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SOLID STATE READOUT DEVICE FOR AN INFRARED ABSORPTION GAS ANALY--ETC(U)

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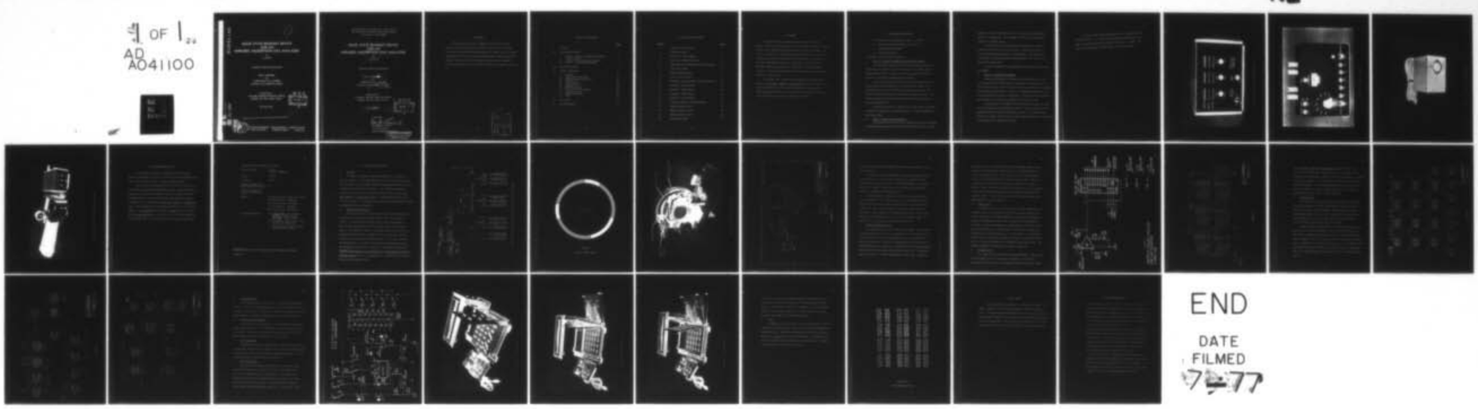

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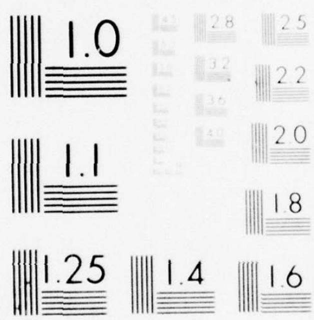

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

SOLID STATE READOUT DEVICE FOR AN INFRARED ABSORPTION GAS ANALYZER

by

R. Lorenz

Southwest Research Institute

FINAL REPORT

for

SwRI Project No. 16-3883

Contract No. F41609-74-C-0017

Prepared for

Aerospace Medical Division (AFSC)

Brooks Air Force Base Texas

24 June 1975

SOUTHWEST RESEARCH INSTITUTE
SAN ANTONIO CORPUS CHRISTI HOUSTON

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Approved:

Douglas N. Travers

Vice President

Electromagnetics Division

ABSTRACT

A Solid State Readout Device (SSRD) to operate with the Wilks Infrared Analyzer was designed, developed, and delivered. The SSRD, in conjunction with the Wilks Infrared Analyzer, compares a gas of unknown contaminant levels to a preset standard and provides a digital accept/reject display. The device provides for simplified operation, the capability of ±0.4% measurement accuracy, and direct readout of the comparison results.

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LIST OF ILLUSTRATIONS

I. PURPOSE

The purpose of the 12-month program described herein was to design, develop, test, and deliver one (1) each automatic Aviator's Breathing Oxygen (ABO) contaminant detector solid state readout device (SSRD). The device is interfaced to a Wilks Infrared Absorption Analyzer which measures contaminant concentration by means of infrared absorption measurement. The SwRI contaminant readout device continuously samples and digitizes the Wilks analyzer analog output over each of three scanned wavelength intervals. Each absorption sample is digitized by the device and compared to stored use limit values.

The results of the comparisons are displayed on front panel light indicators as less than, equal to, or greater than the stored use limits. The use of the SSRD with the Wilks analyzer eliminates the requirement for obtaining analog absorption level curves and visual comparing to use limit curves to determine acceptability of unknown gas samples.

II. PROGRAM DESCRIPTION

The program was divided into three phases as follows:

(1) Design, breadboard, and parts procurement.

(2) Fabrication and assembly.

(3) Test and adjustment.

Each phase is briefly summarized below:

A. Phase 1 - Design, Breadboard, and Parts Procurement

The initial design effort was to determine the required number of digital samples needed to insure total comparison of the Wilks analyzer analog output to stored use limits. Sixty-four (64) samples for each of the three scan intervals provide adequate resolution.

A filter wheel mask which attaches to the filter wheel shaft in the Wilks analyzer was developed to insure equally spaced samples of the absorption levels in each of the three wavelength scan intervals. The method of filter wheel detection is described in detail in Section IV. The binary mask was chosen rather than a positive position shaft encoder to reduce development cost.

Required A/D converter, control circuit, ROM storage, and output storage were designed as described in Section IV. No major difficulties were encountered.

B. Phase 2 - Fabrication and Assembly

Fabrication and assembly were accomplished during the second phase. The light mask was mounted to the filter wheel and A/D converter scaling amplifier circuit and optical detector circuit were constructed and located inside the Wilks analyzer. The remaining circuitry was constructed and installed in a separate chassis.

The filter wheel of the Wilks analyzer was found not to rotate in a fixed plane with reference to the chassis base. The filter wheel was removed and the mounting machined to a better flatness. This improved the "out of plane" rotation and allowed the optical detector circuit to sense the attached filter wheel mask.

No serious problem was encountered in the construction and assembly of the SSRD.

C. Phase 3 - Testing and Adjustment

During the testing phase, difficulty was encountered due to the drift in absorption level of the Wilks analyzer absorption level analog output. It was necessary to reduce the A/D converter accuracy in order to be compatible with the analyzer drift problem. This was accomplished by omitting the four least significant bits from the A/D converter. At one time the Wilks analyzer was returned to the sponsor for realignment of the optical circuit.

During this phase, the ROMs were programmed and comparison made to various gas mixtures provided by the sponsor. Final use limits were programmed and tested against the furnished use limits. The modified Wilks Analyzer, the SSRD, power converter, and the ROM programmer were delivered to the sponsor after completion of testing.

The line item 0001 (Solid State Readout Device) was delivered on 13 February 1975. The system was demonstrated and operated successfully. The deliverable items are pictured in Figures 1, 2, and 3. The entire system including the Wilks analyzer is shown in Figure 4.

