OLD DOMINION UNIVERSITY RESEARCH FOUNDATION

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

Technical Report GSTR-81-8

INVESTIGATION OF POTENTIAL OF DIFFERENTIAL ABSORPTION LIDAR TECHNIQUES FOR REMOTE SENSING OF ATMOSPHERIC POLLUTANTS

By

Carolyn F. Butler
Scott T. Shipley

and

Robert J. Allen

Principal Investigator: Earl C. Kindle

Final Report
For the period December 15, 1978 - June 14, 1980

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

Under
Research Grant NSG-1477
E.V. Browell, Technical Monitor
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Submitted by the
Old Dominion University Research Foundation
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Norfolk, Virginia 23508

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TABLE OF CONTENTS

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LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES - CONTINUED

LIST OF FIGURES - CONCLUDED

INVESTIGATION OF POTENTIAL OF DIFFERENTIAL ABSORPTION LIDAR TECHNIQUES FOR REMOTE SENSING OF ATMOSPHERIC POLLUTANTS

By

Carolyn F Butler[1], Scott T Shipley[1],
and Robert J Allen[2]

INTRODUCTION

This report documents work performed under research grant No NSG-1477 toward the development, fabrication and initial testing of the NASA Multipurpose Differential Absorption Lidar (DIAL) System The NASA Multipurpose 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 O_3 concentrations from an aircraft platform Test flights of the DIAL system were successfully performed onboard the NASA/Wallops Flight Center (WFC) Electra aircraft

The work performed on this project resulted in an operational DIAL lidar system capable of operation in the severe environment typical of experimental aircraft Figure 1 shows a block diagram of the NASA Multipurpose DIAL System mounted in the NASA/WFC Electra aircraft The design of the control electronics and dual-wavelength detector system was accomplished by Robert J Allen of Old Dominion University Research Foundation (ODURF), who was responsible for the overall coordination of the laser-firing and signal-conditioning electronics The real-time computer operating

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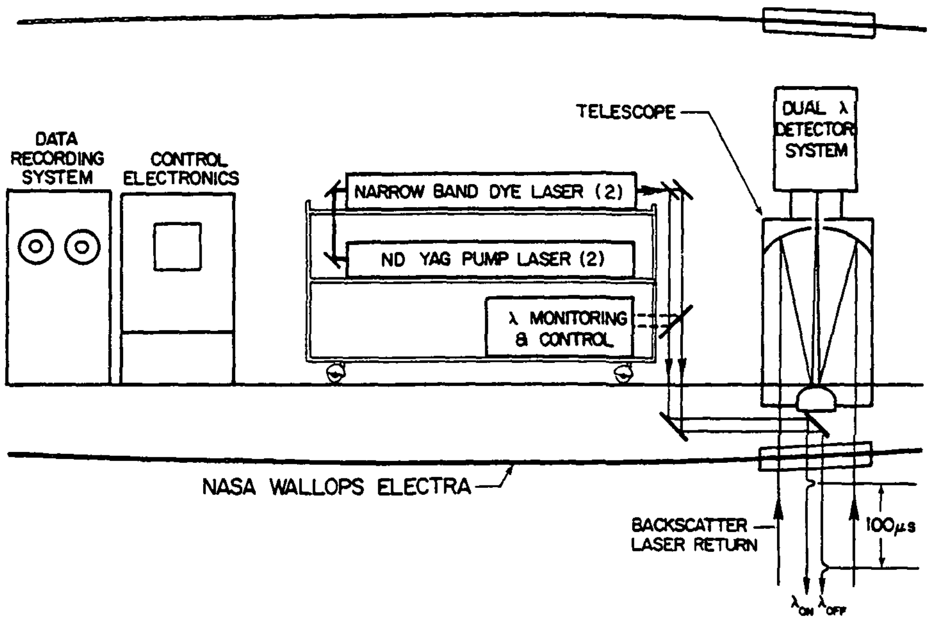


Figure 1   The NASA Multipurpose DIAL System mounted in the NASA/WFC Electra aircraft

system was designed and produced by Ms Carolyn F Butler (ODURF) Ms Butler also performed the duties of data system operator during both ground and flight testing, and she was responsible for the real-time and subsequent off-line analysis of DIAL data for measurements of O_3 concentrations Dr Scott T Shipley (ODURF) designed the computer interface electronics and collaborated as a coinvestigator on various aspects of this experiment with the project's technical monitor, Dr Edward V Browell (NASA/LaRC)

THE DIAL TECHNIQUE

Background

The Differential Absorption Lidar (DIAL) technique has been widely discussed in the literature (refs 1-5), and experimental efforts for the remote DIAL measurement of O_3 concentrations have been reported elsewhere (refs 6-8) Partly as a result of work reported in this document, the NASA Multipurpose DIAL System is the first DIAL System to measure O_3 concentrations remotely from an aircraft platform (ref 9) The results of aircraft experiments performed subsequent to this report period have been presented at various scientific conferences (refs 9-12)

The DIAL technique determines the average gas concentration over some selected range interval by analyzing the difference in lidar backscatter signals for laser wavelengths tuned "on" and "off" a molecular absorption feature of the gas under investigation The value of the average gas concentration N between range R_1 and R_2 can be determined by taking the ratio of the lidar returns at the on and off wavelenths This relationship is given by

$$N = \frac{1}{2(R_1-R_2)\ (\sigma_{on}-\sigma_{off})}\ \ell n \left\{ \frac{P_{off}(R_2)\ P_{on}(R_1)}{P_{off}(R_1)\ P_{on}(R_2)} \right\}$$

where $\sigma_{on}-\sigma_{off}$ is the difference between the absorption cross sections at the on and off wavelengths, and $P_{on}(R)$ and $P_{off}(R)$ are the powers received from range R for the on and off wavelengths, respectively This analysis assumes that the aerosol and molecular scattering parameters are equal at the on and off DIAL wavelengths If there is an interfering gas which does not have the same absorption coefficient at these wavelengths, the concentration of this gas must be known or determined by a separate experiment For airborne DIAL measurements of ozone, the laser wavelengths used are in the Hartley continuum of ozone The absorption cross sections for the on and off wavelengths at 286 and 300 nm are 21 5 $\times 10^{-19}$ and 3 7 $\times 10^{-19}$ cm^2, respectively (ref 13)

Airborne DIAL System

The NASA Multipurpose DIAL System uses two high-conversion efficiency dye lasers which are optically pumped by two frequency-doubled Nd YAG lasers As indicated in figure 1, the two laser pairs are mounted rigidly on a supporting structure which also contains the transmitting and receiving optics The dye laser wavelengths are frequency doubled into the UV to produce on and off wavelengths for the DIAL measurements of ozone These wavelengths are produced sequentially in pulses that are time-separated by less than 100 μs (50 μs typical) to minimize DIAL concentration errors which result from changes in atmospheric scattering during the DIAL measurement sequence The dye laser outputs are directed coaxially with the receiving telescope The DIAL system can be operated through quartz windows on the bottom, side, or top of the aircraft The backscattered lidar returns at the on and off wavelengths are collected by the receiving telescope, detected by a photomultiplier tube, digitized, and then stored on high-speed magnetic tape Ozone concentration profiles are calculated in real-time by means of a minicomputer The following paragraphs describe the laser transmitter, receiver, and data system in greater detail

A Quantel Model 482 frequency-doubled Nd YAG laser is used to pump a Jobin Yvon high-power, high-resolution dye laser The Nd YAG laser has a TEM_{∞} oscillator and two amplifiers producing greater than 1 J/pulse at 10 Hz in a nearly diffraction-limited beam at 1 06 μm Frequency doubling to 532 nm with greater than 40 percent conversion efficiency is achieved with an angle-tuned KDP-II crystal The dye laser contains an oscillator and 3 amplifiers to give a 35 percent overall conversion efficiency (from the pump output at 532 nm to the dye laser output between 572 and 600 nm) A high-efficiency, grazing-incidence holographic grating (2748 l/mm) is used in the oscillator to provide a 4-pm dye laser linewidth The 532-nm laser pump pulse is optically delayed for optimum timing between the oscillator and the 3 amplifier stages While the first amplifier acts as a pre-amplifier, the other two amplifiers operate near saturation The dye solutions for dye laser operation near 572 and 600 nm are Rhodamine 6G and Rhodamine B, respectively, each dissolved in water and Ammonyx An angle-tuned KDP-I crystal frequency doubles the dye laser wavelength into the UV with greater than 25 percent efficiency Dielectric-coated steering optics direct both the UV and visible dye laser outputs coaxially with the telescope through a 40-cm diameter quartz window in the bottom of the aircraft The output energy transmitted from the aircraft is about 25 mJ in the UV and 40 mJ in the visible

Spectral control of the dye lasers is maintained by comparing the laser wavelengths with those from a spectral lamp A small fraction of the visible dye laser output from each laser goes into a light pipe which directs it onto the entrance slit of a monochromator (1-m McPherson) Light from a spectral lamp is also directed into the monochromator The spatial displacement of the dye laser wavelengths from the spectral lines of the reference lamp is detected with a Princeton Applied Research Optical Multichannel Analyzer Coarse adjustment of the holographic grating in the dye laser is made with the wavelength information obtained in real time Wavelength accuracies of better than 10 pm can be achieved with this technique

The receiver consists of a 35-cm diameter Cassegrain telescope with a variable field stop and a detector assembly The light which passes through the field stop is collimated by a quartz lens and directed onto a dichroic beamsplitter which optically separates the UV and visible lidar backscattered returns A UV cut-on filter is used to reject solar background light in the UV channel The UV lidar return is then directed onto an RCA Model 7268 photomultiplier tube which has a UV-enhanced, bialkali photocathode (quantum efficiency of 27 percent at 300 nm) The visible aerosol return is passed through a 0 5-nm bandwidth interference filter for background rejection and is directed onto an RCA Model 7265 photomultiplier tube with an S-20 photocathode response These tubes were chosen for their gating and high-gain characteristics

The photomultiplier control electronics permit the selection of variable gains at variable time intervals for optimization of the lidar-plus-background signal, which varies over a wide dynamic range The background signal level is recorded 100 μs ahead of the sequential on and off wavelength DIAL returns to insure that the appropriate background level is determined for each DIAL measurement The background and UV lidar returns are digitized by a 10-bit, 10-MHz transient digitizer during a single 2048-word sweep of this unit Three Biomation 1010 units have been interfaced to the minicomputer system Two Biomations are used to digitize UV lidar returns, and the third is used for aerosol returns Additional information that can be recorded includes readings from six energy monitors, a shot counter, and a Loran C unit for aircraft velocity and position The data is stored at a 1-, 5-, or 10-Hz repetition rate on a 1600-bpi magnetic tape A PDP 11/34 central processing unit with 28K word memory and a dual drive floppy disk are used for selective processing of the real-time information Displays of the raw data, ozone concentration profiles and/or gray level displays of aerosol scattering can be produced in real time on a TV monitor All recording, data processing, and display parameters are controlled through an operator's console

Ozone and Aerosol Profile Measurements

The first remote measurements of ozone profiles with an airborne DIAL system were made during flight tests between May 22 and June 6, 1980 The UV DIAL System was operated in a nadir-directed mode from the NASA/WFC Electra aircraft at a nominal altitude of 3 2 km The initial measurements of ozone and aerosol profiles with the DIAL system were performed on four flights in the vicinity of the Chesapeake Bay An instrumented Cessna 402 aircraft was used as the principal means of obtaining in situ correlative ozone measurements This aircraft also provided simultaneous information on temperature, dew point, SO_2 concentrations, and aerosol optical extinction coefficients Examples of the intercomparison between the DIAL and in situ ozone profile measurements are given in figure 2 Digitization of the UV returns was optimized at different altitudes by adjusting the photomultiplier tube gating time delay after laser firing and by adjusting the digitizer sensitivity The DIAL measurements represent a 50-shot average (1-km horizontal resolution) with a vertical resolution of 210 m The horizontal bars on the DIAL data in figure 2 represent one standard deviation of the calculated average ozone concentration Average values of ozone concentration obtained by the Cessna instrumentation for constant altitude traverses of 32-km length below the Electra aircraft are also given in the figure The horizontal bars on the Cessna data represent the standard deviation of the ozone measurements along the leg The absolute accuracy of the electrochemical ozone sensor is estimated to be ± 10 percent The DIAL measurements were found to be within 15 percent of the in situ values obtained on the Cessna

The fine vertical structure in the DIAL profiles of ozone in figure 2 may be actual localized variations of ozone concentration A series of six sequential ozone profiles obtained along the Electra flight path is shown in figure 3 The resolution for each profile is 1 km in the horizontal and 210 m in the vertical Persistent layers of increased ozone concentration are indicated at ranges of about 2100 and 2600 m below the aircraft The presence

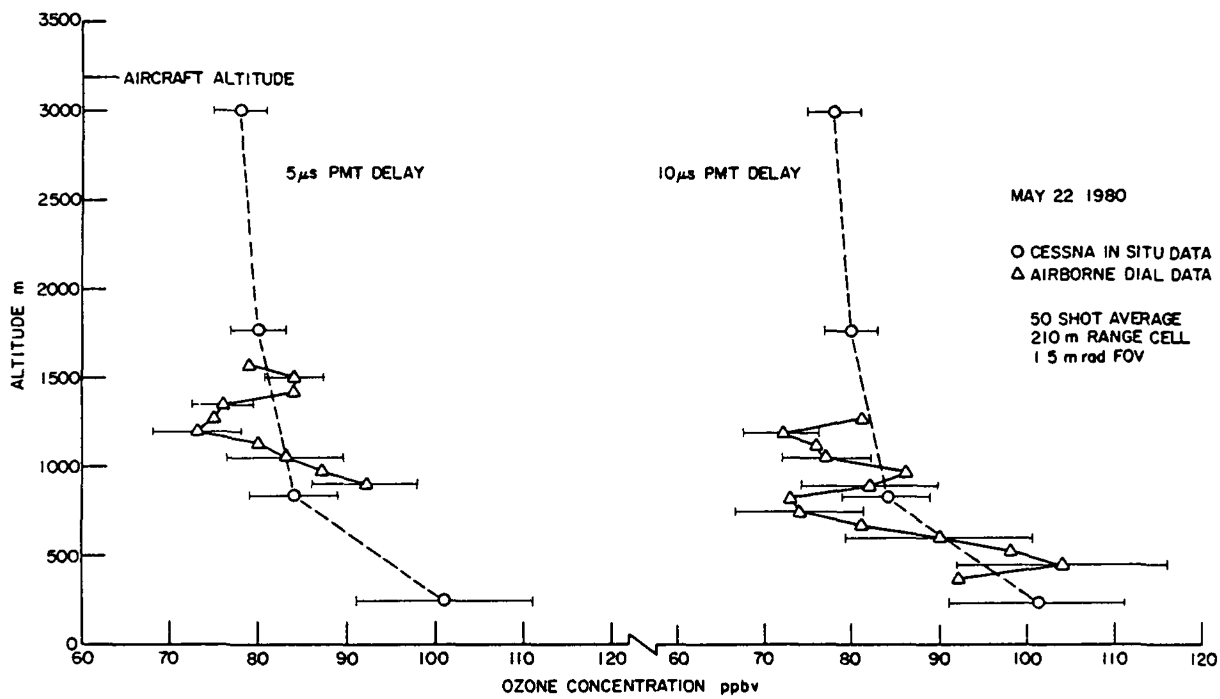


Figure 2 Comparison of May 22, 1980 airborne DIAL ozone data with in situ ozone data obtained by instrumentation mounted in a Cessna 402 aircraft The DIAL data represents a 50 shot average with 1-km horizontal and 210-m vertical spatial resolution

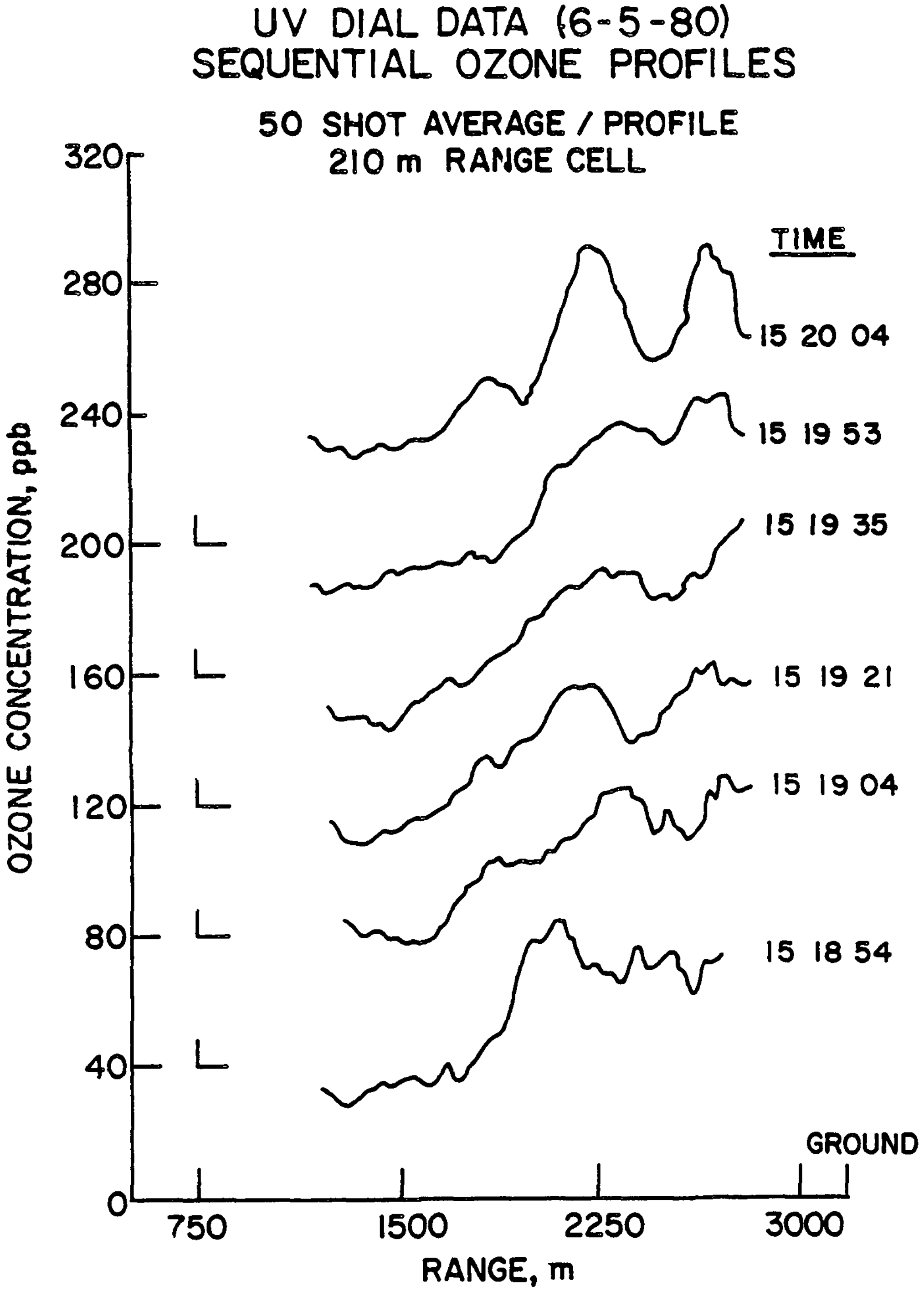


Figure 3 Sequential airborne DIAL ozone data on June 5, 1980 Each profile represents a 50 shot average with 1-km horizontal and 210-m vertical spatial resolution The zero ozone concentration level is shifted vertically by 40 ppb for each successive profile

of these ozone layers in the troposphere can be studied relative to the production, transport, and destruction of ozone on regional and global scales with the airborne DIAL system

Aerosol backscatter profiles are obtained in addition to the UV DIAL data The aerosol data are processed by subtracting the background signal from the lidar-plus-background signal and then multiplying by range-squared, which removes the geometrical dependence of the lidar return signal with range The resulting lidar backscatter profile is indicative of the distribution of aerosols below the aircraft The backscatter signal intensities are converted into a 16-level gray scale display line, where stronger scattering is indicated by higher brightness These gray scale lines are then plotted as adjacent vertical profiles to construct a picture of the aerosol distribution along the Electra flight path An example of this display technique is shown in figure 4 This picture was produced from 600 laser shots along a 90-km flight track of the Electra The ground reflection appears as a bright line at the bottom of the picture The left side of the picture was obtained over land (Virginia) and the right side over the Chesapeake Bay As shown on the left side of the picture, the lidar detects the presence of clouds and provides a direct measurement of cloud top height When these clouds are optically thick, signals are obtained to limit ranges within the cloud, and ground returns cannot be seen The abrupt increase in aerosol scattering above the cloud tops indicates a mixed layer height of about 2 5 km over land It can also be seen from this figure that there is substantially less vertical mixing over the Chesapeake Bay

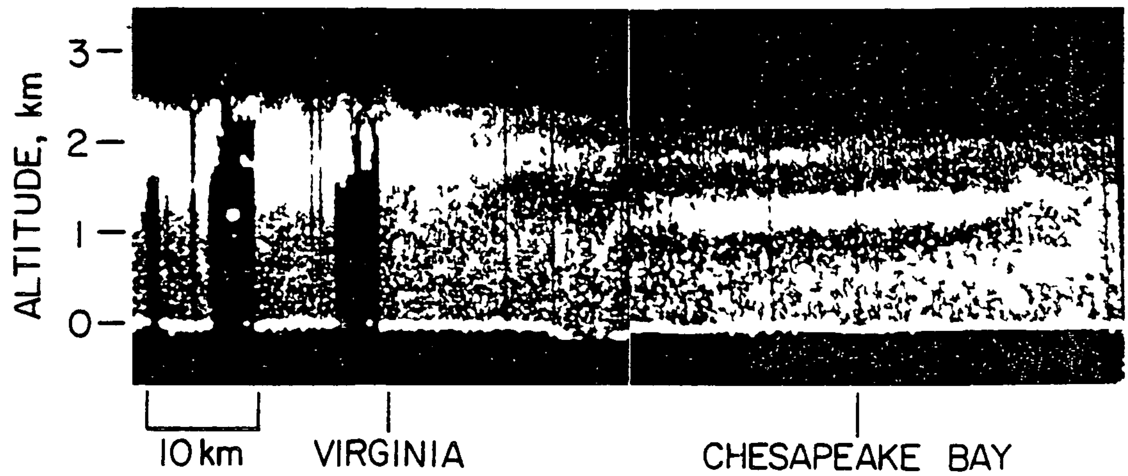


Figure 4 Intensity-modulated display of aerosol data taken on July 24, 1980 at about 1500 EDT over Virginia and the Chesapeake Bay

