N69-16656
RE-ORDER NO. 67-917
NASA CR-77582
OGO-E

ENGINEERING REPORT
OGO-E SEARCH COIL MAGNETOMETER
CONTRACT NO. 951142

Prepared For

JET PROPULSION LABORATORY

CASE FILE
COPY

SEPT. 24, 1967

MARSHALL LABORATORIES
3530 Torrance, Boulevard
Torrance, California

67-917

ENGINEERING REPORT
OGO-E-16 SEARCH COIL MAGNETOMETER
CONTRACT NO. 951142

Prepared By: Robert J. Nahabit
Robert J. Nahabit
Project Engineer

Approved By: Robert Kobayashi
Robert Kobayashi
Program Engineer

Approved By: Eric Azari
Eric Azari
Program Manager

MARSHALL LABORATORIES
3530 Torrance Boulevard
Torrance, California

67-917

ACKNOWLEDGEMENT

The authors wish to express their gratitude to all Jet Propulsion Laboratory and Marshall Laboratories personnel who contributed maximum effort in developing the OGO-E-16 Search Coil Magnetometer and in the preparation of this document.

ABSTRACT

The OGO-E Triaxial Search Coil Magnetometer was designed to measure geomagnetic and interplanetary field fluctuations in the frequency range of less than .01 Hz to above 1000 Hz. The search coil sensor, a critically dampened inductor, consists of 100,000 turns of wire wound on a nickel-steel laminated core. The basic sensitivity of the sensor is approximately 10 microvolts (μv) -per gamma (γ)-per Hertz (Hz). A low noise d-c preamplifier with a high input impedance (10^9 ohms), low input capacity (10 picofarads), and a gain of one hunderd is mounted near the sensors in a boom mounted experiment package of the spacecraft. The main electronics assembly located in the main body of the spacecraft, further amplifies the data from each preamplifier, performs a triaxial spectrum analysis, and generates seven (7) commutated outputs per axis, each a measure of the energy in a given frequency band. Other functions provided by the main assembly are (1) real time data, (2) wideband f-m data, (3) in-flight calibration, (4) gain state data, and (5) operating power conversion and regulation. Special equipment requirements included a portable Bench Test Equipment (BTE) mounted in a single package. The function of this package is to simulate all spacecraft interface signals during preflight calibration and monitor the performance of the instrument.

TABLE OF CONTENTS

	Title		Page
1.0	INTRODUCTION		1
2.0	SYSTEM DESCRIPTION		1
	2.1	Sensor Assemblies	4
	2.1.1	Sensor Electrical Characteristics	4
	2.1.2	Sensor Mechanical Characteristics	8
	2.2	Preamplifier Assemblies	11
	2.2.1	Preamplifier Electrical Characteristics	11
	2.2.2	Preamplifier Mechanical Characteristics	12
	2.3	Heater Electrical Characteristics	12
	2.4	Waveform Channel	12
	2.5	Spectrum and Wave Analyzer Channels	16
	2.6	Sub-Carrier Oscillator (SCO) and Wide-band Detector	19
	2.7	Bandwidth Control	23
	2.8	Wave Analyzer Commutator Control	23
	2.9	IFC Signal, Waveform, and Spectrum Gain Control	26
	2.10	Status Words	28
	2.11	Power Supply	28
	2.12	Test Connector	30
	2.13	Main Assembly Mechanical Description	30
3.0	SPACECRAFT INTERFACES		66
	3.1	Mechanical Interfaces	66
	3.2	Electrical Interfaces	66

	3.2.1	Primary Power Interface	66
	3.2.2	Synchronization Signal Interface	66
	3.2.3	Timing Pulse Interface	66
	3.2.4	Index Pulse Interface	70
	3.2.5	Special Purpose Telemetry Power Command Interface	70
	3.2.6	Impulse Command Interface	70
	3.2.7	Telemetry Status Signal Interface	70
	3.2.8	Waveform and Wideband Output Interface	75
	3.2.9	Wave Analyzer Output Interface	77
	3.2.10	Special Purpose Telemetry Output Interfaces	77
	3.2.11	Instrument Status Output Interfaces	77
4.0	CIRCUIT DESCRIPTIONS		82
	4.1	Search Coil Sensor	82
	4.2	Preamplifier	86
	4.3	Preamplifier Heater Circuit	88
	4.4	400 Hz Notch Filter	90
	4.5	1850 Hz Low Pass Filter	99
	4.6	Waveform Channel Bandpass Control Circuit	106
	4.7	Gain Change Amplifiers	108
	4.8	Output Amplifiers	112
	4.9	Wave Analyzer Bandpass Amplifier	114
	4.10	Peak Detector	126
	4.11	SCO Low Pass Filter	129
	4.12	Subcarrier Oscillator (SCO)	136

	4.13	Wave Analyzer Commutator	141
	4.14	Commutator Gating Circuit	144
	4.15	Complementary Flip Flop	144
	4.16	Seven (7) Bit Binary Counter	144
	4.17	Impulse Command Isolation Amplifier	144
	4.18	SCO Command Detector	149
	4.19	Power Supply Sync Amplifier	151
	4.20	Power Supply Converter	152
	4.21	Power Supply Preregulator (+23.5V)	155
	4.2.2	Power Supply Postregulators	155
5.0	BENCH TEST EQUIPMENT		161
	5.1	Mechanical Description	161
	5.2	Electrical Description	161
	5.2.1	BTE Power System	161
	5.2.2	Sync Signal Generator	166
	5.2.3	Timing and Index Pulse Generator	166
	5.2.4	Telemetry Status Signal Generator	166
	5.2.5	Command Generator	170
	5.2.6	Power Supply Monitor	170
	5.2.7	Test Point Monitor	173
6.0	RECOMMENDATIONS AND IMPROVEMENTS		176
	6.1	Search Coil Sensor and Preamplifier Assembly	176
	6.2	Sensor Coil Winding	176
	6.3	Preamplifier Sensitive to Variation of Power Supply Voltage	176

6.4	400 Hz Notch Filter	176
6.5	Gain Change Amplifier	177
6.6	Bandpass Amplifiers	178
6.7	Subcarrier Oscillator (SCO)	180
7.0	SUMMARY OF CHANGES AFTER INITIAL DELIVERY	180

APPENDICES

A.	Transient Analysis of the Timing and Index Pulse Circuitry for the OGO-E Scientific Experiment	183
B.	Master Drawing Lists	209
	1. Search Coil System-MDL 51896B	210
	2. Mainbody Electronics Assembly MDL 51731B	212
	3. Preamplifier Assembly - MDL51733B	217
C.	Test Specifications	219
	1. Mainbody Electronics - S40843 NC	220
	2. Preamplifier - S40847 NC	240
D.	New Technology Reports	246
	1. Preamplifier	247
	2. Gain Change Amplifier	253
	3. Voltage Controller Oscillator	260

ILLUSTRATIONS

Figure No.	Title	Page
1	System Block Diagram 51747	3
2	Interface Wiring Diagram 51732	5
3	Thermal Diagram 51739	7
4	Probe Assemblies	9
5	Envelope - Sensor 51737	10
6	Envelope - Preamplifier 51736	13
7	Preamplifier Assembly	14
8	Waveform Channel Block Diagram	15
9	Spectrum Amplifier and Wave Analyzer	17
10	Wideband Detector Channel	21
11	SCO Channel	22
12	Bandwidth Control Block Diagram	24
13	Wave Anaylzer Commutator Control Block Diagram	25
14	IFC Signal, Waveform and Spectrum Gain Control Circuit Block Diagram	27
15	Power Supply Circuit Block Diagram	29
16	Envelope - Electronic Unit 51735	31
17	Main Electronic Assembly	32
18	Waveform Blivet - Interconnect Schematic Diagram 51900	33
19	Hook-Up and Positioning Board - Waveform 51951	36

20	Waveform Analyzer Assembly 51899	41
21	Wave Analyzer Blivet Spectrum - Interconnect Schematic Diagram 51902	46
22	Hook-Up and Positioning Board - Wave Analyzer - Spectrum 51954	47
23	Wave Analyzer Assembly 51901	48
24	Schematic Diagram - Power Supply and Control Blivet 51898	49
25	Hook-Up/Support Board Power Supply 51948	50
26	Hook-Up / Support Board Control Circuit T51945	52
27	Power Supply and Control Assembly 51897	57
28	Schematic - Electronic System 51903	65
29	Primary Power Interface	67
30	Sync Signal Interface	68
31	Timing Pulse Interface	69
32	Index Pulse Interface	71
33	Special Purpose Power Command Interface	72
34	Impulse Command Interfaces	73
35	Telemetry Status Signals Interfaces	74
36	Waveform and Wideband Output Interfaces	76
37	Wave Analyzer Outputs Interfaces	78
38	Special Purpose T/M Outputs Interface	79
39	Status Outputs Interfaces	80
40	Status Output Levels	81
41	Effect of Fringing Fields	85
42	Search Coil & Preamplifier Circuit Diagram	87

43	Preamplifier Heater Circuit	89
44	400 Hz Notch Filter Schematic	91
45	400 Hz Notch Filter Equivalent Circuit	92
46	400 Hz Filter Measured Frequency Response	98
47	1850 Hz Low Pass Filter Schematic	100
48	Equivalen Circuit of 1850 Hz Low Pass Filter	101
49	1850 Hz Low Pass Filter Theoretical Frequency Response	105
50	Waveform Channel Bandpass Control Circuit	107
51	Gain Change and Fixed Gain Amplifier Schematic	109
52	Simplified Equivalent Circuit of the Gain Change Amplifier	110
53	Output Amplifier Schematic	113
54	Bandpass Amplifier Schematic	115
55	Bandpass Amplifier Equivalent Circuit	116
56	Peak Detector Schematic Diagram	127
57	Simplified Detector Circuit	128
58	SCO Low Pass Filter Schematic Diagram	130
59	SCO Low Pass Filter Simplified Equivalent Circuit	131
60	SCO Low Pass Filter Theoretical Frequency Response	135
61	SCO Schematic Diagram	137
62	Simplified SCO Schematic Diagram	138

63	SCO Timing Diagram	139
64	SCO Simplified Current Sources Schematic	140
65	Wave Analyzer Commutator Schematic Diagram	142
66	Simplified Wave Analyzer Commutator Circuit	143
67	Commutator Gating Schematic Diagram	145
68	Complementary Flip-Flop Schematic Diagram	146
69	Modulo-Seven Counter Block Diagram	147
70	Impulse Isolation Amplifier Schematic	148
71	Special Purpose Command Detector	150
72	Sync Amplifier Schematic Diagram	151
73	Converter Simplified Schematic	153
74	Converter Module Detailed Schematic Diagram	154
75	Power Supply +23.5V Preregulator Schematic	156
76	Preregulator Module Detailed Schematic Diagram	157
77	+6V Post Regulator Schematic	158
78	+20V Post Regulator Schematic	159
79	-6V Post Regulator Schematic	160
80	Front Panel View of BTE	162
81	Rear View of BTE	163
82	Schematic of BTE - 51977 A	164
83	BTE Power Supplies Block Diagram	165
84	Sync Signal Generator Block Diagram	167
85	Index and Timing Pulse Generator Block Diagram	168

86	Telemetry Status Signals Block Diagram	169
87	Command Generator Block Diagram	171
88	Power Supply Monitor Block Diagram	172
89	Test Point Identification	174
90	Test Point Selector Switching	175
91	Recommended Current Source No. 1 for SCO	181
92	Recommended Current Source No. 2 for SCO	182
93	Original Timing Pulse Interface	185
94	Original Index Pulse Interface	186
95	Complementary Flip-Flop	187

LIST OF DRAWING BY PAGE NUMBER

Page No.	Drawing No.	Title
3	51747 C	System Block Diagram
5	51732 B	Interface Wiring Diagram
6	EO B-1	
7	51739 A	Thermal Diagram
10	51737 A	Envelope - Sensor
13	51736 A	Envelope - Preamplifier
31	51735 B	Envelope - Electronic Unit
33	51900 A	Waveform Blivet - Interconnect Schematic Diagram
34	EO A-1	
35	EO A-2	
36	T51951 NC	Hook-Up and Positioning Board - Waveform
37	EO 1573	
38	EO 1588	
39	EO 1602	
40	EO NC1	
41	51899	Waveform Analyzer Assembly
42	EO 1574	
43	EO 1666	
44	EO NC1	
45	EO NC3	
46	51902 NC	Wave Analyzer Blivet Spectrum - Interconnect Schematic Diagram
47	T51954 NC	Hook-Up and Positioning Board - Wave Analyzer - Spectrum
48	51901	Wave Analyzer
49	51898 C	Schematic Diagram - Power Supply and Control Blivet

50	T51948 NC	Hook-Up/Support Board Power Supply
51	EO 1651	
52	T51945	Hook-Up/Support Board Control Circuit
53	EO 1386	
54	EO 1591	
55	EO 1623	
56	EO NC1	
57	51897	Power Supply and Control Assembly
58	EO 1615	
59	EO 1617	
60	EO 1620	
61	EO 1653	
62	EO NC1	
63	EO NC2	
64	EO NC3	
65	51903 D	Schematic - Electronic System
164	51977 A	Schematic - BTE

1.0 INTRODUCTION

This report summarizes the work carried out by Marshall Laboratories in compliance with JPL Contract 951142, OGO-E Triaxial Search Coil Magnetometer.

The primary task of this contract was to develop, fabricate, and test one (1) breadboard monoaxial magnetometer, two (2) flight models of a Triaxial Search Coil Magnetometer and one (1) Bench Test Equipment.

The primary function of the magnetometer is to measure the geomagnetic and interplanetary field fluctuations in the range of less than .01 Hz to above 1000 Hz. A commutated spectrum analyzer is included to determine the frequency spectrum of the magnetic field fluctuations.

The flight instrument consists of five subassemblies. Three sensor subassemblies contain the search coils, and a preamplifier subassembly contains three low noise preamplifiers. These are all mounted in an experiment package at the end of a long boom (EP-5) to reduce interference from the spacecraft signals. The main equipment package, mounted in the spacecraft body, contains the remaining electronic circuitry.

The portable Bench Test Equipment was designed to generate all spacecraft interface signals for complete laboratory bench checkout. It also provides test points for monitoring all input-output signals, and provides externally programmable commutating and reset functions adaptable to automatic calibration and checkout systems.

This report contains detailed system, electrical and mechanical descriptions of the flight instrument and the Bench Test Equipment.

2.0 SYSTEM DESCRIPTION

The following sections describe the OGO-E Triaxial Search Coil Magnetometer including the mechanical design. A Master Drawing List is contained in Appendix A of this report which references all drawings required for a full evaluation of the magnetometer design. However, smaller and simplified schematic diagrams are presented throughout this report to aid in the analysis of the circuits under discussion.

Figure 1 shows the block diagram of the OGO-E Triaxial Search Coil Magnetometer which consists of three monaxial magnetometer assemblies, a power supply, control circuits, status indicator circuits, and in-flight calibration circuits.

A monaxial magnetometer assembly consists of a search coil sensor, preamplifier, waveform channel, commutated wave analyzer channel, wideband peak detected channel, and a frequency modulated SCO channel. The sensor generates a voltage proportional to the rate of change of the amplitude of the magnetic field component along its axis. This signal is amplified by a low noise preamplifier and presented to the input of a voltage controlled low pass filter, and to the input of a wideband amplifier. The output of the low pass filter drives a waveform gain change amplifier, low pass filter, and a second gain change amplifier, and an output amplifier. The output of this amplifier is an input to the spacecraft telemetry system.

The waveform gain change amplifiers have a voltage controlled gain of either 1.4 or 14. The waveform output amplifier has a gain of 5.1. By a combination of control voltages, the waveform gain may be either 10, 100, or 1000, corresponding to low, medium, or high gain. A voltage is presented at the output of the waveform gain state. The function of the low pass filter in the waveform channel is to limit the response of the channel to the data bit rate of the spacecraft.

The bit rate logic senses the operating mode of the spacecraft data system via the spacecraft bit rate, mode, and switch signals and presents a control voltage to the low pass filters. This voltage will limit the bandpass of the waveform channel to either 64 Hz or 2 Hz corresponding to wide and narrowband operation. Wideband operation occurs at the 64 kilobit rate and narrowband operation occurs at 8 and 1 kilobit rates. The bit rate logic also drives a status logic circuit which gives an output voltage identifying the waveform bandwidth. The output amplifier of the waveform channel is biased to +2.5v d-c and has a maximum excursion of 5v p-p.

The wideband amplifier consists of two (2) cascaded voltage controlled gain change amplifiers identical to the waveform amplifiers. The output of the wideband amplifier provides the input to the wave analyzer channel, wideband peak detected channel, and SCO channel. A monitoring signal is also brought out to the BTE from this point and used for calibration purposes.

There are seven (7) bandpass filters for each wave analyzer channel with center frequencies of 10, 22, 47, 100, 220, 470 and 1000 Hz. The output of each filter is an analog voltage corresponding to the energy in its frequency band. The voltage from the seven (7) bandpass filters is sequentially sampled by a commutator which is controlled via the commutator index logic by the spacecraft index pulses. The data is then presented to the spacecraft telemetry system through a stable d-c amplifier with short circuit protection and low output impedance. The output amplifier resting level is nominally $0 \pm .02$ volts.

67-917
Page 3

PARTS DISPOSITION	DWG NO. 51747	REV C
1. USE 2. REWORK 3. CANNOT BE REWORKED 4. RECORD		

REVISIONS

SHEET #	ECO	ZONE	REV	DESCRIPTION	BY	CK	APPROVED	DATE
			A	GENERAL REVISION - / RELEASE	DG	[illegible]	[illegible]	[illegible]
6	1830		B	CHANGED Z-AXIS SCO OUTPUT AMP TO FURNISH 4 VOLTS PEAK-TO-PEAK OUTPUT VOLTAGE OUTPUT; ADDED [illegible]	PG	[illegible]	[illegible]	B-[illegible]
4	1830 up	C-5	C	ADDED 400HZ AND 1850 HZ L.P. FILTERS	[illegible]	[illegible]	[illegible]	[illegible]

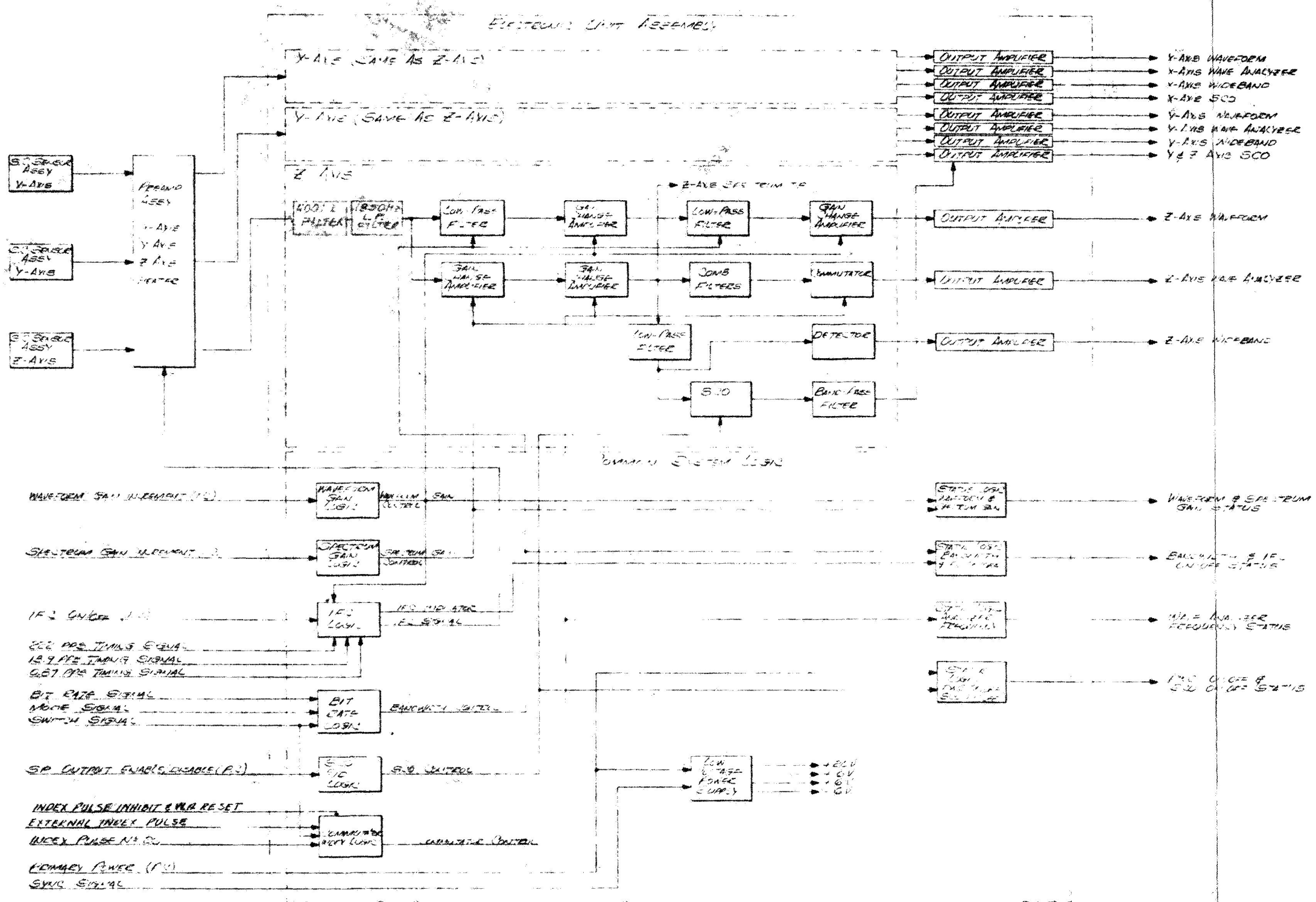


Figure 1

NOTES: UNLESS OTHERWISE SPECIFIED

PART NO	SPECIFICATION	NOMENCLATURE OR DESCRIPTION	USED ON ITEM	CODE IDENT	ITEM NO.
		LIST OF MATERIALS			

QTY REQD PER NOTED ASSY
CONFIGURATION
LAYOUT NO.
SHEET CODE

INTERPRET THIS DRAWING PER STANDARDS IN MIL-D-70327
DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS: X ± .1, XX ± .02, XXX ± .010, XXXX - .0050; ANGLES ± 0° 30'
√ SURFACE ROUGHNESS
HOLE DIA. TOLERANCE

CONTRACT NO. AF 120
DRAWN
CHECK
WELD ENG.
ELEC. ENG.
APPD.
DESIGN ACTIVITY APPD
CUSTOMER

MARSHALL LABORATORIES
TORRANCE, CALIFORNIA

TITLE: SYSTEM BLOCK DIAGRAM - TRIAXIAL SEARCH COIL MAGNETOMETER ENDMONT ETC

SIZE	CODE IDENT NO.	DWG NO.	REV
F	13126	51747	C

SCALE
RELEASED
SHEET 1 OF 1

51747 C

The input to the wideband peak detected channel and the SCO channel is through a low pass filter which has -3db response at 1000 Hz. The purpose of this filter is to limit the voltage swing at higher frequencies to reduce the higher harmonics generated by the SCO frequency modulation process. The output of each SCO (X, Y and Z axes) is passed through a bandpass filter and output amplifier which drives the spacecraft telemetry system. The X, Y and Z axes SCO signals are combined in a single driver amplifier before entering the spacecraft telemetry system. The SCO output amplitude is nominally 1.7V rms with center frequencies of 30KHz, 52.5KHz and 70KHz corresponding to X, Y, and Z axes respectively. The X and Y axes SCO's have a maximum frequency deviation of ± 15% and the Z axis SCO has a maximum frequency deviation of ± 7-1/2%. The selection of these center frequencies and frequency deviations provides approximately 1000 Hz response for each channel. Provision is also made to turn the SCO's "On" and "Off" simultaneously via ground command during time sharing modes of the spacecraft telemetry system. The ground command is sensed by the SCO detector amplifier which turns the SCO's "On" or "Off", and an output is generated by the status logic corresponding to the active or inactive state.

The output of the low pass filter that drives the SCO channel also drives the wideband peak detected output channel. This signal is peak detected and passed through an output amplifier to the spacecraft data system. Although the SCO may at times be commanded off during certain phases of spacecraft operation, the wideband data will still be transmitted.

Figure 2 shows the interface wiring drawing which depicts all interconnections between the five subassemblies as well as all connections to the spacecraft and the signals on the instrument test connector. Figure 3 shows the thermal schematic drawing which depicts the thermal properties of each of the five subassemblies.

2.1 Sensor Assemblies

The three probe assemblies contain the basic instrument sensors and are mounted orthogonally within Experiment Package No. 5.

2.1.1 Characteristics

Each of the sensors consists of a core manufactured from a high permeability magnetic material upon which is placed a coil consisting of many turns of fine copper wire. The approximate characteristics of each is as follows:

51732 B

REVISIONS							
NEXT	USED ON	REV	DESCRIPTION	BY	CHKD	DATE	APPROVAL
1	18UP	A	GEN. REVISION				
4	18UP	B	REVISED CONN. REF. DESIGNATIONS & WIRE Sy—Sn.S OF SENSORS				

E16-3-P1 (DEM-9S-NMC-1-A106)
E16-3-J1 (DEM-9P-NMC-1-A106)
51734-101 X-AXIS SEARCH COIL SENSOR ASSY ML292-1 (1)
X COIL A
X COIL B

E16-2-J2 (DAM-15S-NMC-1-A106)
E16-2-P2 (DAM-15P-NMC-1-A106)
51739-101 PREAMPLIFIER ASSY ML293-1 (1)

E16-2-J1 (DDM-9P-NMC-1-A106)
E16-2-P1 (DEM-9S-NMC-1-A106)
X PREAMP
Y PREAMP
Z PREAMP
PREAMP RETURN
+20 VOLT
I.F.C. SIGNAL
HEATER RETURN

E16-4-P1 (DEM-9S-NMC-1-A106)
E16-4-J1 (DEM-9P-NMC-1-A106)
51734-102 Y-AXIS SEARCH COIL SENSOR ASSY ML292-2 (1)
Y COIL A
Y COIL B

E16-5-P1 (DEM-9S-NMC-1-A106)
E16-5-J1 (DEM-9P-NMC-1-A106)
51734-103 Z-AXIS SEARCH COIL SENSOR ASSY ML292-3 (1)
Z COIL A
Z COIL B

X COIL A TP
X COIL B TP
Y COIL A TP
Y COIL B TP
Z COIL A TP
Z COIL B TP
TEST CONNECTOR

EPSE16 DEM-9S-NMC-1-A106

CHASSIS GROUND
SPECIAL PURPOSE T/M: X AXIS SCO 30KC; Y AXIS SCO 52.5KC; Z AXIS SCO 70 KC
N.C.
N.C.
N.C.

TO T/M MAIN FRAME COMMUTATOR EQUIPMENT GROUP 1&2

WORD 21	X AXIS WAVE ANALYZER	F
14,78	X AXIS WAVEFORM	F
.22	Y AXIS WAVE ANALYZER	F
15,79	Y AXIS WAVEFORM	F
23	Z AXIS WAVE ANALYZER	F
WORD 16,80	Z AXIS WAVEFORM	F

N.C.
N.C.
N.C.

TO T/M EXPERIMENT SUBCOMMUTATOR EQUIPMENT GROUP 1&2

WORD 48	X AXIS WIDEBAND	F
49	Y AXIS WIDEBAND	F
50	Z AXIS WIDEBAND	F
51	W.F. & SPECTRUM GAIN STATUS	F
52	BANDWIDTH & IFC ON/OFF STATUS	F
94	WAVE ANALYZER FREQ STATUS	F
WORD 112	POWER ON/OFF & SCO ON/OFF STATUS	F
	T/M SIGNAL RETURN	F

S.P. POWER COMMAND
IMPULSE COMMANDS: S.P. OUTPUT ENABLE/DISABLE COMMAND (3); WAVEFORM GAIN INCREMENT COMMAND (3); SPECTRUM GAIN INCREMENT COMMAND (3); IFC ON/OFF COMMAND
N.C.

GROUP 1 INDEX PULSE No. EG
GROUP 2 INDEX PULSE No. EG
BIT RATE SIGNAL
MODE SIGNAL
SWITCH SIGNAL
222 PPS TIMING SIGNAL
13.9 PPS TIMING SIGNAL
0.87 PPS TIMING SIGNAL
N.C.
N.C.
CHASSIS GROUND
SPACECRAFT SIGNALS

28 VOLT POWER
28 VOLT RETURN
N.C.
N.C.
SYNC SIGNAL (A)
SYNC SIGNAL RETURN (B)
SYNC SIGNAL C.T.

E16-1-P1 (DDM-50S-NMC-1-A106)
E16-1-J1 (DDM-50P-NMC-1-A106)
51731-101 ELECTRONIC UNIT ASSEMBLY TRIAXIAL SEARCH COIL MAGNETOMETER ML294-1

SECONDARY SIGNAL RETURN
+6 VOLT
+6 VOLT
+6 VOLT
X AXIS SPECTRUM T.P.
Y AXIS SPECTRUM T.P.
Z AXIS SPECTRUM T.P.
+23.5 VOLT RETURN
+23.5 VOLT
EXTERNAL INDEX PULSE
INDEX PULSE INHIBIT & RESET
2.5 VOLTS
2.6 VOLTS
N.C.
CONVERTER T.P.
CONVERTER T.P. RETURN

TEST CONNECTOR SAME AS S/C EXCEPT FOR ADDITIONAL SIGNALS SHOWN
E16-1-J3 (DDM-50S-NMC-1-A106)

E16-1-P2 (DEM-9S-NMC-1-A106)
E16-1-J2 (DEM-9P-NMC-1-A106)

3. ⊜ INDICATES FLOATING SHIELD.
[2] INDICATED UNIT IS LOCATED IN MAIN ASSEMBLY IN SPACECRAFT BODY.
[1] INDICATES UNITS ARE LOCATED IN BOOM.
NOTES: UNLESS OTHERWISE SPECIFIED.

Figure 2

REQD	PART NO	DESCRIPTION	CAT NO	ITEM
		LIST OF MATERIALS		

DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES

HOLE DIA.	TOLERANCE	LINEAR TOLERANCES
.0135 THRU .125	+.004-.001	.XX = ±.010
.126 THRU .250	+.005-.001	.XX = ±.03
.251 THRU .500	+.006-.001	.X = ±.1
.501 THRU .750	+.008-.001	
.751 THRU 1.000	+.010-.001	ANGLES = ±0°30'
1.000 THRU 2.000	+.012-.001	SURFACE ROUGHNESS
2.001 AND OVER	LINEAR	PER MIL-STD-10

NEXT ASSY | USED ON — APPLICATION; NEXT ASSY | FINAL ASSY — QTY REQD

DRAWN Gaddis 6/5/69 | CHKD | STRESS | APPD | APPD | APPD

INTERFACE WIRING DIAGRAM — TRIAXIAL SEARCH COIL MAGNETOMETER (EXPERIMENT E-16)

SCALE | WEIGHT

MARSHALL LABORATORIES

SIZE D | 51732 | B | SHEET 1 OF 1

ENGINEERING CHANGE

11/

3530 TORRANCE BOULEVARD
TORRANCE, CALIFORNIA

DIST 5-120
CODE A, B

ML FORM 157A 12-71

ISED 11/71

DRAWING TITLE	JOB NO.	CODE IDENT NO.	EO
I/F SURFACE WIRING DIAGRAM - TRIAXIAL SENSOR COIL MAGNETOMETER (EXPERIMENT E16)	5-120	13126	EO — 51732-B-1

TYPE OF EO	DISPOSITION OF PARTS			EFFECTIVITY
☒ CHANGE	☒ USE	ORIG [illegible] DATE [illegible]	NEXT ASSY —	1 & UP
☐ VARIANCE	☐ REWORK	CHECK		
☐ SUPERCEDING	☐ SCRAP	ENGR	MODEL NO. —	
☐ NOTED	☐ NOTED BELOW	PM [illegible]		
		APPR [illegible]	OTHER DWG AFFECTED —	
		CUSTOMER		

DESCRIBE CHANGE AND GIVE REASON: WORD DESIGNATION & CONNECTOR DESIGNATION REVISED BY CUSTOME

1. ON PIN 43 P1 CONN UNIT 51731-101
   WORD 47 (WAS) WORD 94

2. ON CONNECTOR DESIGNATIONS

→ 6A16-— (WAS) E16-—

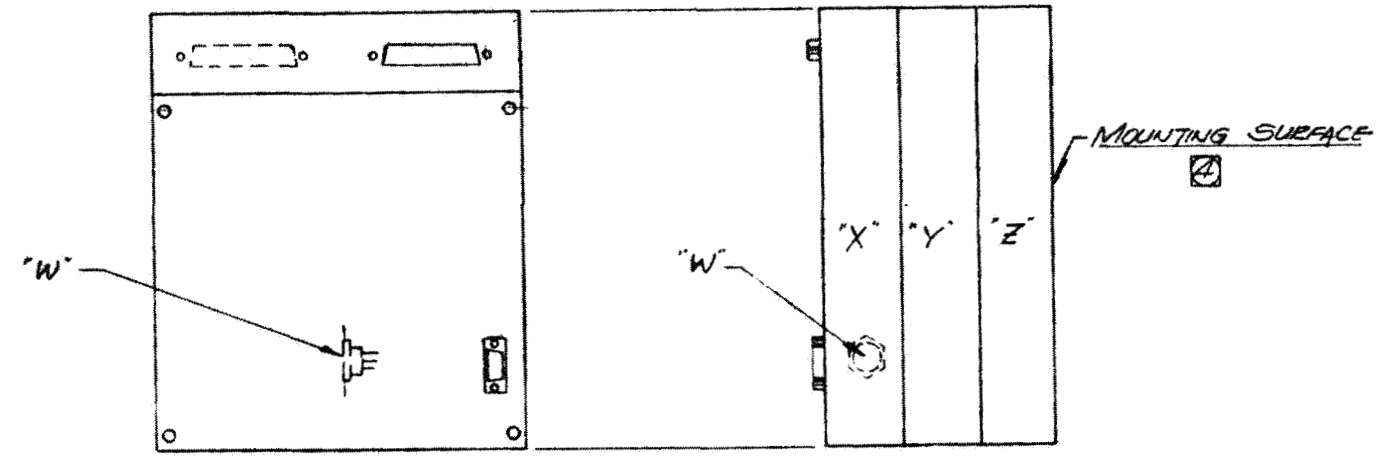
67-917

Page 6

Figure 2-1.

QTY REQD FOR TOTLD ASSY	PART NO.	SPECIFICATION	DESCRIPTION	ELECT REF DES	CODE IDENT	ZONE

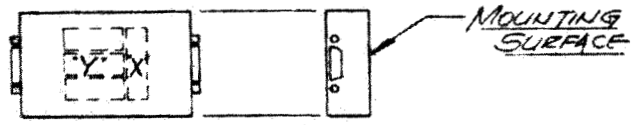
67-917



ELECTRONIC UNIT

THERMAL CHARACTERISTICS

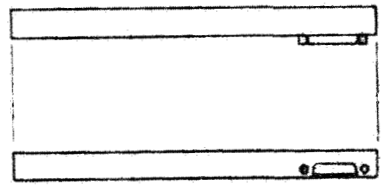
1. POWER DISSIPATION — ZONE "W", MAXIMUM 1.2 WATTS WITH MAXIMUM POWER INPUT
   ZONE "X", MAXIMUM 0.3 WATTS WITH NORMAL POWER INPUT.
   ZONE "Y", MAXIMUM 0.3 WATTS WITH NORMAL POWER INPUT.
   ZONE "Z", MAXIMUM 0.3 WATTS WITH NORMAL POWER INPUT.
2. ALL SURFACES ARE ISOTHERMIC.
3. FINISH: PROTECTIVE PAINT (CAT-A-LAC BLACK) PER MARSHALL LABS. SPECIFICATION S40118, CLASS I, TYPE II, PRIMED. (NOTE: MOUNTING SURFACE NOT PAINTED.)
4. MOUNTING SURFACE: GOLD PLATED PER MARSHALL LABS. SPEC. S40120, CLASS II.
5. MAXIMUM OPERATING TEMPERATURE RANGE 0°C. TO +50°C.



PREAMPLIFIER

THERMAL CHARACTERISTICS

1. POWER DISSIPATION: ZONE "X", 1 WATT WHEN TEMP. IS AT +10°C., 20MW WHEN TEMP. IS AT +25°C.
   ZONE "Y", 60 MW CONTINUOUS.
2. MOUNTING SURFACE SHOULD BE ISOTHERMIC.
3. FINISH: PROTECTIVE PAINT (CAT-A-LAC, BLACK) PER MARSHALL LABS. SPECIFICATION S40118, CLASS I, TYPE II, PRIMED.
4. MAXIMUM OPERATING TEMPERATURE RANGE -50°C. TO +50°C.



SENSOR (TYPICAL)

THERMAL CHARACTERISTICS

1. POWER DISSIPATION: SENSOR IS NON-DISSIPATIVE.
2. ALL SURFACES ARE ISOTHERMIC.
3. FINISH: PROTECTIVE PAINT (CAT-A-LAC, BLACK) PER MARSHALL LABS. SPECIFICATION S40118, CLASS I, TYPE II, PRIMED.
4. MAXIMUM OPERATING TEMPERATURE RANGE -50°C. TO +50°C.

PARTS DISPOSITION 1. USE 2. REWORK 3. CANNOT BE REWORKED 4. RECORD	51739	A

REVISIONS

SHEET	DFF	SYM	DESCRIPTION	BY	DATE	CK'D	APPROVAL
4	1 & UP	4	REVISED OUTLINE TO CONFORM WITH NEW ENVELOPE	RG.	[illegible]	[illegible]	

51739 A

Figure 3

REQD	PART NO	DESCRIPTION	CKT REF	ITEM

LIST OF MATERIALS

FINISH

HEAT TREAT

RELEASED JUN 28 1965

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES

HOLE DIA.	TOLERANCE
.0135 THRU .125	+.004-.001
.126 THRU .250	+.005-.001
.251 THRU .500	+.006-.001
.501 THRU .750	+.008-.001
.751 THRU 1.000	+.010-.001
1.000 THRU 2.000	+.012-.001
2.001 AND OVER	LINEAR

LINEAR TOLERANCES: .XXX = ±.010; .XX = ±.03; .X = ±.1

ANGLES = ±0°30'

SURFACE ROUGHNESS PER MIL-STD-10 ✓

NEXT ASSY	USED ON	NEXT ASSY	FINAL ASSY
APPLICATION		QTY REQD	

DRAWN	R. Gabler	5/24/65
CHECK	[illegible]	
STRESS		
APPD	[illegible]	
APPD	[illegible]	6/24/65
APPD	[illegible]	6/24/65

THERMAL DIAGRAM — TRIAXIAL SEARCH COIL MAGNETOMETER (EXPERIMENT E-16)

SCALE NONE WEIGHT —

MARSHALL LABORATORIES

DRAWING SIZE C — 51739 A — SHEET 1 OF 1

MFG. CODE NO. 13126

5-120-A, B

A. Sensitivity: 10 microvolts per gamma Hertz

B. DC Resistance: 50K ohms

C. Inductance: 1200 Henries

D. Capacitance: 30 Picofarads

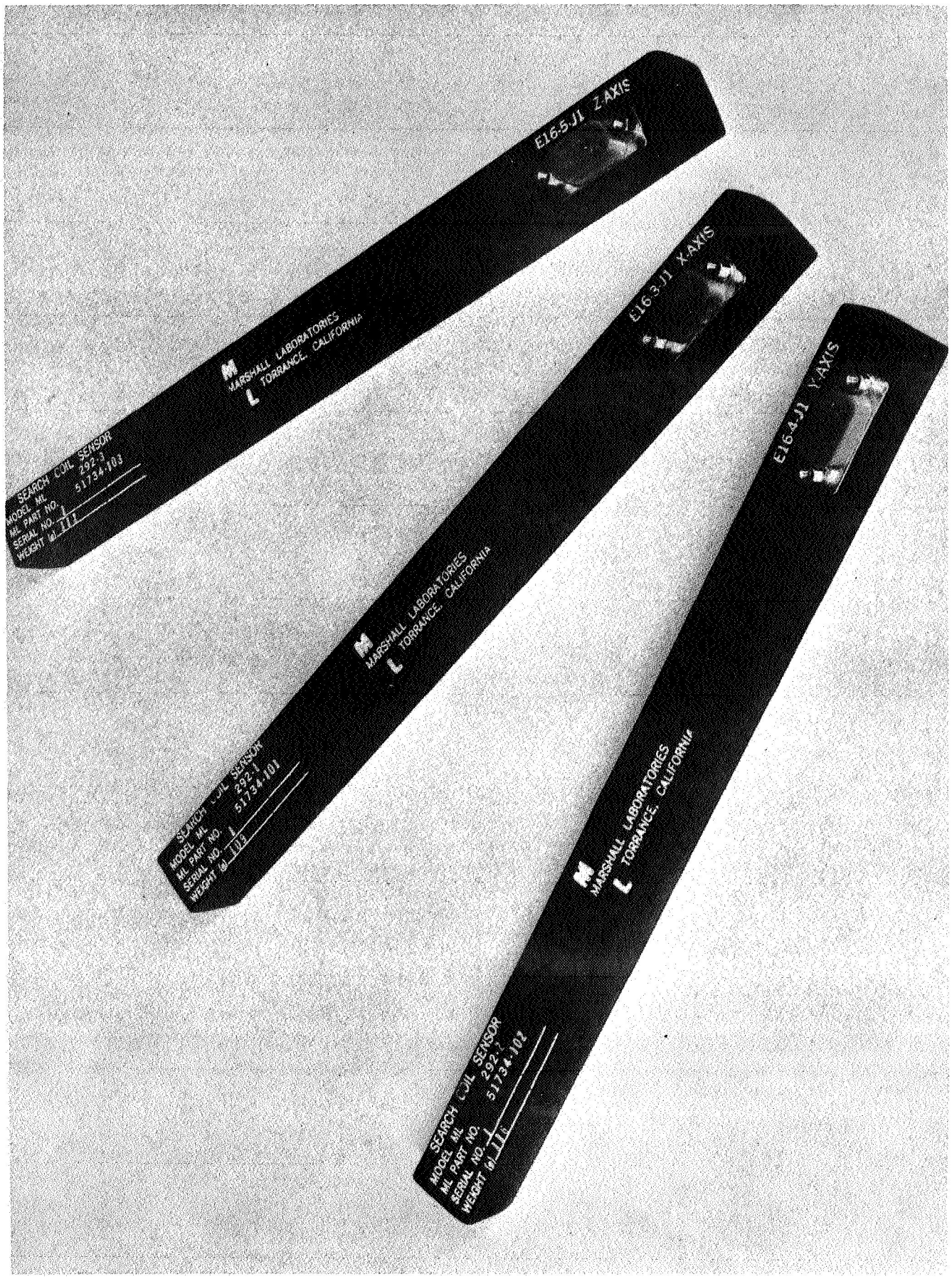
E. Resonant Frequencies: 670 Hz

F. Damping: Critical

Figure 4, shows a photo of the three sensor assemblies.

2.1.2 Mechanical Characteristics

Figure 5, shows the sensor envelope drawing. The sensor housing is constructed of aluminum approximately .02 inches thick. The sensor assembly is held in place within the housing by a light weight foam material. The housing cover is sealed by an epoxy adhesive. The housing is primed and painted with a Cat-a-Lac black epoxy paint.



OGO-E Search Coil Magnetometer Probe Assemblies

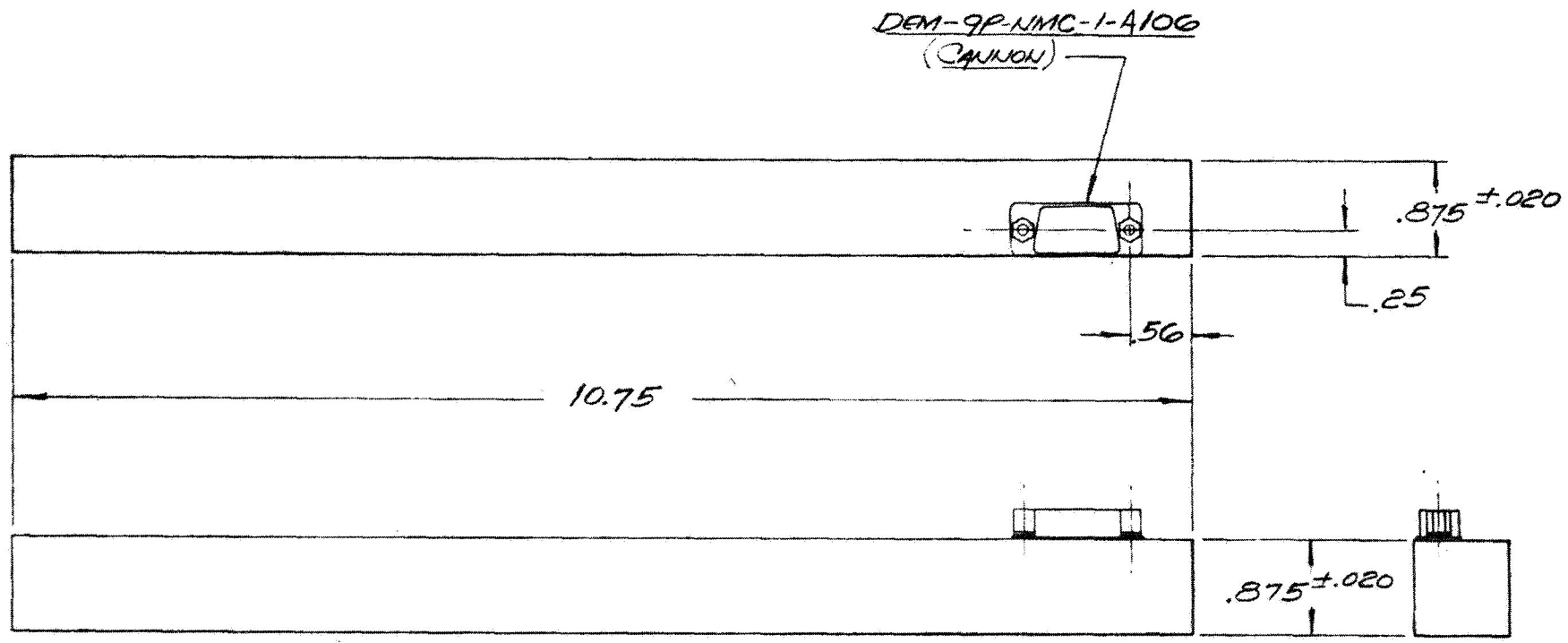
Figure 4

67-917

1. USE 2. REWORK	PARTS DISPOSITION 3. CANNOT BE REWORKED 4. RECORD	5.....	51737	A

REVISIONS

SHEET	QTY	ZONE	DESCRIPTION	BY	DATE	CK'D	APPROVAL
2	REQD	4	CONNECT WAS DEM-9P-NMB-1, .25 DIM. WAS .23	RG			



51737 A

Figure 5

REQD	PART NO	DESCRIPTION	CKT REF	ITEM

LIST OF MATERIALS

FINISH

HEAT TREAT

JUN 11 1965

DO NOT SCALE DRAWING

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES

HOLE DIA.	TOLERANCE
.0135 THRU .125	+.004-.001
.128 THRU .250	+.005-.001
.251 THRU .500	+.008-.001
.501 THRU .750	+.008-.001
.751 THRU 1.000	+.010-.001
1.001 THRU 2.000	+.012-.001
2.001 AND OVER	LINEAR

LINEAR TOLERANCES
.XXX = ±.010
.XX = ±.03
.X = ±.1

ANGLES = ±0°30'
SURFACE ROUGHNESS PER MIL-STD-10 ✓

NEXT ASSY	USED ON	NEXT ASSY	FINAL ASSY
APPLICATION		QTY REQD	

DRAWN R. Gordon Jones 6-4-65
CHECKED
STRESS
APPR. 6-4-65
APPR. 6/10/65
APPR.
SCALE 1/1 WEIGHT

ENVELOPE - SENSOR, TRIAXIAL SEARCH COIL MAGNETOMETER (EXPERIMENT E-16)

MARSHALL LABORATORIES

SIZE C | 51737 A | SHEET 1 OF 1

MFG. CODE NO. 13126

5-120-A, B

2C

2.2 Preamplifier Assembly

Each magnetometer instrument contains one preamplifier assembly which contains three low noise preamplifier modules and one preamplifier heater module. The preamplifier assembly is mounted near the probe assemblies in Experiment Package No. 5.

2.2.1 Preamplifier Electrical Characteristics

Each of the three preamplifiers has the following electrical characteristics:

A. Mid-Frequency Gain: 100 ± 2

B. Frequency Response: DC to 2KHz ± 1 db

C. Input Impedance: Approximately 10^9 ohms shunted by 10 picofarads.

D. Output Impedance: Approximately 100 ohms

E. Minimum Undistorted Output Signal: 1.0 volts RMS into 50K ohm load.

F. Operating Temperature: $-50^{\circ}C$ to $+60^{\circ}C$

G. Input Noise:

1. Less than 1.0 microvolts RMS from 0.1 Hz to 1 Hz.

2. Less than 0.01 microvolts squared per cps from 5 Hz to 1000 Hz.

2.2.2 Preamplifier Mechanical Characteristics

The preamplifier assembly envelope conforms to the drawing shown in Figure 6. Figure 7 is a photograph of the same assembly. The housing is constructed of magnesium coated with Dow 7 and painted with a Cat-a-Lac black paint. The three preamplifier modules and the heater module are electrically connected on a mylar hookup board and thermally insulated with several layers of NRC Super Insulation. The wrapped subassembly is held in place and further insulated by use of a light weight foam material.

2.3 Heater Electrical Characteristics

The proportional heater module is incorporated in the preamplifier assembly in order to allow operation at low ambient temperatures. This module dissipates .02 watts or less when its control thermistor temperature is greater than 15°C, and dissipates at least 0.15 watts when the control thermistor is at 15°C or lower.

2.4 Waveform Channel

The waveform channels assembly contain circuitry to provide waveform information from three different axes. A block diagram of one waveform channel is shown in Figure 8. The characteristics of each waveform output are as follows:

A. Hi Gain: 1000 ± 20

B. Med Gain: 100 ± 2

C. Lo Gain: 10 ± 0.2

D. High Frequency Cut-off (-3db):
Narrowband -1.0Hz ± 20%
Wideband -64.0 Hz ± 20%

E. Low Frequency Cut-off (-3bd):
.01 Hz (-3db) ± 20%
slope = 18 db/octave

F. Output Resting Level: 2.5 ± 0.1 volt

G. Output Impedance: Less than 1000 Ohms

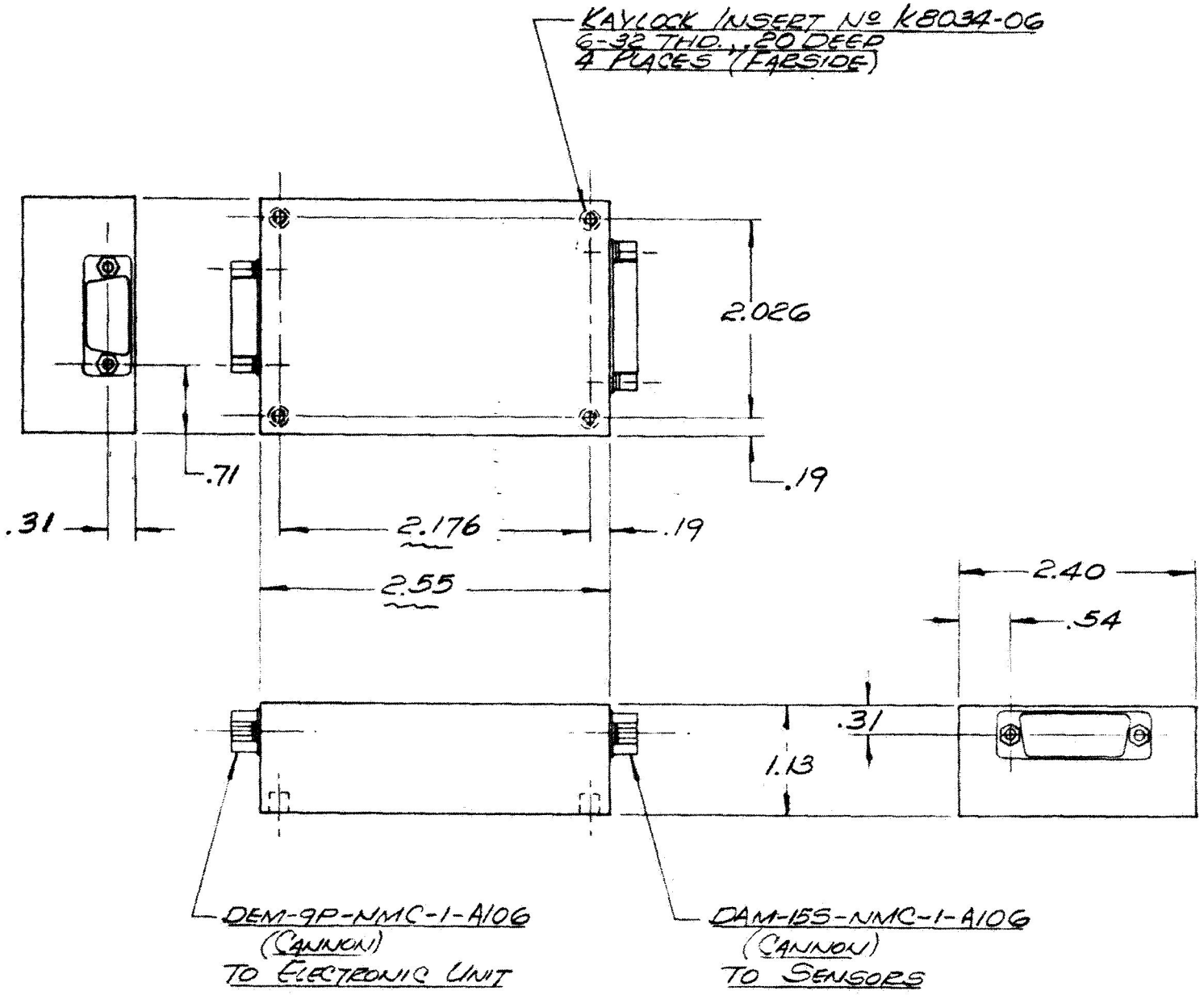
H. Output Voltage Range: From -1.0V to +6.5V maximum. Output signal is distorted between +0.1V and +5.0V.

67-917

PARTS DISPOSITION: 1. USE 2. REWORK 3. CANNOT BE REWORKED 4. SCRAP	51736	A

REVISIONS

DISP	EFF	SYM	DESCRIPTION	BY	DATE	CK'D	APPROVAL
4	1&UP	A	INCORP. CHECK CORRECTION	RAG			



51736 A

Figure 6

REQD	PART NO	DESCRIPTION	CRT REF	ITEM

LIST OF MATERIALS

FINISH

HEAT TREAT

RELEASED JUL [illegible] 1969

DRAWN R. Golden 30 March 68
CHECK
STRESS
APPD
MFG APPD
QUAL APPD

ENVELOPE - PREAMPLIFIER, TRIAXIAL SEARCH COIL MAGNETOMETER (EXPERIMENT E-16)

SCALE None WEIGHT

MARSHALL LABORATORIES

SIZE C | 51736 | A

SHEET 1 OF 1

MFG. CODE NO. 13126

5-120-A

DO NOT SCALE DRAWING

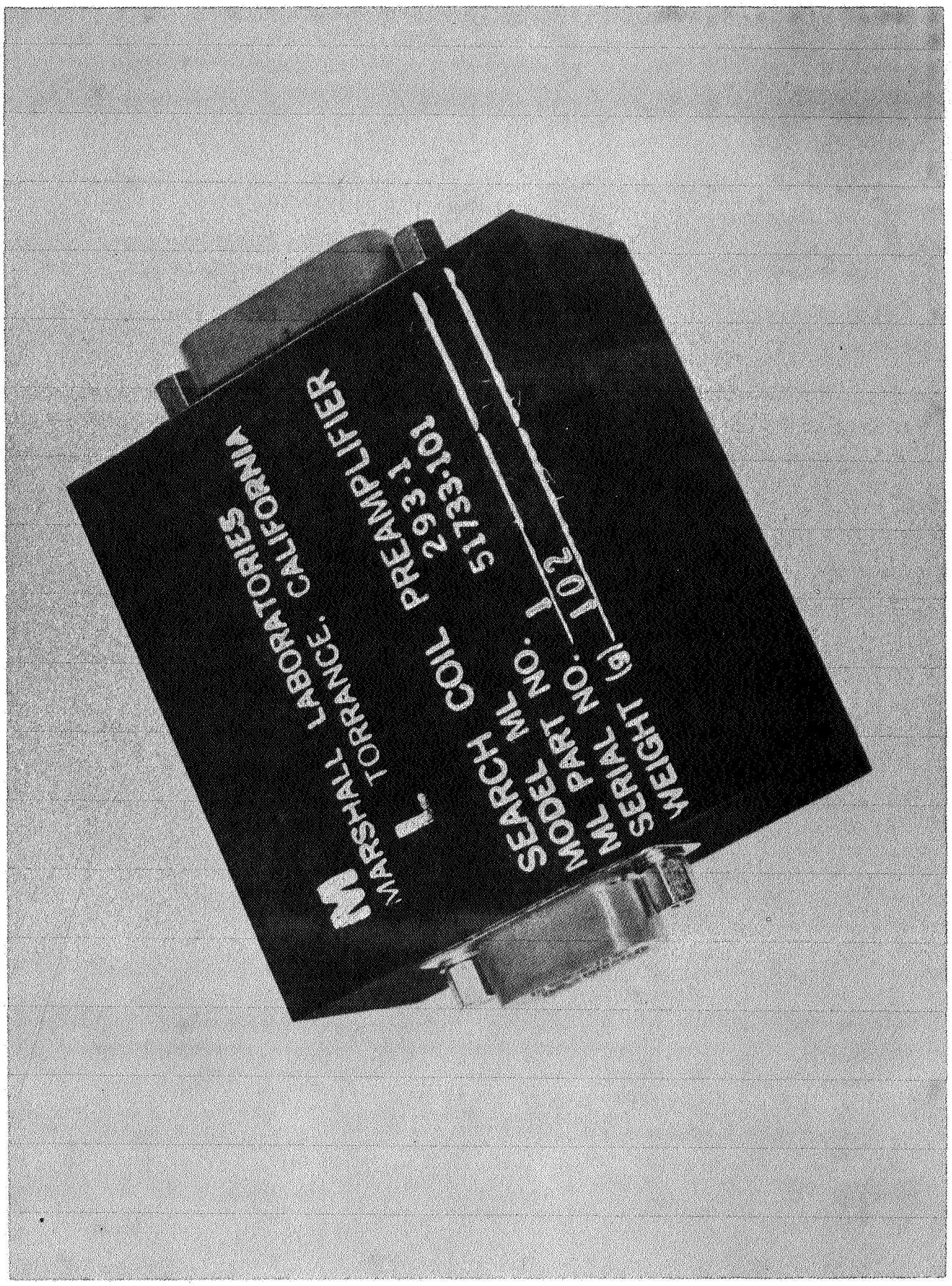
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES

HOLE DIA.	TOLERANCE
.0135 THRU .125	+.004-.001
.126 THRU .250	+.005-.001
.251 THRU .500	+.006-.001
.501 THRU .750	+.008-.001
.751 THRU 1.000	+.010-.001
1.001 THRU 2.000	+.012-.001
2.001 AND OVER	LINEAR

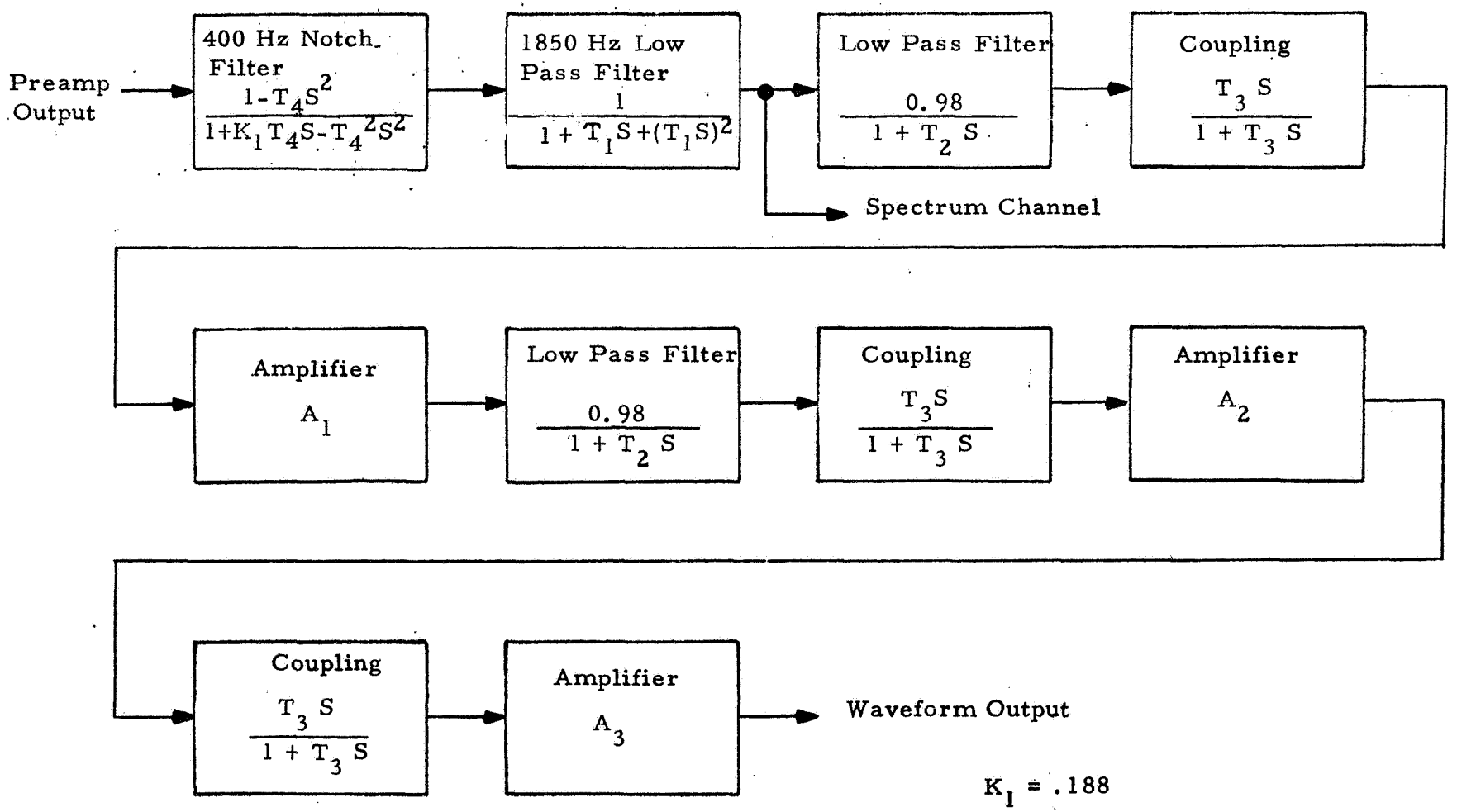
LINEAR TOLERANCES
.XXX = ±.010
.XX = ±.03
.X = ±.1

ANGLES = ±0°30'
SURFACE ROUGHNESS PER MIL-STD-10 ✓

NEXT ASSY	USED ON	NEXT ASSY	FINAL ASSY
APPLICATION		QTY REQD	



OGO-E Search Coil Magnetometer Preamplifier Assembly
Figure 7



Where:

$T_1 = 86.3 \times 10^{-6}$ sec.

$T_2 = 160 \times 10^{-3}$ sec. in Narrow Band

2.5×10^{-3} sec. in Wide Band

$T_3 = 33$ sec.

$T_4 = 0.398 \times 10^{-3}$ sec. (400 Hz)

$K_1 = .188$

$A_1 = 14$ in High Gain

1.4 in Lo and Med Gain

$A_2 = 14$ in High and Med Gain

1.4 in Lo Gain

$A_3 = 5.1$

FIGURE 8

WAVEFORM CHANNEL BLOCK DIAGRAM

I. Gain Change Sequence:
Lo, Med, Hi, Lo, Med, Hi, etc.
controlled by ground impulse command

J. The bandwidth of the waveform output is controlled by logic circuitry utilizing the Bit Rate, Mode and Switch signals of the spacecraft telemetry system. Narrowband operation will take place at all times except when either of the following combinations of Bit Rate, Switch, and Mode signals are present.

1. Bit Rate, 64KHz Switch, V1; Mode, V3
2. Bit Rate, 64KHz; Switch, V2 Mode, V4

2.5 Spectrum and Wave Analyzer Channels

A block diagram of spectrum channel and a seven channel wave analyzer is shown in Figure 9.

The spectrum output for each axis has the following characteristics (these signals are not utilized by the spacecraft):

A. Gain: Lo $2 \pm 2\%$
Med $20 \pm 2\%$
High $200 \pm 2\%$

B. Frequency Response:
1.0 Hz to 2000 Hz ± 3db

C. Output Impedance:
Less than 200 ohms

D. Maximum Undistorted Output Swing:
1.5 volts RMS

E. The gains of all three spectrum channels are controlled simultaneously by a ground impulse command.

Gain Change Sequence: Lo, Med, Hi, Lo, Med, Hi, etc.

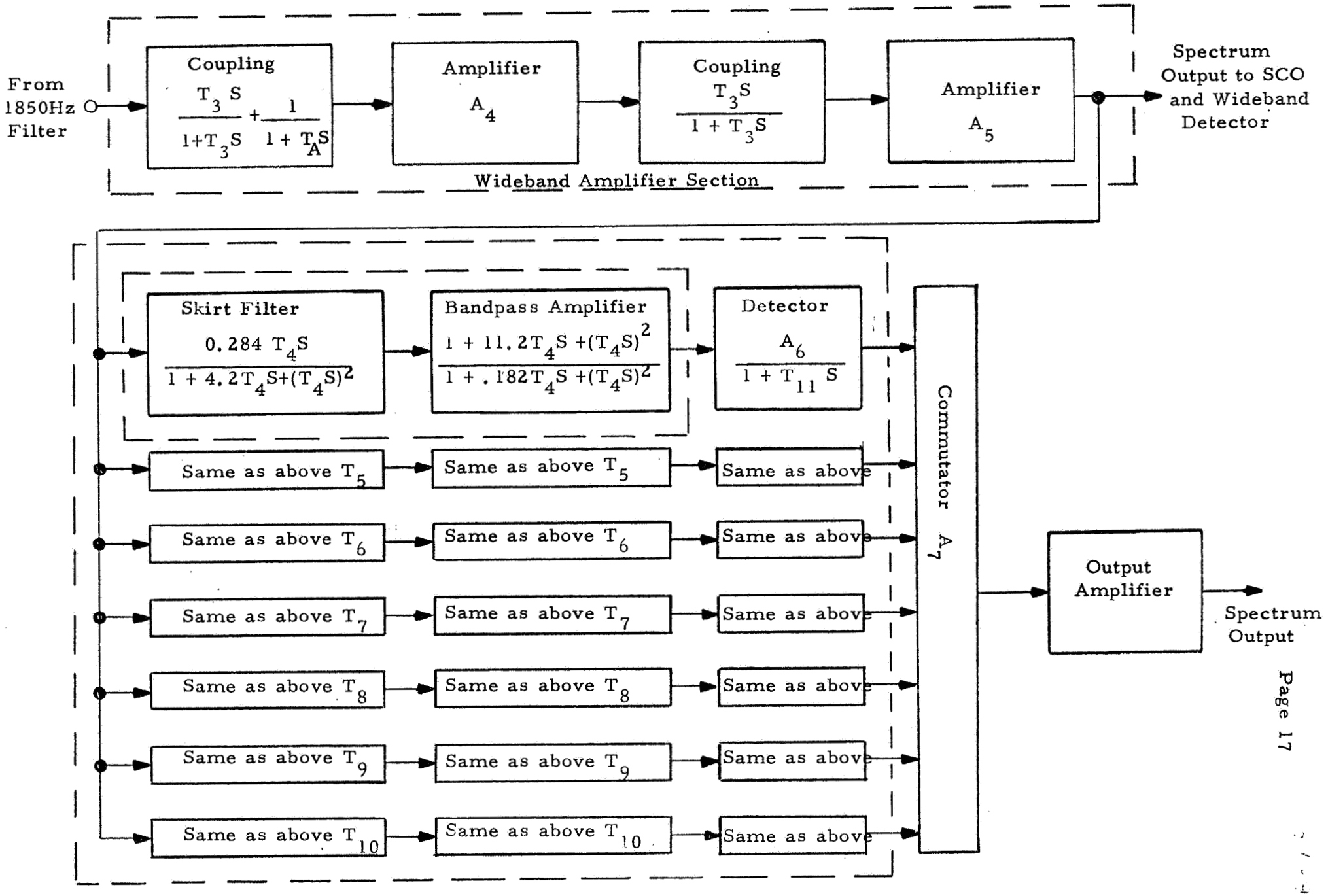


FIGURE 9
SPECTRUM AMPLIFIER AND WAVE ANALYZER

A_4 = 14 in Hi Gain
= 1.4 in Lo and Med Gain

A_5 = 14 in Hi and Med Gain
= 1.4 in Lo Gain

$A_6 = 1.4 \frac{\text{volt dc}}{\text{volt rms}}$

$T_3 = 220 \times 10^{-3}$ sec.

$T_4 = 16 \times 10^{-3}$ sec.

$T_5 = 7.4 \times 10^{-3}$ sec.

$T_6 = 3.4 \times 10^{-3}$ sec.

$T_7 = 1.6 \times 10^{-3}$ sec.

$T_8 = 0.74 \times 10^{-3}$ sec.

$T_9 = 0.34 \times 10^{-3}$ sec.

$T_{10} = 0.16 \times 10^{-3}$ sec.

$T_{11} = 1$ sec.

$T_A = .091 \times 10^{-3}$ sec.

FIGURE 9A

Spectrum Amplifier and Wave Analyzer

The wave analyzers have the following characteristics (these outputs are commutated before being transmitted to the spacecraft telemetry).

A. The gain at resonance of each bandpass filter is 8.5 ± 1.5

B. The resonant frequencies of the seven bandpass filters are 10, 22, 47, 100, 216, 467 and 1000 cps all ± 12%.

C. The AC gain of each channel relative to the resonant frequency gain is as follows:

Frequency	Gain in db
fo x 1.0	0
fo x 1.1	-3 ± 0.5
fo x 1.18	-6 ± 1.0
fo x 1.5	-13.4 ± 1.0
fo x 2.15	-20 ± 1.0
fo x 0.910	-3 ± 0.5
fo x 0.848	-6.0 ± 1.0
fo x 0.667	-13.4 ± 1.0
fo x 0.465	-20 ± 1.0

D. The detector output resting level is 0 ± 20 millivolts. The temperature stability is less than ± 20 millivolts.

E. The detector rise time constant is less than 3 milliseconds.

F. Detector Decay Time constant is one (1) second.

G. The detector output range is nominally 0 to 2.5 vdc.

H. Detector Gain: $1.4 \frac{\text{volts DC}}{\text{volts RMS}}$

2.6 Sub-Carrier Oscillator (SCO) and Wideband Detector

Each axis contains an SCO and Wideband Detector as shown in Figure 10 and 11. Since only two sub-carrier inputs to the spacecraft telemetry systems are available, the Y axis and Z axis SCO outputs are summed and amplified by a single driver amplifier. The

SCO outputs to the telemetry system are (1) X axis subcarrier and (2) summed Y and Z axis subcarriers. The input to each is the spectrum output of Figure 9. The characteristics of the SCO are as follows:

A. Low Pass Filter Cutoff Frequency:
1000 ± 50 Hz

B. SCO Center Frequency:
X Axis; 30KHz ± 0.2%
Y Axis; 52.5KHz ± 0.2%
Z Axis; 70KHz ± 0.2%

C. The frequency deviation is ± 3.00 ± 0.06 percent of center frequency per input volt peak-to-peak for X and Y-axis; and ± 1.50 ± 0.03 percent for Z-axis.

D. The modulation produces less than one percent distortion for the maximum available signal from the low pass filter.

E. Not more than five percent of the SCO output signal lies outside the following bands:

1. X-Axis: 25.5KHz to 34.5KHz
2. Y-Axis: 44.7KHz to 60.5KHz
3. Z-Axis: 64.8KHz to 75.2KHz

F. Output Impedance:
Less than 100 ohms

G. Output Amplitude:
4.75 ± 0.10 volts peak to peak

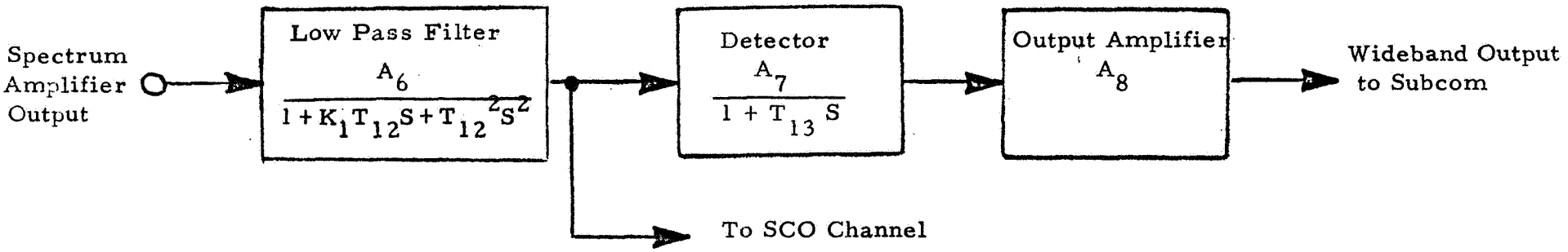
H. The SCO's are turned On and Off by the Special Purpose Power Command.

The wideband circuit has the following characteristics:

A. The wideband detector has a rise time constant of 180×10^{-3} sec., and a decay time constant of 1 second.

B. Output Amplifier Gain:
5.9 ± 1%

C. Amplifier Output Impedance:
Less than 100 ohms



$A_6 = 0.34$

$A_7 = 1.4 \frac{\text{volt DC}}{\text{volt RMS}}$

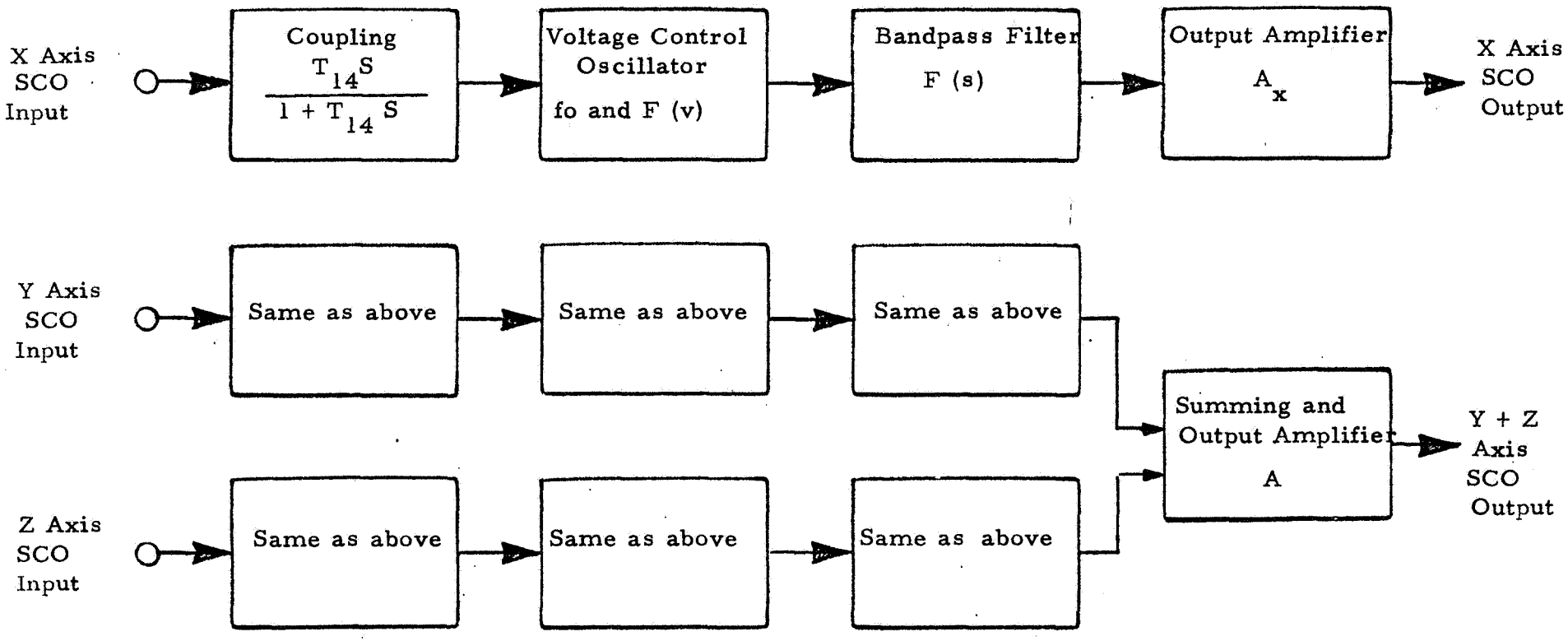
$A_8 = 5.9$

$T_{12} = 0.16 \times 10^{-3}$ sec.

$T_{13} = 1$ sec.

$K_1 = 2$

FIGURE 10
WIDEBAND DETECTOR CHANNEL



$A_x = 3$

A = 1.5 for Y

1.5 for Z

$T_{14} = 0.35$ sec.

F(v) = .03 fo/volt for X and Y Axis

= 0.015 fo/volt for Z Axis

fo = 30KHz for X Axis

= 52.5KHz for Y Axis

= 70KHz for Z Axis

F(s) = 30KHz ± 15% for X Axis

= 52.5KHz ± 15% for Y Axis

= 70KHz ± 7.5% for Z Axis

FIGURE 11
SCO CHANNEL

D. The amplifier resting level:
0v $\pm$ .02 volts

E. Output Voltage Range:
from -1.0v to 6.5v maximum output signal undistorted between +0.1v and +5.0v

2.7 Bandwidth Control

Figure 12 shows the circuit block diagram of the bandwidth control network for the waveform channel. After interface buffering and inversion the Bit Rate, Mode and Switch signals of the spacecraft telemetry system are mechanized by logic AND and OR gates to provide 1 Hz narrow band operation except under either of the following conditions for 64 Hz wideband operation.

1.	Bit Rate	64 Kbps	BR
	Mode	V3	M
	Switch	V1	$\overline{S}$
2.	Bit Rate	64 Kbps	BR
	Mode	V4	$\overline{M}$
	Switch	V2	S

The output control signal is 0 to 0.2 vdc for narrow band operation and +5.8 to +6 vdc for wideband operation.

2.8 Wave Analyzer Commutator Control

The wave analyzer commutator control circuit block diagram is shown in Figure 13. The telemetry equipment group 1 and 2 index pulses are combined in an AND gate with the switch signal and the wave analyzer index pulse inhibit and reset line. The AND function output toggles the 3 bit wave analyzer flip-flops for equipment group 1 or equipment group 2 index pulse operation.

The binaries are connected in a scale of seven counters. Their outputs are converted by seven NAND gates, the commutator gating block, to provide the sequential gating signals for the commutator.

A. Commutating rates:

1. 55.5 cps for 64 kbps
2. 6.9 cps for 8 kbps
3. 0.87 cps for 1 kbps

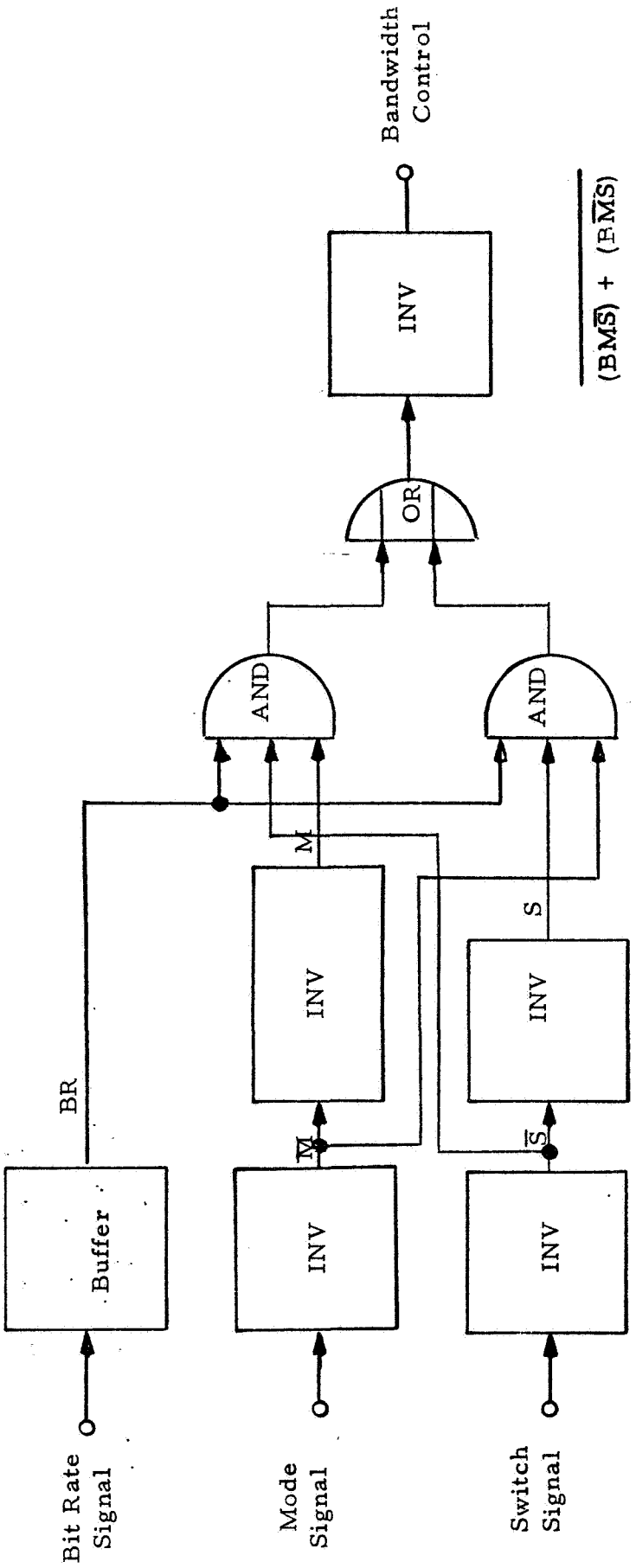
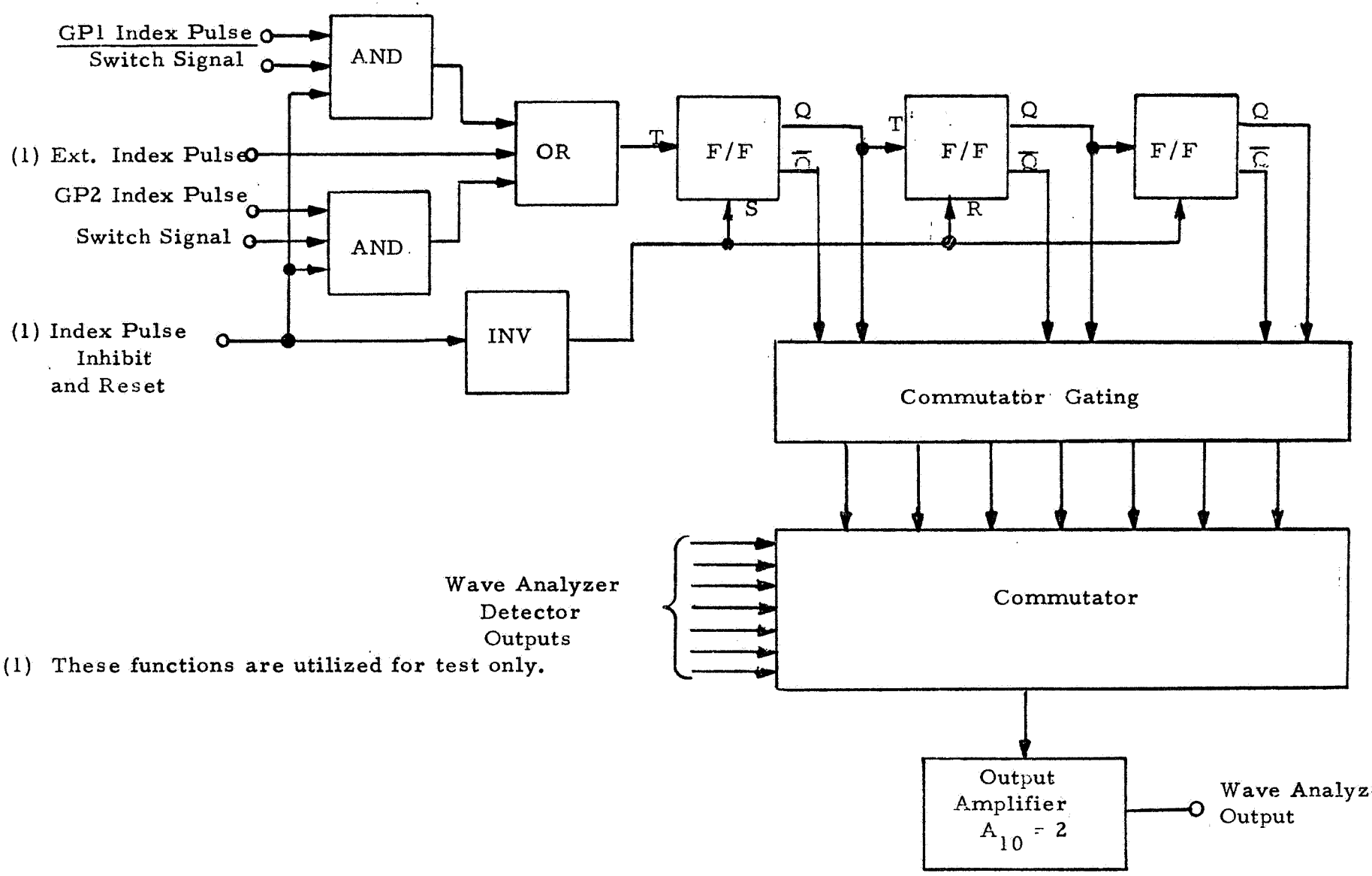


Figure 12 Bandwidth Control
Block Diagram



(1) These functions are utilized for test only.

Figure 13 Wave Analyzer Commutator Control Block Diagram

B. Commutator input impedance:

greater than 22 megohm

C. Commutator amplifier gain: 2 output impedance:

less than 100 ohms

D. Reset & Inhibit signal is +6 volts under normal operation and 0 volts during inhibit. Reset occurs during the negative transition which must be 1 microsecond or less.

E. Wave analyzer output amplitude: 0 to +5 volts

2.9 IFC Signal, Waveform and Spectrum Gain Control

The IFC signal, waveform and spectrum gain control circuit block diagram is shown in Figure 14.

Each of 3 command lines is isolated from primary to secondary grounds by a one-shot blocking oscillator (iso-amp). The three timing signals of 222, 13.9 and .87 pps are buffered by inverters. The timing signals are divided by two, summed and attenuated to give an IFC signal consisting of a 2 millivolt squarewave step for each frequency (111, 6.9 and .43 cps) or a total of 6 millivolts during the high gain state of the waveform channel. Changes in the waveform gain to med and low gain, increases the IFC signal amplitude one magnitude for each gain step decrease. The preamp has a gain of one to the IFC signal. The mixed frequency signal is rich in harmonic content such that an output is detected in all wave analyzer channels.

