NASA CR-180802

"Laser Wavemeter/Spectrometer Operating Manual"

by

Leo J. Cotnoir

(301) 454-4118

February 1986

(NASA-CR-180802) LASER WAVEMETER/SPECTROMETER OPERATING MANUAL Final Report (Maryland Univ.) 49 p CSCL 14B

N89-11195

Unclas

G3/35 0124871

FINAL REPORT

to

National Aeronautics and Space Administration

Goddard Space Flight Center

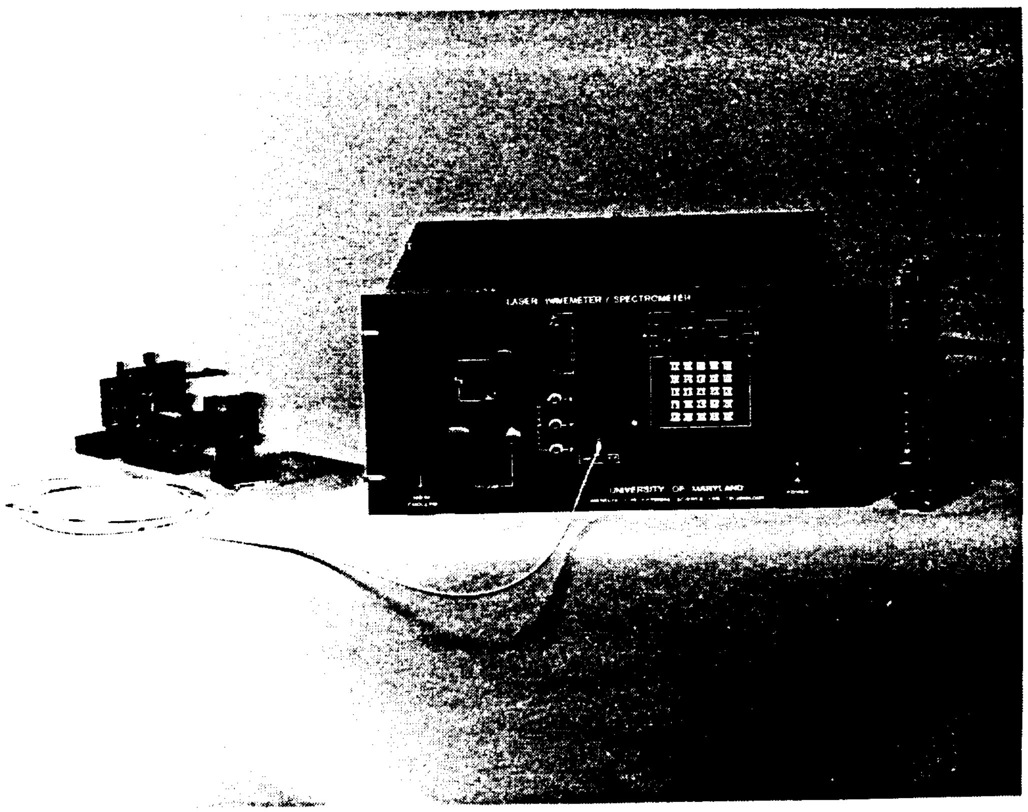
on

Contract NAS5-[illegible]

University of Maryland

Institute for Physical Science and Technology

College Park, MD 20742


LASER WAVEMETER / SPECTROMETER
UNIVERSITY OF MARYLAND

ACKNOWLEDGMENTS

Just as the Wavemeter/Spectrometer is the result of the labor of many hands and minds, so to is this manual. While retaining full responsibility for the inaccuracies, ommissions and other shortcomings certain to be found, the author wishes to acknowledge the contributions of, and to express his sincere thanks to, the following:

Professor T. D. Wilkerson of the Institute for Physical Science and Technology, who, as Program Director, provided encouragment, guidance, and the occasional necessary prodding; Mr. M. Dombrowski of NASA Goddard Space Flight Center, who has been not only Technical Monitor, but also a valued collegue throughout this project; Dr. C. L. Korb of NASA GSFC, whose backing, and patience, have made much of this work possible; Mr. R. Ramaswami, formerly at the University of Maryland, now with Systems and Applied Sciences, Inc, whose version of the SMP-1 monitor first brought the instrument to life; Dr. R. Kagann of RCA Astro, then with Systems and Science Applications, Inc., who refined the SMP-1.4 program; Mr. H. Walden of NASA GSFC, has written much of the host computer applications and test software; Mr. G. Schwemmer, of NASA GSFC, whose insight and skill are always invaluable; Mr. B. Gentry, also of NASA GSFC, for his contributions to the continuing development of the wavemeter; and, Mr. J. Wilkerson, now at the Massachusets Institute of Technology, who helped turn the sketches into reality.

Lastly, this work stands in memory of Mr. Norris Baldwin, late of the Institute for Physical Science and Technology machine shop, who fabricated much of the wavemeter.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1. INTRODUCTION

The University of Maryland Laser Wavemeter/Spectrometer is a compact, rugged instrument using a unique combination of an uncoated (Snyder) wedge interferometer and a coated (Fizeau) wedge interferometer to simultaneously measure the wavelength centroid and spectral characteristics of pulsed or CW lasers. Wavelength centroid measurement accuracies are in the range of 1 part in 10^6 using the Snyder stage alone. The Fizeau wedge section is capable of resolving spectral details to 0.002 cm^{-1} and of locating the position of a fringe to 0.0005 cm^{-1}. Because the Snyder wedge is uncoated, wavelength centroid measurements are possible over the entire detector range of from about 300 nm to greater than 1.0 μm. The coatings of the Fizeau wedge limit spectral analysis to a 200 nm interval in that range. The instrument is currently configured to operate from 600 nm to 800 nm.

The instrument must be operated with a host computer. Usually, this would be the same computer as controls the laser. Wavelengths are calculated at a rate determined mostly by the speed of the host computer. A Motorola MC68000 based microcomputer, for example, can be expected to compute centroids, with an accuracy of 0.0015 cm^{-1}, at about 15 Hz. The data acquisition bandwidth of the wavemeter electronics is in excess of 50 Hz.

This manual describes the various components of the Wavemeter/Spectrometer, along with operation, alignment, calibration and maintenance information. Since the instrument is a prototype still in development, this document can not be considered final. Rather, it is a description of the instrument at a particular stage of maturity. The user must assume a part of the responsibility for keeping the manual current.

2. DESCRIPTION

2.1 OPTICS

2.1.1 Input Optics. The components necessary to couple a laser to the wavemeter through a standard fiber optic cable (50 μm core graded index) are mounted on a small aluminum plate separate from the rest of the instrument. Two mirrors are provided to permit the laser light to be directed through a lens in a 5-axis positioner and into the fiber, which is held by an X-Y mount. The fiber cable in equipped with standard SMA connectors (OFTI 906 series).

2.1.2 Main Optical Board. The optical components of both the wavemeter and the spectrum analyzer are assembled on a common 3/4 inch aluminum plate mounted in a stainless steel vacuum box. The wavemeter section follows Snyder's design, modified to minimize distortion and obscuration of the transmitted beam. The spectrum analyzer is a 5 cm long coated wedge (Fizeau) interferometer positioned in the beam transmitted by the first stage. Figure 1 shows this layout. The input beam is collimated by a 235 mm focal length, 19° off-axis parabola. The Snyder wedge is used in reflection, as shown. The two beam interference pattern is concentrated by a cylindrical lens onto a linear photodiode array at the zero-shear position. To keep the instrument compact, the transmitted beam is redirected by a folding mirror, then passes through the Fizeau wedge, a cylindrical lens and onto a second photodiode array. The apex angle of the Fizeau wedge is chosen so that each element of the corresponding photodiode array subtends a spectral increment of 0.00025 cm^{-1}. Thus the Nyquist criterion is more than met for a resolution of 0.001 cm^{-1}. The resolution of the wedge alone is 0.002 cm^{-1}. Slit function deconvolution is necessary to attain the ultimate goal of 0.001 cm^{-1}. The multilayer dielectric coatings used on the Fizeau wedge plates exhibit substantial phase shift dispersion, resulting in a marked variation in effective plate separation with wavelength. A table of the values of effective plate separation is constructed during instrument calibration. Wavelength centroid measurements are free of such errors because the Snyder wedge is entirely uncoated. Consequently, it is possible to use the Snyder wedge result to retrieve the effective Fizeau wedge length from the table of measured phase shifts.

