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A TRANSIENT WAVEFORM ACQUISITION SYSTEM FOR THE ELMO BUMPY TORUS

K. G. Young
R. D. Burris*
D. H. Hillis
D. R. Overbey

*Computer Services.

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
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ABSTRACT

The transient waveform system described in this report is designed to acquire analog waveforms from the ELMO Bumpy Torus (EBT) diagnostic experiments. Pressure, density, synchrotron radiation, etc., are acquired and digitized with a Kinetic Systems TR812 transient recorder and associated modules located in a CAMAC crate. The system can simultaneously acquire, display, and transmit sets of data consisting of identification parameters and up to 1024 data points for 1 to 64 input signals (frequency range = 0.01 pulse/s to 100 kHz) of data every one or more minutes; thus, it can run continuously without operator intervention. The data are taken on a VAX 11/780 and transmitted to a data base on a DECSystem-10. To aid the programmer in making future modifications to the system, detailed documentation using the Yourdon structural methods has been given.

CONTENTS

1. INTRODUCTION

The ELMO Bumpy Torus (EBT) is a device designed to study the production of energy from the fusion of hydrogen ions. Much current interest centers on the values of temperature, density, and survival time of the ions in the plasma, since these parameters are an indication of the feasibility of such a device. Diagnostic signals of interest on EBT include the pressure, density, synchrotron radiation, gyrotron beam voltage, fluctuation amplitudes from magnetic loops, etc. These analog s gnals are digitized in a system that includes waveform digitizers, trigger control, and frequency selection.

The transient waveform acquisition system is designed to simultaneously acquire, display, and transmit sets of data consisting of identification parameters and up to 1024 data points for 1 to 64 input signals. The system can take sets of data every one or more minutes; thus, it can run continuously without operator intervention. The data are taken on a VAX 11/780 and transmitted to a data base on a DECSystem-10.

2. USER'S GUIDE

In this section we give a description of the system from the user's point of view, present a sample session showing the interaction of the user with the system, and explain how to retrieve the data from the DECSystem-10 data base. In addition, we have included an on-line reference guide. This guide summarizes the steps to be taken in using

the system and includes menus with definitions and ranges for all input parameters.

2.1. DESCRIPTION

2.1.1. Hardware

The hardware consists of modules that digitize the waveform, generate the selected sampling frequency, and properly condition (delay, invert, etc.) the trigger signal. EBT may be run in a pulsed mode, in which case an external waveform is usually used for the trigger, or in steady-state mode, in which case a self-trigger or manual mode is used.

Kinetic Systems TR812 transient recorders are used to digitize and store the input waveform in local memory for later retrieval by the VAX 11/780. The input must be in the range +1.024 V to -1.024 V. (Units that accept signals in the range +5.12 V to -5.12 V are also available.) From 1 to 1024 sample points may be taken on each of 16 channels. The system can be expanded to take up to 64 inputs by adding more modules; it is not necessary to change the software code.

The frequency of sampling is determined by a Jorway 217 gated clock module in combination with a Jorway 220 delay generator. Frequencies from 0.01 pulse/s to 25 kHz may be selected. The clock generates frequencies from 10 Hz to 1 MHz in factor of 10 steps. The delay generator may be used to divide a given input frequency by any integer from 1 to 99. Thus, to generate 25 kHz, we set the clock in software to generate 1 MHz and set the delay generator to divide by 40.

The user need only enter the desired frequency in hertz, and the software will select the appropriate module settings.

There are three choices for the trigger mode of operation: external waveform, manual trigger, and internal trigger. The trigger may also be delayed a selected amount from the initial trigger by the delay generator. The external trigger is usually a waveform at some known repetition rate. If the manual trigger is selected, the user will be asked to enter the amount of time to wait for the external trigger. If no trigger is received in this time, the program will simply exit after informing the user that a timeout has occurred. If the internal trigger is selected, no trigger need be applied, and the system will self-trigger in software. However, the switch on the front of the waveform digitizer must be changed from the usual position of external trigger to internal trigger.

2.1.2. Software

In this section, we first discuss the overall structure of the software system and then discuss the individual parameters used in the system.

The software for this system is menu driven. A diagram of these menus, which shows the overall structure of the system, is shown in Fig. 1. The first menu the user sees is the select menu. Selecting edit acquisition parameters, edit channel parameters, or list parameters will result in a new menu being displayed. The first three menus accept values for the parameters listed below them in the figure.

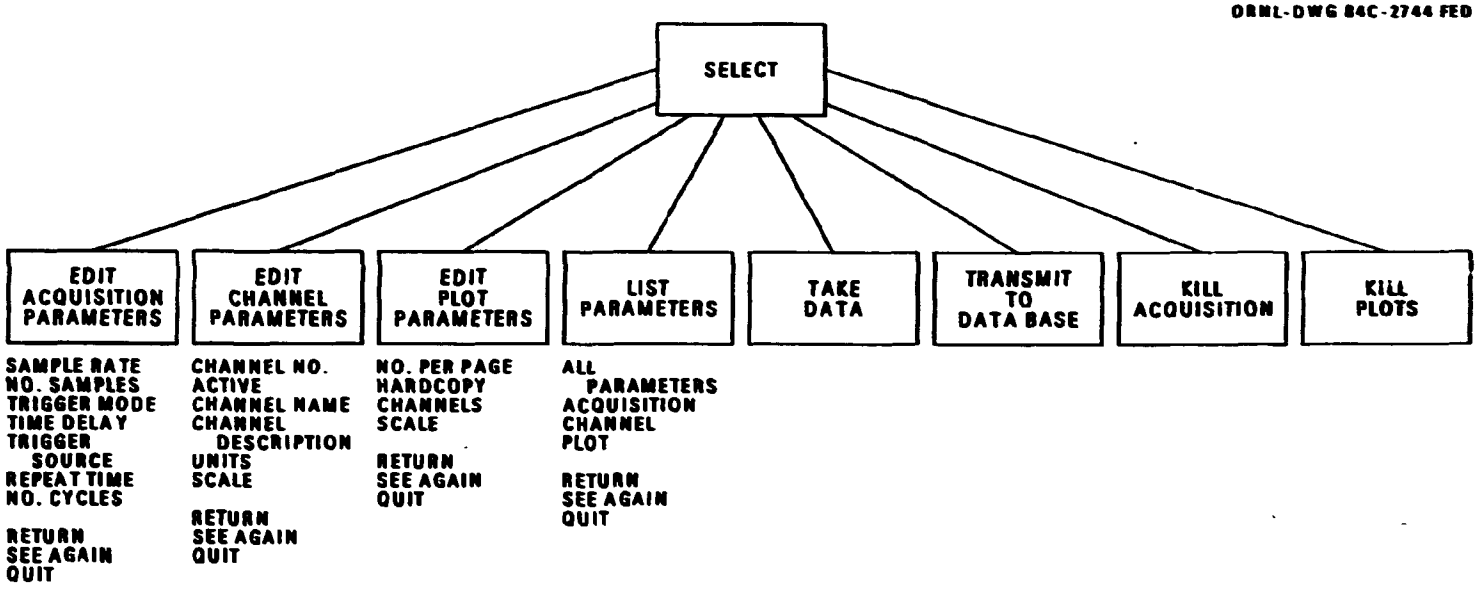

Fig. 1. Software structure and menu options.

The list parameter menu lets the user select all or some portion of the parameters to be listed. As shown in the figure, it is possible to quit, redisplay the minor menu, or return to the major menu from any of the four minor menus.

The most recent values of the acquisition, channel, and plot parameters are stored in disk files. The acquisition parameters apply to all channels, the channel parameters characterize the individual input signals, and the plot parameters relate only to the display on the local computer and have no long-term relevance.

2.1.2.1. Acquisition parameters

The acquisition parameters include the sample rate or frequency, the number of samples, the time delay, the trigger source, the repeat time, and the number of cycles. The sample rate or frequency may be from 0.01 to 25,000 pulses/s and tells how often a sample point on the waveform is taken. The number of samples may be from 1 to 1024 and tells how many of these points to take. The time delay is the amount of time to wait after the trigger before acquiring data. It must be a multiple of the sampling time period. The trigger source is the name of the trigger. The number of cycles is the number of data sets to take, and the repeat time is the time between taking samples. The true repeat time is the entered repeat time plus the processing time.