The waveform and spectrum gain control circuits are identical. The impulse command signals (relay closure to primary 28 vdc return) toggle a divide by 3 counter. The output control signal logic states as a function of gain are as follows:

AMP State	Hi gain	Med gain	Lo gain
Hi gain control	0	0	1
Med gain control	0	1	1

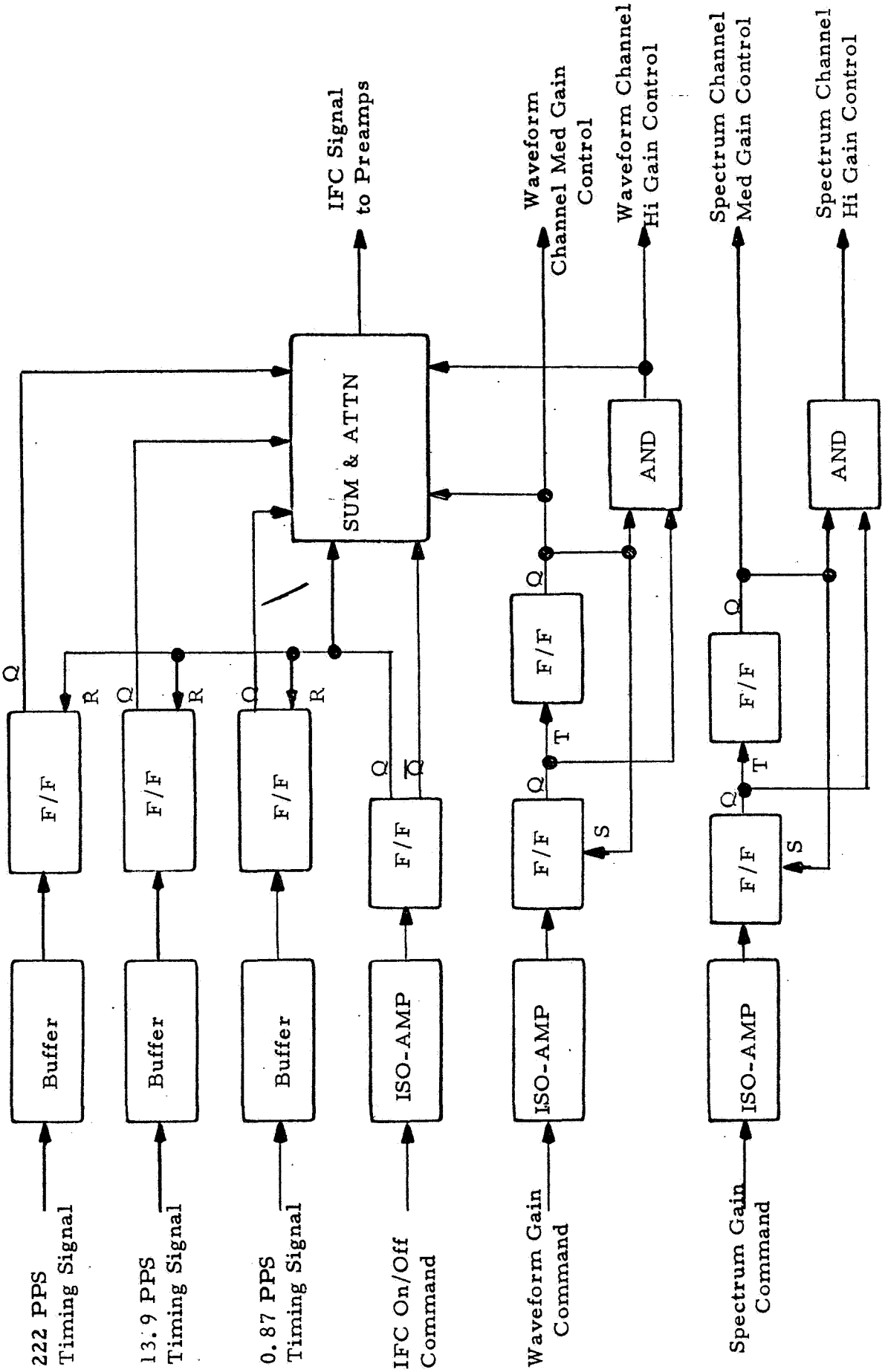


Figure 14 IFC Signal, Waveform and Spectrum Gain Control Circuit Block Diagram

2.10 Status Words

Four analog outputs are provided to indicate the state of the control circuitry. The status outputs are as follows:

A. Waveform Gain - Hi, Med, or Lo and Spectrum Gain - Hi, Med, or Lo (4 bits).

B. Bandwidth -2 or 64 cps and IFC - On/Off (2 bits).

C. Analyzer Frequency (3 bits).

D. Power - On/Off and SCO On/Off (2 bits).

The status words are stable to within ± 100 millivolts under all environmental conditions.

2.11 Power Supply

The unit contains a power supply to provide those voltages necessary to enable other circuitry to meet its specified performance. The ± 0.1% regulated output voltages are -6.0, +6.0 and +20.0 volts. Figure 15 shows the circuit block diagram.

The power supply meets interface requirements including generated noise, surge current limiting, frequency synchronization and ground isolation. Maximum input power is 2 watts (70 ma). The power supply has an efficiency of greater than 60 percent at 1 watt and greater than 67% at 2 watts with a nominal 28 volt inputs.

The power supply circuitry consists of an input noise filter, a pre-regulator with surge current limiting, a synchronized DC/DC converter capable of free-running at 2461 cps ± 5 percent, a sync signal amplifier, and post regulator for providing the -6.0, +6.0 (2), and +20.0 volt outputs.

The pre-regulator and converter output and secondary voltage outputs from the power supply are available as test points on the unit test connector.

The power supply is housed in an isolated cavity with its inputs brought through a separate nine pin connector.

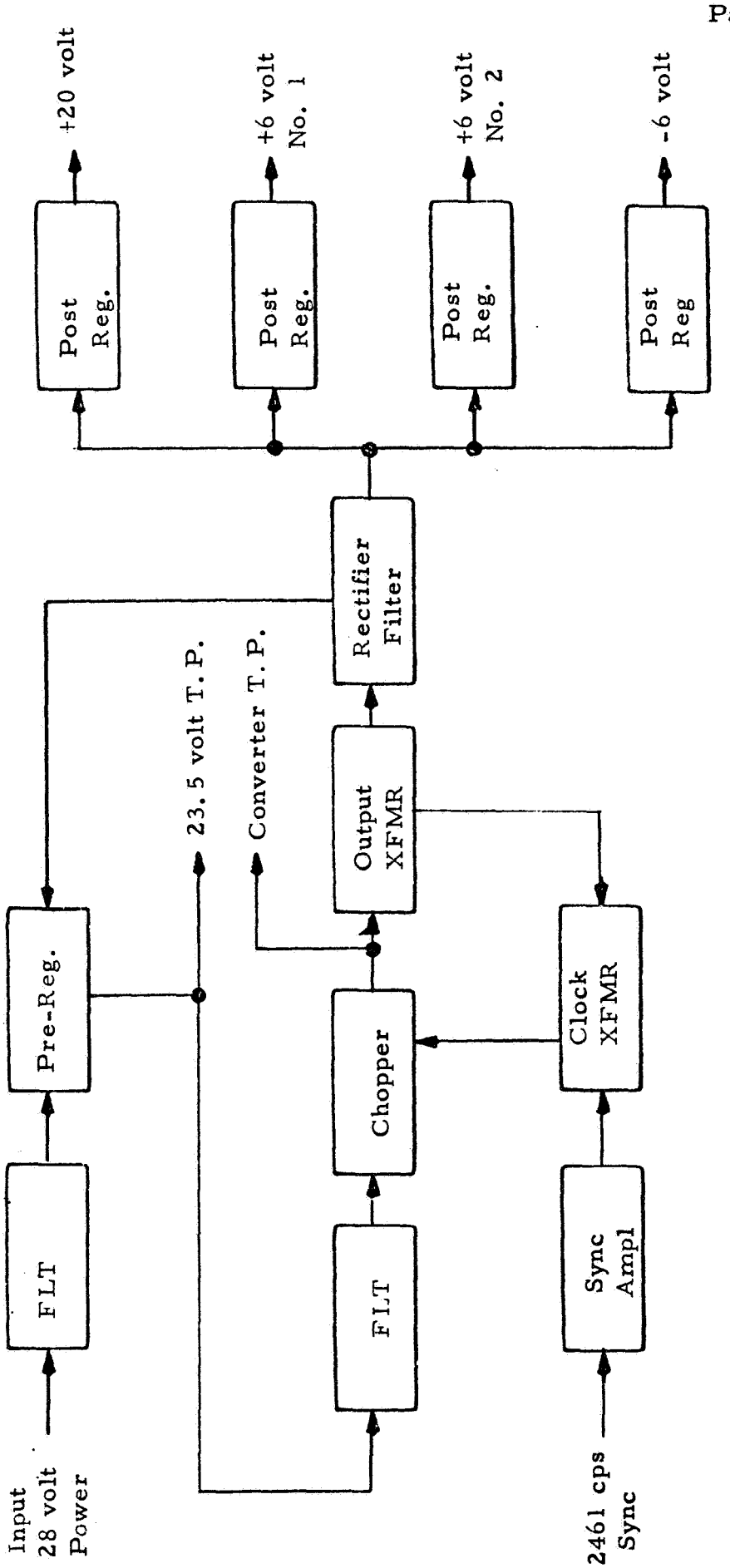


Figure 15 Power Supply Circuit Block Diagram

2.12 Test Connector

A test connector is provided to enable monitoring of the units performance when mounted in the spacecraft. The signals available on this connector include the following:

A. All outputs to the telemetry including the SCO outputs (26 pins) (timing signals are excluded).

B. All signals to the preamps (8 pins).

C. The three spectrum T. P. Signals (3 pins).

D. Power Supply -6.0 volts +6.0 volts (2), 23.5 volts, and converter output (7 pins).

2.13 Main Assembly Mechanical Description

The main assembly envelope conforms to the drawing shown in Figure 16. A photo of the main assembly showing the three electronic blivets together with the connector harness housing to which these blivets are attached is shown in Figure 17. All mechanical structure is machined from AZ31B magnesium tooling plate to provide a high strength-to-weight ratio. All magnesium surfaces are either treated with Dow 7 or are gold plated. The gold plating is utilized where required for electrical bonding and RFI purposes. These surfaces include the mounting base and all mating surfaces between the blivets and covers. The major portion of electrical components are packaged into welded cordwood modules using non magnetic Alloy 180 as the interconnecting material. The fabricated modules after electrical tests are coated with PT4121 which is a low viscosity epoxy and then foamed with a light weight foam material. The modules are interconnected on a modified welded matrix again using Alloy 180 as the interconnecting material. Terminals are mounted on each matrix assembly for interconnecting all input and output leads with the connector on the blivet housing.

In order to facilitate checkout of the magnetometer instrument, Figures 18 through 27 are included in this report. These figures show the schematics for the waveform blivet, the wave analyzer blivet, and the power supply and control blivet.

67-917 Page 31

PARTS DISPOSITION		DWG NO.	REV
1. USE 2. REWORK	3. CANNOT BE REWORKED 4. RECORD	51735	B

REVISIONS

DISP	EFF	ZONE	REV	DESCRIPTION	BY	CK	DATE	APPROVAL
4	16 Ltr		A	REVISED & REDRAWN	[illegible]	[illegible]	1-6	[illegible]
4	16 Ltr		B	REVISED MOUNTING DIM. & CONNECTOR DIAM.	[illegible]	[illegible]	7-16	[illegible]

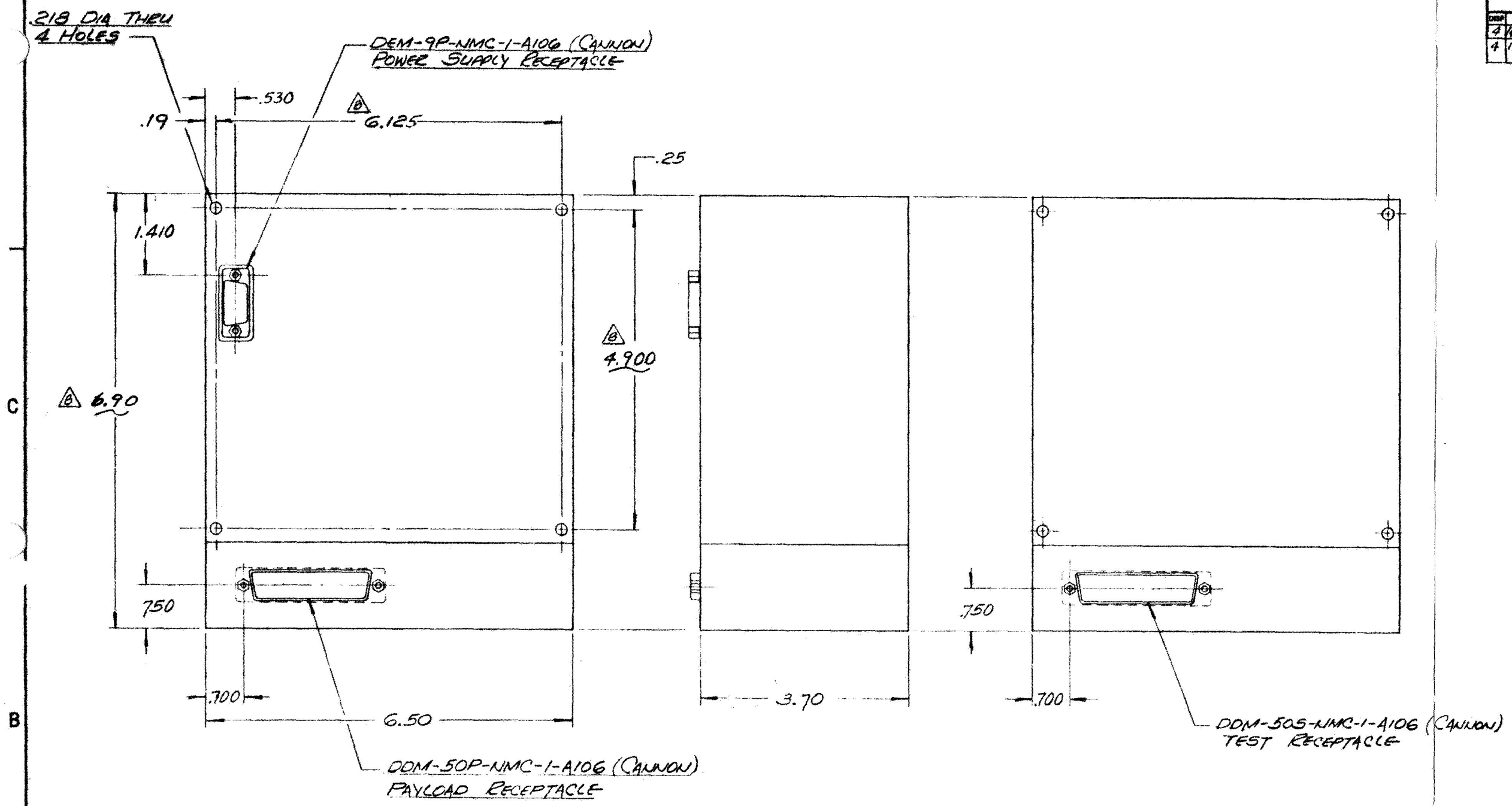


Figure 16

NOTES: UNLESS OTHERWISE SPECIFIED

QTY REQD PER NOTED ASSY
CONFIGURATION
LAYOUT NO.
DIST CODE 5-120 B 5-140 A

DASH NO.	MODEL NO.	NEXT ASSEMBLY	MODEL NO.	FINAL ASSEMBLY	MODEL NO.

APPLICATION

PART NO.	SPECIFICATION	NOMENCLATURE OR DESCRIPTION	ELEC REF DES	CODE IDENT	ZONE	ITEM NO.
		LIST OF MATERIALS				

INTERPRET THIS DRAWING PER STANDARDS IN MIL-D-70327
DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS: X ± .1, XX ± .03, XXX ± .010; ANGLES ± 0° 30'; XXXX ± .0050
✓ SURFACE ROUGHNESS

HOLE DIA.	TOLERANCE
.0135 THRU .125	+ .004 − .001
.126 THRU .250	+ .005 − .001
.251 THRU .500	+ .006 − .001
.501 THRU .750	+ .008 − .003
.751 THRU 1.000	+ .010 − .001
1.000 THRU 2.000	+ .012 − .001
2.001 AND OVER	LINEAR

CONTRACT NO.
DRAWN [illegible] 6-7-65
CHECK [illegible] 6-7-65
MECH ENG [illegible] 6-7-65
ELEC ENG
PROJ ENG [illegible] 6/10/65
APPD
DESIGN ACTIVITY APPD [illegible] 6/11/65
CUSTOMER

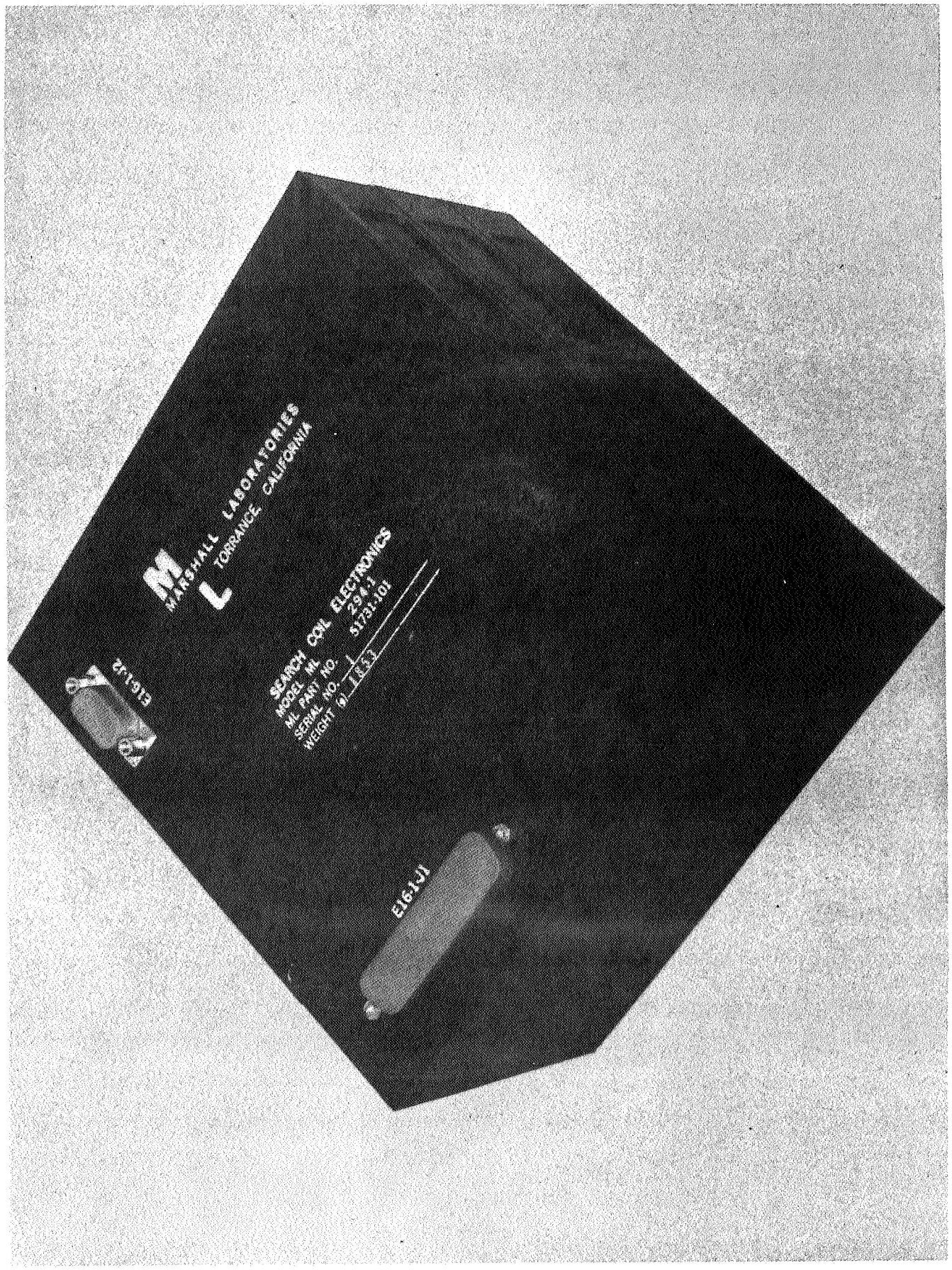
MARSHALL LABORATORIES
TORRANCE, CALIFORNIA

TITLE: ENVELOPE - ELECTRONIC UNIT, TRIAXIAL SEARCH COIL MAGNETOMETER (EXPERIMENT E-16)

SIZE	CODE IDENT NO.	DWG NO.	REV
D	13126	51735	B

SCALE NONE | RELEASED JUN 11 1965 | SHEET 1 OF 1

DWG NO 51735 REV B



OGO-E Search Coil Magnetometer Main Electronic Assembly

Figure 17

(DDM-50P-NMC-1-A106)

P5

P5 (CON T.)

e_{c2} BANDWIDTH CONTROL — 49 — E4

X-AXIS PREAMP — 38 — E30

e_{c1} WAVEFORM GAIN CONTROL (HI) #1 — 35 — E1

e_{c2} WAVEFORM GAIN CONTROL (MED) #2 — 36 — E34

e_{c3} SPECTRUM GAIN CONTROL (HI) #1 — 39 — E28

e_{c4} SPECTRUM GAIN CONTROL (MED) #2 — 48 — E6

e_{c5} SCD CONTROL — 41 — E20

Y-AXIS PREAMP — 5 — E27

Z-AXIS PREAMP — 31 — E5

+20 VOLT — 30 — E7 — +20V

+6 VOLT — 32 — E3 — +6V

-6 VOLT — 50 — E2 — -6V

SEC. RETURN — 23 — E31 — SEC RET

+2.5V — 29 — E9 — +2.5V

Z1 W4316X1 L.P.
Z2 W4316X1 G.C. AMPL.
Z3 W4316X1 L.P.
Z4 W4316X1 G.C. AMPL.
Z5 W4317X1 OUTPUT AMPL.
Z6 W4316X1 G.C. AMPL.
Z7 W4316X2 G.C. AMPL.
Z8 W4298X3 DETECTOR
Z9 W4317X2 OUTPUT AMPL.
Z10 W4312X1 L.P.
Z11 W4313X1 VCO
Z12 W4314X1 DRIVER
Z13 W4315X1 L.P.
Z14 W4316X1 G.C. AMPL.
Z15 W4315X1 L.P.
Z16 W4316X1 G.C. AMPL.
Z17 W4317X1 OUTPUT AMPL.
Z18 W4316X1 G.C. AMPL.
Z19 W4316X2 G.C. AMPL.
Z20 W4298X3 DETECTOR
Z21 W4317X2 OUTPUT AMPL.
Z22 W4312X1 L.P.
Z23 W4313X2 VCO
Z24 W4314X1 DRIVER
Z25 W4315X1 L.P.
Z26 W4316X1 G.C. AMPL.
Z27 W4315X1 L.P.
Z28 W4316X1 G.C. AMPL.
Z29 W4317X1 OUTPUT AMPL.
Z30 W4316X1 G.C. AMPL.
Z31 W4316X2 G.C. AMPL.
Z32 W4298X3 DETECTOR
Z33 W4317X2 OUTPUT AMPL.
Z34 W4312X1 L.P.
Z35 W4313X3 VCO
Z36 W4314X1 DRIVER
Z37 W4911X1 +2.5 VR.

C1 1.8 EPICOT ELECTRON
C2 1.8
C3 1.8
C4 .01 VK30
C5 .01
C6 1.8
C7 1.8
C8 1.8
C9 .01
C10 .01
C11 1.8
C12 1.8
C13 1.8
C14 .01
C15 .01
C16 .027 MF
C17 .027 MF
C18 .027 MF
C19 .027 MF
C20 .027 MF
C21 .027 MF
C22 .027 MF
C23 .027 MF
C24 .027 MF
C25 .027 MF
C26 .027 MF
C27 .027 MF
C28 .027 MF
C29 .027 MF
C30 .027 MF
C31 .027 MF
C32 .027 MF
C33 .027 MF
C34 .027 MF
C35 .027 MF
C36 .027 MF

FL1 WMF 30 UTC
FL2 WMF-52.5 UTC
FL3 WMF-70 UTC

R1 1K
R2 1K
R3 *
R4 *
R5 *
R6 *
R7 *
R8 *
R9 1K
R10 *
R11 *
R12 *
R13 *
R14 *
R15 *
R16 1K
R17 *
R18 *
R19 *
R20 *
R21 *
R22 *
R23 *
R24 *
R25 *
R26 *
R27 *
R28 *
R29 *
R30 *
R31 *

E1 X AXIS WAVEFORM
E19 X AXIS SPECTRUM T.P.
E22 X AXIS SPECTRUM
E4 X AXIS WIDE BAND
E35 X AXIS SCD (30 KC)
E15 Y AXIS WAVEFORM
E16 Y AXIS SPECTRUM T.P.
E18 Y AXIS SPECTRUM
E33 Y AXIS WIDEBAND
E29 Y AXIS SCD (12.5 KC)
E17 Z AXIS WAVEFORM
E13 Z AXIS SPECTRUM T.P.
E11 Z AXIS SPECTRUM
E32 Z AXIS WIDEBAND
E23 Z AXIS SCD (70 KC)

SPARES

NC

R21, E36, C15, E31 — HARVEST REFERENCE INFORMATION USED

9. * INDICATES SELECTED COMPONENTS
8. FOR TEST SPEC SEE MARSHALL LABS S-40845
7. FOR ASSEMBLY DWG SEE S-1877
6. ALL INDUCTANCE VALUE IN HENRYS ± %
5. ALL TRANSISTORS ARE TYPE
4. ALL DIODES ARE TYPE
3. TP = TEST POINT
2. ALL CAPACITANCE VALUES IN MICRO FARADS ± %
1. ALL RESISTANCE VALUES IN OHMS ± 5% ¼ WATT
NOTES: UNLESS OTHERWISE SPECIFIED

Figure 18

MARSHALL LABORATORIES
WAVEFORM BUFFER - INTERCONNECT SCHEMATIC DIAGRAM - 060-E TRIAXIAL S.C. MAGNETOMETER
E 13126 51900 A

2100 A 00615 2100 A 00615 2100 A

ENGINEERING CHANGE

MAGNAVOX RESEARCH LABORATORY
3630 TORRANCE BOULEVARD
TORRANCE, CALIFORNIA

DIST CODE 5-1

MAGNAVOX 15/A

ISSUED 3 198[illegible]

DRAWING TITLE: WAVEFORM BLIVET-INTERCONNECT SCHEMATIC DIAGRAM

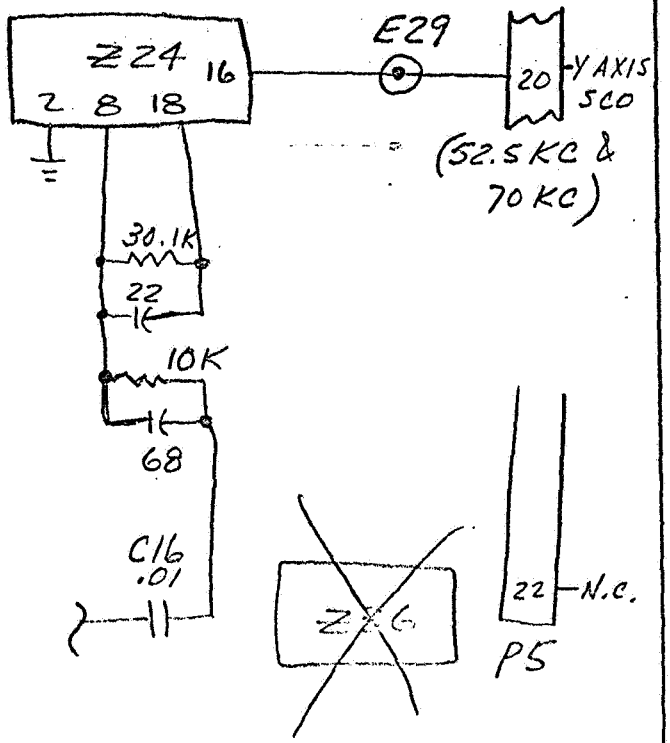
JOB NO.	CODE IDENT NO.	EO — 51900-A1
5-129	13126	

TYPE OF EO	DISPOSITION OF PARTS			EFFECTIVITY
[X] CHANGE	[ ] USE	ORIG PODSTALAJ DATE 8/22/66	NEXT ASSY	1 & UP
[ ] VARIANCE	[ ] REWORK	CHECK	MODEL NO.	
[ ] SUPERCEDING	[ ] SCRAP	ENGR		
[ ] NOTED	[ ] NOTED BELOW	PM [signature illegible] 8/22/66	OTHER DWG AFFECTED	
		APPR [signature]		
		CUSTOMER		

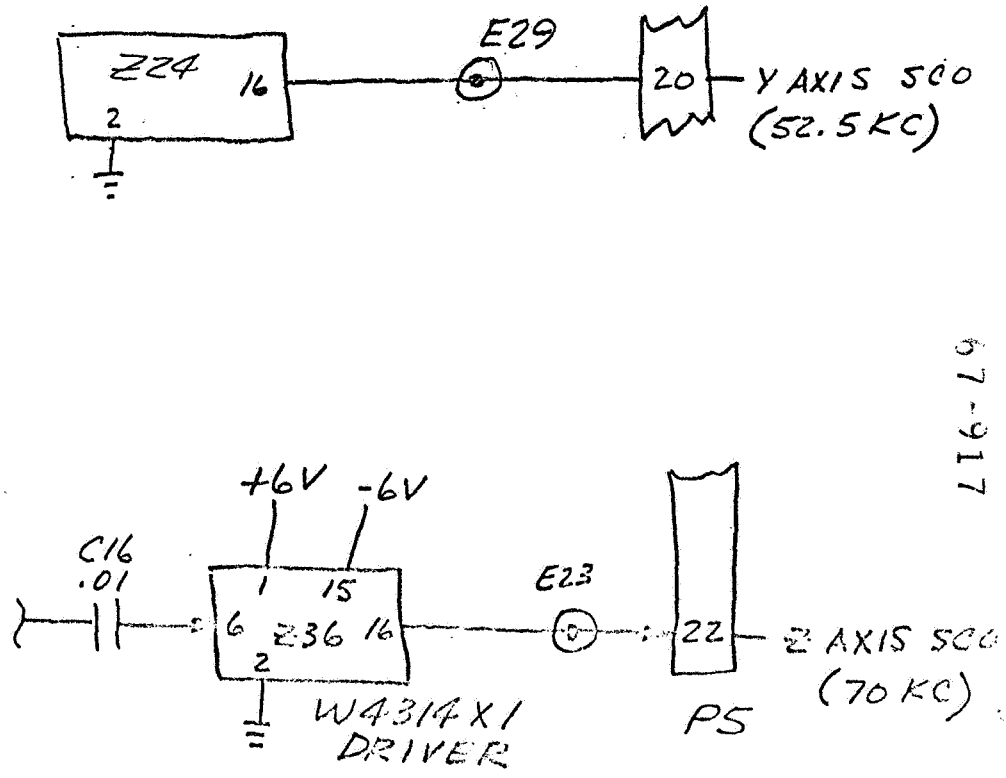
DESCRIBE CHANGE AND GIVE REASON:

ZONES A-2 & B2

IS:



WAS:



67-917

Figure 13-1

49

PART NO.	SPECIFICATION	DESCRIPTION	ELECT REF DES	CODE IDENT	ZONE

ENGINEERING CENTER

MARSHALL LABORATORIES
3530 TORRANCE BOULEVARD
TORRANCE, CALIFORNIA

DIST 5-120
CODE A

ML 157A
RELEASED 12 1957

DRAWING TITLE WAVEFORM BLIVET-
INTERCONNECT SCHEMATIC DIAGRAM

JOB NO.	CODE IDENT NO.	EO — 51900-A 2
5-129	13126	

TYPE OF EO	DISPOSITION OF PARTS		
[X] CHANGE	[ ] USE	ORIG J. LAVERY DATE 10-24-61	NEXT ASSY
[ ] VARIANCE	[X] REWORK	CHECK L. Golden 11-24-61	MODEL NO.
[ ] SUPERCEDING	[ ] SCRAP	ENGR [illegible]	
[ ] NOTED	[ ] NOTED BELOW	PM [illegible] 2/21/62	OTHER DWG AFFECTED
		APPR [illegible]	
		CUSTOMER	

EFFECTIVITY

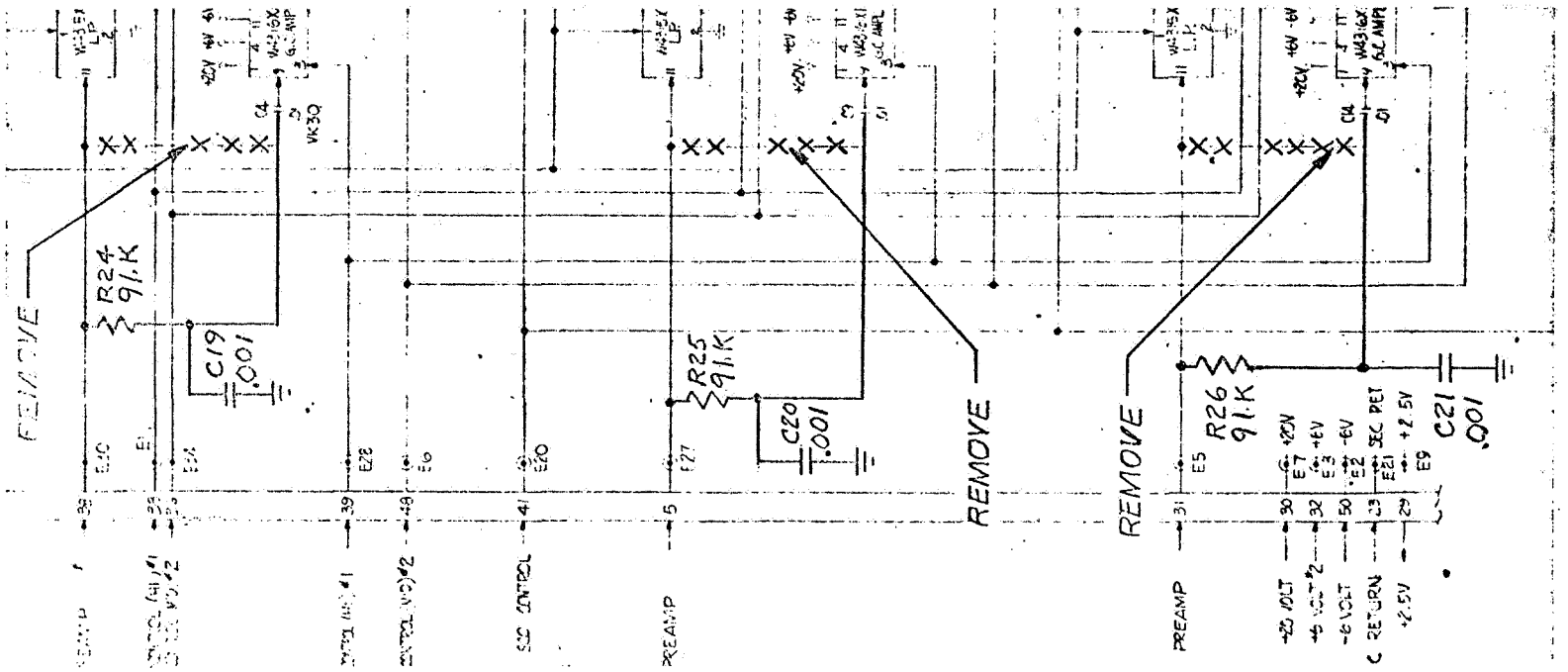
1 & UP

DESCRIBE CHANGE AND GIVE REASON:

REVISE DWG AS SHOWN BELOW & CHANGE REF DESIG BLOCK TO SHOW LATEST CONFIG.

ADD: R24, R25, R26 & C19, C20, C21

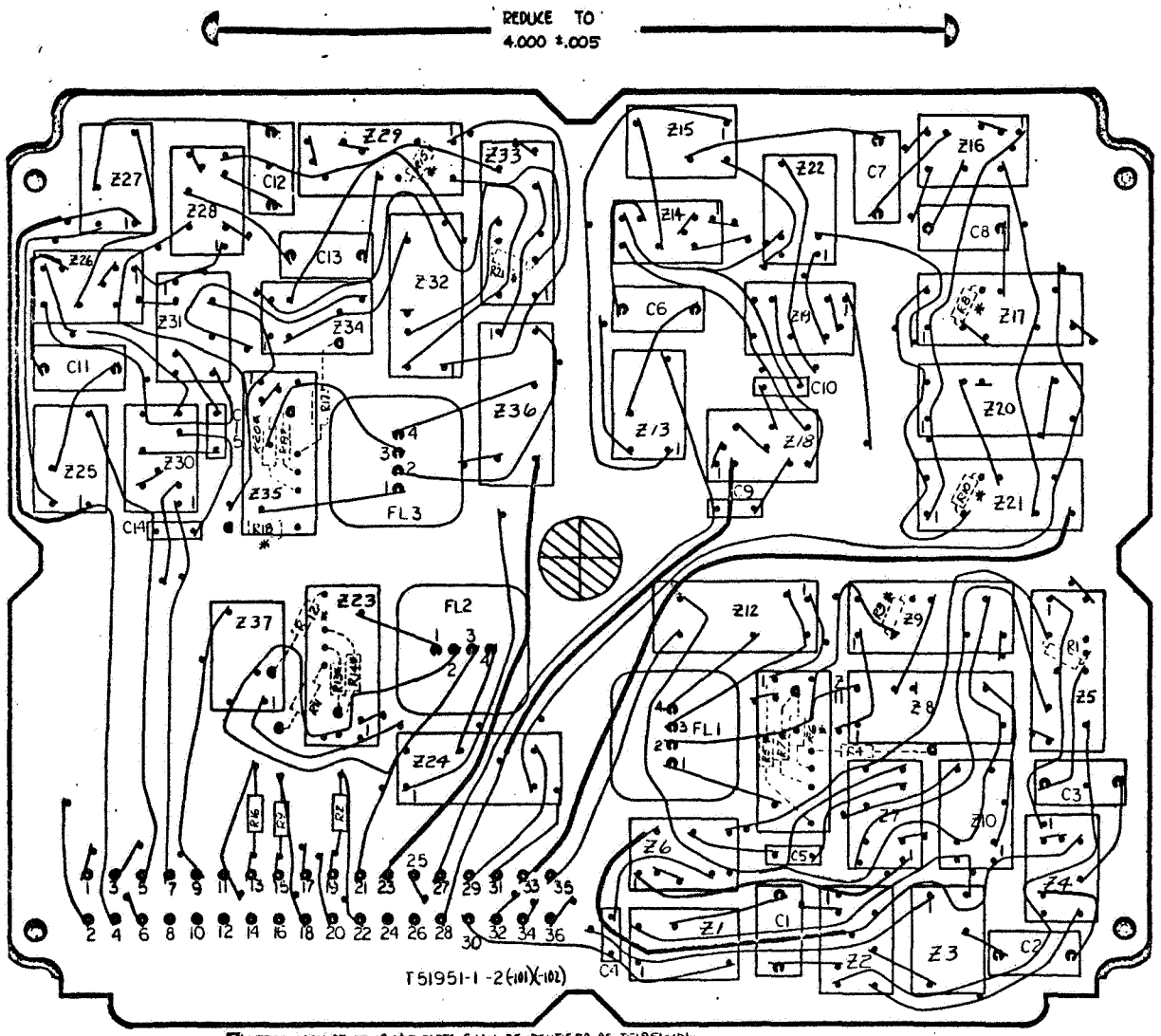
ZONE-5:



67-917

Figure 12-2

PART NO.	SPECIFICATION	DESCRIPTION	ELECT	CODE	ZONE



HOLE CHART			
SYMBOL	HOLE DIA	NE REQ'D	SPECIAL INSTRUCTIONS
•	.029		COMPONENT & MOD LEADS
•	.029		PUSH THRU WIRES
(7) ⊕	.029	36	-1 BOARD ONLY- FEEDTHRU WIRES
(7) ⊕	.067	36	-2 BOARD ONLY-TERMINAL PAD-SIDE
○	.136	4	BOARD MTG
⊕	.040	30	COMPONENT LEAD
(9) ⊕	.067	8	-1 BOARD ONLY-TERMINAL NEAR SIDE
(9) ⊕	.029	8	-2 BOARD ONLY-FEED THRU WIRES
⊕	.437	1	CENTER BOSS CLEARANCE
▬		AR	HOOKUP SLEEVING

(10) AFTER ASSY OF ITEMS 1 & 7 PARTS SHALL BE IDENTIFIED AS T51951-101.
(8) (9) INDICATES .067 DIA HOLE -1 BOARD & .029 DIA HOLE -2 BOARD
(8) AFTER ASSY OF ITEMS 2 & 8 PARTS SHALL BE IDENTIFIED AS T51951-102.
(9) INDICATES .029 DIA HOLE - 1 BOARD & .067 DIA HOLE -2 BOARD.

1. PROTECTIVE FINISH EMULSION SIDE OF -1 AND -2 BOARDS PER MARSHALL LABORATORIES PROCESS SPECIFICATION 84016 BEFORE TAKING BOARDS IN PUNCHING HOLES.
2. USING THE STABLE BASE PANCHROMATIC POSITIVE OBTAINED IN NOTE 1, REPRODUCE 1 POSITIONING BOARD ON .031 INCH THICK EPOXY GLASS BOARD PER MIL-P-18177, TYPE GEE SENSITIZED WITH DIRECT POSITIVE EMULSION.
4. USE -1 HOOK-UP BOARD GUIDE MYLAR SHALL BE FURNISHED TO PRODUCTION AND SHALL BE REPRODUCED ON 5 MIL INCH THICK SENSITISED MYLAR USING CLOSE REGISTER OF NEGATIVES OBTAINED IN NOTES 1 AND 3. (DOUBLE BURN SENSITISED MYLAR USE BROWN OR TAN TONES WITH RED APPEARING BROWN AND BLACK APPEARING BLACK.
5. PHOTO REDUCE .1 ARTWORK SUCH THAT NOTED REDUCTION DIMENSION SCALES 4.000 ± .005 INCHES (ONE REVERSE READING POSITIVE AND NEGATIVE) USING RED FILTER AND STABLE BASE PAN CHROMATIC FILM.
6. USING REDUCED STABLE BASE POSITIVE, REPRODUCE -1 HOOK-UP BOARD ON 5 MIL INCH THICK EPOXY GLASS BOARD PER MIL-P-18177, TYPE GEE SENSITIZED WITH DIRECT POSITIVE EMULSION.
7. PHOTO REDUCE -1 ARTWORK SUCH THAT NOTED REDUCTION DIMENSION SCALES 4.000 ± .005 INCHES (ONE REVERSE READING POSITIVE AND NEGATIVE) USING STABLE BASE FILM.

NOTES: UNLESS OTHERWISE SPECIFIED

	AR	AMS3654		TUBING
(10)	8	3650-037		TERMINAL LYN-TRON
REF	REF		MIL-P-18177	MAT'L SPEC TYPE GEE
REF	REF		S40396	PROTECTIVE FINISH SPEC FOR
(8) 36		3650-1		TERMINAL LYN-TRON
(8) 1		T51951-2		POSITION BOARD (.031)
(10) 1		T51951-1		HOOK-UP BOARD (.016)

	PART NO	SPECIFICATION	DESIGNATIVE OR DESCRIPTION
-102	T51899-1		T51899-101
-101	T51899-1		T51899-101

MARSHALL LABORATORIES
HOOK-UP & POSITIONING BOARD-
WAVEFORM OGO-E TRIAXIAL
S.C. MAGNETOMETER (E-1
13126 T51951

Figure 19

MARSH LABORATORIES
TORRANCE, CALIFORNIA
CODE IDENT NO. 13126

ENGINEERING ORDER

RELEASED NOV 10 1965

T51951	N/C	1573
DRAWING NUMBER	REV. LTR.	E. O. NO.

DWG TITLE: HOOKUP and POSITIONING BOARD - WAVEFORM 060-E TRIAXIAL S.C. MAGNETOMETER SHEET 1 OF 1

NEXT ASSEMBLY: 51899-1 MODEL: — EFFECTIVITY: 1 & UP MJO _____ DATE: 11-10-65

TYPE OF E.O.: ☒ CHANGE (ATTACH TO DRAWING) ☐ DRAWING REVISED ☐ OTHER (NOTED) ☐ EXPEDITED

TO ADD CAPACITORS TO HOOKUP BOARD & POSITIONING BOARD

ON HOOKUP BOARD REPLACE INTERCONNECTING RIBBON WITH CAP'S C16, C17, & C18 AS FOLLOWS:

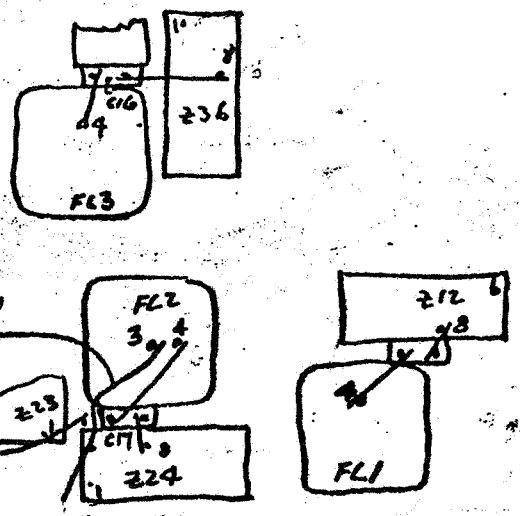


Figure 19-1

PRODUCTION NOTE: USE EXISTING BOARDS (HU/d Pos) BY DRILLING HOLES FOR CAPS

DISPOSITION OF PARTS/MTL	USE	REWORK	SCRAP	NOTED ABOVE
RAW MATERIAL		✓		
IN PROCESS		✓		
FINISHED				
ASSEMBLED				

REASON FOR CHANGE:
CIRCUIT COMPLIANCE REQUIREMENTS

		DATE
ORIG:		11-10-65
CHECK:		
STRESS:		
MTLS & PROCESS:		
WEIGHT:		
DESIGN ENG:		
RESP ENG:		11/11/65

ENGRG DWG LIST IS AFFECTED	YES	NO
DWG TO BE CHANGED	✓	

OTHER DWGS AFFECTED
51899, 51899, 51899-101

T51951 DRAWING NUMBER | 1573 E. O. NO.

67-917 Page 37

ML 157 5-120-6

MARSH LABORATORIES
TORRA[illegible], CALIFORNIA
CODE IDENT NO. 13126

NOV 17 1965

ENGINEERING ORDER

T51951	NC	1588
DRAWING NUMBER	REV. LTR.	E. O. NO.

DWG TITLE HOOKUP & POSITIONING BOARD WAVEFORM OGOE TRUNKAL S.C. SHEET 1 OF 1

NEXT ASSEMBLY: 51899-1 MODEL: — EFFECTIVITY: 14 SP MJO _____ DATE: 11-17-65

TYPE OF E.O.: ☒ CHANGE (ATTACH TO DRAWING) ☐ DRAWING REVISED ☐ OTHER (NOTED) ☐ EXPEDITED

MODULE PIN RELOCATION

1. ON HOOKUP BOARD -1 & POSITIONING BOARD -2 ADD HOLE FOR PIN 6 of Z12, Z24, & Z36. DELETE PIN 8.

PRODUCTION NOTE: PUNCH AND/OR DRILL NEW HOLE IN EXISTING BOARDS. REF EO 1587

67-917

Figure 19-2

DISPOSITION OF PARTS/MTL	USE	REWORK	SCRAP	NOTED ABOVE
RAW MATERIAL		✓		
IN PROCESS		✓		
FINISHED				
ASSEMBLED				

REASON FOR CHANGE: MODULE PIN ERROR

		DATE
ORIG:	[signature]	11-17-65
CHECK:		
STRESS:		
MTLS & PROCESS:		
WEIGHT:		
DESIGN ENG:		
RESP ENG:	[signature]	11/17/65

ENGRG DWG LIST ITS AFFECTED	YES	NO
DWG TO BE CHANGED	✓	
OTHER DWGS AFFECTED T58550, 51500, WDRY		

T61951 DRAWING NUMBER | 1588 E. O. NO.

Page 53

53 ML 157

5-120-B

MARSH LABORATORIES
TORRANCE, CALIFORNIA
CODE IDENT NO. 13126

RELEASED DEC 3 '65

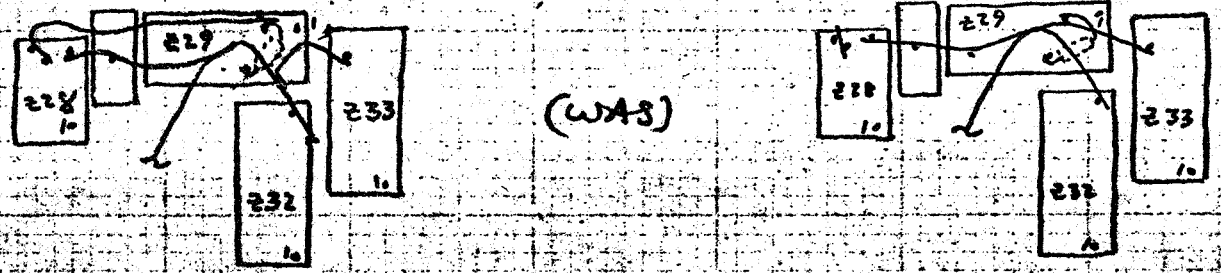
ENGINEERING ORDER

T51951	N/C	1602
DRAWING NUMBER	REV. LTR.	E. O. NO.

DWG TITLE HOOKUP & POSITIONING BOARD WIREFORM CKT E THRU 5 & SHEET 1 OF 1

NEXT ASSEMBLY: 51899-1 MODEL: — EFFECTIVITY: 1 & UP MJO DATE: 12-3-65

TYPE OF E.O.: ☒ CHANGE (ATTACH TO DRAWING) ☐ DRAWING REVISED ☐ OTHER (NOTED) ☐ EXPEDITED



NOTE: PIN 5 of Z29 WAS CONNECTED TO +6 V NOW CONNECTED TO +2.5
Z33 PIN 16 CONNECTS TO Z29 PIN 16 (WAS) Z29 PIN 16 & PIN 5
Z28 PIN 12 CONNECTS TO Z29 PIN 5 (ADDED)

Figure 19-3

67-917 Page 39

DISPOSITION OF PARTS/MTL	USE	REWORK	SCRAP	NOTED ABOVE
RAW MATERIAL				
IN PROCESS				
FINISHED		✓		
ASSEMBLED				

REASON FOR CHANGE: HOOK UP ERROR

		DATE
ORIG:		12-3-65
CHECK:		
STRESS:		
MTLS & PROCESS:		
WEIGHT:		
DESIGN ENG:		
RESP ENG:		12-3-65

	YES	NO
ENGRG DWG LIST IS AFFECTED		✓
DWG TO BE CHANGED	✓	

OTHER DWGS AFFECTED: NONE

T51951	1602
DRAWING NUMBER	E. O. NO.

MI 157

5-120-6

ENGINEERING ORDER

MARSHALL LABORATORIES
3530 TORRANCE BOULEVARD
TORRANCE, CALIFORNIA

DIST CODE 5-120 A

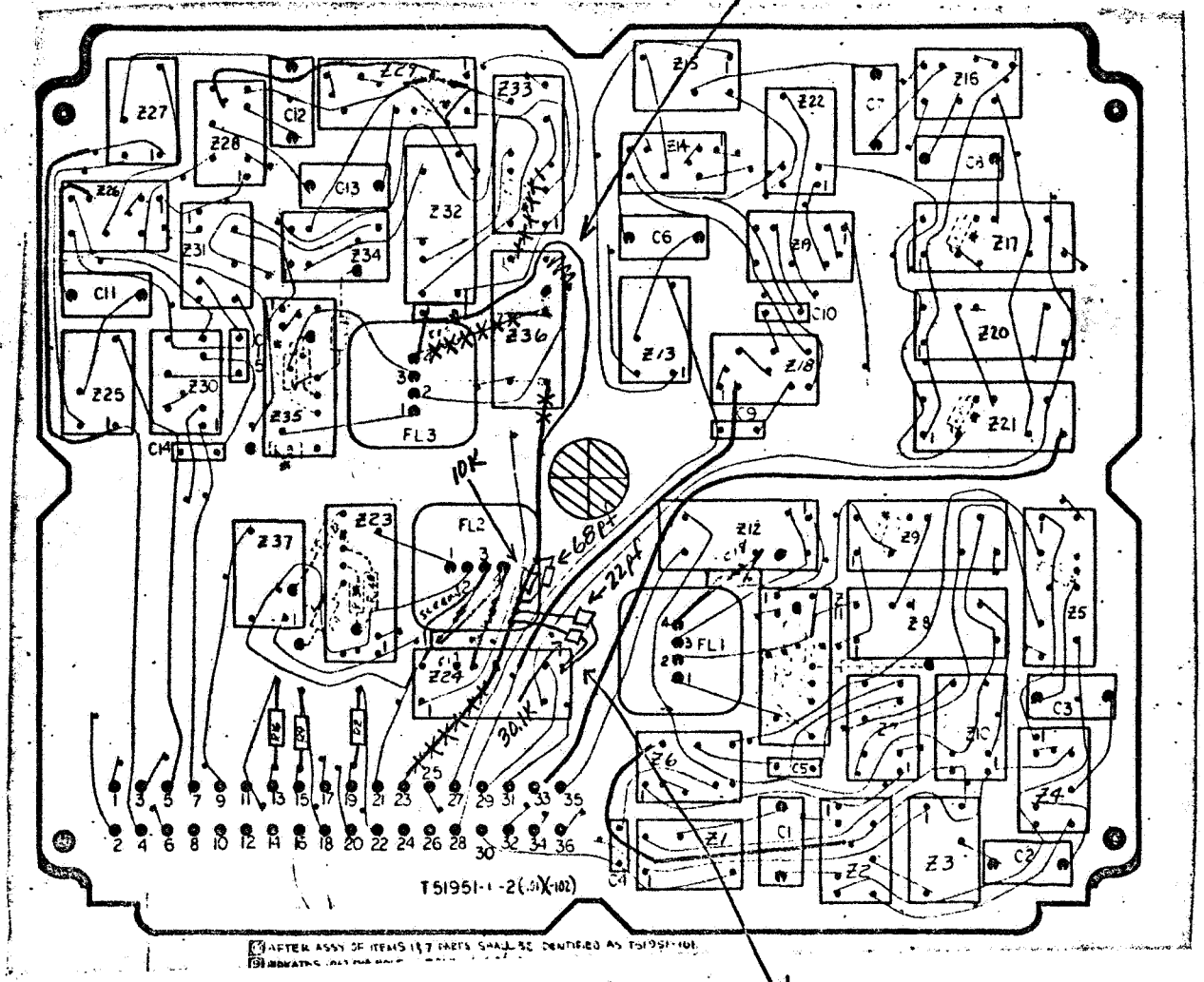
ML FORM RELEASED 3 1966

DRAWING TITLE HOOK-UP & POSITIONING BOARD — WAVEFORM OGO-E TRIAXIAL S.C. MAGN.

JOB NO.	CODE IDENT NO.	EO — T51951-NC1
5-129	13126	

TYPE OF EO	DISPOSITION OF PARTS			
☒ CHANGE	☐ USE	ORIG PODSKALAN DATE 8/22/66	NEXT ASSY	EFFECTIVITY
☐ VARIANCE	☐ REWORK	CHECK		
☐ SUPERCEDING	☐ SCRAP	ENGR	MODEL NO.	1 & UP
☐ NOTED	☐ NOTED BELOW	PM		
		APPR	OTHER DWG AFFECTED	
		CUSTOMER		

DESCRIBE CHANGE AND GIVE REASON:



* DENOTES MODIFICATION

ADD 10K RN55C
" 22pf CAP
" 68pf CAP
" 30.1K RN55C
plus RESPECTIVE HOOKUP

67-917 Page 10

Figure 19-4

QTY REQD PER NOTED ASSY	PART NO.	SPECIFICATION	DESCRIPTION	ELECT REF DES	CODE IDENT	ZONE

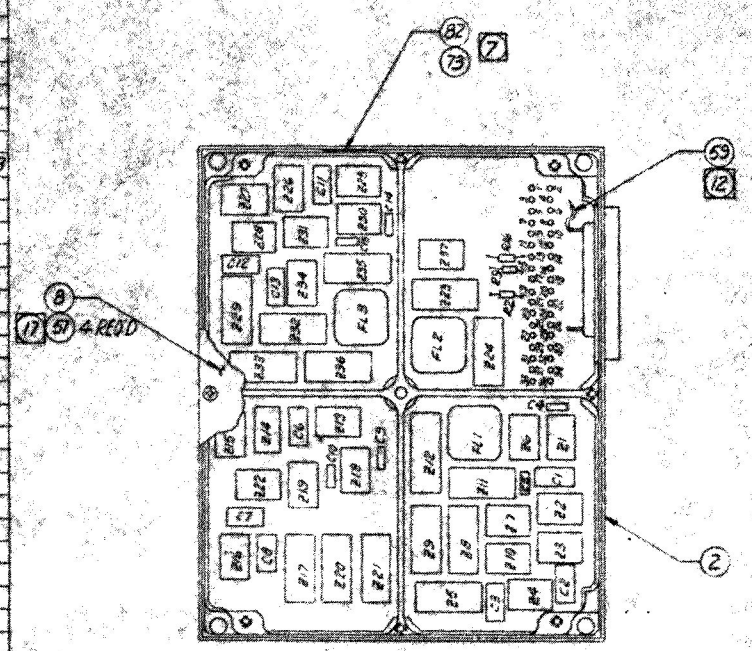
67-917

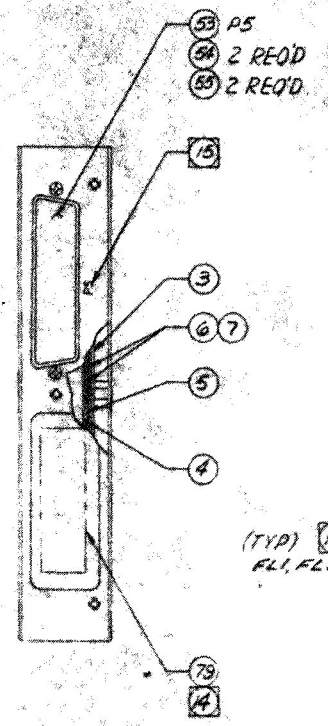
WIRING LIST

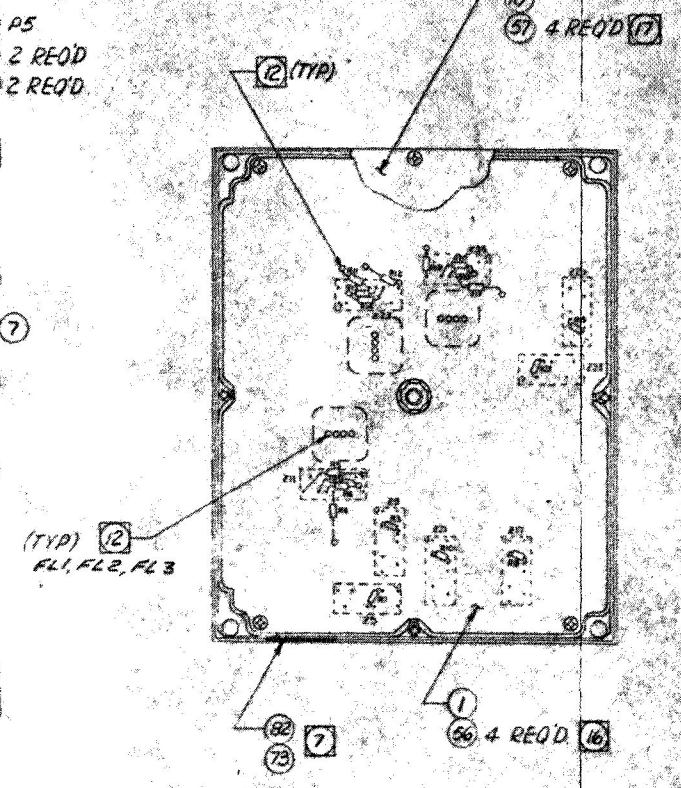
FROM	TO	FUNCTION	WIRE TYPE
P5-1		SPARE	
-2			
-3			
-4		SPARE	
-5	E27	Y-AXIS PREAMP	AWG28
-6		SPARE	
-7			
-8			
-9			
-10			
-11			
-12			
-13			
-14			
-15			
-16			
-17		SPARE	
-18	E33	Y-AXIS WIDEBAND	AWG28
-19	E31	X-AXIS WIDEBAND	
-20	E23	Y-AXIS SCO (52.5 KC)	
-21	E25	X-AXIS WAVEFORM	
-22	E23	Z-AXIS SCO (70 KC)	
-23	E21	SEC RETURN	
-24	E19	X-AXIS SPECTRUM T.P.	
-25	E17	Z-AXIS WAVEFORM	
-26	E15	Y-AXIS SPECTRUM T.P.	
-27	E13	Z-AXIS SPECTRUM T.P.	
-28	E11	Z-AXIS SPECTRUM	
-29	E9	+2.5 VOLT	
-30	E7	+20 VOLT	
-31	E5	Z-AXIS PREAMP	
-32	E3	+6 VOLT #2	
-33	E1	WAVEFORM GAIN CONTROL (HI) #1	
-34	E35	X-AXIS SCO (30 KC)	
-35	E36	Y-AXIS WAVEFORM	
-36	E34	WAVEFORM GAIN CONTROL (MID) #2	
-37	E32	Z-AXIS WIDEBAND	
-38	E30	X-AXIS PREAMP	
-39	E28	SPECTRUM GAIN CONTROL (HI) #1	
-40	E22	X-AXIS SPECTRUM	
-41	E20	SCO CONTROL	
-42	E18	Y-AXIS SPECTRUM	AWG28
-43		SPARE	
-44			
-45			
-46			
-47		SPARE	
-48	E6	SPECTRUM GAIN CONTROL (MID) #2	AWG28
-49	E4	BANDWIDTH CONTROL	AWG28
P5-50	E2	-6 VOLT	AWG28

WIRING LIST

FROM	TO	FUNCTION	WIRE TYPE
E8		SPARE	
E10		SPARE	
E11	R16	RESISTOR 1K	
E12		SPARE	
E13	R16	RESISTOR 1K	
E14		SPARE	
E15	R9	RESISTOR 1K	
E16		SPARE	
E18	R9	RESISTOR 1K	
E19	R2	RESISTOR 1K	
E22	R2	RESISTOR 1K	
E24		SPARE	
E26		SPARE	







18. TEST PER ML SPEC S40845.
17. TORQUE ITEM 57 TO 2.5 INCH LBS +0% -10%.
16. TORQUE ITEM 54 & 56 TO 4.0 INCH LBS +0% -10%.
15. MARKING: BLACK, APPROX AS SHOWN PER ML SPEC S4011, CLASS I, TYPE III.
14. MARKINGS: BLACK, APPROX AS SHOWN USING ITEM 79 PER ML SPEC S4011, CLASS I.
13. CORRELATE REF DESIGNATIONS TO COMPONENTS BY SEPARATE LIST OF MAT'L.
12. SOLDER PER ML SPEC S40126 & ALL TERMINALS AS SHOWN.
11. CONNECTOR TO BE SEALED PER ML SPEC S40093, CLASS III, TYPE I.
10. FOAM-IN-PLACE COMPONENT CAVITIES ONLY, PER ML SPEC S40092, CLASS I, TYPE I, CURE I, @ 170°F, 1 HOUR.
9. CONFORMAL COAT ITEM 1 PER ML SPEC S40091, CLASS I, TYPE I, @ 170°F.
8. SPOT POT (AS REQ'D) PER ML SPEC S40379, CLASS II, TYPE I.
7. BOND ITEM 82 INTO GROVE OF ITEM 2 AT APPROX 1.0 INCH INTERVALS, USING ITEM 73.
6. FILLET BOND ITEM 1 (HOOK-UP & POSITIONING BOARD SIDE) TO ITEM 2 PER ML SPEC S40149.
5. MANUFACTURE PER ML SPEC S40072
4. ASSEMBLE COMPONENTS TO MATRIX PER ML SPEC S40081.
3. USE ASSEMBLE JIG SR30253-9 FOR FAB & ASSY OF ITEMS 3,4,5,6 & 7 & BOND PER ML SPEC S40149.
2. FABRICATE ITEM 1 PER ML SPEC S40094
1. FOR SCHEMATIC REFER TO ML DWG 51900.

NOTES: UNLESS OTHERWISE SPECIFIED

SEE SEPARATE LIST OF MAT'L

Figure

PART NO	SPECIFICATION	NOMENCLATURE OR DESCRIPTION	ASSY USED ON	CODE IDENT	NEXT HIGH ASSY	ITEM NO
		LIST OF MATERIALS				

QTY REQD PER NOTED ASSY — CONFIGURATION — LAYOUT NO. — ASST CODE 51899

INTERPRET THIS DRAWING PER STANDARDS IN MIL-D-7032 — DIMENSIONS ARE IN INCHES — TOLERANCES ON DECIMALS X ± .2, XX ± .03, XXX ± .010 — ANGLES ± 0° 30' — XXXX ± .0050 — SURFACE ROUGHNESS — HOLE DIA / TOLERANCE

CONTRACT NO. 5-120 — DRAWN Brady 9/28/65 — CHECKED — ENGR APPR — REL DATE — PROJ APPR — MFG APPR — DESIGN ACTIVITY APPR 9/28/65 — CUSTOMER APPR

-101		51731-101	MR254-1	51832-101	MR255-1
DASH NO.	MODEL NO.	NEXT ASSEMBLY	MODEL NO.	FINAL ASSEMBLY	MODEL NO.

APPLICATION

MARSHALL LABORATORIES, TORRANCE, CALIFORNIA

TITLE: WAVEFORM ASSY - TRIAXIAL SEARCH COIL MASM EXP (E-16).

SIZE F — CODE IDENT NO. 13126 — DWG NO. 51899 — REV

SCALE 1/1 — RELEASED — SHEET 1 OF 1

51899

MARSH LABORATORIES
TORRANCE, CALIFORNIA
CODE IDENT NO. 13126

ENGINEERING ORDER

RELEASED NOV 10 1965

51899	N/C	1574
DRAWING NUMBER	REV. LTR.	E. O. NO.

DWG TITLE WAVEFORM ASSY - TRIAXIAL SEARCH COIL MARK EXP E-16 SHEET 1 OF 1

NEXT ASSEMBLY: 51731-101 MODEL: — EFFECTIVITY: 18UP MJO _____ DATE: 11-10-65

TYPE OF E.O.: ☑ CHANGE (ATTACH TO DRAWING) ☐ DRAWING REVISED ☐ OTHER (NOTED) ☐ EXPEDITED

ADD CAPS C16, C17, & C18 TO POSITIONING BOARD SIDE OF ASSEMBLY.

IN ZONE C/4-5 ADD PICTURE of CAPACITORS & MODULES

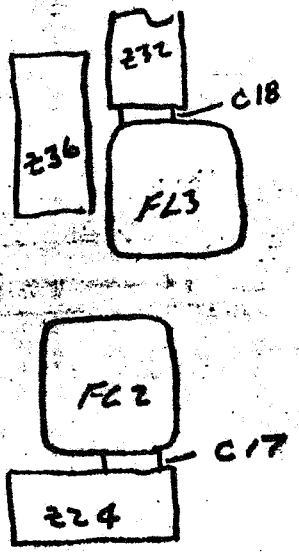


Figure 20-1

PRODUCTION NOTE: SLEEVE LEADS of CAPACITORS UPON ASSEMBLY

DISPOSITION OF PARTS/MTL	USE	REWORK	SCRAP	NOTED ABOVE
RAW MATERIAL	✓			
IN PROCESS	✓			
FINISHED				
ASSEMBLED				

REASON FOR CHANGE:
TO ADD CAPACITORS FOR CIRCUIT COMPLIANCE

		DATE
ORIG:	[signature]	11/10/65
CHECK:	[signature]	
STRESS:		
MTLS & PROCESS:		
WEIGHT:		
DESIGN ENG:		
REQR ENG:	[signature]	11/10/65

ENGRG DWG LIST IS AFFECTED	YES	NO
DWG TO BE CHANGED	✓	

OTHER DWGS AFFECTED
57900, T51951, 51895-A1

51899	1574
DRAWING NUMBER	E. O. NO.

67-911

Page 42

ML 157

5-120-8

RELEASED JAN 18 1966

MARSH LABORATORIES
TORRANCE, CALIFORNIA
CODE IDENT NO. 13126

ENGINEERING ORDER

51899	N/C	1666
DRAWING NUMBER	REV. LTR.	E. O. NO.

DWG TITLE WAVEFORM ASSY - TRIAXIAL SELECT CKT (MOD) SHEET 1 OF 1

NEXT ASSEMBLY: 51731-001 MODEL: — EFFECTIVITY: SN 2 INCL MJO DATE: 1-18-66

TYPE OF E.O.: ☐ CHANGE (ATTACH TO DRAWING) ☐ DRAWING REVISED ☐ OTHER (NOTED) ☐ EXPEDITED

VARIANCE EO SN 2 ONLY

CAPACITORS C16, C17, C18 TO BE SOLDERED ON SN 2 INLIEU OF WELDED

67-917

Figure 20-2

DISPOSITION OF PARTS/MTL	USE	REWORK	SCRAP	NOTED ABOVE
RAW MATERIAL				
IN PROCESS	✓			
FINISHED				
ASSEMBLED				

REASON FOR CHANGE:
WELD SCHEDULE NOT AVAILABLE DUE TO VENDOR MATL CHANGE

		DATE
ORIG:	H Saunders	1-18-66
CHECK:		
STRESS:		
MTLS & PROCESS:		
WEIGHT:		
DESIGN ENG:		
RESP ENG:	H Saunders	1-18-66

ENGRG DWG LIST IS AFFECTED	YES	NO
		✓
DWG TO BE CHANGED		
OTHER DWGS AFFECTED: NONE		

51899	1666
DRAWING NUMBER	E. O. NO.

Page 43

5-120-1

ML 157

ENGINEERING ORDER

3530 TORRANCE BOULEVARD
TORRANCE, CALIFORNIA

DIST CODE A

NEL FORM 1966

DRAWING TITLE	JOB NO.	CODE IDENT NO.	EO
WAVEFORM ASSY - TRIAXIAL SEARCH COIL MAGN. EXP. (E-16)	5-129	13126	EO — 51899-NC 1

TYPE OF EO	DISPOSITION OF PARTS			EFFECTIVITY
☒ CHANGE	☐ USE	ORIG PODSKALAN DATE 8/22/66	NEXT ASSY 51731-101	1 & UP
☐ VARIANCE	☐ REWORK	CHECK		
☐ SUPERCEDING	☐ SCRAP	ENGR	MODEL NO.	
☐ NOTED	☐ NOTED BELOW	PM [signature] 11/11/66		
		APPR [signature]	OTHER DWG AFFECTED	
		CUSTOMER		

DESCRIBE CHANGE AND GIVE REASON:

REMOVE Z36

67-917 Page 44

Figure 20-3

QTY REQD PER NOTED ASSY	PART NO.	SPECIFICATION	DESCRIPTION	ELECT REF DES	CODE IDENT	ZONE

ENGINEERING ORDER

MARSHALL LABORATORIES
3530 TORRANCE BOULEVARD
TORRANCE, CALIFORNIA

DIST 5-120
CODE B

APR 17 1967

DRAWING TITLE	JOB NO.	CODE IDENT NO.	EO
WAVEFORM ASSEMBLY - TRIAXIAL SEARCH COIL MAGN. (EXP. E-16)	5-129	13126	EO - 51899 - NC3

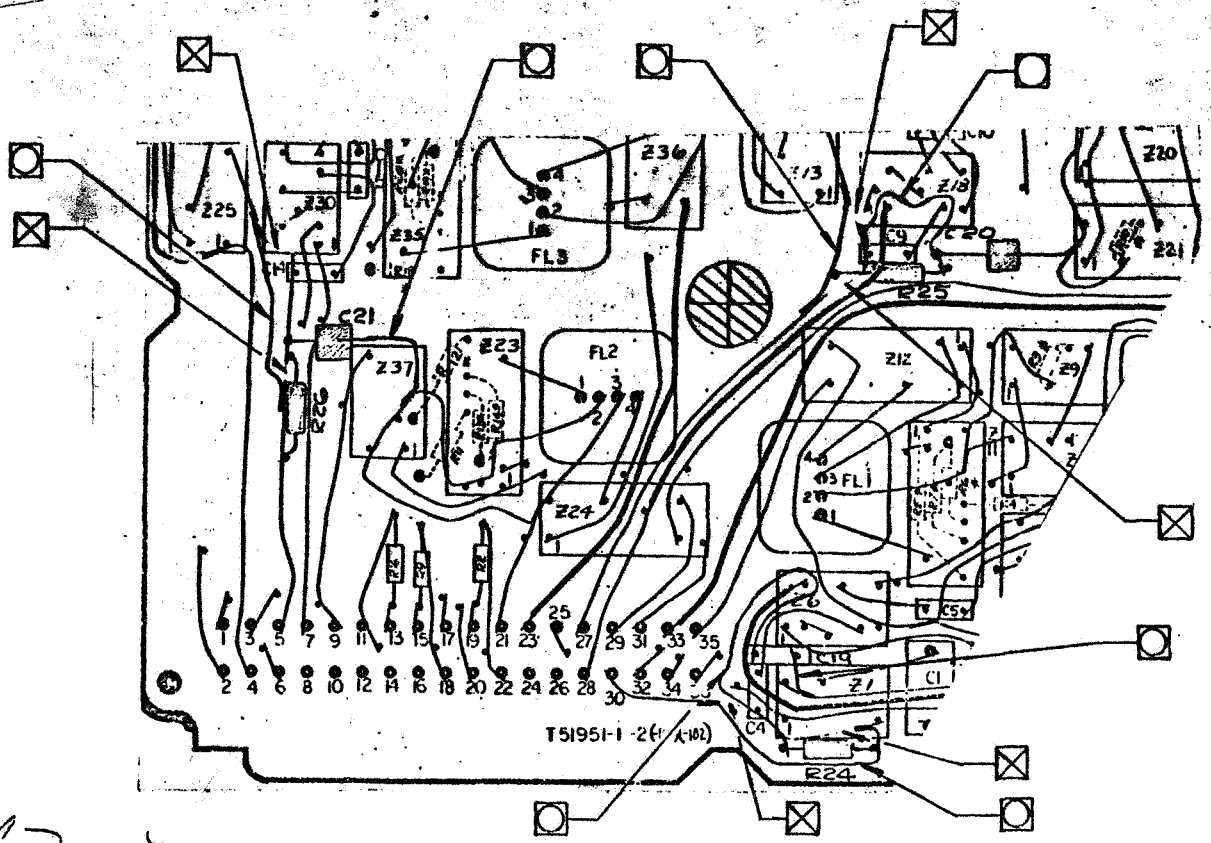
TYPE OF EO	DISPOSITION OF PARTS			
☒ CHANGE	☐ USE	ORIG R Q Mabuchi	DATE 17 Apr 67	NEXT ASSY 51731-101
☐ VARIANCE	☒ REWORK	CHECK	17 APR 67	EFFECTIVITY
☐ SUPERCEDING	☐ SCRAP	ENGR	17 APR 67	MODEL MC294-1
☐ NOTED	☐ NOTED BELOW	PM	17 APR 67	SN 1 & UP
		APPR		OTHER DWG AFFECTED 51900 T51950 & T51951
		CUSTOMER		

DESCRIBE CHANGE AND GIVE REASON: REVISE BY ADDING RESISTORS (R24, R25, R26) & CAPACITORS (C19, C20, C21) - CUT & ADD RIBBON AS SHOWN - USE INSULATIVE TUBING PER AMS3654 AS REQ'D.

CODE

☒ DENOTES RIBBON TO BE CUT.

☐ DENOTES RIBBON ADDED.



THIS E.O. SUPERSEDES E.O. 51899 - N/C 2 IN ITS ENTIRETY

67-917

Figure 20-4

Page 45

ADD TO 4/M

3	SP30275-102	CAPACITOR	(.001 MFD)	KING	C19, C20, C21		
3	RC05GF913J	RESISTOR	(91K ±5%)	MIL-R-11	R24, R25, R26		
-1	PART NO.	SPECIFICATION		DESCRIPTION	ELECT REF DES	CODE IDENT	ZONE

(DBM-35P-NMC-1-A106)

X-AXIS SPECTRUM

Y-AXIS SPECTRUM

Z-AXIS SPECTRUM

PG (CONT)

E25 E16 E12

+20V +6V +2.6V -6V

W429X7 B.P.AMPL 1000

W429X6 B.P.AMPL 470

W429X5 B.P.AMPL 220

W429X4 B.P.AMPL 100

W429X3 B.P.AMPL 47

W429X2 B.P.AMPL 22

W429X1 B.P.AMPL 10

W429BX2 DETECTOR

W429BX1 DETECTOR

W430DX1 COMMUTATOR

E15 E30 E45

E5 E1 E2 E20 E19

E17 E22

E7 E10

E6 E8

E13 E18 E9 E21 E11 E4 E3

E23 E24 E25 E26 E27 E28 E29

E31 E32 E33 E34 E35 E36 E37

E38 E39 E40 E41 E42 E43 E44

SPARES

NC

E26 E45 HIGHEST FREQ. DECOMMUTATOR LOCK

PG (CONT)

25	E26	COMMUTATOR CONTROL, 10 CPS
8	E27	22
9	E28	47
23	E29	100
24	E210	220
13	E211	470
7	E212	COMMUTATOR CONTROL, 1000 CPS
19		X-AXIS WAVE ANALYZER
22	E7	Y-AXIS WAVE ANALYZER
9	E10	Z AXIS WAVE ANALYZER

+20 VOLT	18	E13 +20V
SEC RET	20	E18 SEC RET
+6 VOLT #1	21	E9 +6V COMMUTATOR & W430I
-6 VOLT	11	E6 -6V
+2.6 VOLT	6	E21 +2.6V
+6V #2	10	E8 +6V TO B.P. AMPL

+6V → W430CX1 +2.6V REG. → +2.6V

2. FOR TEST SPEC SEE MIL S 40846
1. FOR ASSEMBLY DWG. SEE 51901

NOTES: UNLESS OTHERWISE SPECIFIED

Fisure 21

MARSHALL LABORATORIES

WAVE ANALYZER BLIVET SPECTRUM-INTERCONNECT SCHEMATIC DIAG. 960 F TRIAXIAL S.C. MAGNETOMETER

E 13126 51902

21605

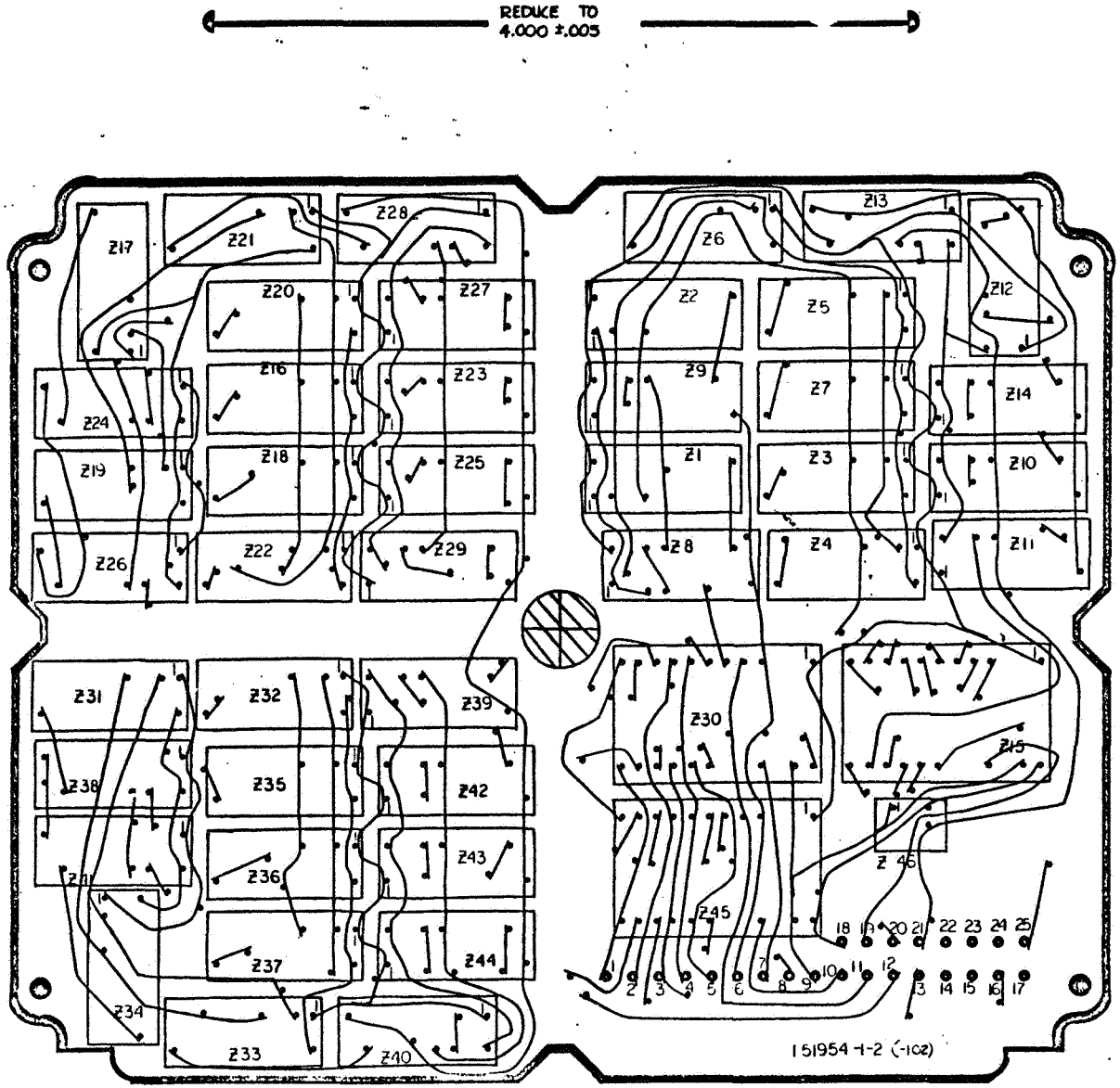


Figure 22

HOLE CHART			
SYMBOL	HOLE DIA	NO. HOLE	SPECIAL INSTRUCTION
•	.029		MODULE LEADS
•	.029		PUSH THRU WIRES
•	.029		-1 BOARD ONLY, FEED THRU WIRES
⊙	.067	25	-2 BOARD ONLY, TERMINAL INSIDE
○	.136	4	BOARD MOUNTS
⊘	.437	1	CLEARANCE CENTER BOSS

REF		MIL-P-18177	MAT'L SPEC GLASS EPOXY BD
REF		540396	PROTECTIVE FINISH SPEC FOR
25	3650-1		TERMINAL LYN-TRON
1	T51954-2		POSITIONING BD (.031)
	T51954-1		HOOK-UP BOARD (.016)

-102

-1	S1981-1		S1901-111
-2	S1981-1		S1901-111

APPLICABLE

HOOK-UP & POSITIONING BD-WAVE ANALYZER-SPECTRUM-060-E TRANSL S.C. MAGNETOMETER (E-16)

MAS 13126 T51954

1. AFTER ASSY OF ITEMS 2 & 3 PARTS SHALL BE GUNNED AS TO ITEM 4 (-2)
2. INDICATES .029 DIA HOLE -1 BOARD & .067 DIA HOLE -2 BOARD
3. PROTECTIVE FINISH EMULSION SIDE OF -1 AND -2 BOARDS PER MARSHALL LABORATORIES PROCESS SPECIFICATION 540396 BEFORE TRIMMING BOARDS OR PUNCHING HOLES.
4. ONE -1 HOOK-UP BOARD GUIDE MYLAR SHALL BE 2 UP MINIMUM TO PRODUCTION AND SHALL BE REPRODUCED ON 0.007 INCH THICK SENSITIZED MYLAR USING CLOSE REGISTER OF NEGATIVES OBTAINED IN NOTES 1 AND 2. DOUBLE BURN SENSITIZED MYLAR FOR BROWN ON TWO TIMES WITH RED APPEARING BROWN AND BLACK APPEARING BLACK.
5. PHOTO REDUCE -1 ARTWORK SUCH THAT NOTED REDUCTION DIMENSION SCALES 1.000 ± .005 INCHES (ONE REVERSE READING POSITIVE AND NEGATIVE) USING RED FILTER AND STABLE BASE PAN CHROMATIC FILM.
6. USING REDUCED STABLE BASE POSITIVE REPRODUCE -1 HOOK-UP BOARD ON 0.016 INCH THICK EPOXY GLASS BOARD PER MIL-P-18177, TYPE GEE SENSITIZED WITH DIRECT POSITIVE EMULSION.
7. PHOTO REDUCE -1 ARTWORK SUCH THAT NOTED REDUCTION DIMENSION SCALES 1.000 ± .001 INCHES (ONE REVERSE READING POSITIVE AND NEGATIVE) USING STABLE BASE FILM.
8. THE STABLE BASE PANCHROMATIC POSITIVE OBTAINED IN NOTE 5, BE [illegible] 2 PRINTMASTER BOARD ON .031 INCH THICK EPOXY GLASS BOARD PER MIL-P-18177, TYPE GEE SENSITIZED WITH DIRECT POSITIVE EMULSION.

DDM-50P-WMC-1-410G

P4

P4 (CONT.)

WAVEFORM GAIN I.C.

SPECTRUM GAIN I.C.

IFC ON/OFF I.C.

+23.5V (TO E53)

23.5V RET. (TO E52)

WA308X1 150 24 AMPL. 23

WA296X1 F/F-A

WA296X1 F/F-B

WA296X1 F/F-C

WA296X1 F/F-D

WA296X1 F/F-E

WA296X1 F/F-F

WA296X1 F/F-G

WA296X1 F/F-H

WA296X1 F/F-J

WA296X1 F/F-K

WA296X1 F/F-L

WA303X1 DUAL AND

WA307X1 STATUS LOGIC

WA306X1 T.S. GATE

WA306X1 B.R. INTFC.

WA305X1 B.R. LOGIC

WA308X1 I.P GATE

WA307X1 SCO DET.

WA295X1 ±20V REG.

WA294X1 +6V REG.

WA294X1 +6V REG.

WA294X1 -6V REG.

WA289X1 INPUT REG.

WA289X1 CHOPPER

WA289X1 SYNC AMP.

WA292X1 OUTPUT XFMR

WA307X1 I.F.C. ATTEN.

WA295X1 -6V REG.

WA295X1 COMM. GATING

WA292X1 CLOCK XFMR

WA292X1 SYNC XFMR

Q1 2854-3

Q2 2854-3

T1 SP30332

T2 SP30333

T3 SP30334

222 PPS TIMING SIG.

13.9 PPS TIMING SIG.

0.87 PPS TIMING SIG.

BT RATE SIGNAL

MODE SIGNAL

SWITCH SIGNAL

EQ. GR 1 INDEX P. 26

EQ. GR 2 INDEX P. 26

EXT. INDEX PULSE

I.P. RESET & PRESET

SPEC. PURPOSE PC SCO ON-OFF

28 VOLT POWER

28 VOLT RETURN

NC

NC

NC

SYNC SIGNAL 'A'

SYNC SIGNAL CT

SYNC SIGNAL 'B'

WAVEFORM GAIN CONTROL NO 2

WAVEFORM GAIN CONTROL NO 1

SPECTRUM GAIN CONTROL NO 1

SPECTRUM GAIN CONTROL NO 2

WAVEFORM & SPECTRUM GAIN STATUS

BANDWIDTH & IFC STATUS

WAVE ANALYZER STATUS

POWER & SCO STATUS

SPARE

IFC SIGNAL

SPARE

BANDWIDTH CONTROL

(100KB)

COMMUTATOR GATE CONTROL

SCO CONTROL

23.5 VOLT RET.

23.5 VOLT

20 VOLT

20 VOLT

20 VOLT

SEC RET.

SEC. RET.

PREAMP RET.

HEATER RET.

T/M SIGNAL RET.

SEC. RET.

+6 VOLT #2

+6 VOLT #2

(+) 6 VOLT #1

(-) 6 VOLT

(-) 6 VOLT

CONVERTER T.P.

CONVERTER T.P. RET.

Z32	J2	P3
E4	P2	P2
C2	E37	P1 J1
LAST	REF.	DES. NOT
NOT USED		USED

NOTES: UNLESS OTHERWISE SPECIFIED.