DESIGN OF THE NASA MULTIPURPOSE DIAL SYSTEM

Introduction

A brief overview of the NASA Airborne DIAL System hardware has been presented In this section, a more detailed exposition of the DIAL System hardware design is given with added emphasis on hardware definitions, system component interconnections, and DIAL Data Acquisition System (DAS) specifications A brief description of the laser firing and signal-acquisition circuitry is given in the next subsection, followed by a description of the DIAL DAS hardware A description of the DIAL DAS operating system and operator command structure is presented in the next section, "DIAL DAS software " Timing diagrams, logic diagrams, schematics and detailed theory of operation of the control electronics and dual-wavelength detector system will be published later in a companion report (ref 14)

Laser-Firing and Signal-Acquisition Electronics

A block diagram of the NASA Multipurpose DIAL System is given in figure 5 The signal abbreviations which are used in this figure are defined in table 1 Five subsystem modules are identified in figure 5, along with information on control and timing interconnections The Master Control Module consists of a Master Control Unit, Laser Control Interface, and two independent, doubled Nd YAG laser subsystems (or pump lasers) for production of laser pulses at 1064 nm and 532 nm An expanded interconnection/block diagram for this module is shown in figure 6 The Master Control Unit is used for precise (±10 ns) coordination of flashlamp firing, lase control, and photomultiplier gating In addition, the Master Control Unit provides control signals to the Biomation 1010 Transient Digitizers for precision synchronization of Biomation data acquisition with laser firing events The entire system is phase locked to a 10-MHz oscillator clock provided by one Biomation 1010 Transient Digitizer when the 0 1-µs sample interval is selected, or 5-MHz clock when the 0 2-µs sample interval is selected

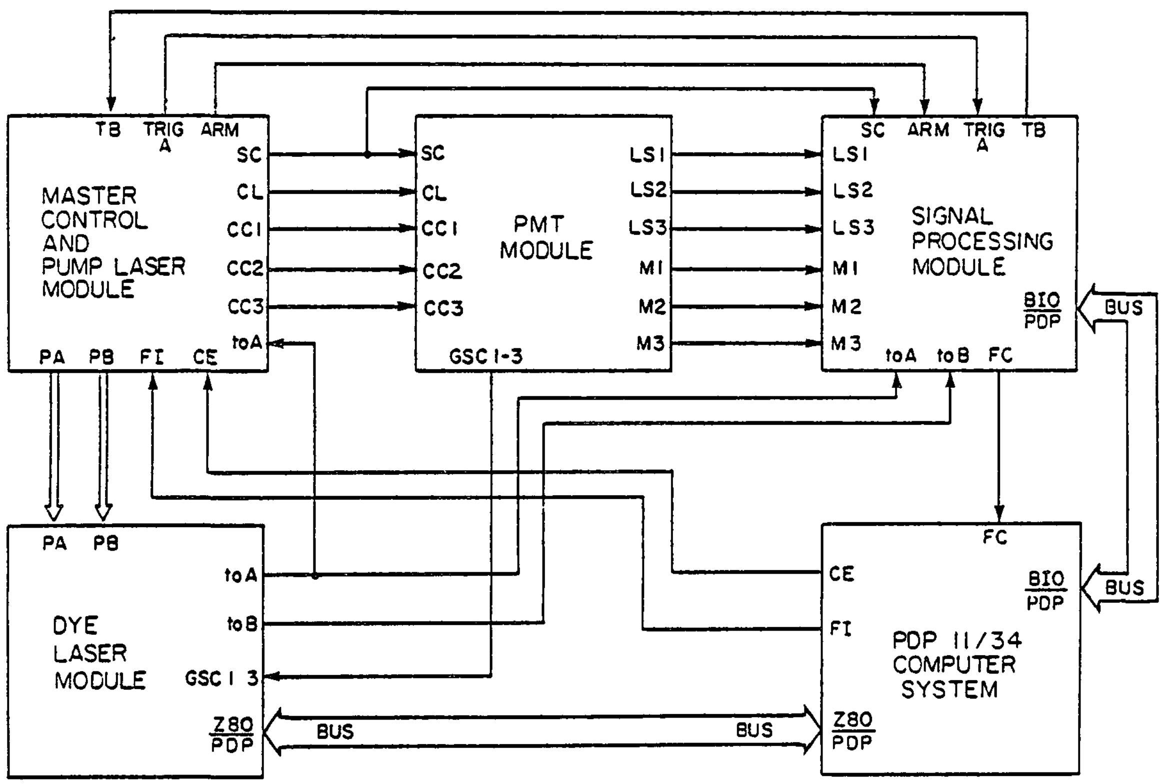


Figure 5 General block diagram of the NASA Multipurpose DIAL System (design date March 27, 1979) Signal abbreviations are defined in table 1

Table 1 Mnemonic definitions for NASA DIAL System schematics (design date March 27, 1979)

Variable	Definition
A	Laser system A First laser to lase (ON-LINE)
ANODE 1	PMT anode signal #1
ANODE 2	PMT anode signal #2
ANODE 3	PMT anode signal #3
ARM	Biomation ARM input
B	Laser system B Second laser to lase 50 or 100 μs after laser A (OFF-LINE)
BIO/PDP	Biomation-PDP 11/34 interface bus
CC1	Calibration control command #1
CC2	Calibration control command #2
CC3	Calibration control command #3
CE	Calibration enable
CL	1-MHz system clock
CO	Charge order
DA	Power envelope from dye laser A sensor
DA1	GFG DAC output (GFG #1)
DA2	GFG DAC output (GFG #2)
DA3	GFG DAC output (GFG #3)
DAC	Digital-to-analog converter
DACON	Digital-to-analog converter
DB	Power envelope from dye laser B sensor
ENERGY	Integrated laser output power (digital)
EOC	End of charges A and B
EXT A	Nd-YAG laser A external control (connector C-7)
EXT B	Nd-YAG laser B external control (connector C-7)
FC	Filter switch codes
FG1	PMT focus gate (PMT #1)
FG2	PMT focus gate (PMT #2)
FG3	PMT focus gate (PMT #3)
FI	Fire interlock

Table 1 (Continued)

Variable	Definition
FOA	Fire order A (laser A)
FOB	Fire order B (laser B)
FT1A	Focus gate trigger A (PMT #1)
FT1B	Focus gate trigger B (PMT #1)
FT2A	Focus gate trigger A (PMT #2)
FT2B	Focus gate trigger B (PMT #2)
FT3A	Focus gate trigger A (PMT #3)
FT3B	Focus gate trigger B (PMT #3)
GFG	PMT gain function generator
GSC1	Gain switch codes (GFG #1)
GSC2	Gain switch codes (GFG #2)
GSC3	Gain switch codes (GFG #3)
HV1	High voltage (PMT #1)
HV2	High voltage (PMT #2)
HV3	High voltage (PMT #3)
LED 1	LED simulator signal #1
LED 2	LED simulator signal #2
LED 3	LED simulator signal #3
LS1	Laser return signal #1
LS2	Laser return signal #2
LS3	Laser return signal #3
M1	Step marker (GFG #1)
M2	Step marker (GFG #2)
M3	Step marker (GFG #3)
PA	532-nm power envelope (pulse) from pump laser A sensor
PB	532-nm power envelope (pulse) from pump laser B sensor
PCA	Pockels cell command A
PCB	Pockels cell command B
SC	System sequence control

Table 1 (Concluded)

Variable	Definition
TB	Time base (crystal controlled)
t_oA	Lase time A control and marker (1st or ON-LINE lase)
t_oB	Lase time B control and marker (2nd or OFF-LINE lase)
TRIG A	Biomation TRIG (trigger) input
V (MOD) 1	Dynode modulation voltage (PMT #1)
V (MOD) 2	Dynode modulation voltage (PMT #2)
V (MOD) 3	Dynode modulation voltage (PMT #3)
XA	Power envelope from doubled dye A output sensor
XB	Power envelope from doubled dye B output sensor
Z80/PDP	Energy monitor Z80 CPU-PDP 11/34 interface bus

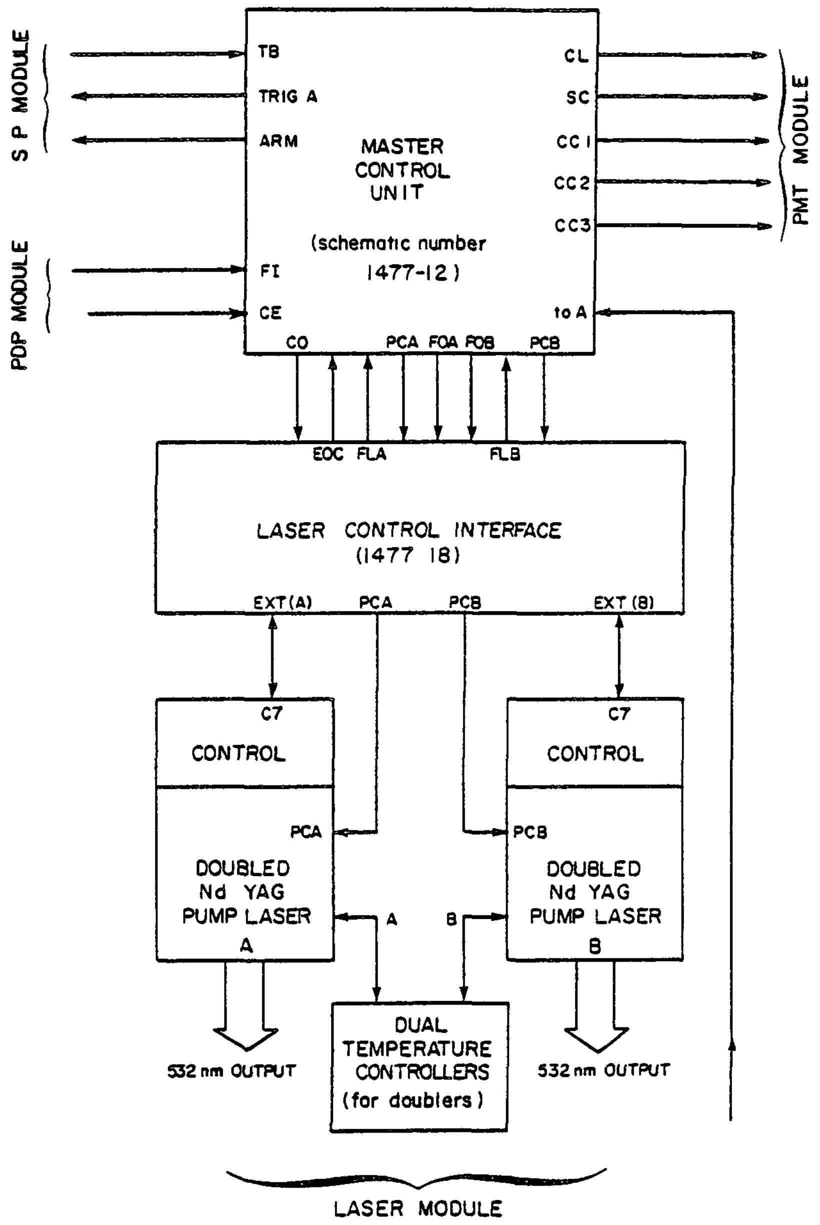


Figure 6   Block diagram showing details of Master Control Unit with coupling to the Nd YAG laser-control electronics (design date March 27, 1979)

An expanded block diagram of the PMT Module is shown in figure 7 A three-channel PMT dynode and focus electrode driver unit is used to drive three independent PMT devices, providing options for variable PMT gain and PMT blinding Each PMT dynode chain is configured for step-gain operation with up to four variable gain, variable width, step-gain increments An LED (light emitting diode) based, laser-return simulator is available for production of synthetic signals without the requirement for actual atmospheric laser returns

The three independent PMT signals are smoothed in the analog domain by linear phase, low-pass, video filters and converted to a digital format by digitization units within the Signal Processing Module (SP Module), as shown in figure 8 The variable selection video filters are provided for removal of very high-frequency noise and signal components which are present in the PMT anode signal outputs A noise compensation system is under development at this time for elimination of large background noise variations which decrease the effective dynamic range of the transient digitizers The signal is synchronously digitized into 10-bit words at a 10-MHz sequential word rate (or 5 MHz if selected) by 3 Biomation 1010 Transient Digitizers configured for parallel operation The Biomation 1010 data is then made available for transfer to the main computer system (PDP 11/34) for real-time data processing by means of a custom designed digital interface The Biomation 1010 to PDP 11/34 interface is elaborated in later subsections of this report and in the Appendix

An expanded block diagram of the Dye Laser Module is shown in figure 9 The doubled outputs of the dual Nd YAG lasers are used to optically pump 2 JY dye lasers for production of laser light in the vicinity of 600 nm Specially coated doubling crystals are then used (UV Double Assemblies A and B) to produce UV light pulses at two independent wavelengths The laser firing sequences for laser systems A and B are phase shifted in time (B fires after A) to reduce receiver hardware requirements The independent

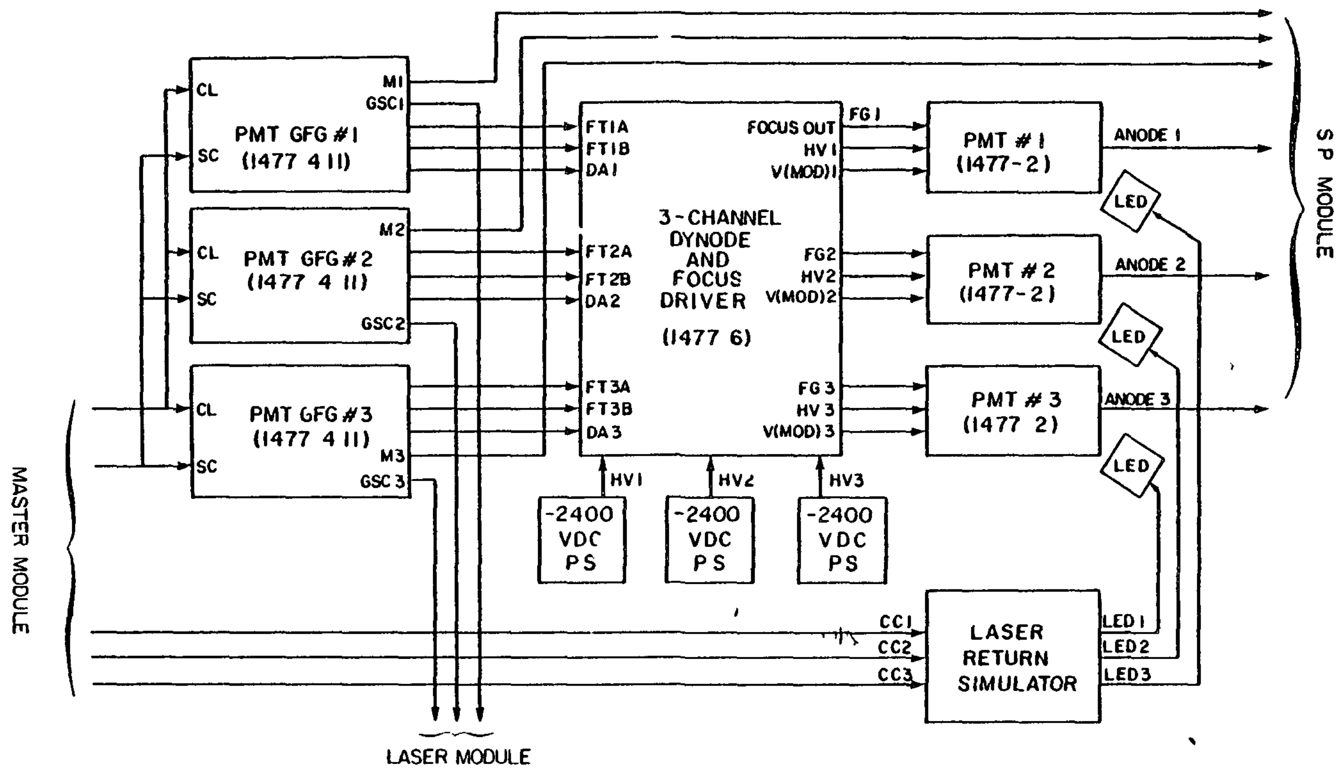


Figure 7 Block diagram showing the triple channel PMT gain-control subsystem and laser-return simulator (design date March 27, 1979)

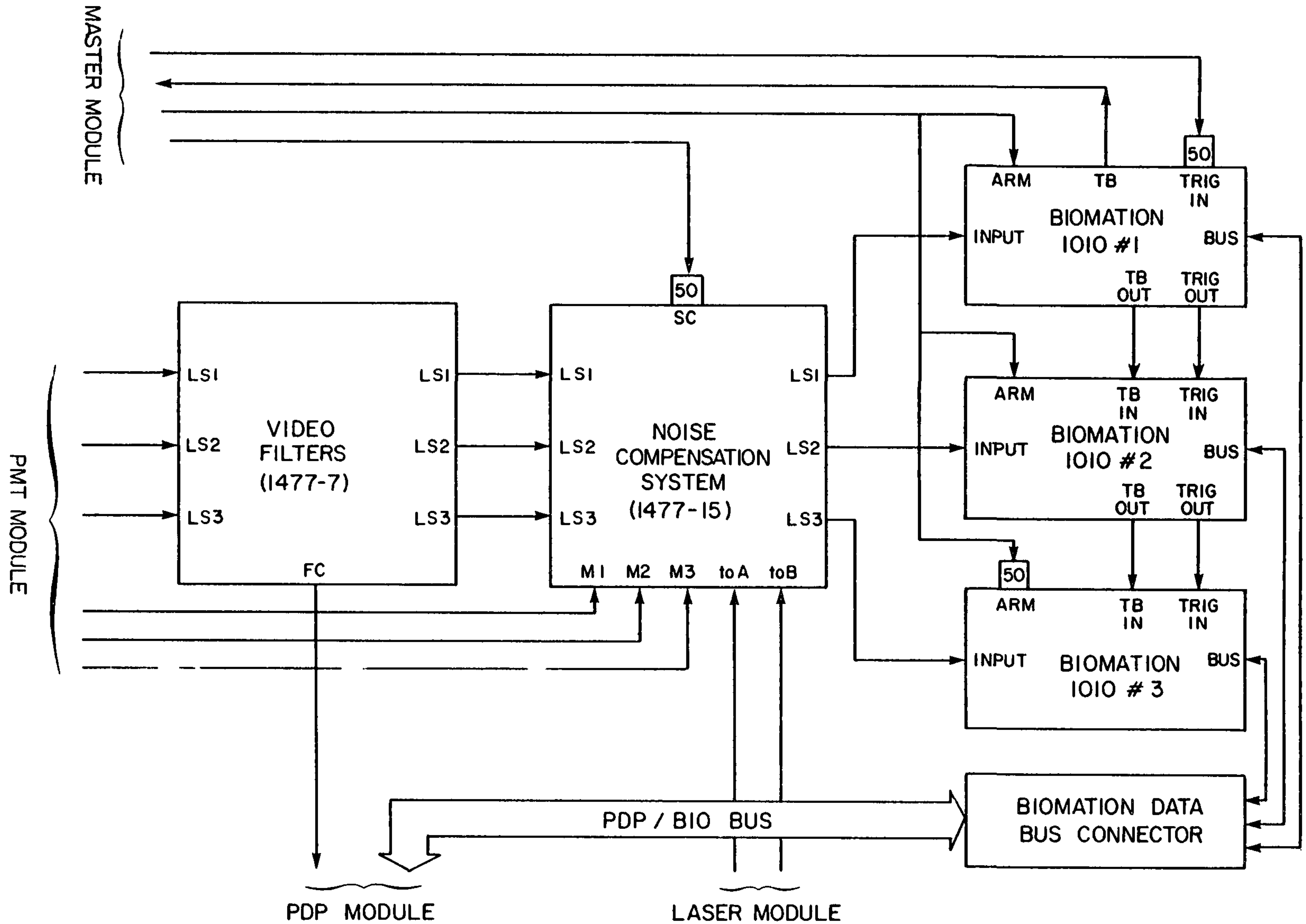


Figure 8 Block diagram showing PMT signal-processing circuitry, including the Biomation 1010 transient digitizers (design date March 27, 1979)

