Title

Chamberlain Proton Spin Resonance RF System 1260 Operating and Service Manual Volume II

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Publication Date

1967-02-01

UCRL-17548
Vol. II

University of California

Ernest O. Lawrence Radiation Laboratory

CHAMBERLAIN PROTON SPIN RESONANCE RF SYSTEM 1260
OPERATING AND SERVICE MANUAL

Volume II

February 21, 1967

Berkeley, California

UCRL-17548
Vol. II

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

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FOREWORD

This description of the 10X1260 rack is intended to familiarize users with its design, construction, and expected performance. System 1260, an electronically-tuned oscillator-amplifier system, was developed in collaboration with the Chamberlain Polarized Target Group over a period of several years to help meet the evolving needs of that group, and should be considered as the current stage of development. The forerunner of 10X1260 should be mentioned here, the 10X1140, developed by R. F. Tusting of the LRL Electronics Research Group. We recognize several possible engineering advances that can be made in System 1260 as physics requirements may warrent.

A preliminary description of the low-noise amplitude-stabilized oscillator appeared in 22 March 1965 "Notes on Oscillator Design for the Chamberlain Polarized Target Spin Resonance Amplifier," Q. A. Kerns. Additional information on selected components for 10X1260 appears in "System 1260 Special Components Log Book," and further measurements in "System 1260 Measurements Log Book." These are available in the LRL Electronics Research Group Office, Building 80, Room 024.

The never-failing encouragement and support of Prof. Chamberlain and his group remains a central factor in this development. Eric Young and Bob Reynolds solved the many assembly problems with enthusiasm. We want to thank A. H. Rehbein for drawings and Mrs. Suzanne Salter for typing the manuscript.

Permission to reprint certain brochures, circuit diagrams and manuals of the commercially produced sub-assemblies of the System 1260 is gratefully acknowledged.

Q. A. Kerns
H. W. Miller
A. K. Wolverton

SYSTEM 1260

RF-OSCILLATOR & AMPLIFIER

Condensed Specification Sheet

Electronic Tuning Range...........	78-79 MHz
RF Amplitude to Target Coil.......	Zero to 200 mV via waveguide attenuator
Oscillator-Amplifier Tracking Error..................	<10 kHz
Oscillator Frequency Stability....	<2 kHz drift/24 hours
Tuning Speed......................	After a step command, the frequency accomplishes 99% of its programmed excursion within 10 μsec.
Amplifier Gain Range..............	5-10-25-50-100
Amplifier Gain Stability..........	<500 ppm drift/72 hours
Amplifier Bandwidth...............	14 MHz between 3 db points, flat to 0.1% over 1 MHz
Detection Bandwidth...............	100 kHz
Detector Voltage Readout..........	VTF converter, 0-100 kHz rate
Readout Settling Time.............	100 μsec to 0.01%
VTF Converter Calibration.........	Rack-mounted Standard Cell
Weight............................	300 lb.
Dimensions........................	51-1/2" X 22" X 18"
Power Input.......................	117 V, 60 Hz, 366 VA
Electrical Shielding..............	Gaussian enclosure, suitable for operation in electrically-noisy environments
Running Time Meter................	Self contained; system is intended for continuous operation
Instrumentation Panel Lettering......................	Functional Flow Diagram integrated with panel controls

SYSTEM 1260

OPERATING AND SERVICE MANUAL

ISSUED IN TWO VOLUMES

21 February 1967

TABLE OF CONTENTS - VOLUMES I AND II

* Sections XIII and XIV appear in Volume II, labeled "System 1260 - Vol. II." All other sections are included in Volume I, labeled "System 1260 - Vol. I."

LIST OF PHOTOGRAPHS

XIII EXPLANATION OF PRINT NUMBERS AND GUIDE TO DRAWINGS

A. System 1260 Items by Subject

1. Entire System ("System 1260")
The number 10X1260 refers to the entire system, i.e., to the complete rack of hardware, which is labeled "Segrè-Chamberlain 10X1260 Proton Spin Resonance System," and abbreviated PSRS on the prints.

2. Individual Chassis
There are four individual chassis, plus one blank panel. Each has a print list "P" number.

   a. Proton Spin Resonance Oscillator-Amplifier (10X1260-P1)

   b. Proton Spin Resonance Oscillator-Amplifier Power Supplies (10X1260-P2)

   c. Voltage-to-Frequency Converter DY-2212A mounted in 10X1260-P3 panel.

   d. Patch Panel (10X1260-P4)

3. Interconnection Diagrams
There are three interconnection diagrams ("S" numbers) or block diagrams ("B" numbers).

   a. PSRS Overall Power Supply Interconnection Schematic (10X1260-S2)

   b. System 1260 Block Wiring Diagram (10X1260-B1)

   c. PSRS RF Rack Block Diagram (10X1260-B2)

4. Sub-Assemblies on a Chassis
There are several sub-assemblies; they have schematic "S" numbers, as follows:

   a. PSRS Varactor-Tuned Oscillator Schematic (10X1260-S1)

   b. PSRS Adjustable-Gain Wide-Band RF Amplifier and Detector Schematic (10X1260-S3)

   c. PSRS Thyrite Shaping Network and Frequency Tracking Circuit Schematic (10X1260-S4)

   d. PSRS +10V and -10V Precision Voltage Regulator and Junction Box for Oscillator Schematic (10X1260-S5)

   e. PSRS +75V and -75V Power Supply for Zeltex Amplifier, Schematic (10X1260-S6)

f. PSRS Varactor Tuner and Input Circuit RF Resonator (10X1260-S7)

g. PSRS RF Frequency Monitor Buffer-Amplifier Schematic (10X1260-S8)

h. PSRS Line Filter Schematic (10X1260-S9)

i. Wide Band dc Amplifier (18X1282-S2B) (1/2 of 3U6781 - PC Board is used to make 10X1260-S8)

j. Coaxial Noise Isolation Filter, Schematic (10X1180-S1)

5. Mechanical and Assembly Drawings.
Assembly drawings use "A" and mechanical drawings use "M".

a. PSRS Modified Heat Sink for SRC Model 3566 DC Power Supply (10X1260-M1)

b. PSRS Oscillator-Attenuator-Input Resonator Assembly (10X1260-A1)

c. PSRS Oscillator Resonator, Clamshells (10X1260-M2)

d. PSRS Oscillator Resonator, Milling and Drilling Pattern (10X1260-M3)

e. PSRS Oscillator Resonator, Center Conductor (10X1260-M4)

f. PSRS RF Frequency Monitor Buffer Amplifier Mounting Box (10X1260-M5)

g. PSRS RF Amplifier Chassis (10X1260-M6)

h. PSRS Input Circuit RF Resonator Clamshells (10X1260-M7)

i. PSRS Input Circuit RF Resonator Center Conductor (10X1260-M8)

6. Test Specifications Use "T"

a. PSRS Power Line Filter Frequency Response (10X1260-T1)

b. PSRS ±75V Power Supply for Zeltex Amplifier, Specification (10X1260-T2)

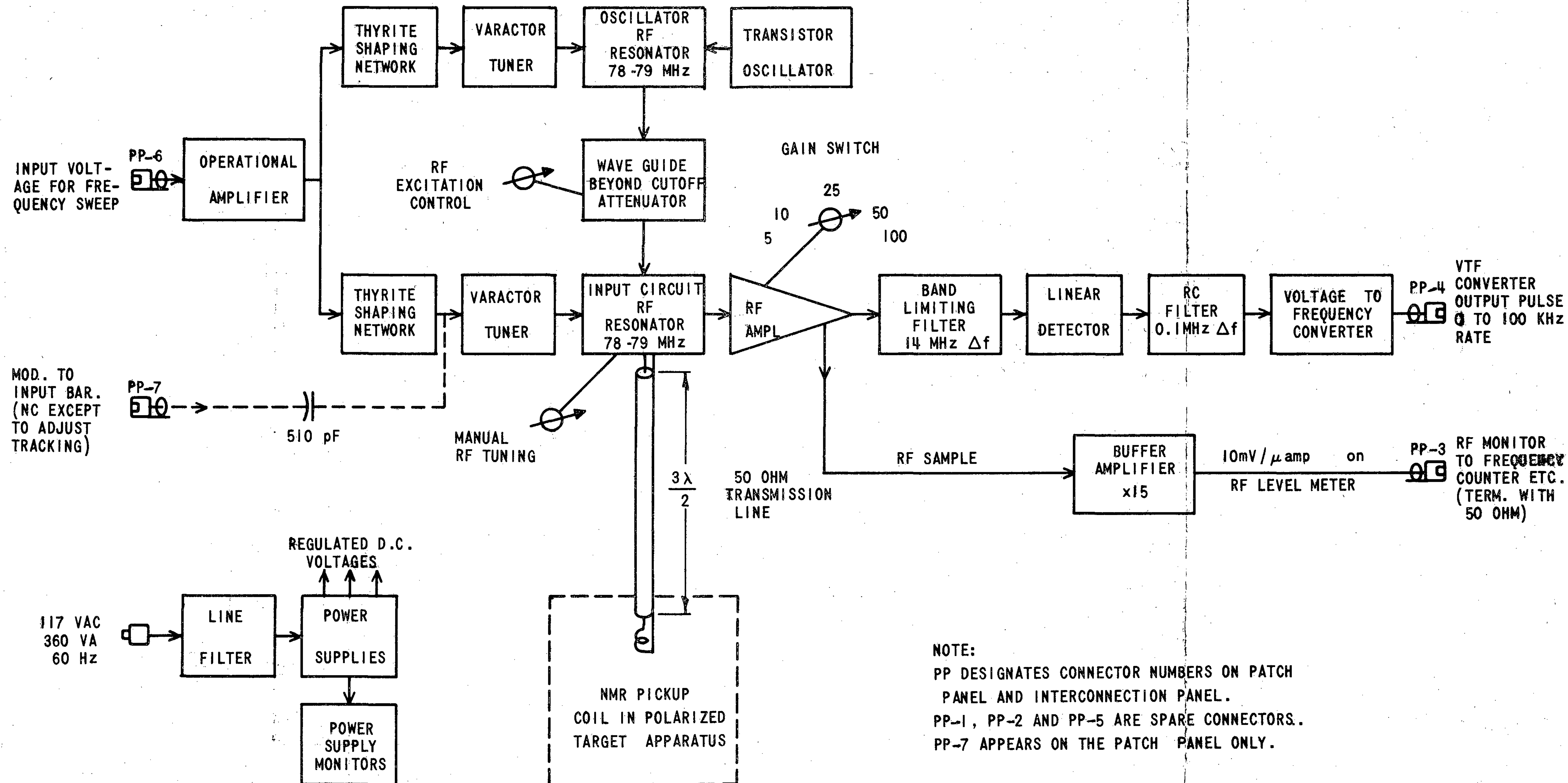
B. System 1260 Items By Number or Symbol

Item	Description
System 1260	Entire rack of equipment
10X1260	Entire rack of equipment
PSRS	Entire rack of equipment
10X1260-P0	Entire rack of equipment
"A" Numbers	Assembly Drawings
"B" Numbers	Block Diagrams
"M" Numbers	Mechanical Drawings
"P" Numbers	Print Lists
"S" Numbers	Interconnection Diagrams or Schematics
"T" Numbers	Test Specifications
10X1260-A1	PSRS Oscillator-Attenuator - Input Resonator Assembly
10X1260-B1	System 1260 Block Wiring Diagram
10X1260-B2	PSRS RF Rack Block Diagram
10X1260-M1	Modified Heat Sink for SRC Model 3566 DC Power Supply
10X1260-M2	PSRS Oscillator Resonator, Clamshells
10X1260-M3	PSRS Oscillator Resonator, Milling and Drilling Pattern
10X1260-M4	PSRS Oscillator Resonator, Center Conductor
10X1260-M5	PSRS RF Frequency Monitor Buffer Amplifier Mounting Box
10X1260-M6	PSRS RF Amplifier Chassis
10X1260-M7	PSRS Input Circuit RF Resonator Clamshells
10X1260-M8	PSRS Input Circuit RF Resonator Center Conductor
10X1260-P1	Proton Spin Resonance Oscillator-Amplifier
10X1260-P2	Proton Spin Resonance Oscillator-Amplifier Power Supply
10X1260-P3	DY-2212A Voltage-to-Frequency Converter Panel
10X1260-P4	Patch Panel
10X1260-S1	PSRS Varactor-Tuned Oscillator Schematic
10X1260-S2	PSRS Overall Power Supply Interconnection Schematic
10X1260-S3	PSRS Adjustable-Gain Wide-Band RF Amplifier and Detector Schematic

10X1260-S4	PSRS Thyrite Shaping Network and Frequency Tracking Circuit
10X1260-S5	PSRS +10 V and -10 V Precision Voltage Regulator and Junction Box for Oscillator, Schematic
10X1260-S6	PSRS +75 V and -75 V Power Supply for Zeltex Amplifier
10X1260-S7	PSRS RF Input Circuit Varactor Tuner
10X1260-S8	PSRS, RF Frequency Monitor Buffer Amplifier Schematic
10X1260-S9	PSRS Line Filter Schematic
10X1260-T1	PSRS Power Line Filter Frequency Response
10X1260-T2	PSRS ±75 V Power Supply for Zeltex Amplifier, Specification
10X1180-S1	Coaxial Noise Isolation Filter, Schematic
18X1282-S2B	Wide Band DC Amplifier (1/2 of 3U6781 - PC Board is used to make 10X1260-S8)

C. Individual Drawings

Note: We regret that some mechanical drawings, "M" numbers, and some assembly drawings, "A" numbers, are not available.



NOTE:
PP DESIGNATES CONNECTOR NUMBERS ON PATCH PANEL AND INTERCONNECTION PANEL.
PP-1, PP-2 AND PP-5 ARE SPARE CONNECTORS.
PP-7 APPEARS ON THE PATCH PANEL ONLY.

CHG.	DRWN. BY	CHKD. BY	DATE	CHANGES

SHWN. ON 10X 1260-P1

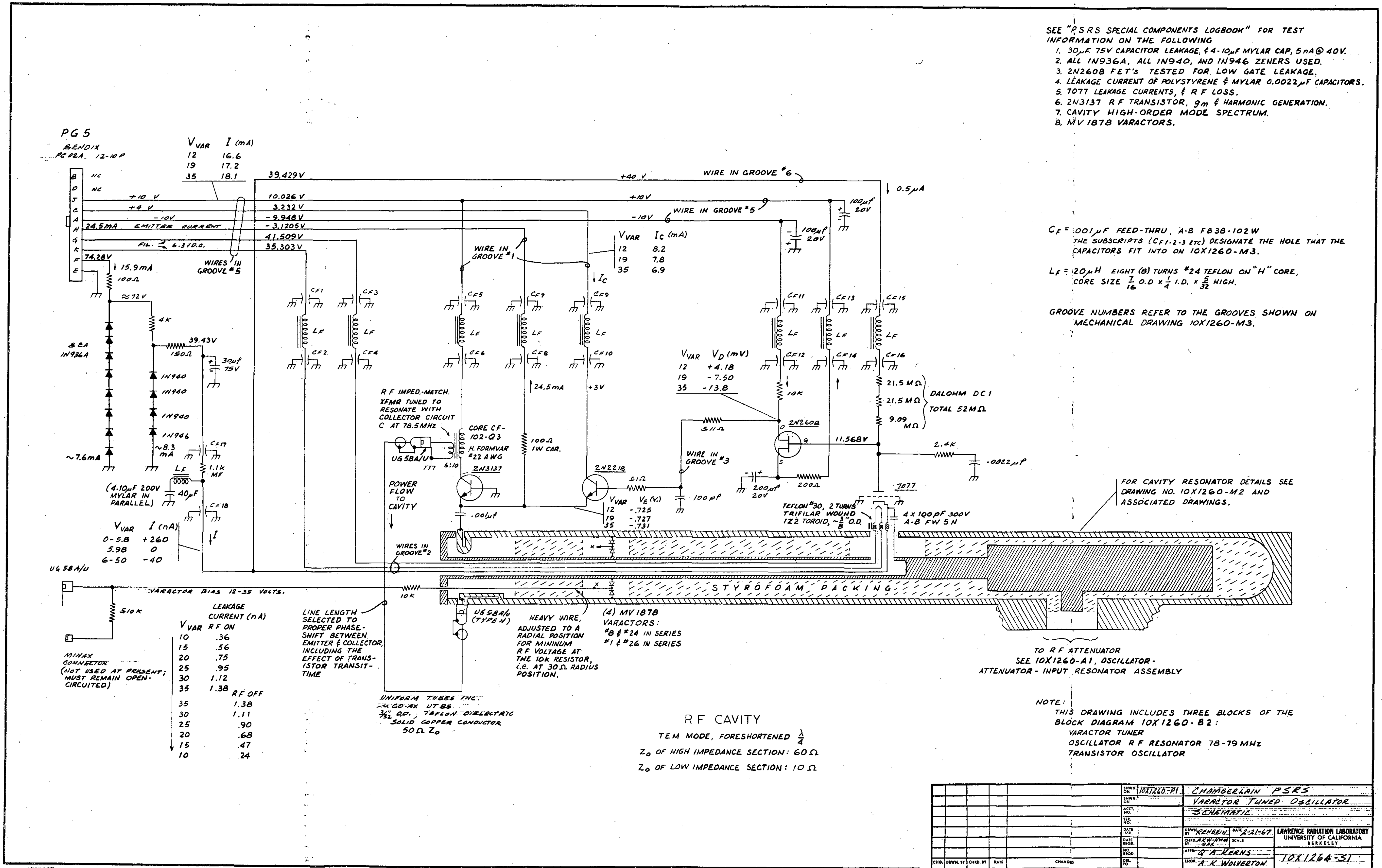
CHAMBERLAIN PSRS
RF RACK BLOCK DIAGRAM

ACCT. NO.
SER. NO.
DATE ISSD.
DATE REQD.
NO. REQD.
DEL. TO

DRWN. BY
DATE 2-1-67
CHKD. BY
SCALE
APPR.
ENGR. KERNS - MILLER

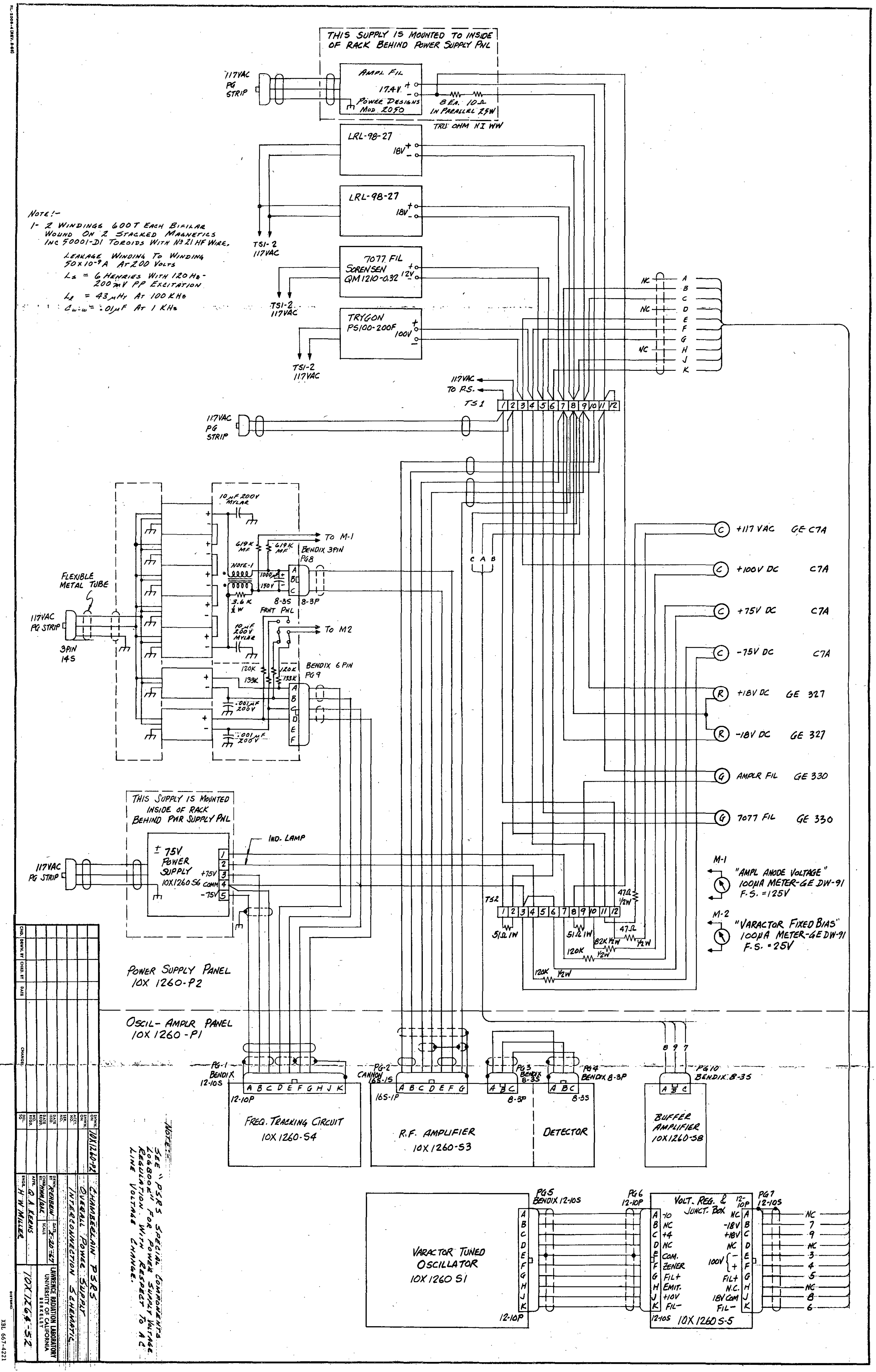
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY

10X 1262 - B2

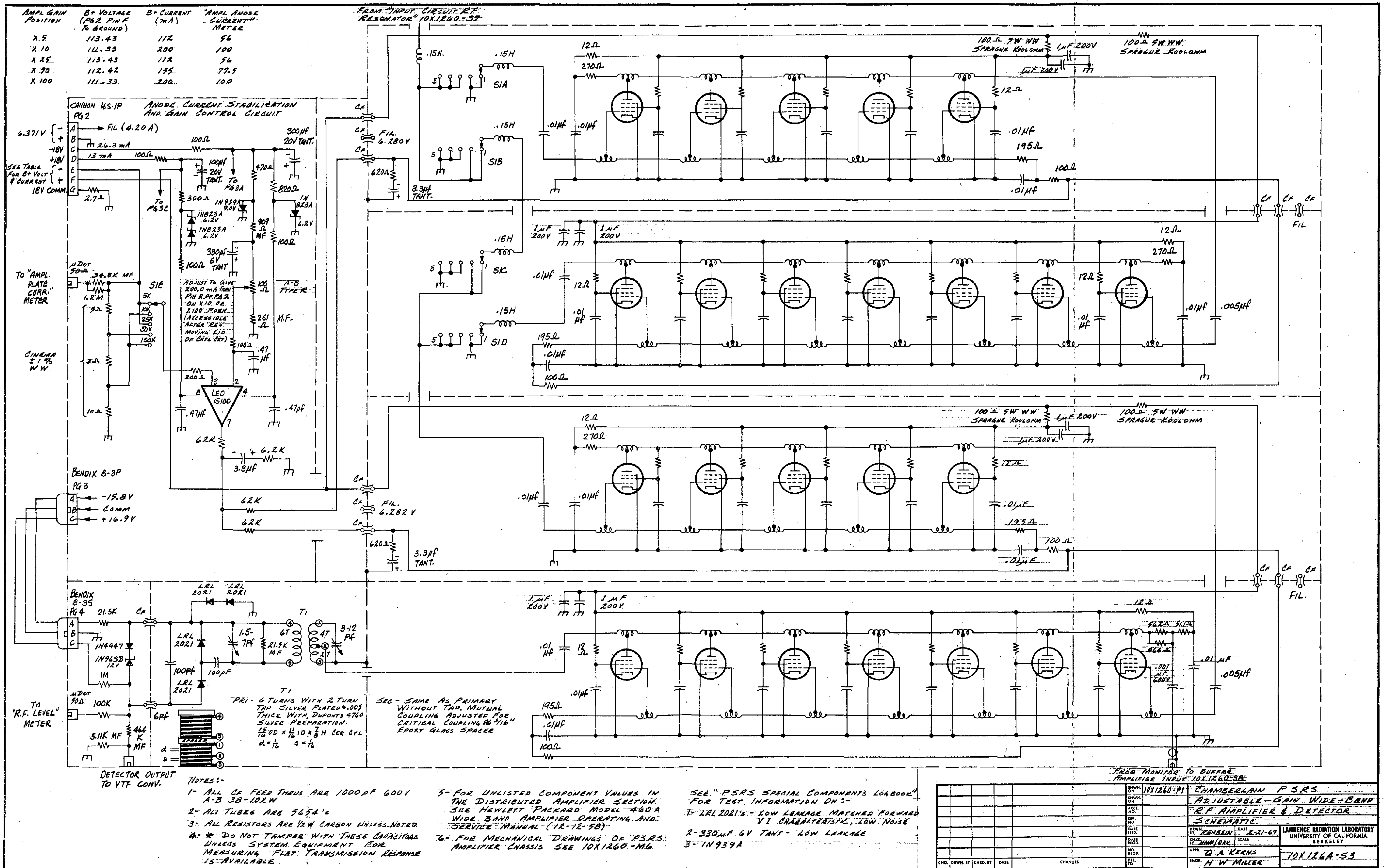


SEE "PSRS SPECIAL COMPONENTS LOGBOOK" FOR TEST INFORMATION ON THE FOLLOWING
1. 30µF 75V CAPACITOR LEAKAGE, & 4-10µF MYLAR CAP, 5nA @ 40V.
2. ALL 1N936A, ALL 1N940, AND 1N946 ZENERS USED.
3. 2N2608 FET'S TESTED FOR LOW GATE LEAKAGE.
4. LEAKAGE CURRENT OF POLYSTYRENE & MYLAR 0.0022µF CAPACITORS.
5. 7077 LEAKAGE CURRENTS, & R F LOSS.
6. 2N3137 R F TRANSISTOR, gm & HARMONIC GENERATION.
7. CAVITY HIGH-ORDER MODE SPECTRUM.
8. MV 1878 VARACTORS.
CF = .001µF FEED-THRU, A-B FB38-102W
THE SUBSCRIPTS (CF1-2-3 ETC) DESIGNATE THE HOLE THAT THE CAPACITORS FIT INTO ON 10X1260-M3.
LF = 20µH EIGHT (8) TURNS #24 TEFLON ON "H" CORE, CORE SIZE 7/16 O.D x 1/4 I.D. x 5/32 HIGH.
GROOVE NUMBERS REFER TO THE GROOVES SHOWN ON MECHANICAL DRAWING 10X1260-M3.
PG 5
BENDIX PC02A 12-10P
VVAR I (mA)
12 16.6
19 17.2
35 18.1
39.429V
10.026V
3.232V
-9.948V
-3.1205V
41.509V
35.303V
+40 V
+10 V
-10V
WIRE IN GROOVE #6
WIRE IN GROOVE #5
WIRE IN GROOVE #1
WIRES IN GROOVE #5
0.5µA
100µF 20V
+10 V
+4 V
-10V
24.5mA EMITTER CURRENT
FIL. 6.3V a.c.
74.28V
15.9mA
100Ω
≈72V
4K
39.43V
150Ω
30µF 75V
8 EA 1N936A
1N940
1N940
1N940
1N946
~8.3 mA
~7.6mA
CF17
1.1k MF
LF
(4-10µF 200V MYLAR IN PARALLEL)
40µF
CF18
VVAR I (nA)
0-5.8 +260
5.98 0
6-50 -40
UG 58A/U
VARACTOR BIAS 12-35 VOLTS.
510K
MINAX CONNECTOR (NOT USED AT PRESENT; MUST REMAIN OPEN-CIRCUITED)
LEAKAGE CURRENT (nA)
VVAR RF ON
10 .36
15 .56
20 .75
25 .95
30 1.12
35 1.38
RF OFF
35 1.38
30 1.11
25 .90
20 .68
15 .47
10 .24
VVAR IC (mA)
12 8.2
19 7.8
35 6.9
R F IMPED.-MATCH. XFMR TUNED TO RESONATE WITH COLLECTOR CIRCUIT C AT 78.5MHz
CORE CF-102-Q3
H. FORMVAR #22 AWG
6:10
UG 58A/U
2N3137
POWER FLOW TO CAVITY
.001µF
24.5mA
100Ω 1W CAR.
+3V
2N2218
51Ω
VVAR VE (V.)
12 -.725
19 -.727
35 -.731
100pF
WIRE IN GROOVE #3
511Ω
200µF 20V
200Ω
VVAR VD (mV)
12 +4.18
19 -7.50
35 -13.8
10K
2N2608
11.568V
21.5MΩ
21.5MΩ
9.09 MΩ
DALOHM DC1 TOTAL 52MΩ
2.4K
.0022µF
7077
TEFLON #30, 2 TURNS TRIFILAR WOUND 1Z2 TOROID, ~3/8 O.D.
4 x 100pF 300V A-B FW 5N
FOR CAVITY RESONATOR DETAILS SEE DRAWING NO. 10X1260-M2 AND ASSOCIATED DRAWINGS.
WIRES IN GROOVE #2
10K
STYROFOAM PACKING
LINE LENGTH SELECTED TO PROPER PHASE-SHIFT BETWEEN EMITTER & COLLECTOR, INCLUDING THE EFFECT OF TRANSISTOR TRANSIT-TIME
UG 58A/U (TYPE N)
HEAVY WIRE, ADJUSTED TO A RADIAL POSITION FOR MINIMUM R F VOLTAGE AT THE 10K RESISTOR, i.e. AT 30Ω RADIUS POSITION.
(4) MV 1878 VARACTORS: #8 & #24 IN SERIES #1 & #26 IN SERIES
TO R F ATTENUATOR SEE 10X1260-A1, OSCILLATOR-ATTENUATOR-INPUT RESONATOR ASSEMBLY
UNIFORM TUBES INC. CO-AX UT 85 3/32 O.D. TEFLON DIELECTRIC SOLID COPPER CONDUCTOR 50Ω Z0
R F CAVITY
TEM MODE, FORESHORTENED λ/4
Z0 OF HIGH IMPEDANCE SECTION: 60Ω
Z0 OF LOW IMPEDANCE SECTION: 10Ω
NOTE: THIS DRAWING INCLUDES THREE BLOCKS OF THE BLOCK DIAGRAM 10X1260-B2:
VARACTOR TUNER
OSCILLATOR R F RESONATOR 78-79 MHz
TRANSISTOR OSCILLATOR
10X1260-P1
CHAMBERLAIN PSRS
VARACTOR TUNED OSCILLATOR
SCHEMATIC
REHBEIN 2-21-67
AKW-HWM
Q A KERNS
A K WOLVERTON
LAWRENCE RADIATION LABORATORY UNIVERSITY OF CALIFORNIA BERKELEY
10X1264-S1

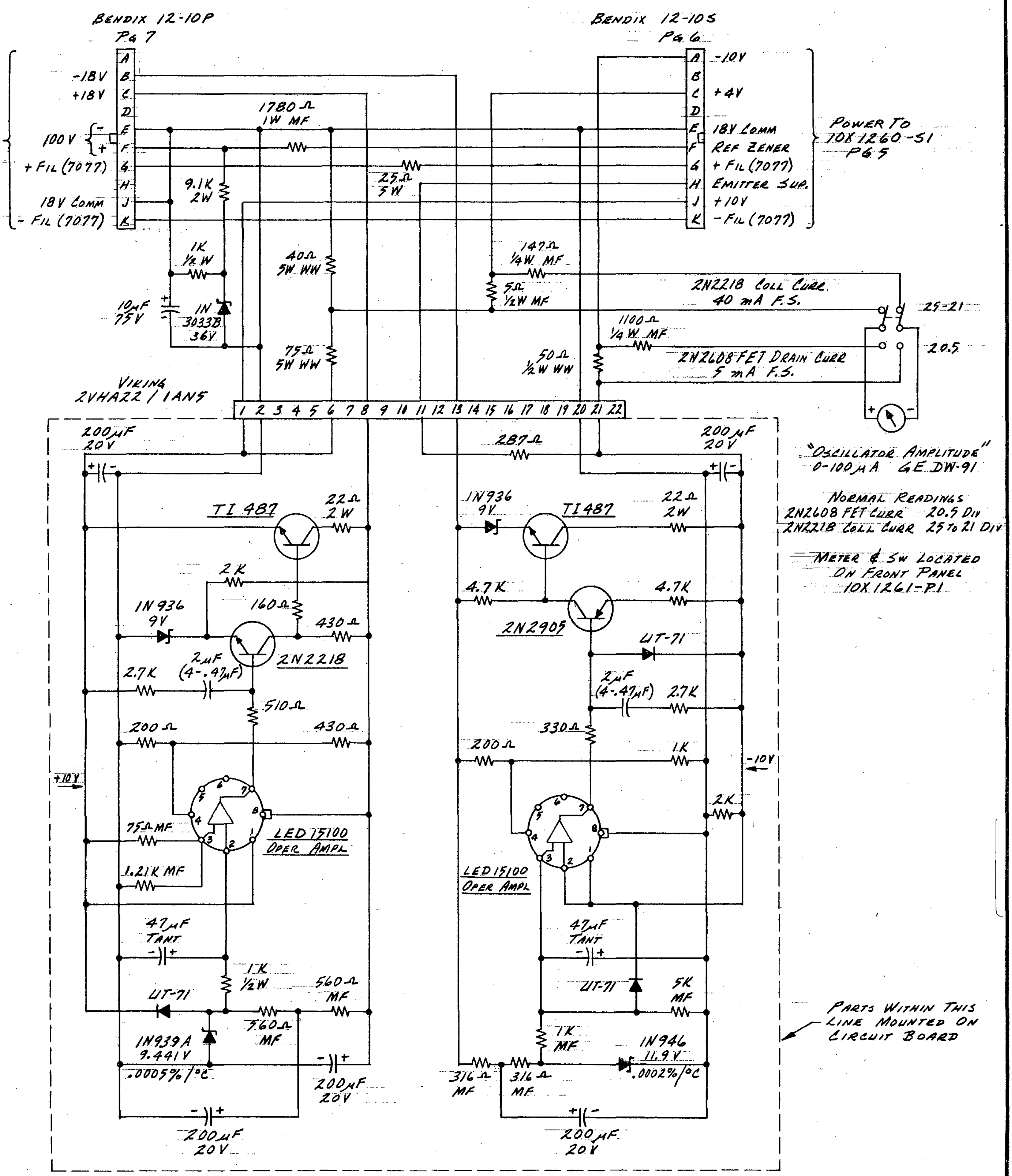
XBL 677-4220



THIS SUPPLY IS MOUNTED TO INSIDE OF RACK BEHIND POWER SUPPLY PNL
117VAC PG STRIP
AMPL FIL 17.4V
POWER DESIGNS MOD 2050
8 EA. 10Ω IN PARALLEL 25W
TRU OHM NI WW
LRL-98-27 18V
LRL-98-27 18V
TS1-2 117VAC
7077 FIL SORENSEN QM1210-0.32 12V
TRYGON PS100-200F 100V
NOTE!-
1- 2 WINDINGS 600T EACH BIFILAR WOUND ON 2 STACKED MAGNETICS INC 50001-D1 TOROIDS WITH No 21 HF WIRE.
LEAKAGE WINDING TO WINDING 50x10⁻⁹A AT 200 VOLTS
Ls = 6 HENRIES WITH 120 Hz 200 mV PP EXCITATION
LR = 43 μHy AT 100 KHz
Cw-w = .01μF AT 1 KHz
117VAC TO P.S.
TS1
10 μF 200V MYLAR
619K MF
TO M-1
BENDIX 3PIN PG8
FLEXIBLE METAL TUBE
3.6K 1W
8-3S 8-3P
FRNT PNL
TO M2
BENDIX 6 PIN PG9
120K 133K
.001μF 200V
3PIN 14S
+117 VAC GE C7A
+100V DC C7A
+75V DC C7A
-75V DC C7A
+18V DC GE 327
-18V DC GE 327
AMPLR FIL GE 330
7077 FIL GE 330
THIS SUPPLY IS MOUNTED INSIDE OF RACK BEHIND PWR SUPPLY PNL
±75V POWER SUPPLY 10X1260 S6
IND. LAMP
TS2
51Ω 1W
47Ω 1/2W
82K 1/2W
120K 1/2W
M-1 "AMPL ANODE VOLTAGE" 100μA METER-GE DW-91 F.S. =125V
M-2 "VARACTOR FIXED BIAS" 100μA METER-GE DW-91 F.S. =25V
POWER SUPPLY PANEL 10X 1260-P2
OSCIL- AMPLR PANEL 10X 1260 -P1
PG-1 BENDIX 12-10S
PG-2 CANNON 16S-1S
PG3 BENDIX 8-3S
PG4 BENDIX 8-3P
PG10 BENDIX 8-3S
FREQ. TRACKING CIRCUIT 10X 1260-S4
R.F. AMPLIFIER 10X 1260-S3
DETECTOR
BUFFER AMPLIFIER 10X1260-S8
NOTE:- SEE "PSRS SPECIAL COMPONENTS LOGBOOK" FOR POWER SUPPLY VOLTAGE REGULATION WITH RESPECT TO A C LINE VOLTAGE CHANGE.
VARACTOR TUNED OSCILLATOR 10X 1260 S1
PG5 BENDIX 12-10S
PG6 12-10P
VOLT. REG. & JUNCT. BOX 10X 1260 S-5
PG7 12-10S
CHAMBERLAIN PSRS
OVERALL POWER SUPPLY
INTERCONNECTION SCHEMATIC
LAWRENCE RADIATION LABORATORY UNIVERSITY OF CALIFORNIA BERKELEY
H.W. MILLER
Q.A. KERNS
XBL 667-4221


AMPL GAIN POSITION
B+ VOLTAGE (PG2 PIN F TO GROUND)
B+ CURRENT (mA)
"AMPL ANODE CURRENT" METER
X 5 113.43 112 56
X 10 111.33 200 100
X 25 113.43 112 56
X 50 112.42 155 77.5
X 100 111.33 200 100
FROM "INPUT CIRCUIT RF RESONATOR" 10X1260-S7
CANNON 16S-1P PG2
ANODE CURRENT STABILIZATION AND GAIN CONTROL CIRCUIT
FIL (4.20 A)
6.371V
-18V
+18V
SEE TABLE FOR B+ VOLT & CURRENT
18V COMM
26.3 mA
13 mA
TO "AMPL. PLATE CURR." METER
CINEMA ±1% WW
LED 15100
ADJUST TO GIVE 200.0 mA THRU PIN E OF PG2 ON X10, OR X100 POSN. (ACCESSIBLE AFTER REMOVING LID OF CKT CKT)
A-B TYPE R
FIL 6.280V
FIL 6.282V
BENDIX 8-3P PG3
-15.8V
COMM
+16.9V
BENDIX 8-3S PG4
TO "R.F. LEVEL" METER
DETECTOR OUTPUT TO VTF CONV.
100Ω 5W WW SPRAGUE KOOLOHM
T1
PRI - 6 TURNS WITH 2 TURN TAP SILVER PLATED .005 THICK WITH DUPONTS 4760 SILVER PREPARATION. 15/16 OD × 11/16 ID × 7/8 H CER CYL d = 1/16 s = 1/16
SEC - SAME AS PRIMARY WITHOUT TAP. MUTUAL COUPLING ADJUSTED FOR CRITICAL COUPLING @ 3/16" EPOXY GLASS SPACER
FREQ MONITOR TO BUFFER AMPLIFIER INPUT 10X1260-S8
NOTES:-
1- ALL CF FEED THRUS ARE 1000pF 600V A-B 38-102W
2- ALL TUBES ARE 5654's
3- ALL RESISTORS ARE 1/2 W CARBON UNLESS NOTED
4- * DO NOT TAMPER WITH THESE CAPACITORS UNLESS SYSTEM EQUIPMENT FOR MEASURING FLAT TRANSMISSION RESPONSE IS AVAILABLE
5- FOR UNLISTED COMPONENT VALUES IN THE DISTRIBUTED AMPLIFIER SECTION. SEE HEWLETT PACKARD MODEL 460A WIDE BAND AMPLIFIER OPERATING AND SERVICE MANUAL (12-12-58)
6- FOR MECHANICAL DRAWINGS OF PSRS AMPLIFIER CHASSIS SEE 10X1260-M6
SEE "PSRS SPECIAL COMPONENTS LOGBOOK" FOR TEST INFORMATION ON:-
1- LRL 2021's - LOW LEAKAGE MATCHED FORWARD VI CHARACTERISTIC, LOW NOISE
2- 330µF 6V TANT - LOW LEAKAGE
3- 1N939A
CHG. DRWN. BY CHKD. BY DATE CHANGES
SHWN. ON 10X1260-P1
CHAMBERLAIN PSRS
ADJUSTABLE-GAIN WIDE-BAND
RF AMPLIFIER & DETECTOR
SCHEMATIC
DRWN. BY REHBEIN DATE 2-21-67
CHKD. BY HWM/QAK SCALE
APPR. Q A KERNS
ENGR. H W MILLER
LAWRENCE RADIATION LABORATORY UNIVERSITY OF CALIFORNIA BERKELEY
10X1264-S3

XBL 677-4222



NOTES:-

SEE "PSRS SPECIAL COMPONENTS LOG BOOK" FOR TEST DATA ON 1N939A & 1N946 ZENER DIODES.

PRECISE OUTPUT VOLTAGES ARE: +10V → +10.026 V
-10V → -9.948 V

P-P RIPPLE: < 2μV, BOTH SUPPLIES

P-P NOISE: ~4μV, BOTH SUPPLIES

TEMPERATURE COEFFICIENT: +10V → 0.0005%/°C
-10V → 0.0002%/°C

CHAMBERLAIN PSRS - +10V & -10V
PRECISION VOLTAGE REGULATOR & JUNCTION BOX FOR OSCILLATOR - SCHEMATIC

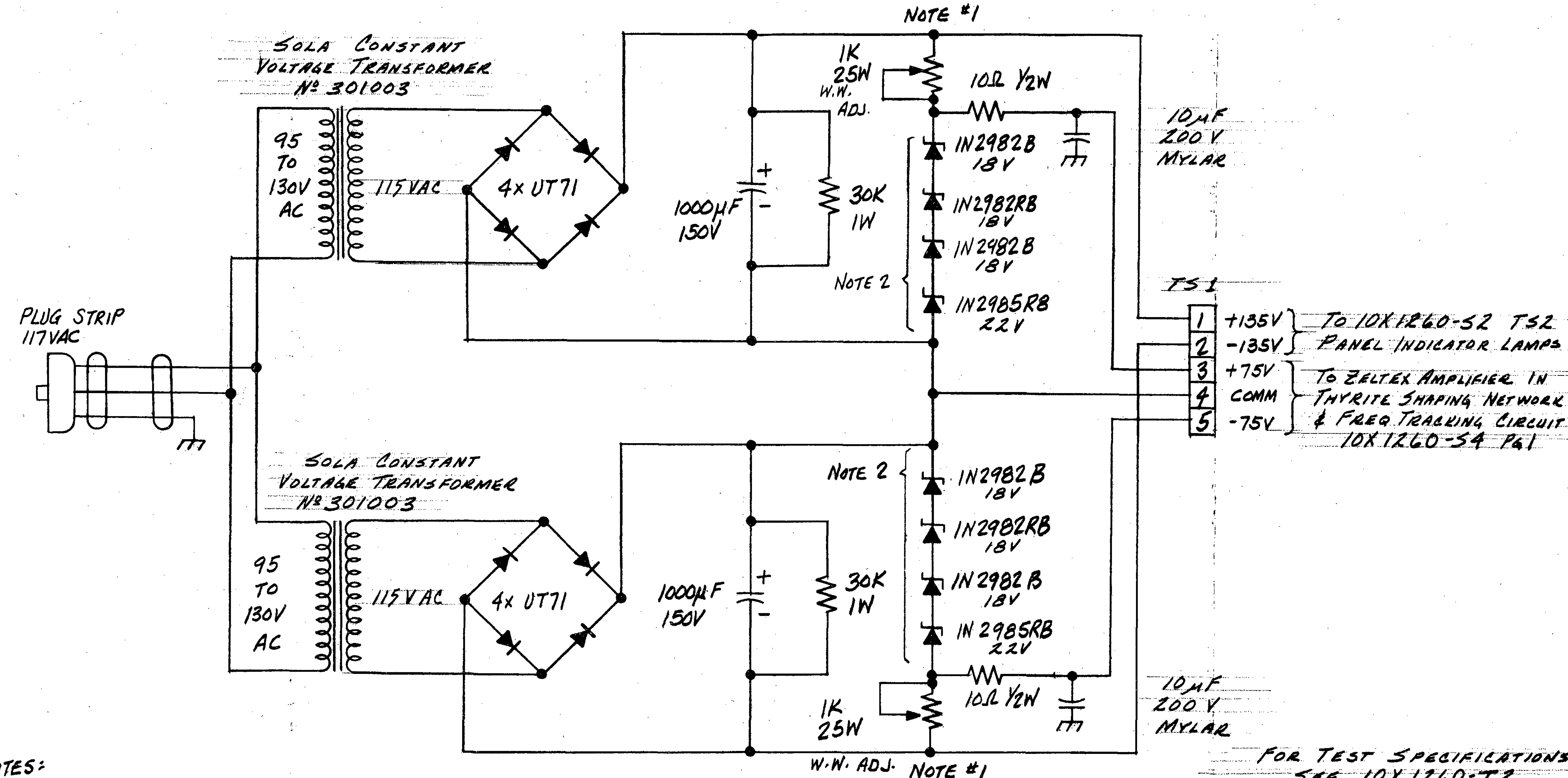
10X1260-P1

LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY

DRWN. BY ZEHREIN — DATE 10-24-66
CHKD. AKW-HWM
APPR. Q. A. KERNS
ENGR. A. K. WOLVERTON

10X1263-S5

XBL 677-4224



NOTES:
1. ADJUST ZENER STRING CURRENT TO 85 MA. WITH NO LOAD ON THE SUPPLIES.
2. SELECT ZENER DIODES FOR 75V ± 1.5V AT A ZENER CURRENT OF 85 MA.

FOR TEST SPECIFICATIONS SEE 10X1260-T2

CHG.	DRWN. BY	CHKD. BY	DATE	CHANGES

SHWN. ON 10X1260-P2
SHWN. ON
ACCT. NO.
SER. NO.
DATE ISSD.
DATE REQD.
NO. REQD.
DEL. TO

CHAMBERLAIN PSRS
+75V & -75V POWER SUPPLY
FOR ZELTEX AMPLIFIER
SCHEMATIC

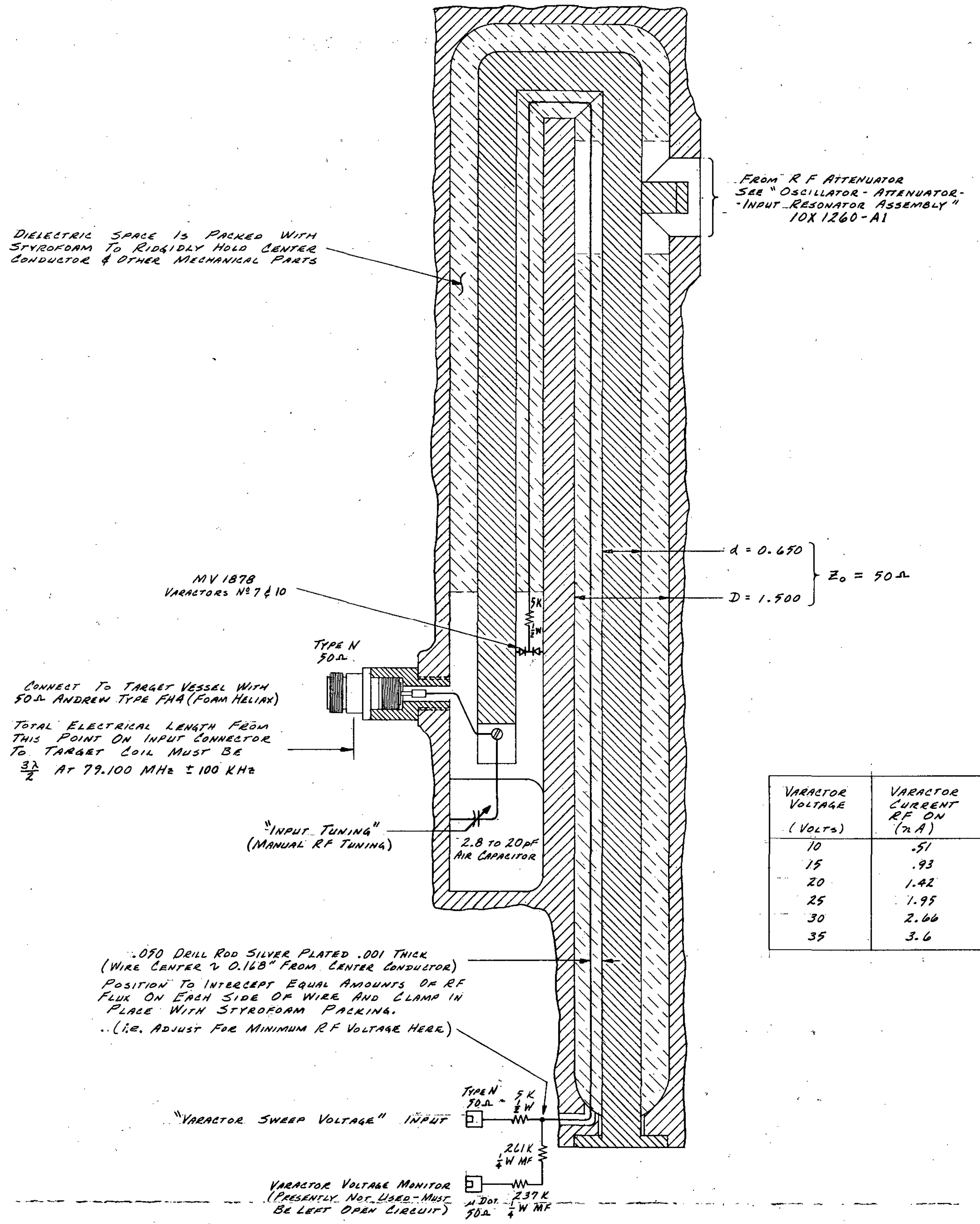
DRWN BY REHBEIN | DATE 10-24-66
CHKD. BY HWM/QAK | SCALE
APPR. Q A KERNS
ENGR. H W MILLER

LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY

10X1262-S6

RL-2009-2 (REV. 2-66)

XBL 677-4225



VARACTOR VOLTAGE (VOLTS)	VARACTOR CURRENT RF ON (nA)	VARACTOR CURRENT RF OFF (nA)
10	.51	.51
15	.93	.91
20	1.42	1.38
25	1.95	1.95
30	2.66	2.68
35	3.6	3.6

SEE "SYSTEM 1260 SPECIAL COMPONENTS LOGBOOK" FOR TEST INFORMATION ON:-
1- MV1878 VARACTOR DIODES

NOTES:-
1- SEE 10X1260-M7 AND ASSOCIATED DRAWINGS FOR MECHANICAL DETAILS

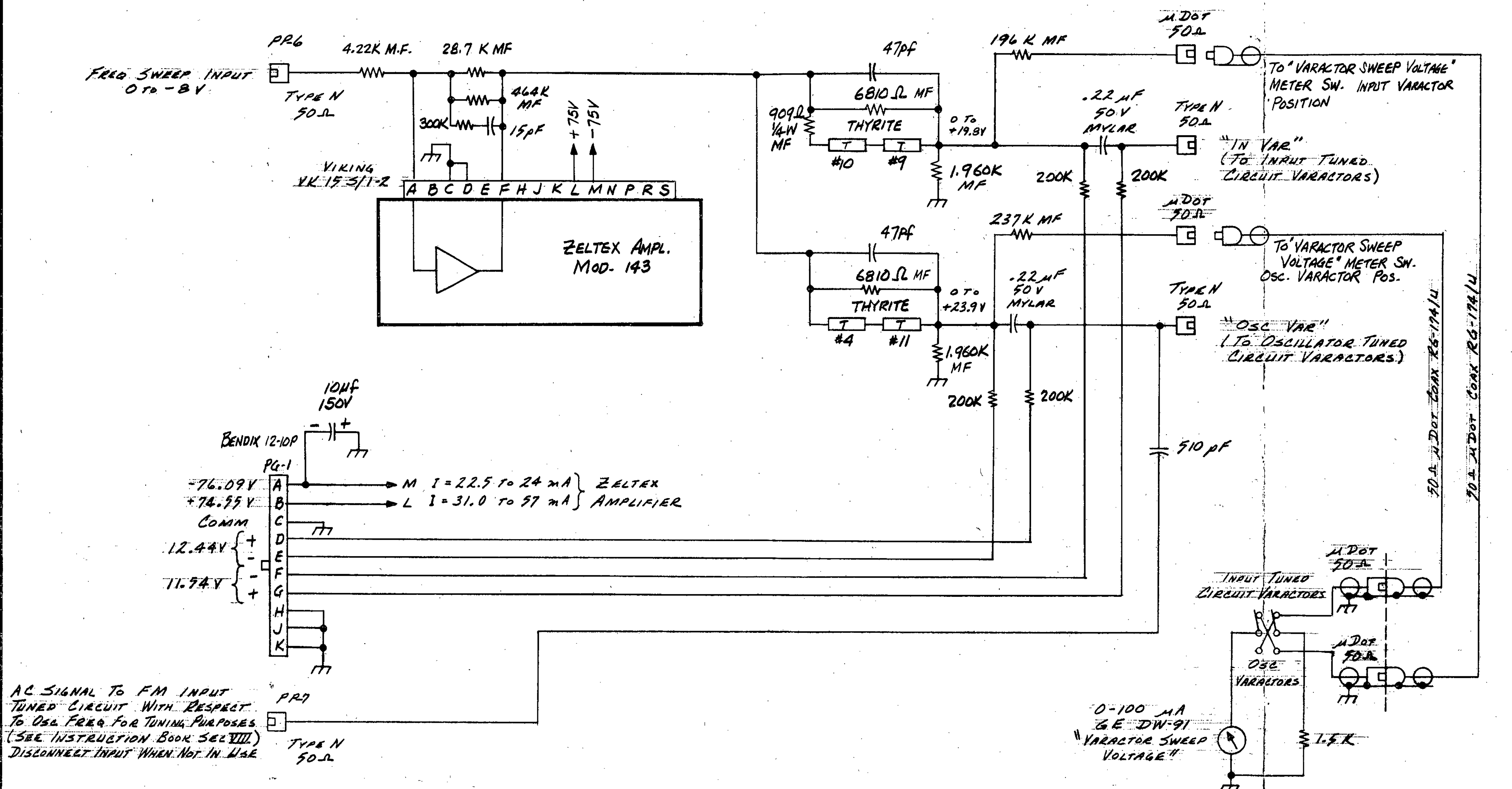
10X1260-P1 CHAMBERLAIN PSRS
VARACTOR TUNER & INPUT CIRCUIT R F RESONATOR SCHEMATIC

LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY

DRAWN BY REHBEIN DATE 2-21-67
CHKD. BY HMW/QAK
APPD. Q. A. KERNS
ENGR. H.W. MILLER

10X 1264-S7

XBL 677-4226



NOTE :-

1.- ALL RESISTORS 1/2 W CARBON UNLESS NOTED

2.- THYRITE Nº 4, 9, 10 & 11 SELECTED FROM GE THYRITE VARISTORS Nº 6SD-5010 (FOR CHARACTERISTICS SEE "PSRS SPECIAL COMPONENTS LOGBOOK")

CHG.	DRWN. BY	CHKD. BY	DATE	CHANGES

SHWN. ON	10X 1260-P1
SHWN. ON	
ACCT. NO.	
SER. NO.	
DATE ISSD.	
DATE REQD.	
NO. REQD.	
DEL. TO	

CHAMBERLAIN PSRS
THYRITE SHAPING NETWORK AND FREQUENCY TRACKING CIRCUIT SCHEMATIC

DRWN. BY REHBEIN	DATE	LAWRENCE RADIATION LABORATORY UNIVERSITY OF CALIFORNIA BERKELEY
CHKD. BY HWM/QAK	SCALE	
APPR. Q A KERNS		10X 1263-S4
ENGR. H W MILLER		

RL-3009-3 (REV. 11-65)

XBL 677-4223

10X1261-T2

±75V POWER SUPPLY
FOR ZELTEX AMPLIFIER, SPECIFICATIONS
10X1260-T2

I Description and Purpose:

This power supply provides the ±75 volts required to power the Zeltex operational amplifier used in the PSRS Frequency Tracking Circuit. Adequate regulation, for both line and load variations, is accomplished with the combination of a Sola Constant voltage transformer and a series string of Zener diodes.

