OFF ERROR
```

```
3280 IF ERRN≠63 THEN 3380                      ! File already exist?
3290 CLEAR @ BEEP                              ! Yes, notify user
3300 DISP "File already exists. Do you want"
3310 DISP "to purge? (Y/N)"
3320 INPUT Q$                                  ! Purge file?
3330 IF Q$="Y" THEN PURGE X$ @ GOTO 2950       ! Yes, purge & cont
3340 CLEAR @ BEEP                              ! No, enter new name
3350 DISP "Enter another name."
3360 INPUT X$
3370 GOTO 2950                                 ! Retry storage
3380 IF ERRN≠130 THEN 2960                     ! Disk error; no, retry
3390 CLEAR @ BEEP                              ! Yes, notify user
3400 DISP "Disk error. Re-enter storage."
3410 WAIT 4500 @ GOTO 2780                     ! Re-assign mass storage
3420 REM *
3430 REM *
3440 REM *  DEVICE DATA
3450 REM *    SUBROUTINE
3460 REM *
3470 REM *
3480 CLEAR @ BEEP
3490 PRINTER IS 2                              ! Use thermal printer
3500 PRINT @ PRINT "Manufacturer - ";
3510 DISP "Enter manufacturer."
3520 INPUT D$ @ PRINT D$
3530 PRINT @ PRINT "Device type - ";
3540 CLEAR @ BEEP
3550 DISP "Enter device type."
3560 INPUT D$ @ PRINT D$
3570 PRINT @ PRINT "Mask type or other applicable"
3580 PRINT "data - ";
3590 CLEAR @ BEEP
3600 DISP "Enter mask type or other"
3610 DISP "applicable data."
```

```
3620 INPUT D$ @ PRINT D$
3630 PRINT @ PRINT "Device number - ";
3640 CLEAR @ BEEP
3650 DISP "Enter device number."
3660 INPUT D$ @ PRINT D$
3670 PRINT @ PRINT "Temperature - ";
3680 CLEAR @ BEEP
3690 DISP "Enter temperature (RT or"
3700 DISP "degrees C.)"
3710 INPUT D$ @ PRINT D$;" C"
3720 PRINT @ PRINT "SB type - ";
3730 CLEAR @ BEEP
3740 DISP "Enter SB type (N,A,B, or C.)"
3750 INPUT D$ @ PRINT D$
3760 PRINT @ PRINT "Forward base current - ";
3770 CLEAR @ BEEP
3780 DISP "Enter forward base current."
3790 INPUT D$ @ PRINT D$
3800 PRINT @ PRINT "Reverse base current:"
3810 PRINT @ PRINT "     Nominal - ";
3820 CLEAR @ BEEP
3830 DISP "Enter nominal reverse base"
3840 DISP "current."
3850 INPUT D$ @ PRINT D$
3860 PRINT @ PRINT "     Actual at SB - ";
3870 CLEAR @ BEEP
3880 DISP "Enter reverse base current"
3890 DISP "at SB."
3900 INPUT D$ @ PRINT D$
3910 PRINT @ PRINT "Comments:"
3920 CLEAR @ BEEP
3930 DISP "Enter any additional comments."
3940 INPUT D$ @ PRINT "     ";D$
3950 PRINT @ PRINT @ PRINT
```

```
3960 RETURN
3970 REM *
3980 REM *
3990 REM *  Unused Softkeys
4000 REM *
4010 REM *
4020 CLEAR @ BEEP
4030 DISP "This softkey performs no"
4040 DISP "function. Please choose"
4050 DISP "another."
4060 N1=N1+1                                 ! Increment nuisance ind
4070 IF N1<4 THEN RETURN                     ! Not a nuisance, return
4080 PLOTTER IS 1                            ! Is a nuisance,
4090 CSIZE 21 @ GCLEAR                       !   notify user!!
4100 SCALE 0,10,0,10
4110 MOVE 1,5
4120 LABEL "BUZZ"
4130 MOVE 2,0
4140 LABEL "OFF"
4150 WAIT 4500 @ GCLEAR
4160 RETURN
4170 REM *
4180 REM *
4190 REM *   ZERO CALIBRATION
4200 REM *     SUBROUTINE
4210 REM *
4220 REM *
4230 CLEAR @ BEEP
4240 DISP "For curve ";VAL$(I);":"
4250 DISP "on a scale of 0 to ";VAL$(P(3,2));", what is"
4260 DISP "the y-coordinate for the origin?"
4270 DISP "(0 = lower left corner,"
4280 DISP " ";VAL$(P(3,2)/2);" = left center, and"
4290 DISP " ";VAL$(P(3,2));" = upper left corner.)"
```

```
4300 INPUT Z(I)                                ! Input zeroline position
4310 IF Z(I)>=0 AND Z(I)<=P(3,2) THEN 4360     ! Entry valid?
4320 CLEAR @ BEEP                              ! No, notify user
4330 DISP "Please choose a number between"
4340 DISP "0 and ";VAL$(P(3,2));"."
4350 WAIT 4500 @ GOTO 4230                     ! Re-enter position
4360 Z(I)=Z(I)*P(I,2)                          ! Set zero offset
4370 RETURN
4380 REM *
4390 REM *
4400 REM *   DUPLICATE CURVE
4410 REM *      SUBROUTINE
4420 REM *
4430 REM *
4440 CLEAR @ BEEP
4450 DISP "The processing package cannot"
4460 DISP "handle 2 curves of the same"
4470 DISP "type, i.e. both current. Do"
4480 DISP "you want the curves stored"
4490 DISP "seperately? (Y/N)"
4500 INPUT C$                                  ! Store separately?
4510 IF C$="N" THEN RETURN                     ! No, return
4520 C$="Y" @ C1=1 @ P1=1                      ! Yes, set flags
4530 CLEAR @ BEEP
4540 DISP "Curve 1 will be stored first."
4550 WAIT 4500 @ RETURN
```

PLOT

The PLOT program generates all plots of curves with respect to time, e.g. voltage vs. time. The data is stored in two (2) possible formats -- unprocessed and processed.

The unprocessed data is read into the computer and plotted using the values stored in the control registers. The control registers contain information regarding the number of points in the curve, the number of x divisions, value per x division (time), value per y division (e.g. voltage), curve type (i.e. voltage or current), and time and date of measurement.

The processed data is read into the computer and plotted using values calculated by the computer. The program scans ;the given curve values, finds the minimum and maximum values, and plots the curve to fill 80% of the plotting area.

The PLOT program allows the operator to plot curves singularly or in groups, and to scale the size of the plot. Also, the program allows the plots to be made on either a grid or an open graph.

Finally, the PLOT program allows the operator to generate a set of second-breakdown statistics, if processed data is being used. The program will print values for voltage, current, power, energy, and time at second-breakdown; for time, t_o, at 10% of second-breakdown voltage; for voltage, current, power, and energy at time, t_o; for time from t_o to second-breakdown; for change in energy from t_o to second-breakdown.

```
10 REM *  PLOT PACKAGE
20 REM *    MAIN PROGRAM
30 REM *Copyright: 11/20/84
40 COM X$[10]                               ! Make file name common
50 SHORT X(2048),Y(2048),P(3,5)
60 DIM A$[40]
70 GOSUB 4060                               ! Initialization routine
80 IF X$≠"NULL" THEN 130                    ! Plot first prog?
90 CLEAR @ BEEP                             ! Yes, enter file name
100 DISP "What is the name of the file";
110 INPUT X$                                ! Input file name
120 IF LEN(X$)>10 THEN CLEAR @ BEEP @ DISP "Name is too large."
   @ WAIT 4500 @ GOTO 90
    ! If name is too long, notify user and re-enter file name
130 CLEAR @ BEEP                            ! No, set mass storage
140 OFF ERROR
150 DISP "Where is ";X$;" stored";
160 DISP "(TAPE/DISK00/DISK01)"
170 INPUT R$                                ! Input data storage
180 GOSUB 650                               ! Mass storage routine
190 ON ERROR GOTO 600                       ! Trap file error
200 ASSIGN# 1 TO X$                         ! Open file
210 OFF ERROR
220 READ# 1,1 ; P1                          ! Read # of curves
230 IF P1>2 THEN T=2 @ P1=2                 ! P1>2 for processed file
240 READ# 1,2 ; P(3,1)                      ! Read # horiz divisions
250 READ# 1,3 ; P(3,2)                      ! Read # vert divisions
260 K=6
270 FOR I=1 TO P1
280 FOR J=1 TO 5
290 READ# 1,K ; P(I,J)                      ! Read control registers
300 K=K+1
310 NEXT J
320 NEXT I
330 READ# 1,4 ; P(1,3)                      ! Read meas date
```

```
340 READ# 1,5 ; P(2,3)                        ! Read meas time
350 CLEAR @ BEEP
360 DISP "Currently operating on ";X$
370 ON KEY# 1,"Plot V" GOTO 850               ! Plot voltage option
380 ON KEY# 2,"Plot I" GOTO 920               ! Plot current option
390 ON KEY# 3,"Plot P" GOTO 990               ! Plot power option
400 ON KEY# 4,"Plot U" GOTO 1020              ! Plot energy option
410 ON KEY# 5,"Scale" GOTO 730                ! Change scale option
420 ON KEY# 6,"New Set" GOTO 460              ! New data set option
430 ON KEY# 7,"Finished" GOTO 510             ! Finished option
440 KEY LABEL
450 GOTO 450                                  ! Loop until choice
460 ASSIGN# 1 TO *                            ! Close file
470 CLEAR @ BEEP
480 DISP "What is the new file name";
490 INPUT X$                                  ! Input new file name
500 GOTO 120                                  ! Restart process
510 ASSIGN# 1 TO *                            ! Close file
520 CLEAR @ BEEP                              ! Return to Autost
530 DISP "    MISSION CONTROL"
540 DISP "will now resume control."
550 FOR I=1 TO 65
560 BEEP 65-I,20
570 NEXT I
580 CHAIN "Autost:D700"                       ! Load Autost prog
590 END
600 OFF ERROR
610 IF ERRN≠130 THEN 200                      ! Disk error; no, retry
620 CLEAR @ BEEP                              ! Yes, notify user
630 DISP "Disk error. Re-enter storage."
640 WAIT 4500 @ GOTO 130                      ! Re-assign mass storage
650 IF R$="TAPE" THEN 710
660 IF R$="DISK01" THEN 690
670 MASS STORAGE IS ":D700"                   ! Select disk 0
680 GOTO 720
```

```
690 MASS STORAGE IS ":D701"                    !  or, select disk 1
700 GOTO 720
710 MASS STORAGE IS ":T"                       !  or, select tape
720 RETURN
730 REM *  SCALE SUBROUTINE
740 CLEAR @ BEEP
750 DISP "Enter the scale factor for"
760 DISP "plotting (less than 2.25.)"
770 INPUT H                                    ! Enter new scale factor
780 IF H<=2.25 AND H>0 THEN 830                ! Scale factor valid?
790 CLEAR @ BEEP                               ! No, notify user
800 DISP "Please pick a scale factor"
810 DISP "on the range 0<H<2.25."
820 WAIT 4500 @ GOTO 740                       ! Re-enter scale factor
830 GOTO 370                                   ! Return to main prog
840 REM *  PLOT SUBROUTINE
850 I=1 @ K=2 @ K$="voltage" @ L=1
    ! I = position of time array in file for voltage curve
    ! K = position of voltage array in file
    ! K$ = type of curve ; L = curve position index
    ! Default values are for processed data files; voltage is curve 1
860 IF CHR$(P(1,5))="A" AND CHR$(P(2,5))≠"V" THEN DISP "Only current."
   @ WAIT 4500 @ GOTO 370
    ! If curve 1 is current and curve 2 is not voltage, notify user
    ! and return to main program
870 IF CHR$(P(2,5))="A" AND CHR$(P(1,5))≠"V" THEN DISP "Only current."
   @ WAIT 4500 @ GOTO 370
    ! If curve 2 is current and curve 1 is not voltage, notify user
    ! and return to main program
880 IF CHR$(P(2,5))="V" THEN K=3               ! Voltage is curve 2
890 IF T=1 AND K=3 THEN I=2 @ K=4
    ! Change values for unprocessed voltage curve 2
900 IF T=1 AND K=2 THEN I=1 @ K=3
    ! Change values for unprocessed voltage curve 1
910 GOTO 1060                                  ! Proceed with plotting
```

```
920 I=1 @ K=3 @ K$="current" @ L=2
    ! I = position of time array in file for current curve
    ! K = position of current array in file
    ! K$ = type of curve ; L = curve position index
    ! Default values are for processed data files; current is curve 1
930 IF CHR$(P(2,5))="V" AND CHR$(P(1,5))≠"A" THEN DISP "Only voltage."
   @ WAIT 4500 @ GOTO 370
    ! If curve 1 is voltage and curve 2 is not current, notify user
    ! and return to main program
940 IF CHR$(P(1,5))="V" AND CHR$(P(2,5))≠"A" THEN DISP "Only voltage."
   @ WAIT 4500 @ GOTO 370
    ! If curve 1 is voltage and curve 2 is not current, notify user
    ! and return to main program
950 IF CHR$(P(1,5))="A" THEN K=2                ! Current is curve 2
960 IF T=1 AND K=3 THEN I=2 @ K=4
    ! Change values for unprocessed current curve 2
970 IF T=1 AND K=2 THEN I=1 @ K=3
    ! Change values for unprocessed current curve 1
980 GOTO 1060                                   ! Proceed with plotting
990 IF T=1 THEN CLEAR @ BEEP @ DISP "No power curve." @ WAIT 4500
    @ GOTO 370
    ! If not processed data file, notify user & return to main prog
1000 I=1 @ K=4 @ K$="power" @ L=3
    ! I = position of time array in file for power curve
    ! K = position of power array in file
    ! K$ = type of curve ; L = curve position index
1010 GOTO 1060                                  ! Proceed with plotting
1020 IF T=1 THEN CLEAR @ BEEP @ DISP "No energy curve." @ WAIT 4500
     @ GOTO 370
    ! If not processed data file, notify user & return to main prog
1030 I=1 @ K=5 @ K$="energy" @ L=4
    ! I = position of time array in file for energy curve
    ! K = position of energy array in file
    ! K$ = type of curve ; L = curve position index
1040 GOTO 1060                                  ! Proceed with plotting
```

```
1050 IF T=1 THEN CLEAR @ BEEP @ DISP "Must be processed first."
    @ WAIT 4500 @ GOTO 370
    ! If not processed data file, notify user & return to main prog
1060 GOSUB 4430                           ! Single plot routine
1070 CLEAR @ BEEP
1080 DISP "What title do you want for the "
1090 DISP I$;" axis of this "
1100 DISP K$;" vs ";I$;" curve";
1110 INPUT U$                             ! Input horiz title
1120 IF LEN(U$)>25 THEN CLEAR @ BEEP @ DISP "No more than 25
     characters." @ WAIT 4500 @ GOTO 1070
    ! If title is too long, notify user and re-enter horizontal title
1130 CLEAR @ BEEP
1140 DISP "What title do you want for the "
1150 DISP K$;" axis of this "
1160 DISP K$;" vs ";I$;" curve";
1170 INPUT V$                             ! Input vertical title
1180 IF LEN(V$)>25 THEN CLEAR @ BEEP @ DISP "No more than 25
     characters." @ WAIT 4500 @ GOTO 1130
    ! If title is too long, notify user and re-enter vertical title
1190 A=P(1,4)/2048                        ! A = # of 2048-byte blks
1200 B=FP(A)                              ! B = fractional part A
1210 Q1=IP(A)+1                           ! Q1 = # of reads curve 1
1220 IF B=0 THEN Q1=Q1-1                  ! Allow for integer A
1230 A=P(2,4)/2048                        ! A = # of 2048-byte blks
1240 B=FP(A)                              ! B = fractional part A
1250 Q2=IP(A)+1                           ! Q2 = # of reads curve 2
1260 IF B=0 THEN Q2=Q2-1                  ! Allow for integer A
1270 CLEAR @ BEEP
1280 DISP "Do you want a grid or graph?"
1290 DISP "(GRID/GRAPH)"
1300 INPUT Q$                             ! Choose grid or graph
1310 A=0 @ B=0
1320 IF S$="Y" THEN A=8
    ! If chose single plot option, set x origin offset
```

```
1330 M=10+FP((L-1)/2)*136+A                    ! Calculate x origin
1340 IF S$="Y" THEN B=4.5
   ! If chose single plot option, set y origin offset
1350 N=15+(1-IP((L+1)/4))*50+B                 ! Calculate y origin
1360 CLEAR @ BEEP @ DISP "Load plotter and press CONTINUE." @ PAUSE
1370 S1=6+P1*5+(K-1)*P(I,4)
   ! Calculate position of first value to be read in processed file
1380 IF T=1 THEN S1=6+P1*5+(K-2)*P(1,4)+P(2,4)
   ! Calculate position of first value to be read in unprocessed file
1390 S2=5+P1*5+K*P(I,4)
   ! Calculate position of last value to be read in processed file
1400 IF T=1 THEN S2=5+P1*5+(K-2)*P(2,4)+2*P(1,4)
   ! Calculate position of last value to be read in unprocessed file
1410 READ# 1,S1 ; B                            ! Read first value
1420 A=B @ C=B                                 ! Set default max & min
1430 CLEAR @ BEEP @ DISP "Scanning"
1440 FOR J=S1+1 TO S2
1450 READ# 1,J ; B
1460 IF B>A THEN A=B                           ! Set if new max
1470 IF B<C THEN C=B                           ! Set if new min
1480 NEXT J
1490 IF T=1 THEN 1580                          ! Branch if unprocessed
1500 V=5/4*(A-C)/P(3,2) @ C1=C
   ! Calculate vertical magn/div:  P(3,2) = # of vertical divisions
   ! A = maximum value in curve ; C = minimum value in curve
1510 IF K<4 THEN W$=CHR$(P(K-1,5))             ! Set units for V or I
1520 IF K=4 THEN W$="W"                        ! Set units for power
1530 IF K=5 THEN W$="J"                        ! Set units for energy
1540 D=V @ Y0=2 @ GOSUB 3200 @ V=D @ C=C1
   ! Set values for magnitude/ division rounding routine (processed)
   ! D = unrounded magn/div ; Y0 = magnitude scaling indicator
   ! V returns as rounded magn/div ; C1 returns as scaled minimum
1550 V1$=W$ @ W$="s"
   ! Assign scaled vertical units; set units for next pass
```

```
1560 D=P(1,1) @ X0=2 @ GOSUB 3200 @ U=D
    ! Set values for time/ division rounding routine (processed)
    ! D = unrounded time/div ; X0 = time scaling indicator
    ! U returns as rounded time/div
1570 U1$=W$ @ GOTO 1630
    ! Assign scaled time units; continue with plotting
1580 W$=CHR$(P(IP(K/2),5)) @ C1=C            ! Set units for V or I
1590 D=P(IP(K/2),2) @ Y0=2 @ GOSUB 3200 @ V=D @ C=C1
    ! Set values for magnitude/ division rounding routine (unprocessed)
    ! D = unrounded magn/div ; Y0 = magnitude scaling indicator
    ! V returns as rounded magn/div ; C1 returns as scaled minimum
1600 V1$=W$ @ W$="s"
    ! Assign scaled vertical units; set units for next pass
1610 D=P(I,1) @ X0=2 @ GOSUB 3200 @ U=D
    ! Set values for time/ division rounding routine (unprocessed)
    ! D = unrounded time/div ; X0 = time scaling indicator
    ! U returns as rounded time/div
1620 U1$=W$                                   ! Scaled time units
1630 IF C>=-(V/10) THEN C=V
    ! Prevent routine from truncating the minimum
1640 P0=P(3,2)
1650 IF FP(C/V)<=-.1 THEN P0=P(3,2)+1
    ! Expand plot to include minimum
1660 LOCATE M,M+H*P(3,1)/P(3,2)*35,N,N+H*35*P0/P(3,2)
    ! Set active plotting area:  N & M are margins; H is scale factor
1670 FRAME @ CSIZE (H*50+10)/22,.4            ! Frame & set char size
1680 SCALE 0,U*P(3,1),(IP(C/V+.9*SGN(C))-1)*V,(IP(C/V+.9*SGN(C))
     -1+P0)*V
    ! Scale active plotting are for values
1690 IF Q$="GRID" THEN 1720                   ! Choose grid?
1700 AXES -U,V,0,0,1,1,5                      ! No, plot open graph
1710 GOTO 1730
1720 GRID -U,V,0,0,1,1                        ! Yes, plot grid
1730 GOSUB 4300                               ! Label axes routine
1740 Q=Q1 @ B=1 @ O=1
```

```
   ! Set number of read cycles, start pen up, start read position
1750 IF T=1 AND I=2 THEN Q=Q2
   ! Change number of read cycles for unprocessed curve 2
1760 FOR J=1 TO Q
1770 CLEAR @ BEEP
1780 DISP "Reading ";VAL$(J)
1790 GOSUB 2990                              ! Read & draw routine
1800 NEXT J
1810 LORG 6                                  ! Label posn upper/center
1820 CSIZE (H*100+10)/16,.5                  ! Increase char size
1830 MOVE .5*U*P(3,1),(IP(C/V+.9*SGN(C))-2)*V
1840 LABEL U$;"(";U1$;")"                    ! Plot time label
1850 DEG @ LDIR 90 @ LORG 4                  ! Setup vertical label
1860 MOVE -((1+(LEN(VAL$(V))-1)*.25)*U),(IP(C/V+.9*SGN(C))-1+P0/ 2)*V
1870 LABEL V$;"(";V1$;")"                    ! Plot magn label
1880 LDIR 0                                  ! Reset orientation
1890 GOSUB 4500                              ! Time/date label routine
1900 CLEAR @ BEEP
1910 DISP "Do you want a copy of the"
1920 DISP "second-breakdown statistics?"
1930 DISP "(Y/N)"
1940 INPUT Q$@ I$="time"                     ! 2nd brkdn?
1950 IF Q$≠"Y" THEN 350                      ! No, return to main prog
1960 IF T≠1 THEN 2000                        ! Yes; processed?
1970 CLEAR @ BEEP                            !   No, notify user
1980 DISP "Data must be processed first."
1990 WAIT 4500 @ GOTO 350                    ! Return to main prog
2000 CLEAR @ BEEP                            ! Yes, print 2nd brkdn
2010 DISP "Load plotter and press CONTINUE." !   char using plotter
2020 PAUSE
2030 PLOTTER IS 705
2040 LOCATE 0,136,0,100
2050 SCALE 0,100,0,100
2060 MOVE 89.4,69.6                          ! Move to origin
2070 PRINTER IS 705,40                       ! Set line length
```

```
2080 PRINT "DI 0,-1"                          ! Set plot direction
2090 PRINT "VS"                               ! Set plot speed
2100 PRINT "SI .18,.26"                       ! Set chac size
2110 PRINT USING "AA" ; "LB"                  ! Place in label mode
2120 A=0 @ K=2 @ I=1
2130 IF CHR$(P(1,5))="A" THEN K=3
2140 FOR J=56 TO P(1,4)-1
2150 READ# 1,15+(K-1)*P(1,4)+J ; B
2160 READ# 1,16+(K-1)*P(1,4)+J ; B0
2170 READ# 1,16+J ; B1
2180 READ# 1,15+J ; B2
2190 A=(B0-B)/(B1-B2)                         ! Condition for 2nd bkdn
2200 IF A<=-100000000 AND B>40 THEN I=J @ C=.1*B @ GOTO 2220
   ! If second-breakdown occured, begin printing info
2210 NEXT J
2220 PRINT "The value for instantaneous"
2230 PRINT "voltage at 2nd-breakdown is"
2240 W$="V" @ D=B @ GOSUB 3290 @ A=D @ A$=W$
   ! Set values for rounding routine:
   ! W$ = unrounded units ; B = unrounded voltage at 2nd-bkdn
   ! D returns as rounded voltage at 2nd-bkdn
   ! A$ returns as rounded units
2250 PRINT VAL$(A);" ";A$;"."
2260 PRINT
2270 A=0 @ K=3
2280 IF CHR$(P(2,5))="V" THEN K=2
2290 READ# 1,13+(K-1)*P(1,4)+I ; A            ! Read current @ 2nd-bkdn
2300 PRINT "The value for instantaneous"
2310 PRINT "current at 2nd-breakdown is"
2320 W$="A" @ D=A @ GOSUB 3290 @ A=D @ A$=W$
   ! Set values for rounding routine:
   ! W$ = unrounded units ; A = unrounded current at 2nd-bkdn
   ! D returns as rounded current at 2nd-bkdn
   ! A$ returns as rounded units
2330 PRINT VAL$(A);" ";A$;"."
```

```
2340 PRINT
2350 READ# 1,13+3*P(1,4)+I ; A                    ! Read power @ 2nd bkdn
2360 PRINT "The value for instantaneous"
2370 PRINT "power at 2nd-breakdown is"
2380 W$="W" @ D=A @ GOSUB 3290 @ A=D @ A$=W$
    ! Set values for rounding routine:
    ! W$ = unrounded units ; A = unrounded power at 2nd-bkdn
    ! D returns as rounded power at 2nd-bkdn
    ! A$ returns as rounded units
2390 PRINT VAL$(A);" ";A$;"."
2400 PRINT
2410 READ# 1,13+4*P(1,4)+I ; A                    ! Read energy @ 2nd bkdn
2420 PRINT "The value for instantaneous"
2430 PRINT "energy at 2nd-breakdown is"
2440 W$="J" @ D=A @ GOSUB 3290 @ A=D @ A$=W$
    ! Set values for rounding routine:
    ! W$ = unrounded units ; A = unrounded energy at 2nd-bkdn
    ! D returns as rounded energy at 2nd-bkdn
    ! A$ returns as rounded units
2450 PRINT VAL$(A);" ";A$;"."
2460 PRINT
2470 READ# 1,13+I ; A                             ! Read time of 2nd bkdn
2480 PRINT "2nd-breakdown occurs at"
2490 W$="s" @ D=A @ GOSUB 3290 @ A=D @ A$=W$
    ! Set values for rounding routine:
    ! W$ = unrounded units ; A = unrounded time at 2nd-bkdn
    ! D returns as rounded time at 2nd-bkdn
    ! A$ returns as rounded units
2500 PRINT VAL$(A);" ";A$;"."
2510 PRINT @ PRINT
2520 A=0
2530 PRINT "To is the time at 10% of the"
2540 PRINT "2nd-breakdown voltage."
2550 K=2
2560 IF CHR$(P(2,5))="V" THEN K=3
```

```
2570 FOR J=1 TO P(1,4)
2580 READ# 1,13+(K-1)*P(1,4)+J ; B
2590 IF B>C THEN 2610                          ! B = 10% 2nd bkdn?
2600 NEXT J                                    ! No, cont
2610 READ# 1,13+J ; A
    ! Yes, read the time associated with B (10% 2nd bkdn voltage)
2620 W$="s" @ D=A @ GOSUB 3290 @ A=D @ A$=W$
    ! Set values for rounding routine:
    ! W$ = unrounded units ; A = unrounded time at 10% of 2nd-bkdn
    ! D returns as rounded time at 10% of 2nd-bkdn
    ! A$ returns as rounded units
2630 PRINT "To = ";VAL$(A);" ";A$;"."
2640 PRINT
2650 W$="V" @ D=C @ GOSUB 3290 @ A=D @ A$=W$
    ! Set values for rounding routine:
    ! W$ = unrounded units ; A = unrounded voltage at 10% of 2nd-bkdn
    ! D returns as rounded voltage at 10% of 2nd-bkdn
    ! A$ returns as rounded units
2660 PRINT "The value for instantaneous"
2670 PRINT "voltage at To is ";VAL$(A);" ";A$;"."
2680 PRINT
2690 K=3
2700 IF CHR$(P(1,5))="A" THEN K=2
2710 READ# 1,13+(K-1)*P(1,4)+J ; A             ! Read current
2720 W$="A" @ D=A @ GOSUB 3290 @ A=D @ A$=W$
    ! Set values for rounding routine:
    ! W$ = unrounded units ; A = unrounded current at 10% of 2nd-bkdn
    ! D returns as rounded current at 10% of 2nd-bkdn
    ! A$ returns as rounded units
2730 PRINT "The value for instantaneous"
2740 PRINT "current at To is ";VAL$(A);" ";A$;"."
2750 PRINT
2760 READ# 1,13+3*P(1,4)+J ; A                 ! Read power
```

```
2770 W$="W" @ D=A @ GOSUB 3290 @ A=D @ A$=W$
    ! Set values for rounding routine:
    ! W$ = unrounded units ; A = unrounded power at 10% of 2nd-bkdn
    ! D returns as rounded power at 10% of 2nd-bkdn
    ! A$ returns as rounded units
2780 PRINT "The value for instantaneous"
2790 PRINT "power at To is ";VAL$(A);" ";A$;"."
2800 PRINT
2810 READ# 1,13+4*P(1,4)+J ; A                   ! Read energy
2820 W$="J" @ D=A @ GOSUB 3290 @ A=D @ A$=W$
    ! Set values for rounding routine:
    ! W$ = unrounded units ; A = unrounded energy at 10% of 2nd-bkdn
    ! D returns as rounded energy at 10% of 2nd-bkdn
    ! A$ returns as rounded units
2830 PRINT "The value for instantaneous"
2840 PRINT "energy at To is ";VAL$(A);" ";A$;"."
2850 PRINT @ PRINT
2860 READ# 1,13+I ; A                            ! Read 2nd bkdn time
2870 READ# 1,13+J ; B                            ! Read 10% 2nd bkdn time
2880 W$="s" @ D=A-B @ GOSUB 3290 @ A=D @ A$=W$
    ! Set values for rounding routine:
    ! W$ = unrounded units ; A = unrounded time from 10% to 2nd bkdn
    ! D returns as rounded time from 10% to 2nd bkdn
    ! A$ returns as rounded units
2890 PRINT "The time from To to"
2900 PRINT "2nd-breakdown is ";VAL$(A);" ";A$;"."
2910 PRINT
2920 READ# 1,13+4*P(1,4)+I ; A
2930 READ# 1,13+4*P(1,4)+J ; B
2940 W$="J" @ D=A-B @ GOSUB 3290  @ A=D @ A$=W$
    ! Set values for rounding routine: W$ = unrounded units
    ! A = unrounded energy change from 10% to 2nd bkdn
    ! D returns as rounded energy change from 10% to 2nd bkdn
    ! A$ returns as rounded units
2950 PRINT "The change in energy from To"
```

```
2960 PRINT "to 2nd-breakdown is";VAL$(A);" ";A$;"."
2970 PRINT " " @ PRINTER IS 2 @ PLOTTER IS 705 ! Close operation
2980 GOTO 160                                  ! Return to main prog
2990 REM *  READ & DRAW PLOT
3000 M=5+P1*5                                  ! First value time 1
3010 IF I=2 THEN M=5+P1*5+P(1,4)               ! First value time 2
3020 S=O+2047                                  ! Last value
3030 IF J=Q THEN S=P(I,4)                      !   last value, last read
3040 FOR L=O TO S
3050 READ# 1,M+L ; X(L-O+1)                    ! Read time value
3060 NEXT L
3070 M=5+P1*5+(K-1)*P(1,4)                     ! 1st value mag 1 (proc)
3080 IF T=1 THEN M=5+P1*5+P(1,4)+P(2,4)        ! 1st value mag 1 (unp)
3090 IF I=2 THEN M=5+P1*5+2*P(1,4)+P(2,4)      ! 1st value mag 2 (unp)
3100 FOR L=O TO S
3110 READ# 1,M+L ; Y(L-O+1)                    ! Read magn value
3120 NEXT L
3130 FOR L=1 TO S-O+1
3140 PLOT X0*X(L),Y0*Y(L),B                    ! Plot value, move if 1st
3150 B=-1                                      ! Set for plot not move
3160 NEXT L
3170 O=O+L-1                                   ! Set start for next read
3180 IF J=Q THEN B=1                           ! Last read, set for move
3190 RETURN
3200 REM *  FUNCTION FNA
3210 E=0
3220 IF D<.1 THEN 3250                         ! Value less than .1?
3230 GOSUB 3380                                ! No, division routine
3240 GOTO 3260
3250 GOSUB 3500                                ! Yes, multiply routine
3260 GOSUB 3620                                ! Rounding routine A
3270 GOSUB 3860                                ! Units routine
3280 RETURN
3290 REM *  FUNCTION FNB
3300 E=0
```

```
3310 IF D<.1 THEN 3340                   ! Value less than .1
3320 GOSUB 3380                          ! No, division routine
3330 GOTO 3350
3340 GOSUB 3500                          ! Yes, multiply routine
3350 GOSUB 3760                          ! Rounding routine B
3360 GOSUB 3860                          ! Units routine
3370 RETURN
3380 REM *  DIVISION SUBROUTINE
3390 E=0
3400 FOR F=1 TO 5                        ! Divide by 10^3
3410 D=D/1000                            !   to calculate engr
3420 IF D<.1 THEN 3450                   !   units
3430 E=E+1                               ! Increment engr ind
3440 NEXT F
3450 D=D*1000
3460 FOR F=1 TO E                        ! Change units to reflect
3470 W$="k"&W$ @ C1=C1/1000              !   change in number
3480 NEXT F
3490 RETURN
3500 REM *  MULTIPLICATION
3510 REM *    SUBROUTINE
3520 E=0
3530 FOR F=1 TO 5                        ! Multiply by 10^3 to
3540 D=D*1000                            !   calculate engr units
3550 E=E+1                               ! Increment engr ind
3560 IF D>=.1 THEN 3580
3570 NEXT F
3580 FOR F=1 TO E                        ! Change units to reflect
3590 W$="m"&W$ @ C1=C1*1000              !   change in number
3600 NEXT F
3610 RETURN
3620 REM *  TESTA SUBROUTINE
    ! Round number to desireable value for graphing purposes
3630 IF D>.1 AND D<=.2 THEN D=.2
3640 IF D>.2 AND D<=.25 THEN D=.25
```

```
3650 IF D>.25 AND D<=.5 THEN D=.5
3660 IF D>.5 AND D<=1 THEN D=1
3670 IF D>1 AND D<=2 THEN D=2
3680 IF D>2 AND D<=2.5 THEN D=2.5
3690 IF D>2.5 AND D<=5 THEN D=5
3700 IF D>5 AND D<=10 THEN D=10
3710 IF D>10 AND D<=20 THEN D=20
3720 IF D>20 AND D<=25 THEN D=25
3730 IF D>25 AND D<=50 THEN D=50
3740 IF D>50 THEN D=.1 @ W$="k"&W$ @ C1=C1/1000
3750 RETURN
3760 REM *  TESTB SUBROUTINE
    ! Round number to 3 significant digits
3770 E=0
3780 FOR F=1 TO 3
3790 D=D/10
3800 IF D<=.1 THEN 3830
3810 E=E+1
3820 NEXT F
3830 D=D*10
3840 D=IP((D+.0005)*1000)/1000*10^E
3850 RETURN
3860 REM *  STRING SUBROUTINE
    ! Change from strings of "m" or "k" to acceptable prefixes
    ! For example, "kkk" corresponds to 10^9 or "G"
3870 E=0
3880 FOR F=1 TO LEN(W$)-1
3890 IF W$[F,F]="k" THEN E=E+3                  ! Increment engr ind
3900 IF W$[F,F]="m" THEN E=E-3                  ! Decrement engr ind
3910 NEXT F
3920 IF E=12 THEN W$="T"&W$[LEN(W$),LEN(W$)]
3930 IF E=9 THEN W$="G"&W$[LEN(W$),LEN(W$)]
3940 IF E=6 THEN W$="M"&W$[LEN(W$),LEN(W$)]
3950 IF E=3 THEN W$="k"&W$[LEN(W$),LEN(W$)]
3960 IF E=0 THEN W$=W$[LEN(W$),LEN(W$)]
```

```
3970 IF E=-3 THEN W$="m"&W$[LEN(W$),LEN(W$)]
3980 IF E=-6 THEN W$="u"&W$[LEN(W$),LEN(W$)]
3990 IF E=-9 THEN W$="n"&W$[LEN(W$),LEN(W$)]
4000 IF E=-12 THEN W$="p"&W$[LEN(W$),LEN(W$)]
4010 IF E=-15 THEN W$="f"&W$[LEN(W$),LEN(W$)]
4020 IF E=-18 THEN W$="a"&W$[LEN(W$),LEN(W$)]
4030 IF X0=2 THEN X0=10^(-E)                  ! Scale for time
4040 IF Y0=2 THEN Y0=10^(-E)                  ! Scale for magn
4050 RETURN
4060 REM *  INITIALIZATION
4070 REM *    SUBROUTINE
4080 CLEAR @ BEEP
4090 DISP @ DISP "Initializing"
4100 T=1                                      ! Unprocessed file
4110 I$="time"                                ! Horiz axis = time
4120 FOR I=1 TO 2048
4130 X(I)=0                                   ! Initialize time reg
4140 Y(I)=0                                   ! Initialize magn reg
4150 NEXT I
4160 FOR I=1 TO 3
4170 FOR J=1 TO 5
4180 P(I,J)=0                                 ! Initialize cntl reg
4190 NEXT J
4200 NEXT I
4210 PLOTTER IS 705
4220 H=.875 @ X0=1 @ Y0=1                     ! Default scale factors
4230 ON ERROR GOSUB 4270                      ! Trap file error
4240 IF NUM(X$[2,2])<48 OR NUM(X$[2,2])>122 THEN X$="NULL"
    !  If name is not alphanumeric, default name is NULL
4250 IF X$="NULL" THEN RETURN
4260 RETURN
4270 IF ERRN=7 THEN X$="NULL"                 ! File error; set default
4280 OFF ERROR
4290 RETURN
4300 REM *  SUPPLEMENTARY LABEL
```

```
4310 REM *    SUBROUTINE
4320 LORG 6                                       ! Label orig: upper/cnt
4330 FOR J=0 TO P(3,1)                            ! Plot x axis labels
4340 MOVE J*U,(IP(C/V+.9*SGN(C))-1.25)*V
4350 LABEL VAL$(J*U)
4360 NEXT J
4370 LORG 8                                       ! Label orig: cnt/rt
4380 FOR J=0 TO P0                                ! Plot y axis labels
4390 MOVE -(.25*U),(IP(C/V+.9*SGN(C))-1+J)*V
4400 LABEL VAL$((IP(C/V+.9*SGN(C))-1+J)*V)
4410 NEXT J
4420 RETURN
4430 REM *  SINGLE PLOT OPTION
4440 CLEAR @ BEEP
4450 DISP "Do you want this plot by itself?"
4460 DISP "(Y/N)"
4470 INPUT S$                                     ! Single plot?
4480 IF S$="Y" THEN L=3                           ! Set plot position
4490 RETURN
4500 REM *  LABELING SUBROUTINE
4510 CLEAR @ BEEP
4520 DISP "Enter the y-coordinate for the"
4530 DISP "date and time."
4540 INPUT A                                      ! Input date/time posn
4550 A$=VAL$(P(1,3))
4560 A$=VAL$(VAL(A$[1,LEN(A$)-2]))&"/"&VAL$(VAL(A$[LEN(A$)-1,LEN(A$)]))
   ! Build month/day portion of string
4570 CLEAR @ BEEP
4580 DISP "Enter the year. Ex - 1985"
4590 INPUT D
4600 B1$=VAL$(D)
4610 A$=A$&"/"&B1$[LEN(B1$)-1,LEN(B1$)]
   ! Add year portion of string
4620 A$=A$&"  "&VAL$(IP(P(2,3)/3600))&":"&VAL$(IP(FP(P(2,3)/3600)*60))
   ! Add hour/minute portion of string
```

```
4630 A$=A$&":"&VAL$(IP(FP(FP(P(2,3)/3600)*60)*60+.5))
   ! Add seconds portion of string
4640 IF IP(FP(FP(P(2,3)/3600)*60)*60)<10 THEN A$=A$&":0"&VAL$(IP(FP(FP
     (P(2,3)/3600)*60)*60+.5))
4650 CSIZE (H*50+10)/18,.4                    ! Change char size
4660 LORG 4                                   ! Label orig: lwr/cnt
4670 MOVE P(3,1)*.5*U,A
4680 LABEL A$                                 ! Plot date/time
4690 CLEAR @ BEEP
4700 DISP "Enter the label for this graph."
4710 DISP @ DISP "(Maximum length of 40 char.)"
4720 INPUT A$                                 ! Input plot title
4730 CLEAR @ BEEP
4740 DISP "Enter the y-coordinate for the"
4750 DISP "label of this graph."
4760 INPUT A                                  ! Input title posn
4770 MOVE P(3,1)*.5*U,A
4780 LABEL A$                                 ! Plot title
4790 RETURN
```

I-V

The I-V program generates a plot for current vs. voltage. The data is read into the computer and plotted using values calculated by the computer. The program scans the given curve values, finds the minimum and maximum values, and plots the curve to fill 80% of the plotting area.

The I-V program allows the operator to scale the size of the plot, and to plot the curves on either a grid or an open graph.

```
10 REM *
20 REM *
30 REM *  I vs V PACKAGE
40 REM *    MAIN PROGRAM
50 REM *
60 REM *Copyright: 11/20/84
70 REM * gandalf software, inc.
80 REM * Chuck Graves, wizard
90 REM *
100 REM *
110 COM X$[10]                                ! Make file name common
120 SHORT X(2048),Y(2048),P(3,5)
130 DIM A$[40]
140 GOSUB 3010                                ! Initialization routine
150 IF X$≠"NULL" THEN 200                     ! I-V first program?
160 CLEAR @ BEEP                              ! Yes, input file name
170 DISP "What is the name of the file";
180 INPUT X$
190 IF LEN(X$)>10 THEN CLEAR @ BEEP @ DISP "Name is too large."
    @ WAIT 4500 @ GOTO 160
    ! If name is too long, notify user and re-enter file name
200 CLEAR @ BEEP
210 OFF ERROR
220 DISP "Where is ";X$;" stored";
230 DISP "(TAPE/DISK00/DISK01)"
240 INPUT R$                                  ! Input mass storage
250 GOSUB 610                                 ! Mass storage routine
260 ASSIGN# 1 TO X$                           ! Open file
270 READ# 1,1 ; P1                            ! Read # of curves
280 IF P1<4 THEN CLEAR @ BEEP @ DISP "Must be processed first."
    @ WAIT 4500 @ GOTO 160
    ! If file not processed, notify user and re-enter file name
290 READ# 1,2 ; P(3,1)                        ! Read # horiz div
300 READ# 1,3 ; P(3,2)                        ! Read # vertical div
310 K=6
```

```
320 FOR I=1 TO 2
330 FOR J=1 TO 5
340 READ# 1,K ; P(I,J)                         ! Read control registers
350 K=K+1
360 NEXT J
370 NEXT I
380 O=K-1                                      ! Set start read posn
390 CLEAR @ BEEP
400 DISP "Currently operating on ";X$
410 ON KEY# 1,"Plot" GOTO 980                  ! Plot option
420 ON KEY# 2,"Scale" GOTO 760                 ! Scale option
430 ON KEY# 3,"New set" GOTO 470               ! New data set option

440 ON KEY# 4,"Finished" GOTO 520              ! Finished option
450 KEY LABEL
460 GOTO 460                                   ! Loop until choice
470 ASSIGN# 1 TO *                             ! Close file
480 CLEAR @ BEEP
490 DISP "What is the new file name";
500 INPUT X$                                   ! Input new file name
510 GOTO 190                                   ! Restart process
520 ASSIGN# 1 TO *                             ! Close file
530 CLEAR @ BEEP                               ! Return to Autost
540 DISP "    MISSION CONTROL"
550 DISP "will now resume control."
560 FOR I=1 TO 65
570 BEEP 65-I,20
580 NEXT I
590 CHAIN "Autost:D700"                        ! Load Autost prog
600 END
610 REM *
620 REM *
630 REM *  MASS STORAGE
640 REM *    SUBROUTINE
650 REM *  1) ESTABLISH MEDIUM
```

```
660 REM *
670 REM *
680 IF R$="TAPE" THEN 740
690 IF R$="DISK01" THEN 720
700 MASS STORAGE IS ":D700"                  ! Set for disk 0
710 GOTO 750
720 MASS STORAGE IS ":D701"                  ! Set for disk 1
730 GOTO 750
740 MASS STORAGE IS ":T"                     ! Set for tape
750 RETURN
760 REM *
770 REM *
780 REM *  SCALE SUBROUTINE
790 REM *
800 REM *
810 CLEAR @ BEEP
820 DISP "Enter the scale factor for"
830 DISP "plotting (less than 2.25.)"
840 INPUT H                                  ! Input scale factor
850 IF H<=2.25 AND H>0 THEN 900              ! Scale factor valid?
860 CLEAR @ BEEP                             ! No, notify user
870 DISP "Please pick a scale factor"
880 DISP "on the range 0<H<2.25."
890 WAIT 4500 @ GOTO 810                     ! Re-enter scale factor
900 GOTO 410                                 ! Yes, return main prog
910 REM *
920 REM *
930 REM *  PLOT SUBROUTINE
940 REM *     1) FIND CURVE
950 REM *     2) PLOT CURVE
960 REM *
970 REM *
980 I=2 @ K=3 @ K$="current" @ I$="voltage" @ L=3
    ! I = position of current array in file
    ! K = position of voltage array in file
```

```
   ! I$ = horiz file type ; K$ = vert file type ; L = curve posn ind
990 IF CHR$(P(2,5))="V" THEN I=3 @ K=2
   ! Switch I for V if stored current then voltage
1000 CLEAR @ BEEP
1010 DISP "What title do you want for the "
1020 DISP I$;" axis of this "
1030 DISP K$;" vs ";I$;" curve";
1040 INPUT U$                                ! Input horiz title
1050 IF LEN(U$)>25 THEN CLEAR @ BEEP @ DISP "No more than 25
     characters." @ WAIT 4500 @ GOTO 1000
   ! If title is too long, notify user and re-enter horiz title
1060 CLEAR @ BEEP
1070 DISP "What title do you want for the "
1080 DISP K$;" axis of this "
1090 DISP K$;" vs ";I$;" curve";
1100 INPUT V$                                ! Input vertical title
1110 IF LEN(V$)>25 THEN CLEAR @ BEEP @ DISP "No more than 25
     characters." @ WAIT 4500 @ GOTO 1060
   ! If title is too long, notify user and re-enter vertical title
1120 A=P(1,4)/2048                           ! A = # of 2048-byte blks
1130 B=FP(A)                                 ! B = fractional part A
1140 Q=IP(A)+1                               ! Q = # of reads curve 1
1150 IF B=0 THEN Q=Q-1                       ! Allow for integer A
1160 CLEAR @ BEEP
1170 DISP "Do you want a grid or graph?"
1180 DISP "(GRID/GRAPH)"
1190 INPUT Q$                                ! Choose grid or graph
1200 M=18+FP((L-1)/2)*136                    ! Calculate x origin
1210 N=19.5+(1-IP((L+1)/4))*50               ! Calculate y origin
1220 CLEAR @ BEEP @ DISP "Load plotter and press CONTINUE." @ PAUSE
1230 S1=4+P1*5+(K-1)*P(1,4)                  ! Calculate 1st V posn
1240 S2=3+P1*5+K*P(1,4)                      ! Calculate last V posn
1250 READ# 1,S1 ; B                          ! Read first value
1260 A=B @ C=B                               ! Set default min & max
1270 CLEAR @ BEEP @ DISP "Scanning A"
```

```
1280 FOR J=S1+1 TO S2
1290 READ# 1,J ; B
1300 IF B>A THEN A=B                          ! Set if new max
1310 IF B<C THEN C=B                          ! Set if new min
1320 NEXT J
1330 V=5/4*(A-C)/P(3,2) @ C1=C
   ! Calculate vertical magn/div: P(3,2) = # of vertical divisions
   ! A = maximum value in curve ; C = minimum value in curve
1340 W$=CHR$(P(K-1,5))                        !  Set units
1350 D=V @ Y0=2 @ GOSUB 2060 @ V=D @ C=C1
   ! Set values for magnitude/division rounding routine
   ! D = unrounded vert magn/div ; Y0 = vert magn scaling indicator
   ! V returns as rounded vert magn/div ; C1 returns as scaled minimum
1360 V1$=W$
   ! Assign scaled vertical units
1370 S1=4+P1*5+(I-1)*P(1,4)                   ! Calculate 1st I posn
1380 S2=3+P1*5+I*P(1,4)                       ! Calculate last I posn
1390 READ# 1,S1 ; B                           ! Read first value
1400 A=B @ G=B                                ! Set default min & max
1410 CLEAR @ BEEP @ DISP "Scanning B"
1420 FOR J=S1+1 TO S2
1430 READ# 1,J ; B
1440 IF B>A THEN A=B                          ! Set if new max
1450 IF B<G THEN G=B                          ! Set if new min
1460 NEXT J
1470 U=5/4*(A-G)/P(3,2) @ C1=G
   ! Calculate horiz magn/div: P(3,2) = # of horiz divisions
   ! A = maximum value in curve ; G = minimum value in curve
1480 W$=CHR$(P(I-1,5))                        ! Set units
1490 D=U @ X0=2 @ GOSUB 2060 @ U=D @ G=C1
   ! Set values for magnitude/division rounding routine
   ! D = unrounded horiz magn/div ; X0 = horiz magn scaling indicator
   ! V returns as rounded horiz magn/div ; C1 returns as scaled min
1500 U1$=W$
   ! Assign scale horizontal units
```

```
1510 LOCATE M,M+H*35,N,N+H*35
    ! Set active plotting area: N & M are margins; H is scale factor
1520 IF C>=-(V/10) THEN C=V
    ! Prevent routine from truncating the vertical minimum
1530 IF FP(C/V)<=-.1 OR FP(G/U)<=-.1 THEN P(3,2)=P(3,2)+1
    ! Expand plot to include minimum
1540 IF G>=-(U/10) THEN G=U
    ! Prevent routine from truncating the horizontal minimum
1550 FRAME @ CSIZE (H*50+10)/22,.4          ! Set char size
1560 A=IP(G/U+.9*SGN(G))-1                 ! Min scale value horiz
1570 B=IP(C/V+.9*SGN(C))-1                 ! Min scale value vert
1580 SCALE A*U,(A+P(3,2))*U,B*V,(B+P(3,2))*V ! Scale active area
1590 IF Q$="GRID" THEN 1620                 ! Chose grid?
1600 AXES -U,V,0,0,1,1,5                    ! No, plot graph
1610 GOTO 1630
1620 GRID -U,V,0,0,1,1                      ! Yes, plot grid
1630 GOSUB 3280                             ! Plot labeling routine
1640 B=1 @ O=1                              ! Start pen up, read posn
1650 FOR J=1 TO Q
1660 CLEAR @ BEEP
1670 DISP "Reading ";VAL$(J);" of ";VAL$(Q);"."
1680 GOSUB 1790                             ! Read & draw routine
1690 NEXT J
1700 LORG 6                                 ! Label posn: upr/cntr
1710 CSIZE (H*100+10)/16,.5                 ! Set char size
1720 MOVE (IP(G/U+.9*SGN(G))-1+P(3,2)/2)*U,(IP(C/V+.9*SGN(C))-2)*V
1730 LABEL U$;"(";U1$;")"                   ! Plot horiz label
1740 DEG @ LDIR 90 @ LORG 4                 ! Setup vert label
1750 MOVE (IP(G/U+.9*SGN(G))-(2+(LEN(VAL$(V))-1)*.25))*U,(IP(C/V+.9*
     SGN(C))-1+P(3,2)/2)*V
1760 LABEL V$;"(";V1$;")"                   ! Plot vert label
1770 LDIR 0                                 ! Reset orientation
1780 GOTO 410                               ! Return main prog
1790 REM *
```

```
1800 REM *
1810 REM *  READ & DRAW
1820 REM *    SUBROUTINE
1830 REM *    1) READS PLOT
1840 REM *    2) DRAW PLOT
1850 REM *
1860 REM *
1870 M=13+(I-1)*P(1,4)                   ! First value volt crv 1
1880 IF I=2 THEN M=13+P(1,4)             ! First value volt crv 2
1890 S=O+2047                            ! Last value
1900 IF J=Q THEN S=P(1,4)                !   last value, last read
1910 FOR L=O TO S
1920 READ# 1,M+L ; X(L-O+1)              ! Read voltage value
1930 NEXT L
1940 M=13+(K-1)*P(1,4)                   ! 1st value current crv 1
1950 IF I=2 THEN M=13+3*P(1,4)           ! 1st value current crv 2
1960 FOR L=O TO S
1970 READ# 1,M+L ; Y(L-O+1)              ! Read current value
1980 NEXT L
1990 FOR L=1 TO S-O+1
2000 PLOT X0*X(L),Y0*Y(L),B              ! Plot value, move if 1st
2010 B=-1                                ! Set for plot not move
2020 NEXT L
2030 O=O+L-1                             ! Set start for next read
2040 IF J=Q THEN B=1                     ! Last read, set for move
2050 RETURN
2060 REM *
2070 REM *
2080 REM *  FUNCTION FNA
2090 REM *    1) MAKES LABELS
2100 REM *    2) ROUNDS TO ENGR
2110 REM *       UNITS
2120 REM *
2130 REM *
2140 E=0
```

```
2150 IF D<.1 THEN 2180                      ! Value less than .1?
2160 GOSUB 2220                             ! No, division routine
2170 GOTO 2190
2180 GOSUB 2390                             ! Yes, multiply routine
2190 GOSUB 2570                             ! Rounding routine
2200 GOSUB 2760                             ! Units routine
2210 RETURN
2220 REM *
2230 REM *
2240 REM *  DIVISION SUBROUTINE
2250 REM *    1) 10^3 DIVISION
2260 REM *         FOR FNA
2270 REM *
2280 E=0
2290 FOR F=1 TO 5                           ! Divide by 10^3
2300 D=D/1000                               !   calculate engr units
2310 IF D<.1 THEN 2340
2320 E=E+1                                  ! Increment engr ind
2330 NEXT F
2340 D=D*1000
2350 FOR F=1 TO E                           ! Change units to reflect
2360 W$="k"&W$ @ C1=C1/1000                 !   change in number
2370 NEXT F
2380 RETURN
2390 REM *
2400 REM *
2410 REM *  MULTIPLICATION
2420 REM *    SUBROUTINE
2430 REM *    1) 10^3 MULTIPLY
2440 REM *         FOR FNA
2450 REM *
2460 REM *
2470 E=0
2480 FOR F=1 TO 5                           ! Multiply by 10^3
2490 D=D*1000                               !   calculate engr units
```

```
2500 E=E+1                                    ! Increment engr ind
2510 IF D>=.1 THEN 2530
2520 NEXT F
2530 FOR F=1 TO E                             ! Change units to reflect
2540 W$="m"&W$ @ C1=C1*1000                   !   change in number
2550 NEXT F
2560 RETURN
2570 REM *
2580 REM *
2590 REM *  TESTA SUBROUTINE                  ! Round number to
2600 REM *    1) TEST FOR FNA                 ! desireable value for
2610 REM *                                    ! graphing purposes
2620 REM *
2630 IF D>.1 AND D<=.2 THEN D=.2
2640 IF D>.2 AND D<=.25 THEN D=.25
2650 IF D>.25 AND D<=.5 THEN D=.5
2660 IF D>.5 AND D<=1 THEN D=1
2670 IF D>1 AND D<=2 THEN D=2
2680 IF D>2 AND D<=2.5 THEN D=2.5
2690 IF D>2.5 AND D<=5 THEN D=5
2700 IF D>5 AND D<=10 THEN D=10
2710 IF D>10 AND D<=20 THEN D=20
2720 IF D>20 AND D<=25 THEN D=25
2730 IF D>25 AND D<=50 THEN D=50
2740 IF D>50 THEN D=.1 @ W$="k"&W$
2750 RETURN
2760 REM *
2770 REM *
2780 REM *  STRING SUBROUTINE                 ! Change from strings of
2790 REM *    1) OUTPUT PREFIX                ! "m" or "k" to
2800 REM *                                    ! acceptable prefixes
2810 REM *                                    ! Ex. "kkk" = "G"
2820 E=0
2830 FOR F=1 TO LEN(W$)-1
2840 IF W$[F,F]="k" THEN E=E+3                ! Increment engr ind
```

```
2850 IF W$[F,F]="m" THEN E=E-3                   ! Decrement engr ind
2860 NEXT F
2870 IF E=12 THEN W$="T"&W$[LEN(W$),LEN(W$)]
2880 IF E=9 THEN W$="G"&W$[LEN(W$),LEN(W$)]
2890 IF E=6 THEN W$="M"&W$[LEN(W$),LEN(W$)]
2900 IF E=3 THEN W$="k"&W$[LEN(W$),LEN(W$)]
2910 IF E=0 THEN W$=W$[LEN(W$),LEN(W$)]
2920 IF E=-3 THEN W$="m"&W$[LEN(W$),LEN(W$)]
2930 IF E=-6 THEN W$="u"&W$[LEN(W$),LEN(W$)]
2940 IF E=-9 THEN W$="n"&W$[LEN(W$),LEN(W$)]
2950 IF E=-12 THEN W$="p"&W$[LEN(W$),LEN(W$)]
2960 IF E=-15 THEN W$="f"&W$[LEN(W$),LEN(W$)]
2970 IF E=-18 THEN W$="a"&W$[LEN(W$),LEN(W$)]
2980 IF X0=2 THEN X0=10^(-E)                     ! Scale for horiz
2990 IF Y0=2 THEN Y0=10^(-E)                     ! Scale for vert
3000 RETURN
3010 REM *
3020 REM *
3030 REM *  INITIALIZATION
3040 REM *    SUBROUTINE
3050 REM *
3060 REM *
3070 CLEAR @ BEEP
3080 DISP @ DISP "Initializing"
3090 T=1                                         ! Unprocessed file
3100 I$="time"                                   ! Horiz axis = time
3110 FOR I=1 TO 2048
3120 X(I)=0                                      ! Initialize horiz reg
3130 Y(I)=0                                      ! Initialize vert reg
3140 NEXT I
3150 FOR I=1 TO 3
3160 FOR J=1 TO 5
3170 P(I,J)=0                                    ! Initialize cntl reg
3180 NEXT J
3190 NEXT I
```

```
3200 PLOTTER IS 705
3210 H=.95 @ X0=1 @ Y0=1                     ! Default scale factors
3220 ON ERROR GOSUB 3250                     ! Trap file error
3230 IF X$="NULL" THEN RETURN
3240 RETURN
3250 IF ERRN=7 THEN X$="NULL"                ! File error; set default
3260 OFF ERROR
3270 RETURN
3280 REM *
3290 REM *
3300 REM *  SUPPLEMENTARY LABEL
3310 REM *     SUBROUTINE
3320 REM *     1) LABEL GRID OR GRAPH
3330 REM *
3340 REM *
3350 LORG 6                                  ! Label posn: upr/cnt
3360 FOR J=0 TO P(3,2)                       ! Plot x axis labels
3370 MOVE (A+J)*U,(B-.25)*V
3380 LABEL VAL$((A+J)*U)
3390 NEXT J
3400 LORG 8                                  ! Label posn: cnt/rt
3410 FOR J=0 TO P(3,2)                       ! Plot y axis labels
3420 MOVE (A-.25)*U,(B+J)*V
3430 LABEL VAL$((B+J)*V)
3440 NEXT J
3450 RETURN
```

MATH

The MATH program conducts all mathematical processing. The program reads in stored data for voltage and current, and generates a time frame for processing based upon the two (2) sets of time data read into the computer. The program interpolates linearly the voltage and current data onto this time frame. Then, the power and energy curves associated with the voltage and current curves.

The MATH program calculates the instantaneous power curve by taking the product of the voltage and current values. The energy curve is calculated by performing an integration of the power curve using a trapezoidal approximation.

Finally, the MATH program stores the processed data files. The curves are stored in the order: (1) time, (2) voltage, (3) current, (4) power, (5) energy.

```
10 REM *
20 REM *     MATH PACKAGE
30 REM *       MAIN PROGRAM
40 REM *
50 REM *Copyright:  10/25/84
60 REM * gandalf software, inc.
70 REM * Chuck Graves, wizard
80 REM *
90 REM *
100 COM X$[10]                                  ! Make file name common
110 SHORT X(2048),Y(256),Z(256),M(4,256),P(3,5),R(2,2)
120 GOSUB 2970                                  ! Initialization routine
130 IF X$≠"NULL" THEN 180                       ! Math first program?
140 CLEAR @ BEEP                                ! Yes, enter file name
150 DISP "What is the name of the file?"
160 INPUT X$
170 IF LEN(X$)>10 THEN CLEAR @ BEEP @ DISP "Name is too large."
    @ WAIT 4500 @ GOTO 140
    ! If name is too long, notify user and re-enter file name
180 CLEAR @ BEEP
190 DISP "Where is ";X$;" stored?"
200 DISP "(TAPE/DISK00/DISK01)"
210 INPUT R$                                    ! Input mass storage
220 GOSUB 2470                                  ! Mass storage routine
230 ON ERROR GOTO 1760                          ! Trap file error
240 ASSIGN# 1 TO X$                             ! Open file
250 OFF ERROR
260 READ# 1,1 ; P1                              ! Read # of curves
270 IF P1=2 THEN 380                            ! Two files?
280 CLEAR @ BEEP                                ! No, notify user
290 DISP "This program is developed for"
300 DISP "the multiplication and "
310 DISP "integration of two curves.  This"
320 DISP "program cannot process this file"
330 DISP "Would you like to work on a"
```

```
340 DISP "different set of curves? (Y/N)"
350 INPUT Q$                                   ! Different curves?
360 IF Q$="Y" THEN 140                         ! Yes, restart process
370 GOTO 1680                                  ! No, return to Autost
380 IF P(1,4)<=1024 AND P(2,4)<=1024 THEN 460  ! Is file too large?
390 CLEAR @ BEEP                               ! Yes, notify user
400 DISP "The file is too large. This "
410 DISP "can process a maximum of 1024 "
420 DISP "points. Would you like to work "
430 DISP "on a different set of curves? "
440 DISP "(Y/N)"
450 GOTO 350                                   ! Branch back for curves
460 READ# 1,2 ; P(3,1)                         ! No, read # of horiz div
470 READ# 1,3 ; P(3,2)                         ! Read # of vert div
480 K=6
490 FOR I=1 TO 2
500 FOR J=1 TO 5
510 READ# 1,K ; P(I,J)                         ! Read control registers
520 K=K+1
530 NEXT J
540 NEXT I
550 READ# 1,4 ; P(1,3)                         ! Read date
560 READ# 1,5 ; P(2,3)                         ! Read time
570 CLEAR @ BEEP
580 DISP "Sorting"
590 GOSUB 2220                                 ! Sort routine
600 A=R(1,2)-R(1,1)                            ! A = # of pts curve 1
610 B=A/256                                    ! B = # of 256-pt blks
620 IF IP(B)=B THEN Q1=B @ GOTO 640
630 Q1=IP(B)+1                                 ! Q1 = # of reads curve 1
640 A=R(2,2)-R(2,1)                            ! A = # of pts curve 2
650 B=A/256                                    ! B = # of 256-pt blks
660 IF IP(B)=B THEN Q2=B @ GOTO 680
670 Q2=IP(B)+1                                 ! Q2 = # of reads curve 2
680 CLEAR @ BEEP
```

```
690 DISP "Initial read and sort"
700 FOR J=R(1,1) TO R(1,2)
710 READ# 1,J ; X(J-R(1,1)+1)                 ! Read good data curve 1
720 NEXT J
730 P(3,4)=J-R(1,1)                           ! Set # of pts workspace
740 J1=P(3,4)+1 @ J2=R(2,1)                   ! Set pts # ind, start rd
750 FOR J=1 TO P(3,4)
760 FOR L=J2 TO R(2,2)
770 J2=L                                      ! Bootstrap curve 2 ind
780 READ# 1,L ; A                             ! Read good data curve 2
790 IF X(J)=A THEN 830
   ! If data already stored, read next piece of data
800 IF X(J)<A THEN 840
   ! If data is larger than upper limit, increment upper limit
810 X(J1)=A                                   ! Store new data
820 J1=J1+1                                   ! Increment curve 1 ind
830 NEXT L
840 NEXT J
850 P(3,3)=J1-1                               ! Set new # of pts
860 IF P(3,3)=P(3,4) THEN 920
   ! If no new data, then do not sort
870 FOR J=1 TO P(3,3)                         ! Yes, sort data together
880 FOR L=J TO P(3,3)
890 IF X(J)>X(L) THEN A=X(J) @ X(J)=X(L) @ X(L)=A
900 NEXT L
910 NEXT J
920 I2=P(3,3)                                 ! Set storage index
930 L=15+5*P(3,3)                             ! Calculate file space
940 CLEAR @ BEEP
950 DISP "Creating file space."
960 CREATE "TEMPX",L,8                        ! Create file space
970 OFF ERROR
980 ASSIGN# 2 TO "TEMPX"                      ! Open new file
990 PRINT# 2,1 ; 4                            ! Store # of curves
1000 PRINT# 2,2 ; P(3,1)                      ! Store # of horiz div
```

```
1010 PRINT# 2,3 ; P(3,2)                     ! Store # of vert div
1020 PRINT# 2,4 ; P(1,3)                     ! Store date
1030 PRINT# 2,5 ; P(2,3)                     ! Store time
1040 K=6
1050 FOR I=1 TO 2
1060 FOR J=1 TO 5
1070 PRINT# 2,K ; P(I,J)                     ! Store control registers
1080 K=K+1
1090 NEXT J
1100 NEXT I
1110 O=K-1
1120 GOSUB 2810                              ! Store routine (store x)
1130 K=1 @ Q=Q1 @ S1=R(1,1) @ T1=P(1,4)+P(2,4) @ P(3,5)=1
   ! Set values: K = process number (1 = interpolation curve 1)
   ! Q = number of read passes ; S1 = start index curve 1
   ! T1 = offset for reading magnitude ; P(3,5) = workspace index
1140 FOR I=1 TO Q
1150 CLEAR @ BEEP
1160 DISP "Process ";K;" of 4"
1170 DISP "Reading ";I;" of ";Q
1180 GOSUB 2610                              ! Read subroutine
1190 CLEAR @ BEEP
1200 DISP "Process ";K;" of 4"
1210 DISP "Working ";I;" of ";Q
1220 GOSUB 1810                              ! Interpolation routine
1230 CLEAR @ BEEP
1240 DISP "Process ";K;" of 4"
1250 DISP "Storing ";I;" of ";Q
1260 GOSUB 2810                              ! Storage routine
1270 NEXT I
1280 IF K≠1 THEN 1310                        ! Curve 2 interpolated?
1290 K=2 @ Q=Q2 @ S1=R(2,1) @ P(3,5)=1
   ! No, set values: K = process number (2 = interpolation curve 2)
   ! Q = number of read passes ; S1 = start index curve 2
   ! P(3,5) = workspace index
```

```
1300 GOTO 1140                              ! Interpolate curve 2
1310 ASSIGN# 1 TO *                         ! Yes, close old file
1320 ASSIGN# 1 TO "TEMPX"                   ! Open new file for read
1330 Q3=IP(P(3,3)/256)+1                    ! Q3 = # of reads (inter)
1340 IF Q3=P(3,3)/256+1 THEN Q3=Q3-1        ! Allow for integer Q3
1350 K=3 @ Q=Q3 @ S1=16+P(3,3) @ T1=P(3,3)
   ! Set values: K = process number (3 = multiply intrp curves 1 & 2)
   ! Q = number of read passes ; S1 = start index intrp curve 1
   ! T1 = read offset for curve 1
1360 FOR I=1 TO Q
1370 CLEAR @ BEEP
1380 DISP "Process ";K;" of 4"
1390 DISP "Reading ";I;" of ";Q
1400 GOSUB 2610                             ! Read routine
1410 CLEAR @ BEEP
1420 DISP "Process ";K;" of 4"
1430 DISP "Working ";I;" of ";Q
1440 IF K=3 THEN GOSUB 2040                 ! Multiply routine
1450 IF K=4 THEN GOSUB 2160                 ! Integrate routine
1460 CLEAR @ BEEP
1470 DISP "Process ";K;" of 4"
1480 DISP "Storing ";I;" of ";Q
1490 GOSUB 2810                             ! Storage routine
1500 NEXT I
1510 IF K≠3 THEN 1550                       ! Curve 3 integrated?
1520 K=4 @ Q=Q3 @ S1=16 @ T1=3*P(3,3) @ A=0
   ! No, set values: K = process number (4 = integrate curve 3)
   ! Q = number of read passes ; S1 = start index time
   ! T1 = read offset for multiplied curve
1530 P(1,4)=P(3,3) @ P(2,4)=P(3,3)          ! Reset # of pts
1540 GOTO 1360                              ! Integrate curve 3
1550 CLEAR @ BEEP                           ! Yes, cont
1560 DISP "What name do you want for the"
1570 DISP "processed data file?"
1580 INPUT Y$                               ! Input new file name
```

```
1590 IF LEN(Y$)>10 THEN CLEAR @ BEEP @ DISP "Name is too large."
   @ WAIT 4500 @ GOTO 1550
   ! If new file name is too long, notify user and re-enter file name
1600 IF Y$=X$ THEN PURGE X$
   ! If same name is chosen, purge the unprocessed file
1610 RENAME "TEMPX" TO Y$                 ! Rename processed file
1620 CLEAR @ BEEP
1630 DISP "The processing is finished."
1640 DISP "Would you like to process"
1650 DISP "another set of curves? (Y/N)"
1660 INPUT Q$                             ! Another set of curves?
1670 IF Q$="Y" THEN 140                   ! Yes, restart process
1680 CLEAR @ BEEP                         ! No, return to Autost
1690 DISP "    MISSION CONTROL"
1700 DISP "will now resume control."
1710 FOR I=1 TO 65
1720 BEEP 65-I,20
1730 NEXT I
1740 CHAIN "Autost:D700"                  ! Load Autost prog
1750 END
1760 OFF ERROR
1770 IF ERRN≠130 THEN 240                 ! Disk error; no, retry
1780 CLEAR @ BEEP                         ! Yes, notify user
1790 DISP "Disk error. Re-enter storage."
1800 WAIT 4500 @ GOTO 180                 ! Re-enter mass storage
1810 REM *
1820 REM *
1830 REM *  INTERPOLATION SUBROUTINE
1840 REM *     1) FIND SLOPES AND INTERCEPTS
1850 REM *     2) EVALUATE SLOW GRAPH
1860 REM *        FOR RAPID GRAPH POINTS
1870 REM *
1880 REM *
1890 FOR I1=1 TO P(3,4)-1
1900 M(1,I1)=(Y(I1+1)-Y(I1))/(Z(I1+1)-Z(I1))  ! Calculate slope
```

```
1910 M(2,I1)=Y(I1)-M(1,I1)*Z(I1)              ! Calculate intercept
1920 NEXT I1
1930 I2=0
1940 FOR I1=2 TO P(3,4)                       ! Evaluate for new times
1950 FOR J=P(3,5) TO P(3,3)
1960 P(3,5)=J                                 ! Update index
1970 IF X(J)>Z(I1) THEN 2020
   ! If new time is outside bounds, change to new bounds
1980 I2=I2+1                                  ! Increment storage index
1990 Y(I2)=M(1,I1-1)*X(J)+M(2,I1-1)           ! Evaluate for new time
2000 IF J=256 AND I1≠P(3,4) THEN GOSUB 2810
   ! If evaluated 256 new pts but not finished, then store now
2010 NEXT J
2020 NEXT I1
2030 RETURN
2040 REM *
2050 REM *
2060 REM *  MATH SUBROUTINE
2070 REM *    1) EVALUATE PRODUCT AND
2080 REM *       TIME INTEGRAL
2090 REM *
2100 REM *
2110 FOR J=1 TO P(3,4)
2120 Y(J)=Y(J)*Z(J)                           ! Multiply curves 1 & 2
2130 NEXT J
2140 I2=J-1                                   ! Set storage index
2150 RETURN
2160 X(1)=A                                   ! Set offset constant
2170 FOR J=2 TO P(3,4)
2180 X(J)=.5*(Z(J)-Z(J-1))*(Y(J)+Y(J-1))+X(J-1)
   ! Evaluate integral using trapezoidal approximation
2190 NEXT J
2200 A=X(J-1) @ I2=J-1
   ! Set new offset and storage index
2210 RETURN
```

```
2220 REM *
2230 REM *
2240 REM *  SORT SUBROUTINE
2250 REM *    1) IDENTIFY USEFUL DATA
2260 REM *
2270 REM *
2280 READ# 1,16 ; R1                          ! Read start time curve 1
2290 READ# 1,16+P(1,4) ; R2                   ! Read start time curve 2
2300 IF R1>R2 THEN R(1,1)=16 @ Q1=2 @ Q2=R1 @ GOTO 2320
    ! Set values: R(1,1) = start index for curve 1
    ! Q1 = curve with beginning to be truncated (curve 2)
    ! Q2 = index for beginning of interpolation (curve 1)
2310 R(2,1)=16+P(1,4) @ Q1=1 @ Q2=R2
    ! Set values: R(2,1) = start index for curve 2
    ! Q1 = curve with beginning to be truncated (curve 1)
    ! Q2 = index for beginning of interpolation (curve 2)
2320 FOR I=1 TO P(Q1,4)
2330 READ# 1,15+I+(Q1-1)*P(1,4); R1           ! Read time to truncate
2340 IF R1>=Q2 THEN 2360                      ! If time ≥ start, exit
2350 NEXT I
2360 R(Q1,1)=15+I+(Q1-1)*P(1,4)               ! Start index for Q1
2370 READ# 1,15+P(1,4) ; R1                   ! Read last time curve 1
2380 READ# 1,15+P(1,4)+P(2,4) ; R2            ! Read last time curve 2
2390 IF R1<R2 THEN R(1,2)=15+P(1,4) @ Q1=2 @ Q2=R1 @ GOTO 2410
    ! Set values: R(1,2) = stop index for curve 1
    ! Q1 = curve with end to be truncated (curve 2)
    ! Q2 = index for end of interpolation (curve 1)
2400 R(2,2)=15+P(1,4)+P(2,4) @ Q1=1 @ Q2=R2
    ! Set values: R(2,2) = stop index for curve 2
    ! Q1 = curve with end to be truncated (curve 1)
    ! Q2 = index for end of interpolation (curve 2)
2410 FOR I=P(Q1,4) TO 1 STEP -1
2420 READ# 1,15+I+(Q1-1)*P(1,4) ; R1          ! Read time to truncate
2430 IF R1<=Q2 THEN 2450                      ! If time ≤ stop, exit
2440 NEXT I
```

```
2450 R(Q1,2)=15+I+(Q1-1)*P(1,4)                    ! Stop index for curve Q1
2460 RETURN
2470 REM *
2480 REM *
2490 REM *  MASS STORAGE SUBROUTINE
2500 REM *     1) ESTABLISH MEDIUM
2510 REM *
2520 REM *
2530 IF R$="TAPE" THEN 2590
2540 IF R$="DISK01" THEN 2570
2550 MASS STORAGE IS ":D700"                       ! Set for disk 0
2560 GOTO 2600
2570 MASS STORAGE IS ":D701"                       ! Set for disk 1
2580 GOTO 2600
2590 MASS STORAGE IS ":T"                          ! Set for tape
2600 RETURN
2610 REM *
2620 REM *
2630 REM *  READ SUBROUTINE
2640 REM *     1) READ CURVES
2650 REM *     2) SORTS FOR INTERPOLATION
2660 REM *     3) CLOSES FILE
2670 REM *
2680 REM *
2690 S2=S1+255                                     ! Set end of read
2700 IF I=Q AND K<3 THEN S2=R(K,2)
    ! If last read and interpolation, stop is set from truncation
2710 IF I=Q AND K>2 THEN S2=15+(5-K)*P(3,3)
    ! If last read and not interpolation, stop set by new # of pts
2720 FOR J=S1 TO S2
2730 READ# 1,J ; Z(J-S1+1)
    ! Read magnitude for multiplication, otherwise read time
2740 NEXT J
2750 P(3,4)=J-S1                                   ! # of data pts read
2760 FOR J=S1+T1 TO S2+T1
```

```
2770 READ# 1,J ; Y(J-S1-T1+1)                    ! Read magnitude
2780 NEXT J
2790 S1=S2+1                                     ! Set for next read cycle
2800 RETURN
2810 REM *
2820 REM *
2830 REM *  STORE SUBROUTINE
2840 REM *    1) STORE ALL
2850 REM *       CURVES
2860 REM *
2870 REM *
2880 FOR J=1 TO I2
2890 IF O=15 OR K=4 THEN PRINT# 2,O+J ; X(J)
    ! If only time data or integral data, store x values
2900 IF O≠15 AND K≠4 THEN PRINT# 2,O+J ; Y(J)
    ! Otherwise, store y values
2910 NEXT J
2920 O=O+I2                                      ! Setup next start index
2930 PRINT# 2,9 ; P(1,4)                         ! Store # of pts curve 1
2940 PRINT# 2,14 ; P(2,4)                        ! Store # of pts curve 2
2950 I2=0 @ J=J-1                                ! Reset storage index
2960 RETURN
2970 REM *
2980 REM *
2990 REM *  INITIALIZATION
3000 REM *    SUBROUTINE
3010 REM *
3020 REM *
3030 CLEAR @ BEEP
3040 DISP @ DISP "Initializing"
3050 FOR I=1 TO 256
3060 X(I)=0                                      ! Initialize time reg
3070 Y(I)=0                                      ! Initialize magn reg
3080 Z(I)=0                                      ! Initialize temp reg
3090 NEXT I
```

```
3100 FOR I=1 TO 3
3110 FOR J=1 TO 5
3120 P(I,J)=0                                   ! Initialize cntl reg
3130 NEXT J
3140 NEXT I
3150 FOR I=1 TO 4
3160 FOR J=1 TO 256
3170 M(I,J)=0                                   ! Initialize intrp reg
3180 NEXT J
3190 NEXT I
3200 FOR I=1 TO 2
3210 FOR J=1 TO 2
3220 R(I,J)=0                                   ! Initialize trnc reg
3230 NEXT J
3240 NEXT I
3250 FOR I=257 TO 2048
3260 X(I)=0
    ! Initialize remaining time register (for new time pts)
3270 NEXT I
3280 ON ERROR GOSUB 3310                        ! Trap file errors
3290 IF X$="NULL" THEN RETURN
3300 RETURN
3310 IF ERRN=7 THEN X$="NULL"                   ! File error; set default
3320 IF ERRN≠63 THEN 3360                       ! Unknown error, retry
3330 PURGE "TEMPX"                              ! Purge work file
3340 CREATE "TEMPX",L,8                         ! Attempt to recreate
3350 OFF ERROR
3360 RETURN
```

VMAUX

The HP85 Desktop Computer has limited memory space. Therefore, during the data acquisition processes using the Tektronix 7612D Programmable Digitizer and the Nicolet 2090-III Digital Oscilloscope, auxiliary data acquired from the HP3497A Data Acquisition/Control Unit (DACU) and HP3437A Digital Voltmeter (DVM) is stored in a compact format. The VMAUX program was written to convert this compact data format into a standard format.

The VMAUX program reads the compact data file into the computer, generates the control registers necessary for later processing, and stores the data in standard format. This program is called automatically by NIC85 and 7612D before they pass control back to Autost.

