OLD DOMINION UNIVERSITY RESEARCH FOUNDATION

DEPARTMENT OF GEOLOGY
SCHOOL OF SCIENCES AND HEALTH PROFESSIONS
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA

TECHNICAL REPORT GSTR-85-1

DEVELOPMENT AND OPERATION OF A REAL-TIME DATA ACQUISITION SYSTEM FOR THE NASA-LaRC DIFFERENTIAL ABSORPTION LIDAR

By

Carolyn Butler

Submitted by Earl C. Kindle, Principal Investigator

Final Report
For the period January 1, 1984 to December 31, 1984

Prepared for the
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23665

Under
Research Grant NCCI-28
Edward Browell, Technical Monitor
Chemistry and Dynamics Branch

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DEVELOPMENT AND OPERATION OF A REAL-TIME DATA ACQUISITION SYSTEM FOR THE NASA/LANGLEY RESEARCH CENTER DIFFERENTIAL ABSORPTION LIDAR

By
Carolyn Butler

INTRODUCTION

This report documents work performed under Research Grant NCCI-28 toward the improvement of computer hardware and software of the NASA Multipurpose Differential Absorption Lidar (DIAL) system. The NASA DIAL system is undergoing development and experimental deployment at NASA/Langley Research Center (LaRC) for the remote measurement of atmospheric trace gas concentrations from ground and aircraft platforms. A viable DIAL system was developed capable of remotely measuring O3 and H2O concentrations from an aircraft platform. Test flights of the DIAL system were sucessfully performed onboard the NASA/Goddard Flight Center Electra aircraft from 1980-1984 (ref.1).

The DIAL Data Acquisition System (DAS) has undergone a number of improvements over the past few years. These have been described in references 2 and 3. During the year of 1984 the new DIAL DAS hardware and software were field tested on two occasions. In April a study of a troposheric fold event was conducted over predominantly Nevada and California. The experiment was very successful. The DIAL system measured ozone and aerosols at two wavelengths (three counting the offline UV return). In June the Electra flew to Barbados, W.I. with a number of experiments aboard to study the marine boundary layer. After some initial problems with the laser cooling unit and trying to line up the 1.06 u return in the detector the DIAL measurements were again successful.

These two experiments were the first opportunity we had to field test the new DIAL DAS -- hardware and software. Several problems were found and most were corrected in the field but on the whole the DAS functioned according to plan. Confidence was gained in the new digitizers -- Transiac 2012's -- and the Biomation was never used. It was discovered, however, that there is "crosstalk" between the Transiac digitizers and their amplifiers if their sides are removed (which was done for cooling purposes). The sides are now replaced on all units and even though there seems to be a lot of heat generated by the Camac Crate it has caused no problems so far. We had no problems with the Cipher streamer tape drives except for dirt collecting on the heads. Due to inaccessability to the tape heads during flight a routine maintenance of the tape units was performed while the Electra was on the ground. Data records of 4020 words were recorded at 5 Hz at streamer speed with ease. The dual computer system proved to be extremely useful in allowing us to generate hard copy real-time ouput of aerosol grayscales while simultaneously recording data on tape and viewing other data output (raw profiles and ozone concentrations) on the video monitor. Noise spikes occasionally caused LSI #2 to get out of synchronization with LSI #1 but this was remedied by a new command called "SYNC", which

resets LSI #2 for the expected response without interrupting any of the functions of LSI #1. A persistent "bug" in the software caused LSI #1 to halt. When this happened, both computers had to be halted and the programs re-loaded. This error was eventually traced but not until the system was back at LaRC.

This report is written to document the changes made to the DIAL DAS in 1984. The hardware is much the same as last year with the following exceptions:

(1) the Biomation 1010 is no longer part of the system
(2) an ACT II color printer now does the realtime grayscales
(3) the energy monitor data is now digitized before it is sent to the computer and is interfaced through a DRV11-C

The software has changed to implement the new hardware. Other software modifications have been made and will be described in the section "Keyboard Commands".

AIRBORNE DIAL SYSTEM

The airborne lidar system uses the DIAL technique for the remote measurement of atmospheric gas profiles. This technique determines the average gas concentration over some selected range interval by differencing the backscatter signals for laser wavelengths tuned on and off the molecular absorption line of the gas under investigation. Two DIAL wavelengths are transmitted with a 100 usec temporal separation. Simultaneously, measurements of aerosol backscatter at multiple wavelengths can be made by transmitting unused (non-doubled) energy from the DIAL system pump lasers. The aerosol measurements are single wavelength returns. A coaxial receiver system is used to collect and optically separate the DIAL and aerosol returns. Photomultipler tubes (PMT) and photodiodes detect the backscattered laser returns after optical filtering, and the analog signals from these tubes are digitized and stored on high-speed magnetic tape.

The lasers can be fired at 1, 5, or 10 Hz. Current objectives are to transmit up to six wavelengths: two on-line UV wavelengths (one for ozone and one for sulfur dioxide); an off-line UV wavelength; two IR wavelengths (one shooting up and one shooting down); and a visible aerosol wavelength. The UV returns would all be detected by the same PMT with 100 usec separation. The visible wavelength (from the off-line) would be collected by a second PMT and the two IR returns would be detected by separate photodiodes. Present software allows up to four digitizers to be used with no more than 4096 words saved in the computer (10 MHz sampling interval). Of the 4096 words alloted per buffer, at least 20 are reserved for shot header information (shot number, navigation information, energy monitors, etc.) so a safe estimate of the number of words to record per return is obtained by dividing 4000 words per buffer by the total number of returns. If there are six returns to be digitized then no more than 650 words per return should be stored (range of 9.75 km from laser platform). This software limitation can be exceeded in one channel only at the expense of decreasing the number of stored

words from another digitizer channel.

DATA ACQUISITION SYSTEM

The NASA multipurpose DIAL DAS is currently housed in half a double rack (see figure 1) with digitizers, control electronics and photomultiplier tube (PMT) power supplies occupying the other half. This is a tremendous improvement over the previous configuration of one double rack for DIAL DAS and another for control electronics. The advantage in space reduction is obvious. It was also discovered that a one rack system considerably reduced 60 Hz noise on signal lines between the PMT's and the computer digitizers.

The DIAL DAS is based upon two Digital Equipment Corporation (DEC) LSI 11/23 processors. Each LSI has 128K words of 16-bit memory. The overall flow chart for the DIAL DAS is shown in figure 2. In general, all data acquisition and storage is performed by the LSI on the left (LSI #1), while all data display and analysis are performed by the LSI on the right (LSI #2). LSI #1 does have one data analysis function. On command, LSI #1 will generate a real-time color scale representation of range resolved data with averaging on the ACT II.

LSI #1 acts as the master computer through which the operator communicates with LSI #2. The operator communicates with the master's software through a modified Ann Arbor keyboard (the Ann Arbor CRT has been replaced by one of the dual Panasonic monitors; the Ann Arbor interface board is mounted in a separate box). Operator input to LSI #1 is to a Plessey PM-DLV11J serial line interface with four serial line ports (the fourth port being the console input). The first serial port on LSI #1 is used to communicate to the console input port on an identical PM-DLV11J on LSI #2.

Data is presented to the operator on either the Panasonic video monitor through the Matrox QRGB-Graph controller and/or the system color printer Act II. Hard copy images of the video graphics display may be obtained through Polaroid photography or through a software copy command to the Trilog (with four size options). The DSD-480 dual floppy disk units (double sided and double density capabilities although not presently configured for either option) are used for storage and retrieval of program information on both LSI's. The DIAL data is stored real-time using one of two Cipher F880 magnetic tape units on 731.5 m (2400 ft) reels of 1.27 cm (.5 inch) wide magnetic tape. Two tape units are required so that continuous data is stored while one unit is rewinding. Tape speeds and densities are as follows:

25 ips @1600 bpi (PE; IBM and ANSI compatible)
100 ips @1600 bpi (PE; IBM and ANSI compatible)
50 ips @3200 bpi (PE; not IBM or ANSI compatible)

A Dilog DQ130 provides Cipher interface with the LSI 11/23.

The acquisition of data is accomplished using four Transiac Model 2012 waveform digitizers. The Transiacs are manually programmable for digitization of analog signals into 12-bit memory of selectable record lengths (2048 words are stored for DIAL applications). The internal memories of these digitizers are made available to the LSI 11/23 through a Kinetics Systems

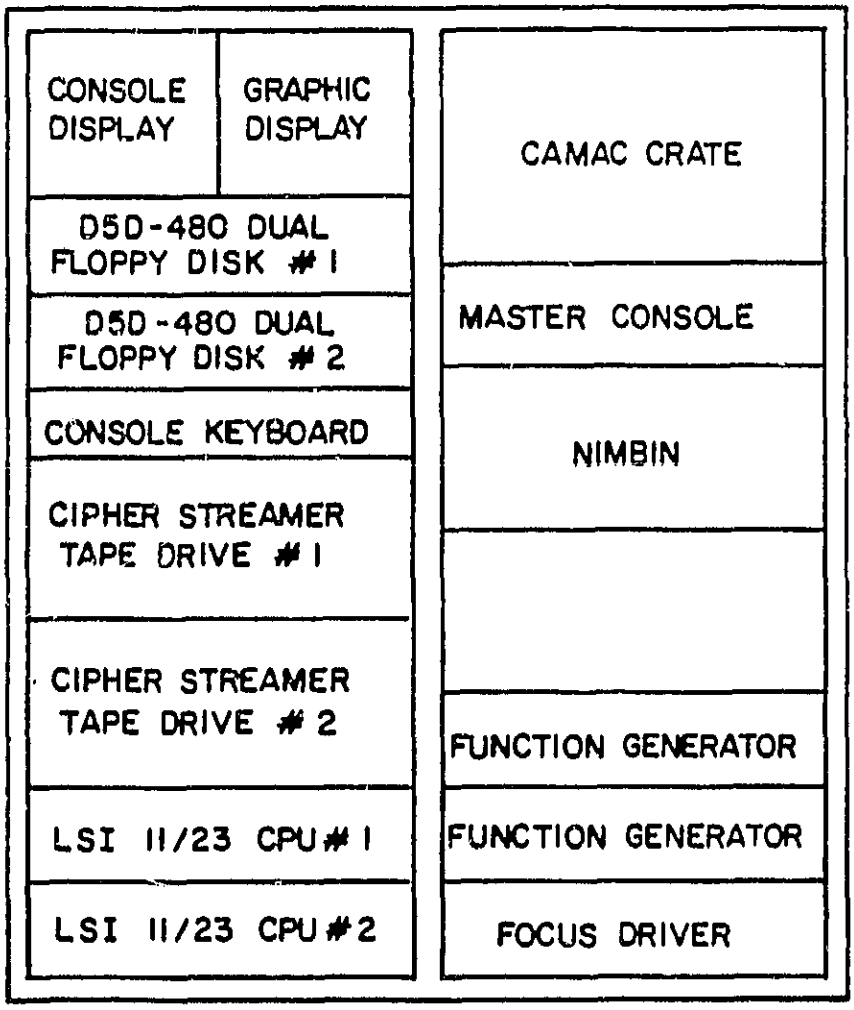


Figure 1. Schematic drawing of the DIAL DAS as configured on January 1, 1984.

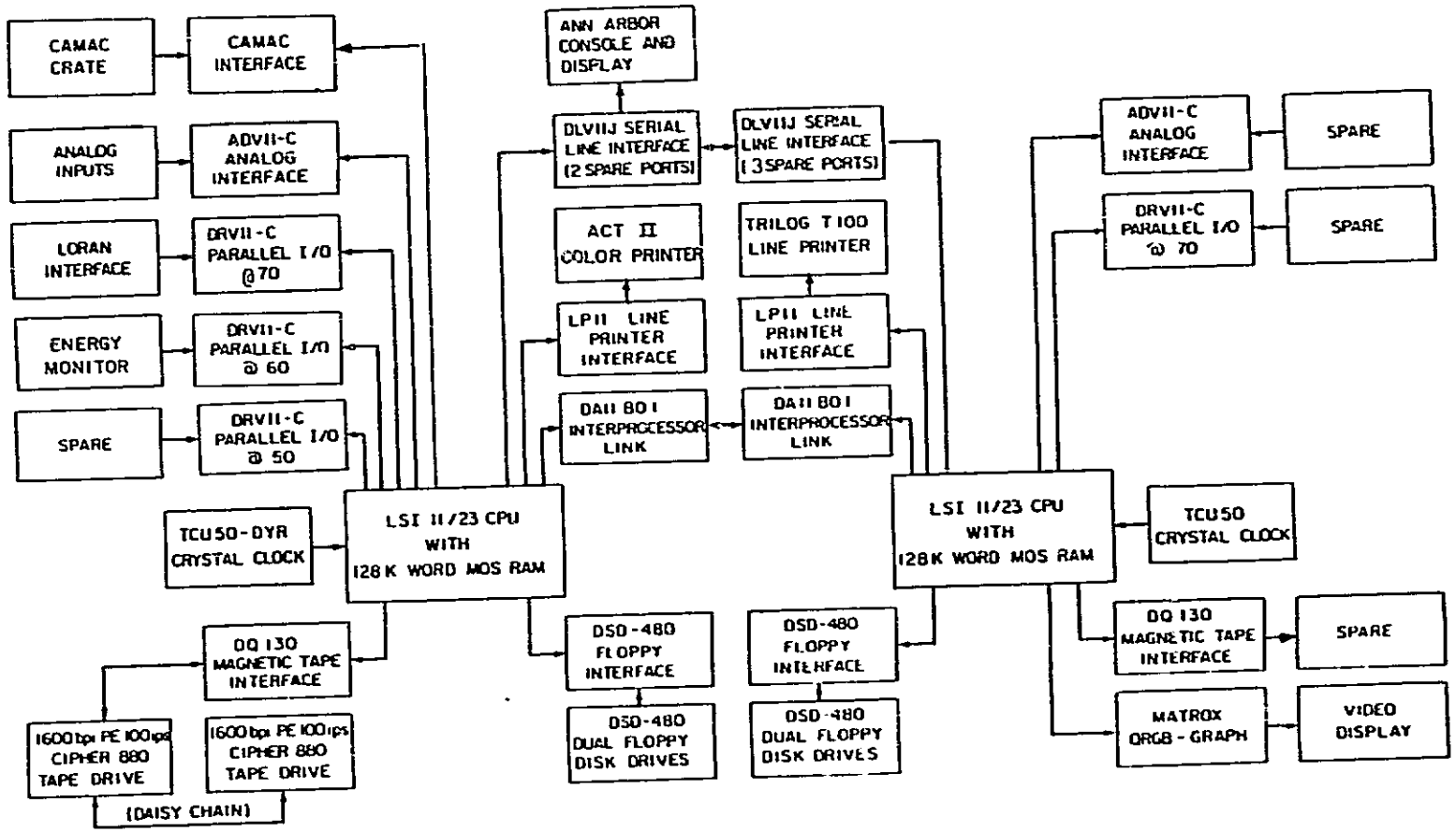


Figure 2. Computer devices flow chart.

