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RADIO AND ELECTRICAL ENGINEERING DIVISION

RESULTS OF QUALIFICATION TESTS ON FLIGHT MODEL 2 OF THE ENERGETIC-PARTICLE-DETECTION DATA ENCODER FOR THE ISIS-A SATELLITE

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OTTAWA

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ABSTRACT

Equipment designed for the ISIS-A satellite must undergo random vibration and thermal-vacuum qualification tests prior to integration into the spacecraft. The energetic-particle-detection experiment on board this satellite uses an integrated-circuit data encoder built by the Radio and Electrical Engineering Division of the National Research Council. Qualification tests on flight model 2 of this encoder were conducted at the Goddard Space Flight Centre from April 22–27, 1968. This report describes the performance of the encoder during these tests.

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RESULTS OF QUALIFICATION TESTS ON FLIGHT MODEL 2 OF THE ENERGETIC-PARTICLE-DETECTION DATA ENCODER FOR THE ISIS-A SATELLITE

– T.H. Shepertycki –

INTRODUCTION

One of the experiments on board the ISIS-A satellite, which is to be launched in late 1968, is an energetic-particle-detection (EPD) experiment that uses an integrated-circuit data encoder built by the Radio and Electrical Engineering Division of the National Research Council [1, 2]. The purpose of this experiment, which was devised by the Division of Pure Physics, is to measure the angular distributions and energy spectra of energetic electrons and protons. Detection of these particles is accomplished by sensors in a detector package built by the Pure Physics Division. Conditioned pulses from this package are sent to the encoder package for further data processing.

The spacecraft must undergo extensive system environmental testing to ensure as far as possible its intended objective. In addition to this testing, experimenters' flight packages must pass qualification tests prior to integration into the spacecraft. These tests are environmental in nature and consist of random vibration done separately in three orthogonal axes followed by thermal-soaking in a vacuum. Flight model 2 of the EPD experiment which consists of a detector and an encoder package was tested at the Telemetry and Environmental Building at the Goddard Space Flight Centre from April 22, 1968 to April 27, 1968. This report documents the performance of the data encoder during these tests.

TEST PROCEDURE

The performance of the EPD data encoder is checked with greatest accuracy by the test set-up shown in Fig. 1 which does not contain the detector package. This arrangement, which allows direct access to the encoder inputs with controlled signals, permits an unambiguous check of encoder operation. However, as an operating experiment

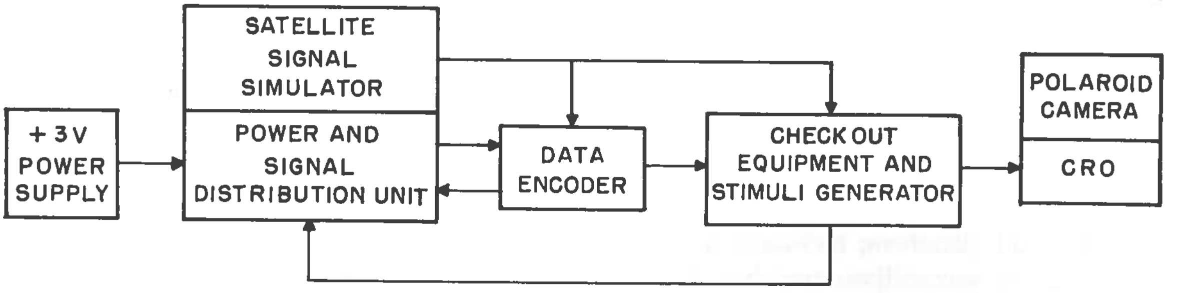

Fig. 1 Block diagram of encoder test set-up

the test set-up shown in Fig. 2 is used. This is, of course, the most realistic set-up although it does have at least one serious drawback for encoder checkout. This is that, except for signals that are supplied by the satellite systems, such as the clock, read-out pulse, and magnetometer outputs, the EPD data encoder inputs are accessible only through circuitry in the detector package. This has two effects. First, when the particle sensors in the detector package are stimulated by a radioactive source, a completely unambiguous check of the encoder becomes difficult. This will be discussed more fully later. Second, in the event of a failure, fault diagnosis is more complicated. Consequently, whenever possible, encoder performance is checked using both test set-ups. The ground support equipment (GSE) which was developed for check-out [3] is not only compatible with either test arrangement but is relatively easy to change from one test set-up to the other.

