ELECTRON BEAM FUSION DATA ACQUISITION PROGRAM
DATAIN (EBD)

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**Sandia Laboratories**

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ELECTRON BEAM FUSION DATA ACQUISITION PROGRAM

DATAIN (EbD)

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ABSTRACT

This report describes the e beam automatic data acquisition program
DATAIN.  The program was written for a Modular Computer Systems Modcomp II
computer interfaced to Tektronix R7912 Transient Digitizers.  Operator Com-
munications and data handling steps are de˴ ibed.

## 1. INTRODUCTION

A data acquisition facility has been assembled to support the electron beam fusion research accelerators Hydra, Proto I, and Proto II. The hardware consists of a Modcomp II computer and Tektronix R7912 Transient Digitizers. A program DATAIN has been written to automate the data acquisition process. The purpose of this report is to describe the operation of that program.

### 1.1 Brief Description

The program starts by allowing the operator to enter various parameters for digitizer set up and signal calibration. It then checks each unit in use for proper set up. After a shot, the computer reads and calibrates the digitized data. Finally the data is stored on the disc and control is transferred to user programs for final processing.

## 2. OPERATION

### 2.1 Activation

The program DATAIN is cataloged as a foreground task under the three character alias EBD in conventional Modcomp fashion.[1]

The program may be directed to start execution at four different points after its initialization process. It may be activated from either the console or the user 4010 terminal by pressing the appropriate control interrupt button and typing one of the following messages depending on where execution should begin:

|            |                                   |
|------------|-----------------------------------|
| GO START   | (Start at beginning.)             |
| GO TV      | (Start at TV & Knob check.)        |
| GO ARM     | (Start at arm 7912's for shot.)    |
| GO READ    | (Start at read data from 7912's.)  |

When the program is activated, it always erases the proper terminal screen and types the following messages.

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machine, shot number

date

PROGRAM EBD ACTIVE

ARE MACHINE AND SHOT NUMBERS OK?

When the computer is first turned on, there are no valid machine and shot
numbers in core. In this case the first line will be blank. If the machine
and shot number are correct, the user should return a 'Y' to continue the
program. If the user wishes to change either entry, he must return an 'N'.
The correct machine and shot numbers should be entered in response to the
message:

ENTER MACHINE AND SHOT NUMBERS.

The machine entry must be a number. Valid entries are outlined below:

| Entry | Machine |
|-------|---------|
| 0 | Hydra |
| 1 | Proto I |
| 2 | Proto II |
| 3 | Special. |

Having the correct machine number is critical since it determines which area
of the disc to read and write data arrays. The shot number may be enterred
on the same line as the machine number. This entry is optional. If it is
omitted, the last shot number used for the selected machine is read from the
disc. This number is then incremented by one to get the shot number for use
in the rest of the program. This new shot number is only written back to
the disc after the user has finished with the output header.

2.2  Headers

The first overlay segment allows the operator to produce a table of
calibration and digitizer set up parameters which are used later in the program.

### 2.2.2  Input Header

#### 2.2.2.1  General

The program reads from the disc the table of input header information that was last used for the machine selected.  Each machine has its own header stored.  In addition an alternate header may be placed on the disc by a FAWTEK shot tape read.[2]  The table is then printed out on the terminal screen and the operator may make additions, deletions, or changes as described in 2.2.4.  A typical page is shown in Fig. 1.  If the number of entries exceeds 20, only the first 20 are printed out on the first page. The remaining entries will be printed out on a second page when the operator finishes.  The maximum number of entries allowed is 25.

#### 2.2.2.2  Entry Parameters

Each line in the table corresponds to an input data array. The various parameters in the table define how the data is to be acquired and calibrated.  The format and significance of each parameter is described below

| Parameter | Format | Significance |
|---|---|---|
| N | Integer | Array number. |
| ID | Alphanumeric (4) | Array name. |
| UN, CH | Integer (2) | R7912 unit and channel number on which signal is to be digitized. |
| ATTEN | Real | Total external attenuation due to attenuators and power dividers. |
| GUAGE | Real | Diagnostic monitor calibration in units/volt. |