9. EG1 & E83 CHASSIS GROUND LUGS.

Figure 24

MARSHALL LABORATORIES

SCHEMATIC DIAGRAM - POWER SUPPLY & CONTROL BOARD, TERMINAL SUBSYS. CONT. ASSY. (EVA E-6)

E 13126 51898 C

5-120-B

REV 10615 ON DWG

PARTS DISPOSITION: 1. USE, 2. REWORK, 3. CANNOT BE REWORKED, 4. RECORD — DWG NO. 51901 REV

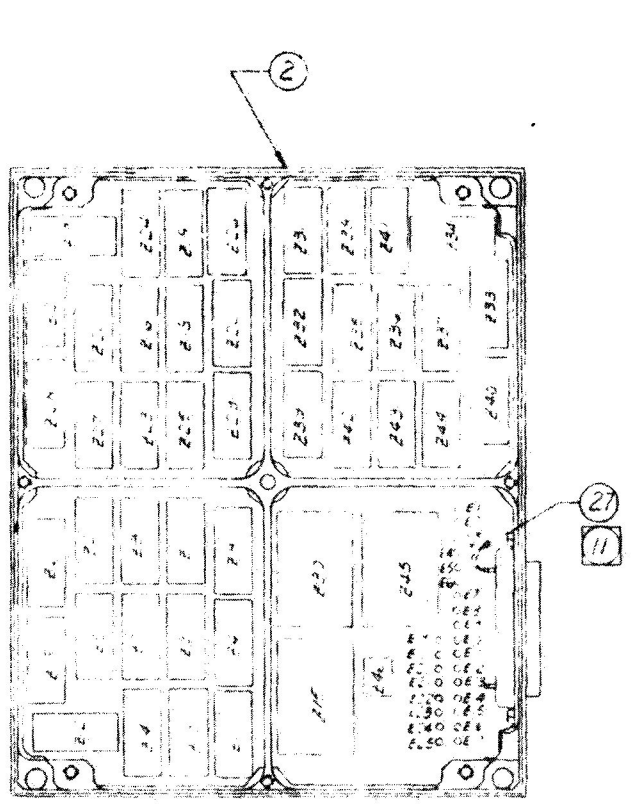
REVISIONS

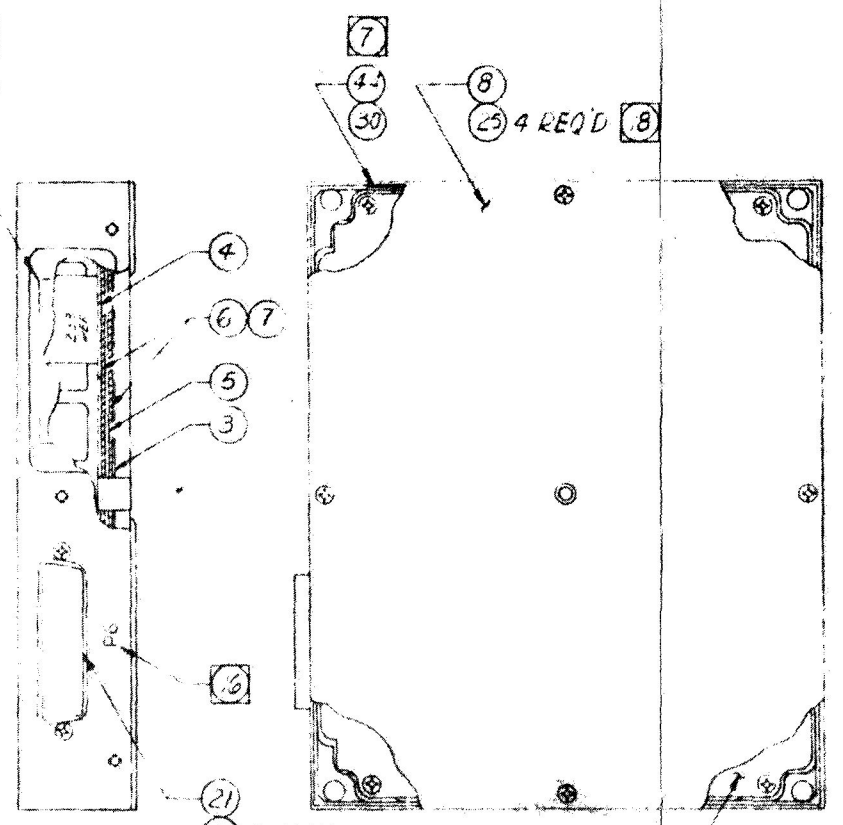
DISP	EFF	ZONE	REV	DESCRIPTION	BY	CK	DATE	APPROVAL

67-917

WIRING LIST

FROM	TO	FUNCTION	WIRE TYPE
PG-1	E25	X-AXIS SPECTRUM	A.I. - 5
-2	E12	Z-AXIS SPECTRUM	A.I. - 9
-3		SPARE	
-4		SPARE	
-5		SPARE	
-6	E21	+2.6 VOLT	A.I. - 7
-7	E20	COMMUNITATOR CONTROL, 1000 CPS	
-8	E11	COMMUNITATOR CONTROL 22 CPS	
-9	E10	Z-AXIS WAVE ANALYZER	
-10	E8	+6 VOLT #2 (SPARE)	
-11	E6	-6 VOLT	
-12	E4	COMMUNITATOR CONTROL 47 CPS	
-13	E2	COMMUNITATOR CONTROL, 470 CPS	
-14	E16	Y-AXIS SPECTRUM	A.I. - 3
-15		SPARE	
-16		SPARE	
-17		SPARE	
-18	E13	+20 VOLT	A.I. - 2
-19	E19	X-AXIS WAVE ANALYZER	
-20	E18	SEC RETURN	
-21	E9	+6 VOLT #1 (COMMUNITATOR & REG)	
-22	E7	Y-AXIS WAVE ANALYZER	
-23	E5	COMMUNITATOR CONTROL, 10 CPS	
-24	E3	COMMUNITATOR CONTROL, 220 CPS	
PG-25	E1	COMMUNITATOR CONTROL 100 CPS	A.I. - 1
E14		SPARE	
E15			
E17			
E22			
E23			
E24		SPARE	





18. TORQUE ITEM 25 TO 2.5 INCH LBS +0% -10%.
17. TEST PER ML SPEC. S40846
16. MARKINGS: BLACK, APPROX. AS SHOWN PER MIL SPEC S40111 CLASS I TYPE II
15. MARKINGS: BLACK, APPROX. AS SHOWN USING ITEM 41 PER MIL SPEC S40111 CLASS I.
14. CORRELATE REF DESIGNATIONS TO COMPONENTS BY SEPARATE LIST OF MAT'L.
13. TORQUE ITEM 24 TO 4.0 INCH LBS +0% -10%.
12. CONNECTOR TO BE SEALED PER ML SPEC S40093, CLASS II, TYPE I.
11. SOLDER PER ML SPEC S40126.
10. FOAM-IN-PLACE COMPONENT CAVITIES ONLY, PER ML SPEC S40092, CLASS I, TYPE I, CURE 4 @ 170°F, 1 HOUR.
9. CONFORMAL COAT ITEM 1 PER ML SPEC S40091, CLASS I, TYPE I @ 170°F.
8. SPOT POT (AS REQ'D) PER ML SPEC S40379, CLASS II, TYPE I.
7. BOND ITEM 44 INTO GROOVE OF ITEM 1 AT APPROX. 1.0 IN. INTERVALS, USING ITEM 30.
6. FILLET BOND ITEM 1 (HOOK-UP & POSITIONING SIDE) TO ITEM 2 PER ML SPEC S40149.
MANUFACTURE PER ML SPEC S40072.
4. ASSEMBLE COMPONENTS TO MATRIX PER ML SPEC S40081.
3. USE ASSEMBLY JIG SP30253-9 FOR FAB & ASSY OF ITEMS 3, 4, 5, 6, & 7 & BOND PER ML SPEC S40149.
2. FABRICATE ITEM 1 PER ML SPEC S40094.
1. FOR SCHEMATIC REFER TO ML DWG 51902.

NOTES: UNLESS OTHERWISE SPECIFIED

SEE SEPARATE LIST MAT'L

Figure 23

PART NO.	SPECIFICATION	NOMENCLATURE OR DESCRIPTION	ELEC REF DES	CODE IDENT	ZONE	ITEM NO.

LIST OF MATERIALS

DASH NO.	MODEL NO.	NEXT ASSEMBLY	MODEL NO.	FINAL ASSEMBLY	MODEL NO.
-101		51731-101	ML2941	51996-101	ML2951

APPLICATION

QTY REQD PER NOTED ASSY
CONFIGURATION
LAYOUT NO.
DIST CODE 5-12-19

INTERPRET THIS DRAWING PER STANDARDS IN MIL-D-70327
DIMENSIONS ARE IN INCHES
TOLERANCES ON DECIMALS: X ± 1, XX ± 03, XXX ± 010; ANGLES ± 0° 30'
SURFACE ROUGHNESS

HOLE DIA.	TOLERANCE
0125 THRU 125	+ 004 - 001
126 THRU 250	+ 005 - 001
251 THRU 500	+ 006 - 001
501 THRU 750	+ 008 - 001
751 THRU 1.000	+ 010 - 001
1.001 THRU 2.000	+ 012 - 001
2.001 AND OVER LINEAR	

CONTRACT NO. 5-120
DRAWN F. Hadley 4-6-
CHECK [illegible] 4-6-
MECH ENG [illegible] 4-6-
ELEC ENG
PROJ ENGR
APPR
DESIGN ACTIVITY APPD
CUSTOMER

MARSHALL LABORATORIES
TORRANCE, CALIFORNIA

TITLE: SPECTRUM ASSY- TRIAXIAL SEARCH COIL MAGN. 000-E (EXP. E-16)

SIZE D | CODE IDENT NO. 13126 | DWG NO. 51901 | REV

SCALE 1/1 | RELEASED | SHEET 1 OF 1

5-120-A

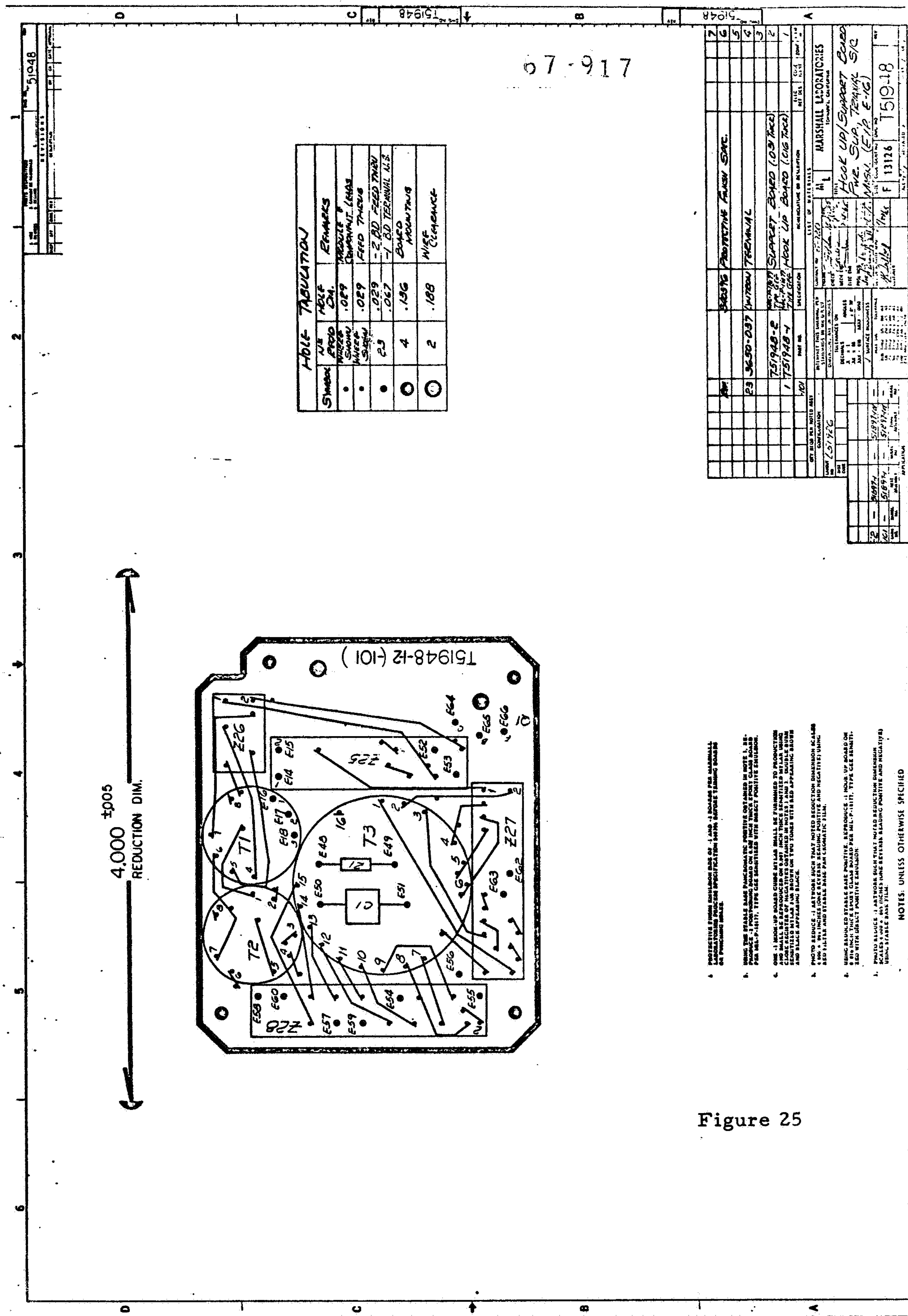

67-917
HOLE TABULATION
T51948-12 (-101)
4,000 ±.005
REDUCTION DIM.
MARSHALL LABORATORIES
T51948
NOTES, UNLESS OTHERWISE SPECIFIED

Figure 25

MARSH LABORATORIES
TORRANCE, CALIFORNIA
CODE IDENT NO. 13113

RELEASED JAN 11 1966

ENGINEERING ORDER

T51948	N/C	1651
DRAWING NUMBER	REV. LTR.	E. O. NO.

DWG TITLE HOOKUP/SUPPORT BOARD PWR SUP, TRIAXIAL S/C HARN SHEET 1 OF 1

NEXT ASSEMBLY: 51897-1 MODEL: — EFFECTIVITY: 12UP MJO _____ DATE: 1-7-66

TYPE OF E.O.: ☒ CHANGE (ATTACH TO DRAWING) ☐ DRAWING REVISED ☐ OTHER (NOTED) ☐ EXPEDITED

1. DELETE HOOKUP HARNESS FROM T3-1 TO Z27-30 & T3-3 TO Z27-23. (MODULE PINS TO BE LEFT LONG)

2. INSTALL CAPACITOR C2 BETWEEN Z27-23 & Z27-30

3. ADD NOTE TO DWG (* USE NEXT AVAILABLE NOTE NO.)

* 2 CONDUCTOR TWISTED SHIELDED WIRE TO BE SOLDERED FROM T3-1 TO Z27-30 & T3-3 TO Z27-23. SHIELD TO BE TERMINATED ON TERMINAL E67 LOCATED ON 51897-2 ASSY.

Figure 25-1

67-917

DISPOSITION OF PARTS/MTL	USE	REWORK	SCRAP	NOTED ABOVE
RAW MATERIAL				
IN PROCESS		✓		
FINISHED				
ASSEMBLED				

REASON FOR CHANGE: NOISE REDUCTION

		DATE
ORIG: R Landon	1/6	1/6
CHECK:		
STRESS:		
MTLS & PROCESS:		
WEIGHT:		
DESIGN ENG:		
RESP ENG: R Kitamura		1/11/66

R Landon 1-11-66

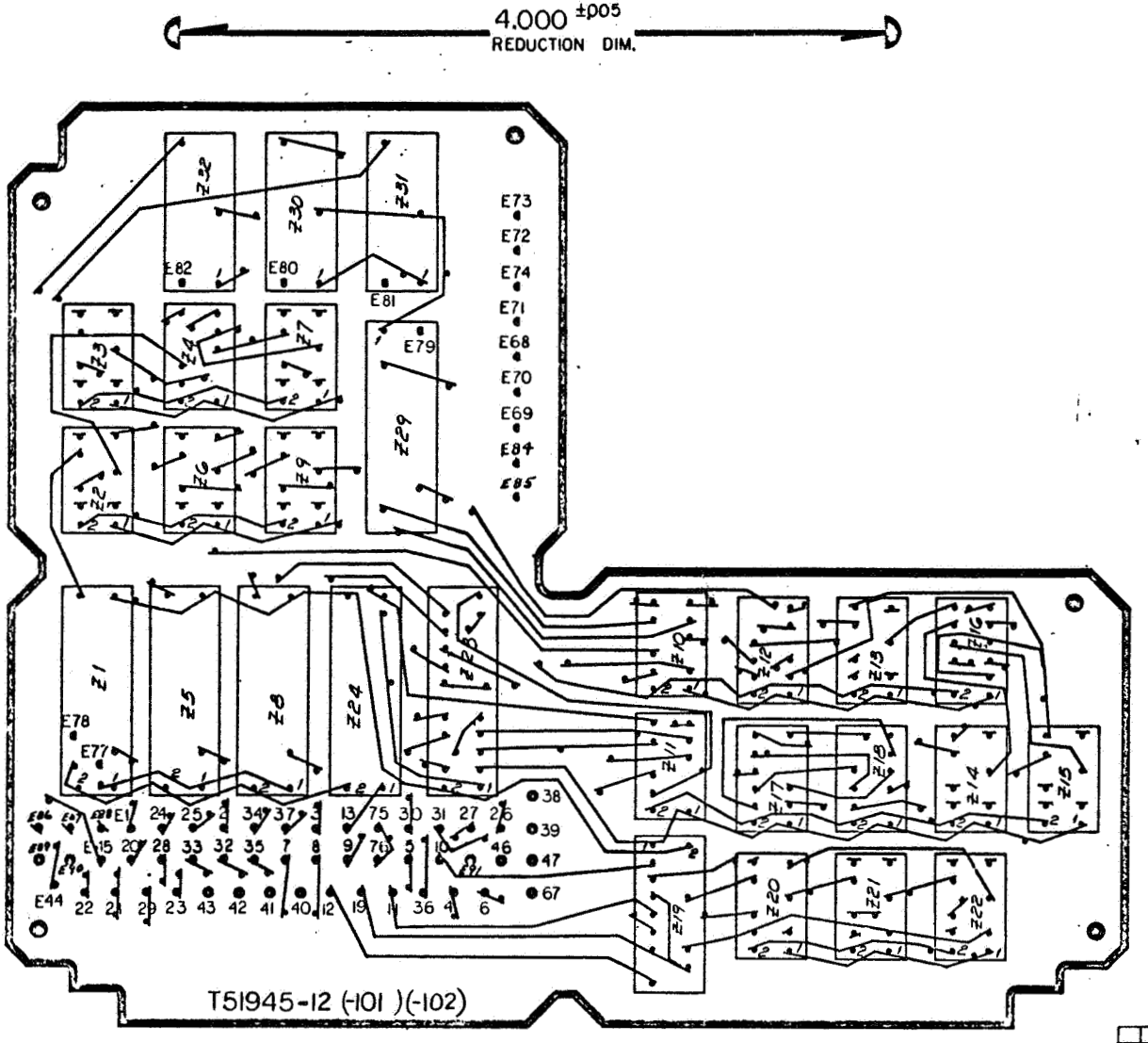
ENGRG DWG LIST IS AFFECTED	YES	NO
DWG TO BE CHANGED	✓	
OTHER DWGS AFFECTED	—	

T51948 DRAWING NUMBER | 1651 E. O. NO.

Page 01

ML 157

5-42-8



HOLE TABULATION

SYMBOL	NO REQD.	HOLE DIA.	REMARKS
•	WHERE SHOWN	.029	MODULE LEADS
•	WHERE SHOWN	.029	FEED THRUS
•	11	.067	TERMINAL MOUNTING (ITEM 4) NEARSIDE -1 HOOK UP BOARD
▲	39	.067	TERMINAL MOUNTING (ITEM 5) FARSIDE -2 SUPPORT BOARD
▲	39	.029	PUSH THRU WIRES -1 HOOK UP BOARD
●	12	.067	TERMINAL MOUNTING (ITEM 4) NEARSIDE -1 HOOK UP BOARD
●	12	.067	TERMINAL MOUNTING (ITEM 5) FARSIDE -2 SUPPORT BOARD
•	4	.067	TERMINAL MOUNTING (ITEM 4) NEARSIDE -1 HOOK UP BOARD
•	4	.029	MODULE LEADS -2 SUPPORT BOARD
⊙	5	.136	BOARD ASSY MOUNTING

REF	QTY	PART NO.	SPECIFICATION	NOMENCLATURE OR DESCRIPTION	ITEM
				EPOXY GLASS MATL SPEC	9
			S40396	PROTECTIVE FINISH SPEC.	8
					7
					6
51		9650-1	LIN-TRON	TERMINAL	5
27		9650-087	LIN-TRON	TERMINAL	4
					3
	1	T51945-2		SUPPORT BOARD (.031 THICK)	2
	1	T51945-1		HOOK UP BOARD (.093 THICK)	1

-102/101

CITY ASSD PER NOTED ASSY

DUPLICATION

LIST OF MATERIALS

MARSHALL LABORATORIES

TOLERANCES ON DECIMALS ANGLES

SURFACE FINISHES

TITLE: HOOK UP/SUPPORT BD CONTROL CKT, TERMINAL SEARCH COIL MSL (EXP E-H)

E 13126 T51945

Page 52
07-917

Figure 26

NOTES. UNLESS OTHERWISE SPECIFIED

1. PROTECTIVE FINISH EMULSION SIDE OF -1 AND -2 BOARDS PER MARSHALL LABORATORIES PROCESS SPECIFICATION S40396 BEFORE TRIMING BOARDS OR PUNCHING HOLES.
2. USING THE STABLE BASE PANCHROMATIC POSITIVE OBTAINED IN NOTE 3, REPRODUCE -2 PUNTBOARD ON 0.031 INCH THICK EPOXY GLASS BOARD PER MIL-P-13949, TYPE GEE SENSITISED WITH DIRECT POSITIVE EMULSION.
3. ONE -1 HOOK-UP BOARD CURE MT LAB SHALL BE FURNISHED TO PRODUCTION AND SHALL BE REPRODUCED ON 0.093 INCH THICK SENSITIZED MT LAB USING CLOSE REGISTER OF NEGATIVES OBTAINED IN NOTES 1 AND 3. DOUBLE RUSH SENSITISED MT LAB FOR ARWEN ON TWO TUNES WITH RED APPEARING BROWN AND BLACK APPEARING BLACK.
4. PHOTO REDUCE -1 ARTWORK SUCH THAT NOTED REDUCTION DIMENSION SCALES 4.000 ± .005 INCHES (ONE REVERSE READING POSITIVE AND NEGATIVE) USING RED FILTER AND STABLE BASE PAN CHROMATIC FILM.
5. USING REDUCED STABLE BASE POSITIVE, REPRODUCE -1 HOOK-UP BOARD ON 0.016 INCH THICK EPOXY GLASS BOARD PER MIL-P-13949, TYPE GEE SENSITISED WITH DIRECT POSITIVE EMULSION.
6. PHOTO REDUCE -1 ARTWORK SUCH THAT NOTED REDUCTION DIMENSION SCALES 4.000 ± .005 INCHES (ONE REVERSE READING POSITIVE AND NEGATIVE) USING STABLE BASE FILM.

MARS . LABORATORIES
TORRANCE, CALIFORNIA
CODE IDENT NO. 13126

RELEASED AUG 6 1965

ENGINEERING ORDER

T51945	NC	1386
DRAWING NUMBER	REV. LTR.	E. O. NO.

DWG TITLE HOOK UP/SUPPORT BAD - CONTROL CKT TRIAXIAL SEALED COIL (E16) SHEET 1 OF 1

NEXT ASSEMBLY: 51897-2 MODEL: ~~[illegible]~~ EFFECTIVITY: 1 & UP MJO _____ DATE: 8-5-65

TYPE OF E.O.: ☑ CHANGE (ATTACH TO DRAWING) ☐ DRAWING REVISED ☐ OTHER (NOTED) ☐ EXPEDITED

ADD RIBBON FROM +6 V LINE TO TERMINAL E 86
ON MATRIX SIDE OF BOARD (REF SCHEMATIC 51898)

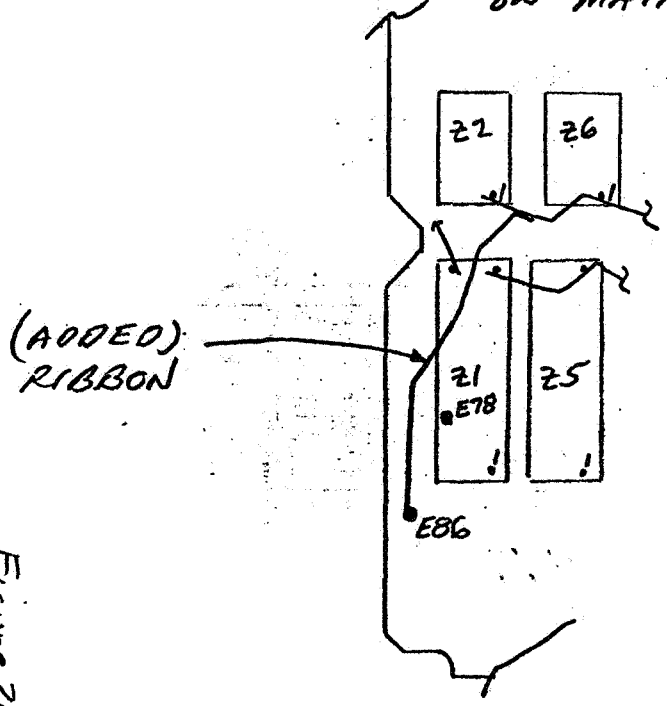


Figure 26-1

67-917

DISPOSITION OF PARTS/MTL	USE	REWORK	SCRAP	NOTED ABOVE
RAW MATERIAL	✓			
IN PROCESS				
FINISHED				
ASSEMBLED				

REASON FOR CHANGE:
TO CONFORM TO SCHEMATIC

		DATE
ORIG:	[signature]	8-5-65
CHECK:	[signature]	
STRESS:		
MTLS & PROCESS:		
WEIGHT:		
DESIGN ENG:	[signature]	
RESP ENG:	[signature]	

ENGRG DWG LIST IS AFFECTED	YES	NO
		✓
DWG TO BE CHANGED	✓	

OTHER DWGS AFFECTED
NONE

T51945 DRAWING NUMBER | 1386 E. O. NO.

Page 68

68

ML 157

5-120-B

MARSH LABORATORIES
TORRANCE, CALIFORNIA
CODE IDENT NO. 13126

ENGINEERING ORDER

NOV 18 1965

T5-1945	N/C	1591
DRAWING NUMBER	REV. LTR.	E. O. NO.

DWG TITLE HOOK UP & SUPPORT BRD CONTROL SET TRANSIT S.C. MODEL SHEET 1 OF 1

NEXT ASSEMBLY: 51897-2 MODEL: — EFFECTIVITY: 18 WD MJO _____ DATE: 11-18-65

TYPE OF E.O.: ☒ CHANGE (ATTACH TO DRAWING) ☐ DRAWING REVISED ☐ OTHER (NOTED) ☐ EXPEDITED

ERROR IN MODULE PIN LOCATION

ON HOOKUP BRD -1 & SUPPORT BD -2 ADD HOLE FOR MODULE PIN -10 ON Z18. REROUTE RIBBON TO PIN 6 of Z18 AS REQ'D TO CLEAR NEW PIN POSITION. REF E 1592.

PROD. NOTE: PUNCH AND/OR DRILL BDS FOR NEW HOLE. USE EXISTING BDS

Figure 26-2

67-917

DISPOSITION OF PARTS/MTL	USE	REWORK	SCRAP	NOTED ABOVE
RAW MATERIAL		✓		
IN PROCESS		✓		
FINISHED				
ASSEMBLED				

REASON FOR CHANGE:
PIN ERROR LOCATION

		DATE
ORIG:	[signature]	11-18-65
CHECK:		
STRESS:		
MTLS & PROCESS:		
WEIGHT:		
DESIGN ENG:		
RESP ENG:	R Rodgers	11/18/65

ENGRG DWG LIST IS AFFECTED	YES	NO
DWG TO BE CHANGED	✓	
OTHER DWGS AFFECTED		

T51945 — DRAWING NUMBER
1591 — E. O. NO.

[signature]

Page 57

ML 157

5-120-B

MARS' LABORATORIES
TORRANCE, CALIFORNIA
CODE IDENT NO. 13126

RELEASED DEC 17 1965

ENGINEERING ORDER

T519145	NC	1623
DRAWING NUMBER	REV. LTR.	E. O. NO.

DWG TITLE HOOKUP/SUBSET BOARD - CONTROL CKT TRANSIT SENSOR CAR SHEET 1 OF 1

NEXT ASSEMBLY: 51897-2 MODEL: — EFFECTIVITY: 1 & UP MJO _____ DATE: 12-6-65

TYPE OF E.O.: ☑ CHANGE (ATTACH TO DRAWING) ☐ DRAWING REVISED ☐ OTHER (NOTED) ☐ EXPEDITED

1. ADD RESISTORS R2, R3, & R4 TO HOOKUP BOARD
REMOVE RIBBON HOOKUP & REPLACE WITH RESISTORS AS SHOWN ON Z2, Z6 ON Z20 REMOVE RIBBON & WELD RESISTOR TO PIN & RIBBON BEFORE LINE ENTERING MATRIX

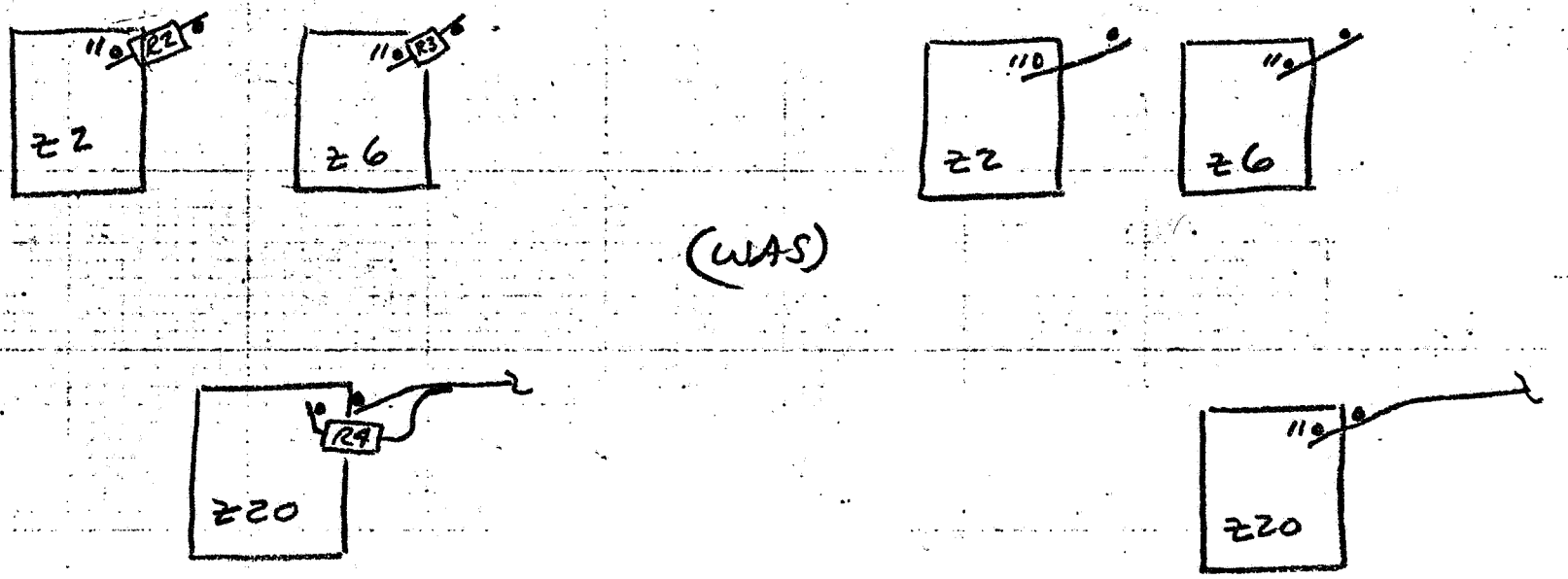


Figure 26-3

67-917

DISPOSITION OF PARTS/MTL	USE	REWORK	SCRAP	NOTED ABOVE
RAW MATERIAL				
IN PROCESS		✓		
FINISHED				
ASSEMBLED				

REASON FOR CHANGE:
TO REMOVE NOISE RIPPLE

		DATE
ORIG:	[illegible]	12-6-65
CHECK:		
STRESS:		
MTLS & PROCESS:		
WEIGHT:		
DESIGN ENG:		
RESP ENG:	R Kofranek	12/6/65

ENGRG DWG LIST IS AFFECTED	YES	NO
DWG TO BE CHANGED	✓	

OTHER DWGS AFFECTED
51898, 51897

T519145	1623
DRAWING NUMBER	E. O. NO.

Page 55

P Sunder McPherson 5-1206-B

ML 157

ENGINEERING ORDER

MARSHALL LABORATORIES
3530 TORRANCE BOULEVARD
TORRANCE, CALIFORNIA

DIST CODE 5-NW A

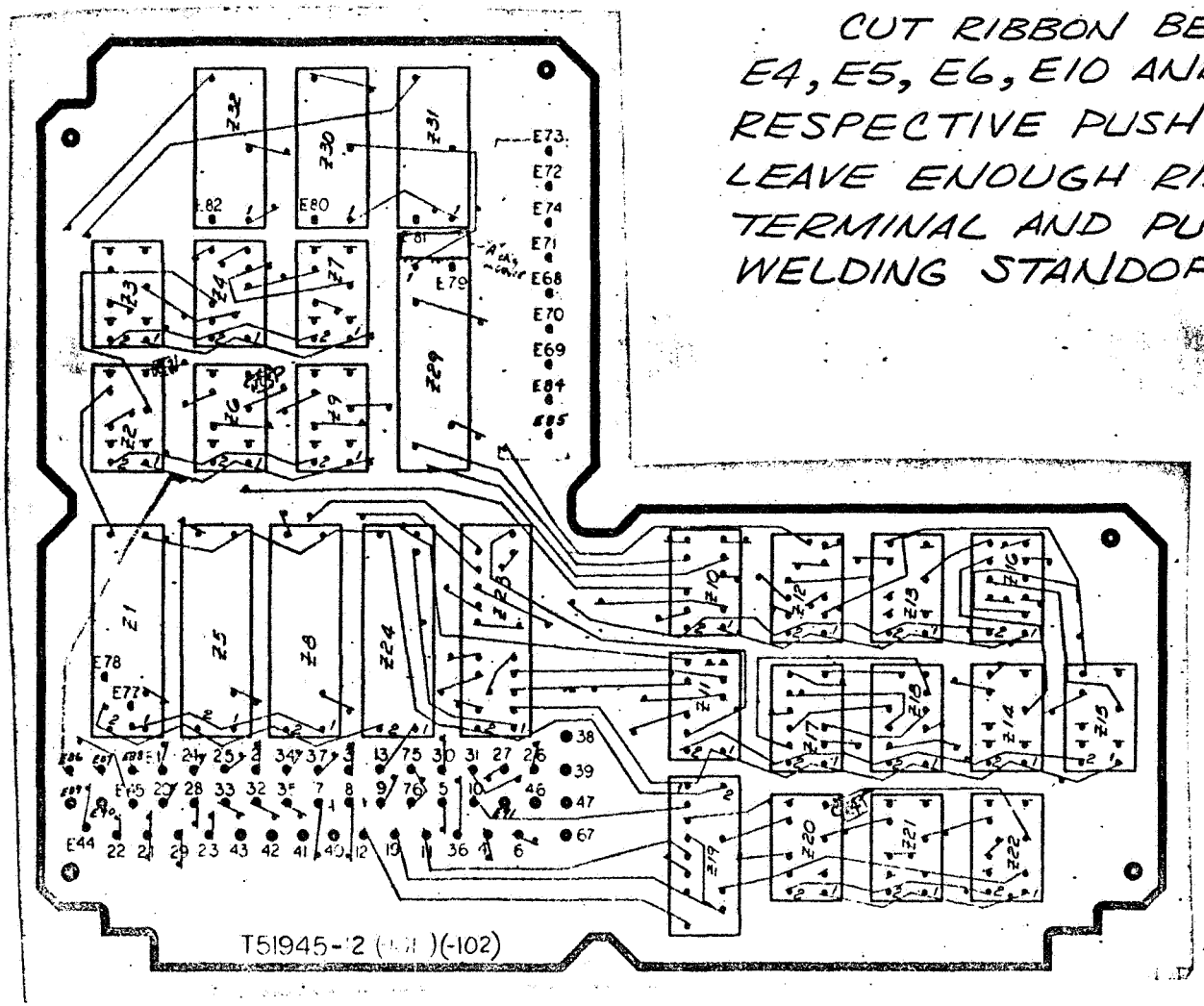
ML FOR RELEASED 3 197?

DRAWING TITLE	JOB NO.	CODE IDENT NO.	EO
HOOK UP/SUPPORT BD — CONTROL CKT TRIAXIAL SEARCH COIL MAGN. (EXP. E-16)	5-129	13126	EO — T51945 -NC 1

TYPE OF EO	DISPOSITION OF PARTS		NEXT ASSY	EFFECTIVITY
☒ CHANGE	☐ USE	ORIG PODSKALAN DATE 2/23/66		1 & UP
☐ VARIANCE	☐ REWORK	CHECK	MODEL NO.	
☐ SUPERCEDING	☐ SCRAP	ENGR		
☐ NOTED	☐ NOTED BELOW	PM	OTHER DWG AFFECTED	
		APPR		
		CUSTOMER		

DESCRIBE CHANGE AND GIVE REASON:

CUT RIBBON BETWEEN TERMINALS E4, E5, E6, E10 AND E11 AND THEIR RESPECTIVE PUSHTHROUGHS. LEAVE ENOUGH RIBBON ON BOTH TERMINAL AND PUSHTHROUGH FOR WELDING STANDOFF.



67-917

Page 56

Figure 26-4

QTY REQD PER NOTED ASSY	PART NO.	SPECIFICATION	DESCRIPTION	ELECT REF DES	CODE IDENT	ZONE
1						

WIRING LIST (23)(22)(21)

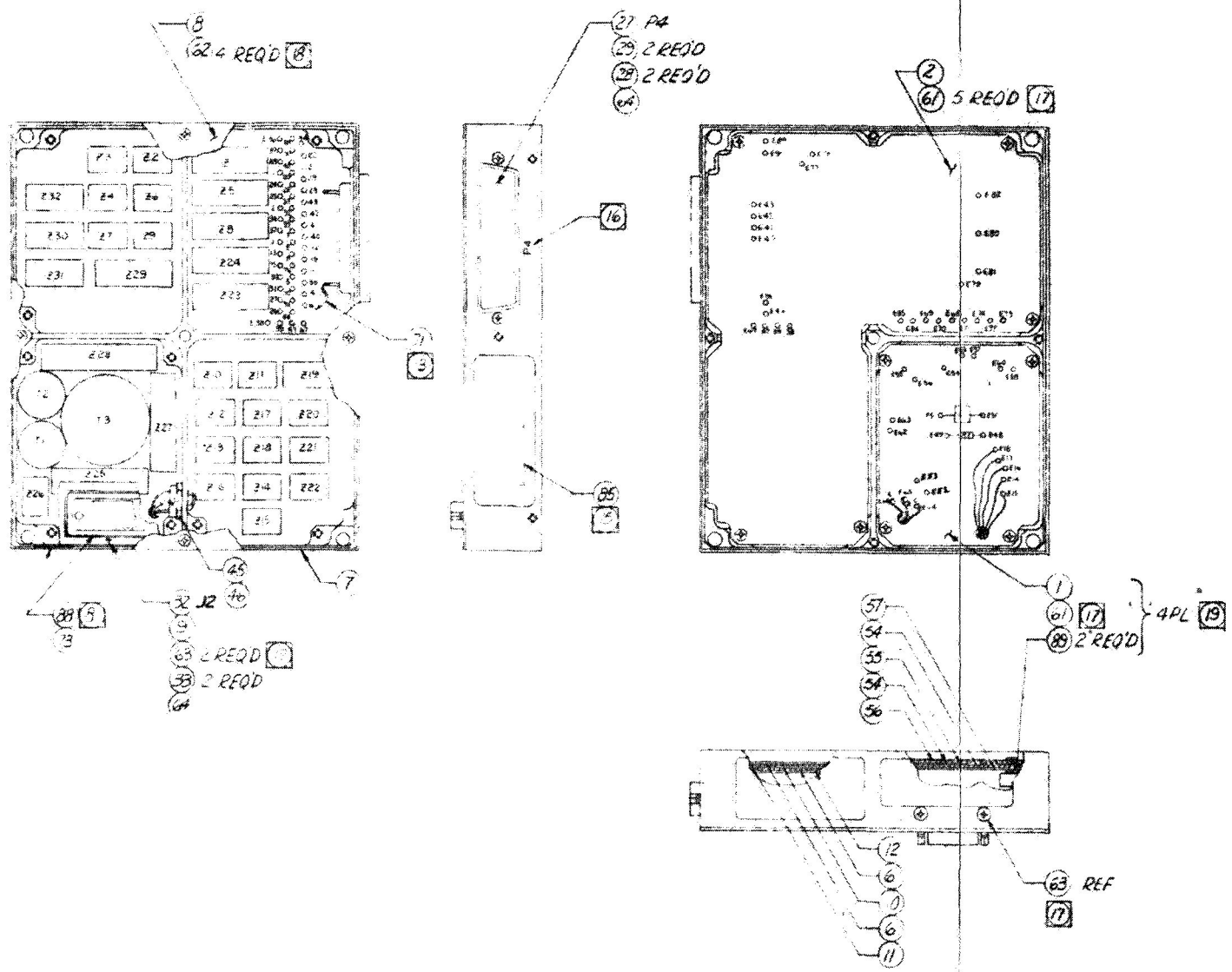
FROM	TO	FUNCTION	WIRE TYPE
P4-1	E41(NS)	CONVERTER T.P. RETURN	AWG 23
-2	E40(NS)	CONVERTER T.P.	
-3	(E39)(FS)	23.5 VOLT	
-4	E38(NS)	23.5 VOLT RETURN	
-5	E26	WAVE ANALYZER STATUS	
-6	E27	POWER & SCO STATUS	
-7	E31	COMMUNITATOR GATE CONTROL 10 CPS	
-8	E30	COMMUNITATOR GATE CONTROL 10 CPS	
-9	E15	+20 VOLT	
-10	E13	SPEC. PURPOSE PC SCO ON/OFF	
-11	E3	IFC ON/OFF (-)	
-12	E37	SCO CONTROL	
-13	E34	COMMUNITATOR GATE CONTROL 220 CPS	
-14	E2	SPECTRUM GAIN I.C.	
-15	E25	BANDWIDTH & IFC STATUS	
-16	E24	WAVEFORM & SPECTRUM GAIN STATUS	
-17	E1	WAVEFORM GAIN (-)	
-18	E10	EQ GP INDEX P 26	
-19	E5	13.9 PPS TIMING SIGNAL	
-20	(E76)	+20 V VOLT	
-21	(E76)	+20 V VOLT	
-22	E9	SWITCH SIGNAL	
-23	E8	MODE SIGNAL	
-24	E7	BIT RATE SIGNAL	
-25	E35	COMMUNITATOR GATE CONTROL 47 CPS	
-26	E32	COMMUNITATOR GATE CONTROL 47 CPS	
-27	E33	COMMUNITATOR GATE CONTROL 100 CPS	
-28	E28	IFC SIGNAL	
-29	E20	WAVEFORM GAIN CONTROL NO. 2	
-30	(E45)	-6 VOLT	
-31	(E45)	-6 VOLT	
-32	E86	+6 VOLT #1	
-33	(E44)	+6 VOLT #2	
-34	E6	0.87 PPS TIMING SIGNAL	
-35	E4	222 PPS TIMING SIGNAL	
-36	E36	COMMUNITATOR GATE CONTROL 1000 CPS	
-37	E11	EQ GP2 INDEX P 26	
-38	E19	I.P. INHIBIT & RESESET	
-39	E12	EXT. INDEX PULSE	
-40	(E40)(NS)	SEC RETURN	
-41	(E40)(NS)	SEC RETURN	
-42	(E42)	PREAMPLIFIER RETURN	
-43	(E42)(NS)	HEATER RETURN	
-44	(E43)(NS)	TIM SIGNAL RETURN	
-45	(E43)(NS)	SEC RETURN	
-46	E23	SPECTRUM GAIN CONTROL NO. 2	
-47	E29	BANDWIDTH CONTROL	
-48	E21	WAVEFORM GAIN CONTROL NO. 1	
-49	E22	SPECTRUM GAIN CONTROL NO. 1	
P4-50	(E44)	+6 VOLT #2	AWG 28

WIRING LIST (21)(22)(23)

FROM	TO	FUNCTION	WIRE TYPE
J2-1	E41(FS)	+28 VOLT POWER (TWISTED WITH J2-6)	AWG 28
-2		SPARE	
-3		SPARE	
-4	E17(FS)	SYNC SIGNAL C.T. (TWISTED WITH J2-7)	AWG 28
-5	E16(FS)	SYNC SIGNAL 'A' (TWISTED WITH J2-11)	AWG 28
-6	E15(FS)	+28 VOLT RETURN (TWISTED WITH J2-1)	AWG 28
-7		SPARE	
-8	E61(NS)	CHASSIS GRD (CONNECTOR MOUNTING)	AWG 28 #24 OK
J2-9	E18(FS)	SYNC SIGNAL 'B' (TWISTED WITH J2-5)	AWG 28

WIRING LIST (21)(22)(23)

FROM	TO	FUNCTION	WIRE TYPE
E53(FS)	E52	+23.5 VOLT RETURN	AWG 28
E39(FS)	E55	+23.5 VOLT	
E43(FS)	BUSS	SEC RETURN	
E41(FS)		RETURN	
E42(FS)		PREAMP & HEATER RETURN	
E43(FS)		TIM SIGNAL & SEC RETURN	
(E41)(FS)	E70	RETURN	AWG 28
E46(FS)	E62	CONVERTER T.P.	
E47(FS)	E63	CONVERTER T.P. RETURN	
E48	E49	SELECT RESISTOR (R1)	
E50	E51	CAPACITOR (C1)	
(E52)	E77		
(E53)	E78		
E54	E33		AWG 23
E55	E69		
E56	(E73)	RETURN	
E57	E71		
E58	E72		
E59	E74		
E60	(E73)	RETURN	AWG 28
E64	01 (E)		
E65	21 (E)		
E66	21 (E)		
E67(FS)		SHIELD RETURN	TERMINAL
E68(NS)	E83	SHIELD RETURN	AWG 28 #24 OK
(E70)	(E39)(E41)	RETURN	AWG 28
(E73)	(E39)(E68)	RETURN	
(E80)	E82	RETURN	
(E81)	(E80)	RETURN	AWG 28
E84		SPARE	
E85			
E87			
E88			
E89			
E90			
E91		SPARE	



9. SPOT POT AS REQ'D PER MIL SPEC S40379 CLASS II TYPE I.
8. BOND ITEM 88 INTO GROVE OF ITEM 7 & ITEM 9 AT APPROX 1.0 IN INTERVALS USING ITEM 73.
7. FILLET BOND ITEM 1 & 2 (HOOK-UP & POSITIONING BD SIDE) TO ITEM 7 PER MIL SPEC S40149.
6. MANUFACTURE PER MIL SPEC S40072.
5. ASSEMBLE COMPONENTS TO MATRIX PER MIL SPEC S40081.
4. USE ASSEMBLY JIG SP30253-8 FOR FAB & ASSY OF ITEMS 54, 55, 56 & 57 & BOND PER MIL SPEC S40149.
3. USE ASSEMBLY JIG SP30347-4 FOR FAB & ASSY OF ITEMS 6, 10, 11 & 12 & BOND PER MIL SPEC S40149.
2. FABRICATE ITEM 1 & 2 PER MIL SPEC S40094.
1. FOR SCHEMATIC REFER TO ML DWG 51898.

(25) SHIELDS TIED COMMON AT WIRE TERMINATION TERMINALS E38, E39, E46 & E47
(24) SHIELDS TIED COMMON AT WIRE TERMINATION TERMINALS E52 & E53 (REF 51898 SCHEMATIC)
(EXA) INDICATES MORE THAN ONE WIRE PER TERMINAL
(FS) INDICATES TERMINAL ON HOOK-UP BOARD SIDE.
(NS) INDICATES TERMINAL ON POSITIONING BOARD SIDE.
(20) TEST PER ML SPEC S47844.
(9) SHIM ITEM 1 AS SHOWN USING ITEM 89 TO PREVENT INTERFERENCE WITH ITEM 9.
(6) TORQUE ITEM 62 TO 2.5 INCH LBS. +5% -10%
(5) TORQUE ITEM 33, 61, 63 TO 4.0 INCH LBS. +5% -10%
(4) MARKINGS: BLACK APPROX AS SHOWN PER MIL S40111 CLASS I, TYPE III.
(3) MARKINGS: BLACK APPROX AS SHOWN USING ITEM 85 PER MIL SPEC S40111 CLASS I
(2) CORRELATE REF DESIGNATORS TO COMPONENTS BY SEPARATE LIST OF MAT'L.
(1) SOLDER PER MIL SPEC S40126
2 CONNECTOR TO BE SEALED PER MIL SPEC S40093 CLASS II TYPE I
1. FOAM-IN-PLACE COMPONENT CAVITIES ONLY PER MIL SPEC S40092, CLASS I, TYPE I, TYPE I @ 170°F 1 HOUR.
10 CONFORMAL COAT ITEM 1 & 2 PER MIL SPEC S40091 CLASS I, TYPE I @ 170°F

NOTES: UNLESS OTHERWISE SPECIFIED

SEE SEPARATE LIST OF MAT'L

Figure 27

QTY REQD PER NOTED ASSY	PART NO	SPECIFICATION	NOMENCLATURE OR DESCRIPTION	ELEC REF DES	CODE IDENT	ZONE	ITEM NO.
CONFIGURATION			LIST OF MATERIALS				

INTERPRET THIS DRAWING PER STANDARDS IN MIL-D-7327
DIMENSIONS ARE IN INCHES
TOLERANCES ON: DECIMALS X ± .1, XX ± .03, XXX ± .010; ANGLES ± 0° 30'; XXXX .0050
SURFACE ROUGHNESS
HOLE DIA — TOLERANCE: 11 to THRU .17 = .004–.001; .174 THRU .250 = .005–.001; .251 THRU .500 = .006–.001; .501 THRU .750 = .008–.001; .751 THRU 1.000 = .010–.001; 1.001 AND OVER = .012–.001

CONTRACT NO. 5-120
DRAWN — CHECK — MECH. ENGR. — ELEC. ENGR. — PROJ. MGR. — APPR. —
DESIGN ACTIVITY APPD — CUSTOMER

MARSHALL LABORATORIES, TORRANCE, CALIFORNIA

TITLE: PWR. SUP. & CONTROL ASSY — TRIAXIAL SEARCH COIL MAGN. (EXP. E-16)

SIZE F | CODE IDENT NO. 13126 | DWG NO. 51897 | REV

SCALE 1/1 | RELEASED | SHEET 1 OF 1

APPLICATION: DASH NO. | MODEL NO. | NEXT ASSEMBLY | MODEL NO. | FINAL ASSEMBLY | MODEL NO. — 51731-101 | MR-2584 | 51730-101 | MR-2583

ML FORM 209

MARSH LABORATORIES
TORRANCE, CALIFORNIA
CODE IDENT NO. 13126

DEC 13 1965

ENGINEERING ORDER

51897	N/C	1615
DRAWING NUMBER	REV. LTR.	E. O. NO.

DWG TITLE PWR SUPPLY & CONTROL ASSY - TRIAXIAL SEARCH COIL SHEET 1 OF 1

NEXT ASSEMBLY: 51731-101 MODEL: — EFFECTIVITY: 1 & UP MJO _____ DATE: 12-13-65

TYPE OF E.O.: ☑ CHANGE (ATTACH TO DRAWING) ☐ DRAWING REVISED ☐ OTHER (NOTED) ☐ EXPEDITED

IN WIRE LIST ZONE D/S

FROM	TO		TO
(E52)	E78	(WAS)	E77
(E53)	E77		E78
↓			
(SAME)			

Figure 27-1

67-917

DISPOSITION OF PARTS/MTL	USE	REWORK	SCRAP	NOTED ABOVE
RAW MATERIAL				
IN PROCESS		✓		
FINISHED				
ASSEMBLED				

REASON FOR CHANGE: SCHEMATIC ERROR

		DATE
ORIG:	Chandler	12-13-65
CHECK:		
STRESS:		
MTLS & PROCESS:		
WEIGHT:		
DESIGN ENG:		
RESP ENG:		

ENGRG DWG LIST IS AFFECTED	YES	NO
		✓
DWG TO BE CHANGED	✓	

OTHER DWGS AFFECTED
51898

51897	1615
DRAWING NUMBER	E. O. NO.

Page 58

ML 157

5-28-7

MARSH LABORATORIES
TORRANCE, CALIFORNIA
CODE IDENT NO. 13126

DEC 13 1965

ENGINEERING ORDER

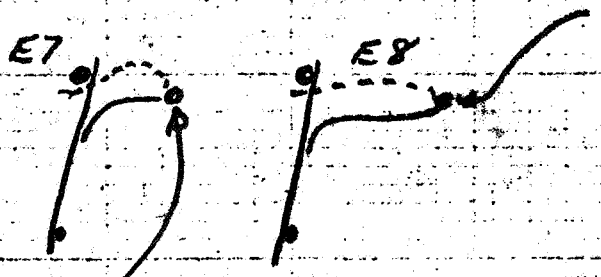
51897	N/C	1617
DRAWING NUMBER	REV. LTR.	E. O. NO.

DWG TITLE PWR SUPPLY & CONTROL ASSY - TRIAXIAL SEARCH COIL SHEET 1 OF 1

NEXT ASSEMBLY: 51731-001 MODEL: _____ EFFECTIVITY: NOTED MJO _____ DATE: 12-13-65

TYPE OF E.O.: ☐ CHANGE (ATTACH TO DRAWING) ☐ DRAWING REVISED ☒ OTHER (NOTED) ☐ EXPEDITED

VARIANCE EO SN1 ONLY



ADD HOLE THRU HOOKUP, POSITIONING & MATRIX, SOLDER WIRE (SLEEVE IF REQ'D) TO TERMINAL E8, ROUTE THRU HOLE & WELD TO HOOKUP RIBBON

ADD HOLE THRU HOOKUP, POSITIONING & MATRIX
SOLDER WIRE (SLEEVE IF REQ'D) TO TERMINAL E7
ROUTE THRU HOLE & WELD TO HOOKUP RIBBON.

Figure 27-2

67-917

Page 54

DISPOSITION OF PARTS/MTL	USE	REWORK	SCRAP	NOTED ABOVE
RAW MATERIAL				
IN PROCESS		✓		
FINISHED				
ASSEMBLED				

REASON FOR CHANGE:
MATRIX ERROR RESULTING IN CIRCUIT CONTINUITY

		DATE
ORIG:	[signature]	13-12-65
CHECK:		
STRESS:		
MTLS & PROCESS:		
WEIGHT:		
DESIGN ENG:		
RESP ENG:	[signature]	12/13/65

ENGRG DWG LIST RE-AFFECTED	YES	NO
DWG TO BE CHANGED		✓
OTHER DWGS AFFECTED: NONE		

51897	1617
DRAWING NUMBER	E. O. NO.

ML 157

5-120

MARSH LABORATORIES
TORRANCE, CALIFORNIA
CODE IDENT NO. 13126

RELEASED DEC 17 1965

ENGINEERING ORDER

51897	N/C	1620
DRAWING NUMBER	REV. LTR.	E. O. NO.

DWG TITLE PWR SUPPLY & CONTROL ASSY - TRIAXIAL SEMICON COIL MAGN SHEET 1 OF 1

NEXT ASSEMBLY: 51731-101 MODEL: — EFFECTIVITY: 1 EOP MJO _____ DATE: 12-16-65

TYPE OF E.O.: ☑ CHANGE (ATTACH TO DRAWING) ☐ DRAWING REVISED ☐ OTHER (NOTED) ☐ EXPEDITED

1. ADD R2, R3, R4 RESISTORS TO HOOKUP BOARD OF -2 ASSY
REF EO 1621 (51897-101) & EO 1622 (51898) & EO 1623 (TS1795.

67-917

Figure 27-3

DISPOSITION OF PARTS/MTL	USE	REWORK	SCRAP	NOTED ABOVE
RAW MATERIAL				
IN PROCESS		✓		
FINISHED				
ASSEMBLED				

REASON FOR CHANGE:
TO REMOVE NOISE RIPPLE

		DATE
ORIG:	[signature]	12/16/65
CHECK:		
STRESS:		
MTLS & PROCESS:		
WEIGHT:		
DESIGN ENG:		
RESP ENG:	[signature]	12/16/65

ENGRG DWG LIST IS AFFECTED	YES	NO
DWG TO BE CHANGED	✓	
OTHER DWGS AFFECTED: TS1795, 51898		

51897	1620
DRAWING NUMBER	E. O. NO.

[signature] 12/16/65

Page 60

25

ML 157

5-120

MARSH LABORATORIES
TORRANCE, CALIFORNIA
CODE IDENT NO. 13126

RELEASED JAN 11 1966

ENGINEERING ORDER

51897	NC	1653
DRAWING NUMBER	REV. LTR.	E. O. NO.

DWG TITLE PWR SUPPLY & CONTROL ASSY - TRIAXIAL S.C. MOD SW SHEET 1 OF 1

NEXT ASSEMBLY: 51731-101 MODEL: — EFFECTIVITY: 1 PWP MJO _____ DATE: 1-7-66

TYPE OF E.O.: ☑ CHANGE (ATTACH TO DRAWING) ☐ DRAWING REVISED ☐ OTHER (NOTED) ☐ EXPEDITED

1. IN ZONE C2 SHOW CAPACITOR "C2" ON MODULE LEADS 23 & 30 of Z27
   SHOW " "C1" AS (SELECT)

2. IN WIRING LIST ADD THE FOLLOWING

FROM	TO	WIRE TYPE
Z27-23	T3-3	SHIELDED 2 COND AWG 28
Z27-30	T3-1	

3. IN GENERAL NOTES ADD FOLLOWING TO NOTE 25

(25) ——— LEFT AND T3-1 & -3 (SAME)

Figure 27-1

67-917

DISPOSITION OF PARTS/MTL	USE	REWORK	SCRAP	NOTED ABOVE
RAW MATERIAL		✓		
IN PROCESS				
FINISHED				
ASSEMBLED				

REASON FOR CHANGE: NOISE REDUCTION

		DATE
ORIG:	R SNIDER	1-7-66
CHECK:		
STRESS:		
MTLS & PROCESS:		
WEIGHT:		
DESIGN ENG:		
RESP ENG:	R Knight	1/11/66

ENGRG DWG LIST IS AFFECTED	YES	NO
DWG TO BE CHANGED	✓	
OTHER DWGS AFFECTED	—	

51897	1653
DRAWING NUMBER	E. O. NO.

Page 61

ML 157

J Chandler 1-11-66

5-120-1

ENGINEERING ORDER

3530 TORRANCE BOULEVARD
TORRANCE, CALIFORNIA

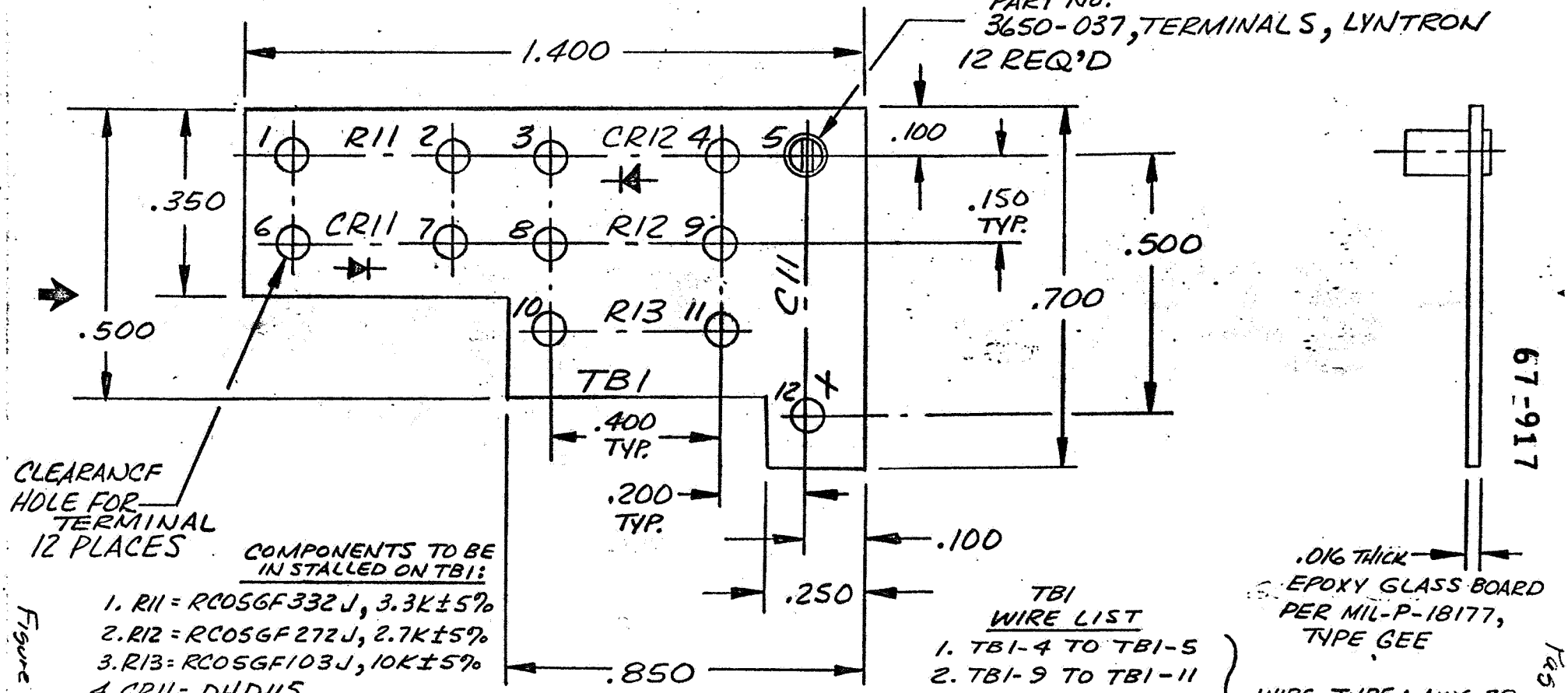
DIST CODE 5120 A

RELEASED 3 1966

DRAWING TITLE	JOB NO.	CODE IDENT NO.	EO
PWR SUP. & CONTROL ASSY- TRIAXIAL SEARCH COIL MAGN. (EXP. E-16)	5-129	13126	EO — 51897-NC 1

TYPE OF EO	DISPOSITION OF PARTS			
☒ CHANGE	☐ USE	ORIG PODSKALAN DATE 8/20/66	NEXT ASSY 51731-101	EFFECTIVITY
☐ VARIANCE	☐ REWORK	CHECK		
☐ SUPERCEDING	☐ SCRAP	ENGR	MODEL NO.	1 & UP
☐ NOTED	☐ NOTED BELOW	PM 11/2/66		
		APPR	OTHER DWG AFFECTED	
		CUSTOMER		

DESCRIBE CHANGE AND GIVE REASON:



COMPONENTS TO BE INSTALLED ON TB1:

1. R11 = RC05GF332J, 3.3K ±5%
2. R12 = RC05GF272J, 2.7K ±5%
3. R13 = RC05GF103J, 10K ±5%
4. CR11 = DHD11S
5. CR12 = IN972B
6. C11 = .47UF, 75V

TB1 WIRE LIST

1. TB1-4 TO TB1-5
2. TB1-9 TO TB1-11
3. TB1-9 TO TB1-12
4. TB1-11 TO TB1-7
5. TB1-3 TO TB1-8
6. TB1-1 TO TB1-6

WIRE TYPE: AWG 28

NO DWG NUMERS ASSIGNED FOR TB1 DETAIL AND ASSY DRAWINGS.

Figure 27-5

Page 62

*REF. E.O. —

QTY REQD PER NOTED ASSY	PART NO.	SPECIFICATION	DESCRIPTION	ELECT REF DES	CODE IDENT	ZONE

ENGINEERING ORDER

MARSHALL DISTRIBUTORS
3530 TORRANCE BOULEVARD
TORRANCE, CALIFORNIA

DIST CODE 1 60

RELEASED

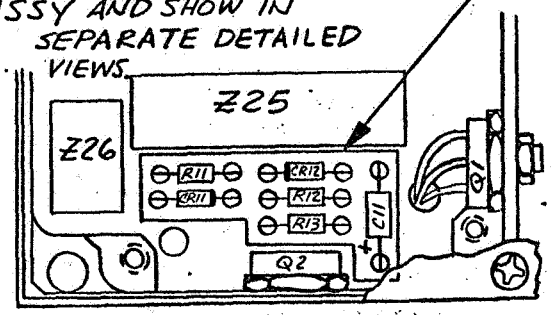
NOV 3 1966

DRAWING TITLE	JOB NO.	CODE IDENT NO.	EO
PWR. SUP. & CONTROL ASSY — TRIAXIAL SEARCH COIL MAGN. (EXP. E-16)	5-129	13126	EO — 51897-NC 2

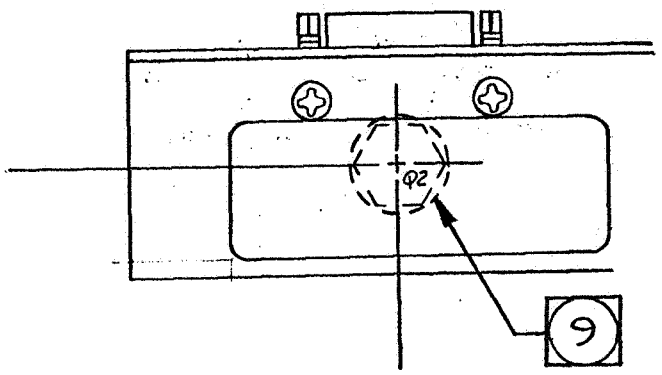
TYPE OF EO	DISPOSITION OF PARTS			EFFECTIVITY
☒ CHANGE	☐ USE	ORIG PODSKALAN DATE 8/20/66	NEXT ASSY 51731-101	1 & UP
☐ VARIANCE	☐ REWORK	CHECK		
☐ SUPERCEDING	☐ SCRAP	ENGR	MODEL NO.	
☐ NOTED	☐ NOTED BELOW	PM [illegible] 11/2/66		
		APPR [illegible]	OTHER DWG AFFECTED	
		CUSTOMER		

DESCRIBE CHANGE AND GIVE REASON:

ADD TB1 AND Q2 TO ASSY AND SHOW IN SEPARATE DETAILED VIEWS.



(9) (SPOT BOND) IN APPROXIMATE POSITION AS SHOWN. (ALSO CONFORMAL COAT AFTER FINAL WIRING: REF. NOTE 10)



(9) (SPOT BOND Q2 TO FARSIDE OF WALL)

INSULATE Q2 FROM WALL BY USING MICA WASHER.
MOUNT IN APPROXIMATE POSITION SO AS TO CLEAR CONNECTOR AND TB1.
Q2 HAS MOUNTING STUD SAWED OFF SO THAT IT CAN BE FLUSH MOUNTED TO WALL.

WIRE LIST CHANGES:

1. ZONE BG IS:

FROM	TO
J2-1	TB1-2

WAS:

FROM	TO
J2-1	E14(FS)

2. ADD:

FROM	TO	WIRE TYPE
TB1-5	E15(FS)	AWG 28
Q2-C	TB1-2	
Q2-B	TB1-3	
Q2-E	E14(FS)	
TB1-10	Z25-8	

67-917

Page 63

Figure 27-6

*REF. E.O. —

QTY REQD PER NOTED ASSY	PART NO.	SPECIFICATION	DESCRIPTION	ELECT REF DES	CODE IDENT	ZONE

ENGINEERING ORDER

MARSHALL LABORATORIES
3530 TORRANCE BOULEVARD
TORRANCE, CALIFORNIA

DIST CODE 5-140 4

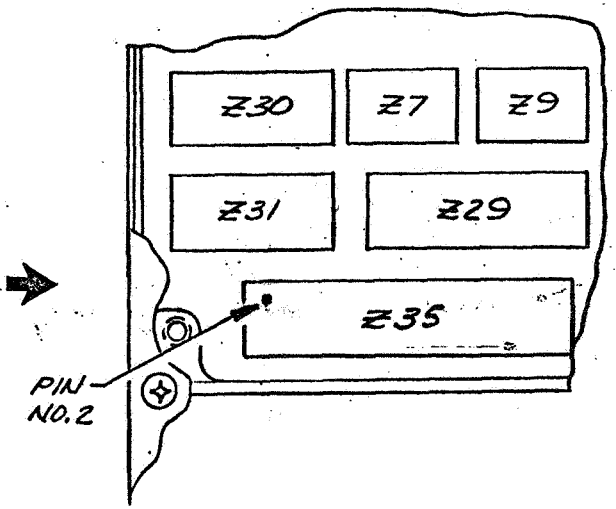
ML F 57A

RELEASED

DRAWING TITLE	JOB NO.	CODE IDENT NO.	EO
PWR SUP. & CONTROL ASSY-TRIAXIAL SEARCH COIL MAGN. (EXP. E-16)	5-129	13126	EO — 51897 - NC3 NOV 3 1966

TYPE OF EO	DISPOSITION OF PARTS			EFFECTIVITY
☒ CHANGE	☐ USE	ORIG PODSKALAN DATE 8/20/66	NEXT ASSY 51731-101	1 & UP
☐ VARIANCE	☐ REWORK	CHECK		
☐ SUPERCEDING	☐ SCRAP	ENGR	MODEL NO.	
☐ NOTED	☐ NOTED BELOW	PM 11/2/66		
		APPR	OTHER DWG AFFECTED	
		CUSTOMER		

DESCRIBE CHANGE AND GIVE REASON: ADDED NEW MODULE Z35, W4460



LOCATE Z35 PINS SO AS TO MISS ALL RIBBONS ON MATRIX ASSY.

WIRE LIST (USING SLEEVED 180 WIRE)

Z35-2 TO E10
Z35-4 TO Z19-3
Z35-12 TO E11
Z35-14 TO Z19-9
Z35-18 TO E4
Z35-20 TO Z12-5
Z35-24 TO E5
Z35-26 TO Z12-11
Z35-30 TO E6
Z35-32 TO Z12-9
Z35-34 TO +6V
Z35-36 TO GRD

67-917

Page 64

Figure 27-7

* REF. E.O. —

QTY REQD PER NOTED ASSY	PART NO.	SPECIFICATION	DESCRIPTION	ELECT REF DES	CODE IDENT	ZONE
1						

SPACECRAFT CONNECTOR J1 (DDM-50P-NMC-1-A106)

TEST CONNECTOR (DDM-50S-NMC-1-A106) J3

POWER & SCO STATUS
BANDWITH & IFC STATUS
SPEC PURPOSE RC SCO ON/OFF
EQ GP1 INDEX PULSE 26
MODE SIGNAL
IFC OFF/ON I.C.
WAVEFORM GAIN I.C.
X-AXIS ANALYZER
Z-AXIS ANALYZER
X-AXIS WIDEBAND
Y-AXIS WAVEFORM
Y-AXIS SCO 52.5K
Z-AXIS WIDEBAND
EXT INDEX PULSE
+23.5 V
SECONDARY RETURN
CONVERTER T.R
WAVEFORM GAIN CONTROL NO.1
SPECTRUM GAIN CONTROL NO.2
SCO CONTROL
+20 V
+6V#2
WAVEFORM GAIN CONTROL NO.2
SPECTRUM GAIN CONTROL NO.1
BANDWIDTH CONTROL
SEC RETURN
-6V
+2.6V

IFC SIGNAL
WAVE ANALYZER STATUS
WAVEFORM & SPECTRUM GAIN
EQ GP2 INDEX PULSE 26
SWITCH SIGNAL
BIT RATE SIGNAL
SPECTRUM GAIN I.C
Y-AXIS WAVE ANALYZER
Z-AXIS WAVE ANALYZER
Z-AXIS SCO 70KC
Z-AXIS WAVEFORM
Y-AXIS WIDEBAND
X-AXIS SCO 30KC
X-AXIS WAVEFORM
EXT INDEX PULSE
+23.5 V
PREAMP RETURN
CONVERTER T.R RETURN
+2.6V
SECONDARY RETURN
Y-AXIS SPECTRUM T.R
+2.5 V
+20V
-6V
+6V#2
+6V#1
Y-AXIS WAVE ANALYZER ◀—TO J3-34
X-AXIS WAVEFORM
X-AXIS SCO 30KC
Y-AXIS WIDEBAND
Z-AXIS WAVEFORM
Z-AXIS SCO 70KC
Y-AXIS PREAMP ◀—TO J1-18
PREAMPLIFIER RETURN ◀—TO J1-1
I.R INHIBIT & RESET
+23.5V RETURN
CONVERTER T.R
WAVEFORM GAIN CONTROL NO.2
SPECTRUM GAIN CONTROL NO.1
BANDWIDTH CONTROL
SEC RETURN
-6V
+2.6V

TO J3-1
TO J3-18
TO J3-34
X-AXIS PREAMP
WM5121K
WM5122K
WM5123K
WM5124K
WM5125K
WM5126K
WM5127K

LSB PPS TIMING SIG.
+20V
HEATER RETURN
WAVEFORM GAIN I.C.
IFC OFF/ON I.C.
MODE SIGNAL
EQ GP1 INDEX PULSE 26
SPEC PURPOSE RC SCO ON/OFF
BANDWIDTH/IFC STATUS
POWER/SCO STATUS
(DDM-50S-NMC-1-A106) J4
-28V PPS TIMING SIG.
-5V PPS TIMING SIG.
PRE-AMPLIFIER RETURN
SIGNAL RETURN
SPECTRUM GAIN I.C.
BIT RATE SIGNAL
SWITCH SIGNAL
EQ GP2 INDEX PULSE 26
WAVE FORM/SPECTRUM GAIN STATUS
WAVE ANALYZER STATUS
IFC SIGNAL
I.R. INHIBIT & RESET
+23.5 V RETURN
CONVERTER T.R.
WAVEFORM GAIN CONTROL NO.2
SPECTRUM GAIN CONTROL NO.1
BANDWIDTH CONTROL
SEC RETURN
-6V
+20V
+6V#1
-6V
22 CPS
100 CPS
470 CPS
COMMUTATOR CONTROL
(DDM-25S-NMC-1-A106) J6
1000 CPS
220 CPS
47 CPS
10 CPS
+6V#2
SEC RETURN
X-AXIS WAVE ANALYZER
Z-AXIS WAVE ANALYZER
+2.6V
X-AXIS SPECTRUM
Z-AXIS SPECTRUM
(DDM-50S-NMC-1-A106) J5
Y-AXIS SPECTRUM
+6V#2
+20V
SCO CONTROL
SPECTRUM GAIN CONTROL NO.2
WAVEFORM GAIN CONTROL NO.1
Y-AXIS PREAMP
Z-AXIS PREAMP
Y-AXIS WIDEBAND
Y-AXIS SCO 52.5K
Y-AXIS WAVEFORM
Y-AXIS WIDE BAND
Y-AXIS SPECTRUM T.R
Z-AXIS SPECTRUM T.R

P4 (DDM-50P-NMC-1-A106)
POWER SUPPLY & CONTROL (51897-101)
FOR SCHEMATIC SEE 51898

P6 (DDM-25P-NMC-1-A106)
SPECTRUM (51901-101)
FOR SCHEMATIC SEE 51902

P5 (DDM-50P-NMC-1-A106)
WAVE FORM (51899-101)
FOR SCHEMATIC SEE 51900

(DDM-35-NMC-1-A106) P2
J2 (DDM-9P-NMC-1-A106)
+28V PWR
+28V RET
SYNC SIG. H
SYNC SIG. C
SYNC SIG. D

4. FOR WIRING LIST SEE 51904.
5. ⊢ INDICATES SHIELDED WIRE (GROUNDED SHIELD).
4. ⊢ INDICATES SHIELDED WIRE (FLOATING SHIELD).
3. ⏚ INDICATES CHASSIS GROUND.
2. FOR TEST SPEC SEE MARSHALL LABS S40843.
1. FOR ASSEMBLY DWG SEE 51731.
NOTES: UNLESS OTHERWISE SPECIFIED

Figure 28

MARSHALL LABORATORIES
SCHEMATIC - ELECTRONIC SYSTEM Q60-E (EXP E-K)
E 73126 51903

3.0 SPACECRAFT INTERFACES

3.1 Mechanical Interfaces

The characteristics of all mechanical interfaces are depicted on figures which are part of the preceeding test. These include Figure 3, the thermal schematic; Figure 5, the sensor pre-amplifier envelope drawing; Figure 16, the main electronic assembly envelope drawing.

3.2 Electrical Interfaces

The following subparagraphs include figures showing the schematic of each instrument spacecraft interface. All grounds shown are signal (telemetry) ground.

3.2.1 Primary Power Interface

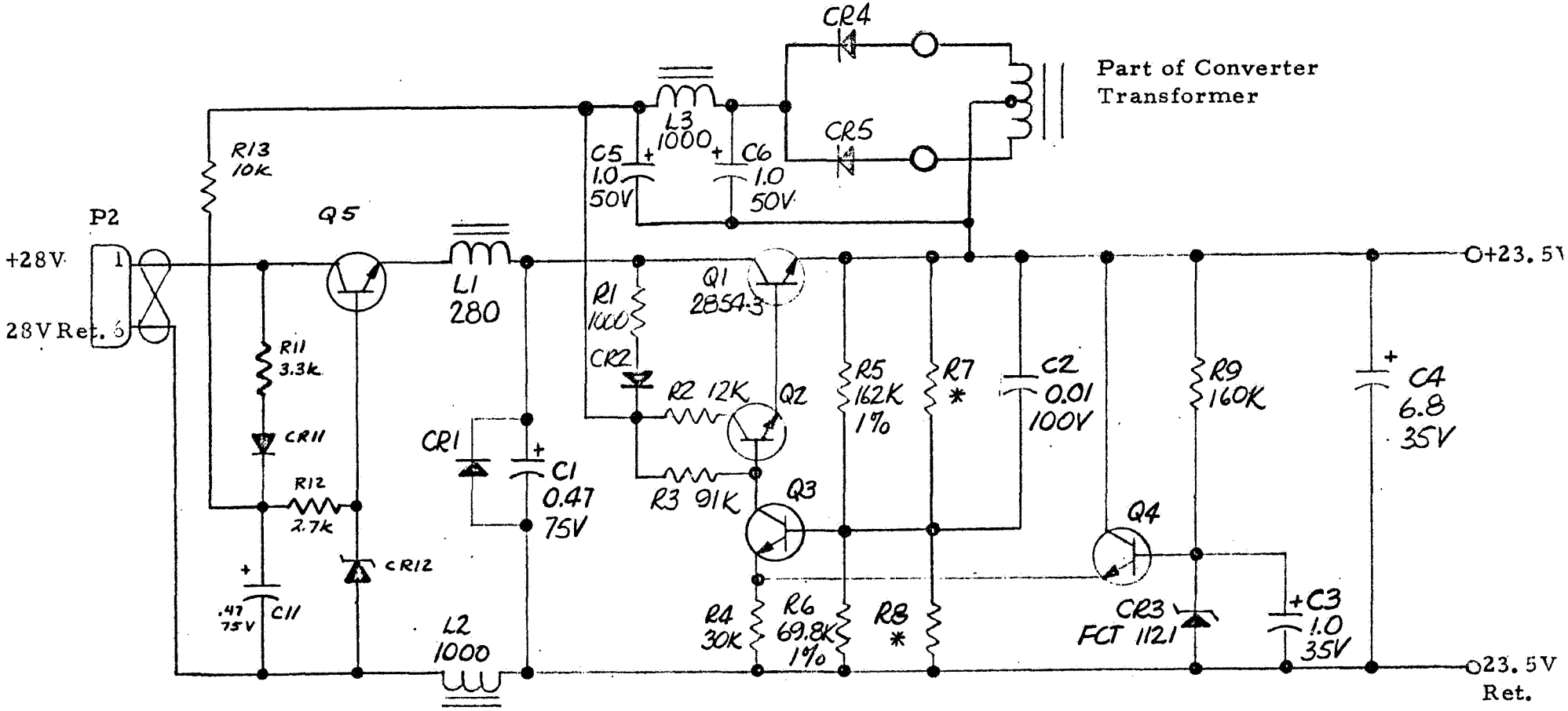
Figure 29 shows the schematic of the interface presented to the +28VDC primary power lines. As indicated, the series regulator receives the +28 VDC. An auxiliary supply from a winding of the power transformer used to increase the efficiency of the regulator driver transistors. The +28 VDC return is isolated from signal (telemetry) ground and from chassis ground.

3.2.2 Synchronization Signal Interface

Figure 30 shows the schematic of the interface presented to the spacecraft 2461 Hz sync signal. The three wire input is applied to the primary of an isolation transformer. This primary is completely isolated from all other circuitry within the instrument. The secondary outputs of the transformer are applied to a complementary transistor amplifier through suitable isolation networks. The output of this amplifier is applied to the converter for synchronization. The +23.5 VDC and +23.5 VDC return are obtained from the primary power interface circuit.

3.2.3 Timing Pulse Interface

Figure 31 shows the schematic diagram of the interfaces which are presented to the spacecraft timing signal. The three frequencies utilized are 0.87 pulses per second, 13.9 pps,



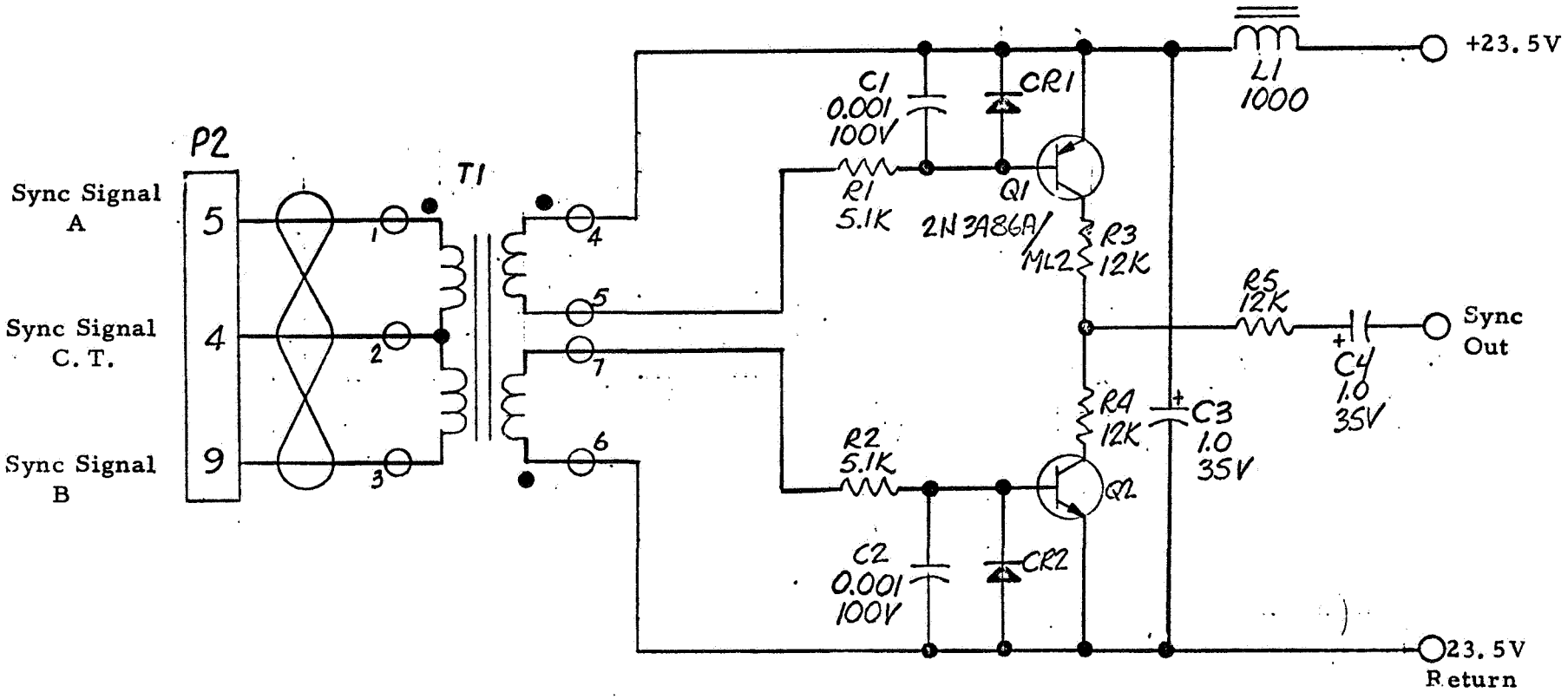
* Selected Value

1. All resistances in ohms ± 5% 1/4W.
2. All capacitances in microfarads ± 10%
3. All inductance in microhenries ± 5%
4. All transistors 2N2484/46 (Amelco)
5. All diodes are GE DHD 115 (1N4150)

NOTES: Unless Otherwise specified

Primary Power Interface

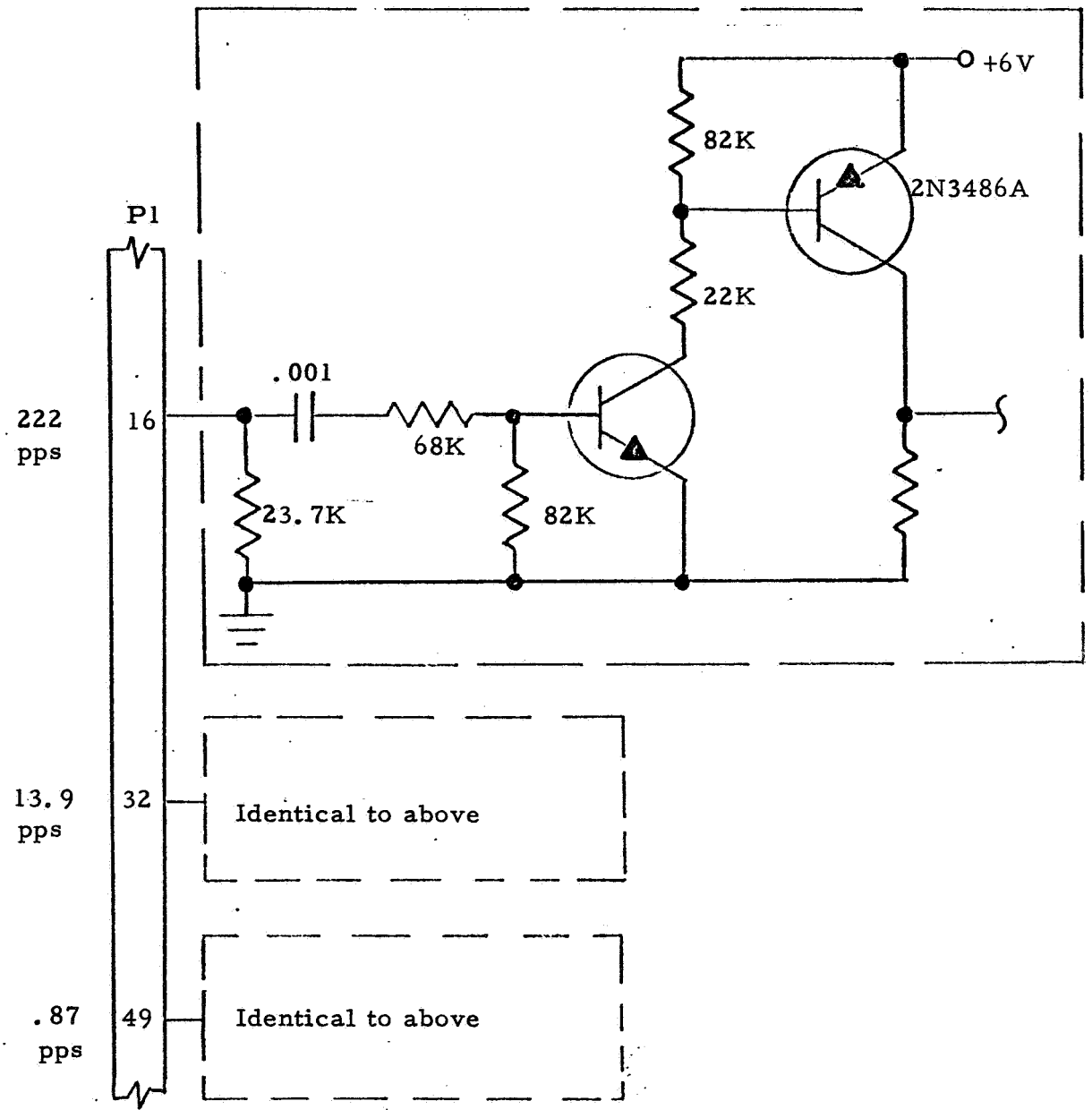
Figure 29



1. All resistances in ohms ± 5% 1/4W
2. All capacitances in microfarads ± 10%
3. All inductance in microhenries ± 5%
4. All transistors 2N2484/46 (Amelco)
5. All diodes are GE DHD115 (1N 4150)
6. T_1 exitation current less than 50 μa rms
7. On T_1 windings 1-2, 2-3, 4-5, & 6-7. All equal number of turns.