2.1.2.2. Channel parameters

Each channel or input signal has a number, a name, a version number, a description, and a calibration, consisting of the physical units and the calibration scale in physical units per volt. The data is recorded in volts, and physical units may be kilowatts, torr, etc.

The channel name is a unique ten-character name, and the description is 80 characters. When a change in the description of the signal is made but the signal still has the same name, a new version number should be entered. There is also a field to indicate whether the channel is active. If the value equals Y, data will be taken in that channel. If not, the parameters entered are still stored in a disk file, but no data are taken for that channel. Thus, the parameters for the channels may be set up ahead of time and used selectively as desired.

2.1.2.3. Plot parameters

Plot options include the number of channels to be displayed (1 to 8) and the decision of whether or not a hard copy should be made. Manual hard copies may also be made by pressing the hard copy button before the next data set is shown. A minimum and a maximum value in volts may be entered for each channel. The defaults are +1.0 V to -1.0 V.

2.2. SAMPLE SESSION

In this example, the user first lists all the parameters and then chooses to acquire data for one input in channel 2.

The parameters selected are 25 kHz, 800 data points, external waveform trigger, gyrotron beam voltage trigger source, 1-min. repeat time, and run until told to stop. The maximum available range will be plotted. After several cycles the acquisition is terminated. The following represents the interaction of the computer and the user. User input is underlined.

1. List parameters

```
MENU MPD
-------------------------------------------------------
*SUPERMENU FOR MACHINE PULSED DIAGNOSTICS*

01  FILE NAME FOR PARAMETERS =
02  TAKE DATA
03  EDIT ACQUISITION PARAMETERS
04  EDIT CHANNEL PARAMETERS
05  EDIT PLOT PARAMETERS
06  SAVE ON DECSystem-10?
07  KILL ACQUISITION
08  KILL PLOTS
09  LIST PARAMETERS
00  QUIT
PLEASE ENTER ACQUISITION PARAMETER FILE NAME: YNAME
PLEASE ENTER DESIRED OPERATION: 9


-------------------------------------------------------
*MENU FOR LISTING PARAMETERS*

01  LIST ACQUISITION PARAMETERS        98  RETURN TO SUPERMENU
02  LIST CHANNEL PARAMETERS            CR  TO SEE THIS MENU AGAIN
03  LIST PLOT PARAMETERS                0  QUIT
04  LIST ALL PARAMETERS

ENTER DESIRED OPERATION: 4

*ACQUISITION PARAMETERS*

SAMPLE RATE   = 25000 HERTZ
 NO. SAMPLES  = 800
 TRIGGER MODE = EXTERNAL WAVEFORM
 TIME DELAY   = 0.0
 REPEAT TIME  = 1 MIN
 NO. CYCLES   = 0

*CHANNEL PARAMETERS*

   CHN  ACTIVE    NAME        UNITS      SCALE     DESCRIPTION

    1     N     GYRO MODUL    VOLTS     1.0000    GYROTRON MODULATION
    2     Y     PRESS S4      VOLTS     1.0000    PRESSURE IN SOUTH 4
    3     N     SYNC 138GH    VOLTS     1.0000    SYNC. RADIATION 138 GHZ
    4     N     PRESS S4      VOLTS     1.0000    PRESSURE IN S4 138 GHZ
    5     N                             0.0000

    6     N                             0.0000
```

```
    7     N                              0.0000

    8     N                              0.0000

*PLOT PARAMETERS*

NUMBER PER PAGE =  1
 HARDCOPY       =  Y
 CHANNELS       =  2
 SCALE MIN      = -1.00
 SCALE MAX      =  1.00
```

2. Set up new parameters

```
RUN SELMPD
-------------------------------------------------------------
*SUPERMENU FOR MACHINE PULSED DIAGNOSTICS*

01  FILE NAME FOR PARAMETERS =
02  TAKE DATA
03  EDIT ACQUISITION PARAMETERS
04  EDIT CHANNEL PARAMETERS
05  EDIT PLOT PARAMETERS
06  SAVE ON DECSystem-10?
07  KILL ACQUISITION
08  KILL PLOTS
09  LIST PARAMETERS
00  QUIT
PLEASE ENTER ACQUISITION PARAMETER FILE NAME: YNAME
PLEASE ENTER DESIRED OPERATION: 3


-----------------------------------
*EDIT ACQUISITION PARAMETERS*

01  SAMPLE RATE    =  10000              98  TO RETURN TO SUPERMENU
02  NO. SAMPLES    =  800                CR  TO SEE THIS MENU AGAIN
03  TRIGGER MODE   =  EXTERNAL WAVEFORM   0  TO QUIT
04  TIME DELAY     =  0.0 MSEC
05  TRIGGER SOURCE =  POWER
06  REPEAT TIME    =  1 MM
07  NO. CYCLES     =  1

ENTER DESIRED OPERATION: 1
SAMPLE RATE = 25000
ENTER DESIRED OPERATION: 5
TRIGGER SOURCE = (80 CHARACTERS) GYROTRON BEAM VOLTAGE
ENTER DESIRED OPERATION: 7
NO. OF CYCLES (0 = GO ALL THE TIME) 0
ENTER DESIRED OPERATION: 98
```

```
*SUPERMENU FOR MACHINE PULSED DIAGNOSTICS*

01  FILE NAME FOR PARAMETERS = YNAME
02  TAKE DATA
03  EDIT ACQUISITION PARAMETERS
04  EDIT CHANNEL PARAMETERS
05  EDIT PLOT PARAMETERS
06  SAVE ON DECSystem-10?
07  KILL ACQUISITION
08  KILL PLOTS
09  LIST PARAMETERS
00  QUIT

ENTER DESIRED OPERATION: 4
```

```
*EDIT CHANNEL PARAMETERS*

01  CHANNEL NUMBER      = 1                  98  RETURN TO SUPERMENU
02  ACTIVE               = Y                  CR  TO SEE THIS MENU AGAIN
03  CHANNEL NAME         = GYRO MODUL          0  QUIT
04  CHANNEL DESCRIPTION = GYROTRON MODULATION
05  UNITS                = VOLTS
06  SCALE (UNITS/VOLT)   = 1.0000

 ENTER DESIRED OPERATION: 2
DO YOU WISH TO ACTIVATE THIS CHANNEL? N
ENTER DESIRED OPERATION: 1
WHICH CHANNEL DO YOU WISH TO CHANGE? 2
```

```
*EDIT CHANNEL PARAMETERS*

01  CHANNEL NUMBER      = 2                  98  RETURN TO SUPERMENU
02  ACTIVE               = Y                  CR  TO SEE THIS MENU AGAIN
03  CHANNEL NAME         = DENSITY             0  QUIT
04  CHANNEL DESCRIPTION = INTERFEROMETER DENSITY
05  UNITS                = VOLTS
06  SCALE (UNITS/VOLT)   = 1.0000

ENTER DESIRED OPERATION: 3
WHAT DO YOU WANT TO NAME THIS CHANNEL? (10 CHAR OR LESS) PRESS S4
ENTER DESIRED OPERATION: 4
DESCRIBE THE CHANNEL (80 CHARS OR LESS) PRESSURE IN SOUTH 4
ENTER DESIRED OPERATION: 98
```

```
*SUPERMENU FOR MACHINE PULSED DIAGNOSTICS*

01  FILE NAME FOR PARAMETERS = YNAME
02  TAKE DATA
03  EDIT ACQUISITION PARAMETERS
04  EDIT CHANNEL PARAMETERS
```

```
05  EDIT PLOT PARAMETERS
06  SAVE ON PDP 10?
07  KILL ACQUISITION
08  KILL PLOTS
09  LIST PARAMETERS
00  QUIT

ENTER DESIRED OPERATION: 5
```

```
*EDIT PLOT PARAMETERS*

01 NUMBER PER PAGE   4                    98 TO RETURN TO SUPERMENU
02 HARD COPY? Y                            0 TO QUIT
                                          CR TO SEE THIS MENU AGAIN
03 CHANNELS          1        2        3        4
04 SCALE MIN     -1.00    -1.00    -0.20    -1.00
         MAX      1.00     1.00     0.20     1.00
ENTER DESIRED OPERATION: 1
ENTER NUMBER OF PLOTS PER PAGE (MAX = 8)  1
ENTER DESIRED OPERATION: 3
ENTER CHANNEL NUMBER: 2
ENTER MINIMUM VALUE (F.P., DEFAULT = -1) CR
ENTER MAXIMUM VALUE (F.P., DEFAULT = 1.0) CR
ENTER NEXT CHANNEL NUMBER (CR IF NO MORE ENTRIES) CR
ENTER DESIRED OPERATION: 98
```