Direct Memory Access (DMA) interface board. Sixteen Analog-to-Digital Conversion (ADC) single ended inputs (or eight differential) are available to the system through an ADV11-C board. Unipolar inputs can range from 0V to 10V and bipolar inputs from -10V to +10V. Data can be converted with programmable gains of 1,2,4, or 8 times the input voltage. In addition, there are four DRV11-C modules (three in LSI #1 and one in LSI #2) available for parallel interfacing of TTL digital signals.

SYSTEM CONFIGURATION AND CONNECTION

Data on system component size, weight, and power consumption requirements are given in table 1. A drawing of the two controller box distributions is shown in figure 3.

One advantage to going with a two computer system is that one computer can be dedicated to data acquisition while the second is dedicated to data analysis, thus allowing for much more real-time processing of the data. An additional advantage is hardware backup. Should one LSI fail, then the other computer can be used as a totally independent data acquisition system with limited real-time display capabilities. In fact, the boards have been configured inside each LSI (figure 3) so that minimal changes would be necessary for fall back to a one computer system.

Table 1. DIAL DAS component specifications for size, weight, and power requirements.

DIAL DAS COMPONENT	Height (in)	Weight (lb)	Power (amp @ 115 Vac)
Magnetic tape drive (2)	8.75	80	1
LSI 11/23 (2)	5.5	35	4
DSD-480 floppy disk (2)	5.5	60	1.5
Panasonic dual monitors	8.75	27	.5
Console keyboard	3.0	2	.5
Camac crate (full)	12.5	105	12
Trilog Printer (HxWxD)	38.5 x 30 x 24.25	185	7
Act II Printer (HxWxD)	8.2 x 22 x 17.9	40	3
Total		710	30

Table 2a shows connections from the two LSI's. LSI #2 houses spare boards which need not be connected to anything at present. Table 2b shows various other connections that need be made in order to get the DAS up and running. Table 3 lists the necessary connections to the digitizers. The first item on 2b is a "daisy chain" connection between the two Cipher tape drives. The Cipher 880 manual shows no twist for these cables

1	M 8186 CPU	DSD-480 FLOPPY INTERFACE
2	DA11 B0I INTERPROCESSOR LINK	
3	DQ 130 MAG TAPE INTERFACE	
4	CAMAC INTERFACE	
5	DRV11-C @ 50	DRV11-C @ 60
6	DRV11-C @ 70	ADV11-C
7	LP 11	DLV11-J
8	M8059 MEMORY (128K)	TCU 50-DYR

1	M 8186 CPU	DSD-480 FLOPPY INTERFACE
2	DA11 B0I INTERPROCESSOR LINK	
3	DQ 130 MAG TAPE INTERFACE	
4	MATROX QRGB-GRAPH	
5	DRV11-C @ 70	ADV11-C
6	LP11	DLV11-J
	M8059 MEMORY (128K)	TCU 50
8		

Figure 3. Internal computer configurations.

Table 2a. DAS component interconnections.

LSI #1 Board	Connector Type	Destination
DSD-480 floppy interface	26p flat cable	DSD-480 #1
DA11BOI interprocessor link	dual 50p flat cables	LSI #2 DA11BOI (P1→P2;P2→P1)
DQ130 magtape interface	dual 50p flat cables	Cipher #1 (J1→P2;J2→P1)
Camac crate interface	50p flat cable	Camac crate
DRV11-C digital interface (@60)	40p flat cable (customized)	Energy monitor
DRV11-C digital interface (@70)	40p flat cable (customized)	Nav interface
ADV11-C ADC		ADC BNC panel
LP11 line printer controller	36p flat cable	Act II printer
DLV11-J serial line interface	2p EIA (port 4) 2p EIA (port 1)	Ann Arbor LSI #2 DLV11 (port 4)

LSI #2 Board	Connector Type	Destination
DSD-480 floppy interface	26p flat cable	DSD-480 #2
DA11BOI interprocessor link	dual 50p flat cables	LSI #1 DA11BOI
DQ130 magtape interface	dual 50p flat cables	spare
Matrox QRGB-Graph	75Ω BNC cable	Panasonic #2
LP11 line printer controller	36p flat cable	Trilog T100
DLV11-J serial line	2p EIA (port 4)	LSI #1 DLV11 (port 1)

Table 2b. Other interconnections.

Source	Connector Type	Destination
Cipher #1	50p dual flat cables (half twist)	Cipher #2 (P1→P1;P2→P2)
Ann Arbor interface	26p flat cable	keyboard
	BNC cable	Panasonic #1
	power cable	Power supply

Table 3. Impedences for digitizer connections.

Transiac	Internal 50Ω
Trigger	N
Time Base	Y
Input	Y
Amp Input	Y

Available Connections for Digitizers

Lase-Coherent trigger
Master Control trigger
T-0 markers (positive)
T-0 markers (negative)
Diode clippers

---

but we found a half twist was necessary to make the tape drives function properly. Also, Cipher #1 must not be terminated and Cipher #2 must have its unit number changed to two to make this configuration work.

The Ann Arbor keyboard/display has functioned reliably and yields good quality characters. The display, however, is large and bulky. A VK-170 (DEC) keyboard kit was tried but the lettering was poor and characters were often thrown out to the screen at random. A new keyboard kit is being investigated but for now the Ann Arbor keyboard and its interface board are being used. The interface board is mounted in a separate box with an external power supply.

It is not always easy to determine where a problem is occurring. The DIAL DAS programs have been written to provide error messages when detection is possible through software techniques. These messages and appropriate action will be detailed in a later section. The following section is provided to help identify problems with peripheral devices.

PERIPHERAL PROGRAMMING INFORMATION

Table 4 is a summary of the base registers and trap vectors for all the peripheral devices associated with the two LSI computers. The magtape interface is the only device at BR7 -- the highest priority interrupt. The components marked with an asterisk are spare boards with switch registers set as shown.

Table 4. Base addresses for registers used by peripheral devices.

Device	Base Address	Trap Vector
LSI #1		
Floppy Disk	777170	264
Interprocessor Link	772410	124
Mag-tape Interface	772520	224
Camac Interface	777550	400
*DRV11-C @50		
DRV11-C @60	767760	
DRV11-C @70	767770	300
ADV11-C	770400	340
Line Printer Controller	777514	200
Serial Link (Console)	777560	60
Serial Link (to LSI #2)	776500	320
TCU 50-DYR	760770	
LSI #2		
Floppy Disk	777170	264
Interprocessor Link	772410	124
*Mag-tape Interface	772520	224
Matrox	764400	
*DRV11-C @70	767770	
*ADV11-C	770400	
Line Printer Controller	777514	200
Serial Link	777560	60
*TCU 50	760770	

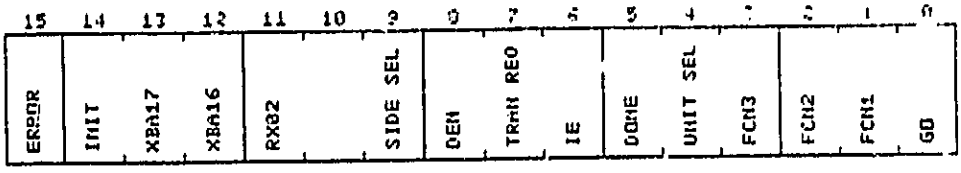
On the following pages each of these peripheral devices will be discussed in a little more detail. The intention here is to provide only enough information to determine if a particular device is functioning properly and for more involved programming requirements references are given for each item.

DSD 480 Floppy Disk System

The DSD 480 is a double sided, double density flexible disk system which is RX02 compatible with RT-11 V3B. However, since the existing DIAL computer system is using RT11 V3 internal switches were set to make it RX01 compatible (single sided, single density). The floppy disk registers are outlined below.

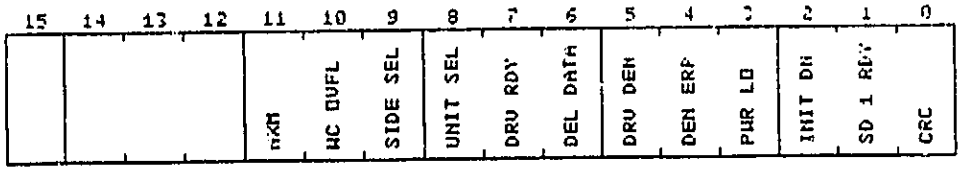
RXICS @ 777170 command and status register
RXIDB @ 777172 data buffer register

RXICS
@ 777170



ERROR	Error detected.
INIT	Initialize the DSD 480.
XBA17,XBA16	Extended address bits.
RX02	RX02 system identification bit.
SIDE SEL	Side select: =1 for side 0; =0 for side 1.
DEN	Density of the function encoded in FCN1-FCN3.
TRAN REQ	Transfer request flag.
IE	Allows DONE to interrupt.
DONE	Operation completed.
UNIT SEL	Drive unit select.
FCN3-FCN1	Function select: 000 fill buffer 001 empty buffer 010 write sector 011 read sector 100 set media density 101 read status 110 write deleted data sector 111 read error code
GO	Execute the function.

RXIES
@ 777172



NXM	Non-existent memory error.
WC OVL	Word count overflow.
SIDE SEL	Indicates side selected during last operation.
UNIT SEL	Indicates unit selected during last operation.
DRV RDY	Drive ready -- disk installed and ready to go.
DEL DATA	Deleted data -- indicates deleted data address mark was found on last operation.
DRV DEN	Density of diskette.
DEN ERR	Diskette density did not match DEN.
PWR LO	Power failure in the controller/drive subsystem.
INIT DN	Initialize done.
SD 1 RDY	Set for double sided diskette when ready.

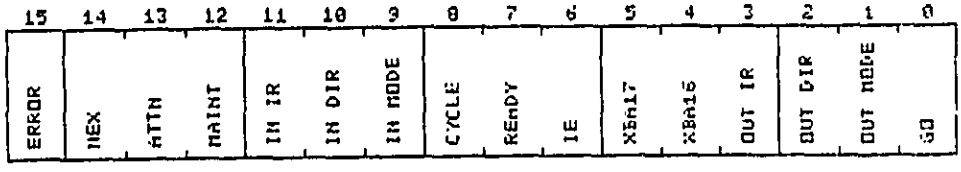
CRC Cyclic redundancy error.

Interprocessor Link (DA11BOI)

The Interprocessor Link provides a means of transferring data through DMA between two LSI 11/23 processors. This is the device used by the DIAL DAS software to transfer a data record from LSI #1 to LSI #2 to be processed and plotted.

WCNT	@ 772410	word count
ADDR	@ 772412	bus address
STATUS	@ 772414	control/status
DATA	@ 772416	data buffer

STATUS @ 772414



ERROR	Set by NEX, ATTN from the other computer or by bus address overflow.
NEX	Non-existent memory.
ATTN	Reads ATTN from the other computer.
MAINT	Maintenance.
IN IR	Input interrupt request. Reads status of the OUT IR from the other computer.
IN DIR	Input direction. Reads status of OUT DIR from the other computer.
IN MODE	Input mode. Reads status of OUT MODE from other computer.
CYCLE	Initiates a DMA transfer when the generating DA11BOI is both the requested computer and the transmitter. When CYCLE and GO are both set, an immediate bus cycle is executed.
READY	Must be cleared before a block transfer can be done.
IE	Allows READY, IN IR or ERROR to cause interrupt.
XBA17,XBA16	Extended memory bits.
OUT IR	Causes IN IR and READY in the other computer.
OUT DIR	During block transfer: =0 for transmitter; = 1 for receiver. Must be opposite of IN DIR.
OUT MODE	Output mode: =0 for DMA; =1 for program mode.
GO	Executes.

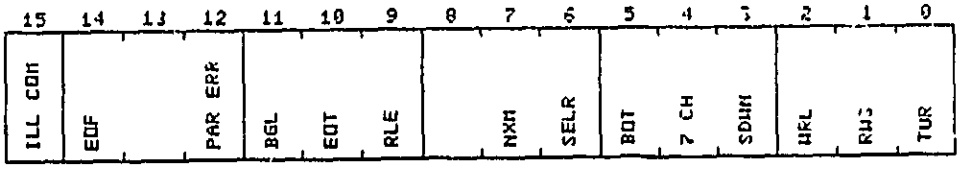
Cipher F880 Interface (Dilog D0130)

Two Cipher F880 tape drives ar available for storage of data. This allows for continuous data sition when one drive is rewinding. The two units are cable cogether by a "daisy chain" configuration and interfaced to the LSI 11/23 through a

Dilog DQ130 tape coupler. Tape density is determined by a button on each Cipher unit and tape speed is software selectable. The fast speed (100 ips) or streamer mode requires a longer repositioning time if the tape motion stops during read or write operations. The DIAL DAS software must stack data records in extended memory during repositioning times to take advantage of the streamer mode. Tests showed that for 4096 word buffers and 10 Hz DIAL data, 11 or 12 records would get stacked during repositioning. The interface registers are outlined below.

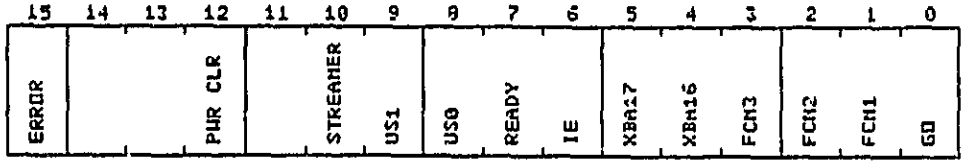
MTS	@ 772520	status
MTC	@ 772522	command
MTBRC	@ 772524	byte/record counter
MTCMA	@ 772526	current memory address
MTD	@ 772530	data buffer
MTRD	@ 772532	tape read lines

MTS
@ 772520



ILL COM	Occurs if (a) a new instruction is issued before last one has finished, (b) no write ring when told to write, (c) a command to unit whose SELR is 0, or (d) SELR becomes 0 during tape operation.
EOF	Set when end of file is detected during tape operation.
PAR ERR	Parity error.
BGL	Bus grant late.
EOT	End of tape marker detected.
RLE	Record length error -- detected during read operations if tape record is too long.
NXM	Non-existent memory.
SELR	Indicates unit addressed is on-line.
BOT	Beginning of tape.
7 CH	Set to indicate 7-channel tape unit.
SDWN	Will accept new command during settle down as long as it is in the same direction.
WRL	Write lock set if no write ring is on tape.
RWS	Rewind status set when rewind command given, cleared at BOT.
TUR	Tape unit ready is cleared by GO and function occurs.

