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NASA CR 86

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CP 030
NOVEMBER 1973

Space Systems

INSTRUMENTATION FOR THE ATMOSPHERE EXPLORER PHOTOELECTRON SPECTROMETER

by D. P. PELETIER

(NASA-CR-138986) INSTRUMENTATION FOR THE ATMOSPHERIC EXPLORER PHOTOELECTRON SPECTROMETER (Applied Physics Lab.) ~~143~~ p HC $10.25 CSCL 14B
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N74-21029
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THE JOHNS HOPKINS UNIVERSITY • APPLIED PHYSICS LABORATORY

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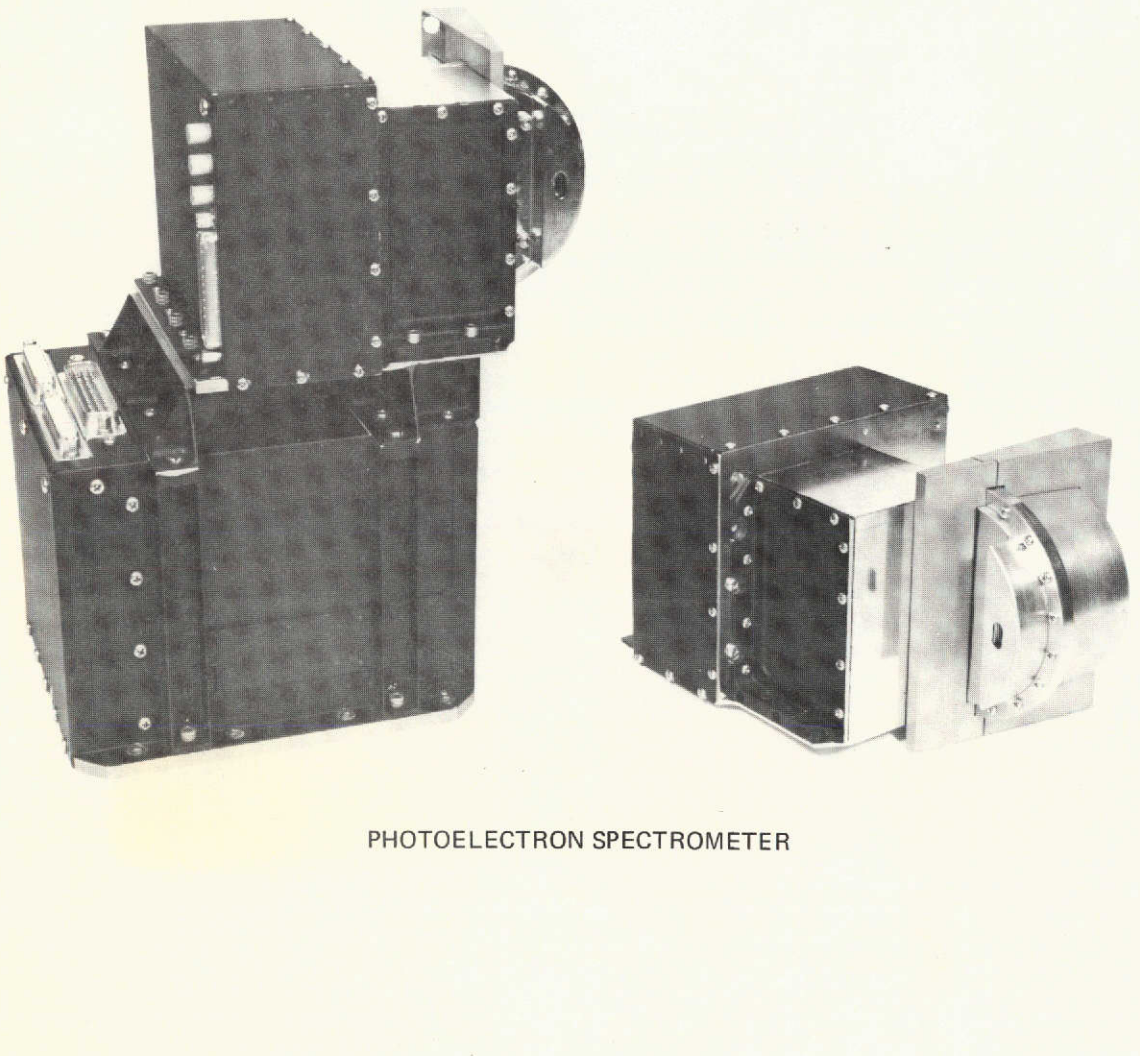

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This work was supported by the National Aeronautics
and Space Administration Office of Space Science and
Applications under Task I of Contract N00017-72-C-4401

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ABSTRACT

The Photoelectron Spectrometer (PES) is part of the complements of scientific instruments aboard three NASA Atmosphere Explorer (AE) satellites. The launch of the first spacecraft, AE-C, is planned for December 1973.

The PES measures the energy spectrum, angular distribution, and intensity of electrons in the earth's thermosphere. Measurements of energies between 2 and 500 eV are made at altitudes as low as 130 km. The design, characteristics, and performance of the instrument are described in this document.

Section 1 outlines the basic operation and summarizes overall performance. Section 2 is devoted to detailed circuit design and performance. Section 3 describes the mechanical design, and Section 4 describes the ground support system built to simulate the spacecraft/instrument interface and to test the instrument's electronics.

ACKNOWLEDGMENT

The author wishes to thank the personnel in the AE Project Office, at the support facilities at NASA Goddard Space Flight Center, and at RCA-AED for their assistance during the development of the Photoelectron Spectrometer.

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ILLUSTRATIONS

TABLES

1. GENERAL INSTRUMENT DESCRIPTION

The principal investigator for the Photoelectron Spectrometer experiment (Ref. 1) is Dr. J. P. Doering of The Johns Hopkins University Department of Chemistry; Dr. C. O. Bostrom and J. C. Armstrong of the Applied Physics Laboratory are coinvestigators. The experiment is similar to those used by Doering et al. (Refs. 1 and 2) on sounding rocket experiments, but modifications are incorporated that make the instrument suitable for satellite use.

SCIENTIFIC OBJECTIVES

The objective of the experiment is to provide information about the intensity, angular distribution, and energy spectrum of low-energy electrons in the thermosphere. The instrument measures electrons with energies from 2 to 500 eV. Two high-resolution modes allow detailed observation of electrons with energies between 2 and 100 eV and between 2 and 25 eV. This capability is particularly valuable, since there are no data about the electron distribution below 10 eV.

Electron fluxes between approximately 10^5 and 10^9 electrons $cm^{-2}s^{-1}\ sr^{-1}eV^{-1}$ are measured at altitudes as low as 130 km. The experiment sweeps through a 64-step energy ramp in 1 second; consequently at a 1 RPM (revolution per minute) satellite spin rate, a single energy sweep is completed within 6° of satellite rotation. At faster spin rates, the experiment sweeps through a 16-step energy ramp in 0.25 second, so that adequate angular resolution is maintained.

INSTRUMENT CONFIGURATION AND OPERATION

The Photoelectron Spectrometer contains two identical electron detectors (sensor assemblies) and one control and data-handling package (main electronics assembly). Sensor No. 1 is mounted on the satellite upper baseplate approximately 20° off the +X axis, as shown in Fig. 1. Sensor No. 2 is mounted on the main electronics assembly and secured to the upper baseplate approximately 20° off the -X axis. The sensors protrude through the spacecraft's thermal blanket and solar panel and are rotated so that the sensor field of view is not obstructed by the spacecraft surface. In this configuration the sensors are capable of monitoring simultaneous electron activity in both directions along the geomagnetic field lines.

In order to avoid shadowing of electrons by the spacecraft, the sensors should be as close to the spacecraft's upper (or lower) surface as possible (Ref. 3). As a mechanical configuration compromise, the sensors are elevated from the upper baseplate by 5.5 inches, resulting in a vantage point 6 inches below the spacecraft's upper surface.

Sensor Assembly

Each sensor contains a concentric hemisphere electrostatic analyzer, an electron multiplier and its associated high-voltage bias supply, and analog electronics, including a preamplifier, amplifier, discriminator, and rate limiter. Figure 2 is a block diagram of the sensor.

Electrostatic Analyzer. Electrons enter the electrostatic analyzer via a 9° by 20° collimator. If the voltage difference between the hemispheres is ΔV, electrons with energy of approximately $2\Delta V$ will be bent in a semicircle between the hemispheres and will strike the electron multiplier. Electrons with energy of less than $2\Delta V$ are collected on the inner hemisphere, and electrons with energy of more than $2\Delta V$ are collected on the outer hemisphere.

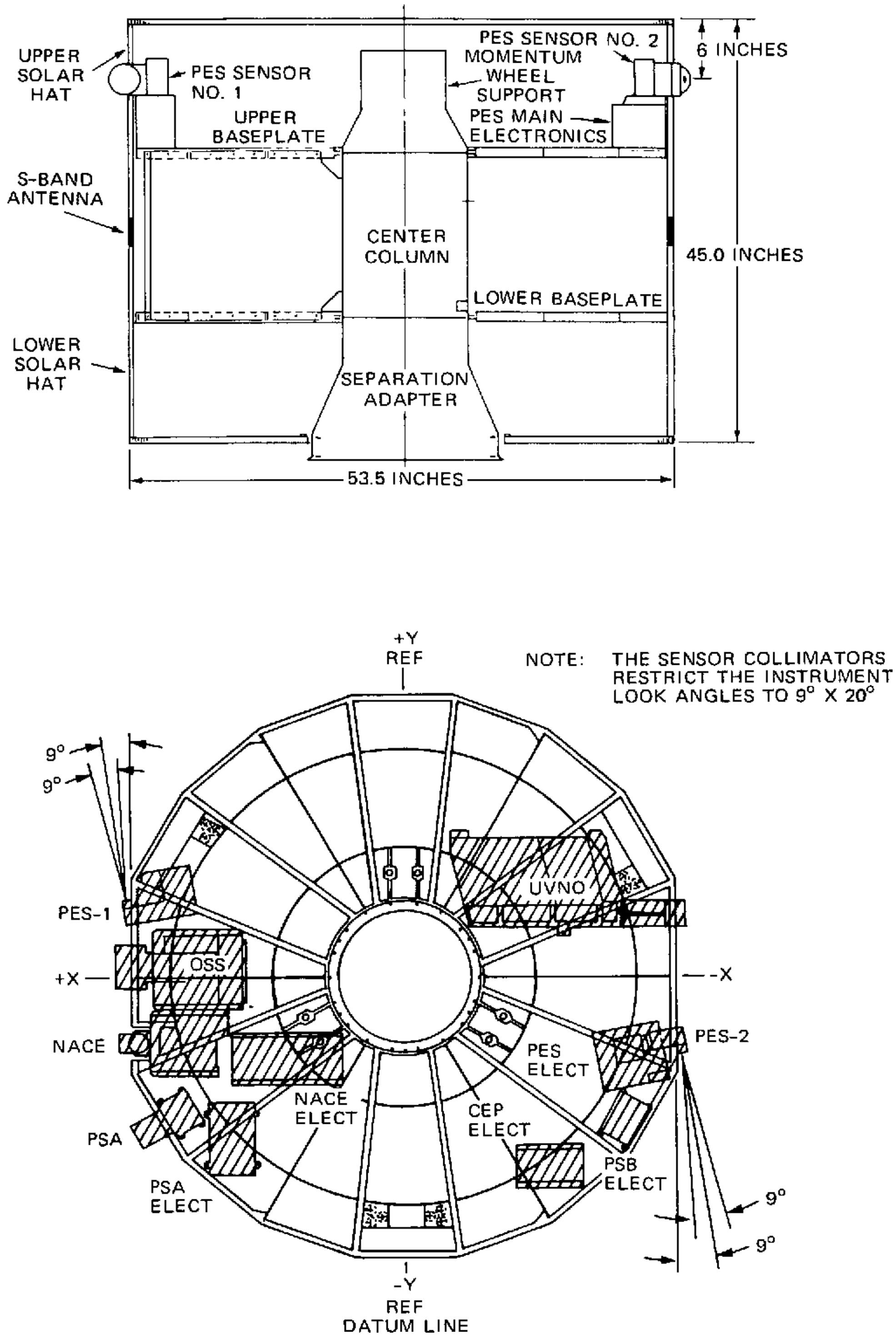

Fig. 1 LOCATION OF THE PHOTOELECTRON SPECTROMETER ON THE ATMOSPHERE EXPLORER-C UPPER BASEPLATE

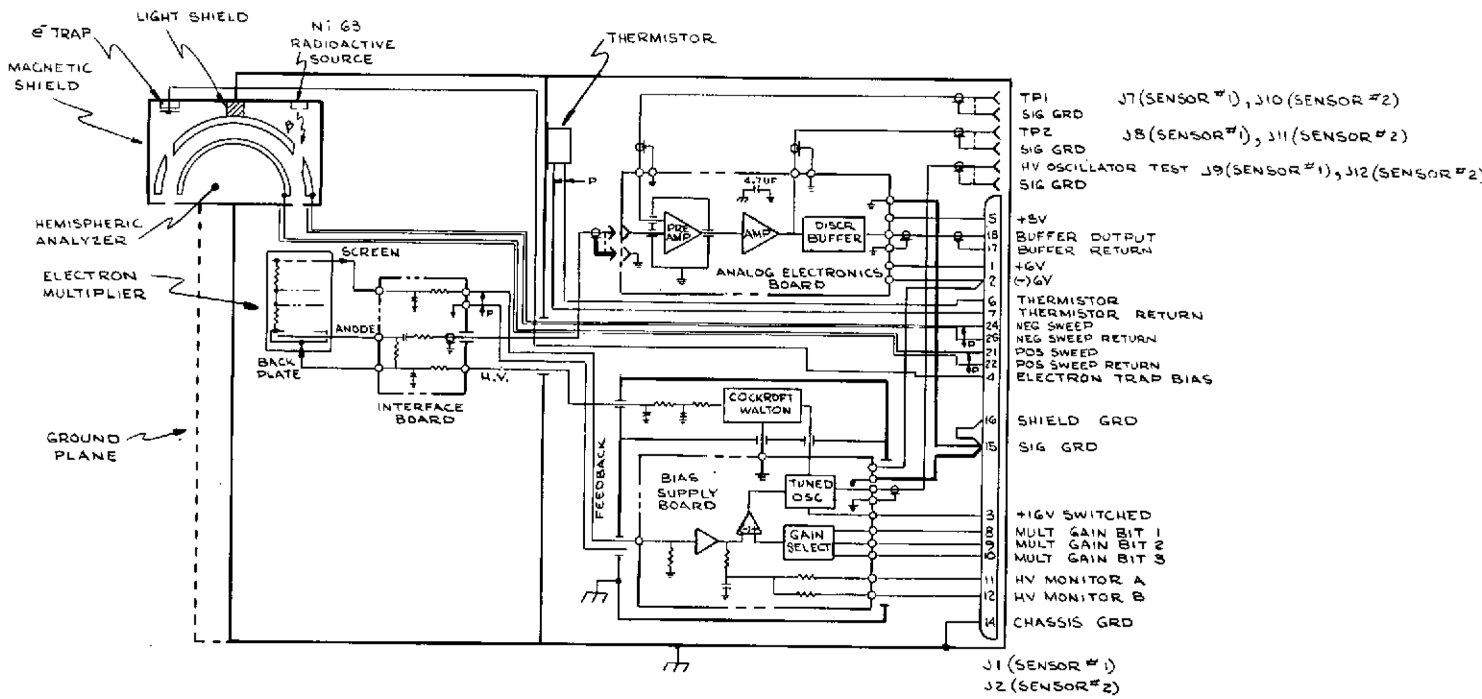

Fig. 2 BLOCK DIAGRAM OF PHOTOELECTRON SPECTROMETER SENSOR

A ground plane is provided near the collimator entrance to reduce the effect of the spacecraft electric fields on the electrons' trajectories prior to their entering the analyzer. After entering the analyzer, the electrons remain subject to path distortion because of magnetic fields, including those generated by the spacecraft and the earth; therefore the hemispheres are enclosed with magnetic shielding material. The highly permeable shields are composed of 80% Ni, 15% Fe, and 5% Mo and are a minimum of 0.030 inch thick. Joints are overlapped and in intimate contact, and holes in the shield are minimized. A Helmholtz coil used to test the effectiveness of the shield indicated that a field strength of 7 gauss could be applied along the most susceptible axis before particle data were seriously compromised. The shield of the electron gun (used as the particle source) may have become ineffective at the higher field intensities, and therefore 7 gauss is the minimum upper useful limit of the flight magnetic shield.

Distortion of the magnetic field in the vicinity of the instrument muddles a clear interpretation of the apparent measured electron energy and angular distribution. A field of several hundred gamma may in fact distort the distribution of low-energy electrons entering into the instrument field of view. Consequently a great deal of attention has been given to the problem of assuring a magnetically clean spacecraft. This will be discussed in detail in later reports concerning the reduction of scientific data.

If ultraviolet light is allowed to pass through the analyzer into the electron multiplier, the light will cause counts that are indistinguishable from electron counts. To reduce this possibility, holes are cut in the outer hemisphere to baffle the light. Secondary electron emission is collected on an electron trap composed of a copper plate biased at +50 volts.

The baffle hole in the exit portion of the electrostatic analyzer is a convenient opening for β particles from a Ni-63 radioactive source. These β particles provide a known background count to calibrate the electron multiplier gain. The nominal calibration count rate is 2 to 3 per second, which exceeds the estimated cosmic ray background count of less than 1 per second.

Electron Multiplier. After the electron emerges from the electrostatic analyzer, it strikes the first dynode of a 20-stage Johnston Laboratories focused mesh electron multiplier (MM-1-5NG). The screen of the multiplier is biased at 9% of the total multiplier voltage and is used to accelerate the electron to an energy sufficient to produce secondary emission upon contact with the first dynode of the multiplier. Each subsequent dynode liberates additional electrons, resulting in a nominal gain of 10^6 for a multiplier bias voltage of 3000 volts (screen voltage of 270 volts). Increasing the bias to 4500 volts raises the gain to about 10^9. One should note, however, that these are average gain values, and the multiplier actually displays a rather broad pulse height distribution that must be considered during calibration of the instrument.

The electron multiplier is housed in a compartment separated from the other electronic circuits and kept free of materials that may degrade the exposed multiplier. Only the necessary bias and filter components are mounted with the multiplier.

Electron Multiplier Bias Supply. As the electron multiplier operates, degradation occurs in the final dynode stages because these stages emit the greatest number of electrons per pulse. The resulting loss in multiplier gain is offset by the use of a commandable bias supply. Initially the multiplier is biased near the minimum bias supply output of 3000 volts. The bias is increased upon command as required in seven equal increments to a maximum output of 4500 volts.

Analog Electronics. The charge output of the electron multiplier is collected at the input of a charge-sensitive preamplifier. Two pulse shaping and amplifying stages, a discriminator, and a rate limiter follow the preamplifier.

Experimental results show that a discriminator setting of 10^5 electrons is adequate to produce a counting efficiency of approximately 80% at a bias supply setting of 3200 volts when the multiplier is new.

Bipolar pulse shaping is used with a zero crossing time of about 0.5 μs in the unsaturated mode, resulting in amplifier rate limiting of about 2 million pps (particles per second). The buffer circuit is rate-limited so that the maximum electron count rate from the sensor is nominally 250 000 pps.

Main Electronics Assembly

The main electronics assembly houses the circuits that produce the required sensor signals including power, hemisphere sweep voltages, and high-voltage commands.

The main electronics circuits also adjust the experiment operating mode, calibrate the hemisphere deflection sweep supply, accumulate the sensor output pulses, monitor housekeeping items, and handle data going to and from the spacecraft subsystems. All PES/spacecraft electrical interfaces are made through a 50-pin connector mounted in the main electronics assembly. Figure 3 is a block diagram of the main electronics assembly.

Deflection Sweep Supply. The PES electrostatic analyzer selects electrons with energy of $2\Delta V$ if ΔV volts are applied across the hemispheres. However the electron enters the analyzer on a zero-potential electric field line with respect to the spacecraft chassis. Therefore the ratio of hemisphere potentials must be carefully selected to maintain the electron path at zero potential so that the electron will travel in a smooth semicircle between the hemispheres. It has been determined (Ref. 4) that for the PES analyzer dimensions, a 500 eV electron requires +140.35 volts applied to the inner hemisphere and -109.65 volts applied to the outer hemisphere.

The deflection sweep supply is a digital/analog (D/A) converter that produces synchronized positive and negative linear ramps with maximum voltages of +140.4 and -109.6 volts. The ramps contain 64 steps and have

FOLDOUT FRAME 1

FOLDOUT FRAME 2

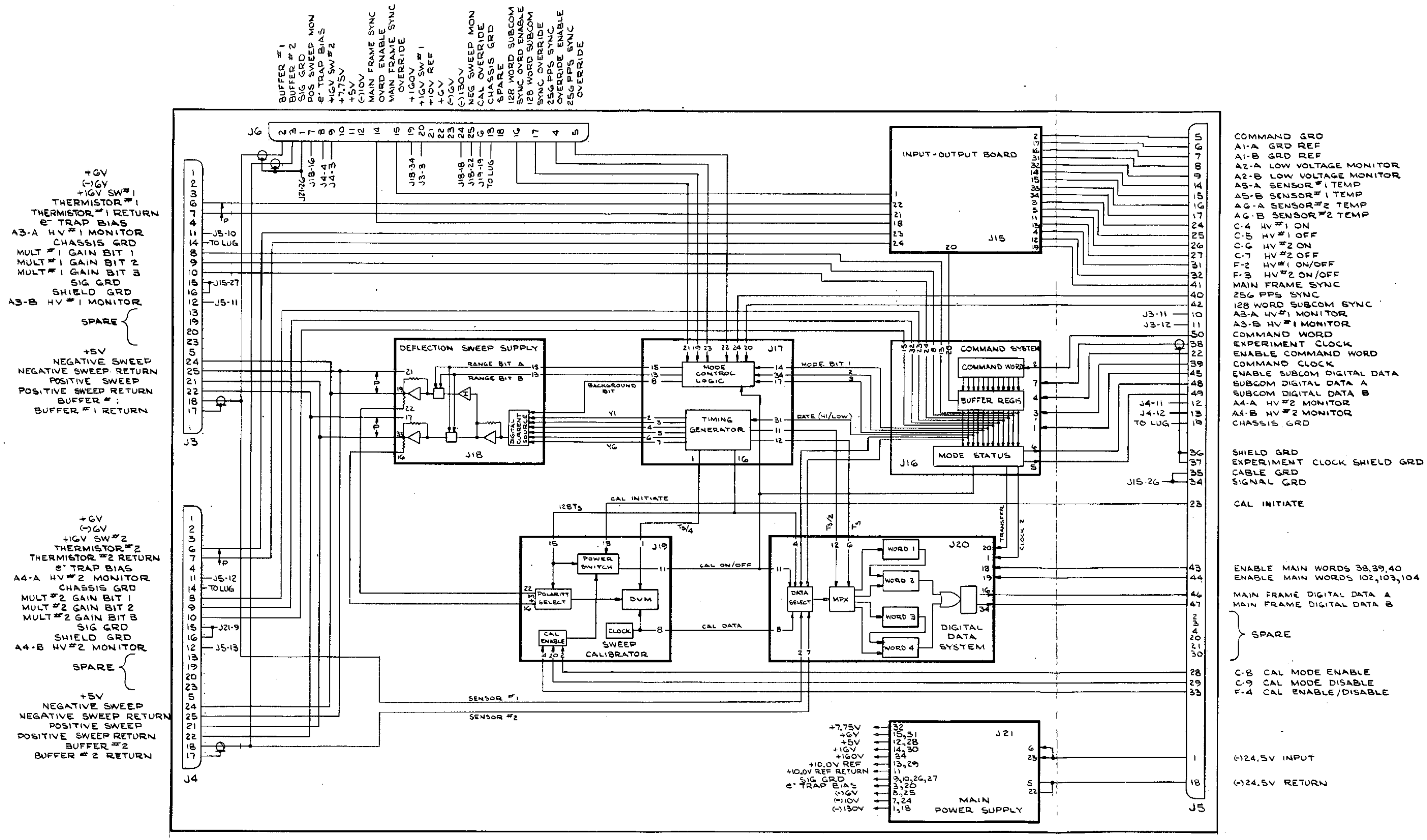

Fig. 3 BLOCK DIAGRAM OF PHOTOELECTRON SPECTROMETER MAIN ELECTRONICS

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commandable gain networks that provide for a selection of one of three sweeps with maximum sweep energies of 500, 100, or 25 eV. Consequently the theoretical analyzer resolution is 25 eV/63 ≈ 0.4 eV. Local electric and magnetic fields, however, limit the practical resolution to about 2 eV.

Experiment Operating Modes. The three deflection sweeps are used in combinations that produce five energy range operating modes (see Fig. 4):

1. In Mode I, all three ramps are used, with the 25 eV ramp being used 50% of the time and the remaining time being equally shared by the 100 and 500 eV ramps.

2. In Mode II, the 25 and 500 eV ramps are alternated.

3. Modes III, IV, and V use single ramps with peaks of 25, 100, and 500 eV, respectively.

In addition to the five energy range modes, there are fast and slow modes. When the satellite spin rate is less than approximately 4 RPM, the deflection sweep operates in the slow mode in which there are 64 voltage steps and 64 data words per ramp, as shown in Fig. 5. At higher spin rates, the deflection sweep operates in the fast mode in which there are still 64 steps per ramp but only 16 data words per ramp; i.e., each data word contains data from four steps on the ramp (see Fig. 6).

The PES is allotted four main frame telemetry words for sensor (particle) data. These words may be used to transmit any of the following information:

1. Sensor No. 1, particle data only;

2. Sensor No. 2, particle data only;

3. "Sensor Alternate," in which particle data are taken alternately from each sensor at 4-second intervals; and