II Input: 95-125 VAC, 60 Hz

III Outputs:

A. ±75 volts @ 75ma maximum load current. The plus and minus supplies are adjusted to within 2% of 75 volts by selecting and grouping Zener diodes in each section of the supply.

B. ±135 volts @ 500μa to light two neon indicator lamps.

IV Regulation and Ripple:

A. Line variations: The output voltage varies by less than 0.2% for power line voltage changes from 95V rms to 125V rms. The load current is constant and at 60ma for this test.

B. Load variations: The 75 volt output varies by less than 1% for changes in load current from 20ma to 75ma.

C. Temperature coefficient: The output voltage varies by less than 0.1%/°C.

D. Ripple: A 120 Hz A-C ripple of $210mV_{p-p}$ is present on the output voltage when the supply is loaded to its maximum current output of 75ma.

See Schematic 10X1260-S6.

CHAMBERLAIN PSRS
+75V and -75V POWER SUPPLY
FOR ZELTEX AMPLIFIER
SPECIFICATIONS

SHWN. ON 10X1260-P2
SHWN. ON 10X1260-S6
ACCT. NO.
SER. NO.

DRWN. BY Salter DATE 2-22-67
CHKD. BY HWM/OAK SCALE
APPR. Q. A. Kerns
ENGR. H. W. Miller

DATE ISSD. DATE REQD. NO. REQD. DEL. TO

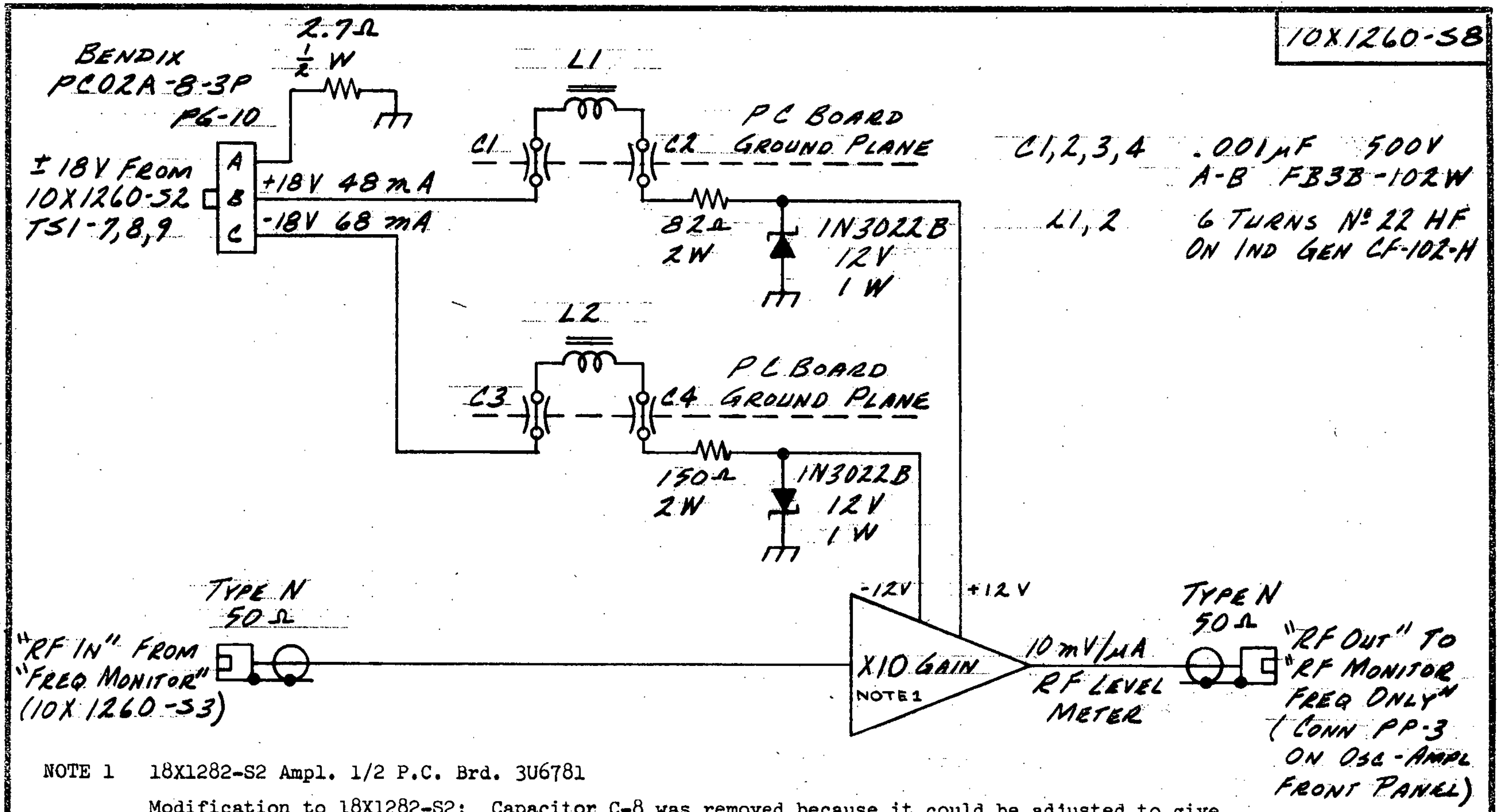
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY

10X1261-T2

CHANGES

CHG. DRWN. BY CHKD. BY DATE

10X1260-S8



NOTE 1 18X1282-S2 Ampl. 1/2 P.C. Brd. 3U6781

Modification to 18X1282-S2: Capacitor C-8 was removed because it could be adjusted to give unstable operation (self oscillations) of the amplifier. The resulting amplifier bandwidth is reduced but it is still adequate for the present use as a buffer amplifier in System 1260.

For Mounting Box See 10X1260-M5

CHG.	DRWN. BY	CHKD. BY	DATE	CHANGES

SHWN. ON 10X1260-P1
ACCT. NO.
SER. NO.
DATE ISSD.
DATE REQD.
NO. REQD.
DEL. TO

CHAMBERLAIN PSRS
RF FREQ MONITOR BUFFER AMPLIFIER
SCHEMATIC

DRWN. BY REHBEIN DATE 2-20-67
CHKD. BY HWM/QAK SCALE
APPR. Q A KERNS
ENGR. H W MILLER

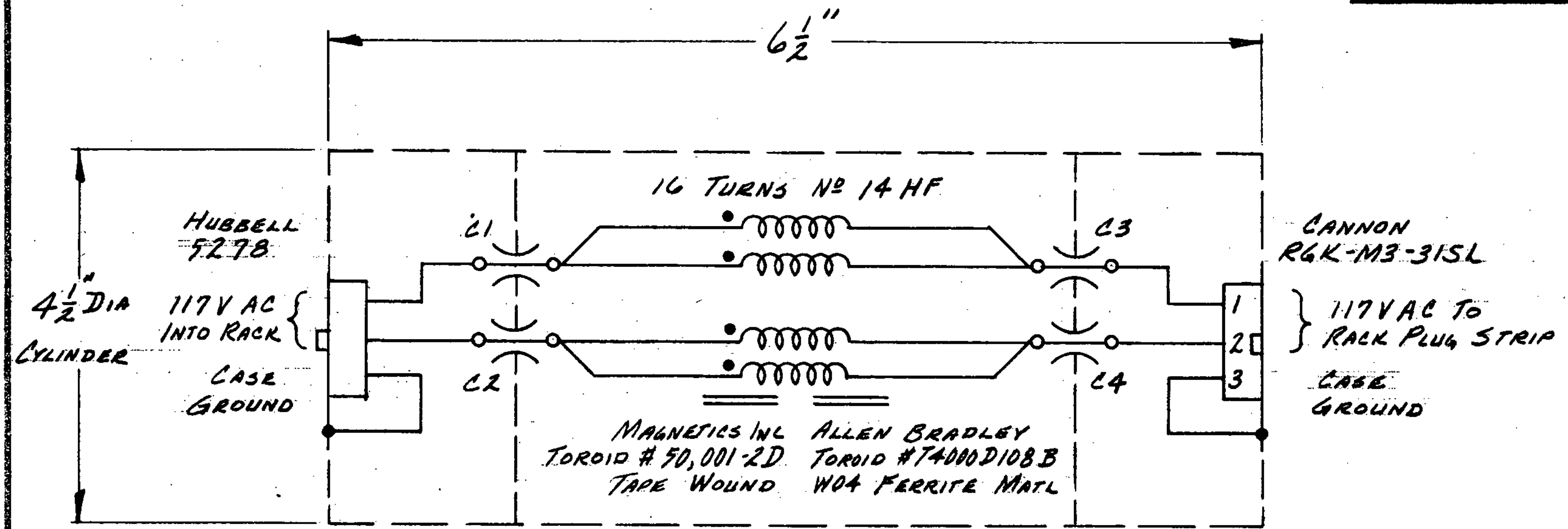
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY

10X1261-S8

RL-2009-1 (REV. 3-63)

XBL 677-4228

10X1260-S9



C1, 2, 3, 4 – 0.1 μF 600V 20 A
SPRAGUE BYPASS 80P3

NOTE:-
MAXIMUM RMS CURRENT RATING 15A
QUADRIFILAR WINDING PREVENTS CORE SATURATION BECAUSE ROUNDTRIP A TURNS = ZERO

MEASURED CHARACTERISTICS

ROUNDTRIP D.C. SERIES RESISTANCE @ 25°C	$26.5 \times 10^{-3}\,\Omega$
TOTAL SHUNT CAPACITANCE @ 1 KHz	0.41×10^{-6} F
TOTAL LEAKAGE CURRENT @ 400 V DC TO GROUND	0.25×10^{-6} A
VOLTAGE ATTENUATION 30 MHz TO 200 MHz	$> 2 \times 10^{3}$

POWER LINE FILTER FREQUENCY RESPONSE CURVE SEE 10X1260-T1

CHG.	DRWN. BY	CHKD. BY	DATE	CHANGES		
					SHWN. ON	10X1260-P2
					ACCT. NO.	
					SER. NO.	
					DATE ISSD.	
					DATE REQD.	
					NO. REQD.	
					DEL. TO	

CHAMBERLAIN PSRS
LINE FILTER
SCHEMATIC

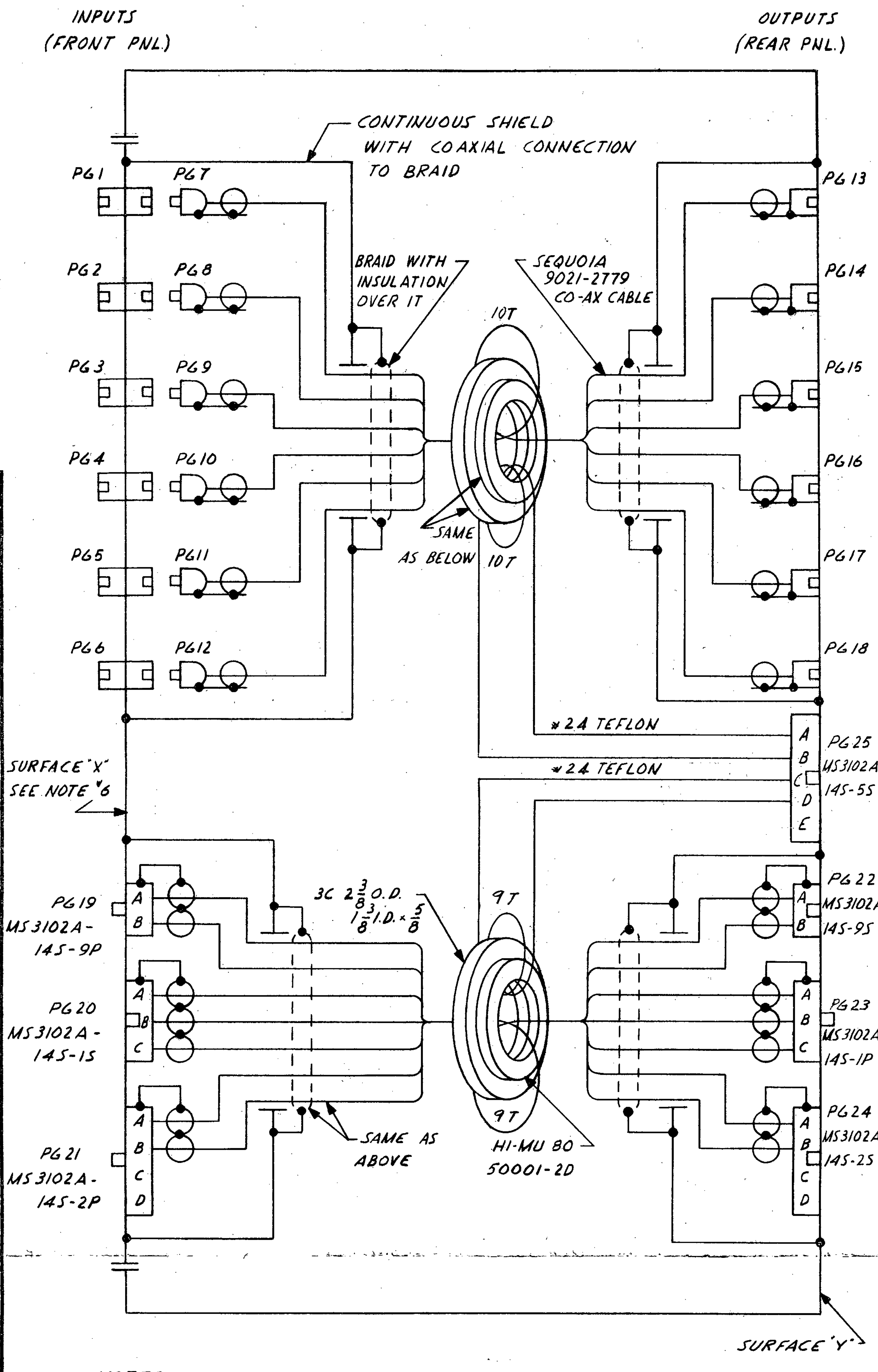
DRWN. BY REHBEIN — DATE 2-16-67
CHKD. BY HWM/QAK — SCALE
APPR. Q. A. KERNS
ENGR. H. W. MILLER

LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY

10X1261-S9

RL-2009-1 (REV. 3-63)

XBL 677-4229



NOTES:

1) PG 1-6 ARE UG 30 D/U TYPE "N"
2) PG 7-12 ARE UG 21 D/U TYPE "N"
3) PG 13-18 ARE AMPHENOL 31-369 TYPE "BNC"
4) PG 19-24 ARE MODIFIED TO TAKE A SPLIT BACK SHELL & CABLE CLAMP FOR CONCENTRIC (NOT PIGTAIL) CONNECTION TO SHIELD
5) MOUNTS ON $3\frac{1}{2}$" × 19" PANEL
6) PG 1-6 19-21 ARE MOUNTED ON A METAL PNL. WITH FIBERGLASS INSULATION
7) SEE PHOTOGRAPHS #2556, 7, 8 FOR ADDITIONAL INFORMATION

SHIELDING TECHNIQUES & COMPONENTS
COAXIAL NOISE ISOLATION FILTER
SCHEMATIC

DRWN. BY	DATE 2-4-62
CHKD. BY	SCALE NONE
APPR.	
ENGR. TUSTING	

LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY

10X1182-S-1

CHG. | DRWN. BY | CHKD. BY | DATE | CHANGES

DEL. TO | NO. REQD. | DATE REQD. | DATE ISSD. | SER. NO. | ACT. NO. | SHWN. ON

XBL 677-4230

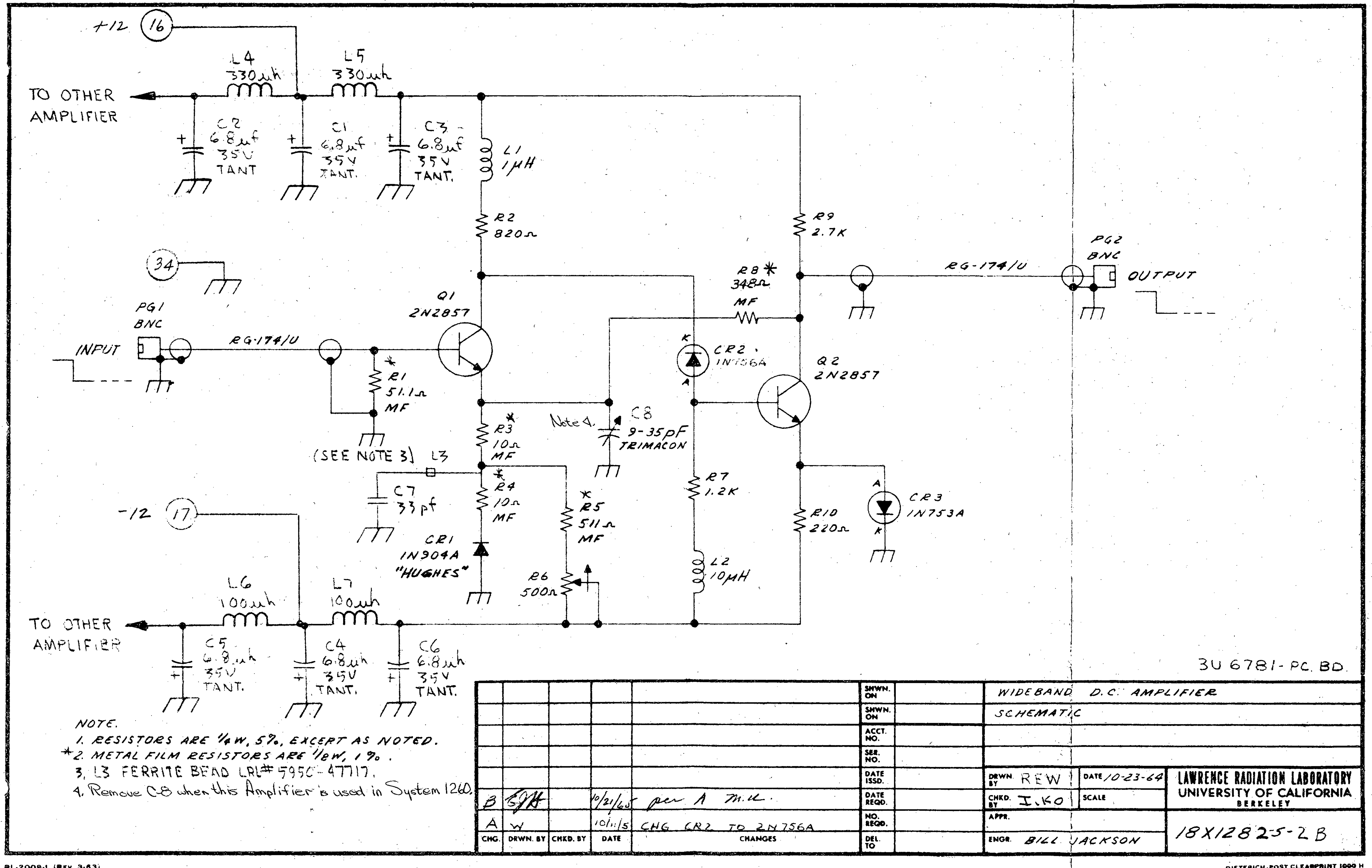
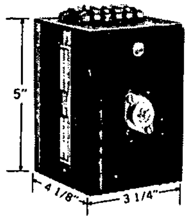


Fig. 1 - Amplifier Schematic

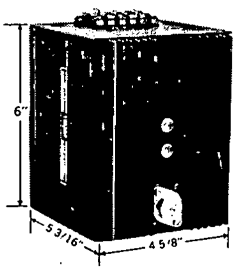
XBL 677-4231

APPENDIX A

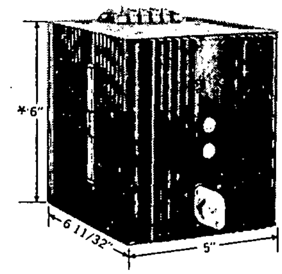
SILICON MODULE SERIES



SERIES 1



SERIES 2



SERIES 4

*6½" for PS6-5

ELECTRICAL SPECIFICATIONS

INPUT: Series 1 — 105-125 VAC, 57-400 cps
Series 2 and 4 — 105-125 VAC, 55-65 cps. (400 cps on special order).

Output: Floating; Isolated from ground, 300 VDC max.

Regulation, Line: 0.01% or 3 mv*, for 105-125 VAC line change at any output within specifications.

Regulation, Load: 0.02% or 5 mv*, no load to full load at any output within specifications.

Ripple: Less than 0.5 mv RMS. (2 mv for modules over 100 volts output.)

Stability: 0.05% or 10 mv*, for 8 hours after warm-up. Measured at constant line voltage, load and ambient temperature.

Temperature Coefficient: (0.02% + 400μv)/°C.

High Stability Option (X): 0.01% or 4 mv* with a T.C. of (0.01% + 200 μv)/°C.

Temperature Range: 0° to +71°C.

Recovery Time: 25 microseconds to recover within 0.05% or 15 mv* of output voltage for 100% step change in rated load.

Short Circuit Protection: All narrow range units (F suffix) have automatic Current Foldback. All other units have Current Limiting. All are self-resetting when overload is removed.

Remote Programming: Narrow range units (F suffix) are approximately 50 ohms/volt except PS100-200F and PS150-120F. All other units are approximately 100 ohms/volt.

Remote Sensing: Maintains rated regulation directly at the load. Maximum line drop 0.5 volts per leg.

*Whichever is greater

GENERAL AND PHYSICAL SPECIFICATIONS

Controls: Recessed screwdriver voltage adjust.

Terminals: Terminal Strip (Standard Models). Octal sockets (OS) or Solder Lugs (SL) available as options.

Connections: Pos. Output (+V) — Neg. Output (—V) — Pos. Sensing (+S) — Neg. Sensing (—S) — Remote Programming (REM) — Ground (G) — AC Input (AC).

Rack Mounting: Supplies may be mounted in a vertical or horizontal position. Rack mount RPS-V mounts 1 to 15 modules vertically. Rack mount RPS-H mounts 1 to 4 modules horizontally.

Weight: Series 1: 5 lbs.
Series 2: 9 lbs.
Series 4: 12 lbs.

TABLE 1

OUTPUT					PRICE				
Series	Model	Volts	Amps	Nominal Impedance DC-1KC	1-8	9-49	50-up	Overvoltage Protection	High Stability (X) (0.01%)
1	PS3-1.5F	2.5-3.5	0-1.5	0.010	90	82	79	—	—
	PS6-500F	4-8	0-0.5	0.020	84	78	76	—	—
	PS6-1F	4-8	0-1	0.010	89	81	78	—	—
	PS12-500F	10-14	0-0.5	0.020	79	74	72	—	—
	PS12-900F	10-14	0-0.9	0.011	89	82	79	—	—
	PS15-800F	13-17	0-0.8	0.011	92	85	82	—	—
	PS18-800F	16-20	0-0.8	0.013	92	85	82	—	—
	PS20-400	0-20	0-0.4	0.025	90	82	79	✓	✓
	PS24-760F	22-26	0-0.7	0.015	92	85	82	—	—
	PS28-600F	26-30	0-0.6	0.017	85	78	75	—	—
	PS32-250	0-32	0-0.25	0.040	92	83	80	✓	✓
	PS48-400F	46-50	0-0.4	0.025	87	79	76	—	—
	PS50-150	0-50	0-0.15	0.065	89	81	78	✓	✓
	PS100-200F	90-110	0-0.2	0.065	119	110	107	—	—
	PS150-120F	140-160	0-0.12	0.067	135	126	122	—	—
	PS200-100F	190-210	0-0.1	0.1	135	126	122	—	—
2	PS12-2	0-12.5	0-2	0.005	160	147	141	✓	✓
	PS20-1.5	0-20	0-1.5	0.006	160	147	141	✓	✓
	PS32-1.25	0-32	0-1.25	0.008	165	158	146	✓	✓
	PS50-750	0-50	0-0.75	0.015	175	158	148	✓	✓
	PS100-400	0-100	0-0.4	0.065	185	170	164	✓	✓
	PS160-250(1)	0-160	0-0.25	0.067	190	175	169	✓	✓
4	PS6-5	0-6	0-5	0.0010	175	159	153	✓	✓
	PS12-4	0-12.5	0-4	0.0025	175	159	153	✓	✓
	PS20-3	0-20	0-3	0.0030	175	159	153	✓	✓
	PS32-2.5	0-32	0-2.5	0.0040	180	167	156	✓	✓
	PS50-1.5	0-50	0-1.5	0.0075	185	167	156	✓	✓
	PS100-750	0-100	0-0.75	0.0070	195	178	172	✓	✓
	PS160-500(1)	0-160	0-0.5	0.0070	200	183	177	✓	✓

(1) Recessed screwdriver voltage adjustment range 80v to 160v, rémote programming over full range 0 to 160v.

Option Prices — PS Series 1, 2, and 4

	1-8	9-49	50-up
Overvoltage Protection	$150	$90	$55
High Stability	75	75	75
Special Voltages	40	15	8
Series Start	5	5	5
Solder Lugs	15	8	5
Octal Sockets	25	12	5
Horizontal Mounting	5	5	5

Overvoltage Protection — OV
Provides a maximum output voltage clamp for internal and external OV protection.

High Stability — X
0.01% stability with a T.C. of (0.01% + 200 μv)/°C.

Special Voltages — F
Special voltage available for suffix F units. The available current output will be that of the next higher voltage standard unit.

Series Start Option — D
Available for Series 1 Modules only. Not required for PS3, PS6, Series 2,4,8 and wide range units.

Solder Lug Terminals — SL

Octal Socket (plug-in) — OS

Horizontal Mounting — HM

e.g. PS6-1FOS

APPENDIX B

ELECTRONICS ENGINEERING DEPARTMENT
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY 4, CALIFORNIA

POWER SUPPLY SPECIFICATIONS

1.0 General Description of Application:

1.1 A general purpose transistorized power supply for instrument applications.

2.0 Output Requirements

2.1 Output No. 1: Adjustable continuously from 10.5 to 18.5 volts for nominal line

2.1.1 Voltage adjustment

a) Type of adjustment: Screwdriver control. Transformer taps to limit regulator transistor dissipation are acceptable.

b) Location of control: On panel (see outline drawing)

2.1.2 Maximum Current: 1 amp between 10.5 - 18.5 volts

2.1.3 Maximum ripple and noise: 3 millivolts peak to peak

2.1.4 Insulation to line and chassis: 500 volts

2.1.5 Regulation

a) Line regulation (max. change in output voltage for line variations from 105 to 125 V A.C.): 0.1%.

b) Load regulation (max. change in output voltage for load variations from no load to full load): 0.1%.

2.1.6 Maximum output impedance:

a) The output voltage shall remain within (1/2) volts of the steady-state value for the period 1 to 50 microseconds following any step function load change of I amperes (within rating). Then, after 50 microseconds, within 0.1% of the steady-state voltage.

b) When the ac supply is turned on and off, the output voltage excursion shall not exceed 110% of the set value.

2.1.7 Drift (% change in output voltage after 10 minutes warm-up): 0.1% max.

a) Period of time: 8 hours

2.1.8 Temperature Characteristics

a) Ambient temperature range to 50° C max.

b) Maximum temperature coefficient: 0.01%/°C.

2.1.9 Polarity: Floating

3.0 Style of Construction

3.1 As shown on outline drawing. All exposed leads shall be protected by a protective cover or other means.

3.2 Power supply mounting plate to be fastened by LRL to 18 gauge steel sheet having an area of at least 84 square inches. This is available for use as heat sink.

3.3 All exposed insulating materials shall be " flame- retardant ".

4.0 Connections

4.1 Solder terminal posts

#1 and 2 AC power

#3 and 4 DC + and DC -

#5 Chassis

5.0 Overload Protection

5.1 Input: Fuse in fuse post holder.

5.2 Output: Thermal protection to open circuit for ambient temperature in excess of 50° C.

5.3 Provide means for limiting transistor dissipations so that junction temperatures never exceed 90% of the manufacturer's recommended value.

6.0 Finish

6.1 Base plate shall be caustic etched or preferably golden irridite.

7.0 Quality

7.1 Specifications as to minimum quality of material and workmanship will conform with standards generally obtainable from high quality custom electronic equipment fabricators. Power supplies procured to this specification will be inspected upon receipt by LRL Electronics Department Production Control.

8.0 Markings on Chassis

8.1 All major components, such as transistors, transformers (including taps), inductances, can type capacitors, controls, large resistors, terminal posts, plugs, etc., shall be marked in the most readable position on the chassis. The lettering shall be at least 3/16 inch high where possible, but in all cases legible to the satisfaction of the University.

9.0 Name Plate Data

LRL Spec. No. LRL-98-27 Serial No. ______

Voltage Range 10.5 - 18.5 Current 1 amp

% Regulation 0.1

10.0 Prototype

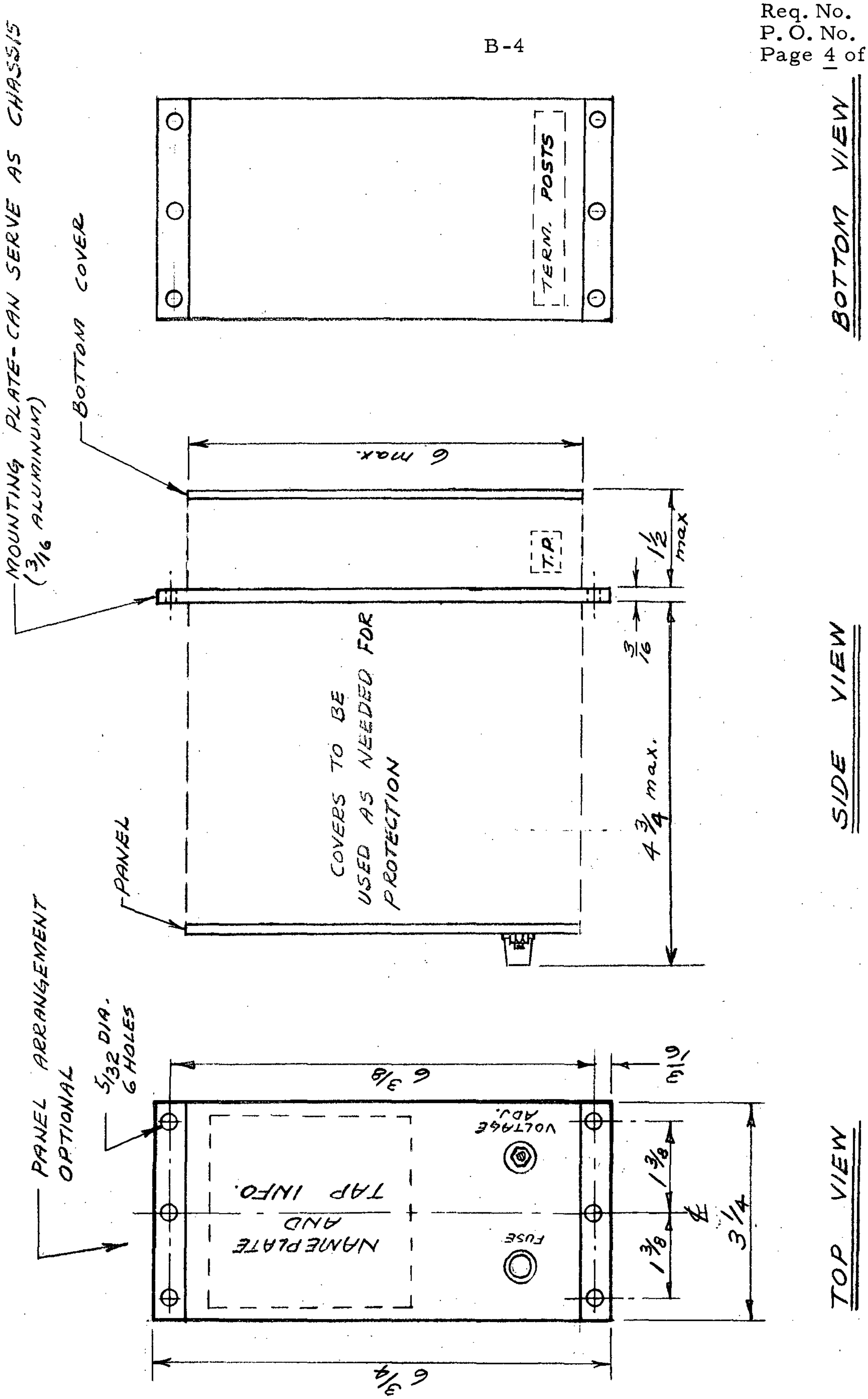
10.1 The manufacturer shall provide two prototype units. The construction and operation of the prototypes shall be approved by the University in writing before delivery of the remainder of the order.

11.0 Schematic and Instruction Manual

11.1 A schematic and instruction manual, with parts list, shall be provided for each supply (including prototypes).

Prepared by E. Hazelton Date 12/19/61 Approved by [signature] Date 12/19/61
Revised by E. Hazelton Date 2-1-62

Spec. No. LRL-98-27
Req. No. 1695-68
P. O. No.
Page 4 of 4



XBL 677-4233

APPENDIX C

Power Design Transistorized Power Supply Model 2050

Electrical Specifications: (Taken from manufacturers operating instructions dated 1962.)

OUTPUT: 1-20 volts d-c continuously variable at 0-5.0 amperes.

INPUT: 105-125 volts, 55-440 cycles/sec., *175 wattts.

REGULATION: 10 millivolts or 0.05% (whichever is greater).

RIPPLE: Less than 500 microvolts rms.

SOURCE IMPEDANCE: 0.005 ohms to 20 kc; 0.5 ohms to 1 megacycle.

RESPONSE TIME: Less than 50 microseconds for 100% step change in rated load.

TEMPERATURE: Continuous duty at full load to 50°C ambient.

POLARITY: Either positive or negative output terminal may be grounded.

* At Nominal Line Voltage

OPERATING INSTRUCTIONS

MODEL 2050

TRANSISTORIZED POWER SUPPLY

1. GENERAL:

MODEL 2050 IS A PORTABLE COMPACT TRANSISTORIZED POWER SOURCE DESIGNED TO FURNISH STABLE, LOW RIPPLE D-C POWER FOR ELECTRONIC INSTRUMENTATION. EMPLOYING SEMICONDUCTOR DEVICES THROUGHOUT, THE UNIT IS DESIGNED FOR HIGH EFFICIENCY AND LONG LIFE EXPECTANCY. COMPONENTS ARE CHOSEN AND RATED TO PROVIDE EQUIPMENT LIFE EXPECTANCY CONSISTENT WITH THAT OF THE SEMICONDUCTOR COMPONENTS EMPLOYED.

UNIQUE PROTECTIVE CIRCUITRY IS EMPLOYED TO PREVENT INTERNAL DAMAGE TO THE POWER SUPPLY OR EXTERNAL DAMAGE TO LOAD CIRCUITS IN THE EVENT OF SHORT CIRCUITS. ("ROBOTEC").

A NOVEL POWER DISSIPATION SHIFT CIRCUIT IS EMPLOYED TO REDUCE POWER TRANSISTOR HEAT DISSIPATION UNDER EXTREME LINE AND LOAD OPERATING CONDITIONS BY SHIFTING OR TRANSFERRING THE INCREASED POWER INTO HIGH WATTAGE RATING RESISTORS, THUS REDUCING THE POWER TRANSISTOR HEAT RISE AND IMPROVING RELIABILITY AND OPERATION AT ELEVATED TEMPERATURES. ("ROBOTEC").

2. ELECTRICAL AND MECHANICAL SPECIFICATIONS:

IN ACCORDANCE WITH THE SPECIFICATIONS FOR MODEL 2050 IN THE ATTACHED BROCHURE.

3. OPERATING INSTRUCTIONS:

THE POWER SUPPLY MAY BE PLACED IN OPERATION BY CONNECTING THE A-C LINE CORD ON THE REAR OF THE INSTRUMENT TO ANY CONVENIENT SOURCE OF 105-125 VOLTS A-C, 55-440 CYCLES. D-C OUTPUT CONNECTIONS ARE ACCESSIBLE AT THE FRONT PANEL TERMINALS APPROPRIATELY MARKED. THE POWER SUPPLY MAY BE OPERATED WITH EITHER THE POSITIVE OR NEGATIVE D-C OUTPUT TERMINAL CONNECTED TO GROUND OR LEFT FLOATING. UNDER CERTAIN OPERATING CONDITIONS AN INCREASE IN RIPPLE OUTPUT MAY RESULT WITH BOTH OUTPUT TERMINALS FLOATING. GROUNDING EITHER OF THESE TERMINALS WILL SUBSTANTIALLY REDUCE THIS RIPPLE OUTPUT. THE POWER SUPPLY MAY BE TURNED ON BY THROWING THE A-C TOGGLE SWITCH TO THE "ON" POSITION AND SETTING THE "VOLTAGE ADJUST" TO THE DESIRED OUTPUT VOLTAGE AS INDICATED ON THE PANEL METER. THE PANEL METER MAY BE UTILIZED TO MONITOR OUTPUT VOLTAGE OR CURRENT BY THE DESIRED POSITION OF THE TOGGLE SWITCH MARKED "VOLTS", "AMPS", TO THE IMMEDIATE RIGHT OF THE PANEL METER. A "REGULATION COMPENSATOR" ADJUSTMENT IS PROVIDED TO COMPENSATE FOR THE LOSS OF REGULATION (LOAD) DUE TO THE D-C LEAD DROP BETWEEN THE OUTPUT TERMINALS OF THE POWER SUPPLY AND THE LOAD. IT IS IMPORTANT THAT HEAVY ENOUGH WIRE SHOULD BE EMPLOYED TO MINIMIZE THIS DROP. TO COMPENSATE FOR THE LEAD DROP A VOLTMETER SHOULD BE CONNECTED ACROSS THE LOAD TERMINALS AT THE LOAD END OF THE LEADS BETWEEN THE POWER SUPPLY AND THE EXTERNAL LOAD. THE "REGULATION COMPENSATOR" SHOULD THEN BE TURNED CLOCKWISE UNTIL NO MOVEMENT IS DISCERNIBLE WHEN THE LOAD IS ALTERNATELY CONNECTED AND DISCONNECTED. NOTE: WHEN THE "REGULATION COMPENSATOR" ADJUSTMENT IS UTILIZED THE PANEL VOLTMETER READING WILL SHOW A VOLTAGE RISE WHEN THE REMOTE LOAD IS CONNECTED OR A VOLTAGE FALL WHEN DISCONNECTED. THIS IS NORMAL AND THE CHANGE IN VOLTAGE READING INDICATES THE

DEGREE OF COMPENSATION. APPROXIMATELY 250 MILLIVOLTS OR LEAD DROP MAY BE COMPENSATED FOR BY THIS ADJUSTMENT.

4. CIRCUIT PROTECTION:

4.1 FUSES: A-C FUSE: A 3 AMPERE TYPE 3AG "SLO BLO" FUSE IS CONNECTED IN SERIES WITH THE A-C INPUT LINE TO THE POWER SUPPLY. THIS FUSE WILL FAIL ONLY IN THE EVENT OF INTERNAL TRANSFORMER, RECTIFIER, OR WIRING SHORT CIRCUITS.

D-C FUSE: A 5 AMPERE TYPE 3AG FUSE IS CONNECTED IN SERIES WITH THE TRANSISTOR REGULATOR SYSTEM. THIS FUSE WILL BLOW IN THE EVENT OF INTERNAL REGULATOR SYSTEM FAILURE OR EXTERNAL D-C OVERLOAD CURRENT IN EXCESS OF 5 AMPERES. (SEE PARAGRAPH 4.2)

4.2 SHORT CIRCUIT AND OVERLOAD PROTECTION: THE INTERNAL CIRCUITRY OF THE REGULATOR SYSTEM IS DESIGNED TO PROTECT THE POWER SUPPLY AND EXTERNAL LOAD CIRCUITS AGAINST SHORT CIRCUITS OR OVERLOAD. THEY FUNCTION AS FOLLOWS:

A: IF A SHORT CIRCUIT EXISTS ACROSS THE OUTPUT TERMINALS OF THE POWER SUPPLY AND THE UNIT IS TURNED ON, THE REGULATOR CIRCUIT IS AUTOMATICALLY HELD IN A "LATCHED OUT" CONDITION AND THE OUTPUT VOLTAGE OF THE POWER SUPPLY CANNOT RISE. THE MAXIMUM LOAD CURRENT THAT FLOWS IN THE EXTERNAL LOAD OR SHORT CIRCUIT IS LIMITED TO APPROXIMATELY 0.1 AMPERES.

B: IF THE POWER SUPPLY IS OPERATED NORMALLY AND A SHORT CIRCUIT IS SUDDENLY PLACED ACROSS THE OUTPUT TERMINALS, THE POWER SUPPLY REGULATOR SYSTEM "LATCHES OUT" IN APPROXIMATELY 30 MICROSECONDS AND THE D-C OUTPUT VOLTAGE COLLAPSES AT A RATE DETERMINED BY THE OUTPUT CAPACITOR (4500 MFD) AND THE EXTERNAL SHORT CIRCUIT RESISTANCE. REGARDLESS OF THE NATURE OF THE SHORT THE A-C INPUT POWER TO THE POWER SUPPLY WILL FALL TO APPROXIMATELY 25 WATTS. IF THE SHORT CIRCUIT IS REMOVED THE POWER SUPPLY MAY BE RESTORED TO NORMAL OPERATION BY TURNING OFF THE A-C TOGGLE SWITCH AND TURNING IT BACK ON AGAIN. IF THE SHORT CIRCUIT STILL EXISTS THE POWER SUPPLY OUTPUT VOLTAGE WILL NOT RISE AS PER PARAGRAPH A ABOVE.

C. IF A CURRENT OVERLOAD IN EXCESS OF 5 AMPERES OR A SLOWLY INCREASING CURRENT OVERLOAD IN EXCESS OF 5 AMPERES IS PLACED ACROSS THE OUTPUT OF THE POWER SUPPLY (SLOW AS CONTRASTED WITH AN INSTANTANEOUS SHORT AS PER PARAGRAPH B), THE 5 AMPERE D-C FUSE WILL BLOW. INTERNAL DAMAGE TO THE POWER TRANSISTORS IN THE POWER SUPPLY IS AVOIDED DURING THE TIME INTERVAL REQUIRED TO BLOW THE D-C FUSE BY INTRINSIC CIRCUIT PROTECTION WHICH DRIVES THESE POWER TRANSISTORS INTO COLLECTOR SATURATION (LOW COLLECTOR-EMITTER VOLTAGE DROP) THUS LIMITING THE DISSIPATION IN THE POWER TRANSISTORS UNTIL FUSE FAILURE OCCURS.

4.3 "HEATRAN" POWER TRANSFER CIRCUIT:

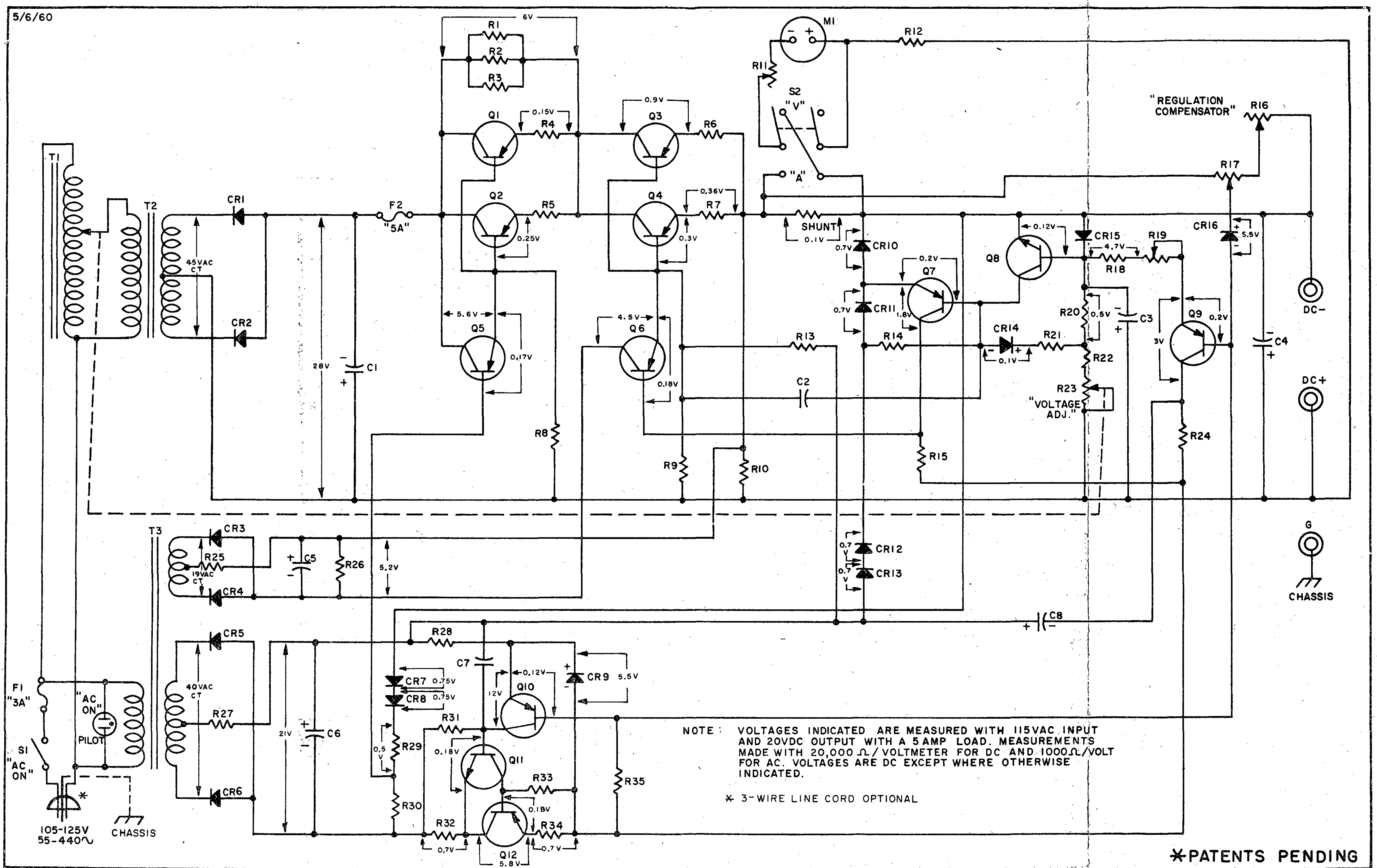
"HEATRAN" IS A TRANSISTORIZED ELECTRONIC CIRCUIT CONTINUOUSLY MONITORING POWER DISSIPATION IN THE SERIES TRANSISTORS OF THE

REGULATOR SYSTEM AND AUTOMATICALLY TRANSFERRING DISSIPATION ABOVE A PRESET MAXIMUM VALUE INTO EXTERNAL VITREOUS ENAMEL RESISTORS. THESE RESISTORS ARE MOUNTED IN A CAGE AT THE REAR OF THE CABINET. THIS CIRCUITRY THUS PERMITS FEWER TRANSISTORS FOR A GIVEN POWER SUPPLY CAPACITY, MORE COMPACT DESIGN WITH INCREASED RELIABILITY AND PRACTICAL CONVECTION COOLING WITHOUT THE NEED FOR BLOWERS. REFERRING TO THE SCHEMATIC DIAGRAM Q1, Q2 AND Q5 FORM AN AUXILIARY REGULATOR IN SERIES WITH Q3 AND Q4, THE SERIES POWER TRANSISTORS OF THE CONVENTIONAL VOLTAGE REGULATOR. Q5 CONTINUOUSLY COMPARES THE COLLECTOR-EMITTER VOLTAGE DROP ACROSS Q3 AND Q4 WITH THE VOLTAGE REFERENCE ESTABLISHED BY THE SILICON DIODES AND RESISTOR, CR7, CR8 AND R29. IF THE VOLTAGE DROP EXCEEDS 1.6 VOLTS APPROXIMATELY Q5 OPERATES TO DRIVE HEAT TRANSFER POWER TRANSISTORS Q1 AND Q2 OUT OF SATURATION. IN THIS CONDITION A SUBSTANTIAL PORTION OF THE POWER SUPPLY OUTPUT CURRENT IS THEN DIVERTED INTO RESISTORS R1, R2 AND R3, THE HEAT DISSIPATING VITREOUS ENAMEL RESISTORS EXTENDING FROM THE REAR OF THE EQUIPMENT. TYPICAL OF THE EFFECTIVENESS OF THIS CIRCUITRY IS THE POWER DISSIPATION RATIO BETWEEN THE POWER TRANSISTORS IN THE POWER SUPPLY AND THAT OF THE HEAT TRANSFER RESISTORS WHEN THE POWER SUPPLY IS OPERATED AT 125 LINE VOLTS INPUT AND AN OUTPUT OF 20 VOLTS AT 5 AMPERES. UNDER THESE CONDITIONS THE COMBINED DISSIPATION OF THE POWER TRANSISTORS AND HEAT TRANSFER TRANSISTORS IS APPROXIMATELY 12 WATTS WHILE THE DISSIPATION IN THE VITREOUS ENAMEL RESISTORS IS 36 WATTS. IN A NORMAL REGULATED POWER SUPPLY OF CONVENTIONAL DESIGN THE COMPLETE DISSIPATION OF 48 WATTS WOULD HAVE TO BE CARRIED BY THE POWER TRANSISTORS OF THE REGULATOR.

5. MAINTENANCE:

UNDER NORMAL CONDITIONS NO SPECIAL MAINTENANCE OF THE EQUIPMENT IS REQUIRED DURING ITS LIFE.

WHEN REPLACING TRANSISTORS EMPLOY ONLY TRANSISTORS PURCHASED FROM THE FACTORY. AT THE PRESENT TIME PARAMETER TOLERANCES ON GERMANIUM TRANSISTORS NORMALLY AVAILABLE ARE NOT HELD SUFFICIENTLY CLOSE BY THE TRANSISTOR MANUFACTURER TO GUARANTEE INTERCHANGEABILITY. THE TRANSISTORS EMPLOYED IN THIS POWER SUPPLY ARE SPECIALLY PROCESSED UNITS WHOSE PARAMETERS ARE HELD SUFFICIENTLY TO GUARANTEE INTERCHANGEABILITY IN ANY OF THE POWER SUPPLIES MANUFACTURED BY POWER DESIGNS INC. COMMERCIALLY PURCHASED UNITS MAY, IN SOME CASES, DEGRADE THE PERFORMANCE OR TEMPERATURE STABILITY OF THE EQUIPMENT.



✱MODEL 2050
TRANSISTORIZED POWER SUPPLY

1-20 VDC, 0-5A

POWER DESIGNS INC.
NEW YORK

ELECTRICAL PARTS LIST, MODEL 2050

NOTES: 1. ITEMS WHICH BEAR NO FACTORY PART NUMBER ARE STANDARD COMPONENTS AVAILABLE FROM YOUR REGULAR ELECTRONIC PARTS DISTRIBUTOR.

2. REPLACEMENT TRANSISTORS SHOULD BE OBTAINED FROM POWER DESIGNS INC. COMMERCIALLY EQUIVALENT TRANSISTORS HAVE WIDE PARAMETER TOLERANCES WHICH MAY RENDER THEM UNSUITABLE FOR USE IN D-C AMPLIFIER CIRCUITRY. REPLACEMENT OF TRANSISTORS WITH COMMERCIAL EQUIVALENTS MAY RESULT IN DEGRADATION OF PERFORMANCE.

CIRCUIT DESIGNATION	DESCRIPTION	FACTORY PART NO.
C1	Capacitor, 11,000 MFD, 35 VDC, electrolytic	CE-30-.35
C2	Capacitor, .02 MFD, 500 VDC, ceramic disc	CC-10-5
C3	Capacitor, 35 MFD, 25 VDC, electrolytic	CE-16-.25
C4	Capacitor, 4500 MFD, 35 VDC, electrolytic	CE-14-.35
C5	Capacitor, 100 MFD, 15 VDC, electrolytic	CE-20-.15
C6	Capacitor, 70 MFD, 25 VDC, electrolytic	CE-19-.25
C7	Capacitor, .01 MFD, 500 VDC, ceramic disc	CC-4-5
C8	Capacitor, 8 MFD, 25 VDC, electrolytic	CE-21-.25
CR1, CR2	Diode, silicon rectifier, 20.0 A, 100 PIV	SR-9
CR3 to CR6	Diode, silicon rectifier, .5A, 50 PIV	SR-2
CR7, CR8, CR10 to CR15	Diode, silicon rectifier, controlled forward drop	SVR-3
CR9, CR16	Diode, silicon, zener, voltage reference	SVR-2
F1	Fuse, 3A, type 3AG "slo blo"	---
F2	Fuse, 5A, type 3AG "slo blo"	---
M1	Meter, dual, volt-ammeter, 0-25V/0-5A, 2½" rect	MVA-89
R1, R2	Resistor, 5 Ω ± 5%, 25W, wirewound	RW-050-3G
R3	Resistor, 10 Ω, ± 5%, 25W, wirewound	RW-100-3G
R4 to R7	Resistor, 0.15 Ω, ± 1%, 10W, wirewound	RW-0015-1E
R8	Resistor, 1000 Ω, ± 10%, 2W, composition	---
R9	Resistor, 560 Ω, ± 10%, 2W, composition	---
R10	Resistor, 270 Ω, ± 10%, 2W, composition	---
R11	Resistor, adj trimmer, 50 Ω ± 10%, 2W	RTW-510-4C
R12	Resistor, 24,900 Ω ± .5%, ½W, wirewound	RW-2492-6A
R13	Resistor, 100 Ω ± 10%, ½W composition	---
R14, R31	Resistor, 5600 Ω ± 10%, ½W, composition	---
R15	Resistor, 2200 Ω ± 10%, ½W, composition	---
R16	Resistor, variable ("REGULATION COMPENSATOR"), 8 Ω ± 10%, 2W, wirewound	RVW-080-4C
R17	Resistor, adj trimmer, 2 Ω ± 10%, 2W	---
R18, R33	Resistor, 560 Ω ± 10%, ½W, composition	---
R19	Resistor, adj trimmer, 100 Ω ± 10%, 2W	RTW-101-4C
R20	Resistor, 56 Ω ± 5%, ½W, composition	---
R21, R24	Resistor, 330 Ω ± 10%, ½W, composition	---
R22	Resistor, 10 Ω ± 10%, ½W, composition	---
R23	Resistor, variable, ("VOLTAGE ADJUST") 3000 Ω ± 5%, 4W, wirewound, part of ganged T1-R23 Assembly	RVW-302-3M

ELECTRICAL PARTS LIST, MODEL 2050 CON'T.