MTC
@772522



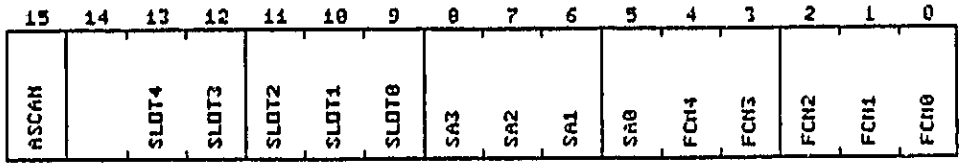
ERROR	Set by bits 7-15 of the status register.
PWR CLR	Clears the control unit and tape units.
STREAMER	Selects streamer mode.
US1,US0	Selects unit number for MTS operation.
READY	Control unit ready.
IE	Interrupt enable.
XBA17,XBA16	Extended memory bits.
FCN3-FCN1	Function bits (with GO set):
	000 (1) Off line
	001 (3) Read
	010 (5) Write
	011 (7) Write EOF
	100 (11) Space Forward
	101 (13) Space Reverse
	110 (15) Write with Extended Interrecord Gap
	111 (17) Rewind
GO	When set, begins operation defined by function.

Transiac 2012 Interface (Kinetics 2920-Z2B bus adaptor)

The Transiac 2012 digitizers are interfaced to the LSI 11/23 through a Kinetics 3920 Crate Controller and a Kinetics Bus Adaptor board. The interface is versatile in that any unit in the Camac crate can be addressed by its slot number. The function codes will be defined by the type of hardware being used in that slot. Since this interface is presently being used only for the Transiac digitizers, only those function codes will be listed here. The interface has four directly addressable registers plus an additional 6 registers addressed by offsets.

DLO	@ 777550	data low	(RA2 = 0, RA1 = 0)
LLO		lam low	(RA2 = 0, RA1 = 1)
MAR		memory address	(RA2 = 1, RA1 = 0)
DMACSR		DMA control/status	(RA2 = 1, RA1 = 1)
DHI	@ 777552	data high	(RA2 = 0, RA1 = 0)
LHI		lam high	(RA2 = 0, RA1 = 1)
WCR		word count	(RA2 = 1, RA1 = 0)
EMA		extended memory	(RA2 = 1, RA1 = 1)
NAF	@ 777554	station/function	
CACSR	@ 777556	control/status	

NAF
@ 777554

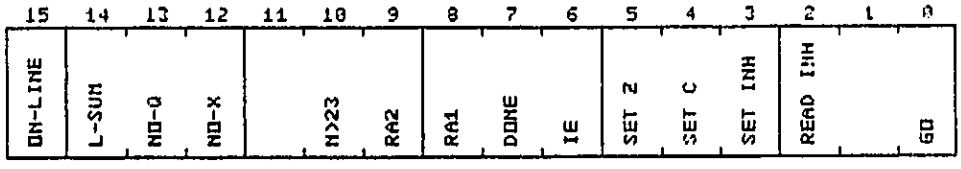


ASCAN	Enables the crate controller to increment the Camac address on completion of a Dataway Cycle.
SLOT0-SLOT4	Station or slot number of Camac device.
SA0-SA3	Sub-address of Camac device (not used with Transiacs.)
FCN0-FCN4	Function code defined by user device.

Transiac Function Codes

0	00000	Read front panel switch settings. Sets Q = 1.
1	00001	Read status of overtemperature indicator.
2	00010	Read data sequentially from memory. The N+1 word (N = record length) will return Q = 0.
10	01000	Tests LAM and returns Q = 1 if ready for readout. Must be preceded by funtion 32 (11010).
11	01001	Resets to sampling mode--all previous data is written over. Q = 1 returned.
12	01010	Clears LAM. Q = 1 returned.
13	01011	Computer generated sampling clock. Sets Q = 1.
30	11000	Disables LAM and switches from readout mode to display mode. Sets Q = 1.
31	11001	Generates stop trigger. Sets Q = 1.
32	11010	Enables LAM -- enables unit for readout. Sets Q = 1.
33	11011	Enables offset measurement logic. Sets Q = 1.

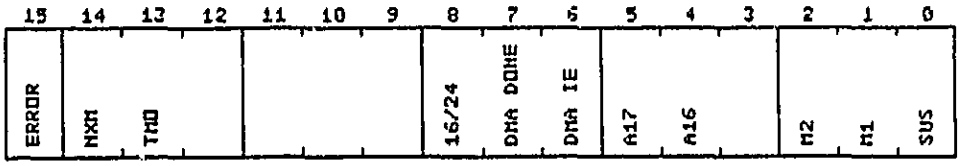
CACSR
@ 777556



ON-LINE (R)	True when 3920 is powered and on-line.
L-SUM (R)	True if any LAM is set in crate (causes interrupt).
NO-Q (R/W)	Updated by 3920 during every Dataway Cycle.
NO-X (R/W)	Updated by 3920 during every Dataway Cycle.
N>23 (R)	During address scan operations, indicates the slot number has been incremented past 23.
RA2,RA1 (R/W)	Used to select registers defined above.
DONE (R)	True when 3920 has completed a progammed control operation (i.e. non-DMA).
IE (R/W)	When set, allows L-SUM to cause interrupt.
SET Z (W)	Dataway initialize.
SET C (W)	Dataway clear (does not affect registers).
SET INH (R/W)	Sets state of Dataway inhibit line.

READ INH (R)	Reflects status of Dataway inhibit line.
GO (W)	Starts 3920 operation defined in NAF and DMACSR.

DMACSR
@ 777550
RA2 = 1
RA1 = 1



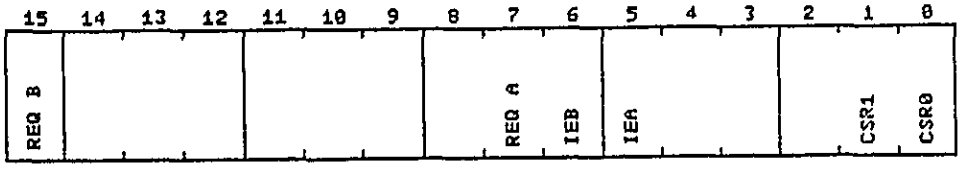
ERROR (R)	Set by NXM, NO-X, N>23, or TMO; cleared by INIT or GO.
NXM (R)	DMA transfer to non-existent memory attempted.
TMO (R)	Time-out condition during Q-Repeat DMA mode (mode 3).
16/24 (R/W)	Specifies 16 or 24 bit data transfers (16-bit = 1).
DMA DONE (R)	Set when DMA operation is done.
DMA IE (R/W)	Enables DMA DONE to interrupt.
A17,A16 (R/W)	Extended memory bits used with MAR during DMA.
M2,M1 (R/W)	Specify mode when GO of CACSR is set.
	mode 0 programmed transfer
	mode 1 Q-stop/stop on word count
	mode 2 address scan
	mode 3 Q-repeat/stop on word count
SUS (R/W)	Set to suspend DMA operation.

Parallel Line Interface Module (DRV11-C)

This module acts as an interface between the LSI 11/23 and a peripheral device. The DIAL DAS presently uses one of these modules to pass data from the LORAN or INS interface to the computer. There are three spare DRV11-C modules in LSI #2 which are not being used.

DRSR	@ 767770	control/status
DRO	@ 767772	output buffer
DRI	@ 767774	input buffer

DRSR
@ 767770



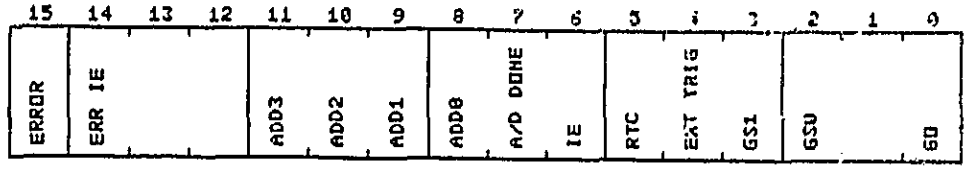
REQ B	Set by user device and causes interrupt if IEB set.
REQ A	Set by user device and causes interrupt if IEA set.
IEB	Interrupt enable for REQ B.
IEA	Interrupt enable for REQ A.
CSR1	User defined function -- if linked to another DRV11-C causes REQ B.
CSR0	User defined function -- if linked to another DRV11-C causes REQ

Analog-to-Digital Converter (ADV11-C)

Sixteen Analog-to Digital Conversion single ended inputs (or eight differential) are available to the DIAL DAS through an ADV11-C board. Unipolar inputs can range from 0V to 10V and bipolar inputs from -10V to +10V and can be stored with programmable gains of 1, 2, 4, or 8 times the input voltage.

ADST	@ 770400	control/status
ADBF	@ 770402	data buffer

ADST
@ 770400



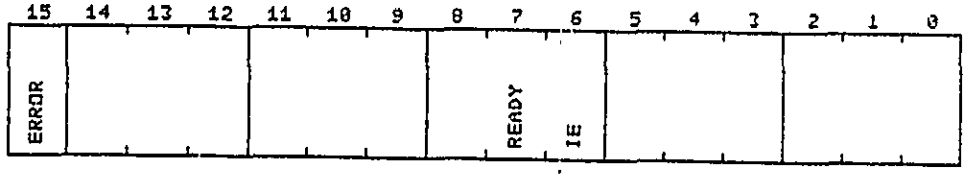
ERROR	Caused by doing a GO when A/D DONE is set or A/D still in progress.
ERR IE	Allows ERROR to interrupt.
ADD3-ADD0	Channel address.
A/D DONE	Set when A/D done, cleared by reading A/D data buffer.
IE	Interrupt enable.
RTC	Enables real-time-clock input to start A/D conversion.
EXT TRIG	When set allows external trigger to start A/D.
GS1-GS0	Gain select: 00=1, 01=2, 10=4, 11=8.
GO	Starts an A/D conversion -- cleared after starting.

Line Printer Controller (MLSI-LP11)

The LP11 provides the interface between the LSI 11/23 computers and the TRILOG T100 printer. Each computer has its own interface board and care must be taken to cable up the desired computer to the Trilog. Eventually, we hope to have either a software instruction or a manual switch to select which computer's output to send to the Trilog.

LPS	@ 777514	status
LPB	@ 777516	data buffer

LPS
@ 777514



Teletype (Plessey PM-DLV11J Serial Line Interface)

The Plessey PM-DLV11J is a 4-channel asynchronous serial line interface between the LSI 11/23 bus and standard I/O devices. On LSI #1 one port is used to communicate with the teletype and another port is used to communicate with a second PM-DLV11J interface on LSI #2. Baud rates on both boards have been wire-wrapped for 9600 baud.

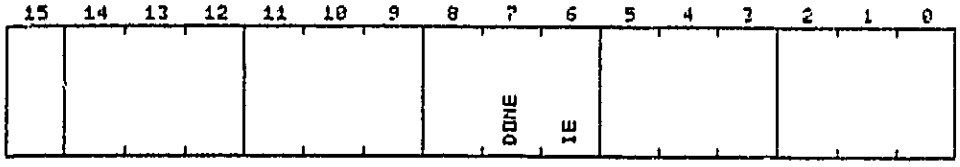
From LSI #1 port #1 to LSI #2 port #4:

RCSR	@ 776500	receiver control/status	(port 1)
RBUF	@ 776502	receiver buffer	(port 1)
XCSR	@ 776504	transmitter control/status	(port 1)
XBUF	@ 776506	transmitter buffer	(port 1)

From LSI #1 to console device:

RCSR	@ 777560	receiver control/status	(port 4)
RBUF	@ 777562	receiver buffer	(port 4)
XCSR	@ 777564	transmitter control/status	(port 4)
XBUF	@ 777566	Transmitter buffer	(port 4)

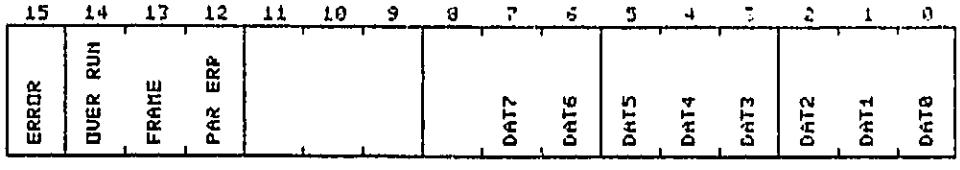
RCSR
@ 776500
@ 777560



DONE — Set when entire word has been received and is ready for transmission.

IE — When set, allows DONE to cause interrupt.

RBUF
@ 776502
@ 777562



ERROR — Set by bits 14,13, or 12.

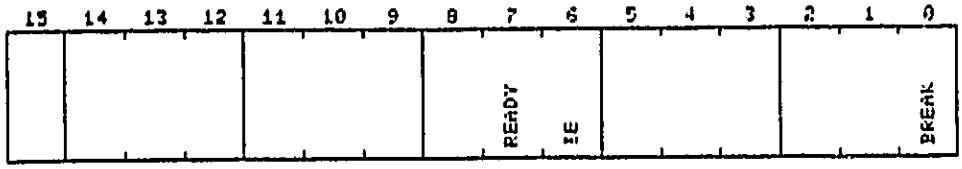
OVER RUN — Set when previous character was not completely read prior to receiving a new character.

FRAME — Set when no valid stop bit for character.

PAR ERR — Parity error.

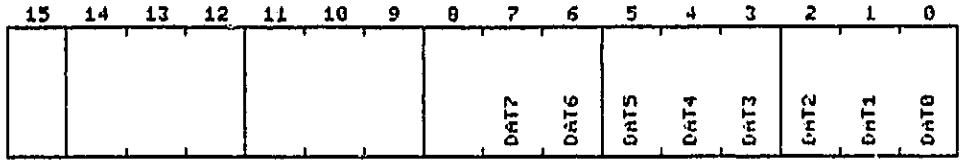
DAT7-DAT0 — Received data bits.

XCSR
@ 776504
@ 777564



READY — Set when XBUF is ready to receive another character.
IE — Enables READY to cause interrupt.
BREAK — When set, causes a continuous space level to be transmitted.

XBUF
@ 776506
@ 777566



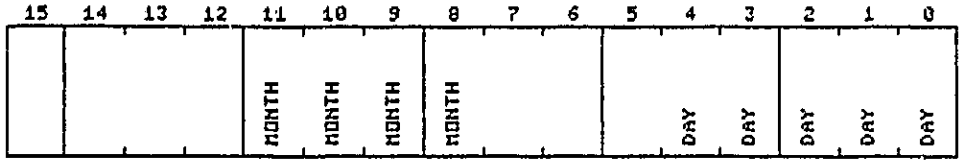
DAT7-DAT0 — Transmitter data bits.