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```
PROTO 1, SHOT #   ⁻ˑ
1/26/77
N   ID     UN/CH    ATTEN      GUAGE      TKNOB  UKNOB UPOS     DELAY   CAB
1   VMTP    8,1    500.00    0.1070E+04   10NS    1U    150     0.0NS    14
2   VMBT    9,1    500.00    0.1070E+04   10NS    1U    150     0.0NS    14
3   BDOT   10,1    100.00   -0.5477E+11   10NS    1U    320    -2.2NS    14
4   BD2T    6,1     20.00   -0.3858E+12   10NS    1U    320     7.2NS    14
5   BDKT    7,1     50.00   -0.1334E+12   10NS    1U    360     9.6NS    14
6   BDOB   11,1    100.00   -0.6177E+11   10NS    1U    320    -1.0NS    14
7   BD2B   14,1     20.00   -0.3020E+12   10NS    1U    320     3.3NS    14
8   BDKB   13,1     50.00   -0.1022E+12   10NS    1U    360     9.7NS    14
9   XRT    12,1      1.00    0.1000E+01   20NS   500MU  430    22.8NS    15
10  XRAY   12,2     10.00    0.1000E+01   100     1U    439    22.8NS    11
READY
Q
```

FIGURE 1   Example input header for Proto 1.  Note split screen delay entry in
line 10 under TKNOB.

| TKNOB | Alphanumeric (6) | Desired time base sweep speed or 2nd signal delay for split screen channel 2 entry. |
| VKNOB | Alphanumeric (6) | Desired vertical amplifier sensitivity setting. |
| VPOS | Integer | Desired trace vertical position. |
| DELAY | Real | Time in nanoseconds at which 1st data point occurs. |
| CABLE | Integer | Pointer to compensation filter curve stored on disc to be used for cable compensation. |

### 2.2.2.3 GO Command

In addition to the text editing commands described in 2.2.2 the input header program also accepts the command

GO (destination).

| Destination | Effect |
|---|---|
| (none) | Program prints a second header page if it exists. If there is none, the parameter validity checks are made. If all parameters are okay, the output header program is entered. |
| START | The program is restarted at the enter machine and shot number point. |
| PAGE | The current page is reprinted with any new entries inserted. |

This command may be entered at any time.

2.2.2.4  Parameter Validity Checks

When the operator has finished making changes to the various
entries, the program makes validity checks on some of the parameters.  The
checks performed are described below.

2.2.2.4.1  Unit Channel (UN, CH)

Allowable R7912 unit and channel numbers are 0-14
and 1-2, respectively.  No unit/channel combination may be used twice.  Chan-
nel 2 may only be used as 2nd input for split screen operation.  If any errors
are detected, no further validity checks are made for this array.

2.2.2.4.2  Knobs Settings (TKNOBS, VKNOBS)

The files of calibration curves on the disc are
searched to insure that horizontal and vertical calibration curves exist
for the unit/channel and knobs settings selected.  The TKNOBS calibration
data is used to generate a sampling interval for the unit selected.  The
split screen delay must be half of the total trace length $\pm \frac{1}{2}$ division.

2.2.2.4.3  Vertical Position (VPOS)

Valid vertical positions are from 0 to 511 corres-
ponding to bottom to top of 7912 screen.

2.2.2.4.4  Delay

Valid delays are 0. to +999.9 nanoseconds.

2.2.2.4.5  Cable

Valid cable compensator arrays are 1-20.  An entry
of zero means no compensation is desired.  The time scale of the requested
compensation curve must correspond to the time scale of the unit selected.

2.2.2.4.6  Error Message

If any errors are detected in an entry line, the
following message is printed:

ERRORS IN LINE n1, DEV. ERR n2, KNOBS ERR n3, MISC ERR n4.

'N1' is the input header line number containing the error.  The meaning of
the error codes are described below.

n2

0        no error.

1        invalid unit or channel.

2        unit/channel used twice.

n3

0        no error.

1        VKNOBS invalid.

2        TKNOBS invalid.

3        both VKNOBS and TKNOBS invalid.

n4

0        no error.

1        VPOS invalid.

2        DELAY invlaid; VPOS may be invalid.

3        CABLE invalid; VPOS, DELAY may be invalid.

4        compensator sampling interval not equal to
         time base sampling interval.

In addition if the split screen delay is bad, the following message is
printed:

INVALID SPLIT SCREEN DELAY, Unit n.

Error messages will remain on the screen for operator review until the RETURN
key is struck.  The input header will then be reprinted so the operator can
correct the errors.  All errors must be corrected before the program will
continue.

2.2.3  Output Header

2.2.3.1  General

Output header information is used by various applications programs to define how the input data arrays are to be processed.  When the operator has finished with the input header, the table of output header information last used for the machine selected is read from the disc and printed out.  An example is shown in Fig. 2.

2.2.3.2  Diode Setup Entries

The first two rows of information in the output header contain information about the diode setup.  The top row is for the north line on HYDRA and the top line on PROTO I or PROTO II.  The second row pertains to the south line on HYDRA and the bottom line on PROTO I or PROTO II.  The format and significance of the various entries are described below.

| Parameter | Format | Significance |
|-----------|--------|--------------|
| N | Integer | Row number. |
| LOC | Alphanumeric (2) | Line location. |
| CATH | Alphanumeric (4) | Line cathode type. |
| ANODE | Alphanumeric (4) | Line anode type. |
| GAP | Floating point | Diode gap in cm. |
| INDUCT | Floating point | Line inductance in nanohenrys. |
| TSIZE | Floating point | Target size in mm. |
| TARGET | Alphanumeric (4) | Target type. |
| SHOT | Alphanumeric (4) | Shot type |
| USER | Alphanumeric (4) | User name. |

Entries may be modified by the CHANGE command described in 2.2.4.5.