PRECEDING PAGE BLANK NOT FILMED

The electronics are constructed on standard 11.5 cm by 15.25 cm ciruit boards. The digital boards are STD bus compatible and have a 56 pin edge connector. The analog board and the photodiode array mother boards use 44 pin edge connectors. The CAMAC driver board attaches to the 2DB52P front panel connector through a non-STD bus 56 pin connnector.

2.3.2. CPU Board. The microprocessor CPU board is a ProLog model 7804 STDbus single board computer with a 4 MHz Z80A microprocessor and an Intel 8253 counter-timer. The operating manual for this board is included as an appendix. Familiarity with the operation of the 7804 is assumed in the discussion that follows.

Each four byte-wide JEDEC memory sockets on the board occupies 4 kbytes of memory space (see decoder option 3 in the 7804 manual). Table 1 shows the complete memory map. Note that partial decoding leads to address redundancy in a few cases.

The CPU board uses I/O ports F0h through F5h for various controls, including the counter-timer. The Intel 8253 counter-timer has three independent channels, each of which can operate in one of 6 modes (see 7804 manual). In the wavemeter, channel 0, operating in mode 2, divides the 4 MHz CPU clock to a programmable lower frequency to drive the other two channels. When the wavemeter is operated in the INTERNAL trigger mode (used with CW lasers), Channel 1 (mode 4) provides the array read command. In the EXTERNAL mode (used with pulsed lasers), this channel causes a program interrupt to occur if the time since the last trigger is greater than the acceptable dark current integration interval of the photodiode arrays. The CPU then executes a program that recharges both arrays simultaneously. Channel 2 (mode 2) is a timeout counter for data transfer operations. At the expiration of a preset delay, this channel clears the BUSRQ* or WAITRQ* flip-flop and generates a TIMEOUT error interrupt to the CPU.

2.3.3 Keyboard/Display. A ProLog model 7303 keyboard card is mounted in the front panel of the spectrometer. It is accessed through I/O ports D0h and D1h. The key functions are defined in software and depend upon which program priority encoder uses these bits to generate the two most significant bits of the interrupt vector. If the source of the interrupt is the CAMAC module, the remaining bits of the vector come from the CAMAC instruction port. Otherwise, these bits are ignored. The interrupt status and mask registers are available through I/O port 0Eh.

2.3.5 CAMAC Board. This board contains a dual-port buffer memory, a 16-bit output port (to the main computer), a 13-bit instruction input port and CAMAC control signal decoding logic. A schematic diagram is shown in figures 5a and 5b. A bidirectional line driver board, while physically separate, is logically part of the CAMAC board and will be covered in this section. It is shown schematically in figure 5c.

2.3.5.1 The dual port buffer memory appears to the Z80 bus as 4k x 8, but as 2k x 16 to the CAMAC module. To accomplish this, the Z80 bus addresses are decoded so that one memory chip contains all even addresses (ending in 0) and the other, all odd addresses. The 16 bit path to the CAMAC module is enabled by the BUSAK* signal, giving the host computer priority and preventing access contention. The Z80 addresses the buffer at <u>byte</u> addresses 4000h - 4FFFh, while the host computer addresses it at <u>word</u> addresses 0000h - 07FFh. The bytes stored by the Z80 at locations 4000h and 4001h are read by the host as a word at 0000h. The least significant bit (LSB) of the byte at 4000h is the LSB of the word at 0000h and the most significant bit (MSB) of the byte at 4001h is the MSB of the same word.

The memory address register, used by the host computer to access data words in the dual port buffer, has an auto-increment feature. The host computer loads a block start address into this register. Successive read or write cycles over the CAMAC dataway then automatically step through the memory, permitting transfers at the full dataway rate of 2 Mbyte/sec. (Actual transfer rate may, in practice, be limited by program execution overhead during operation of the CAMAC crate controller by the host computer). Random access is also possible if an address is written into the address register before each operation.

2.3.5.2. The 16-bit output port appears to the Z80 as I/O ports 0Ch and 0Dh. The appropriate CAMAC command transfers whatever data have been stored at these

2.3.6 Analog I/O Board. Under the control of the Z80, this board multiplexes the various analog input signals (conditioned to a uniform 0 to 10 Volt span) into a high speed analog to digital converter and places the results onto the CPU data bus. In addition, digital data can be converted back into analog signals to drive an X-Y display. The schematic diagram is in figure 6.

2.3.6.1 The circuit board is laid out with separate digital and analog ground planes connected at a single point. Such precautions are necessary in systems, such as the spectrometer, where low level analog signals are processed in close proximity to digital circuitry.

> **CAUTION:** When the analog board is not in place, the ±15V and +5V power supplies float with respect to each other.

2.3.6.2 An eight input multiplexer controlled by port 08h selects the signal to be digitized. The signals are:

- The output of each photodiode array sample-and-hold board, amplified and inverted by an LF356AH JFET operational amplifier to a 10V full scale range.

- Temperature of the wedge interferometers measured by Analog Devices AD590 current mode temperature probes: To minimize self-heating errors, the bias voltage to the probes is strobed by bit 6 or 7 of port 08h. Since the unbiased probe has a high output impedance, the two probes can be connected together at the input of a single AD524 instrumentation amplifier.

- Vacuum box pressure monitored using a thermocouple gauge in an AC bridge: A 6.3 VAC bias signal is provided to the gauge by a small circuit board located at the rear to the spectrometer. An AD524 instrumentation amplifier is used to condition the signal. Any residual 60 Hz modulation can be removed by Z80 software (not implemented yet).

- The remaining four inputs are available for self-testing: They are attached to ANALOG GROUND, YDACOUT, XDACOUT and an external test point, TP1.

port 0Bh to 00, 01, 10 or 11 respectively.

2.3.7 Photodiode Array Sample and Hold Boards. These are EG&G Reticon RC100 motherboards configured to accept external CLOCK and START signals. Each board is mated to an RC106 board containing the photodiode array proper. These are mounted in the vacuum box. The Reticon manual in the appendix should be consulted for details.

2.3.8 CAMAC Module. The CAMAC interface is constructed in a BiRa MK-1, two slot "Kluge" module with a custom front panel. Schematic diagrams are shown in figures 7a and 7b. LEDs indicate the state of the N, L and Q signals. A pushbutton allows a manual reset of the module, and, if the interface is enabled, of the Z80. The module and the spectrometer are connected by a 2 meter cable of 26 twisted wire pairs. Standard 2DB-52 connectors are used at each end. The CAMAC functions implemented in the module, and the control signals each generates , are listed in Tables 8 and 9. Note that the buffer address must always be initialized.

Two submodules (see CAMAC description in appendix) are implemented. All LAM gating functions required by IEEE-583 and most control functions are performed by submodule A(0). Data transfers are handled by submodule A(1). The submodule address lines are fully decoded as required by the CAMAC standard, so no unexpected operations will occur if other submodules are inadvertently addressed.

2.3.9 Miscellaneous. Connectors have been chosen to minimize the chance of incorrect hook-up. The only non-unique connectors are those to the two arrays and to the X, Y, and Z axes. The power supplies are located beneath the card cage and extend under the vacuum box. They provide 3.5A @ +5V, 1.0A @ ±15V for the logic and analog circuitry, respectively; and 2.2A @ +4V for the array coolers.

2.4 SOFTWARE

2.4.1 Overview. The Wavemeter operating software can be divided into two

2.4.3.1 Computation of laser wavelengths from the uncoated wedge fringe data is accomplished by a program developed by J. J. Snyder of NBS. (Hence our use of the term "Snyder wedge" for the uncoated interferometer). A version of this program for PDP-11 has been obtained from M. Morris, formerly of the University of Maryland. This latter version has been translated into HPL for use on an HP-9825.

2.4.3.2 An important feature of the Wavemeter software is a program that uses Snyder wedge fringe data to remove spatial noise from the Fizeau wedge fringes. It is assumed (and appears to be confirmed by observation) that the spatial frequencies in the noise envelope are sufficiently low that interpolation between the Snyder wedge fringe peaks will provide an adequate reconstruction of this envelope. Initial observations indicate that the envelope on each array is indeed the same.

