The Modular Auroral Probe

W. J. Heikkila, Editor

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The rocket payload and ground support equipment described in this report has been tested in actual use. Improvements suggested by this experience have already been incorporated, but nevertheless, further changes and improvements will no doubt continue to be made. Anyone interested in these should contact one of the authors.

TABLE OF CONTENTS

8.0 Auxiliary Payload Systems (W. W. Wright, R. L. Bickel, R. H. Morgan J. B. Carnahan, E. C. Lee)

- 8.1 Mechanical Structure
- 8.2 Power System
- 8.3 Encoder
- 8.4 Telemetry
- 8.5 Umbilical Connector
- 8.6 Magnetic Aspect Instrumentation
- 8.7 Door Controls
- 8.8 Altitude Controls

9.0 Central Ground Support Equipment (R. L. Bickel, E. C. Lee)

- 9.1 Receiver
- 9.2 Tape Recorder
- 9.3 Demodulators
- 9.4 Visicorder
- 9.5 Sync Unit
- 9.6 Time Base
- 9.7 Format Memory
- 9.8 Check-out Panel
- 9.9 Print Control

10.0 Payload Control and Checkout (N. Eaker)

- 10.1 Instrumentation
- 10.2 Automatic Go, No-Go Tester

ABSTRACT

This report constitutes a description of a Modular Auroral Probe (MAP) payload for rocket investigations of auroral zone disturbances. The payload includes a parachute for recovery purposes, with a view to repeated use of the instrumentation. The modular concept for experiments was then adopted in order to permit changes in the experiments as suggested by experience. The modular concept involved the generous provision of services such as power, timing signals, umbilical lines, and telemetry channels. The auxiliary equipment developed to meet this need is described in some detail. The first payloads carried six experiments as follows: Energetic particle detectors, soft electron spectrometer, photometers, frequency shift capacitance probe, Langmuir probe, and a pulse receiver. The principal theoretical and instrumental features of the different probes are presented in rather brief form; more complete descriptions will be published elsewhere.

ILLUSTRATIONS

TABLES

I. INTRODUCTION

W. J. Heikkila

High latitude ionospheric and auroral disturbances are the result of solar disturbances. Observations carried out during the past solar cycle by means of rocket, satellite, and ground-based instrumentation have permitted a broad picture of this association to be developed (Odishaw, 1964). A sudden ionospheric disturbance (SID) is usually observed coincident with a major flare on the sun. SID is observed only on the sunlit hemisphere; it is caused by an enhanced ultraviolet and X-ray flux, and lasts for some 10 or 20 minutes. One or more hours later, an intense flux of high-energy protons arrives over the polar regions; the protons penetrate deep into the atmosphere and produce extra ionization in the lower D-region, thereby causing strong absorption of high frequency radio waves. This condition may last for several days, and it is referred to as "A Polar Cap Absorption (PCA) Event." The flare initiates a shock wave in the interplanetary plasma which reaches the Earth some 24 to 72 hours after the occurrence of the flare. The plasma in the shock front compresses the geomagnetic field, initiating a geomagnetic storm. At this time, intense fluxes of electrons are observed precipitating into the auroral zones, and their secondary X-rays penetrate to the E- and D-regions. This stage of the disturbance is characterized by large and rapid spatial and temporal variations of several geophysical features, including visual and radar aurora, the geomagnetic field, and ionospheric radio-wave absorption. It is sometimes called an "Auroral Absorption Event" or 'AA'. This disturbance may last for several days.

A great variety of ground-based techniques may be employed to yield information on these disturbances. Riometers are used for continuous monitoring of the radio wave absorption. Amplitude and phase of LF and VLF transmissions over both short and long paths are very useful in indicating D-region heights. Ionospheric sounders give some information, although the absorption interferes with normal sounder operation. VHF radar can be used to detect enhanced ionization. Visual and optical observations of aurora can be made during clear nights. Geomagnetic fluctuations and earth currents indicate the presence of ionospheric currents. The various ground-based observations have been most useful in uncovering synoptic effects.

Some observations were carried out by means of satellite instrumentation during the previous solar cycle, particularly on the nature and intensity of the corpuscular radiation. Considerably greater use of satellite instrumentation will undoubtedly be made during the coming sunspot cycle, particularly in ionospheric measurements with topside sounders. Satellite techniques should be particularly useful in providing a description of the flux of particles which is a cause of the atmospheric effects, and for synoptic studies.

Balloon instrumentation has been used frequently in the past, particularly for X-ray measurements. These X-rays at balloon altitudes are indicative of interactions occurring in the D- and E-Regions. Balloon observations are particularly attractive for the study of the time development of a disturbance because of the long observation periods at one location that are possible.

Rocket instrumentation has been and remains the only way for carrying out observations in the actual region of interaction between the energetic particles and the atmosphere. This region extends from 50- to 200-kilometers, is too low for satellite observations and too high for balloon observations. A variety of observations can be carried out by means of rockets, but the sampling time for any one rocket flight is rather short. A few successful observations were carried out during the previous active period, but the present state of rocket research techniques should permit much more conclusive experiments to be carried out during the coming solar cycle.

While a broad picture of the high-latitude disturbances has evolved from the observations that have been carried out during the past solar cycle, nevertheless, many questions remain unanswered. The altitude profile of radio-wave absorption has not been uniquely determined, particularly its relation to the sunrise/sunset effect; the negative ions that are formed during the night-time have not been uniquely identified; no information on the possible variation of electron collision frequency during a disturbance has been obtained; the few data obtained on corpuscular radiations have shown great variability in the spatial structure and the nature and composition of the flux; no quantitative observations of auroral emissions have been made simultaneously with the observations of the ionospheric effects and the corpuscular flux; very few observations of the very low-energy primary and secondary fluxes have been carried out; the midday recovery during PCA remains a mystery. In short, many parameters have been observed one way or another at one time or another, but the observations all show great variability. Consequently, they are difficult to piece together into a coherent whole; other observations have not been carried out at all, or have been carried out only in a very preliminary way.

With the new solar cycle now commencing, it may be expected that high-latitude disturbances will again become common in one or two years' time. New techniques developed during the intervening solar minimum period permit the planning of comprehensive and balanced experimental programs, and many experimental groups will probably be involved in such studies. The COSPAR Panel on Polar Cap Experiments is taking an active part in coordinating their work.

1.1 Program Philosophy

The present program is a comprehensive, experimental investigation of high-latitude disturbances. It is primarily a rocket investigation, but active cooperation with other experimenters using rocket, satellite, balloon, and ground techniques is planned. The payloads will include many experiments, each providing a detailed observation of some aspect of auroral zone phenomena. Some experiments cover the energetic particles that cause the disturbances, and some cover the various geophysical effects that are a result. The measurement of a number of parameters simultaneously, and at the same point in space, will alleviate the problem of interpretation in the face of variability. We hope to achieve a large number of flights by means of recovery and reuse of a modest number of payloads.

Each rocket payload consists of a flexible and comprehensive support system plus a number of experiments. The support system provides a wide range of services such as power, timing, control, and telemetry. The services actually required by an individual experiment are chosen from all the possible services by a suitable switchboard in a control unit called the encoder. Should it become necessary to replace an experiment by another one, a new set of services can be chosen by simple changes in the encoder. Normally, such new requirements will be foreseen, and the new control circuitry appropriate to the replacement experiment will be prepared beforehand. It is our ambition, however, to permit some changes on very short notice, and perhaps even in the field; how well this works out in practice remains to be seen.

1.2 The Modular Auroral Probe

The name Modular Auroral Probe (MAP) used for these rockets is meant to convey this concept of interchangeable experiments. The systems design is described in Chapter 8 and a diagram of the payload is shown in Fig. 1.1. The six experiments are housed above station 62; the auxiliary system instrumentation from station 62 to 79, and the parachute recovery section from station 79 to 94.

Many of the experiments produce digital rather than analogue outputs, and it was decided to include a PCM (Pulse Code Modulation) telemetry channel for these. This PCM system operates at a bit rate of 16 KHz, and is carried on Channel H of an IRIG standard FM/FM system. Eleven other FM channels carry a PAM (Pulse Amplitude Modulated) commutator, and analogue signals. All channel assignments are made by means of a switchboard in the encoder.

Several regulated power lines with voltage from -15 to +28 volts DC and 100 volts PTP AC at 32 KHz are available from a central converter. Timing pulses at 250 KHz and its subharmonics are available from a central clock. A modest number of connections come through the umbilical connector. All these services are also routed by means of the switchboard.

1.3 The Experiments

Six experiments have been instrumented for the first MAP flights. Energetic particles are studied by means of several detectors described in Chapter 2. A soft electron spectrometer, for the energy range 10 ev to 10,000 ev, is based on an electron multiplier (Chapter 3). Photometers and ultraviolet detectors (Chapter 4) are included for auroral emissions. A radio frequency capacitance probe (Chapter 5) and a Langmuir probe (Chapter 6) both permit ionospheric plasma studies, and a pulse receiver (Chapter 7) permits a check on the probe results.

Other experiments being considered for the future include nuclear emulsions for energetic particles, a swept frequency admittance probe, a magnetometer, an ion mass spectrometer, and more photometers.

1.4 Checkout and Launch Procedures

The first launch campaign took place in May 1967 at the Churchill Research Range in the Canadian auroral zone. It was hoped that successful recovery of the two payloads would permit four launchings. Unfortunately a recovery pack failure occurred on the first flight, and no further launchings were carried out. The operation did permit a comprehensive test of the payload ground support equipment (GSE) and procedures under actual launch conditions.

The payload can be controlled and monitored through the umbilical cable by means of the checkout console described in Ch. 10. The operation of this particular console does not depend on telemetry, and if necessary a complete checkout of the experiments for a launching can be based solely on the use of this equipment, in the blockhouse, with only one person at the controls. Additional checkout using the telemetry signals from the payload would however be normally utilized. In that case the separate FM channels from ground station discriminators can be fed to the checkout equipment for analysis in the blockhouse; alternatively they can be monitored on other equipment elsewhere, e.g. in the Operations Building at CRR.

The PCM signal requires further equipment for its convenient presentation and analysis; this is described in Ch. 9. Status indicators can again by made available in the blockhouse or elsewhere.

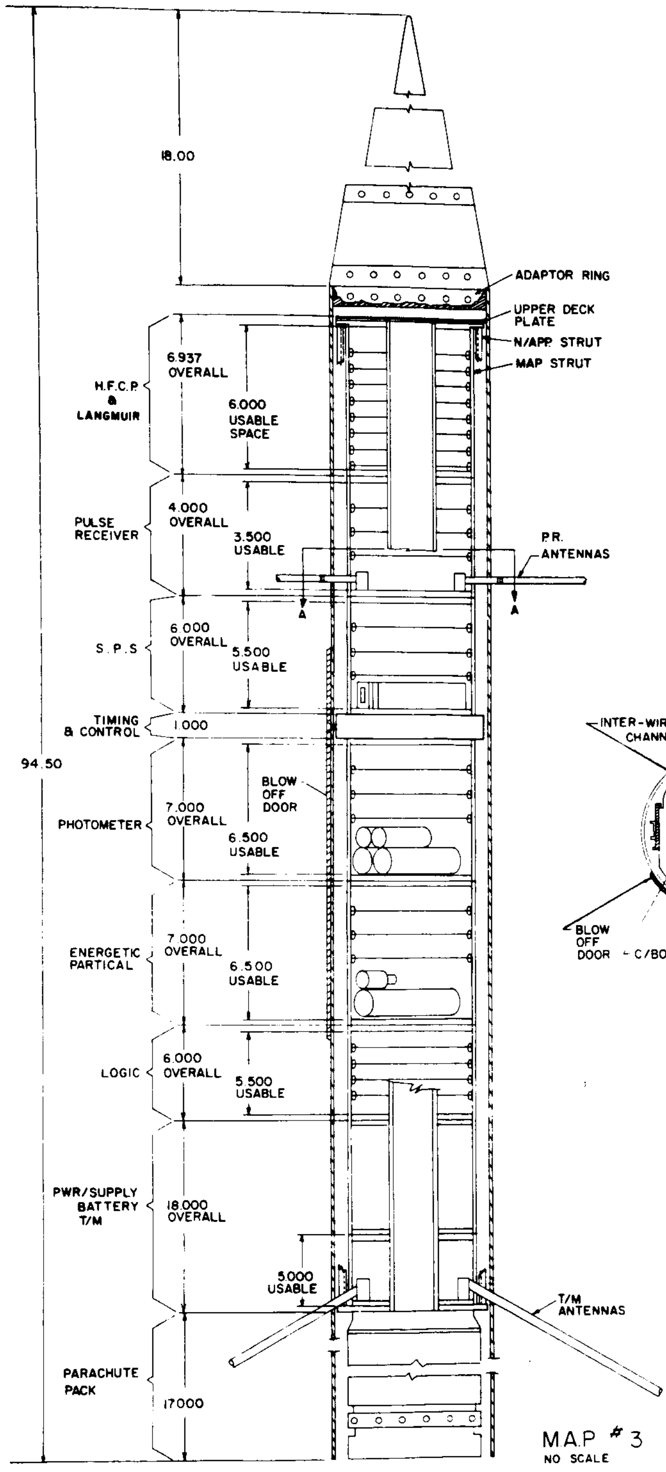
More than a dozen persons were involved in the first launch campaign in order to check each of the half dozen experiments, and the various parts of the payload auxiliary equipment and GSE. With this experience in hand, it is now possible to draw up rather simple checkout procedures for each unit which can be carried out by persons other than those directly involved in their design and construction. The next field trip should now be possible with only 5 or 6 persons, and after more experience this complement might be reduced by another factor of 2.

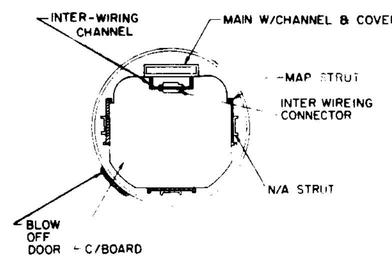
A typical (or ideal) launch campaign for the study of auroral zone disturbances might then go as follows. When the rockets are ready, they will be taken to the range and each one checked for satisfactory operation in dry runs. Other ground instrumentation and procedures will also be activated. When all equipment is in satisfactory operating condition, and one or two instrumentation flights have been conducted, the rockets and instrumentation will be set aside with only routine maintenance. At this point, the waiting period for a suitable PCA or AA disturbance may begin. Advantage will be taken of any world-wide warning services by means of which early warning of a developing disturbance may reach the launch site. Such warning will be of great value when local observations do not yet indicate than an event is in progress. When an event is indicated, the range will be requested to proceed with the countdown for a launch. When a suitable disturbance does take place, several firings may be carried out within a period of a few days.

In the following chapters the experiments are described briefly, and the auxiliary payload instrumentation is described in some detail.

Reference:

Odishaw, Hugh: Research in Geophysics, Sun, Upper Atmosphere, and Space, Vol. 1., 1964.





SECTION A-A
TOP VIEW OF TYP SUGGESTED MAP C/B ARRANGEMENT
NO SCALE

M.A.P. PAYLOAD

FIGURE 1.1

2.0 ENERGETIC PARTICLE DETECTOR

W. R. Sheldon
K. G. McCracken

2.1 Introduction

The energetic particle detector module contains three instruments: a proton/alpha particle telescope, a soft electron detector and a thin window Geiger counter. This instrumentation was selected to provide data on the charged particle fluxes during a PCA event. The data will be telemetered in eight bit words, as words 7 through 11 of a 16 word quarter-frame in the following sequence:

Word 7 - Geiger counter rate
Word 8 - Low energy particle counting rate
Word 9 - Proton/alpha particle dE/dx and energy
Word 10- " " " " "
Word 11- Soft electron flux

2.2 Proton/Alpha Particle Telescope

The proton/alpha particle telescope consists of two solid state detectors and a CsI (Na) scintillator as shown in Figure 2.1. The two solid state detectors (D_1,100 microns thick and D_2,300 microns) are totally depleted silicon surface barrier detectors with an active area of 1 cm^2. The scintillator is coupled through a lucite light pipe to a type 4460 photomultiplier tube.

The telescope operates in two modes. In one mode it is a telescope with a half-angle of 26^o, whose aperture is determined by D_1 and D_2. In this mode the spectrums of protons and alpha particles are determined by pulse height analysis of D_1 and the CsI scintillator. The energy of the particle is measured by the scintillator and its dE/dx by the solid state detector. In this way the proton spectrum from 3.5 to 60 Mev and the alpha particle spectrum from 12 to 1000 Mev are measured. Response curves for the detectors are shown in Figure 2.2.

In the other mode of operation only the solid state detector D_1 is employed. All of the charged particles impinging on D_1 (i.e., within an aperture of nearly 2π steradians) are measured in eight energy increments from 0.2 to 5.0 Mev. The data will be supercommutated every 8 milliseconds within the PCM format in the following measurement sequence:

>0.2 Mev
>1.0 Mev
>0.4 Mev
>2.0 Mev
>0.7 Mev
>3.5 Mev
>1.0 Mev
>5.0 Mev

which will be repeated every two frames (64 milliseconds). These data are presented as word 8. The energy discrimination level, along with overflow pulses from the accumulator, are telemetered on channel 15 of the FM system.

A block diagram of the electronics is shown in Figure 2.3. Counting of integral flux rates (>E) of D_1 is accomplished by presenting a reference voltage to the two discriminators, which receive D_1 pulses from gain-of-5 and gain-of-25 amplifiers. The L pulse from the master timing circuit engages each discriminator for alternate words. The discriminator reference voltage level is changed every second quarter frame by the M and N pulses. Data on particles >1 Mev acquired in two ways will provide an internal check on the instrument.

The pulse height analyzer circuits are gated on by either a double coincidence between D_1 through the gain-of-5 amplifier (E>1 Mev) and D_2 through the gain-of-10 amplifier (E >0.8 Mev), or a triple coincidence between D_1 through the gain-of-25 amplifier (E >0.2 Mev), D_2 through the gain-of-20 amplifier (E> 0.4 Mev) and the CsI scintillator. In both cases a "strobe" pulse of short duration (0.2 microseconds) from D_1 has been added to the coincidence requirement. This coincidence logic has been designed to count only protons and alpha particles in an anticipated high background of energetic electrons by the high energy loss requirement in D_1 and D_2 when a double coincidence is used, and by the additional requirement of an energy loss >1 Mev in the scintillator when the D_1 and D_2 requirements are lowered. Only one particle per quarter frame can be analyzed using the pulse height to pulse length converter; therefore, the "busy flip-flop" is engaged by the gate pulse to the pulse height analyzer circuits. The busy flip-flop is reset to allow another particle to be analyzed by the accumulator pulse which occurs at the beginning of each sixteen word subframe. The analyzer accumulators are read out as words 9 and 10 which are eight bit words. Since the pulse train to the analyzer circuits is a 256 kc/sec signal, a maximum of 1.0 millisecond is required to fill one of the accumulators. To prevent accumulator dump occurring while the word 9 and 10 accumulators are in the process of being filled, the busy flip-flop is set to "busy" 1.0 milliseconds before the start of each subframe. Pulse height analyzer live time is obtained by telemetering the "busy" signal on FM channel 10.

2.3 Soft Electron Detector

The soft electron detector employs channel electron multipliers to measure the fluxes of electrons at angles of 60°, 90° and 120° to the spin axis of the rocket. Since the rocket spin axis should be approximately along a magnetic field line these angles will be approximately the electron pitch angles (the actual orientation will be accurately determined by magnetic sensors on board). A diagram of the detector is shown in Figure 2.4. The entrance apertures have a half angle of 5°. Energy selection is accomplished with a small electromagnet which focuses electrons in two energy bands: 0.5 to 1.0 kev and 1.0 to 2.0 kev. Switching between the two energy bands is initiated every 32 milliseconds by the N pulse and is accomplished by changing the current in the magnet coil. Measurements at a pitch angle of 60° and of background at 90°, are made by reversing the direction of the field in the electromagnet by actuating a relay every 64 milliseconds with the 0 timing pulse. The electronics for the soft electron detector are shown in Figure 2.5. Data from the soft electron detector is commutated every 8 milliseconds as follows:

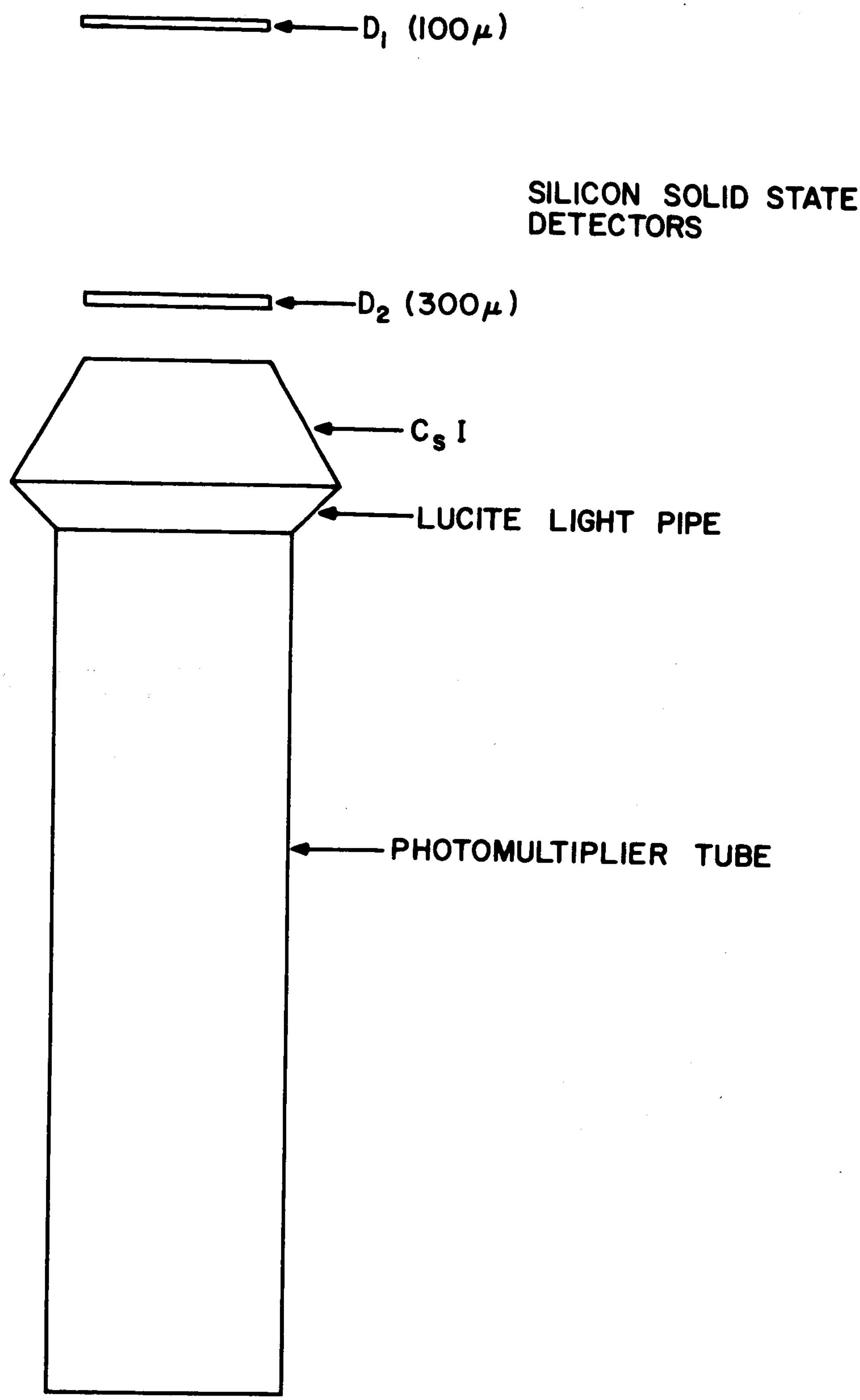
0.5 - 1.0 kev at 90°
0.5 - 1.0 kev at 120°
1.0 - 2.0 kev at 90°
1.0 - 2.0 kev at 120°
0.5 - 1.0 kev background at 90°
0.5 - 1.0 kev at 60°
1.0 - 2.0 kev background at 90°
1.0 - 2.0 kev at 60°

This sequence is repeated every four frames (128 milliseconds). Information on the energy level and accumulator overflow is telemetered on the PAM commutator channel 28.

A particle with a pitch angle of 90° is at its mirror point and hence is trapped (at least for this bounce period). A particle with a pitch angle of 120° has reached its mirror point and is returning to the equator; at the same altitude the pitch angle on its inbound trajectory was 60°. Since both trapped and precipitating particles are at pitch angles of 60°, the difference in fluxes at 60° and 120° represents the flux of precipitating particles.

2.4 Geiger Counter

An EON 6213 counter with a 1.4 mg/cm^2 mica window is mounted with the window parallel to the spin axis of the rocket. Similar detectors often have been flown as rocket instrumentation, thus these measurements can easily be compared to data reported by others. The detection threshold is 1.9 Mev for protons; for electrons the transmission is 0.48 at 50 kev, rising to 0.96 at 610 kev. The detection efficiency is 0.85 for relativistic charged particles and less than 0.004 for photons. The counting rate of the geiger counter is telemetered as word 7.