Notes: Unless otherwise specified

Figure 30
Sync Signal Interface



1. All resistance in ohms ± 5% 1/4W
2. All capacitance in microfarads ± 10%

Note: Unless otherwise specified

Timing Pulse Interface

Figure 31

and 222 pps. The input circuit to all three of these signals is identical. Each input circuit consists of suitable isolation resistors, which present the proper input impedance, together with an amplifier which acts as a buffer to a logic AND circuit. All of the returns for these signals are referenced to signal or telemetry ground.

3.2.4 Index Pulse Interface

Figure 32 shows the schematic diagram of the Index Pulse interface. As indicated, both the group one index pulse No. 26 and that from group 2 are applied through suitable isolation resistors into amplifiers which buffer the AND/OR logic circuit which follows. The control inputs to the two AND gates are the switch signal and its complement. These signals are not the spacecraft signals but are those which are derived from the spacecraft through suitable buffering amplifiers. The index pulse signals are returned through the signal ground line.

3.2.5 Special Purpose Telemetry Power Command Interface

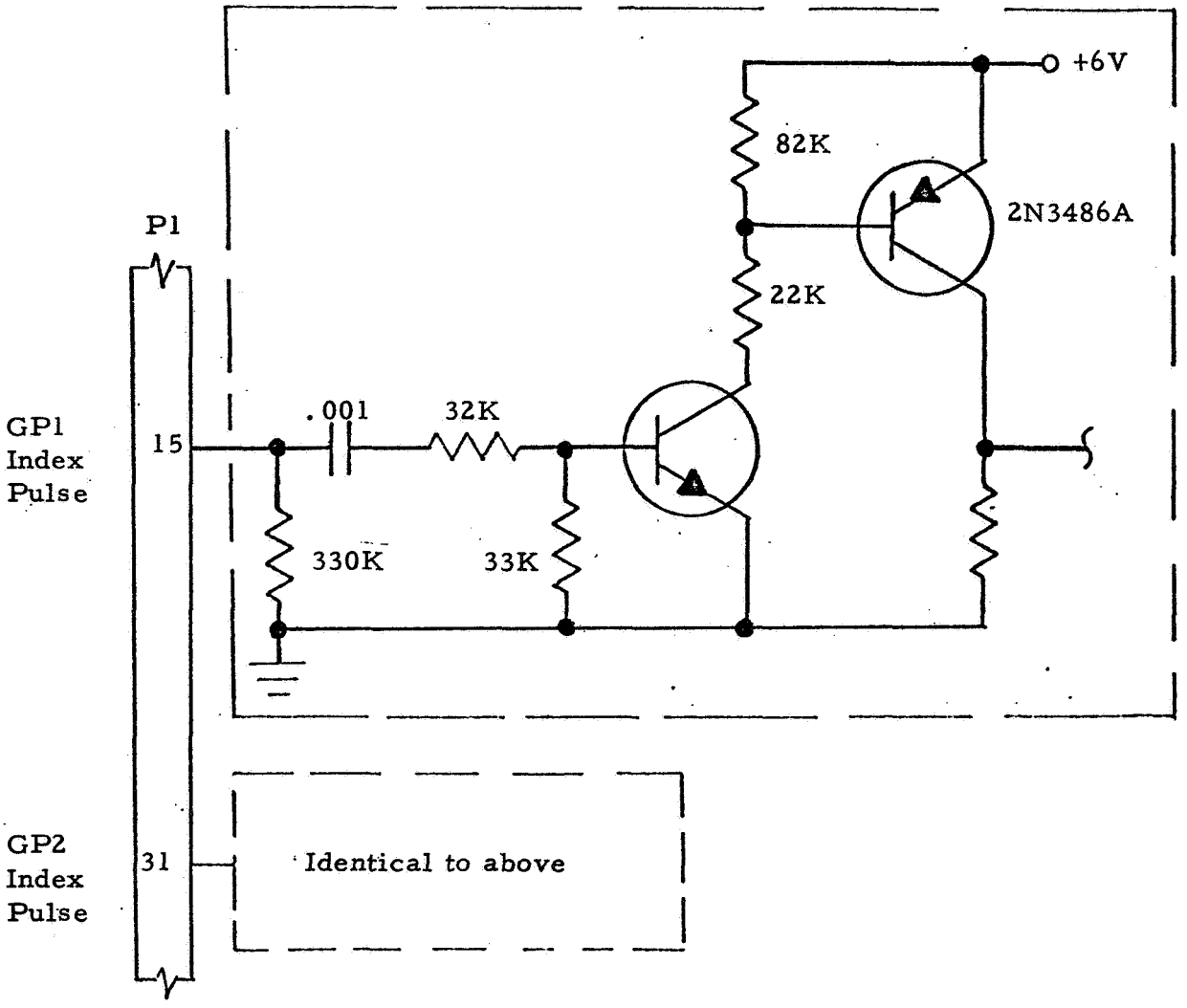
Figure 33 shows the schematic for the interface to the special purpose telemetry power command. When the command is in the enable state, the 28 volt input is regulated and applied to an oscillator as the supply voltage. The command input is returned on the 23.5 volt return line. The oscillator is transformer coupled and rectified for use as the instrument control signal which is referenced to signal ground.

3.2.6 Impulse Command Interface

Figure 34 shows the schematic of the circuitry which is used for the three spacecraft impulse commands. These commands consist of the Waveform Gain Increment Command, the Spectrum Gain Increment Command, and the IFC On-Off Command. Each of the three input circuits is identical. The command input is filtered to obtain maximum noise rejection and is then applied to a blocking oscillator. All power for this circuit is derived from the +23.5 volt return and signal ground.

3.2.7 Telemetry Status Signals Interface

Figure 35 shows the interface circuits for the telemetry status signal. The signals utilized are the Bit Rate

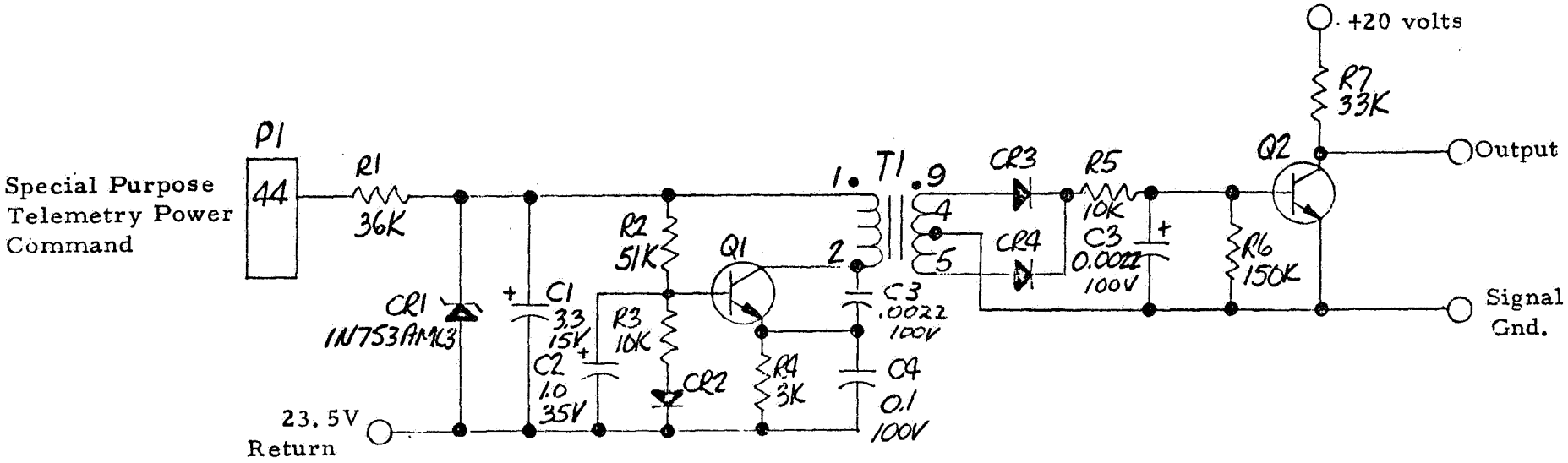


1. All resistance in ohms ± 5%, 1/4W
2. All capacitance in microfarads ± 10%

Notes: Unless otherwise specified

Index Pulse Interface

Figure 32

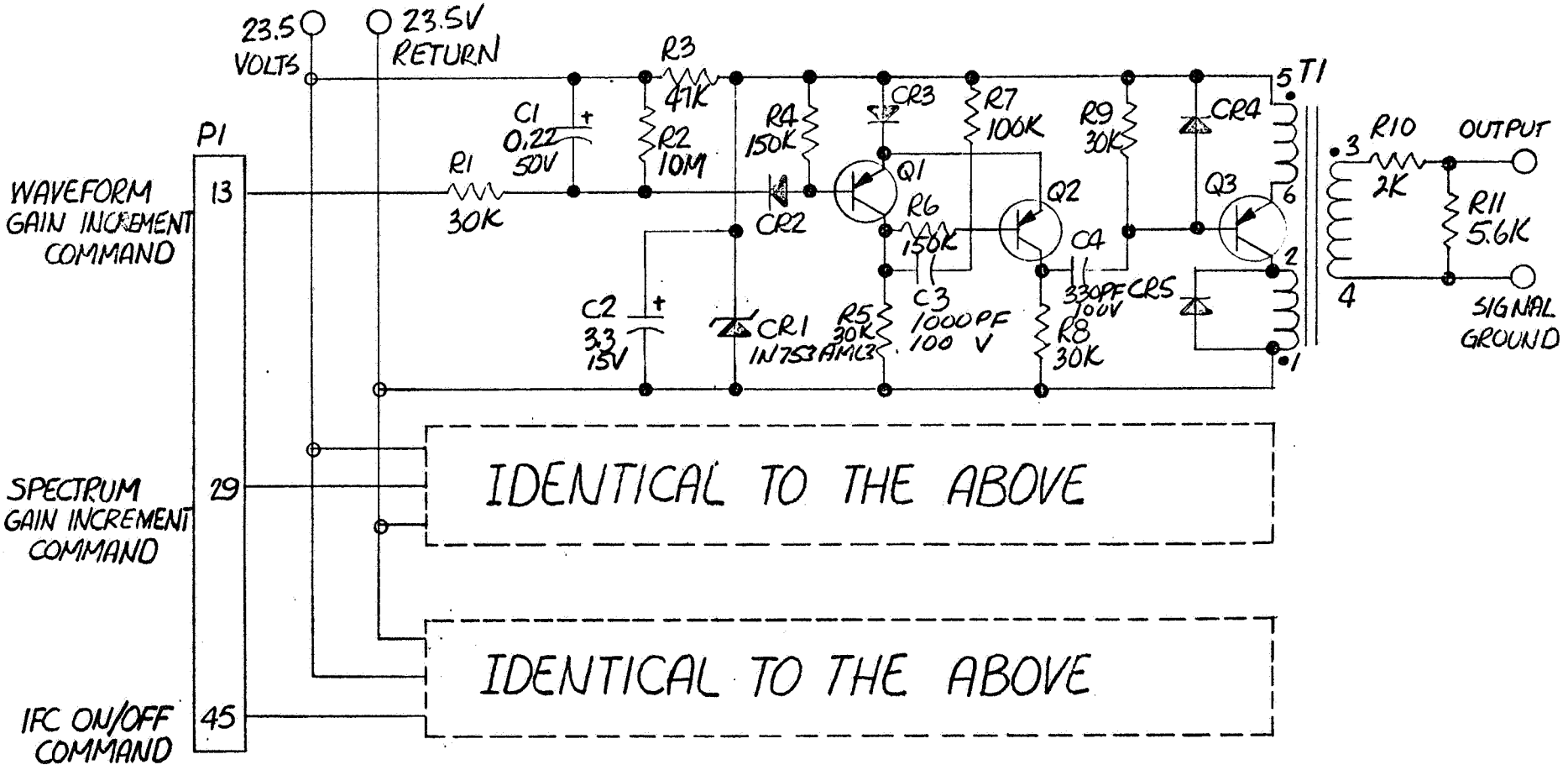


1. All resistances in ohms ± 5% 1/4W
2. All capacitances in microfarads ± 10%
3. All transistors 2N2484/46 (Amelco)
4. All diodes are GE DHD 115 (1N4150)

Note: Unless otherwise specified

Special Purpose Power
Command Interface

Figure 33

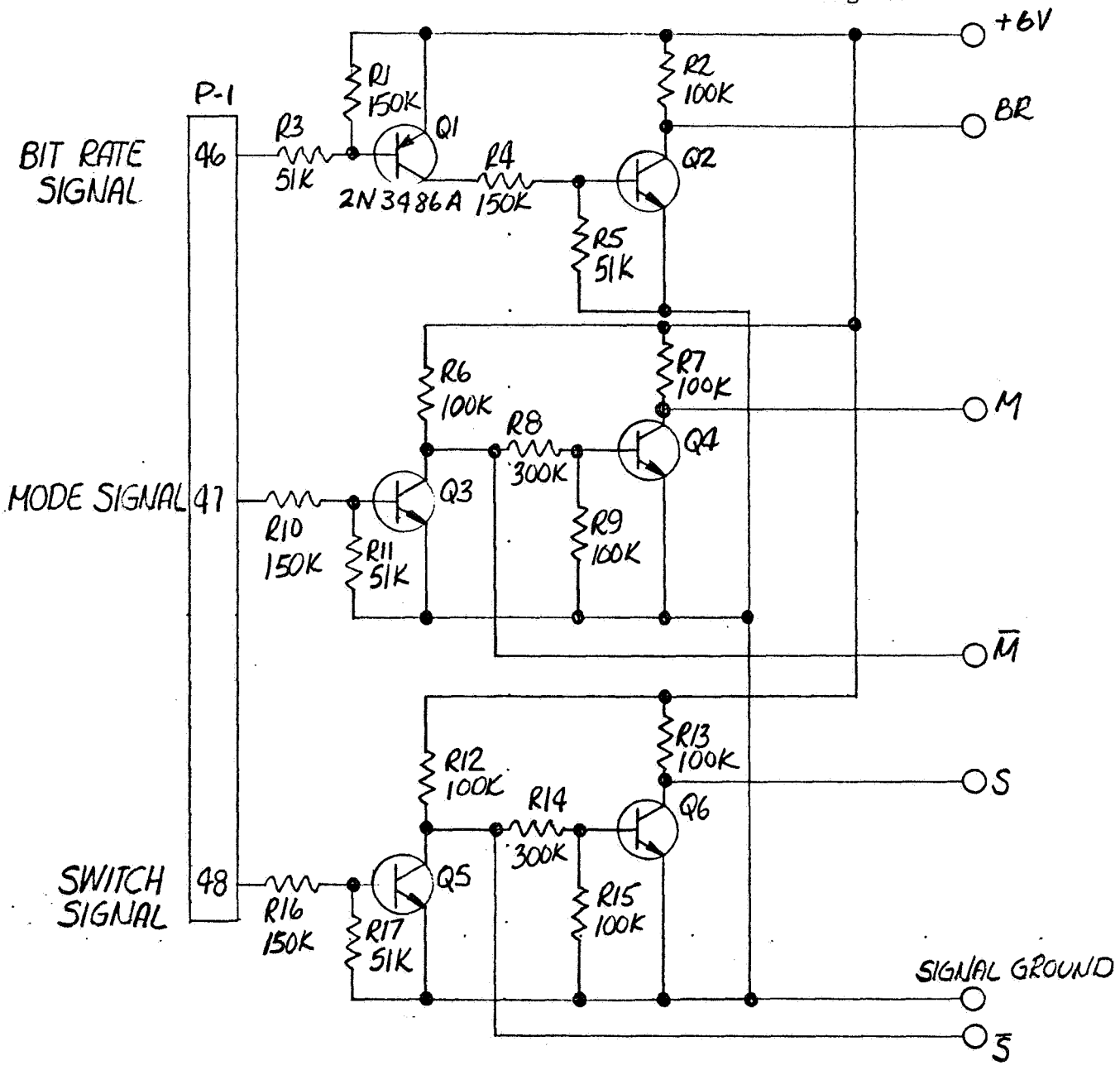


4. ALL DIODES ARE GE DHD115 (IN4150)
3. ALL TRANSISTORS SM9139H (MOTOROLA) PNP
2. ALL CAPACITANCES IN MICROFARADS ±10%
1. ALL RESISTANCES IN OHMS ±5% 1/4W

NOTES: UNLESS OTHERWISE SPECIFIED

Impulse Ccmmand Interfaces

Figure 34



2. ALL TRANSISTORS 2N 2484/46 (AMELCO)

1. ALL RESISTANCES IN OHMS ±5% 1/4W

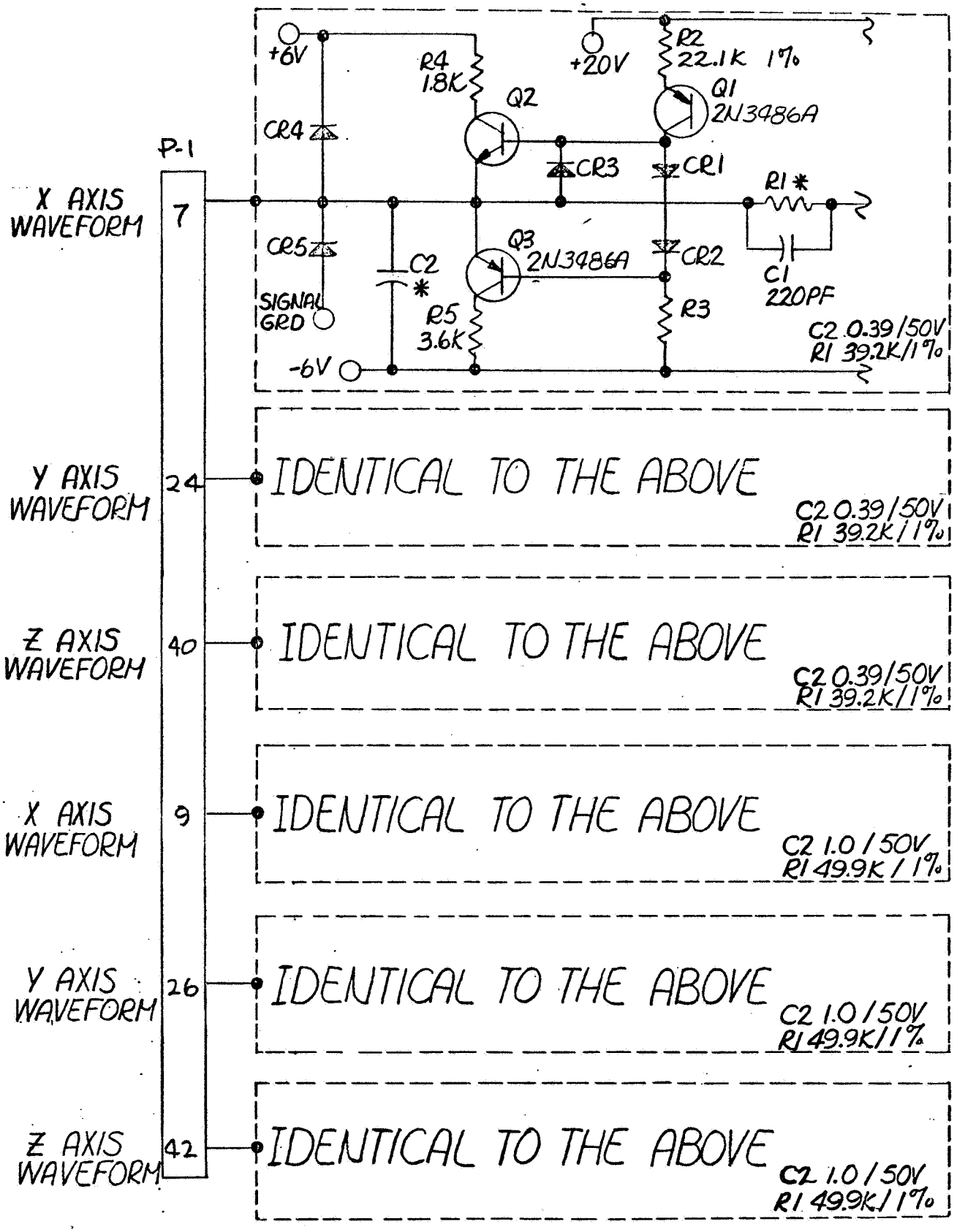
NOTES: UNLESS OTHERWISE SPECIFIED

Telemetry Status Signals Interfaces
Figure 35

Signal, the Mode Signal, and the Switch Signal. The circuitry for the Mode and the Switch Signals is identical both utilizing isolation resistors to present the proper input impedance, and amplifiers which provide the output corresponding to the input signal and also its complement. The circuit for the Bit Rate Signal is similar except that it utilizes a complementary symmetry amplifier. All of these signals are returned through signal ground.

3.2.8 Waveform and Wideband Output Interfaces

Figure 36 shows a schematic diagram of the interface circuit for the waveform and wideband output signals. These six outputs are identical except for the value of output capacitor and feedback resistor between the waveform outputs and the wideband outputs. These component variations are indicated on the interface schematic. The actual output circuit consists of a complementary emitter follower driven by a PNP amplifier. Also connected to the output is a feedback network consisting of R1 and C1, a capacitor C2 which provides the necessary surge current for the ADHA input capacitance, and CR4 and CR5 which clamp the output to prevent large output excursions below signal ground and above plus 6 volts. The high open loop gain of the amplifier results in a very low dynamic output impedance of this circuit.



1. Resistances in ohms ± 5% 1/4W
2. Capacitances in microfarads ± 10%
3. Transistors 2N2484/46 (Amelco)
4. Diodes GE DHD 115 (1N4150)

Notes: Unless otherwise specified

Waveform and Wideband Output Interfaces
Figure 36

3.2.9 Wave Analyzer Output Interface

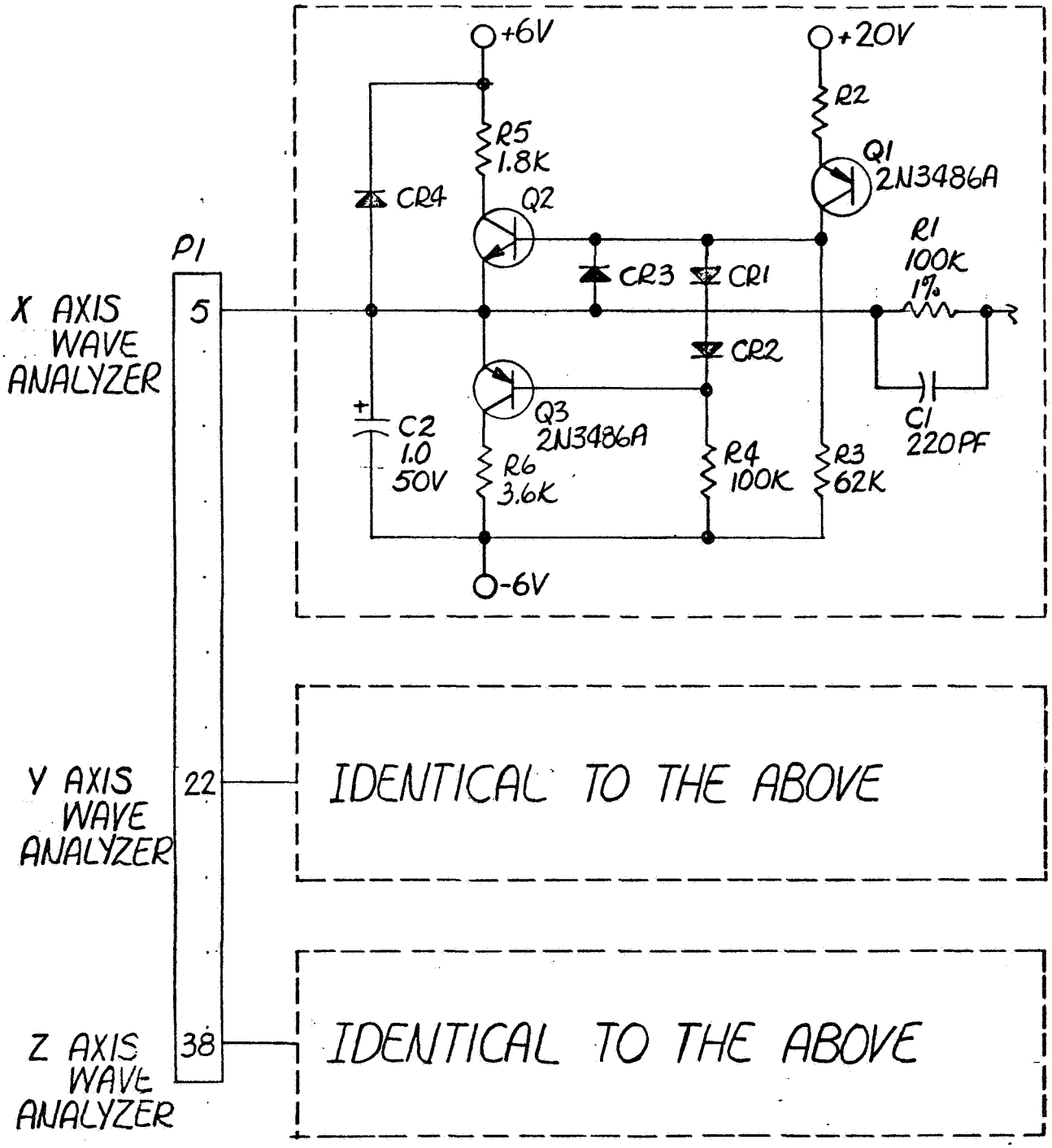
Figure 37 shows the schematic diagram of the wave analyzer outputs. The outputs for all three axes are identical. These output circuits are identical to those shown in Figure 36 except that the clamping diode to ground is not included due to the fact that the input to these circuits is d-c rather than a-c, and will not cause the output to go more than 20 millivolts below ground potential.

3.2.10 Special Purpose Telemetry Output Interfaces

Figure 38 shows a schematic diagram of the output circuits for the three signals which are utilized by the Special Purpose Telemetry. These output circuits are identical except for SCO frequencies which are being passed, these consisting of 30 KHZ for the X-Axis, 52.5 KHZ for the Y-Axis, and 70 KHZ for the Z-Axis. The Y and Z axes SCO signals (52.5 KHZ and 70 KHZ) are summed within the output amplifier in order to conserve one Special Purpose Telemetry Output channel. The output circuit consists of a complementary emitter follower output stage which is part of a feedback amplifier. These amplifiers are very similar to those shown in Figures 36 and 37. As a result of the emitter follower output stage, the output impedance of these circuits is extremely low. Both output circuits are capacitor coupled in order to remove the d-c component of the signal.

3.2.11 Instrument Status Output Interfaces

Figure 39 shows a schematic of the output circuit for the four status output lines. Each of these circuits is identical with the exception of the wave analyzer output which has a .01 microfarad capacitor rather than a 1.0 microfarad capacitor across the output. This is required due to the relatively high frequency at which this output changes. These capacitors are used as hold devices to stabilize the input to the analog to digital converter. Figure 40 indicates typical output levels on the four status lines for all combinations of the control circuitry within the instrument.



4. Diodes GE DHD115 (1N4150)

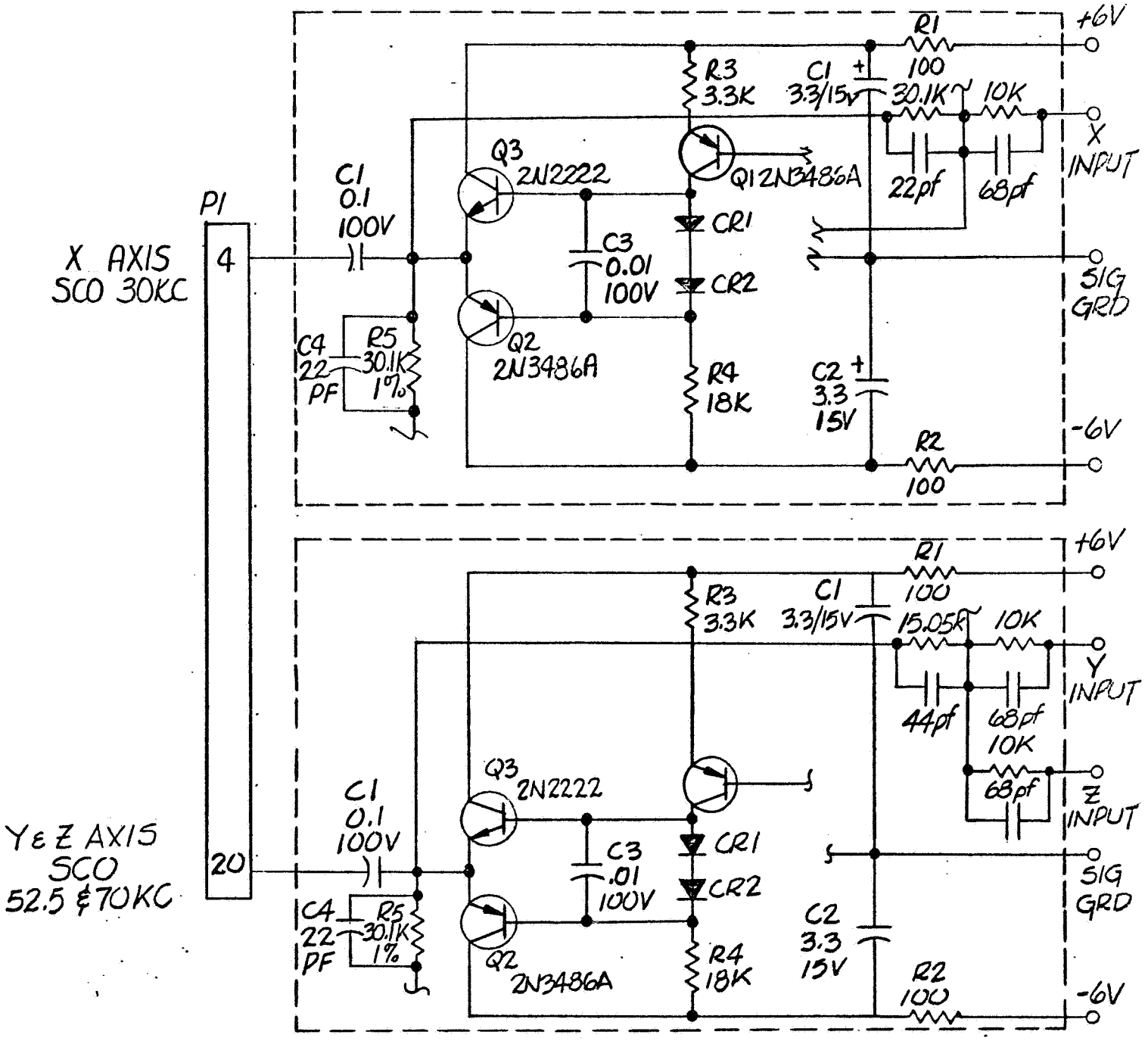
3. Transistors 2N 2484/46 (Amelco)

2. Capacitances in microfarads ±10%

1. Resistances in ohms ±5% 1/4w

Notes: Unless otherwise specified.

Figure 37. Wave Analyzer Outputs Interfaces



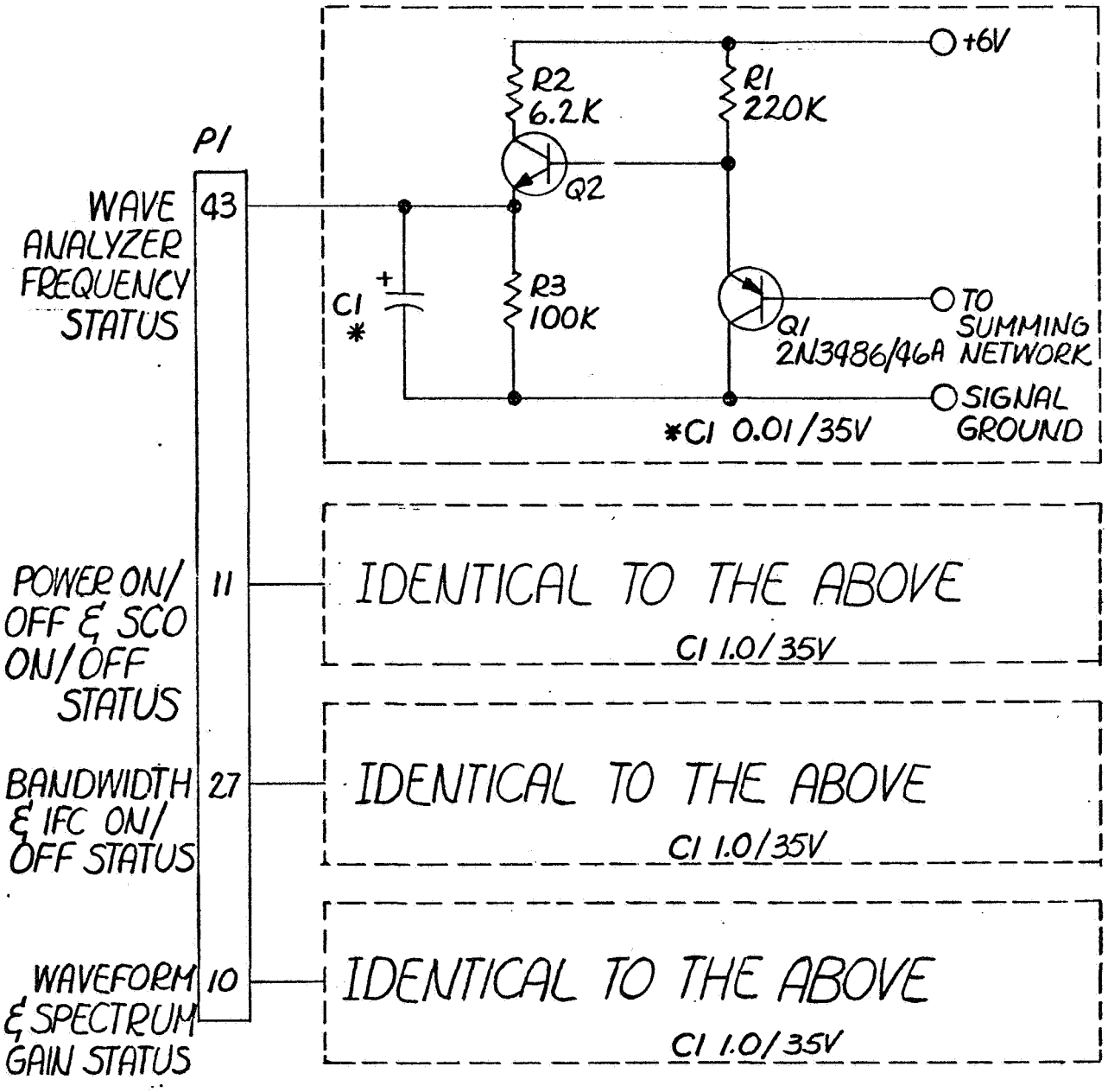
3. Diodes GE DHD115 (1N4150)

2. Capacitances in microfarads ±10%

1. Resistances in ohms ±5% 1/4w

Notes: Unless otherwise specified

Figure 38. Special Purpose T/M Outputs Interface



3. Transistors 2N2484/46 (Amelco)

2. Capacitances in microfarads ±10%

1. Resistances in ohms ±5% 1/4w

Notes: Unless otherwise specified

Figure 39. Status Outputs Interfaces

WAVE ANALYZER FREQUENCY STATUS	
FREQ. CPS	OUTPUT VOLTS
10	.76
22	1.44
47	2.10
100	2.80
216	3.46
467	4.15
1000	4.79

POWER ON/OFF & SCO ON/OFF STATUS		
POWER STATUS	SCO STATUS	OUTPUT VOLTS
OFF	OFF	0
OFF	ON	0
ON	OFF	3.6
ON	ON	1.6

BANDWIDTH & IFC ON/OFF STATUS		
IFC STATUS	BAND-WIDTH	OUTPUT VOLTS
OFF	WIDE	.14
OFF	NAR	1.54
ON	WIDE	2.97
ON	NAR	4.41

WAVEFORM & SPECTRUM GAIN STATUS		
W.F. GAIN	SP. GAIN	OUTPUT VOLTS
LO	LO	3.70
MED.	LO	3.35
HI	LO	3.00
LO	MED.	2.20
MED.	MED.	1.90
HI	MED.	1.55
LO	HI	.80
MED.	HI	.45
HI	HI	.13

Figure 40. Status Output Levels

4.0 CIRCUIT DESCRIPTIONS

The following paragraphs describe, in detail, circuits which were utilized in the OGO-E-16 Search Coil Magnetometer. They are the following:

1. Search Coil Sensor
2. Preamplifier
3. Heater
4. 400 Hz Notch Filter
5. 1850 Hz Low Pass Filter
6. Waveform Channel Bandpass Control Circuit
7. Gain Change Amplifiers
8. Output Amplifier
9. Wave Analyzer Bandpass Amplifiers
10. Peak Detector
11. SCO Low Pass Filter
12. Subcarrier Oscillator (SCO)
13. Wave Analyzer Commutator
14. Commutator Gating Circuit
15. Complementary Flip Flop
16. Seven (7) Bit Binary Counter
17. Impulse Command Isolation Amplifier
18. SCO Command Detector
19. Power Supply Synch Amplifier
20. Power Supply Converter
21. Power Supply Preregulator (+23.5v)
22. Power Supply Postregulators

4.1 Search Coil Sensor

In past years, Marshall Laboratories has been actively engaged in the field of search coil magnetometer development. Part of this work has entailed the design and evaluation of the basic sensor itself. We used this knowledge to design a sensor, the OGO-E Magnetometer.

The basic sensitivity for a search coil magnetometer is:

$$K = 2\pi N A \mu_e \times 10^{-7} \quad \frac{\text{microvolts } (\mu v) \text{ seconds (sec)}}{\text{gamma } (\gamma)}$$

where N = number of turns

A = area in cm^2

μ_e = effective mu of the sensor

This formula neglects any fringing effects which may take place.

The parameters N and A are rather obvious and need no further discussion at this point; however, value for the effective mu of the core needs further evaluation. In his book, "Ferro Magnetism", Bozorth describes the relationship between the real mu and the effective mu of a search coil. On Page 848, he depicts the relationship of real mu to effective mu as a function of the $\frac{\ell}{d}$ ratio of the core of a search coil. If one assumes that the real mu of the core is infinity, then the expression for the approximate effective mu, is:

$$\mu_e \approx 1.6 \left(\frac{\ell}{d}\right)^{1.6}$$

where ℓ = length of core

d = effective core diameter

Combining the two above equations, leads one to the following result:

$$K \approx 2\pi N (1.6)^{1.6} d^{0.4} \times 10^{-7} \quad \frac{\mu v - sec}{\gamma}$$

From the above, it can be seen that the sensitivity of the search coil is a much stronger function of its length rather than of its diameter.

At first glance, it might appear that d should be chosen to be as large as practical; however, the obvious limitations are those of weight of the core itself and also the winding. On the other hand, d cannot be too small since then the effective mu will become too large and the assumption that the real mu is much greater than the effective mu will no longer be a valid one. One would then be operating in a region where changes in the real mu of the core material would drastically affect the effective mu and therefore the sensitivity of the sensor. Too large an effective mu can cause problems as a result of operation in a d-c magnetic field which can saturate the core. For example, if the effective mu of the core were 30,000 and if it were placed in the earth's magnetic field, one would find approximately 15,000 gauss in the core. This flux density will saturate the types of materials which are best for this application. Another real factor involved in the selection of the core cross section is the availability of material. Experience has shown that delivery problems can be expected when other than standard material is requested from a magnetic material manufacturer. It is thus extremely advantageous to use a standard size and type of material.

Based upon the above considerations, Marshall Laboratories fabricated the core from 4 mil laminations 1/8" wide of Round HyMu 80 with a build up of one eighth of an inch. This core geometry provided an effective mu of approximately 1600. This value is conservative from the standpoint of variations of real mu because the effective mu of the material is as large as 24,000.

The location of the windings on the cores is important from the consideration of fringing fields. Figure 41 shows the measured sensitivity of one winding of 12,500 turns as a function of its location along the core. Any winding mounted near the end of the core will have its sensitivity reduced by more than 50% as a result of fringing effects. For OGO-E, the windings are placed within one inch of the center of the core.

The parameters which remain to be determined now are the number of turns to be placed upon the coils and the winding methods used. Both of these parameters are dictated, to a large degree, by the required resonant frequency of the sensor. There is also a strong inter-relation between the number of turns (therefore the core inductance) and the signal to noise ratio of the sensor preamp combination.

The winding techniques used are important in that they affect the winding capacity and therefore the resonant frequency of the sensor. The windings used for this system consists of 100,000 turns of No. 47 wire which are wound upon 2 equal sized sections each with a width of approximately 1.0" and containing 50,000 turns of wire each.

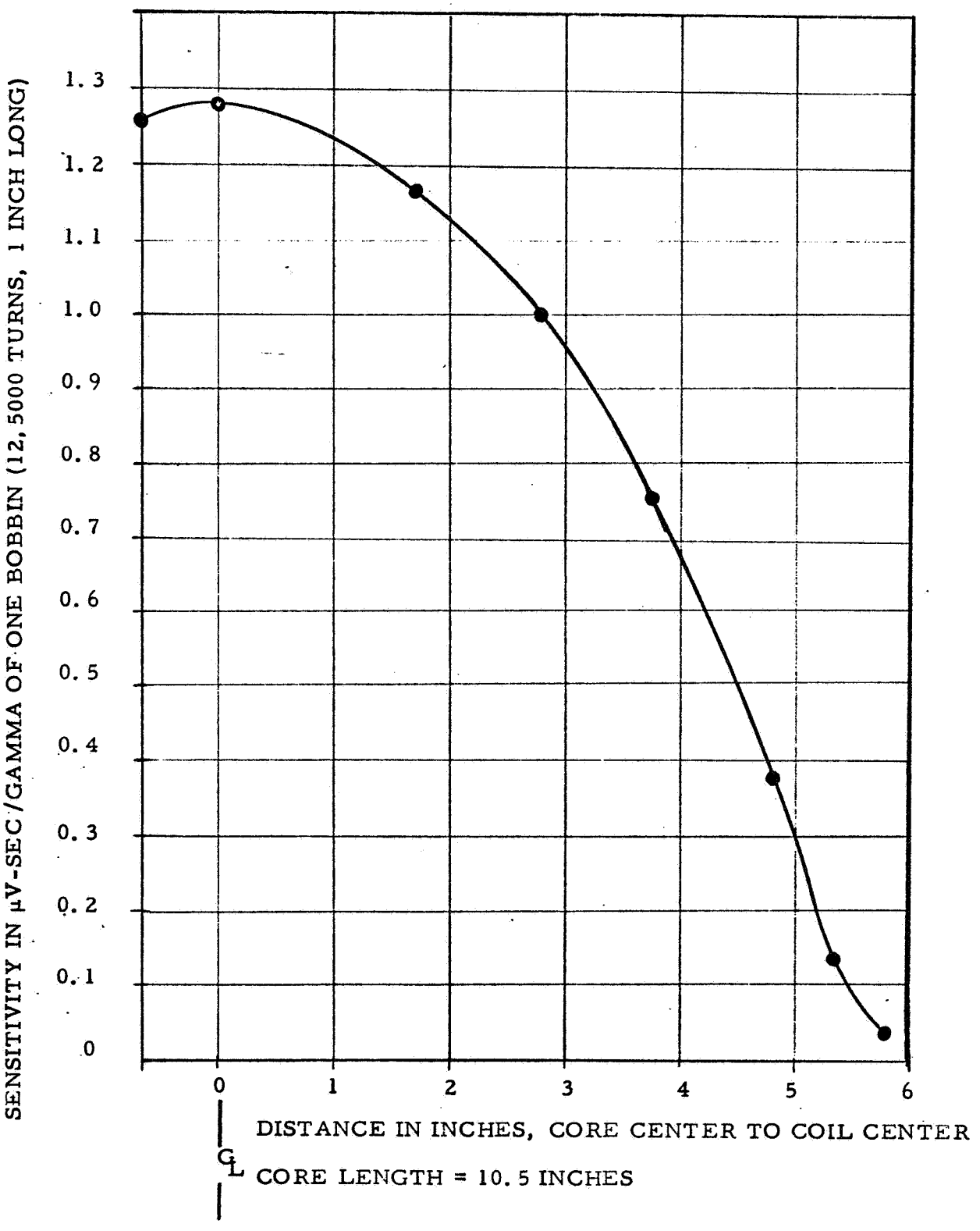


Figure 41. Effect of Fringing Fields

Each of three search coil sensors has the following characteristics:

a.	Sensitivity:	10 μv/γ/Hz
b.	D-C Resistance:	50K ohms
c.	Inductance:	1600 Henries
d.	Capacitance:	30 Picofarads
e.	Resonant Frequency:	670 cps
f.	Damping:	Critical

The sensor equivalent is shown in Figure 41.

4.2 Preamplifier

The preamplifier (Figure 42) consists of cascade amplifier, Q1 and Q2, driving a matched differential amplifier, Q3, which drives differential amplifier Q4 and Q5. Output short circuit protection is provided by R16 in the collector circuit of Q6.

The open loop gain of the preamplifier is about 10^4, and the closed loop low frequency gain is 100, determined by the ratio of R5, and R12. Capacitor C3, shunting R12, limits the high frequency response by increasing the feedback at higher frequencies resulting in decreased gain. The -3db break point occurs at about 3.6 KC.

The bias point of the field effect transistors Q1 and Q2 is determined by resistors R1 through R6. By proper selection of R3, R4, and R6, a quiescent drain current is set such that the cascade amplifier exhibits a near zero temperature coefficient over the operating range of $-50^{\circ}C$ to $+40^{\circ}C$. The thermal stability of the cascade amplifier in conjunction with the inherent stability of the differential amplifier ensures bias point stability over the entire operating temperature range of $-50^{\circ}C$ to $+60^{\circ}C$.

Capacitors C1 and C2 provide power supply decoupling improving the low noise characteristic of the preamplifier. Resistors R13 and R5 form a 100:1 voltage divider for the injection of the in-flight calibration signals provided by the main electronics assembly.

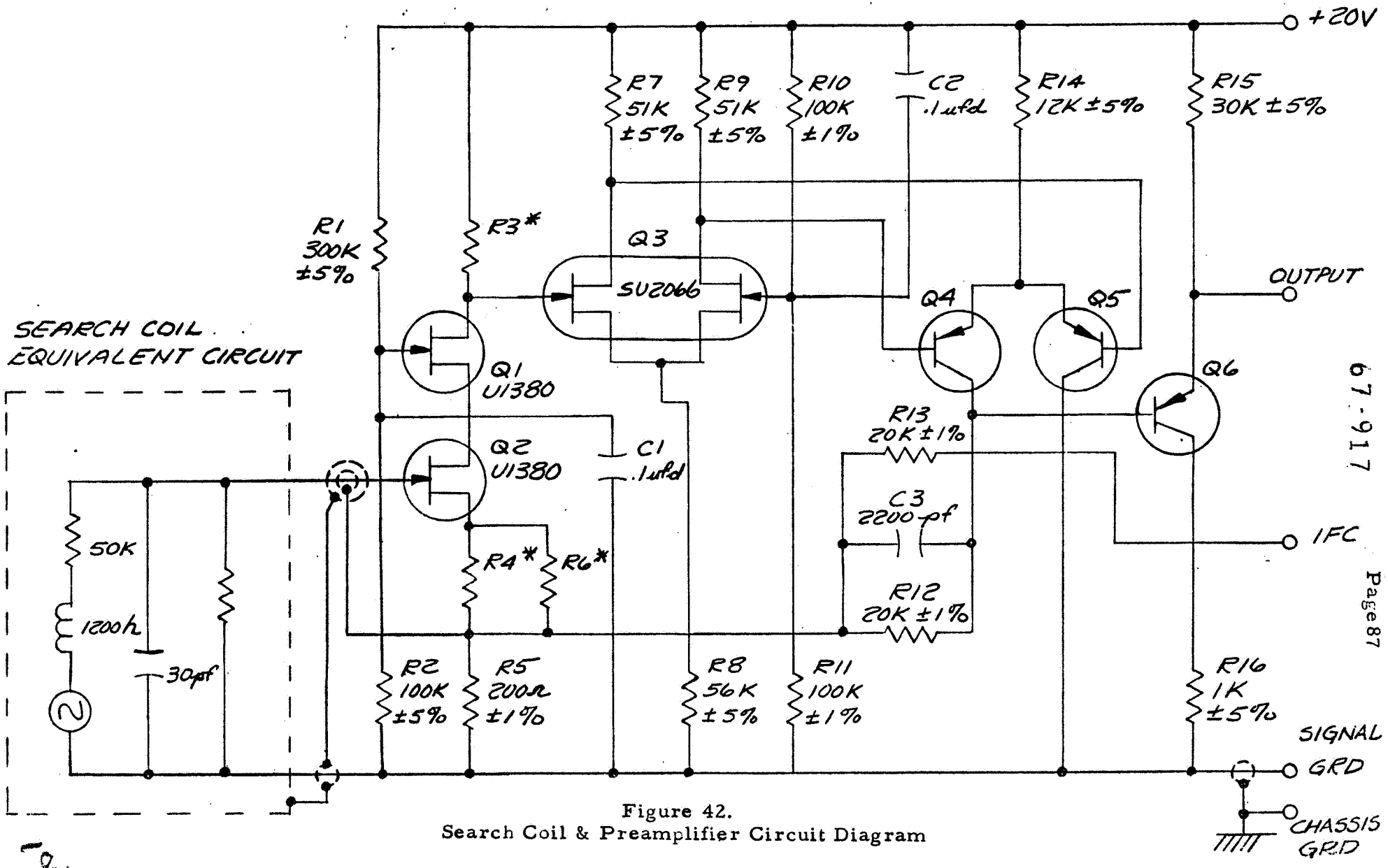


Figure 42.
Search Coil & Preamplifier Circuit Diagram

The preamplifier characteristics are as follows:

Input Impedance	$\geq 10^9$ ohms shunted by 10 picofarads
Output Impedance	$< 10^2$ ohms
Frequency Response	D-C to 3600 Hz (-3db)
Output Voltage	1 volt RMS into 50K ohm
Gain	100 ± 1
Noise	a) < 1 microvolt RMS from 0.01 Hz to 1 Hz b) < 0.01 microvolt squared per Hz from 5 Hz to 1 K Hz
Operating Temperature	-50°C to +60°C

4.3 Preamplifier Heater Circuit

The preamplifier proportional heater was designed to ensure the proper operation of the preamplifier below +15°C. Figure 43 shows the schematic diagram of the proportional heater. Transistors Q1 and Q2 form a differential amplifier with fixed bias resistors R1, R2, and R3. Transistor Q2 is controlled by a temperature sensitive bias network consisting of R5, R6, and RT1. RT1 has a negative temperature coefficient. When the temperature goes below +15°C, the resistance of RT1 increases which increases the bias voltage and turns Q2 on. When Q2 is turned on, the voltage across R4 decreases which turns Q3 on. The maximum power, determined by the collector resistors of Q3 (R7 and R8), is approximately 125 milliwatts.

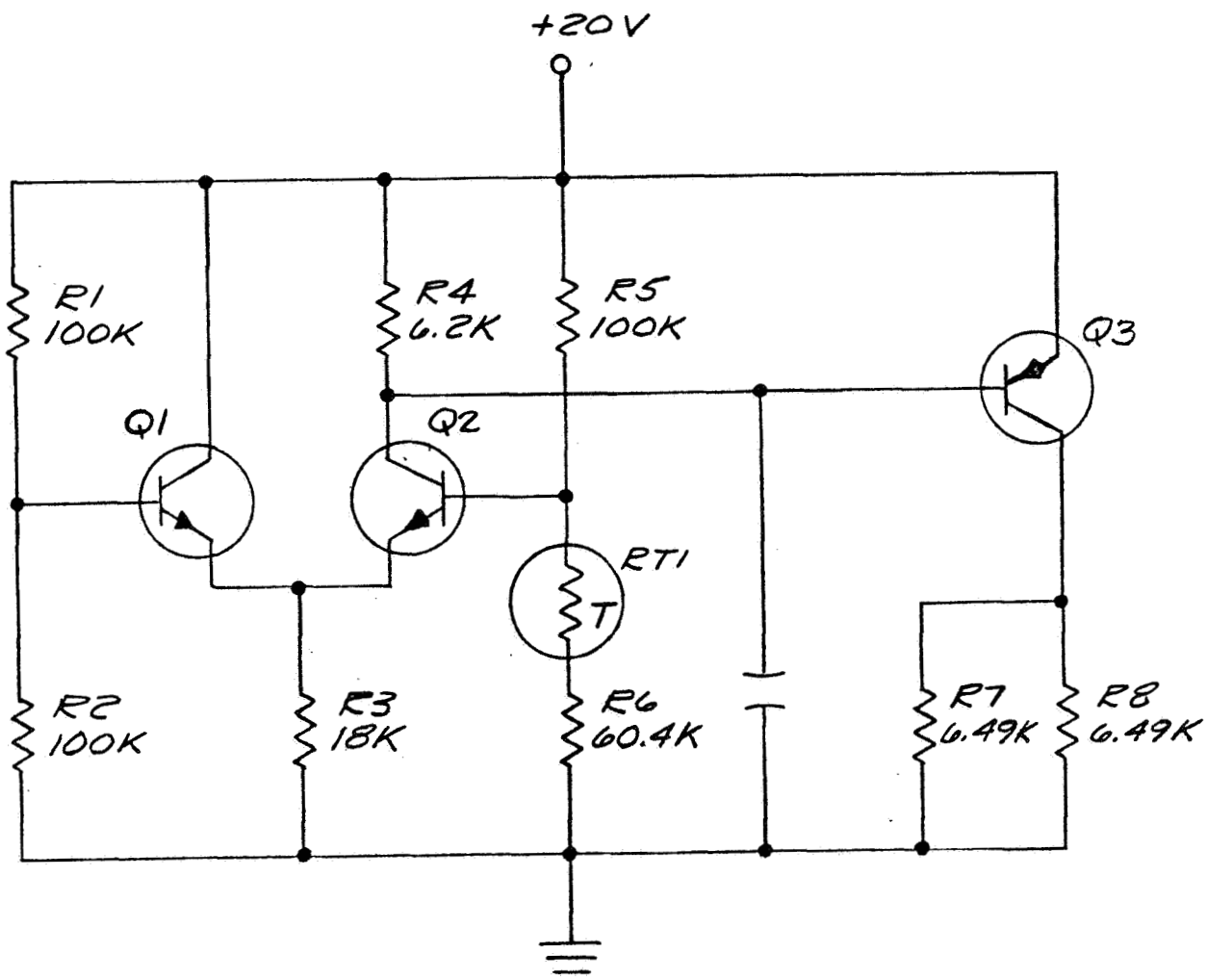


Figure 43. Preamplifier Heater Circuit

4.4 400 Hz Notch Filter

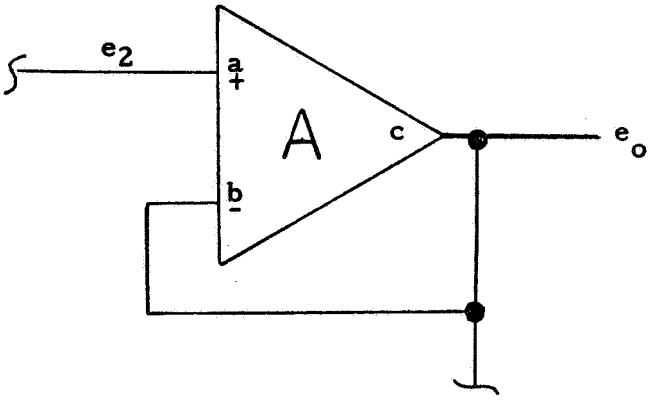
The function of this circuit is to attenuate 400Hz signal (Spacecraft Power Sync Frequency) component and pass with unity gain all other signals.

Figure 44 shows a schematic of the circuit.

Figure 45 shows a simplified equivalent circuit. In Figure 45 the input signal e_{in} passes through the symmetric parallel-T network (G) into a high gain amplifier (A) which is used as a follower, through the resistor attenuator network R1-R2 and back to the network G.

The transfer function is derived as follows:

First consider the following -



A is the gain of the differential amplifier

$$v_c = A (v_a - v_b)$$

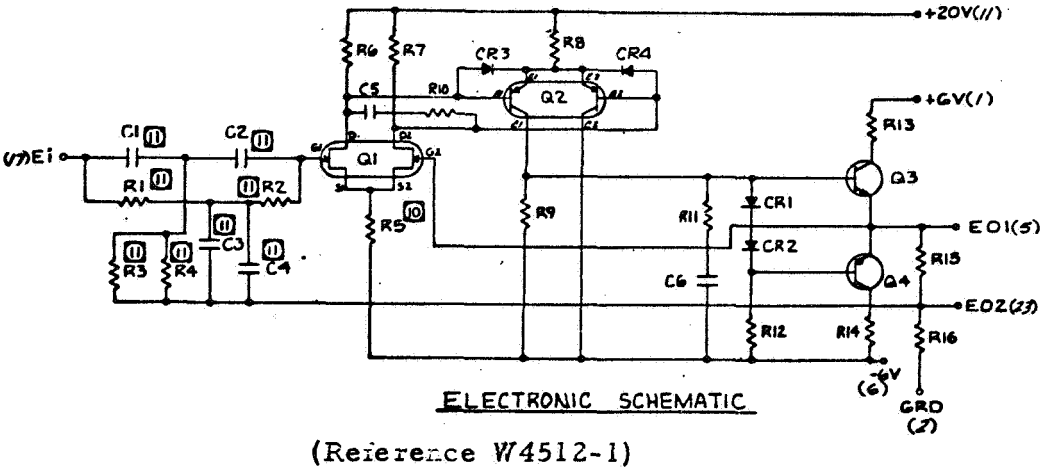
thus $e_o = A (e_2 - e_o)$

$$e_o = A e_2 - A e_o$$

$$A e_2 = e_o + A e_o = e_o (1 + A)$$

$$\frac{e_o}{e_2} = \frac{A}{1 + A} = \frac{1}{1 + \frac{(1)}{A}}$$

$$\boxed{e_2 = e_o \left(1 + \frac{1}{A}\right)} \quad \text{— — — — — —(1)}$$

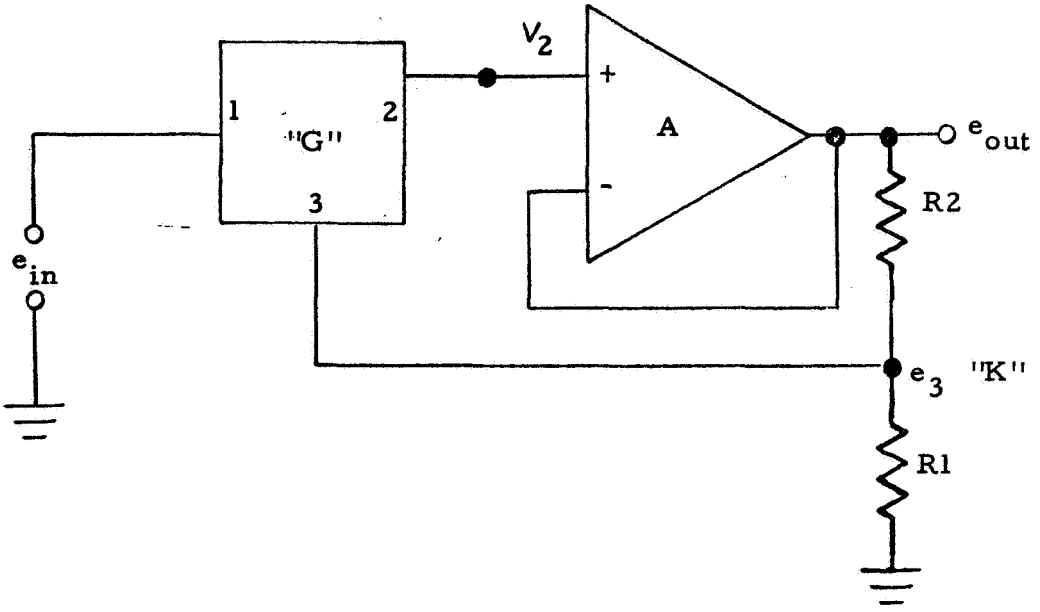


(Reference W4512-1)

C1 = C2 = C3 = C4 = 1200 pf ± 1%
C5 = 470 pf
C6 = 1000 pf
R1 = R2= R3 = R4= 332K ± 1%
R5 = Select
R6 = R7 = 40.2K
R8 = 16.9K
R9 = 10 Meg
R10 = 510 Ω
R11 = 1K
R12 = 47K
R13 = R14 = 200 Ω
R15 = 499Ω
R16 = 10K

Q1 = 2N3954
Q2 = 2N4024
Q3 = FM2484
Q4 = ML20001

Figure 44. 400 Hz Notch Filter Schematic



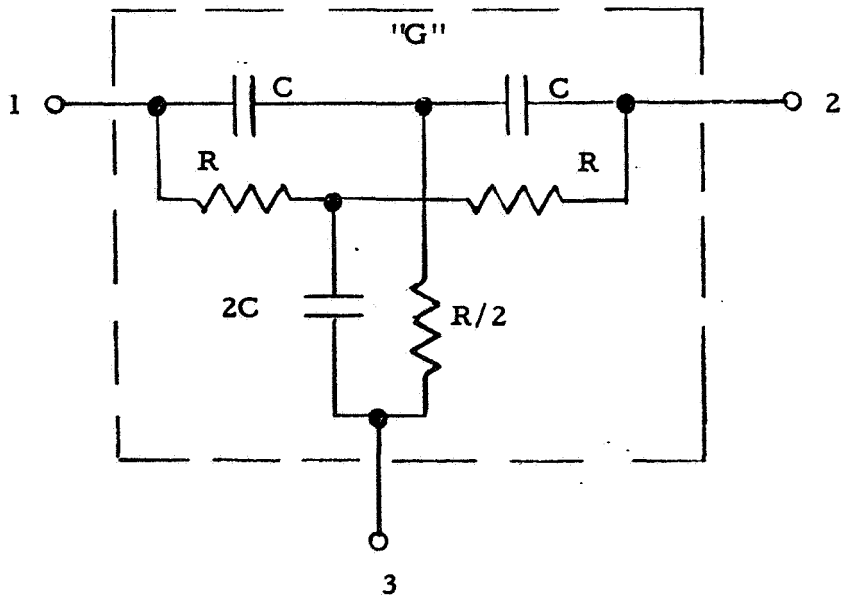
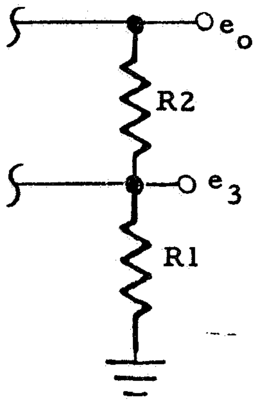


Figure 45. 400 Hz Notch Filter Equivalent Circuit

Now consider the K network:

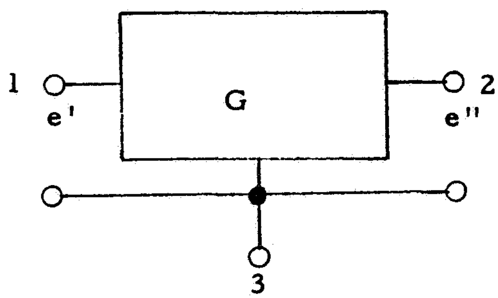


$$e_3 = \left[\frac{R1}{R1 + R2} \right] e_o$$

$$\text{Let } K_o = \frac{R1}{R1 + R2}$$

then $\boxed{e_3 = K_o e_o}$ - - - - (2)

Now consider the parallel T network:



and let $G = \dfrac{e''}{e'} = \dfrac{e_2 - e_3}{e_1 - e_3}$.

$\boxed{e_1 = e_{in}}$ - (3)

Substitute equations 1, 2, and 3 in the expression for G, which yields:

$$G = \frac{\left[e_o\left(1 + \frac{1}{A}\right)\right] - \left[K_o e_o\right]}{\left[e_{in}\right] - \left[K_o e_o\right]}$$

Solving for $\frac{e_o}{e_{in}}$ yields:

$$\boxed{\frac{e_o}{e_{in}} = \frac{1}{K_o + \left(\frac{1-K_o}{G}\right) + \frac{1}{AG}}} \quad \text{- - - - - - - - - - - - - - - - - (4)}$$

The transfer function for G as given in "Feedback Control System Analysis and Synthesis" by D'Azzo + Houpis (page 577) is:

$$G = \frac{1 - \omega^2 R^2 C^2}{1 - \omega^2 R^2 C^2 + j\,4\,RC\omega}$$

which reduces to:

$$\boxed{G = \frac{1 - T_7^{\,2} S^2}{1 + K_1 T_7 S - T_7^{\,2} S^2}} \quad \text{- - - - - - - - - - - - - - - - - (5)}$$

Substituting equation 5 into 4 yields:

$$\frac{e_o}{e_{in}} = \frac{1 - T_7^{\,2} S^2}{1 + (1-K_o) K_1 T_7 S - T_7^{\,2} S^2 + \left(\frac{1 + K_1 T_7 S - T_7^{\,2} S^2}{A}\right)}$$

Let $\alpha = \left(\frac{1 + K_1 T_7 S - T_7^{\,2} S^2}{A}\right)$ if A is in

the form of $A = \frac{K_2}{1 + S T_2}$

and $A >> 1$, $T_2 \ll T_7$, then $\alpha \Rightarrow 0$

then:

$$\frac{e_o}{e_{in}} = \text{Closed Loop Gain} = \frac{1 - T_7^2 S^2}{1 + (1 - K_o) K_1 T_7 S - T_7^2 S^2}$$

for values used:

$$T_7 = RC = (332K)\,(1200\ pf)$$

$$T_7 = 3.32 \times 10^5 \times 1.2 \times 10^{-9} = 3.98 \times 10^{-4}$$

$$T_7 = 398\ \mu sec.$$

$$f_1 = \frac{1}{2\pi RC} = \frac{0.1592}{398\ \mu sec.} = 400\ Hz$$

$$K_1 = 4$$

$$K_o = \frac{R_1}{R_1 + R_2} = \frac{10K}{10K + 499} = 0.953$$

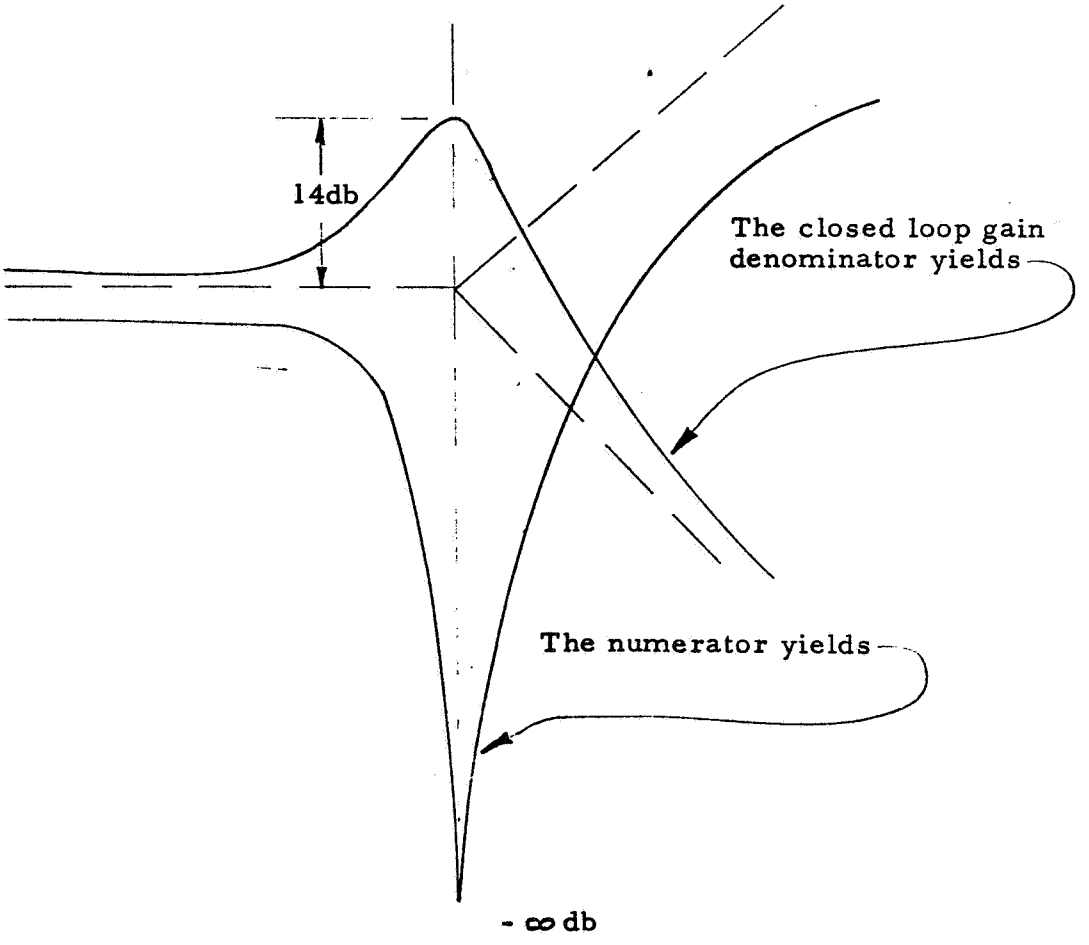
$$K_2 = (1 + K_o)\, K_1 = (1 - 0.953)\,(4) = 0.188$$

$$\boxed{\text{Closed Loop Gain} = \frac{1 - T_7^2 S^2}{1 + K_2 T_7 S - T_7^2 S^2}} \quad \text{- - - - - - - - - -(6)}$$

$$\zeta = \frac{0.188}{2} = 0.094$$

From "Feedback Control Systems Analysis and Synthesis", page 294

$\zeta = 0.094$ db peak = 14 db


14db
The closed loop gain denominator yields
The numerator yields
- ∞ db

Yielding:

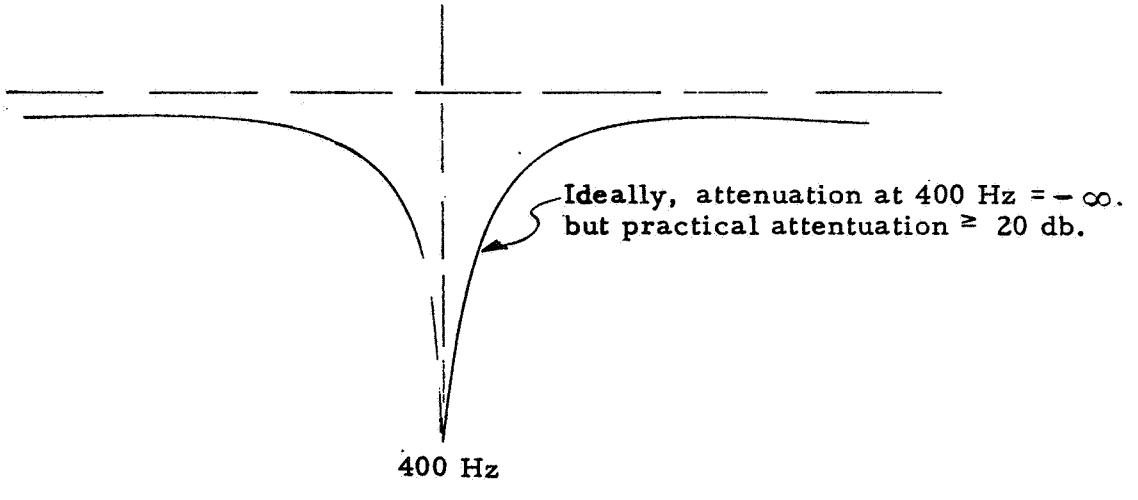

Ideally, attenuation at 400 Hz = - ∞.
but practical attentuation ≥ 20 db.
400 Hz

Figure 46 is a plot of measured test data of the 400 Hz Notch Filter Frequency Response. Using equation No. 6, page 96 , as the transfer characteristic for the 400 Hz filter, a computer derived frequency response was run. The results are tabulated below, for $K2 = .188$, $T7 = .398 \times 10^{-3}$ and $S = j\omega$.

400HZ 9:08 LA SYSM 3/05/68

OGO E 16 SEARCH COIL
400 HZ NOTCH FILTER
THEORETICAL FREQUENCY RESPONSE

ROBERT J NAHABIT

FREQUENCY	NOTCH GAIN	DB
1	1	0
2	1	0
5	1	0
10	1	0
20	1	0
50	.9997	0
100	.9987	-.01
200	.9922	-.07
300	.9517	-.43
350	.8179	-1.74
364.03	.7074	-3
390	.2574	-11.77
395	.1297	-17.71
397	.0768	-22.25
399	.0236	-32.49
400	.003	-50.35
401	.0296	-30.54
403	.0822	-21.67
405	.134	-17.44
410	.2568	-11.79
439.28	.7075	-3
450	.783	-2.12
500	.9229	-.7
700	.9875	-.11
1000	.996	-.03
1850	.9991	-.01
2461	.9995	0
3000	.9997	0

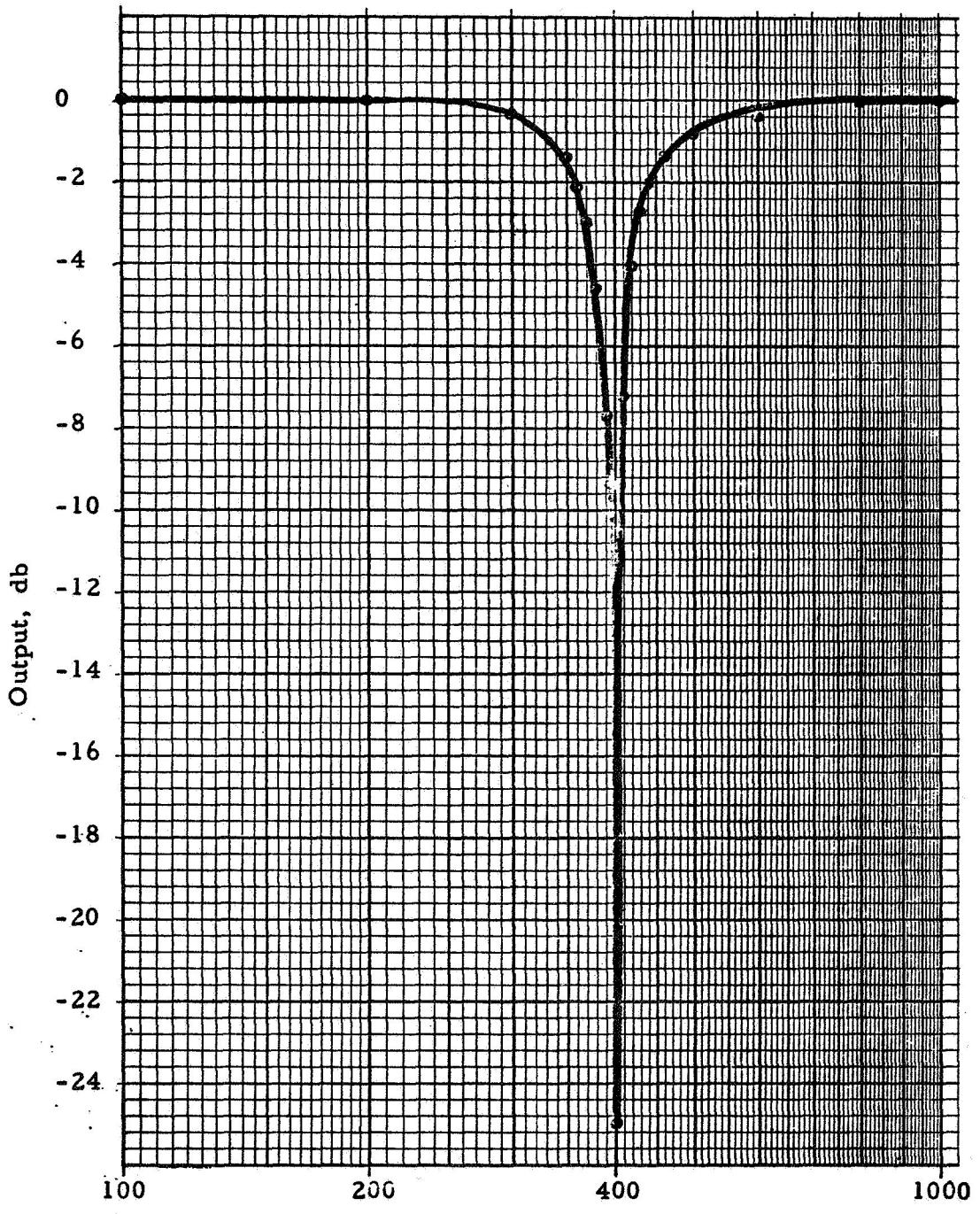
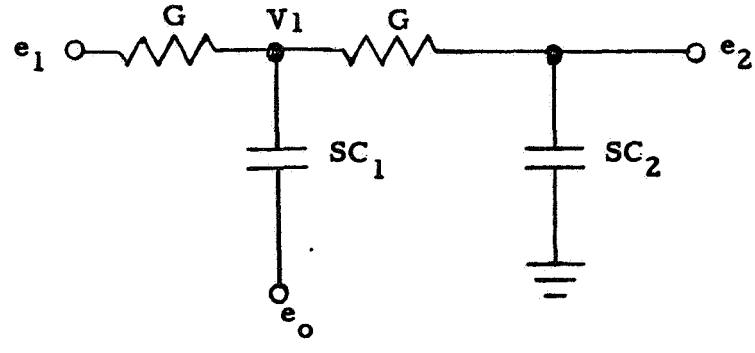


Figure 46. 400 Hz Filter Measured Frequency Response

4.5 1850 Hz Low Pass Filter

Figure 47 illustrates the detailed schematic diagram of the 1850 Hz Low Pass Filter. Figure 48 is a simplified equivalent circuit. In Figure 48 the input e_{in} passes through the RC filter network into a unity gain amplifier (A) which is used as a follower. The output of the amplifier is fed back into the filter network via C1. The transfer function is described as follows:

Assume the input impedance of A is infinite, the output impedance = 0.



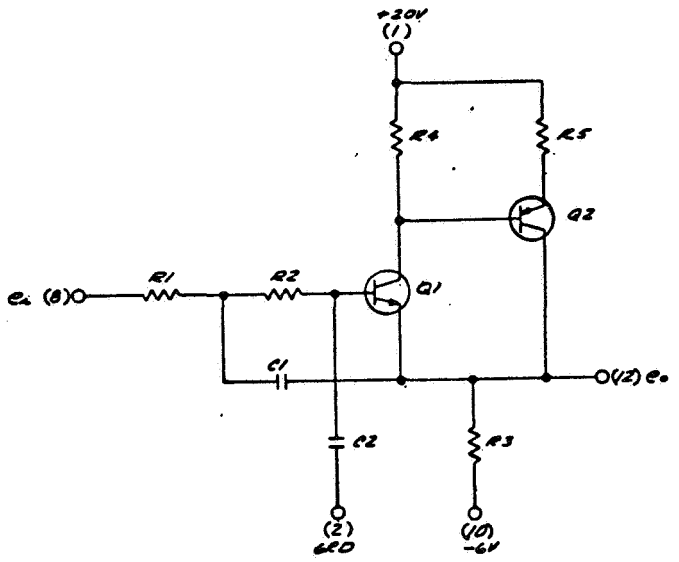
$$V_1 (2G + SC_1) + e_2 (-G) = e_1 G + e_o SC_1$$

$$V_1 (-G \quad) + e_2 (G + SC_2) = 0$$

$$e_2 = \frac{(2G + SC_1)(0) - (-G)(e_1 G + e_o SC_1)}{(2G + SC_1)(G + SC_2) - (-G)(-G)}$$

But $e_2 = e_o$, thus

$$e_o = \frac{e_1 G^2 + e_o SC_1 G}{G^2 + 2SC_2 G + SC_1 G + S^2 C_1 C_2}$$



C1 = 3000 pf

C2 = 750 pf

R1 = R2 = 57.6K

R3 = R5 = 30K

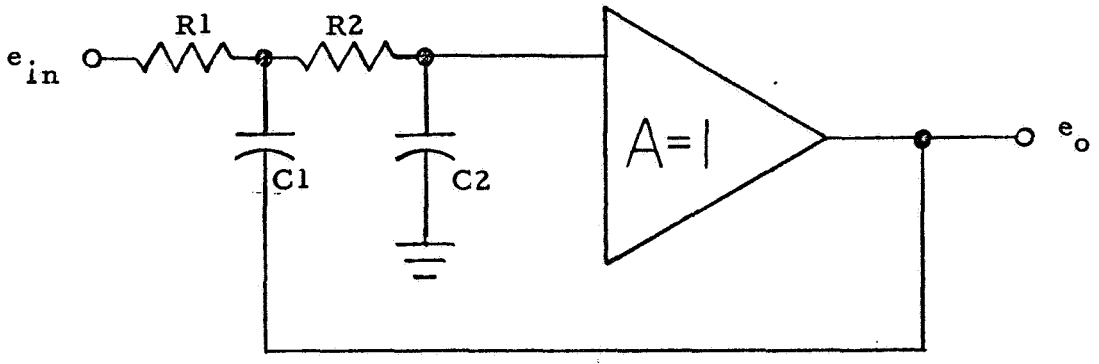
R4 = 1.5 meg

Q1 = FM 2484

Q2 = ML 20001

Figure 47.

1850 Hz Low Pass Filter Schematic



C1 = 3000 pf

C2 = 750 pf

$R_1 = R_2 = 57.6K$

Figure 48.
Equivalent Circuit of 1850 Hz Low Pass Filter

$$\frac{e_o}{e_1} = \frac{1}{1 + 2SC_2R + S^2 C_1 C_2 R^2}$$

$$G = \frac{1}{1 + (2C_2R)\, S + (C_1 C_2 R^2)\, S^2}$$

We want this in the form

$$1 + K_1 T_1 S + T_1^2 S^2$$

$$1 + 2\zeta T_1 S + T_1^2 S^2$$

thus $2\zeta T_1 = 2C_2R$

$$T_1^2 = C_1 C_2 R^2$$

$$T_1 = \sqrt{C_1 C_2 R^2}$$

$$\boxed{T_1 = \left(\sqrt{C_1 C_2}\right) R}$$

$$2\zeta T_1 = K_1 T_1 = 2C_2R$$

$$K_1 = \frac{2C_2R}{T_1} = \frac{2C_2 R}{\sqrt{C_1 C_2}\, R} = \frac{2C_2}{\sqrt{C_1 C_2}}$$

$$\boxed{K_1 = \frac{2C_2}{\sqrt{C_1 C_2}}}$$

$$\boxed{G = \frac{1}{1 + K_1 T_1 S + T_1^2 S^2}}$$

C_1 = 3000 pf R = 57.6K

C_2 = 750 pf

$\sqrt{C_1C_2} = \sqrt{(3,000)(750)} = 1500$ pf

$T_1 = (1,500 \text{ pf})(57.6\text{K}) = (1.5)(10^{-9})(57.6)(10^3)$

$$\boxed{T_1 = 86.4 \times 10^{-6}}$$

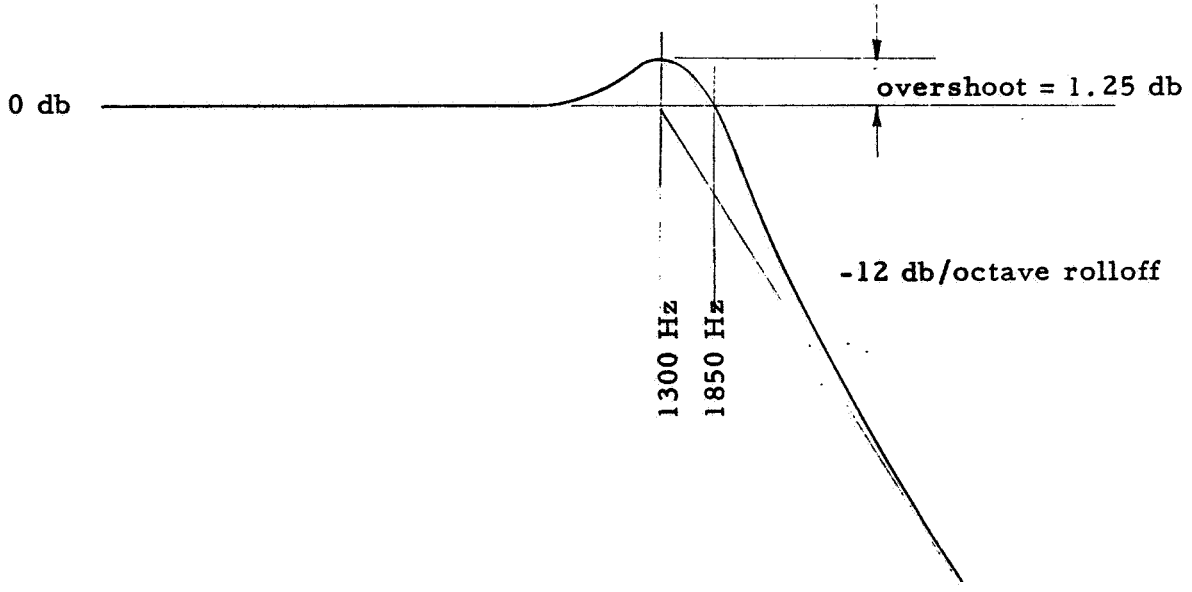
$$f_1 = \frac{.1591}{86.4 \times 10^{6}} = \frac{159.1 \times 10^3}{86.4} = 1,850 \text{ KHz}$$

$$K_1 = \frac{2(750)}{1500} = \frac{1500}{1500} = 1.0$$

$$\boxed{K_1 = 1.0}$$

$$2\zeta = K_1, \ \zeta = \frac{K_1}{2} = \frac{1}{2} = 0.5$$

from Feedback Control System Analysis and Synthesis, page 294, the overshoot is 1.25 db.



$$\text{gain of the circuit} = \frac{1}{1 + T_1 S + T_1^2 S^2} \qquad \ldots\ldots\ldots\ldots \quad (1)$$

Where $T_1 = 86.3 \times 10^{-6}$ seconds.

Equation 1 is the transfer equation shown in Figure 8, page 16, to describe the characteristics of this filter. The tabulation listed below is a computer print out of the Theoretical Frequency Response based on Equation 1. The result is also plotted out on page 106, Figure 49.