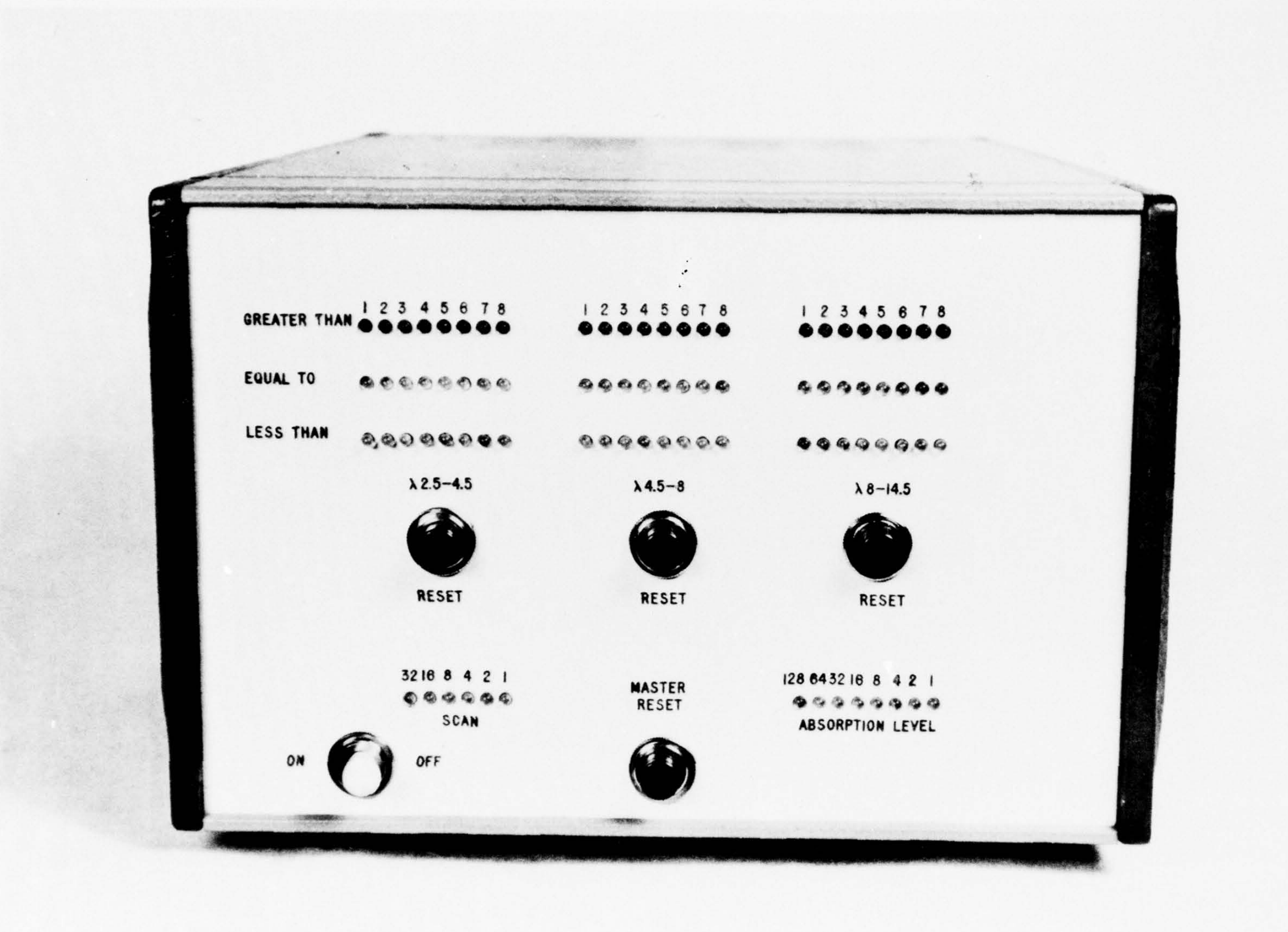

FIGURE 1. SOLID STATE READOUT DEVICE

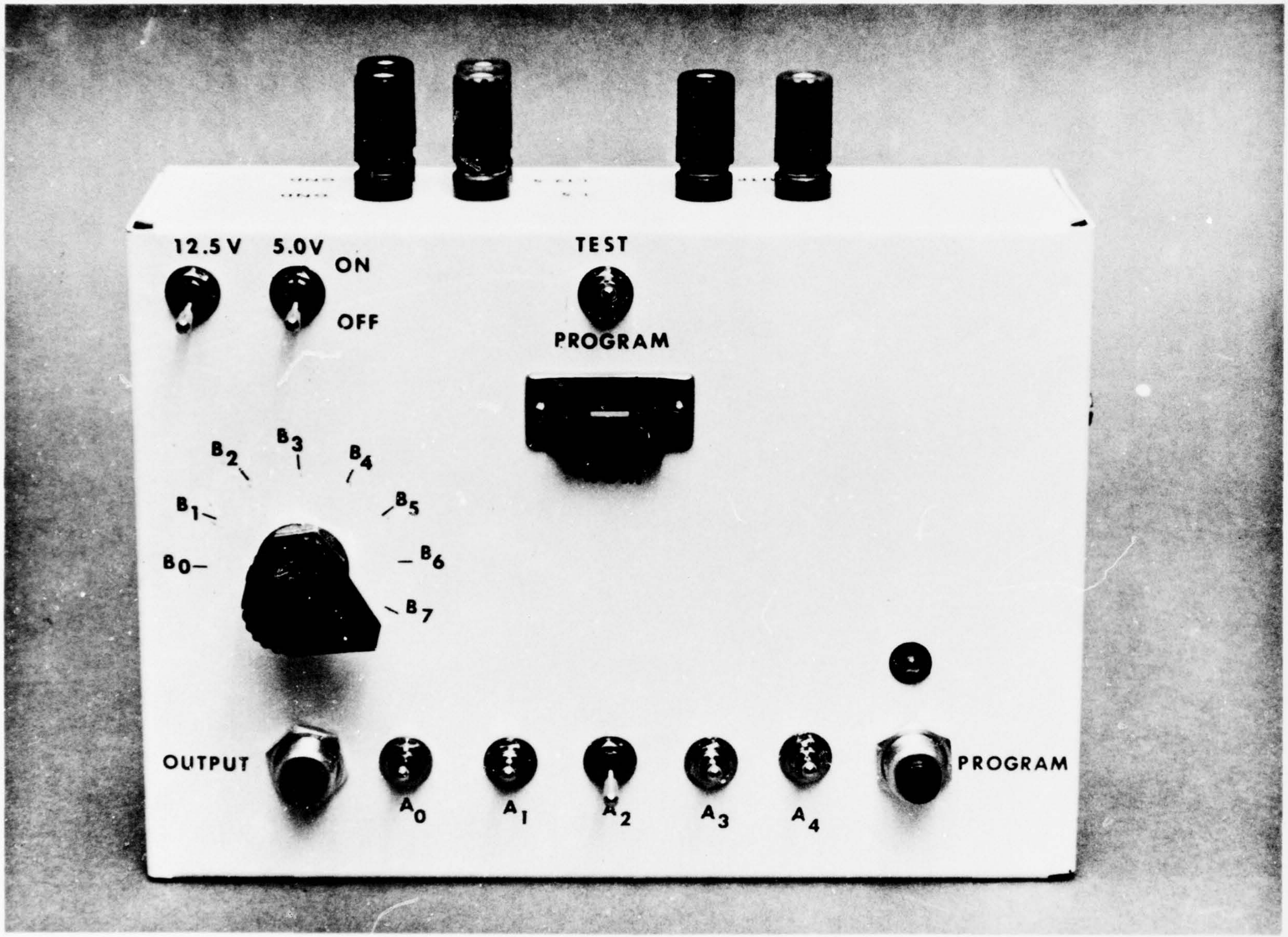

FIGURE 2. ROM PROGRAMMER

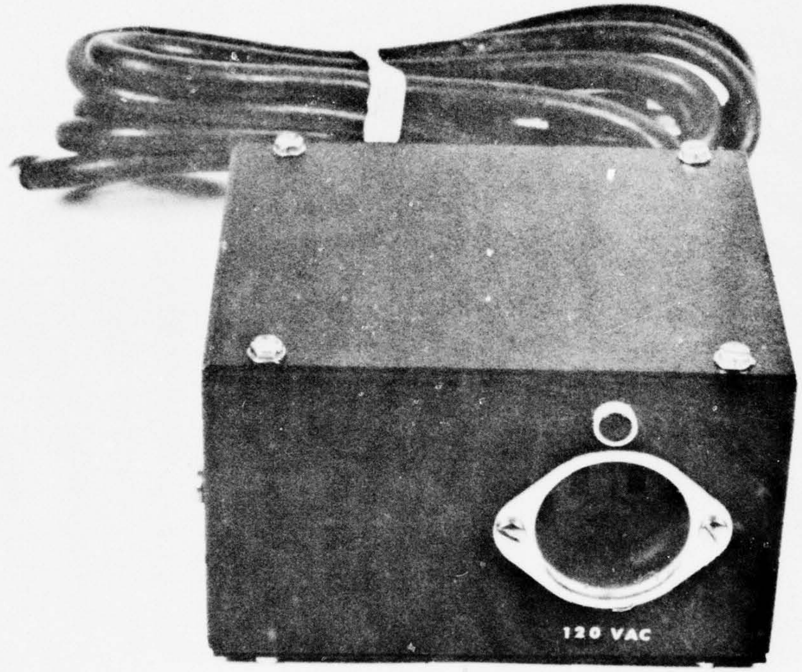

FIGURE 3. 110-220 VAC POWER ADAPTER

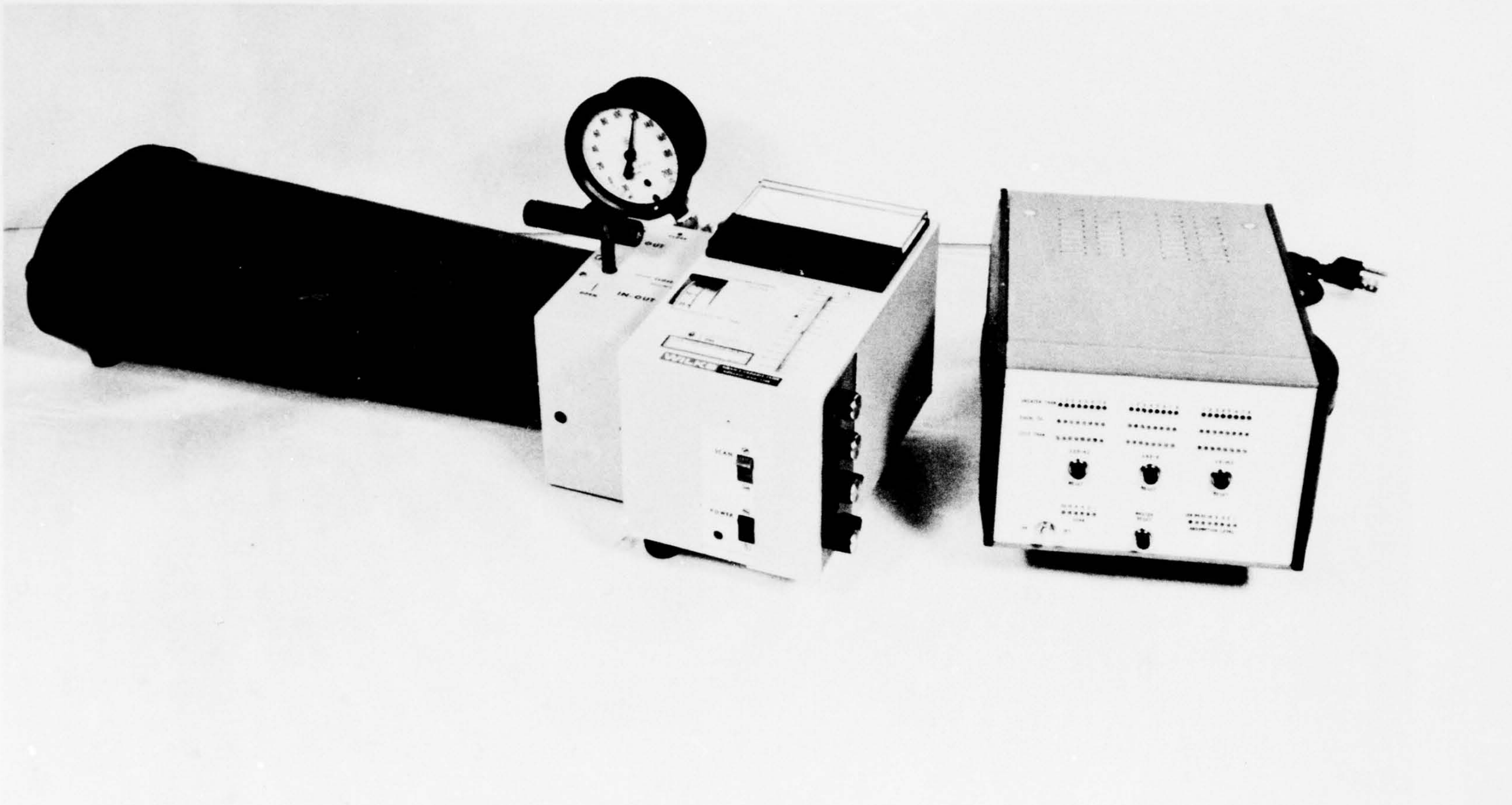

FIGURE 4. ANALYZER AND SSRD INTERCONNECT

III. SYSTEM DESCRIPTION

The Solid State Readout Device (SSRD) continuously samples, digitizes, and compares to stored use limits the ABO contaminant detector analog output over each of three scanned wavelength intervals.

Each of the three wavelength scans (2.5 to 4.5Å, 4.5-8.0Å, and 8-14.5Å) have been divided into eight (8) segments. Eight (8) samples are digitized for each segment resulting in sixty-four (64) data samples per wavelength interval. Each sample of the gas being analyzed is digitally compared to the use limit storage as less than, equal to, or greater than value. Each segment light group displays the highest value of the eight (8) samples. The less than lights are green, the equal to lights are yellow, and the greater than lights are red. Note that each of the 64 samples per wavelength interval occur at given positions of the analyzer filter wheel.