PROTON /ALPHA PARTICLE TELESCOPE

FIGURE 2.1

DETECTOR RESPONSE FOR PROTONS AND ALPHA PARTICLES

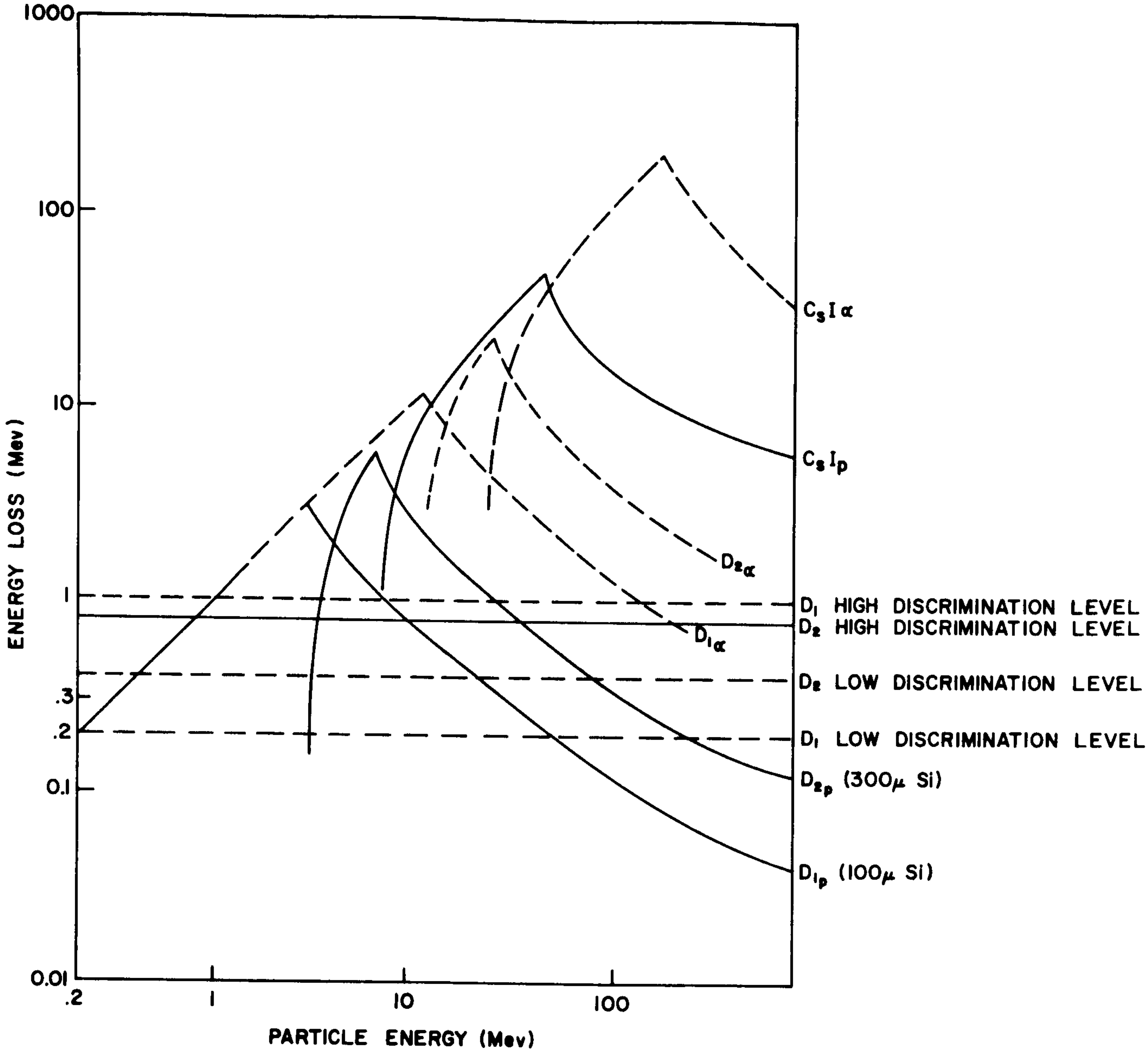
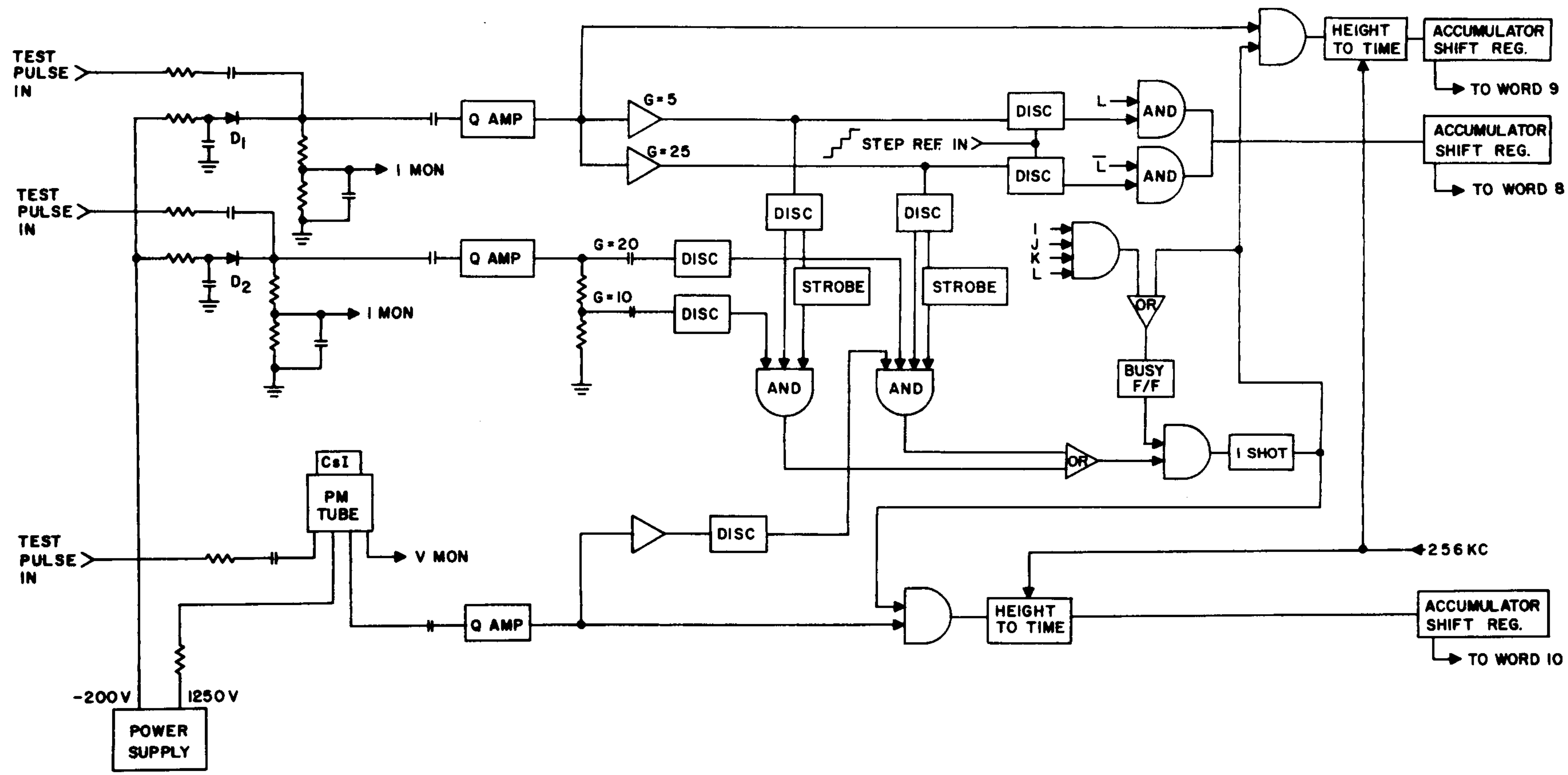
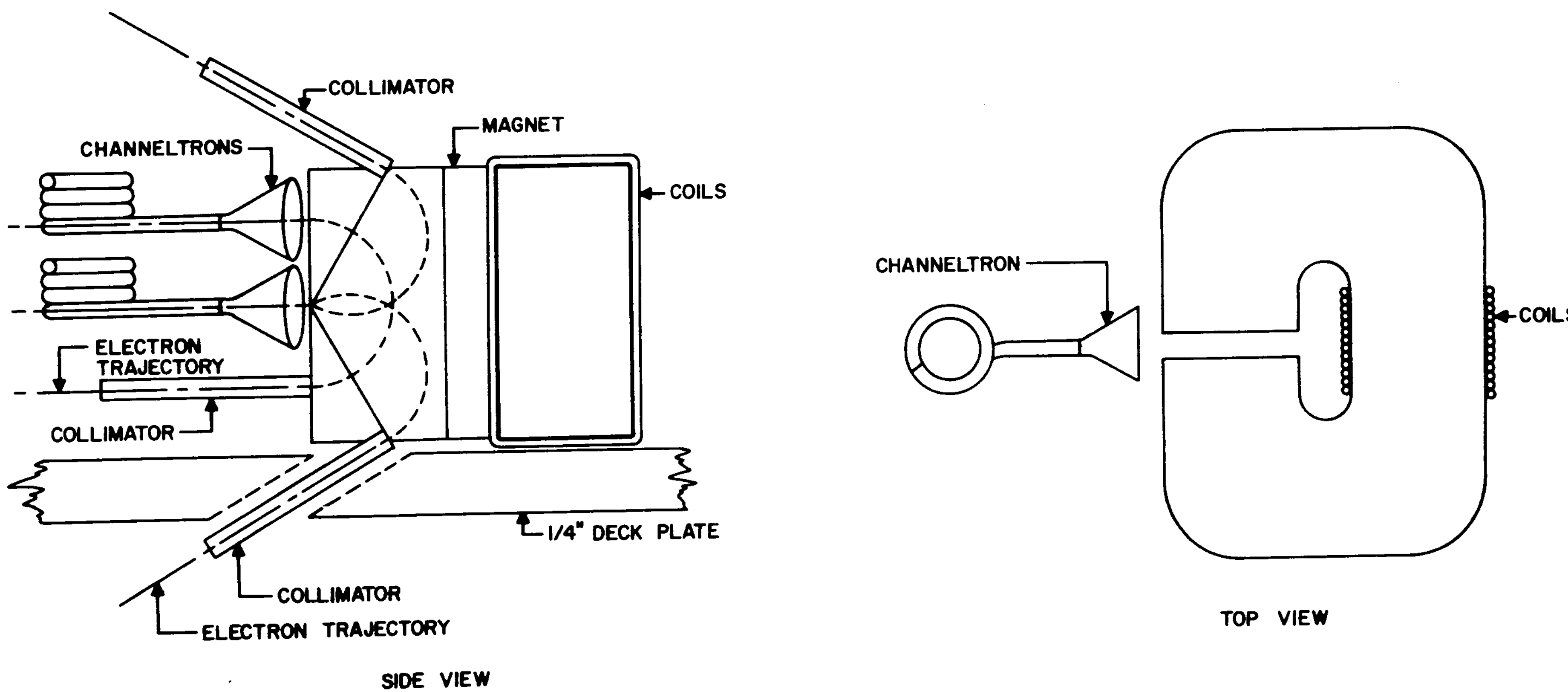


FIGURE 2.2



BLOCK DIAGRAM.– PROTON / ALPHA PARTICLE DETECTOR

FIGURE 2.3



SOFT ELECTRON DETECTOR

FIGURE 2.4

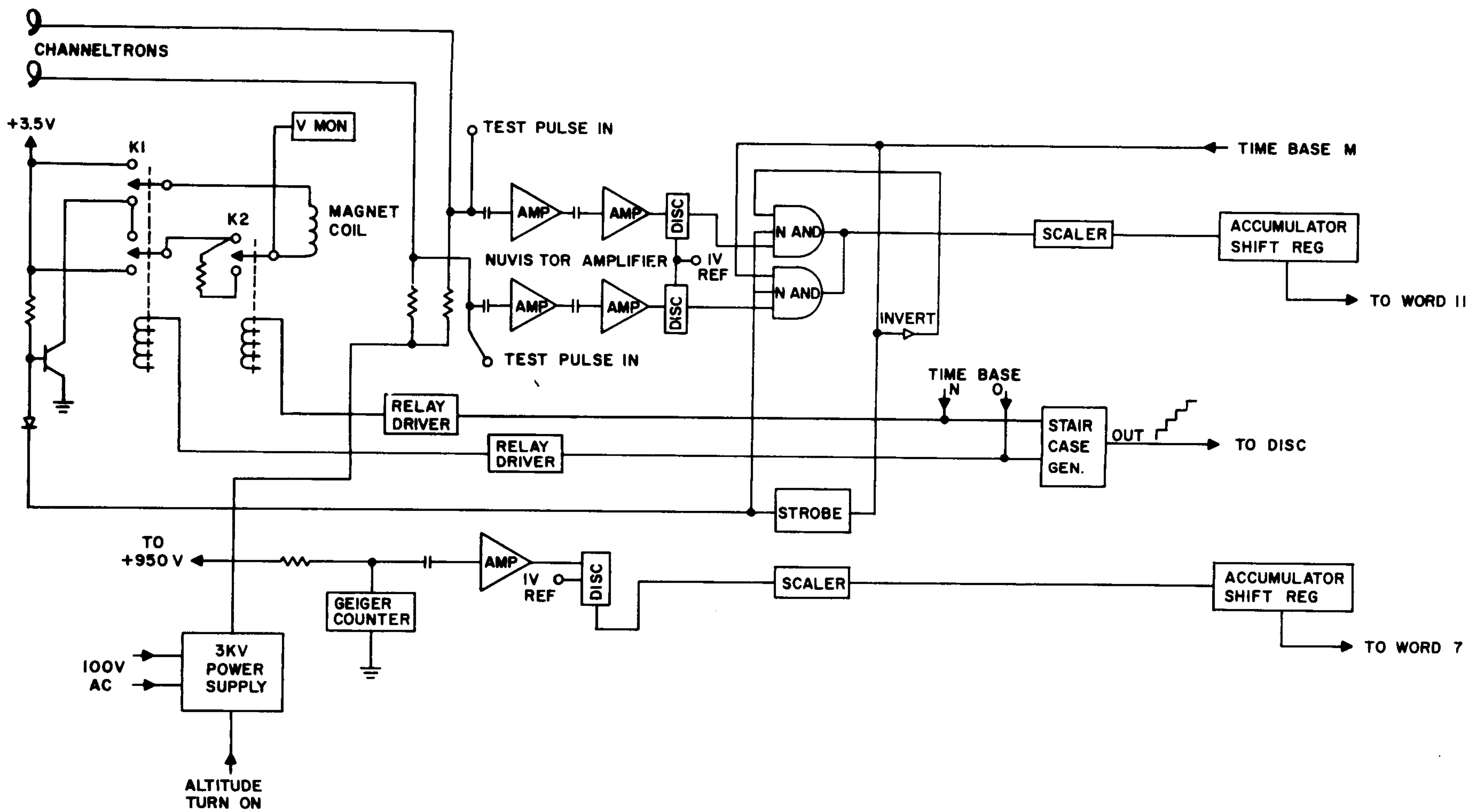


Fig. 2.5 BLOCK DIAGRAM - SOFT ELECTRON DETECTOR AND GEIGER COUNTER

3.0 THE SOFT ELECTRON SPECTROMETER FOR MAP

J. B. Smith
W. H. Wright
W. J. Heikkila

3.1 Introduction

Particle radiation entering the atmosphere is responsible for auroras, geomagnetic disturbances and certain ionospheric features. Estimates of the effects of these particles, which are mainly electrons and protons, have been made possible by the acquisition of data from recent satellite and rocket experiments. However, very little data has been obtained on particles with energies less than 40 KeV partly because of experimental difficulties in this energy region. This is unfortunate both because observed spectral intensities increase rapidly toward lower energies and because some of the effects of interest appear to be brought about principally by the lower energy particles. The Soft Electron Spectrometer on MAP is designed to obtain data on the low energy electrons. The spectrometer measures the differential energy spectrum in the energy range 10eV to 10KeV with 20% energy resolution. The flux and direction of the particles is also obtained. The instrument is similar to the Soft Particle Spectrometers to be flown on the ISIS-A satellite in 1968 and ISIS-B in 1970.

3.2 Instrumentation

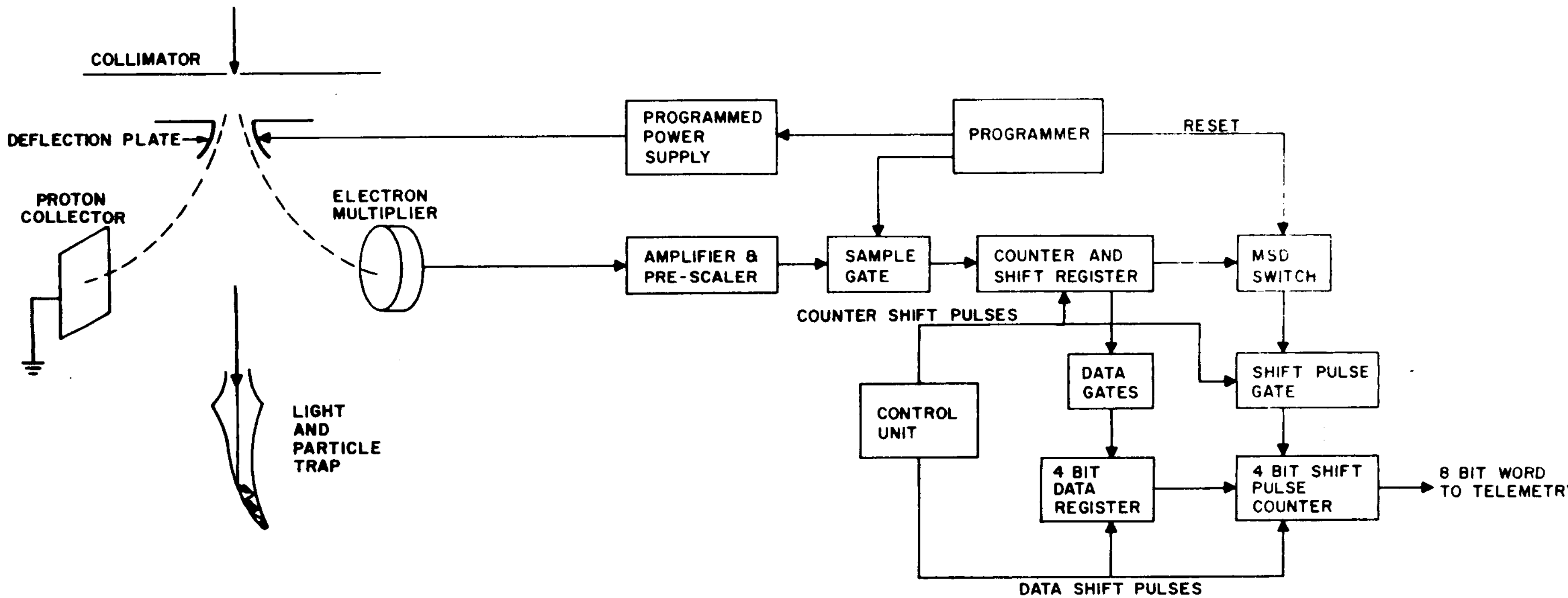
Figure 3.1 is a simplified block diagram of the Soft Electron Spectrometer. The particles of interest are admitted to the sensor through a collimator situated behind an ejectable door in the skin of the rocket. The slit assembly defines a beam of rectangular cross section with accurately known angular dimensions so that the solid angle viewed by the sensor is known. Particles of all energies from this collimator pass between a pair of deflection plates; one of which has a positive potential, and the other an equal negative potential. For a given potential on the plates, the trajectories of electrons within a certain energy range will be such that these electrons strike a rectangular area defined by the first dynode of an electron multiplier. Electrons with lower energies will have more sharply curved trajectories and will miss this dynode area; they will be collected primarily by the positive deflection plate. Electrons with energies above the value determined by the deflection plate potentials will similarly miss the first dynode and will be collected at the back of the instrument. The energy of the electrons striking the first dynode is thus a function of deflection plate potential.

Each particle striking the first dynode produces a cascade of secondary electrons along the dynodes, resulting in a shower of electrons which are collected by the anode. The shower lasts for 10 to 15 nanoseconds and produces a negative pulse at the anode. These output pulses are amplified, shaped, and counted.

Electronic gates admit these pulses to the counter during timed intervals of about 11 milliseconds duration. These samples are taken at a rate of 60/sec. and telemetered in digital format. The maximum and minimum pulse rates are about 4×10^7 per second and 60 per second.

The data processor is an assemblage of digital circuit elements, the main purpose of which is to compress the raw data count from a maximum of 18 binary bits to uniform output code of 8 binary bits. Four of these bits are the 2nd, 3rd, 4th, and 5th most significant bits of the original count; (the most significant bit is known to be 1 and is not telemetered), and the other four comprise an "exponent" which indicates in a logarithmic fashion the size of the original count. This method of compression still allows the original count to be known to within ±3% with a dynamic range of 10^6.

Another essential component of the experiment is the programmed high voltage power supply which provides the program of voltages applied to the deflection plates. The output voltage sweeps from about ±2.3 volts to ±2300 volts in about 0.15 seconds and then decays exponentially to ±3 volts in 0.35 seconds. The decay is divided into 20 equal time intervals during each of which electrons are counted. Thus, the flux of particles in 20 narrow energy bands is obtained, yielding an energy spectrum ranging from 10eV to 10KeV.



BLOCK DIAGRAM - ELECTRON SPECTROMETER FOR MODULAR AURORAL PROBE

FIGURE 3.1

4.0 AURORAL PHOTOMETER

G. G. O'Connor, P. J. Edwards, J. H. Carver

University of Adelaide

4.1 Introduction

The purpose of the auroral photometry experiment is to determine the intensity of selected x-ray, ultraviolet and visible emissions during auroral and "polar-cap" events with rocket-borne photometers. The auroral brightness data so obtained will be correlated with energetic particle and ionospheric measurements made from the same rocket vehicle and from ground-based and balloon-borne instruments. Particular emphasis will be placed upon observations of the "ultraviolet aurora" unobservable at ground level because of atmospheric absorption.

4.2 Organization

The photometric instrumentation for MAP has been designed and constructed by members of the Physics Department of the University of Adelaide, Australia under the direction of Prof. J. H. Carver. Mr. G. O'Connor is scientific officer for the photometer modules which will be assembled in Australia. All electronic design and fabrication with the exception of the digital accumulators and registers will be carried out at Adelaide. Ground Support Equipment (GSE) has been constructed for the Energetic Particles Experiment (EPE) (Sheldon and McCracken). This unit may be programmed to decode and display the photometer data from the main PCM telemetry channel. A second unit will be used in conjunction with the central GSE to provide continuous visual binary and analogue display of the outputs of selected detector channels.

4.3 Instrumentation

1. Detectors

Two basic types of detectors are to be flown initially:

(a) Gas filled ionization chambers sensitive to vacuum ultra-violet radiation.

(b) Photomultiplier - interference filter photometers sensitive to selected emissions in the visible spectrum.

It is planned to fly two visible and three ultraviolet photometers in the first rounds. The visible photometers will be sensitive to (a) the 3914°A band of ionized molecular nitrogen; (b) the atomic oxygen green line at 5770A.

The importance of observations of the N_2+ emission has been pointed out by Sandford (1963). This emission arises from an allowed transition from a state excited simultaneously with the ionization of N_2. The emission height profile for λ3914 therefore follows the ionization height profile and its intensity does not depend on the electron removal processes which must be taken into account in interpreting radio wave observations. The λ 3914 emissions will also provide useful data for the further study of the fast time variations (10^{-2} sec) in the electron flux recently suggested by satellite and balloon observations (Edwards, McCracken, et al. 1966).

(a) Ultraviolet Detectors

Ion chambers sensitive to radiation in the range 1050-1480 Å have been constructed and successfully flown in Australian rockets by the Adelaide group. A full description of these detectors has been given by J. H. Carver and P. Mitchell (1964). A spectral resolution of 100°A is readily attainable by suitable choice of filling gas (long wavelength cut off) and entrance window (short wavelength cut off). These chambers have been designed primarily for solar ultraviolet observations and normally operate without gas gain. Under these conditions the chamber sensitivity is circa 10^{-8} amp/erg-sec.

The ultraviolet luminosity of auroras is not yet well known and its determination will be one of the main objectives of this study. Measurements by H. M. Crosswhite (1962), W. B. Murcray (1964) and calculations by Green and Barth (1965) suggest the Lyman-Birge-Hopfield bands of molecular nitrogen to be the main contributors to auroral radiation in the range 1100-1800 $\AA$. In an IBC III aurora the mean intensity of these bands may be as high as 10 kR/ $\AA$ and, if so, a Li F - NO ion chamber, collimated to 30° (geometric factor, $G \sim 10^{-1}$ cm^2 - Sterad) would intercept 3×10^{10} photons/sec. The corresponding energy flux is about 4 ergs/cm^2 - sec- sterad and would result in a signal current of about 4×10^{-9} amps. (N.B. The solar Lyman - flux is close to 4 ergs/cm^2-sec).

In anticipation of a wide range of ultraviolet fluxes the ionization chamber signals are handled by logarithmic electrometer amplifiers.

The chambers selected for inclusion in the first two flights are as follows:

GROUP	WINDOW	GAS	RESPONSE ($\AA$)
	Calcium Fluoride	Nitric Oxide	1220 - 1350
A	Lithium Fluoride	Nitric Oxide	1050 - 1350
	Lithium Fluoride	Ethyl Bromide	1050 - 1200
	Barium Fluoride	Xylene	1350 - 1480
B	Calcium Fluoride	Nitric Oxide	1220 - 1350
	Lithium Fluoride	Nitric Oxide	1050 - 1350

Group A has a reduced spectral coverage, but is suitable for easy separation of Lyman α solar radiation which is expected to be strongly in evidence during portions of the daylight flight.

The detectors were calibrated in Adelaide and will be checked against a secondary standard using a portable hydrogen lamp at Churchill. No in-flight calibration is proposed.

Calibration of Ultraviolet Ion Chambers

The procedure used in determining the quantum efficiency is to first calibrate a Lyman-a chamber (lithium fluoride window with nitric oxide filling) at Lyman-a (1216A) and then use this together with a sodium salicylate-photomultiplier combination to obtain the calibration of chambers sensitive to other wavelengths. The determination of the quantum efficiency of the Lyman-a Chamber is based on a measured value of the photoionization efficiency of nitric oxide at Lyman-a. A standard ion chamber is used for the calibration.

Pre-launch Checking of Ion Chambers

Periodic semi-quantitative measurements of responses of the ion chambers are made with a portable hydrogen lamp. It has a lithium fluoride window and is filled with hydrogen. The mounting for the lamp enables the space between the lamp and ion chamber to be flushed with O_2-free nitrogen, which is continuously flowed through the mounting while measurements are being made. The lamp provides a many-line spectrum extending from 1050Å to 1850A with a maximum at approximately 1600Å. The absolute value of the intensity of the radiation from the lamp cannot be relied upon to remain constant and the checking is done by comparing a number of ion chambers with one another. This procedure allows the failure of any one of them to be detected.

(b) Visible Spectrum Instrumentation

Photo-multiplier-interference filter photometers have been designed by the Adelaide group for rocket-borne lunar and air glow photometry. The auroral photometers are similar in design. Each detector consists of a RCA type 4460 photomultiplier, a mechanical collimator and a multilayer interference filter. Within the 30^{o} total field of fiew, the aperture $A(\theta)$ is a triangular function of the look angle (θ), and the geometric factor $G = \int A(\theta)\, d\Omega$ is 0.19 cm^2-sterad. The angular response of all photometers, visible and ultraviolet, is identical.

Calibration of Visible Photometers

Initial calibration was carried out in Australia. This was done by using a calibrated secondary standard incandescent lamp of known colour temperature and intensity. Preflight-calibration will take place at Churchill using the photometric facilities available there. Inflight calibration will be accomplished with a flashing incandescent lamp controlled from the payload timing chain. This will provide a light pulse of known intensity at the cathodes of both photomultipliers at 16 second intervals during the flight.

2. Electronics

(a) Detector Circuits

The 45 volt bias for the ion chambers is provided by a dry-cell battery pack carried within the photometer package. All other power is drawn from the external supplies. The battery is connected permanently to the 45 volt supply rail unless a bridge link is removed for transit or storage. The cases of the ion chambers are biased positively, so that positive signal current flows from the chambers into the grid circuit of the amplifiers.

The photomultipliers are operated between two supply rails, one positive and one negative, such that the last dynode is at approximately zero volts, and the signal current is in the same sense as that from the ion chambers.