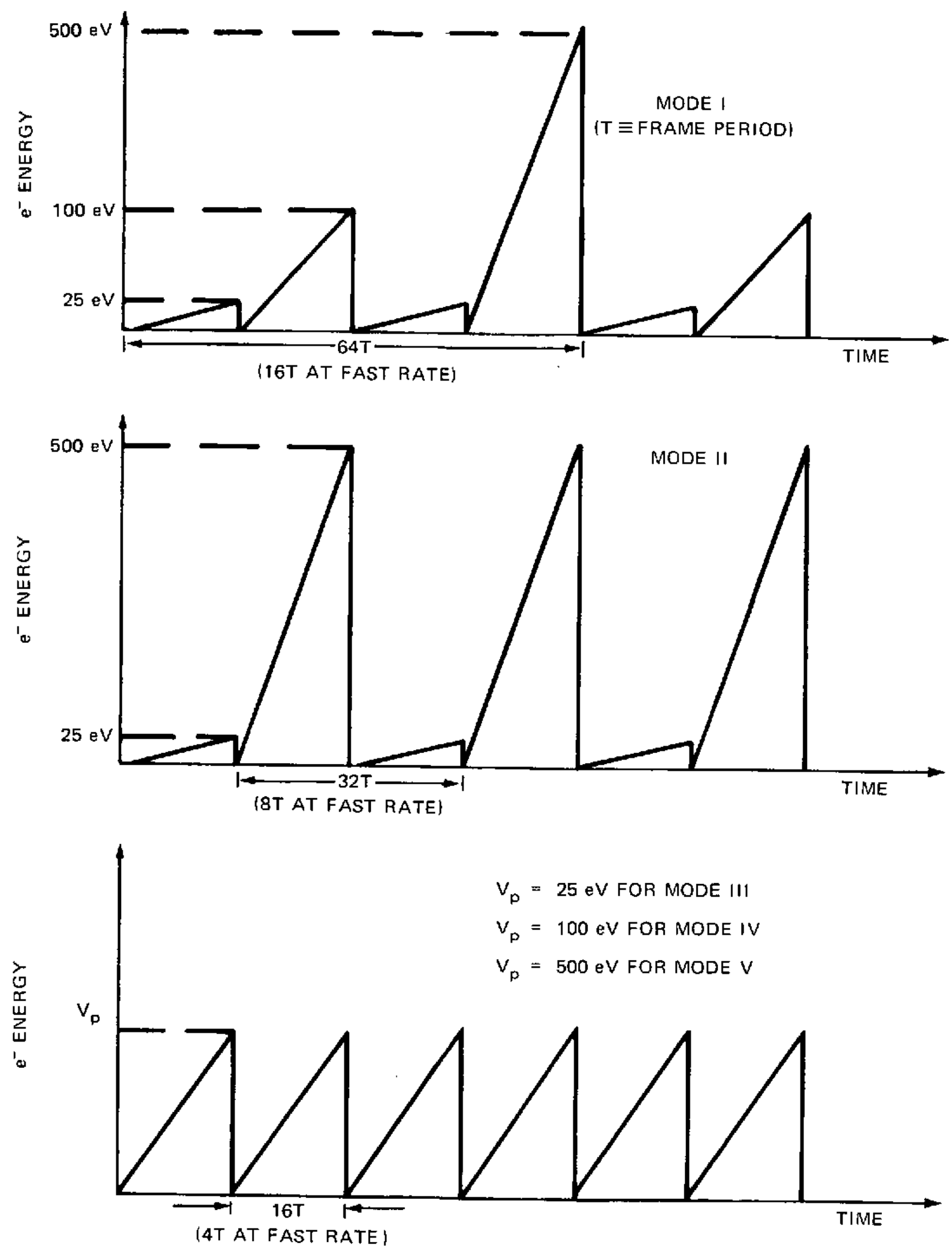


Fig. 4 DEFLECTION SWEEP OPERATING MODES

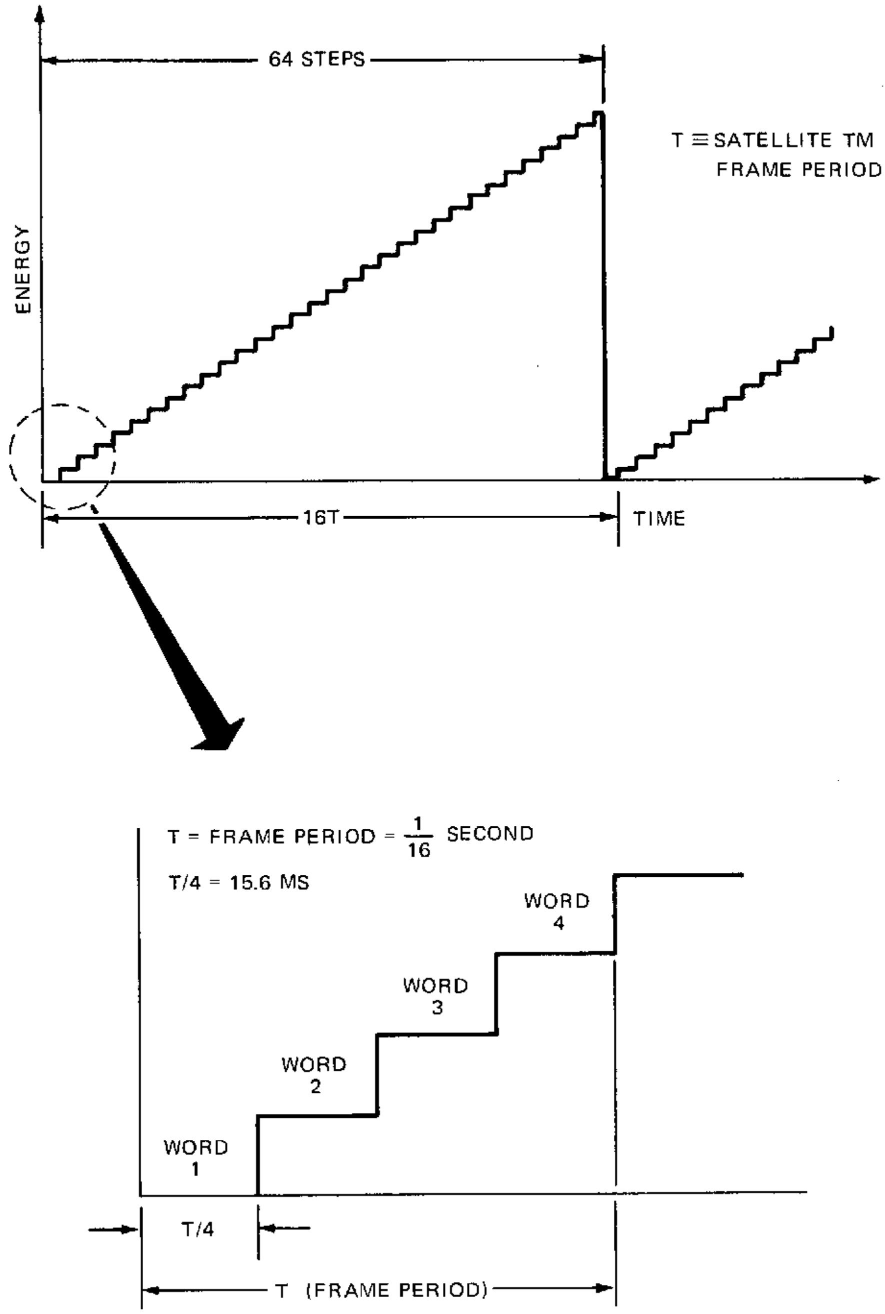


Fig. 5 A TYPICAL ANALYZER SWEEP FOR SATELLITE SPIN RATES BELOW 4 RPM

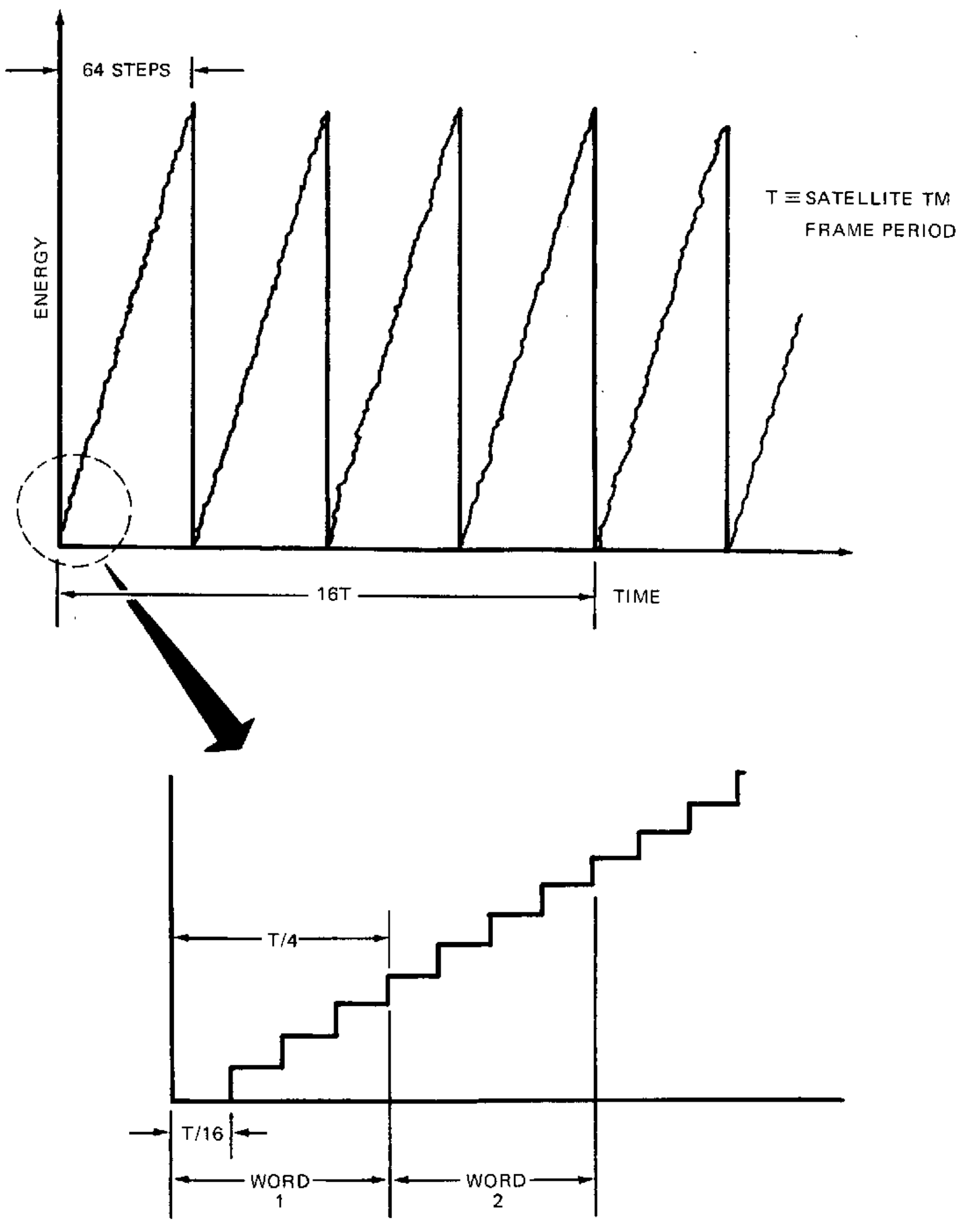


Fig. 6 A TYPICAL ANALYZER SWEEP FOR SATELLITE SPIN RATES ABOVE 4 RPM

4. Deflection sweep calibration data, an 8-second sequence, initiated by command, which measures and transmits the deflection sweep voltage at each step of the deflection sweep ramp.

Command System. The PES uses three relay pulse commands, a logic pulse command, and a 12-bit logic command word.

One relay is in series with the 16 volt power line to each of the two electron multiplier bias supplies. Consequently either or both high-voltage supplies may be turned off without affecting the operation of the rest of the instrument. Since the 16 volt power comes from the PES main converter, neither high-voltage supply can be turned on unless the PES power is on.

The deflection sweep calibrator precludes particle counting during the calibration sequence. As a safety precaution, a relay is used to "enable" power to the calibrator. If the calibrator fails in the active condition, the relay is used to disable the calibrator power and thereby return the instrument to the particle counting mode.

In normal operation, the calibrator is enabled, but the 8-second calibration sequence does not occur until the cal initiate logic pulse command is sent.

The 12-bit PES logic command word is (in spacecraft terms) part of the PES minor mode command word. The word is used to make adjustments in the operating mode of the instrument and covers the following items:

1. Three bits select the operating voltage of the sensor No. 1 bias supply.

2. Three bits select the operating voltage of the sensor No. 2 bias supply.

3. Three bits select one of the five energy range modes.

4. One bit selects fast or slow operation.

5. Two bits select data from the desired sensor or select the "Sensor Alternate" mode.

PES Data System. The PES digital data system consists of four 12-bit accumulators and four 12-bit temporary storage registers. Each accumulator counts for one-fourth of a spacecraft main frame. At the beginning of each new frame, the data are parallel-transferred into temporary storage and the accumulators are reset. Data are read out one frame after they are accumulated. This sequence is synchronized with the spacecraft telemetry system and is independent of the operational mode of the experiment. Figure 7 illustrates the data system timing.

Data are transferred to temporary storage within the PES data system at the beginning of each frame. Particle counting at this time is inhibited for 350 μs, which not only allows adequate time for data transfer but also allows adequate time for the sweep supply to return to zero at the end of its sweep.

Housekeeping. The PES is allotted six analog words that are read every 8 seconds.

The PES signal ground and the 5 volt output from the secondary of the PES converter are monitored to verify overall instrument integrity and to indicate any offset between the PES signal ground and the spacecraft ground. The 5 volt monitor is attenuated to 4 volts in order for the voltage to fall within the range of the spacecraft A/D converter.

Two analog words are transmitted to indicate the voltage applied to each electron multiplier. The signal is attenuated 1000:1, so that a 3 volt reading indicates an applied bias of 3 kV.

Each PES sensor contains a thermistor that is secured with epoxy in an aluminum housing and mounted to

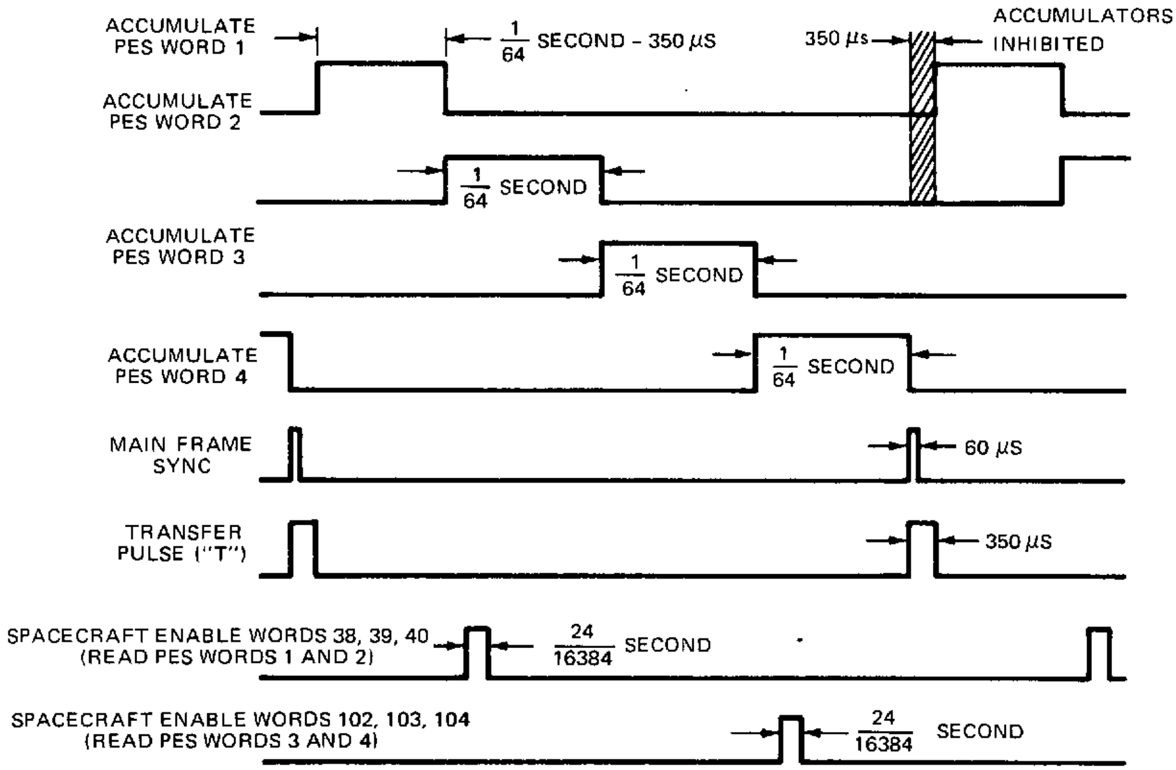


Fig. 7 PARTICLE DATA TIMING

the aluminum wall between the electron multiplier and the bias supply. The thermistor therefore gives a temperature indicative of the average case temperature of the sensor electronics.

Table 1 compares nominal voltage out of the buffer with temperature within the sensor. Assuming a 5 ± 1 MΩ load, the voltage error caused by loading uncertainty is ± 0.04%, which is small compared with the design goal of 1%. If either of the redundant outputs is shorted to ground, the voltage at the remaining output must be multiplied by 1.196 in order to use the table.

Table 1

Nominal Sensor Temperature Monitor Characteristics

Temperature (°C)	Nominal Output (volts)	Input Loaded by 5 MΩ (volts)
-40	4.822	4.812
-30	4.460	4.449
-20	3.970	3.960
-10	3.385	3.377
0	2.756	2.750
+10	2.156	2.151
+20	1.634	1.630
+30	1.214	1.211
+40	0.893	0.890
+50	0.654	0.653
+60	0.481	0.480
+70	0.356	0.355
+80	0.265	0.265

<u>DC/DC Converter</u>. The PES main converter receives power from the -24.5 volt regulated spacecraft bus and converts this to power at voltages between -130 and +160 volts. The converter features input current limiting, foldover current limiting, and an overvoltage protection circuit.

There is no DC line regulation since the spacecraft's regulation of 2% is adequate for most of the PES requirements. Only the 10.000 volt calibrator reference voltage requires additional regulation.

DATA FORMAT

Main Frame Digital Data

The spacecraft main digital data telemetry frame contains 128 eight-bit words and repeats at a rate of 16 frames per second. The PES is allotted words 38, 39, and 40 and words 102, 103, and 104, which are used to store the four PES 12-bit particle data words (see Fig. 8). PES word 1 contains particle data accumulated during the first quarter of the previous frame, PES word 2 contains particle data accumulated during the second quarter of the previous frame, etc.

Subcom Analog Data

The six PES analog housekeeping words are located in the 8-second subcom frame. This subcom uses word 68 of the main frame to transmit 128 different information words, of which subcom words 91 through 96 contain the PES analog housekeeping data shown below:

PES Analog Item	8-Second Subcom Word
PES signal ground reference	91
PES low-voltage monitor	92
PES high-voltage monitor 1	93
PES high-voltage monitor 2	94
PES sensor No. 1 temperature	95
PES sensor No. 2 temperature	96

Subcom Digital Data

The three PES relay status bits are also transmitted on the experiment 8-second subcom. The word and bit assignments are listed below:

1	2	3	4	5	6	7	8
9							16
17							24
25							32
33					38 ←PES WORD 2	39 →│←	40 PES WORD 1→
41							48
49							56
57							64
65	66	67 EXP 4-SECOND SUBCOM	68 EXP 8-SECOND SUBCOM				72
73							80
81							88
89							96
97					102 ←PES WORD 4	103 →│←	104 PES WORD 3→
105							112
113							120
121	122	123	124	125	126	127	128

Fig. 8 PES PARTICLE DATA LOCATION IN THE AE-C MAIN FRAME (Frame Period = $\frac{1}{16}$ Second)

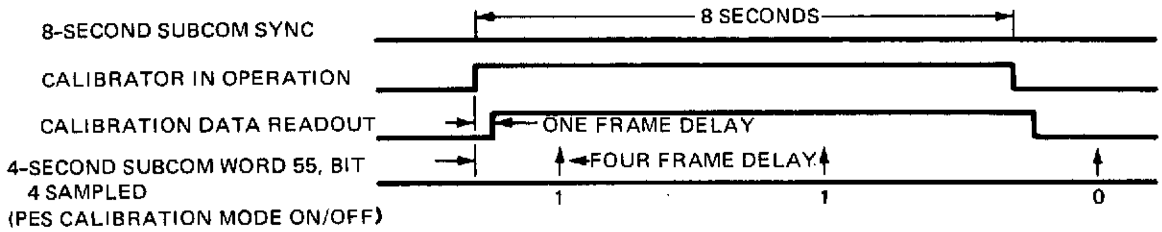
PES Relay Status Bit	8-Second Subcom Word	Bit
PES high-voltage monitor 1 on/off	12	1
PES high-voltage monitor 2 on/off	12	2
PES calibration mode enable/disable	12	3

The PES also transmits a 16-bit status word containing bits that show the present instrument mode of operation. This 16-bit word is transmitted once every 4 seconds on main frame words 68 (8-second subcom) and 67 (4-second subcom). The 8- and 4-second subcom word enables are joined to produce the required 16-bit enable. The bit assignments are shown below:

PES Digital Status Bit	4-Second Subcom Word	Bit
Spare	55	1
Spare	55	2
Spare	55	3
PES calibration mode on/off	55	4
PES multiplier 2 gain bit 1	55	5
PES multiplier 1 gain bit 3	55	6
PES multiplier 1 gain bit 2	55	7
PES multiplier 1 gain bit 1	55	8

	8-Second Subcom Words	Bit
PES mode select bit 1	55 and 119	1
PES sweep rate fast/slow	55 and 119	2
PES multiplier 2 gain bit 3	55 and 119	3
PES multiplier 2 gain bit 2	55 and 119	4
PES sensor alternate/alternate	55 and 119	5
PES sensor No. 1 data/sensor No. 2 data	55 and 119	6
PES mode select bit 3	55 and 119	7
PES mode select bit 2	55 and 119	8

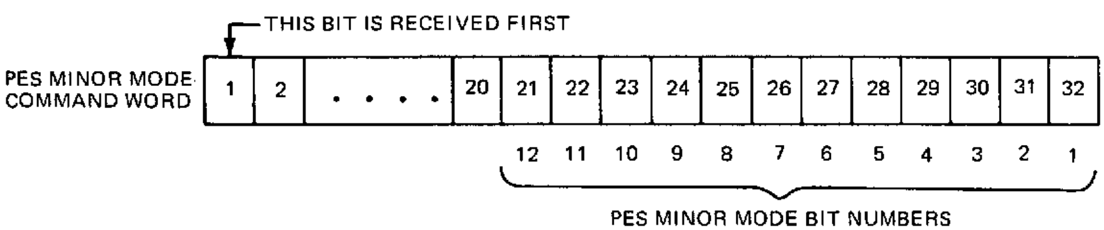
When the PES calibration mode on/off is "1," the deflection sweep calibrator is in operation, and calibration data are read out as shown below:



The remaining subcom status bits verify that the PES 12-bit minor mode command word is correctly received at the instrument.

Minor Mode Commands

The spacecraft provides a 32-bit minor mode command word to adjust the operating mode of the PES. Only 12 of the available 32 bits are required, and the relationship of the PES minor mode command bits to the PES minor mode command word is shown below:



The first three PES command bits select the operating voltage of the sensor No. 1 bias supply as follows:

PES bit 1	0	1	0	1	0	1	0	1
PES bit 2	0	0	1	1	0	0	1	1
PES bit 3	0	0	0	0	1	1	1	1
Commanded high voltage monitor 1 (kV)	3.00	3.21	3.43	3.65	3.86	4.07	4.29	4.50

The next three PES command bits similarly adjust the high-voltage monitor 2 voltage. PES command bit 7 is used to set the PES deflection sweep rate:

Fast sweep rate = "1"
Slow sweep rate = "0"

Bits 8, 9, and 10 select one of the five energy sweeps as follows:

PES bit 8	0	1	0	1	0	1	0	1
PES bit 9	0	1	1	0	0	0	1	1
PES bit 10	1	0	0	0	0	1	1	1
Sweep Mode	I	II	III	IV	V	*	*	*

where

Sweep Mode	Sweep Sequence
I	ABACABAC..
II	ACAC.......
III	AAAA.......
IV	BBBB.......
V	CCCC.......

and A = 0 to 25 eV, B = 0 to 100 eV, and C = 0 to 500 eV.

*These conditions are considered "illegal." If they are sent,. the experiment will be placed in Sweep Mode V.

PES bits 11 and 12 are used to select data from the desired sensor or to select the sensor alternate mode. In the sensor alternate mode, these bits are used in conjunction with an 8-second squarewave (128 T_s) that is synchronized with the 8-second subcom. The mode is selected as follows:

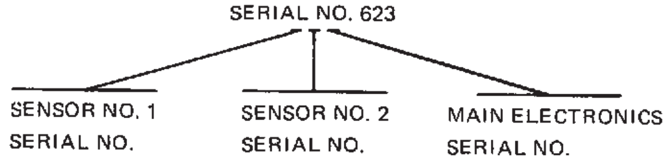
Command Bits		128 T_s	Sensor Selected	
Bit 11	Bit 12		Sensor No. 1	Sensor No. 2
0	Ø	Ø		X
1	0	Ø	X	
1	1	0	X	
1	1	1		X

Ø = Do not care
X = Sensor active

SPECIFICATIONS AND PERFORMANCE

Serial Numbers

The PES assemblies are numbered sequentially, SN01 through SN06 for the sensors, and SN01 through SN03 for the main electronics. The experiment serial numbers are three-digit numbers derived from the assembly serial numbers. The serial number for sensor No. 1 (the remote sensor) appears first, followed by the serial number for sensor No. 2 (located on top of the main electronics) and finally the main electronics number. For example, if sensor No. 1 is SN06, sensor No. 2 is SN02, and the main electronics is SN03, then the experiment serial number is:



Dimensions, Look Angle, and Alignment

The experiment dimensions are shown in Figs. 9 and 10. The location of the center of gravity of each assembly is also indicated.

The sensor surface, which is flush with the thermal light shield, is the reference for collimator and hemispheres. It is therefore used during the optical alignment of the experiment. The perpendicular to this surface is set at 9° ± 1° with respect to the spacecraft +X axis for sensor No. 1 and 189° ± 1° for sensor No. 2. This allows 4-1/2° of clearance between the sensor field of view and the outer spacecraft surface.

The sensor field of view is 9° by 20°, as shown in Fig. 9.

Weight*

Present Serial Nos.	Experiment Designation	Sensor No. 1	Sensor No. 2 plus Main Electronics
SN121	Protoflight instrument	1338 g**	2827 g**
SN342	First flight instrument	1274 g	2771 g
SN563	Second flight instrument	1266 g	2761 g

*Weights include the thermal shields and the test connector cover but not the external cables.

**Sensors SN01 and SN02 use Kel-F (2.1 g/cc) and the original thermal shields. Sensors SN03 through SN06 use Vespel-1 (1.4 g/cc) and the modified thermal shields (which are lighter than the original design).

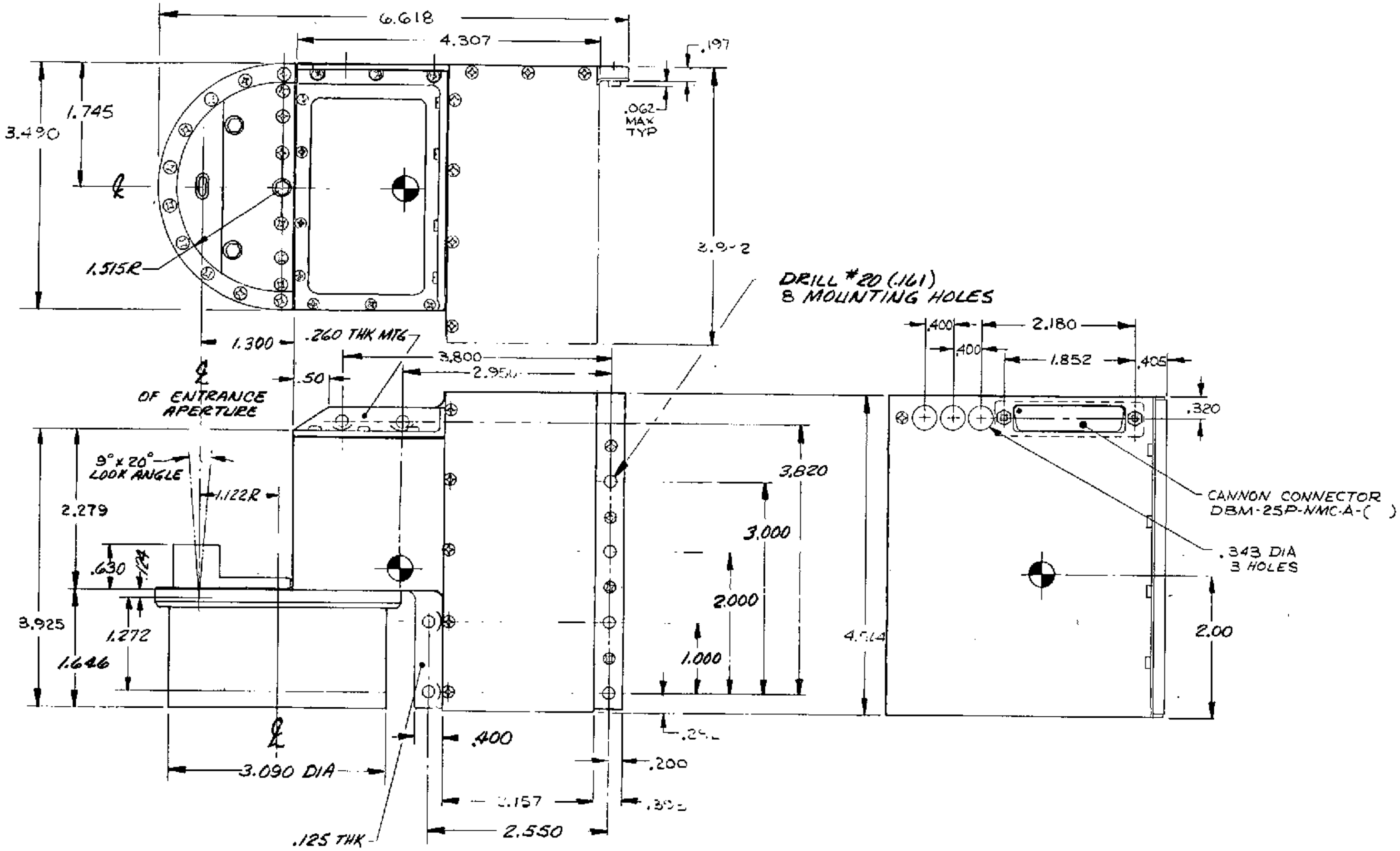
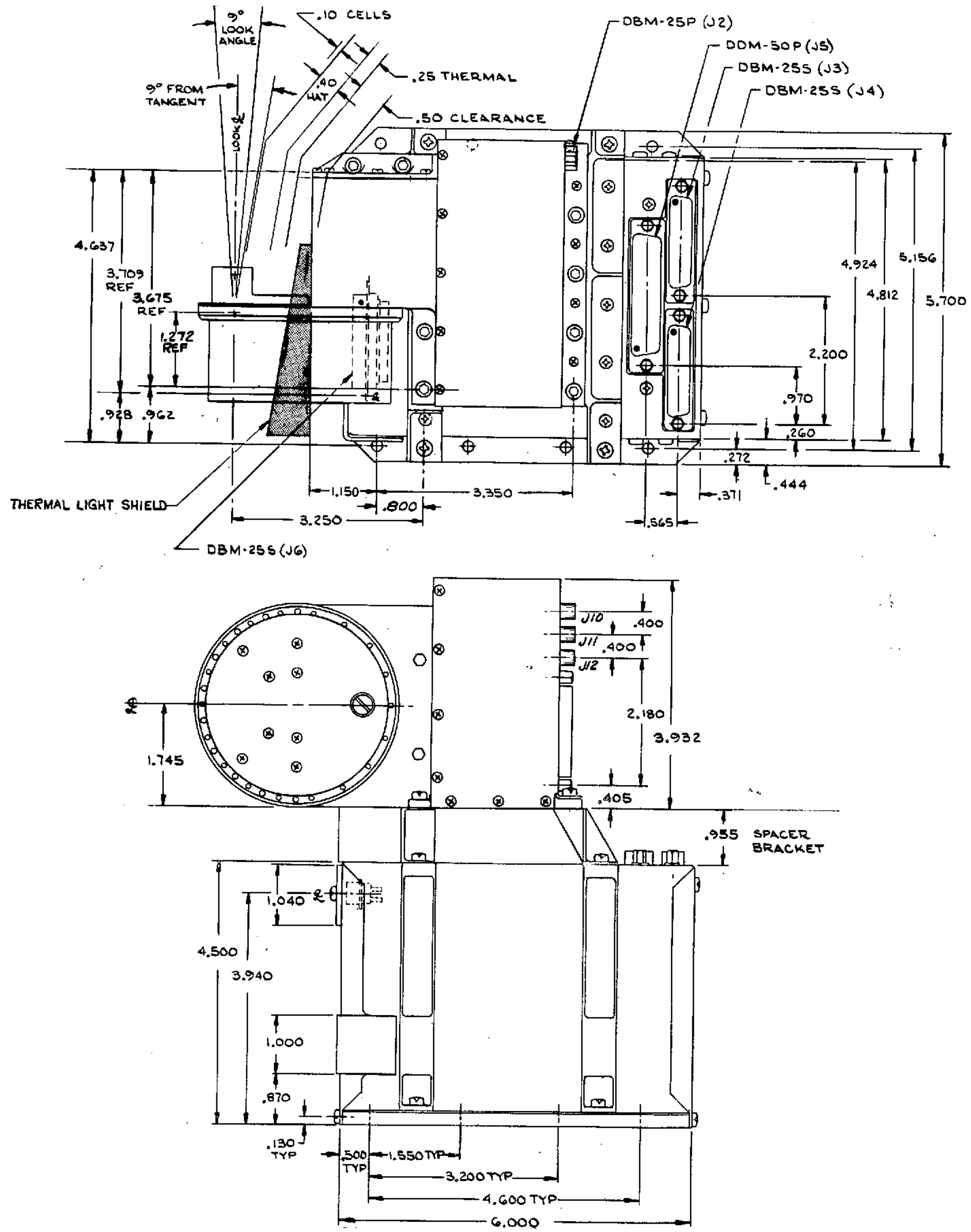


Fig. 9 OUTLINE DRAWING OF PHOTOELECTRON SPECTROMETER SENSOR ASSEMBLY

FOLDOUT FRAME 1

FOLDOUT FRAME 2



NOTES: UNLESS OTHERWISE SPECIFIED.
1. *SENSOR ASSEMBLY – SRA-6778 (JHU/APL)*
   SENSOR OUTLINE JHU/APL NO. SRA-6726
   RCA NO. 2270504 SHEET 1
2. *MAIN ELECTRONICS ASSEMBLY – SRA-6780 (JHU/APL)*
   ELECTRONICS OUTLINE – RCA NO. 2270504 SHEET 2

Fig. 10 OUTLINE DRAWING OF PHOTOELECTRON SPECTROMETER SENSOR NO. 2 AND MAIN ELECTRONICS

Power Consumption

	Experiment Configuration			Current Drain from -24.5 Volt Bus (mA)		
	High-Voltage Monitor 1	High-Voltage Monitor 2	Calibrator	SN121	SN342	SN563
	Off	Off	Off	80	80	81
	Off	Off	On	105	105	106
Normal Operating Condition	3.86 kV	3.86 kV	Off	103	103	105
	4.5 kV	4.5 kV	Off	108	108	110

Energy Scale Calibration

Calibration data taken at The Johns Hopkins University indicate that the six PES sensors exhibit full-scale energies that are within the following limits:

Theoretical full-scale energy (eV)	25	100	500
Measured full-scale energy (eV)	24.6 ±4%	96 ±2%	445 ±3%

Radioactive Source Calibration

Data taken during thermal vacuum tests at GSFC indicate the following radioactive source counting rates:

Sensor Serial No.	Radioactive Source Serial No.	Count Rate (counts/s)
01	VIII	2.0
02	II	2.0
03	VII	2.0
04	VI	1.5
05	III	2.0
06	IV	1.5

Counting Rate

The preamplifiers are designed to rate limit at 250 000 pps. The actual output count rate versus input particle rate for each sensor is somewhat lower because of interaction between the discriminator and buffer circuits. A rate calibration is presently being done at JHU, and curves will be available for each sensor.

Dead Time

Particle counting is inhibited for 350 μs at the start of each main frame.

Angular Resolution/Data Rate

The PES data rate is 64 12-bit words per second. This corresponds to one energy sweep per second in the PES slow sweep rate mode and four sweeps per second in the PES fast sweep rate mode, resulting in the following angular resolution:

Satellite Spin Rate	Angular Resolution per Sweep	
	Slow Sweep	Fast Sweep
1 RPM	6°	1.5°
4 RPM	24°	6°

Thermal Analysis*

The PES main electronics assembly is entirely within the spacecraft and will exhibit a temperature that is very similar to the upper baseplate temperature (nominally +16°C).

A 22-node mathematical thermal model** was used to estimate the temperature variations in the PES sensor. During the aerodynamic heating caused by the spacecraft spinning at 1 RPM in a 120-km perigee, 3800-km apogee orbit, the PES sensor outer metal parts (far removed from any electronic parts) will reach a temperature as high as +54°C. The temperature of the main sensor structural member, which holds the electronic subassemblies, rises smoothly from +16° to +30°C, as shown in Fig. 11.

*Recent spacecraft measurements indicate that all temperatures in this section should be increased by about 10°C (including Figs. 11 and 12).