Specification for the SSRD are as follows:

Power Required:	42 watts 115 Vac, 0.408 amps
Weight:	11.8 lbs
Accuracy:	±0.4%*
Number of Samples per Wavelength Scan Segment:	64
Number of Samples per Light Level Indicator:	8
Switches:	(1) Power On-Off - Toggle two position (2) Master Reset - Pushbutton (3) λ2.5-4.5 Reset - Pushbutton (4) λ4.5-8 Reset - Pushbutton (5) λ8-14.5 Reset - Pushbutton
Front Panel Indicators	(1) Greater Than - Red, 24 total Equal To - Yellow, 24 total Less Than - Green, 24 total (2) Scan address lights (binary, 6 each for addresses from 0-63) (3) Binary analog-to-digital converter output (8 each for 8 bits)

*Unit accuracy set at ±2.9% to allow for Wilks analyzer and operator variation.

IV. THEORY OF OPERATION

A. General

The SSRD is dependent on analog information received from the Wilks gas analyzer.* This information consists of the filter wheel position which determines the wavelength of the gas being analyzed and the associated absorption level of the infrared detector. This combined information is compared to pre-recorded use limits data and the results indicate a less than, equal to, or greater than condition. A block diagram of the system is shown in Figure 5. The detailed discussion will be broken down into groups corresponding to this block diagram.

B. Optical Detection System

In order to determine the filter wheel position of the Wilks analyzer, an optical mask is mounted to the filter wheel. This mask is shown in Figure 6. An optical detector shown in Figure 7 and schematically in Figure 8 detects the transition from dark to light spaces or light to dark spaces. Each transition initiates an analog-to-digital conversion of the absorption level and initiates a comparison of the results with the stored use limits. A count is made for each transition. This count is called the wavelength address. The address represents the wavelength of the gas at that instant the absorption level is digitized. This address also indicates

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*Oxygen Contaminant Detection: Procedures for Field Analysis of Aviator's Breathing Oxygen, Crow, W.L. and Ikels, K.G., USAF School of Aerospace Medicine Report SAM-TR-74-24.