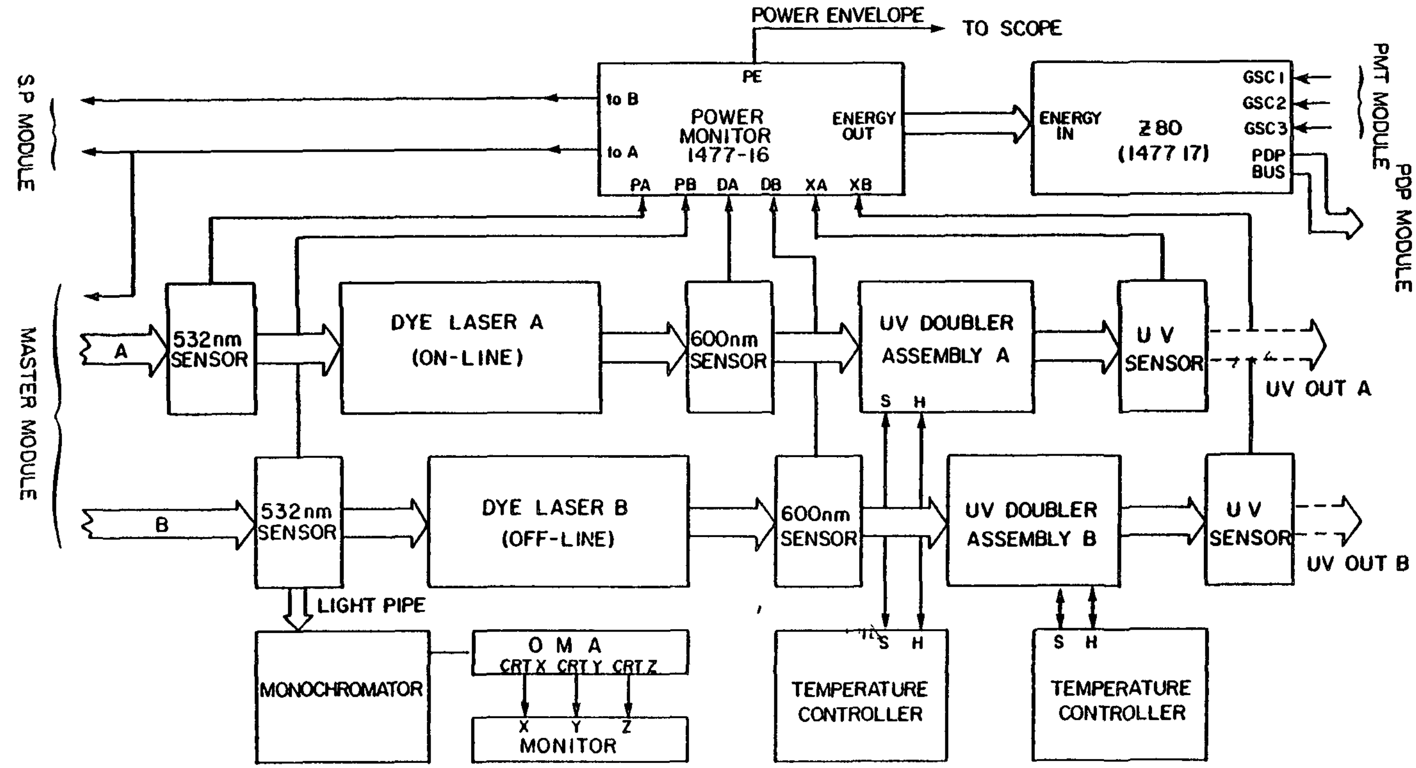


Figure 9 Block diagram showing dye laser and doubler optical paths with interfacing to the laser energy monitor subsystem (design date March 27, 1979)

laser pulses are normally separated by 50 μs The minimum time separation is determined by atmospheric return-signal overlapping A high-resolution monochromator is provided for wavelength measurement of the dye laser output In addition, a comprehensive laser energy-monitoring system is under construction for real-time measurement of laser power levels and laser system conversion efficiencies

Characteristics of the DIAL System

Atmospheric Return Signal

The timing characteristics of the DIAL System return signal train are outlined in figure 10, shown as configured on March 30, 1981 The Biomation 1010 units are operated in Pre-Trigger mode with synchronization to the TRIG A signal which is output by the Master Control Module Certainty in synchronization to actual laser firing events is obtained by superposition of the t_oA and t_oB lase markers onto the DIAL signal train Both t_oA and t_oB are derived from photodiode conversion of A and B pump laser radiation

Each PMT device is gated on and brought to predetermined gain levels four times* during the DIAL System shot cycle During the first and second cycle phases, the PMTs become operational in the absence of laser firing to obtain background signal levels at the gain levels used for returns A and B The PMT devices are then gated on during the third and fourth cycle phases just following the firing of each laser for acquisition of atmospheric return signals A and B The DIAL DAS operating system is configured with options for signal analysis coordinated either to TRIG A or to the laser trigger markers t_oA and t_oB

The ARM command occurs a few hundred microseconds prior to the zero time indicated in figure 10 The CHARGE ORDER (CO) is

*Two additional sequences are used with the Noise Compensation Subsystem (presently under development) A discussion of the noise compensation technique is presented in reference 15

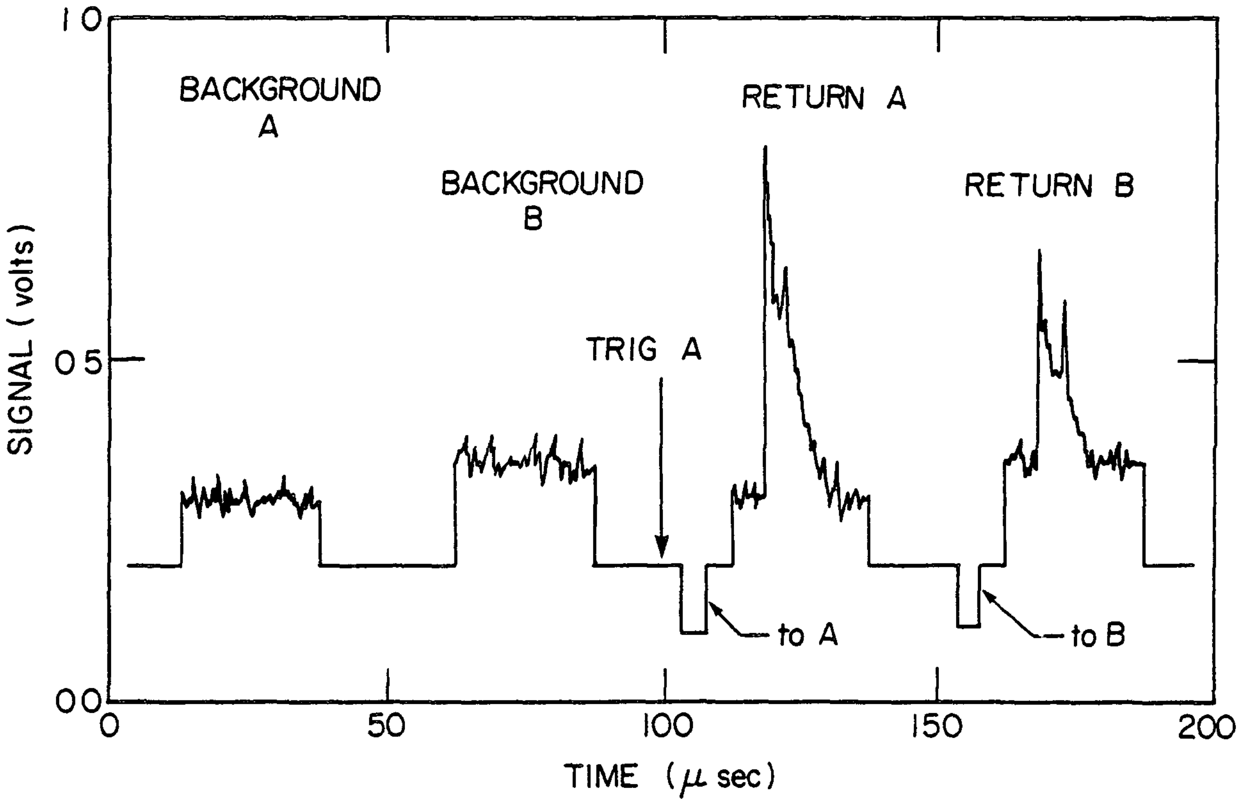


Figure 10 The DIAL System atmospheric return-signal train as input to the Biomation 1010 transient digitizers The DIAL System signals shown in this figure are displayed without step-gain amplification (0 1-μs Biomation sample interval)

synchronized to follow the second lase Detailed timing diagrams will be published in a later report (ref 14)

DATA ACQUISITION SYSTEM

Introduction

The NASA Multipurpose DIAL DAS is based upon the Digitial Equipment Corporation (DEC) PDP-11/34 processor with 28K words of 16-bit MOS RAM memory * The overall flow chart for the DIAL DAS is shown in figure 11 In general, data input/output (I/O) functions are shown on the left-hand side of this figure, with data storage and operator I/O functions shown on the right The operator communicates with the software operating system through a ruggedized, Ann Arbor 400S, console terminal Data is presented to the operator on either the Lexidata 3400 Video Graphics System or the system line printer (TRILOG T100 Graphics Line Printer or DEC La36 DECwriter) Hard copy images of the video graphics display may be obtained through Polaroid photography The DEC RX01 dual floppy disc units (single side, single density) are used for storage and retrieval of program information (not a real-time function) The DIAL data is stored in real time using a single 1600 bpi PE 45 ips magnetic tape unit on 731 5-m (2,400-ft) reels of 1 27-cm (0 5-in) wide magnetic tape

The acquisition of DIAL data is accomplished using three Biomation Model 1010 Transient Digitizers These units are manually programmable for digitization of analog signals into a 2048 word by 10-bit memory at rates up to 10 MHz (2 5-MHz bandwidth max) The internal memories of these transient digitizers are made available to the PDP-11/34 CPU through a Direct Memory Access (DMA) interface

*Two additional pages of memory were acquired during this report period This memory board (Monolithic Systems MSC 3605) uses socketed memory, which was determined to be incompatible with Electra flight applications

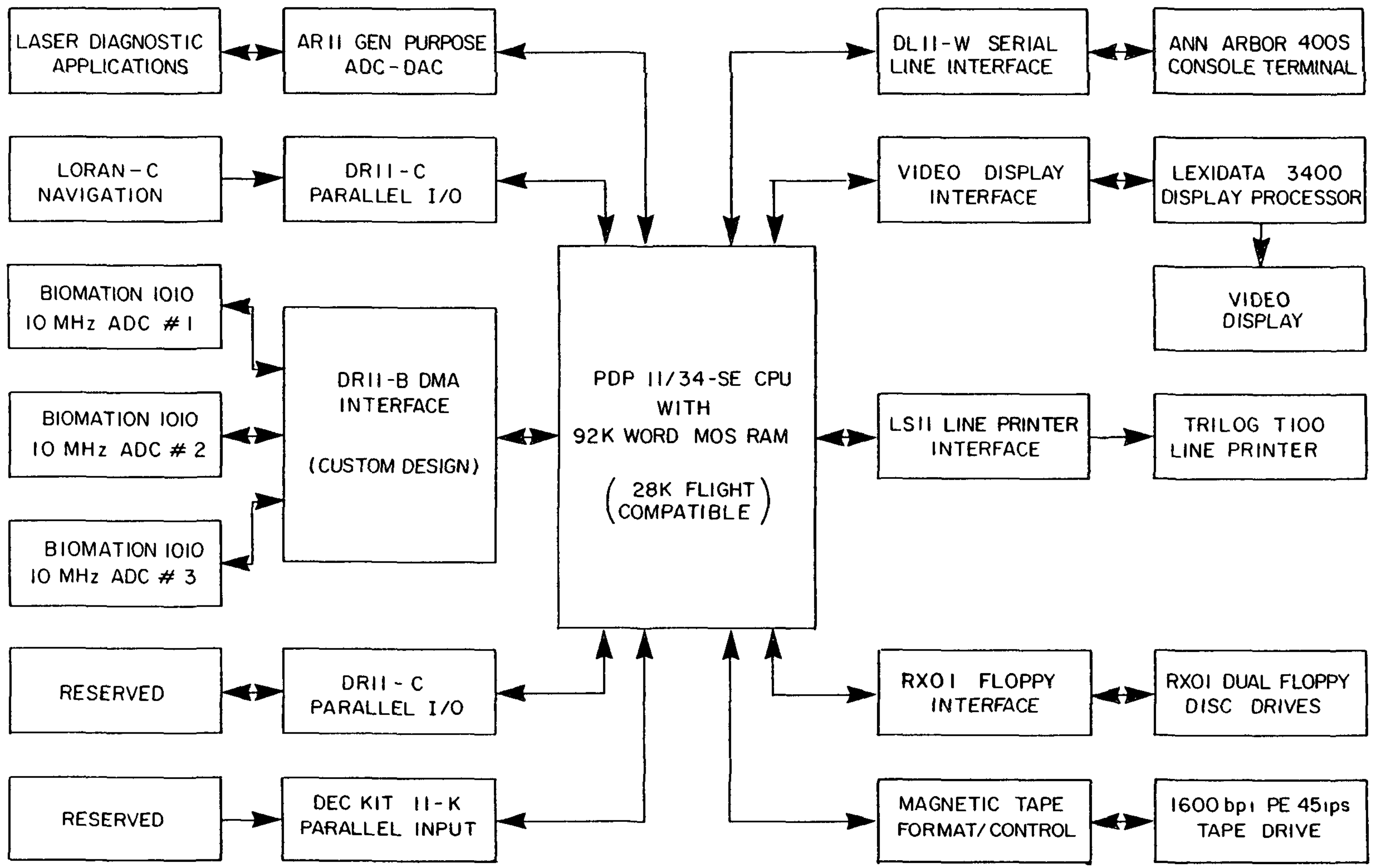


Figure 11 Configuration of NASA Multipurpose Airborne DIAL Data-Acquisition System (NASA/LaRC ADP ID No 4-118/C2, January 1981)

interface of custom design The Biomation 1010 custom interface is described in detail in a later subsection

Eight Analog-to-Digital Conversion (ADC) and two Digital-to-Analog Conversion (DAC) channels are available for system diagnostic applications through the DEC AR11 Analog Realtime Subsystem module In addition, two DR11-C modules and one DEC KIT 11-K are available for parallel interfacing of TTL digital signals

Various operational aspects of the DIAL DAS are discussed in the remainder of this section The DAS component interconnections are outlined under "DIAL DAS Connection Guide" and in table 2 The programming characteristics for each PDP-11/34 peripheral device are given under "PDP-11/34 CPU Peripheral Programming Information," and a listing of available documentation and DEC-supplied diagnostic programs is then given under "Available Documentation " The software operating system which manages the flow of DIAL information is discussed in "DIAL DAS Software," and schematics for the Biomation 1010 DMA custom interface are provided in the Appendix

DIAL DAS Connection Guide

A schematic drawing of the DIAL DAS layout (front view) as configured on March 30, 1981 is shown in figure 12 Data on system component size, weight, and power consumption requirements are given in table 3 A drawing of the PDP-11/34 backplane device distribution is shown in figure 13 System component interconnections by individual cabling are detailed in table 2

Biomation 1010 Transient Digitizers —The Biomation Model 1010 Transient Digitizers are connected in parallel as shown in figure 14, where the control signals TRIG (OUT/IN), TIME BASE (OUT/IN) and ARM (IN) are connected as shown for parallel simultaneous operation A drawing of the Biomation 1010 front panel showing typical switch positions and external data/trigger BNC connections (both terminated in 50 Ω) is given in figure 15 Internal switch selections on each Biomation 1010 unit are set as shown in table 4 Note that only

Table 2 DIAL DAS component interconnections

	DAS Component	Connector Description	Destination
1	RX01 Floppy Disc	single 50p flat cable	M7846
2	Lexidata 3400	dual 50p flat twisted pair cables	LEXIDATA
		single 75 Ω BNC cable	Video display
3	Console Keyboard	single EIA 5p shielded cable to CPU	MDB DL11W
		single 50p flat shielded cable to Display	——
4	Biomation Interface	dual 40p flat cables (within CPU casing)	MDB DR11B
		single 24p flat cable	BIOMATION 1010
5	AR11 Terminal Interface Board	single 50p flat cable	M7809
6	Line Printer (La36)	single current loop 6p shielded cable	M7856

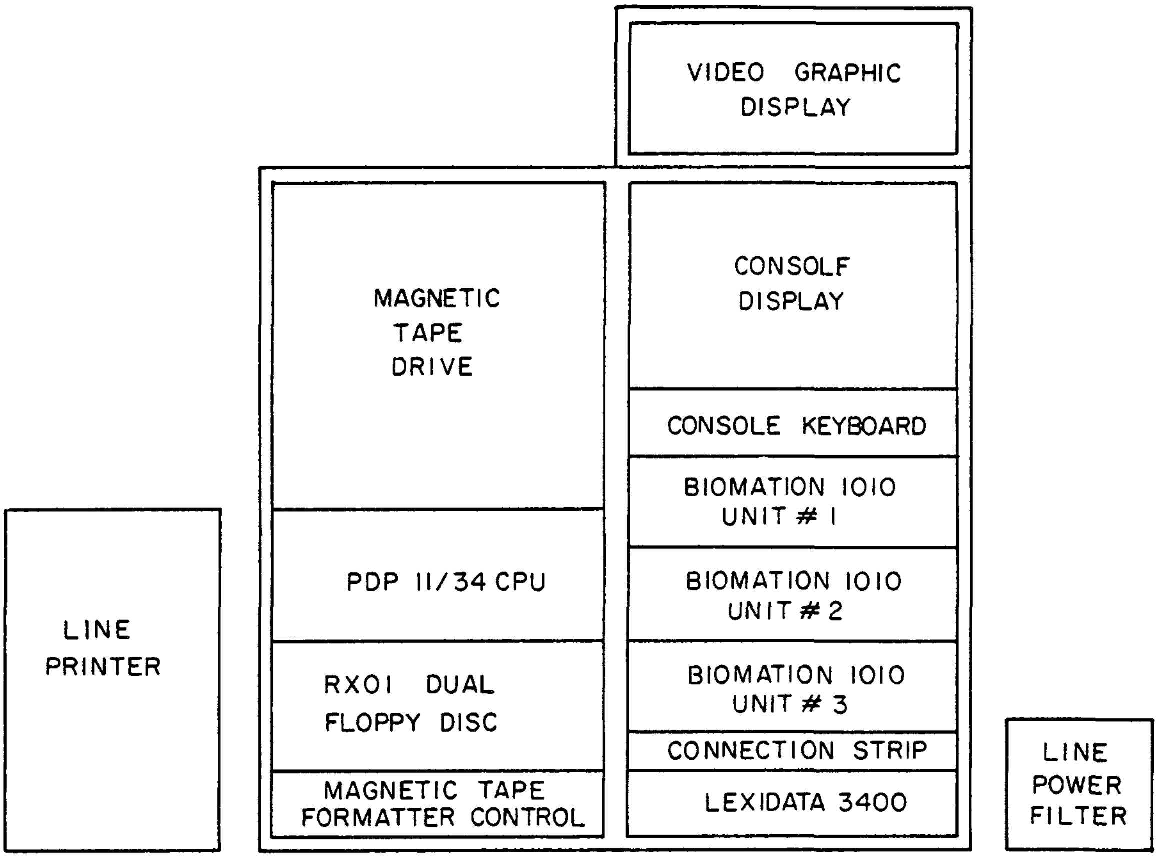


Figure 12 Schematic drawing of the DIAL DAS, front view (configured on March 30, 1981) Data on system component size, weight, and power requirements are given in table 3

Table 3 DIAL DAS component specifications for size, weight, and power requirements (effective date March 30, 1981)

DIAL DAS Component	Height (in)	Weight (lb)	Power (amp @ 115 Vac)
Magnetic Tape Drive	24 50	75	0 7
PDP-11/34 CPU	10 50	110	2 7
RX01 Floppy Disc	10 50	40	2 4
Magtape Formatter/Control	3 50	25	1 2
Video Graphics Display	10 50	10	0 2
Console Display	15 75		
Console Keyboard	3 50	35	0 4
Biomation 1010 (3 each)	7 00 (× 3)	40 (× 3)	1 1 (× 3)
Lexidata 3400	5 25	50	2 5
Line Printer (La36)	32 00	102	1 4
Line Power Filter	10 00	55	—
Totals	147 00	622	23 8

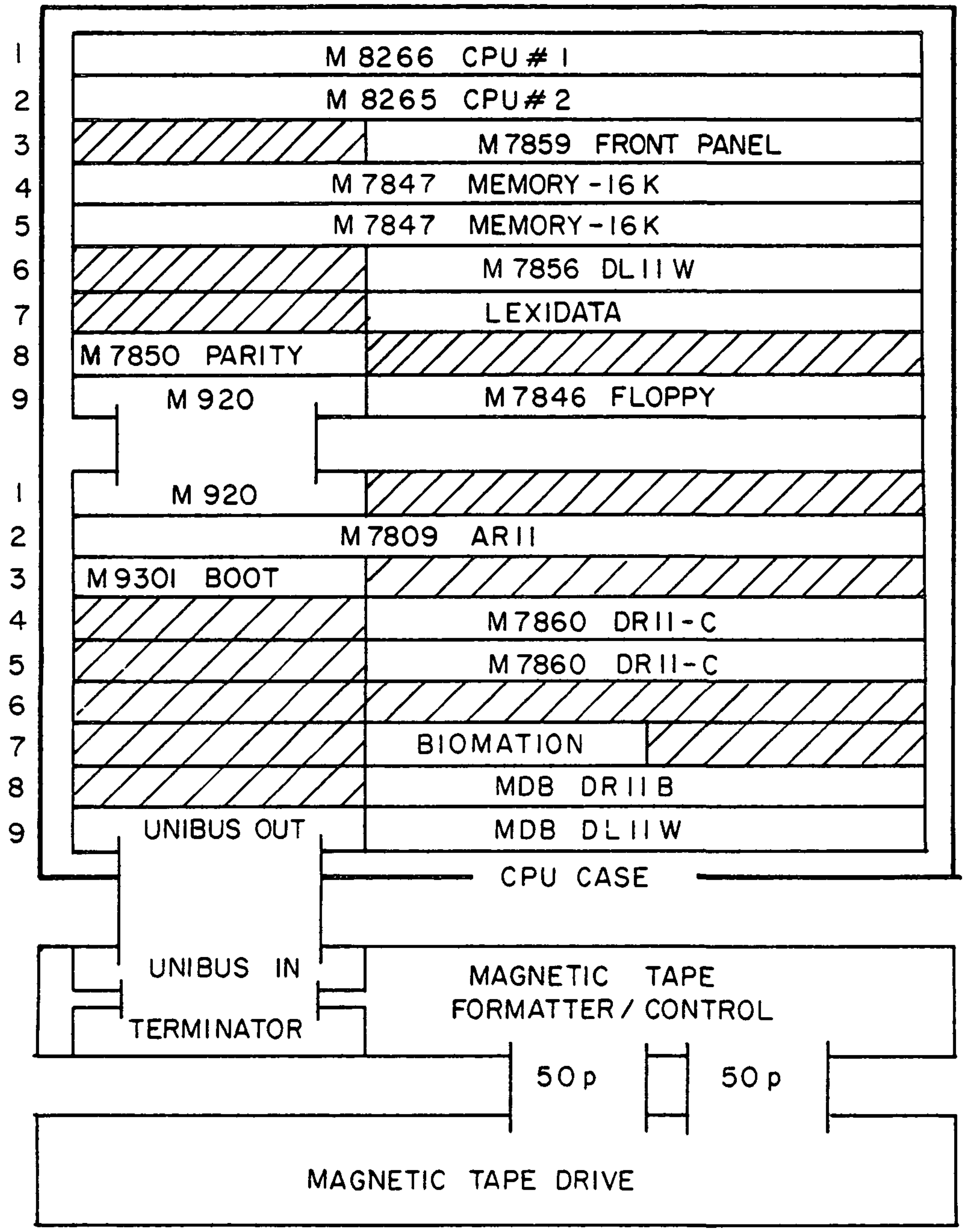


Figure 13 PDP-11/34 CPU UNIBUS and backplane assignments (configured on March 30, 1981)