2.4.3.3 Once the spatial noise envelope is recovered from the Snyder fringe data, it must be removed it from the Fizeau wedge fringes. This is done by dividing each element in the line shape fringe data set by the corresponding element of the envelope. The result is the unfiltered line shape data set.

2.4.3.4 The background corrected line shape fringe data generated by the previous program still contains Snyder wedge fringes at about 8% modulation. The exact spatial frequency of these fringes is known from the wavemeter program. A high-Q digital notch filter centered at this frequency will remove the Snyder wedge fringes with little effect on the line shape determination. The output of this program will be line shape data uncorrected for fringe assymetry.

2.4.3.5 The high resolution wedge used in the line shape portion of the spectrometer produces assymetric fringes. The availability of a very narrow band laser (1 MHz) allows the instrumental profile to be determined experimentally if necessary, so that a deconvolution could be done if desired. Individual pulsed laser modes are narrow enough, however, that it is generally sufficient to know the position of each fringe, the details of its shape being unimportant.

3. INSTALLATION

3.1.1 Wavemeter main assembly. The Wavemeter can either be installed in a standard 19" equipment rack or set on a table. Because of the length of the box and the position of its center of gravity, support should be provided at the rear when rack mounted. Only a power cord receptacle and the vacuum gauge balance pot are located at the rear, so access is not normally required. Space must be left for the cooling fan located on the front left side. The power cord must be connected to a 120 VAC, 60 Hz line capable of at least 5 A. A low pass line filter is included in the spectrometer. If large fluctuations in the power source are expected, a voltage stabilizer should be provided. A vacuum pump, equipped with an oil vapor filter, must be connected to the 3/8" Swagelok fitting on the front panel. The present box is not entirely airtight, so the pump must be left on while measurements are being made. The 1/4" Swagelok fitting should be connected to a source of dry nitrogen or filtered dry air. The box has a check valve to prevent overpressure. Because the photodiode arrays are somewhat deliquescent, the box should be backfilled with this dry gas whenever it is not under vacuum.

3.1.2 Input optics. The input optics should be placed in a convenient location near the laser to be monitored and firmly anchored. It is useful to align the fiber optic cable using a small HeNe laser. With the fiber optic and input lens removed, position the beam using the two mirrors so that it passes through the center of the fiber receptacle. Install the optical cable and adjust the mirrors for maximum throughput. Replace the lens and, using only the adjustments on the lens mount, tweak for optimum coupling.

> **WARNING:** Do not look into the end of the fiber optic cable. When the lens is in place, the light emitted may exceed the threshold for safe intrabeam viewing of the laser.

3.1.3 Electronics. Installation of the electronic components of the spectrometer is very simple. The CAMAC module must be installed in the crate

PRECEDING PAGE BLANK NOT FILMED

4. OPTICAL ALIGNMENT (see figure 1)

1. Disconnect the D connectors from both sides of the feedthrough and remove the optical base plate from the vacuum box. Attach the four pieces of threaded rod to the mounting holes in the corners of the plate so that the bottom is accessible. Position this assembly convenient to the right side of the spectrometer and attach the D connectors (they mate directly without the feedthrough).

2. Remove the interferometers, cylindrical lenses and turning mirror from the optical base plate.

3. Using the procedure in section 3.1.2, admit HeNe laser light to the fiber cable. Observe the collimated light from the parabolic mirror at a distance of at least 3 meters. Adjust the parabola so that this beam is well collimated and anastigmatic.

4. Install the Snyder wedge and position it centered in the beam. Adjust it so that the reflected portion of the beam is centered on the photodiode array.

5. Install the cylindrical lens. Adjust it while monitoring the fringes on the X-Y display. (Do not turn on the coolers.)

6. Install the turning mirror so that the beam is centered on the other photodiode array.

7. Install the Fizeau wedge centered in this beam and adjust it until fringes are formed at the photodiode array. Monitor these fringes on the X-Y display and tweak for sharpness.

8. Install the cylidrical lens and, while monitoring the display, adjust for the sharpest fringes.

9. Replace the optical base plate in the vacuum box, seal and recalibrate the instrument.

5. Z80 SOFTWARE PROGRAM

5.1 INTRODUCTION

There are two different programs resident in the Laser Wavemeter: the ProLog Corp. MP-5 Keyboard Monitor and the SMP 1.4 Laser Wavemeter Monitor. The MP-5 Monitor, residing in read only memory at address 0000h, can be used for program development and debugging. It provides data and program entry and editing in hexadecimal, as well as single step and breakpoint utilities. A complete description may be found in the ProLog MP-5 Monitor manual included as an appendix.

The SMP 1.4 Laser Wavemeter Monitor, contained in a separate EPROM chip at 1000h, performs all of the wavemeter tasks. Primary among these is the collection of data from the photodiode arrays. When the data acquisition cycle is complete, an interrupt is sent to the host computer. It responds by placing the Z80 in a HOLD state, suspending SMP 1.4 execution. The host computer then reads the data directly from the dual port buffer memory by way of the CAMAC dataway. Should the HOLD state not be cleared after an appropriate time (about 100 msec), a timeout error will occur, and SMP 1.4 program execution will continue.

When the Z80 is not collecting data and providing it to the host computer, it is refreshing the XY display and scanning the front panel keyboard. These functions are interrupted for data acquisition and host computer command execution. The service routines for the four interrupts are part of the SMP 1.4 program.

5.2 MP-5 KEYBOARD MONITOR PROGRAM

A complete description of this program can be found in the ProLog manual included as an appendix.

5.3 SMP 1.4 WAVEMETER MONITOR PROGRAM

5.3.1 The SMP 1.4 Monitor program occupies Z80 addresses 1000h through 1FFFh.

entry. The digit(s) may then be re-entered. All corrections must be made before SST is depressed.

5.4 SMP-1.4 MONITOR PROGRAM FUNCTIONS

MDEF : Modify Default Initialization (Key Code = 10h). This function modifies the contents of the machine status flag resister from the default value to a user specified value. When this function is selected, "MDEF" is displayed for about one second, followed by the prompt "DATA". The user then enters a 2-digit value. The selection is completed by pressing the SST key. The program responds by displaying a message confirming the operation performed.

CYTEX: Cycle Time for Pulsed Laser Mode (Key Code = 11h). This function changes the value entered in channel 1 of the 8253 counter/timer is loaded. When selected, this function displays "CYTEX" for about one second, followed by the current channel 1 count value. The display then shows the prompt "----". The desired value (4 hexadecimal digits) is terminated by SST.

CYT1: Cycle Time for CW Laser Mode (Key Code = Sft11h). This function varies the time between internal triggers when the wavemeter is operated in CW laser mode. When selected, "CYT" is displayed for about 1 second, followed by the current value and the entry prompt "----". A 4-digit value, terminated by SST, is required.

TOUT: Timeout Value (Key Code = 12h). This function changes the value of the time permitted for data transfers. It is essential that a valid value be entered if system lockup is to be prevented. Operation is similar to that of the other functions.

DATLOK: Data Write Lockout (Key Code = Sft12h). When the wavemeter is operated in CW laser mode, it is not always desirable to store every scan of the arrays. This generally the case when the trigger rate exceeds the rate at which the host computer can handle the data produce. The DATLOK function sets the ratio of actual scans to stored scans. Default value is 10, resulting in a 1 Hz data rate with the default value of CYT1. This function is operated similarly to the others, except that only 2-digit data are entered.