(b) Amplifiers

The signal currents from all five detectors are fed into similar logarithmic amplifiers. The ion chamber amplifiers are adjusted to have ten times the sensitivity of the photomultiplier amplifiers. The ranges to be covered are:

Ion Chambers	10^{-11} amp to 10^{-7} amp
Photomultipliers	10^{-10} amp to 10^{-6} amp

Each amplifier produces an output voltage proportional to the logarithm of the input current, with a swing from 0 to + 3 volts. The amplifier outputs are clamped at approximately + 0.2v and +2.8 v to ensure correct counting in the accumulators (see explanation later).

(c) Analogue to Digital Converters

The output from each amplifier drives a voltage controlled oscillator. The oscillator frequency varies linearly from 32 KHZ for an input of 0v to 64 KHZ, for an input of 3 volts. That is, the oscillator dynamic range is 2:1.

The output pulses from each oscillator are counted for 8 msec periods and stored in an 8 bit recycling accumulator. The minimum frequency of the oscillator (32 KHZ) is such as to completely fill the accumulator in 8 msec. When the amplifier output is greater than 0 volts, the accumulator is filled before the 8 ms counting period has expired. The accumulator resets to zero and continues to accumulate pulses to the end of the counting period. The number of counts in this second cycle of the accumulator then gives the deviation of the oscillator frequency, up to a maximum count of 256 for full scale deviation when the oscillator frequency is 64 KHZ. Each amplifier output range is limited to keep the oscillator rate between the 32 KHZ and 64 KHZ extreme frequencies. This ensures that the stored count is part of the second, rather than either the first or third, accumulator cycle. Occurrence of the latter two cases would produce misleading results, against which there is no check in the instrumentation.

(d) Data Readout

The counts in the five accumulators are transferred simultaneously to a 40 bit shift register and the accumulators are reset to commence another sampling period. All accumulators are read out simultaneously with those of the EPE to facilitate data correlation. At an appropriate point in the telemetry frame, the 40 stored bits are shifted serially onto the PCM telemetry line.

(e) In-flight Calibration

In addition to the flashing-light calibration of the photomultipliers, at 16 second intervals, a known calibration current is fed into the grid circuit of each amplifier. This gives a one-point measurement of shifts in the input/output transfer characteristic curve of each channel and will be used to supply corrections to data during processing.

(f) Solar Turn-off

Because the experiments are to be flown on occasions in sunlit conditions, precautions have been taken to prevent saturation of the photomultiplier channels. A silicon cell solar aspect sensor will be mounted on the timing and control unit. The output of its amplifier will be monitored, and when this exceeds a selected level, the calibration current will be substituted for the photomultiplier output currents in those two channels. If this were not done, the photomultipliers amplifiers would remain in saturation, even after the sun had passed out of the field of view.

5.0 THE FREQUENCY SHIFT CAPACITANCE PROBE

N. Eaker
W. J. Heikkila

5.1 Introduction

During polar cap absorption events and other auroral zone events, it is of interest to measure various parameters of the ionosphere. Radio propagation experiments between the rocket and a ground station measure the integral of refractive index along the transmission path. The interpretation of such a measurement is complicated by the presence of both time and space variations, such as are common in the auroral zone. Localized measurements by means of plasma probes on the rocket are, therefore, required; a radio frequency probe and a Langmuir probe are included in each MAP payload for this purpose.

The radio frequency probe makes use of the capacitive impedance property of an antenna. Both the theory and the instrumentation are simplified by the choice of a high operating frequency; i.e., a frequency well above the electron gyro-frequency (about 1.5 MHz) and the ionospheric plasma frequency (typically 3.5 MHz in the E region); the theory for this high frequency operation is outlined in the next section. The probe impedance may be inductive near the plasma frequency, but it is again capacitive at lower frequencies. In principle, it should be possible to deduce electron temperature from the low frequency capacitance, since it depends upon the ion sheath thickness, provided other independent information on the electron density is available (e.g. high frequency capacitance or Langmuir probe measurements). Such a set of measurements will be made to provide some redundancy in the measurement of both electron density and temperature.

In fact, two operating frequencies are chosen in this present instrument. The main reason for this is an attempt to evaluate electron collision frequency in the D region. One frequency has been chosen at the low value of 1 MHz for good D region sensitivity; in the D region collisional effects dominate over geomagnetic field effects in the Appleton Hartree equation. In the E region the 1 MHz operation provides the low frequency capacitance referred to above. The other frequency is chosen high enough (5 MHz) to provide a high frequency capacitance measurement under normal E region conditions.

The present RF probe thus operates as either a low frequency or high frequency capacitance probe. The name frequency shift capacitance probe (FSCP) is meant to indicate both the dependence on probe capacitance (whatever its physical explanation) and the instrumental technique described below (where the probe capacitance determines the resonant frequency of an oscillator).

5.2 Theory of the High Frequency Capacitance Probe

At frequencies well above all resonance and gyro-frequencies the ionospheric plasma may be considered a simple dielectric with relative dielectric constant slightly less than unity. The impedance of an isolated body, such as the truncated cone used as the sensing element of the Frequency shift Capacitance Probe is then capacitive with capacitance slightly below its free space value; this capacitance is a measure of the dielectric constant.

If the dielectric constant $\varepsilon = \varepsilon'\varepsilon_0$, with ε_0 being the value in free space and ε' the relative dielectric constant of the plasma, then we may set $\varepsilon' = 1 + \Delta$ with Δ a small quantity. It may be shown that the capacitance C of a sphere immersed in the plasma is given by the formula:

$$C = -4\pi\varepsilon_0 \left[\int_{\infty}^{r_p} \frac{dr}{\varepsilon' r^2} \right]^{-1}$$

If C_0 is the capacitance in free space and distance $x = r/r_p$ is measured in units of probe radius, the fractional change in capacitance, caused by the plasma is then given by the formula:

$$\frac{\Delta C}{C_0} = \frac{C - C_0}{C_0} \approx \int_1^{\infty} \frac{\Delta(x)}{x^2}\, dx$$

The variation of dielectric constant is part of the integrand since it is a function of position in the ion sheath. The formula shows that a net decrease in capacitance results from the introduction of the plasma, since Δ is then negative.

The dependence of the dielectric constant on electron collision frequency is given by the Appleton-Hartree magnetoionic formula (Ratcliffe, 1959) under the assumption that there is no dependence on electron energy. In fact the collision frequency has been shown to be a function of the energy, and a generalized magnetoionic theory (Budden, 1965) may be required for a proper interpretation of experimental results. In either case, both the electron concentration and the collision frequency can be evaluated by means of sufficiently accurate measurements of the probe capacitance at two frequencies. In the present instrument the two frequencies used are 1 and 5 MHz.

In the present instrument the probe is a truncated cone (an insulated section of the nose-cone) whose capacitance is used in an LC oscillator circuit, and the frequency of oscillation is measured,(hence the name frequency shift capacitance probe). This frequency is given in terms of the sensing capacitance C_p, stray capacitance Cc, inductance L, and relative dielectric constant ε' as

$$f = \frac{1}{2\pi\sqrt{L(C_c+\epsilon' C_p}}$$

In practice the oscillator frequency may drift slowly due to a variety of causes, thus introducing error into the probe data. This drift may be evaluated by applying periodically a large negative bias to the probe; with the electrons repelled far away from the probe,the frequency returns towards its free space value f_o (Heikkila et al, 1966). Making the approximation $\Delta \ll 1$ as appropriate to a high operating frequency, the relative frequency change may be written as

$$\frac{\Delta f}{f_o} \approx K\frac{\Delta}{2}$$

The constant $K = \frac{Cp}{Cp+C_c}$ may be regarded as an instrumental merit factor since it is equal to unity for an ideal probe with no stray capacitance. It may be evaluated by calibration, as described below.

The presence of an ion sheath about the probe depresses this response considerably, by about a factor of 2 in the E region (Heikkila et al, 1966, 1967). The required correction factor can be evaluated empirically as has been done for spherical geometry in the Multiple Ionospheric Probe program. Other experiments will be included in the MAP program for this purpose; e.g., the pulse receiver, and in the future a swept frequency admittance probe. However, this correction factor is already known approximately and in any case it does not affect relative measurements.

5.3 Instrumentation

A simplified block diagram of the Frequency Shift Capacitance Probe is shown in Figure 5.1.The instrument measures small changes in probe capacitance at two operating frequencies (1 MHz and 5 MHz) in order to provide a determination of both electron concentration and collision frequency in the D and E regions of the ionosphere. The oscillator frequency is allowed to accumulate in a ripple counter for a given amount of time; the data is then transferred into a storage register and shifted into the telemetry channel at the proper time. Actually, two different accumulation times and two different accumulators are used as will be discussed in the following paragraphs.

5.3.1 Oscillator Circuit

Figure1.2shows the rocket nose-cone which has insulating sections for use as Langmuir (nose-cone tip) and FSCP (nose-cone center section probes. A description of the construction of the nose-cone is contained elsewhere in this report. The center section of the nose-cone forms the capacitance, approximately 12 pf, for the series tuned LC circuit of the Clapp oscillator shown in figure 5.1.It is connected to the oscillator circuit through either a high or low frequency inductor by the use of a reed relay. The low frequency inductor allows the oscillator to operate at approximately 1 MHz, and using the high frequency inductor the oscillator operates at approximately 5 MHz.

The output of the oscillator is fed into a video amplifier and a d-c multiplier where an AGC voltage is generated to be fed back to the control grid of the nuvistor. This AGC action keeps the r-f voltage on the probe at approximately 1v p-p. The Clapp oscillator offers good frequency stability against supply voltage variations. The capacitors C_1 and C_2 provide good isolation against circuit stray capacitance. The series resonant circuit of the inductor and probe offers a low impedance at the control grid of the oscillator which allows connections to be made to the resonant circuit without seriously affecting the frequency of oscillation. The oscillator output is fed through a video amplifier to the counter circuits where it is accumulated and stored.

The probe will operate at each frequency in turn for 512 ms, under the control of gate G9. Gate G11 controls a relay which switches a temperature stable calibrating capacitor into the oscillator circuit for the purpose of checking the operation of the complete FSCP circuit. This capacitor is switched into the circuit for 512 ms each 32 seconds. The oscillator will be cut off by G15 on alternate 16 ms periods. Once each 512 ms a -100v bias is placed on the probe for 64 ms by gate G10, as a further method of calibration. For 448 ms of each 512 ms period the probe is biased at plus 1.4v.

5.3.2 Frequency Counter

The counter is composed of two complete independent sections of accumulation, transfer and storage. Section A with accumulation input controlled by gate G1 is used to count the short (29 ms) samples. Section B with accumulation input controlled by gate G12, is used to count the long (440 ms) samples. Section A has a 4 bit tag word which is placed at the beginning of each 29 ms sample. This tag word is used to identify each sample with a binary number 1 through 14 and 16. This word is used in data handling and checkout of the FSCP system. In place of word 15 of accumulator A, accumulator B (section "B") shifts its 440 ms word into the data stream.

A typical sequence of operation for a complete 512 ms period is as follows: The oscillator output is fed through buffer amplifiers to the trigger circuit of both sections. Gate G1 allows accumulator "A" to accumulate for 29 ms and then stops accumulations. Accumulator "B" starts to accumulate 8 ms after "A" in order to allow any transients which might be generated when switching from the low to high frequency and back again at the end of each 512 ms period. The first 19 ms sample of accumulator "A" will also be affected by the transient; however, with 14 additional samples during the 512 ms period, this entire sample can be discarded if necessary. At 29.5 ms the pulse count will be transferred in parallel by gate G4 to the storage register. A transfer time of 0.5 ms is allowed. At 38 ms after the start of the frame the first word will be commanded to shift out data to the PCM encoder of the payload. The shift out pulse is generated by using the word gate supplied by the PCM encoder. The above process is repeated each 32 ms until 14 words in sequence, with each word having its own tag word, is shifted to the PCM encoder. The 15th word is not accumulated or stored, and in its place the data word from accumulator "B" is shifted out with its associated tag word. Accumulator "B" accumulates for 440 ms. Four PCM words of 8 bits are used to handle the 32 bits of stored data in each counter section. The 16th word, associated with the -100V measurement is accumulated following the 15th word. No data is accumulated during the time shown for word 15.

The counter is constructed using Texas Instruments series 53 integrated circuits. A discrete component flip-flop is used as the first (least significant) bit of accumulator chain. This flip-flop is used to bring the input frequency to a range easily handled by the series 53 circuits. The trigger circuits are also constructed of discrete components.

5.3.3 Logic

Logic circuits are required to perform the various gating functions required in the oscillator and counter sections. The logic section is composed of a ripple counter and NAND NOR logic all constructed from Texas Instruments series 53 integrated circuits. The ripple counter receives its 1 KHz input signal from the payload timing and encoder section.

The following is a list of all the signals now being supplied by the timing and encoder section.

1. 16 KHz bit rate. Used to shift out data from storage registers.
2. Time base H - 1 KHz. Used as input to logic ripple counter.
3. Word gate for words 14, 15, 16 and 17. Words 54, 55, 56, and 57 may be used on later flights for a higher sampling rate. FSCP instrument identifies this gate as G2.
4. Time base Q - 256 ms on; 256 ms off. Used to synchronize the ripple counter with the timing and encoder section of the payload.
5. Time base V - 8.192 ms on; 8.192 ms off. Used to calibrate the oscillator.
6. Time Base R - Aids generation of G9 and G14
7. Time Base S - Aids generation of G10, G11, and G15.
8. Time Base T - Aids generation of G10, G11, and G15.
9. Time Base U - Aids generation of G10, G11, and G15.
10. Time Base W - Aids generation of G15

The following is a list of the gates generated within the logic section of the FSCP instrument.

Gate Number	
1	Gates the FSCP oscillator into accumulator "A"
2	Clears accumulator "A"
3	Clears Accumulator "B" and tag word for accumulator "A"
4	Transfers accumulator "A" into storage register
5	Input to accumulator "A" tag word
6	Gates shift pulses into storage register "A"
7	Transfers accumulator "B"
8	Gates shift pulses into register "B"
9	Switches oscillator frequency
10	Switches -100v to probe
11	Calibrates oscillator and counter circuits
12	Gates the oscillator into accumulator "B"
13	Holds the Langmuir probe at plus 2.8v for 16 ms (Note: The Langmuir probe receives power and gating pulses from the FSCP instrument).
14	Langmuir calibration
15	FSCP oscillator ON-OFF

5.3.4 Data Handling and Checkout

In order to aid real time and post flight data processing as well as instrument checkout, an automatic data processor is required. The processor operates in the following manner. The data word will be separated from the PCM data by the main payload ground support equipment, and the data word will be placed in storage in the PCM decoder to be updated each 32 ms. The FSCP checkout equipment will be connected by cable to the PCM encoder and will transfer the FSCP data word from the PCM encoder upon command of time base M, or once each 32 ms, or when a preselected word (1 through 16) has been chosen. The checkout equipment will feed a D to A converter or a printer. Octal notation will be used for printer output.

In order to aid in automatic go, no-go checkout of the FSCP instrument the output of the storage register will feed a 23 bit comparator which may be set to produce a go condition as long as the data falls within a preset range.

The following output functions may be compared or observed on the A to D converter and/or printer. In most cases both readout devices could be used. The functions will be selected by a switch located on the front panel of the checkout equipment.

1. Low frequency, selected short word, and -100v word
2. High frequency, selected short word, and -100v word
3. Low frequency, long word, and -100v word
4. High frequency, long word, and -100v word
5. Low and High frequency, selected short word, and -100 v word
6. Low and High Frequency, long word, and -100v word
7. Low frequency, all short and long words (analog readout only)
8. High frequency, all short and long words (analog readout only)
9. Calibrate only

References:

Ratcliffe, J. A.: The Magneto-Ionic Theory and its Applications to the Ionosphere, 1959

Budden, K. G.: "Effect of Electron Collisions on the Formulas of Magneto-ionic Theory", Radio Science Journal of Research NBS/USNC-URSI, Vol. 69D, No. 2, Feb., 1965

Heikkila, W. J. and Fejer, J. A.: Comparison of Ionospheric Probe Techniques, DASS-66-5, Rev. Prepared for COSPAR Seventh International Space Symposium, Vienna, Austria

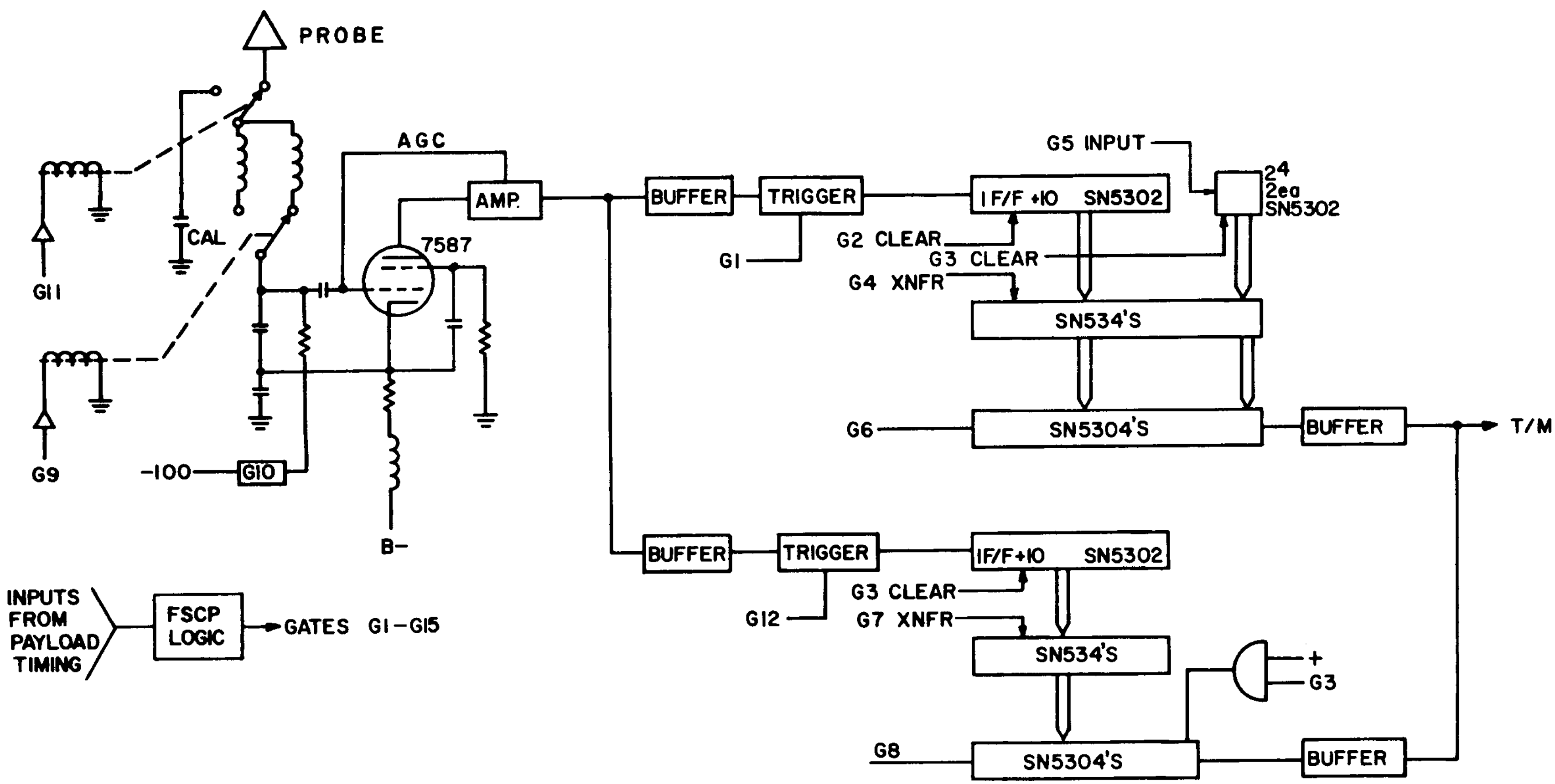


FIG. 5.1 BLOCK DIAGRAM – FREQUENCY SHIFT CAPACITANCE PROBE

6.0 LANGMUIR PROBE

N. Eaker
W.J. Heikkila

6.1 Introduction

A Langmuir probe is used to provide measurements of electron temperature and to give a comparison of electron densities with the Frequency Shift Capacitance Probe.

6.2 Instrumentation

Figure 6.1 is a block diagram of the Langmuir probe instrumentation. Also shown in Figure 6.1 is the voltage program which is imposed upon the probe.

The instrument consists of the insulated ogive tip of the nose cone as the sensing probe, a floating voltage programmer, a logarithmic electrometer, an absolute value amplifier, a fixed gain amplifier, and a low pass output filter.

The voltage programmer places on the tip a constant 2.8v level for 16 ms and then a 48 ms sweep voltage from plus 2.8 to -2.8v. This program takes place eight times per 512 ms period. Once each 1.024 sec. the voltage program is switched to a calibrating resistor for the full 64 ms.

The logarithmic amplifier is composed of an FET input operational amplifier which uses transistors as the logarithmic feedback elements. The amplifier produces a logarithmic output for positive and negative currents over the range of 10^{-9} to 10^{-4} amps.

The logarithmic amplifier is followed by a network using two operational amplifiers which produce a positive output for both positive and negative inputs. The output is fed into a non-inverting amplifier for final gain and offset adjustments. A low pass filter is provided to limit the frequency range being fed to telemetry channel 14.

New instrumentation is presently being designed to make use of both a-c (1 KHz) and d-c voltages on the probe, both currents to be measured simultaneously. This combination is a form of on board data reduction, and facilitates electron temperature measurement.

A guard ring will also be used between the ogive tip and the nosecone for the purpose of minimizing leakage current. Finally, linear electrometers with programmed range changing and a slower sweep will be used because of difficulties encountered with data analysis using the first instrument.

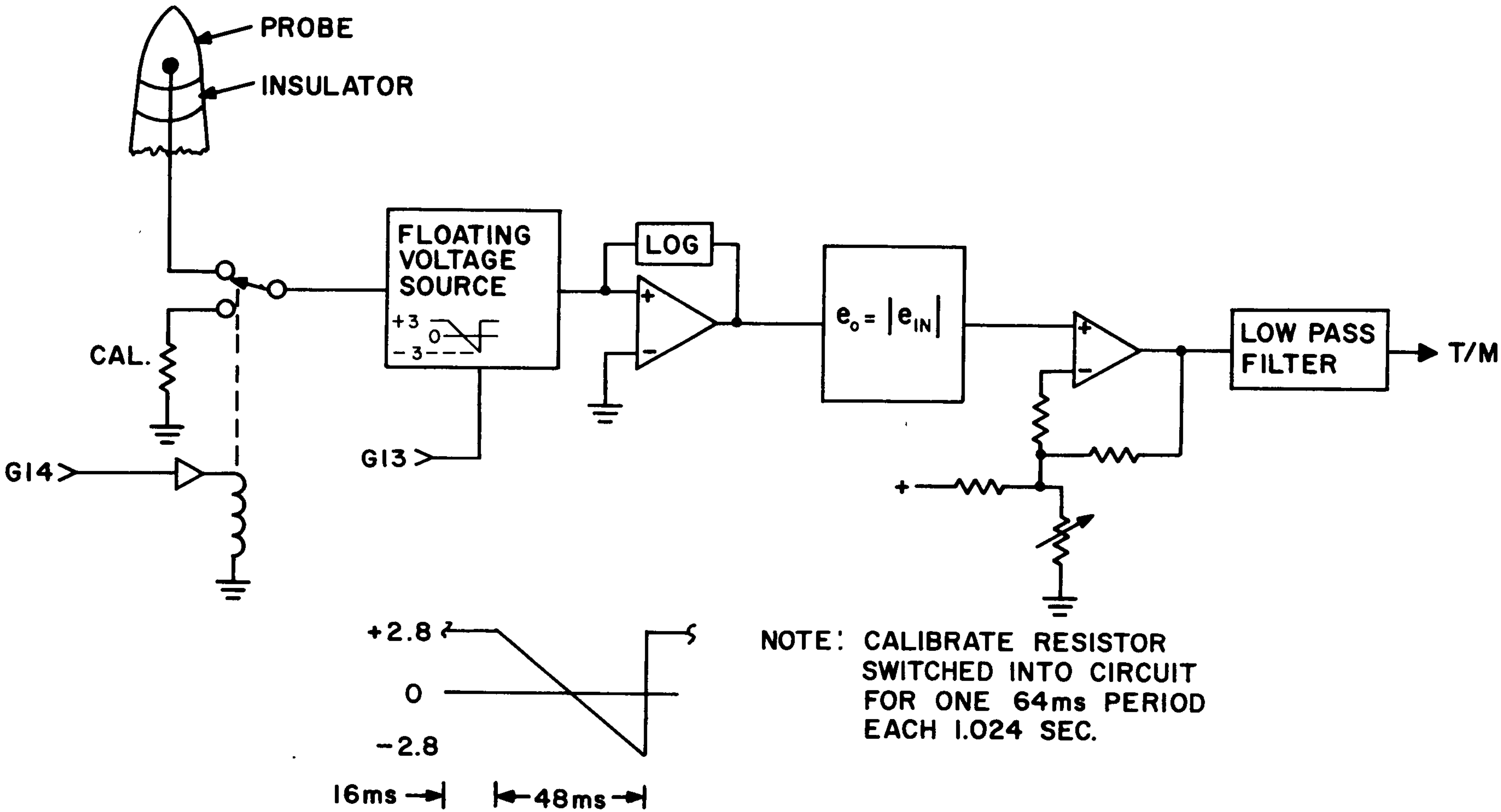


FIG. 6.1 - BLOCK DIAGRAM - LANGMUIR PROBE

7.0 PULSE RECEIVER PROPAGATION EXPERIMENT

K. Tipple
W. J. Heikkila

7.1 Introduction

A radio propagation experiment with one end of the propagation path at the rocket can theoretically provide an accurate method of measuring ionospheric properties when ionospheric conditions are stable. It may also serve to check and calibrate probe experiments.

The propagation experiments used in the initial MAP flight will consist of a rocket-borne antenna and receiver tuned to 2.66 MHz since a suitable transmitter is operated at Churchill on this frequency by Dr. J. S. Belrose of the Defence Research Telecommunications Establishment. The transmitter is pulsed with the antenna polarization being alternately left and right handed circular. Signal strength measurements can thus yield the differential absorption which depends strongly on electron collision frequency, as well as concentration.

The transmitted signal consists of 50 microsecond pulses of 2.66 MHz carrier wave. These pulses will alternate in polarization and will be transmitted alternately at 40 and 60 millisecond intervals. The receiver system includes a suitable antenna, 2.66 MHz receiver and signal processing circuits to provide a relatively narrow bandwidth output signal proportional to received signal strength. The output will be telemetered on channel 17 (52.5 KHz).

7.2 Instrumentation

7.2.1 The Antenna

Although loop antennas have been used in the past by other researchers with varying degrees of success, the need for a linearly polarized antenna which will respond equally well to either right or left handed circularly polarized signals introduces a space requirement for a relatively large, uncluttered area in the nose of the payload if a loop is used. To avoid this space requirement, it was decided to use a very short symmetrical dipole antenna for this particular effort.

