CENTER FOR SPACE RESEARCH

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Final Project Report

for

OGO-1 and OGO-3

M.I.T. PLASMA EXPERIMENTS S4903

Contract No. NAS 5-2053

30 June 1968

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Prepared by

Center for Space Research

Massachusetts Institute of Technology

for

Goddard Space Flight Center

Greenbelt, Maryland

Final Project Report

for

OGO-1 and OGO-3

M.I.T. PLASMA EXPERIMENTS S4903

Contract No. NAS 5-2053

Goddard Space Flight Center

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1.0 Summary

1.1 Object of the Report

To provide a comprehensive and detailed description of the OGO-1 and OGO-3 Plasma Experiments at the Massachusetts Institute of Technology for the Goddard Space Flight Center under Contract No. NAS 5-2053.

1.2 Scope of Work

1.2.1 Experiment Models

Design, fabricate, test and deliver the following models of a plasma experiment:

a. 1 plasma proton prototype model

b. 1 plasma electron prototype model

c. 3 plasma proton flight models

d. 3 plasma electron flight models

1.2.2 Ground Support Equipment

Design, fabricate, test and deliver five sets of Ground Support Equipment (GSE) for the above experiment models.

1.2.3 Services

a. Provide engineering liaison with the Goddard Space Flight Center.

b. Provide qualified personnel to perform engineering services at the Goddard Space Flight Center and at the John F. Kennedy Space Center as required.

1.2.4 Documentation

Provide detailed technical and financial documentation for the project.

1.3 Conclusions

Flight models of a plasma proton and a plasma electron experiment were launched aboard the first Orbiting Geophysical Observatory (OGO-1) spacecraft on 4 September 1964 and aboard the third Orbiting Geophysical Observatory (OGO-3) spacecraft on 6 June 1966. These experiments have generally functioned in accordance with the design specifications and useful data are still being received.

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5.0 General Description

5.1 Mission Objectives

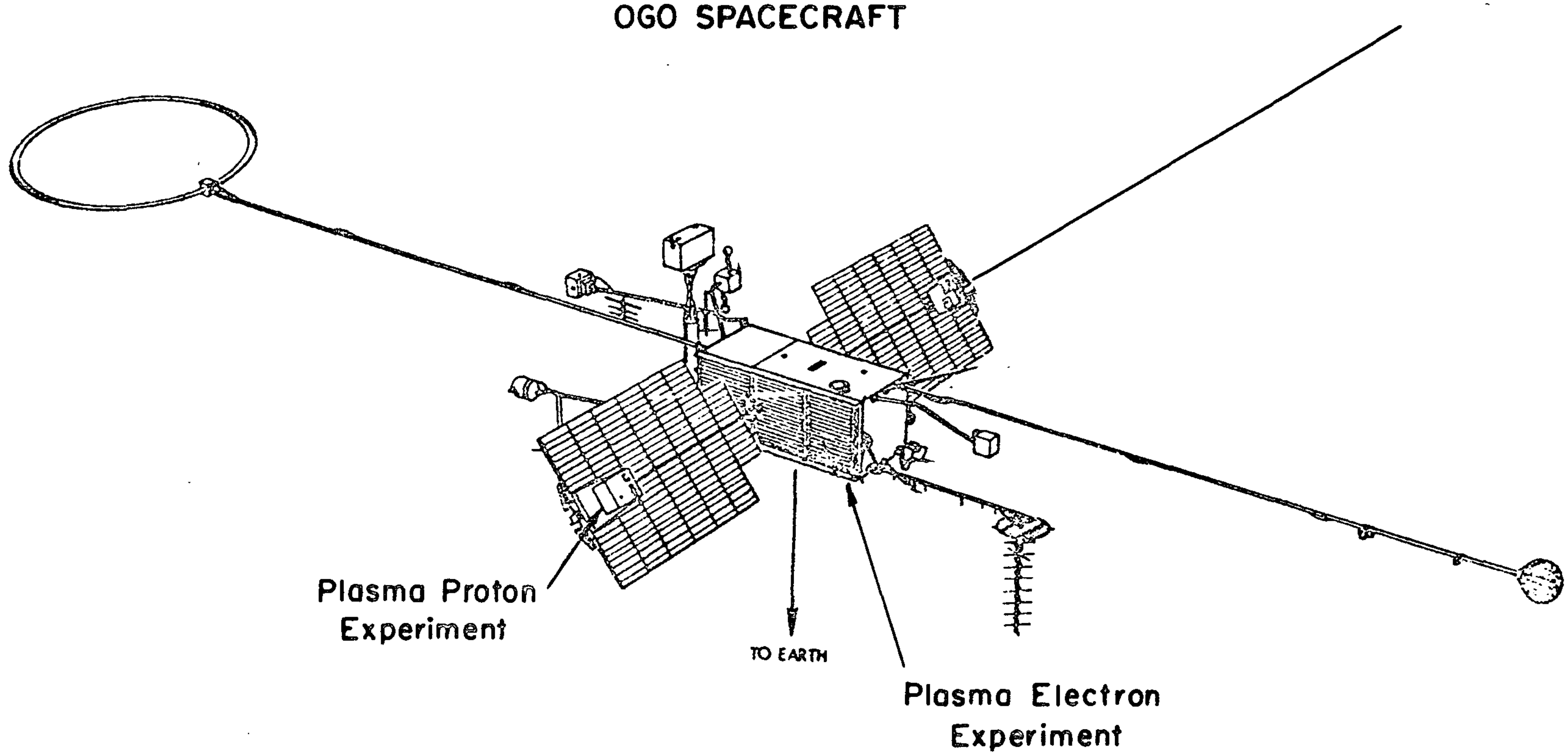
To study the properties of plasma from the sun by measuring proton and electron flux, the energy spectrum, the direction of flux and temporal and spatial variation of these quantities in the energy range from ten electron volts to ten thousand electron volts.

5.2 General

The Massachusetts Institute of Technology plasma protons and electrons (Faraday cup) experiments are designated as Experiment No. 4903. The proton flight model is mounted in the spacecraft (Figure 5-1) solar array and is commonly referred to as the solar-oriented experiment package (SOEP) whereas the electron flight model is mounted on the door panel and is referred to as the main body (MB) experiment. The EOGO-A or OGO-A spacecraft has been designated OGO-1 and the EOGO-B or OGO-B spacecraft has been designated OGO-3. The four flight models remaining after the OGO-1 launch were modified to a considerable extent. In this report, all discussion will be applicable to both OGO-1 and the OGO-3 flight models unless otherwise noted in the text.

The design and circuit layout for the experiments was accomplished by the M.I.T. Lincoln Laboratory and the assembly by the Hazeltine Corporation, New York. Power converters for the OGO-1 units were designed and

OGO SPACECRAFT



EXPERIMENT MOUNTING LOCATIONS

Fig. 5-1

built by Matrix Corporation, New Hampshire; the OGO-3 power converters were designed and built by Mil Associates, New Hampshire. Sensors (Faraday cup) were designed and constructed at the Massachusetts Institute of Technology. Field engineering services were provided by Hazeltine Corporation. In accordance with Contract No. NAS 5-2053, the Massachusetts Institute of Technology designed, constructed, tested and delivered the following units:

5.2.1 <u>Engineering Prototype Models</u>

One plasma proton prototype model and one plasma electron prototype model were built. The mass and size of these units were a very close approximation of the subsequent flight models. They were constructed as fully operational units and were subjected to and passed the environmental tests as outlined in GSFC Specification No. S-4-101.

5.2.2 <u>Flight Models</u>

a. Three plasma proton flight models were constructed. Serial No. 2 was flown aboard the OGO-1 spacecraft; Serial No. 1 was flown aboard the OGO-3 spacecraft; and Serial No. 3 was the back-up unit for the flight models.

b. Three plasma electron flight models were constructed. Serial No. 2 was flown aboard the OGO-1 spacecraft; Serial No. 3 was flown aboard the OGO-3 spacecraft; and Serial No. 1 was the back-up unit for the flight models.

c. All flight models were subjected to and passed the environmental tests as outlined in GSFC Specification No. S-4-201.

5.3 Ground Support Equipment

Five complete units were designed, constructed, assembled and tested. Two units were shipped to the Goddard Space Flight Center and the remaining units were retained at the Massachusetts Institute of Technology for bench testing and calibrating the experiment flight models. One unit was modified to provide a more complete checkout of the OGO-3 units.

5.4 Physical Configuration

Each plasma experiment consists of two physically separate units interconnected by cabling. The larger unit contains all the electronic circuits and the other unit is the sensor (Faraday cup). The plasma proton electronics unit occupies a space approximately 7-1/2" x 7" x 6" and weighs 5.5 lbs. The proton sensor is 6" in diameter and 4" deep; it weighs 1.5 lbs. A cover plate over the front of the sensor contains a 3" diameter hole in the center, allowing plasma to enter. The plasma electron electronics unit occupies a space approximately 8-1/2" x 7-1/2" x 6-1/2" and weighs 5.5 lbs. The electron sensor (Faraday cup) is 4-1/2" in diameter and 3" de it weighs 0.5 lbs. A 3.8" diameter opening allows plasma to enter the sensor.

5.5 Electrical Characteristics

Each plasma experiment was designed to operate off 28 vdc $\pm$ 5.5 v supplied from the spacecraft. The proton model current was 156 ma and the electron model was 123 ma when the instruments were not cycling. A converter in each unit transforms the 28 vdc input to the several dc voltages required to operate the experiment.

6.0 System Description

The two Massachusetts Institute of Technology plasma experiments aboard the OGO spacecraft measure the proton and electron flux densities at several energy levels; in addition, the proton experiment measures the directional properties of the plasma flow. The spacecraft converts the experiment data from analog to digital and telemeters the 8-bit result together with results from the other experiments to the ground receiving stations.

One aim of data reduction is construction of a plasma flow model from profiles of particle flux density vs particle velocity taken at many points throughout the observatory orbit. In the Faraday cup, these two parameters correspond to collector currents for known net aperture area and to mean particle energies as defined by the modulating electrode voltage for known charge and mass. The experiments produce measurements of flux as a function of energy using small overlapping modulation "windows." The proton energy spectrum of interest from approximately 10 electron volts to 10,000 electron volts is divided into 16 windows, and the electron spectrum of interest from approximately 40 to 2,000 electron volts is divided into 4 windows. A collector current measurement is taken for each energy window.

It is impractical to attempt a bulk direction determination for electrons because their relatively large thermal velocity results in a nearly isotropic directional distribution. The heavier protons have a thermal velocity that is small compared with bulk velocity; therefore, proton velocity direction sensing is feasible. The electron sensor (Faraday cup) is a single collector device with axially symmetrical response whereas the proton experiment uses a 3-collector cup for direction sensing within the incidence angle response range. OGO is intended to be a stabilized satellite. Two surfaces in the main body are directed toward and away from the earth and a pair of solar paddles always faces the sun. One of the paddles carries the directional proton sensor and the electron sensor is mounted on the main body surface directed toward the earth.

For direction sensing, each proton measurement cycle requires a fairly complex program. The experiment first measures total sensor response at each energy level (16 steps); it then samples the individual collector output at each energy level for direction determination (48 steps) and finally the "bookkeeping" (4 steps) monitors conditions within the experiment. The program for the electron experiment is considerably simpler in that sensor output readings are taken at 4 energy levels followed by 3 bookkeeping steps. A complete proton cycle requires approximately 40 seconds for the OGO-1 experiment and 20 seconds for the OGO-3 experiment. The electron cycle requires 9.2 seconds for the OGO-1 experiment and 4.6 seconds for the OGO-3 experiment.

6.1 Spacecraft Telemetry Format

Maximum real time telemetry bit rates vary widely for the OGO experiments. Available spacecraft rates are 1 kc, 8 kc or 64 kc. A command from the ground selects the rate consistent with range limitations and information demand. The data transmitter can be turned off by command, stopping real time telemetry if conditions do not permit at least the 1 kc bit rate. In this event data are placed in storage via a tape recorder. The bit rate for storage is always 1 kc but the recorder operates intermittently if demand is low.

The two telemetry systems, real time and storage, do not necessarily receive data from the same experiments. The experiments are multiplexed separately. Experiments in Equipment Group One (EG1) are normally assigned to the real time system, and the Equipment Group Two (EG2) experiments normally feed the storage system. The assignments can be reversed by ground command. Both M.I.T. plasma experiments are active for real time telemetry and storage; therefore, they have format positions in both equipment groups, but the electron experiment is turned off at the two higher real time bit rates. The proton experiment operates at a constant rate even at the higher bit rates.

Figure 6-1 shows a single frame of the spacecraft time-division telemetry format. Each frame consists of 128 "slots," each slot representing the time interval taken by 9 bits at the prevailing bit rate. The labeled slots are those occupied by the plasma experiments. EG1 and EG2 frames are identical and the same slots are assigned. Electron experiment is indicated by the slot prefix E and proton experiment is indicated by a P. Each slot has two pulses available to the analog experiments, namely an index pulse (I) which triggers a measurement step and a word pulse (W) which reads the measurement data out to telemetry. The numbers in the slots show the experiment indexing and sampling order in relation to the left-to-right, top-to-bottom frame scan. At the 1 kc bit rate, 17 slots or 153 milliseconds always elapse between an index pulse and the corresponding word pulse.

At higher bit rates, EI pulses arrive more frequently but are disregarded. Only the EW pulses at the 1 kc bit rate

1	2	3	4	5	6	7	8	9	10 PW	11	12	13	14	15	16
17	18	19 EI	20	21	22	23	24	25 PI	26	27	28	29	30	31	32
33	34	35	36 EW	37	38	39	40	41	42 PW	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57 PI	58	59	60	61	62	63	64
65	66	67	68	69	70	71	72	73	74 PW	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89 PI	90 EI	91	92	93	94	95	96
97	98	99	100	101	102	103	104	105	106 PW	107 EW	108	109	110	111	112
113	114	115	116	117	118	119	120	121 PI	122	123	124	125	126	127	128

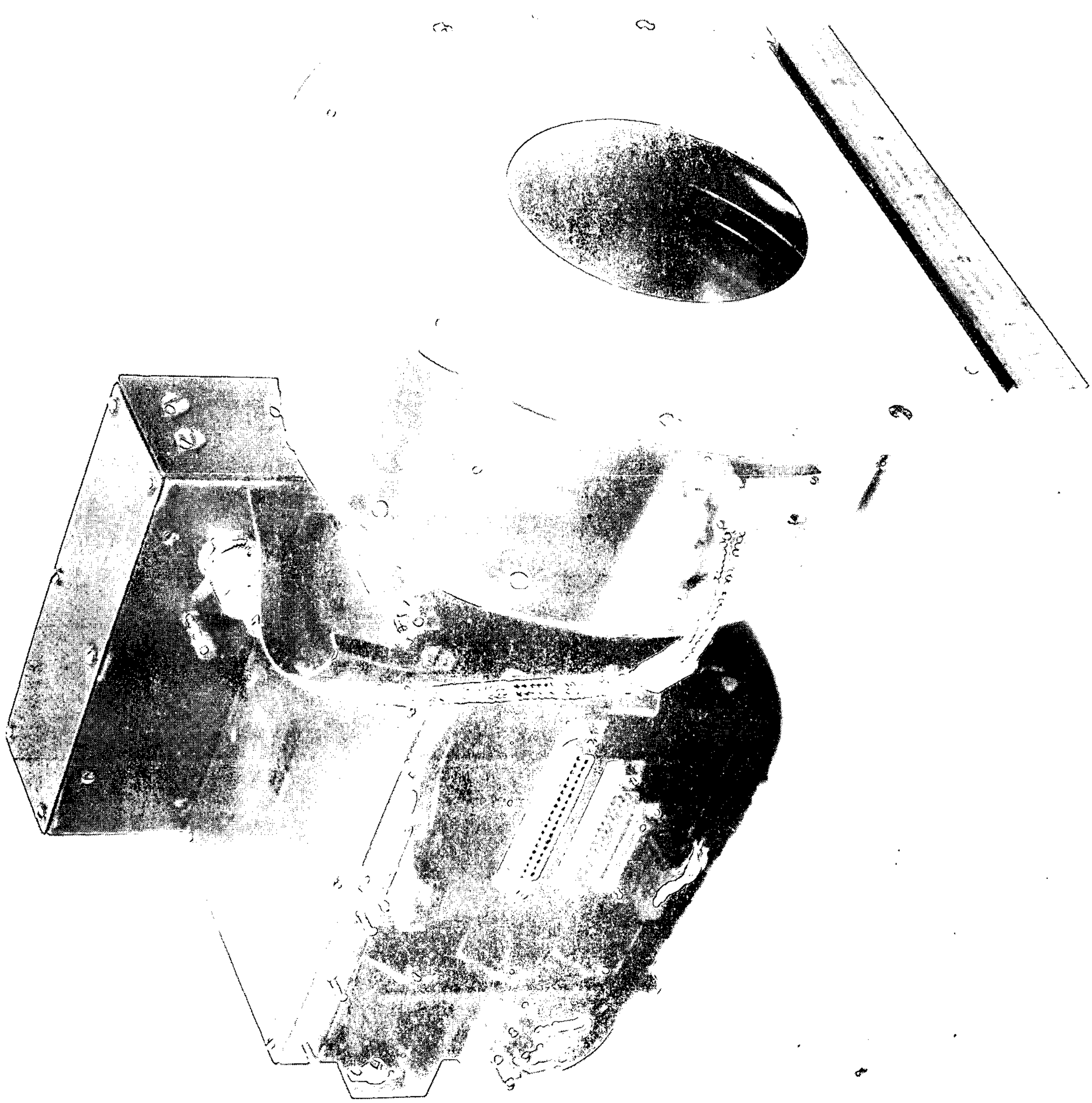
OGO TELEMETRY FORMAT
Equipment Groups 1 & 2
Fig. 6-1

produce any meaningful data from the electron experiment. In the proton experiment, indexing is more complex. The logic permits a constant stepping rate regardless of the bit rate by responding only to every eighth PI pulse at 8 kc and to every 64th PI pulse at 64 kc. PW pulses occur at a frequency proportional to the bit rate so the spacecraft samples the experiment output every 36 milliseconds (ms) at 8 kc and every 4.5 ms at 64 kc. The correct output is determined from the multiple samples by the data reduction program (see section 11).

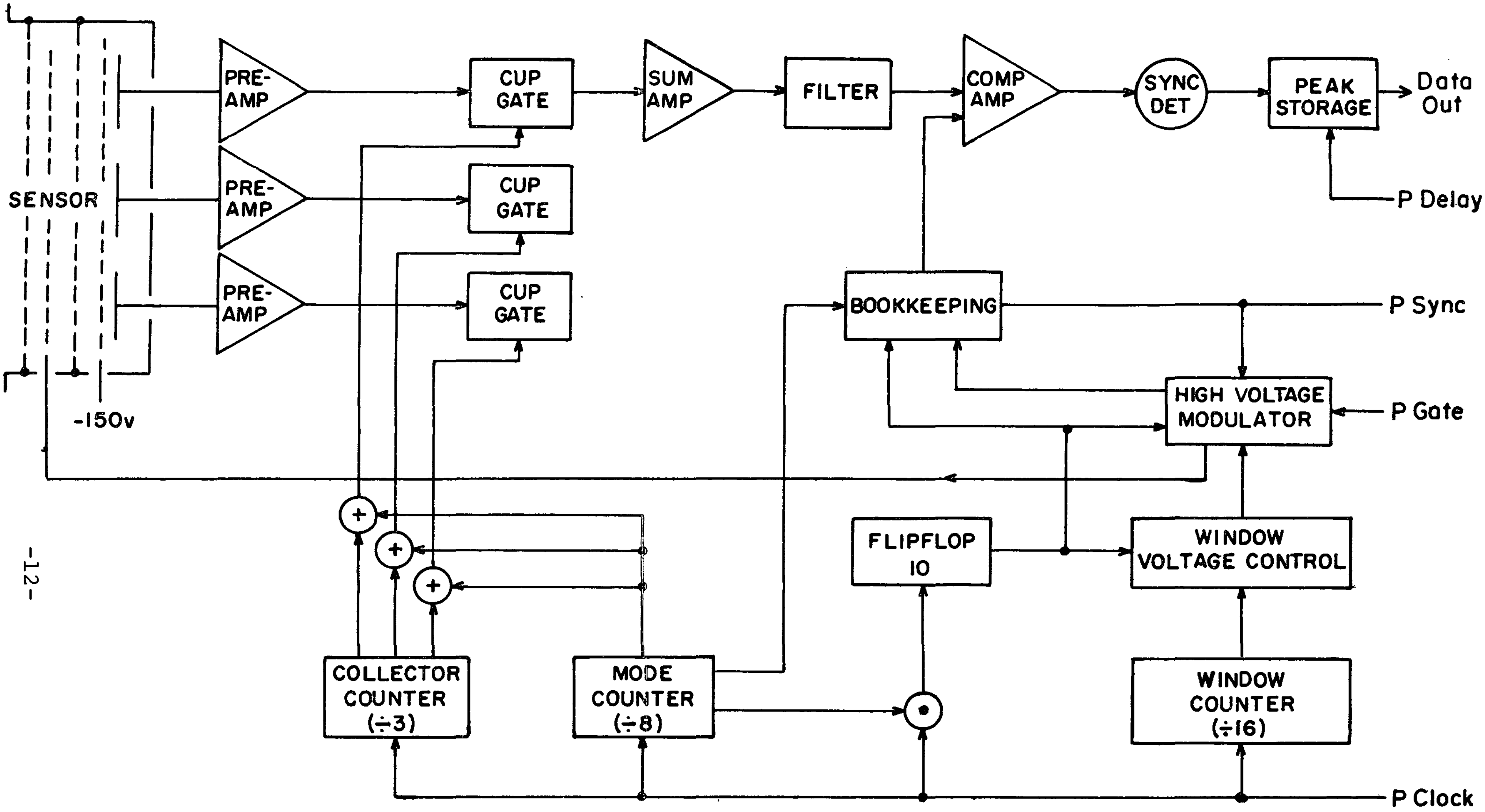
6.2 Plasma Proton Experiment

The experiment (Figure 6-2) consists basically of a plasma sensor, a variable modulating-electrode voltage supply, a measurement chain that converts the small collector currents to analog voltages suitable for the spacecraft analog-to-digital converters and logic that interfaces the experiment to the vehicle and governs the measurement and bookkeeping program. The logic is discussed in detail in section 7 and the measurement chain circuits are covered in section 8.

Figure 6-3 is the experiment block diagram. The modulator generates a square wave signal superimposed on a positive direct-current (dc) voltage. The average voltage output is variable in 16 steps and is governed by the window voltage control. The ratio of peak-to-peak square wave amplitude or energy window to mean dc is fixed to ~ 0.25. The gate signal from the timing chain turns on the modulator, and the internally generated sync governs the frequency of the alternating-current (ac) component.



PLASMA PROTON EXPERIMENT
Fig. 6-2



PROTON EXPERIMENT BLOCK DIAGRAM

Fig. 6-3

The modulator output is applied to a grid in the proton sensor to modulate the particle stream. The resulting ac collector current variations are amplified in three preamplifiers whose outputs are applied to a set of analog gates. In the all-collector measurement mode, the three gates are enabled together. In the sequential-collector measurement mode, they are selected in the order 2-3-1 as governed by the collector counter. The gate outputs are summed to a single ac signal, amplified and fed to a bandpass filter. The filter, peaked at the sync frequency, attenuates noise outside the passband to produce a relatively pure ac voltage of the summed collector currents. The transfer function of the compression amplifier following the filter closely approximates a logarithmic characteristic over the anticipated four-decade dynamic range of the signal. It accommodates this wide range to the spacecraft telemetry equipment by providing an output change of about one volt for every decade input change. A second input to the compression amplifier comes from the bookkeeping circuits.

The synchronous detector receives the compressed ac signal and demodulates it using the sync frequency as a reference. Signal phasing is such that the data output is positive to conform to spacecraft requirements. The detector serves the additional purpose of further reducing system noise bandwidth. Its output drives the peak storage circuit in the OGO-1 unit which makes the analog data available to the spacecraft. At the beginning of each measurement step, a dump gate discharges the previous measurement data from the storage circuit. In the OGO-3 experiments, a readout circuit was substituted for the peak storage circuit.

Fixed frequency amplitude response of the chain is somewhat nonlinear due to phase variations with amplitude from various effects such as minority carrier storage, inherent phase characteristics of the twin-T filter and slight asymmetry in the clippers preceding each compression amplifier stage. The synchronous detector interprets such slight phase shifts as a small change in center frequency, causing predictable amplitude nonlinearity. In order to take greatest advantage of the noise rejection properties of the filter which are most needed at low levels, the twin-T filter is adjusted to the system center frequency under minimum signal conditions using a test signal at the low end of the dynamic range.

The 69-step experiment program consists of two measurements, 4 bookkeeping and a single reset mode. The measurement modes use the entire measurement chain to develop the proton current analog signal. The bookkeeping modes consist of 3 self-check levels and a marker which in the OGO-1 unit are fed into the measurement chain at the compression amplifier input. The OGO-3 unit was changed so that only one of the bookkeeping signals is fed to the compression amplifier input; the other three are fed directly to the readout circuit.

The reset mode is not intended to produce an analog signal. In order of occurrence, the modes for the OGO-1 unit are:

a. All collector (total flux): measurement of the summed outputs of the three cup collectors at each of 16 energy levels (16 steps).

b. Sequential collector (flux direction): measurement of each collector output in turn, also at each of 16 energy windows (48 steps).

c. High voltage: check of ac voltage at the modulator output transformer primary at a selected energy window (1 step).

d. Temperature: measurement of ambient temperature within the experiment package (1 step).

e. Marker: generation of cycle identification level for use in data reduction (1 step).

f. Calibrate: generation of a standard signal level (1 step).

g. Reset: redundant counter clear before start of next program cycle to confine any loss of synchronization to one cycle (1 step).

The mode order was changed in the OGO-3 units as follows:

a. All collector (16 steps)

b. Sequential collector (48 steps)

c. High voltage (1 step)

d. Marker (1 step)

e. Temperature (1 step)

f. Calibrate (1 step)

g. Reset (1 step)

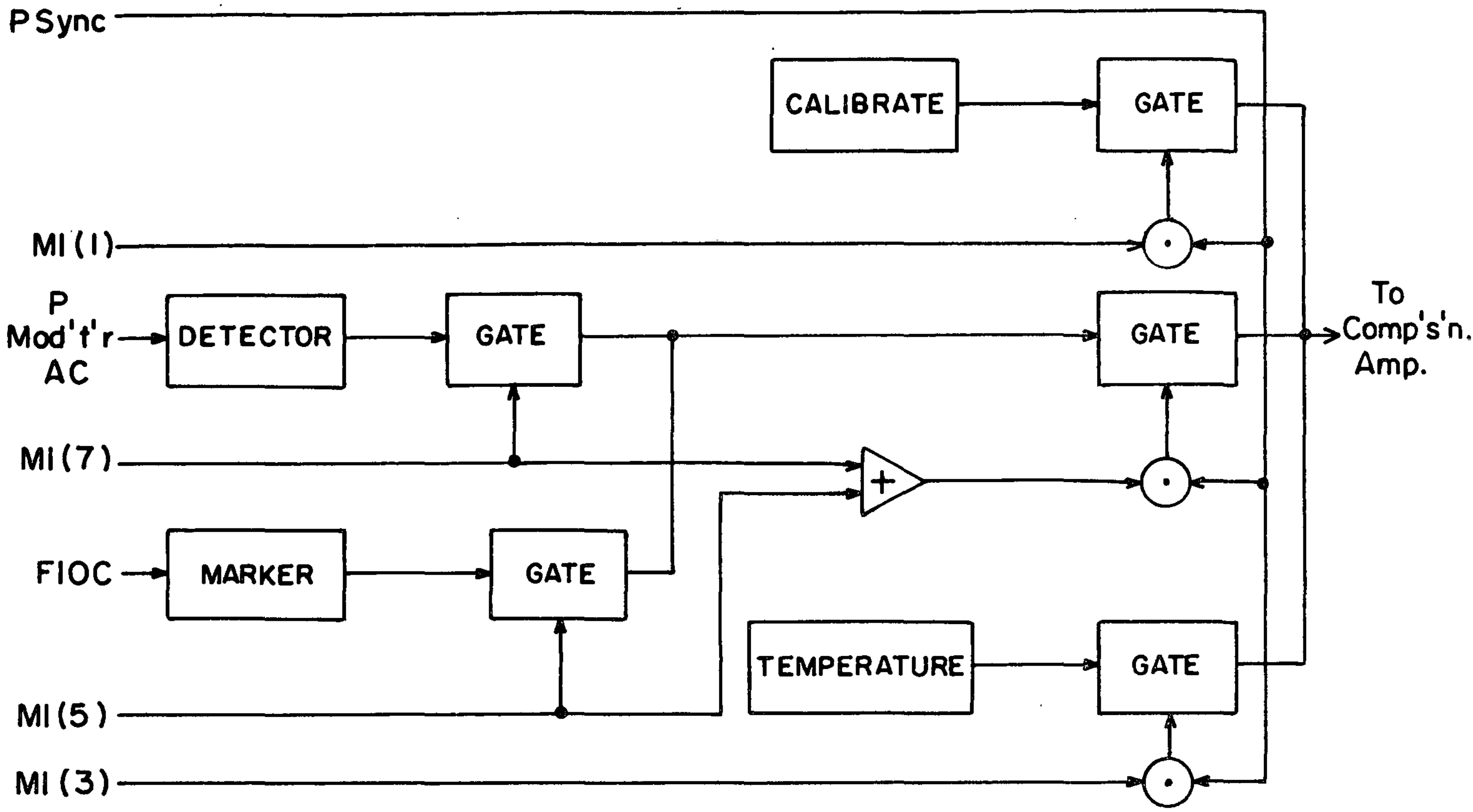
The high voltage bookkeeping is a check of the high voltage rectifier output. An entire measurement sequence comprises two such program cycles end to end. In the OGO-1 unit, the second cycle is identified by a reduced marker and the modulator is gated off to reduce average spacecraft power consumed by the experiment. Therefore, only the temperature, marker and calibrate data are meaningful. The second cycle of the OGO-3 unit is identical in all respects to the first cycle.

The experiment mode counter executes a complete 8-count once per program or half sequence. The collector counter is a divide-by-3 circuit that enables the analog preamp gates one at a time to provide the sequential-collector measurements. In the all-collector mode, the mode counter overrides these individual selections and gates the three preamp outputs together into the summing amplifier. The divide-by-16 window counter drives the window voltage control. It makes two complete counts per half sequence, once in the all-collector mode and once at one-third the rate in the sequential-collector mode.

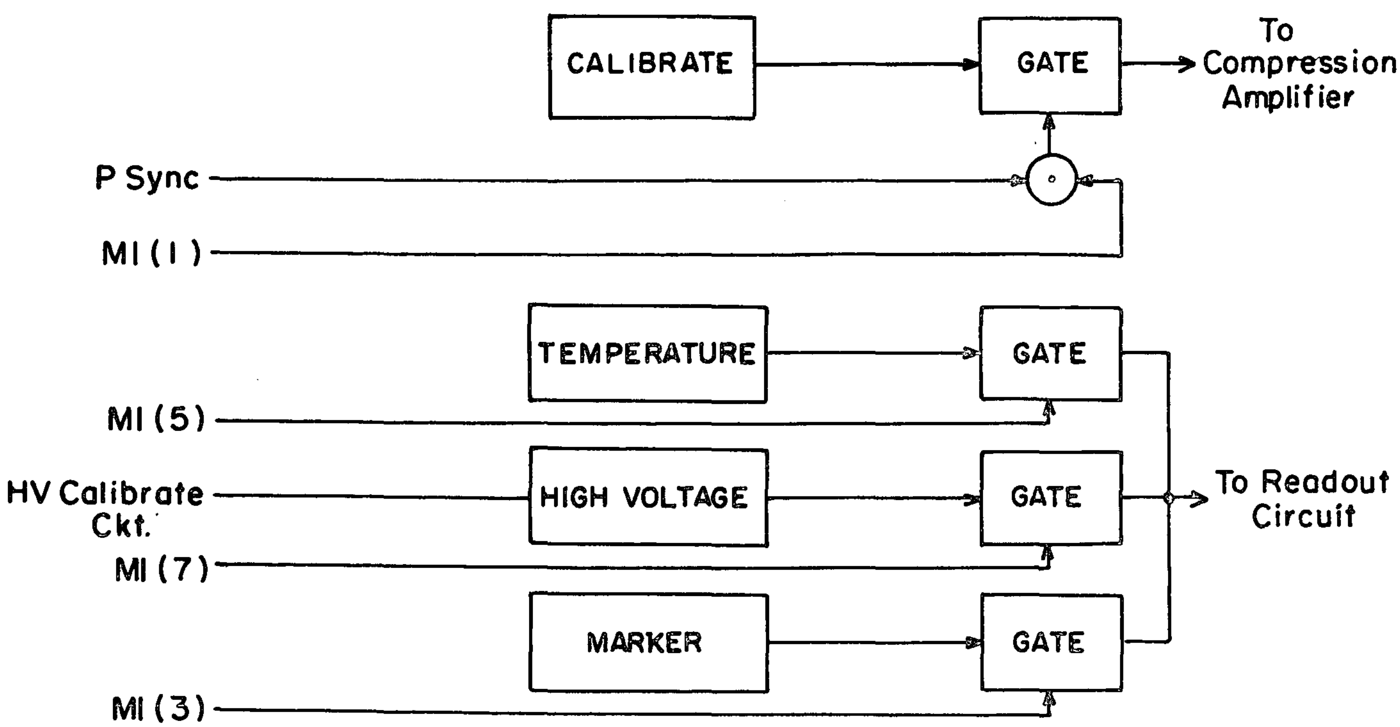
The window voltage control is a logarithmic digital-to-analog converter supplying modulator primary power in 16 logarithmically related steps according to the input count.

The mean levels at the high voltage output range from ∿ 15 volts to ∿ 7 kilovolts. The ratio of the mean levels of any two adjacent windows is approximately 1:1.4. Once per cycle the mode counter complements sequence flipflop (F10). The F10 output gates the power control logic and changes the marker amplitude to generate the full two-cycle sequence in the OGO-1 experiment. The OGO-3 differs in that F10 has no effect on the power control logic or the marker amplitude.

Figure 6-4 shows the bookkeeping system in simplified form. For the OGO-1 experiment, the bookkeeping circuits supply to the compression amplifier a sequence of 4 ac signals corresponding in amplitude to the modulator ac voltage, the experiment temperature, the calibration or standard signal and the marker levels. Except for the modulator output, the bookkeeping signals originate as dc. The calibrate reference signal is obtained from a zener diode, the marker reference from a voltage divider controlled by F10 and the temperature signal from a thermistor driven by a constant current source. A detector produces a dc analog from the modulator output. The four levels are gated by the mode counter and chopped at the sync frequency to provide a usable signal to the ac-coupled compression amplifier and detector. For the OGO-3 experiment, only the calibrate signal is supplied to the compression amplifier. The high voltage bookkeeping pulse is taken from the high voltage



OGO-1 PROTON BOOKKEEPING



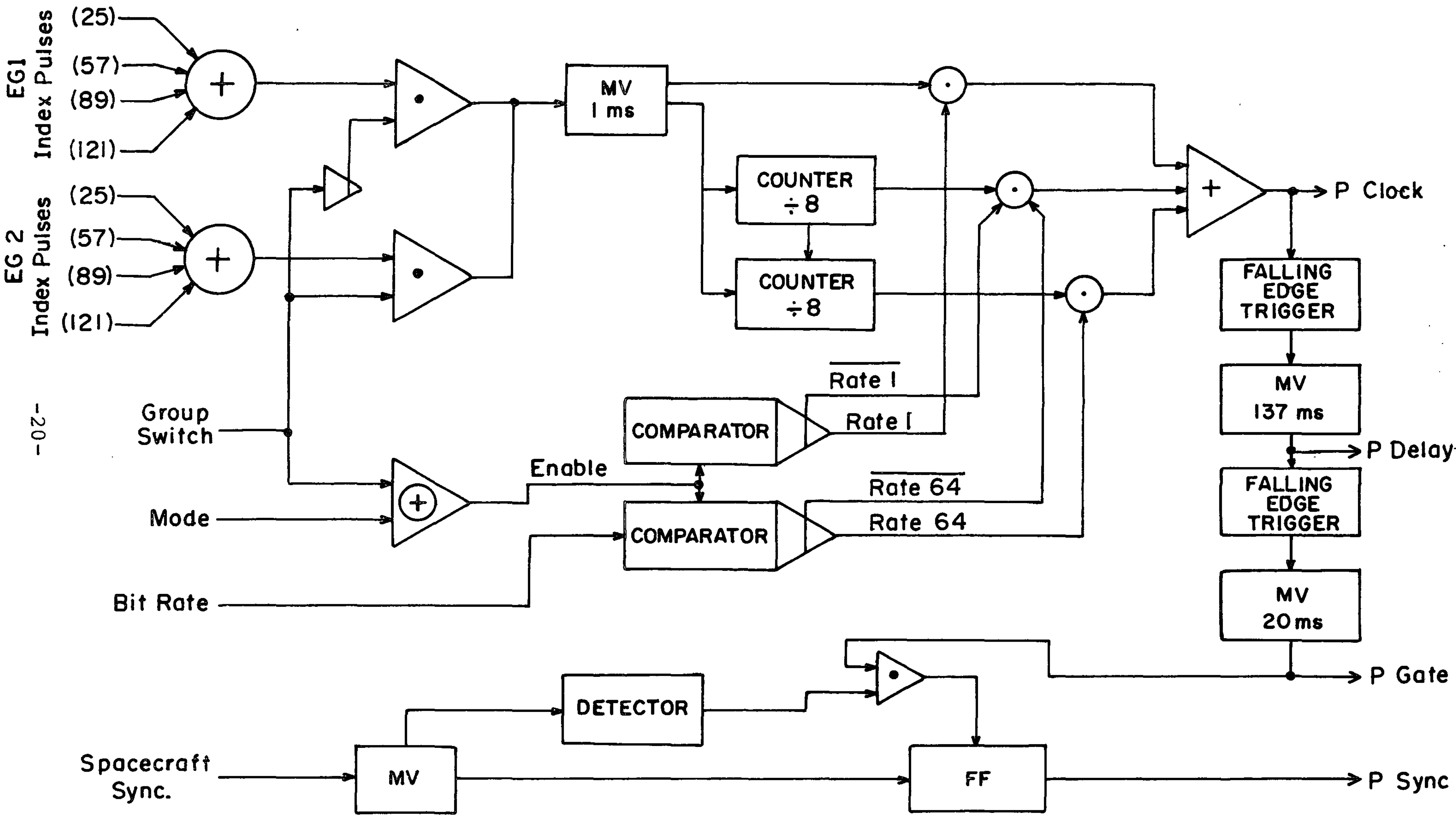
OGO-3 PROTON BOOKKEEPING

Fig. 6-4

rectified output rather than the modulator. The temperature, marker and high voltage signals are routed directly to the readout circuit.

Figure 6-5 shows the experiment interface. The group switch signal assigns the experiment to an equipment group by selecting one of two groups of ORed PI pulses. The leading edge of each selected pulse triggers the count multivibrator (MV). The experiment operates at a fixed stepping rate of 288 ms corresponding to the lowest spacecraft bit rate of 1 kc. To generate constant-rate clock pulses from variable-rate index pulses, every 8th and every 64th count pulse is made available separately by two cascaded divided-by-8 counters. Selection among the direct and counted down pulses for system clock generation is determined by the vehicle bit rate signal. A pair of comparators generate gating levels from the 3-state bit rate signal to select increasing count division with increasing bit rate.

The real-time bit rate signal is supplied from the spacecraft whether the experiment is feeding real-time telemetry or not; therefore, it must be disregarded for storage telemetry which always operates at 1 kc. In case of malfunction in the real-time telemetry system, the spacecraft logic can assign all real-time experiments to storage by exchanging group assignments. The mode signal indicates whether the equipment group (EG) connections to telemetry are normal or cross-strapped. The assertion levels of the



PROTON INTERFACE

Fig. 6-5

switch and mode signals differ only for real time and are both high or low for storage. The comparators are disabled by the exclusive OR circuit for storage telemetry, preventing unnecessary stepping rate division. For a chart of the different types of operation, see Figure 6-6.

In addition to stepping the experiment logic, the falling edge of the 1 ms clock pulse initiates the event-timing sequence by triggering the 137 ms delay MV which provides the main measurement delay interval. The delay MV falling edge in turn triggers the 20 ms gate MV. In the OGO-3 experiment, the 137 ms delay MV was changed to 100 ms and the 20 ms gate MV was changed to 65 ms.

The sync signal is derived from the spacecraft sync reference, frequency is doubled in an astable multivibrator and divided by 2 to the original frequency by a flipflop. If the MV failed, the flipflop would latch causing undue power consumption and possible component burnout in the modulator or detector. The enabling AND gate to the flipflop prevents this condition by turning off flipflop power when excitation fails as determined by the detector; therefore, neither flipflop output can then be asserted. The second input to the AND gate is the 20 ms (or 65 ms) gate because the sync frequency is needed only during the measurement interval.

6.3 Plasma Electron Experiment

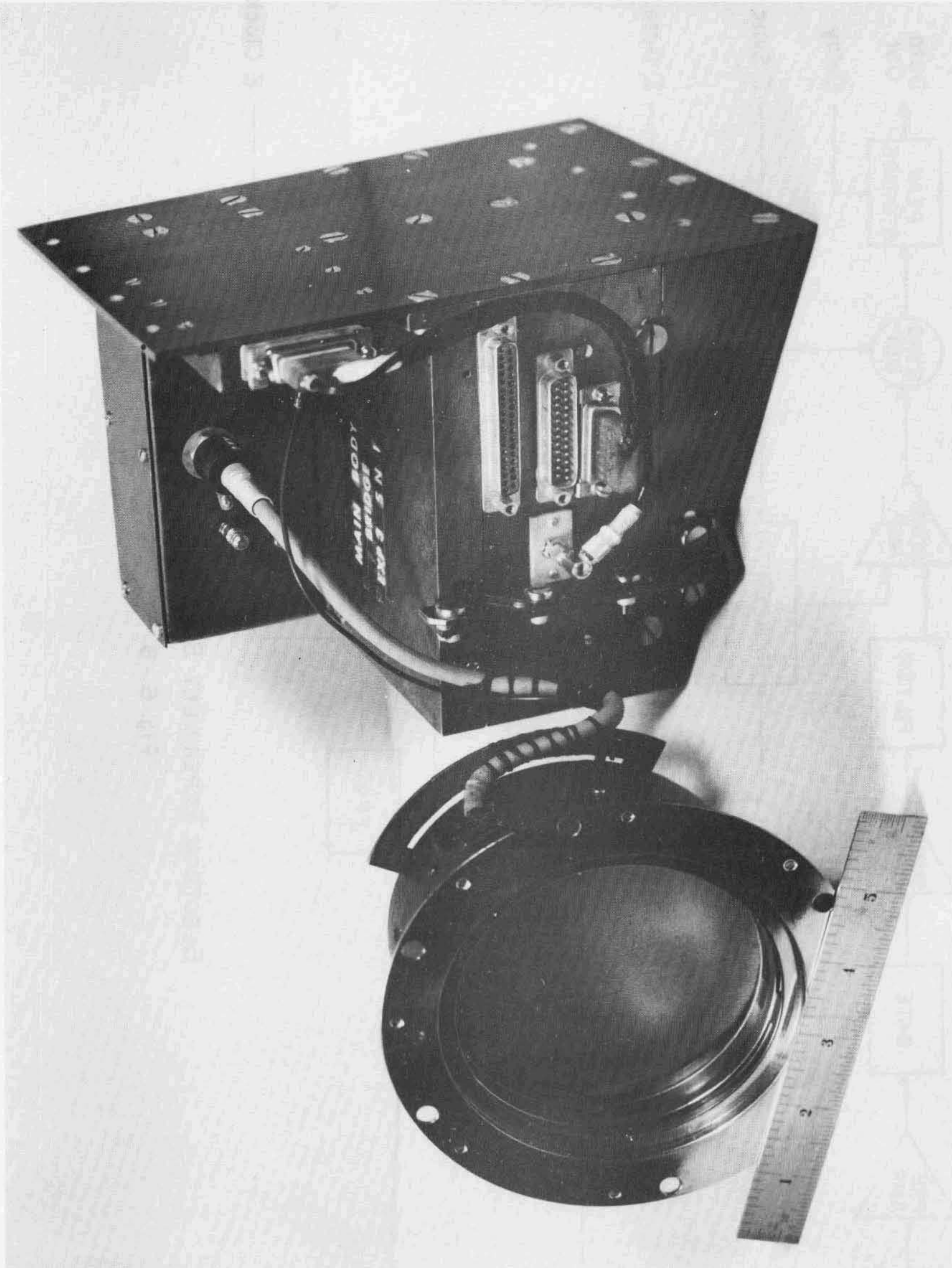
This system (Figure 6-7) is basically similar to the proton experiment but is much simpler. Figure 6-8 is the block

OPERATION	SWITCH	MODE	EG	TYPE OF OPERATION
NORMAL	LO	HI	1	REAL TIME , WIDE BAND TRANSMITTER ON
	HI	HI	2	DATA STORAGE, " " " OFF
	HI	HI	2	DATA PLAYBACK, " " ON
CROSS STRAPPED	HI	LO	2	REAL TIME , " " " ON
	LO	LO	1	DATA STORAGE, " " " OFF
	LO	LO	1	DATA PLAYBACK, " " ON

PULSE	VOLTS	VOLTS
SWITCH	$0 \le LO \le 2.0$	$7 \le HI \le 33.5$
MODE	$0 \le LO \le 0.6$	$3.9 \le HI \le 9.0$

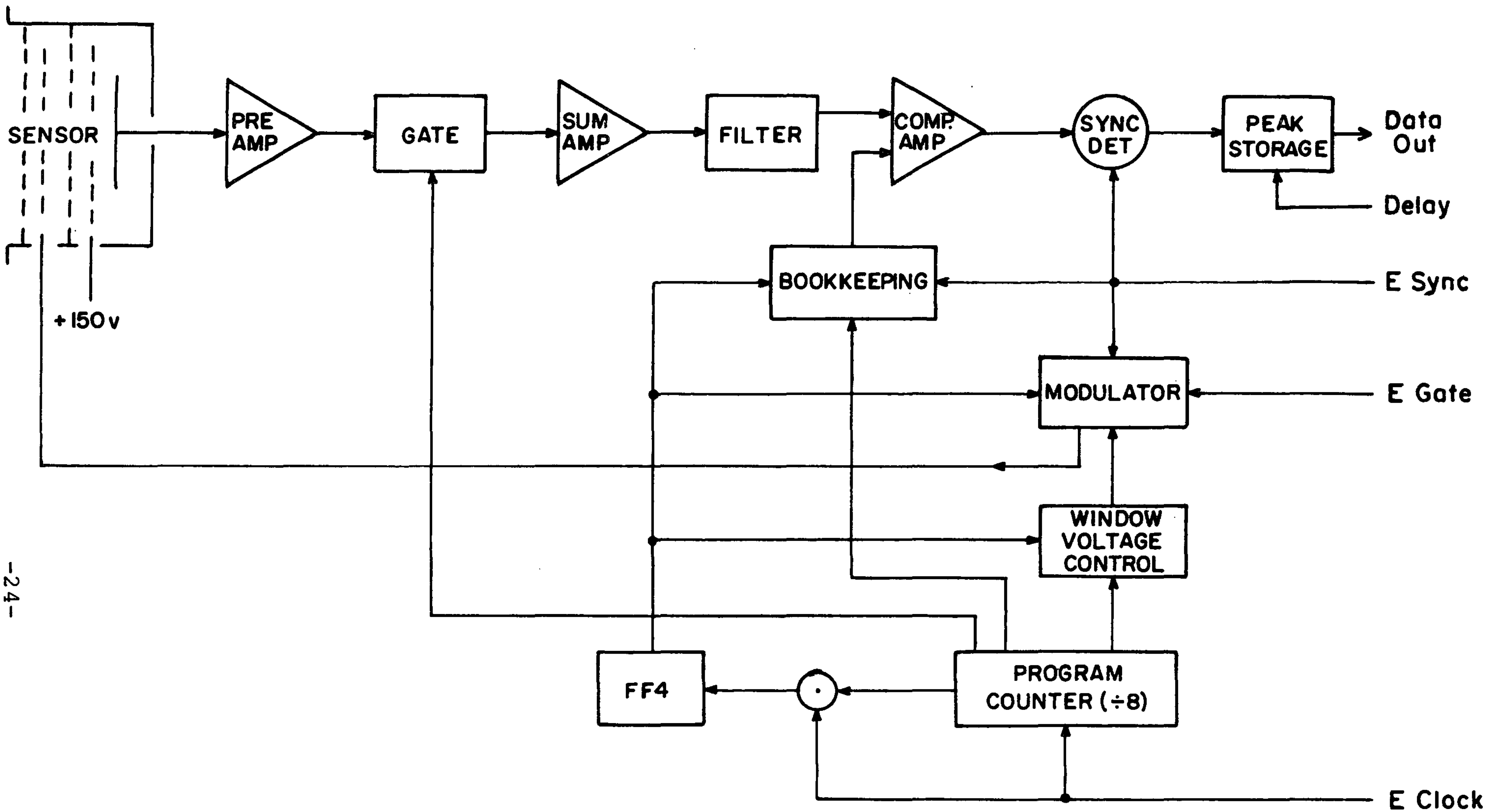
EXPERIMENT OPERATION MODES

Fig. 6-6



PLASMA ELECTRON EXPERIMENT

Fig. 6-7



ELECTRON EXPERIMENT BLOCK DIAGRAM

Fig. 6-8

diagram. The modulator generates a square wave superimposed on a negative dc level. The peak-to-peak square wave amplitude is equal to the mean dc level; therefore, the energy window to mean dc ratio is unity. This high voltage output is variable in 4 steps. Two interface signals control the modulator: the gate turns it on and the sync establishes the square wave frequency at 2461 Hz. The window voltage control output varies the voltage according to the experiment program.