```
10 REM *
20 REM *
30 REM *  AUXILIARY PROCESSING
40 REM *    MAIN PROGRAM
50 REM *
60 REM *Copyright:  5/31/85
70 REM * gandalf software, inc.
80 REM * Chuck Graves, wizard
90 REM *
100 REM *
110 COM X$[10]                                 ! Make file name common
120 DIM A(2,69),P(5),Y$[10],Z$[10]
130 CLEAR @ BEEP
140 DISP "Initializing"
150 GOSUB 750                                  ! Initialization routine
160 CLEAR @ BEEP
170 DISP "What is name of the auxiliary"
180 DISP "voltage file associated with "
190 DISP X$;"?"
200 INPUT Y$                                   ! Input name of aux file
210 IF LEN(Y$)>0 AND LEN(Y$)<11 THEN 260       ! File name too long?
220 CLEAR @ BEEP                               ! Yes, notify user
230 DISP "Name is too large. Pick a name"
240 DISP "with less than 11 letters."
250 WAIT 4500 @ GOTO 160                       ! Re-enter aux file name
260 CLEAR @ BEEP                               ! No, enter mass storage
270 DISP "Where is ";Y$;" stored?"
280 DISP "(DISK00/DISK01/TAPE)"
290 INPUT Q$                                   ! Input mass storage
300 IF Q$="TAPE" THEN R$=":T"
310 IF Q$="DISK01" THEN R$=":D701"
320 ON ERROR GOTO 1790                         ! Trap mass storage error
330 MASS STORAGE IS R$                         ! Assign mass storage
340 OFF ERROR
350 CLEAR @ BEEP
```

```
360 DISP "Reading"
370 GOSUB 920                               ! Read routine
380 CLEAR @ BEEP
390 DISP "There are ";P1;" curves."
400 FOR I=1 TO P1
410 DISP "Enter the name for curve ";VAL$(I);"."
420 INPUT Z$                                ! Input new file name
430 IF LEN(Z$)>0 AND LEN(Z$)<11 THEN 490    ! File name too long?
440 CLEAR @ BEEP                            ! Yes, notify user
450 DISP "Name is too large. Pick a name"
460 DISP "with less than 11 letters."
470 WAIT 4500 @ CLEAR
480 BEEP @ GOTO 410                         ! Re-enter file name
490 CLEAR @ BEEP
500 DISP "Storing ";Z$
510 GOSUB 1350                              ! Storage routine
520 CLEAR @ BEEP
530 NEXT I
540 DISP "Did you store any curves other"
550 DISP "than ";X$;"? (Y/N)"
560 INPUT Q$                                ! Another set of curves?
570 IF Q$="N" THEN 670                      ! No, return to Autost
580 CLEAR @ BEEP
590 DISP "What is the name of the stored"
600 DISP "file?"
610 INPUT X$                                ! Yes, enter file name
620 IF LEN(X$)>0 AND LEN(X$)<11 THEN 130    ! File name too long?
630 CLEAR @ BEEP                            ! Yes, notify user
640 DISP "Name is too large. Pick a name"
650 DISP "with less than 11 letters."
660 WAIT 4500 @ GOTO 580                    ! Re-enter file name
670 CLEAR @ BEEP                            ! Return to Autost
680 DISP "    MISSION CONTROL"
690 DISP "will now resume control."
700 FOR I=1 TO 65
```

```
710 BEEP 65-I,20
720 NEXT I
730 CHAIN "Autost:D700"                    ! Load Autost prog
740 END
750 REM *
760 REM *
770 REM *  INITIALIZATION
780 REM *    SUBROUTINE
790 REM *
800 REM *
810 FOR I=1 TO 2
820 FOR J=1 TO 69
830 A(I,J)=0                               ! Initialize work reg
840 NEXT J
850 NEXT I
860 FOR I=1 TO 5
870 P(I)=0                                 ! Initialize control reg
880 NEXT I
890 R$=":D700"                             ! Default mass storage
900 P1=1 @ P(5)=86
    ! Default # of curves, units (V)
910 RETURN
920 REM *
930 REM *
940 REM *  READ SUBROUTINE
950 REM *    1) READ CURVE
960 REM *    2) READ DATE & TIME
970 REM *    3) CLOSE FILES
980 REM *
990 REM *
1000 ON ERROR GOTO 1300                    ! Trap disk errors
1010 ASSIGN# 1 TO Y$                       ! Open aux file
1020 ASSIGN# 2 TO X$                       ! Open main file
1030 OFF ERROR
1040 READ# 2,4 ; P(2)                      ! Read date
```

```
1050 READ# 1,134 ; P(3)                            ! Read start time
1060 ASSIGN# 2 TO *                                ! Close main file
1070 K=1
1080 FOR I=1 TO 2
1090 FOR J=1 TO 69
1100 READ# 1,K ; A(I,J)                            ! Read aux data
1110 K=K+1
1120 NEXT J
1130 NEXT I
1140 ASSIGN# 1 TO *                                ! Close aux file
1150 REM *
1160 REM *
1170 REM *  SORT SUBROUTINE
1180 REM *    1) FIND # CHANNELS
1190 REM *    2) FIND # DATA
1200 REM *
1210 FOR I=69 TO 66 STEP -1
1220 IF A(1,I)=9999 THEN 1240                      ! Find last channel
1230 NEXT I
1240 P1=69-I                                       ! Set # of curves
1250 FOR I=1 TO 64
1260 IF A(1,I)=9999 THEN 1280                      ! Find last data pt
1270 NEXT I
1280 P(4)=(I-1)/P1                                 ! Calculate # of pts
1290 RETURN
1300 OFF ERROR
1310 IF ERRN≠130 THEN 1010                         ! Disk error; no, retry
1320 CLEAR @ BEEP                                  ! Yes, notify user
1330 DISP "Disk error. Re-enter storage."
1340 WAIT 4500 @ GOTO 260                          ! Re-enter mass storage
1350 REM *
1360 REM *
1370 REM *  STORE SUBROUTINE
1380 REM *    1) CREATE FILE
1390 REM *    2) STORE CURVE
```

```
1400 REM *
1410 REM *
1420 ON ERROR GOTO 1680                       ! Trap file errors
1430 CREATE Z$,10+2*P(4),8                    ! Create file space
1440 OFF ERROR
1450 ASSIGN# 1 TO Z$                          ! Open new file
1460 PRINT# 1,1 ; 1                           ! Store # of curves
1470 PRINT# 1,2 ; 10                          ! Store # of horiz div
1480 PRINT# 1,3 ; 8                           ! Store # of vertical div
1490 PRINT# 1,4 ; P(2)                        ! Store date
1500 PRINT# 1,5 ; P(3)                        ! Store meas time
1510 GOSUB 1830                               ! Conversion routine
1520 GOSUB 2140                               ! Sort routine
1530 K=6
1540 FOR J=1 TO 5
1550 PRINT# 1,K ; P(J)                        ! Store control reg
1560 K=K+1
1570 NEXT J
1580 FOR J=0 TO P(4)-1
1590 PRINT# 1,K ; A(2,I+J*P1)                 ! Store time array
1600 K=K+1
1610 NEXT J
1620 FOR J=0 TO P(4)-1
1630 PRINT# 1,K ; A(1,I+J*P1)*M               ! Store magn array
1640 K=K+1
1650 NEXT J
1660 ASSIGN# 1 TO *                           ! Close file
1670 RETURN
1680 OFF ERROR
1690 IF ERRN≠63 THEN 1430                     ! File already exist?
1700 CLEAR @ BEEP                             ! Yes, notify user
1710 DISP "File already exists. Do you want"
1720 DISP "to purge? (Y/N)"
1730 INPUT Q$                                 !   Purge file?
1740 IF Q$="Y" THEN PURGE Z$ @ GOTO 1430      !   Yes, purge & cont
```

```
1750 CLEAR @ BEEP                              !   No, enter new name
1760 DISP "Enter another name."
1770 INPUT Z$
1780 GOTO 1420                                 !    Retry storage
1790 IF ERRN≠130 THEN 330
   ! No. If there is not a disk error, retry
1800 CLEAR @ BEEP                              ! Yes, notify user
1810 DISP "Disk error. Re-enter storage."
1820 WAIT 4500 @ GOTO 260                      ! Re-assign mass storage
1830 REM *
1840 REM *
1850 REM * CONVERSION SUBROUTINE
1860 REM *   1) SCALE INPUT
1870 REM *
1880 REM *
1890 CLEAR @ BEEP @ M=1
1900 DISP "Is an attenuator, current"
1910 DISP "transformer, thermocouple, etc.,"
1920 DISP "being used? (Y/N)"
1930 INPUT Q$                                  ! Conversion?
1940 IF Q$≠"Y" THEN RETURN                     ! No, return
1950 CLEAR @ BEEP                              ! Yes, cont
1960 DISP "What is the conversion process?"
1970 DISP @ DISP "(For example, a 6 dB attenuator"
1980 DISP "converts a 2-volt input at the"
1990 DISP "source to a 1-volt input at the"
2000 DISP "scope. So conversion is 2V to"
2010 DISP "1V - entered 2V, 1V. Enter using"
2020 DISP "scientific notation and proper"
2030 DISP "units - A, V, K, etc.)"
2040 INPUT W$,Q$                               ! Input conversion
2050 P(5)=NUM(W$[LEN(W$),LEN(W$)])
2060 IF NUM(Q$[LEN(Q$),LEN(Q$)])=86 THEN 2120  ! Conversion valid?
2070 CLEAR @ BEEP                              ! No, notify user
2080 DISP "Incorrect entry. The voltage "
```

```
2090 DISP "entry should be on the right."
2100 DISP "Re-enter."
2110 WAIT 4500 @ GOTO 1950                  ! Re-enter conversion
2120 M=VAL(W$)/VAL(Q$)                      ! Calculate scale factor
2130 RETURN
2140 REM *
2150 REM *
2160 REM *  SORT SUBROUTINE
2170 REM *    1) FIND UNIT/DIV
2180 REM *
2190 REM *
2200 G=A(1,I)                               ! Default minimum
2210 H=A(1,I)                               ! Default maximum
2220 FOR J=1 TO P(4)-1
2230 IF A(1,I+J*P1)<G THEN G=A(1,I+J*P1)    ! Set if new min
2240 IF A(1,I+J*P1)>H THEN H=A(1,I+J*P1)    ! Set if new max
2250 NEXT J
2260 P(1)=A(2,I+P1*(P(4)-1))/10             ! Calculate time/div
2270 P(2)=(H-G)/8                           ! Calculate magn/div
2280 IF H-G<H THEN P(2)=H/8                 ! If max & min > 0, set
2290 RETURN                                 !   magn/div so min = 0
```

APPENDIX B

PROGRAM PROTECTION CODES

An integral part of any software-based system is the security of the program files. Key security concerns are the accidental overwriting and the indiscriminate changing of program files. To protect the system programs, the HP85 Desktop Computer's file security system. The command to secure a file is

SECURE "file name","security code",security type

where the file name and security code are alphanumeric strings, and the security type is a number.

The security types which are available from the computer and the type of security which they provide are: 0 inhibits LIST, PLIST, and all editing; 1 inhibits LIST, PLIST, STORE (duplication), and all editing; 2 inhibits STORE (overwriting), PRINT#, and STOREBIN, and; 3 inhibits CAT (a blank appears where the file name should be).

The latter three (3) of these codes are used in the security of the system program codes. At present, all of the system programs are coded against duplication, editing, and overwriting. The protection codes used are listed in the program named KEY, as follows:

```
10  REM *
20  REM *     MAGICIAN'S KEY
30  REM *     --------------
40  REM *      SECURE CODES
50  REM *
60  REM *     "KEY","WZ",2&3
70  REM *     "Autost","WZ",1&2
80  REM *     "NORML","CG",1&2
90  REM *     "7612D","CG",1&2
100 REM *     "VMAUX","CG",1&2
110 REM *     "HP-DAS","CG",1&2
120 REM *     "NIC85","CG",1&2
130 REM *     "TABLET","CG",1&2
140 REM *     "MATH","CM",1&2
150 REM *     "PLOT","CM",1&2
160 REM *     "I-V","CM",1&2
170 REM *
180 END
```

This program documents all of the security codes and security types associated with each of the program files. However, the security types must be entered one (1) at a time.

Therefore, to remove both the overwrite protection and the duplicate protection for the program file, Autost, two (2) separate UNSECURE commands will have to be used. Respectively, they are:

UNSECURE "Autost","WZ",1

and

UNSECURE "Autost","WZ",2

After entering these commands, the operator can work freely on the Autost program.

In addition, the KEY program is secured using security type 3. This was done to discourage the casual user from changing the programs. Instead, there is a program named SECURITY which lists the name of the KEY program. The program listing for SECURITY is:

```
10  REM *
20  REM *
30  REM *     SECURITY CODE
40  REM *     -------------
50  REM *
60  REM *     blank = "KEY"
70  REM *
80  REM *
90  END
```

Thus, if the operator does not have ready access to this document while using the system, the information regarding protection codes is still obtainable during system use.

To navigate through the process of unsecuring any files:

1) get a catalog of the tape or disk -- CAT
2) load the program SECURITY -- LOAD "SECURITY"
3) list the program -- LIST
4) get the name of the blank file -- blank file = "KEY"
5) load the program KEY -- LOAD "KEY"
6) list the program to the printer -- PLIST
7) unsecure the desired program.

In this manner, the operator can open any program for editing without leaving the computer.

A DATA ACQ

VOLUME II

APPENDIX C

USER'S MANUAL

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APPENDICES

CHAPTER 1

INTRODUCTION

The systems software is a package of programs designed to control a set of digital data takers using a Hewlett-Packard 85 desktop computer. The software was prepared with the intent of simplifying the data acquisition process by providing: 1) an operator-computer interface which minimizes the need for operator expertise with each individual machine, 2) a consistent data format for ease of future data retrieval and manipulation, and 3) a consistent package of data conditioning programs to handle preliminary conditioning of data.

The systems software was designed with emphasis on flexibility and ease of use. As a result, some compromises were necessary for the final development of the programs. In developing an easily understood, or "user-friendly", system, the necessity arose to place limitations on size of data files and time from measurement to storage. These limitations are covered during the operation of the individual programs so the operator is reminded without causing any undue problems.

This manual is an effort to catalog the capabilities and limitations of the systems software package. The operator should read this to gain a preliminary view of the system. The first chapter is an overview of system operations providing step-by-step instructions for starting the system and taking measurements. The succeeding chapters provide step-by-step instructions for preparing, making, and storing measurements on each of the instruments in the system. The final chapter covers data storage format.

In addition, appendices are provided for aiding the user should any unusual circumstances arise during the operation of the system including flow charts for each of the programs and a copy of the HP-85 error codes.

Please keep in mind this manual assumes the operator is familiar with the instrument being used for measurement. To receive better results in the operation of this system, the operator is recommended to first make a series of simple measurements with the test instrument without the aid of the system. This exercise should provide valuable insight into the operation of the experiment.

In conclusion, do not hesitate to refer to the manuals on each instrument if there is any doubt about the validity of the measurement.

CHAPTER 2

SYSTEM STARTUP

2.1 Overview

The systems software package is controlled by a central processing program, Autost. This program is outlined more thoroughly in Chapter 3, but a brief overview is useful at this time.

The principal duties of Autost are: 1) initialization of the system clock and calendar, 2) polling devices to see if they are present on the interface bus, and most importantly, 3) loading and running the necessary programs for the specific data acquisition processes. This program is designed so that the operator need only select from menus of desired functions or equipment. The program handles the rest of the housekeeping and organization.

2.2 Setup and Error Prevention

For a smooth system startup, the operator only need follow a short series of operations to load and run Autost:

1) turn on the disk drive;
2) insert the SYSTEMS MASTER disk into drive 00;
3) turn on the HP-85 computer;
4) type: *CHAIN "Autost";*
5) press ENDLINE.

If the computer is turned on first, the computer will generate **ERROR 131: CARTRIDGE OUT**. Since the computer has a Mass Storage ROM, the computer polls the Hewlett-Packard Interface Bus (HPIB) for a mass storage device. If it finds none, the computer defaults to its internal tape drive. By turning on the disk drive first, the computer has a mass storage device on-line and assigns the disk drive to be the system's mass storage unit.

2.3 Unusual Error Actions

On rare occasions, the computer does not recognize the disk drive and generates the error mentioned previously (**ERROR 131: CARTRIDGE**

OUT). If the computer should generate ERROR 131,

1) type: ***MASS STORAGE IS ":D700";***

2) press ENDLINE;

3) repeat steps 4) and 5) from the previous procedure.

This should load and run the central processing program, Autost, without any problems.

2.4 Reference

A complete outline of the startup procedure is given in flow chart form in Appendix A.

CHAPTER 3

CENTRAL PROGRAM CONTROL

3.1 Overview

As mentioned in the previous chapter, the central processing program, Autost, serves as the nerve center of the system. The principal operations of Autost are: 1) initialization of the system clock and calendar, 2) polling devices to see if they are present on the HPIB, and, 3) loading and running the necessary programs for the data acquisition and conditioning processes. Once the operator has completed the system startup procedures, outlined in Chapter 2, Autost will begin to carry out these operations.

3.2 Input Types

The program will prompt the operator periodically for input. These prompts will take two (2) forms. The first form will be requests for typed information, i.e., operator must type in a response. The second form will be a list of key assignments. Whenever the program requests typed information, type one (1) of the responses requested by the computer. The valid responses are in parentheses next to the question. The information is verified. If the input is invalid, the program will notify the operator to enter a valid input. The program the proceeds based upon the valid entry.

Whenever the program offers a list of key assignments, the operator only need press the key assigned to initiate a given operation. (Note: The keys referred to are those marked K1 through K10 just above the standard typewriter keyboard area.) The keyed responses are used wherever there are more than two (2) choices. Only those keys listed in the program prompt are active. If the operator presses a key which is inactive, the machine will generate an error stating the key is not assigned. This error will not cause the program to fail. If the program stops with an unassigned key error, press CONTINUE and press a key with an assignment.

3.3 Initialization

The first operation which Autost carries out is initialization of the system clock and calendar. If the operator has just powered up the system, the program will ask for the date. After receiving a valid date, the system will ask for the time of day. The program then sets the computer's clock and calendar. Once the system is initialized, the program proceeds to the next operation.

3.4 Main Program

The program lists the functions which the system is capable of carrying out:

(1) take data	depress K1;
(2) process data	depress K2;
(3) plot curves	depress K3;
(4) plot I vs. V only	depress K4;
(5) use graphics	depress K5.

3.5 Data Acquisition

If the operator chooses to take data (K1), the program lists the equipment available for taking data:

(1) Tektronix 7612D Digitizer	depress K1;
(2) Nicolet Digital O-scope	depress K2;
(3) HP Multiplexer and Voltmeter	depress K3;
(4) HP Graphics Tablet	depress K4.

Should the operator opt to use the Tektronix 7612D (K1) or the Nicolet Digital O-scope (K2), the program will ask if the operator wants to take additional measurements with the HP Multiplexer and HP Voltmeter.

3.6 Equipment Availability and Error Handling

Thus, based upon the operator's choice, the program polls the HPIB to see if the equipment necessary for the desired operation is present. The pieces of equipment necessary for each operation are: 1) taking data: disk drive and selected instrument(s); 2) processing data: disk drive; 3) plotting curves: disk drive and plotter; 4) plotting I vs.

V only: **disk drive and plotter,** and; 5) using graphics: not functional at this time.

If the program cannot locate the device(s) on the HPIB, the program will print the message, **The DEVICE$ is OFF. Turn ON the DEVICE$ and press CONTINUE.** In this case, DEVICE$ is the name of the device which is not present on the HPIB. In most cases, the device mentioned has not been turned on. If the operator finds that the device is on and still receives the message to turn on the device, check to make sure the HPIB has been connected from the computer to the device. These actions should cure most problems.

3.7 Unusual Error Actions

However, if the device is on and connected to the HPIB and the computer still generates the message to turn the device on, there is a definite problem. Under these circumstances, a hardware problem probably exists. Four (4) probable areas to consider are: 1) the HPIB does not have enough devices on-line and powered up; 2) the address of the machine's HPIB address has been changed; 3) the HPIB card in the computer has failed, or; 4) the Input/Output (I/O) ROM in the computer has failed.

3.7.1 Insufficient Power

The most likely problem is the HPIB does not have enough active listeners. The HPIB has a limited transmission length. These limitations are outlined in the various user's manuals. These manuals each have a section on HPIB structure and operations. The quickest way to ascertain whether the HPIB has adequate power is to turn on all of the devices attached to the HPIB. The program should function properly.

3.7.2 Incorrect Address

The next probable problem is the machine's HPIB address has been changed. Appendix B has a list of the HPIB addresses for the devices in the system. Compare the device address on this list to the DIP switch which controls the machine's address. In most cases, the DIP switch for the address is on the back panel of the machine. In all cases, the location of the DIP switch is listed in that machine's user's manual.

3.7.3 Hardware Failure

If these actions do not remedy the situation, the computer probably has experienced hardware failure. At this point, refer to the service section of the user's manual for the HP-85. The manual has a list of actions to locate and remedy hardware errors.

3.8 Normal Operations

Once the computer has located all the desired equipment on the HPIB, the program will load and run the program which carries out the desired function using the necessary equipment. Based upon the operator's selection, Autost will load and run one (1) of the following programs:

1) take data using:	
a) Tektronix 7612D as normal o-scope	NORML;
b) Tektronix 7612D as one-shot o-scope	7612D;
c) Nicolet Digital O-scope	NIC85;
d) HP Multiplexer and Voltmeter	HP-DAS;
e) HP Graphics Tablet	TABLET;
2) process data	MATH;
3) plot curves	PLOT;
4) plot I vs. V only	I-V;
5) use graphics	not functional.

3.9 Reference

A complete outline of Autost is given in flow chart form in Appendix C, pages 279 through 290.

CHAPTER 4

MATHEMATICAL PROCESSING PACKAGE

4.1 Overview

In addition to taking data, covered in Chapter 7 through Chapter 11, the systems package contains programs to calculate the product and the time-integral of two (2) curves. Each pair of curves needs to have a voltage and a current curve. Otherwise, the processing program, MATH, cannot and will not work on them. To process the pair of curves, simply select process data when in Autost. When the computer has loaded and begun running MATH, the operator will be prompted to enter a file name if the system was just turned on. Otherwise, the program presumes the operator wishes to work on the curves which were just taken.

4.2 Main Program

MATH will request the location of the curves, i.e,. which mass storage device. The program will load the curves from that device, if possible. The program was developed to trap mass storage errors. However, MATH will not test to see if a file is on the mass storage device. If the file is not on the mass storage device, the operator will be notified and the program will stop. In this case, change the medium, e.g., floppy disk or tape, and rerun the program. If MATH generates a mass storage medium error, enter a different mass storage device or make sure the medium is engaged properly, e.g., disk drive door is closed.

At this point, MATH will verify whether or not the file can be processed. If not, the program will ask whether or not the operator wishes to process a different set of curves. Should the operator not wish to process a different file, the program will return to Autost. Otherwise, MATH will request a file name and repeat the aforementioned verificaton process.

4.3 Processing

Once MATH has obtained the name of a file which can be processed, the program will proceed to read both of the stored curves. The program then carries out the following processes: 1) reads through both curves to find the time frame which is common; 2) sorts all time values within that time frame together; 3) interpolates both curves for each of the time data; 4) evaluates the product for the curves; 5) evaluates the time-integral for the product curve, and; 6) stores all of these curves in a new file.

4.3.1 Read

In the process of reading through the curves, MATH establishes a common time frame which is shared by the curves. For example, if curve one (1) has data over the time period from 5 ns to 50 µs in 5-ns steps and curve two (2) has data over the time period from 10 ns to 100 µs in 10-ns steps, then the data is useful only from 10 ns to 50 µs. Outside that area, the data cannot be used because only one (1) value is known, and the program needs two (2) values to evaluate a non-zero product.

4.3.2 Sort, Interpolate, and Evaluate

Next, MATH sorts all of the values of time together. This is followed by developing a linear interpolation between each y value for both curves. The program evaluates both curves for each time value using the linear interpolation. In this manner, the program has developed two (2) curves of equivalent size which have y values evaluated at the same times. Thus, MATH can evaluate a product curve corresponding to instantaneous power by simple multiplication.

4.3.3 Time-Integral

After evaluating the product curve, MATH evaluates the time-integral of the product curve using a trapezoidal approximation. Due to the geometry of these curves, the trapezoid is the sum of the area of a triangle and the area of a rectangle. Using the values given in Figure 4.1, the triangular area is given by

$$A_t = .5(X_{i+1} - X_i)(Y_{i+1} - Y_i)$$

and the rectangular area is given by

$$A_r = Y_i(X_{i+1} - X_i)$$

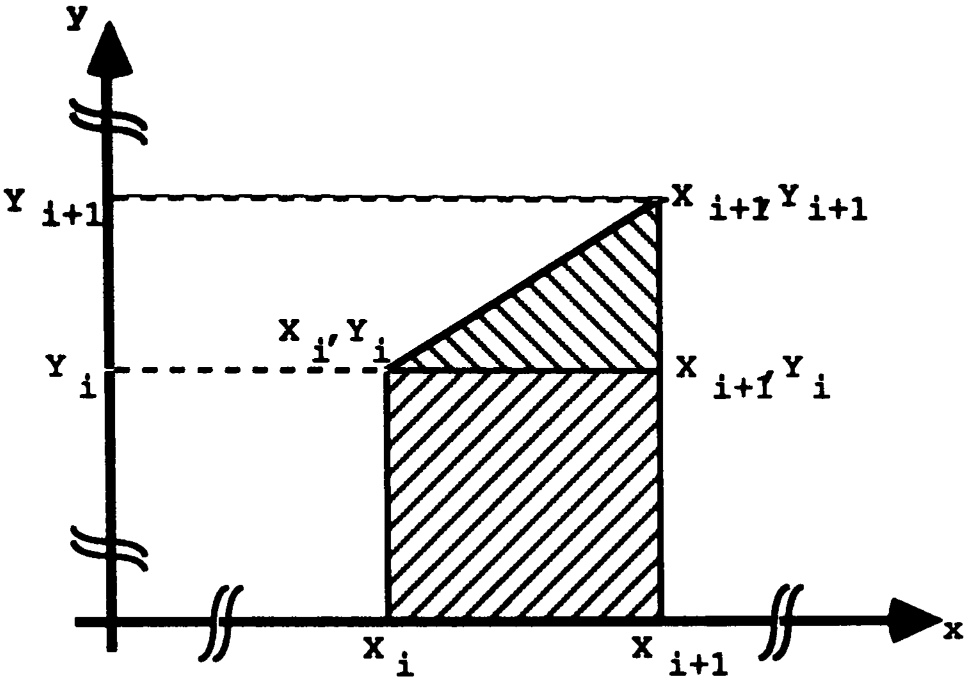


Figure 4.1. Trapezoidal Approximation

Taking the sum,

$$A = (.5Y_{i+1} - .5Y_i + Y_i)(X_{i+1} - X_i)$$

$$A = (.5Y_{i+1} + .5Y_i)(X_{i+1} - X_i)$$

$$A = .5(Y_{i+1} + Y_i)(X_{i+1} - X_i)$$

This value is added to the previous area to evaluate an approximate value for the time-integral.

4.4 Storage

MATH stores all these curves in a new file. After the program has completed storing, the operator is prompted to enter a name for the new file. If the old name is entered, the program will purge the old file. Therefore, if the operator wishes to keep the old unprocessed file, the operator will need to enter a different file name for the processed file.

4.5 Completion

Finally, MATH will ask whether or not the operator wishes to process a new file. If so, the program will load the new file and start again. Otherwise, the program will return to Autost.

4.6 Reference

A complete outline of MATH is given in flow chart form in Appendix C, pages 292 through 298.

CHAPTER 5

PLOTTING PACKAGE

5.1 Overview

The SYSTEMS package contains a program, PLOT, which plots any curve stored by the system. The program is designed to read and plot both processed and unprocessed curves with four (4) curves on an 8.5" x 11" piece of paper. Therefore, PLOT defaults to a plotting scale and layout which allow this. At the beginning of each plotting process, the operator can request a single plot to be made. This is done to allow plotting of one (1) curve per page.

In addition, the operator has the option of changing the scale of the plot to increase or reduce the final size of the plot. The default scaling value is one (1). Thus, to reduce a standard plot to 1/4 the original size, go to the scaling section and input .25.

Besides the plotting capabilities, PLOT also allows the operator to generate a printout of the second-breakdown characteristics of the device under test. The option to get these statistics is located at the end of the plotting process.

5.2 Main Program

If PLOT is the first program called after the system is powered up, the program will ask for the name of the file to be processed. Otherwise, the program presumes the last file to be worked on is to be used. PLOT prompts for the location of the file, i.e., the mass storage unit. The program will load the curves from that device, if possible. The program was developed to trap mass storage errors. However, PLOT will not test to see if a file is on the mass storage device. If the file is not on the mass storage device, the operator will be notified and the program will stop. In this case, change the medium, e.g., floppy disk or tape, and rerun the program. If PLOT generates a mass storage error, enter a different mass storage device or make sure the medium is engaged properly, e.g., disk door is closed.

At this point, PLOT will prompt the operator to choose a function:

(1) plot V (voltage)	**depress K1;**
(2) plot I (current)	**depress K2;**
(3) plot P (power or product)	**depress K3;**
(4) plot U (energy or integral)	**depress K4;**
(5) scale plot	**depress K5;**
(6) new set of curves	**depress K6;**
(7) finished	**depress K7.**

If the operator chooses any of the plot routines (K1 through K4), the program checks to see whether or not the file has that curve. For example, an unprocessed file does not have a power or energy curve. Also, some curves will be stored as single curves. Should the curve not be present in the file, the program will notify the operator and go back to the key selections. If the curve exists, PLOT will proceed with the plotting process.

5.3 Scaling Option

If the "scale plot" option (K5) is chosen, PLOT will ask for a numerical scale factor. The program compares the input to the valid range. If the number is within the given range, the program will store the scale factor and return to the key selections.

5.4 New Curve Set

Should the operator choose to plot a new set of curves (K6), PLOT will ask for a new file name and revert to the beginning of the process outlined thus far.

5.5 Quit

If the operator is finished (K7), PLOT will return to Autost.

5.6 Plotting Options

For any of the plotting operations, PLOT asks if the plot is to be made by itself. This effects where the plot is placed on the page. The program asks for the title for the x-axis; then, the program asks for the title of the y-axis. After verifying the titles are not too long, PLOT asks the operator for a preference of grid or graph. Next, the program prompts the operator to load the plotter and pauses.

Once the plotter is loaded, press CONTINUE. PLOT will take the x per division and y per division information from the control register, if file is unprocessed, or calculate the y per division, if processed, and round the values to the nearest value of .1, .2, .25, .5, 1, 2, 2.5, 5, 10, 20, 25, or 50. The program will evaluate the unit values to the nearest engineering unit, e.g., 10^{-3} V gives 1 mV, 10^3 V gives 1 kV. Using these values, the program will draw and label the grid, or graph, and begin reading the data from the file.

Since PLOT has a limited space for data storage, the program will carry out the plot in segments of 2048 points. The program will read the first segment, then plot it; read the second segment, then plot it; and so on. After completing the plot, PLOT will label the x-axis and the y-axis. The program will prompt for the desired location on the plot for the date and time the curve was taken. The program then asks for the year and plots the date and time at the desired y-coordinate.

Next, PLOT asks for a label to put on the graph. This is any name the operator wants to put on the plot to use as a general title. This is as a supplement to the axes titles. At this point, the program will ask the operator if second-breakdown statistics are desired. If not, the program returns to the key operations.

5.7 Second-breakdown Statistics

PLOT will carry out second-breakdown calculations only on processed data files. If the file being read is unprocessed, the program will notify the user the file is unprocessed and will return to the key operations.

Otherwise, PLOT will proceed to place the plotter into print mode. In this mode, the plotter functions as a very precise, very slow, printer. The program first searches the voltage curve for the peak voltage. This it takes to be the second-breakdown voltage. The program prints this value with a label to indicate the particular quantity.

PLOT prints the values for the instantaneous current, instantaneous power, instantaneous energy, and time which correspond to the second-breakdown voltage.

Next, PLOT scans through the voltage curve to find the value of voltage closest to 10% of the second-breakdown voltage. The program prints the time associated with this voltage. The program prints the instantaneous voltage, instantaneous current, instantaneous power, and instantaneous energy values which correspond to this time, t_o.

Finally, PLOT calculates the change in time from t_o to second-breakdown, and prints it; then, the program calculates the change in energy from to to second-breakdown, and prints it. After this operation, the program places the plotter back in plot mode and returns to the key operations.

5.8 Reference

A complete outline of PLOT is given in flow chart form in Appendix C, pages 300 through 318.

CHAPTER 6

I VS. V PLOTTING PACKAGE

6.1 Overview

The SYSTEMS package contains a program, I-V, which plots only I vs. V curves. Initially, this program was a subroutine in PLOT. However, the space available in memory in the HP-85 is limited. Therefore, the necessity arose to make this function a separate program. As a result, I-V functions in essentially the same manner as PLOT.

The basic difference between I-V and PLOT is the operator has one (1) plot that can be generated in I-V where the operator had a choice of four (4) in PLOT. In addition, I-V does not contain the option of generating second-breakdown characteristics.