3. Take data

```
*SUPERMENU FOR MACHINE PULSED DIAGNOSTICS*

01  FILE NAME FOR PARAMETERS = YNAME
02  TAKE DATA
03  EDIT ACQUISITION PARAMETERS
04  EDIT CHANNEL PARAMETERS
05  EDIT PLOT PARAMETERS
06  SAVE ON PDP 10?
07  KILL ACQUISITION
08  KILL PLOTS
09  LIST PARAMETERS
00  QUIT

ENTER DESIRED OPERATION: 2

(Menu exits; time passes; finally, user
decides to kill it.)
```

4. Quit

```
MENU MPD
-----------------------------------------------------
*SUPERMENU FOR MACHINE PULSED DIAGNOSTICS*

01  FILE NAME FOR PARAMETERS =
02  TAKE DATA
03  EDIT ACQUISITION PARAMETERS
04  EDIT CHANNEL PARAMETERS
05  EDIT PLOT PARAMETERS
06  SAVE ON PDP 10?
07  KILL ACQUISITION
08  KILL PLOTS
09  LIST PARAMETERS
00  QUIT

PLEASE ENTER ACQUISITION PARAMETER FILE NAME: YNAME
ENTER DESIRED OPERATION: 7
DO YOU WANT TO KILL ACQUISITION? Y OR N Y
ENTER DESIRED OPERATION: 8
DO YOU WANT TO KILL THE PLOTS? Y OR N Y
ENTER DESIRED OPERATION: 0
```

2.3. DATA RETRIEVAL FROM THE DECSystem-10

Retrieving data from the PDP 10 data base involves writing a program to open the data file and retrieve the specified piece of data. To do this, one needs to know parameters that were generated when the data entry was set up and the names of the data items.

In this section we first list the names of the data items for the MPD (Machine Pulsed Diagnostic) — the name that identifies this data set on the PDP 10. Then, we will outline the steps to be taken in retrieving the data and present a listing of a sample retrieval program. The names of the items are given in Table 1.

Table 1

Name	Item
SRATE	Sample rate or frequency
TRMOD	Trigger mode
TDELA	Time delay
TRSOR	Trigger source
RETIM	Repeat time
GCOM	General comment
NOSAM	Number of data points
CHNUM	Channel number
CHNAM	Channel name
VERNO	Version number
CHDES	Channel description
UNITS	Calibration units
SCALE	Calibration value in units/volt
CHN1	Data for channel 1
.	
.	
.	
CHN64	Data for channel 64

The arrays CHN1, CHN2, CHN3, etc., contain NOSAM data points. Note that since there may be more than one channel, the channel parameters (NOSAM, CHNUM, CHNAM, VERNO, CHDES, UNITS, and SCALE) have been stored in arrays. The variable CHNUM(K) contains the channel number, and the corresponding CHNAM(K) contains the name of the channel, etc.

A rough outline for retrieving data is given below:

I. Include DSKB

To do this, either type R SETSRC and then respond INC DSKB and "control c" to quit or have the command in your log-in file.

II. Write the program.

A. Set up.

1. Set the parameters.

   For this version of this diagnostic, this means put the parameter statement PARAMETER ARSIZ=84, HARSIZ=7, GRPSIZ=1 in your program.

2. Set the dimensions of the variables to receive the desired items.

3. Put the following statements next:

   INCLUDE 'DSKB:NEWEBT.COM [210,2000]

   INCLUDE 'DSKB:NEWEBT.FOR [210,2000]

4. Read in the sequence number for the desired file.

5. Open the file.

B. Get the desired item.

To do this, call GETDAT with the following variables:

1. The name of the desired item
2. The number of the desired items
3. An error variable
4. A variable to receive the desired item

III. Execute the program.

The following is a sample program to retrieve data from input channel 1, called 'CHN1' in the data base. The data will be retrieved into the array MYDATA.

```
C
C  Set the parameters
 PARAMETER ARSIZ=84, HARSIZ=7, GRPSIZ=1
C  Set the dimensions
 DIMENSION MYDATA(1024),MNOSAM(8),MCHNUM(8)
 DIMENSION MYGCOM(12),MCHNAM(16)
C
C  Include the specified commons
 INCLUDE 'DSKB:NEWEBT.COM[210,2000]
C=======
C
C  Executable code:
 INCLUDE 'DSKB:NEWEBT.FOR[210,2000]
C
C  Get the sequence number
 WRITE(5,100)
```

```
100      FORMAT(' ENTER SEQ. NO.')
 READ(5,110)SEQNUM
110      FORMAT(A5)
C
C  Open the file
 CALL OPNDAT('MPD',SEQNUM,IFLAG)
C
C  Get the desired item
 ICOUNT=1024
 CALL GETDAT('CHN1',ICOUNT,IFLAG,MYDATA)
 STOP
 END
```

3. PROGRAMMER'S GUIDE

3.1. HARDWARE

In this section, we describe the system, discuss each module in the system, and describe the connections between the modules.

The hardware system consists of a CAMAC crate with a Kinetic Systems 3952 serial crate controller and a Kinetic Systems 3952 Dataway Display, four logic modules, and one to eight waveform digitizers. The logic modules include an in-house trigger control module, a Joerger TTL fanout/inverter module, a Jorway 217 gated clock, and a Jorway 220 gate and delay generator.

3.1.1. Trigger Control Module

The purpose of the trigger control module is to present only one trigger to the clock module. Thus, if the input to the trigger module is a repetitive train of signals, the trigger control module is first armed in software with an F26. Then, it will pass the next trigger and will pass no more until rearmed in software.

3.1.2. Joerger TTL Fanout/I verter

An inverter is necessary t present the proper signal to the clock.

3.1.3. Gated Clock

The gated clock can be controlled by a three-position external switch:

1. All outputs on — this generates continuous output.
2. Gated — every time a start is present, the clock will turn on. There is also an input for a stop signal which we do not use.
3. Off — there is no output.

There is an LED on the front of the clock that indicates when output is being generated.

The gated clock provides up to eight decade-divided outputs derived from a single 10-MHz oscillator. Thus, the available signals are 10 MHz, 1 MHz, ... 1 Hz.

In addition, modules with option 1 provide the feature of controlling the module operation from the dataway. The MUX output is patched to one of the eight gateable output connectors — in our case to

the #8 (1-Hz) output. The signals may now be selected from the dataway.

The details of frequency selection are discussed in Appendix A.

3.1.4. Gate and Delay Generator

The gate and delay generator used in this system has options 2 and 3. The module may be set either from the dataway or from the front panel. Option 2 permits one to read the front panel settings. Option 3 allows one to divide the clock input by N as well as the delay by N.

The delay generator is a triple-width C4MAC module providing eight individual delay channels. Each channel has a clock input, a start input, and an output. The output pulse is delayed relative to the input pulse by N times the input clock interval. N may be set from 0 to 99. Delays that are set are not cleared by the clear or initialize function. Clearing and initializing stop the delay generator and reload the stored delay in each appropriate channel for the next operation. Delay begins at the next negative-going clock transition after a start (negative-going) pulse has been applied. If the clock is already low (less than 0.4 V), the delay will begin with the start pulse.