CIRCUIT DESIGNATION	DESCRIPTION	FACTORY PART NO.
R25	Resistor, 22 Ω ± 10%, 1W, composition	---
R26	Resistor, 120 Ω ± 10%, 1W, composition	---
R27, R32, R34	Resistor, 22 Ω ± 10%, $\frac{1}{2}$W, composition	---
R28	Resistor, 680 Ω ± 10%, $\frac{1}{2}$W, composition	---
R29	Resistor, 18 Ω ± 10%, $\frac{1}{2}$W, composition	---
R30	Resistor, 560 Ω ± 10%, 1W, composition	---
R35	Resistor, 680 Ω ± 5%, $\frac{1}{2}$W, composition	---
Q1 to Q4	Transistor, 1518 (Clevite)	1518
Q5, Q6, Q12	Transistor, CTP1150 (Clevite)	CTP1150
Q7, Q9, Q10	Transistor, 2N360PD (Industro)	2N360PD
Q8, Q11	Transistor, 2N35P (General Transistor)	2N35P
S1	Switch, toggle, SPST, 15A, 125 VAC	ST-5
S2	Switch, toggle, DPDT, 15A, 125 VAC	ST-2
T1	Transformer, variac type, part of ganged T1-R23 Assembly	TTV-3
T2	Transformer, power	TTM-17
T3	Transformer, auxiliary	TTH-11

APPENDIX D

Sorensen D.C. Power Supply
Model QM 12.0-0.32

Specifications: (Taken from Instruction Manual A14-2646D, September 1962)

INPUT:	Voltage	115 VAC nominal 105 to 125 voltage range
	Frequency	50/60 cps or 400 cps (For 400 cps input frequency add prefix "D" when ordering).
OUTPUT:	Voltage	12.0 d-c output voltage is factory set with ±5% internal adjustment.
	Current	Zero to 0.32 amperes.
	Regulation, Line and Load	±0.05%
	Ripple	1 MV. rms
	Output Impedance at 1KC	Less than 2.5 mv/amp. load
	Recovery Time	50 microseconds
	Overload	Unit not damaged from momentary overloads or continuous shorts.
	Isolation	Input to output isolation
	Temperature Coeffieient	0.03% per degree C
	Maximum Ambient Temperature	0°C to +50°C
	Heat Sink	For continuous operation, hold base of power supply at +60°C max. by means of heat sink or external means.
	Size	4-5/16" X 3-11/16" X 5-11/16"

APPENDIX E

VARIABLE VOLTAGE TRANSDUCER POWER SUPPLY Model 3566

SRC

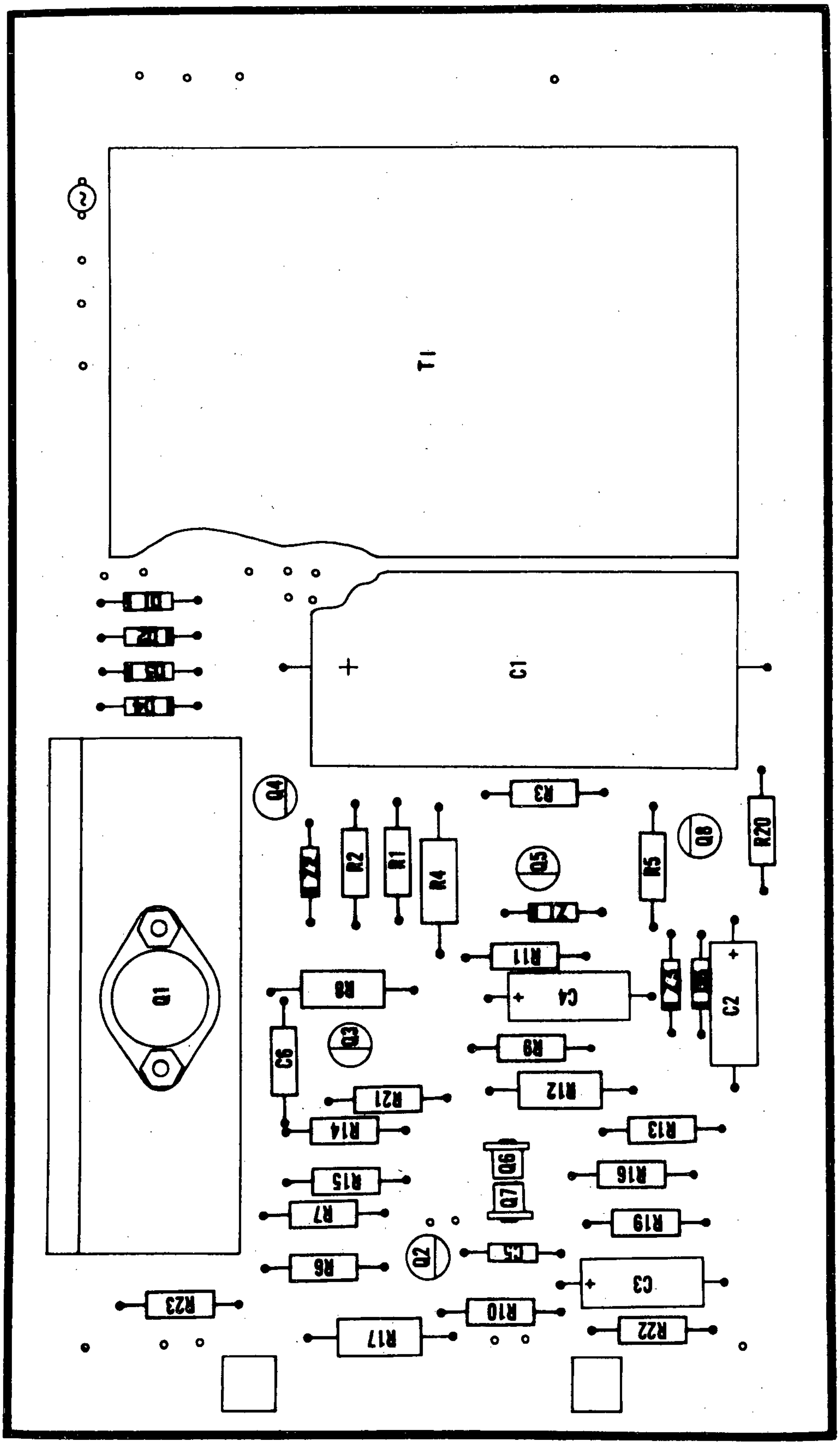
SPECIFICATIONS

Input Voltage	105-125 VAC, 60 cps
Output Voltage	4-25 VDC, continuously variable
Output Current	0-200 ma
Output Regulation	Less than 0.02% NL/FL and line voltage change of 10%
Output Ripple & Noise	Less than 500 microvolts peak-to-peak
Resolution	5 mv.
Recovery Time	Less than 100 micro-seconds NL/FL
Short Circuit Protection	Current limiting to less than 300 ma
Output Impedance	Less than .02 ohms at DC.
AC Isolation	Less than 0.1 pico-farad
DC Isolation	10,000 megohms
Temp. Stability	.005%/°F
Temp. Range	35°F to 130°F
Time Stability	Less than .01% change per 8 hours
Controls	Front panel screw driver adjust for multi-turn pot
Excitation	Front panel binding posts
Sensing	Front panel binding posts for local and remote sensing
Weight	1 3/4 lbs.
Size	1 3/4" high, 3 1/2" wide, 6 1/4" deep

Warranty---Parts and labor---1 year

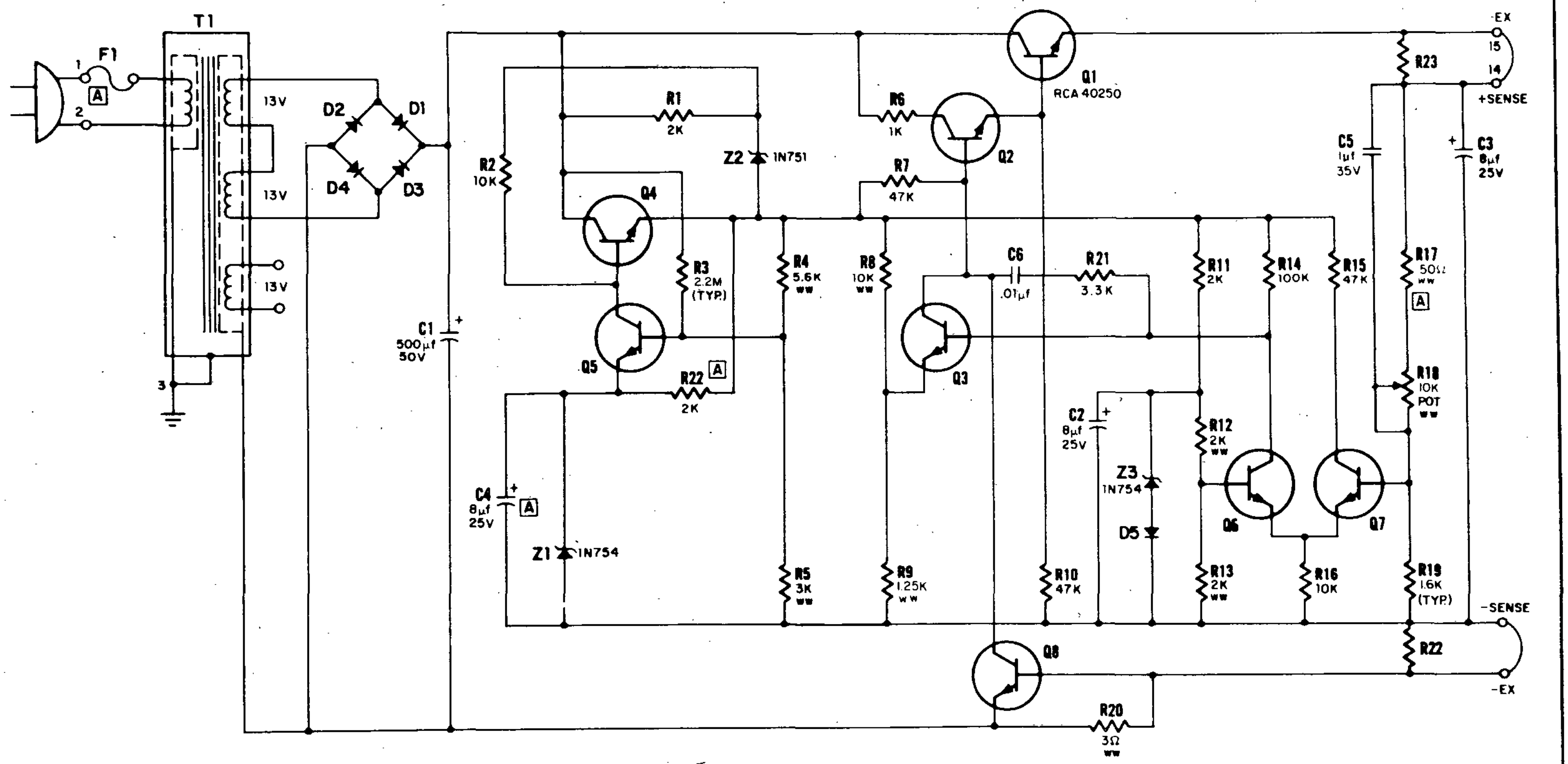
NOTE: For Remote Sensing---disconnect jumpers between voltage and sensing terminals on front panel.
Best regulation is obtained by sensing at the load.

LRL NOTE: To achieve adequate ac isolation at the dc output terminals of this supply, the heatsink on which Q1 is mounted was modified. The modification is described on print number 10X1260-M1. (See power supply schematic list).



COMPONENT BOARD LAYOUT - MODEL 3566

SYSTEMS RESEARCH CORPORATION



REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL

3. D1 THRU D5 = SC-1
2. Q2 THRU Q8 = 2N2925
1. [A] TO BE ADDED BY FACTORY AS REQUIRED

NOTES; UNLESS OTHERWISE SPECIFIED.

SRC SYSTEMS RESEARCH CORPORATION
2309 PONTIUS AVENUE, LOS ANGELES, CALIFORNIA

TITLE SCHEMATIC, POWER SUPPLY
MODEL 3566

DATE | NO.

PARTS LIST
MODEL 3566

PART NO.	QUANTITY	DESCRIPTION	MFG.
C1	1	Capacitor 500 mfd 50 v	CDE
C2	1	Capacitor 8 mfd 25 v	CDE
C3	1	Capacitor 8 mfd 25 v	CDE
C4	1	Capacitor 8 mfd 25 v	CDE
C5	1	Capacitor 1 mfd 25 v	CDE
C6	1	Capacitor 0.01 mfd 50 v ceramic disc	Sprague
Q1	1	Transistor	RCA
Q2-Q8	7	Transistor	GE
R1	1	Resistor 2K ohm 1/2 watt carbon	Ohmite
R2	1	Resistor 10K ohm 1/2 watt carbon	Ohmite
R3	1	Resistor 2.2M ohm 1/2 watt carbon type	Ohmite
R4	1	Resistor 10K ohm 3 watt wire wound	Ohmite
R5	1	Resistor 3K ohm 3 watt wire wound	Ohmite
R6	1	Resistor 1K ohm 1/2 watt carbon	Ohmite
R7	1	Resistor 47K ohm 1/2 watt carbon	Ohmite
R8	1	Resistor 10K ohm 3 watt wire wound	Ohmite
R9	1	Resistor 1.25K ohm 3 watt wire wound	Ohmite
R10	1	Resistor 47K ohm 1/2 watt carbon	Ohmite
R11	1	Resistor 2K ohm 1/2 watt carbon	Ohmite
R12	1	Resistor 2K ohm 3 watt wire wound	Ohmite
R13	1	Resistor 2K ohm 3 watt wire wound	Ohmite
R14	1	Resistor 100K ohm 1/2 watt carbon	Ohmite
R15	1	Resistor 47K ohm 1/2 watt carbon	Ohmite
R16	1	Resistor 10K ohm 1/2 watt carbon	Ohmite
R17	1	Resistor 50 ohm 3 watt wire wound typ.	Ohmite
R19	1	Resistor 1.600K ohm 3 watt wire wound typ.	Ohmite
R20	1	Resistor 2 ohm 3 watt wire wound	Ohmite
R21	1	Resistor 3.3k ohm 1/2 watt carbon	Ohmite
R22	1	Resistor 22 ohm 1/2 watt carbon	Ohmite
T1	1	Transformer	SRC
F1	1	Fuse 1/4 amp	Littlefuse
D1-D5	5	Diode	Semtech
Z1	1	Zener diode	Tex. Inst.
Z2	1	Zener diode	Hughes
Z3	1	Zener diode	Tex. Inst.
R18	1	Potentiometer 10 turn 10K ohm	SRC
	1	Power Cord	Beldon

APPENDIX F

APPLICATION FILE

ZELTEX, INC.

2350 Willow Pass Road
Concord, California

phone 686-6660 Area Code 415

INSTALLATION NOTES

Models 140, 140B, 143, & 510 Dual

These amplifiers are solid state-chopper stabilized models which are supplied in open loop form. It is necessary to connect input and feedback components to and around the amplifier to have it function in the desired manner. For purposes of incoming inspection test, we suggest connecting a 100 k ohm resistance between input and output and a 100 k ohm resistance between the input and signal source.

In common with other transistorized equipment, a few simple precautions should be observed in first connecting the amplifier to the power source; be careful to observe proper polarity and avoid the older types of power supplies which greatly overshoot the desired voltage when first energized.

These amplifiers are supplied with separate signal and power ground returns; be certain to connect these two points together.

Where it is desired to coaxially shield the leads connected to the input terminal while preserving the widest bandwidth and dynamic stability, the shield of the coaxial cable should be lifted off of ground and attached to the amplifier shield driving point, where it will be driven in phase with the incoming signal. If conventional shielding is desired, do not connect to the amplifier shield driving point.

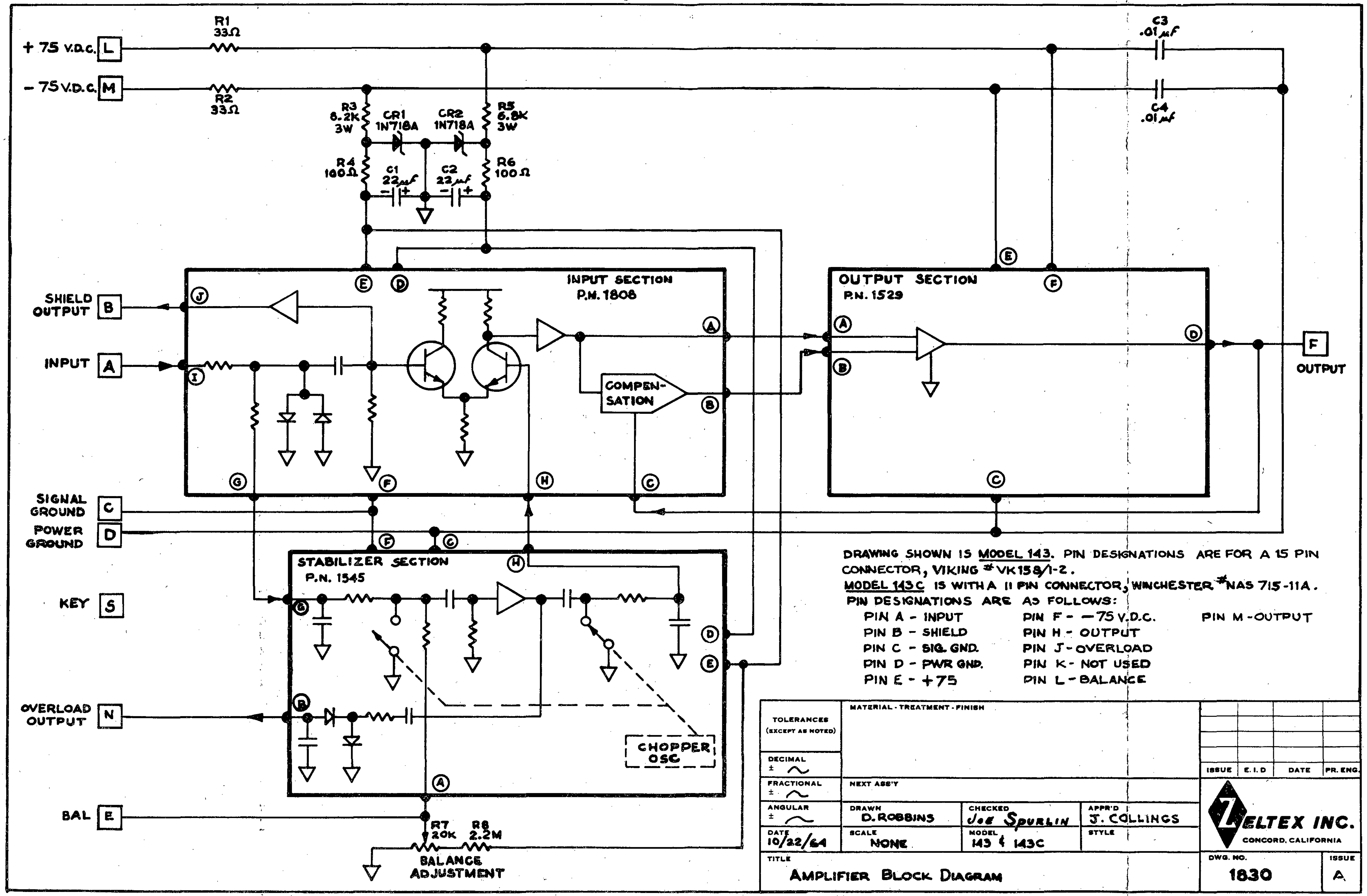
Amplifier Balance: To adjust amplifier balance, connect the amplifier as a X100 or X1000 inverter (1 k input resistor, 100 k feedback). Ground the input terminal to the circuit and adjust the balance potentiometer for zero volts output.

Attachments: Amplifier data sheet
Outline drawing

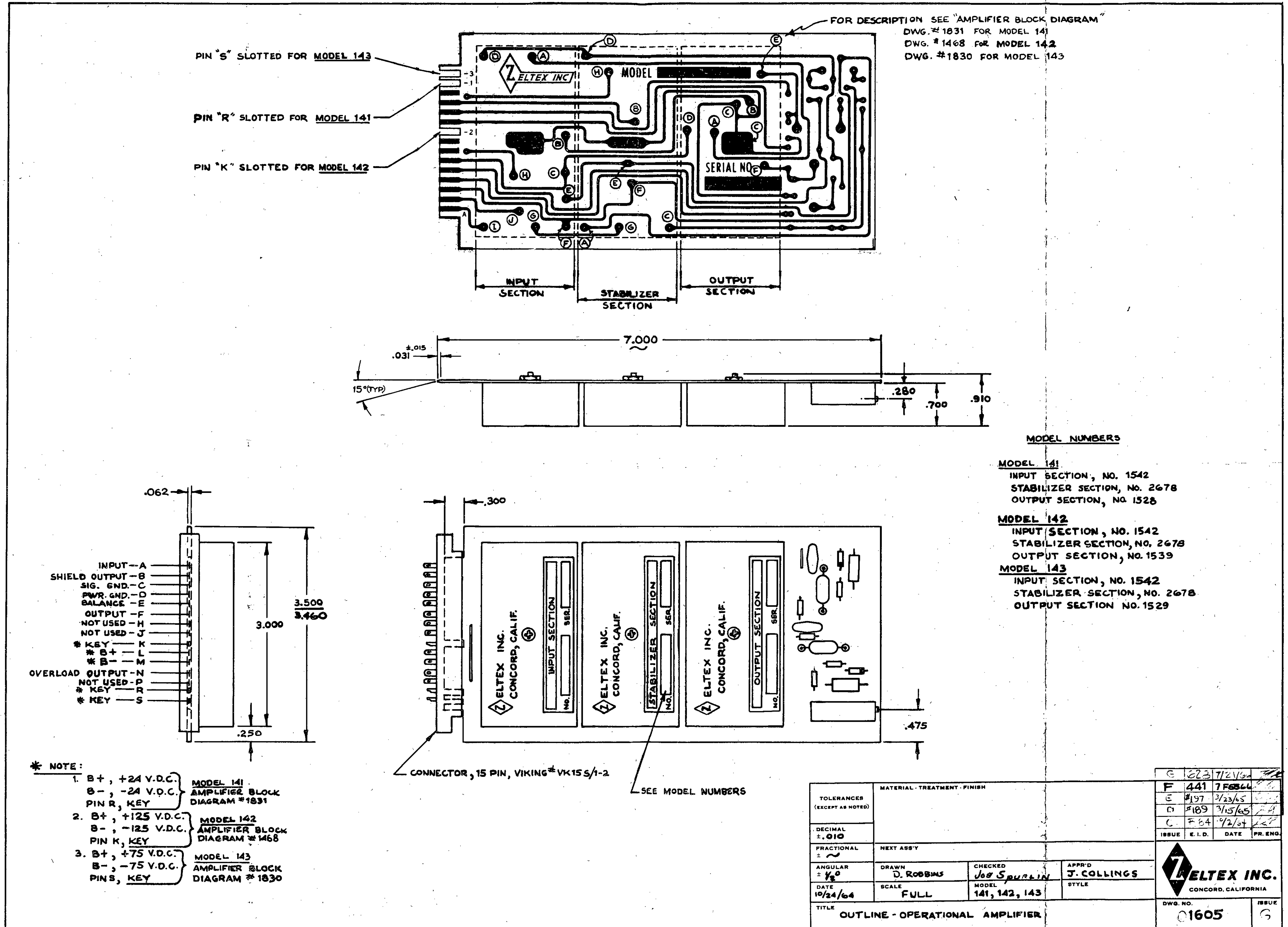
ZELTEX MODEL 143

Operational Amplifier Specifications
From Manufacturer's Condensed Catalog (6/66)

RATED OUTPUT:		±50 V minimum
		50 mA minimum
DC GAIN:		50×10^6 minimum
BANDWIDTH:	Unity Gain	1 MHz
	Full Output	25 kHz minimum
	Slew Rate	7 V/μs minimum
INPUT VOLTAGE:	Drift	0.5 μV/°C typical
		1 μV/°C maximum
	vs. Time	10 μV/day
	vs. Supply	1 μV/% - supply change
INPUT CURRENT:	Offset @ 25°C	0.005 nA typical
		0.01 nA maximum
	Drift	0.001 nA/°C maximum
INPUT IMPEDANCE:	Diff.	1 Meg.
INPUT NOISE:	to 50 Hz	30 μV, PK
	to 10 kHz	500 μV, PK
POWER SUPPLY:	Voltage	±75 V nominal
	Quies. Curr.	25 mA
OPERATING TEMPERATURE:		0°C minimum
		+60°C maximum



+75 V.D.C. L
-75 V.D.C. M
R1 33Ω
R2 33Ω
R3 8.2K 3W
CR1 1N718A
CR2 1N718A
R5 6.8K 3W
R4 100Ω
C1 22μf
C2 22μf
R6 100Ω
C3 .01μf
C4 .01μf
SHIELD OUTPUT B
INPUT A
SIGNAL GROUND C
POWER GROUND D
KEY S
OVERLOAD OUTPUT N
BAL E
INPUT SECTION P.N. 1808
COMPEN-SATION
OUTPUT SECTION P.N. 1529
F OUTPUT
STABILIZER SECTION P.N. 1545
CHOPPER OSC
R7 20K
R8 2.2M
BALANCE ADJUSTMENT
DRAWING SHOWN IS MODEL 143. PIN DESIGNATIONS ARE FOR A 15 PIN CONNECTOR, VIKING # VK158/1-2.
MODEL 143C IS WITH A 11 PIN CONNECTOR, WINCHESTER # NAS 715-11A.
PIN DESIGNATIONS ARE AS FOLLOWS:
PIN A - INPUT
PIN B - SHIELD
PIN C - SIG. GND.
PIN D - PWR GND.
PIN E - +75
PIN F - -75 V.D.C.
PIN H - OUTPUT
PIN J - OVERLOAD
PIN K - NOT USED
PIN L - BALANCE
PIN M - OUTPUT
TOLERANCES (EXCEPT AS NOTED)
DECIMAL ±
FRACTIONAL ±
ANGULAR ±
MATERIAL - TREATMENT - FINISH
NEXT ASS'Y
DRAWN D. ROBBINS
CHECKED JOE SPURLIN
APPR'D J. COLLINGS
DATE 10/22/64
SCALE NONE
MODEL 143 & 143C
STYLE
ISSUE
E.I.D
DATE
PR. ENG.
ZELTEX INC. CONCORD, CALIFORNIA
TITLE AMPLIFIER BLOCK DIAGRAM
DWG. NO. 1830
ISSUE A



FOR DESCRIPTION SEE "AMPLIFIER BLOCK DIAGRAM"
DWG. #1831 FOR MODEL 141
DWG. #1468 FOR MODEL 142
DWG. #1830 FOR MODEL 143
PIN "S" SLOTTED FOR MODEL 143
PIN "R" SLOTTED FOR MODEL 141
PIN "K" SLOTTED FOR MODEL 142
ZELTEX INC
MODEL
SERIAL NO.
INPUT SECTION
STABILIZER SECTION
OUTPUT SECTION
7.000
.031 ±.015
15°(TYP)
.280
.700
.910
MODEL NUMBERS
MODEL 141
INPUT SECTION, NO. 1542
STABILIZER SECTION, NO. 2678
OUTPUT SECTION, NO. 1528
MODEL 142
INPUT SECTION, NO. 1542
STABILIZER SECTION, NO. 2678
OUTPUT SECTION, NO. 1539
MODEL 143
INPUT SECTION, NO. 1542
STABILIZER SECTION, NO. 2678
OUTPUT SECTION NO. 1529
.062
INPUT - A
SHIELD OUTPUT - B
SIG. GND. - C
PWR. GND. - D
BALANCE - E
OUTPUT - F
NOT USED - H
NOT USED - J
* KEY - K
* B+ - L
* B- - M
OVERLOAD OUTPUT - N
NOT USED - P
* KEY - R
* KEY - S
3.000
3.500
3.460
.250
.300
ZELTEX INC. CONCORD, CALIF.
INPUT SECTION
STABILIZER SECTION
OUTPUT SECTION
SER.
NO.
.475
CONNECTOR, 15 PIN, VIKING # VK15 S/1-2
SEE MODEL NUMBERS
* NOTE:
1. B+, +24 V.D.C. B-, -24 V.D.C. PIN R, KEY — MODEL 141 AMPLIFIER BLOCK DIAGRAM #1831
2. B+, +125 V.D.C. B-, -125 V.D.C. PIN K, KEY — MODEL 142 AMPLIFIER BLOCK DIAGRAM #1468
3. B+, +75 V.D.C. B-, -75 V.D.C. PIN S, KEY — MODEL 143 AMPLIFIER BLOCK DIAGRAM #1830
TOLERANCES (EXCEPT AS NOTED)
DECIMAL ±.010
FRACTIONAL ± ~
ANGULAR ± 1/2°
MATERIAL - TREATMENT - FINISH
NEXT ASS'Y
DRAWN D. ROBBINS
CHECKED Joe Spurlin
APPR'D J. COLLINGS
DATE 10/24/64
SCALE FULL
MODEL 141, 142, 143
STYLE
TITLE OUTLINE - OPERATIONAL AMPLIFIER
ZELTEX INC. CONCORD, CALIFORNIA
DWG. NO. 01605
ISSUE G
ISSUE | E.I.D. | DATE | PR. ENG.
G 623 7/21/66
F 441 7 F6866
E #197 3/23/65
D #189 3/15/65
C F64 9/2/64

OPERATING AND SERVICE MANUAL

(HP PART NO. 02212-9036)

MODEL 2212A

VOLTAGE-TO-FREQUENCY CONVERTER

SERIAL NUMBERS PREFIXED 714-

This manual applies directly to Model 2212A Voltage-to-Frequency Converters having serial prefix number 714-.

OLDER INSTRUMENTS

With backdating changes provided at the rear in a supplement this manual also applies to instruments having serial prefix numbers 644, 607 and 603.

MODIFICATIONS

This manual covers instruments equipped with any of optional modifications M1, M2, and M3, as well as standard instruments. Any other modification will be covered in a separate supplement.

02409-1 MAY 1967

CONTENTS

NOTE: Schematics and parts location illustrations are in Section 5.

ILLUSTRATIONS

TABLES

Figure 1-1. HP-2212A Voltage-to-Frequency Converter on HP-12501A Bench Stand

SECTION I
GENERAL DESCRIPTION

1-1. FUNCTIONAL DESCRIPTION.

1-2. The Model 2212A (Figure 1-1) is a bipolar Voltage-to-Frequency Converter (vfc) that produces an output pulse rate directly proportional to the amplitude of dc voltage applied to the input terminals. Full scale output is 100 kHz for full scale inputs from 1 volt to as low as 10 millivolts and the 2212A is linear to beyond 150 kHz. Polarity is identified by "+" and "-" indicators on the front panel and by a two-state polarity output signal. The positive state of the polarity signal (0 to -1 volt) identifies rates produced in response to positive input voltage; the negative state (-23 to -31 volts) identifies rates produced in response to negative input voltage. Typical signal sources are thermocouples, strain gages, and other resistive transducers with output resistances of 1000 ohms or less.

1-3. Conversion is accomplished by an integrating process which averages out noise and ripple superimposed on the signal. Differential input assures low zero drift (±5 μv ±0.5 namp referred to input ±0.005% referred to output – per day) and high common mode rejection (120 db). The differential input resistance is extremely high (at least 1000 Megohms) even at 95% relative humidity. There is no need to correct readings for source resistance because voltage division between source resistance and the input resistance is virtually non-existent.

1-4. The 2212A is designed to operate as specified with differential input source resistance of 1000 ohms or less, all of which can be in either input line. The common mode return resistance (the resistance between input common and output common) can be up to 1 megohm. Connecting the guard shields to either input terminal assures this return.

1-5. PHYSICAL DESCRIPTION.

1-6. The 2212A Voltage-to-Frequency Converter is fully enclosed and can be adapted for bench operation by a bench stand or a signal and power cable assembly. The bench stand tilts up the vfc front panel and provides identified input terminals and a BNC output receptacle for convenient use. Physical measurements are listed in the Specifications. The 2212A is housed in a rugged plastic case that takes more punishment than comparable metal enclosures. Moreover, since the finish is in plastic, it is not easily chipped or scratched. Control titles and settings are lithographed on the plastic. A combining case is available which accommodates up to ten 2212A vfc's. This can be used on the bench or it can be mounted in a standard 19-inch rack. The case requires only 5-1/4 inches of vertical panel space.

1-7. OPTIONAL MODIFICATIONS.

1-8. The following standard modifications of the 2212A vfc are available; their presence is denoted by one or more M-numbers stamped on an identification plate on the rear of the unit. The capabilities added by the various modifications are as follows:

M1 Provides five ranges of .01, .03, .1, .3, and 1 volt instead of the three ranges (.01, .1, and 1 volt) that are standard. M1 is not compatible with M3.

NOTE

On special order any other fixed ranges, up to six, between .01 and 1 volt may be supplied in place of the .01, .1, and 1 volt ranges of the standard 2212A.

M2 Provides a continuously-variable range vernier that multiplies the range as specified in paragraph 2-43, page 2-9.

M3 Provides internal 1 volt calibration source with less than 0.02% drift in 6 months. Additional range switch positions of ZERO, CAL+, and CAL- permit control of calibration from the front panel. Because of these three extra positions, M3 is not compatible with M1.

1-9. ACCESSORIES.

1-10. MATING REAR CONNECTOR. The mating rear connector is required if no other means of connecting power and input-output signals to and from the vfc has been obtained. Parts included are the connector, connector latch, three coaxial inserts, and a protective hood. The accessory number of the mating rear connector is 12502A.

1-11. SIGNAL AND POWER CABLE ASSEMBLY. The signal and power cable assembly (Figure 1-2) consists of a mating rear connector for the vfc with hood, latch, and with a 3-foot signal input cable terminated by copper alligator clips; a 3-foot signal output cable terminated by a 2-pin banana plug; and a 5-foot power cable terminated by a NEMA connector. The accessory number of this assembly is 12503A.

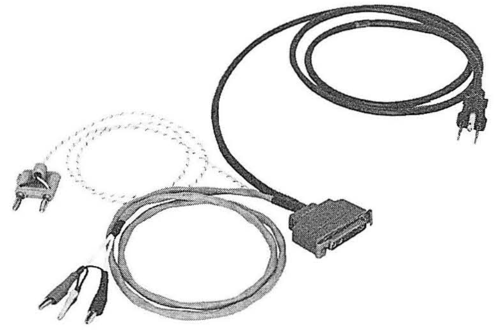


Figure 1-2. HP 12503A Cable Assembly

1-12. BENCH STAND. The bench stand (Figure 1-1) provides bench support for one vfc and includes two gold plated copper signal input binding posts with a guard binding post. It also includes a BNC signal output receptacle, a separate option (polarity) output binding post, and the mating rear connector wired to the bench stand and to power through a 5-foot power cable terminated with a NEMA plug. A power switch on the bench stand panel includes a lamp that lights when power is turned on. The accessory number of the bench stand is 12501A.

1-13. COMBINING CASE. The combining case (Figure 1-3) contains up to ten vfc's and includes wired mating connectors for all units. The ac power connections are brought out to a single receptacle at the rear of the case and a 7-1/2 foot NEMA-terminated power cable is furnished. System connections are wired to a rear panel receptacle with capacity for 50 contacts. Sufficient coaxial inserts (30) are supplied to complete input and output signal wiring to the mating receptacles at the rear of the case. Rack mount adapters and a 50-60 Hz fan for cooling the vfc's are included. A 115/230V switch on the rear panel of the case sets the fan for operation from the line voltage being used. The combining case accessory number is 12500A. A blank panel to cover unused space in this case to assure correct ventilation of instruments is accessory number 12504A. Mating plug for the system connector is stock number 5060-2464.

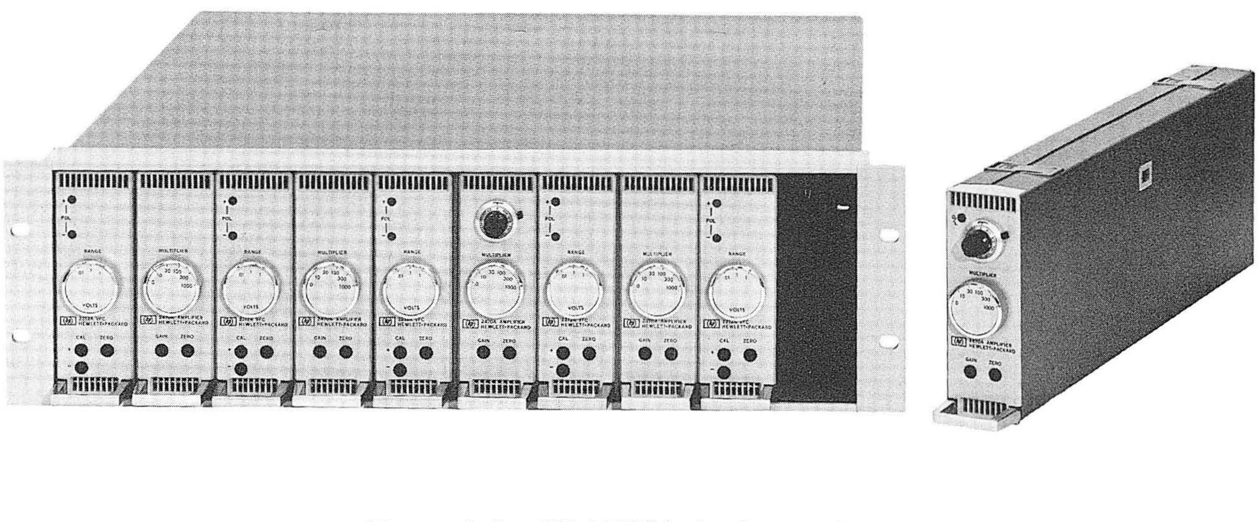


Figure 1-3. HP 12500A Combining Case

Table 1-1. Specifications

Specifications include ±10% line voltage variation, hold for 1K max. source resistance (any unbalance), and assume daily calibration after specified warmup. (The abbreviation rti means referred to input.)

DC VOLTAGE RANGES

Standard: 3 ranges; 0 to 10 mv, 100 mv, 1v. Selected at front panel.

Option M1: 5 ranges; 0 to 10 mv, 30 mv, 100 mv, 300 mv, 1v. Selected at front panel.

Special: On special order, any other ranges between 10mv and 1v can be provided, with a maximum of 6 ranges.

Vernier (Option M2): 10-turn potentiometer (front panel) extends range up to x3.5, for any range setting.

Overrange: 150% of full scale, all ranges.

Polarity: Instrument is sensitive to positive and negative inputs. Polarity indication and output signal provided.

ACCURACY

'Worst case' accuracy of pulse rate over 1-second sample period with respect to the source used for calibration – does not include accuracy of counter used to totalize out-out pulses.

	% rdg All Ranges	% fs RANGE .01v	.03v ①	.1v	.3v ①	1v
STABILITY (8 hours at calibration temp.)						
Scale Factor	.02 ②					
Zero Drift (not range-dependent)		.005	.005	.005	.005	.005
Zero Drift (5µv rti)		.05	.016	.005	.002	.001
LINEARITY (Referred to straight line through zero and full scale.)		.01 ③	.01 ③	.01 ③	.01 ③	.01 ③
TOTALS	.02 ②	.065	.031	.02	.017	.016

① HP-2212A-M1.
② On calibrated range — other ranges are ±.02% rdg with respect to calibrated range.
③ Or .01% rdg for readings between full scale and 150% of full scale.

TEMP. COEFFICIENT PER °C		.01v	.03v	.1v	.3v	1v
Scale Factor (10 to 40°C)	.004 ④					
Zero Drift (0 – 55°C) (not range-dependent)		.001	.001	.001	.001	.001
Zero Drift (0 – 55°C) (1µv rti)		.01	.0033	.001	.00033	.0001
Zero Drift (0 – 55°C) (.5 namp rti x 1000Ω)		.005	.0017	.0005	.00017	.0001
TOTALS	.004 ④	.016	.006	.0025	.0015	.0012

④ Scale factor temperature coefficient is .01% rdg from 0 to 10°C and 40 to 55°C.

Vernier (Option M2):

Dial Accuracy: ±3%.

Resolution: ±.05%.

Resettability: ±.08%.

Zero Stability: add ±.0075% fs.

Temp. Coeff: add ±.002% rdg ±.0015% fs per °C.

INTERNAL CALIBRATION SOURCE

(With Option M3.)

1v internal standard provided for self-calibration. Accuracy: within ±.02% for six months.

Temp. Coeff: ±.005% per °C (0 to 55°C).

Occupies 3 positions of range switch, for Calibrate +, Calibrate −, and Zero Set respectively.

DIFFERENTIAL INPUT IMPEDANCE

1000M shunted by .001 µf.

COMMON MODE REJECTION

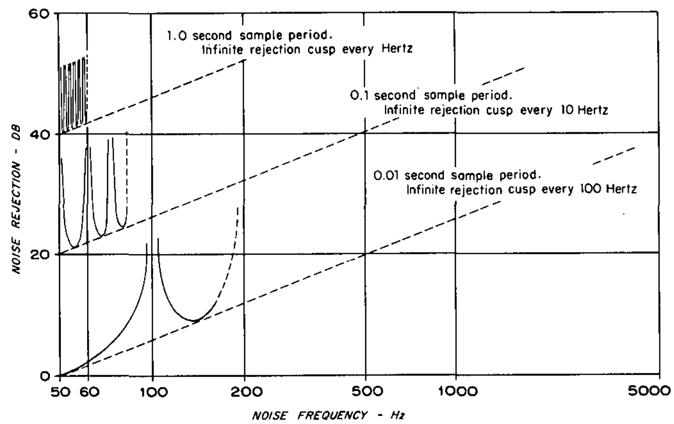
120 db, dc to 60 Hz. (With Option M3 and 1K source unbalance, CMR decreases to 114 db at 60 Hz.)

COMMON MODE RETURN

From input common to output common: 1 megohm, max. (Provided internally when input lead shields are connected to either side of input.)

NORMAL MODE REJECTION

More than 40 db at 55 Hz with 1 second sample period; increases 20 db per decade increase in noise frequency. Infinite rejection cusp every cycle.



SUPERIMPOSED NOISE REJECTION

SLEWING

10^6v/sec rti with dc offset caused by slew limiting less than .1% of peak ac, provided 150% of full scale is not exceeded.

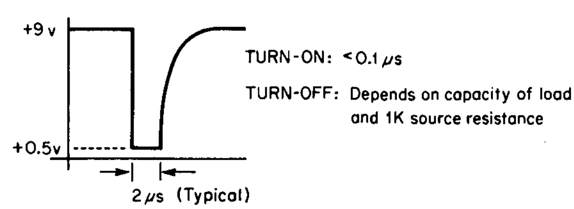
MAXIMUM INPUT SIGNAL

±11v, signal plus common mode. Combined input up to ±20v will not damage instrument.

OUTPUT

Frequency: 0 to 100 KHz fs, overranging to 150 KHz.

Waveform:



Load: 5 ma available. Short circuit will not damage instrument.

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Table 1-1. (Cont'd.)

SETTLING TIME

100 μs to within .01% of final pulse rate.

OVERLOAD RECOVERY

Settling time plus 100 μs for signal of 10 times full scale. Less than 5 ms for signal plus common mode input up to 20v.

▲ POLARITY INDICATION

Display: Front panel lamps for + and -.

Signal:
For + input: 0 to -1v, 5 ma available.
For - input: -(23 to 31)v, 2K source res.

Timing: Polarity signal switches when integrator crosses zero, hence normally anticipates output pulse at least 3 μs.

REAR CONNECTOR

All signal input/output and power connections at rear connector. Mating connector listed under Accessories Available. Accessory Combining Case includes mating connectors.

▲ Pin Connections:

1	Output common
2	Polarity signal
3,5,8,10	Chassis ground
4	AC line (fused)
6,7	No connection
9	AC line (return)
A1	Output (shield is common)
A2	+ Input (shields are guard)
A3	- Input (shields are guard)

ENVIRONMENTAL CONDITIONS

Operating: Ambient temperatures from 0 to 55°C. Relative humidity to 95% at 40°C. When used individually, instruments are self-cooled by convection. Accessory Combining Case includes fan for additional cooling.

Storage: -40 to +75°C.

▲ WARMUP

Instrument operates immediately after turn-on, but requires 1-1/2 hours in free air, 30 minutes in Combining Case, (plus 1 hour additional warmup for each 10°C difference between storage temperature and operating ambient) for specified accuracy and zero drift.

RELIABILITY

Predicted mean time between failures (with 90% confidence) is 10,000 hours — over one year of continuous operation — when operated at 25°C ambient.

POWER REQUIRED

115/230v ±10%, 50 to 400 Hz, 9w approx. Fuse, 115/230v and on/off switches on rear panel.

WEIGHT

Net wt. 4 lb. (1,8 kg), shipping wt. 6-1/2 lb. (2,9 kg).

Combining Case
Net wt. 12-1/2 lb. (5,7 kg); shipping wt. 27 lb. (12,3 kg).

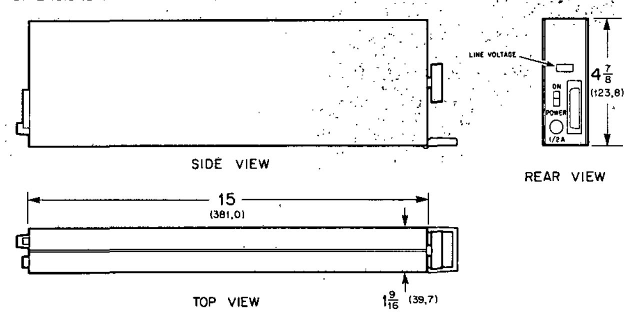
FINISH

Light grey panel; blue-grey texture-finish case.

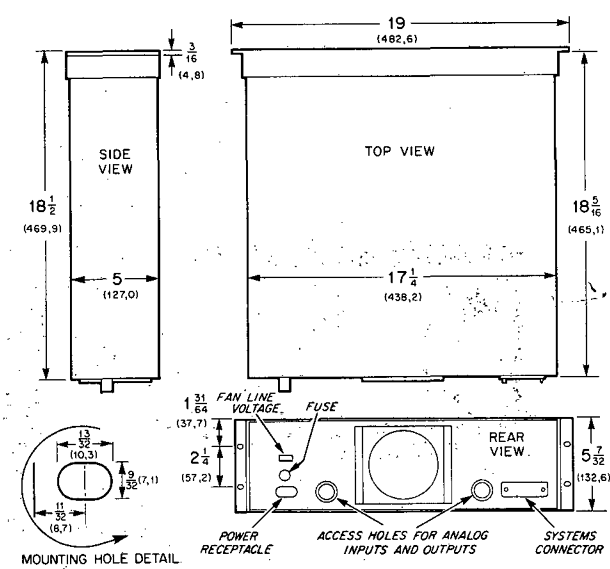
DIMENSIONS

2212A:

DIMENSIONS IN INCHES AND (MILLIMETERS)



COMBINING CASE:



DIMENSIONS IN INCHES AND (MILLIMETERS)

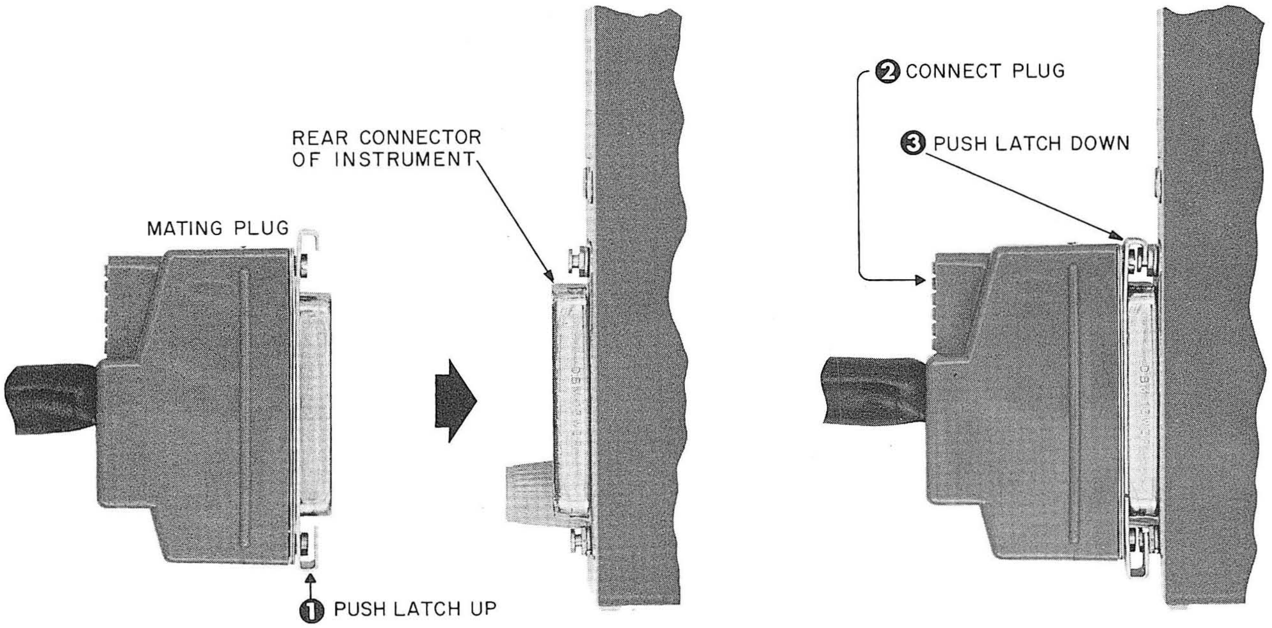


Figure 2-1. Connection of Mating Plug

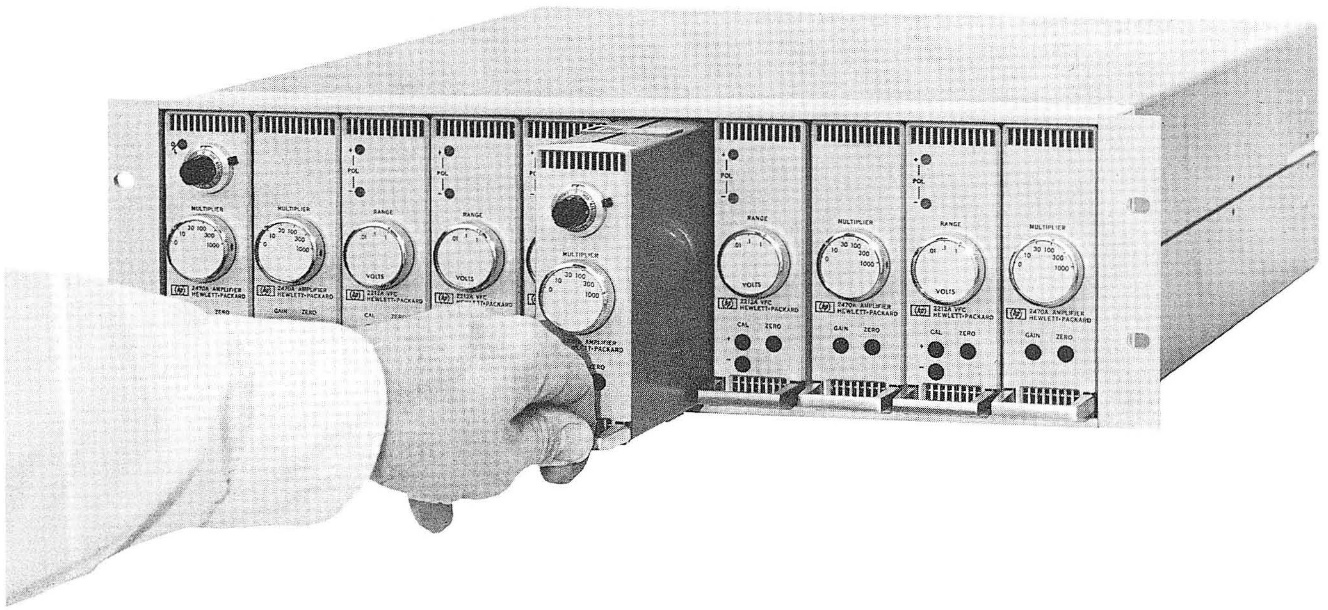


Figure 2-2. Installation in Combining Case

SECTION II
INSTALLATION AND OPERATION

2-1. INSTALLATION.

2-2. GENERAL. The 2212A Voltage-to-Frequency Converter (vfc) is a fully-enclosed, self-contained instrument that requires only suitable connection of signal inputs and outputs and ac power to its rear panel connector for operation. The 2212A is intended to operate with an Electronic Counter that totalizes its pulse rate output over a fixed sample period. Controls, indicators, adjustments, and the connector of the various versions of the 2212A are illustrated and described in Figure 2-13 (unfold page 2-9). The user may select any of four installation arrangements. The 12501A Bench Stand and the 12503A Signal and Power Cable Assembly are intended for use with the 2212A operated as a bench instrument. The 12500A Combining Case houses and connects ac power and signal inputs and outputs to as many as ten 2212A instruments used in multi-channel data system applications. The 12502A Mating Plug is available for users wishing to complete their own wiring arrangements.

2-3. COOLING. The 2212A is self-cooled by convection when operated in free air. It is ready to operate immediately after turn-on, but meets its stability specifications only after 1-1/2 hour warmup in free air. Forced air ventilation provided during operation in the Combining Case reduces warmup time to 30 minutes provided all unoccupied spaces in the case are covered by blank filler panels and the air filter on the rear of the case is cleaned regularly as specified on page 6 of the instruction booklet supplied with the Combining Case.

2-4. FUSE. The power line fuse of the 2212A is located beneath a knurled cap (1, Figure 2-13), immediately below the POWER switch (4, Figure 2-13). The replacement for this plug-in fuse is a BUSS GMW 1/2, HP Stock Number 2110-0046.

2-5. OPERATION FROM 115 OR 230 VOLTS. The LINE VOLTAGE switch (2, Figure 2-13) on the rear of the 2212A allows the instrument to be set for operation from either 115 or 230-volt ac power, at 50 to 400 Hz. The 2212A is normally supplied from the factory with the LINE VOLTAGE switch set to the 115 position.

CAUTION

Before connecting power to the 2212A, make certain that the LINE VOLTAGE switch is set correctly. Slide this switch to the left for operation from 115v, or to the right to operate the 2212A from 230v.

2-6. INSTALLATION ON BENCH STAND. Connect the mating plug of the bench stand to the 2212A rear panel connector (3, Figure 2-13) and lock it in place as shown in Figure 2-1 (facing page). Place the 2212A between the bench stand side supports. Turn the rear panel POWER switch (4, Figure 2-13) ON to permit power on/off control by the Bench Stand POWER switch. Power and signal connections are covered in paragraphs 2-16 through 2-25 and Figure 2-6.

2-7. INSTALLATION WITH CABLE ASSEMBLY. Connect the mating plug of the Signal and Power Cable Assembly to the 2212A rear panel receptacle and lock it in place as shown in Figure 2-1. Power and signal connections are completed per paragraphs 2-16 through 2-25 and Figure 2-7.

2-8. INSTALLATION IN COMBINING CASE. After signal wiring has been completed per paragraphs 2-10 through 2-14, installation of 2212A instruments is simple. Turn the 2212A rear panel POWER switch (4, Figure 2-13) ON and insert the 2212A into the desired position in the case as shown in Figure 2-2 (facing page). Make certain the 2212A rear panel connector mates properly with the correct connector in the rear of the Combining Case and slowly push the 2212A into the case until its handle detent locks into the slot in the front of the Combining Case. To assure correct ventilation of all instruments in the case, install 12504A Blank Panels to cover any vacant spaces.

NOTE A

The line voltage switch on the rear of the Combining Case sets only the line voltage to the fan. LINE VOLTAGE switches on the instruments inside the case must be set individually to the correct voltage.