Timing Control Unit (TCU-50 and TCU-50 DYR)

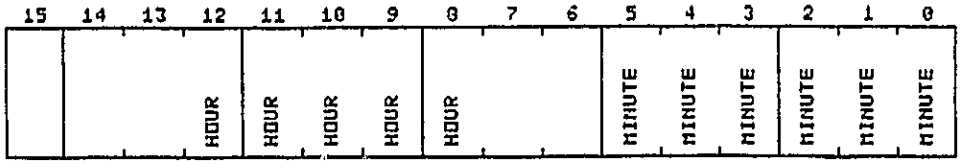
These two timing control units are similar in that they are both crystal clocks that continue to operate even after the computer has been powered down. The TCU-50 has month, day, hours, minutes and seconds while the TCU-50 DYR also has year, day of week as well as .1, .01 and .001 seconds. The two clocks are set and read differently so both are outlined below. The TCU-50 DYR is used in LSI #1 while the TCU-50 resides in LSI #2 but is not currently being used by the DIAL DAS -- it is maintained for back-up purposes.

TCU-50:

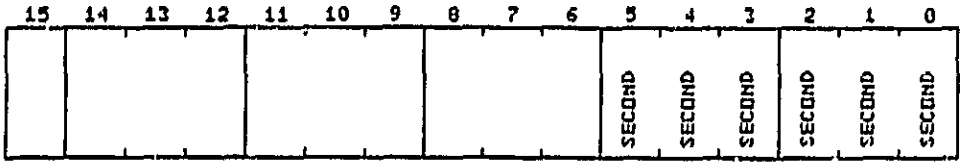
MNTH/DAY
@ 760770



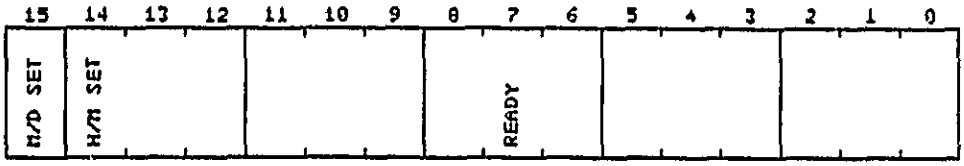
HR/MIN
@ 760772



SECND
@ 760774



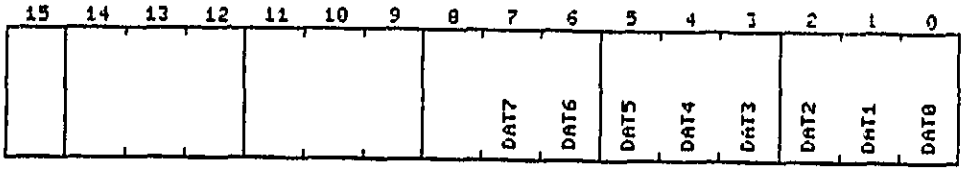
STATUS
@ 760776



M/D SET — Month/day being set -- fast clock on.
H/M SET — Hour/minute being set -- fast clock on when 1.
READY — TCU ready.

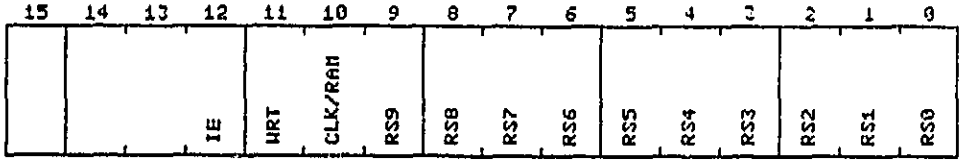
TCU-50 DYR:

DATA
@ 760770



DAT7-DAT0 — Read/write data bits. When reading a counter or latch register, the bits are 2 BCD numbers packed in 8 binary bits (eg. 23 = 00010011 = 0001 0011 = 13).

CTRL
@ 760772



IE — Interrupt enable if switch SW3-1 is on.
WRT — Write enable -- allows writing to the clock or RAM registers.
CLK/RAM — If this bit is 0, then bits 0-4 select one of the 32 clock registers. If 1, then bits 0-9 select one of the 1024 CMOS RAM registers.
RS9-RS0 — Register select:

00000 counter - .001 secs
00001 counter - .1 and .01 secs
00010 counter - secs
00011 counter - mins
00100 counter - hours
00101 counter - day of week
00110 counter - day of month

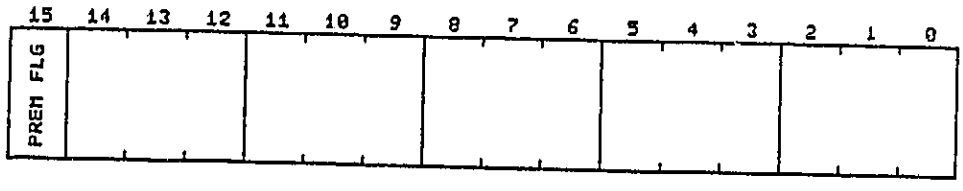
00111	counter - month
01000	latch - .001 secs
01001	latch - .1 and .01 decs
01010	latch - secs
01011	latch - mins
01100	latch - hours
01101	latch - day of week
01110	latch - day of month
01111	latch - months
10000	interrupt status register (R)
10001	interrupt control register (W)
10100	status bit
10101	GO command
10110	standby interrupt

Matrox QRGB-GRAPH Controller

The Matrox QRGB-GRAPH controller is a color graphics interface for use with RGB monitors. Contained in a PROM is a color look-up table which has been modified by Norman McCrae for gray-scale operations. I have written general purpose software routines to be used with the Matrox board and these are printed out in Appendix I. There are 512 x 512 pixels available but due to some flaw in the design of the Matrox board the software only uses 256 pixels in the Y direction. There are 11 directly accessed registers plus 14 CRTC registers that are indirectly accessed through an address register (VECT) and data port (CRT5). The CRTC registers will not be discussed here -- they are used only for initialization procedures and their use can be found in the Matrox manual. Not all mnemonics for the directly accessible registers will be defined in this report as they are not used in the DIAL DAS software.

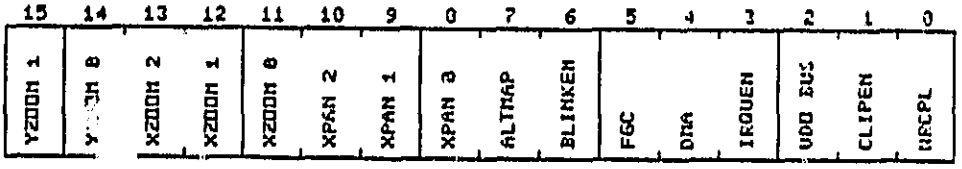
XREG		@ 764400	X coordinate (10 bits)
YREG		@ 764402	Y coordinate (10 bits)
DATA		@ 764404	data register (4 bits)
ST1	(R)	@ 764406	preset memory status
CTR1	(W)	@ 764406	zoom/pan control
ALP	(R)	@ 764410	auxiliary light pen register
CTR3	(W)	@ 764410	color map select
CTR4		@ 764412	write plane enable
ST2	(R)	@ 764414	vertical blanking status
VECT	(W)	@ 764414	CRTC address/vector register
CTR5		@ 764416	CRTC data register/preset control

ST1
@ 764406



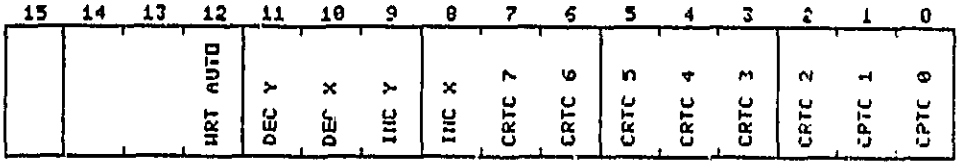
PREM FLG If 1, memory is being preset or frame grab in progress.

CRT1
@ 764406



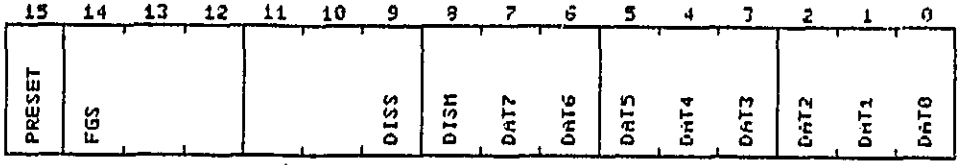
YZOOM1-YZOOM0 Y-zoom: 00 = 1, 01 = 2, 10 = 4
XZOOM2-XZOOM0 X-zoom: 111 = 1, 110 = 2, 101 = 3, 100 = 4, 011 = 5, 010 = 6, 001 = 7, 000 = 8
XPAN2-XPAN0 Horizontal display pan delay.
ALTMAP Selects A or B color-look-up table.
BLINKEN When set, blinks display.
FGC Continuous frame grab (not used).
DMA When 1, the display memory can be accessed by DMA.
IRQUEN Interrupt enable.
VDO BUS Video bus enable when 0.
CLIPEN Clipping enabled when 1.
WRCPL Data at X,Y is complemented when 1.

VECT
@ 764414



WRT AUTO When 0, data in DATA is automatically written to X,Y when VECT is loaded.
DEC Y When 1, auto-decrement of Y is in effect.
DEC X When 1, auto-decrement of X is in effect.
INC Y When 1, auto-increment of Y is in effect.
INC X When 1, auto-increment of X is in effect.
CRTC7-CRTC0 Address of CRTC register (used only at start-up).

CRT5
@ 764416



PRESET When 1, the part of display memory appearing on the screen is preset to the value in DATA.

FGS	Frame grab control.
DATA7-DATA0	Data port to and from the CRTC registers.

DIAL DAS SOFTWARE

The DIAL DAS Operating System (OS) software consists of two programs which run simultaneously on the two LSI computers. The program on LSI #1 is called "MASTER" and is dedicated to data transfer and storage. The LSI #2 program is called "SLAVE" and is responsible for data analysis and display. The user communicates with both programs through LSI #1 which passes data buffers and display options to LSI #2 as necessary. During real-time experimental situations, the MASTER program gathers digitized laser signals from the Transiac 2012's. It also gathers laser energies through a DRV11-C interface, temperatures and pressure altitude from the ADV11-C (analog-to-digital converter), time of day from the TCU-50 DYR, and position information from the Loran or INS navigation devices through a second DRV11-C. Data acquisition is interrupt driven by the Lase Coherent Trigger into the Transiacs. After the data is packed into one continuous buffer, the record is written to magnetic tape. If LSI #2 has finished processing the previous laser shot, the new data buffer is transferred to LSI #2 from LSI #1 through a DMA interprocessor link. The display rate in real-time depends on the amount of data to be plotted and on the complexity of the data analysis to be performed. For example, at 5 Hz laser firing, 2048 words of raw data from one unit (no analysis) will be viewed every third shot. Real-time profiles of ozone or water vapor concentrations are updated every fifth shot. These displays of raw and processed DIAL information allow for real-time system optimization as well as flight path decisions during flight operations.

Data transfer operations from the digitizing units (2048 words each) are readily accomplished within the minimum 100 ms operation time envelope between laser firings. Not all of the words from each unit are saved in computer memory, but each unit is completely read to obtain the proper sequence of device responses or error conditions. Software commands are available which control the starting point and number of words for data storage for each signal return. The maximum buffer size is presently set at 4096 words. The combined data stored from all the digitizers in use plus the shot header information must not exceed 4096 words.

Getting Started

Since the teletype is interfaced to LSI #1, a short program is available on each of the system diskettes which allows the user to communicate directly with LSI #2. Once LSI #1 is booted, type "R LSI2" to access LSI #2. Thereafter, each character is sent through the serial line interface to LSI #2. To exit, hit the "BREAK" key -- this returns the user to ODT (on line debug-technique) on LSI #1.

To run the MASTER and SLAVE programs, LSI #2 must start out in ODT. This allows program MASTER to boot LSI #2 and run program SLAVE. The procedure to start up the MASTER/SLAVE programs is outlined below. System diskettes with the RT11 monitor on them have blue labels. The diskettes with the

programs "MASTER" and "SLAVE" have yellow labels.

1. Place system diskettes (blue) in drive 0 of both disk drives.
2. Place MASTER (yellow) in drive 1 of LSI #1 and SLAVE (yellow) in drive 1 of LSI #2.
3. Boot LSI #1 by typing: 173000g
4. Run program MASTER by typing: RUN MASTER
5. MASTER will load and in turn call SLAVE. LSI #2 is ready when "MATROX" is visible on the video display. LSI #1 is ready when the default banner record is printed out on the console display.
6. You are now under the DIAL DAS OS. Anything you type in from now on will be interpreted by program MASTER. To return to the monitor use the instruction KILL. To return to ODT hit the BREAK key.
7. To erase one character hit the "backspace" key. To erase a whole line hit the DEL key.
8. Valid instructions are listed in the section "Keyboard Commands".
9. If LSI #1 bombs, halt both computers and start back at step 4.
10. If LSI #2 bombs to ODT (indicated by "@"), then type BOOT. If LSI #2 bombs to Monitor (indicated by RT-11 error message), type SLAVE.

The user now has the capability to fully control data buffering and recording, as well as many other aspects of data analysis and display. A sample user dialogue is given at the end of the section "Keyboard Commands". Comments are made on each line to describe what the user is doing (those preceded by two hyphens) or what action the computer is taking (comments in parentheses). Commands marked "--*" have arguments which are already program defaults so they did not need to be entered. They are included to demonstrate the use of these commands.

Data Acquisition

Data acquisition is controlled by hardware switches on the digitizing units and by keyboard commands. On the Transiac 2012 a knob setting selects the number of pre-trigger samples in increments of 1/8 of the total record (a selected record length of 2048 words would have pre-trigger increments of 256). A certain number of pre-trigger samples are desirable (about 10 to 20) to provide a good window for the trigger marker but certainly not all 256 of the Transiac pre-trigger words need be saved. There is also the case where a unit is used to digitize only an offline return which occurs 100 usecs (or 1000 words) after that unit was triggered. The first 100 usecs of data must be read by the program, but only the data from the second 100 usecs need be saved. The instruction " STORE U1,U2,U3,U4" determines the starting word for each unit at which data is to be saved. For those units storing two returns (both online and offline), the first return is saved starting at Ui and the second return is saved starting at Ui + 1000, i = 1, 2, 3, OR 4. The number of words saved for each unit is determined by the instruction "POINTS U1,U2,U3,U4". An example of data acquisition will be

given at the end of the section "Keyboard Commands".