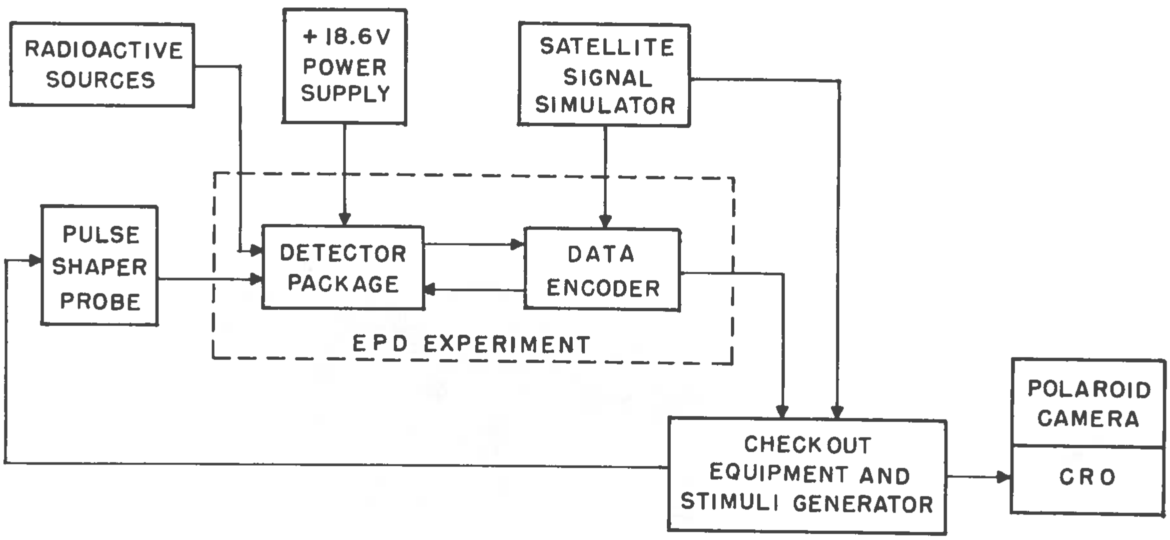

Fig. 2 Block diagram of detector-encoder test set-up

Normally, encoder check-out involves verifying proper operation of:

(a) the frame synchronization pattern generator,
(b) the 16 binary counters,
(c) the 5 digital flags
(d) the 6-channel analog multiplexer, and
(e) the analog–digital converter.

Details about the function of these items have been described previously [1, 2, 3]. Test results are permanently recorded in a log book. A real-time oscilloscope display is used to monitor continuously all of the encoder output data. Polaroid photographs of this display are taken periodically to augment the written records.

TEST RESULTS

Random Vibration (April 23, 1968)

Since the EPD experiment is not expected to be electrically active during launch, the vibration test plan consisted of encoder check-out, as indicated above, before and after the package was vibrated according to the flight vibration levels shown in Table I, in each of the three orthogonal axes X, Y, and Z shown in Fig. 3.

TABLE I

Random vibration (all axes)

Frequency range (cps)	Power spectral density (g^2/cps)	g (rms)	Test duration
20–2000	0.022	6.1	2 min/axis

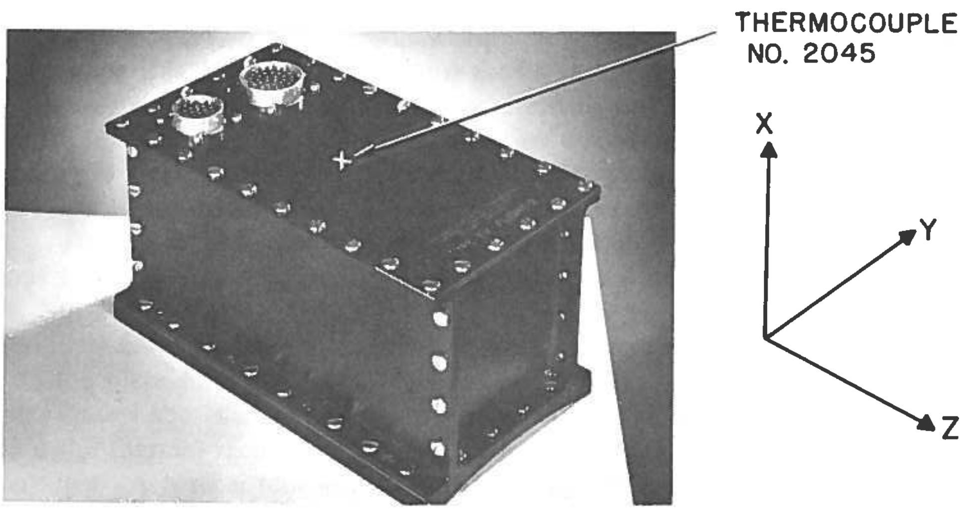

Fig. 3 Pictorial diagram showing orientation of EPD encoder

A vibration plate, which accommodates only one package at a time, was used to mount the packages on the vibration machine. The test consisted of subjecting the encoder package to vibration in one of the axes and checking it out by the method shown in Fig. 1 while the detector package was undergoing vibration in the same axis. This was repeated for all axes. Of course, proper experiment operation was also verified before and after each vibration test. The encoder performed without error throughout these random vibration tests. Further details about the check-out procedure are given in the section describing the thermal-vacuum tests. The photographs in Fig. 5*a, b, c* show typical output frames from the encoder after undergoing random vibration in the X, Y, and Z axes. These frames, obtained with the encoder integrated to the detector package, show the output with and without a radioactive source (Co^{60}) stimulating the detectors in the detector package.

