NASA TECHNICAL NOTE

NASA TN D-3679

c. 1

LOAN COPY: RETURN TO
AFWL (WLIL-2)
KIRTLAND AFB, N MEX

TECH LIBRARY KAFB, NM
0130690

NASA TN D-3679

DATA CONVERTER AND DISPLAY SYSTEM FOR THE WISCONSIN EXPERIMENT ON THE ORBITING ASTRONOMICAL OBSERVATORY

by Sterling R. Smith

Goddard Space Flight Center
Greenbelt, Md.

RECEIVED 1 NOV 1966

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • OCTOBER 1966

TECH LIBRARY KAFB, NM
0130690

NASA TN D-3679

DATA CONVERTER AND DISPLAY SYSTEM FOR THE WISCONSIN EXPERIMENT ON THE ORBITING ASTRONOMICAL OBSERVATORY

By Sterling R. Smith

Goddard Space Flight Center
Greenbelt, Md.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – Price $1.00

ABSTRACT

The design of a Data Converter and Display System (DCDS) used during the environmental testing of the Wisconsin Experiment Package (WEP) carried aboard the first Orbiting Astronimical Observatory is described. It is the function of the DCDS to accept, store, decode, convert, and display data from the WEP. The report includes electronic interface requirements, data conversion and display requirements, logic design, and implementation into final hardware.

CONTENTS

DATA CONVERTER AND DISPLAY SYSTEM FOR THE WISCONSIN EXPERIMENT ON THE ORBITING ASTRONOMICAL OBSERVATORY*

by
Sterling R. Smith
Goddard Space Flight Center

INTRODUCTION

The Wisconsin Experiment Package (WEP) is one of the experiments aboard the first Orbiting Astronomical Observatory (OAO), a standardized spacecraft in which various optical experiments will be orbited (References 1 and 2).

The primary objective of the WEP is to determine the spectral energy distribution of selected stars in the 3300 A to 900 A region and the emission line intensities of selected diffuse nebulae in the same region. To do this, the WEP is comprised of a prime system of four stellar photometers and one nebular photometer, and a backup system of two scanning spectrometers.

The WEP is required to undergo environmental testing which includes optical calibration in a vacuum-optical chamber, vibration, cold temperature tests in a large temperature chamber, and a thermal-vacuum test in another chamber. Because of the large size of the spacecraft compared to the chamber sizes, the WEP cannot be housed in the spacecraft during testing. The encoding and telemetry equipment is a part of the spacecraft. Since experiment data will not be available through normal telemetry channels, part of the spacecraft electronics has been simulated so that the WEP will electronically "see" the spacecraft while it is being tested. This also helps to simulate the orbit environment. The spacecraft simulator, called the Experimenters Test Control Unit (ETCU) is capable of issuing commands to the WEP and receiving and storing its data output. In order to provide immediate data retrieval in engineering units, a Data Converter and Display System (DCDS) was conceived. The DCDS receives the data via the ETCU before it is stored in the ETCU memory. It is the function of the DCDS to accept, store, decode, convert, and display data from the WEP. The real-time display is required because a normal checkout of the WEP takes approximately four hours and it is necessary to keep a running check on the functioning of the WEP. Data transferred to the ETCU are stored until the conclusion of the test, at which time

*A dissertation submitted to the faculty of the School of Engineering and Architecture of the Catholic University of America in partial fulfillment of the requirements for the degree of Master of Science in Space Science

BIT NUMBER	1 2 3	4 5 6 7 8 9 10 11	12 13 14	15 16	17	18 19	20 21 22	23 24	25
GATE NO. 1 (WORD NO. 1)	WORD I.D. CODES 0 0 0	STELLAR PHOTOMETER MEASUREMENT DATA NO. 1	FILTER POS NO. 1	EXPOSURE TIME #1	APERTURE STATUS #1	MODE ID	NEBULAR FILTER POSITION	NEB EXPOS TIME	NEB APER
GATE NO. 2 (WORD NO. 2)	" 0 0 1	" NO. 2	" NO. 2	EXPOSURE TIME #2	APERTURE STATUS #2	NEBULAR PHOTOMETER MEASUREMENT DATA			
GATE NO. 3 (WORD NO. 3)	" 0 1 0	" NO. 3	" NO. 3	EXPOSURE TIME #3	APERTURE STATUS #3	SCANNING SPECTROMETER MEASUREMENT DATA			
GATE NO. 4 (WORD NO. 4)	SC SP ID (bit 1); " 1 1	" NO. 4	" NO. 4	EXPOSURE TIME #4	APERTURE STATUS #4	STELLAR PH. COLLIMAT. 1 2 3 4 (bits 18–21)	SC SP BAND (bits 22–23)	SP EXP TIME (bit 24)	SP AP STATUS

COLLIMATION STATUS IS 0 WHEN AT A LIMIT SWITCH, OTHERWISE AT 1
APERTURE STATUS: 1 = SMALL APERTURE, 0 = LARGE APERTURE
SPECTROMETER ID: 0 = NO. 2, 1 = NO. 1
SPECTRO EXPOSURE TIME: 0 = 8 SEC, 1 = 64 SEC.
PHOTOMETER MEASUREMENT DATA LEAST SIGNIFICANT BIT ON LEFT

STELLAR FILTER POSITION

NO.	12	13	14
1	0	1	1
2	1	0	1
3	0	0	1
4	1	1	0
5	0	1	0

A

EXPOSURE TIME

STEL	15	16
1/8^s	1	1
1^s	0	1
8^s	1	0
64^s	0	0
NEB	23	24

B

MODE ID

MODE	18	19
A	0	0
B	0	1
C	1	0

C

NEBULAR FILTER POSITION

NO.	20	21	22
1	0	1	1
2	1	0	1
3	0	0	1
4	1	1	0
5	0	1	0
6	1	0	0

D

FORWARD STEP DIRECTION

SCANNING SPECTROMETER BAND

SPEC NO. 1	22	23	SPEC NO. 2	DCDS ID
2000-2500	0	0	1000-1250	1
2500-3000	1	0	1250-1500	2
3000-3500	1	1	1500-1750	3
3500-4000	0	1	1750-2000	4

E

Figure 1—WEP digital output format (Reference 1).

they are processed by an IBM 1401 computer. During optical calibration of the WEP, which can take a number of hours, a real-time data conversion and display is also needed.

This dissertation presents the design of the DCDS from its conception through the implementation into the final hardware.

WEP-ETCU DATA FORMAT

In its normal mode of operation, the WEP will sequentially provide an output of four 25-bit, parallel digital words. These words contain the filter setting of each photometer, time interval of exposure, aperture size of the optical instruments, operating band of the scanning spectrometers, and output measurement data from each sensor. Figure 1 shows the digital output format. In addition to these digital data, 15 analog voltage lines are sampled by the ETCU. The ETCU employs an analog-to-digital converter to encode each voltage into an 8-bit binary syllable. The 15 syllables are grouped into five words of three syllables each. A dummy bit is added to each of these five words to make up five 25-bit words. These analog voltages represent sensor measurement data, status of power supplies, and package temperatures, as shown in Figure 2.

In normal operation, the data under the control of the WEP are transferred through the system in the following manner:

1. ETCU sends a spacecraft status word.
2. ETCU sends two ETCU words.
3. WEP sends four digital words in any sequence and at a rate not to exceed 100,000 words per second.
4. WEP sends five digitally-encoded analog words.
5. ETCU sends a spacecraft status word.

Steps 2 through 4 are repeated six times for a total of 58 words.