A model of the payload with Apache rocket motor was constructed and used with a receiver front end circuit in a series of antenna range tests to obtain a preliminary indication of the type of performance to be expected from such a system. These tests indicated that with the DRTE estimated field strength of 8×10^{-10} watts/cm^2, a receiver input signal of approximately 6 millivolts might be expected with an antenna consisting of two 8" poles.

7.2.2 Discussion of Receiver Circuits

Because of the very short length of the antenna dipole, its impedance is essentially capacitive and of the order of two or three picofarads. Using the antenna capacitance as part of a tuned input circuit was considered undesirable because of the variable nature of the antenna impedance in a plasma. Therefore, it was decided to use an untuned input circuit with as high an input impedance to the first stage as possible. (Fig.7.1). The problem was further complicated by the need for a balanced input which might normally suggest an input transformer. However, it was considered unlikely that a transformer could be constructed which would have sufficiently small stray capacitances as to permit the necessary high input impedance. After some investigation, a circuit utilizing a configuration of field effect transistors operating as source followers driving a pair of conventional transistors operating in push-pull to provide a single ended output was decided upon, since this configuration appeared to give the best combination of low noise, high input impedance and temperature stability. A resistor in series with each input in conjunction with the stage input capacitance produces an RC filter which provides a measure of rejection of frequencies above the receiver frequency. It might be noted at this point that a slightly better performance compromise might have been achieved with miniature tubes such as Nuvistors, but the obvious advantages of keeping the receiver entirely solid state led to the final choice described above.

The tuned radio frequency amplifier consists of three common emitter stages with slug tuned, shielded coils and temperature compensating capacitors. An umbipassed resistor is included in the emitter circuit of each stage. These resistors may be changed to alter the overall gain of the receiver, if such a change is considered desirable at a later date. A gate signal which is supplied every other 512 millisecond period from the central payload programmer activates diode switches which change the collector loads of each of the three stages so as to obtain an overall gain change by a factor of 10. With the two ranges, the receiver has a usable calibrated dynamic range of approximately 57 db. A clipper circuit which only operates in the top 30% of the total telemetry capability adds approximately 14 db of non-calibrated dynamic range to the overall response.

The pulse of carrier wave is detected and its peak level is stored in the .01 picofarad storage capacitor for approximately 8 milliseconds. The dc amplifier following the capacitor has a very high input impedance so as not to load the capacitor. The dc return resistor for the input circuit is 100 megohms, thereby giving the storage circuit a one second time constant which produces negligible decay of the pulse level during the 8 millisecond period.

The same pulse of carrier wave is also detected by the gate generator detector and used to activate a Schmidt trigger which in turn initiates the start of an 8 millisecond cycle in a monostable multivibrator. At the end of the multivibrator cycle, a gate is activated which discharges the storage capacitor. The circuit then waits for the next pulse.

A filter is provided to reduce the bandwidth of the receiver output pulse to correspond to the limitations of the telemetry system. The resulting rounded edges of the output pulse are of no consequence since the amplitude of the pulse contains the desired information.

Two monitor outputs are fed to the telemetry commutator for periodic sampling. One output provides a monitor of the state of the gain-controlled circuit; the other output is used as a check on the level of the plus and minus 15 volt power supplied to the receiver.

As an aid to checkout, a 2.66 MHz crystal oscillator is contained in a shield can on the input circuit board. This oscillator will provide a continuous input signal to check operation of the signal channel of the receiver during ground checkout prior to launch. The oscillator receives its power through the umbilical cable and is activated by a switch on the checkout console. Since the only source of power for the oscillator is through the umbilical cable, there is no possibility of the oscillator being in operation during flight.

7.3 Mechanical Construction

The dipole antenna is mounted directly on the receiver module base plate. Input circuitry is constructed on a circuit board which is mounted on the base plate of the receiver between the antenna mounts. All other receiver circuitry is constructed on two plug-in boards which may be removed for servicing. Because of the calibrated nature of the circuits involved, the circuit boards of one receiver are not interchangeable with those of another receiver without recalibration of the whole unit afterwards.

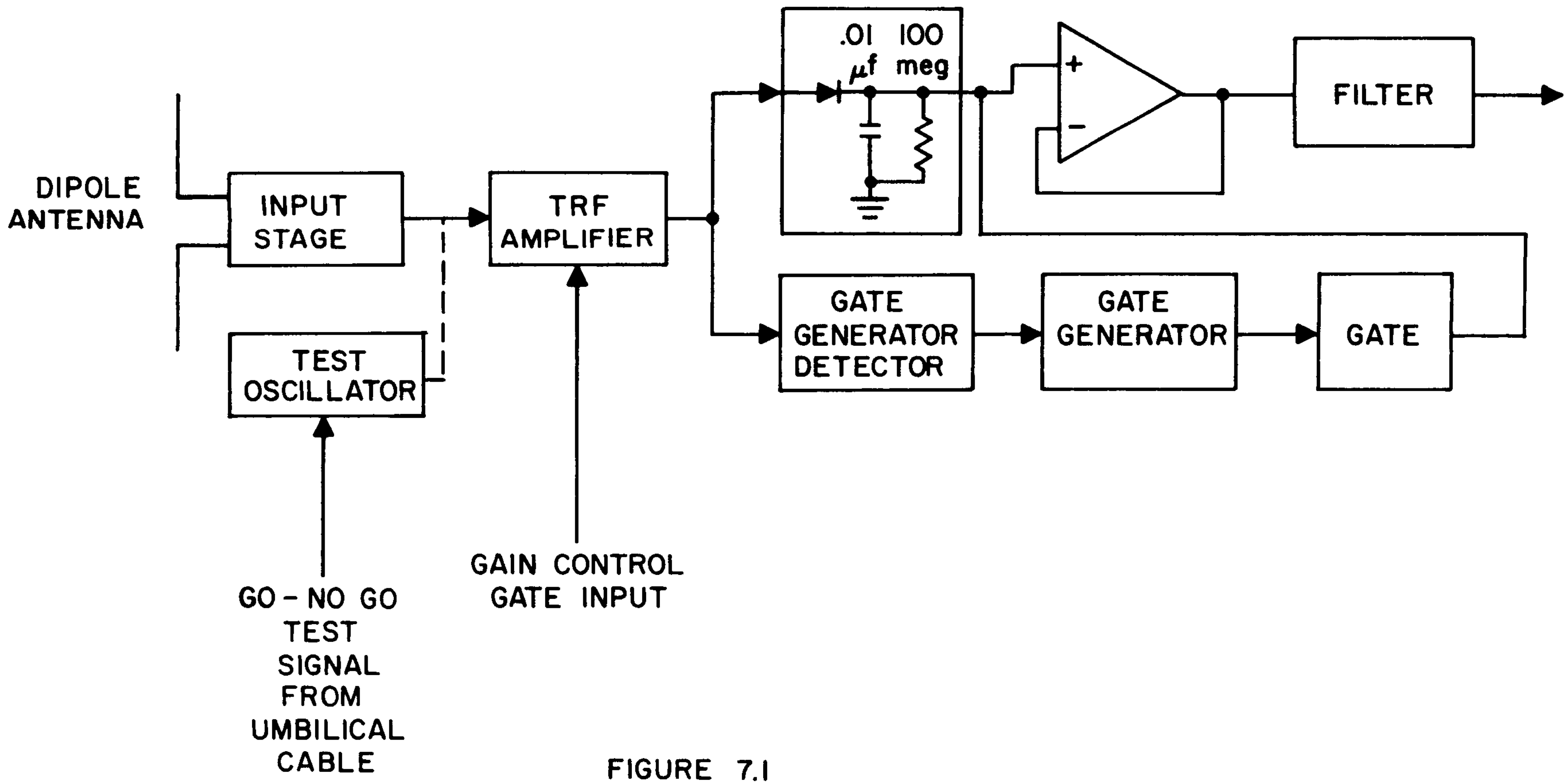


FIGURE 7.1

PULSE RECEIVER SYSTEM BLOCK DIAGRAM

8. AUXILIARY PAYLOAD SYSTEMS

R. H. Morgan
W. W. Wright

8.0 Introduction

The auxiliary payload systems provide all the experiment support functions not provided within the experiments. These are logically divided into the following major assemblies.

a) Mechanical structure

b) Encoder

c) Timing and Control Unit

d) PAM Commutator

e) Telemetry

f) Power Supply

g) Fly-away umbilical connector

h) Aspect instrumentation

Each of the major assemblies will be discussed in the following sections with particular emphasis given to the areas of interface with the scientific experiments.

The system design has been proved structually sound by testing to shock and vibration specifications. Further confidence in system design has resulted from an analysis of the MAP rocket flight No. NASA 14.268UI (May 8, 1967). Further changes in the NIKE Payload design will be limited to refinements and minor modifications to accommodate modular length changes in the various experiments making up a payload.

8.1 Mechanical Structure

The rocket assembly used on the first MAP flight had a length of 94.00 inches as shown by Figure 1.1. The structure has been designed to accept modular experiment packages.

The modular concept implies that all experimental packages must satisfy certain form factors. The payload frame has been designed to accept packages whose heights vary in one inch increments. Connector provisions are available to accommodate six experiment packages. Each of the six experiments will be connected to the rocket support system by means of a cable to the encoder terminated in a subminiature D series 25 pin connector.

The entire structure is designed to be reusable after parachute recovery and possible water immersion.

8.1.1 Housing and Blow-Off Door

The cylindrical payload housing for MAP is the standard Nike-Apache payload housing. The attachment of the nosecone and the parachute pack are by radial 1/4-20 stainless steel screws. Antenna and umbilical connector openings are cut as required in the housing.

In the first MAP payload, three experiments require viewports for their instruments. Holes with diameters of approximately two inches are cut in the housing for this purpose with a single ejectible door as a cover. This door is external to the housing. Ejection will be accomplished using a compressed spring released by a redundant pyrotechnique device. The pyrotechnics will be controlled by timing circuitry located in the timing and control unit. The door will be located as shown in the mechanical layout.

8.1.2 Nosecone

A 20° included angle aluminum nosecone is attached to the forward end of the payload. This nosecone is comprised of two probe assemblies; (1) a Langmuir Probe and (2) a capacitance probe. The probes are insulated from each other and from the payload by Boron Nitride insulating sections.

The Langmuir Probe is at the apex of the nosecone. It is a 1.5, 3:1 Ogive shape machined out of aluminum. The Langmuir Probe and its insulator section are assembled together and these are attached to the capacitance probe through an insulated mounting. Thermal expansion differences are accounted for in the design. The signal from the Langmuir Probe is carried via a rigid coax cable to the payload where an appropriate termination is made. This conductor is supported throughout its length.

The capacitance probe section is conical in shape and approximately 9.25 inches long. The probe is machined out of aluminum and is insulated from the payload by a 2.5 inch long conical boron nitride insulator. Thermal expansion differences of the two materials are taken up by a segmented ring mounting. The signal from this probe is conducted to the payload through a rigid conductor. The spacing between this conductor, the Langmuir Probe conductor, and the walls of the nosecone are rigidly maintained by appropriate mounting brackets. A suitable termination for the probe conductor is made at the payload.

8.1.3 Rack Structure

There are two structures involved in this payload. With the modularized experiment packaging concept each experiment must be mechanically independent. This necessitates a substructure or experimental package structure which need not be the same in the different experiments. This substructure then mounts to the main payload rack structure which is common to all experiments.

The main payload structure is the standard Nike-Apache structure with the exception of the wiring channel. A special wiring channel of SCAS design is used to allow a larger amount of channel wiring and to provide easier access into the wiring channel. All experiment packages attach to the main structure with 6-32 stainless steel screws. The structure is predrilled at one inch intervals to accept any MAP modular size package.

The substructure is part of the experimenter's package. The so-called standard substructure is shown in Figure 1.1. This incorporates two Z channels, one small U-channel and a wiring U-channel. The substructure wiring channel contains intra-experiment wiring and provides space for mounting printed circuit board connectors. The frame members are positioned by a deck plate at the top and bottom. The struts may be fitted with card guides for packages with electronics mounted on plug-in boards. Other package designs are permissible so long as they mount within the main rack structure in the same way.

8.1.4 Parachute Package

The MAP rocket payload will utilize a parachute recovery system. The payload recovery system is being furnished by GSFC and is manufactured by Space General Corporation of El Monte, California. The system is intended for use with the Apache motor. The recovery system consists of a parachute assembly a severence section assembly, a recovery sequence assembly, and a recovery beacon.

The length of the system is 17.25 inches, diameter 6.75 inches, and the weight is approximately 26 pounds. The recovery package has internal threads on the aft end which allows it to be screwed onto the Apache head drop. The forward end is attached to the payload by 16 screws equally spaced around the periphery.

The parachute assembly uses a two-stage parachute. Initial stabilization and deceleration is provided by a 2.7 foot nominal diameter flat circular type chute attached to an eight foot bridle. The main chute canopy is a solid skirt type with a nominal diameter of 14.9 feet.

The severance system is designed to house two separate flexible linear shaped charges, which are used for first and second severance.

The recovery sequencer assembly contains the components which supply the necessary logic and power to perform the electrical events for payload recovery. The Apache motor is separated from the payload on the downleg of the trajectory between 300K feet and 200K feet. The parachute is deployed at about 17K feet.

The recovery system includes a recovery beacon operating at 243.0 MHz. The beacon will have a transmitter power of 300m watts and a life of approximately eight hours. Quadra-loop antennas are used.

Changes contemplated for future parachute packs include (1) a larger first stage chute, (2) a change to 240.2MHz for all future Sarah Beacons, and (3) the inclusion of a radar beacon to aid in the delayed recovery of night-time flights.

8.1.5 Shock and Vibration

The entire rocket assembly including payloads will be mechanically tested to the following vibration specification:

Thrust Axis-Sinusoidal:	10-120 Hz	3g
	120-150 Hz	25g
	150-300 Hz	5g
	300-400 Hz	10g
	400-2K Hz	5g
Lateral Axis Sinusoidal:	7-10 Hz	.4 inch double amp.
	10-40 Hz	2g
	40-120Hz	.02 inch double amp.
	120-2 Hz	5g

Rate: 4.0 Octaves/min.

Random: Three Axis 20-2000 H — $.2g^2$H equivalent to 20g R.M.S., 10 sec. each axis.

8.2 Power System

The power system supplies all "in-flight" power for the MAP rocket. The power is stored by a package of twenty HR-3 Silvercels. The secondary power is developed by a series of inverters and regulators operating on the primary power. A simplified block schematic of the power system is given in Figure 8.1.

8.2.1 Primary Battery Package

Twenty HR-3 Yardney Silvercels are connected in series to provide a nominal 30 volt-3 ampere hour power source. These batteries are packaged in an airtight, watertight container which has a pressure relief valve and electrolyte absorbing material to prevent explosive pressures from developing should the batteries break upon landing. The container is designed so that the batteries may easily be removed and replaced between flights. The sealed compartment contains a cut-off relay which removes voltage from all wires external to the compartment. This prevents erosion of wires, connectors and circuit board conductors due to electrolytic action if the rocket should land in water.

8.2.2 Secondary Power Supply

The 30 volt battery supply is converted into five other potentials for the experimenters by the secondary power supply. Each secondary output voltage is regulated to within one percent of its nominal voltage. Each experiment is powered through separate circuits and each circuit contains a load limiting device. The load limiting devices are fuses on the +28v, +3.5v, and 100v P-P 32KC outputs. The +15v, -15v, and -6.3v are protected by "series" transistors whose base currents are controlled so as to limit their collector currents. If the experiment load current exceeds a preset amount, the voltage across the series transistor increases, thus dropping the voltage to the load. The series transistor normally operates in its saturated condition and therefore has only a few tenths of a volt drop across it.

Because of variability of the power loading that may result from experiments each supply is designed to handle load currents several times greater than normally expected. Below is a listing of the total current capabilities of each supply. The actual requirements on the first two flights are shown in table 8.1; there is adequate reserve in each supply.

Supply	Total Load Current	Power
+28V battery	3 AMPS	90 watts
+15V DC	2 AMPS	30 watts
+3.5V DC	10AMPS	35 watts
-6.3V DC	2 AMPS	12.6watts
-15V DC	1 AMP	15 watts
100VP-P 32KC	0.1 AMP	10 watts

8.2.3 Power Supply

The block diagram in figure 8.1 shows the basic form of the power supply. The fuses and load limiters are shown along the upper and right edges of the diagram. The outputs from each limiter-block go to the six experiment positions with the seventh output for the support equipment. Fuses instead of transistor load limiters are used on the 28v and the 3.5v supplies because of the high currents involved. Fuses are also selected for the 100V P-P 32KC supply because of the voltages and polarity problems of an AC supply. The transistor load limiters work nicely on the other three supplies.

All supplies use switching regulators as the regulating element. In addition, the +3.5V, -15V, -6.3V, and 100VAC P-P 32KC supplies use converters to obtain characteristics beyond the range of switching regulators. The reference source provides the reference and operating voltages needed by the switching regulators as well as a sawtooth waveform. It also provides 32KC and 16KC drive signals for the inverters. These signals are normally synchronized to the crystal time base in the encoder section, but will free-run at a slightly lower frequency should the synchronizing signal be lost.

8.2.4 Battery Control Relays

In addition to the batteries, battery control relay is housed within the Battery Box. This relay determines the operating mode of the power system as follows:

a) External Power--Batteries disconnected, power source through umbilical cable.

b) Internal Power--Batteries supplying all rocket power

8.2.5 Physical Description

The total height of the power system is 11 1/2 inches. Its weight is approximately fifteen pounds. It is composed of three parts (battery box, regulator box, and inverter-converter box). The inverter-converter section contains signals having high frequency components. All lines to and from this section have RF filters to prevent leakage of RF signals into the "clean" areas.

The regulator box contains the load limiters, connectors, monitor module, and reference source The fuses are mounted on "plug-in" boards for easy replacement. Control resistors for the transistor load limiters are also mounted on "plug-in" boards. The monitor module provides signals to the PAM Commutator for each of the output voltages.

8.3 Encoder

The MAP encoder generates the basic timing and gating functions required to provide synchronization and PCM transmission of the digital data generated by each of the experiments. The encoder package also determines the routing of all payload services to each experiment.

The encoder formats the digital data into a serial bit stream. Each group of eight bits represents a data word. Each PCM frame consists of 64 eight bit words. Experiments are assigned PCM words prior to each flight. Fifty-eight of the sixty-four words in each PCM frame are available for assignment to the various experiments. Six words of each frame are reserved for housekeeping functions.

The encoder exchanges signals with each experiment payload via a 25 pin subminiature D series connector. The encoder serves as the switchboard or controller for all functions going to and from each experiment package.

Figure 8.2 is a simplified block diagram of the PCM encoder as designed for the MAP project. The following paragraphs will provide a detailed description of the operation of the encoder on a section by section basis.

8.3.1 Time Base Generator

The time base generator is the heart of the logic encoder. The time base is derived from a 256KHz crystal controlled oscillator. The crystal oscillator provides a sinusoidal output which is shaped to a square wave by an SN535 inverter. A free running multivibrator is provided as a standby for the crystal clock. The 256KHz square wave is used to drive a 28 position ripple counter. Including the 256KHz clock, the time base generator provides 29 time base signals for use by the payload. The 29 basic timing signals are brought into a switchboard from which they are patched to the experiment connector in accordance with the requirements established by the cognizant experimenter.

Each of the time base signals has been assigned a designator dependent upon the stage of the ripple counter in which it originates. Table 8.2 is a tabulation of the pertinent characteristics of each time base signal as it appears at the cable connector of the encoder. Figure 8.3 and figure 8.4 provide typical waveform timing and electrical characteristics.

The encoder is designed to make maximum use of integrated circuits in order to achieve good reliability and minimum size. The Series 53 modified-DTL digital integrated circuits have been selected to implement the logic encoder. These circuits have multiple functions per package and utilize fully saturated NAND/NOR logic flexibility. The Series 53 circuits are specified to operate over the full military temperature range of -55°C to +125°C. The encoder will operate from 0°C to +50°C. Figure 8.5 depicts the basic configuration of the binary ripple counter used to derive the time base signals.

Time base signals A through M provide the logic signals required to generate the PCM frame and word timing. Time base signals N through CC constitute a 16 position (2 word) frame counter. The frame count is used as frame identification and is transmitted during each frame. Time base signals from the frame may be used by the experimenter to subcommutate their assigned word positions. The frame count may be reset to zero by a control switch on the check-out console.

8.3.2 Word Gate Generator

Word gate logic signals are provided by the encoder to enable the experiment package to "read out" its PCM digital data word at the proper time. The PCM frame is divided into 64 words. The basic PCM frame is defined in time by the frame rate time base signal (time base designator M). M has a period of 32m seconds. Each word of the frame is identified by a word gate which is set to a logic "1" for the duration of the word time. Time zero (t_0) or the beginning of frame is measured from logic "1" to logic "0" transition of time base M. Word gates are designated in accordance with the octal notation for the word position. Table 8.3 is a list of frame words and their assignment for flights 1 and 2. A similar list will be prepared for subsequent flights.

One logic line is furnished to each experiment for the purpose of gating the PCM data word. If the experiment has been assigned WG14 through WG17 (octal notation) the word gate logic line to that experiment will go to a logic "1" for 2m seconds beginning at 6.0m seconds past the start of frame (t_0) and ending at 8.0m seconds past the t_0. The word gates for each of the 64 possible words are derived from time base signals H, I, J, K, L, and M. H, I, and J are used to define the eight columns of the 8X8 matrix with K, L, and M being used to define the rows. Each word gate is obtained by effectively "ANDing" a particular row and column. Where more than one word gate is required for a single experiment, the required word gates are effectively "ORed" into a composite word gate. Each experiment word gate will be logically derived on a separate .5 by 2 inch module. Word gate assignments may be changed by changing the word gate module. A new word gate module can be provided in approximately one week.

8.3.3 Programmer

The programmer has been designed to provide maximum flexibility in the support of present and future experiments. Flexibility is obtained through the use of plug-in program boards. The program boards are wired prior to flight time in accordance with the logic requirements of the experiments to be flown. The program board will allow proper distribution of time base signals, word gates, TM channels, umbilical cable connections and PAM Commutator channels.

All connections between the payload support functions and the individual experiments will be through the encoder. This arrangement will facilitate the modular concept of experimental rocketry as outlined for MAP. The encoder is equipped with six 25 pin subminiature "D" series connectors for mating with similar connectors attached via cable to each experiment. Five modular experiment packages were flown on the first MAP rocket. Subsequent flights will be capable of connecting up to six modular packages into the encoder. Each experimenter must furnish the encoder programmer with a list of MAP Service requirements. A representative list is shown in Table 8.4. The encoder will present the requested signals on pins 10 through 24 of the 25 pin connector. Pins 1 through 9 and 25 have standard assignments as shown below:

Standard Pin Assignments

Pin 1- +15VDC	Pin 6- 100VAC p-p 32KHz
Pin 2- -15VDC	Pin 7- Ground (CKT/PWR)
Pin 3- -6.3VDC	Pin 8- PCM to TM
Pin 4- +3.5VDC	Pin 9- "D" Timebase (bit clock) 16KHz
Pin 5- +28VDC	Pin 25 Chassis connection

8.3.4 Sync Word Generator

The Sync Word will consist of a 16 bit sequence derived from the time base signals. The word is generated using NAND/NOR and Inverter logic functions. The sync word binary sequence is a special pattern of bits which is recognized by the ground station receiver as identifying a specific time in the PCM digital data transmission frame. The sync word is selected to give a high probability of correct synchronization at the receiver for the conditions of noise and distortion to be encountered in the communications links.

The MAP sync word has been selected to yield a maximum auto-correlation function. The basic bit sequence is "0000011100110101". The complement is transmitted on alternate frames. The sync word is transmitted as words 76 and 77 (octal notation).

8.3.5 Parity Checking

The PCM digital data is parity checked on a row and column basis. Each row of 8 words is checked for parity as well as each column of 8 words. The first 8 bit word of each frame represents the horizontal parity for the previous frame. The second 8 bits represent the vertical parity for the preceding frame. Horizontal parity is generated by counting the number of "1"'s present in each row. If the row contains an even number of "1"'s, the bit of the horizontal parity word corresponding to that row is set to a "1". The vertical parity word is generated in a similar manner. In each parity word the bit which occurs earliest in time represents row (0) or column (0).

When the row and column parity words are checked against ground station parity words, a single bit error in a frame can be isolated to a single word position. More than one parity error would result in ambiguity in the definition of words containing errors.

8.3.6 PAM Commutator

The PAM commutator accepts 30 analog functions, and it time division multiplexs the 30 functions into a serial PAM signal. The PAM signal FM modulates the channel F(93kc) subcarrier.

The Commutator timing is obtained from the encoder time base such that the commutator operates at a 1 KHz rate. Field effect transistors and discrete components are used in the construction of the commutator.

It is physically located within the encoder package. The input impedance is greater than 1KMegohm. The input signal must be between -0.5 volts and +5.0 volts. The input to each commutator channel is protected by diode clippers in the input circuitry. Each experiment package must scale the analog signals prior to the encoder input.

Table 8.5 provides a listing of the PAM Commutator channel assignments for the first flight. Subsequent flights will have similar assignments. Channel 1 is used to establish a zero voltage reference for scale purposes in decoding the received data. Channels 31 and 32 are used to synchronize the PAM decommutator to the frame rate and to provide a 5VDC voltage reference. The remaining channels are assigned to the various payload functions as required.

8.4 Telemetry

The TM Subsystem includes a Vector 1/4 watt transmitter and 12 subcarrier VCO's. A mixer amplifier combines the 12 subcarriers into a composite signal which modulates the transmitter.

The transmitter is coupled by a phasing network to 60° sweep turnstile antennas. The TM channels assignments for the first launching is shown by Table 8.6. A channel assignment sheet will be provided for later launches. Figure 8.7 provides a block schematic.

8.4.1 Calibration

All calibration will be accomplished prior to flight time through the umbilical cable. Three 4-pole relays are provided to allow calibration signals to be substituted for the analog data signals. Calibration control and signals are available from the checkout console.

8.5 Umbilical Connector

The umbilical connector is of the fly-away type mounted in the TM section of the payload. Umbilical functions are acquired through a 27 pin Duetsch connector assembly. Umbilical assignments for the MAP flights are given by Table 8.7 . The umbilical cable is designed for use on either the Nike Apache launcher or the Universal launcher at Churchill. The cable length is 60 feet. A four foot section including the Duetsch connector is replaceable. One end will mate to a junction box with a male 35 pin connector. The connectors required are listed below.

a) 27 pin receptacle on Rocket--Part No. DM9601-27S

b) 27 pin plug on cable--Part No. DM9703-27P

c) 35 pin 4 ft. cable -- Part No. 3106E36-15P

d) 35 pin 56 ft. cable--Part No. 3106E36-15S

e) 35 pin 56ft. cable -- Part No. 3106E36-15P

f) 35 pin Junction box -- Part No. 3102E36-15S

8.6 Magnetic Aspect Instrumentation

The aspect of the payload will be determined by the use of a magnetometer and a solar cell.