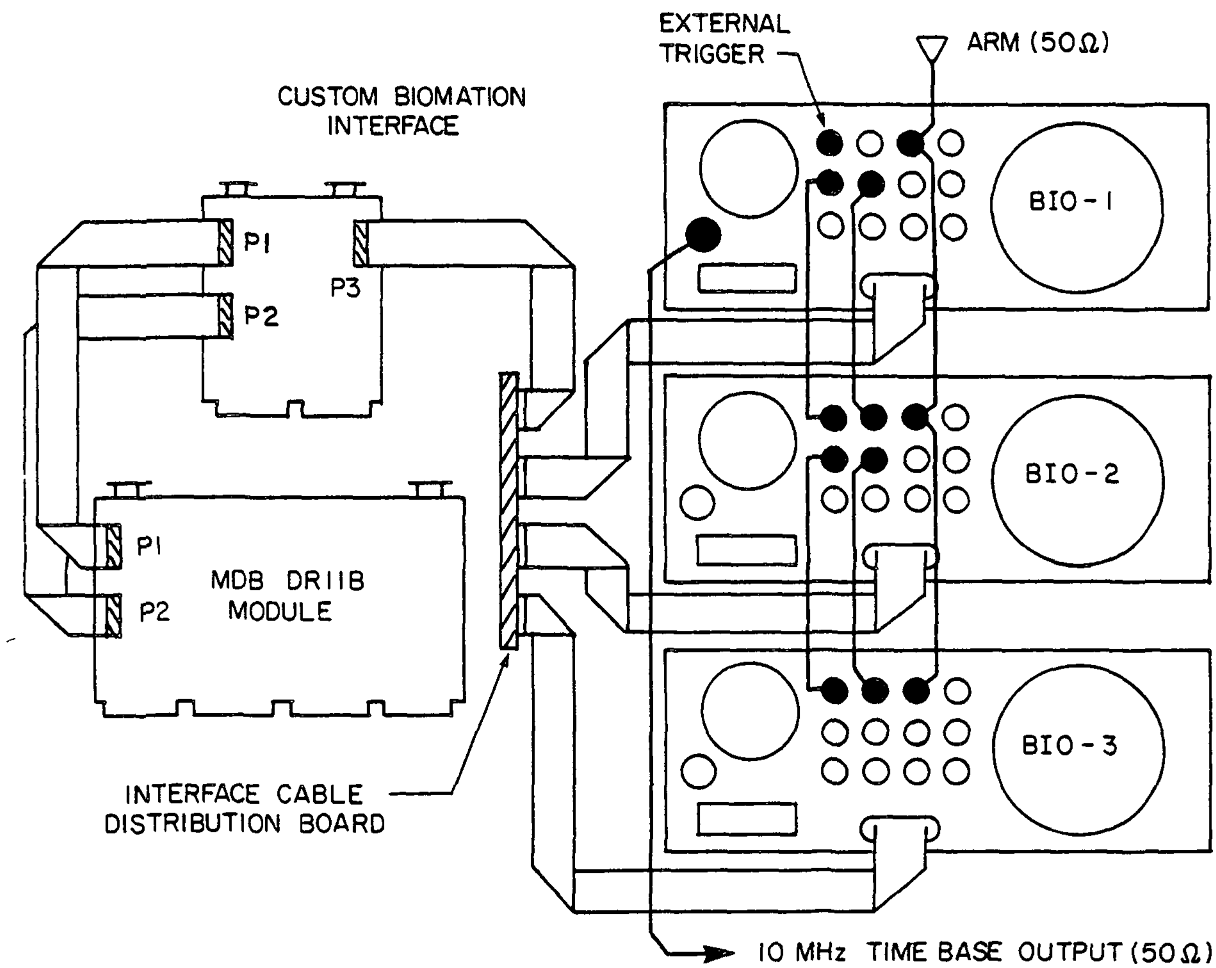


Figure 14 Biomation 1010 transient digitizer interconnections for parallel operation through a custom interface to the MDB DR11B module (configured March 30, 1981)

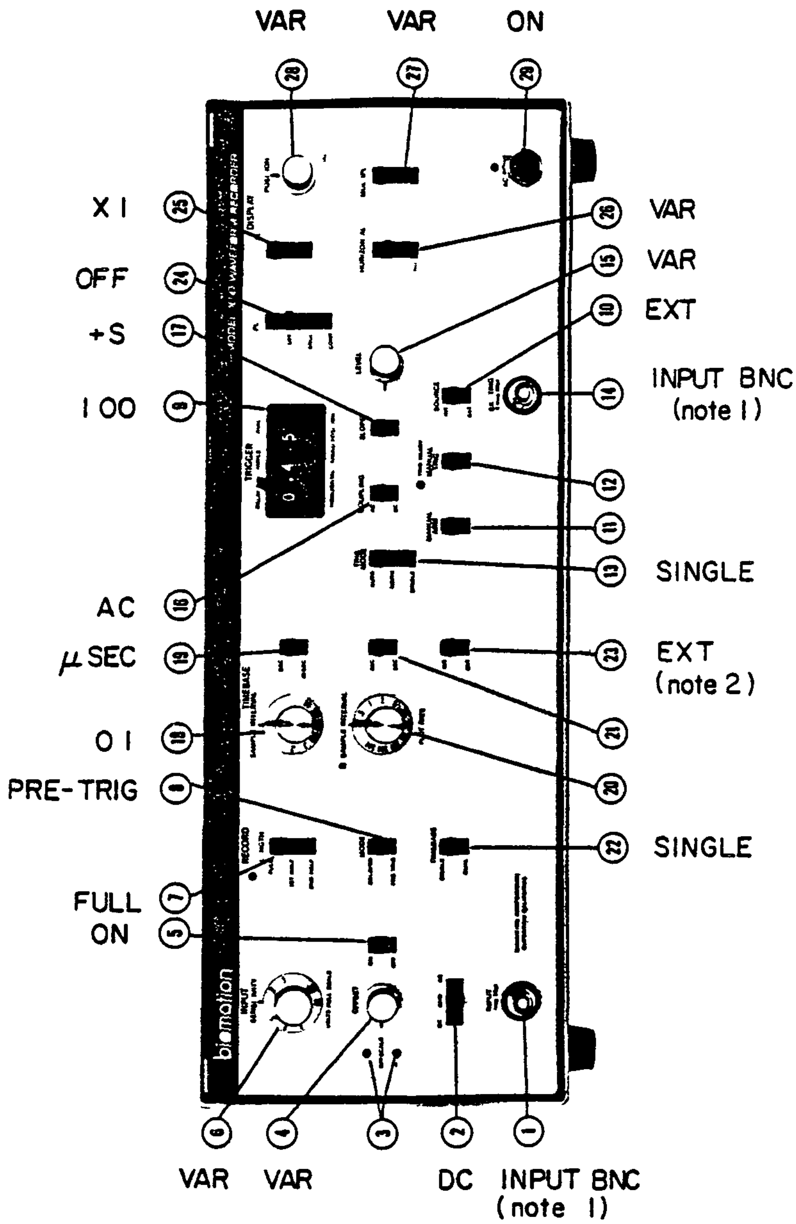


Figure 15 Biomation 1010 transient digitizer—front-panel switch settings for standard pretrigger operation Figure from Biomation 1010 Operation and Service Manual (*by permission of Biomation*) Note (1) Signal inputs are terminated in 50 Ω (2) Switch to INT when Biomation is providing time base

Table 4   Biomation 1010 internal switch selections

Switch #	Signal Name	On	Off	Comments
1	APA		123	Unit address MSB
2	APB	3	12	Unit address
3	APC	2	13	Unit address LSB
4	OPD	123		Signal polarity
5	#REL	1	23	Interrupt Master
6	#XPT		123	na
7	EPC		123	na
8	SHP		123	na

one Biomation 1010 can assert the master interrupt signal #REL The model 1010 information presented in this section is disclosed by permission from Biomation

The 24-pin rear panel connector provides the physical interface for digital data output The connector is an Amphenol Micro-Ribbon 57-40240 The mating connector is an Amphenol part number 57-30240 The pin assignments for the digital interface are listed in table 5

The Data Output is tristate, addressable by 3-bit words on pins 18 to 20 (IAA-IAC) Address polarity is set by switches 1 to 3 on the DIP-switch located under the access plug at the rear of the instrument, which is uncovered by removing the instrument's top cover Polarities are set as shown in table 6 A switch in the ON position indicates that a logic "one" is the address, a switch in the OFF position indicates that a "zero" is the address Data polarity is set by switch 4 on the same switch ON indicates positive true, OFF indicates negative true Data is output in pure binary form The value represented by each word in the memory represents an instantaneous voltage level of the input signal, and the input signal may be any value between zero and the full scale selected on the input attenuator (depending on the amount of input offset selected) Zero volts is represented by all zeros in the binary code, and full-scale saturation is represented by all ones Each LSB (least significant bit) therefore represents 1/1024 of the full-scale voltage set on the input attenuator

Lexidata 3400 video graphics display driver —The Lexidata System 3400 Video Graphics Display pin assignments for interconnection to the Lexidata CPU interface are given in table 7 A reference drawing for board placement inside the Lexidata 3400 mainframe is shown in figure 16 Switch settings on the CPU interface board for operation in the DIAL DAS are as follows

Table 5 Pin assignments for Biomation 1010 Digital Interface

Pin #	Mnemonic	Description	Input/Output
1	ODA	Output Data 2^0	0 Tri-State
2	ODB	Output Data 2^1	0 Tri-State
3	ODC	Output Data 2^2	0 Tri-State
4	ODD	Output Data 2^3	0 Tri-State
5	ODE	Output Data 2^4	0 Tri-State
6	DOR	Digital Output Mode Request	I
7	FLG	Output Flag	0 Tri-State
8	OSR	Output Stop	I
9	$\overline{FWR}$	Output Word Command	I
10	$\overline{REL}$	Record Mode Status	0
11	$\overline{XPT}$	External Plot Time Base Command	I
12	+5 V	-	-
13	ODF	Output Data 2^5	0 Tri-State
14	ODG	Output Data 2^6	0 Tri-State
15	ODH	Output Data 2^7	0 Tri-State
16	ODI	Output Data 2^8	0 Tri-State
17	ODJ	Output Data 2^9	0 Tri-State
18	IAA	Unit Address	I
19	IAB	Unit Address	I
20	IAC	Unit Address	I
21	GND	-	-
22	DOG	Output Mode Status	0 Tri-State
23	EPC	External Plot Time Base	1
24	GND	-	-

Table 6 Biomation 1010 address polarities

Address	Pin Mnemonic	Switch
18	IAA	1
19	IAB	2
20	IAC	3

Table 7 System 3400 input/output signals *

CABLE A

Wire Number	Signal Name	System 3400 Backplane Connection
1	ODATA 0	A61 (Most significant bit)
2	Ground	
3	ODATA 1	A63
4	Ground	
5	ODATA 2	A67
6	Ground	
7	ODATA 3	A69
8	Ground	
9	ODATA 4	A71
10	Ground	
11	ODATA 5	A73
12	Ground	
13	ODATA 6	A75
14	Ground	
15	ODATA 7	A76
16	Ground	
17	ODATA 8	A77
18	Ground	
19	ODATA 9	A78
20	Ground	
21	ODATA 10	A79
22	Ground	
23	ODATA 11	A81
24	Ground	
25	ODATA 12	A83
26	Ground	
27	ODATA 13	A84
28	Ground	
29	ODATA 14	A85
30	Ground	
31	ODATA 15	A86 (Least significant bit)
32	Ground	
33	$\overline{\text{OFIR}}$	A87
34	OFIR	A88
35	$\overline{\text{OFSI}}$	A89
36	OFSI	A90
37	PLOAD	A91
38	Ground	
39	PSTART	A92
40	Ground	

Differential Pair

CABLE B

Wire Number	Signal Name	System 3400 Backplane Connection
1	IDATA 0	B5 (Most significant bit)
2	Ground	
3	IDATA 1	B6
4	Ground	
5	IDATA 2	B7
6	Ground	
7	IDATA 3	B8
8	Ground	
9	IDATA 4	B9
10	Ground	
11	IDATA 5	B10
12	Ground	
13	IDATA 6	B11
14	Ground	
15	IDATA 7	B12
16	Ground	
17	IDATA 8	B13
18	Ground	
19	IDATA 9	B14
20	Ground	
21	IDATA 10	B15
22	Ground	
23	IDATA 11	B16
24	Ground	
25	IDATA 12	B18
26	Ground	
27	IDATA 13	B19
28	Ground	
29	IDATA 14	B20
30	Ground	
31	IDATA 15	B22 (Least significant bit)
32	Ground	
33	IFSO	B23
34	$\overline{\text{IFSO}}$	B24
35	$\overline{\text{IFOR}}$	B25
36	IFOR	B26

*This material reproduced here from reference RA8a by permission of Lexidata Corporation

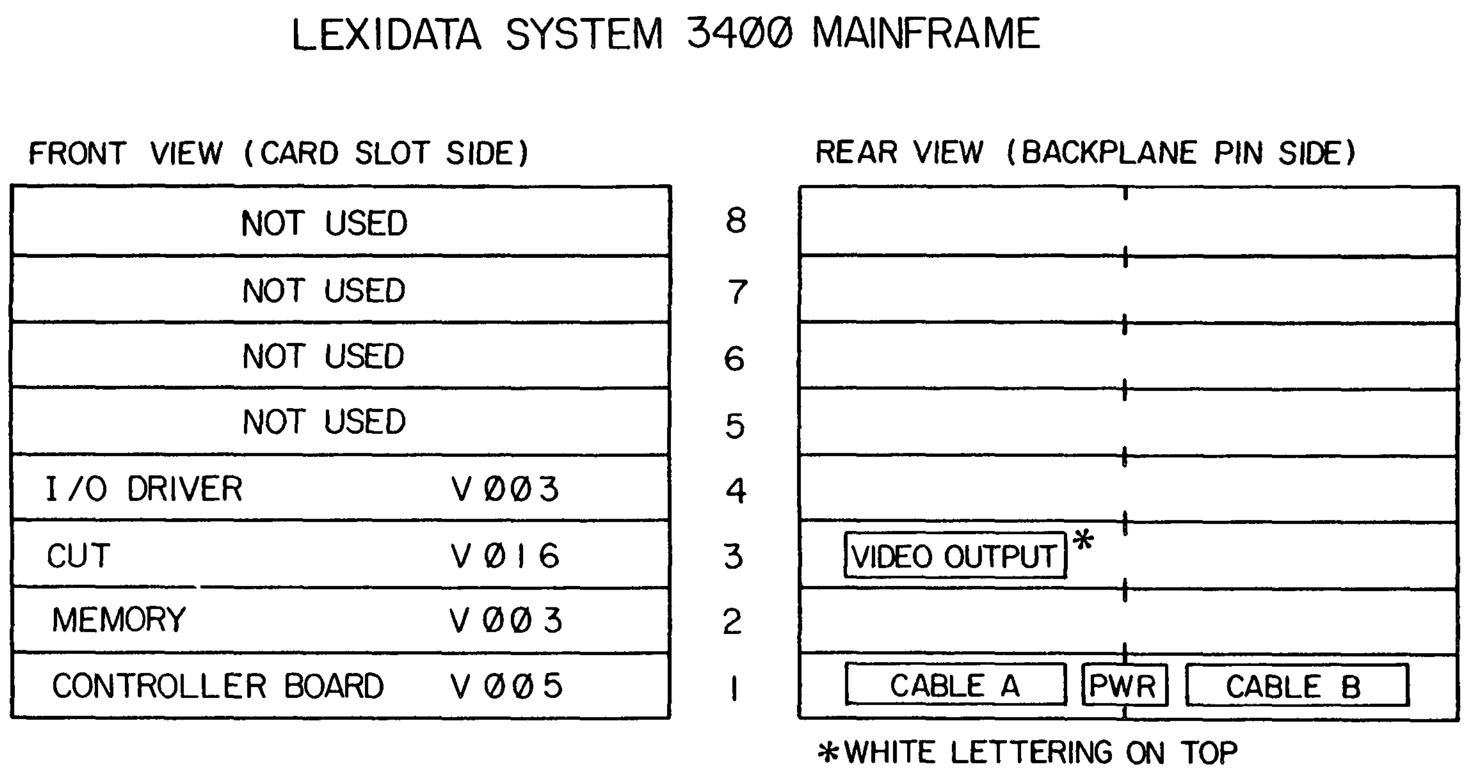


Figure 16 Schematic drawing for connections and board placement inside Lexidata System 3400 mainframe

BASE ADDRESS = 764100_8

DIP Pack 9F

Switch	Setting	Function
S1	off	A08
S2	off	A03
S3	off	A02
S4	off	A07
S5	off	A04
S6	off	A14
S7	on	A06
S8	off	A05
S9	on	test
S10	on	test

VECTOR ADDRESS = 370_8

DIP Pack 9D

Switch	Setting	Function
S1	on	D7
S2	on	D6
S3	on	D5
S4	on	D4
S5	on	D3
S6	off	D2
S7	on	test
S8	off	test

BURST COUNT

DIP Pack 1D

Switch	Setting	Function
S1	on	2^4
S2	on	2^0

BURST COUNT

DIP Pack 1D (Concluded)

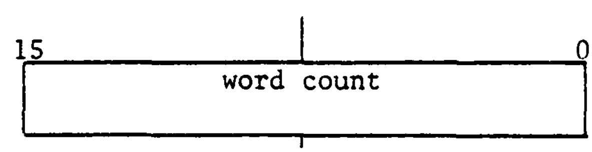
Switch	Setting	Function
S3	on	2^5
S4	on	2^1
S5	on	2^6
S6	on	2^2
S7	on	2^3
S8	on	2^7

<u>DR11-C general purpose UNIBUS interface</u> —Pin assignment conventions for the DR11-C General Purpose UNIBUS Interface are given in table 8 for reference purposes This interface device is used for coupling of navigation, laser energy, and other DIAL System information Figure 17 shows the Digi-Data magnetic tape transport formatter/controller with UNIBUS connection

PDP-11/34 CPU Peripheral Programming Information

<u>Biomation 1010 Interface</u> —The Biomation Model 1010 Transient Digitizer Interface is custom designed using the DR11B Direct Memory Access (DMA) method for fast data transfer to CPU memory This custom interface allows for sequential communication with up to 8 Biomation 1010 units operating in parallel The DR11B module registers are implemented as follows

DRWC
@ 772 410_8
word count register
(2's complement)



DRBA
@ 772 412_8
buffer address
register

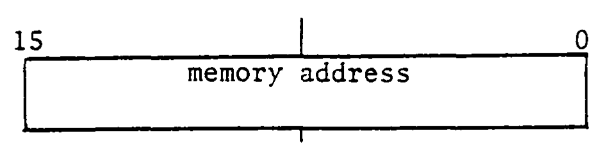


Table 8 DR11-C Interface pin assignments

M971		M7860					M971
		Connector No 2		Connector No 1			
Board	Berg Header	Pin	Name	Name	Pin	Berg Header	Board
V2	A	VV	OPEN	OPEN	A	VV	A1
U1	B	UU	GND	OPEN	B	UU	A2
U2	C	TT	IN00	OUT00	C	TT	A1
V1	D	SS	GND	OPEN	D	SS	A2
T2	E	RR	INIT H	NEW DATA RDY HI	E	RR	B1
T1	F	PP	GND	OPEN	F	PP	B2
T2	H	NN	INIT H	NEW DATA RDY LO	H	NN	C1
T1	J	MM	GND	GND	J	MM	C2
S2	K	LL	IN01	OUT01	K	LL	D1
S1	L	KK	IN04	OUT04	L	KK	D2
R2	M	JJ	GND	GND	M	JJ	E1
R1	N	HH	IN05	OUT05	N	HH	E2
P2	P	FF	OPEN	INIT H	P	FF	F1
P1	R	EE	IN06	OUT06	R	EE	F2
N2	S	DD	GND	GND	S	DD	H1
N1	T	CC	IN07	OUT07	T	CC	H2
M2	U	BB	IN03	OUT03	U	BB	J1
M1	V	AA	GND	GND	V	AA	J2
L2	W	Z	IN08	OUT	W	Z	K1
L1	X	Y	IN09	OUT	X	Y	K2
K2	Y	X	GND	GND	Y	X	L1
K1	Z	W	IN10	OUT	Z	W	L2
J2	AA	V	IN11	OUT11	AA	V	M1
J1	BB	U	IN12	OUT12	BB	U	M2
H2	CC	T	GND	GND	CC	T	N1
H1	DD	S	REQ B	CSR1	DD	S	N2

Table 8 (Concluded)

M971		M7860						M971	
		Connector No 2		Connector No 1					
Board	Berg Header	Pin	Name	Name	Pin			Berg Header	Board
F2	EE	R	GND	GND	EE			R	P1
F1	FF	P	IN13	OUT13	FF			P	P2
E2	HH	N	IN14	OUT14	HH			N	R1
E1	JJ	M	IN15	OUT15	JJ			M	R2
D2	KK	L	GND	GND	KK			L	S1
D1	LL	K	CSR0	REQ A	LL			K	S2
C2	MM	J	GND	GND	MM			J	T1
C1	NN	H	IN02	OUT02	NN			H	T2
B2	PP	F	OPEN	GND	PP			F	T1
B1	RR	E	OPEN	OPEN	RR			E	T2
A2	SS	D	OPEN	GND	SS			D	V1
A1	TT	C	DATA TRANS	OPEN	TT			C	U2
A2	UU	B	OPEN	GND	UU			B	U1
A1	VV	A	OPEN	NEW DATA RDY	VV			A	V2