```
PROTO 1, SHOT # 786
1/26/77
N  LOC  CATH  ANODE   CAP    INDUCT  TSIZE  TARG  SHOT  USER
1  TO   1X.9  AL    0.33CM  42.00NH  0.00MM  NO   PSDS  SAG
2  BO   1X.5  AL    0.31CM  42.00NH  0.00MM  NO   PSDS  CWM

OUTPUT ARRAYS
N   ID    STAT  PAR1        N   ID    STAT  PAR1
1   URTP   0     0          21  IOT    0     0
2   UROT   0     0          22  ZOT    0     0
3   BOOT   10    3          23  POT    0     0
4   BO2T   6     5          24  EOT    0     0
5   BOXT   6     5          25  UC2T   0     0
6   BOOB   10    3          26  I2T    0     0
7   BO2B   6     7          27  Z2T    0     3
8   BOXB   6     7          28  P2T    0     0
9   XRT    0     2          29  E2T    0     0
10  XRAY   0     2          30  UOXT   0     3
11  B2TX   0     0          31  IKT    0     3
12  BKTX   0     0          32  ZXT    0     0
13  UTOX   0     0          33  PKT    0     0
14  UBOX   0     0          34  EXT    0     0
15  BTOX   0     0          35  UC1B   0     0
16  BBOX   0     0          36  IOB    6     0
17  XRXX   0     0          37  ZOB    3     0
18  BXBX   0     0          38  POB    0     0
19  B2BX   0     0          39  EOB    0     0
20  UC1T   0     0          40  UC2B   0     0