The magnetometer used is the Heliflux Magnetic Aspect Sensor type RAM-5C. It is manufactured by the Schounstedt Instrument Company, Silver Springs, Maryland. The sensor is mounted in the nosecone of the payload at approximately 54° with respect to the top surface of the payload. The magnetometer electronics is mounted within the encoder section of the payload. TM channel 8 monitors the magnetometer signal.

8.6.1 Solar Aspect Instrumentation

The solar cell is mounted behind a cutout in the rocket door. The sensor and electronics are mounted with the timing and control equipment TM channel 7 is used to relay the solar aspect data to the ground station. The solar cell is a Hoffman n-on-p cell. The cell is calibrated for maximum response on an axis perpendicular to the thrust axis. The solar cell is illuminated over a $1cm^2$ area by a 70° field of view.

8.7 Door Controls

The experiments which require openings in the rocket skin for operation are mounted behind an ejectable blow off door which is released under the control of altitude switches and a timer. Four altitude switches are connected in a series-parallel combination for redundancy. The door will be released at 50km during ascent.

8.8 Altitude Controls

Altitude status will be furnished in the form of two gate signals from the encoder. The gate signals will go to logic "1" at 60KM and 90KM on ascent and remain there until approximately 60KM on descent. These altitude status gates are for use by the experiments in turning on and off high voltage supplies. These signals are generated by separate timers and may be set to operate at any time after 10,000 feet.

The altitude switches will be used in conjunction with a latching relay to turn off all power during the descent phase of the flight in order to decrease damage due to electrolysis in the event that the payload lands in water.

8.8.1 Event Timing

All payload event timing is timed from the operation of redundant altitude switches at 10,000 feet. Time delays are realized by solid state conjunction timing circuits. Figure 8.6 is a functional block diagram of the timing and control sections. Table 8.8 is a list of the main events during flight.

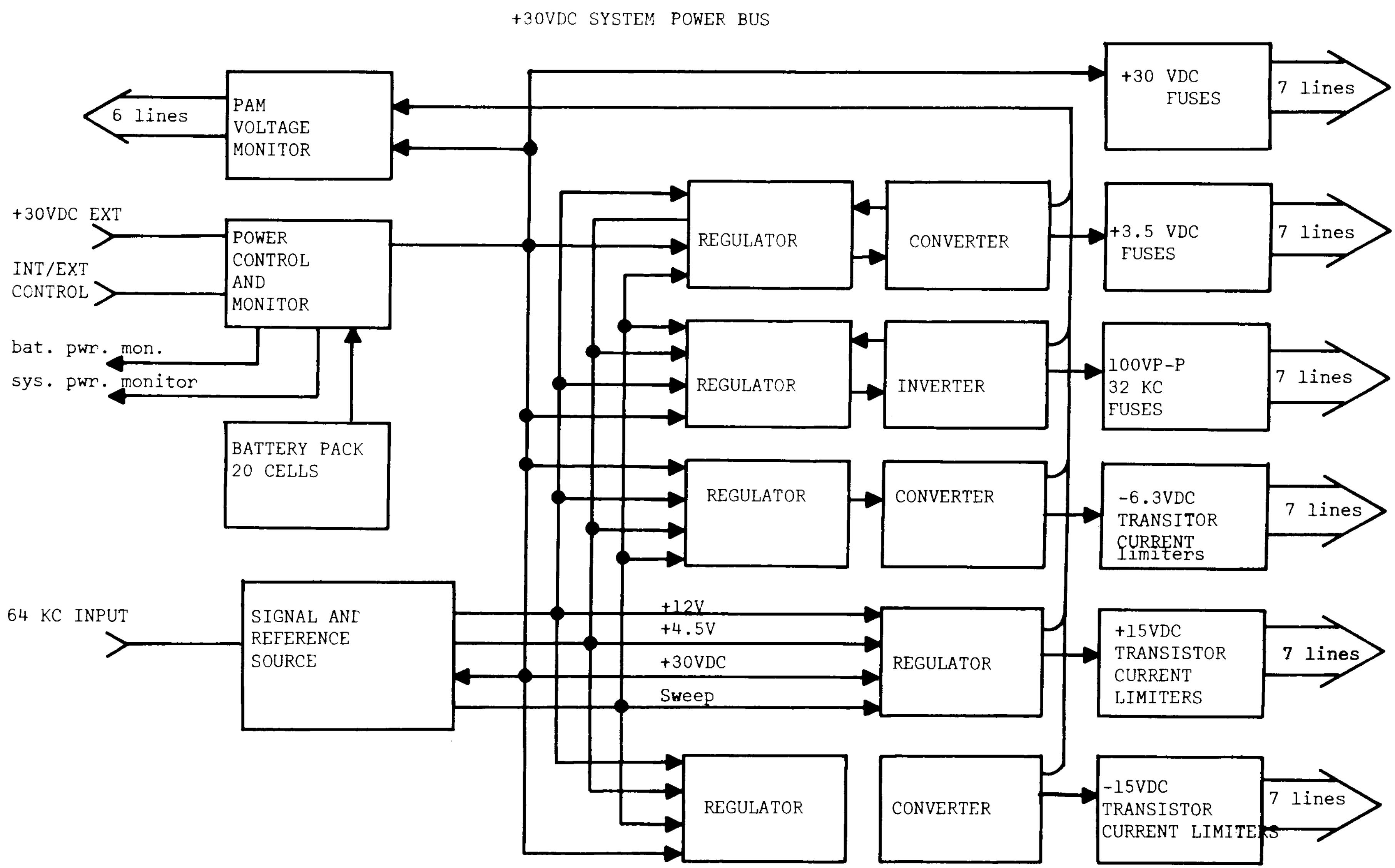


FIGURE 8.1 MAP POWER SUPPLY SIMPLIFIED BLOCK SCHEMATIC

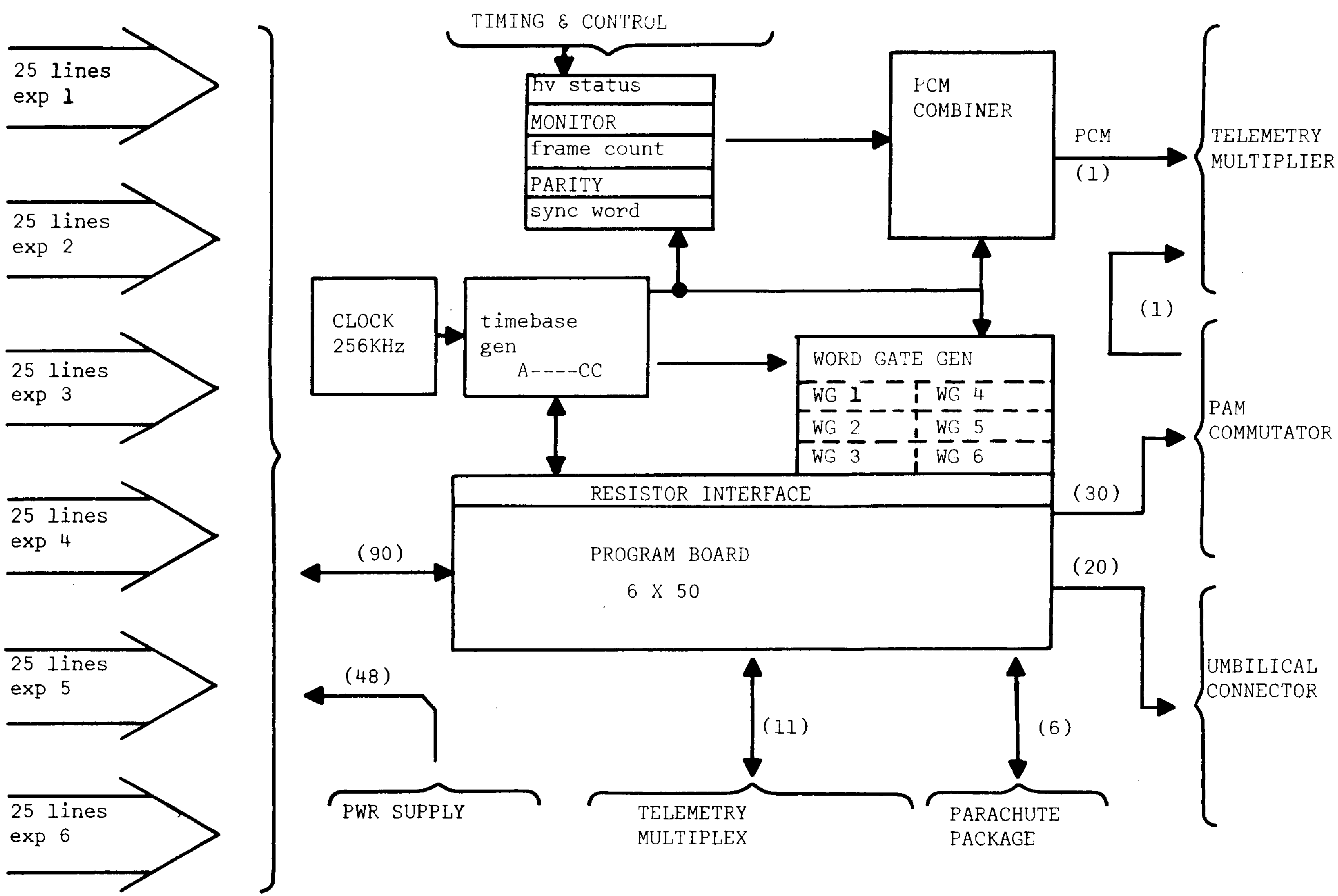
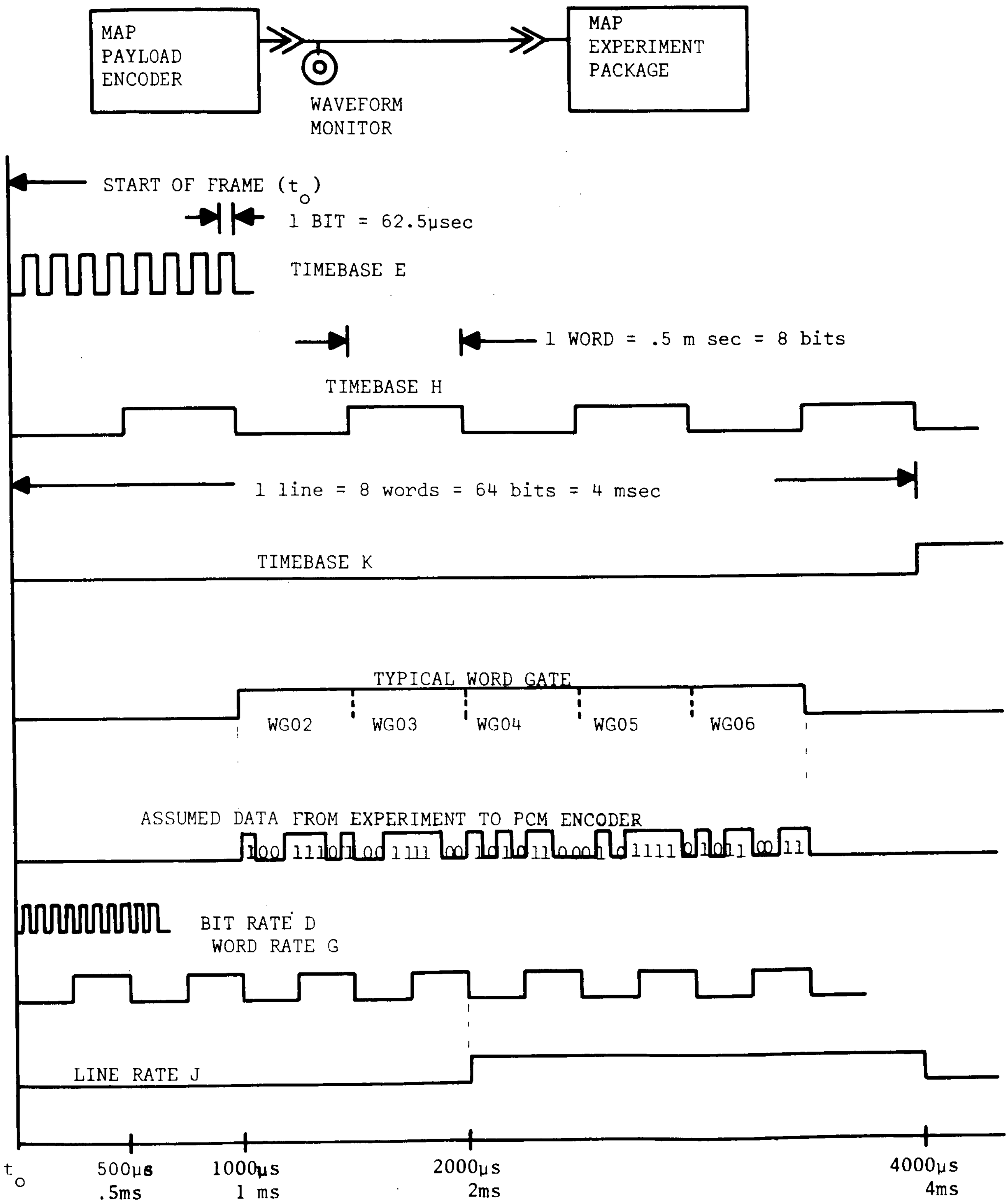
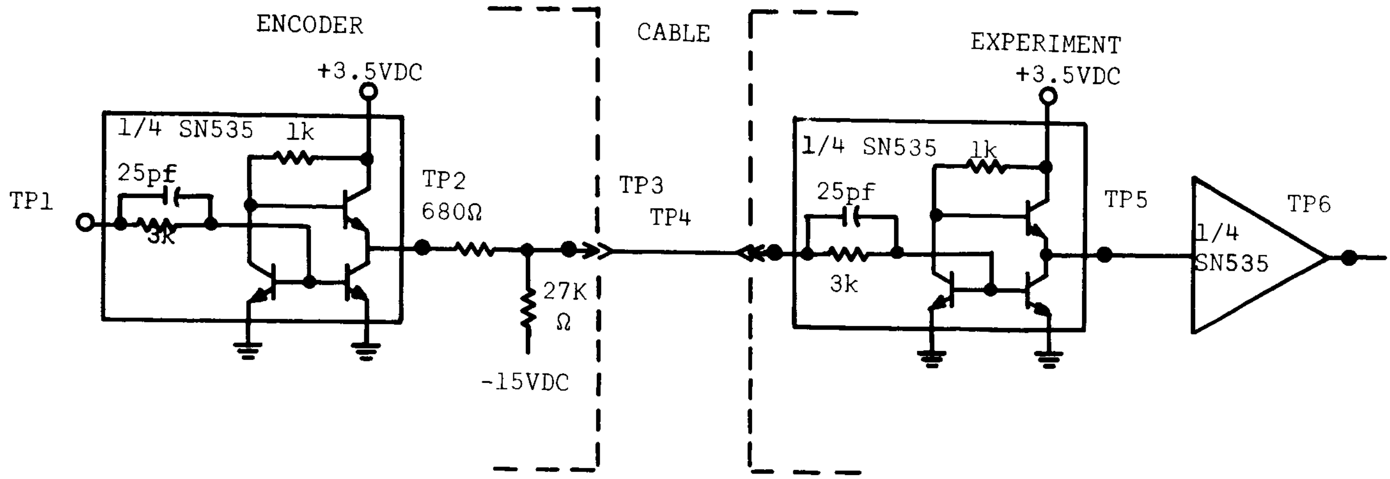


FIGURE 8.2 BLOCK SCHEMATIC LOGIC UNIT



NOTE: Timing is shown as seen on the cable between Encoder and Experiment

FIGURE 8.3 INTERFACE LINE TIMING



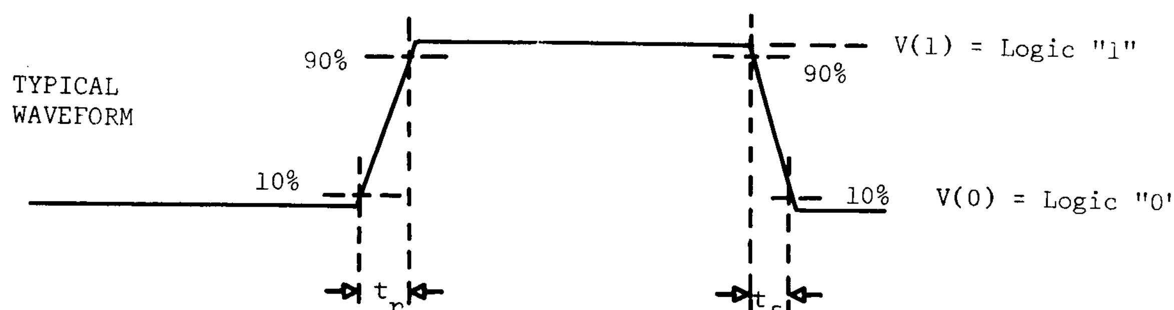
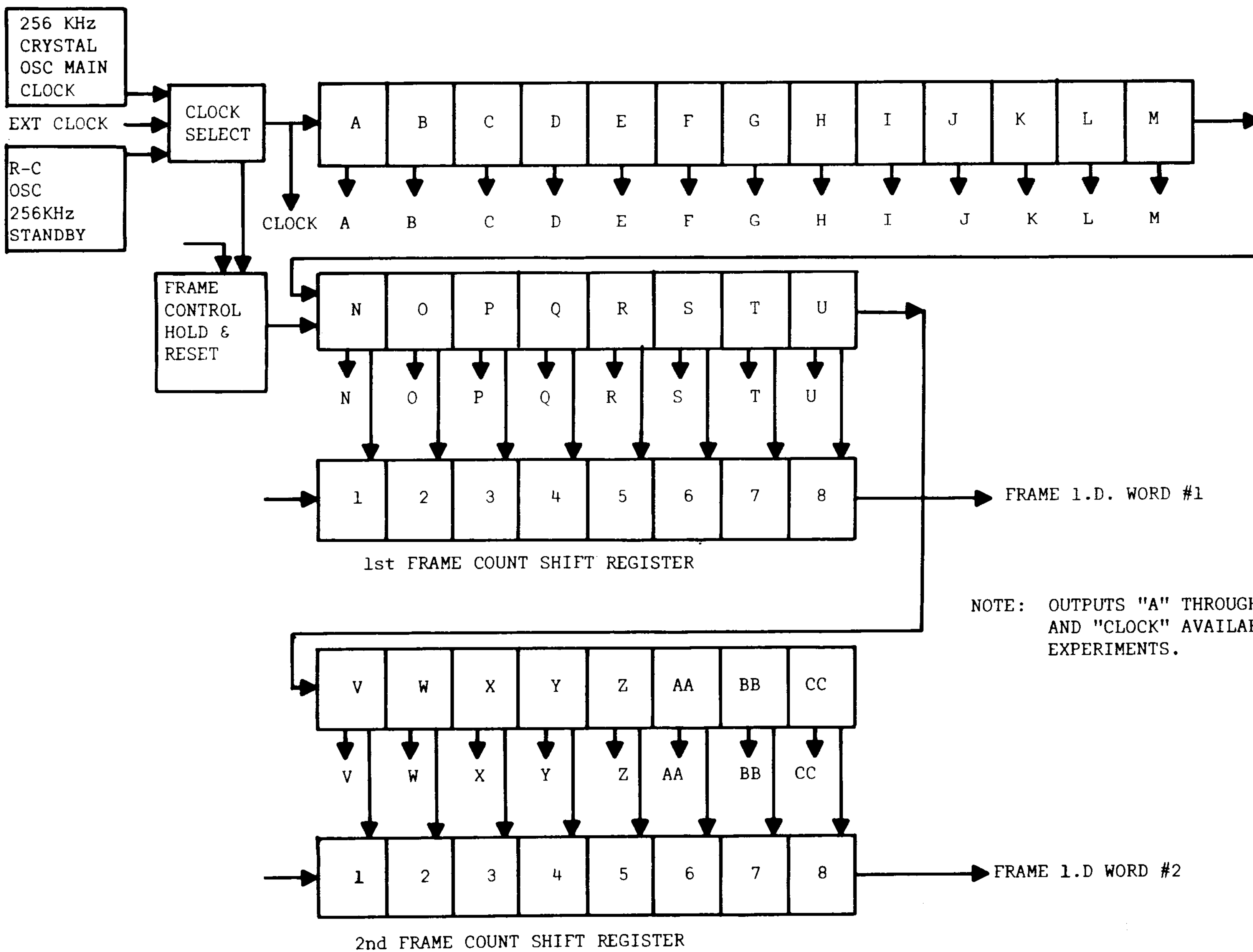


TABLE I

TEST POINT	t_r nsec	t_f n sec	V(1) volts	V(0) volts	
1	35	40	+2.6	+.05	
2	50	20	+2.6	0	
3	290	400	+2.1	-.3	
4	240	400	+2.1	-.3	
5	90	60	+2.6	0	
6	20	30	+2.9	0	

Note: Measurements of TABLE I were made with Type 432 Scope. The cable connecting the Encoder and Experiment was 12 feet of 50 wire cable (#24).

FIGURE 8.4 ENCODER TO EXPERIMENT INTERFACE WAVEFORMS



NOTE: OUTPUTS "A" THROUGH "CC" AND "CLOCK" AVAILABLE TO EXPERIMENTS.

FIGURE 8.5 TIME BASE GENERATOR

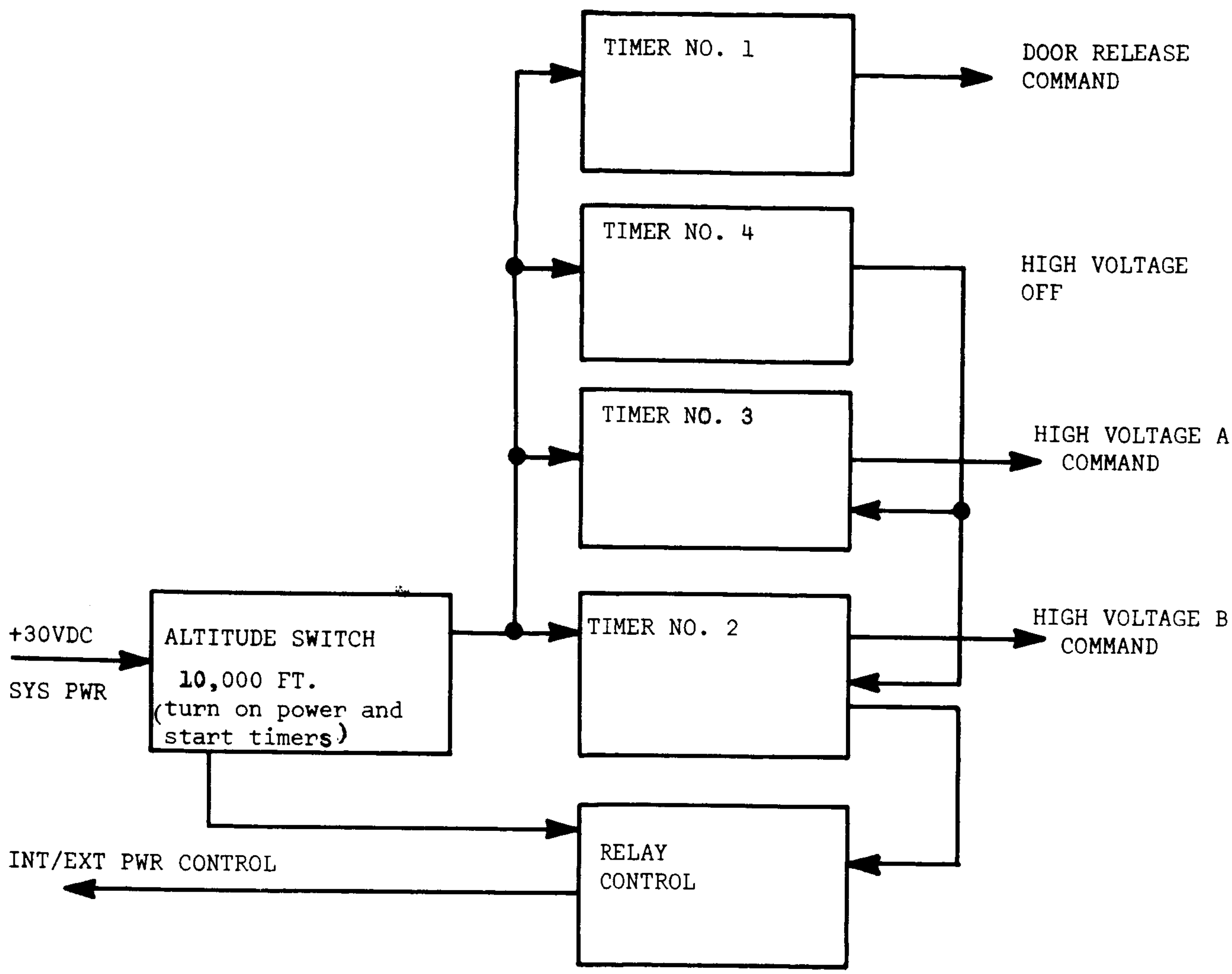


FIGURE 8.6 TIMING AND CONTROL SIMPLIFIED BLOCK SCHEMATIC

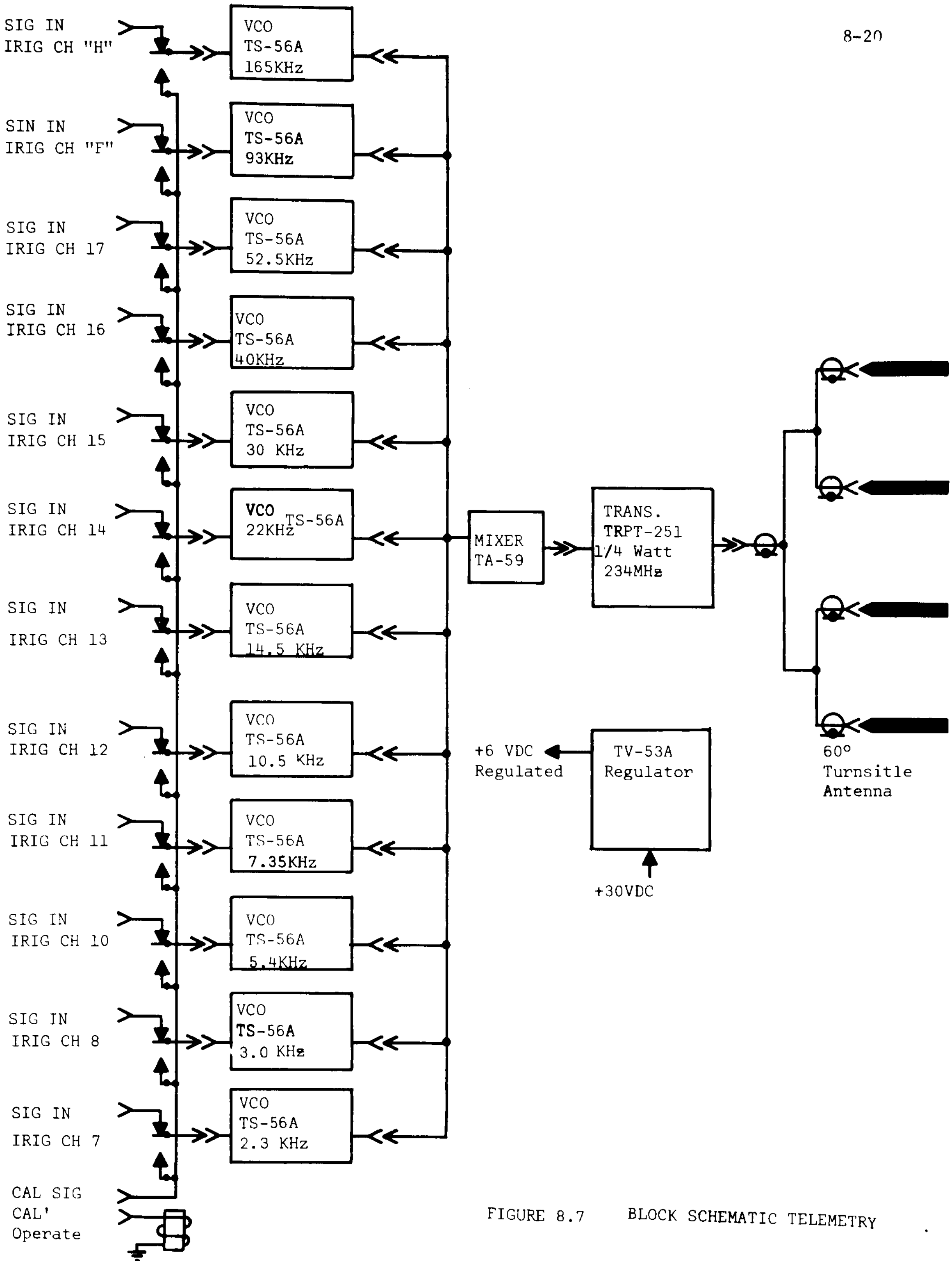


FIGURE 8.7 BLOCK SCHEMATIC TELEMETRY

TABLE 8.1

TYPICAL MAP POWER REQUIREMENTS

	PWR SUPPLY VOLTAGE						TOTAL
NAME	+3.5V	-6.3V	+15V	-15V	+30V	100VAC	PWR
EXP 1 --FSCP	4.5w	2.2w	1.2w	.2w	.5w	4.0w	12.6w
EXP 2 --Pulse Rec.	----	----	2.2w	1.5w	2A/5ms	----	3.7w
EXP 3 --SES	4.2w	10μa	.8w	.2w	1.2w	.6w	7.0w
EXP 4 --Photometer	3.5w	1.0w	1.0w	1.0w	1.0w	1.0w	
EXP 5 --Ener. Part.(A)	5.5w	2.0w	2.0w	.1w	2.8w	.04w	12.5w
EXP 6 --Ener. Part.(B)	----	----	----	----	----	----	-----
Encoder	6.0w	----	1.0w	1.0w	1.0w	----	8.0w
Timing and Control	----	----	1.0w	1.0w	.5w*	----	2.5w
Telemetry Unit	----	----	----	----	5.6w	----	5.6w
Power Supply	----	----	----	----	60.0w	----	60.0w
Total Pwr/voltage	23.7w	5.2w	9.2w	5.0w	72.6w	5.64w	
Total not to exceed	24.0w	9.0w	20.0w	6.6w	80.0w	6.6w	

*Squibs require 5A/5MS.