Table 1 Z80 Memory Map

Address	Function	Location
0000h - 07FFh	MP-5 Monitor Program	7804 Socket 0
0800h - 0FFFh	available EPROM	7804 Socket 0
1000h - 1FFFh	SMP-1 Program	7804 Socket 1
2000h - 2FFFh	available EPROM or RAM	7804 Socket 2
3000h - 3049h	reserved by MP-5	7804 Socket 3
3050h - 37FFh	available RAM (used by SMP-1)	7804 Socket 3
3800h - 3FFFh	do not use	7804 Socket 3
4000h - 4FFFh	Buffer RAM	CAMAC Board
5000h - 7FFFh	not used (redundant w/buffer)	
8000h - BFFFh	YDAC (write only)	Analog Board
C000h - FFFFh	ADC (read only)	Analog Board

Table 2 Z80 I/O Ports

Port	Write Function	Read Function
Ø8h	GDAC MSB, MUX, Temp. select	ADC least significant byte
Ø9h	GDAC least significant byte	ADC most significant byte (left justified)
ØAh	XDAC data	XDAC read back
ØBh	XDAC control, Z-AXIS	(not used)
ØCh	CAMAC most significant byte	(not used)
ØDh	CAMAC least significant byte	CAMAC instruction modifier
ØEh	Interrupt mask, Q, L	Interrupt status
ØFh	CONTROL	(not used, reserved for STATUS)
DØh	73Ø3 data	(not used)
D1h	73Ø3 control	(not used)
FØh	timer channel Ø	timer channel Ø
F1h	timer channel 1	timer channel 1
F2h	timer channel 2	timer channel 2
F3h	timer mode control	(not used)
F4h	timer interrupt mask, CAMAC interface enable	timer interrupt status
F5h	MEMEX control (not used)	(not used)

Table 3   Port Ø8h Bit Assignments

Bit	Name	Function
Ø	GDACD8	X-axis gain control DAC data bit
1	GDACD9	X-axis gain control DAC most significant bit
2	MUXEN-	Multiplexer enable (negative true)
3	MUXAØ	Multiplexer address bit Ø
4	MUXA1	Multiplexer address bit 1
5	MUXA2	Multiplexer address bit 2
6	TEMP1	Snyder wedge temperature probe bias
7	TEMP2	Fizeau wedge temperature probe bias

Table 4 Port ØBh Bit Assignments

Bit	Name	Function
Ø	XDACDOR-	XDAC data override (reset to zero)
1	XDACCTL1	XDAC control bit 1
2	XDACCTL2	XDAC control bit 2
3	XDACLS/MS-	XDAC least/most significant byte select
4	XDACLDAC-	XDAC load data strobe
5		(not used)
6	ZAXIS1	Z-axis bit 1
7	ZAXIS2	Z-axis bit 2

Table 5 Port ØEh Bit Assignments

Bit	Name	Function
Ø	ENIA	Trigger interrupt enable/status
1	ENIB	Cycle/internal trigger interrupt enable/status
2	ENIC	Instruction load interrupt enable/status
3	ENID	Timeout interrupt enable/status
4	Q	CAMAC response signal
5	L	CAMAC "look at me" signal
6		(not used)
7		(not used)

Table 6   Port ØFh Bit Assignments

Bit	Name	Function
Ø	START1	Snyder wedge photodiode array start pulse
1	START2	Fizeau wedge photodiode array start pulse
2	ACLKEN	Photodiode array clock enable
3	HIRES	High resolution, sets ADC to 1Ø bits
4	ADCSING	ADC single cycle start
5		(not used)
6		(not used)
7		(not used)

Note: All bits are latched.

Table 7 Interrupts

	Name	Function
(1)	TRIG	Initiates read cycle in external trigger mode
(2)	CYCLE	In external trigger mode, refreshes photodiode arrays In internal trigger mode, initiates read cycle
(3)	INSTLD	Indicates that instruction has been downloaded by host
(4)	TIMEOUT	Data transfer timeout error

Table 8 CAMAC Functions

Submodule A(0)

Function	Operation
F(0)	Read from dual port buffer and increment address register
F(1)	Read from 16-bit output port (Z80 ports 0Ch and 0Dh
F(8)	Test LAM (required by IEEE-583 standard)
F(10)	Clear LAM (required by IEEE-583 standard)
F(16)	Write to dual port buffer and increment address register
F(24)	Disable module and LAM (required by IEEE-583 standard)
F(26)	Enable module and LAM (required by IEEE-583 standard)
F(27)	Test LAM status (required by IEEE-583 standard)

Submodule A(1)

Function	Operation
F(16)	Write start address to dual port buffer address register
F(17)	Write instruction to 13-bit instruction port
F(22)	Reset Z80
F(24)	Disable dual port buffer access; clear BUSRQ*; clear Z80 hold
F(25)	Execute external trigger interrupt
F(26)	Enable dual port buffer access; set BUSRQ*; set Z80 hold

Table 9 CAMAC Module Function Encoding

Submodule	Function	Code
A(0)	F(0)	CA(2) · CRD · CCLK
A(0)	F(1)	CA(1) · CRD
A(0)	F(8)	(in module only)
A(0)	F(10)	(in module only)
A(0)	F(16)	CA(2) · CWR · CCLK
A(0)	F(24)	(in module only)
A(0)	F(26)	(in module only)
A(0)	F(27)	(in module only)
A(1)	F(16)	CA(0) · CCLK
A(1)	F(17)	CA(1) · CWR
A(1)	F(22)	CA(0) · CCLR
A(1)	F(24)	CA(1) · CCLR
A(1)	F(25)	CA(0) · CSET
A(1)	F(26)	CA(1) · CSET