READY
%
```

FIGURE 2    Example output header for Proto I.

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2.2.3.3.  Array Name List

The two rows of diode setup parameters are followed by the array name list.  This list defines which arrays are to be transferred to the archive tape.  The number of list entry rows is variable.  The maximum number allowed is 62.  Up to 40 rows will be printed out on the page with the diode setup information.  Any remaining lines will be printed on the next page after the user enters a GO command (2.2.4.6).

The format and significance of the entry columns in each row are described below.

| Column | Format | Meaning |
|--------|--------|---------|
| N | Integer | Line number. |
| ID | Alphanumeric (4) | Array name. |
| STAT | Integer | Array status for user programs. |
| PAR1 | Integer | Array option parameter for user programs. |

The data in the output header is not used by the data acquisition program EBD.  And no validity checks are made on any entry.  It is intended to be utilized by user programs to define what calculations should be made on the data arrays.  For example the diode analysis program DIODEØ has many restrictions on the various entries in the output header.[4]  However if the user wishes to make the output header compatible with the way EBD writes the input data arrays to disc, the following conventions should be observed.

1.  The first group of entries should be in the same order as the input header entries.  These will be the fully calibrated data arrays produced by the program from the raw 7912 data (3.2 - 3.5).

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2.  The second group of entries should be in order of increasing unit numbers of the entries in the input header.  These entries will be the normalized raw data arrays produced by the program (3.1).  Only one entry per unit is required in case of split screen operation.  The raw data entries may be flagged by making the last character in the ID a '*'. Changes may be made to any line or individual entry by using the text editing commands described in 2.2.4.2 - 2.2.4.5.

### 2.2.4  Commands

#### 2.2.4.1  General

The commands described below are used to modify the current page of the header table or transfer program control.  Parameters in parentheses are optional.  Commands are entered in response to


|     READY     |     or     |     READY     |
| @ |  | % |


If an invalid command is entered, the message

<p align="center">COMMAND ERROR</p>

is printed and operator may try again.

#### 2.2.4.2  NEW, n, (NO)

This command is used to add an entire new line after line 'n' in an array name list.  Valid line numbers are 1 less than the first line number printed thru the last line number printed on the current page.  After the command has been correctly interpreted, the computer issues a carriage return/line feed.  The operator then enters the new line.  Parameters for the new line are read from fixed length fields, so entries in the new line must line up under previous lines.  Unless the third parameter is present and equal to 'NO', the current page will be immediately erased and rewritten with the new entry.  Otherwise the operator simply enters the next command.

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2.2.4.3  DEL, n, (NO)

The entire line number 'n' in the array name list is deleted.
Valid line numbers are any presently on the screen.  The significance of the
parameter 'NO' is described in 2.2.4.2.

2.2.4.4  CHANCE, n, (NO)

Change entire line number 'n' in the array name list.  Valid
values for 'n' are any line number currently on the screen.  When the command
has been correctly interpreted, the operator enters the new line as described
in 2.2.4.2.  The significance of parameter 'NO' is also described in 2.2.4.2.

2.2.4.5  CHANGE, par, n, (NO)

Change the value of the parameter 'par' in line 'n'.  Valid
parameters are any column heading names except 'N' and 'LOC'.  Only the first
two characters need be entered.  Valid values for 'n' are any line number
currently on the screen.  When the command has been correctly interpreted,
the computer will issue a carriage return/line feed; and the operator may
enter the new value.  The parameter 'NO' is described in 2.2.4.2.  The dimen-
sion characters must not be entered for the floating point parameters that
use them.  For example when changing the TSIZE parameter the characters 'MM'
will not be accepted.  However these characters must be entered for the
alphanumeric parameters TKNOBS and VKNOBS.

2.2.4.6  DWRITE 'machine'

This command is used to transfer the current input or out-
put header to another machine's area of the disc.  It is intended to be used
in conjunction with a FAWTEK shot tape read.  This tape read copies the input
and output headers to the 'SPECIAL' header disc areas.  These headers can
then be read up by selecting machine number 3.  The DWRITE command can then
be used to transfer the header over to the desired machine.  Thus if an old

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shot is to be duplicated, the old header can be restored without having to
type it in again line by line. The parameter 'machine' is the disc area