	ANALOG DATA FUNCTIONS
1	STELLAR PHOTOMETER #1
2	STELLAR PHOTOMETER #2
3	STELLAR PHOTOMETER #3
4	STELLAR PHOTOMETER #4
5	NEBULAR PHOTOMETER
6	SCANNING SPECTROMETER #1
7	SCANNING SPECTROMETER #2
8	+10 VDC POWER SUPPLY
9	-10 VDC POWER SUPPLY
10	+15 VDC POWER SUPPLY
11	-15 VDC POWER SUPPLY
12	HIGH VOLTAGE POWER SUPPLY
13	CONTROL ELECTRONICS TEMPERATURE
14	NEBULAR TOP TEMPERATURE
15	PRIMARY STRUCTURE TEMPERATURE

Figure 2—WEP analog output data.

WEP-ETCU COMMUNICATIONS

Table 1 shows the signals between ETCU and WEP which are necessary to perform the operations previously described.

A normal data sequence is summarized below.

1. To begin operation, an experiment command is issued to WEP through ETCU.
2. WEP issues "repeat command" to signal beginning of operation and to request a spacecraft status word. As a result, ETCU stores a spacecraft status word.

Table 1

Signals Between ETCU and WEP Necessary to Transfer WEP Controlled Data Through the System

Signal	Source
Repeat command	WEP
Program complete	ETCU
Repeat sequence start	WEP
Store mode ready	ETCU
Store digital word (1, 2, 3, or 4)	WEP
Store analog group I	WEP
Analog cycle complete	ETCU

3. ETCU then issues "program complete" to WEP, which indicates that step 2 is complete.

4. By a "repeat sequence start" signal, WEP requests the two ETCU identification words. Then ETCU issues two 25-bit words, a program code word signifying ETCU's mode of operation, and an identification and time word which provides decoding and elapsed time information.

5. ETCU now informs WEP that it has completed its transmission by issuing "store mode ready."

6. WEP is now ready to relay the data it has generated. It begins by signalling ETCU to accept a digital data word with "store digital word 1."

7. Three more digital words are accepted by ETCU after WEP sends:

   "Store digital word 2"
   "Store digital word 3"
   "Store digital word 4"

   It must be remembered that "store digital word" commands may be issued in any order. That is, the digital words are sent sequentially as a group, but in any order depending on the initial command sent to WEP.

8. On completion of steps 6 and 7, WEP requests ETCU to sample and encode the 15 analog data lines by issuing "store analog group I."

9. After ETCU has completed encoding the analog words, it issues an "analog cycle complete" signal.

10. In a normal data sequence, steps 6 through 9 are repeated six times.

11. To signify the end of a data sequence in the telemetered data, WEP requests a spacecraft status word by issuing a "repeat command." ETCU then stores the spacecraft status word.

DESIGN CRITERIA FOR THE DCDS

The requirements for the display unit were determined as follows:

1. Filter position of each stellar photometer.
2. Exposure time of each stellar photometer.
3. Aperture status for each stellar photometer.
4. Filter position for the nebular photometer.
5. Exposure time for the nebular photometer.
6. Aperture status for the nebular photometer.
7. Spectrometer band.
8. Exposure time for the spectrometers.
9. Aperture status for spectrometers.
10. Spectrometer identification.
11. Mode identification.
12. Eight-bit digital measurement data for the four stellar photometers, nebular photometer, and scanning spectrometers.
13. Eight-bit display for analog functions 1 through 5, 6 or 7, and one of functions 8 through 15 (Figure 2).
14. A binary-to-decimal converter, which selects and displays one of the digital measurement words.
15. A converter which selects and displays one of the binary analog words as a decimal voltage.
16. Formatting and printing of items 1 through 11 on a line printer.

The display system operates in real time. The printer prints after a sequence of four digital data words are received.

ETCU-DCDS COMMUNICATIONS

The following signal lines from ETCU are needed for the operation of the DCDS:

1. Repeat command—Signals DCDS that spacecraft status word is in the output register and may be sampled.
2. Data store—Signals DCDS that a 25-bit data word is in the output register.
3. Store digital word 1—WEP digital word 1 is in the output register.
4. Store digital word 2—WEP digital word 2 is in the output register.

5. Store digital word 3—WEP digital word 3 is in the output register.

6. Store digital word 4—WEP digital word 4 is in the output register.

7. Store analog group I—Signals DCDS that WEP analog words are about to be encoded.

8. Analog cycle complete—Signals DCDS that analog encoding has been completed.

Seven of these are signals listed under "WEP-ETCU Communications." They are routed to the DCDS via ETCU. The "data store" command in generated in the ETCU.

In the original ETCU system, "repeat command" and "data store" were the only signals available to the DCDS, due to cable restrictions imposed by the ETCU Flight Model Subsystem. The DCDS was designed to this constraint. Later the ETCU was modified to replace the flight subsystem with a unit that made the remaining signals available. The DCDS was also modified to operate with these signals.

DISPLAY FUNCTIONS

Figure 3 shows the operation of the display. Receipt of a "repeat command" resets the 0-to-8 word counter to 7. The counter provides synchronization for the DCDS. Since WEP normally uses a sequence of four digital and five analog words (always in that order), a counter with nine states was needed. The data store (DS) line, on which a pulse appears every time a new data word appears, steps the word counter (WC). It also gates the pulse so that the 25-bit data register can accept and store the data. Thus, the first two data store pulses after "repeat command," advance the word counter to 8 and 0. These ETCU words are disregarded by the display. The next data store steps the word counter to 1. Since a count of 1, 2, 3, or 4 denotes digital words, the word counter matrix enables the digital word (DW) line. The digital word decommutator then interrogates data bits 2 and 3 to determine which digital word is in the data register. With this information and the digital word pulse, a digital word gate (DW x GT) is generated and a pulse is put on one of four lines, enabling one of the digital word registers (DW x REG) to accept the data bits from the data register.

On the count of 5, the first of five analog words is in the data register. The problem now is to separate this word into three 8-bit syllables for transmittal to three registers for display. Thus on count 5, the C5 line is enabled, gating data bits 2 through 9 into analog 1 register (AN 1 REG), bits 10 through 17 into AN 2 REG, and bits 18 through 25 into AN 3 REG. As shown in Figure 2, this corresponds to separating and storing data from stellar photometers 1, 2, and 3. On count 6, AN 4 REG and AN 5 REG are filled in a similar manner. The AN 6 or 7 REG can be filled on either a count of 6 or a count of 7. This is needed because at any one time data is needed from only one spectrometer. The choice is left to the experimenter, who uses a toggle switch (SW1) that connects either C6 or C7 to the gating input of the register.