ORIGINAL PAGE IS
OF POOR QUALITY

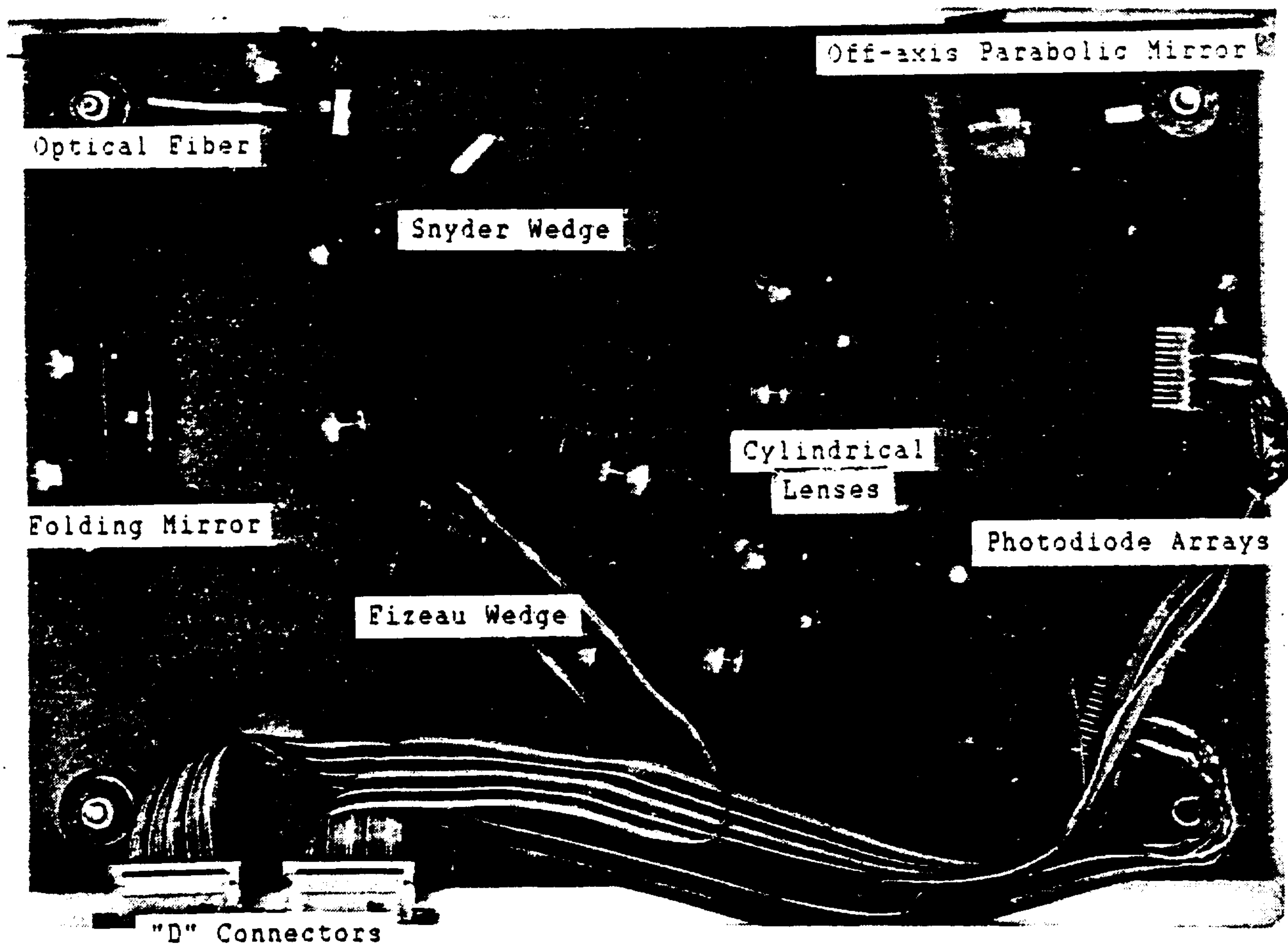


Figure 1 OPTICAL LAYOUT

ORIGINAL PAGE IS
OF POOR QUALITY

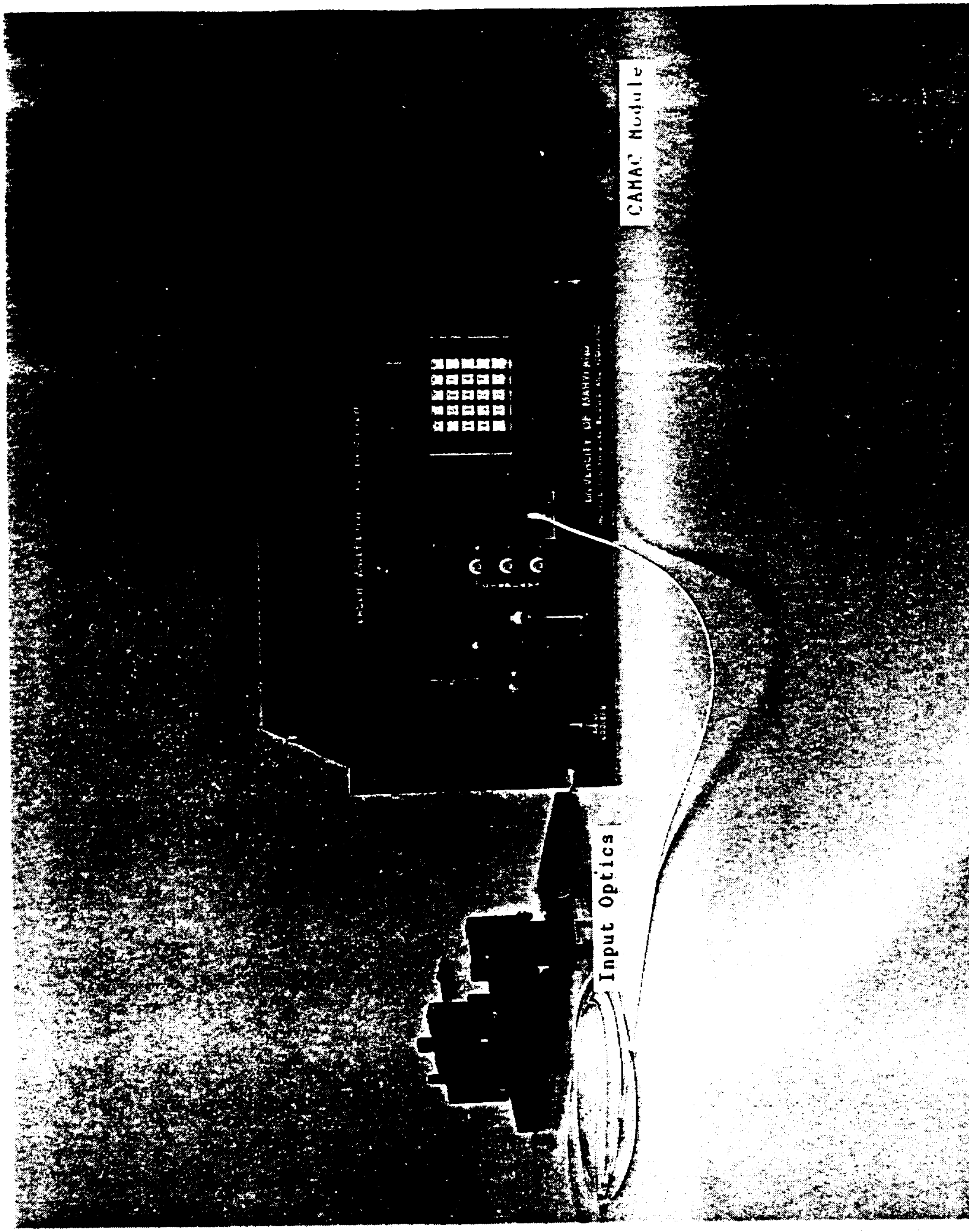


Figure 2 WAVEMETER MAIN ASSEMBLY

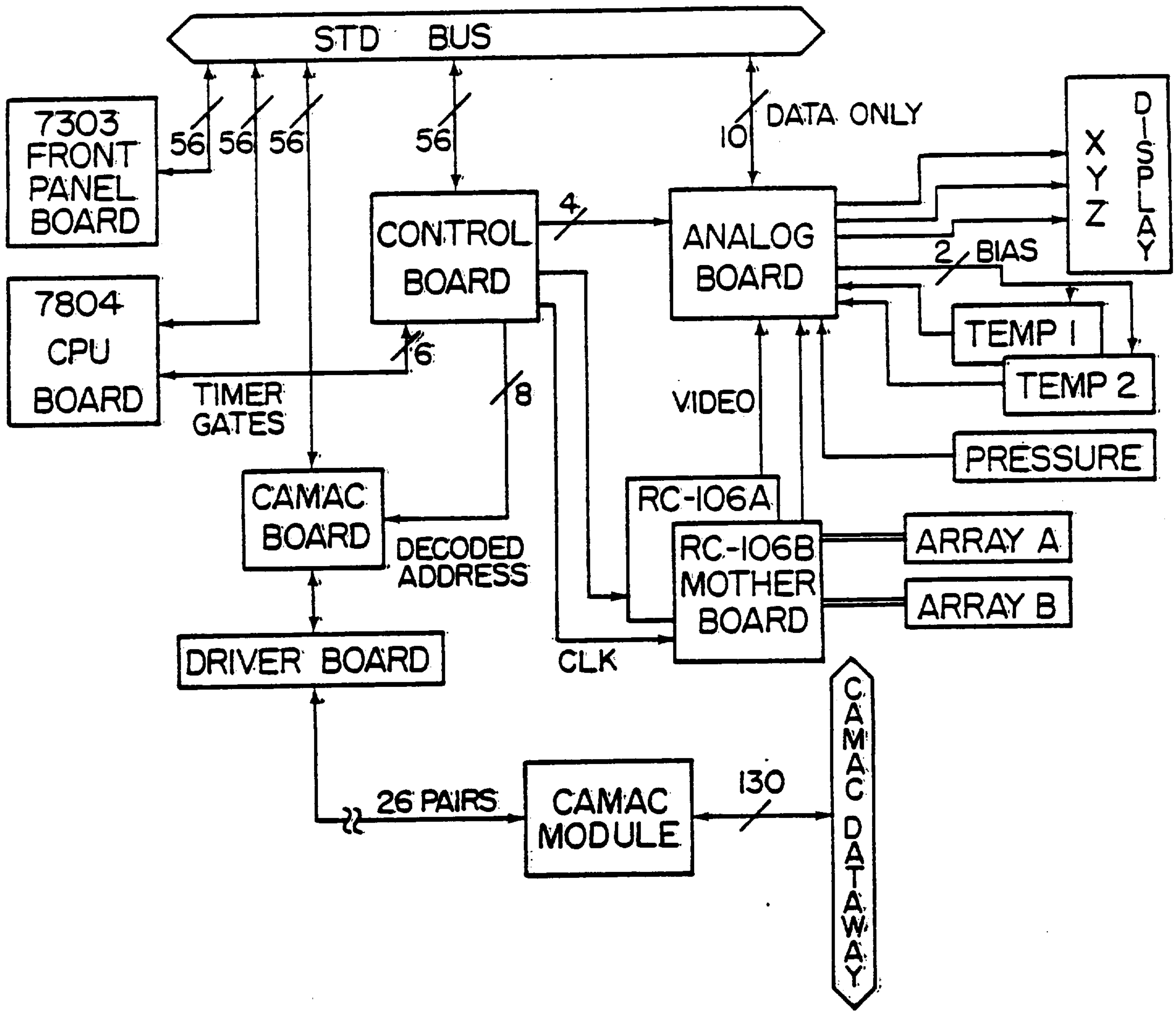


Figure 3 ELECTRONIC BLOCK DIAGRAM