NOTE B

Although the 2212A will operate from power at line frequencies of 50 to 400 Hz, the fan in the Combining Case operates only from 50 to 60 Hz ac. A special fan must be provided in the Combining Case for operation from other line frequencies, such as 400 Hz. Fan line frequency must be specified when the Combining Case is ordered.

2-9. WIRING INSTRUCTIONS FOR INSTALLATION.

2-10. COMPLETION OF COMBINING CASE WIRING. The 12500A Combining Case is supplied with all but the signal input and vfc pulse output connections fully wired. Completion of wiring consists of connecting the signal input and output leads to the 30 coaxial inserts provided for this purpose and installing these inserts into the correct connector mounting holes. Proceed as follows:

1. Pull out on the two plastic quick-release fasteners to remove the rear panel, exposing the instrument mating receptacles as shown in Figure 2-3.

2. Connect the signal input and output cables to the coaxial inserts per paragraphs 2-11 through 2-13.

3. Bring the signal leads through the cable access holes in the rear panel as indicated in Figure 2-3.

4. At each instrument mating receptacle install the coaxial inserts by pushing them into the correct holes until they snap into place. The lowest hole is for -input lead connector A3, the middle hole is for +input lead connector A2, and the upper hole is for output connector A1.

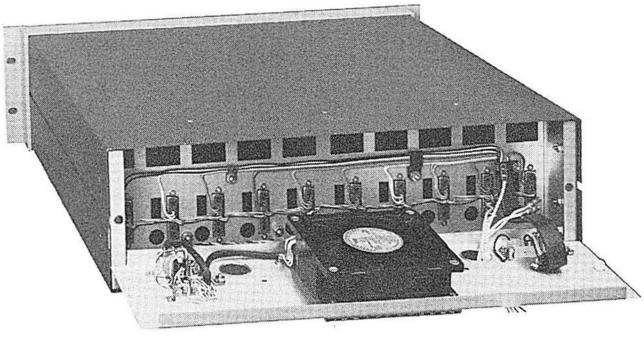


Figure 2-3. Inside Rear of Combining Case

2-11. Recommended Signal Cabling. Although 22 gauge shielded hookup wire can be used for connections terminated by the coaxial inserts, teflon-insulated wire is recommended for the following two reasons:

1. Teflon insulation is not subject to the melting experienced when soldering wires insulated with other materials.

2. Teflon insulation preserves the extremely high input impedance of the 2212A, even at high humidity.

2-12. Teflon-insulated cabling of the recommended type is available from:

- American Super Temp Wires
  Division of Haveg Industries
  Los Angeles, California
  Order cable type T-22-1934-STJ

- Tensolite Insulated Wire Co., Inc.
  Tarrytown, New York
  Order cable type 1934TX10C1SW

2-13. Connection to Coaxial Inserts. The procedure for connection of shielded cabling to coaxial inserts is as follows (see Figure 2-4):

1. Slip the rear shell of the connector over the cable, small end first. Strip 3/8 inch of outer insulation from the tip of the cable, carefully to avoid breaking the shield braid. Then trim the exposed shield back to 3/16 inch length and strip off 3/32 inch of the inner insulation to expose the inner conductor.

2. Slip the connector over the inner insulation and under the shield, with the inner wire fitting into the connector pin. Use a fully-heated soldering iron with a very small tip to solder the inner wire to the pin. (Solder should be 60-40 rosin core.) Wipe the solder joint clean with a small camel's hair brush moistened in Dupont Freon T-E35 or an exact equivalent solvent to remove rosin. Then dry the brush and use it to remove any excess solvent.

3. Slip the rear shell of the connector over the shield and the connector. Then heat and solder the rear shell to shield and connector by applying solder through the hole indicated in Figure 2-4.

2-14. Insertion and Removal of Coaxial Inserts. The coaxial inserts snap into individual connector mounting holes when pressed in from the rear. Coaxial inserts installed in the wrong position may be removed with a Cannon Electric connector extraction tool, model CET-C6-B, or equivalent. From the front of the connector, slip the outer sleeve of the tool around the insert. Press in to release the insert, permitting its removal. Experimentation may be required to get some inserts to release.

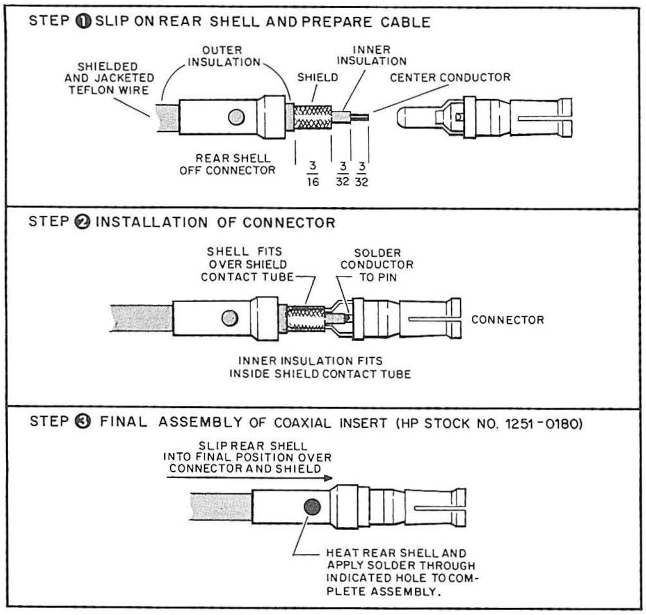
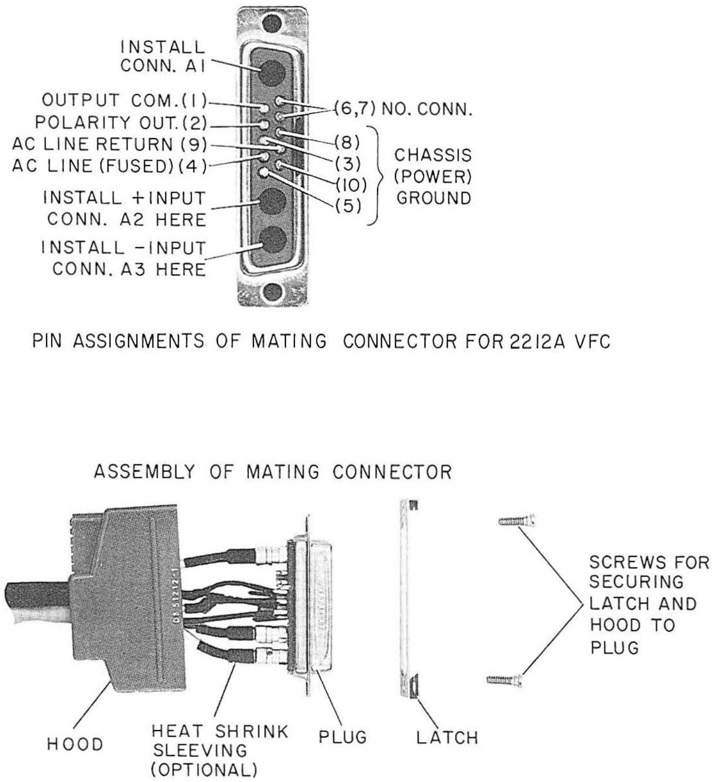


Figure 2-4. Connection to Coaxial Inserts

let. When only a two-blade outlet is available, use a connector adapter (HP Stock Number 1251-0048) and connect the short wire from the side of the adapter to ground.



Pin Assignments and Assembly of Mating Plug

Figure 2-5.

2-15. WIRING AND ASSEMBLY OF MATING PLUG. The Mating Plug for the 2212A rear panel connector, accessory number 12502A, is supplied with a hood, latch, and three coaxial inserts. Except for signal input and output connections, covered in paragraphs 2-11 through 2-14, wiring of the mating plug is simple and straightforward. Pin-function assignments and assembly of the mating plug are shown in Figure 2-5.

2-16. CONNECTIONS.

2-17. POWER GROUND CONNECTION. The 2212A vfc contains an internal shield that serves as a chassis ground. This shield must be connected to power ground through any one of rear panel connector pins 3, 5, 8, and 10 to realize correct performance of the 2212A. When the Bench Stand, the Signal and Power Cable Assembly, or the Combining Case power cable is used for connecting power to the 2212A, connect the power plug to a three-wire (grounded) power outlet.

2-18. SIGNAL CONNECTIONS. Connect the 2212A vfc input and output in accordance with the information in the following paragraphs to achieve most satisfactory operation. Signal connectors of the bench stand are shown in Figure 2-6. Figure 2-7 indicates signal connectors of the signal and power cable assembly. Figure 2-8 shows connections to various types of signal sources.

2-19. Output Grounding. Output common of the 2212A is connected to the instrument chassis ground internally, and to power (earth) ground through the power cable, to minimize noise pickup by the input circuits. This arrangement allows the device receiving the 2212A output to be either grounded or floating. The important point to remember is that the internal ground connection must be completed to power ground, as outlined in paragraph 2-17.

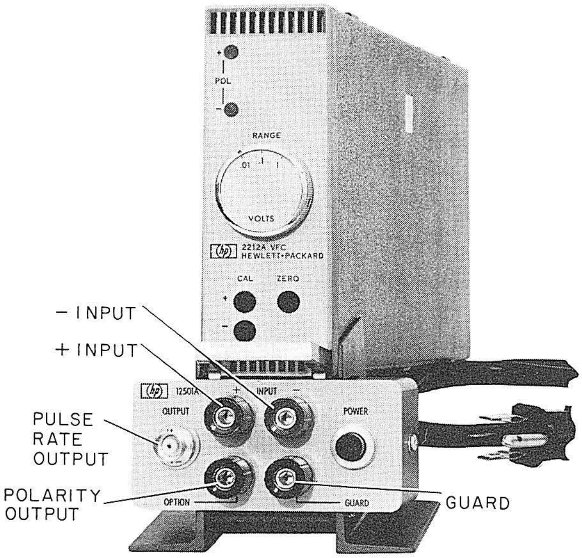


Figure 2-6. Bench Stand Signal Connections

2-20. Input Grounding and CMV Rating. The 2212A is a four-terminal vfc whose input may be grounded at a remote point. Nevertheless the potential between the input and output grounds must not exceed the common mode voltage (cmv) rating of the 2212A. For normal operation, the common mode plus signal input voltage of the 2212A must not exceed ±11v dc or peak ac, but the instrument will tolerate ±20v peak common mode plus signal voltage without damage. The common mode return resistance between source common and output common can be fairly high, but should not exceed 1 megohm.

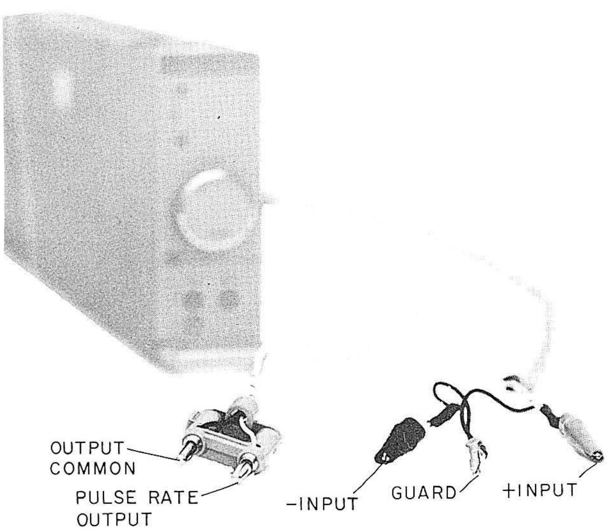
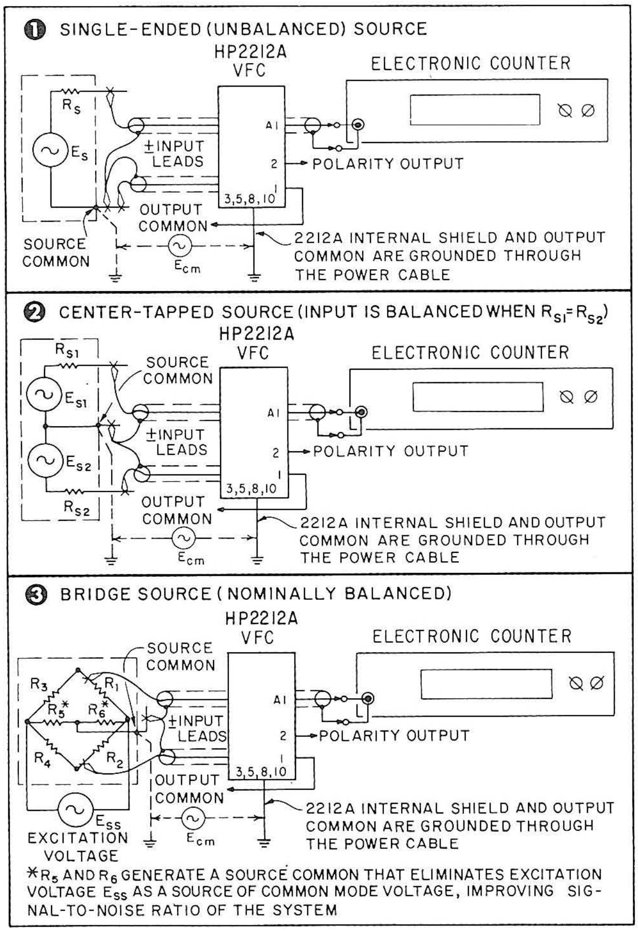


Figure 2-7. Cable Assembly Signal Connections

2-21. Guarding. The signal source and input lead A2 and A3 shields are called 'guard', and must be connected to the signal source common through a relatively low impedance (certainly less than 10K). Deterioration of common mode rejection and unnecessary reading errors are likely to result from neglect of guarding requirements.

2-22. Grounding of Signal Source. The signal source common should normally be grounded at the source to minimize noise pickup. EXCEPTION: if the source is not grounded, but is well shielded, source common may be returned to output common at pin 1 of the 2212A rear panel connector. This reduces the common mode voltage which the vfc must reject, and consequently improves the signal-to-noise ratio of the source-vfc system.

2-23. When the source must be left floating with respect to ground, the return normally provided through earth or power ground may be provided by connecting the guard shields to either vfc input lead. This provides a dc return with resistance no greater than 1 megohm, through resistors installed in the 2212A.



Connections to Various Signal Sources

Figure 2-8.

2-24. Connection Hardware. Only copper wire, lugs, banana plugs, or alligator clips, preferably gold or silver plated, should be used for input connections to the 2212A or the Bench Stand. Dissimilar metals used for input connection can act as a thermocouple, introducing significant errors caused by thermally-generated voltages. For example, steel alligator clips used with copper wire can produce a thermal emf as high as 40 microvolts per °C. On any range, but particularly on the .01 VOLT range, this can introduce serious and entirely unnecessary errors.

2-25. Differential Source Resistance. Although the 2212A is designed to work with signal sources having resistance of 1000 ohms or less, it also handles signals from sources with resistance greater than 1000 ohms. However, the following effects derate performance.

1. Zero drift referred to input increases by an amount that can be determined by multiplying the source resistance by 0.5 namp (the rti offset current). This effect normally overrides the other two effects; increased zero drift is particularly troublesome on the .01 VOLT range.

2. Common mode rejection decreases about 6 db for each doubling of unbalanced source resistance.

3. Noise increases by approximately the same factor as zero drift.

NOTE

The latter two effects are usually masked by superimposed noise rejection of the 2212A. Where not masked, they will show up as erratic readings on the Electronic Counter. Zero drift will usually become intolerable before either the CMR or the noise effect starts to contribute significantly to error.

2-26. OUTPUTS.

2-27. PULSE TRAIN (RATE) OUTPUT. The 2212A vfc supplies a pulse train output whose rate is directly proportional to the amplitude of the voltage differential across input terminals A2 and A3. The full-scale rate is 100 kHz and conversion by the 2212A is linear and accurate for rates well beyond 150 kHz (150% of full scale). The pulse train output is supplied from coaxial connector A1 in the rear panel receptacle.

2-28. When the pulse train output is unloaded, the individual pulses are approximately as shown in Figure 2-9. The output circuit is designed so that loading reduces the pulse baseline voltage, and consequently reduces pulse amplitude. For example, connecting a 2K load resistor across the output reduces pulse amplitude from about 8.5 volts to about 5.5 volts. External loads with smaller resistance value reduce baseline voltage and pulse amplitude even more. The bonus feature of this design is that the output circuit is not damaged by overload, not even by a short circuit.

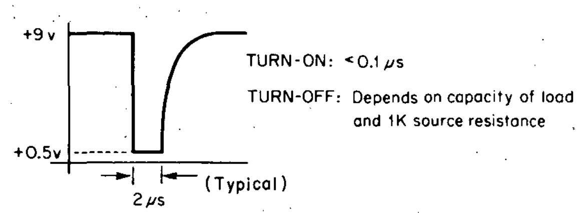


Figure 2-9. Output Pulse (Idealized)

CAUTION

Although the 2212A is not damaged by passive overload, external sources of ac or dc voltage should never be connected across the output; they can damage the 2212A.

2-29. POLARITY OUTPUT. The 2212A provides a polarity output that may be used externally to distinguish rate pulses caused by positive input voltage from those caused by negative input voltage. The polarity output signal level for negative input is -(23 to 31) volts; for positive input the level is 0 to -1 volt.

2-30. SELECTION AND SETUP OF COUNTER.

2-31. SELECTION OF COUNTER. The selection of a counter for operation with the 2212A vfc depends upon the results required. Most counters are non-reversing. During their gate times, non-reversing counters will count all rate pulses from the 2212A regardless of whether they result from positive input voltage, negative input voltage, or both. This matters little when the signal or signal plus noise does not cross zero during the gate period, since the counter will read the true average dc value of the 2212A input voltage. However, when the signal or signal plus noise crosses zero during the counter gate time, a non-reversing counter does not read the true average dc value of the 2212A input voltage. Instead, it reads the total of all voltage deviations from zero, which may differ considerably from the average dc value.

2-32. If a reading of average dc value is required for signals that cross zero, a reversing counter, such as the Hewlett-Packard H19-5280A Counter with 5285A plug-in unit, must be used. When this counter is operated in the Af(B) mode, 2212A output pulses applied to the A input are counted up when the 2212A polarity signal applied to the B input is positive and are counted down when the polarity signal to input B is negative. This counter offers .1, 1, and 10 second gate times, 6-digit readout with polarity indication, and 8-4-2-1 bcd data output for digital recording.

2-33. SETUP OF PULSE COUNTING BY COUNTER. Many ac-coupled electronic counters, including the HP-5212A/5512A, 5232A/5532A, and 3734A may require readjustment of their triggering circuits for counting pulses. The trigger level required for pulse input differs from that suitable for sine wave input because the dc value of a sine wave is zero volts while the dc value of a pulse train varies with pulse frequency (assuming constant pulse duration) and is rarely zero volts.

NOTE

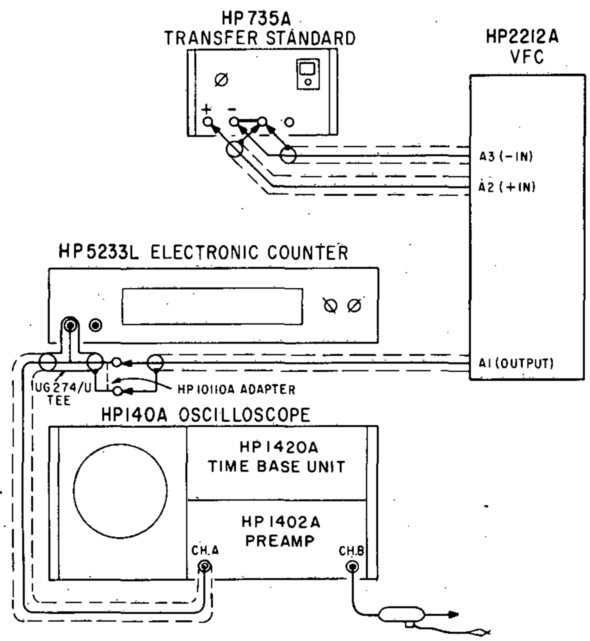
Counters with dc-coupled input should not require special setup, since the amplitude discriminator can be set to count leading at +4V, using '-' slope.

2-34. Equipment Required. In addition to the 2212A and the counter, the following equipment is required for setup of pulse counting:

1. HP-735A Transfer Standard.
2. HP-140A Oscilloscope with HP-1420 (or 1422) and HP-1402A plug-in units.

2-35. Procedure.

1. Connect setup shown in Figure 2-10.
2. Set 2212A to 1 VOLT range, vernier (if any) fully counterclockwise.
3. Set Transfer Standard for 1.000V output.
4. Set Oscilloscope channel A for 2v/cm and '+' polarity. Set time base for auto triggering from INT- and 1 μsec/cm sweep time. Adjust trace controls for best display of 2212A output pulse.
5. Set Electronic Counter to measure 2212A output frequency using 1 second gate and slightly less than maximum sensitivity, with display control set for conveniently-observed sampling rate.
6. Check several successive counts with the Transfer Standard first set to 1.000V, then to 0-1000 μV with the MICROVOLTS control set to 050. Readings should be consistent within ±1 count at approximately 100 kHz and 0.005 kHz, respectively. If counting is not correct perform steps 7 through 9. If counting is correct, the counter is ready for operation with the 2212A.
7. Set the Oscilloscope for alternate triggering synchronized with channel A. Set channel B for .5v/cm (actually 5v/cm because of probe attenuation) and adjust controls to make both traces visible.
8. Open the counter for access to the trigger level adjustment on the trigger circuit board and connect the Probe from Oscilloscope channel B to the trigger circuit output. See the counter handbook for locations.
9. Set the trigger level adjustment to obtain a steady B trace pulse with the Transfer Standard set to 1.000V and with it set to 0-1000 μV. Then close the counter, set sensitivity to maximum, and tag the counter with a note stating that it is set to count pulses from the 2212A.



Connections for Setup of Pulse Counting

Figure 2-10.

2-36. PREOPERATIONAL CALIBRATION.

2-37. EQUIPMENT REQUIRED. In addition to the counter that is normally used to count the 2212A output pulses, the following items are required for calibration:

1. Combining Case, Cable Assembly, or Bench Stand.

2. HP-735A Transfer Standard (not required for 2212A-M3 if internal calibration standard is used).

3. Precision Dekavider, Electro-Scientific Industries Model RV722, and 100K load (required only for calibration of .01, .03, .1, or .3V range).

NOTE

Warmup and calibration of the 2212A should be accomplished with the instrument in the attitude (upright or on its side) in which it will be used. Changing the instrument's attitude changes internal temperature gradients, affecting calibration.

2-38. TURN-ON AND WARMUP. Turn on the 2212A and all equipment to be used during calibration. Operation of the 2212A is signalled by a lighted "+" or "-" POL indicator. Allow 1/2 hour warmup when the 2212A is operated in the Combining Case, at least 1-1/2 hour warmup if the 2212A is operated in free air.

2-39. CALIBRATION PROCEDURE.

1. Set Transfer Standard (if used) for 0-1000 μV ($\triangle$) output with MICROVOLTS control set to 000.

2. Connect setup shown in Figure 2-11A, including the shorting plug between the Transfer Standard '+' and '-' terminals. Turn on the 2212A and all equipment.

3. Set vernier of 2212A-M2 (10, Figure 2-13) fully counterclockwise and lock it there.

4. Set 2212A RANGE switch (5, Figure 2-13) to .01 VOLT (or to ZERO on 2212A-M3).

5. After specified warmup per paragraph 2-38, use screwdriver to set ZERO (6, Figure 2-13) for minimum count (less than 10) on the counter (set for 1 second gate and maximum sensitivity.

NOTE

Switching of the POL indicators (9, Figure 2-13) can help to locate the best ZERO setting.

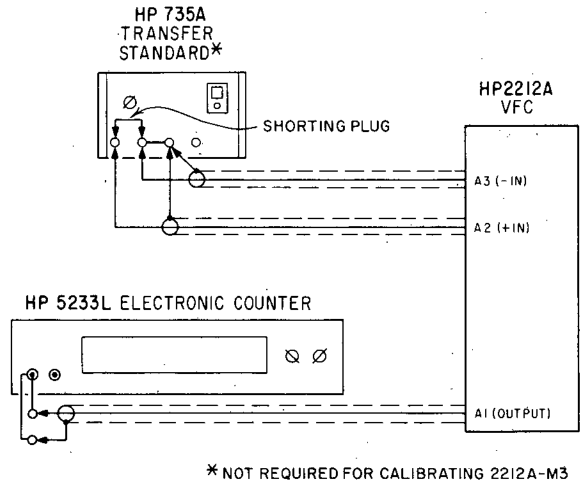


Figure 2-11A. 1V Range Calibration Setup

6. Set 2212A RANGE switch (5, Figure 2-13 to 1 VOLT, disconnect the shorting plug, and set the Transfer Standard for 1.000V output. (On 2212A-M3, set RANGE switch to CAL+.) The '+' POL indicator should be lighted.

7. With screwdriver, set CAL+ (7, Figure 2-13) for 100.000 kHz (kc) counter reading.

8. Reverse A2 and A3 input connections of the 2212A to the Transfer Standard '+' and '-' terminals. (On 2212A-M3, set RANGE switch to CAL-.) The '-' POL indicator should be lighted.

9. With screwdriver, set CAL- (8, Figure 2-13) for 100.000 kHz (kc) counter reading.

NOTE

Step 9 completes calibration of the 1 VOLT RANGE. For maximum accuracy on another range, perform the remaining steps of this procedure. Calibration of the range to be used eliminates .02% maximum % of reading error of that range with respect to the 1 VOLT range.

10. Connect setup shown in Figure 2-11B (page 2-8) and set the 2212A to 1 VOLT RANGE and the Dekavider to 999999TEN.

11. Note 2212A POL indication and average several zero reading counts to the nearest digit, using 1 second counter gate time.

12. Shift the lead connections to the Transfer Standard one set of terminals to the left.

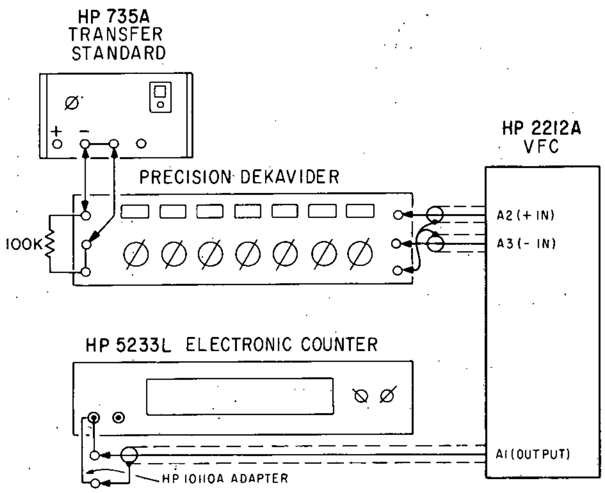


Figure 2-11B. Setup for Calibrating Other Ranges

13. Set Transfer Standard for 1.019 + (Δ) output and MICROVOLTS control for 100.000 kHz (kc) plus the zero reading average obtained in step 11.

    EXAMPLE: If zero reading was +0.002, set Transfer Standard for 100.002 kHz; if zero was -0.001, set Transfer Standard for 99.999 kHz.

14. Shift lead connections to the Transfer Standard one set of terminals to the right (connections shown in Figure 2-11B).

15. Set the Dekavider according to the 2212A range that is to be calibrated, as follows:

RANGE	Dekavider Setting
.01 VOLT	0100000
.03 VOLT*	0300000
.1 VOLT	1000000
.3 VOLT*	3000000

*2212A-M1 only

16. Repeat steps 11 and 12.

17. Set CAL+ for 100.000 kHz (kc) plus the zero reading average obtained in step 16. (Subtract negative zero readings, add positive zero readings.)

18. Reverse A2 and A3 connections to the Dekavider so that the '-' POL indicator is lighted.

19. Set CAL- for 100.000 kHz (kc) minus the zero reading obtained in step 16. (Subtract positive zero readings, add negative zero readings.)

2-40. OPERATION.

2-41. GENERAL. (See Figures 2-13 and 2-8).

1. Set LINE VOLTAGE switch (2, Figure 2-13) to show the line voltage (115 or 230v) from which the 2212A is to be operated.

2. Install the 2212A per paragraph 2-6, 2-7, or 2-8.

3. Connect the 2212A to external power per paragraph 2-17.

4. If necessary, prepare the counter to count 2212A output pulses according to paragraphs 2-33 through 2-35.

5. Calibrate the 2212A for operation per paragraphs 2-36 through 2-39.

6. Connect the 2212A input and output as indicated in the appropriate diagram of Figure 2-8. Observe the specific instructions in paragraphs 2-18 through 2-25.

NOTE

Poor connection to the source through either input lead, or open-circuited common mode return, can cause the 2212A to produce an output rate greater than 300 kHz that does not respond to input signal changes. Before ascribing this condition to a failure inside the 2212A, make certain that all input and output connections are good and in accord with the instructions referenced in step 6 (above).

7. Set the RANGE switch (5, Figure 2-13) according to the input voltage, as follows:

Input Voltage*	RANGE
to 15 millivolts	.01 VOLT
to 45 millivolts	.03 VOLT**
to 150 millivolts	.1 VOLT
to 450 millivolts	.3 VOLT**
to 1.5 volts	1 VOLT

*Maximum input voltage produces 150 kHz (150% of full scale) output from the 2212A.
**With Option M1.

2-42. CONVERSION OF FREQUENCY COUNTER READINGS TO VOLTAGE READINGS. Counter readings of the average 2212A output frequency can be converted to voltage according to the selected range of the 2212A, as follows:

2212A RANGE	Multiply Counter Reading in kHz by	For result in
.01V	0.1	millivolts
.03V	0.3	millivolts
.1V	1.0	millivolts
.3V	3.0	millivolts
1.0V	10.0	millivolts
1.0V	0.01	volts

2-43. USING THE OPTIONAL VERNIER. The vernier (10, Figure 2-13) on the 2212A with Option M2 permits multiplication of the fixed full scale setting of the RANGE switch by any factor from 1 to 3.5. When the 2212A is equipped with both M1 and M2, any full-scale range from .01 to 3.5 volts may be selected. The 150% overrange capability permits the 2212A with M2 to handle input voltage to ±5.25 volts.

2-44. The turns-counting dial of the vernier provides a three-digit indication that can be used to determine the full-scale range, or to set up a specific range. Since the vernier adds a 2.5X maximum multiplication factor to the basic range, each turn of this ten-turn control adds a 0.25X multiplication factor. Range multiplication (Rm) of the fixed range setting by the vernier is given by the following expression:

$$Rm = 1 + 0.25\ Vs$$

Where Vs is the number of turns indicated by the turns-counting dial of the vernier.

At dial settings (Vs) of 8.00 or 3.54:

$$Rm = 1 + (0.25 \times 8.00) = 3$$

$$Rm = 1 + (0.25 \times 3.54) = 1.885$$

The dial setting (Vs) for a specific range multiplier (Rm) is given by the following expression:

$$Vs = \frac{Rm - 1}{0.25}$$

For Rm of 1.5 or 2.5:

$$Vs = \frac{1.5 - 1}{0.25} = 2.00 \text{ (2 turns)}$$

$$Vs = \frac{2.5 - 1}{0.25} = 6.00 \text{ (6 turns)}$$

2-45. SUPERIMPOSED NOISE REJECTION. Superimposed noise rejection will be as shown in Figure 2-12 under the following conditions:

1. Signal plus noise must not exceed ±150% of full scale on the selected range.

2. The vfc-counter combination must pass check 2 in Table 4-3.

3. A reversing counter must be used where peak noise is greater than the dc input so that signal plus noise crosses zero during the integration period.

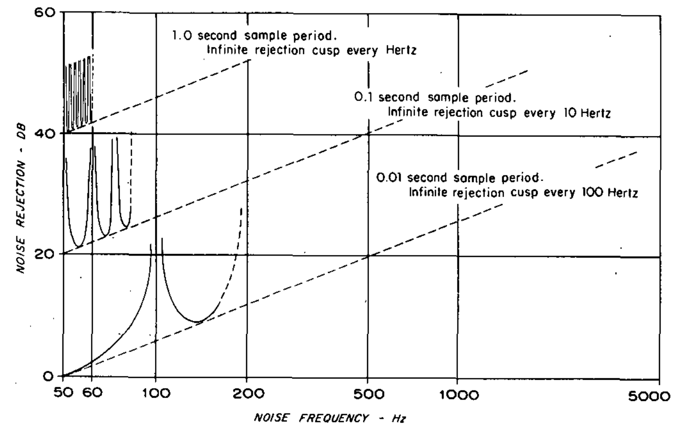
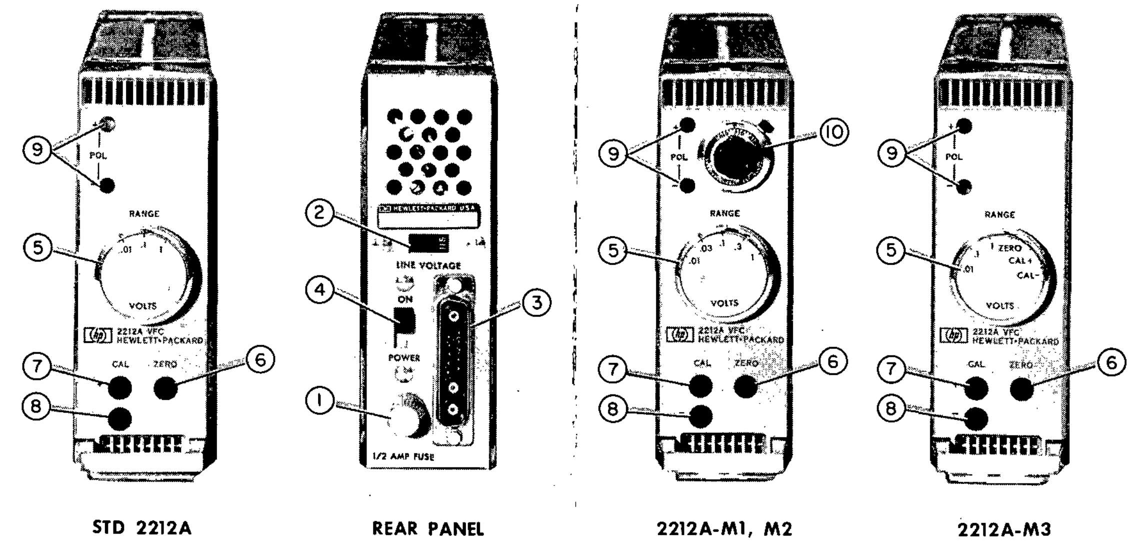


Figure 2-12. Superimposed Noise Rejection

2-46. INTEGRATION OF HIGH-FREQUENCY INPUT. The ability of the 2212A to integrate high frequency signals or noise is limited by the slewing rate of its input preamplifier. This slewing rate, 10^6 volts per second, is the product of the maximum output amplitude and frequency that the 2212A can respond to without exceeding a specified dc offset that appears in the final reading. At 10^6 volts per second (a .5 volt change in 1/2 microsecond), the offset will not exceed .1% of peak ac. The offset is negligible at slewing rates less than 10^6 volts per second, but increases sharply at greater rates, even to the extent of driving the 2212A into overload and preventing meaningful readings until the slewing rate is reduced. The slewing rate may be reduced by decreasing signal frequency, signal amplitude, or both.

2-47. OVERALL ACCURACY.

2-48. Overall accuracy of the 2212A is defined in Table 2-1. To determine the maximum uncertainty of your reading, in counts, first multiply the reading by .02% (calibrated range) or .04% (other range). Then multiply full scale (100 kHz) by the applicable % fs figure. Add the results to obtain a basic uncertainty figure. Temperature coefficients converted to counts in the same way must be added to the basic figure when ambient temperature has changed more than 1 °C since calibration.



1 Fuseholder with 1/2 amp fuse.

2 LINE VOLTAGE switch for selection of voltage to be used.

3 Power and signal input/output receptacle; mates with plug of Cable Assembly or Bench Stand, or connectors in rear of Combining Case.

4 POWER switch for control of ac power to the 2212A.

5 RANGE switch with STD, M1, or M3 settings as shown above.

6 ZERO adjustment for zeroing the 2212A on the .01 VOLT range.

7 CAL+ adjustment for calibrating response to positive input voltage.

8 CAL- adjustment for calibrating response to negative input voltage.

9 POL '+' or '-' indicator lights to signal

10 Vernier (ten-turn) control on 2212A with M2 for multiplying fixed full scale RANGE setting by any factor from x1 to x3.5.

Figure 2-13. Front and Rear Panel Description

Table 2-1. Accuracy *

	% rdg All Ranges	% fs RANGE .01v	.03v ①	.1v	.3v ①	1v
STABILITY (8 hours at calibration temp.)						
Scale Factor	.02②					
Zero Drift (not range-dependent)		.005	.005	.005	.005	.005
Zero Drift (5µv rti)		.05	.016	.005	.002	.001
LINEARITY (Referred to straight line through zero and full scale.)		.01③	.01③	.01③	.01③	.01③
TOTALS	.02②	.065	.031	.02	.017	.016

① HP-2212A-M1.
② On calibrated range — other ranges are ±.02% rdg with respect to calibrated range.
③ Or .01% rdg for readings between full scale and 150% of full scale.

TEMP. COEFFICIENT PER °C		.01v	.03v ①	.1v	.3v ①	1v
Scale Factor (10 to 40°C)	.004④					
Zero Drift (0 - 55°C) (not range-dependent)		.001	.001	.001	.001	.001
Zero Drift (0 - 55°C) (1µv rti)		.01	.0033	.001	.00033	.0001
Zero Drift (0 - 55°C) (.5 namp rti x 1000Ω)		.005	.0017	.0005	.00017	.0001
TOTALS	.004④	.016	.006	.0025	.0015	.0012

④ Scale factor temperature coefficient is .01% rdg from 0 to 10°C and 40 to 55°C.

*Table 2-1 specifies accuracy of the pulse rate over a 1-second sample period with respect to the calibration standard, assuming daily calibration after 30 minute warmup in Combining Case or 1-1/2 hour warmup in free air. The specification does not include accuracy of the counter used to totalize 2212A vfc output pulses.

2-49. APPLICATIONS.

2-50. DATA ACQUISITION. Conversion of low-level dc output signals from transducers to a digital rate simplifies subsequent handling of the data. When the pulse rate is counted for a decimal multiple of 1 second, a digital readout convertible to voltage is produced. (See paragraph 2-42.) Summing of the vfc output by the counter yields a parallel digital output suitable for input to a computer, such as the HP-2116A. Because the counter reads the average value of the dc input over the selected gate period, noise and ripple voltage superimposed on the signal are largely averaged out. (See paragraph 2-45 and Figure 2-12.)

2-51. In data acquisition the optional vernier can be used to 'scale' the digital rate output of the 2212A to produce a readout in engineering units instead of voltage. Suppose, for example, that direct readout is desired from a strain gage pressure transducer that produces 3.2 millivolts per volt of excitation at a full-scale pressure of 2500 psig (2500 times atmospheric pressure). If excitation is 10 volts dc, the transducer output for 2500 psig input will be 32 millivolts. On the .1 VOLT range, the 2212A output with the vernier set at 000 will be 32.000 kHz. It would be desirable instead to have the 2212A output be 25.000 kHz, which corresponds to the full-scale psig input to the transducer (except for decimal position). This correspondence can be achieved by applying a 32 millivolt input to the 2212A on the .1 VOLT range and setting the vernier to produce a 25.00 kHz reading on the counter. The vernier dial setting will be approximately 1.12, given by the following calculations:

1. Determine the range multiplier (Rm) required to make 32 millivolt input produce 25 kHz output:

$$Rm = \frac{32}{25} = 1.28$$

2. Determine the vernier dial setting (Vs) required for this range multiplier (Rm):

$$Vs = \frac{1.28-1}{0.25} = 1.12$$

NOTE

In this example, the psig readings produced by scaling require correction of the decimal place, but this is obviously more convenient than calculating psig for each reading.

2-52. INTEGRATING DIGITAL VOLTMETER. The 2212A converts an electronic counter to an integrating digital voltmeter. One point to remember, however, is that source resistances greater than 1000 ohms result in increased zero drift. (See paragraph 2-25.) For example, operation of the 2212A with a source resistance of 100K may produce 500 μV additional rti zero drift over an 8 hour period. On the .01 VOLT range, this results in an error of 5% of full scale; on the .1 and 1 VOLT ranges, the respective errors are .5% and .05% of full scale. Source resistances less than 100K cause proportionally less zero drift error.

2-53. DIGITAL TRANSFER STANDARD. Because of its excellent stability and 1000 Megohm input impedance, the 2212A is an excellent digital transfer standard. Operated on the 1 VOLT range, the 2212A can be calibrated to produce a digital counter readout of the exact output voltage from a standard cell. While the 2212A is operating on the 1 VOLT range, its input impedance is so high that there is no loading of the standard cell so the standard voltage remains accurate. It is important to remember, however, that the input impedance remains high only while the 2212A is turned on and is not overloaded. After calibration of the 2212A from the standard cell, the 2212A can be connected to other voltage sources which can be calibrated within an accuracy of a few microvolts.

2-54. Since the 2212A also has very good linearity (±0.01%), its use as a digital transfer standard can include setting of up-scale and down-scale voltages with all of the advantages of digital readout. With the use of a decade-multiple precision voltage divider, accurate setting of voltages considerably higher than 1 volt also becomes possible, though the error introduced by voltage divider tolerances and loading of the source being calibrated reduces accuracy when voltages are being set by this method.

SECTION III
THEORY OF OPERATION

3-1. GENERAL.

3-2. Voltage-to-Frequency Converters (vfc's) produce an output pulse train whose frequency is proportional to the input voltage. Ideally, with no input, no output pulses are produced. As input voltage is increased from zero, the output pulse rate rises from zero proportionally, ultimately reaching a specified full scale rate. In the 2212A, full scale is 100 kHz and voltage-to-rate conversion is extremely linear through 150% of full scale.

3-3. OVERALL DESCRIPTION.

3-4. The functional elements of the 2212A vfc are shown in Figure 3-1. Amplifiers A and B, with gain-bandwidth products characteristic of operational amplifiers, serve as the differential input preamplifier of the 2212A. They supply drive current to amplifier C that is directly proportional to the differential input voltage and inversely proportional to the value of R_g. Amplifier C is also operational, and similar in design to amplifiers A and B. Capacitor C1 from output to input connects amplifier C as a linear integrator.

3-5. The output from amplifier C is determined by the input to amplifiers A and B. When the input to A is positive with respect to B, the output from amplifier C is a positive-going capacitor-charge signal. If the input signal polarity is reversed, the output from amplifier C is negative-going. Regardless of polarity, the amplifier C output triggers the polarity and level detector at a certain level. The level detector is triggered at approximately ±1.2 volts, which is higher than the voltage that is required to switch the polarity indicators and polarity output signal from plus to minus, or vice versa.

3-6. The pulse generator produces a constant volt-time area feedback pulse each time it is triggered by the output from the level detector. Meanwhile, in response to a polarity signal from the polarity and level detector, the feedback polarity switch is enabled to gate positive or negative pulses through a feedback current divider network (R_{1f}, R_{2f}, and R_{3f}) to the amplifier C input. At the amplifier C input, the pulse current equals the current applied to amplifier C from the preamplifier, but is of opposite polarity.

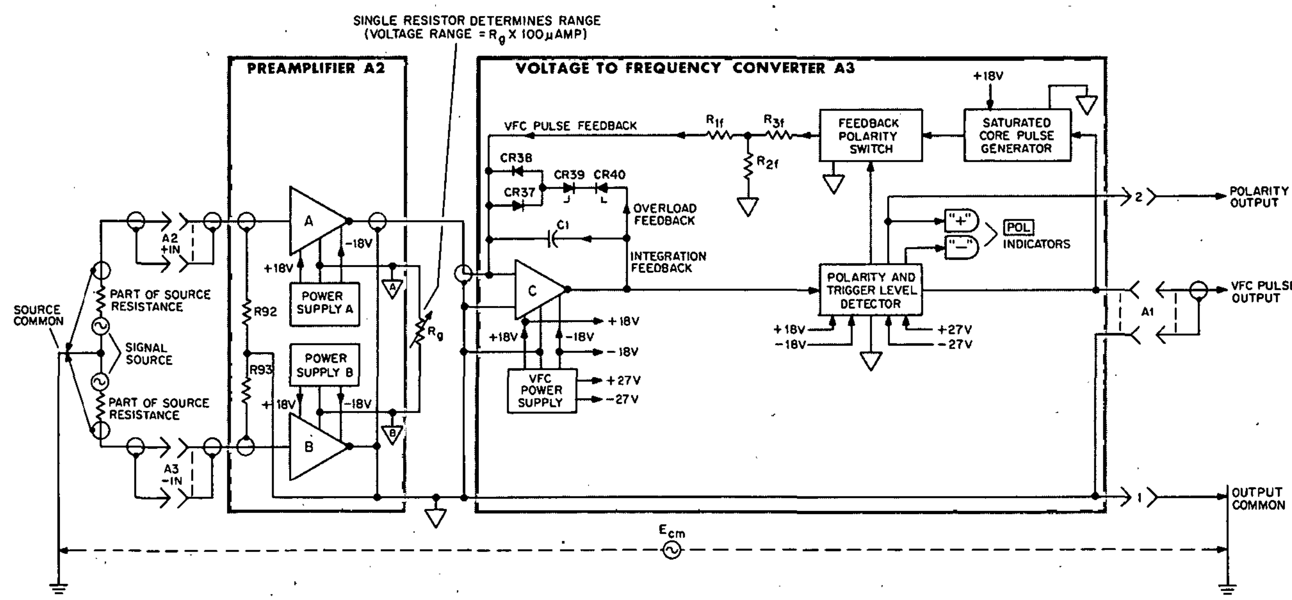


Figure 3-1. 2212A VFC Functions

3-7. When zero input is applied to the 2212A, preamplifier A-B and integrating amplifier C produce no output. The level detector and the pulse generator are not triggered. Therefore, no vfc output pulses are produced.

3-8. If an input voltage is applied to the 2212A, the preamplifier and integrating amplifier produce outputs, the level detector and the pulse generator are triggered, and vfc output pulses are produced. The rate at which the integrator output approaches triggering level depends upon the input voltage. With increasing input voltage, the interval between feedback pulses decreases and the vfc output pulse rate therefore increases.

3-9. The amplifier C input currents arising from the volt-time integral of the external input voltage and the total of the volt-time areas of the feedback pulses are kept in balance by the rate at which the feedback pulses are generated. For example, the current arising from a 1 volt input would be balanced at the amplifier C input over a period of 1 second by the current arising from 100, 000 feedback pulses with a volt-time area of 10 microvolt-seconds (100,000 times 10 microvolt-seconds equals 1 volt-second).

3-10. The 2212A vfc is calibrated by R_{1f}, R_{2f}, and R_{3f} so that ±100 microamperes input current from the preamplifier produces 100 kHz (full scale) output frequency. The differential input voltage required to produce 100 microamperes from the preamplifier is determined by the value of R_g, which is selected by the RANGE switch. The voltage range equals 100 microamperes times the value of R_g. The values of R_g provided in the standard and M1 instruments are as follows:

RANGE (VOLTS)	R_g Value
.01	100Ω
.03 (M1 only)	300Ω
.1	1K
.3 (M1 only)	3K
1.0	10K

3-11. When the input to the 2212A exceeds about 250% of full scale for the selected range, the feedback pulses cannot be produced rapidly enough to keep the integrator output from exceeding its normal peak voltage (approximately ±1. 2 volts). To avoid saturation of integrating amplifier C under such circumstances, an overload feedback network is connected from output to input, in parallel with integration capacitor C1. The overload feedback network is effectively an open circuit until the integrator output tries to exceed ±10. 5 volts. At ±10. 5 to ±12. 5 volts, either CR39 or CR40 breaks down, coupling additional feedback to the amplifier C input. This feedback keeps the amplifier C output voltage from exceeding ±12. 5 volts. Because it prevents saturation, the overload feedback helps to assure rapid recovery of the 2212A vfc from input overload.

3-12. An inherent requirement of the preamplifier used in the 2212A vfc, is a dc return between input (source) common and integrating amplifier C common. This return is completed in the 2212A through R92 and R93 of the preamplifier when the guard shields of the coaxial inputs are connected to one side of the input.

3-13. COMMON MODE REJECTION (CMR).

3-14. Rejection of common mode signal voltage (E_{cm}) existing between source common and output ground is set at 120 db (one million to one) by the open-loop gains (-10^6) of amplifiers A and B. Because amplifiers A and B have equal gains:

$$CMR = \frac{K \cdot R_{in}}{R_g + R_{iu}}$$

WHERE: K = OPEN-LOOP GAIN OF AMPLIFIER A OR B
R_{in} = OPEN-LOOP INPUT RESISTANCE OF THE 2212A (>100K)
R_{iu} = INPUT UNBALANCE

3-15. The relationship presented above is valid only because amplifiers A and B are powered by supplies that are completely isolated from each other and from the vfc power supply. The only connection between power supplies A, B, and the vfc power supply is through amplifiers A and B and through R_g. This isolation is assured by driving the individual power supplies with ac power from three separately-shielded secondaries of the power transformer. Insulation between windings and between the power supplies is so high that leakage current between supplies is less than 10 nanoamperes. Guarded capacitances are less than 0. 25 picofarads.

3-16. RANGE SWITCH ASSEMBLY A1

NOTE

Unless otherwise specified, incomplete reference designations (R1, S1, C1, Q1, CR1, etc.) in the following descriptions (paragraphs 3-17 through 3-60) pertain to components of the assembly being described.

3-17. RANGE switch assembly A1 selects the range-determining resistor, R_g, that connects amplifier A common to amplifier B common. The same function is performed by RANGE switch assembly A1M1 in 2212A-M1 instruments. RANGE switch assembly A1M3 in 2212A instruments with internal calibrate Option M3 also controls the input switching to preamplifier assembly A2. The external connections and schematics of A1, A1M1, and A1M3 are shown in Figures 5-1 and 5-4.

3-18. In the 2212A vfc without Optional Modification M3, the RANGE switch assembly consists of two-pole rotary switch S1, three (std 2212A) or five (2212A-M1) precision R_g resistors, and a buss lug. The R_g resistance values are accurate to ±0.01% and have excellent temperature stability (±5 ppm per °C). The precision of these resistors assures that the range-to-range error cannot exceed ±0.02%. (Range-to-range error equals ±0.02% only when the resistor for the 1 volt range is -0.01% and that for another range is +0.01%, or vice versa.)

3-19. The design and construction of the RANGE switch assembly preserve the resistor accuracy by separately connecting the high-quality and low-quality grounds of the preamplifier to the selected Rg resistor. This technique (similar to the four-wire connections used for highly-accurate resistance measurement by the 2410B/2401C digital ohmmeter) eliminates the effects of switch contact resistance and lead length.

3-20. In the 2212A vfc with Internal Calibrate Option M3, RANGE switch S1 has four poles, two of which select the input to preamplifier assembly A2. When the .01, .1, or 1 volt RANGE is selected, S1 connects the input from J1A2 and J1A3 to preamplifier assembly A2. When any of the calibration positions is selected, J1A2 and J1A3 are disconnected. When ZERO is selected, S1 shorts the preamplifier input and selects the .01 volt range for zeroing the vfc. Selection of CAL+ or CAL- connects the 1.00000 volt output from vfc assembly A3M3 to preamplifier assembly A2 and sets the 2212A-M3 to 1 volt range.

3-21. PREAMPLIFIER ASSEMBLY A2

3-22. The functional elements of preamplifier assembly A2 are shown in Figure 3-2; the preamplifier circuit is shown in Figure 5-4. The preamplifier consists of identical amplifiers A and B and identical, completely-isolated power supplies A and B.

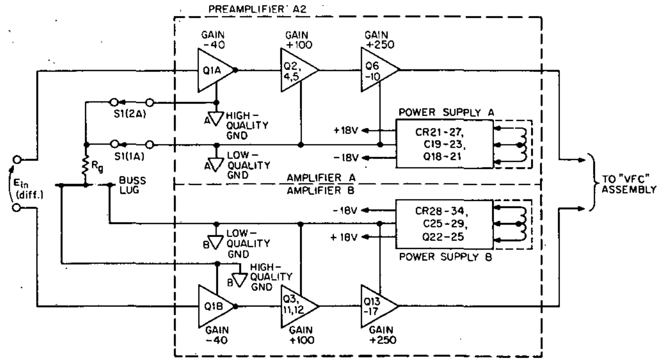


Figure 3-2. Preamplifier Functions

3-23. AMPLIFIER A. Amplifier A actually consists of three cascaded amplifiers, with gains of -40, +100, and +250. The minus sign in front of the gain of 40 denotes inversion; inversion is also indicated independently by the dot at the output of the gain of -40 amplifier symbol (Figure 3-2). The circuit details of the individual amplifiers are discussed in the following paragraphs.

3-24. First Amplifier. The first amplifier consists of transistor Q1A and related circuit elements. This common-emitter amplifier is powered by +6.2 volts that is regulated with respect to high quality ground by voltage reference diode CR6, in isolation from power supply A. Amplifier Q1A is biased class A through resistors R3 and R5, and variable resistor R4, the rti offset current null adjustment. The gain of Q1A is -40 from dc to the -3 db point (200 Hz); thereafter r-c (resistance-capacitance) network R11-C1 rolls off gain as indicated in Figure 3-3. Diode CR5 connected between the base and emitter protects Q1A from reverse bias punch-through in the event of overload.

3-25. Second Amplifier. The second amplifier consists of transistors Q2, Q4, and Q5, and related circuit elements. The transistors are connected in differential configuration, Q2A with Q2B and Q4 with Q5. The bias applied to the transistors of each differential pair is identical. Temperature-induced changes of bias on one transistor are cancelled by like changes of bias on the companion transistor. In effect, temperature-induced bias changes become a common mode signal that is greatly attenuated, assuring minimum drift. A dual transistor is used for the first differential stage to assure that the transistors share the same temperature environment as nearly as possible.

3-26. The gain-bandwidth characteristics of the second amplifier are determined by r-c feedback from the collector of Q4 to the emitter of Q2A via R20, R21-C4, R22-C5, and C3. See Figure 3-3 for response of amplifier 2.

3-27. Diodes CR7 and CR8, connected between the collectors of Q2A and Q2B, keep the input to Q4-Q5 from exceeding ±0.4 to 0.7 volts differential. This limits saturation of subsequent circuits in the event of overload.

3-28. Third Amplifier. The third amplifier consists of common-emitter stages Q6 and Q7, a complementary push-pull output stage, Q9-Q10, a constant-current coupling network, CR9-CR10-Q8, and related circuit elements. The collector current from Q8 is held constant at approximately 6 milliamperes by the (R30-R31) divider-developed voltage at the base and by the value of emitter resistor R32. Constant current maintains a constant voltage across diodes CR9 and CR10 so that signal voltages at the Q7 collector are coupled, without attenuation, to the base of Q10 as well as to the base of Q9. The voltage drop across CR9 and CR10 forward-biases Q9 and Q10 slightly, avoiding crossover distortion (which would result if one transistor started to cut off before the other turned on).

3-29. The gain of the third amplifier is +250 from dc to the -3 db point (4 kHz); thereafter feedback coupled through C8 rolls off gain at a rate of 6 db per octave. Gain is down to +1 at 2 MHz. (See Figure 3-3.)