Thus, by combining selected values of available 217 clock signals (10 MHz, 1 MHz, 100 Hz, ...) with a divide by N (n = 1 to 99), we can produce outputs of 0.01 pulse/s to 10 MHz. (See Appendix A for details.)

3.1.5. Waveform Digitizer

The TR812 transient waveform recorder is designed to acquire transient waveforms from up to eight different sources simultaneously and then to digitize and store the data for retrieval by a host processor. The TR812 has an input range from +1.024 to -1.024, 12-bit resolution, and 8K of memory shared between 1, 2, 4, or 8 channels. Digitizing may be controlled by an internal clock (strapped to 20, 25, 50, or 100 kHz) or by an external clock. Maximum rates are 100 kHz for 1 channel, 75 kHz for 2 channels, 50 kHz for 3 channels, and 25 kHz for 8 channels. There are three external switches: one to select 1-, 2-, 4-, or 8-channel operation; one to select internal or external clock; and one to select internal or external trigger. In our application we use the external clock and generally use 8-channel operation. The internal or external trigger is an option in the program menu and may be changed from one experiment to another. There is no reason to change the 8 channel select switch unless one needs to digitize faster (up to 100 kHz) or needs more than 1024 data points for one input.

Figure 2 shows the connection of the modules. Module settings are listed below.

Module Settings

Clock: oscillator - internal

gate - center position (gated)

software-controlled MUX output patched to output No. 7

Waveform digitizer: trigger - external

clock - external

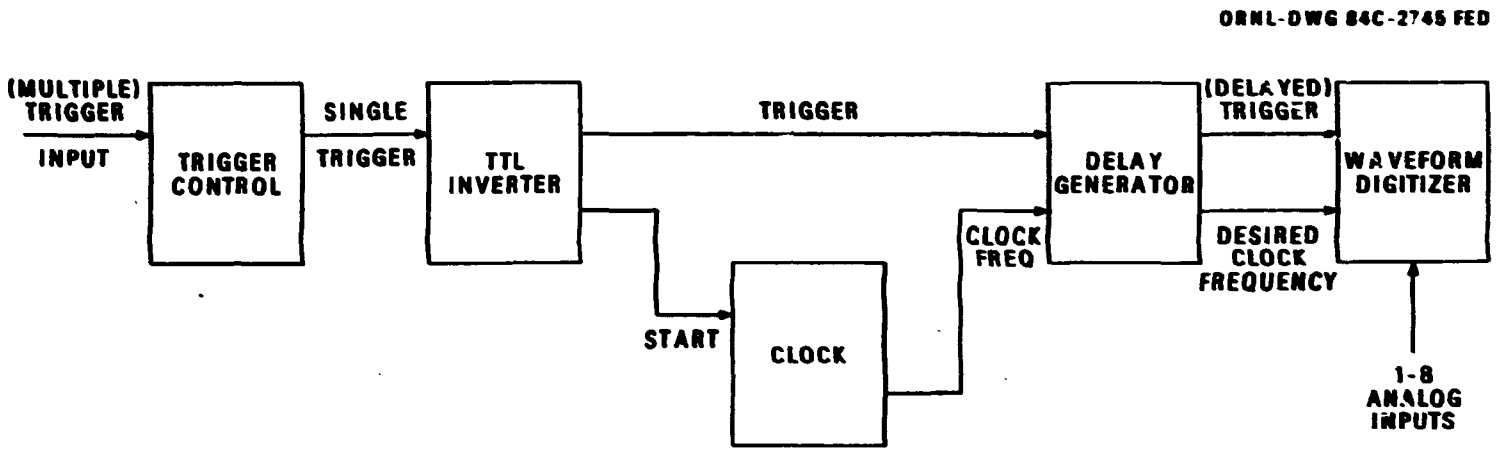

Fig. 2. Wiring diagram for machine-pulsed diagnostics.

3.2. SOFTWARE

The software documentation for the programmer has been done according to the method of Yourdon and de Marco. (See refs. 1 and 2 for detailed information on this method.) Briefly, the method consists of five parts:

1. Data flow diagrams. Data flow diagrams consist of data flows represented by named vectors, processes represented by circles or bubbles, files or data bases represented by straight lines, and data sources and sinks represented by boxes. The data flow diagrams form a hierarchy in that there is a top level diagram with the major processes and in that each major process may be broken into its own data flow diagram. A process that is not further decomposed is called primitive.
2. State diagrams. These diagrams are similar to data flow diagrams except that they show flow of control rather than flow of data.
3. Minispecs. Each primitive process is described in a minispec.
4. Data dictionary. All terms used in the data flow diagrams are defined in the data dictionary.
5. Structure chart. These charts show all the subroutines and the calling connections between subroutines. All information passed between subroutines is also shown.

The above brief description of the method will be further developed in the following sections as it is applied to the transient waveform diagnostic system.

8.2.1. Data Flow Diagrams

The first data flow diagram is usually a context diagram, which defines the domain of the system. As shown in Fig. 3, the user, detectors, and data base are outside the domain of the system. The transient waveform acquisition system is represented by the large bubble in the center. The arrows show the flow of data input parameters from the user, analog waveforms from the detectors, and translated digitized waveform files to the data base. The top or level 0 diagram (Fig. 4) shows the flow of data through the system. There are four bubbles: select action, acquire digitized waveforms, plot digitized waveforms, and transmit translated digitized waveforms. Digitized waveform files, acquisition parameters, channel parameters, and plot parameters represent files whose contents are specified in the data dictionary. (Unlabelled arrows indicate that the data flow consists of the entire contents of the data file.) The double-headed arrow in the diagram indicates that information may flow in both directions. Select action and transmit translated digitized waveform files are primitives because there are no further decompositions of these processes.

The data acquisition bubble is decomposed into three primitives (Fig. 5): get acquisition parameters, initialize modules, and construct digitized waveform file. The frequency generator and waveform digitizer are shown in square boxes; although they are part of the system, they are not processes and, thus, would not be represented by a bubble. They are pieces of hardware that accept software commands and

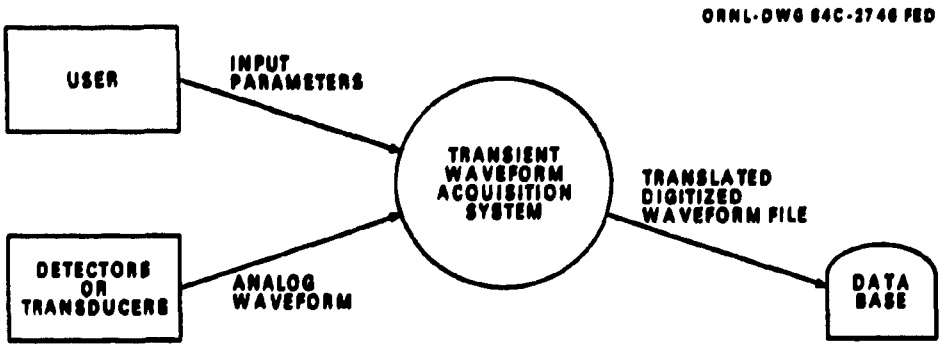

Fig. 8. Transient waveform acquisition context diagram.