The ac component in the sensor collector output is amplified in the preamplifier and gated into an amplifier and a bandpass filter centered at the modulation or sync frequency. A logarithmic compression amplifier then reduces the dynamic range of the signal for spacecraft A-D conversion and telemetry. The synchronous detector converts the compressed ac signal to positive dc which is made available to the spacecraft by the peak detection and storage output circuit. The analog store is discharged by a dump gate prior to each measurement. In the OGO-3 experiment, a readout circuit was substituted for the peak storage circuit.

During the 8-step cycle, the experiment operates in 4 modes: one for measurement and four for bookkeeping. The measurement mode uses the entire measurement chain to develop the electron current analog signal. The bookkeeping group injects two self-check levels and a marker into the measurement chain at the compression amplifier input. In order of occurrence, the modes are:

a. Collector (total flux): measurement of the output of the single collector at each of 4 energy levels (4 steps).

b. Blank: noise measurement (1 step).

c. Calibrate: generation of standard signal (1 step).

d. Temperature: measurement of ambient temperature within the experiment package (1 step).

e. Marker: generation of cycle identification level for use in data reduction (1 step).

The mode order was changed for the OGO-3 experiment as follows:

a. Collector (4 steps)

b. High voltage (1 step)

c. Calibrate (1 step)

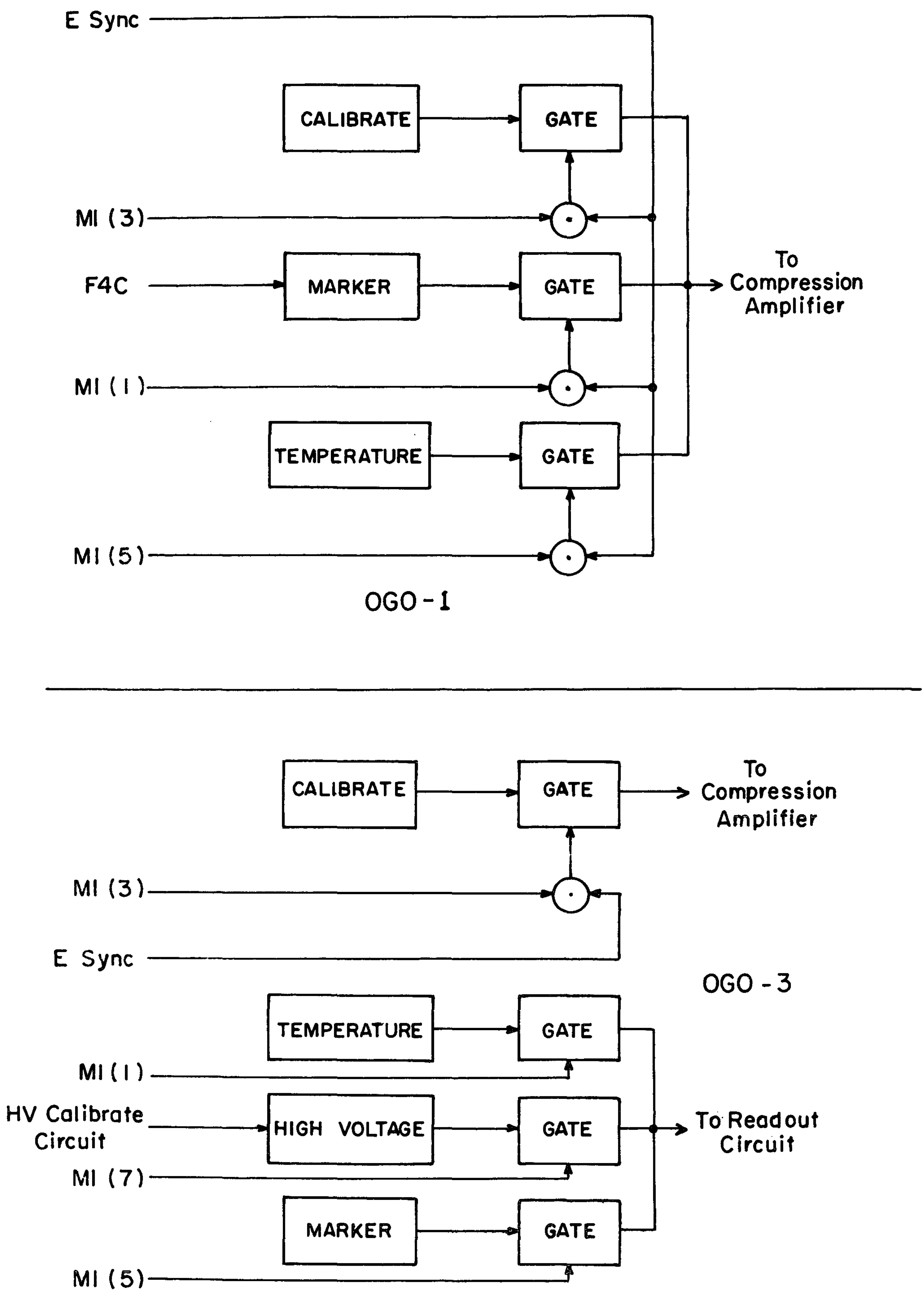
d. Marker (1 step)

e. Temperature (1 step)

The high voltage is a measurement of the high voltage rectified output.

The logic governing the electron experiment comprises a divide-by-8 program counter, a window voltage control and sequence flipflop F4. The program counter indexes the experiment through a cycle which consists of electron flux current measurements at 4 energy levels selected through the window voltage control and three bookkeeping measurements. The preamplifier signal is gated off during the bookkeeping measurements. F4 is complemented once per program cycle. In the OGO-1 unit, F4 gates off the HV modulator and changes one bookkeeping measurement on alternate cycles. For the OGO-3 unit, the HV modulator is not gated off on the alternate cycle, and there are four bookkeeping measurements taken instead of three, none of which are changed on the alternate cycle.

The bookkeeping circuits are shown in block form in Figure 6-9. The calibrate and marker references are derived respectively from a zener and from a voltage divider between a positive supply and F4. The temperature analog comes from a thermistor driven by a constant current supply. All three dc levels are gated by the indicated program counter outputs ANDed with the sync frequency which serves as a chopper. The parallel gate outputs feed the logarithmic amplifier. OGO-3 was changed so that the calibrate signal is the only bookkeeping pulse sent through the compression amplifier. A new circuit was added to provide a high voltage bookkeeping signal. The temperature, marker and high voltage pulses are inserted directly into the readout circuit.

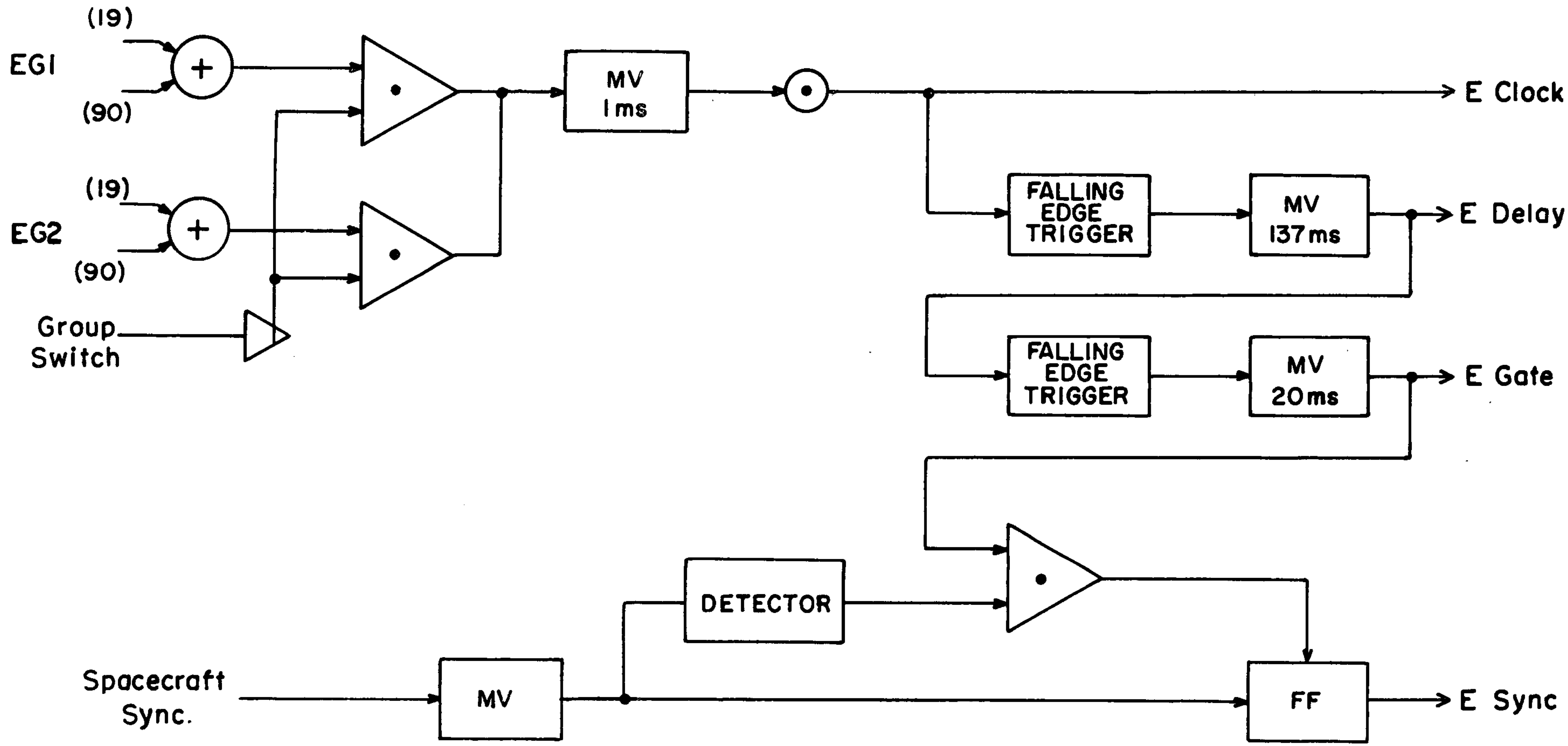


ELECTRON BOOKKEEPING
Fig. 6-9

The electron interface shown in Figure 6-10 separately ORs the two equipment group EI pulses and selects the proper EI pulse to trigger the count MV which generates the clock pulse. As well as providing basic experiment timing to the control logic, the clock pulse falling edge triggers the delay MV whose falling edge in turn gates the modulator through the gate MV. The spacecraft sync generates the local sync frequency through a multivibrator and gated flipflop. The sync MV is free running in absence of input signal to ensure that the experiment can continue in case of spacecraft sync failure. The sync flipflop enable gate driven by the detector prevents power wastage and possible component damage in case of MV failure and consequent FF lockup. Under circumstances of FF lockup, the power is removed from the flipflop to negate both outputs. Since sync is only necessary during measurements, a second flip-flop enabling condition is the gate.

6.4 Timing and Program Sequence

Figure 6-11 is a timing diagram for a typical step in either the proton or electron program. It is intended primarily to illustrate a plasma measurement but it also applies to bookkeeping with the exception of the last three waveforms. Index (I) and word (W) pulses occur every 288 ms at 1 kc bit rate, 36 ms at 8 kc bit rate and 4.5 ms at 64 kc bit rate. The width of the I pulse is inversely proportional to bit rate. To maintain a constant measurement duration,



ELECTRON INTERFACE

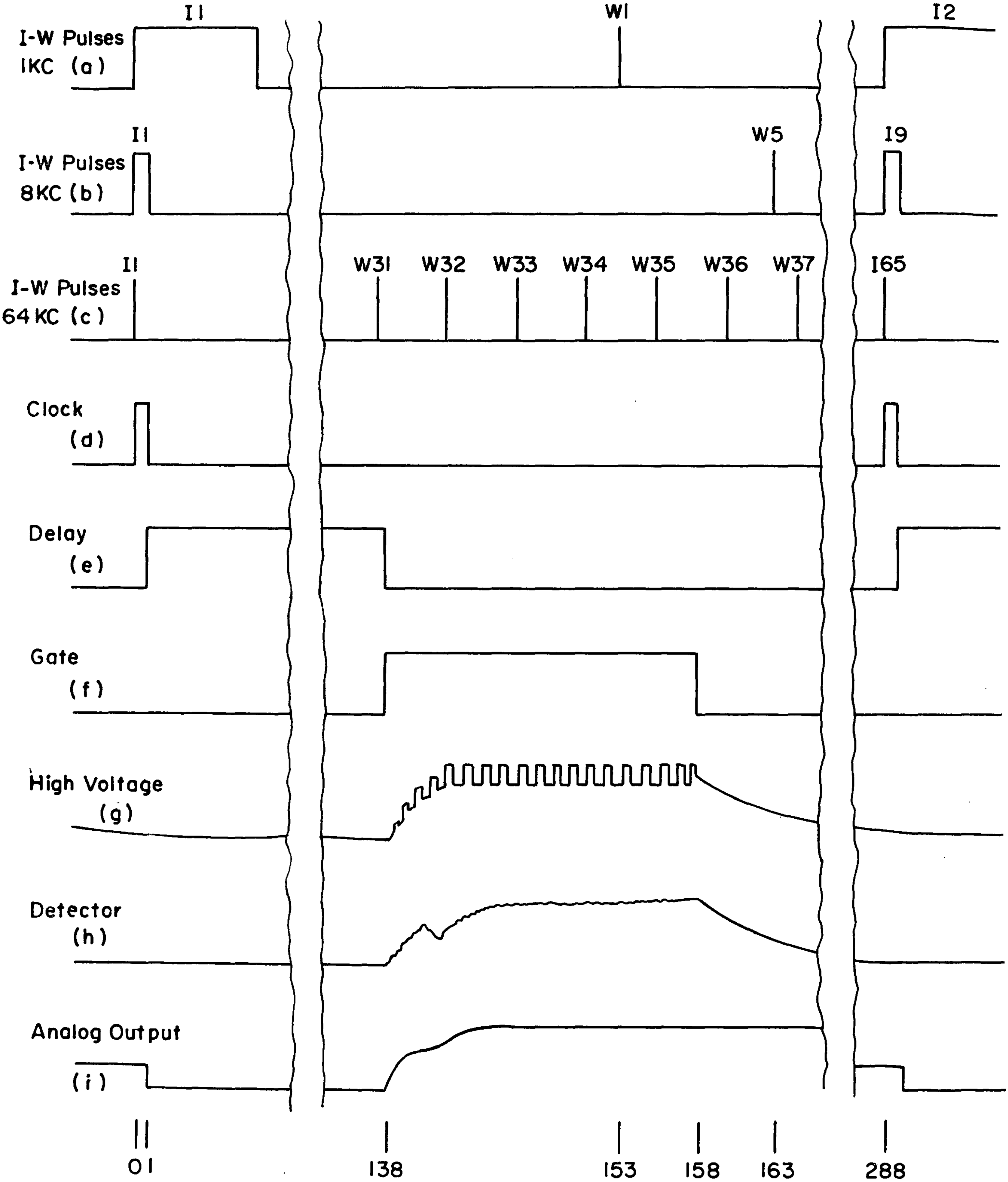
Fig. 6-10

the time chain is triggered by the leading edge of the I pulse. The electron experiment responds only to the 1 kc bit rate.

Index pulse I1 triggers the 1 ms clock MV (d). At 8 kc, the proton logic disregards the next 7 and at 64 kc the next 63 index pulses. The clock pulse falling edge triggers the delay MV (e) to empty the analog storage circuit until t = 138 ms. The delay MV trailing edge starts the measurement by causing the gate MV (f) to enable the modulator and sync flipflop.

Both the dc and ac components of the HV output rise at a rate determined by the modulator output impedance and capacitive loading (g). For approximately 10 ms of the 20 ms measurement interval, therefore, the synchronous detector output (h) is a time compressed nonlinear profile of particle density from 0 up to the nominal energy for the step, then it levels off to the terminal value. The peak storage data output stage in OGO-1 follows upward changes in the synchronous detector rapidly and stores the peak level with a time constant of approximately 200 ms; therefore, it does not follow downward changes (i).

Each measurement must make accurate data available at the time the spacecraft A-D converter samples the experiment. To save spacecraft power, the HV modulator is designed with a 95% risetime of approximately 10 ms and is gated on for



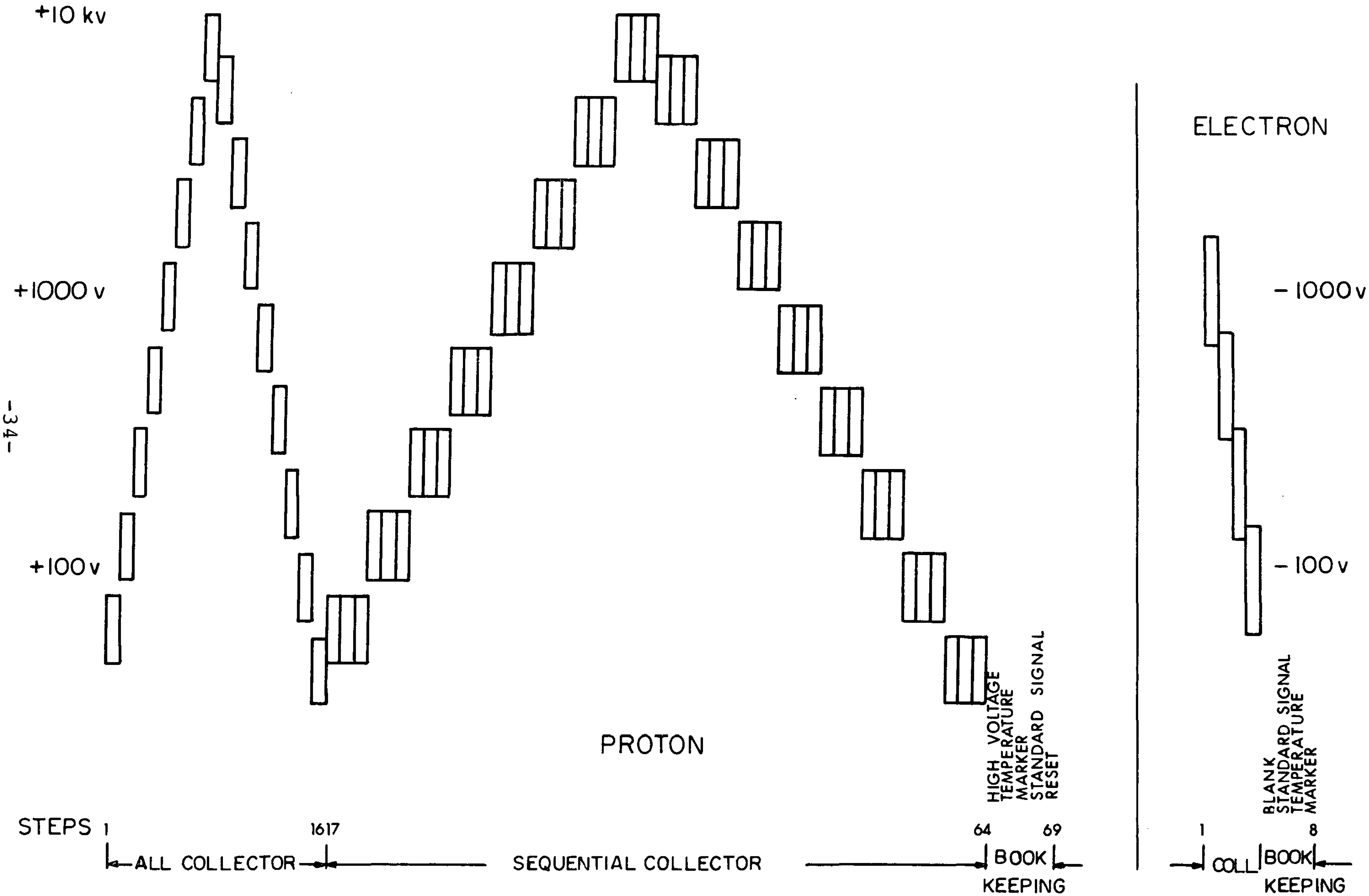
TIMING DIAGRAM

Fig. 6-11

20 ms. An accurate measurement analog output is available over the 20 ms time interval from 10 ms before the measurement gate termination (when the HV is within 5% of its maximum) to 10 ms after it (when the storage decay is about 5%). The time interval between the index and write pulses at the 1 kc bit rate is 153 ms. At 8 kc, the fifth W pulse occurs 163 ms after the I pulse, and at 64 kc about 5 W pulses fall within the accurate data time interval. The proton measurement delay MV is adjusted to start the measurement gate 138 ms after the I pulse so that the accurate data time interval extends from I + 138 ms to I + 168 ms bracketing the sampling times for all kilobit data rates. Some changes were made in the OGO-3 experiment, namely the delay MV was changed from 138 ms to 100 ms and the gate MV was changed from 20 ms to 65 ms. The peak storage output stage was replaced with a readout circuit. These changes allowed the HV modulator to produce an optimum waveform during the readout time resulting in greater data accuracy. The effective accurate data time interval for OGO-3 was from I + 120 ms to I + 165 ms.

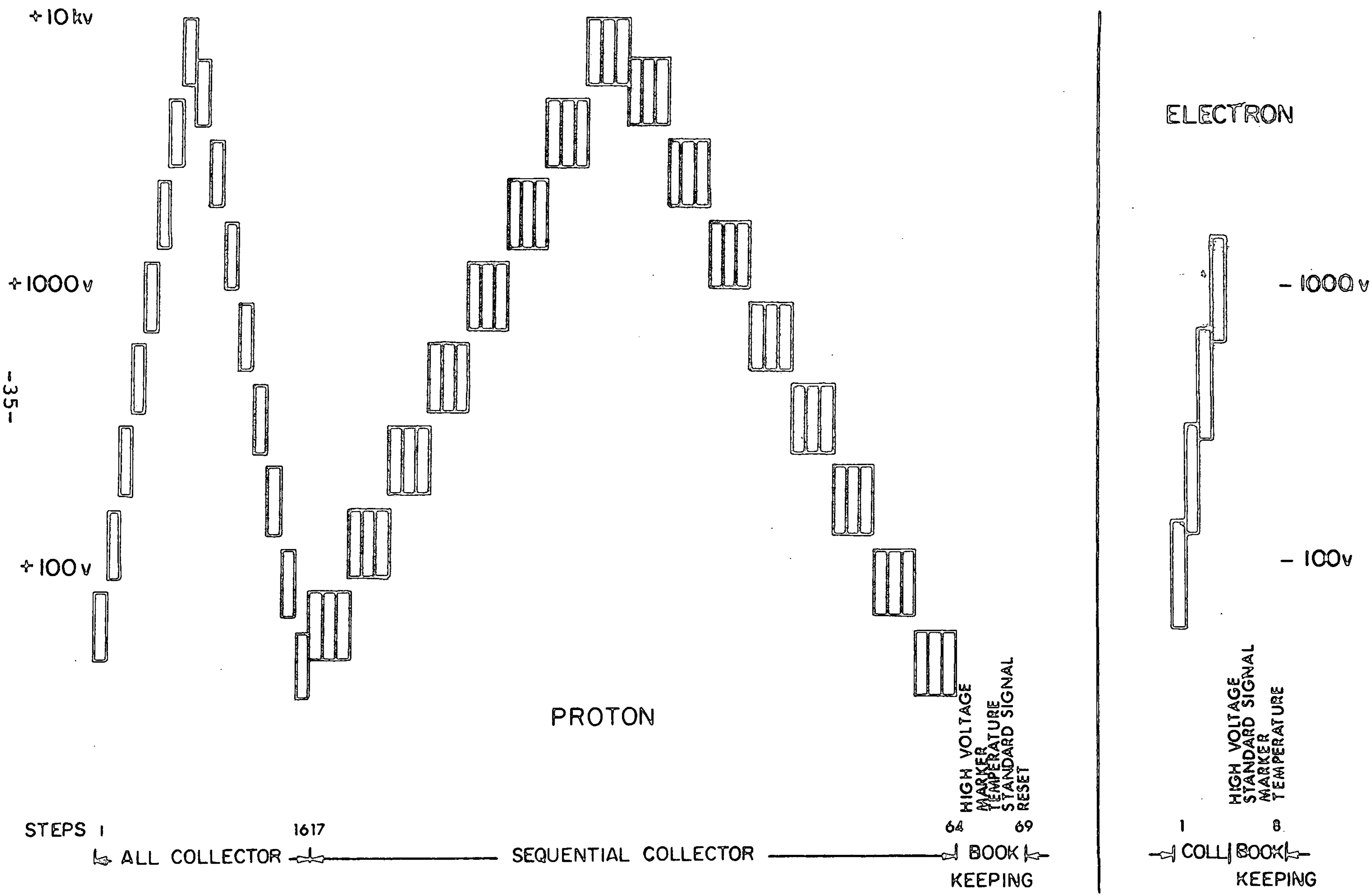
Figure 6-12 shows the measurement step sequences for the OGO-1 experiment and Figure 6-13 for the OGO-3 experiment.* The logarithmically scaled ordinate is modulator energy level. High voltage rise and fall times in the proton experiment make it advantageous to follow the even-steps-up and odd-steps-down sequence. A high energy step is thus not

* These figures are illustrative sketches only; the precise values of the energy levels are discussed in section 10.



OGO -1 PROGRAM

Fig. 6-12



OGO-3 PROGRAM

Fig. 6-13

required to charge output capacitances from 0 to full value nor need a low level step begin with a high residual charge from the preceding step. The OGO-1 electron experiment uses a maximum-to-minimum scheme; however, this was changed in the OGO-3 experiment to the minimum-to-maximum sequence and resulted in more uniform windows. As mentioned previously, both programs in the OGO-1 experiment change on alternate cycles while in OGO-3 each cycle is identical.

The bookkeeping sequence was changed in the OGO-3 unit because of circuit changes. Though giving no meaningful measurement, the last step in the proton program generates a reset that clears all counters for continuity of program cycles. It gives redundant assurance that the collector-counter samples the same collector at the same time in successive cycles by making the total number of steps divisible by 3. The redundancy also applies to the other two counters in the proton logic whose gating is tailored to the 69-step program.

7.0 Experiment Logic

Two independent logic systems implement the proton and electron experiment programs discussed in section 6. To synchronize the experiment and to inform it of data processing conditions, the spacecraft supplies the following five signals:

a. Index Pulses (I). The number and frequency of the pulses are in accordance with the spacecraft telemetry format. For the proton experiment, there is a set of four incoming proton index (PI) pulses. Within each 4-group, the PIs signal that experiment data will be sampled in approximately 160 ms. The index pulse has a base line of 0.65 $\pm$ 0.65 v, and the pulse rises to between +5 and +11 v with a rise time less than 1 μs. Pulse duration (9 bits) and repetition rate are functions of the spacecraft bit rate: at the 1 kc rate, 9 ms PIs occur every 228 ms; at 8 kc, 1.125 ms PIs occur every 36 ms; and at 64 kc rate, 141 μs PIs occur every 4.5 ms. For the electron experiment, there are two sets of electron index (EI) pulses; however, the EI pulses are not evenly spaced in the spacecraft telemetry format as are the PIs. The electron experiment operates only at the 1 kc bit rate, and the time interval between EI 19 and EI 90 is 639 ms; between EI 90 and the following EI 19 is 513 ms.

b. Switch Signal (SW). This level assigns the experiment to one of the two equipment groups (EG). The switch signal is between ground and +2 v for EG1 and between +7 v and +33.5 v for EG2.

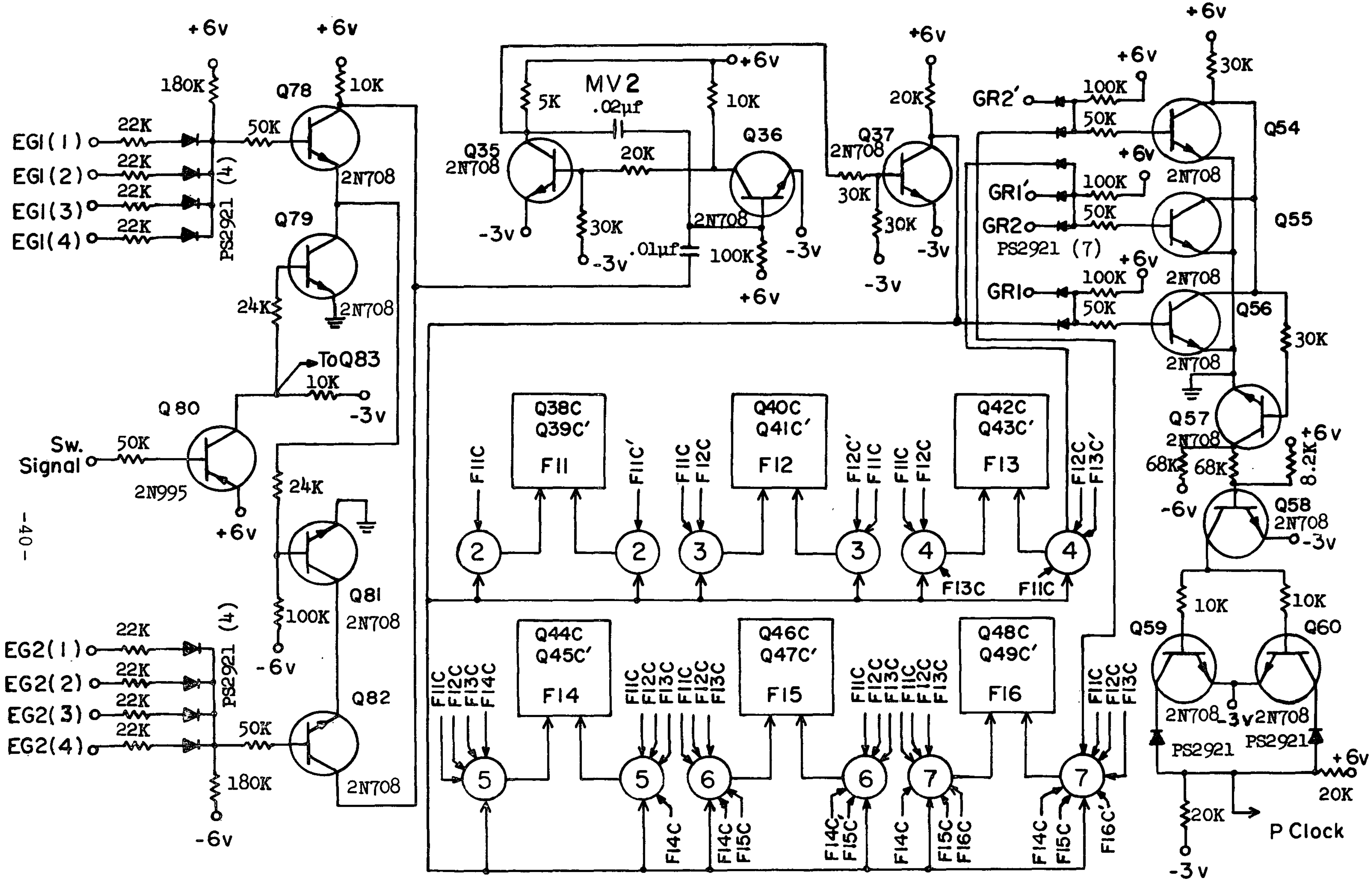
c. Mode Signal (MODE). This level indicates which equipment group is assigned to real-time telemetry and which to storage. When MODE is between +3.9 and +9.0 v, all experiments assigned by SW to EG1 operate into real-time telemetry and data from EG2 experiments are stored. When MODE is between ground and +0.6 v, the equipment groups are reversed and real-time telemetry accepts data from experiments assigned by SW to EG2 while EG1 data are stored. The plasma data are thus stored when both SW and MODE are high or both are low, and real-time telemetered when the two levels differ as outlined in Figure 6-6.

d. Real-Time Telemetry Bit Rate Signal (BIT RATE). This 3-state signal indicates the real-time data rate and thus the proportional rate at which PIs arrive at the inputs corresponding to the real-time equipment group. The level signals the 1 kc rate at +3.3 v, 8 kc at +5.1 v and 64 kc at +7.5 v; all within ± 5%. One of these levels is always present, even when the real-time telemetry system is inactive. The spacecraft circuit that generates BIT RATE requires the experiment input impedance to be greater than 50,000 ohms returned to ground whether the experiment is operating or turned off.

e. Spacecraft Power Frequency (SP SYNC). This 2461.11 cycle square wave synchronizes all spacecraft and experiment power converters so that random coupling among experiment interfaces cannot result in beats or other noise. The amplitude is 6 v peak-to-peak. The signal is supplied from a floating 270 ohm source and cannot carry a dc load to ground. Within the plasma experiments, SP SYNC is the frequency reference for the modulator, synchronous detector and power converter.

7.1 Proton Experiment

Two active AND gates (Q78 to Q82) select the index pulses from EG1 and EG2 as shown on Figure 7-1. One input to each gate receives the ORed PI pulses. The second input is the SW signal which is inverted for the EG1 gate and inverted again for the EG2 gate. The output of the selected gate is a positive-to-ground transition of each PI leading edge. The ORed gate outputs are capacitively coupled to the count multivibrator (MV2) as negative triggers. MV2 in turn generates a positive pulse of 1 ms duration which drives two cascaded ÷ 8 counters, F11-12-13 and F14-15-16. The MV2 output (COUNT) and the two counter outputs (COUNT/8, COUNT/64) feed three positive AND gates. The RATE levels that select one of these gates are generated by the bit rate comparators (Q50 to Q53). From the selected gate output,

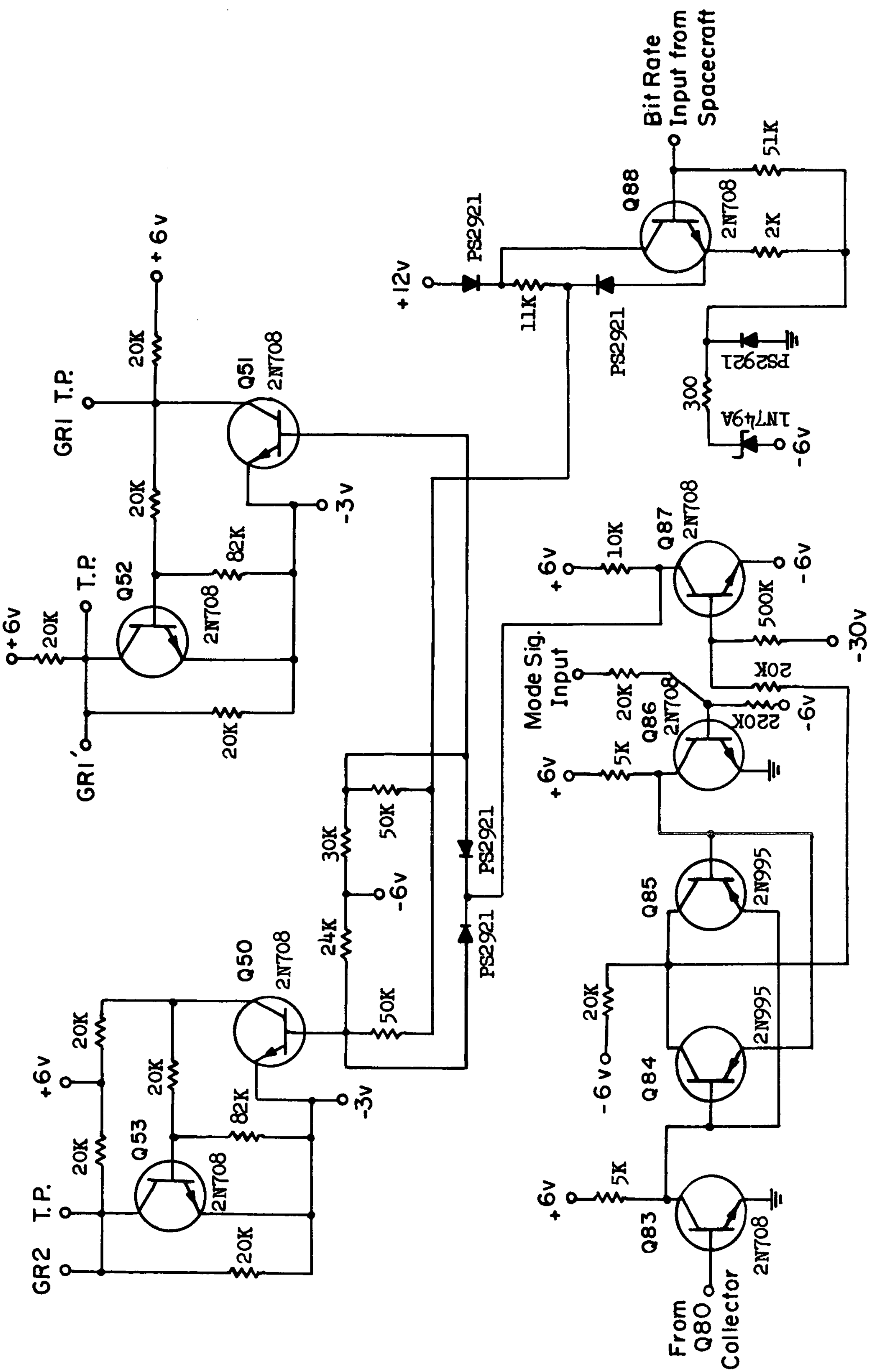


Proton Countdown Circuits
Fig. 7-1

an active NOR gate, two inverters and a parallel driver (Q54 to Q60) generate the system P CLOCK pulse, a 1 ms pulse rising from a -3 volt base line to +1.5 volts. The active negative output insures a sharp trailing edge to drive the program logic.

Two comparators (Q50-Q51) derive the clock division gates from the incoming BIT RATE signal (Figure 7-2). An emitter follower transfers the 3-state rate signal to a pair of voltage dividers returned to -6 volts. When a divider output exceeds -3 volts, the associated comparator turns on. The resistive dividers are adjusted to negate the RATE 1 level at +4.2 volts, the midpoint of the two lower input levels, and assert RATE 64 midway between the upper two levels, at +6.3 volts. Thus the comparators can easily accommodate a poorer signal tolerance than the specified BIT RATE of $\pm 5\%$.

Only real-time data telemetry requires variable bit rates; therefore, variable format frame rates. Approximately 4, 32, 256 index pulses per second may be received at the EG input corresponding to the real-time system while the storage group always receives 4 pulses per second. The comparators may be disabled, forcing the low bit-rate indication and hence undivided clock rate, by a negative level applied through isolating diodes to the comparator inputs (Q50, Q51). The circuits (Q83 to Q87) produce this inhibit



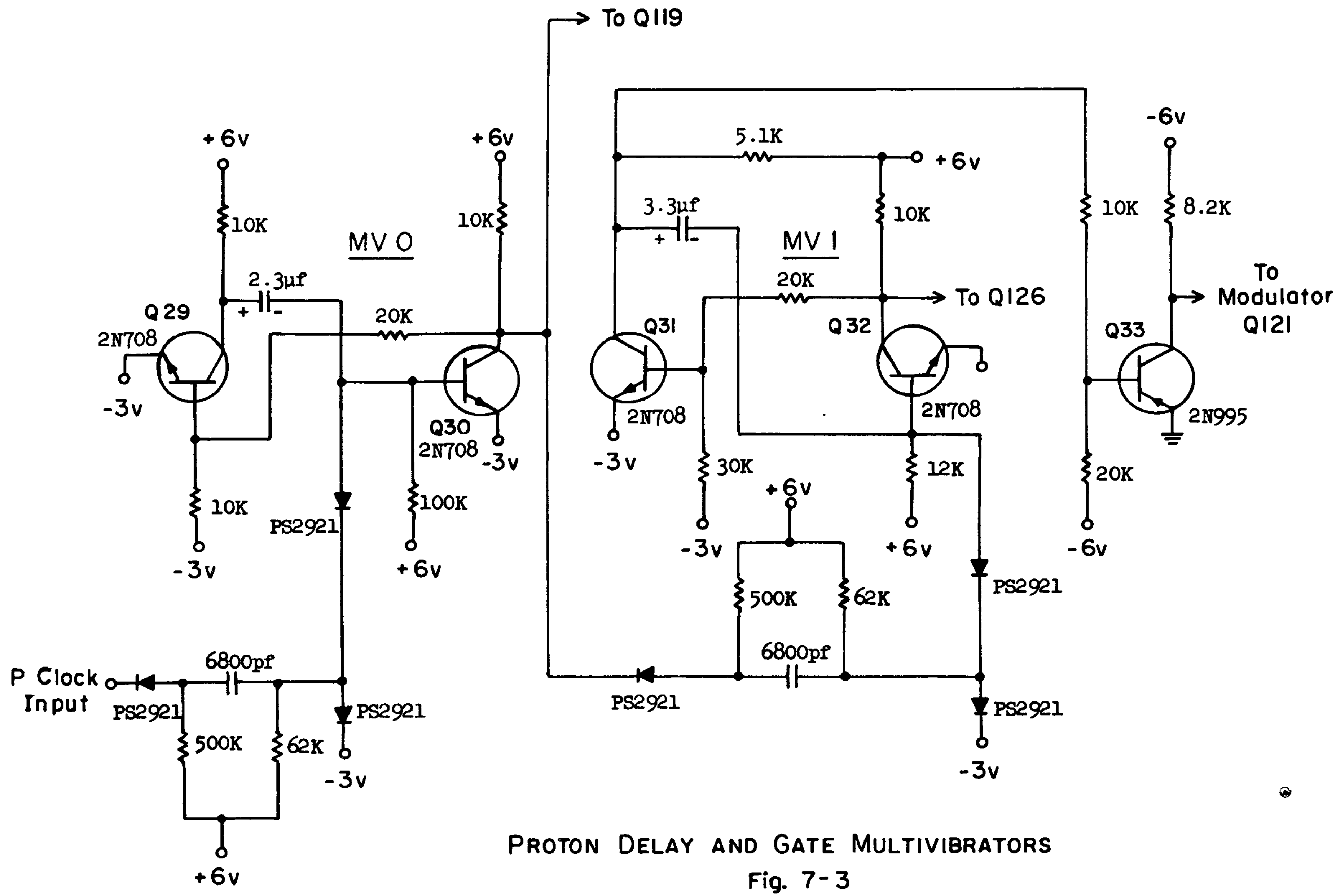
PROTON OPERATING MODE CIRCUITS

Fig. 7-2

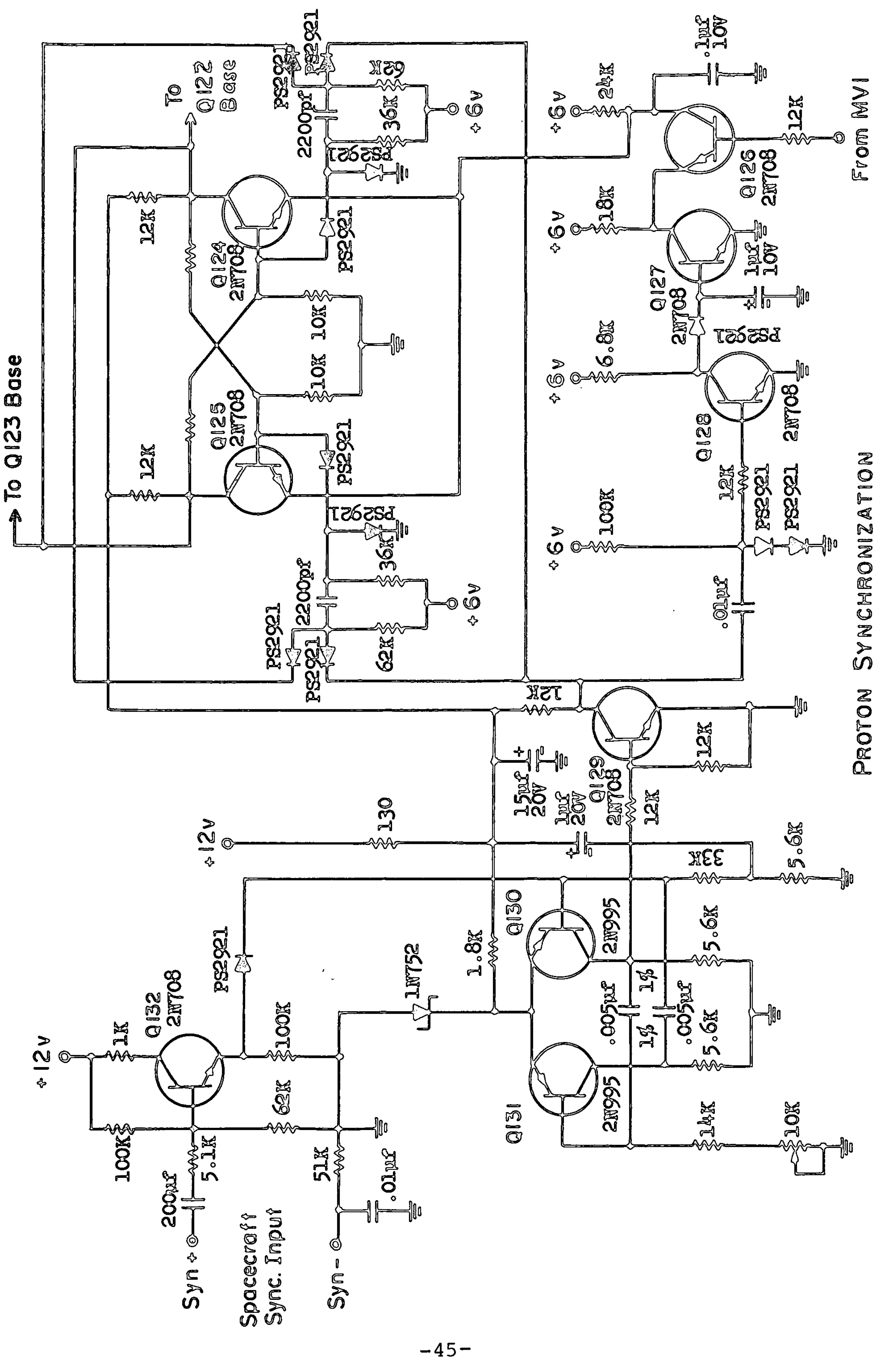
whenever the experiment is operating into tape storage which is determined by comparing the inverted SW level with MODE in the active exclusive OR gate. If both inputs to this gate are the same (i.e., the spacecraft signals differ, signifying real-time telemetry), Q84 and Q85 remain off and there is no inhibit; whereas if the gate inputs differ (storage telemetry), one of the pair turns on and the inverted gate output disables the bit-rate comparators.