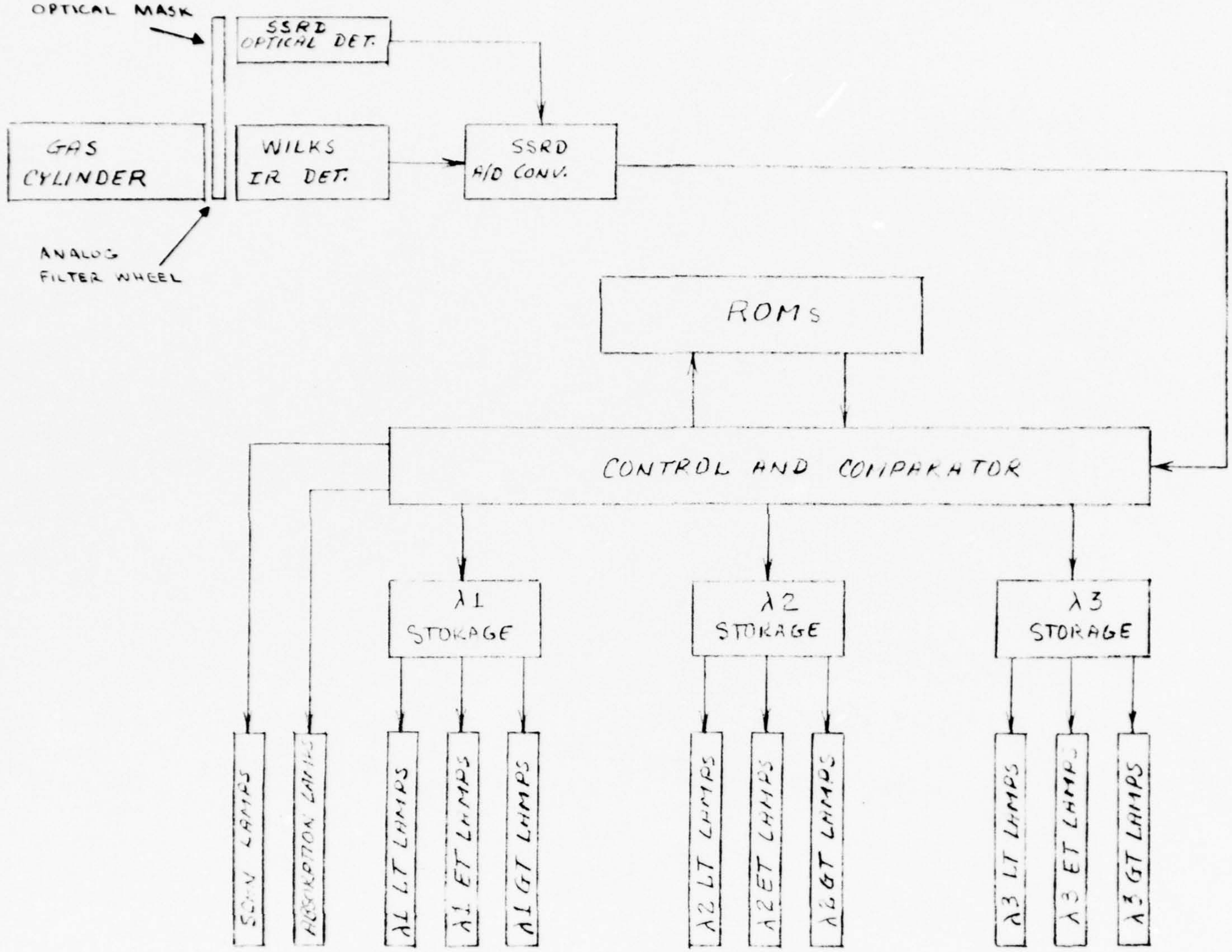

FIGURE 5. WILKS ANALYZER AND SSRD SYSTEM BLOCK DIAGRAM

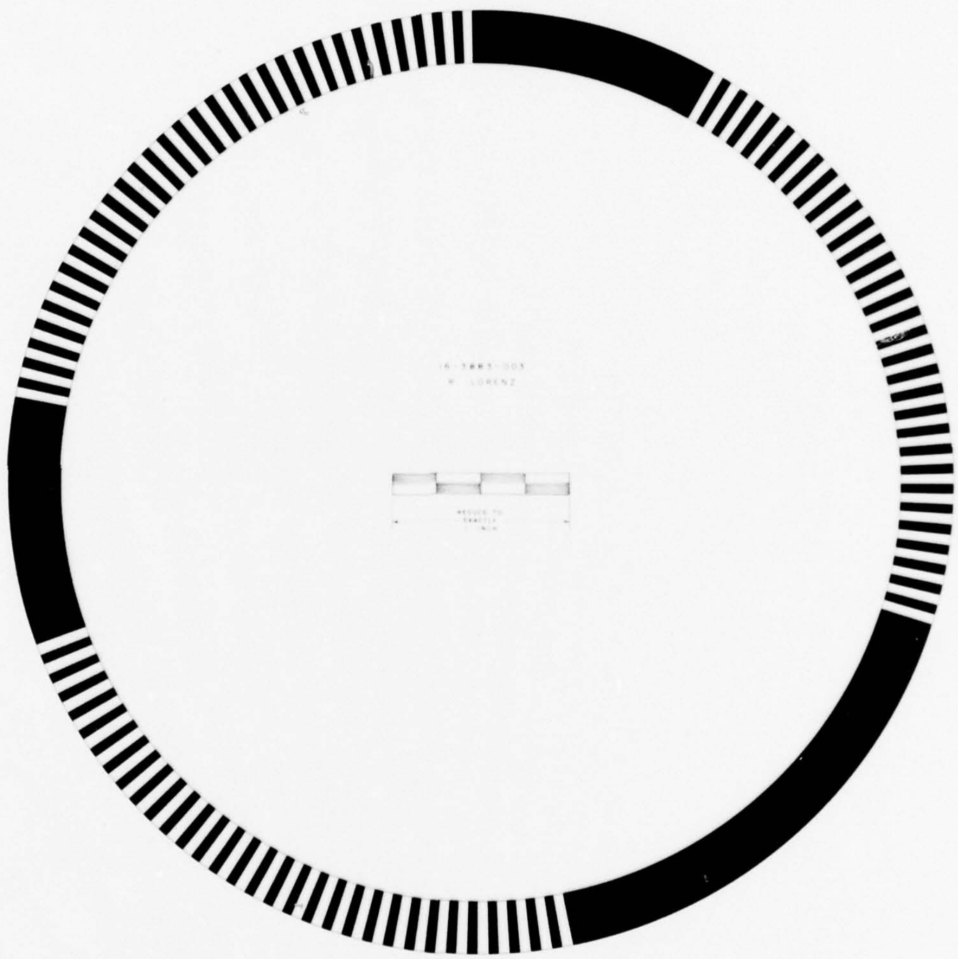

FIGURE 6

FILTER WHEEL MASK

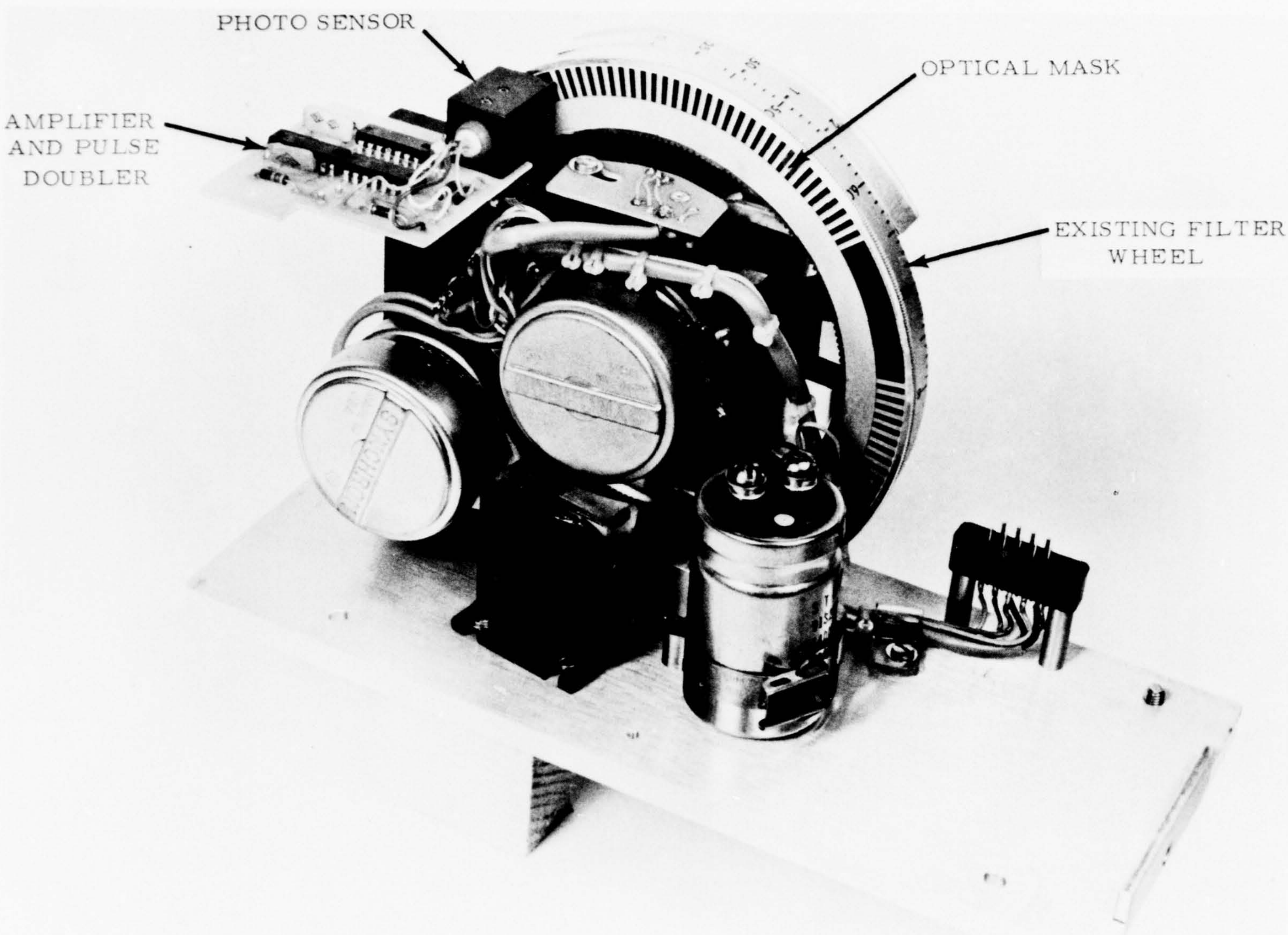

FIGURE 7. OPTICAL SENSOR MOUNTING

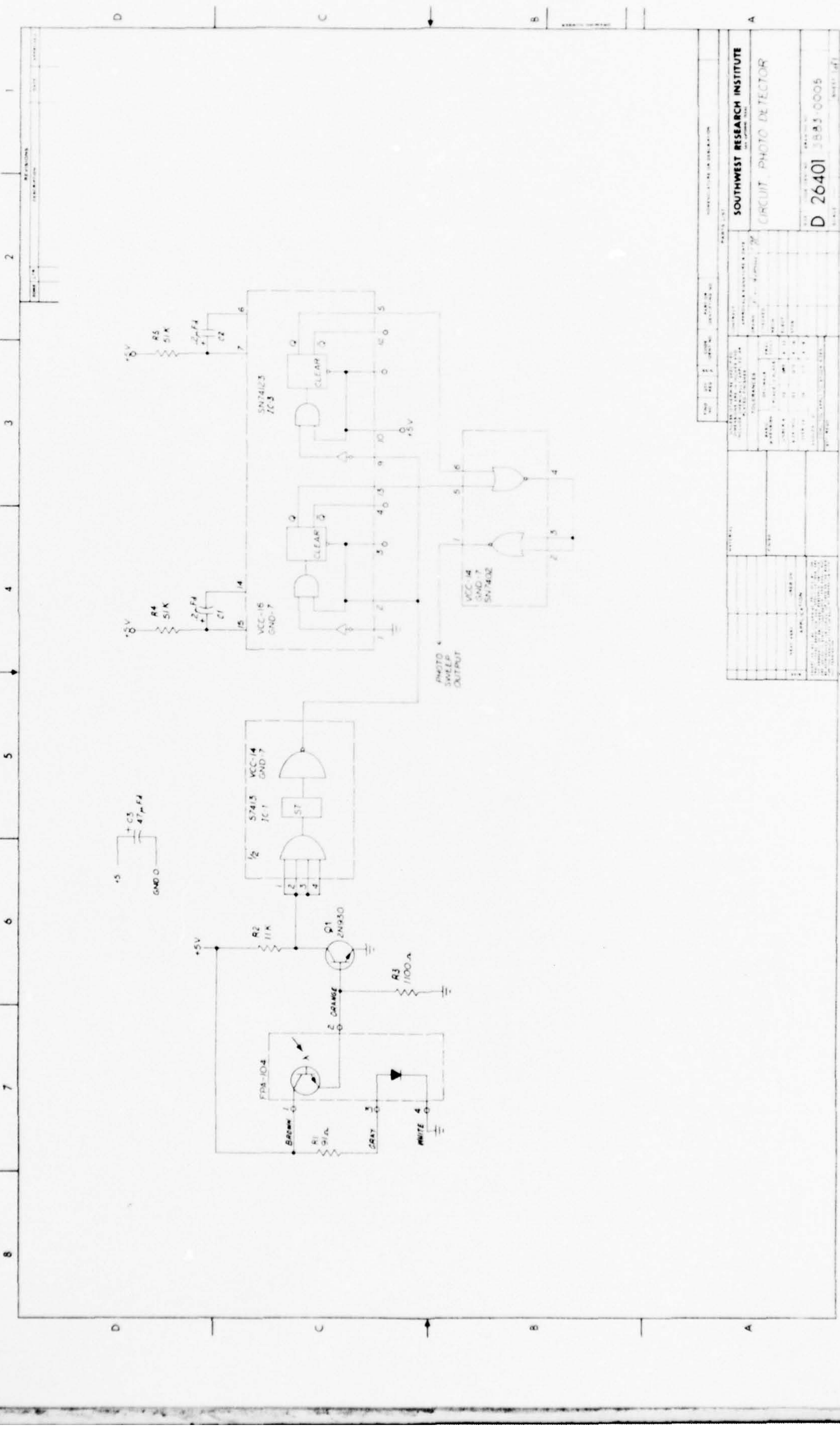
SOUTHWEST RESEARCH INSTITUTE
CIRCUIT, PHOTO DETECTOR
D 26401 3883-0005
PHOTO SWEEP OUTPUT
FPA-104
2N1930
SN74123
SN7402
VCC-14 GND 7
VCC-16 GND 7

FIGURE 8

to the memory unit which wavelength of the stored use limit should be used in the comparison.

The optical system is dependent on the sequential forward movement of the filter wheel. It does not sense direction, i.e., whether the filter wheel motion is forward or reverse. As the Wilks analyzer is used in the automatic scan mode, it always proceeds in a forward direction and the address is recorded in the proper direction.

The optical detector contains the light source and sensing element in a common holder. The sensing element output is detected by a Schmitt trigger to provide a sharp voltage transition output. Two one-shot multivibrators are used to generate a positive voltage pulse for each positive and negative voltage transition of the Schmitt trigger output. The two one-shot outputs are coupled through a gate circuit to a common output. This output is the convert command input to the A/D converter.

C. Analog-to-Digital Converter

The analog-to-digital converter requires two inputs. The first input is the analog information which is to be digitized. The second input is the convert command. An operational amplifier is used to scale the Wilks analyzer absorption level output to be compatible with the 0 to 10 volt A/D converter analog input requirement. This amplifier receives the absorption level output of the Wilks analyzer and provides a gain of 10. An eight digit output represents the converted analog signal in binary form. In order to match the accuracy of the A/D converter to be compatible with the reduced accuracy of the Wilks analyzer only, the four most significant digits are used in the comparison mode. This allows an accuracy of approximately ±2.9%. A status output of the A/D converter indicates when a conversion is in progress. At the end of the conversion command, the λ address is updated. After a short delay (provided by the control circuit), a comparison is made, the digitized absorption level of the unknown gas being the A/D converter output. The schematic diagram of the A/D converter and operational amplifier is shown in Figure 9.

D. ROM Circuit

The ROMs necessary to store the digitized use limit information are contained on the top circuit board. The ROMs are located in plug-in type sockets for ease of removal and installation. This allows other ROMs programmed for different use limits to be used without circuit mofidication. Two ROM 16 pin in-line integrated circuit packages are used for each of the three wavelength scans (six total required). This provides for storage of 64 eight bit words per wavelength scan. The front panel λ reset pushbutton controls which set of ROMs are enabled. The address counter then controls which 8 bit word is available to the comparator of the control circuit. The schematic diagram of the ROM circuit is shown in Figure 10.

E. Storage Circuit

The storage circuit consists of three identical boards. These boards store the highest level received from the comparator. Each board is associated with one of the three wavelength scan intervals and contain eight