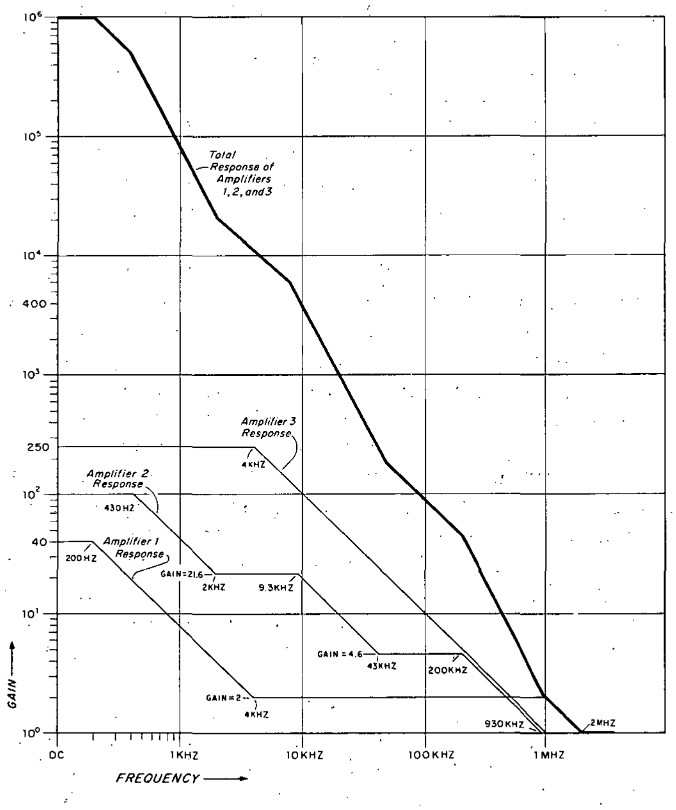


Figure 3-3. Amplifier A Response (idealized)

3-30. AMPLIFIER B. Amplifier B is identical to amplifier A, except for the coarse and fine zero adjustments in the bias circuit of Q3B (corresponds to Q2B of amplifier A). The coarse zero adjustment is R45 and the fine adjustment is R46, which is the front panel ZERO setting.

3-31. OVERALL OPERATION. The differential input signal path for otherwise separate amplifiers A and B is completed through RANGE switch-selected resistor R_g. Differential signal current proportional to E_{in} flows through R_g. The differential output current drives amplifier C of the Voltage - to - Frequency Converter. Integration feedback current from the output to the input of amplifier C almost exactly balances Preamplifier output current. Thus, the Preamplifier supplies its output to a virtual short circuit. The signal current passing between the A and B grounds through R_g develops a voltage drop across R_g that is precisely equal to E_{in}. This current feedback holds the differential signal current through the base-emitters of Q1A and Q1B to an extremely small value, producing an extremely high effective input resistance. The theoretical input resistance is approximated by the following expression:

$$R_{in(diff)} = R_{in(A)} \times GAIN$$

Since $R_{in(A)}$, the open-loop input resistance of amplifier A or B, is greater than 100K and gain is one million, the theoretical differential input resistance is greater than 100,000 megohms. However, insulation resistance may by considerably lower, particularly at high humidity. So the effective input resistance of the 2212A is specified to be greater than 1000 megohms, even at 95% relative humidity.

3-32. In addition to circuits already discussed, the Preamplifier includes 1K resistors R1 and R38, which limit current through the Q1A and Q1B base-emitters and diodes CR5 and CR15. This action protects the Preamplifier if greater than ±11 volts is applied to the input, at the price of slightly increased noise and drift referred to the input.

3-33. Capacitors C32, C33, and C34 form a low-pass filter with R1 and R38. This filter has negligible effect upon signals within the passband of the Preamplifier, but greatly attenuates radio frequency interference starting at approximately 100 kHz.

3-34. Capacitor C17 is necessary because the Preamplifier is designed to work into the virtual short circuit presented by current feedback from the integrating amplifier in the vfc. As amplifier C current feedback falls off at higher frequencies the Preamplifier might tend to become unstable.

High frequency instability is prevented by C17 because it presents a very low X_c and a virtual short circuit to signal frequencies above 100 kHz.

3-35. POWER SUPPLIES. The two Preamplifier power supplies (Figure 5-2) are identical circuits, each referenced to its own common and fully isolated from the other, and from the vfc power supply on vfc assembly A3. The supplies are driven by ac power from separate, well-shielded secondaries of the 2212A power transformer.

3-36. Power supply A is typical. The ac input from the power transformer secondary is rectified by CR24-27, filtered by C22 and C23, and regulated by transistors Q18-21. Voltage reference diode CR23 and voltage reference diodes CR21 and CR22 break down at 18 volts ±5%, causing the ±18 volt regulators to stabilize at an output of 18.5 ±1 volts with respect to 'A' common. Output variations, including ripple voltage, are coupled to dc amplifier Q20 or Q21 through CR23 or CR21 and CR22. Negative feedback that greatly attenuates ripple voltage and keeps output voltage essentially constant is provided by the amplified and inverted outputs from the collectors of Q20 and Q21, which are applied to the bases of series regulators Q18 and Q19.

3-37. VFC ASSEMBLY A3

3-38. The Voltage-to-Frequency Converter assembly actually consists of four functional elements, as follows:

1. An integrator (amplifier C in Figure 3-1).
2. A polarity and trigger level detector.
3. A feedback pulse generator.
4. The vfc power supply.

3-39. INTEGRATOR. The integrator is actually an operational amplifier that consists of three amplifiers, all with gains of +100. (See Figures 3-4 and 5-6.) The first two amplifiers have differential input and differential output. The inversion required by the integrator design is provided by cross-coupling the outputs of the second amplifier to ground and to the input stage of the third amplifier. Circuit details of the individual amplifiers are discussed in the following paragraphs.

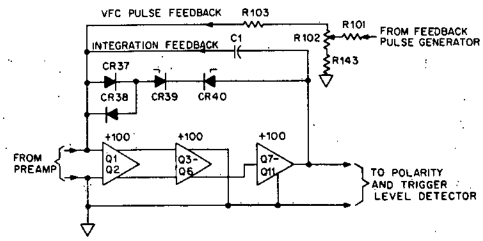


Figure 3-4. Integrator Functions

3-40. First Amplifier. The first amplifier is a two-stage differential circuit consisting of dual transistors Q1A/B and Q2A/B and related circuit elements. With differential input, temperature-induced changes of bias effectively become a common mode signal that is greatly attenuated. Second stage Q2A/B is balanced by adjustment of variable resistor R28. The input stage is balanced by R11. The base currents of Q1A and Q1B are equalized by adjustment of R4 and R6. The gain of the first amplifier is +100 from dc to the -3 db point (500 Hz). Thereafter r-c networks C3-R22 and C4-R23 roll off gain at a rate of 6 db per octave. Gain is down to +1 at 50 kHz, then flat beyond 5 MHz. (See Figure 3-5.)

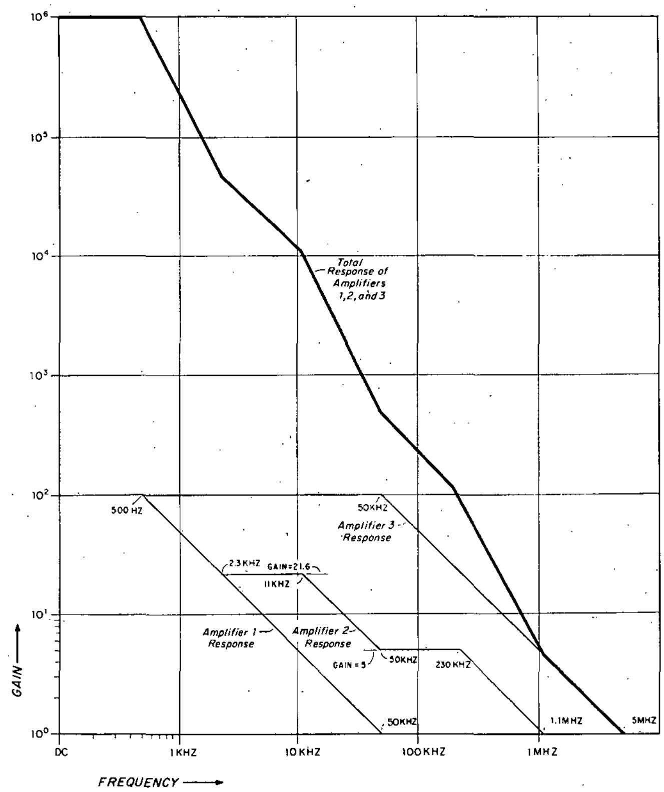


Figure 3-5. Integrator Response (idealized)

3-41. Resistor R93 isolates the input of the first amplifier from A2C17, the Preamplifier capacitive output load. The isolation provided by R93 assures the stability of the integrating amplifier and helps to limit overload input signals.

3-42. Clipper diodes CR1 and CR2 limit signal amplitude at the first amplifier input. This adds to the overload protection provided by the overload feedback network (diodes CR37-40) from integrating amplifier output to input.

3-43. Second Amplifier. The second amplifier consists of transistors Q3 through Q6, connected as a two-stage differential feedback pair, and related circuit elements. The output from the Q5 collector, which is in-phase with respect to the high side of the input from the Preamplifier, is grounded. The output from the Q4 collector, which is inverted with respect to the high side of the input from the Preamplifier, is applied to the third amplifier. This connection inverts the integrating amplifier output with respect to the input.

3-44. The gain-bandwidth characteristics of the second amplifier are determined by r-c feedback from the collectors of Q5 and Q6 to the emitters of Q3 and Q4. Feedback from the Q5 collector is coupled through R41, R40-C7, R39-C6, and C5. Feedback to the Q4 emitter is coupled through R42, R43-C8, R44-C9, and C10. The overall response of the second differential feedback pair is diagrammed in Figure 3-5.

3-45. Third Amplifier. The third amplifier consists of common-emitter stages Q7 and Q8, a complementary push-pull output stage, Q10-Q11, a constant-current coupling network, CR7-R59-CR8-Q9, and related circuit elements. The collector current from Q9 is held constant at approximately 12.5 milliamperes by the (R56-R57) divider-developed voltage at the base and by the value of emitter resistor R58. Constant current maintains a constant voltage differential between the bases of Q10 and Q11 so that signal voltages from the Q8 collector are coupled, without attenuation, to the base of Q11 as well as the base of Q10. The voltage differential forward biases both Q10 and Q11 slightly, avoiding crossover distortion (which would result if one transistor started to cut off before the other turned on).

3-46. The gain of the third amplifier is +100 from dc to the -3 db point (50 kHz); thereafter feedback coupled through C13 rolls off gain at a rate of 6 db per octave. Gain is down to +1 at 5 MHz. (See Figure 3-5.)

3-47. Integration Feedback. Integration feedback current coupled from integrator output to input via C1 essentially equals the sum of Preamplifier and feedback pulse input currents, which are of opposite polarity. Between pulses, integration feedback equalling Preamplifier current charges C1. At ±1.2 volts the C1 voltage triggers a feedback pulse that reverses current input to the integrator, partly discharging C1. The current-time integral of the feedback pulses is made equal to the current-time integral of the Preamplifier output by variation of the feedback pulse rate (i.e., pulses are triggered more frequently or less frequently). The voltage developed across C1 is applied to the polarity and trigger level detector.

3-48. Overload Feedback. Overload feedback from the integrator output to input is coupled through diode CR37 or CR38 and voltage breakdown diodes CR39 and CR40 if the output voltage exceeds ±10.5 volts for any reason. This feedback assures rapid recovery from overload whenever pulse feedback cannot be generated rapidly enough to keep the integrator output between zero and ±1.2 volts.

3-49. POLARITY-TRIGGER LEVEL DETECTOR. The polarity-trigger level detector consists of the polarity detector and signaller and trigger level detector, both functionally illustrated in Figure 3-6. These and the related feedback pulse flip-flop and vfc pulse driver circuits are discussed in the following paragraphs. (Also see Figure 5-6.)

3-50. Polarity Detector and Signaller. The polarity detector is a differential amplifier (Q12-13) with emitter follower (Q14) output. The positive and negative output levels from the detector are limited by feedback from an output divider-limiter (R68-70, 109, and CR9-10). The sensitivity of the differential amplifier is such that very small positive input (with respect to ground) drives output signals B, K, and L to their most negative level. And very small negative input drives these output signals to their most positive level.

3-51. Signal B is typical of signals K and L. Its most negative level (-2.8 volts), produced when 2212A input is positive, turns on Q28. This lights "+" polarity indicator DS1 and clamps the polarity signal line to ground, its most positive level. The most positive level of signal B (+2. 8 volts) is produced when input to the 2212A is negative. The +2. 8 volt level cuts off Q28, allowing the polarity signal line to go to its most negative state (about -27 volts), and turns on Q27, lighting the "-" polarity indicator, DS2.

3-52. Signals B and K also control the positive and negative pulse feedback switches. The most negative level of signal B turns on the positive pulse feedback switch and cuts off the negative pulse feedback switch. The most positive level of signal K cuts off the positive pulse switch and turns on the negative pulse switch. Signals B and L are used by the trigger level detector as described below.

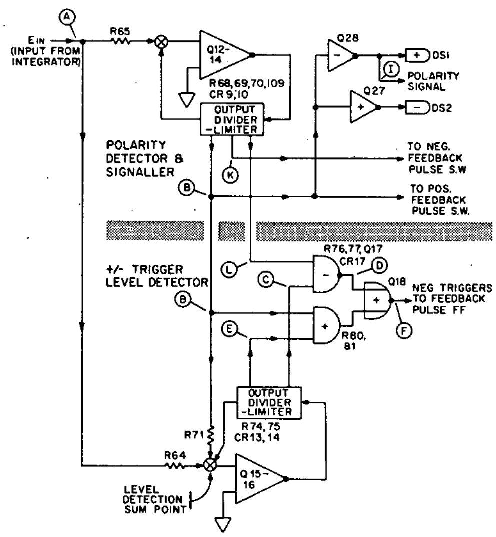


Figure 3-6. Polarity – Trigger Level Detector Functions

3-53. Trigger Level Detector. The heart of the trigger level detector is a circuit (Q15A, 15B, 16, R74, 75, and CR13, 14) similar to the polarity detector circuit. Signal B from the polarity detector establishes the baseline output from the trigger level detector and the positive or negative level at which triggers are generated. (See vfc timing in Figure 5-6) The -2. 8 volt level of signal B opposes positive input signal A from the integrating amplifier until signal A reaches +1.2 volts. Similarly, the +2. 8 volt level of signal B opposes negative signal A input until signal A reaches -1. 2 volts. At the ±1. 2 volt triggering level, trigger signals C and E switch from positive or negative baseline potential, forming negative-going or positive-going triggers. Negative-going C triggers combined with the negative level of signal L turn on NOR gate Q18 via NAND gate R76,77, Q17, CR17, producing negative-going triggers at the Q18 collector. Positive-going E triggers combined with the +2. 8 volt level of signal B turn on NOR gate Q18 through AND gate R80, 81, also producing negative-going triggers at the Q18 collector. The Q18 output triggers the feedback pulse flip-flop and the vfc pulse driver.

3-54. Feedback Pulse Flip-Flop. Flip-flop Q19-22 provides the transitions that are used to trigger the vfc pulse driver and switch constant volt-time area pulse transformer T1, generating feedback pulses. (See Figure 5-6.) The action of this flip-flop is most easily understood by assuming it is in one state, such as Q19 off and Q21 on. Between negative-going triggers, about +1. 2 volts is applied from divider R83-84 to coupling transistors Q20 and Q22 through diodes CR20 and CR21. When Q21 is on, Q20 is also on. When Q19 is off, Q22 is reverse-biased and is also off. Conduction through Q20 and Q21 clamps the anode of CR19 near ground, holding Q19 cut off. Because Q22 is off, Q21 is biased on through R87 and CR23. Each negative-going trigger from the Q18 collector cuts off both coupling transistors (Q20 and Q22). This permits turn-on of the flip-flop transistor (Q19) that was previously cut off. Turn-on of Q19 applies a negative-going signal to the anode of CR23. This disconnects forward bias from Q21, cutting it off. Turn-off of Q21 applies a positive-going signal to the base of Q19 through C14 and CR18, assuring that it remains on until the end of the negative-going trigger from the Q18 collector turns on Q22, stabilizing the new states (Q19 on, Q21 off). The next negative trigger causes a reversal of states back to Q21 on, Q19 off.

3-55. VFC Pulse Driver. VFC pulse driver Q29 is normally off, with +9 volts at the collector. Positive-going transitions from the collector of Q19 or Q21, differentiated by C19-R120 or C20-R121, and coupled through CR26 or CR27 and CR18 and R118 turn on Q29, producing negative-going pulses. These pulses are coupled from the Q29 collector to coaxial connector A1 in receptacle J1 on the rear panel.

3-56. FEEDBACK PULSE GENERATOR. The feedback pulse generator consists of saturable core transformer T1, core drivers, Q23 and Q24, feedback polarity switches Q25 and Q26, and related calibration circuits. (See Figure 5-6.) Each change of feedback pulse flip-flop states turns on core driver Q23 and turns off core driver Q24, or vice versa. This reverses the polarity of current flow in the transformer primary and the polarity of core magnetization. Because core saturation characteristics and transformer construction are carefully controlled during manufacture, the output from the transformer secondary is a pulse that has constant volt-time area over a wide range of repetition rates, from 0 to more than 150 kHz.

The secondary is connected for full-wave rectification, making possible either positive or negative feedback pulses. The selection of feedback pulse polarity is made by feedback polarity switch transistors Q25 and Q26, in response to signals from the polarity detector. Individual CAL+ and CAL- adjustments in the lines to the feedback polarity switches provide fine adjustment of the volt-time integral of feedback pulses individually for positive or negative inputs. Resistors R101-103 and R143 form an attenuator that includes a coarse adjustment (R102) for calibration of feedback pulse volt-time integrals. These adjustments determine the full-scale rate at which the volt-time integrals of the feedback pulses balance the volt-time integral of the input to the integrating amplifier.

3-57. VFC POWER SUPPLY. The vfc power supply provides unregulated ±27 volts and regulated ±18 and ±6.2 volt outputs, all with respect to output common. As indicated in Figure 5-6, the ac input from the power transformer secondary is rectified by CR31-34, filtered by C21 and C22, and regulated by transistors Q30-37. The unregulated 27 volt outputs are taken from the collectors of ±18 volt series regulators Q30 and Q33 for powering the polarity signalling circuit, including polarity indicators DS1 and DS2.

3-58. The +18 volt regulator circuit consists of series regulator Q30, dc amplifier Q31, differential amplifiers Q35-36 and Q37A-B, and voltage reference diode CR28. First differential amplifier Q37A-B compares a sample of the +18 volt output, tapped by R141, to the reference voltage developed across CR28. Output voltage variations, successively amplified and inverted by Q37B, Q35, and Q31, provide negative feedback to the base of Q30 that holds the +18 volt output essentially constant in the face of line voltage and load variations.

3-59. The -18 volt regulator consists of series regulator Q33, dc amplifier Q32, and reference coupler Q34. Voltage divider R130-131 in the base of the reference coupler compares the -18 volt output to the +18 volt output, which serves as a reference. Variations of the -18 volt output from approximate equality to the +18 volt output, coupled through Q34 and amplified and inverted by Q32, provide negative feedback that regulates the output voltage from series regulator Q33.

3-60. The ±6.2 volt regulators are simple voltage reference diode shunt regulators that are connected across the ±18 volt outputs. The ±6.2 volt outputs provide bias for the input stages of the integrating amplifier.

SECTION IV
MAINTENANCE

4-1. GENERAL

4-2. This section contains instructions for maintenance of the 2212A Voltage-to-Frequency Converter. Included are a maintenance schedule (Table 4-1), a list of recommended test equipment (Table 4-2), in-cabinet performance checks (Table 4-3), and instructions for access to assemblies, troubleshooting, repair, cleaning, and calibration. Parts locations and schematic diagrams are in Section 5 with the parts list.

NOTE

If it should become necessary to communicate with the factory or your Hewlett-Packard Field Service Facility regarding your 2212A, be sure to specify the instrument's complete serial number and all modifications.

4-3. IN-CABINET PERFORMANCE CHECKS AND TEST CARD

4-4. The in-cabinet performance checks in Table 4-3 may be used to verify specifications of the 2212A. The Performance Check Test Card at the end of Table 4-3 may be filled out to provide a record of the instrument's performance. Separate columns are provided for entry of measurement result(s) and whether the result is acceptable. The determination of result acceptability is based upon the limits entered in a specification limits column. The entry numbering on the test card corresponds to the check numbers and step in Table 4-3. The checks in Table 4-3 may be used to verify all important 2212A performance specifications for the following purposes:

1. As part of an incoming inspection check of instrument specifications.
2. Periodically, as specified in Table 4-1, to verify correct operation.
3. After repairs and adjustments, to verify correct operation before returning the 2212A to regular service.

NOTE

The 2212A Voltage-to-Frequency Converter is a highly-sensitive precision instrument whose performance must be checked carefully to assure valid results. For example, clips making intermittent connections to test voltage sources may cause serious errors by violating the requirement for 1K source resistance; in extreme instances, intermittent input connections may even cause the 2212A to be self-driven to an output pulse rate greater than 300 kHz that does not respond to variations of the input voltage. Another pitfall to avoid is using dissimilar metals for input connections. Using steel clips with copper wire, for instance, may introduce thermally-generated voltage into test setups, completely obscuring the actual zero drift performance of the 2212A.

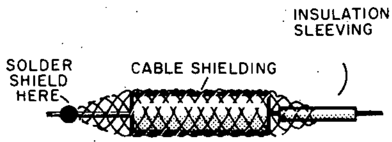
Table 4-1. Maintenance Schedule

Recommended Interval	Maintenance Operation
Daily or before data run	Zero and calibrate 2212A as instructed in paragraphs 2-36 through 2-39.
Monthly	If using 2212A in Combining Case, clean air filter per 'Air Filter' paragraph on page 6 of Combining Case instructions.
Quarterly (every 90 days)	Zero preamplifier and vfc, as instructed in paragraphs 4-30 and 4-31.
Semi-Annually	Vacuum inside of the 2212A in a clean atmosphere. Do not use air blast.
	Check performance of 2212A per Table 4-3, checks 1 through 5.
	Calibrate the internal calibration source of 2212A-M3 as instructed in paragraph 4-32.

Table 4-2. Recommended Test Equipment

Equipment	Use and Required Characteristics	Recommended Model or Equivalent
Combining Case and Bench Stand or Cable Assembly.	Power and signal input-output connections to 2212A, including connections to polarity output (pin 2) of rear panel connector.	HP-12500A Combining Case and HP-12501A Bench Stand or HP-12503A Cable Assembly with added lead to pin 2.
VTVM	Performance checks and troubleshooting; dc voltage measurements to 30v and ac voltage measurements to 7v, 3% accuracy.	HP-410C Electronic Voltmeter
Precision DC Voltage Source	Performance checks and calibration requiring 1.000V, 1.019V, and 0-1000μV outputs, .002% accuracy of 1.000V output for 1 month (with respect to primary standard) after calibration.	HP-735A Transfer Standard (there is no direct equivalent for this instrument).
Frequency Counter	Performance checks and calibration, requiring resolution of ±1 count in 100,000, 1 second sample period, time base accuracy better than ±2 ppm in 10^6 per week, at least 5-digit readout, 6 digits desirable.	HP-5233L Electronic Counter.
Oscilloscope	Performance checks and general troubleshooting with dual-trace capability. 5mv/cm vertical sensitivity, rise time less than .01 μsec, calibrated sweep rates from .5 μsec/cm to 5 sec/cm, triggering from one of the inputs with alternate display of both.	HP-140A Oscilloscope with HP-1402A Dual-Trace Amplifier and HP-1420A Time Base plug-in units.
Oscillator	Performance checks with .3v rms output across 51 ohms at 50.5, 505, and 5050 Hz and 7v rms across 600 ohms at 70 Hz.	HP-200AB, 200CD, 200J, 201C, or 202C Audio oscillator, or 205AG or 206A Audio Signal Generator.
Precision Voltage Divider	Linearity and overrange checks, requiring constant 100K input resistance, 5 ppm accuracy.	Electro-Scientific Industries Model RV722A Dekavider
Precision 100K Load Resistor	Linearity and overrange checks, requiring 100K 1% resistance	Any good quality precision 100K 1% deposited carbon resistor.

Table 4-2. (Cont'd.)

Equipment	Use and Required Characteristics	Recommended Model or Equivalent
Shielded 1K unbalance resistor	Performance checks, requiring a 1K deposited carbon resistor with copper leads to avoid thermal emf effects, shielded as shown below. 	As described at left.
Oscillator load resistors	51 ohm, 1/2 watt, and 560 ohm, 1/2 watt resistors.	Any good quality composition resistor.
BNC Tee	Connection of performance check test setups.	UG-274/U
BNC-to-GR Adapter	Connection of 2212A vfc output from GR plug to BNC connector of Counter, Tee, or Oscilloscope for performance checks and trouble-shooting.	HP-10110A Adapter
Coaxial Cable, BNC-BNC	4-foot length for connection between Oscilloscope and Counter (and between Bench Stand and Counter if Bench Stand is used).	HP-10503A Cable Assembly (one required if HP-12503A Cable Assembly is used for 2212A, two are required if Bench Stand is used).
Coaxial Cable, GR-GR	44-inch length for connection between Dekavider and Transfer Standard	HP-11000A Cable Assembly
Inductor	>100 μh inductive short for zeroing vfc circuit	not applicable
Bypassed Unbalance Resistor	10K deposited carbon resistor with copper leads, bypassed with a .001 μf parallel-connected capacitor, for internal zeroing of the preamp section.	As described at left.
Jumpers	Two short jumpers for preamp zeroing, with copper clips and copper wire.	

NOTE: Bear in mind that procedures will probably have to be modified if an equivalent instrument is used instead of the recommended model.

Table 4-3. In-Cabinet Performance Checks

CHECK 1

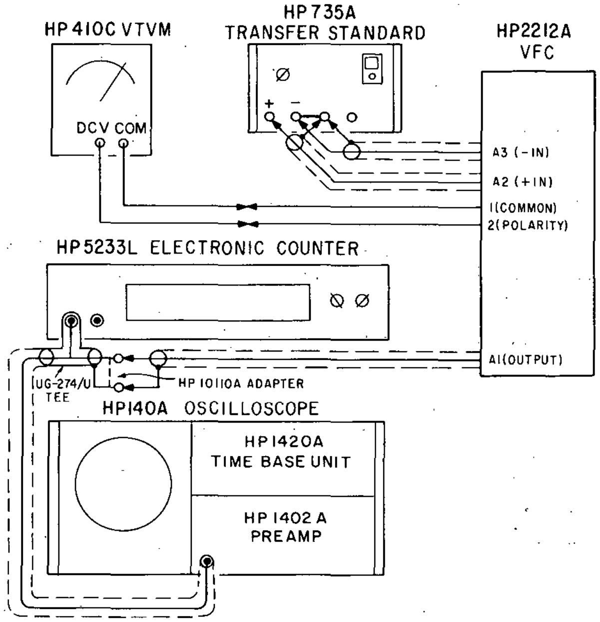
2212 OUTPUTS AND INITIAL SETUP OF COUNTER

The 2212A outputs consist of:

Negative pulses recurring at a rate proportional to input voltage with about 9v amplitude, 2μsec duration, and rise time less than .1μsec when not loaded.

A polarity signal that is 0 to -1v for positive input to the 2212A or -(23 to 31)v for negative input to the 2212A.

The counter must be initially set up to accurately count pulses at both low and high repetition rates to prepare for later checks, especially if ac-coupled counter is used.



CONNECTIONS FOR OUTPUTS CHECK & INITIAL SETUP OF COUNTER

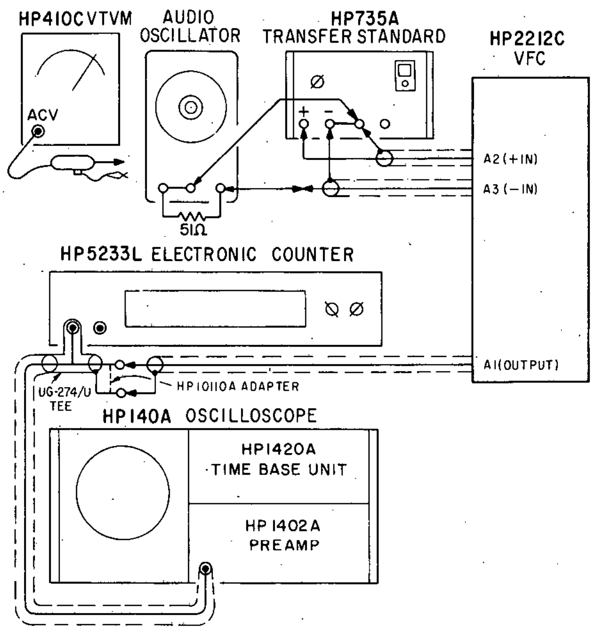
1. Make connections as shown above and turn on the 2212A and all test equipment.
2. Note time; checks 4, 5, and 6 are valid only after specified warm-up of the 2212A, which must be timed. In the Combining Case, 30 minute warm-up; in free air, 1-1/2 hour (minimum) warm-up is required.
3. Set the Transfer Standard for 1.000V output.
4. Set the 2212A to 1 VOLT range and vernier (on 2212A-M2) fully counter-clockwise to 0 and locked there.
5. Set Oscilloscope channel 'A' for 2v/cm and '+' polarity, time base for automatic triggering from INT- and .5 μsec/cm sweep, and trace controls for best display of 2212A output pulse
6. Enter pulse characteristics on the performance check test card.
7. Enter VTVM (1v range) reading and 2212A POL indication on test card.
8. Reverse connections of 2212A +IN and -IN leads to Transfer Standard '+' and '-' terminals.
9. Enter VTVM (30v range) reading and 2212A POL indication on test card.
10. Set Electronic Counter to count 2212A output pulses using 1-second gate time and +4v dc level setting and -slope or, with ac-coupled counters, set sensitivity to maximum. Where necessary, set trigger level of ac-coupled Counter to count pulses, per paragraphs 2-33 through 2-35.
11. Verify correct Counter performance by checking several successive counts with the Transfer Standard set first to 1.000V, then to 0-1000 μv with the MICROVOLT control set to 050. Readings should be consistent within ±1 count at approximately 100 kHz and 0.005 kHz. Readjust level setting if necessary to achieve consistent counting for both inputs.

Table 4-3 (Cont'd.)

CHECK 2

SUPERIMPOSED NOISE REJECTION

Subject to the restrictions in paragraph 2-45, superimposed noise rejection by the 2212A depends upon integration interval and noise frequency as shown in Figure 2-12. In this check, superimposed noise rejection is verified at .01, .1, and 1 second gate times for 50.5, 505, and 5050 Hz noise frequencies at noise amplitude of .3v rms on the 1 VOLT range. Superimposed noise rejection is checked on the 1 VOLT range to assure separation of superimposed noise effects from other effects that become dominant on the more sensitive ranges of the 2212A.



SETUP FOR SUPERIMPOSED NOISE REJECTION CHECK

1. Following check 1, connect setup as shown at left and turn on the Audio Oscillator.
2. Set the 2212A to 1 VOLT range and set the Transfer Standard for 1.000V output.
3. Using .01, .1, and 1 second gates, check the difference between Counter readings with the Audio Oscillator set for minimum 50.5 Hz output, then set for .3v rms output measured with VTVM. Enter count differences on the test card.
4. Repeat step 3 at 505 Hz.
5. Repeat step 3 at 5050 Hz.

NOTE

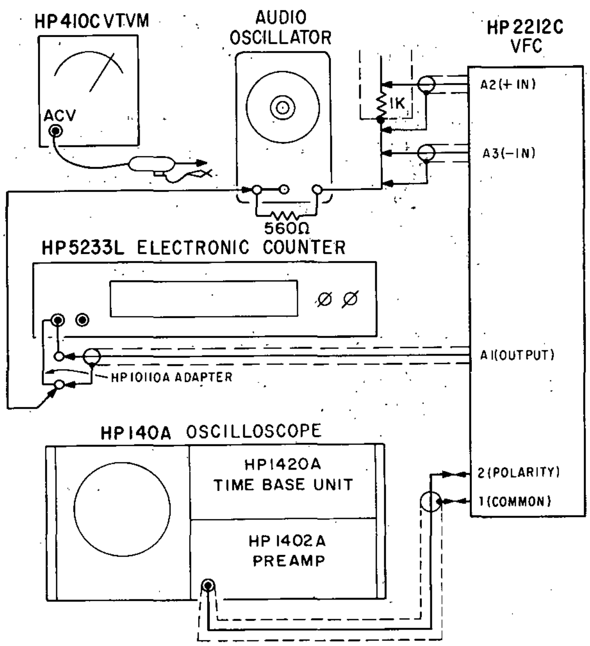
Any sharp change in the count as superimposed noise amplitude is increased to .3v rms during this check is probably caused by inability of the counter to count pulses when the 2212A pulse rate changes as a result of modulation by the superimposed noise. The loss of counts because of pulse rate modulation is particularly likely when an ac-coupled counter is used for this check. Make certain that sensitivity of the ac-coupled counter is set to maximum. If loss of counts occurs at maximum sensitivity, reset the internal trigger level adjustment according to the instructions in paragraph 2-35, but using the Transfer Standard 1.000V output and Oscillator as signal sources. The counter should be capable of counting all pulses when the rate is varying continually between a few counts per second and 150 kHz.

Table 4-3 (Cont'd.)

CHECK 3

COMMON MODE REJECTION

Common mode rejection of the 2212A without M3 is 120 db from dc to 60 Hz, which means that only one millionth of common mode signal voltage at the input is translated into differential signal voltage. (Common mode rejection of 2212A-M3 is 114 db, 500,000 to 1, when source unbalance is 1K.) Common mode rejection is checked by applying a 70 Hz common mode signal at 7.8v rms (11v peak) amplitude between input common and output common, with the 2212A set to .01 VOLT range and for approximately +24 microvolts initial dc offset. The effect of the common mode signal, referred to the input, is less than 11 microvolts peak (22 microvolts peak on 2212A-M3). The actual peak effect of the common mode input is detected by reducing the dc offset until the polarity output is seen to switch an average of once per second.



SETUP FOR COMMON MODE REJECTION CHECK

1. Following check 2, connect setup as shown at left.
2. Set 2212A to .01 VOLT range and Audio Oscillator for minimum output. Then set 2212A ZERO for positive polarity and 0.24 kHz reading on the Counter (set for 1 second gate).
3. Set Audio Oscillator for 70 Hz output at 7.8v rms, measured with VTVM; then disconnect VTVM. Set Oscilloscope for 1 sec/cm, 5v/cm, and line sync.
4. Reduce offset with 2212A ZERO adjustment until negative spikes at an average rate of 1 per second (1 per cm) appear on the trace. Enter the Counter (zero offset) reading on the test card. Reading for 2212A without M3 should not exceed 0.110 kHz; with M3, count should not exceed 0.220 kHz.
5. Reverse connections of +IN and -IN leads to the 1K resistor without changing shield or oscillator connections.
6. Set 2212A ZERO for about +0.24 kHz offset and repeat step 4. Enter the Counter reading on the test card.

Table 4-3 (Cont'd.)

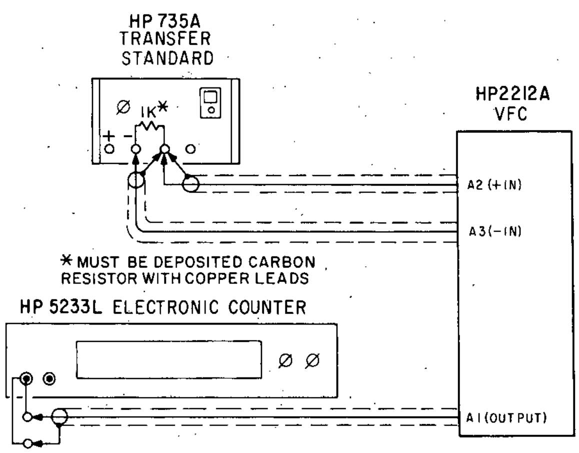
CHECK 4

CALIBRATION AND INTERNAL CALIBRATION SOURCE

The 2212A is calibrated to prepare for check of the internal calibration source (on 2212A-M3) and for performance checks 5 and 6.

With respect to the reference voltage used for its calibration, the internal calibration source drifts less than .02% (20 counts in 100,000) in six months. The temperature coefficient is less than .005% (5 counts in 100,000) per °C differential between ambient and the temperature at which the internal source was calibrated (factory calibrates at 22-25°C).

NOTE: The 2212A operated in the 12500A Combining Case must be given 30 minutes warm-up following turn-on before proceeding with this check. The 2212A operated in free air requires at least 1-1/2 hour warm-up. These times are with respect to the time noted in step 2 of check 1 provided that the 2212A has been operated continuously.



SETUP FOR CALIBRATION & INTERNAL CALIBRATION SOURCE CHECK

1. Following check 3, connect setup as shown above. Note than the +IN and -IN leads are initially connected together through a 1K resistor.
2. Set the 2212A to .01 VOLT range and set the front panel ZERO (screwdriver) adjustment for minimum reading (0±20 counts) in 1 second count time. Use switching of the POL indicators to help locate best zero setting.
3. Record average zero offset (determined from several counts on the 2212A 1 VOLT range) on the test card along with the POL indication.
4. Connect the +IN lead to the Transfer Standard '+' terminal and set the Transfer Standard for 1.000V output.
5. Set the 2212A front panel CAL+ (screwdriver) adjustment for a counter reading that differs from the step 3 zero offset reading by +100,000 counts. That is, if the step 3 offset was +2 counts, set CAL+for 100.002 kHz reading.
6. Reverse +IN and -IN lead connections to the Transfer Standard '+' and '-' terminals and set CAL- (screwdriver) adjustment for a Counter reading that differs from the step 3 reading by -100,000 counts. That is, if the step 3 offset was +2 counts, set CAL- for 99.998 kHz reading. Enter time on test card.

NOTE

Steps 7 and 8 apply only to 2212A with M3.

7. Set the 2212A to CAL+and record the Counter reading on the test card. When checking at normal room temperature (22-25°C), this reading should be within ±20 counts of 100.000 kHz (0.02% stability for 6 months). However, if the internal source has been calibrated at a temperature different from ambient during this check, the temperature coefficient may add up to 0.005% output error (±5 counts) per °C of temperature difference.
8. Set the 2212A to CAL- and record Counter reading on the test card. The test limits and explanation of step 7 apply also to this step.

4-3 (Cont'd.)

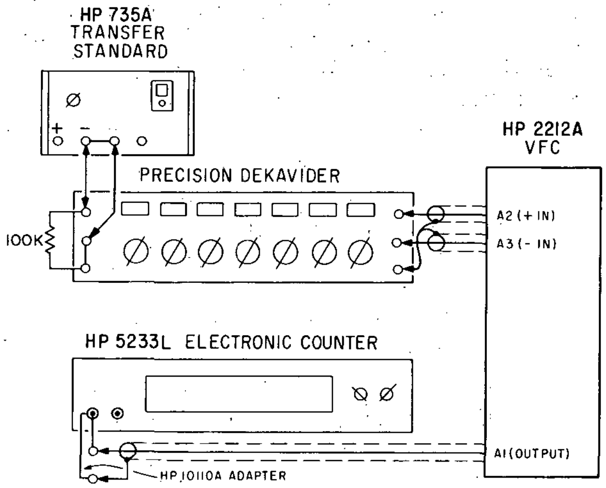
CHECK 5

LINEARITY, ACCURACY, AND OVERRANGING

Linearity of the 2212A, zero to full scale, is .01% of full scale (10 counts in 100,000).

Accuracy of pulse count is .02% of reading (20 counts in 100,000 for FS input) for any range relative to calibrated range.

Overranging of the 2212A is linear within .01% of reading to 150% of full scale (15 counts in 150,000 for 150% FS input).



SETUP FOR LINEARITY, ACCURACY, AND OVERRANGING CHECK

1. Following check 4, connect set up shown above.
2. Set the 2212A to 1 VOLT range and set the Dekavider to 999999TEN.
3. Note the polarity indication of 2212A and the zero reading of the Counter over 1 second count time. Average several readings to the nearest digit and enter the result on the test card.
4. Shift the lead connections to the Transfer Standard one set of terminals to the left (+IN and -IN to '+' and '-' Transfer Standard terminals).
5. Set Transfer Standard to 1.019V + (△) and MICROVOLTS control for 100.000 kHz plus the average zero reading entered on the test card at the end of step 3. (For example, if the zero reading was +0.002 kHz, set the MICROVOLTS control for +100.002 kHz; if the reading was -0.001 kHz, set the control for +99.999 kHz.)
6. Set the Dekavider to 900000 and connect the +IN and -IN leads from the Dekavider across the short on the Transfer Standard (as shown in the setup diagram) to check polarity and magnitude of zero reading.
7. Shift the lead connections to the Transfer Standard as in step 4 and take a +Lin reading. Subtract the step 6 zero reading from the +Lin reading and enter the result on the test card.
8. Repeat steps 6 and 7 with 2212A +IN and -IN leads connections to Dekavider terminals 3 and 4 reversed. Enter result on the test card.

NOTE

The specification limits on the test card include ±1 count ambiguity of the Counter.

9. Repeat steps 6 and 7 with 2212A +IN and -IN leads connected for '-', then for '+' indication, but at the following Dekavider settings. Enter results on the test card.

Dekavider setting	Corrected Counter Readings*
8000000	±80.0 ±0.011 kHz
7000000	±70.0 ±0.011 kHz
6000000	±60.0 ±0.011 kHz
5000000	±50.0 ±0.011 kHz
4000000	±40.0 ±0.011 kHz
3000000	±30.0 ±0.011 kHz
2000000	±20.0 ±0.011 kHz
1000000	±10.0 ±0.011 kHz

* ±0.011 kHz tolerance includes .01% FS non-linearity ±1 count ambiguity.

10. Repeat step 6 with the Dekavider at 1000000 and the 2212A set to .1 VOLT range. Average several zero readings to the nearest digit and enter the result including polarity on the test card.

TABLE 4-3 (Cont'd.)

CHECK 5 (Cont'd.)

11. Shift the lead connections to the Transfer Standard as in step 4 and take a reading. Subtract the step 10 entry from this reading (observing polarity), and enter result on the test card.

12. Repeat step 6 with the Dekavider at 0100000 and the 2212A set to .01 VOLT range. Average several zero readings to the nearest digit and enter the result, including polarity, on the test card.

13. Shift the lead connections to the Transfer Standard as in step 4 and take a reading. Subtract the step 12 entry from this reading (observing polarity) and record the result on the test card.

14. On 2212A-M1 perform the procedure outlined in steps 10 and 11 for the following Dekavider and 2212 A range switch settings and enter results on the test card.

Dekavider setting	2212A-M1 Range
030000	.03 VOLT
300000	.3 VOLT

NOTE

The tolerance on the test card for .01 and .03 VOLT ranges includes .02% range-range error, .002% Dekavider error and count ambiguity.

15. Repeat step 6 with the Dekavider at 125000 and the 2212A set to .1 VOLT range. Average several zero readings to the nearest digit and enter the result, including polarity, on the test card.

16. Shift the lead connections to the Transfer Standard as in step 4 and take a reading. Subtract the step 15 entry from that reading (observing polarity) and enter the result on the test card.

17. Perform the procedure outlined in steps 15 and 16 with the Dekavider at 1500000 and enter the result on the test card.

Table 4-3 (Cont'd.)

CHECK 6

ZERO DRIFT AND CALIBRATION STABILITY

Zero drift of the 2212A operated at constant ambient temperature does not exceed ±5 μv rti ±.005% FS rto in 8 hours (±55 counts in 100,000 on .01 VOLT range).

Calibration of the 2212A remains within ±.02% of reading (±20 counts in 100,000 for FS input) for 8 hours.

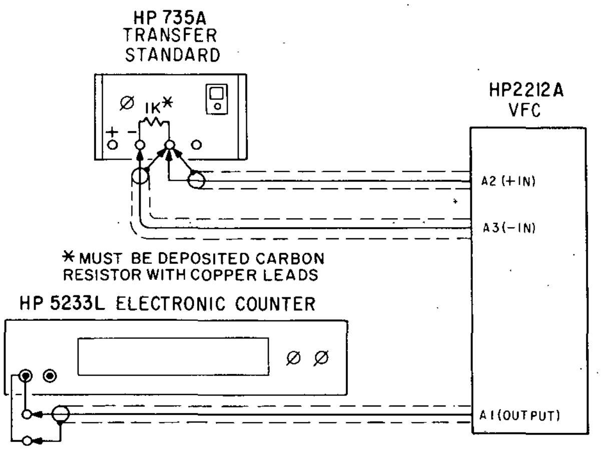
Temperature coefficients:

Zero drift: ±1 μv ±.5 namp rti ±.001% FS rto per °C.

Calibration: ±.004% of reading per °C (10-40°C)
±.01% of reading per °C (0-10°C or 40-55°C)

NOTE: The following are required for verifying temperature coefficients:

1. A temperature chamber capable of housing the 2212A installed in a 12500A Combining Case at any temperature in the range of 0 to 55°C for 6 hours.
2. A 12500A Combining Case wired with teflon-insulated input leads long enough to run outside of the temperature chamber to the HP 735A Transfer Standard; the input leads must be copper wire, terminated with copper clips or banana plugs. The coaxial output lead must be long enough to run outside of the temperature chamber to the Electronic Counter.



SETUP FOR ZERO DRIFT & CALIBRATION STABILITY CHECK

1. Following check 5, and after the 2212A has been on and operating 8 hours at reasonably constant temperature (±2°C) since calibration in step 4, connect setup as shown above.

2. Set the 2212A to .01 VOLT range and enter polarity indication and Counter reading on the test card. The reading should not exceed ±0.056 kHz.

3. Set the 2212A to 1 VOLT range and check several counts to determine average zero offset. Enter the POL indication and the Counter reading on the test card.

4. Connect the +IN lead to the Transfer Standard '+' terminal, set the Transfer Standard for 1.000V output, and note the Counter reading. Subtract the zero reading taken in step 3 from the Counter reading (observing polarity) and record the result on the test card.

5. Reverse +IN and -IN lead connections to the Transfer Standard '+' and '-' terminals and note the Counter reading. Subtract the zero reading of step 3 from the Counter reading (observing polarity) and record the result on the test card.

6. For temperature coefficient checks, install the 2212A in a Combining Case with all spaces filled, by instruments or HP 12504A Blank Panels. Then install the Combining Case in a temperature chamber at 25°C so that power and signal leads run outside of the chamber.

7. Reset the 2212A ZERO, CAL +, and CAL- per steps 1 through 6 of check 4.

Table 4-3 (Cont'd.)

CHECK 6 (Cont'd.)

8. Close the temperature chamber and set it for 10°C.

9. After the chamber has been at 10°C for three hours, check zero drift and calibration errors per steps 2 through 5. Enter the results on the test card. Total zero drift should not exceed ±296 counts, including 55 counts possible at constant temperature, 240 counts caused by temperature change, and 1 count ambiguity of the Counter. Total calibration error (after correction for zero shift) should not exceed ±81 counts, including 20 counts possible at constant temperature, 60 counts caused by temperature change, and 1 count ambiguity of Counter.

10. Close the temperature chamber and set it for 0°C.

11. After the chamber has been at 0°C for two hours, check zero drift and calibration errors per steps 2 through 5. Enter the results on the test card. Total zero drift should not exceed ±456 counts. Total calibration error (after correction for zero shift) should not exceed ±181 counts.

12. Close the temperature chamber and set it for +25°C.

13. After the chamber has been at 25°C for five hours, reset the 2212A ZERO, CAL+, and CAL- per steps 1 through 6 of check 4.

14. Close the temperature chamber and set it for +40°C.

15. After the chamber has been at 40°C for three hours, check zero drift and calibration errors per steps 2 through 5. Enter the results on the test card. Total zero drift error should not exceed ±296 counts. Total calibration error (after correction for zero shift) should not exceed ±81 counts.

16. Close the temperature chamber and set it for +55°C.

17. After the chamber has been at 55°C for three hours, check zero drift and calibration errors per steps 2 through 5. Enter the results on the test card. Total zero drift should not exceed ±536 counts. Total calibration error (after correction for zero shift) should not exceed ±231 counts.

NOTE

Following this check, allow the 2212A six hours to cool down to 25°C and recalibrate ZERO, CAL+, and CAL- per steps 1 through 6 of check 4 so that the 2212A will be ready for use.

4-5. ACCESS TO INTERNAL ADJUSTMENTS AND COMPONENTS

4-6. For access to adjustments and components inside of the 2212A, release the plastic cross straps at the top and open the case. All internal adjustments are now accessible.

4-7. For access to test points and components on the Preamplifier circuit board, remove the three cover shield attaching screws and lift off the cover shield. Remove the isothermal cover for access to Q1, Q2, and Q3 and related preamplifier components.

4-8. For replacement of components on either circuit board, the eight snap fasteners attaching the board to the case must be snapped out. If board removal is required, pliers may have to be used, gently but firmly, to remove snap fasteners that fit too snugly to be removed by the fingers alone.

4-9. Access for replacement of parts on the front or rear panel is provided by sliding the panel upward out of the section of case in which it is installed. The inside view of the rear panel in Figure 5-2 (page 5-5) shows it partly removed in this manner.

4-10. Reassembly of the 2212A after all internal maintenance has been accomplished is essentially the reverse of the procedure used to gain access. Slide the front or rear panel down into place on the dowel rods that are integral with the case. Line up the printed circuit board with the holes molded in the case and snap in the plastic fasteners. Reinstall the isothermal cover on the Preamplifier board, placing it as indicated in Figure 5-3 (page 5-6). Replace the Preamplifier cover shield and secure it with the attaching screws; be sure to install the nylon screw in the rear-most hole, as marked on the cover shield. Close the case and secure the cross-straps.

4-11. TROUBLESHOOTING

4-12. SYSTEM TROUBLESHOOTING. The 2212A is a highly-reliable vfc that is designed for a predicted* MTBF (mean time between failures) of 10,000 hours (more than one year of continuous operation) at 25°C ambient. It should give little if any trouble for several years. Troubles of the signal source-vfc-counter system are most often traceable to open-circuiting of the input leads, the signal source, or the common mode return, or to incorrect control settings on the Counter or the 2212A, not to trouble in the 2212A.

*Using component-count technique.

4-13. In multi-channel data systems with one vfc-counter channel apparently faulty and others performing correctly, the simplest method of system troubleshooting is as follows:

1. Remove the suspected 2212A and check fuse, correct setting of the LINE VOLTAGE switch, and make certain the POWER switch is ON.

2. Interchange the suspected 2212A with one known to be operating correctly; make certain that their control settings agree.

3. If trouble does not move with the suspected 2212A, look for bad connections to the signal source, open-circuited signal source, open-circuited common mode return, or incorrectly set Counter controls. The general instructions for connection and operation, presented in section 2 of this manual, must be followed to achieve correct performance of the 2212A.

4. If trouble does move with the suspected 2212A, it may be faulty and should be checked according to the instructions in paragraphs 4-14 through 4-20.

4-14. The basic functioning of a single 2212A can be verified by doing checks 1 and 2 in Table 4-3, using the same counter for the performance checks that is being used for operation.

4-15. TROUBLES IN THE 2212A. The principal troubles that may be encountered in the 2212A are summarized below, with suggested causes of the trouble. Assembly numbers A1, A2, and A3 identify components on the RANGE switch assembly, the Preamplifier assembly, and the VFC assembly, respectively. The theory of operation in section 3, schematics and parts location illustrations in section 5, and additional instructions in paragraphs 4-16 through 4-20 are provided to assist isolation of these troubles.

<u>POL indication not visible, or incorrect for:</u>
either input polarity: fuse open, LINE VOLTAGE switch set incorrectly, POWER switch not ON, power supply on VFC assembly A3 defective, or A3-R114 open.

+input only: A3-DS1, R113, Q28, Q12, or Q14 open - or A3-Q13 shorted.

-input only: A3-DS2, R112, Q27, or Q13 open - or A3-Q12 or Q14 shorted.

<u>POL indication correct, but no count for:</u> either polarity of input signal: A3-Q16 or Q18 open - or any of A3-Q19, 21, or 29 or output lead open or shorted.

+input only: A3-Q15B open - or A3-Q17 shorted.

-input only: A3-R80 or R81 open - or A3-Q15A shorted.

<u>Half count:</u> A3-CR26 or CR27 - (or trouble in the Counter).

<u>Double count:</u> A3-T1, Q23, or Q24 open.

<u>Erratic count:</u> Counter set incorrectly - faulty return from source common to output common - Preamplifier A2 or Integrating amplifier on VFC assembly A3 oscillating.

<u>Count > 300 kHz for:</u>
either polarity of input signal: A3-T1, R101-103 or R110 open - or trouble in Preamplifier A2 or Integrating amplifier on A3.

+input only: A3-Q25, R105, R106, or R1 open - or A3-Q26 shorted.

-input only: A3-Q26, R107, R108, or T1 open - or A3-Q25 shorted.

<u>Count low, calibration impossible</u>: A3-R143 or R102 open - Rg connection through RANGE switch assembly A1 open - A2 or A3 Integrating Amplifier on A3 producing low output.

PERFORMANCE CHECK TEST CARD

FOR

HP 2212A VOLTAGE-TO-FREQUENCY CONVERTER

Serial No. ______________ Date ______________

Step	Item(s) Checked	Measurement Result	Specification Limit (s)	Is Result Acceptable?
CHECK 1: 2212A OUTPUTS AND INITIAL SETUP OF COUNTER				
6	Pulse Amplitude	______	-9v, typical, no load	______
	Pulse Duration	______	2 μs, typical, no load	______
	Rise Time	______	.1 μs maximum	______
7	VTVM reading	______	0 to -1v	______
	POL indication	______	'+' lighted	______
9	VTVM reading	______	-(23 to 31)v	______
	POL indication	______	'-' lighted	______
CHECK 2: SUPERIMPOSED NOISE REJECTION				
3	50.5 Hz superimposed noise		Maximum Count Difference	
	.01 sec gate	______	±300 counts (0 db)	______
	.1 sec gate	______	±300 counts (20 db)	______
	1 sec gate	______	±300 counts (40 db)	______
4	505 Hz superimposed noise		Maximum Count Difference	
	.01 sec gate	______	±30 counts (20 db)	______
	.1 sec gate	______	±30 counts (40 db)	______
	1 sec gate	______	±30 counts (60 db)	______
5	5050 Hz superimposed noise		Maximum Count Difference	
	.01 sec gate	______	±3 counts (40 db)	______
	.1 sec gate	______	±3 counts (60 db)	______
	1 sec gate	______	±3 counts (80 db)	______
CHECK 3: COMMON MODE REJECTION				
4	Common mode output with 1K unbalance in series with +IN lead	______	0.110 kHz max, or 0.220 kHz max (2212A-M3 only)	______
6	Common mode output with 1K unbalance in series with -IN lead	______	0.110 kHz max, or 0.220 kHz max (2212A-M3 only)	______
CHECK 4: CALIBRATION AND INTERNAL CALIBRATION SOURCE				
6	Calibration completed	______	(date and time of day)	Not Applicable
7	CAL+ (w/Option M3 only)	______	100.000 ±0.020 kHz*	______
8	CAL- (w/Option M3 only)	______	100.000 ±0.020 kHz*	______
			*Assuming temperature coefficient of ±5 counts per °C does not apply	

PERFORMANCE CHECK TEST CARD

FOR

HP 2212A VOLTAGE-TO-FREQUENCY CONVERTER

Serial No. ______________ Date ______________

CHECK 5: LINEARITY, ACCURACY, AND OVERRANGING

Step	Item(s) Checked	Measurement Result	Specification Limit(s)	Is Result Acceptable?
3	Zero (1 VOLT range)		Not Applicable	Not Applicable
7	+90% full scale		+90.000 ±0.011 kHz ①	
8	-90% full scale		-90.000 ±0.011 kHz ①	
9	-80% full scale		-80.000 ±0.011 kHz ①	
	+80% full scale		+80.000 ±0.011 kHz ①	
	+70% full scale		+70.000 ±0.011 kHz ①	
	-70% full scale		-70.000 ±0.011 kHz ①	
	+60% full scale		+60.000 ±0.011 kHz ①	
	-60% full scale		-60.000 ±0.011 kHz ①	
	-50% full scale		-50.000 ±0.011 kHz ①	
	+50% full scale		+50.000 ±0.011 kHz ①	
	+40% full scale		+40.000 ±0.011 kHz ①	
	-40% full scale		-40.000 ±0.011 kHz ①	
	-30% full scale		-30.000 ±0.011 kHz ①	
	+30% full scale		+30.000 ±0.011 kHz ①	
	+20% full scale		+20.000 ±0.011 kHz ①	
	-20% full scale		-20.000 ±0.011 kHz ①	
	-10% full scale		-10.000 ±0.011 kHz ①	
	+10% full scale		+10.000 ±0.011 kHz ①	
10	Zero (.1 VOLT range)		Not Applicable	Not Applicable
11	1v to .1v range error		+100.000 ±0.021 kHz ①	
12	Zero (.01 VOLT range)		Not Applicable	Not Applicable
13	1v to .01v range error		+100.000 ±0.023 kHz ②	
14	Zero (.03v range)‡		Not Applicable	Not Applicable
	1v to .03v range error‡		100.000 ±0.023 kHz ②	
	Zero (.3v range)‡		Not Applicable	Not Applicable
	1v to .3v range error‡		100.000 ±0.021 kHz ①	
15	Zero (.1 VOLT range)		Not Applicable	Not Applicable
16	125% FS (.1 VOLT range)		±0.038 kHz ③	
17	150% FS (.1 VOLT range)		±0.045 kHz ③	

‡ 2212A-M1 instruments only

① Limits include ±1 count ambiguity of Counter.