In addition to sequencing the experiment by means of the program control logic, the system clock triggers the 137 ms (100 ms for OGO-3) delay multivibrator MVO (Q29, Q30) through a falling edge trigger (Figure 7-3). The output of the delay MV grounds the data storage capacitor (OGO-1) or the synchronous detector capacitor (OGO-3) until just prior to a new measurement. The falling edge of the delay MV output turns on the gate multivibrator (MV1). The output of MV1 turns on the measurement chain for 20 ms (65 ms for OGO-3) by gating on the modulator and the sync flipflop.

Figure 7-4 shows the spacecraft synchronization of the experiment. SP SYNC (2.461 kc) triggers the sync multivibrator (Q130, Q131) which free-runs a little slower than 4.922 kc and thus is synchronized every second cycle. Each output falling edge complements the sync flipflop (Q124, Q125) thus dividing the frequency back down to 2.461 kc. This frequency doubling and division-by-2 scheme allows



PROTON DELAY AND GATE MULTIVIBRATORS
Fig. 7-3



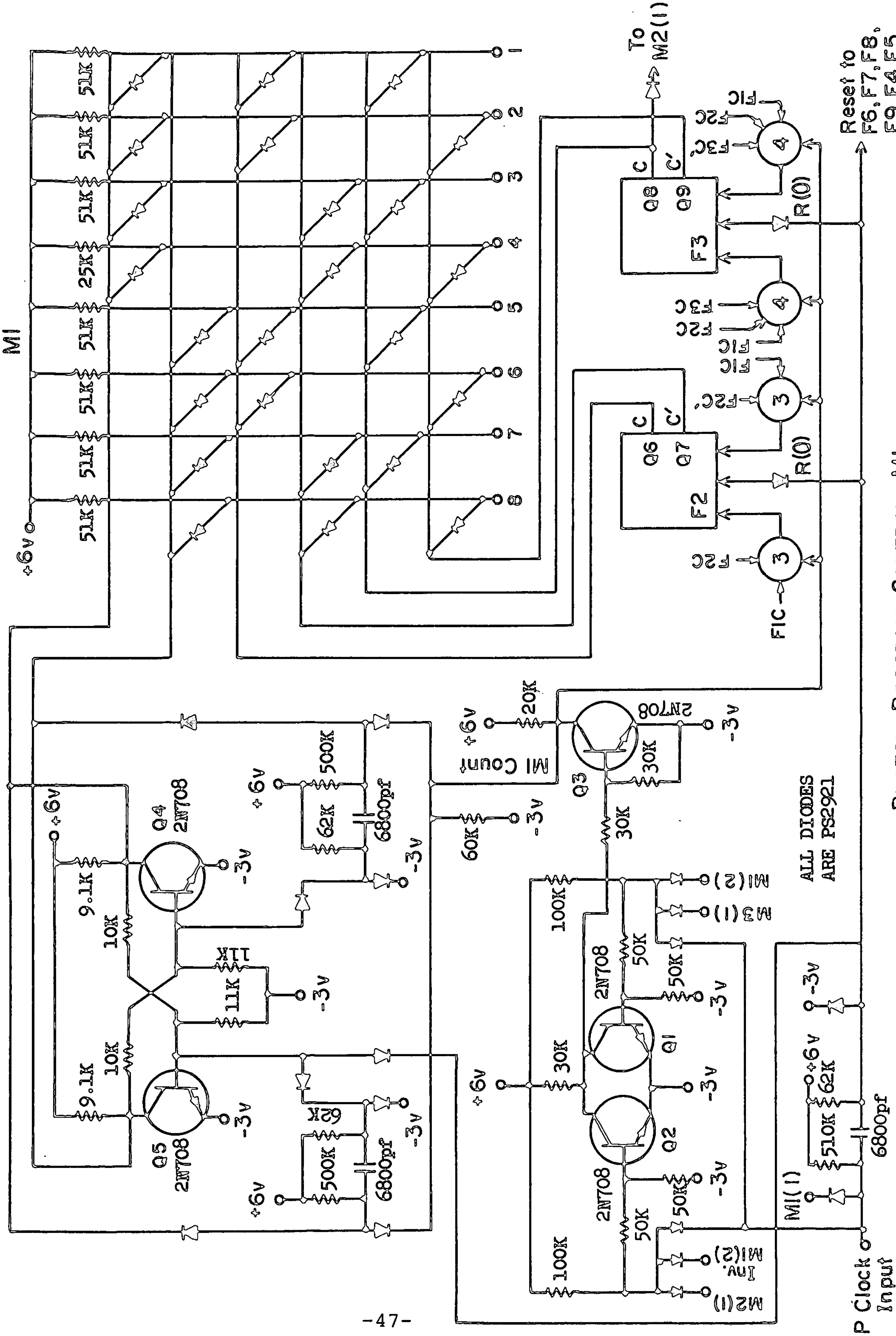
PROTON SYNCHRONIZATION

Fig. 7-4

very light loading on the sync input and ensures that a commutating signal is available to the modulator in spite of a possible SP SYNC failure. However, loss of excitation is still possible in the event of failure of the sync multivibrator. The ac detector-and-gate combination of Q127-Q128 prevents such an occurrence from causing useless power consumption and possible modulator component damage by opening the dc power return for both transistors in the sync flipflop, thus negating both flipflop output and gating off the modulator. The capacitor-coupled sync multivibrator output alternates Q128, whose rectified and filtered output holds Q127 on to provide a path to ground for the sync flipflop emitters, conditioned by the assertion of the MV1 gate. With no ac input, Q128 turns on, grounding the input to the detector. The detector smoothing capacitor then discharges into the Q127 base until the gate turns off and blocks the dc path for the flipflop.

7.2 Proton Program Control

The logic that sequences the system through the 69-step measurement and bookkeeping program is shown on Figures 7-5, 7-6 and 7-7; an associated timing chart are drawings DX-4856-5A for OGO-1 and DX-4856-5B for OGO-3 (Appendix C) which show the logic levels and counts. Basically the logic comprises three counters, M1, M2 and M3, which have 8, 16 and 3 states respectively and which control the program mode, window and collector sequences discussed in section 6.2. An additional flipflop, F10, alternates the program cycles.



PROTON PROGRAM CONTROL MI

Fig. 7-5

Flipflop F1, the least significant bit of mode counter M1, is shown as a circuit model. Outputs are asserted or true when positive with respect to ground, negated when at -3 vdc. Incoming pulses change the state of the flipflop by turning off the on transistor through a capacitor-diode gate. Each flipflop has individual set and clear gates; an additional reset input is common to all flipflops. A capacitor-diode gate may have any number of inputs, each isolated by a diode; a system with common anode-diode connections forms an AND gate for positive levels. The flipflop changes state in response to the first negative transition in any input signal following satisfaction of the gate.

The remaining counter flipflops (F2 to F9) are shown as blocks with their input gates represented as circles. The numeral within a circle designates the number of inputs required to satisfy the gate. The gate that clears a flipflop is always at the lower left and that which sets it is at the lower right. One pair of inputs for each flipflop performs the steering-gate function, i.e. the set and clear inputs are conditioned by the opposite state of the flipflop. The 1 and 0 outputs for a flipflop are designated as C and C' preceded by the flipflop number: e.g., F2C is the 1 output of F2.

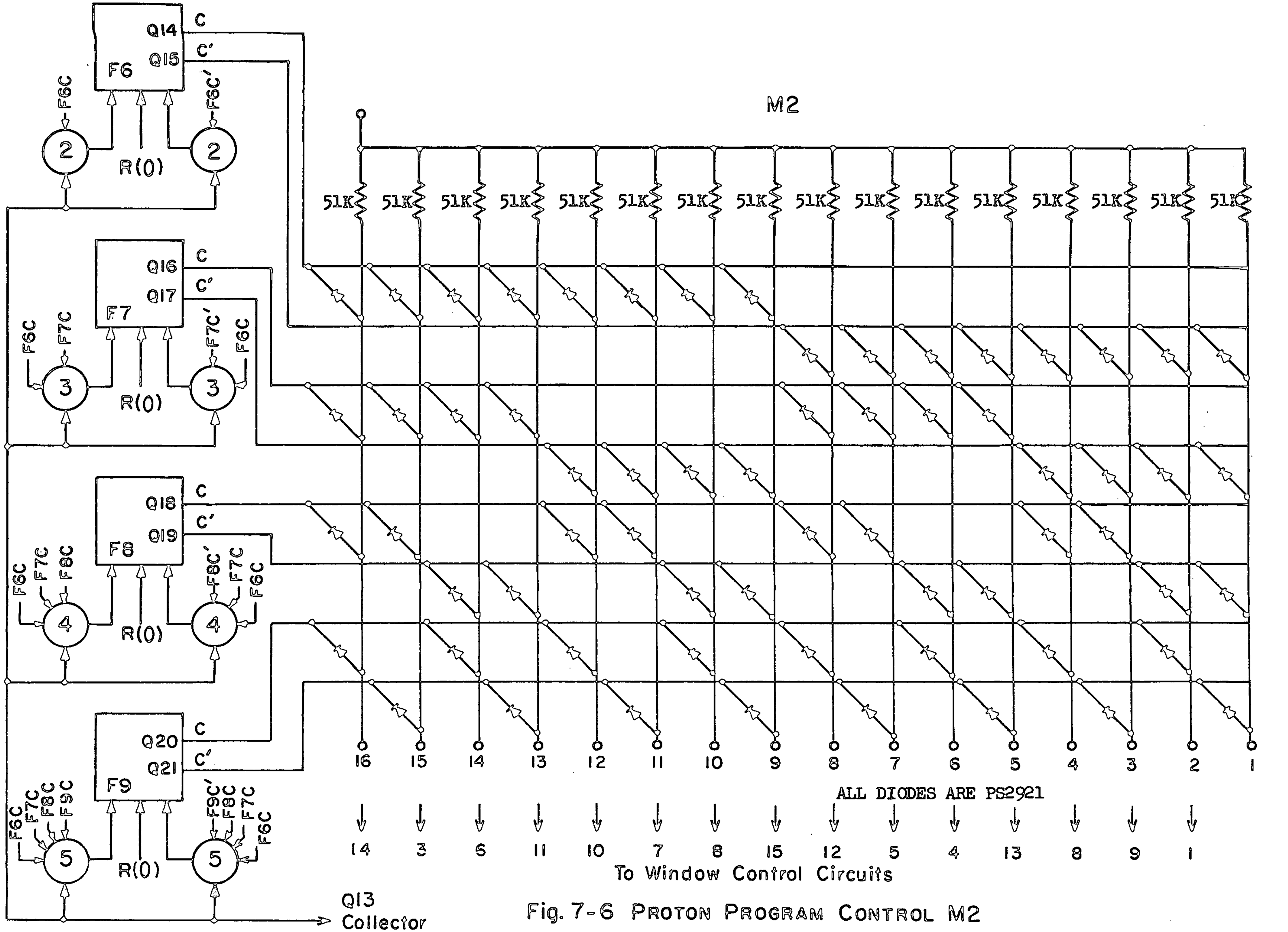
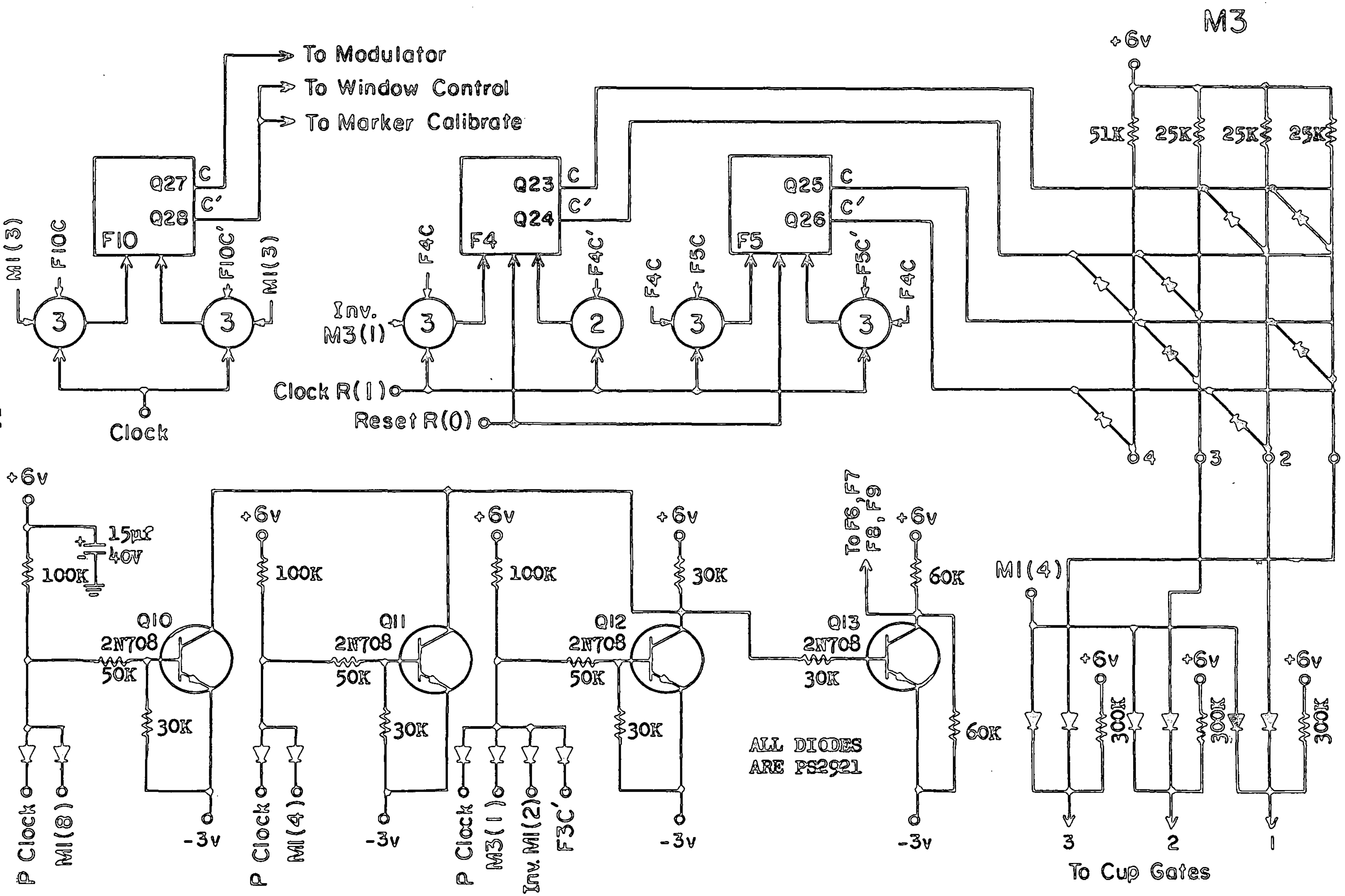


Fig. 7-6 Proton Program Control M2

Each counter indexes in straightforward binary fashion. The flipflops drive a decoder matrix, a single output of which is asserted for each counter state. Output numbering for M1 and M2 is such that counting is not in numerical order; for instance, the M1 sequence, starting with all flipflops clear, is 8-4-6-2-7-3-5-1. Individual outputs are denoted by the number of the output line preceded by the matrix designation. For example, M1(6) means the 6 assertion of counter M1.

The common reset pulse is driven by a capacitor-diode gate. This gate sets F5 and clears all the other counter flipflops on the first clock after M1(1). The reset returns the logic to M1(8), M2(1), M3(3), the state in which the experiment enters a measurement cycle. The next clock pulse indexes M1 to 4 which enables all three preamp gates (Figure 8-4) and also produces M2(9) to select energy level 2 for the window voltage control. This clock is the first in the 16-step all-collector mode; the remaining 15 clocks continue window stepping through the center section of the M2 count gate. M1 remains at 4 throughout the all-collector mode, since an M1 count can now occur only on M2(1), i.e., after the experiment has sequenced to the last energy level. The M1 count logic that sets this condition appears on drawing 7-5. During the all-collector mode, M1(4) enables all cup gates simultaneously, overriding the M3 selections. However, M3 continues to count these first 16 steps so the



Proton Program Control M3
Fig. 7-7

sequential-collector mode begins M3 at 2, resulting in a 2-3-1 collector sequence at each energy level.

M2 becomes 1 after sequencing through all energy levels in all-collector mode (step 16). This gates an M1 count that indexes M1 to 6 for the sequential-collector mode (step 17). Now M2 must wait until M3 has sampled each of the three collectors before stepping to the next higher energy level. M2 thus no longer indexes for every clock since M1 is no longer at 4; instead it indexes for every third clock, that is, when M3 is 1 through the right section of the M2 count gate (Q10 to Q13). This gate affects M2 only when M1 is 6, i.e., an even number (F3C') which is not 2 [M1(2')], but also not 4 or 8 because these already index M2 on every clock pulse through the left and center sections of the gate.

Near the end of the sequential-collector mode (step 62) M2 again contains 1 which enables an M1 count through the left half of the count gate (Q2-Q3). On step 63, M1 indexes to 2, and M3 goes to 3 for the collector 3 measurement. Collector 1 remains to be sampled so M1 stays at 2 for the last measurement step. After this step, at the end of the sequential-collector mode, M3 is 1 and M1 is 2. These conditions enable an M1 count through the gate (Q2-Q3) indexing M1 to 7 to start bookkeeping. Throughout the next five steps M2 remains at 1 because none of its count gates are satisfied, and this allows M1 to index at each clock. M3 is indexed directly by the clock pulse so it sequences through the bookkeeping mode as it does through the all-collector mode, but again with no effect.

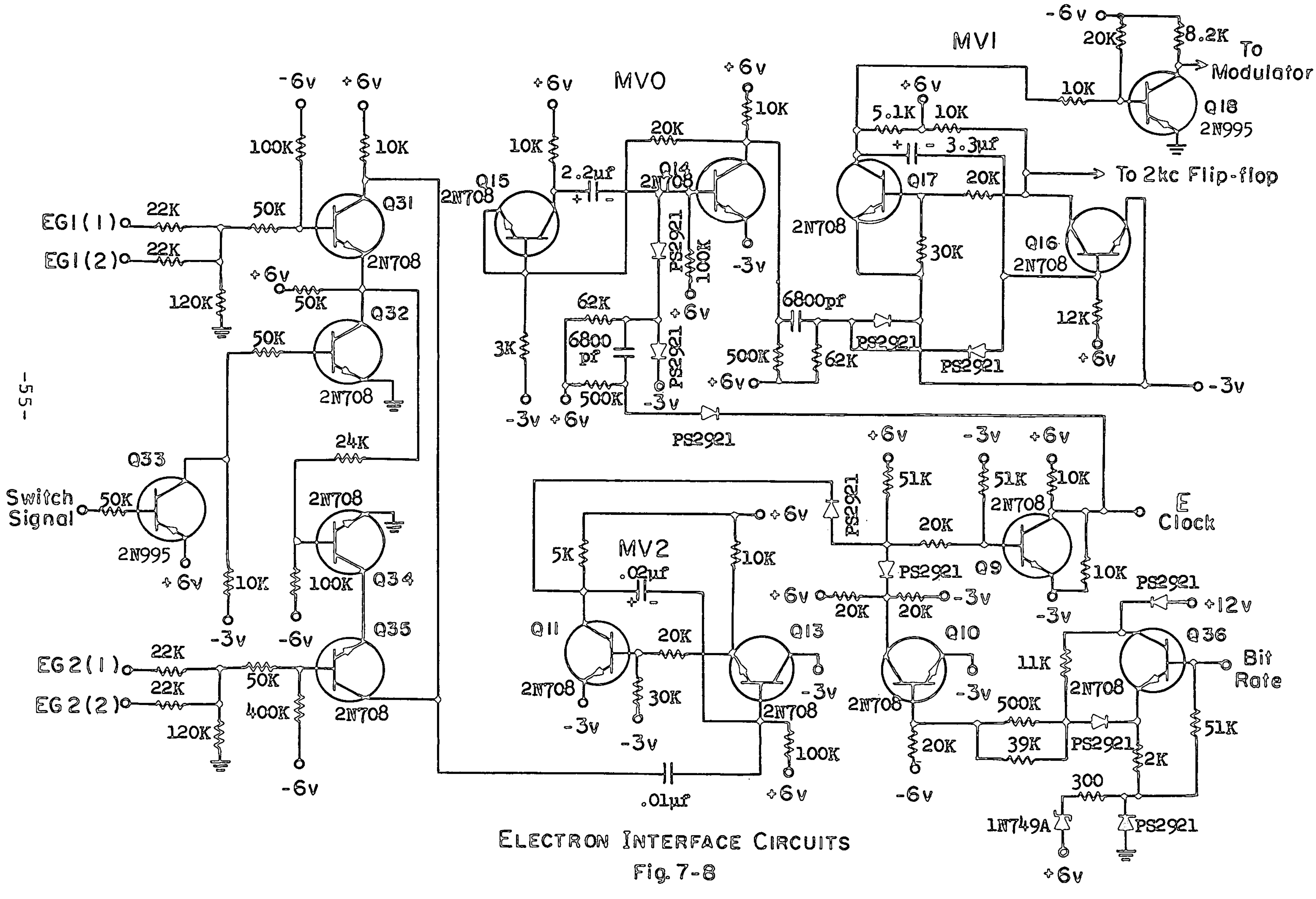
F10 changes certain conditions in alternate cycles of the program. It is complemented just before the first marker signal, when M1 is 3. On alternate cycles, F10 gates off the high voltage and the window voltage control and reduces the amplitude of the marker reference in the OGO-1 unit. In two successive cycles starting with F10 set, the sequence makes measurements with the high voltage on, followed by modulator and temperature bookkeeping. F10 is now cleared, causing reduced marker reference; the calibrate reference and reset step conclude the cycle. Thus the low marker precedes and identifies each "live" measurement cycle. The next cycle activates the measurement chain but without high voltage, then modulator (vacant in this cycle) and temperature bookkeeping and sets F10 again to produce the high marker followed by calibration and reset. In the OGO-3 unit, F10 has been deactivated and has no effect on the high-voltage modulator, window-voltage control or the marker. High voltage is on during each cycle and there is no change in the amplitude of the marker. As mentioned previously, the bookkeeping sequence on OGO-3 was changed to high voltage, marker, temperature, calibrate (standard signal) and reset.

7.3 Electron Logic

These circuits include an interface that synchronizes each step of the electron experiment program to the spacecraft indexing and data collection times, a 3-bit program counter that indexes the experiment through an 8-step measurement and bookkeeping sequence and a flipflop that changes certain experiment conditions on alternate program cycles.

The electron experiment receives interface signals EI, SW and SP SYNC from the spacecraft. Function and logic levels of these signals are described in section 7. Four EI inputs, two from each EG format frame, feed the active AND gates (Q31 to Q35) shown in Figure 7-8. Depending upon its state, SW enables one of these gates. The ORed EI pulses generate negative transitions at the output of the enable gate, capacitively coupled to the 1 ms count multivibrator MV2 (Q11-Q13) which develops the system clock pulse.

Through a falling-edge gate, the clock triggers program mode counter M1, program cycle flipflop F4 and MVO (Q14-Q15), the delay multivibrator. The positive delay output dumps the data storage capacitor (OGO-1) or the synchronous detector capacitor (OGO-3) and its termination triggers the 20 ms (65 ms in OGO-3) gate multivibrator MV1 (Q16-Q17). Electron experiment synchronization to SP SYNC is identical to that of the proton experiment.



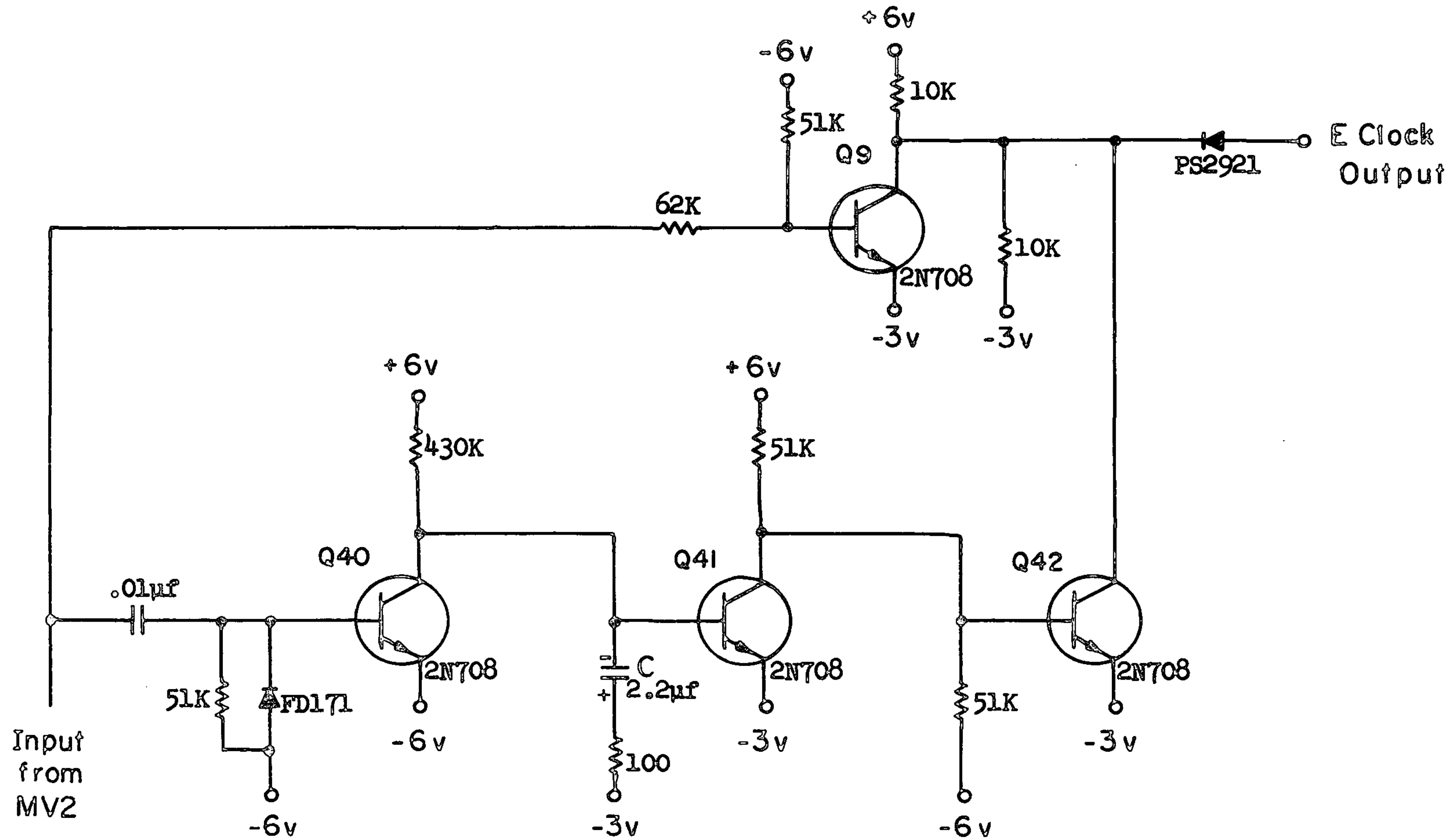
ELECTRON INTERFACE CIRCUITS

Fig. 7-8

The BIT RATE signal was originally used in the electron experiment to disable the clock circuit at the higher bit rates of 8 kc and 64 kc. Unfortunately, it was found that the spacecraft BIT RATE could be high since some experiments were operating at the 8 and 64 kc rates when the electron unit data were supposed to be going to data storage. Under these conditions, the electron unit was disabled. In the OGO-1 unit, the BIT RATE input was disconnected so the electron experiment operates at all input rates but only the 1 kc rate produces any useful data. In the OGO-3 unit, a circuit (Figure 7-9) keeps the electron experiment from cycling at the higher bit rates.

At the 1 kc rate, the circuit does not inhibit the Q9 output, allowing the E clock pulses to pass to the logic circuits. for the 8 kc and 64 kc rates, capacitor C charges to a value high enough to cut off Q41 and start Q42 conducting, which disables the E clock.

The measurement and bookkeeping sequence control, the timing diagram are shown on Figure 7-10 with the associated logic levels and counts. Since M1 governs the 8-step cycle exclusively, it requires no input gating other than normal counter steering; M1 indexes once for each clock pulse. A reset pulse generated at M1(1) clears the M1 flipflops; the count sequence, starting clear, is 8-4-6-2-7-3-5-1. The 8, 4 and 6 outputs gate the window voltage control to generate windows



INHIBIT CIRCUIT
Fig.7-9

1, 2 and 3. The succeeding M1(2) does not select a window directly, but the window voltage control generates a window 4 during this interval. There were some changes made for the OGO-3 unit to allow the high voltage steps to proceed from a low value for the first step to the highest negative window at the fourth step. The count sequence remains the same; however, the 4, 6 and 2 output gates control the window voltage control to generate the windows 2, 3 and 4, respectively.

For the first four measurement steps, F3 is clear and the positive F3C' output enables the measurement chain through Q38 and Q39. The following four steps include a noise check for the measurement chain beyond the preamp and three bookkeeping measurements during which the negative F3C' level grounds the measurement chain input for greater accuracy. The bookkeeping circuits insert the calibrate reference (standard signal), temperature and two level marker signals into the compression amplifier at the specified steps. The above procedure holds for the OGO-1 experiment; however, the OGO-3 unit was changed in that the bookkeeping order was changed and a high voltage pulse was available. Further, only the standard signal is fed into the compression amplifier; all other bookkeeping pulses are fed directly into the readout circuit.

In the OGO-1 unit, F4 complemented once per program cycle by M1(5), alternates active and inactive cycles. When this flip-flop is set, F4C enables the window voltage control and F4C' (negative) enables the modulator. The next M1(5) then clears

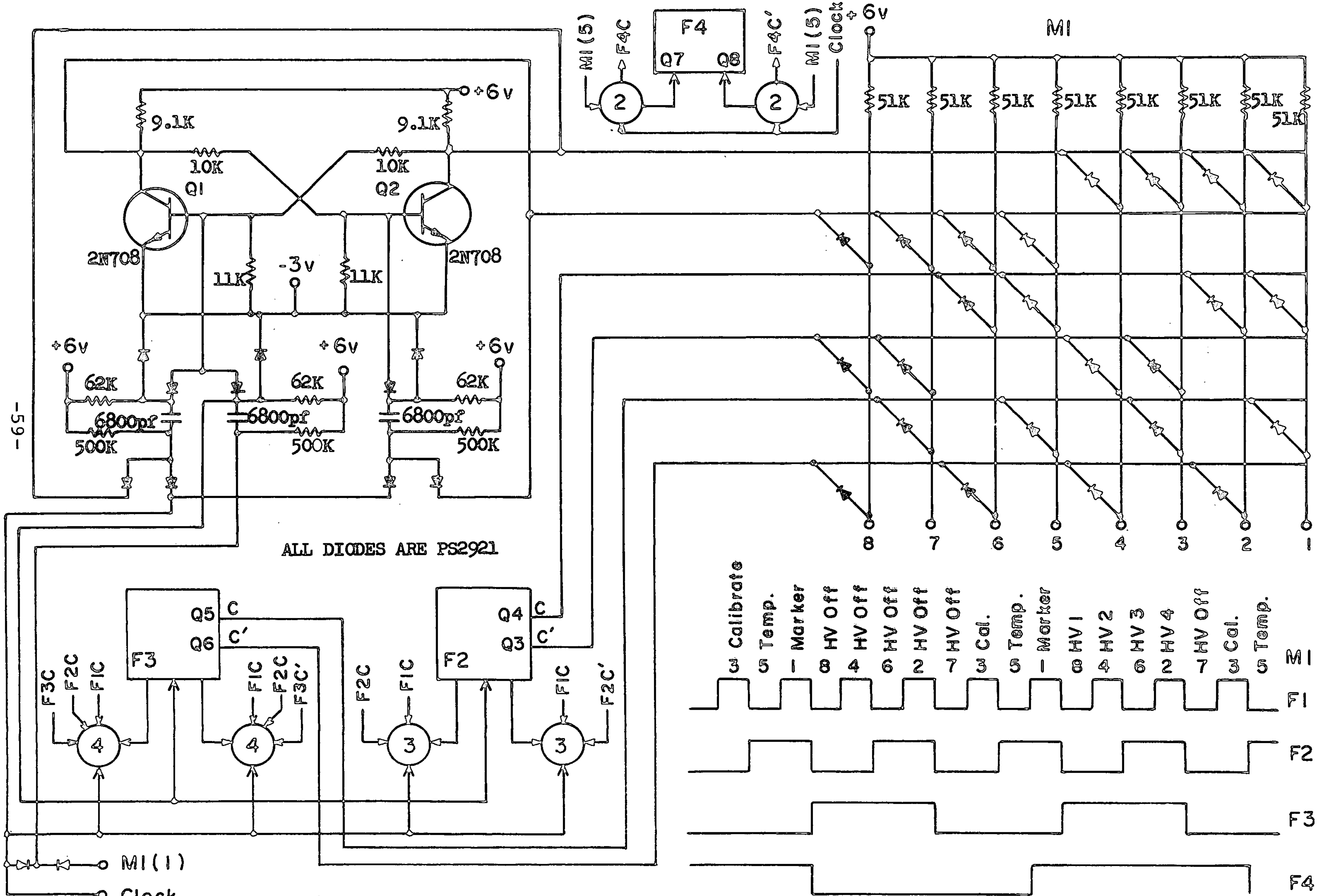


Fig. 7-10 ELECTRON TIMING DIAGRAM

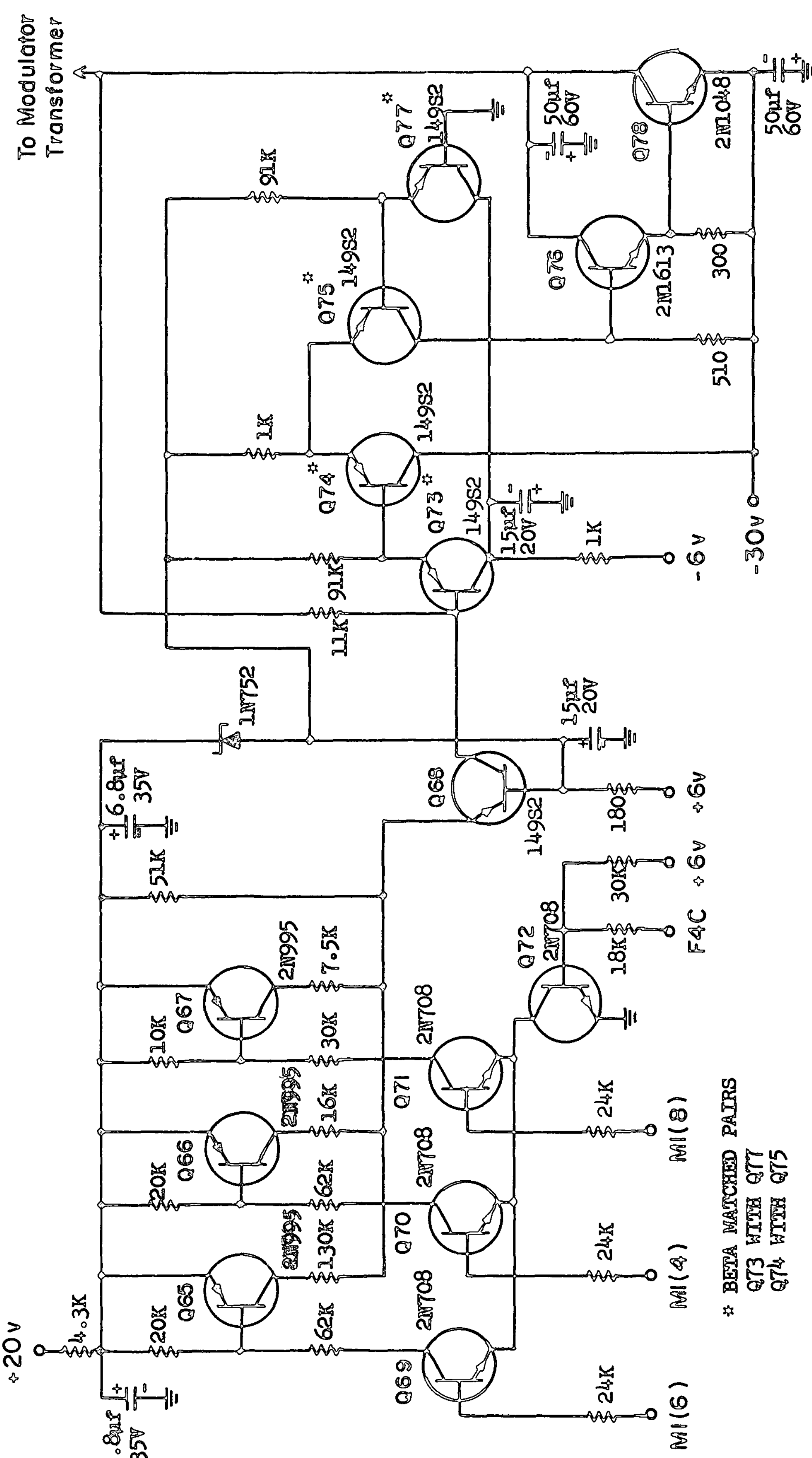
F4 to provide the low marker as identification for the preceding active measurement cycle. In the following cycle there is no HV and the only meaningful steps are calibrate, temperature and high marker. In the OGO-3 experiment, F4 does not control the selection register, modulator or marker circuit so that each cycle is identical to each other and the marker value is constant.

8.0 Electronic Circuits

This section describes significant modulator, measurement and time-share circuits. It assumes familiarity with basic solid-state circuit elements (inverters, emitter followers, multivibrators, etc.) and does not elaborate on these circuits. Unless otherwise noted, the descriptions apply to the circuits used in all OGO-1 and OGO-3 proton and electron experiments.

8.1 Window Voltage Control

This section describes the control register and amplifier in the electron experiment; those in the proton experiment are identical except for the additional register elements that allow finer subdivision of the proton energy range. In the electron experiment (Figure 8-1), the register consists of a zener-regulated voltage source driving common-base stage Q68 through a variable resistance comprising current drivers Q65-66-67 and their collector loads in parallel with a 51K resistor. A current driver is selected by M1 through gates G69-70-71 when enabled by F4C (OGO-1 only) through Q72. A selected driver thus specifies an input current to Q68, which supplies this current to the output amplifier over a wide voltage range.



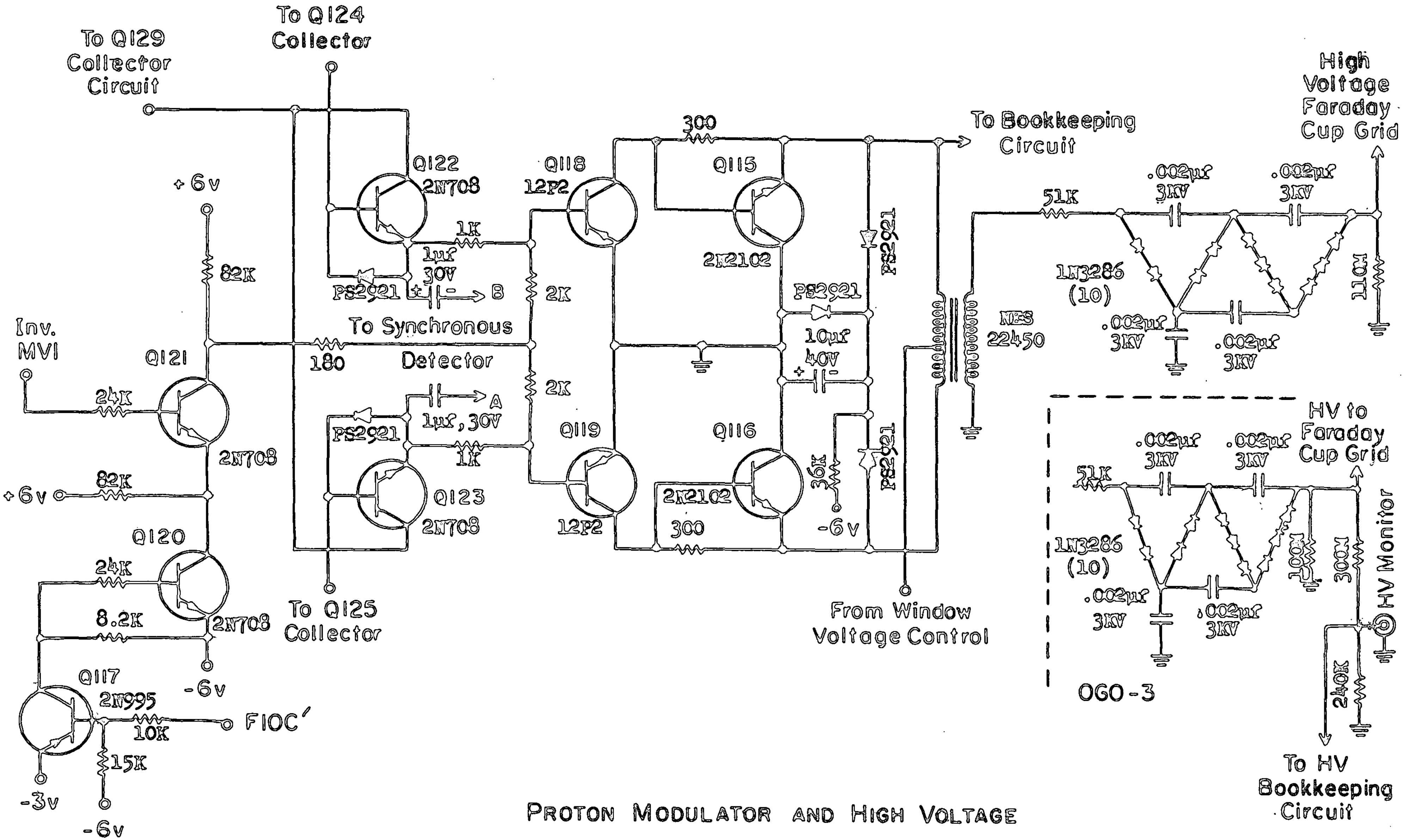
ELECTRON WINDOW CONTROL

Fig. 8-1

The control register and the amplifier consist of difference amplifier Q74-75 with emitter-follower input stage Q73-77, driver Q76 and output stage Q78. It performs as an operational amplifier due to its negative gain and the 11K feedback resistor to the Q73 base. The selected Q68 collector current results in a positive voltage at the error point (Q73 base). The amplifier responds by increasing the negative output voltage until the current drain through the feedback resistor very nearly matches the current input. The voltage output feeds the center tap of the modulator transformer.

8.2 Modulator and HV Supply

The proton modulator, Figure 8-2, is a push-pull switching amplifier, transformer coupled to the HV multiplier. The modulator is commutated by the buffered output of the sync flipflop when enabled by F10C and MV1. Since the logic accepts a negative enable level, the MV1 input is inverted by Q121. The F10C' input is negative when F10 is set, thus it is twice inverted by Q117-120 to drive the Q121 emitter. When the enable is present, the sync commutates output drivers Q118-119 which in turn switch the output stage by alternately grounding and open-circuiting the Q115-116 bases. Turn-on current for the output transistors is supplied by autotransformer action: the output transformer inductance maintains one primary terminal at about twice the negative center tap supply voltage while the other is grounded.

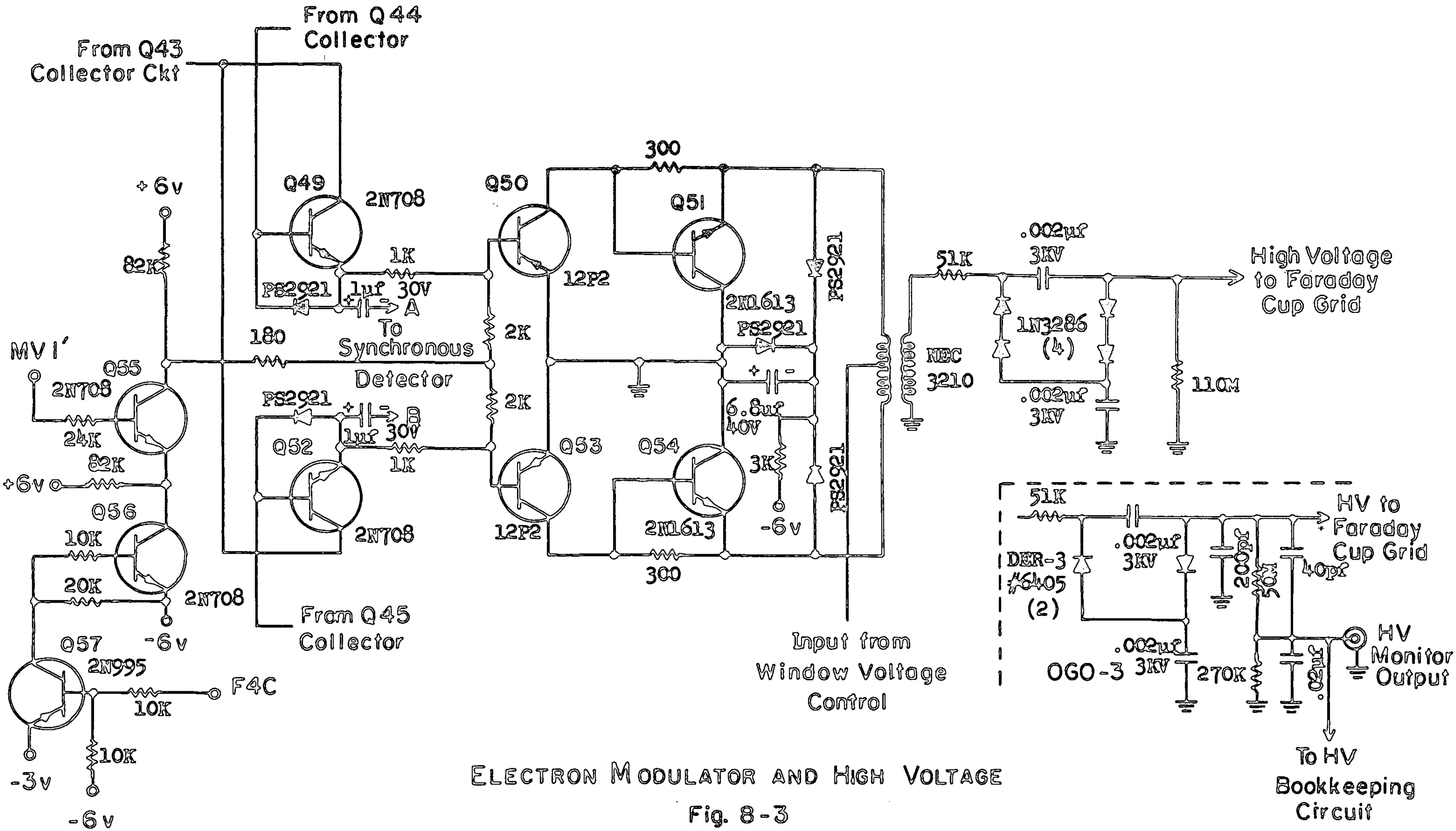


PROTON MODULATOR AND HIGH VOLTAGE

Fig. 8-2

The termination of each gate level interrupts switching, and if this occurs at the end of a half cycle when current is quite high, the resulting positive pulse to the off transistor could be damaging. The transformer terminals are, therefore, diode-clamped to prevent excessive positive excursions. A capacitor, maintained one diode drop negative, absorbs the positive pulses and discharge current is provided by a resistor to -6 v.