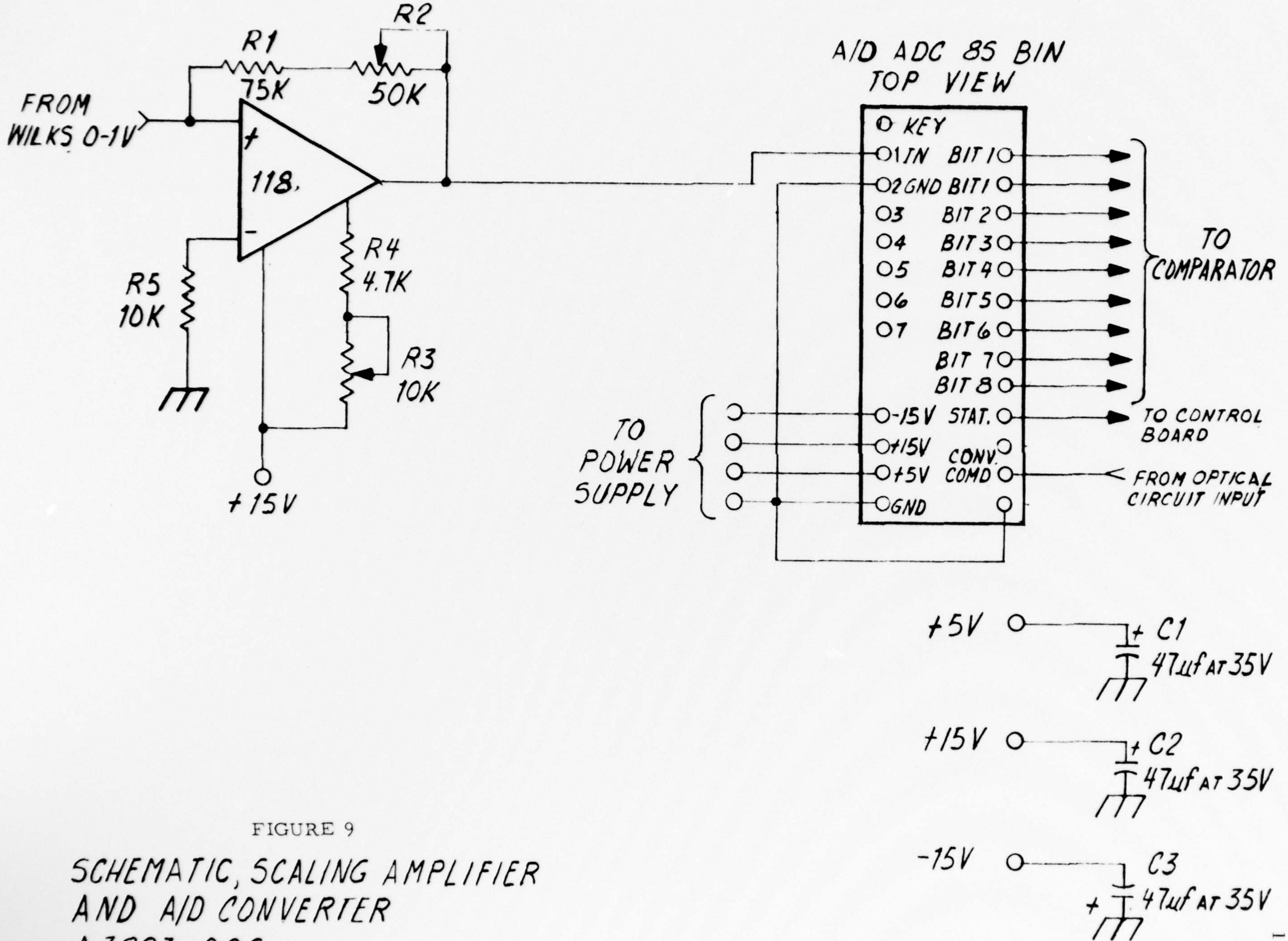

FIGURE 9

SCHEMATIC, SCALING AMPLIFIER
AND A/D CONVERTER
A3883-006

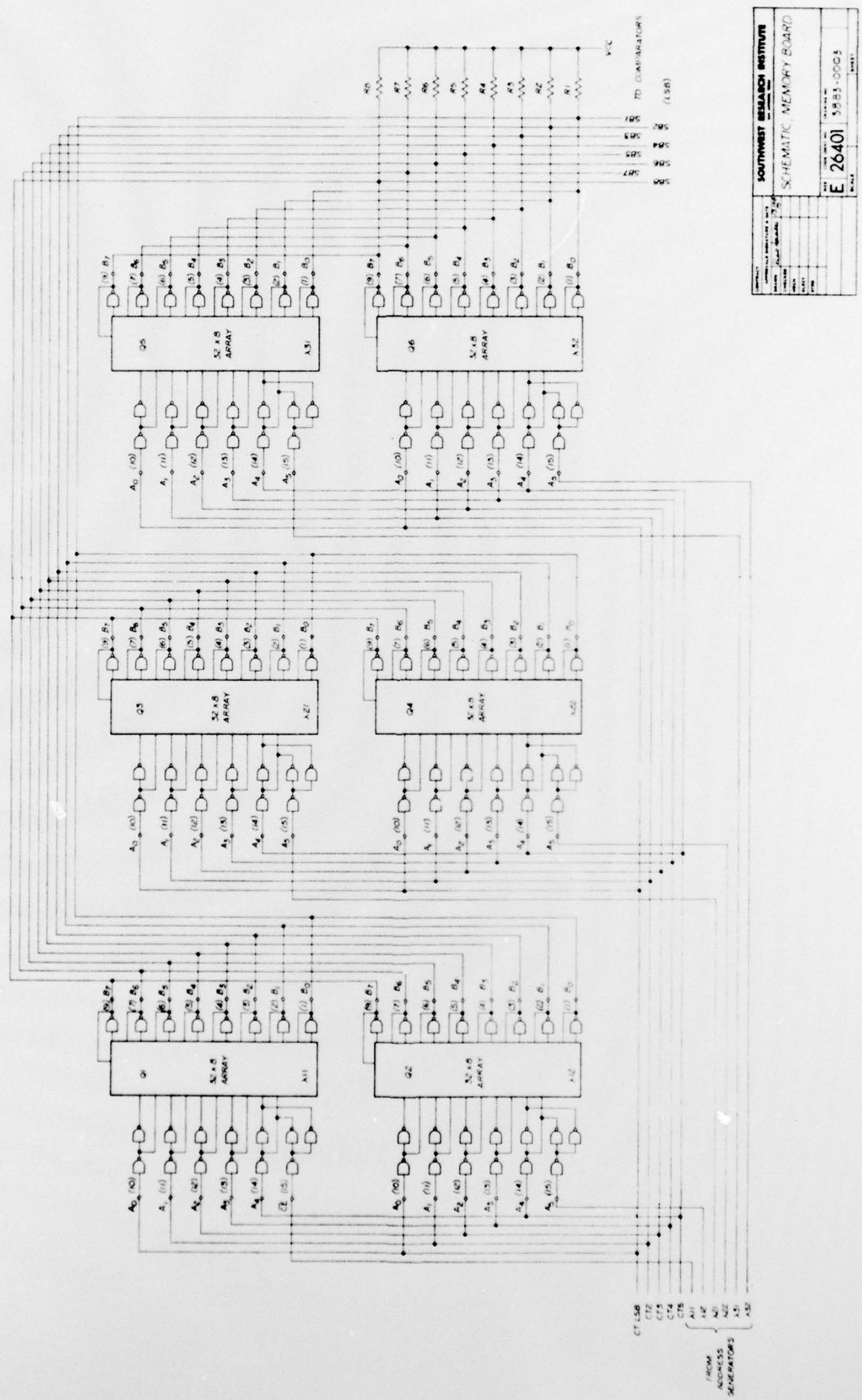
SOUTHWEST RESEARCH INSTITUTE
SCHEMATIC, MEMORY BOARD
E
26401
5983-0003
TO COMPARATORS
VCC
32 x 8 ARRAY
FROM ADDRESS GENERATORS

FIGURE 10

sets of less than, equal to, and greater than storage flip-flops. Each storage circuit board is reset and selected by the corresponding λ reset pushbutton on the front panel. Enabling of the set of 8 flip-flops is controlled by the address counter. The output of these flip-flops controls the front panel lamp indicators. This front panel pushbutton switch also controls which set of ROMs are used for comparison purposes. The schematic diagram of the storage circuit is shown in Figure 11.

F. Control Circuit

The control circuit contains the address counter, the comparator circuits, and generates the pulses which update the display. Additional circuitry necessary to direct the address counter output to the proper storage board and pulse delays are also contained in the control circuit. After completion of a scan sector, the control circuit automatically "locks" the data storage lights for the sector scanned.

When the status command from the A/D converter indicates a completion of the conversion, the address counter is incremented one count. This enables the ROM to display the associated use limit absorption level to the comparator. After a few microseconds the output of the comparator circuit is allowed to be recorded by the storage circuit. The address counter also enables the associated storage circuit which records the comparison level. The schematic diagram of the control circuit is shown in Figure 12 and 13.