number where the header is to be copied. Valid 'machine' entries are
0, 1, 2, 3.

### 2.2.4.7 GO, (destination)

This command either advances the program EBD or causes
program control to be transferred. If the 'destination' parameter is omitted,
the EBD program advances to its next step. This will either be to print
another page of header information or to go to the baseline and unit check-
out overlay (2.3). The effect of the various 'destinations' for the out-
put header program are described below. 'Destination' for the input header
is described in 2.2.2.3.

| 'Destination' | Effect |
|---|---|
| (NONE) | EBD advances to next step. |
| START | EBD restarts from beginning. |
| FAWTEK | EBD exits, and FAWTEK is activated.[1] |
| DIODE | EBD exits, and DIODE∅ is activated.[4] |
| USER | EBD exits, and user plot program is activated. |
| TV | EBD goes on to baseline overlay. |
| EXIT | EBD exits; no new program is activated. |
| CAL | Autocal program is activated.[5] |

If there is a second page to be printed, the 'destination' entry will be
ignored. Any 'destination' entry other than those listed above will give
a command error.

### 2.3 Unit Setup and Checkout

After the input and output header tables have been satisfactorily set
up, the program loads and executes the second overlay segment. This pro-
gram checks each R7912 to be used for proper knob settings.

2.3.1 Autocal Switches.

The input to each channel for each unit is controlled by a 4 position coaxial 50Ω rotary switch. These switches are part of the automatic calibration (Autocal) system.[5] The first thing the second overlay segment does is to turn each rotary switch to the position corresponding to the machine in use. The switch positions are:

| Machine | Position |
|---------|----------|
| Hydra | 1 |
| Proto I | 2 |
| Proto II | 3    . |

In addition all unused switches, i.e. those that don't correspond to any unit, are placed in the positions described above. This is done to properly route trigger or marker signals. Some checks are made on the status of the Autocal hardware. If an error is detected, the program prints:

AUTOCAL OFF   .

The operator then must decide what to do as described in 2.3.5.

2.3.2 TV Select

The program then lets the operator decide which (if any) units need to be set up with the tv monitor. Operator response is to the message:

ENTER UNITS FOR TV MODE.

Valid responses and their effects are described below.

(1) (blanks) program accepts GO command (2.3.5).

(2) ALL   all units to be used are placed in TV mode.

(3) NONE   no units are placed in TV mode.

(4) n1, n2,... unit numbers selected will be placed in TV mode.

The dot graticule will also be enabled on all units selected for TV checkout. If an invalid response is entered, the message

ILLEGAL ENTRY

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is printed and the operator tries again.  Since up to 8 seconds are required

to switch the R7912's back into digital mode, only those units which need

to be visually set up should be placed in TV mode.  If a selected unit is

offline, a 'STAT' error message is printed; and the operator must redo the

TV mode selection process.  The format of this type of error message is

described in 4.1.  After the selected units are placed in TV mode, they will

be continuously armed and triggered by the computer at about a 2 pulse/second

rate.  The trigger pulse is provided by an external trigger pulse to

each digitizer time base external trigger input.  Thus the units should be

in single sweep/external trigger mode.  The fiducial marker pulse will also

appear on the trace.  The operator should use this opportunity to insure that

all the digitizer knobs settings are correct.  When all units are properly

set up, the operator must strike the RETURN key to continue the program.

### 2.3.3  Arm Sequence

#### 2.3.3.1  Arm and Trigger Check

After units have been set up, the program goes into the arm-

ing sequence.  All units selected for use in the input header have the dot

graticule disabled and memories unlocked.  The computer then attempts to arm

them in the single sweep mode.  If any unit is off line or not in single

sweep mode, an 'ARM' error message is printed; and the operator must make a

decision what to do.  The decision making process is described in 2.3.3.2.

When all units have been properly armed, the terminal bell sounds; and the

following message is printed

<div align="center">TRIGGER WHEN READY.</div>

The computer then waits for an external trigger to be applied.  This may be

done manually by pressing the trigger button above the terminal.  After any

unit is triggered, the computer checks each unit in use to make sure it

<div align="right">21</div>

triggered. For every unit that did not trigger, a 'TRIG' error message is printed. Memories are locked on units that did trigger.

### 2.3.3.2 Error Response

If any error occurred during the arm sequence, the operator must decide what to do next. Commands are in response the message:

<div align="center">

READY
@    .

</div>

The only command accepted is:

<div align="center">

GO (destination).

</div>

Valid 'destinations' are described below.