Each trace in a frame represents one 16-bit word with the most significant bit (MSB), bit No. 1, at the extreme left of the word and the parity bit, bit No. 16, at the extreme right of the word. The first eight bits of words 10, 15, and 16 are designated 10A, 15A, 16A respectively. Similarly the latter eight bits of words 10, 15, and 16 are designated as 10B, 15B, and 16B. Sixteen words comprise each frame. Word order from the top to the bottom trace in each frame is as follows: 15, 14, 13, 12, ... 3, 2, 1, 16.

Thermal-Vacuum (April 24, 1968 – April 27, 1968)

Thermal-vacuum qualification tests for experimenters' packages consist of the following two cycles:

Cold soak – 24 hours at $-20°C$, pressure $\leqslant 10^{-5}$ mm Hg (Torr)
Hot soak – 24 hours at $+50°C$, pressure $\leqslant 10^{-5}$ mm Hg (Torr)

The time consuming nature of these tests did not permit independent as well as integrated thermal-vacuum tests on the two packages, as was possible during vibration tests. Consequently thermal-vacuum testing was done with the set-up shown in Fig. 2. The radioactive source was mounted on the detector package to check the operation of the particle sensors in this package. Under these conditions only the most significant bits of the counters can be unambiguously checked by feeding in a controlled group of pulses, since the lower-order bits are activated by pulses which are due to the radioactive stimulation of the detectors.

Throughout these tests, the temperature of the encoder was monitored by mounting two thermocouples, No. 2045 and No. 2240, on the top and side plate of the encoder. The location of thermocouple No. 2045 is indicated in Fig. 3. Thermocouple No. 2040, which was mounted on the plate supporting the two packages, was used for controlling the temperature of the chamber. Plate I shows a view of the detector-encoder package configuration as it appeared outside the thermal-vacuum chamber. Plate II shows the test set-up at some time during the 4-day test. A typical temperature print-out as supplied by a central computer* once per minute to a nearby printer is shown in Fig. 4. This record shows that at 1421 hours of

2	4	4	0	L	-	0	2	0	9
2	2	4	5	L	-	0	2	0	9
2	2	4	0	L	-	0	2	1	0
2	0	4	5	L	-	0	2	0	9
2	0	4	0	L	-	0	2	0	7
0	1	1	6	T	-	1	4	2	1

Fig. 4 Typical temperature print-out

*Data Central, Telemetry and Environmental Building, GSFC the 116th day of the year (April 25th) the control temperature was -20.7°C while the encoder temperatures as measured by thermocouples No. 2045 and No. 2240 were -20.9 and -21.0°C, respectively. The pressure at the time was recorded as 2.9×10^{-7} Torr.

The photographs in Fig. 5, *d, e, f* show typical output frames from the encoder just before thermal-vacuum testing while the frames shown in Fig. 6 were obtained while the encoder was operating at a temperature of -20.4°C and a pressure of 2.7×10^{-7} Torr. Note from Fig. 6*a* that radioactive stimulation of the detectors activates the lower-order bits of all counters except those represented by words 12, 13, 14, 15A, and 16B where only an occasional count of 1 or 2 is recorded. This makes complete checkout of these latter counters possible by introducing a controlled number of pulses by a pulse shaper probe into the appropriate pins of a test connector which is brought out of the chamber on a hard line. Figures 6*b, c, d,* and *e* show one phase of this checkout in which the number of pulses injected into these counters was selected to produce an alternating series of ones and zeroes in the word bit pattern. Words which are already active due to the radioactive source are checked by feeding in a pulse burst that will give an alternating series of ones and zeroes in those bit positions which are not affected by the source. See, for example, word 6 in Fig. 6*f*.

Figures 7 and 8 show encoder output frames at temperatures of +50°C, 6.7×10^{-7} Torr and +20°C, 600 Torr, respectively.

Operation of the 6-channel multiplexer and analog-digital converter is easily checked by feeding 0–5 volt dc signals, monitored with a digital voltmeter, into the four analog channels while using the 8-channel subcommutator in the GSE to display the appropriate channels of word 10 which represents the output of the analog-digital converter. A record is also made of the count representing the internally-generated 5-volt and 2.5-volt calibration signals.

In addition to this a complete input-output characteristic of the analog-digital converter is taken by feeding a series of digitally-measured analog voltages into channel 2 and recording the count as displayed in channel 2 of word 10A. The results of these measurements taken at -20°C, +50°C, and +20°C are shown in Fig. 9*a, b* for levels near 0 volts and 5 volts, respectively.

A measure of the differences between channels is made by measuring the minimum analog voltage required to produce a particular count in each of the four channels. The results of some of these measurements at +50°C and +25°C are shown in Table II. Spot checks at -20°C showed disparities between channels similar to that at 50 and 25°C.

DISCUSSION

Before qualification testing at GSFC, flight model 2 of the encoder had undergone some 200 hours of testing at temperatures between -20°C and +50°C at normal atmospheric pressures. In comparing results of this testing with that obtained at GSFC, no differences were noted which were greater than the experimental accuracy of the instruments used. The encoder was again successfully operated and checked for 13½ hours at 20°C upon its return to the Radio and Electrical Engineering Division of the National Research Council in Ottawa.