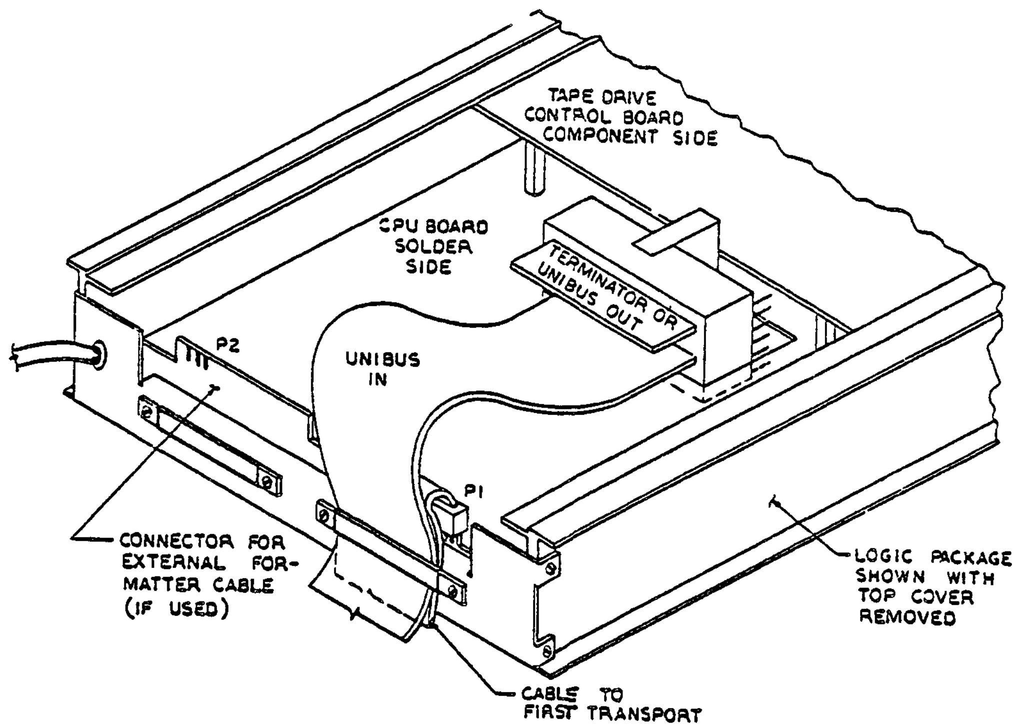


Figure 17 Digi-Data magnetic tape transport formatter/controller, showing UNIBUS connection (Drawing reproduced by permission from Digi-Data part #0550017-000)

DRST
@772 414_8
control and
status register

15	0
control and status (see below)	

DRDB
@ 772 416_8
data register

15	0
data register (see below)	

Trap vector address = $\emptyset 124_8$ at interrupt priority level BR5

DRST @ 772 414_8

Command and Status Register Assignments

15							8	7						0
ERROR	NEX	ATTN		$\overline{\text{REL}}$	DOG	FLAG	CYCLE	READY	IE		FCN 3	FCN 2	FCN 1	GO

Bit	Name	Description and Effect
15	ERROR (read only)	a Indicates error as follows 1 NEX (bit 14), or 2 ATTN (bit 13), or 3 Interlock error (module/connector discontinuity), or 4 Bus address overflow (address changes from all "1's" to all "0's") b Sets READY (bit 7) and causes interrupt if IE (bit 6) has been set c ERROR is cleared by clearing all error conditions, as follows 1 Module is seated in connector 2 Bus address is cleared or reloaded 3 Bit 14 is loaded with a "0" 4 Bit 13 is cleared by the user device

Bit	Name		Description and Effect
14	NEX (read/write)	a	Non-Existent Memory Indicates that the module, acting as bus master, failed to receive a SSYN response within 20 microseconds after asserting MSYN
		b	NEX sets ERROR bit
		c	Cleared by INIT or by program
13	ATTN (read only)*	a	Attention Shows state of user device ATTN signal
		b	Sets ERROR for device-initiated interrupt
		c	Set and cleared only by user device
12	MAINT (read/write)	a	Maintenance Used to enable execution of diagnostic programs Not used in March 30, 1981 configuration
		b	Cleared by INIT
11	$\overline{\text{REL}}$ (DSTATA)	a	Indicates that new data is available in the Biomation 1010 memories
10	DOG (DSTATB)	a	Indicates that the selected Biomation (unit which is addressed) is in the Digital Output mode
09	FLAG (DSTATC)	a	Occurs only when set Indicates that the selected Biomation (unit which is addressed) has gated data to the data input register (DRDB)
08	CYCLE (read/write)	a	If set when GO is issued, enables an immediate bus cycle
		b	Cleared by INIT, or start of bus cycle

*For BIO 1010 interface, ATTN is set by 0 to 1 transitions of $\overline{\text{REL}}$ or DOG, ATTN can be cleared by sending CLR

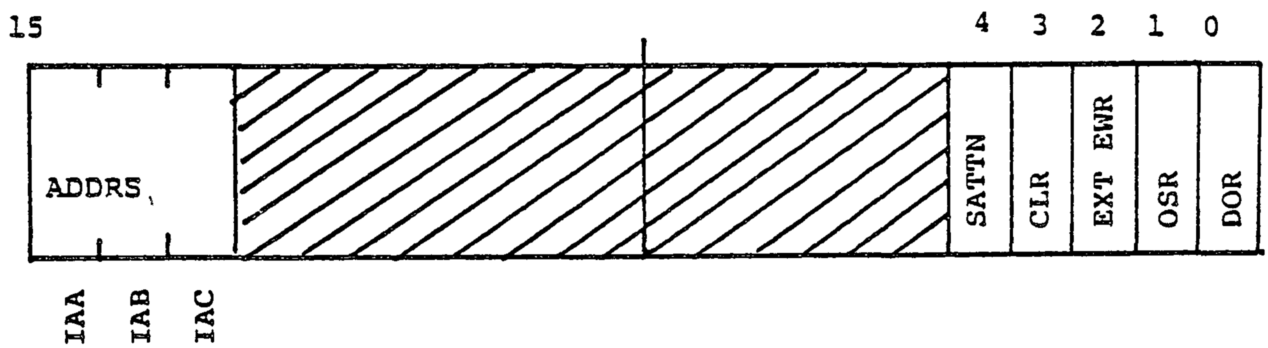
Bit	Name	Description and Effect
07	READY (read only)*	a Indicates that the MDB-DR11B is able to accept a new command b Set by INIT or ERROR, or by word count overflow c Cleared by GO d If bit 6 is set, READY causes an interrupt, forcing module to release the UNIBUS
06	IE (read/write)	a Interrupt Enable Enables either ERROR or READY to set an interrupt b Cleared by INIT
05	XBA17 (read/write)	a Extended Bus Address Along with contents of Bus Address Register, specify address for indirect memory transfers Not used in March 30, 1981 configuration b Cleared by INIT c Bits XBA17 and XBA16 are not incremented when Bus Address Register overflows, but ERROR is set
04	XBA16 (read/write)	
03	FCN 3	a When set, enables add-to-memory function b When clear, enables transfer to memory function
02	FCN 2	a When set, inhibits normal address increments between data transfers to memory

*If ATTN, NEX and ERROR are cleared, then READY can be cleared by setting DRST = 3 This action initiates a Dummy DMA operation which will hang the device with FCN 1 set (program mode) The READY bit can then be reset by ATTN or any ERROR condition, or by sending the SATTN command

Bit	Name	Description and Effect
01	FCN 1	a When set, enables program controlled transfers to the Biomation 1010 interface via the DRDB register b When clear, enables DMA operation
00	GO (write only)	a Causes MDB-DR11B to signal user device that a command has been issued b Clears READY

DRDB @ 772 416

Data Register (output mode)



bits 13 - 15 BIOMATION ADDRESS

Bit	Name	Description and Effect
04	SATTN	This command resets ATTN when set from 0 to 1 with FCN 1 set
03	CLR	This command clears ATTN and $\overline{\text{REL}}$ when set from 0 to 1 with FCN 1 set
02	EXT EWR	When set from 0 to 1 with bit 03 and FCN 1 = 1, then an EWR pulse is sent to the currently addressed Biomation unit

Bit	Name	Description and Effect
01	OSR	When set from 0 to 1 with FCN 1 = 1, this command causes the currently addressed Biomation unit to EXIT the Digital Output mode
00	DOR	When set from 0 to 1 with FCN 1 = 1, this command causes the currently addressed Biomation unit to ENTER the Digital Output mode

The Biomation 1010's are operated in parallel and are selected by these address bits as follows

000 = first Biomation (master)

001 = second

010 = third

111 = eighth (last)

These address bits are latched in the interface when FCN 1 is cleared When FCN 1 is set, then the address lines are active and can be changed under program control

Operation examples for the Biomation 1010 Interface are outlined below

1 Detection of new data

(a) CLR all conditions which will set READY

(b) Clear READY by initiating a dummy DMA operation, viz, DRST = 03

(c) READY will remain clear until set by $\overline{\text{REL}}$, DOG or SATTN

2 Select Biomation by setting ADDRS in DRDB register under PGM mode (FCN 1 = 1)

3 Send DOR to force the selected unit into Digital Output mode DOR clears ATTN and $\overline{\text{REL}}$, and ATTN is reset when DOG undergoes transition from 0 to 1

4 After DOG is set, the selected Biomation is ready to transfer data to PDP-11 memory

(a) Set DRWC to 2's complement of number of words to be transferred

(b) Set DRBA to address of data buffer to be used

(c) Put MDB-DR11B into DMA mode (FCN 1 = 0) with "add-to-memory" and "address incrementing" selected as desired (FCN 2 and FCN 3)

(d) Initiate data transfer by setting GO READY will come true when data transfer has been completed Several sequential transfers may be performed

(e) When finished with data transfers, send OSR command to get Biomation out of Digital Output mode Note that it may take as much as 1 ms (approximately) after the OSR is issued before DOG is removed

(f) Alternatively, the currently addressed Biomation may be forced out of Digital Output mode by EXT EWR after 2049$_{10}$ words have been transferred This procedure can be used to assure integrity of data transfers (i e , that no words have been skipped or multiply transferred)

<u>Lexidata 3400 video graphics display driver</u> —The Lexidata 3400 PDP-11 interface is a 16-bit parallel device which supports both programmed and DMA I/O data transfer Interrupt logic is provided under program control which allows operations in either polling loop or interrupt-based applications The Lexidata 3400 PDP-11 interface module registers are implemented as follows

LXWC @ 764 1ØØ$_8$
word count register
(2's complement)

15	0
word count	

LXBA @ 764 1Ø2$_8$ buffer address register	15 memory address 0
LXSR @ 764 1Ø4$_8$ control and status register	15 control and status (see below) 0
LXDB @ 764 1Ø6$_8$ data register	15 data register 0

Trap vector address is set to @ ØØØ370$_8$ at interrupt priority level BR4

LXSR @ 7641Ø4$_8$

Control and Status Register

15							8	7				1
PERR	NEX	SERR	I/O	IDR	IDIE	ODR	ODIE	DMAR	DMIE	MEX	FCN	GO

Bit	Name	Description and Effect
15	PERR (read only)	Power ERRor, set whenever the power error condition at the display system is sensed An occurrence of this condition will set DMAR If DMA is in progress and DMIE is set, an interrupt will occur (Disabled under March 30, 1981 configuration)
14	NEX (read/write)	Non-Existent Memory, set whenever a bus timeout occurs during DMA An occurrence of this condition will set DMAR If DMA is in progress and DMIE is set, an interrupt will occur Cleared by writing to the LXSR

Bit	Name	Description and Effect
13	SERR (read/write)	System ERRor, set whenever an overflow occurs out of LXBA An occurrence of this condition will set DMAR If DMA is in progress and DMIE is set, an interrupt will occur Cleared by writing to the LXSR
12	I/O (read/write)	I/O Mode, set to indicate transfer from the PDP-11 to the display system Clear for transfers from the display system to the PDP-11 Note this bit must be set appropriately for both programmed I/O and DMA
11	IDR (read only)	Input Data Ready, set if the display system is ready to transfer data to the PDP-11 Clear otherwise
10	IDIE (read/write)	Input Data Interrupt Enable, set to generate an interrupt when input data is ready Clear to disable input data interrupts
09	ODR (read only)	Output Data Ready, set if the display system is ready to receive data from the PDP-11 Clear otherwise
08	ODIE (read/write)	Output Data Interrupt Enable, set to generate an interrupt when output data is ready Clear to disable output data interrupts
07	DMAR (read only)	DMA Ready, set if interface is ready to execute DMA transfer Clear if DMA in progress
06	DMIE (read/write)	DMA Interrupt Enable, set to generate an interrupt upon completion of DMA transfers Clear to disable DMA interrupt

Bit	Name	Description and Effect
05	MEX17	Extended address, used for extended bus
04	MEX16 (read/write)	address bits 17 and 16 Not used in March 30, 1981 configuration
		These bits represent the selected function to be performed
03	FCN 3	Transfer (000)
02	FCN 2	Program Load (001)
01	FCN 1	Program Start (010)
		Test Clock (011)
00	GO (write only)	Set to initiate DMA transfer

The following paragraphs present operation examples for the Lexidata 3400 interface See table 9 for details of the IDOS program

1 Programmed I/O

To perform programmed I/O the following steps should be taken Set the Function code and I/O Mode in LXSR appropriately (Function = Transfer), wait for the appropriate data ready (IDR or ODR), and then input or output (read or write) via the data register Note that alternating write/read cycles require the I/O mode bit in LXSR to be set appropriately before each transfer

2 DMA

To perform DMA the following steps should be taken Wait for the DMA ready and load the starting buffer address and the two's complement of the word count into LXBA and LXWC respectively Next set the function bits, the I/O Mode, and the GO bit in the LXSR appropriately (Function = Transfer) The DMA is complete when DMA Ready (DMAR) is reset The maximum number of consecutive DMA cycles attempted by the interface before releasing the bus is set by the burst count (hardware switch settings) A high burst count will minimize bus overheads, but maximize latency for other devices

Table 9 Lexidata 3400 Interface—details of IDOS program (This material reproduced here by permission from Lexidata Corp)

IDOS provides a means for controlling the System 3400 from the host computer With IDOS running, the host can request block transfers of picture data generation of alphanumeric characters and other useful functions

The host computer controls the IDOS program by sending a series of commands to the System 3400 Each command tells IDOS to perform a specific function For each command that is required the host transfers a variable-length block of data to the System 3400 The first word of each block is the Function Code which indicates which function is to be performed The rest of the block consists of the parameters and data words for that function All data is transmitted and received as 16 bit words Negative numbers are represented in a 16-bit two s complement format

The host computer initializes the IDOS by pulsing the program-start control signal (PSTART) After a PSTART pulse the IDOS program performs the following operations

1) Erases the entire Display Memory
2) Sets Zoom Controller to display Full View starting at (0 0) using the maximum display area (no extra margins)
3) Writes maximum white value into all Look-Up Table addresses except zero
4) Writes the text string LEXIDATA 3400 starting at (0 0) as an automatic test

After completing the above steps IDOS waits for a command from the host computer The following IDOS commands are currently implemented

IDOS Calling Sequences (ZOOM option not implemented in March 30, 1981 configuration)

LUTBL **Generates Look-Up Table Ram**

Generates a continuous ramp function between the points specified (Z1 V1) to (Z2 V2)

Calling Sequence		FUNCTION CODE = 0
		Z1
		V1
		Z2
		V2
Where	Z1	is the LUT starting address of the ramp
	V1	is the starting LUT data value
	Z2	is the LUT ending address
	V2	is the ending LUT data value

RTLIM **Display Rectangular Limits**

Sets position of rectangular area of display involved in block transfers This routine must be called before SEQW or SEQR are used

Calling Sequence		FUNCTION CODE = 1
		X1
		Y1
		X2
		Y2
Where	X1 Y1	are the coordinates of the upperleft corner
	X2 Y2	are the coordinates of the lowerright corner

CHSEL **Select Display Channels**

Selects the memory planes to be used for text graphics and images

Calling Sequence		FUNCTION CODE = 2
		TCHAN
		GCHAN
		ICHAN
Where	TCHAN	specifies the text channel used by TEXT
	GCHAN	specifies the graphics channel used by VECTOR and POINT
	ICHAN	specifies the image channel used by SEQW SEQR RANW and RANR

For each bit of TCHAN GCHAN or ICHAN that is a one the corresponding memory plane is enabled

ERASE **Clear Display**

Erases the display

Calling Sequence		FUNCTION CODE = 3
		PLANES
Where	PLANES	is a memory plane enable word For each bit of PLANES that is a one the corresponding plane of the 3400 refresh memory is erased (set to zero)

Table 9 (Continued)

SEQW **Send Data to Display**

Sends a block of data to the 3400 and writes it into the image channel of the refresh memory The position in the picture into which the data is written was defined by a previous call to RTLIM The rectangle specified by RTLIM need not be completely written in one call to SEQW Each call to SEQW will start writing where the last SEQW finished

Calling Sequence FUNCTION CODE = 4
N
DATA 1
DATA 2

DATA N

Where N is the number of points to transfer
DATA(1 N) are the data values to write into memory

SEQR **Get Data from Display**

Reads a block of picture data from the 3400 refresh memory (image channel) into a buffer in the host computer The position in the picture from which the data is read was defined by a previous call to RTLIM The rectangle specified by RTLIM need not be completely read in one call to SEQR Each call to SEQR will start reading where the last SEQR finished

Calling Sequence FUNCTION CODE = 6
N

Where N is the number of points to transfer

Data values can then be read from the input port as follows DATA 1
DATA 2
•
DATA N

TEXT **Display Text**

Writes or erases alphanumeric characters on the display text channel The character set includes only those characters with a 7 bit ASCII codes from 40 octal through 137 This consists of the upper case alphabet numbers and the basic punctuation All other characters are printed as asterisks ( )

The text string must be packed left to right two characters per word in sequential memory locations A null character (zero) is used to terminate the string

Read the descriptions of CHSEL on how to select the text channel

Read the descriptions of SAO on how to specify the display parameters for text

Calling Sequence FUNCTION CODE = 11
N
CHAR 1 / CHAR 2
CHAR 3 / CHAR 4
• /

Where N is the number of characters to be written
CHAR(1 N) are the ASCII characters

VECTOR **Display a Vector**

Writes or erases a vector on the display graphics channel

Calling Sequence FUNCTION CODE = 14
X1
Y1
X2
Y2
Z

Where X1 Y1 are the coordinates of the starting point
X2 Y2 are the coordinates of the end point
Z is the intensity level

RANR **Random Pixel Read**

Reads random points from the image channel

Calling Sequence FUNCTION CODE = 20
N
X1
Y1
Z1
X2
Y2
Z2
•
XN
YN
ZN

Where N is the number of pixels to read
X(1 N) are the X coordinates of the pixels
Y(1 N) are the Y coordinates
Z(1 N) are the intensity values which are read by the host computer from the input port

RANW **Random Write Into Image Channel**

Calling Sequence FUNCTION CODE = 21
N
X1
Y1
Z1
X2
Y2
Z2
•
XN
YN
ZN

Where N is the number of pixels to write
X(1 N) are the X coordinates of the pixels
Y(1 N) are the Y coordinates
Z(1 N) are the intensities to write into memory

Table 9 (Concluded)

POINT — **Random Write into Graphics Channel**

Writes the same Z value into N randomly addressed pixels

Calling Sequence FUNCTION CODE = 22
N
Z
X1
Y1
X2
Y2
• • •
XN
YN

Where N is the number of points to write
Z is the intensity
X1 Y1 are the coordinates of the points

SAO — **Set Alphanumeric Display Parameters**

Specifies display parameters to be used by TEXT

Calling Sequence FUNCTION CODE = 23
X
Y
FONT
SIZE

Where (X Y) specifies the starting position of character display
Z is the intensity level of display
FONT is not currently used
SIZE is the multiplication factor
SIZE = 1 produces 5 x 7 char
SIZE = 2 produces 10 x 14 char
SIZE = N produces 5N x 7N char

Each subsequent TEXT without a SAO call will cause the characters to be written where the last display character routine has left off

LUTWT — **Look-Up Table Block Write**

Writes data from the host into sequential LUT addresses

Calling Sequence FUNCTION CODE = 24
LUTADR
N
DATA 1
DATA 2
• •
DATA N

Where LUTADR is the starting address in the Look Up Table
N is the number of words to write
DATA(1 N) are the data values to write into the LUT

LUTRD — **Look-Up Table Block Read**

Reads data from sequential LUT addresses into the host

Calling Sequence FUNCTION CODE = 25
LUTADR
N

Where LUTADR is the starting address in the Look Up Table
N is the number of words to read

Data values can then be read from the input port as follows
DATA
DATA 2
•
DATA N

CONFIG — **Setup for Hardware Configuration**

Sets up parameters of refreshed memory for erase command

Calling Sequence FUNCTION CODE = 30
XMAX
YMAX
WDSIZ

Where XMAX is the maximum X address
YMAX is the maximum Y address
WDSIZ is the memory word size as given below

XMAX	I/NI	WDSIZ
255	NI	4
319	NI	5
511	I	8
639	I	10
511	NI	16
639	NI	20
1023	I	32
1279	I	40

I = Interlaced display NI = Noninterlaced display

3 Function Pulses

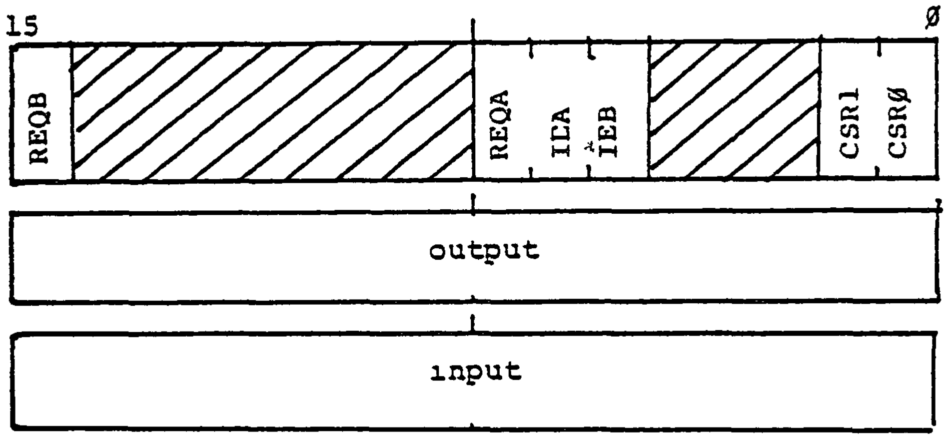
To perform a PLOAD or PSTART, first load the corresponding function into the LXSR All other bits (particularly the interrupt enables) should be cleared Next write a dummy value to LXDB Each dummy write will produce the selected function pulse