    1. (none)      - continue despite errors.

    2. START      - restart program at beginning.

    3. TV      - restart at TV and knob checks.

    4. ARM      - rearm units.

    5. FAWTEK      - activate FAWTEK program.

    6. CAL      - activate calibration program.

    7. Exit      - program exits.

### 2.3.4 Unit Setup Checkout

The computer now reads and normalizes data from each unit in turn and makes the following checks.

### 2.3.4.1 Data Integrity

If the unit did not trigger or the R7912 memory was not loaded, a 'DATA' error message is printed. If the raw data from the memory is invlaid, a 'RAW' error message is printed. Both of these errors inhibit further processing of the data. They may indicate serious hardware malfunction.

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### 2.3.4.2  Horizontal Position

The normalized data is examined to see if the trace is posi-
tioned properly, i.e., within 10 addresses of left and right edges.  If the
horizontal position is incorrect, either a 'LPOS' or 'RPOS' error message
is printed.

### 2.3.4.3  Intensity

If there were fewer than 450 scans with less than two valid
vertical trace addresses, an 'INTY' error message is printed.  To be valid,
the trace position addresses must be less than 25 and greater than 5 vertical
points apart.

### 2.3.4.4  Knobs Settings

The R7912 knobs for the vertical sensitivity setting and
the time base sweep speed setting are compared to the values requested by
the operator in the input header table.  If they do not match, the following
message is printed.

UNIT n KNOBS WRONG.  DESIRED _____ ACTUAL _____.

### 2.3.4.5  Split Screen

If split screen operation was selected, the location of the
channel switch is determined by looking for the channel switching transient
in the trace.  If the screen is not split in the sixth division, a 'SPLT'
error message is printed.

### 2.3.4.6  Vertical Positions

The average vertical position of the trace is computed.  If
it is not within half a division of the desired value, a 'VPOS' error message
is printed.  If split screen operation is requested, this procedure is carried
out independently for each channel.

### 2.3.4.7 Baseline

A 20 point baseline array for the unit is computed from the trace data. This gives two baseline values per division. In general each baseline point is computed by averaging all the points in each half division. The first division is handled differently since the fiducial marker is supposed to be there. If the first five points of the trace are constant to within 5 addresses, the first baseline value for the first division is computed by averaging the first 5 points. The second baseline point is then computed by averaging the first and third baseline values. If the first five points are not constant, the two baseline values for the first division are set equal to the first baseline value for the second division. The baseline data is then written to the disc on special random access file 28.[3]

The program searches for the fiducial marker in the first division. The criteria for presence is the maximum deviation from the average signal of at least 1/6 of a division in amplitude. In addition, the maximum deviation may not occur at the end points of the division. The location of the marker is saved for possible use later. If the fiducial is not found, a 'FIDU' error message is printed.

### 2.3.5 Branch Selection

If there were no errors in any unit, the following message is printed:

                    ALL KNOBS OK.

Whether there were errors or not, the operator must decide what to do next in response to the message

                    READY
                    ?      .

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The only valid response is

GO (destination).

| Destination | Effect |
|---|---|
| (none) | Continue wi n program (2.4) (despite errors if any). |
| TV (SWITCH) | Redo TV setup. If the 'SWITCH' option is present the Autocal switches will be repositioned as described in 2.3.1. Otherwise this lengthy process is skipped. This option allows the user to continue the program if the Autocal hardware fails. However, he must by-pass the coaxial switches by manually jumpering cables. |
| FAWTEK | Activate FAWTEK program. |
| EXIT | Stop program. |

2.4 ARM for Shot

After baseline acquisition and unit checkout is completed, the next step in the program is to arm units for the actual shot. The following message is printed:

ARMING FOR SHOT.

The selected units are then armed and await trigger as described in 2.3.1.

2.5 Readout

If all units trigger when the shot is fired, the following message is printed:

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ALL UNITS SUCCESSFULLY TRIGGERED.

The date and time of day are stored in the output header on disc. The computer then automatically reads and calibrates the data from each unit. If any unit trace goes off scale, the OFFS message will be printed on the screen. Both the raw and calibrated data arrays are written to the disc. The calibration procedures are described in detail in section 3.

2.6  Exit Decision

When the readout process is completed, the program automatically makes a hard copy of the screen. The operator must then decide what to do next by typing a