② Including 2 ppm maximum error of Dekavider and count ambiguity.

③ Including .01% of reading linearity error, .02% of reading range-range error, ±1 count ambiguity of Counter

PERFORMANCE CHECK TEST CARD

FOR

HP 2212A VOLTAGE-TO-FREQUENCY CONVERTER

Serial No. ________________ Date ________________

Step	Item(s) Checked	Measurement Result	Specification Limit (s)	Is Result Acceptable?
	CHECK 6: ZERO DRIFT AND CALIBRATION STABILITY			
2	Zero (.01v range) 8 hours after calibration	________	±0.056 kHz ①	________
3	Zero (1v range)	________	±0.006 kHz ①	________
4	Reading from +1.000V input 8 hours after calibration	________	100.000 ±0.021 kHz ②	________
5	Reading from -1.000V input 8 hours after calibration	________	100.000 ±0.021 kHz ②	________
9	Zero shift (.01v range) (25 to 10°C temp change)	________	±0.296 kHz ①	________
	Reading from +1.000V input (25 to 10°C temp change)	________	100.000 ±0.081 kHz ②	________
	Reading from -1.000V input (25 to 10°C temp change)	________	100.000 ±0.081 kHz ②	________
11	Zero shift (.01v range) (25 to 0°C temp change)	________	±0.456 kHz ①	________
	Reading of +1.000V input (25 to 0°C temp change)	________	100.000 ±0.181 kHz ②	________
	Reading of -1.000V input (25 to 0°C temp change)	________	100.000 ±0.181 kHz ②	________
15	Zero shift (.01v range) (25 to 40°C temp change)	________	±0.296 kHz ①	________
	Reading of +1.000v input (25 to 40°C temp change)	________	100.000 ±0.081 kHz ②	________
	Reading of -1.000v input (25 to 40°C temp change)	________	100.000 ±0.081 kHz ②	________
17	Zero shift (.01v range) (25 to 55°C temp change)	________	±0.536 kHz ①	________
	Reading of +1.000v input (25 to 55°C temp change)	________	100.000 ±0.231 kHz ②	________
	Reading of -1.000v input (25 to 55°C temp change)	________	100.000 ±0.231 kHz ②	________

① Limits include ±1 count ambiguity of counter.

② Limits shown are corrected for zero and include count ambiguity.

4-16. Most of the troubles listed in paragraph 4-15 can be located rather easily by signal tracing, assuming a good understanding of the 2212A theory of operation in section 3. However, troubles involving Preamplifier A2 or the Integrator on VFC assembly A3 can be quite difficult to isolate because of the high open-loop gains of these circuits. For this reason, paragraphs 4-17 through 4-20 provide additional guidance for troubleshooting these circuits.

4-17. ISOLATION OF TROUBLE TO A2 or A3. Troubles such as erratic counting and pulse rates greater than 300 kHz should be isolated to A2 or A3 as follows:

1. Connect a short across the input to the 2212A and the input to VFC assembly A3 as indicated in Figure 4-1.
2. Recheck the condition; if it is persisting, trouble is on VFC assembly A3. If the condition is no longer evident, trouble is on Preamplifier assembly A2.

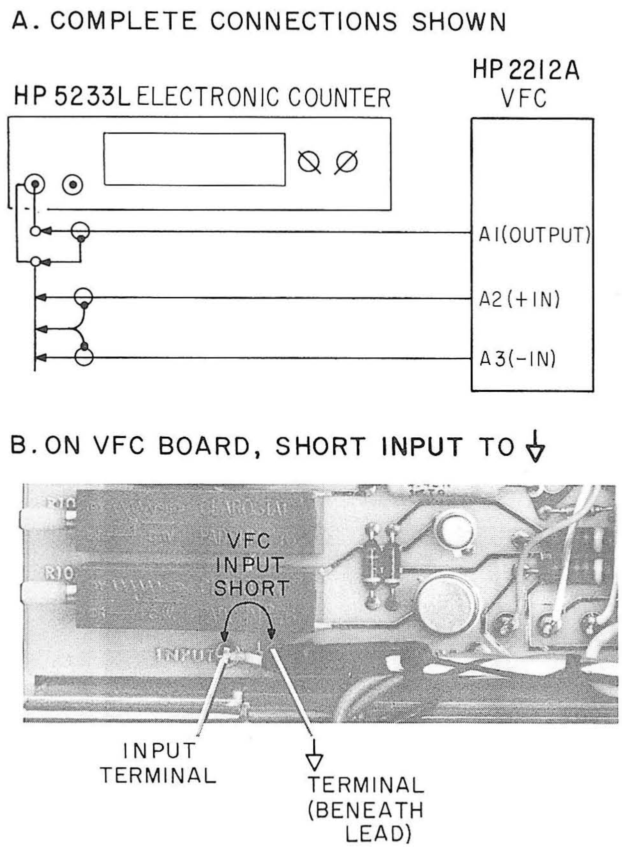


Figure 4-1. Connections for Trouble Isolation

4-18. REPLACEMENT WITH SPARE ASSEMBLIES. Often repair time can be minimized by replacing a faulty printed circuit assembly with a spare. Then the instrument can be gotten back in service rapidly and the defective board can be repaired at leisure, or sent to a Hewlett-Packard field office for repair. VFC assembly A3 should be replaced with a temperature compensated assembly.

4-19. ISOLATION OF TROUBLE TO PREAMP SECTION A OR B. Proceed as follows:

1. Connect 2212A input leads as shown in Figure 4-1.
2. Remove the preamplifier cover shield.
3. Referring to Figure 5-3, connect jumper:

   'A' between lead to +IN pad and lead to OUT pad on the board.

   'B' between lead to -IN pad and lead to GND pad (between C17 and R77) on the board.
4. With VTVM measure voltage between R83 lead to SHIELD pad (+) and C17 lead to OUT pad (-). If voltage is not -(0.47 to 0.57)v, trouble is in preamp section A.
5. With VTVM measure voltage between R84 lead to GUARD pad (+) and C17 lead to GND pad (-). If voltage is not -(0.47 to 0.57)v, trouble is in preamp section B.

NOTE

Once trouble is isolated to either section of the preamplifier, the other section can be used as a standard for comparison of voltages, assisting further isolation of trouble.

4-20. FURTHER TROUBLE ISOLATION.

1. Oscillation of Preamplifier section A or B or the Integrating amplifier on VFC assembly A3 with its input shorted is generally caused by an open or shorted capacitor or an open resistor in one of the gain-bandwidth control networks discussed in section 3.
2. Noisy output may be caused by a noisy input transistor or by a defective gain-bandwidth feedback resistor or capacitor.
3. Count greater than 300 kHz with zero (shorted) input that is not caused by lack of vfc pulse feedback to the Integrator input is probably caused by an open transistor or resistor in one of the stages preceding the Integrator output stage, or by shorted A3-Q9 or Q10.

4-21. REPAIR

4-22. SPECIAL PRECAUTIONS. Performance of high-impedance analog circuits, such as those of the Preamplifier and the Integrator on A3, is degraded by contamination of the surface of the circuit board or components. Contaminants to be avoided are finger marks, oil droplets, and the rosin fluxes commonly used in soldering. To minimize the chance of contamination, the following precautions should be observed when replacing Preamplifier A2, VFC assembly A3, or components on either of these assemblies.

1. Wear clean gloves at all times when handling the circuit board, or handle the board only by its edges or in areas not containing critical circuits. Handle critical components by leads or conducting surfaces rather than bodies or insulating surfaces.
2. Accomplish repairs in the cleanest environment available.
3. Do not use rosin-core solder; employ only the soldering technique detailed in paragraph 4-25 and Table 4-4.

4-23. RECOMMENDED TOOLS AND SUPPLIES. The following (or equivalent) tools and supplies are recommended for use in repairing the 2212A VFC:

1. Soldering Iron: 35-50 watt, Ungar number 776 handle with number 1237 heating unit and PL113 tip, manufactured by:

   Ungar Electric Tools
   2701 El Segundo Blvd.
   Hawthorne, California 90252

2. Soldapulit desoldering tool; manufactured by:

   The Edysyn Company
   Box 868
   Arleta, California

3. Solder: Solid 60/40 tin-lead (no rosin)
4. Soldering Flux: number 1429 Organic Flux, manufactured by:

   Kester Solder Company
   4203 Wrightwood Ave.
   Chicago, Illinois 60639

5. Distilled Water (for flushing away organic flux after soldering).
6. Cleaning Solvent (for removal of contaminants from circuit board and component surfaces): Freon T-E35 (formerly Freon PC), available from:

   Dupont Freon Products Division
   701 Welsh Road
   Palo Alto, California

7. Silicone Grease (to assure heat transfer between transistor and heat sink): number 5 silicone grease, manufactured by:

   Dow Corning Corporation
   Midland, Michigan

8. Long-Nose Pliers

4-24. SOLDERING IRON TEMPERATURE AND CLEANLINESS. Use a soldering iron with 35-50 watt rating and chisel tip. Allow it to reach full operating temperature (about 800°F) before unsoldering or soldering. A fully-heated soldering iron assures quick completion of soldering operations and minimizes the chance that the etched wiring, parts, or the board will be damaged by overheating. Before using the soldering iron, wipe it off to remove excess solder and oxides.

4-25. REPLACEMENT OF CIRCUIT BOARD.

1. Gain access to the circuit board per instructions in applicable paragraphs 4-5 through 4-7. Do not remove snap fasteners.
2. Record the color coding of wires connected to the board being replaced to assure accurate rewiring. (This can be done while the soldering iron is heating.)
3. In the most convenient sequence, unsolder all external connections to the circuit board, using long-nose pliers with gentle pressure to pull the leads free as soon as the solder has become fluid.

CAUTION

Do not let the soldering iron touch the plastic case of the 2212A or the bodies of components, especially transistors.

4. Unsnap all fasteners and remove the circuit board.
5. Install the new circuit board, secure it in place with the snap fasteners, and shape and tin leads for soldering to the new board.

6. Barely moisten the points to which leads must be soldered, and only those points, with a mild, water-soluble, organic flux, such as Kester 1429, using a small brush.
7. Insert and solder leads to the correct points, referring to the record made in step 2 where necessary, using solder containing no flux, and applying heat and solder sparingly.

NOTE

Certain points may have more than one lead connected to them. Make certain all leads are connected before soldering.

8. After all leads are correctly soldered to the new board, repeatedly flush the soldered points with distilled water and scrub and dry them to remove remaining traces of organic flux.
9. Replace the Preamplifier cover shield if it has been removed and calibrate the 2212A per applicable instructions in paragraphs 4-30 through 4-32.

4-26. PARTS REPLACEMENT. General parts replacement instructions are presented in Table 4-4. However, certain parts on VFC circuit board A3 should not be replaced without recompensation of the 2212A because of their effect upon temperature stability of calibration. Temperature compensation performed at the factory reduces the temperature coefficient of calibration stability from as much as ±0.07% of reading per °C to no more than ±0.004% of reading per °C, the specification of the 2212A for the temperature range of 10 to 40°C. Because satisfactory compensation is difficult and extremely time-consuming for technicians without special training and special equipment, field replacement of the VFC circuit board components associated with pulse feedback transformer T1 is not recommended. When A3T1 or related components must be replaced, the VFC board, or the 2212A should be returned to the factory for repair and recompensation.

4-27. CLEANING

4-28. Routine cleaning of the 2212A vfc, accomplished every 180 days, should consist only of vacuuming the interior. Air blast cleaning should be avoided because compressed air frequently contains tiny droplets of oil which adhere to circuit boards and parts, causing rapid accumulation of dust and dirt and deterioration of performance.

4-29. CALIBRATION

4-30. PREAMPLIFIER INTERNAL ZEROING. Every 90 days, or after repairing the Preamplifier circuit, reset internal zero adjustments of the Preamplifier as follows:

1. Connect setup as shown in Figure 4-2 and turn on all equipment. Note the time; the 2212A will require at least 1/2 hour warm-up in the Combining Case or 1-1/2 hour warm-up in free air.

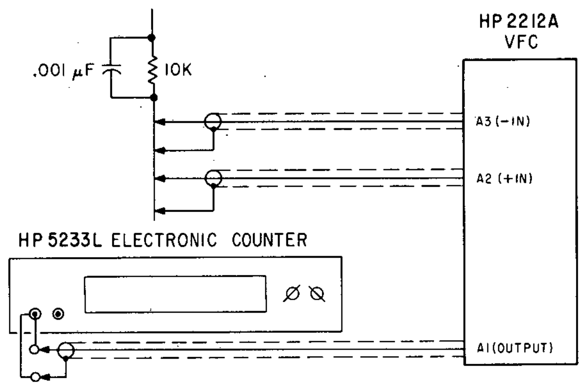


Figure 4-2. Setup for Preamplifier Zeroing

2. After correct warm-up of 2212A, Set Counter to count 2212A output pulses at +4v level and -slope (dc coupled counters) or maximum sensitivity (ac coupled counters) over 1 second gate period.
3. Set the 2212A RANGE switch to .01 VOLT position and the vernier (on 2212A-M2) fully counter-clockwise to 0 and lock it there.
4. Set the front panel ZERO to within ±20 counts of 000.000 kc. The switching of the '+' and '-' POL indicators may be helpful in locating the best zero setting.

NOTE

If zero cannot be set within ±20 counts from the front panel, perform steps 5 and 6. If zero sets correctly, skip to step 7.

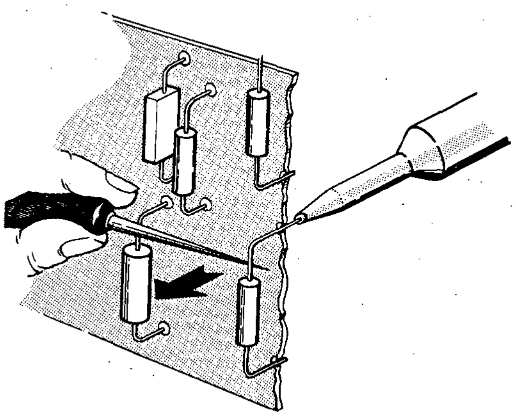
5. Set the front panel ZERO adjustment to mid-range (10 turns from either extreme of adjustment).
6. Use Figure 5-2, page 5-5, to locate position of R45 on the Preamplifier board. Then, working quickly to minimize temperature change while the case is open, open the case and set R45 for a minimum reading (less than ±100 counts from zero). Close the case immediately and repeat step 4.

Table 4-4. Parts Replacement Checklist

1. Heat Sinks: If necessary to permit replacement of a transistor, remove top clamp of heat sink.

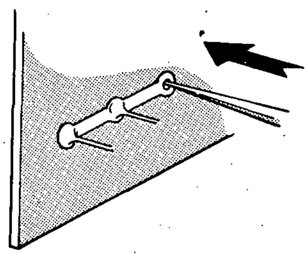
2. Access to Circuit Board: Remove snap fasteners, detach circuit board from case, and secure circuit board in an upright position. (If Preamplifier board is to be worked on, also detach the front panel from the case.)

3. Unsoldering and Removal of Components: In turn, heat each lead of the part being replaced, pulling the leads free with an awl (as shown below) or with long-nose pliers, while the solder is fluid.

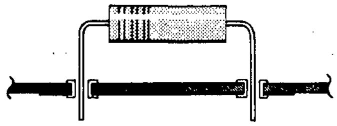


NOTE: Transistors and other parts with more than two leads present a special problem. If possible, clip the leads to remove the old part, then unsolder the bits of lead that remain. When clipping leads is not possible, heat each lead in turn from the rear of the board, repeating several times until the solder is fluid enough that the part can be separated from the board. Work quickly to minimize heating of the etched circuits and the board.

4. Cleaning Component Lead Holes: Melt solder in component lead holes and use a suction device, such as Soldapulit or twisted shield braid to remove excess solder at the other side of the hole. Finish cleaning holes with a toothpick or wooden splinter as shown below, working rapidly. Do not use a metal tool for final cleaning because it may damage through-hole plating.



5. Installation of New Parts: Shape the leads of new parts to match spacing of the mounting holes, as show below.



Where a new transistor is installed with a heat sink, apply a thin coating of silicone grease, such as Dow Corning No. 5, to mating surfaces of the heat sink and the transistor. Make certain that transistor pads or similar items removed from old parts are installed correctly on new parts. Tin and insert leads, making certain that new diodes or new capacitors are oriented correctly - polarity is very important. Secure the new part to the board with whatever heat sink or attaching hardware was used to secure the old part.

6. Soldering: Barely moisten the points to be soldered, and only those points, with a mild, water-soluble organic flux, such as Kester 1429, using a small brush to apply flux. Then hold each new part against the board and solder it in place with solid solder (containing no flux), using heat and solder sparingly.

7. Trimming Leads: Cut off surplus lead length at the rear of the circuit board to less than 1/16 inch.

8. Removal of Excess Flux: Repeatedly flush the soldered points with distilled water at both sides of the board and scrub and dry them to remove any remaining organic flux.

NOTE: Where distilled water may have become entrapped in potentiometers or other parts, drying may be completed by baking the circuit board (or the entire 2212A) in a clean atmosphere at a maximum temperature of 60°C for several hours.

9. Reassemble the 2212A and calibrate it per instructions in paragraphs 4-30 through 4-32.

7. Connect the 2212A +IN lead (A2 center contact) to the high side of the 10K unbalance resistor and check the Counter reading. The reading should be within ±50 counts of zero. If the reading is greater, check Figure 5-2 for location of R4 on the Preamplifier board. Then, working quickly to minimize temperature change while the case is open, open the case and set R4 for a minimum reading (less than ±50 counts). Close the case immediately and proceed with step 8.

8. Reverse the connections of the 2212A +IN and -IN leads to the 10K unbalance resistor, without changing shield connections, and again check the Counter reading. The reading should be within ±50 counts of zero. If the reading is greater, open the case and set R41 on the Preamplifier board for a minimum reading (less than ±50 counts). Work quickly and close the case immediately to minimize temperature change.

4-31. VFC ASSEMBLY ZEROING. Every 90 days, or after repairing the 2212A, reset internal zero of the VFC assembly as follows:

1. Connect setup as shown in Figure 4-3 and turn on all equipment.

2. Set Counter to count 2212A output pulses at +4v level and -slope (dc coupled counters) or maximum sensitivity (ac coupled counters) over 1 second gate period.

3. Set the 2212A RANGE switch to 1 VOLT position and the vernier (on 2212A-M2) fully counter-clockwise to 0 and lock it there.

4. The zero reading on the Counter should not exceed ±2 counts on 2212A without M2 or ±5 counts on 2212A with M2. If reading is within specification, no VFC internal zero adjustment will be required.

NOTE

If reading is greater than specification, but no more than five times specification (±10 counts for 2212A without M2 or ±25 counts for 2212A-M2), skip to step 10. If reading is more than five times specification, perform all of steps 5 through 11. See Figure 4-3 for locations.

5. Temporarily connect jumpers and 100 μh inductor to the VFC circuit board as indicated in Figure 4-3.

6. Set R14 for less than 100 count reading in 1 second gate time on the Counter.

7. Disconnect the inductor and set R8 for less than 100 counts.

8. Disconnect the short from TP5 and TP6 and set R4 for less than 100 counts.

9. Disconnect short from the input.

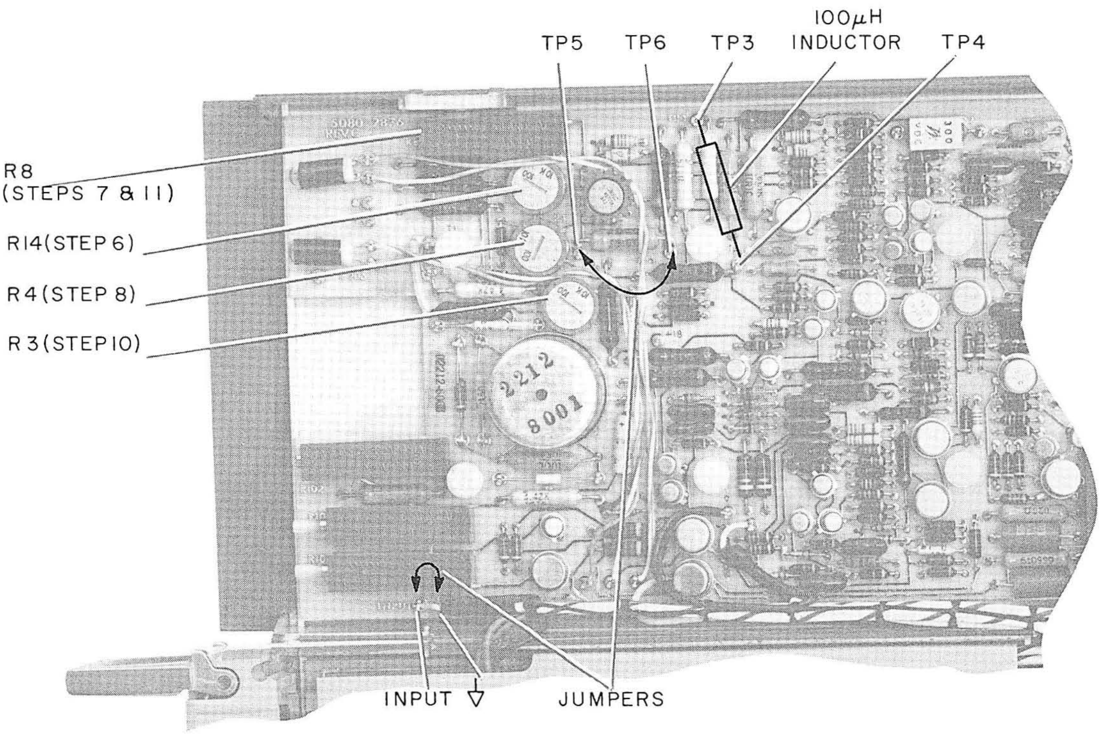


Figure 4-3. Setup for Zeroing A3

10. Set R3 for all zeros ±1 count reading on the Counter.

11. Close the case and recheck zero. Readjust R8 to correct zero shift beyond the range of the front panel ZERO. Then close the case and disconnect the test setup.

4-32. CALIBRATION OF INTERNAL STANDARD (2212A-M3 ONLY). Every 180 days, or whenever Performance Check 4 shows the 1 volt standard to be out of tolerance, reset this internal calibration voltage as follows:

1. Turn on the 2212A-M3, connect it as indicated in Figure 4-4, and turn on the Counter and the Transfer Standard.

2. After the 2212A-M3 has been on and operating for a minimum warm-up time (1-1/2 hours in free air) set it to 1 VOLT range and set the Transfer Standard for 1.000V output.

3. Open the case of the 2212A, noting the reading for 1.000V input (which may not be exactly 100.000 kHz because of the change in distributed capacitances caused by opening the case).

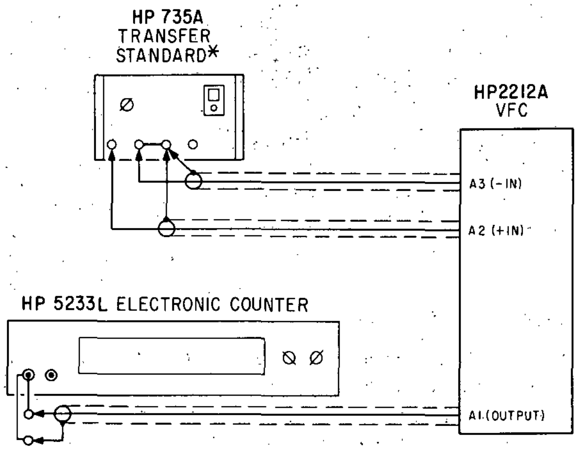


Figure 4-4. Setup for Calibrating 1V Internal Standard

4. Switch the 2212A-M3 to CAL+ and note the Counter reading. If the Counter reading differs from that taken in step 3 by more than 20 counts, set internal standard adjustment R201 to make the CAL+ reading agree exactly with the reading of 1.000V input on the 1 VOLT range. (See Figure 5-2, page 5-5, for location of R201 on 2212A-M3 instruments.)

SECTION V
REPLACEABLE PARTS

5-1. INTRODUCTION

5-2. This section contains identification and ordering information for replacement parts. Also included are parts location illustrations and schematic diagrams. Any changes to the parts list tables will be listed on a change sheet at the rear of this handbook. A part described as "HP only" is a special part that can be obtained only from the Hewlett-Packard Company. If another manufacturer's stock (part) number is listed, the part may be obtained directly from that manufacturer. A list of manufacturer's code numbers will be found in the Appendix at the end of this section. Usually, parts available from manufacturers other than those listed may be used when the part has equivalent electrical and physical characteristics and quality.

5-3. As noted on the schematic diagrams in this section, the optimum electrical value of certain components may be selected at the factory to compensate for variations in other components or wiring capacitance. In some instruments, a selected part may be omitted (i. e., a selected resistor might be a wire or an open circuit). The nominal or average value, or the range of values on the schematic diagram. When replacing a selected part, order a part with the value that was originally installed in your instrument.

5-4. The Tables list parts in alpha-numerical order of the reference designation and provides the following information for each part:

a. Description (see list of abbreviations used, paragraph 5-10).

b. HP stock number or drawing number.

c. Typical manufacturer of the part in a five-digit code (see list of manufacturers in the Appendix.)

d. Manufacturer's part, stock or drawing number.

e. Total quantity used in this listing.

f. Recommended spare part quantity for complete maintenance during one year of isolated service.

5-5. Miscellaneous and mechanical parts not indexed by reference designation are listed at the end of each of the Tables.

5-6. ORDERING INFORMATION

5-7. To order a replacement part, address your order or inquiry either to your local Hewlett-Packard field office (listed on the last page of this handbook) or to:

United States	Western Europe
CUSTOMER SERVICE Hewlett-Packard Co. 333 Logue Mountain View, California	Hewlett-Packard S. A. 54 Route des Acacias Geneva, Switzerland

5-8. Specify the following information on each part:

a. HP model number and complete serial number of instrument.

b. HP stock number.

c. Circuit reference designation.

d. Description.

5-9. To order a part not listed in the Tables, give complete description with function and location of the part in the instrument and/or system.

5-10. ABBREVIATIONS USED

Reference Designation Column

A	= assembly	MP	= mechanical part
B	= motor	P	= plug
C	= capacitor	Q	= transistor
CR	= diode	R	= resistor
DL	= delay line	RT	= thermistor
DS	= device signaling (lamp)	RV	= varistor
E	= misc electronic part	S	= switch
F	= fuse	T	= transformer
FL	= filter	V	= vacuum tube, neon bulb, photocell, etc.
J	= jack	W	= cable
K	= relay	X	= socket
L	= inductor	Z	= network
M	= meter		

Description Column

a	= amperes	OBD	= order by description
c	= carbon	pc	= printed circuit board
cer	= ceramic	pf	= picofarad
coef	= coefficient	piv	= peak inverse voltage
comp	= composition	PNP	= positive-negative-positive
conn	= connector	pos	= position(s)
depc	= deposited carbon	poly	= polystyrene
elect	= electrolytic	pot	= potentiometer
f	= farads	rect	= rectifier
f-a	= fast acting	rot	= rotary
fxd	= fixed	s-b	= slow-blow
Ge	= germanium	Se	= selenium
incd	= incandescent	sect	= section(s)
K	= kilo	Si	= silicon
metflm	= metal film	SPL	= special
metex	= metalic oxide	Ta	= tantalum
MFR	= manufacturer	Ti	= titanium dioxide
my	= mylar	tog	= toggle
n	= nano (10^{-9})	tol	= tolerance
NC	= normally closed	v	= volts
Ne	= neon	var	= variable
NFR	= not field replaceable	w/	= with
NO	= normally open	w	= watts
NPN	= negative-positive-negative	ww	= wirewound
NPO	= zero tem coeff	w/o	= without
NSN	= no stock number	*	= optimum value selected, nominal value shown (component may be omitted)
NSR	= not separately replaceable		

5-11. RECOMMENDED INDUSTRIAL SPARES

5-12. In situations where equipment down-time is critically important, it is recommended that one of each of the following etched circuit boards or assemblies be stocked. This instrument can then be kept in operation while the faulty board or assembly is being repaired. The items listed without designation or stock number are for page number reference only.

For Standard 2212A:		HP Stock No.	See Table	Page(s)
A1	RANGE Switch Assembly	02212-6001	5-2	5-6
A2	Preamplifier Assembly, temperature compensated	02212-6011	5-2	5-6, 7
A3	Voltage-to-Frequency Converter Assembly, temperature compensated	02212-6014	5-3	5-8, 9

For 2212A-M1:		HP Stock No.	See Table	Page(s)
A1M1	RANGE Switch Assembly	02212-6002	5-2	5-6
A2	Preamplifier Assembly, temperature compensated	02212-6011	5-2	5-6, 7
A3	Voltage-to-Frequency Converter Assembly, temperature compensated	02212-6014	5-3	5-8, 9

For 2212A-M3:		HP Stock No.	See Table	Page(s)
A1M3	RANGE Switch Assembly	02212-6003	5-2	5-6
A2	Preamplifier Assembly, temperature compensated	02212-6011	5-2	5-6, 7
A3M3	Voltage-to-Frequency Converter Assembly, temperature compensated	02212-6015	5-3	5-8, 9

Parts locations and Schematics

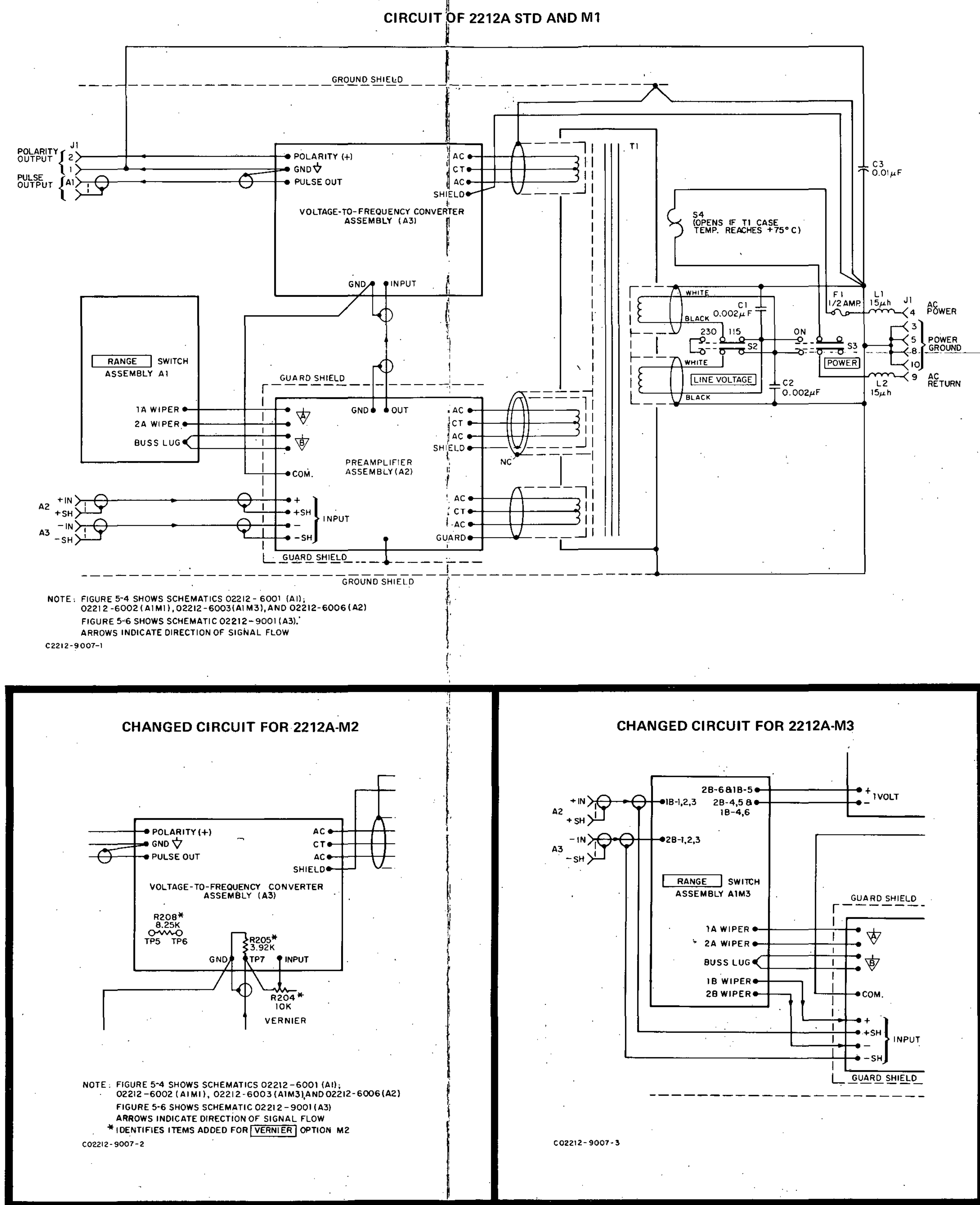
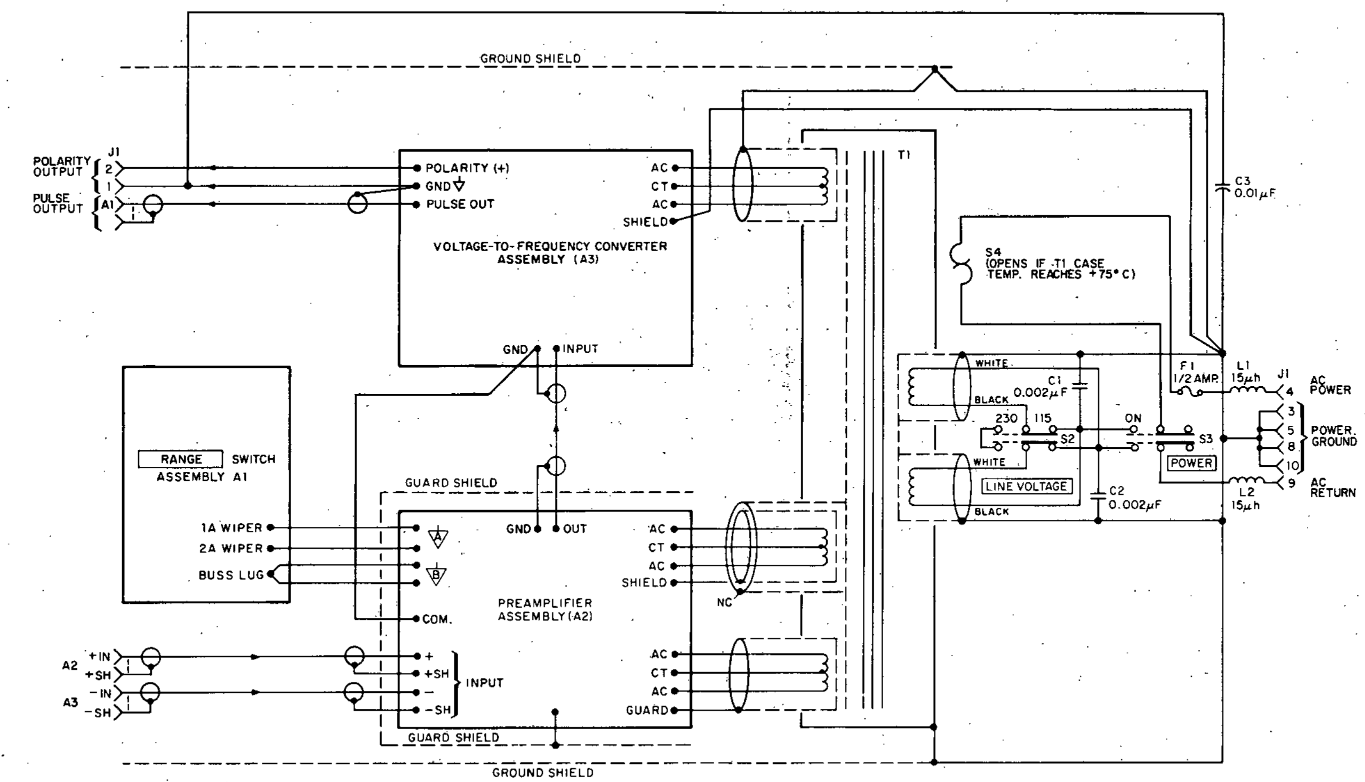


Figure 5-1. Overall Schematic

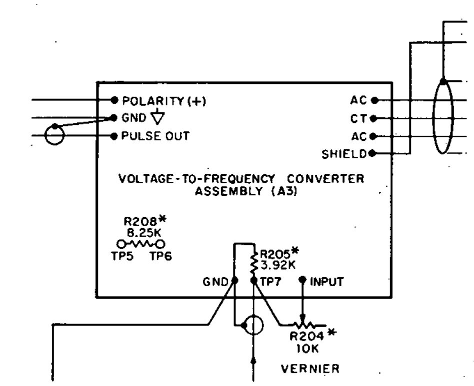
CIRCUIT OF 2212A STD AND M1



NOTE: FIGURE 5-4 SHOWS SCHEMATICS 02212-6001 (A1); 02212-6002 (A1M1), 02212-6003(A1M3), AND 02212-6006 (A2)
FIGURE 5-6 SHOWS SCHEMATIC 02212-9001 (A3).
ARROWS INDICATE DIRECTION OF SIGNAL FLOW

C2212-9007-1

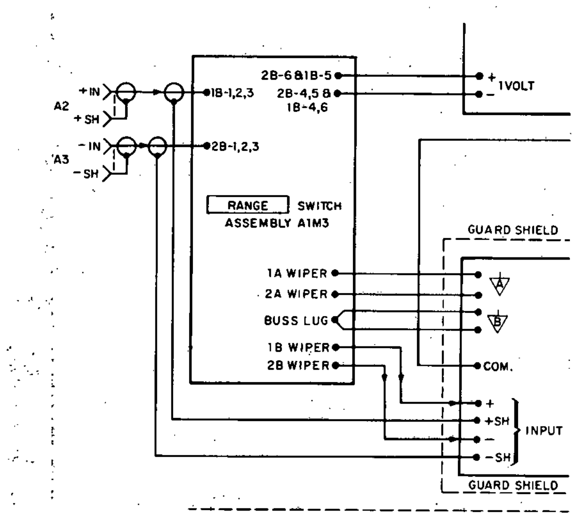
CHANGED CIRCUIT FOR 2212A-M2



NOTE: FIGURE 5-4 SHOWS SCHEMATICS 02212-6001 (A1); 02212-6002 (A1M1), 02212-6003 (A1M3) AND 02212-6006 (A2)
FIGURE 5-6 SHOWS SCHEMATIC 02212-9001 (A3)
ARROWS INDICATE DIRECTION OF SIGNAL FLOW
* IDENTIFIES ITEMS ADDED FOR VERNIER OPTION M2

C02212-9007-2

CHANGED CIRCUIT FOR 2212A-M3



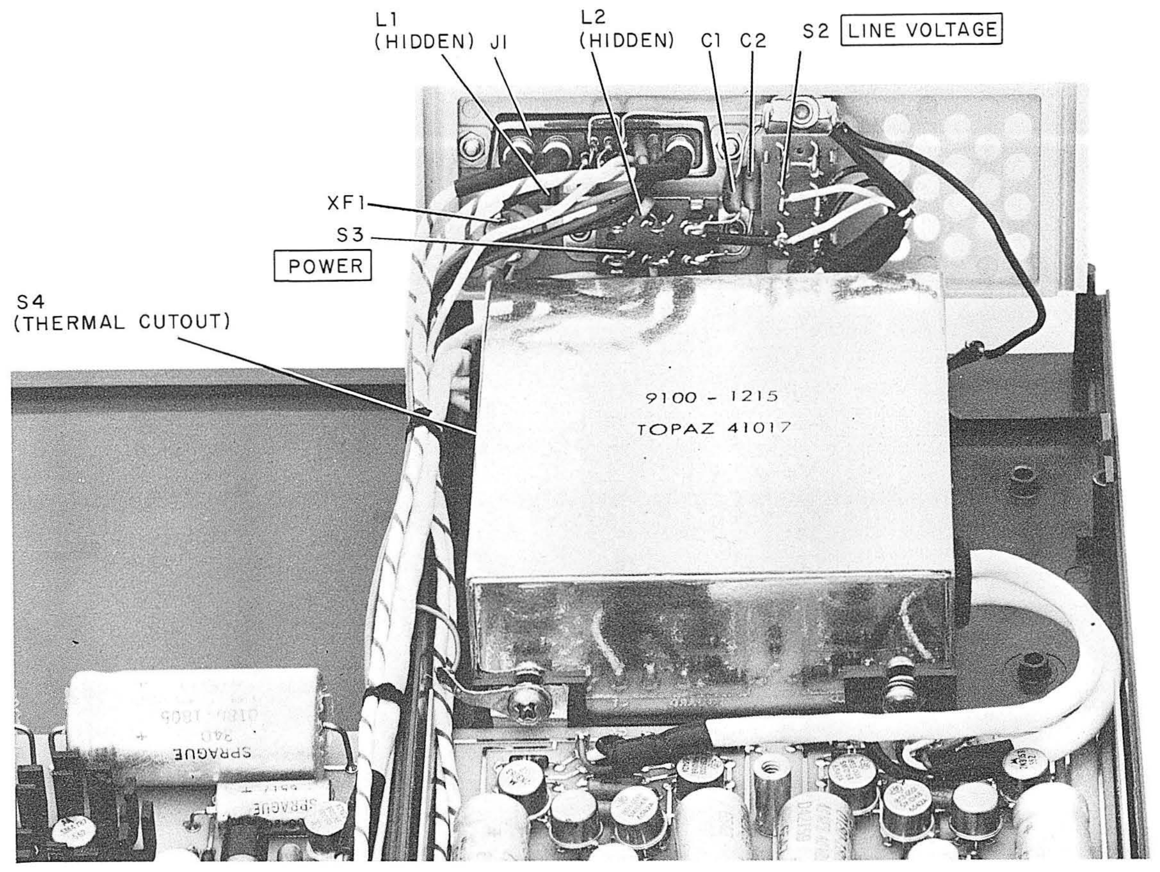
C02212-9007-3

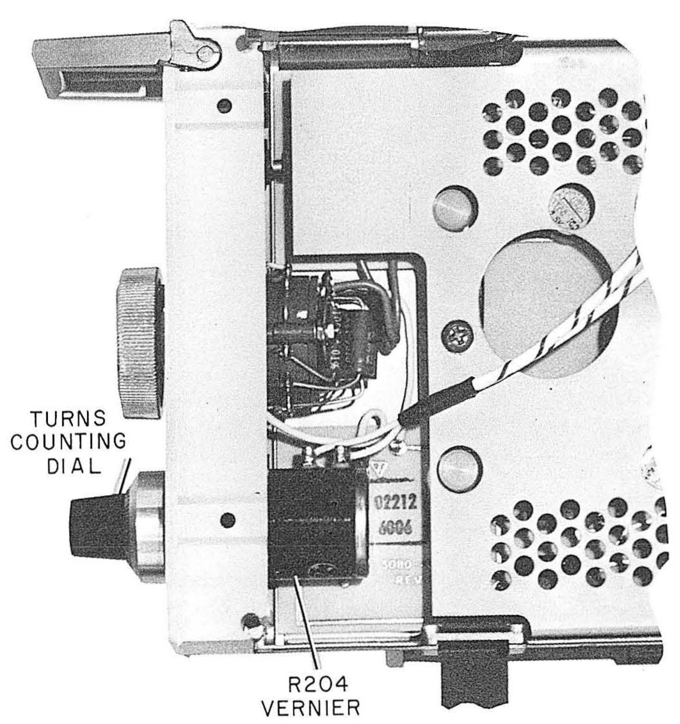
Figure 5-1. Overall Schematic

Table 5-1. Main Parts List

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
	BASIC 2212A					
A1	Switch Assembly (RANGE)	02212-6001	04404		1	1
A2	Preamplifier Assembly, temperature compensated	02212-6011	04404		1	1
A3	Voltage-to-Frequency Converter Assembly, temperature compensated	02212-6014	04404		1	1
C1, 2	C: fxd, my, 0.002 μf, 20%, 1000v	0150-0023	56289	19C203A	2	1
C3	C: fxd, my, 0.01 μf, 10%, 200v	0160-0161	28480		1	1
F1	Fuse: plug-in, 1/2a	2110-0046	71400	GMW-1/2	1	10
J1	Conn: recep, 10-contact	1251-0344	71468	DBM-13W3P	1	1
	Coaxial insert for J1	1251-0179	71468	DM-53740-5001	3	1
L1, 2	Inductor: fxd, 15 μh	9140-0082	95265	NA-15, 0-I	2	2
S2	Switch: slide, DPDT (LINE VOLTAGE)	3101-0011	82389	11A-1013	1	1
S3	Switch: slide, DPDT (POWER)	3101-0033	79727	6510C	1	1
S4	Switch: thermal cutout, 75°C	5080-6574	28480		1	1
T1	Transformer: power	9100-1215	28480		1	1
XF1	Fuseholder	1400-0112	71400	HWA holder	1	1
	Cap for XF1	1400-0110	71400	AF for HWA	1	1
	Cover, Isothermal	5000-5709	04404		1	1
	Decal: knob center plate	7120-1004	04404		1	1
	Fastener: snap-on, snap-off	0510-0941	28480		16	4
	Knob	02402-2040	04404		1	1
	Knob Center Plate: plastic, molded	5040-1465	04404		1	1
	MODIFICATIONS					
	2212A-M1					
	DELETE:					
	RANGE switch assembly A1 (02212-6001) and Decal (7120-1004)					
	ADD:					
A1M1	Switch Assembly (RANGE)	02212-6002	04404		1	1
	Decal: knob center plate	7120-1005	04404		1	1
	2212A-M2					
	ADD:					
R204	R: var, ww, 10K, 3%, 2w (Vernier)	2100-1992	28480		1	1
R205*	R: fxd, metoxide, 3.92K, 1%, 1/2 w	0757-0744	28480		1	1
R208*	R: fxd, metoxide, 8.25K, 1%, 1/2 w	0757-0441	28480		1	1
	Dial: turns-counting for R204	1140-0013	73138	Model 2601	1	1
	2212A-M3					
	DELETE:					
	RANGE switch assembly A1 (02212-6001); Voltage-to-Frequency Converter Assembly A3 (02212-6014); and Decal (7120-1004)					
	ADD:					
A1M3	Switch Assembly (RANGE)	02212-6003	04404		1	1
A3M3	Voltage-to-Frequency Converter Assemblv. Temperature compensated	02212-6015	04404		1	1
	Decal: knob center plate	7120-1006	04404		1	1

M0183





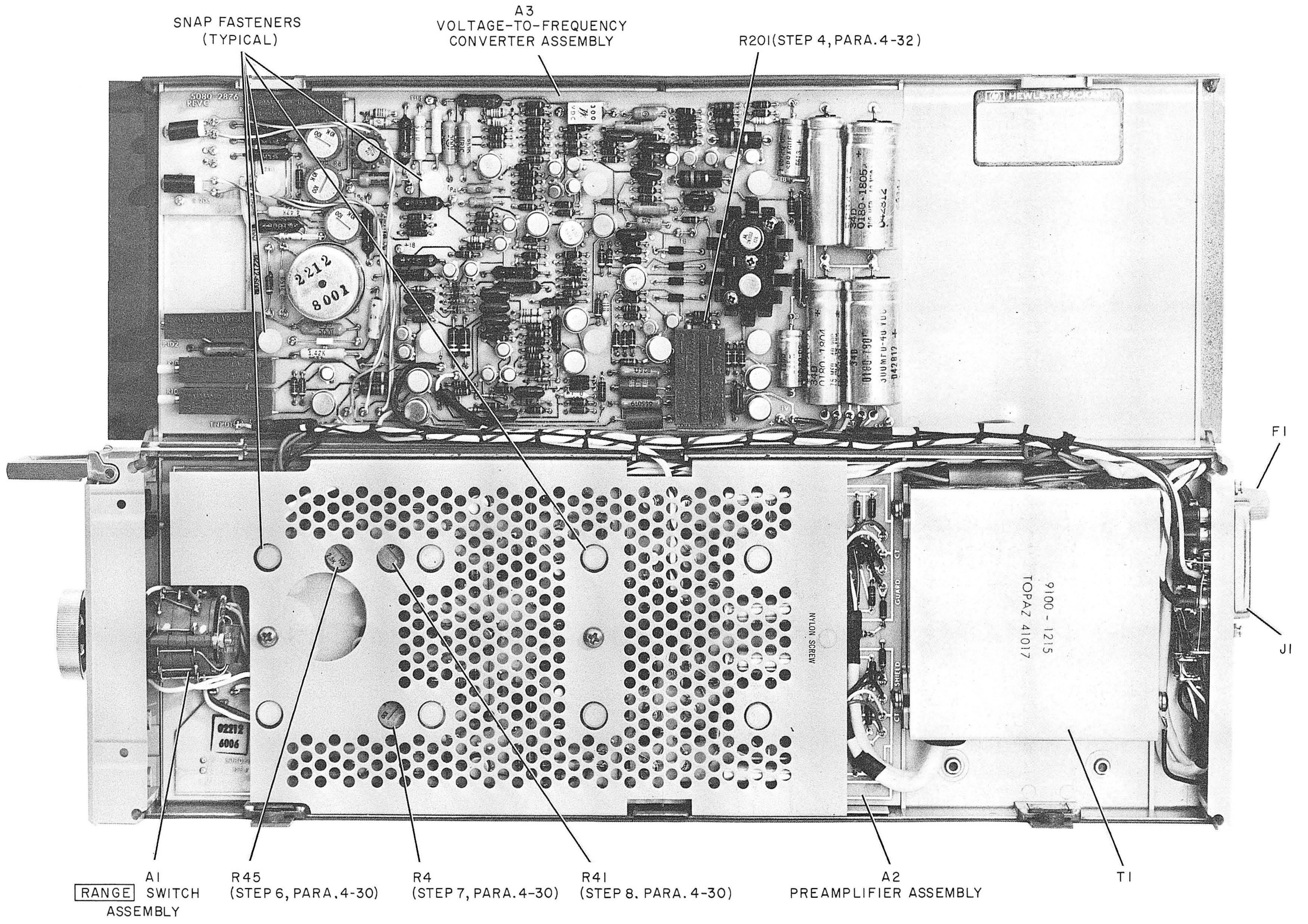
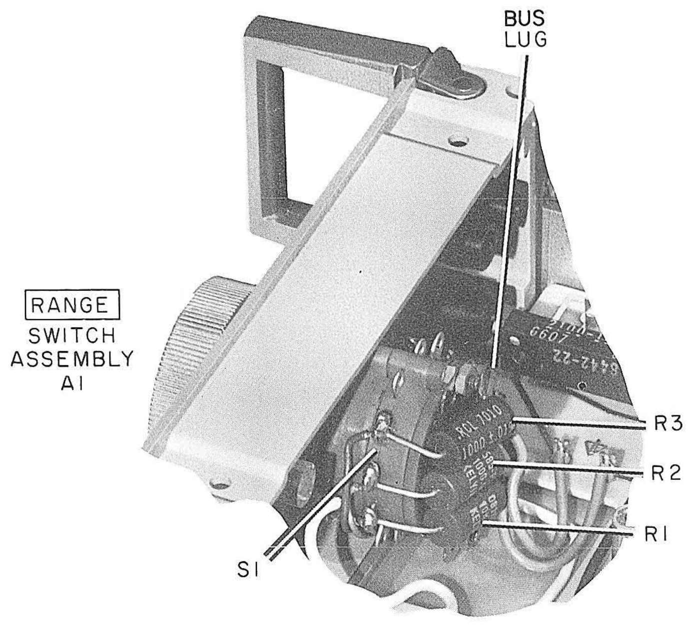
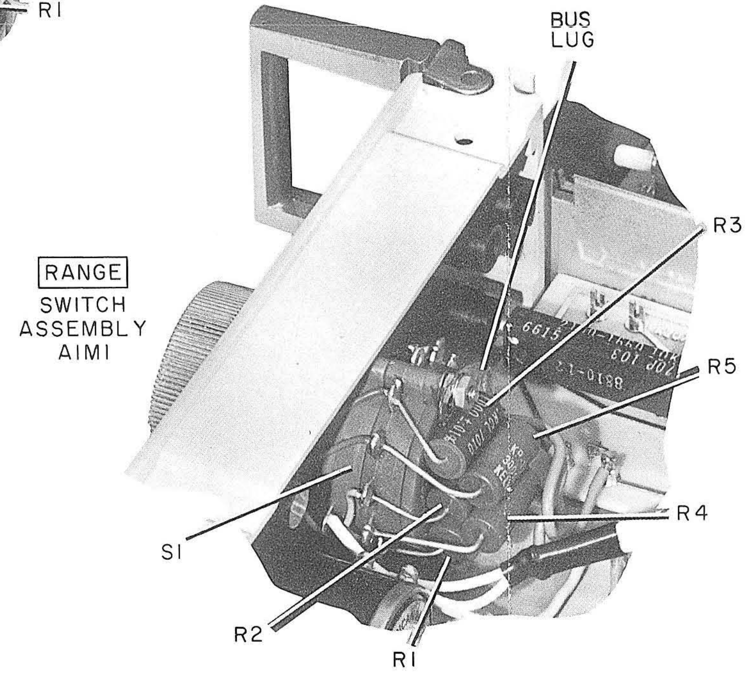