Real-Time Data Display

All data processing and display to the video screen are performed by the SLAVE program on LSI #2. LSI #1 is reserved for data transfer from the digitizers, for magnetic tape operations, and for console keyboard communications. However, on request, LSI #1 will produce real-time color representation of range resolved profiles on the Act II printer. On LSI #2, four basic modes for DIAL data display are available, each with a variety of display options. At the same time several other pieces of information can be shown on the right hand side of the screen. Data inputs from the ADV11-C and laser energies from the DRV11-C interface can be viewed. Certain hook-up conventions must be observed for the ADV11-C and energy monitor channels in order to get default conversion constants and labeling to correspond:

ADV11-C Channel	Input	Label	Units
1	aircraft altitude	ALT	ft
2	dewpoint temperature	DPT	°C
3	temperature	T	°C
4	total temperature	TT	°C

Energy Monitor Channel

1	online UV laser energy	UVN	MJ
2	offline UV " "	UVF	MJ
3	online IR " "	IRN	MJ
4	offline IR " "	IRF	MJ
5	visible " "	VIS	MJ
6	spare " "	---	MJ

The DIAL DAS command language allows the user to input a slope and intercept to the banner record for each ADV11-C channel to convert the digitized counts to the units shown above. The laser energies need only a slope which is also specified through the DIAL DAS command language. Conversion constants must be input as integers. So each slope and intercept is represented by an integer mantissa and corresponding exponent of 10. These four words per conversion channel are stored in the banner record. The user also has options to update the plot side of the screen (left) by itself, update the right side by itself, or both sides at the same time (UPDATE command).

The different display options are summarized below. Each display mode has a number of default options associated with it. These are summarized in table 6. The default values can be changed by various keyboard commands. Display options are available for background subtraction, range-square correction, overlaying data of different digitizers, scale and more. Each display option can be activated or de-activated in real-time to observe signal features in the most useful format.

Raw Data (MODE1)

This is the basic display mode which presents raw data from each of the digitizing units as it exists in computer memory (figure 4). The abscissa represents word sequence in memory while the ordinate is adjusted to present the 12-bit signal magnitude with variable magnification. The one word instruction "MODE1" calls up all the options listed as defaults in table 5.

Table 5. Default plotting parameters.

PARAMETER	MODE1	MODE2	OZONE	GRYSCL
unit select	all	all	UNIT1	UNIT2
y-axis scale	0-4096	0-4096	0-800	150m/tic
x-axis scale	all data	150m/tic	150m/tic	---
background word	750	750	750	0
background window	30	30	30	5
trigger search	no	yes	yes	yes
smooth	no	105m	105m	no
average shots	no	no	100	no
range cell	---	---	210m	---
gas exponent	---	---	-10	---
atmospheric correction		---	yes	---
Rayleigh correction		---	6.7 ppb	---
shift toa	---	no	no	---
update right screen	yes	no	no	no

Online/Offline Overlay (MODE2)

A second display mode presents the raw data signals in an overlapped format. As shown in figure 5, the online and offline UV signals are overlayed when the data is tagged as a DIAL type measurement. The top 2 profiles in figure 5 represent aerosol returns (single wavelength measurements) at 600nm and 1060nm. By default, each of these returns have been smoothed over 105m and plotted as a function of range , each tic mark representing 1 usec. Each data shot is plotted in this mode starting after the PMT gate delay. In this mode a search is also performed for a trigger position to line up each of the returns with respect to the laser firings. This trigger position word number is displayed on the right hand side of the screen. The user specifies the trigger ordinate level to be used for each digitizer unit along with the number of words it is nominally delayed. The lase-coherent trigger markers are electronically delayed 14 words from the actual laser firing but a breakthrough pulse occurs at the same word as the laser firing.

Figure 6 shows the effect of activating the background subtraction and range squared options on the profile of UNIT1 in figure 5 (MODE2).

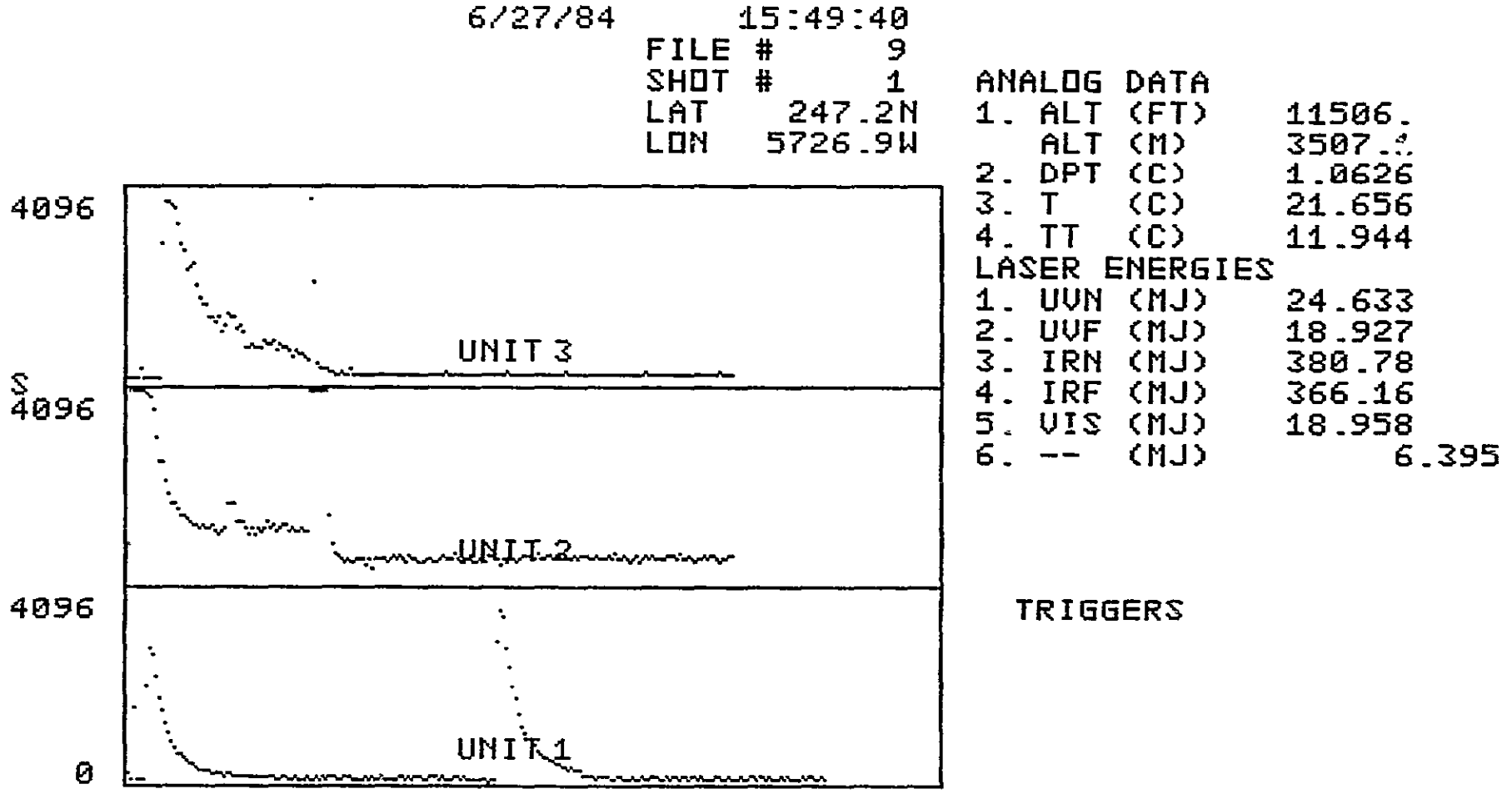


Figure 4. Example of MODE1 display. (Copied to Trilog by COPY -2 command.)

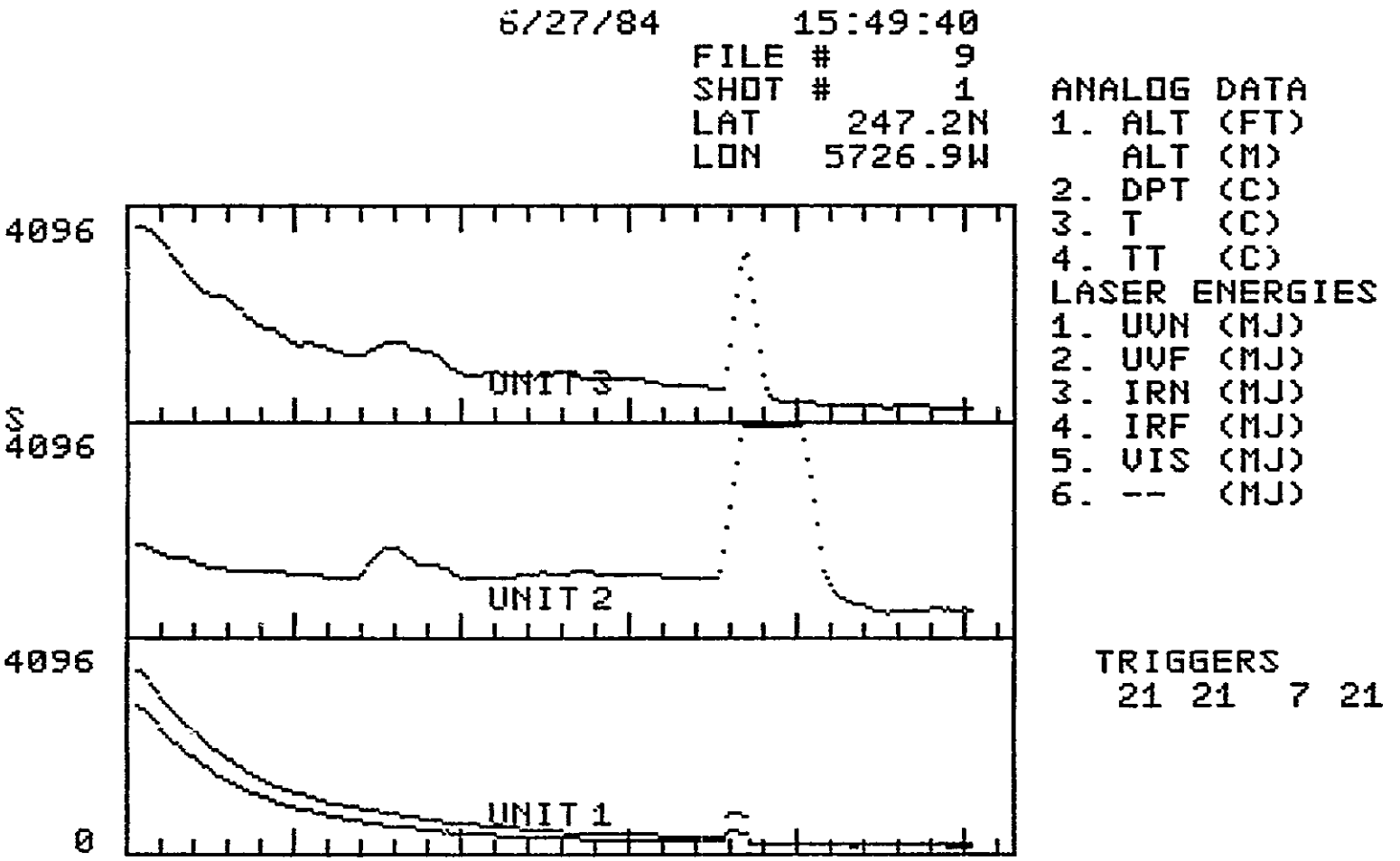


Figure 5. Example of MODE2 display.

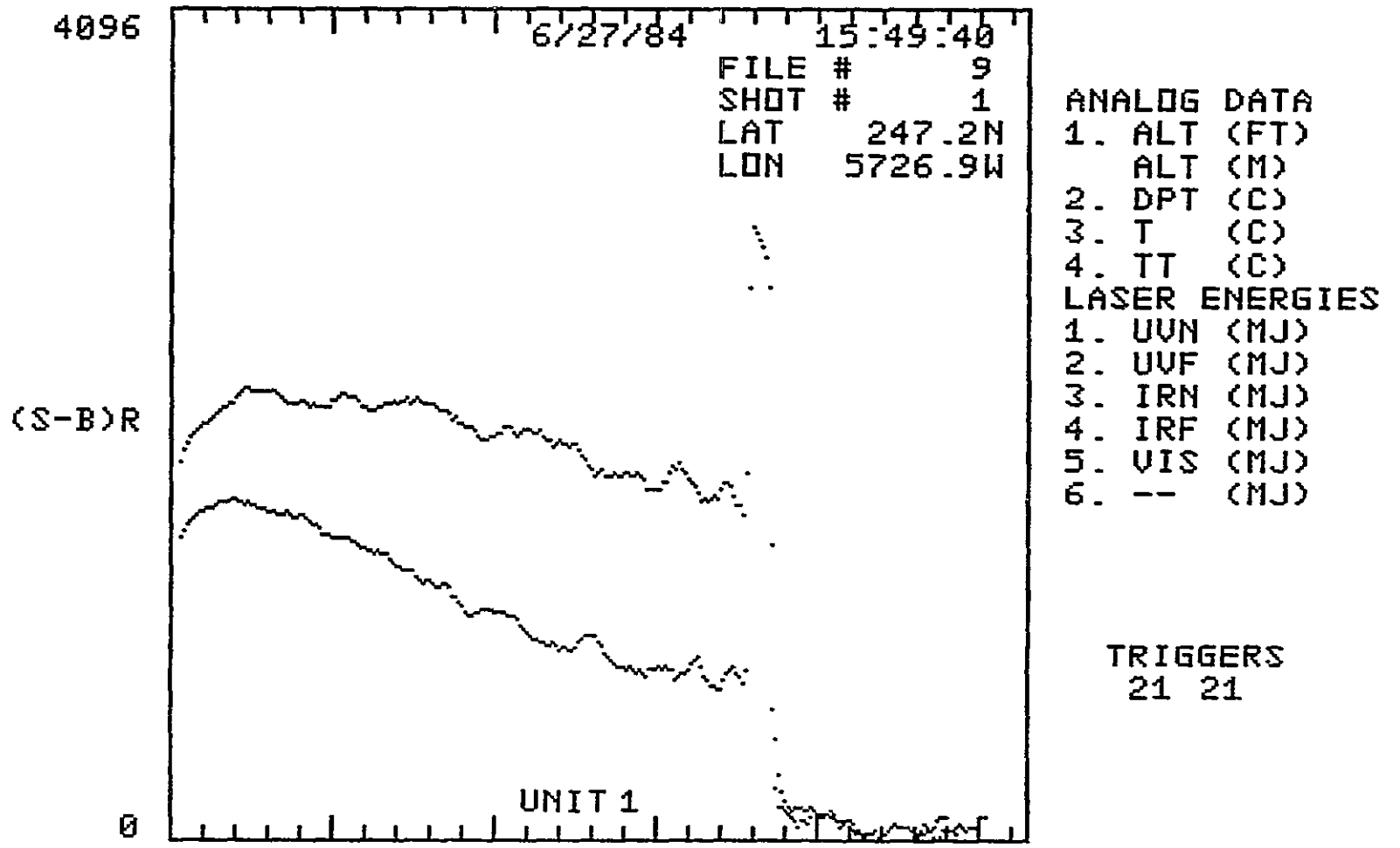


Figure 6. MODE2 display with background subtraction and range-squared options in effect.