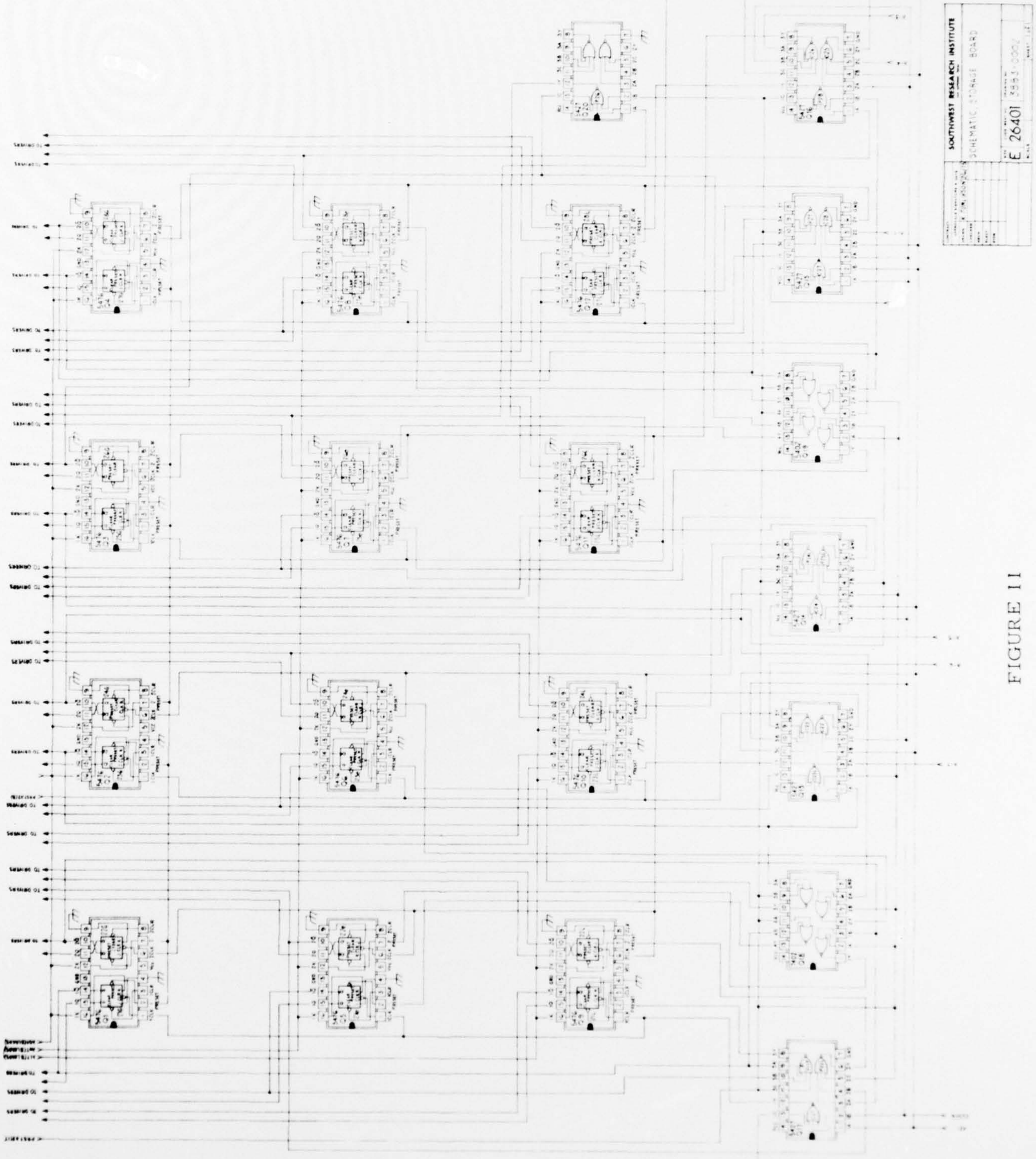
SOUTHWEST RESEARCH INSTITUTE
SCHEMATIC STORAGE BOARD
E 26401

FIGURE 11

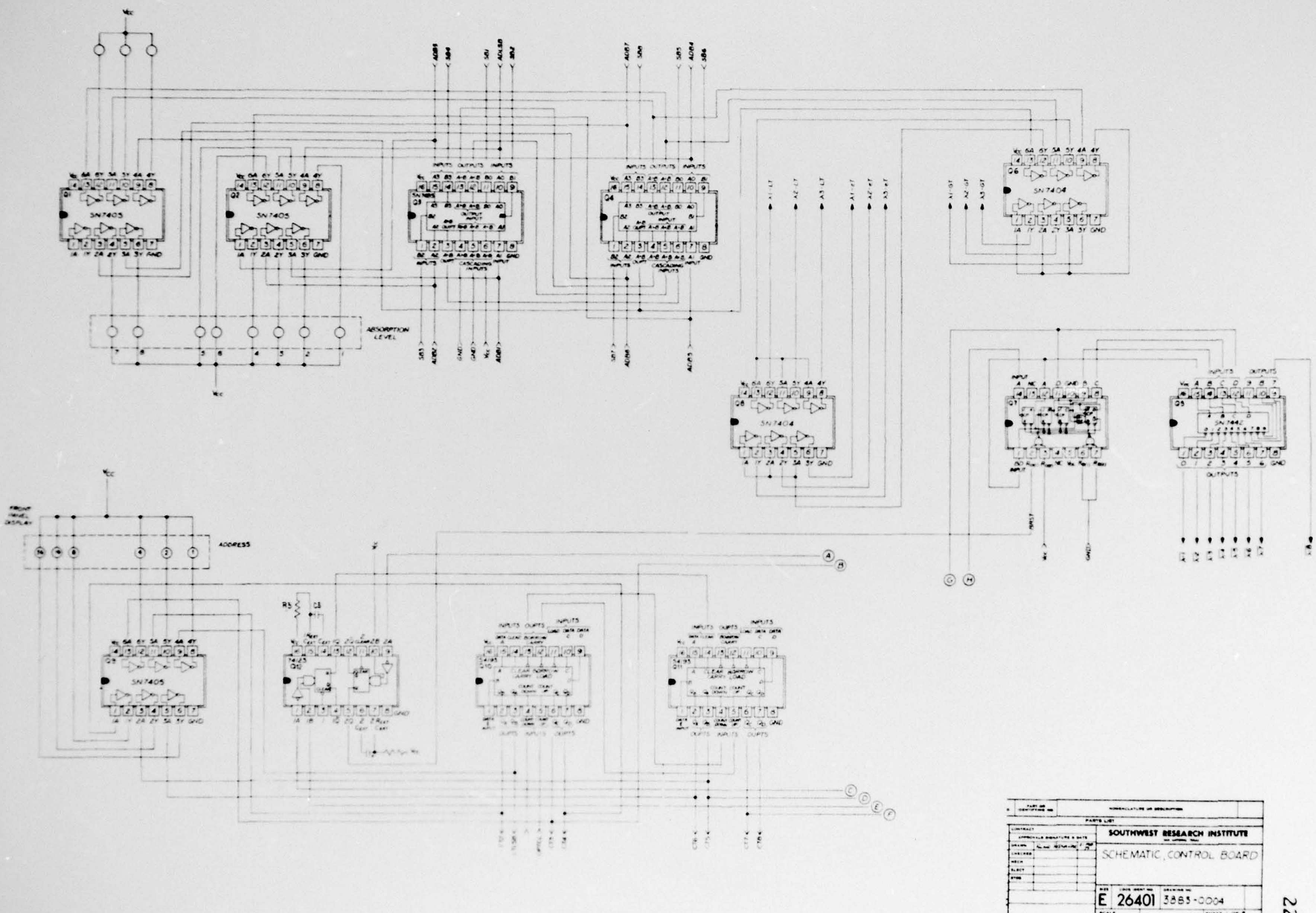
SN7405
SN7405
SN7404
SN7404
SN7442
SN7405
ABSORPTION LEVEL
FRONT PANEL DISPLAY
ADDRESS
SOUTHWEST RESEARCH INSTITUTE
SCHEMATIC, CONTROL BOARD
E 26401 3883-0004

FIGURE 12

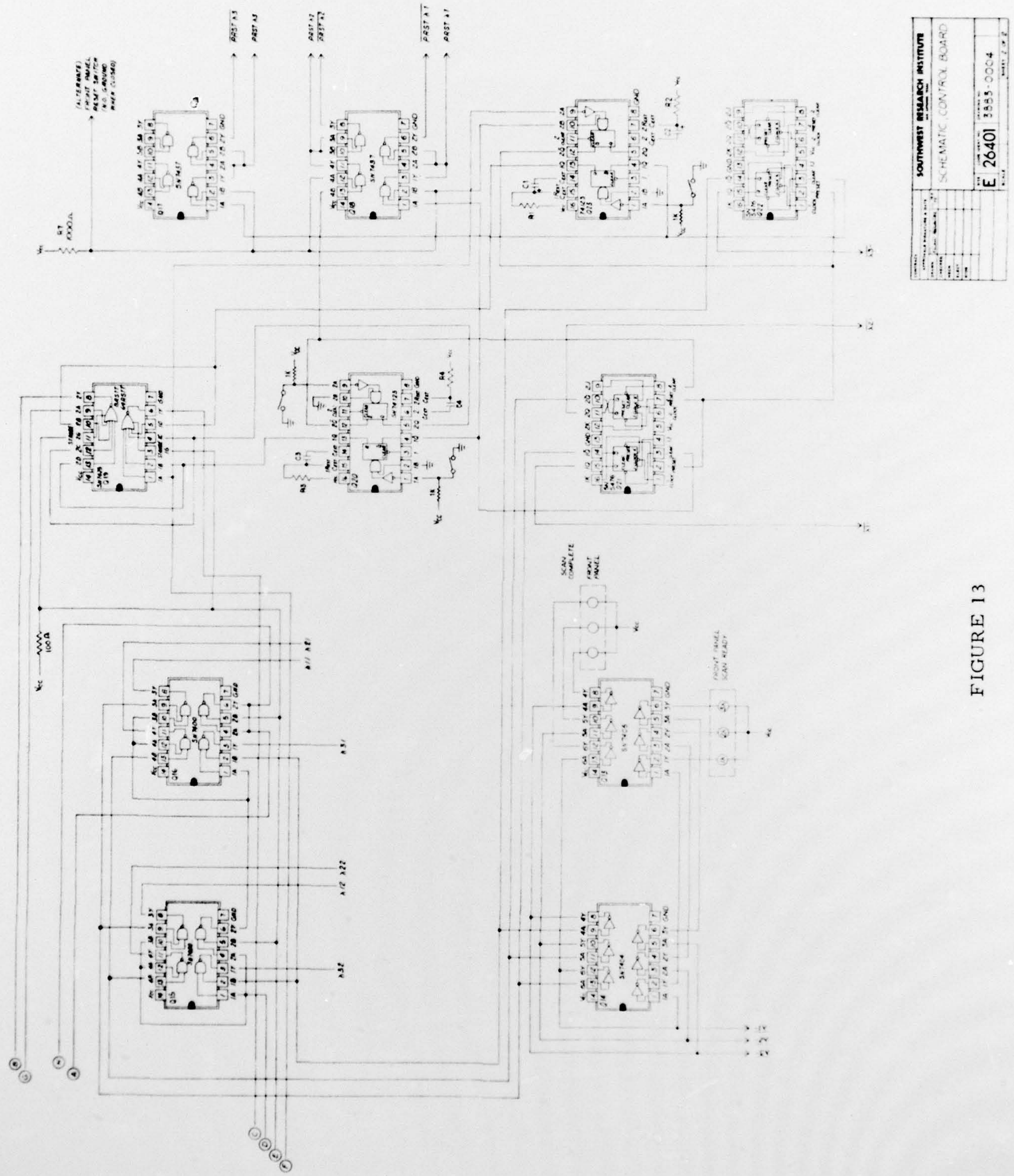
SOUTHWEST RESEARCH INSTITUTE
SCHEMATIC, CONTROL BOARD
E 26401
3883-0004
SCAN COMPLETE
FRONT PANEL
FRONT PANEL SCAN READY

FIGURE 13

G. ROM Programmer

The ROM programmer was designed as specified by the ROM manufacturer. It is a self-contained package and is used to program the digitized use limits. The sequence of operation is detailed in the operation and maintenance manual. A schematic diagram of the unit is shown in Figure 14.

H. 230 Vac to 115 Vac Adapter

The 230 Vac to 115 Vac adapter is a self-contained step-down transformer shown in Figure 3. It is intended for use where only 230 Vac power is available. The unit's ac power cord is plugged into the 230 Vac outlet and the SSRD power cord is plugged into the 115 Vac outlet.

I. Unit Construction

The SSRD chassis and circuit assembly is constructed for easy access to each board. Wire connections between circuit boards are soldered rather than plug-type in order to insure minimum operational problems. The disassembled system is shown in Figures 15 through 17.