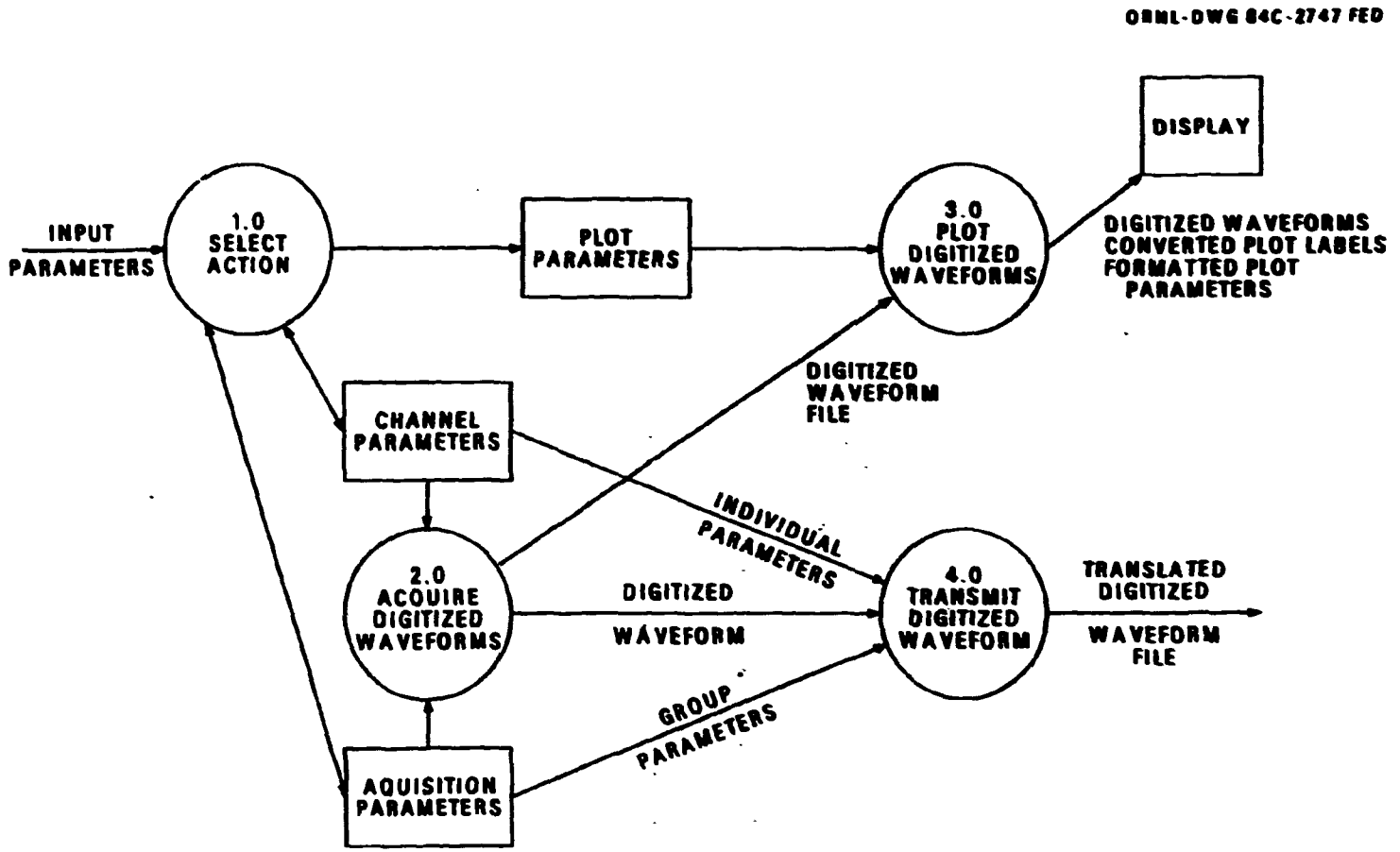

Fig. 4. 0 Machine-pulsed acquisition.

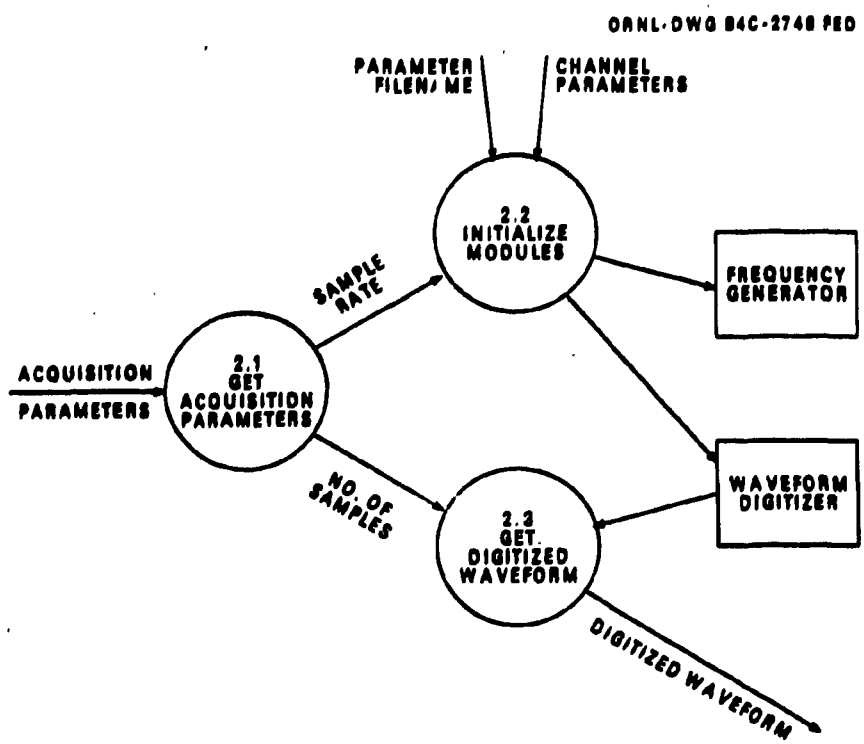

Fig. 5. 2.0 Acquire digitized waveforms.

present digitized data to the system. Decomposition of the plot digitized waveform bubble is shown in Fig. 6.

3.2.2. State Diagrams

Two state diagrams showing flow of control are included: one for level 0 of the system (Fig, 7) and one for the process select (Fig. 8). These are considered control rather than data flow diagrams because messages or data sent from one bubble to another cause changes in the state of the system. In the select state diagram, the numbers on the vectors represent the number on the menu that the user typed to cause the action given in the bubble at the end of the vector.

3.2.3. Minispecs

The minispecs for each of the primitive processes are given below.

1.0 Select

```
Print Supermenu.
Ask for parameter file name.
Read user's selection of options.
If edit acquisition, channel, or plot parameters,
  call appropriate subroutine to show menu; read in new values.
If list parameters, list parameters.
If kill acquisition, set kill acquisition flag in shared common.
If kill plots, set kill plots flag in shared common.
If quit, quit.
```

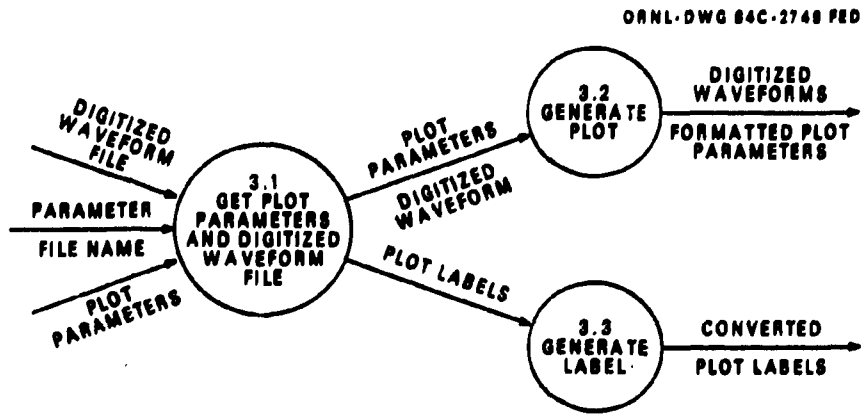

Fig. 6. 3.0 Plot digitized waveforms.

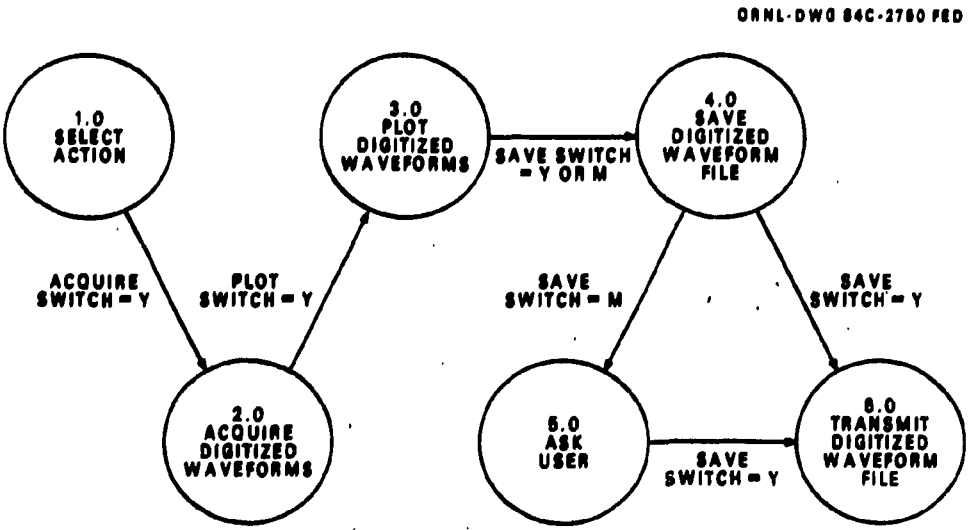

Fig. 7. Transient waveform acquisition state diagram.

