

KH KROHN-HITE CORPORATION

Operating and Maintenance Manual

Ultra-Low Distortion RC Oscillator

1Hz to 110kHz

Model 4500

Figure 1. Model 4500 Ultra-Low Distortion Oscillator

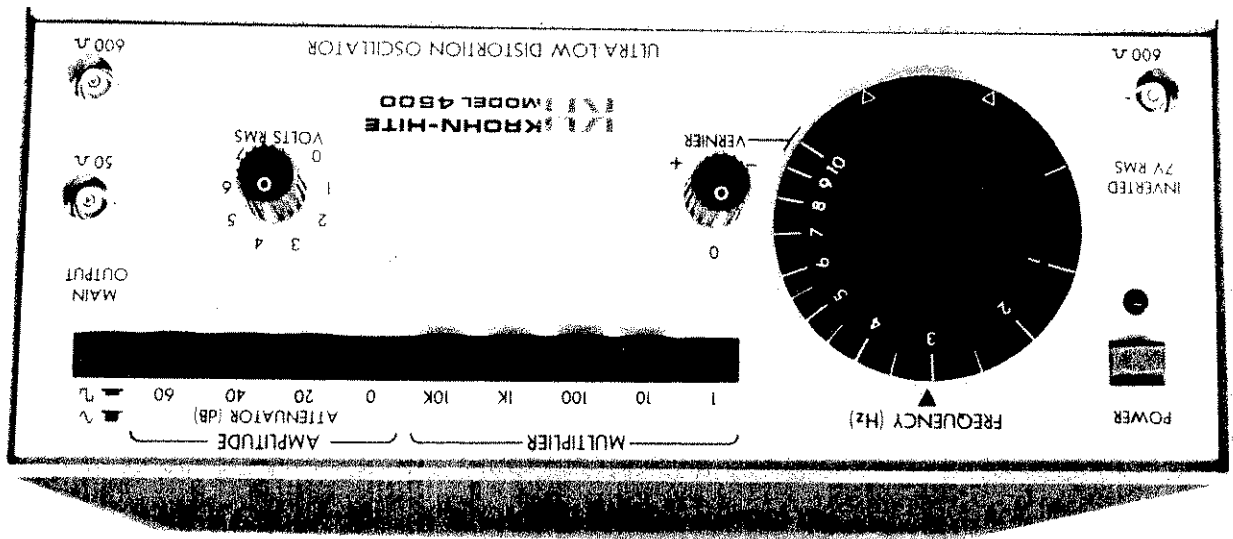


TABLE OF CONTENTS

PAGE SECTION

1	1.1 INTRODUCTION	1
1	1.2 SPECIFICATIONS	1
1	1.3 GENERAL SPECIFICATIONS	1
2	OPERATION	2.0
5	2.1 INTRODUCTION	2.0
5	2.2 POWER REQUIREMENTS	2.0
5	2.3 TURN-ON PROCEDURE	2.0
5	2.4 CONTROLS AND CONNECTORS	2.0
5	2.5 OPERATION	2.0
9	3.1 INTRODUCTION	3.0
9	3.2 PROCEDURE	3.0
13	4.1 THEORY OF OPERATION	4.0
13	4.2 AVC OPERATION	4.0
15	5.1 INTRODUCTION	5.0
15	5.2 CALIBRATION PROCEDURE	5.0
15	5.3 POWER SUPPLY	5.0
16	5.4 OUTPUT DC LEVEL ADJUSTMENTS	5.0
16	5.5 DIAL CALIBRATION	5.0
16	5.6 FREQUENCY CALIBRATION (XI, XIO, XIK)	5.0
16	5.7 FREQUENCY CALIBRATION (XIOK)	5.0
16	5.8 DIAL CONFORMITY CHECK	5.0
17	5.9 DISTORTION ADJUSTMENT	5.0
17	5.10 SQUAREWAVE CALIBRATION	5.0
19	6.1 INTRODUCTION	6.0
19	6.2 MAINTENANCE PROCEDURE	6.0
21	PARTS LIST, SCHEMATICS AND BOARD LAYOUTS	7.0
21	7.1 ORDERING INFORMATION	7.0
21	7.2 ORDERING UNLISTED PARTS	7.0

SECTION 1

GENERAL DESCRIPTION

1.1 INTRODUCTION

The Krohn-Hite Model 4500 is an ultra-low distortion, stable amplitude oscillator designed for test and measurement applications in the 1Hz to 100KHz frequency range.