The current reversals in the output transformer primary induce a secondary ac voltage which drives the voltage multiplier through a surge-protecting resistor. In the electron experiment (Figure 8-3), the multiplier is a half-wave negative doubler. After the doubler output has reached maximum, each negative cycle charges the grounded capacitor to -V, where V is the zero-to-peak transformer voltage. The positive half cycle then transfers the charge from the grounded capacitor to the series capacitor. The input and output terminals of the series capacitor are now at +V and -V. The next negative half cycle sends a -2V pulse to the output through the series capacitor and recharges the grounded capacitor. Subsequent cycles repeat this sequence and the output is a -V to -3V square wave. The multiplier in the proton experiment consists of two half-wave positive doublers in series. The two sections are identical except that the "grounded" capacitor for the second section is



Electron Modulator and High Voltage

Fig. 8-3

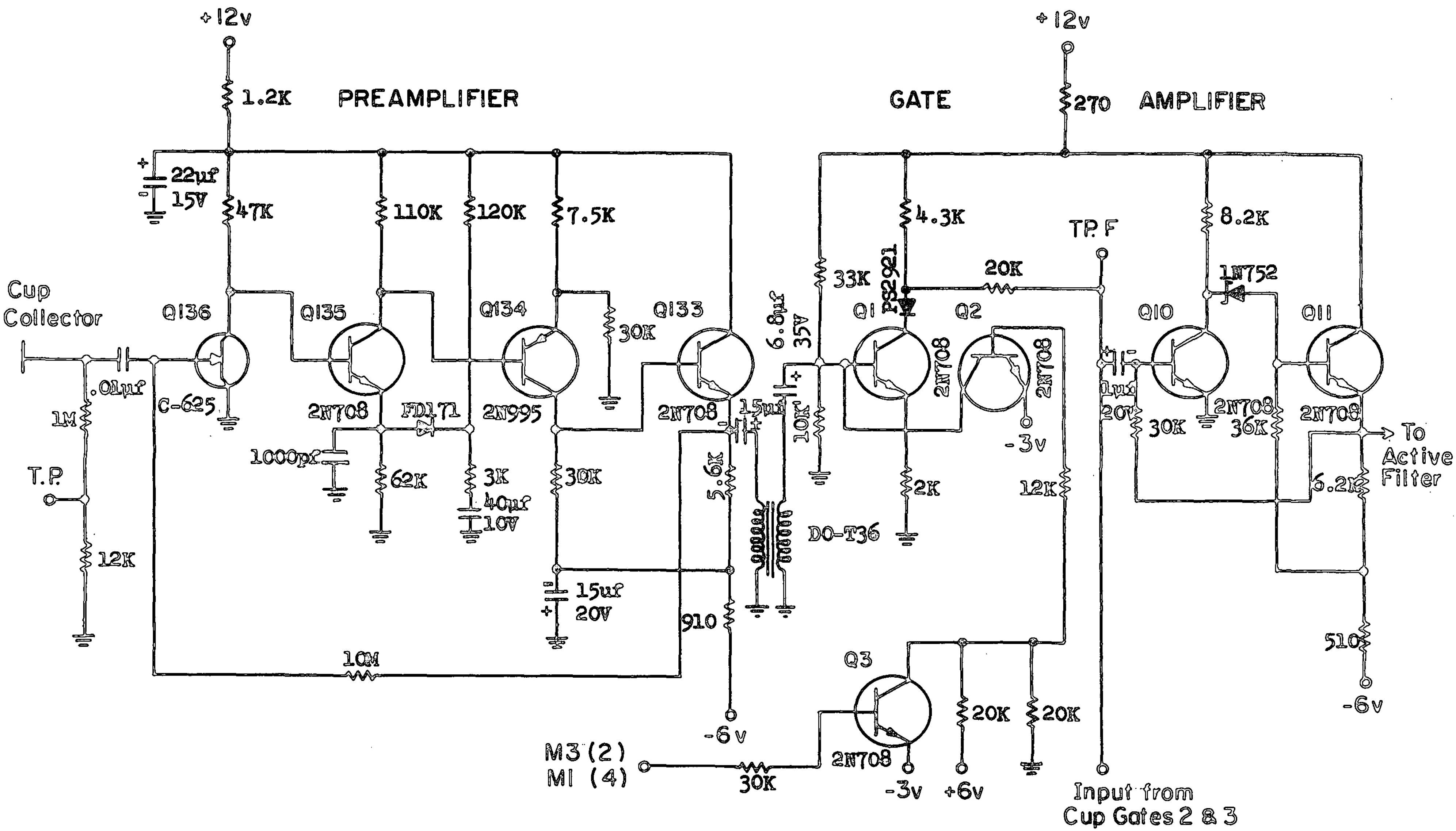
series-connected with that for the first section to reduce voltage-rating requirements.

Since neither multiplier employs filter capacitors, the transformer secondary ac appears in the output. The transformer peak-to-peak voltage thus determines the window aperture, and the number of doubler stages specifies mean dc level as a factor of 0 to peak ac. This factor increases arithmetically with successive stages 2, 4, 6, etc. In the electron HV output, therefore, if the transformer output is between V and -V, the modulating electrode receives a waveform between -V and -3V (neglecting diode drops and loading) or -2V mean; proton modulation voltage is from 3V to 5V and the mean is 4V.

The high resistance load at the multiplier output serves three purposes: it is a bleeder that discharges the multiplier capacitors prior to downward energy-level steps; it is a fixed load to compensate for the inherently poor zero-to-load voltage regulation of a multiplier (the load would otherwise be purely dependent upon incident proton density); and it is part of a 1250:1 voltage divider that allows monitoring the modulation voltage (OGO-3 only).

8.3 Preamplifier and Input Circuits

The basic preamplifier (Figure 8-4) is a 4-stage feedback-stabilized circuit using a crystallonics C-625 high-input impedance, low-noise field effect device as the input stage.

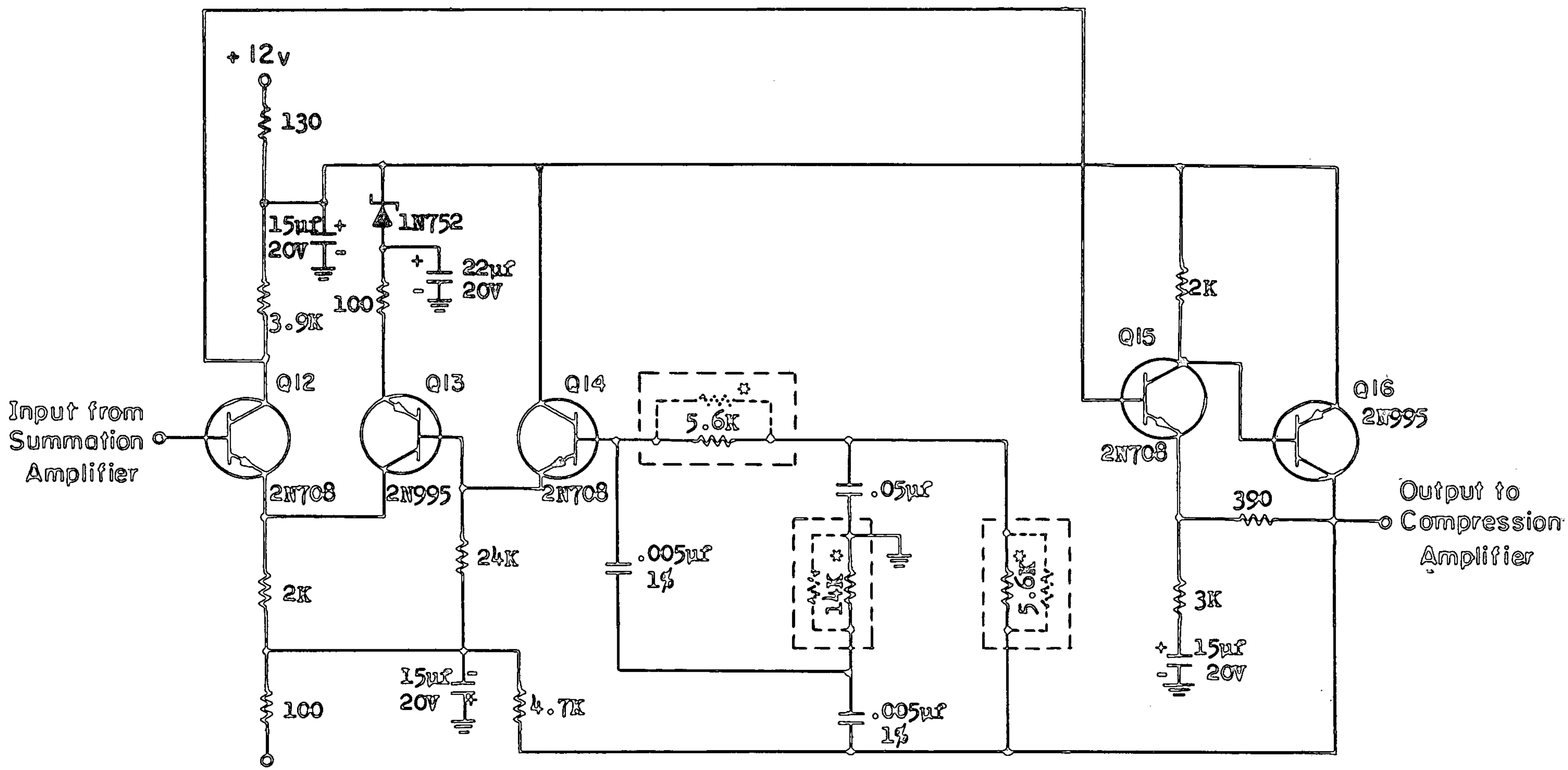


PREAMPLIFIER AND INPUT CIRCUITS
Fig. 8-4

Since the open loop gain of this amplifier is quite high (at least 10^3), the output voltage is very closely equal to the product of the 10M feedback resistance and the input current.

The cup gate consists of amplifying stage Q1 and gate inverters Q3 and Q2. Asserting the gate input floats the Q1 base, allowing it to follow the input signals; gate negation shorts the analog signal to -3 vdc, reverse biasing Q1 and interrupting the signal from the associated sensor collector, meanwhile maintaining a constant load at the summing point (test point F). The summing amplifier consists of inverter Q10 and emitter follower Q11. Gain is close to unity for each input (for the single input in the electron experiment).

The active bandpass filter (Figure 8-5) is an amplifier with an active negative feedback loop containing a twin-T notch filter. Since the feedback network response has a notch at the center frequency, overall amplifier-filter response is peaked there. The active feedback network consists of the filter, emitter follower Q14 and inverter Q13; negative feedback is applied to the Q12 emitter. The ideal twin-T filter has infinite attenuation at the notch, and a Q of 1/2. The filter used in these experiments is adapted to the amplifier and has a slightly lower Q, but notch attenuation is peaked at the sync frequency by resistor selection.



☆ RESISTORS SELECTED TO OBTAIN CENTER FREQUENCY OF 2460Hz.

ACTIVE BANDPASS FILTER

Fig. 8-5

To a 1% approximation, the overall Q of an active filter of this type is (A + 1)/4 for A > 15, where A is the open-loop gain of the amplifier*. For the purpose of measuring A, the amplifier input is the base of Q14; from this point to the output, the amplifier has a voltage gain of approximately 20. Consequently the overall Q is a little more than 5, so the response is 3 db down at frequencies 10% removed from the sync frequency. If the signal from the summing amplifier were introduced at the Q14 base, it would realize the full gain at center frequency and thus overload following circuits. To limit signal gain while still maintaining desirable skirt attenuation, most of the gain is placed in the feedback loop, and signal gain from the Q12 base to the output is approximately 2.

8.4 Compression Amplifier

The compression amplifier (Figure 8-6) consists of 7 cascaded amplifying stages and an active network that sums the input signal and each stage output. Each stage has a gain of about 4 and amplifies linearly over a signal range that is restricted by diode limiters; thus the summed output of the compression amplifier approximates log (input) by a succession of 8 logarithmically spaced semilinear curves, over an input dynamic range of roughly 4^8 or 65,000; i.e., nearly 5 decades. This corresponds to a filter output range of 60

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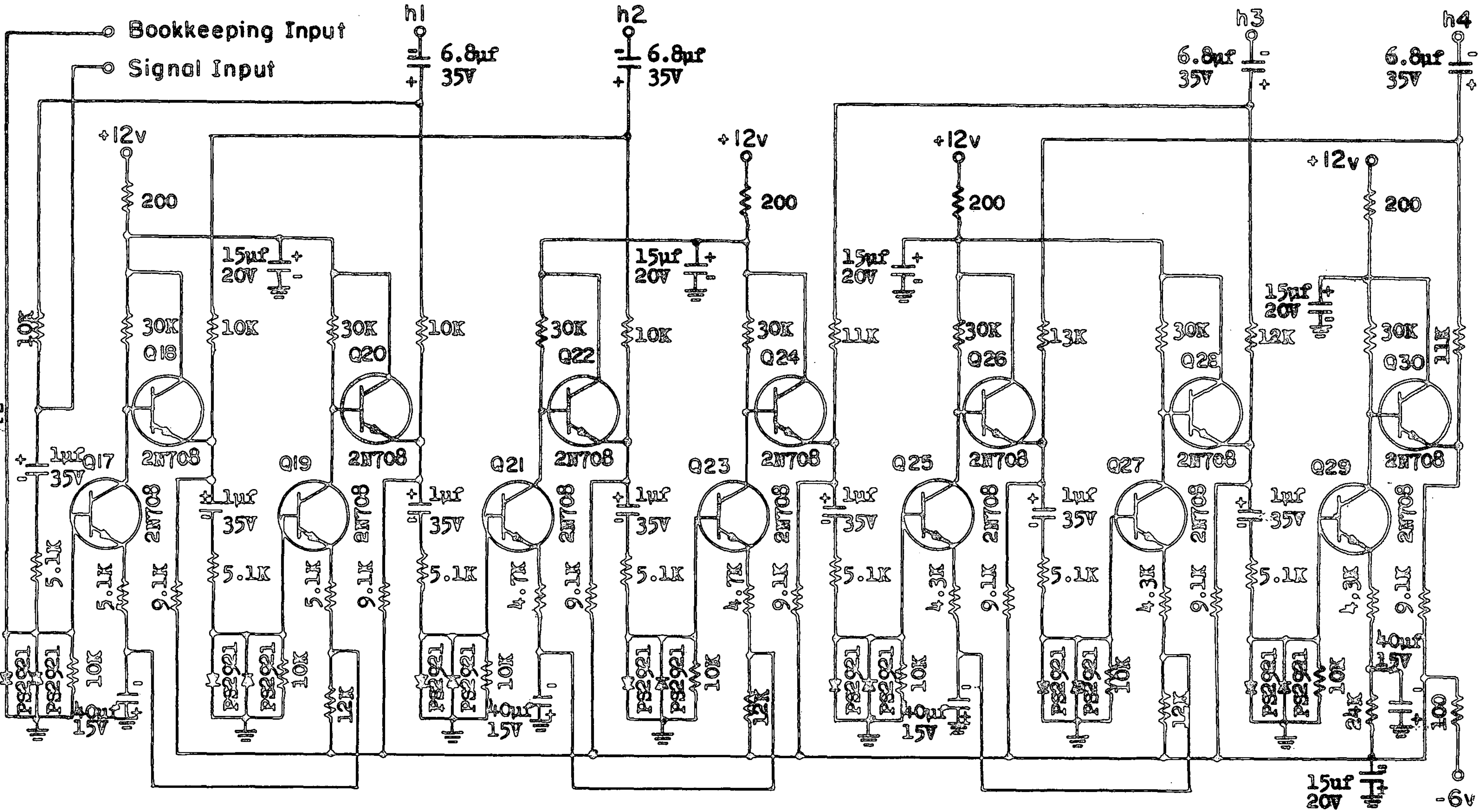
* Valley & Wallman: Vacuum Tube Amplifiers, MIT Rad Lab Series, McGraw-Hill, 1948, Chapter 10.

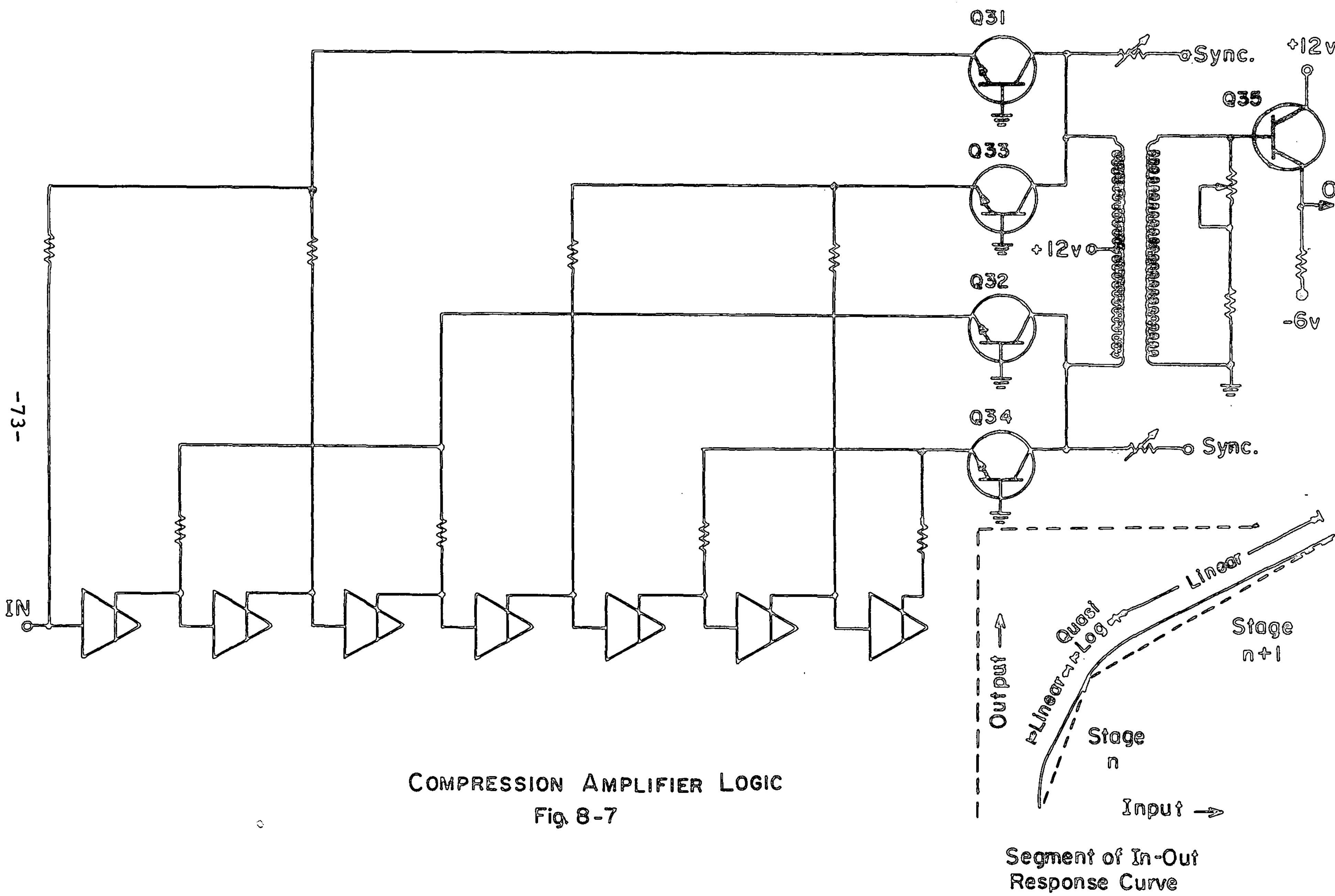


COMPRESSION AMPLIFIER
Fig. 8-6

microvolts to 4 volts peak-to-peak; above and below these limits the amplifier response is linear. The compression amplifier would have a rather jagged transfer curve (dashed lines) if the limiting diodes were ideal and individual stage response perfectly linear; however, diode square law characteristics and amplifier nonlinearity round off the response to that shown by the solid line (Figure 8-7).

The input circuit of each stage is a voltage divider (X0.66) feeding a parallel diode peak clipper. The remainder of the stage comprises a class A inverting-voltage amplifier driving an emitter follower. Stage ac voltage gain is roughly equal to 0.66 R1/R2. To achieve better overall fit to a logarithmic characteristic, gain is increased slightly in successive stages so that the gain of a non-limiting stage is proportional to the signal sum from the previous stages. Thus each of the first two stages amplifies by 3.7; stages 3 and 4 have a gain of 4.0 and the gain of the last three stages is 4.4.

An amplifier stage is approximately linear for any input signal below 0.7 volts (0.5 volts at the limiting diodes); from 0.7 to 1.0 volts, stage response is roughly logarithmic; and above 1.0 volts the input limiter is saturated and there is little further increase in stage output. An input to the compression amplifier from 0 to 150 μv peak-to-peak is amplified linearly in all stages. Increasing the input level



COMPRESSION AMPLIFIER LOGIC
Fig. 8-7

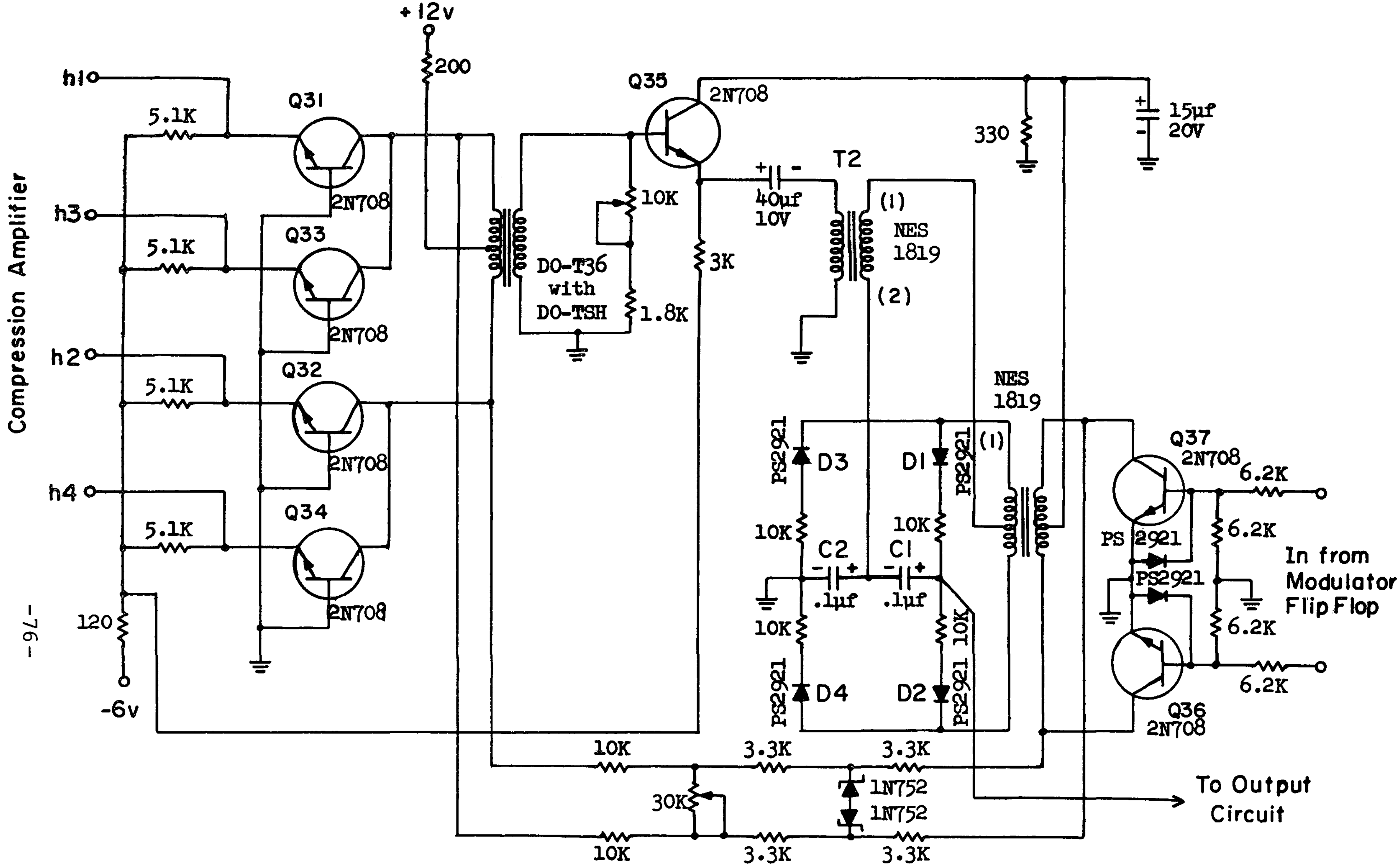
to 220 μv limits stage 7 while the remaining stages continue to amplify linearly. A further increase to 1 mv limits stage 6; at 4 mv, stage 5 limits; and so on. Individual selection of the summing amplifier input resistor values is made to compensate for variations in component parameters.

The signal phase at the input and at even-numbered stage outputs is opposite to that of the odd-numbered stage outputs; summation must restore proper phase relationship. Furthermore, to avoid instability, resistive summation is restricted to adjacent in-phase stages. Consequently the summing amplifier consists of 4 common-base stages in push-pull parallel, each of which receives 2 outputs from the compression chain. If the input signal is considered the reference, the in-phase partial sum appears at the top of the center-tapped transformer primary and the out-of-phase partial sum at the bottom, and the transformer thus performs the summation. The variable load resistance across the single-ended secondary of the transformer determines the gain, i.e., the slope of the logarithmic in-out transfer curve, of the compression amplifier and synchronous detector. This control is set to deliver a full-scale signal to spacecraft telemetry at the maximum signal level of interest. The variable sync reference added to the transformer primary is an offset signal; adjusting it effectively varies the bias on the diodes in the synchronous detector and moves the transfer curve up or down without changing its slope.

This adjustment is made to optimize linearity, compensating for offset in the output emitter follower and the synchronous detector.

8.5 Synchronous Detector

The synchronous detector (Figure 8-8) is a ring bridge demodulator driven by the input signal and the sync reference. T1 couples the sync to the bridge, forward-biasing D1-D2 and D3-D4 alternately, thus commutating the T2 signal input between C1 and C2. With a positive half cycle at the (1) terminals of T1 and T2, D1 and D2 are forward-biased, allowing the signal to charge C1 in the polarity shown. The charging current path is from T2(1) through both halves of T1 secondary, and through the forward-biased diode pair to C1 and T2(2). Similarly, the negative half-cycle charges C2. The positive output at the upper bridge junction feeds the analog storage and output circuit referenced to ground; with the high load impedance presented by the following stages, the output approaches a pure dc. With constant frequency, the output voltage is directly proportional to the signal amplitude, provided the latter does not exceed the sync half-winding amplitude. Allowing E_{sig} to exceed $E_{sync}/2$ for any portion of the half cycle introduces nonlinearity by reverse biasing one diode of the normally forward-biased pair. To avoid this trouble, the switching circuit in the T1 primary standardizes the sync input so that detector output is a linear function of the signal.



SYNCHRONOUS DETECTOR

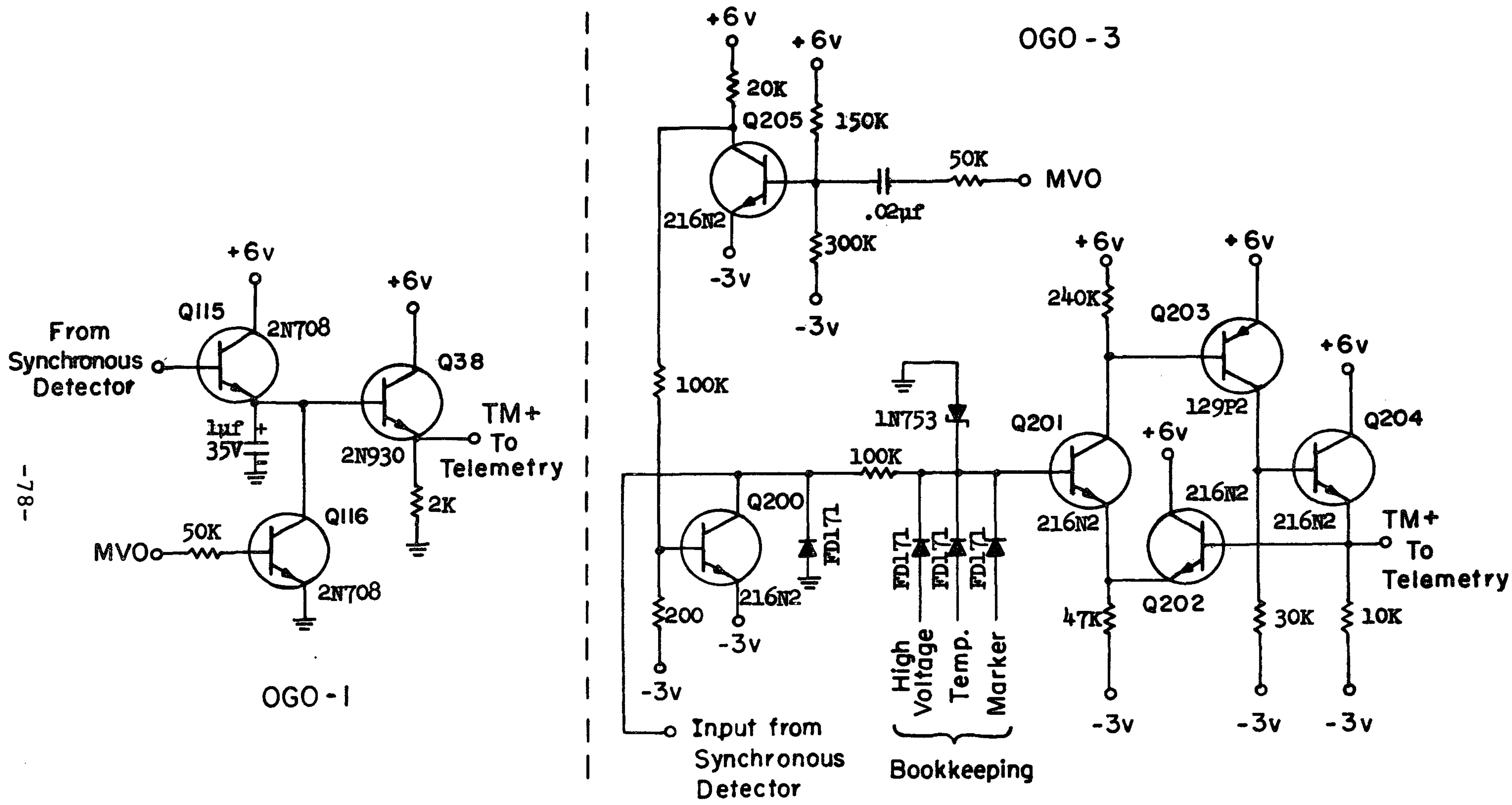
Fig. 8-8

A significant property of this detector is that of bandwidth reduction. In this respect, it is similar to most modulators whose output contains both sum and difference components of the input frequencies. The 4.922 kc sum component is filtered by the series combination of C1 and C2 across the bridge output. Since the inputs are mutually coherent, the difference is the dc analog with no near sidebands.

8.6 Output Circuit

The analog storage circuit used in the OGO-1 experiments is shown in Figure 8-9. An emitter follower stores the detector output in a 1 μf capacitor. This voltage is then transferred to spacecraft telemetry by a second emitter follower at a minimum current gain of 100. The storage capacitor thus sees a load of at least 150K (100 times the output load), so the storage time constant is at least 150 ms. A dump switch triggered by the delay MV gate provides a fast discharge after a measurement has been telemetered and before a new one begins.

The output circuit of the OGO-3 experiment was changed from a storage circuit to a direct readout circuit (see discussion on page 33). The charging capacitors in the synchronous detector were also changed from 0.1 μf to 1.5 μf. The detector output together with the high voltage, temperature and marker signals are inserted at the input to the readout circuit which is a negative feedback amplifier



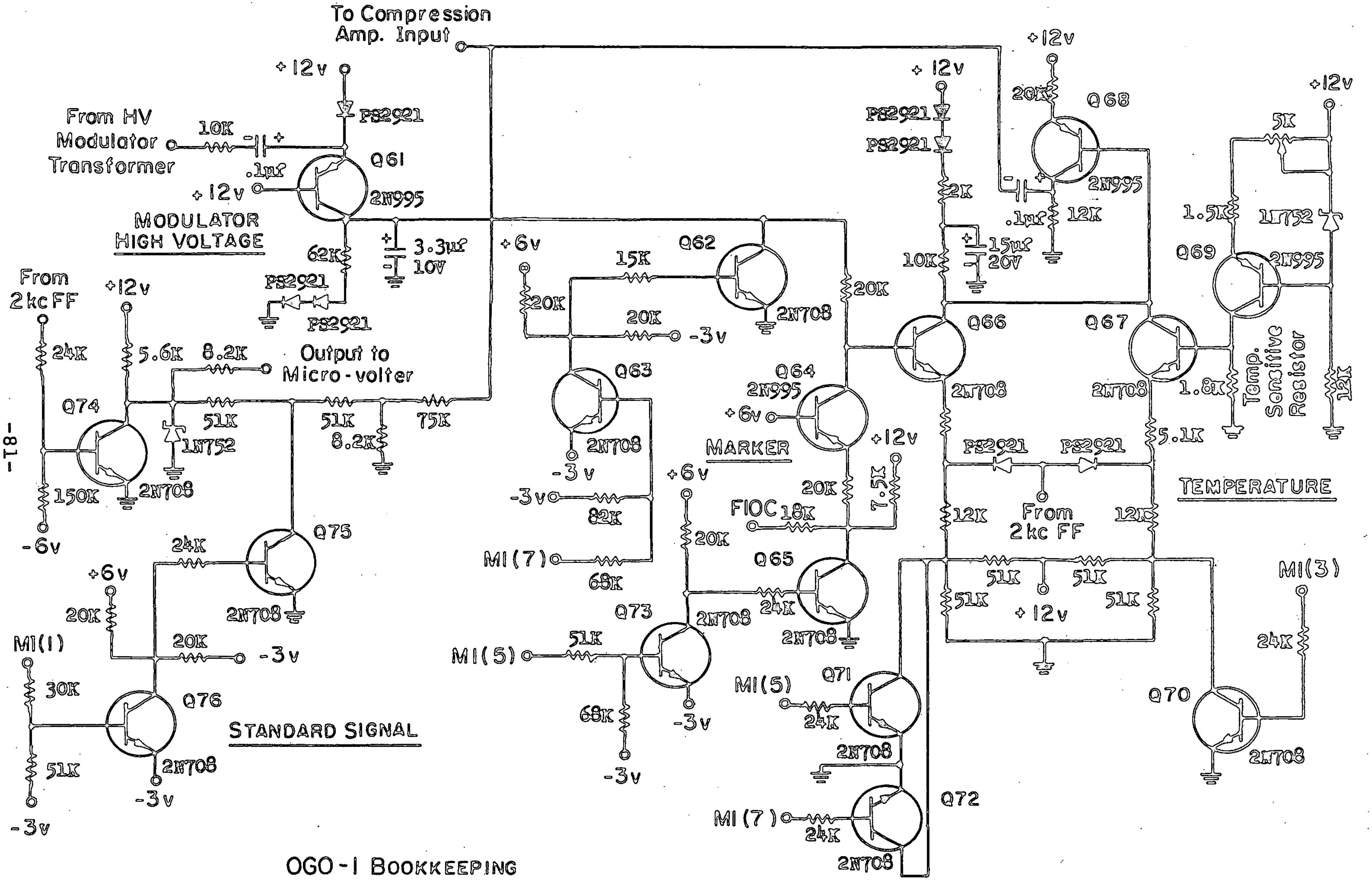
Output Circuits
Fig. 8-9

with unity gain. The readout circuit is open for the first 100 ms after the clock pulse; however, only the marker and temperature appear for the full 288 ms because of the action of MVO, the delay multivibrator. At the start of the measurement period, MVO goes negative; the input to Q105 is differentiated and Q105 cuts off for about 10 ms which clamps the synchronous detector output during the time when the high voltage is rising to its predetermined window value. At about 110 ms after the clock pulse, Q105 conducts and Q100 unclamps the input to the readout circuit, allowing signals to proceed through the circuit. The output is telemetered at the same times as the OGO-1 experiment in accordance with the spacecraft telemetry format.

8.7 Bookkeeping

The bookkeeping circuits for the OGO-1 electron and proton experiments are similar except that the electron unit does not have a high voltage bookkeeping circuit. Transistor symbol numbers and input logic are also different. Figure 8-10 shows the circuits for the proton unit which consists of high voltage, temperature, marker, standard signal (calibrate) and reset in that order. M1(7) logic controls the high voltage circuit consisting of transistors Q61, Q62, Q63, Q66 and Q72. The voltage at the primary of the high voltage modulator transformer is coupled to Q61 whose output is a dc analog voltage. When M1(7) is positive, the Q61 output drives Q66 which is modulated at 2.461 kc. The temperature circuit consisting of Q67, Q69 and Q70 is controlled by logic M1(3). Transistor circuit Q69 is a constant current source whose output is dependent on the temperature-sensitive resistor connected to the transistor base. An output is produced at Q67 modulated at 2.461 kc when M1(3) is positive. Logic M1(5) controls the marker circuit consisting of Q64, Q65, Q66, Q71 and Q73. Transistor circuit Q64 is a voltage divider influenced by F10c. When M1(3) is positive, Q64 drives Q66 whose output is modulated at 2.461 kc. The action of F10c is to produce a high or a low amplitude marker for cycle identification. High voltage, temperature and marker pulses are inserted into the compression amplifier through transistor Q68.

The standard signal circuit comprises Q74, Q75 and Q76 controlled by M1(1). Input to Q74 is derived from the 2 kc flipflop and its output is regulated by a zener diode. When M1(1) is positive, the output of Q74 is coupled to the compression amplifier input. Reset does not produce a bookkeeping pulse, it being a function in the logic circuits only. The bookkeeping sequence for the electron unit is blank, standard signal (calibrate), temperature and marker. The bookkeeping circuits for the OGO-3 electron and proton experiments are basically the same. Figure 8-11



OGO-1 Bookkeeping

Fig. 8-10

is the bookkeeping circuits for the proton unit. The order of signals is high voltage, marker, temperature, standard signal (calibrate) and reset. High voltage circuit comprising Q302, Q303, Q304 and Q305 is controlled by M1(7). Input to Q305 is from the high voltage rectified output (see Figure 8-2). When M1(7) is positive, the Q305 output is coupled directly to the readout circuit. Temperature circuit (Q65, Q69, Q73) is a constant current source and its unmodulated output controlled by M1(5) is inserted into the readout circuit. The marker circuit (Q300, Q301) is a voltage divider controlled by M1(3) and its output is fed into the readout circuit. The marker is the same amplitude for each cycle. The standard signal is identical to the OGO-1 circuit and its modulated output is fed to the compression amplifier. Reset has no bookkeeping pulse. The OGO-3 electron bookkeeping sequence is high voltage, standard signal, marker and temperature. The only circuit which differs from the proton unit is the high voltage. A resistor has been added to the input circuit of Q305 because the electron high voltage is negative rather than positive.

8.8 Power Converter

The OGO-1 power converter generates all experiment operating power at the various required voltages (drawings CX-4856-6 and CX-4856-8 for the proton unit; CX-5367-4 and CX-5367-5 for the electron unit in Appendix C). It

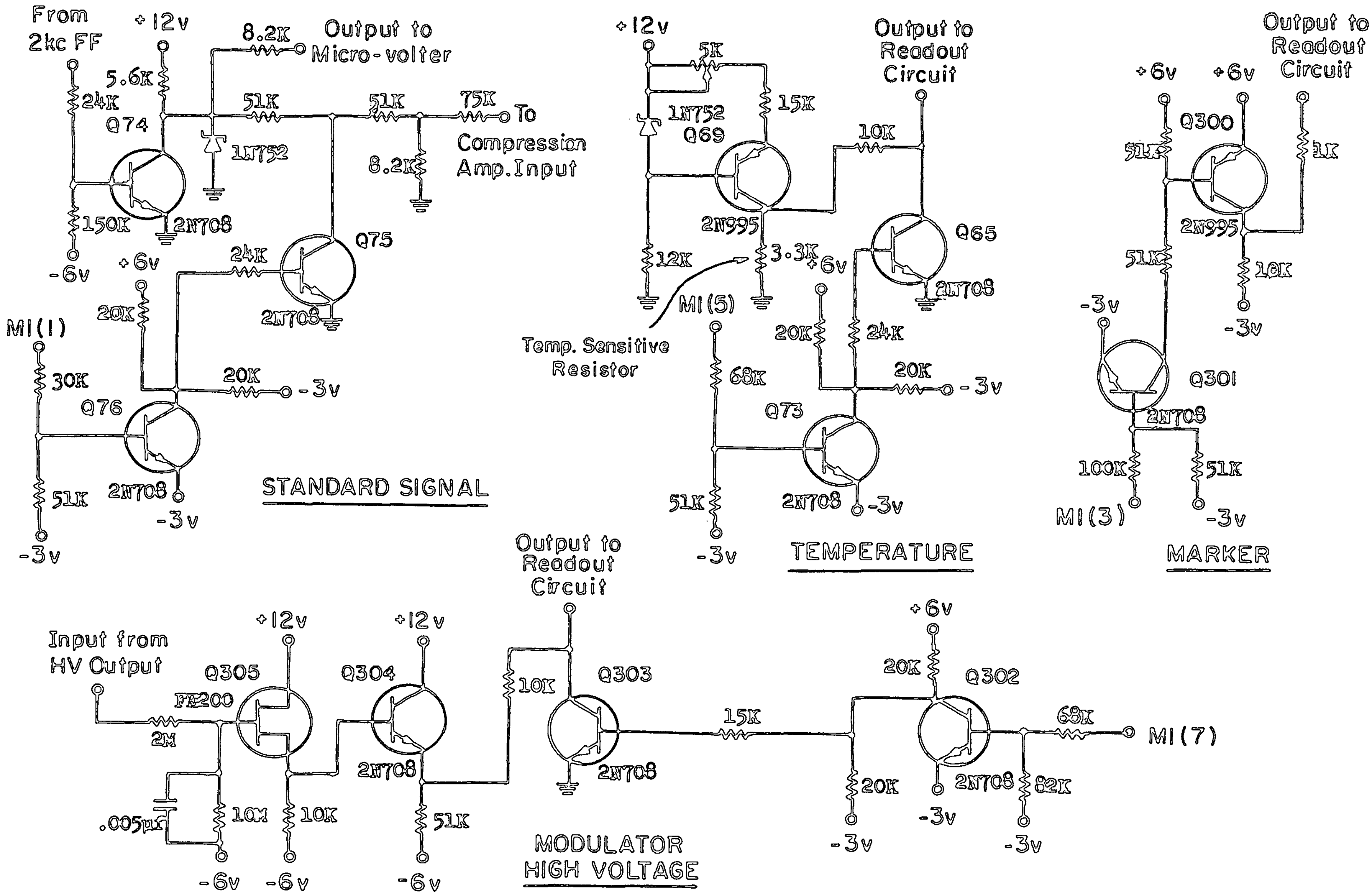


Fig. 8-11 OGO-3 Bookkeeping

accepts 28 vdc primary power and the frequency reference (SP SYNC) from the spacecraft. The converter consists basically of a synchronized, transformer-coupled oscillator that drives a push-pull output stage. Experiment power is rectified and filtered from the output transformer windings; an additional secondary is a feedback input to a pulse-width modulation regulator that controls primary power to the output stage.

When the spacecraft selects the experiment by applying power to the converter, CR8 and Q3-4 provide +10 v starting power to oscillator Q7-8. Speedup capacitor C1 ensures that this supply has a relatively rapid rise time at turn-on, and C16-CR16-C11 couple the positive transition to T3-8 (and by induction to T3-11) to provide a rapid start for the oscillator. The oscillator will self-start in any case; its free-running frequency is determined primarily by C10 and the T3 primary inductance and is somewhat lower than the sync frequency.

C16 and C11 are a capacitive load on the Q8 collector. When Q8 turns on, this load is applied through CR16; however, application of the load for the positive Q8 collector swing is delayed until CR15 is triggered by a positive transition at the SP SYNC + input line. This couples a negative pulse to the Q8 collector, and the T3 9-10-11 winding commutates the oscillator. At this transition, current flow through C11 reverses, forward biasing CR16 and allowing CR15 to cut off and await the next trigger pulse. Thus the Q8-on half cycle is timed by the resonant frequency of the oscillator, and synchronization occurs on the other half cycle. Since no dc may flow into the SP SYNC lines, the trigger circuit is dc isolated.

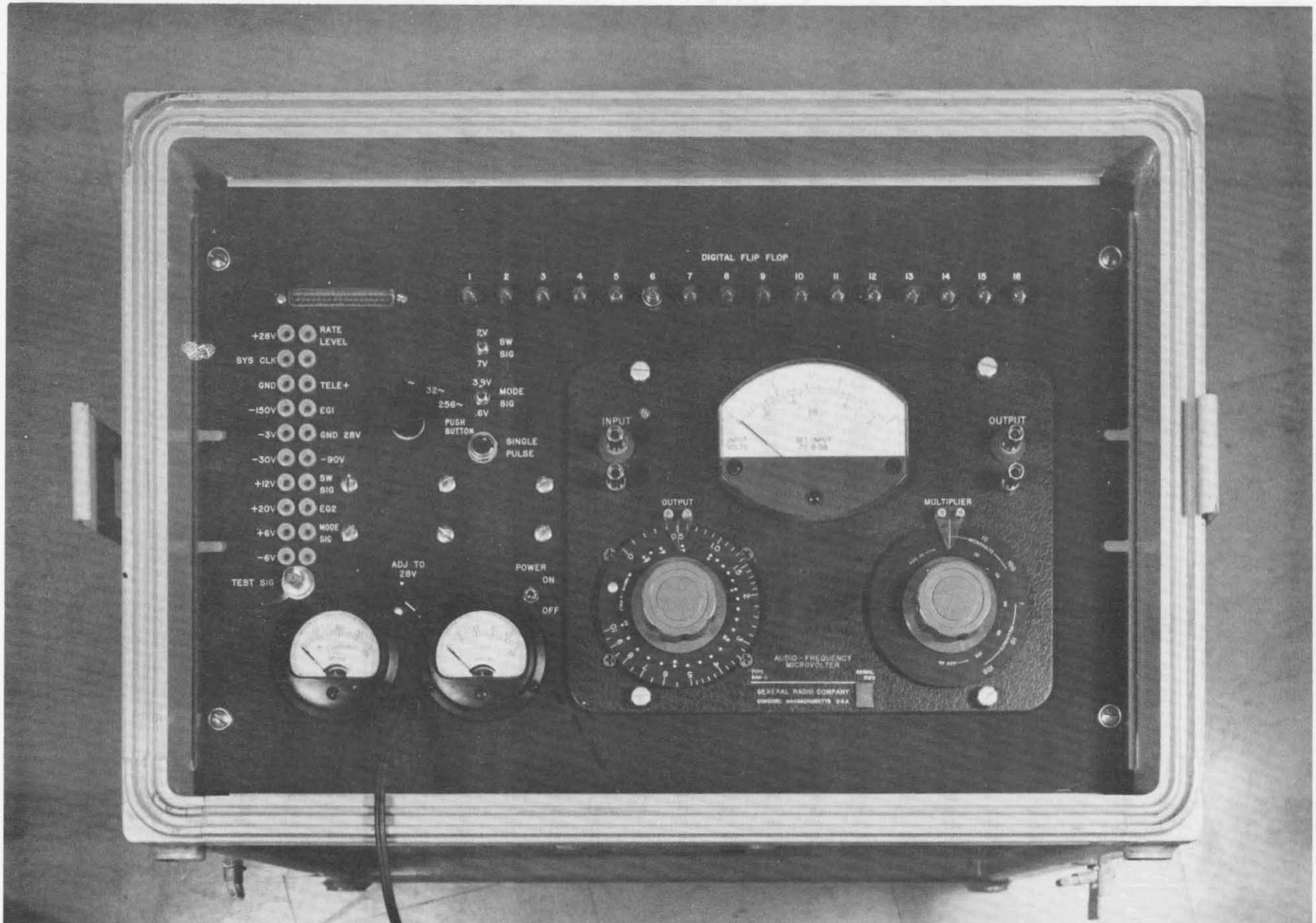
Power output stage Q9-10 amplifies the oscillator output. Once the converter has swung into operation, the rectified output of T1 winding 4-5-6 rises to approximately +12 v and replaces Q3-4 as the oscillator power source. This winding also serves to sense the output level. Difference amplifier Q5-6 compares a fraction of the sense winding dc output with 8.4 v reference CR9. The output of this stage drives the control windings of magnetic amplifier T2. The load windings (T2-B) govern the converter output by modulating the width of the rectified oscillator pulses fed to the base of pass transistor Q1. If the T1 sense winding output tends to rise, the resulting current imbalance in the opposed T2 control windings is in the direction of opposition to the dc magnetic bias resulting in decreased core energy and consequently increased load winding inductance. This increases the time required for the rectified oscillator pulse into T2-B to saturate T2 and pass through T2-B to turn on Q1. As the oscillator pulse decays at the end of a half cycle, T2 falls out of saturation and Q1 begins to turn off. C6, C5 and voltage amplifier Q2 are a regenerative ac bootstrap circuit to reduce Q1 dissipation by accelerating its drive toward saturation and cutoff. When Q1 begins to turn on, this circuit amplifies the resulting output rise and applies it to the Q1 base, driving Q1 rapidly into saturation. At the end of the rectified half cycle, the beginning of the downward output transition pulls the Q2 emitter further negative; the resultant collector negative pulse accelerates Q1 turnoff.