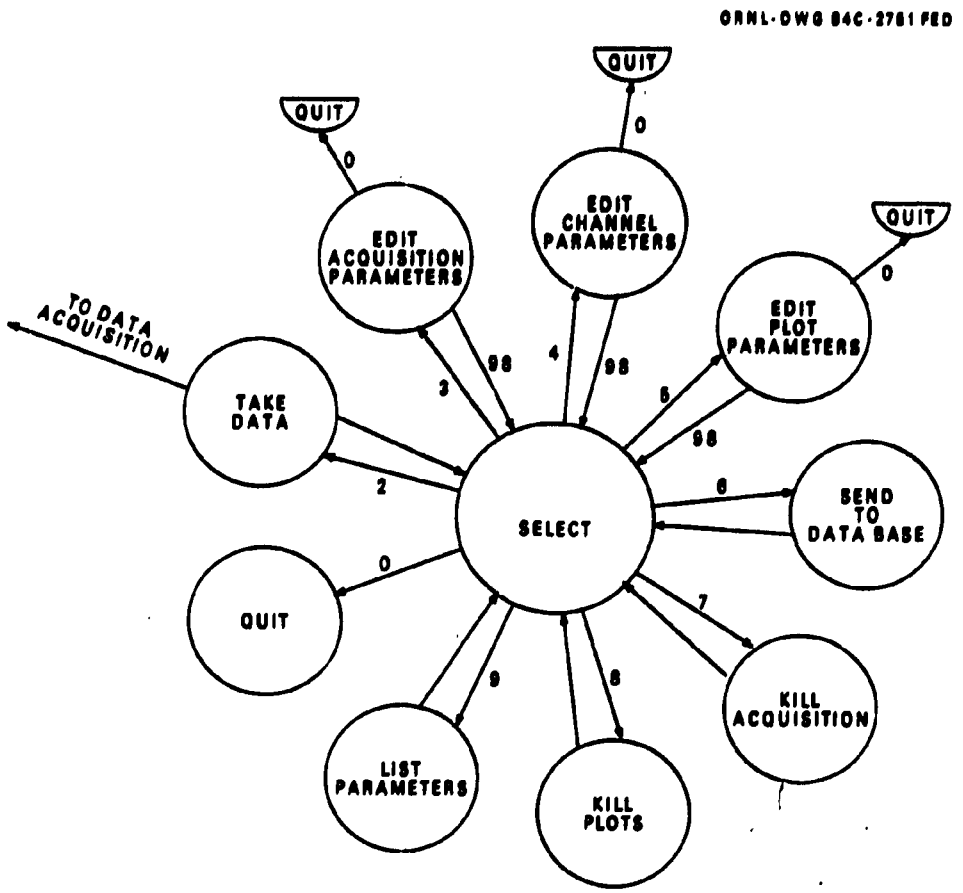

Fig. 8. 1.0 Select state diagram.

2.1 Get acquisition parameters

Read acquisition parameters.

Read channel parameters.

2.2 Initialize modules

Read acquisition and channel files for acquisition parameters.

Assign logical units to modules.

Initialize modules.

Get start time.

Enable modules.

Set clock module.

2.3 Acquire digitized waveform

If trigger mode equals self-trigger, trigger in software.

Check for completion of acquisition.

If completed, read out.

If not, wait 1 s and recheck.

Get end time.

3.1 Plot digitized waveforms

Get plot parameters and digitized waveform file.

Get parameter file name.

Get plot parameters.

Read digitized waveform file.

Initialize plot routines.

3.2 Generate plot

Do for all channels.

Read data.

Scale values.

Plot

  Set max, min values.

  Log or lin scale.

  Draw axes.

  Label axes.

  Plot data.

3.3 Generate labels

Set row, column, change in row.

Encode parameters.

Do for all parameters.

Write parameters.

New row = row + change in row

4.0 Transmit

Initialize translation routines.

Set up paramters for translation routines

length of data

type of data.

Call translation routines.

3.2.4. Data Dictionary

Data flows, processes, files, and data elements are defined in a data dictionary. A data element is a data flow that cannot be further decomposed.

Symbols and definitions of symbols used in the data dictionary are:

SYMBOL	DEFINITION
*	data element
items separated by a slash	either/or
items underlined	iterations of items
	(Enclosed component is optional.)

DATA DICTIONARY

FLOWS, FILES, ELEMENTS	DEFINITIONS
ACQUIRE SWITCH	*IF Y, WILL ACQUIRE; IF N, WILL NOT*
ACQUISITION PARAMETERS	GROUP PARAMETERS+NUMBER OF CYCLES+ DESCRIPTOR KEY
ANALOG WAVEFORM	*ADC INPUT*
ANSWER	*ANSWER RETURNED FROM QUEST*
CALIBRATION FACTOR	*Y VALUES WILL BE MULTIPLIED BY THIS*
CAMAC MODULE ID	*3 CHARACTER CAMAC NAME OF MODULE*
CAMAC SELF-TRIGGER	*SOFTWARE CONTROL OF TRIGGER*
CHANNEL ACTIVE SWITCH	*Y IF CHANNEL IS USED, N IF NOT*
CHANNEL NAME	*NAME OF INPUT SIGNAL*
CHANNEL NUMBER	*ONE OF 64 CHANNELS, 8 CHANNELS PER MODULE*
CHANNEL NUMBER TO PLOT	*NUMBER BETWEEN 1 AND 64*
CHANNEL PARAMETERS	INDIVIDUAL PARAMETERS+CHANNEL ACTIVE SWITCH
CONVERTED PLOT LABELS	*ENCODED PLOT LABELS*
DESCRIPTION OF CHANNEL	*COMMENTS TO DESCRIBE CHANNELS*
DESCRIPTOR KEY	*KEY FOR UNPACKING THE DIGITIZED WAVEFORM FILE AT THE PDP-10*
DIAGNOSTIC ID	*THREE CHARACTER IDENTIFICATION CODE FOR A DIAGNOSTIC*

DIGITIZED WAVEFORM	*ADC CONVERSIONS*
DIGITIZED WAVEFORM FILE	GROUP PARAMETERS+INDIVIDUAL PARAMETERS+ DIGITIZED WAVEFORM
DIGITIZED WAVEFORM FILE NAME	*NAME OF THE DIGITIZED WAVEFORM FILE*
DONE	*INDICATES ACQUISITION COMPLETED*
END TIME	*TIME ACQUISITION ENDED*
ERROR FLAG	*RETURNED BY QUEST*
EXTERNAL TRIGGER	PULSED WAVEFORM/OPERATOR GENERATED TRIGGER
FORMATTED PLOT PARAMETERS	*ARGUMENTS FOR GRAPHICS SUBROUTINES*
GDG CHANNEL	*CHANNEL TO USE ON THE DELAY GENERATOR MODULE*
GROUP PARAMETERS	SAMPLE RATE+TIME DELAY+REPEAT TIME+TRIGGER MODE+TRIGGER SOURCE
IDOWHAT	*TELLS WHETHER TO EXIT OR REDISPLAY SELECT MENU*
INDIVIDUAL PARAMETERS	NUMBER OF SAMPLES+CHANNEL NUMBER+CHANNEL NAME+VERSION NUMBER+DESCRIPTION OF CHANNEL+UNITS+CALIBRATION FACTOR
INPUT PARAMETERS	ACQUISITION PARAMETERS+CHANNEL PARAMETERS+PLOT PARAMETERS
LENGTH	*LENGTH OF ASCII ANSWER RETURNED BY QUEST*
LOGICAL UNIT	*LOGICAL UNIT NO. FOR THE COMPUTER*