Concentration Profiles (OZONE and WATER)

This display mode presents the gas concentration mixing ratios as a function of altitude or range calculated from the DIAL signal pair (figure 7). For each DIAL return, the background signal level is integrated over a specified interval. The starting point of this integration is selected by the command "BGWORD" and the number of words to average over is specified by "BGWIND". This average background is subtracted from the return signal, and the resulting data is then smoothed with a running mean over the specified range interval (see "SMOOTH"). This smoothing technique does not introduce errors only for those atmospheric conditions where the aerosol scattering is not changing rapidly along the DIAL measurement path. The DIAL equation (ref. 1) is evaluated using the smoothed lidar returns over a specified range cell size, usually 210 m. Ozone mixing ratios are determined by dividing each range cell concentration by the corresponding standard atmospheric number density at that altitude. A correction factor specified by "RAYCOR' is subtracted from the ozone mixing ratio to compensate for Raleigh extinction differences between the on and off lines. Water vapor mixing ratios are determined by dividing each range cell by the standard number density at sea level since the product of the water vapor absorption cross section at line center and the atmospheric number density is independent of pressure. This pressure dependence correction can be activated, however, by the instruction "ATMCOR". Each DIAL signal pair produces a mixing ratio profile. Any number of DIAL measurements can be averaged together to improve the profile statistics at the expense of increased horizontal integration for the measurement. The standard deviation for the resulting averaged profile is computed at increments equivalent to the range cell size and displayed on the mixing ratio profile.

Gray-Scale Display (GRYSCL)

A 16 level gray scale display format is available for presentation of the spatial distribution of aerosol scattering (figure 8). In processing the aerosol lidar return, the background signal level is subtracted from the lidar-plus-background signal and the geometrical range squared lidar signal dependence is eliminated. The resulting lidar backscatter profile is indicative of the distribution of aerosols along the lidar line-of-sight. The vertical resolution of the aerosol data is 15 m. The nominal horizontal resolution is 10 m for aircraft operation at a 10 Hz repetition rate. The backscatter signal level is converted into a 16 level gray scale display line where stronger scattering is indicated by higher brightness on the monitor or a darker dot pattern on the printed version of the display. Sequential gray scale lines are used to construct a real-time picture of the aerosol vertical distribution along the Electra flight path. Each of the gray scale displays can contain 300 individual or integrated aerosol profiles. At a laser pulse repetition rate of 1 or 10 Hz, the 300 individual profiles correspond to a nominal horizontal traverse of 30 or 3 km,

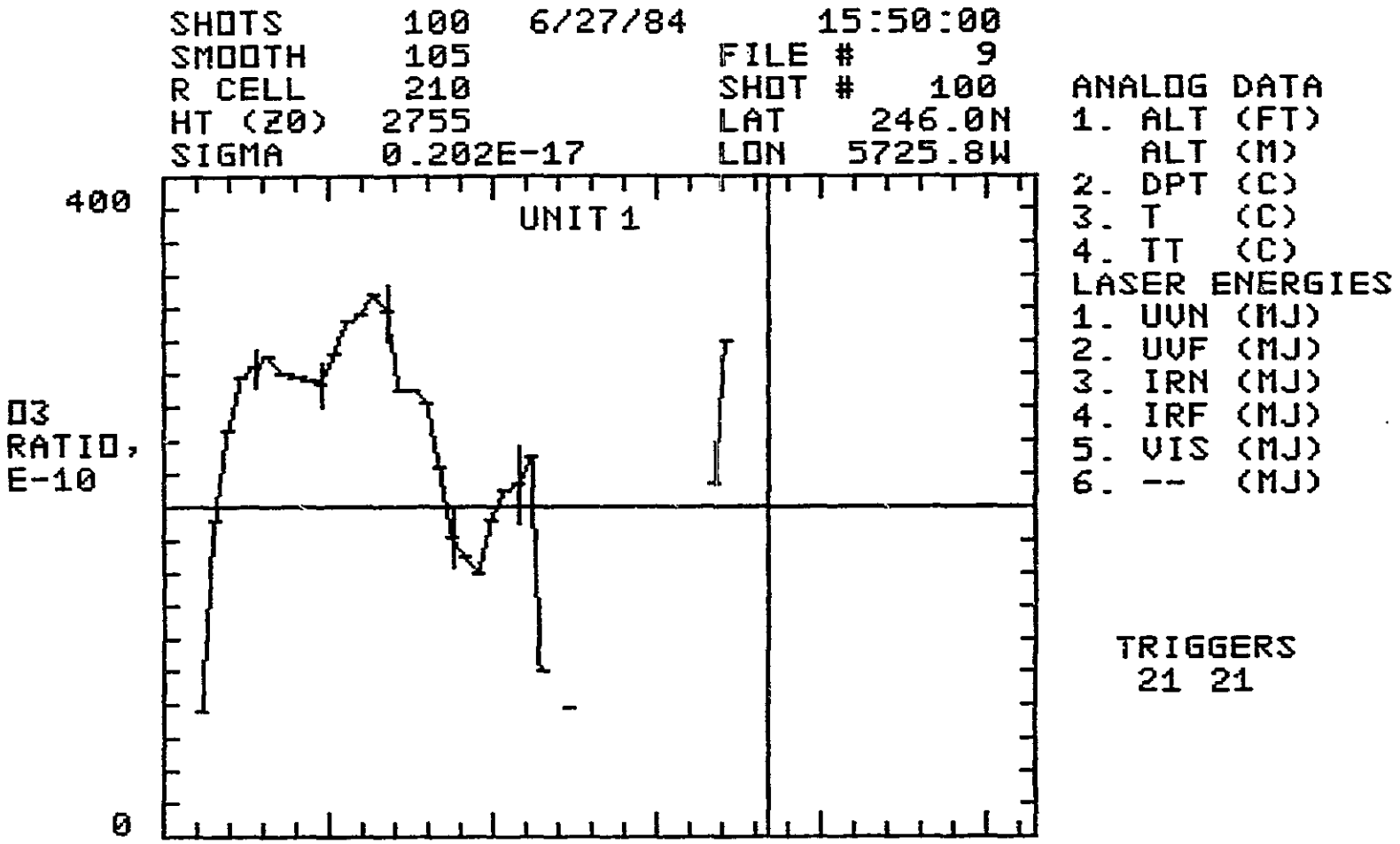


Figure 7. Example of OZONE display (100 shots averaged).

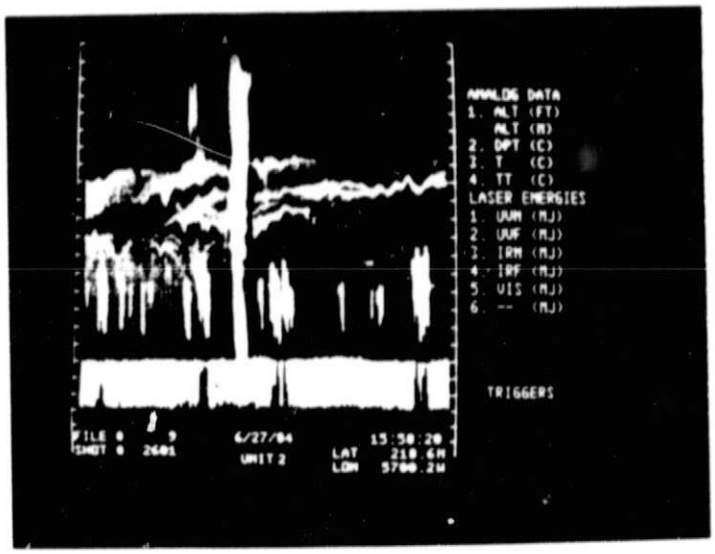


Figure 8. Example of GRYSCL.

respectively. This horizontal scale assumes a nominal ground speed of 100 m/sec for the Electra aircraft. The gray scale format shows the terrain profile, and it clearly identifies the distribution of aerosols in the boundary layer and the free troposphere.

Hard Copy Color-Scale (ACTON)

This option represents the same type of display as described for "GRYSCL"; however, it is done in color on the ACT II printer. When this option is activated, the current banner record and ACTON plotting parameters are printed followed by a 25 shade color scale display of relative aerosol concentrations. The color scale which follows the color spectrum is shown at the top of each plot. White is on the low end of the scale and black is on the high end. The user specifies a minimum value below which all data will appear as white ("WHITE") and a maximum value above which all data will appear as black ("BLACK"). Data shots may be averaged (up to 15 shots) or plotted individually. During real-time operations the computer can plot about one profile a second (either averaged or individual). Time, latitude and longitude are printed at each minute marker (figure 9). The hard copy continues until turned off with the instruction "ACTOFF" or whenever any of the ACTON plotting parameters are changed. The user must re-start the "ACTON" after changing plotting parameters. This allows the new plotting parameters to be printed so that an updated record is always available.

Magnetic Tape Storage and Format

The DIAL data is stored in real-time using one of two Cipher tape drives. This allows for constant recording of data while one unit is rewinding. The data is recorded at 100 ips in "streamer" mode. Streamer mode is the only method we found to record the 4K blocks of DIAL data at 10 Hz operation. The disadvantage of streamer mode is that if the tape unit does not get a new instruction within a small period of time it requires a long repositioning time. The DIAL DAS software was written so that each data transfer from the digitizers is stored in a consecutive block of extended memory -- up to 23 blocks are available. Once transfer to the top block (@ 740000) is done data transfer continues to the bottom block (@ 200000). When a request is made to commence recording data, the first available block is transferred to tape as soon as the tape has repositioned. During repositioning time other data blocks will be stored in memory and these are queued as they come along. As soon as the tape is again ready it is given the next queued block to record. This procedure produces a streaming operation with minimal need to reposition. Tests show that 4k blocks are written to tape at 10 Hz with upto 10 blocks getting queued, at 5 Hz 5 blocks get queued and at 1 Hz no blocks get queued.

Data is written using 1600 bpi PE magnetic tape format on 2400-ft reels of .5 in wide magnetic tape. Each data storage file begins with a 256 word banner record (16 bits per word) with

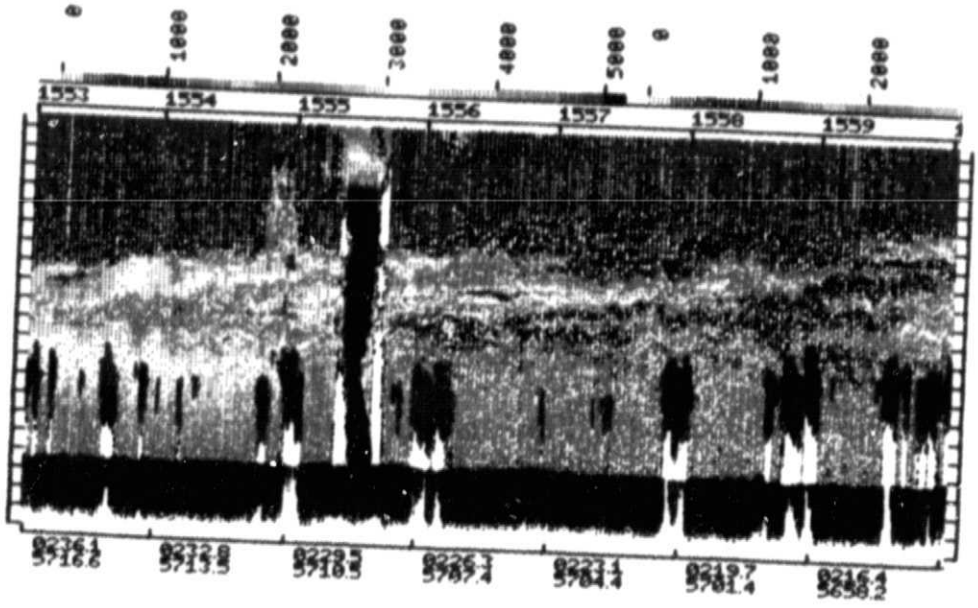


Figure 9. Example of ACTON.

Table 6. Banner record word assignments (dimensioned 256).

Word	Description
1	banner record format
2	tape #
3	file #
4	# words in shot header
5	date
6	plane altitude (feet)
7	up/down mode (0=down; 1=up)
8	sampling frequency (MHz)
9	laser fire word #
10	laser rep rate (Hz)
11	absorption coefficient (mantissa)
12	absorption coefficient (exponent)
13-16	spares
17	words/return unit 1
18	words/return unit 2
19	words/return unit 3
20	words/return unit 4
21	# returns unit 1
22	# returns unit 2
23	# returns unit 3
24	# returns unit 4
25	starting storage word unit 1
26	starting storage word unit 2
27	starting storage word unit 3
28	starting storage word unit 4
29	baseline unit 1
30	baseline unit 2
31	baseline unit 3
32	baseline unit 4
33,34	direction and magnitude of trigger marker unit 1
35,36	direction and magnitude of trigger marker unit 2
37,38	direction and magnitude of trigger marker unit 3
39,40	direction and magnitude of trigger marker unit 4
41	post-trigger delay (usecs) unit 1
42	post-trigger delay (usecs) unit 2
43	post-trigger delay (usecs) unit 3
44	post-trigger delay (usecs) unit 4
45	species identifier (RAD50) unit 1
46	species identifier (RAD50) unit 2
47	species identifier (RAD50) unit 3
48	species identifier (RAD50) unit 4
49	trigger marker delay (words) unit 1
50	trigger marker delay (words) unit 2
51	trigger marker delay (words) unit 3
52	trigger marker delay (words) unit 4
53-64	spares
65-104	ADV11-C calibration constants for channels 1-10 4 words per channel (slope mantissa, slope exponent, intercept mantissa, intercept exponent)
105-144	Energy monitor calibration constants for channels 1-6 4 words per channel (same as ADV11-C constants above)

Table 7. Data record structure for shot buffers.