TABLE II

Analog channel disparities

COUNT	April 26, 1968 Start 2020; End 2055 T = 50°C, P = 6.5 × 10^{-7} Torr			April 27, 1968 Start 1730; End 1750 T = 25°C, P = 600 Torr		
	Threshold voltage (mV)			Threshold voltage (mV)		
	Channel no.			Channel no.		
	6	1,5	3,7	6	1,5	3,7
6	5	5	4	-	-	-
7	20	20	21	-	-	-
8	36	34	36	-	-	-
9	52	54	53	12	12	13
10	70	69	68	30	29	30
11	88	87	87	48	48	48
12	106	105	104	65	65	65
13	124	124	125	86	84	83
14	143	144	142	102	104	102
15	163	163	162	122	123	123
16	181	181	181	141	143	141
32	505	505	505	467	466	466
64	1179	1178	1178	1141	1142	1141
128	2539	2538	2539	2505	2506	2505
256	5264	5265	5264	5232	5237	5238

ACKNOWLEDGMENTS

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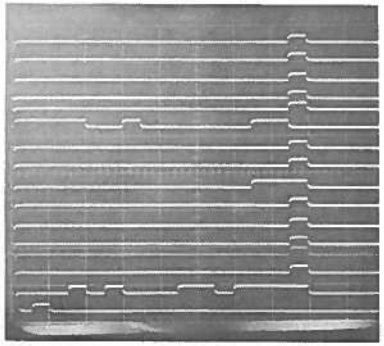
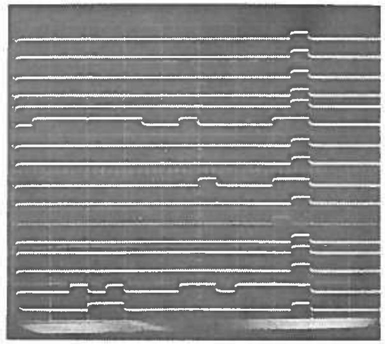
2. Shepertycki, T.H. Sixteen-channel silicon integrated-circuit encoder for the ISIS-A satellite particle-counting experiment. CAS Journal, 12 (10): 403–408; 1966.

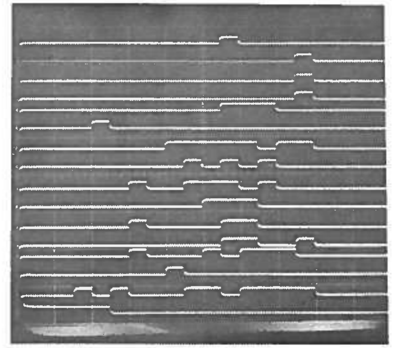
3. Shepertycki, T.H. An integrated-circuit check-out system for a satellite data encoder. CAS Journal, 13 (10): 457–459; 1967.



a) No Stimulation

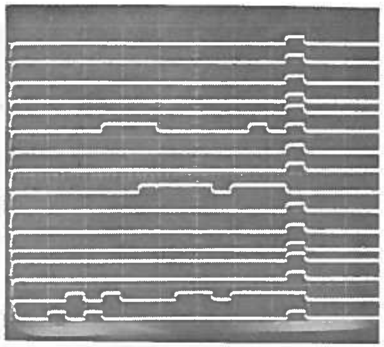


b) No Stimulation

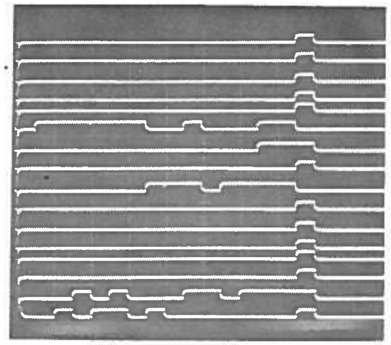


c) CO^{60} Stimulation

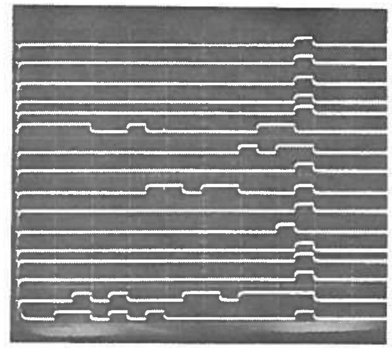
a, b, c, April 23, 1968, After vibration in X, Y, Z axes