6.2 Action

Otherwise, I-V is functionally equivalent to PLOT. Therefore, the operator will find system discussion from Chapter 5 to be most useful. To avoid redundancy, the operator is referred to sections 5.2 through 5.6 for a discussion of system operations.

6.3 Reference

A complete outline of I-V is given in flow chart form in Appendix C, pages 320 through 327.

CHAPTER 7

USING TEKTRONIX 7612D AS A STANDARD OSCILLOSCOPE

7.1 Overview

The SYSTEMS package has the capabilities to use several data takers. One such device is the Tektronix 7612D Programmable Digitizer. The device was designed primarily as a single-shot storage device. However, a program, NORML, exists to use the device in a more standard mode. This program was designed to aid in setting the device for later single-shot activities. The operator is referred to the device's user's manual for detailed capabilities of the device.

7.2 Main Program

NORML was designed as an aid to the operator by triggering the device at a rate which simulates more standard scopes. The program offers the operator two (2) possible choices of action:

(1) pause to change settings	**depress K1;**
(2) finished	**depress K2.**

After displaying this message, the program proceeds to arm and trigger the device approximately once every 100 ms. NORML will continue sweeping until a key is depressed.

7.3 Change Settings

If the operator decides to change settings (K1), NORML will pause and allow the operator to change any settings on the device. Thus, the program acts as an aid in finding reasonable settings for the data acquisition process, e.g., triggering, voltage per division, or sample period. When the operator has changed the desired settings on the front panel, press CONTINUE to restart the program. The operator should repeat this process until finding adequate settings for a single-shot test.

7.4 Quit

When the operator is finished (K2), NORML will return to Autost. The settings will be maintained by the device since the other program, 7612D, never initializes the Tektronix 7612D.

7.5 Reference

A complete outline of NORML is given in flow chart form in Appendix C, page 329.

CHAPTER 8

USING TEKTRONIX 7612D AS A SINGLE-SHOT OSCILLOSCOPE

8.1 Overview

As mentioned in Chapter 7, the Tektronix 7612D Programmable Digitizer is designed primarily as a single-shot oscilloscope. The program, 7612D, was developed to use the digitizer in this capacity. NORML, discussed in Chapter 7, was developed to help the operator find adequate settings for single-shot operations. Thus, the operator has cut down significantly the number of measurements before receiving a measurement worth storing. After finding proper settings, 7612D will work to store the measurement. The program is designed to store up to two (2) curves with as many as 1024 points per curve.

From reading the digitizer's user's manual, the operator will find that the digitizer can take multiple record readings. 7612D is not designed to take this type of measurement. The program will not allow more than one (1) record. However, the program will accommodate curves with any number of breakpoints. (Note: For a discussion of breakpoints, refer to the digitizer's user's manual.) 7612D allows for taking a set of measurements using the HP3497A DAS/Control Unit and the HP3437A Digital Voltmeter during the storage cycle of the program. The program also is designed to compensate for dc error voltages. In addition, 7612D has a section which will translate the voltages read for a curve into the true units. In other words, the program will translate for an attenuator or multiplying probe; as well as, converting a voltage to a current knowing the current probe conversion or current-sensing resistor value. The true unit readings are the values stored in the file.

8.2 Main Program Setup

After initializing all the registers, 7612D will ask the operator for the number of curves to be stored. The program will store up to two (2) curves. If the operator does not enter one (1) or two (2), the program will prompt the operator for a correct entry. After receiving a correct entry, 7612D will ask the operator if a repetitive set of measurements is desired. In this case, "repetitive" refers to whether or not a set of measurements will be taken with the same settings. Thus, if the operator wishes to take a set of measurements using one (1) set of instrument settings, the program will not go back to the setting entry after each measurement. Instead, the program will default to the previous settings and continue.

8.2.1 Voltmeter Setup

Next, 7612D will ask whether or not the operator wishes to take additional measurements using the system voltmeter. If not, the program will proceed with the baseline orientation (section 8.2.2). Otherwise, the program will ask for the number of channels to be monitored by the HP DAS/Control Unit, referred to as the system multiplexer. The program is designed to store a maximum of four (4) channels.

Once the operator has entered a valid entry, 7612D will ask for the system multiplexer channel number and the system voltmeter voltage range for the measurement. The channel number is a number on the range, zero (0) to 999. The voltage range sets the maximum voltage the voltmeter can read. The three (3) voltage ranges are .1 volt, 1 volt, and 10 volts. After each entry, the program will verify whether: 1) the entry is valid, i.e., valid channel number and valid voltage range; 2) the entry is new, i.e., the program will notify the operator if a channel number has been entered previously.

8.2.2 Baseline Orientation

7612D will notify the operator to adjust the position of the curve trace on the xy monitor. The program does this to allow the operator to set an easily readable baseline. If the operator has chosen to take two (2) curves, the program will ask the operator to set both baselines beginning with plug-in A.

7612D will arm and trigger the particular plug-in to generate a grounded trace. This process will continue until the operator is finished. When the operator has set the baseline for the trace, the operator will press K1 to continue.

8.2.3 Instrument Setup

7612D will ask the operator to enter the instrument settings on the front panel. When the program delivers this message, the program activates the REMOTE switch on the front panel. After the setting entry is finished, the operator pushes the REMOTE switch. This tells the program the entry is complete, and 7612D loads all the settings from the digitizer.

7612D will decompose the instrument settings coming from the digitizer, and display those settings on the computer screen. After displaying all of the instrument settings, the program will ask the operator whether or not the settings are correct. If they are, the program sets a software flag to that effect.

8.2.4 Zero Compensation

7612D grounds the input of the plug-in to be used. Then, the program arms and triggers the sweep. If there is any dc drift in the plug-in, the program will receive a non-zero sweep. This is typically the case although the error is rarely large.

7612D calculates the average value of the first ten (10) data points. The program stores this value as the zero (0) correction factor for that plug-in. The program then repeats the process if two (2) curves are to be taken.

8.2.5 Settings Checkout

If the software flag for correct settings is not set, 7612D returns to the instrument setup process (section 8.2.3). Otherwise, the program checks for multiple records. As mentioned earlier, the program is limited to a single record with a maximum length of 1024 data points.

If either the records are multiple or the record length is greater than 1024 points, 7612D notifies the operator of the error and returns to the instrument setup process (section 8.2.3). Otherwise, the program proceeds with true unit computation.

8.2.6 True Unit Computation

7612D asks whether or not a device other than a voltage probe is used. If so, the program asks for the plug-in(s) with some conversion process. The program asks for the particular conversion process on a given plug-in. 7612D will accept only a voltage-to-voltage or current-to-voltage conversion process. The program was not written for conversion processes such as temperature-to-voltage or pressure-to-voltage. Neither was the program designed to accept algebraic relationships. 7612D was written to accept numeric pairs and calculate a conversion coefficient for multiplicative conversion processes. Entry of multiplying voltage probes, however, is not necessary.

The digitizer has the capability to tell whether a multiplying voltage probe is being used on a plug-in. Therefore, 7612D will include that constant in the calculation without operator entry. The program then verifies whether or not the internal clock is being used. If not, the program asks for the external clock frequency and calculates the sampling period.

8.3 Data Acquisition

After finishing the instrument setup process, 7612D will ask the operator to enter the time base to be armed. If the entry is not valid, the program will ask the operator to make a valid entry. Otherwise, the program will arm the time base and tell the operator to take a measurement.

After taking a measurement, the operator needs to press CONTINUE. However, 7612D only arms the digitizer for one (1) measurement. If the measurement is not desireable, the operator has two (2) courses of action. The first course is to press LOCAL on the front panel and manually arm the time base being used. This is done by pressing the appropriate switch on the front panel, and taking another measurement.

This procedure is fine if the operator feels that the settings are correct but the measurement went awry.

The second course is to press CONTINUE and allow 7612D to take control. This is an alternative to the previous process, and is desireable if the operator feels the settings are inadequate.

The program will ask whether or not the operator wishes to keep the data. If so, the program will proceed to read the curve. Otherwise, 7612D will ask whether or not the operator wishes to change the instrument settings. If so, the program will return to the instrument setup (section 8.2.3). Otherwise, the program will re-arm the digitizer and await a measurement.

8.4 Data Storage

Should the operator choose to keep the data, 7612D will read the channel(s). The program will ask where the operator wishes the data to be stored. Next, the program will ask for a file name. The file name cannot be longer than six (6) characters. If the operator enters too long a file name, 7612D will ask the operator to enter a valid name.

If the operator is storing two (2) curves, the program checks to see if both curves are the same type, e.g., both curves are current. If the curves are the same, the program notifies the operator of the error and asks whether or not the operator wants to store the curves separately.

If the operator does not wish to store the curves separately, 7612D returns to the true unit computation (section 8.2.6). Otherwise, the operator is notified the curves will be stored in the order: channel A, then channel B; a software flag is set to indicate the curves will be stored separately.

If the curves are not the same or are flagged to be separated, or only one (1) curve is to be stored, 7612D will notify the operator the data is being stored.

8.4.1 File Creation Errors

7612D will attempt to create a file for storage. At this point, two (2) common errors arise. One (1) is a duplicate file error. This arises when the program attempts to create a file that already exists on the mass storage device. The program will notify the user of the error. 7612D then asks whether or not the operator wishes to purge the existing file.

If so, 7612D will purge the existing file and create the file for storage. Otherwise, the program will ask for a new file name. With the new file name, the program will try to create a file again.

The second common error arises from a problem with the mass storage device. Typically, the problem comes from telling 7612D to create a file on a mass storage device that does not have mass storage media in it, i.e., no disk or tape. The program will notify the operator to choose a new mass storage and return to the beginning of the data storage process (section 8.4).

On rare occasion, other errors may arise. If this occurs, 7612D will notify the operator of an unusual error and halt the program. If this happens, refer to Appendix D for an explanation of the error code.

8.4.2 Normal Operations

Once 7612D has created a file, the program stores the control registers and begins sequentially storing all data. If the operator chooses to use the system multiplexer and system voltmeter, the program will take data on the various channels once every 256 storage operations. This is done because the time necessary to take a measurement with the digitizer is typically short. However, the time required to store data is relatively long.

Therefore, the auxiliary data taken by the system multiplexer and system voltmeter are acquired during the data storage phase. In addition, acquiring data from the system multiplexer and the system voltmeter takes about .5 s per datum. This delay is to allow the voltage to settle. Keep in mind the system multiplexer and system voltmeter are used for slowly changing quantities such as temperature.

When 7612D finishes the normal data storage process, the program proceeds to store the auxiliary data. If no auxiliary data was taken, the program proceeds with the program wrapup (section 8.5). Otherwise, 7612D asks for a file name for the auxiliary file.

7612D notifies the operator that auxiliary data is storing. The program then creates an auxiliary file and stores the auxiliary data in it. This storage operation, however, does not use the data format used by the rest of the program.

A different format is used for auxiliary files because of the restricted program space in the computer. This made necessary the quicker data storage process. To make these auxiliary files readable for normal processing, a further program, VMAUX, is used to change to a standard format. This program will be referred to later in this chapter.

8.5 Program Wrapup

If the software flag to separate curves is set, 7612D returns to the beginning of the data storage process (section 8.4) and asks for a second file name. Otherwise, the program will notify the operator that the data is stored. At this point, the program will ask whether or not the operator wishes to take more data.

If so, 7612D will check for the software flag which indicates a repetitive set of measurements. If that flag is set, the program will return to the beginning of the data acquisition process (section 8.3). If that flag is not set, the program will return to the main program setup (section 8.2).

If the operator does not wish to take more data, 7612D will load and run one (1) of two (2) programs. If auxiliary data was taken using the system multiplexer and system voltmeter, the program will load and run VMAUX. VMAUX is a supplementary program discussed in Chapter 12. This program takes care of separating, reformatting, and restoring the auxiliary data in files which can be processed in the future.

If no auxiliary data was taken, 7612D will return to Autost.

8.6 Reference

A complete outline of 7612D is given in flow chart form in Appendix C, pages 331 through 343.

CHAPTER 9

NICOLET DIGITAL OSCILLOSCOPE CONTROL PACKAGE

9.1 Overview

The Nicolet Digital Oscilloscope, referred to hereafter as the Nicolet, is set up much more like a normal oscilloscope. Where the Tektronix 7612D needed a program to simulate normal oscilloscope action, the Nicolet was developed as an oscilloscope with normal properties. The Nicolet, however, is not capable of the digitizing rate which the Tektronix 7612D can achieve.

In many areas, the Nicolet is not as flexible as the Tektronix 7612D, however, the Nicolet has much more flexibility in its storage capabilities. The operator is referred to the Nicolet's user's manual for specific device capabilities. The software controlling the Nicolet is a highly modified version of a software package purchased from Software Consulting Group. The program, NIC85, will store up to four (4) curves with 1024 points per curve. Much like the program for the Tektronix 7612D, NIC85 allows the operator to make auxiliary measurements with the system multiplexer and system voltmeter. However, the program is less interactive with the operator. NIC85 does not have the zero (0) compensation capabilities of 7612D. NIC85 does have the true unit computation.

9.2 Main Program Setup

After initializing all the registers, NIC85 will ask whether or not the operator wishes to use the system voltmeter to take additional measurements. If not, the program will proceed to the measurement process. Otherwise, the program will ask for the number of channels to be monitored by the system multiplexer. The program is designed to store a maximum of four (4) channels.

Once the operator has entered a valid entry, 7612D will ask for the system multiplexer channel number and the system voltmeter voltage range for the measurement. The channel number is a number on the range, zero (0) to 999. The voltage range sets the maximum voltage the voltmeter can read. The three (3) voltage ranges are .1 volt, 1 volt, and 10 volts. After each entry, the program will verify whether: 1) the entry is valid, i.e. valid channel number and valid voltage range; 2) the entry is new, i.e. the program will notify the operator if a channel number has been entered previously.

9.3 Data Acquisition

NIC85 will notify the operator to take a measurement and pause. The program waits until the operator has pressed CONTINUE. At this point, the operator needs to take the measurement. Unlike 7612D, NIC85 does not trigger the Nicolet. Instead, the program waits for the operator to make a valid measurement.

Once the operator has taken a measurement and presses CONTINUE, NIC85 will input normalization factors from the Nicolet. These factors tell the program, among other things, how many curves are stored. Based on this, the program will load the curves.

NIC85 will notify the user that only 1024 points will be stored from each curve. If the Nicolet has more than 1024 points in a curve, the program will take data from the curve at regular intervals For example, if the Nicolet has a curve with 4096 points, the program will store every fourth point.

NIC85 will check the number of curves. If there are more than four (4) curves, the progam will notify the operator of the error and return to the beginning of the data acquisition process. Otherwise, the program will load the normalization factors for all of the curves. After loading the normalization factors, NIC85 loads the curve data.

9.4 Main Program Execution

After loading the curve data, NIC85 will prompt the operator to choose a function:

(1) store all data	depress K1;
(2) process a new set of curves	depress K2;
(3) finished	depress K3.

If the operator chooses to process a new set of curves, the program will ask whether or not the present data is stored. If so, the program will return to the main program setup (section 9.2). Otherwise, NIC85 will proceed to the data storage process (section 9.5).

If the operator is finished, NIC85 will ask if the present data is stored. If not, the program will proceed to the data storage process (section 9.5). Otherwise, the program will ask whether or not the operator wants to take more data. If the operator wants to take more data, NIC85 will return to the main program set up (section 9.2). Otherwise, the program will load and run one (1) of two (2) programs. If auxiliary data was taken using the system multiplexer and system voltmeter, the program will load and run VMAUX. VMAUX is a supplementary program discussed in Chapter 12. This program takes care of separating, reformatting, and restoring the auxiliary data in files which can be processed in the future. If no auxiliary data was taken, NIC85 will return to Autost.

9.5 Data Storage Setup

NIC85 will ask for a file name. The file name cannot be longer than six (6) characters. If the operator enters too long a file name, the program will ask the operator to enter a valid name. Next, the program will ask where the operator wants the data stored.

If there are more than two (2) curves, NIC85 will ask the operator which curves are to be paired together. This is done since the processing package, MATH, cannot process more than two (2) curves at a time. The operator can opt to store the curves separately, as well as in pairs.

9.6 True Unit Computation

NIC85 asks whether or not a device other than a voltage probe is use. If so, the program asks for the curve(s) with some conversion process. The program asks for the particular conversion process on a given curve. NIC85 will accept only a voltage-to-voltage or current-to-voltage conversion process. The program was not written for conversion processes such as temperature-to-voltage or pressure-to-voltage. Neither was the program designed to accept algebraic relationships. NIC85 was written to accept numeric pairs and calculate a conversion coefficient for multiplicative conversion processes. However, unlike 7612D, the operator needs to enter multiplying probes such as a 10x probe.

9.7 Data Storage

If the operator is storing two (2) curves, once the voltage conversion processes are entered, NIC85 will see if the two curves to be stored together are the same type, e.g,. both curves are current. If the curves are the same, the program returns to the data storage setup process where the operator is asked to enter curve pairs for storage (section 9.5). Otherwise, the program notifies the operator the data is being stored.

9.7.1 File Creation Errors

NIC85 will attempt to create a file for storage. At this point, two (2) common errors arise. One (1) is a duplicate file error. This arises when the program attempts to create a file that already exists on the mass storage device. The program will notify the user of the error. NIC85 then asks whether or not the operator wishes to purge the existing file.

If so, NIC85 will purge the existing file and create the file for storage. Otherwise, the program will ask for a new file name. With a new file name, the program will try to create a file again.

The second common error arises from a problem with the mass storage device. Typically, the problem arises from telling NIC85 to create a file on a mass storage device that does not have mass storage media in it, i.e., no disk or tape. The program will notify the operator to choose a new mass storage and return to the beginning of the data storage process (section 9.5).