The 4500 produces a virtually "distortion free" (<0.001%) sine wave for measuring harmonic distortion in audio pre-amplifier and power amplifier circuits. It also generates square waves with aberrations of less than 5% peak to peak amplitude. The exceptionally flat response of the 4500 (+0.05dB) eliminates the need to constantly monitor voltage levels during amplifier response tests.

The unit delivers up to 7 volts rms open circuit to MAIN and INVERTED OUTPUTS of 600 ohm impedance. A MAIN OUTPUT of 50 ohms impedance is also provided. A four position pushbutton ATTENUATOR calibrated in 20dB steps together with a 30dB vernier provides a total dynamic range of 90dB. Amplitude and frequency stability varies less than 0.001% with a 10% change in line voltage.

Simultaneous INVERTED (180°) OUTPUT is provided for synchronizing a scope or as an auxiliary output. The output is fixed at 7 volts rms from a 600 ohm source impedance.

Frequency tuning is provided by a 10:1 tuning dial and a 5 band decade multiplier.

When combined with Krohn-Hite's Ultra-Low Distortion Analyzer 6800A/6900 Series, it provides a complete distortion measurement system.

The Model 4500 has been carefully inspected, tested and aged before shipment to insure that it is working properly. If the oscillator appears to have been damaged in shipment, inform the freight carrier of the damage and notify Krohn-Hite or its nearest sales office immediately.

1.2 SPECIFICATIONS

FREQUENCY RANGE: 1Hz to 100Hz.

FREQUENCY CONTROL: Five pushbuttons of decade multiplication with an infinite resolution single turn dial calibrated in Hz from 1 to 10 provides continuous frequency coverage. Also, a vernier covering +5% of the frequency setting is provided for intricate adjustments.

FREQUENCY ACCURACY: +2% of setting calibrated at 3 dial settings (1, 3, 10).

FREQUENCY STABILITY:

vs Time: +0.002% in 1 minute or less; 0.01% in 1 hour or less.

vs Temperature: 0.05%/°C.

vs Line: >0.001% for 10% change in line voltage.

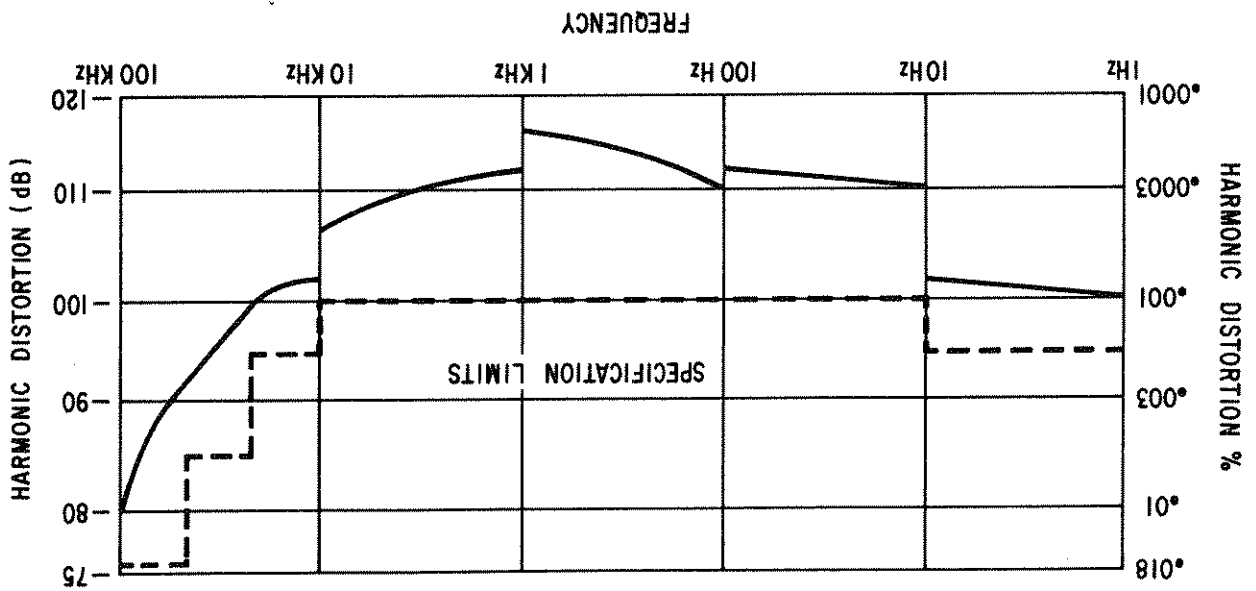


Figure 2. Typical Output Distortion

SECTION 2

OPERATION

2.1 INTRODUCTION

This section describes the basic operation of the Model 4500. It includes the proper ac requirements, the recommended turn-on procedure and a detailed explanation of all operating controls.