Word #	Description
1	shot number
2	# shots in buffer
3-4	time of day
5-6	unused
7	latitude (low order)
8	latitude (high order)
9	longitude (low order)
10	longitude (high order)
11	altitude
12	dew point temperature
13	temperature
14	total temperature
15-20	spare ADV11-C channels
21	online UV energy
22	offline UV energy
23	online IR energy
24	offline IR energy
25	visible energy
26-30	spare energy monitor channels

The above constitutes the existing shot header. After this data the record buffer will contain the data stored from the various digitizers. The banner record whose values were defined in table 6 (IBAN) determines the storage of data:

if L=IBAN(4),M1=IBAN(17),M2=IBAN(18),M3=IBAN(19),M4=IBAN(20)
N1=IBAN(21),N2=IBAN(22),N3=IBAN(23),N4=IBAN(24)
then the data is located in the buffer as follows

start word #	end word #	contents
1	L	shot header
L+1	L+M1*N1 = K1	Unit 1 data
K1+1	K1+M2*N2 = K2	Unit 2 data
K2+1	K2+M3*N3 = K3	Unit 3 data
K3+1	K3+M4*N4	Unit 4 data

DIAL DAS information as shown on table 6. The data from each laser shot is packed into one large record on magnetic tape (data from all digitizer units are packed into one single buffer). Each data record begins with a shot header of information required on a shot-by-shot basis. This includes time, shot number, latitude, longitude, altitude, temperature data, and laser energies. The number of words in the header is currently 30 but this number can be changed with the instruction "HDRPTS". Table 7 shows the structure of a typical data record. At the end of the tape or at the end of the information stored on that tape there are 2 file marks (EOF) to denote end of information.

While recording data, if one tape drive reaches an end of tape marker then it will automatically back up two records, write two EOF's, start rewinding the tape, and start recording a new file on the alternate tape drive.

Decoding Information

This section provides information necessary to decode and convert various information in the banner (IBAN) and shot header (IBUF).

DATE IBAN(5)

bit: 14 (month) 10 9 (day) 5 4 (year) 0 (binary)

To get the actual year, add 1972 to the value in bits 4-0.

TRIGGER MARKERS IBAN(33)-IBAN(40)

Odd words are ASCII representations of < (073), = (074), or > (075). Even words are some count value between -2048 and +2047.

GAS SPECIES IBAN(45)-IBAN(48)

Radix-50 values are stored, up to three charcters per word, by packing them into single numeric values according to the formula:

((i * 50 + j) * 50 + k)

where "i", "j", and "k" represent the octal code values:

Space	0
A - Z	1-32
0 - 9	36-47

ADV11-C DATA IBAN(65)-IBAN(104)
IBUF(11)-IBUF(20)

The banner record contains the conversion constants for the ADV11-C channels which are read in on a shot by shot basis and stored in the shot header. The programmable gain of 1 (-10v to +10v) was used with a format of offset binary so:

counts = IBUF(10+ICh), where ICH = channel #
volts = (counts-2048) * (10v/2048counts)
and conversion to desired units is accomplished by:

volts*IBAN(65+I4)*10**IBAN(66+I4)+IBAN(67+I4)*10**IBAN(68+I4)
where I4 is 4 * (channel # -1).

ENERGY MONITOR DATA IBAN(105)-IBAN(144)
IBUF(21)-IBUF(30)

As for the ADV11-C data, the conversion constants are stored in the banner record and the laser energies are stored on a shot by shot basis in the shot header. The values in the header are 2's complement binary counts which have been calibrated to read in millivolts. To convert to millijoules:

IBUF(15+ICH)*(IBAN(105+I4)**IBAN(106+I4))+IBAN(107+I4)*10**IBAN(108+I4)
where ICH is the channel and ICH = 4 * (channel # -1).

NAVIGATION DATA IBUF(7)-IBUF(10)

Latitude and longitude are each 2 16-bit word integers coded in BCD. Bits 7-0 of the low order word are labels (latitude label in hex is 10 and longitude is 90). The information is then stored in bits 15-8 of the low order word and bits 13-0 of the high order word with .1 min resolution. Bits 14 and 15 of the high order word designate east, west, north or south .
Some examples:

	IBUF(8)				IBUF(7)			
N8125.8	0000	1000	0001	0010	0101	1000	0001	0000
	IBUF(10)				IBUF(9)			
W16637.8	1101	0110	0110	0011	0111	1000	1001	0000
E07654.1	0000	0111	0110	0101	0100	0001	1001	000

KEYBOARD COMMANDS

After the start-up procedure outlined above, all further keyboard input is interpreted by the program MASTER. A complete set of legal commands are listed on the following pages. A single character of operator input can be erased by means of the BACKSPACE (←) key. An entire line can be erased using the DEL key. The DIAL DAS OS is brought on-line with predefined option defaults. Data transfer from the digitizers can be initiated immediately if these defaults are suitable by means of the START command. Once START has been entered the program is interrupt-driven by the digitizers and certain paramaters should not be changed. Commands that change these parameters are listed in the section "Stop Mode Commands" and can be used only after STOP has been entered. Also included in the "Stop Mode Commands" are those commands which deal with the interaction of the two LSI's. These commands can only be issued in stop mode to prevent the computers from getting out of sync. Error messages are detailed in Appendix III.

In the following list of commands, the variables U1, U2, U3, and U4 are used to refer to input parameters for digitizer units #1, #2, #3, and #4 respectively. The Transiacs can be used in any order which is determined by the command CAMACS whose input parameters list the station numbers of each unit in the sequence in which they are to be read.

Commands which have been changed or added since last year's report are denoted by an asterisk.

Stop Mode Commands

1. Digitizer Storage Commands:

POINTS	U1,U2,U3,U4	# points/return for each unit
RETRNS	U1,U2,U3,U4	# returns for each unit
STORE	U1,U2,U3,U4	store from this word for each unit
CAMACS	I,J,K,L	station # for Transiacs to be used

2. Play-Back Commands:

	PLOT	I	plot I shots from tape if I=-1 plot from memory
*	ARCHIV		This command causes successive profiles being plotted on the ACT II to also be written to tape on Cipher #2. Another program can then be used to quickly make additional copies.

3. LSI #2 Program Control Commands:

BOOT	boot LSI #2 then run program SLAVE
SLAVE	run program SLAVE on LSI #2

Start or Stop Mode Commands

1. Program Control Commands:

	START		start data transfer from digitizers
	STOP		stop data transfer
	RESTRT		clears interrupts and issues a macro RESET command which returns all units to their status at power-up time
*	SYNC		synchronize the two computers --used when monitor display fails to update
	KILL		kill program MASTER and return to Monitor
	SHTSET		reset shot counter to zero
*	LSTBNR		print out current banner record
*	LSTPLT		print out current plotting options
*	COPY	I	copy CRT to Trilog (sizes: I=1-4)
*	PRINT		plot buffer is printed out on Trilog
*	LIST	I,J	print data buffer from word I to J if I<0 print buffer in memory if I>0 read buffer from tape

2. Banner Record Input:

FORMAT	I	format # (=2 presently)
TAPE	I	tape #
FILE	I	file #
HDRPTS	I	reserve I words in shot header
UPDOWN	I	I=0 down-looking; I=1 up-looking
PULFRE	I	pulse repetition frequency (Hz)
SAMFRE	I	sampling rate (MHz)
HEIGHT	I	plane altitude (ft)
PRETRG	I	# words stored before trigger marker
ABSCOF	I,J	absorption coefficient I*10**J (atm-cm)-1
TODLY	U1,U2,U3,U4	# words offset between marker and actual laser firing
DELAY	U1,U2,U3,U4	usecs after trigger to start of return
GASES	U1,U2,U3,U4	3-letter gas identifier (AER,O3,H2O)
BASLIN	U1,U2,U3,U4	base line for returns
TRGLEV	aU1,bU2,cU3,dU4	trigger marker level where a,b,c,d can be = or < or >

3a. Calibration Constants For Met Data:

*	ADCH1	I,J,K,L	altitude	slope (I*10**J) and intercept (K*10**L)
*	ADCH2	"	dewpoint	"
*	ADCH3	"	PRT temp	"
*	ADCH4	"	total temp	"

3b. Conversion Constants For Laser Energy Data:

*	EMCH1	I,J,K,L	channel 1	slope (I*10**J) and intercept (K*10**L)
*	EMCH2	"	channel 2	"
*	EMCH3	"	channel 3	"
*	EMCH4	"	channel 4	"
*	EMCH5	"	channel 5	"

*	EMCH6	"	channel 6 "

4. Magnetic Tape Commands:

	CIPHER	I	cipher unit # (I=1 or 2)
	RECORD		write banner and start recording
	BANNER		write banner
	ENDFIL		write EOF and stop recording
	REWIND		rewind tape to BOT
	SKPEOI		skip to 2 consecutive EOF's
	FNDFIL	I	search for file I (forward only)
	SKPFIL	I	skip forward I files
	BAKFIL	I	skip backward I files
	SKPREC	I	skip forward I records
	BAKREC	I	skip backward I records

5. Plotting Options Commands:

	PLTMOD	I	select plot mode I (I=0 for no display)
	MODE1		raw data display
	MODE2		on/off line overlay display
*	OZONE		ozone concentration display mode
*	WATER		water vapor concentration display mode
	PLTGRY	I	plot gray scale if I=1
	GRYSCL		CRT aerosol gray scale display
	UNIT1		display unit #1 data only
	UNIT2		display unit #2 data only
	UNIT3		display unit #3 data only
	UNIT4		display unit #4 data only
	ONLINE		show on-line return only
	OFFLINE		show off-line return only
*	BOTH		show both on-line and off-line
	RETURN	U1,U2,U3,U4	plot return # for each unit (both=7)
	SCALE	I	plot scale factor where scale=2**I
	YMAX	I	display range interval (see note #2)
	LITER		causes gray scale to be one scale lighter
	DARKER		causes gray scale to be one scale darker
	OFFSET	I	offset x-axis by I
	CLEAR	I	clear CRT (0=no clear;1=data only;15=all)
	OVRLAY	I	overlay data from different units if I=1
	BGWORD	I	start word # for background average
*	BGWIND	I	# words to average for background (window)
	SUBBAK	I	subtract background if I=1
	RNGCOR	I	range correct if I=1
	SMOOTH	I	smooth data over I meters (max 105m)
	PLTAVG	I	average I shots in display
	INDEX	I	index of I through data buffer (if I=0 program computes index necessary to fit data on screen)
	PIXPNT	I	I pixels plotted per data point
*	UPDATE	I	I = 0 update plot and right screen I = 1 update plot only I = 2 update right screen only
	RNGCEL	I	use range cell of I meters
	GASEXP	I	concentrations in parts *10**I

	SHFTOA	I	shift TOA marker by I words
*	ATMCOR	I	if I=1 correct concentrations for altitude change of standard atmosphere (this correction not necessary when the absorption cross-section is changing with altitude as well)
*	RAYCOR	I	Rayleigh correction in same units as GASEXP above

6. ACT II Color-Scale Commands:

*	ACTON		start real-time color scale on Act II
*	ACTOFF		stop real-time color on Act II
*	EXPAND	I	zoom factor (default is 3)
*	WHITE	I	minimum value of range corrected signal -- when it falls below this value it will be white
*	BLACK	I	maximum value of range corrected signal -- when it falls above this value it will be black

The following commands are identical in function as those listed in the previous section but the "@" preceding each command directs the action to the gray-scale display on the Act II.

@UNIT1	@UNIT2	@UNIT3	@UNIT4	@RETURN
@BGWORD	@BGWIND	@INDEX	@PLTAVG	

Trigger Markers

It has been found that it is extremely important to precisely line up the on and off line returns. Even a one word offset can cause oscillations in the concentration profiles. Therefore, there are several commands available to tell the program how to find a trigger marker. The trigger markers provided by the lase-coherent time base are electronically delayed from the actual laser firing so that any noise due to flash lamp firing will not mask the markers. These markers are the most accurate so they are used for the DIAL type returns. There are no trigger markers available for the one-wavelength returns so either flash lamp noise, or a breakthrough spike as the signal hits the aircraft window, or in the case of the 1.06 return where the diode detector is always on the return itself can be used to line up these returns with the DIAL returns. These types of markers occur at the time of laser firing. The first step is to determine at what word number the actual laser firing occurs. This can be done by looking at any one of the three types mentioned above which are not electronically delayed. The LIST instruction is used to display the word values in computer memory. When the word number of the laser fire has been noted it is entered with the command LASFIR. The next step is to tell the program whether a delayed type marker is to be used or one which occurs at laser firing. This is done with the command TODLY (this delay must be entered

for each digitizer unit being used). The lase-coherent markers are presently delayed by 14 words (1.4 usecs) from the laser firing. The final step is to specify the actual level for the trigger with the command TRGLEV. Again, each digitizer unit will have its own trigger marker level. The trigger level is entered as less than (<), greater than (>), or equal to (=) some value (eg. < 0, > 900, = -2048).

The trigger search routine looks for the trigger marker in the 11 words centered around where it expects to find one as specified by the inputs LASFIR and TODLY. For example, LASFIR is set for 6, TODLY is 14, and TRGLEV is =2048 then the trigger search routine expects to find a value of 2048 between word 15 and word 25 of the online return and between POINTS + 15 and POINTS + 25 for the offline. If a value is found before that window or no value is found at all within the 11 words searched then the data shot is not included in the concentration calculation. MODE2 display does a trigger search on each return so inputs can be checked by displaying MODE2. The valid trigger words are displayed in the lower righthand side of the screen as they are found. Invalid markers are denoted by an asterisk.

One more word of caution. The occurrence of the trigger marker in the data stream can be altered by switch settings on the digitizers as well as by the command STORE. The Transiacs have a pre-trigger dial which increments by 256 words (for 2048 word record length). To allow for an ample window for the trigger marker the Transiac should be set at 1/8 (1892 words stored after the trigger and 256 words before). When the data from the digitizers is transferred into computer memory for storage to magnetic tape, the operator has the option of selecting where to begin storage with the instruction STORE. This command is especially useful with the Transiacs since so many pre-trigger words need be digitized. It also helps to conserve on storage when the first 100 usecs (1000 words) of data in the digitizer are of no interest and only the second return need be saved (such as the visible aerosol measurement). A STORE value of 234 for the Transiac places the laser firing at word 6 in the data stream and the trigger marker at word 20. If only the second laser return were to be saved on a Transiac then a STORE value of 1234 might be used (the extra 1000 to skip the first 100 usecs). Figure 10 shows digitizer memory as compared to computer memory for the keyboard commands as follows:

```
STORE  234,234,1234
POINTS 500,500,500
RETRNS 2,1,1
```

The sample dialogue on the following page shows how to start the computer and run the DIAL DAS OS. Lines followed by comments preceded by two hyphens (--) are user inputs. Lines followed by comments in parentheses are computer responses. The use of some of the DIAL DAS OS commands are shown. Those commands with comments marked by --* need not be entered as the arguments provided are already default values. They have been included for demonstration purposes.