The Q1 output, a 4.9 kc variable-width positive pulse train, is L-C filtered and applied to the switching amplifier output stage. The T2 winding in series with the output filter provides core magnetic bias and positive current feedback to the magnetic amplifier. Proper selection of shunt R18 adjusts the feedback for maximum compensation, within the stable range, for experiment load variations. Full wave rectification and filtering after the output transformer provides experiment power at -3v, ±6v, ±12v, -30v and either +30v, +120v and +150v (electron experiment) or -30v, -120v and -150v (proton experiment).

The OGO-3 power converter (drawing D-5465-A in Appendix C) differs from the OGO-1 in that the frequency portion operates at three times that of the OGO-1 unit. The principles of operation are the same with some added refinements made to eliminate interaction between the outputs. The inputs receive the +28vdc and SP SYNC from the spacecraft. The power converter is a synchronized transformer-coupled oscillator driving a push-pull output stage. The oscillator circuit free runs at a frequency of approximately 7.5 kc and is synched to 7.389 kc. The oscillator output is the push-pull output stages Q20 and Q21 via T3 and Q18, Q19. The secondary of T4 drives T5 and T6 through their associated push-pull circuits. The output of T6 is rectified and provides the power to drive the high voltage modulator. The outputs from T5 are rectified and filtered to provide the +20v, +12v, +6v, -3v, -6v and ±150v power to the experiment. The +28v input circuit was designed to operate over a range from 22v to 34v. The circuit provides protection to the incoming power should an overload develop within the converter. Output power supplies +12v, +6v and -6v contain regulating and overload protection circuits.

9.0 Ground Support Equipment

The complete checkout procedure includes tests of the digital and analog portions of the proton and electron experiments. The OGO-1 ground support equipment (GSE) shown in Figure 9-1 duplicates all input signals from the spacecraft and allows examination of experiment response.



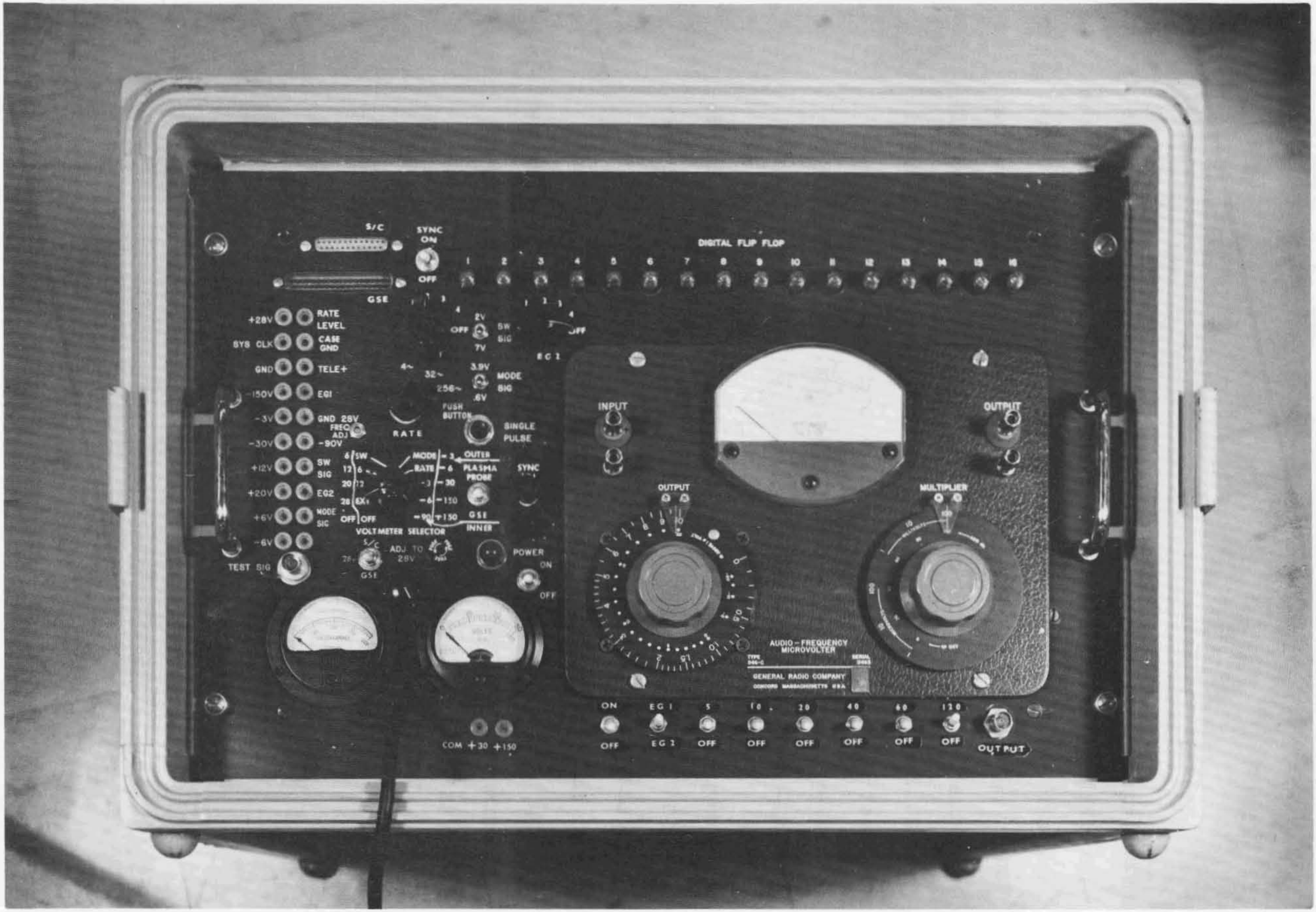
OGO-1 GSE

Fig. 9-1

Auxiliary equipment required includes an oscilloscope to check waveforms and event timing, an accurate vacuum tube voltmeter (VTVM) for power supply voltage measurements, and high voltage probes for both test equipments for measuring the modulator output. The GSE does not supply a sync signal; therefore, it is necessary to insert a 2.461 kc square wave at pins 3 and 4 of the experiment SPACECRAFT jack for measurements requiring the sync. A precision attenuator (General Radio microvolter) mounted on the GSE front panel can be used to furnish calibrated input signals.

The 37-pin connector located in the upper left-hand section of the GSE is connected to the GSE TEST plug on the assembled flight unit. A metered, adjustable, full-wave bridge power supply feeds 28 volt primary power to the experiment. The RATE switch allows operation at a simulated spacecraft data rate of 1, 8 or 64 kilobits (roughly 4, 32 or 256 index pulses per second) and provides the corresponding bit rate level. Index pulse repetition rate is governed by selecting a commutating capacitor for astable multivibrator Q2-Q3. Amplifier Q4-Q5 generates a 0 to +6v fast-rise pulse for every positive transition at the Q2 collector. The PUSH BUTTON position of the RATE switch allows the operator to step the experiment with the SINGLE PULSE button. The SW SIG switch simulates the equipment group (EG) assignment level and directs the index pulses to the appropriate input. A third selector, MODE SIG, generates the 2-level MODE signal. The GSE receives the 1 outputs of all flipflops in the experiment digital sections and shows each assertion by an indicator lamp. The electron experiment, whose program contains only 4 flipflops, connects to indicators 1 to 4; the proton experiment uses all 16 lamps. A set of jacks permits monitoring the experiment system clock (SYS CLOCK), analog output (TELE +) and all dc power (jacks labeled with corresponding voltages) as well as the outputs of the GSE. The TEST SIG jack receives a precision amplitude square wave at the sync frequency from the experiment; two cables transfer the signal through the microvolter to experiment test jack J9. Drawing D-5650-A in Appendix C is a schematic of the OGO-1 GSE.

The OGO-3 GSE (Figure 9-2) is a modified version of the OGO-1 unit; the major changes included additional power supplies, a square wave oscillator tunable to 2.461 kc, a multi-position switch for monitoring either the GSE or the experiment voltages, a delayed trigger circuit, and the addition of a 25-pin connector together with several switches. The additional power supplies were incorporated to provide the power for the circuits in the GSE which previously acquired this power from the experiment. The square wave oscillator eliminated the need for a separate piece of

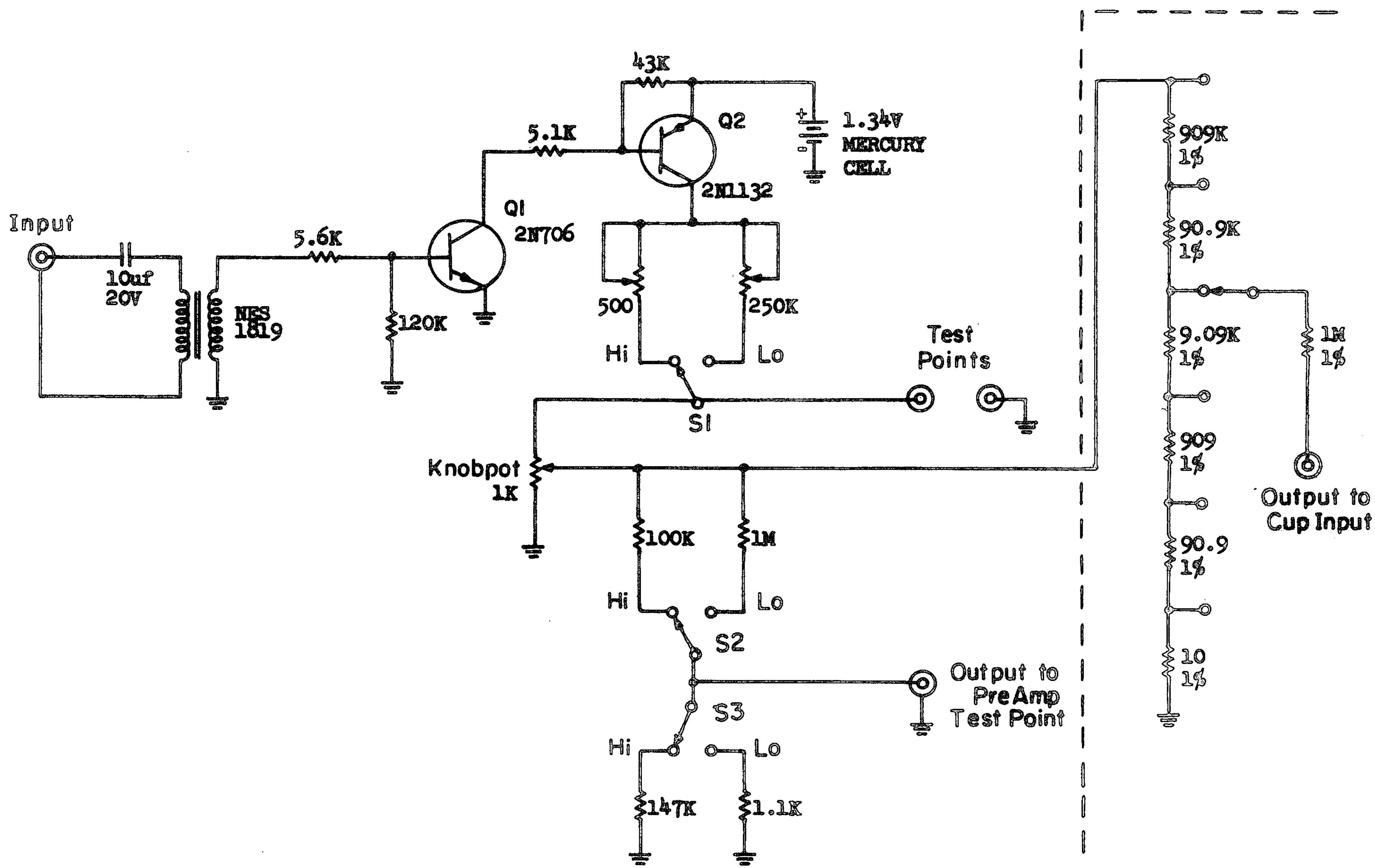


OGO-3 GSE

Fig. 9-2

test equipment. Installation of the multi-position switch provided a quick means of monitoring the voltage within both the GSE or experiment. The 25-pin connector labeled SPACECRAFT on the GSE is connected to the spacecraft jack on the experiment. This addition provided a means of checking all the EG inputs and inserting the sync frequency. A delayed trigger circuit was added to allow a trigger delay to an oscilloscope not incorporating this feature. Drawing D-5465-B in Appendix C is a schematic of the GSE.

To provide an easier method for calibrating the experiments, an OGO "calibration box" (Figure 9-3) was designed and constructed. The input to this box was from the GSE "TEST JACK" and the output was generally fed to the experiment preamp test point. An alternate output could be fed to the experiment input from the Faraday cup. The output signal from the calibration box was continuously variable from 1×10^{-7} to 1×10^{-12} amperes.



OGO Calibration Box

Fig. 9-3

10.0 Response of the Detectors to a Particle Beam

The signal produced by a specified distribution of particles incident on the detector can be calculated if one knows two functions that characterize the detector:

a. The current produced by a monoenergetic unidirectional beam of particles of energy E incident at angles θ, ϕ with respect to the detector axis. For a Faraday cup, the current can be approximately factored into a function of the angles θ, ϕ (the angular response of the detector) and a function of $E \cos^2\theta$ (the energy window). If the incident beam contains n particles cm^{-3} of mass m and charge e, the current in the k_{th} channel can be written as:

$$i_k = e\ n\ v \cos\theta\ A_o\ G(\theta,\phi)\ W_k\ (E \cos^2 \theta)$$

where $v = (2E/m)^{1/2}$, A_o is the effective area at normal incidence, and $G(\theta,\phi)$ and $W_k\ (E \cos^2\theta)$ are the functions describing the angular response and the energy windows, respectively.

b. The telemetry signal produced by a specified collector current (the "calibration curve").

Detailed descriptions of these functions have been given in references 1 and 3 (see Bibliography at the end of section 12). Here we merely summarize the numerical results.

10.1 Angular Response Functions

These are identical for OGO-1 and OGO-3.

a. MB experiment:

$A_o = 18.3 \text{ cm}^2 (1 + \lambda), \lambda = 1.0 \pm 0.5$

$$G(\theta,\phi) \simeq 1.408 \cos^2\theta - 0.451 \qquad 0 \leq \theta < 55.5°$$

$$= 0 \qquad 55.5° < \theta$$

($G(\theta,\phi)$ is independent of ϕ.)

b. SOEP experiment:

$A_o = 13.6 \text{ cm}^2$

The function $G(\theta,\phi)$ for a single collector is tabulated in Table 10.1; ϕ is measured from the center of the collector, and $G(\theta,-\phi) = G(\theta,\phi)$. For the three collectors summed together:

$$G_{sum}(\theta,\phi) = G(\theta,\phi) + G(\theta,\phi + 120°) + G(\theta,\phi - 120°)$$

(independent of ϕ).

10.2 Energy Windows

For OGO-1 MB, the function W_k $(E \cos^2 \theta)$ has the form

$$W_k(x) = 0 \qquad x < E_1$$

$$= a_\ell \qquad E_1 < x < E_2$$

$$= 1 \qquad E_2 < x < E_3$$

$$= a_u \qquad E_3 < x < E_4$$

$$= 0 \qquad E_4 < x$$

For OGO-1 SOEP and OGO-3 MB and SOEP, the function W_k ($E \cos^2 \theta$) has the form:

$$W_k(x) = 0 \qquad x < E_1$$
$$= 1 \qquad E_1 < x < E_2$$
$$= 0 \qquad E_2 < x$$

The quantities E_1, E_2, etc. (in electron volts), a_ℓ, a_u for the various experiments are given in Tables 10.2, 10.3, 10.4 and 10.5.

10.3 MB Response to Protons

The electron detectors have a slight response to protons due to energy-dependent secondary electron production, as described in references 1 and 3. The current produced by a flux of F protons $cm^{-2}sec^{-1}$ is given by:

$$i_k \simeq - e A_o \eta_k F$$

The quantities η_k are tabulated in Table 10.6.

10.4 Calibration Curves

The telemetry signal is an integer I that can take values from 0 to 255. It is related to the collector current i as follows:

a. OGO-1 SOEP

$$\log_{10} i = -10 + 0.225 + 0.014 I$$

b. OGO-1 MB

$$\log_{10} i = -11 + \alpha + \beta \quad \frac{I + 1 - I_m}{I_M + 1 - I_m} \qquad I_m \leq I \leq I_M$$

where α, β are different for each range of I; the quantities I_m, I_M, α, β are given in Table 10.7.

c. The calibration curve for OGO-3 appears to have changed after launch. Determination of the change by possible intercomparison with OGO-1 is presently being studied.

Table 10.1

SOEP ANGULAR RESPONSE FUNCTION $G(\theta,\phi)$

	θ												
φ	0°	5°	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	60°
0°	0.333	0.437	0.534	0.654	0.749	0.837	0.807	0.645	0.490	0.272	0.104	0.006	0
15°	0.333	0.430	0.526	0.639	0.726	0.807	0.766	0.644	0.490	0.272	0.104	0.006	0
30°	0.333	0.419	0.506	0.599	0.667	0.724	0.670	0.566	0.459	0.272	0.104	0.006	0
45°	0.333	0.403	0.467	0.533	0.574	0.605	0.537	0.446	0.353	0.212	0.085	0.006	0
60°	0.333	0.381	0.419	0.456	0.468	0.464	0.403	0.323	0.245	0.136	0.052	0.003	0
75°	0.333	0.359	0.368	0.373	0.354	0.325	0.269	0.199	0.136	0.060	0.019	0	0
90°	0.333	0.332	0.314	0.294	0.254	0.202	0.136	0.079	0.030	0	0	0	0
105°	0.333	0.305	0.268	0.225	0.168	0.104	0.041	0.001	0	0	0	0	0
120°	0.333	0.283	0.228	0.170	0.105	0.044	0	0	0	0	0	0	0
135°	0.333	0.266	0.196	0.130	0.065	0.014	0	0	0	0	0	0	0
150°	0.333	0.251	0.173	0.103	0.045	0.003	0	0	0	0	0	0	0
165°	0.333	0.242	0.161	0.090	0.032	0.002	0	0	0	0	0	0	0
180°	0.333	0.240	0.158	0.087	0.030	0.002	0	0	0	0	0	0	0

Table 10.2

OGO-1 MB ENERGY WINDOWS

Channel	E_1	E_2	E_3	E_4	a_ℓ	a_u
1	549	695	1653	1757	0.16	0.23
2	317	410	942	1015	0.23	0.27
3	181	240	501	552	0.27	0.31
4	126	168	315	352	0.23	0.27

Table 10.3

OGO-1 SOEP ENERGY WINDOWS

(Preliminary Values)

Channel	E_1	E_2
1	26	50
2	64	110
3	145	240
4	280	480
5	620	1080
6	1400	2250
7	2500	4440
8	5600	9600
9	3800	6400
10	1800	3000
11	900	1600
12	420	700
13	200	340
14	100	170
15	40	70
16	18	30

Table 10.4

OGO-3 MB ENERGY WINDOWS

Channel	E_1	E_2
1	42	118
2	100	275
3	240	660
4	630	1640

Table 10.5

OGO-3 SOEP ENERGY WINDOWS

Channel	E_1	E_2
1	45	85
2	96	136
3	155	265
4	260	440
5	580	920
6	1200	1900
7	2300	3700
8	4600	7600
9	3100	5100
10	1700	2800
11	820	1360
12	380	620
13	195	330
14	105	180
15	60	106
16	6	17

Table 10.6

MB EFFICIENCY FOR DETECTING PROTONS

Channel	OGO-1	OGO-3
1	0.0070	0.0005
2	0.0040	0.0012
3	0.0021	0.0029
4	0.0012	0.0071

Table 10.7

CALIBRATION CURVE PARAMETERS FOR OGO-1 MB

I_m	I_M	α	β
0	20	*	*
21	28	0.063462	0
29	42	0.063462	0.936538
43	77	1.0	0.301030
78	127	1.301030	0.397940
128	155	1.698970	0.301030
156	225	2.0	1.0
226	255	3.0	0.602060

* Note: $I < 20$ is below the noise level of the instrument.

11.0 Data Processing

11.1 Output Data of the Experiments

As already described in section 6, the experiments generate a continuous sequence of signals, as follows:

a. SOEP (Proton Experiment)

Housekeeping (5 signals)

Flux,	energy	window	1	collectors	summed	Start program cycle
"	"	"	2	"	"	
"	"	"	3	"	"	
"	"	"	4	"	"	
"	"	"	5	"	"	
"	"	"	6	"	"	
"	"	"	7	"	"	
"	"	"	8	"	"	
"	"	"	9	"	"	
"	"	"	10	"	"	
"	"	"	11	"	"	
"	"	"	12	"	"	
"	"	"	13	"	"	
"	"	"	14	"	"	
"	"	"	15	"	"	
"	"	"	16	"	"	
Flux,	energy	window	1	collector	1	
"	"	"	1	"	2	
"	"	"	1	"	3	
"	"	"	2	"	1	

Flux,	energy	window	2	collector	2
"	"	"	2	"	3
"	"	"	3	"	1
"	"	"	3	"	2
"	"	"	3	"	3
"	"	"	4	"	1
"	"	"	4	"	2
"	"	"	4	"	3
"	"	"	5	"	1
"	"	"	5	"	2
"	"	"	5	"	3
"	"	"	6	"	1
"	"	"	6	"	2
"	"	"	6	"	3
"	"	"	7	"	1
"	"	"	7	"	2
"	"	"	7	"	3
"	"	"	8	"	1
"	"	"	8	"	2
"	"	"	8	"	3
"	"	"	9	"	1
"	"	"	9	"	2
"	"	"	9	"	3
"	"	"	10	"	1
"	"	"	10	"	2

Flux,	energy	window	10	collector	3	
"	"	"	11	"	1	
"	"	"	11	"	2	
"	"	"	11	"	3	
"	"	"	12	"	1	
"	"	"	12	"	2	
"	"	"	12	"	3	
"	"	"	13	"	1	
"	"	"	13	"	2	
"	"	"	13	"	3	
"	"	"	14	"	1	
"	"	"	14	"	2	
"	"	"	14	"	3	
"	"	"	15	"	1	
"	"	"	15	"	2	
"	"	"	15	"	3	
"	"	"	16	"	1	
"	"	"	16	"	2	
"	"	"	16	"	3	End program cycle
Housekeeping, etc.						

b. <u>MB (Electron Experiment)</u>

Housekeeping (4 signals)				
Flux,	energy	window	1	One program cycle
"	"	"	2	
"	"	"	3	
"	"	"	4	
Housekeeping, etc.				

The housekeeping signals are the following (cf. section 6):

a. OGO-1, SOEP

High voltage

Temperature

Marker

Standard signal

Reset

b. OGO-3, SOEP

High voltage

Marker

Temperature

Standard signal

Reset

c. OGO-1, MB

High voltage (blank)

Standard signal

Temperature

Marker

d. OGO-3, MB

High voltage

Standard signal

Marker

Temperature

In OGO-1, the modulator high voltage is turned off on alternate program cycles. In the housekeeping sequence preceding the voltage on cycle, the marker is low for SOEP, high for MB. In OGO-3, the modulator high voltage is on during all cycles and the markers are always high.

11.2 Format of Input Data

Data are made available to M.I.T. by GSFC on magnetic tapes; prior processing of the data at GSFC is described in "Data Processing Plan for Eccentric Orbiting Geophysical Observatory (OGO-B)," GSFC publication X-564-66-101 (referred to hereafter as DPPOGO). All tapes received from GSFC or generated at M.I.T. are recorded in seven tracks, odd parity.

Each reel of tape received from GSFC contains up to nine files of data. The first record of each file is a label record containing 20 words (36 bits each) of alphanumeric information (in 5 code). The format of the label record is given in Figure 39 of DPPOGO, but the following corrections should be made: Characters 79 through 90 and 99 through 113 are blank; character 67 representation should be:

0 = 1 kilobit real time
1 = 8 " " "
2 = 64 " " "
3 = command storage playback

The succeeding records are each 392 36-bit words and contain binary data organized into 12-bit, 2-character groups, as follows: If the required data for any particular 12-bit group are not available, the group is said to be "filled," the first bit is set to 1 and the rest to zero (for a discussion of "fill" data, see DPPOGO, page 62); otherwise, the first three bits are set to zero and the remaining nine bits constitute the data. The detailed format of the data record is shown in Table 11.1. (Throughout this report, the 36-bit word is taken as the basic unit, and the bits are designated 0, 1, 2, . . . 35.) As can be seen, each record contains (a) day count of year, (b) eleven items of spacecraft engineering data, (c) time at start of record, (d) spacecraft clock reading at start of record, (e) 128 frames of data, each of which contains four SOEP signals and two MB signals, and (f) time and spacecraft clock reading at end of record. The experiment signals are simply telemetered as they occur; the program cycle described earlier is in no way synchronized with the telemetry, or between the two experiments (in fact, the SOEP program cycle is incommensurate with the telemetry record). Furthermore, at the 8 or 64 kilobit rates the SOEP experiment continues to cycle at the same rate it had at 1 kilobit, with the result that each experiment signal is telemetered 8 or 64 times. The basic initial task of the data processing program is to reconstruct the sequence of program cycles from the data provided in the telemetry records.

11.3 Outline of Data Processing Program

The initial processing program, named PACK, consists of 22 subroutines (coded in IBM 7044 assembler language) plus a special highly efficient input-output routine. The program first reads the input tape, picks up the experiment signals (eliminating the repetitions at the higher bit rates) and stores the SOEP and MB signals in separate buffers. Then the program searches these buffers for markers and associated housekeeping signals; having found them, it moves the data, one experiment cycle at a time, to output buffers. The output buffer is written onto the output tape whenever any of the following conditions occurs: (a) the output buffer is full (this is the "normal end" of the record); (b) no marker signal is found in the input data at the point where one is expected; (c) the start time of a newly read input record differs by more than one msec from the end time of the previously processed record; (d) an end of file on the input tape is encountered; (e) end of input tape is encountered. After the output record is written, in cases (b), (c) and (d) processing is restarted with a new search for markers. The program thus generates two output tapes, one containing SOEP, the other MB data. The tapes contain the following information: (a) the label record of each file, copied from the input tape with no change, except translation, from 5 code to 9 code;

(b) the spacecraft engineering data and the spacecraft clock reading, taken from the first of the several input records that went into each output record; (c) location within the input record of the first marker in the output record; (d) start time (day count and msec of day) of the output record, computed from the start time of the first input record and the information in (c) (if the time in the first input record was filled, however, the time in the second, or third, etc., input record was used); (e) end time of the output record, computed from (d) and the length of the record; (f) experiment data. Typically, a single output reel contains data from $\sim$ 100 input reels (corresponding to two to three months of spacecraft operation) and requires $\sim$ four hours of IBM 7044 time.

The output tapes from the PACK program are then processed by the EDIT program, which removes the file marks and label records (essential information from the label record is here incorporated into each data record) and sorts the tape to arrange all records in time sequence. The output tapes from the edit program constitute the basic data from the OGO experiments, and all further processing and analysis are done from them; the original input tapes are returned to GSFC.

11.4 Format of the Output Tapes

The format of the tapes produced by the EDIT program is shown in Table 11.2. Words 1-2 contain information from the original file label record. Words 3-5 contain timing information. Words 6 and 8-10 contain spacecraft clock and engineering data. Word 7 records some of the processing in PACK (see section 11.3). The rest of the record contains experiment data, stored four signals per word or nine bits per signal; the first bit of nine is the execute relay flag, the remaining eight are the actual signal. A "filled" signal is indicated by nine bits of one's.

Each record contains an integral number of contiguous experiment cycles. (For OGO-1, the modulator-voltage-off cycles are omitted on the SOEP tapes but included on the MB tapes.) On the SOEP tapes, each cycle consists of 17 words, 16 words of measured fluxes plus 1 word of housekeeping (the reset signal is omitted); one record contains up to ten cycles and thus is 10 + 17N words long ($1 \leq N \leq 10$). On the MB tapes, each cycle consists of two words, one word of measured fluxes and one of housekeeping; one record contains up to 100 cycles and is 10 + 2N words long ($1 \leq N \leq 100$).

Table 11.1

FORMAT OF INPUT DATA RECORD

Word	Bits	Representation	
1	0-11	Day count of year	
	12-23	D (98, 47)*	
	24-35	D (98, 82)	
2	0-11	D (99, 81)	
	12-23	D (98, 83)	
	24-35	D (99, 92)	
3	0-11	D (98, 84)	
	12-23	D (99, 83)	
	24-35	D (99, 85)	
4	0-11	D (99, 37)	
	12-23	D (99, 40)	
	24-35	D (99, 30)	
5	0-35	Time (msec of day) for frame #1	
6	0-35	Spacecraft clock (sec) for frame #1	
7+3(N-1)	0-11	Status field F1**	Frame N
	12-21	Subcommutator count ***	N=1, 2, . . . 128
	22	Execute relay flag	
	23	Cross-strap flag	
	24-35	Status field F2**	

Word	Bits	Representation	
8+3(N-1)	0-11 12-23 24-35	Proton data	Frame N N = 1, 2, . . . 128
9+3(N-1)	0-11 12-23 24-35	Electron data	
391	0-35	Time (msec of day) for frame #128	
392	0-35	Spacecraft clock for frame #128	

NOTES

* D (n, m) stands for output m of word n of main frame. These are explained in DPPOGO, Figure 20. (See also Table 11.2.)

** Formats of the status fields are given in Figures 42 and 43 of DPPOGO. (Note that in these figures bits are numbered backwards.)

*** Bits 12-23 of this word constitute the first of spacecraft ID words (word 65 of main frame). Subcommutator count equals frame number N. Execute relay flag bit = 1 is intended to indicate that a spacecraft command is being executed; cross-strap flag bit = 1 is intended to indicate that equipment groups 1 and 2 have been interchanged. In practice, it has been found that the occurrence of one's in these bits is mostly random and serves to indicate a high bit error rate.

Table 11.2

FORMAT OF EDITED OUTPUT TAPE

Word	Bits	Representation
1	0	Experiment (SOEP=0, MB=1)
	1-2	Unused
	3-20	Satellite ID (OGO-1 = 64541, OGO-3 = 66491)
	21-32	Decom run number
	33-35	Reel number
2	0-2	Bit rate (1 kb real time = 0, 8 kb = 1, 64 kb = 2, playback = 3)
	3-14	Station*
	15-20	Analog file number
	21-35	Analog tape number
3	0-2	Unused
	3-17	Year (last two digits)
	18-20	Unused
	21-35	Day count of year
4	0-35	Start time of record (msec of day)
5	0-35	End time of record
6	0-35	Spacecraft clock for frame #1
7	0	If = 1, normal record end
	1	If = 1, record ended by loss of marker
	2	If = 1, record ended by time gap or error

Word	Bits	Representation
	3	If = 1, record ended by end of file
	4	If = 1, record ended by end of tape
	5-17	Number of input record from which time was obtained
	18-20	Unused
	21-35	Location of first marker in input record
8	0-8	Unused
	9-17	D (99, 37) + Z panel temperature
	18-26	D (99, 40) SOEP 2 + X (+ Y) temperature
	27-35	D (99, 30) SOEF 2 + X (- Y) temperature
9	0-8	D (98, 47) Load bus voltage
	9-17	D (98, 82) SC calibration.**
	18-26	D (99, 81) SC calibration.**
	27-35	D (98, 83) SC calibration.**
10	0-8	D (99, 92) SC calibration.**
	9-17	D (98, 84) SC calibration.**
	18-26	D (99, 83) SC calibration.**
	27-35	D (99, 85) SC calibration.**
11	0-8	Experiment data
	9-17	Experiment data
	18-26	Experiment data
	27-35	Experiment data

Word	Bits	Representation
12	0-8	Experiment data
	9-17	
	18-26	
	27-35	

NOTES

* A list of station codes is given in DPPOGO, page 38.

** See DPPOGO, Figure 20.

12.0 Scientific Results

The scientific results obtained from the M.I.T. experiments on OGO-1 and OGO-3 have been described in a number of publications, listed in the Bibliography at the end of this section; also listed are presentations of results at scientific conferences. Most of the effort to date has been concentrated on analysis of the electron (MB) data. Among the principal results are the following:

a. Mapping of the spatial structure of the low energy electron population in the outer magnetosphere and the magnetotail in the evening sector[1,3,5].

b. Measurement of electron energies and densities and their variations within the plasma sheet[1,3].

c. The definitive observation of the inner boundary of the plasma sheet, determination of the change of electron spectrum across it, and observation of its motion in response to magnetic bay activity[1,3,5].

d. Observation of the coincidence between the inner edge of the plasma sheet and the equatorward edge of the auroral oval; observation that the electron energy flux within the plasma sheet constitutes an adequate source for auroral precipitation; observation that the variation of the electron mean energy with distance from the neutral sheet is the same as the variation of auroral electron energy with latitude, lending further support to the view that the auroral oval is simply the extension of the plasma sheet to ionospheric heights[6,7].

e. The first detailed mapping of the low energy electron population in the day side of the magnetosphere[4].

f. Observation of the magnetosheath electron energy spectrum, establishing that the peak of the spectrum lies below 100 eV[1].

g. Observation of bow shock motion and demonstration, using simultaneous data from IMP-2 and IMP-1 satellites, that the shock motion can be quantitatively accounted for by solar wind dynamic pressure changes[2].

12.1 Bibliography

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3. Vasyliunas, V. M.: "A Survey of Low Energy Electrons in the Evening Sector of the Magnetosphere with OGO-1 and OGO-3," J. Geophys. Res., 73, 2839-2884, 1968.

4. Vasyliunas, V. M.: "Low Energy Electrons on the Day Side of the Magnetosphere," J. Geophys. Res., 73, 7519-7523, 1968.

5. Vasyliunas, V. M.: "Low Energy Electrons in the Magnetosphere as Observed by OGO-1 and OGO-3," Physics of the Magnetosphere, edited by R. Carovillano, J. McClay and H. Radoski. D. Reidel Publishing Co., Dordrecht, Holland, 1968.

6. Vasyliunas, V. M.: "Low Energy Particle Fluxes in the Geomagnetic Tail," to appear in Production and Maintenance of the Polar Ionosphere, edited by G. Skovli.

7. Vasyliunas, V. M.: "Relation of the Plasma Sheet to the Auroral Oval," in preparation.

12.2 Presentations at Scientific Conferences

Vasyliunas, V. M.: "Observations of 50 to 2000 eV Electrons with OGO-A," AGU 47th Annual Meeting, Washington, D. C., April 1966.

Binsack, J. H. and V. M. Vasyliunas: "Simultaneous Shock Compressions Observed by the M.I.T. Plasma Experiments on IMP-2 and OGO-1," AGU 48th Annual Meeting, Washington, D. C., April 1967.

Vasyliunas, V. M.: "Preliminary Results of the M.I.T. Plasma Experiment on OGO-3," AGU 48th Annual Meeting, Washington, D. C., April 1967.

Vasyliunas, V. M.: "Low Energy Electrons in the Magnetosphere as Observed by OGO-1 and OGO-3," AFCRL--B. C. Summer Institute on Physics of the Magnetosphere, Boston College, Chestnut Hill, Mass., June 19-28, 1967.

Vasyliunas, V. M.: "OGO-1 Observations of the Magnetospheric Plasma Sheet and Its Relation to the Auroral Belt," AGU Meeting, Washington, D. C., April 8, 1968.

Vasyliunas, V. M.: "Low Energy Electrons Near the Trapping Boundary," Gordon Research Conference on Space Plasma Physics, Tilton, N. H., July 1, 1968.

Vasyliunas, V. M.: "A Survey of Low Energy Electrons on the Day Side of the Magnetosphere with OGO-3," presented at the International Symposium on the Physics of the Magnetosphere, Washington, D. C., September 3, 1968.

Vasyliunas, V. M.: "Low Energy Particle Fluxes in the Geomagnetic Tail," presented at NATO Advanced Study Institute on the Production and Maintenance of the Polar Ionosphere, Tretten, Norway, April 10-18, 1969.

Vasyliunas, V. M.: "Low Energy Untrapped Electrons," Summer Advanced Study Institute--Earth's Particles and Fields 1969, Santa Barbara, California, August 4-15, 1969.

Appendix A

EQUIPMENT CONSTRUCTION

The proton experiment is housed in one of the solar-oriented experiment packages (SOEPs) located at the extremity of each paddle of the solar array. It occupies approximately half of the one cubic foot package. A three-inch diameter hole in the SOEP cover plate exposes the sensor; inside the package, the sensor is completely shielded from the experiment electronics. There are two connecting cables between the electronics assembly and the sensor, one to carry high voltage to the modulator electrode, and one to convey collector signals to the preamplifiers and voltage to the sensor suppressor grid. Two additional connectors interface the experiment to the spacecraft and the group support equipment. Circuit modules are listed in Table A-1.

The electron experiment is housed in the spacecraft main body; both the single-collector sensor and the electronics assembly are skin-mounted. Two cables connecting the sensor and the electronics carry modulator high voltage and the collector output; the electronics assembly package also has two connectors that interface the experiment to the spacecraft and to the GSE. Circuit modules are listed in Table A-2.

Module Fabrication

The electronics modules consist of rectangular metal frames to which are mounted the circuit boards and necessary connectors. In the assembled package, the modules are stacked. Mating connectors inside the frames carry signals between modules and minimize the need for interface cabling and attendant disadvantages of vibration susceptibility and additional weight. Each frame is milled from a block of magnesium and contains an inside flange. Circuit boards may be mounted to one or both sides of this flange. The boards are etched on both sides with electrical crossover by through-plated holes (rather than eyelets) for rigidity. Components are hand-soldered to one side of the board. After assembly the boards are coated with an epoxy compound to reduce vibration and arcing hazards.

Sensor Construction

Each sensor consists of a cup-like shell enclosing a number of electrodes. The shell comprises a cylindrical wall and a circular back plate, both machined from magnesium and gold-plated. The cylinder has an outside front flange for attachment to the spacecraft mounting surface, and inner flanges to support the grids. The grids are discs of tungsten mesh with rim frames for support. The outer and shield grids are electrically connected to the shell, and so are mounted directly to the inner flanges, while the modulator grid (as well as the suppressor grid in the proton sensor) is supported by insulating standoffs.

The high voltage modulator grid connector appears on the outside surface of the wall.

The back plate of the shell carries the collector electrode(s), also constructed of gold-plated magnesium. In the electron sensor, the collector is a single disc. In addition to carrying the collector output to the electronics assembly, the electron signal connector brings in the +150 v collector bias. The three proton collectors are 120° sectors separated at the edges by 1/16 inch. The connector that carries their signals to the preamps also brings in the -150 v suppressor grid voltage. Both sensors measure approximately 4-1/2 inches in overall depth and have a 3-inch viewing aperture for the electron unit and 3.8 inch for the proton unit. Excluding mounting flanges, the outside diameter of the electron sensor is 4-1/2 inches; of the proton sensor, 6 inches.

Table A-1

PROTON EXPERIMENT CIRCUITS

Module	Side	Circuit Designation*	Description
1	A	Selection register 312PW2288	Sync MV and FF, window power control and output amplifier, modulator through output transistors and associated gates
1	B	Digital #1 312PW2335	Program, window and collector counters
2	A	Digital #2 312PW2336	Interface (except for sync) and bookkeeping
2	B	Compression amplifier 312PW2339	Measurement chain from analog gates through output
3	-	Power converter (supplied by Matrix or Mil Associates)	
-	-	Preamplifier 36PW2494	Three preamplifiers
-	-	High voltage 312PW2319	Modulator output transformer, dc multiplier, bleeder

Digital count matrix 312PW2264 is mounted to the outer surface of module 1B.

* Lincoln Laboratory printed circuits are identified by number.

Table A-2

ELECTRON EXPERIMENT CIRCUITS

Module	Side	Circuit Designation*	Description
1	A	(Blank side)	
1	B	Selection register 312PW2363	Sync MV and FF, window power control and output amplifier, modulator through output transistors and associated gates
2	A	Digital 312PW2359	Interface, program counter, bookkeeping
2	B	Compression amplifier 312PW2339	Measurement chain from analog gate through output
3	-	Power converter (supplied by Matrix or Mil Associates)	
-	-	Preamplifier 36PW3501	
-	-	High voltage 312PW2368	Modulator output transformer, dc multiplier, bleeder

* Lincoln Laboratory printed circuits are identified by number.

Appendix B

OGO TEST PROCEDURES

OGO-A SOEP PLASMA PROBE
ELECTRICAL PERFORMANCE
TEST PROCEDURE

I. GENERAL

A. Scope and Purpose

1. The SOEP Plasma Probe is an instrument designed to measure the particle-number density, energy spectra and the direction of motion of the proton plasma in outer space and to relay this information to earth via the spacecraft's communication system. This test procedure is to determine that the Plasma Probe is operating in a satisfactory manner to accomplish its mission.

B. Data Sheets

1. Sample Data Sheets are included at the end of this test procedure and similar sheets are to be filled out at the time of the test in accordance with instructions set forth in this procedure.

II TEST EQUIPMENT AND POWER REQUIRED

A. Test Equipment

1. Hewlett Packard Square Wave Generator Model 211a or equivalent.
2. Simpson Multimeter Model 260 or equivalent.
3. Tektronix Oscilloscope Type 536 or equivalent.
4. Tektronix Preamp Type M or equivalent.
5. Tektronix Probe Type P6000 or equivalent.
6. Tektronix Probe Type P6013 or equivalent.
7. OGO-A Ground Support Equipment(GSE).
8. OGO Calibration Box.

B. Power Required

1. 115 volts, 60 cps., single phase, 10 amperes.

III SET-UP AND CALIBRATION OF TEST EQUIPMENT

A. Set-Up

1. The test equipment shall be set-up in accordance with the instructions set forth in this procedure.

B. Calibration

1. All test equipment shall be calibrated prior to being used in these tests.

IV OPERATIONAL TESTS

A. Initial Set-Up

1. Equipment POWER switches must be in the OFF position prior to interconnecting the units.

2. Connect the Plasma Probe under test to the test equipment as follows (see Figure 1):

   a. Cable A from GSE 37 pin connector to Plasma Probe J3.

   b. Cable B from GSE TEST SIG. jack to OGO Calibration Box INPUT.

   c. Cable C from OGO Calibration Box TP OUTPUT to Plasma Probe Preamplifier TP.

3. Set the following GSE controls:

   a. RATE to PUSH BUTTON.

   b. POWER ON-OFF to ON.

   c. Turn ADJ TO 28V to indicate 28 volts on GSE voltmeter.

4. Record on Data Sheet the readings of GSE voltmeter and milliammeter.

B. System Voltage Measurements

1. Using the multimeter, measure the voltages at the GSE TEST POINTS and record the results on Data Sheet.

2. Using the multimeter, measure the control voltages at the GSE TEST POINTS and record the results on Data Sheet.

C. System Clock

1. Set the following GSE switches:

    a. SW. SIG. to 2V.

    b. MODE SIG. to 3.9V.

    c. RATE to 4 CYCLES.

2. Connect a wire from GSE GND test point to Oscilloscope ground terminal.

3. Connect a wire from Oscilloscope TRIGGER INPUT to Oscilloscope VERT SIG. OUT.

4. Connect the 10:1 probe (P6000) cable to Oscilloscope SIGNAL INPUT.

5. Connect the 10:1 probe to GSE SYS. CLOCK test point.

6. Set Oscilloscope time scale to 0.2 milliseconds per centimeter.

7. Set Oscilloscope voltage scale to 0.1 volts per centimeter.

8. Set Oscilloscope to trigger on + EXT mode.

9. Observe the pulse on the Oscilloscope and record on Data Sheet the pulse amplitude and width for the 4 CYCLES, 32 CYCLES, 256 CYCLES and PUSH BUTTON positions of the GSE RATE switch. Note: When the RATE switch is in the PUSH BUTTON position, the SINGLE PULSE switch must be depressed to obtain each SYSTEM CLOCK pulse.

10. Set GSE POWER ON-OFF to OFF.

D. Gates MV0 and MV1

1. Disassemble the trays of the Plasma Probe so that the SELECTION REGISTER AND MATRIX CARD ASSEMBLY (312PW2288) and DIGITAL #2 CARD ASSEMBLY (312PW2336) are accessible for making measurements.

2. Interconnect the trays together using patch cables (see Figure 2).

3. Set GSE RATE to 4 CYCLES.

4. Set Oscilloscope time scale to 20 milliseconds per centimeter.

5. Set Oscilloscope voltage scale to 0.2 volts per centimeter.

6. Disconnect the 10:1 probe from GSE SYS CLOCK test point and connect to Q30 collector on Card Assembly 312PW2336.

7. Set GSE POWER ON-OFF to ON

8. Observe the gate on the Oscilloscope and record on Data Sheet the gate amplitude and width of MV0.

9. Set Oscilloscope time scale to 5 milliseconds per centimeter.

10. Disconnect the 10:1 probe from Q30 collector and connect to Q32 collector on Card Assembly 312PW2336.

11. Observe the gate on the Oscilloscope and record on Data Sheet the gate amplitude and width of MV1.

E. Free Running Oscillator.

1. Set GSE Rate to PUSH BUTTON.

2. Set Oscilloscope time scale to 50 microseconds per centimeter.

3. Disconnect the 10:1 probe from Q32 collector and connect to Q129 collector on Card Assembly 312PW2288.

4. Observe the waveshape on the Oscilloscope and record the amplitude and width for one cycle and calculate the frequency. If necessary, adjust R9 for 2400 cycles per second.

5. Set GSE POWER ON-OFF to OFF.

6. Disconnect the 10:1 probe from Q129 collector.

7. Reassemble the Plasma Probe trays.

F. Programmer

1. Set GSE POWER ON-OFF to ON.

2. Set GSE RATE to 4 CYCLES and allow the Plasma Probe to operate through the complete program several times.

3. Set the H-P Square Wave Generator POWER ON-OFF to ON.

4. Tune the Square Wave Generator to 2461 cps and an output amplitude of 6 volts peak to peak.

5. Connect Cable D from the Square Wave Generator to the Plasma Probe Spacecraft connector.

6. Set GSE RATE to PUSH BUTTON.

7. Observe the GSE DIGITAL FLIP FLOP indicator lights and momentarily depress the GSE SINGLE PULSE switch.

8. Check the Data Sheet for the program step associated with those indicator lights in the ON condition. Continue momentarily depressing the SINGLE PULSE switch and check that each succeeding sequence of the DIGITAL FLIP FLOP indicator lights turned ON corresponds to that listed on the Data Sheet for that particular step. Continue advancing the program manually until returning to the step at which the test was started.