2.2 POWER REQUIREMENTS

The Model 4500 is designed to operate from a single phase, 50-60Hz ac power source of 90-132 volts or 180-264 volts. A LINE selector switch on the rear panel selects the desired voltage range. The ac power receptacle is a standard 3-pin connector, and complies with the European I.E.C. standard. A detachable 3-wire line cord is provided with the instrument. The fuse receptacle contains a 1/16 ampere slow blow fuse for 120 volt operation, or a 1/32 ampere slow blow fuse for 240 volt (overseas) operation.

2.3 TURN-ON PROCEDURE

- a. Set the LINE switch for the correct voltage range.
- b. Make sure the POWER switch is in the off position.
- c. Plug the line cord into the unit and into an ac outlet.

WARNING

The chassis of this instrument is connected to ground. For safety purposes, connect the line cord to a grounded, 3 terminal ac outlet.

- d. Turn the POWER switch on, and allow the unit to warm up for several minutes.

CAUTION

Because of the potentially dangerous voltages that exist within the unit, the cover of this instrument should not be removed when the instrument is connected to an ac power source.

2.4 CONTROLS AND CONNECTORS (see Figure 3)

FRONT PANEL:



1. POWER: On-Off pushbutton switch with power-on indicator LED.

Attenuator Volts rms Range

0dB	220mV to 7V
20dB	22mV to 700mV
40dB	2mV to 70mV
60dB	220µV to 7mV

To optimize the resolution of adjustment, use the lower of two attenuator settings (i.e. if the application requires a 500mV rms signal, use the 20dB setting rather than the 0dB setting). The INVERTED (180°) OUTPUT is fixed at 7 volts rms. The output impedance of the INVERTED OUTPUT is 600 ohms ±1%.

FLOATING GROUND OPERATION

The CIRCUIT GROUND switch allows you to "float" or isolate the oscillator circuit or signal ground () from the chassis or earth ground (). The maximum allowable dc isolation is 100V.

Set the oscillator frequency to 1kHz. Connect the ACVM to the MAIN OUTPUT. With the VOLTS RMS control turned up to maximum, the MAIN OUTPUT should be greater than or equal to 7 volts rms. Turn the VOLTS RMS control counterclockwise (minimum). The MAIN OUTPUT should drop to less than 220mV. Turn the

MAIN OUTPUT AMPLITUDE

Connect the frequency counter to the MAIN OUTPUT and verify that the frequency accuracy is within +10% of the FREQUENCY Hz setting, between 1Hz and 100kHz.

FREQUENCY ACCURACY

Turn the AMPLITUDE vernier completely clockwise (CW). Adjust the rear panel screwdriver control labeled "DC OUTPUT LEVEL MAX" for a reading of 0 volts.

Connect the DVM to the MAIN OUTPUT. Turn the AMPLITUDE vernier completely counterclockwise (CCW). Adjust the rear panel screwdriver control labeled "DC OUTPUT LEVEL MIN" for a reading of 0 volts.

DC LEVEL ADJUSTMENTS

FREQUENCY Hz; 1kHz (MULTIPLIER X1K, VERNIER set at zero)
AMPLITUDE; ATTENUATOR (dB) set for 0 (zero), VOLTS RMS set for maximum CW
CIRCUIT GROUND; Chassis
WAVEFORM: sine wave

Allow the oscillator to warm up for at least 30 minutes, then set the controls initially to the following:

For the equipment required, see Section 5.2 on page 15.

3.2 PROCEDURE

Because of the potentially dangerous voltages that exist within the unit, the cover of this instrument should not be removed when the instrument is connected to an ac power source.

CAUTION

The following procedure should be used to verify the oscillator is operating within specifications, both for incoming inspection and for routine servicing. Tests should be made with the cover in place. The procedure given below should be followed in sequence. Familiarize yourself with the initial set-up and operating procedures outlined in Section 2.