1850 10:28 LA SYSM 3/05/68

OGO E 16 SEARCH COIL
1850 HZ LOW PASS FILTER
THEORETICAL FREQUENCY RESPONSE

ROBERT J NAHABIT
MARSHALL LABS

FREQUENCY	E OUT/E IN	DB GAIN
1	1	0
2	1	0
5	1	0
10	1	0
20	1.0001	0
50	1.0004	0
100	1.0015	.01
200	1.0059	.05
400	1.0232	.2
500	1.0359	.31
700	1.068	.57
800	1.0864	.72
1000	1.1234	1.01
1100	1.139	1.13
1200	1.1502	1.21
1300	1.1547	1.25
1500	1.1351	1.1
1800	1.0234	.2
1850	.9968	-.03
2000	.9102	-.82
2461	.6468	-3.78
3000	.4321	-7.28
4000	.233	-12.64
5000	.1448	-16.76
7500	.0623	-24.08

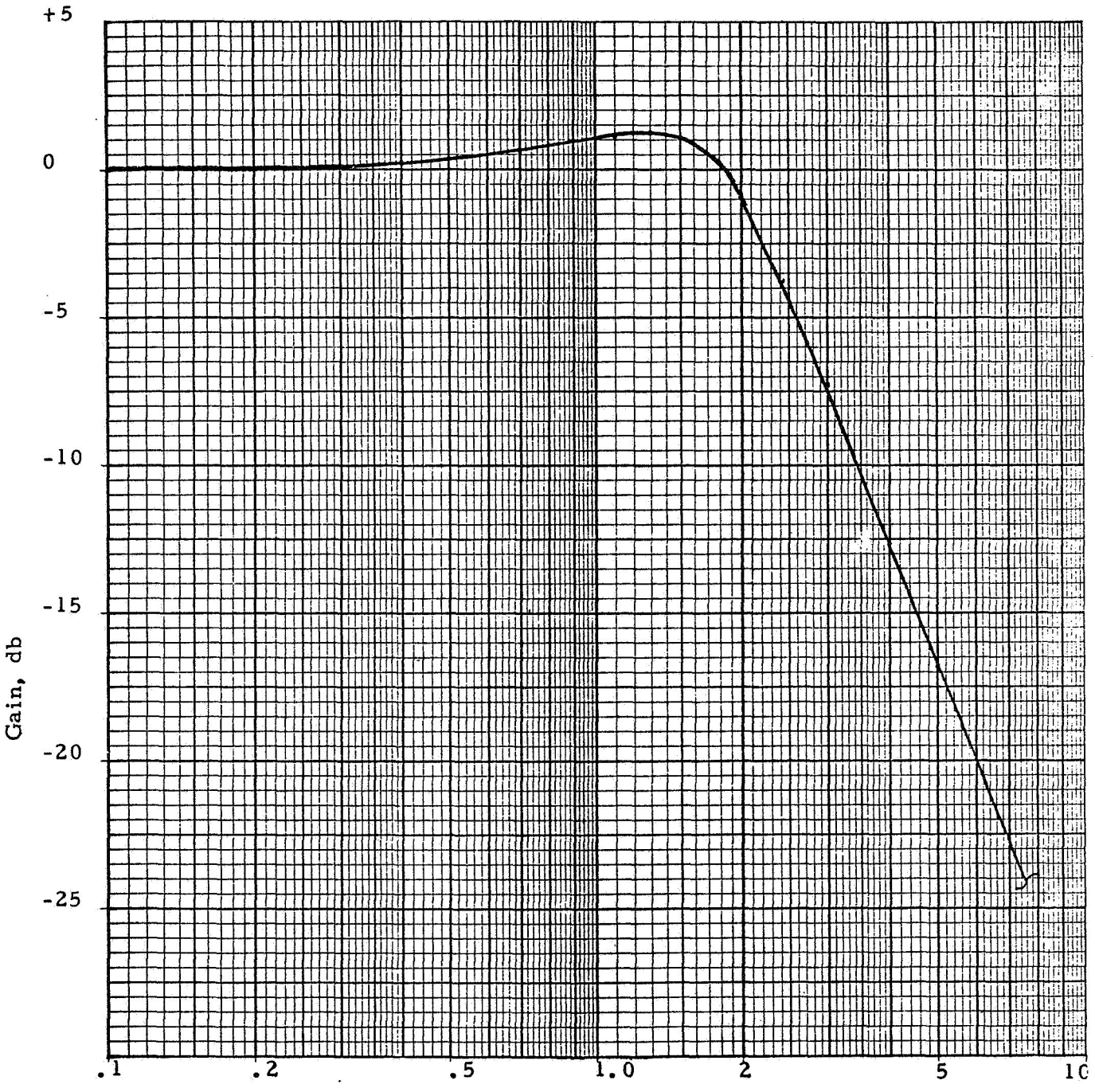


Figure 49.

1850 Hz Low Pass Filter Theoretical
Frequency Response

4.6 Waveform Channel Bandpass Control Circuit

The output signal of the 1850 Hz Low Pass Filter is applied to the input of the first bandpass control circuit. Q1 is a static switch controlled by the Bandpass Control signal. With Q1, non-conducting, the high frequency cutoff point is determined by R1 C1 (nominally 60 Hz). With Q1 conducting, C2 is placed in parallel with C1 and the cutoff frequency is reduced to about 1 Hz. Two of these controlled bandpass filter networks are employed to provide 12 db/octave rolloff characteristics. Figure 50 is a schematic of one of the bandpass filter networks.

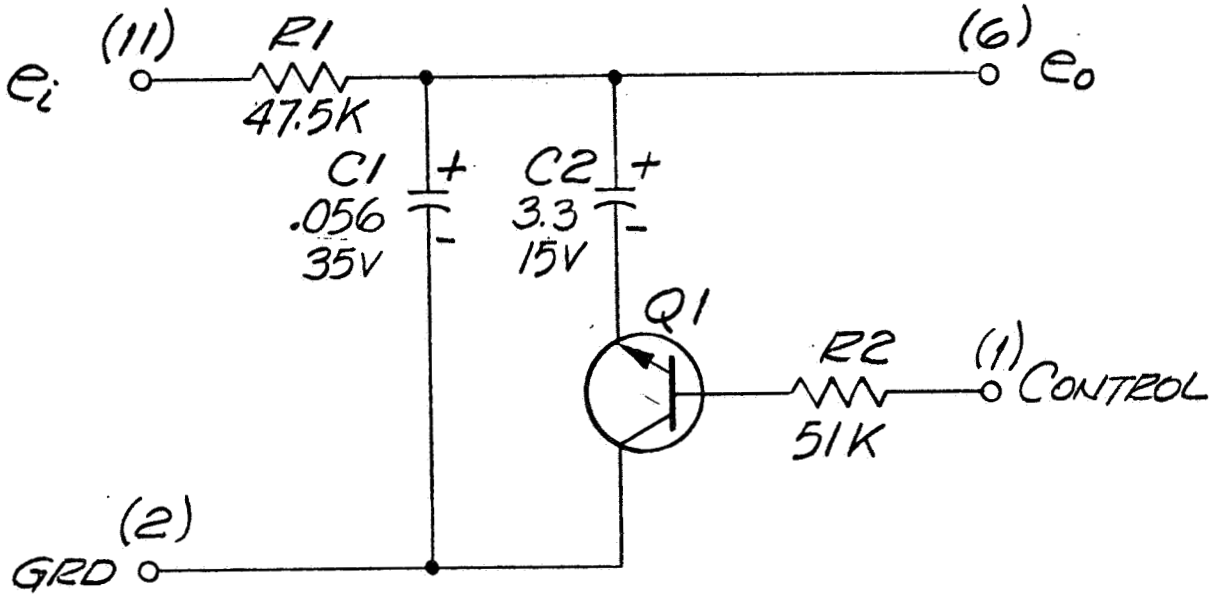


Figure 50. Waveform Channel Bandpass Control Circuit

4.7 Gain Change Amplifiers

Figure 51 is a detailed schematic diagram of the Gain Change Amplifiers. Figure 52 is a simplified equivalent circuit. Q1 is a matched pair of N-channel field effect transistors used in a differential amplifier circuit to optimize the thermal stability of the bias current. Resistors R4 and R5 are selected to equalize the drain currents in Q1. Q1 has a nominal voltage gain of 2.5 and drives differential amplifier Q3 and Q4. Q3 and Q4 are selected for matched characteristics for maximum bias point temperature stability. The voltage gain of Q3 and Q4 is nominally 400. Isolation amplifier Q5 is operated in the emitter follower mode and has essentially unity gain. The open loop gain, being the product of the gains of the individual stages, is nominally 10^3. Closed loop gain is determined by the ratio of R11 to the parallel combination of R7 and R8 when control transistor Q2 is "off", and by the ratio of R11 to the parallel combination of R7, R8, R9, and R10 when the control transistor Q2 is "on". R14, C1, R15, and C2 form a filter network that prevents high frequency oscillations inherent in high gain amplifiers. The gain change amplifier is characterized by a very high input impedance, low output impedance, stable gain change, and very good gain stability over the temperature range of -15°C to +60°C.

Refer to Figure 52. The gain is determined by the feedback resistors R11 and the parallel combination of R7 through R10.

In the Low Gain State, S1 is opened which removes R9 // R10 thus the gain is given by:

$$\text{Gain}_{\text{Low}} = 1 + \frac{R11}{R7 \parallel R10}$$

Typical values are:

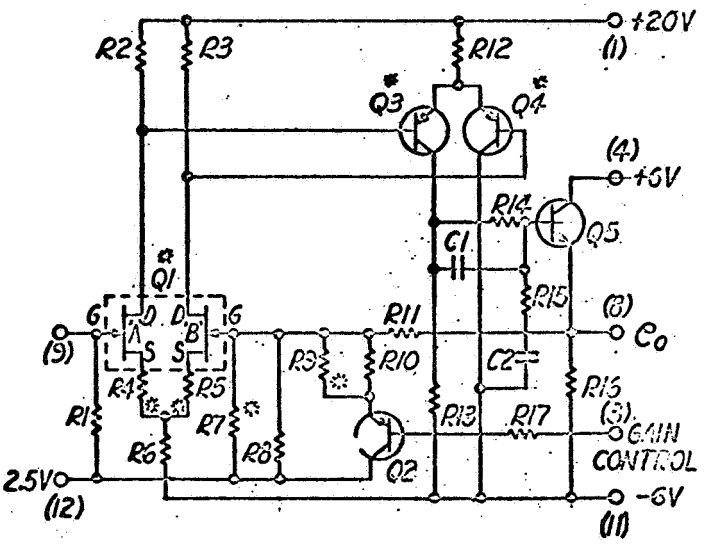
$$R11 = 40.2K$$

$$R7 \parallel R8 = 100.5K$$

$$R9 \parallel R10 = 3.17K$$

$$\text{Gain}_{\text{Low}} = 1 + \frac{40.2K}{100.5K} = 1 + 0.4 = 1.4$$

$$\boxed{\text{Gain}_{\text{Low}} = 1.4}$$

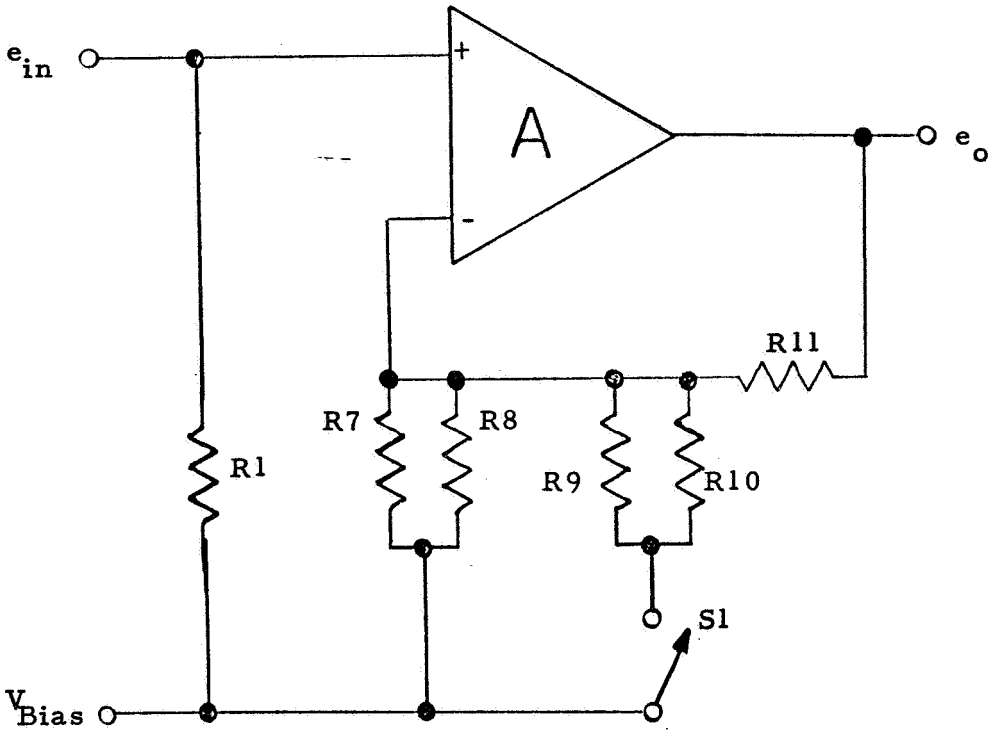


Gain Change Amp
(reference W4316)

C1	=	120 pf
C2	=	1000 pf
Q1	=	SU2066
Q2	=	GT5968
Q3	=	Q4 = SM9139H
Q5	=	2N2484/46

R1	=	22 Meg
R2	=	R3 = 47.5K
R4	=	R5, R6, R7, R9, R13, R16 = Select
R11	=	40.2K
R10	=	3.24K
R12	=	25.5K
R14	=	10K
R15	=	1K
R17	=	39K
R18	=	4.64K
R8	=	100K

Figure 51
Gain Change and Fixed Gain Amplifier Schematic



Note: R7 and R9 are Gain Trim Resistors.

Figure 52
Simplified Equivalent Circuit of the Gain Change Amplifier

In the high gain state, S1 is closed which places R9 R10 in parallel with the parallel combination of R7 and R8. Thus the expression for high gain is:

$$G_{High} = 1 + \frac{R11}{(R7 \parallel R8 \parallel R9 \parallel R10)}$$

Let the parallel combination of R7 through R10 = R_T

$$R_T = \frac{1}{\frac{1}{R_7} + \frac{1}{R_8} + \frac{1}{R_9} + \frac{1}{R_{10}}} \cong 3.08K$$

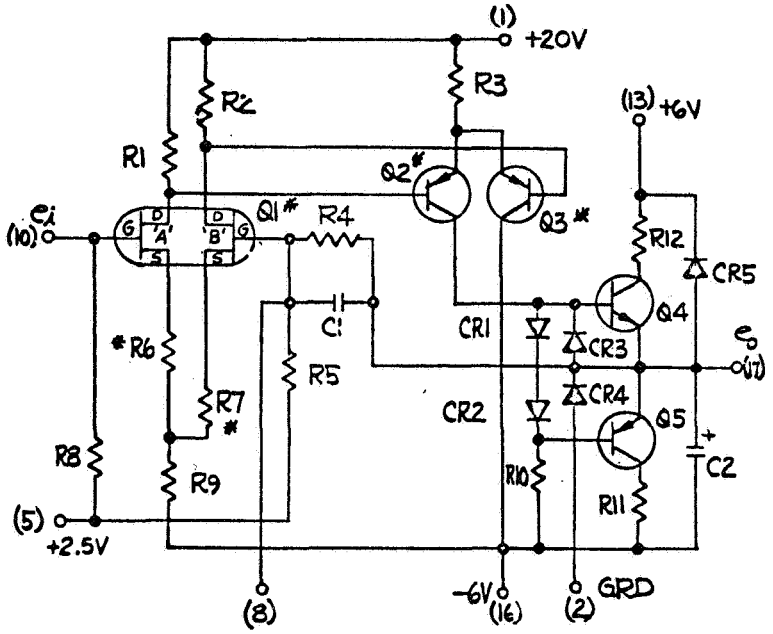
$$G_{High} = 1 + \frac{R11}{R_T} = 1 + \frac{40.2K}{3.08K} = 1 + 13$$

$$\boxed{G_{High} = 14.0}$$

Note that transistor Q2 in Figure 51 is used as S1 to change the gains.

4.8 Output Amplifier

Figure 53 depicts the output amplifier configuration as used in the Waveform Channels. The +2.5v supply that biases Q1 also sets the output resting level through resistors R4 and R5, to +2.5v ± 0.02v. When this amplifier is used as the output stage for the Wave Analyzer and Wideband Channels, the +2.5v bias point is tied to ground and the resting level will be 0 ± 20 millivolts. The operation of Q1, Q2, and Q3 is identical to that of the gain change amplifier. The output stage, Q4, Q5, utilizes a complementary push-pull circuit to minimize the quiescent bias current yet provides relatively high power output. Diodes CR1 and CR2 establish the bias point for Q4 and Q5. Diodes CR4 and CR5 limit the output voltage swing to +6.5 and -0.5v. CR3 protects the base-emitter junction of Q4 against large signal excursions. Capacitor C1 limits the high frequency response for amplifier stability. The function of capacitor C2 is to decrease the output impedance of the amplifier at high frequencies in order to increase the response to load transient. The spacecraft telemetry commutator appears as a transient load with some capacity. To minimize telemetry error, this external capacity must be charged or discharged to the same voltage as that of the amplifier within a specified period of time. C2 increases the transient load response of the amplifier to satisfy this requirement.



ELECTRONIC SCHEMATIC

(Reference W4317)

C1 = 220 pf

C2 = .39 μf

R1 = R2 = 47.8K

R3 = 22.1K

R4 = 39.2K

R5 = 10K

R6, R7 = select

R8 = 22 meg

R9 = 49.9K

R10 = 82K

R11 = 3.6K

R12 = 1.8K

Q1 = SU2066

Q2 = Q3 = Q5 = SM9139H

Q4 = 2N2484/46

Figure 53

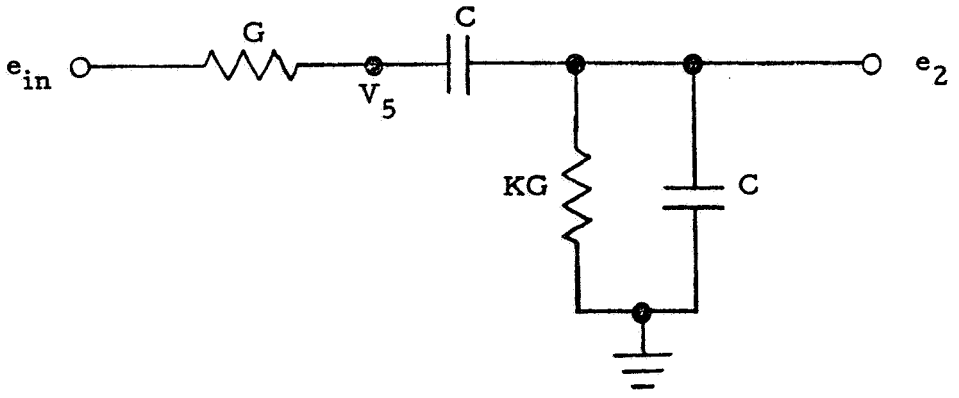
Output Amplifier Schematic

4.9 Wave Analyzer Bandpass Amplifier

The Wave Analyzer consists of seven bandpass amplifiers per axis. The bandpass amplifiers differ only in the value of the capacitors C1, C2, C4 and C5 used to set the center frequencies. A detailed schematic diagram of the bandpass amplifier is shown in Figure 54. Figure 55 is a simplified equivalent circuit diagram.

The bandpass amplifier consists of a D-C coupled negative feedback amplifier with a bridge T filter in the feedback loop. The input coupling network, consisting of C1, R1, C2 and the amplifier input impedance is parallel with R3, provide a low Q bandpass filter. At the resonant frequency of the feedback network, negative feedback is a minimum, that is, the amplifier gain st at maximum and the desired bandpass frequency is achieved.

For Filter No. 1:



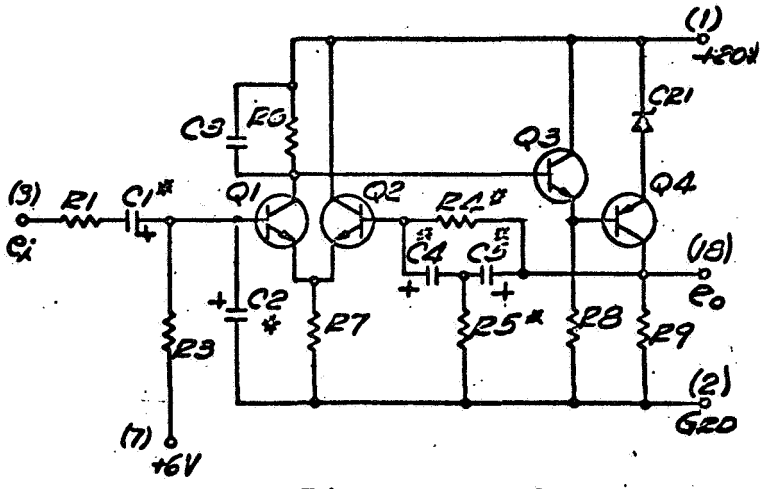
where

$$K = \frac{R1}{R2} = \frac{261K}{20.5K} = 12.7$$

$$G = \frac{1}{R_1} \quad SC = \frac{1}{Z_C} \quad G' = \frac{1}{R_{2,}} \quad K = \left(\frac{1}{G}\right)\left(\frac{\frac{1}{1}}{\frac{1}{G'}}\right) = \frac{G'}{G}, \; G' = KG$$

$$V_5 (G + SC) + e_2 (-SC) = G\, e_{in}$$

$$V_5 (- SC) + e_2 (KG + 2\, SC) = 0$$



ELECTRONIC SCHEMATIC

C1 = C2 = C4 = C5 = 0.22 μf (10 Hz)
= 0.1 μf (22 Hz)
= 0.047 μf (47 Hz)
= 0.022 μf (100 Hz)
= 0.01 μf (216 Hz)
= 0.0039 μf (467 Hz)
= 0.0022 μf (1000 Hz)

C3 = 1000 pf
R1 = 261 K
R3 = 20.5 K
R4 = 806 K
R5 = 6.65 K
R6 = 200 K
R7 = 100 K
R8 = 430 K
R9 = 47 K
Q1 = Q2 = Q3 = FM 2484
Q4 = ML 20001

Figure 54
Bandpass Amplifier Schematic

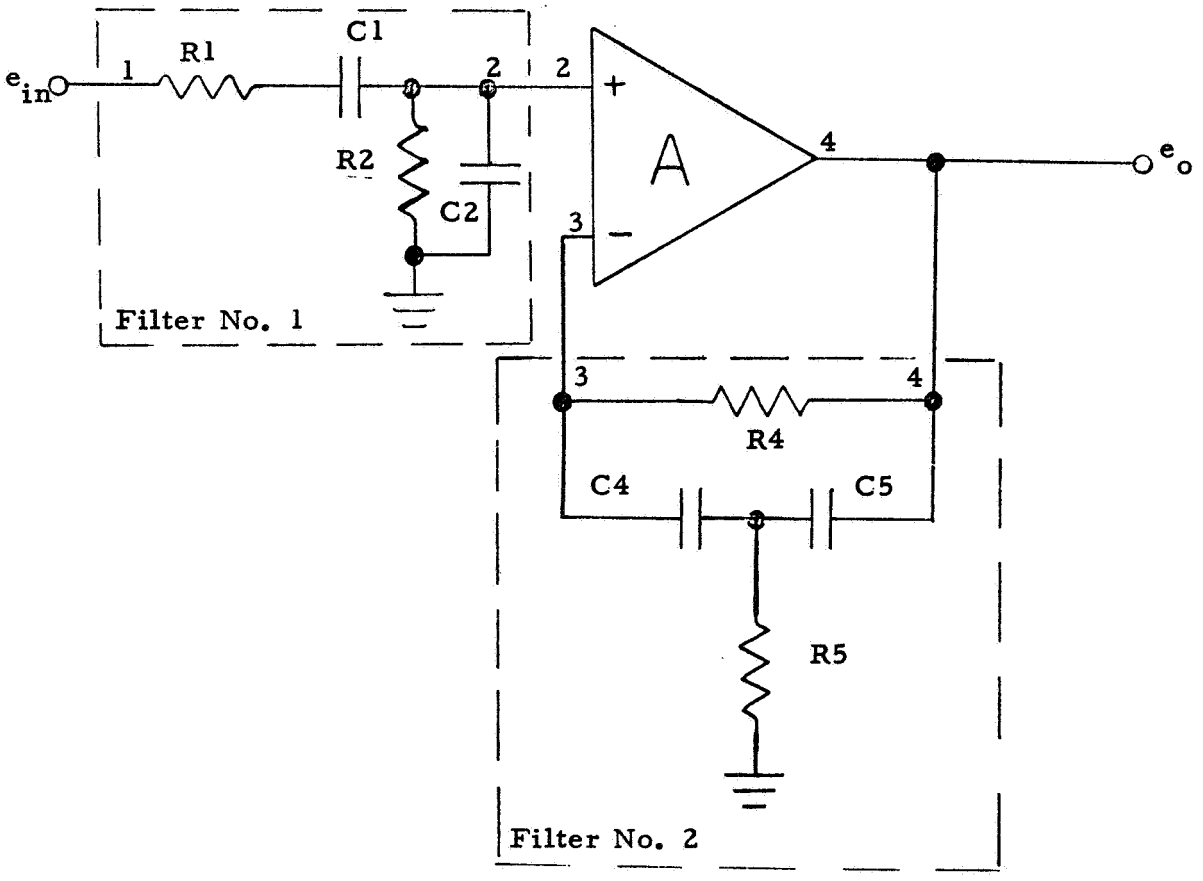


Figure 55
Bandpass Amplifier Equivalent Circuit

$$e_2 = \frac{\begin{vmatrix} (G + SC) & (G\, e_{in}) \\ (-SC) & (0) \end{vmatrix}}{\begin{vmatrix} (G + SC) & (-SC) \\ (-SC) & (KG + 2SC) \end{vmatrix}}$$

$$e_2 = \frac{0 - (-SC)\ (G\, e_{in})}{(G + SC)\ (KG + 2SC) - (-SC)\ (-SC)}$$

$$\frac{e_2}{e_{in}} = \frac{SCG}{KG^2 + 2\,SGC + SKGC + S^2 C^2}$$

$$\frac{e_2}{e_{in}} = \frac{SCR}{K + 2SCR + SKCR + S^2 C^2 R^2}$$

$$\frac{e_2}{e_{in}} = \frac{\frac{1}{\sqrt{K}} \quad (\frac{RC}{\sqrt{K}})\ S}{1 + \left|\frac{2 + K}{\sqrt{K}}\right| \left|\frac{RC}{\sqrt{K}}\right| S + \left|\frac{CR}{\sqrt{K}}\right|^2 S^2}$$

let $T_o = \frac{RC}{K}$

$$\frac{e_2}{e_{in}} = \frac{\left|\frac{1}{\sqrt{K}}\right| (T_o)\ S}{1 + \left|\frac{2 + K}{\sqrt{K}}\right| T_o S + T_o^2 S^2} \text{ ---------- (1)}$$

$K = \frac{261\ K}{20.5\ K} = 12.7$ $\qquad \frac{2 + K}{\sqrt{K}} = \frac{2 + 12.7}{3.57} = \frac{14.7}{3.57}$

$= 4.15$

$\sqrt{K} = \sqrt{12.7} = 3.57$

$\frac{1}{\sqrt{K}} = 0.28$

$$\text{Gain of 1st Filter} = \frac{0.28\, T_o\, S}{1 + 4.15\, T_o\, S + T_o^{\,2}\, S^2} \qquad \text{-----(2)}$$

for 100 Hz:

$$T_o = \frac{RC}{\sqrt{K}} = \frac{(261K)\,(0.022\mu)}{3.57}$$

$$T_o = 1.61 \text{ milliseconds}$$

$$f_o = \frac{1}{2\pi\, T_o} = \frac{.16}{1.61K} = \frac{160}{1.61} = 100 \text{ Hz}$$

From equation 1 the denominator is:

$$1 + 4.15\, T_o S + T_o^{\,2}\, S^2$$

factoring reveals roots of 3.82 and 0.365

Thus equation 1 becomes

$$\frac{e_2}{e_{in}} = \frac{0.28\, T_o\, S}{(1 + 3.82\, T_o S)\;(1 + 0.365\, T_o S}$$

let $f_o = \frac{1}{2\pi\, T_o}$

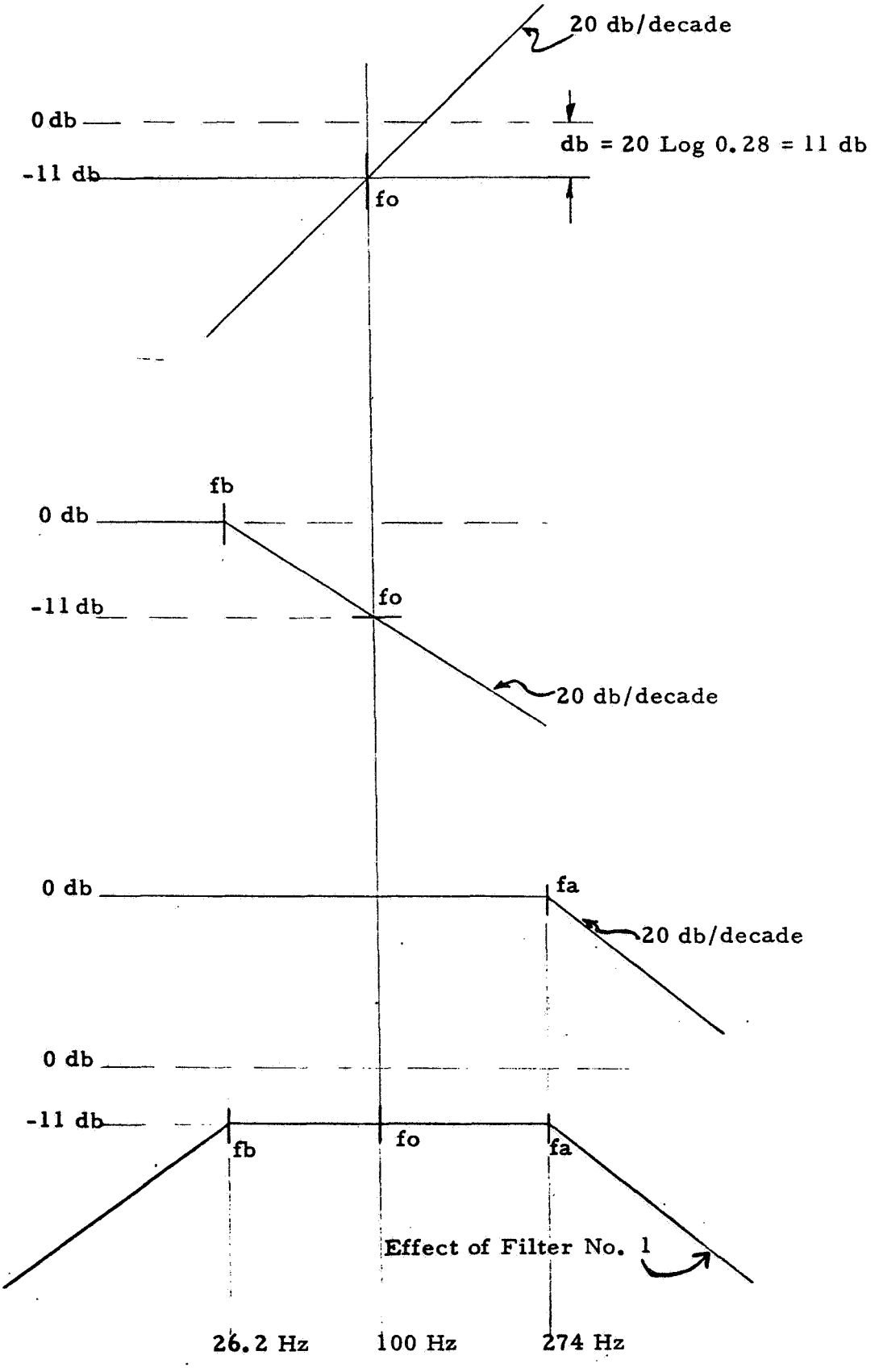
$$f_a = \frac{1}{2\pi\, T_o\,(0.365)} = \frac{f_o}{.365} = 2.74\, f_o$$

$$= 274 \text{ Hz}$$

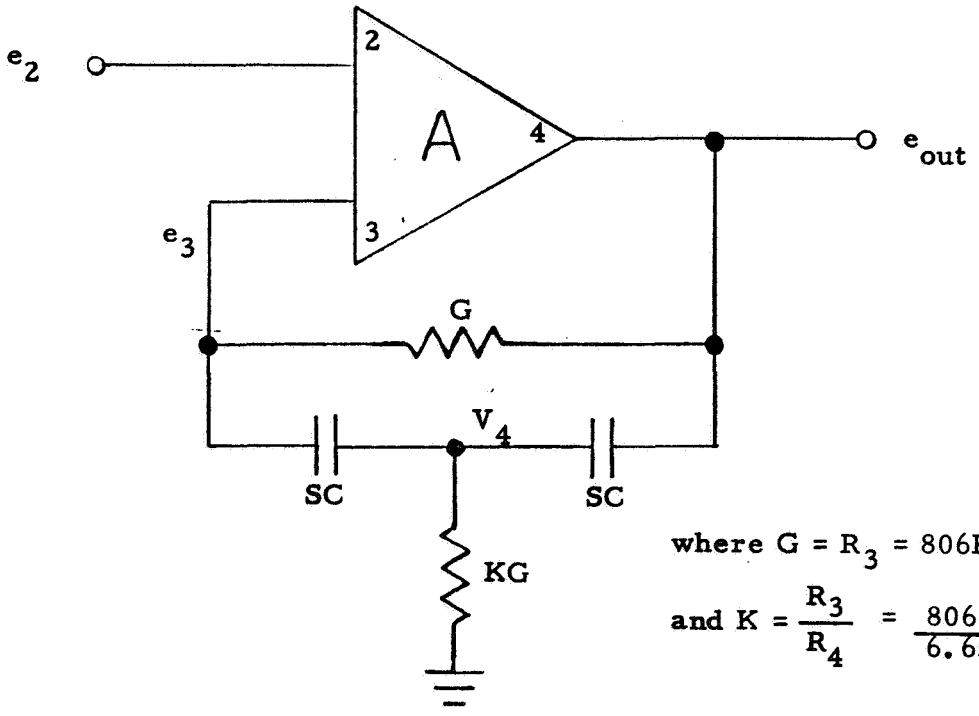
$$f_b = \frac{1}{2\pi\, T_o\,(3.82)} = \frac{fo}{3.82} = 0.262\, fo$$

$$= 26.2 \text{ Hz}$$

Which plots thus:



For Filter No. 2 and A:



where $G = R_3 = 806K$

and $K = \frac{R_3}{R_4} = \frac{806}{6.65} = 121$

Assume A $\longrightarrow$ infinity

then $e_3 \longrightarrow e_2$

$$\text{gain} = \frac{e_{out}}{e_2} = \frac{e_{out}}{e_3}$$

$$V_4 \ (KG + 2SC) + e_3 \ (-SC) = e_o \ SC$$

$$V_4 \ (-SC) + e_3 \ (G + SC) = e_o \ G$$

Note that e_o is the independent variable since it has a very low source impedance (i.e. the output Z of the amplifier) while e_3 has a very high load Z.

$$e_3 = \frac{\begin{vmatrix} (KG + 2SC) & (e_o\, SC) \\ (-SC) & (e_o\, G) \end{vmatrix}}{\begin{vmatrix} (KG + 2SC) & (-SC) \\ (-SC) & (G + SC) \end{vmatrix}}$$

$$\frac{e_3}{e_o} = \frac{(KG + 2SC)\ (G) - (-SC)\ (SC)}{(KG + 2SC)\ (G + SC) - (-SC)\ (-SC)}$$

$$\frac{e_3}{e_o} = \frac{1 + \frac{2}{\sqrt{K}} \left[\frac{RC}{\sqrt{K}}\right] S + \left[\frac{RC}{\sqrt{K}}\right]^2 S^2}{1 + \frac{2+K}{\sqrt{K}} \left[\frac{RC}{\sqrt{K}}\right] S + \left[\frac{RC}{\sqrt{K}}\right]^2 S^2}$$

let $T_o = \frac{RC}{\sqrt{K}}$

$$\frac{e_3}{e_0} = \frac{1 + \frac{2}{\sqrt{K}} T_o S + T_o^2 S^2}{1 + \frac{2+K}{\sqrt{K}} T_o S + T_o^2 S^2}$$

$K = 121$

$\sqrt{K} = \sqrt{121} = 11$

for 100 Hz filter

$$T_o = \frac{RC}{\sqrt{K}} = \frac{(806K)\ (.022\ \mu)}{11} = 1.61 \text{ msec}$$

$$f_o = \frac{1}{2\pi T_o} = \frac{0.16}{1.61 \text{ ms}} = \frac{160}{1.61} = 100 \text{ Hz}$$

$$\frac{2}{\sqrt{K}} = \frac{2}{11} = 0.182$$

$$\frac{2+K}{\sqrt{K}} = \frac{2+121}{11} = \frac{123}{11} = 11.2$$

$$\frac{e_3}{e_o} = \frac{1 + (0.182)\ T_o S + T_o^2 S^2}{1 + (11.2)\ T_o S + T_o^2 S^2}$$

but gain $= \dfrac{e_o}{e_3}$

$$\frac{e_o}{e_3} = \boxed{\text{Gain of filter No. 2} = \frac{1 + 11.2\ T_o S + T_o^2 S^2}{1 + 0.182\ T_o S + T_o^2 S^2}} \quad \text{------ (2)}$$

factoring the numerator $1 + 11.2\ X + 1\ X^2$ yields roots of 11 and 0.1.

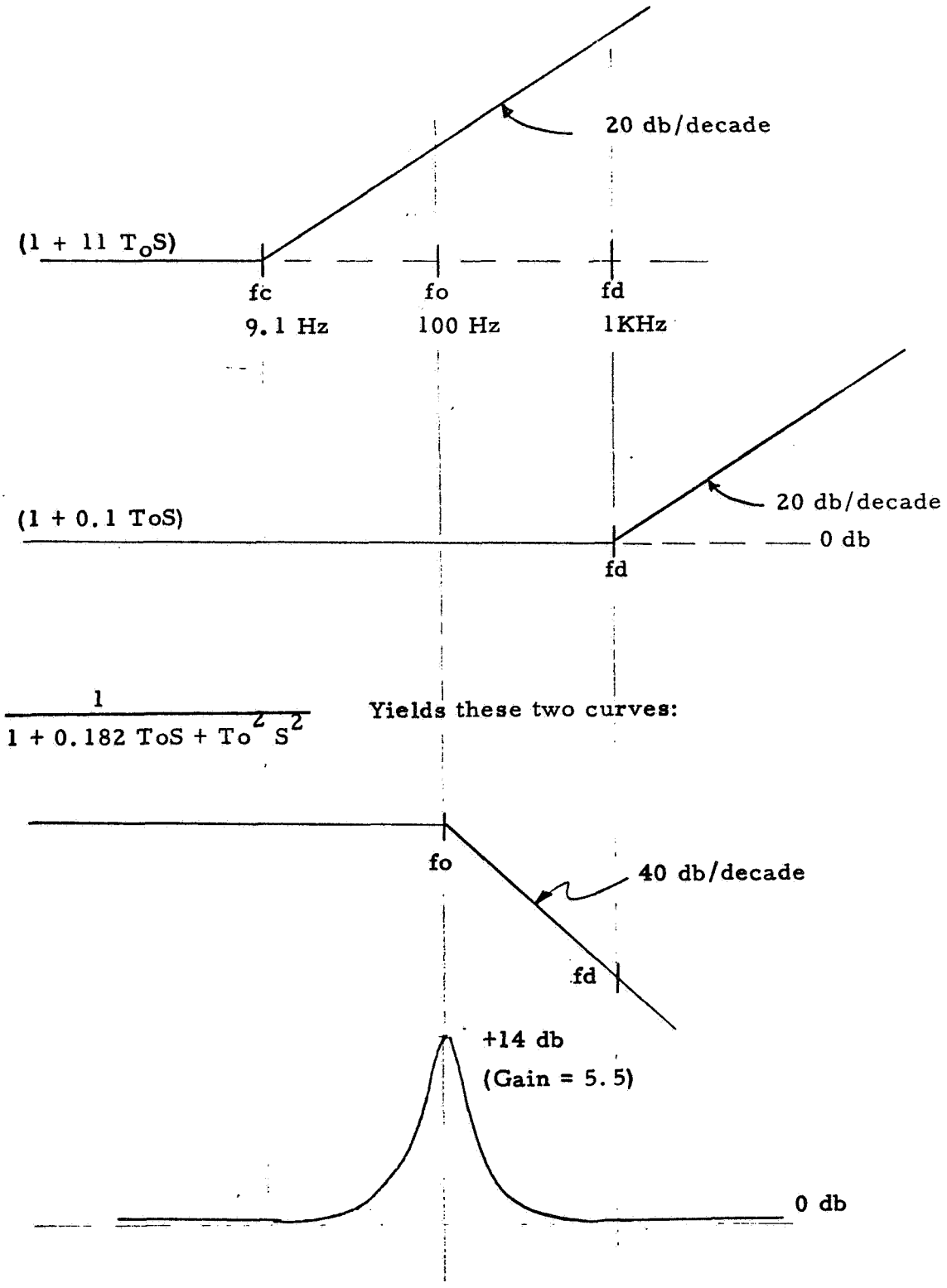
thus: $\boxed{\text{Gain} = \frac{(1 + 11\ ToS)\ (1 + 0.1\ ToS)}{1 + (0.182)\ ToS + To^2 S^2}}$

$$f_o = \frac{1}{2\pi To}$$

$$f_c = \frac{1}{(2\pi To)\ 11} = \frac{fo}{11} = .091\ fo \cong 9.1\ Hz$$

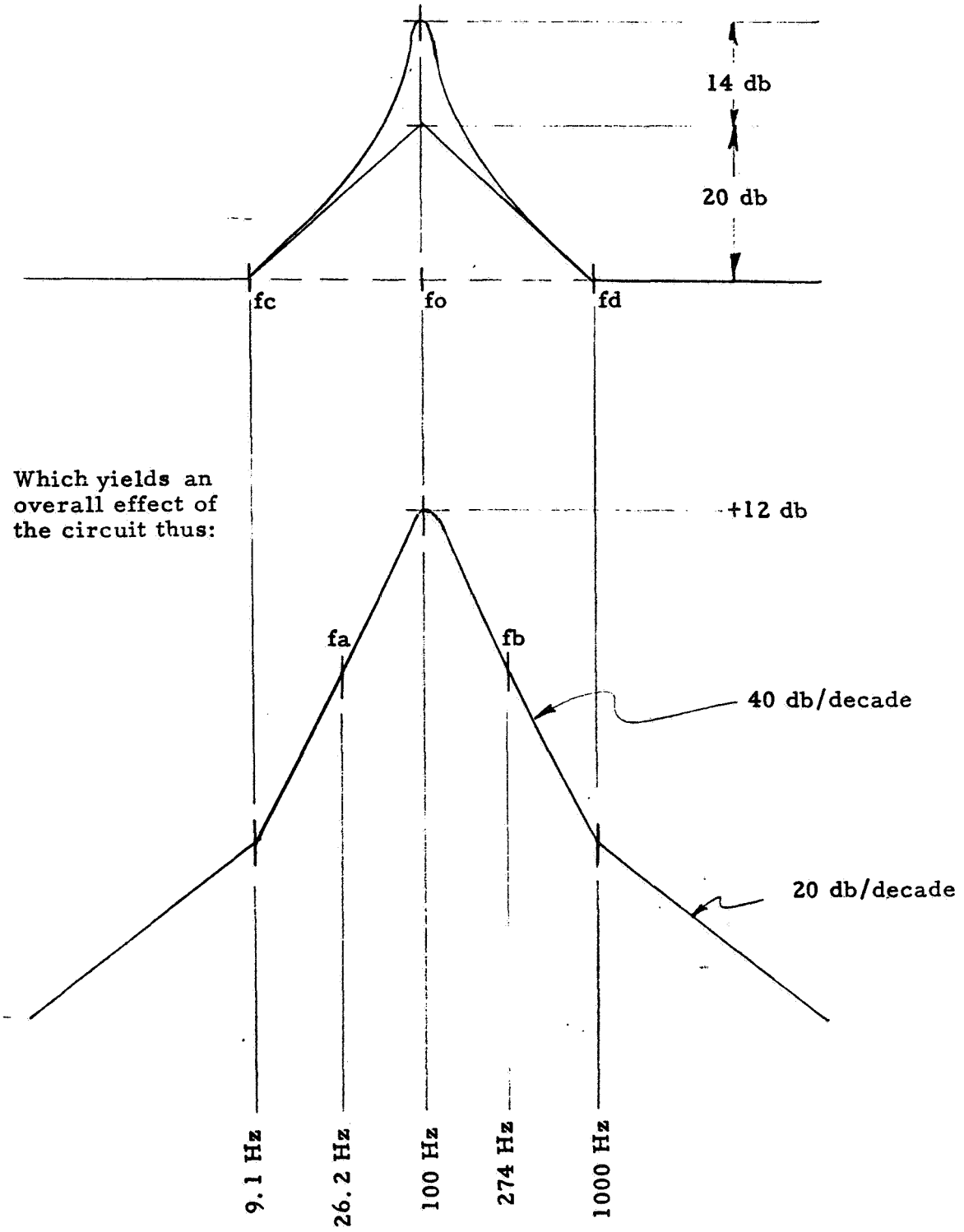
$$f_d = \frac{1}{(2\pi To)\ 0.1} = \frac{fo}{0.1} = 10\ fo = 1\ K\ Hz$$

Thus:


20 db/decade
(1 + 11 T_oS)
fc
9.1 Hz
fo
100 Hz
fd
1KHz
20 db/decade
(1 + 0.1 ToS)
0 db
fd
$\frac{1}{1 + 0.182\ ToS + To^2 S^2}$
Yields these two curves:
fo
40 db/decade
fd
+14 db
(Gain = 5.5)
0 db

67-917

$2\delta = 0.182$ $\delta = 0.091$, from "Feedback Control Systems Analysis and Synthesis", page 294 $\zeta = 0.10$, db = +14. Thus the total effect of Filter No. 2 is:



The overall gain at fo equals the gain of Filter No. 1 plus the gain of Filter No. 2.

Gain = (-11 db - 11 db) + (+14 db + 20 db) = +12 db

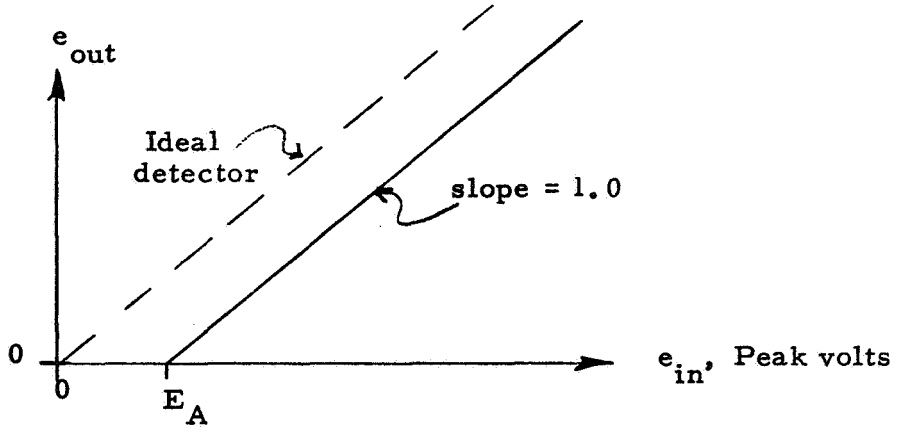
12 db = 3.9811 or 4.0.

Thus the overall gain of the bandpass Filter at fo = 4.0.

4.10 Peak Detector

Figure 56 is a detailed schematic of the peak detector. Figure 56 is a simplified schematic. In Figure 57 an input signal (e_{in}) is AC coupled to R3 and the input 1 of Amplifier A. CR1 serves to limit the peak value of this signal to ±3.2 volts p-p. (+2.6V + V diode). Amplifier A causes point 2 to "follow" positive value only (because of CR2) of signal at point 1. C2 and R7 form a large time constant network that serve to hold the peak positive output value of the amplifier. $T_{(R7, C2)} \cong 10$ seconds.

The D.C. characteristics of the peak detector is as shown.



The value of the offset voltages E_A is given by:

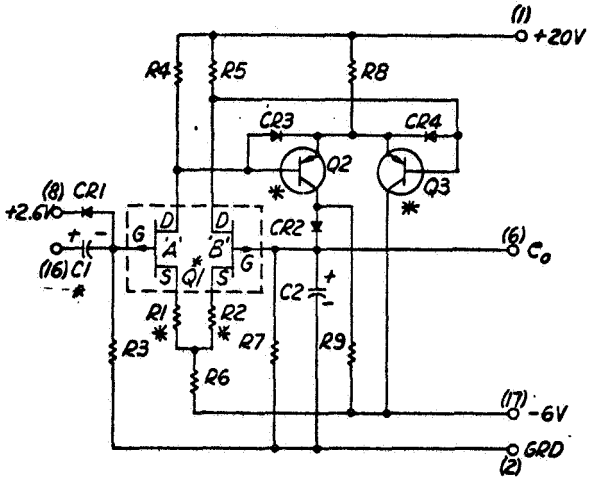
$$E_A = \frac{V_{on\ (CR2)}}{A_{OL}}$$

Where A_{OL} = open loop voltage gain of amplifier A.

The slope thereafter is $1 - \frac{1}{A}$ (i.e. the closed, gain of a follower amplifier with open loop gain A). The open loop gain A can be considered larger than 1,000

thus E_A is less then $\frac{600\ mv}{1000} = 0.6$ mv

and the linearity of the output to input signal is better then 0.1%.



(Reference W4298)

C1 = select (1.0 μf, 3.3 μf)
C2 = .47 μf
Q1 = SU2066
Q2 = Q3 = SM9139H

R1, R2 = select
R3 = 56K
R4 = R5 = 73.2K
R6 = 76.8K
R7 = 22 meg
R8 = 15K
R9 = 62K

Figure 56
Peak Detector Schematic Diagram

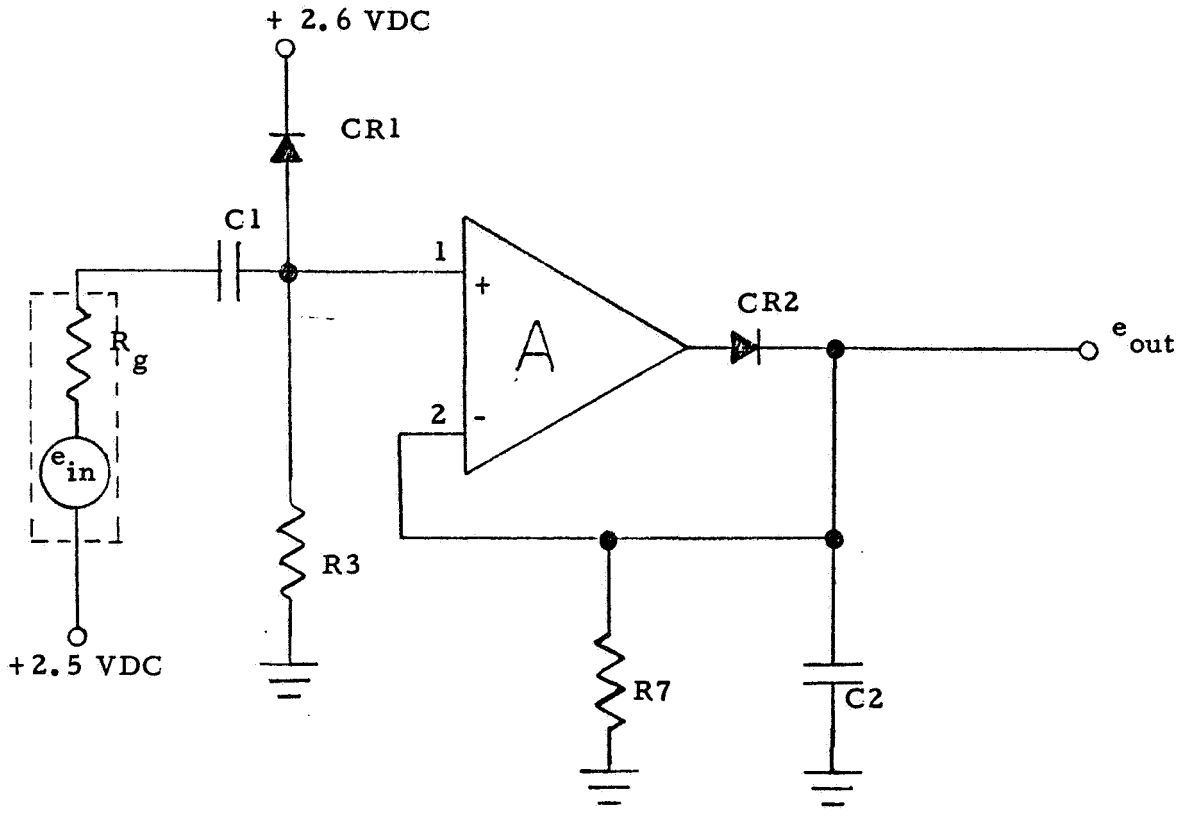


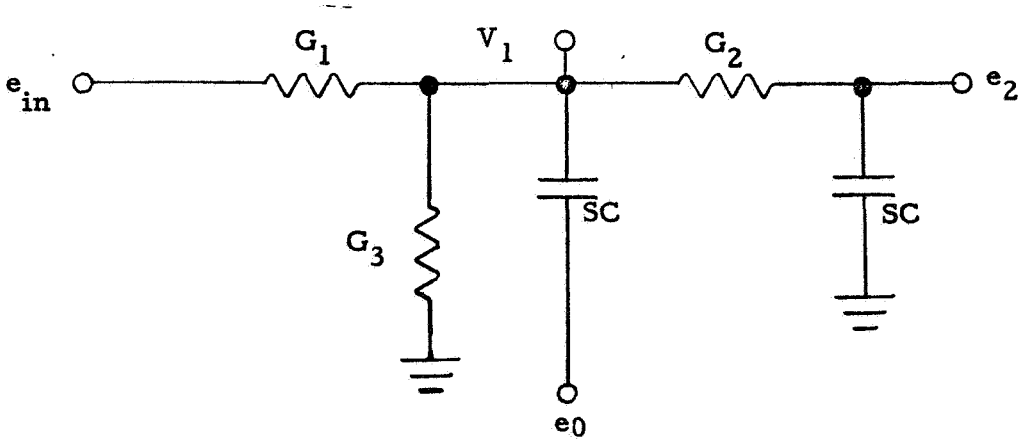
Figure 57

Simplified Detector Circuit

4.11 SCO Low Pass Filter

Figure 58 is a detailed schematic diagram of the SCO Low Pass Filter. Figure 59 is a simplified equivalent circuit, which is useful in the description of the circuit. The input (e_{in}) passes through the RC filter network into a unity gain amplifier (A) which is used as a follower. The output of the amplifier is fedback into the filter network via C1. The transfer function is described as follows:

Assume the input impedance of A = Infinity
the output impedance of A = Zero.



$$e_{in} = e_1$$

$$V1\,(G_1 + G_2 + G_3 + SC) + e_2\,(-G_2) = e_1\,G_1 + e_0\,SC$$

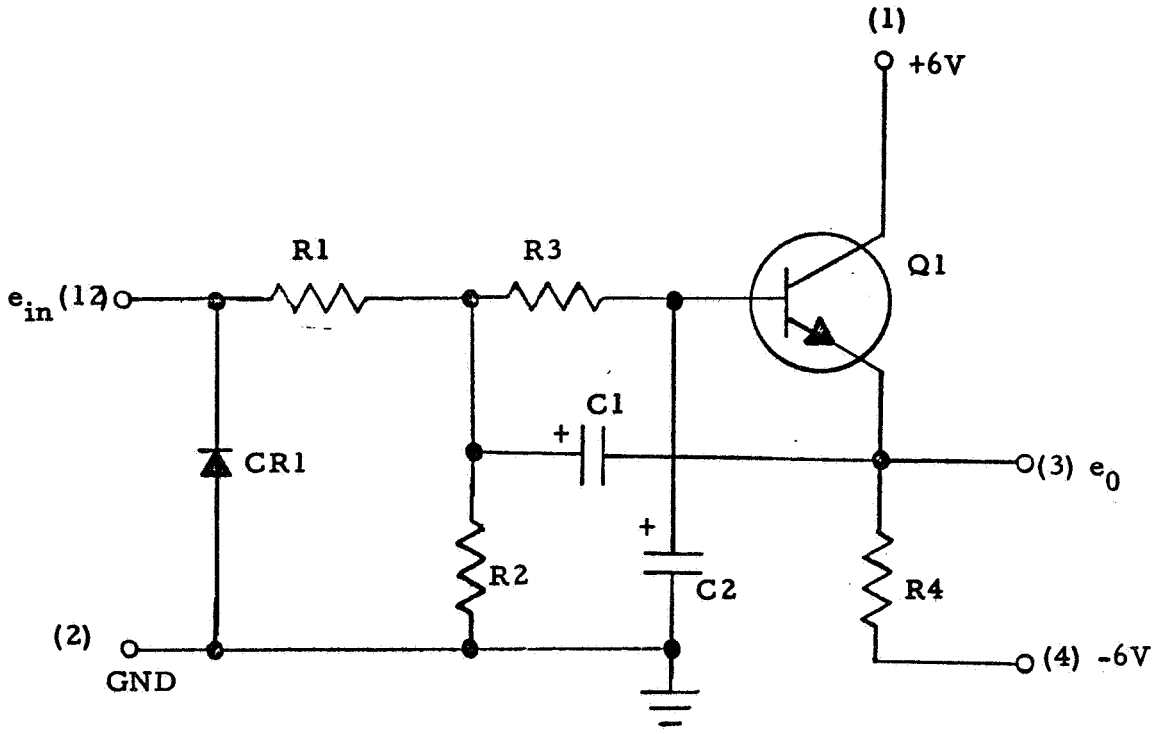
$$V1\,(-G_2) + e_2\,(G_2 + SC) = 0$$

$$e_0 = e_2 = \frac{(G_1 + G_2 + G_3 + SC)\,(0) - (-G_2)\,(e_1\,G_1 + e_0\,SC)}{(G_1 + G_2 + G_3 + SC)\,(G_2 + SC) - (-G_2)\,(-G_2)}$$

$$e_0 = \frac{e_1\,G_1\,G_2 + e_0\,SC\,G_2}{G_2\,G_1 + G_2\,G_3 + SCG_2 + SCG_1 + SCG_2 + SCG_3 + S^2C^2}$$

$$e_0\,(G_1\,G_2 + G_2\,G_3 + SCG_1 + SCG_2 + SCG_3 + S^2C^2) = e_1G_1G_2$$

$$\frac{e_0}{e_1} = \frac{G_1\,G_2}{G_1\,G_2 + G_2\,G_3 + SC\,(G_1 + G_2 + G_3) + S^2\,C^2}$$



(Reference W4312)

C1 = C2 = .0047 μf
R1 = 100K
R2 = 53.6K
R3 = 34.0K
R4 = 33K
Q1 = 2N2484/47

Figure 58
SCO LOW PASS FILTER SCHEMATIC DIAGRAM

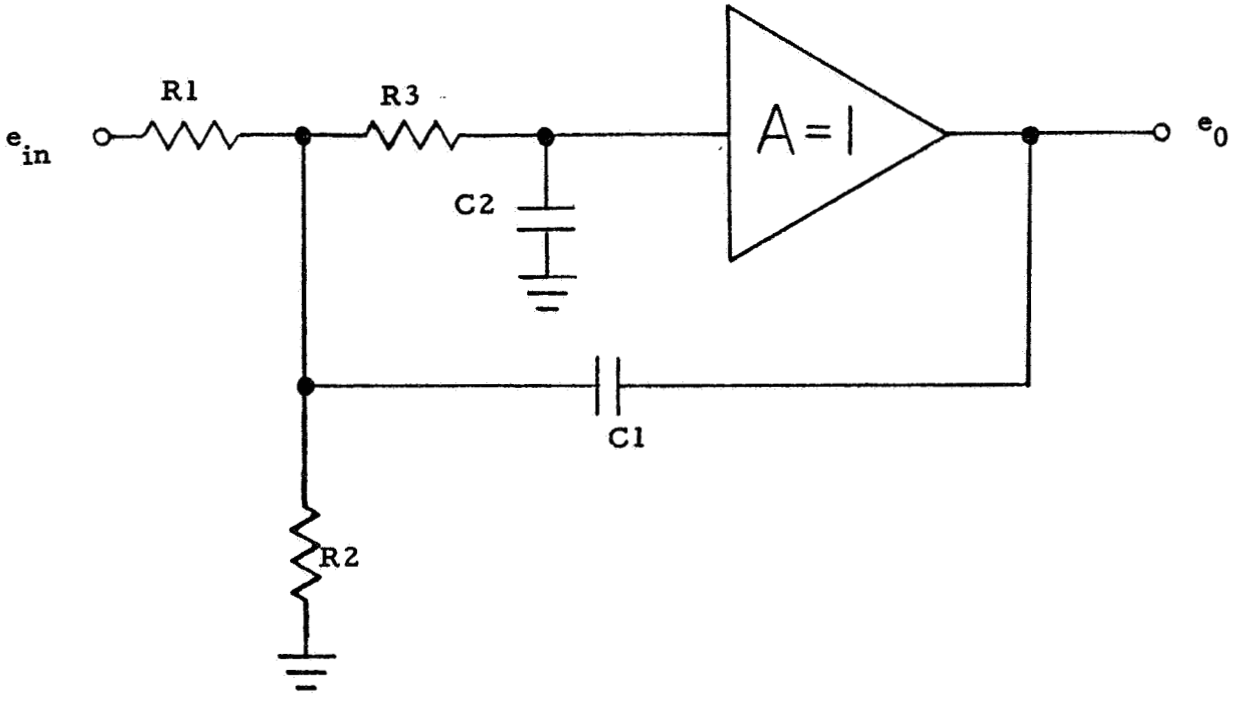


Figure 59

SCO LOW PASS FILTER
SIMPLIFIED EQUIVALENT CIRCUIT

$$\frac{e_0}{e_1} = \frac{G_1 G_2 / (G_1 G_2 + G_2 G_3)}{1 + SC\left[\frac{G_1 + G_2 + G_3}{G_1 G_2 + G_2 G_3}\right] + S^2\left[\frac{C^2}{G_1 G_2 + G_2 G_3}\right]}$$

This is in the form of

$$\frac{e_0}{e_1} = \frac{A_1}{1 + K_1 T_1 S + (T_1)^2 S^2}$$

$R_1 = 100K,\ G1 = 1 \times 10^{-5}$

$R_2 = 34K,\ G2 = 2.96\ 10^{-5}$

$R_3 = 53.6K,\ G3 = 1.82\ 10^{-5}$

$C = .0047\mu\ C = 47 \times 10^{-10}$

$$A_1 = \frac{G_1 G_2}{G_1 G_2 + G_2 G_3} = \frac{1}{1 + \frac{G_3}{G_1}} = \frac{1}{1 + \frac{1.82}{1}}$$

$$A_1 = \frac{1}{1 + 1.82} = \frac{1}{2.82} = 0.35 \cong 0.34$$

$A_1 = .34$

$$(T_1)^2 = \frac{C_2}{G_1 G_2 + G_2 G_3} = \frac{C^2 R_2}{G_1 + G_3}$$

$$T_1 = C\sqrt{\frac{R_2}{G_1 + G_3}} = C\sqrt{\frac{34\ 10^3}{2.82\ 10\text{-}5}} = C\sqrt{12.05 \times 10^8}$$

$$T_1 = C\sqrt{12.05 \times 10^8} = (C)\ (3.47)\ 10^4$$

$$T_1 = (.0047)\ (3.47)\ 10^{-6}\ 10^4 = (47)\ (3.47)\ 10^{-6}$$

$$T_1 = 163 \times 10^{-6} = 0.163 \times 10^{-3}$$

$$f = \frac{1}{2\pi T_1} = \frac{.1592}{.163\ 10^{-3}} = .98 \times 10^3 \approx 1\ \text{KHz}$$

$f = 1$ KHz

$$K_1 T_1 = \frac{C\left(G_1 + G_2 + G_3\right)}{G_1 G_2 + G_2 G_3}$$

$$= (.0047)\,(10^{-6}) \times \left| \frac{1 + 2.96 + 1.82}{1 \times 2.96 + 2.96 \times 1.82 \times 10^{-5}} \right|$$

$$K_1 = \frac{.0047\,(10^{-1})}{T_1} \times \frac{5.78}{(2.96) + (5.4)}$$

$$K_1 = \frac{.00047}{.000162} \times \frac{5.78}{8.4}$$

$$K_1 = \frac{47}{162} \times \frac{5.78}{8.4} = 2$$

$$2 = K_1, \qquad \zeta = 1$$

Thus $$\boxed{\frac{e_0}{e_1} = \frac{A_1}{1 + K_1 T_1 S + T_1^2 S^2}} \qquad \text{----------(1)}$$

Where $A_1 = 0.34$

$K_1 = 2$

$T_1 = 163 \times 10^{-6}$ sec.

Equation 1 is the transfer equation shown in Figure 10, page 21, to describe the characteristics of this filter. The tabulation listed on page 135 is a computer print-out of the Theoretical Frequency Response based on Equation 1. The result is also plotted out in graph form on page 136 Figure 60.

SCOLP 16:14 LA SYSM 3/05/68

OGO E 16 SEARCH COIL
SCO LOW PASS FILTER
THEORETICAL FREQUENCY RESPONSE

ROBERT J NAHABIT
MARSHALL LABS

FREQUENCY	E OUT/E IN	DB GAIN
1	.34	-9.36
2	.34	-9.36
5	.34	-9.36
10	.34	-9.36
20	.3399	-9.36
50	.3391	-9.38
100	.3365	-9.45
200	.3263	-9.71
400	.2911	-10.7
500	.2694	-11.38
700	.2246	-12.95
800	.2034	-13.81
1000	.1659	-15.58
1100	.1498	-16.46
1200	.1354	-17.34
1300	.1226	-18.2
1500	.1012	-19.87
1800	.0773	-22.2
1850	.0741	-22.57
2000	.0654	-23.65
2461	.0462	-26.66
3000	.0326	-29.7
4000	.0191	-34.32
5000	.0125	-38.01
7500	.0057	-44.87

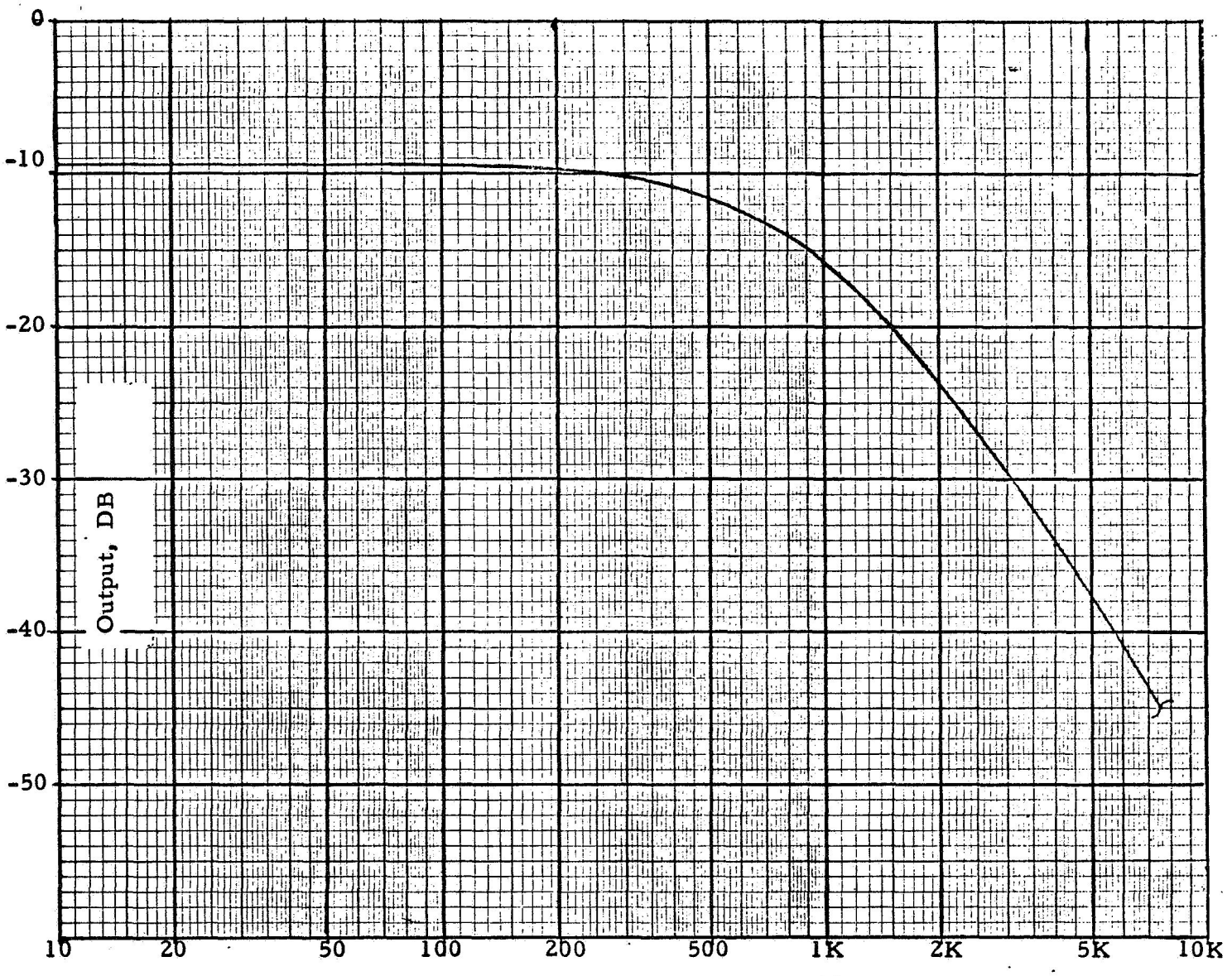


FIGURE 60
SCO LOW PASS FILTER
THEORETICAL FREQUENCY RESPONSE

4.12 Subcarrier Oscillator (SCO)

Figure 61 is a complete schematic of the SCO. Figure 62 is a simplified schematic of the SCO. The SCO consists basically of a free running multivibrator composed of switching transistors Q1 and Q2, current sources I_1 and I_2, and timing capacitors C1 and C2. Figure 63 is a timing diagram showing the voltage waveform within the harmonics filtered and rejected by a wideband telemetry filter. The frequency of the output signal is dependent upon T_1 and T_2 which in turn are dependent upon current sources I_1 and I_2. I_1 and I_2 are both made to vary simultaneously about their quiescent value by an amount proportional to the instantaneous value of the input signal voltage. Thus, the frequency of the output varies about its quiescent value (center frequency) by an amount proportional to the instantaneous value of the input signal voltage. Bias current stability of Q3 and Q4 is provided by the complementary emitter follower Q5. The variations in the base-emitter junctions of Q3 and Q4 with temperature will be cancelled by the opposing change in the base-emitter junction of Q5. Q5 also sets the bias current in Q3 and Q4. Diode CR2 provides isolation between the SCO and output amplifier Q6. CR3 serves to stabilize the bias of Q6. The output of Q6 drives a wideband telemetry bandpass filter referred to above. The SCO is turned off by clamping the base of Q1 to +6 volts via CR1.

Current Sources I_1 and I_2

Frequency stability is also dependent upon the d-c stability of I_1 and I_2. Figure 64 is a schematic of the I_1 and I_2 current sources. The quiescence (d-c) value of I_1 is given by:

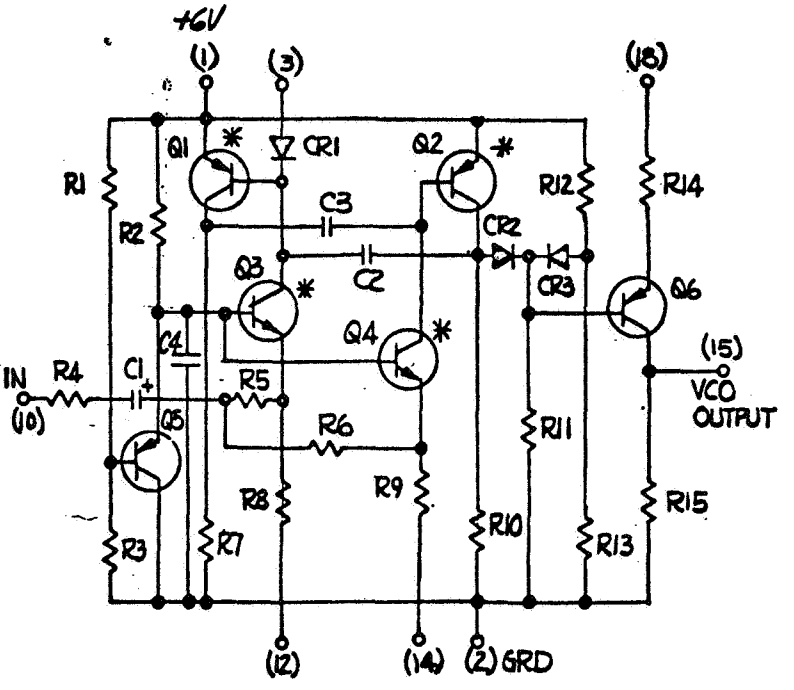
$$I_1 = I_{R8} - I_{bQ3}$$

$$I_{R8} = \left| \frac{V_2 - V_{eQ3}}{R_8} \right|$$

Center frequency is trimmed by adding two resistors in series with R8 and R9.

$$I_{Q3\ Base} = \frac{I_c}{H_{fe}} \quad \text{and} \quad \Delta I_{Q3\ Base} = \frac{I_c}{\Delta H_{fe}}$$

$(I_c = I_1)$



(Reference W4313)

C1 = select
C2 = C3 = select
C4 = 10,000 pf
Q1 = Q2 = 2N3486AML2
Q3 = Q4 = 2N2484/46
Q5 = Q6 = SM9139H
R1 = R5 = R6 = 100K
R2 = 68K
R3 = 90.9K
R4 = Select
R7 = R10 = 6.8K
R8 = R9 = R13 = 30.1K
R11 = 220K
R12 = R15 = 10K
R14 = 4.42K

Figure 61. SCO Schematic Diagram

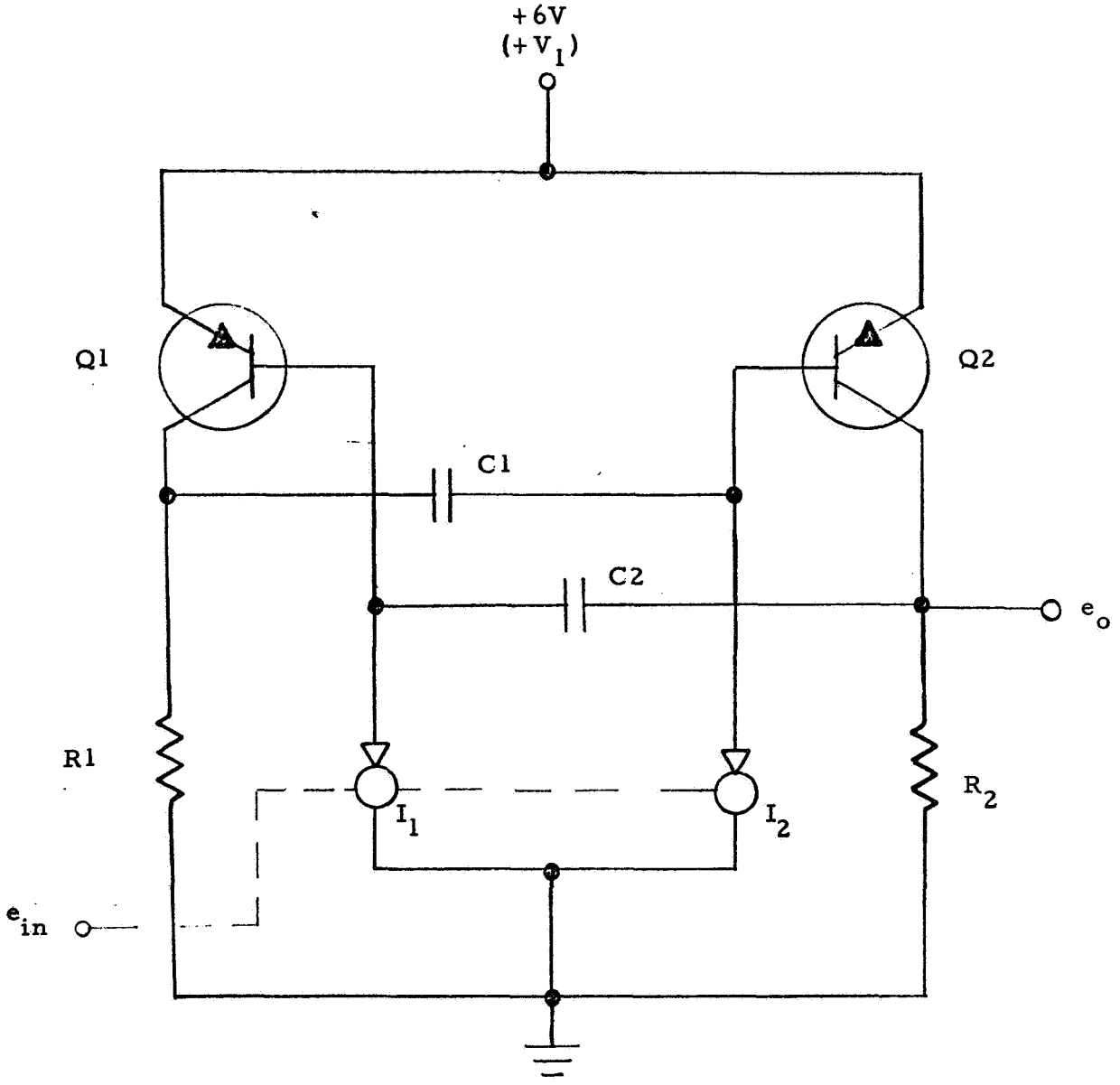
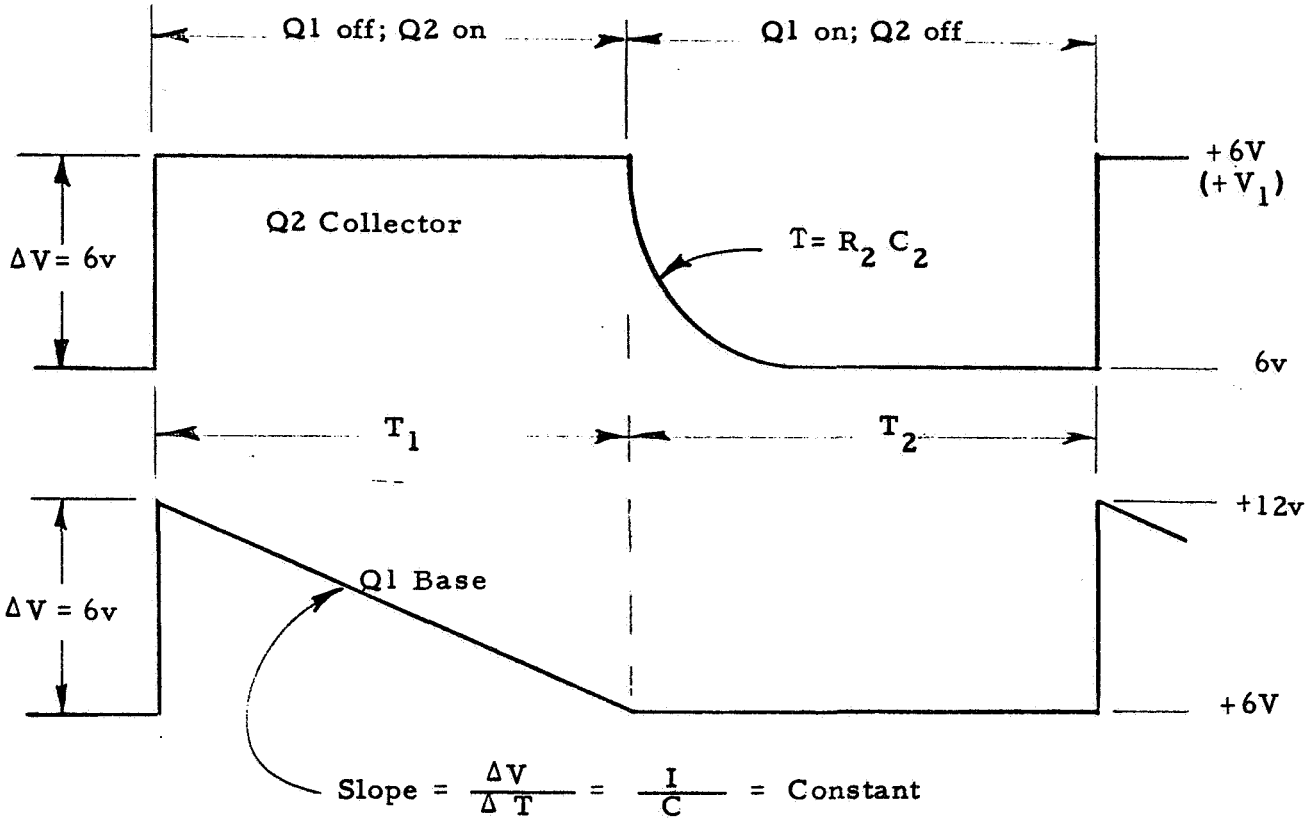


Figure 62
Simplified SCO Schematic Diagram



Given by $e = \frac{1}{c}\int i\,dt$

$$\Delta V = \frac{I}{c}\,\Delta T, \quad \frac{\Delta V}{\Delta T} = \frac{I}{C}$$

$$T_1 + T_2 = T_3$$

$$T_3 = \frac{1}{f}$$

where f is in the frequency of oscillation of the SCO.

Figure 63
SCO Timing Diagram

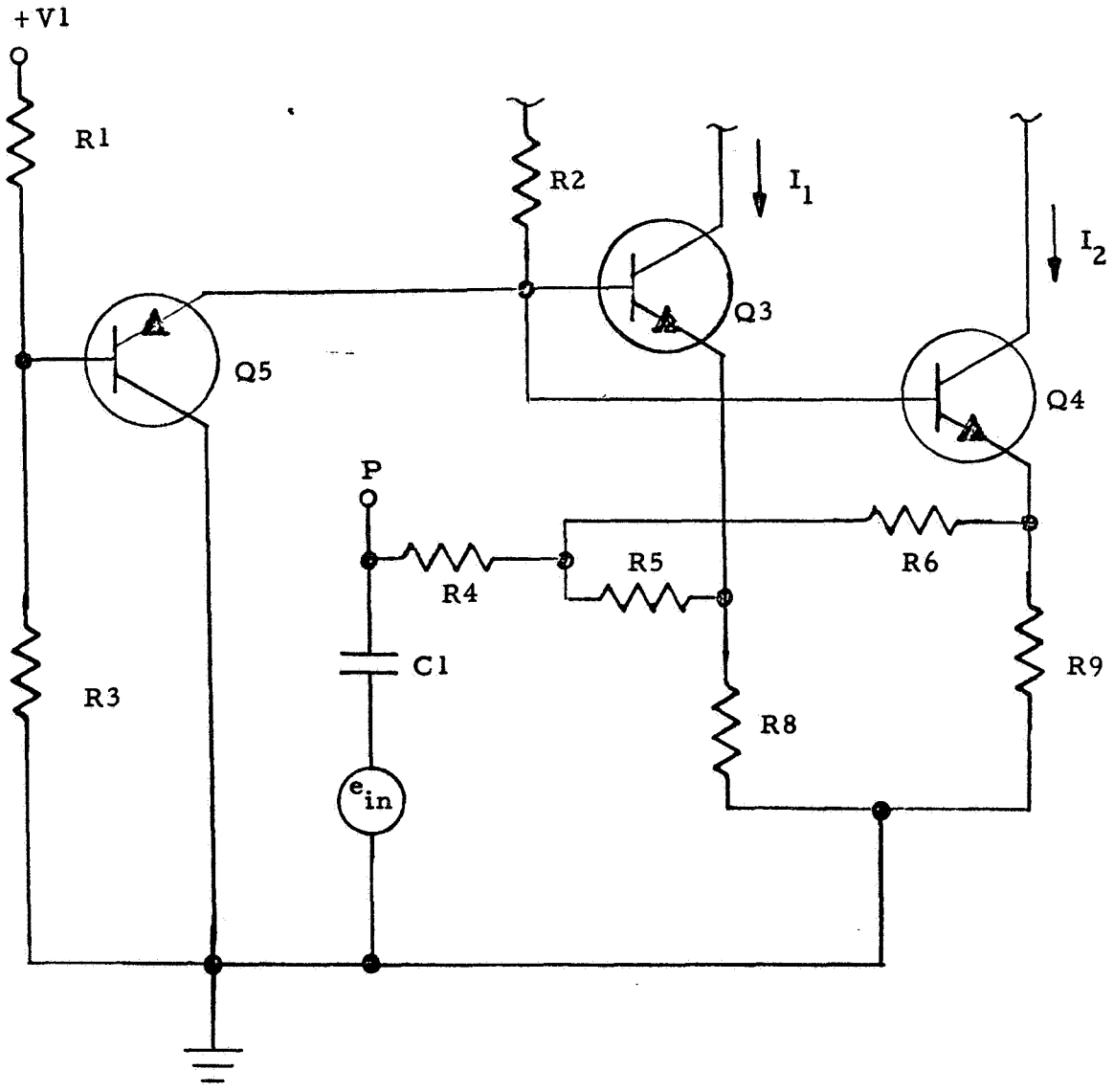


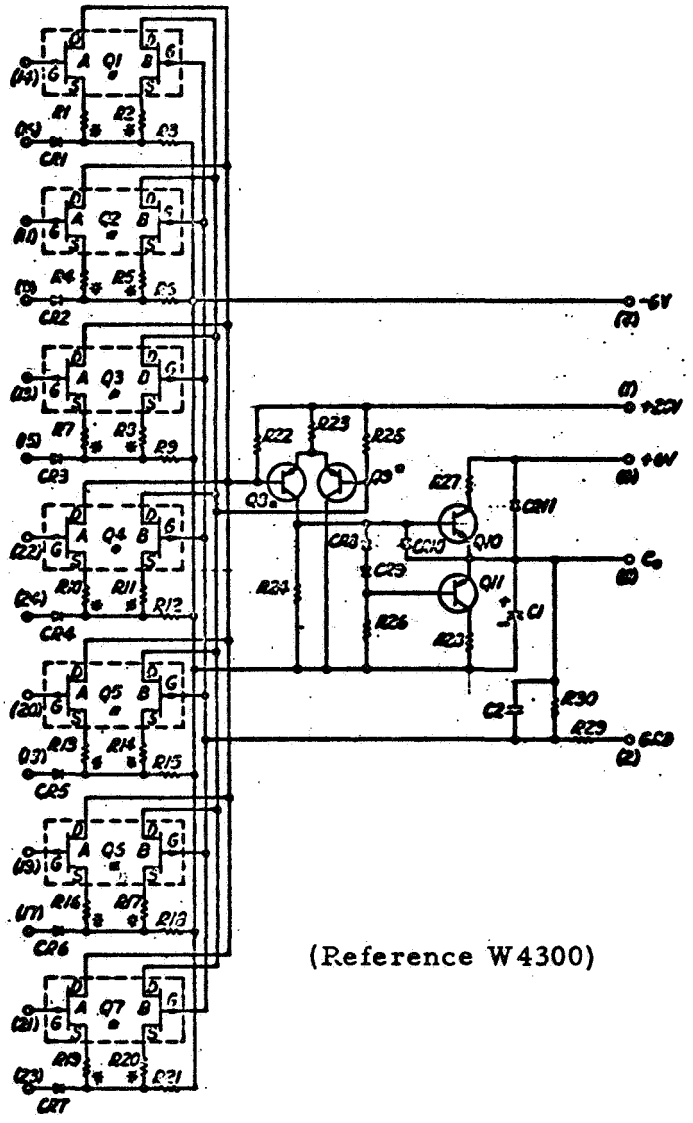
Figure 64
SCO Simplified Current Sources Schematic

4.13 Wave Analyzer Commutator

The Spectrum Commutator, Figures 65 and 66, consists of seven (7) voltage controlled switching amplifiers driving a common output amplifier. Each switch is turned on in sequence, and the gating arrangement is such that only one (1) switch may be "on" at any one time. The data input to the switching amplifiers is provided by the peak detectors. To insure no loading of this output, high impedance FET's are employed for the input stage. Control of the switching amplifier Q1 is provided by diode CR1. If the control voltage is 6v or greater the transistor is biased off. Clamping CR1 to ground via the commutator gating circuit allows Q1 to function as a linear amplifier. The output amplifier, including the "on" operation of Q1, functions the same as the output amplifier used in the Waveform and Wideband Channels. The major difference is that seven (7) input stages are tied in parallel and sequentially turned "on" and "off" by a gating circuit.