   Note: At step 69, either indicator light 5 or lights 5 and 10 will be in the ON condition, therefore a complete cycle will consist of 138 steps.

9. Set GSE POWER ON-OFF to OFF.

G. <u>High Voltage</u>

1. Disconnect the 10:1 probe cable from the Oscilloscope SIGNAL INPUT and connect the 1000:1 probe (P6013) cable to the Oscilloscope SIGNAL INPUT.

2. Disconnect the CUP from the Plasma Probe and insert an adapter into the Plasma Probe high voltage connector.

3. Connect the 1000:1 probe to the adapter.

4. Set Oscilloscope voltage scale to 5 volts per centimeter.

5. Set GSE RATE to 4 CYCLES.

6. Set GSE POWER ON-OFF to ON.

7. Allow the Plasma Probe to operate through the complete program several times.

8. Set GSE RATE to PUSH BUTTON.

9. Using the GSE SINGLE PULSE switch, advance the program until the DIGITAL FLIP FLOP indicator lights 5 and 10 are in the ON condition.

10. Set Oscilloscope time scale to 5 milliseconds per centimeter and the voltage scale in accordance with the Data Sheet for each step.

11. Advance each step manually using the GSE SINGLE PULSE switch and record on Data Sheet, the High Voltage peak and valley readings for the appropriate DIGITAL FLIP FLOP indicator lights in the ON condition. Read all pulse levels at the maximum level.

H. <u>High Voltage Phase Relationship</u>

1. Connect a coax cable from GSE TEST SIG to Oscilloscope dual channel SIGNAL INPUT.

2. Set GSE RATE to 4 CYCLES.

3. Adjust Oscilloscope to obtain a dual trace.

4. Set Oscilloscope time scale to 0.1 milliseconds per centimeter, voltage scale to 1.0 volts per centimeter for TEST SIG input and 2.0 volts per centimeter for High Voltage input.

5. Observe the phase relationship of the two signals and compare with Data Sheet.

   Note: The above test may require some adjustment of the Oscilloscope controls to obtain the desired results since the High Voltage waveshape is constantly changing in amplitude.

6. Set GSE POWER ON-OFF to OFF.

7. Disconnect the 1000:1 probe from the adapter and the cable from the Oscilloscope.

8. Remove the adapter from the Plasma Probe High Voltage connector and reconnect the CUP.

9. Remove the coax cable from the GSE TEST SIG and from the Oscilloscope.

10. Remove cable from Oscilloscope TRIGGER INPUT to VERT. SIG. OUT.

I. Telemetry

1. Connect a wire from GSE SYS CLOCK to Oscilloscope TRIGGER INPUT.

2. Connect the 10:1 probe cable to Oscilloscope SIGNAL INPUT and connect the 10:1 probe to GSE TELE +.

3. Set Oscilloscope time scale to 0.2 seconds per centimeter and voltage scale to 0.1 volts per centimeter.

4. Set OGO Calibration Box for 1×10^{-7} signal.

5. Set GSE POWER ON-OFF to ON.

6. Observe and record on Data Sheet the pulse amplitude of the output signal for the input signals in accordance with the Data Sheet.

7. Record the OGO Calibration Box setting at which the signal output equals the noise amplitude.

8. Repeat steps 6 and 7 for signal inputs into the other two preamplifiers.

9. With the OGO Calibration Box output connected to one of the Preamplifier Test Point input, set the Calibration Box for 1×10^{-7} signal.

10. Observe changes in the signal output of the Plasma Probe for the various settings of the GSE switches in accordance with the Data Sheet and log the results.

J. Bookeeping Pulses

1. Set GSE RATE to PUSH BUTTON.

2. Set Oscilloscope time scale to 20 milliseconds per centimeter.

3. Disconnect the OGO Calibration Box from the Plasma Probe.

4. Advance the Plasma Probe program to step using the GSE SINGLE PULSE switch.

5. Measure and record the pulse amplitude of the Bookeeping signals in accordance with the Data Sheet.
   Note: Measure the pulse amplitude at 150 milliseconds after the clock pulse.

6. Set GSE POWER ON-OFF to OFF.

7. Set Oscilloscope POWER ON-OFF to OFF.

8. Disconnect all interconnecting cables and wires from the equipment.

9. Test is completed.

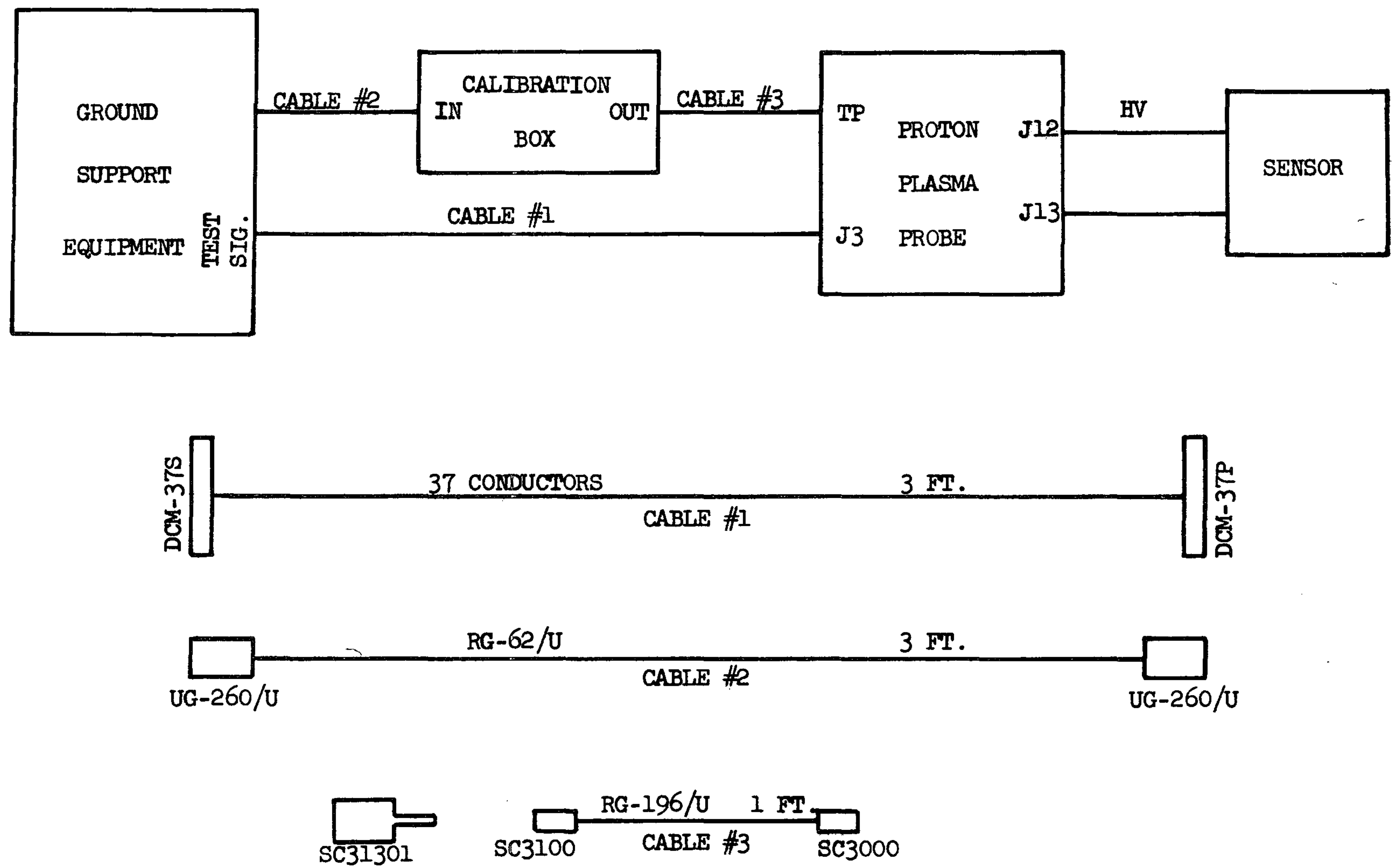

GROUND
SUPPORT
EQUIPMENT
TEST SIG.
CABLE #2
CALIBRATION
IN
OUT
BOX
CABLE #3
CABLE #1
TP
PROTON
PLASMA
PROBE
J3
J12
J13
HV
SENSOR
DCM-37S
37 CONDUCTORS
3 FT.
CABLE #1
DCM-37P
RG-62/U
3 FT.
CABLE #2
UG-260/U
UG-260/U
SC31301
SC3100
RG-196/U
1 FT.
CABLE #3
SC3000

Figure 1

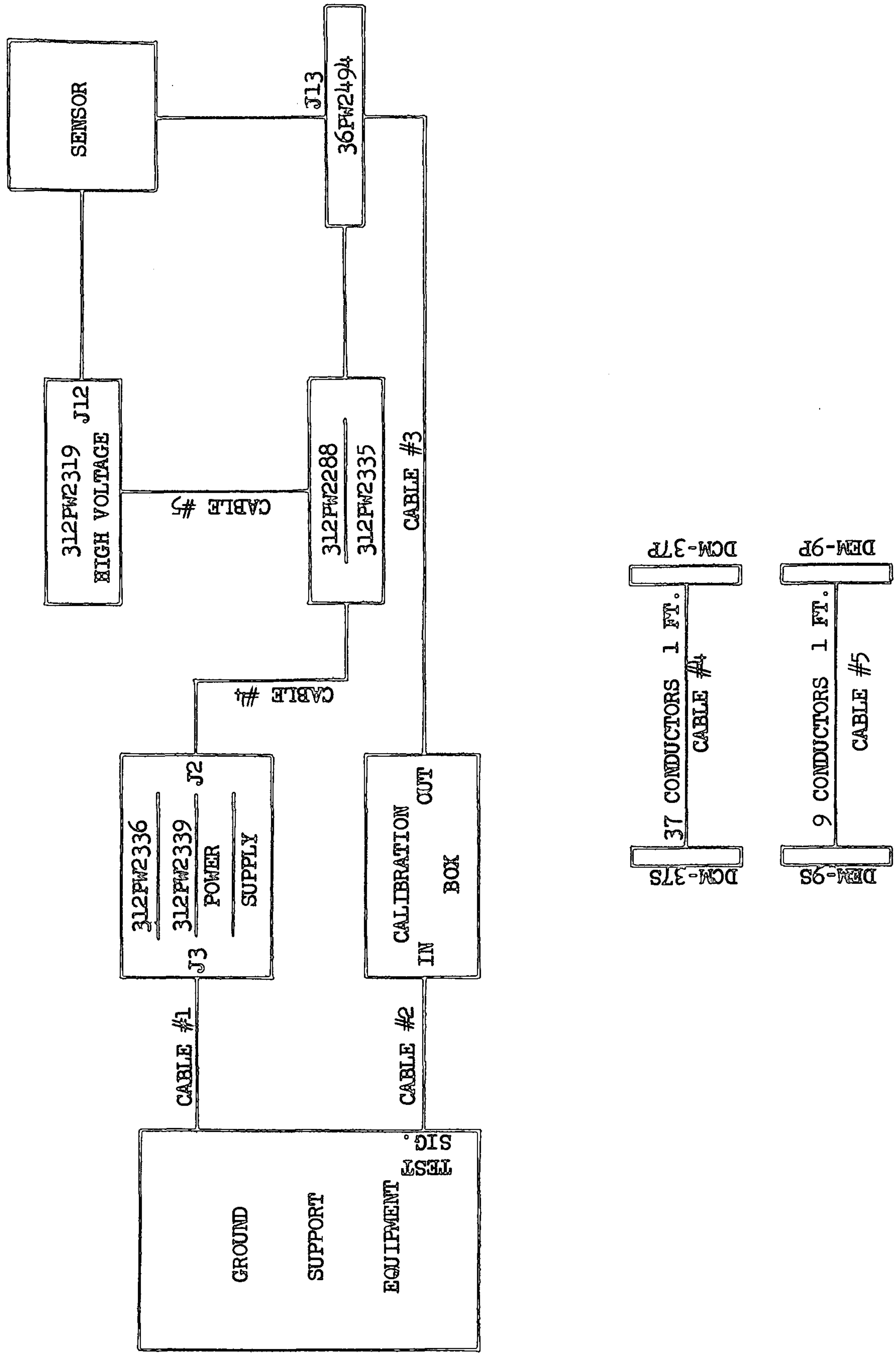

SENSOR
J13
36PW2494
312PW2319
HIGH VOLTAGE
J12
CABLE #5
312PW2288
312PW2335
CABLE #3
CABLE #4
312PW2336
312PW2339
POWER
SUPPLY
J2
J3
CALIBRATION
IN
OUT
BOX
CABLE #1
CABLE #2
GROUND
SUPPORT
EQUIPMENT
TEST
SIG.
DCM-37P
DCM-37S
37 CONDUCTORS 1 FT.
CABLE #4
DEM-9P
DEM-9S
9 CONDUCTORS 1 FT.
CABLE #5

Figure 2

OGO-A SOEP PLASMA PROBE
ELECTRICAL PERFORMANCE
TEST PROCEDURE

Data Sheet

Serial ____________ Date ______________ Tester ___________

IV A. Initial Set-Up

4. Meter / Reading

Meter	Reading
Voltmeter	_______ volts
Milliammeter	_______ milliamperes

B. System Voltage Measurements.

1.

Test Point	Reading	Test Point	Reading
-3V	____volts	-6V	_____ volts
-30V	____volts	-90V	_____ volts
-150V	____volts	+6V	_____ volts
+12V	____volts	+20V	_____ volts

2.

Test Point	Switch Position	Reading
SW.SIG.	SW.SIG.: 2V	______ volts
SW.SIG.	SW.SIG.: 7V	______ volts
MODE SIG.	MODE SIG.: 0.6V	______ volts
MODE SIG.	MODE SIG.: 3.9V	______ volts
RATE LEVEL	RATE: 4 CYCLES	______ volts

Test Point	Switch Position	Reading
RATE LEVEL	RATE: 32 CYCLES	_____ volts
RATE LEVEL	RATE: 256 CYCLES	_____ volts
RATE LEVEL	RATE: PUSH BUTTON	_____ volts

C. System Clock

9.

RATE Switch	Amplitude	Width
4 CYCLES	_____ volts	_____ milliseconds
32 CYCLES	_____ volts	_____ milliseconds
256 CYCLES	_____ volts	_____ milliseconds
PUSH BUTTON	_____ volts	_____ milliseconds

m D. Gates MVO and MV1

	Gate	Amplitude	Width
8.	MVO	______ volts	_____ milliseconds
11.	MV1	______ volts	_____ milliseconds

E. Free Running Oscillator

4.

Signal	Amplitude	Width
1 CYCLE	_____ volts	_____ milliseconds

Frequency calculated: _________ cycles per second

Frequency adjusted to: _________ cycles per second

F. Programmer

8.

Program Step	FLIP FLOP Indicators ON									Check	
	1	2	3	4	5	6	7	8	9	1-69	70-138
1	1			4	5	6					
2	1			4			7				
3	1				5	6	7				
4	1			4	5			8			
5	1			4		6		8			
6	1				5		7	8			
7	1			4	5	6	7	8			
8	1			4					9		
9	1				5	6			9		
10	1			4	5		7		9		
11	1			4		6	7		9		
12	1				5			8	9		
13	1			4	5	6		8	9		
14	1			4			7	8	9		
15	1				5	6	7	8	9		
16	1			4	5						
17		2		4		6					
18		2			5	6					
19		2		4	5	6					
20		2		4			7				
21		2			5		7				
22		2		4	5		7				
23		2		4		6	7				
24		2			5	6	7				
25		2		4	5	6	7				
26		2		4				8			
27		2			5			8			
28		2		4	5			8			
29		2		4		6		8			
30		2			5	6		8			
31		2		4	5	6		8			
32		2		4			7	8			
33		2			5		7	8			
34		2		4	5		7	8			
35		2		4		6	7	8			
36		2			5	6	7	8			
37		2		4	5	6	7	8			
38		2		4					9		
39		2			5				9		
40		2		4	5				9		
41		2		4		6			9		
42		2			5	6			9		
43		2		4	5	6			9		
44		2		4			7		9		
45		2			5		7		9		

8. Program Step / FLIP FLOP Indicators ON / Check

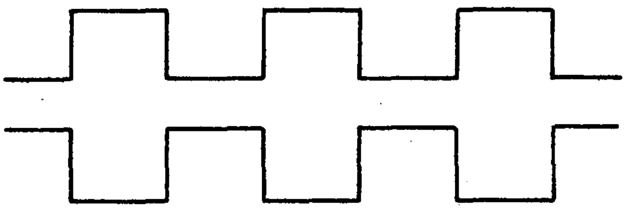
Program Step	1	2	3	4	5	6	7	8	9	Check 1-69	Check 70-138
46		2		4	5		7		9		
47		2		4		6	7		9		
48		2			5	6	7		9		
49		2		4				8	9		
50		2		4				8	9		
51		2			5			8	9		
52		2		4	5			8	9		
53		2		4		6		8	9		
54		2			5	6		8	9		
55		2		4	5	6		8	9		
56		2		4			7	8	9		
57		2			5		7	8	9		
58		2		4	5		7	8	9		
59		2		4		6	7	8	9		
60		2			5	6	7	8	9		
61		2		4	5	6	7	8	9		
62		2		4							
63	1	2			5						
64	1	2		4	5						
65			3	4							
66	1		3		5						
67		2	3	4	5						
68	1	2	3	4							
69					5						

G. High Voltage

11. Program Step / Oscilloscope Voltage Scale / FLIP FLOP Indicators ON / High Voltage

Program Step	Oscilloscope Voltage Scale	1	2	3	4	5	6	7	8	9	10	High Voltage Peak	High Voltage Valley
1	.02	1			4	5	6				10		
2	.02	1			4			7			10		
3	.05	1				5	6	7			10		
4	.1	1			4	5			8		10		
5	.2	1			4		6		8		10		
6	.5	1				5		7	8		10		
7	.5	1			4	5	6	7	8		10		
8	1	1			4					9	10		
9	1	1				5	6			9	10		
10	.5	1			4	5		7		9	10		
11	.2	1			4		6	7		9	10		
12	.1	1				5			8	9	10		
13	.05	1			4	5	6		8	9	10		
14	.02	1			4			7	8	9	10		
15	.02	1				5	6	7	8	9	10		
16	.02	1			4	5					10		
65	.5			3	4						10		

H. High Voltage Phase Realtionship

5. 

Correct Phase Relationship. __________ Check

I. Telemetry.

6 & 8.

Signal Input Amperes	Telemetry Output PA1	PA2	PA3	Units
1×10^{-7}	___	___	___	Volts
1×10^{-8}	___	___	___	Volts
1×10^{-9}	___	___	___	Volts
1×10^{-10}	___	___	___	Volts
1×10^{-11}	___	___	___	Volts

7. Signal: Noise = 1 ___ ___ ___ amperes

10.

RATE	SW.SIG.	MODE SIG.	Normal	Distorted
4 CYCLES	2V.	.6V	______	______check
4 CYCLES	7V.	.6V	______	______check
4 CYCLES	7V.	3.9V.	______	______check
4 CYCLES	2 V.	3.9V.	______	______check
32 CYCLES	2V.	3.9V.	______	______check
32 CYCLES	7V.	3.9V.	______	______check
32 CYCLES	7V.	.6V.	______	______check
32 CYCLES	2V	.6V.	______	______check
256 CYCLES	2V.	.6V.	______	______check
256 CYCLES	7V.	.6V.	______	______check
256 CYCLES	7V.	3.9V.	______	______check
256 CYCLES	2V.	3.9V.	______	______check

J. Bookeeping Pulses.

5.

Step	Pulse	FLIP FLOP Indicators ON	Output
64	Signal	1 2 4 5	_____volts
65	High Voltage	3 4	_____volts
66	Std. Signal	1 3 5	_____volts

Step	Pulse	FLIP FLOP Indicators ON		Output
67	Marker	2 3 4 5		______ volts
68	Temperature	1 2 3 4		______ volts
69	Reset	5		______ volts
133	Signal	1 2 4 5	10	______ volts
134	High Voltage	3 4	10	______ volts
135	Std. Signal	1 3 5	10	______ volts
136	Marker	2 3 4 5	10	______ volts
137	Temperature	1 2 3 4	10	______ volts

OGO-A MAIN BODY PLASMA PROBE
ELECTRICAL PERFORMANCE
TEST PROCEDURE

I. GENERAL

A. Scope and Purpose

1. The Main Body Plasma Probe is an instrument designed to measure the particle-number density and energy spectra of the electron plasma in outer space and to relay this information to earth via the spacecraft's communication system. The purpose of this test procedure is to determine that the Plasma Probe is operating in a satisfactory manner to accomplish its mission.

B. Data Sheets

1. Sample Data Sheets are included at the end of this test procedure and similar sheets are to be filled out at the time of the test in accordance with instructions set forth in this procedure.

II TEST EQUIPMENT AND POWER REQUIRED

A. Test Equipment

1. Hewlett Packard Square Wave Generator Model 211a or equivalent.
2. Simpson Multimeter Model 260 or equivalent.
3. Tektronix Oscilloscope Type 536 or equivalent.
4. Tektronix Preamp Type M or equivalent.
5. Tektronix Probe Type P6000 or equivalent.
6. Tektronix Probe Type P6013 or equivalent.
7. OGO-A Ground Support Equipment(GSE).
8. OGO Calibration Box.

B. Power Required

1. 115 volts, 60 cps., single phase, 10 amperes.

III SET-UP AND CALIBRATION OF TEST EQUIPMENT

A. Set-Up

1. The test equipment shall be set-up in accordance with the instructions set forth in this procedure.

B. Calibration

1. All test equipment shall be calibrated prior to being used in these tests.

IV OPERATIONAL TESTS

A. Initial Set-Up

1. Equipment POWER switches must be in the OFF position prior to interconnecting the units.

2. Connect the Plasma Probe under test to the test equipment as follows (see Figure 1):

   a. Cable A from GSE 37 pin connector to Plasma Probe J3.

   b. Cable B from GSE TEST SIG. jack to OGO Calibration Box INPUT.

   c. Cable C from OGO Calibration Box TP OUTPUT to Plasma Probe Preamplifier TP.

3. Set the following GSE controls:

   a. RATE to PUSH BUTTON.

   b. POWER ON-OFF to ON.

   c. Turn ADJ TO 28V to indicate 28 volts on GSE voltmeter.

4. Record on Data Sheet the readings of GSE voltmeter and milliammeter.

B. System Voltage Measurements

1. Using the multimeter, measure the voltages at the GSE TEST POINTS and record the results on Data Sheet.

2. Using the multimeter, measure the control voltages at the GSE TEST POINTS and record the results on Data Sheet.

C. System Clock

1. Set the following GSE switches:

   a. SW. SIG. to 2V.

   b. MODE SIG. to 3.9V.

   c. RATE to 4 CYCLES.

2. Connect a wire from GSE GND test point to Oscilloscope ground terminal.

3. Connect a wire from Oscilloscope TRIGGER INPUT to Oscilloscope VERT SIG. OUT.

4. Connect the 10:1 probe (P6000) cable to Oscilloscope SIGNAL INPUT.

5. Connect the 10:1 probe to GSE SYS. CLOCK test point.

6. Set Oscilloscope time scale to 0.2 milliseconds per centimeter.

7. Set Oscilloscope voltage scale to 0.1 volts per centimeter.

8. Set Oscilloscope to trigger on + EXT mode.

9. Observe the pulse on the Oscilloscope and record on Data Sheet the pulse amplitude and width for the 4 CYCLES and PUSH BUTTON positions of the GSE RATE switch. Note: When the RATE switch is in the PUSH BUTTON position, the SINGLE PULSE switch must be depressed to obtain each SYSTEM CLOCK pulse.

10. Set GSE POWER ON-OFF to OFF.

D. Gates MV0 and MV1

1. Disassemble the trays of the Plasma Probe so that the DIGITAL CARD ASSEMBLY (312PW2359) and SELECTION REGISTER CARD ASSEMBLY (312PW2363) are accessible for making measurements.

2. Interconnect the trays together using patch cables (see Figure 2).

3. Set GSE RATE to 4 CYCLES.

4. Set Oscilloscope time scale to 20 milliseconds per centimeter.

5. Set Oscilloscope voltage scale to 0.2 volts per centimeter.

6. Disconnect the 10:1 probe from GSE SYS CLOCK test point and connect to Q14 collector on Card Assembly 312PW2359.

7. Set GSE POWER ON-OFF to ON

8. Observe the gate on the Oscilloscope and record on Data Sheet the gate amplitude and width of MV0.

9. Set Oscilloscope time scale to 5 milliseconds per centimeter.

10. Disconnect the 10:1 probe from Q14 collector and connect to Q16 collector on Card Assembly 312PW2359.

11. Observe the gate on the Oscilloscope and record on Data Sheet the gate amplitude and width of MV1.

E. Free Running Oscillator.

1. Set GSE Rate to PUSH BUTTON.

2. Set Oscilloscope time scale to 50 microseconds per centimeter.

3. Disconnect the 10:1 probe from Q16 collector and connect to Q43 collector on Card Assembly 312PW2359.

4. Observe the waveshape on the Oscilloscope and record the amplitude and width for one cycle and calculate the frequency. If necessary, adjust R9 for 2400 cycles per second.

5. Set GSE POWER ON-OFF to OFF.

6. Disconnect the 10:1 probe from Q129 collector.

7. Reassemble the Plasma Probe trays.

F. Programmer

1. Set GSE POWER ON-OFF to ON.

2. Set GSE RATE to 4 CYCLES and allow the Plasma Probe to operate through the complete program several times.

3. Set the H-P Square Wave Generator POWER ON-OFF to ON.

4. Tune the Square Wave Generator to 2461 cps and an output amplitude of 6 volts peak to peak.

5. Connect Cable D from the Square Wave Generator to the Plasma Probe Spacecraft connector.

6. Set GSE RATE to PUSH BUTTON.

7. Observe the GSE DIGITAL FLIP FLOP indicator lights and momentarily depress the GSE SINGLE PULSE switch.

8. Check the Data Sheet for the program step associated with those indicator lights in the ON condition. Continue momentarily depressing the SINGLE PULSE switch and check that each succeeding sequence of the DIGITAL FLIP FLOP indicator lights turned ON corresponds to that listed on the Data Sheet for that particular step. Continue advancing the program manually until returning to the step at which the test was started.

9. Set GSE POWER ON-OFF to OFF.

G. <u>High Voltage</u>

1. Disconnect the 10:1 probe cable from the Oscilloscope SIGNAL INPUT and connect the 1000:1 probe (P6013) cable to the Oscilloscope SIGNAL INPUT.

2. Disconnect the CUP from the Plasma Probe and insert an adapter into the Plasma Probe high voltage connector.

3. Connect the 1000:1 probe to the adapter.

4. Set Oscilloscope voltage scale to 5 volts per centimeter.

5. Set GSE RATE to 4 CYCLES.

6. Set GSE POWER ON-OFF to ON.

7. Allow the Plasma Probe to operate through the complete program several times.

8. Set GSE RATE to PUSH BUTTON.

9. Using the GSE SINGLE PULSE switch, advance the program until the DIGITAL FLIP FLOP indicator lights 1, 2, 4 are in the ON condition.

10. Set Oscilloscope time scale to 5 milliseconds per centimeter and the voltage scale in accordance with the Data Sheet for each step.

11. Advance each step manually using the GSE SINGLE PULSE switch and record on Data Sheet, the High Voltage peak and valley readings for the appropriate DIGITAL FLIP FLOP indicator lights in the ON condition. Read all pulse levels at the maximum level.

H. <u>High Voltage Phase Relationship</u>

1. Connect a coax cable from GSE TEST SIG to Oscilloscope dual channel SIGNAL INPUT.

2. Set GSE RATE TO 4 CYCLES.

3. Adjust Oscilloscope to obtain a dual trace.

4. Set Oscilloscope time scale to 0.1 milliseconds per centimeter, voltage scale to 1.0 volts per centimeter for TEST SIG input and 2.0 volts per centimeter for High Voltage input.

5. Observe the phase relationship of the two signals and compare with Data Sheet.

   Note: The above test may require some adjustment of the Oscilloscope controls to obtain the desired results since the High Voltage waveshape is constantly changing in amplitude.

6. Set GSE POWER ON-OFF to OFF.

7. Disconnect the 1000:1 probe from the adapter and the cable from the Oscilloscope.

8. Remove the adapter from the Plasma Probe High Voltage connector and reconnect the CUP.

9. Remove the coax cable from the GSE TEST SIG and from the Oscilloscope.

10. Remove cable from Oscilloscope TRIGGER INPUT TO VERT. SIG. OUT.

I. Telemetry

1. Connect a wire from GSE SYS CLOCK to Oscilloscope TRIGGER INPUT.

2. Connect the 10:1 probe cable to Oscilloscope SIGNAL INPUT and connect the 10:1 probe to GSE TELE +.

3. Set Oscilloscope time scale to 0.2 seconds per centimeter and voltage scale to 0.1 volts per centimeter.

4. Set OGO Calibration Box for 1×10^{-7} signal.

5. Set GSE POWER ON-OFF to ON.

6. Observe and record on Data Sheet the pulse amplitude of the output signal for the input signals in accordance with the Data Sheet.

7. Record the OGO Calibration Box setting at which the signal output equals the noise amplitude.

J. Bookeeping Pulses

1. Set GSE RATE to PUSH BUTTON.

2. Set Oscilloscope time scale to 20 milliseconds per centimeter.

3. Disconnect the OGO Calibration Box from the Plasma Probe.

4. Advance the Plasma Probe program to step using the GSE SINGLE PULSE switch.

5. Measure and record the pulse amplitude of the Bookeeping signals in accordance with the Data Sheet.

   Note: Measure the pulse amplitude at 150 milliseconds after the clock pulse.

6. Set GSE POWER ON-OFF to OFF.

7. Set Oscilloscope POWER ON-OFF to OFF.

8. Disconnect all interconnecting cables and wires from the equipments.

9. Test is completed.

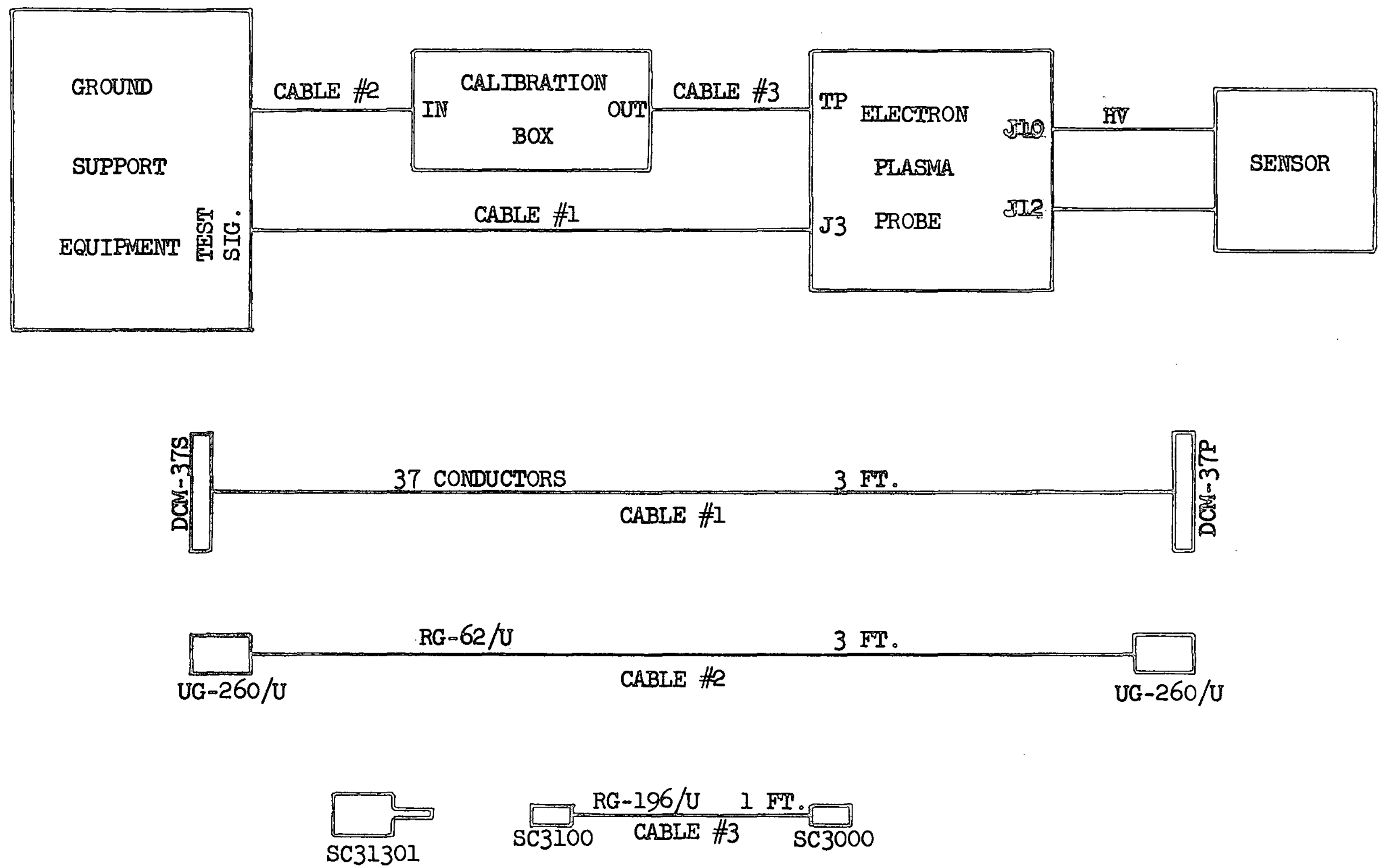

GROUND
SUPPORT
EQUIPMENT
TEST SIG.
CABLE #2
CALIBRATION
IN
OUT
BOX
CABLE #3
TP
ELECTRON
PLASMA
PROBE
J3
J10
J12
HV
SENSOR
CABLE #1
DCM-37S
37 CONDUCTORS
3 FT.
CABLE #1
DCM-37P
RG-62/U
3 FT.
UG-260/U
CABLE #2
UG-260/U
SC31301
RG-196/U
1 FT.
SC3100
CABLE #3
SC3000

Figure 1

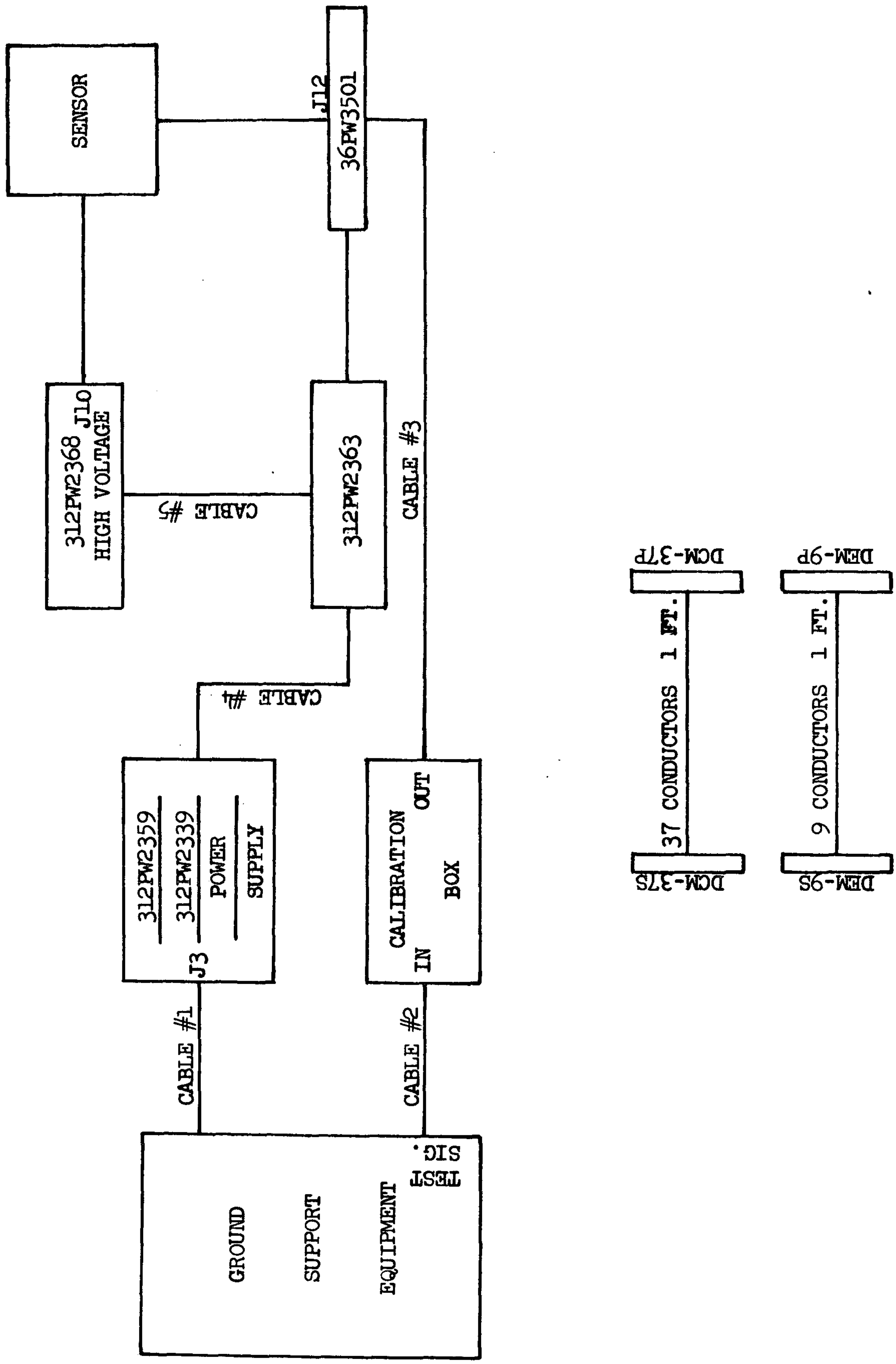

SENSOR
J12
36PW3501
312PW2368 J10
HIGH VOLTAGE
CABLE #5
312PW2363
CABLE #3
CABLE #4
312PW2359
312PW2339
POWER
SUPPLY
J3
CALIBRATION
IN
OUT
BOX
CABLE #1
CABLE #2
GROUND
SUPPORT
EQUIPMENT
TEST
SIG.
DCM-37P
37 CONDUCTORS 1 FT.
DCM-37S
DEM-9P
9 CONDUCTORS 1 FT.
DEM-9S

Figure 2

OGO-A MAIN BODY PLASMA PROBE

ELECTRICAL PERFORMANCE

TEST PROCEDURE

Data Sheet

Serial __________ Date __________ Tester __________

IV A. Initial Set-Up

4. Meter / Reading

Meter	Reading
Voltmeter	_______ volts
Milliammeter	_______ milliamperes

B. System Voltage Measurements.

1.

Test Point	Reading	Test Point	Reading
-3V	____volts	-6V	____volts
-30V	____volts	+6V	____volts
+12V	____volts	+20V	____volts

2.

Test Point	Switch Position	Reading
SW.SIG.	SW.SIG.: 2V	_______ volts
SW.SIG.	SW.SIG.: 7V	_______ volts
MODE SIG.	MODE SIG.: 0.6V	_______ volts
MODE SIG.	MODE SIG.: 3.9V	_______ volts
RATE LEVEL	RATE: 4 CYCLES	_______ volts
RATE LEVEL	RATE: 32 CYCLES	_______ volts
RATE LEVEL	RATE: 256 CYCLES	_______ volts
RATE LEVEL	RATE: PUSH BUTTON	_______ volts

C. System Clock

9.

RATE Switch	Amplitude	Width
4 CYCLES	_____ volts	_____ milliseconds
PUSH BUTTON	_____ volts	_____ milliseconds

D. Gates MVO and MV1.

	Gate	Amplitude	Width
8.	MVO	_____ volts	______ milliseconds
11.	MV1	_____ volts	______ milliseconds

E. Free Running Oscillator

4.	Signal	Amplitude	Width
	1 CYCLE	_____ volts	______ milliseconds

Frequency calculated: __________ cycles per second
Frequency adjusted to: __________ cycles per second

F. Programmer

8.

Program Step	FLIP FLOP Indicator ON 1	2	3	4	Check
1	-	-	-	-	_____
2	1	-	-	-	_____
3	-	2	-	-	_____
4	1	2	-	4	_____
5	-	-	3	4	_____
6	1	-	3	4	_____
7	-	2	3	4	_____
8	1	2	3	4	_____
9	-	-	-	4	_____
10	1	-	-	4	_____
11	-	2	-	4	_____
12	1	2	-	-	_____
13	-	-	3	-	_____
14	1	-	3	-	_____
15	-	2	3	-	_____
16	1	2	3	-	_____

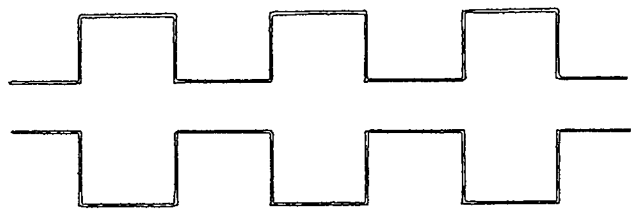
G. High Voltage.

11.

Program Step	Oscilloscope Voltage Scale	FLIP FLOP Indicators ON 1	2	3	4	High Voltage Peak	Valley
5	2V.	-	-	3	4	_____	_____
6	1V.	1	-	3	4	_____	_____
7	.5V	-	2	3	4	_____	_____
8	.2V	1	2	3	4	_____	_____

H. High Voltage Phase Relationship

5.



Correct Phase Relationship. _______ Check.

I. Telemetry.

6.

Signal Input (Amperes)	Telemetry Output (Volts)
1×10^{-7}	__________
1×10^{-8}	__________
1×10^{-9}	__________
1×10^{-10}	__________
1×10^{-11}	__________

7. Signal: Noise = 1 _________ amperes

J. Bookeeping Pulses.

5.