On rare occasions, other errors may arise. If this occurs, NIC85 will notify the operator of an unusual error and halt the program. If this happens, refer to Appendix D for an explanation of the error code.

9.7.2 Normal Operations

Once NIC85 has created a file, the program stores the control registers and begins sequentially storing all data. If the operator chooses to use the system multiplexer and system voltmeter, the program will take data on the various channels once every 256 storage operations. This is done because the time necessary to take a measurement with the Nicolet is typically short. However, the time required to store data is relatively long.

Therefore, the auxiliary data taken by the system multiplexer and system voltmeter are acquired during the data storage phase. In addition, acquiring data from the system multiplexer and system voltmeter takes about .5 s per data to allow the voltage to settle. Keep in mind the system multiplexer and system voltmeter are used for slowly changing quantities such as temperature.

When NIC85 finishes the normal data storage process, the program asks whether or not the operator wishes to store another pair of curves. If so, the program will return to the data storage setup process where the operator is asked to enter curves pairs for storage (section 9.5). Otherwise, NIC85 proceeds to store the auxiliary data. If no auxiliary data was taken, the program will return to the main program execution where the operator is asked whether or not to take more data (section 9.4).

If auxiliary data was taken, NIC85 asks for a file name for the auxiliary file. The program notifies the operator that auxiliary data is storing once the program receives a valid name. NIC85 then attempts to create a file. The program is written to trap a duplicate file error. The process that was outlined in file creation errors (section 9.7.1) is used for the duplicate file error.

Should another error occur, NIC85 will notify the operator of the unusual error and halt the program. If this happens, refer to Appendix D for an explanation of the error code.

Once NIC85 has created the file, the program will store the auxiliary data. This storage operation, however, does not use the data format used by the rest of the program.

A different format is used for auxiliary files because of the restricted program space in the computer. This made necessary the quicker data storage process. To make these auxiliary files readable for normal processing, a further program, VMAUX, is used to change to a standard format.

9.8 Program Wrapup

Once NIC85 has stored the auxiliary file, the program returns to the main program execution where the operator is asked whether or not to take more data (section 9.4).

9.9 Reference

A complete outline of NIC85 is given in flow chart form in Appendix C, pages 345 through 354.

CHAPTER 10

SYSTEM MULTIPLEXER AND SYSTEM VOLTMETER CONTROL PACKAGE

10.1 Overview

In Chapters 7 through 9, use of the two (2) fastest data takers, the Tektronix 7612D Programmable Digitizer and the Nicolet 4090-III Digital Oscilloscope, was discussed. The software controlling those machines was designed to store data for a sweep up to 20 megasamples per second (20 megasamples per second corresponds to a 5 ns sampling period). In addition, those programs were capable of taking an auxiliary set of much slower measurements using the HP3497A DAS/Control Unit and the HP3437A System Voltmeter. The SYSTEMS software package also has a stand-alone program, HP-DAS, for controlling the auxiliary data takers.

HP-DAS will monitor a maximum of four (4) channels at 256 points per channel. The program structure is quite simple.

HP-DAS operates much as a system clock. The program can delay up to 27.775 minutes between sample sets. Since the storage capacity of the program is 256 points, the operator can take measurements over a maximum period of approximately 4 days 22.5 hours. This time scale is better suited for measurement of such quantities as temperature, humidity, and barometric pressure.

During each storage operation, HP-DAS has built-in delay of approximately 2 s to allow the voltages to settle on the channels. This limits the minimum sample period to 2 s, or 30 sample sets per minute.

In addition, HP-DAS operates in much the same manner as the auxiliary voltage measurements mentioned in Chapters 8 and 9. This program, however, does not require the reformatting capabilities of VMAUX. Instead, HP-DAS stores all data in the standard format.

10.2 Main Program Setup

After initializing all the registers, HP-DAS will ask the operator for the number of channels to be monitored by the system multiplexer. The program can monitor as many as four (4) channels. If the operator enters a number not on the range, one (1) to four (4), the program will ask for a valid entry.

When HP-DAS receives a valid entry, the program will ask for the system multiplexer channel number and the system voltmeter voltage range for the measurement. The channel number is a number on the range, zero (0) to 999. The voltage range sets the maximum voltage the voltmeter can read. The three (3) voltage ranges are .1 volt, 1 volt, and 10 volts. After each entry, the program will verify whether: 1) the entry is valid, i.e., valid channel number and valid voltage range; 2) the entry is new, i.e., HP-DAS will notify the operator if a channel number has been entered previously.

HP-DAS asks the operator for the sample interval. This interval is limited to a maximum of 27.775 minutes, and must be labeled as minutes or seconds. If either the entry does not include the units--S for seconds, M for minutes--or the entry exceeds the maximum sample interval, the program will notify the operator of the error and ask for a valid entry.

Once HP-DAS has received a valid entry, the program will ask for the total time over which to take samples. Since the program is limited to 256 points, the maximum total time is 256 times the sample interval. Again, if the entry does not include the units--S for seconds, M for minutes--or the entry exceeds the maximum total time, HP-DAS will notify the operator of the error and ask for a valid entry. From the sample time and the total time entries, the program calculates the number of data to be taken, and stores the date and starting time.

10.3 Data Acquisition

HP-DAS will notify the operator that the program is taking data. The program then will choose a channel and set the voltage range. After setting up the measurement, HP-DAS waits .5 s to allow the voltage to settle. Then, the program triggers the voltmeter, stores the voltage reading, and stores the time of the measurement. If there is more than one (1) channel, the program repeats the process for each channel in the same manner.

Once HP-DAS has taken a measurement for all of the channels, the program waits for a period equal to the sample time. If the total time has not expired, the program will repeat the process of data acquisition. Otherwise, HP-DAS will notify the operator that the program is finished by generating an alarm sequence. To continue the program, the operator presses K1.

10.4 Data Storage

HP-DAS will ask where the operator wants the data stored. Then, the program will ask for a file name. The file name cannot be longer than six (6) characters. If the operator enters too long a file name, the program will ask the operator to enter a valid name. After receiving a valid file name, HP-DAS notifies the operator the data is being stored.

10.4.1 File Creation Errors

HP-DAS will attempt to create a file for storage. At this point, two (2) common errors arise. One (1) is a duplicate file error. This arises when the program attempts to create a file that already exists on the mass storage device. The program will notify the user of the error. HP-DAS then asks whether or not the operator wishes to purge the existing file.

If so, HP-DAS will purge the existing file and create the file for storage. Otherwise, the program will ask for a new file name. With a new file name, the program will try to create a file again.

The second common error arises from a problem with the mass storage device. Typically, the problem arises from telling HP-DAS to create a file on a mass storage device that does not have mass storage media in it, i.e., no disk or tape. The program will notify the operator to choose a new mass storage and return to the beginning of the data storage process.

On rare occasions, other errors may arise. If this occurs, HP-DAS will notify the operator of an unusual error and halt the program. If this happens, refer to Appendix D for an explanation of the error code.

10.4.2 True Unit Computation

Once HP-DAS has created a file, the program stores a portion of the control file. Then, the program asks whether or not a device other than a voltage probe is used. If so, HP-DAS asks for the particular conversion process on a given curve. Unlike the processes outlined in Chapters 8 and 9, HP-DAS will accept processes other then voltage-to-voltage and current-to-voltage. However, the process must be quantity-to-voltage, i.e., the voltage entry must be the right-hand entry.

As was the case with 7612D and NIC85, HP-DAS was written to accept numeric pairs and calculate a conversion coefficient for multiplicative conversion processes. Also, like NIC85, the operator needs to enter multiplying probes such as a 10x probe.

10.4.3 Normal Operations

After the voltage conversion process is complete, or if there is no voltage conversion process, HP-DAS sorts the minimum and maximum voltage values out of the data. The program uses these values and the final storage time to calculate the x per division and the y per division values for this curve. The program stores the remainder of the control register(s), the x-data, and the y-data.

If there is another curve, HP-DAS will accept a new file name and begin the storage routine over again (section 10.4). Otherwise, the program asks whether or not the operator wishes to take more data.

If so, HP-DAS returns to the main program setup (section 10.2) and begins the entire process again. Otherwise, the program will return to Autost.

10.5 Reference

A complete outline of HP-DAS is given in flow chart form in Appendix C, pages 356 through 360.

CHAPTER 11

GRAPHICS TABLET CONTROL PACKAGE

11.1 Overview

In addition to taking data directly from measurement devices, discussed in Chapters 7 through 10, the SYSTEMS software package contains a program, TABLET, for digitizing data by hand. TABLET was developed as a complement to the other programs since the system would be limited by the resolution of the measurement equipment and by the date the measurement equipment was first used. The program takes care of these two (2) problems and allows the operator to enter almost any type of graphics data.

TABLET will allow digitization of two (2) curves with a maximum of 512 data points each. The program will compensate the data for any rotational errors due to poor orientation of the curves on the tablet surface. In addition, the program allows the operator to print out pertinent test information.

11.2 Data Preparation

TABLET is developed to allow entry of data from almost any type of media. The program is developed so that the operator only need attach the media, e.g., photographs, manuscript, or periodical, to the graphics tablet and run the program. The operator should keep in mind some of the constraints of the system, however.

First, TABLET polls the graphics tablet periodically to see if there has been a digitization. The timing of the operation can occasionally lose the digitized point. To minimize this problem, the program will cause the graphics tablet to respond audibly after each digitizing operation. There will occur one (1) beep for a digitized data point, or two (2) beeps for a digitized softkey. If the operator does not hear a response from the graphics tablet, i.e., tone(s), then the point or softkey was not digitized. In that case, redigitize the point or softkey.

Second, only points digitized within the bounded area of the graphics tablet (area occupies approximately 90% of the tablet's surface area) will be stored as data points. Any points outside that area will either be ignored or be interpreted as a softkey (active areas above the digitizing platen).

Third, TABLET is developed to correct for rotational orientation errors. Therefore, the data does not have to be placed so that the borders of the graph are parallel to the boundaries of the graphics tablet.

Lastly, the graphics tablet operates by sensing the pen location on the platen by capacitive means. The process accuracy can be affected adversely if the medium on the tablet is electrically conductive. Therefore, do not use conductive media. This includes electrically conductive coatings on photographs and manuscripts, and marks made by the operator on the media using either pencils or eraseable pens. If the data must be marked, use a pen with permanent ink.

11.3 Main Program Operation

After initializing all the registers, TABLET prints out a copy of the functions assigned to the softkeys on the graphics tablet. These softkeys allow the operator to choose from several functions without leaving the graphics tablet. Digitizing a softkey is functionally equivalent to pressing one (1) of the keys (K1 through K10), discussed in the preceding chapters.

11.3.1 Main Program Setup

TABLET will ask for the number of curves to be digitized. The program can store two (2) curves with a maximum of 512 points each. If the operator inputs a number other than one (1) or two (2), the program will request a valid input, i.e., ask the operator to enter one (1) or two (2). Once TABLET has received a valid entry, the program will initialize the graphics tablet and ask the operator to digitize the corners of the graph grid.

TABLET uses the next four (4) points to calculate the position of the graph relative to the graphics tablet and the rotational orientation of the graph relative to the graphics tablet. During this operation, the program will not allow the operator to use the softkeys. If a softkey is digitized, the program simply ignores the choice. In addition, TABLET must receive the points in the order: upper left, upper right, lower left, lower right. In so doing, the program is capable of compensating the curve for any rotational error as great as 180 degrees. If the operator does not digitize the corners in that specific order, the program will rotate the curve incorrectly.

TABLET also uses the corners to calculate the distance from the horizontal and vertical boundaries of the graphics tablet. Thus, the program can calculate the origin of the graph and compensate for the offsets. These offsets are necessary to store the digitized curve in an area which is bounded by the graph on the graphics tablet and not the graphics tablet itself.

Next, TABLET asks for the number of horizontal and vertical divisions on the graph, and the value per division of the vertical and horizontal axes. The program uses these entries to calculate the scale factors to scale the values being entered. All data entered from the graphics tablet is in x-y format. The graph being digitized, however, is not necessarily x-y in nature. The graph may be voltage vs. time or current vs. temperature. Therefore, the program needs the previous data entries to calculate the proper values for the data being digitized.

After calculating the scaling factors, TABLET will ask for the position of the zeroline. This entry allows the operator to use data which has positive and negative values. The operator needs to enter the position relative to graph. For example, if the zeroline is 3.5 divisions above the graph boundary, the operator will enter 3.5. The entry cannot be larger than the number of vertical positions, however. Therefore, the program can compensate for a constant value offset.

TABLET will repeat the previous operation for the second curve, if there are two (2) curves. Thus, the program allows the operator to store two (2) curves on the same graph with different zero (0) locations.

11.3.2 Data Entry

TABLET will notify the operator of the key functions, and will ask the operator to begin digitizing the curve. During the digitizaiton process, the program will accept both data for the curve and softkey, or key, function choices. If the operator digitizes data, the program will compensate the data for rotational error and stored the corrected data.

TABLET will continue this process until a softkey is digitized, a key is pressed, or the data register is full. The program can store only 512 data points. If the operator enters 512 points, the program will notify the operator that the data register is full. Then, TABLET will ask whether or not the operator wishes to re-enter the data. The data should be re-entered if the important data from the curve has not been digitized completely. If the operator chooses not to re-enter the data, the program wil either proceed to the next curve digitization, if one is necessary, or notify the operator that the digitization is complete and ask for a softkey or key choice.

11.3.3 Functional Branching

TABLET is developed to allow functional choices using either the function keys (K1 through K10) or the softkeys on the graphics tablet (SK1 through SK16). The program allows the operator to choose a key's function:

(1) end of curve	depress K1;
(2) store data	depress K2;
(3) process new data	depress K3;
(4) finished	depress K4;
(5) print device data	depress K5.

The program also allows the operator to digitize a softkey:

(1) end of curve	digitize SK1;
(2) store data	digitize SK2;
(3) process new data	digitize SK3;
(4) finished	digitize SK4;
(5) print device data	digitize SK5.

11.4 End of Curve Option

The "end of curve" option (chosen by depressing K1 or digitizing SK1) notifies TABLET that the previous data point is the last one in the curve. If there is another curve to be digitized, the program will return to the beginning of the data entry cycle (section 11.3.2).

Otherwise, TABLET notifies the operator that the digitization is complete and asks for a softkey or key choice. If the operator chooses the "end of curve" option after the digitization has been completed, nothing will happen. The program will simply repeat the message and wait for a proper softkey or key choice.

11.5 Data Storage

When the operator chooses to store data, TABLET will ask for a file name. The file name cannot be longer than six (6) characters. If the operator enters too long a name, the program will ask the operator to enter a valid name. Once the program has received a valid file name, TABLET will ask where the operator wishes the data to be stored.

Then, if the operator is storing two (2) curves, TABLET will see if the two (2) curves are the same type, e.g., both curves are voltage. If the curves are the same, the program notifies the operator of the error and asks whether or not the operator wants to store the curves separately.

If the operator does not wish to store the curves separately, TABLET returns to the main program setup (section 11.3.1) where the program asks for the value per division entries. Otherwise, the operator is notified the curves will be stored in the order: curve one (1), then curve two (2); a software flag is set to indicate the curves will be stored separately.

If the curves are not the same or are flagged to be separated, or only one (1) curve is to be stored, TABLET will notify the operator the data is being stored.

11.5.1 File Creation Errors

TABLET will attempt to create a file for storage. At this point, two (2) common errors arise. One (1) is a duplicate file error. This arises when the program attempts to create a file that already exists on the mass storage device. The program will notify the user of the error. TABLET then asks whether or not the operator wishes to purge the existing file.

If so, TABLET will purge the existing file and create the file for storage. Otherwise, the program will ask for a new file name. With a new file name, the program will try to create a file again.

The second common error arises from a problem with the mass storage device. Typically, the problem arises from telling TABLET to create a file on a mass storage device that does not have mass storage media in it, i.e., no disk or tape. The program will notify the operator to choose a new mass storage and return to the beginning of the data storage process.

On rare occasions, other errors may arise. If this occurs, TABLET will notify the operator of an unusual error and halt the program. If this happens, refer to Appendix D for an explanation of the error code.

11.5.2 Normal Operations

Once TABLET has created a file, the program stores the control register(s) and begins sequentially storing all data. The program stores the x-data first, then the y-data.

If the operator has chosen to store the curves separately, TABLET will return to the beginning of the data storage cycle (section 11.5) to store the second curve. Otherwise, the program will notify the operator the data is stored.

After TABLET has finished the storage cycle, the program will ask if the operator wishes to digitize more data. If the operator does wish to digitize more data, the program will return to the beginning of the main program (section 11.3) and wait for the operator to finish with the data preparation (section 11.2). If the operator does not wish to digitize more data, TABLET will return to Autost.

11.6 Print Device Data

TABLET was developed as support for testing of semiconductor devices. Documentation of information regarding manufacture and experimental environment is necessary for future reference. The "print device data" option is designed to support this documentation need.

TABLET requests the following information:

1) manufacturer,
2) device type,
3) mask type,
4) device number,
5) temperature,
6) second-breakdown type,
7) forward base current,
8) nominal reverse base current,
9) second-breakdown reverse base current,
10) comments.

The program will print the information on the internal printer in the order shown. The operator will notice that entries six (6) through nine (9) are pertinent only to second-breakdown characteristics. Once the device data has been printed, the program either will return to the digitization process (section 11.3.2), if the curve is not complete, or will notify the operator that the digitization is complete and ask for a softkey or key choice.

11.7 New Curve Set

When the operator decides to digitize a new set of curves, TABLET will ask if the present data has been stored. If the data has not been stored, the program will return to the data storage cycle (section 11.5). Otherwise, the program will return to the beginning of the main program (section 11.3) and wait for the operator to finish with the data preparation (section 11.2).

11.8 Finished