NUMBER	*NUMBER OF ITEMS FOR PUTDAT*
NUMBER OF CYCLES	*NUMBER OF TIMES TO FILL AND READ MODULE 0 MEANS CONTINUOUS*
NUMBER OF SAMPLES	*NUMBER OF ADC CONVERSIONS TO SAVE FOR EACH CHANNEL*
OPERATOR-GENERATED TRIGGER	*OPERATOR PUSHES BUTTON*
PARAMETER FILE NAME	*NAME TO USE FOR THE PLOT, ACQUISITION, AND CHANNEL FILES*
PLOT LABELS	START TIME+ACQUIRE SWITCH +SAMPLE RATE+CHANNEL NAME +NUMBER OF SAMPLES+NUMBER OF CYCLES+SEQUENCE NUMBER
PMAX	MAXIMUM SCALE FOR PLOTS
PMIN	MINIMUM SCALE FOR PLOTS
PLOT PARAMETERS	CHANNEL NUMBER TO PLOT+PMAX+PMIN +NUMBER PER PAGE+HARDCOPY +SAVE SWITCH
PLOT SWITCH	*IF Y, WILL PLOT; IF N, WILL NOT*
PULSED WAVEFORM	*REPETITIVE TRIGGERS FROM THE EXPERIMENT*
QUEST SWITCH	*INPUT SWITCHES FOR QUEST*
QUESTION NUMBER	*NUMBER IN THE QUESTION FILE FOR QUEST*
REPEAT TIME	*TIME BETWEEN CYCLES*
SAMPLE RATE	*NUMBER OF SAMPLES PER SECOND*

SAVE SWITCH	*IF Y, WILL SEND TO PDP-10; IF N,WILL NOT SEND; IF M, WILL ASK BEFORE SENDING*
SEQUENCE NUMBER	*USED TO NUMBER SETS OF DATA*
TIME DELAY	*NUMBER OF MILLISECONDS TO DELAY TRIGGER*
TRIGGER MODE	CAMAC SELF-TRIGGER/EXTERNAL TRIGGER
TRIGGER SOURCE	*THE NAME OF WHAT IS TRIGGERING THE EXPERIMENT*
TYPE	*CODE TO TYPE OF DATA FOR X1110*
UNITS	*CALIBRATION FACTOR IN UNITS PER VOLT*
VERSION NUMBER	*FOR CHANNEL NAME INDICATES MINOR CHANGE IN CHANNEL*

3.2.5. Structure Chart

The structure chart for this system is shown in Fig. 9. Arrows with an open tail represent data being passed in the direction of the arrow; closed tails represent the flow of control information. Boxes with vertical lines on the sides represent external routines used by this program.

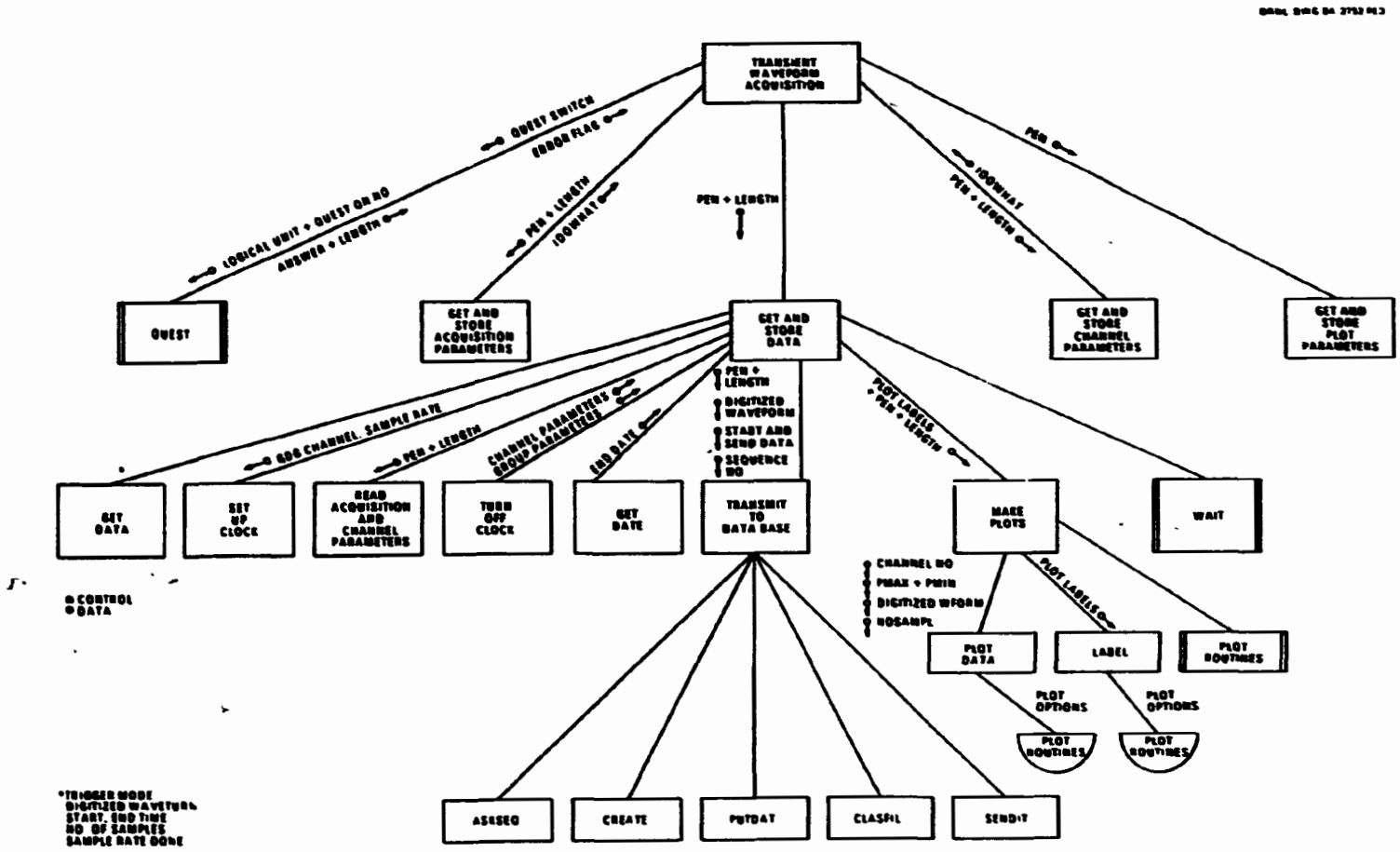

Fig. 9. Structure chart.

4. SUMMARY

This report contains a detailed description of a system for sampling transient waveforms at frequencies between 0.01 pulses/s and 100 kHz. It also contains discussions of the display and transmission of the data. Included in this report is an on-line guide or cookbook procedure for the user to follow in the laboratory. To aid the programmer in making future modifications to the system, detailed documentation using the Yourdon structural methods has been given.

Appendix A. FREQUENCY SELECTION

For this sytem, we wished to have a wide range of frequencies or sampling rates available to the user. The TR812 waveform digitizer has only four internally available sampling rates: 20, 25, 50, and 100 kHz. However, external sampling rates may be used, up to a maximum rate of 100 kHz. The gated clock model 217 will produce eight sampling rates: 10 MHz, 1 MHz, 100 kHz, 10 kHz and 100, 10, and 1 pulses/s. By using the gated clock with a delay generator of 200 A that has the ability to divide a given input frequency by the integers 1 to 99, it is possible to generate frequencies from 1 to 99 pulses/s to 10 MHz. However, the precision for the different frequencies varies: 15 kHz is obtained by dividing 1 MHz by 66, yielding 15.15 or 0.6% error, whereas 20 kHz is precisely equal to 1 MHz divided by 40. ALso, 20 kHz may be obtained equally well by dividing 100 kHz by 5, but using 100 kHz to generate 15 kHz would result in 14.2857 (divide by 7) or 16.666 (divide by 6). In order to determine the error, one needs to know the original frequencies and divide values that were used. The following table gives the original frequencies and final values; the divide factor and, thus, the error may be determined using this table.