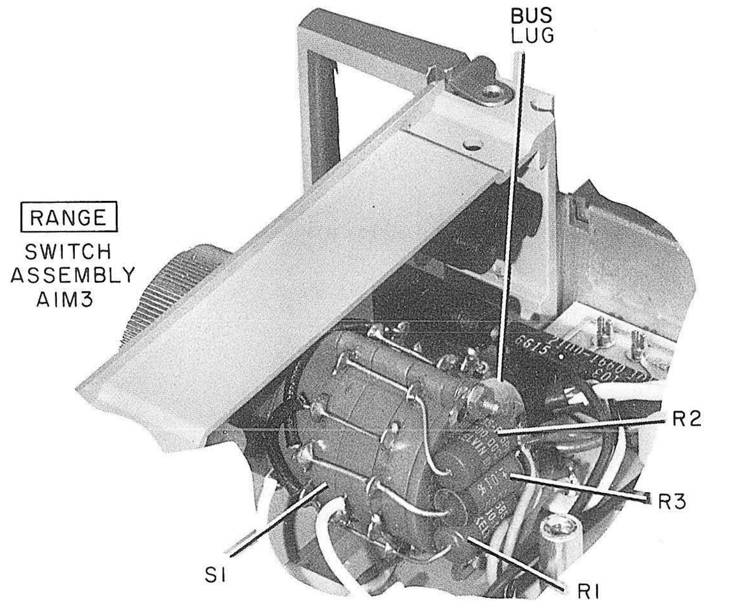
Figure 5-2. 2212A Parts and Assemblies



UNFOLD TO VIEW

Figure 5-2. 2212A Parts and Assemblies
Table 5-1. Main Parts List
on Page 5-5





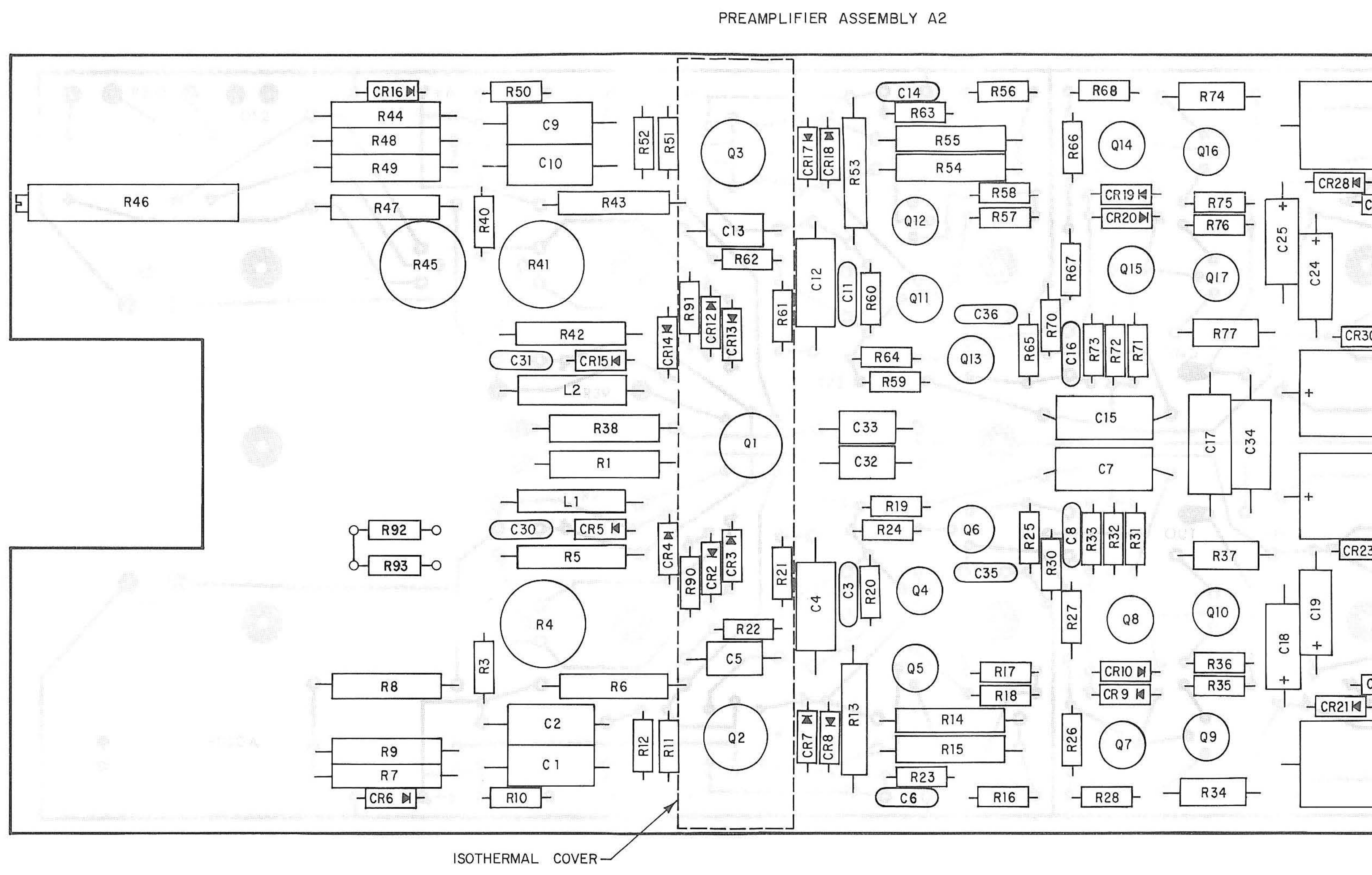


Figure 5-3. Parts on Assemblies A1, A1M1, A1M3, and A2

Table 5-2. A1 and A2 Parts Lists

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
A1	RANGE SWITCH ASSEMBLY	02212-6001	04404			
E1	Lug: solder bus	5020-5117	28480	-	1	1
R1	R: fxd, ww, 10K, 0.01%, 1/16 w	0811-1701	28480	-	1	1
R2	R: fxd, ww, 1K, 0.1%, ±5 ppm/°C	0811-1697	28480	-	1	1
R3	R: fxd, ww, 100Ω, 0.01%, 1/16 w	0811-1694	28480	-	1	1
S1	Switch: rotary, 2-pole, 6-position	3100-1408	83332*	SPL-3A2N6-1	1	1
A1M1	RANGE SWITCH ASSEMBLY	02212-6002	04404			
	(replaces A1 in 2212A-M1 instruments)					
	Add the following resistors to Range Switch Assembly A1 (02212-6001):					
R4	R: fxd, ww, 3K, 0.01%, 1/16 w	0811-1755	28480	-	1	1
R5	R: fxd, ww, 300Ω, 0.01%, 1/16 w	0811-1756	28480	-	1	1
A1M3	RANGE SWITCH ASSEMBLY	02212-6003	04404			
	(replaces A1 in 2212A-M3 instruments)					
	Replace S1 (3100-1408) with:					
S1	Switch: rotary, 4-pole, 6-position	3100-1409	83332*	SPL-3A2N6-2	1	1
A2	PREAMPLIFIER ASSEMBLY, Temperature Compensated	02212-6011	04404			
C1, 2, 9, 10	C: fxd, my, 0.015 μf, 10%, 200v	0160-0194	28480	-	4	1
C3, 6, 11, 14	C: fxd, mica, 270 pf, 5%, 500v	0140-0206	04062	DM15F271J	4	1
C4, 12	C: fxd, my, 0.0047 μf, 10%, 200v	0160-0157	28480	-	2	1
C5, 13, 20, 21, 26, 27	C: fxd, my, 0.001 μf, 10%, 200v	0160-0153	28480	-	6	1
C7, 15	C: fxd, my, 0.047 μf, 10%, 200v	0170-0040	28480	-	2	1
C8, 16	C: fxd, mica, 680 pf, 5%, 300v	0140-0208	28480	-	2	1
C17	C: fxd, my, 0.018 μf, 10%, 200v	0160-0302	28480	-	1	1
C18,19,24,25	C: fxd, elect, Ta, 4.7 μf, 10%, 35v	0180-0100	56289	150D475X9035B2	4	2
C22,23,28,29	C: fxd, elect, al, 75 μf, -10 +100%, 50v	0180-0277	14655	NLW75-50	4	2
C32, 33	C: fxd, my, 0.0018 μf, 10%, 200v	0160-0299	28480	-	2	1
C34	C: fxd, my, 0.01 μf, 10%, 200v	0160-0161	28480	-	1	1
C35, 36	C: fxd, mica, 22 pf, 5%, 500v	0140-0145	04062	DM15C220J	2	1
CR2, 3, 12, 13	Diode: Ge	1910-0016	28480	-	4	1
CR4, 9, 10, 14 19, 20	Diode: Si	1901-0025	28480	-	6	1
CR5, 15	Diode: Si	1901-0156	28480	-	2	1
CR6, 16	Diode: avalanche, 6.1v	1902-0777	03877	1N825	2	1
CR7, 8, 17, 18	Diode: switching, Si, 50v	1901-0081	28480	-	4	1
CR21, 22, 28 29	Diode: avalanche, 9v, JEDEC IN935	1902-0772	04713	-	4	1
CR23, 30	Diode: avalanche, Si, 17.8v	1902-3224	28480	-	2	1
CR24-27, 31-34	Diode: Si	1901-0033	28480	-	8	1
L1, 2	Inductor: 15 μh	9140-0082	28480	-	2	1
Q1	Transistor: dual: Si, NPN	1854-0208	28480	-	1	1
Q2, 3	Transistor: dual: Si, NPN	1854-0207	28480	-	2	1
Q4-5, 11-12	Transistor, Selected Pair: Si, PNP	5080-5964	04404	-	2	1
Q6, 13	Transistor: Si, NPN, JEDEC 2N2501	1854-0211	28480	-	2	1
Q7, 10, 14, 17	Transistor: Si, PNP	1853-0008	04713	2N3250	4	1
Q8, 9, 15, 16	Transistor: Si, NPN, JEDEC 2N2897	1854-0212	02735	-	4	1
Q18, 22	Transistor: Si, NPN	1854-0039	02735	2N3053	2	1
Q19,21,23,25	Transistor: Si, PNP	1853-0001	28480	-	4	1
Q20, 24	Transistor: Si, NPN	1854-0003	28480	-	2	1

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*Not on Mfr Code: 83332, Tech Labs, Palisades Park, New Jersey

Table 5-2 (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	ⓗⓟ STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
R1, 38	R: fxd, cflm, 1K, 1%, 1/2 w	0727-0100	28480		2	1
R2, 39	R: fxd, selected in test; may be a jumper	OBD	28480		2	1
R3, 40	R: fxd, metoxide, 100K, 2%, 1/8 w	0757-0972	28480		2	1
R4, 41	R: var, ww, 10K, 5%, 1 w	2100-0363	28480		2	1
R5, 42	R: fxd, cflm, 1.96 Meg, 1%, 1/2 w	0727-0847	28480		2	1
R6, 14, 15, 43, 54, 55	R: fxd, metflm, 56.2K, 1%, 1/2 w	0698-4321	28480		6	2
R7	R: fxd, 5.62K, 1%, 1/2 w	0698-4317	28480		1	1
R8, 47	R: fxd, mtflm, 28.7K, 1%, 1/2 w	0698-4319	28480		2	1
R9, 48	R: fxd, mtflm, 51.1K, 1%, 1/2 w	0698-4320	28480		2	1
R10, 50	R: fxd, metoxide, 1.6K, 1%, 1/8 w	0757-0929	28480		2	1
R11, 51	R: fxd, metoxide, 2.7K, 2%, 1/8 w	0757-0934	28480		2	1
R12, 52	R: fxd, metoxide, 1.3K, 2%, 1/8 w	0757-0927	28480		2	1
R13, 53	R: fxd, metflm, 825Ω, 1%, 1/2 w	0698-4310	28480		2	1
R16, 22, 26, 56, 62, 66	R: fxd, metoxide, 3.9K, 2%, 1/8 w	0757-0938	28480		6	2
R17, 19, 25, 57, 58, 65	R: fxd, metoxide, 220Ω, 2%, 1/8 w	0757-0908	28480		6	2
R19, 59	R: fxd, metoxide, 75K, 2%, 1/8 w	0757-0969	28480		2	1
R20, 60	R: fxd, metoxide, 82K, 2%, 1/8 w	0757-0970	28480		2	1
R21, 61	R: fxd, metoxide, 22K, 2%, 1/8 w	0757-0956	28480		2	1
R23, 63	R: fxd, metoxide, 91K, 2%, 1/8 w	0757-0971	28480		2	1
R24, 64, 83-85, 94	R: fxd, metoxide, 100Ω, 2%, 1/8 w	0757-0900	28480		6	3
R27, 67	R: fxd, metoxide, 10K, 2%, 1/8 w	0757-0948	28480		2	1
R28, 32, 68, 72	R: fxd, metoxide, 620Ω, 2%, 1/8 w	0757-0919	28480		4	2
R30, 70	R: fxd, metoxide, 18K, 2%, 1/8 w	0757-0954	28480		2	1
R31, 71	R: fxd, metoxide, 5.1K, 2%, 1/8 w	0757-0941	28480		2	1
R33, 73	R: fxd, metoxide, 68K, 2%, 1/8 w	0757-0968	28480		2	1
R34, 37, 74, 77	R: fxd, comp, 470Ω, 5%, 1/2 w	0686-4715	28480		4	2
R35, 36, 75, 76	R: fxd, comp, 22Ω, 5%, 1/4 w	0683-2205	28480		4	2
R44	R: fxd, metflm, 4.87K, 1%, 1/2 w	0698-4315	28480		1	1
R45	R: var, ww, 2.5K, 5%, 1 w	2100-1451	28480		1	1
R46	R: var, ww, 10K, 10%, 1 w, 20 turns, (ZERO)	2100-1660	28480		1	1
R49	R: fxd, cflm, 1 Meg, 1%, 1/2 w	0727-0274	28480		1	1
R79, 81, 82, 86, 88, 89, 90, 91	R: fxd, metoxide, 3.3K, 2%, 1/8 w	0757-0936	28480		8	3
R80, 87	R: fxd, metoxide, 2.4K, 2%, 1/8 w	0757-0933	28480		2	1
R92, 93	R: fxd, comp, 2.2 Meg. 5%, 1/4 w	0683-2255	28480		2	1

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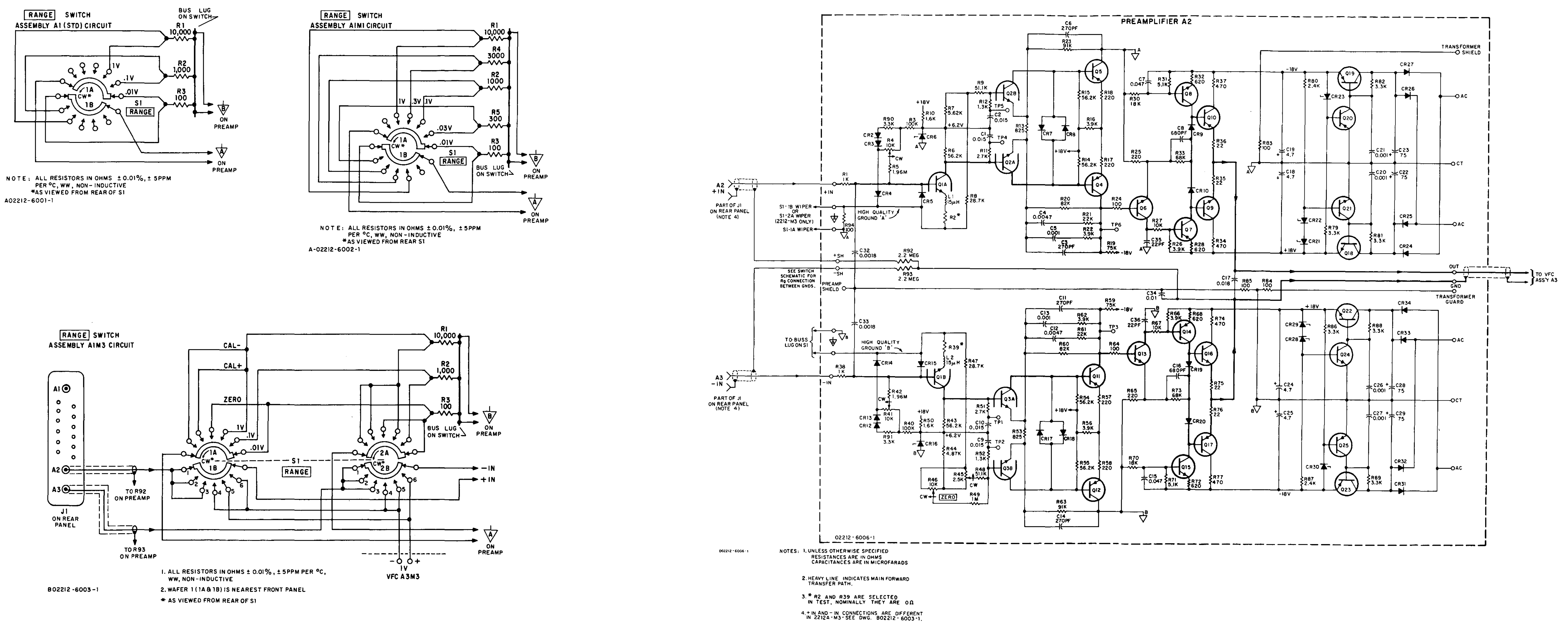


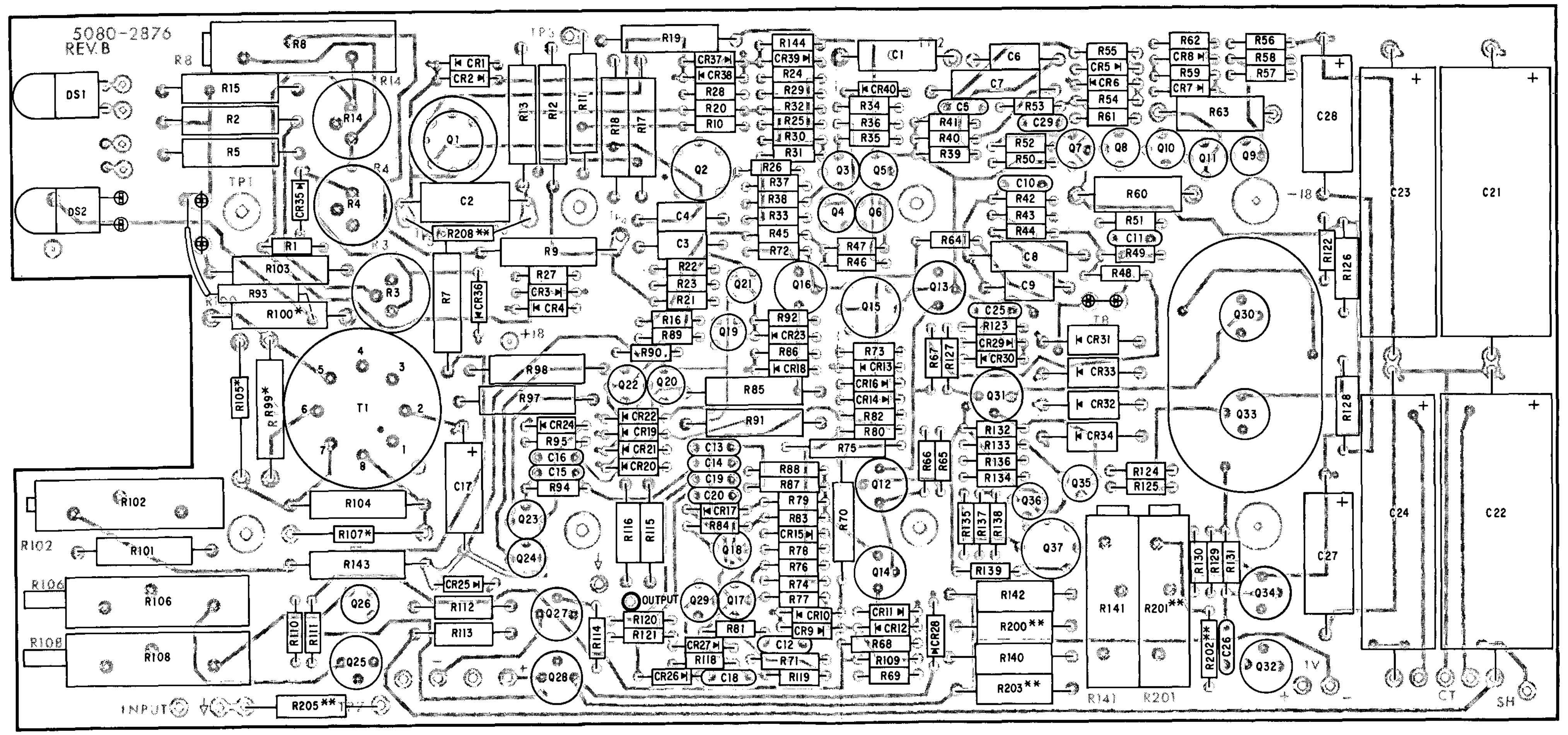
Figure 5-4. RANGE Switch and Preamplifier Schematics

UNFOLD TO VIEW

Figure 5-4. RANGE Switch and Preamplifier Schematics
Table 5-2. A1 and A2 Parts Lists (Cont'd.)

on Page 5-7

VFC ASSEMBLY A3



* R99, R100, R105, & R107 VALUES ARE SELECTED IN TEST
** R200, R201, R202, & R203 ARE ADDED AS PART OF MODIFICATION M3 (INTERNAL CALIBRATION)
R205 & R208 ARE ADDED AS PART OF VERNIER MODIFICATION M2

Figure 5-5. Parts on A3

Table 5-3. A3 Parts List

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
A3	**VOLTAGE-TO-FREQUENCY CONVERTER ASSEMBLY, Temperature Compensated**	02212-6014	04404			
C1	C: fxd, cer, 1000 pf, 2%, 300v	0160-2309	95275	VY17C102G	1	1
C2	C: fxd, my, 0.018 µf, 10%, 200v	0160-0302	28480	-	1	1
C3, 4	C: fxd, my, 1500 pf, 10%, 200v	0160-0298	28480	-	2	1
C5, 10	C: fxd, mica, 560 pf, 2%, 300v	0140-0178	28480	-	2	1
C6, 9	C: fxd, my, 2700 pf, 10%, 200v	0160-0300	28480	-	2	1
C7, 8	C: fxd, my 0.01 µf, 10%, 200v	0160-0161	28480	-	2	1
C11	C: fxd, mica, 270 pf, 5%, 500v	0140-0206	04062	DM15F271J	1	1
C12, 18-20	C: fxd, mica, 110 pf, 5%, 300v	0140-0194	28480	-	4	1
C13, 14	C: fxd, mica, 150 pf, 5%, 300v	0140-0196	28480	-	2	1
C15, 16	C: fxd, mica, 22 pf, 5%, 500v	0140-0145	04062	DM15C220J	2	1
C17	C: fxd, elect, Ta, 22 µf, 20%, 35v	0180-0160	28480	-	1	1
C21, 22	C: fxd, elect, 300 µf, -10 +75%, 40v	0180-1805	28480	-	2	1
C23, 24	C: fxd, elect, al, 75 µf, -10 +75%, 40v	0180-1804	28480	-	2	1
C25	C: fxd, mica, 220 pf, 5%, 300v	0160-0134	14655	CD15F221J(300v)	1	1
C26	C: fxd, mica, 56 pf, 5%, 300v	0140-0191	04062	DM15E560J300v	1	1
C27, 38	C: fxd, elect, Ta, 100 µf, +20 -15%, 20v	0180-0098	28480	-	2	1
C29	C: fxd, mica, 10 pf, 5%, 500v	0160-0205	28480	-	1	1
CR1,2,37,38	Diode: Si	1901-0156	28480	-	4	1
CR3, 4, 28	Diode: avalanche, 6.2v	1902-0033	03877	1N823	3	1
CR5-8, 11, 12, 15, 16, 29, 30, 35	Diode: Si	1901-0025	28480	-	11	1
CR9, 10, 17, 18, 23-27	Diode: switching, Si, 50v	1901-0081	28480	-	9	1
CR13, 14, 19-22, 36	Diode: Ge	1910-0016	28480	-	7	1
CR31-34	Diode: Si	1901-0158	28480	-	4	1
CR39, 40	Diode: avalanche, Si, 10.5v	1902-0570	28480	-	2	1
DS1, 2	Lamp: incandescent	2140-0090	92966	2308	2	2
Q1 A and B	Transistor: dual, Si, NPN	1854-0208	28480	-	1	1
Q2 A and B	Transistor: dual, Si, PNP	1853-0032	28480	-	1	1
Q3, 4, 7, 19, 21, 23, 24	Transistor: Si, NPN, JEDEC 2N2501	1854-0211	04713	-	7	1
Q5, 6, 8, 11, 35, 36	Transistor: Si, PNP	1853-0008	04713	2N3250	6	1
Q9	Transistor: Si, NPN, JEDEC 2N2897	1854-0212	02735	-	1	1
Q10, 26	Transistor: Si, NPN, JEDEC 2N2222	1854-0210	04713	-	2	1
Q12-14, 16, 27, 31, 34	Transistor: Si, NPN, similar to 2N1711	1854-0003	28480	-	7	1
Q15 A/B, 37 A/B	Transistor: dual, Si, NPN	1854-0014	28480	-	2	1
Q17, 18, 20, 22, 29	Transistor: Si, planar, NPN	1854-0005	07263	2N708	5	1
Q25	Transistor: Si, PNP, JEDEC 2N3318	1853-0033	56289	-	1	1
Q28, 32	Transistor: Si, PNP	1853-0001	28480	-	2	1
Q30	Transistor: Si, NPN	1854-0039	04713	2N3053	1	1
Q33	Transistor: Si, PNP	1853-0027	28480	-	1	1
R1	R: fxd, metoxide, 56K, 2%, 1/8 w	0757-0966	28480	-	1	1
R2, 5	R: fxd, cflm, 1M, 1%, 1/2 w	0727-0274	28480	-	2	1
R3, 4, 14	R: var, ww, 10K, 5%, 1 w	2100-0363	28480	-	3	1
R7	R: fxd, cflm, 10K, 1%, 1/2 w	0727-0891	28480	-	1	1
R8	R: var, ww, 10K, 5%, 3/4 w	2100-1645	28480	-	1	1
R9, 13, 15, 19	R: fxd, metoxide, 383K, 1%, 1/2 w	0757-0133	28480	-	4	2
R10	R: fxd, metoxide, 82K, 2%, 1/8 w	0757-0970	28480	-	1	1
R11, 12	R: fxd, metflm, 511Ω, 1%, 1/2 w	0698-4309	28480	-	2	1
R16	R: fxd, metoxide, 51K, 2%, 1/8 w	0757-0965	28480		1	1
R17, 18	R: fxd, metflm, 51.1K, 1%, 1/2 w	0698-4320	28480	-	2	1
R20, 21	R: fxd, metoxide, 62K, 2%, 1/8 w	0757-0967	28480	-	2	1
R22, 23, 49, 123	R: fxd, metoxide, 560Ω, 2%, 1/8 w	0757-0918	28480	-	4	2
R24	R: fxd, metoxide, 15K, 2%, 1/8 w	0757-0952	28480	-	1	1

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Table 5-3 (Cont'd.)

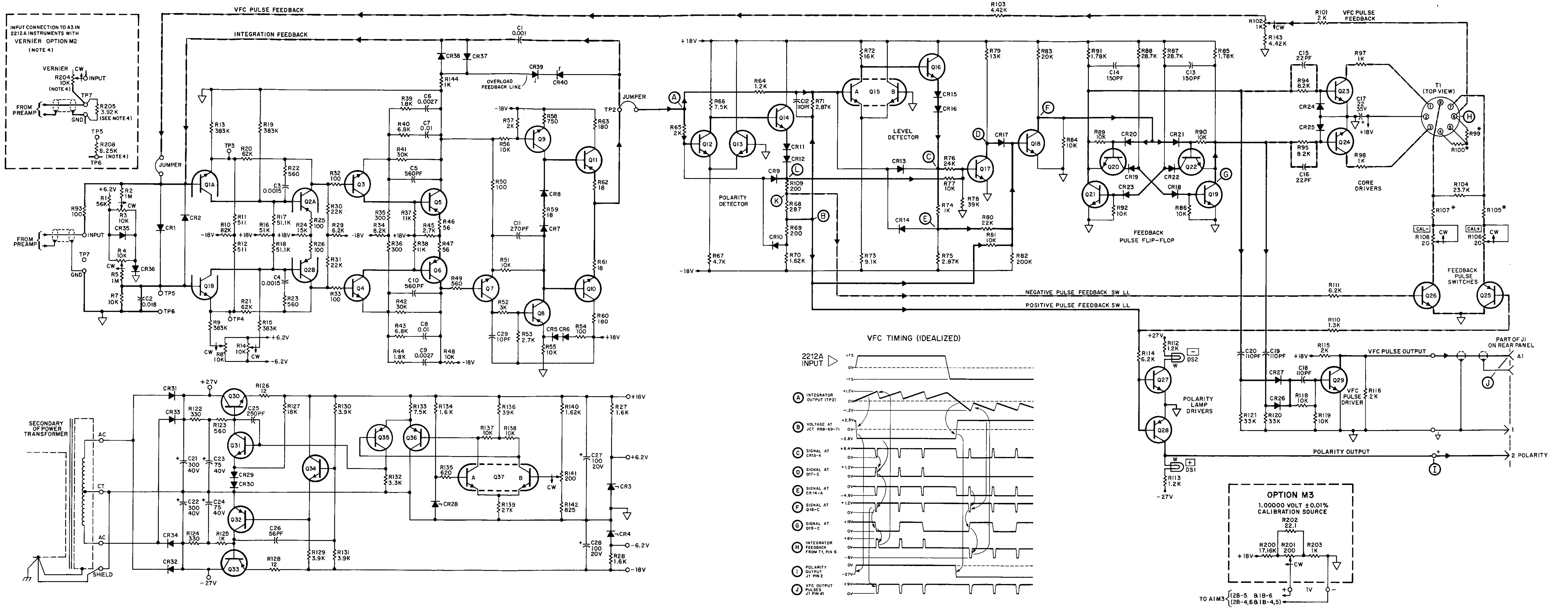
CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
R25, 26, 32, 33, 50, 54	R: fxd, metoxide, 100Ω, 2%, 1/8 w	0757-0900	28480	-	6	2
R27, 28, 134	R: fxd, metoxide, 1.6K, 2%, 1/8 w	0757-0929	28480	-	3	1
R29, 111, 114	R: fxd, metoxide, 6.2K, 2%, 1/8 w	0757-0943	28480	-	3	1
R30, 31, 80	R: fxd, metoxide, 22K, 2%, 1/8 w	0757-0956	28480	-	3	1
R34, 94, 95	R: fxd, metoxide, 8.2K, 2%, 1/8 w	0757-0946	28480	-	3	1
R35, 36	R: fxd, metoxide, 300Ω, 2%, 1/8 w	0757-0911	28480	-	2	1
R37, 38	R: fxd, metoxide, 11K, 2%, 1/8 w	0757-0949	28480	-	2	1
R39, 44	R: fxd, metoxide, 1.8K, 2%, 1/8 w	0757-0930	28480	-	2	1
R40, 43	R: fxd, metoxide, 6.8K, 2%, 1/8 w	0757-0944	28480	-	2	1
R41, 42	R: fxd, metoxide, 30K, 2%, 1/8 w	0757-0959	28480	-	2	1
R45, 53	R: fxd, metoxide, 2.7K, 2%, 1/8 w	0757-0934	28480	-	2	1
R46, 47	R: fxd, metoxide, 56Ω, 2%, 1/8 w	0757-0894	28480	-	2	1
R48, 51, 55, 56, 77, 81, 84, 86, 89, 90, 92, 118, 119, 137, 138	R: fxd, metoxide, 10K, 2%, 1/8 w	0757-0948	28480	-	15	3
R52	R: fxd, metoxide, 3K, 2%, 1/8 w	0757-0935	28480	-	1	1
R57, 65	R: fxd, metoxide, 2K, 1%, 1/8 w	0757-0931	28480	-	2	1
R58	R: fxd, metoxide, 750-, 2%, 1/8 w	0757-0921	28480	-	1	1
R59, 61, 62	R: fxd, comp, 18Ω, 5%, 1/4 w	0683-1805	28480	-	3	1
R60, 63	R: fxd, comp, 180Ω, 5%, 1 w	0689-1815	28480	-	2	1
R64	R: fxd, metoxide, 1.2K, 2%, 1/8 w	0757-0926	28480	-	1	1
R66, 133	R: fxd, metoxide, 7.5K, 2%, 1/8 w	0757-0945	28480	-	2	1
R67	R: fxd, metoxide, 4.7K, 2%, 1/8 w	0757-0940	28480	-	1	1
R68	R: fxd, metflm, 287Ω, 1%, 1/8 w	0698-3443	-		1	1
R69, 109	R: fxd, metoxide, 200Ω, 2%, 1/8 w	0757-0907	28480	-	2	1
R70	R: fxd, metoxide, 1.62K, 1%, 1/4 w	0757-0737	28480	-	1	1
R71	R: fxd, metflm, 2.87K, 1%, 1/8 w	0698-3151	28480	-	1	1
R72	R: fxd, metoxide, 16K, 2%, 1/8 w	0757-0953	28480	-	1	1
R73	R: fxd, metoxide, 9.1K, 2%, 1/8 w	0757-0947	28480	-	1	1
R74, 125, 144	R: fxd, metoxide, 1K, 2%, 1/8 w	0757-0924	28480	-	3	2
R75	R: fxd, metflm, 2.87K, 1%, 1/4 w	0698-0086	28480	-	1	1
R76	R: fxd, metoxide, 24K, 2%, 1/8 w	0757-0957	28480	-	1	1
R78, 136	R: fxd, metoxide, 39K, 2%, 1/8 w	0757-0962	28480	-	1	1
R79	R: fxd, metoxide, 13K, 2%, 1/8 w	0757-0951	28480	-	1	1
R82	R: fxd, comp, 200K, 5%, 1/4 w	0683-2045	28480	-	1	1
R83	R: fxd, metoxide, 20K, 2%, 1/8 w	0757-0955	28480	-	1	1
R85, 91	R: fxd, metflm, 1.78, 1%, 1/2 w	0698-0089	28480	-	2	1
R87, 88	R: fxd, metflm, 28.7K, 1%, 1/8 w	0698-3449	28480	-	2	1
R93	R: fxd, cflm, 100Ω, 1%, 1/2 w	0727-0864	28480	-	1	1
R97, 98	R: fxd, metflm, 1K, 1%, 1/2 w	0698-4311	28480	-	2	1
R99	R: fxd, metflm, 215Ω, 1%, 1/8 w	0698-4328	28480	-	1	1
R100	R: fxd, metflm, 348Ω, 1%, 1/8 w	0698-4333	28480	-	1	1
R101	R: fxd, metflm, 2K, 1%, 1/2 w	0698-4336	28480	-	1	1
R102	R: var, ww, 1K, 5%, 3/4 w	2100-1642	28480	-	1	1
R103, 143	R: fxd, metflm, 4.42K, 1%, 1/2 w	0698-4314	28480	-	2	1
R104	R: fxd, metflm, 23.7K, 1%, 1/2 w	0698-4318	28480	-	1	1
R105, 107	R: fxd, selected in test; may be a jumper	OBD	28480	-	2	1
R106, 108	R: var, ww, 20Ω, 10%, 3/4 w (CAL+, CAL-)	2100-1740	28480	-	2	1
R110	R: fxd, metoxide, 1.3K, 2%, 1/8 w	0757-0927	28480	-	1	1
R112, 113	R: fxd, metoxide, 1.2K, 2%, 1/2 w	0757-0077	28480	-	2	1
R115, 116	R: fxd, metoxide, 2K, 5%, 1/2 w	0758-0033	28480	-	2	1
R120, 121	R: fxd, metoxide, 33K, 2%, 1/8 w	0757-0960	28480	-	2	1
R122, 124	R: fxd, metoxide, 330Ω, 2%, 1/8 w	0757-0912	27479	-	2	1
R126, 128	R: fxd, comp, 12Ω, 5%, 1/2 w	0686-1205	28480	-	2	1
R127	R: fxd, metoxide, 18K, 2%, 1/8 w	0757-0954	28480	-	1	1
R129-131	R: fxd, metoxide, 3.9K, 2%, 1/8 w	0757-0938	28480	-	3	1
R132	R: fxd, metoxide, 3.3K, 2%, 1/8 w	0757-0936	28480	-	1	1
R135	R: fxd, metoxide, 620Ω, 2%, 1/8 w	0757-0919	28480	-	1	1
R139	R: fxd, metoxide, 27K, 2%, 1/8 w	0757-0958	28480	-	1	1
R140	R: fxd, metflm, 1.62K, 1%, 1/2 w	0698-4312	28480	-	1	1
R141	R: var, ww, 200Ω, 5%, 3/4 w	2100-1420	28480	-	1	1
R142	R: fxd, metflm, 825Ω, 1%, 1/2 w	0698-4310	28480	-	1	1
T1	Transformer: pulse, feedback	02212-8001	04404	-	1	NFR

M0183

Table 5-3 (Cont'd.)

CIRCUIT REFERENCE	DESCRIPTION	hp STOCK NO.	MFR. CODE NO.	MFR. PART NO.	QTY.	1-YR. SPA.
A3M3	**VOLTAGE-TO-FREQUENCY CONVERTER ASSEMBLY, Temperature Compensated** (replaces A3 in 2212A-M3 instruments)	02212-6015	04404			
	Change Voltage-to-Frequency Converter Assembly A3 (02212-6014) as follows:					
	DELETE:					
	CR28 Diode, avalanche, 6.2v (1902-0033)					
	ADD:					
CR28	Diode: avalanche	1902-0112	28480	-	1	1
R200	R: fxd, ww, 17.16K, .05%, 1/16 w	0811-1702	28480	-	1	1
R201	R: var, ww, 200Ω, 5%, 3/4 w	2100-1420	28480	-	1	1
R202	R: fxd, metoxide, 22.1Ω, 1%, 1/8 w	0757-0385	28480	-	1	1
R203	R: fxd, ww, 1K, .05%, 1/16 w	0811-1698	28480	-	1	1

M0183



NOTES:

1. UNLESS OTHERWISE NOTED:
   RESISTANCE IS IN OHMS
   CAPACITANCE IS IN MICROFARADS
2. HEAVY LINE IDENTIFIES MAIN FORWARD TRANSFER PATH.
3. LINES WITH HEAVY DASHES IDENTIFY INTEGRATION FEEDBACK AND VFC PULSE FEEDBACK PATHS.
4. R204, R205, AND R208 ARE ADDED TO THE 2212A AND TO A3 ONLY AS PART OF OPTION M2

* SELECTED DURING PRODUCTION

D02212-9001-2 (1/2)

Figure 5-6. VFC Assembly Schematic

UNFOLD TO VIEW
Figure 5-6. VFC Assembly Schematic
Table 5-3. A3 Parts List (Cont'd.)
on Page 5-9

APPENDIX 5.1
CODE LIST OF MANUFACTURERS

The following code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) and their latest supplements. The date of revision and the date of the supplements used appear at the bottom of each page. Alphabetical codes have been arbitrarily assigned to suppliers not appearing in the H4 Handbooks.

Code No.	Manufacturer	Address
00000	U. S. A. Common	Any supplier of U. S.
00136	McCoy Electronics	Mount Holly Springs, Pa.
00213	Sage Electronics Corp.	Rochester, N.Y.
00287	Cemco Inc.	Danielson, Conn.
00334	Humidial	Colton, Calif.
00348	Microtron Co., Inc.	Valley Stream, N.Y.
00373	Garlock Inc., Electronics Products Div.	Camden, N.J.
00656	Aerovox Corp.	New Bedford, Mass.
00779	Amp. Inc.	Harrisburg, Pa.
00781	Aircraft Radio Corp.	Boonton, N.J.
00815	Northern Engineering Laboratories, Inc.	Burlington, Wis.
00853	Sangamo Electric Co., Pickens Div.	Pickens, S.C.
00866	Goe Engineering Co.	Los Angeles, Calif.
00891	Carl E. Holmes Corp.	Los Angeles, Calif.
00929	Microlab Inc.	Livingston, N.J.
01009	Alden Products Co.	Brockton, Mass.
01121	Allen Bradley Co.	Milwaukee, Wis.
01255	Litton Industries, Inc.	Beverly Hills, Calif.
01281	TRW Semiconductors, Inc.	Lawndale, Calif.
01295	Texas Instruments, Inc., Transistor Products Div.	Dallas, Texas
01349	The Alliance Mfg. Co.	Alliance, Ohio
01589	Pacific Relays, Inc.	Van Nuys, Calif.
01930	Amerock Corp.	Rockford, Ill.
01961	Pulse Engineering Co.	Santa Clara, Calif.
02114	Ferroxcube Corp. of America	Saugerties, N.Y.
02286	Cole Rubber and Plastics Inc.	Sunnyvale, Calif.
02660	Amphenol-Borg Electronics Corp.	Chicago, Ill.
02735	Radio Corp. of America, Semiconductor and Materials Div.	Somerville, N.J.
02771	Vocaline Co. of America, Inc.	Old Saybrook, Conn.
02777	Hopkins Engineering Co.	San Fernando, Calif.
03508	G.E. Semiconductor Prod. Dept.	Syracuse, N.Y.
03705	Apex Machine & Tool Co.	Dayton, Ohio
03797	Eldema Corp.	Compton, Calif.
03877	Transitron Electric Corp.	Wakefield, Mass.
03888	Pyrofilm Resistor Co., Inc.	Cedar Knolls, N.J.
03954	Singer Co., Diehl Div. Finderne Plant	Somerville, N.J.
04009	Arrow, Hart and Hegeman Elect. Co.	Hartford, Conn.
04013	Taurus Corp.	Lambertville, N.J.
04222	Hi-Q Division of Aerovox	Myrtle Beach, S.C.
04354	Precision Paper Tube Co.	Chicago, Ill.
04404	Dymec Division of Hewlett-Packard Co.	Palo Alto, Calif.
04651	Sylvania Electric Products, Microwave Device Div.	Mountain View, Calif.
04713	Motorola, Inc., Semiconductor Prod. Div.	Phoenix, Arizona
04732	Filtron Co., Inc. Western Div.	Culver City, Calif.
04773	Automatic Electric Co.	Northlake, Ill.
04796	Sequoia Wire Co.	Redwood City, Calif.
04811	Precision Coil Spring Co.	El Monte, Calif.
04870	P.M. Motor Company	Westchester, Ill.
05006	Twentieth Century Plastics, Inc.	Los Angeles, Calif.
05277	Westinghouse Electric Corp. Semi-Conductor Dept.	Youngwood, Pa.
05347	Ultronix, Inc.	San Mateo, Calif.
05593	Illumitronic Engineering Co.	Sunnyvale, Calif.
05616	Cosmo Plastic (c/o Electrical Spec. Co.)	Cleveland, Ohio
05624	Barber Colman Co.	Rockford, Ill.
05728	Tiffen Optical Co.	Roslyn Heights, Long Island, N.Y.
05729	Metro-Tel Corp.	Westbury, N.Y.
05783	Stewart Engineering Co.	Santa Cruz, Calif.
05820	Wakefield Engineering Inc.	Wakefield, Mass.
06004	Bassick Co., The	Bridgeport, Conn.
06090	Raychem Corp.	Redwood City, Calif.
06175	Bausch and Lomb Optical Co.	Rochester, N.Y.
06402	E.T.A. Products Co. of America	Chicago, Ill.
06540	Amatom Electronic Hardware Co., Inc.	New Rochelle, N.Y.
06555	Beede Electrical Instrument Co., Inc.	Penacook, N.H.
06666	General Devices Co., Inc.	Indianapolis, Ind.
06751	Semcor Div. Components Inc.	Phoenix, Ariz.
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.
06980	Varian Assoc. Eimac Div.	San Carlos, Calif.
07088	Kelvin Electric Co.	Van Nuys, Calif.
07126	Digitran Co.	Pasadena, Calif.
07137	Transistor Electronics Corp.	Minneapolis, Minn.
07138	Westinghouse Electric Corp. Electronic Tube Div.	Elmira, N.Y.
07149	Filmohm Corp.	New York, N.Y.
07233	Cinch-Graphik Co.	City of Industry, Calif.
07261	Avnet Corp.	Culver City, Calif.
07263	Fairchild Camera & Inst. Corp. Semiconductor Div.	Mountain View, Calif.
07322	Minnesota Rubber Co.	Minneapolis, Minn.
07387	Birtcher Corp., The	Monterey Park, Calif.
07700	Technical Wire Products Inc.	Cranford, N.J.
07910	Continental Device Corp.	Hawthorne, Calif.
07933	Raytheon Mfg. Co., Semiconductor Div.	Mountain View, Calif.
07966	Shockley Semi-Conductor Laboratories	Palo Alto, Calif.
07980	Hewlett-Packard Co., Boonton Radio Div.	Rockaway, N.J.
08145	U.S. Engineering Co.	Los Angeles, Calif.
08289	Blinn, Delbert Co.	Pomona, Calif.
08358	Burgess Battery Co.	Niagara Falls, Ontario, Canada
08664	Bristol Co., The	Waterbury, Conn.
08717	Sloan Company	Sun Valley, Calif.
08718	ITT Cannon Electric Inc., Phoenix Div.	Phoenix, Arizona
08792	CBS Electronics Semiconductor Operations, Div of C.B.S. Inc.	Lowell, Mass.
08984	Mel-Rain	Indianapolis, Ind.
09026	Babcock Relays Div.	Costa Mesa, Calif.
09134	Texas Capacitor Co.	Houston, Texas
09145	Atohm Electronics	Sun Valley, Calif.
09250	Electro Assemblies, Inc.	Chicago, Ill.
09569	Mallory Battery Co. of Canada, Ltd.	Toronto, Ontario, Canada
10214	General Transistor Western Corp.	Los Angeles, Calif.
10411	Ti-Tal, Inc.	Berkeley, Calif.
10646	Carborundum Co.	Niagara Falls, N.Y.
11236	CTS of Berne, Inc.	Berne, Ind.
11237	Chicago Telephone of California, Inc.	So. Pasadena, Calif.
11242	Bay State Electronics Corp.	Waltham, Mass.
11312	Teledyne Inc., Microwave Div.	Palo Alto, Calif.
11534	Duncan Electronics Inc.	Costa Mesa, Calif.
11711	General Instrument Corp., Semiconductor Div., Products Group	Newark, N.J.
11717	Imperial Electronic, Inc.	Buena Park, Calif.
11870	Melabs, Inc.	Palo Alto, Calif.
12136	Philadelphia Handle Co.	Camden, N.J.
12697	Clarostat Mfg. Co.	Dover, N.H.
12859	Nippon Electric Co., Ltd.	Tokyo, Japan
12881	Metex Electronics Corp.	Clark, N.J.
12930	Delta Semiconductor Inc.	Newport Beach, Calif.
12954	Dickson Electronics Corp.	Scottsdale, Arizona
13103	Thermolloy	Dallas, Texas
13396	Telefunken (GmbH)	Hanover, Germany
13835	Midland-Wright Div. of Pacific Industries, Inc.	Kansas City, Kansas
14099	Sem-Tech	Newbury Park, Calif.
14193	Calif. Resistor Corp.	Santa Monica, Calif.
14298	American Components, Inc.	Conshohocken, Pa.
14433	ITT Semiconductor, A Div. of Int. Telephone & Telegraph Corp.	West Palm Beach, Fla.
14493	Hewlett-Packard Company	Loveland, Colo.
14655	Cornell Dublier Electric Corp.	Newark, N.J.
14674	Corning Glass Works	Corning, N.Y.
14752	Electro Cube Inc.	So. Pasadena, Calif.
14960	Williams Mfg. Co.	San Jose, Calif.
15203	Webster Electronics Co.	New York, N.Y.
15291	Adjustable Bushing Co.	N. Hollywood, Calif.
15558	Micron Electronics	Garden City, Long Island, N.Y.
15566	Amprobe Inst. Corp.	Lynbrook, N.Y.
15772	Twentieth Century Coil Spring Co.	Santa Clara, Calif.
15818	Amelco Inc.	Mt. View, Calif.
15909	Daven Div. Thomas A. Edison Ind. McGraw-Edison Co.	Long Island City, N.Y.
16037	Spruce Pine Mica Co.	Spruce Pine, N.C.
16179	Omni-Spectra Inc.	Detroit, Ill.
16352	Computer Diode Corp.	Lodi, N.J.
16688	Ideal Prec. Meter Co., Inc. De Jur Meter Div.	Brooklyn, N.Y.
16758	Delco Radio Div. of G.M. Corp.	Kokomo, Inc.
17109	Thermonetics Inc.	Canoga Park, Calif.
17474	Tranex Company	Mountain View, Calif.
17675	Hamlin Metal Products Corp.	Akron, Ohio
17745	Angstrohm Prec. Inc.	No. Hollywood, Calif.
18042	Power Design Pacific Inc.	Palo Alto, Calif.
18476	Ty-Car Mfg. Co., Inc.	Holliston, Mass.
18486	TRW Elect. Comp. Div.	Des Plaines, Ill.
18583	Curtis Instrument, Inc.	Mt. Kisco, N.Y.
18873	E.I. DuPont and Co., Inc.	Wilmington, Del.
18911	Durant Mfg. Co.	Milwaukee, Wis.
19315	Bendix Corp., The Eclipse-Poineer Div.	Teterboro, N.J.
19500	Thomas A. Edison Industries, Div. of McGraw-Edison Co.	West Orange, N.J.
19644	LRC Electronics	Horseheads, N.Y.
19701	Electra Mfg. Co.	Independence, Kansas
20183	General Atronics Corp.	Philadelphia, Pa.
21226	Executone, Inc.	Long Island City, N.Y.
21335	Fafnir Bearing Co., The	New Britain, Conn.
21520	Fansteel Metallurgical Corp.	N. Chicago, Ill.
23783	British Radio Electronics Ltd.	Washington, D.C.
24455	G.E. Lamp Division	Nela Park, Cleveland, Ohio
24655	General Radio Co.	West Concord, Mass.
26365	Gries Reproducer Corp.	New Rochelle, N.Y.
26462	Grobet File Co. of America, Inc.	Carlstadt, N.J.
26992	Hamilton Watch Co.	Lancaster, Pa.
28480	Hewlett-Packard Co.	Palo Alto, Calif.
33173	G.E. Receiving Tube Dept.	Owensboro, Ky.
35434	Lectrohm Inc.	Chicago, Ill.
36196	Stanwyck Coil Products Ltd.	Hawkesbury, Ontario, Canada
37942	P.R. Mallory & Co. Inc.	Indianapolis, Ind.
39543	Mechanical Industries Prod. Co.	Akron, Ohio
40920	Miniature Precision Bearings, Inc.	Keene, N.H.
42190	Muter Co.	Chicago, Ill.
43990	C.A. Norgren Co.	Englewood, Colo.
44655	Ohmite Mfg. Co.	Skokie, Ill.
46384	Penn Eng. & Mfg. Corp.	Doylestown, Pa.
47904	Polaroid Corp.	Cambridge, Mass.
48620	Precision Thermometer & Inst. Co.	Southampton, Pa.
49956	Microwave & Power Tube Div.	Waltham, Mass.
52090	Rowan Controller Co.	Westminster, Md.
52983	Sanborn Company	Waltham, Mass.
54294	Shallcross Mfg. Co.	Selma, N.C.
55026	Simpson Electric Co.	Chicago, Ill.
55933	Sonotone Corp.	Elmsford, N.Y.
55938	Raytheon Co. Commercial Apparatus & Systems Div.	So. Norwalk, Conn.
56137	Spaulding Fibre Co., Inc.	Tonawanda, N.Y.
56289	Sprague Electric Co.	North Adams, Mass.
59446	Telex, Inc.	St. Paul, Minn.
59730	Thomas & Betts Co.	Elizabeth, N.J.
60741	Triplett Electrical Inst. Co.	Bluffton, Ohio
61775	Union Switch and Signal, Div. of Westinghouse Air Brake Co.	Pittsburgh, Pa.
62119	Universal Electric Co.	Owosso, Mich.
63743	Ward-Leonard Electric Co.	Mt. Vernon, N.Y.
64959	Western Electric Co., Inc.	New York, N.Y.
65092	Weston Inst. Inc. Weston-Newark	Newark, N.J.
66295	Wittek Mfg. Co.	Chicago, Ill.
66346	Revere Wollansak Div. Minn. Mining & Mfg. Co.	St. Paul, Minn.
70276	Allen Mfg. Co.	Hartford, Conn.
70318	Allmetal Screw Product Co., Inc.	Garden City, N.Y.
70485	Atlantic India Rubber Works, Inc.	Chicago, Ill.
70563	Amperite Co., Inc.	Union City, N.J.
70903	Belden Mfg. Co.	Chicago, Ill.
70998	Bird Electronic Corp.	Cleveland, Ohio
71002	Birnbach Radio Co.	New York, N.Y.
71041	Boston Gear Works Div. of Murray Co. of Texas	Quincy, Mass.
71218	Bud Radio, Inc.	Willoughby, Ohio
71286	Camloc Fastener Corp.	Paramus, N.J.
71313	Cardwell Condenser Corp.	Lindenhurst L.I., N.Y.
71400	Bussmann Mfg. Div. of McGraw-Edison Co.	St. Louis, Mo.
71436	Chicago Condenser Corp.	Chicago, Ill.
71447	Calif. Spring Co., Inc.	Pico-Rivera, Calif.
71450	CTS Corp.	Elkhart, Ind.
71468	ITT Cannon Electric Inc.	Los Angeles, Calif.
71471	Cinema Plant, Hi-Q Div. Aerovox Corp.	Burbank, Calif.
71482	C.P. Clare & Co.	Chicago, Ill.
71590	Centralab Div. of Globe Union Inc.	Milwaukee, Wis.
71616	Commercial Plastics Co.	Chicago, Ill.
71700	Cornish Wire Co., The	New York, N.Y.
71707	Coto Coil Co., Inc.	Providence, R.I.
71744	Chicago Miniature Lamp Works	Chicago, Ill.
71753	A.O. Smith Corp., Crowley Div.	West Orange, N.J.
71785	Cinch Mfg. Co., Howard B. Jones Div.	Chicago, Ill.
71984	Dow Corning Corp.	Midland, Mich.
72136	Electro Motive Mfg. Co., Inc.	Willimantic, Conn.
72354	John E. Fast Co., Div. Victoreen Instr. Co.	Chicago, Ill.
72619	Dialight Corp.	Brooklyn, N.Y.
72656	Indiana General Corp., Electronics Div.	Keasby, N.J.
72699	General Instrument Corp., Cap. Div.	Newark, N.J.
72765	Drake Mfg. Co.	Chicago, Ill.
72825	Hugh H. Eby Inc.	Philadelphia, Pa.
72928	Gudeman Co.	Chicago, Ill.
72964	Robert M. Hadley Co.	Los Angeles, Calif.
72982	Erie Technological Products, Inc.	Erie, Pa.
73061	Hansen Mfg. Co., Inc.	Princeton, Ind.
73076	H.M. Harper Co.	Chicago, Ill.
73138	Helipot Div. of Beckman Inst., Inc.	Fullerton, Calif.
73293	Hughes Products Division of Hughes Aircraft Co.	Newport Beach, Calif.
73445	Amperex Electronic Co., Div. of North American Phillips Co., Inc.	Hicksville, N.Y.
73506	Bradley Semiconductor Corp.	New Haven, Conn.
73559	Carling Electric, Inc.	Hartford, Conn.
73682	George K. Garrett Co., Div. MSL Industries Inc.	Philadelphia, Pa.
73734	Federal Screw Products Inc.	Chicago, Ill.
73743	Fischer Special Mfg. Co.	Cincinnati, Ohio
73793	General Industries Co., The	Elyria, Ohio
73846	Goshen Stamping & Tool Co.	Goshen, Ind.
73899	JFD Electronics Corp.	Brooklyn, N.Y.
73905	Jennings Radio Mfg. Corp.	San Jose, Calif.
74276	Signalite Inc.	Neptune, N.J.
74455	J.H. Winns, and Sons	Winchester, Mass.
74861	Industrial Condenser Corp.	Chicago, Ill.
74868	R.F. Products Division of Amphenol-Borg Electronics Corp.	Danbury, Conn.
74970	E.F. Johnson Co.	Waseca, Minn.
75042	International Resistance Co.	Philadelphia, Pa.
75378	CTS Knights Inc.	Sandwich, Ill.
75382	Kulka Electric Corporation	Mt. Vernon, N.Y.
75818	Lenz Electric Mfg. Co.	Chicago, Ill.
75915	Littlefuse, Inc.	Des Plaines, Ill.
76005	Lord Mfg. Co.	Erie, Pa.
76210	C.W. Marwedel	San Francisco, Calif.
76487	James Millen Mfg. Co., Inc.	Malden, Mass.
76493	J.W. Miller Co.	Los Angeles, Calif.
76530	Cinch-Monadnock, Div. of United Carr Fastener Corp.	San Leandro, Calif.
76545	Mueller Electric Co.	Cleveland, Ohio
76703	National Union	Newark, N.J.
76854	Oak Manufacturing Co.	Crystal Lake, Ill.
77068	Bendix Corp., The Bendix Pacific Div.	N. Hollywood, Calif.
77075	Pacific Metals Co.	San Francisco, Calif.
77221	Phanostran Instrument and Electronic Co.	South Pasadena, Calif.
77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.
77342	American Machine & Foundry Co. Potter & Brumfield Div.	Princeton, Ind.
77630	TRW Electronic Components Div.	Camden, N.J.
77638	General Instrument Corp., Rectifier Div.	Brooklyn, N.Y.
77764	Resistance Products Co.	Harrisburg, Pa.
77969	Rubbercraft Corp. of Calif.	Torrance, Calif.
78189	Shakeproof Division of Illinois Tool Works	Elgin, Ill.
78283	Signal Indicator Corp.	New York, N.Y.
78290	Struthers-Dunn Inc.	Pitman, N.J.
78452	Thompson-Bremer & Co.	Chicago, Ill.
78471	Tilley Mfg. Co.	San Francisco, Calif.
78488	Stackpole Carbon Co.	St. Marys, Pa.
78493	Standard Thomson Corp.	Waltham, Mass.
78553	Tinnerman Products, Inc.	Cleveland, Ohio
78790	Transformer Engineers	San Gabriel, Calif.
78947	Ucinite Co.	Newtonville, Mass.
79136	Waldes Kohinoor Inc.	Long Island City, N.Y.
79142	Veeder Root, Inc.	Hartford, Conn.
79251	Wenco Mfg. Co.	Chicago, Ill.
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.
79963	Zierick Mfg. Corp.	New Rochelle, N.Y.
80031	Mepco Division of Sessions Clock Co.	Morristown, N.J.
80120	Schnitzer Alloy Products Co.	Elizabeth, N.J.
80130	Times Telephoto Equipment	New York, N.Y.
80131	Electronic Industries Association. Any brand Tube meeting EIA Standards-Washington, DC.	
80207	Unimax Switch, Div. Maxon Electronics Corp.	Wallingford, Conn.
80223	United Transformer Corp.	New York, N.Y.
80248	Oxford Electric Corp.	Chicago, Ill.
80294	Bourns Inc.	Riverside, Calif.
80411	Acro Div. of Robertshaw Controls Co.	Columbus, Ohio
80486	All Star Products Inc.	Defiance, Ohio
80509	Avery Adhesive Label Corp.	Monrovia, Calif.
80583	Hammarlund Co., Inc.	New York, N.Y.
80640	Stevens, Arnold, Co., Inc.	Boston, Mass.
81030	International Instruments Inc.	Orange, Conn.
81073	Grayhill Co.	LaGrange, Ill.
81095	Triad Transfoimer Corp.	Venice, Calif.
81312	Winchester Elec. Div. Litton Ind., Inc.	Oakville, Conn.
81349	Military Specification	. . . .
81483	International Rectifier Corp.	El Segundo, Calif.
81541	Airpax Electronics, Inc.	Cambridge, Mass.
81860	Barry Controls, Div. Barry Wright Corp.	Watertown, Mass.
82042	Carter Precision Electric Co.	Skokie, Ill.
82047	Sperti Faraday Inc., Copper Hewitt Electric Div.	Hoboken, N.J.
82142	Jeffers Electronics Division of Speer Carbon Co.	Du Bois, Pa.
82170	Fairchild Camera & Inst. Corp., Defense Prod. Division	Clifton, N.J.
82209	Maguire Industries, Inc.	Greenwich, Conn.
82219	Sylvania Electric Prod. Inc. Electronic Tube Division	Emporium, Pa.
82376	Astron Corp.	East Newark, Harrison, N.J.
82389	Switchcraft, Inc.	Chicago, Ill.
82647	Metals & Controls Inc. Spencer Products	Attleboro, Mass.
82768	Phillips-Advance Control Co.	Joliet, Ill.
82866	Research Products Corp.	Madison, Wis.
82877	Rotron Mfg. Co., Inc.	Woodstock, N.Y.
82893	Vector Electronic Co.	Glendale, Calif.
83053	Western Washer Mfg. Co.	Los Angeles, Calif.
83058	Carr Fastener Co.	Cambridge, Mass.
83086	New Hampshire Ball Bearing, Inc.	Peterborough, N.H.
83125	General Instrument Corp., Capacitor Div.	Darlington, S.C.
83148	ITT Wire and Cable Div.	Los Angeles, Calif.
83186	Victory Engineering Corp.	Springfield, N.J.
83298	Bendix Corp., Red Bank Div.	Red Bank, N.J.
83315	Hubbell Corp.	Mundelein, Ill.
83330	Smith, Herman H., Inc.	Brooklyn, N.Y.
83385	Central Screw Co.	Chicago, Ill.
83501	Gavitt Wire and Cable Co. Div. of Amerace Corp.	Brookfield, Mass.
83594	Burroughs Corp. Electronic Tube Div.	Plainfield, N.J.
83740	Union Carbide Corp. Consumer Prod. Div.	New York, N.Y.
83777	Model Eng. and Mfg., Inc.	Huntington, Ind.
83821	Loyd Scruggs Co.	Festus, Mo.
83942	Aeronautical Inst. & Radio Co.	Lodi, N.J.
84171	Arco Electronics Inc.	Great Neck, N.Y.
84396	A.J. Glesener Co., Inc.	San Francisco, Calif.
84411	TRW Capacitor Div.	Ogallala, Neb.
84970	Sarkes Tarzian, Inc.	Bloomington, Ind.
85454	Boonton Molding Company	Boonton, N.J.