<u>DR11-C general-purpose UNIBUS Interface</u> —This section presents a detailed description of the three DR11-C registers These registers are assigned bus addresses and can be read or loaded (with the exceptions noted) using any instruction that refers to their addresses The mnemonic INIT refers to the initialization signal issued by the processor Initialization is caused by one of the following issuing a programmed RESET instruction, depressing the START switch on the processor console, or the occurrence of a power-up or power-down condition of a system power supply

DRSR
@ 767 7XØ$_8$

DRO
@ 767 7X2$_8$

DRI
@ 767 7X4$_8$



Trap vector address is set to @ 3ØØ$_8$ at variable interrupt priority levels In the March 30, 1981 configuration, DR11-C #1 is addressed to @ 76777Ø$_8$ (BR5), and DR11-C #2 is addressed to @ 76776Ø$_8$ (BR5)

DRSR @ 767 7XØ$_8$

Control and Status Register

Bit	Name	Description and Effect
15	REQUEST B	This bit is under control of the user's device and may be used to initiate an

Bit	Name	Description and Effect
15	REQUEST B (concl'd)	interrupt sequence or to generate a flag that may be tested by the program When used as an interrupt request, it is set by the external device and initiates an interrupt provided the INT ENB B bit (bit 05) is also set When used as a flag, this bit can be read by the program to monitor external device status When the maintenance cable is used, the state of this bit is dependent on the state of CSR1 (bit 01) This permits checking interface operation by loading a 0 or 1 into CSR1 and then verifying that REQUEST B is the same value Read-only bit Cleared by INIT
14-08	Unused	Not applicable
07	REQUEST A	Performs the same function as REQUEST B (bit 15) except that an interrupt is generated only if INT ENB A (bit 06) is also set When the maintenance cable is used, the state of REQUEST A is identical to that of CSRO (bit 00) Read-only bit Cleared by INIT
06	INT ENB A	Interrupt enable bit When set, allows an interrupt sequence to be initiated, provided REQUEST A (bit 07) becomes set Can be loaded or read by the program (read/write bit) Cleared by INIT
05	INT ENB B	Interrupt enable bit When set, allows an interrupt sequence to be initiated, provided REQUEST B (bit 15) becomes set

Bit	Name	Description and Effect
05	INT ENB B (concl'd)	Can be loaded or read by the program (read/write bit) Cleared by INIT
04-02	Unused	Not applicable
01	CSR1	This bit can be loaded or read (under program control) from the UNIBUS and can be used for a user-defined command to the device (appears only on Connector No 1) When the maintenance cable is used, setting or clearing this bit causes an identical state in bit 15 (REQUEST B) This permits checking operation of bit 15 which cannot be loaded by the program Read/write bit (can be loaded or read by the program) Cleared by INIT
00	CSR0	Performs the same function as CSR1 (bit 01) but appears only on Connector No 2 When the maintenance cable is used, the state of this bit controls the state of bit 07 (REQUEST A) Read/write bit Cleared by INIT

Digi-Data digital magnetic tape transport —The Digi-Data 1700 series Digital Magnetic Tape Transport System is interfaced to the PDP-11 CPU through eight registers, all of which are accessible to the processor The CPU controls all tape operations through these eight registers DEC has assigned a standard set of addresses for the DEC TM11 tape systems, and the Digi-Data TM11 compatible tape system employs the same register assignments shown in table 10 Trap vector address is set to @ 240_8 at interrupt priority level BR5

Table 10 Digi-Data magnetic tape transport—device register address assignments

Register Name	Mnemonic	Standard Address
Status	MTS	772520_8
Command	MTC	772522_8
Byte record counter	MTBRC	772524_8
Current memory address	MTCMA	772526_8

MTS Magnetic Tape Status Register @ 77252Ø$_8$ (read only)

15							8	7							Ø
ILLC	EOF	Ø	PAE	BGL	EOT	RLE	BTE	NXM	SELR	BOT	7CH	SDWN	FPRO	RSTAT	TUR

MTS, the status register, contains a number of one bit indicators These can be read by the processor, but they can be set and cleared only by the CU The usage of these bits is described below

Bit	Name	Description and Effect
15	ILLC	Illegal command This bit is set whenever any of the following illegal conditions occur 1 A command is loaded into MTC while the CU is not ready (MTCØ7, CURD, is clear) 2 Any write or write EOF operation is commanded on a file-protected tape (i e if MTSØ2, FPRO, is set) 3 The selected tape unit goes off-line during an operation other than an offline command (i e if MTSØ6, SELR, is clear), or a command is issued to a tape unit that is already offline 4 Command is issued with incorrect density bits (MTC14 13) An illegal command will be loaded into MTC, but the GO pulse will not be generated to the tape unit ILLC direct sets the ERR bit (MTC15) ILLC is cleared by INIT (the PDP-11's system initialization line) or by a new, legal command
14	EOF	End of File This bit is set when an End of File character is detected during a write (read after write dual gap head), read, or space operation EOF will cause the ERR bit (MTC15) to set when CURD (MTCØ7) sets EOF is cleared by INIT or GO

Bit	Name	Description and Effect
13		This bit is not used
12	PAE	Parity Error This bit is set when a parity error is detected during a read or write operation PAE will cause the ERR bit (MTC15) to set when CURD (MTCØ7) sets PAE is cleared by INIT or GO
11	BGL	Bus Grant Late This bit is set during a read or write operation when a bus request is not granted before the next access is requested BGL terminates data transfers for the current operation, inhibits counting for MTBRC and MTCMA, and direct sets ERR (MTC15) BGL is cleared by INIT or GO
1Ø	EOT	End of Tape This bit is set when the EOT marker is detected during forward motion EOT will cause the ERR bit (MTC15) to set at the end of the record in which EOT is detected EOT is cleared by reverse spacing past the EOT marker, or by rewinding Note that the EOT marker is on the reverse side of the tape, and does not inhibit writing data
Ø9	RLE	Record Length Error This bit is set in a read operation when the number of characters in the tape record exceeds the record length loaded in the MTBRC RLE is set at the time MTBRC attempts to count beyond Ø RLE inhibits further counting of MTBRC and MTCMA, but control continues until the inter-record gap is detected RLE will cause the ERR bit (MTC15) to set when CURD (MTCØ7) sets RLE is cleared by INIT or GO

Bit	Name	Description and Effect
Ø8	BTE	Bad Tape Error This bit is set when a character is detected (read strobe transmitted) during the gap shut-down period BTE will cause the ERR bit (MTC15) to set when CURD (MTCØ7) sets BTE is cleared by INIT or GO
Ø7	NXM	Non-Existent Memory This bit is set during a read or write operation when the CU is bus master and does not receive a SSYN response from memory within 10 µs after it issues a MSYN signal NXM inhibits counting for MTBRC and MCTMA, and direct sets the ERR bit (MTC15) NXM is cleared by INIT or GO
Ø6	SELR	Select Remote This bit is true when the selected tape unit has been loaded to BOT or beyond BOT, and has been placed online, i e , placed under remote command control
Ø5	BOT	Beginning of Tape This bit is set when the selected unit is online and positioned at the BOT marker (load point)
Ø4	7CH	Seven Channel This bit is set when the selected transport is a 7-track unit, not set indicates a 9-track unit
Ø3	SDWN	Settle Down This bit is set when the selected unit completes an operation at speed, and begins to slow to a halt Any new command that does not change write/not-write or forward/reverse status will be initiated at this time Write write WEG and write EOF are all considered write operations for this purpose Other commands are not initiated until the tape unit stops at which time TUR (MTSØØ) sets and SDWN clears

Bit	Name	Description and Effect
Ø2	FPRO	File Protect This bit is set when the selected unit is not equipped with a write ring FPRO inhibits all write operations so that data on the tape is protected
Ø1	RSTAT	Rewind Status This bit sets when a rewind command is issued to the selected transport and remains set until the unit is positioned at BOT
ØØ	TUR	Tape Unit Ready This bit is set when the selected transport is online and stopped

MTC Magnetic Tape Command Register @ 772522_8

15															Ø
ERR*	DEN2	DEN1	PCLR	PEVN	USL3	USL2	USL1	CURD*	INBL	CMA17	CMA16	FUNC3	FUNC2	FUNC1	GO

*Read Only

MTC, the command register, contains a number of bits that can be set by the processor to control the operation of the CU Note, however, that MTC bits 15 and Ø7 (ERR and CURD) are status indicators, and cannot be set by the processor The usage of the MTC bits is described below

Bit	Name	Description and Effect
15	ERR	Error This bit indicates that one or more of MTS15 Ø7 is set ERR causes CURD (MTCØ7) to set, and generates an interrupt if INBL (MTCØ6) is set ERR is cleared by INIT, or whenever a GO pulse is generated to the tape unit

Bit	Name	Description and Effect
14	DEN2 DEN1	Density bits These bits must be set by the processor to select the desired character density on tape for all commands except rewind and offline The selected density is a function of DEN2 and DEN1, and also depends upon the type of transport selected Density selection information is summarized in table 11
12	PCLR	Power Clear The processor sets this bit when it is desired to clear the CU PCLR has the same effect as INIT, but other devices on the UNIBUS are not cleared PCLR is automatically cleared by the CU, and is always read back by the processor as Ø
11	PEVN	Parity Even This bit is used to select even or odd vertical parity of 7-track units PEVN is 1 to select even parity, and Ø to select odd parity Note that odd parity is always used with 9-track units Note also that, when even parity is used, Digi-Data Corporation formatters replace all the Ø's characters ØØØØØØ with ØØ1Ø1Ø Seven-track core-dump operations should be done with odd parity
1Ø Ø9 Ø8	USL3 USL2 USL1	Unit select bits These bits are used to select one of eight possible transports USL3 is used to select one of two formatters or, in the case of a 9-track dual density system, to select NRZ1 or PE formatting (USL3 set selects PE) USL2 and USL1 are used to select one of four transports associated with the selected formatter
Ø7	CURD	Control Unit Ready This bit is set whenever the CU is ready to accept a command from the processor It is cleared at the start of a tape operation and sets when a new command can be accepted, at which time it will generate an interrupt if INBL (MTCØ6) is set

Table 11 Magnetic tape density selection

DEN2 (MTC14)	DEN1 (MTC13)	Type of Transport	Selected Density (BPI)
Ø	Ø	7 TRK	200
Ø	1	7 TRK	556
1	Ø	7 TRK	800
1	1	7 TRK	CORE DUMP*
1	1	9 TRK, NRZ1	800
1	1	9 TRK, PE	1600

*CORE DUMP operations are performed at the highest available density

Bit	Name	Description and Effect
Ø6	INBL	Interrupt Enable The processor sets this bit to enable interrupts, or clears it to disable them When INBL is set, any of the following events will cause an interrupt 1 CURD (MTCØ7) or ERR (MTC15) changes from Ø to 1 2 A command is loaded into MTC with INBL set and GO (MTCØØ) not set 3 A rewind operation completes before a new command is issued
Ø5 Ø4	CMA17 CMA16	Extended Address Bits These bits are an extension of the MTCMA register and correspond to bits 17 and 16, respectively, of the bus address
Ø3 Ø2 Ø1	FUNC3 FUNC2 FUNC1	Function bits These bits are used to select one of eight commands accepted by the CU Function selection information is summarized in table 12
ØØ	GO	

MTBRC Magnetic Tape Byte Record Counter @ 772524_8 In the space operations MTBRC must be preset by the processor to contain the 2's complement of the number of records to be spaced MTBRC is incremented for each record that is spaced until MTBRC overflows, or until EOF or BOT is detected

MTCMA Magnetic Tape Current Memory Address @ 772526_8 MTCMA, the current memory address register, functions as the least significant 16 bits of an 18-bit address counter that is used in read, write, and write with extended gap operations The two most significant bits CMA17 and CMA16, are contained in MTC These 18 bits are preset by the processor to designate the area in memory that is to be used for data transfer

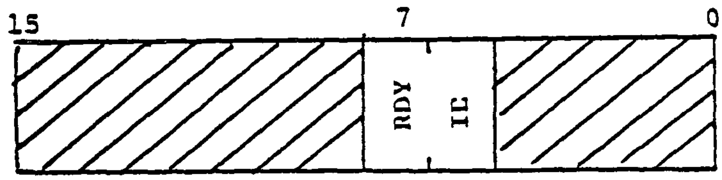
Table 12 Magnetic tape function selection

FUNC3 (MTCØ3)	FUNC2 (MTCØ2)	FUNC1 (MTCØ1)	Selected Function
Ø	Ø	Ø	Offline
Ø	Ø	1	Read
Ø	1	Ø	Write
Ø	1	1	Write End of File
1	Ø	Ø	Space Forward
1	Ø	1	Space Reverse
1	1	Ø	Write with Extended Gap
1	1	1	Rewind

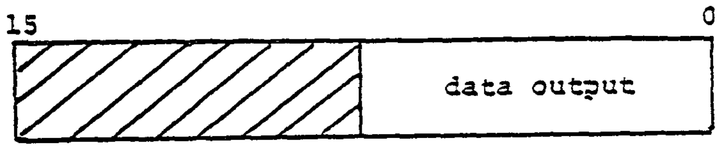
Register assignments for other DEC peripherals —The address, trap vector, and bit usage assignments for the standard DEC peripherals in use on the DIAL DAS are briefly described in this subsection For programming information, the reader is referred to the appropriate manuals as listed in the next subsection

Console Device

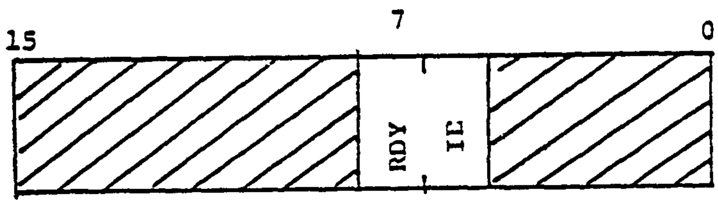
KSR @ 77756Ø$_8$
Keyboard Status
Register



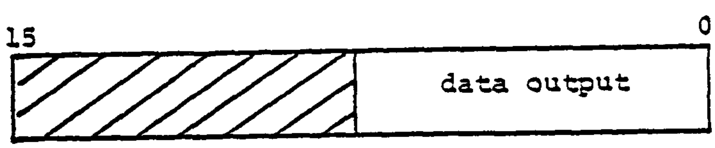
KDB
@ 777562$_8$
Keyboard Data
Buffer



TPS
@ 777564$_8$
Printer Status
Register



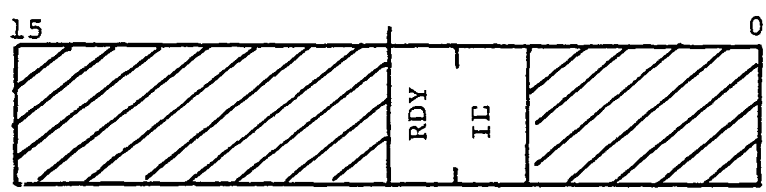
TPB
@ 777566$_8$
Printer Data
Buffer



Trap vector set to @ Ø64$_8$ at interrupt priority level BR4

Line Printer (La36)

LPS
@ 777514$_8$
Line Printer
Status Buffer



LPDB @ 777516$_8$ Line Printer Data Buffer	15 (bits 15–8: unused)	data output 0

Trap vector is set to @ 0200$_8$ at interrupt priority level BR4

AR11 Analog Realtime Subsystem

Address	Function
770400$_8$	A/D Status
770402$_8$	A/D Buffer
770404$_8$	Clock Status
770406$_8$	Clock Buffer/Preset
770414$_8$	Display Status
770412$_8$	X Buffer
770414$_8$	Y Buffer
770416$_8$	Clock Counter

Vectors for AR11

A/D Converter	Ø34Ø$_8$	BR6
Clock	Ø344$_8$	BR6
Display Control	Ø35Ø$_8$	BR4

Available Documentation

A listing of available documentation for DIAL DAS instrumentation and PDP-11 software is given in this subsection All manuals and electronic print sets have been combined for transport with the DIAL DAS for field testing, fault diagnosis and instrument repair

Instrumentation manuals —

RA 1 Ann Arbor Model 400S Display Terminal, in three sections
part # 208534, Model 400S
part # 205305 03, Rack mount
part # 205294 29, Bell

RA 2 Biomation Model 1010 Waveform Recorder, Operating and Service Manual, part # 0101-0091

RA 3 Digi-Data Logic Package Operation Manual, part # 0550017-000

RA 4 Digi-Data Synchronous Transport Operation and Maintenance Manual, part # 0550024, Rev E

RA 5 Digi-Data Synchronous Digital Tape Transport, 1600 and 1700 Series, Operating and Service Manual, (no part #) May 1979

RA 6 Digi-Data Phase Encoded Formatter, Operation Manual, part # 0551207, Rev A

RA 7 Digi-Data, Technical Information Manual, PDP-11 Direct Memory Access Interface for Synchronous Tape Transport, part # 05-1-50014-0000, Rev D

RA 8 Lexidata System 3400, manual package

a Lexidata System 3400, Description Manual, part #900-034, Oct 1978

b Lexidata System 3400, User Manual #3480-1/2 for RT-11 HOSTS, Revision 2 2, 1980

c Lexidata System 3400, Theory of Operation Manual #3481, Revision 2 1, 1980

d Lexidata System 3400, Interface Manual, Revision 3 0, 1980

Digital Equipment Corporation (DEC) instrumentation manuals —

Rb 1 DL11-W Serial Line Unit/Real-Time Clock Option, Operator's Manual, part # EK-DL11W-OP-00

Rb 2 DR11-C General Device Interface, User's Manual, part #EK-DR11C-OP-001

Rb 3 861-A, -B, -C, -D, -E, -F Power Controller, User's Manual, part # EK-861AB-OP-001

Rb 4 PDP 1134A Power System Description, part # EK-1134A-TM-002

Rb 5 MS11-E-J MOS Memory, User's Manual, part # EK-MS11E-OP-001

Rb 6 BA11-K Mounting Box, User's Manual, part # EK-BA11K-OP-001

Rb 7 LA36/LA35 DECwriter II, User's Manual, part # EK-LA3635-OP-002

Rb 8 M9301 Bootstrap/Terminator, Module Maintenance and Operator's Manual, part # EK-M901-TM-001

Rb 9 PDP-11/34 System User's Manual, part # EK-11034-UG-001

Rb 10 AR11 User's Gudie (no part #)

Rb 11 RX8/RX11 Floppy Disc System, User's Manual, part # EK-RX01-OP-001

PDP-11 device manuals from other manufacturers —

Rc 1 MDB Systems MDB-DR11B Direct Memory Access Module Instruction Manual (no part #)

Rc 2 MDB Systems MDL-11W Asynchronous Serial Line Adapter and Line Frequency Clock for PDP-11 Computers, part # PN 40521, Rev D

Rc 3 Monolithic systems MSC 3605 Planar Memory System (Preliminary)

Digital Equipment Corporation (DEC) software manuals —

Rd 1 Volume 1

a RT-11 Documentation Directory (V03), part # AA-5285B-TC

b RT-11 System Release Notes (V03), part # DEC-11-ORNRB-A-D

c RT-11 System Generation Manual (V03), part # DEC-11-ORGMB-A-D

d Introduction to RT-11 (V03), part # DEC-11-ORITA-A-D

Rd 2 Volume 2

a RT-11 System User's Guide (V03), part # DEC-11-ORGDA-A-D

b PDP-11 TECO User's Guide, part # DEC-11-UTECA-A-D (not dated)

c RT-11 System Message Manual (V03), part # DEC-11*-ORMEB-A-D

Rd 3 Volume 3

a RT-11 Advanced Programmer's Guide (V03), part # DEC-11* ORAPA-A-D

b PDP-11 MACRO-11, Language Reference Manual, part # AA-5075A-TC, Aug 1977

Rd 4 Volume 4 RT-11 Software Support Manual (V2), part # DEC-11-ORGPA-B-D, Dn1

Rd 5 Volume 5

a RT-11 FORTRAN IV, Installation Guide (V03), part # DEC-11-LRSIA-A-D

b RT-11/RSTS/E FORTRAN IV User's Guide (V03), part # DEC-11-LRRUB-A-D

c PDP-11 FORTRAN, Language Reference Reference Manual (V03), part # DEC-11-LFLRA-C-D

Rd 6 PDP11 04/05/10/35/40/45 Processor Handbook (1975)

Rd 7 PDP11 Peripherals Handbook (1975)

Rd 8 BASIC - A Reference Manual for use with the REBEL System, M C Zarnstorff and J R Greenwood, University of Wisconsin, part # PLP-662

Rd 9 REBEL/BASIC Methodology, A User's Guide, J R Greenwood and M C Zarnstorff, Lawrence Livermore Laboratory, part # UCID-17686

Rd 10 REBEL/BASIC Commands, A User's Guide, J R Greenwood and M C Zarnstorff, Lawrence Livermore Laboratory, part # UCID-17685