Sample DIAL DAS Dialogue. User input are those lines followed by comments marked --. Computer responses are those lines followed by comments enclosed in ( ).

```
@1730000                          -- BOOT LSI #1
RT-11SJ   V03-02                     (LSI #1 COMES UP IN RT11 SJ MONITOR)
.ASSIGN DX1: DK:                     (DX1 IS TARGET DISK DRIVE)
.R RTSET                             (SET RT11 DATE FROM TCU-50 DYR)
.DATE                                (PRINT DATE)
20-JAN-85                            (DATE PRINTED IF TCU-50 DYR RESIDENT)
.RUN MASTER                       -- RUN PROGRAM "MASTER"
@1730000                             (LSI #1 SENDS BOOT COMMAND TO LSI #2)
RT-11SJ   V03-02                     (LSI #2 COMES UP IN RT11 SJ MONITOR)
.ASSIGN DX1: DK:                     (DX1 IS TARGET DISK ON LSI #2)
.R RTSET                             (SET DATE FROM TCU-50 DYR)
.DATE                                (PRINT DATE)
.NO DATE                             (TCU-50 DYR NOT RESIDENT ON LSI #2)
.RUN SLAVE                           (LSI #1 TELLS LSI #2 TO RUN PROGRAM "SLAVE")
                                     (LSI #1 PRINTS OUT RESIDENT BANNER RECORD)
...  BANNER RECORD  ...
TAPE:     0   FILE:     0   HEADER WORDS: 10   DATE:  1-20-85

ALT:          0   UP/DOWN:   0   SAMP FRE:    10   LASE FIRE AT    6
REP RATE:     5   ABS COEF:  202E-20
UNIT   WRDS  RTRNS      START   BASE    TRIG    DELAY   SPECIES   TO DELAY
   1    800      2        234   2047  < 1500        5        03         14
   2    800      1        234   2047  =-2048        5        IR          0
   3    800      1       1234  -2048  >-1800        5       VIS         14
UNIT 1 : TRANSIAC 2
UNIT 2 : TRANSIAC 6
UNIT 3 : TRANSIAC 10
ADV11-C CONVERSION CONSTANTS              ENERGY MONITOR CONVERSIONS
CHAN     SLOPE      OFFSET                CHAN             SLOPE
   1     4000.      -1000.                   1              1.0
   2       15.        -75.                   2              1.0
   3       10.        -10.                   3              1.0
   4       20.        -50.                   4              1.0
                                             5              1.0
                                             6              1.0


?CAMACS 2,6,10                    --* USE THE TRANSIACS IN SLOTS 2, 6, AND 10
?POINTS 500,500,500               --  STORE 500 POINTS/RETURN IN EACH UNIT
?RETRNS 2,1,1                     --* STORE 2 RETURNS FROM UNIT 1; STORE 1 RETURN FROM 2 AND 3
?STORE 234,234,1234               --* START DATA STORAGE FROM DIGITIZERS AT THESE WORDS
?BASLIN 2047,2047,-2048           --* BASE-LINE OF EACH DIGITIZER
?DELAY 5,5,5                      --* GATE TURN ON DELAY (USECS) AFTER LASER FIRE
?LASFIR 6                         --* LASER FIRES AROUND WORD 6
?TODLY 14,0,14                    --* UNITS 1 & 3 USE TO MARKERS WHICH ARE DELAYED BY 14 WORDS
?HDRPTS 20                        --* THERE WILL BE 20 WORDS OF SHOT HEADER INFORMATION
?GASES 03,IR,VIS                  --* IDENTIFIES TYPE OF MEASUREMENT FOR EACH UNIT
?ABSCOF 176,-20                   --  ABSORPTION COEFFICIENT TO BE USED FOR 03 CALCULATIONS
?HEIGHT 13000                     --  PLANE ALTITUDE IN FEET
?UPDOWN 0                         --* INDICATES DOWN-LOOKING MODE
?ADCH1 15.0,-75.0                 --* SECOND ADV11-C CHANNEL WILL BE 15 * VOLTS -75.
?ENCH1 2.0                        --  CHANNEL 1 ENERGY IN MJ WILL BE 2.0 * COUNTS
?LSTBNR                           --  LIST OUT NEW BANNER RECORD


...  BANNER RECORD  ...
TAPE:     0   FILE:     0   HEADER WORDS: 20   DATE:  1/20/85

ALT:      13000   UP/DOWN:   0   SAMP FRE:    10   LASE FIRE AT    6
REP RATE:     5   ABS COEF:  176E-20
UNIT   WRDS  RTRNS      START   BASE    TRIG    DELAY   SPECIES   TO DELAY
   1    500      2        234   2047  < 1500        5        03         14
   2    500      1        234   2047  =-2048        5        IR          0
   3    500      1       1234  -2048  >-1800        5       VIS         14
UNIT 1 : TRANSIAC  2
UNIT 2 : TRANSIAC  6
UNIT 3 : TRANSIAC 10
ADV11-C CONVERSION CONSTANTS              ENERGY MONITOR CONVERSIONS
CHAN     SLOPE      OFFSET                CHAN             SLOPE
   1     4000.      -1000.                   1              1.0
   2       15.        -75.                   2              1.0
   3       10.        -10.                   3              1.0
   4       20.        -50.                   4              1.0
                                             5              1.0
                                             6              2.0

?START                            --  START DATA TRANSFER FROM DIGITIZERS
?LIST -1,30                       --  LIST LAST BUFFER FROM WORDS 1 TO 30
SHOT:   151
              1     2     3     4     5     6     7     8     9    10

     0     1900  1902  1899  1905  1901  2011  1899  1900  1902  1901
    10     1900  1903  1905  1902  1900  1901  1899  1901  1900  1900
    20     1631  1823  1902  1900  1900  1904  1900  1902  1903  1901
?TRGLEV 1,1700                    --  CHANGE TRIGGER LEVEL OF UNIT1 TO 1700
                                  --  NOTE THAT THERE IS SOME NOISE AT WORD 6 WHEN THE LASER FIRES
                                  --  BUT THE TRIGGER MARKER DOES NOT OCCUR FOR ANOTHER 14 WORDS (WORD 20
```

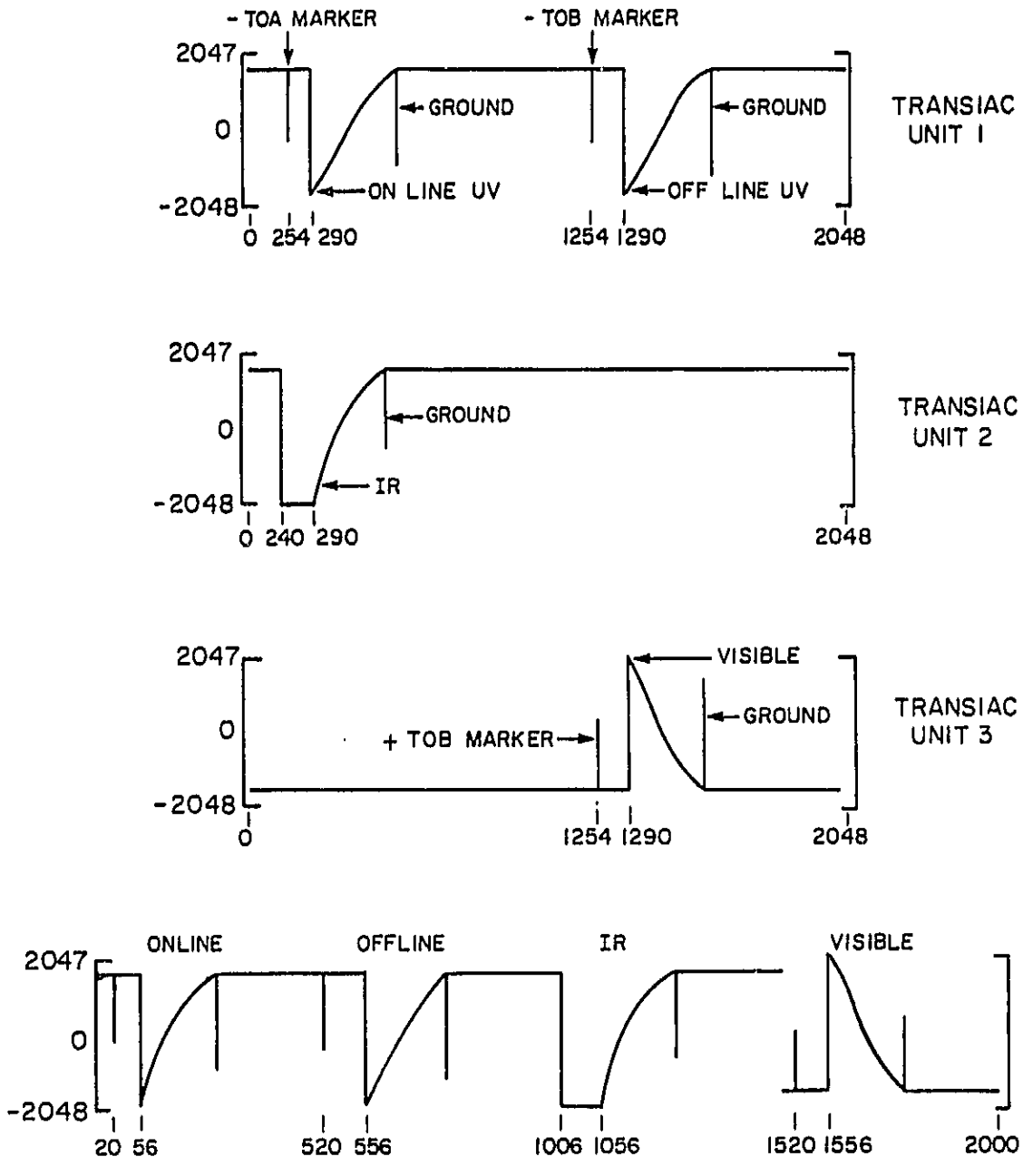


Figure 10. Example of digitizer memory as compared to saved buffer memory.

Scaling

The scale factor "I" for MODE1, MODE2 and MODE3 is such that

displayed range interval = 256 * (2 ** -I)/(2 ** N-1)

where N = # digitizers in use.

So if a range interval of 4096 is desired with 4 units, the scale factor must be -7. An easier instruction to use is YMAX I which automatically scales the data for you so that your resulting range interval is equal to or the next power of two less than the input value I. For the gray-scales the scale factor must reduce range corrected signals to values between 0 and 15. This scale is typically -8 (i.e. S*R*R * 2 ** -8 < 16). The instructions LITER and DARKER will either increment or decrement the scale factor by one.

REFERENCES

1. E. V. Browell, A. F. Carter, S. T. Shipley, R. J. Allen, C. F. Butler, M. N. Mayo, J. H. Siviter, and W. M. Hall, "NASA Multipurpose Airborne DIAL System and Measurements of Ozone and Aerosol Profiles", Appl. Opt. 22, p522, 1983.

2. C. F. Butler, "Development and Operation of a Real-Time Data Acquisition System for the NASA-LaRC Differential Absorption Lidar", Old Dominion University, Norfolk, Va., Tech. Report GSTR-84-5 (1982).

HARDWARE MANUALS

Chassis
MLSI-BA11-600 Series of Chassis Assemblies for use with DEC LSI-11 Computers, MDB Systems, Inc. 1982 P/N 80033600.

Disk Drive
DSD-480 Flexible Disk System Installation and Programming Manual, Data Systems Design, Inc., 1980, P/N DSD 040003-01.
DSD 440/480 Flexible Disk Data Storage Systems Service Manual, Data Systems Designs, Inc., 1983, P/N DSD 040023-01.

Interprocessor Link
MLSI-DA11BOI Interprocessor Link Instruction Manual, MDB Systems, Inc. 1980

Magnetic Tape Drive
Model F880 Magnetic Tape Transport, Volume 1, Operation and Maintenance, Cipher Data Products, 1983, P/N 799816-003E.
Model D0130 Magnetic Tape Coupler Instruction Manual, Distributed Logic Corp., 1982, P/N 30002-1.
Magnetic Tape Software Aids and Diagnostics, Distributed Logic Corp., 1982, P/N 30050-0.

Transiac Digitizers
Transiac Model 2012 Waveform Digitizer, Transiac Corp.
Transiac Model 1020 Differential Amplifier, Transiac Corp.
Model 1500 Powered Camac Crate, Kinetic Systems, 1982
Model 3920-Z1B General Purpose Crate Controller, Kinetics Systems, 1982.

Model 2920-Z1D LSI-11/PDP-11 Bus Adaptors, Kinetics Systems, 1982.
Model 6210 Driver Series, Kinetic Systems, 1982.

Loran Interface
MLSI-DRV11-C Parallel Line Interface Module Instruction Manual, MDB Systems, Inc., 1978, P/N 800403346.

A/D Converter
PDP-11 Microcomputer Interfaces Handbook 1983-84, Digital Equipment Corp, 1983 (ADV11-C p. 53).

Line Printer
Trilog T-100 Applications Manual, Trilog Inc., 1981, P/N 110007 Rev. B.
MLSI-LP11 Line Printer Controller for use with DEc LSI-11 Computers Instruction Manual, MDB Systems, Inc., 1977, P/N 80040318.

Teletype
Ann Arbor Model 4008 Display Terminal, Ann Arbor Terminals, Inc., 1977, P/N 208534.
PM-DLV11J Serial Line Interface Module, Plessey Peripheral Systems, 1982, P/N MA 705020.

Time
Timing Control Unit TCU-50 DYR, Digital Pathways, Inc., 1982.
Timing Control Unit TCU-50, Digital Pathways.

Graphic Display
QRGB-GRAPH, Colour Graphics Controller, Manual No. 173-A50-02/11, 1983.

APPENDIX

DIAL DAS ERROR MESSAGES

TTY ERROR	Teletype input error or attempt to use STuP mode command while transferring data.
CAMAC: DMA XFER ERROR	Transiac transfer error -- check to see that triggers and time bases for all units being used are properly connected.
CAMAC: NO-Q NOT SET	"
CAMAC: LAMS NOT SET	"
CAMAC: LAMS NOT CLEARED	"
MT: QUEUE EXCEEDS 22	Mag tape streamer queue cannot keep up.
MT: ILLEGAL COMMAND	Occurs if (a) a new instruction is issued before last one has finished, (b) no write ring when told to write, (c) tape unit is off-line or becomes off-line.
MT: END OF FILE	
MT: CYCLICAL REDUNDANCY	
MT: PARITY ERROR	
MT: BUS GRANT LATE	
MT: END OF TAPE	If data is being recorded when EOT is detected, an alarm sounds, 2 EOF's are written, the tape starts rewinding, and data is transferred to the second tape drive.
MT: RECORD LENGTH ERROR	
MT: BAD TAPE ERROR	
MT: NON-EXISTENT MEMORY	
MT: ERROR?	This is an unrecognizable tape error.
MT: TAPE UNIT OFF-LINE	
MT: NEED WRITE RING	
MT: ACTION COMPLETE	
MEMORY SWAP ERROR	This could occur when swapping in extended memory -- but has not so far.
NAV INTERFACE NOT RESPONDING	This usually means that the Loran interface is not hooked up.
170400 (ADV11-C) NOT THERE	This occurs if the ADV11-C board is not resident.