The input switches, Q1 to Q7, are matched pair N channel FET's. Their output offset is further reduced to zero with select source resistors. All drains are connected in parallel to the second stage PNP differential amplifier Q8 and Q9. Low output impedance is achieved by the complementary NPN-PNP emitter follower. The commutator gain of 2 is derived from feedback resistors R29 and R30.

$$A_G = \frac{R29 + R30}{R29} = \frac{100K + 100K}{100K} = 2$$



(Reference W4300)

R1 = R4 = R7 = R10 = R13 = R16 = R19 = Select
R2 = R5 = R8 = R11, R14, R17, R20 = Select
R3 = R6 = R9 = R12 = R15 = R18 = R21 = 76.8K
R22 = R25 = 73.25K
R23 = 10K
R24 = 62K
R26 = 100 K
R27 = 1.8K
R28 = 3.6K
R29 = R30 = 100K

C1 = 1.0 μf
C2 = 220 pf
Q1 thru Q7 = SU20266
Q8 = Q9 = SM9139H
Q10 = 2N2484/46

Figure 65

Wave Analyzer Commutator Schematic Diagram

151

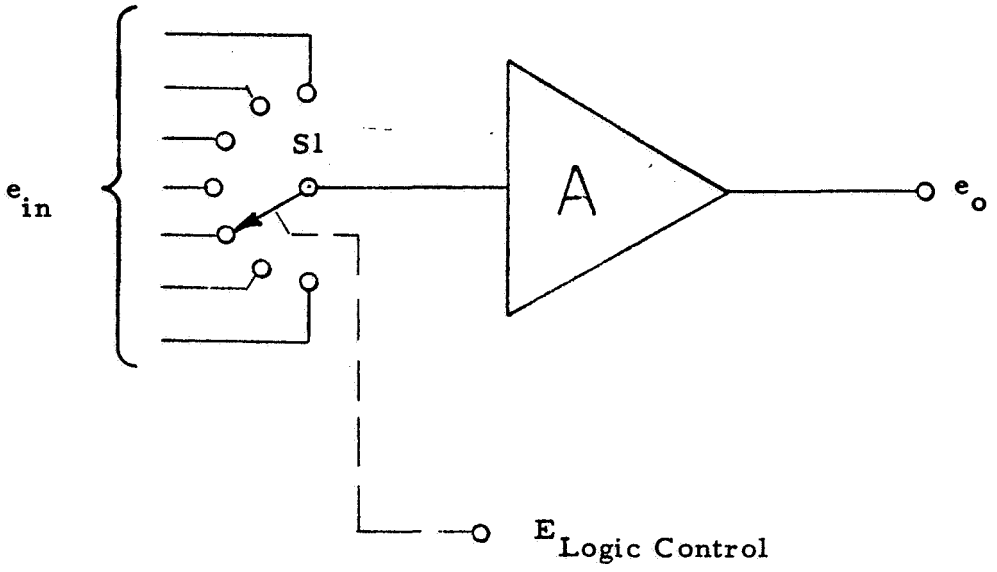


Figure 66
Simplified Wave Analyzer Commutator Circuit

4.14 Commutator Gating Circuit

The commutator gating logic consists of seven (7) "AND" gates connected such that only one (1) output will be true at any one time. Following is an example of the gate operation using the 1000 Hz control gate with inputs QJ, QK, and QL. See Figure 67. When any of the before mentioned inputs are at ground potential, the bias current through R1 is shunted to ground through either CR1, CR2, and CR3. Transistor Q1 is turned "off" and the collector voltage goes to +20v which is a false output. The forward voltage drops of CR1, CR2, and CR3 are cancelled by CR22 which enables Q1 to turn off. If all inputs are at +6v, the bias current through R1 is routed through CR22 to the base of Q1, turning Q1 on. The collector voltage goes to 0 volts and the output is true. This output is used to gate the Wave Analyzer Commutator discussed in Section 41.13.

4.15 Complementary Flip Flop

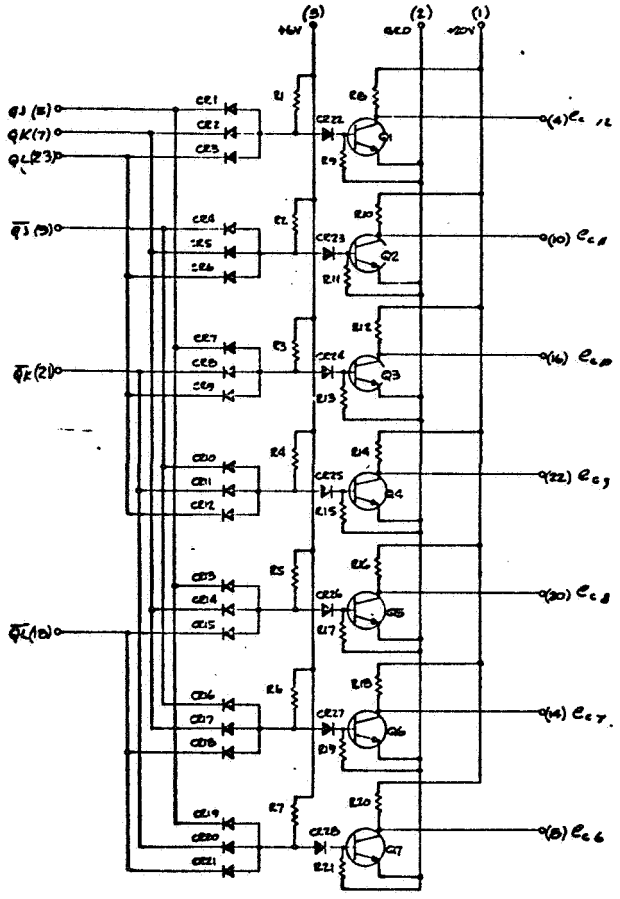
The complementary flip flop was designed to have a low output impedance in both the high and low output states. Figure 68 shows a simplified schematic of the flip flop. Assume initially that Q2 and Q3 are "on" and the output at Q4 is +6 volts. Capacitor C6 will charge to +6 volts through R2, CR2, CR3, and R7. Since Q3 is "on", C5 will charge to +6 volts through R2 and Q3. Because $\overline{Q}$ is at 0 volts, capacitors C3 and C4 will not be charged. A negative trigger pulse will be coupled through C7 to steering diodes CR1 and CR2. The negative pulse is coupled through CR1 and C3 to the base of Q2 and through C4 to the base of Q4. This negative pulse is the polarity required to turn Q2 "on" and Q4 "off". But, since Q2 is "on" and Q4 is "off", this pulse has no effect. However, the negative pulse coupled through CR2 and C6 to the base of Q1, turns Q1 "on". Simultaneously, the pulse is coupled through C5 to the base of Q3, turning Q3 "off". $\overline{Q}$ now goes through a transition from 0v to +6 volts. The +6 volts through R1 turns Q2 "off" and through R4 turns Q4 "on". Q is now at 0 volts and the flip flop has changed state. Note that the output impedance is low in both the high and low states since one transistor in each leg is always "on".

4.16 Modulo-Seven Binary Counter

The modulo seven binary counter is used to control the gating circuit for the Wave Analyzer Commutator. Figure 69 gives a block diagram of the counter. Note that F/F A is initially set and F/F B and C are reset. When the count reaches seven, F/F A, F/F B, and F/F C are all true. The next pulse will set F/F A "false" which sets F/F B "false" which in turn sets F/F C "false". But, when F/F C goes "false", it sets F/F A "true". This is the required reset state for a binary one (1).

4.17 Impulse Command Isolation Amplifier

Figure 70 shows a schematic diagram of the isolation amplifier.



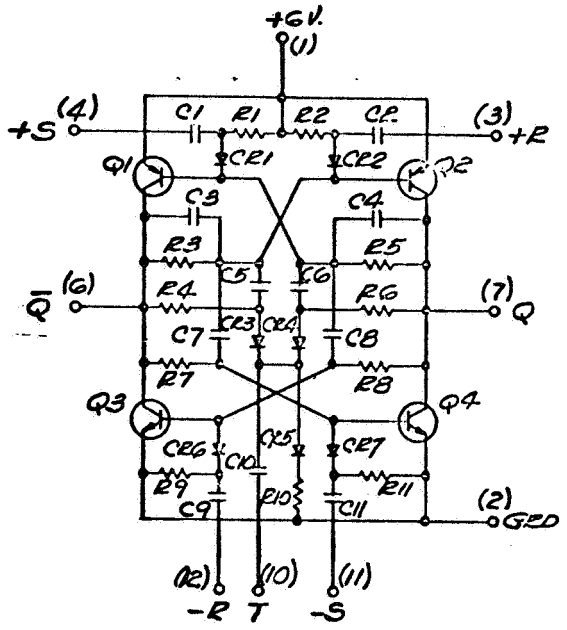
(Reference W4299)

CR1 thru CR28 = DHD115
R1 thru R7 = 75K
R8 = R10 = R12 = R14 = R16 =R18 = R20 = 24K

R9 = R11 = R13 = R15 = R17 = R19 =R21 = 51K

Q1 thru Q7 = 2N2484/46

Figure 67
Commutator Gating Schematic Diagram



(Reference W4296)

C1 thru C6 = 150 pf
C7 = 560 pf

CR1 thru CR3 = DHD115

R1 thru R6 = 62K

R7 = 1K

Q1 = Q2 = SM9139H

Q3 = Q4 = 2N2484/46

Figure 68

Complementary Flip Flop Schematic Diagram

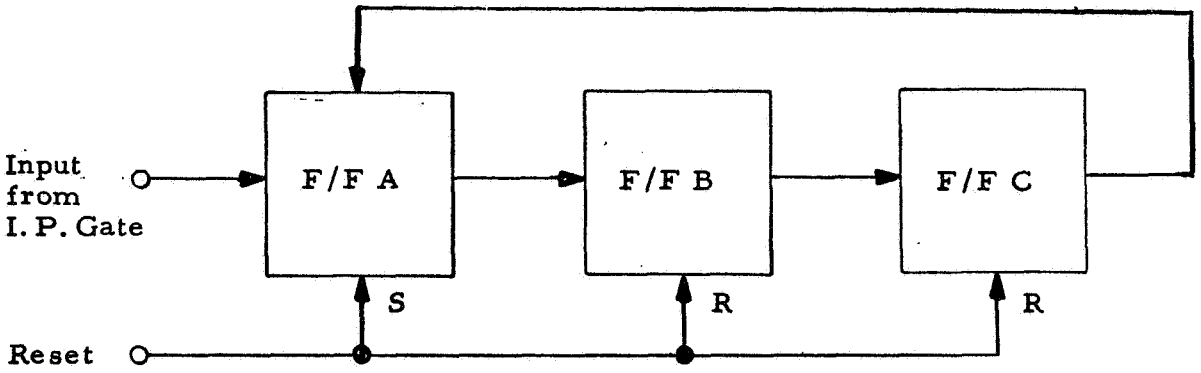
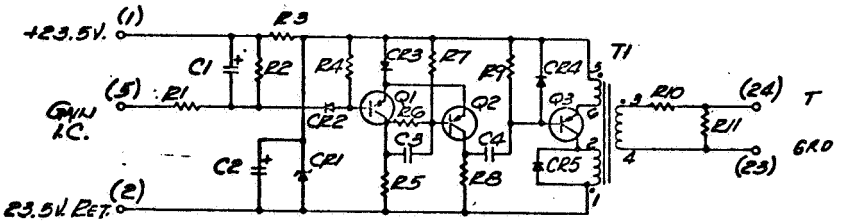


Figure 69
Modulo-Seven Counter Block Diagram



(Reference W4308)

C1 = .22 μf
C2 = 3.3 μf
C3 = 1000 pf
C4 = 330 pf
R1 = 30K
R2 = 10 Mes
R3 = 47K
R4 = 150K

R5 = 30K
R6 = 150K
R7 = 100K
R8 = 30K
R9 = 30K
R10 = 2K
R11 = Select

Q1 = 2N3486A
Q2 = 2N3486A
Q3 = 2N3486A
CR1 = 1N753A

Figure 70

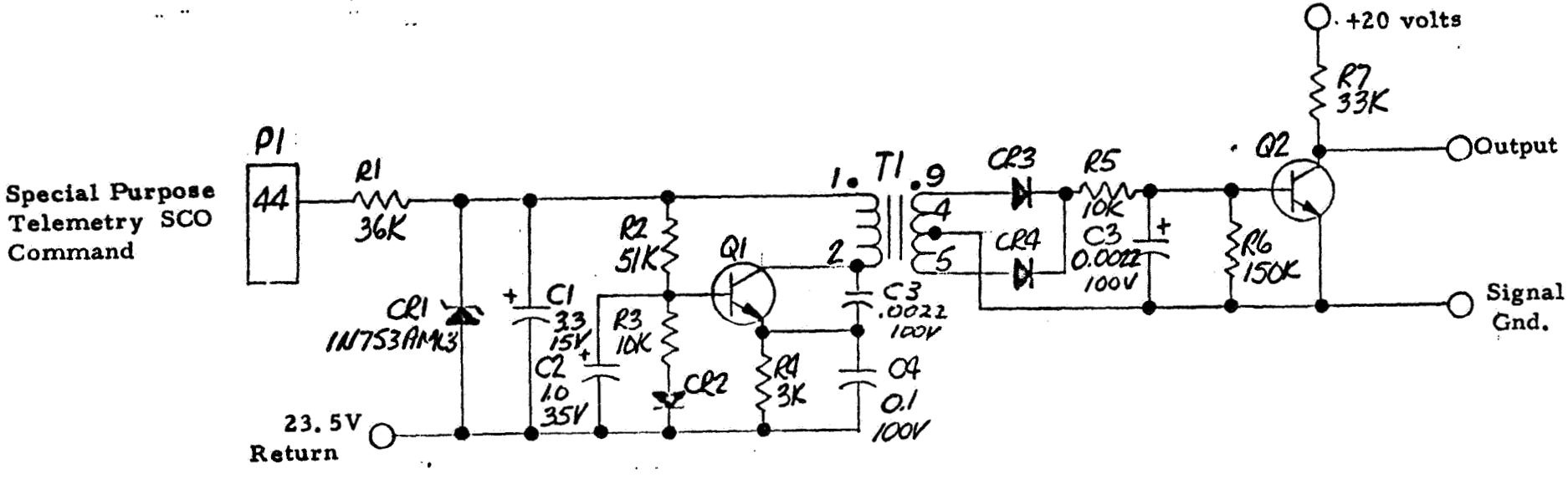
Impulse Isolation Amplifier Schematic

Resistor R1 and C1 form a 5 ms delay circuit that prevents relay contact bounce from triggering the amplifier. When R1 is tied to ground via the spacecraft command relay, capacitor C1 begins to charge. After approximately 5 ms, the voltage across C1 will exceed the circuit threshold and Q1 will conduct. This Schmitt-Trigger drives a blocking oscillator, Q3 and T1, which produces an output pulse of approximately .5 μs rise time and 10 μs duration. This pulse is used to control the state of a flip flop.

In the quiescent state, transistor Q1 is "off", Q2 "on", and Q3 "off". The trigger circuit reference is at +6v and is determined by diode CR1 and resistor R3. The voltage necessary to fire the trigger (referenced to ground) must exceed the +6v reference plus the sum of the drops across CR2, CR3, and base emitter junction of Q1. The time required for the voltage across C1 to exceed the threshold value is given by the product of R1-C1. R2 serves as a discharge path for C1 between impulse commands.

4.18 SCO Command Detector

The purpose of the SCO detector, Figure 71, is to isolate the magnetometer circuitry from the spacecraft command lines. This is accomplished by using the +28v command signal as the supply voltage for an oscillator circuit. The oscillator signal is then transformer coupled, rectified, filtered, and used as the control voltage of transistor Q2. The frequency os oscillation is determined by the inductance in the primary of T1 and capacitors C3 and C4, and is nominally 100 KHz.



1. All resistances in ohms ± 5% 1/4W
2. All capacitances in microfarads ± 10%
3. All transistors 2N2484/46 (Amelco)
4. All diodes are GE DHD 115 (1N4150)

Note: Unless otherwise specified

Special Purpose SCO
Command Detector

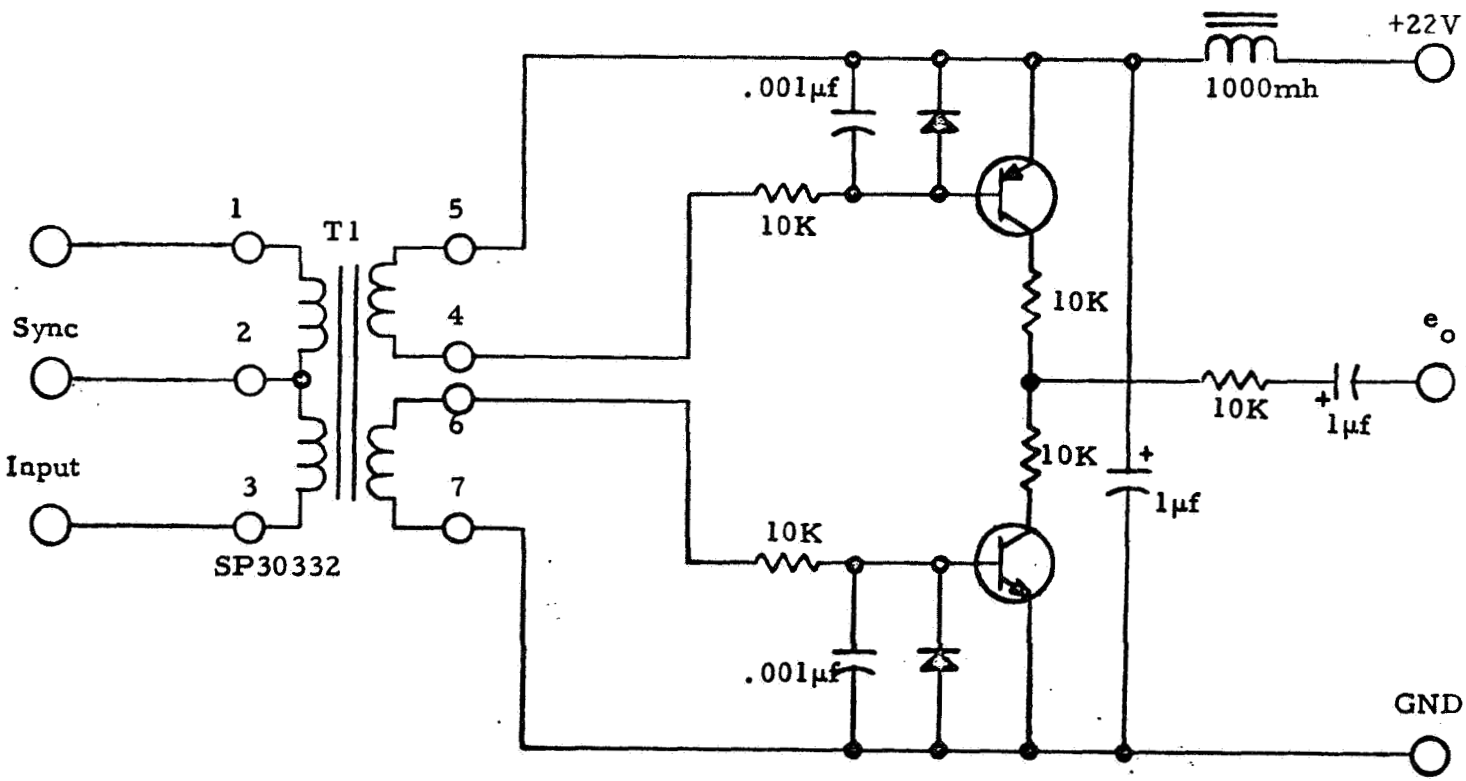
Figure 71

4.19 Sync Amplifier

The Sync Amplifier is used to buffer the 2461 Hz sync signal from the spacecraft. It also enables the power supply to meet the interface requirements for this signal.

Figure 72 shows the sync amplifier circuit schematic. The circuit utilizes a transformer coupled amplifier. The amplifiers are a complementary pair which use the pre-regulated voltage (+22 volts) as their supply.

A square wave synchronization signal of less than 4 volts peak to peak will sync the instrument's power supply. The input impedance for the synchronization signal is greater than 9000 ohms.



(Reference W4290)

FIGURE 72
SYNC AMPLIFIER SCHEMATIC DIAGRAM

4.20 Power Supply Converter

The operation of the converter is discussed under two major headings: Oscillation and Synchronization. Refer to Figure 73 for the discussion. Figure 74 is the detailed circuit diagram of the converver module W4291.

Oscillation

Upon turn on, +23.5 volts is applied to the emitter of Q7, Q8 and pin 5 of T3. Pin 2 of T3 is held at ground. The +47 volts appearing across pins 1 and 3 of T3 are coupled via the select resistors to pin 1 and 2 of T2 (the feedback winding) of T2. This voltage at pins 1 and 2 of T2 induces a voltage at pins 3-4 and 4-5 of T2 such that pin 3 goes positive and pin 5 goes negative turning on Q8 and holding off Q7. After a specified time the current in the winding 1-2 of T3 reaches a level such that T2 is saturated, i.e. $(N_{12})(I_{12}) \leq (NI_{\text{saturation for T2}})$ at which time the voltage at pins 3 and 5 of T2 drops to zero. This kills the base drive to Q8 and it starts to cut off. This removes the short to ground at pin 3 of T1, causing the voltage at pin 3 to rise toward +23.5 volts (and causing the voltage at pin 1 of T1 to drop toward +23.5 volts). This couples a step voltage of such polarity to the feedback winding of T2 such that it removes it from saturation and couples a negative voltage to pin 3 of T2 and a positive voltage to pin 5. This cuts off Q8 and turns Q7 on. This state is maintained until the current in pins 1 and 2 of T2 once again reaches a level to cause T2 to saturate and the whole process is repeated over and over. Thus, oscillation occurs.

Synchronization

The sync input signal couples currents into the sync winding (pins 6-7 of T2) to aid or retard the feedback winding current such that synchronization between the feedback winding voltage and the sync voltage occurs. These two square waves are of the same frequency, but nominally at a phase difference of 90°; i.e., when ($f_{in} = f_{\text{free run of converter}}$).

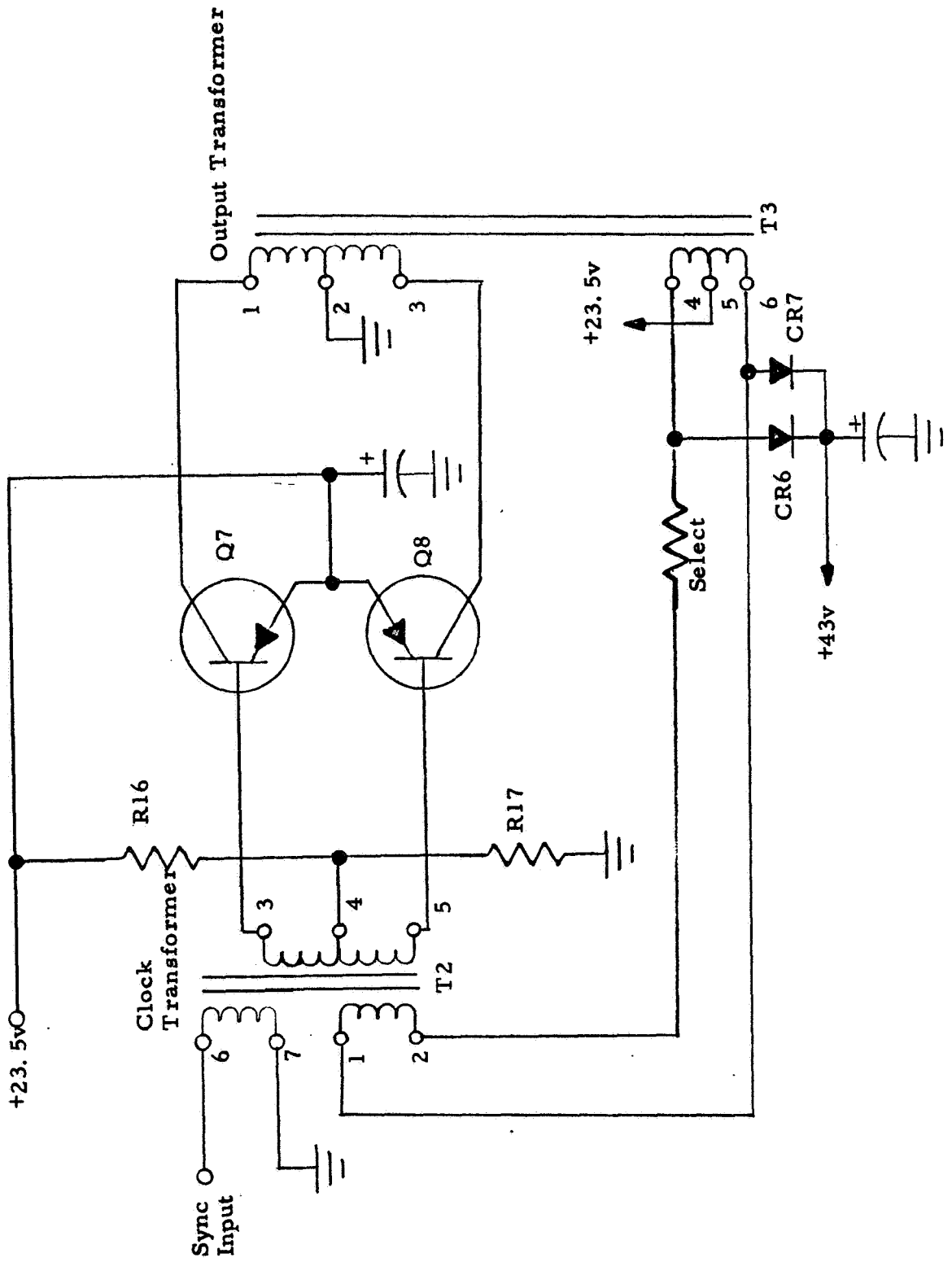
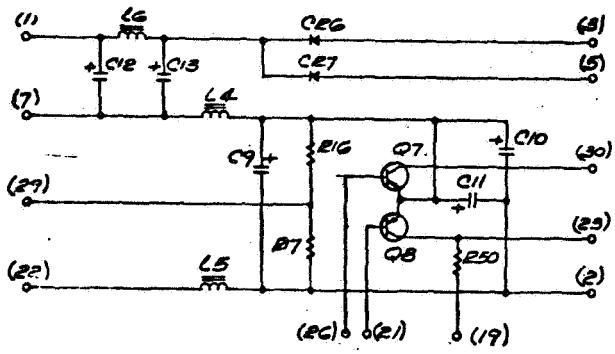


Figure 73
Converter Simplified Schematic



(Reference W4291)

C9 = C10 = C11 = 6.8 μf
C12 = C13 = 1.0 μf
L4 = 280 μh
L5 = 1000 μh
L6 = 1000 μh

R16 = 1K
R17 = 24K
R50 = 47K
Q7 = Q8 = SM9139H

Figure 74

Converter Module Detailed Schematic Diagram

4.21 Power Supply Preregulator

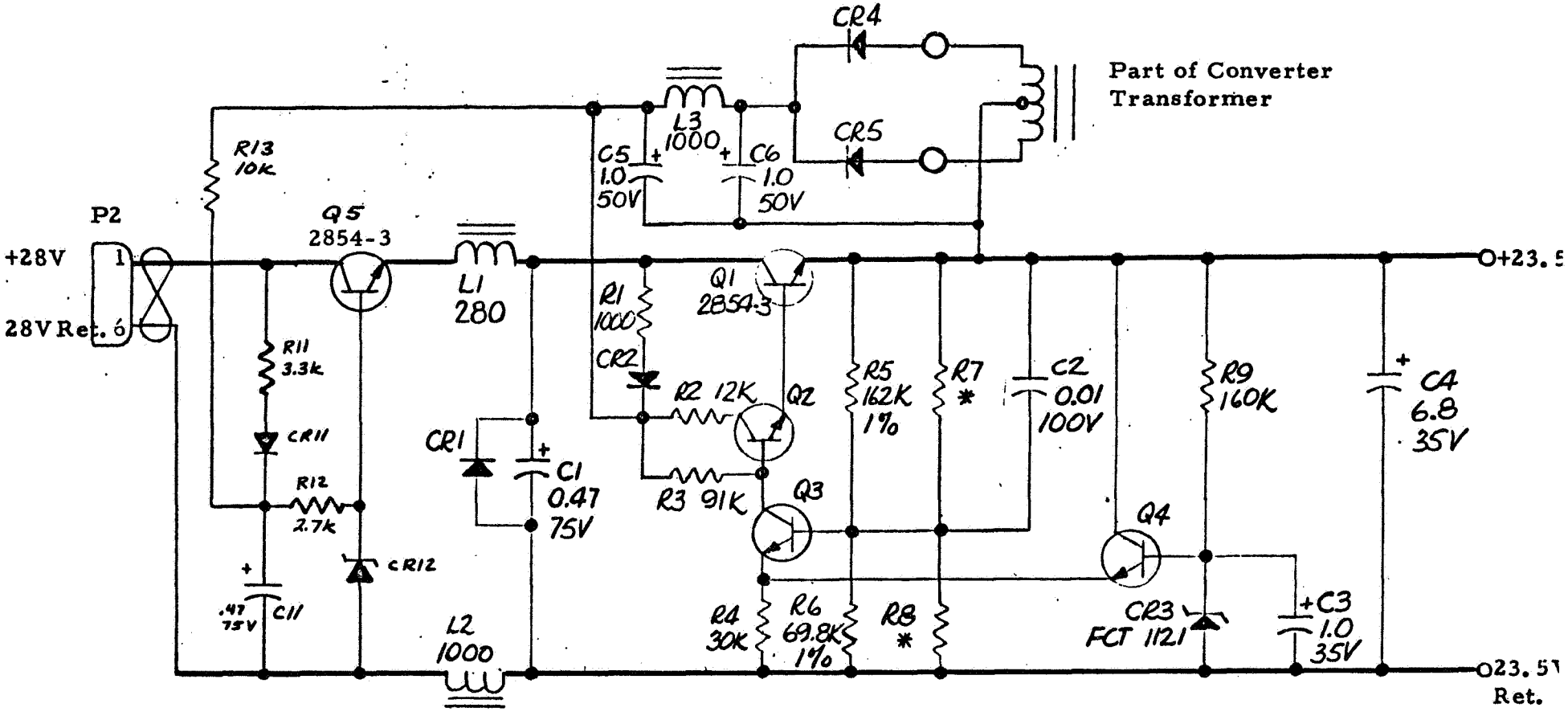
The power supply preregulator consists of a series voltage regulator that provides stable operating voltage to the d-c to d-c converter ensuring reliable operation. The circuit is relatively straight forward, see Figure 75. CR3, a Zener diode, provides the reference voltage to Q3-Q4, a differential amplifier, which drives Q1 and Q2. Voltage divider R5 and R6 is selected to set the output voltage to +23.5v d-c. The collector voltage supply , +47 volts, for Q2 is provided by an isolated source which is higher than that for Q1. The higher potential allows Q1 to operate at a low collector voltage which minimizes power loss. Q1 and Q5 are mounted on the housing for heat dissipation. Figure 76 shows the detailed schematic diagram of the preregulator module.

In order to stay within the spacecrafts' reflected noise and turn-on surge current requirements, transistor Q5 and its associated components were introduced into the circuit. The turn-on sequence is as follows: At time T = 0 capacitor C11 has zero volts across it and begins to charge up to 28 volts through R11, and CR11. Once C11 begins to charge, Q5 begins to pass voltage to the +23.5 volt preregulator volt output. The converter begins to run and couples a voltage via T3 back to the preregulator. It is rectified by CR4-CR5, and again is applied to capacitor C11. This voltage (+47 volts) back biases CR2 and CR11 and acts as Vcc for Q2 and Q3.

4.2.2 Power Supply Post Regulators

There are four post regulators utilized within the power supply. Of these, 6 volts and the rest are +20 volts, and -6 volts, respectively.

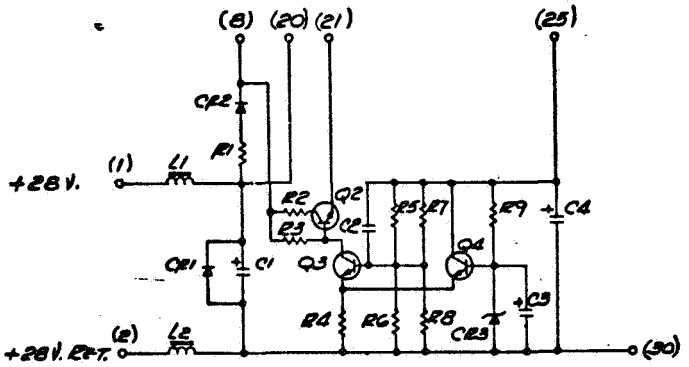
The regulators provide regulation of the power provided by the converter and reduces noise and ripple on the output lines. The circuits are conventional series regulators with Zener reference diodes, and differential error detection amplifiers that sense voltage variations in the output lines. In each case transistors amplify the error signals which drive Darlington connected pass transistors. The circuit of each regulator is illustrated in Figures 77 thru 79.



Q2 thru Q4 = 2N2484/46

Figure 75

Power Supply +23.5 Volt Preregulator Schematic



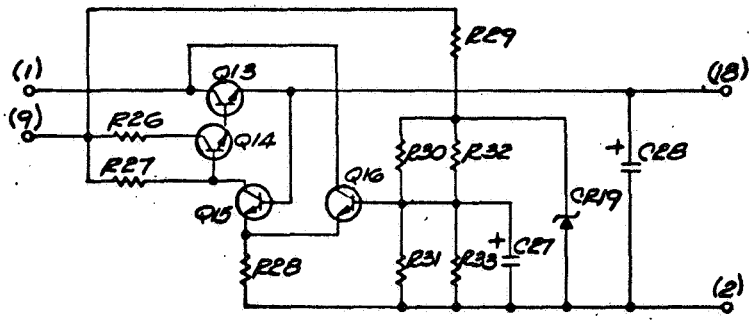
(Reference W4289)

C1 = .47 μf
C2 = .01 μf
C3 = 1 μf
C4 = 6.8 μf
L1 = 280 μh
L2 = 1000 μh
Q2 thru Q4 = 2N2484/46

R1 = 1K
R2 = 12K
R3 = 91K
R4 = 30K
R5 = 162K
R6 = 69.8K
R7, R8 = Select
R9 = 160K

Figure 76

Preregulator Module Detailed Schematic Diagram



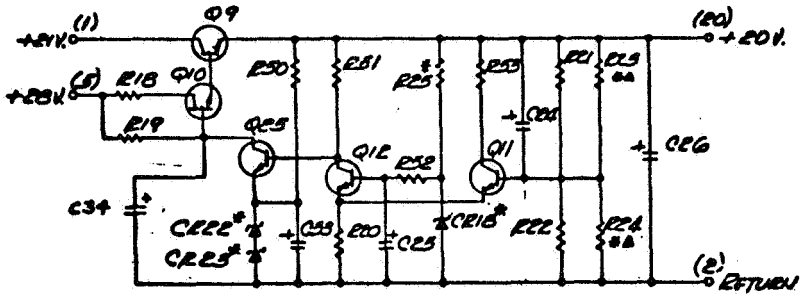
(Reference W4294)

C27 = 1 μf
C28 = 22μf
Q13 = GT 5968
Q14 = Q15 = Q16 = 2N2484/46
CR19 = FCT1121

R26 = 33K
R27 = 130K
R28 = 27K
R29 = 75K
R30 = 8.25K
R31 = 60.4K
R32, R33 = Select

Figure 77

+6 Volt Post Regulator Schematic



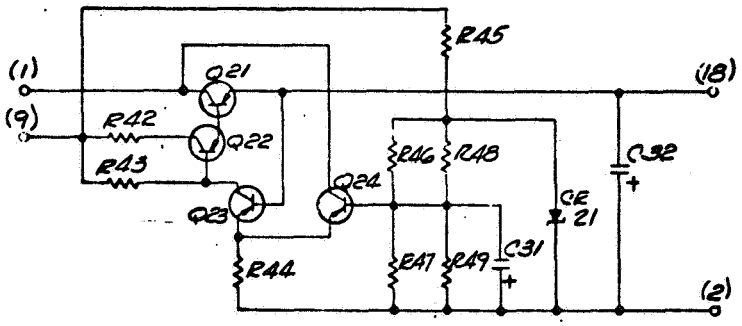
(Reference W4321)

C24 = C33 = 1μf
C25 = 3.3 μf
C26 = 6.8μf
C34 = 1.0μf
CR18 = CR22 = CR23 = 1N753A
Q9 = GT5968
Q10 = Q11 = Q12 = Q25 = 2N2484/46

R18 = 6.2K
R19 = 62K
R20 = 27K
R21 = 150K
R22 = 61.9K
R23, R24, R25 = Select
R50 = 150K
R51 = R53 = 75K
R52 = 10K

Figure 78

+20 Volt Post Regulator Schematic



C31 = 1.0 μf
C32 = 22 μf
CR21 = FCT 1121
Q21 thru Q24 = SM9139H

R42 = 33K
R43 = 130K
R44 = 27K
R45 = 75K
R46 = 8.25K
R47 = 60.4K
R48, R49 = Select

Figure 79

-6 Volt Post Regulator Schematic

5.0 BENCH TEST EQUIPMENT

The purpose of the OGO-E Bench Test Equipment (BTE) is to simulate the spacecraft interface signals and to monitor the functioning of the OGO-E Search Coil Magnetometer (SCM). The BTE also contains provisions for convenient use of auxiliary test equipment to enable complete calibration of the SCM.

5.1 Mechanical Description

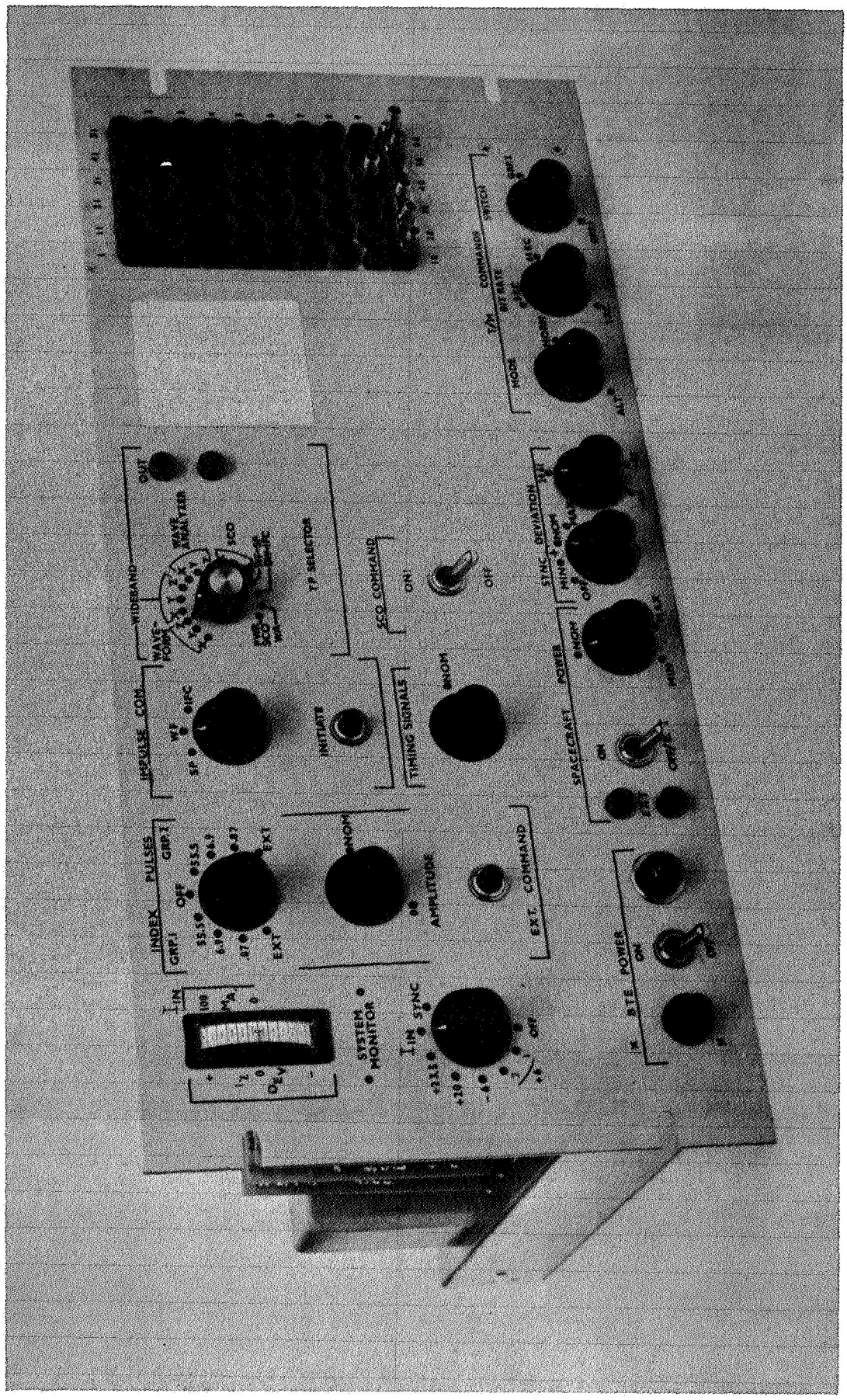
As indicated in Figure 80, which shows a front panel view of the BTE and Figure 81 which shows the rear of the unit, it is fabricated of a chassis mounted behind a standard 19 inch panel upon which the majority of the controls and test points are available. All connectors are mounted on the rear of the panel together with some of the controls and test points associated with the power supply. The major portion of the circuitry is mounted on printed circuit boards some of which are contained within shielded enclosures. As a means of minimizing the equipment cost, the entire BTE was fabricated utilizing high quality breadboard type construction. The front panel is painted per ML S40118, Class II, Type V, light blue. All markings and lettering are dry transferred DATAK color black. Also located on the front panel together with the controls, are 60 test points which enable monitoring of all of the important signals from the SCM as well as some of the signals which are generated through the BTE.

5.2 Electrical Description

All of the electrical functions provided by the BTE are described in the following paragraphs. A complete schematic of the BTE is shown in Figure 82.

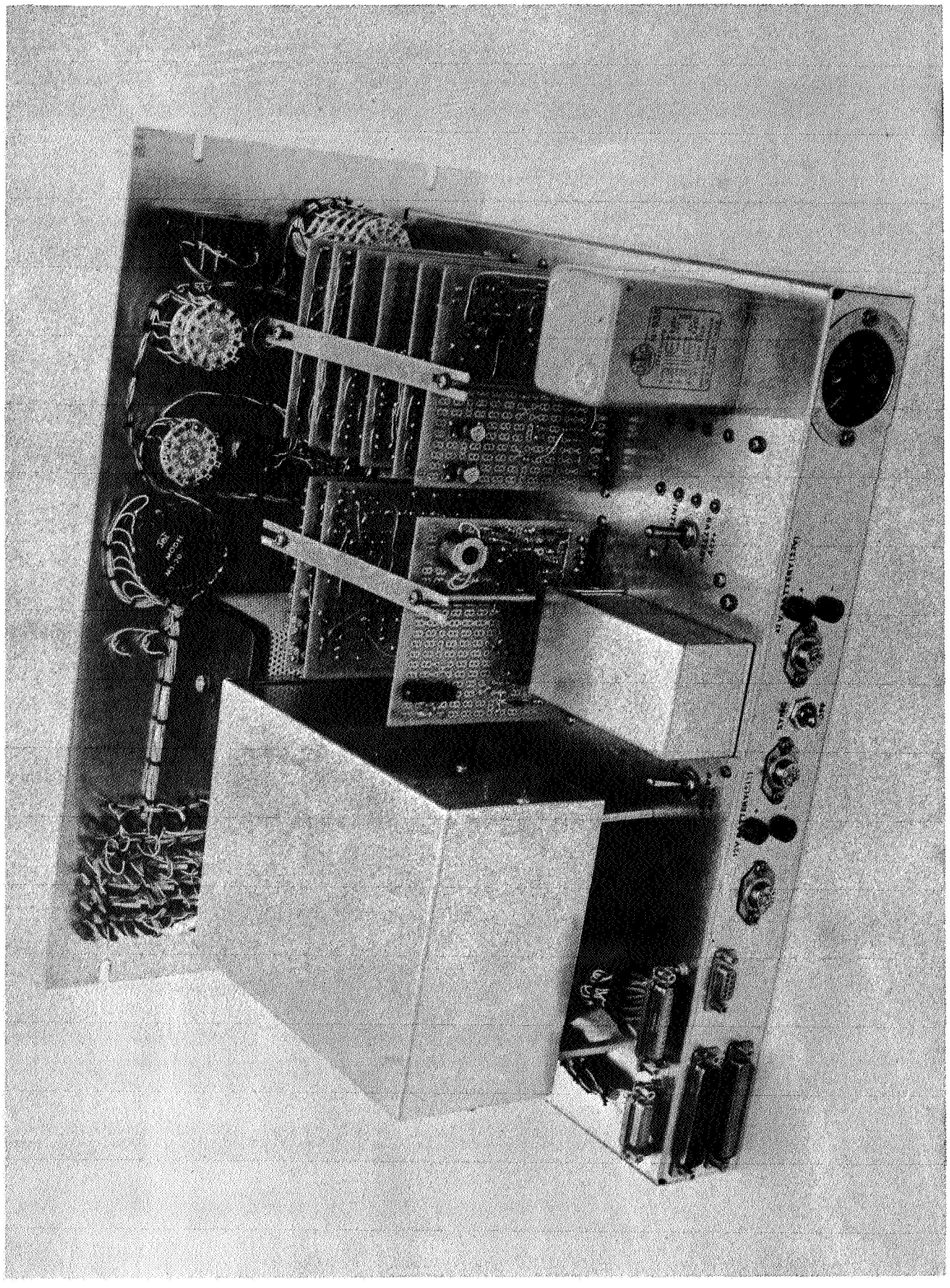
5.2.1 BTE Power System

Figure 83 shows a simplified diagram of the BTE power supplies. Under normal operation, the BTE power is generated by use of power supplies which utilize the 60 cycle 110 volt line for primary power. This ac power is applied to a 12 volt regulated supply which is utilized in the BTE and is also rectified and filtered for a 25 volt regulated supply again for use in the BTE. It is also used for a current limited regulated supply which is variable in output voltage from 23 to 33 volts. The output of this latter supply is that which is used to power the SCM. As indicated, the setting of the voltage to the instrument is regulated by a front panel control which is marked as shown. A set of test jacks is available on the front panel so that in the OFF-EXTERNAL position, an external power supply may be used to power the instrument. Other capabilities are built in by way of rear panel mounted switches and test jacks to enable the use of external batteries to power both the BTE and the instrument for remote site operations.



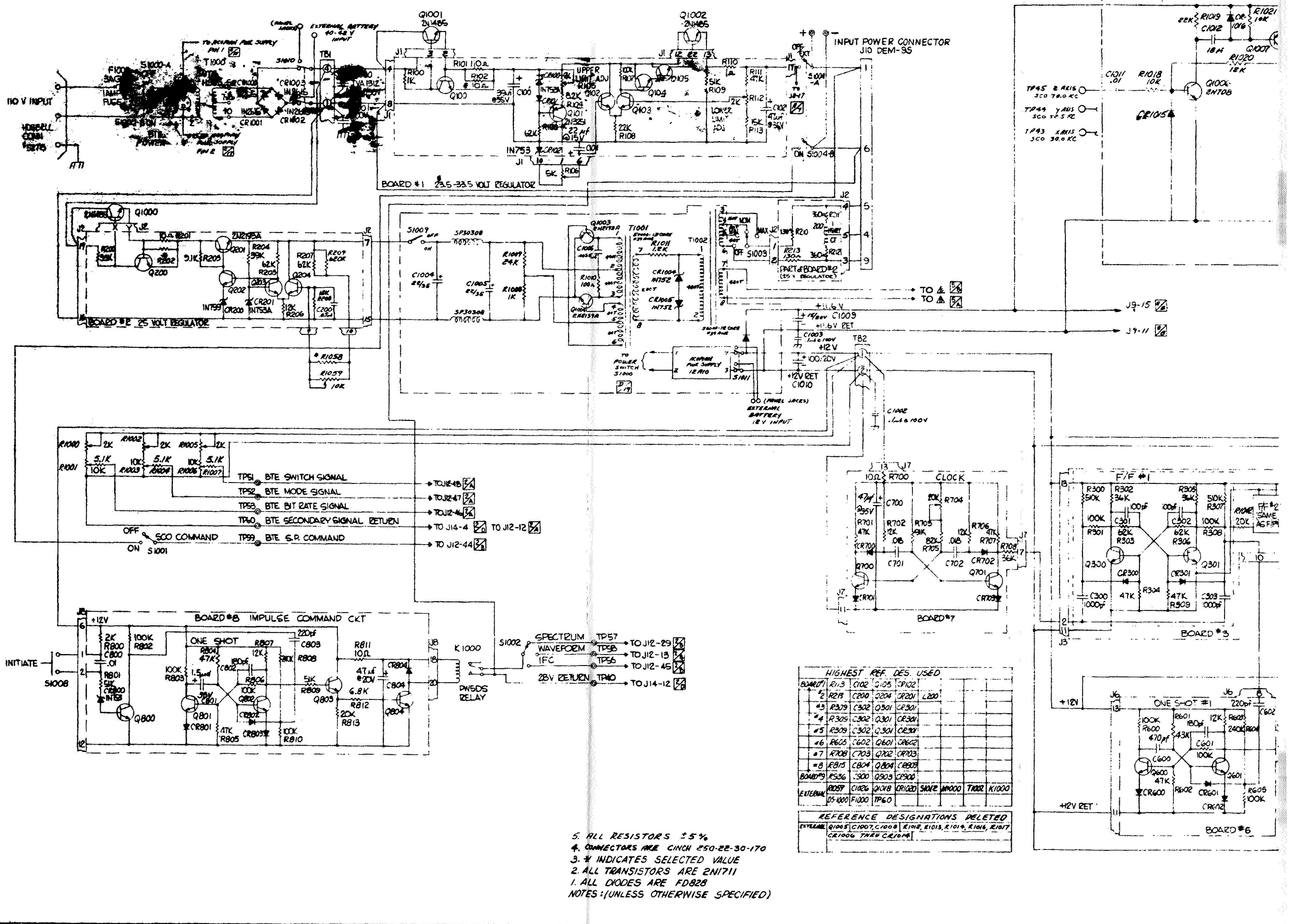
Front Panel View of OGO-E Search Coil Magnetometer Bench Test Equipment

Figure 80



Rear Panel View of OGO-E Search Coil Magnetometer Bench Test Equipment

Figure 81



HIGHEST REF. DES. USED									
BOARD #1	R113	C102	Q105	CR102					
#2	R213	C200	Q204	CR201	L200				
#3	R309	C302	Q301	CR301					
#4	R305	C302	Q301	CR301					
#5	R309	C302	Q301	CR301					
#6	R605	C602	Q601	CR602					
#7	R708	C703	Q702	CR703					
#8	R815	C804	Q804	CR803					
BOARD #9	RS36	C900	Q903	CR900					
EXTERNAL	RD57	C1026	Q1018	CR1020	S1012	M1000	T1002	K1000	
	DS-1000	F1000	TP60						

REFERENCE DESIGNATIONS DELETED						
EXTERNAL	Q1005	C1007, C1008	R1012, R1013, R1014, R1016, R1017			
	CR1006 THRU CR1014					

5. ALL RESISTORS ±5%
4. CONNECTORS ARE CINCH 250-22-30-170
3. * INDICATES SELECTED VALUE
2. ALL TRANSISTORS ARE 2N1711
1. ALL DIODES ARE FD828
NOTES: (UNLESS OTHERWISE SPECIFIED)

X,Y,&Z DEMOD REF SUPPLY

DEMOD CIRCUIT (Z AXIS SHOWN) X,&Y AXIS SAME EXCEPT AS NOTED

EXT COMMAND

S1005

GROUP 1 GROUP 2

S1006-A

S1006-B

BTE INDEX PULSE GROUP №1 TP55 TO J12-15

BTE INDEX PULSE GROUP №2 TP54 TO J12-31

To TP2

+2V

+2V RET

BOARD #4

BOARD #5

BOARD #6

BOARD #9

+12V

+12V RET

+11.6V

+11.6V RET

R926 825Ω 1%

CR900 IN827

REF VOLTAGE

METER M100

S1007

TO TP3 TO TP4 TO TP1 TO TP38

TP39 +23.5V RET

TP40 +6V#1 RET, +6V#2 RET, +20V RET

+V GAIN ADJ

-V GAIN ADJ

TO J1-P

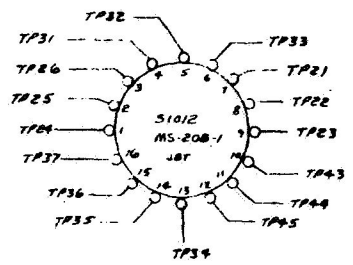
TO J1-T

TP49 BTE 0.87PPS-TIMING SIGNAL TO J12-49

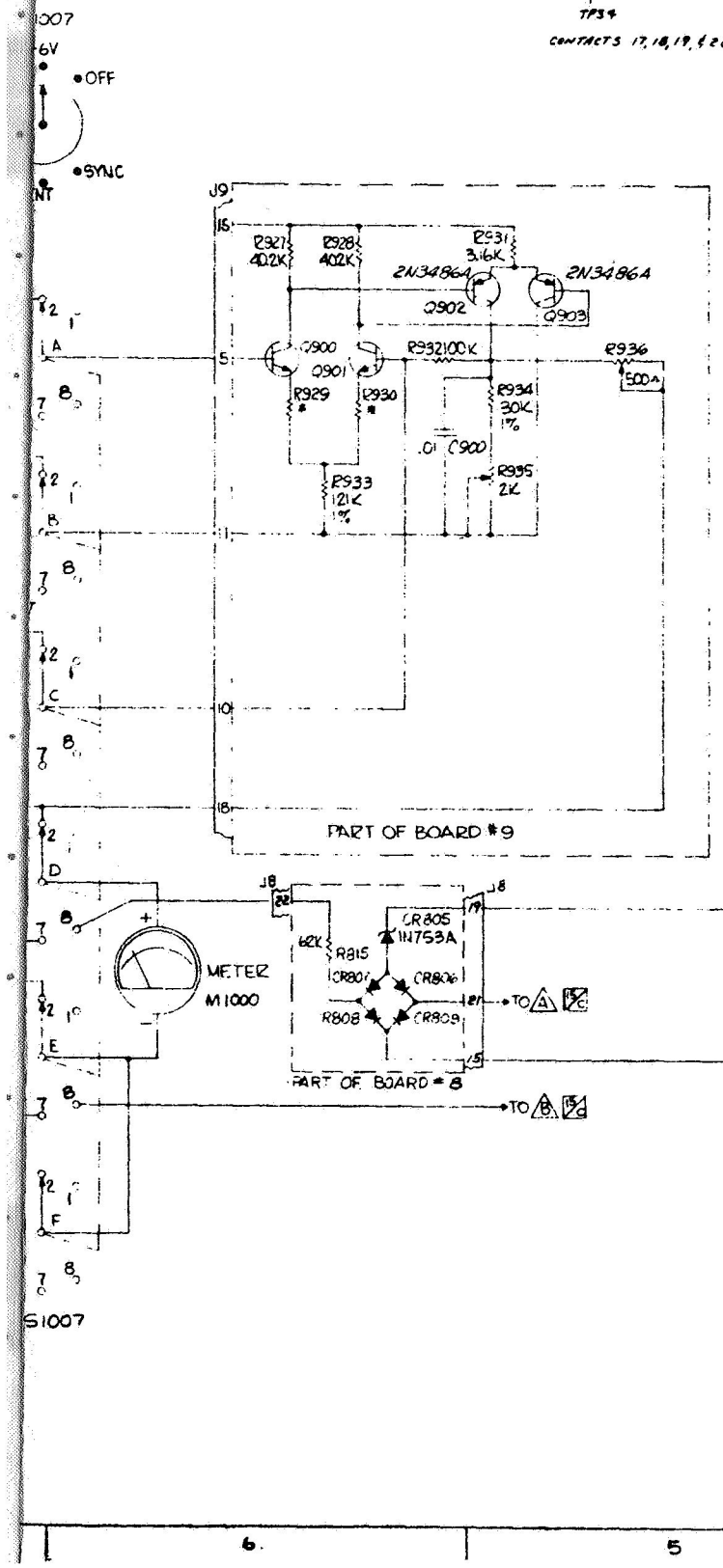
TP48 BTE 3.9 PPS-TIMING SIGNAL TO J12-32

TP47 BTE 222 PPS-TIMING SIGNAL TO J12-16

TIMING PULSES 1* AMPLITUDE CONTROLLED BY GANGED POT (FRONT PANEL)



CONTACTS 17, 18, 19, & 20 NC



DATA MONITOR CONNECTOR
J11 DD-50S

TP1		1	X PRE AMP
TP2		18	Y PRE AMP
TP28		34	Z PRE AMP
TP20		2	PRE AMP RETURN
TP30		19	SHIELD RETURN
TP1		3	+20 VOLTS
TP7		35	IFC SIGNAL
TP10		20	SEC SIGNAL RETURN
TP50		36	BTE CHASSIS GROUND
TP43		4	X AXIS SCO 30 KC
TP44	S1012-18	21	Y AXIS SCO 52.5 KC
TP45	S1012-11	37	Z AXIS SCO 70.0 KC
TP2	S1012-12	6	+6 VOLT NR1
TP3		23	+6 VOLT NR2
TP4		39	-6 VOLT
TP21		5	X AXIS WAVE ANALYZER
TP34	S1012-7	7	X AXIS WAVE FORM
TP22	S1012-1	22	Y AXIS WAVE ANALYZER
TP24	S1012-8	24	Y AXIS WAVE FORM
TP23	S1012-2	38	Z AXIS WAVE ANALYZER
TP26	S1012-9	40	Z AXIS WAVE FORM
TP31	S1012-3	8	X AXIS SPECTRUM
TP28		25	Y AXIS SPECTRUM
TP29		41	Z AXIS SPECTRUM
TP31		9	X AXIS WIDEBAND
TP32	S1012-4	26	Y AXIS WIDEBAND
TP33	S1012-5	42	Z AXIS WIDEBAND
TP34	S1012-6	10	STATUS-WAVEFORM-SPECTRUM
TP35	S1012-13	27	STATUS-BANDWIDTH-IFC
TP36	S1012-14	43	STATUS-WAVE ANALYZER
TP37	S1012-15	11	STATUS-POWER-SCO
TP39	S1012-16	12	+28.5 VOLT RETURN
TP38		28	+28.5 VOLTS
	N/C	44	S P COMMAND
	TO J14-9	13	EXT WAVEFORM COMMAND
	TO J14-10	29	EXT SPECTRUM COMMAND
	TO J14-11	45	EXT IFC COMMAND
TP4		4	EXTERNAL INDEX PULSE
	N/C	15	INDEX PULSE GROUP NR1
TP42		30	INDEX PULSE INHIBIT
	N/C	31	INDEX PULSE GROUP NR2
	NC	46	BIT RATE SIGNAL
	NC	47	MODE SIGNAL
	NC	48	SWITCH SIGNAL
TP5		16	2.5 VOLT
TP6		32	2.6 VOLT
	NC	49	SPARE
TP8		17	CONVERTER T.P.
TP9		33	CONVERTER T.P. RETURN
TP50		50	CHASSIS GRD

SPECIAL PURPOSE COMMAND AND INPUT CONNECTOR
J14 DA-15S

TO TP41		1	EXTERNAL INDEX PULSE
TO TP42		2	INDEX PULSE INHIBIT
TO TP49		3	BTE 0.8? PPS-TIMING
TO TP60		4	BTE SECONDARY SIGNAL RETURN
TP50		5	BTE CHASSIS GROUND
		6	NC
		7	NC
		8	NC
TO J11-13		9	EXT. WAVEFORM GAIN IMPULSE COMMAND
TO J11-29		10	EXT. SPECTRUM GAIN IMPULSE COMMAND
TO J11-45		11	EXT. IFC ON/OFF IMPULSE COMMAND
TP40		12	28 VOLT RETURN
TO TP30		13	SHIELD RETURN
		14	NC
		15	NC

SPECIAL PURPOSE OUTPUT SIGNAL CONNECTOR
J13 DB-25S

TO TP24	1	X AXIS WAVEFORM
TO TP25	2	Y AXIS WAVEFORM
TO TP26	3	Z AXIS WAVEFORM
TO TP21	4	X AXIS WAVE ANALYZER
TO TP22	5	Y AXIS WAVE ANALYZER
TO TP23	6	Z AXIS WAVE ANALYZER
TO TP31	7	X AXIS WIDEBAND
TO TP32	8	Y AXIS WIDEBAND
TO TP33	9	Z AXIS WIDEBAND
TO TP43	10	X AXIS SCO 30KC
TO TP44	11	Y AXIS SCO 52.5 KC
TO TP45	12	Z AXIS SCO 70.0 KC
TO TP50	13	BTE CHASSIS GROUND
TO TP10	14	SEC SIGNAL RETURN
TO TP34	15	STATUS-WAVEFORM-SPECTRUM
TO TP35	16	STATUS-BANDWIDTH-IFC
TO TP36	17	STATUS-WAVE ANALYZER
TO TP37	18	STATUS-POWER-SCO
	19	NC
	20	NC

SPACECRAFT SIGNAL AND COMMAND CONNECTOR
J12 DD-50P

TO TP59	44	BTE S P COMMAND
TO TP58	13	BTE WAVEFORM COMMAND
TO TP57	29	BTE SPECTRUM COMMAND
TO TP56	45	BTE IFC COMMAND
TO TP55	15	BTE INDEX PULSE GROUP NR1
TO TP54	31	BTE INDEX PULSE GROUP NR2
TO TP53	46	BTE BIT RATE SIGNAL
TO TP52	47	BTE MODE SIGNAL
TO TP51	48	BTE SWITCH SIGNAL
TO TP47	16	BTE 222 PPS-TIMING SIGNAL
TO TP48	32	BTE 13.9 PPS-TIMING SIGNAL
TO TP49	49	BTE 0.8? PPS-TIMING SIGNAL
TO TP50	50	BTE CHASSIS GROUND
TO TP60	12	BTE SECONDARY SIGNAL RETURN

Figure 82

MARSHALL LABORATORIES
SCHEMATIC-
BTE, OGO E SEARCH
COIL (EXP. E-16)

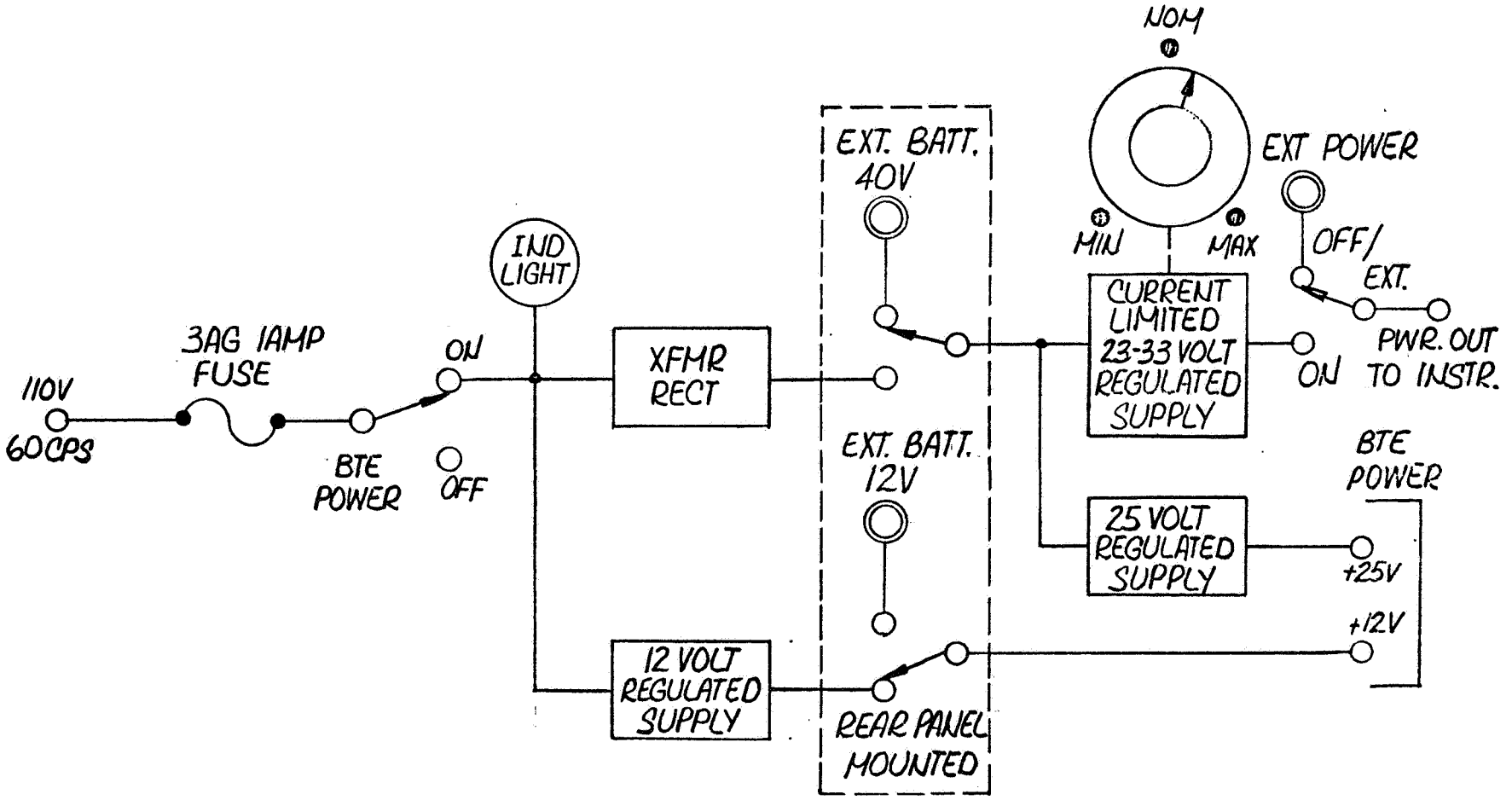


Figure 83

BTE Power Supplies
Block Diagram

5.2.2 Sync Signal Generator

Figure 84 shows a block diagram of the circuit which generates the synchronization signal for the instrument power supply. A front panel control enables the sync signal frequency to be varied ±5% from the nominal frequency of 2461 cps. This control adjusts the output voltage from the nominally +25 volt regulated supply. This voltage is applied to the dc/ac inverter through a rear panel mounted switch which permits the disabling of the inverter. The output of the inverter is passed through a multi tap transformer which enables selection by use of a front panel switch of nominal, min, and max levels (4, 6, 7v P/P) of the sync signal. Suitable loads are placed across this attenuator so that the output impedance of this signal is the same as that of the spacecraft.

5.2.3 Timing and Index Pulse Generator

Figure 85 shows a block diagram of the circuit which generates the timing and index pulses. As indicated, a 444 cps clock with an accuracy of one percent is counted down in a binary countdown chain to the minimum frequency of 0.87 pulses per second (pps). The output of this final countdown circuit is applied to a one shot multivibrator which shapes the pulse to worst case conditions of the interface specification and is then passed through an attenuator which can be used to vary the signals from a zero to 10 volt range. The 13.9 pps and 222 pps timing signals are generated, shaped, and attenuated in a similar manner except that their inputs are taken from different points in the countdown chain. The amplitude of all three of these timing signals is controlled by a single front panel control.

The index pulses for either Group 1 or Group 2 are selected by a front panel control which indicates the frequency of the selected index pulse. The 55.5 pps index pulse corresponds to 2 64 kc bit rate. As with the timing pulses, the output is passed through a shaper and attenuator which controls the output over a zero to 10 volt range. A push button switch is included to enable the application of single index pulses if required.

5.2.4 Telemetry Status Signal Generator

Figure 86 shows the block diagram of the circuit which generates the telemetry status signals. Each of these three signals are generated in a similar fashion. The circuitry consists of an attenuator for each output which is controlled by a front panel control. These attenuators utilize the regulated +12 volts as their inputs.

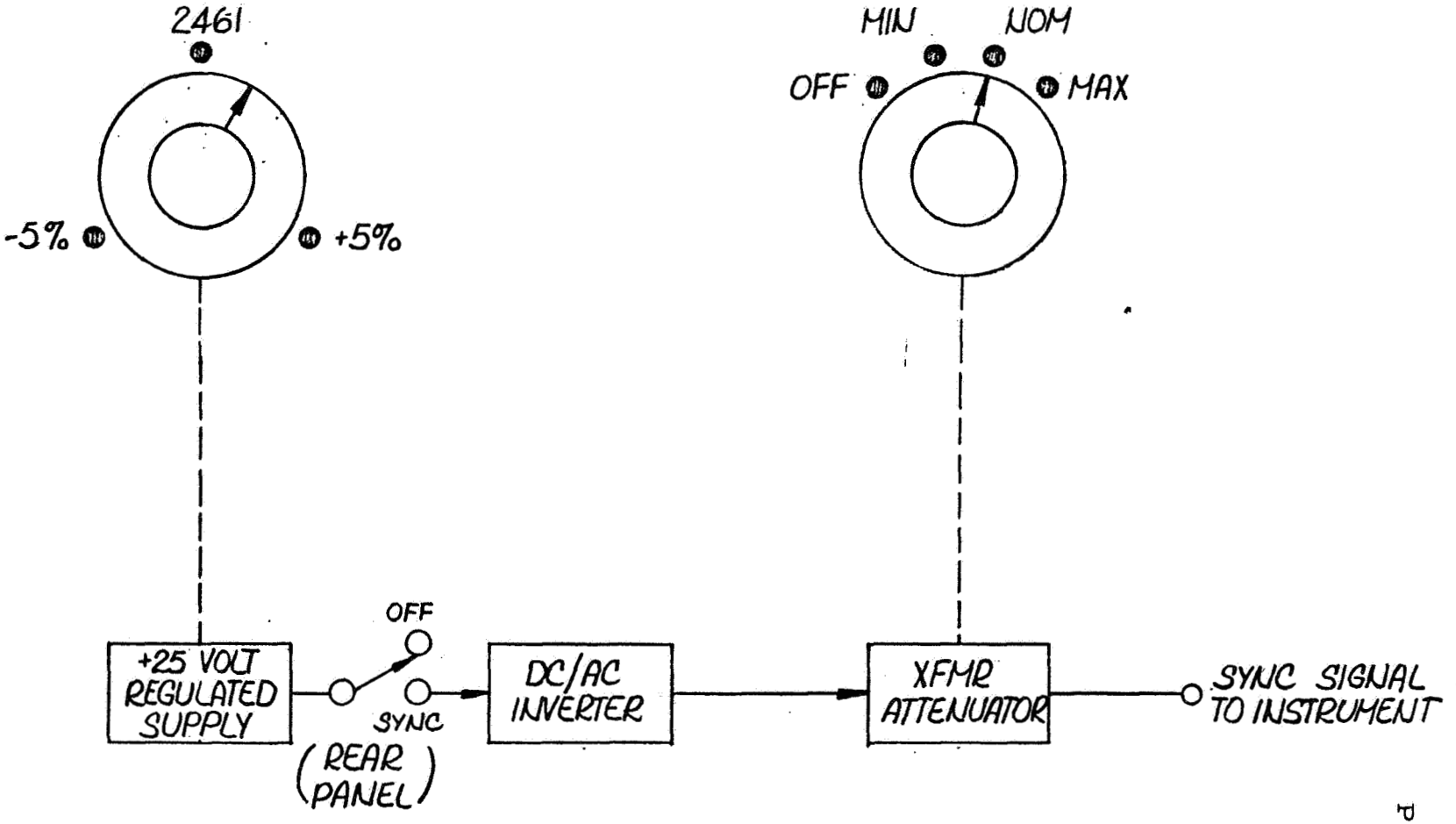


Figure 84

Sync Signal Generator
Block Diagram

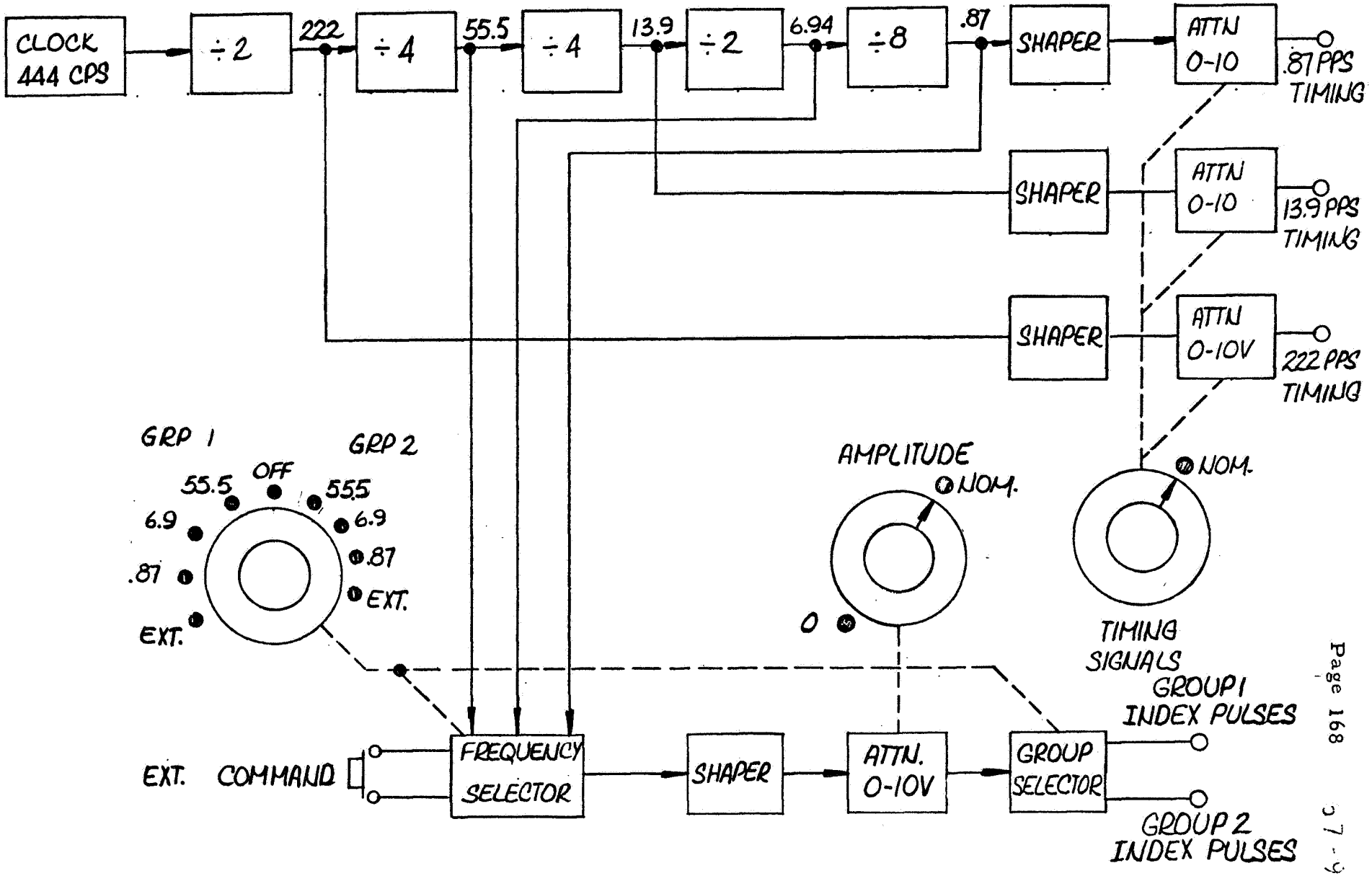


Figure 85

Index & Timing Pulse Generator
Block Diagram

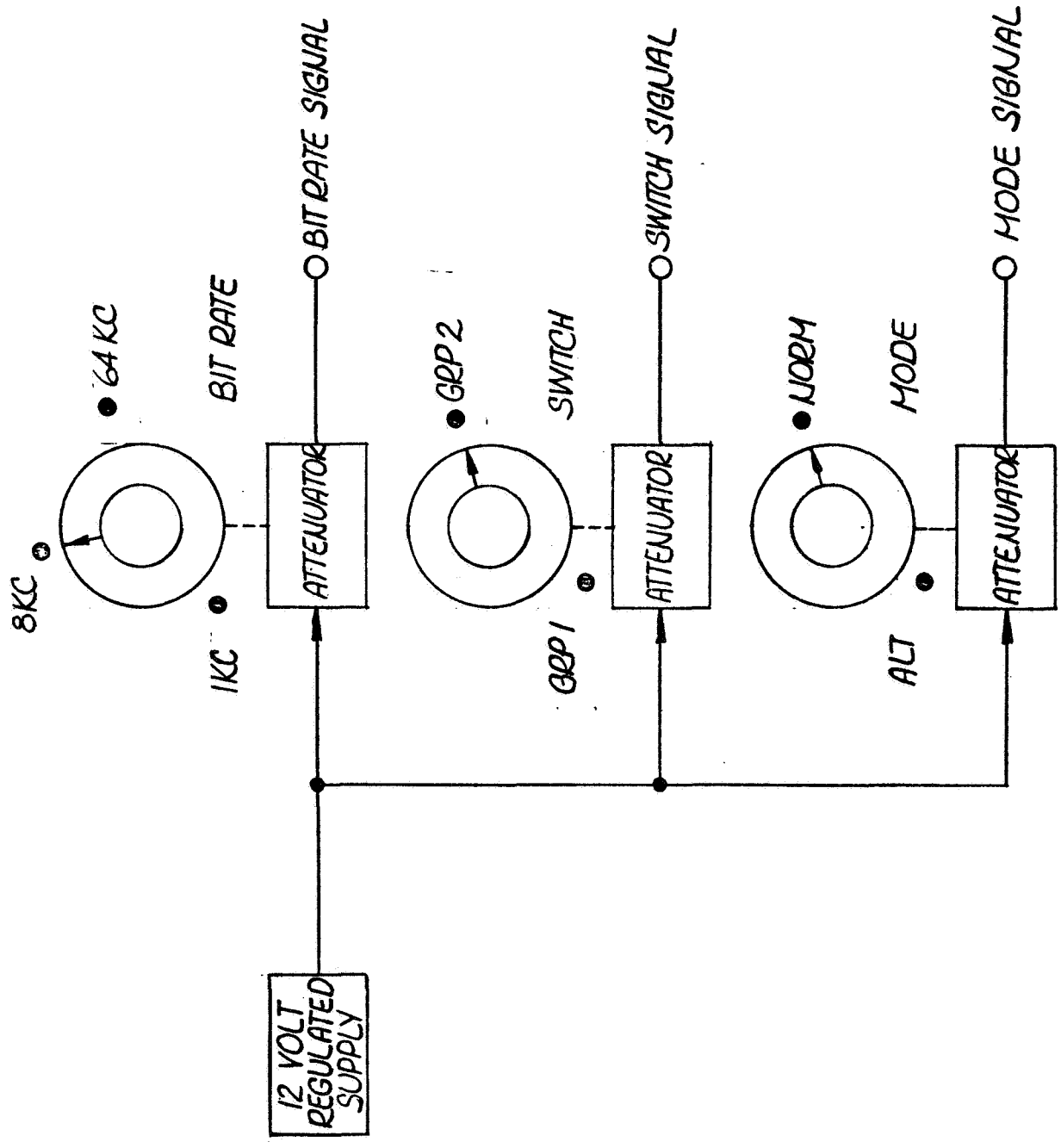


Figure 86

Telemetry Status Signals
Block Diagram

Each front panel control is calibrated showing the nominal voltages for each of the states of the signals. Thus, the Bit Rate control is labeled 1 kc, 8 kc, and 64 kc; the Switch Signal, Group 1 and Group 2; and the Mode Signal Normal and Alternate. All of these controls are continuously variable from 0 to +12 volts.

5.2.5 Command Generator

Figure 87 shows a block diagram of the circuit which generates the three impulse commands used by the instrument and also the power command which controls the special purpose telemetry. The impulse commands are initiated by a push button switch on the front panel. The output of this switch is filtered to eliminate transients and applied to a one shot multivibrator which generates the proper pulse width. This multivibrator energizes a relay which closes the output to power ground. A front panel switch selects the line into which this impulse command is generated. The Special Purpose Telemetry ON/OFF command is simply a toggle switch which either opens the command line or returns it to the instrument 28 volt power.

5.2.6 Power Supply Monitor

The BTE contains facilities for conveniently checking all of the instrument power supply functions. A block diagram of this system is shown in Figure 88. Three types of functions are provided consisting of an expanded scale volt meter for precisely measuring the outputs of the instrument power supply, a current monitor for monitoring the current drawn by the instrument, and a sync signal demodulator which enables a measure of the frequency of the free running instrument converter.

The five outputs of the instrument power supply are applied through a voltage selector and attenuator to a variable gain dc amplifier. The input voltage, attenuation and the gain of the amplifier are selected by a front panel control. During this type of operation, the output of the variable gain amplifier is applied through the meter select circuit, through the dc meter, and then to a precision reference voltage. This system is calibrated so that a center (zero) reading of the meter indicates that the input voltage is exactly what it should be while a full scale deflection in either direction corresponds to a ±0.2% deviation in that voltage.

During current monitoring operation, the instrument power, as generated in the BTE, is applied through the meter select circuits to the dc meter and then out to the instrument.

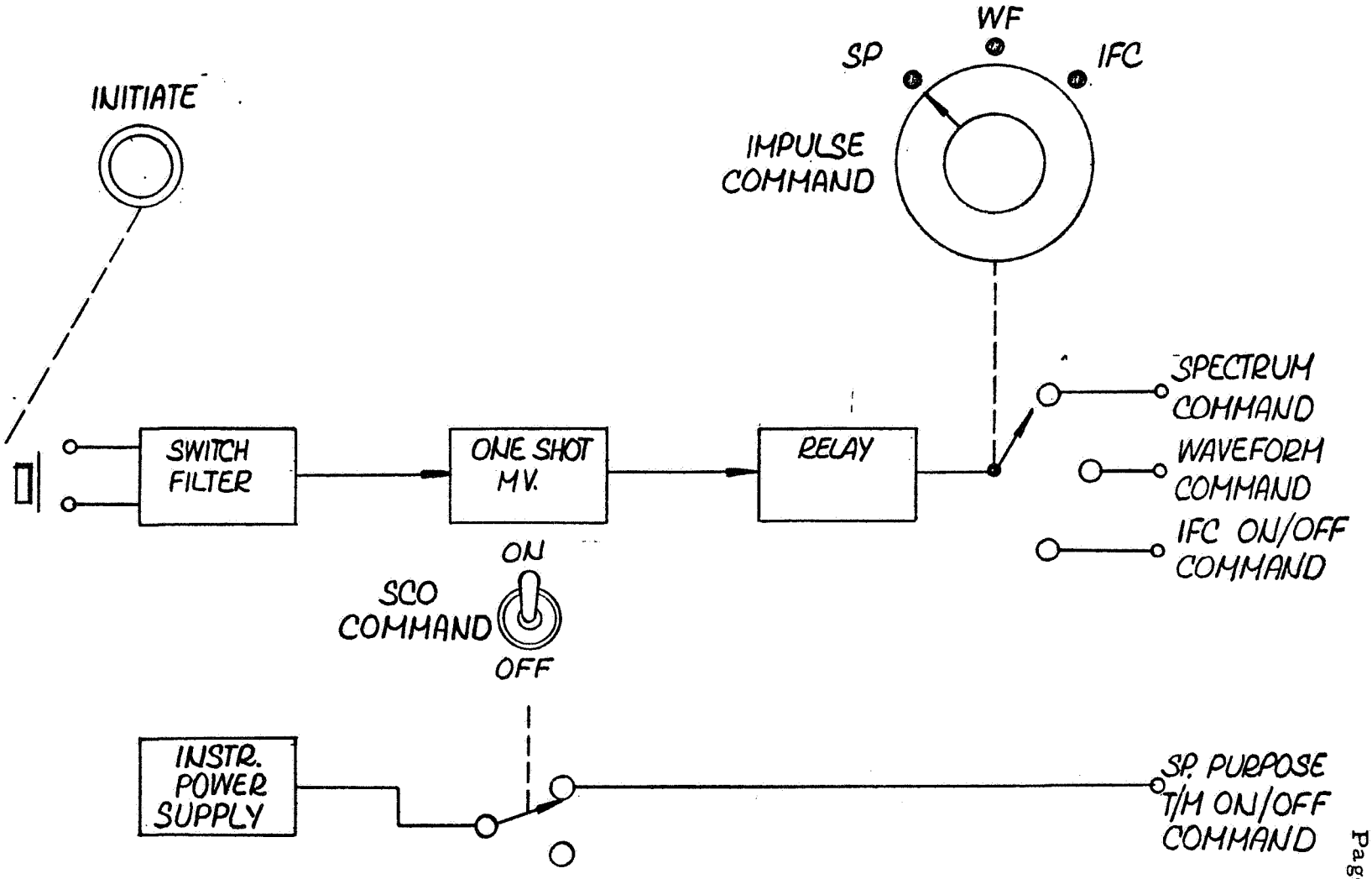


Figure 87

Command Generator
Block Diagram

67-917

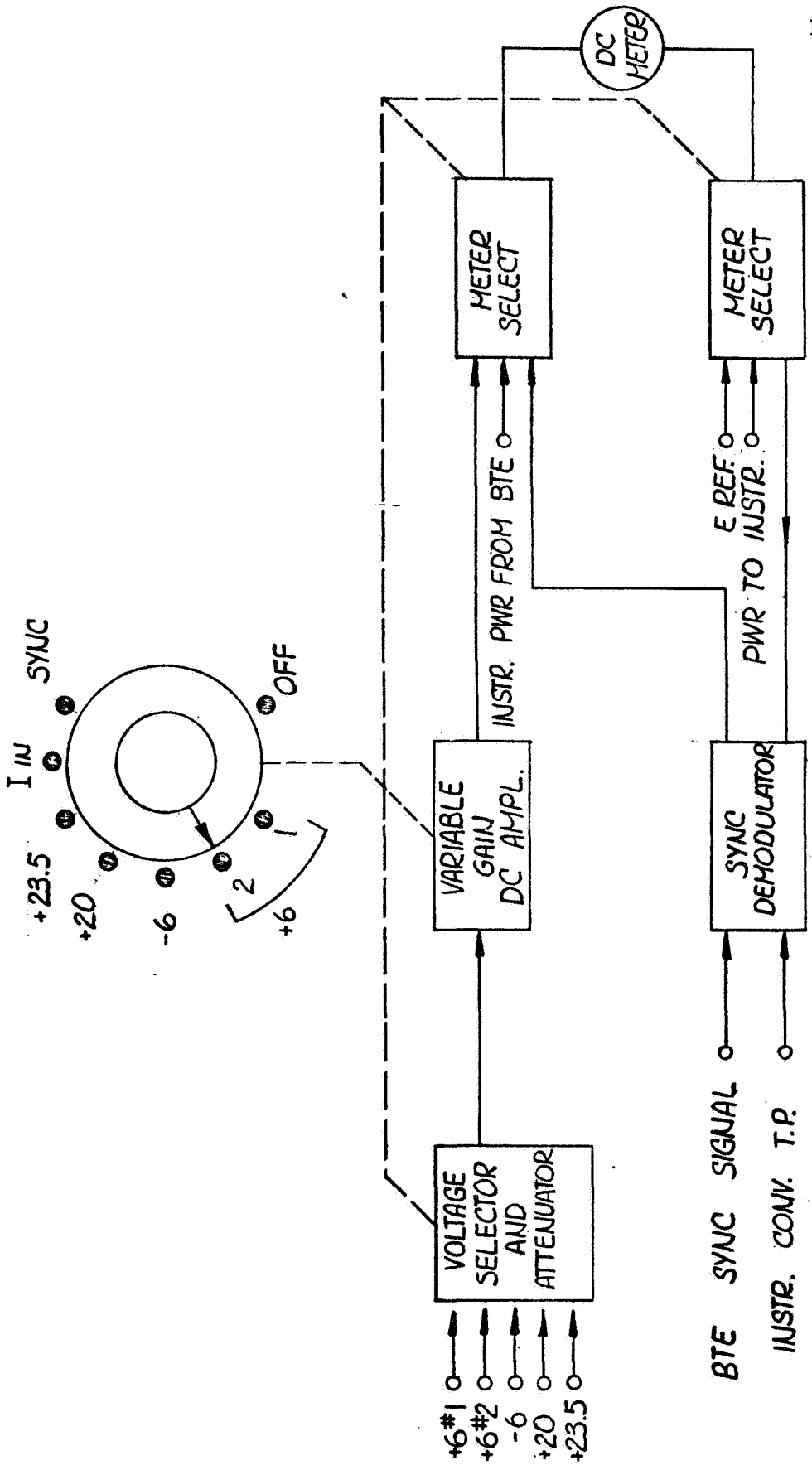


Figure 88

Power Supply Monitor
Block Diagram

Under this mode of operation, the meter is calibrated so that zero or center scale corresponds to 0 current and upward full scale deviation corresponds to 100 milliamps.