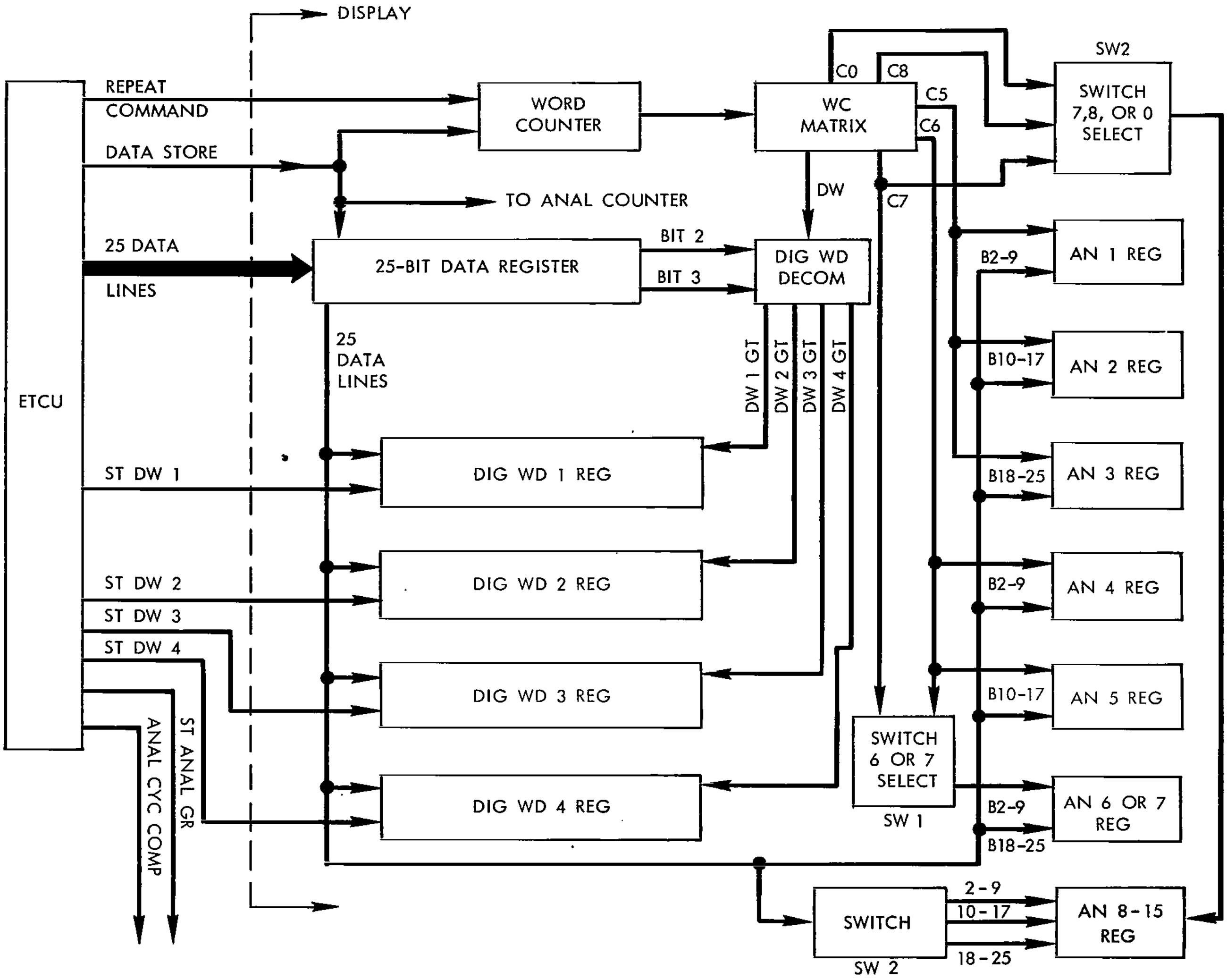

Figure 3—Display system diagram.

Since analog functions 8 through 15 are status data which are monitored only occasionally (Figure 2), only one register is required. By means of a rotary switch (SW2) the desired analog word can be selected, enabling the proper gating pulse and data lines into AN 8 through 15 REG.

The above discussion describes the gating operation when the only communications lines used are "repeat command" and "data store." The operation with the remaining communications lines, or Mode 2, is described below.

In Mode 2, communications lines available are: ST DW 1, ST DW 2, ST DW 3, ST DW 4, ST ANAL GR, and ANAL CYC COMP, in addition to "repeat command" and "data store." When ST DW 1 is pulsed, the data lines contain digital word 1 information; "data store" gates this information into the 25-bit data register, and ST DW 1 pulse then gates this data into DIG WD 1 REG.

Similar data transfer occurs with the remaining digital words. Now, remembering that a ST ANAL GR signal is issued prior to receiving analog words, the ST ANAL GR command is used to set the control flip-flop to the T state (Figure 4). This enables the binary analog counter to accept a gating pulse derived from "data store." The control flip-flop is reset and the analog counter is reset to zero by the ANAL CYC COMP. The output of the analog counter is decoded by the analog counter matrix (AC MATRIX). The AC MATRIX accepts this information, decodes it, and logically uses a delayed "data store" pulse to generate gating pulses to the seven analog registers, corresponding to pulses C5, C6, C7, C8, and C0 generated in Mode 1.

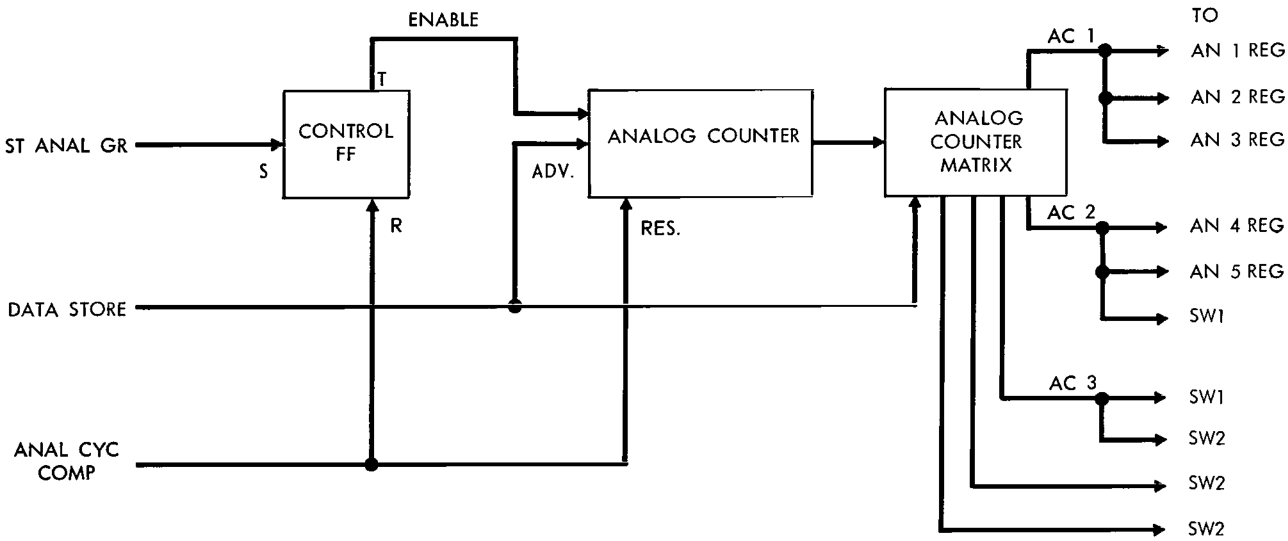

Figure 4—Mode 2 analog control.

To summarize the operation in Mode 2, a "repeat command" is issued but is ignored by the display. A sequence of four digital words is then stored in the proper digital word register by the coincidence of the proper ST DW gating pulse and "data store" pulse. The next pulse is ST ANAL GR, which sets the control flip-flop. The next five "data store" pulses cause the analog counter to count from 1 through 5, generating the gating pulses to store the data in the proper analog registers.

Thus, control and synchronization functions have been completed. Now we turn our attention to the description of the display functions.

DIGITAL DATA DISPLAY

From the digital output format (Figure 1), it can be seen that the filter position information for stellar photometer no. 1 is contained in bits 12, 13, and 14 of digital word 1; exposure time, in bits 15 and 16; and aperture status, in bit 17. The "true" or "one" output of bits 12, 13, and 14 are sent to the filter position matrix, which decodes the bits into the proper decimal number (Figure 1A).