Figure 4 CONTROL BOARD SCHEMATIC DIAGRAM

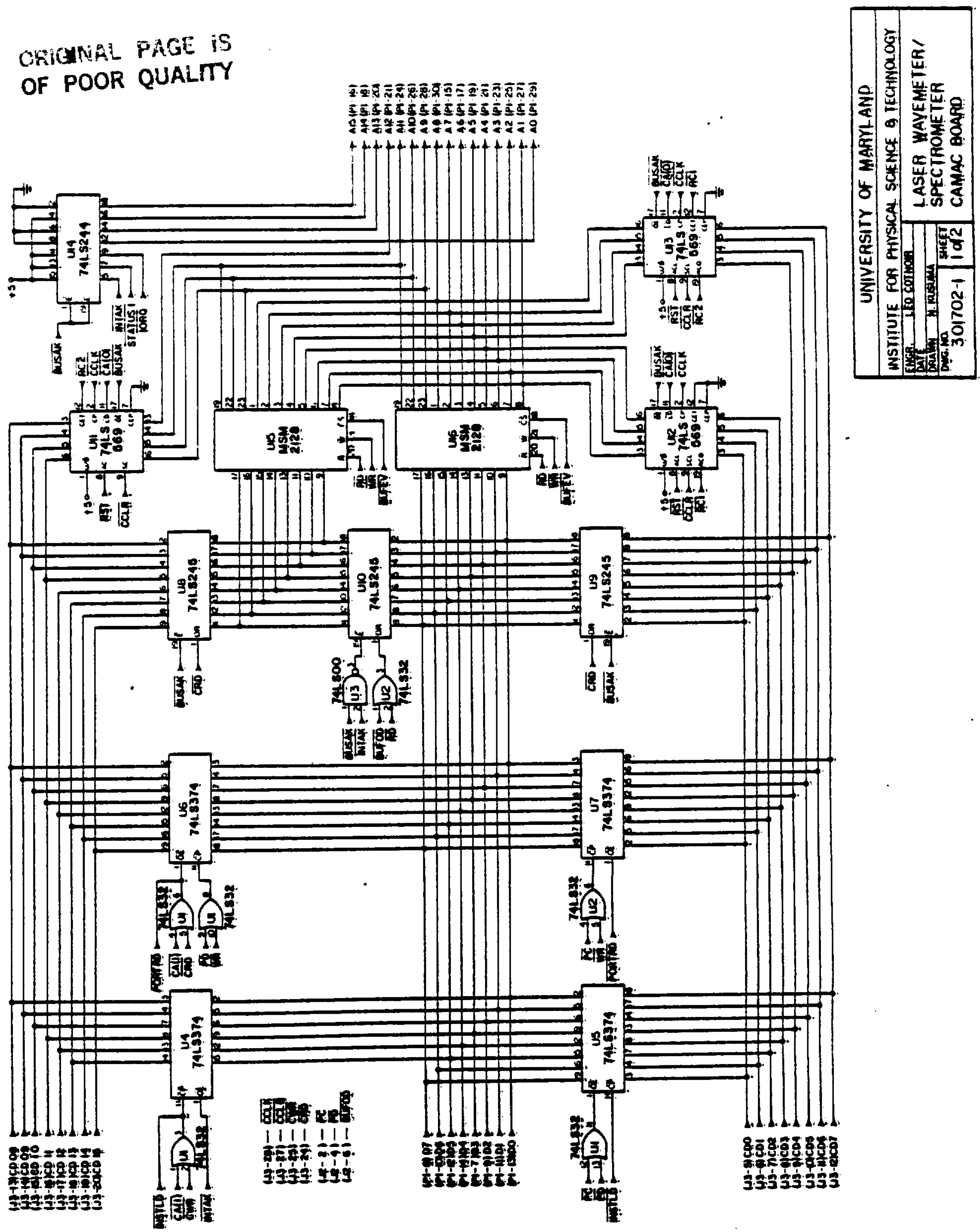


Figure 5a CAMAC BOARD SCHEMATIC DIAGRAM (1 of 2)

ORIGINAL PAGE IS OF POOR QUALITY

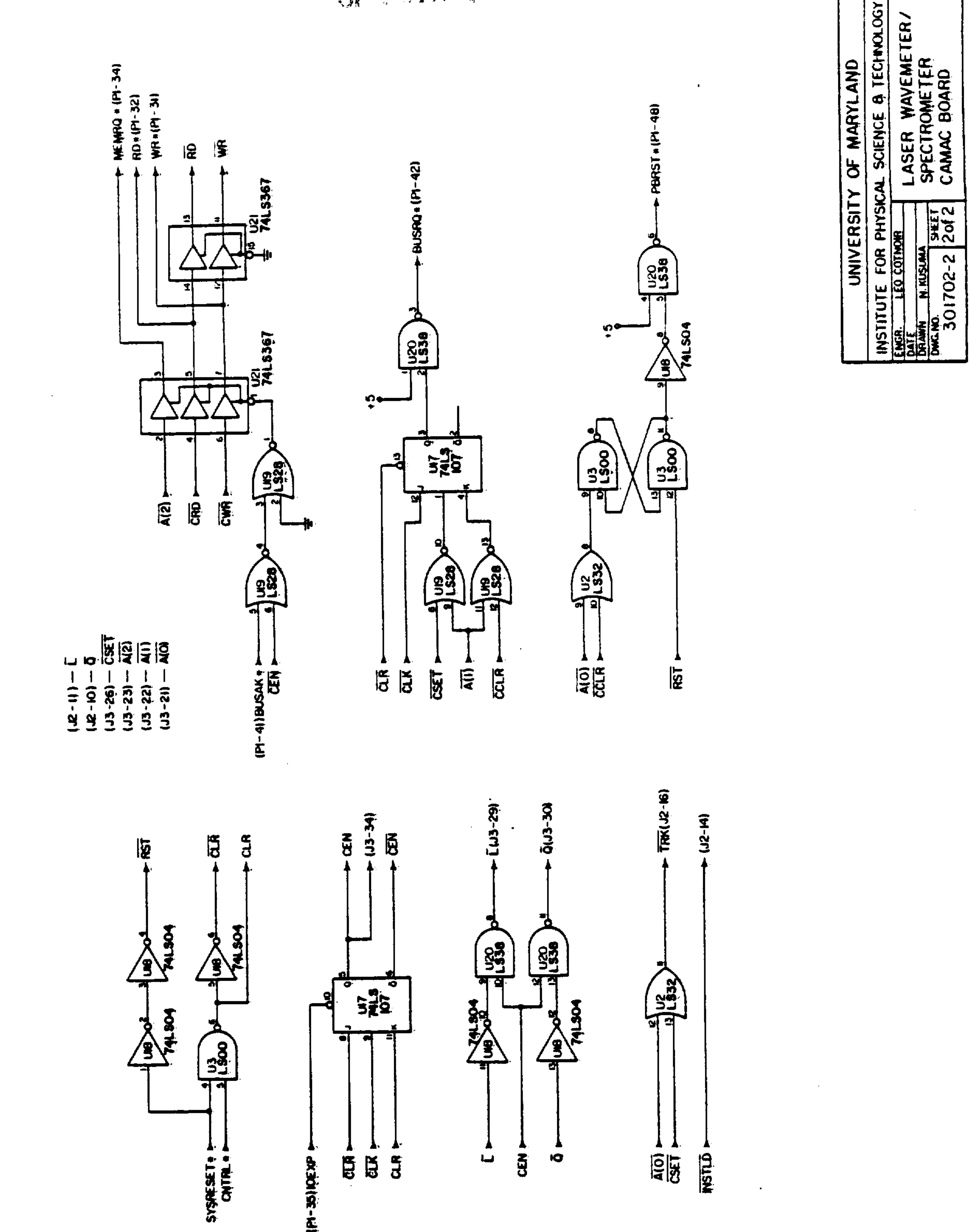


Figure 5b CAMAC BOARD SCHEMATIC DIAGRAM (2 of 2)