When the operator is finished, TABLET will ask if the present data has been stored. If the data has not been stored, the program will return to the data storage cycle (section 11.5). Otherwise, the program will ask whether or not the operator wishes to digitize another set of curves.

If the operator wishes to digitize another set of curves, TABLET will return to the beginning of the main program (section 11.3) and wait for the operator to finish with the data preparation (section 11.2). Otherwise, the program will return to Autost.

11.9 Reference

A complete outline of TABLET is given in flow chart form in Appendix C, pages 362 through 374.

CHAPTER 12

AUXILIARY FORMATTING PACKAGE

12.1 Overview

In Chapters 8 and 9, the program controlling the Tektronix 7612D Programmable Digitizer and the Nicolet 4090-III Digital Oscilloscope were discussed. In both of those programs, the operator is afforded the opportunity to take auxiliary data using the HP3497A DAS/Control Unit and the HP3437A System Voltmeter. In both cases, however, due to the restricted program space in the computer, a unique data format was developed for temporary storage of the data.

Since the data format is not consistent with the remainder of the data stored by the system, an extra program, VMAUX, was developed to reformat and store the data obtained from the system multiplexer and the system voltmeter. This program was referred to on pages 246, 250, and 253.

VMAUX reads the data stored in the auxiliary format and restores the data in the normal data format. During the processing, the program also allows the operator to enter any voltage conversion processes such as those discussed in section 9.6.

12.2 Data Retrieval

When VMAUX is loaded, the last regular file name is loaded as well. After initializing all the registers, the program will ask for the name of the auxiliary file associated with the last regular file. The auxiliary file name cannot be longer than six (6) characters. If the operator enters too long a name, the program will ask the operator to enter a valid name. Once VMAUX has received a valid file name, the program will ask where the operator stored the data.

12.2.1 Read Errors

VMAUX will attempt to access the mass storage device to read the file. Occasionally, an error may arise at this point. Typically, the problem comes from telling the program to read a file on a mass storage device that does not have mass storage media in it, i.e., no disk or tape. The program will notify the operator to choose a new mass storage device and will attempt to access the new mass storage.

On rare occasions, other errors may arise. If this occurs, VMAUX will notify the operator of an unusual error and halt the program. If this happens, refer to Appendix D for an explanation of the error code.

12.2.2 Normal Read Operations

Once VMAUX has accessed the auxiliary file, the program will read the date from the regular file and the start time from the auxiliary file. Next, the program will read the data from the auxiliary file.

Using the auxiliary data, VMAUX calculates the number of curves which were stored and the number of data points in each curve. These numbers will be stored in the contol registers.

12.3 Data Storage

VMAUX was developed to store each of the curves separately. The curves stored in the auxiliary files cannot be stored in pairs. The program will ask for a name under which to store the curve. Unlike previous programs, however, VMAUX will not ask for a mass storage device. Instead, the program defaults to the mass storage device from which the data was read.

12.3.1 File Creation Errors

VMAUX will attempt to create a file for storage. At this point, two (2) common errors arise. One (1) is a duplicate file error. This arises when the program attempts to create a file that already exists on the mass storage device. The program will notify the user of the error. VMAUX then asks whether or not the operator wishes to purge the existing file.

Keep in mind that the auxiliary file name has all of the curve data stored in it. If the operator chooses the new file name to be the same as the auxiliary file name, VMAUX will purge the file. Therefore, do not ask the program to purge the auxiliary file name unless all of the important curve information has been stored. The program does not have the capabilities to restore the data after it has been purged.

If the operator chooses to purge, VMAUX will purge the existing file and create the file for storage. Otherwise, the program will ask for a new file name. With a new file name, the program will try to create a file again.

The second common error arises from a problem with the mass storage device. Typically, the problem arises from telling VMAUX to create a file on a mass storage device that does not have mass storage media in it, i.e., no disk or tape. The program will notify the operator to choose a new mass storage and return to the beginning of the data storage process.

On rare occasions, other errors may arise. If this occurs, VMAUX will notify the operator of an unusual error and halt the program. If this happens, refer to Appendix D for an explanation of the error code.

12.3.2 True Unit Computation

Once VMAUX has created a file, the program stores a portion of the control file. Then, the program asks whether or not a device other than a voltage probe is used. If so, VMAUX asks for the particular conversion process on a given curve. Unlike the processes outlined in Chapters 8 and 9, VMAUX will accept processes other then voltage-to-voltage and current-to-voltage. However, the process must be quantity-to-voltage, i.e. the voltage entry must be the right-hand entry.

As was the case with 7612D and NIC85, VMAUX was written to accept numeric pairs and calculate a conversion coefficient for multiplicative conversion processes. Also, like NIC85, the operator needs to enter multiplying probes such as a 10x probe.

12.3.3 Normal Storage Operations

After the voltage conversion process is complete, or if there is no voltage conversion process, VMAUX sorts the minimum and maximum voltage values out of the data. The program uses these values and the final storage time to calculate the x per division and the y per division values for this curve. The program stores the remainder of the control register(s), the x-data, and the y-data.

If there is another curve, VMAUX will accept a new file name and begin the storage routine over again (section 12.3). Otherwise, the program asks whether or not the operator stored another regular file.

If so, VMAUX asks for a new regular file name. The file name cannot be longer than six (6) characters. If the operator enters too long a name, the program will ask the operator to enter a valid name. After receiving a valid file name, the program will return to the beginning of the data retrieval process (section 12.2). If the operator did not store another regular file with an attendant auxiliary file, VMAUX will return to Autost.

12.4 Reference

A complete outline of VMAUX is given in flow chart form in Appendix C, pages 376 through 379.

CHAPTER 13

NORMAL FILE FORMAT

13.1 Overview

In each of the data acquisition processes, data is stored in a consistent format. This is done so the processing and plotting packages will work on all storage files. The only files that have a different format are the auxiliary files referred to in Chapters 8 and 9. The auxiliary files, however, should be processed by VMAUX, discussed in Chapter 12, so that they are in the standard format.

If the operator decides to write more software in the future, this discussion should help in developing consistent read and write formats.

13.2 Logical File Size

The format of the data file was developed to take up a minimum of space on the disk, or tape, and to be flexible and accept any size of data file. (The restrictions on space in the processing and plotting packages are overcome by processing, or plotting, in blocks.)

The files are created in logical blocks of eight (8) bits each. The number of logical blocks is dependent upon the particular curve data. The file has to have enough room to store the number of curves, the number of x-divisions, the number of y-divisions, the date of the data acquisition process, the time at the beginning of the data acquisition process, the control register(s) (one (1) register for each curve to be stored with five (5) values per control register), and two (2) times the number of data points (this allows for the x and y value of each data point).

Thus, the storage files have a length given by

$$N = 5 + (C*5) + (2*P)$$

where

C = number of curves,

P = total number of points for all curves,

and

N = total number of logical blocks.

13.3 File Format

The order in which the data is stored in a file is the same as above:

1) number of curves in file;
2) number of x-divisions;
3) number of y-divisions;
4) date of the data acquisition process;
5) time at the beginning of the data acquisition process;
6) control register(s) (one for each curve);
7) x-data for curve(s);
8) y-data for curve(s).

13.4 Control Register Format

The control register(s) have five (5) entries each. They are stored in the order:

1) value of x per division;
2) value of y per division;
3) zero location;
4) number of data points in curve;
5) letter representing units of curve (e.g., V for voltage)

There is a control register maintained for each curve that is stored. However, the zero location, item (3), is not used in any programs other than TABLET. In the other programs, item (3) of the control register is used as temporary storage of either the date or the time.

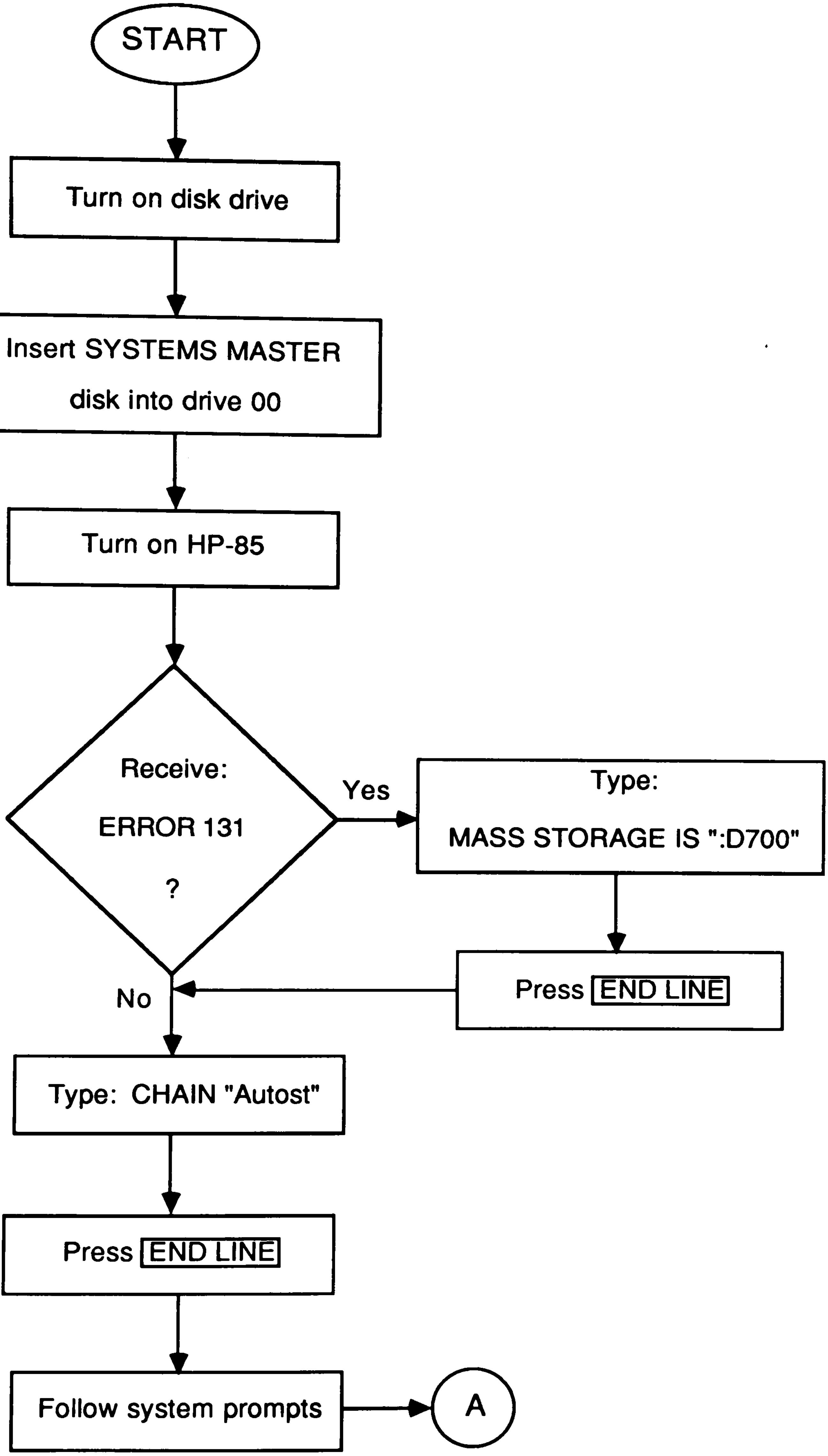
13.5 Remarks

This format was developed along the following premises: 1) the first entry, the number of curves, tells the program how many control registers to read; 2) the following four (4) entries are always read; 3) the control registers tell the program the number of data points stored in each curve, and; 4) the number of data points tells the program how to read the data so that x-data and y-data are kept separate.

By storing in this format, the program can use a minimum of space on the disk, or tape, to store all pertinent information.

APPENDIX A

STARTUP PROCEDURE


START
Turn on disk drive
Insert SYSTEMS MASTER disk into drive 00
Turn on HP-85
Receive: ERROR 131 ?
Yes
Type: MASS STORAGE IS ":D700"
Press END LINE
No
Type: CHAIN "Autost"
Press END LINE
Follow system prompts
A

APPENDIX B

SYSTEM HPIB ADDRESSES

Device	Address
HP9895A Disk Drive	700
Tektronix 7612D Programmable Digitizer	702
HP7470A Plotter	705
HP9111A Graphics Tablet	706
HP3497A Data Acquisition/Control Unit	709
Nicolet 2090-III Digital Oscilloscope	714
HP3437A System Voltmeter	724

APPENDIX C

SYSTEM FLOW CHARTS

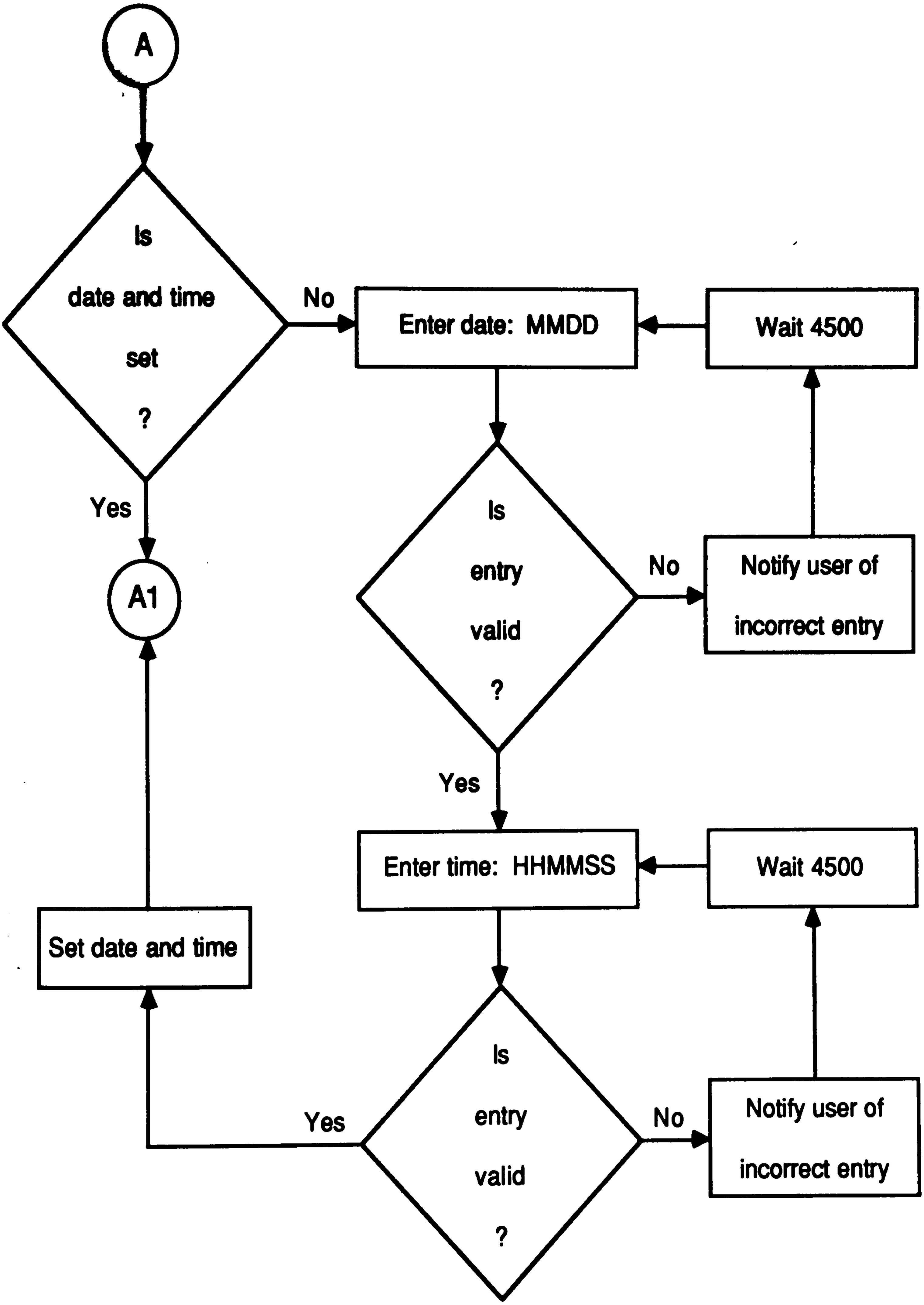
INDEX

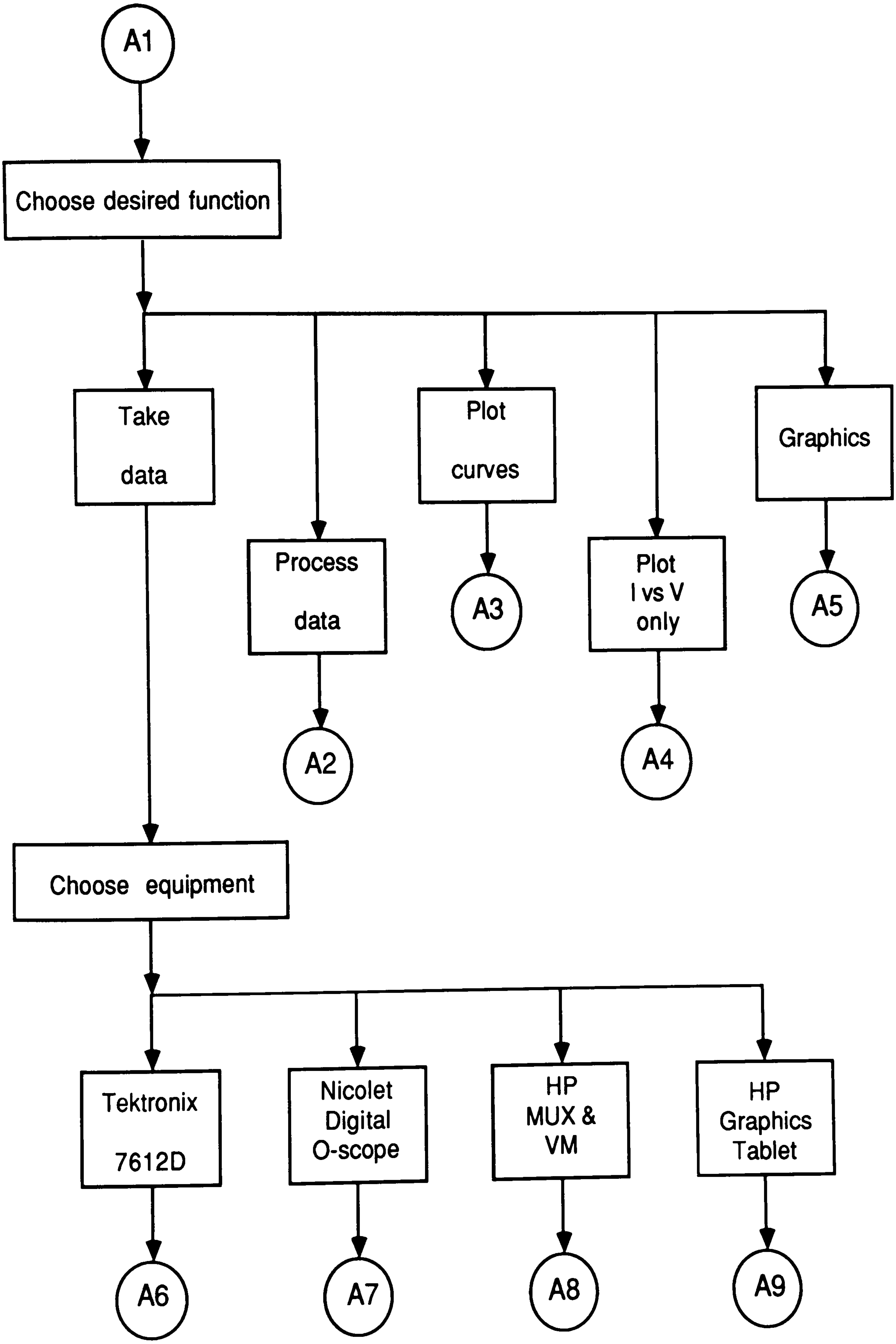
Autost

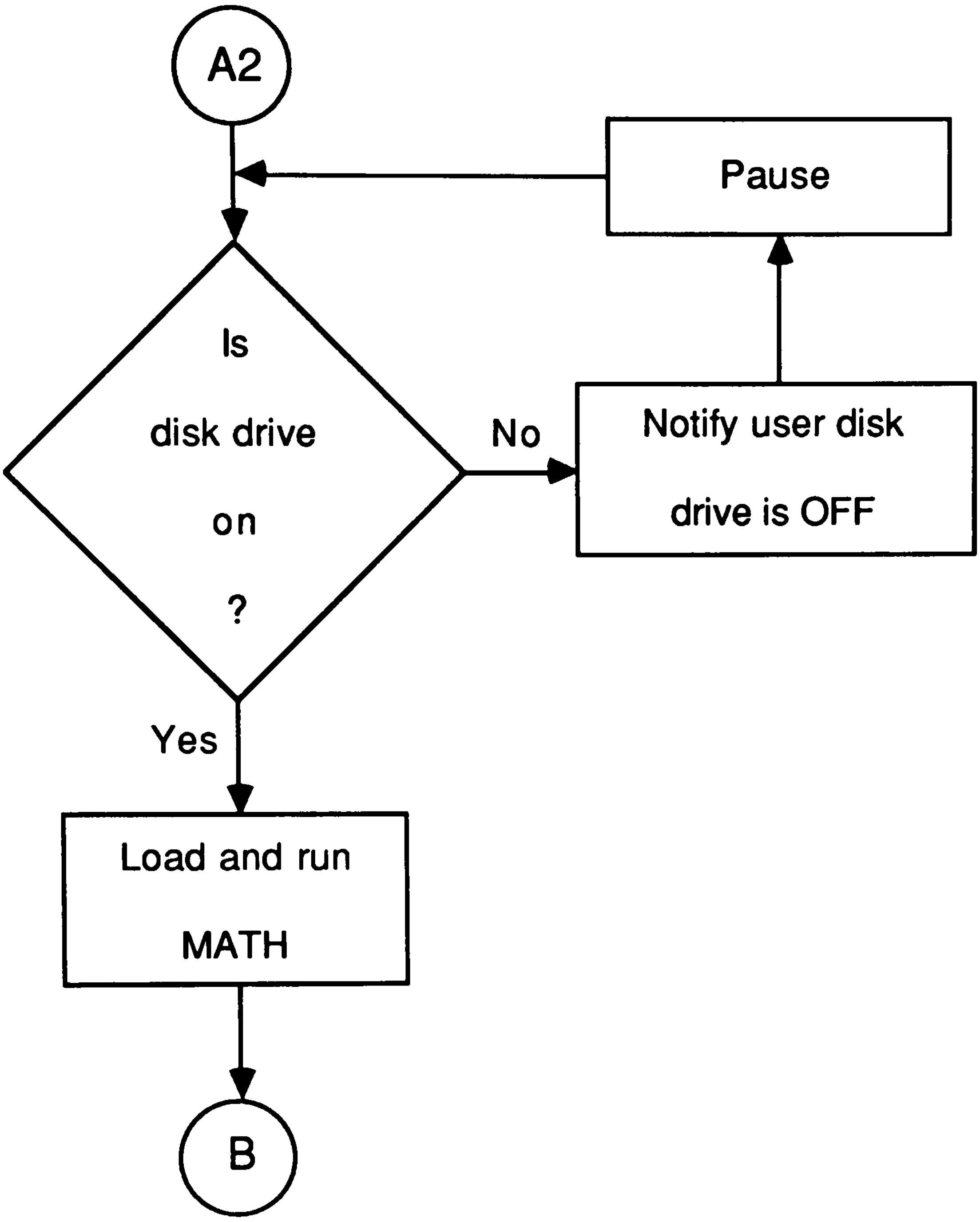
The HP85 Desktop Computer has limited memory space. Therefore, to develop an effective data acquisition system the software was divided into several smaller packages. These packages are controlled and accessed by *Autost*.

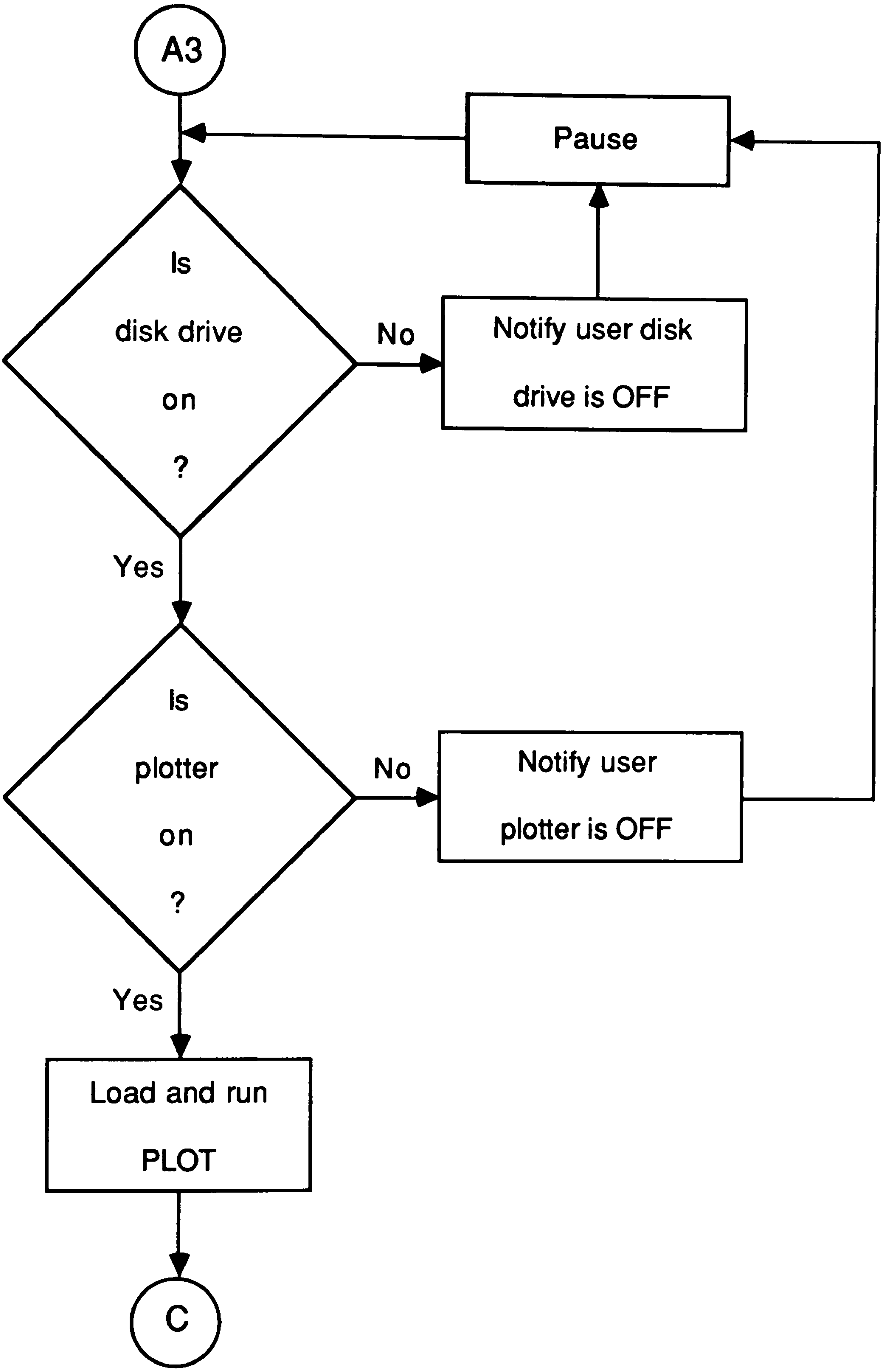
The *Autost* program serves as the central program control for the system. The program controls initialization of the system clock and calendar and functional program branching.

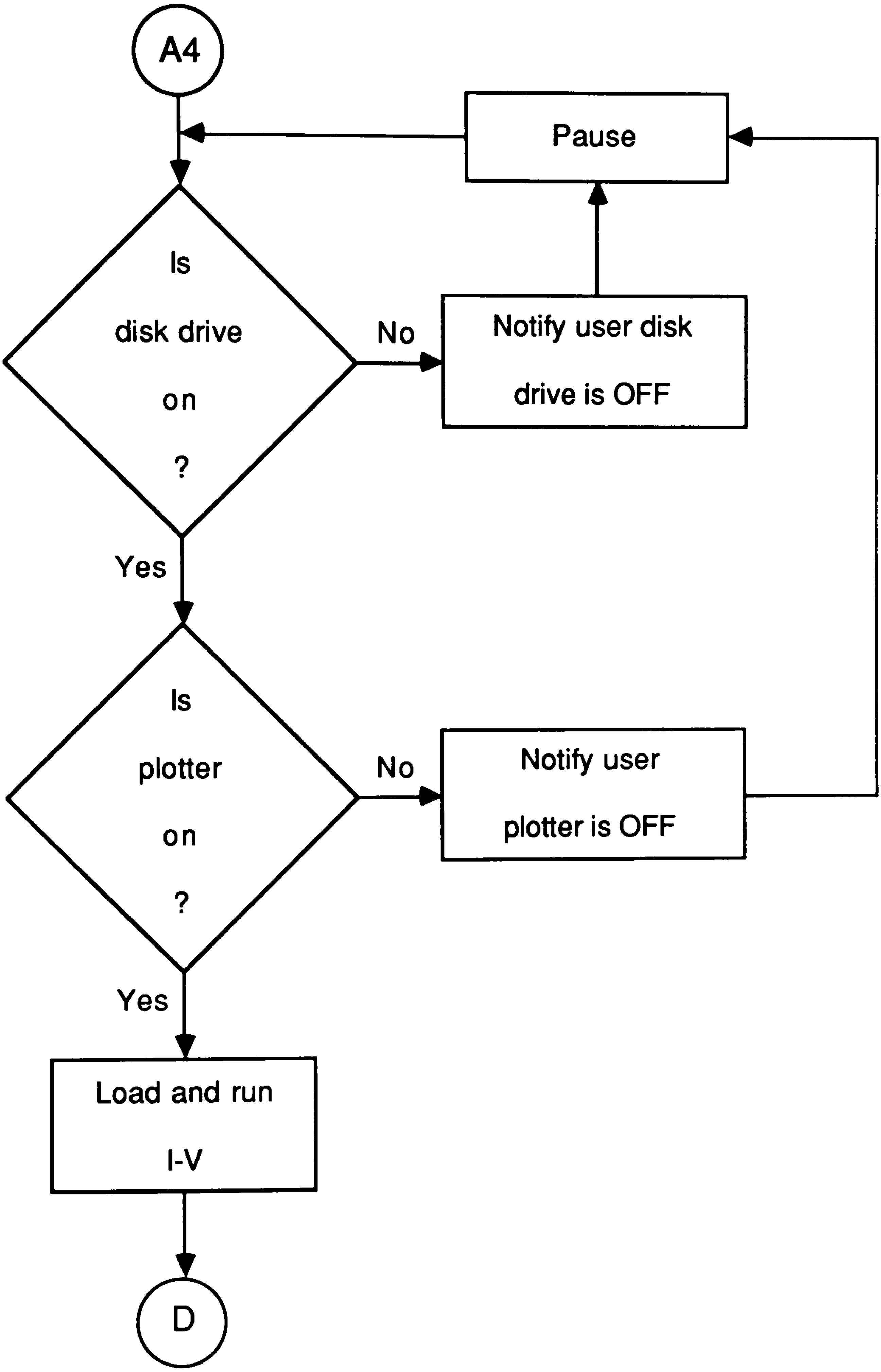
The *Autost* program allows the operator to select from the functions: (1) data acquisition, (2) data processing, (3) data plotting. Based upon the selections made by the operator, the program ascertains whether the devices necessary to carry out the desired function is online, and runs the program which performs the desired function. After completion, each of the programs return to *Autost*.

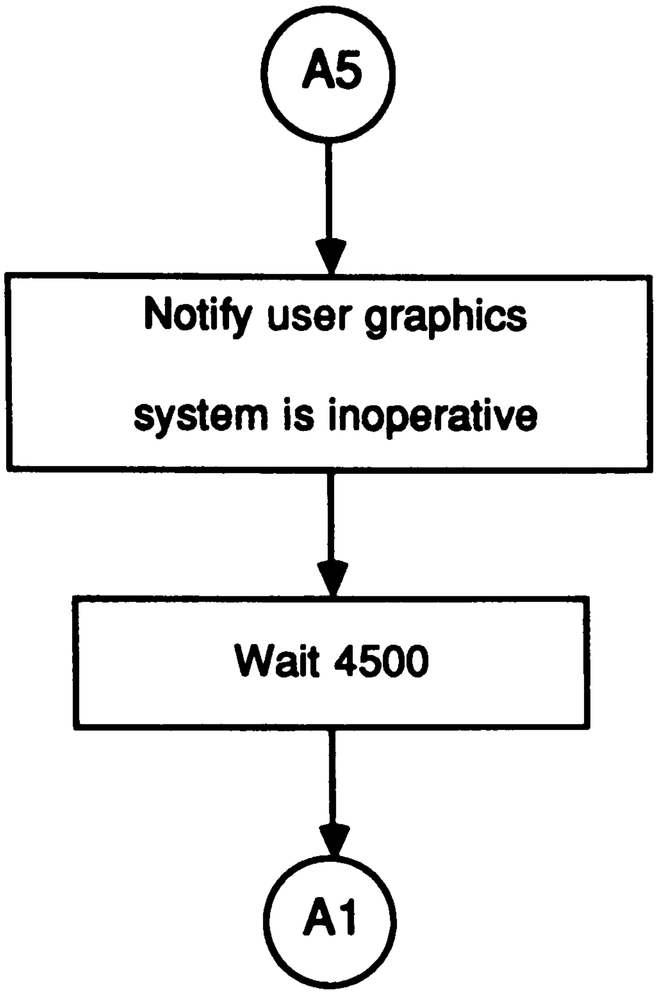

A
Is
date and time
set
?
No
Yes
A1
Enter date: MMDD
Wait 4500
Is
entry
valid
?
No
Notify user of
incorrect entry
Yes
Enter time: HHMMSS
Wait 4500
Set date and time
Is
entry
valid
?
Yes
No
Notify user of
incorrect entry

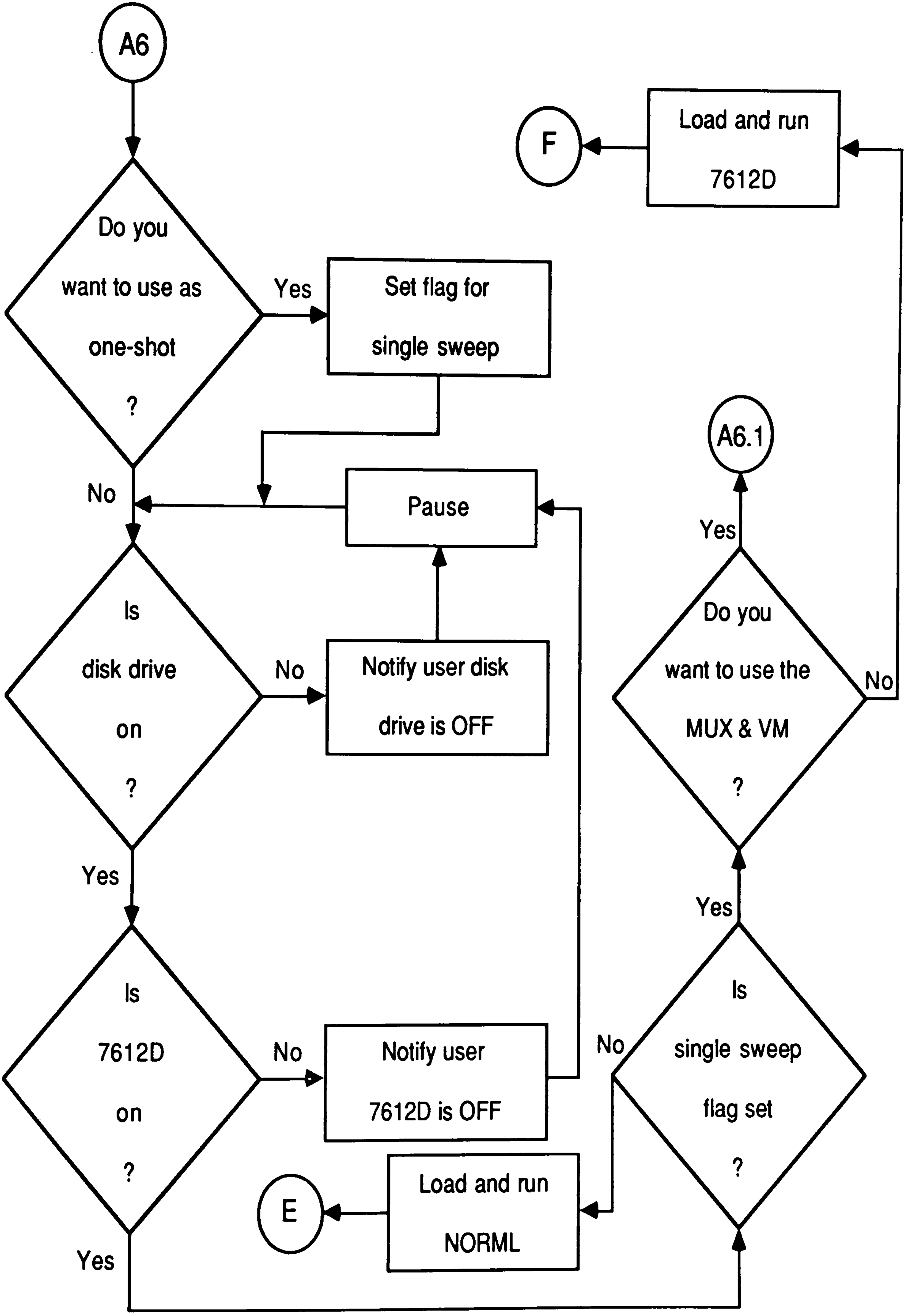

A1
Choose desired function
Take data
Process data
Plot curves
Plot I vs V only
Graphics
A2
A3
A4
A5
Choose equipment
Tektronix 7612D
Nicolet Digital O-scope
HP MUX & VM
HP Graphics Tablet
A6
A7
A8
A9

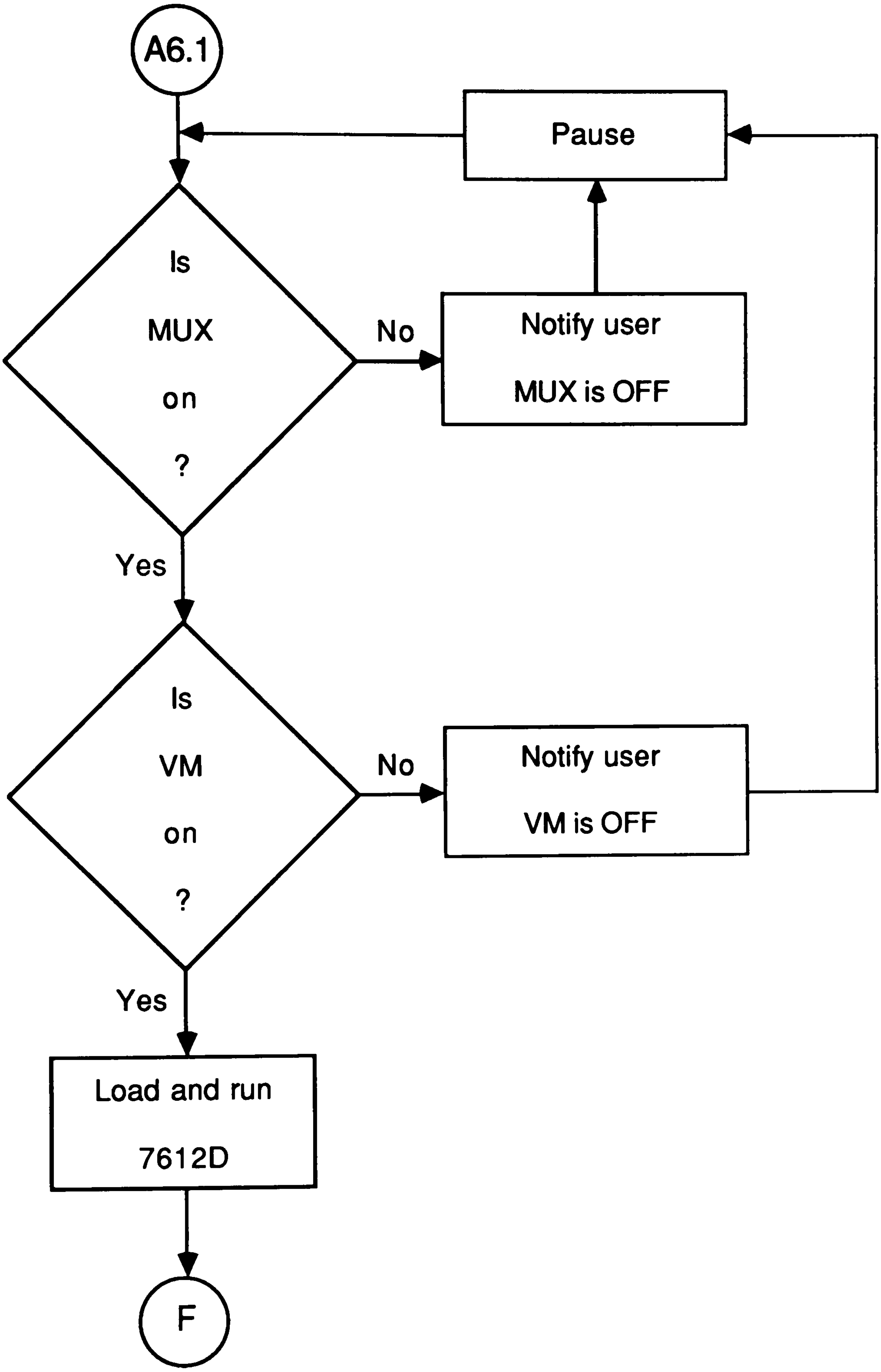

A2
Pause
Is
disk drive
on
?
No
Notify user disk
drive is OFF
Yes
Load and run
MATH
B

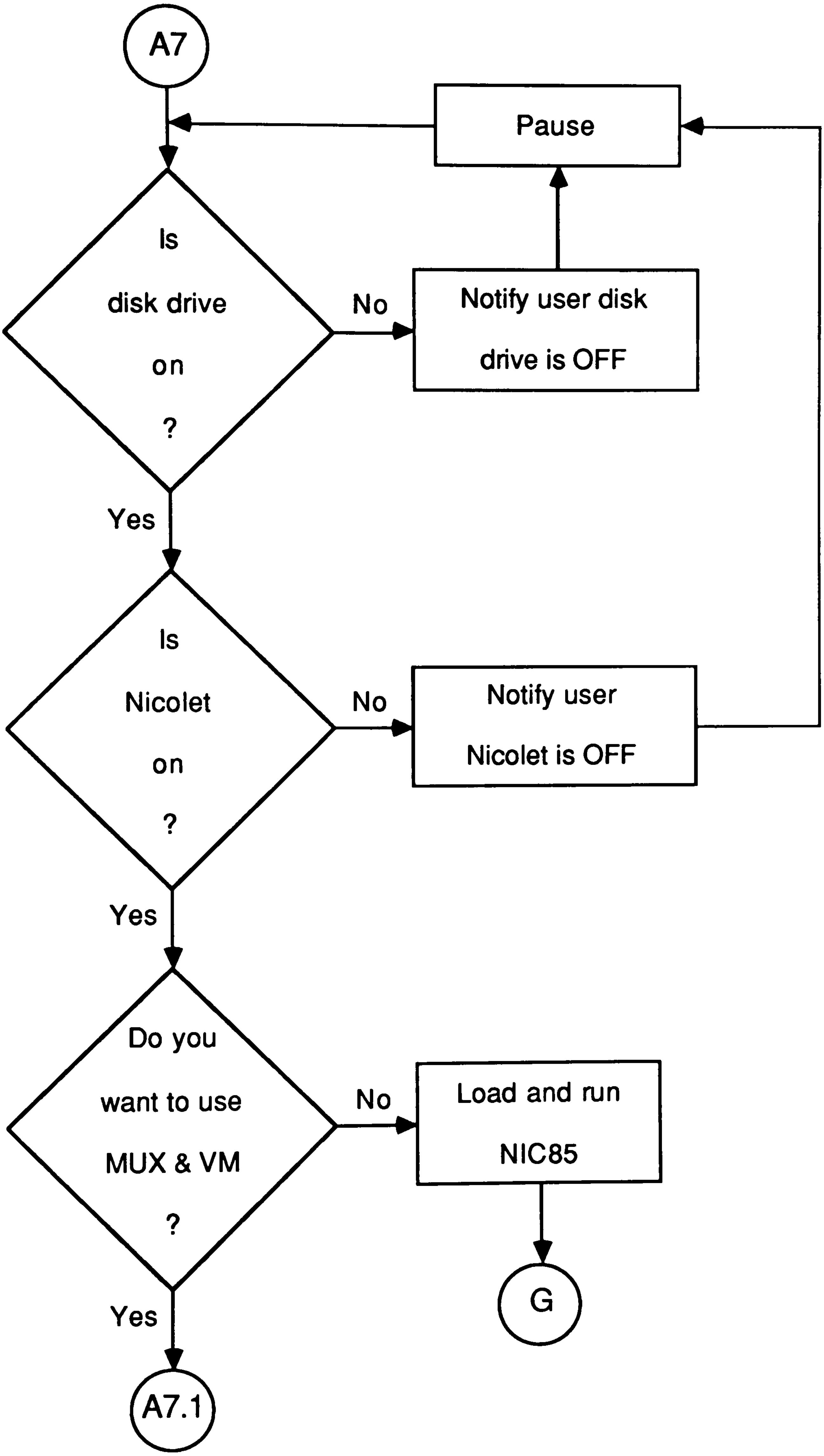

A3
Pause
Is
disk drive
on
?
No
Notify user disk
drive is OFF
Yes
Is
plotter
on
?
No
Notify user
plotter is OFF
Yes
Load and run
PLOT
C

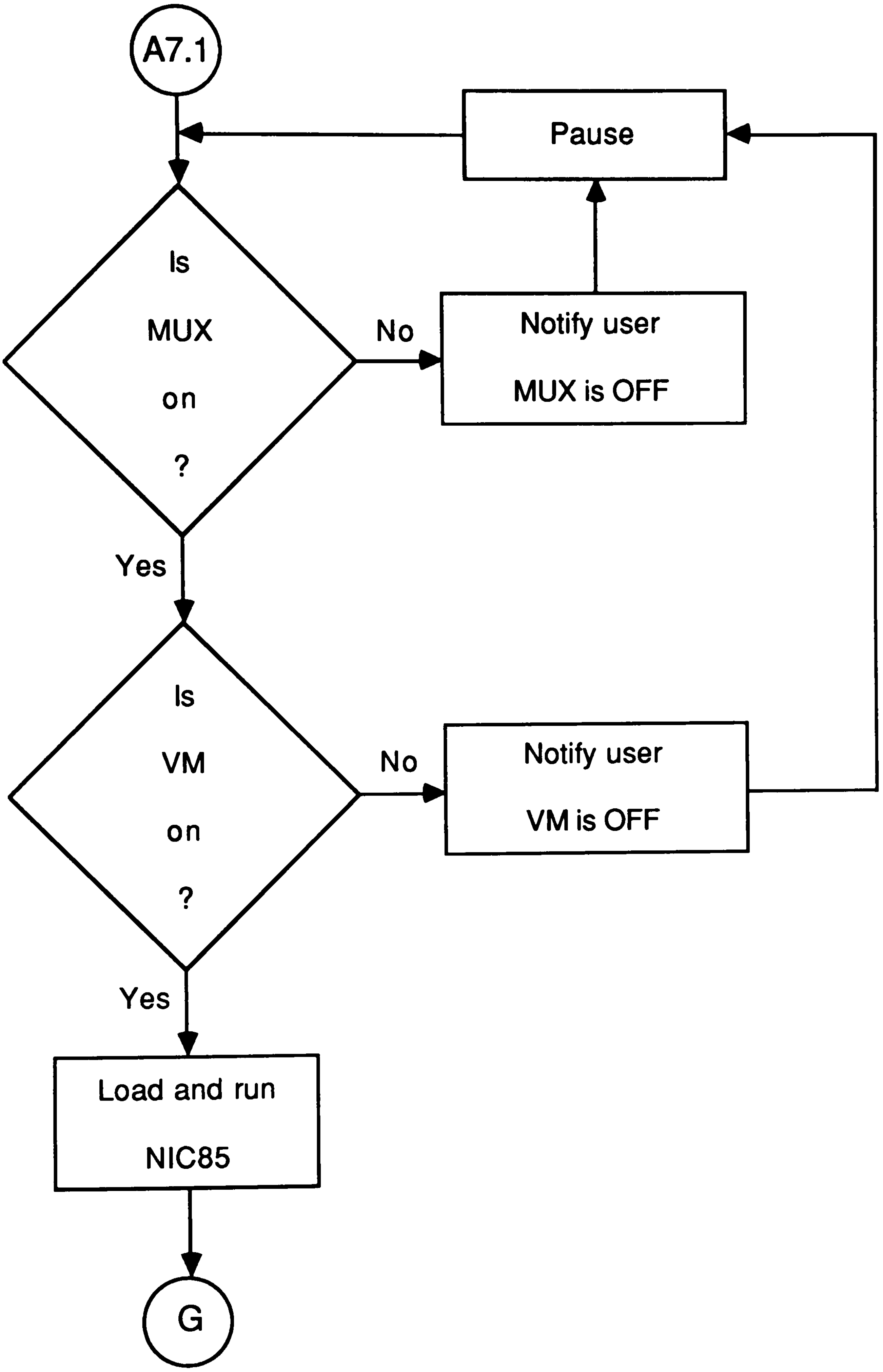

A4
Pause
Is disk drive on ?
No
Notify user disk drive is OFF
Yes
Is plotter on ?
No
Notify user plotter is OFF
Yes
Load and run I-V
D

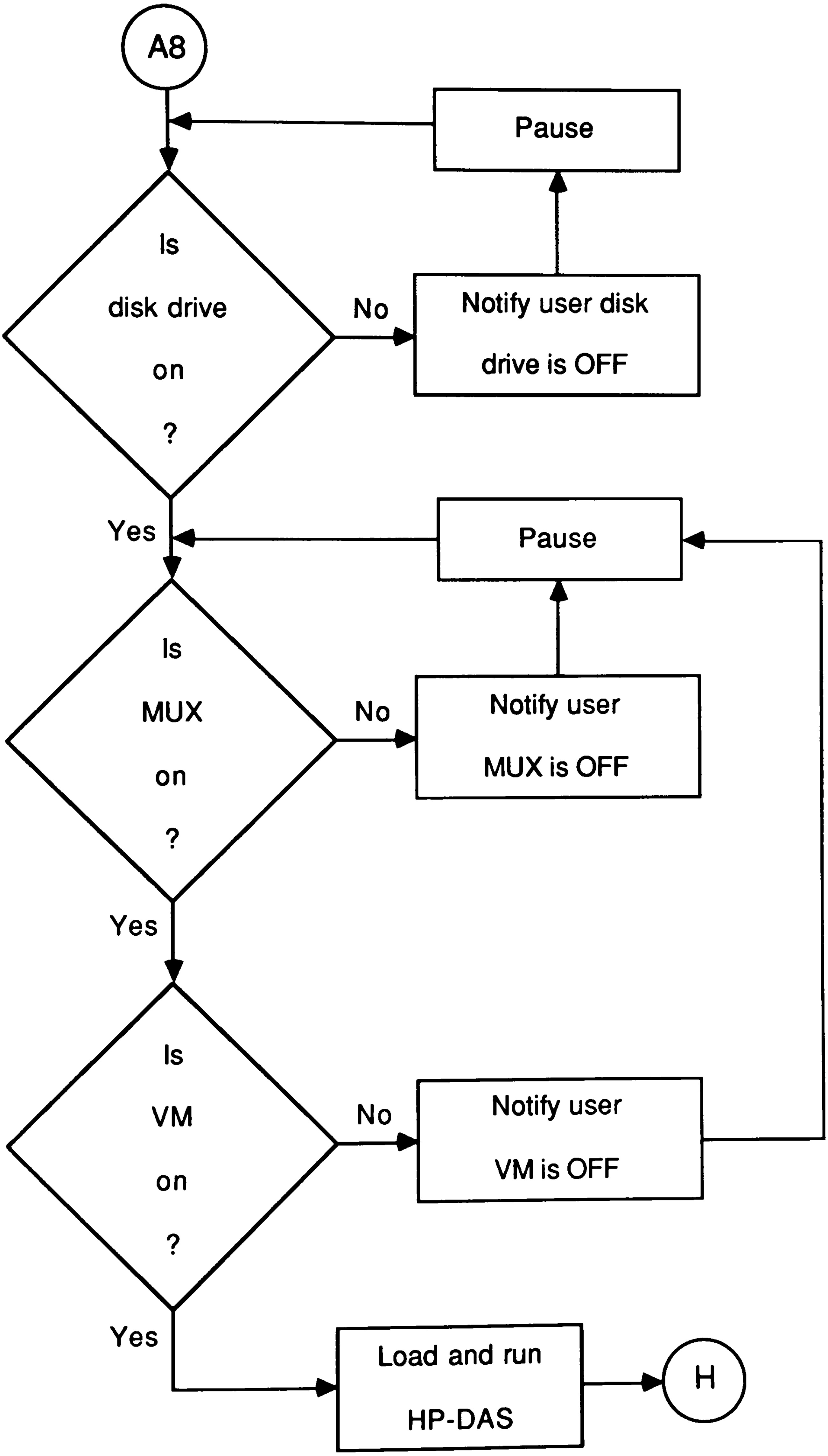

A5
Notify user graphics system is inoperative
Wait 4500
A1

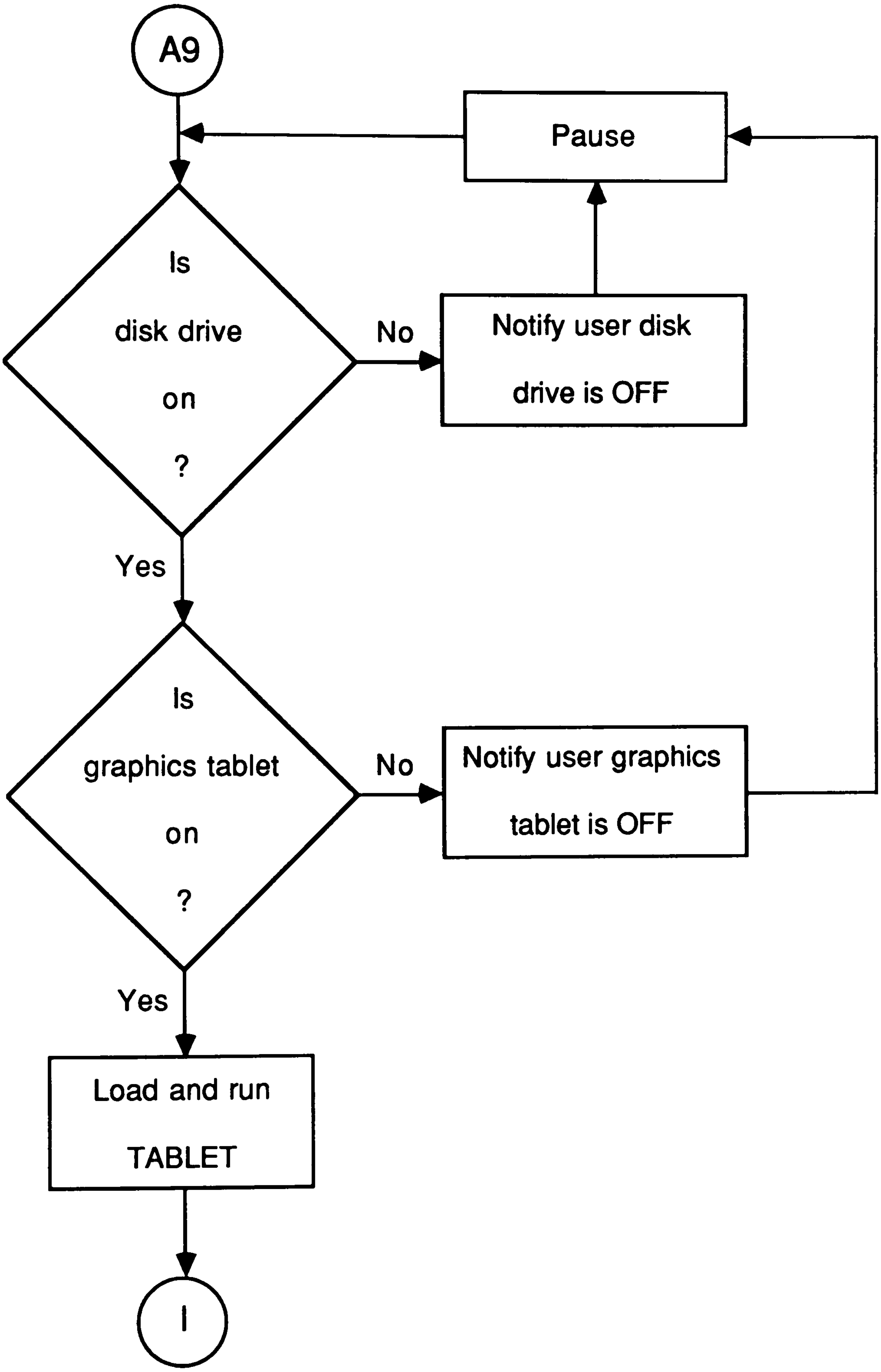

A6
Do you want to use as one-shot ?
Yes
Set flag for single sweep
No
Pause
Is disk drive on ?
No
Notify user disk drive is OFF
Yes
Is 7612D on ?
No
Notify user 7612D is OFF
Yes
E
Load and run NORML
F
Load and run 7612D
A6.1
Yes
Do you want to use the MUX & VM ?
No
Yes
Is single sweep flag set ?
No


A6.1
Pause
Is
MUX
on
?
No
Notify user
MUX is OFF
Yes
Is
VM
on
?
No
Notify user
VM is OFF
Yes
Load and run
7612D
F


A7
Pause
Is disk drive on ?
No
Notify user disk drive is OFF
Yes
Is Nicolet on ?
No
Notify user Nicolet is OFF
Yes
Do you want to use MUX & VM ?
No
Load and run NIC85
G
Yes
A7.1


A7.1
Pause
Is
MUX
on
?
No
Notify user
MUX is OFF
Yes
Is
VM
on
?
No
Notify user
VM is OFF
Yes
Load and run
NIC85
G


A8
Pause
Is disk drive on ?
No
Notify user disk drive is OFF
Yes
Pause
Is MUX on ?
No
Notify user MUX is OFF
Yes
Is VM on ?
No
Notify user VM is OFF
Yes
Load and run HP-DAS
H

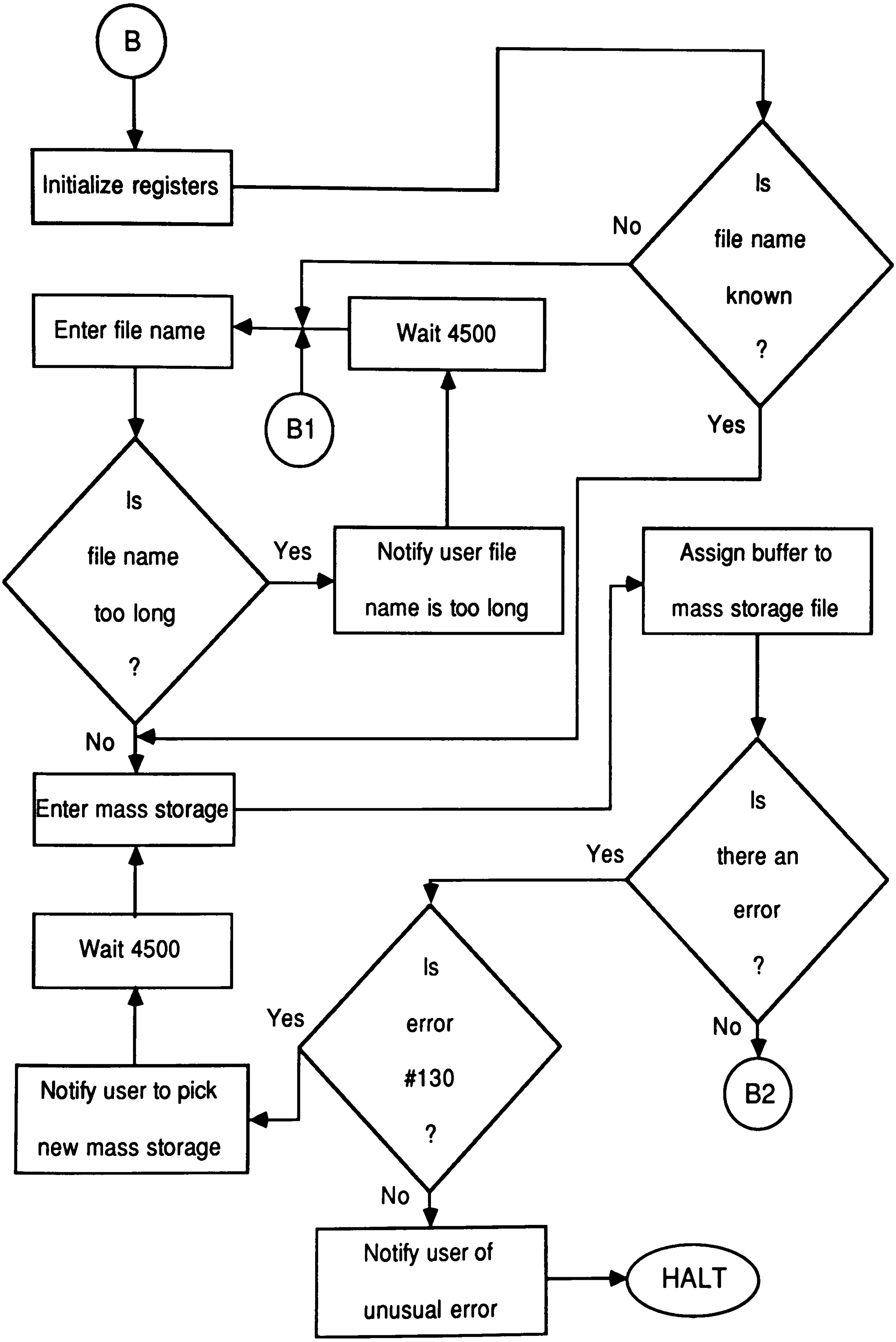

A9
Pause
Is disk drive on ?
No
Notify user disk drive is OFF
Yes
Is graphics tablet on ?
No
Notify user graphics tablet is OFF
Yes
Load and run TABLET
I

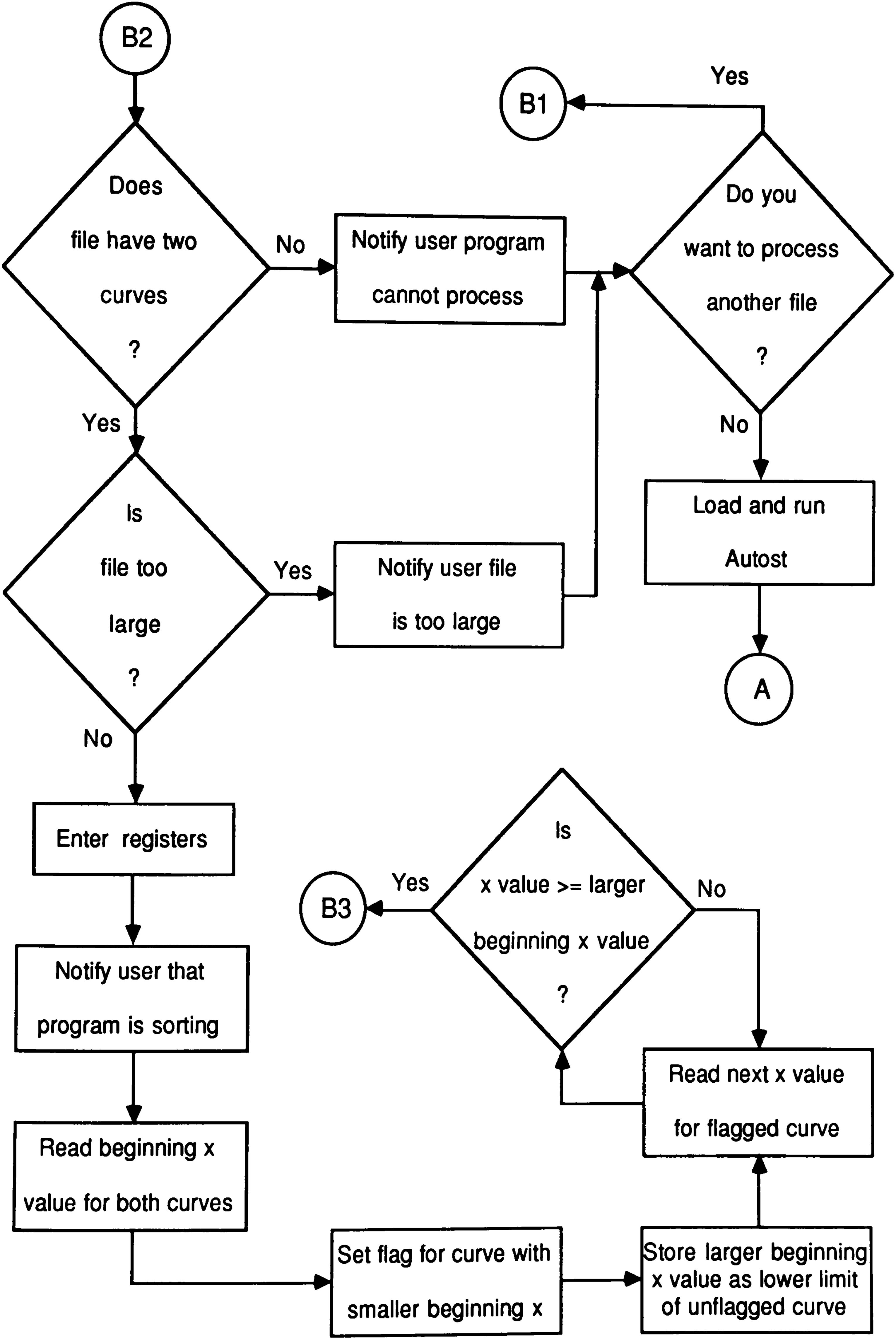
MATH

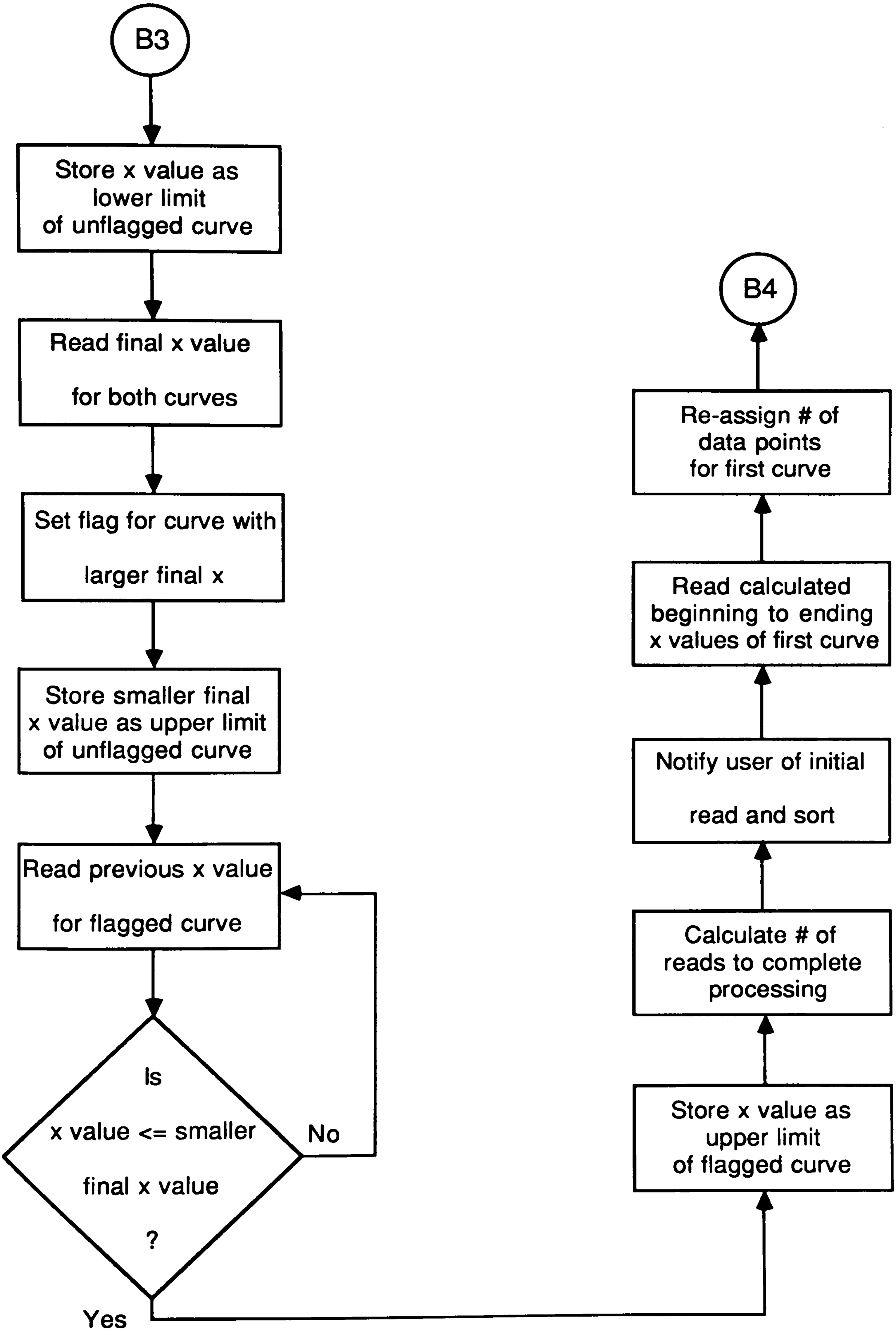
The MATH program conducts all mathematical processing. The program reads in stored data for voltage and current, and generates a time frame for processing based upon the two (2) sets of time data read into the computer. The program interpolates linearly the voltage and current data onto this time frame. Then, the power and energy curves associated with the voltage and current curves.

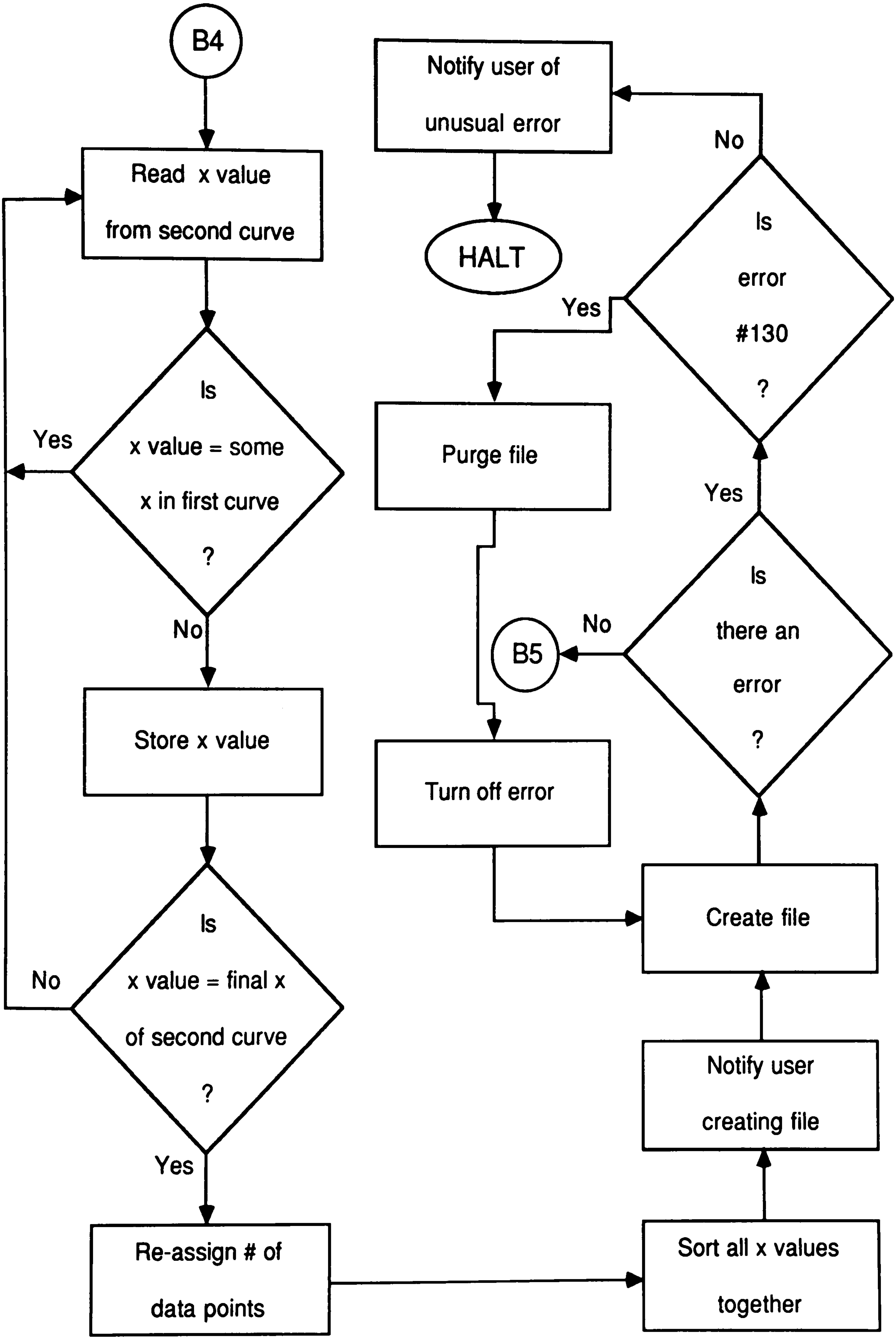
The MATH program calculates the instantaneous power curve by taking the product of the voltage and current values. The energy curve ;is calculated by performing an integration of the power curve using a trapezoidal approximation.

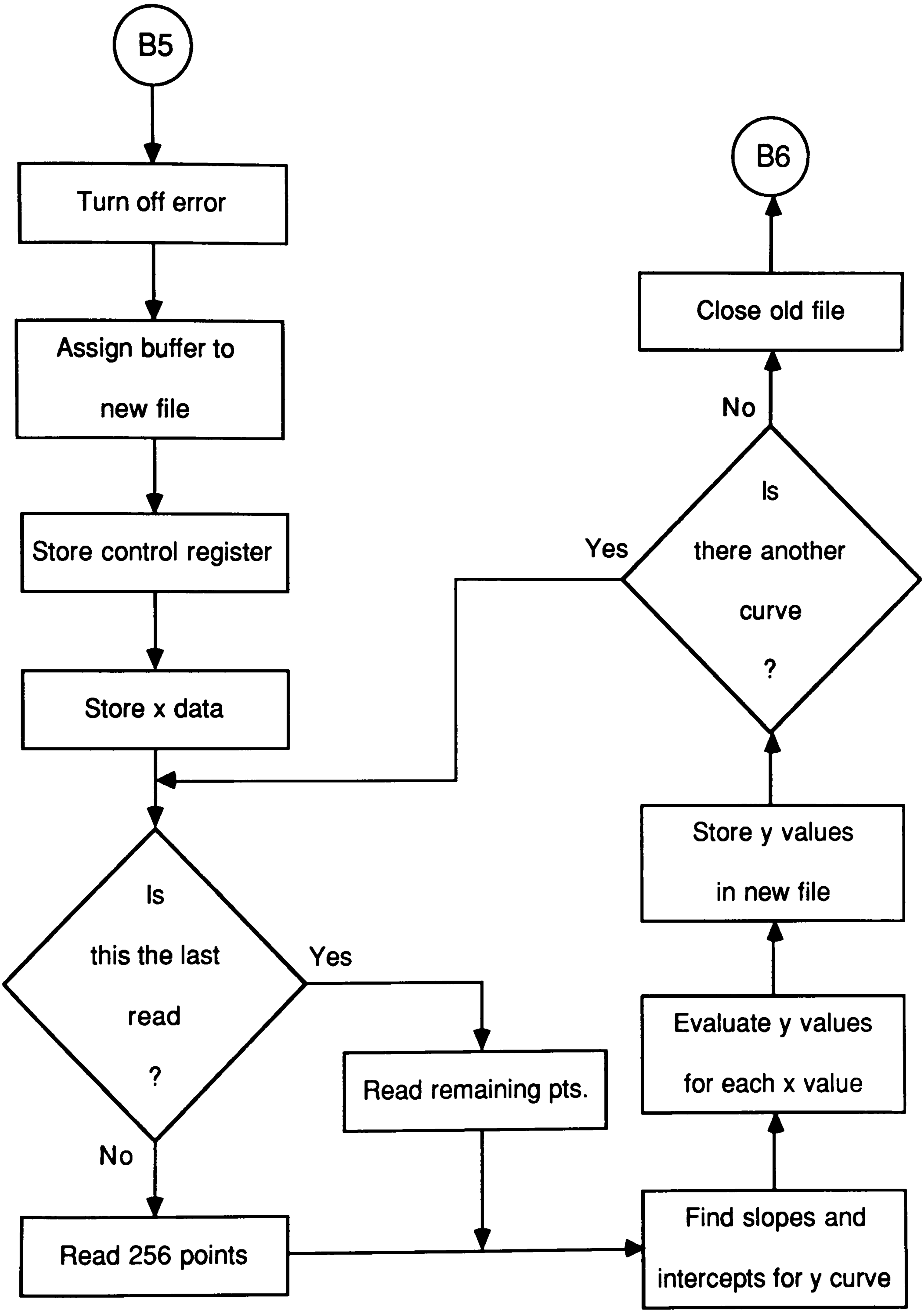
Finally, the MATH program stores the processed data files. The curves are stored in the order: (1) time, (2) voltage, (3) current, (4) power, (5) energy.

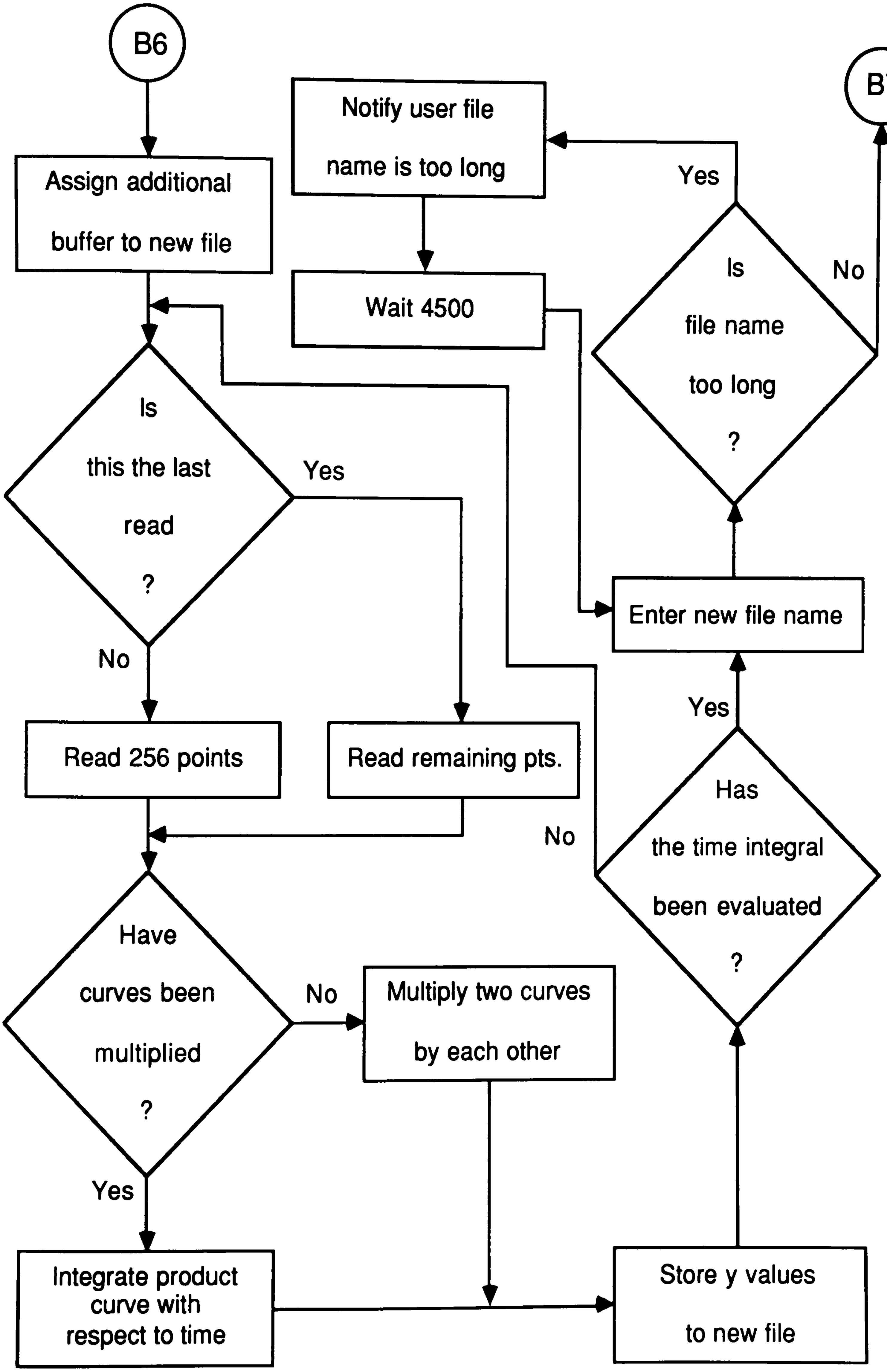

B
Initialize registers
Is file name known ?
No
Yes
Enter file name
Wait 4500
B1
Is file name too long ?
Yes
No
Notify user file name is too long
Assign buffer to mass storage file
Enter mass storage
Is there an error ?
Yes
No
B2
Wait 4500
Is error #130 ?
Yes
No
Notify user to pick new mass storage
Notify user of unusual error
HALT

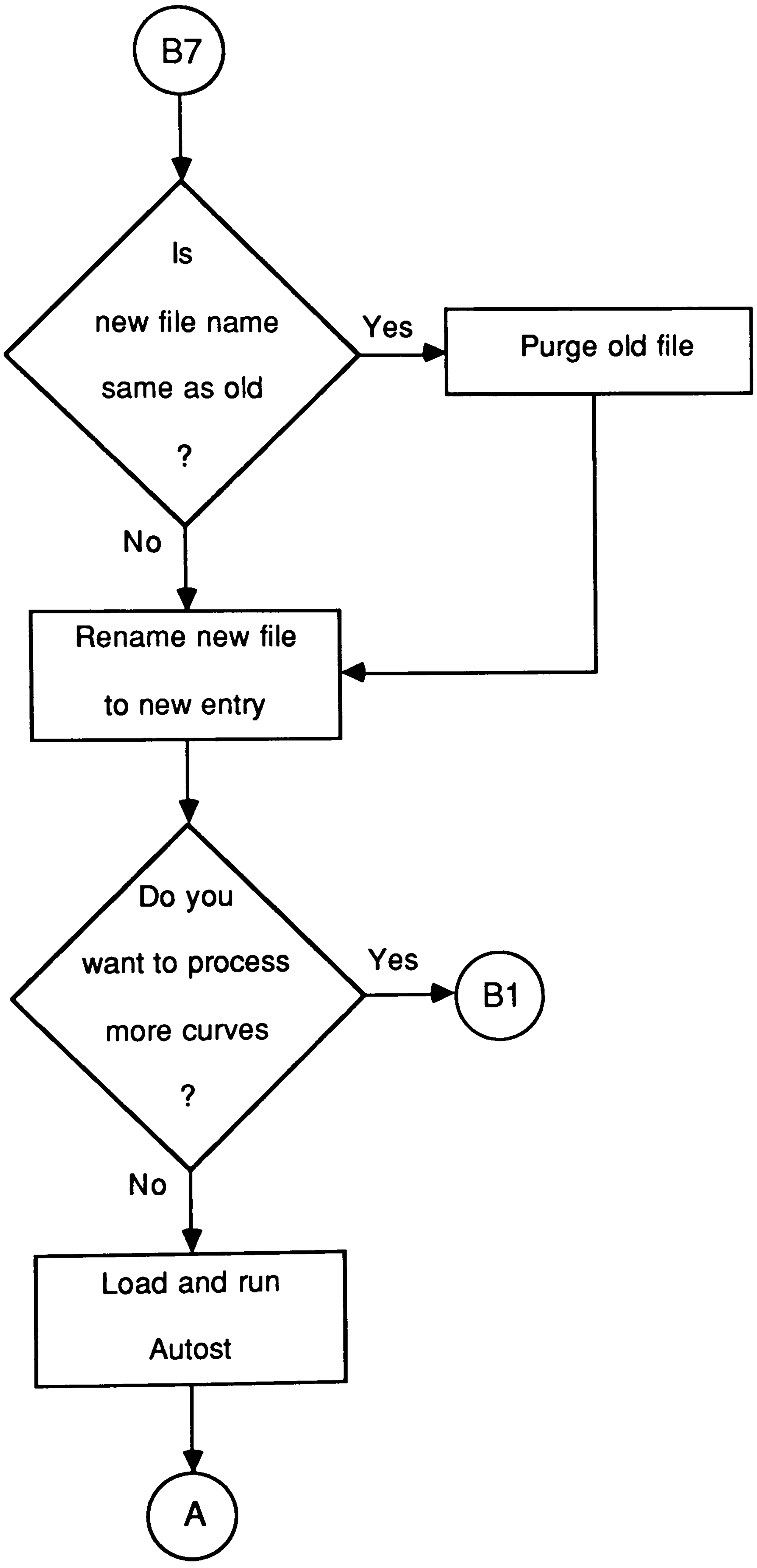

B2
Does file have two curves ?
No
Notify user program cannot process
Yes
B1
Do you want to process another file ?
Yes
Is file too large ?
Yes
Notify user file is too large
No
Load and run Autost
A
No
Enter registers
Notify user that program is sorting
Read beginning x value for both curves
Set flag for curve with smaller beginning x
Store larger beginning x value as lower limit of unflagged curve
Read next x value for flagged curve
Is x value >= larger beginning x value ?
Yes
B3
No


B3
Store x value as lower limit of unflagged curve
Read final x value for both curves
Set flag for curve with larger final x
Store smaller final x value as upper limit of unflagged curve
Read previous x value for flagged curve
Is x value <= smaller final x value ?
No
Yes
Store x value as upper limit of flagged curve
Calculate # of reads to complete processing
Notify user of initial read and sort
Read calculated beginning to ending x values of first curve
Re-assign # of data points for first curve
B4


B4
Read x value from second curve
Is x value = some x in first curve ?
Yes
No
Store x value
Is x value = final x of second curve ?
No
Yes
Re-assign # of data points
Sort all x values together
Notify user creating file
Create file
Is there an error ?
No
B5
Yes
Is error #130 ?
No
Notify user of unusual error
HALT
Yes
Purge file
Turn off error


B5
Turn off error
Assign buffer to new file
Store control register
Store x data
Is this the last read ?
Yes
No
Read remaining pts.
Read 256 points
Find slopes and intercepts for y curve
Evaluate y values for each x value
Store y values in new file
Is there another curve ?
Yes
No
Close old file
B6


B6
Assign additional buffer to new file
Is this the last read ?
Yes
No
Read 256 points
Read remaining pts.
Have curves been multiplied ?
No
Yes
Multiply two curves by each other
Integrate product curve with respect to time
Store y values to new file
Has the time integral been evaluated ?
No
Yes
Enter new file name
Is file name too long ?
Yes
No
Notify user file name is too long
Wait 4500
B7


B7
Is
new file name
same as old
?
Yes
Purge old file
No
Rename new file
to new entry
Do you
want to process
more curves
?
Yes
B1
No
Load and run
Autost
A

PLOT

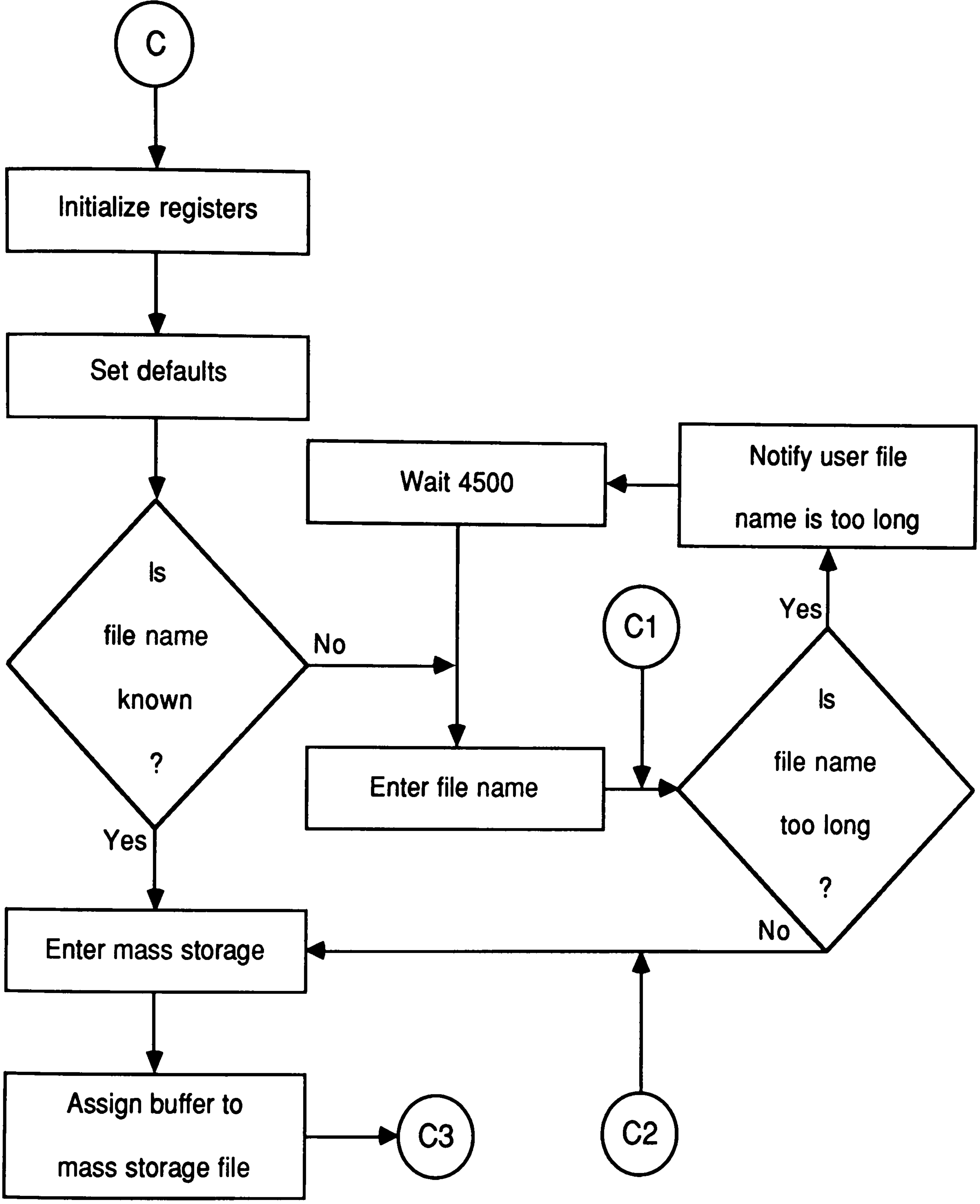
The PLOT program generates all plots of curves with respect to time, e.g. voltage vs. time. The data is stored in two (2) possible formats -- unprocessed and processed.

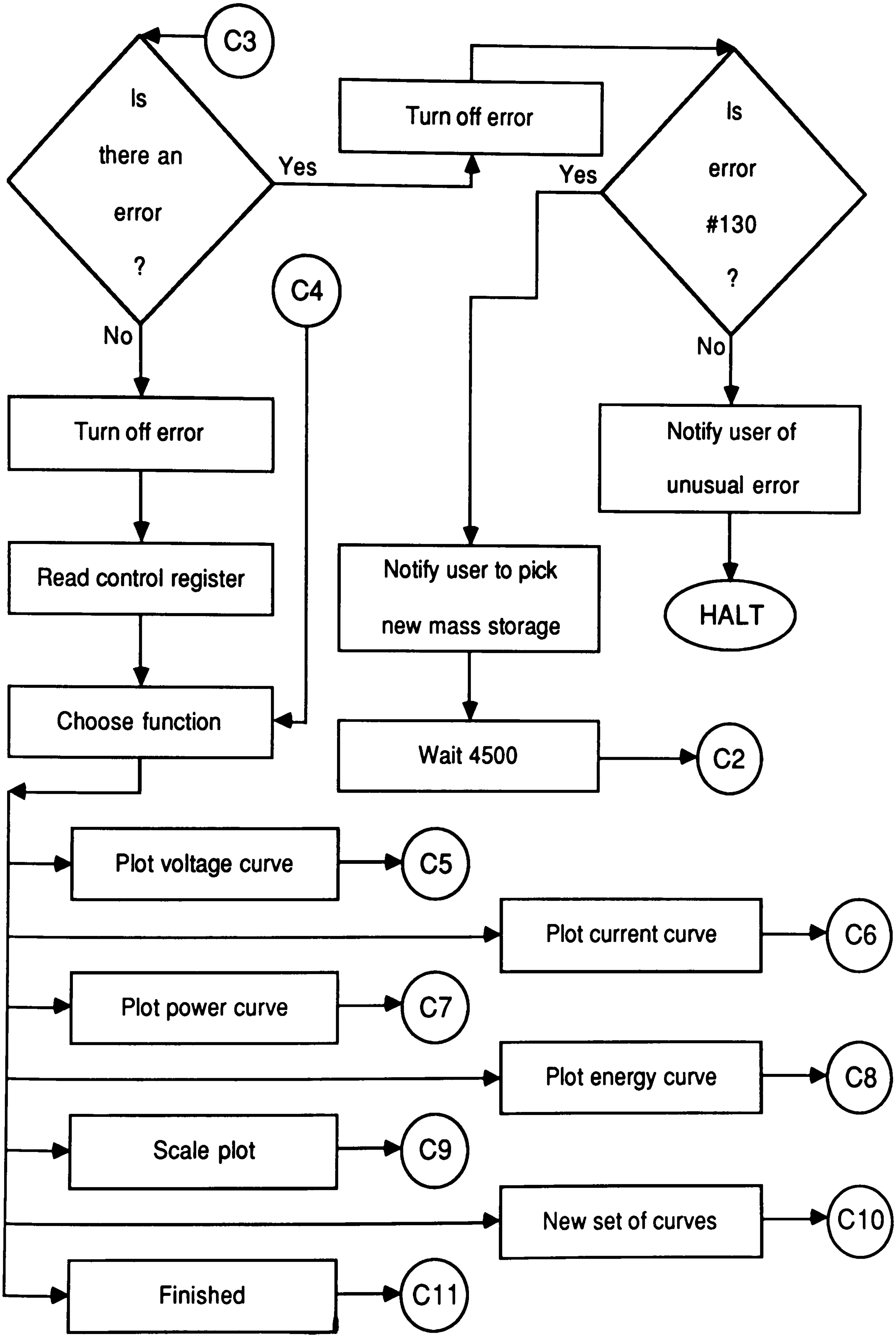
The unprocessed data is read into the computer and plotted using the values stored in the control registers. The control registers contain information regarding the number of points in the curve, the number of x divisions, value per x division (time), value per y division (e.g. voltage), curve type (i.e. voltage or current), and time and date of measurement.

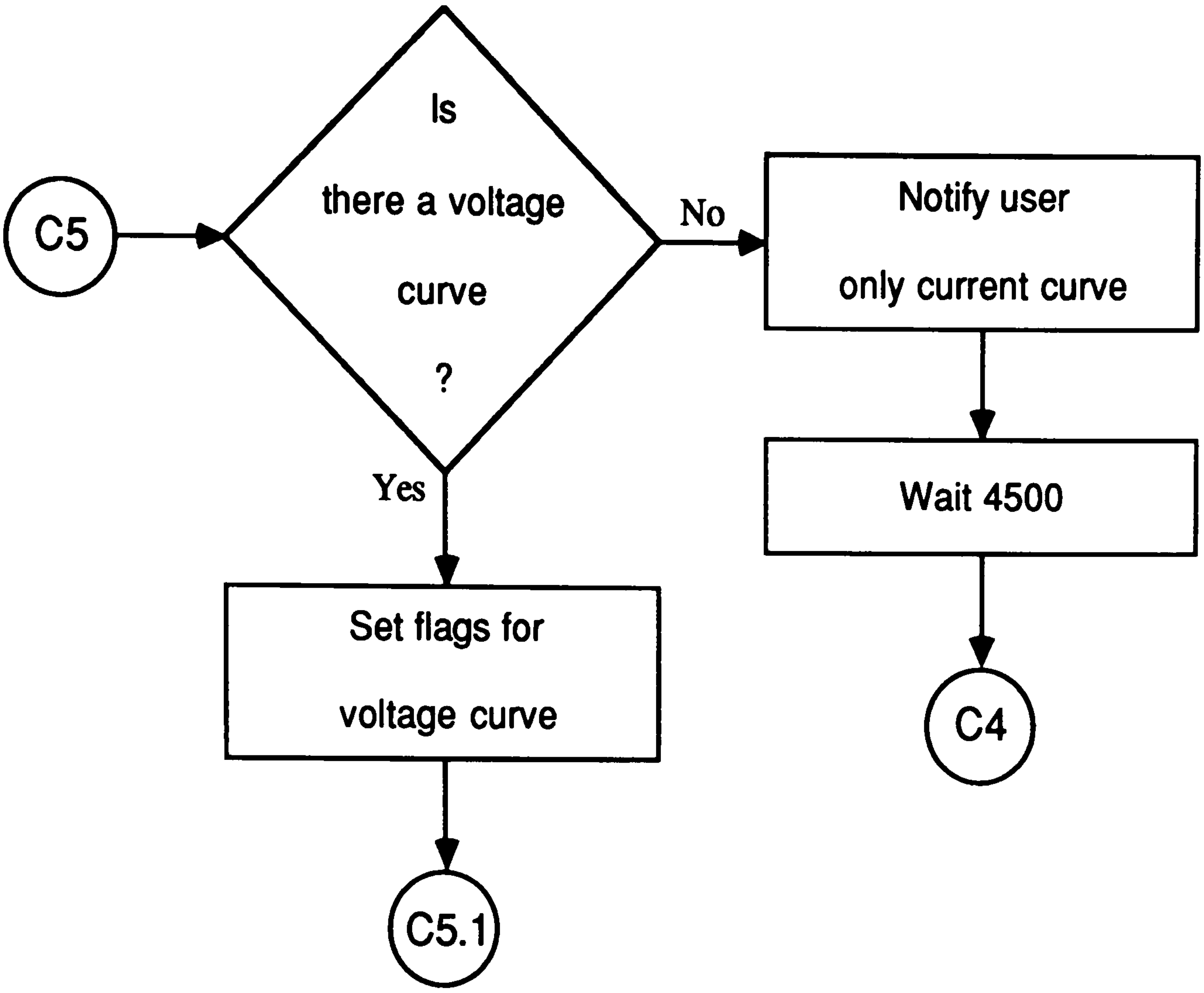
The processed data is read into the computer and plotted using values calculated by the computer. The program scans ;the given curve values, finds the minimum and maximum values, and plots the curve to fill 80% of the plotting area.

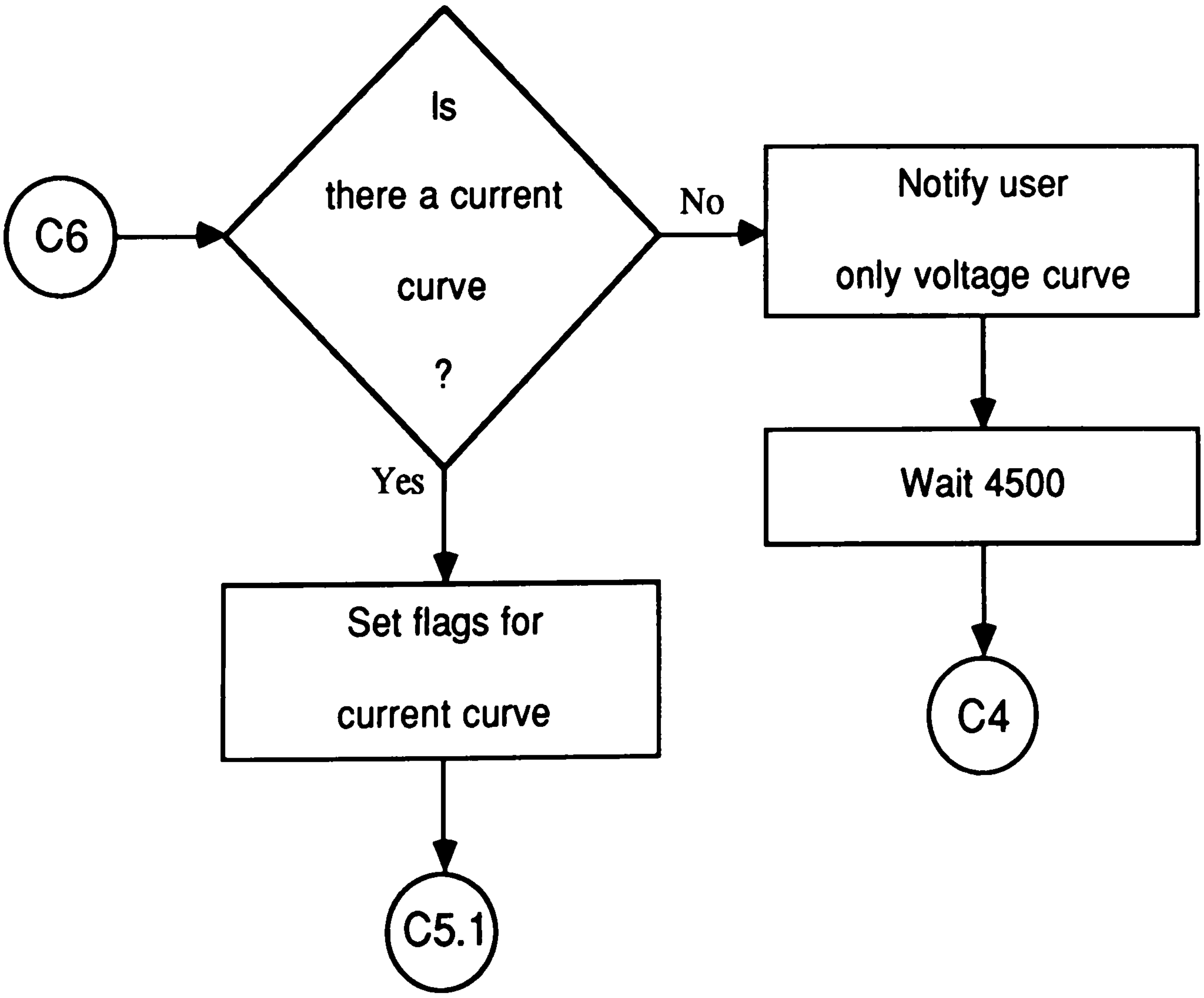
The PLOT program allows the operator to plot curves singularly or in groups, and to scale the size of the plot. Also, the program allows the plots to be made on either a grid or an open graph.

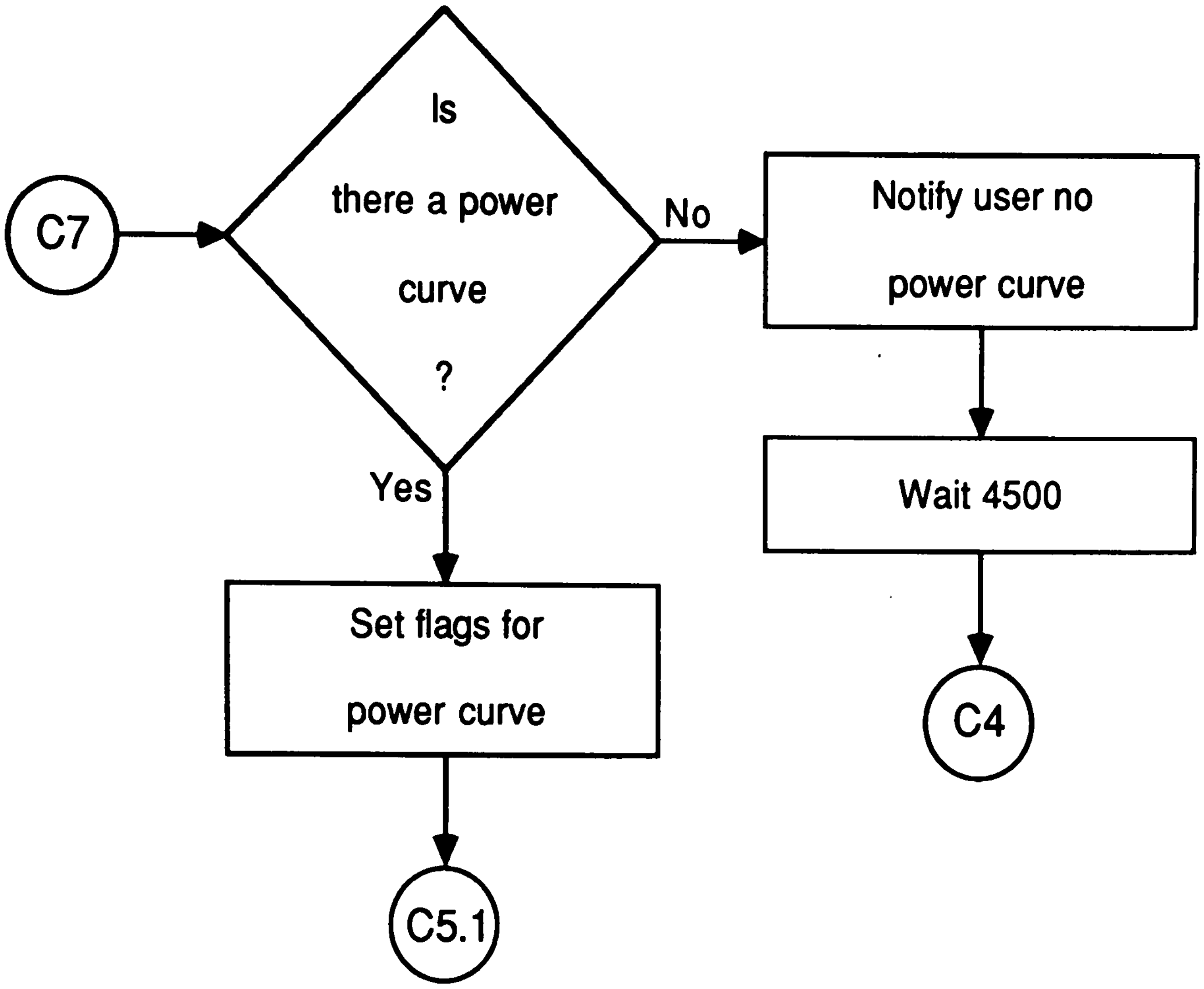
Finally, the PLOT program allows the operator to generate a set of second-breakdown statistics, if processed data is being used. The program will print values for voltage, current, power, energy, and time at second-breakdown; for time, t_o, at 10% of second-breakdown voltage; for voltage, current, power, and energy at time, t_o; for time from t_o to second-breakdown; for change in energy from t_o to second-breakdown.

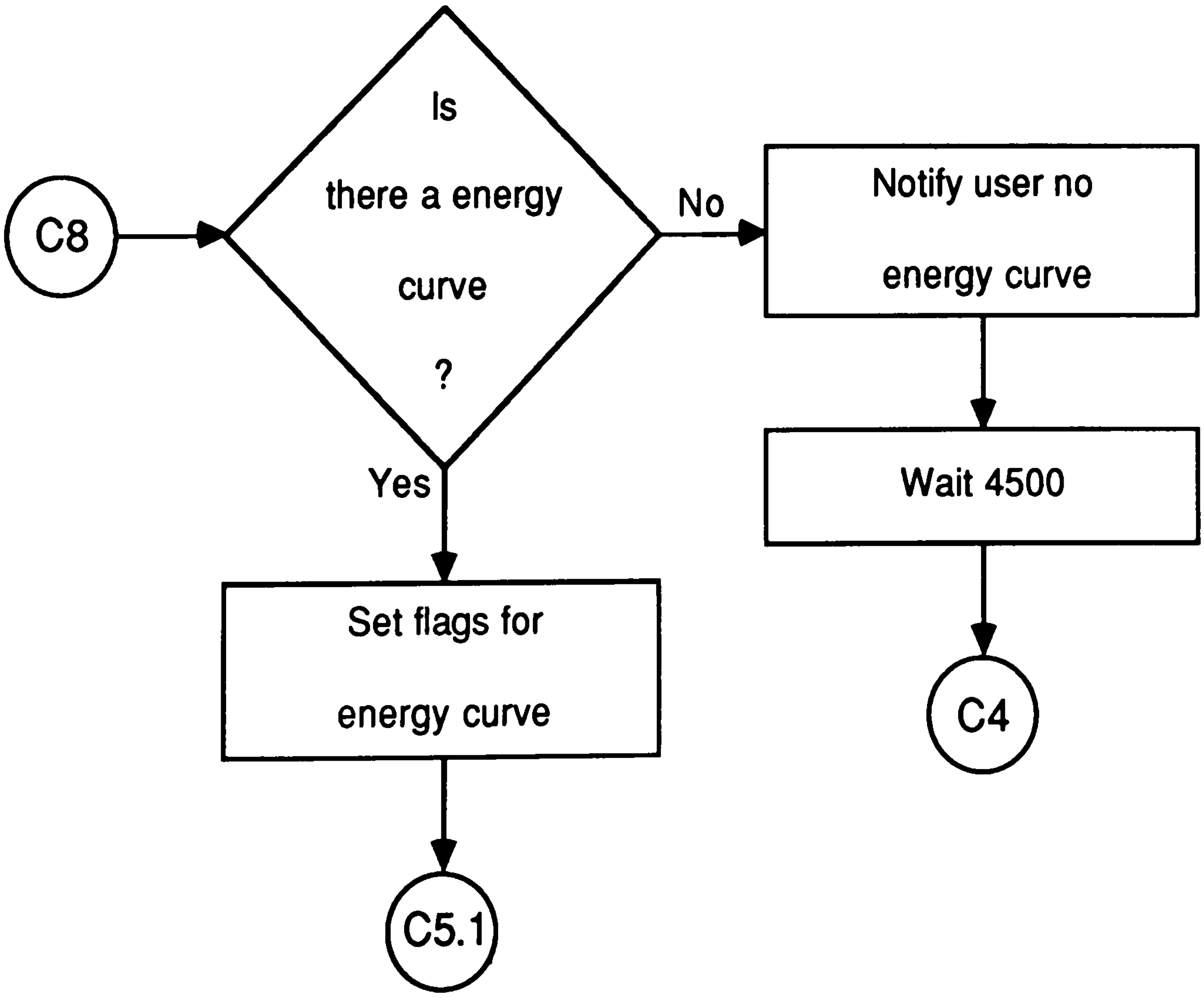

C
Initialize registers
Set defaults
Is file name known ?
No
Yes
Wait 4500
Notify user file name is too long
C1
Enter file name
Is file name too long ?
Yes
No
Enter mass storage
Assign buffer to mass storage file
C3
C2

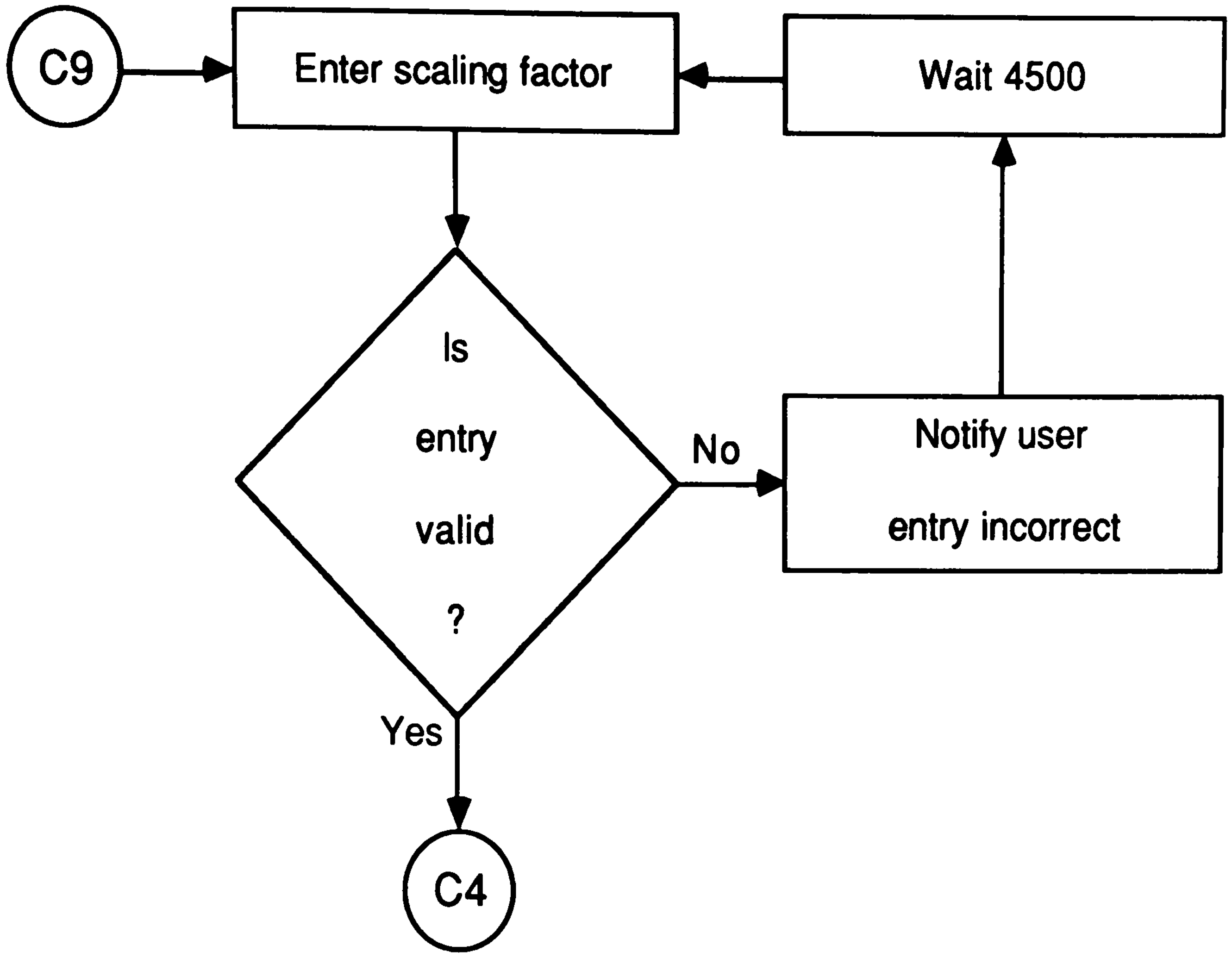

C3
Is there an error ?
Yes
No
Turn off error
Is error #130 ?
Yes
No
C4
Turn off error
Notify user of unusual error
HALT
Read control register
Notify user to pick new mass storage
Choose function
Wait 4500
C2
Plot voltage curve
C5
Plot current curve
C6
Plot power curve
C7
Plot energy curve
C8
Scale plot
C9
New set of curves
C10
Finished
C11

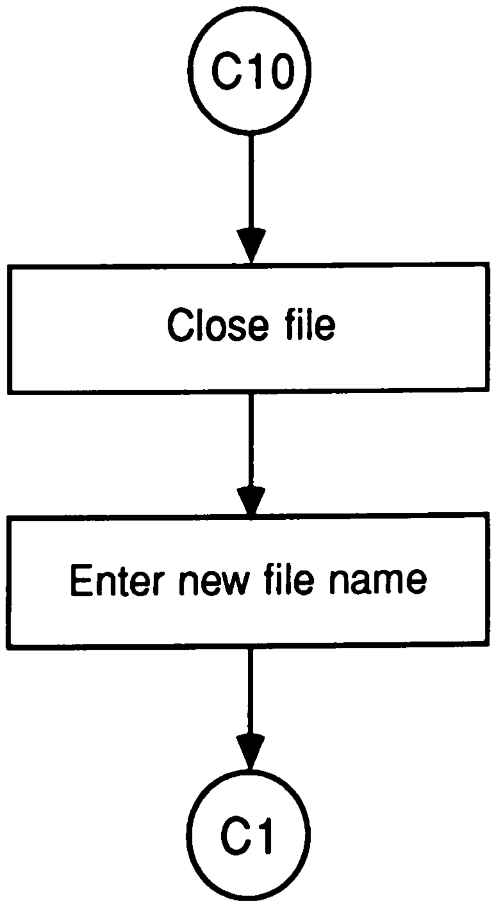

C5
Is there a voltage curve ?
No
Notify user only current curve
Wait 4500
C4
Yes
Set flags for voltage curve
C5.1

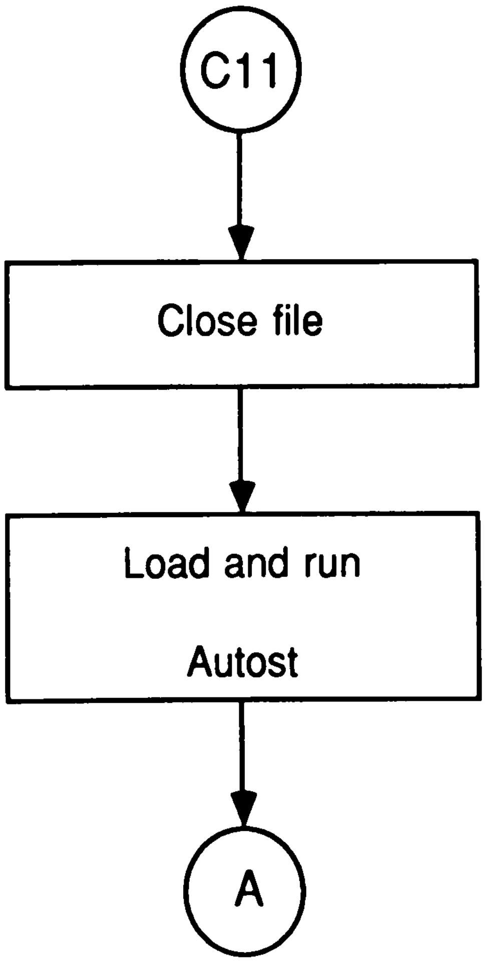

C6
Is there a current curve ?
No
Notify user only voltage curve
Wait 4500
C4
Yes
Set flags for current curve
C5.1

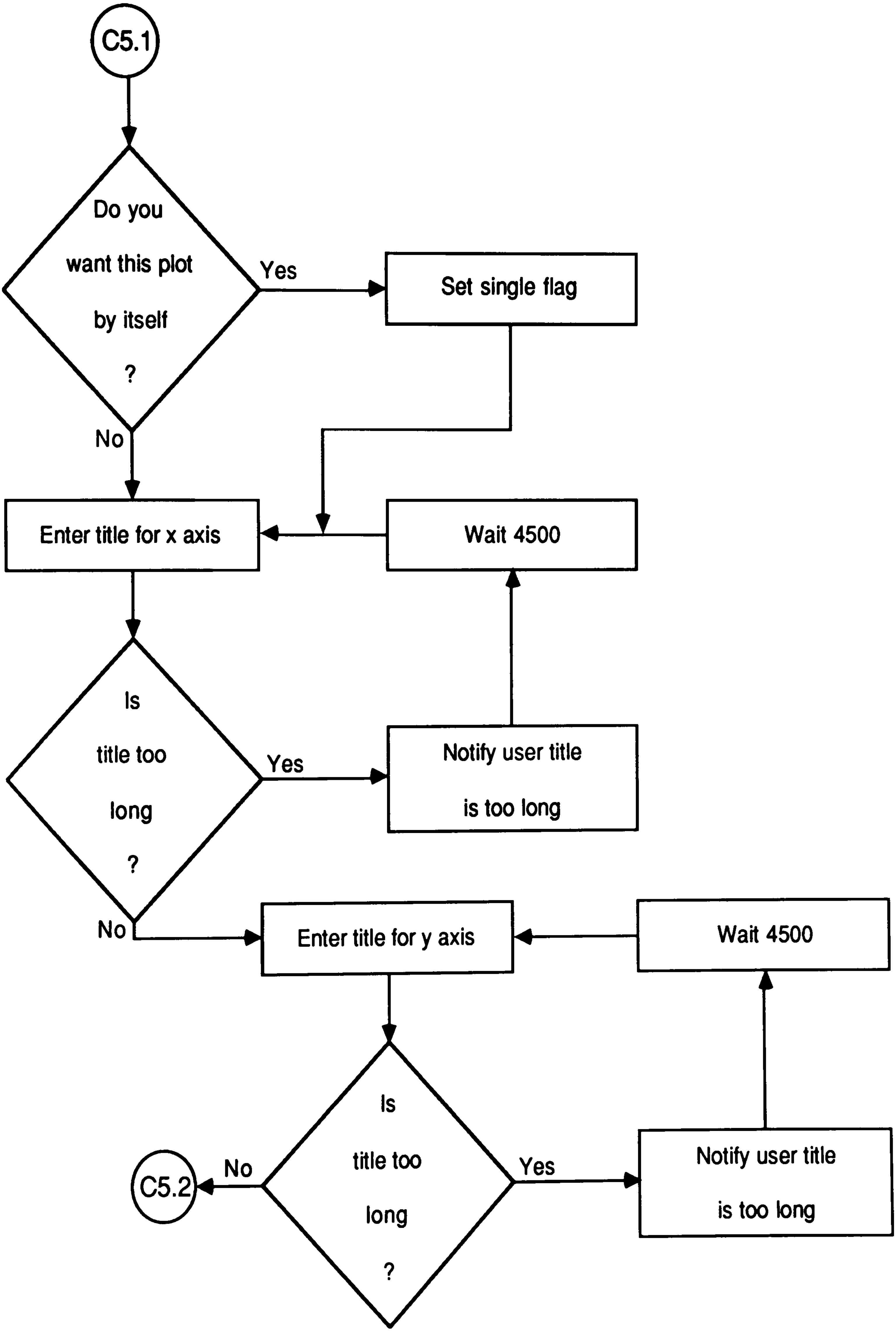

C7
Is there a power curve ?
No
Notify user no power curve
Wait 4500
C4
Yes
Set flags for power curve
C5.1

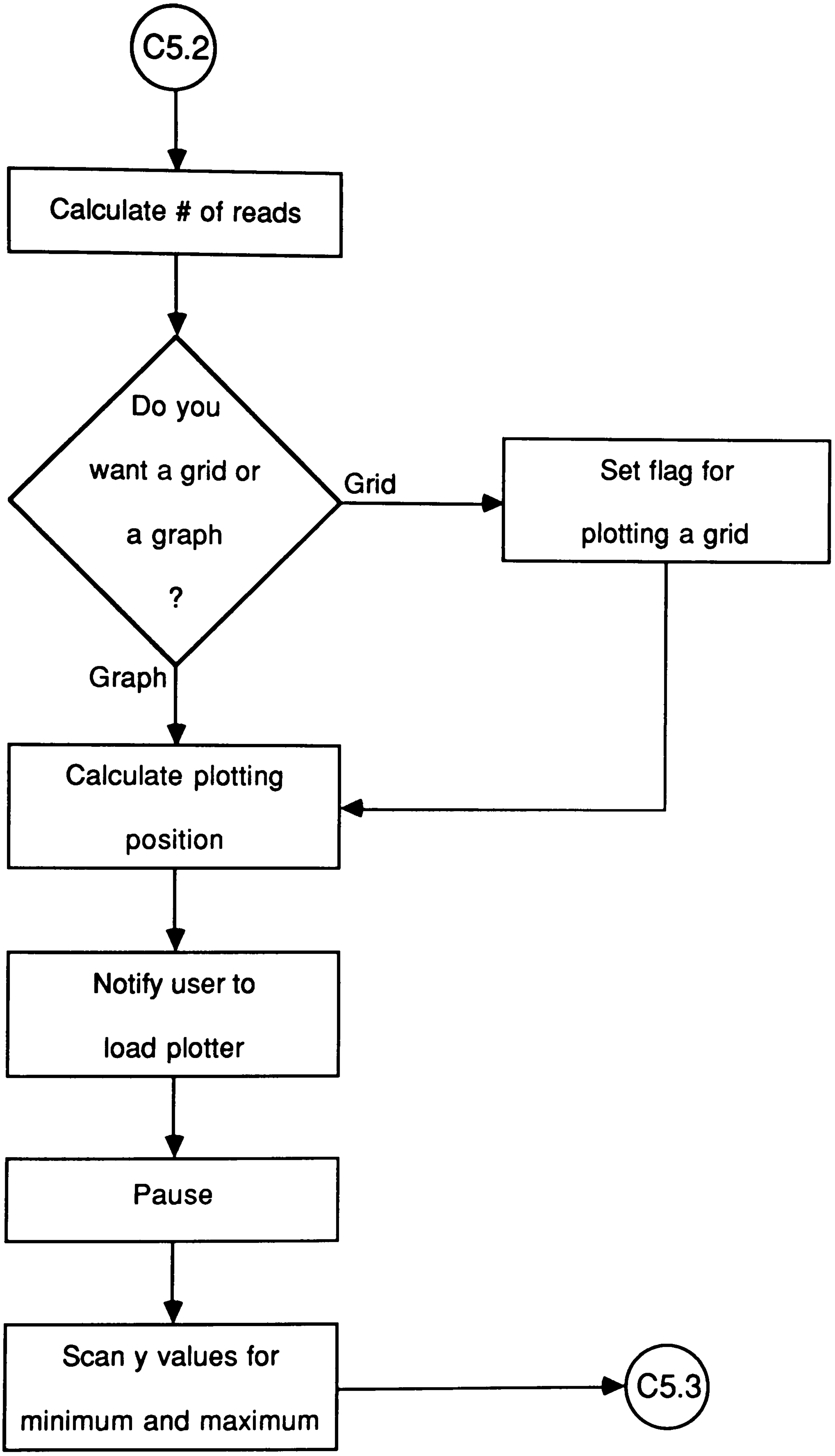

C8
Is there a energy curve ?
No
Notify user no energy curve
Wait 4500
C4
Yes
Set flags for energy curve
C5.1

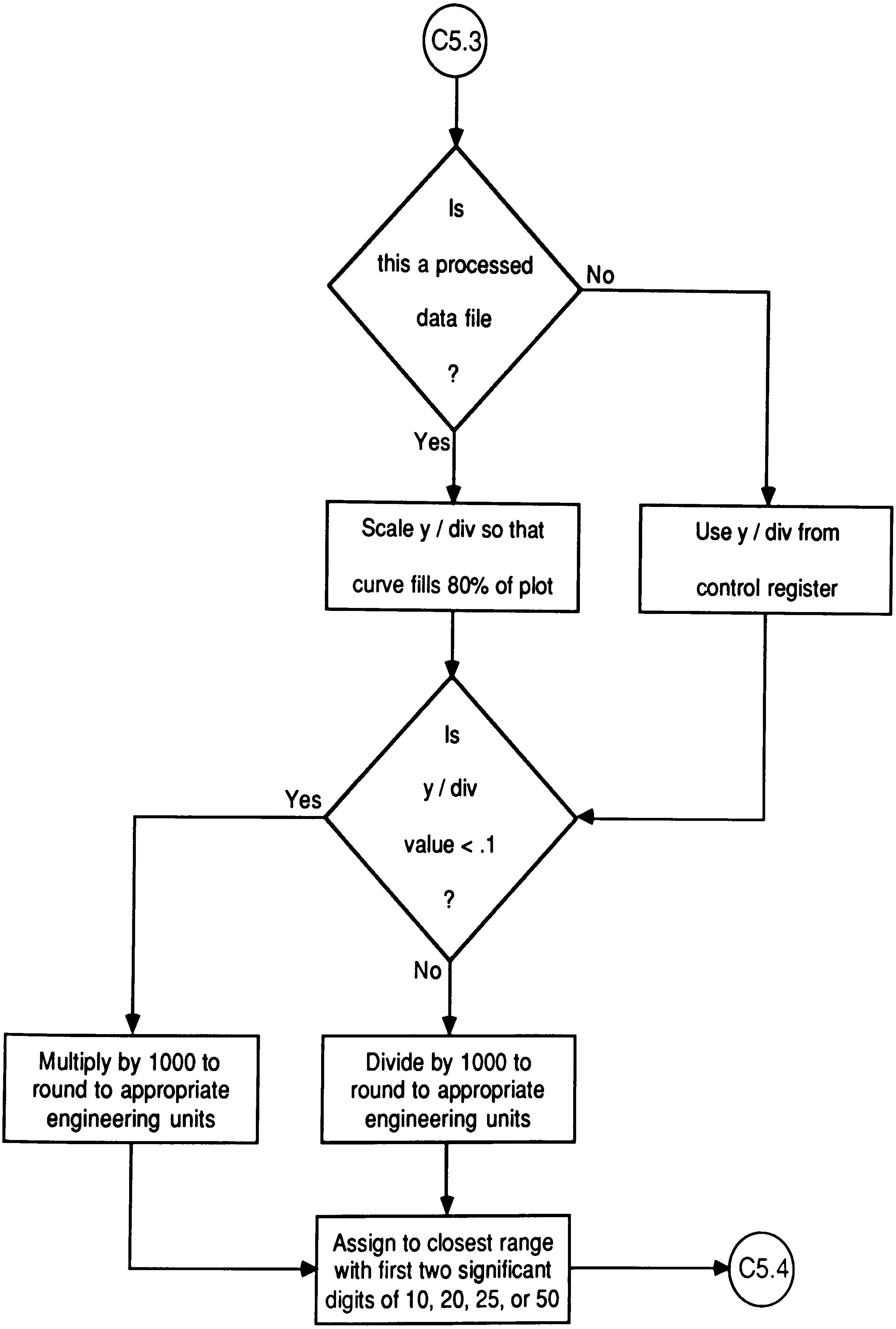

C9
Enter scaling factor
Wait 4500
Is
entry
valid
?
No
Notify user
entry incorrect
Yes
C4

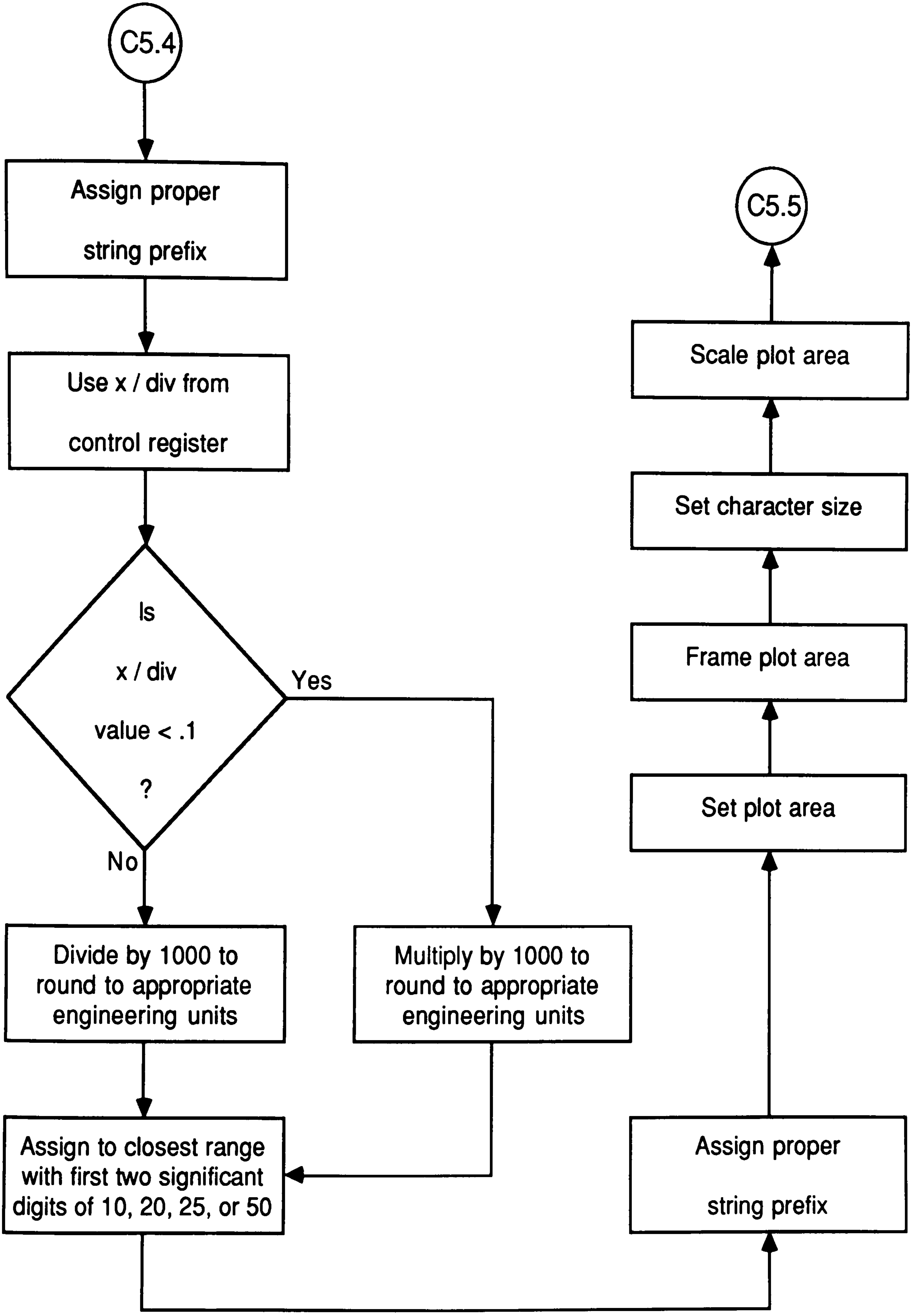

C10
Close file
Enter new file name
C1

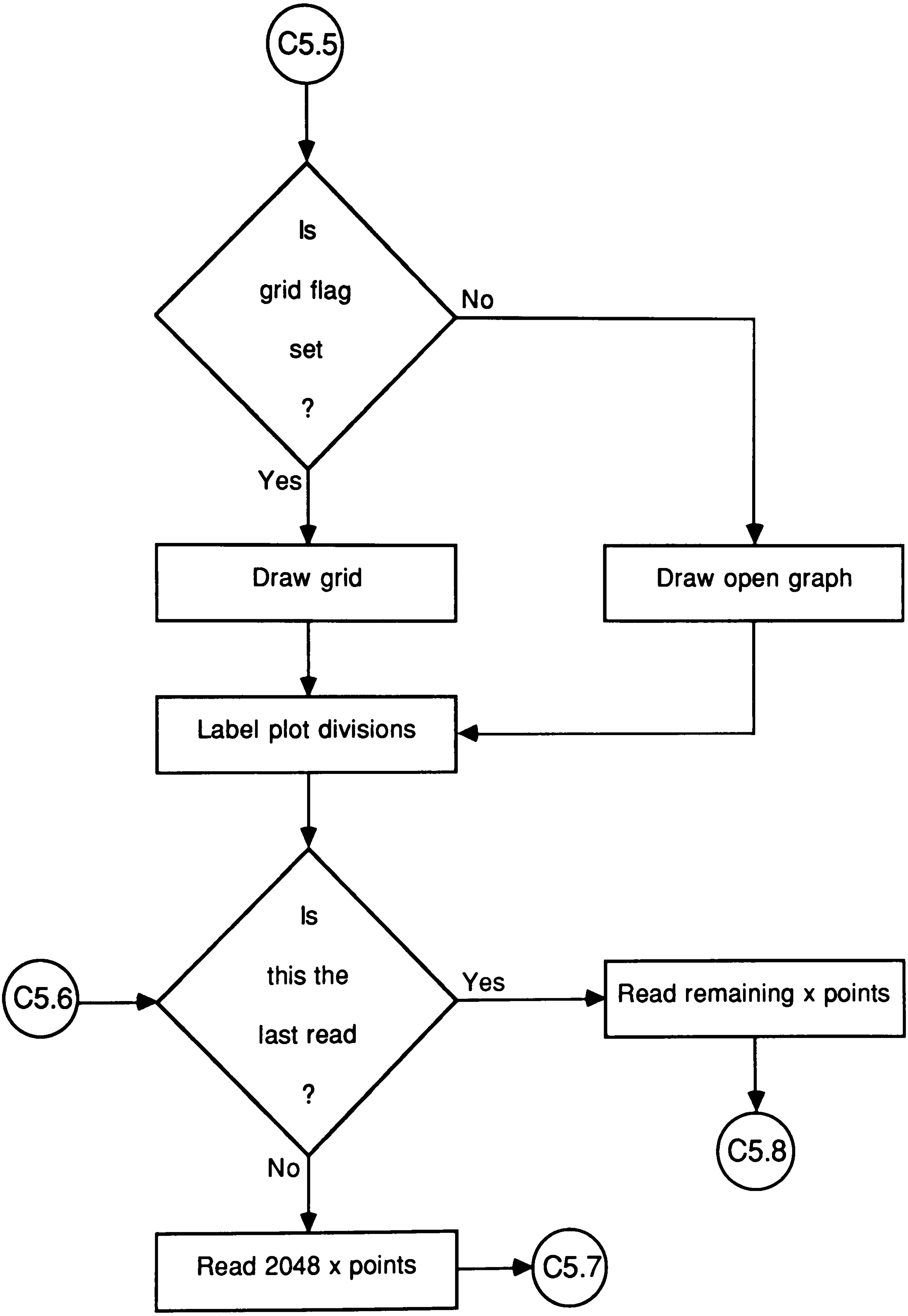

C11
Close file
Load and run
Autost
A

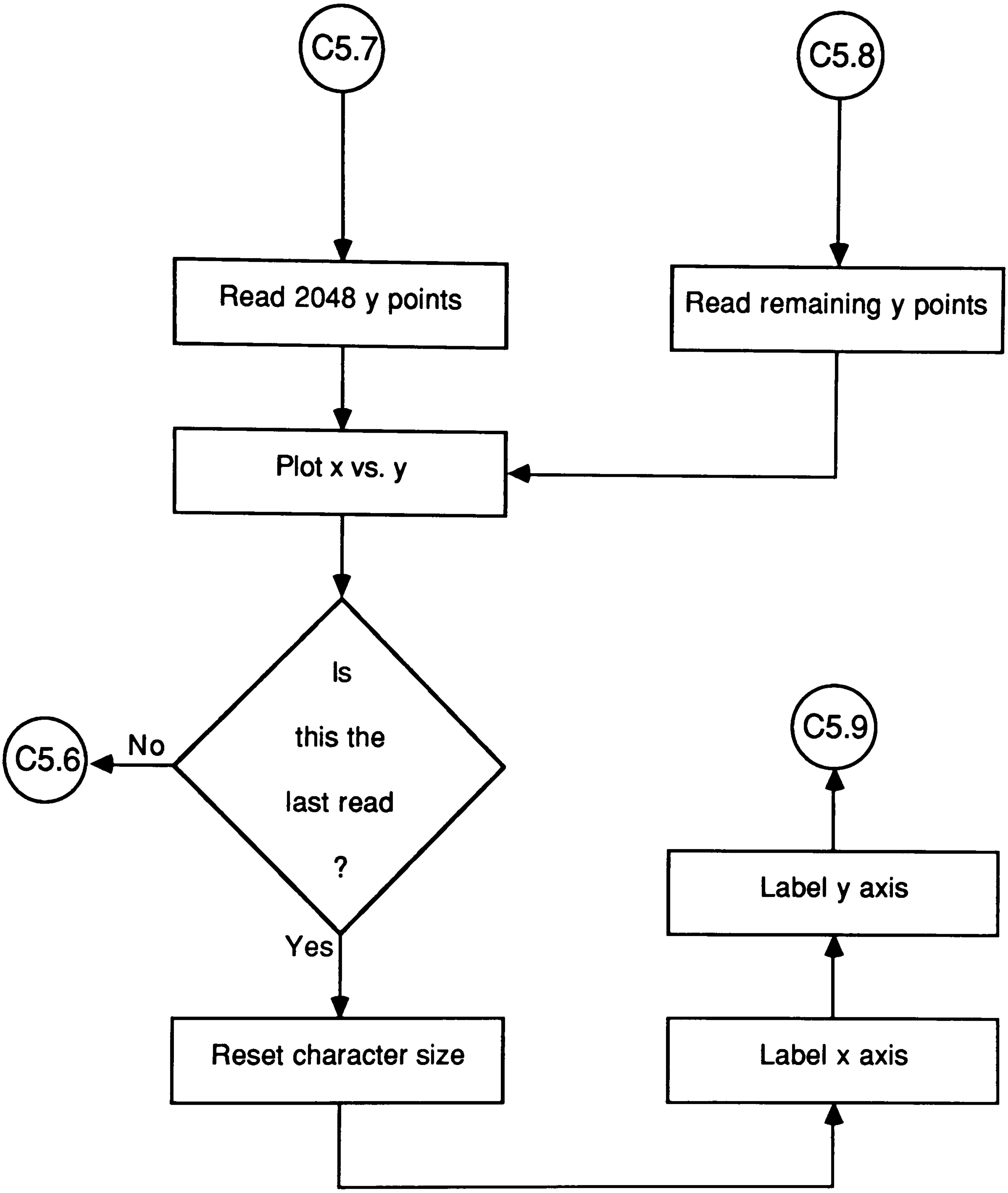

C5.1
Do you want this plot by itself ?
Yes
Set single flag
No
Enter title for x axis
Wait 4500
Is title too long ?
Yes
Notify user title is too long
No
Enter title for y axis
Wait 4500
Is title too long ?
No
C5.2
Yes
Notify user title is too long

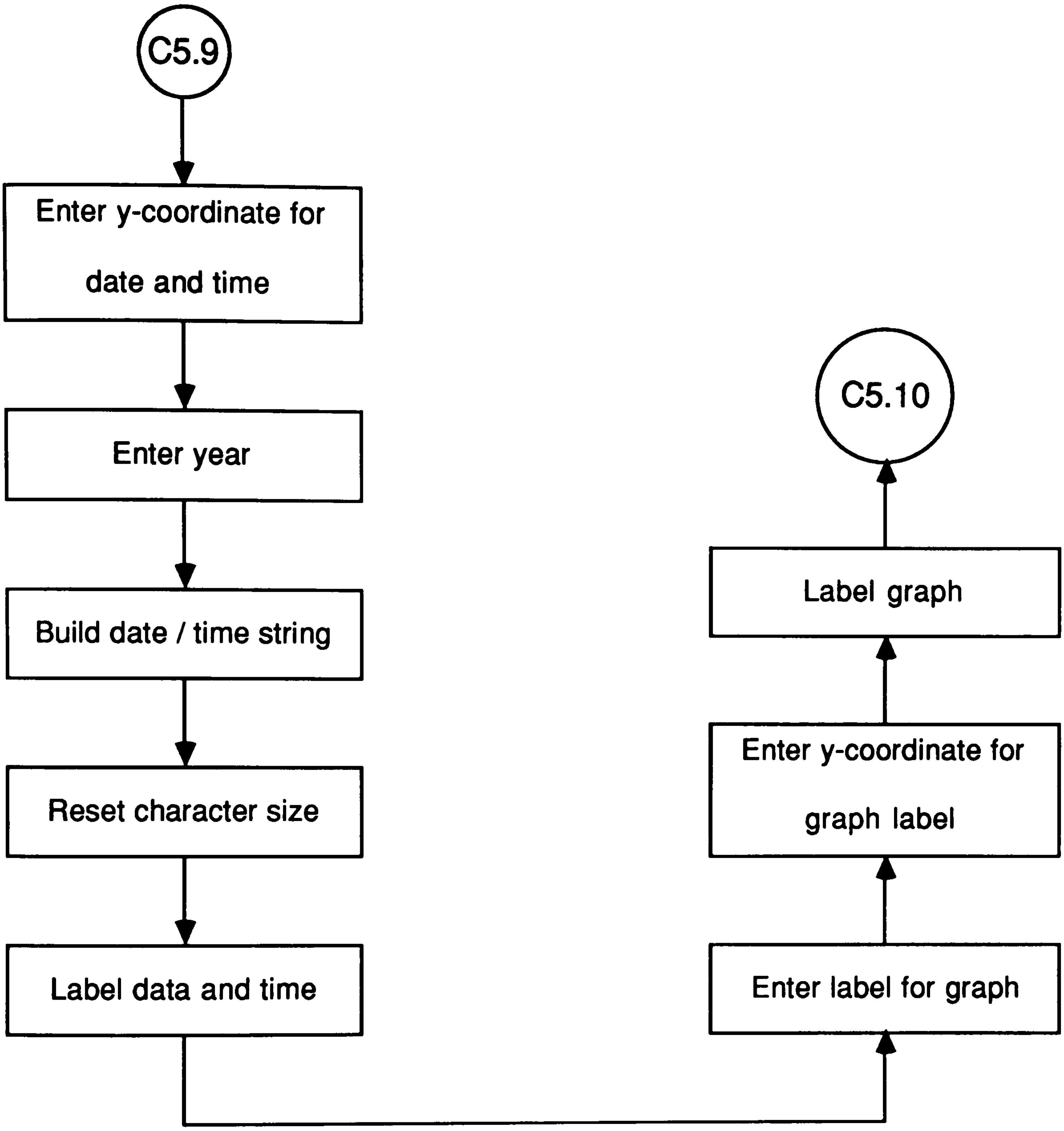

C5.2
Calculate # of reads
Do you want a grid or a graph ?
Grid
Set flag for plotting a grid
Graph
Calculate plotting position
Notify user to load plotter
Pause
Scan y values for minimum and maximum
C5.3

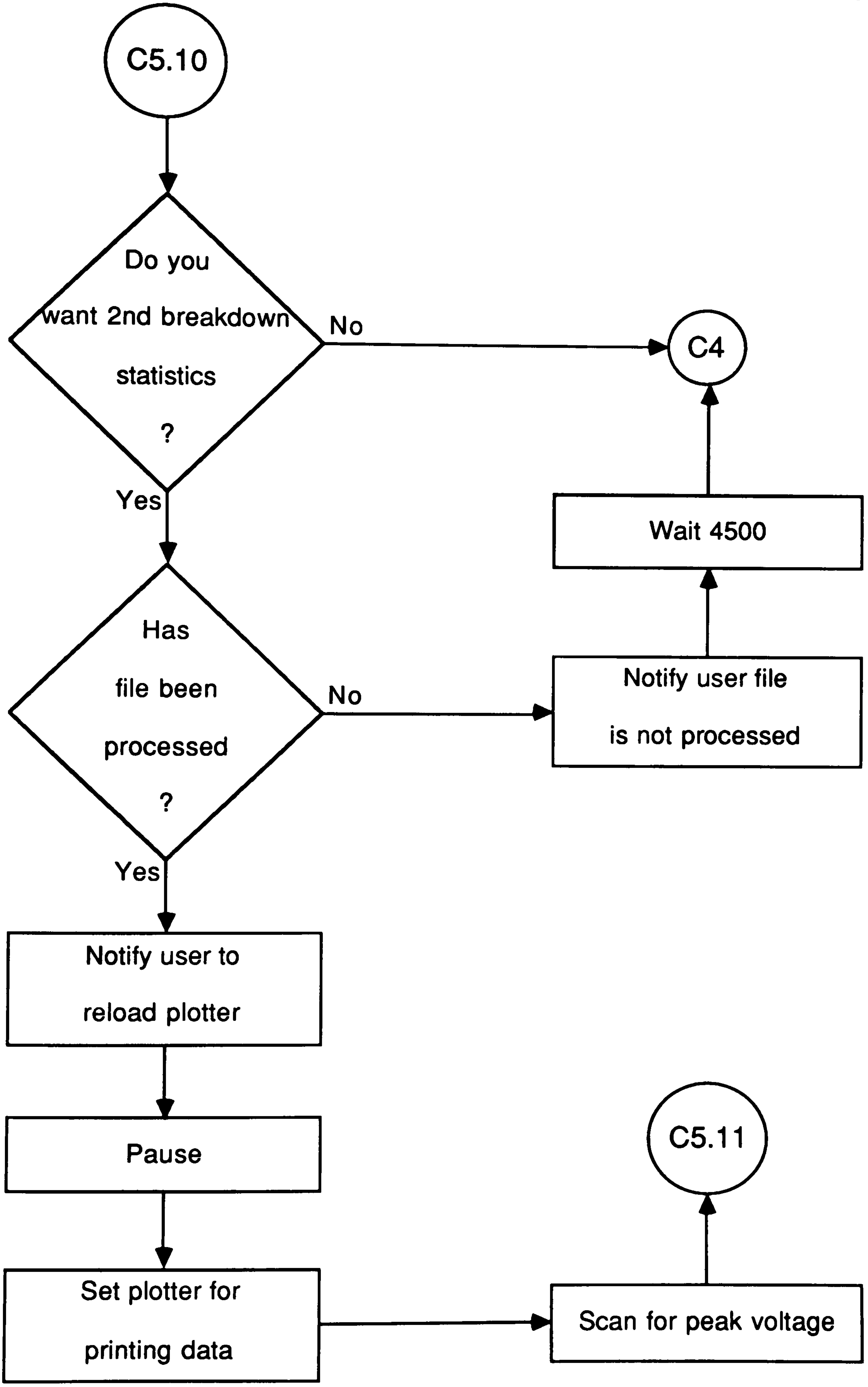

C5.3
Is this a processed data file ?
No
Yes
Scale y / div so that curve fills 80% of plot
Use y / div from control register
Is y / div value < .1 ?
Yes
No
Multiply by 1000 to round to appropriate engineering units
Divide by 1000 to round to appropriate engineering units
Assign to closest range with first two significant digits of 10, 20, 25, or 50
C5.4

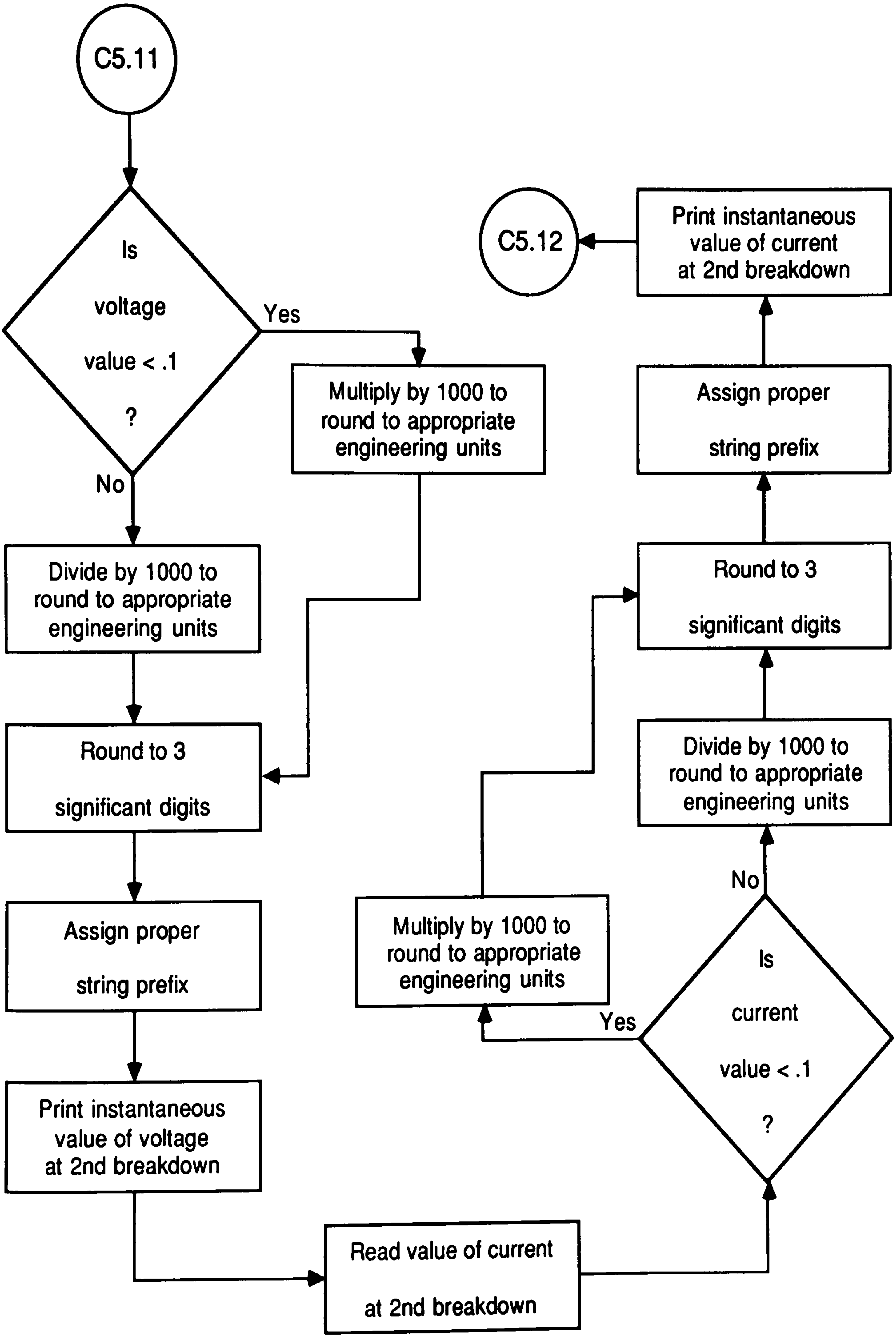

C5.4
Assign proper string prefix
Use x / div from control register
Is x / div value < .1 ?
Yes
No
Divide by 1000 to round to appropriate engineering units
Multiply by 1000 to round to appropriate engineering units
Assign to closest range with first two significant digits of 10, 20, 25, or 50
Assign proper string prefix
Set plot area
Frame plot area
Set character size
Scale plot area
C5.5

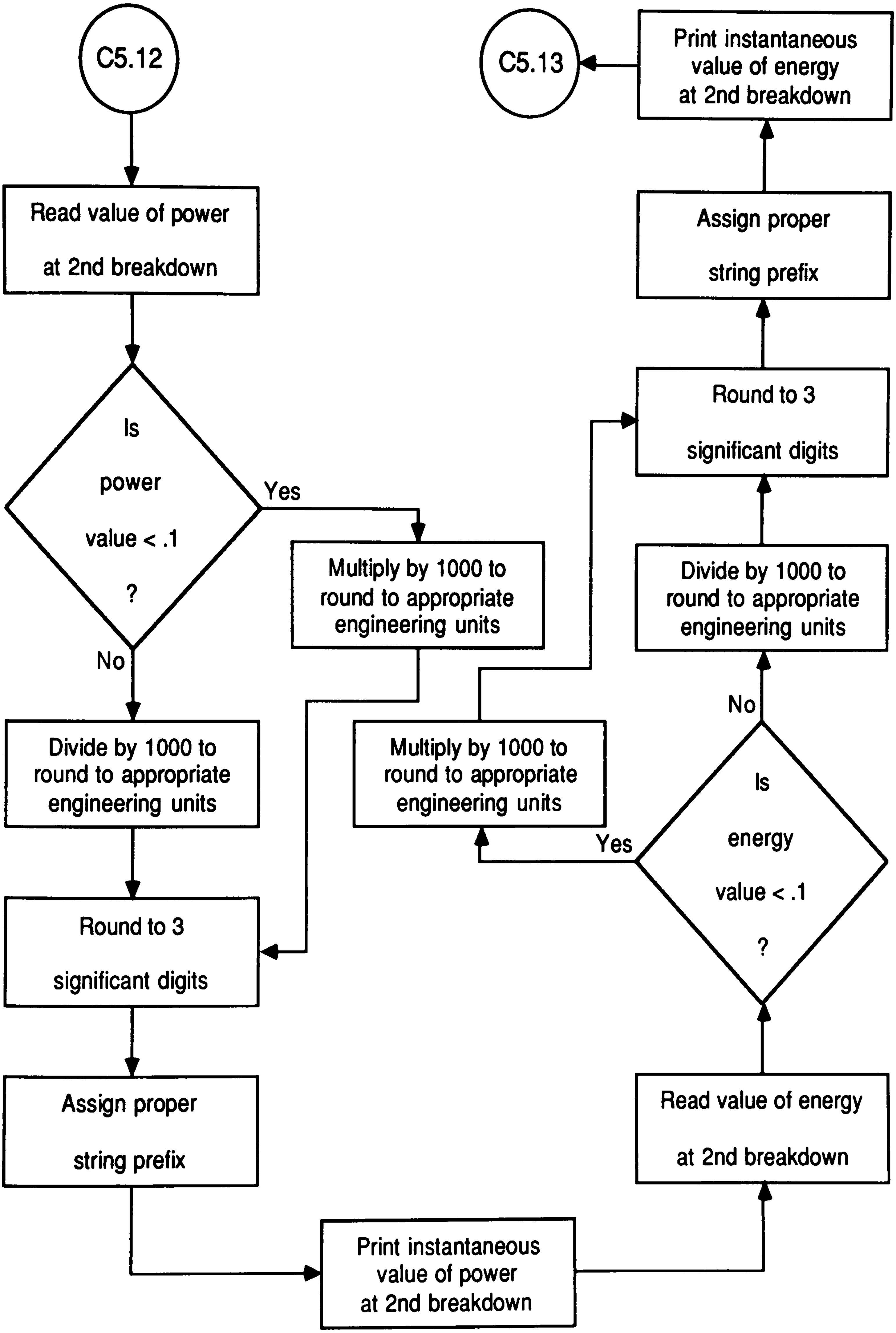

C5.5
Is
grid flag
set
?
No
Yes
Draw grid
Draw open graph
Label plot divisions
Is
this the
last read
?
C5.6
Yes
Read remaining x points
C5.8
No
Read 2048 x points
C5.7

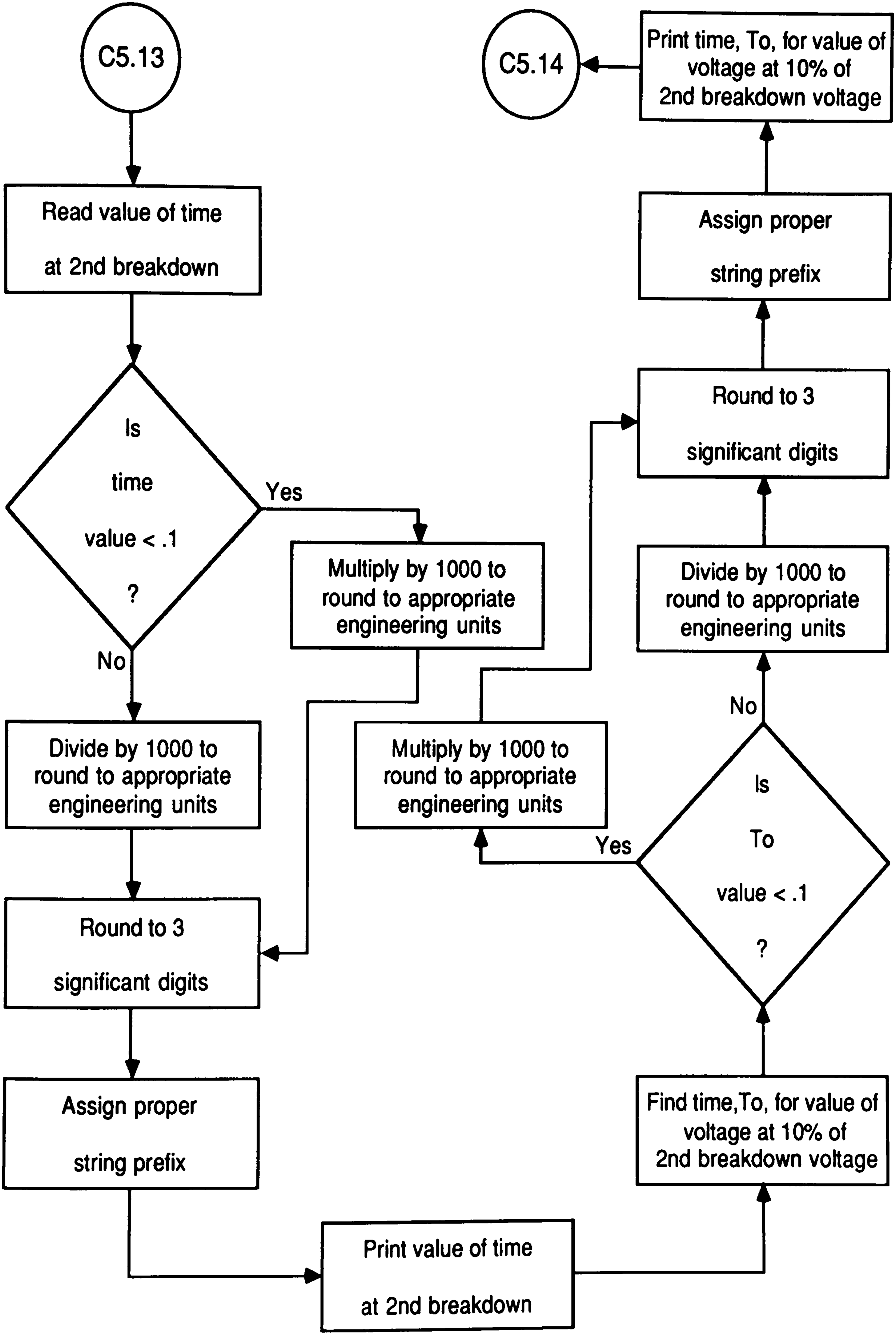

C5.7
C5.8
Read 2048 y points
Read remaining y points
Plot x vs. y
Is
this the
last read
?
No
C5.6
Yes
C5.9
Label y axis
Reset character size
Label x axis

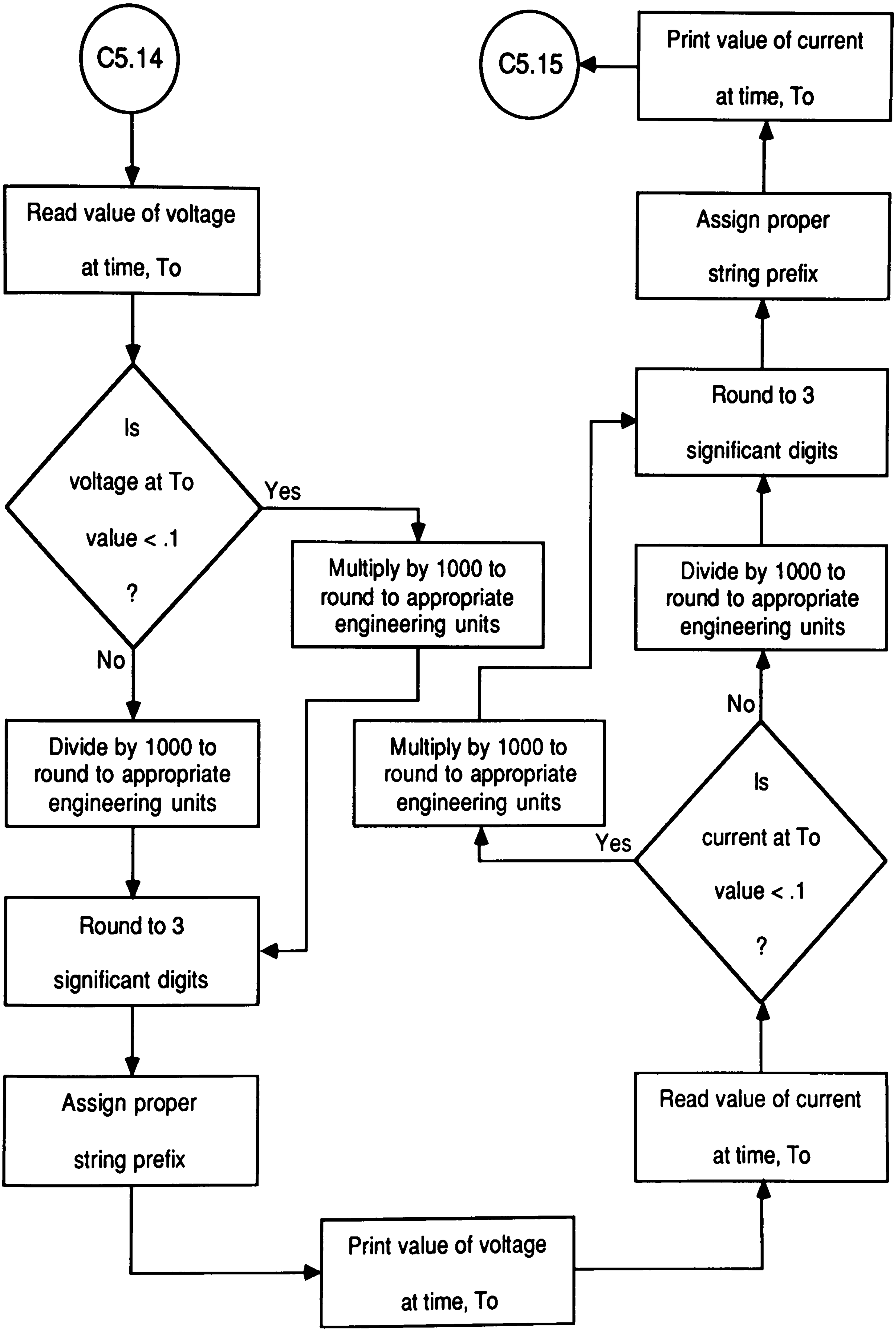

C5.9
Enter y-coordinate for date and time
Enter year
Build date / time string
Reset character size
Label data and time
Enter label for graph
Enter y-coordinate for graph label
Label graph
C5.10

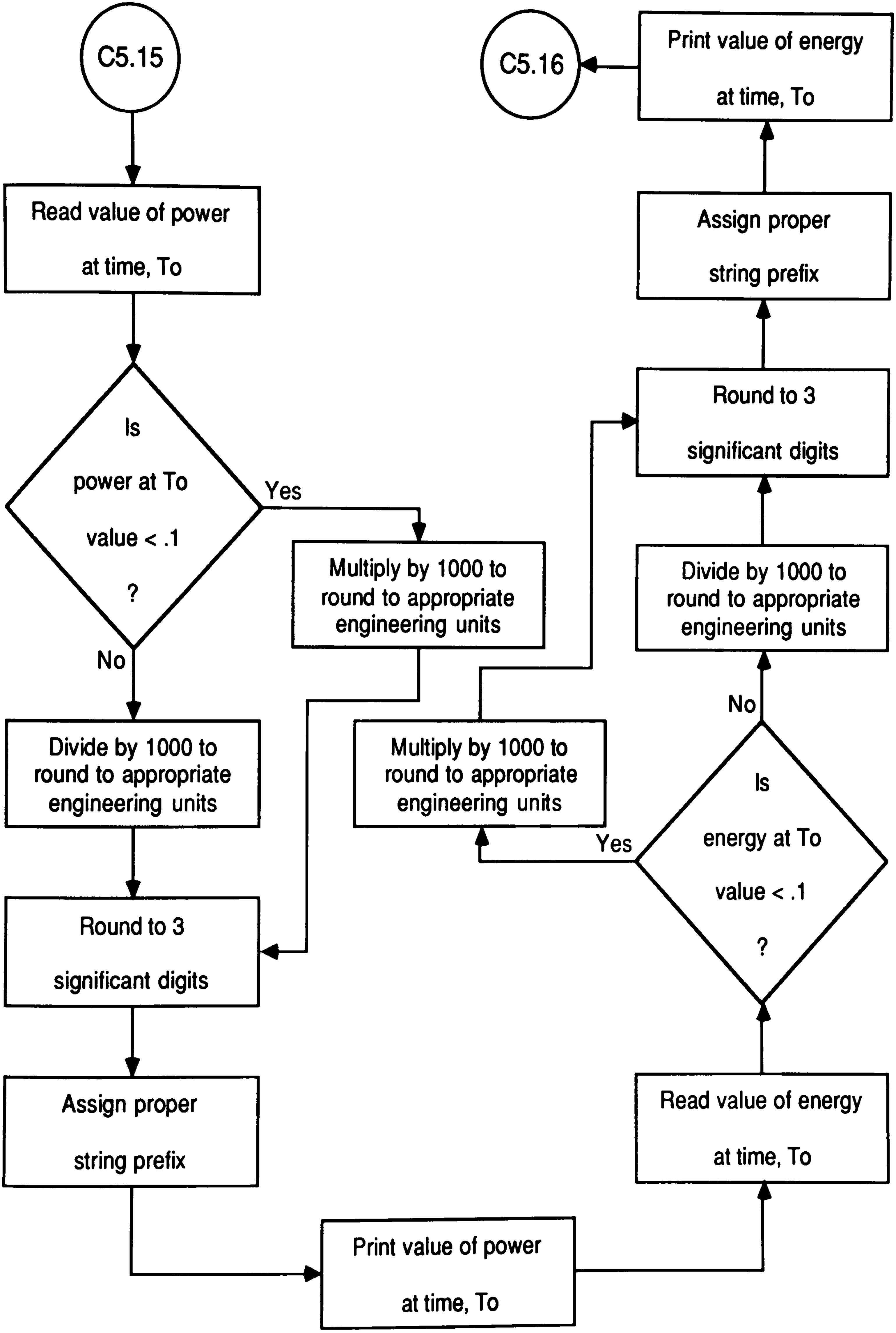

C5.10
Do you want 2nd breakdown statistics ?
No
C4
Yes
Wait 4500
Has file been processed ?
No
Notify user file is not processed
Yes
Notify user to reload plotter
Pause
C5.11
Set plotter for printing data
Scan for peak voltage