J. ROM Programming

The ROMs were programmed according to the use limits sample provided by Brooks AFB. The first set of programmed ROMs were in error due to malfunctioning of the Wilks analyzer. The analyzer was returned to Brooks AFB for realignment and a new sample of use limits gas was introduced into the analyzer. The digitized data was obtained using a digitial storage and display oscilloscope. The results are shown

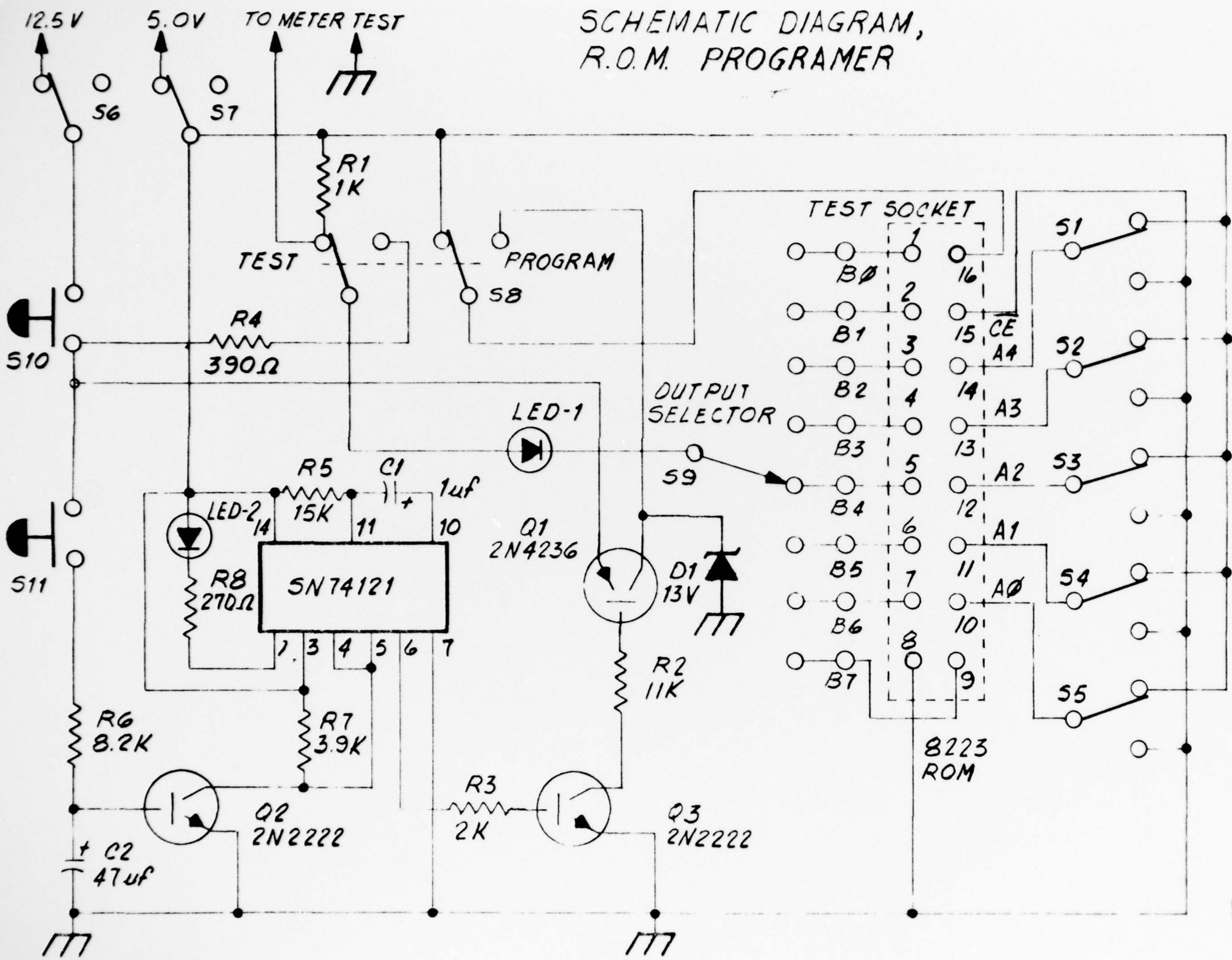
SCHEMATIC DIAGRAM,
R.O.M. PROGRAMER
12.5 V
5.0V
TO METER TEST
S6
S7
R1
1K
TEST
PROGRAM
S8
S10
R4
390Ω
S11
TEST SOCKET
BØ
B1
B2
B3
B4
B5
B6
B7
CE
A4
A3
A2
A1
AØ
S1
S2
S3
S4
S5
OUTPUT
SELECTOR
S9
LED-1
R5
15K
C1
1uf
LED-2
R8
270Ω
SN74121
Q1
2N4236
D1
13V
R2
11K
R6
8.2K
R7
3.9K
C2
47uf
Q2
2N2222
R3
2K
Q3
2N2222
8223
ROM