ORIGINAL PAGE IS
OF POOR QUALITY

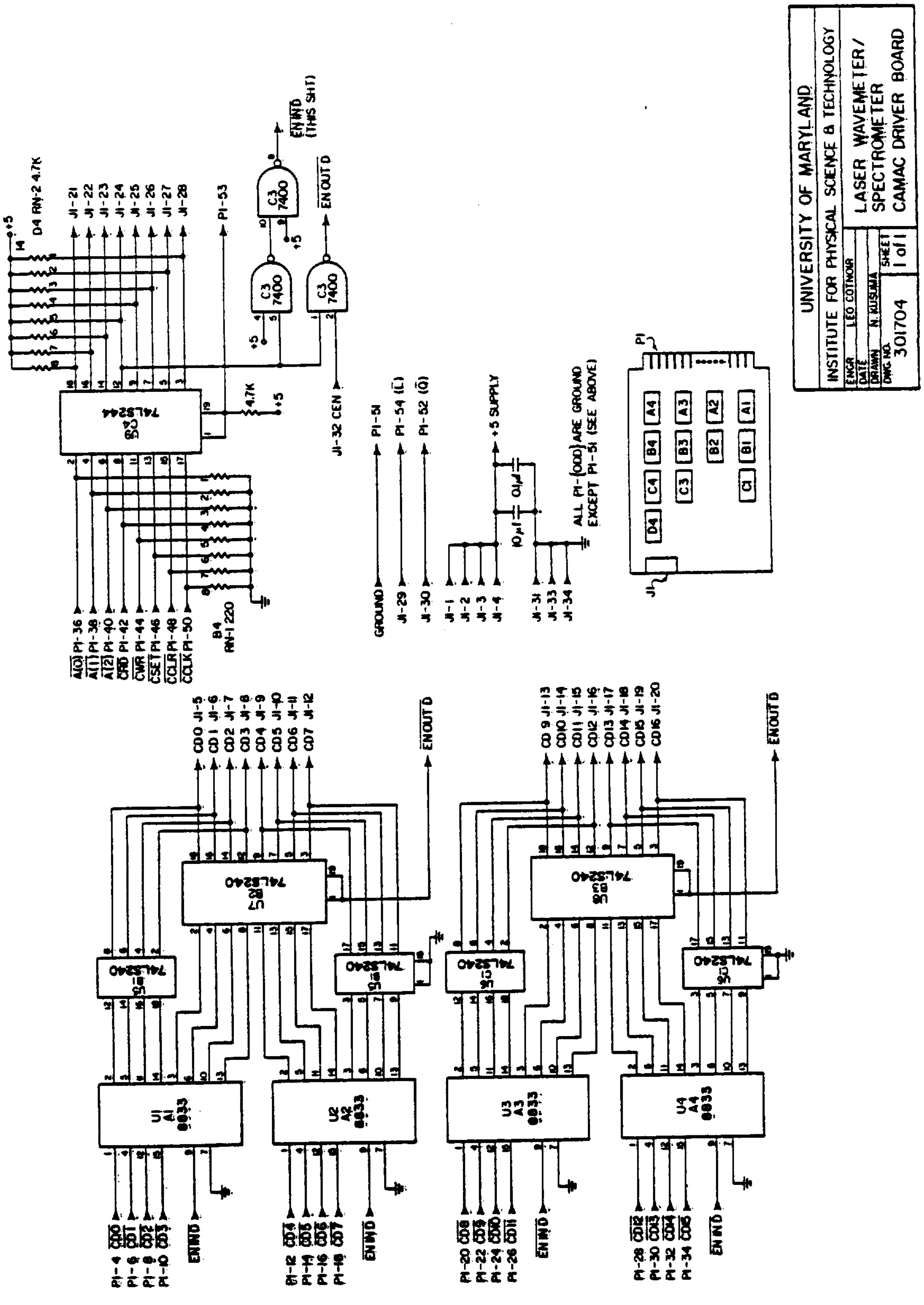


Figure 5c   CAMAC DRIVER BOARD SCHEMATIC DIAGRAM

ORIGINAL PAGE IS
OF POOR QUALITY

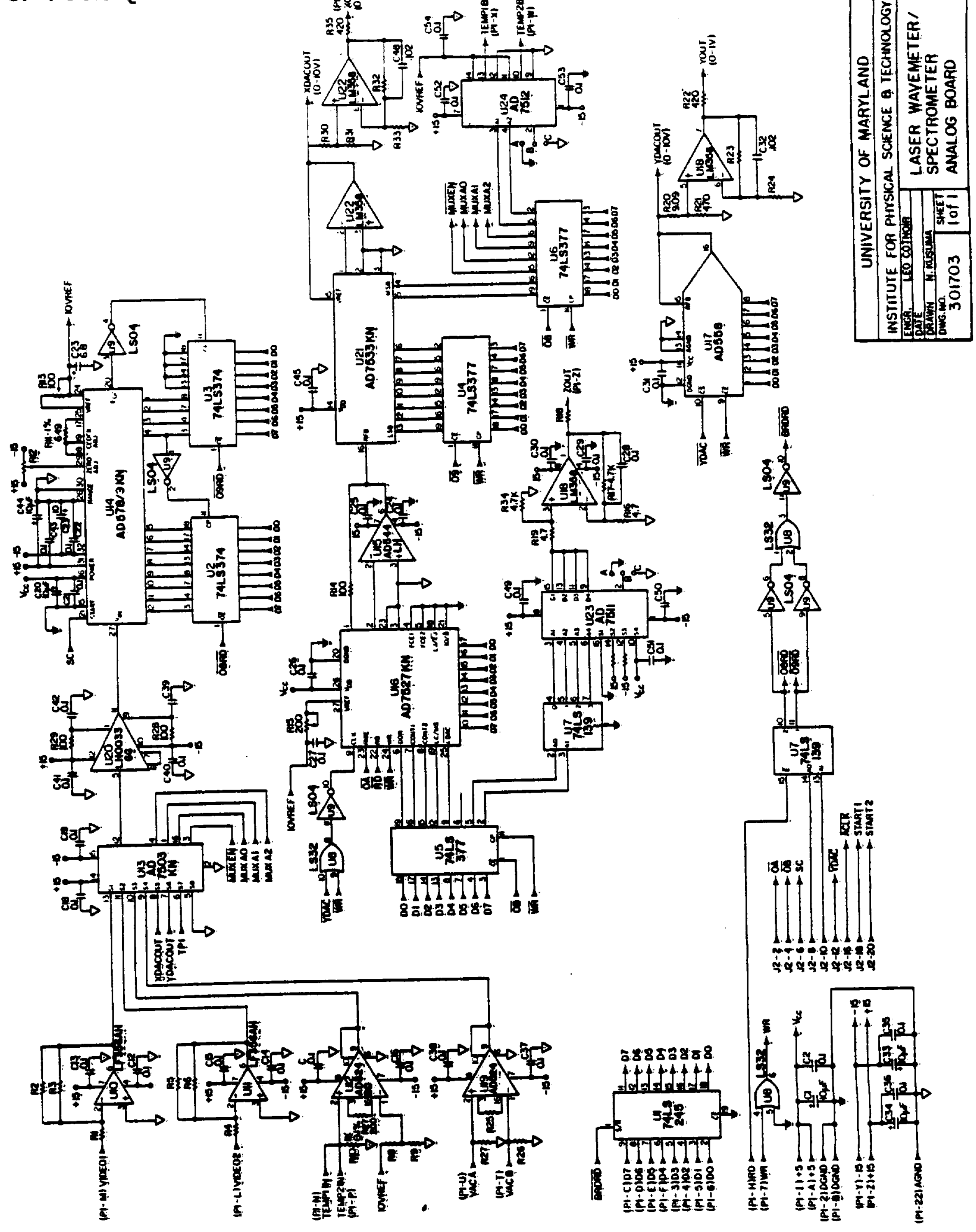


Figure 6 ANALOG BOARD SCHEMATIC DIAGRAM

ORIGINAL PAGE IS
OF POOR QUALITY