GO destination

command in response to

READY
%        .

Valid 'destinations' are described below.

| Destination | Effect |
|---|---|
| START | Program is restarted at machine and shot number selection. |
| TV | Program is restarted at units for TV selection. |
| EXIT | Program exits. |
| FAWTEK | Program exits and FAWTEK is activated. |
| USER | User program is activated. |
| DIODE | Diode program is activated. |
| CAL | Autocal program is activated. |

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Any other 'destination' entry gives a command error. Whenever EBD exits, it copies the following information to disc direct access file 27.

1. Sampling interval for each unit.

2. Average baseline for each channel of each unit.

3. Location on disc of vertical amplifier calibration curves for each channel of each unit.

4. Location of each unit's time base cal curve.

5. R7912 user file table.

6. Cross reference array of unit/channel numbers to input header line numbers.

7. Marker positions and split screen delays for each unit.

This information is required whenever EBD is activated at any step other than the start.

3. SIGNAL PROCESSING

3.1 Normalization

This section describes the various steps in normalizing and calibrating each data array. The operation and data format of the R7912 Transient Digitizers is described in reference 6. Ideally the raw data array consists of 512 scans containing three words each: the scan number, the top of the trace, and the bottom of the trace. In general the trace position is found by averaging the top and bottom addresses. However either excess data or data deficiencies may exist for various reasons. Our program for estimating true trace position in regions of bad data is the same as that developed by Tektronix with the following exceptions.[6] First, no extrapolations of the end points are performed. Leading and trailing blank scans are simply ignored. The normalized signal is always left justified, and it may contain less than 512 points. Second, our normalization program examines scans with no vertical addresses to see if the trace went off scale. This is done by checking

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to see if an extrapolation of the last three good data points before the blank scan would be off the screen. If so, an 'OFFS' error message is printed. Only one such message is printed for each signal. The missing data points are filled in by linear interpolating between the nearest good scans on either side of the bad region.

### 3.2  Time step Calibration

The possibility that the time base sweep ramp may be incorrect or non-linear is accounted for in the calibration process. Cal curves are stored on the disc for various time base sweep speeds for each unit. The appropriate curve for each unit is read from the disc. This curve is used to generate a complete array of the times at which each data point actually occurred. The method used is a double sliding parabola interpolation developed by Marv Bauder and Bill Swartz, Organization 9424.[7] The measured signal data points are then converted to an array of constant sampling interval points by linear interpolation. The sampling interval chosen is computed from the average slope of the time base calibration curve. The sampling interval is approximately equal to the sweep time/division divided by the nominal cal factor of 51.2 points/division.

### 3.3  Baseline Subtraction

The 20 baseline values computed during the unit checkout stage are read in from the disc. These values are subtracted from the appropriate data trace elements.

### 3.4  Time Shifting

If no fiducial marker was found during the unit checkout, no time shifting is done on the data array. If there was a marker, the array is searched for a new marker position as described in 2.3.4.8. If no marker is found, the location of the new marker is assumed to be the same as the previous

value.  The data array is then shifted left so the first data point occurs
5 ns after the marker position.  Points occurring before this time are deleted
from the array.

### 3.5  Amplitude Calibration

Calibration curves for various sensitivity settings for each channel of
each R7912 are stored on the disc.  The appropriate curve is read into core.
The method of dual sliding parabolas described in 3.1 is used to calibrate
the signal data with respect to the amplifier deflection factor.  Each data
value is then multiplied by the attenuation and gauge factors from the input
header.

### 3.6  Cable Compensation

The long cable runs used between the machine diagnostics and the data
acquisition facility attenuate the high frequency components of the signal.
The frequency response of the cables has been measured.  A set of compensat-
ing filter arrays have been computed to restore the high frequency components
originally in the signal.  The set of filters correspond to commonly used
time base settings and various combinations of cable runs.  The maximum cut-
off frequency to which the data can be compensated is limited by wide band
noise.[10]  If the operator selects a valid compensation curve in the input