The Boolean equations for such a code are the following:

Letting	1 in 12 = A,
	0 in 12 = $\bar{A}$,
	1 in 13 = B,
	0 in 13 = $\bar{B}$,
	1 in 14 = C,
and	0 in 14 = $\bar{C}$;
then	$1 = \bar{A}\,B\,C$,
	$2 = A\,\bar{B}\,C$,
	$3 = \bar{A}\,\bar{B}\,C$,
	$4 = A\,B\,\bar{C}$,
and	$5 = \bar{A}\,B\,\bar{C}$.

It is to be noticed that with three bits there are eight possible combinations, but only five are used. Therefore, the equations can be reduced by using the Veitch diagram (Reference 4) shown in Figure 5 to produce:

	$1 = B\,C$,
	$2 = A\,C$,
	$3 = \bar{A}\,\bar{B}$,
	$4 = A\,B$,
and	$5 = \bar{A}\,\bar{C}$.

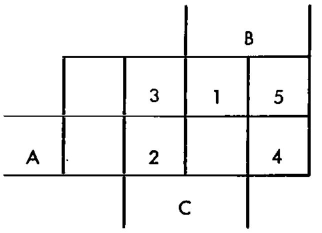

Figure 5—Veitch diagram used to reduce the stellar filter position's Boolean equations.

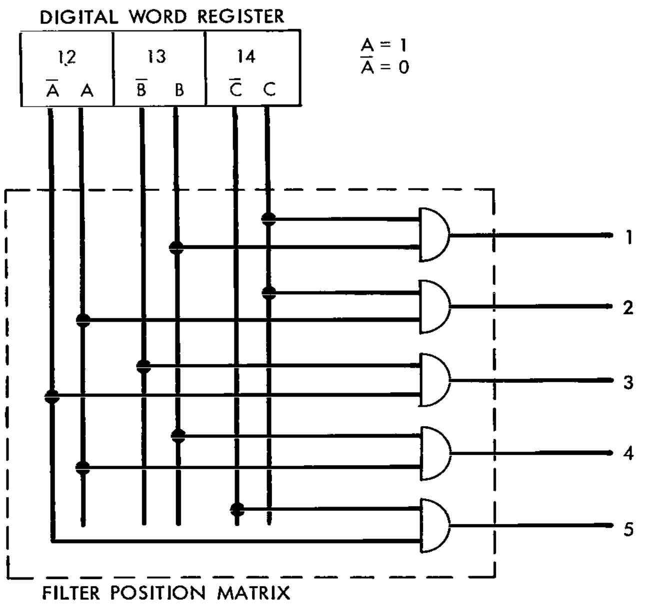

Figure 6—Stellar filter position logic.

These are the equations for the logic diagram of Figure 6, where the blocks at the top indicate flip-flops with 1 and 0 outputs. The area enclosed by the dotted line is the filter position matrix for stellar photometer no. 1, shown in Figure 7.

The exposure time matrix decodes bits 15 and 16 of digital word 1 according to the table shown in Figure 1B. Calling 15 and 16, C and D respectively, the equations for exposure time are:

	$1/8 = C\,D$,
	$1 = \bar{C}\,D$,
	$8 = C\,\bar{D}$,
and	$64 = \bar{C}\,\bar{D}$.

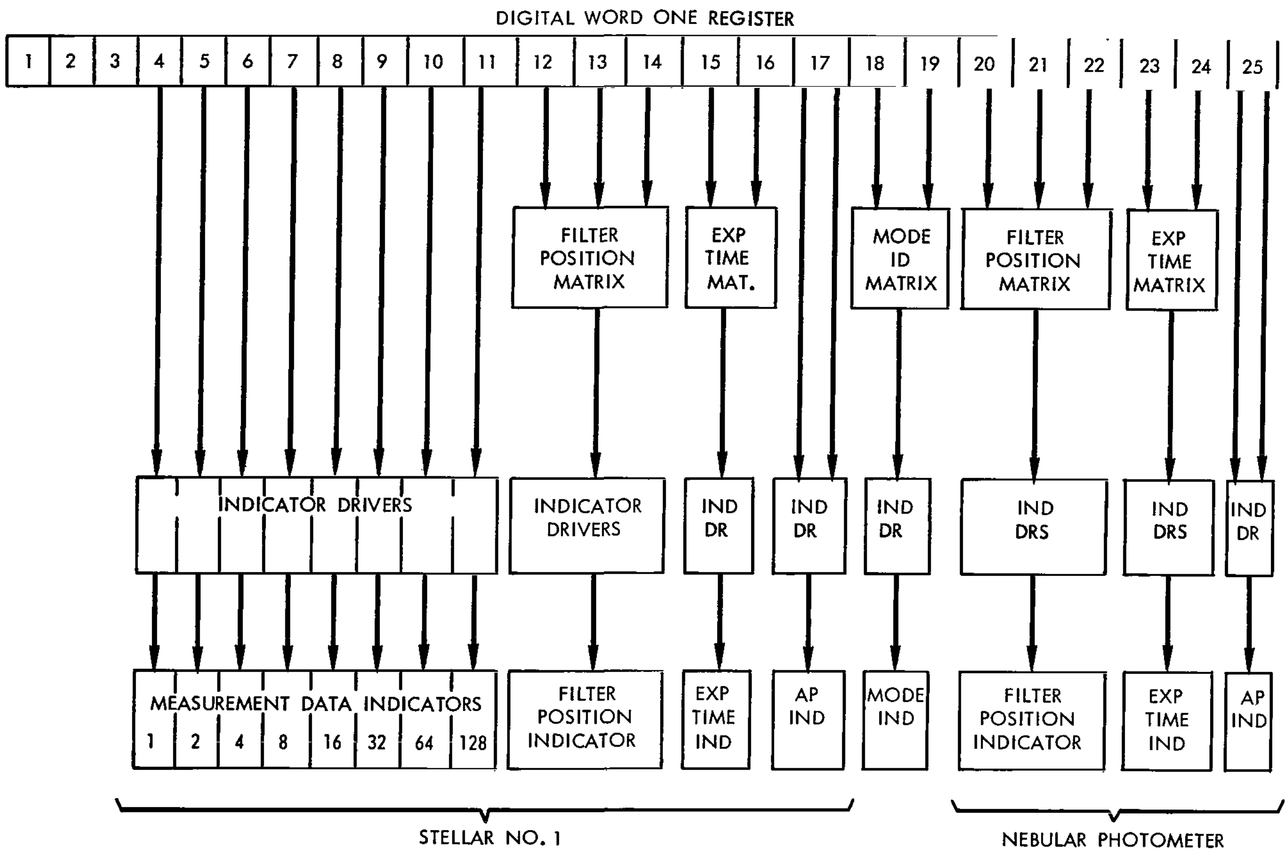

Figure 7—Display functions for stellar no. 1, experiment mode identification, and nebular photometer.