d) No Stimulation



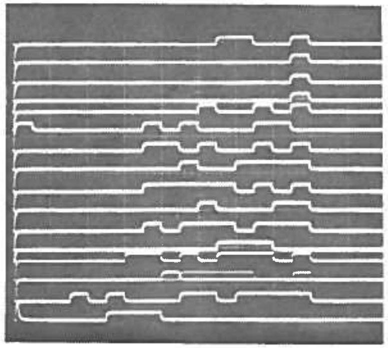
e) No Stimulation



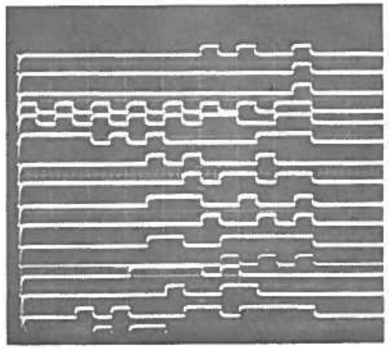
f) No Stimulation

d, e, f, April 24, 1968, T=+20°C, P=atmos., just prior to thermal-vacuum tests

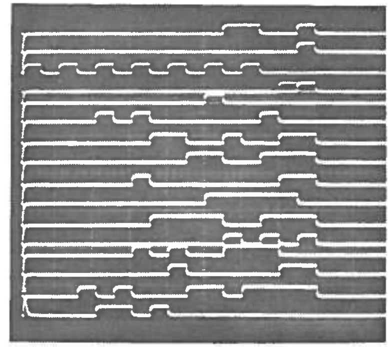
Fig. 5 Typical encoder output frames



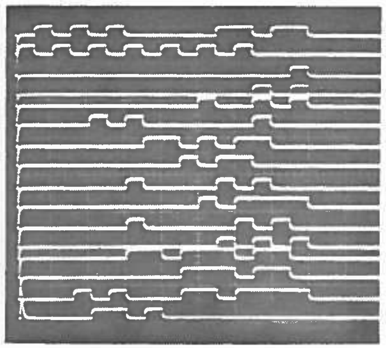
a) 1450 hrs.



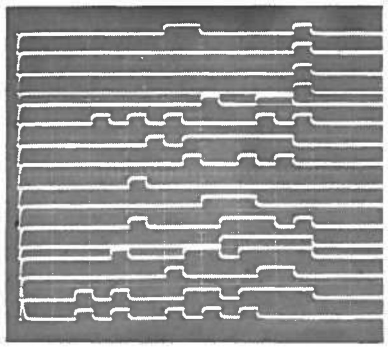
b) Words 11, 12 Test,
1927 hrs.



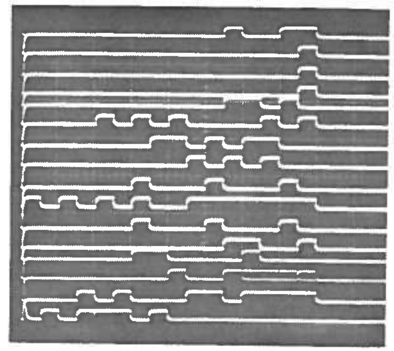
c) Word 13 Test,
1929 hrs.



d) Words 14, 15A Test,
1932 hrs.

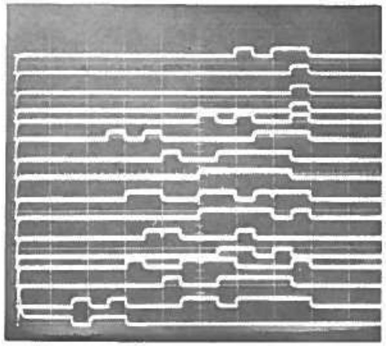


e) Word 16B Test,
1936 hrs.

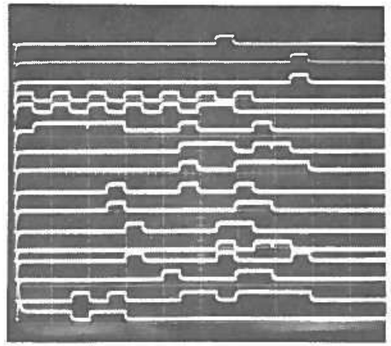


f) Word 6 Test,
1940 hrs.

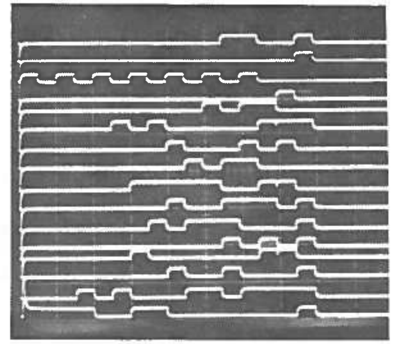
Fig. 6 Typical encoder output frames (April 25, 1968, $T = -20^{\circ}C$, $P = 2.7 \times 10^{-7}$ Torr, Co^{60} simulation)



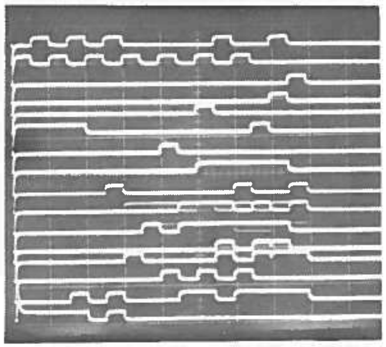
a) 1455 hrs.



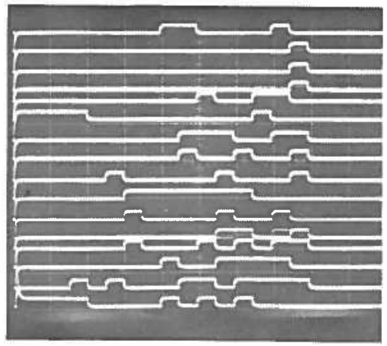
b) Words 11, 12 Test, 2013 hrs.