FIGURE 14

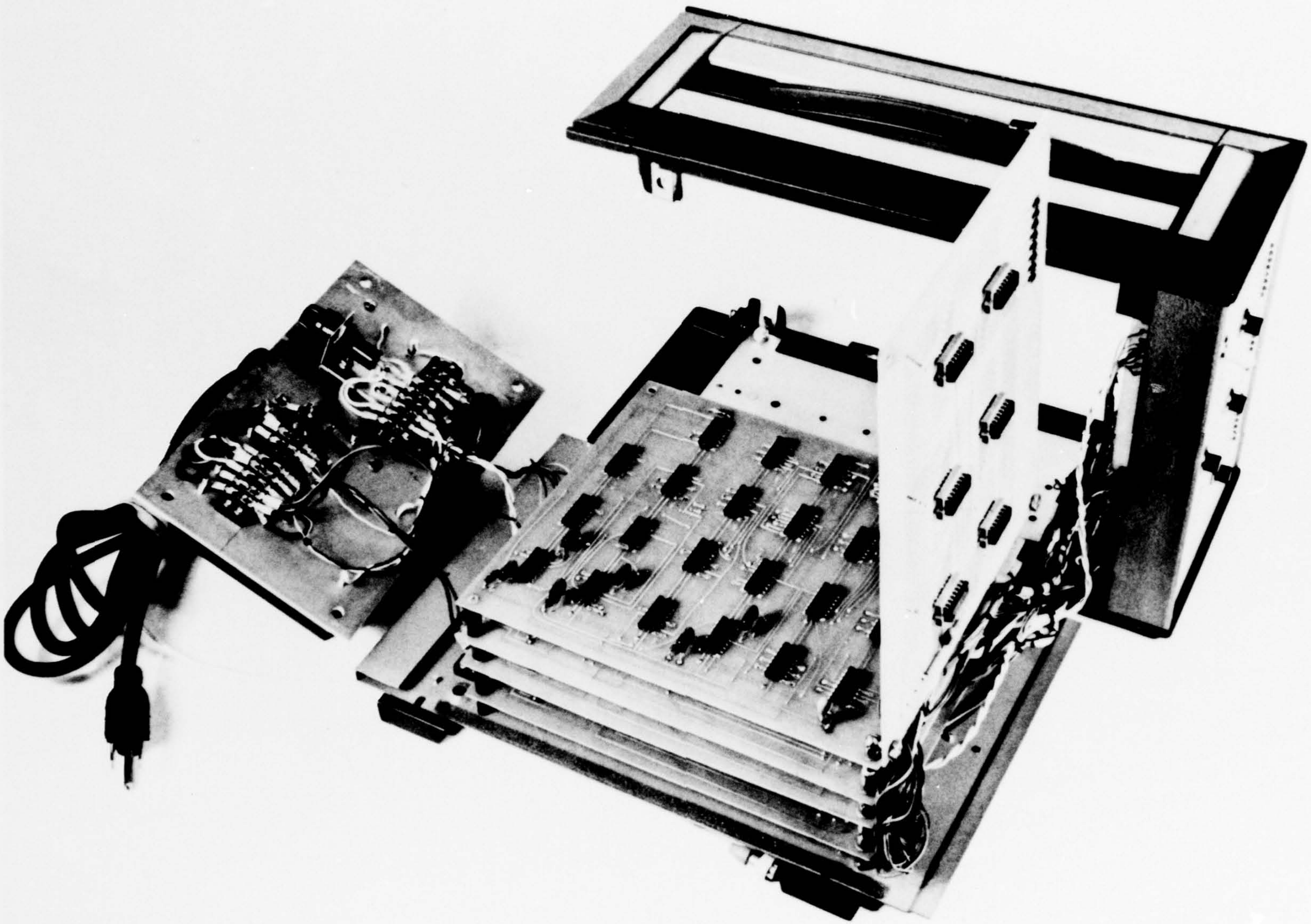

FIGURE 15. SSRD ASSEMBLY, VIEW 1

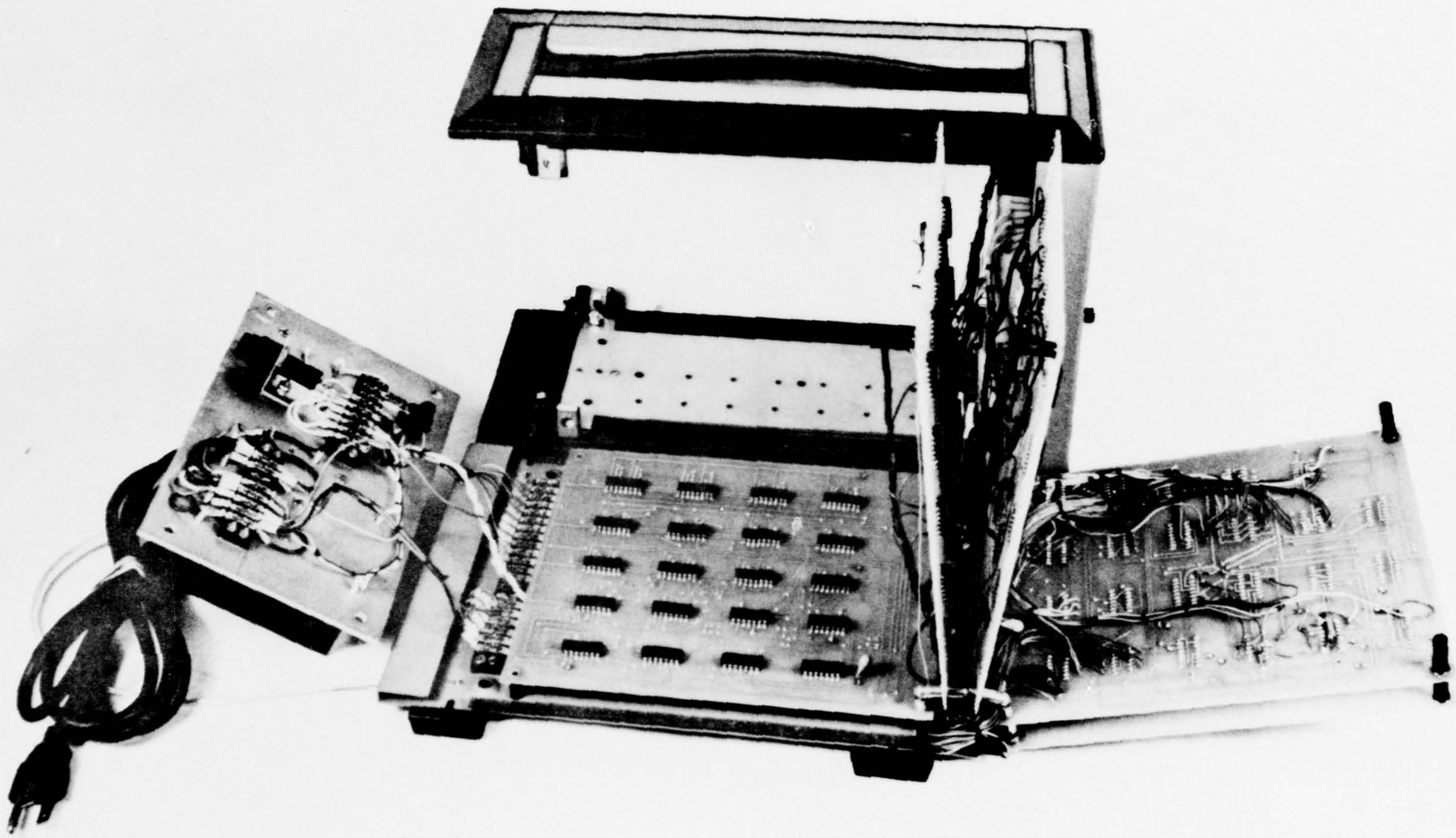

FIGURE 16. SSRD ASSEMBLY, VIEW 2

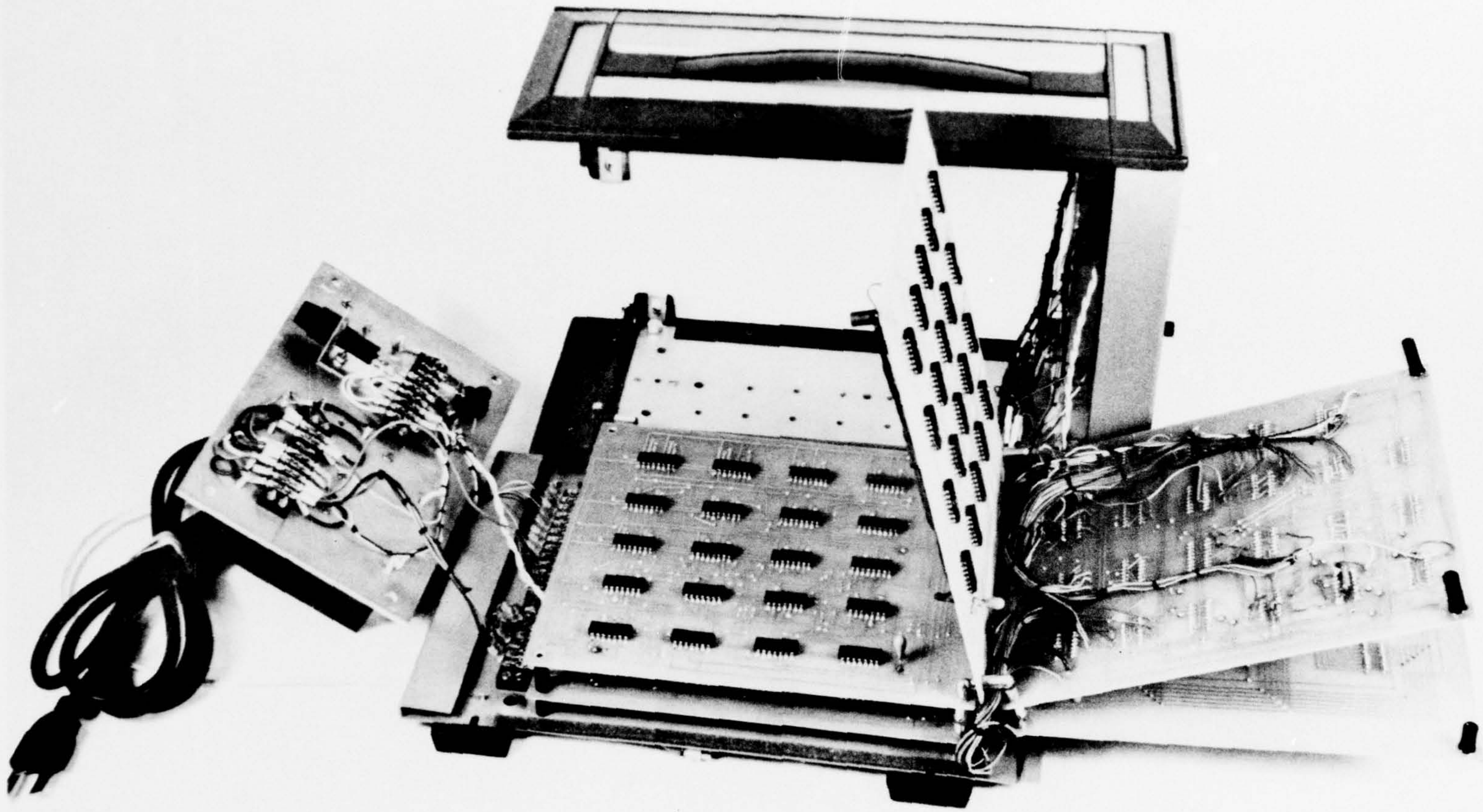

FIGURE 17. SSRD ASSEMBLY, VIEW 3

in Figure 18. The first four significant digits are locked in the logic 1 state in order to reduce the sensitivity of the SSRD to that of the Wilks analyzer. As the digital oscilloscope recorded the actual A/D converter output, the last four digits (LSBs) were rounded off and the necessary weighing factor applied to the fifth significant digit.

K. Tests

The SSRD was tested at SwRI for a period of three days. This test compared the use limit gas from which the ROMs were programmed to the ROM stored value. The SSRD continuously provided the desired results which were an equal to indication on the front panel. The SSRD was then delivered to Brooks Aerospace Medicine for demonstration. The demonstration continued to provide desired results.

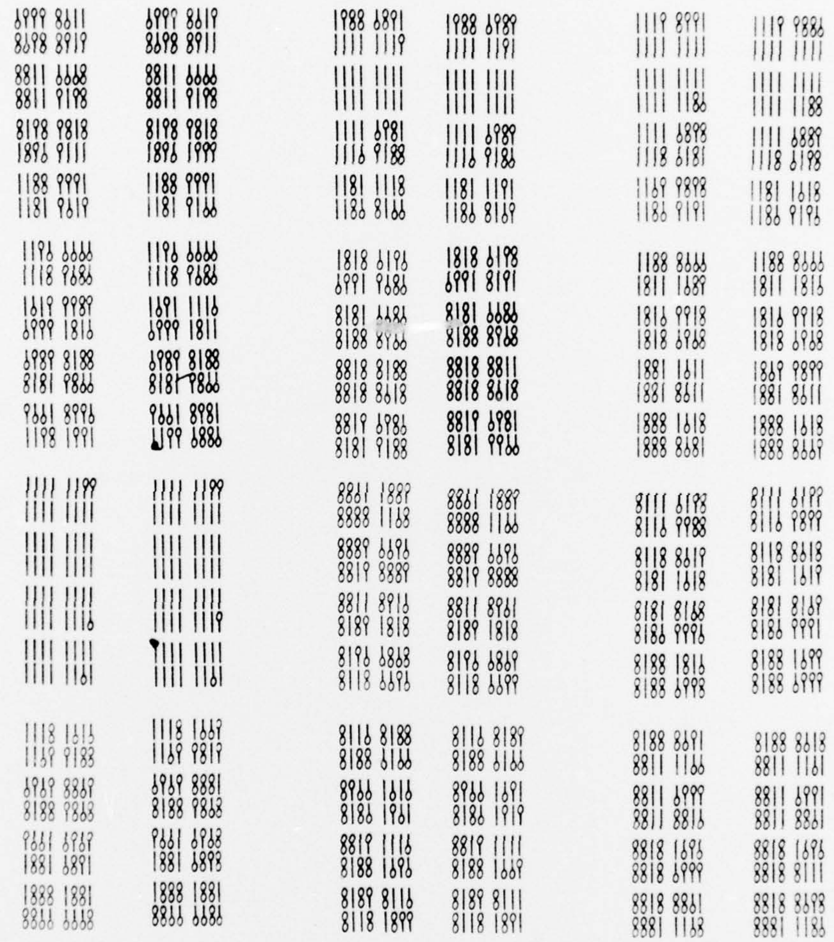

FIGURE 18

ROM PROGRAM DATA

V. CONCLUSIONS

A reliable Solid State Readout Device (SSRD) was developed. The SSRD is capable of ±0.4% accuracy and allows simple operating procedures. The digital output with light display produces an easily understood and repeatable condition of the sampled gas eliminating the requirement for measured interpretation. The device has been operated in excess of 100 hours with no failures and continues satisfactory operating performance.

VI. RECOMMENDATIONS

1. In order to provide a more accurate overall system, the drift in absorption level output of the Wilks analyzer should be corrected. Drift in absorption level output has, at times, been as great as ±2%. When obtaining data for ROM programming, if the analyzer is at a -2% error and when analyzing an unknown sample gas the analyzer is +2%, an overall error of 4% could occur.
2. An improved method of obtaining filter wheel position (relating to the wavelength) should be employed. An improved method would sense the actual position of the wheel at all times rather than be dependent on the filter wheel forward motion. Employment of a shaft encoder can replace the existing binary filter wheel mask thus allowing the analyzer scan to begin at any point.
3. If the requirement exists for multi-deployment of infrared gas analyzers with an SSRD, modification of the SSRD can be accomplished to allow operation with a remote located computer. In this manner many types of use limits can be stored in the central computer for various gases and contaminants of interest.