TABLE 8.2

Time Base Signals For Experiment Timing

Time Base Designator	Repetition Rate F_r	Period T_{rr}	Description
CLOCK	256K Hz	3.90625μ sec.	Basic Clock Frequency
A	128K Hz	7.8125μ sec.	
B	64K Hz	15.725μ sec.	
C	32K Hz	31.25μ sec.	
D	16K Hz	62.5μ sec.	Bit Rate
E	8K Hz	125μ sec.	
F	4K Hz	250μ sec.	
G	2K Hz	500μ sec.	Word Rate
H	1K Hz	1 m sec.	
I	500 Hz	2 m sec.	
J	250 Hz	4 m sec.	Line Rate
K	125 Hz	8 m sec.	
L	62.5 Hz	16 m sec.	
M	31.25 Hz	32 m sec.	Frame Rate
N	15.625Hz	64 m sec.	Frame Counter Pos. 1
O	7.8125Hz	128 m sec.	" " " 2
P	3.90625Hz	256 m sec.	" " " 3
Q	1.953125Hz	512 m sec.	" " " 4
R	.9765625Hz	1024 m sec.	" " " 5
S		2.048 sec.	" " " 6
T		4.096 sec.	" " " 7
U		8.192 sec.	" " " 8
V		16.384 sec.	" " " 9
W		32.768 sec.	" " " 10
X		65.536 sec.	" " " 11
Y		2M 11.072 sec.	" " " 12
Z		4M 22.144 sec.	" " " 13
AA		8M 44.288 sec.	" " " 14
BB		16M 88.576 sec.	" " " 15
CC		34M 57.152 sec.	Frame Counter Pos.16

TABLE 8.3

TYPICAL PCM WORD ASSIGNMENTS FOR MAP FLIGHTS

Word Number	Time From To	Word Gate Octal Notation	Assigned Function	Word No.	Time From To	Octal Notation	Assigned Function
1	Omsec	WG00	Horiz.Parity	33	16.0ms	WG40	Frame I.D.
2	.5msec	WG01	Vert. Parity	34	16.5ms	WG41	Frame I.D.
3	1.0msec	WG02	PHOTOMETER	35	17.0ms	WG42	PHOTOMETER
4	1.5msec	WG03	PHOTOMETER	36	17.5ms	WG43	PHOTOMETER
5	2.0msec	WG04	PHOTOMETER	37	18.0ms	WG44	PHOTOMETER
6	2.5msec	WG05	PHOTOMETER	38	18.5ms	WG45	PHOTOMETER
7	3.0msec	WG06	PHOTOMETER	39	19.0ms	WG46	PHOTOMETER
8	3.5msec	WG07	EP	40	19.5ms	WG47	EP
9	4.0msec	WG10	EP	41	20.0ms	WG50	EP
10	4.5msec	WG11	EP	42	20.5ms	WG51	EP
11	5.0msec	WG12	EP	43	21.0ms	WG52	EP
12	5.5msec	WG13	EP	44	21.5ms	WG53	EP
13	6.0msec	WG14	FSCP	45	22.0ms	WG54	FSCP
14	6.5msec	WG15	FSCP	46	22.5ms	WG55	FSCP
15	7.0msec	WG16	FSCP	47	23.0ms	WG56	FSCP
16	7.5msec	WG17	FSCP	48	23.5ms	WG57	FSCP
17	8.0msec	WG20	BLANK	49	24.0ms	WG60	BLANK
18	8.5msec	WG21	SES	50	24.5ms	WG61	SES
19	9.0msec	WG22	PHOTOMETER	51	25.0ms	WG62	PHOTOMETER
20	9.5msec	WG23	PHOTOMETER	52	25.5ms	WG63	PHOTOMETER
21	10.0ms	WG24	PHOTOMETER	53	26.0ms	WG64	PHOTOMETER
22	10.5ms	WG25	PHOTOMETER	54	26.5ms	WG65	PHOTOMETER
23	11.0ms	WG26	EP	55	27.0ms	WG66	PHOTOMETER
24	11.5ms	WG27	EP	56	27.5ms	WG67	EP
25	12.0ms	WG30	EP	57	28.0ms	WG70	EP
26	12.5ms	WG31	EP	58	28.5ms	WG71	EP
27	13.0ms	WG32	EP	59	29.0ms	WG72	EP
28	13.5ms	WG33	EP	60	29.5ms	WG73	EP
29	14.0ms	WG34	BLANK	61	30.0ms	WG74	MON 1
30	14.5ms	WG35	BLANK	62	30.5ms	WG75	MON 2
31	15.0ms	WG36	BLANK	63	31.0ms	WG76	SYNC CODE
32	15.5ms	WG37	BLANK	64	31.5ms	WG77	SYNC CODE

TABLE 8.4

TYPICAL MAP SERVICES LIST

Experiment Name	Responsible Scientist	Connector Assignment J704
Photometer	G. O'Connor	Flight No. 68-1,2,3....

Terminal No.	Function
10	"K" Timebase - Accumulator Transister Control
11	PCM Word Gate WG02-06,22-26,42-46,62-66
12	"M" Timebase
13	Solar Cell Output
14	"V" Timebase
15	TM Ch 12
16	"Clock" Timebase
17	PAM Comm. Ch19
18	" " "
19	" " "
20	" " "
21	Umbilical #15 - Cal 1
22	" #16 - Cal 2
23	" #17 - EHT Holdoff
24	" #18 -

TABLE 8.5

TYPICAL PAM COMMUTATOR ASSIGNMENT LIST

CHANNEL NO.	EXPERIMENT	FUNCTION
1	SUPPORT	REFERENCE (OVDC)
2	SUPPORT	PARACHUTE MONITOR 1
3	PULSE REC	POWER MONITOR
4	PULSE REC	GAIN MONITOR
5	SUPPORT	VOLTAGE MONITOR -6.3VDC
6	SUPPORT	VOLTAGE MONITOR +15VDC
7	SUPPORT	VOLTAGE MONITOR -15VDC
8	SUPPORT	VOLTAGE MONITOR +30VDC
9	SUPPORT	VOLTAGE MONITOR +3.5VDC
10	SUPPORT	VOLTAGE MONITOR 100 VAC
11	SUPPORT	REFERENCE (+2.5 VDC)
12	SUPPORT	MAGNETOMETER BIAS
13	SUPPORT	TIMER MONITOR
14	SUPPORT	DOOR MONITOR
15	SUPPORT	REFERENCE (+5VDC)
16	HFCP	
17	SUPPORT	REFERENCE (OVDC)
18	HFCP	TM 14
19	PHOTOMETER	NO. 1
20	PHOTOMETER	NO. 2
21	EP	TM16
22	EP	TEMP.
23	PHOTOMETER	NO. 3
24	PHOTOMETER	NO. 4
25	EP	
26	SUPPORT	REFERENCE (2.5VDC)
27	SUPPORT	PARACHUTE MONITOR 2
28	EP	TM 10
29	SES	4KV PWR SUPPLY
30	SES	PROGRAM PWR SUPPLY
31	SYNC	
32	SYNC	REFERENCE (5VDC)

TABLE 8.6

TYPICAL TELEMETRY CHANNEL ASSIGNMENTS

Irig Band	Center Frequency	Percent Deviation	Modulation Index	Max.Intel. Frequency	Experiment	Description
H	165KHz	±15	2.5	10KHz	PCM	16KBS
F	93KHz	±15	5	2800Hz	PAM	COMMUTATOR
17	52.5KHz	±7.5	5	790Hz	Pulse Rec	
16	40KHz	±7.5	1.5	2KHz	EP	MAG Volt
15	30KH	±7.5	1.2	2KHz	EP	Staircase
14	22KHz	±7.5	5	330KHz	FSCP(L)	Capacitance Probe
13	14.5KHz	±7.5	5	220Hz	EP	Busy FF
12	10.5KHz	±7.5	2.5	320Hz	Photometer	
11	7.35KHz	±7.5	5	110Hz	FSCP	Langmuir Probe
10	5.4KHz	±7.5	5	81Hz		Parachute
8	3.0KHz	±7.5	5	45Hz		Magnetometer
7	2.3KHz	±7.5	5	35Hz		Solar Cell

TABLE 8.7

TYPICAL MAP UMBILICAL ASSIGNMENTS

PIN NO.	DESCRIPTION	EXPERIMENT
1	EXT. PWR +30VDC	POWER SUPPLY
2	+30 VDC BATTERY POUR MONITOR	POWER SUPPLY
3	FRAME CONTROL (HOLD RESET)	ENCODER
4	PWR RELAY LATCH (INT/EXT)	ENCODER (PS)
5	+30VDC INSTR PWR MONITOR	POWER SUPPLY
6	PWR GND	POWER SUPPLY
7	CKT/SIGNAL/MONITOR GND	POWER SUPPLY
8	CLOCK/SYNC	ENCODER
9	CALIBRATE RELAY ON/OFF	TM
10	CALIBRATE VOLTAGE IN	TM
11	TIMER MONITOR	TIMING AND CONTROL
12	CALIBRATION GATE	PULSE REC.
13	G11	HFCP
14	ON/OFF	LANGMUIR
15	NO. 1-DATA SELECT (1)	PHOTOMETER
16	" 2 " " (2)	PHOTOMETER
17	" 3 " " (3)	PHOTOMETER
18	" 4 " " (4)	PHOTOMETER
19	NO. 1 COUNT/READY SELECT	ENERGETIC PARTICLE
20	" 2 DATA SELECT	" "
21	" 3 DATA SELECT	" "
22	" 4 EHT MONITOR	" "
23	NO. 1-GO-NO-GO TEST	SES
24	G9	HFCP
25	TM CAL MONITOR	TM
26	K4 ON/OFF	TIMING AND CONTROL
27	TIMER COMMAND	TIMING AND CONTROL

TABLE 8.8

TYPICAL SCHEDULE OF MAJOR EVENTS

EVENT.NO.	TIME	ALTITUDE	FUNCTION
1	0 sec.	launch site	launch
2	3.5 sec.	5,280 feet	booster burnout
*3	7.0 sec.	10,000 feet	Altitude switch make-start timers
4	20.0 sec.	39,000 feet	Apache Ignition
5	26.4 sec.	62,000 feet	Apache Burnout
*6	47.0 sec	50KM	Eject Door
*7	64.0 sec	89KM	High Voltage ON A
7A	65.0	90KM	High Voltage ON B
8	185.0 sec	140KM	Top of Trajectory
**9	285 to 317s	300,000 to 200,000 ft.	Severance of Stage (Apache)
*10	317 sec.	60KM	High Voltage Off (A&B)
**11	350 sec.	17,000feet	Deploy Chute
*12	355	10,000 ft.	Power off--Altitude Switch open
13	360 sec.	0	Impact (without chute)
14			Recovery

* Events programmed by support timing system

** Events programmed by parachute timing system

9.0 CENTRAL GROUND SUPPORT EQUIPMENT

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The M.A.P. Central Ground Support Equipment (GSE) consists of nine main parts (Fig. 9.1). Each of these parts are described as to function.

9.1 Receiver

The receiver is used with the GSE only during checkout, both in the laboratory and at the launch site. All signals during flight are obtained by the launch facility's equipment.

9.2 Tape Recorder

The tape recorder is used in the laboratory to play back tapes recorded at the launch facilities.

9.3 Demodulators

The demodulators in the Central GSE are used for laboratory checkout and tape playback. All signals during flight are demodulated by the launch facility's equipment.

9.4 Visicorder

The Visicorder is used to record analog data during checkout and playback.

9.5 Sync Unit (Fig. 9.2)

The inputs to the sync unit are obtained from the Time Base, Demodulators, and the Frame Memory. The Time Base signals consist of the outputs from the flip-flop count-down chain. All signals from the 256,000cps clock to the 32nd subframe (approx. 1 sec.) are available.

The sync unit also obtains the frame identification number and the parity words from the Frame Memory. It uses this information to establish synchronization and to provide a parity check. The results of the parity check are given to the experimenters through connections in the Frame Memory.

The Sync Unit performs the following functions:

1.	One increment speedup	1/16 bit	primary function
2.	One increment slowdown		
3.	Frame reset		
4.	Subframe reset		
5.	Regenerate the PCM data stream		
6.	Sync code autocorrelation factor		oscilloscope display
7.	Bit timing displacement		
8.	Selected words		
9.	PAM display		
10.	Vertical parity check		to exterimenters
11.	Horizontal parity check		
12.	Parity information		

Sync Unit Operation

Detection of bit timing offset - The Sync Unit detects all bit transitions in the TM data stream and compares their timing to the 32KC signal in the GSE Time Base. When the timing error exceeds a predetermined amount, a speedup or slowdown command is presented to the time base. Speedup or slowdown is accomplished by inserting an extra pulse or removing a regular pulse from the output of the crystal clock. Maximum correction rates are limited and this limit is selected by a switch on the Time Base chassis. Higher correction rates might be required for tape playbacks where tape speed varies. However, if the 32KC output of the Time Base is recorded with the original data and is used as the clock on playback, further phase correction is unnecessary.

Frame Reset- The frame reset synchronizes the frame timing signals in the Time Base so that the data bits in the telemetry stream are decommutated into their proper positions in the Frame Memory. This is accomplished by two alternate schemes:

A. PAM Detection- The frame rates of the PAM (Pulse Amplitude Modulation) data and the PCM (Pulse Code Modulation) are identical. The frame sync pulse from the PAM data is easier to detect than the sync word in the PCM data because certain data combinations in the PCM signal can generate a false sync signal. The Master Pulse in the PAM data is distinct and (with proper timing allowances) is used to reset the flip-flop dividers in the Time Base which are important to frame synchronization (from 8KC to 32ms). This circuitry operates by push button command.

B. PCM Detection - A sixteen bit word is encoded into each frame of the PCM data stream. This word is selected to provide a minimum autocorrelation function when compared to any random selection of data bits. The PCM data stream is then compared bit by bit to the sync word and any complete correlations indicate a possible timing reference point for GSE Time Base. Since some unfortunate sequence of data bits might generate the same sync word at another point in the data stream, it is essential to change the sync word in a predetermined manner so that the true sync word might be verified. This may be accomplished by complementing the sync word on alternate frames. The sync word detector may easily discover the complemented word since the correlation factor will drop to zero instead of one. Thus the sync detector will recognize the true sync word by the alterations of one and zero correlation factors. Once synchronization is established, the sync detector is programmed to look at the data stream only during the appropriate time and ignore false sync signals. Absence of proper code words starts operation in the search mode.

Sync code autocorrelation factor - If the autocorrelation factor is defined as the algebraic sum of the sixteen bit factors, and each bit factor is determined by multiplying a given bit by an unknown bit and assigning a value of +1 when the bits match and a value of -1 when the bits do not match, the sum can attain any even value between +16 and -16. This sum is created by comparing the bits in the data stream to a fixed number (the sync code) in a group of half adder circuits. The outputs of the sixteen half adder circuits are algebraically added to form the autocorrelation factor. This factor is then displayed on a built-in oscilloscope. This display is secondary in nature in that it is not necessary for system operation; but, it is easy to obtain since most of the circuitry is already required, and it allows the operator to inspect the data stream for possible false sync code combinations.

Sub-frame Reset - The sync circuitry examines the frame count in the Frame Memory and determines when the frame count is a multiple of thirty-two. At this time, the flip-flop dividers in the subframe portion of the Time Base are reset to zero.

Regeneration of the PCM Data Stream - The data pulses from the rocket are distorted by the bandwidth limitations of the subcarrier channels and might be deteriorated by noise and other factors. It is desirable that the data be presented to the GSE circuitry in a standardized form (in regard to amplitude and wave shape). Therefore it is necessary to detect and regenerate the data bits and to synchronize them to the GSE Time Base. The data stream regenerator integrates the PCM signal from the demodulator and detects this signal's polarity at the optimum instant.

Bit Timing Displacement- The bit timing displacement measurement is useful in determining the proper operation of the bit synchronization circuit. The built-in oscilloscope is triggered by the GSE Time Base and the data stream from the TM system is observed on the vertical axis.

Selected Words- The oscilloscope is also used to display various words in the PCM format. The scope is triggered by signals from the Time Base and, by means of selector switches, may be triggered at the start of any of the sixty-four words. The sweep speed may then be adjusted to view any desired number of words thereafter.

PAM Display- The oscilloscope may also be used to view the PAM signals. The scope is triggered by the Time Base so that Channel 1 is at the start of the trace.

Parity Check- Although the parity function is not associated with synchronization, the Sync Unit is used to house this circuitry because of the availability of the proper signals and data. Two words (horizontal and vertical parity) are generated within the encoder circuitry in the rocket. There is a bit of information in these words for every row and every column of the format. Every "one" bit in a typical row or column triggers a flip-flop. The state of this flip-flop at the end of the frame indicates whether an odd or an even number of "ones" were counted. This information from all sixteen flip-flops is then encoded into the data stream and stored in the Frame Memory in the Central GSE. The same information is obtained from the regenerated PCM data stream as this data is received. The new information (generated on the ground) is compared with the information obtained in the rocket and any discrepancies are noted. The discrepancy information is stored in sixteen flip-flop circuits--one for each row and one for each column. The outputs of these flip-flops go into the Frame Memory and on to the Experimenter's GSE. As each word is associated with a particular row and column on the format, the parity check signals are distributed only to the corresponding words. If a particular word receives parity error signals in both its row and column inputs, then a parity error is contained within that word.

Several parity error situations might arise which are not simple to analyze. One such situation occurs if a single row indicates a parity error, but none of the columns show an error. This indicates that the parity check system is not functioning properly or that an error has occurred within the parity words. Another possible situation is an indication that more than one row and/or column has parity errors. It is then impossible to pinpoint the exact word or words which are in error. In these cases a general warning signal is distributed to all experimenters warning them to use care in accepting the data within that frame.

9.6 Time Base (Fig. 9.3)

The Time Base uses a crystal controlled oscillator to establish a precise frequency of 256KC. This frequency is counted down to 16KC by a series of four flip-flop circuits. This 16KC signal establishes the bit rate and must be phase synchronized to the bit signals in the PCM data stream. This is accomplished by the phase correction circuit. The rest of the flip-flop counters provide outputs at the various frequencies from the bit rate through the thirty-second subframe.

256KC Crystal Clock - The crystal clock provides a sine wave output with an amplitude of 0.7 volts (rms). The frequency of this oscillator is rated to be accurate within ±.008% or 80 parts per million. This clock is identical to the clock in the rocket payload.

Phase Correction Circuit- The phase correction circuit obtains signals (from the Sync Unit) which dictate the need to either slow down or speed up the time base. A speed-up command indicates that the bit transitions in the PCM data are arriving ahead of time when compared to the bit timing signal in the Time Base.

This command causes an extra pulse to be inserted in the input signal of the countdown chain. A slow down command causes the removal of a pulse in the same signal.

The timing pulses from the phase correction circuit are normally supplied every 3.90625 microseconds (256KC). An addition or subtraction of one pulse to this signal shifts the time base by about 4 microseconds or 1/16th of a bit time. The Sync Unit determines the phase error only when transitions are observed in the PCM data stream; therefore, the effect of a phase correction cannot be determined until another bit transition is detected. Under some conditions,a considerable number of bit times may pass before the timing is reevaluated. It is thus necessary to limit the correction rate to prevent over correction because of lack of information. This is achieved by allowing the corrections to occur only at specific times in the frame. A selector switch on the front panel chooses the maximum frequency of corrections, i.e. one, two, four, etc. per frame. The maximum correction rate is determined in the following manner. Assume the crystal clock in the rocket is running at the maximum deviation in one direction and the crystal clock on the ground is operating at the other extreme. The total difference is 160 parts per million or one part per 6,000. This means the error accrues at the rate of four microseconds (one increment of correction) every 24 milliseconds, or slightly more than one increment per frame (32 milliseconds).

One additional factor might be considered in this estimate. The rocket will be moving away from the ground station with an approximate maximum slant range velocity of 6,500 feet per second. The propogation time for the radio signals increases at the rate of about six and a half microseconds per second. This corresponds to one increment of phase correction (4 microseconds) every 0.6 second (19 frames). The effect of doppler shift is thus much smaller than the expected error due to crystal clock inaccuracies.

An additional problem arises if the TM signals should suffer drop-out during the flight. The phase error can accumulate during this period because of the absence of corrective action. If the phase error exceeds 8 increments (32 microseconds) the bit timing detector will lock on an adjacent bit when the signals return. This then requires a resynchronization of the frame sync circuits (Data is lost until this is accomplished). This problem is avoided by remembering the error correction rate prior to dropout and applying the same correction rate until the signals return. This is accomplished by counting the number of corrections per period of time and storing this information in a storage register. When a dropout occurs, the storage register is consulted for the proper correction rate to be applied to the Time Base.

Preframe countdown - The preframe countdown contains four flip-flop circuits which reduce the 256KC output of the pulse correction circuit to the 16KC bit rate of the PCM signal. When the direct signals from the rocket are being processed, the countdown circuitry operates as a normal frequency divider. The output of the third flip-flop circuit (32KC) is recorded on the tape recorder along with the data from the rocket. This signal is synchronized with the data by the action of the phase correction circuit. During playback of the data for later analysis, the variations of tape speed in the recorder may severely tax the capabilities of the phase correction circuit. If, however, the 32KC signal which was recorded synchronously with the data is used for the generation of the time base, the bit synchronization is automatically provided. The wave shaper-timer improves the rise time and corrects for timing offset in the 32KC signal from the tape recorder.

Frame countdown - The frame countdown consists of nine flip-flop counters which reduce the 16KC bit rate signal to a 32 millisecond square wave corresponding to the frame length. The outputs of these flip-flops are used to generate the various gates and triggers necessary for synchronization, observation, reduction, and storage of the PCM, and PAM data from the rocket.

Subframe countdown- When storing the phase correction rates for use during dropouts, it may be necessary to refer to more than one frame. The subframe counter will be used in this function.

9.7 Format Memory (Figure 9.4)

The Format Memory presents the latest data to the experimenter's GSE units. It also provides six communication lines for each word which the experimenters may use to obtain Time Base signals, Analog Data, and the PAM signal. These lines may also be used to connect Go, No-Go signals from the experimenter's GSE to the check-out panel. This unit contains 128 bits of shift register, 496 bits of flip-flop memory with buffered outputs, six frame identification outputs, a timing and control circuit, and an experimenter's program panel.

Word Memory- Each word memory board contains eight flip-flop circuits and nine communication lines. The outputs from these boards are located at the rear of the Format Memory console so that cables to the experimenter's GSE units are out of the way. Eighteen pin circuit board connectors and cables are provided for each word. The experimenter's terminations are not provided. Each of the eighteen wires is color coded to prevent confusion. The connections and color codes are given in the following table:

Data Word Connections

Pin	Connection	Wire Color
1	Communication line 1	wht/brown
2	Communication line 2	wht/red
3	Communication line 3	wht/orange
4	Communication line 4	wht/yellow
5	Communication line 5	wht/green
6	Communication line 6	wht/blue
7	Parity Flag	wht/black
8	Horizontal parity	wht/violet
9	Vertical Parity	wht/gray
10	Bit #8 Most Significant	Gray
11	Bit #7	Violet
12	Bit #6	Blue
13	Bit #5	Green
14	Bit #4	Yellow
15	Bit #3	Orange
16	Bit #2	Red
17	Bit #1 Lease Significant	Brown
18	Signal Ground	Black

All output signals to the experimenter are buffered from the driving circuit by a 3.3K resistor. All output voltages extend from -0.6 volts (logic "zero") to +3.0 volts (logic "one"), open circuit. These lines may be loaded in any manner without affecting the equipment operation or equivalent generator ouptut voltage. Signals from the experimenter's GSE unit into the communication lines should have the following characteristics:

Logic "Zero"; less than +1 volt,

Logic "one"; over +2 volts,

Source Impedance; 1K to 10K ohms,

Loading; several microamps from - voltage.