From: FSC. Handbook Supplements
H4-1 Dated JULY 1965
H4-2 Dated NOV 1962

APPENDIX 5.1
CODE LIST OF MANUFACTURERS
(Continued)

Code No.	Manufacturer	Address
85471	A.B. Boyd Co.	San Francisco, Calif.
85474	R.M. Bracamonte & Co.	San Francisco, Calif.
85660	Koiled Kords, Inc.	Hamden, Conn.
85911	Seamless Rubber Co.	Chicago, Ill.
86197	Clifton Precision Products Co., Inc.	Clifton Heights, Pa.
86579	Precision Rubber Products Corp.	Dayton, Ohio
86684	Radio Corp. of America, Electronic Comp. & Devices Div.	Harrison, N.J.
87034	Marco Industries	Anaheim, Calif.
87216	Philco Corporation (Lansdale Division)	Lansdale, Pa.
87473	Western Fibrous Glass Products Co.	San Francisco, Calif.
87664	Van Waters & Rogers Inc.	San Francisco, Calif.
87930	Tower Mfg. Corp.	Providence, R.I.
88140	Cutler-Hammer, Inc.	Lincoln, Ill.
88220	Gould-National Batteries, Inc.	St. Paul, Minn.
88421	Federal Telephone & Radio Corp.	Clifton, N.J.
88698	General Mills, Inc.	Buffalo, N.Y.
89231	Graybar Electric Co.	Oakland, Calif.
89665	United Transformer Co.	Chicago, Ill.
90179	US Rubber Co., Consumer Ind. & Plastics Prod. Div.	Passaic, N.J.
90970	Bearing Engineering Co.	San Francisco, Calif.
91260	Connor Spring Mfg. Co.	San Francisco, Calif.
91345	Miller Dial & Nameplate Co.	El Monte, Calif.
91418	Radio Materials Co.	Chicago, Ill.
91506	Augat Inc.	Attleboro, Mass.
91637	Dale Electronics, Inc.	Columbus, Nebr.
91662	Elco Corp.	Willow Grove, Pa.
91737	Gremar Mfg. Co., Inc.	Wakefield, Mass.
91827	K F Development Co.	Redwood City, Calif.
91929	Honeywell Inc., Micro Switch Div.	Freeport, Ill.
91961	Nahm-Bros. Spring Co.	Oakland, Calif.
92180	Tru-Connector Corp.	Peabody, Mass.
92367	Elgeet Optical Co. Inc.	Rochester, N.Y.
92196	Universal Industries, Inc.	City of Industry, Calif.
92607	Tensolite Insulated Wire Co., Inc.	Tarrytown, N.Y.
93332	Sylvania Electric Prod. Inc. Semiconductor Div.	Woburn, Mass.
93369	Robbins and Myers, Inc.	New York, N.Y.
93410	Stevens Mfg. Co., Inc.	Mansfield, Ohio
93929	G.V. Controls	Livingston, N.J.
94137	General Cable Corp.	Bayonne, N.J.
94144	Raytheon Co., Comp. Div., Ind. Comp. Operations	Quincy, Mass.
94148	Scientific Electronics Products, Inc.	Loveland, Colo.
94154	Tung-Sol Electric, Inc.	Newark, N.J.
94197	Curtiss-Wright Corp. Electronics Div.	East Paterson, N.J.
94222	South Chester Corp.	Chester, Pa.
94310	Tru-Ohm Products Memcor Components Div.	Huntington, Ind.
94330	Wire Cloth Products, Inc.	Bellwood, Ill.
94682	Worcester Pressed Aluminum Corp.	Worcester, Mass.
94696	Magnecraft Electric Co.	Chicago, Ill.
95023	George A. Philbrick Researchers, Inc.	Boston, Mass.
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95275	Vitramon, Inc.	Bridgeport, Conn.
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96067	Huggins Laboratories	Sunnyvale, Calif.
96095	Hi-Q Div. of Aerovox Corp.	Olean, N.Y.
96256	Thordarson-Meissner Inc.	Mt. Carmel, Ill.
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96341	Microwave Associates, Inc.	Burlington, Mass.
96501	Excel Transformer Co.	Oakland, Calif.
97464	Industrial Retaining Ring Co.	Irvington, N.J.
97539	Automatic & Precision Mfg.	Englewood, N.J.
97979	Reon Resistor Corp.	Yonkers, N.Y.
97983	Litton System Inc., Adler-Westrex Commun. Div.	New Rochelle, N.Y.
98141	R-Troncis, Inc.	Jamaica, N.Y.
98159	Rubber Teck, Inc.	Gardena, Calif.
98220	Hewlett-Packard Co., Moseley Div.	Pasadena, Calif.
98278	Microdot, Inc.	So. Pasadena, Calif.
98291	Sealectro Corp.	Mamaroneck, N.Y.
98376	Zero Mfg. Co.	Burbank, Calif.
98731	General Mills Inc., Electronics Div.	Minneapolis, Minn.
98734	Paeco Div. of Hewlett-Packard Co.	Palo Alto, Calif.
98821	North Hills Electronics, Inc.	Glen Cove, N.Y.
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99313	Varian Associates	Palo Alto, Calif.
99378	Atlee Corp.	Winchester, Mass.
99515	Marshall Ind. Elect. Products Div.	San Marino, Calif.
99707	Control Switch Division, Controls Co. of America	El Segundo, Calif.
99800	Delevan Electronics Corp.	East Aurora, N.Y.
99848	Wilco Corporation	Indianapolis, Ind.
99934	Renbrandt, Inc.	Boston, Mass.
99942	Hoffman Electronics Corp. Semiconductor Div.	El Monte, Calif.
99957	Technology Instrument Corp. of Calif.	Newbury Park, Calif.

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Code No.	Manufacturer	Address
0000F	Malco Tool and Die	Los Angeles, Calif.
0000M	Western Coil Div. of Automatic Ind., Inc.	Redwood City, Calif.
0000Z	Willow Leather Products Corp.	Newark, N.J.
000AA	British Radio Electronics Ltd.	Washington, D.C.
000AB	ETA	England
000BB	Precision Instrument Components Co.	Van Nuys, Calif.
000MM	Rubber Eng. & Development	Hayward, Calif.
000NN	A "N" D Mfg. Co.	San Jose, Calif.
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000WW	California Eastern Lab.	Burlington, Calif.
000YY	S.K. Smith Co.	Los Angeles, Calif.

VOLTAGE-TO-FREQUENCY CONVERTER

model 2212A

BACKDATING MANUAL SUPPLEMENT

MANUAL IDENTIFICATION

Manual Serial Prefixed: 714
Manual Printed: May 1967
Manual Part Number: 02212-9036

SUPPLEMENT DESCRIPTION

The purpose of this supplement is to correct manual errors (Errata) and to adapt the manual to instruments having serial prefixes listed in the table below. Enter the new information (or the Change Number, if more convenient) into the appropriate places in the manual.

Instrument Serial	Changes
644-	1
607-	1, 2
603-	1, 2, 3

CHANGE 1

Section I, page 1-3 and Section III, page 2-9.
Replace Accuracy Tabulations with the following.

	% rdg All Ranges	% fs RANGE .01v	.03v ①	.1v	.3v ①	1v
STABILITY (8 hours at calibration temp.)						
Scale Factor	.02②					
Zero Drift (not range-dependent)		.005	.005	.005	.005	.005
Zero Drift (5µv rti)⑤		.05⑤	.016⑤	.005⑤	.002⑤	.001⑤
LINEARITY (Referred to straight line through zero and full scale.)		.01③	.01③	.01③	.01③	.01③
TOTALS	.02②	.065	.031	.02	.017	.016

① HP-2212A-M1.
② On calibrated range — other ranges are ±.02% rdg with respect to calibrated range.
③ Or .01% rdg for readings between full scale and 150% of full scale.

	% rdg All Ranges	.01v	.03v ①	.1v	.3v ①	1v
TEMP. COEFFICIENT PER °C						
Scale Factor (10 to 40°C)	.004④					
Zero Drift (0 - 55°C) (not range-dependent)		.001	.001	.001	.001	.001
Zero Drift (0 - 55°C) (1µv rti)		.01	.0033	.001	.00033	.0001
Zero Drift (0 - 55°C) (.5 namp rti x 1000Ω)		.005	.0017	.0005	.00017	.0001
TOTALS	.004④	.016	.006	.0025	.0015	.0012

④ Scale factor temperature coefficient is .01% rdg from 0 to 10°C and 40 to 55°C.
⑤ During operation in free air (without forced air ventilation through the 2212 from rear to front at 1 cfm, minimum) rti zero drift can be up to three times the figures listed.

	% rdg All Ranges	% fs RANGE .01v	.03v ①	.1v	.3v ①	1v
STABILITY (8 hours at calibration temp.)						
Scale Factor	.02②					
Zero Drift (not range-dependent)		.005	.005	.005	.005	.005
Zero Drift (5µv rti)⑤		.05⑤	.016⑤	.005⑤	.002⑤	.001⑤
LINEARITY (Referred to straight line through zero and full scale.)		.01③	.01③	.01③	.01③	.01③
TOTALS	.02②	.065	.031	.02	.017	.016

① HP-2212A-M1.
② On calibrated range — other ranges are ±.02% rdg with respect to calibrated range.
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	% rdg All Ranges	.01v	.03v ①	.1v	.3v ①	1v
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Zero Drift (0 - 55°C) (.5 namp rti x 1000Ω)		.005	.0017	.0005	.00017	.0001
TOTALS	.004④	.016	.006	.0025	.0015	.0012

④ Scale factor temperature coefficient is .01% rdg from 0 to 10°C and 40 to 55°C.
⑤ During operation in free air (without forced air ventilation through the 2212 from rear to front at 1 cfm, minimum) rti zero drift can be up to three times the figures listed.

Section IV, page 4-11, paragraphs 4-7 and 4-10, delete references to the isothermal cover.

Section V, page 5-4, Table 5-1, delete Cover, Isothermal HP Stock No. 5000-5709.

Section V, page 5-6, Figure 5-3, delete dotted lines showing placement of isothermal cover on PREAMPLIFIER ASSEMBLY A2

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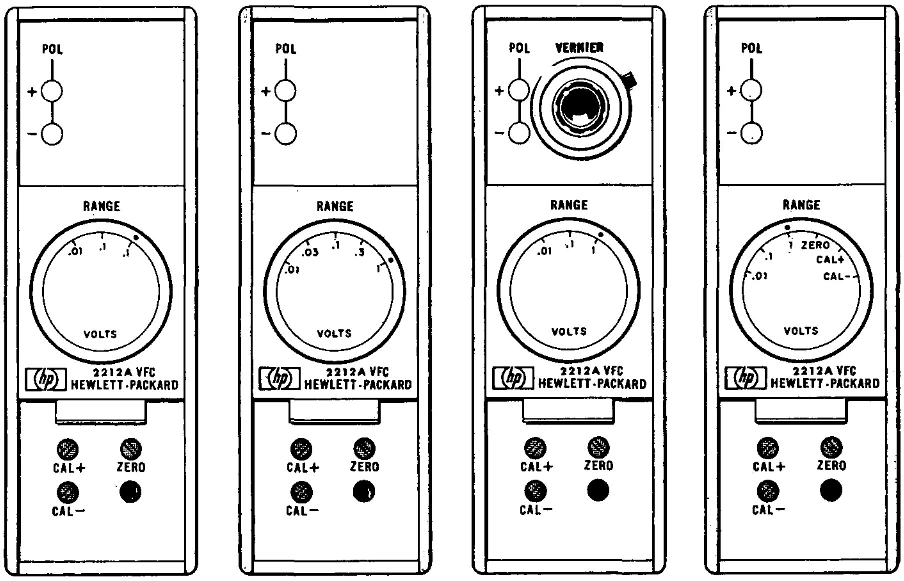
CHANGE 2

Sections I, III, IV, and V. In all illustrations, the front panels should be as shown below.



STD 2212A 2212A-M1 2212A-M2 2212A-M4

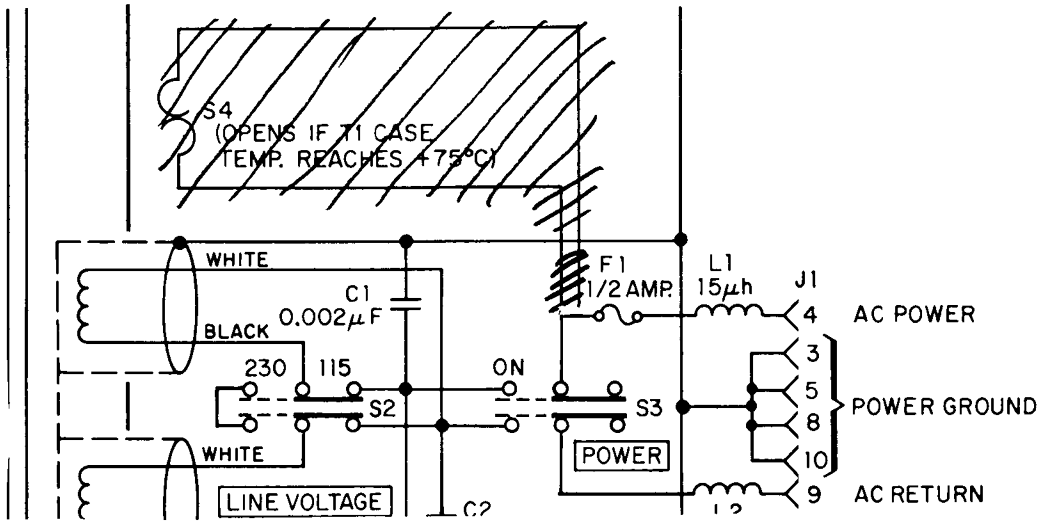
Section II, page 2-1, paragraph 2-8:
change last 5 lines of paragraph to read: Case and slowly push the 2212A into the case with the bar beneath the RANGE switch squeezed upward. Releasing the bar engages a detent that locks the 2212A in the case. To assure correct ventilation of all instruments in the case, install 12504A Blank Panels to cover any vacant spaces.

Section V, page 5-3, paragraph 5-4;
Page 5-4, Table 5-1; Pages 5-8, Table 5-3; and Page 5-9, Table 5-3 (Cont'd.): change HP Stock No. of A3 from 02212-6014 to 02212-6012 and Stock No. of A3M3 from 02212-6015 to 02212-6013.

CHANGE 3

Section V, Pages 5-3 and 5-4, Figure 5-1: delete S4 and related information and connect F1 to S3 as shown on the following page.

CHANGE 3 (Cont'd.)



Section V, page 5-4, Table 5-1:
delete S4, Switch, Thermal cutout, 75°C, HP Stock No. 5080-6574.

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Cable: COOPERATOR Dacca

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Cable: AUTOPHONE Cape Town

F. H. Flanter & Co. (Pty.), Ltd.
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614 Sukhumvit Road
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Landis Brothers and Company, Inc.
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Cable: LANBROCOMP Saigon

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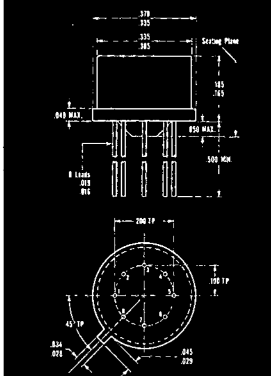
[redacted]

GENERAL DESCRIPTION - The μA702A is a complete DC amplifier constructed on a single silicon chip, using the Fairchild Planar epitaxial process. It is intended for use as an operational amplifier in high speed analog computers, as a precision instrumentation amplifier, or in other applications requiring a feedback amplifier useful from DC to 30 MHz.

ABSOLUTE MAXIMUM RATINGS

Voltage Between V^+ and V^- Terminals	21 V
Peak Output Current	50 mA
Differential Input Voltage	± 5.0 V
Input Voltage	+1.5 V to -6.0 V
Internal Power Dissipation	
TO-5 (Note 1)	300 mW
Flat Package (Note 2)	200 mW
Operating Temperature Range	-55°C to +125°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 60 sec.)	300°C

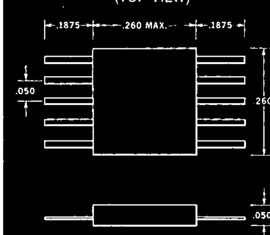
PHYSICAL DIMENSIONS
(SIMILAR TO TO-5)



NOTES: Dimensions as per latest J-10 committee
All dimensions in inches
Leads are gold-plated kovar
Package weight is 1.22 grams

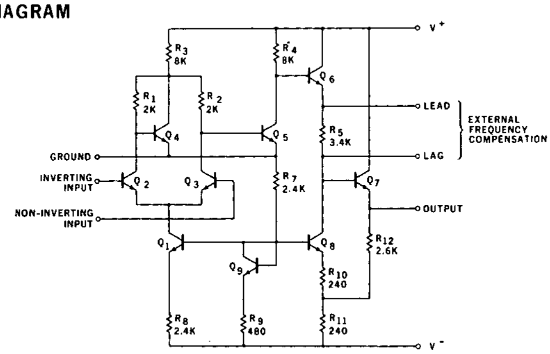
ORDER PART NO.
U5B771231X

PHYSICAL DIMENSIONS
(TYPICAL FLAT PACKAGE)
(TOP VIEW)

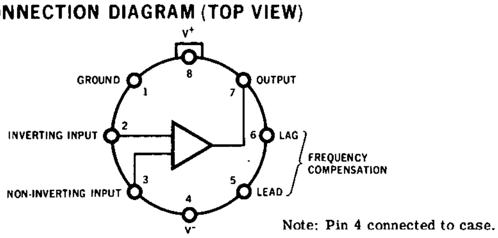


ORDER PART NO.
U3H771231X

SCHEMATIC DIAGRAM

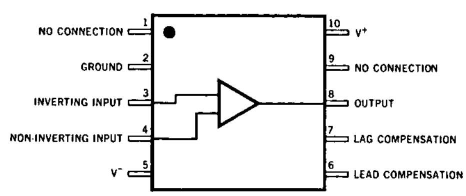


TO-5 CONNECTION DIAGRAM (TOP VIEW)



Note: Pin 4 connected to case.

FLAT PACKAGE CONNECTION DIAGRAM (TOP VIEW)



Notes on page 2

[redacted]

FAIRCHILD LINEAR INTEGRATED CIRCUITS μA702A

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise specified)

Parameter (see definitions)	Conditions	V^+ = 12.0 V, V^- = -6.0 V Min.	Typ.	Max.	V^+ = 6.0 V, V^- = -3.0 V Min.	Typ.	Max.	Units
Input Offset Voltage	$R_S \leq 2$ K		2.0	5.0		2.0	5.0	mV
Input Offset Current			0.7	2.0		0.5	2.0	μA
Input Bias Current			4.0	10		2.5	7.0	μA
Input Resistance		8.0	25		12	40		KΩ
Input Voltage Range		-4.0		+0.5	-1.5		+0.5	V
Common Mode Rejection Ratio	$R_S \leq 2$ K, $f \leq 1$ KHz	70	80		70	80		dB
Supply Voltage Rejection Ratio	$R_S \leq 2$ K; V^+ = 12 V, V^- = -6.0 V to V^+ = 6.0 V, V^- = -3.0 V		60	300		60	300	μV/V
Large-Signal Voltage Gain	$R_L \geq 100$ K, $V_{out} = \pm 5.0$ V	1400	2600					
	$R_L \geq 100$ K, $V_{out} = \pm 2.5$ V				380	700		
Output Voltage Swing	$R_L \geq 100$ K	±5.0	±5.3		±2.5	±2.7		V
Output Resistance			200	500		300	700	Ω
Power Consumption	$V_{out} = 0$		70	120		17	35	mW
Transient Response (unity-gain)	$C_1 = 0.01$ μf, $R_1 = 20\,\Omega$, V_{in} = 10 mV, $R_L \geq 100$ K							
Risetime			25	120				ns
Overshoot	$C_L \leq 100$ pf		10	50				%
Transient Response (x100 Gain)	$C_3 = 50$ pf, $V_{in} = 1$ mV, $R_L \geq 100$ K							
Risetime			10	30				ns
Overshoot			20	40				%
The following specifications apply for $-55°C \leq T_A \leq +125°C$:								
Input Offset Voltage	$R_S \leq 2$ K			6.0			6.0	mV
Average Temperature Coefficient of Input Offset Voltage	$R_S = 50\,\Omega$		5			5		μV/°C
	$R_S = 2$ K		10			10		μV/°C
Input Offset Current				3.0			3.0	μA
Input Bias Current				20			14	μA
Input Resistance		3.0			4.0			KΩ
Large-Signal Voltage Gain	$R_L \geq 100$ K, $V_{out} = \pm 5.0$ V	1000						

NOTES:

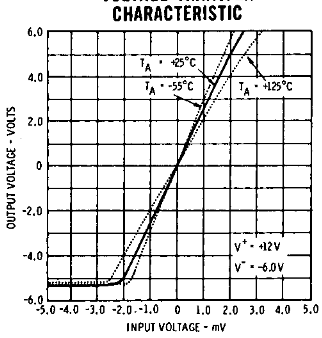
(1) Rating applies for case temperatures to +125°C; derate linearly at 5.6 mW/°C for ambient temperatures above +105°C.

(2) Derate linearly at 4.4 mW/°C for case temperatures above +115°C; derate linearly at 3.3 mW/°C for ambient temperatures above +100°C.

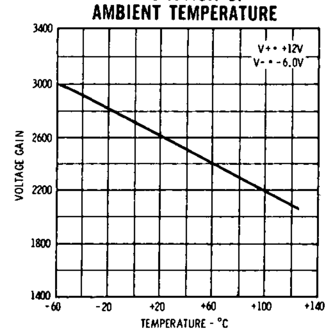
(3) Refer to Fairchild APP-117 for further details.

TYPICAL PERFORMANCE CURVES

VOLTAGE TRANSFER CHARACTERISTIC



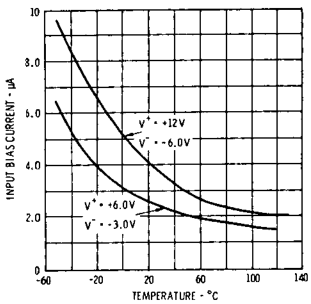
VOLTAGE GAIN AS A FUNCTION OF AMBIENT TEMPERATURE



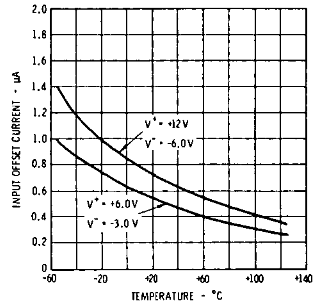
FAIRCHILD LINEAR INTEGRATED CIRCUITS μA702A

TYPICAL PERFORMANCE CURVES

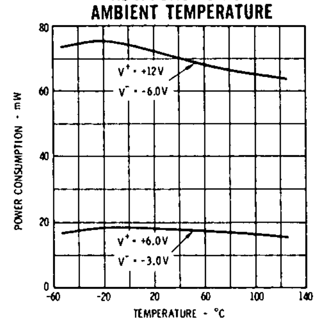
INPUT BIAS CURRENT AS A FUNCTION OF AMBIENT TEMPERATURE



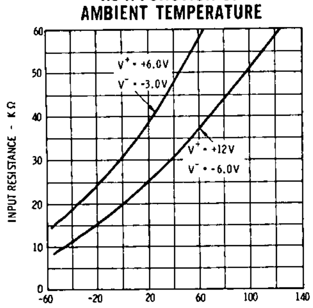
INPUT OFFSET CURRENT AS A FUNCTION OF AMBIENT TEMPERATURE



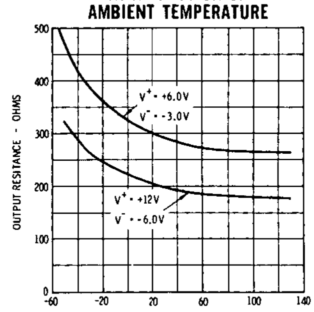
POWER CONSUMPTION AS A FUNCTION OF AMBIENT TEMPERATURE



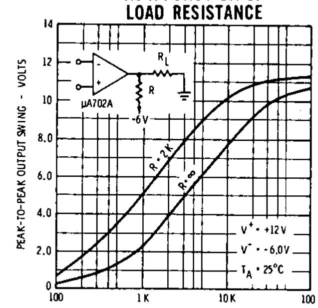
INPUT RESISTANCE AS A FUNCTION OF AMBIENT TEMPERATURE



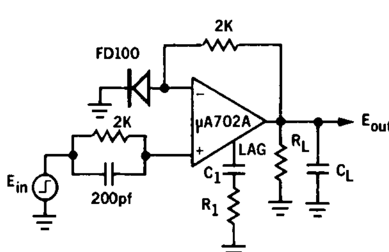
OUTPUT RESISTANCE AS A FUNCTION OF AMBIENT TEMPERATURE



OUTPUT VOLTAGE SWING AS A FUNCTION OF LOAD RESISTANCE

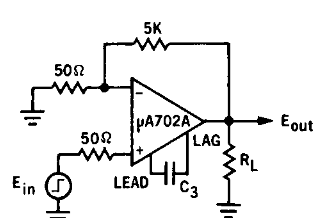


TRANSIENT RESPONSE TEST CIRCUITS



UNITY-GAIN AMPLIFIER

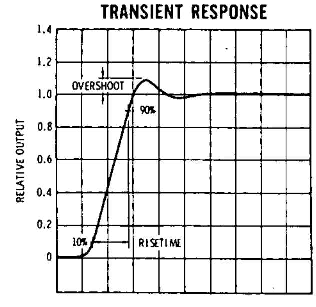
(LAG COMPENSATION)



X100 AMPLIFIER

(LEAD COMPENSATION)

TRANSIENT RESPONSE



DEFINITION OF TERMS

INPUT OFFSET VOLTAGE - That voltage which must be applied between the input terminals to obtain zero output voltage. The input offset voltage may also be defined for the case where two equal resistances are inserted in series with the input leads.

INPUT OFFSET CURRENT - The difference in the currents into the two input terminals with the output at zero volts.

INPUT RESISTANCE - The resistance looking into either input terminal with the other grounded.

INPUT BIAS CURRENT - The average of the two input currents.

INPUT VOLTAGE RANGE - The range of voltage which, if exceeded on either input terminal, could cause the amplifier to cease functioning properly.

INPUT COMMON MODE REJECTION RATIO - The ratio of the input voltage range to the maximum change in input offset voltage over this range.

SUPPLY VOLTAGE REJECTION RATIO - The ratio of the change in input offset voltage to the change in supply voltage producing it.

LARGE-SIGNAL VOLTAGE GAIN - The ratio of the maximum output voltage swing with load to the change in input voltage required to drive the output from zero to this voltage.

OUTPUT VOLTAGE SWING - The peak output swing, referred to zero, that can be obtained without clipping.

OUTPUT RESISTANCE - The resistance seen looking into the output terminal with the output at null. This parameter is defined only under small signal conditions at frequencies above a few hundred cycles to eliminate the influence of drift and thermal feedback.

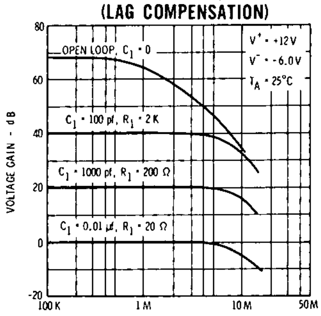
POWER CONSUMPTION - The DC power required to operate the amplifier with the output at zero and with no load current.

TRANSIENT RESPONSE - The closed-loop step-function response of the amplifier under small-signal conditions.

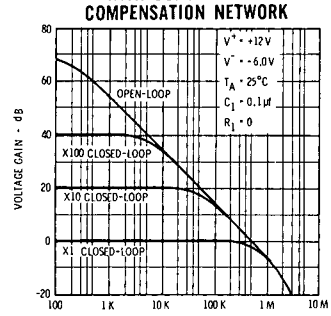
PEAK OUTPUT CURRENT - The maximum current that may flow in the output load without causing damage to the unit.

TYPICAL PERFORMANCE CURVES

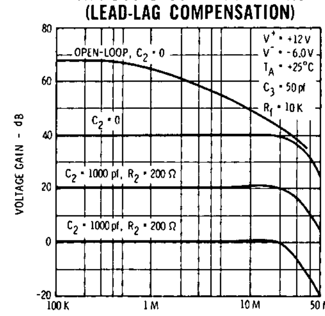
FREQUENCY RESPONSE FOR VARIOUS CLOSED-LOOP GAINS (LAG COMPENSATION)



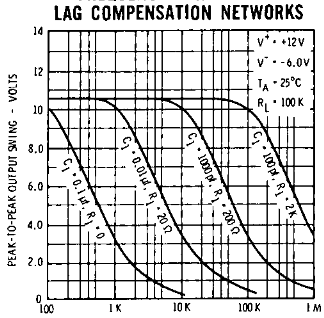
FREQUENCY RESPONSE WITH CONSERVATIVE COMPENSATION NETWORK



FREQUENCY RESPONSE FOR VARIOUS CLOSED-LOOP GAINS (LEAD-LAG COMPENSATION)

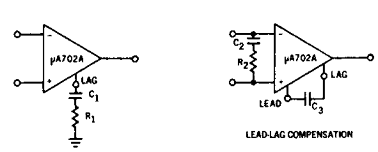


OUTPUT VOLTAGE SWING AS A FUNCTION OF FREQUENCY FOR VARIOUS LAG COMPENSATION NETWORKS

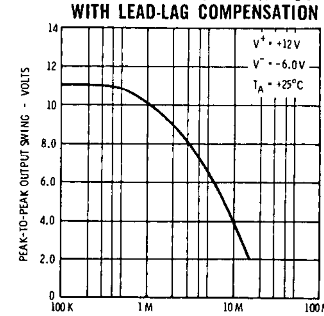


FREQUENCY COMPENSATION CIRCUITS

(see note 3 on page 2)



OUTPUT VOLTAGE SWING AS A FUNCTION OF FREQUENCY WITH LEAD-LAG COMPENSATION



APPENDIX I

GLOSSARY

OPERATIONAL AMPLIFIER

Originally the term "Operational Amplifier" was used in the computing field to describe amplifiers that performed various mathematical operations. The application of negative feedback around a high gain dc amplifier produces a circuit with a precise gain characteristic that depends only on the feedback used. By the proper selection of feedback components (the network), the amplifier circuit can be used to add, subtract, average, integrate, differentiate, etc.

The amplifier acts to enforce a null in the feedback network at the input terminals of the amplifier, thereby allowing the network characteristic to dominate. In the PSRS, a Zeltex Model 143 is used to drive the thyrite shaping network. The 143 is a solid-state, chopper stabilized model supplied in open loop form. It is necessary to provide feedback components around the amplifier to have it function in the desired manner, as is done in the PSRS.

For further reading:

1. Zeltex brochure, Appendix F.

2. Philbrick Researches, Inc., "Applications Manual for Computing Amplifiers for Modelling Measuring Manipulating and Much Else", Nimrod Press, 1966.

3. Burr-Brown Research Corporation. "Handbook of Operational Amplifier Applications", 1963.

4. Kepco, Inc., Paul Birman, "Power Supply Handbook", pp. 31-44, Flushing, N.Y., 1965.

NOISE PICKUP, RFI/EMI, STATIC, CROSS-TALK, EMC

These names are equivalent; the choice depends upon one's inclination.
RFI/EMI = Radiofrequency Interference/Electromagnetic Interference
EMC = Electromagnetic Compatibility

Discussion:
Electrical interference from neighboring powerful electrical devices can cloud or obliterate the desired signal in sensitive apparatus. The usual accelerator environment is particularly noisy. Nevertheless all pickup can be eliminated by understanding the problem and acting accordingly, since the undesired effect is non-fundamental. Noise pickup therefore should be carefully distinguished from two other types of noise which are fundamental: Shot noise and thermal noise.

Shot noise in the usual flow of current I depends on the quantized nature of electric charge and the statistics of random numbers. The mean shot noise in current is $\overline{I^2} = 2eI\Delta f$ where Δf is the bandwidth, I the current and e the electronic charge.

Thermal noise depends on the thermodynamic fluctuations in the ceaseless tendency toward equipartition of energy (1/2 kT/degree of freedom). In this case thermal and electrical energy are coupled. A resistor is the mutual element effecting the coupling; across a resistor a thermal noise emf $\overline{E^2} = 4kTR\Delta f$ appears. At room temperature, $\overline{E^2} \approx 1.6 \times 10^{-20} R\Delta f$.

Returning to man-made noise, which may be completely excluded if desired, it is well to list some sources. Below 1000 MHz, automotive ignition systems, high-voltage transmission lines and generating equipment, gaseous discharge devices, such as spark chambers, fluorescent lights, heliarc welding equipment, diathermy, rf systems, arcing, and switching gear such as ignitrons, thyratrons and SCR's are the principal sources of man-made noise. Power lines are capable of supporting long-distance, low attenuation propagation of high-frequency transients because of their ability to function as either coaxial guides or as a single line above ground. The consolidated effect of these noise sources and propagation phenomena is to produce a radio-noise ambient that is appreciably higher than cosmic and atmospheric noise levels throughout the range from less than 10 kHz to 700 MHz.

For further reading:

1. M. R. Pelissier, "Les Perturbatious Radiophoniques Emises par les Lignes a Tres Haute Teusion", Bulletin la Society Francais Elecriciens, pp. 409-418, July 1953.

2. E. N. Skomal, "Distribution and Frequency Dependence of Unintentionally Generated Man-Made VHF/UHF noise in Metropoliton Areas, Part II, Theory," IEEE Transactions on Electromagnetic Compatibility, December 1965.

3. A. P. Barsis and M. J. Miles, "Cumulative Distributions of VHF Field Strength Over Irregular Terrain Using Low Antenna Heights," NBS Report 8891, October 1965.

4. W. D. Hayter, "High Voltage Nanosecond Duration Power Line Transients," Tenth Tri-Service Conference on Electromagnetic Compatibility, November 1964.

WAVEGUIDE BEYOND CUTOFF ATTENUATOR

For propagation of energy at microwave frequencies through a hollow metal tube, several different types of waves are available, namely

TE waves - E vector always perpendicular to the direction of propagation. This means that $E_z \equiv 0$, where z is the direction of propagation.

TM waves - H vector always perpendicular to the direction of propagation, ∴ $H_z \equiv 0$.
TEM waves - Both E vector and H vector are always perpendicular to the direction of propagation. This means that $E_z = H_z = 0$ where z is the direction of propagation. This is the mode propagated in coaxial and oper-wire lines. It cannot be propagated in a waveguide.

The solutions for the field configurations in waveguides are characterized by the integers m and n which can take on separate values from 0 or 1 to infinity. Only a limited number of these different m, n modes can be propagated, depending on the dimensions of the guide and the frequency of excitation. For each mode there is a definite lower limit or cutoff frequency below which the wave is not propagated. For any mode in a rectangular guide of dimensions x_o and y_o, propagation takes place when

$$\omega^2 \mu\varepsilon > \left(\frac{m\pi}{x_o}\right)^2 + \left(\frac{n\pi}{y_o}\right)^2 .$$

When a waveguide is used at a wavelength greater than the cutoff wavelength, there is no real propagation and the waves are attenuated exponentially with distance.

In the PSRS, an aperture of variable cross-section but always below the cutoff dimension is provided between the oscillator resonant circuit and the input circuit. An adjustable amount of energy is thus permitted to leak from the oscillator to the input circuit via an attenuated $TM_{o,1}$ wave in a circular guide. One may also speak of the attenuator as a mutual capacity type of attenuator. The justification for this nomenclature would be that the attenuator dimensions are much less than the rf wavelength, hence the attenuator parts may be considered as lumped. Nevertheless the wave point of view is preferable to the circuit point of view in giving a broader understanding of the coupling of wave energy.

The choice of this attenuator is based on the need to minimize extraneous noise. A resistive attenuator, for example, would unavoidably add thermal noise. In addition, the waveguide beyond cutoff attenuator is mechanically simple and rugged.

For further reading:

1. Reference Data for Radio Engineers, 4th edition, International Telephone and Telgraph Corporation, New York, 1956.

2. Fundamentals of Electric Waves H. H. Skilling, John Wiley and Sons, New York 1942.

THYRITE

A General Electric trade name for a non-linear resistance material in which current I varies as voltage E to the nth power. The exponent n is typically

3.5, but may be chosen between 2 and 7 by varying the fabrication process. Thyrite is made by pressing silicon carbide with a suitable ceramic binder at high pressure followed by a firing operation at high temperature (approximately 1200°C). Electrical contact is made by a coating of sprayed metal on the surfaces. The reason for the non-linearity of silicon carbide "varistor" characteristics is the rectification occurring at the places inside the element where the granules touch each other. Carbide granules are believed to have n and p regions which are brought out by the heat treatment. A large number of rectifiers connected together in a random array of series and parallel connections will give a network composite characteristic similar to that observed. A simple hook-up of two rectifiers in parallel, back to back, will reproduce the characteristic, though at low voltage.

For further reading:

1. McEachron, K. B., "Thyrite, A New Material for Lightning Arrestors," Transactions of the A.I.E.E., 1930, Vol.49, p.410.

2. Grisdale, R.O., "Silicon Carbide Varistors," Bell Laboratories Record, 1940, Vol. 19, p. 46.

3. Frosch, C. J., "Improved Silicon Carbide Varistors," Bell Laboratories Record, 1954, Vol. 32, p. 336.

4. Dienel, H. F., "Silicon Carbide Varistors: Properties and Construction," Bell Laboratories Record, 1956, Vol. 34, p. 407.

VARISTOR - see THYRITE

VARACTOR, DIODE CAPACITOR, VARICAP, EPICAP

The Varactor was named originally by M. E. Hines, then of Bell Labs. Varicap (Hughes) and Epicap (Motorola) are trade names.

Varactors are semiconductor PN junction diodes which exhibit a useful voltage-dependent junction capacitance. Most varactor diodes are made from silicon, gallium-arsenide or germanium.

Silicon diffused junction varactors obey the following relationship:

$$C_t = C_p + C_j = C_p + \frac{C_{jo}}{\left[1 + \frac{V_{bias}}{\phi}\right]^n}$$

C_t = total capacitance of varactor

C_p = package capacitance

C_j = junction capacitance

C_{jo} = junction capacitance at zero bias

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NVERSE VOLTS	CAPACITANCE IN PF	LOG(10)(VOLTAGE)	LOG(10)(CAPACITANCE)
1.00	83.40	0.00	1.92
1.25	78.58	0.10	1.90
1.50	74.60	0.18	1.87
1.75	71.20	0.24	1.85
2.00	68.25	0.30	1.83
2.33	64.87	0.37	1.81
2.67	62.02	0.43	1.79
3.00	59.49	0.48	1.77
3.50	56.24	0.54	1.75
4.00	53.65	0.60	1.73
5.00	49.15	0.70	1.69
6.00	45.73	0.78	1.66
7.00	42.96	0.85	1.63
8.00	40.63	0.90	1.61
9.00	38.72	0.95	1.59
10.00	37.02	1.00	1.57
12.50	33.64	1.10	1.53
15.00	31.05	1.18	1.49
17.51	29.01	1.24	1.46
20.01	27.30	1.30	1.44
23.34	25.49	1.37	1.41
26.66	23.97	1.43	1.38
30.01	22.74	1.48	1.36
35.01	21.16	1.54	1.33
40.01	19.87	1.60	1.30
50.01	17.90	1.70	1.25
60.02	16.45	1.78	1.22

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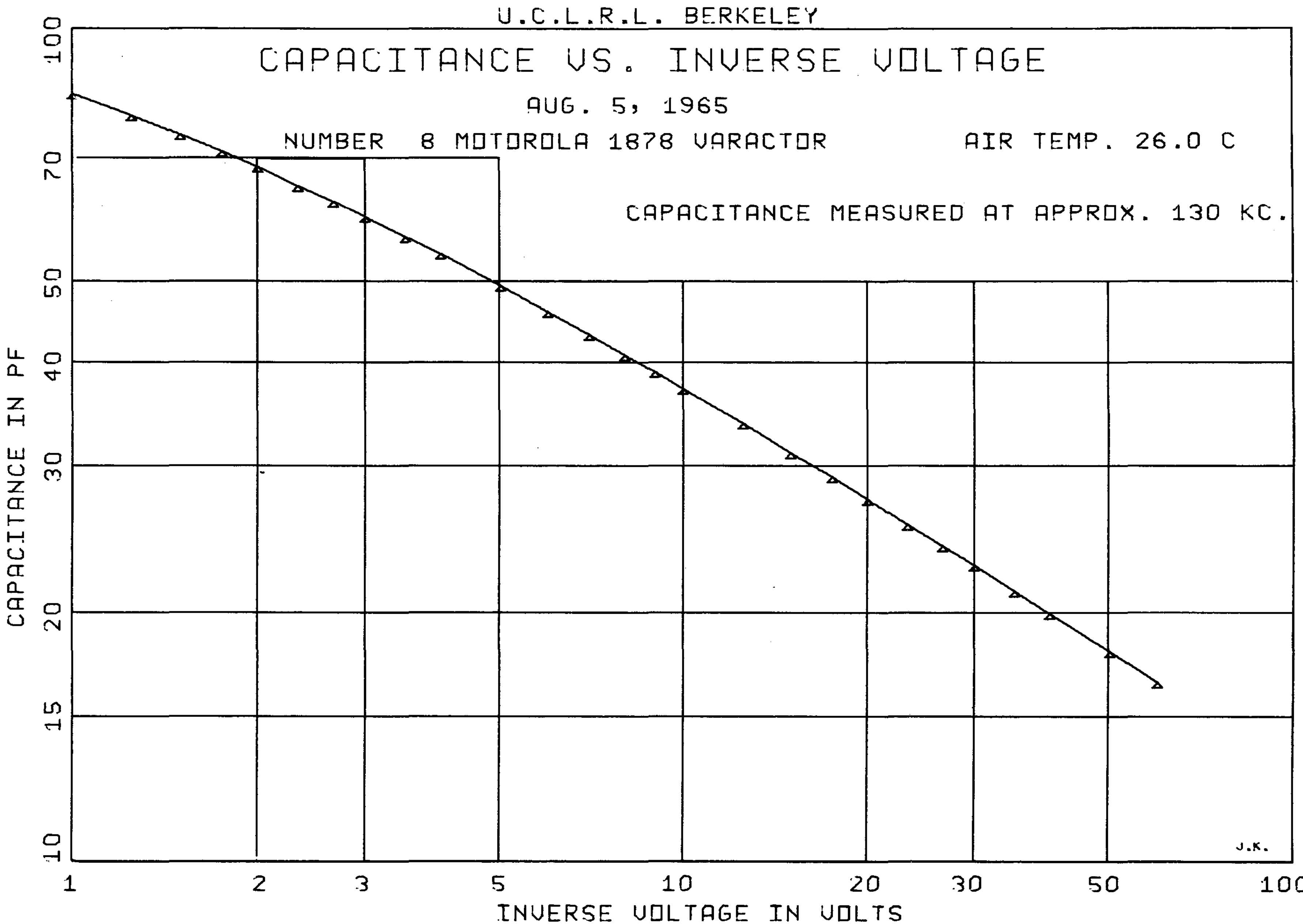
U.C.L.R.L. BERKELEY
CAPACITANCE VS. INVERSE VOLTAGE
AUG. 5, 1965
NUMBER 8 MOTOROLA 1878 VARACTOR
AIR TEMP. 26.0 C
CAPACITANCE MEASURED AT APPROX. 130 KC.
CAPACITANCE IN PF
INVERSE VOLTAGE IN VOLTS
100
70
50
40
30
20
15
10
1
2
3
5
10
20
30
50
100
J.K.

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V_{bias} = applied reverse bias

ϕ = contact potential, a function of the semiconductor and contact doping level

n = exponent of capacitance variation.

The value of ϕ is 0.5 to 0.7 volt for silicon and 1.1-1.2 volts for gallium arsenide. For abrupt (alloyed) junctions, n = 1/2; for graded (diffused) junctions, n = 1/3 ideally.

In actual devices, there is a small equivalent series resistance which wastes some power and prevents the varactor from being an ideal voltage-variable capacitor. The Q of the varactor is $1/\omega RC$, and is a function of voltage, as both R and C are voltage dependent.

It is worth noting that the PSRS uses varactors always combined in pairs; symmetry permits best utilization of the variable displacement current, which would otherwise have to flow through a series blocking capacitor. Such a blocking capacitor would be thoroughly undesirable because it would slow down the tuning rate needlessly. An additional point one may note from the circuit schematics is the use of a carefully positioned D.C. bias wire which intercepts zero net rf flux in the resonator. This principle also permits fast tuning rate becuase it makes cumbersome filter capacitors unnecessary on the varactor bias wire.

For further reading:

1. Paul Penfield, Jr. and Robert P. Rafuse, "Varactor Applications," MIT Press, Cambridge, Mass. 1962.

2. Varactor Handbook SM-2973 Sylvania, 1964.

3. Motorola Application Note 196, "Epicap Tuning of Resonance Circuits".

4. C-V Tabulation and Cal Comp Plot.

ZENER DIODE, BREAKDOWN DIODE, AVALANCHE DIODE (See also Microplasma)

The name derives from one of the possible mechanisms of breakdown suggested by Clarence Zener.

In all real diodes there is a limiting value of reverse voltage beyond which the reverse current increases greatly without significant increase of reverse voltage. The abrupt breakdown of silicon (and well-cooled germanium) types has a useful non-destructive range, which depends on reproducible electronic mechanisms. Such diodes are widely used as voltage regulators, and devices intended for this service are called Zener diodes or breakdown diodes.

There are two electronic breakdown mechanisms in the bulk semiconductor which can cause a voltage-saturated breakdown - Zener breakdown and avalanche breakdown. Zener breakdown is a direct disruption of interatomic bonds in the space-charge layer by very high electric fields (greater than 10^6 volts/cm), which produce mobile hole-electron pairs. It is the mechanism of breakdown in good crystalline insulators and it occurs in abrupt junctions between highly doped regions. Avalanche breakdown occurs when the acceleration of carriers in the space-charge region is great enough to cause ionizing collisions with atoms, thus producing mobile hole-electron pairs. Since avalanche multiplication can occur at electric fields appreciably lower than those required for Zener breakdown, avalanche breakdown will occur before the Zener voltage can be reached, except in diodes with very large impurity concentrations. Silicon voltage-regulator diodes which breakdown above 8 volts probably use the avalanche mechanism, whereas those which breakdown below 5 volts work by Zener breakdown. Both mechanisms can be present in the same diode. Note that the term Zener diode is often used without regard to the mechanism to identify a diode intended to operate at breakdown.

Zener diodes (unfortunately) generate noise internally as a result of the so-called microplasmas, q.v.

A particular case of avalanche breakdown important in cooled semiconductors is termed <u>impact ionization</u>. At low temperatures (4.2°K), most of the impurity doped semiconductors have their charge carriers "frozen out" so that their resistivities are extremely high. With the application of an electric field E above some critical Ec, the free carriers acquire sufficient energy to ionize neutral impurities, causing an abrupt change in conductivity (>5 orders of magnitude). The critical electric field is

$$Ec = \frac{V}{u}\,\frac{(2\Delta E-4)^{1/2}}{kT}$$

where V = longitudinal velocity of sound

u = mobility

ΔE = impurity ionization energy

k = Boltzmann's constant

Measurements on n=type germanium at 4.2°K have shown Ec to be in the relatively low range of 4-10 volts/cm.

For further reading:

1. W. W. Heinz and S. Okwit, "Low Level Microwave Limiting Utilizing Impact Ionization at 4.2°K," 1965 G-Mtt Symposium, submitted for publication in Proceedings of IEEE.

2. "Physical Electronics and Circuit Models of Transistors" P. E. Gray, D. DeWitt, A. R. Boothroyd, J. F. Gibbons; John Wiley and Sons, Inc. New York, 1964.

3. "Zener Voltage Regulator", Sarkes Tarzian Inc., Bloomington, Ind. Catalog No. 66-ZR-2.

4. "Avalanche Breakdown in Silicon", Phys. Rev., 94, 877-884, May 15, 1954.

5. "Internal Field Emission in Silicon Junctions", Phys. Rev., 106 418-426, May 1, 1957. Chynoweth, A. G. and K. G. McKay

Rectifier and Diode Index, see section entitled Silicon Zener Diodes

Motorola Semiconductor Products Inc., October 1, 1964, Phoenix, Arizona.

"Zener Diode Stability", W. Bostwick, LRL Livermore engineering note LEN 22081, January 12, 1966.

MICROPLASMAS

Avalanche Breakdown in PN junctions is generally localized within small regions, so-called microplasmas, having a diameter of 1μ or less. At the outset of breakdown each of these microplasmas shows random on-off fluctuations.

This behavior explains the observed excess noise of Zener diodes.

For further reading:

1. "Noise in Semiconductors and in Semiconductor Diodes", M. J. O. Strutt, Scientia Electrica, Vol. XII, 1966, pp. 1-31.

2. "Microplasma Interaction in Silicon P-N Junctions," Roland H. Haitz, Solid State Electronics, Vol.7, 1964, pp. 439-444.

3. "Effect of Dislocations on Breakdown in Silicon p-n Junctions," A. G. Chynoweth and G. L. Pearson, Journal of Applied Physics, Vol. 29, No. 7, July 1938, pp. 1103-1110.

4. "Uniform Silicon p-n Junctions. I. Broad Area Breakdown," R. L. Batdorf, A. G. Chynoweth, G. C. Dacey, and P.W. Fox, Journal of Applied Physics, Vol. 29, No. 7, July 1938, pp. 1153-1160.

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