header table, the signal data is convolved with the compensation curve.
Thus, the output signal will have its original high frequency components
restored.

### 3.7  Split Screen Data

Each Signal acquired in the split screen mode is calibrated separately
once the raw data has gone through normalization, baseline subtraction, and
time shifting.  The mechanics of the split screen modification are such that
the signal input to amplifier channel 2 occurs on the screen first.[8]

Therefore, this signal is calibrated first. The end of this signal is defined to be the end of the fifth division (element 256) less any time shifting. The first signal is amplitude calibrated and cable compensated as required. It is stored on the disc in standard format (sec. 4) even though there are typically only about 200 valid data points. The second signal in the trace is fed in through amplifier channel 1. The start of this signal is defined to be $t_d$ nanoseconds after the time shifted start of the first signal. The value $t_d$ is the TKNOBS entry in the input header for the line corresponding to unit channel 2. The input to channel 1 must be externally delayed, e.g., by a cable, for $t_d$ nanoseconds from the channel 2 signal. The second signal is amplitude calibrated and cable compensated as required. It is also stored on disc in standard format.

4. STORED ARRAYS

After each signal has been processed as described above, it is stored on the disc for later access by user programs. Each data array is stored in unformatted binary form on direct access disc files 22 and 23. Each array contains 515 real numbers. The first real number location contains N, the number of data points in the processed array. The second location contains the sampling interval for the array. Locations 3 thru N + 2 contain the data. Location 515 contains the DELAY parameter. Locations N + 3 to 514 are not used. Each array is located on the disc in the record number given in the input header table. The mechanics of reading and writing to and from direct access files are described in reference 3. In addition to the calibrated data, the normalized arrays are also stored on the disc. They are in sequential records immediatley following the block of calibrated arrays. These are stored in the format described above except that the unit average baseline is stored in element 514.

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## 5. ERROR MESSAGES

When an error is found in R7912 setup or data processing, an error message of the following type is printed:

ERROR*'name', CLUE = n1, UNIT = n2.

The types of errors and meaning of the parameter CLUE are described below. The parameter 'n2' after UNIT is the R7912 unit number.

| ERROR | DESCRIPTION | CLUE |
|-------|-------------|------|
| DATA | A 7912 memory read failed because no data was available. | R7912 status |
| FIDU | Fiducial marker not found. | |
| INTY | Intensity setting too high or too low. | Number of scans with valid trace width. |
| LPOS | Trace positioned more than 10 scans from left edge. | First good scan number. + 1024 bias. |
| OFFS | Trace went off scale. | Extrapolated data point. |
| RAW | Error in RAW array. This indicates serious hardware malfunction or intensity off. | 1 = no raw data. 2 = first address not a scan #. 3 = too many (> 64) verticals in a scan. |
| RPOS | Trace positioned more than 10 scans from right edge. | Last good scan number + 1024 bias. |
| SPLT | Screen is not split in the 6th division. | Scan where screen is split. |
| STAT | Error encountered in communications with R7912. | R7912 status. |

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TRIG        Unit did not trigger.                    R7912 status.

VPOS        Baseline more than half a divi-          Baseline average.

            sion from selected vlaue.

The R7912 status word is in hexadecimal format.  The word is divided into four
characters.  Each character represent one of 16 possible 4 bit patterns.

| CHARACTER | BIT PATTERN |
|-----------|-------------|
| 1 = | 0001 |
| 2 = | 0010 |
| 3 = | 0011 |
| 4 = | 0100 |
| 5 = | 0101 |
| 6 = | 0110 |
| 7 = | 0111 |
| 8 = | 1000 |
| 9 = | 1001 |
| A = | 1010 |
| B = | 1011 |
| C = | 1100 |
| D = | 1101 |
| E = | 1110 |
| F = | 1111 |

Thus, the four character hexadecimal word defines the entire 16 bit computer
status word.  The significance of the R7912 status word bits is described
below.[9]

| BIT | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|------|----|-----|-----|-----|-----|-----|----|----|----|-----|-----|-----|----|----|----|----|
| NAME | ER | OFF | BTL | MOD | MPE | ND | MF | O | O | BSY | SS | SSA | O | O | BB | UB |

ER:     Indicates some error exists as defined in bits 1-6.

OFF:    Indicates digitizer or multiplexer is powered down.

BTL·    Digitizer stayed busy too long.

MOD:    Mode requested in arm command is incorrect.

MPE:    Memory parity error.

ND:     No valid data in 7912 local memory.

MF:     Digitizer local memory failure.

BSY:    Digitizer is busy.

SSS:    Digitizer in single sweep mode.

SSA:    Single sweep is armed.

BB:     A read request is being processed.

UB:     I/O operation in progress.

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