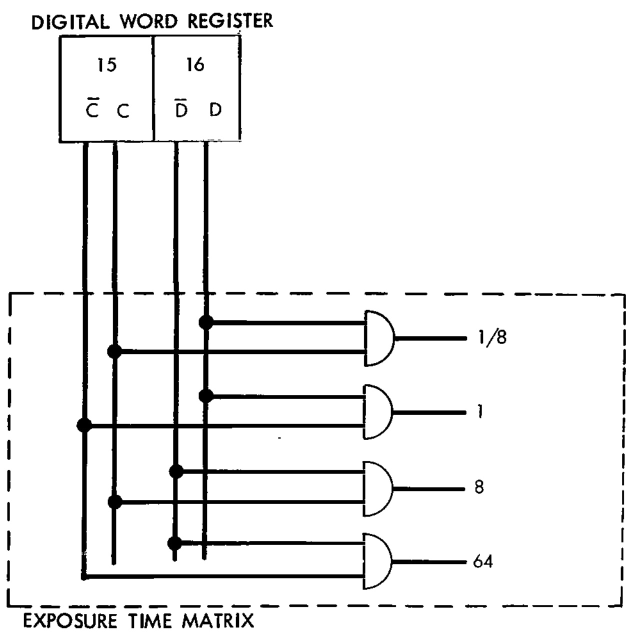

Figure 8—Exposure time logic.

Four segments of information are given by two digital bits, and no reduction can be made. The logic diagram for the exposure time decoding is shown in Figure 8. The area enclosed in the dotted line is the exposure time matrix for stellar photometer no. 1 (Figure 8). A 1 in bit 17 indicates that the photometer aperture is small; a 0, that it is large. No matrix is needed to decode this. The aperture status information for all four stellar photometers is developed in the same manner. Figures 7, 9, 10, and 11 show this.

Since the nebular photometer has six filter positions, a different matrix had to be developed. The bit configurations used by the WEP to identify these positions are shown in Figure 1D. Calling 20, 21, and 22, respectively E, F, and G,

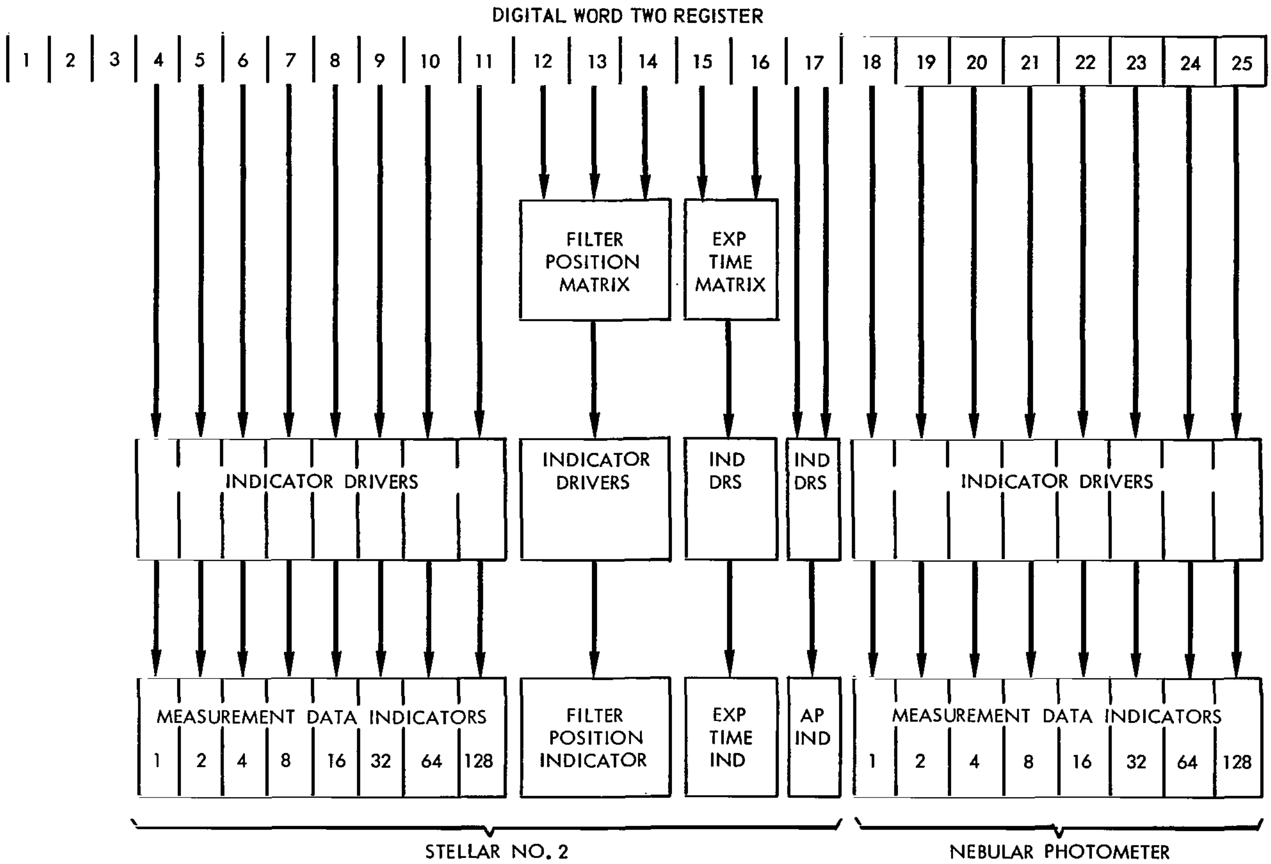

Figure 9—Display functions for stellar no. 2 and nebular photometer.

the Boolean equations are:

$$1 = \overline{E}\,F\,G,$$
$$2 = E\,\overline{F}\,G,$$
$$3 = \overline{E}\,\overline{F}\,G,$$
$$4 = E\,F\,\overline{G},$$
$$5 = \overline{E}\,F\,\overline{G},$$
and
$$6 = E\,\overline{F}\,\overline{G}.$$

Again, reduction is performed by use of the Veitch diagram method (Figure 12) to obtain the following equations:

$$1 = F\,G,$$
$$2 = E\,G,$$
$$3 = \overline{E}\,\overline{F},$$
$$4 = E\,F,$$

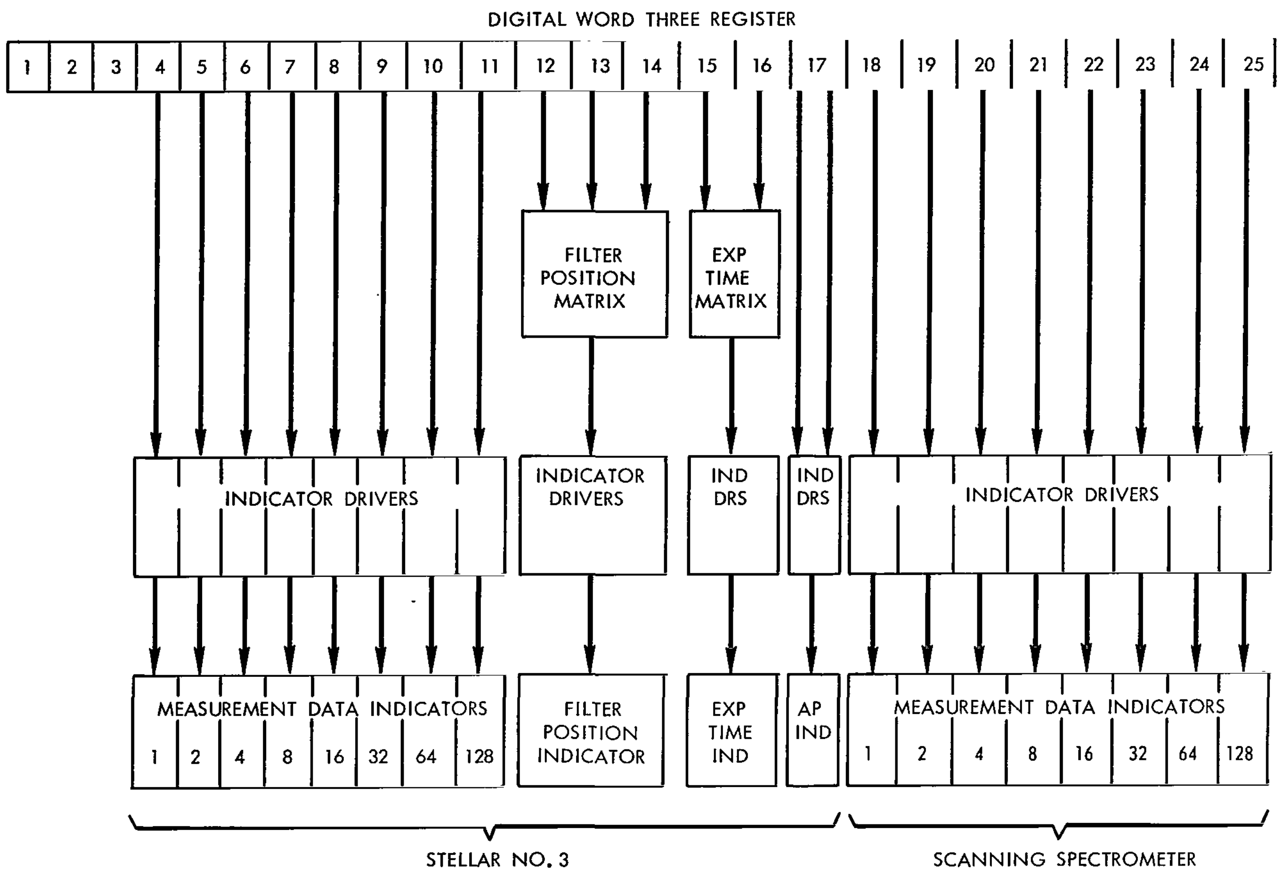

Figure 10—Display functions for stellar no. 3 and scanning spectrometer.

$$5 = \overline{E}\,\overline{G},$$

and

$$6 = \overline{F}\,\overline{G}.$$

From these reduced equations, the logic diagram is obtained and presented in Figure 13. The area enclosed by the dotted line is the nebular filter position matrix. The nebular exposure time matrix and aperture identification are the same as for the stellar photometers.

Bits 22 and 23 of digital word 4 identify the band being used by the spectrometer in operation. The spectrometer identification is obtained from bit 1 of word 4, which identifies the spectrometer in action. The digital output format (Figure 1) shows how the bands are identified. Again, two digital bits are used to identify four parcels of information, and a matrix similar to the stellar exposure time matrix (Figure 8) is used to decode this data.

Since the scanning spectrometers have exposure times of only 8 and 64 seconds, only one data bit (Bit 24) was needed to identify the time, and it was handled similar to the aperture status.

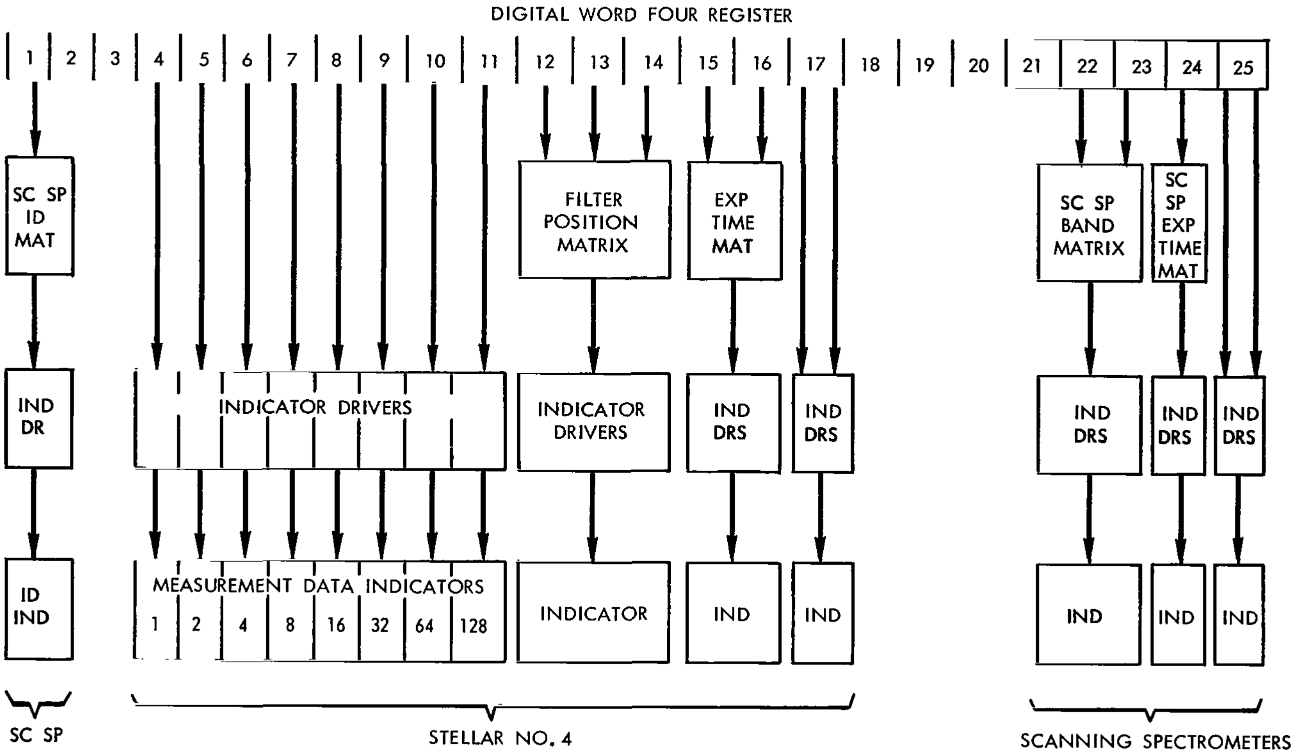

Figure 11—Display functions for stellar no. 4 and scanning spectrometers.

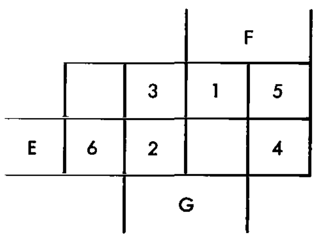

Figure 12—Veitch diagram used to reduce the nebular filter position's Boolean equations.

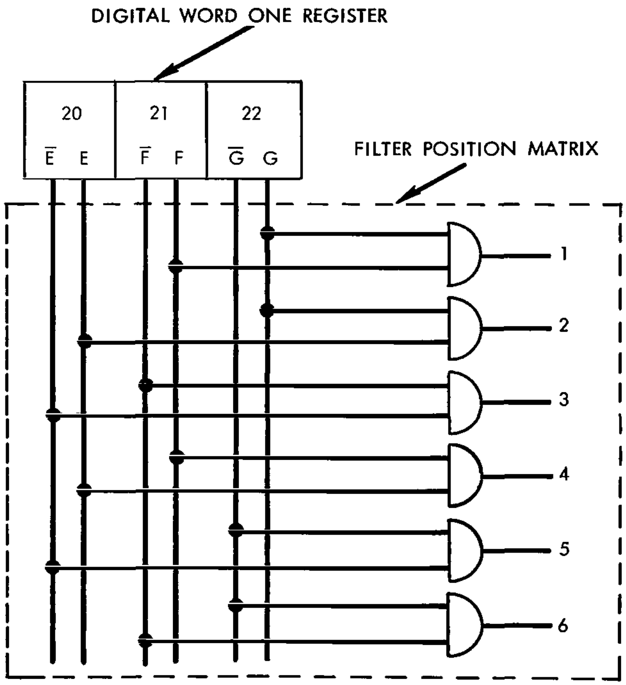

Figure 13—Nebular filter position logic.