An open line is interpreted as a logic "zero" by the Central GSE.

Shift Register - The shift register contains 128 bits of flip-flop shift circuitry. The data from the PCM channel are shifted into this register. When the bits thus stored in the shift register correspond to sixteen words on two rows of the telemetry frame, a gate signal is applied to the corresponding row in the Format Memory. This causes a broadside transfer of data from the shift register to the Format Memory. One-fourth frame (128 bits) later, a gate signal is applied to the next sixteen words in the Frame Memory. This stores the next one-fourth telemetry frame in the Frame Memory. This action occurs twice more in order to store the entire frame of data. This action continues indefinitely with the result that the Frame Memory is continuously updated four times per frame.

Frame Identification - A frame identification word (16 bits) is transmitted with each frame of data. The length of this word allows the specific identification of 65,536 frames without repetition. Thus, the recycle time of the identification word is approximately 35 minutes. The frame identification word is supplied to each experimenter through special connectors located in the Frame Memory console. An eighteen pin printed circuit connector is supplied along with a nonterminated cable and has the following pin connections and wire color code.

Frame Identification Connections

Pin	Connection	Wire Color
1	Bit 1 (least significance)	Brown
2	Bit 2	Red
3	Bit 3	Orange
4	Bit 4	Yellow
5	Bit 5	Green
6	Bit 6	Blue
7	Bit 7	Violet
8	Bit 8	Gray
9	Bit 9	White
10	Bit 10	wht/black
11	Bit 11	wht/brown
12	Bit 12	wht/red
13	Bit 13	wht/orange
14	Bit 14	wht/yellow
15	Bit 15	wht/green
16	Bit 16 (most significant)	wht/blue
17	Blank	-----------
18	Signal Ground	Black

The output potentials and impedances are identical to the outputs of the word memories. Any experimenter desiring subframe information will obtain this data from the frame identification word.

Experimenter's Program Panel- The program panel consists of a plug board (removable) with jumpers which allow the interconnection of any communication line (from the data word circuit board) to either the Time Base, the analog and the PAM data channels from the demodulators or the Check-Out Panel. Thus the experimenters may obtain any timing wave forms desired or any analog or PAM data from the rocket. He, in turn, can generate a Go, No-Go signal which will appear on the Check-Out Panels both in the Central GSE and at the Payload Control Console. The experimenter can in this manner analyze the condition of his experiment through the data link and prevent firing of the rocket if the data indicates trouble.

Timing and Control - The timing and control circuitry obtains signals from the Time Base unit and provides the gate and shift signals necessary for proper operation of the Format Memory unit.

9.8 Check-out Panel

The Check-Out Panel contains various indicators which inform the operator of the condition of various experiments and the transmission and decoding system. Each signal line to the Check-Out Panel controls two lights, one red and the other green. One of these lights will be on and the other off at all times. The red light indicates an unsatisfactory condition and the green light indicates proper operation. A "test" push button switch is provided to illuminate all light bulbs simultaneously. In this manner, the operator may discover any defective lamps. The total quantity of check-circuits will be determined later.

9.9 Print Control (Fig. 9.5) (to be built later)

The Print Control Unit has direct access to the PCM data stream in real time. From this data stream, it selects specific data words and, after due process, prints the data in decimal form at the rate of five words per second. In the check-mode, the Print Control Unit compares data from the PCM data stream to preset values and determines a Go, No-Go condition. The operation of the Print Control Unit is determined by program boards on the front panel. A maximum of 20 words may be selected from the data stream for sequential printing. The selected words do not need to correspond to the words designated in the TM format. For example, a print word may consist of the last two bits of the TM word number 13, extend through TM words 14 and 15 and end with the third bit in TM word 16. The maximum number of bits which can be printed in any single print-out is 27. The minimum is one. In the Check-Out mode, the maximum word length is ten bits because of programming limitations.

Typical Print Sequence - The data from the PCM data stream is shifted into the storage register of the arithmetic unit at the rate of 16,000 bits per second. The initial bit number and the word length are selected on the print program board. The Master Controller and sequence generator initiates and terminates this data entry. Binary equivalents of decimal numbers are then subtracted from the binary word in the storage register.

If the subtraction is successful, the remainder in the adder register is gated into the storage register to replace the original number. This number is reduced by successive subtractions until the remainder is "zero". An unsuccessful subtraction does not alter the number in the storage register. Each successful subtraction is denoted by placing a "one" in the BCD storage register. Conversely, a "zero" is placed into the BCD storage register for each unsuccessful subtraction. Each entry into the BCD storage register is shifted to the left once for each trial subtraction. The trial subtractions begin with the largest decimal component and proceed to the smallest component. A maximum of 32 trial subtractions are required to reduce the largest possible 27 bit binary number. The BCD numbers in the BCD storage register have a 8-4-2-1 code because the subtracted numbers have a 8-4-2-1 code sequence. The BCD storage register then contains eight decimal characters which are entered into the printer inputs. A print command then completes the typical print sequence.

Typical Check-Out Sequence - The typical check-out sequence starts in much the same manner as the typical print sequence. The proper word is selected from the PCM telemetry stream and entered into the storage register of the arithmetic unit. The only difference to this point is a limitation on the maximum number of bits to be examined. The check-out procedure can handle no more than ten bits because of programming limitations. This places no unacceptable restraints upon this function because the experimenter can elect to compare only the more significant or less significant parts of his data words. When the data word is entered into the storage register, the master controller commands one of the two comparison words in the check-out program to be subtracted from the storage register. The "carry" output of the adder circuits indicates that the subtracted word is larger (no carry) or smaller (carry) than the data word in the storage register. The second check word in the check-out program is then compared in a similar manner. One of these check-out words is designated as the upper limit and the other is designated as the lower limit. The results of these two tests are logically combined in the master controller and a final decision is placed in the Go, No-Go data memory. Other data words are then examined in sequence. The maximum number of words which can be examined is ten. The outputs of the Go, No-Go data memory are connected to the Check-Out Panel where they are observed by the operator.

Arithmetic Unit - The arithmetic unit contains a 27 bit storage register, a 27 bit adder, and a 27 bit operand generator. Data are shifted into the storage register directly from the PCM data stream. The timing and control of this shifting operation is controlled by the Master Controller. A binary word is then subtracted from the data word by the adder. This is accomplished by complementing the operand, inserting a "carry in", and adding. The sum outputs of the adder circuits contain the difference of the two numbers if a carry output is generated (successful subtraction). The sum outputs of the adder circuits contain the complements of the difference minus one if a carry is not generated (unsuccessful subtraction). The following example will illustrate the typical operation of the arithmetic unit:

Let the binary number 0110 (6) be placed in the storage register. The trial subtraction of (8), (4), (2), and (1) will be performed in sequence. When the trial is successful, the sum is placed in the storage register for the next trial. If it is not successful, the storage register is unchanged.

1. Storage register 0110
   Operand (8 complement) 0111

   Sum plus "carry in" 1101 + 1 = 1110

   No carry results so trial is unsuccessful.

   BCD storage register entry is "zero"

   BCD storage register 000 0 ←

2. Storage register 0110
   Operand (4 complement) 1011
   Sum plus "carry in" 1← 0001 + 1 = 1 ← 0010

   A carry results and a "one" is shifted into the BCD storage register 000 1←
   The sum is then gated into the storage register for the next operation.

3. Storage register 0010
   Operand (2 complement) 1101
   Sum plus "carry in" 1111 + 1 = 1 ← 0000
   A carry results and another "one" is shifted into the BCD storage register 001 1←
   The sum is then gated into the storage register for the next operation.

4. Storage register   0000
   Operand (1 complement)   1110
   Sum plus "carry in"   1110 + 1 = 1111

   No carry results so a "zero" is entered into the BCD storage register 011 :0:←

The data storage register now contains zero and the BCD register contains (6) 0110 in BCD form.

Thirty-two trial subtractions are necessary for each conversion. In the first trial subtraction the operand is the decimal number 80,000,000 in binary form (complemented). The second trial subtraction is with 40,000,000; then 20,000,000; then 10,000,000. This completes the first decimal digit. The second decimal digit is generated by subtracting 8,000,000; 4,000,000; 2,000,000; and then 1,000,000. This process continues until the 32nd trial subtraction (1) is completed.

The operand generator has three sets of inputs so that the operand may be obtained from three sources: The binary - BCD diode matrix, a maximum limit and a minimum limit on the checkout program.

Binary - BCD Diode Matrix -- The Binary - BCD Diode Matrix generates the operands for the arithmetic unit. A sequence of 32 input signals cause the generation of the binary coded outputs necessary for the conversion. The following table 9.1 shows the outputs of the diode matrix. The Binary - BCD Diode Matrix is contained on one circuit board (P229) along with a diode decoder. The diode decoder takes ten outputs from five successive flip-flop circuits in the Time Base, and causes 32 binary words to be generated in two milliseconds.

Print Program - The Print Program board constitutes a 20 x 20 diode matrix where the diodes are inserted or removed from the matrix at the discretion of the operator. Each of the twenty lines in the matrix are scanned in sequence by the master controller and the column outputs are in turn energized by the diodes in the matrix. The first nine columns determine the opening of a gate which allows the PCM data to be shifted into the arithmetic-unit storage-register. The next five columns program the number of bits to be admitted into the storage register. The next five bits allow the selection of a subcommutated word, and the last bit is a print command signal. The print command

4. Storage register 0000
   Operand (1 complement) 1110
   Sum plus "carry in" 1110 +1 = 1111

   No carry results so a "zero" is entered into the BCD storage register 011 :0:←

The data storage register now contains zero and the BCD register contains (6) 0110 in BCD form.

Thirty-two trial subtractions are necessary for each conversion. In the first trial subtraction the operand is the decimal number 80,000,000 in binary form (complemented). The second trial subtraction is with 40,000,000; then 20,000,000; then 10,000,000. This completes the first decimal digit. The second decimal digit is generated by subtracting 8,000,000; 4,000,000; 2,000,000; and then 1,000,000. This process continues until the 32nd trial subtraction (1) is completed.

The operand generator has three sets of inputs so that the operand may be obtained from three sources: The binary - BCD diode matrix, a maximum limit and a minimum limit on the checkout program.

Binary - BCD Diode Matrix-- The Binary - BCD Diode Matrix generates the operands for the arithmetic unit. A sequence of 32 input signals cause the generation of the binary coded outputs necessary for the conversion. The following table 9.1 shows the outputs of the diode matrix. The Binary - BCD Diode Matrix is contained on one circuit board (P229) along with a diode decoder. The diode decoder takes ten outputs from five successive flip-flop circuits in the Time Base, and causes 32 binary words to be generated in two milliseconds.

Print Program- The Print Program board constitutes a 20 by 20 diode matrix where the diodes are inserted or removed from the matrix at the discretion of the operator. Each of the twenty lines in the matrix are scanned in sequence by the master controller and the column outputs are in turn energized by the diodes in the matrix. The first nine columns determine the opening of a gate which allows the PCM data to be shifted into the arithmetic-unit storage-register. The next five columns program the number of bits to be admitted into the storage register. The next five bits allow the selection of a subcommutated word, and the last bit is a print command signal. The print command signal will include the programmed word in the print sequence when a diode is placed in that position. Otherwise, that word is skipped and the next word programmed for printing is located. The diagram in Fig. 9.6 shows the appearance of the Print Program board.

Check-Out Program - The Check-Out Program board is similar to the Print Program board in selecting a word for the Arithmetic Unit. However, the Check-Out Program does not cause the word to be reduced to decimal form. Instead, the Arithmetic Unit compares the data word to two ten-bit words selected on the second half of the Check-Out Program. The first word is a lower limit and the second is an upper limit. If the data word is less in value than the lower limit, a No-Go light is turned "on" on the Check-Out Panel. Likewise, an upper limit excess is similarly noted. The Check-Out Program board is illustrated in Fig. 9.7.

Master Controller and Sequence Generator - The Master Controller and Sequence Generator performs the following functions:

1. Print Mode
   - 1.1 Shift a data word (selected by the Print Program) into the Storage Register of the Arithmetic Unit.
   - 1.2 Gate the Diode Matrix to cause a sequence of 32 operands to be generated.
   - 1.3 Detect the carry output of the adder and:
     - 1.3.1 If the carry is "1", place a "1" in the BCD Storage Register and transfer the sum output of the adder into the storage register.
     - 1.3.2 If the carry is "0", place a "0" in the BCD Storage Register.
   - 1.4 Shift the BCD Storage Register after each subtraction.
   - 1.5 Stop shifting BCD Storage Register after 32 operations.
   - 1.6 Search Print Program for next word to be printed.
   - 1.7 Halt until ready signal is received from printer.
2. Check-Out Mode
   - 2.1 Shift a data word (selected by the Check-Out Program) into the Storage Register of the Arithmetic Unit.
   - 2.2 Gate the lower limit from the Check-Out Program into the Operand Generator (if programmed).