Step	Pulse	FLIP FLOP Indicators ON	Output
9	Blank	4	_____ volts
10	Std.Signal	1-4	_____ volts
11	Temperature	2-4	_____ volts
12	Marker	1-2	_____ volts
1	Blank	0	_____ volts
2	Std.Signal	1	_____ volts
3	Temperature	2	_____ volts
4	Marker	1-2-4	_____ volts

Appendix C

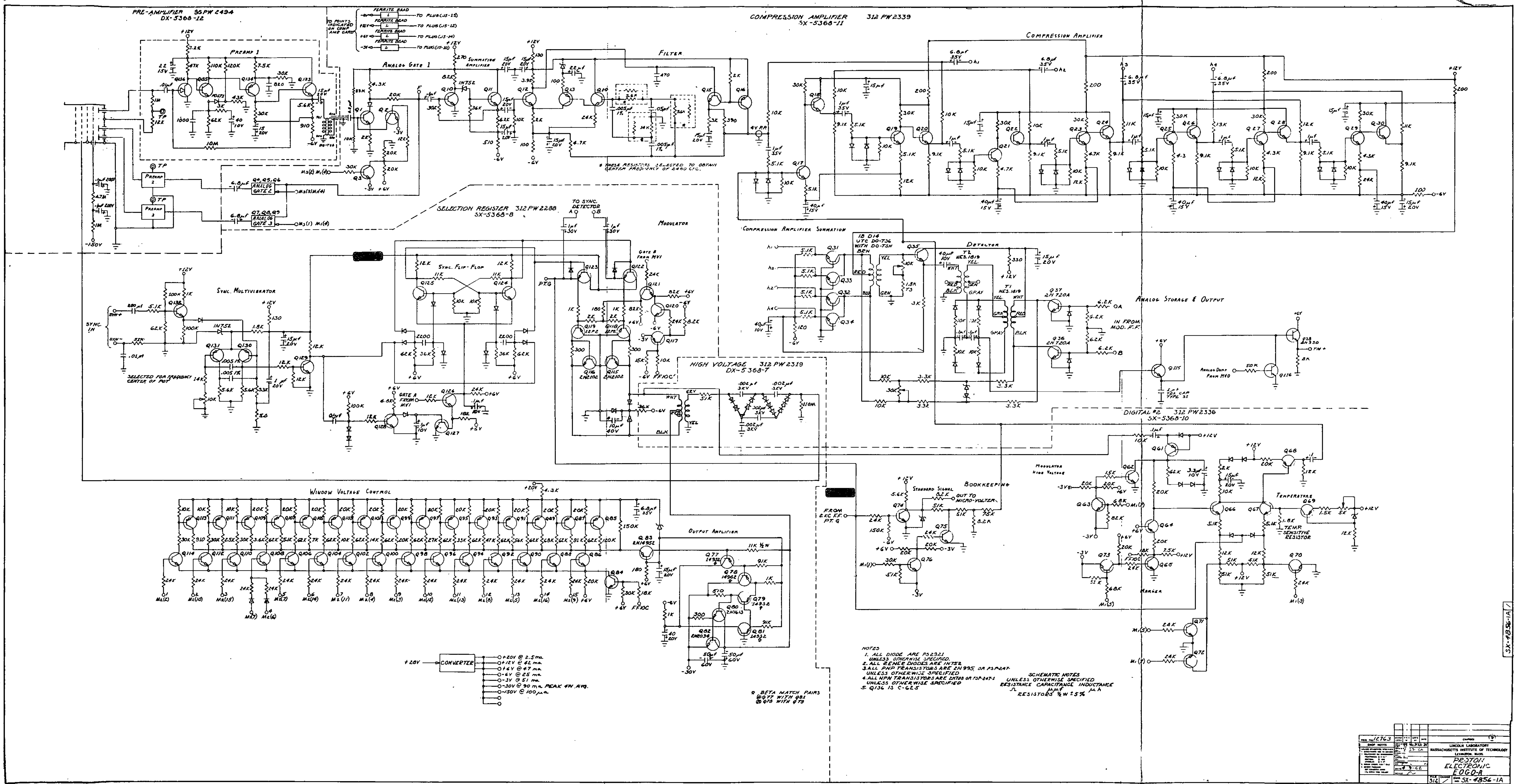
EXPERIMENT DRAWINGS

Drawing No.	Title
SX-4856-1A	Proton Electronic, EOGO-A
SX-4856-2A	Logic Diagrams #1 and #2, Proton Schematic, EOGO-A
SX-4856-3A	Logic and Wiring Diagram, Proton, EOGO-A
SX-4856-4A	Voltage Wiring Diagram, Proton, EOGO-A
DX-4856-5A	Timing Diagram, Proton, EOGO-A
CX-4856-6A	Power Converter Oscillator and Regulator, Proton, EOGO-A
CX-4856-7A	Power Converter Voltage Output, Proton, EOGO-A
SX-5367-1A	Electron Electronics, EOGO-A
DX-5367-2A	Electron and Digital Calibrate, EOGO-A
SX-5367-3A	Logic and Wiring Diagram, Electron, EOGO-A
CX-5367-4A	Power Converter Oscillator and Regulator, Electron, EOGO-A
CX-5367-5A	Power Converter Voltage Output, Electron, EOGO-A
D-5650-A	EOGO-A GSE
SX-4856-1B	Proton Electronic, EOGO-B
SX-4856-2B	Logic Diagrams #1 and #2, Proton Schematic, EOGO-B

SX-4856-3B	Logic Wiring Diagram, Proton, EOGO-B
SX-4856-4B	Voltage Wiring Diagram, Proton, EOGO-B
DX-4856-5B	Timing Diagram, Proton, EOGO-B
SX-5367-1B	Electron Electronic, EOGO-B
DX-5367-2B	Electron and Digital Calibrate, EOGO-B
SX-5367-3B	Logic and Wiring Diagram, Electron, EOGO-B
D-5465-A	Power Converter, EOGO-B
D-5465-B	EOGO-B GSE

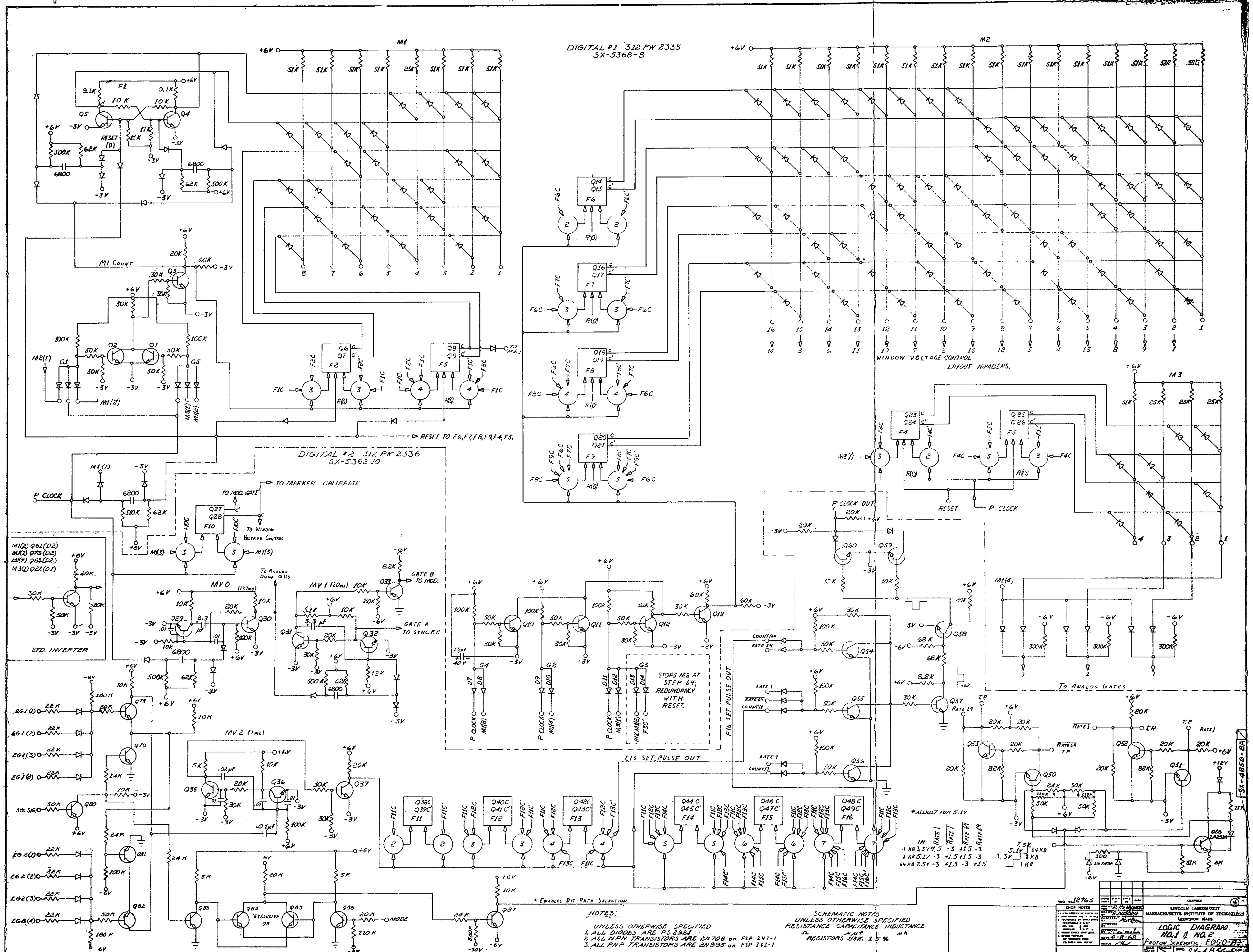
FOLDOUT FRAME 1

FOLDOUT FRAME 2



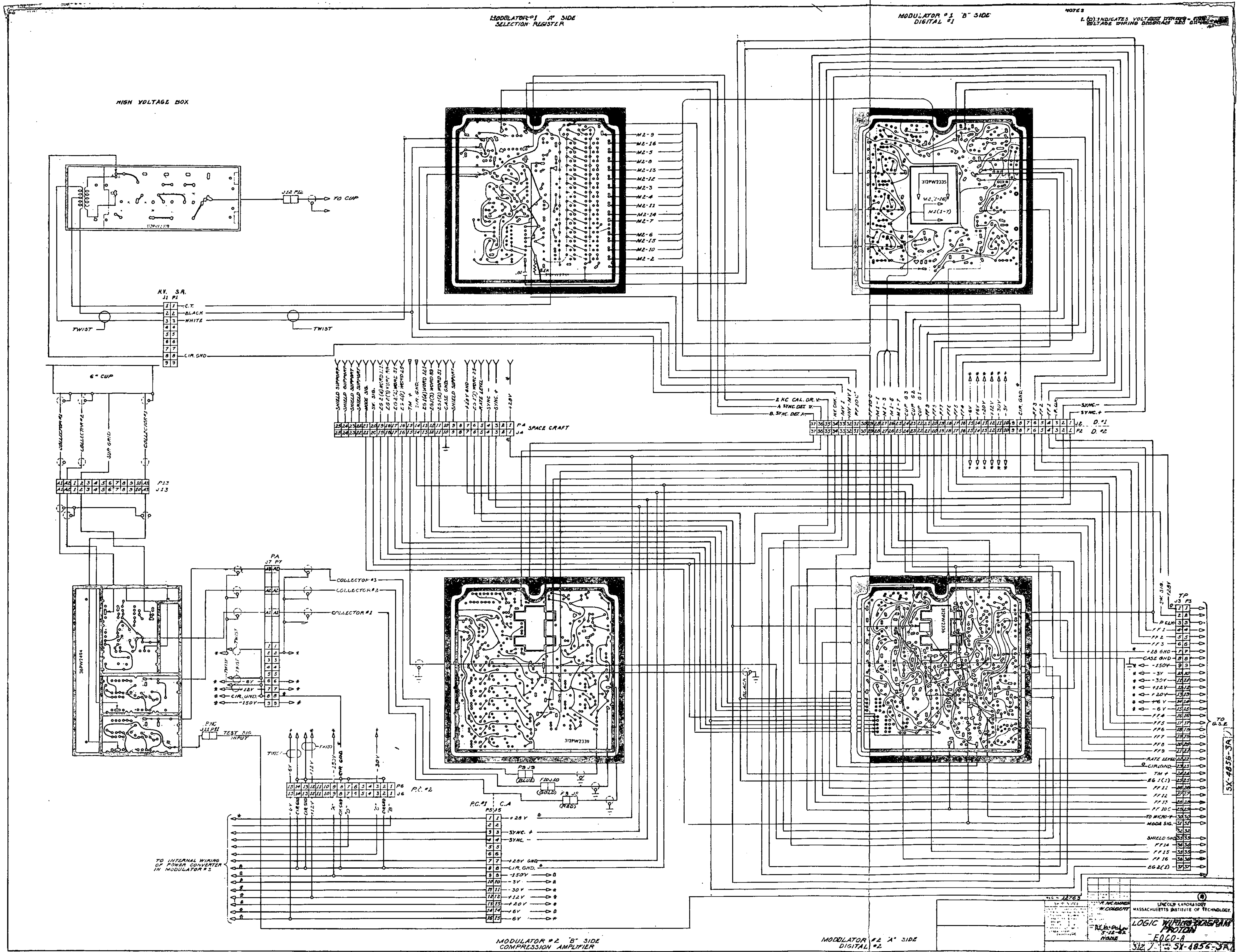
FOLDOUT FRAME 1

FOLDOUT FRAME 2



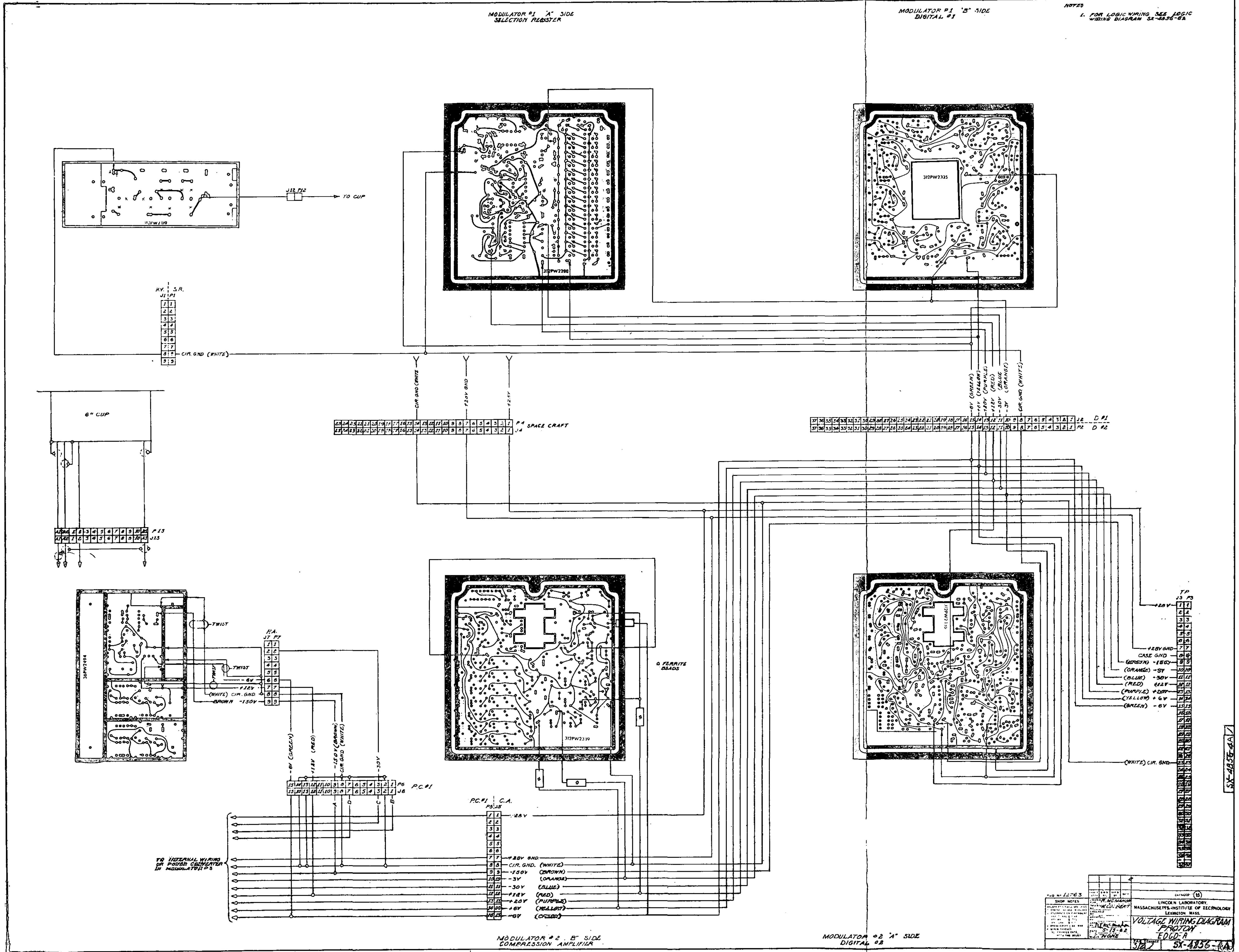
FOLDOUT FRAME 1

FOLDOUT FRAME 2

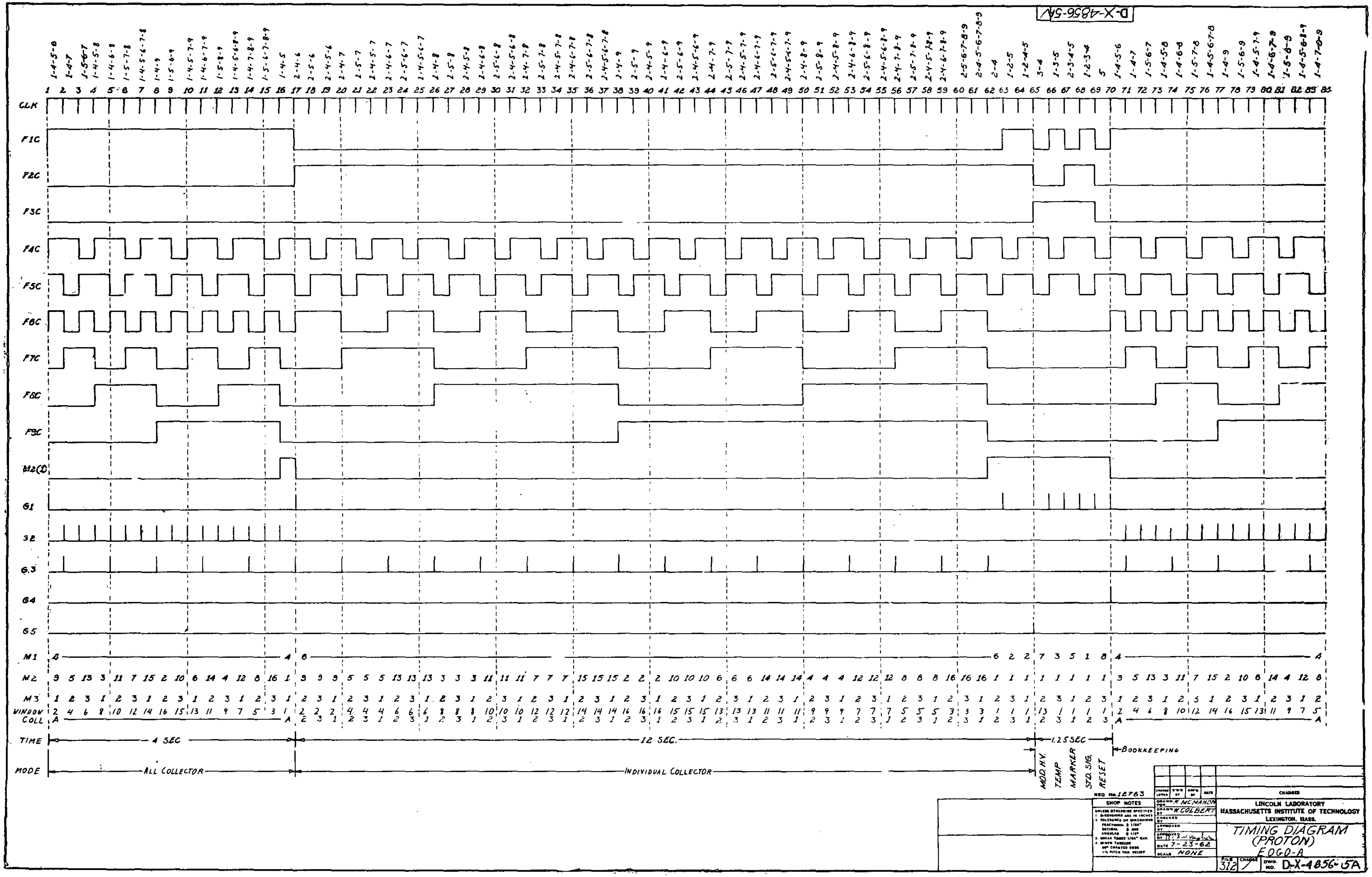


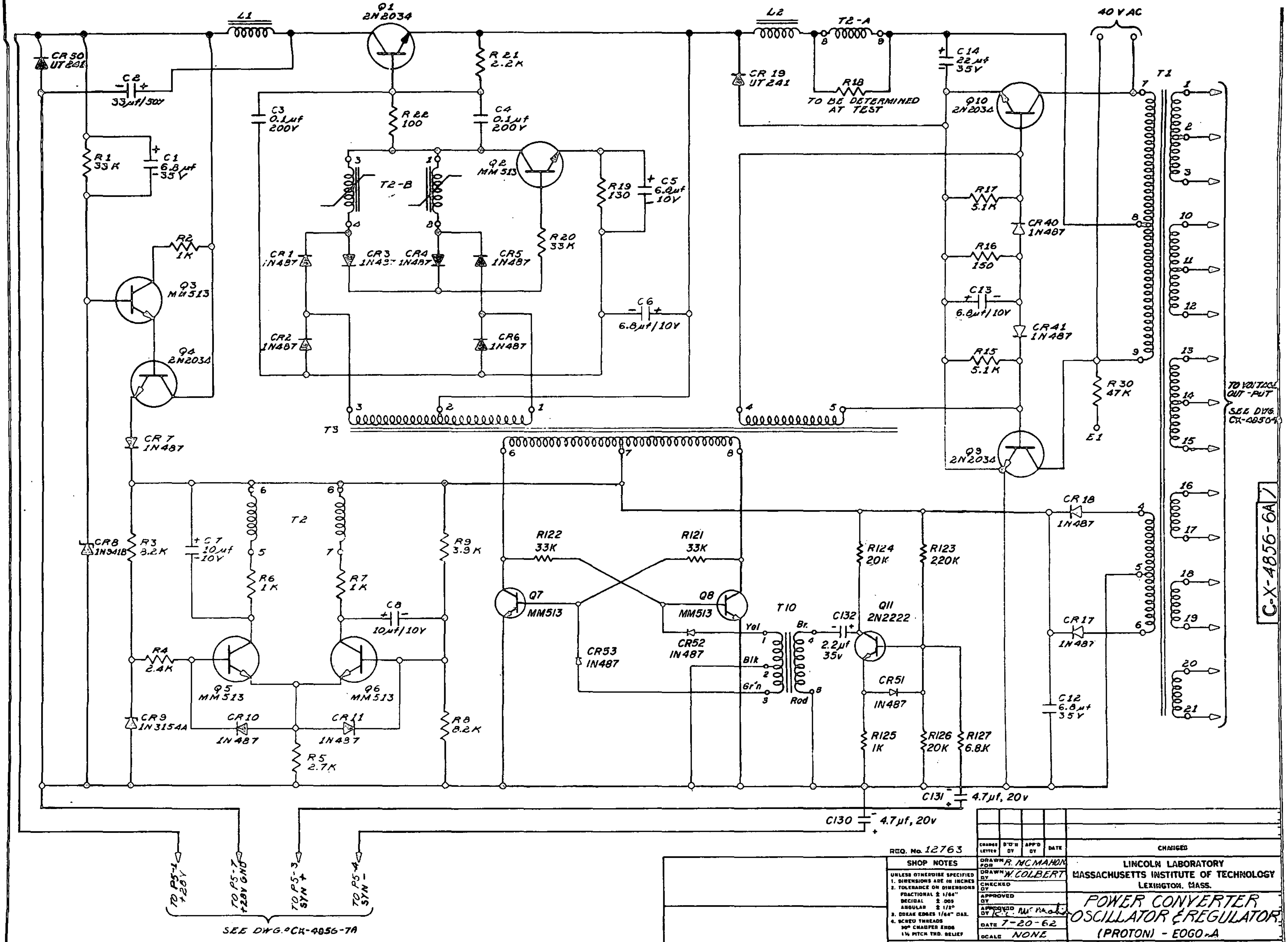
FOLDOUT FRAME 1

FOLDOUT FRAME 2



4A


D-X-4856-5A
CLK
F1C
F2C
F3C
F4C
F5C
F6C
F7C
F8C
F9C
M2(C)
G1
G2
G3
G4
G5
M1
M2
M3
WINDOW COLL
TIME
MODE
4 SEC
12 SEC.
1.25 SEC
BOOKKEEPING
ALL COLLECTOR
INDIVIDUAL COLLECTOR
MOD.H.V.
TEMP
MARKER
STD. SIG.
RESET
REQ. No. 18763
SHOP NOTES
DRAWN R. MC MAHON
W. COLBERT
DATE 7-23-62
SCALE NONE
CHANGES
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.
TIMING DIAGRAM
(PROTON)
EOGO-A
FILE 312
DWG. NO. D-X-4856-5A



REQ. No. 12763

SHOP NOTES

UNLESS OTHERWISE SPECIFIED
1. DIMENSIONS ARE IN INCHES
2. TOLERANCE ON DIMENSIONS
FRACTIONAL ± 1/64"
DECIMAL ± .005
ANGULAR ± 1/2°
3. BREAK EDGES 1/64" MAX.
4. SCREW THREADS 90° CHAMFER ENDS 1½ PITCH THD. RELIEF

CHANGE LETTER	D'D'R BY	APP'D BY	DATE

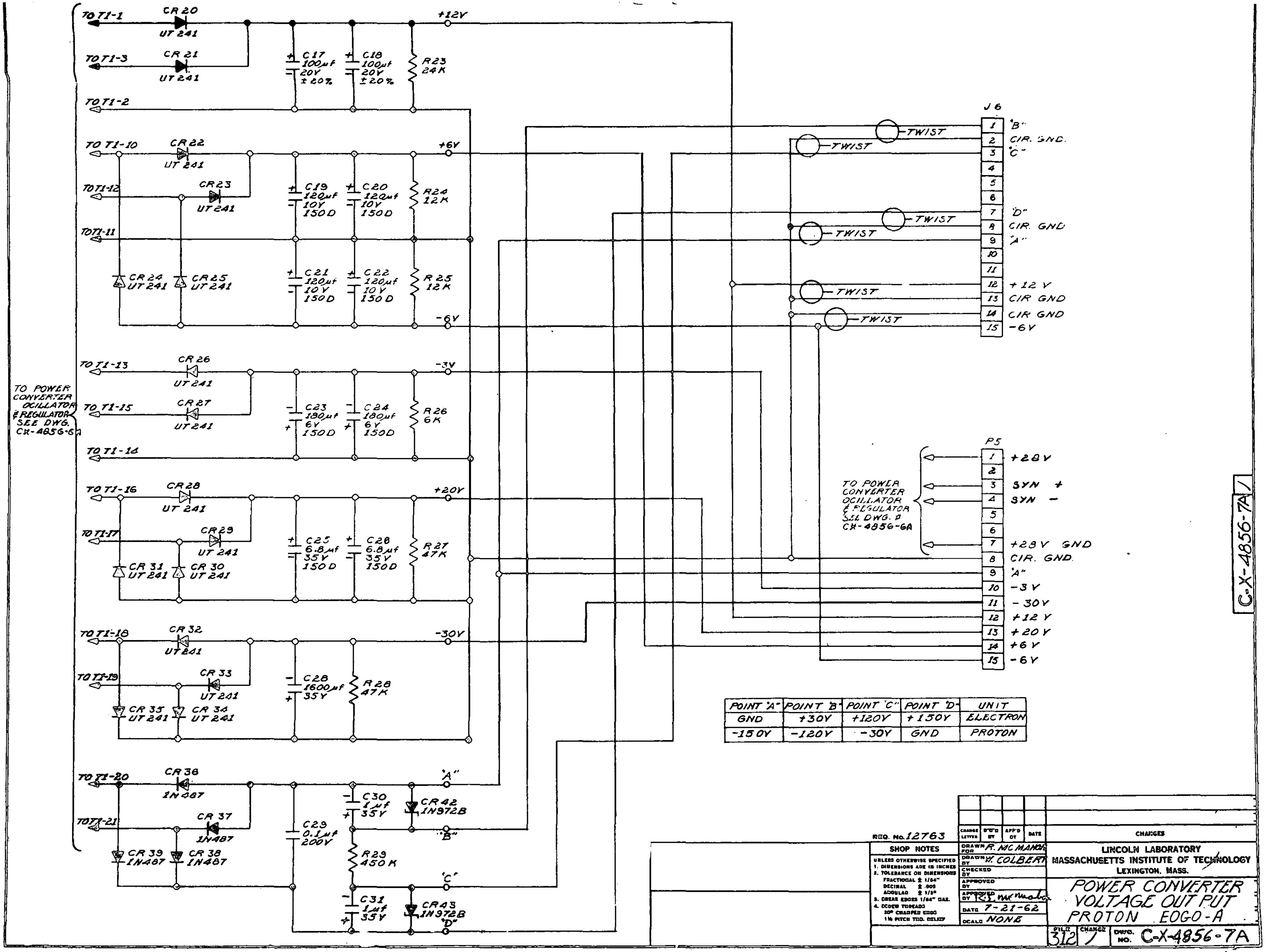
CHANGED

DRAWN FOR	R. MCMAHON
DRAWN BY	W. COLBERT
CHECKED BY	
APPROVED BY	
APPROVED BY	R. McMahon
DATE	7-20-62
SCALE	NONE

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.

POWER CONVERTER OSCILLATOR & REGULATOR (PROTON) - EOGO-A

FILE 312 | CHANGE / | DWG. NO. C-X-4856-6A



POINT "A"	POINT "B"	POINT "C"	POINT "D"	UNIT
GND	+30V	+120V	+150V	ELECTRON
-150V	-120V	-30V	GND	PROTON

REQ. No. 12763

SHOP NOTES
UNLESS OTHERWISE SPECIFIED
1. DIMENSIONS ARE IN INCHES
2. TOLERANCE ON DIMENSIONS FRACTIONAL ± 1/64" DECIMAL ± .005 ANGULAR ± 1/2°
3. BREAK EDGES 1/64" MAX.
4. SCREW THREADS 30° CHAMFER ENDS 1½ PITCH THD. RELIEF

CHANGE LETTER	DRW'N BY	APP'D BY	DATE	CHANGES

DRAWN FOR R. MC MAHON
DRAWN BY V. COLBERT
CHECKED BY
APPROVED BY
APPROVED BY R.S. McMahon
DATE 7-21-62
SCALE NONE

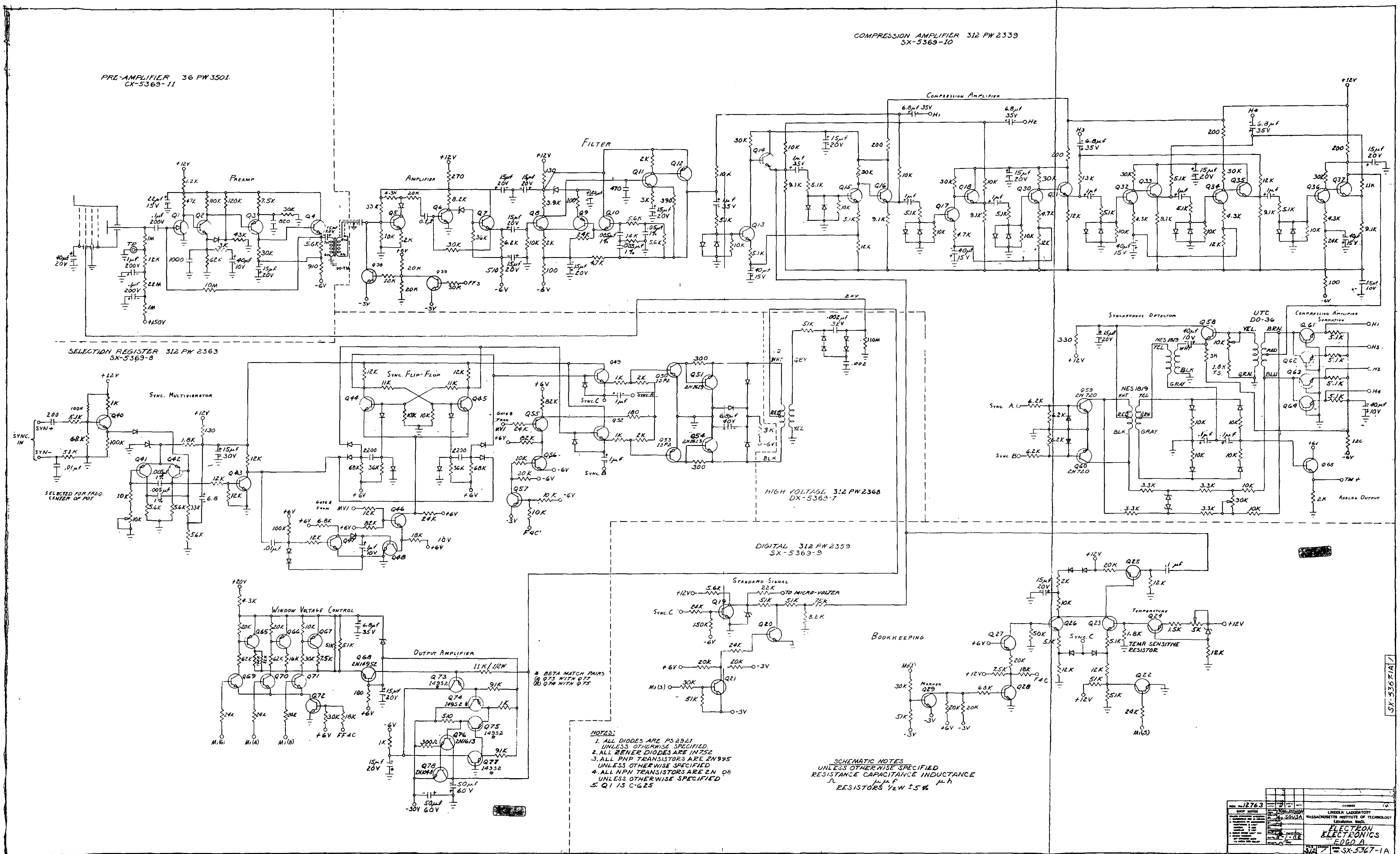
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.

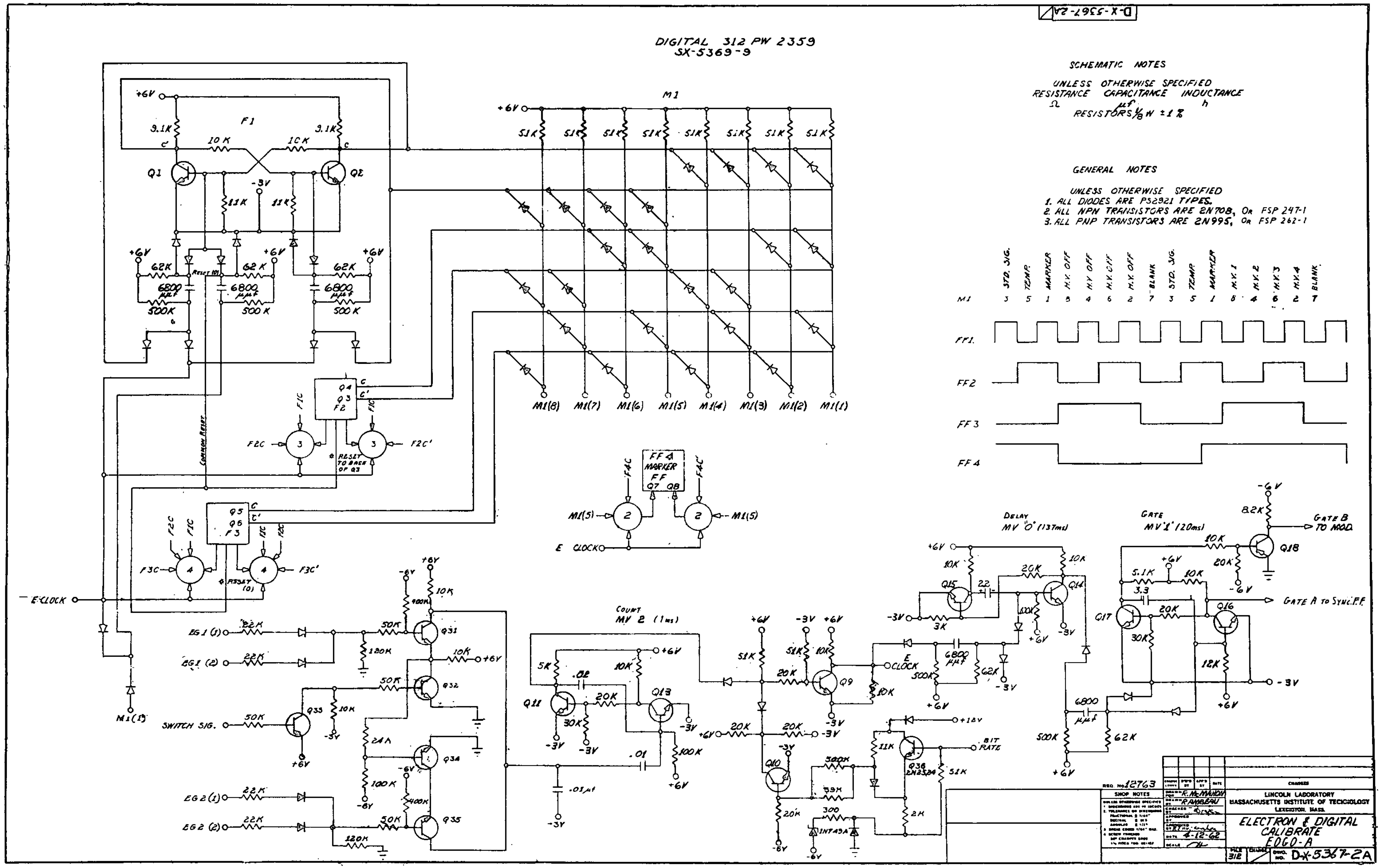
POWER CONVERTER
VOLTAGE OUTPUT
PROTON EOGO-A

FILE 312 CHANGE / DWG. NO. C-X-4856-7A

FOLDOUT FRAME 1

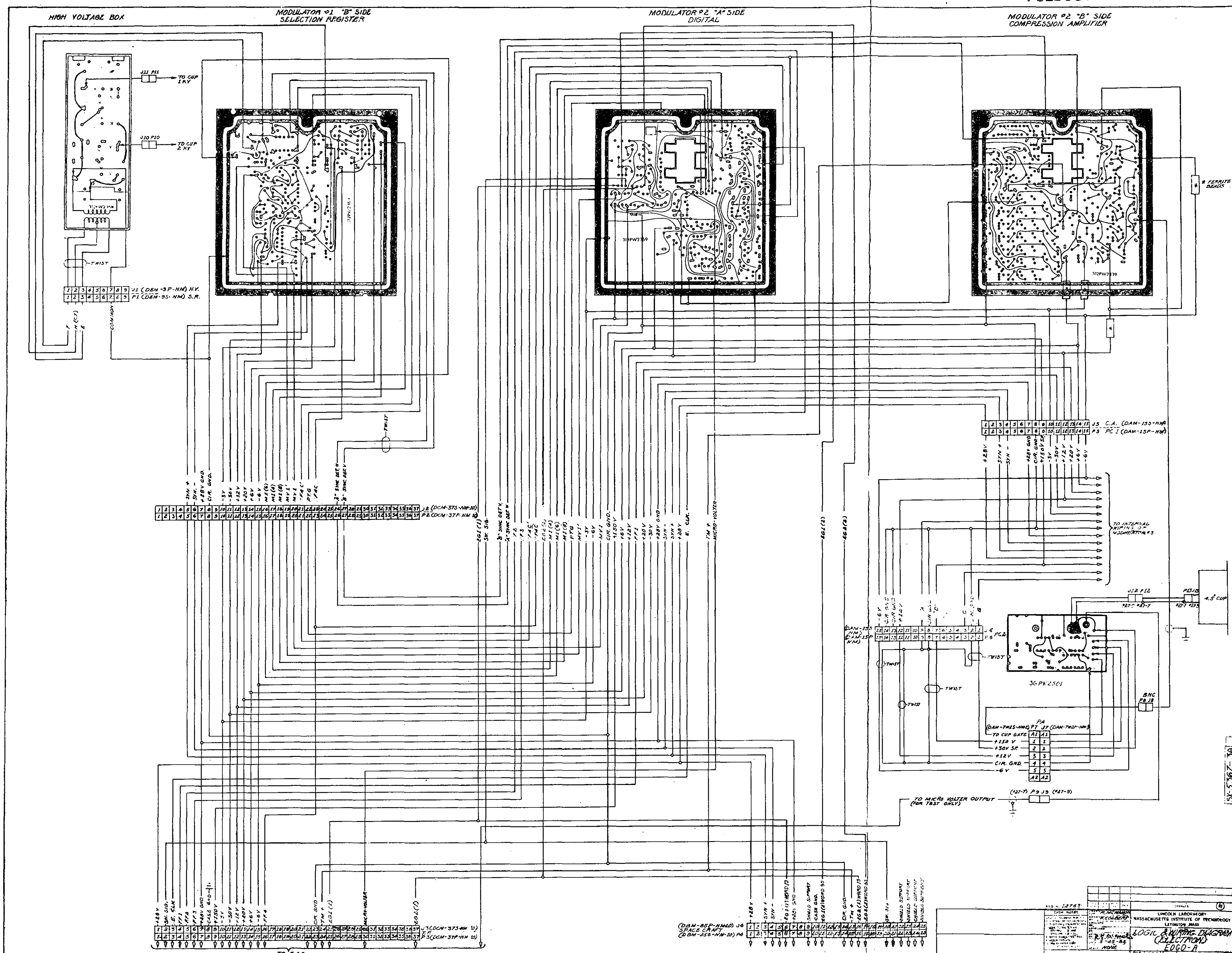
FOLDOUT FRAME 2

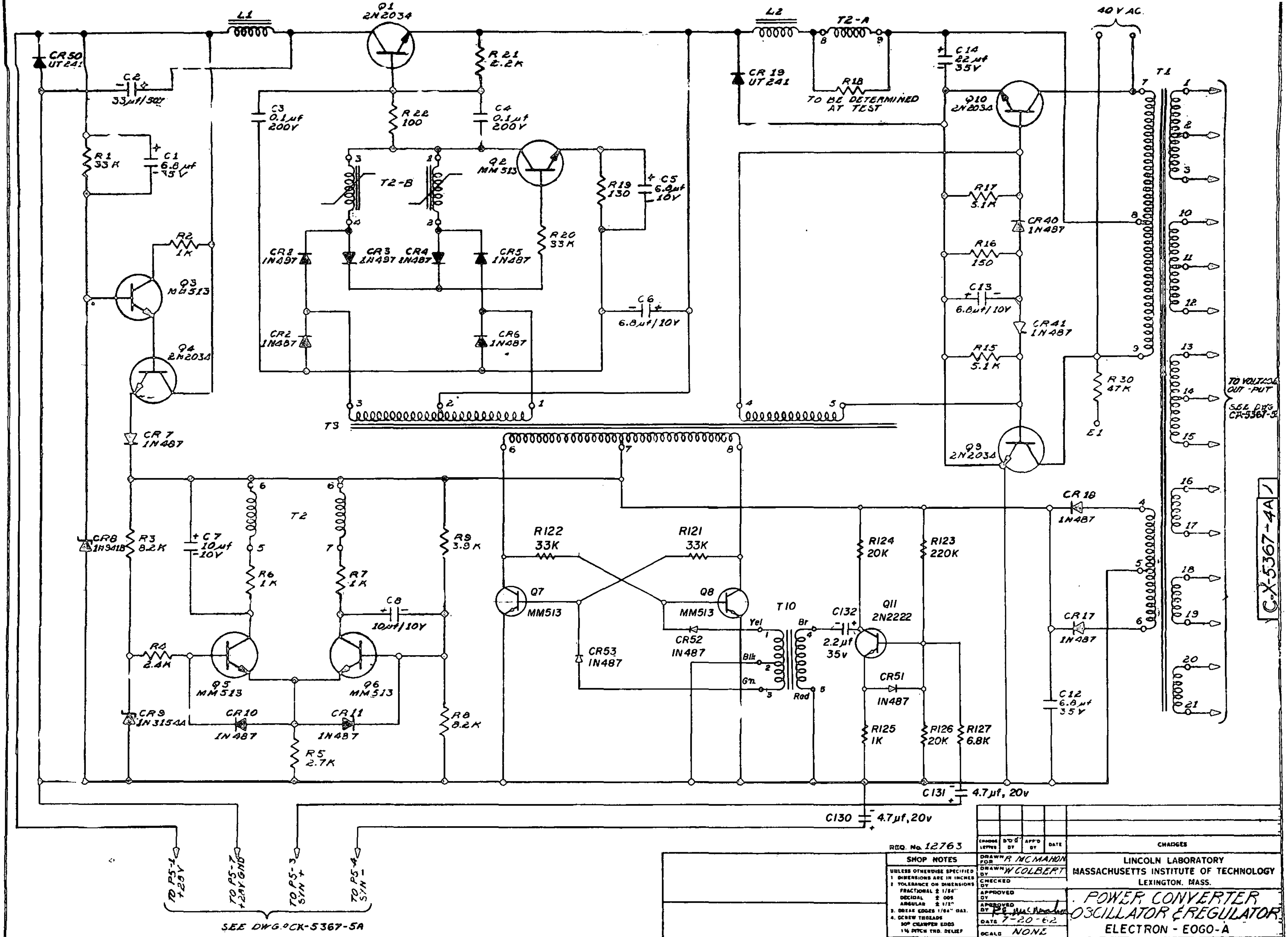



D-X-5367-2A
DIGITAL 312 PW 2359
SX-5369-9
SCHEMATIC NOTES
UNLESS OTHERWISE SPECIFIED
RESISTANCE CAPACITANCE INDUCTANCE
Ω µf h
RESISTORS 1/8 W ±1%
GENERAL NOTES
UNLESS OTHERWISE SPECIFIED
1. ALL DIODES ARE PS2921 TYPES.
2. ALL NPN TRANSISTORS ARE 2N708, OR FSP 247-1
3. ALL PNP TRANSISTORS ARE 2N995, OR FSP 262-1
STD. SIG. TEMP. MARKER H.V. OFF H.V. OFF H.V. OFF H.V. OFF BLANK STD. SIG. TEMP. MARKER H.V. 1 H.V. 2 H.V. 3 H.V. 4 BLANK
M1 3 5 1 8 4 6 2 7 3 5 1 8 4 6 2 7
FF1
FF2
FF3
FF4
M1
F1
Q1
Q2
RESET (0)
COMMON RESET
F2
F3
FF 4 MARKER FF Q7 Q8
E CLOCK
DELAY MV "0" (137ms)
GATE MV "1" (20ms)
COUNT MV 2 (1ms)
GATE B TO MOD.
GATE A TO SYNC.F.F.
BIT RATE
EG 1 (1)
EG 1 (2)
SWITCH SIG.
EG 2 (1)
EG 2 (2)
M1(8) M1(7) M1(6) M1(5) M1(4) M1(3) M1(2) M1(1)
REG. No. 12763
SHOP NOTES
R. McMAHON
R. AMBEAU
4-12-62
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.
ELECTRON & DIGITAL CALIBRATE E060-A
312
D-X-5367-2A

FOLDOUT FRAME 1

FOLDOUT FRAME 2





REQ. No. 12763

SHOP NOTES

UNLESS OTHERWISE SPECIFIED
1. DIMENSIONS ARE IN INCHES
2. TOLERANCE ON DIMENSIONS
FRACTIONAL ± 1/64"
DECIMAL ± .005
ANGULAR ± 1/2°
3. BREAK EDGES 1/64" MAX.
4. SCREW THREADS 30° CHAMFER ENDS 1½ PITCH THD. RELIEF

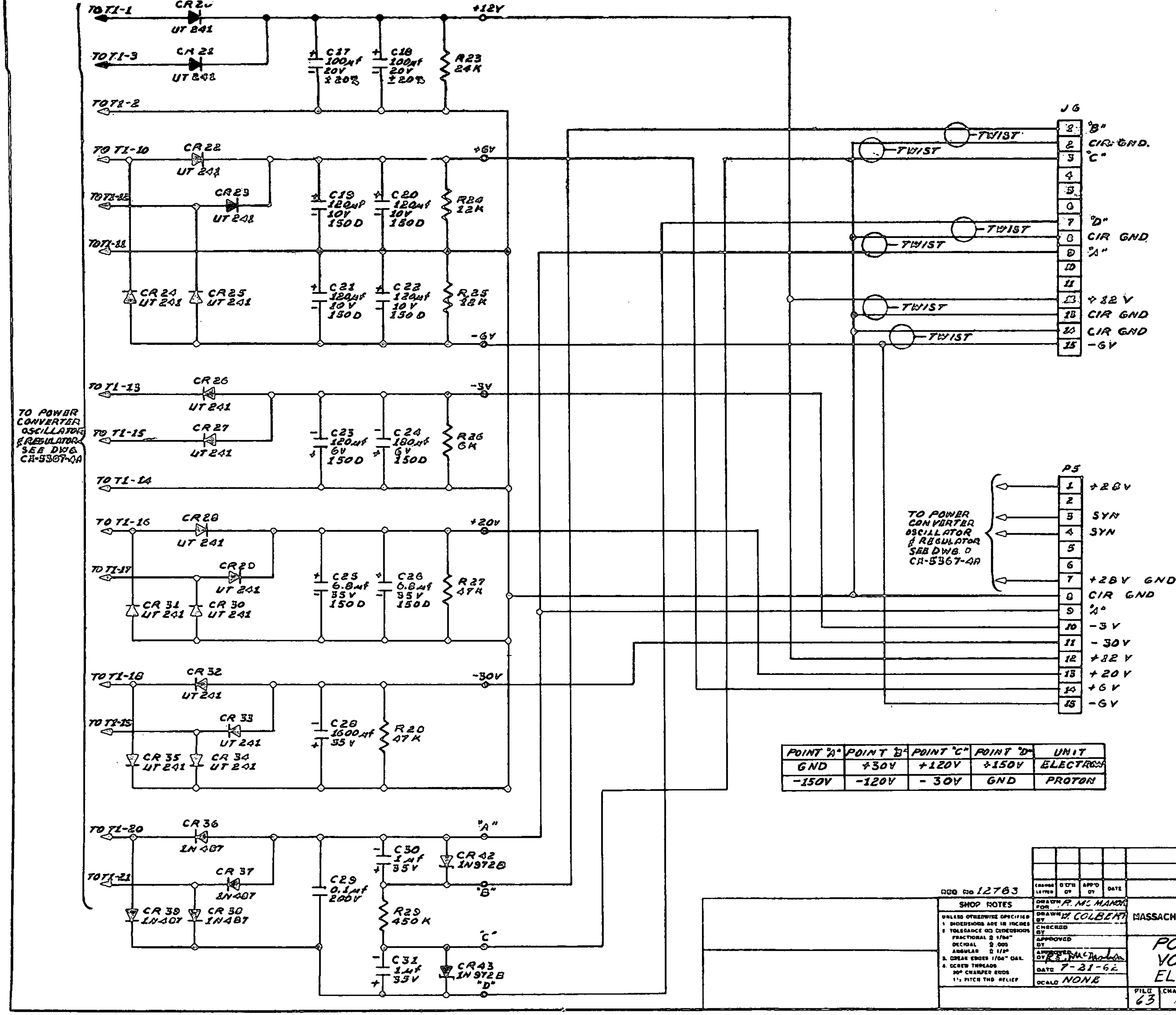
CHANGE LETTER	DWG BY	APP'D BY	DATE	CHANGES

DRAWN FOR R. MCMAHON
DRAWN BY W. COLBERT
CHECKED BY
APPROVED BY
APPROVED BY R. McMahon
DATE 7-20-62
SCALE NONE

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.