**Prepared for GSFC by Fairchild Industries under contract NAS5-11823PC402-65428.

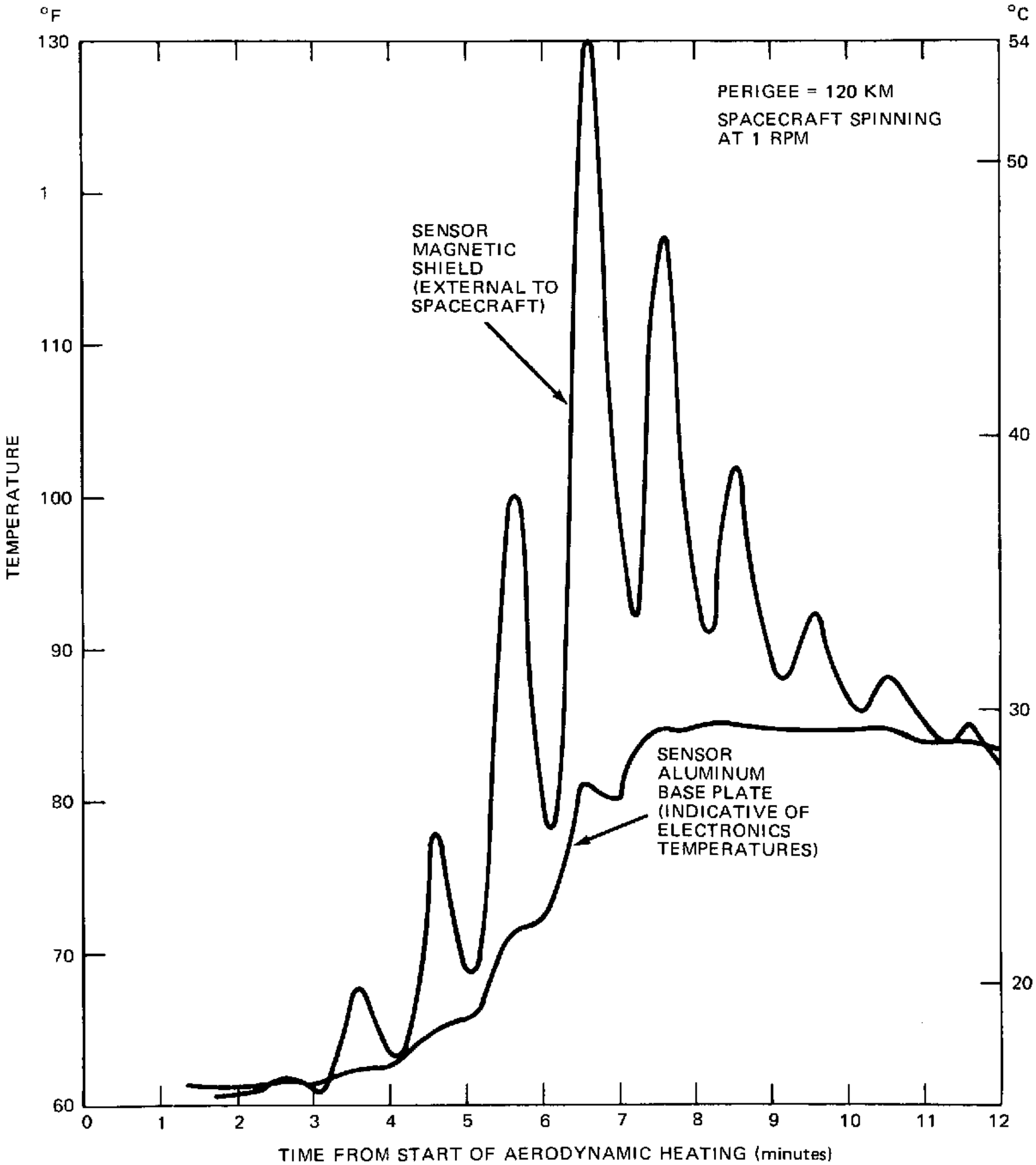


Fig. 11 SENSOR TEMPERATURE CHANGE CAUSED BY AERODYNAMIC HEATING

When the spacecraft is spinning at 1 RPO (revolution per orbit) in a 150-km perigee, 3800-km apogee orbit, solar heating causes the sensor temperature to change from approximately 15° to 25°C, as shown in Fig. 12.

Stress Analysis

A stress analysis (Ref. 5) was undertaken to establish the capability of the PES instrument to withstand the AE-C protoflight vibration levels listed in Table 2. Subsequent environmental tests verified the integrity of the mechanical design.

Table 2

Experiment Protoflight Level Vibration and Acceleration Limits

Protoflight Vibration Test		
Parameter	Random* (Three Orthogonal Axes)	Sinusoidal** (Three Orthogonal Axes)
Bandwidth	20-2000 Hz	5-2000 Hz
Duration	2 minutes/axis	4 octaves/min
Vibration level	0. 2 g^2/Hz (20 g rms)	10 g, 0 to peak

*A 12-dB/octave minimum rolloff shall be applied at both ends of the frequency bandwidth. Prior to testing, the prototype component and vibration facility shall be equalized for a flat response within ±3 dB with a low-level vibration input (1. 5 g rms maximum) for each orthogonal axis. An equalization plot shall be obtained for each axis and held on record.

**When the specified accelerations cannot be attained because of armature displacement limitations, the input may be a constant displacement not less than 0. 5 inch, double amplitude.

Protoflight Steady-State Acceleration Test			
Description	Level (g)	Duration (minutes)	No. of Tests
Positive, in each of three axes	24 ± 2	1 ± 0. 1	1
Negative, in each of three axes	24 ± 2	1 ± 0. 1	1

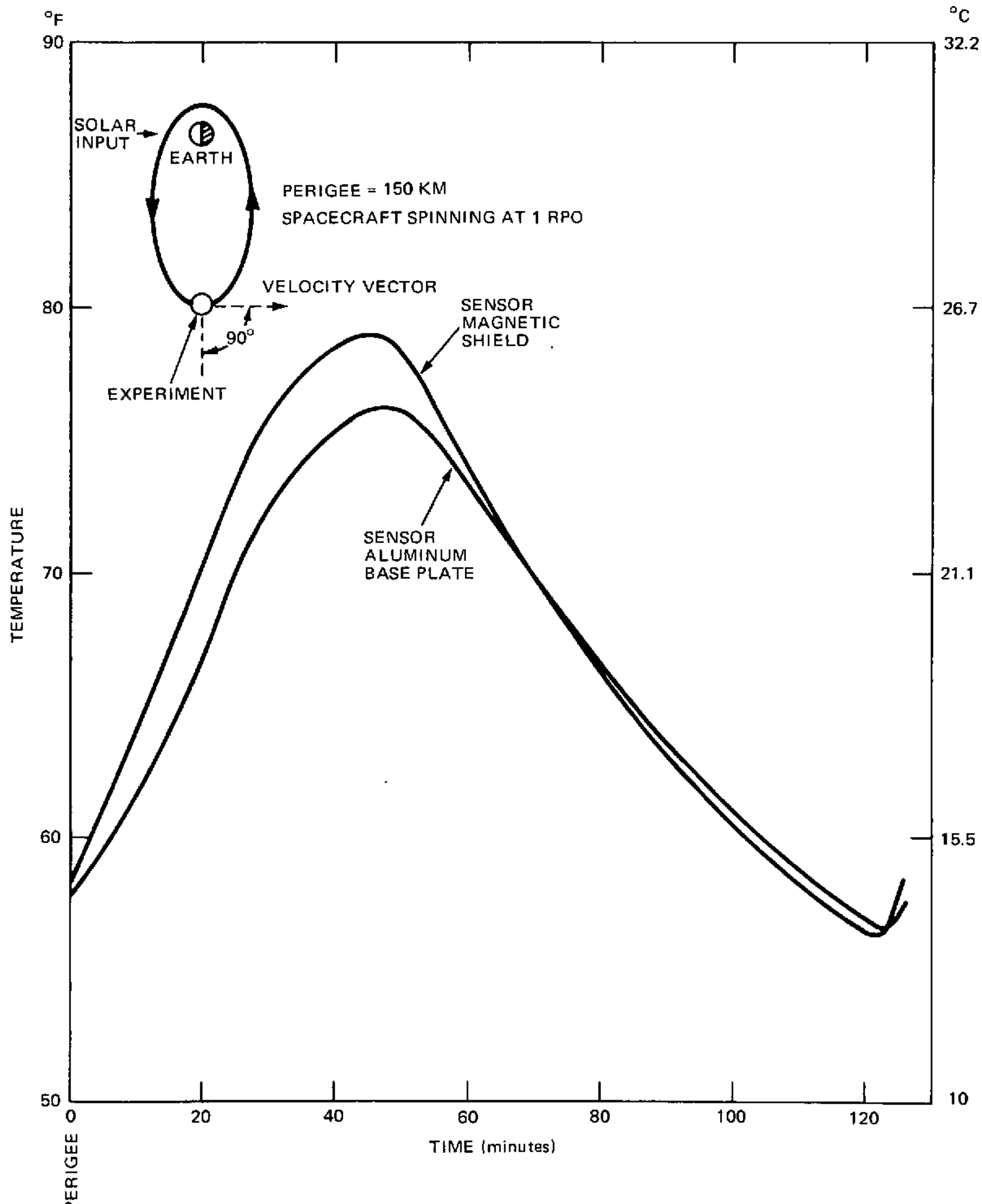


Fig. 12 SENSOR TEMPERATURE CHANGE CAUSED BY SOLAR HEATING

2. CIRCUIT DESCRIPTION

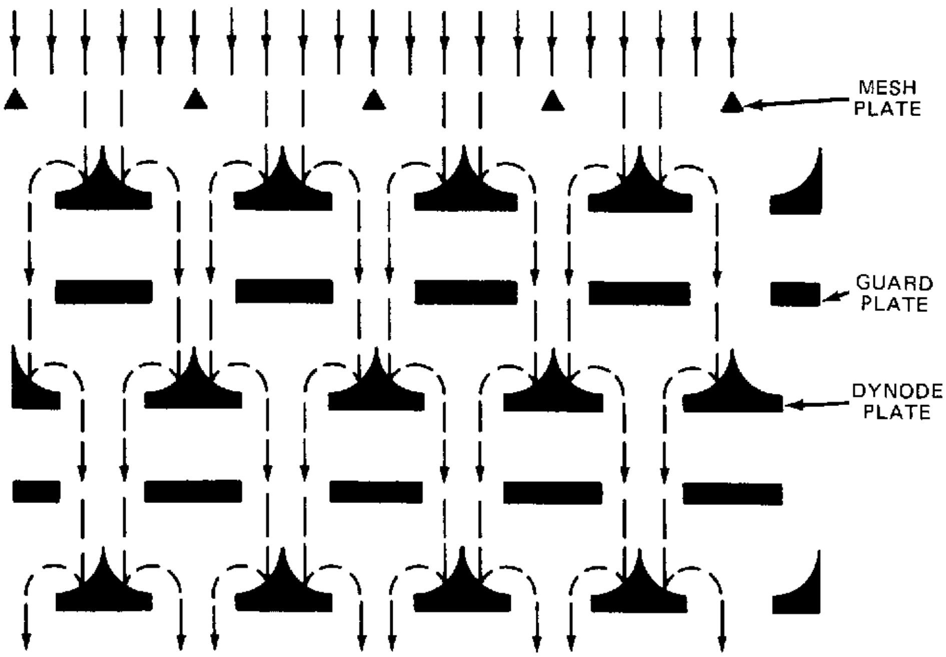
ELECTRON MULTIPLIER

The PES electron multiplier is a MM-1-5NG focused mesh type manufactured by Johnston Laboratories. It is a 20-stage secondary emission electron multiplier and uses activated copper-beryllium dynodes, each of which has many cusp-shaped surfaces separated by holes. A cross-sectional view is shown in Fig. 13. Attached to all dynodes except the first is a guard plate with many holes exactly aligned with the points of the cusps. Adjacent dynodes are separated by ceramic insulators and connected electrically by 5 MΩ inter-dynode resistors. The first dynode differs from all the others in that it has a very fine, high-transmission mesh placed in front of it. This mesh is biased positively with respect to ground via a 10 MΩ resistor and negatively with respect to the first dynode via a 1.5 MΩ resistor. Thus particles are accelerated from the analyzer toward the first dynode with a net voltage of:

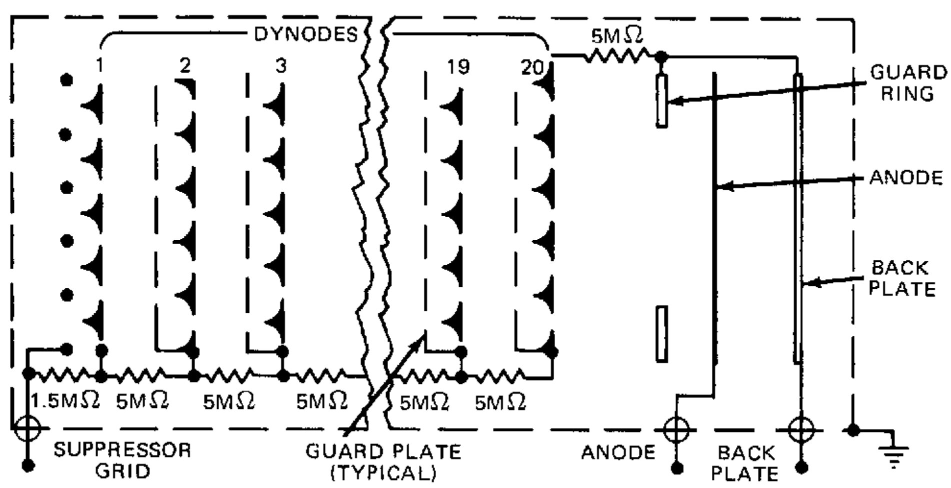
$$\frac{11.5\ \mathrm{M\Omega}}{R_B\ \mathrm{M\Omega}} \times V_{bias} \approx 0.1\ V_{bias}$$

where R_B is the total bias resistance of 112.8 MΩ, including filter and protection resistors. For example, if 4000 volts bias is applied, the electron energy is increased by 400 eV before it strikes the first dynode. Since the grid is negatively biased with respect to the first dynode, the secondary electrons are driven toward the second dynode, and so on.

The bias and filter resistors are located on a Vespel-1 board mounted at the anode end of the multiplier (see Fig. 14). R4 and C3 make up the final stage of a three-section RC filter that reduces the ripple on the bias line to less than 0.5 mV. The first two filter stages are in the bias supply. R3 is part of a voltage-limiting circuit that protects the preamplifier input stage from damage caused by



(a) LONGITUDINAL CROSS SECTION THROUGH FOCUSED MESH MULTIPLIER



(b) ELECTRICAL CONNECTIONS TO MM-1-5NG MULTIPLIER

Fig. 13 SCHEMATIC CROSS SECTIONS OF THE MM-1-5NG ELECTRON MULTIPLIER

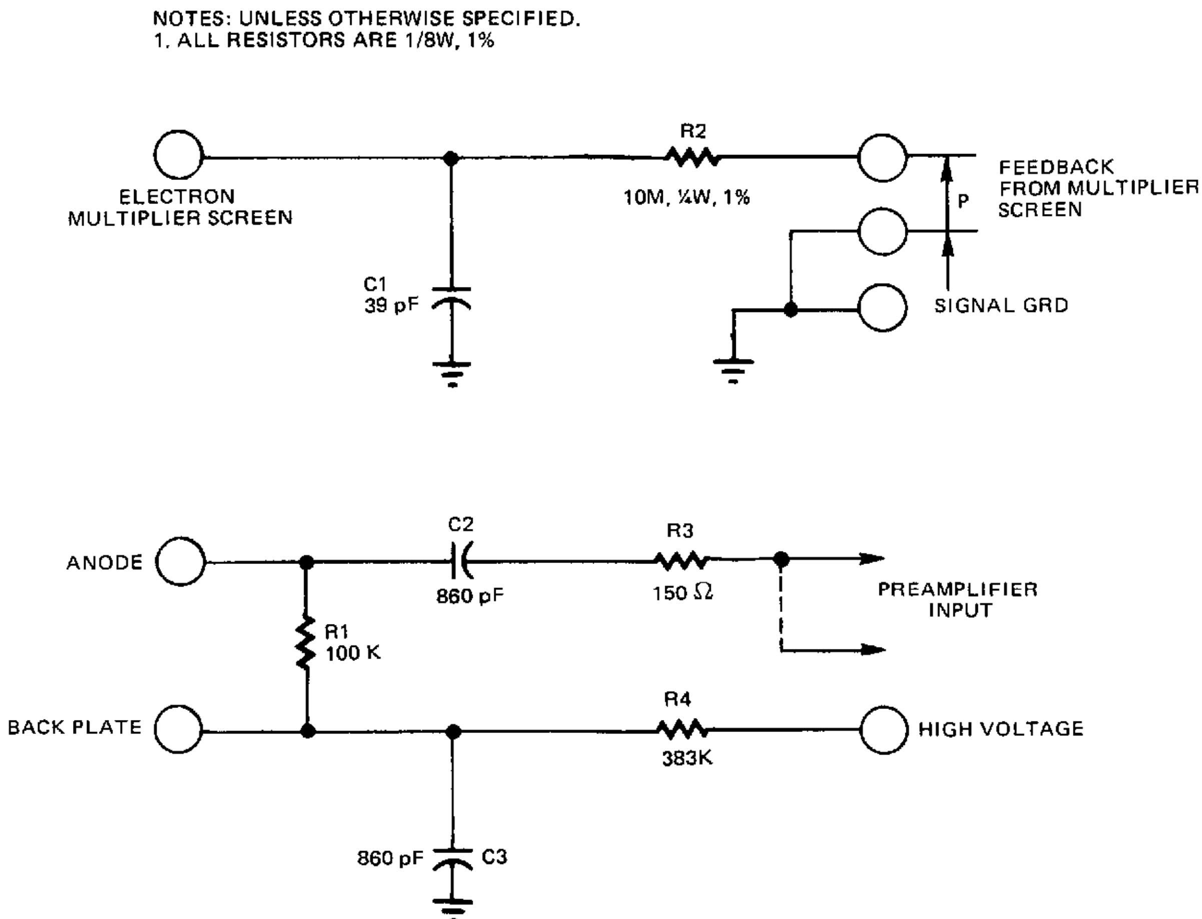


Fig. 14 SCHEMATIC DIAGRAM OF ELECTRON MULTIPLIER INTERFACE BOARD

arcing. The remaining limiting components are on the preamplifier board mounted in a separate compartment containing no high voltages.

ANALOG ELECTRONICS

The PES analog electronics* consists of a charge-sensitive preamplifier, a pair of amplifiers, a voltage discriminator, and an output buffer, as shown in Fig. 15.

Preamplifier

The preamplifier collects the charge appearing at the electron multiplier anode and produces a voltage output proportional to the magnitude of charge collected. Coupling between the multiplier and the preamplifier is through a 6 kV, 860 pF capacitor.

A network containing CR1, CR2, R1, and a resistor mounted with the electron multiplier is used to protect the preamplifier input transistor from damage caused by corona discharge in the multiplier compartment.

The basic components of the preamplifier circuit are a field-effect transistor, Q1, driving a common base stage, Q2, with the collector load bootstrapped by an emitter follower, Q3. The value of the feedback capacitor, C3, establishes the preamplifier sensitivity at approximately 30 nV per electron. The overall current drain is 2.2 mA from the +6 volt supply and 0.8 mA from the -6 volt supply, or 18 mW total.

Pulse Amplifiers

The output signal from the preamplifier is processed by a cascaded pair of pulse amplifiers before being applied

*The analog electronics circuit design was done by S. A. Gary (Ref. 6).

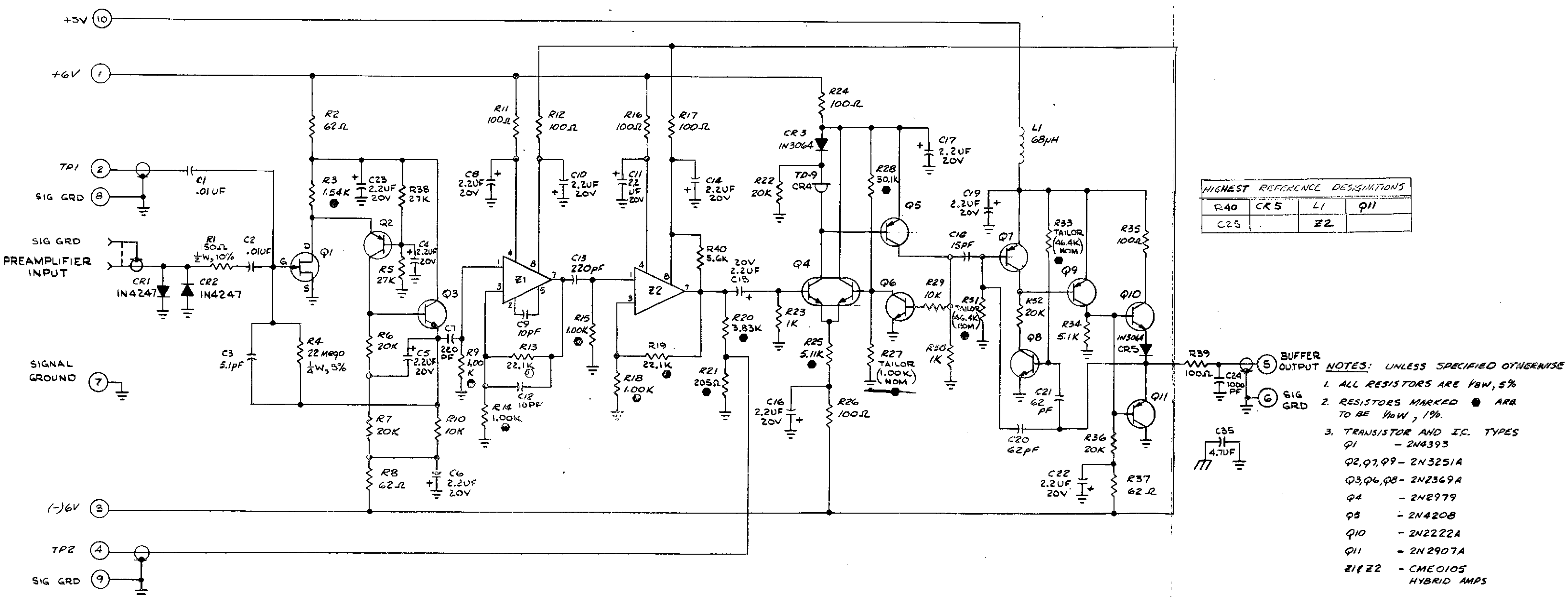


Fig. 15 SCHEMATIC DIAGRAM OF ANALOG ELECTRONICS

to the pulse height discriminator. The amplifiers are hybrid integrated circuits with decoupling and feedback elements connected externally. Figure 16 is a schematic drawing of the internal circuitry for these amplifiers.

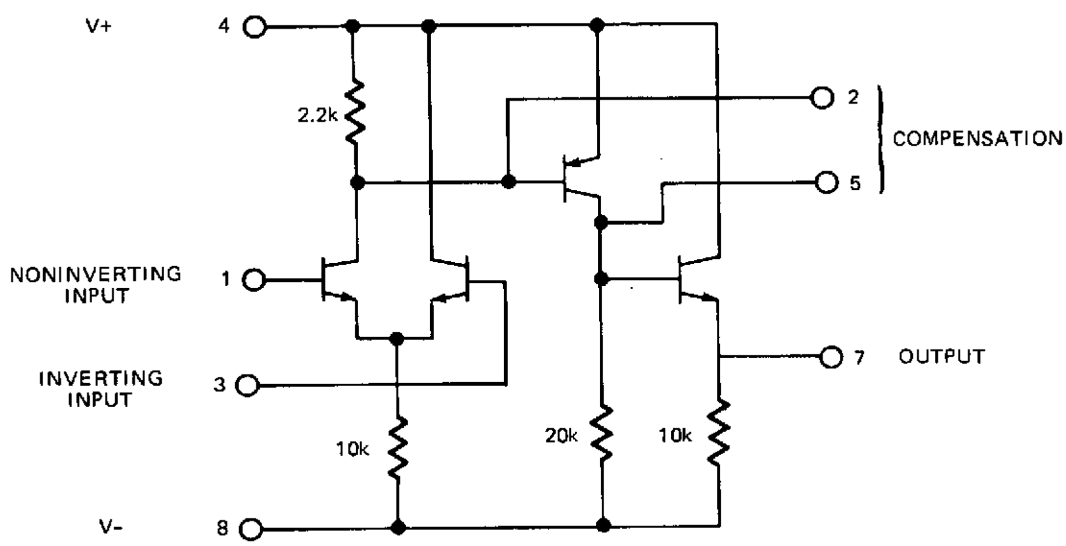
Both amplifiers are connected in a noninverting configuration (see Fig. 15) with a DC feedback ratio of 23 (determined by R13, R14, R18, and R19). Inputs to each stage are through RC differentiation networks (C7, R9 and C13, R15) having equal time constants of 220 ns. The first amplifier stage contains a capacitor, C12, in parallel with the feedback resistor to yield a single integrating time constant at 220 ns. Dynamic stability considerations require the compensation capacitor, C9, in the integrating stage.

The recovery time for return of the amplifier to within the system noise level is 3.0 μs for a signal of 10^7 electrons and 3.5 μs for 2.0×10^7 electrons.

Power consumption for the amplifier pair is 3.8 mA from each of the supply voltages, or 45 mW total. The preamplifier and amplifiers account for most of the system temperature drift, which is on the order of 5% gain variation between -20° and +50°C and 10% between -30° and +50°C. This is adequate for the experiment objectives.

Pulse Height Discriminator

The output of the second amplifier is coupled to the discriminator through the capacitor, C15. The transistor pair, Q4, serves as a differential comparator between the analog signal amplitude and a DC reference voltage set by R27 and R28. Feedback through R29 turns on Q6, reducing the reference voltage and causing regeneration. In the on state, Q6 is in saturation and the reference is within a few millivolts of zero. When the input voltage goes through its zero crossover, regeneration in the opposite direction takes place and the circuit returns to the quiescent state.



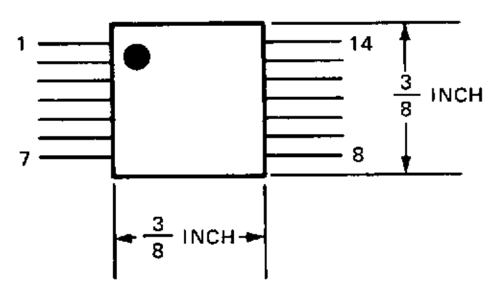


Fig. 16 PHOTOELECTRON SPECTROMETER HYBRID AMPLIFIER

The dead time associated with the discriminator is therefore governed primarily by the shape of the amplifier signal and is equal to the width of the positive lobe, or 500 ns under nonoverload conditions. This leads to a maximum repetition rate for the discrimination of 2 MHz.

The nominal design value for the Q4 reference level is 200 mV, corresponding to 1.0×10^5 electrons at the preamplifier input.

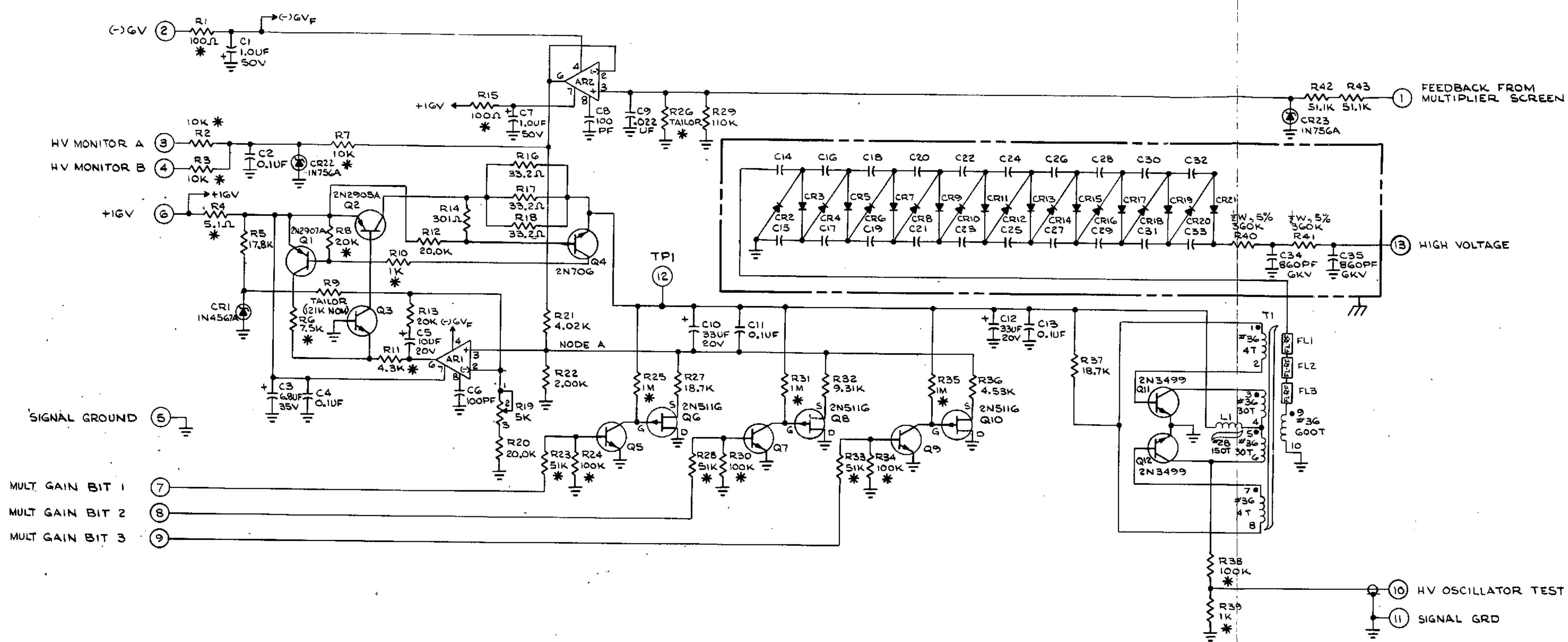
Output Buffer

The output buffer serves a dual function. It converts counts from the discriminator into pulses of fixed amplitude, width, and transition time from a low impedance source, suitable for coupling into the data system through a long transmission line. In addition, it limits the experiment counting rate by establishing a fixed dead time between successive counts. The relation between the data system count rate and the electron intensity incident on the multiplier is thus determined by the characteristics of the output buffer.

ELECTRON MULTIPLIER BIAS SUPPLY

The electron multiplier bias supply (Ref. 7) (see Fig. 17) consists of a tuned-transformer sinewave oscillator (Q11 and Q12), which provides a 500 to 600 volts peak-to-peak sinewave at the secondary of T1. The secondary drives a Cockcroft-Walton multiplier, which develops a 4.5 kV maximum output to bias the electron multiplier. A resistive divider taken from the multiplier screen produces a known fraction of the high voltage output, which is buffered by AR2 and fed back to AR1 via R21 and R22 where it is compared to a reference voltage (set by CR1). An error signal thereby produced controls the multiplier bias.

The feedback ratio is changed by switching any or all of R27, R32, or R36 across R22. The result is seven



NOTES-UNLESS OTHERWISE SPECIFIED:

1. ALL RESISTORS ARE $\frac{1}{10}$W, 1%.
2. ALL RESISTORS MARKED * ARE $\frac{1}{8}$W, 5%.
3. ALL DIODES ARE MH402, 2KV, PIV.
4. ALL CAPACITORS ARE 1000PF, 1KV.
5. ALL TRANSISTORS ARE 2N2222A.
6. OPERATOINAL AMPLIFIERS (AR1 + AR2) ARE LM108H.
7. CORES FOR L1 + T1 ARE FERROXCUBE 2213-3B7.
8. FILTERS (FL1, FL2, FL3) ARE FERRITE BEADS 56-590-65-3B.
9. TAILOR R9 BY SETTING R19 AT APPROX 2.5K AND TAILORING R9 TO MAKE NODE A POTENTIAL ABOUT 1.00V.
10. SET POTENTIAL AT NODE A TO 1.000V BY ADJUSTING R19.
11. TAILOR R26 AFTER SELECTING R9 AND ADJUSTING R19. CHOOSE R26 SUCH THAT HV MONITOR = 4.5V WHEN HV OUTPUT = 4.5KV UNDER 110 MEGΩ LOAD.

HIGHEST REF DESIGNATIONS	
R43	C35
CR23	Q12
L1	T1
AR2	FL3

Fig. 17 SCHEMATIC DIAGRAM OF ELECTRON MULTIPLIER BIAS SUPPLY

equal bias increments from 3 to 4.5 kV. The FET switches are controlled by three minor mode commands, multiplier gain bits 1, 2, and 3. The electron multiplier bias as a function of command state is shown in Table 3.