In the sync signal position, the bench test equipment sync signal is applied together with the output of the instrument converter test point to a synchronous demodulator. The output of this demodulator is applied through the meter select circuits to the dc meter. One useful mode of operation of this function is to disconnect the sync signals from the BTE to the instrument allowing the instrument converter to free run. The meter can then be utilized together with the variable frequency control of the sync generator to zero beat the converter test point with the BTE sync signal. This enables an accurate measurement of the free running frequency of the instrument converter. When the sync signal from the BTE is connected to the instrument, a non zero reading of the meter indicates that the instrument is locked to the BTE sync signal.

5.2.7 Test Point Monitor

In order to allow auxiliary equipment to conveniently monitor internal instrument and BTE signals, 60 test points are available on the front panel. The identification of the signal available at each of these test points is shown in Figure 89. In addition to these test points, there is one major test point labeled OUT which enables the monitoring of the most important data outputs of the instrument at that one test point by use of the test point selector switch. The front panel layout of this switch is shown in Figure 90. This function is extremely useful when utilizing one instrument such as an oscilloscope to quickly check all of the instrument outputs. The four outputs at the lower part of the switch refer to the instrument status outputs.

07-917

OGO-E S/C BTE TP Location

TP-1	+20 volt	TP-31	X Axis Wideband
TP-2	+6 volt No. 1	TP-32	Y Axis Wideband
TP-3	+6 volt No. 2	TP-33	Z Axis Wideband
TP-4	-6 volt	TP-34	Status - Waveform - Spectrum
TP-5	2.5 volt	TP-35	Status - Bandwidth - IFC
TP-6	2.6 volt	TP-36	Status - Wave Analyzer
TP-7	IFC Signal	TP-37	Status - Power - SCO
TP-8	Converter TP	TP-38	+23.5 volts
TP-9	Converter TP Return	TP-39	+23.5 volt Return
TP-10	Sec Signal Return	TP-40	28 volt Return
TP-11	X Pre Amp	TP-41	External Index Pulse
TP-12	Y Pre Amp	TP-42	Index Pulse Inhibit
TP-13	Z Pre Amp	TP-43	X Axis SCO 30 KC
TP-14	NC	TP-44	Y Axis SCO 52.5 KC
TP-15	NC	TP-45	Z Axis SCO 70.0 KC
TP-16	NC	TP-46	NC
TP-17	X Axis Demod	TP-47	BTE 222 PPS - Timing Signal
TP-18	Y Axis Demod	TP-48	BTE 13.9 PPS - Timing Signal
TP-19	Z Axis Demod	TP-49	BTE 0.87 PPS - Timing Signal
TP-20	Pre Amp Return	TP-50	BTE Chassis Ground
TP-21	X Axis Wave Analyzer	TP-51	BTE Switch Signal
TP-22	Y Axis Wave Analyzer	TP-52	BTE Mode Signal
TP-23	Z Axis Wave Analyzer	TP-53	BTE Bit Rate Signal
TP-24	X Axis Waveform	TP-54	BTE Index Pulse Group No. 2
TP-25	Y Axis Waveform	TP-55	BTE Index Pulse Group No. 1
TP-26	Z Axis Waveform	TP-56	BTE IFC Command
TP-27	X Axis Spectrum	TP-57	BTE Spectrum Command
TP-28	Y Axis Spectrum	TP-58	BTE Waveform Command
TP-29	Z. Axis Spectrum	TP-59	BTE S P Command
TP-30	Shield Return	TP-60	BTE Secondary Signal Return

Figure 89. Test Point Identification

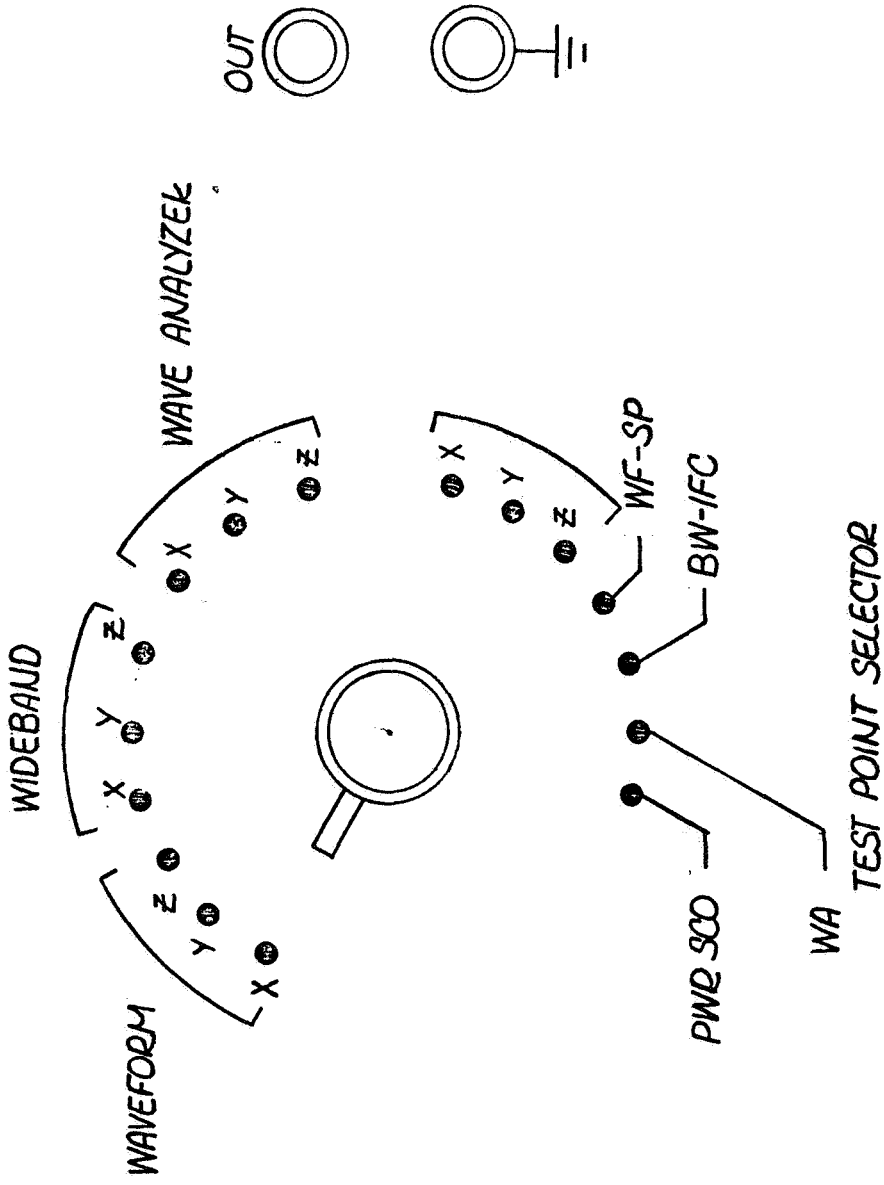


Figure 90.
Test Point Selector Switching

6.0 RECOMMENDATIONS AND IMPROVEMENTS

6.1 Search Coil Sensor and Preamplifier Assembly

It is recommended that the search coil sensor and preamplifier be integrated into a single package for each axis. A proportional heater could be built right into the sensor housing. Presently the OGO-E system has a 14 inch coax cable joining the sensor to the preamplifier. Experience shows that a situation of this type can allow RFI to be introduced into the interconnecting cabling. Secondly, the interconnecting cable added capacity in the order of 500 pf which lowers the resonance frequency of the sensor coil. If the preamp was relocated to within the sensor housing, it would be positioned close to the coil to minimize these undesirable effects.

6.2 Sensor Coil Winding

On the OGO-E Search Coil Magnetometer, two one-inch bobbins were randomly wound with 50,000 turns of wire each. It is recommended that the next instrument have a continuous strand of No. 47 AWG-SF magnet wire wound on two 10 section bobbins yielding twenty individually wound segments, 5000 turns each, or a total of 100,000 turns. This technique will improve the self resonant frequency from 500 Hz to 1.0 K Hz.

6.3 Preamplifier Sensitive to Variation of Power Supply Voltage

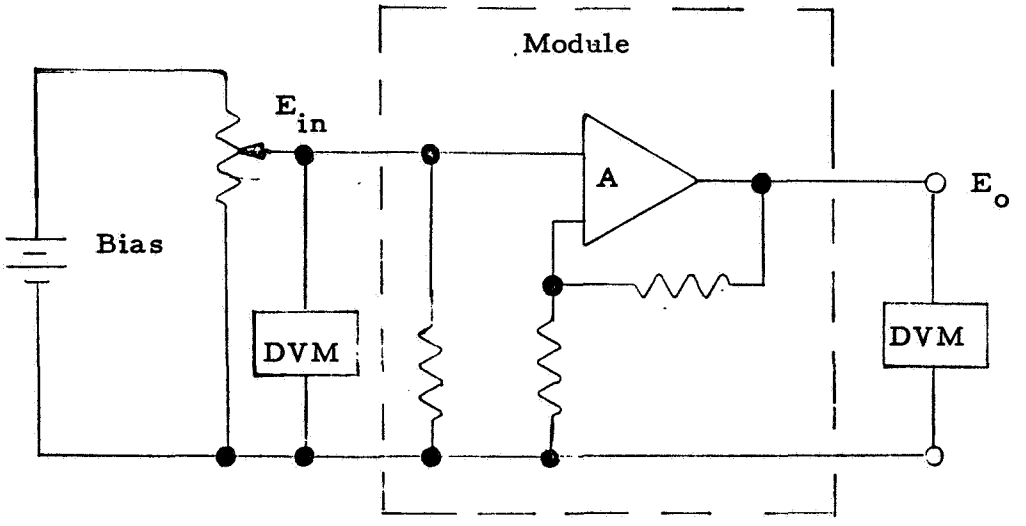
The OGO-E Search Coil Magnetometer Preamplifier was sensitive to B^+ voltage variations. This produced the undesirable effect of having a high signal to noise ratio whenever the cabling between the Main Body and the Preamplifier was subjected to a noisy environment. The noise which was induced into the power line cabling would be amplified within the Preamplifier and appear on the output leads as a signal. The design of the Preamplifier could be improved to eliminate this problem by designing the circuit not to be sensitive to variation in power supply voltages thus yielding a high power line noise rejection.

6.4 400 Hz Notch Filter

C1 thru C4 and R1 thru R4 should have been purchased as ± 0.1% components in order to achieve a sharper and more accurate notch at 400 Hz.

6.5 Gain Change Amplifier

Change the module test spec so that the gain measurements for the gain trim is made with DC input and output signals instead of AC signals. The measurement of AC signals, to better than 1%, is very difficult. Time was wasted in module test trying to make these AC measurements. The test set up should be as follows:



With e_{Bias} at +2.5 volts, the drive current into the base of Q2 should be checked for sufficient drive to turn Q2 (in the inverted mode) on HARD. I_{Base} should equal at least to I_c for inverted mode switching. See Figure 51, Page 109.

Note that I_{bQ2} = voltage at pin 3 minus the bias voltage at pin 12 divided by R17.

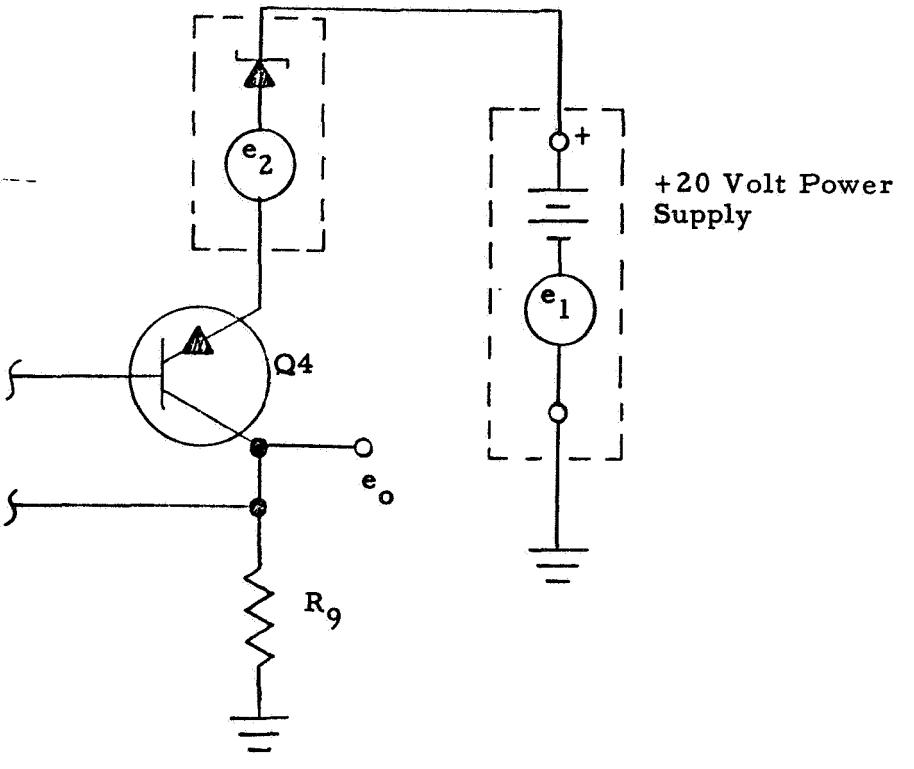
$$I_{bQ2} = \frac{V3 - V12}{R17}$$

Also note that R17 might have to be changed as the bias is changed and that the voltage for cut off of Q2 at pin 3 is negative for a bias of gnd at pin 12.

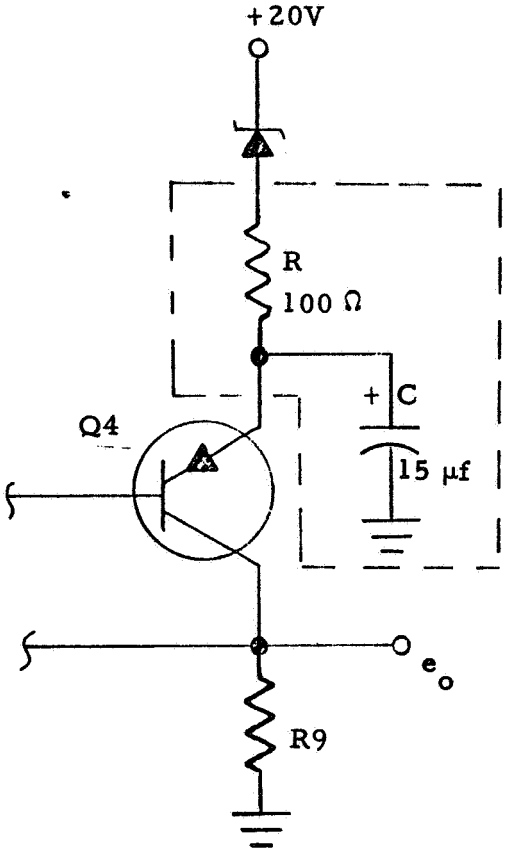
6.6 Bandpass Amplifiers

A. Noise at Output

CR1 in Figure 54, Page 115 is a source of wideband noise. The following illustration shows the equivalent output stage:

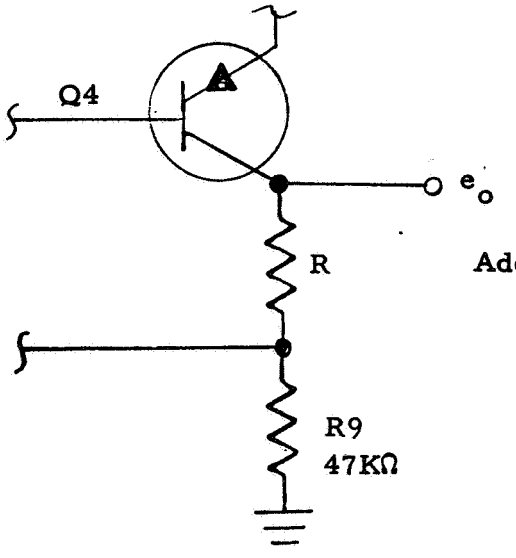


As shown e_1 is a noise source contained within the +20 volt power supply and e_2 is a noise source in the zenor diode CR1. The gain, to these noise sources, is quite high and they create noise voltages at e_o if the net gain around the amplifier feedback loop is less than unity at these noise frequencies. In production units considerable noise above 10 KHZ was found to be present at the output. To eliminate this problem it is recommended that an RC filter be added as shown:



Network to be added

Inability to trim gain at f_o without also changing f_o's value. A trim resistor should be inserted between Q4 and R9 as shown:



Add R for gain trim

R = 2.2KΩ ± 2KΩ
for a gain trim of ± 5%

However R9 must be changed to a 1% resistor and R must also be a 1% resistor.

6.7 Subcarrier Oscillator (SCO)

It is recommended that a new circuit be adopted for the SCO circuit,where the (R7 and R10) collector resistors of the oscillator and the emitter resistors of the current sources (R12 and R14), be returned to a negative supply rather than to a ground potential. See Figure 61, Page 137. This approach will exceed all specifications required of the SCO. A more complex approach may be taken, but may not be warranted. This approach is shown below.

PROPOSED NEW SCO WITH HIGH STABILITY

Figure 91 shows the proposed new current sources I_1 and I_2. As shown, Q10-Q11 and Q14-Q15 are dual acting as differentail amplifiers. Point M and N are servoed by the amplifier to zero volts DC at all times. Thus I_1 and I_2 are determined only by R10, R11, and -20V. Notice that the changes in transconductance of Q12 and Q13 are so that Q11 and Q14 have at least 2 volts drain to source bias. The modulation input E_{in} circuitry functions similar to the present SCO. Test point P is brought out for DC calibration of modulation index. The switching transistor section of this proposed SCO can be identical or similar to the circuit for the OGO-F SCO. The V_{be} specification of a 2N2945 is 35V, thus a greater ΔV could be used but the gain band width of the transistor is lower.

A second solution for generation of the constant current source using less parts and affording a 22M Ω input impedance to the modulation signed is shown in Figure 92. Note that a search coil could be connected directly to the input.

7.0 SUMMARY OF CHANGES AFTER INITIAL DELIVERY

The OGO-E Search Coil Magnetometer was designed, fabricated, tested, and delivered to JPL; however, during compliance testing at TRW, it was discovered that the instrument would not properly interface with the spacecraft. The instrument was returned to Marshall Laboratories for three basic modifications. These modifications are documented throughout the text by the use of Engineering Orders. The basic modifications are:

A. Interface of the Timing and Index Pulse Circuitries to improve the instrument's response to slow rise-times.

B. Power Supply Interface to eliminate ringing of the turn-on current surge pulse.

C. Addition of a 400 Hz Notch Filter and a 1850 Hz Low Pass Filter to reduce noise pickup of the instrument.

D. Introduction of RF filters into the Power and Ground Lines to reduce the noise susceptibility.

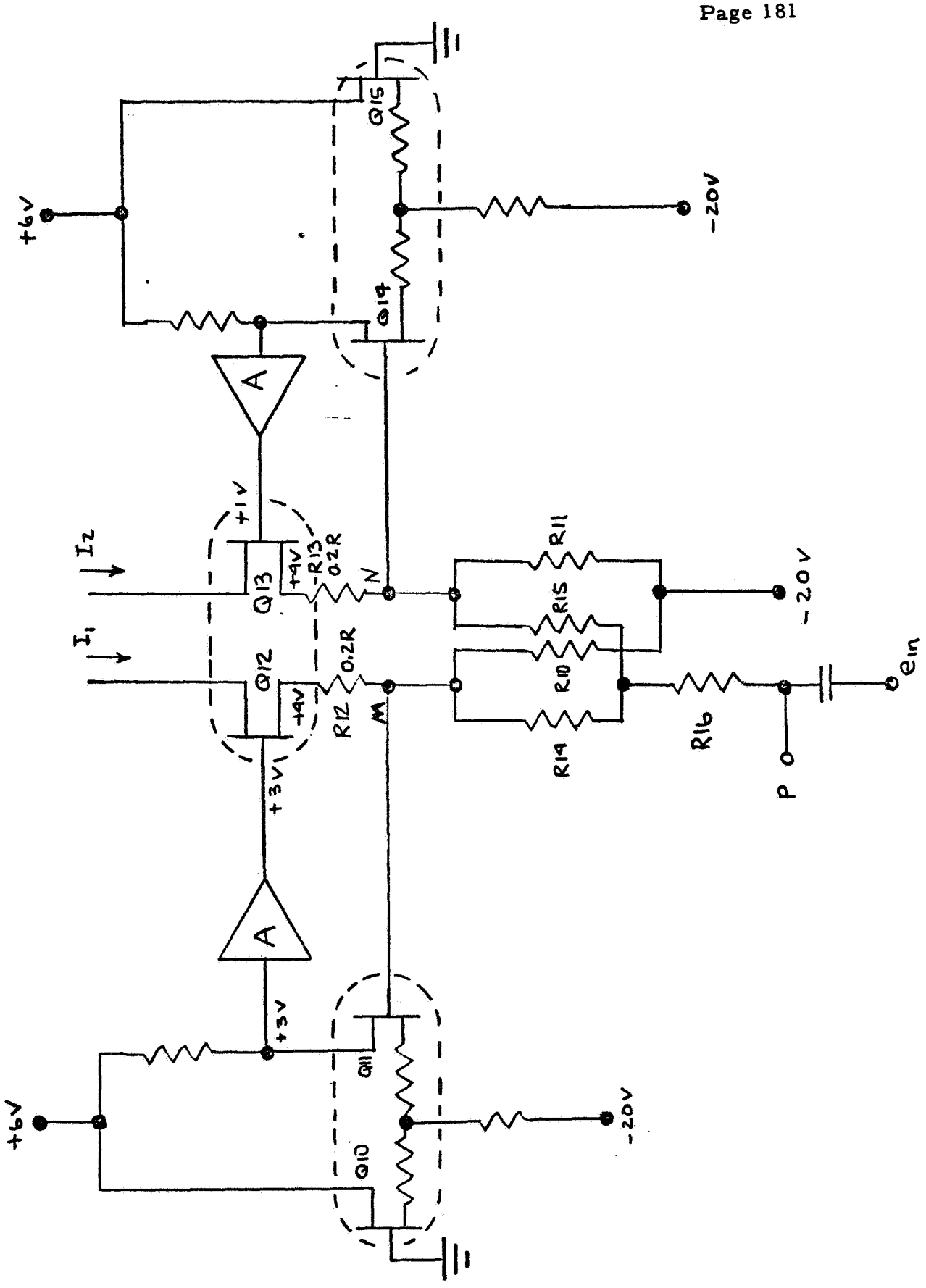


FIGURE 91

RECOMMENDED CURRENT SOURCE NO. 1 FOR SCO

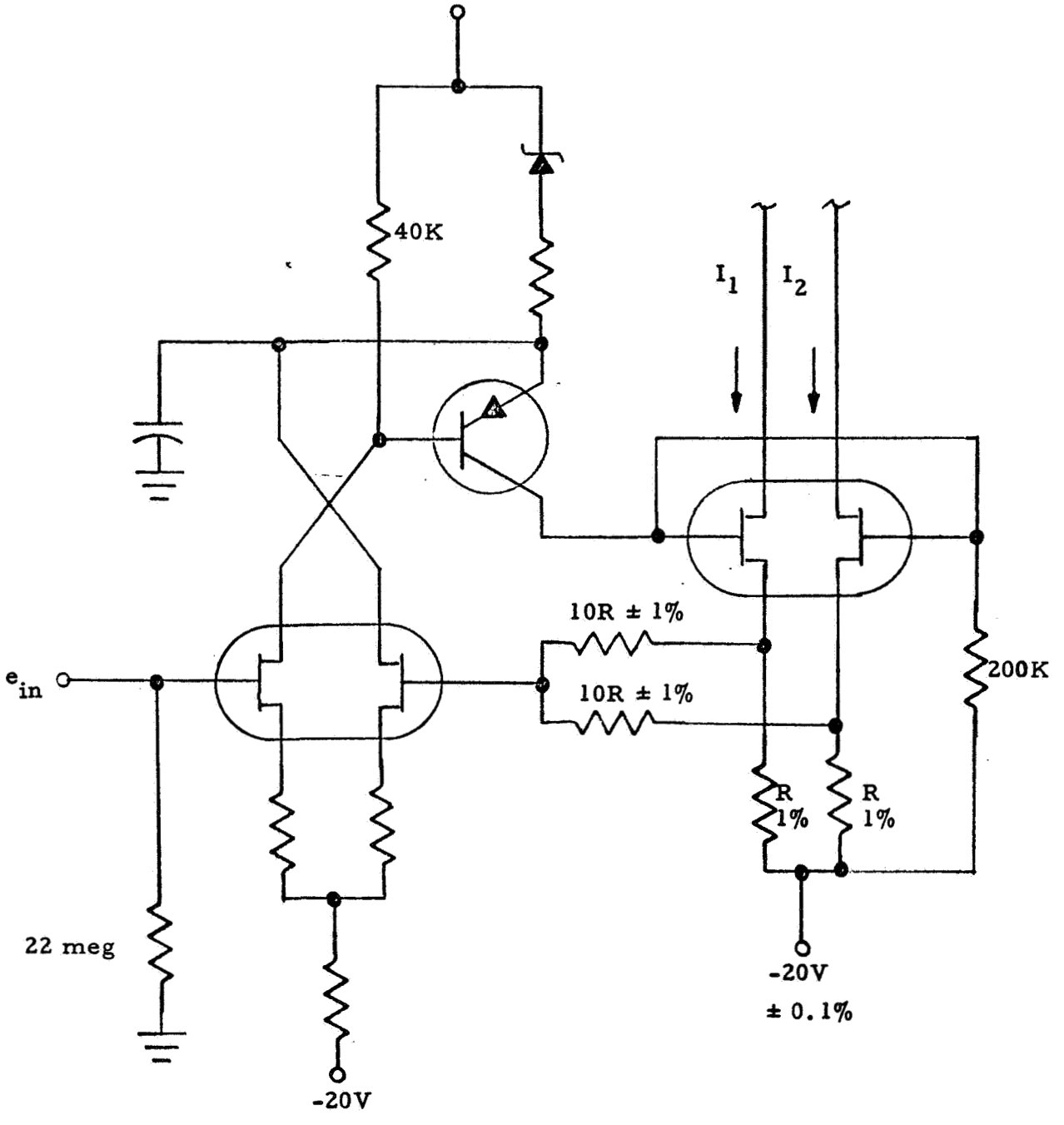


FIGURE 92
RECOMMENDED CURRENT SOURCE NO. 2 FOR SCO

APPENDIX A

TRANSIENTS ANALYSIS OF THE TIMING AND INDEX PULSE CIRCUITRY FOR THE OGO-E SCIENTIFIC EXPERIMENT

Note: As a result of this study, the Timing Pulse and Index Pulse Interface Circuits were modified to that which is shown in Figures 31 and 32 respectively.

TRANSIENTS ANALYSIS OF THE TIMING AND INDEX PULSE CIRCUITRY FOR THE OGO-E SCIENTIFIC EXPERIMENT

The schematic for the timing pulse circuitry is shown in Figure 93 complete with details of input waveform characteristics. The schematic for the index pulse circuitry is shown in Figure 94 The load which the outputs of these two circuits drive is shown schematically in Figure 95.

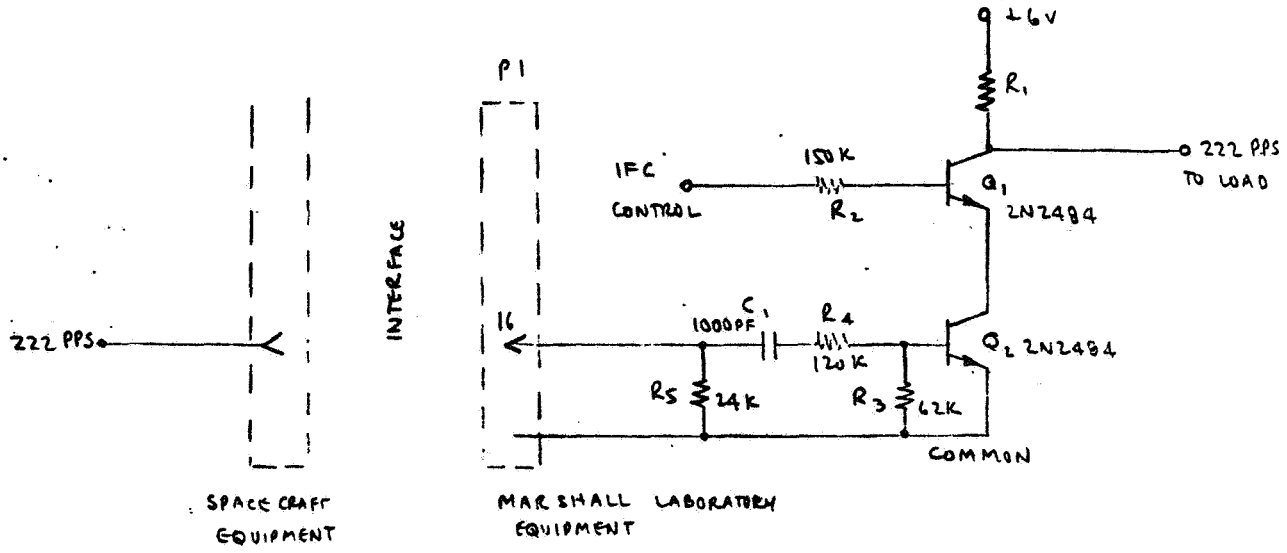
Analysis of the transient response of the timing and index pulse circuitry is carried out in the following approach:

(a) Determine the fall time ($t_f \equiv$ cutoff to saturation time, 10 - 90%) of Q2 for the present circuit configuration.

(b) Determine the needed rise time ($t_r \equiv$ input signal "0" to "+v" time, 10 - 90%) to generate a $t_f < .5$ usec into the load.

(c) Design the necessary interface electronics to achieve the results of (b).

The transient response of the timing pulse circuitry is evaluated first. The pulse circuitry is comprised of 3 identical switching stages. Therefore, only one will be analyzed. The fall time of the present circuitry configuration will be calculated at the 25°C condition for worst case components. The circuit schematic is shown below:



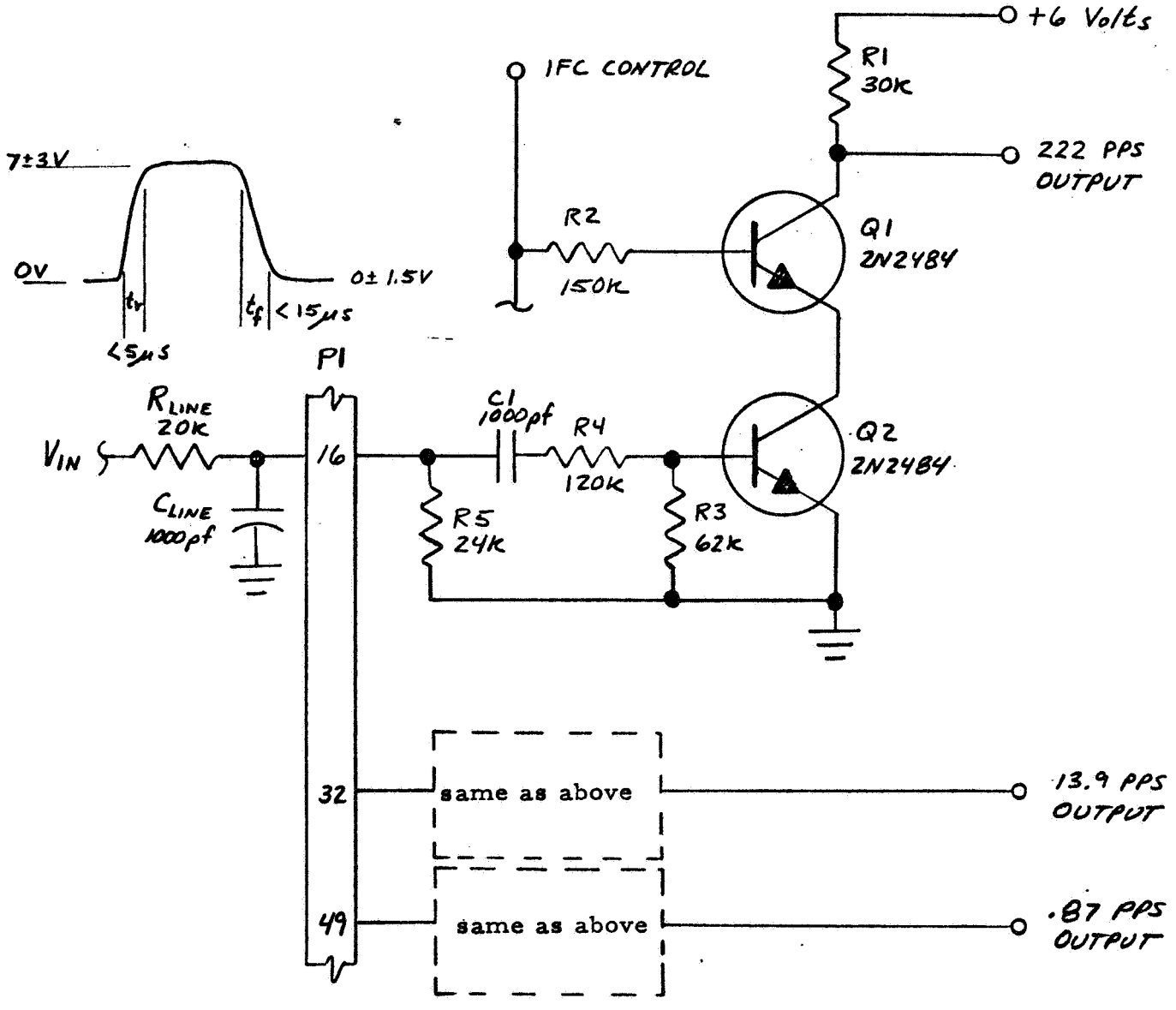


Figure 93

Original Timing Pulse Interface

Note: Refer to Figure 31 for final configuration.

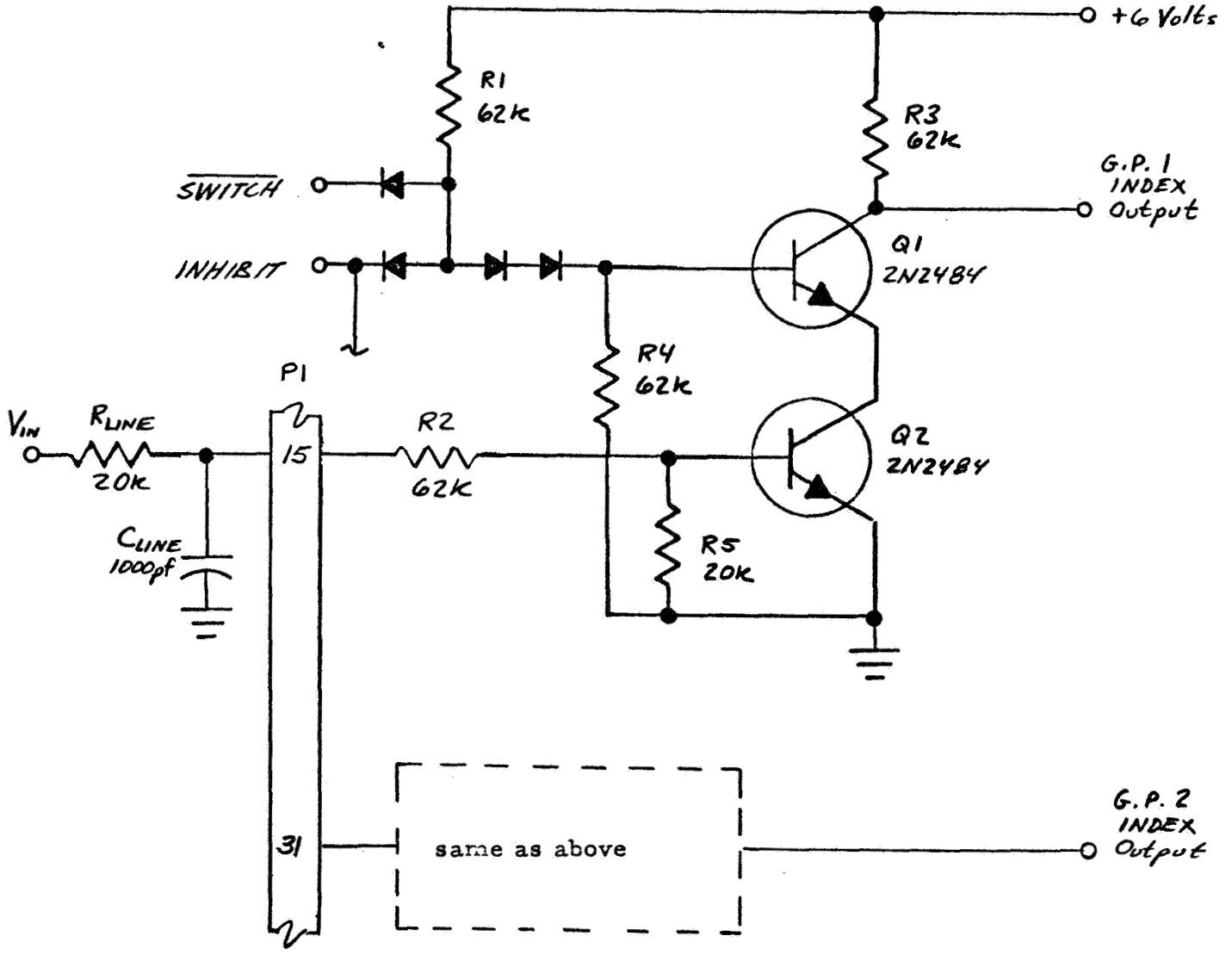


Figure 94
Original Index Pulse Interface

Note: Refer to Figure 32 for final configuration.

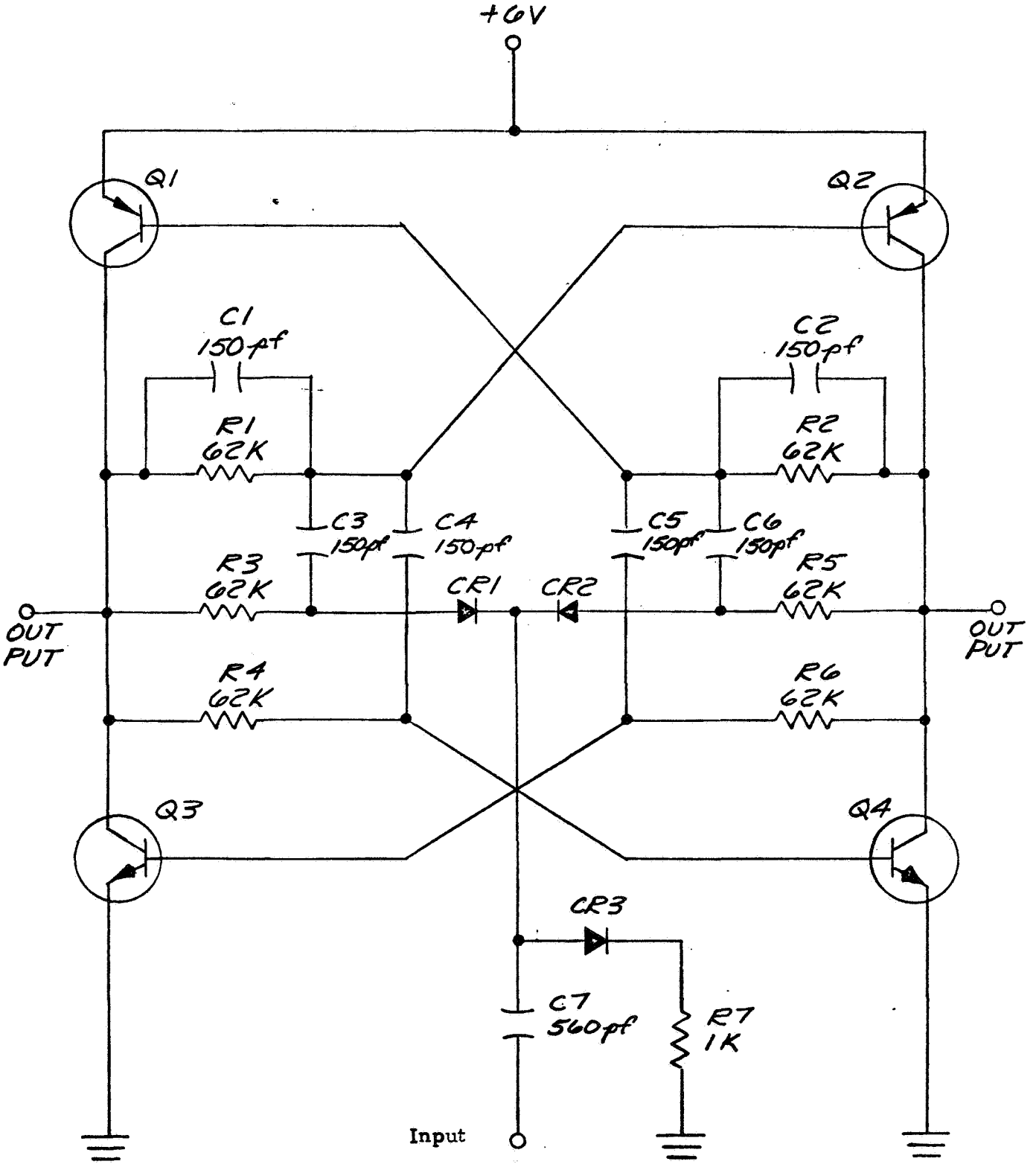
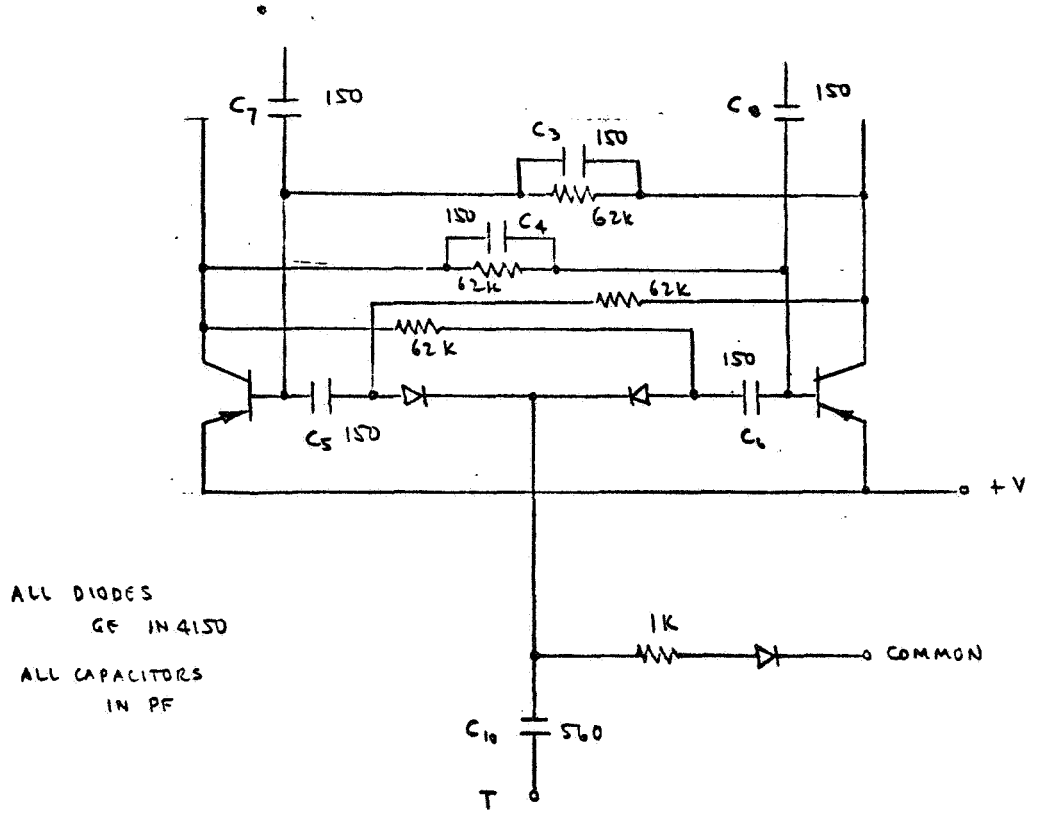


Figure 95

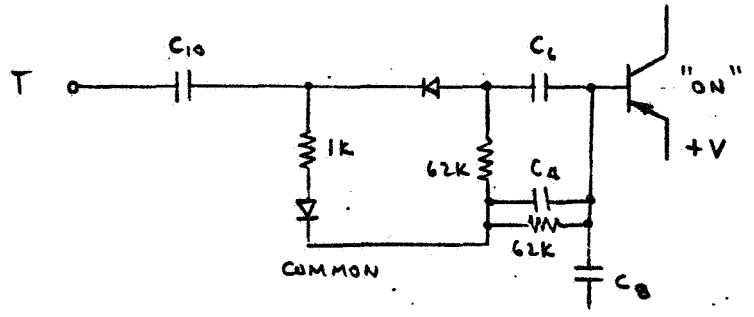
Complementary Flip-Flop

The load in the collector of Q, is the trigger input of a complementary RST multivibrator, ML drawing #W4296



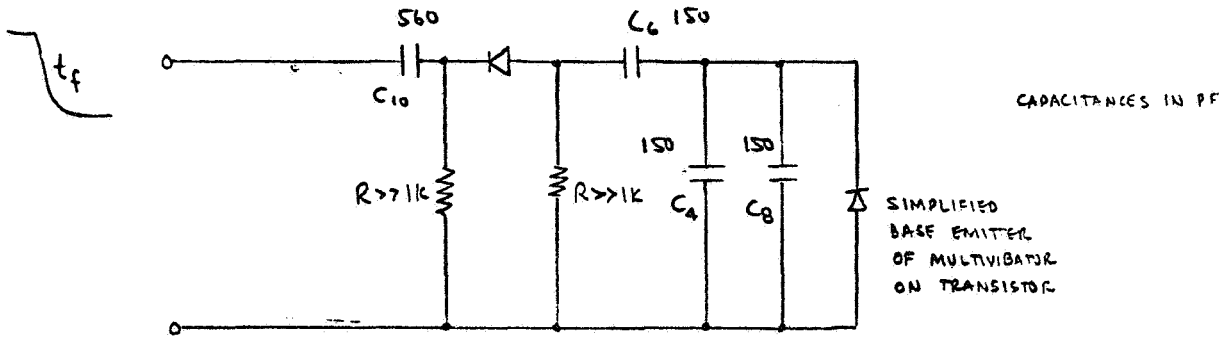
The above circuit is too complex and must be reduced to a simplified equivalent circuit, for evaluation of the load on the source.

Normally one side of the multivibrator is off, and the other side is on. Therefore a first simplification may be made.

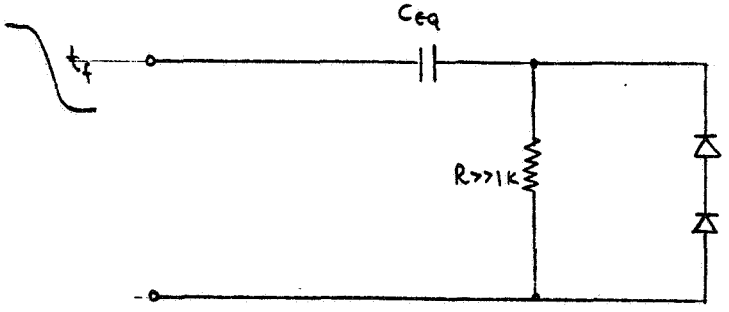


Page 189

A further simplification may be made by considering only the time when the transistor Q_2 is saturating. Thus

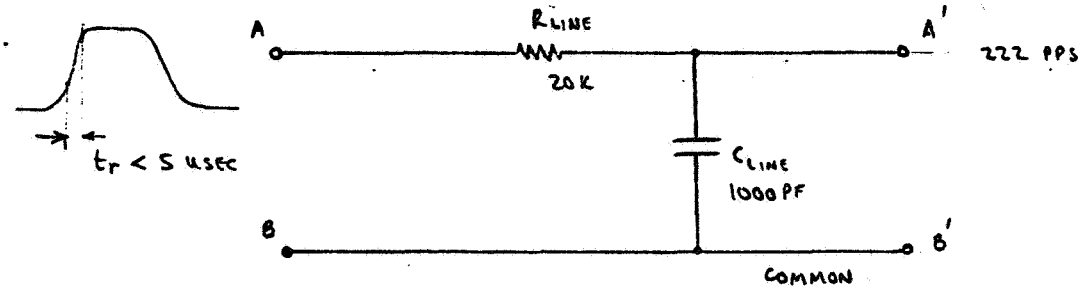


A last simplification is made by rearranging the configuration somewhat as the two capacitors C_4 and C_8 do not accumulate charge once V_{BE} rises to conduction level of approximately .7 volts



$$C_{eq} = \frac{C_{10}\, C_6}{C_{10} + C_6} = 113\ pF$$

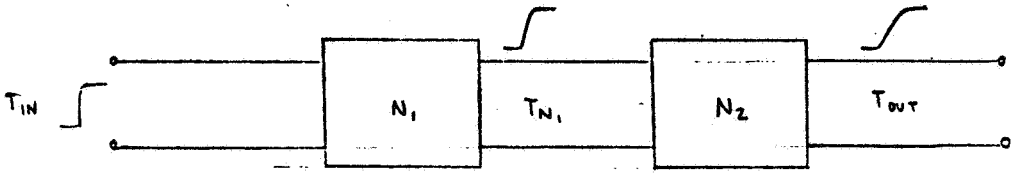
Now, the input waveform to the timing pulse circuitry will be considered



The unloaded rise time across $\overline{A'B'}$ for $T_{r\ INPUT} = 0$ (step*

$$T_{A'B'} = R_L C_L = 20\ 10^3\ 1000\ 10^{-12} = 20\ 10^{-6} \text{ sec}$$

In a two time constant system, comprised of linear passive networks, which are independent (that is...N_2 is not an appreciable load on N_1)



For $T_{N_1} > T_{N_2}$

$$T_{OUT} \doteq T_{N_1}$$

For $T_{N_1} = T_{N_2}$

$$T_{OUT} = \sqrt{T_{N_1}\ T_{N_2}}$$

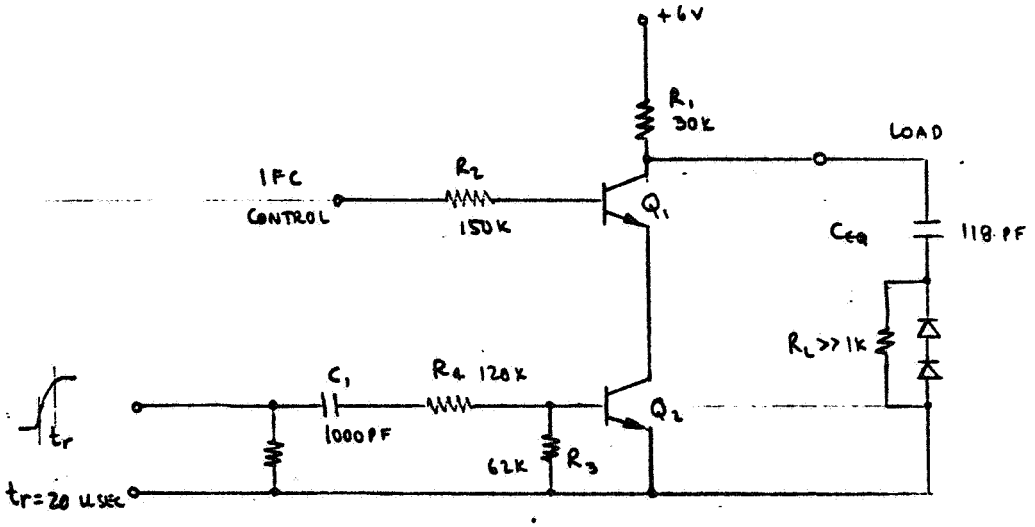
For $T_{N_2} > T_{N_1}$

$$T_{OUT} \doteq T_{N_2}$$

Therefore, for all practical purposes

$$T_{A'B'} = 20 \text{ usec}$$

The details of the pulse circuitry are now examined.



205

For IFC control signal = +6 volts, Q_1 will be automatically turned on when Q_2 is turned on by a positive going pulse at input AB.

The minimum base drive at 25°C for R_2 +5% high

$$I_{BQ_1} = \frac{V_{IFC} - (V_{BEQ_1} + V_{CEQ_2})}{1.05\ (150k)} = \frac{6 - (.7 + .2)}{157.5k} = \frac{5.1}{157.5k} = 32.4\ uA$$

At V_{AB} = nominal condition

"0" nominal = 0v

"1" nominal = +7v

The minimum voltage at A'B'

$$V_{A'B'} = V_{AB} \frac{R_{5\,MIN}}{R_{LINE_{MAX}} + R_{5\,MIN}} = \frac{7.95\ \ 24k}{1.05\ \ 20k + .95\ \ 24k} = 7\,\frac{22.8k}{43.8k} = 5.2v$$

The minimum base current into Q_2 with R_4 maximum, R_3 minimum

$$I_{BQ_2\,MIN} = \frac{\Delta V_{A'B'} - V_{BEQ_2}}{R_{4\,MAX}} - \frac{V_{BEQ_2}}{R_{3\,MIN}} = \frac{5.2 - .7}{1.05\ \ 120k} - \frac{.7}{.95\ \ 62k}$$

$$= (35.7 - 11.9)\ 10^{-6} = 23.8\ uA$$

The maximum current that can flow in R_1

$$I_{R_1} = \frac{V_s - (V_{CE\,SAT\,Q_1} + V_{CE\,SAT\,Q_2})}{R_{1\,MIN}} = \frac{6 - (.2 + .2)}{.95\ \ 30k} = 196.5\ uA$$

Since C_{LEQ} is in parallel with R_1, the collector current of Q_2 and therefore Q_1 will be greater than I_{R_1}.

The h_{FE} of the 2N2484 transistors are now determined from the data sheets.

h_{FE} @ 25°C , V_{CE} + 5v					h_{FE} @ -55°C I_c = 10 uA V_{CE} = 5v
I_C = 10 uA	I_c = 100 uA	I_c = 500 uA	I_c = 1 MA	I_c = 10 MA	
100 min	175 min	200 min 430 typ	250 min 450 typ	430 typ 800 max	20 min

Use $h_{FE\ 25°C\ MIN}\Big]_{I_C = 196.5\ uA\ MIN} = h_{FE\ MIN\ 25°C\ 100\ uA} + \frac{(h_{FE\ 500\ uA} - h_{100\ uA})}{400\ uA}\ 96.5\ uA$

$$= 175 + \frac{25}{400}\,96.5 = 175 + 10.35 = 185.35$$

Therefore at $I_{C_{Q_1}} = I_{C_{Q_2}} \geq 196.5$ uA

$$h_{FE\ 25°C\ MIN} \geq 185.35$$

The change in output voltage

$$\Delta V_{C_{Q_1}} = V_S - (V_{CE\,SAT\,Q_1} + V_{CE\,SAT\,Q_2}) = 6 - (.2 + .2) = 5.6\ v$$

And the final charge given up by C_{LEQ}

$$Q = CV = 118\ 10^{-12}\ 5.6 = 661\ 10^{-12}\ \text{coulombs.}$$

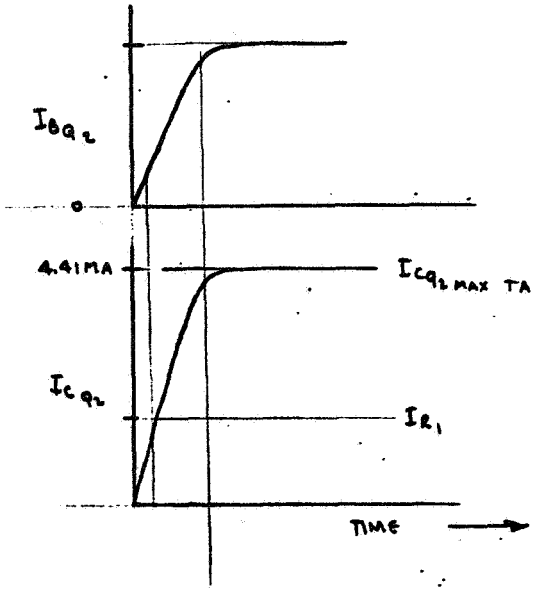
The maximum current that is theoretically available from the collector of Q_2

$$I_{C_{Q_2\,MAX\,TA}} = h_{FE\,Q_2\,MIN}\, I_{B_{Q_2}} = 185.35\ \underset{115}{23.8}\ 10^{-6} = 4.41\ MA$$

The waveform of the input base current to Q_2 and the collector current is shown below:

Since the load on Q_2 collector = load on Q_1 collector = C_{LEQ} in parallel with R_1, the current flowing through R_1 is small compared to that discharging C_{LEQ}.

$I_{C_{LEQ.\ DURING\ DISCHARGE}} > I_{R_1\,MAX}$



201

Now the time to discharge C_{LEQ} from 6 volts to 2 $V_{CE\,SAT}$

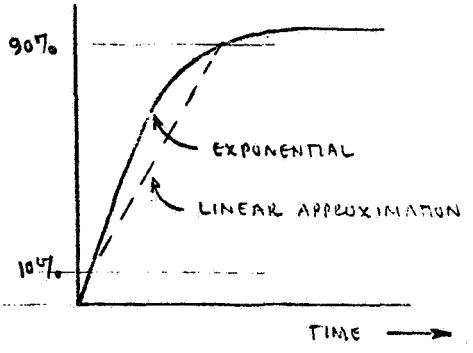
$$Q = It$$

$$t = \frac{Q}{I_{AV}} = \frac{661\ 10^{-12}}{I_{AV}}$$

The 4.41 MA or 100% I_c has a risetime of 20 usec.

The rate of collector current change assuming a linear approximation to the exponential waveform

$$\frac{MA}{usec} = \frac{4.41}{20}\ .8 = .1763\ MA/usec$$



At the end of the first usec

$$Q_1 = I_{AV}\ (t_1 - t_0)$$
$$= \frac{.176}{2}\ 10^{-3}\ 10^{-6}$$
$$= 83\ 10^{-12}\ \text{coulombs}$$

At the end of the second usec

$$Q_2 = Q_1 + I_{AV}\ (t_2 - t_1) = 83\ 10^{-12} + \frac{.5289}{2}\ 10^{-3}\ 10^{-6}$$
$$= 347.5\ 10^{-12}\ \text{coulombs}$$

At the time the equivalent load capacitor discharges $661\ 10^{-12}$ coulombs

$$t_3 - t_2 = \frac{661\ 10^{-12} - 34\ 7.5\ 10^{-12}}{I_{AV}} = \frac{313.5\ 10^{-12}}{I_{AV}}$$

$t_3 - t_2 < 1$ usec since $I_{AV_{t_3-t_2}} = \frac{.8815}{2} = .4407$ MA

and $Q_3 = 347.5\ 10^{-12} + .441\ 10^{-3}\ 10^{-6} = 788.5\ 10^{-12}$ coulombs $> Q_{C_{LEQ\ DISCH.}}$

The needed charge to discharge C_{LEQ}

$$\therefore Q_{t_3-t_2} = 313.5\ 10^{-12}\ \text{coulombs}$$

208

The time required for the $t_3 - t_2$ increment

$$\Delta Q_{t_3-t_2} = I_{AV} (t_3 - t_2)$$

$$= \frac{(.3526 + x)}{2} 10^{-3} (t_x - 2) 10^{-6}$$

The 100% discharge time

$$t_x = 2.75 \text{ usec}$$

$$t_3 - t_2 = .75 \text{ usec}$$

The 10 to 90% response time

$$t_x = .8 \quad t = 2 \text{ usec}$$

Since I_{CQ_1} exceeded 196.5 uA, the $h_{FE\ MIN}$ actually will exceed the 185.35 value employed in the calculation, and a value of

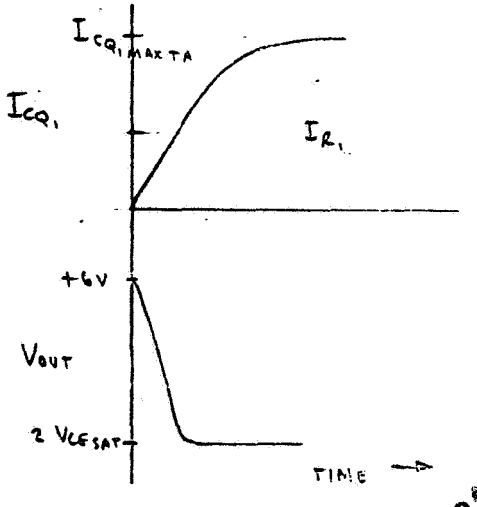
$h_{FE\ MIN\ I_C = 500\ uA\ 25°C} = 200$ would have been more appropriate. However, this rigorous approach allows some flexibility since the 196.5 uA of R_1 current was set aside to allow a simple calculation of the capacitor load discharge time.

For a transistor with nominal h_{FE} at 25°C

$$h_{FE\ NOMINAL\ 25°C}\Big|_{I_C = 500\ uA} = 430$$

The 10 to 90% response time of the output current and consequently the output voltage

$$t = \frac{200}{430} 2 = .91 \text{ usec}$$



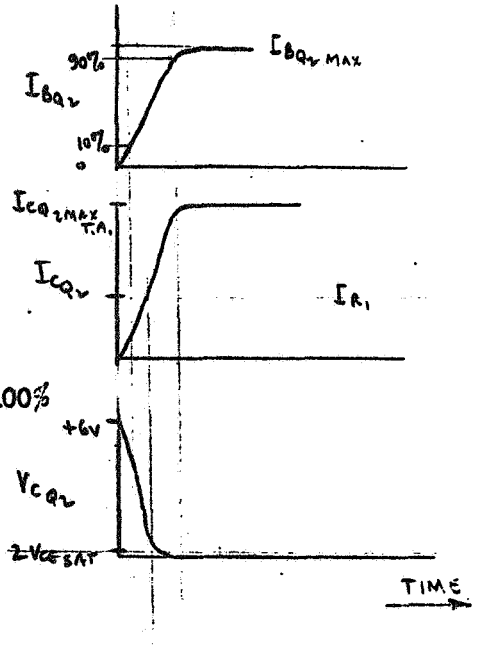
The above analysis points out the lack of fast falltime of the output signal due to the slow input waveform response and lack of sufficient gain in the timing pulse circuitry.

A cursory review of the same circuitry at -10°C and nominal input voltage, indicates that the fall time is very degraded for the same input stimuli. For a worst case input voltage

$$\Delta V = V_{IN(1)\,MIN} - V_{IN(0)\,MAX} = 4 - 1.5 = 2.5 \text{ volts}$$

at - 10°C, the timing pulse circuitry has hardly sufficient gain to drive the resistive load R_1, let alone the equivalent capacitive load.

The determination of the needed rise time to generate a $t_f < .5$ usec at the load, $C_{L_{EQ}}$, is now undertaken. The calculation will be made at 25°C and nominal input voltage, then modified for extremes of the applicable temperature range.



At 25°C and $V_{INPUT\ NOMINAL}$

The input V_{AB}

$V_{INPUT(1)} = 7.0$ v

$V_{INPUT(0)} = 0$ v

For $h_{FE\ Q_1\ 25°C\ MIN}\Big|_{I_C = 1915\ \mu A} = 185.35$

The time in which the capacitor must discharge 100%

$$t_x = \frac{.5}{.8} = .625 \text{ usec}$$

To discharge $C_{L_{EQ}}$ in .625 usec

$$I_{AV\,C_L} = \frac{Q}{t} = \frac{661\ 10^{-12}}{.625\ 10^{-6}} = 1.056\ MA$$

$$I_{F\ .625\ usec} = 2\ I_{AV} = 2.112\ MA$$

Since $I_{CQ,\ MAX.T.A.} = 4.41$ MA as previously calculated on page 9.

The time for 80% (10 to 90% response time) for a waveform changing

$$\frac{\Delta I_{PU}}{t} = \frac{2.112}{4.41} \text{ in } .625 \text{ usec} = 47.8\% \text{ in } .625 \text{ usec}$$

The required rise time of the input signal to generate the desired fall time

$$t_{R\,INPUT} = \frac{80}{47.5}\ .625 = 1.05 \text{ usec}$$

Consideration is made for nominal input at -10°C ambient temperature.

At -10°C the h_{fe} of Q_2

$$h_{FE\ Q_2\ MIN\ -10°C}\Big|_{I_C \geq 196.5\ uA} = 185.35 - \frac{(185.35 - \frac{20}{100}\ 185.35)}{(25--50)}\ (25--20)$$

$$= 185.35 - (148.3\ \frac{45}{75}) = 96.45$$

$$I_{CQ_1\ MAX\ -10°C} = h_{FE\ MIN\ -10°C}\ I_{BQ_1} = 96.45\ \ 23.8\ \ 10^{-6} = 2.29\ MA$$

The time for 80% (10 to 90% response time) for a waveform changing

$$\frac{\Delta I_{PU}}{t} = \frac{2.112}{2.29} \text{ in } .625 \text{ usec} = 92.2\% \text{ in } .625 \text{ usec}$$

The required rise time of the input signal to generate the desired fall time

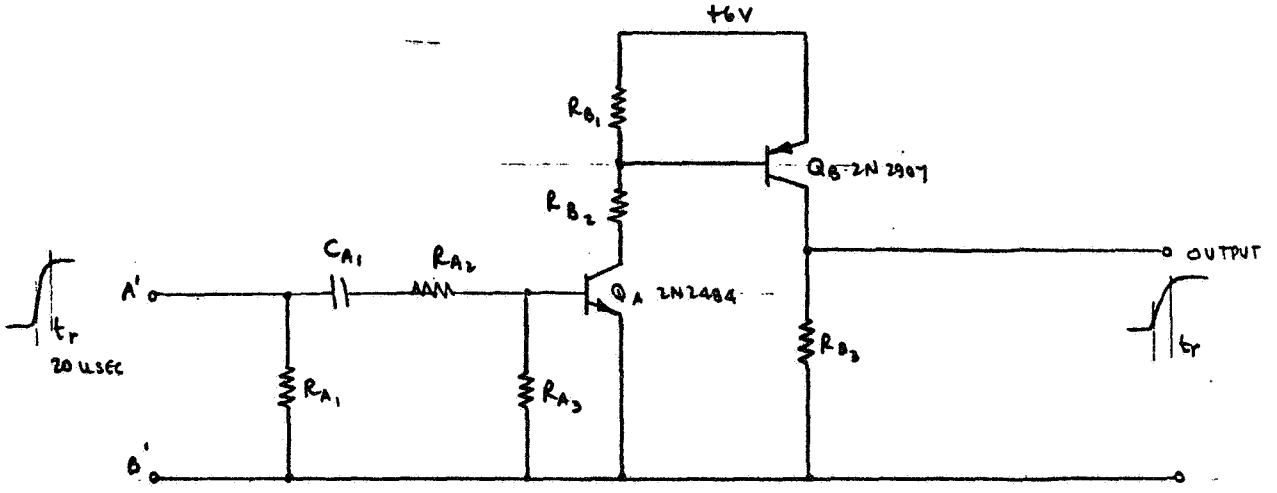
$$t_{r\ INPUT} = \frac{80}{92.2}\ .625 = .543 \text{ usec}$$

The necessary electronics interface to achieve the results of calculations for required rise time are now developed. The requirement necessitates a

211

non-inverting switching stage with rise time improvement of the order of 40. This is required due to the fact that the present input rise time is 20 usec while the input rise time required to effect a .5 usec fall time at -10°C is .543 usec.

The following circuit is provided to achieve the waveform improvement as well as regenerate and improve the input signal ▷V characteristics.



PROPOSED INTERFACE CIRCUITRY

C_{A_1} = 1000 PF
R_{A_1} = 100 K
R_{A_2} = 68 K
R_{A_3}, R_{B_1} = 82K
$R_{B_2}; R_{B_3}$ = 22K

The minimum input $\triangleright V_{AB}$ is

$$V_{(1)\ MIN.} = 4\ v$$

$$V_{(0)\ MAX.} = 1.5\ v$$

The calculation will be made on the 222 PPS timing pulse circuit. The time constant

$$3\ T_{DECAY} < P_{222\ PPS}$$

So that C_{LINE} may discharge via R_{A1} and be ready to accept a new charge upon the receipt of a following timing pulse

$$3\,T_{DECAY} = 3\,R_{A_1}\,C_{LINE} < 4.5 \text{ millisec}$$

$$R_{A_1} < \frac{4.5\ 10^{-3}}{3\ 1000\ 10^{-12}} = 1.5\ 10^{+6}$$

And for maximum input signal efficiency

$$\frac{R_{LINE}}{R_{A_1}} \rightarrow 0 \quad \text{or} \quad R_{A_1} >> R_{LINE} \qquad \text{Use } R_{A_1} = 100\text{ k}$$
Type BB 1/8 w 5%

As a starting point in the design operate Q_A and Q_B at

$$I_{CQ_A} = I_{CQ_B} = .25 \text{ MA}$$

Therefore

$$R_{B_2} = \frac{V_S - (V_{CE\,SAT\,Q_A} + V_{BE\,Q_B})}{I_{CQ_A}} = \frac{6 - (.2 + .7)}{.25\ 10^{-3}} = 20.4\text{k}$$

Use $R_{B_2} = 22\text{k}$

$$R_{B_3} = \frac{V_S - V_{CE\,SAT}}{I_{CQ_B}} = \frac{6 - .2}{.25\ 10^{-3}} = 23.2\text{k}$$

Use $R_{B_3} = 22\text{k}$

The minimum ΔV appearing at $V_{A'B'}$

$$\Delta V_{A'B'\,MIN} = \Delta V_{AB\,MIN} \frac{R_{A_1}}{R_{A_1} + R_{LINE}} = \frac{(4 - 1.5)\ 100\text{k}}{100\text{k} + 20\text{k}} = 2.08\text{v}$$

For a minimum h_{FE} of the 2N2484 at -10°C from page 1e

$$h_{FE\,MIN\ -10°C}\ \big]_{I_C = 196.5\ uA} = 96.45$$

the required base current

$$I_{BQ_A} = \frac{I_{CQ_A}}{h_{FE\ Q_A\ MIN.\ -10°C}} = \frac{.25\ 10^{-3}}{96.45} = 2.59\ \text{uA}$$

The value of R_{A_3}, the hold off resistor

$$R_{A_3} < \frac{V_{BE\ MAX\ ALLOW.\ IN\ OFF\ CONDITION}}{I_{CBO\,MAX}}$$

$$< \frac{.200}{2\ 10^{-6}} = 100\text{k}$$

$I_{CBO\,MAX}$ 150°C = 10 uA
V_{CBO} = 45 v

Use $I_{CBO\,MAX}$ 50°C
V_{CBO} = 6v
= 2 uA

The value of R_{A_3} is now calculated Use R_{A_3} = 82 k

$$I_{R_{A_2}} = I_{B_{Q_A}} + I_{R_{A_3}} = (2.59 + I_{R_{A_3}})\ uA$$

$$I_{R_{A_3}} = \frac{V_{BE\,Q_A}}{R_{A_3}} = \frac{.7}{82k} = 8.54\ uA$$

$$R_{A_2} = \frac{\Delta V_{A'B'} - V_{BE\,Q_A}}{I_{R_{A_2}}} = \frac{2.08 - .7}{(2.59 + 8.54)\ 10^{-6}} = 122k$$

Use R_{A_2} = 68k

For the 2N2907A PNP employed for Q_B

I_{CBO} = 10 ua max V_{CBO} = 50 v @ 150°C

Use $I_{CBO\,MAX}$ = 2uA @ 50°C V_{CBO} = 6 v

The hold off resistor

$$R_{B_1} < \frac{V_{CB\,Q_B\ MAX.\,ALLOW.\,OFF\,COND}}{I_{CBO\,MAX}} = \frac{.200}{2\ \ 10^{-3}} = 100\ k$$

Use R_{B_1} = 82k

Calculation of input capacitor C_{A_1}

With a 20 usec input t_r

$$f_{INPUT} = \frac{.35}{t_r} = \frac{.35}{20\ \ 10^{-6}} = .0175\ \ 10^{6} = 17.5\ kH_z$$

The reactance of the capacitor C_{A_1} should be

$$X_{C_{A_1}} < R_{A_2}$$

$$\doteq \frac{R_{A_2}}{10}$$

$$C_{A_1} = \frac{10}{R_{A_2}\ 2\pi f_{INPUT}} = \frac{10}{68\ \ 10^{3}\ \ 6.28\ \ 17.5\ \ 10^{3}}$$

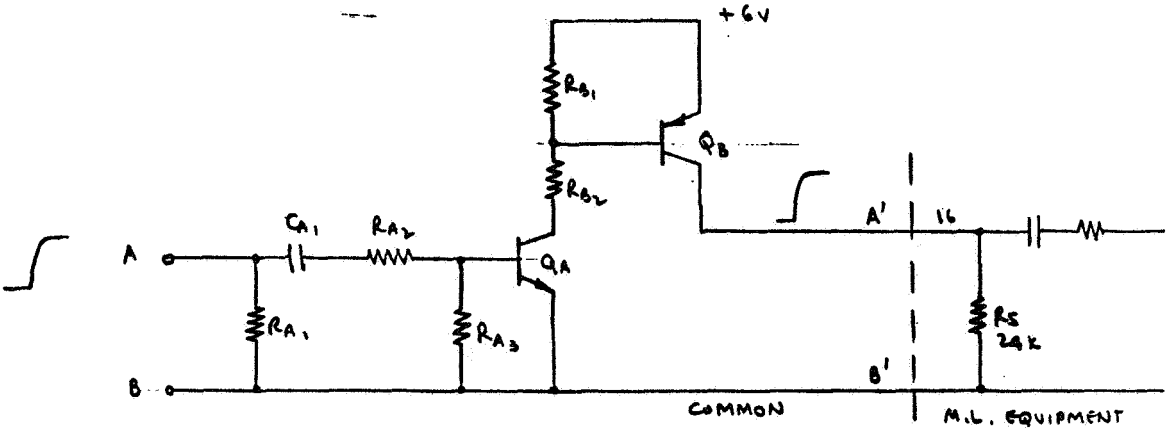
$$= \frac{10^{-6}\ 10}{68\ \ 6.28\ \ 17.5} = 1335\ \ 10^{-12}$$

Use C_{A_1} = 1000 PF

NOTE: As long as the necessary electronics interface is connected to the original timing pulse circuitry, R_{B_3} is unnecessary as R_5(24k) will provide the collector (Q_B) return to common.

The calculation of the output rise time into the equivalent input of the initial timing pulse circuitry is now made.

The equivalent circuit of the section is



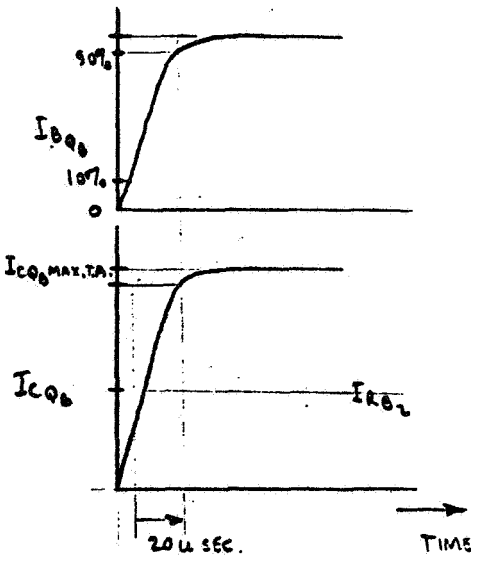
An examination of the load lines reveals that for all practical purposes Q_A and Q_B drive resistive loads.

The collector current of Q_A will rise at the time constant of the input to the maximum current theoretically available from Q_A. The maximum current theoretically available from Q_A

$$I_{CQA\ MAX\ T.A.} = h_{FE\ QA\ MIN\ 25°C}\ I_{BQA}$$

The base current of Q_A

$$I_{BQA} = \frac{(4 - 1.5) - .7}{1.05\ \ 68k} - \frac{.7}{.95\ \ 82k}$$



215

$$= (25.2 - 8.98)\ 10^{-6}$$

$$= 16.22\ uA$$

$$I_{CQ_B\ MAX\ AVAIL} = 185.35\ \ 17.22\ \ 10^{-6} = 3.01\ MA$$

The rate of rise of I_{CQ_A}, 10 to 90%

$$\frac{MA}{usec} = \frac{(.80)\ 3.01}{20} = .1204\ \frac{MA}{usec}$$

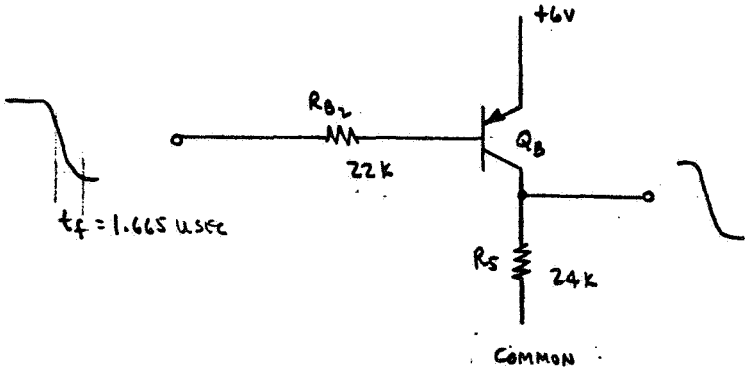
The time to achieve $I_{R_{B2}} = .25\ MA$

$$t_{r_{Q_A}} = \frac{.25}{.1204} = 2.08\ usec$$

The normally defined response time

$$t_{r_{Q_A}} = .8\ \ 2.08 = 1.665\ usec$$

The calculation of rise time is now made for Q_B. The equivalent circuit for this stage is as follows:



The base current to Q_b

$$I_{BQ_{B\,MIN}} = \frac{V_S - V_{CE\ SAT\ Q_A} - V_{BE\ Q_B}}{R_{B2\ MAX}} = \frac{6 - (.2 - .7)}{1.05\ \ 68k} = 71.5\ uA$$

816

The dc current gain of the 2N2907A

h_{FE} @ 25°C V_{CE} = 10 v		
I_C = .1 MA	I_C = 1 MA	I_C = 10 MA
75 min	100 min	100 min

The h_{FE} at .25 MA I_C

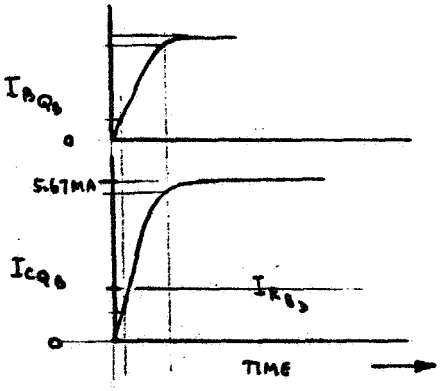
$$h_{FE\ MIN\ 25°C}\Big|_{I_C=.25MA} = h_{FE\ 25°C}\Big|_{.1MA} + \frac{h_{FE\ 1MA} - h_{FE\ .1MA}}{.9} .15$$

$$= 75 + \frac{25}{9} .15 = 79.17$$

The maximum current theoretically available from the collector of Q_B is

$$I_{CQ_B\ MAX\ T.A.} = h_{FE\ 25°C\ MIN}\ I_{BQ_B} = 79.17\ \ 71.5\ \ 10^{-6} = 5.67\ MA$$

The maximum theoretically available collector current waveform rises at the time constant of the base input current.



The rate of rise of collector current

$$\frac{MA}{usec} = \frac{5.67}{1.665} = \frac{3.4\ MA}{usec}$$

Since $I_{C_{Q_B}}$ is limited to

$$I_{C_{Q_B}} = \frac{V_S - V_{CE\ SAT\ Q_A}}{R_{S\ MIN}} = \frac{6 - .3}{.95\ \ 24k} = .25\ MA$$

The time required to reach $I_{C_{Q_B}}$ = .25 MA

$$t = \frac{.25\ MA}{\frac{3.4\ MA}{usec}} = 76.3\ \ 10^{-9} = 76.3\ \text{nonoseconds}$$

The normal response time (10 to 90%)

$$t_r = .8\ \ 76.3\ \ 10^{-9} = 61.1\ \text{nonoseconds}$$

Therefore, the interface circuitry will meet the needs as defined in the analysis.

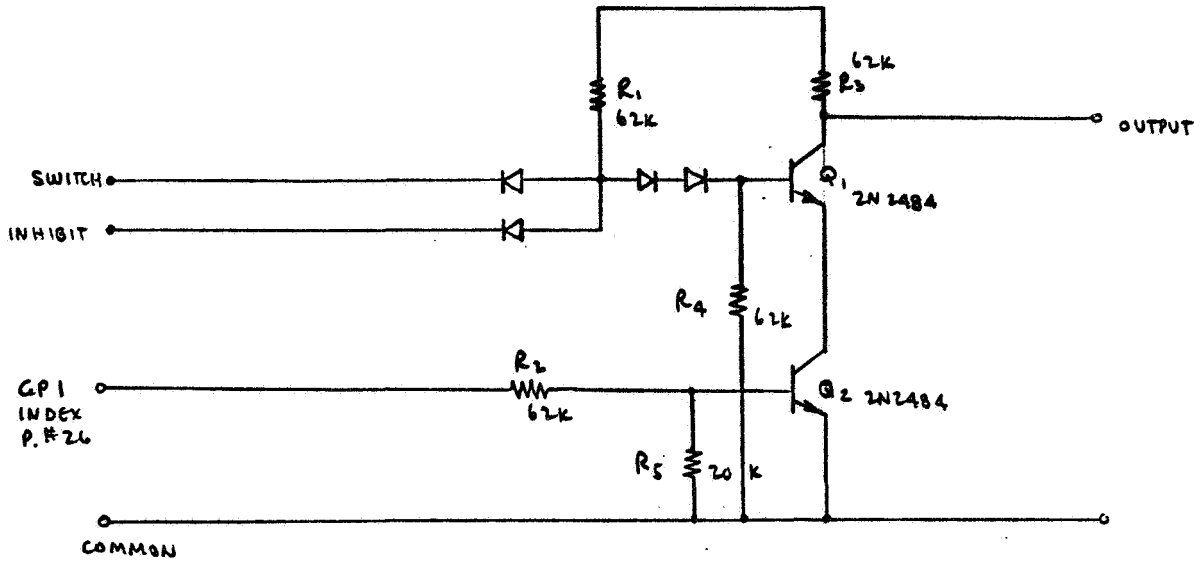
An examination of the NPN/PNP interface circuitry at the lower and upper temperatures revealed

(a) - 10°C t_r increases considerably but is < .5 usec
dc drive is adequate (dc stability is good)

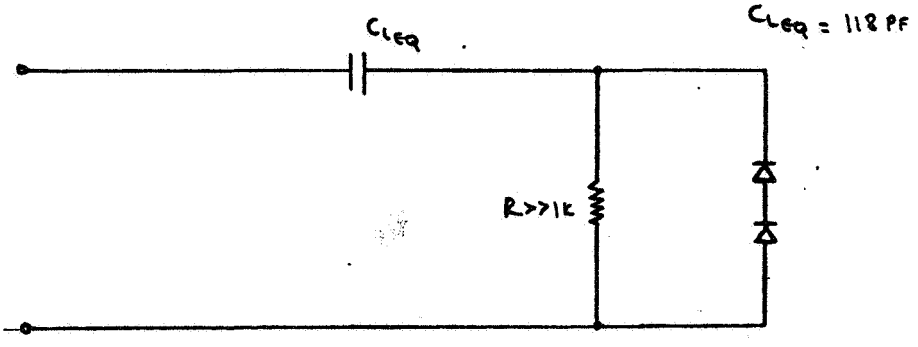
(b) +50°C t_r decreases slightly
dc stability is good

The transient response of the index pulse circuitry is now evaluated.

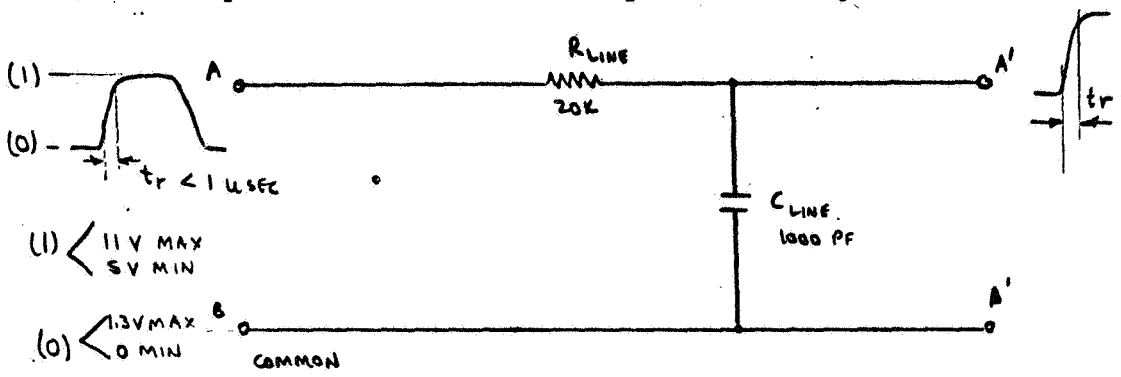
The pulse circuitry is comprised of 2 identical switching stages, one of which is on while the other is off. The fall time of the present circuit configuration will be calculated at the 25°C condition for worst case components. The circuit schematic is shown below.



The load on the output is identical to that on the timing pulse circuits. Refer to pages 5 and 6 for simplified equivalent circuit of the load. It reduces to



Now the input waveform to the index pulse circuitry



Refer to pages 6 and 7. For all practical purposes

$$t_{r\,A'B'} = 20 \text{ usec}$$

The details of the index pulse circuitry are now examined. For the inhibit signal and switch signal = +6 volts Q_1 will be automatically turned on when Q_2 is turned on by a positive going pulse at input AB.

The minimum base drive at 25°C for R_1 5% high, R'_4 5% low

$$I_{BQ_1} = \frac{V_{supply} - 2V_F - V_{BEQ_1}}{1.05\ R_1} - \frac{V_{BEQ_1} + V_{CE\,Q_2}}{.95\ 62k}$$

$$= \frac{6 - 2(.7) - .7}{1.05\ 62k} - \frac{.7 + .2}{.95\ 62k} = 44.9 \text{ uA}$$

At V_{AB} = nominal condition

"0" nominal = .65 v

"1" nominal = +8 v

The minimum voltage at A'B'

$$V_{A'B'} = V_{AB}\ \frac{R_{B\,MIN}}{R_{B\,MIN} + R_{LINE\,MAX}} = 8\ \frac{62k\ .95}{62k\ .95 + 20k\ 1.05} = 5.9 \text{ v}$$

The minimum base current into Q_2 with R_3 maximum, R_4 minimum

$$I_{BQ_2\,MIN} = \frac{V_{A'B'} - V_{BEQ_2}}{R_{B\,MAX}} - \frac{V_{EEQ_2}}{R_{4\,MIN}} = \frac{5.9 - .7}{1.05\ \ 62k} - \frac{.7}{.95\ \ 20k}$$

$$\doteq (79.8 - 36.8)\ uA = 33\ uA$$

The maximum current that can flow in R_3

$$I_{R_3\,MAX} = \frac{V_S - (V_{CE\,SAT\,Q_1} + V_{CE\,SAT\,Q_2})}{R_{1\,MIN}} = \frac{6 - (.2 + .2)}{.95\ \ 62k} = 95\ uA$$

Since C_{LEQ} is in parallel with R_1 the collector current of Q_2 and therefore Q_1 will be greater than I_{R_1}.