Original frequency	Selected frequency (Hz)
1 MHz	> 10,000 to 25,000
100 kHz	> 1000 to 10,000
10 kHz	> 100 to 1000
1 kHz	> 10 to 100
100 Hz	> 1 to 10
10 Hz	> 0.1 to 1
1 Hz	> 0.01 to 0.01

1 MHz > 10,000 to 25,000

Appendix B. ON-LINE REFERENCE GUIDE

This section is designed to be used as a practical guide to using the system. First, hardware setup is discussed; then, how to use the software is covered. Software input is handled via menus; definitions and ranges are given for all items in the menus.

HARDWARE SETUP

The input signals for this system consist of from 1 to 64 analog signals and an optional trigger signal. The analog signals must be in the range of +1.024 V to -1.024 V. The trigger may be an external waveform, it may be generated when the user flips a switch, or it may be internally generated. If it is desired to use the internal trigger, the switch on the front of the waveform digitizer must be moved from external to internal.

SOFTWARE SETUP

After connecting the appropriate signals, log in to the terminal by typing

carriage return

and responding to the prompt name with

EC.

Then, enter

EC

for the password. Next type

MENU MPD.

This will cause a supermenu to be displayed.

THE SUPERMENU

The supermenu is listed below:

SUPERMENU FOR MACHINE PULSED DIAGNOSTICS

01 FILE NAME FOR PARAMETERS =

02 TAKE DATA

03 EDIT ACQUISITION PARAMETERS

04 EDIT CHANNEL PARAMETERS

05 EDIT PLOT PARAMETERS

06 SAVE ON PDP 10?

07 KILL ACQUISITION

08 KILL PLOTS

09 LIST PARAMETERS

00 QUIT

The first thing the system needs is the name of the parameter file (the user is expected to know the name of the parameter file he wishes to use). After entering the name, you may select any of the options on the menu. Options 3, 4, and 5 will bring you to other menus. Initially, you may start by using options 3, 4, and 5 to check and change desired parameters. If you merely wishes to list the parameters, option 9 may be selected.

After selecting the desired parameters, you may select option 2, which will cause the menu to exit and the system to begin acquiring data. If the program is in a recycle mode, it will acquire sets of data every x minutes (selected from the acquisition parameter menu).

To communicate with the system once the menu is exited, type

RUN SELMPD

and the menu will be displayed. You may kill acquisition by entering 7 and answering Y to the question "Kill acquisition?" If it is desired to also kill the remaining plots, 8 should be entered and a response of Y made to the question "Kill plots?" If you wish to acquire without plotting, merely answer Y to "Kill plots?" If you wish to change any of the parameters (sampling frequency, plot ranges, etc.), these may be edited while data acquisition is in progress, and the next set of data will use the new parameters. Note that you must exit from the acquisition menu to have these parameters updated and similarly for the channel and plot menus.

THE ACQUISITION PARAMETER MENU

The acquisition parameter menu displays the options and the values for the options read from the file selected in the supermenu. The acquisition parameters apply to all the channels; the parameters that characterize the individual channels are described in the next section. On all the minor (acquisition, channel, and plot parameters) menus, 98 is used to return to the supermenu, 0 is used to quit the program, and

a carriage return is used to display the menu again with the updated parameters. Note that these are not updated in the disk file until the menu is left, either by a 98 or a 0. The acquisition parameter menu appears below, followed by the definition and range (if applicable) for every term in the menu.

```
*EDIT ACQUISITION PARAMETERS*
01  SAMPLE RATE     = 10000          98  TO RETURN TO SUPERMENU
02  NO. SAMPLES     = 800            CR  TO SEE THIS MENU AGAIN
03  TRIGGER MODE    = EXTERNAL WAVEFORM  0  TO QUIT
04  TIME DELAY      = 0.0 MSEC
05  TRIGGER SOURCE  = POWER
06  REPEAT TIME     = 1 M
07  NO. CYCLES      = 1
```

Name	Range	Definition
Sample rate	0.01 to 25000 Hz	Sampling frequency — the number of times per second the waveform will be sampled
Number of samples	1 to 1024	Number of data points to take

Trigger mode	external waveform	Usually a repetitive square wave pulse
	external manual	User presses a switch to generate trigger
	Internal	Self-trigger generated in software switch on front of TR812 needs to be set to internal
Wait time	1 to 999 s	For manual trigger only, time to wait for trigger before timing out without taking data
Time delay	1 to 99 times	Sampling period (sampling period = 1/sample rate). For external triggers, time to wait after receiving trigger before taking data
Repeat time	1 to 480 min	Time to wait after acquiring data and before starting to acquire next set
Number of cycles	0, 1 to 999	Number of sets of data to acquire. If 0, acquire repetitively until told to stop by "Kill acquisition" option

THE CHANNEL PARAMETER MENU

The channel parameters have different values for each channel. The menu is shown below:

```
*EDIT CHANNEL PARAMETERS*
01  CHANNEL NUMBER       = 1                98  RETURN TO SUPERMENU
02  ACTIVE               = Y                CR  TO SEE THIS MENU AGAIN
03  CHANNEL NAME         = GYRO MODUL        0  QUIT
04  CHANNEL DESCRIPTION = GYROTRON MODULATION
05  UNITS                = VOLTS
06  SCALE (UNITS/VOLT)   = 1.0000
```

This shows the current values for channel 1. By entering the numbers 2 through 6, the values of parameters 2 through 6 may be changed. To edit the parameters for channel 2, enter 1 for the desired operation and answer the question "Which channel do you wish to change?" The menu will be redisplayed with the values for the selected channel. For example, if 2 were selected, the menu would be

```
*EDIT CHANNEL PARAMETERS*
01  CHANNEL NUMBER       = 2                98  RETURN TO SUPERMENU
02  ACTIVE               = Y                CR  TO SEE THIS MENU AGAIN
03  CHANNEL NAME         = DENSITY           0  QUIT
04  CHANNEL DESCRIPTION = INTERFEROMETER DENSITY
05  UNITS                = VOLTS
```

06 SCALE (UNITS/VOLT) = 1.0000

The names, ranges, and definitions for the channel parameters are given below.

Name	Range	Definition
Channel no.	1 to 64	The number of the input signal The parameters in this menu apply to this channel
Active	Y or N	Y means data is taken in this channel; N means it is not
Channel name	1 to 10 characters	Unique 10-character name for the channel
Channel description	1 to 80 characters	Description of the channel
Units	1 to 10 characters	User-selected physical units (kW, torr, etc.)
Scale(units/V)	6 to 999	Calibration value

THE PLOT PARAMETER MENU

Note that the plot parameters apply to on-line plotting and are not kept in the data file. The menu is given below, followed by the definitions and ranges of the items contained in the menu.

```
*EDIT PLOT PARAMETERS*
01 NUMBER PER PAGE   4                    98 TO RETURN TO SUPERMENU
02 HARD COPY? Y                           0 TO QUIT
                                          CR TO SEE THIS MENU AGAIN
03 CHANNELS          1       2       3       4
04 SCALE MIN     -1.00   -1.00   -0.20   -1.00
         MAX      1.00    1.00    0.20    1.00
```

Name	Range	Definition
Number per page	1 to 8	Number that will be displayed on the screen
Hard copy	Y or N	Y means hard copy will be generated automatically
Channels	1 to 64	The 1 to 8 channels that will be displayed

Scale		
Min	-1.0 to < 1.0	Min value for each channel
Max	1.0 to > -1.	Max value for each channel

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1. T. deMarco, Structured Analysis and System Specification, Prentice-Hall, Englewood Cliffs, N.J., 1979.

2. E. Yourdon and L. S. Constantine, Structured Design, 2d ed., Yourdon Press, New York, 1978.

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