Table 3

Electron Multiplier Bias as a Function of Command State

Multiplier gain bit 1	0	1	0	1	0	1	0	1
Multiplier gain bit 2	0	0	1	1	0	0	1	1
Multiplier gain bit 3	0	0	0	0	1	1	1	1
Electron multiplier bias (kV)	3.0	3.21	3.43	3.65	3.86	4.07	4.29	4.5

A current-limiting signal developed across R16, R17, and R18 forward-biases the emitter-base junction of Q4 when the load current exceeds about 40 mA at room temperature. R12 and R14 provide an additional feedback voltage that is proportional to the output voltage. As the output voltage drops, R12 and R14 further limit the current, thus reducing the power dissipation in the series pass transistor, Q2. The equation describing the limiting circuit is:

$$V_{be} = R_p I_o + (16 - V_o)\frac{R14}{R20 + R14 + R_p}$$

where

V_{be} = the Q14 base-to-emitter voltage,

V_o, I_o = oscillator drive voltage and current, and

R_p = R16//R17//R18.

Substituting the actual resistor values yields:

$$V_{be} \approx 11 \times 10^3\ I_o - 0.015\ V_o + 0.240.$$

Q4 turns on when V_{be} is about 500 mV, and the nominal voltage/current charcteristics are shown in Fig. 18. The temperature dependence is due to V_{be} shift.

A high-voltage monitor is telemetered as one of the PES 8-second analog subcom words. The redundant outputs (R2 and R3) are voltage-limited to 8 volts by CR22 to protect the spacecraft A/D converter if a PES malfunction shorts R7 to +16 volts. A drive voltage of 4.5 kV yields a 4.5 volt monitor voltage.

CR23 is used to protect AR3 in case arcing in the electron multiplier chamber causes excessive voltage transients at the R43 terminal.

The Cockcroft-Walton multiplier is electrostatically shielded from the tuned oscillator to prevent pickup. A double RC filter reduces the ripple on the high-voltage output to about 40 mV peak to peak. A third RC filter located at the electron multiplier reduces the ripple to less than 0.5 mV peak to peak. The high-voltage power supply leads are returned directly to the +16 volt return, eliminating ground loops through the electron multiplier.

The oscillator draws about 22 mA at 12 volts and delivers 40 μA at 4.5 kV. The oscillator efficiency is therefore about 75%. The control circuitry requires about 3 to 4 volts to operate the series pass transistor, and consequently the bias supply power consumption is about 360 mV when operating at 4.5 kV. The power drain is reduced to about 250 mW when operating at 3.0 kV.

INPUT-OUTPUT BOARD

Certain interface and miscellaneous circuits in the PES cannot be conveniently packaged in any of the experiment subassemblies. Instead these circuits are mounted in a separate subassembly called the input-output board. These circuits consist of the main frame sync buffer and one-shot, the thermistor No. 1 and thermistor

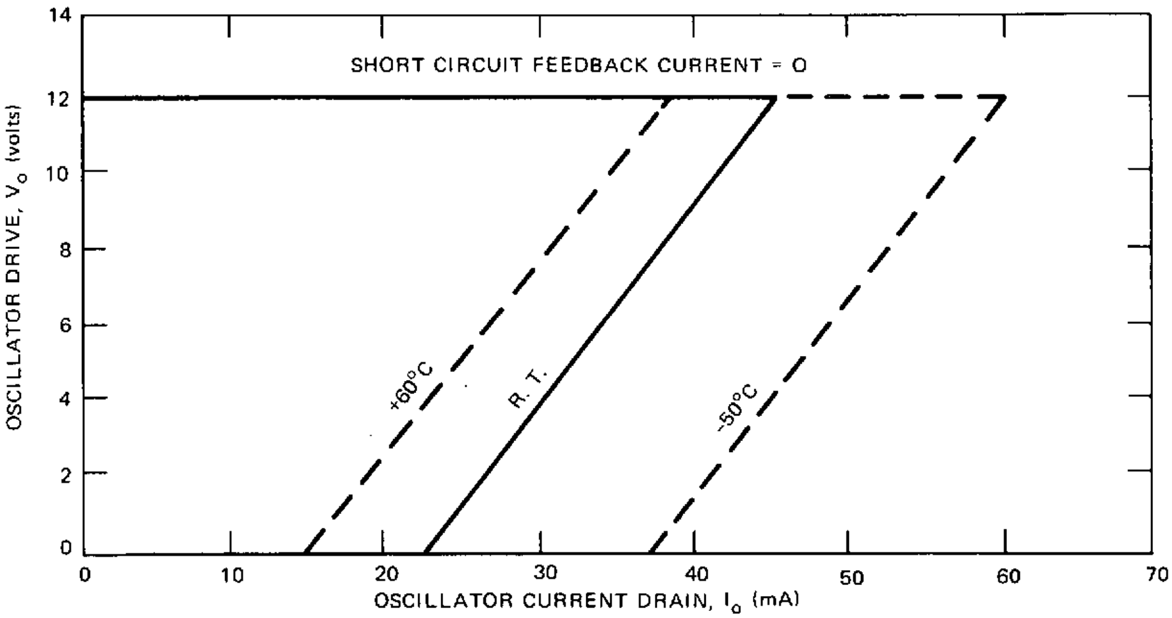


Fig. 18 TUNED OSCILLATOR VOLTAGE/CURRENT CHARACTERISTICS

No. 2 buffers, and the relays for the +16 volt switched No. 1 and +16 volt switched No. 2 voltages. Figure 19 is a schematic of the input-output board.

PES Main Frame Synchronization

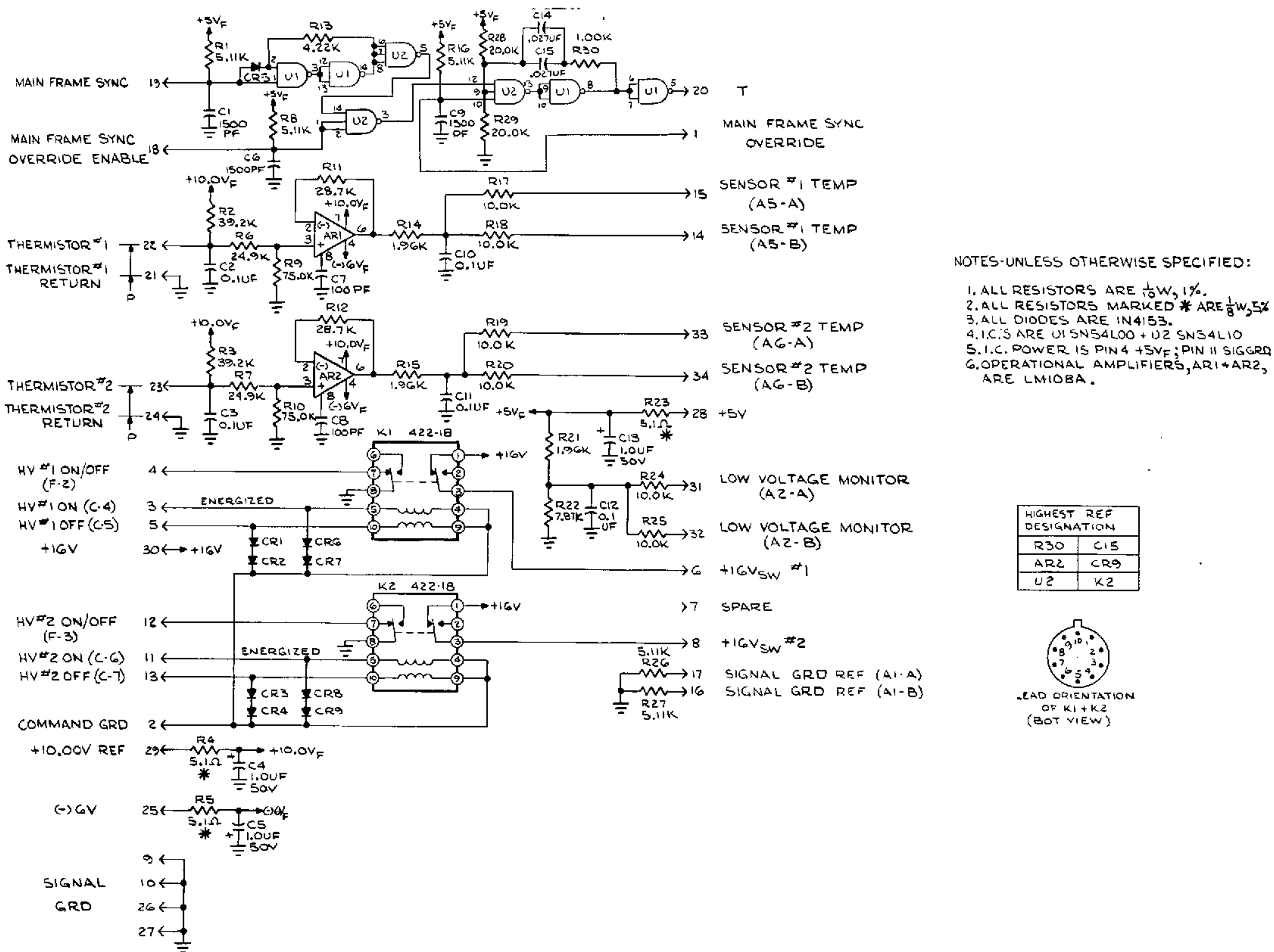
The main frame sync buffer is the standard interface circuit required in GSFC Specification SK-2260216. The sync signal from U1 pin 3 passes through an override gate. In normal operation, pins 1 and 2 of U1 are pulled high by R8, and the override gate acts as an inverter. The main frame sync signal (from the satellite) triggers a 350-μs one-shot, which is constructed from the remaining gates of U1 and U2. In the override condition, U2 pin 3 is forced high by grounding pins 1 and 2 of U2, and the 350-μs one-shot is triggered only by the main frame sync override signal, which is generated in the PES ground support equipment (GSE).

The buffered and stretched main frame sync signal is renamed "T" and is used to parallel-dump data in the PES command and digital data systems. T goes high when the main frame sync goes active. It remains high for a time determined primarily by C14, R28, and R29. The pulse width variation caused by temperature and power supply changes is shown in Table 4.

Table 4

Variation of 350-μs One-Shot Pulse Width as a Function of Power Supply Voltage and Temperature

	Pulse Width Variation (μs)		
	Power Supply Voltage		
Temperature	+4.5	+5.0	+5.5
+60°C	360	337	315
+40°C	365	340	320
+25°C	370	350	325
+10°C	380	355	330
-20°C	387	360	340
-50°C	390	365	340



NOTES-UNLESS OTHERWISE SPECIFIED:

1. ALL RESISTORS ARE $\frac{1}{10}$W, 1%.
2. ALL RESISTORS MARKED * ARE $\frac{1}{8}$W, 5%
3. ALL DIODES ARE 1N4153.
4. I.C.'S ARE U1 SN54L00 + U2 SN54L10
5. I.C. POWER IS PIN 4 $+5V_F$; PIN 11 SIGGRD
6. OPERATIONAL AMPLIFIERS, AR1 + AR2, ARE LM108A.

HIGHEST REF DESIGNATION	
R30	C15
AR2	CR9
U2	K2

Fig. 19 SCHEMATIC DIAGRAM OF INPUT-OUTPUT BOARD

Temperature Sensors

Each PES sensor contains a thermistor that is secured with epoxy in an aluminum housing and mounted to the aluminum wall between the electron multiplier and the bias supply. The thermistor therefore gives a temperature indicative of the average case temperature of the sensor electronics.

Table 1 compares nominal voltage out of the buffer with temperature within the sensor. Assuming a 5 ± 1 MΩ load, the voltage error caused by loading uncertainty is ±0.04%, which is small compared with the design goal of 1%. If either of the redundant outputs is shorted to ground, the voltage at the remaining output must be multiplied by 1.196 in order to use the table.

Command Relays

The command relays, K1 and K2, supply or remove +16 volt power to the sensor No. 1 and No. 2 electron multiplier bias supplies, respectively. They are Teledyne Inc. No. 422-18 latching relays, which have a nominal DC coil resistance of 1130 ohms and a maximum required pulse width of 1.5 ms at the nominal coil voltage of 18 volts. The relay will activate at any voltage between 13.5 and 24 volts. Redundant clamping diodes and flag contacts are provided in accordance with GSFC Specification SK-2260216.

A resistive divider (R21 and R22) monitors the +5 volt line from the main power supply. The information is telemetered as one of the PES 8-second subcom analog words. The signal ground reference is also telemetered (R26 and R27) to monitor the offset between the spacecraft A/D converter ground and the PES signal ground as well as the offset voltage of the A/D converter.

MINOR MODE COMMAND SYSTEM

Commands that make small adjustments to experiment operational modes aboard the AE-C satellite are classified as minor mode commands. This section describes the electronics that receive the PES minor mode command word and produce a 16-bit word indicating the mode status of the experiment.

The command word is 32 bits long, as shown in Fig. 20.

The command word is clocked into a 12-bit shift register (U6, U9, U12) in the PES minor mode command system (see Fig. 21).

When the 34 command clock pulses stop, the desired PES command word resides in the shift register. The enable command word signal that brackets the clock pulses parallel-enters the command word into U5, U8, and U11, which distribute the commands to the experiment subassemblies.

The last 12 bits of the PES command word perform the functions listed in Table 5, which are discussed in the writeup of each applicable subassembly.

Table 5

Minor Mode Command Functions

PES Bit No.	PES Command Function
1	Multiplier 1 gain bit 1
2	Multiplier 1 gain bit 2
3	Multiplier 1 gain bit 3
4	Multiplier 2 gain bit 1
5	Multiplier 2 gain bit 2
6	Multiplier 2 gain bit 3
7	Sweep rate, fast/slow
8	Mode select bit 1
9	Mode select bit 2
10	Mode select bit 3
11	Sensor No. 1 (only)/Sensor No. 2 (only)
12	Sensor alternate/$\overline{\text{alternate}}$

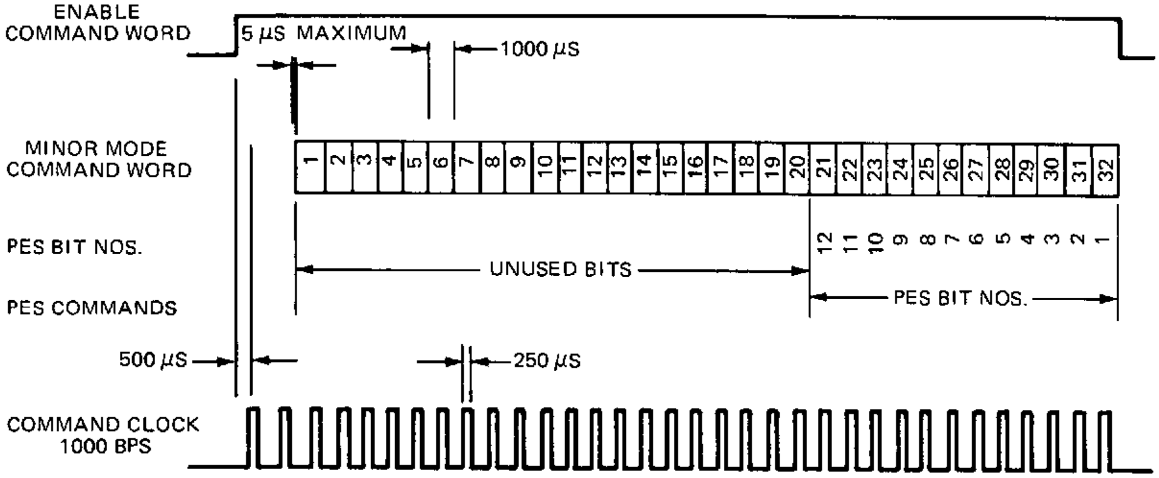
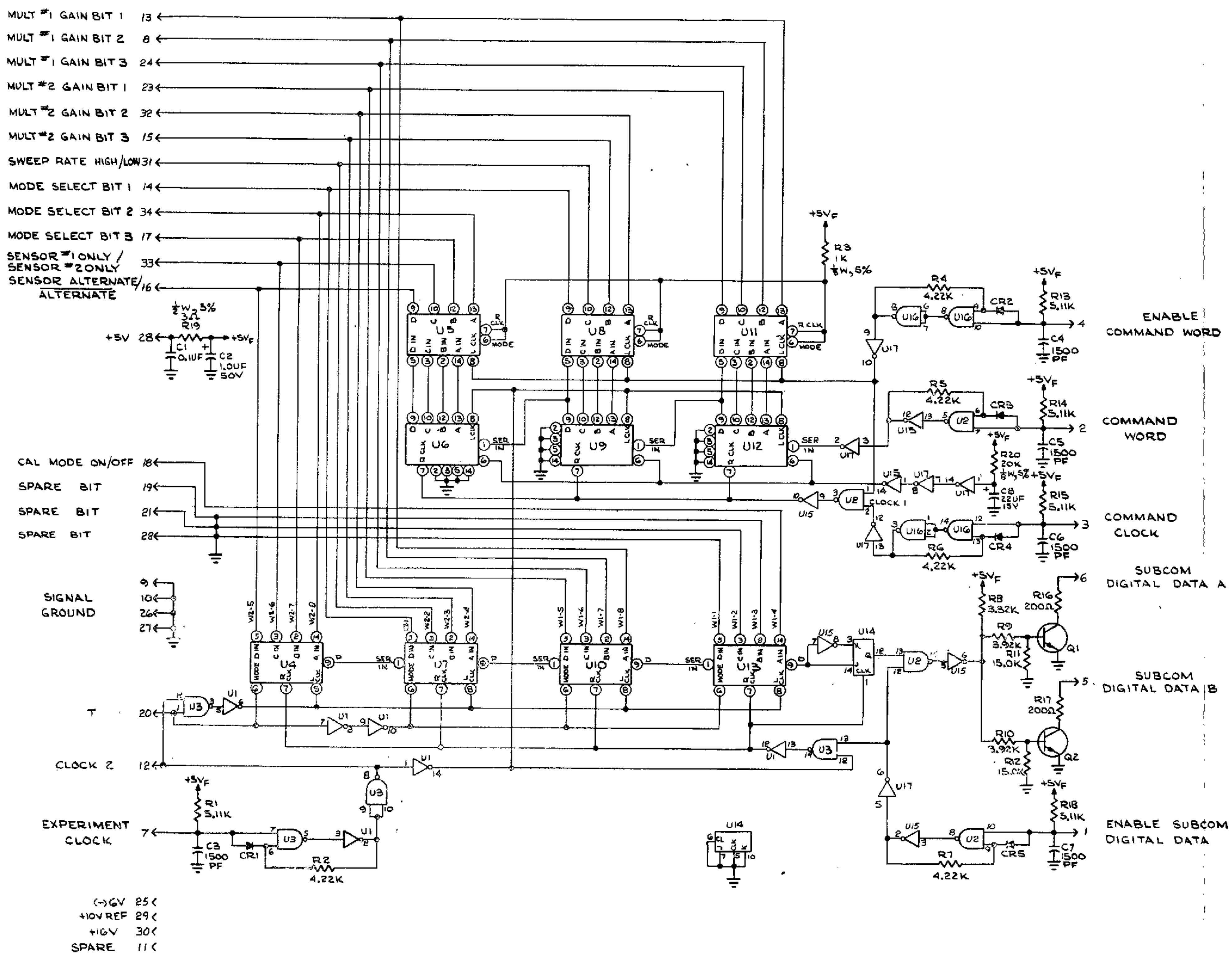


Fig. 20 PES MINOR MODE COMMAND BITS AND CLOCK TIMING

FOLDOUT FRAME 1

FOLDOUT FRAME 2



NOTES - UNLESS OTHERWISE SPECIFIED:

1. INTEGRATED CIRCUITS ARE:
   SN54L04 - U1, U17, U15
   SN54L00 - U3, U16, U2
   SN54L95 - U4 THRU U13
   SN54L73 - U14
2. ALL TRANSISTORS ARE 2N2222A.
3. ALL DIODES ARE 1N4153.
4. I.C. POWER IS PIN 4 +5VF; PIN 11 SIG GRD.
5. ALL RESISTORS ARE 1/8W, 1%.

HIGHEST REF DESIGNATION	
R20	C8
CR5	Q2
U17	

Fig. 21 SCHEMATIC DIAGRAM OF MINOR MODE COMMAND SYSTEM

The commands received in the experiment are parallel-dumped into U4, U7, and U10 at the beginning of each frame by the buffered main frame sync signal, T (see Fig. 22). These bits are read as part of the PES subcom digital data and are used to verify proper receipt of the PES command word.

A cal enable/disable signal indicates when +16 volt power is made available to the calibrator. Should a calibrator malfunction occur, a cal disable relay command will be sent, and +16 volt power is removed from the calibrator. In addition, a cal mode on/off signal indicates when the calibrator is in use, i.e., when it is drawing current from the +16 volt line. Both the cal enable/disable and the cal mode on/off indicators are telemetered as part of the PES 16-bit subcom digital data word.

A 16-bit-long enable subcom digital data signal is required from the spacecraft to read the PES subcom digital data. Readout occurs at a 4-second rate on word 55 of the 64-word subcom and words 55 and 119 of the 128-word subcom (see Fig. 23).

The minor mode command system power consumption is 230 mW at +5 volts.

DEFLECTION SWEEP SUPPLY

The sweep voltages for the analyzer hemispheres are obtained from the digital staircase generator* shown schematically in Fig. 24.

D/A Converter

The transistor switches, Q1 through Q14, the precision resistors, R27 through R33, and the AR1 summing amplifier constitute the D/A converter that is the basis for

*The PES deflection sweep supply and associated control logic were designed by R. W. Young (Ref. 8).

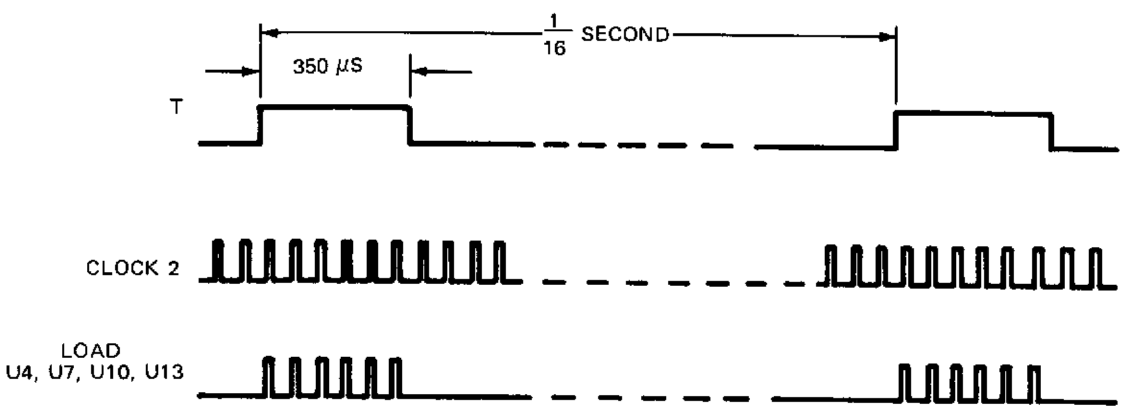


Fig. 22 CLOCK TIMING FOR THE SUBCOM DIGITAL DATA PARALLEL LOAD

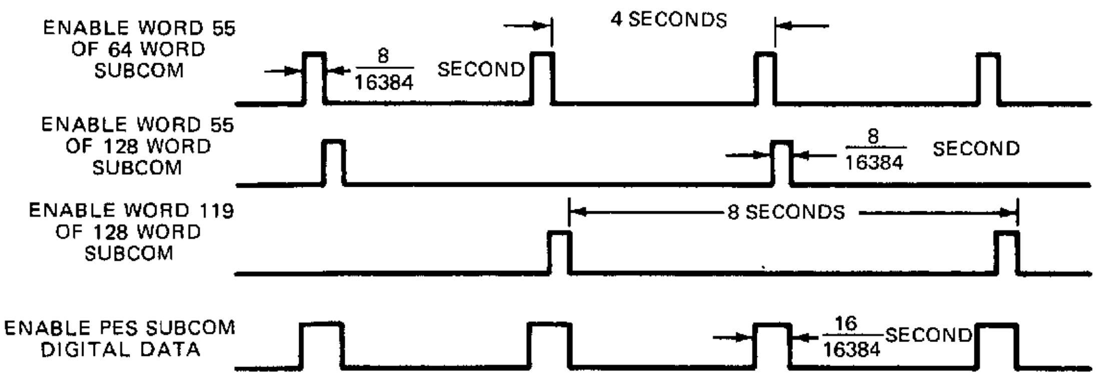
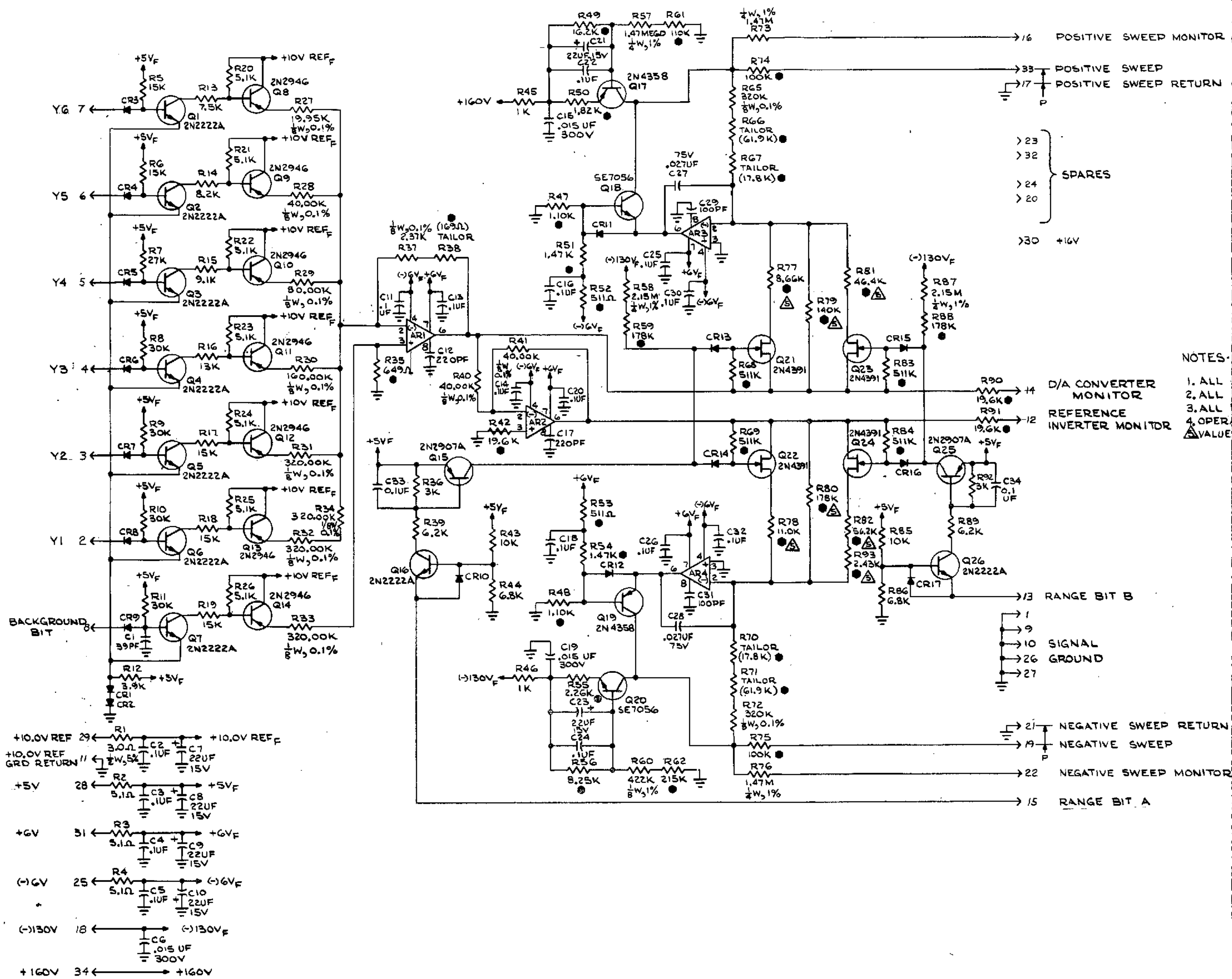


Fig. 23 TIMING FOR THE PES SUBCOM DIGITAL DATA ENABLE SIGNALS

FOLDOUT FRAME 1

FOLDOUT FRAME 2



NOTES: UNLESS OTHERWISE SPECIFIED:
1. ALL RESISTORS ARE 1/8W, 5%
2. ALL RESISTORS MARKED ● ARE 1/8W, 1%
3. ALL DIODES ARE IN4153
4. OPERATIONAL AMPLIFIERS (AR1 THRU AR4) ARE LM108A
5. VALUES OF R77 THRU R82 + R93 TO BE SELECTED TO ±0.25%.

HIGHEST REF DESIGNATION		UNUSED REF DESIGNATIONS
R93	Q26	R63, R64
CR17	C34	
AR4		

Fig. 24 SCHEMATIC DIAGRAM OF DEFLECTION SWEEP SUPPLY

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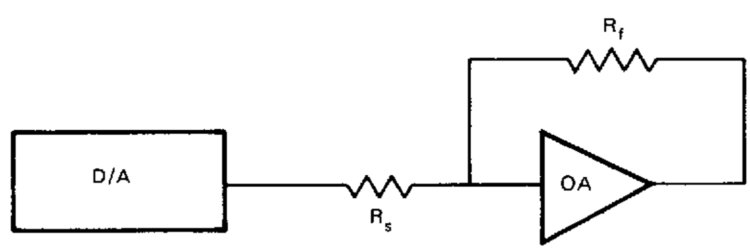
the deflection sweep supply. The Y1 through Y6 signals are derived from a binary counter, and R27 through R32 provide the corresponding binary weighted currents that are summed in AR1. The resulting AR1 output is a 64-step linear ramp with a maximum value of (-) 2.500 volts and a precision of 0.1%.

At the 0.00 volt step, a reverse voltage is applied to the hemispheres via the background bit (Q7). This prevents low-energy electrons from traversing the analyzer so that the 0.00 volt step provides a true indication of the background count rate caused by the radioactive calibration source plus cosmic rays.

High-Voltage Amplifiers

The basic high-voltage amplifier is shown below:



D

In the case of the positive sweep, R5 is a combination of R77, R79, and R81; R_f is R68, R66, and R67; and the OA consists of AR3 (which provides gain) and Q17 and Q18 (which provide high-voltage capability).

Loop stability is provided by C29, C27, and R63.

Q21 and Q23 switch various combinations of source resistors to obtain the three desired maximum sweep voltages:

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Maximum Positive Sweep Voltages		Corresponding Electron Energy
140.4 volts	for	500 eV
28.1	for	100
7.02	for	25

The operation of the negative high-voltage amplifier is analogous and produces maximum sweep voltages of:

(-)109.6 volts	for	500 eV
(-) 21.9	for	100
(-) 5.48	for	25

Performance

The primary sources of DC error are the AR1 and AR2 voltage offsets and resistor temperature drift. In the worst case, this error could be 0.3% full scale (on all ranges), which is about one-fifth of the value of the least significant bit and which more than satisfies the experiment requirements.

The majority of the sweep supply power is consumed in the high-voltage amplifiers. Since Q17 and Q20 are constant current sources, power dissipation is essentially constant at 320 mW.

MODE CONTROL LOGIC

The mode control logic accepts signals from the command system and the timing signal generator, and combines them to determine the dwell time of the positive and negative high-voltage supplies in their various gain ranges. The control logic outputs drive the gain switching network, which adjusts the sweep supplies to three full-scale output levels (corresponding to 25, 100, and 500 eV). The command signals are combined to obtain the three ranges, while the timing signals determine the range dwell. The dwell is also variable and corresponds to either fast or slow spin rate.

Refer to Fig. 25 for the mode control logic implementation. There are five deflection swept range modes (Figs. 26 through 29). Y7 and Y8 are timing signals from the timing signal generator. The period of Y7 is either 32T (slow spin rate) or 8T (fast spin rate). The period of Y8 is always twice the period of Y7. The signals from the command system are cal and mode select bits 1, 2, and 3. The mode signals, Modes I, II, III, IV, and V, are generated from the commands by the mode control logic. Range bits A and B are the mode control logic outputs to the gain switching circuit. These range bits adjust the sweep supply gains for the three full-scale swept outputs.

The logic equations were written by observing the waveform relationships of Figs. 26 through 29. The mode control output "states" that define the three gain ranges are given in Table 6.