Refer to page 9 for the h_{FE} of the 2N2484 transistors.

Since I_{R_1} max is 95 uA, use the $h_{FE\,MIN}$ of the 2N2484 at $I_C \geq .1MA$

Use $h_{FE\,+25°C\,MIN}\Big|_{I_C = .1MA} \geq 175$

The change in output voltage and final charge given up by C_{LEQ} from page 9

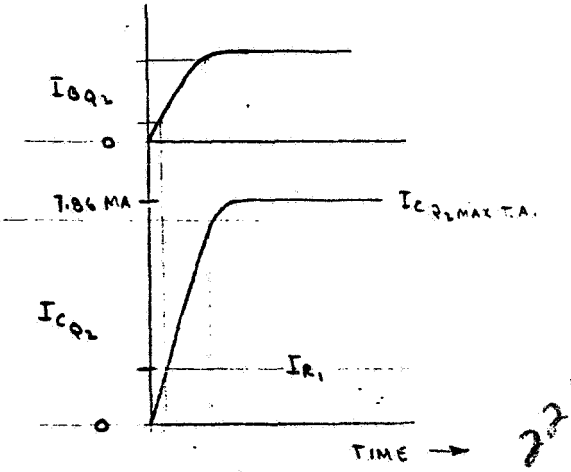
$\Delta V_{CQ_1} = 5.6$ v

$Q = 661\ \ 10^{-12}$ coulombs

The maximum current that is theoretically available from the collector of Q_2

$$I_{C\,Q_2\,MAX\,TA} = h_{FE\,Q_2\,MIN}\, I_{BQ_2} = 175\ \ 44.9\ uA = 7.86\ MA$$

The waveform of the input base current to Q_2 and the collector current is shown below.



As explained at the bottom of page 9

$I_{C_{LEQ}\ \text{DURING DISCHARGE}} > I_{R_1\,MAX}$

And the time to discharge C_{LEQ} from 6 v to 2 $V_{CE\,SAT}$

$$t = \frac{Q}{I_{AV}} = \frac{661\ 10^{-12}}{I_{AV}}$$

The rate of rise of collector current of Q_2

$$\frac{MA}{usec} = \frac{7.86\ \ .8}{20} = \frac{.314\ MA}{usec}$$

At the end of the first usec

$$Q_1 = I_{AV}\ (t_1 - t_0) = \frac{.314}{2}\ 10^{-3}\ \ 10^{-6} = 157\ \ 10^{-12} \text{ coulombs}$$

At the end of the second usec

$$Q_2 = Q_1 + I_{AV}\ (t_2 - t_1) = 157\ \ 10^{-12} + \frac{.942}{2}\ 10^{-3}\ \ 10^{-6}$$

$$= 628\ \ 10^{-12} \text{ coulombs}$$

The time t_3 at which the equivalent load capacitor reaches full discharge

$$t_3 - t_2 = \frac{661\ \ 10^{-12} - 628\ \ 10^{-12}}{I_{AV}}$$

$t_3 - t_2 <$ 1 usec since in the next 1 usec

$$Q_{3\ 1\,usec} = Q_2 + I_{AV}\ (t_3 - t_2) = 628\ \ 10^{-12} + \frac{1.570}{2}\ 10^{-3}\ \ 10^{-6}$$

$$= 628\ \ 10^{-12} + 785\ \ 10^{-12}$$

$$= 1413\ \ 10^{-12} > C_{LEQ\ \text{DISCHARGED}}$$

The needed charge to discharge C_{LEQ} completely

$$\Delta Q_{t_3-t_2} = 661\ \ 10^{-12} - 628\ \ 10^{-12} = 31\ \ 10^{-12} \text{ coulombs}$$

The time required for the $t_3 - t_2$ increment

$$\Delta Q_{t_3-t_2} = I_{AV}\ (t_3 - t_2)$$

$$= \left(\frac{.628 + x}{2}\right) 10^{-3}\ \ (t_x - 2)\ 10^{-6}$$

$$t_x = 2.05 \text{ sec}$$

The 10 to 90% response time

$$t = .8\ t_x = 1.64 \text{ usec}$$

Since I_{CQ_1} exceeded 95 uA, the $h_{FE\ MIN}$ actually will exceed the 175 value employed in the calculation, and a value of $h_{FE\ MIN}\Big|_{I_C = 500uA\ 25°C} = 200$ would have been more appropriate.

For a transistor with a nominal h_{FE} at 25°C

$$h_{FE\ NOMINAL\ 25°C}\Big|_{I_C = 500\ uA} = 430$$

The 10 to 90% response time of the output current and consequently the output voltage

$$t = \frac{175}{430}\ 1.64 = .467 \text{ usec}$$

The above calculations are similar to those made on the timing pulse circuitry, except are not as deficient in gain and waveform improvement. Therefore, the same corrective interface circuitry is recommended here.

APPENDIX B

MASTER DRAWING LISTS

1. Search Coil System - MDL 51896 B
2. Mainbody Electronics Assembly - MDL 51731 B
3. Preamplifier Assembly - MDL 51733 B

APPLICATION	
NEXT ASSY	FINAL ASSY
	ML295-1

PARTS DISPOSITION
1. USE 3. CANNOT BE REWORKED
2. REWORK 4. RECORD 5. .....

DWG. NO. MDL51896 REV B

REVISIONS

DISP	EFF	REV	DESCRIPTION	BY	CK	DATE	APPD
4	Rco	A	REVISE CHANGE LETTER BLOCK	LFS	LFS	9/5/17	
4	Rco	B	REVISE CHANGE LETTER BLOCK	LDM		3/5/65	

SHEET INDEX	REV	B B
	SHEET	1 2

INTERPRET THIS DRAWING PER STANDARDS IN MIL-D-70327
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS: .X ± .1; .XX ± .03; .XXX ± .010; .XXXX ± .0050
ANGLES ± 0° 30'
✓ SURFACE ROUGHNESS

HOLE DIA.	TOLERANCE
.0135 THRU .125	± .004 – .001
.126 THRU .250	± .005 – .001
.251 THRU .500	± .006 – .001
.501 THRU .750	± .008 – .001
.751 THRU 1.000	± .010 – .001
1.000 THRU 2.000	± .012 – .001
2.001 AND OVER	LINEAR

CONTRACT NO. 5-120

DRAWN RSanders	8-15-65
CHECK RSanders	8-17-65
MECH ENGR RSanders	8-19-65
ELECT ENGR	
PROJ MGR	10/5/65
APPD	
DESIGN ACTIVITY APPD	10/6/65
CUSTOMER	

ML MARSHALL LABORATORIES
TORRANCE, CALIFORNIA

TITLE: MASTER DRAWING LIST-SEARCH COIL SYSTEM

SIZE	CODE IDENT NO.	DWG NO.	REV
A	13126	MDL51896	B

SCALE | RELEASED | SHEET 1 OF 2

ML FORM 34A

5-120-B

LINE NO.	ASSEMBLY POSITION 1	2	3	4	5	6	7	8	9	QTY	DRAWING NUMBER	REV LTR	DRAWING TITLE	DWG SIZE
1	X										51896-101	NC	SEARCH COIL SYSTEM EXP E16 OGE	C
2		X								1	51734-101	NC	SENSOR ASSY (X-AXIS) ML292-1	D
3		X								1	51734-102	NC	SENSOR ASSY (Y-AXIS) ML292-2	D
4		X								1	51734-103	NC	SENSOR ASSY (Z-AXIS) ML292-3	D
5		X								1	51733-101	NC	PREAMPLIFIER ASSY ML293-1	F
6		X								1	51731-101	NC	ELECTRONICS ASSY ML294-1	F
7														
8														
9														
10		X								REF	51747	C	SYSTEM BLOCK DIAGRAM	F
11		X									51732	B	INTERFACE WIRING DIAGRAM	D
12		X									51739	A	THERMAL DIAGRAM	C
13		X									51735	B	ENVELOPE DWG - ELECTRONIC	D
14		X									51736	A	ENVELOPE DWG - PREAMPLIFIER	C
15		X								REF	51737	A	ENVELOPE DWG - SENSOR	C
16														
17														
18		X								REF	51977	A	SCHEMATIC, BTE, OGOE, (E16)	J
19														
20		X								REF	540843	NC	TEST SPEC	A
21														
22														
23														
24														
25														
26														
27														
28														
29														
30														
31														
32														
33														
34														
35														
36														
37														
38														
39														
40														
41														
42														
43														
44														
45														
46														
47														
48														
49														
50														

MODEL NO. ML295-1

TITLE—	SIZE	CODE IDENT NO.	DWG NO.	REV
MASTER DRAWING LIST — SEARCH COIL SYSTEM, EXP E16, OGOE	A	13126	MDL 51896	B
	SCALE —	RELEASED	SHEET 2 OF 2	

APPLICATION	
NEXT ASSY	FINAL ASSY
	ML294-1

PARTS DISPOSITION
1. USE 3. CANNOT BE REWORKED
2. REWORK 4. RECORD 5. ....

DWG. NO. MDL 51731 REV B

REVISIONS

DISP	EFF	REV	DESCRIPTION	BY	CK	DATE	APPD
4	RCO	A	REVISED CHANGE LETTER BLOCK	LFS	LFS	9-7-7	
4	RCO	B	REVISED CHANGE LETTER BLOCK	LDM		3/8/68	

SHEET INDEX	REV	B	B	B	B	A
	SHEET	1	2	3	4	5

INTERPRET THIS DRAWING PER STANDARDS IN MIL-D-70327
DIMENSIONS ARE IN INCHES
TOLERANCES ON
DECIMALS X ± .1 .XX ± .03 .XXX ± .010 ANGLES ± 0° 30' .XXXX ± .0050
√ SURFACE ROUGHNESS

HOLE DIA.	TOLERANCE
.0135 THRU .125	+ .004 - .001
.126 THRU .250	+ .005 - .001
.251 THRU .500	+ .006 - .001
.501 THRU .750	+ .008 - .001
.751 THRU 1.000	+ .010 - .001
1.000 THRU 2.000	+ .012 - .001
2.001 AND OVER	LINEAR

CONTRACT NO. 5-120
DRAWN Beasley 8-23-6
CHECK
MECH ENGR
ELECT ENGR
PROJ MGR
APPD
DESIGN ACTIVITY APPD 10/6/65
CUSTOMER

ML — MARSHALL LABORATORIES
TORRANCE, CALIFORNIA

TITLE MASTER DRAWING LIST ELECTRONICS UNIT OGO-E (EXP E-16)

SIZE	CODE IDENT NO.	DWG NO.	REV
A	13126	MDL 51731	B

SCALE — RELEASED OCT 6 1965 SHEET 1 OF 5

ML FORM 34A

5-120B

LINE NO.	ASSEMBLY POSITION 1	2	3	4	5	6	7	8	9	QTY	DRAWING NUMBER	REV LTR	DRAWING TITLE	DWG SIZE
1	X										51731-101	NC	ELECTRONIC ASSY	F
2		X								1	SP30344-1	A	HOUSING, HARNESS	J
3		X								1	SP30344-2	A	COVER, HARNESS HOUSING	J
4		X								REF	L51926	NC	LAYOUT	J
5		X								↕	51961	NC	SURFACE FINISH	E
6		X									51735	B	ENVELOPE	D
7		X									51903	D	ELECTRONICS SCHEMATIC	E
8		X									51904	B	SYSTEM WIRING	A
9		X									T51492-1	NC	TEMPLATE	C
10		X									SP30306-3	X	STAMP, MODEL & PART NUMBER	D
11		X									SP30305-1	B	↕ , NAME PLATE	C
12		X									SP30307-14	P	, UNIVERSAL	C
13		X									SP30307-13	P	, UNIVERSAL	C
14		X								↕	SP30307-12	P	STAMP, UNIVERSAL	C
15		X								REF	S40843	NC	TEST SPEC	A
16														
17														
18														
19														
20		X								1	51897-101	NC	POWER SUPPLY & CONTROL ASSY	A/F
21			X							1	SP30341-101	A	HOUSING	J
22				X						1	SP30341-1	A	HOUSING	J
23			X							1	SP30343-1	G	COVER	J
24			X							1	SP30193-2	A	BRACKET	C
25			X							REF	51898	C	SCHEMATIC	E
26			X							REF	SP30307-4	P	STAMP, UNIVERSAL	C
27			X							REF	S40744	NC	TEST SPEC	A
28														
29														
30			X							1	51897-1	NC	POWER SUPPLY ASSY	A/F
31				X						1	T51948-2	NC	SUPPORT BOARD	AW
32				X						2	T51949-1	↕	SPACER	AW
33				X						1	T51947-101	↓	MATRIX	AW
34				X						1	T51948-101	NC	HOOK-UP BOARD	AW
35				X						REF	SP30253-3	G	JIG - MATRIX	D
36				X						REF	51898	C	SCHEMATIC	E
37				X						1	W4289X1	A	MODULE, INPUT REGULATOR	A
38					X					REF	S40748	NC	TEST SPEC	↕
39				X						1	W4290X1	B	MODULE, SYNC AMPLIFIER	
40					X					REF	S40749	NC	TEST SPEC	
41				X						1	W4291X1	B	MODULE, CHOPPER	
42					X					REF	S40750	A	TEST SPEC	
43				X						1	W4292X1	A	MODULE, RECTIFIER FILTER	↓
44					X					REF	S40751	A	TEST SPEC	A
45				X						1	SP30332	A	TRANSFORMER, SYNC	D
46					X					REF	S40757	NC	TEST SPEC	A
47				X						1	SP30333	A	TRANSFORMER, CLOCK	D
48					X					REF	S40758	NC	TEST SPEC	A
49				X						1	SP30334	A	TRANSFORMER, OUTPUT	D
50					X					REF	S40759	A	TEST SPEC	A

DEL NO. ML 294-1

TITLE—	SIZE	CODE IDENT NO.	DWG NO.	REV
MASTER DRAWING LIST ELECTRONICS UNIT OGO-E (EXP. E16)	A	13126	MDL 51731	B
	SCALE —	RELEASED	SHEET 2 OF	

ML FORM 204

LINE NO.	ASSEMBLY POSITION 1	2	3	4	5	6	7	8	9	QTY	DRAWING NUMBER	REV LTR	DRAWING TITLE	DWG SIZE
1				X						AR	SP30275-( )	D	CAPACITOR	C
2														
3			X							1	51897-2	NC	CONTROL ASSY	A/F
4				X						1	T51945-102	NC	SUPPORT BOARD	A/W
5				X						2	T51946-1	↑	SPACER	A/W
6				X						1	T51944-101	↕	MATRIX	A/W
7				X						1	T51945-101	↓	HOOK-UP BOARD	A/W
8				X						REF	SP30347-4	E	JIG - MATRIX	F
9				X						REF	51898	C	SCHEMATIC	E
10				X						3	W4308X1	C	MODULE, 150. AMPL.	A
11					X					REF	S40830	NC	TEST SPEC	↕
12				X						11	W4296X1	C	MODULE, FLIP-FLOP	
13					X					REF	S40756	NC	TEST SPEC	
14				X						1	W4303X1	A	MODULE DUAL AND	
15					X					REF	S40823	A	TEST SPEC	
16				X						1	W4310X1	A	MODULE STATUS LOGIC	
17					X					REF	S40832	NC	TEST SPEC	
18				X						1	W4309X1	A	MODULE, STATUS LOGIC	
19					X					REF	S40831	NC	TEST SPEC	
20				X						1	W4320X1	NC	MODULE TIMING SIGNAL GATE	
21					X					REF	S40842	A	TEST SPEC	
22				X						1	W4304X1	B	MODULE I.F.C. ATTEN.	
23					X					REF	S40824	A	TEST SPEC	
24				X						1	W4306X1	A	MODULE, BIT RATE INTERFACE	
25					X					REF	S40828	NC	TEST SPEC	
26				X						1	W4305X1	A	MODULE, B.R. LOGIC	
27					X					REF	S40827	A	TEST SPEC	
28				X						1	W4302X1	C	MODULE, I.D. GATE	
29					X					REF	S40822	A	TEST SPEC	
30				X						1	W4299X1	NC	MODULE, COMM. GATING	
31					X					REF	S40814	B	TEST SPEC	
32				X						1	W4321X1	A	MODULE +20V REGULATOR	
33					X					REF	S40851	NC	TEST SPEC	
34				X						1	W4294X1	A	MODULE, +6V REGULATOR	
35					X					REF	S40753	NC	TEST SPEC	
36				X						1	W4295X1	B	MODULE, -6V REGULATOR	
37					X					REF	S40754	NC	TEST SPEC	
38				X						1	W4307X1	↑	MODULE, SCO DET.	↓
39					X					REF	S40829	↕	TEST SPEC	A
40					X					1	SP30345	↓	TRANSFORMER, SCO	C
41						X				REF	S40825	NC	TEST SPEC	A
42				X						2	SP30308	A	INDUCTOR	B
43											S40635	NC	TEST SPEC	A
44				X						2	SP30331	NC	INDUCTOR	C
45														
46		X								1	51899-101	NC	WAVEFORM ASSY	A/F
47			X							1	SP30342-101	F	HOUSING	J
48				X						1	SP30342-1	F	HOUSING	J
49			X							1	SP30343-2	G	COVER	J
50			X							1	SP30343-3	G	COVER	J

MODEL NO. ML 294-1

TITLE—	SIZE	CODE IDENT NO.	DWG NO.	REV
MASTER DRAWING LIST ELECTRONICS UNIT OGO-E (EXP. E16)	A	13126	MDL 51731	B
	SCALE ——	RELEASED	SHEET 3 OF	

ML FORM 204

LINE NO.	ASSEMBLY POSITION 1	2	3	4	5	6	7	8	9	QTY	DRAWING NUMBER	REV LTR	DRAWING TITLE	DWG SIZE
1			X							REF	51900	A	SCHEMATIC	E
2			X							REF	SP30307-5	P	STAMP, UNIVERSAL	C
3			X							REF	S40845	NC	TEST SPEC	A
4														
5														
6			X							1	51399-1	NC	MATRIX SUB ASSY	A/F
7				X						1	T51951-101	NC	SUPPORT BOARD	A/H
8				X						2	T51952-1	↑	SPACER	A/H
9				X						2	T51952-2		SPACER-WASHER	A/H
10				X						1	T51950-101	↓	MATRIX ASSY	A/H
11				X						1	T51951-102	NC	HOOK-UP BOARD	A/H
12				X						REF	SP30253-9	G	JIG-MATRIX	D
13				X						REF	51900	A	SCHEMATIC	E
14				X						1	W4311X1	A	MODULE, +2.5V REGULATOR	A
15					X					REF	S40833	C	TEST SPEC	↓
16				X						3	W4312X1	NC	MODULE, VCO LOW PASS FILTER	
17					X					REF	S40834	B	TEST SPEC	
18				X						1	W4313X1	A	MODULE, VCO	
19					X					REF	S40835	A	TEST SPEC	
20				X						1	W4313X2	A	MODULE, VCO	
21					X					REF	S40835	A	TEST SPEC	
22				X						1	W4313X3	A	MODULE, VCO	
23					X					REF	S40835	A	TEST SPEC	
24				X						3	W4314X1	A	MODULE, VCO OUTPUT DRIVER	
25					X					REF	S40836	A	TEST SPEC	
				X						6	W4315X1	NC	MODULE, WAVEFORM LOW PASS FILTER	
27					X					REF	S40837	NC	TEST SPEC	
28				X						9	W4316X1	A	MODULE, GAIN CHANGE AMPL SPECTRUM	
29					X					REF	S40838	D	TEST SPEC	
30				X						3	W4316X2	A	MODULE, GAIN CHANGE AMPL SPECTRUM	
31					X					REF	S40838	D	TEST SPEC	
32				X						3	W4317X1	B	MODULE, OUTPUT AMPL	
33					X					REF	S40839	D	TEST SPEC	
34				X						3	W4317X2	B	MODULE, OUTPUT AMPL	
35					X					REF	S40839	D	TEST SPEC	
36				X						3	W4298X3	A	MODULE, DETECTOR	↓
37					X					REF	S40813	B	TEST SPEC	A
38														
39														
40														
41														
42			X							1	51901-101	NC	SPECTRUM ASSY	A/D
43				X						1	SP30342-103	F	HOUSING	J
44					X					1	SP30342-2	F	HOUSING	J
45				X						1	SP30343-4	G	COVER	J
46				X						REF	51902	NC	SCHEMATIC	E
47				X						REF	SP30307-6	P	STAMP, UNIVERSAL	C
48				X						REF	S40846	A	TEST SPEC	A
49														
50														

MODEL NO. ML 294-1

TITLE—	SIZE	CODE IDENT NO.	DWG NO.	REV
MASTER DRAWING LIST ELECTRONICS UNIT OGO-E (EXP E-16)	A	13126	MDL 51731	B
	SCALE —	RELEASED	SHEET 4 OF 230	

ML FORM 204

67-917

LINE NO.	ASSEMBLY POSITION 1	2	3	4	5	6	7	8	9	QTY	DRAWING NUMBER	REV LTR	DRAWING TITLE	DWG SIZE
1			X							1	51901-1	NC	MATRIX SUB ASSY	
2				X						1	T51954-102	↑	SUPPORT BOARD	A/N
3				X						2	T51952-1		SPACER	AN
4				X						2	T51952-2		SPACER, WASHER	AN
5				X						1	T51953-101	↓	MATRIX	AN
6				X						1	T51954-1	NC	HOOK-UP BOARD	AN
7				X						REF	SP30253-9	G	JIG-MATRIX	D
8				X						REF	51902	NC	SCHEMATIC	E
9				X						3	W4297X1	A	MODULE, BAND PASS AMPLIFIER	A
10					X					REF	S40812	B	TEST SPEC	↑
11				X						3	W4297X2	A	MODULE, BAND PASS AMPLIFIER	
12					X					REF	S40812	B	TEST SPEC	
13				X						3	W4297X3	A	MODULE, BAND PASS AMPLIFIER	
14					X					REF	S40812	B	TEST SPEC	
15				X						3	W4297X4	A	MODULE, BAND PASS AMPLIFIER	
16					X					REF	S40812	B	TEST SPEC	
17				X						3	W4297X5	A	MODULE, BAND PASS AMPLIFIER	
18					X					REF	S40812	B	TEST SPEC	
19				X						3	W4297X6	A	MODULE, BAND PASS AMPLIFIER	
20					X					REF	S40812	B	TEST SPEC	
21				X						3	W4297X7	A	MODULE, BAND PASS AMPLIFIER	
22					X					REF	S40812	B	TEST SPEC	
23				X						6	W4298X1	A	MODULE, DETECTOR	
24					X					REF	S40813	B	TEST SPEC	
25				X						15	W4298X2	A	MODULE, DETECTOR	
26					X					REF	S40813	B	TEST SPEC	
27				X						1	W4301X1	A	MODULE, +2.6V REG.	
28					X					REF	S40821	NC	TEST SPEC	
29				X						3	W4300X1	A	MODULE, COMMUTATOR	↓
30					X					REF	S40815	A	TEST SPEC	A
31														
32														
33				X						AIR	SP30348	NC	INSULATOR	A/N
34		X		X						REF	S40072	A	FAB & WORKMANSHIP SPEC	
35				X						↑	S40081	B	WELD MODULE SPEC	
36				X							S40091	NC	CONFORMAL COATING SPEC	
37			X								S40092	B	FOAMING SPEC	
38				X							S40094	A	MATRIX MODULE FAB	
39			X								S40149	A	BONDING SPEC	
40				X							S40379	NC	SPOT POTTING SPEC	
41		X	X								S40093	A	POTTING OF CONNECTORS SPEC	
42		X		X							S40126	NC	SOLDER SPEC	
43		X	X								S40111	B	IDENTIFICATION SPEC	
44				X							S40138	E	RIBBON	
45				X							S40139	E	WIRE	
46				X							S40396	NC	PROTECTIVE FINISH SPEC	
47				X							S40848	B	SELECTION SPEC	
48			X	X							AMS3654		TUBING SPEC	
49			X	X							MIL-W-16878		WIRE SPEC	
50				X						REF	MIL-P-18177		MIL-SPEC. EPOXY-GLASS SHT.	

MDL NO. ML 294-1

TITLE—	SIZE	CODE IDENT NO.	DWG NO.	REV
MASTER DRAWING LIST ELECTRONICS UNIT OGO-E (EXP E-16)	A	13126	MDL 51731	A
	SCALE —	RELEASED	SHEET 5 OF 231	

ML FORM 204

APPLICATION	
NEXT ASSY	FINAL ASSY
	ML293-1

PARTS DISPOSITION
1. USE 3. CANNOT BE REWORKED
2. REWORK 4. RECORD 5. .....

DWG. NO. MDL51733 REV B

REVISIONS

DISP	EFF	REV	DESCRIPTION	BY	CK	DATE	APPD
4	RCO	A	REVISE CHANGE LETTER BLOCK	LFS	LFS	2/7/7	
4	RCO	B	REVISED CHANGE LETTER BLK.	LDM		3/8/68	

SHEET INDEX	REV	B	B
	SHEET	1	2

INTERPRET THIS DRAWING PER STANDARDS IN MIL-D-70327
DIMENSIONS ARE IN INCHES
TOLERANCES ON

DECIMALS	ANGLES
± .1	± 0° 30′
X ± .03	
XX ± .010	.XXXX ± .0050

✓ SURFACE ROUGHNESS

HOLE DIA.	TOLERANCE
.0135 THRU .125	+ .004 - .001
.126 THRU .250	+ .005 - .001
.251 THRU .500	+ .006 - .001
.501 THRU .750	+ .008 - .001
.751 THRU 1.000	+ .010 - .001
1.000 THRU 2.000	+ .012 - .001
2.001 AND OVER	LINEAR

CONTRACT NO. 5-120
DRAWN [signature] 6/15/65
CHECK [signature] 6/15/65
MECH ENGR [signature] 6/15/65
ELECT ENGR
PROJ MGR [signature] 6/16/65
APPD
DESIGN ACTIVITY APPD [signature] 10/6/65
CUSTOMER

ML

MARSHALL LABORATORIES
TORRANCE, CALIFORNIA

TITLE MASTER DRAWING LIST PREAMPLIFIER ASSEMBLY OGO E, EXP E16

SIZE	CODE IDENT NO.	DWG NO.	REV
A	13126	MDL51733	B

SCALE —— RELEASED OCT 6 1965 SHEET 1 OF 2

ML FORM 34A

LINE NO.	ASSEMBLY POSITION 1	2	3	4	5	6	7	8	9	QTY	DRAWING NUMBER	REV LTR	DRAWING TITLE	DWG SIZE
1	X										51733-101	NC	PREAMPLIFIER ASSY	F
2		X								1	51733-1	NC	PREAMP SUB ASSY	F
3			X							3	W4319X1	A	PREAMP MODULE	A
4				X						REF	S40840	NC	TEST SPEC	A
5			X							1	W4319X1	A	HEATER MODULE	A
6				X						REF	S40841	NC	TEST SPEC	A
7			X							2	T51943-1	NC	SUPPORT BOARD	B
8		X	X							REF	S40847	NC	TEST SPEC (SYSTEM)	A
9			X							A/R	NRC-2		INSULATION (NATIONAL RESEARCH)	
10		X								1	SP30346-101	NC	HOUSING	E
11			X							1	SP30346-1	NC	HOUSING	E
12		X								1	SP30346-2	NC	COVER	E
13														
14														
15		X								REF	SP30305-2	B	STAMP	C
16		X									SP30306-8	X	STAMP	D
17		X									SP30307-10	P	STAMP	C
18		X									SP30307-11	P	STAMP	C
19		X									51736	A	ENVELOPE DWG	C
20		X								REF	SP30275-( )	D	CAPACITOR	C
21														
22														
23														
24		X	X							REF	S40072	A	FAB & WORKMANSHIP SPEC	
25		X									S40092	B	FOAMING SPEC	
26		X									S40093	A	CONNECTOR POTTING SPEC	
27		X									S40111	B	IDENTIFICATION SPEC	
28		X									S40118	A	PROTECTIVE FINISH SPEC	
29		X									S40126	NC	SOLDERING SPEC	
30			X								S40379	NC	SPOT POTTING SPEC (RTV891)	
31			X							REF	S40522	NC	ADHESIVE BONDING SPEC	
32														
33														
34		X								REF	AMS3654		TUBING SPEC	
35		X								REF	MIL-W-16878		WIRE SPEC	
36			X							REF	MIL-P-18177		EPOXY BOARD SPEC	
37														
38														
39														
40														
41														
42														
43														
44														
45														
46														
47														
48														
49														
50														

MODEL NO. ML293-1

TITLE— MASTER DRAWING LIST —	SIZE	CODE IDENT NO.	DWG NO.	REV
PREAMPLIFIER ASSY, OGOE (EXP E16)	A	13126	MDL 51733	B
	SCALE —	RELEASED	SHEET 2 OF 2	

APPENDIX C

TEST SPECIFICATIONS

1. Mainbody Electronics - S40843
2. Preamplifier - S40847

PARTS DISPOSITION
1. USE
2. REWORK
3. CANNOT BE REWORKED
4. RECORD
5. _____

SPEC NO. S 40843 REV

REVISIONS

DISP	EFF	REV	DESCRIPTION	BY	CK	DATE	APPROVAL

SPEC NO. S 40843 REV

SHEET INDEX	REV																									
	SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20					
SHEET INDEX	REV																									
	SHEET																									

CONTRACT NO. S-120

PREP		
CK	[illegible]	4-27-66
ENGR	R. Lawler	4/27/66
APPD	[illegible]	4/28/66
APPD		
QC APPD	R. Hoffman	4-27-66
DESIGN APPD	[illegible]	4-28-66
CUSTOMER		

M L

MARSHALL LABORATORIES
TORRANCE, CALIFORNIA

TITLE
OGO-E Triaxial Magnetometer
Assembled Unit
Module 51731-101
Test Procedure for

SIZE	CODE IDENT NO.	SPECIFICATION NO.	REV
A	13126	S 40843	

RELEASED

SHEET 1 OF 20

225

ML FORM 202

S-120-7

51-917

1.0 SCOPE

This specification convers the electrical checkout of the OGO-E, Triaxial Magnetometer Assembled Unit.

2.0 APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on the date of invitation for bids, form a part of this specification.

DRAWINGS

Marshall Laboratories	
51731-101	Electronic Assembly
51903	Electronic Schematic
51904	System Wiring
51732	Interface Wiring

2.2 Precedence of Governing Documents. Unless otherwise specified when a requirement of an applicable drawing is in conflict with a requirement specified herin, the requirement specified on the drawing shall apply.

3.0 REQUIREMENTS

3.1 Acceptable results are contingent upon the use of the material and equipment as specified herin. Substitution of material or equipment will not be allowed without prior written approval of Marshall Laboratories Engineering and Quality Control Groups.

3.2 Test Equipment The following test equipment, or equivalent, shall be used to test the Unit.

A. Oscilloscope, Tektronix, Model 502 A.
B. Power Supply, Hewlett-Packard, Model HP 721A.
C. Voltmeter, Triplett, Model 630 NA.
D. Function Generator, Hewlett-Packard, Model 202A.
E. Digital Voltmeter, Cubic Corporation, Model V 71.
F. B.T.E. OGO-E, Triaxial Magnetometer. (Special)
G. Stat-O-Lite, Marshall Laboratories, (Special)
H. Counter, Hewlett Packard, Model 521A.

67-917

1. Complete setup per Figure (1).

2. Set the SYSTEM MONITOR knob to I in.

3. Set the BTE Controls per following:

BTE Power ON	ON
SPACERAFT POWER	ON
INDEX PULSES	EXT
AMPLITUDE	NOM
TIMING SIGNALS	NOM
SCO COMMAND	OFF

4. Check the System Monitor Deviation meter reading. It shall be 27 ± 3 max.

POWER SUPPLY CHECK

1. Set the System Monitor knob to SYNC. Set the SYNC. DEVIATION knob to Min. Vary frequency from + 5% to -5%. System Monitor Meter shall follow changes in frequency. (If the system is not in SYNC; the meter would not move).

2. Check the following test points for proper voltages.

TP	Nominal Voltage (Volts)	Measured Voltage	Remarks
1	+ 20.0 ± 0.020		
2	+ 6.00 ± 0.006		+ 6 volts No. 1
3	+ 6.00 ± 0.006		+ 6 volts No. 2
4	- 6.000 ± 0.006		
5	2.500 ± 0.005		
6	2.60 ± 0.12		
38	+ 23.5 ± 0.025		

27-917

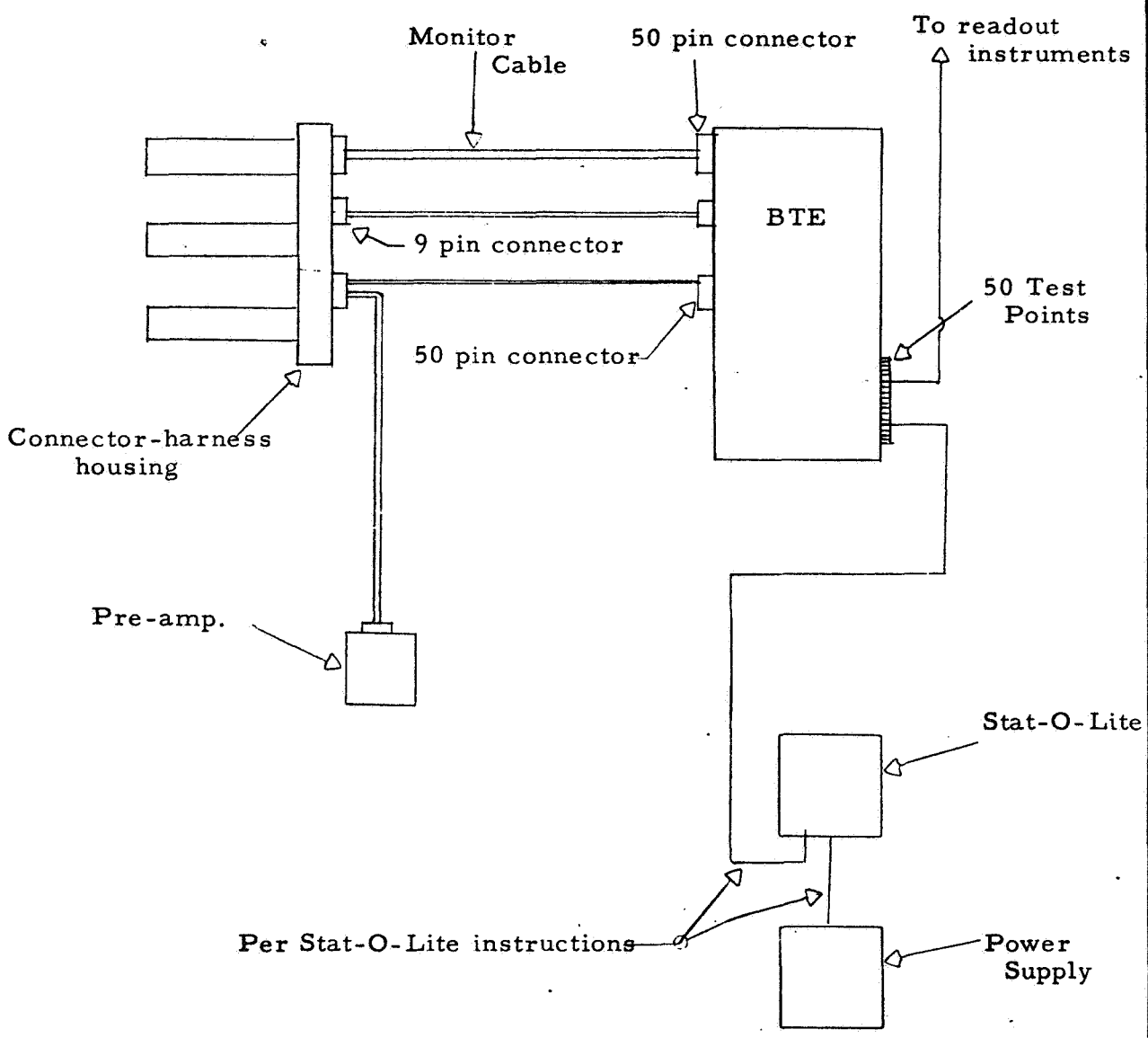


Figure 1. Test setup

ML	MARSHALL LABORATORIES TORRANCE CALIFORNIA	TITLE OGO-E Triaxial Magn. Assembled Unit, Module 51723-101 Test Procedure for	SPECIFICATION NO. S 40823	REV
CODE IDENT NO. 13126			SHEET 4 OF	238

ML FORM 201

67-917

ANALOG AND LOGIC CHECKOUT

1. Check to make sure that IFC is off (Stat-O-Lite, IFC - off light indicator is on. If not, turn the IMPULSE Com. dial to IFC and then push the INITIATE push button once).

2. Ground TP7
   Measure voltage at following test points.

57-917

Test Point Identification	Expected Voltage M volts	Measured Voltage M volts
TP-17, X Axis Demod		
TP-18, Y Axis Demod		
TP-19, Z Axis Demod		
TP-21, X Axis Wave Analyzer spectrum gain = 200		
10 cps channel	± 10	
22 cps channel	± 10	
47 cps channel	± 10	
100 cps channel	± 10	
220 cps channel	± 10	
470 cps channel	± 10	
1000 cps channel	± 10	
TP-22 Y Axis Wave Analyzer spectrum gainin = 200		
10 cps channel	± 10	
22 cps	± 10	
47 cps	± 10	

57-917

Test Point Identification		Expected Voltage M volts	Measured Voltage M volts
	100 cps channel	± 10	
	220 cps channel	± 10	
	470 cps	± 10	
	1000 cps	± 10	
TP-23 Z Axis Wave Analyzer spectrum gain=200			
	10 cps Channel	± 10	
	22 cps Channel	± 10	
	47 cps Channel	± 10	
	100 cps Channel	± 10	
	220 cps Channel	± 10	
	470 cps Channel	± 10	
	1000 cps Channel	± 10	

27-913

Test Point Identification	Expected Voltage MV	Measured Voltage MV
TP-24 X Axis Waveform, gain = 10	2500 ± 15	
gain = 100	2500 ± 15	
gain = 1000	2500 ± 15	
TP-25 Y Axis Waveform, gain = 10	2500 ± 15	
gain = 100	2500 ± 15	
gain = 1000	2500 ± 15	
TP-26 Z Axis Waveform, gain = 10	2500 ± 15	
gain = 100	2500 ± 15	
gain = 1000	2500 ± 15	
TP-27 X Axis Spectrum, gain = 200	2500 ± 15	
TP-28 Y Axis Spectrum, gain = 200	2500 ± 15	
TP-29 Z Axis Spectrum, gain = 200	2500 ± 15	
TP-31 X Axis Wideband Spectrum Gain = 200	± 20	
TP-32 Y Axis Wideband Spectrum gain = 200	± 20	
TP-32 Z Axis Wideband Spectrum gain = 200	± 20	

07-917

3. Check waveform channel per following Table.

* (1)	* (2)	* (3)	* (4)	* (5)	* (6)	* (7)
Input Sinewave p-p Amplitude in MV e_i ± 0.4%	Input Frequency cps ± 2%	Waveform Bandwidth Setting cps	Waveform Gain Setting	Test Point to Measure	Measured Output p-p Amplitude e_o ± 0.4%	Calculated $\frac{e_o}{e_i}$ shall be
200	1	64	10	24		10 ± 0.2
200	1	64	10	25		10 ± 0.2
200	1	64	10	26		10 ± 0.2
200	0.1	64	10	24		10 ± 0.2
200	0.1	64	10	25		10 ± 0.2
200	0.1	64	10	26		10 ± 0.2
200	64	64	10	24		5 ± 2
200	64	64	10	25		5 ± 2
200	64	64	10	26		5 ± 2
200	0.01	64	10	24		5 ± 2
200	0.01	64	10	25		5 ± 2
200	0.01	64	10	26		5 ± 2

67-917

* (1)	* (2)	* (3)	* (4)	* (5)	* (6)	* (7)
Input Sine Wave p-p Amplitude in MV, $e_i \pm 0.4\%$	Input Frequency cps ± 2%	Waveform Bondwidth Setting cps	Waveform Gain Setting	Test Point to Measure	Measured Output p-p Amplitude $e_o \pm 0.4\%$	Calculated $\frac{e_o}{e_i}$ shall be
200	0.1	1	10	24		10 ± 0.01
200	0.1	1	10	25		10 ± 0.1
200	0.1	1	10	26		10 ± 0.1
200	1	1	10	24		5 ± 2
200	1	1	10	25		5 ± 2
200	1	1	10	26		5 ± 2
20	2	64	100	24		100 ± 2
20	2	64	100	25		100 ± 2
20	2	64	100	26		100 ± 2
2	2	64	1000	24		1000 ± 20
2	2	64	1000	25		1000 ± 20
2	2	64	1000	26		1000 ± 20

67-917

* (1) Input sine wave p-p amplitude in MV, $e_i \pm 0.4\%$ Column (1) gives the input signal p-p amplitude written in M volts. The measurement accuracy is ± 0.4%.

* (2) Input frequency cps ± 2%. Column (2) gives the frequency of the input signal. The accuracy of the measurements shall be ± 2%.

* (3) Waveform Bandwidth setting cps. Column (3) gives the bandwidth of waveform channel. Waveform bandwidth may be checked on the Stat-O-Lite.

* (4) Waveform gain setting. Column (4) gives the waveform gain setting. Gain setting may be verified on the Stat-O-Lite and changed by the BTE Initiate Push Button when IMPULSE Com. dial is at WG setting.

* (5) Test point to measure. Column (5) gives the test point number which output shall be measured at.

* (6) Measured output p-p amplitude $e_o \pm 0.4\%$. Column (6) is provided to record the measured output at test p int indicated in Column (5). The output p-p amplitude shall be measured within ± 0,4% accuracy.

* (7) Calculated $\frac{e_o}{e_i}$ shall be. Column (7) gives the acceptable range of the gain

$$\frac{e_o}{e_i} = \left(\frac{\text{Column (6) reading}}{\text{Column (1) reading}}\right).$$

57-917

4. Check spectrum channel. Proceed per following Table.

* (1)	* (2)	* (3)	* (4)			* (5)
Input Amplitude MV ± 0.4%	Input Frequency cps ± 2%	Spectrum Gain Setting	Record Output Signal Amplitude TP-27	TP-28	TP-29	Calculated Gain, (1)/(4) shall be
1000	1	2				1.4 ± 0.5
1000	30	2				2.0 ± 0.04
1000	2000	2				2.0 ± 0.04
100.0	30	20				20 ± 0.4
10.00	30	200				200 ± 4

* (1) Input signal shall be a sine wave, column (1) gives the input signal p-p amplitude in M volts. Measurements shall be done with ± 40% relative accuracy. Input shall be applied to TP-7. Check Stat-O-Lite to make sure that IFC is off.

* (2) Input frequency measured within ± 2% accuracy.

* (3) Spectrum gain setting. Spectrum gain may be verified on the Stat-O-Lite and changed by BTE Initiate. push button when IMPULSE com. dials is set at ST.

* (4) Column 4 is provided to record the measured output. Output shall be measured within ± 0.4% accuracy. Output shall be measured at TP-27, TP-28, and TP-29.

* (5) Column 5 gives the acceptable range of the spectrum gain.

5. Check SCO.

   1. Turn the SCO Command Switch of the BTE to on position. Set the spectrum gain for 2.

   2. Apply 1000 ± 5 M volts p-p 33 ± 1 cps sine wave to TP-7. Check TP-17, TP-18, and TP-19 for a 500 ± 10 M volts p-p 33 ± 1 cps sine wave.

   3. Apply 1000 ± 5 M volts p-p 1 ± 0.02 cps sine wave to TP-7. Check TP-17, TP-18, and TP-19 for a 350 ± 120 M volts p-p 1 ± 0.02 cps sine wave.

   4. Apply 1000 ± 5 M volts p-p 1000 ± 5 cps sine wave to TP-7. Check TP-17, TP-18, and TP-19 for a 500 ± 200 M volts, p-p 1000 ± 5 cps sine wave.

6 Check wave analyzer channel.

6.1 Apply a 235 ± 2 M volts sine wave to TP-3. Make sure that spectrum gain is set at .2. Proceed per following table. Output measurements shall be done at TP- 21.

Channel No. to be measured	Resonance Frequency Expected cps ± 5%	Resonance Frequency Measured ± 1%	Peak Amplitude Expected ± 2% Mvolts	Peak Amplitude Measured ± 0.5% M volts
Channel 1	10		2000	
Channel 2	21.7		2000	
Channel 3	46.7		2000	
Channel 4	100		2000	
Channel 5	217		2000	
Channel 6	467		2000	
Channel 7	1000		2000	

67-917

6.2 Apply a 235 ± 2 M volts sine wave to P18. Make sure that spectrum gain is set at 2. Proceed per following table. Output measurements shall be done at TP- 22

Channel No. to be measured	Resonance Frequency Expected cps ± 5%	Resonance Frequency Measured ± 1%	Peak Amplitude Expected ± 2% Mvolts	Peak Amplitude Measured ± 0.5% M volts
Channel 1	10		2000	
Channel 2	21.7		2000	
Channel 3	46.7		2000	
Channel 4	100		2000	
Channel 5	217		2000	
Channel 6	467		2000	
Channel 7	1000		2000	

67-917

6.3 Apply a 235 ± 2 M volts sine wave to TP-8. Make sure that spectrum gain is set at .2. Proceed per following table. Output measurements shall be done at TP-23

Channel No. to be measured	Resonance Frequency Expected cps ± 5%	Resonance Frequency Measured ± 1%	Peak Amplitude Expected ± 2% Mvolts	Peak Amplitude Measured ± 0.5% M volts
Channel 1	10		2000	
Channel 2	21.7		2000	
Channel 3	46.7		2000	
Channel 4	100		2000	
Channel 5	217		2000	
Channel 6	467		2000	
Channel 7	1000		2000	

37-917

6.4

Input Frequency cps ± 1%	Output Signal in Mvolts measured at TP- 2\ Use Digital voltmeter						
	Chan. 1	Chan. 2	Chan. 3	Chan. 4	Chan. 5	Chan.6	Chan.7
10							
22							
47							
100							
220							
470							
1000							

Input signal shall be applied to TP-8. Channels may be verified on the Stat-O - Lite and changed by the Ext. COMMAND push button of the ETE when the INDEX PULSES dial is set at EXT. position. Record the output measurements in the above table. The above table shall be approved by the project engineer.

Approved .....

Not Approved .....

67-917

6.5

Input Frequency cps ± 1%	Output Signal in Mvolts measured at TP-22 Use Digital voltmeter						
	Chan. 1	Chan. 2	Chan. 3	Chan. 4	Chan. 5	Chan.6	Chan.7
10							
22							
47							
100							
220							
470							
1000							

Input signal shall be applied to TP-8. Channels may be verified on the Stat-/0 - Lite and changed by the Ext. COMMAND push button of the STE when the INDEX PULSES dial is set at EXT. position. Record the output measurements in the above table. The above table shall be approved by the project engineer.

Approved .....

Not Approved .....

6.6

Input Frequency cps ± 1%	Output Signal in Mvolts measured at TP- 23 Use Digital voltmeter						
	Chan. 1	Chan. 2	Chan. 3	Chan. 4	Chan. 5	Chan.6	Chan.7
10							
22							
47							
100							
220							
470							
1000							

Input signal shall be applied to TP-8. Channels may be verified on the Stat-O - Lite and changed by the Ext. COMMAND push button of the STE when the INDEX PULSES dial is set at EXT. position. Record the output measurements in the above table. The above table shall be approved by the project engineer.

Approved .....

Not Approved .....

07-917

7.0 Wide Band Channel Checkout

7.1 Apply a 2.000 ± 0.005V p-p 30 ± 2% cps sine wave to TP-8. Make sure that the Spectrum gain is set at 2. Measure output at TP-31, TP-32, and TP33. Output shall be a DC level, 4.000 ± 0.80V.

7.2 Apply a 2.000 ± 0.005V p-p 1000 ± 2% cps sine wave to TP-8. Make sure that the Spectrum gain is set at 2. Measure output at TP-31, TP-32, and TP-33. The output shall be 2.000 ± 0.800 V DC.

7.3 Apply a 2.000 ± 0.005V p-p 1.0 ± 2% cps sine wave to TP-8. Make sure that the Spectrum gain is set at 2. Measure output at TP-31, 32, and 33. The output shall be 2.000 ± 0.800V DC.

8.0 Status-Power-SCO

8.1 Turn the SCO COMMAND switch to OFF position. Voltage at TP-37 shall be 3.37 ± 0.17 DC.

8.2 Turn the SCO COMMAND switch to ON position. Voltage at TP-37 shall be 1.70 ± 0.17V DC.

PARTS DISPOSITION	SPEC NO.	REV
1. USE 3. CANNOT BE REWORKED 2. REWORK 4. RECORD 5.	S 07-917	

REVISIONS

DISP	EFF	REV	DESCRIPTION	BY	CK	DATE	APPROVAL

REV

SPEC NO. S

SHEET INDEX	REV / SHEET																										
	REV																										
	SHEET																										
SHEET INDEX	REV / SHEET																										

CONTRACT NO. 5-120		M L	MARSHALL LABORATORIES TORRANCE, CALIFORNIA
PREP		TITLE	Preamplifier Assembly, OGO-E Triaxial S. C. Magnetometer Test Procedure for
CK	4-27-66		
ENGR	4/27/66		
APPD	4/27/66		
APPD			
QC APPD	4-28-66		
DESIGN APPD	5/3/66		
CUSTOMER			

SIZE	CODE IDENT NO.	SPECIFICATION NO.	REV
A	13126	S40847	

RELEASED

SHEET 1 OF 25

1.0 SCOPE

This specification covers the electrical checkout of the Preamplifier Assembly, OGO-E Triaxial S.C. Magnetometer.

2.0 APPLICABLE DOCUMENTS

2.1 The following documents, of the issue and revision in effect on the date of invitation for bids, form a part of this specification to the extent specified herein:

DRAWINGS

Marshall Laboratories

51733-101	Preamplifier Assembly
51734-101	Sensor Assembly
51732	Interface Wiring Diagram

2.2 Precedence of Governing Documents. Unless otherwise specified, when a requirement of an applicable specification is in conflict with a requirement specified herein, the requirement specified herein shall apply. When a requirement of an applicable drawing is in conflict with a requirement specified herein, the requirement specified on the drawing shall apply.

3.0 REQUIREMENTS

3.1 Acceptable results are contingent upon the use of the equipment and test procedures as specified herein. The test shall be performed in the exact order specified herein.

3.2 Standard Test Equipment. The following standard test equipment, OR EQUIVALENT, shall be used to check out the unit:

A. Oscilloscope, Tektronix, Model 535A.
B. Plug-In Unit, Tektronix, Type CA.
C. Power Supply, Hewlett-Packard, Model HP721A.
D. Voltmeter, Triplett, Model 630NA.
E. Audio Oscillator, Hewlett-Packard, Model HP200CD.
F. Digital Voltmeter, Cubic, Model V-71.
G. Vacuum Tube Volt Meter, Hewlett-Packard, Model HP400H.
H. Recorder, Texas Instruments, Oscilo/riter.

3.3 Special Test Equipment. The following special test equipment, not available commercially, shall be used to check out the module:

A. Noise Amplifier, ML, Special.

07-917

3.4 Test Procedure

3.4.1 Connect test equipment as shown in Test Setup No. 1.

3.4.2 Output dc resting level test.

3.4.2.1 Short pin 5 (IFC Signal) to ground.

3.4.2.2 Measure output voltage at pins 1, 2 and 6. (X, Y and Z Axis, respectively). Output voltage should be +5 ± 1.5 volts dc.

3.4.2.3 Record data in Table 1.

3.4.3 Output ac gain and response test.

3.4.3.1 Place a 100 ± 10 cps, 1.000 ± 0.005 Vrms sine wave signal into pin 5.

3.4.3.2 Outputs at pins 1, 2 and 6 shall be 1.000 ± 0.015 Vrms.

3.4.3.3 Record data in Table 1.

3.4.3.4 Change input signal to 1000 ± 50 cps with same amplitude as 3.4.3.1.

3.4.3.5 Outputs shall be 0.97 ± .02 Vrms.

3.4.4 Heater Test.

3.4.4.1 Place a milliammeter (VO19) from pin 4 to ground.

3.4.4.2 Current should measure 720 ± 100 μa at +25° C (RT) and + 50° C. Current should be 6.8 ± .5 ma at -50° C.

3.4.4.3 Record data in Table 1.

3.4.5 The above steps shall be performed at +25° C (RT), +50° C and -50° C.

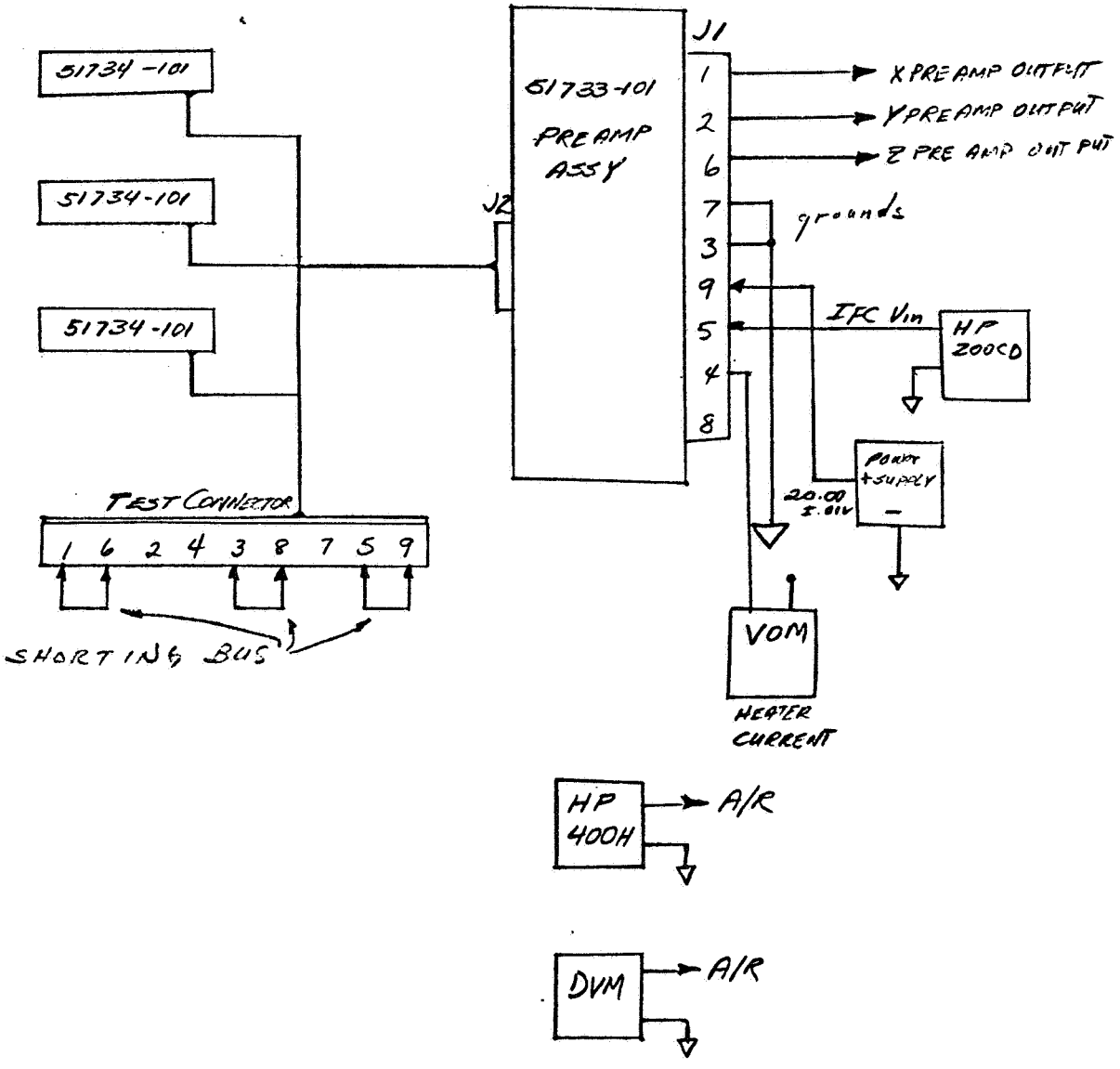
3.4.6 Noise test (RT only)

3.4.6.1 Connect test equipment as shown in Test Setup No. 2.

3.4.6.2 Measured output noise shall be less than 5 millivolts pk-pk over a 100 second interval.

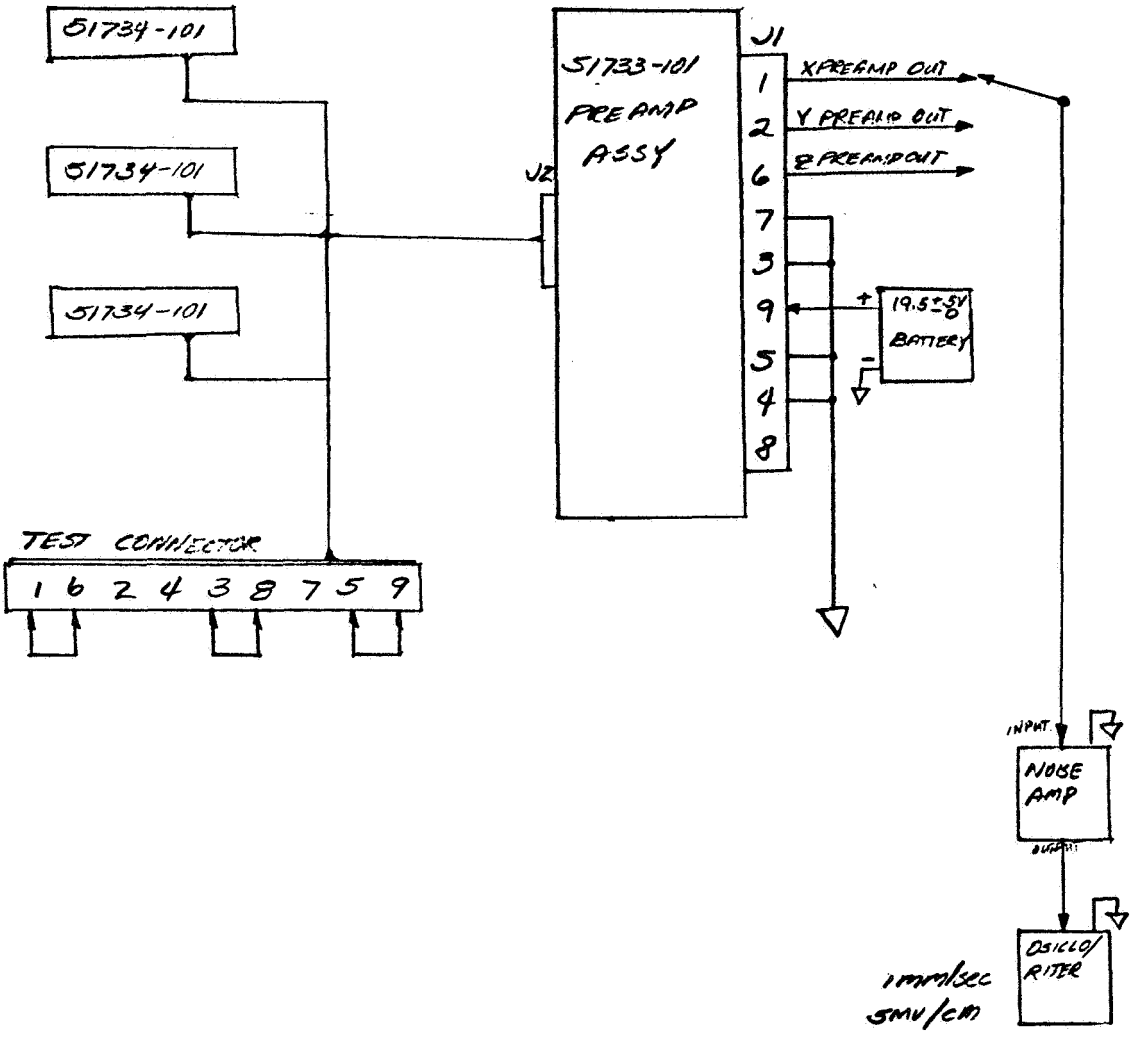
3.4.6.3 Record data in Table 1.

07-917



TEST SETUP #1

M L MARSHALL LABORATORIES TORRANCE CALIFORNIA		TITLE Preamplifier Assembly, OGO-E Triaxial S.C. Magnetometer Test Procedure for	SPECIFICATION NO. S 40847	REV
CODE IDENT NO 13126			SHEET 4 OF 7	



TEST SETUP #2

M L MARSHALL LABORATORIES TORRANCE CALIFORNIA	TITLE Preamplifier Assembly, OGO-E Triaxial S.C. Magnetometer Test Procedure for	SPECIFICATION NO. S 40847	REV
CODE IDENT NO 13126		SHEET 5 OF	

TABLE I

67-917

Test	Axis	Output Data		
		+25° C (RT)	+ 50° C	- 50° C
Para 3.4.2.3 DC Level	X	Vdc	Vdc	Vdc
	Y	Vdc	Vdc	Vdc
	Z	Vdc	Vdc	Vdc
Para 3.4.3.3 100 cps Gain	X	Vrms	Vrms	Vrms
	Y	Vrms	Vrms	Vrms
	Z	Vrms	Vrms	Vrms
Para 3.4.3.5 100 cps Gain	X	Vrms	Vrms	Vrms
	Y	Vrms	Vrms	Vrms
	Z	Vrms	Vrms	Vrms
Para 3.4.4.3 Heater Current		μa	ma	ma
Para 3.4.6.3 NOISE	X	mv p-p	NA	NA
	Y	mv p-p	NA	NA
	Z	mv p-p	NA	NA

NOTE: X Axis Output = Pin 1
Y Axis Output = Pin 2
Z Axis Output = Pin 6

APPENDIX D

NEW TECHNOLOGY REPORTS

1. Preamplifier
2. Gain Change Amplifier
3. Voltage Controlled Oscillator

NEW TECHNOLOGY DISCLOSURE REPORTABLE ITEM	1. Reporting Organization: Marshall Laboratories Address: 3530 Torrance Boulevard, Torrance, California 90503	
	2. Contract Number: JPL 951142	

A "Reportable Item" is any innovation, invention, improvement or discovery conceived or first reduced to practice in performing work under the above identified NASA contract and includes (but is not limited to) any new or improved product, device, material, process or method and should be promptly reported to the Contractor's New Technology Representative.

The questions below are not intended to limit information regarding the Reportable Items; however, it must be complete enough for others to fully understand the disclosures and its implications and possible applications.

3. Title of Disclosure: Search Coil Magnetometer Sensor Preamplifier

4. Brief (Abstract) Description: The preamplifier was designed and developed to amplify the low level output of a passive search coil sensor from DC to 1000 Hz. Field effect transistors (FET) employed were selected for their very low noise and high input impedance.

5. Description (Attach sheets as required)

A. Give complete information in the following order:

(1) General purpose of the item.
(2) Improvement and/or advantages over prior methods, materials, or devices.
(3) Detailed description including as applicable the explanation of the principle of operation: details of the preparation of the process and/or materials; technical data, drawings, and sketches. These should be included as required to fully describe the Item. Include reference drawings, specifications, technical reports, test reports, and other technical information which will be useful in the evaluation of the Disclosure. (If a document containing excerpts of the requested description exists, it may be attached to meet this requirement).
(4) Features of the Item believed to be new.
(5) Additional information to more fully describe the Item.
(6) Does the contractor intend to file a patent application?

Yes X No TBD

B. Identify any previous publication of the Disclosure.

None ___X___ See attached sheet _____

C. List publications pertaining to this Item and where they may be obtained.

None ___X___ See attached sheet _____

6. Applications: Include possible industrial and other non-aerospace uses. Identify specific industries, processes, or products in which the Reportable Item might find application or to which it might be related.

This preamplifier could be employed for amplification of extremely low level signals.

7. What are possible extensions of this Item: NA

8. Degree of Development. Check applicable stage:

_____ Concept only _____ Development completed; prototype available

___X___ Limited production _____ Other-Remarks _____

9. Technological significance: In relation to the present state of technology, this Reportable Item is considered to be a:

_____ Major improvement _____ Substantial advance in the art ___X___

Design improvement

10. Optional-Publication of Reportable Items

It appears at this time that publication of this reportable item:

a. _____ would be of value to the Aerospace Industry

b. _____ would be of value outside the Aerospace Industry. If so, one or more of the following are recommended:

(1) _____ a multiple-page Contractor Report

(2) _____ a brief draft of a scientific Journal Announcement

(3) ___X___ a brief announcement (NASA Tech Brief) for republication on a technical or trade publication

c. _____ publication is not warranted at this stage of development.

11. Innovator's Name(s)

Signature Norman Katz Date 1/31/68

Type or print name Norman Katz PE

12. Technical Supervisor of Innovator(s)

Signature Robert Kobayashi Date 1/31/68

Type or print name Robert Kobayashi

13. Contractor's Technology Utilization Representative

Signature George R. Mohler Date 2/1/68

Type or print name George R. Mohler

5. A Description of the Search Coil Magnetometer Sensor Preamplifier

JPL Contract 951142

1.0 PURPOSE

The purpose of the preamplifier is to amplify the output signal from a passive search coil magnetometer sensor. This preamplifier circuit was designed as part of the OGO-E-16 Triaxial Search Coil Magnetometer.

2.0 IMPROVEMENT and/or ADVANTAGE OF DESIGN

This design incorporates for the first time for the OGO-E Search Coil Magnetometer the use of field effect transistors for the input stage and a matched differential dual FET amplifier for the second stage. To increase frequency response, the input cable and sensor shunt capacitance is cancelled by driving it with a unity gain output stage.

These changes have resulted in a lower noise figure than have previously been achieved in the frequency range from DC to 1 K Hz.

3.0 DETAILED DESCRIPTION

The preamplifier characteristics are as follows:

Input Impedance	$\geq 10^9$ ohms shunted by 10 picofarads
Output Impedance	$< 10^2$ ohms +20 volts at 1.5 ma
Frequency Response	DC to 3600 Hz (-3db)
Output Voltage	1 volt RMS into 50 K ohm
Gain	100 ± 1
Noise	a) <1 microvolt RMS from 0.01 Hz to 1 Hz b) <0.01 microvolt squared per Hz from 5 Hz to 1 K Hz
Operating Temperature	-50°C to $+60^\circ$C

Figure 1 shows the circuit diagram of the OGO-E Search Coil Magnetometer preamplifier. The amplifier consists of a cascode N channel FET amplifier, Q_3 which in turn drives the PNP differential amplifier Q_4 and Q_5. The output stage is a PNP emitter follower to provide low output impedance.

The open loop gain of the preamplifier is about 10^4, and the closed loop low frequency gain is 100, determined by the ratio of R5 and R12. Capacitor C3, shunting R12, limits the high frequency response by increasing the feedback at higher frequencies resulting in decreased gain. The -3db break point occurs at about 3.6 KHz.

The bias point of the field transistors Q_1 and Q_2 is determined by resistors R1 through R6. By proper selection of R3, R4 and R6 a quiescent drain current is set such that the cascode amplifier exhibits a near zero temperature coefficient over the operating range of -50°C to +40°C. The thermal stability of the cascode amplifier in conjunction with the inherent stability of the differential amplifier ensures bias point stability over the entire operating temperature range of -50°C to +60°C.

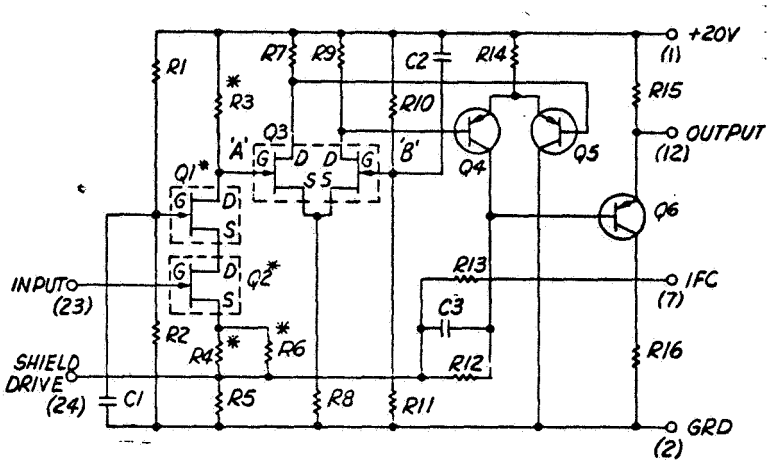
Capacitors C1 and C2 provide power supply decoupling, improving the low noise characteristic of the preamplifier. Resistors R13 and R5 form a 100:1 voltage divider for the injection of the in flight calibration signals provided by the main electronics assembly.

4.0 NEW FEATURES

The usage of selected very low noise N channel field effect transistors for high input impedance and low noise.

5.0 ADDITIONAL INFORMATION

For additional information reference OGO-E Search Coil Magnetometer Final Engineering Report and/or Marshall Laboratories, 3530 Torrance Boulevard, Torrance, California 90503.



Preamplifier Module
Figure 1

$Q_1 = Q_2$ = U1380	Transistor	$C_1 = C_2$ = .1 ufd
Q_3 = SU2066	"	C_3 = 2200 pf
$Q_4 = Q_5 = Q_6$ = SM9139H	"	
R_1 = 300K ± 5%	Resistor	
R_2 = 100K ± 5%	"	
R_3 = Select	"	
R_4 = Select	"	
R_5 = 200 ohm ± 1%	"	
R_6 = Select	"	
$R_7 = R_9$ = 51K ± 5%	"	
R_8 = 56K ± 5%	"	
$R_{10} = R_{11}$ = 100K ± 1%	"	
$R_{12} = R_{13}$ = 20K ± 1%	"	
R_{14} = 12K ± 5%	"	
R_{15} = 30K ± 5%	"	
R_{16} = 1K ± 5%	"	

NEW TECHNOLOGY DISCLOSURE REPORTABLE ITEM

1. Reporting Organization: Marshall Laboratories
   Address: 3530 Torrance Boulevard, Torrance, California 90503
2. Contract Number: JPL 951142

A "Reportable Item" is any innovation, invention, improvement or discovery conceived or first reduced to practice in performing work under the above identified NASA contract and includes (but is not limited to) any new or improved product, device, material, process or method and should be promptly reported to the Contractor's New Technology Representative.

The questions below are not intended to limit information regarding the Reportable Items; however, it must be complete enough for others to fully understand the disclosures and its implications and possible applications.

3. Title of Disclosure: Gain Change Amplifier

4. Brief (Abstract) Description: The GCA can have a fixed gain of 1.4 or 14 depending on the gain control state. Two gain states allow an instrument gain to cover a wide dynamic range of input signals.

5. Description (Attach sheets as required)

A. Give complete information in the following order:

(1) General purpose of the item.
(2) Improvement and/or advantages over prior methods, materials, or devices.
(3) Detailed description including as applicable the explanation of the principle of operation: details of the preparation of the process and/or materials; technical data, drawings, and sketches. These should be included as required to fully describe the Item. Include reference drawings, specifications, technical reports, test reports, and other technical information which will be useful in the evaluation of the Disclosure. (If a document containing excerpts of the requested description exists, it may be attached to meet this requirement).
(4) Features of the Item believed to be new.
(5) Additional information to more fully describe the Item.
(6) Does the contractor intend to file a patent application?

Yes X No TBD

B. Identify any previous publication of the Disclosure.

None X See attached sheet _____

C. List publications pertaining to this Item and where they may be obtained.

None X See attached sheet _____

6. Applications: Include possible industrial and other non-aerospace uses. Identify specific industries, processes, or products in which the Reportable Item might find application or to which it might be related.

The amplifier can be employed wherever there is a need for a fixed controllable gain.

7. What are possible extensions of this Item: NA

8. Degree of Development. Check applicable stage:

_____ Concept only _____ Development completed; prototype available

X Limited production _____ Other-Remarks _____

9. Technological significance: In relation to the present state of technology, this Reportable Item is considered to be a:

_____ Major improvement _____ Substantial advance in the art X

Design improvement

10. Optional-Publication of Reportable Items

It appears at this time that publication of this reportable item:

a. _____ would be of value to the Aerospace Industry

b. _____ would be of value outside the Aerospace Industry. If so, one or more of the following are recommended:

(1) _____ a multiple-page Contractor Report

(2) _____ a brief draft of a scientific Journal Announcement

(3) X a brief announcement (NASA Tech Brief) for republication on a technical or trade publication

c. _____ publication is not warranted at this stage of development.

269

11. Innovator's Name(s)

Signature Dean Aalami Date 1-30-68

Type or print name Dean Aalami

12. Technical Supervisor of Innovator(s)

Signature Robert Kobayashi Date 1-30-68

Type or print name Robert Kobayashi

13. Contractor's Technology Utilization Representative

Signature George R. Mohler Date 2/1/68

Type or print name George R. Mohler

5. A Description of the Gain Change Amplifier JPL Contract 951142

1.0 PURPOSE

The purpose of the gain change amplifier is to provide an amplification of 1.4 or 14 upon a command control.

2.0 IMPROVEMENT AND/OR ADVANTAGE OF DESIGN

This design incorporates for the first time for the OGO-E Search Coil Magnetometer a dual FET input stage for high input impedance. This allows the usage of a smaller ceramic, low leakage capacitor between amplifiers. For a high pass frequency of .004Hz a 1.8μf capacitor can be employed.

3.0 DETAILED DESCRIPTION

The gain change amplifier is essentially a two stage differential amplifier followed by an emitter follower. A high input impedance is realized by use of an FET differential input stage. The gain of the amplifier is a function of the feedback elements.

Figure 1 shows a detailed schematic of the gain change amplifier. Q_1 is a matched N channel field effect transistor used in a differential circuit to optimize the thermal stability of the bias current. The offset compensation of this stage is accomplished by use of select resistor R4 and R5. This stage has a nominal gain of 2.5 and drives a differential amplifier made of matched PNP transistors Q_3 and Q_4. This helps achieve maximum bias point temperature stability. The voltage gain of the second stage is nominally 400. This isolation amplifier Q_5 is operated in the emitter follower mode and has unity gain. The open loop gain, being the product of the gains of the individual stages, is nominally 10^3. The closed loop gain is determined by the ratio of R11 to the parallel combination of R7 and R8 where the control transistor Q_2 is "Off". The control transistor is kept "Off" as long as there is no positive signal applied to its base. When such a signal appears, the control transistor turns "On" and the closed loop gain is determined by the ratio of R11 to the parallel combination of R7, R8, R9 and R10. See Figure 2. In order to prevent high frequency oscillations inherent in high gain amplifiers, the filter network R14, C1 and R15, C2 is inserted in the circuit. The change gain amplifier is characterized by a low output impedance, stable gain change and a very good gain stability over a temperature of $-15^{\circ}C$ to $+60^{\circ}C$.

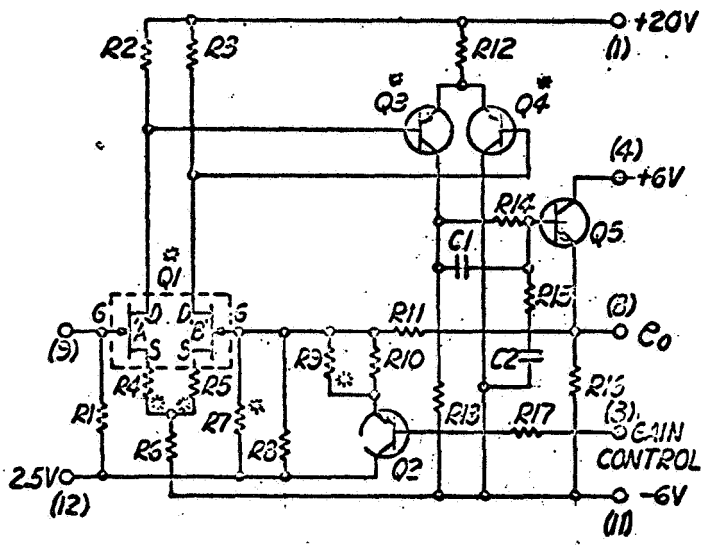
4.0 NEW FEATURES

The usage of a matched pair field effect transistors to achieve very high input impedance and low noise.

271

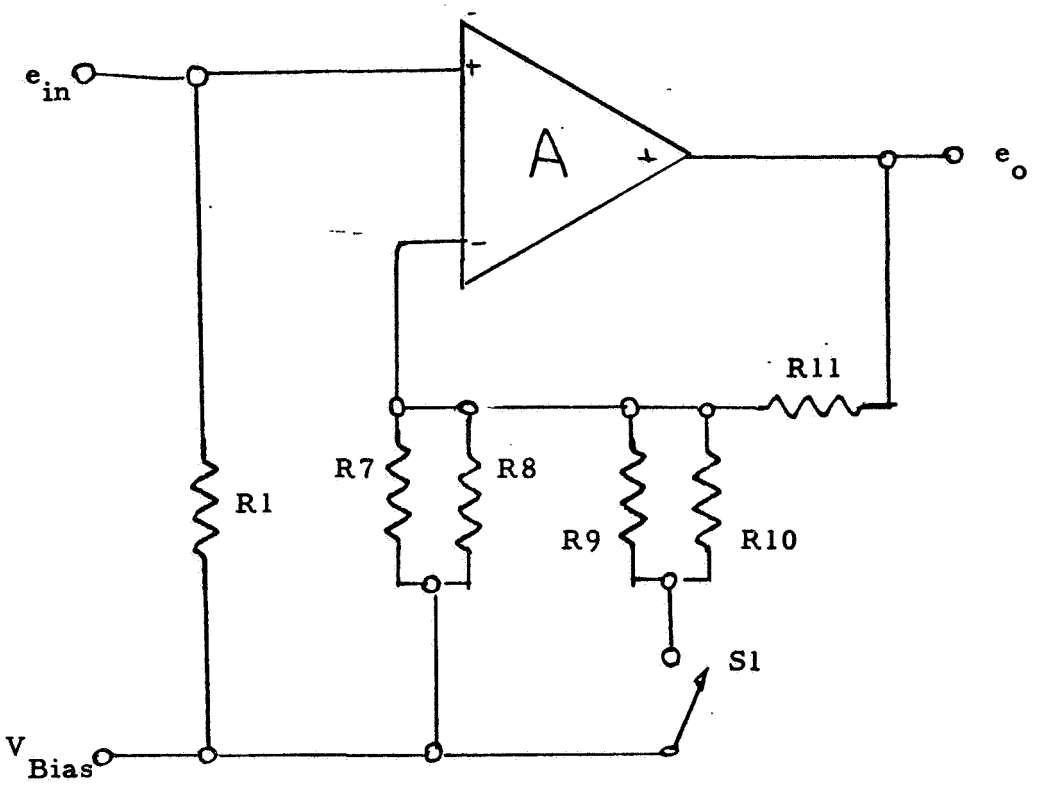
5.0 ADDITIONAL INFORMATION

For additional information reference OGO-E Search Coil Magnetometer Final Engineering Report and/or Marshall Laboratories, 3530 Torrance Boulevard, Torrance, California 90503.



Gain Change Amplifier Module
(Figure 1)

Q_1 = SU2066	Transistor	R_{14} = 10K ± 5%	Resistor
Q_2 = GT5968	"	R_{15} = 1K ± 5%	"
Q_3 = Q_4 = SM9139H	"	R_{16} = 33K ± 5%	"
Q_5 = 2N2484	Transistor	R_{17} = 39K ± 5%	Resistor
R_1 = 22 Meg. ± 5%	Resistor	C_1 = 120pf	Capacitor
R_2 = R_3 = 47.5K ± 1%	"	C_2 = 1000 pf	Capacitor
R_4 & R_5 = Select ± 5%	"		
R_6 = 49.9K ± 1%	"		
R_7 & R_9 = Select ± 5%	"		
R_8 = 100K ± 1%	"		
R_{10} = 3.24K ± 1%	"		
R_{11} = 40.2K ± 1%	"		
R_{12} = 25.5K ± 1%	"		
R_{13} = 120K ± 5%	"		



Note: R7 and R9 are Gain Trim Resistors

Figure 2
Simplified Equivalent Circuit of Gain Change

67-917

NEW TECHNOLOGY DISCLOSURE REPORTABLE ITEM	1. Reporting Organization: Marshall Laboratories Address: 3530 Torrance Boulevard, Torrance, California 90503	
	2. Contract Number: JPL 951142	

A "Reportable Item" is any innovation, invention, improvement or discovery conceived or first reduced to practice in performing work under the above identified NASA contract and includes (but is not limited to) any new or improved product, device, material, process or method and should be promptly reported to the Contractor's New Technology Representative.

The questions below are not intended to limit information regarding the Reportable Items; however, it must be complete enough for others to fully understand the disclosures and its implications and possible applications.

3. Title of Disclosure: Voltage controlled oscillator

4. Brief (Abstract) Description: The miniature VCO was designed to telemeter real time waveform of a triaxial S. C. Magnetometer. Center frequencies of 40K, 52. 5K and 70K Hz were employed. Frequency deviation sufficient to handle up to 1 KHz input signal were employed.

5. Description (Attach sheets as required)

A. Give complete information in the following order:

(1) General purpose of the item.
(2) Improvement and/or advantages over prior methods, materials, or devices.
(3) Detailed description including as applicable the explanation of the principle of operation: details of the preparation of the process and/or materials; technical data, drawings, and sketches. These should be included as required to fully describe the Item. Include reference drawings, specifications, technical reports, test reports, and other technical information which will be useful in the evaluation of the Disclosure. (If a document containing excerpts of the requested description exists, it may be attached to meet this requirement).
(4) Features of the Item believed to be new.
(5) Additional information to more fully describe the Item.
(6) Does the contractor intend to file a patent application?

Yes X No TBD

B. Identify any previous publication of the Disclosure. 21917

None X See attached sheet _____

C. List publications pertaining to this Item and where they may be obtained.

None X See attached sheet _____

6. Applications: Include possible industrial and other non-aerospace uses. Identify specific industries, processes, or products in which the Reportable Item might find application or to which it might be related.

The VCO can be employed where signals from 1 to 1000 Hz are desired to be transmitted through a FM/FM system.

7. What are possible extensions of this Item: NA

8. Degree of Development. Check applicable stage:

_____ Concept only _____ Development completed; prototype available

X Limited production _____ Other-Remarks _____

9. Technological significance: In relation to the present state of technology, this Reportable Item is considered to be a:

_____ Major improvement _____ Substantial advance in the art X

Design improvement

10. Optional-Publication of Reportable Items

It appears at this time that publication of this reportable item:

a. _____ would be of value to the Aerospace Industry

b. _____ would be of value outside the Aerospace Industry. If so, one or more of the following are recommended:

(1) _____ a multiple-page Contractor Report

(2) _____ a brief draft of a scientific Journal Announcement

(3) X a brief announcement (NASA Tech Brief) for republication on a technical or trade publication

c. _____ publication is not warranted at this stage of development.

11. Innovator's Name(s)

Signature Norman Katz Date 1/31/68

Type or print name Norman Katz PE

12. Technical Supervisor of Innovator(s)

Signature Robert Kobayashi Date 1/31/68

Type or print name Robert Kobayashi

13. Contractor's Technology Utilization Representative

Signature George Mohler Date 2/1/68

Type or print name George Mohler

5.A Description of the Voltage Controlled Oscillator JPL Contract 951142

1.0 PURPOSE

The purpose of the subcarrier oscillator is to frequency modulate the wideband signals from the X, Y and Z axis of the OGO-E Search Coil Magnetometer for special purpose telemetry transmission.

2.0 IMPROVEMENT AND/OR ADVANTAGE OF DESIGN

This design incorporates for the Search Coil Magnetometer, a low power circuit with improved stability as a function of temperature and greater linearity over the modulating frequency range of 1Hz to 100 Hz.

Frequency deviations of ± 15% was used for the 40 KC SCO and ± 7.5% for the 52.5 KC and 70 KC SCO's.

3.0 DETAILED DESCRIPTION

The subcarrier oscillator is, essentially, a frequency controlled astable multivibrator driven by a current source. Better stability over temperature is realized by operating the current source in a common base mode and input signal coupled to the emitter.

Figure 1 shows a detailed circuit schematic of the subcarrier oscillator. Transistor Q_1 and Q_2 along with timing capacitors C2 and C3 constitute the multivibrator. Transistors Q_3 and Q_4 control the charging current through C2 and C3. Increasing the charging current decreases the charge time of the capacitors, thereby, increasing the frequency of oscillation. The output frequency of the SCO is, therefore, proportional to the amplitude of the input signal. Bias current stability is provided by the complementary emitter follower Q_5. The variations in the base emitter junctions of Q_3 and Q_4 with temperature will be cancelled out by the opposing base emitter junction of Q_5. The diode CR2 provides isolation between the SCO and the output amplifier Q_6. The diode CR3 serves to stabilize the bias of Q_6, and CR1 turns "Off" the SCO by clamping the base of Q_1 to +6 volts.

4.0 NEW FEATURES

The application of many known techniques were applied to achieve an overall improved circuit.

5.0 ADDITIONAL INFORMATION

For additional information reference OGO-E Search Coil Magnetometer Final Engineering Report and/or Marshall Laboratories, 3530 Torrance, Boulevard, Torrance, California 90503.

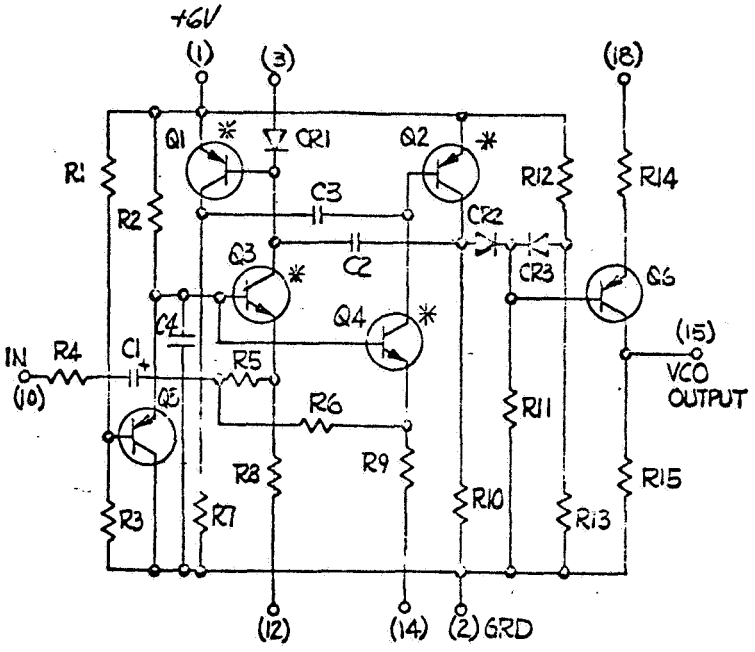


Figure 1

$Q_1 Q_2$ = 2N3486	Transistor	C_1 = 4.7 μfd	Capacitor
$Q_3 = Q_4$ = 2N2484	"	$C_2 = C_3$ = 270 pf	"
$Q_5 = Q_6$ = SM9139H	"	C_4 = 10,000 pf	"
CR1 = CR2 = CR3 = DHD115	Diode		
$R_1 = R_5 = R_6$ = 100K ± 1%	Resistor		
R_2 = 68K ± 5%	"		
R_3 = 90.9K ± 1%	"		
$R_4 = R_8 = R_9 = R_{13}$ = 30.1K ± 1%	"		
$R_7 = R_{10}$ = 6.8K ± 5%	"		
R_{11} = 220K ± 5%	"		
R_{12} = 63K ± 5%	"		
R_{14} = 4.42K ± 1%	"		