Before proceeding further, it would be advantageous to see what is done with the outputs of the matrices explained above. In the case of filter identification and exposure times, each output is sent through a one transistor amplifier that switches the ground on and off an incandescent light bulb indicator. The indicators used were of the rear projection type in which the light projects a number on a screen. Each decade has ten bulbs with a number pattern in front of it. For example, suppose filter position no. 1 is identified, the "and" gate associated with the one output in the filter position matrix is enabled. This switches on the transistor gate for the light bulb associated with numeral 1 and projects it on the screen.

For the aperture status of each photometer there are two indicators on the display panel. Above one is engraved "small," and above the other, "large." Digital word 2 contains a zero in bit 17. The output associated with the flip-flop "zero" output would be at a negative 6 volt level. This voltage would switch on the PNP transistor associated with the "large" indicator lamp.

Associated with each stellar photometer, nebular photometer, and selected scanning spectrometer is an 8-bit binary number representing the output of one of these sensors as the result of an exposure. As can be seen from the digital output format (Figure 1), stellar photometer no. 1 data are found in bits 4 through 11 of digital word 1; stellar photometer no. 2, in digital word 2, etc. (Figures 7, 9, 10, and 11). To display this information, the true output of each bit is connected to a lamp driver and then to a single indicator. The indicators are arranged on the display panel as shown in Figure 14. Since bit 4 is the least significant bit, it goes to the first binary digit indicator, and bit 5 goes to the second digit indicator, etc.

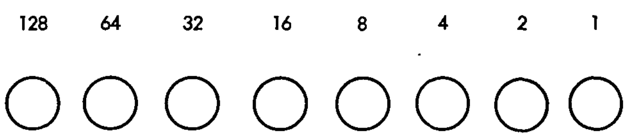

Figure 14—Measurement data indicators.

As mentioned above, there are six such digital count registers. The system has the built-in capability of selecting any one of these six registers and converting the binary number to a binary-coded decimal number and displaying it as a decimal number.

MEASUREMENT DATA CONVERTER

The measurement data converter is made up of a binary to decimal converter that converts and displays a selected digital measurement data word to a decimal number. Also employed in the measurement data converter is another converter which accepts a digitally encoded analog word, multiplies it by 0.02, converts the result to the decimal equivalent, and displays the analog data in decimal form. The reasoning behind this is that the original analog word had been encoded in binary form by the ETCU in such a way that the full count of eight binary bits represents 5.12 volts of analog signal, or each count represents 20 millivolts.

Binary-To-Decimal Converter

The development of the binary-to-decimal converter is based on the "Bidec System" (Reference 5). The 8-bit word is serially shifted into a register with the most significant bit first. After each shift, the new register, which is divided into three groups of four bits each, is interrogated to see if the binary number appearing in each or any group is 10 or greater. If so, a binary 6 is added to that register, plus the carry bit from the previous stage. If a 1 is shifted from the most significant bit of one of the groups to the least significant bit of the next, a 6 must also be added to thè original group. The basis for this conversion is the following: The original number is binary. The new number is a binary-coded decimal number. The first four bits of the binary number has a modulus 16 or a maximum value of 15. The BCD first four bits has a modulus 10 or a maximum value of 9. Thus, if after a shift, the BCD digit (four bits) contains a 10 or greater (an invalid BCD code), a 1 must be added to the next decade and a 10 subtracted from the decade in question. This can be accomplished by adding a 6 to the decade. Table 2 is an example of a conversion of the binary number 11101101 to its BCD equivalent, 237. The decimal equivalent of the original binary number is 237. Thus, the conversion is correct.

In step 7, it is noted that the units digit contains an invalid BCD code. Thus, a binary 6 is added to that digit in step 8.

In step 11, it is noted that a 1 has been shifted from the units digit to the 10's digit. Thus, a binary 6 is added to the units in step 12.

Step 13 is of particular interest. A 1 has been shifted from the units digit to the 10's digit, with the resulting 10's digit having an invalid BCD code. Thus in step 14, a binary 6 is added to both the 10's and the units digit.

In this method, the conversion takes 16 clock times, one for each shift and one for each addition. In the system developed, it was desirable to find a faster method. The first approach is to interrogate and add before the shift. Remembering that a left shift in binary is equivalent to multiplication by 2, the interrogation then looks for a 5 or greater, instead of 10. If this condition is satisfied, a binary 3 is added to the applicable digit. The contents of the register is then shifted one bit, resulting in a valid BCD code in each digit location. Thus, this method takes care of both conditions existing in the previous method since an invalid BCD code cannot appear after the shift, and if a 1 is shifted to the next register, the binary 3 has already been added. Also, it is noted that a carry to the next digit never occurs as a direct result of addition.

Table 2

Example of a Conversion of the Binary Number 11101101 to its BCD Equivalent.

Step		100's	10's	1's
1	Shift	0000	0000	0001
2	I&A	+0	+0	+0
		0000	0000	0001
3	Shift	0000	0000	0011
4	I&A	+0	+0	+0
		0000	0000	0011
5	Shift	0000	0000	0111
6	I&A	+0	+0	+0
		0000	0000	0111
7	Shift	0000	0000	1110
8	I&A	+0	+0	+110
		0000	0001	0100
9	Shift	0000	0010	1001
10	I&A	+0	+0	+0
		0000	0010	1001
11	Shift	0000	0101	0011
12	I&A	+0	+0	+110
		0000	0101	1001
13	Shift	0000	1011	0010
14	I&A	+0	+110	+110
		0001	0001	1000
15	Shift	0010	0011	0001
16	I&A	+0	+0	+110
		0010	0011	0111

The conversion of the binary number 11101101 is again performed, but this time by the new method (Table 3). The BCD number is 237, which is the correct result. This procedure has reduced the number of clock times from 16 to 15, and the number of types of interrogations from 2 to 1. Through the proper logic implementation, this method has been reduced to 8 clock times, the interrogation and addition being accomplished simultaneously through the use of AC gated flip-flops and diode matrix techniques.*

In the display, the BCD output is transformed to a unitary code with diode gates and sent through drivers to the decimal indicators.

Table 3

Example of a Simplified Conversion of the Binary Number 11101101 to its BCD Equivalent.

Step		100's	10's	1's
1	Shift	0000	0000	0001
2	I&A	+0	+0	+0
		0000	0000	0001
3	Shift	0000	0000	0011
4	I&A	+0	+0	+0
		0000	0000	0011
5	Shift	0000	0000	0111
6	I&A	+0	+0	+11
		0000	0000	1010
7	Shift	0000	0001	0100
8	I&A	+0	+0	+0
		0000	0001	0100
9	Shift	0000	0010	1001
10	I&A	+0	+0	+11
		0000	0010	1100
11	Shift	0000	0101	1001
12	I&A	+0	+11	+11
		0000	1000	1100
13	Shift	0001	0001	1000
14	I&A	+0	+0	+11
		0001	0001	+11
15	Shift	0010	0011	0111

Analog Code-To-Decimal Converter

The analog code-to-decimal display converter is similar to that described for the binary-to-decimal converter. The words are again 8 bits, with each bit representing 20 millivolts. Thus, the conversion is made by first multiplying the binary number by 2 and then converting to decimal. This can be accomplished easily by using the same converter and shifting nine times instead of eight. The same type of unitary converter, drivers, and indicators are used with the decimal point between the 100's and 10's digit being continuously illuminated.