Table 6

Relationship of Range Bit "States" to Full-Scale Electron Energy Level

Range Bits		Full-Scale Electron Energy Level		
A	B	25 eV	100 eV	500 eV
1	1	X		
1	0		X	
0	0			X

SWEEP CALIBRATOR

The sweep calibrator* makes an 11-bit A/D conversion of each step of the positive and negative deflection sweeps. Figure 30 is a schematic diagram of the calibrator. All steps are monitored by forcing the experiment into

*The sweep calibrator circuit was designed by R. W. Young (Ref. 9).

FOLDOUT FRAME 1

FOLDOUT FRAME 2

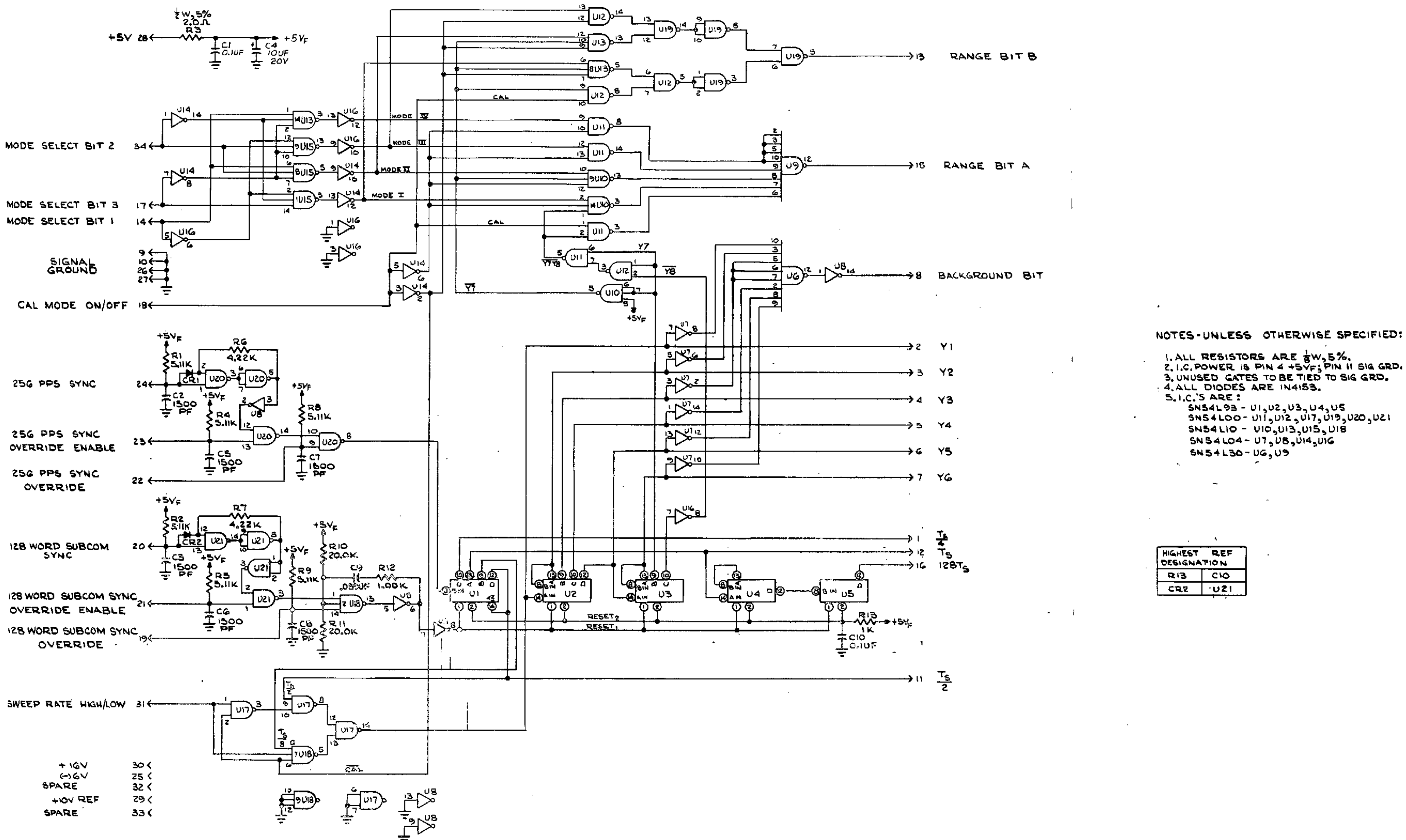

Fig. 25 SCHEMATIC DIAGRAM OF TIMING AND MODE CONTROL LOGIC

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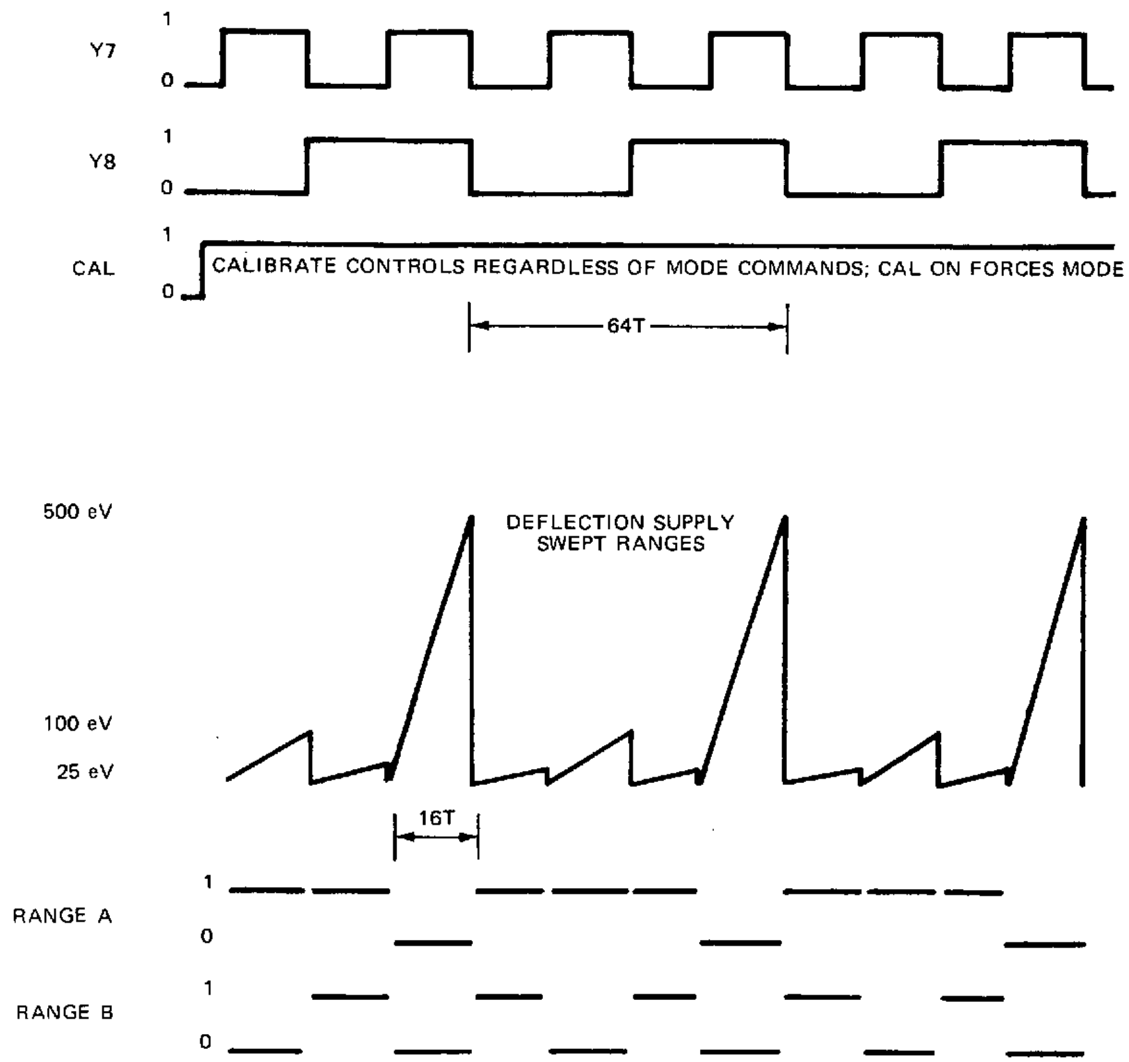


Fig. 26 MODE CONTROL LOGIC: CALIBRATE FORCES THE INSTRUMENT TO MODE I, LOW SWEEP RATE

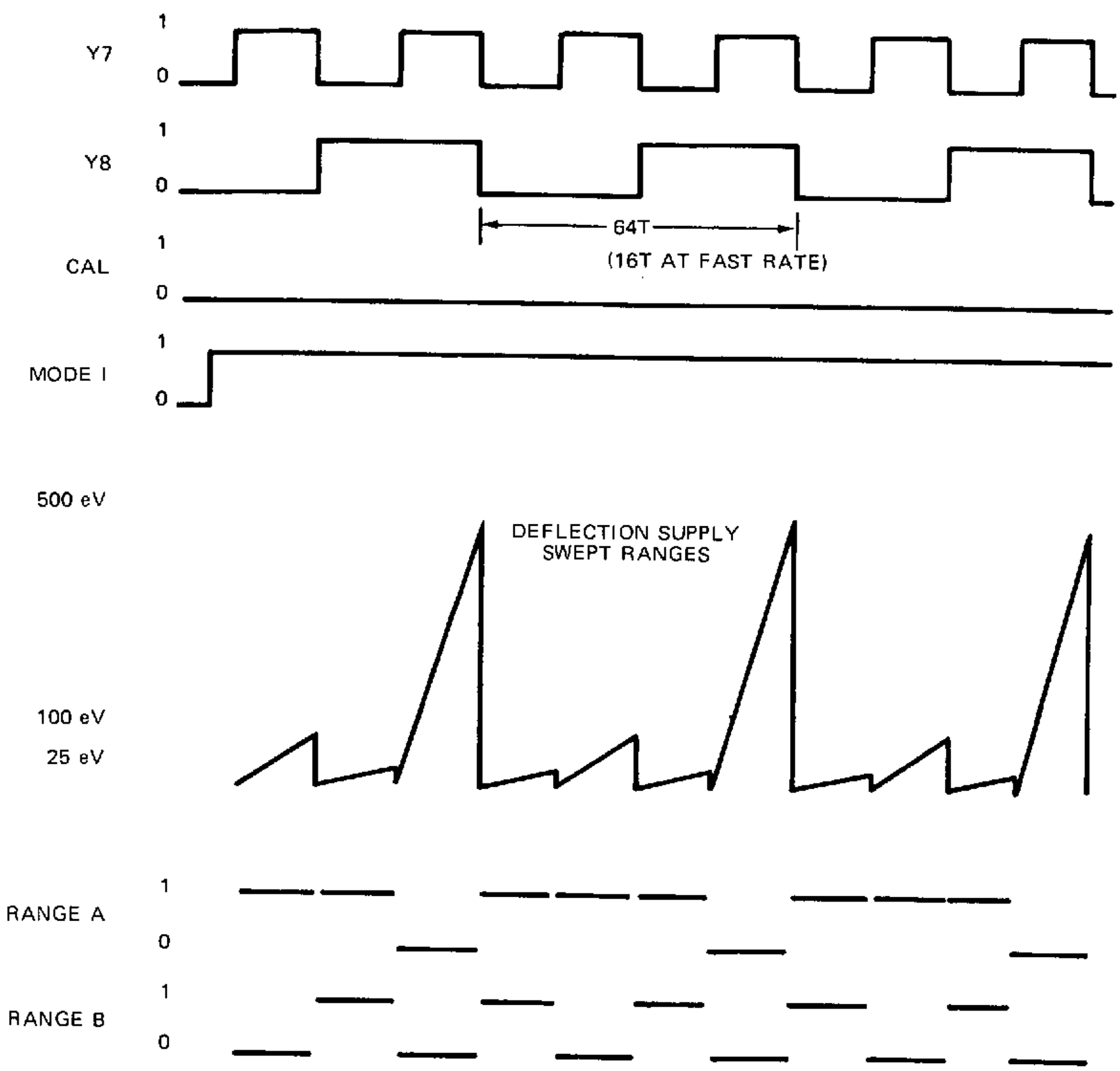


Fig. 27 MODE CONTROL LOGIC: MODE I—HIGH/LOW SWEEP RATE

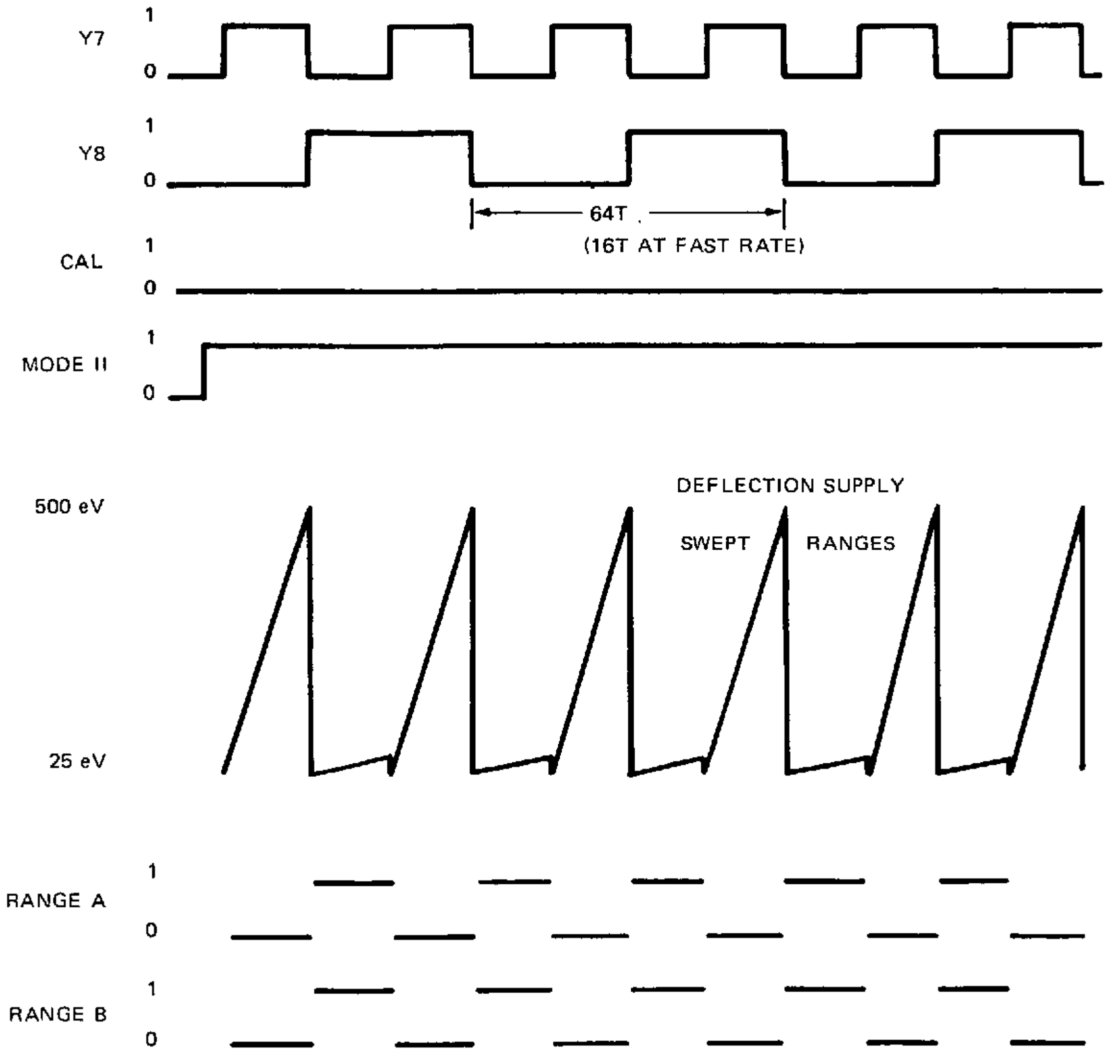


Fig. 28 MODE CONTROL LOGIC: MODE II—HIGH/LOW SWEEP RATE

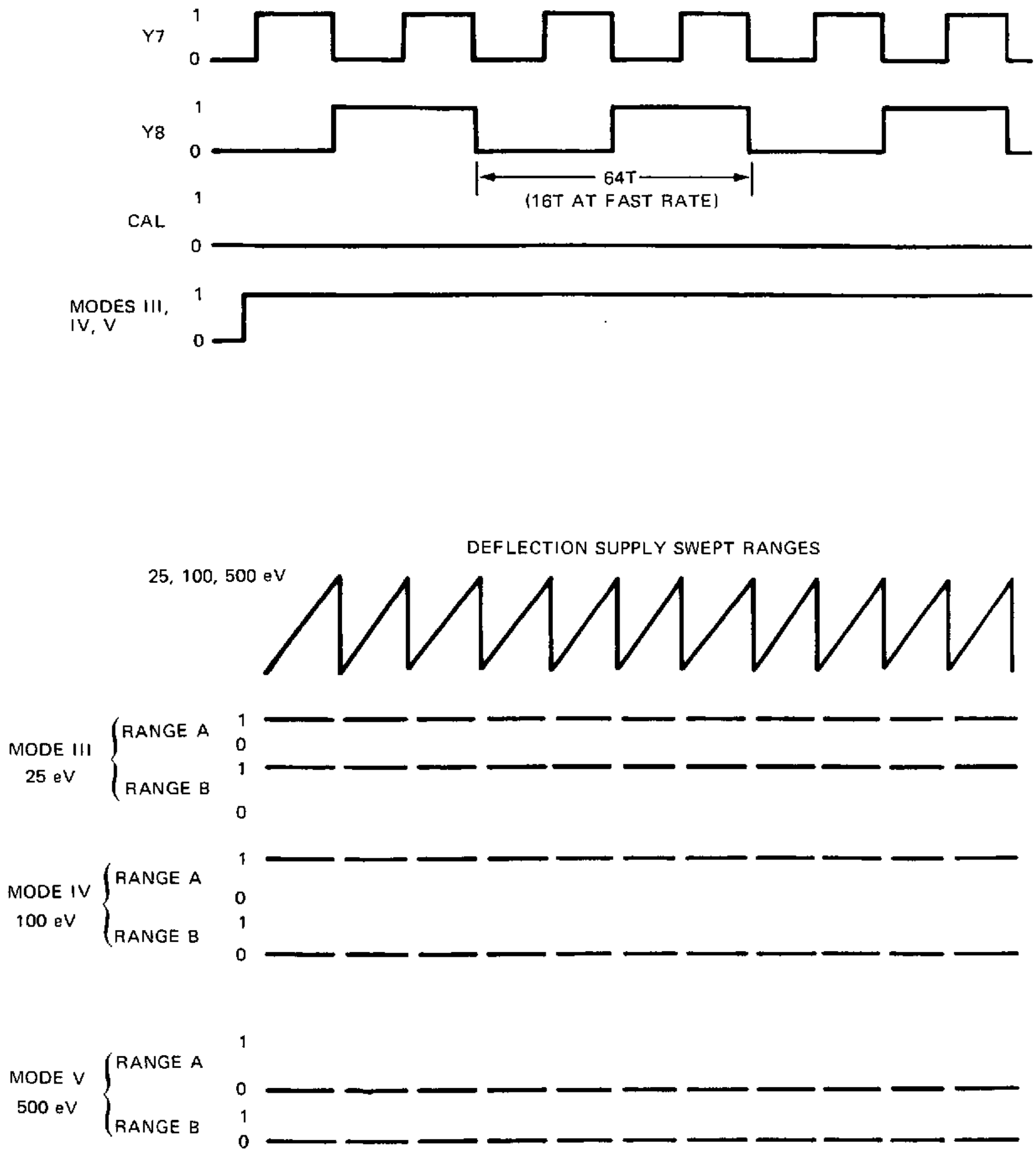
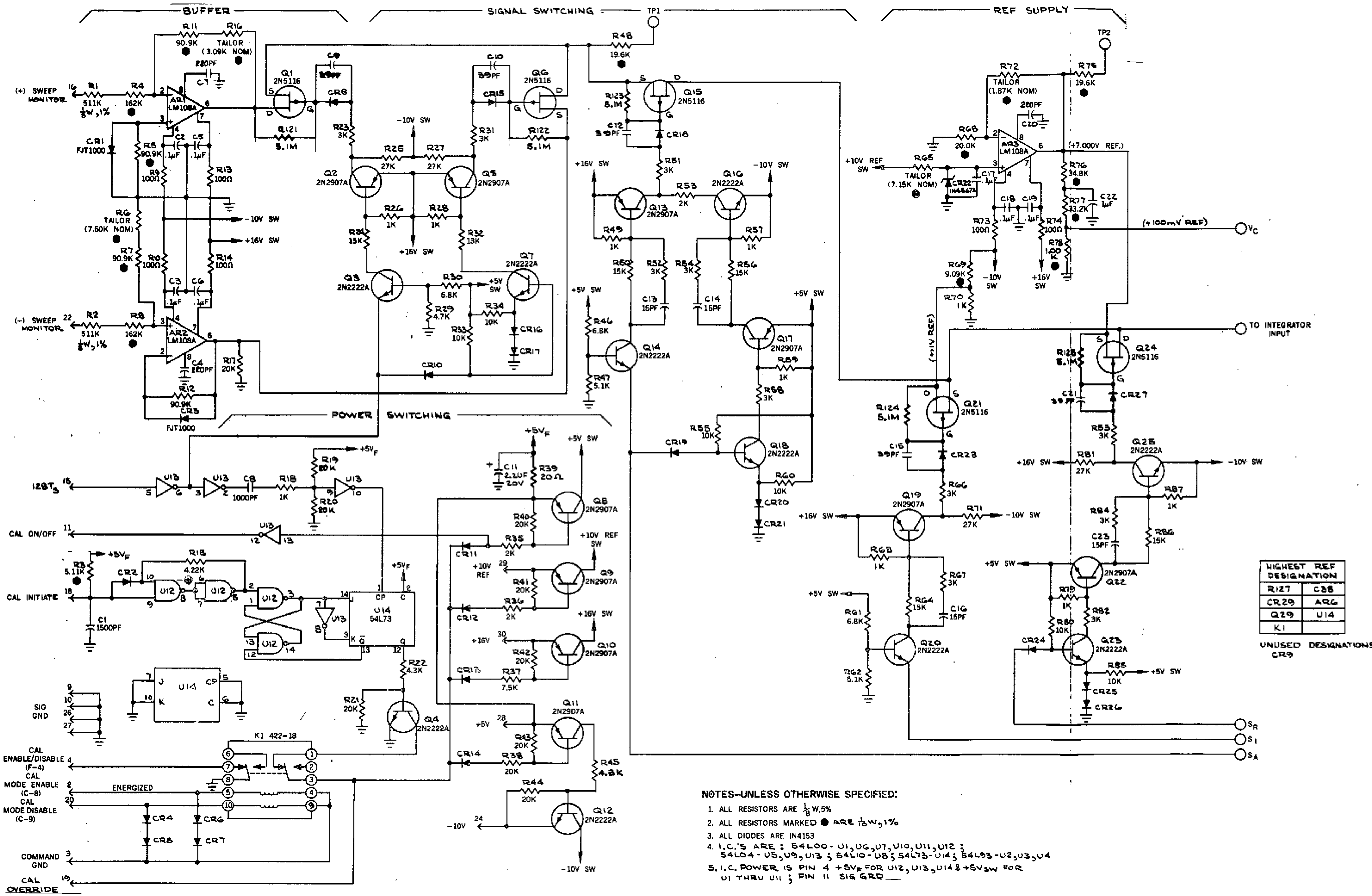


Fig. 29 MODE CONTROL LOGIC: MODES III, IV, V—HIGH/LOW SWEEP RATE

FOLDOUT FRAME 1 FOLDOUT FRAME 2



HIGHEST REF DESIGNATION	
R127	C38
CR29	AR6
Q29	U14
K1	

UNUSED DESIGNATIONS CR9

NOTES–UNLESS OTHERWISE SPECIFIED:

1. ALL RESISTORS ARE 1/8 W,5%
2. ALL RESISTORS MARKED ● ARE 1/10 W, 1%
3. ALL DIODES ARE IN4153
4. I.C.'S ARE: 54L00 - U1, U6, U7, U10, U11, U12; 54L04 - U5, U9, U13; 54L10 - U8; 54L73 - U14; 54L93 - U2, U3, U4
5. I.C. POWER IS PIN 4 $+5V_F$ FOR U12, U13, U14 & $+5V_{SW}$ FOR U1 THRU U11; PIN 11 SIG GRD

Fig. 30 SCHEMATIC DIAGRAM OF SWEEP CALIBRATOR

FOLDOUT FRAME 1

FOLDOUT FRAME 2

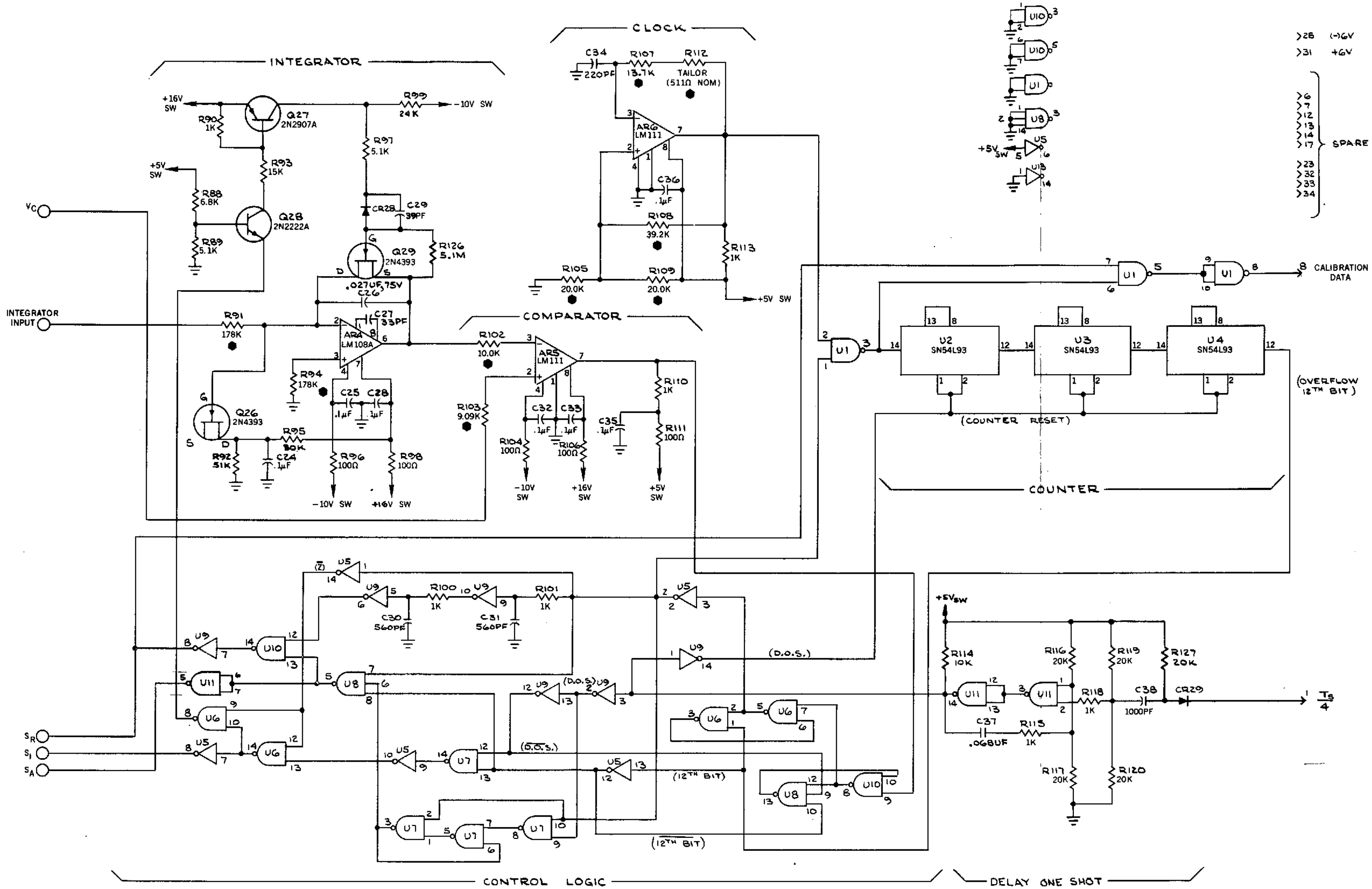


Fig. 30 SCHEMATIC DIAGRAM OF SWEEP CALIBRATOR (continued)

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Mode I (ABAC sweep sequence) during calibration. The experiment is also forced into the slow sweep rate mode and synchronized with the 128 word subcom sync signal. The positive sweep steps are measured during the first 4 seconds after the subcom sync signal, and the negative sweep steps are measured during the remaining 4 seconds.

During the calibration sequence, particle data are inhibited and the PES digital data system is used to store and transmit calibration data.

Calibration Enable and Initiate

The basic A/D converter is synchronized with the telemetry main frame sync signal and makes conversions at 4 times the main frame data rate. However the calibrator power is normally off. When a cal initiate command is received, the power switching network (U12, U14, and Q4) looks for the next 128 word subcom sync signal and then turns the calibrator on. When the next sync signal arrives (8 seconds later), the switching network shuts the calibrator off.

A relay, K1, is used as an override to remove power from the calibrator in case of calibrator malfunction.

The A/D Converter

The A/D converter is a dual-slope integrating type. It consists of a voltage reference, an integrator, a comparator, an oscillator, and an 11-bit counter with an overflow bit, as shown in Fig. 31. At the beginning of the conversion, the integration capacitor is charged to the comparator reference voltage, V_c. The unknown voltage, V_A, is inverted and applied to the integrator input, the comparator output changes, and clock counts are gated into the counter. When the counter overflows, the reference voltage replaces the unknown voltage and discharges the integration capacitor to V_c, at which time the comparator output changes and the conversion is complete.

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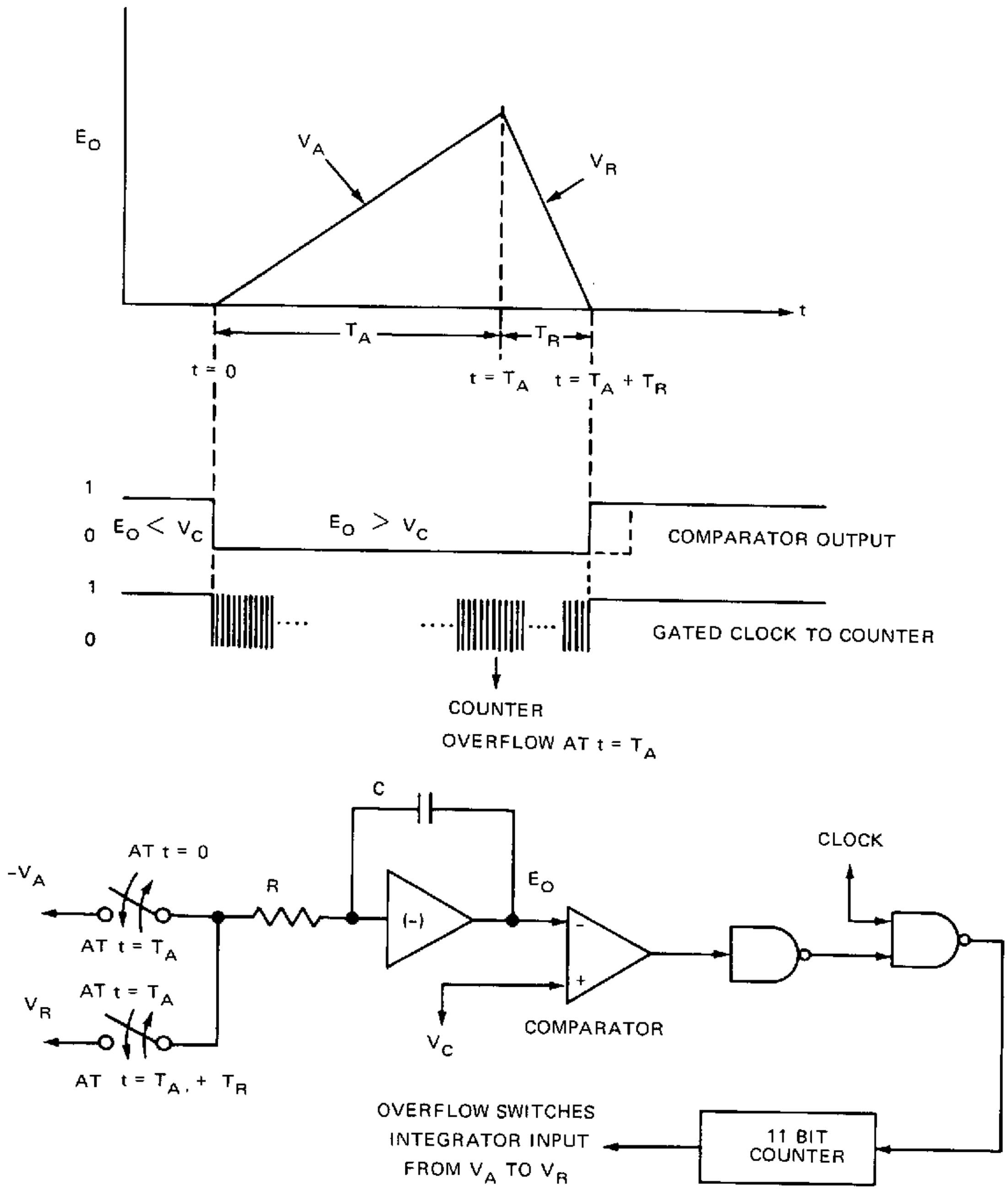


Fig. 31 DUAL-SLOPE INTEGRATING A/D CONVERTER BLOCK DIAGRAM

The charge added to the capacitor by the unknown voltage must equal the charge removed by the reference voltage. In equation form:

$$Q = \frac{V_A}{R} T_A = \frac{V_R}{R} T_R ,$$

where

Q = charge transfer,

V_A = average input voltage during T_A,

T_A = time to counter overflow = integrating capacitor charge time,

V_R = reference voltage, and

T_R = integrating capacitor discharge time.