3.1 INTRODUCTION

INCOMING ACCEPTANCE AND ROUTINE PERFORMANCE TESTS

SECTION 3

Adaptive Sweep	off
Display	clear write
Frequency	1kHz
Amplitude Mode	LOG dB/div
Amplitude Ref Level	0 (zero)
Input Sensitivity	+20dB (10V)
Resolution Bandwidth	100Hz
Freq Span/div	0.5kHz
Sweep Time/div	1 sec
Sweep Mode	repetitive

2. Set switch SI (Figure 5) to the "Input" position. Adjust the 4500 frequency to correspond to the twin tee null frequency.
3. Adjust the Input Sensitivity vernier on the analyzer to obtain a 0dB reference at the fundamental frequency.
4. Switch SI to the "Output" position. Adjust the frequency of the 4500 to null the fundamental frequency.
5. Increase the Input Sensitivity in dB steps until the harmonic components are visible.

The dB level of each harmonic component is the sum of the dB below the Odd reference level on the display, plus the change in the Input Sensitivity level, in dB.

To compensate for loss through the twin tee filter, add +9dB to the second harmonic component and +5dB to the 3rd harmonic component.

For example, if the 2nd harmonic is -118dB,

$$-118\text{dB} + 9\text{dB} = -109\text{dB}$$

Total harmonic distortion may then be calculated as follows:

$$\text{T.H.D. (dB)} = 20 \log \sqrt{\log^{-1} \frac{10}{2nd} + \log^{-1} \frac{10}{3rd} + \dots + \log^{-1} \frac{10}{nth}}$$

$$= 10 \log \sum \log^{-1} \frac{10}{dn} ; n = 2nd \text{ to } nth \text{ harmonic}$$

Where dn = Value of the nth harmonic in dB.

or,

$$\text{T.H.D. (\%)} = 100 \sqrt{\sum \left[\log^{-1} \frac{10}{dn} \right]} ; n = 2nd \text{ to } nth \text{ harmonic}$$

Where dn = Value of the nth harmonic in dB.

The AVC system is shown in Figure 7. The oscillator loop output signal in Figure 6 is fed to peak detector diode CR12 and the voltage divider formed by R181 and Q199. Q199 is a FET operated as a voltage controlled resistor. The peak detector charges its capacitor to the plus peak value of the sine wave and is fed to one input of U211, the Detector Buffer. A difference or error voltage proportional to the difference between the reference and detected value is produced on the output of U211. This error voltage is fed to U193, the AVC amplifier, for additional filtering and dc gain. The AVC amplifier output feeds the AVC FET Driver Amplifier U196 which in turn drives the gate of Q199.

This control loop varies the voltage dividers loss there by controlling the gain of U174 in the oscillator loop.

4.2 AVC OPERATION

The signal on the common point of the bridge T capacitors is lagging the oscillator loop output signal by 90°. This signal is buffered by amplifier U143 and fed to the frequency vernier (R140) and the band calibration potentiometers (R110-R114).

The INVERTED OUTPUT is derived from the oscillator loop.

The MAIN OUTPUT is provided by U251 which is fed from the VOLTS RMS control potentiometer (R245).

The network R value to ground is set by the FREQUENCY Hz dial and the two C values are selected by the FREQUENCY MULTIPLIER switch (S110).

The transfer function of the bridge T network is that of a notch filter. Degenerative feedback around U158 is through the notch filter. Regenerative feedback is provided by U174 to the bottom of the network. At all frequencies, except the notch frequency, the degenerative feedback is greater than the regenerative feedback, the degenerative feedback is balanced out by the regenerative feedback and is slightly in favor of the regenerative feedback. At that frequency the loop will oscillate. The regenerative gain is controlled by the Automatic Voltage Control (AVC) to maintain the oscillation at its proper amplitude.

It consists of two feedback loop systems, one to produce the sine waves and one to maintain stable amplitude.

The Model 4500 oscillator is a true RC sinusoidal oscillator designed for ultra low waveform distortion and flat amplitude response.

A simplified diagram of the oscillating loop is shown in Figure 6.

4.1 THEORY OF OPERATION

CIRCUIT DESCRIPTION

SECTION 4

SECTION 5

CALIBRATION

WARNING

This calibration procedure should be performed by qualified personnel only. It is strongly recommended that extra precautions be taken when working with exposed circuitry, and that only insulated probes and tools be used.