Schematic drawings and print sets —

Re 1 DEC DD11-D 9-Slot Backplane

Re 2 DEC RX01 Dual Floppy Disc Drive

Re 3 DEC H322 AR11 Terminal Panel

Re 4 DEC RX11 Floppy UNIBUS Interface Module

Re 5 DEC DR11-C General Purpose UNIBUS Interface

Re 6 DEC LA36 DECwriter II Hard Copy Terminal

Re 7 DEC AR11 Analog Realtime Subsystem

Re 8 DEC Field Maintenance Print Set

a	FIELD MAINTENANCE PRINT SET (1134A)	B-TC-1134A-0-1
b	UNIT ASSEMBLY (1134A)	E-UA-1134A-0-0
c	PARTS LIST (1134A)	C-PL-1134A-0-0
d	DRAWING DIRECTORY (1134A)	B-DD-1134A-0-0
e	PRINT SET KD11-EA (COMPLETE SET)	MP00192
f	UNIBUS TERMINATOR/BOOT STRAP	D-CS-M9301-0-1
g	UNIBUS TERMINATOR	D-CS-M9302-0-1
h	PRINT SET KY11-LA (COMPLETE SET)	MP00017
i	PRINT SET KY11-LB (COMPLETE SET)	MP00015
j	PRINT SET DL11-W (COMPLETE SET)	MP00016
k	PARITY MODULE	B-CS-M7850-0-1
l	GRANT CONTINUITY	B-CS-G727-0-1
m	PRINT SET MS11-E (COMPLETE SET)	MP00021
n	PRINT SET MM1-D (COMPLETE SET)	MP00032
o	PRINT SET MM1-YP (COMPLETE SET)	MP00317
p	DRAWING DIRECTORY DD11-P (COMPLETE SET)	B-DD-DD11-P
q	PRINT SET BA11-L (COMPLETE SET)	MP00018
r	UNIT ASSY BA11-K	E-UA-BA11-K-0
s	UNIT ASSY BA11-K (PL)	A-PL-BA11-K-0
t	DRAWING DIRECTORY BA11-K	B-DD-BA11-K
u	PRINT SET 1134A P S (COMPLETE SET)	MP00270
v	EXTERNAL BOOT CABLE	C-IA-7011413-0-0

Re 9 Custom design interface for Biomation 1010, ODURF, 3 sheets

Re 10 Lexidata 3400 PDP-11 Interface, 3 sheets

XXDP dıagnostıc software package —

XXDP diagnostic manuals on microfiche

Rf1	FKAAB1 BIC	24*	PDP 11/34 CPU Test
Rf2	FKABCØ BIC	15	PDP 11/34 Trap Test
Rf3	FKACAØ BIC	16	PDP 11/34 EIS Instruction Tests
Rf4	FKTHAØ BIN	43	PDP 11/34 Memory Management Diagnostic
Rf5	ZTMAHØ BIN	17	TM,A,B-11/TSØ3, TU1Ø, N,W Instruction Test
Rf6	ZTMBDØ BIC	13	TM11 Data Reliability (9 Track)
Rf7	ZTMDEØ BIN	1Ø	TM11 Drive Function Timer
Rf8	ZRXAEØ BIC	2Ø	RX11 System Reliability Test
Rf9	ZRXBEØ BIC	17	RXLL Interface Diagnostic
Rf10	ZKAQGØ BIC	6	PDP-11 Power Fail Diagnostic
Rf11	ZKMADØ BIC	9	MOS/CORE Memory Exerciser for Ø to 124 K, with or without parity bits
Rf12	ZQKCFØ BIC	16	11 Family Instruction Exerciser
Rf13	ZM9ADØ BIC	7	Bootstrap/Terminator (M93Ø1, M94ØØ)

XXDP driver software

Rf14	MAINDEC-11-DZQXA-ID (hardcopy) "XXDP USER MANUAL," 21 July 1976		
Rf15	UPD2 BIN	31	XXDP Update Routines
Rf16	XTECO BIN	29	XXDP TECO Routines
Rf17	COPY1 BIN	22	XXDP COPY Routines
Rf18	TMDP BIN	17	XXDP Diagnostics on TM11
Rf19	RXDP BIN	17	XXDP Diagnostics on RX11

Note The XXDP software package is provided on one IBM 347Ø format floppy discette in 329 blocks (out of 4ØØ)

*Block Size

DIAL DAS SOFTWARE

Introduction

The DIAL DAS Operating System (OS) software is written to take full advantage of the computer hardware and interface design The operating system software is interrupt-driven primarily through the Biomation 1010 Transient Digitizer Interface, where it is coordinated to the system ARM and TRIGGER signals Software action priorities are assigned as follows

(1) data transfer from Biomations to magnetic tape storage (highest priority),

(2) execution of operator commands,

(3) data analysis and display (lowest priority)

Although data analysis and display tasks are given the lowest priority, real-time displays of raw and processed DIAL information are obtained and adjustments for system operations can be accomplished in real-time

Data transfer operations from each of the three Biomation 1010 Transient Digitizers (2048 words each) require approximately 2 ms, and the entire data transfer operation is readily accomplished within the 10-Hz operation time envelope The primary limitation to repetition rate and data volume magnitude resides in the digital magnetic tape transport A triple buffering system is implemented to speed the average data transfer rate from CPU memory to magnetic tape while providing a complete data set for simultaneous display operations

Real-Time Data Display

Four basic modes for DIAL data display are available, each provided with a variety of display options The first and most fundamental display mode presents raw data for each of the Biomation 1010 transient digitizers without background signal subtraction as shown in figure 18 This display mode allows operator viewing of all DIAL data as it exists in each of the Biomation 1010 memories The abscissa represents Biomation word numbers from 1 to 2000 The ordinate is adjusted to present the 10-bit signal magnitude with variable magnification The profiles BIO2 and BIO1 present DIAL measurements in Biomation Nos 2 and 1 DIAL signals are typically obtained in these Biomation units with different gain settings to enhance signal dynamic range

A second display mode presents the raw data signals with or without background subtraction in an overlapped format As shown in figure 19, the on- and off-line UV signals (BIO1 and BIO2) are overlayed when the data is tagged as a DIAL type measurement The top profile in figure 19 (BIO3) presents an "aerosol return," a single return-signal profile obtained at a wavelength of 600 nm, shown as a function of range Display options are available for background signal subtraction, data smoothing over any specified range interval (running mean), and correction for range-squared "attenuation" as shown in figure 20 (mode 2) Each display option or combination of display options may be activated or deactivated in real-time to observe signal features in the most useful format

A 16-shade gray scale display format is available for presentation of the spatial distribution of relative aerosol concentrations A typical display of the aerosol spatial distribution below the Electra aircraft on August 13, 1980 is shown in figure 21 The ordinate is adjusted to present altitude or vertical range with tick marks placed at 150-m vertical intervals (300-m interval option also available) The ordinate represents time or horizontal position from left to right Three-hundred individual or integrated signal profiles are shown in each of the gray scale displays At a laser pulse repetition rate of 1 Hz, the 300 individual signal profile displays would correspond to a transit time of 300 s (5 min), which corresponds to a nominal horizontal traverse of 30 km * This

*The Electra aircraft ground speed has a nominal value of 100 ms^{-1}

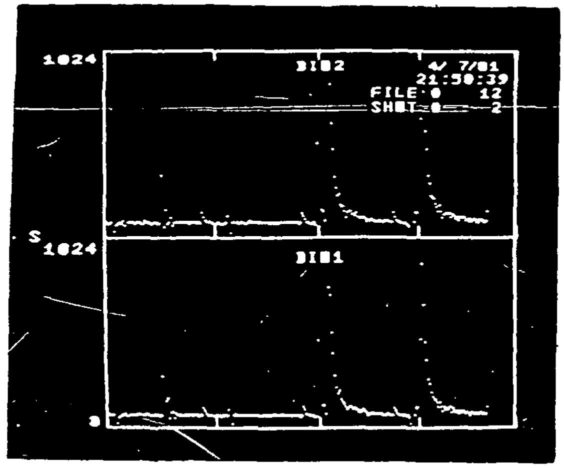


Figure 18 Display mode 1 for presentation of raw data The signal return profiles are presented as a function of range R Any combination of signals can be displayed in adjacent or overlapped format

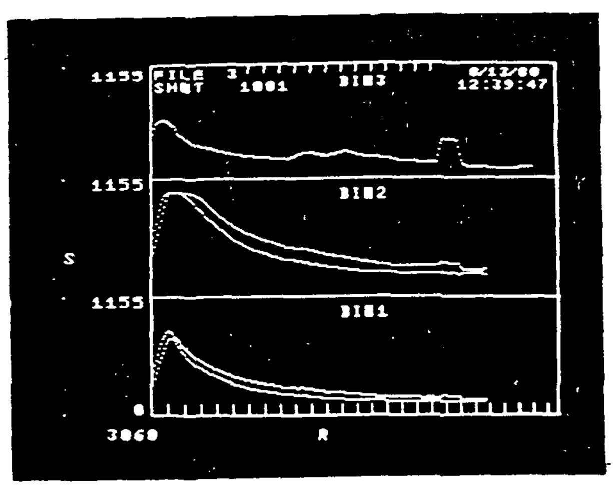


Figure 19 Display mode 2 or raw DIAL signals without subtraction of signal background

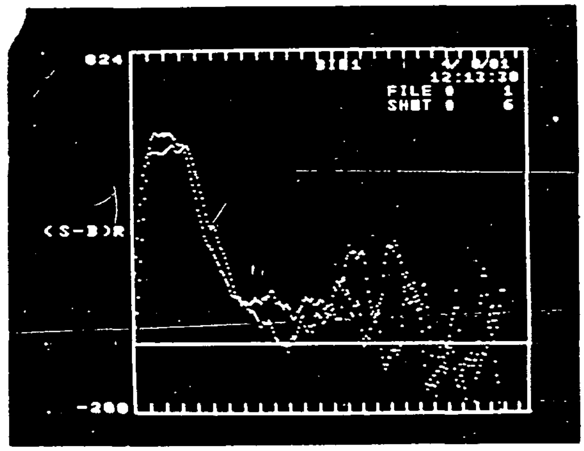


Figure 20   Display mode 2 of raw DIAL signals (BIO1 only) corrected for range-squared attenuation

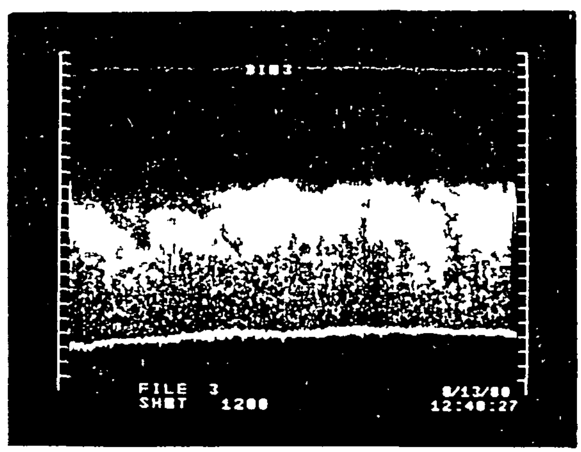


Figure 21   Gray scale display (mode GRYSCL) of the spatial distribution of aerosol signal backscatter intensity This display is constructed from 300 sequential profiles obtained at a pulse repetition rate of 1 Hz Time or horizontal distance is shown horizontally from left to right (300 s corresponding to 30 km traverse) Altitude of vertical range is presented along the ordinate with tick marks at 150-m intervals

display format shows the terrain profile and allows easy operator identification of the size and location of clouds, mixed layer heights, and tropospheric features outlined by variations in aerosol layering

A final display mode is provided for presentation of the DIAL measured gas concentration mixing ratio as a function of altitude or vertical range This display product is shown in figure 22, where ozone concentration in parts per billion by volume is plotted as a function of range R (150-m intervals) Options are available for selection of range cell size, length of a running mean smoothing interval, and the number of shots averaged

Operator Commands

To run the data-acquisition program, the following preliminary steps are necessary

(1) boot the PDP-11/34 CPU,

(2) enter the DATE (e g DATE 14-MAR-81),

(3) enter the TIME (e g TIME 14 30 22), and

(4) type "RUN MADSYS"

Once the program has been transferred from floppy-disc program storage to the PDP 11/34 CPU memory, the software operating system is ready for operator intervention and a question mark prompt character is printed All further operator input is DIAL DAS software defined An entire line of operator input can be erased using the "DELETE" key A single character of operator input can be erased by means of the "BACKSPACE" key The DIAL DAS OS is brought online with predefined option defaults, and data transfer from Biomations to magnetic tape can be initiated in default mode by means of the "START" command Program defaults for ozone and water vapor operation are different, and two versions of the DIAL DAS OS (O3 and H2O) are therefore available to facilitate DIAL DAS operations

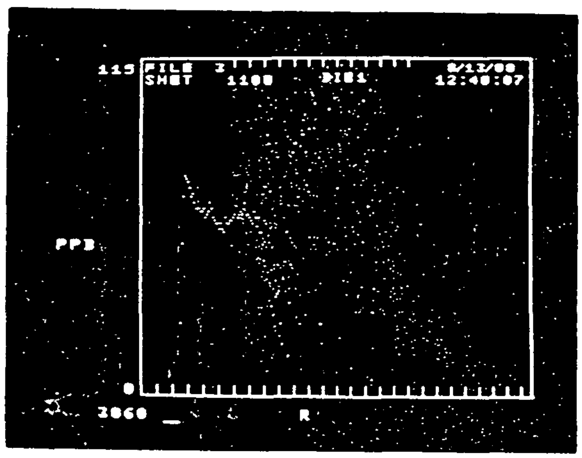


Figure 22 Display mode 3—ozone concentration in parts per billion (PPB) plotted as a function of range R (150-m intervals) This DIAL result was obtained on August 13, 1980 Maximum scale concentration is 115 ppb

Each data-storage file on digital magnetic tape begins with a 256-word (16-bits per word) banner record with DIAL DAS information as shown in table 13 The data from each laser shot is packed into one large record on magnetic tape irrespective of the number or combination of Biomation units used Each data record begins with a 6-word identification message which defines the time of signal acquisition and shot number DIAL DAS operator commands are detailed in the following subsections, and table 14 lists various operation modes

Program and Data-Acquisition Control

1	START	Sets Biomation interrupt and begins reading DMA
2	STOP	Turns off Biomation interrupt (also magtape if in use)
3	KILL	Kills program and returns to monitor
4	RESTRT	Issues the "RESET" command which returns all units on the UNIBUS to their status at power-up time Once this command is issued, the clock time is lost and the "KILL" command will not return control to monitor These two problems may be eliminated in the future
5	BIOPTS X, Y, Z	# points/return in BIO-1 (X), BIO-2 (Y), and BIO-3 (Z)
6	BIORTS X, Y, Z	# returns in BIO-1 (X), BIO-2 (Y), and BIO-3 (Z)
7	BIOTRG I, J, K, L	Starting locations in DMA for return #1 (I), return #2 (J), return #3 (K) and return #4 (L)
8	TRGPNT A, B, C,	Search for trigger on returns A, B, C,
9	DATAVG I	Number of shots to average
10	CALAVG I	Number of calibration shots to average

(cont'd)

Table 13 Sample banner record showing typical DIAL DAS OS initiation and operation

```
$DX
RT-11SJ        VØ3-Ø2
>
 ASSIGN DY1  DK
 DATE 18-APR-81
 TIME 13 Ø2 ØØ
 RUN MADSYS
? LSTBNR
FORMAT = 1    TAPE = Ø   FILE = Ø
WORDS IN HEADER = 6
DATE = 4/18/81

BIO      WRDS      RTRNS      DELAY      SPECIES
 1       5ØØ         4          5         H2O
 2       5ØØ         4          5         H2O
ALTITUDE = Ø
SAMP FRE = 1Ø
PULSE REP =  5
ABSORPTION COEFFICIENT = 836E-25
```

Table 14 Operation modes

	MODE 1	MODE 2	MODE 3	GRYSCL
BIOMATIONS	1, 2 3	1, 2 3	1	3
RETURNS	BACKGROUND + DATA	DATA ONLY	DATA (PPB)	DATA ONLY
BACKGROUND SUBTRACTION	NO	NO	YES	YES
RANGE CORRECTION	NO	NO	YES	YES
TRIGGER MARKER CORRECTION	NO	NO	NO	NO
LINEAR SCALE	1/15	1/15	1	1
EXPONENTIAL SCALE	-	-	-	$*2^{-8}$
OFFSET	0	0	0	-200
SMOOTHING	0	0	210 M	0
AVERAGING	0	0	50 (REALTIME) 100 (PLABAK)	0
PLOT FIRST 250 WORDS	-	YES	YES	YES
SQUEEZE DATA INTO 250 WORDS	YES	-	-	-
POINTS/PIXEL	1	1	1	1
PRINT DATA PLOTTED (Only Available in PLABAK)	NO	NO	NO (REALTIME) YES (PLABAK)	NO

NOTE If any of the biomations are not being used, they will not be plotted and the scaling will be adjusted accordingly

11	INTCAL I	Number data shots to take between calibration runs
12	SHTSET	Reset shot counter to 0

Mag Tape Control

1	RECORD	Writes banner record and initiates data transfer to magnetic tape
2	ENDFIL	Stops magnetic tape and writes EOF
3	BANNER	Writes a banner record on tape (first checks for EOF and writes EOF if not there)
4	REWIND	Rewind tape to BOT
5	SKPFIL I	Forward I files
6	BAKFIL I	Skip reverse I files
7	FNDFIL I	Search for file I (forward direction only)
8	SKPREC I	Skip over I records (can be used to jump over EOF)
9	BAKREC I	Back up I records
10	SKPEOI	Skips files until two sequential EOFs are found

Plotting Controls

1	MODE1	A one-word instruction to select plotting MODE 1 using the defaults in the table
2	MODE2	A one-word instruction to select plotting MODE 2 using the defaults in the table
3	MODE3	A one-word instruction to select plotting MODE 3 using the defaults in the table
4	GRYSCL	A one-word instruction to select plotting gray scale using the defaults in the table

5	BIO1	Selects BIO1 for display
6	BIO2	Selects BIO2 for display
7	BIO3	Selects BIO3 for display
8	ONLINE	Selects online signal for display
9	OFFLINE	Selects offline signal for display
10	PLTMOD I	Plot mode where I = 0 for no plotting, I = 1 for raw data, I = 2 for online offline overlay, I = 3 for PPB plot
11	PLTGRY I	I = 1 Plot Gray Scale, I = 0 Do not plot Gray Scale
12	PLTBIO X, Y, Z	Selects which Biomation to plot and which returns for BIO-1 (X), BIO-2 (Y), BIO-3 (Z) 0 = No plot from that Biomation
	a If PLTMOD =	1 Then X, Y, Z = 1, 2, 3, or 4 mean plot return #1, #2, #3, or #4 respectively, X, Y, Z = 5 means plot data returns only (#3 and #4), X, Y, Z = 7 means plot all
	b If PLTMOD =	2 Then X, Y, Z = 1 to plot the background returns overlayed, X, Y, Z $\neq$ 1 to plot the data returns overlayed
	c If PLTMOD =	3 Then X, Y, Z $\neq$ 0 plots PPB for that Biomation unless the return is aerosol
13	SCALE I	Scale factor where scale = 2^I
14	GASEXP I	Scaling factor for gas concentrations
15	OFFSET I	Offsets the plot by the integer I (either + or -)
16	CLEAR I	Clear screen options I = 0 no clear, I = 1 clear data, I = 4 clear legends, I = 8 clear axis, I = 15 clear all

17	OVRLAY I	Overlay data from the different Biomations I = 0 off, I = 1 on
18	SUBBAK I	Subtract background return I = 0 off, I = 1 on
19	RNGCOR I	Range correct data I = 0 off, I = 1 on
20	SMOOTH I	Smooth raw data interval of I meters before calculating PPB
21	PLTAVG I	Calculate PPB over I shots and average
22	RNGCEL I	Calculate PPB over range cell of I meters
23	TRGLEV I	Value of trigger marker (either 0 or 1023)
24	SKPPTS I	I = 0 Squeeze all data into 250 word-buffer, I = 1 Plot first 250 words only
25	SKPPIX I	I > 1 Skip I pixels per point, I < 1 Plot each point over I pixels

Banner Record Input

1	FORMAT I	Format number I
2	TAPE I	Tape ID number I
3	FILE I	File number I
4	HEADER I	I number words in shot header
5	DELAY X, Y, Z	Usecs after trigger to start of return for BIO-1 (X), BIO-2 (Y), and BIO-3 (Z)
6	PRETRG I	Usecs prior to laser firing (only valid when program does not search for triggers)
7	HEIGHT I	Plane altitude (ft)
8	SAMFRE I	Biomation sampling frequency
9	PULFRE I	Pulse repetition frequency
10	BIOGAS X, Y, Z	Three-letter representation of gas species for BIO-1 (X), BIO-2 (Y), and BIO-3 (Z)

11 ABSCOF I, J — Absorption coefficient $I \times 10^{J}$ (atm cm)$^{-1}$

12 COMENT — This instruction with a carriage return puts the user in a comment field input mode Type in comments, and when done type "$" to return to regular input mode

Play-Back and List Controls

1 LSTBNR — Print out banner record currently in memory

2 LSTPLT — List out current plotting options

3 LIST I, J — Read a tape record and print that record from words I to J If I is negative, a new tape record is not read

4 PLOT I — Read from tape and plot I records If I is -1, then a new record is not read

5 LSTDAT I — If I = 1, printout data plotted on screen (also standard deviation on every tenth point for PPB data)

If I = 0, no printout

This instruction is not available in the real-time version

6 TIME — Printout time of present shot

Error Messages

BIO - TRANSFER

B1 = DUMMY GO DID NOT CLR READY
B2 = 202 NOT SET FOR DOR
B3 = REL SET WHILE WAITING DOG
B4 = WORD COUNT UNCHANGED AFTER GO
B5 = STATB DISAPPEARED AFTER READY
B6 = DOG SET AFTER EWR

MT - TRANSFER

M1 = MT ERROR BIT SET
M2 = ATTEMPT TO QUEUE MORE THAN ONE BUFFER
M3 = ATTEMPT TO X-FER BIO DATA TO CURRENT MT BUFFER
M4 = MT OFF LINE

MT - TRANSFER (concl'd)

M5 = NEED WRITE RING
M6 = START NEW TAPE WITH A BANNER RECORD
M7 = END OF TAPE (PROGRAM PLACES EOF, REWINDS THE TAPE, SETS THE BELL RINGING WHEN DONE UNTIL THE COMMAND "SHUTUP" IS ENTERED)