In terms of the oscillator period, T_{osc}:

$$V_A(2^{11} T_{osc}) = V_R(\dot{n}\ T_{osc})$$

where n is the number of counts received by the counter after overflow. Solving for V_A:

$$V_A = n \frac{V_R}{2^{11}} .$$

Figure 30, sheet 1, shows the buffer amplifiers for the positive sweep (AR1, inverting) and negative sweep (AR2, noninverting). Selection of the positive or negative sweep monitor mode is controlled by the 128T squarewave; which is switched to the low state by the 128 word subcom sync signal. During the first phase of the 128T squarewave, the FET switch, Q1, is on and the positive sweep steps are measured. During the next squarewave phase, Q6 is on and the negative sweep steps are measured.

The reference voltages, V_R and V_C, are set by CR22 and AR3, and V_R is switched via Q24. The unknown voltage, V_A, is switched via Q15, and a 1 volt signal used to drive the initial integrating capacitor voltage to V_c is switched via Q21.

Figure 30, sheet 2, contains the integrator, comparator, clock, and counter discussed earlier and also the associated control logic.

The clock runs at 300 kHz ±3% over a -50° to +60°C temperature range. The maximum conversion time is therefore 14.1 ms plus an additional 1 ms for turn-on and initializing times.

The integration time constant is 4.8 ms, which allows a maximum integrator output voltage of 10.5 volts. Initial capacitance tolerance and temperature sensitivity may extend this maximum to 12 volts.

The accuracy of the converter is 0.2% ± 1 bit over the temperature range. The timing of the converter is such that it puts out one count more than the expected number. The PES digital data system, however, is set up to put out one count less than it receives as an aid in data system checkout (see following Section). Consequently the PES reads the expected calibration number.

The calibrator power consumption is 575 mW when operating and is essentially zero when in standby.

DIGITAL DATA SYSTEM

The PES digital data system consists of four 12-bit accumulators and four 12-bit temporary storage registers. Each accumulator counts for one-fourth of a frame. At the beginning of each new frame, the data are parallel-transferred into temporary storage and the accumulators are reset. This sequence is in sync with the spacecraft telemetry system and is independent of the operational mode of the experiment. Figure 32 illustrates the data system timing.

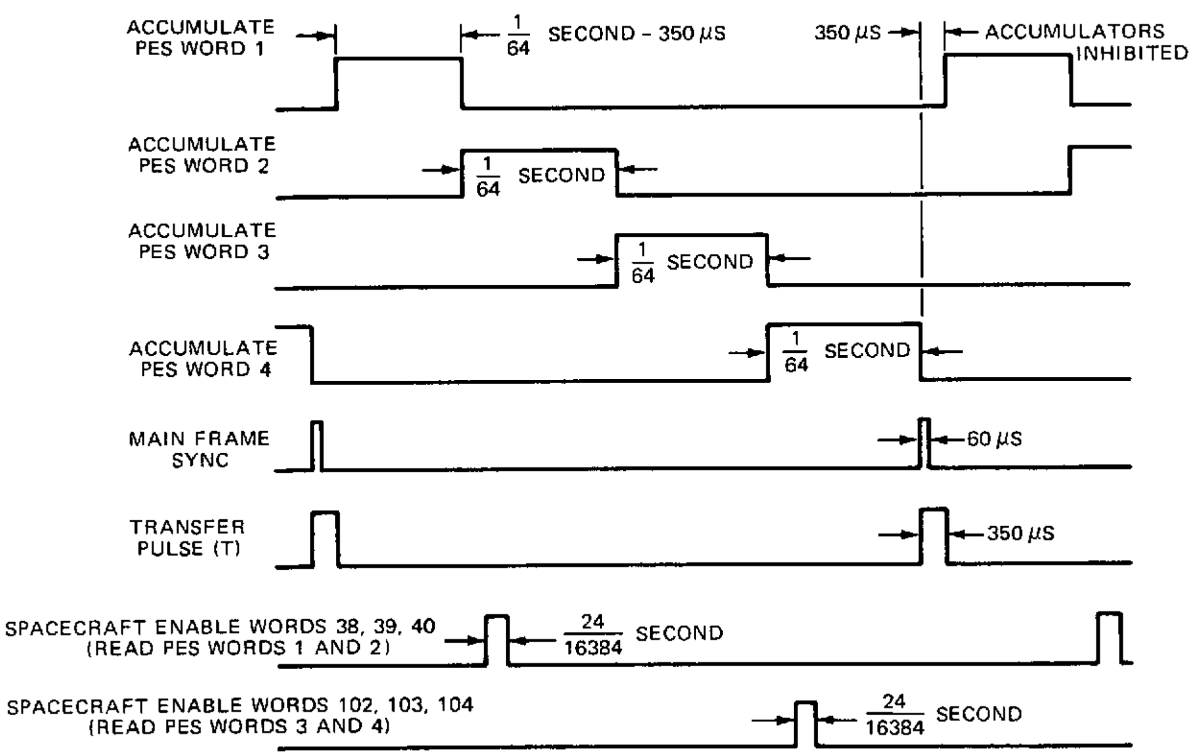


Fig. 32 TIMING FOR THE PES PARTICLE DATA WORD ENABLES

Figure 32 shows that the data are read out one frame after they are accumulated. At the beginning of each frame, the 350-μs transfer and reset signal, T, is generated, and during this time accumulation is inhibited. The accumulation time for every fourth word is therefore reduced by 350 μs, or about 2%. Since the 350 μs is ±10% stable with temperature, the error variation is 0.2% from -50° to +60°C. A temperature calibration could be used to reduce the error further, but this is considered unnecessary.

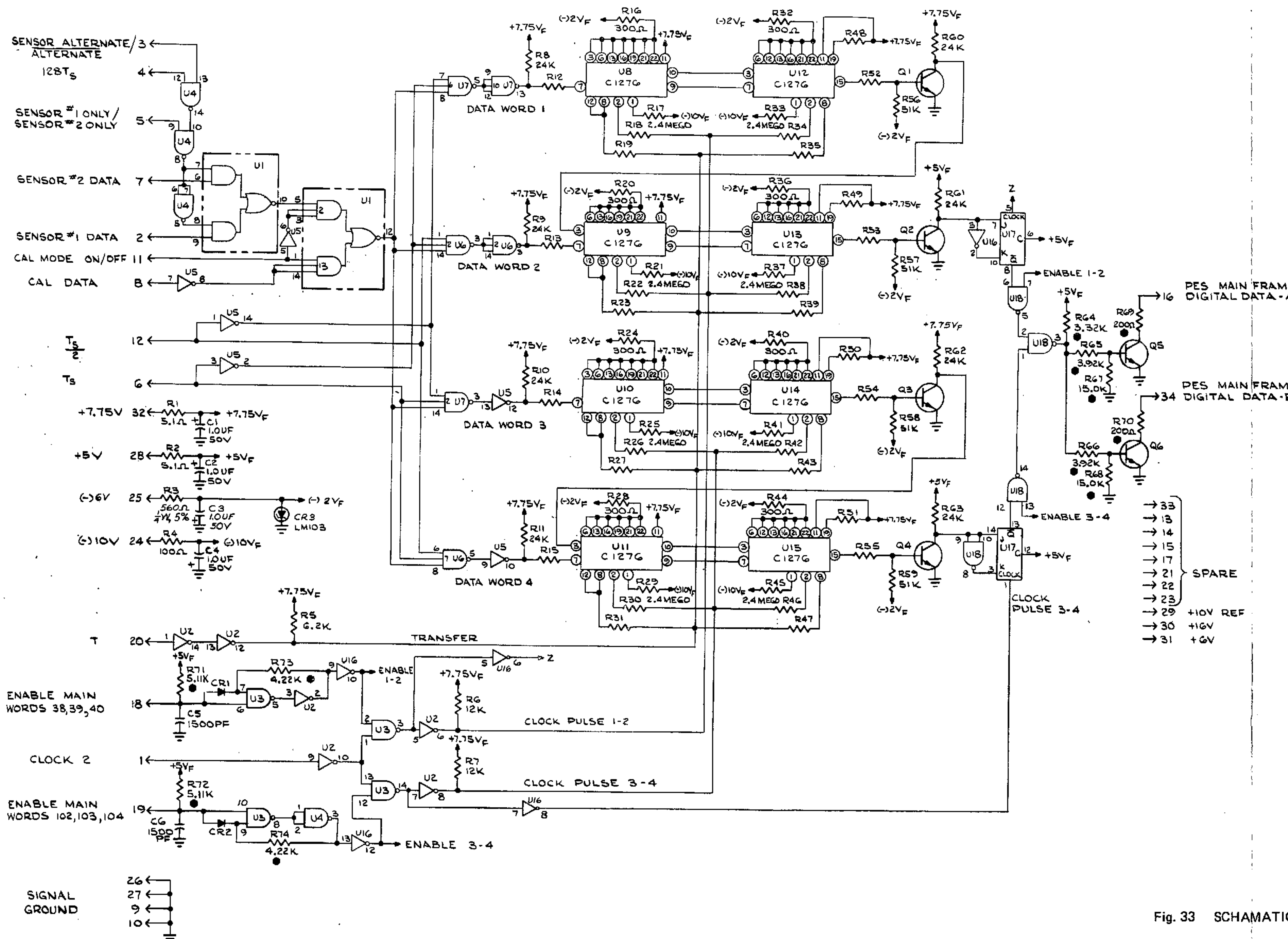
The T signal resets the accumulators to all "1's." Consequently the first particle count causes the accumulators to read all "0's," and the data must be adjusted by adding one count to the transmitted numbers.

The word enables from the spacecraft occur eight bits prior to the word positions in the main frame. The enable for PES words 1 and 2 occurs during main frame words 37, 38, and 39, and the data appear in 38, 39, and 40. Similarly, words 3 and 4 are clocked out during main frame words 101, 102, and 103 and appear in positions 102, 103, and 104.

Figure 33 is a schematic of the PES digital data system. P-channel enhancement mode MOS/LSI chips (U8 through U15) perform the storage functions. Each chip contains an eight-bit accumulator and an eight-bit shift register. PES word 1, for example, consists of eight bits from U8 and four bits from U12.

The words 1 and 2 shift registers are connected in series via the Q1 buffer. Data from these two registers are clocked out of the experiment via a one-bit delay (U17). The enable, clock, and bit relations are shown in Fig. 34.

PES words 3 and 4 are clocked out in a similar manner when the enable for main words 102, 103, and 104 occurs. All four PES words are "or-ed" to a single output and presented to the spacecraft via redundant buffers, as shown in Fig. 35.



NOTES-UNLESS OTHERWISE SPECIFIED:
1. ALL RESISTORS ARE $\frac{1}{8}$W, 5%
2. ALL RESISTORS ARE 100K.
3. ALL RESISTORS MARKED ● ARE $\frac{1}{10}$W, 1%
4. ALL DIODES ARE IN4153
5. ALL TRANSISTORS ARE 2N2222A
6. INTEGRATED CIRCUITS ARE:
   SN54L00 U3, U4, U18
   SN54L10 U6, U7
   SN54L04 U2, U5, U16
   SN54L73 U17
   SN54LS1 U1
   C127G U8, U9, U10, U11, U12, U13, U14, U15
7. I.C. POWER FOR U1 THRU U7, U16, U17 + U18 IS: PIN 4 +5VF; PIN 11 SIG GRD.

HIGHEST REF DESIGNATIONS	
R74	Q6
C6	U18
CR3	

Fig. 33 SCHAMATIC DIAGRAM OF PES DIGITAL DATA SYSTEM

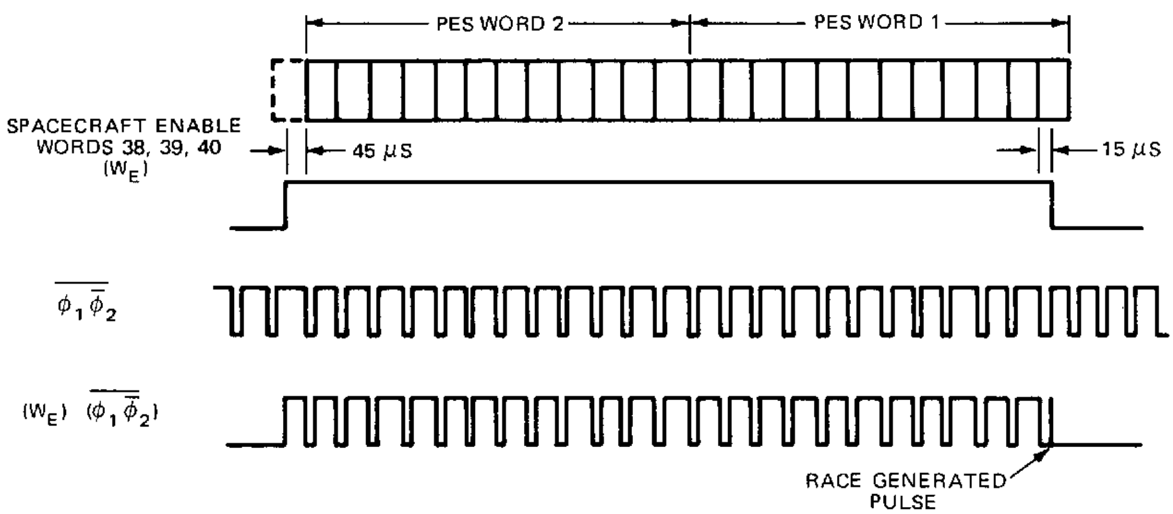


Fig. 34 TIMING FOR MAIN FRAME PES BIT READOUT

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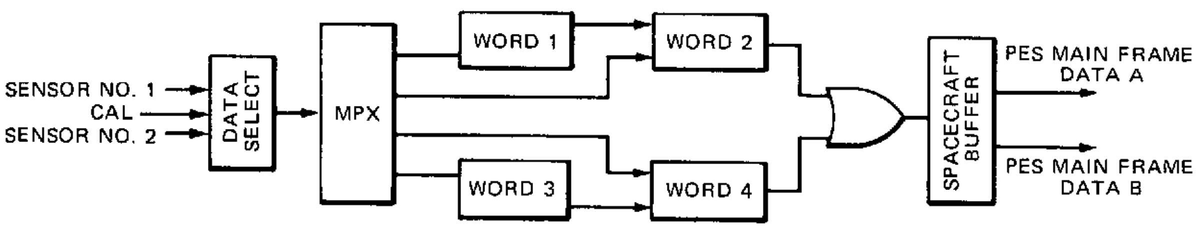


Fig. 35 BLOCK DIAGRAM OF THE PES DIGITAL DATA SYSTEM

Low-power TTL gates are used to select and multiplex the data into the accumulators. U1, for example, is used to select either sensor data if the cal mode on/off signal is low or calibration data if the cal mode on/off signal is high. In addition, minor mode commands are used to select which sensor data are accepted by the digital data system. The defining truth table is shown in Fig. 36.

The digital data system consumes about 130 mW distributed in the following manner: 4.8 mA at -6 volts, ~ 0 mA at -10 volts, 8.0 mA at +5 volts, and 8.0 mA at 7.75 volts.

MAIN CONVERTER

Circuit Design

The design of the PES main converter* is a two-transformer squarewave oscillator of the type described by Jensen. The first transformer, T1 (see Fig. 37) is driven to saturation flux levels and determines the operating frequency. T2 is a nonsaturating design from which the output voltages are taken from secondary windings. The 16 volt output is used in the high-voltage regulator for the electron multiplier. The load on this line varies from no load to as high as 690 mW, depending on the anode voltages required on the two electron multipliers. A separate secondary winding on T2 prevents changes in the 16 volt load current from causing copper loss voltage drops in the other output windings.

All output voltages except the +10 volts do not require a highly regulated source. The input voltage varies ±2%, and thermal changes in the rectifier diodes give a maximum change of ±5% for the 5 volt output and lesser amounts for the others since the diode drop is a smaller percentage of the output voltage. This is adequate except for the reference voltage for the D/A converter in the sweep supply and for the A/D converter in the in-flight

*The main converter circuit was designed by R. E. Cashion (Ref. 10).

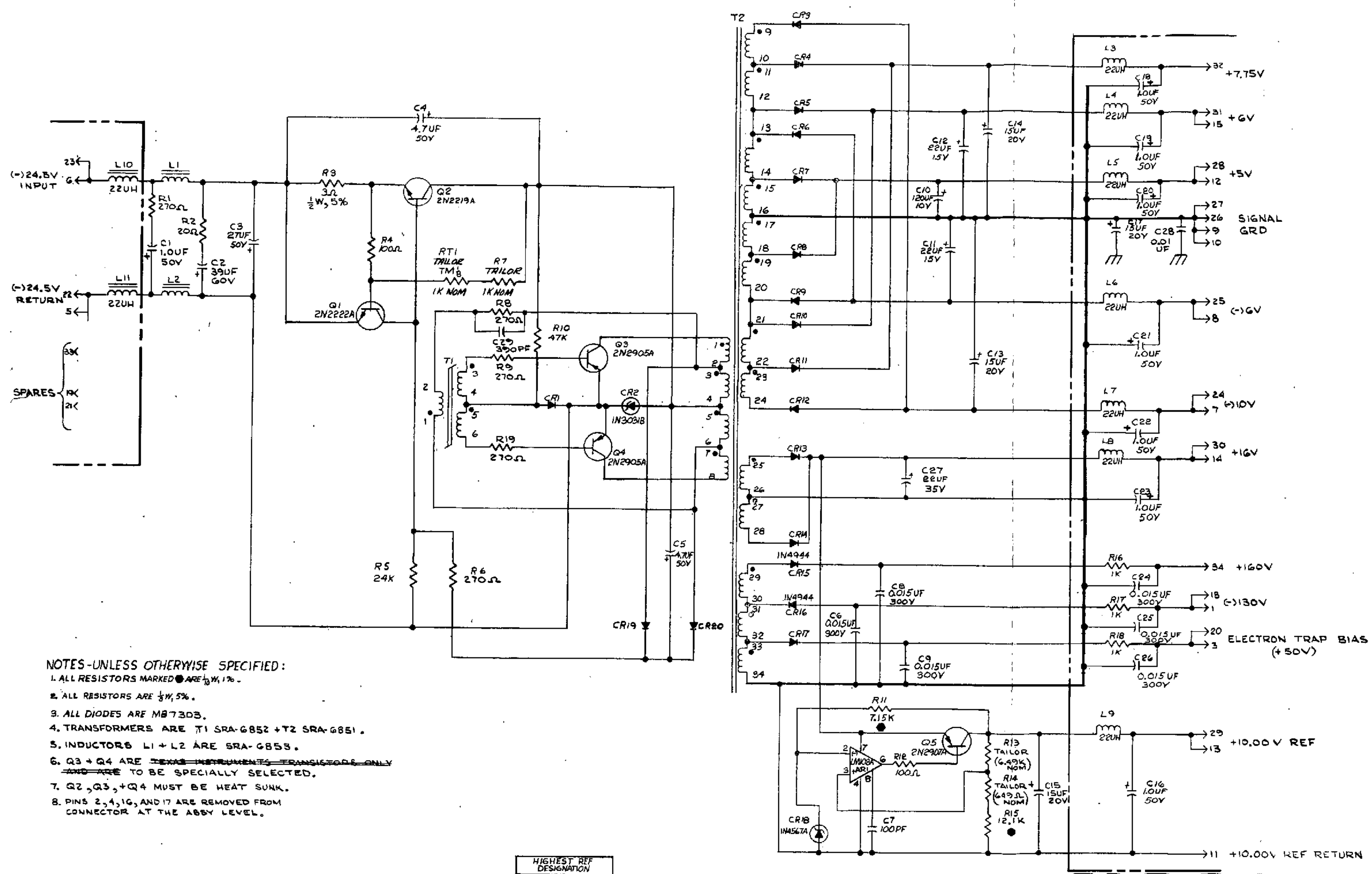
INPUTS				OUTPUTS		
SENSOR ALTERNATE COMMAND	128 T_S	SENSOR NO. 1/ SENSOR NO. 2 COMMAND	CAL ON/OFF	SENSOR NO. 1 DATA	SENSOR NO. 2 DATA	CAL DATA
ϕ	ϕ	0	0		X	
0	ϕ	1	0	X		
1	0	1	0	X		
1	1	1	0		X	
ϕ	ϕ	ϕ	1			X

ϕ = DO NOT CARE
X = OUTPUT DATA

Fig. 36 TRUTH TABLE FOR DIGITAL DATA SECTION

FOLDOUT FRAME 1

FOLDOUT FRAME 2



NOTES-UNLESS OTHERWISE SPECIFIED:

1. ALL RESISTORS MARKED ● ARE 1/8 W, 1%.
2. ALL RESISTORS ARE 1/4 W, 5%.
3. ALL DIODES ARE MB7303.
4. TRANSFORMERS ARE T1 SRA-6852 + T2 SRA-6851.
5. INDUCTORS L1 + L2 ARE SRA-6853.
6. Q3 + Q4 ARE ~~TEXAS INSTRUMENTS TRANSISTORS ONLY AND ARE~~ TO BE SPECIALLY SELECTED.
7. Q2, Q3, + Q4 MUST BE HEAT SUNK.
8. PINS 2, 4, 16, AND 17 ARE REMOVED FROM CONNECTOR AT THE ASSY LEVEL.

HIGHEST REF DESIGNATION	
R19	C29
CR20	Q5
T2	AR1
L11	RT1

Fig. 37 SCHAMATIC DIAGRAM OF MAIN POWER SUPPLY

calibrator. Here a voltage stable to 0.1% or better is needed. The regulator made up of CR18, Z1, and Q5 gives an output of +10.00 ±0.01 volts over a 100°C temperature variation and the required load changes.

Circuit Protection

The input is current limited by the foldback limit circuit made up of Q1 and Q2. The foldback point is set at 200 mA, or twice the nominal load, and folds back to 60 mA at a dead short. The most attractive feature of the current limit circuit is protection during testing phases.

The current is limited at turn-on to 2 amperes by the dynamic damper made up of L1, L2, R2, C2, and C3. The voltage swing at turn-off is similarly limited by the dynamic damper of R1 and C1.

Electrical specifications in the AE-Experiment Interface Specification SK-2260216 give a transient overvoltage of ringing to -47 and -36 volts for 100 ms. The output voltages are prevented from following the input by the zener diode, CR2. Current into the zener diode is limited to about 100 mA by the current limiter, Q2.

All output lines are filtered to remove converter noise. The inductor-capacitor pairs are located in a separate shielding enclosure.

3. INSTRUMENT MECHANICAL DESIGN*

ELECTOSTATIC ANALYZER

The PES dual-hemisphere electrostatic analyzer is modeled after the rocket instruments flown by Doering et al. (Ref. 2). The analyzer consists of two metal hemispheres mounted concentrically and insulated electrically from each other as well as ground (see Fig. 38). The insulator (item 7 of Fig. 38) also acts as the base for construction and alignment of the hemispheres. The inner hemisphere is located with respect to the insulating base via a stainless steel pin (item 9) and mounted via a single centrally located screw (item 17). The location of the outer hemisphere with respect to the inner hemisphere is then determined by the precision of machining of the insulating base.

A molybdenum annulus restricts particle access to the analyzer except through a 1.3-mm hole at the analyzer entrance and a 1.3-mm by 6°1' opening at the exit (see Fig. 39). Molybdenum was chosen for this application because of its dimensional and surface stability. Surface stability is essential for preventing charge accumulation (and therefore field distortion) at the analyzer apertures.

An aluminum alignment plate (item 3 of Fig. 38) locates the hemispheres and insulating base with respect to the molybdenum ring and is used to mount them. The structure is then surrounded by a magnetic shielding material (item 5) and secured with a retaining ring (item 4).

Lugged wires are screwed to each hemisphere as a method of applying the voltages from the deflection sweep supply.

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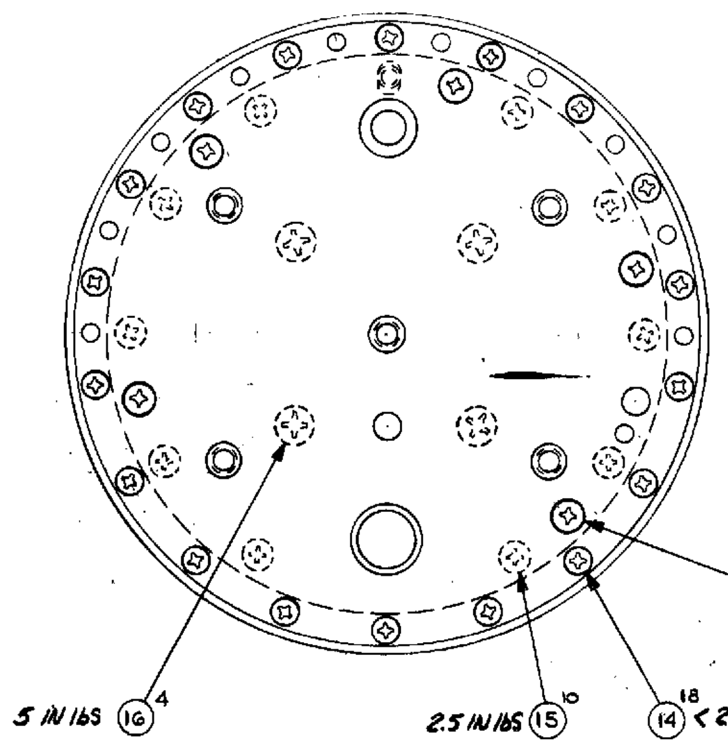
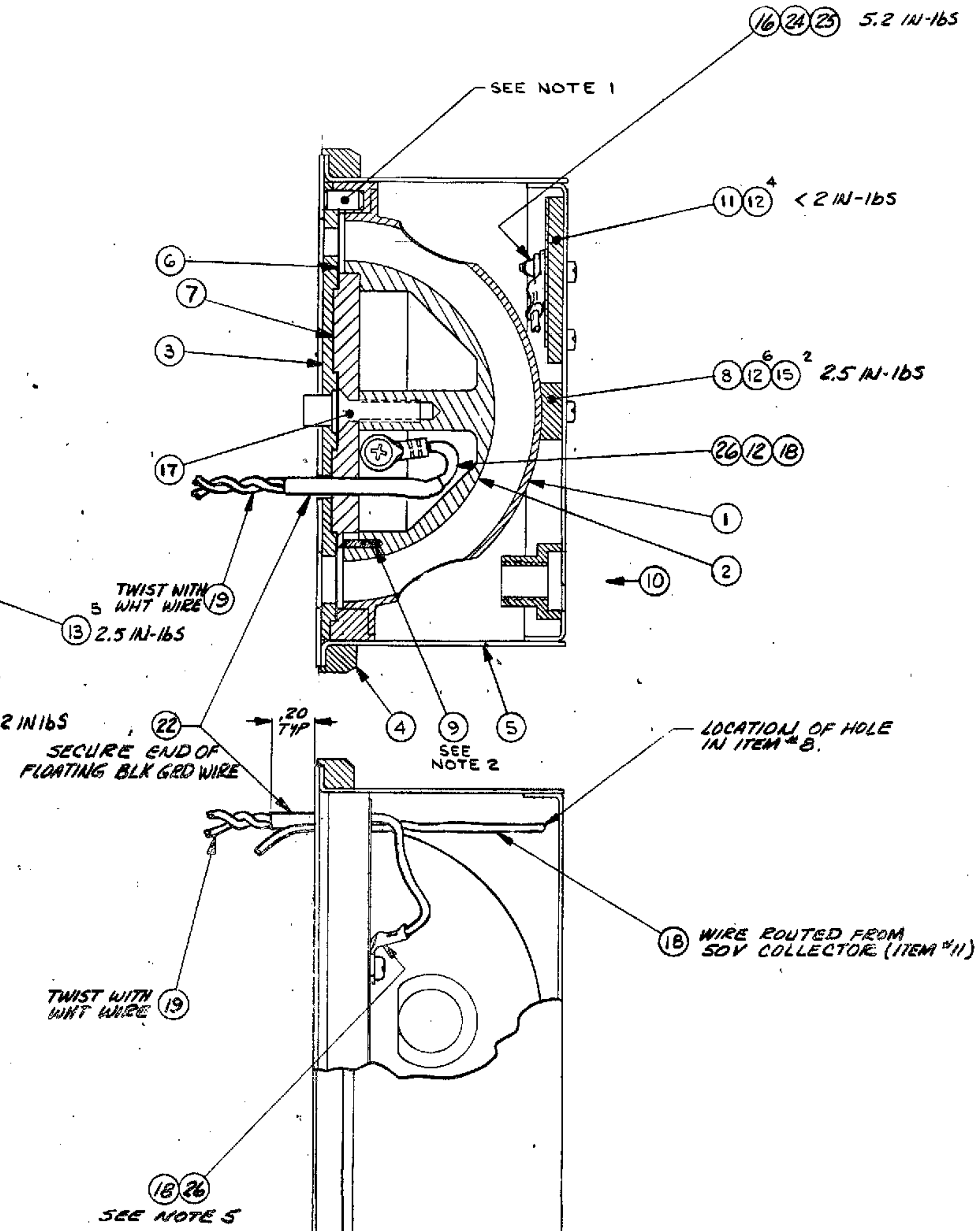
*The PES mechanical design was done by R. S. Glaeser, and layouts were done by J. T. Mueller. See the Appendix for a mechanical drawing list.