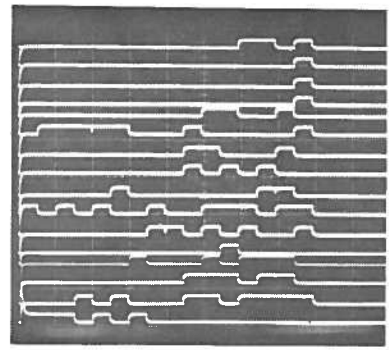
c) Word 13 Test, 2015 hrs.



d) Word 14, 15A Test, 2010 hrs.

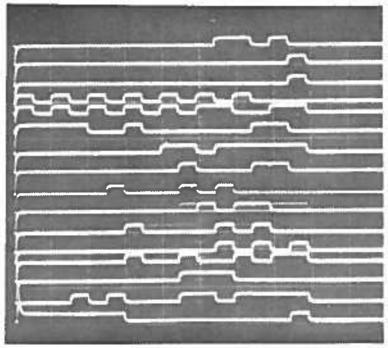


e) Word 16B Test, 2019 hrs.

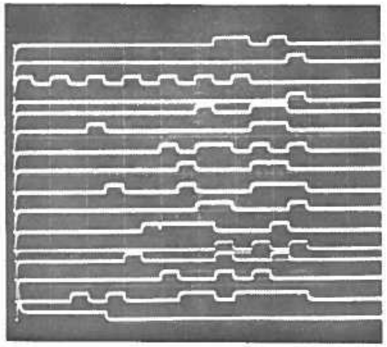


f) Word 6 Test, 2020 hrs.

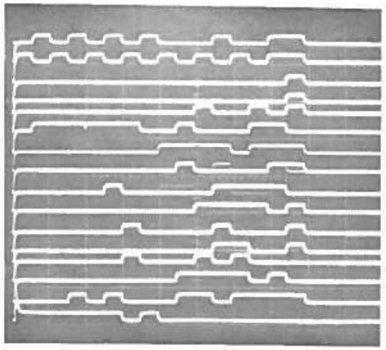
Fig. 7 Typical encoder output frames (April 26, 1968, $T = +50^{\circ}C$, $P = 6.7 \times 10^{-7}$ Torr, Co^{60} simulation)



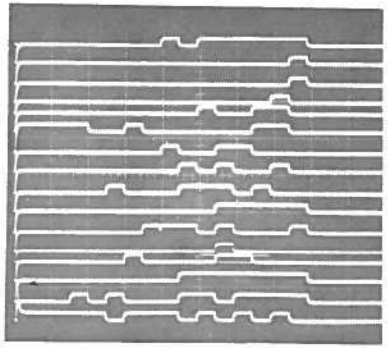
a) Word 11, 12 Test, 1802 hrs.



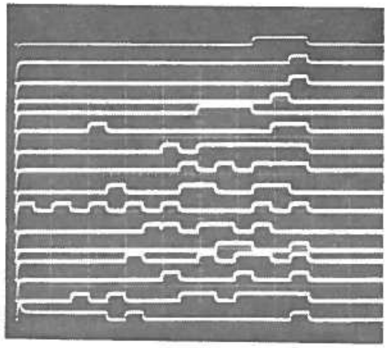
b) Word 13 Test, 1803 hrs.



c) Word 14, 15A Test, 1800 hrs.



d) Word 16B Test, 1804 hrs.



e) Word 6 Test, 1807 hrs.

Fig. 8 Typical encoder output frames (April 27, 1968, $T = +20^{\circ}C$, $P = 600$ Torr, Co^{60} simulation)