5.1 INTRODUCTION

The following procedure is provided for the calibration and adjustment of the Model 4500 in the field. Adherence to this procedure should restore the Oscillator to its original performance specifications. If the Oscillator cannot be calibrated by the procedure given, see Section 6, Maintenance, or consult our Factory Service Department. For the location of all test points and adjustable components, see Figure 8.

5.2 CALIBRATION PROCEDURE

See Section 2 for the correct turn-on procedure. Allow the instrument to warm up for at least 30 minutes.

Required Test Equipment:

1. Oscilloscope: bandwidth of at least 1MHz, vertical sensitivity; 10mV/cm, ac/dc coupled.

2. DC Voltmeter: zero to ± 15 volts.

3. AC Voltmeter: frequency range less than 1Hz to greater than 100kHz, to measure between zero and greater than 7 volts rms, better than 3% accuracy.

4. Amplitude Flatness Measuring Equipment:

a. RMS Voltmeter that will measure ac voltage variations of less than 0.05dB (0.6%) from 1Hz to 100kHz.

OR

b. High Frequency Thermal Converter (Fluke Model A55) and either a DC Differential Voltmeter (Fluke Model 895A), or a DC Null Detector (Fluke Model 845A) with a stable dc reference supply.

5. Spectrum or Wave Analyzer: to measure harmonic components down to 0.001% (-100dB).

6. Frequency/Period Counter: accuracy better than 1%, 1Hz to 100kHz.

Set the controls initially to the following:

FREQUENCY Hz; 1kHz (MULTIPLIER X1K, VERNIER set at zero)
AMPLITUDE; CHASSIS
CIRCUIT GROUND; CHASSIS
WAVEFORM: sine wave

Connect the DVM to the MAIN OUTPUT (50 ohm). Adjust R232 for a dc level of less than $\pm 1mV$.
 Switch to the squarewave waveform. Adjust R230 for a squarewave amplitude equal to the peak to peak sinewave amplitude.
 Note the peak to peak amplitude.

Select the sinewave waveform. Set the scope gain for 5V/cm.
 Set the frequency to 1kHz (1 X1K). Connect the scope to the 50 ohm MAIN OUTPUT with 3 feet of 50 ohm cable. Set the output AMPLITUDE for maximum amplitude.

5.10 SQUAREWAVE CALIBRATION

The total harmonic distortion, as defined by equations 1, 2 or 3 on page 11, should be greater than or equal to -100dB, or less than or equal to 0.001%.

Refer to "OUTPUT DISTORTION" in Section 3, page 10, for the correct test set-up and procedure. Perform steps 1 through 5. Adjust R208 for a minimum 2nd harmonic component. Also, at 100kHz adjust C152 for a minimum 2nd harmonic component.

5.9 DISTORTION ADJUSTMENT

1.5	6200 - 6666 - 7133
2.0	4650 - 5000 - 5350
2.5	3720 - 4000 - 4280
3.5	2657 - 2857 - 3057
4.0	2325 - 2500 - 2675
5.0	1860 - 2000 - 2140
6.0	1550 - 1666 - 1783
7.0	1328 - 1428 - 1528
8.0	1162 - 1250 - 1337
9.0	1033 - 1111 - 1188

Min. Norm Max.

Dial Setting Reading Range

Set the MULTIPLIER to X100. Set the frequency counter for period operation.