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
SILVER SPRING, MARYLAND

FOLDOUT FRAME 1

FOLDOUT FRAME 2





NOTES-UNLESS OTHERWISE SPECIFIED:

1. LOCATING PIN FOR ITEMS 1, 3 + 6.
2. LOCATING PIN FOR ITEMS 2 + 7.
3. LEAVE APPROX 12 INCHES OF WIRE ON ALL COLLECTIONS.
4. CRIMP ITEM #25 & 26 WITH HAND TOOL #49935 (AMP INC.)
5. BEND TERMINAL BACKWARD (APPROX 80°), FILE BOTH SIDES OF ITEM #26 FLAT AND SECURE WITH EXISTING SCREW
6. FABRICATE PER SIP-936-72

BASIC QTY/ASSY	ITEM NO.	DWG SIZE	PART OR IDENTIFYING NUMBER	CIRCUIT SYMBOL OR ZONE	NOMENCLATURE OR DESCRIPTION	STOCK SIZE	MATERIAL AND/OR MATERIAL SPECIFICATION	MFG CODE	ISSUE REV
2	26		2-34103-2		TERMINAL, SOLID RING	#2	(GOLD PLATED)	AMP	
1	25		2-34104-1		TERMINAL, SOLID RING	#4	(GOLD PLATED)	AMP	
1	24		HW42-04		NUT, CAPTIVE WASH	#4-40	(18-8 SST)	KAYNAR	
	23								
AR	22				TUBING, HEAT SHRINK	3/16 I.D.		SHELL	
	21								
AR	20		CE1155		CONFORMAL COATING			CONAP	
AR	19		E22		WIRE, STRANDED, BLK		MIL-W-16878A/4		
AR	18		E22		WIRE, STRANDED WHT		MIL-W-16878A/4		
1	17				SCREW, 100°CSK, LKG	#6-32UNC x 1/2	18-8 SST, KEL F		
5	16				SCREW, 100°CSK, LKG	#4-40UNC x 1/4	18-8 SST, KEL F		
12	15				SCREW, 100°CSK, LKG	#2-56UNC x 1/4	18-8 SST, KEL F		
18	14				SCREW, 100°CSK, LKG	#1-72UNC x 1/4	18-8 SST, KEL F		
5	13				SCREW, PAN HD, LKG	#2-56UNC x 5/16	18-8 SST, KEL F		
11	12				SCREW, PAN, LKG	#2-56UNC x 3/16	18-8 SST, KEL F		
1	11	C	SRA-6775		COLLECTOR, PHOTOELECTRON		(VESPEL, COPPER)		
1	10	B	SRA-6834		SOURCE HOLDER		(MU 30, GOLD PLATE)		
1	9		SRA-6779-1		PIN, .062 DIA x .280 LG MAX		SST		
1	8	C	SRA-6743		LIGHT SHIELD		(VESPEL)		
1	7	C	SRA-6740		BASE, HEMISPHERE		(VESPEL)		
1	6	C	SRA-6739		RING, APERTURE		(MOLYBDENUM)		
1	5	D	SRA-6744		MAGNETIC SHIELD				
1	4	B	SRA-6746		RING, TIE DOWN		(6061-T6 AL)		
1	3	D	SRA-6738		PLATE, ALIGNMENT		(6061-T6 AL)		
1	2	C	SRA-6741		HEMISPHERE, INNER		(6061-T6 AL)		
1	1	D	SRA-6742		HEMISPHERE, OUTER		(6061-T6 AL)		

Fig. 38 ASSEMBLY DRAWING OF DUAL HEMISPHERE ANALYZER

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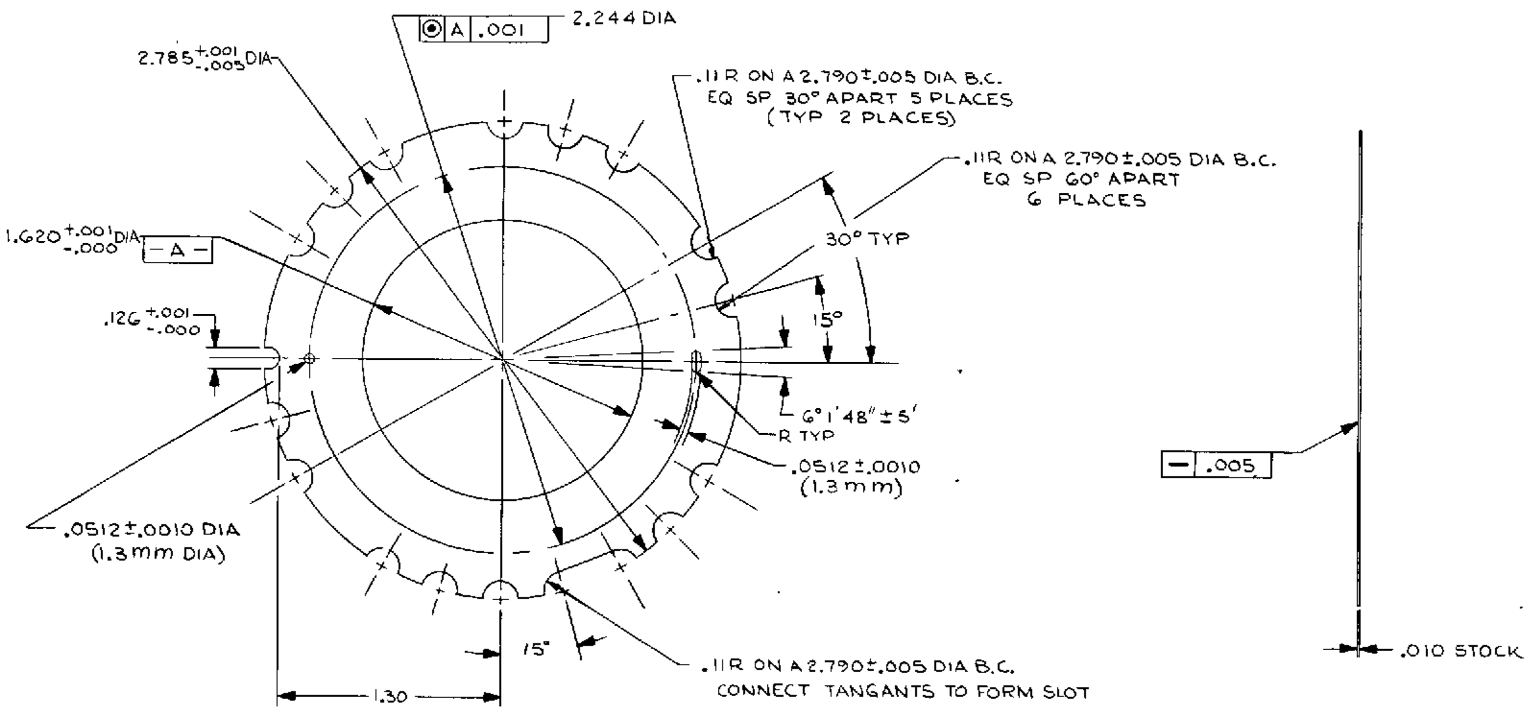

Fig. 39 MOLYBDENUM APERTURE RING FOR DUAL HEMISPHERE ANALYZER.

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Ultraviolet light entering the analyzer and reflecting from the hemisphere surfaces could strike the electron multiplier and cause counts that are indistinguishable from counts caused by electrons. Consequently both the entrance and exit apertures are baffled to reduce the amount of data contamination from ultraviolet light. The baffles consist of holes in the outer hemisphere large enough to include the solid angle determined by the entrance and exit collimators, yet small enough to leave the electric field between the hemispheres virtually undisturbed. Ultraviolet light passing through the entrance baffle causes secondary electron emission when it strikes the rear cover. A copper plate biased at ±50 volts is installed behind the entrance baffle to collect these secondary electrons.

A Ni-63 radioactive source (item 10 of Fig. 38) is installed in the magnetic shield directly above the exit aperture baffle hole. Because of this position, the β emission from the source passes through the baffle and strikes the electron multiplier, producing a background count for calibration of the sensor electronics. The integrity of the magnetic shield is maintained by machining the source mount from magnetic shielding material and welding it to the shield prior to heat treatment. The Ni-63 source is deposited on the end of a special screw made from magnetic shielding material. The source is then sealed and the holder is gold plated, screwed into its mount, and locked with a small set screw.

ELECTRON MULTIPLIER BIAS SUPPLY

The electron multiplier bias supply (Ref. 7) produces voltages up to 4500 volts, and special packaging techniques are required to avoid damage from corona discharge.

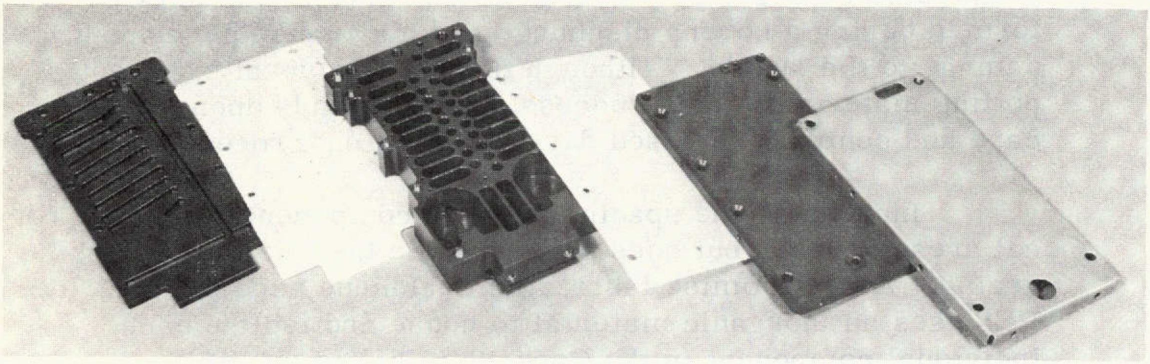
All materials outgas to some degree in a high vacuum. It is likely that a high-voltage supply will experience occasional arcing because of increased local pressure caused by outgassing either in a vacuum chamber or in orbit. Encapsulation helps protect the supply from the atmosphere, but under the relentless vacuum of space the potting material itself may outgas and produce high internal pressure regions and associated arcing. Since most potting materials are organic, low impedance carbon paths may be formed during a corona discharge and may cause permanent damage to the supply. Although there are several excellent potting materials, their successful use depends upon the care and control exercised during the potting procedure.

Increasing the spacing between components in critical areas reduces but does not eliminate the likelihood of arcing. A compromise fabrication technique used for the PES uses an inorganic material to house and isolate each individual component in the Cockcroft-Walton multiplier. The components are laid out with minimum spacing, and cavities are machined into an inorganic material (in this case Vespel-1), as shown in Fig. 40a. Corona paths exist only in the seams between cavities. If arcing occurs, no permanent low impedance paths are formed.

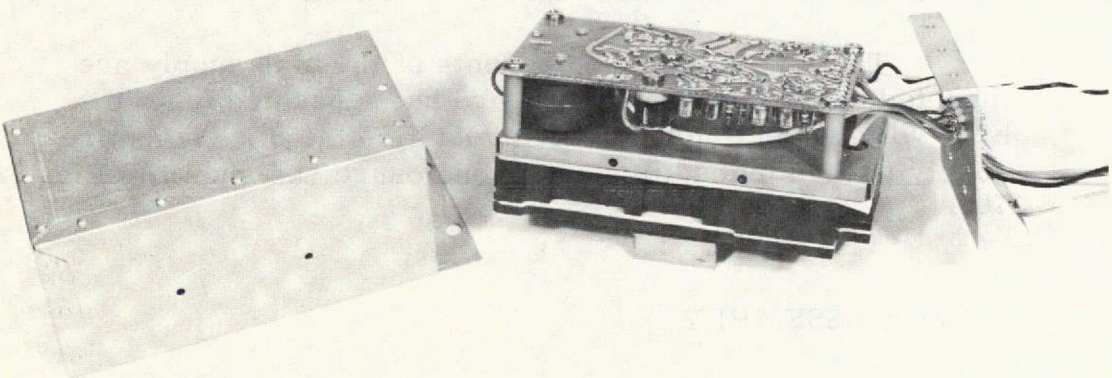
The low-voltage components of the bias supply are mounted on a printed circuit board but separated from the high-voltage section by an electrostatic shield. The entire supply is then placed in a metal enclosure, as shown in Fig. 40b.

SENSOR ASSEMBLY

A housing (item 1 of Fig. 41) machined from a single piece of aluminum is used to mount the analyzer and bias supply as well as the analog electronics and the electron multiplier. The electron multiplier (item 7) is in a separate compartment, which contains only the necessary bias and filter components (item 6). Electrical connections in this compartment (as well as in the analyzer) are either welded or crimped to avoid placing the electron multiplier near solder, which would contaminate the dynodes. However, braid on the preamplifier coaxial cable is soldered



a

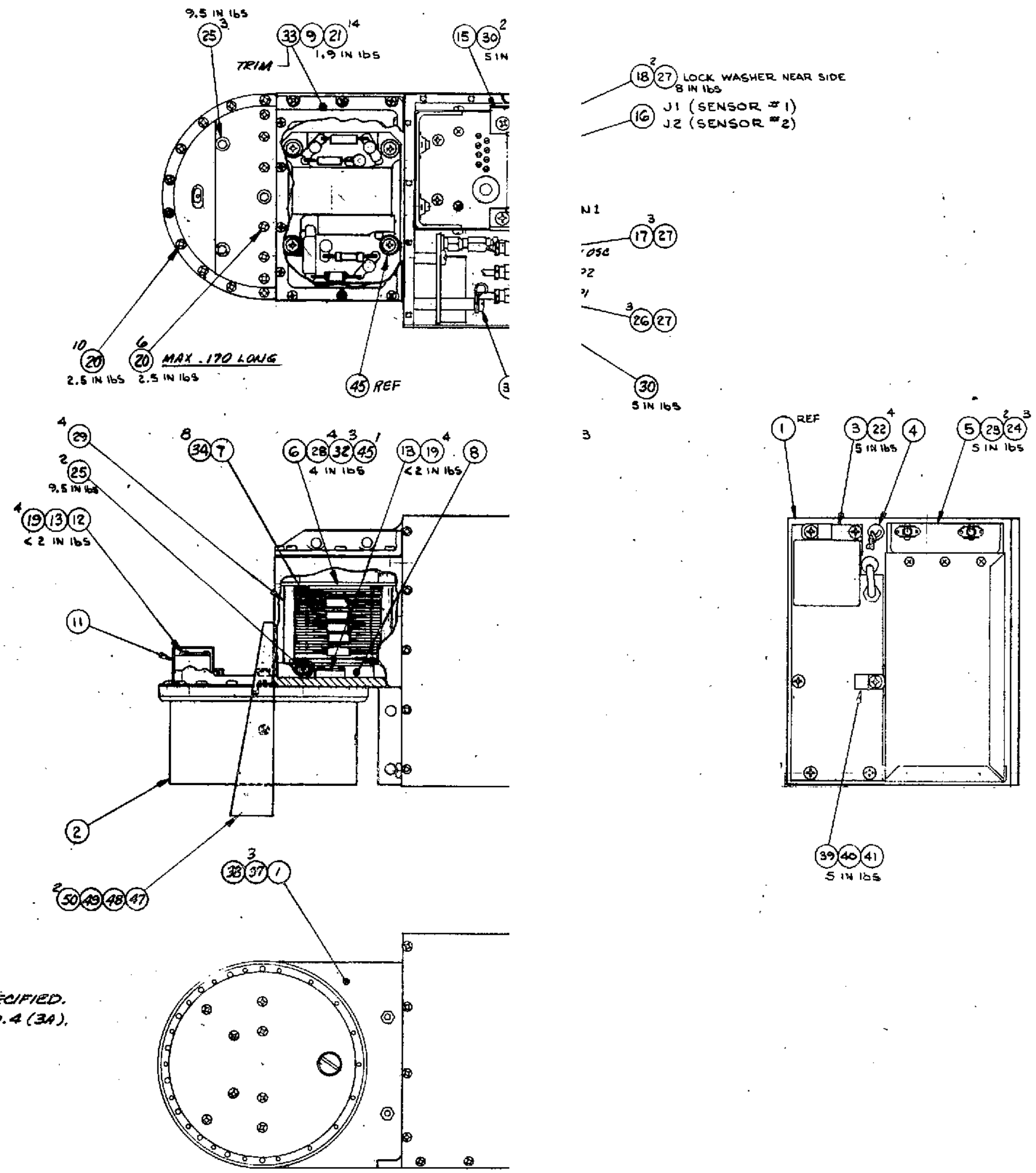


b

Fig. 40 BIAS SUPPLY CONSTRUCTION AND COCKCROFT-WALTON COMPONENT ISOLATION TO REDUCE CORONA EFFECTS

FOLDOUT FRAME 1

FOLDOUT FRAME 2



NOTES - UNLESS OTHERWISE SPECIFIED.
1. FABRICATE PER NHB-5300.4 (3A).

BASIC QTY/ASSY	ITEM NO.	DWG SIZE	PART OR IDENTIFYING NUMBER	CIRCUIT SYMBOL OR ZONE	NOMENCLATURE OR DESCRIPTION	STOCK SIZE	MATERIAL AND/OR MATERIAL SPECIFICATION	MFG CODE	ISSUE REV
2	50				SCREW, SOCKET (ALLEN) LKG	#6-32x ½ LG	18-8 SST, KEL-F		
1	49		SRA-6910-2		GASKET, SMALL				
1	48		SRA-6910-1		GASKET, LARGE				
1	47		SRA-6908		SHIELD, LIGHT, THERMAL				
AR	46		RG-196		COAX CABLE				
1	45		SRA-6886-2		CUP, INSULATOR, SCREW		(VESPEL)		
AR	44		E-24		WIRE, STRANDED		MIL-W-16878A/4		
AR	43		E-22		WIRE, STRANDED		MIL-W-16878A/4		
AR	42		LC-136/BLK		CORD, LACING			ALPHA WIRE CORP	
2	41				CLAMP, CABLE		(TEFLON)		
2	40	B	SRA-6827-4		SPACER		(EPOXYGLASS)		
2	39				SCREW, PH PAN HD, LKG	#4-40 x1¼ LG	18-8 SST, KEL-F		
1	38		2-014		"O" RING, 77-545		VITON	PARKER	
3	37		2-012		"O" RING, 77-545		VITON	PARKER	
1	36		SRA-5111		CAP, ENTRANCE APERTURE				
1	35	C	SRA-6903		INSULATOR, INTERFACE BOARD				
8	34	B	SRA-6900		CUSHION, RING, VITON		(VITON A)		
1	33	B	SRA-6901		SEAL, LIGHT		(VITON A)		
3	32	B	SRA-6886-1		CUP, INSULATOR, SCREW		(VESPEL)		
REF	31	C	SRA-6726		OUTLINE DWG				
3	30				SCREW, PH PAN HD, LKG	#4-40 x 3/16 LG	18-8 SST, KEL-F		
4	29	B	SRA-6875		SPACER		(EPOXYGLASS)		
4	28				SCREW, PH PAN HD	4-40 x 27/32 LG	18-8 SST		
AR	27		CE 1155		CONFORMAL COATING			CONAP INC.	
3	26		SRA-6904		CAP, COAX, TEST		(6061-T6 AL)		
5	25				SCREW, SOC CAP, LKG	#6-32 x ¼ LG	18-8 SST, KEL-F		
3	24				SCREW, PH PAN HD	#4-40 x 5/8 LG	18-8 SST		
2	23				SCREW, PH PAN HD, LKG	#4-40 x 7/16 LG	18-8 SST, KEL-F		
4	22				SCREW, PH PAN HD, LKG	#4-40 x 9/16 LG	18-8 SST, KEL-F		
14	21				SCREW, PH PAN HD, LKG	#2-56 x 1/4 LG	18-8 SST, KEL-F		
39	20				SCREW, PH PAN HD, LKG	#2-56 x 3/16 LG	18-8 SST, KEL-F		
8	19				SCREW, PH PAN HD, LKG	#1-72 x 3/16 LG	18-8 SST		
2	18		D20418-52		SCREW LOCK ASSY, FEMALE		CANNON		
3	17		50-010-3196		JACK, BULKHEAD, SCREW-ON		PER UG 1463/U	SEALECTRO	
1	16		DBM-25P-NMB-1-A106		CONNECTOR, MALE		CANNON		
1	15	C	SRA-6804		BRACKET, CONNECTOR				
1	14	D	SRA-6797		WIRING DIAGRAM				
2	13	B	SRA-6781		CAP, APERTURE		(6061-T6 AL)		
1	12	B	SRA-6806		ENTRANCE APERTURE		(MOLYBDENUM)		
1	11	C	SRA-6745		MAGNETIC SHIELD				
1	10	C	SRA-6776		COVER, ELECTRONIC		(5052-H32 AL)		
1	9	C	SRA-6777		COVER, MULTIPLIER		(6061-T6 AL)		
1	8	C	SRA-6768		INSULATOR, MULTR		(VESPEL)		
1	7		MM1-5NG		ELECTRON MULTIPLIER		JOHNSON LABORATORIES INC		
1	6	C	SRA-6845		ELECTRON MULTR INTERFACE BD ASSY				
1	5	D	SRA-6805		ELECTRON MULTR BIAS SUPPLY ASSY				
1	4	C	SRA-6798		THERMISTOR ASSEMBLY				
1	3	D	SRA-6812		ANALOG ELECTRONICS BD ASSY				
1	2	D	SRA-6779		HEMISPHERIC ANALYZER ASSY				
1	1	D	SRA-6747		HOUSING		(6061-T6 AL)		

Fig. 41 ASSEMBLY DRAWING OF PHOTOELECTRON SPECTROMETER SENSOR

since this is considered the only reliable method of connecting the braid. Nevertheless, this solder connection is coated with conformal coating and protected with a Kel-F cover.

The sides of the analyzer collimator are machined as part of the aluminum housing, and a rectangular molybdenum plate is screwed to the front of the collimator. The plate contains a 5.8 by 2.6 mm hole and is located 16.5 mm in front of the hole in the analyzer entrance aperture. The collimator holes thereby restrict the sensor look angle to a cone of approximately 9° by 20°.

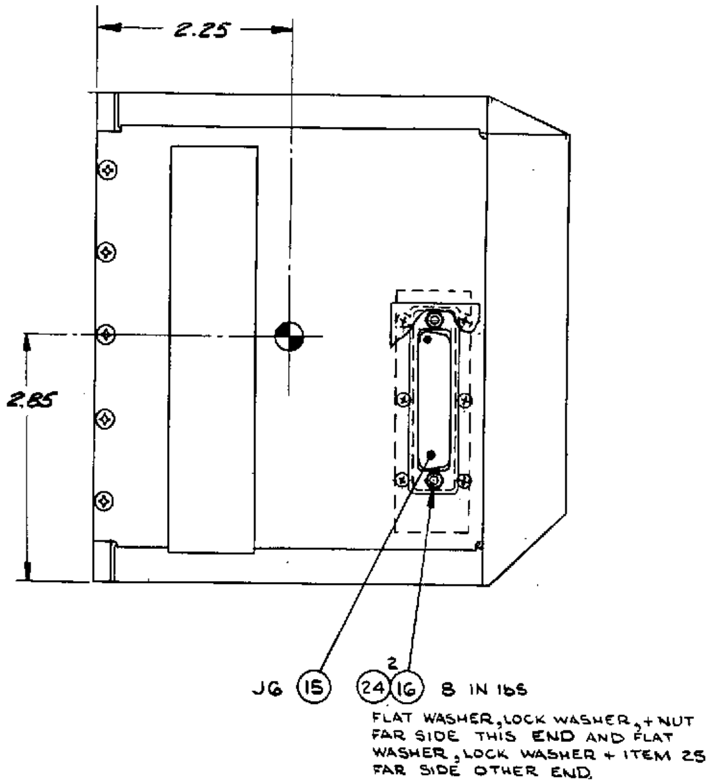
Three coaxial test connectors (item 17 of Fig. 41) are mounted on a Vespel-1 bracket (item 15) to isolate the shields (which are at signal ground) from chassis ground. A single 25-pin Cannon connector (item 16), which connects to a cable going to the main electronics assembly, is also mounted on the Vespel-1 bracket, but its shell is in contact with chassis ground.

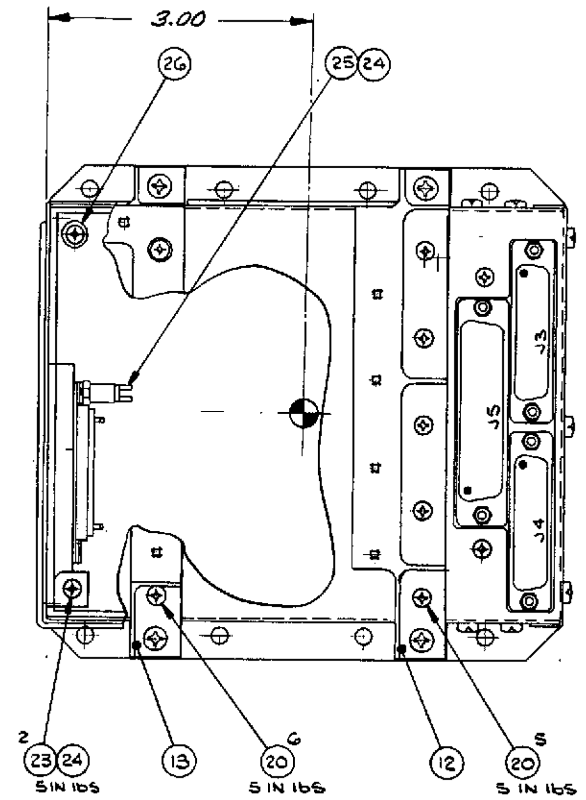
MAIN ELECTRONICS ASSEMBLY

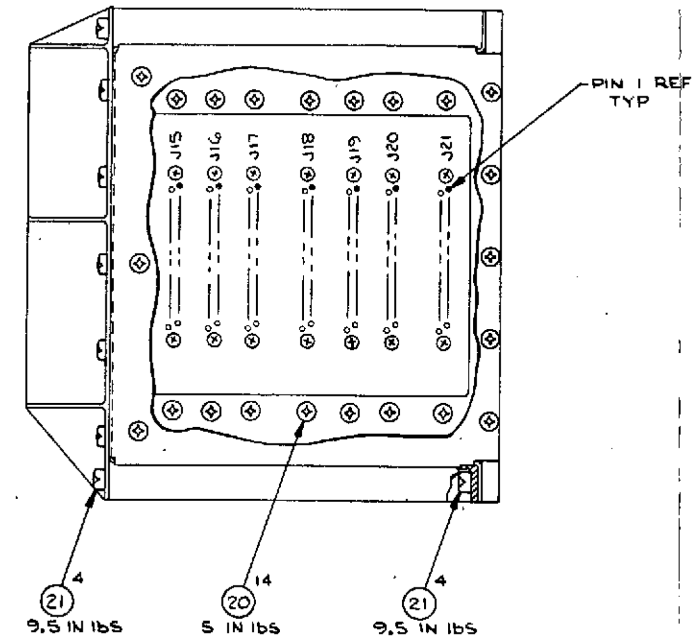
The main electronics assembly drawing is shown in Fig. 42. All subassemblies (items 2 through 8) plug into a "mother board" (item 9). Wiring goes directly from the mother board to the spacecraft interface connector (J5), the sensor assembly interface connectors (J3 and J4), and the PES ground support equipment connector (J6).

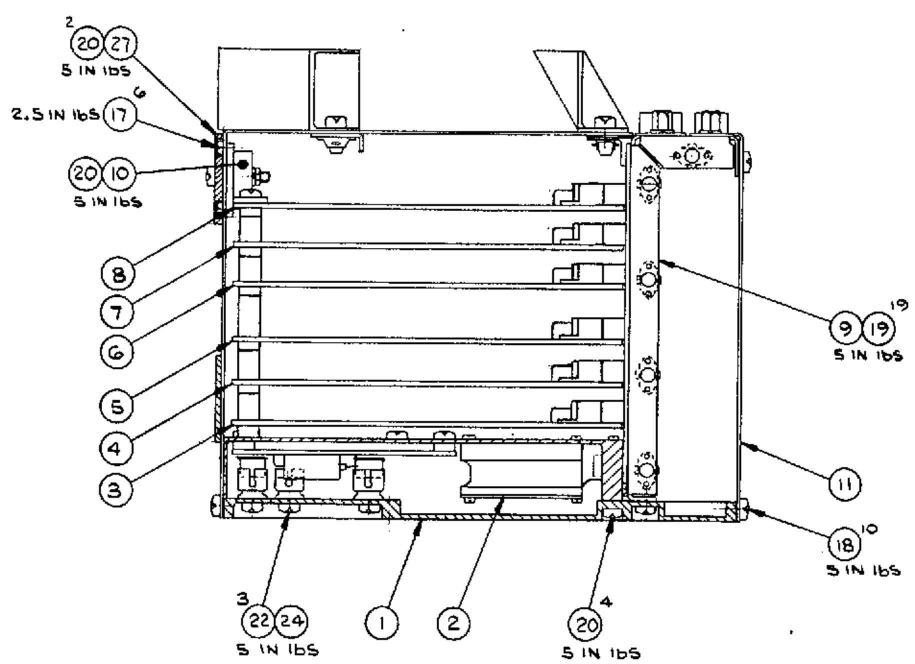
The main power supply (item 2) is mounted in an electrostatically shielded enclosure to minimize radiated RFI (radio frequency interference).

The PES digital data system (item 3) contains PMOS data registers, which are more susceptible to radiation damage than are TTL registers. Consequently the PES digital data system is placed in a location that takes maximum advantage of incidental shielding. In addition, two









BASIC QTY/ASSY	ITEM NO.	DWG SIZE	PART OR IDENTIFYING NUMBER	CIRCUIT SYMBOL OR ZONE	NOMENCLATURE OR DESCRIPTION	STOCK SIZE	MATERIAL AND/OR MATERIAL SPECIFICATION	MFG CODE	ISSUE REV
1	27	B	SRA-6902		COVER, TEST CONN		(6061-T6 AL)		
1	26				WASHER	1/16 THK	BRASS		
1	25		#756		TERMINAL		LITTON WINCHESTER		
AR	24		CE1155		CONFORMAL COATING			CONAP	
2	23				SCREW, PH PAN HD	4-40UNC×3 11/16	18-8 SST		
3	22				SCREW, PH PAN HD	4-40UNC×3/16LG	18-8 SST		
8	21				SCREW, PH PAN HD, LKG	6-32UNC×5/16LG	18-8 SST, KEL-F		
31	20				SCREW, PH PAN HD, LKG	4-40UNC×5/16LG	18-8 SST, KEL-F		
19	19				SCREW, PH PAN HD, LKG	4-40UNC×1/4LG	18-8 SST, KEL-F		
10	18				SCREW, PH PAN HD, LKG	4-40UNC×3/16LG	18-8 SST, KEL-F		
6	17				SCREW, PH PAN HD, LKG	2-56UNC×3/16LG	18-8 SST, KEL-F		
2	16		D20418-52		SCREW LOCK ASSY, FEMALE			CANNON	
1	15		DBM-25S-NMB-1-A106		CONNECTOR, RECTANGULAR			CANNON	
REF	14	D	SRA-5110		EXTENSION CARD BD ASSY				
1	13	C	SRA-6892		SPACER, "B" BRACKET		(6061-T6 AL)		
1	12	C	SRA-6891		SPACER, "A" BRACKET		(6061-T6 AL)		
1	11	D	SRA-6879		COVER ASSY		(5052-H32 AL)		
1	10	C	SRA-6865		BLOCK, MOUNTING, CONNECTOR		(2024-T4 AL)		
1	9	D	SRA-6894		MOTHER BOARD FRAME ASSY				
1	8	D	SRA-6837		INPUT-OUTPUT BOARD BD ASSY				
1	7	D	SRA-6820		MINOR MODE COMMAND SYSTEM BD ASSY				
1	6	D	SRA-6856		TIMING AND MODE CONTROL LOGIC BD ASSY				
1	5	D	SRA-6824		DEFLECTION SWEEP SUPPLY BD ASSY				
1	4	D	SRA-6889		SWEEP CALIBRATOR BD ASSY				
1	3	D	SRA-6816		DIGITAL DATA SYSTEM BD ASSY				
1	2	D	SRA-6868		MAIN POWER SUPPLY ASSY				
1	1	D	SRA-6877		PLATE, BASE		(6061-T6 AL)		

Fig. 42 MAIN ELECTRONICS ASSEMBLY

0.063-inch aluminum plates are riveted to the side of the main electronics cover to increase shielding against radiation that impinges perpendicularly to the solar panels.

Sensor assembly No. 2 is mounted on top of the main electronics assembly. Items 12 and 13 provide the proper spacing and mechanical support for the sensor.

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4. GROUND SUPPORT EQUIPMENT

GENERAL

The PES ground support equipment (GSE) stimulates and monitors the PES experiment in all of its operational modes. It is used during the PES assembly and experimental level checkout, during calibration tests, and during environmental qualification tests.

The GSE consists of a printer and a special-purpose interfacer, which contains a digital voltmeter with BCD (binary coded decimal) outputs. This allows the experiment analog and digital data to be monitored visually and/or recorded as permanent test records.

The experiment is set into the desired operating mode by a command system simulator that is activated by switches on the front panel of the GSE. Panel lights indicate the command states.