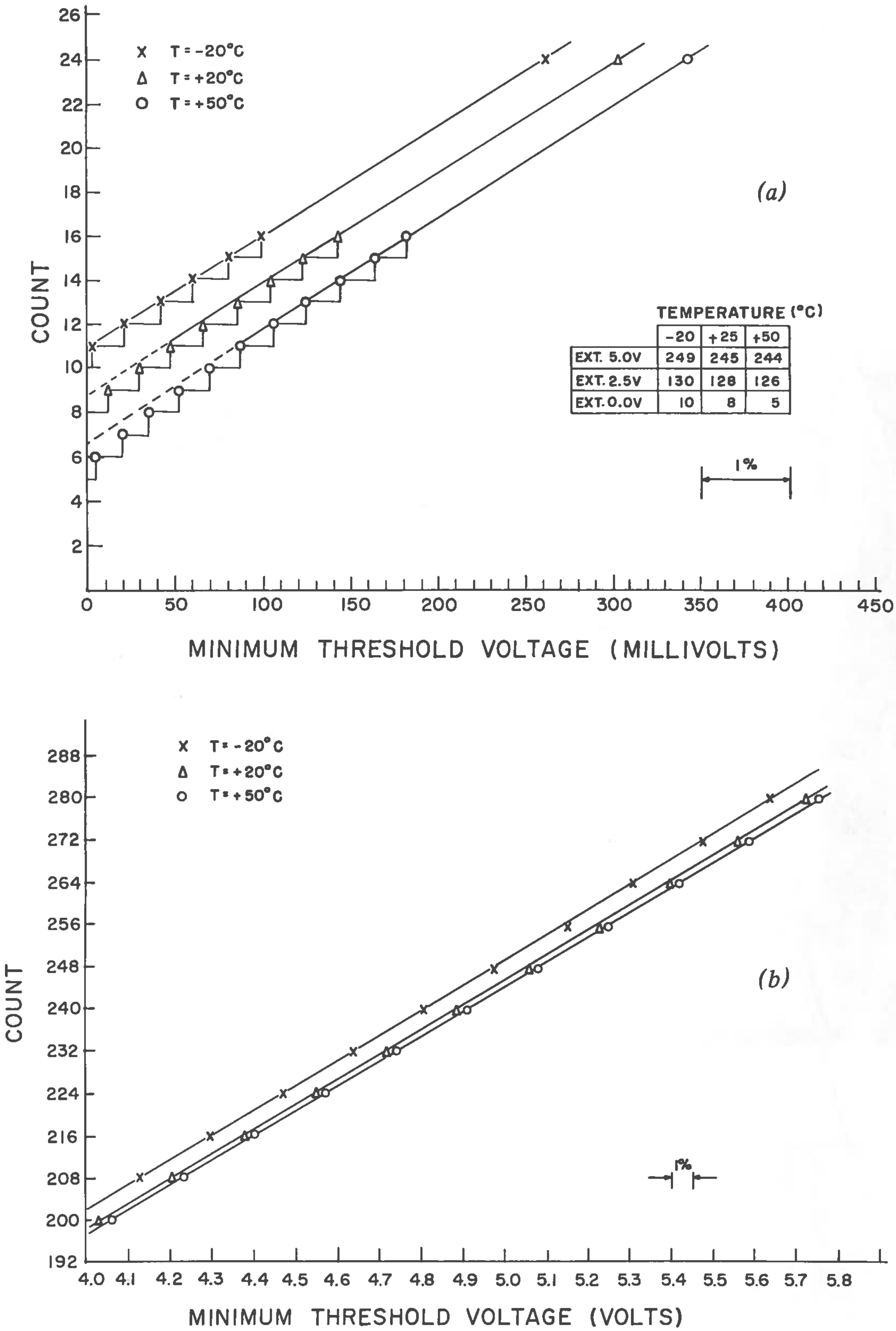


Fig. 9 Input-output characteristic of A/D converter

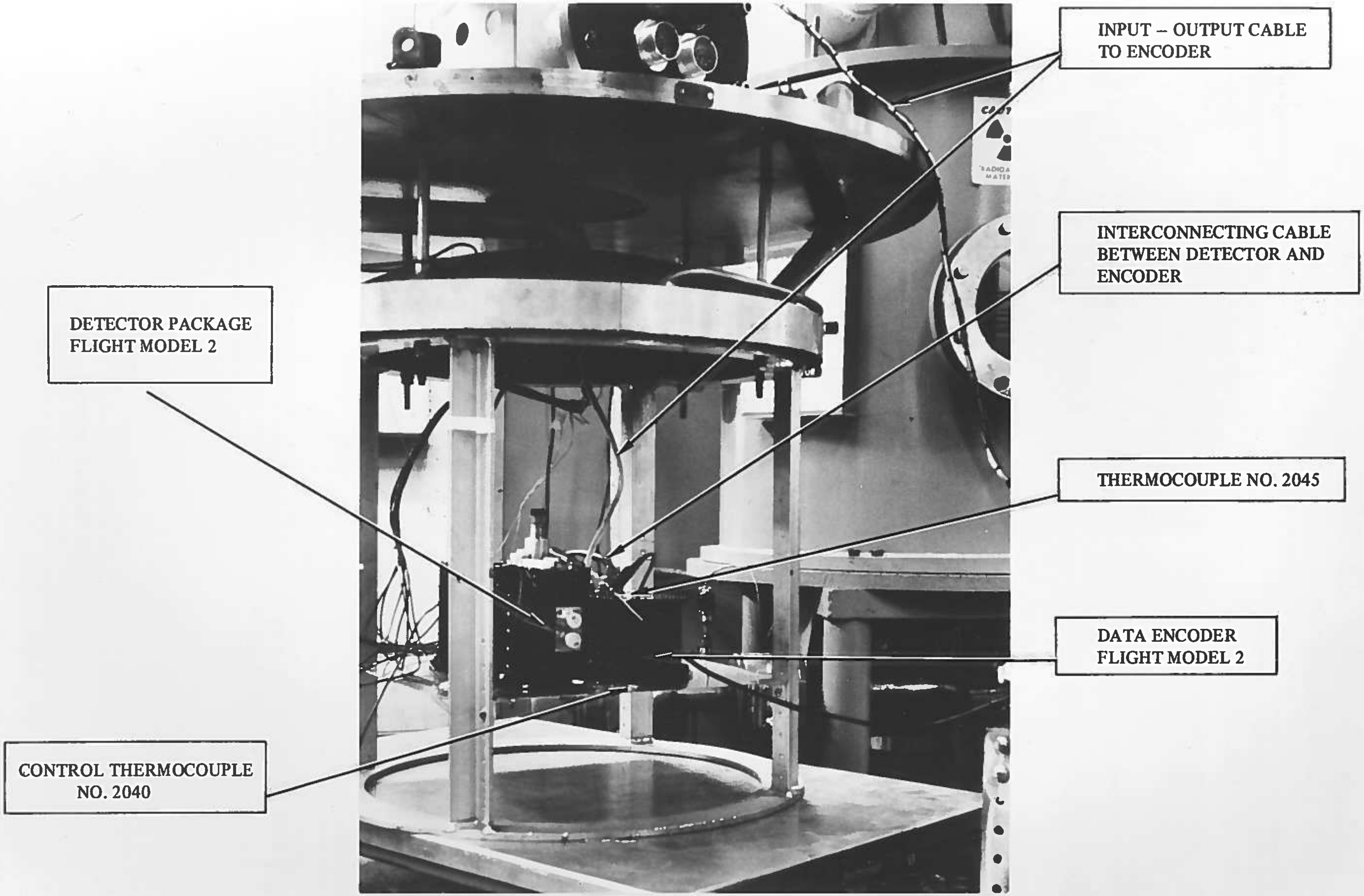