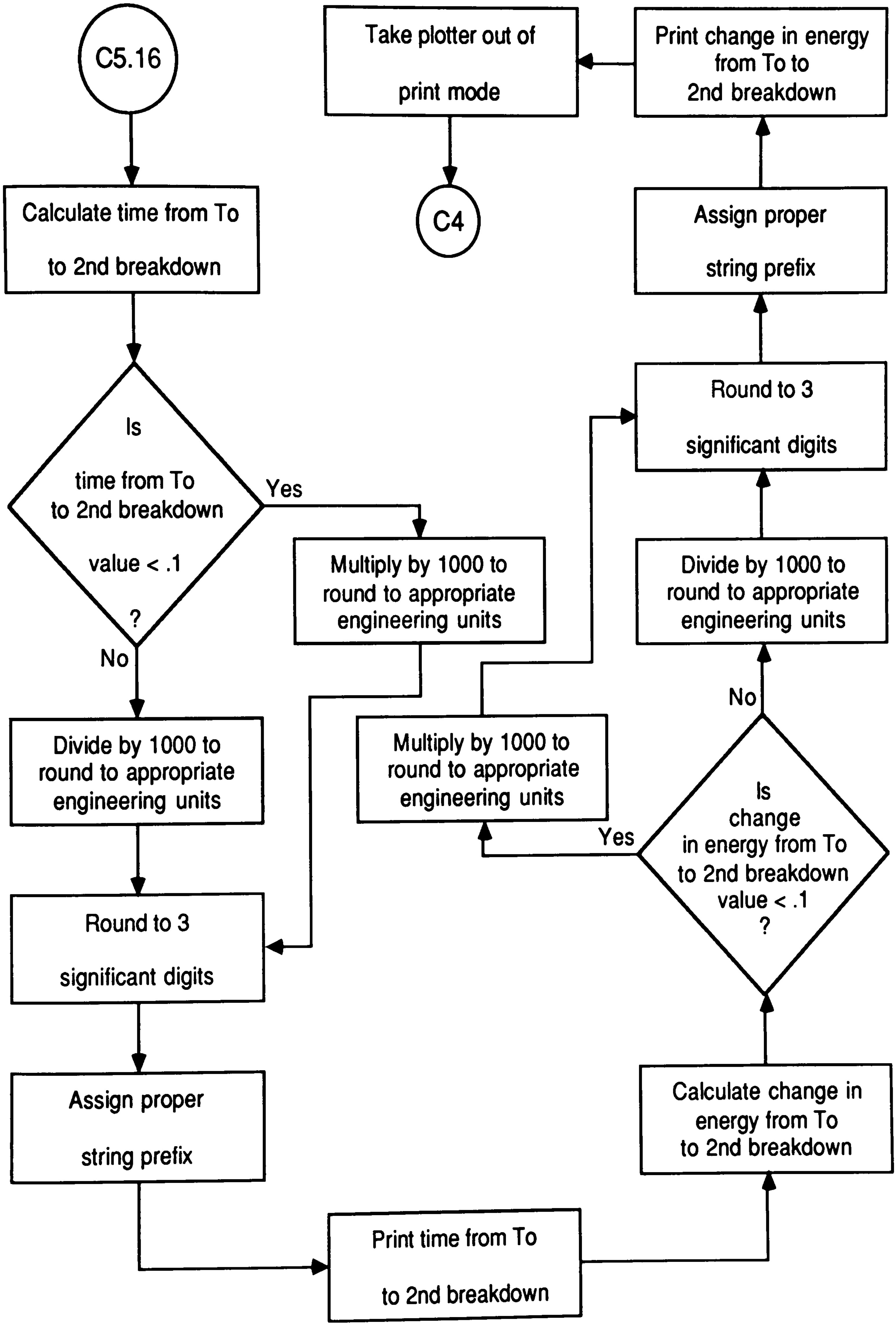

C5.11
Is voltage value < .1 ?
Yes
No
Multiply by 1000 to round to appropriate engineering units
Divide by 1000 to round to appropriate engineering units
Round to 3 significant digits
Assign proper string prefix
Print instantaneous value of voltage at 2nd breakdown
Read value of current at 2nd breakdown
Is current value < .1 ?
Yes
No
Multiply by 1000 to round to appropriate engineering units
Divide by 1000 to round to appropriate engineering units
Round to 3 significant digits
Assign proper string prefix
Print instantaneous value of current at 2nd breakdown
C5.12


C5.12
Read value of power at 2nd breakdown
Is power value < .1 ?
Yes
No
Multiply by 1000 to round to appropriate engineering units
Divide by 1000 to round to appropriate engineering units
Round to 3 significant digits
Assign proper string prefix
Print instantaneous value of power at 2nd breakdown
Read value of energy at 2nd breakdown
Is energy value < .1 ?
Yes
No
Multiply by 1000 to round to appropriate engineering units
Divide by 1000 to round to appropriate engineering units
Round to 3 significant digits
Assign proper string prefix
Print instantaneous value of energy at 2nd breakdown
C5.13


C5.13
Read value of time at 2nd breakdown
Is time value < .1 ?
Yes
No
Multiply by 1000 to round to appropriate engineering units
Divide by 1000 to round to appropriate engineering units
Round to 3 significant digits
Assign proper string prefix
Print value of time at 2nd breakdown
Find time,To, for value of voltage at 10% of 2nd breakdown voltage
Is To value < .1 ?
Yes
No
Multiply by 1000 to round to appropriate engineering units
Divide by 1000 to round to appropriate engineering units
Round to 3 significant digits
Assign proper string prefix
Print time, To, for value of voltage at 10% of 2nd breakdown voltage
C5.14


C5.14
Read value of voltage at time, To
Is voltage at To value < .1 ?
Yes
No
Multiply by 1000 to round to appropriate engineering units
Divide by 1000 to round to appropriate engineering units
Round to 3 significant digits
Assign proper string prefix
Print value of voltage at time, To
Read value of current at time, To
Is current at To value < .1 ?
Yes
No
Multiply by 1000 to round to appropriate engineering units
Divide by 1000 to round to appropriate engineering units
Round to 3 significant digits
Assign proper string prefix
Print value of current at time, To
C5.15

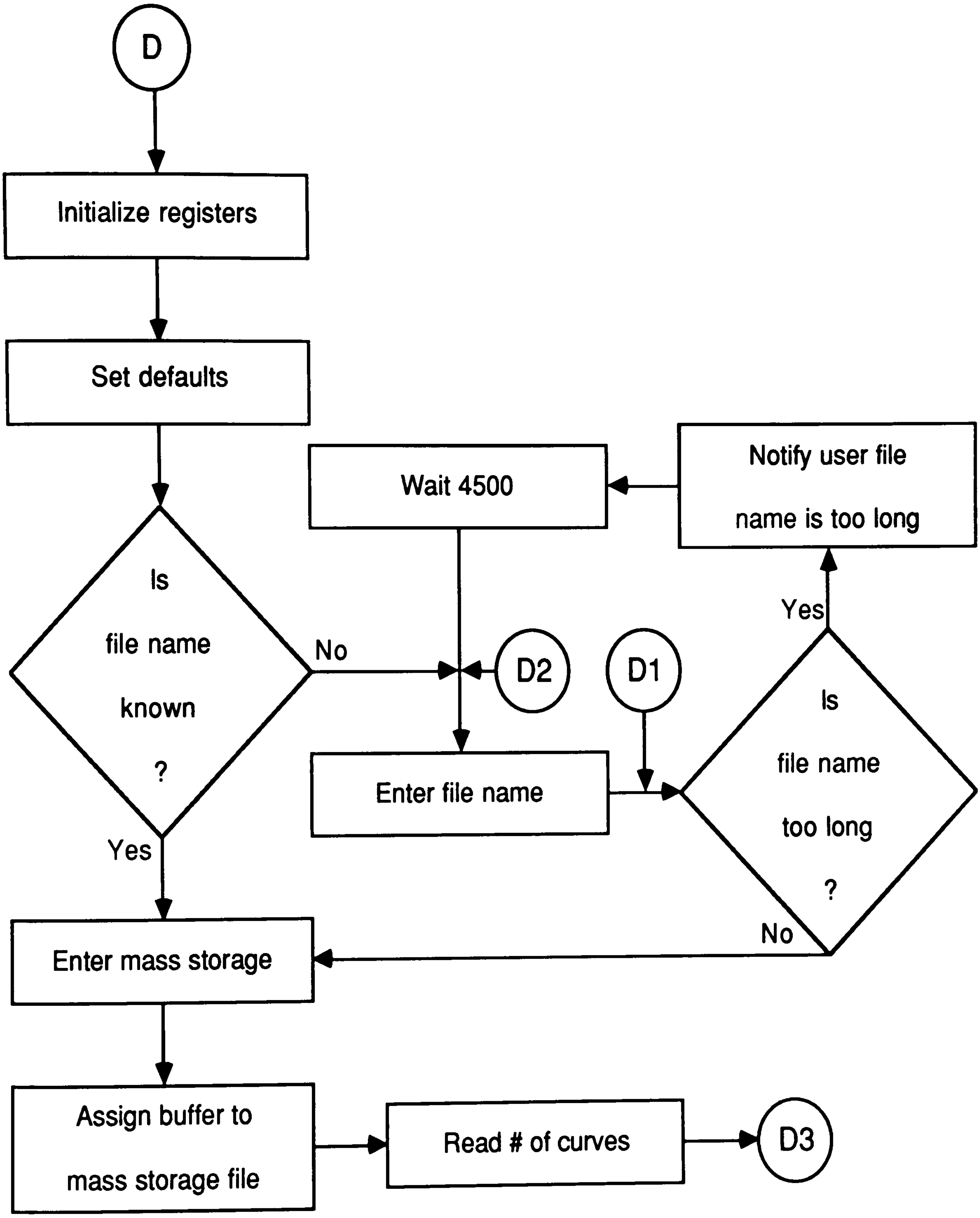

C5.15
Read value of power at time, To
Is power at To value < .1 ?
Yes
No
Multiply by 1000 to round to appropriate engineering units
Divide by 1000 to round to appropriate engineering units
Round to 3 significant digits
Assign proper string prefix
Print value of power at time, To
Read value of energy at time, To
Is energy at To value < .1 ?
Yes
No
Multiply by 1000 to round to appropriate engineering units
Divide by 1000 to round to appropriate engineering units
Round to 3 significant digits
Assign proper string prefix
Print value of energy at time, To
C5.16

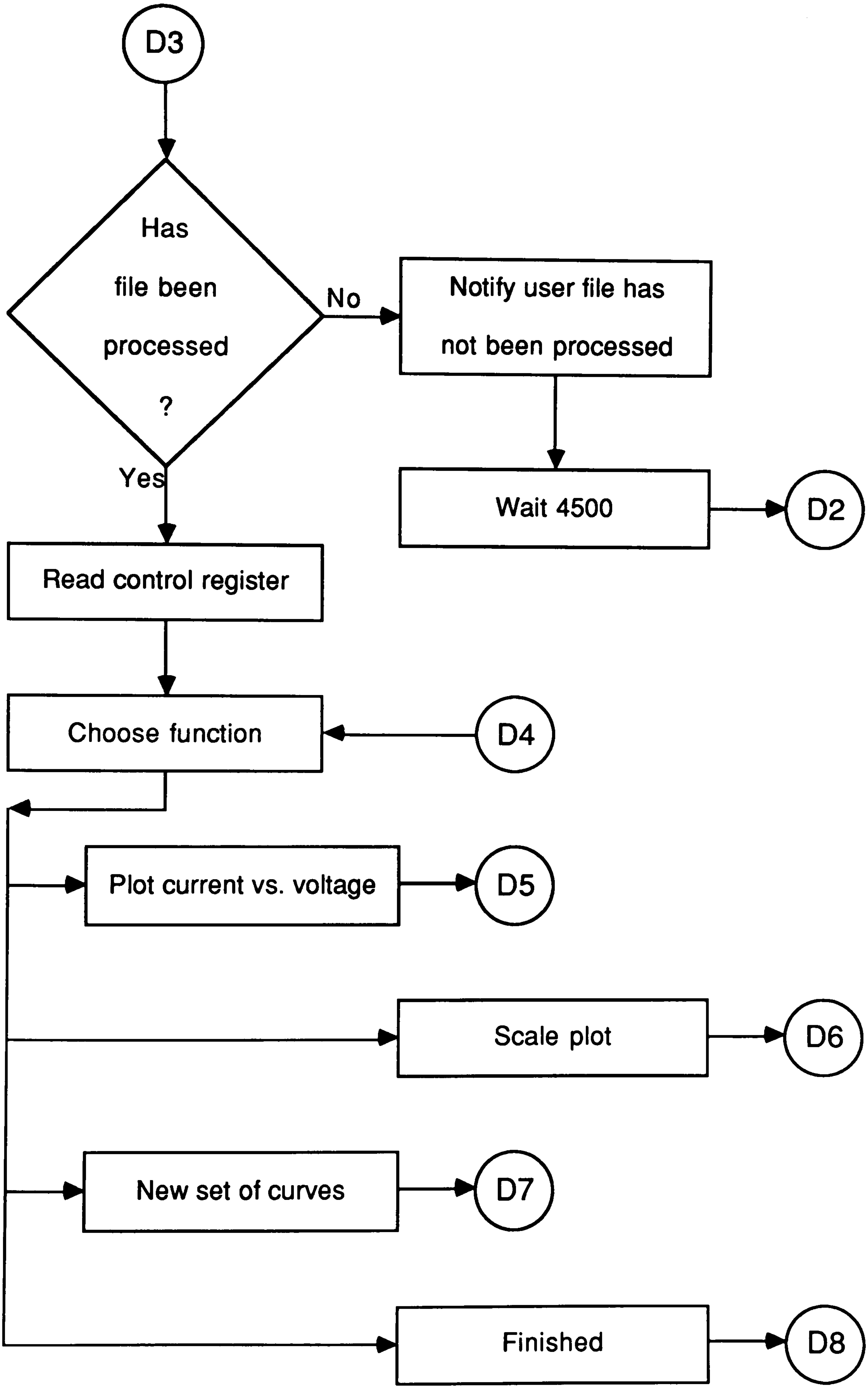

C5.16
Calculate time from To to 2nd breakdown
Is time from To to 2nd breakdown value < .1 ?
Yes
No
Multiply by 1000 to round to appropriate engineering units
Divide by 1000 to round to appropriate engineering units
Round to 3 significant digits
Assign proper string prefix
Print time from To to 2nd breakdown
Calculate change in energy from To to 2nd breakdown
Is change in energy from To to 2nd breakdown value < .1 ?
Yes
No
Multiply by 1000 to round to appropriate engineering units
Divide by 1000 to round to appropriate engineering units
Round to 3 significant digits
Assign proper string prefix
Print change in energy from To to 2nd breakdown
Take plotter out of print mode
C4

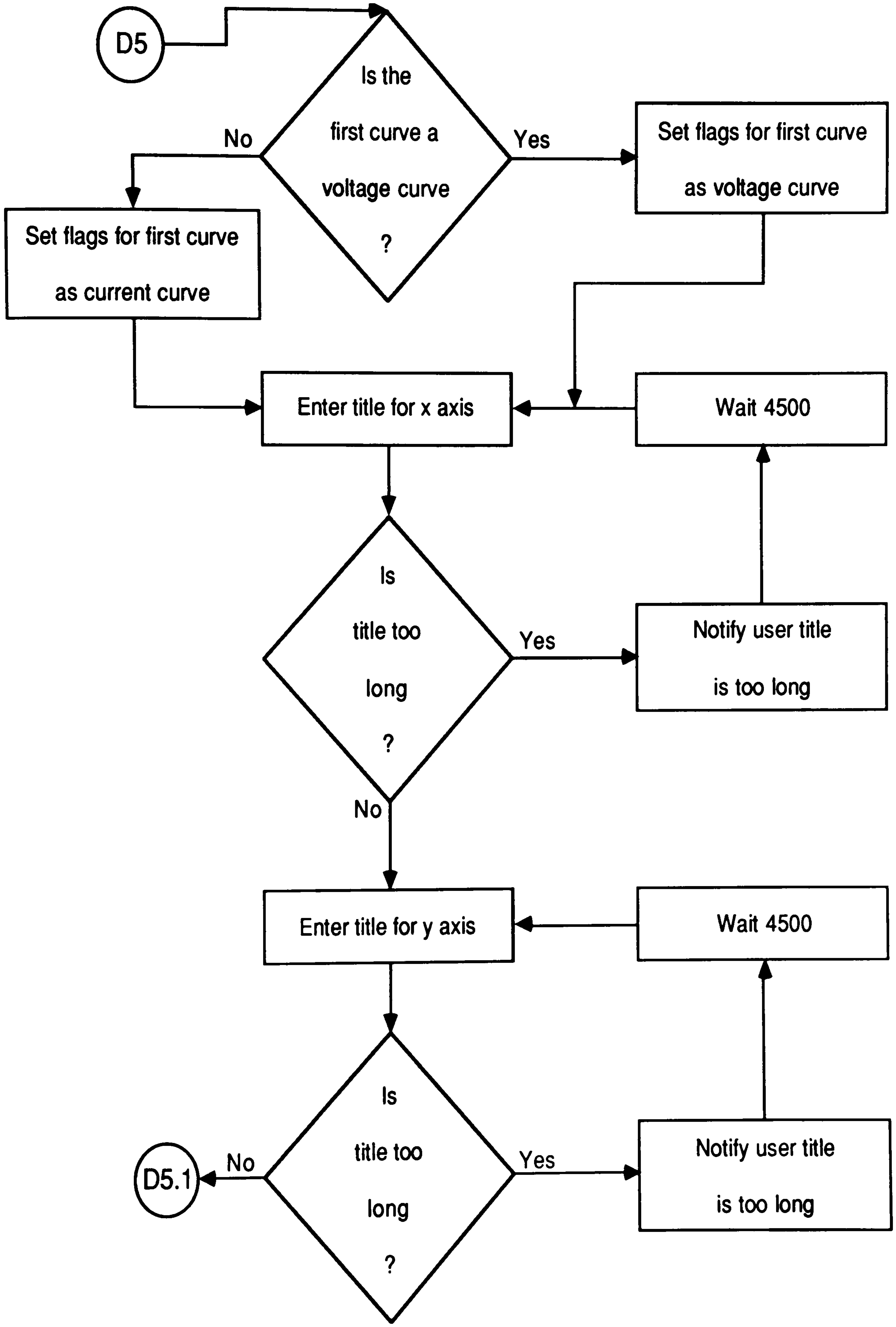
I-V

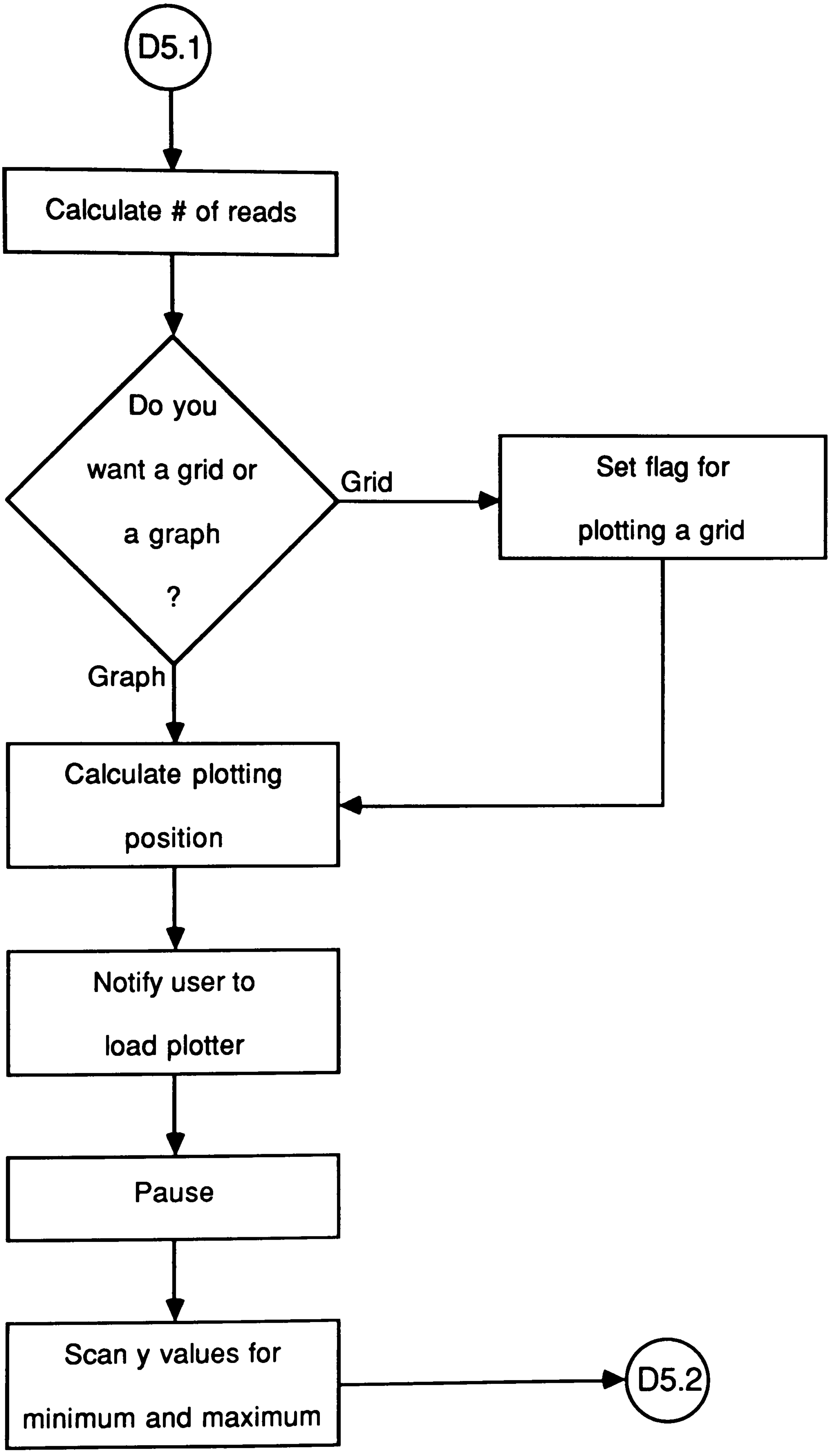
The I-V program generates a plot for current vs. voltage. The data is read into the computer and plotted using values calculated by the computer. The program scans the given curve values, finds the minimum and maximum values, and plots the curve to fill 80% of the plotting area.

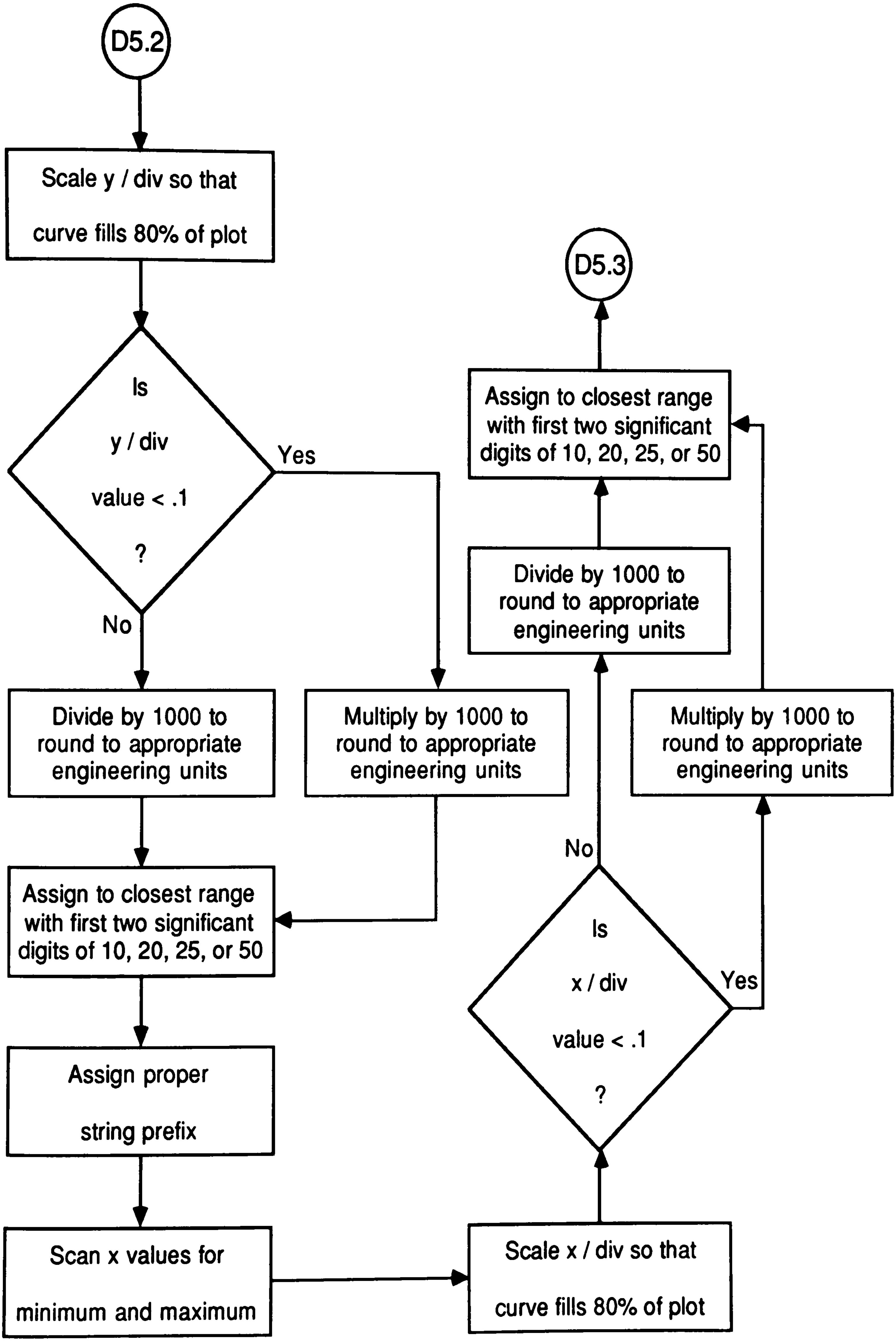
The I-V program allows the operator to scale the size of the plot, and to plot the curves on either a grid or an open graph.

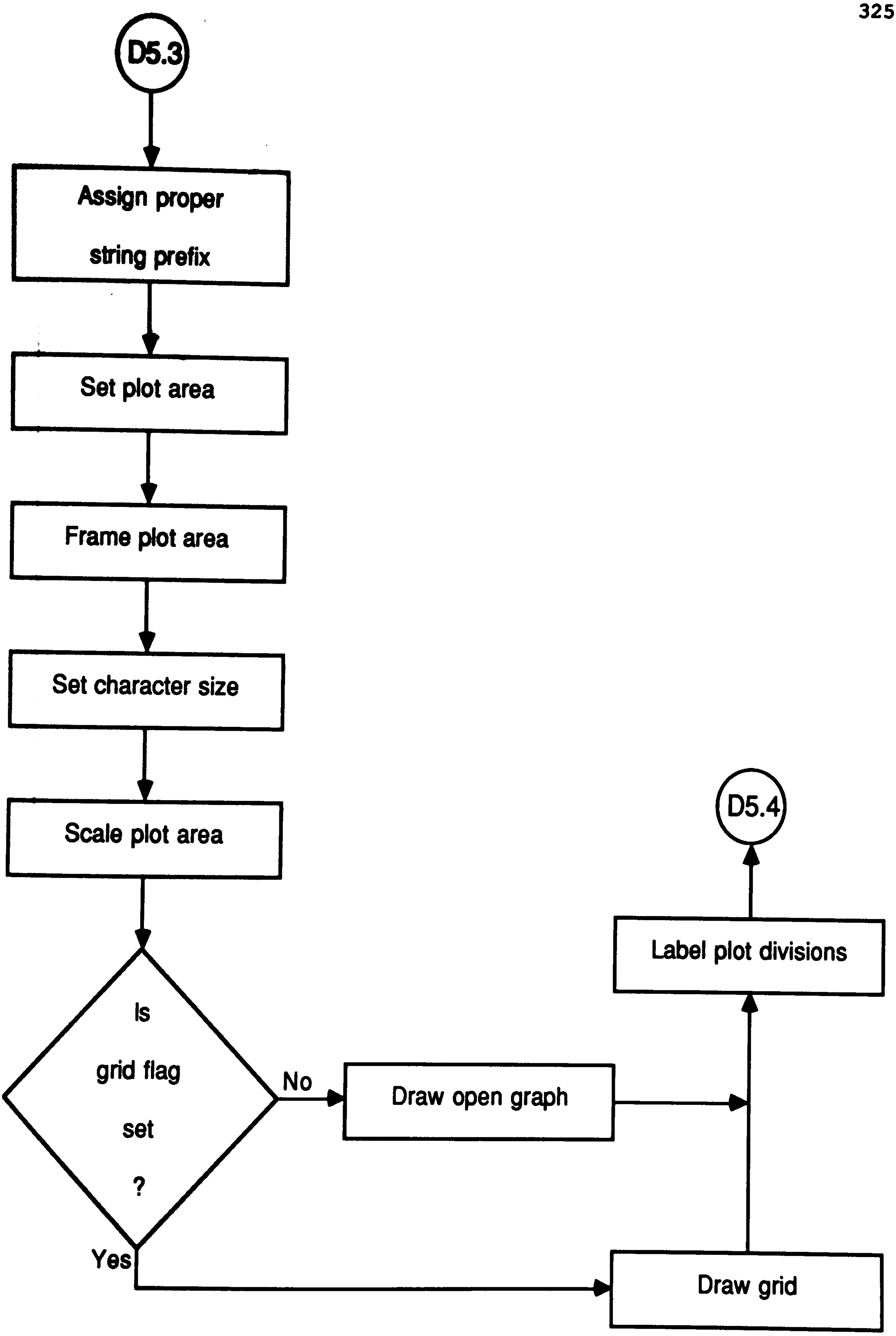

D
Initialize registers
Set defaults
Is file name known ?
No
Yes
Wait 4500
Notify user file name is too long
D2
D1
Enter file name
Is file name too long ?
Yes
No
Enter mass storage
Assign buffer to mass storage file
Read # of curves
D3

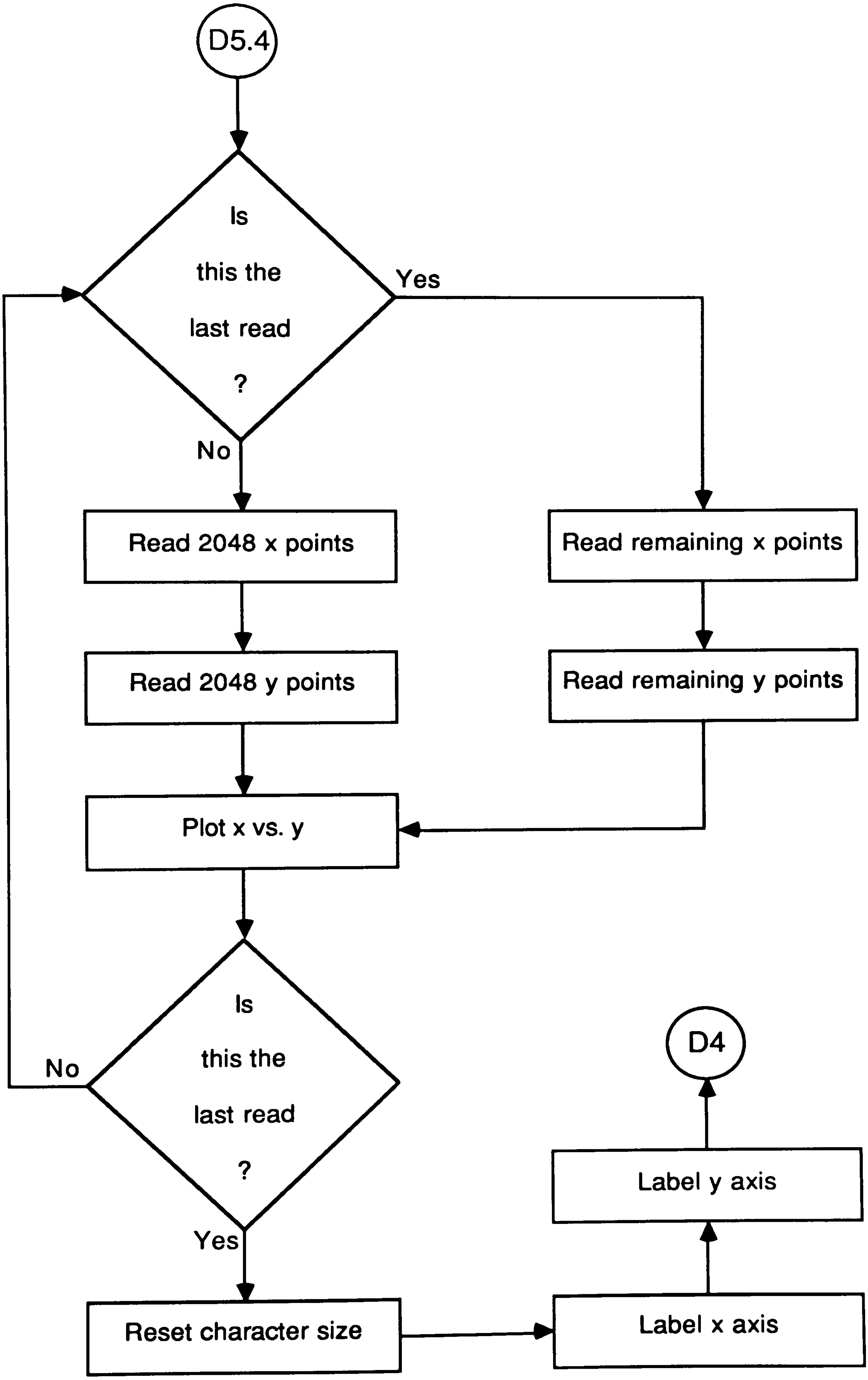

D3
Has file been processed ?
No
Yes
Notify user file has not been processed
Wait 4500
D2
Read control register
Choose function
D4
Plot current vs. voltage
D5
Scale plot
D6
New set of curves
D7
Finished
D8

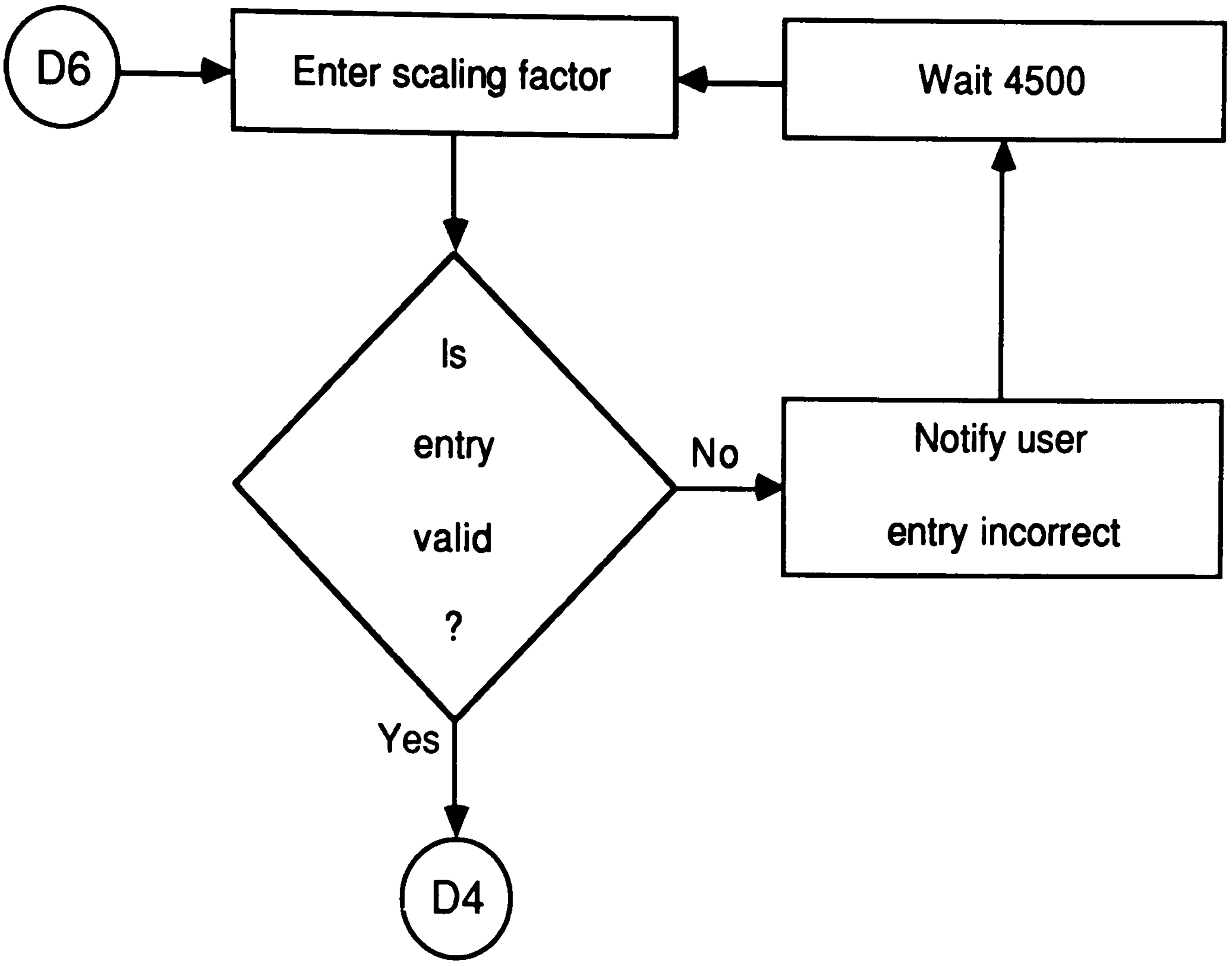

D5
Is the first curve a voltage curve ?
No
Yes
Set flags for first curve as voltage curve
Set flags for first curve as current curve
Enter title for x axis
Wait 4500
Is title too long ?
Yes
Notify user title is too long
No
Enter title for y axis
Wait 4500
Is title too long ?
No
D5.1
Yes
Notify user title is too long

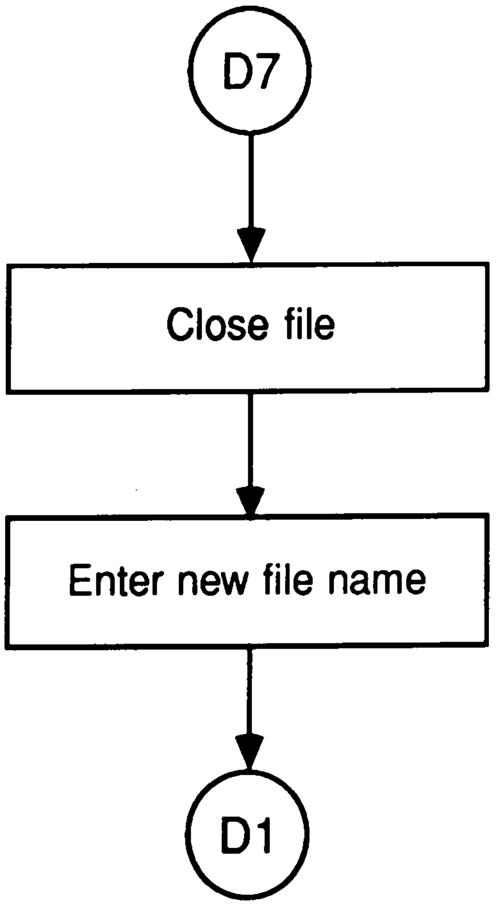

D5.1
Calculate # of reads
Do you want a grid or a graph ?
Grid
Set flag for plotting a grid
Graph
Calculate plotting position
Notify user to load plotter
Pause
Scan y values for minimum and maximum
D5.2

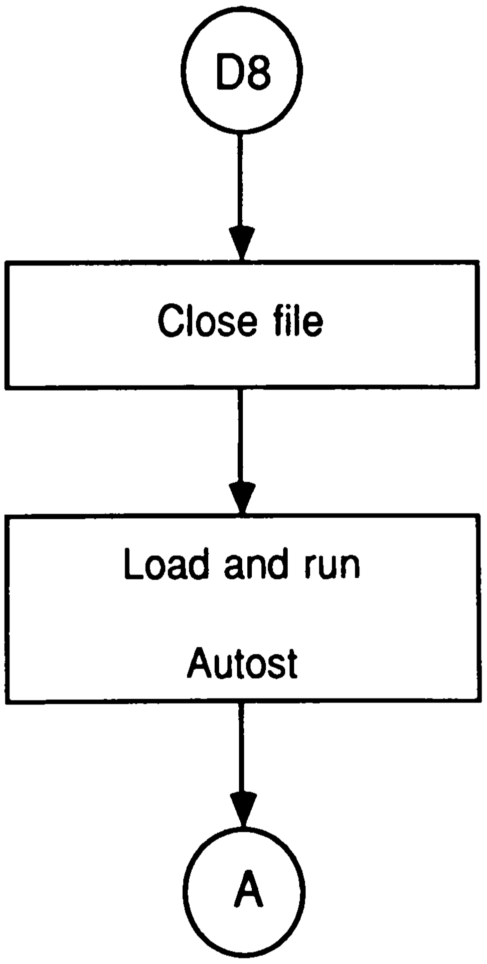

D5.2
Scale y / div so that curve fills 80% of plot
Is y / div value < .1 ?
Yes
No
Divide by 1000 to round to appropriate engineering units
Multiply by 1000 to round to appropriate engineering units
Assign to closest range with first two significant digits of 10, 20, 25, or 50
Assign proper string prefix
Scan x values for minimum and maximum
Scale x / div so that curve fills 80% of plot
Is x / div value < .1 ?
No
Yes
Divide by 1000 to round to appropriate engineering units
Multiply by 1000 to round to appropriate engineering units
Assign to closest range with first two significant digits of 10, 20, 25, or 50
D5.3


D5.3
Assign proper string prefix
Set plot area
Frame plot area
Set character size
Scale plot area
Is grid flag set ?
No
Draw open graph
Yes
Draw grid
Label plot divisions
D5.4


D5.4
Is this the last read ?
Yes
No
Read 2048 x points
Read 2048 y points
Plot x vs. y
Read remaining x points
Read remaining y points
Is this the last read ?
No
Yes
Reset character size
Label x axis
Label y axis
D4


D6
Enter scaling factor
Wait 4500
Is entry valid ?
No
Notify user entry incorrect
Yes
D4

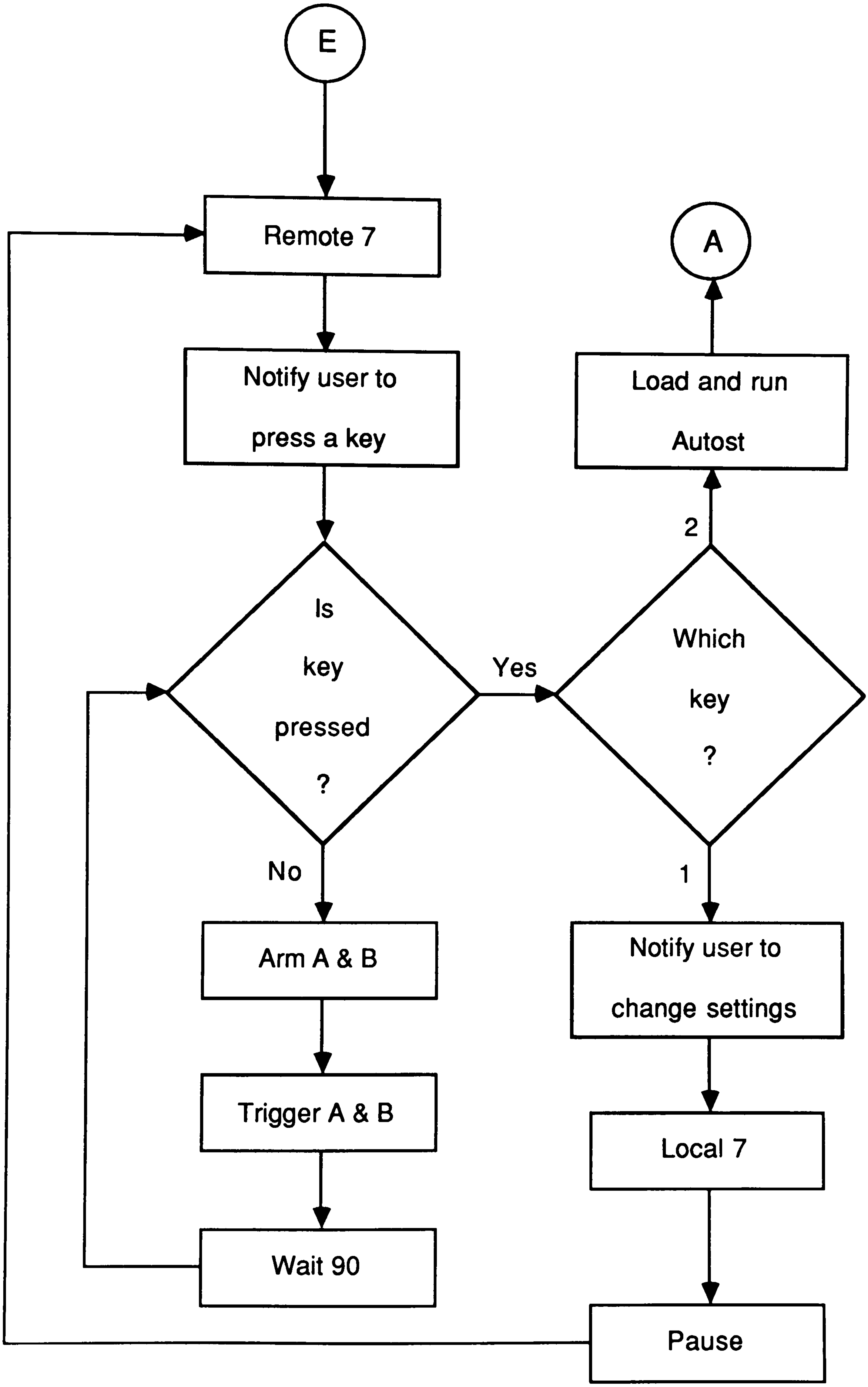

D7
Close file
Enter new file name
D1


D8
Close file
Load and run Autost
A

NORML

The Tektronix 7612D Programmable Digitizer was developed as a single-shot transient digitizer. Therefore, the NORML program was written to simulate a normal oscilloscope.

The NORML program continuously arms and triggers the Tektronix 7612D Programmable Digitizer to simulate a free-running state. To change settings on the digitizer, the operator pauses the program, makes the desired changes, and continues the program.

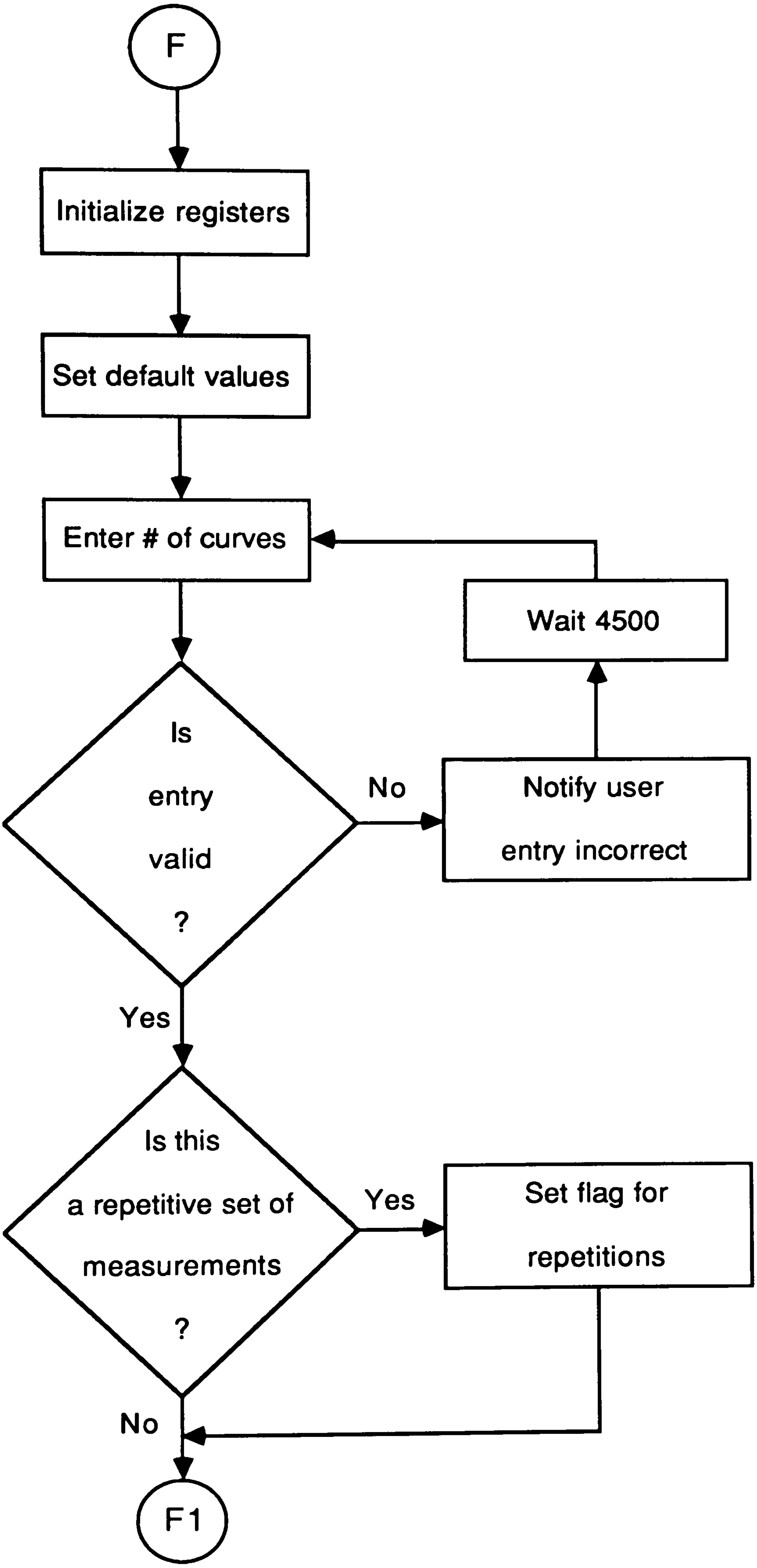

E
Remote 7
Notify user to press a key
Is key pressed ?
Yes
No
Arm A & B
Trigger A & B
Wait 90
Which key ?
2
1
Load and run Autost
A
Notify user to change settings
Local 7
Pause

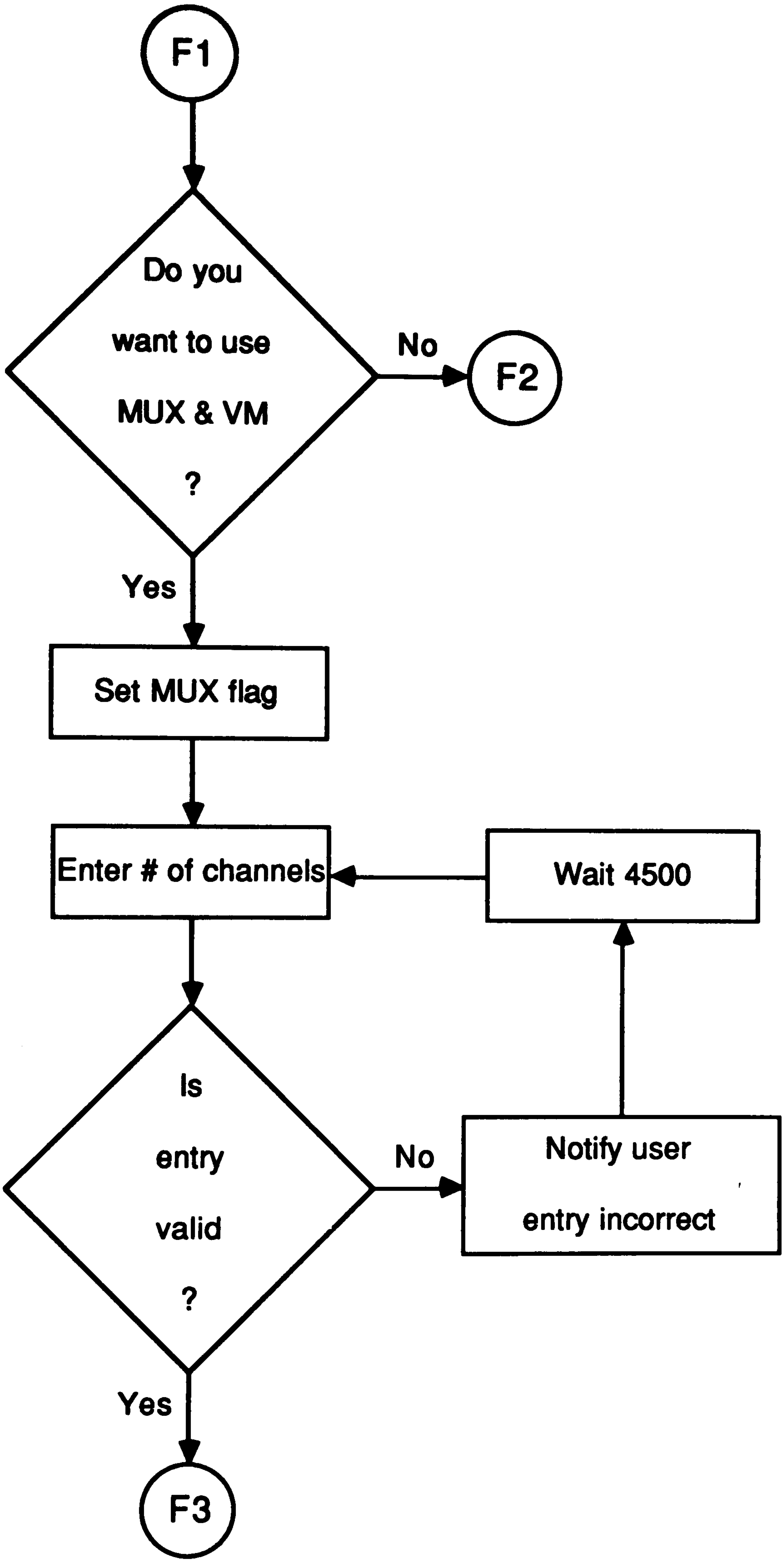
7612D

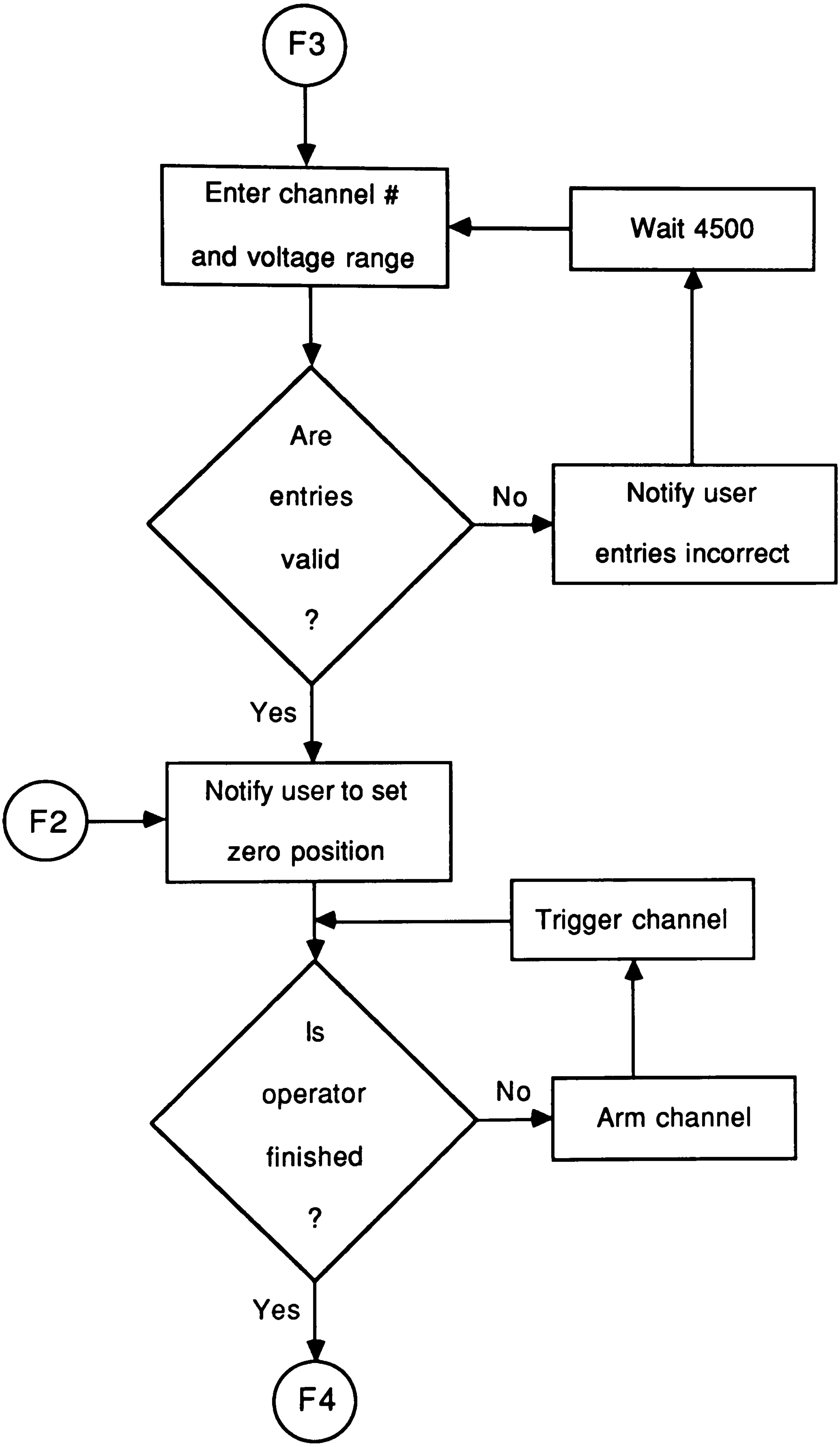
The 7612D program controls the Tektronix 7612D Programmable Digitizer and, if desired, the HP3497A Data Acquisition/Control Unit (DACU) and HP3437A Digital Voltmeter (DVM).

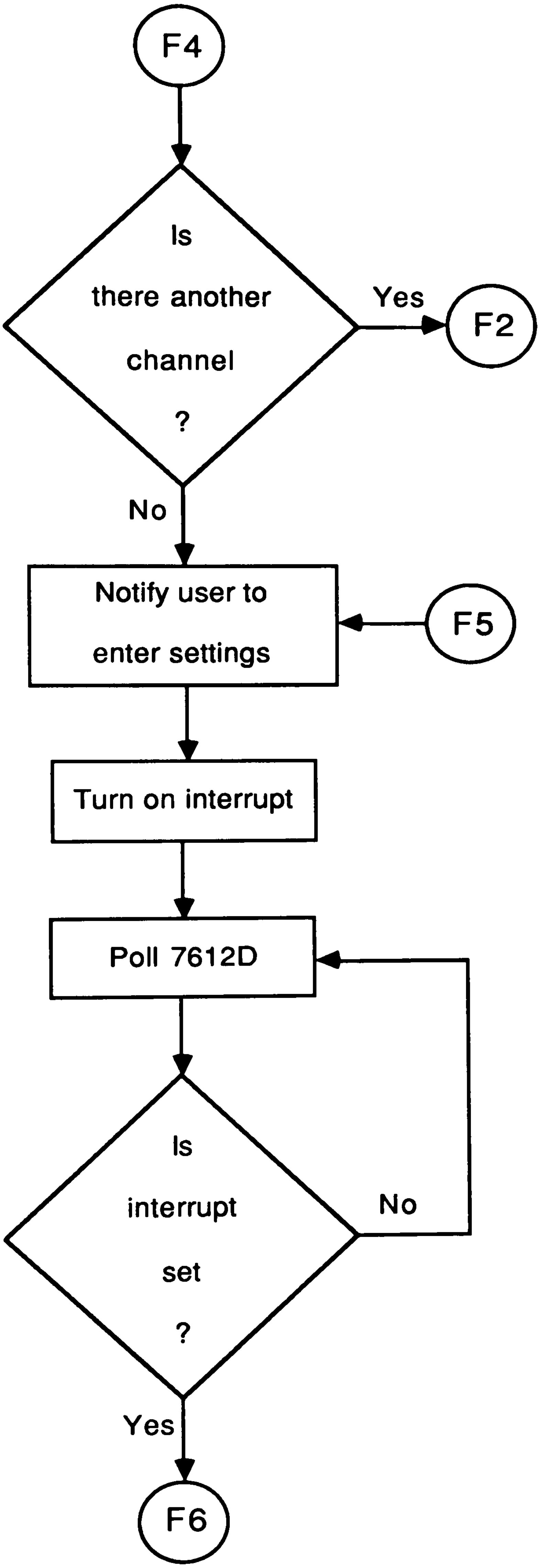
The digitizer is used to make up to two (2) 1024-point measurements. The operator enters the measurement settings on the front panel of the digitizer. The program loads these settings and asks the operator for verification. Then, the program arms the digitizer for a measurement. Once a good measurement is acquired, the program stores the data.

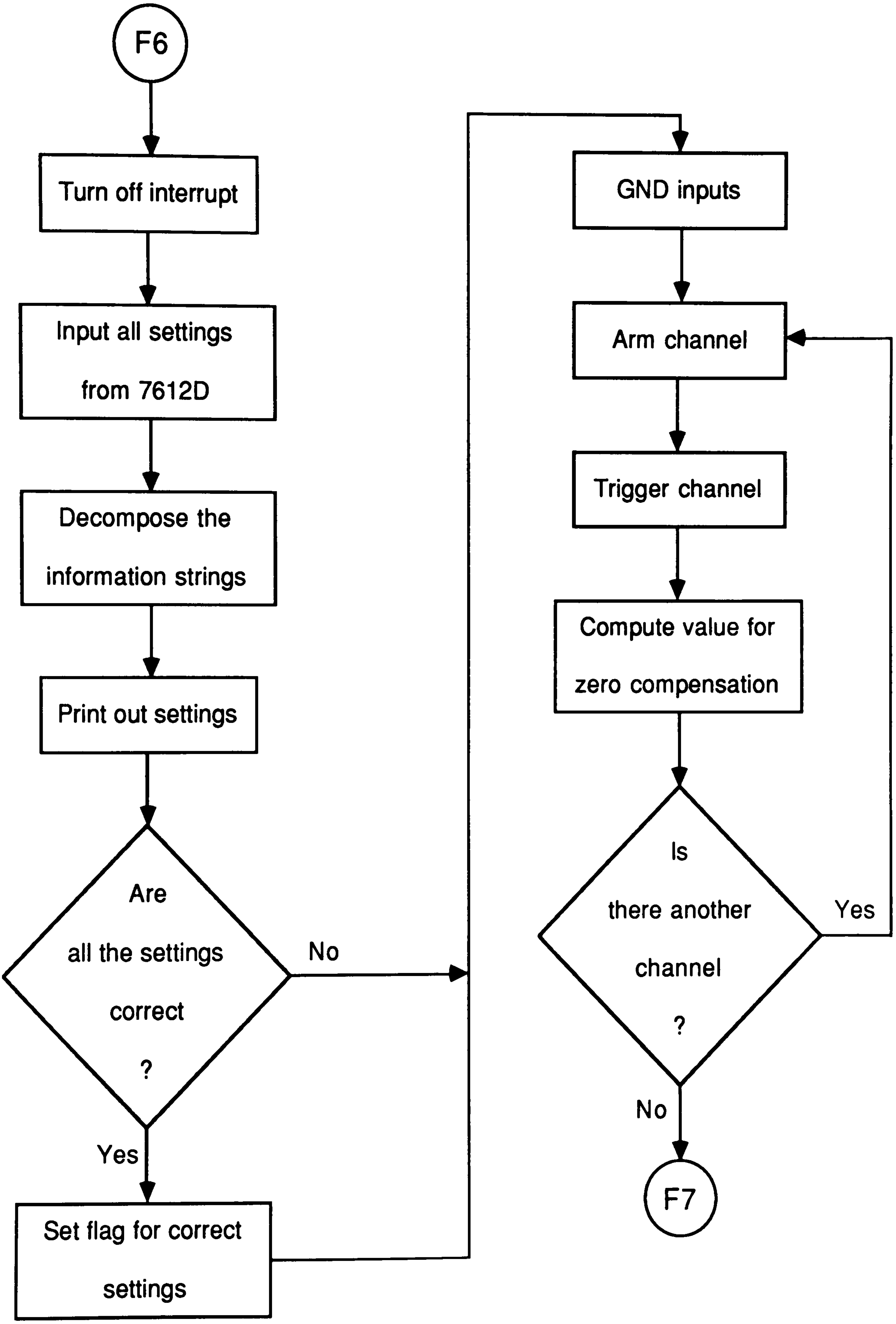
The DACU and DVM are used to take measurements of slower phenomena. They are used to make up to four (4) 16-point measurements. These instruments are used during the storage cycle of the program. This data is stored by the program, and, later, processed using the VMAUX program.

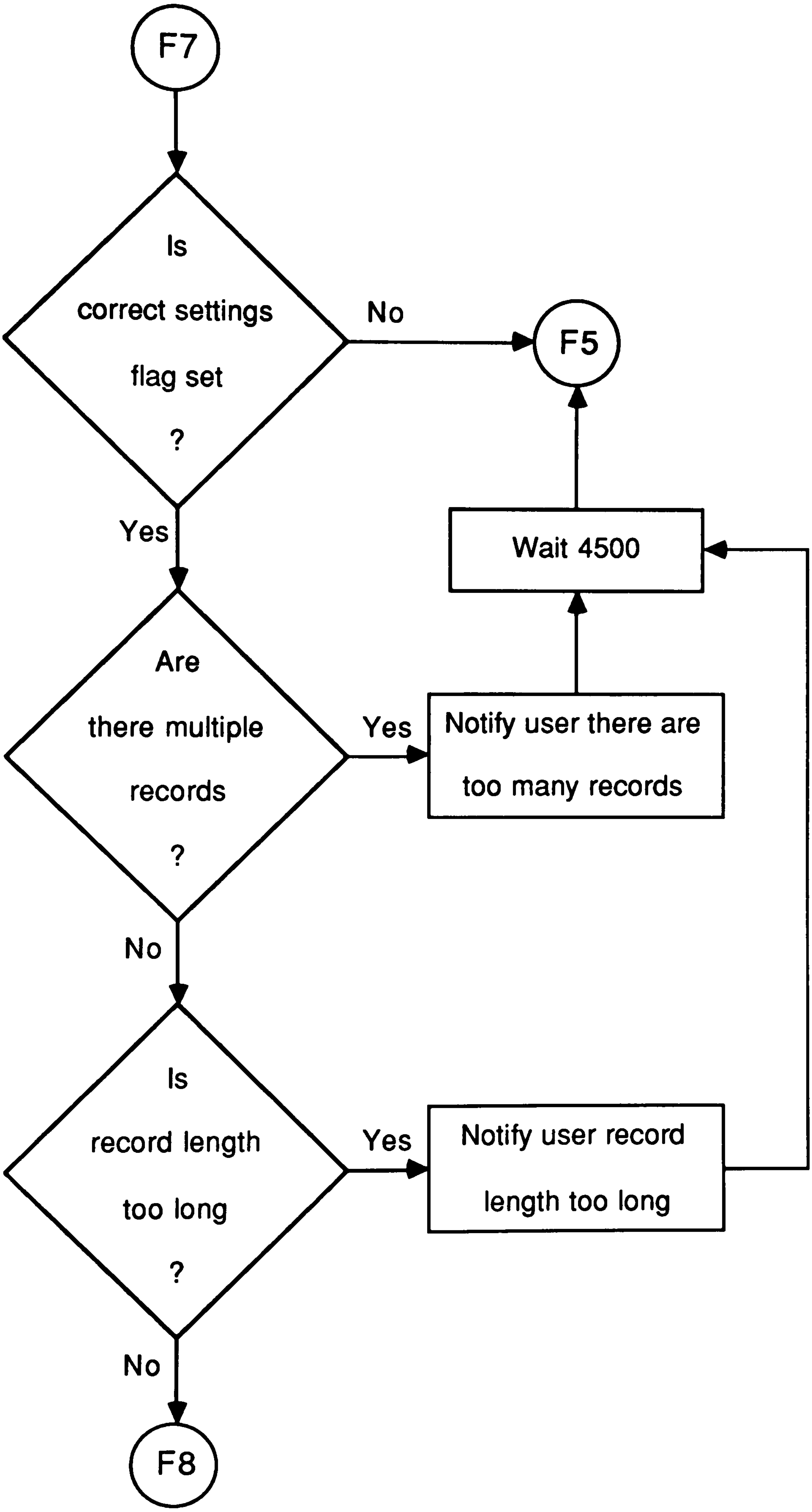

F
Initialize registers
Set default values
Enter # of curves
Wait 4500
Is
entry
valid
?
No
Notify user
entry incorrect
Yes
Is this
a repetitive set of
measurements
?
Yes
Set flag for
repetitions
No
F1

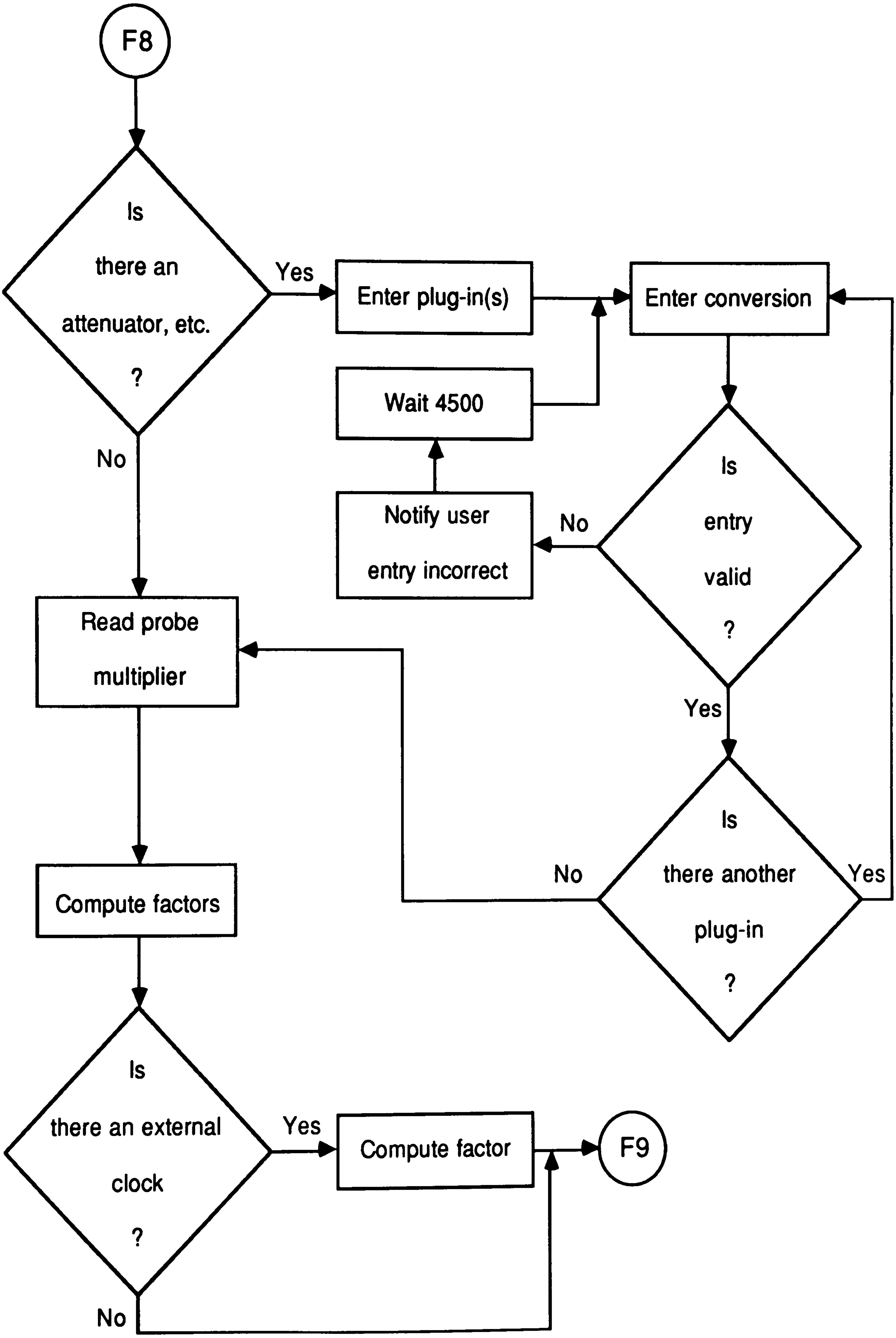

F1
Do you want to use MUX & VM ?
No
F2
Yes
Set MUX flag
Enter # of channels
Wait 4500
Is entry valid ?
No
Notify user entry incorrect
Yes
F3

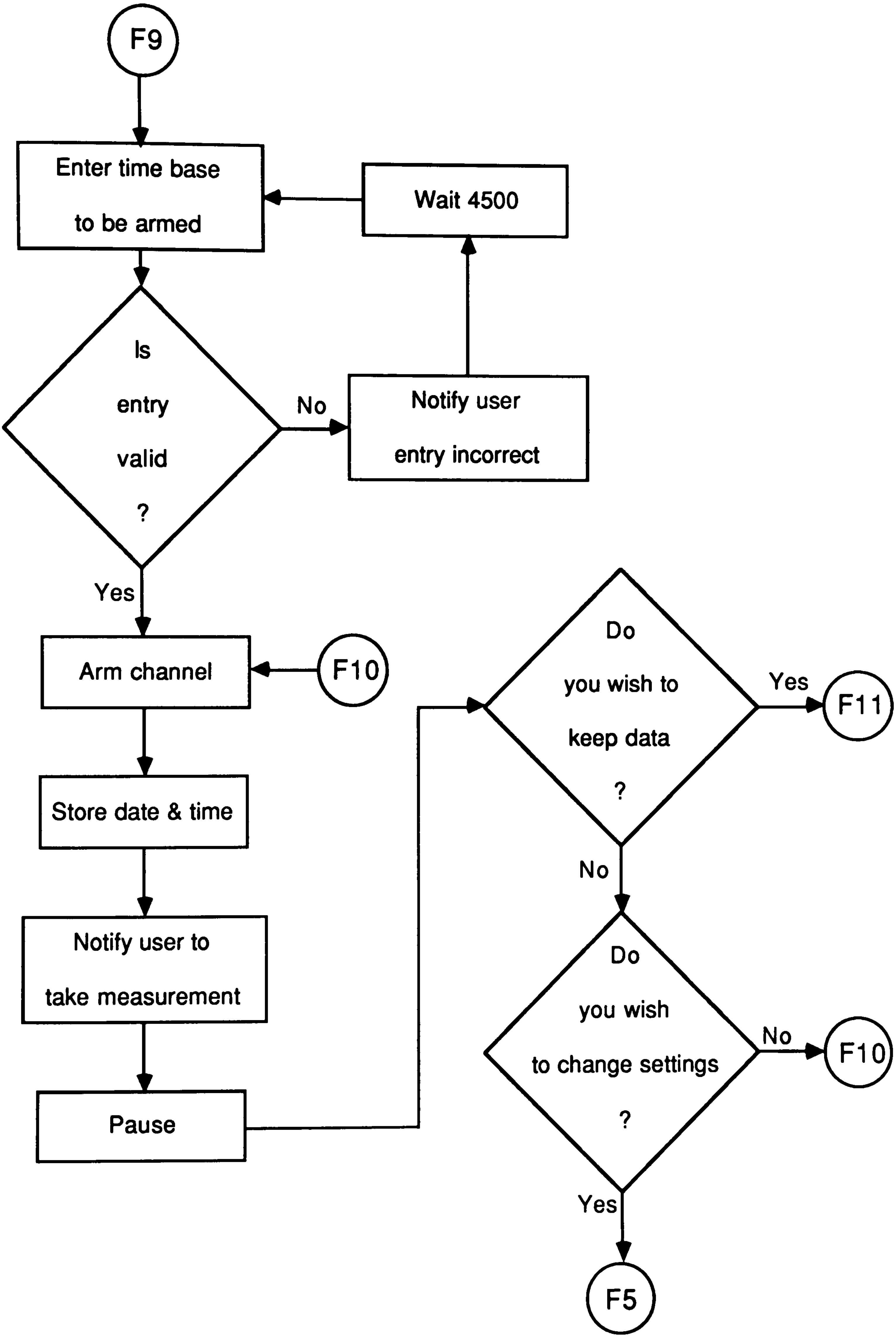

F3
Enter channel # and voltage range
Wait 4500
Are entries valid ?
No
Notify user entries incorrect
Yes
F2
Notify user to set zero position
Trigger channel
Is operator finished ?
No
Arm channel
Yes
F4

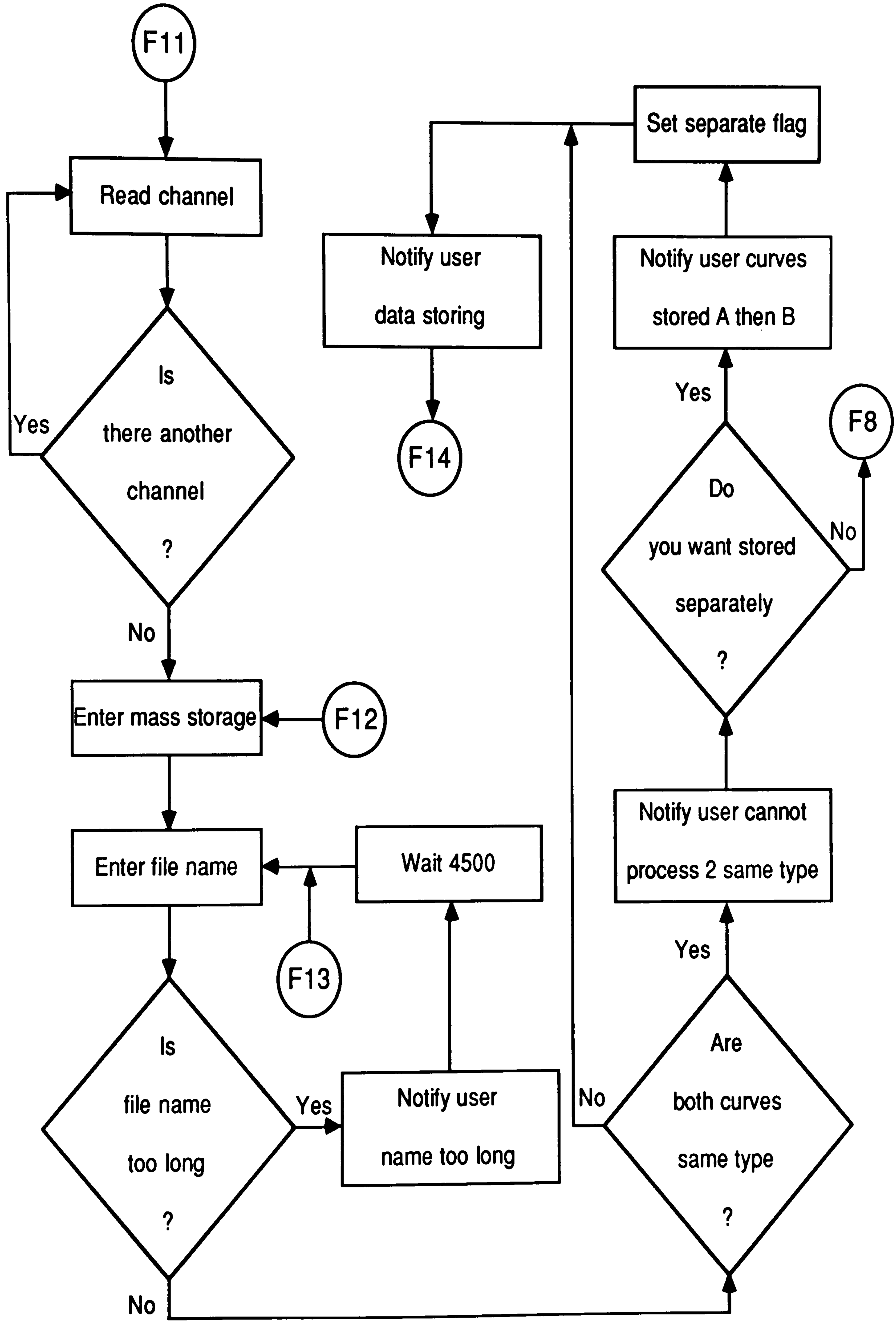

F4
Is there another channel ?
Yes
F2
No
Notify user to enter settings
F5
Turn on interrupt
Poll 7612D
Is interrupt set ?
No
Yes
F6

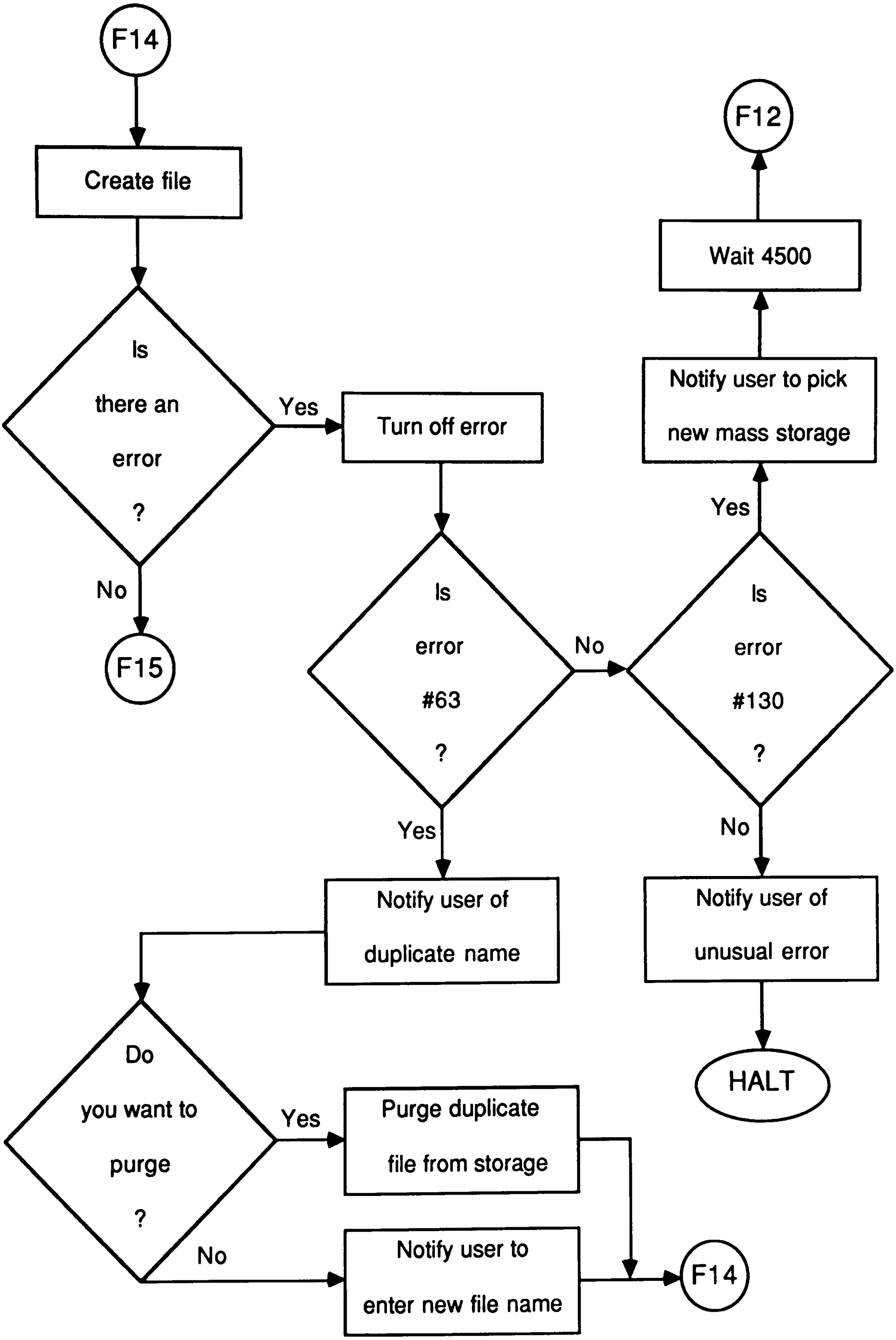

F6
Turn off interrupt
Input all settings from 7612D
Decompose the information strings
Print out settings
Are all the settings correct ?
No
Yes
Set flag for correct settings
GND inputs
Arm channel
Trigger channel
Compute value for zero compensation
Is there another channel ?
Yes
No
F7

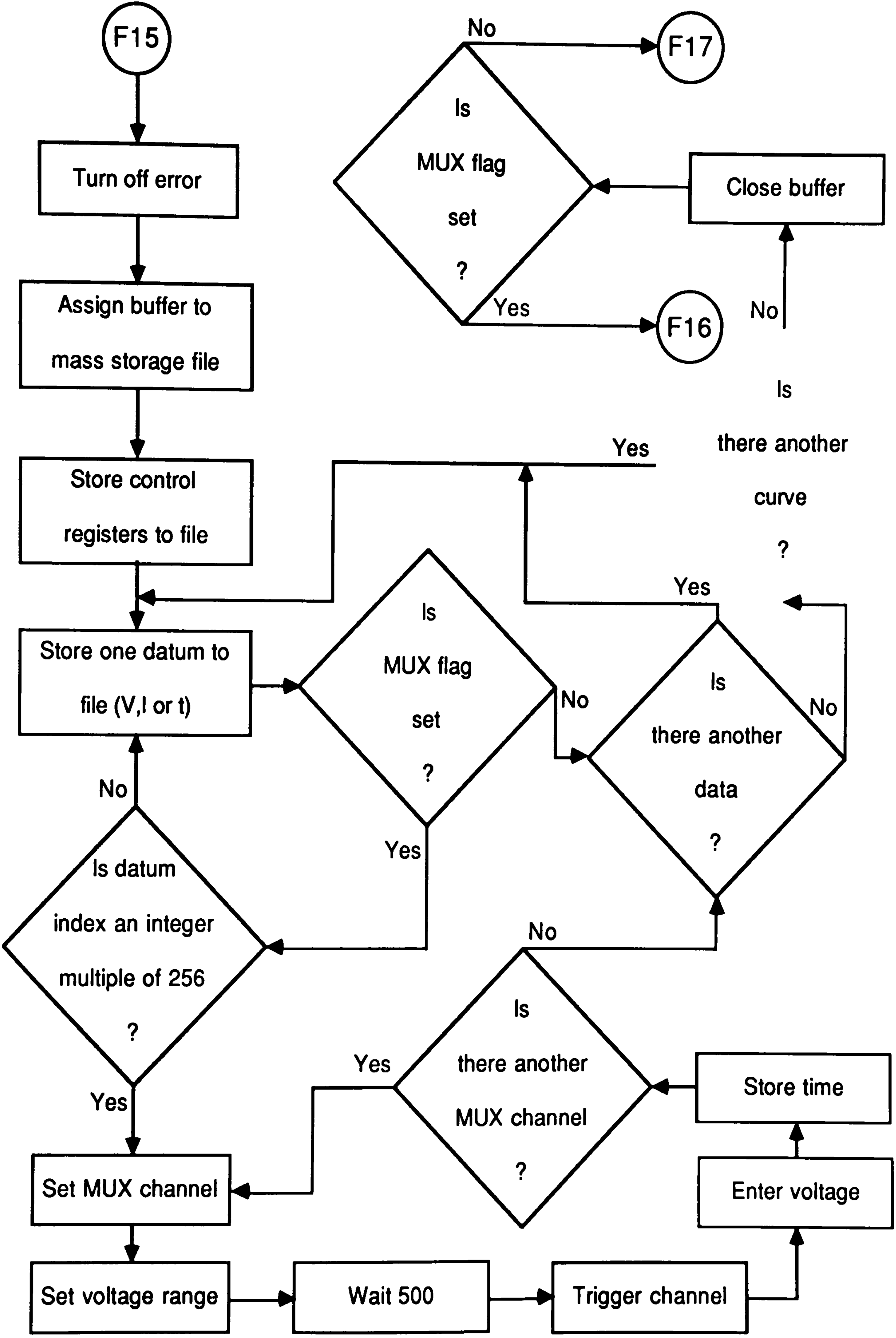

F7
Is correct settings flag set ?
No
F5
Yes
Wait 4500
Are there multiple records ?
Yes
Notify user there are too many records
No
Is record length too long ?
Yes
Notify user record length too long
No
F8

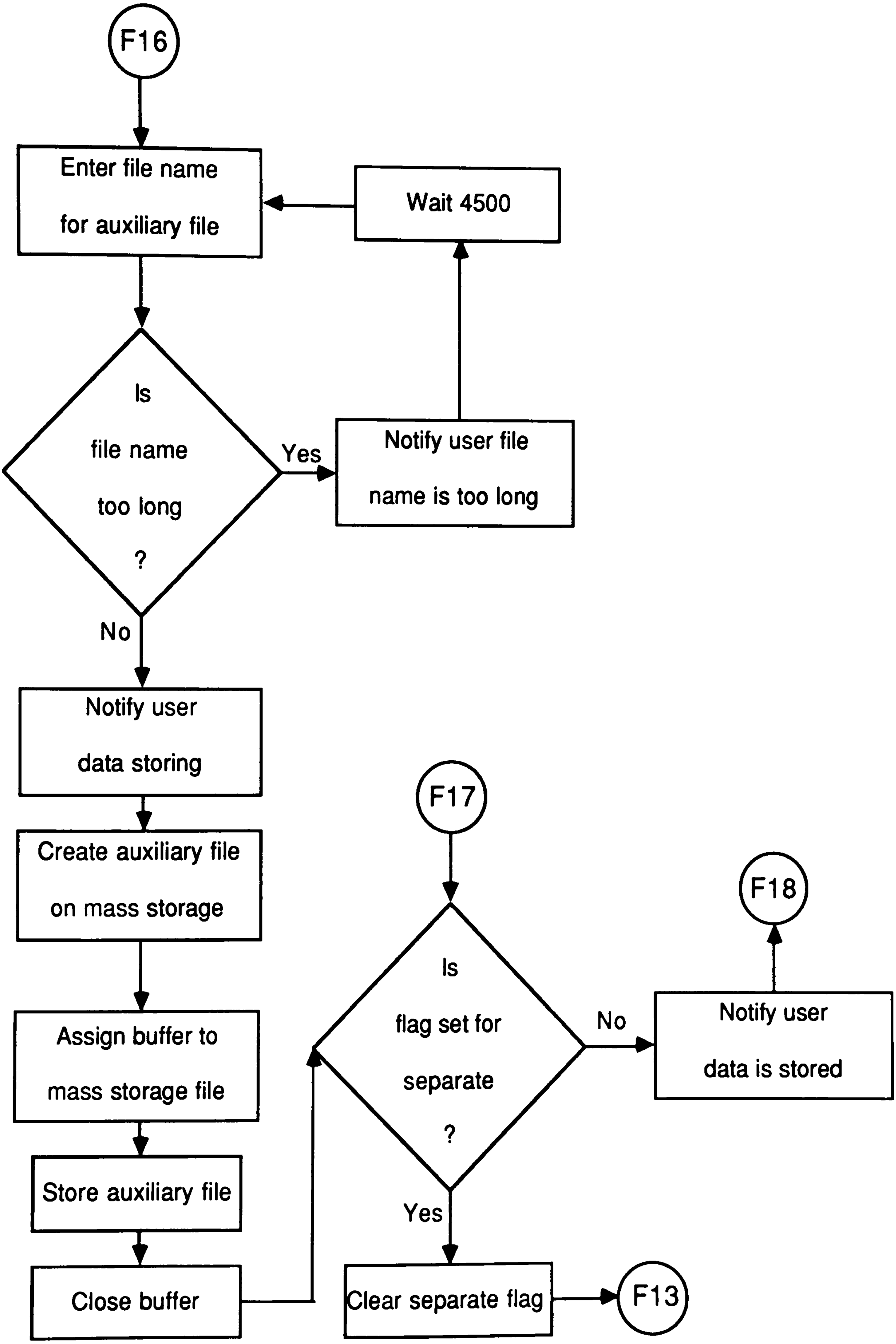

F8
Is there an attenuator, etc. ?
Yes
No
Enter plug-in(s)
Enter conversion
Wait 4500
Notify user entry incorrect
No
Is entry valid ?
Yes
Read probe multiplier
Is there another plug-in ?
No
Yes
Compute factors
Is there an external clock ?
Yes
Compute factor
F9
No

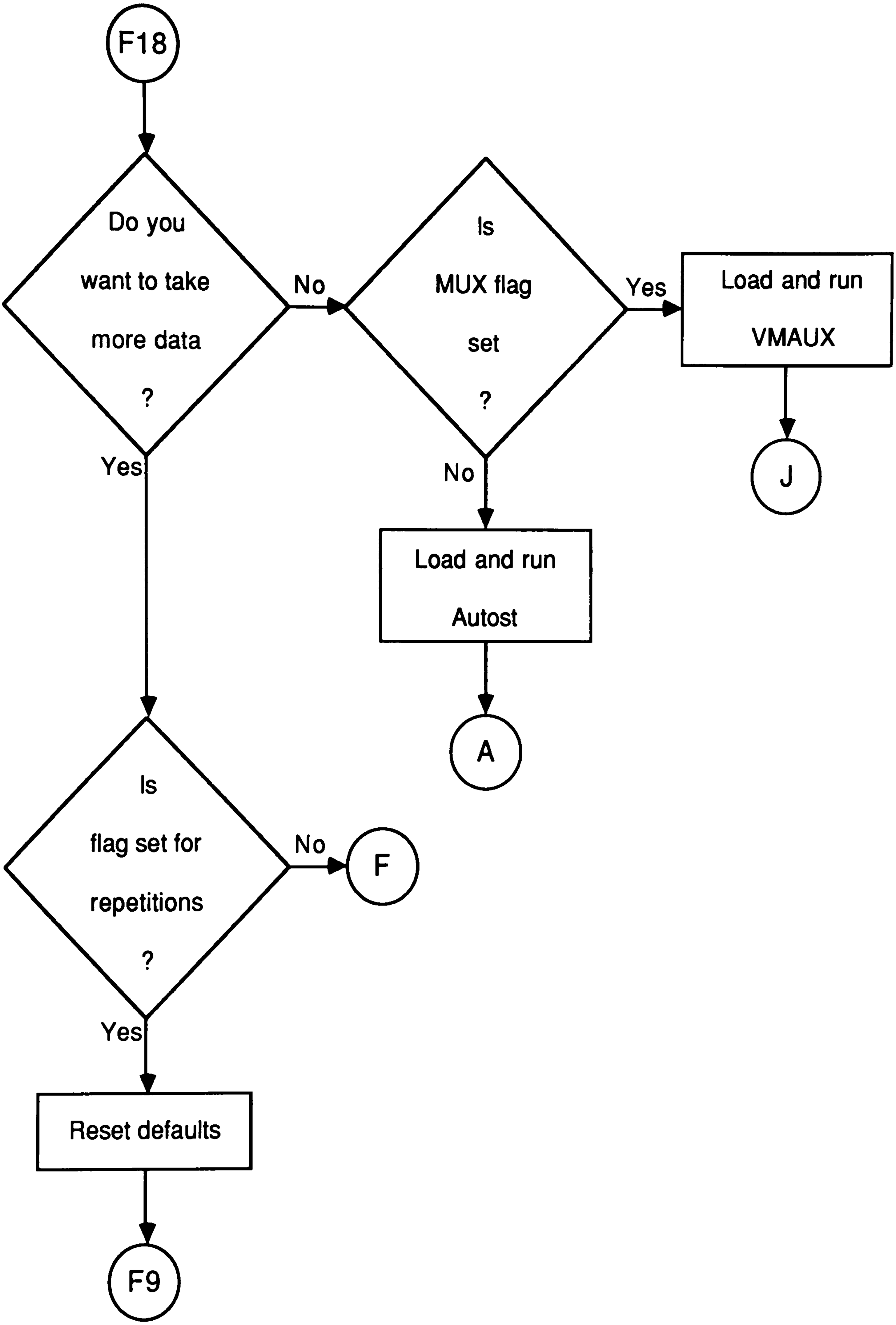

F9
Enter time base to be armed
Wait 4500
Is entry valid ?
No
Notify user entry incorrect
Yes
Arm channel
F10
Store date & time
Notify user to take measurement
Pause
Do you wish to keep data ?
Yes
F11
No
Do you wish to change settings ?
No
F10
Yes
F5


F11
Read channel
Is there another channel ?
Yes
No
Enter mass storage
F12
Enter file name
Wait 4500
F13
Is file name too long ?
Yes
Notify user name too long
No
Are both curves same type ?
No
Yes
Notify user cannot process 2 same type
Do you want stored separately ?
No
F8
Yes
Notify user curves stored A then B
Set separate flag
Notify user data storing
F14


F14
Create file
Is there an error ?
Yes
No
F15
Turn off error
Is error #63 ?
No
Yes
Notify user of duplicate name
Is error #130 ?
Yes
No
Notify user to pick new mass storage
Wait 4500
F12
Notify user of unusual error
HALT
Do you want to purge ?
Yes
No
Purge duplicate file from storage
Notify user to enter new file name
F14


F15
Turn off error
Assign buffer to mass storage file
Store control registers to file
Store one datum to file (V,I or t)
No
Is datum index an integer multiple of 256 ?
Yes
Set MUX channel
Set voltage range
Wait 500
Trigger channel
Enter voltage
Store time
Is there another MUX channel ?
Yes
No
Is MUX flag set ?
Yes
No
Is there another data ?
Yes
No
Yes
Is there another curve ?
No
Close buffer
Is MUX flag set ?
No
F17
Yes
F16


F16
Enter file name for auxiliary file
Wait 4500
Is file name too long ?
Yes
Notify user file name is too long
No
Notify user data storing
Create auxiliary file on mass storage
Assign buffer to mass storage file
Store auxiliary file
Close buffer
F17
Is flag set for separate ?
No
Notify user data is stored
F18
Yes
Clear separate flag
F13

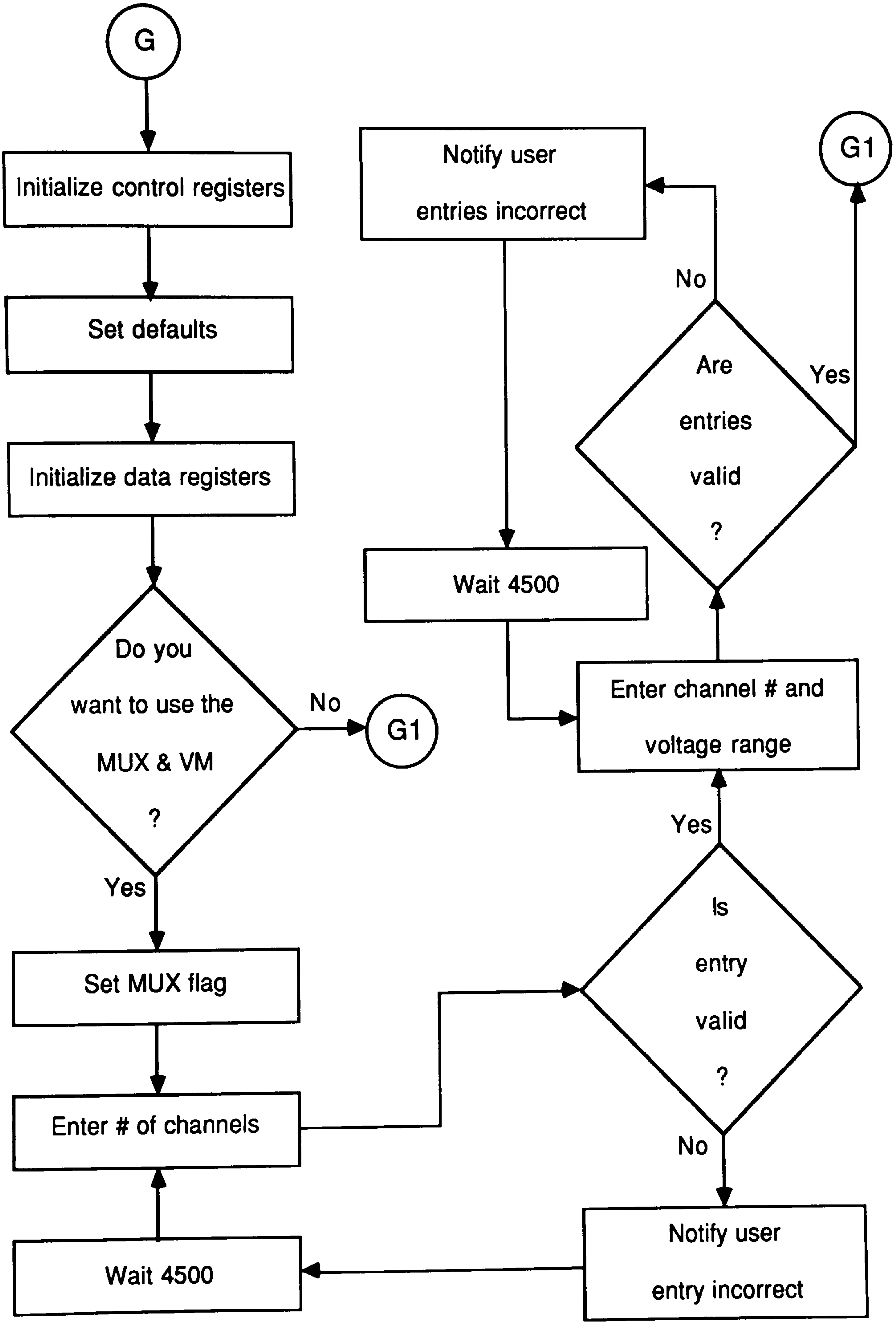

F18
Do you want to take more data ?
No
Yes
Is MUX flag set ?
Yes
No
Load and run VMAUX
J
Load and run Autost
A
Is flag set for repetitions ?
No
F
Yes
Reset defaults
F9

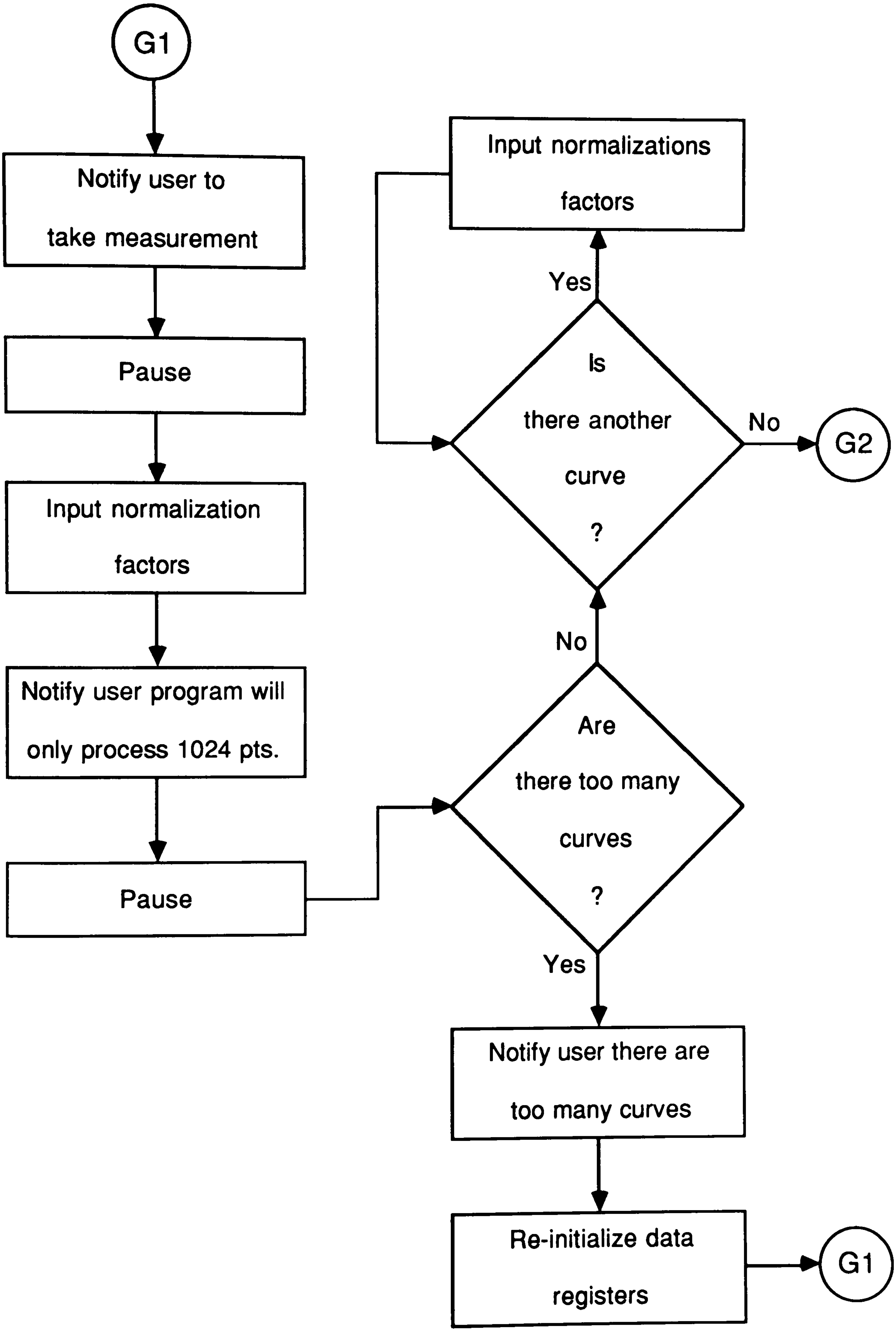
NIC85

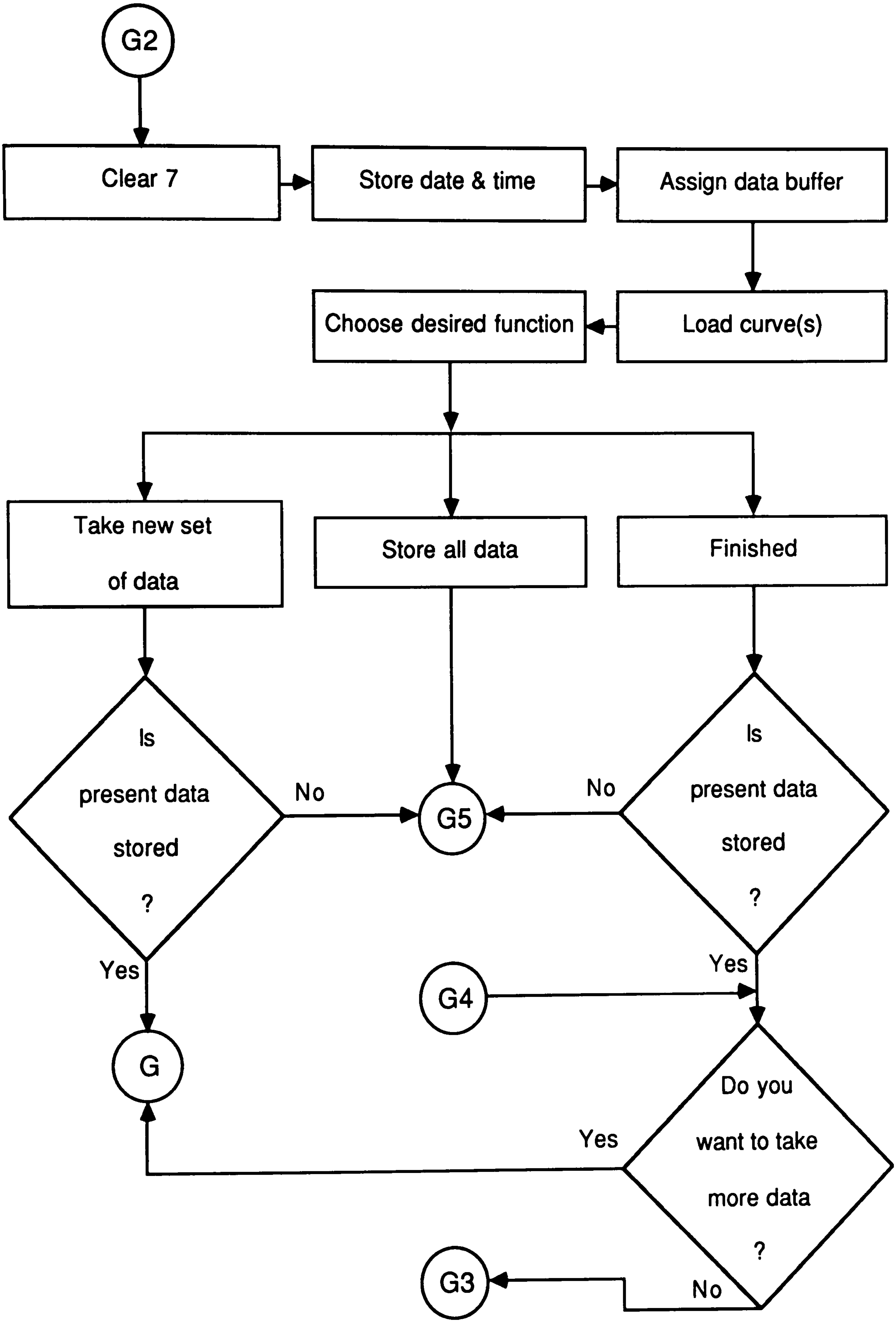
The NIC85 program is a highly modified version of a software package purchased from Software Consulting Group of Santa Clara, California. The program controls the Nicolet 2090-III Digital Oscilloscope and, if desired, the HP3497A Data Acquisition/Control Unit (DACU) and HP3437A Digital Voltmeter (DVM).

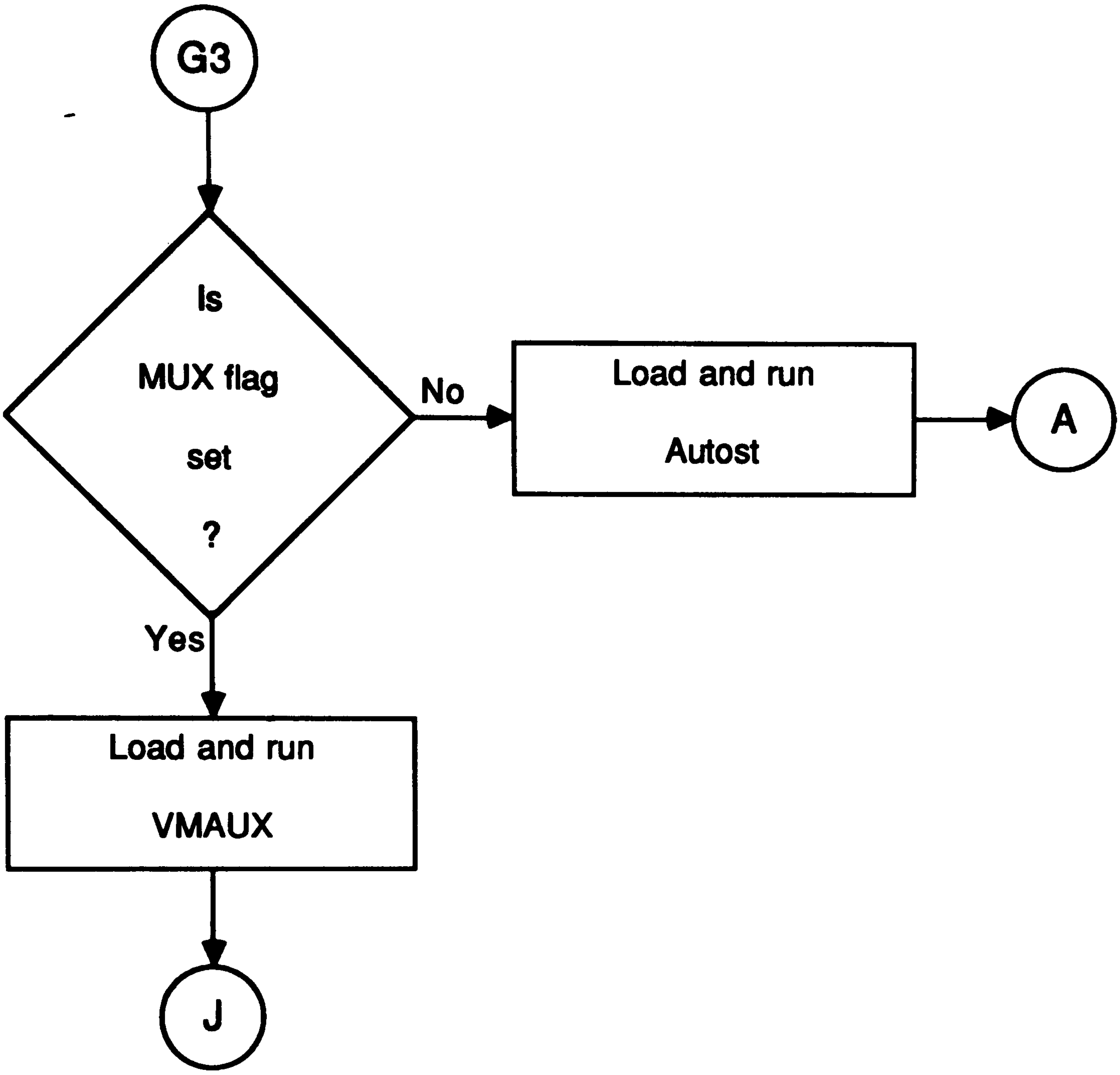
The oscilloscope is used to make up to four (4) 1024-point measurements. The operator takes the measurements using the oscilloscope. Once a good measurement is acquired, the program stores the curves in pairs. These pairs are selected by the operator.

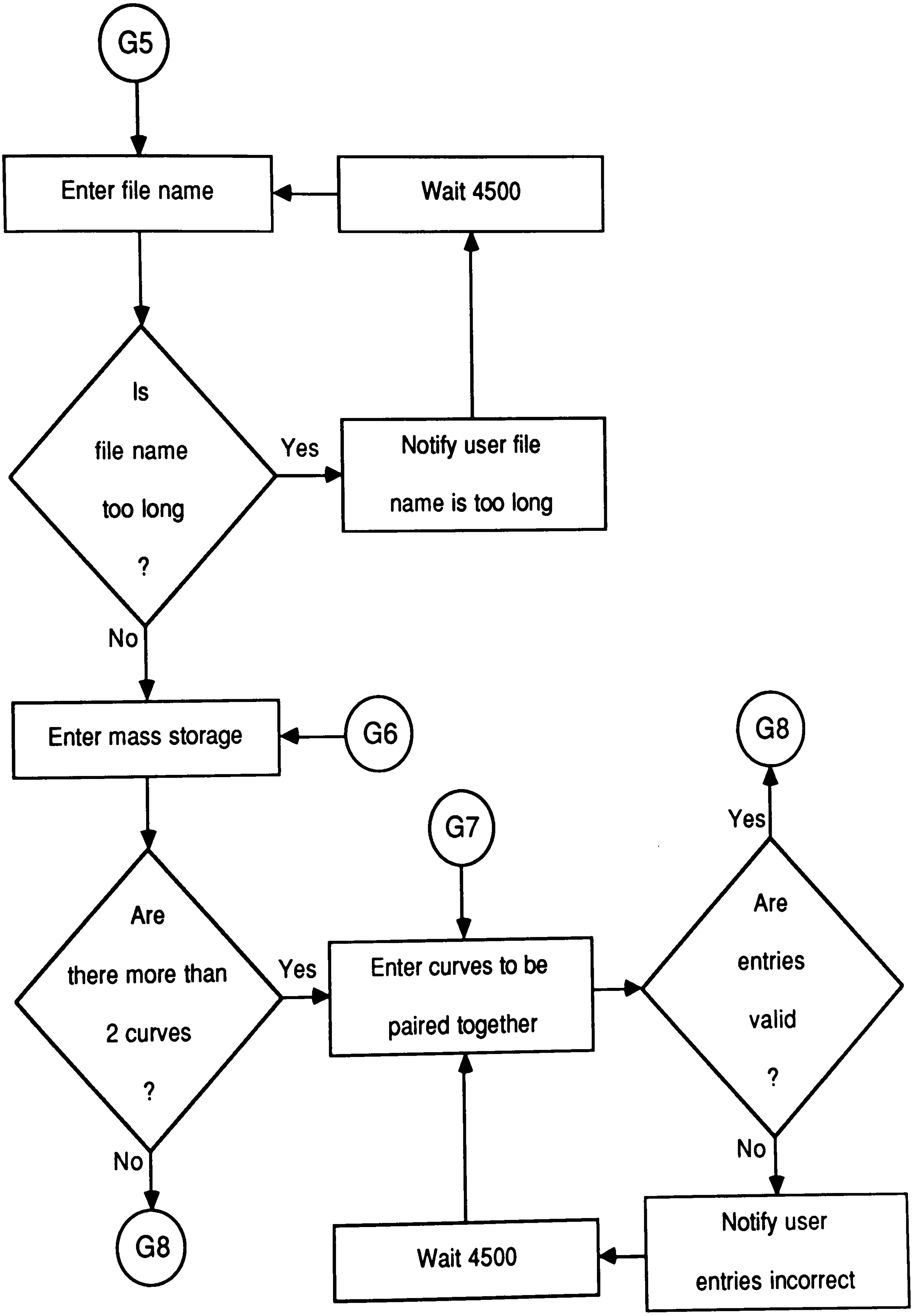
The DACU and DVM are used to take measurements of slower phenomena. They are used to make up to four (4) 16-point measurements. These instruments are used during the storage cycle of the program. This data is stored by the program, and, later, processed using the VMAUX program.

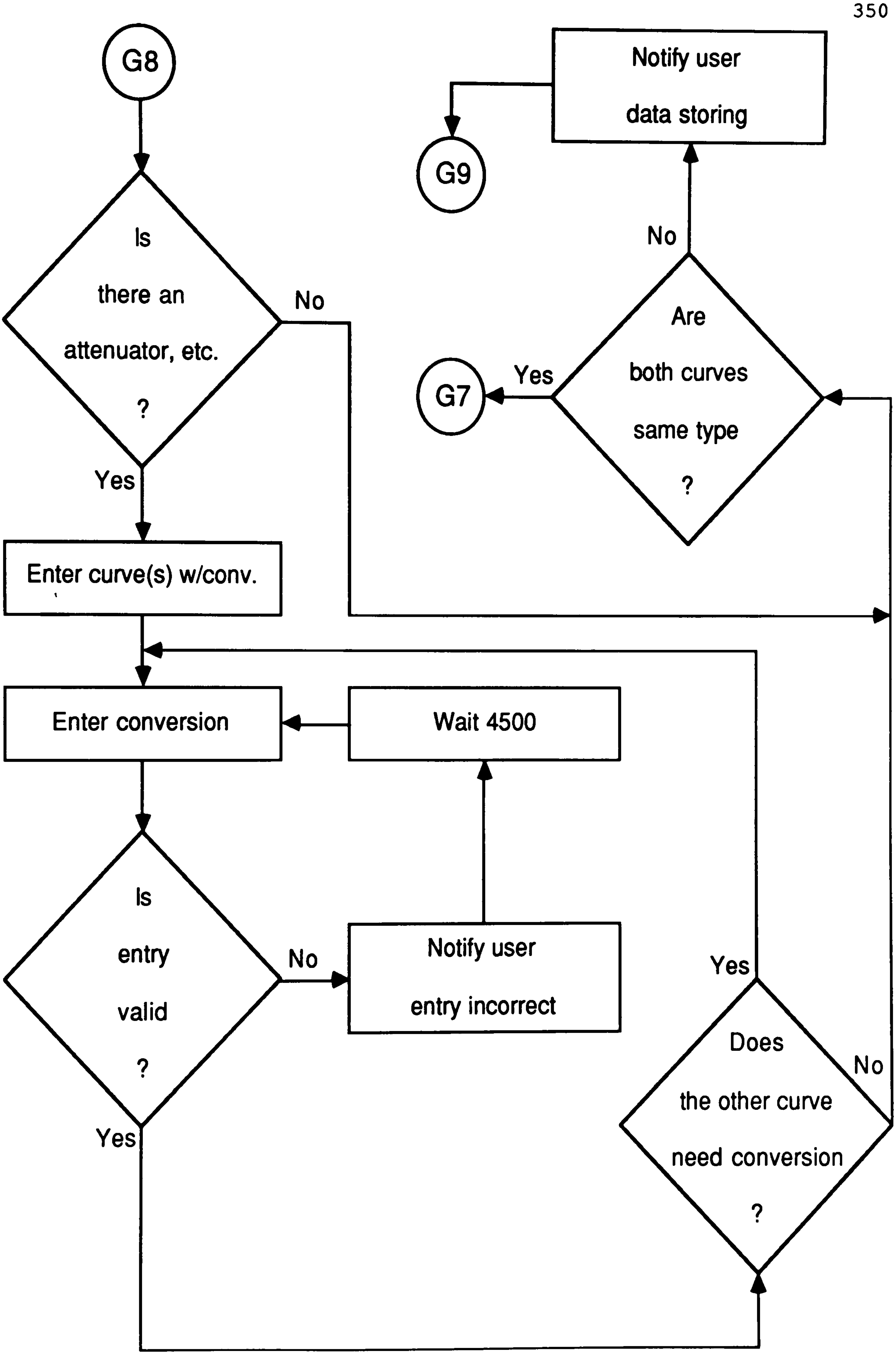

G
Initialize control registers
Set defaults
Initialize data registers
Do you want to use the MUX & VM ?
No
G1
Yes
Set MUX flag
Enter # of channels
Wait 4500
Is entry valid ?
No
Notify user entry incorrect
Yes
Enter channel # and voltage range
Are entries valid ?
No
Notify user entries incorrect
Wait 4500
Yes
G1

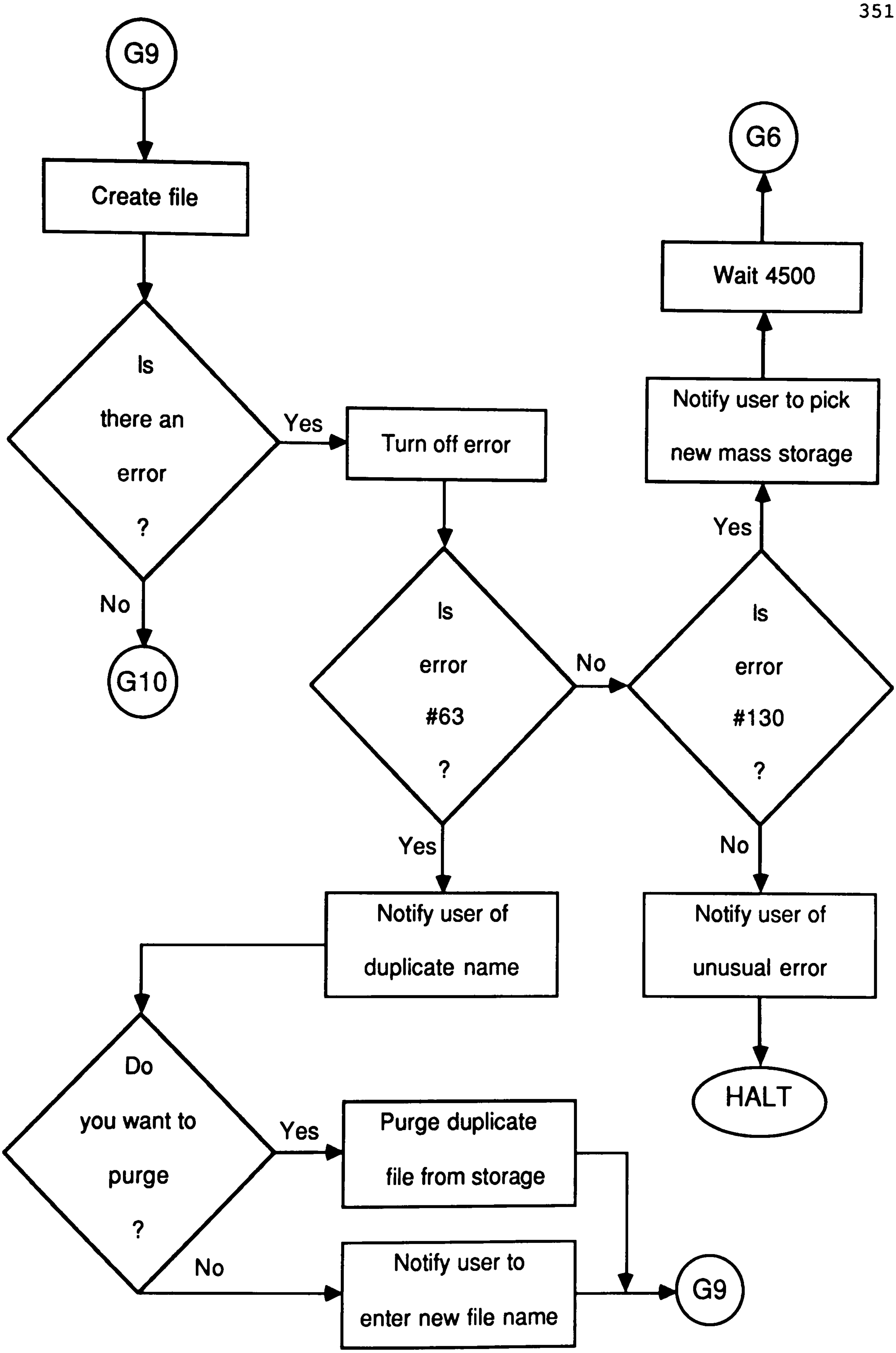

G1
Notify user to take measurement
Pause
Input normalization factors
Notify user program will only process 1024 pts.
Pause
Input normalizations factors
Yes
Is there another curve ?
No
G2
No
Are there too many curves ?
Yes
Notify user there are too many curves
Re-initialize data registers
G1

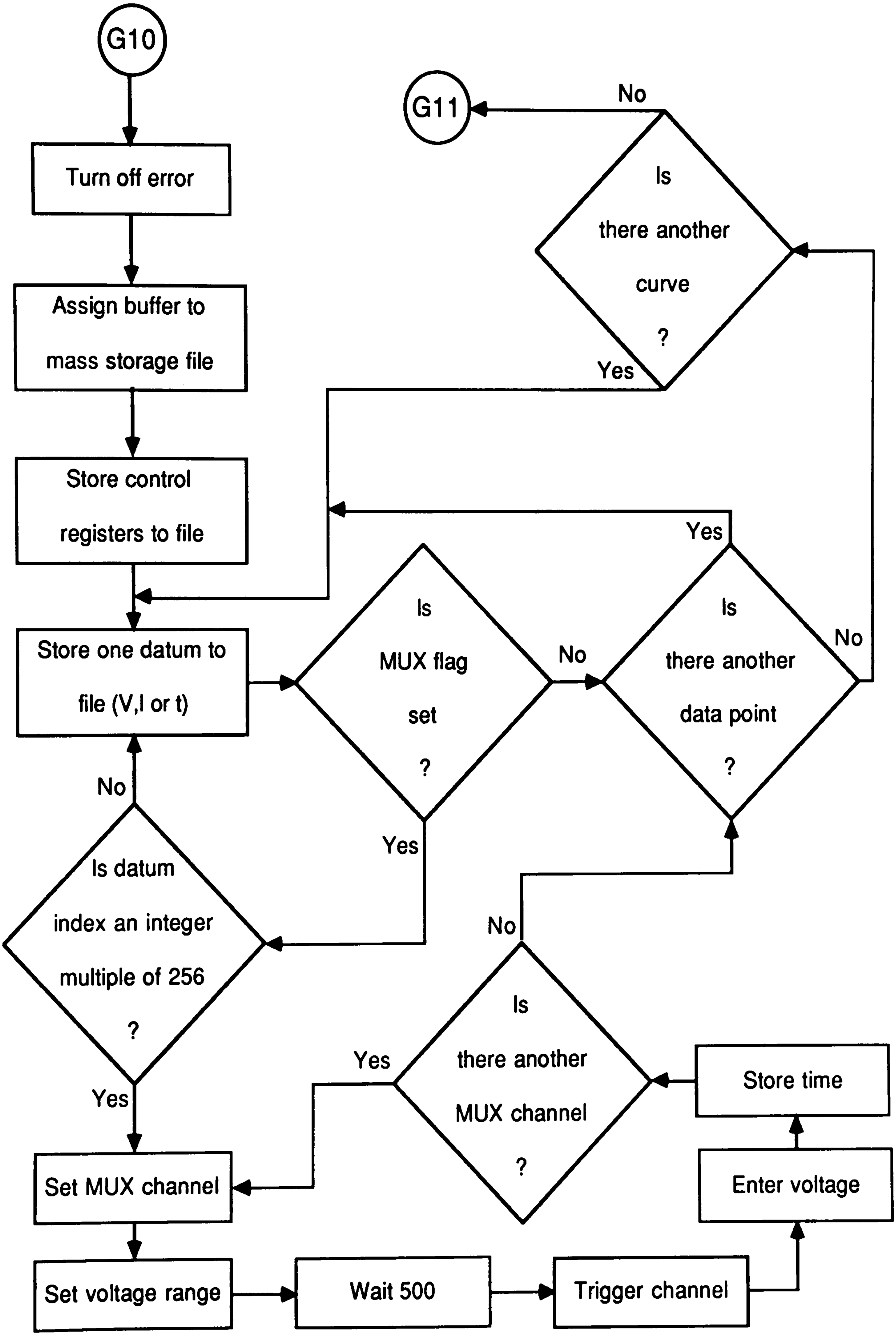

G2
Clear 7
Store date & time
Assign data buffer
Load curve(s)
Choose desired function
Take new set of data
Store all data
Finished
Is present data stored ?
No
G5
No
Is present data stored ?
Yes
Yes
G4
G
Do you want to take more data ?
Yes
G3
No

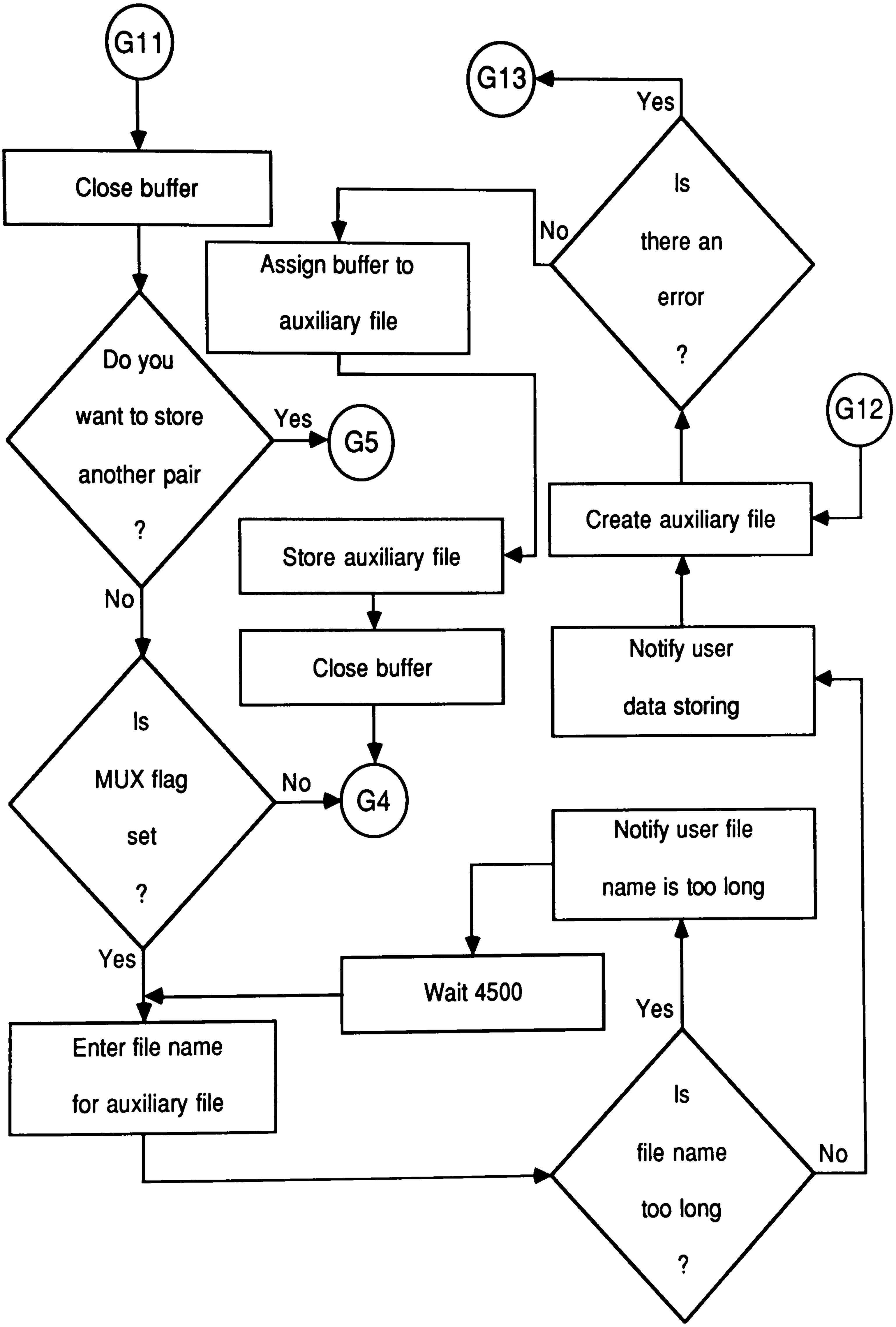

G3
Is
MUX flag
set
?
No
Load and run
Autost
A
Yes
Load and run
VMAUX
J

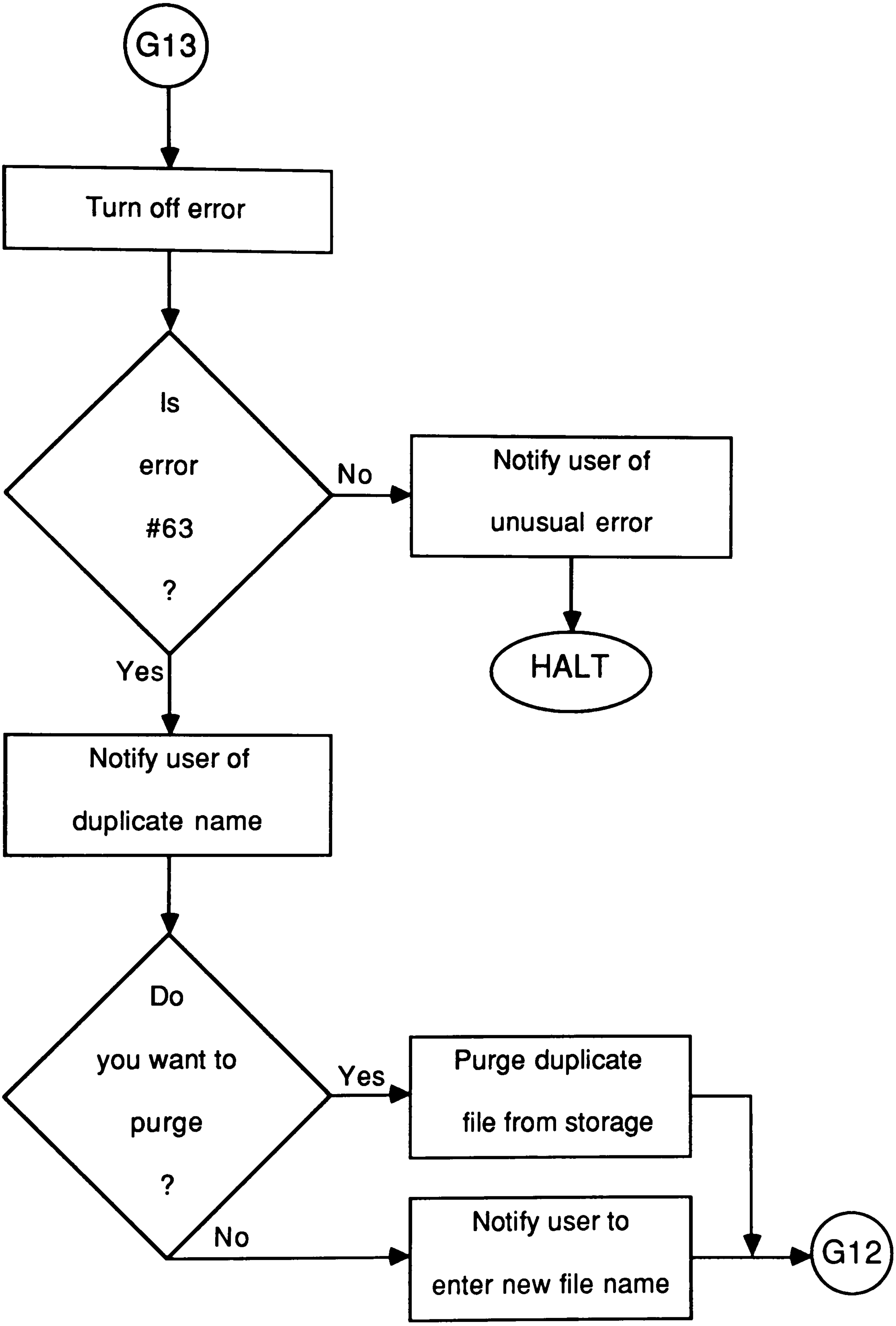

G5
Enter file name
Wait 4500
Is file name too long ?
Yes
Notify user file name is too long
No
Enter mass storage
G6
G8
G7
Yes
Are there more than 2 curves ?
Yes
Enter curves to be paired together
Are entries valid ?
No
No
G8
Notify user entries incorrect
Wait 4500


350
G8
Is there an attenuator, etc. ?
No
Yes
Enter curve(s) w/conv.
Enter conversion
Wait 4500
Is entry valid ?
No
Yes
Notify user entry incorrect
Notify user data storing
G9
No
Are both curves same type ?
Yes
G7
Yes
Does the other curve need conversion ?
No


G9
Create file
Is there an error ?
Yes
No
G10
Turn off error
Is error #63 ?
No
Yes
Is error #130 ?
Yes
No
Notify user to pick new mass storage
Wait 4500
G6
Notify user of unusual error
HALT
Notify user of duplicate name
Do you want to purge ?
Yes
No
Purge duplicate file from storage
Notify user to enter new file name
G9

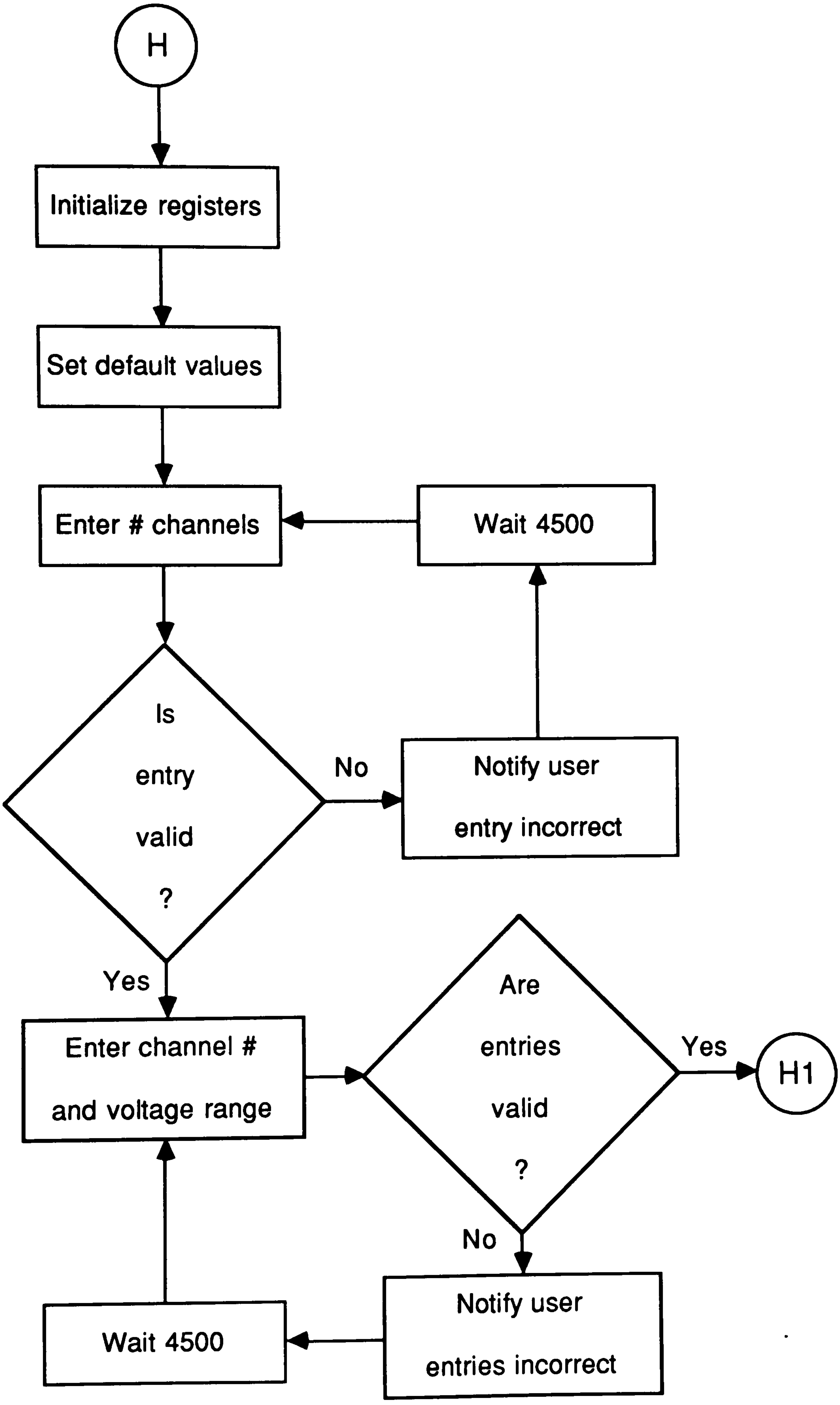

G10
Turn off error
Assign buffer to mass storage file
Store control registers to file
Store one datum to file (V,I or t)
Is datum index an integer multiple of 256 ?
No
Yes
Set MUX channel
Set voltage range
Wait 500
Trigger channel
Enter voltage
Store time
Is there another MUX channel ?
Yes
No
Is MUX flag set ?
Yes
No
Is there another data point ?
Yes
No
Is there another curve ?
Yes
No
G11

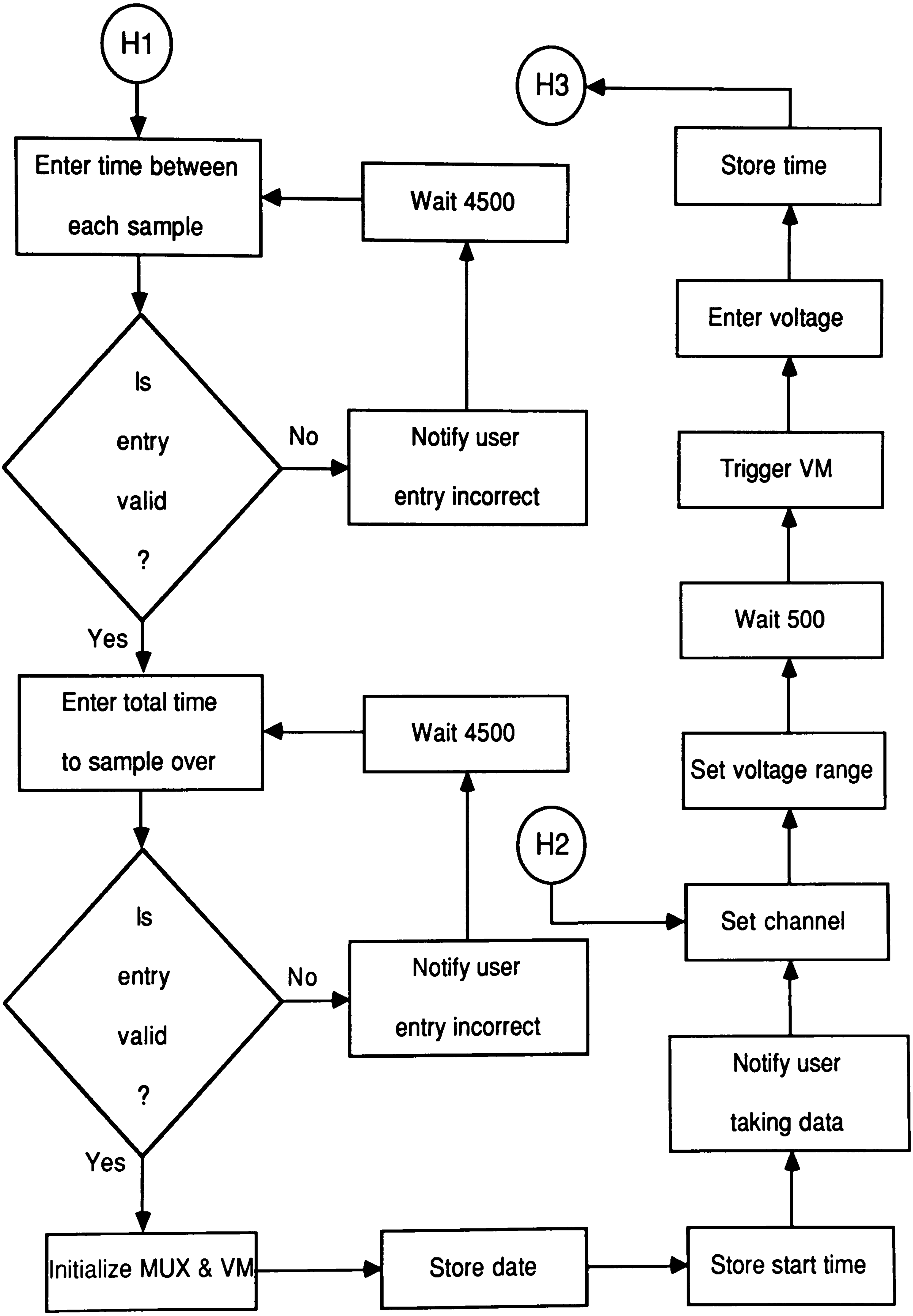

G11
Close buffer
Do you want to store another pair ?
Yes
G5
No
Is MUX flag set ?
No
G4
Yes
Enter file name for auxiliary file
Wait 4500
Is file name too long ?
Yes
No
Notify user file name is too long
Notify user data storing
Create auxiliary file
G12
Is there an error ?
Yes
G13
No
Assign buffer to auxiliary file
Store auxiliary file
Close buffer
G4

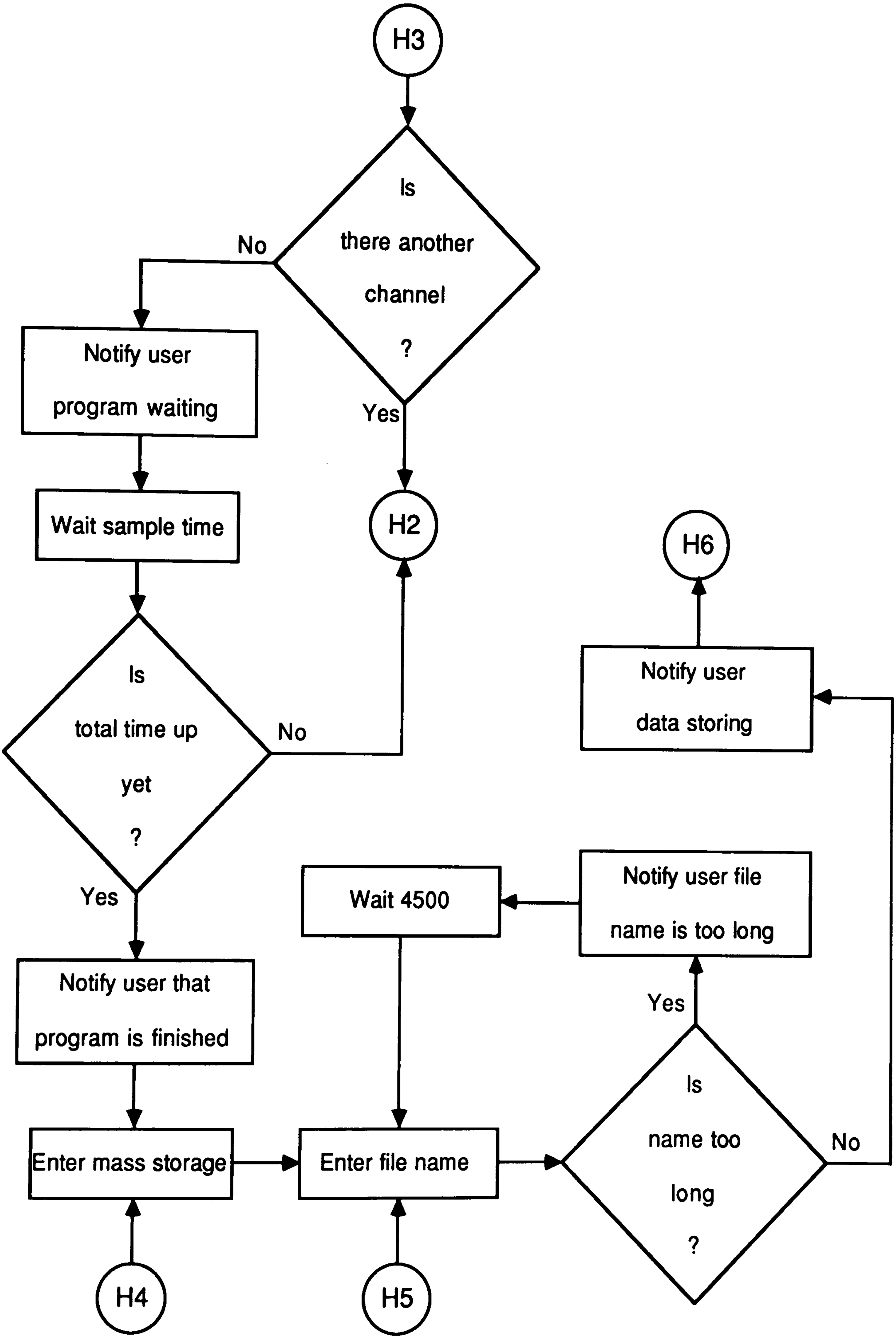

G13
Turn off error
Is
error
#63
?
No
Notify user of
unusual error
HALT
Yes
Notify user of
duplicate name
Do
you want to
purge
?
Yes
Purge duplicate
file from storage
No
Notify user to
enter new file name
G12

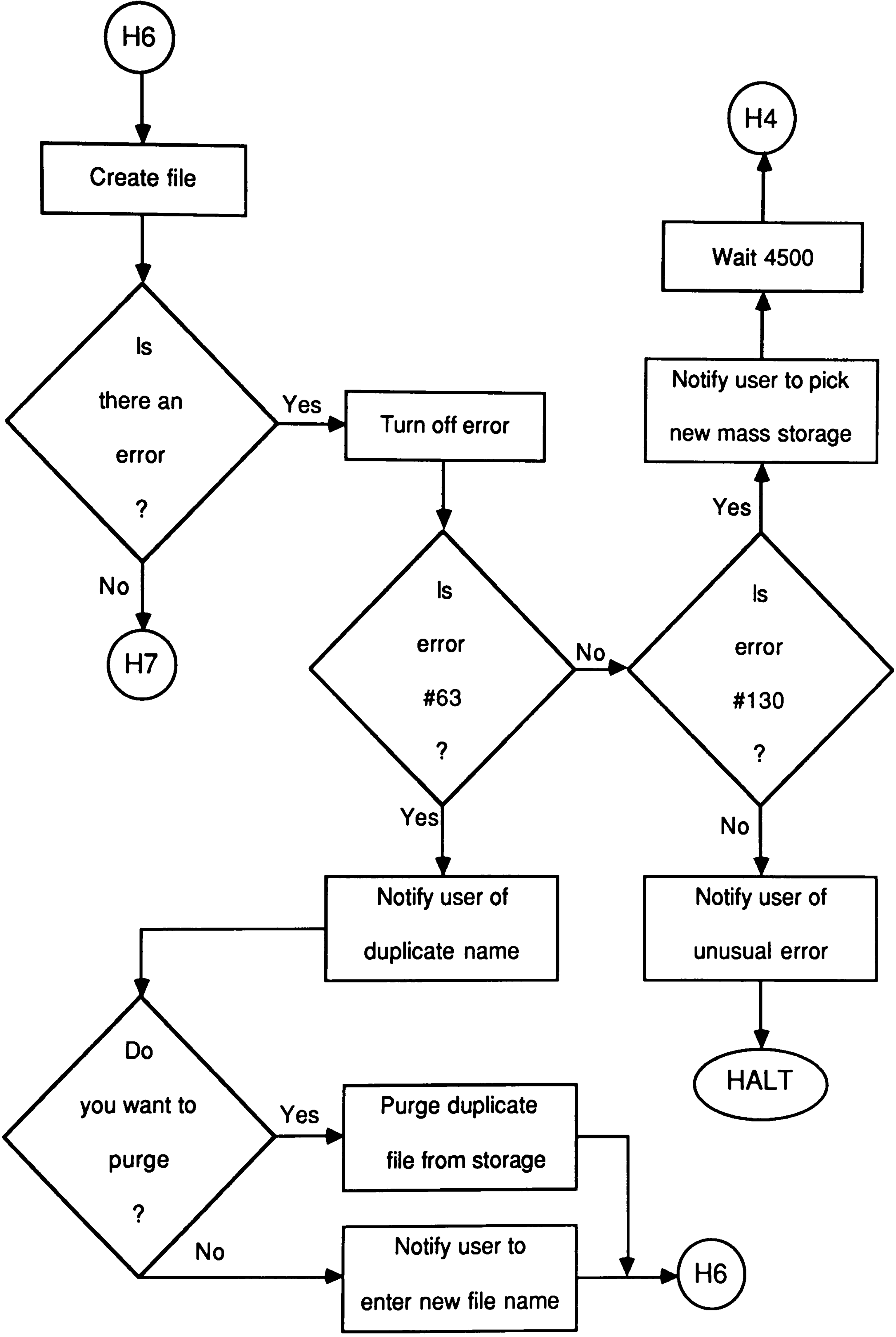
HP-DAS

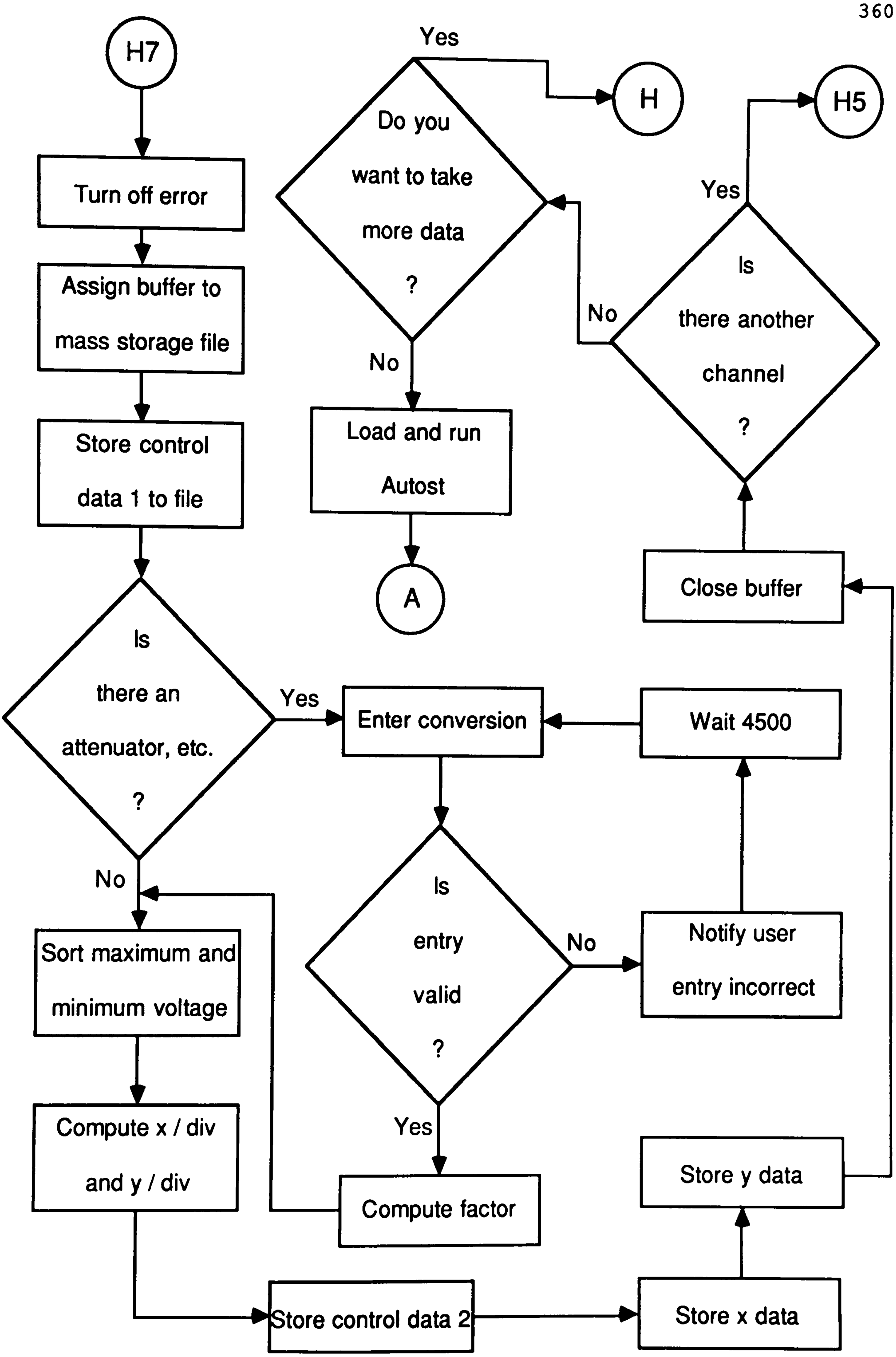
The HP-DAS program controls the HP3497A Data Acquisition/Control Unit (DACU) and HP3437A Digital Voltmeter (DVM). These instruments are used to make up to four (4) 256-point measurements. The operator selects the input channel(s), voltage range(s), sampling time, and test period. The program uses these quantities to acquire data. After completion, the program generates an alarm to notify the operator. The program, then, stores the curves in pairs. These pairs are selected by the operator.


H
Initialize registers
Set default values
Enter # channels
Wait 4500
Is
entry
valid
?
No
Notify user
entry incorrect
Yes
Enter channel #
and voltage range
Are
entries
valid
?
Yes
H1
No
Notify user
entries incorrect
Wait 4500


H1
Enter time between each sample
Is entry valid ?
No
Notify user entry incorrect
Wait 4500
Yes
Enter total time to sample over
Is entry valid ?
No
Notify user entry incorrect
Wait 4500
Yes
Initialize MUX & VM
Store date
Store start time
Notify user taking data
Set channel
H2
Set voltage range
Wait 500
Trigger VM
Enter voltage
Store time
H3


H3
Is there another channel ?
No
Yes
Notify user program waiting
Wait sample time
H2
Is total time up yet ?
No
Yes
Notify user that program is finished
Enter mass storage
H4
Enter file name
H5
Wait 4500
Notify user file name is too long
Yes
Is name too long ?
No
Notify user data storing
H6


H6
Create file
Is there an error ?
Yes
No
H7
Turn off error
Is error #63 ?
No
Yes
Is error #130 ?
Yes
No
Notify user to pick new mass storage
Wait 4500
H4
Notify user of duplicate name
Notify user of unusual error
HALT
Do you want to purge ?
Yes
No
Purge duplicate file from storage
Notify user to enter new file name
H6

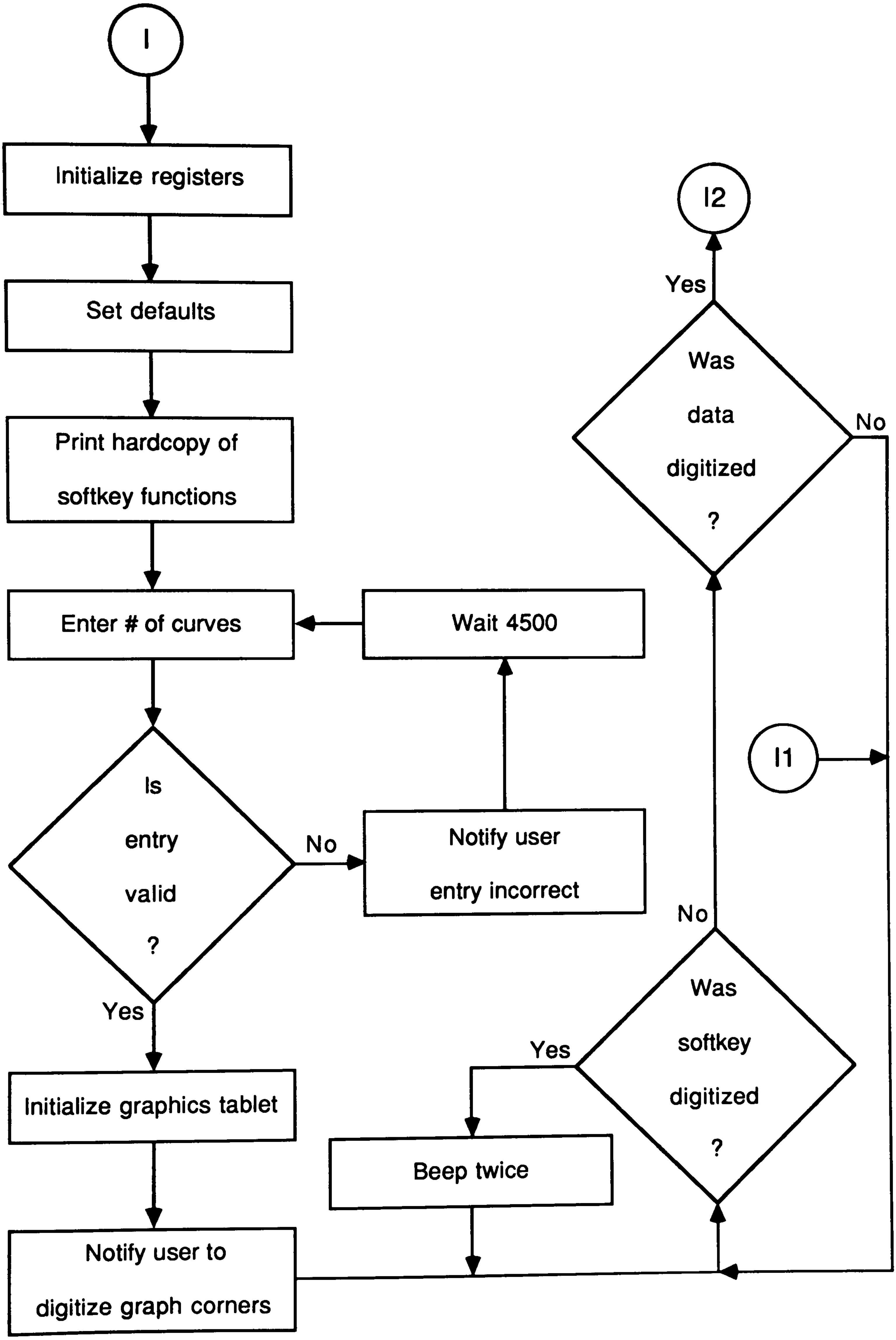

H7
Turn off error
Assign buffer to mass storage file
Store control data 1 to file
Is there an attenuator, etc. ?
Yes
No
Enter conversion
Is entry valid ?
No
Yes
Notify user entry incorrect
Wait 4500
Compute factor
Sort maximum and minimum voltage
Compute x / div and y / div
Store control data 2
Store x data
Store y data
Close buffer
Is there another channel ?
Yes
No
H5
Do you want to take more data ?
Yes
No
H
Load and run Autost
A

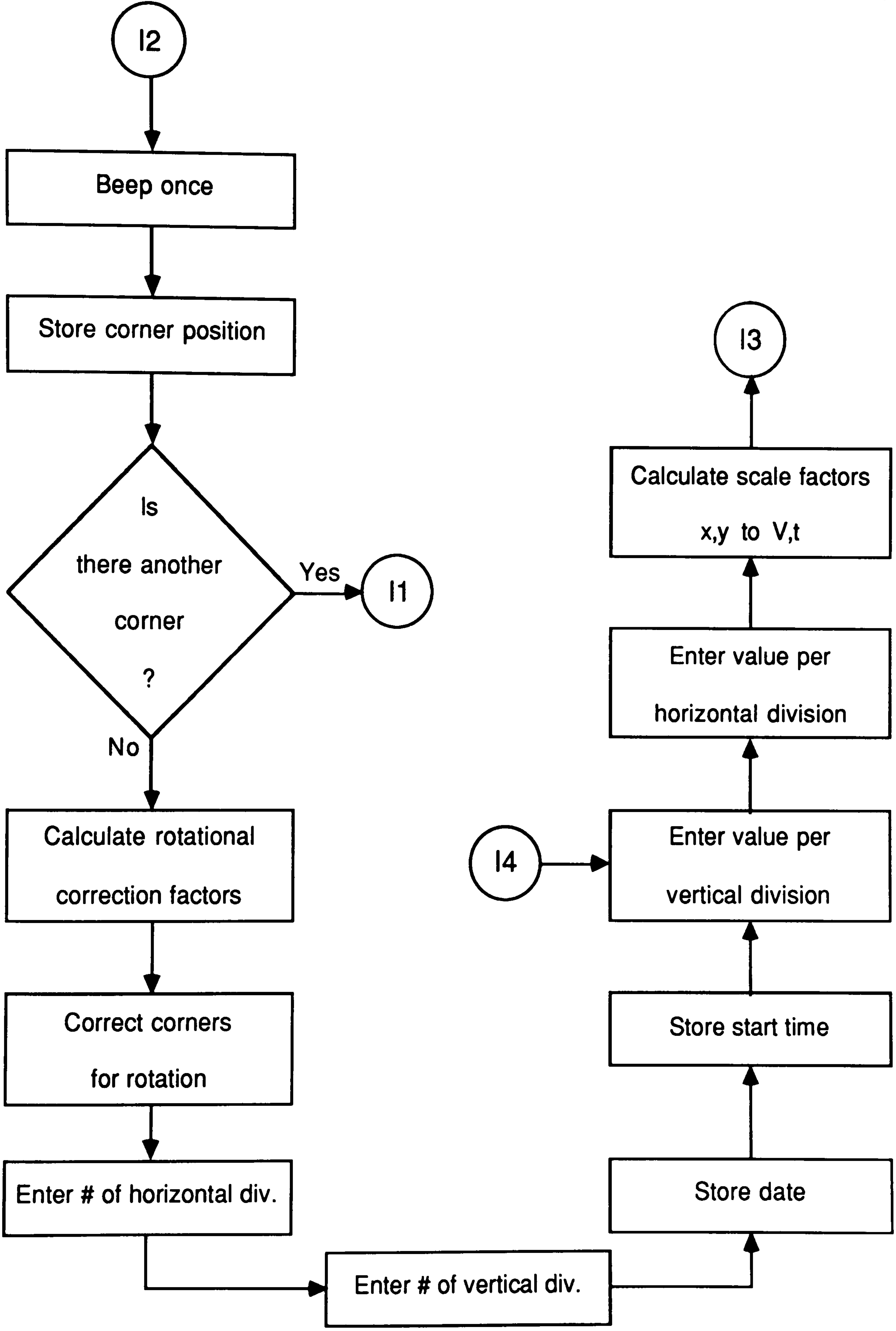
TABLET

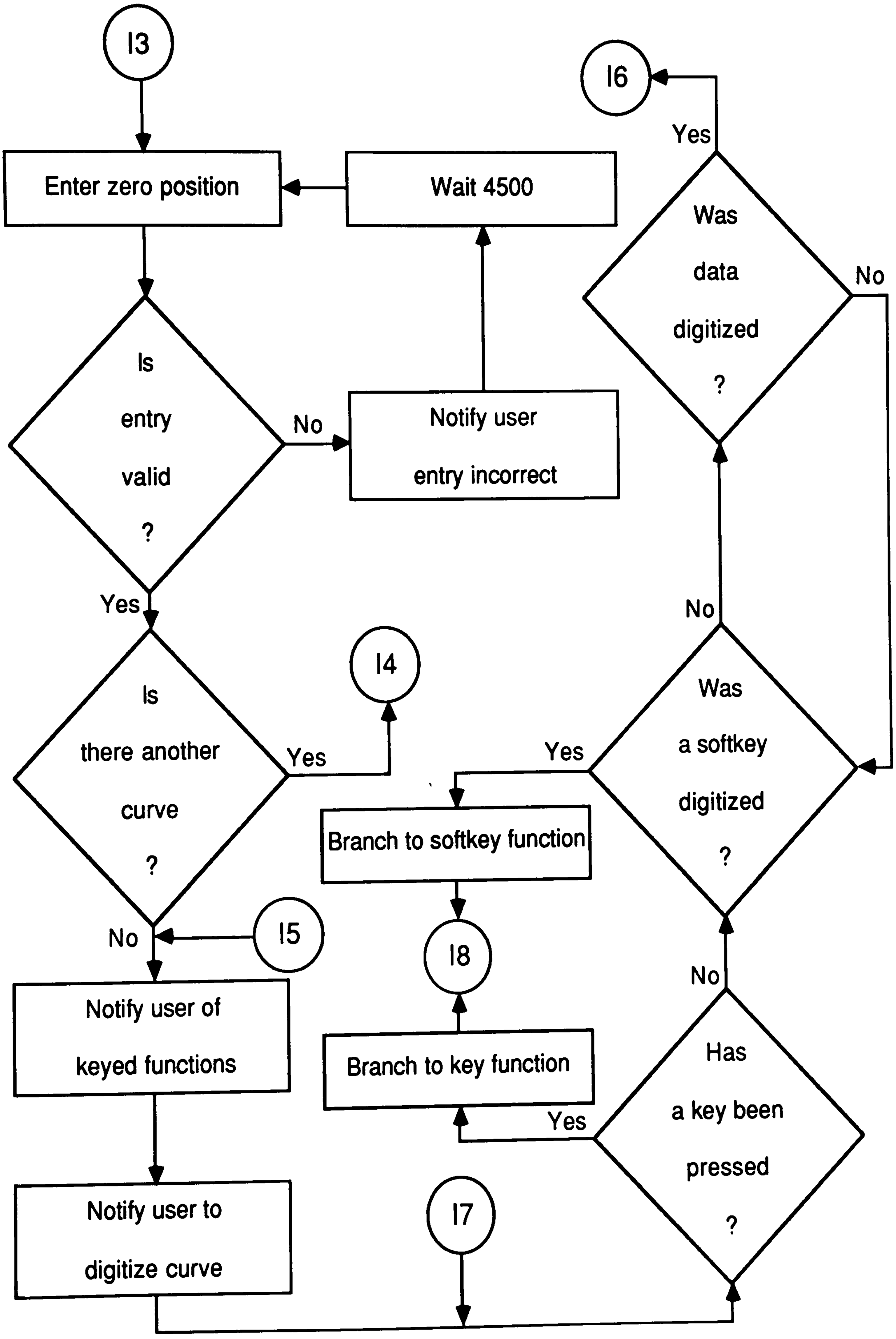
The TABLET program controls the HP9111A Graphics Tablet. The tablet is used to digitize up to two (2) 1024-point curves by hand.

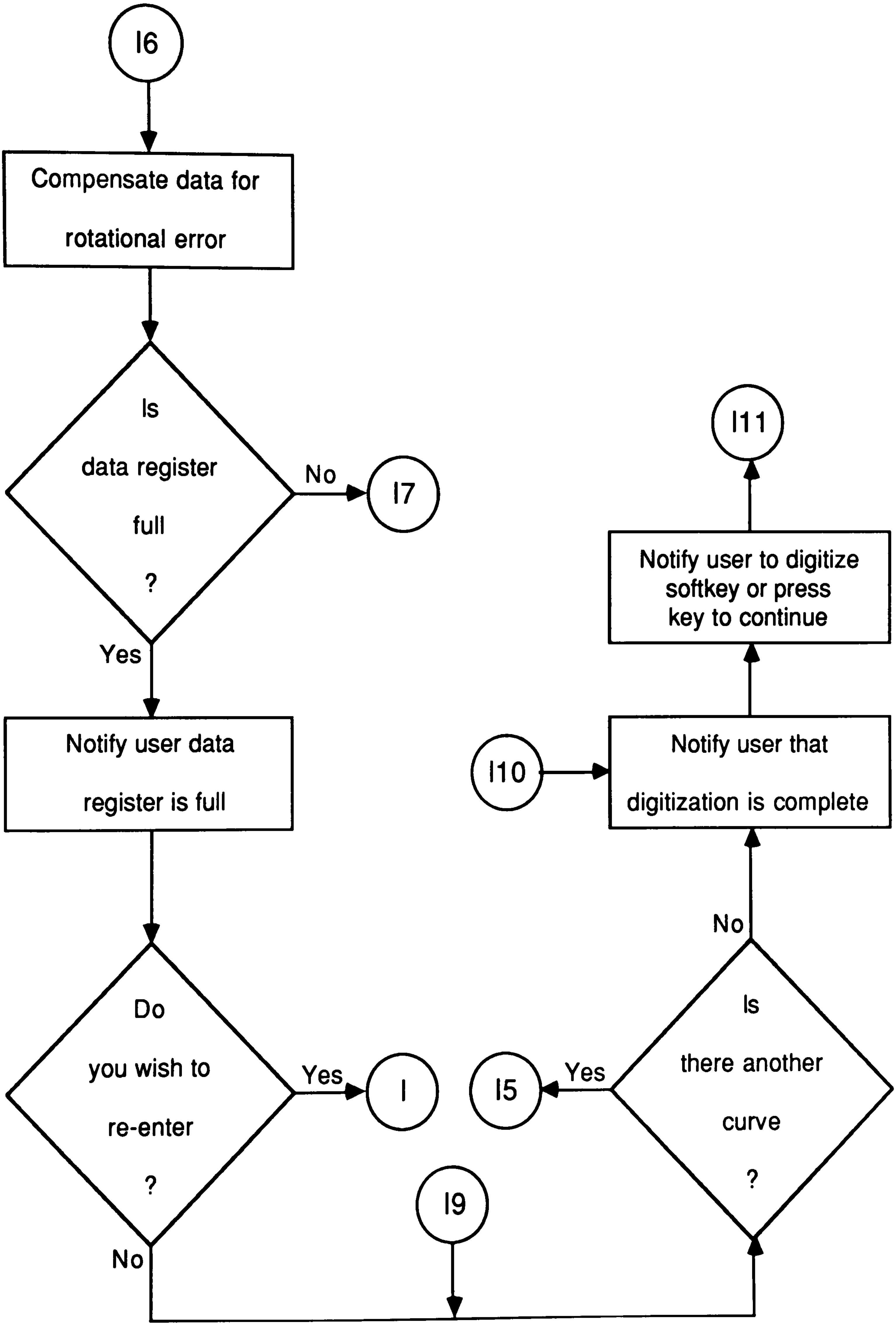
The operator enters the corners of the graph, the number of x divisions, value per x division (time), the number of y divisions, value per y divisions (e.g. voltage), and the location of the zero line. The program uses these values to correct the data for rotational and translational digitizing errors, and scales the data to represent the curves digitized, i.e. converts xy coordinates to voltage vs. time data. This converted data is stored.

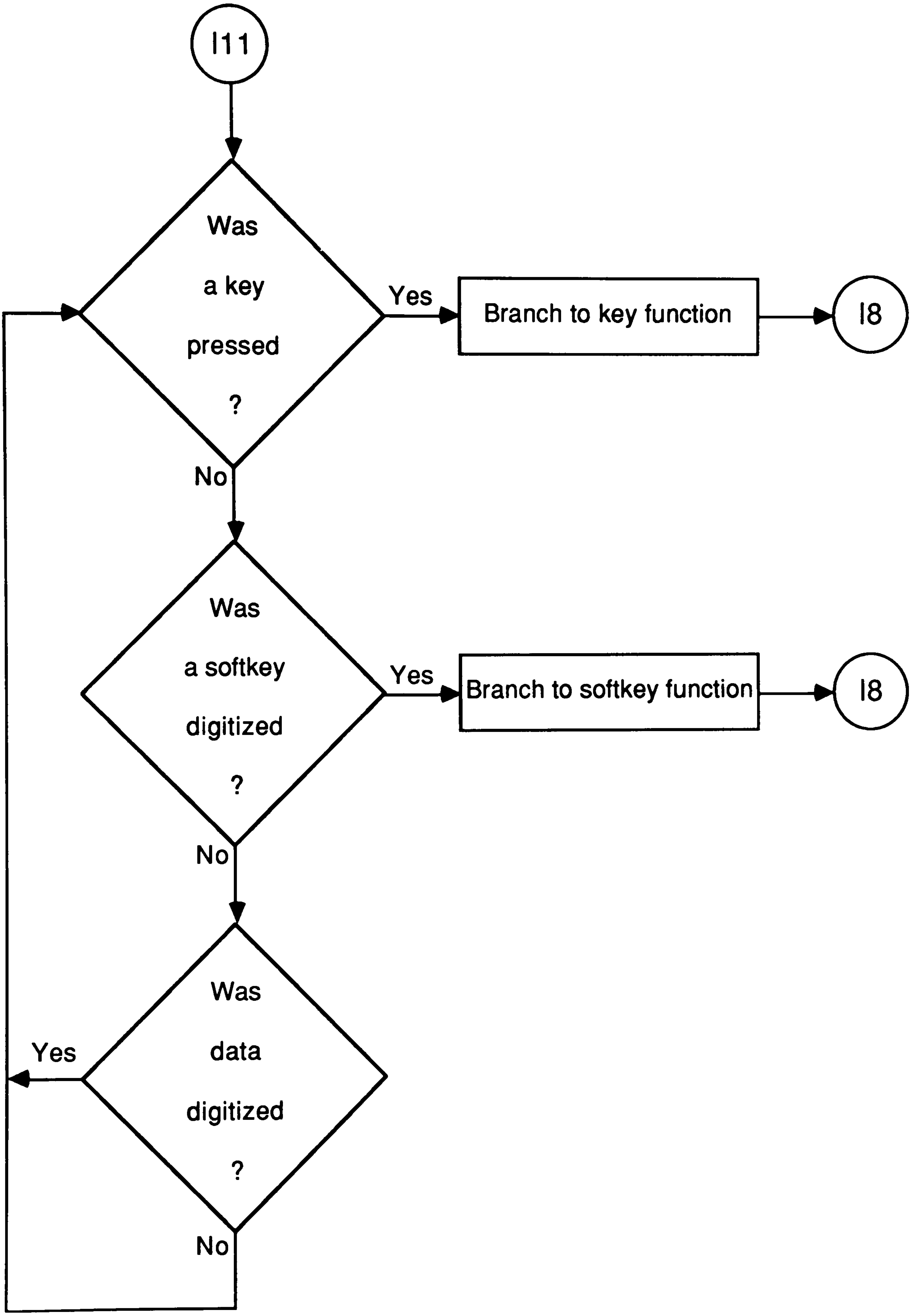
The TABLET program also allows the operator to generate a hardcopy of device data. The program will list manufacturer, device type, mask type, device number, temperature, second-breakdown type, forward base current, nominal reverse base current, reverse base current at second-breakdown, and comments. These device data are not stored, however.

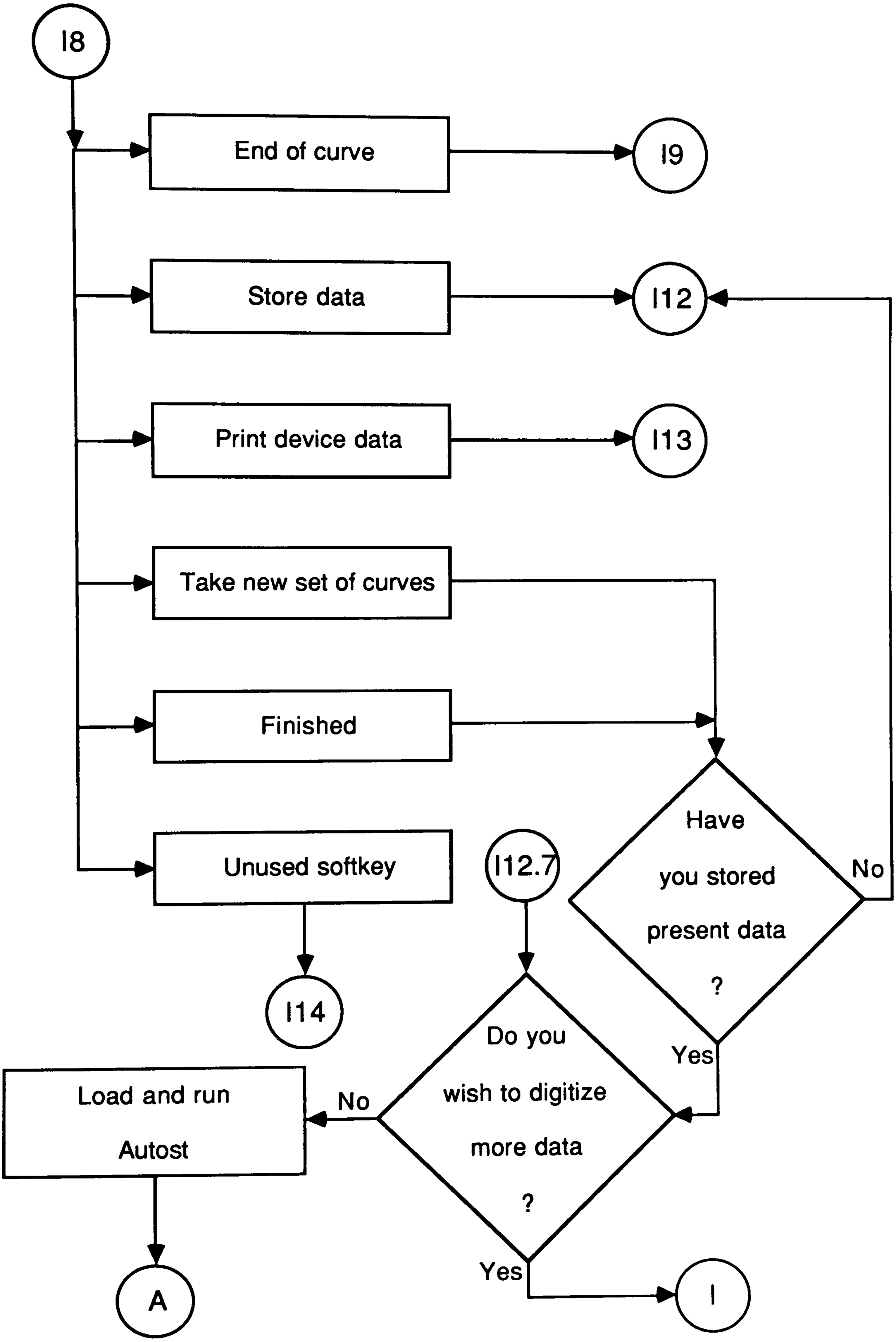

I
Initialize registers
Set defaults
Print hardcopy of softkey functions
Enter # of curves
Wait 4500
Is entry valid ?
No
Notify user entry incorrect
Yes
Initialize graphics tablet
Notify user to digitize graph corners
Beep twice
Yes
Was softkey digitized ?
No
Was data digitized ?
Yes
No
I2
I1

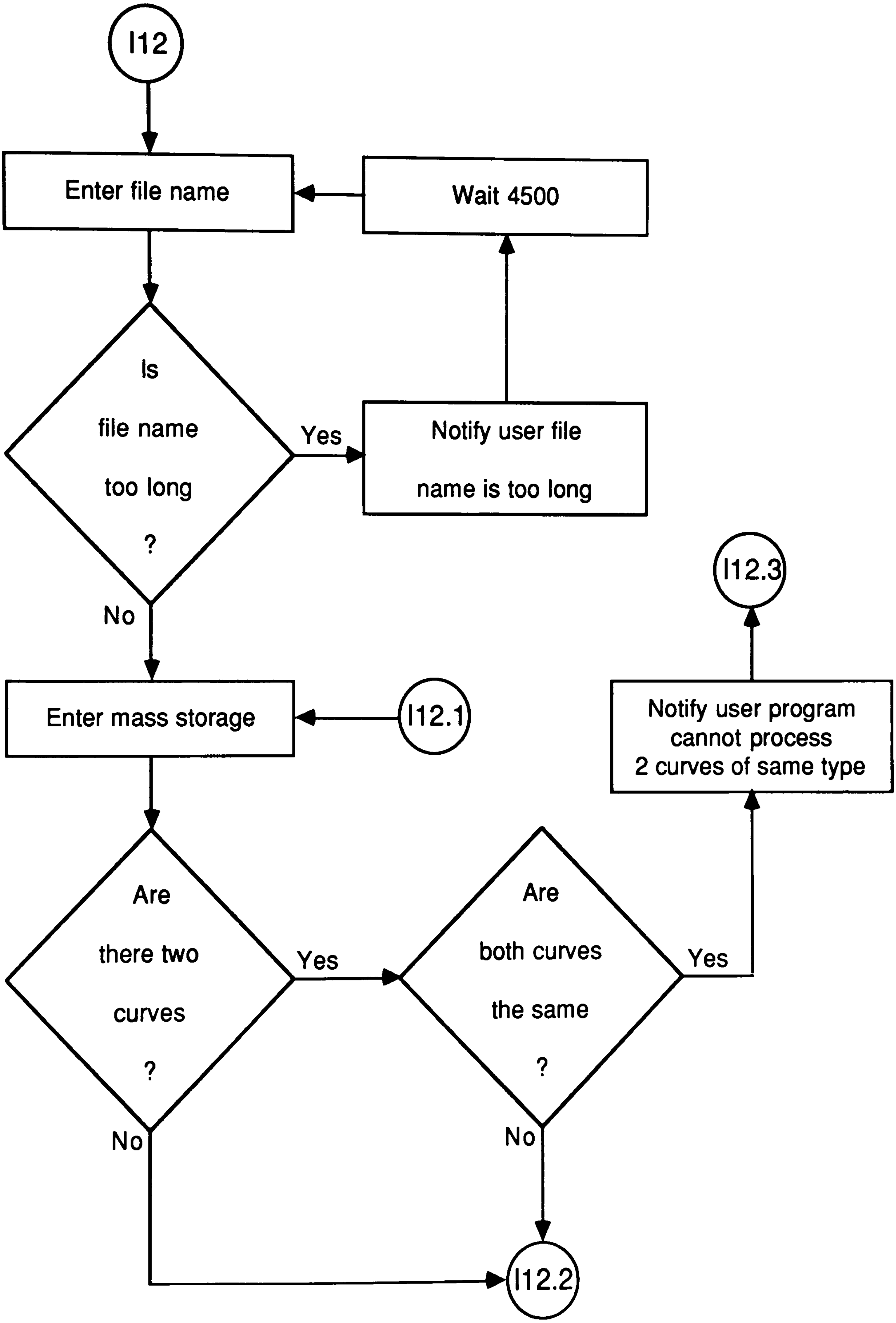

I2
Beep once
Store corner position
Is there another corner ?
Yes
I1
No
Calculate rotational correction factors
Correct corners for rotation
Enter # of horizontal div.
Enter # of vertical div.
Store date
Store start time
I4
Enter value per vertical division
Enter value per horizontal division
Calculate scale factors x,y to V,t
I3

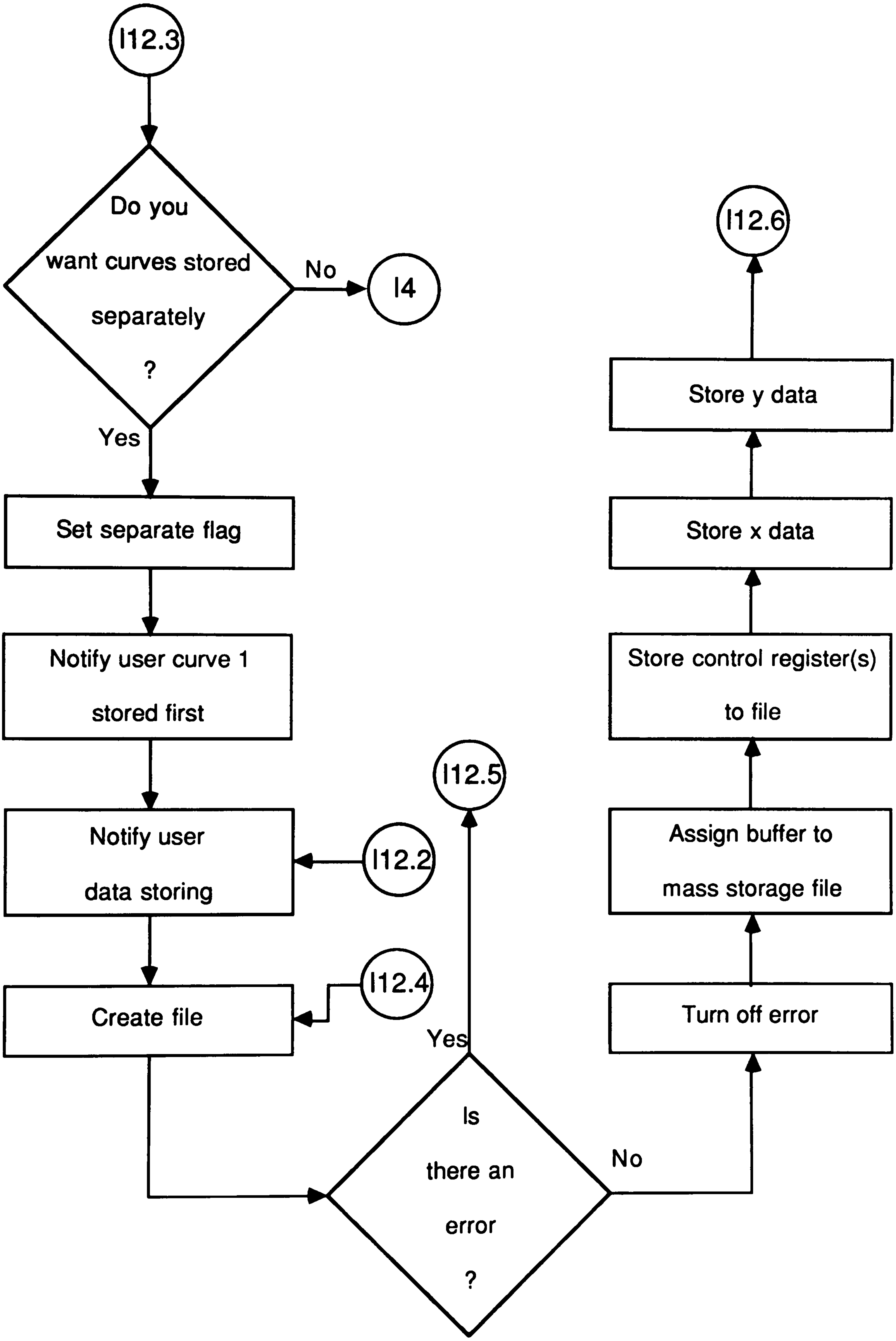

13
Enter zero position
Wait 4500
16
Yes
Was data digitized ?
No
Is entry valid ?
No
Notify user entry incorrect
Yes
No
Is there another curve ?
Yes
14
Yes
Was a softkey digitized ?
Branch to softkey function
No
15
18
No
Notify user of keyed functions
Has a key been pressed ?
Branch to key function
Yes
Notify user to digitize curve
17

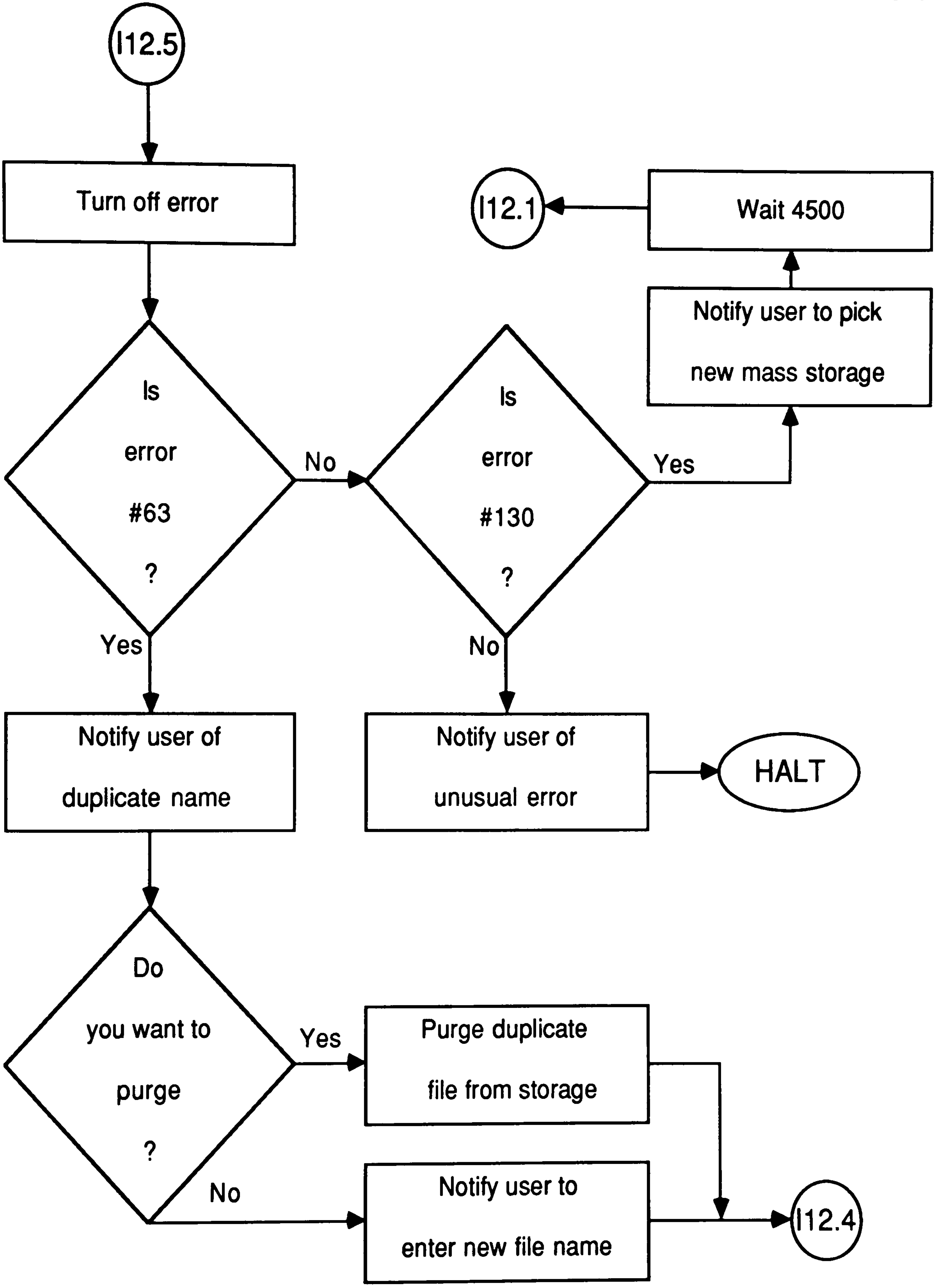

I6
Compensate data for rotational error
Is data register full ?
No
I7
Yes
Notify user data register is full
Do you wish to re-enter ?
Yes
I
No
I9
I5
Yes
Is there another curve ?
No
Notify user that digitization is complete
I10
Notify user to digitize softkey or press key to continue
I11

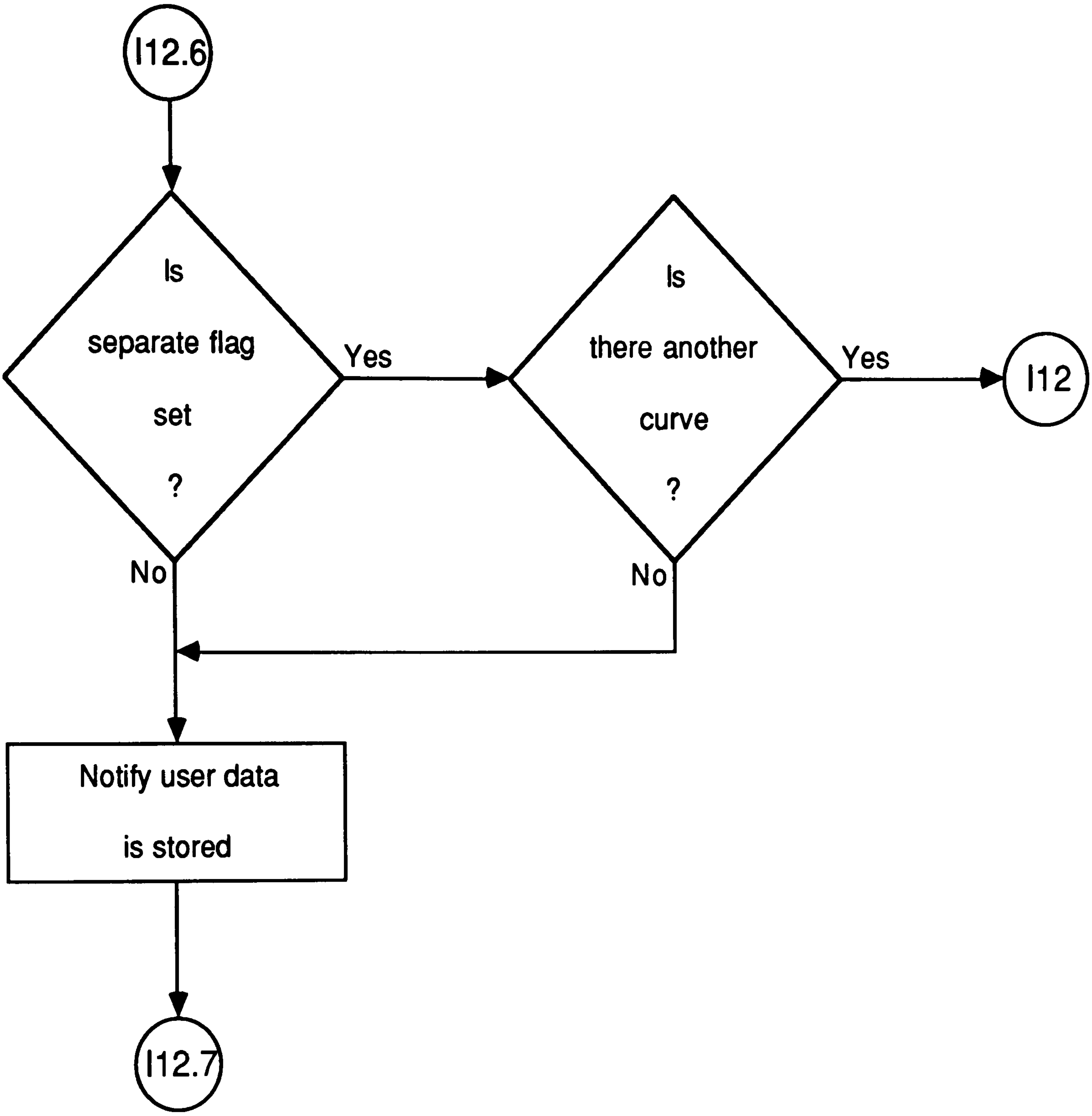

I11
Was a key pressed ?
Yes
Branch to key function
I8
No
Was a softkey digitized ?
Yes
Branch to softkey function
I8
No
Was data digitized ?
Yes
No

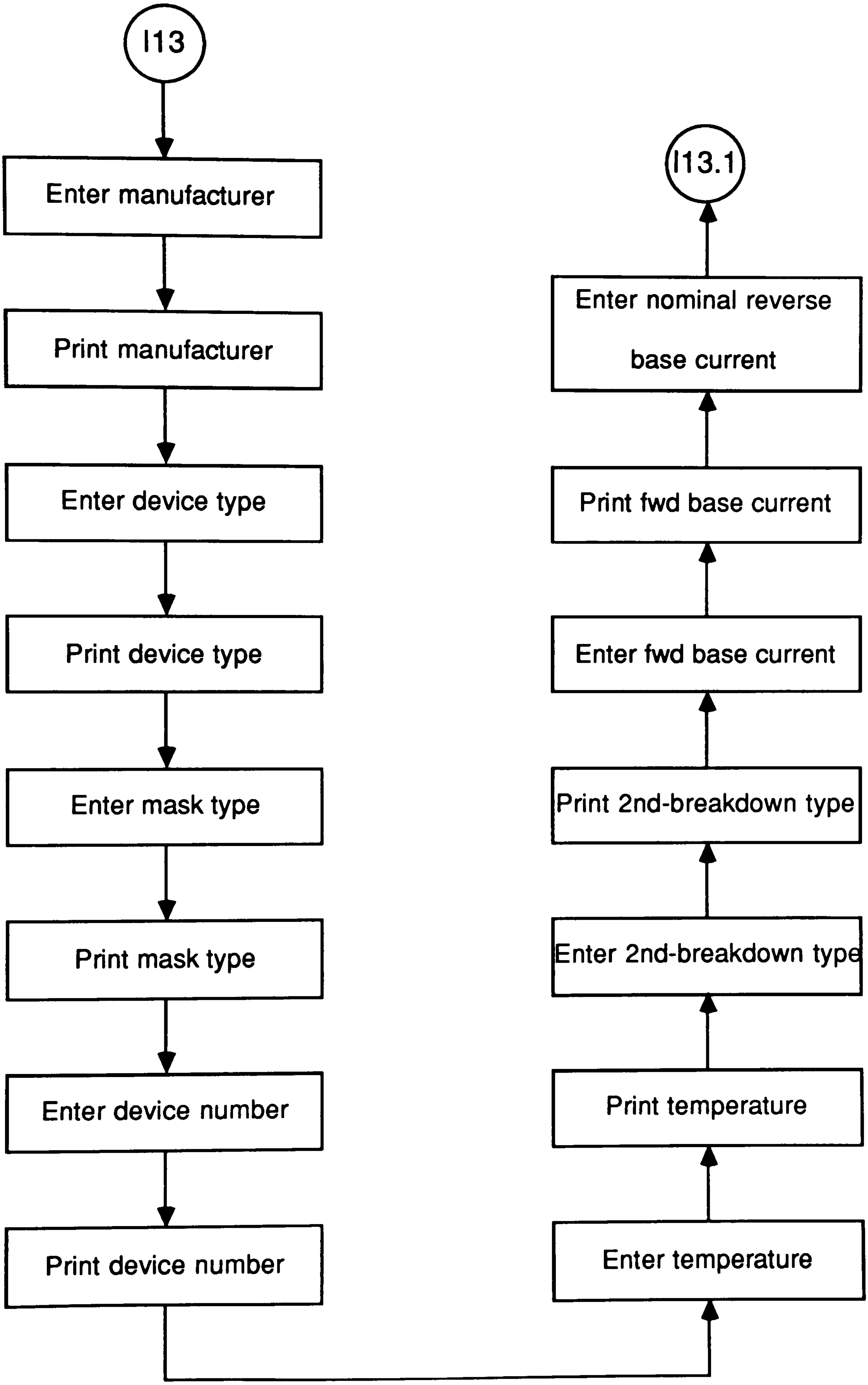

I8
End of curve
I9
Store data
I12
Print device data
I13
Take new set of curves
Finished
Unused softkey
I14
I12.7
Have
you stored
present data
?
No
Yes
Do you
wish to digitize
more data
?
No
Yes
Load and run
Autost
A
I

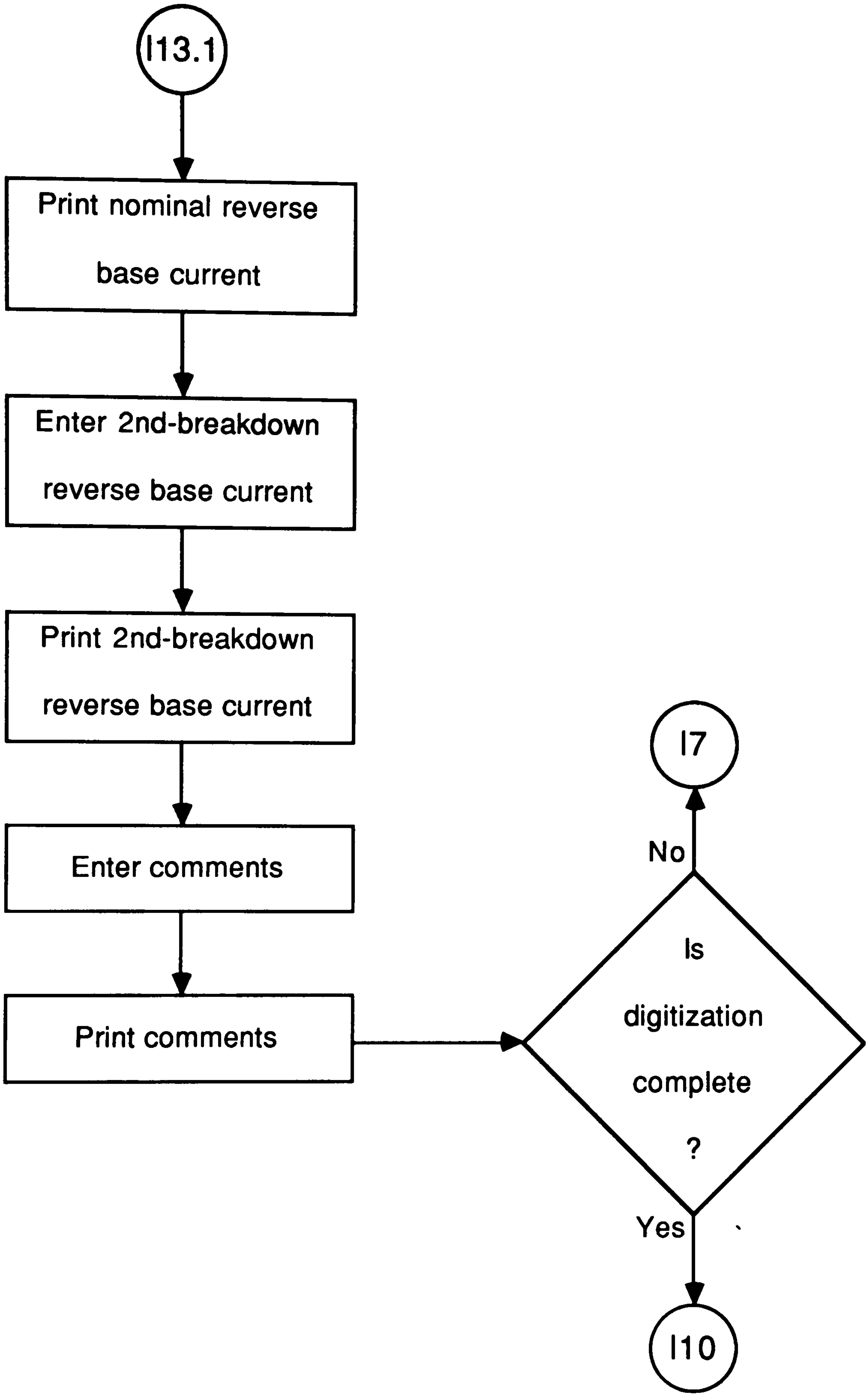

I12
Enter file name
Wait 4500
Is
file name
too long
?
Yes
Notify user file
name is too long
No
I12.3
Enter mass storage
I12.1
Notify user program
cannot process
2 curves of same type
Are
there two
curves
?
Yes
Are
both curves
the same
?
Yes
No
No
I12.2

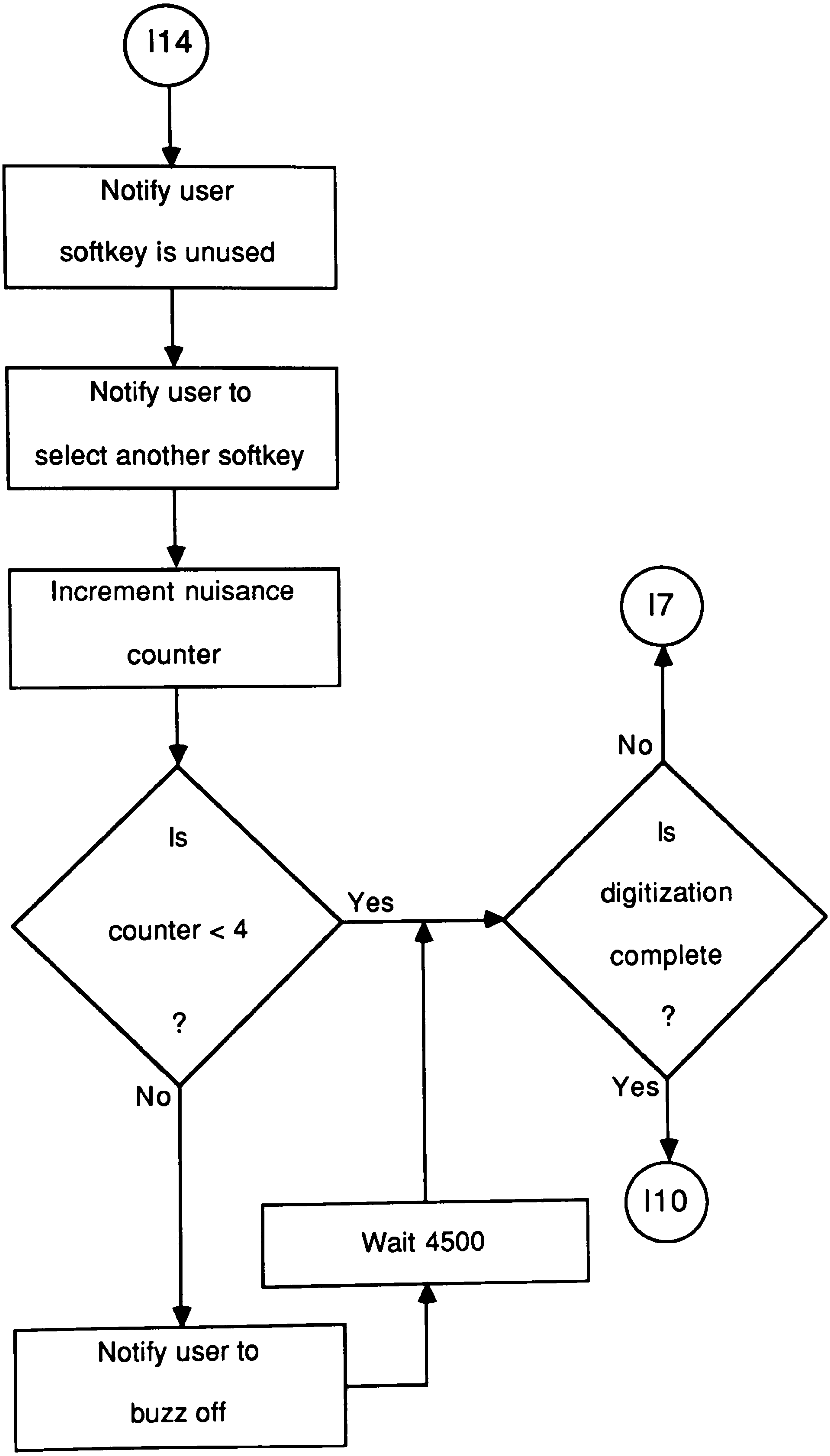

I12.3
Do you want curves stored separately ?
No
I4
Yes
Set separate flag
Notify user curve 1 stored first
Notify user data storing
I12.2
Create file
I12.4
I12.5
Yes
Is there an error ?
No
Turn off error
Assign buffer to mass storage file
Store control register(s) to file
Store x data
Store y data
I12.6


I12.5
Turn off error
Is error #63 ?
No
Yes
Is error #130 ?
Yes
No
Notify user to pick new mass storage
Wait 4500
I12.1
Notify user of duplicate name
Notify user of unusual error
HALT
Do you want to purge ?
Yes
No
Purge duplicate file from storage
Notify user to enter new file name
I12.4


I12.6
Is
separate flag
set
?
Yes
Is
there another
curve
?
Yes
I12
No
No
Notify user data
is stored
I12.7


I13
Enter manufacturer
Print manufacturer
Enter device type
Print device type
Enter mask type
Print mask type
Enter device number
Print device number
Enter temperature
Print temperature
Enter 2nd-breakdown type
Print 2nd-breakdown type
Enter fwd base current
Print fwd base current
Enter nominal reverse base current
I13.1

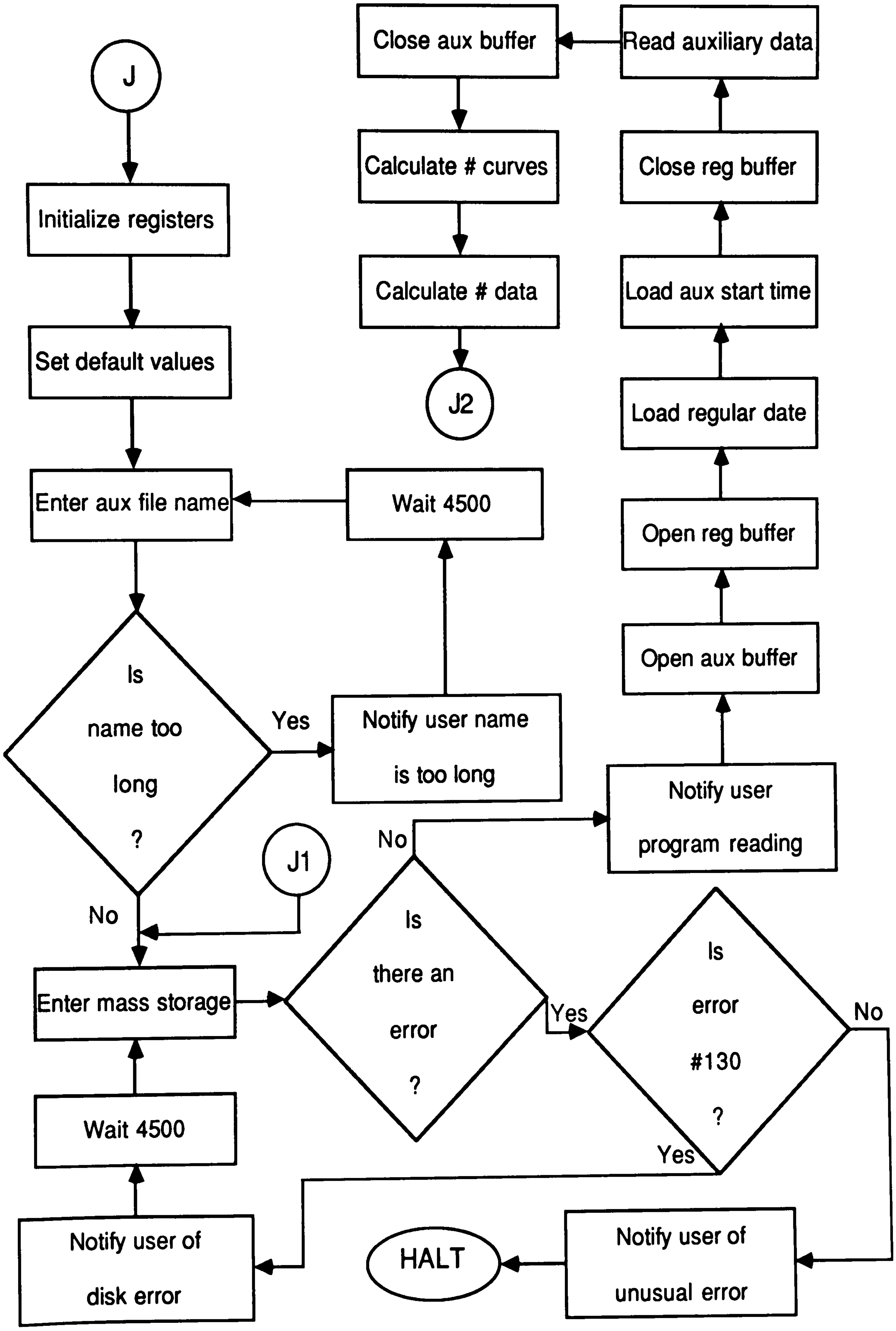

I13.1
Print nominal reverse base current
Enter 2nd-breakdown reverse base current
Print 2nd-breakdown reverse base current
Enter comments
Print comments
Is digitization complete ?
No
I7
Yes
I10

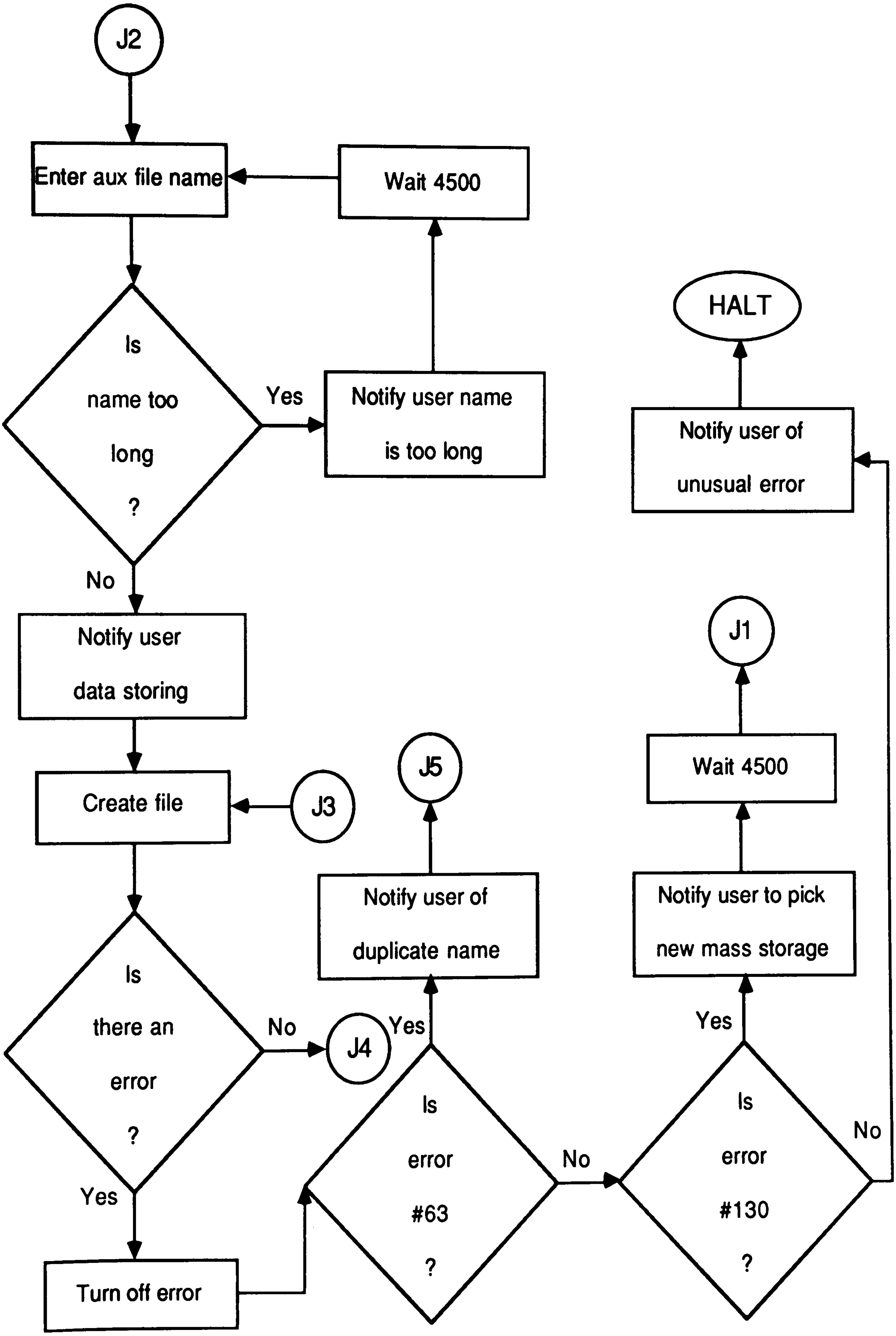

I14
Notify user
softkey is unused
Notify user to
select another softkey
Increment nuisance
counter