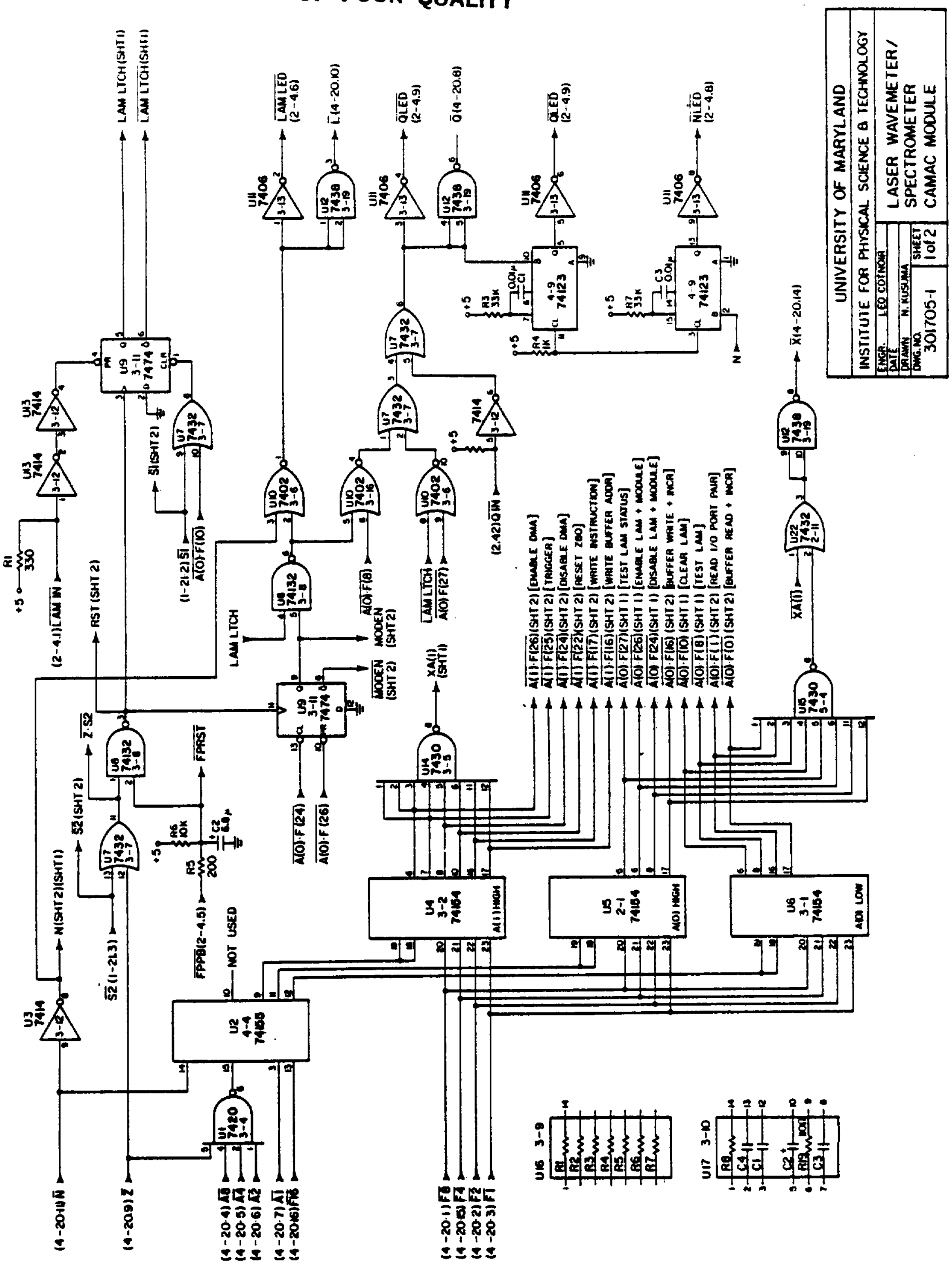


Figure 7a CAMAC MODULE SCHEMATIC DIAGRAM (1 of 2)

ORIGINAL PAGE IS
OF POOR QUALITY

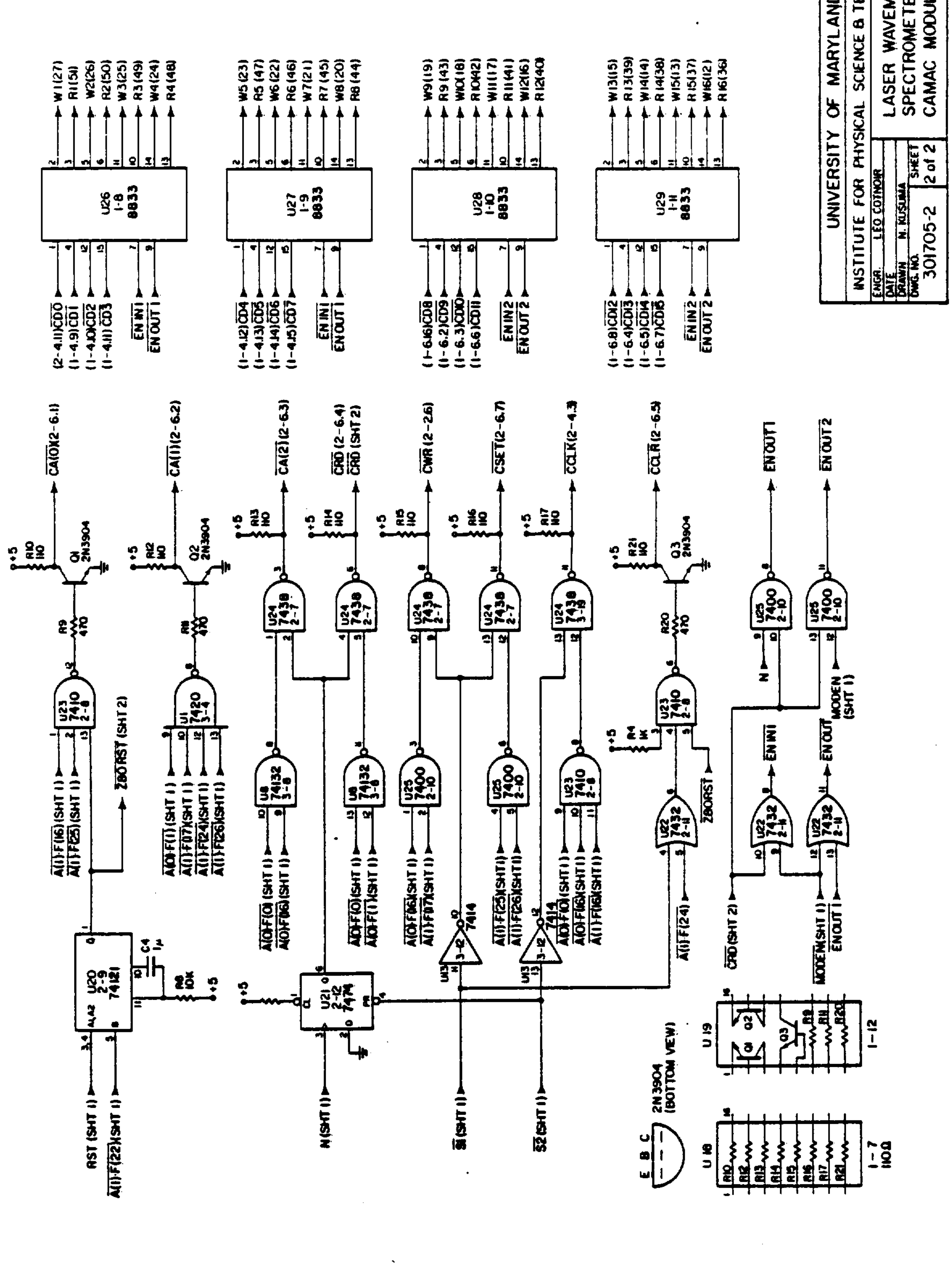


Figure 7b CAMAC MODULE SCHEMATIC DIAGRAM (2 of 2)

NOTE: The appendices are included in the ring-bound operating manual only.