In addition to command simulation, the GSE reads and logs analog housekeeping data and generates the clock, timing, and enable signals required to read the experiment digital data. (Digital data include command status and science data.)

DATA ENCODING

Both the analog and digital data received by the GSE are identified and recorded according to the following eight column format:

Code	Step	Data
XX	XX	XXXX

The code identifies what type of data is being read and indicates the operational mode of the experiment. The code is octal and takes values from 00 to 77. Code numbers from 00 to 47 indicate that digital data are being received from the experiment (see Table 7). Code 77 indicates that analog data are being read and codes 50 through 76 are unassigned.

The step has had two different meanings, depending on whether analog or digital data are being displayed. If analog data appear (code 77), the step indicates the position of the analog multiplexer which feeds data to the digital voltmeter. Table 8 shows the assignment of analog data for each analog step.

If digital data appear (codes 00 through 47), the step indicates the position on the energy sweep corresponding to the data being displayed. For example, the format:

Code	Step	Data
12	31	3729

indicates that the experiment is in fast sweep rate, Mode I on the 0 to 500 eV sweep. Furthermore, since there are 64 steps per sweep starting from 0, step 31 is 31/63 of the maximum sweep energy. Consequently the data indicate that 3729 electrons of 246 eV energy have been observed by sensor No. 1

"FREE RUN" OPERATION (DIGITAL DATA ONLY)

If the GSE clock is allowed to "free run," digital data will be obtained from the experiment at the rate of four words per second, which is the maximum reliable printer speed. Four lines per second, however, is 16 times slower than the spacecraft readout rate. In order to check the complete experiment, the GSE operates at a slow enable speed and reads every digital data word. In addition, to check the experiment time response at the satellite clock rate, the GSE also operates at a fast enable speed and reads every sixteenth digital data word. For example, the code 00 through 02 (positive calibration) would be as follows:

Table 7

PES GSE Digital Data Code Assignments

Code		
00	Positive cal,	0 to 25 eV
01		0 to 100 eV
02		0 to 500 eV
03	Unassigned	
04	Negative cal,	0 to 25 eV
05		0 to 100 eV
06		0 to 500 eV
07	Unassigned	
10	Sensor 1 data, slow rate,	Mode I, 0 - 25 eV
11		Mode I, 0 - 100 eV
12		Mode I, 0 - 500 eV
13		Mode II, 0 - 25 eV
14		Mode III, 0 - 25 eV
15		Mode IV, 0 - 100 eV
16		Mode V, 0 - 500 eV
17		Mode II, 0 - 500 eV
20	Sensor 1 data, fast rate,	Mode I, 0 - 25 eV
21		Mode I, 0 - 100 eV
22		Mode I, 0 - 500 eV
23		Mode II, 0 - 25 eV
24		Mode III, 0 - 25 eV
25		Mode IV, 0 - 100 eV
26		Mode V, 0 - 500 eV
27		Mode II, 0 - 500 eV
30	Sensor 2 data, slow rate,	Mode I, 0 - 25 eV
31		Mode I, 0 - 100 eV
32		Mode I, 0 - 500 eV
33		Mode II, 0 - 25 eV
34		Mode III, 0 - 25 eV
35		Mode IV, 0 - 100 eV
36		Mode V, 0 - 500 eV
37		Mode II, 0 - 500 eV
40	Sensor 2 data, fast rate,	Mode I, 0 - 25 eV
41		Mode I, 0 - 100 eV
42		Mode I, 0 - 500 eV
43		Mode II, 0 - 25 eV
44		Mode III, 0 - 25 eV
45		Mode IV, 0 - 100 eV
46		Mode V, 0 - 500 eV
47		Mode II, 0 - 500 eV

Table 8

PES GSE Analog Data Code Assignments

Code	Step, GSE Trigger	Step, DVM Self-Trigger	Analog Data
77	1	0	-24.5 Volts
77	2	1	-24.5 Volt current drain
77	3	2	A1-A, Ground reference
77	4	3	A2-A, Low-voltage monitor
77	5	4	A3-A, High-voltage monitor 1
77	6	5	A4-A, High-voltage monitor 2
77	7	6	A5-A, Sensor No. 1 temperature
77	8	7	A6-A, Sensor No. 2 temperature
77	9	8	Electron trap bias
77	10	9	+16 Volt switched No. 2
77	11	10	+7.75 Volt
77	12	11	+5 Volt
77	13	12	-10 Volt
77	14	13	+160 Volt
77	15	14	+16 Volt switched No. 1
77	16	15	10.0 Volt REF
77	17	16	+6 Volt
77	18	17	-6 Volt
77	19	18	-130 Volt
77	20	19	Blank
77	21	20	Blank
77	.	.	Blank
77	.	.	Blank
77	31	31	Blank

GSE = ground support equipment
DVM = digital voltmeter

Code	Slow Enable Data Sequence	Fast Enable Data Sequence
00	0, 1, 2, . . . , 63	15, 31, 47, 63
01	0, 1, 2, . . . , 63	15, 31, 47, 63
00	0, 1, 2, . . . , 63	15, 31, 47, 63
02	0, 1, 2, . . . , 63	15, 31, 47, 63
	Total print time = 64 seconds	Total print time = 4 seconds

"STOP ON STEP" OPERATION

Two thumbwheel switches on the GSE front panel can be set to monitor data continuously at any step. In this mode, the GSE clock runs until the desired step is reached and then stops. Once the GSE clock stops, no further timing or data enable signals are generated, and further data must be obtained via external trigger signals.

To obtain continuous digital data, set the enable toggle switch to "ext" and send a transfer pulse and then an enable pulse, either by the pushbuttons or the BNC's located on the GSE front panel. If the BNC's are used, a 10-μs closure to ground is required for each signal.

Note: The experiment data system stores data for four steps prior to transferring the digital data to the GSE. Consequently the GSE clock has been advanced by four steps with respect to the experiment sync signals. Table 9 shows the implication of this statement.

Accurate analog data can be obtained in the "stop on step" mode only. A complete analog readout can be obtained by stopping on step 00 and incrementing the thumbwheels by hand at about 1-second intervals. In this condition, one DVM conversion and one print command occur per step.

A toggle switch on the rear of the GSE allows the DVM to self-trigger for continuous monitoring of a particular analog voltage. A one-step delay is incurred in this mode, as illustrated in Table 8.

Table 9

"Step" Meaning for Digital Data in the "Free Run" and "Stop on Step" Modes

Step		Energy, Using 500 eV Full Scale as an Example (eV)
"Stop-on-Step" Mode	"Free-Run" Mode	
60	0	0
61	1	7.94
62	2	15.9
63	3	23.8
0	4	31.8
1	5	39.7
2	6	47.6
.	.	.
.	.	.
.	.	.
58	62	592.1
59	63	500
60	0	0

GSE OPERATION INSTRUCTIONS

Figure 43, which shows the GSE special-purpose interfacer, will be useful in the following discussion.

Minor Mode Commands and Subcom Status ("Free Run" Mode)

To transmit the PES minor mode command word, 12 toggle switches (marked C10 through C21) are set in the desired position (high = "1," low = "0"). Hold the enable subcom button in the depressed position; depress and release the load command button once; depress and release the enable command button once; then release the subcom status button.

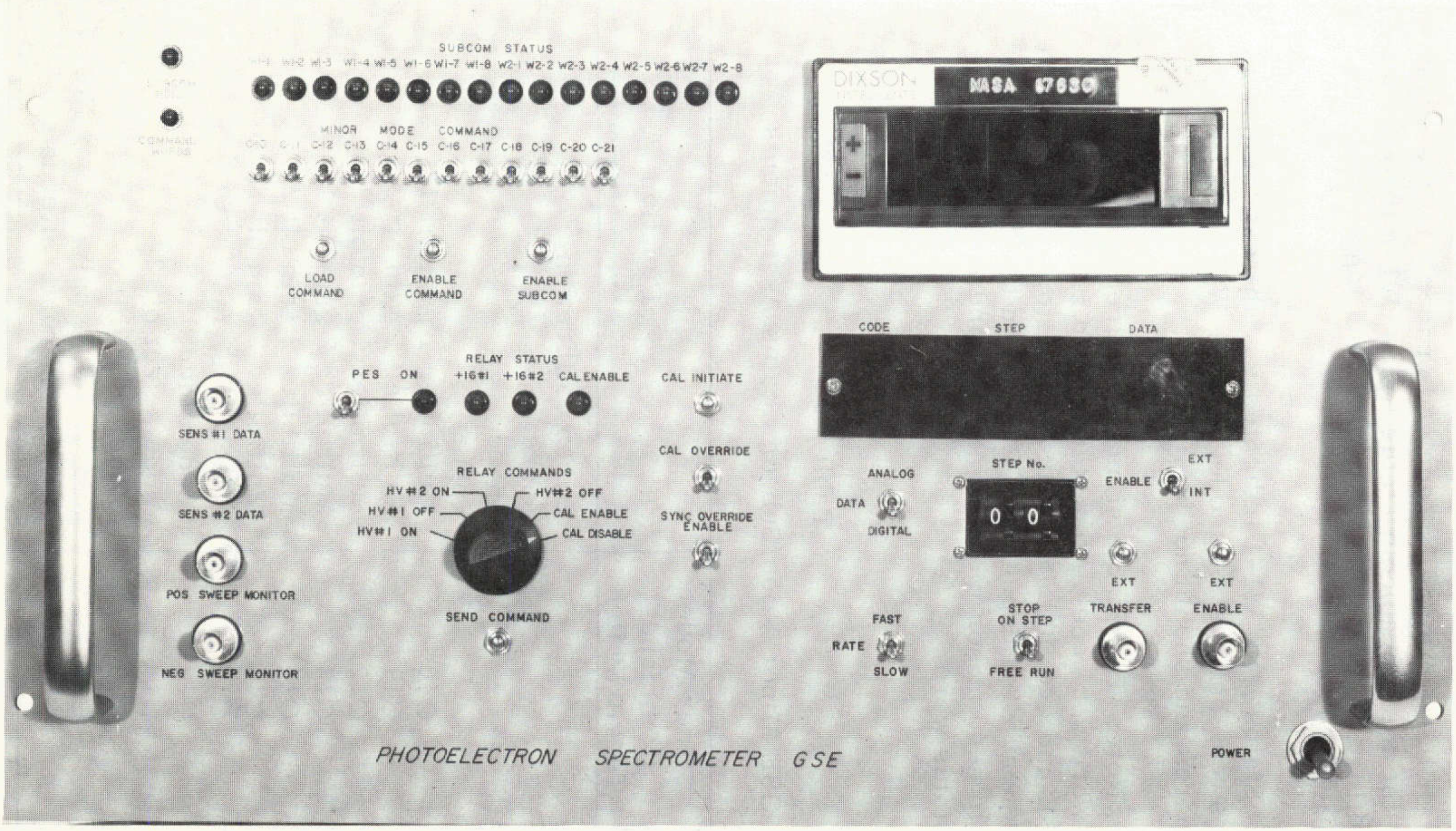

Fig. 43 PES GSE SPECIAL PURPOSE INTERFACER

If the command is received properly by the experiment, the last 12 subcom status lights (W1-5 through W2-8) will reflect the position of the command toggle switches (see Table 10).

Status light W1-1 indicates that the experiment is in the sweep calibration mode. W1-2, W1-3, and W1-4 are spares and should not be lit.

Note: The enable signals required to send the command word and receive the status word are generated by the GSE and are inhibited during the "stop-on-step" mode. Consequently the experiment must be in the "free-run" mode to send minor mode commands and update the subcom status word.

Table 10

GSE Minor Mode/Subcom Status Assignments

Subcom Status Light	Minor Mode Command Toggle Switch	Function
W1-1		Sweep calibration
W1-2		Spare
W1-3		Spare
W1-4		Spare
W1-5	C10	Multiplier 1 gain bit 1
W1-6	C11	Multiplier 1 gain bit 2
W1-7	C12	Multiplier 1 gain bit 3
W1-8	C13	Multiplier 2 gain bit 1
W2-1	C14	Multiplier 2 gain bit 2
W2-2	C15	Multiplier 2 gain bit 3
W2-3	C16	Sweep rate, fast/slow
W2-4	C17	Mode select bit 1
W2-5	C18	Mode select bit 2
W2-6	C19	Mode select bit 3
W2-7	C20	Sensor No. 1 only/$\overline{\text{Sensor}}$ No. 2 only
W2-8	C21	Sensor alternate/$\overline{\text{alternate}}$

Multiplier	Gain	Bits	Result
1	2	3	High-Voltage (kV)
0	0	0	3.00
0	0	1	3.21
0	1	0	3.42
0	1	1	3.65
1	0	0	3.86
1	0	1	4.07
1	1	0	4.29
1	1	1	4.50

Mode	Select	Bits	Result
1	2	3	Mode
0	0	0	V
0	0	1	I
0	1	0	III
0	1	1	Not used
1	0	0	IV
1	0	1	Not used
1	1	0	II
1	1	1	Not used

C20	C21	$128T_S$	Result
0	∅	∅	Sensor No. 2
1	0	∅	Sensor No. 1
1	1	0	Sensor No. 1
1	1	1	Sensor No. 2

Relay Commands

The desired relay command is selected via a six-position switch, and the command is executed by depressing the send command button.

Three panel lights indicate the relay status. The light is on when the relay is active.

Digital and Analog Data

The printer cable (J13) must be connected and the printer must be turned on before the code, step, and data digits will be meaningful.

For more information see the General Section under Section 4.

EXPERIMENT HOOKUP

There are three cables connected to the rear of the GSE interfacer. J10 (50 pins) mates with the experiment flight connector, J11 (25 pins) with the experiment test connector, and J13 (25 pins) with the HP5055A printer.

Note: Do not interchange the 25-pin cables.

GSE INTERFACER CIRCUITS

There are eight plug-in circuit boards as well as a power supply and incidental circuits within the GSE interfacer. Figure 44 shows the primary signal flow paths within the interfacer; Fig. 45 shows the significant GSE timing signals; Table 11 is the GSE "code" truth table. The GSE schematic drawings SRA-5112 through SRA-5123 are included in Ref. 11.

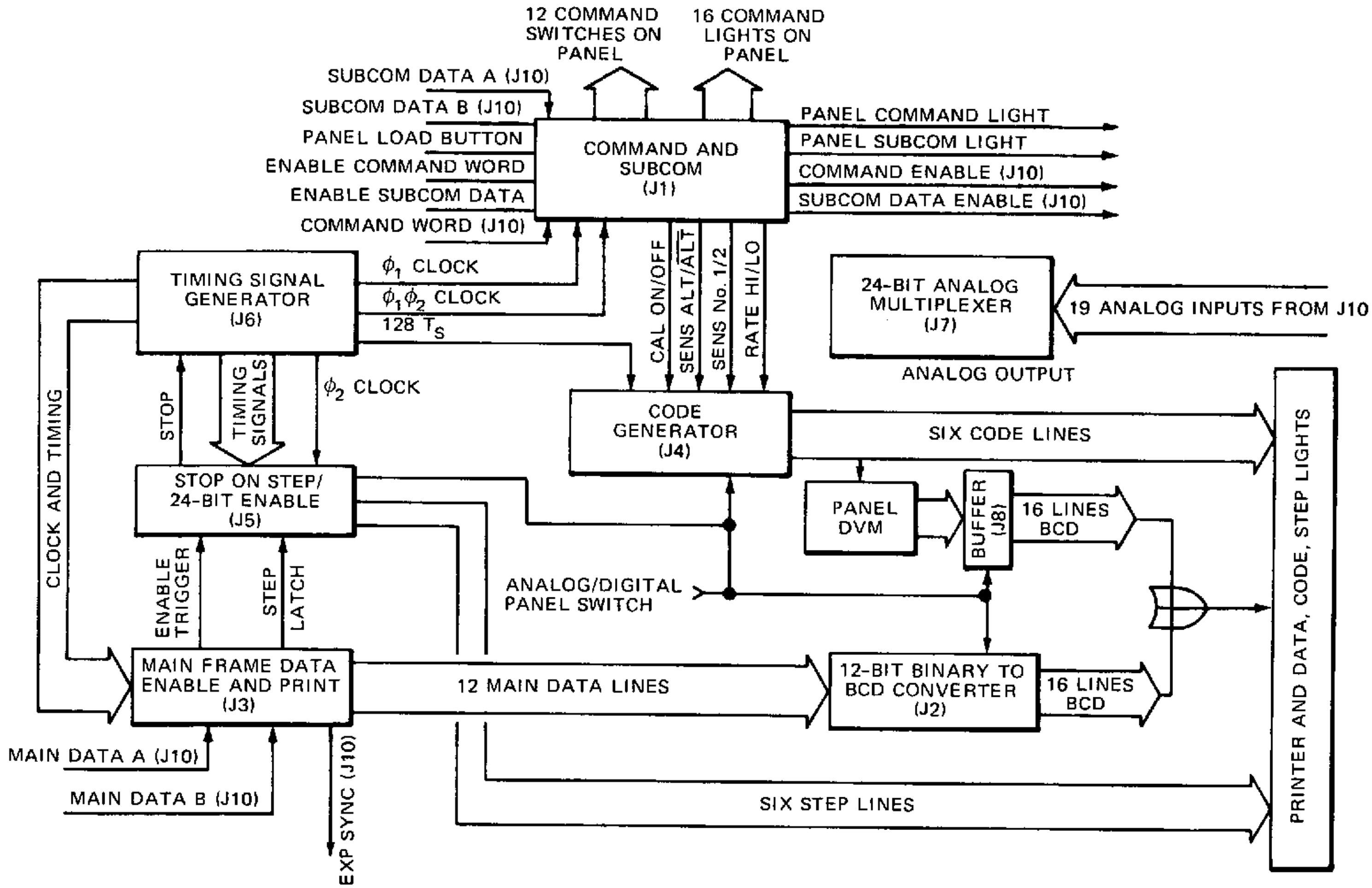

Fig. 44 PES GSE SIGNAL FLOW

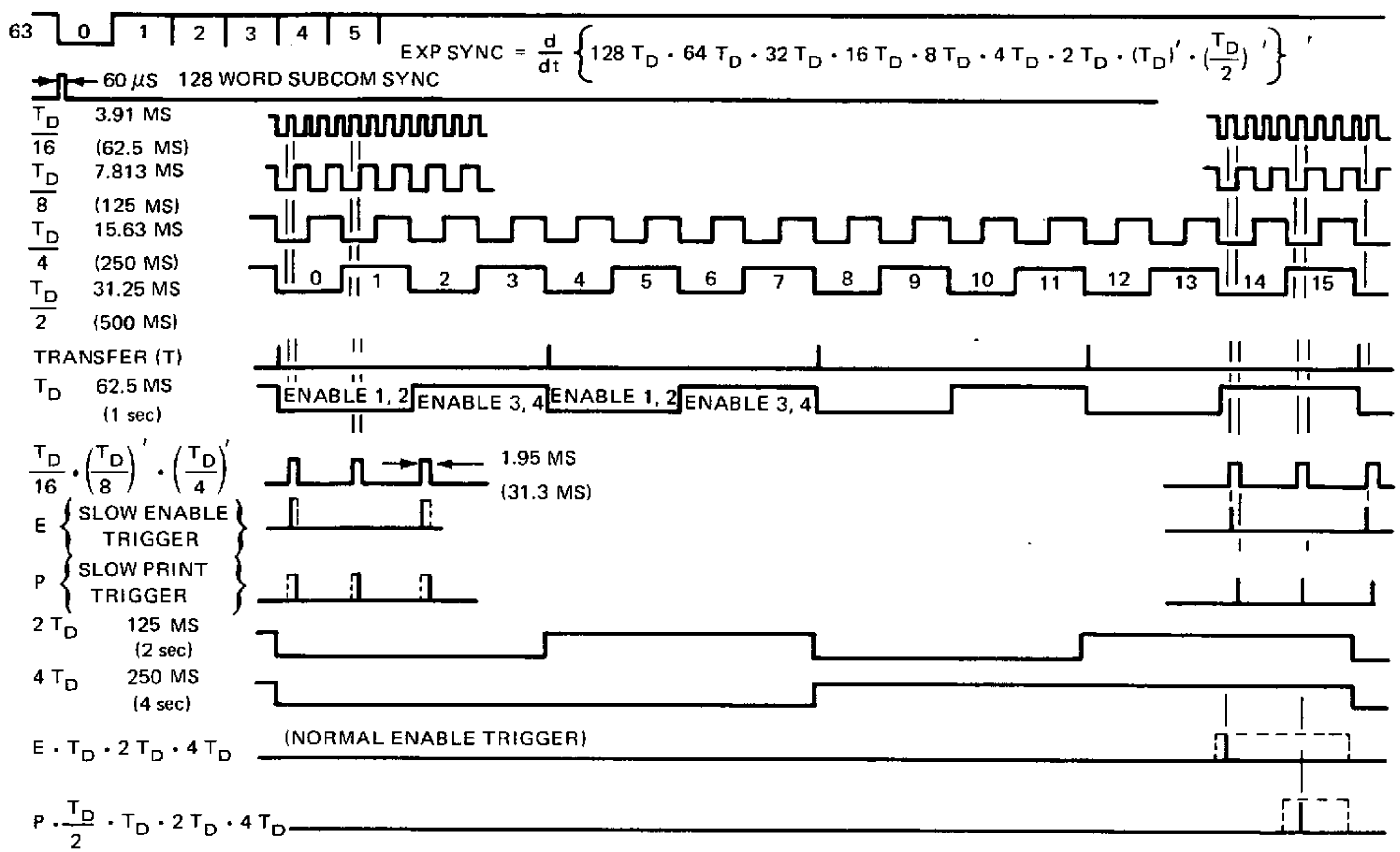

Fig. 45 PHOTOELECTRON SPECTROMETER GSE—EXPERIMENT TIMING

Table 11

PES GSE "Code" Truth Table

Function	Mode Bit 1	Mode Bit 2	Mode Bit 3	Y7	Y8	Sensor Alternate	128 T_D	Sensors No. 1/No. 2	Cal On/Off	Rate Fast/Slow	Code	
J4 Pin	19	17	18	20	21	5	13	7	22	8		
	Ø	Ø	Ø	0	1	Ø	0	Ø	1	Ø	0	0
				1	0	↓	0	↓	↓	↓	0	1
				1	1	↓	0	↓	↓	↓	0	2
	-	-	-	-	-	-	-	-	-	-	0	3
	Ø	Ø	Ø	0	1	Ø	1	Ø	1	Ø	0	4
				1	0	↓	1	↓	↓	↓	0	5
				1	1	↓	1	↓	↓	↓	0	6
	-	-	-	-	-	-	-	-	-	-	0	7
	0	0	1	0	1	0	0	1	0	0(1)	1(2)	0
	0	0	1	1	0	↕	↕	↓	↕	0(1)	1(2)	1
	0	0	1	1	1	↕	↕	↓	↕	0(1)	1(2)	2
	1	1	0	0	Ø	↕	↕	↓	↕	0(1)	1(2)	3
	0	1	0	Ø	Ø	↕	↕	↓	↕	0(1)	1(2)	4
	1	0	0	Ø	Ø	↕	↕	↓	↕	0(1)	1(2)	5
	0	0	0	Ø	Ø	↕	↕	↓	↕	0(1)	1(2)	6
	1	1	0	1	Ø	↕	↕	↓	↕	0(1)	1(2)	7
	0	0	1	0	1	↕	↕	0	↕	0(1)	3(4)	0
	0	0	1	1	0	↕	↕	↓	↕	0(1)	3(4)	1
	0	0	1	1	1	↕	↕	↓	↕	0(1)	3(4)	2
	1	1	0	0	Ø	↕	↕	↓	↕	0(1)	3(4)	3
	0	1	0	Ø	Ø	↕	↕	↓	↕	0(1)	3(4)	4
	1	0	0	Ø	Ø	↕	↕	↓	↕	0(1)	3(4)	5
	0	0	0	Ø	Ø	↕	↕	↓	↕	0(1)	3(4)	6
	1	1	0	1	Ø	↕	↕	↓	↕	0(1)	3(4)	7

Note: Analog = Code 77

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APPENDIX

Mechanical Drawing List

	Drawing Size	SRA Drawing No.	Revisions	Drawing Description
0	C	6726	D	Outline Drawing Sensor Assembly
1	D	6738	B	Plate Alignment Hemispheric Analyzer
2	C	6739	A	Ring Aperture Hemispheric Analyzer
3	C	6740	B	Base, Hemisphere, Inner Hemispheric Analyzer
4	C	6741	C	Hemisphere Inner Hemispheric Analyzer
5	D	6742	D	Hemisphere Outer Hemispheric Analyzer
6	C	6743	B	Light Shield Hemispheric Analyzer
7	D	6744	B	Magnetic Shield
8	C	6745	B	Magnetic Shield Entrance Aperture Detector Head
9	B	6746	C	Ring Tie Down Hemispheric Analyzer
10	D	6747	D	Housing Sensor
11	C	6768	C D	Insulator Multiplier Sensor
12	C	6775	B	Collector Photoelectron Hemispheric Analyzer
13	C	6776	B	Cover Electronic Sensor
14	C	6777	C	Cover Multiplier Sensor
15	D	6778	A	Sensor Assembly Photoelectron Spectrometer
16	D	6779	A	Hemispheric Analyzer Assembly Sensor
17	D	6780	A	Electronics Assembly Photoelectron Spectrometer
18	B	6781	A	Cap Aperture Hemispheric Analyzer
19	D	6782	B	Schematic Electron Multiplier Bias Supply
20	D	6783	B	Artwork E Multiplier Bias Supply
21	D	6784	C	Assembly E Multiplier Bias Supply Detector Head
22	A	6785	A	Parts List F Multiplier Bias Supply
23	B	6786	A	Inductor E Multiplier Bias Supply
24	C	6787	B	Transformer E Multiplier Bias Supply
25	C	6794	B	Cover Multiplier Bias Supply Sensor
26	C	6795	C	End Plate Bias Supply
27	C	6796	A	Shield Bias Supply Sensor
28	D	6797	A	Wiring Diagram Sensor
29	C	6798	A B	Thermistor Assembly Sensor
30	D	6799	C	Insulator Top Bias Supply Sensor
31	C	6800	C	Insulator Bottom Bias Supply
32	C	6801	A	Solder Board Top Bias Supply
33	C	6802	A	Solder Board Bottom Bias Supply Sensor
34	D	6803	B	Insulator Components Bias Supply
35	C	6804	B	Bracket Connector Sensor
36	D	6805	B	Electron Multiplier Bias Supply Assembly Sensor
37	B	6806	B	Entrance Aperture Sensor
38	D	6810	B	Schematic Analog Electronics
39	D	6811	C	Artwork Analog Electronics
40	D	6812	D	Assembly Analog Electronics
41	A	6813	B	Parts List Analog Electronics
42	D	6814	B	Schematic Digital Data Systems
43	D	6815	D	Artwork Digital Data Systems
44	D	6816	C	Assembly Digital Data Systems
45	A	6817	B	Parts List Digital Data Systems
46	D	6818	D	Schematic Minor Mode Command
47	D	6819	C	Artwork Minor Mode Command
48	D	6820	C	Assembly Minor Mode Command
49	A	6821	C	Parts List Minor Mode Command
50	D	6822	D	Schematic Deflection Sweep Supply
51	D	6823	C	Artwork Reflection Sweep Supply
52	D	6824	E	Assembly Deflection Sweep Supply
53	A	6825	C D	Electronics Parts List Deflection Sweep Supply
54	C	6826		Block Diagram Magnetometer Experiment

	Drawing Size	SRA Drawing No.	Revisions	Drawing Description
55	B	6827	C	Spacer General Usage
56	B	6828	A	Spacer General Usage
57	B	6829	A	Shield Analog Electronics
58	B	6834	B	Source-Holder
59	C	6835	A	Schematic Diameter Input Output Board
60	D	6836	B	Artwork Input Output
61	D	6837	B	Assembly Input Output Board
62	A	6838	A	Electronics Parts List Input Output Board
63	D	6839	C D E	Schematic Diameter Main Power Supply
64	D	6840	C	Artwork Main Power Supply
65	D	6841	C D E	Assembly PC Main Power Supply
66	A	6842	B C D	Electronics Parts List Main Power Supply
67	B	6843	A	Schematic Diagram Electron Multiplier Interface Board
68	C	6844	B	Artwork EM Interface Board Sensor
69	C	6845	B	Assembly EM Interface Board Sensor
70	A	6846	A	Electronics Parts List EM Interface Board
71	B	6847	B	Post Welding Component EM Interface Board Sensor
72	C	6848	B C	Resistor Assembly EM Interface Board Sensor
73	C	6851	A	Transformer Main Power Supply
74	B	6852	A	Transformer Main Power Supply
75	B	6853	A	Transformer Main Power Supply
76	D	6854	B	Schematic Timing and Mode Control Logic
77	D	6855	B	Artwork Timing and Mode Control Logic
78	D	6856	B	Assembly Timing and Mode Control Logic
79	A	6857	A	Electronics Parts List Timing and Mode Control Logic
80	B	6858	A	Block Tie Down PC Board Main Electronic Assembly
81	C	6859	A	Spacer Prt. Circuit Board Main Electronic Assembly
82	B	6860	A	Insulator TTL Main Electronic Assembly
83	D	6861	B	Frame Mother Board Assembly Main Electronics
84	C	6862	A	Brace Tie-Down Cover Main Electronic Assembly
85	B	6864	A	Insulator MSI Main Electronic Assembly
86	C	6865	A	Block Mounting Connector Input-Output Board M E
87	C	6866	C	Block Diagram Sensor
88	B	6867	B	Heat Sink Transformer Main Power Supply
89	D	6868	A B	Main Power Supply Assembly Main Electronic Assembly
90	C	6869	B	Artwork Transformer T2 Assembly
91	D	6870	B C	Transformer T2 Assembly Main Power Supply
92	D	6871	A	Housing Main Power Supply
93	D	6872	B C D	Outline Drawing Sensor and Main Electronics
94	D	6873	B	Block Diagram Main Electronics
95	B	6875	A	Spacer Electron Multiplier Sensor
96	C	6876	B	Support Cover MB Frame Assembly Main Electronics
97	D	6877	B	Plate Base Main Electronic Assembly
98	C	6878	A	Housing Filter Main Power Supply Main Electronics
99	D	6879	C D	Cover Assembly Main Electronics
100	C	6880	A	Channel Main Electronics Cover Assembly
101	C	6881	A	Angle Shield Main Electronics Cover
102	B	6882	B	Plate Shield Main Electronics Cover
103	C	6883	B C	Insulator EM Interface Board Sensor
104	D	6884	A	Artwork RF Section Main PS Main Electronics

	Drawing Size	SRA Drawing No.	Revisions	Drawing Description
105	D	6885	A B	Assembly Printed Circuit RF Section Main RS Main Electronics
106	B	6886	B	Cup Insulator Screw Sensor
107	D	6887	A	Schematic Sweep Calibrator
108	D	6888	C	Artwork Sweep Calibrator
109	D	6889	A	Assembly Sweep Calibrator
110	A	6890	A	Electronics Parts List Sweep Calibrator
111	C	6891	A	Spacer "A" Bracket
112	C	6892	A	Spacer "B" Bracket
113	D	6893	A	Artwork Master Mother Board
114	D	6894	A	Mother Board Frame Assembly Main Electronics
115	D	6895	A	Artwork Silk Screen Mother Board
116	B	6896	A	Top Board Transformer Main PS Main Electronics
117	B	6897	A	Cup Transformer Main PS Main Electronics
118	B	6898	A	Cover Filter Main PS Main Electronics Assembly
119	D	6899	A	Mother Board Assembly MB Frame Assembly Main Electronics
120	B	6900	A	Cushion Ring Viton Sensor
121	B	6901	A	Seal Light Sensor
122	B	6902	B	Cover, Test Connector Main Electronics
123	C	6903	A B	Insulator Interface Board Sensor
124	B	6904	A	Cap Coaxial Connector Sensor
125	D	6905	A	Wiring Diagram MB Frame Assembly Main Electronics
126	C	6906	A	Nameplate Sensor
127	C	6907	A	Nameplate Main Electronics
128	C	6908	B C	Shield Light Thermal Sensor
129	B	6910	A B	Gasket, Shield, Light, Thermal
130	C	6991	A	Isolation Assembly Kit – Outline Drawing