Plate I   Detector-encoder arrangement outside thermal-vacuum chamber

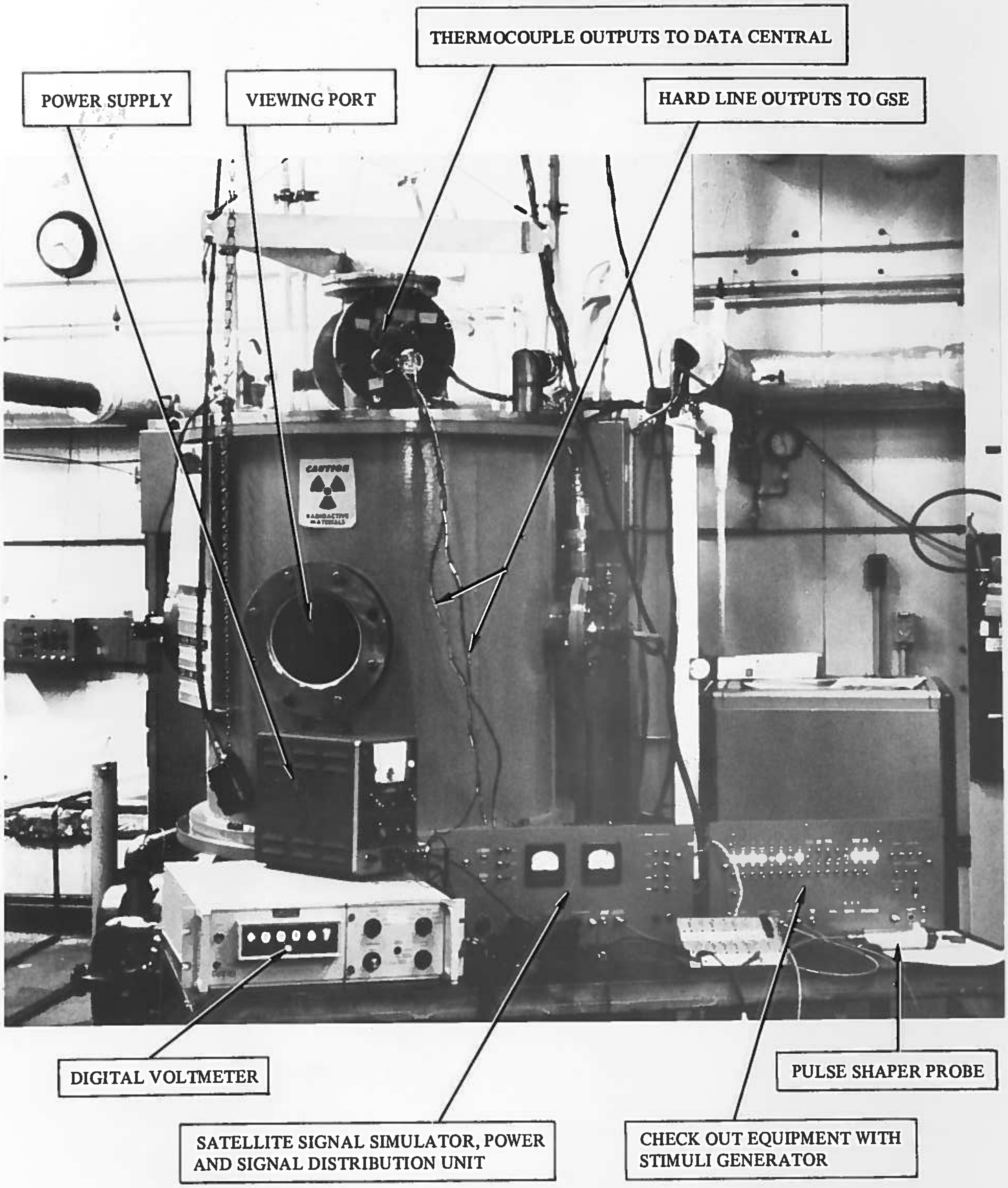


Plate II   Thermal-vacuum test setup