2.3 If the carry output is "1" turn on the proper flip-flop in the Go, No-Go Data Memory, (Go Condition).

2.4 If the carry output is "0" turn off the same flip-flop (No-Go condition).

2.5 Check the upper limit from the Check-Out Program in the same manner except the Go, No-Go conditions are reversed.

2.6 Search for the next word in the Check-Out Program panel and repeat above operation.

2.7 Gate the Go, No-Go information into the correct flip-flop in the Go, No-Go Data Memory.

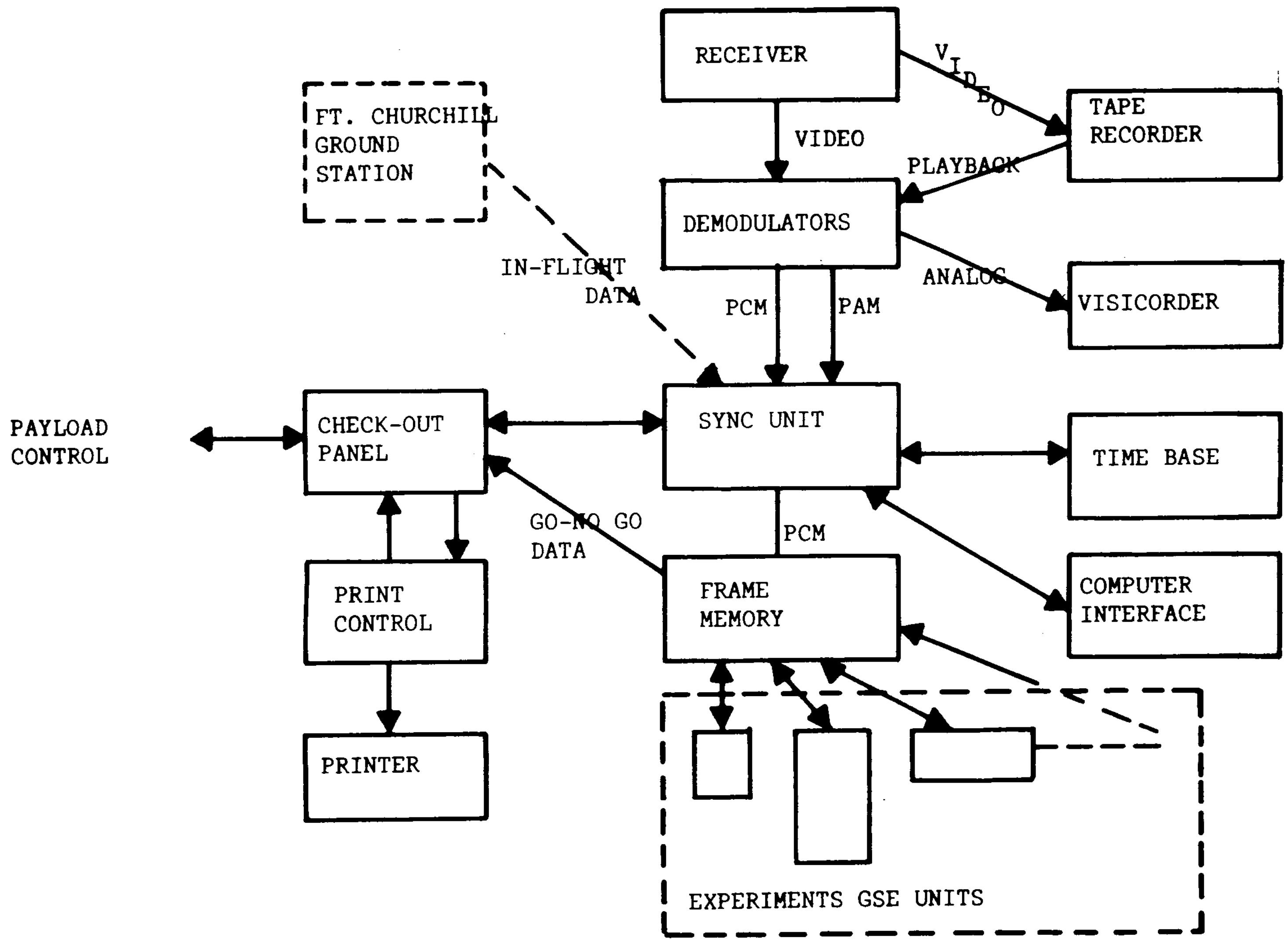

FIGURE 9.1 MAP -- CENTRAL GSE BLOCK DIAGRAM

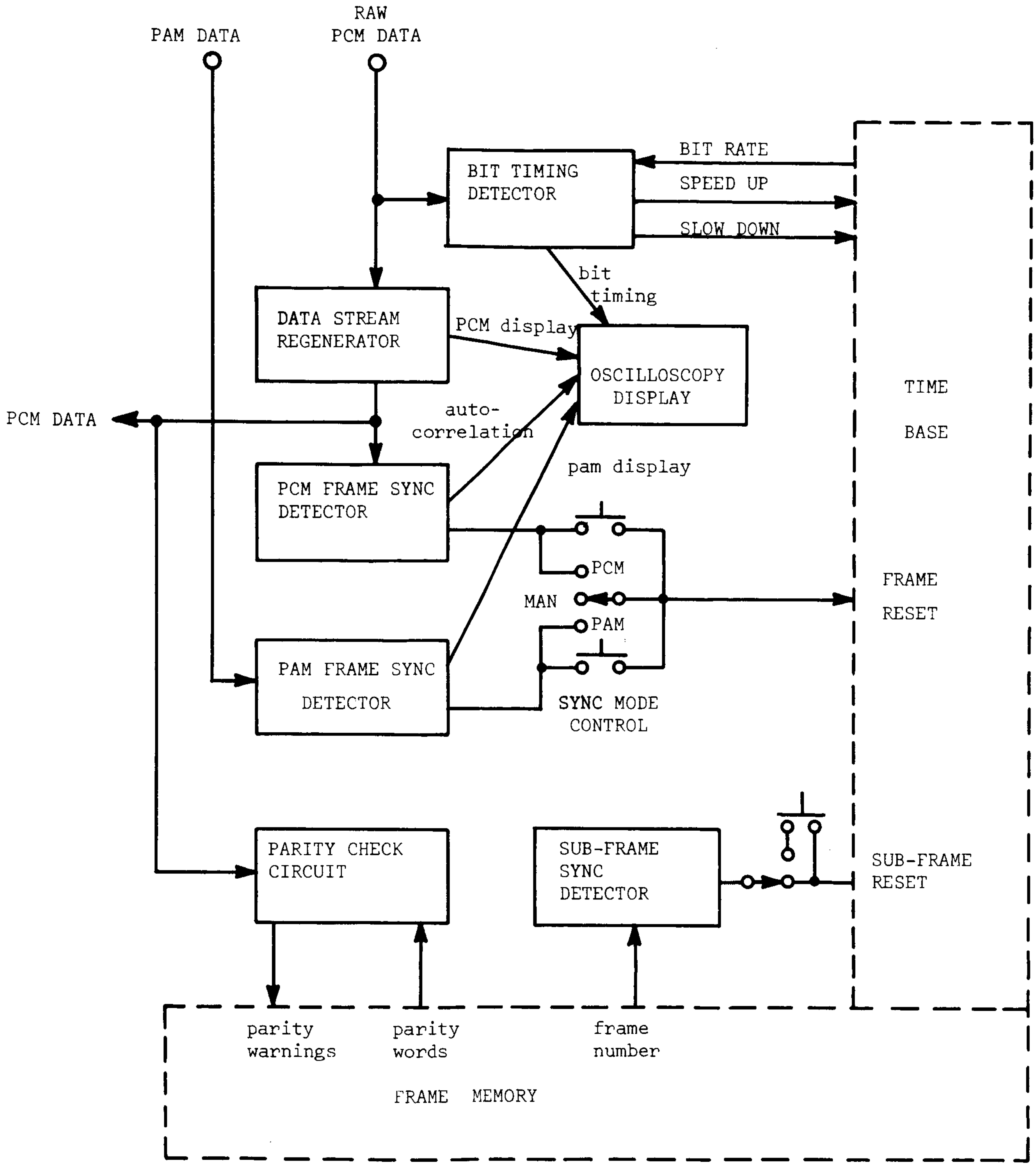

FIGURE 9.2 BLOCK DIAGRAM -- SYNC UNIT

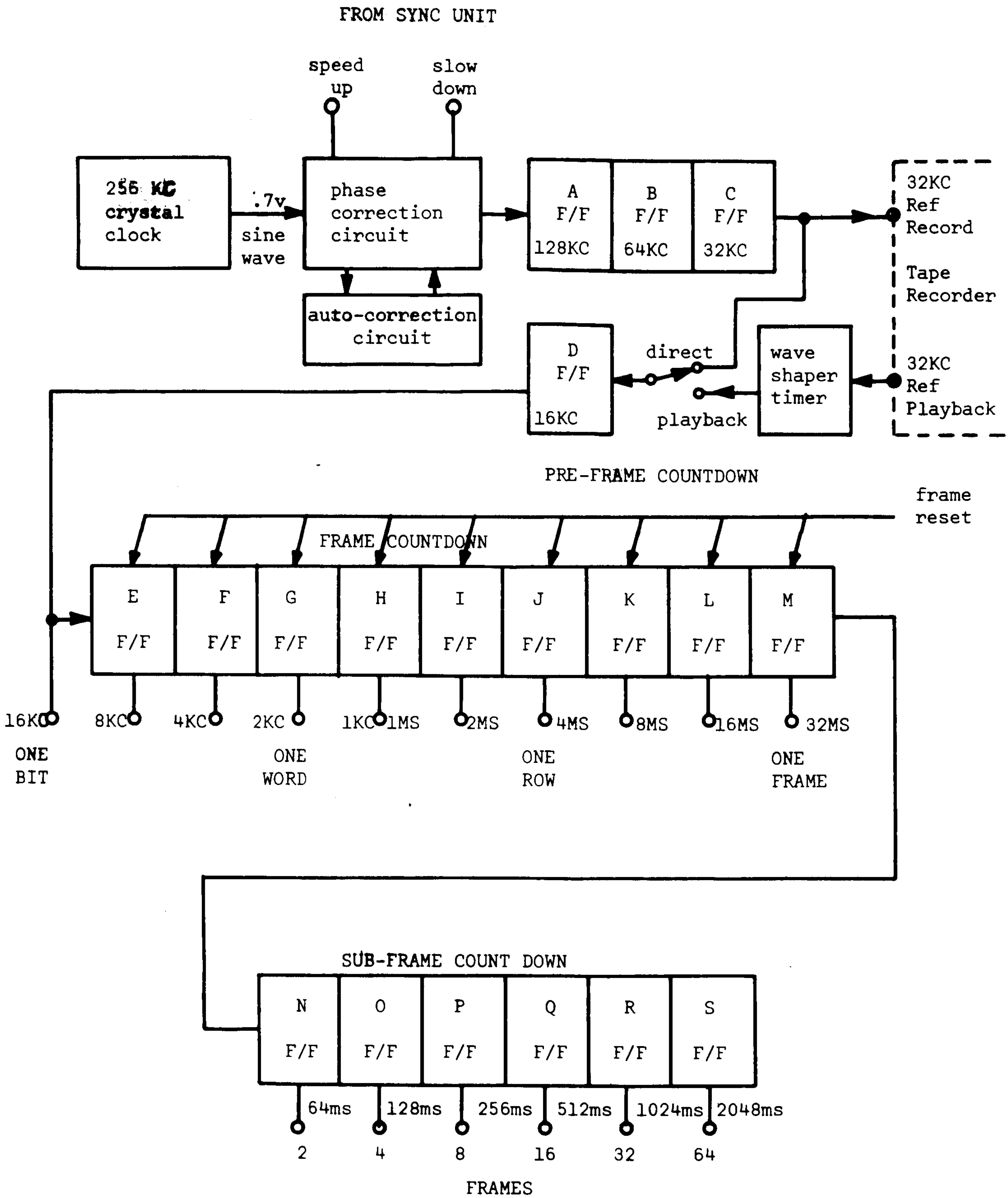

FIGURE 9.3 BLOCK DIAGRAM - TIME BASE

NOTE: WORDS NUMBERED IN OCTAL NOTATION

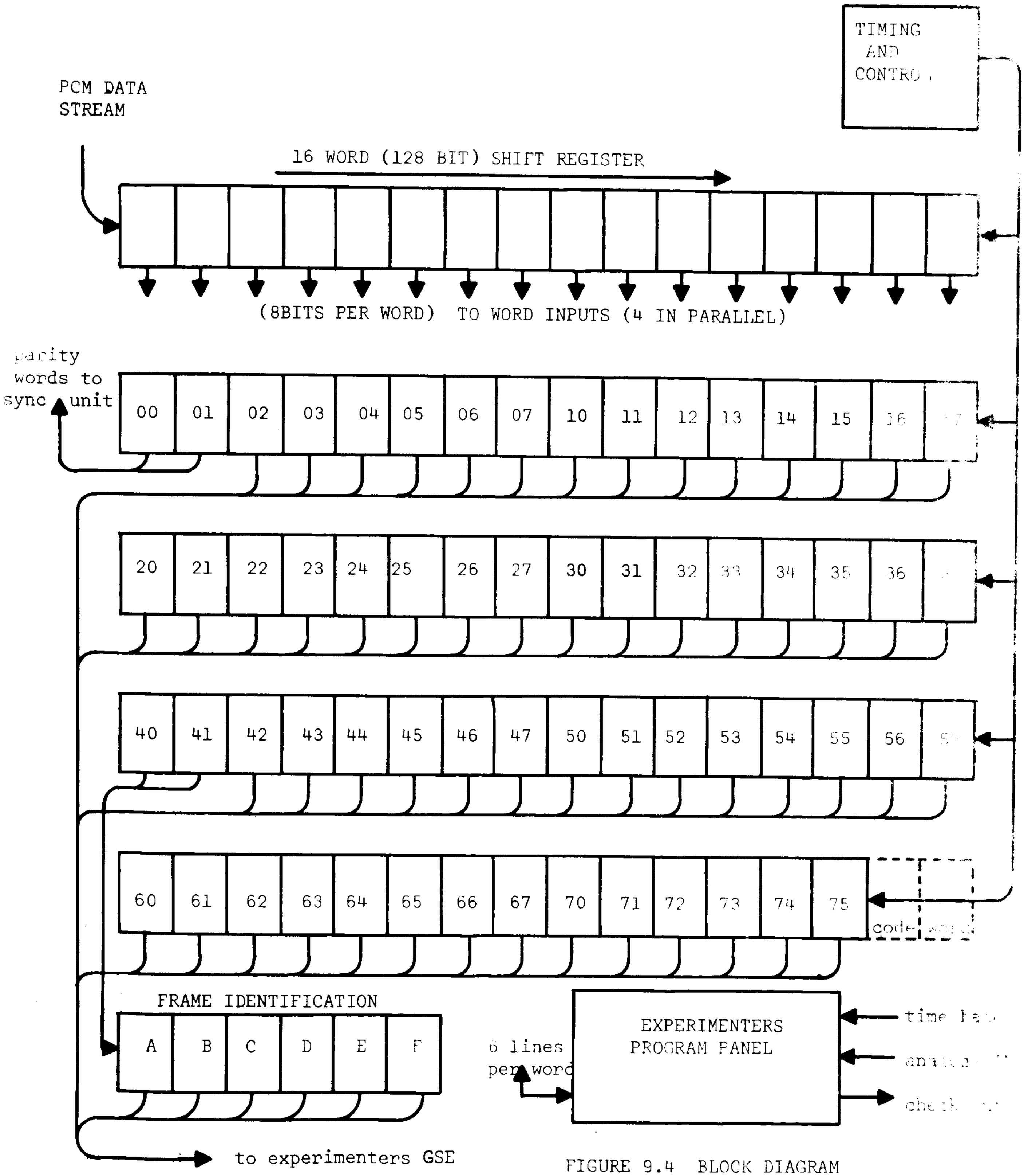

FIGURE 9.4 BLOCK DIAGRAM
FRAME MEMORY

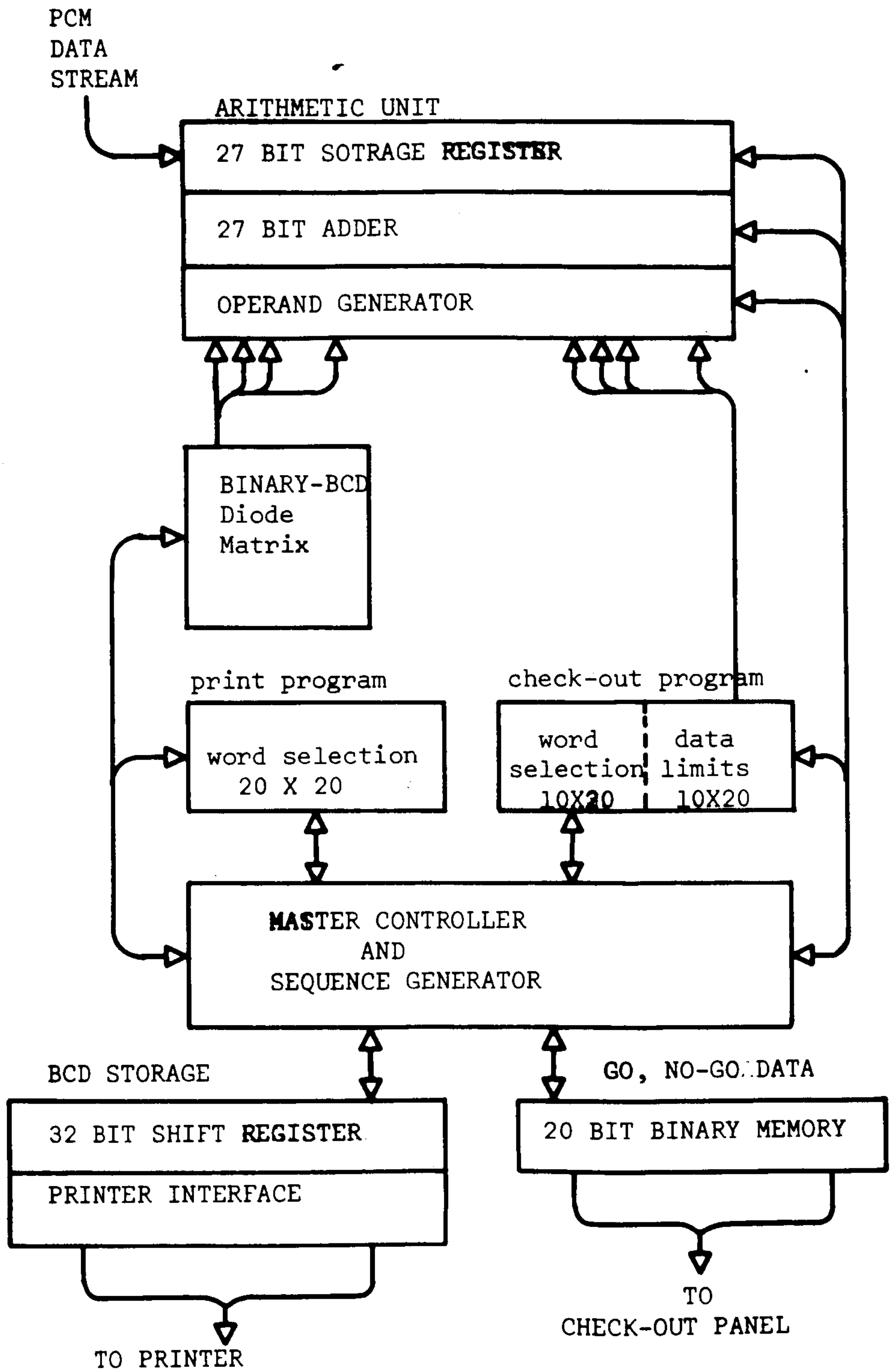

FIGURE 9.5 BLOCK DIAGRAM - PRINT CONTROL

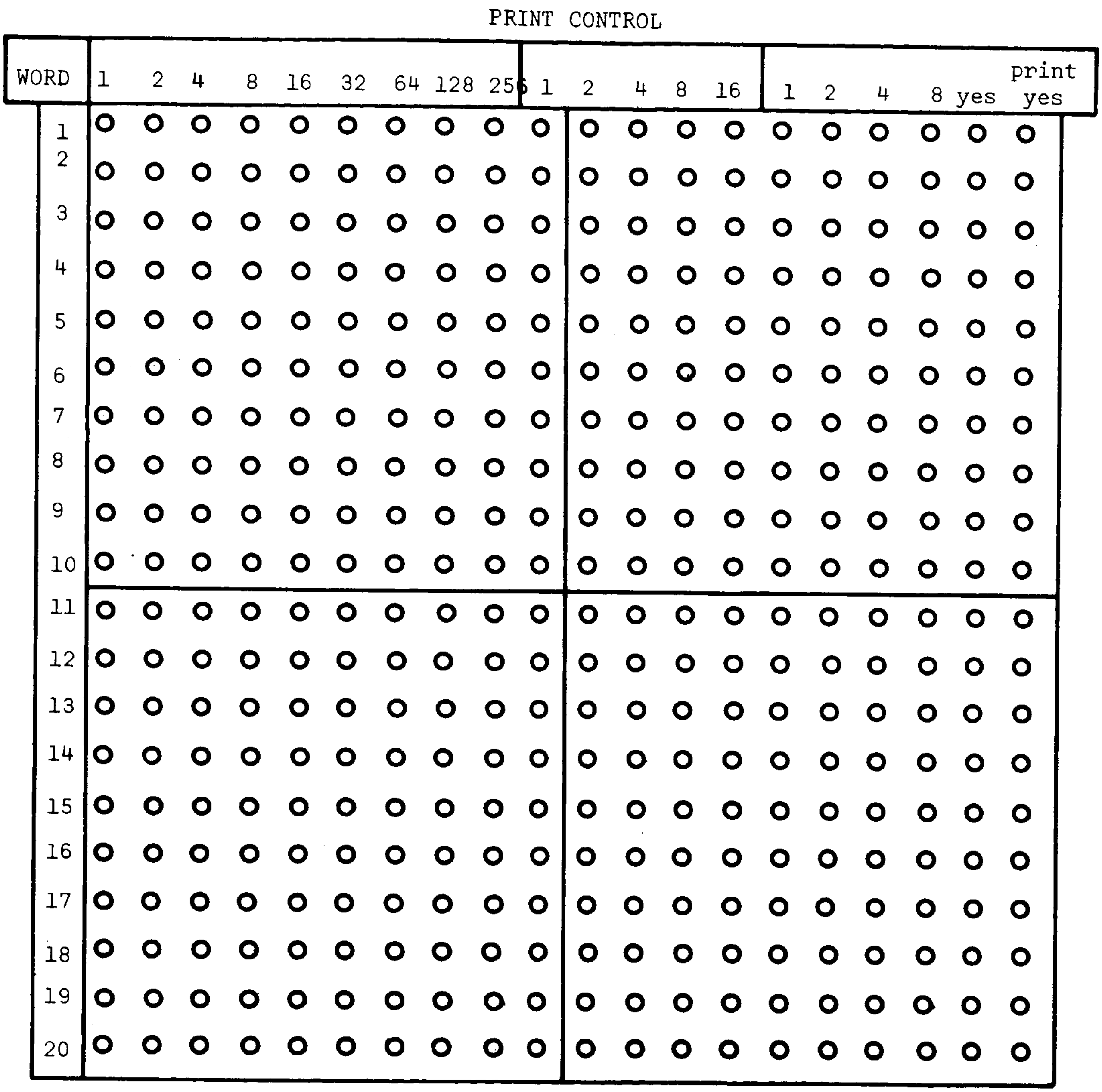

FIGURE 9.6 DIAGRAM: PRINT CONTROL PANEL

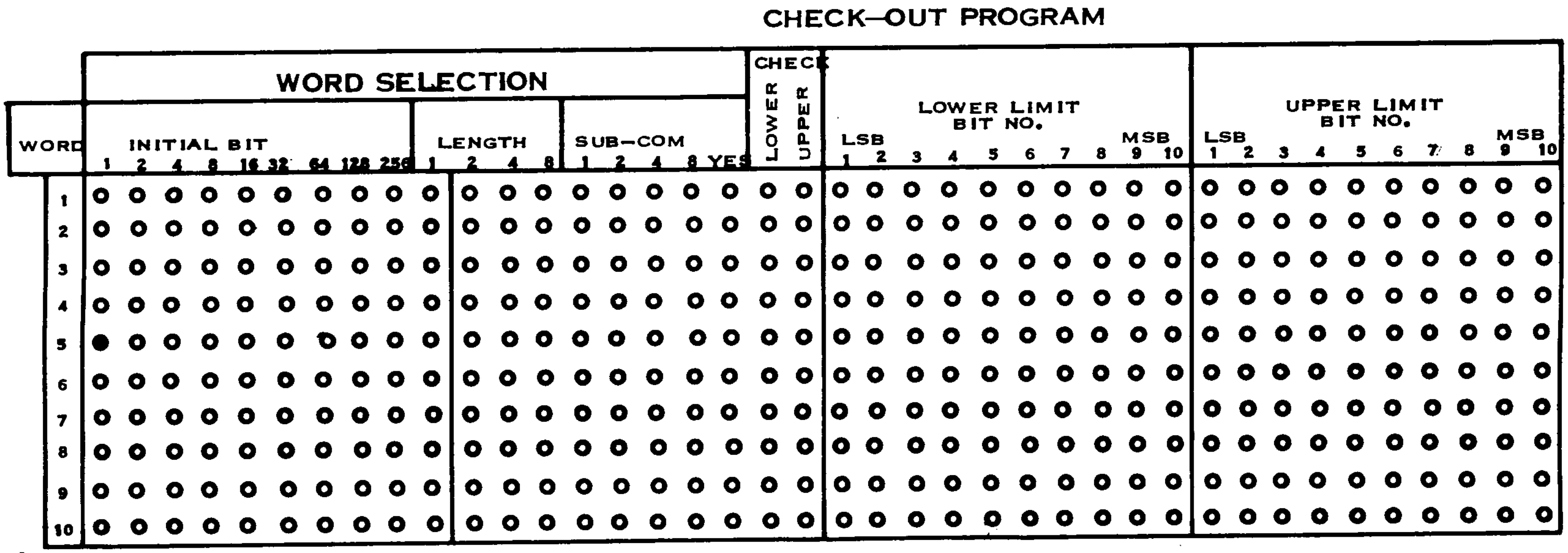

FIG. 9.7 DIAGRAM. CHECK—OUT PROGRAM PANEL

TABLE 9.1

OUTPUTS OF BINARY-BCD DIODE MATRIX

SEQUENCE	BINARY NUMBER	DECIMAL EQUIV.	
1	100110001001011010000000000	80000000	8
2	010011000100101101000000000	40000000	8
3	001001100010010110100000000	20000000	8
4	000100110001001011010000000	10000000	8
5	000011110100001001000000000	08000000	7
6	000001111010000100100000000	04000000	7
7	000000111101000010010000000	02000000	7
8	000000011110100001001000000	01000000	7
9	000000011000011010100000000	00800000	6
10	000000001100001101010000000	00400000	6
11	000000000110000110101000000	00200000	6
12	000000000011000011010100000	00100000	6
13	000000000010011100010000000	00080000	5
14	000000000001001110001000000	00040000	5
15	000000000000100111000100000	00020000	5
16	000000000000010011100010000	00010000	5
17	000000000000001111101000000	00008000	6
18	000000000000000111110100000	00004000	6
19	000000000000000011111010000	00002000	6
20	000000000000000001111101000	00001000	6
21	000000000000000001100100000	00000800	3
22	000000000000000000110010000	00000400	3
23	000000000000000000011001000	00000200	3
24	000000000000000000001100100	00000100	3
25	000000000000000000001010000	00000080	2
26	000000000000000000000101000	00000040	2
27	000000000000000000000010100	00000020	2
28	0000000000000000000001010	00000010	2
29	0000000000000000000001000	00000008	1
30	0000000000000000000000100	00000004	1
31	0000000000000000000000010	00000002	1
32	0000000000000000000000001	00000001	1
	1112345666653591013131110975532l	152 DIODES	

10.0 PAYLOAD CONTROL AND CHECKOUT

N. Eaker

The payload control and checkout equipment is that equipment which actually controls the payload during integration and testing, and also during pre-launch checkout. The payload control equipment consists of the payload control console which includes an automatic go, no-go checkout panel. Figure 10.1 is a simplified block diagram of the complete payload data recovery and payload checkout system. The following description will only be concerned with the payload control console and go, no-go tester.

The equipment is assembled in a commercially available 19-inch wide rack with large rubber casters. The purpose of the console is to provide control functions needed for checkout and calibration of the payload through the umbilical cable. The console is of versatile design, adaptable to the checkout of other payloads with ease.

The heart of the console is an 820 contact patch panel with program board. All functions, including console switches, power supplies, etc. are connected to the patch panel. By means of the removable program board, any combination of switches, meters, etc. can be interconnected to perform a given function. Figure 10.2 is a top view of the patch panel.

10.1 Instrumentation

Power Supplies

Two power supplies are used in the console for the present payload.

(1) Console power supply: This supply is used to supply power to console lamps, relays, and other internal circuits. The supply is patched into the patch panel to be used for any function internal to the console. The supply furnishes a nominal 25.7 volts, variable plus or minus 10%, at 6 amps.

(2) Payload power supply: This supply is also connected to the patch panel for the purpose of supplying power to the payload through the umbilical connector. This is used during preflight checkout and calibration of payload instrumentation. This supply provides for 0-36 volts D.C. at 10 amps. Controls and output are available on console front panel.

Oscilloscope

A Tektronix RM 504 is mounted at the top of the sloping front panel of the console. The oscilloscope input connections are available at the patch panel as well as on the front of the oscilloscope. The oscilloscope has a calibrated sensitivity from 5mv/cm to 20 v/cm with a passband from DC to 450 KHz. It has a calibrated sweep range from 1 usec/cm to 0.5 sec/cm.

Multimeter

A Simpson model 269 multimeter is mounted on the front panel of the console. The inputs to the meter are available either through the patch panel or from the front panel.

DC Voltmeter

A Weston model 1941, 0-50 DC voltmeter is located on the front panel. This meter is available only through the patch panel. During MIP checkout this meter will be used to monitor external payload power.

Running Time Meters

There are two General Electric running time meters located on the front panel. The meters are connected through the patch panel. During MAP checkout one meter will be used to monitor "ON" time for the flight payload. Since relays are used in the instruments it is desired to know their operating cycles. Also, during checkout one running time meter will be used to monitor time on internal power before firing.

General purpose switches

Pushbutton switches with red and green indicator lights are mounted on the front panel and are connected to the patch panel. There are two 3PDT switches with holding coils, four 3PDT momentary switches, and twelve 2PDT switches.

Automatic Telemetry Calibrator

The individual subcarrier oscillators of the telemetry may be calibrated during checkout, and during final pre-flight check by the use of an automatic calibrator built into the console. The controls for the calibrator are available on the front panel, and the calibrator is connected through the patch panel. The calibrator voltages may be monitored by the console meters if desired. The calibrator has three operating conditions as follows:

(1) Automatic: With the control set for automatic operation the calibrator will automatically step from 0 to plus 5v in half volt steps and then step back to zero. The calibrator will continue to cycle as long as the controls are left in the automatic position.

(2) Manual - Continuously variable: During this mode of operation the calibrating voltage may be adjusted continuously from 0 to plus 5v by using the front panel variable resistor.

(3) Manual - Stepped Variable: The calibrator may be set to three fixed steps of 0, 2.5 and 5 volts. This mode of operation allows the subcarrier oscillators to be calibrated for center frequency as well as band edges.

10.2 Automatic Go, No-Go Tester

The purpose of the automatic go, no-go tester is to allow the payload controller a means for obtaining a "quick look" at the status of the payload and instrumentation prior to launch.

The tester is housed in a 19 x 19 x 7 inch rack-mounted enclosure, which is mounted in the payload control console. The tester has 24 go, no-go indicator lamps, 12 of which have associated level detectors. The level detectors may be adjusted for both an upper and a lower level between -5 and +5 volts. If the input signal is between the upper and lower levels a go indication will be produced. The 12 lamp drivers require a level greater than 800 mv to produce a go indication. The maximum input levels should be ± 5 volts on the level detectors and 0 and +5 volts on the lamp drivers. The input impedance on all inputs is greater than 100 K ohms.

All the inputs enter the tester through a 50 pin connector and are connected to a patch panel. The inputs may be patched to lamp drivers, level detectors or they may be patched through the go, no-go tester and on to the payload umbilical. The "thru patching" allows the experimenter to connect to the payload from his own GSE equipment.

A voltmeter is provided on the unit to act as a monitor for any of the inputs and to allow the level detectors to be adjusted, using screwdriver adjustments located on the front panel. An output jack is placed in parallel to the voltmeter and is located on the front panel for digital voltmeter measurements.

A push to test switch is placed on the front panel to allow all the go, no-go lamps and circuits to be checked for proper operation.

One main go, no-go lamp combination is provided to give the status of all functions.

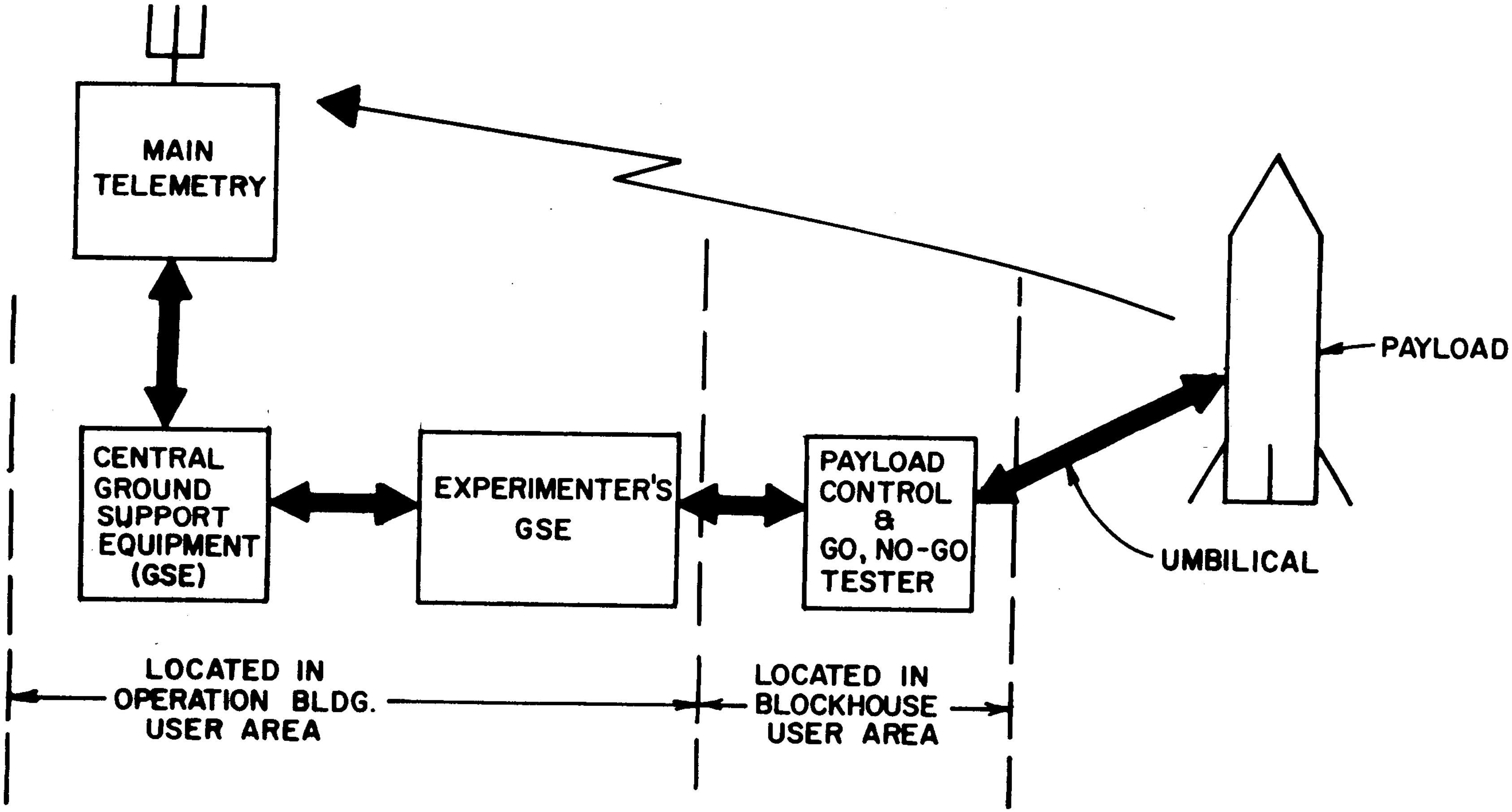

FIGURE 10.1: BLOCK DIAGRAM – M.A.P. PAYLOAD CONTROL SYSTEM

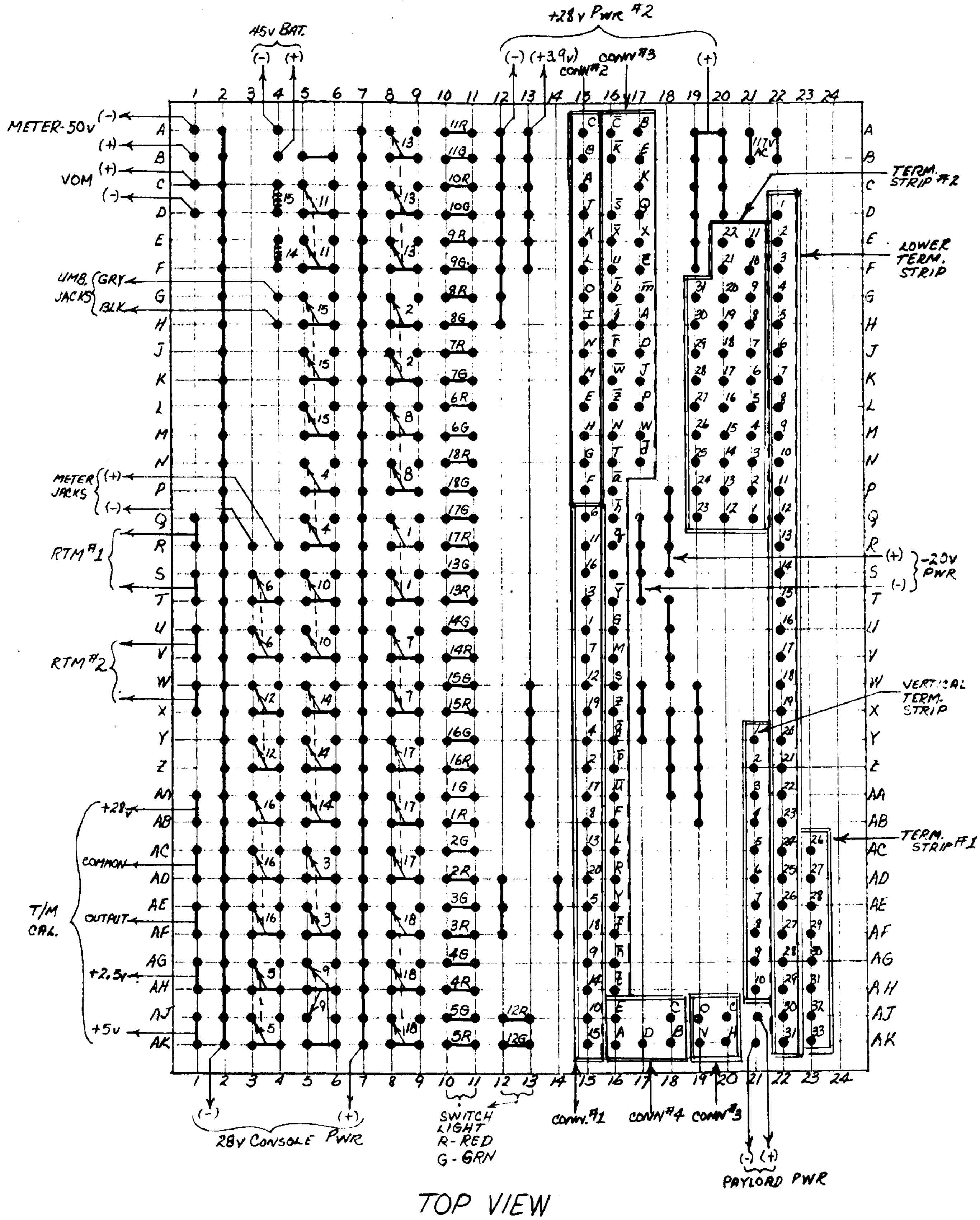

FIG 10. 2 - CONSOLE PATCH PANEL