POWER CONVERTER OSCILLATOR & REGULATOR
ELECTRON - EOGO-A

FILE 312 CHANGE / DWG. NO. C-X-5367-4A



POINT "A"	POINT "B"	POINT "C"	POINT "D"	UNIT
GND	+30V	+120V	+150V	ELECTRON
-150V	-120V	- 30V	GND	PROTON

DDQ No 12763

SHOP NOTES

UNLESS OTHERWISE SPECIFIED
1. DIMENSIONS ARE IN INCHES
2. TOLERANCE ON DIMENSIONS
FRACTIONAL ± 1/64"
DECIMAL ± .005
ANGULAR ± 1/2°
3. BREAK EDGES 1/64" MAX.
4. SCREW THREADS
30° CHAMFER ENDS
1½ PITCH THD RELIEF

CHANGE LETTER	D'T'N BY	APP'D BY	DATE	CHANGES

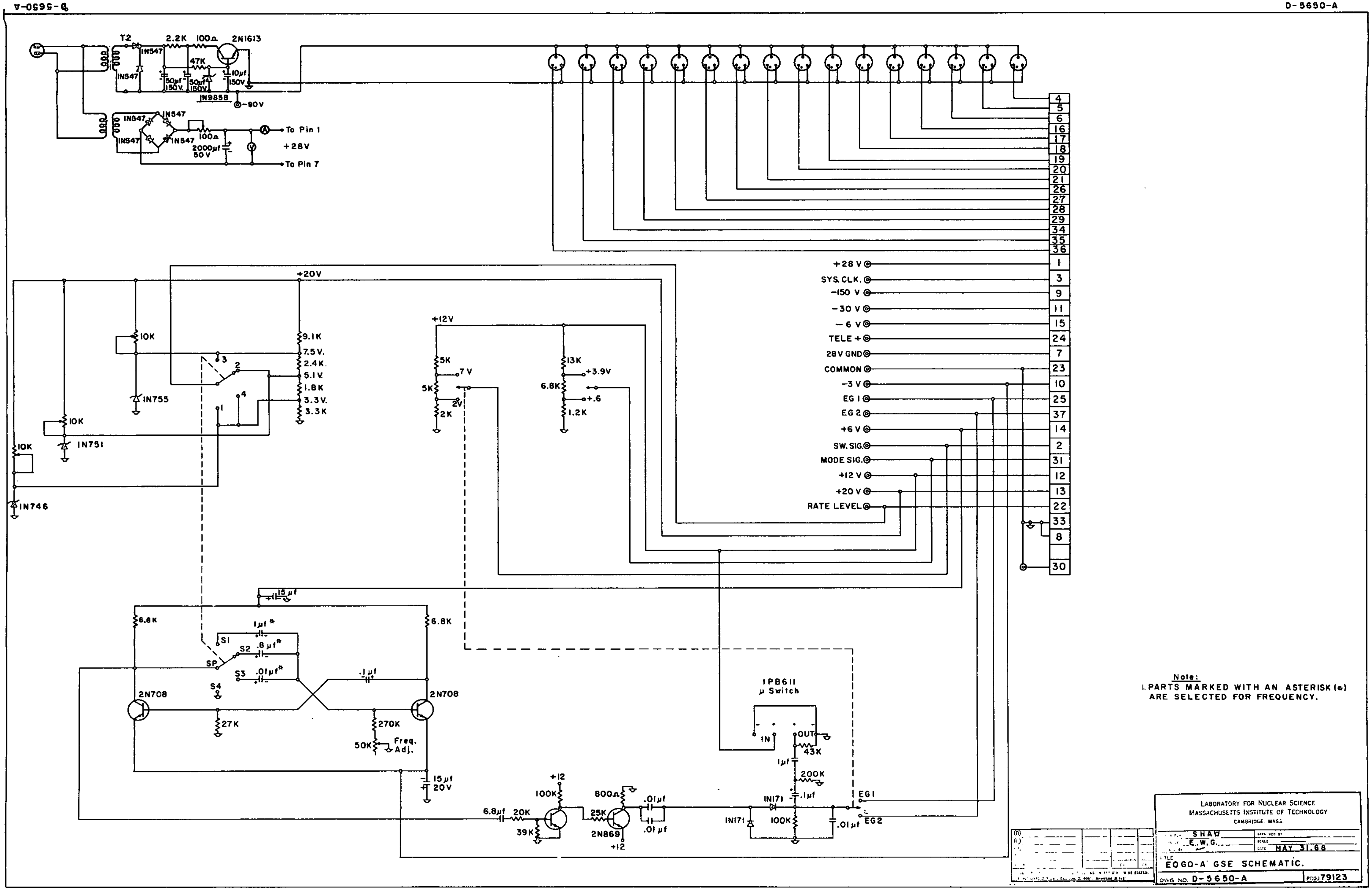
DRAWN FOR R. MC MANUS
DRAWN BY W. COLBERT
CHECKED BY
APPROVED BY
APPROVED BY R.S. McManus
DATE 7-31-62
SCALE NONE

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.

POWER CONVERTER
VOLTAGE OUT PUT
ELECTRON EOGO-A

FILE 63 | CHANGE / | DWG. NO. C-X-5367-5A

D-5650-A



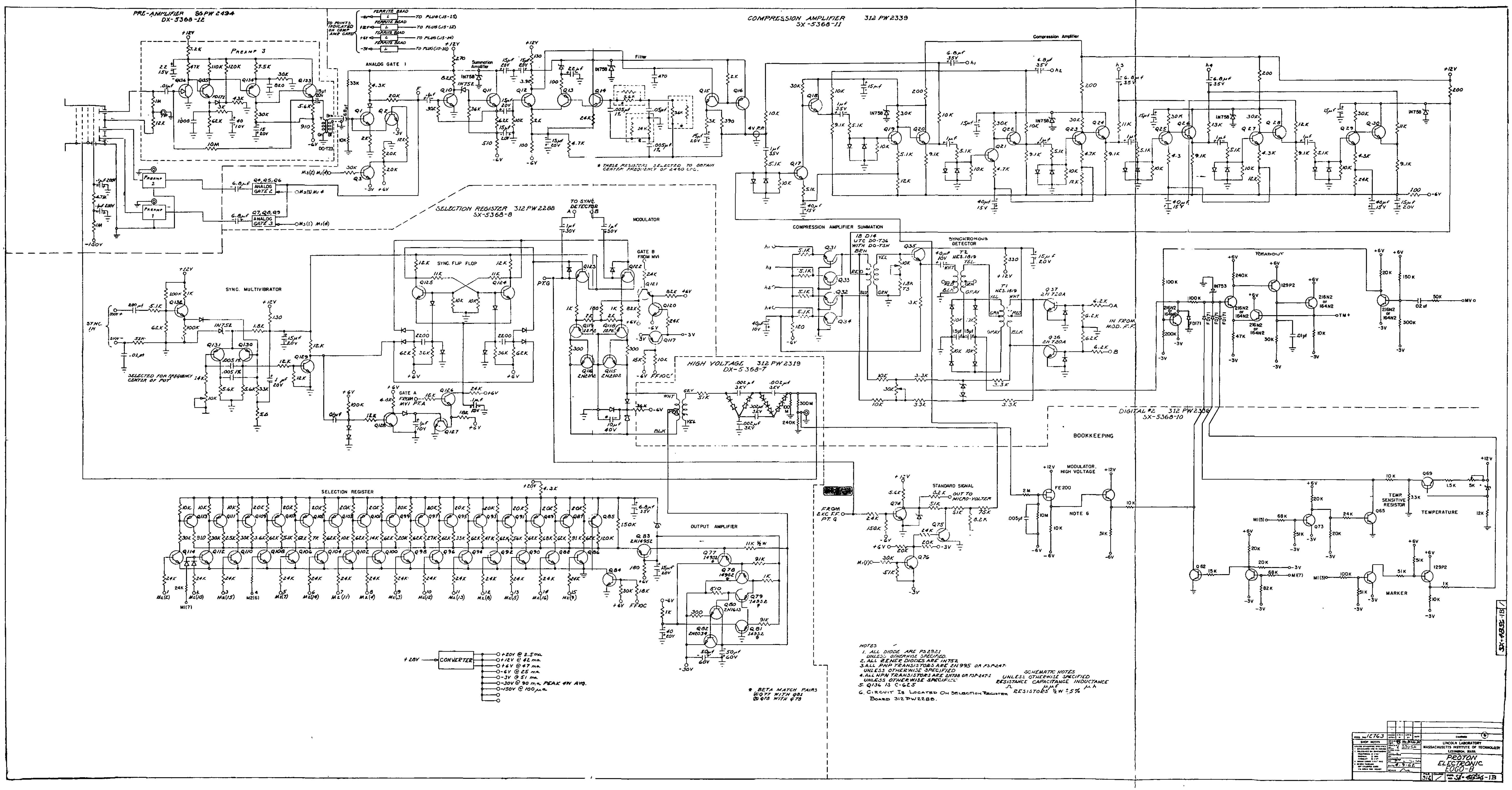
Note:
1. PARTS MARKED WITH AN ASTERISK (*) ARE SELECTED FOR FREQUENCY.

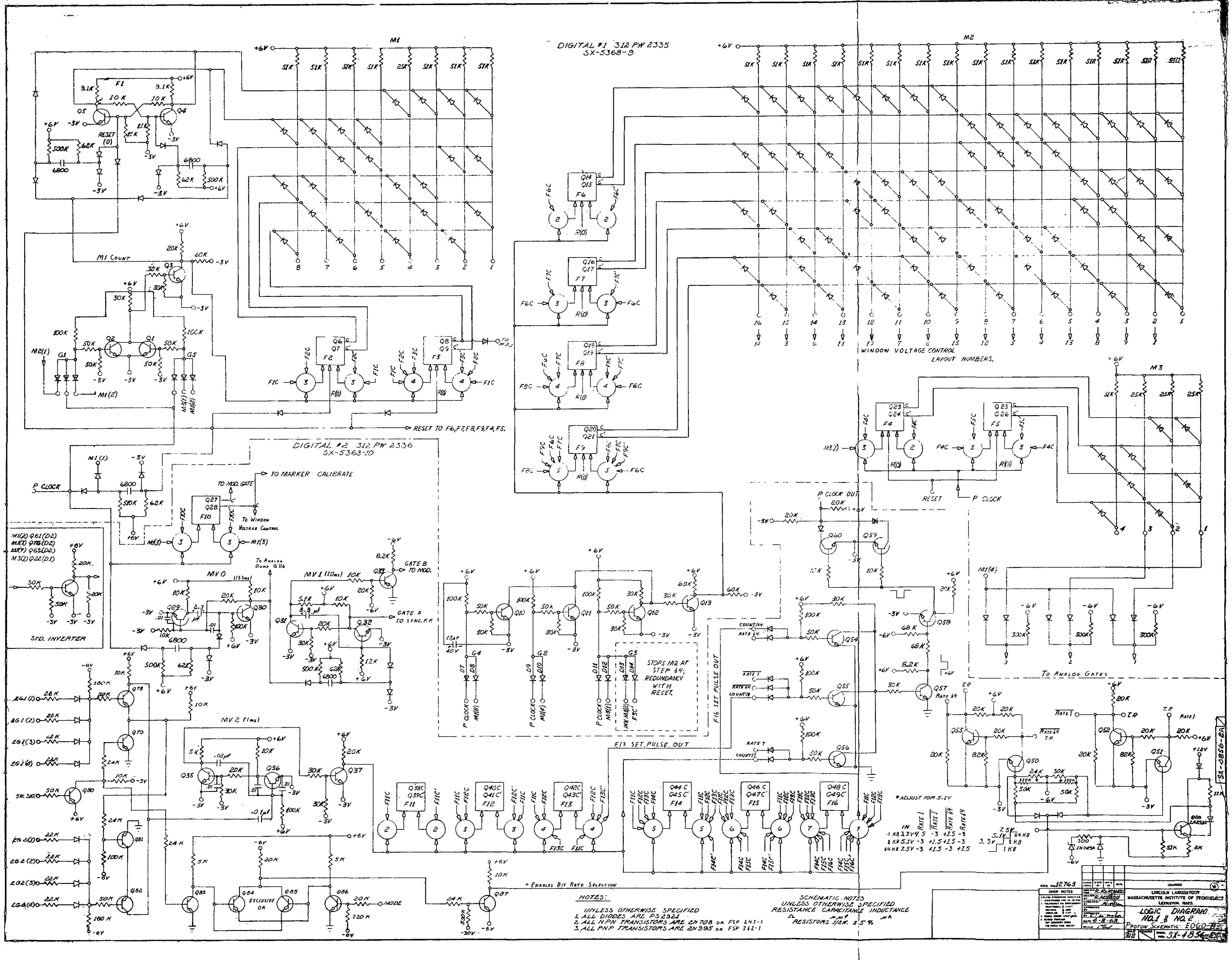
LABORATORY FOR NUCLEAR SCIENCE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASS.

SHAW
E. W. G.
DATE MAY 31, 68
TITLE EOGO-A' GSE SCHEMATIC.
DWG NO. D-5650-A
PROJ 79123

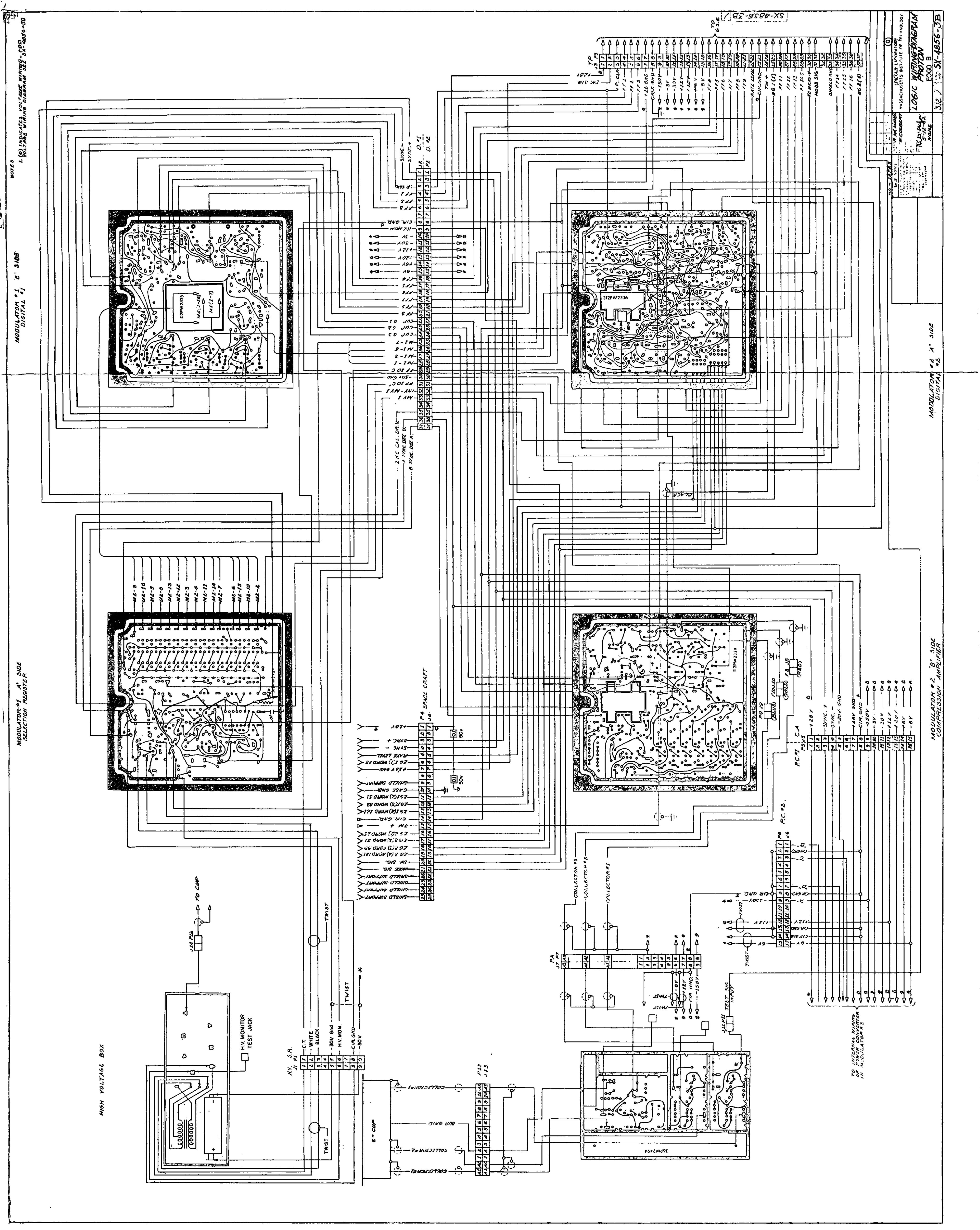
FOLDOUT FRAME 1

FOLDOUT FRAME 2




DIGITAL #1 312 PW 2335
SX-5368-9
DIGITAL #2 312 PW 2336
SX-5363-10
M1
M2
M3
M1 COUNT
WINDOW VOLTAGE CONTROL
LAYOUT NUMBERS.
RESET TO F6,F7,F8,F9,F4,F5.
TO MARKER CALIBRATE
P CLOCK
STD. INVERTER
MV 0
MV 1 (10ms)
MV 2 (1ms)
GATE B TO MOD.
GATE A TO SYNC.F.F.
STOPS M2 AT STEP 64; REDUNDANCY WITH RESET.
F16 SET PULSE OUT
F13 SET PULSE OUT
TO ANALOG GATES
P CLOCK OUT
EXCLUSIVE OR
+ ENABLES BIT RATE SELECTION
NOTES:
UNLESS OTHERWISE SPECIFIED
1. ALL DIODES ARE PS 2321
2. ALL NPN TRANSISTORS ARE 2N708 OR FSP 241-1
3. ALL PNP TRANSISTORS ARE 2N995 OR FSP 261-1
SCHEMATIC NOTES
UNLESS OTHERWISE SPECIFIED
RESISTANCE CAPACITANCE INDUCTANCE
RESISTORS 1/2W. ± 5%
*ADJUST FOR 5.1V
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.
LOGIC DIAGRAM NO.1 & NO.2
PROTON SCHEMATIC: EOGO-EXP
SX-4856-EA

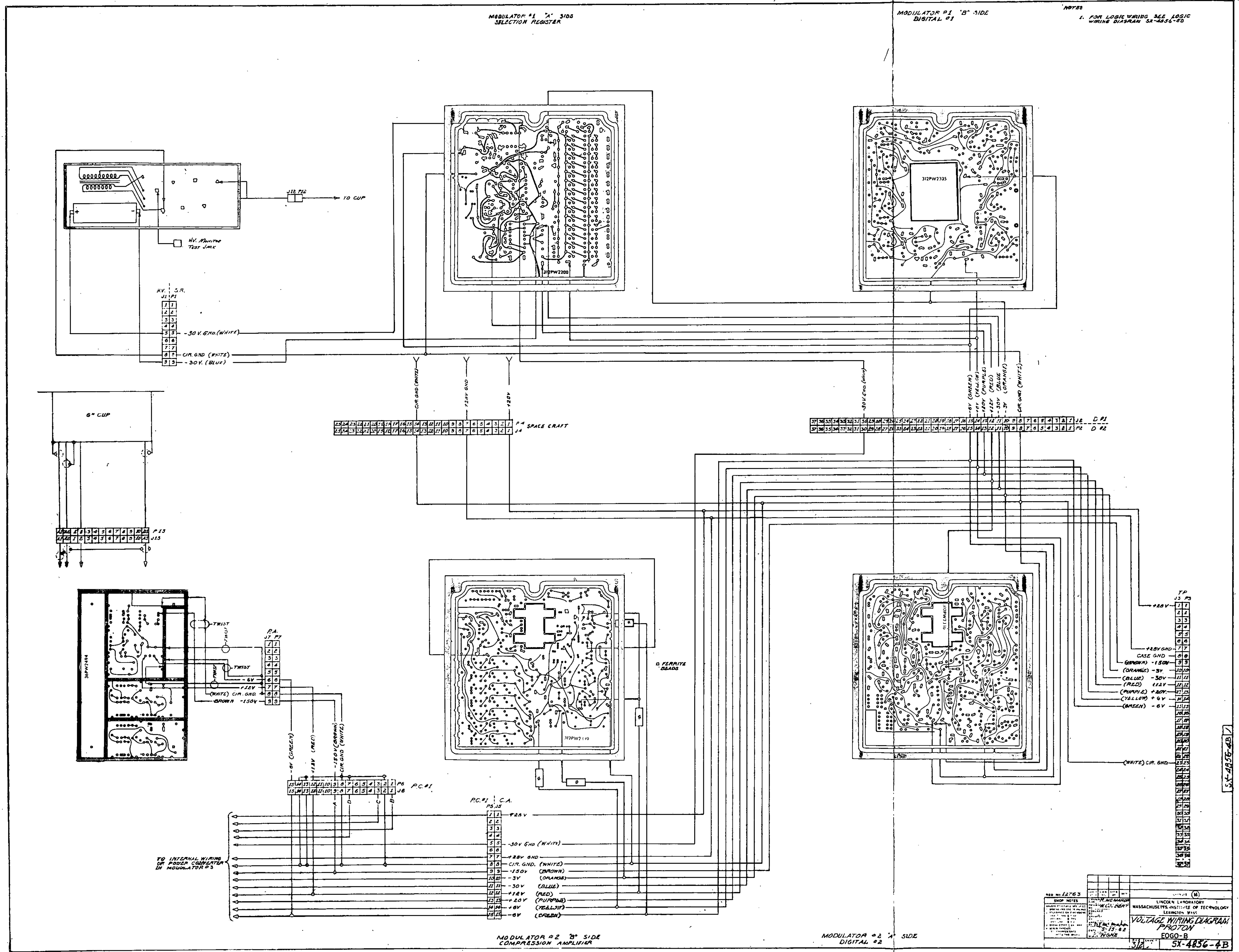
FOLDOUT FRAME 2

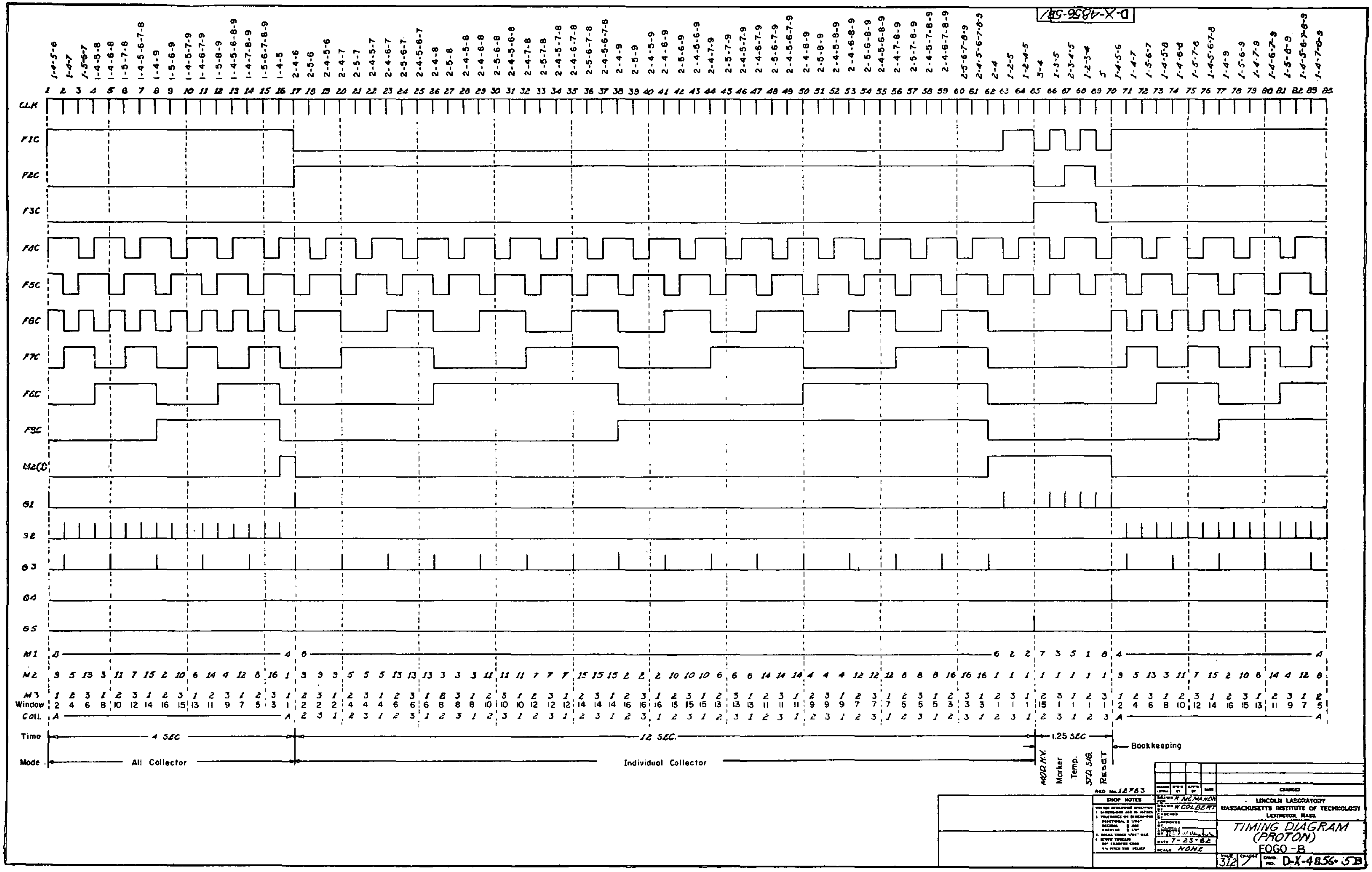


FOLDOUT FRAME 1

FOLDOUT FRAME 1

FOLDOUT FRAME 2

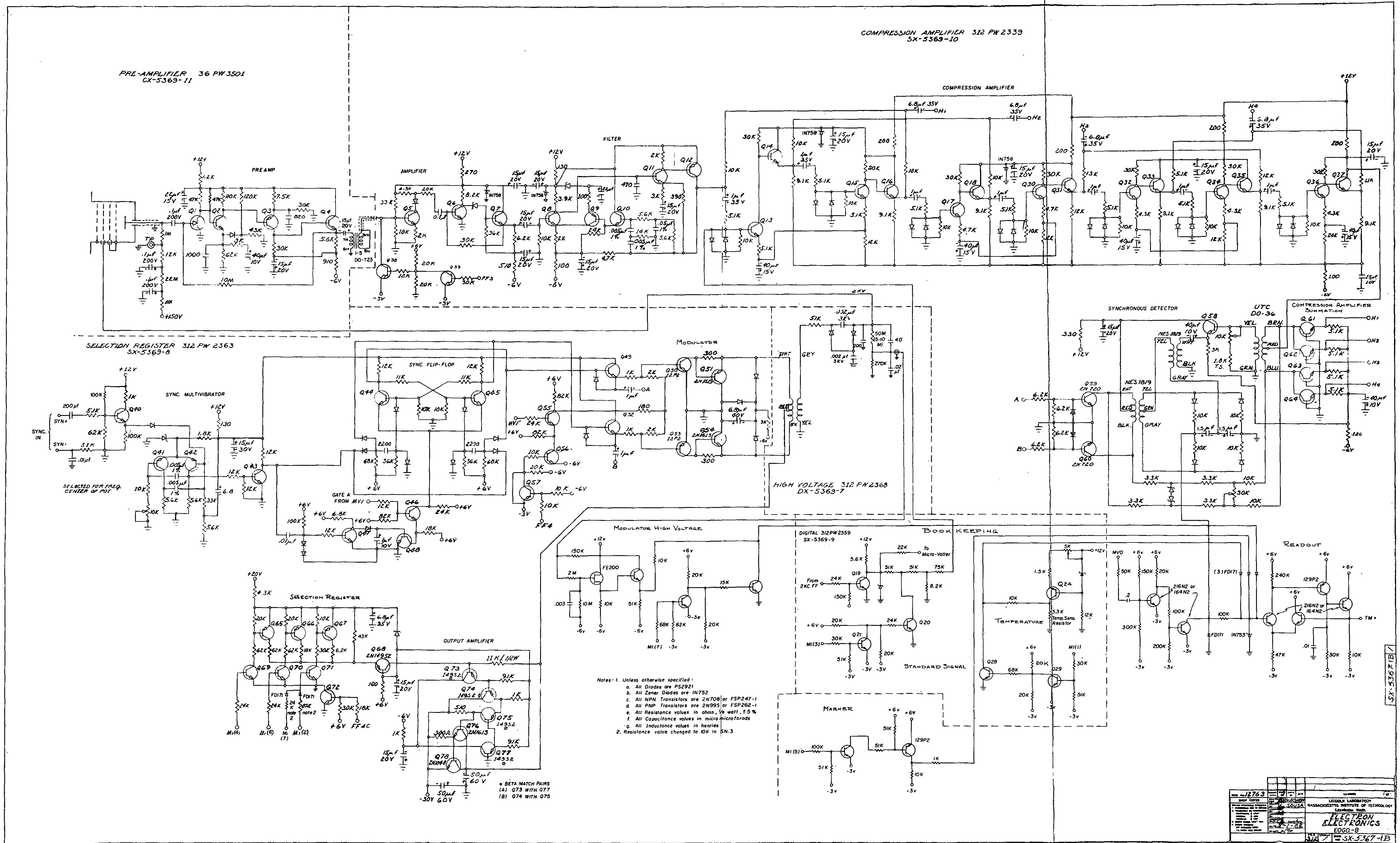


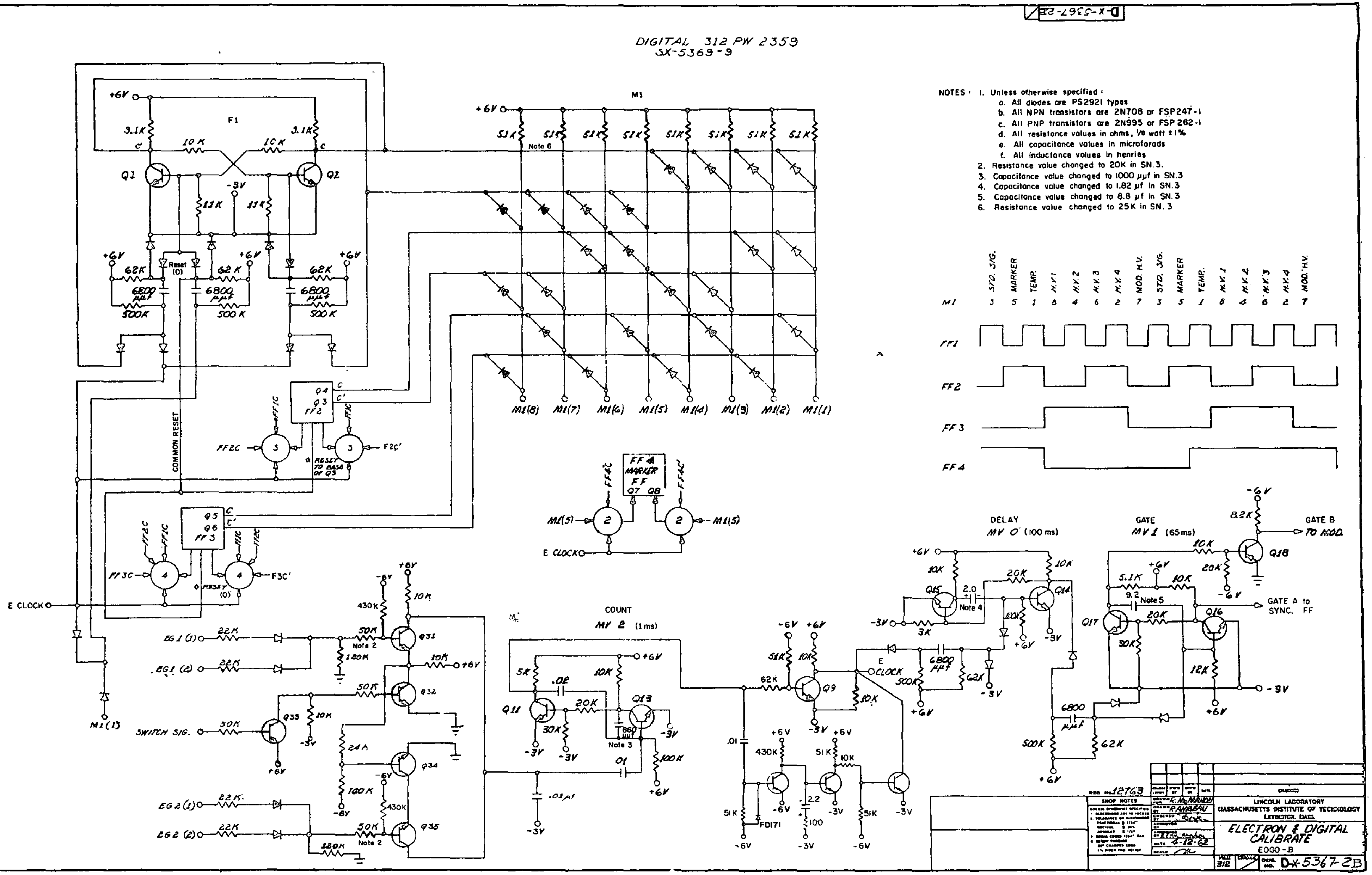


D-X-4856-5B
CLK
F1C
F2C
F3C
F4C
F5C
F6C
F7C
F8C
F9C
M2(C)
G1
G2
G3
G4
G5
M1
M2
M3
Window
Coil.
Time
Mode
4 SEC
12 SEC.
1.25 SEC
Bookkeeping
All Collector
Individual Collector
MOD H.V.
Marker
Temp.
STD. SIG.
RESET
SHOP NOTES
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.
TIMING DIAGRAM
(PROTON)
FOGO - B
DRAWN R. McMAHON
A. COLBERT
DATE 7-23-62
SCALE NONE
D-X-4856-5B

FOLDOUT FRAME 1

FOLDOUT FRAME 2





NOTES: 1. Unless otherwise specified:
a. All diodes are PS2921 types
b. All NPN transistors are 2N708 or FSP247-1
c. All PNP transistors are 2N995 or FSP 262-1
d. All resistance values in ohms, 1/8 watt ±1%
e. All capacitance values in microfarads
f. All inductance values in henries
2. Resistance value changed to 20K in SN.3.
3. Capacitance value changed to 1000 μμf in SN.3
4. Capacitance value changed to 1.82 μf in SN.3
5. Capacitance value changed to 8.8 μf in SN.3
6. Resistance value changed to 25K in SN.3

REQ. No. 12763

SHOP NOTES

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASS.

ELECTRON & DIGITAL CALIBRATE

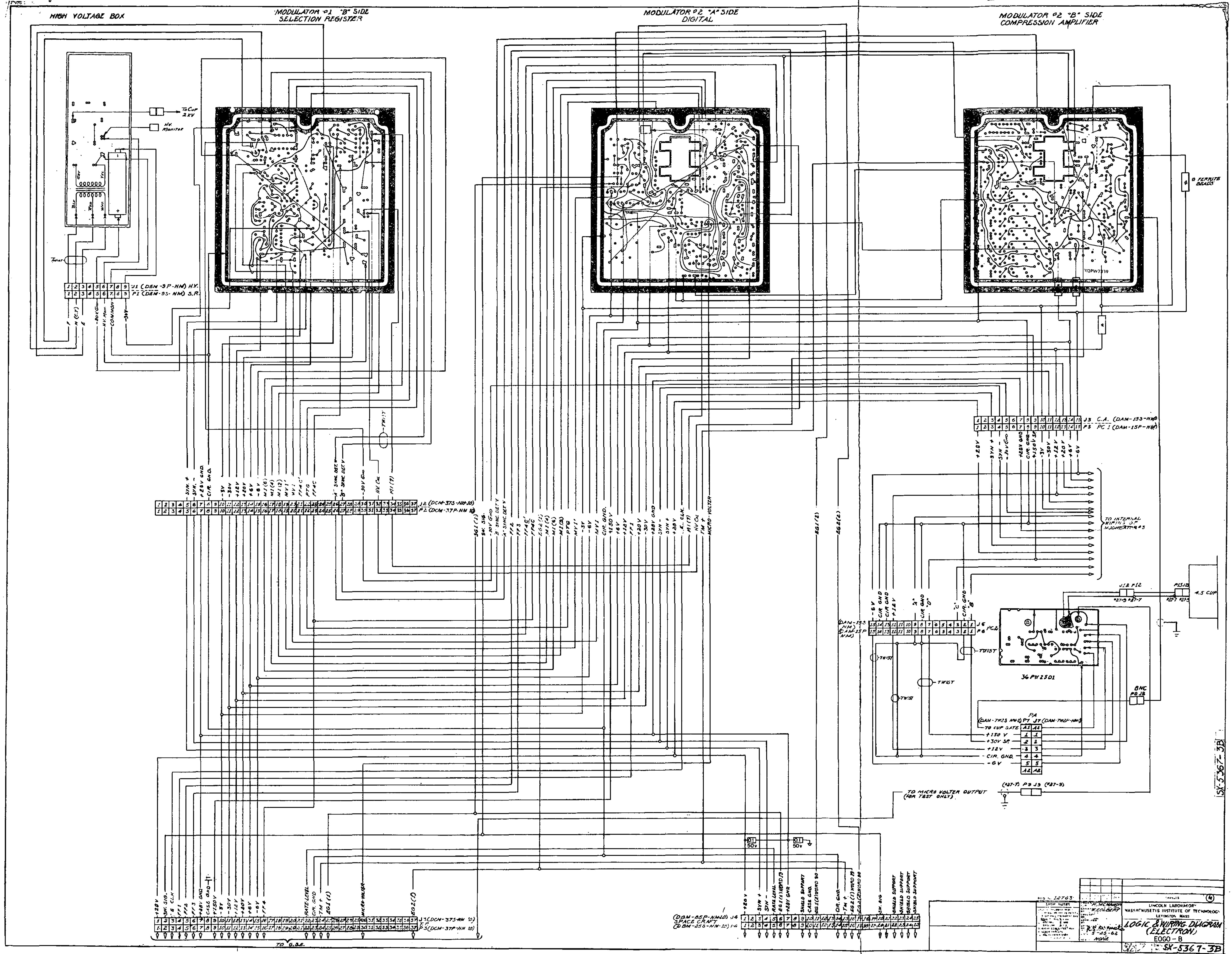
E0GO-B

DATE 3-12-62

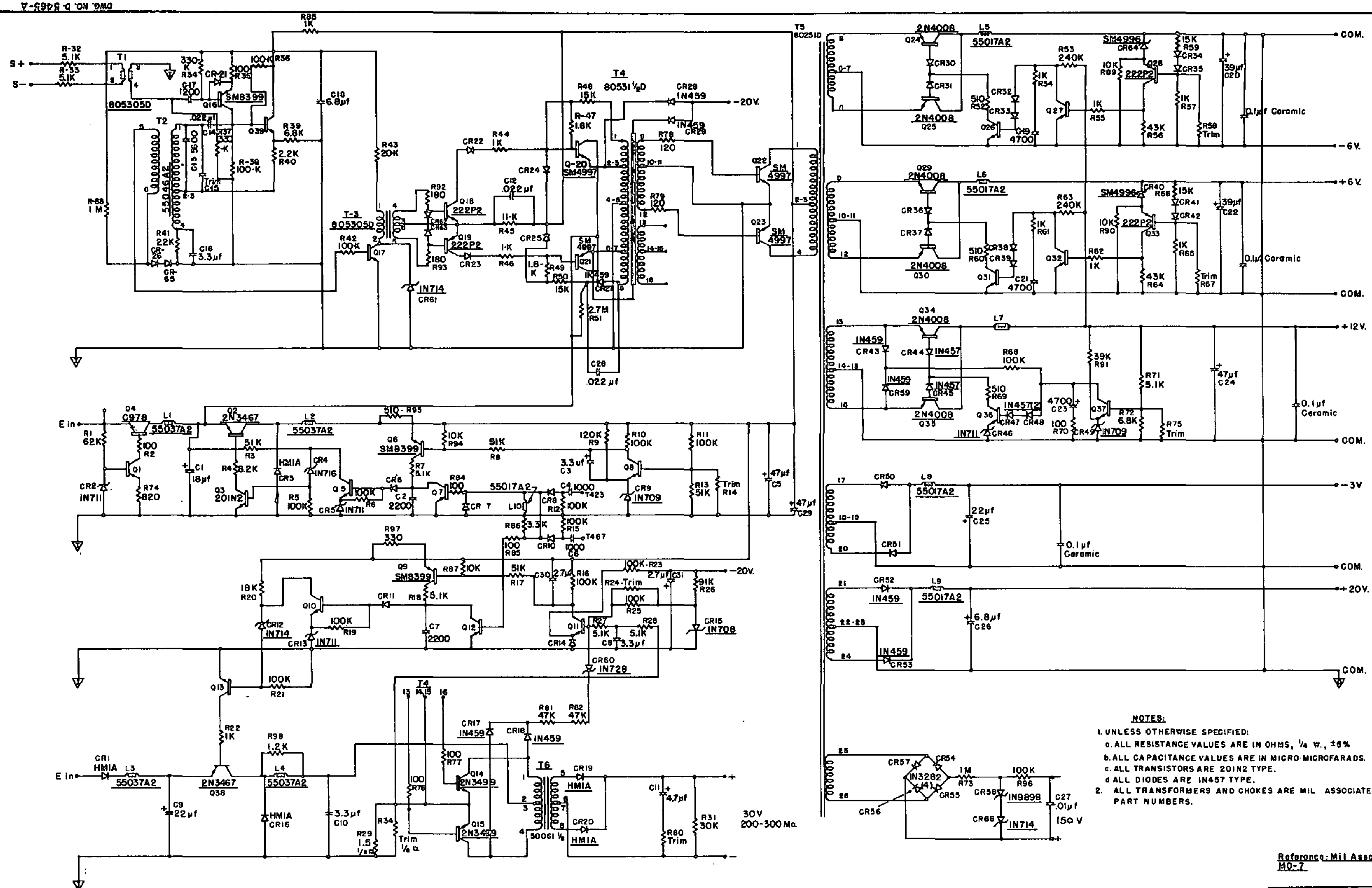
D-X-5367-2B

FOLDOUT FRAME 1

FOLDOUT FRAME 2



DWG. NO. D-5465-A



NOTES:

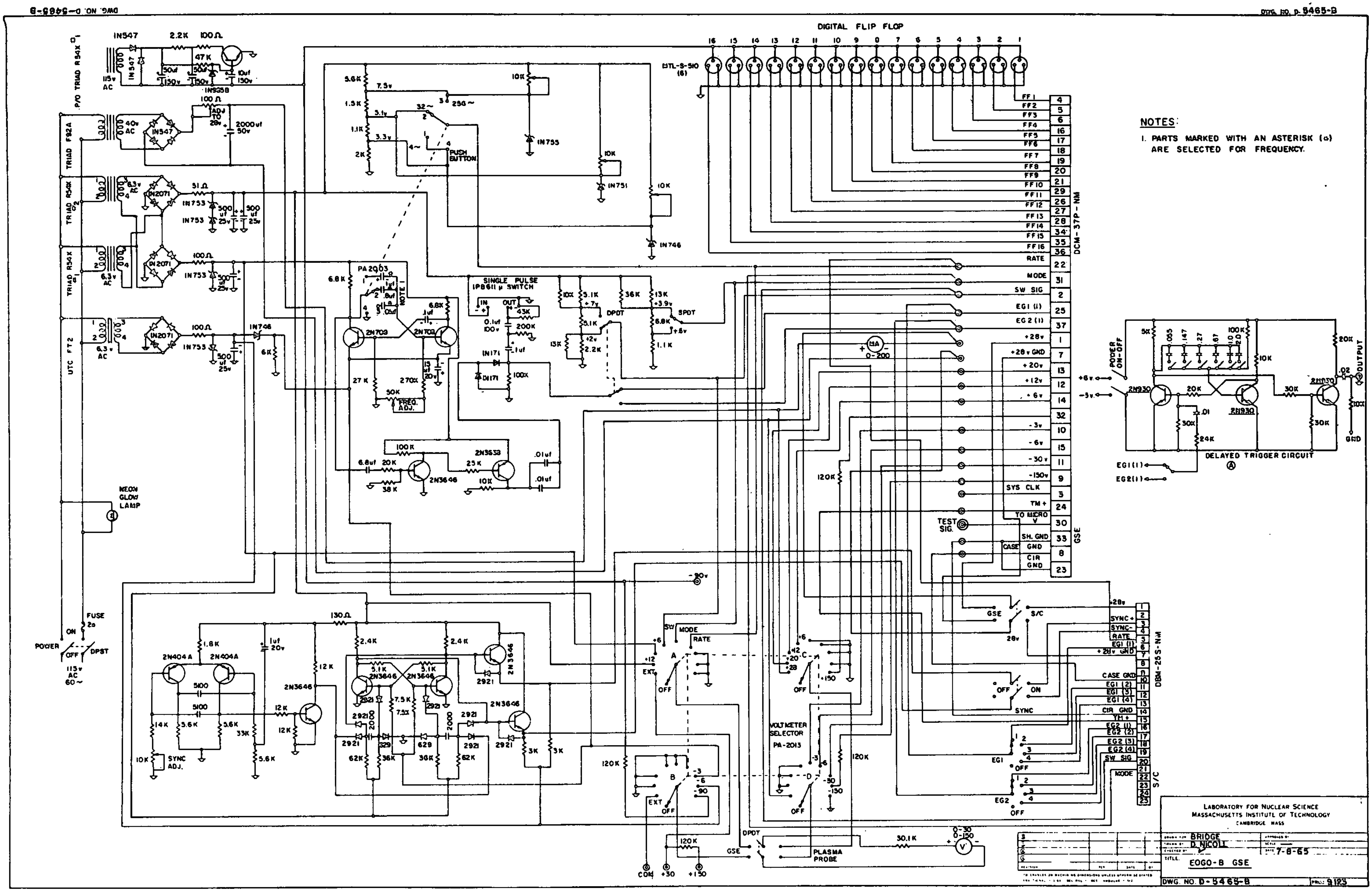
1. UNLESS OTHERWISE SPECIFIED:
   a. ALL RESISTANCE VALUES ARE IN OHMS, 1/4 W., ±5%
   b. ALL CAPACITANCE VALUES ARE IN MICRO-MICROFARADS.
   c. ALL TRANSISTORS ARE 2O1N2 TYPE.
   d. ALL DIODES ARE IN457 TYPE.
2. ALL TRANSFORMERS AND CHOKES ARE MIL ASSOCIATES PART NUMBERS.

Reference: Mil Associates Inc. Dwg. S-22-3-MO-7

LABORATORY FOR NUCLEAR SCIENCE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASS

DRAWN FOR: BRIDGE
DRAWN BY: E.W.G.
DATE: MAY 18, 66
TITLE: POWER CONVERTER EOGO-B

DWG. NO. D-5465-A
PROJ. 9123


DWG. NO. D-5465-B
DIGITAL FLIP FLOP
MTL-S-510 (6)
FF1
FF2
FF3
FF4
FF5
FF6
FF7
FF8
FF9
FF10
FF11
FF12
FF13
FF14
FF15
FF16
RATE
MODE
SW SIG
EG1 (1)
EG2 (1)
+28v
+28v GND
+20v
+12v
+6v
-3v
-6v
-30v
-150v
SYS CLK
TM+
TO MICRO V
TEST SIG.
SH. GND
CASE GND
CIR GND
DCM-37P-NM
GSE
NOTES:
1. PARTS MARKED WITH AN ASTERISK (*) ARE SELECTED FOR FREQUENCY.
DELAYED TRIGGER CIRCUIT
POWER ON-OFF
OUTPUT
GND
2N930
SINGLE PULSE
1PB611 μ SWITCH
PUSH BUTTON
FREQ. ADJ.
PA2003
NOTE 1
DPDT
SPDT
NEON GLOW LAMP
P/O TRIAD R54X
TRIAD F92A
TRIAD R54X
UTC FT2
115v AC
40v AC
6.3v AC
POWER
ON
OFF
DPST
FUSE 2a
115v AC 60~
SYNC ADJ.
2N404A
2N3646
2N703
2N3633
VOLTMETER SELECTOR PA-2013
PLASMA PROBE
GSE
S/C
SYNC
EG1
EG2
EXT
OFF
COM
+30
+150
-30v
0-30 0-150
DBM-25S-NM
28v
SYNC+
SYNC-
RATE
EG1 (1)
+28v GND
CASE GND
EG1 (2)
EG1 (3)
EG1 (4)
CIR GND
YH+
EG2 (1)
EG2 (2)
EG2 (3)
EG2 (4)
SW SIG
MODE
LABORATORY FOR NUCLEAR SCIENCE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE MASS
BRIDGE
D. NICOLL
7-8-65
TITLE EOGO-B GSE
DWG. NO. D-5465-B
PROJ. 9123