Is
counter < 4
?
Yes
No
I7
No
Is
digitization
complete
?
Yes
I10
Wait 4500
Notify user to
buzz off

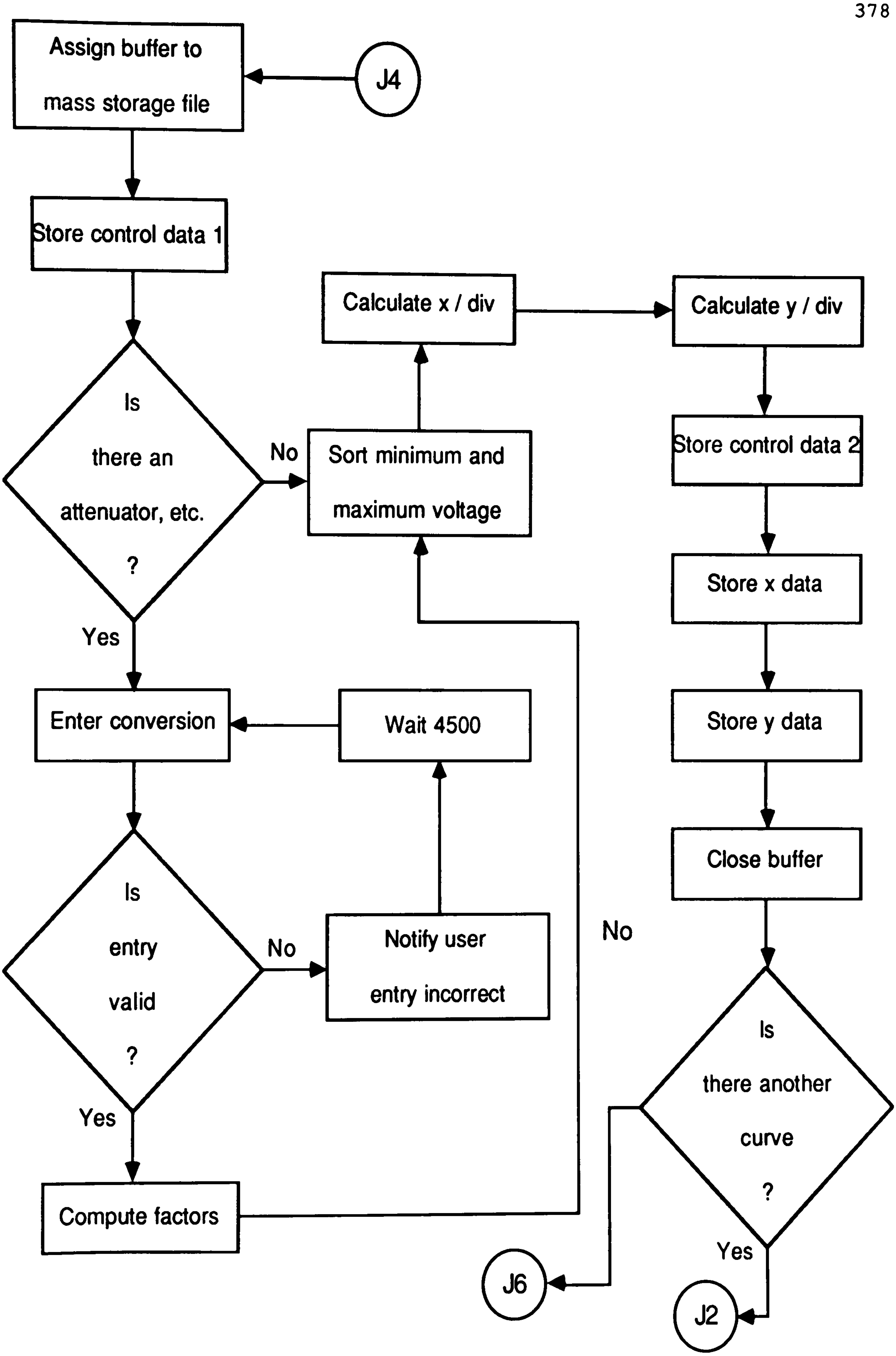
VMAUX

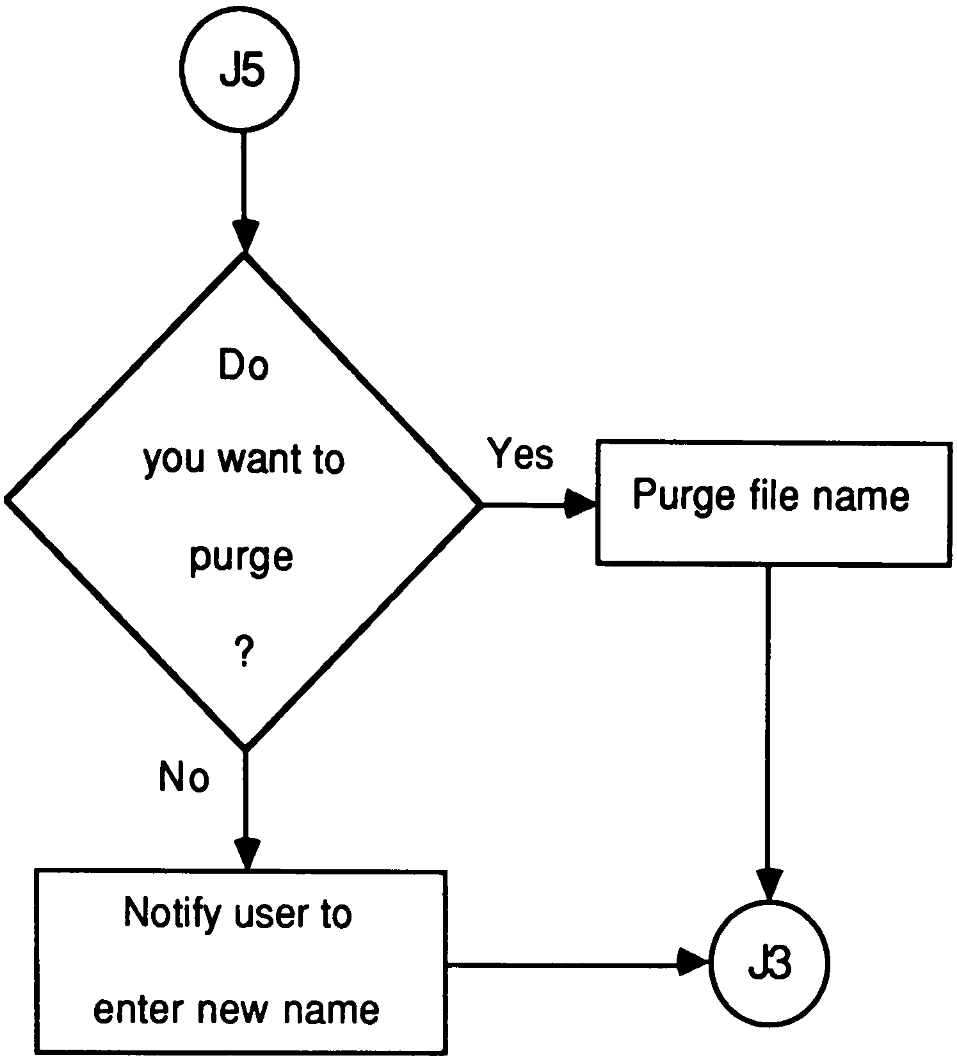
The HP85 Desktop Computer has limited memory space. Therefore, during the data acquisition processes using the Tektronix 7612D Programmable Digitizer and the Nicolet 2090-III Digital Oscilloscope, auxiliary data acquired from the HP3497A Data Acquisition/Control Unit (DACU) and HP3437A Digital Voltmeter (DVM) is stored in a compact format. The VMAUX program was written to convert this compact data format into a standard format.

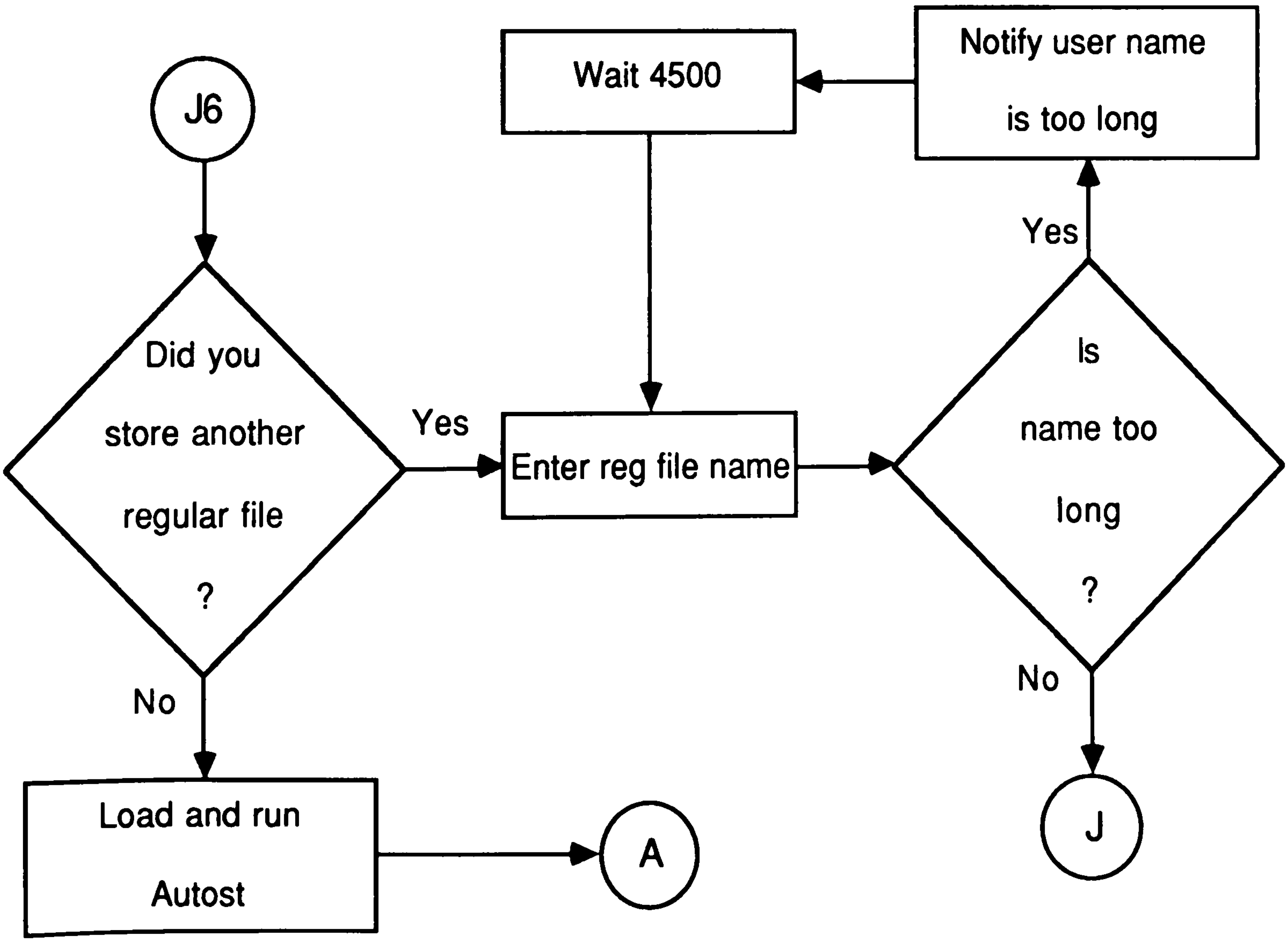
The VMAUX program reads the compact data file into the computer, generates the control registers necessary for later processing, and stores the data in standard format. This program is called automatically by NIC85 and 7612D before they pass control back to Autost.


J
Initialize registers
Set default values
Enter aux file name
Is name too long ?
Yes
No
Notify user name is too long
Wait 4500
J1
Enter mass storage
Is there an error ?
No
Yes
Notify user program reading
Is error #130 ?
Yes
No
Wait 4500
Notify user of disk error
HALT
Notify user of unusual error
Open aux buffer
Open reg buffer
Load regular date
Load aux start time
Close reg buffer
Read auxiliary data
Close aux buffer
Calculate # curves
Calculate # data
J2


J2
Enter aux file name
Wait 4500
Is name too long ?
Yes
Notify user name is too long
No
HALT
Notify user of unusual error
Notify user data storing
J1
Create file
J3
J5
Wait 4500
Notify user of duplicate name
Notify user to pick new mass storage
Is there an error ?
No
J4
Yes
Yes
Is error #63 ?
No
Is error #130 ?
No
Yes
Turn off error


J4
Assign buffer to mass storage file
Store control data 1
Is there an attenuator, etc. ?
No
Yes
Sort minimum and maximum voltage
Calculate x / div
Calculate y / div
Store control data 2
Store x data
Store y data
Close buffer
Enter conversion
Wait 4500
Is entry valid ?
No
Yes
Notify user entry incorrect
No
Compute factors
Is there another curve ?
Yes
J6
J2


J5
Do you want to purge ?
Yes
Purge file name
No
Notify user to enter new name
J3


J6
Did you store another regular file ?
Yes
Enter reg file name
Is name too long ?
Yes
Notify user name is too long
Wait 4500
No
J
No
Load and run Autost
A

APPENDIX D

HP-85 ERROR CODES

A list of the error codes which may be encountered in the operation of the system follows. The error numbers and messages, error conditions, meanings, and corrective actions are taken from the operating manuals for the HP-85 computer, for the I/O ROM, for the Printer/Plotter ROM, and for the Mass Storage ROM, respectively.

HP-85 Computer Error Codes

Error Number	Error Condition	Default values (errors 1-8 only) with DEFAULT ON
	Math Errors (1 thru 13)	
1	Underflow: expression underflows machine	0
2	Overflow:	±9.99999999999E499
	- Expression overflows machine	
	- Attempt to store value > 99999 or < -99999 in INTEGER variable	±99999
	- Attempt to store value > 9.9999E99 or < -9.9999E99 in SHORT variable	±9.9999E99
3	COT or CSC of n*180 ; n=integer	±9.99999999999E499
4	TAN or SEC of n*90 ; n=odd integer	±9.99999999999E499
5	Zero raised to negative power	±9.99999999999E499
6	Zero raised to zero power	1
7	Null data:	
	- Uninitialized string variable, or missing string function assignment	""
	- Uninitialized numeric variable, or missing numeric function assignment	0
8	Division by zero	±9.99999999999E499
9	Negative value raised to non-integer power	Remaining errors are non-defautable.
10	Square root of negative number	
11	Argument (parameter) out of range	
	- ATN2(0,0)	
	- ASN or ACSN(-1 < n < +1)	

Error Number — Error Condition

- ON expression GOTO/GOSUB; expression out of range

12 Logarithm of zero

13 Logarithm of negative number

14 Not used

System Errors (15 thru 25)

15 System error; correct by reloading program, pressing ENDLINE, or turning system off, then on again

16 Continue before run; program not allocated

17 FOR nesting too deep; more than 255 active FOR-NEXT loops

18 GOSUB nesting too deep; more than 255 nested subroutines

19 Memory overflow:

- Attempting to RUN a program that requires more than given memory
- Attempting to edit too large a program; delete a nonexisting line to deallocate program, then edit
- Attempting to load a program larger than available memory
- Attempting to open a file with no available buffer space
- Attempting any operation that requires more memory than available
- Attempting to load or run a large program after a ROM has been installed. ROMs use up a certain amount of memory. Refer to the appropriate ROM manual

20 Not used

Error Number — Error Condition

21 ROM missing; attempting to RUN program that requires ROM. An attempt to edit program with missing ROM will usually SCRATCH memory

22 Attempt to edit, list store, or overwrite a SECUREd program

23 Self-test error; system need repair

24 Too many (more than 14) ROMs

25 Two binary programs; attempting to load a second binary program into memory (only one binary program allowed in memory at any time

26-29 Not used

Program Errors (30 thru 57)

30 OPTION BASE error:

- Duplicate OPTION BASE declaration
- OPTION BASE after array declaration
- OPTION BASE parameter not 0 or 1

31 CHAIN error; CHAIN to a program other than a BASIC main program; e.g. CHAINing to a binary program

32 COMmon variable mismatch

33 DATA type mismatch:

- READ variable and DATA type do not agree
- READ# found a string but required a number

34 No DATA to read:

- READ and DATA expired
- RESTORE executed with no DATA statement

35 Dimensioned existing variable; attempt to dimension a variable that has been previously declared or used. Move DIM statement to beginning of program and try again

36 Illegal dimension:

- Illegal dimension in default array declaration

Error Number	Error Condition
	- Array dimensions don't agree; e.g. referencing A(2) when A(5,5) is dimensioned or referencing A(0) when OPTION BASE 1 declared
37	Duplicate user-defined function
38	Function definition within function definition; needs FN END
39	Reference to a nonexistent user-defined function: - Finding FN END with no matching DEF FN - Exiting a function that was not entered with a function call after branching to the middle of a multi-line function
40	Illegal function parameter; function parameter mismatch (e.g. declared as string, called as numeric)
41	FN=; user-defined function assignment. Function assignment does not occur between DEF FN and FN END
42	Recursive user-defined function
43	Numeric input wanted
44	Too few inputs. Less items were given than requested by an INPUT statement
45	Too many inputs. More items were given than requested by an INPUT statement
46	NEXT missing; FOR with no matching NEXT
47	FOR missing; NEXT with no matching FOR
48	END statement necessary
49	Null data; uninitialized data
50	Binary program missing; attempting to RUN program requires binary program. An attempt to edit will usually SCRATCH memory
51	RETURN without GOSUB reference
52	Illegal IMAGE format string; unrecognized character in IMAGE
53	Illegal PRINT USING: - Data overflows IMAGE declaration

Error Number	Error Condition
	- Numeric data with string IMAGE - String data with numeric IMAGE - PRINT USING image format string is not correct
54	Illegal TAB argument. With DEFAULT ON, an illegal TAB argument gives a warning message and defaults to TAB(1)
55	Array subscript out of range
56	String variable overflow; string too big for variable
57	Missing line; reference to a nonexistent statement number
58-59	Not used

Tape Errors (60 thru 75)

60	Tape cartridge is write-protected; RECORD slide tab is in left-most position
61	Attempting to create/record more than 42 files on tape
62	Cartridge out when attempting tape operations
63	Duplicate file name for RENAME or CREATE
64	Empty file; attempting to access file that was never recorded e.g. tape was ejected before program was stored but after name was written in directory). Refer to PURGE
65	End of tape: - Tape is run-off; check cartridge - Tape is full - Not enough space to CREATE data file
66	File closed: - Attempting READ#/PRINT# to file that has not been opened with ASSIGN# - Attempting to close a closed file (warning only) - Tape has been ejected and reinserted

Error Number	Error Condition
67	File name: - Name does not exist when attempt to LOAD, ASSIGN#, LOAD BIN, PURGE, RENAME, or SECURE - Name not in quotes - Attempt to PURGE an open file
68	File type mismatch: - Attempting to treat program as data file, or vice versa - Attempting to treat binary program as BASIC main program file, or vice versa - Attempting to treat data as binary program, or vice versa
69	Random overflow; attempting to READ#/PRINT# beyond existing number of bytes in logically-defined record with random file access
70	READ error; system cannot read tape
71	End-of-file; no data beyond EOF mark in data file
72	Record: - Attempting to READ#/PRINT# to record that doesn't exist; e.g. READ# 1,120 when only 100 records in file - Attempting to READ#/PRINT# at end of file - Lost in record: close file to release buffer
73	Searches and does not find: - Bad tape cartridge; may have been exposed to magnet field - Cannot find directory, tape may need to be initialized
74	Stall; either bad tape cartridge or transport problem, refer to Tape Operations, appendix B (HP-85 User's Manual)
75	Not an HP-85 file; cannot read
76-79	Not used

Error
Number   Error Condition

Syntax Errors (80 thru 92)

80 Right parentheses,), expected

81 Bad BASIC statement or bad expression. If it is an expression, try it again with DISP <expression> to get a better error message

82 String expression error; e.g. right quote missing or null string given for file name

83 Comma missing or more parameters expected (separated by commas)

84 Excess characters; delete characters at end of good line, then press ENDLINE

85 Expression too big for system to interpret

86 Illegal statement after THEN

87 Bad DIM statement

88 Bad statement

- COM in calculator mode
- User-defined function in calculator mode
- INPUT in calculator mode

89 Invalid parameter:

- ON KEY# less than 1 or greater than 8
- Attempt to TRACE a calculator mode variable
- PRINTER IS or CRT IS with invalid parameter
- CREATE with invalid parameters
- ASSIGN#, PRINT#, or READ# with buffer number other than 1 through 10
- Random READ# to record 0
- SETTIME with illegal time parameter
- ON TIMER#, OFF TIMER# with number other than 1, 2, or 3
- SCALE with invalid parameters
  AUTO or REN with invalid parameters
- LIST with invalid parameters
  DELETE with invalid parameters

Error Number & Code	Error Condition	Possible Corrective Action
	- VAL$ with non-numeric parameter - Any statement, command, or function for which parameters are given but they are invalid	
90	Line number too large; greater than 9999	
91	Missing parameter; e.g. DELETE with missing or invalid parameters	
92	Syntax error. Cursor returns to character where error was found	

I/O ROM Error Codes

Error Number & Code	Error Condition	Possible Corrective Action
101 XF	This is only a warning. It is issued when a program is paused with an I/O TRANSFER still active. Do not attempt to modify a program when a TRANSFER is active.	Before you modify or rerun the program, stop all active with a RESET, HALT, or ABORTIO instruction; or press the RESET key.
110 I/O CARD	An interface has failed self-test. This indicates a probable hardware problem.	ERRSC can be used to determine which interface has failed. Try recycling the power (turn computer off, then back on again). If the interface still fails, contact the authorized HP-85 dealer or the HP sales and service office from which you purchased your HP-85.
111 I/O OPER	The I/O operation attempted is not valid with the type of interface being used. Some examples are: specifying a status or control register that does not exist, using a primary address with an RS-232 interface, or using an I/O statement that is not	ERRL can be used to identify the improper statement. Check this statement in the Syntax Reference section to determine if it is defined for the interface being

	defined for the interface being used.	used. If the statement is valid, check the appropriate Interface Programming section to get details on the proper mode or configuration required for the statement used.
112 ROM	The I/O ROM has failed the checksum self-test. This indicates a probable hardware problem.	Try recycling the I/O power (turn the computer off, then back on again). If the error keeps recurring contact the authorized HP-85 dealer or the HP sales and service office from which you purchased your HP-85.
113	An interface-dependent error HP-IB: The statement used requires the interface to be system controller. Serial: UART receiver overrun; data has been lost. BCD: Attempting to put the interface into an illegal mode. GPIO: An odd number of bytes was transferred when the interface was configured for for 16-bit words.	ERRSC can be used to determine the source of the error. Refer to the appropriate Interface Programming section to get details on the error and possible corrective actions.

Error Number & Code	Error Condition	Possible Corrective Action
114	An interface-dependent error. HP-IB: The statement used requires the interface to be active controller. Serial: Receiver buffer overrun; data has been lost. BCD: Port 10 not currently available. GPIO: FHS TRANSFER aborted by ST0.	ERRSC can be used to determine the source of the error. Refer to the appropriate Interface Programming section to get details on the error and possible corrective actions.
115	An interface-dependent error. HP-IB: The statement used requires the interface to be addressed to talk. Serial: Automatic disconnect forced. BCD: FHS TRANSFER aborted by FLGB. GPIO: Interface configuration does not allow an output enable or output operation on Port A or Port B.	ERRSC can be used to determine the source of the error. Refer to the appropriate Interface Programming section to get details on the error and possible corrective actions.
116	An interface-dependent error. HP-IB: The statement used requires the interface to be addressed to listen. Serial: This error number not currently used. BCD: Data direction mismatch on current operation. GPIO: Cannot start operation because handshake CTL line is not in proper state.	ERRSC can be used to determine the source of the error. Refer to the appropriate Interface Programming section to get details on the error and possible corrective actions.

Error Number & Code	Error Condition	Possible Corrective Action
117	An interface-dependent error HP-IB: The statement used requires the interface to be non-controller. Serial: This error number not currently used. BCD: Interface command has been directed to a non-existent field. GPIO: This error number not currently used.	ERRSC can be used to determine the source of the error. Refer to the appropriate Interface Programming section to get details on the error and possible corrective actions.
118	An interface-dependent error. HP-IB: This error number not currently used. Serial: This error number not currently used. BCD: Cannot start operation because CTL line is not in proper state. GPIO: This error number not currently used.	ERRSC can be used to determine the source of the error. Refer to the appropriate Interface Programming section to get details on the error and possible corrective actions.
119	An interface-dependent error. HP-IB: This error number not currently used. Serial: This error number not currently used. BCD: Data format does not match the mode of the interface. GPIO: This error number not currently used.	ERRSC can be used to determine the source of the error. Refer to the appropriate Interface Programming section to get details on the error and possible corrective actions.

Error Number & Code	Error Condition	Possible Corrective Action
120	An interface-dependent error. This error number not currently used.	
121	An interface-dependent error. This error number not currently used.	
122	An interface-dependent error. This error number not currently used.	
123 NO ";"	Syntax error. A semicolon delimiter was expected in the statement.	Put the semicolon where it belongs.
124 ISC	Either the interface select code specified is out of range, or there is no interface present set to the specified select code. Interface select codes must be in the range of 3 thru 10. Codes 1 (CRT) and 2 (internal printer) are allowed for OUTPUT statements only.	Be sure that the interface select code is within the proper range. Pay special attention to variables that are used to hold interface select codes. If the interface select code is OK, be sure that the interface is plugged in properly. Finally, check the switch settings on the interface. (Someone might have changed them last weekend.)

Error Number & Code	Error Condition	Possible Corrective Action
125	The primary address specified is improper. Only addresses 00 thru 31 are allowed, but not all interfaces use this entire range.	Be sure that the ADDR primary address is within the proper range. Pay special attention to variables that are used to hold addresses or device selectors.
126 BUFFER	Four possible buffer problems: (1) The string variable specified has not been declared as an IOBUFFER. (2) Attempting to ENTER from a buffer which is out of data. (3) Attempting to OUTPUT to a buffer which is already full. (4) Attempting an output TRANSFER with an empty buffer.	Be sure that you have included the necessary IOBUFFER statement. Check the logical flow of your program (in what order are the statements executed). Buffer contents can be examined at any time by simply printing or diplaying the string variable being used as the buffer. If this doesn't provide enough information, the buffer pointers can be examined with the STATUS statement.

Error Number & Code	Error Condition	Possible Corrective Action
127 NUMBER	An incoming character sequence does not constitute a valid number, or a number being output requires three exponent digits and an "e" format was specified.	If the error is from an output operation, check the magnitude of the number and the format used. If the error is from an input operation, there are many possible causes. Here are some things to look for: more than 255 leading non-numeric character unexpected spaces in a character stream when a character-count format is used, punctuation that include potentially numeric used in an order that is numerically meaningless.
128 EARLY TERM	A buffer was emptied before all the ENTER fields were satisfied, or a field terminator was encountered before the specified character count was reached.	Check your incoming character stream, ENTER list, and image specifiers.

Error Number & Code	Error Condition	
129 VAR TYPE	The type (string or numeric) of a variable in an ENTER list does not match with the image specified for that variable.	Check your ENTER list and image specifiers.
130 NO TERM	A required terminator was not received from an interface or buffer during an ENTER statement. Remember that there is a default requirement for a linefeed statement terminator.	Check your incoming character stream, ENTER list and image specifiers.

Mass Storage ROM Error Codes

Error Number & Code	Error Condition
60 WRITE PROTECT	The mass storage medium is write protected.
61 >42 FILES	HP-83: Not used HP-85: Attempting to store more than 42 files on a tape.
62 CARTRIDGE OUT	HP-83: Not used HP-85: Cartridge is out when attempting a tape operation.
63 DUP NAME	Duplicate file name.
64 EMPTY FILE	Attempting to access an empty program file.
65 END OF TAPE	HP-83: Not used HP-85: Tape run-off or tape is full.
66 FILE CLOSED	Attempting to READ#/PRINT# to a closed file (A warning is issued for attempting to close a closed file.)
67 FILE NAME	Name does not exist, or name not in quotes
68 FILE TYPE	File type mismatch: - Attempting to treat program file as data file, or vice versa - Attempting to treat binary program as BASIC program, or vice versa - Attempting to treat data as binary program, or vice versa
69 RANDOM OVF	Attempting to access beyond existing number of bytes in logical record, using random file access
70 READ	System cannot read mass storage medium

Error Number & Code	Error Condition
71 EOF	End-of-file
72 RECORD	Record: - Attempting to access a record that doesn't exist - Attempting to READ#/PRINT# at the end of file - Lost in record--close file to release the buffer
73 SEARCH	HP-83: Not used HP-85: Bad tape cartridge, or tape not initialized
74 STALL	HP-83: Attempting to use non-existent tape drive HP-85: Tape is stalled
75 NOT HP-85 FILE	HP-83: Not used HP-85: Not an HP-85 file; cannot read
110 I/O CARD	The I/O card failed self-test and requires service
111 IOP	An invalid I/O operation has been attempted
112 M.S. ROM	The Mass Storage ROM failed self-test
123 DISC ONLY	The command or statement is valid for disc only
124 FILES	The file directory on the storage medium is full
125 VOLUME	The specified volume label wasn't found
126 MSUS	The specified mass storage unit specifier is invalid
127 READ VFY	A read verify error was encountered
128 FULL	The command cannot be executed because the mass storage medium is full

Error Number & Code	Error Condition
129 MEDIUM	The storage medium is damaged
130 DISC	The storage medium is not initialized, the drive latch is open, or the drive number specified is not present
131 TIMEOUT	The interface select code or device address specified is not present, or system hardware has failed

Plotter/Printer ROM Error Codes

Error Number & Code	Error Condition
110 I/O CARD	The interface module failed self-test and therefore needs repair
111 I/O OPER	An invalid operation has been sent to the interface module
112 P/P ROM	The Plotter/Printer ROM failed self-test. If this error should occur, do not use the ROM with your HP-83/85. Contact your local HP-83/85 dealer or HP sales and service office
113-122	These error numbers are reserved for I/O module errors. Please refer to the appropriate interface installation document for the error conditions that generate these error numbers
123 DIGITIZE	1. Digitize process for DIGITIZE, LIMIT, LOCATE, or CLIP has been interrupted from the HP-83/85 keyboard and thus aborted 2. Attempting to digitize from the CRT
124 ISC	1. Invalid select code in PLOTTER IS, PRINTER IS, or CRT IS. The error will not occur until you try to output to the non-existing interface card 2. The I/O card may not have identified itself at power on. Turn the HP-83/85 off, check all connections, then turn it on again
125 ADDR	Invalid address in PLOTTER IS, PRINTER IS, or CRT IS. (E.g., specifying PLOTTER IS 750. The largest HP-IB address is 31.)
126 PLOTTER	The addressed peripheral device does not respond. If the device does not respond within 2 seconds after it is addressed with a PLOTTER IS, PRINTER IS, or CRT IS statement, this error will occur

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