Converter Clock Control

The clock control of these converters uses a 50 kc multivibrator and a binary counter. A block diagram is shown in Figure 15. The transfer pulse generated by the word counter and the word counter matrix is sent to the binary counter and the shift register. This pulse resets the counter to zero. The clock begins to run, advancing the counter until the count of 8 (9 in analog conversion) is reached.

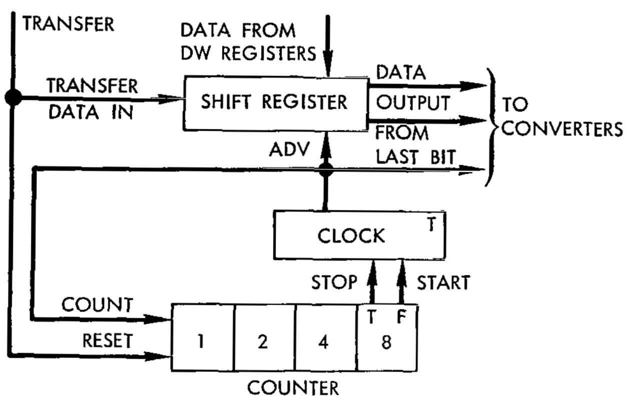

Figure 15—Converter clock control.

*Such as obtained from product data sheet entitled *Pulse Techniques*, Vol. 9, No. 29; published by the Navigation Computer Corp., Norristown, Pa.

RESULTS AND CONCLUSIONS

The completed DCDS is shown in Figure 16. The status panel is shown in the upper left. The upper right panel shows the binary measurement data display. Immediately below this panel is the decimal display of the converted binary data and a small test panel to exercise the DCDS. The printer is located in the middle right and is used to print the information on the status panel using

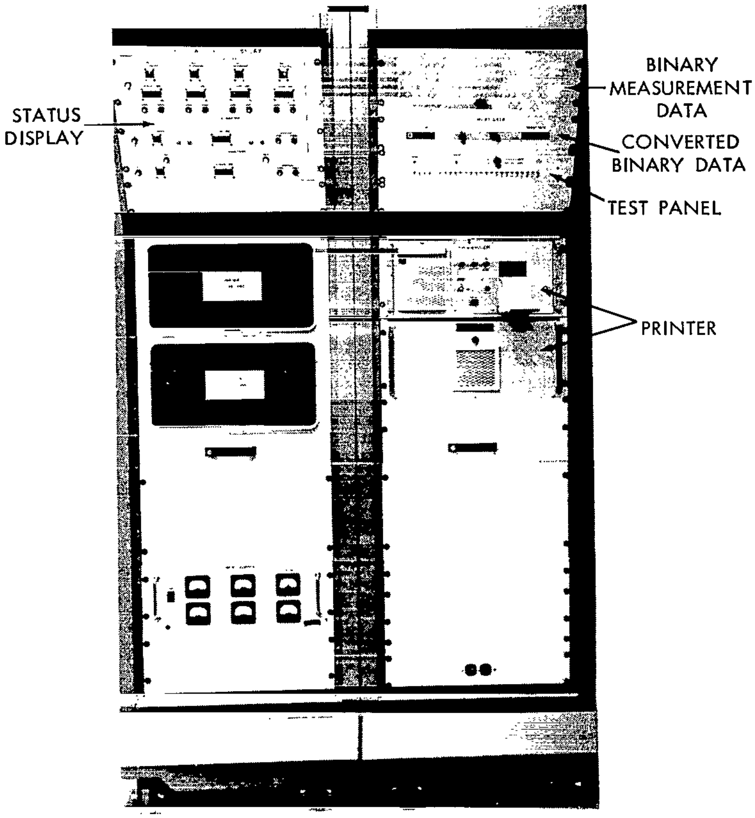

Figure 16—Data converter and display system.

standard formatting techniques. The remainder of the cabinet houses the power supplies and logic circuits.

Figure 17 shows one of the logic card housings extended and two logic cards partially removed from their sockets.

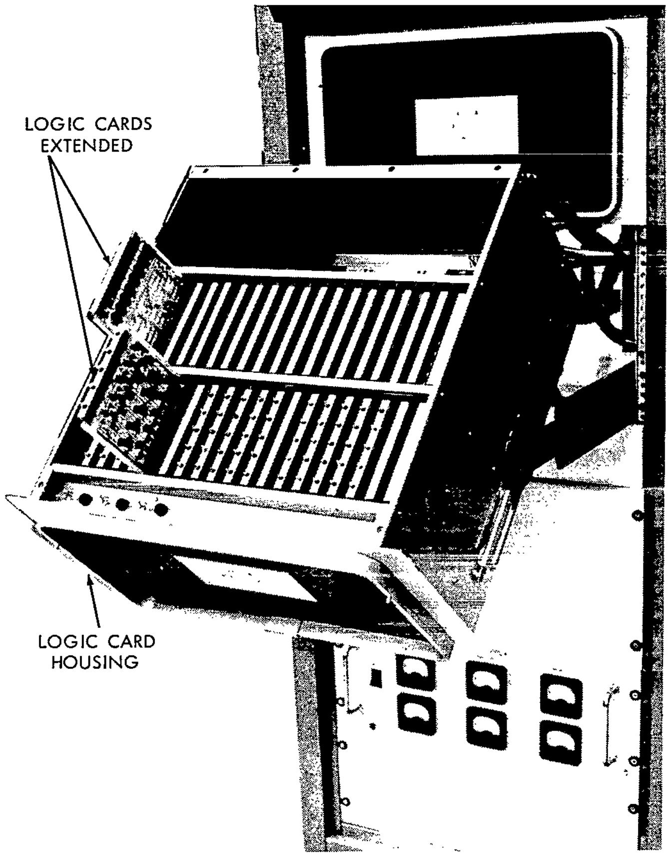

Figure 17—Logic card housing.

The DCDS has been used extensively during the environmental testing of the WEP prototype and first flight model. Its operation has been quite successful, with only a few minor developmental problems arising from the binary converters.

In the future, the DCDS will be used in a similar manner with the second flight model of the WEP.

ACKNOWLEDGMENT

The author gratefully acknowledges the assistance and encouragement given him by Dr. S. C. Ling of The Catholic University of America. The assistance and invaluable suggestions given the author by members of the Electronics Test Branch of the Goddard Space Flight Center are also greatly appreciated.

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland, April, 1966
831-12-03-01-51

REFERENCES

1. "OAO-A Wisconsin Experiment Package Description," Space Astronomy Laboratory, University of Wisconsin, Madison, Wisconsin, July 1964.
2. "OAO Spacecraft Handbook," Grumman Aircraft Engineering Corp., September 1961.
3. Primary Processor and Data Storage Simulator for OAO, Vol. 1, Kingston, N. Y: International Business Machines Corp., November 1963.
4. Chu, Yaohan, "Digital Computer Design Fundamentals, New York: McGraw-Hill, 1962.
5. Couleur, John F., "BIDEC—A Binary-to-Decimal or Decimal-to-Binary Converter," *IRE Transactions on Electronic Computers*, December 1958.

NASA-Langley, 1966

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Technical information generated in connection with a NASA contract or grant and released under NASA auspices.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

TECHNICAL REPRINTS: Information derived from NASA activities and initially published in the form of journal articles.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities but not necessarily reporting the results of individual NASA-programmed scientific efforts. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION DIVISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546