TTY - TRANSFER

TT = EITHER UNRECOGNIZABLE COMMAND OR STOP ONLY TYPE COMMAND

Banner and Data Record Structure

A description of word assignments for the 256-word Banner Record is given in table 15 An outline of the Data Record structure is given in table 16 Each DIAL data file contains an arbitrary number of Data Records, beginning with a Banner Record and followed by an End of File tape mark Each DIAL magnetic tape reel with valid data ends with a double end of file tape mark Each tape is unlabeled and is written in the 9-track 1600 bpi phase encoded (PE) format

Table 15 Banner Record word assignments

Item Order		Word No -Octal Location	Description
BIOTAB	.WORD 1	1-0	BANNER RECORD AND TAPE FORMAT #
	.WORD Ø	2-2	TAPE ID #
	.WORD Ø	3-4	FILE ID #
	WORD 6	4-6	# WORDS IN SHOT HEADER
	WORD Ø	5-10	DATE
	WORD 5ØØ	6-12	WORDS/RETURN BIO-1
	WORD 5ØØ	7-14	WORDS/RETURN BIO-2
	WORD Ø	8-16	WORDS/RETURN BIO-3
	WORD 4	9-20	RETURNS/BIO-1
	WORD 4	10-22	RETURNS/BIO-2
	.WORD Ø	11-24	RETURNS/BIO-3
	WORD 5	12-26	POST-TRIGGER DELAY (μs) BIO-1
	WORD 5	13-30	POST-TRIGGER DELAY (μs) BIO-2
	WORD 5	14-32	POST-TRIGGER DELAY (μs) BIO-3
	WORD 1Ø5ØØ.	15-34	ALTITUDE OF PLANE (FEET)
	WORD Ø	16-36	SHOTS IN CALIBRATION AVERAGE
	WORD Ø	17-40	INTERVAL BETWEEN CALIBRATIONS
	WORD 1Ø	18-42	SAMPLING FREQUENCY (MHz)
	.WORD 59	19-44	PRETRIGGER DELAY (WORDS)
	WORD 5	20-46	PULSE REPETITION FREQUENCY (Hz)
	RAD5Ø /H20/	21-50	BIO-1 SPECIES (RAD5Ø)
	RAD5Ø /H20/	22-52	BIO-2 SPECIES (RAD5Ø)
	RAD5Ø /AER/	23-54	BIO-3 SPECIES (RAD5Ø)
	WORD Ø	24-56	DIFF AMP GAIN BIO-1
	WORD Ø	25-60	DIFF AMP GAIN BIO-2
	.WORD Ø	26-62	DIFF AMP GAIN BIO-3
	.WORD Ø	27-64	PMT VOLTAGE 1
	WORD Ø	28-66	PMT VOLTAGE 2
	WORD Ø	29-70	PMT VOLTAGE 3
	WORD Ø	30-72	FOCUS VOLTAGE 1
	WORD Ø	31-74	FOCUS VOLTAGE 2
	WORD Ø	32-76	FOCUS VOLTAGE 3
	WORD Ø	33-100	ELECTRONIC FILTER 1
	WORD Ø	34-102	ELECTRONIC FILTER 2
	WORD Ø	35-104	ELECTRONIC FILTER 3
	WORD Ø	36-106	ON WAVELENGTH
	WORD Ø	37-110	OFF WAVELENGTH
	WORD Ø	38-112	# STATISTICAL POINTS PER RETURN
	WORD 314	39-114	ABS COEF MANTISSA (ATM^{-1} CM^{-1})
	WORD -25.	40-116	ABS COEF EXPONENT
	WORD Ø	41-120	# BYTES IN COMMENT FIELD
	BLKB 654	42-122	COMMENTS (ASCII)

Table 16   Data record structure for M-word signal buffers*

Word #	Description	
1	Shot number	
2	# shots in buffer average	
3 4	time of day in units of 1/60 seconds past midnight (32-bit integer)	
5 6		
7	$background_1$	
7 + M	$background_2$	BIO1 (UV1)
7 + 2M	$signal_1$	
7 + 3M	$signal_2$	
7 + 4M	$background_1$	
7 + 5M	$background_2$	BIO2 (UV2)
7 + 6M	$signal_1$	
7 + 7M	$signal_2$	
7 + 8M	$background_1$	BIO3 (aerosol)
7 + 9M	$signal_1$	

*Note that background and signal information are stored only for actual information obtained, as defined in the Banner Record (words 6 to 10)

FORTRAN Calling Sequences for Machine Language Display Subroutines

FORTRAN subroutines to handle graphics on Lexidata 3400 (based upon original work of Jeff Bower, written 23 July 1979 by Scott Shipley, modified 27 June 1980) are presented below

```
CALL LRESET(TCHAN,GCHAN,ICHAN), WHERE
     TCHAN = BIT FLANES SET BY LTEXT
     GCHAN = BIT FLANES SET BY FLOT & LINE
     ICHAN = BIT PLANES SET BY IMAGE
     THIS FUNCTION SENDS A FSTART FULSE TO THE LEXIDATA
     3400.  MEMORY IS ERASED AND THE IMAGE ENHANCEMENT
     TABLE IS SET TO ALL ONES.  THE LOGO 'SYSTEM 3400'
     IS THEN FRINTED IN THE UFFER LEFT HAND COFNER OF
     THE DISPLAY SCREEN AREA.


CALL ERASE(FLANES), WHEFE
     FLANES   = BIT MAF FOF LEXIDATA FEFRESH MEMOFY
FOR EACH BIT SET IN 'FLANES', THE COFFESFONDING
LEXIDATA MEMORY FLANE IS CLEARED.
               0 ´= FLANES  = 017


CALL LTABLE(Z1,V1,Z2,V2), WHERE
     Z1,Z2    = INTENSITY INFORMATION IN LEXIDATA MEMOFY
     V1,V2    = GREY SCALE TRANSFOFM FOR (Z1,Z2)
THE DATA VALUES Z1-Z2 ARE MAFFED ONTO THE LEXIDATA
DISPLAY AREA USING THE LINEAR GREY SCALE RAMF V1-V2.
               0 ´= Z1,Z2,V1,V2 ´= 017


CALL LINE(X1,Y1,X2,Y2,INTEN), WHERE
     X1,Y1    = STARTING FOSITION OF LINE (PIXELS)
     X2,Y2    = ENDING FOSITION OF LINE    (FIXELS)
     INTEN    = DISPLAY INTENSITY LEVEL, 000 - 017 (4 BITS)


CALL IMAGE(DX,DY,DATA(I),NPTS,XO,YO,ZO,SHFZ,OFSET), WHERE
     DX,DY    = FIXEL SEPARATION (PLOT COORDINATES)
     DATA(I)  = INTEGER ARRAY
     NPTS     = #INTEGERS FOR DISFLAY
     XO,YO    = ORIGIN OF FLOT
     ZO       = Z AXIS TRANSLATION
     SHFZ     = Z MAGNIFICATION (SEE FLOT)
     OFSET    = Z AXIS OFSET
GREY SCALE INFORMATION IS DRAWN USING THE FOLLOWING
DATA TRANSFORM:
     Z = (DATA(I) + OFSET) * 2**SHFZ + ZO
```

```
CALL PLOT(STEP,DATA,NPTS,X0,Y0,SHFY,OFSET,INTEN), WHERE
     STEP      = ARRAY INDEXING PARAMETER
                  -0   ARRAY INDEX INCREMENT
                  0    #PIXELS DRAWN PER POINT
     DATA      = INTEGER ARRAY OF DATA VALUES, Y = F( )
     NPTS      = # PTS IN DATA ARRAY TO BE PLOTTED
     X0,Y0     = GRAPH ORIGIN              (PIXELS)
     SHFY      = Y MAGNIFICATION           (DATA VALUE)
     OFSET     = Y OFFSET                  (DATA VALUE)
     INTEN     = DISPLAY INTENSITY LEVEL, 000 TO 017 (4 BITS)

NOTES:
1.   THE DISPLAY SCREEN AREA IS ORGANIZED IN CARTESIAN
     COORDINATES. LOWER LEFT = (0,0), UPPER RIGHT = (319,255).
2.   DATA VALUES ARE TRANSFORMED INTO THE DISPLAY Y
     COORDINATE BY THE FOLLOWING EQUATION:

              Y = (DATA(I) + OFSET) * (2**SHFY) + Y0



CALL LTEXT(X,Y,INTEN,SIZE,NCHAR,LIST(I)), WHERE
     X,Y       =  SCREEN COORDINATES OF STARTING POSITION
                 FOR THE ASCII STRING.  THIS POSITION IS DEFINED
                 AS THE UPPER LEFT CORNER OF THE FIRST CHARACTER.
     INTEN     = DISPLAY INTENSITY LEVEL, 000 TO 017 (4 BITS)
     SIZE      = CHARACTER MAGNIFICATION.  SIZE = 1 WILL CREATE
                 A 5X7 DOT MATRIX CHARACTER.
     NCHAR     = # CHARACTERS IN THE ASCII STRING
     LIST(I)   = ASCII STRING (SEQUENTIAL BYTES)

NOTES:
1    ALL CHARACTERS ARE TRUNCATED TO 7-BIT ASCII, AND
     CONTROL CHARACTERS 000 - 037 ARE SET TO SPACES.



CALL PWRITE/IIPAU(DATA,X1,Y1,X2,Y2,NPTS), WHERE
     DATA      = INTEGER ARRAY WITH PACKED IMAGE
                 (4 NIBBLES PER INTEGER)
     X1,Y1     - PLOT COOR OF UPPER LEFT CORNER
     X2,Y2     = PLOT COOR OF LOWER RIGHT CORNER
     NPTS      = # INTEGERS (*4 FOR # POINTS)
```


C-2

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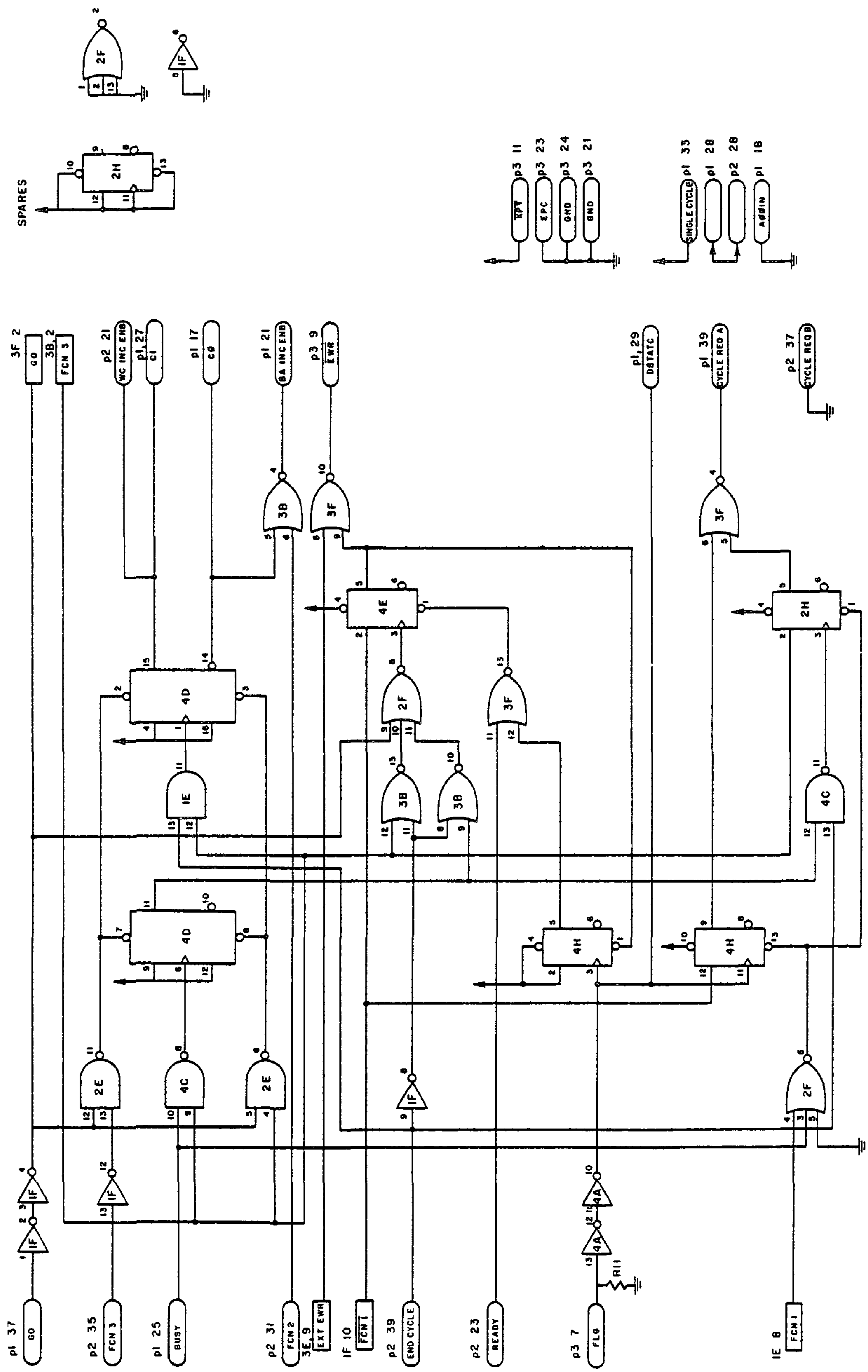
APPENDIX

SCHEMATICS FOR BIOMATION 1010 INTERFACE



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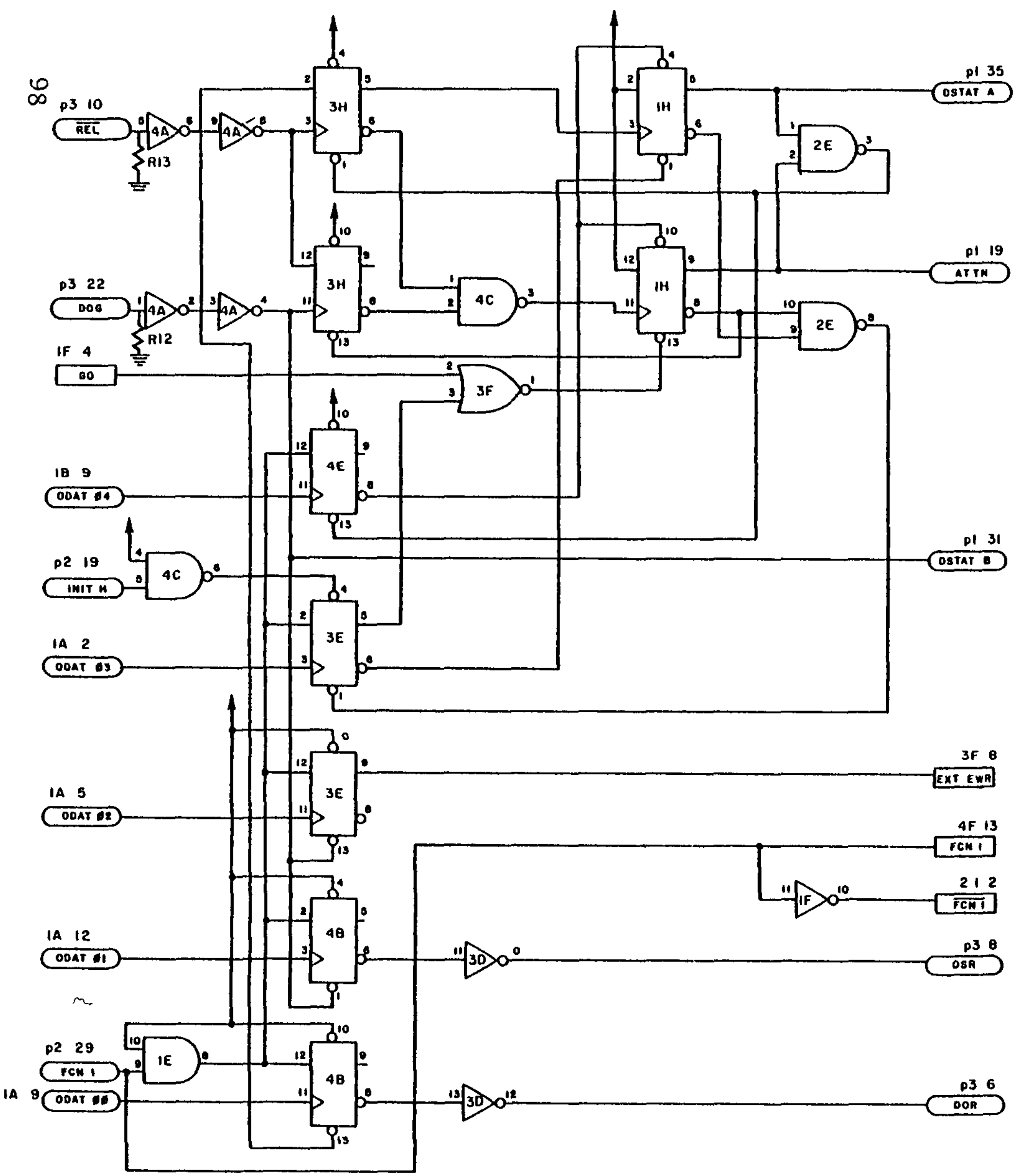
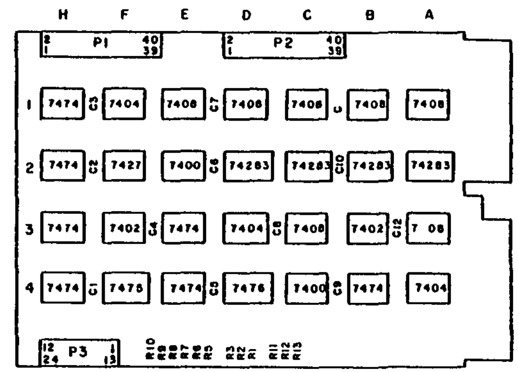


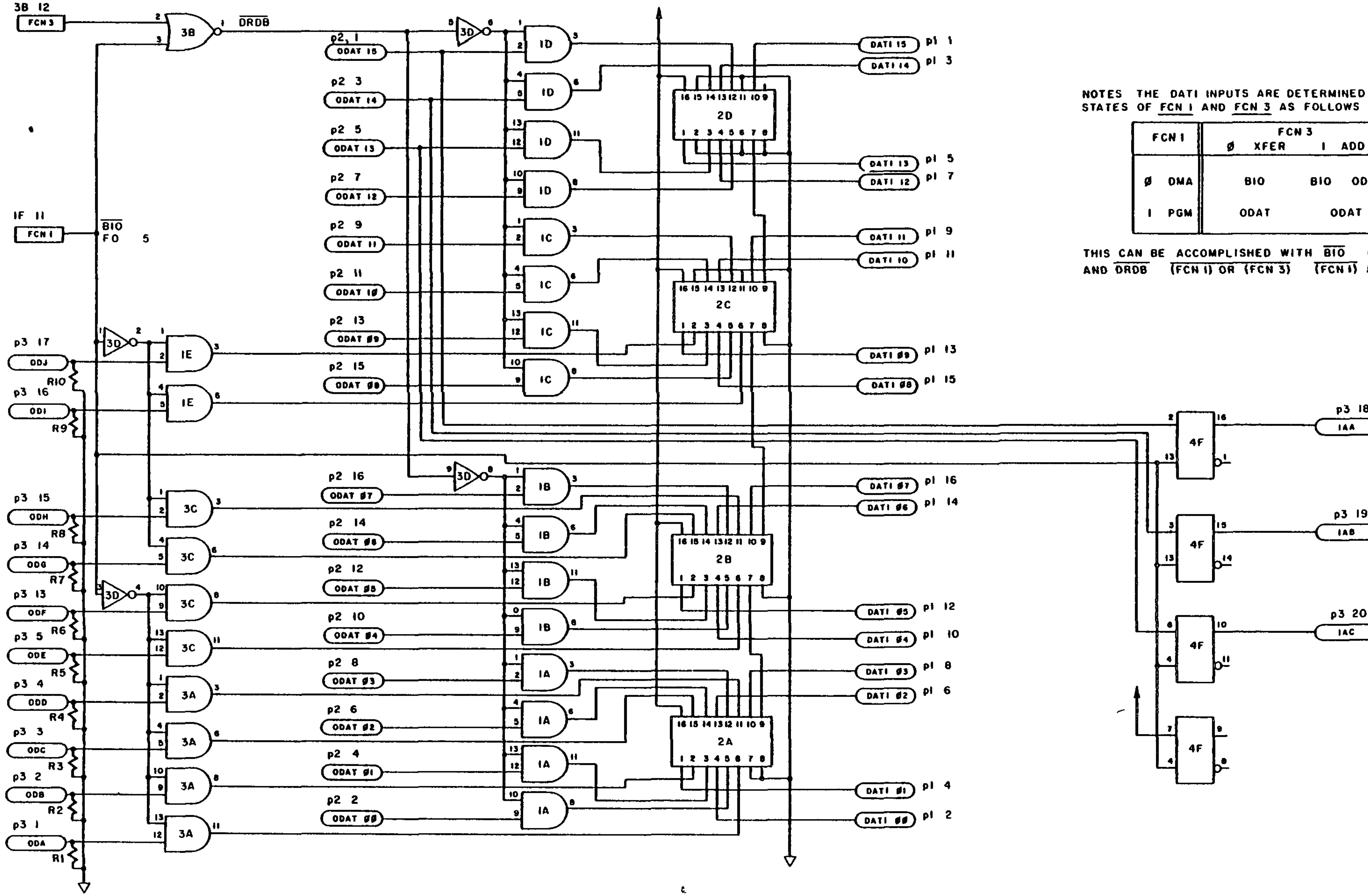
COMPONENT SIDE VIEW



ONLY BACKPLANE PINS USED ARE 5V AND GND

ALL Cs 0.1

ALL Rs 1.8k



NOTES THE DATI INPUTS ARE DETERMINED BY THE STATES OF FCN 1 AND FCN 3 AS FOLLOWS

FCN 1	FCN 3 Ø XFER	FCN 3 1 ADD
Ø DMA	BIO	BIO ODAT
1 PGM	ODAT	ODAT

THIS CAN BE ACCOMPLISHED WITH $\overline{\text{BIO}}$ FCN 1 AND $\overline{\text{DRDB}}$ $\overline{\text{(FCN 1)}}$ OR $\overline{\text{(FCN 3)}}$ $\overline{\text{(FCN 1)}}$ AND $\overline{\text{(FCN 3)}}$

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