5.8 DIAL CONFORMITY CHECK

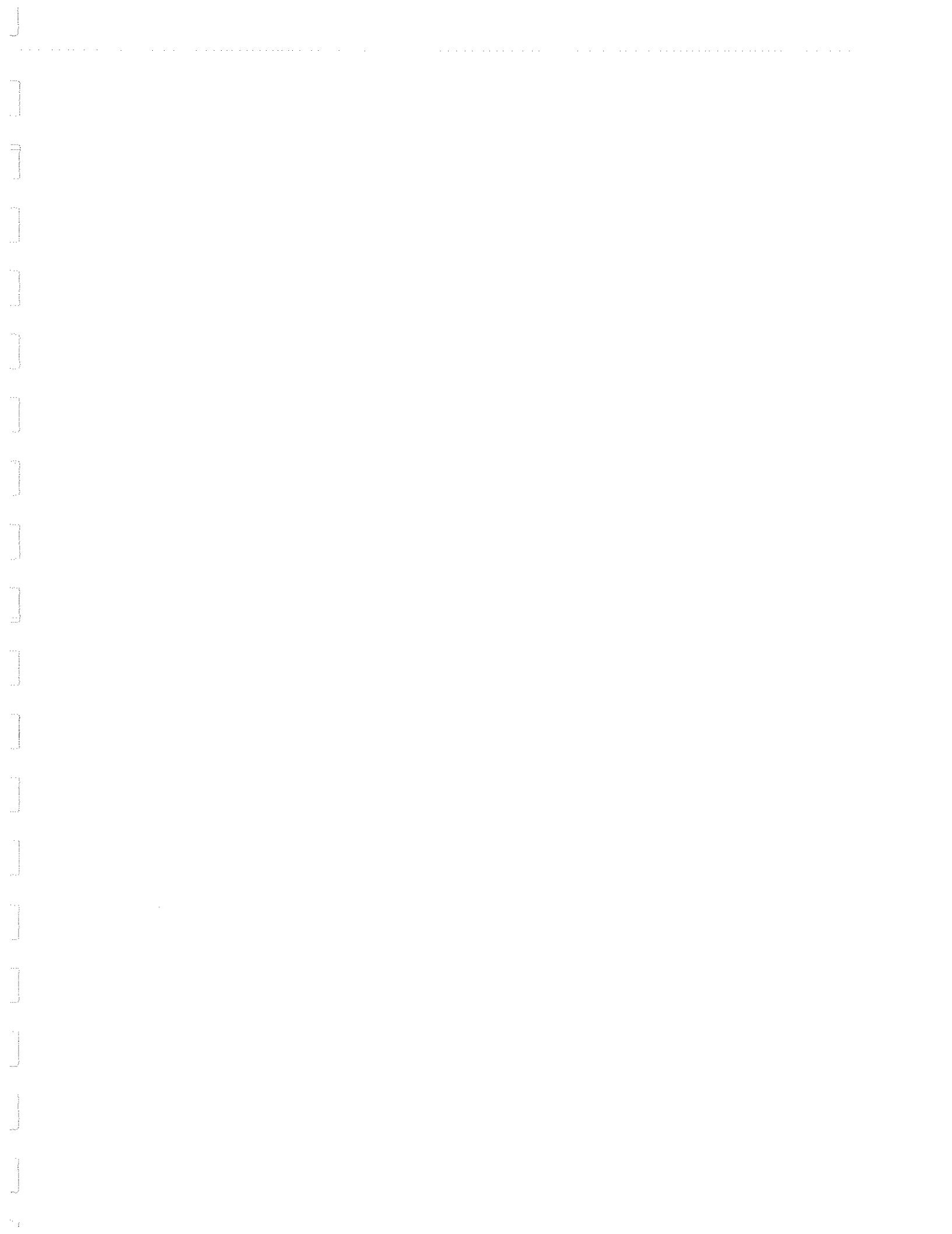
Due to interaction, repeat step 5.7.

Again, the AVC voltage should remain the same as on X100 band $\pm 0.2V$.

Set the dial to 10. Adjust C178 for the correct frequency and C170 for the correct AVC voltage at TP4. The counter reading should be 1000 ± 2 digits.

The AVC voltage should remain the same as on X100 band $\pm 0.2V$.

frequency and adjust C118 for the correct AVC voltage at TP4. The counter reading should be 1000 ± 2 digits.



Use the trouble-shooting flow chart to localize the source of the problem.

FREQUENCY Hz: 1kHz (MULTIPLIER X1K, VERNIER set at zero)
 AMPLITUDE: ATTENUATOR (dB) set for 0 (zero), VOLTS RMS set for maximum CW
 CIRCUIT GROUND: Chassis
 WAVEFORM: sine wave

Set the controls initially to the following:

For the equipment required, see Section 5.2 on page 15.

up for at least 30 minutes.

See Section 2 for the correct turn-on procedure. Allow the instrument to warm

6.2 MAINTENANCE PROCEDURE

Before trouble-shooting, it should be determined if the normal adjustments mentioned in Section 5 will correct the problem. The trouble-shooting of the oscillator will be simplified if there is a basic understanding of the oscillator's operating theory as described in Section 4. Simplified diagrams are provided in the Circuit Description that appreciably reduce the learning time and minimize the need for using the complete circuit diagrams.

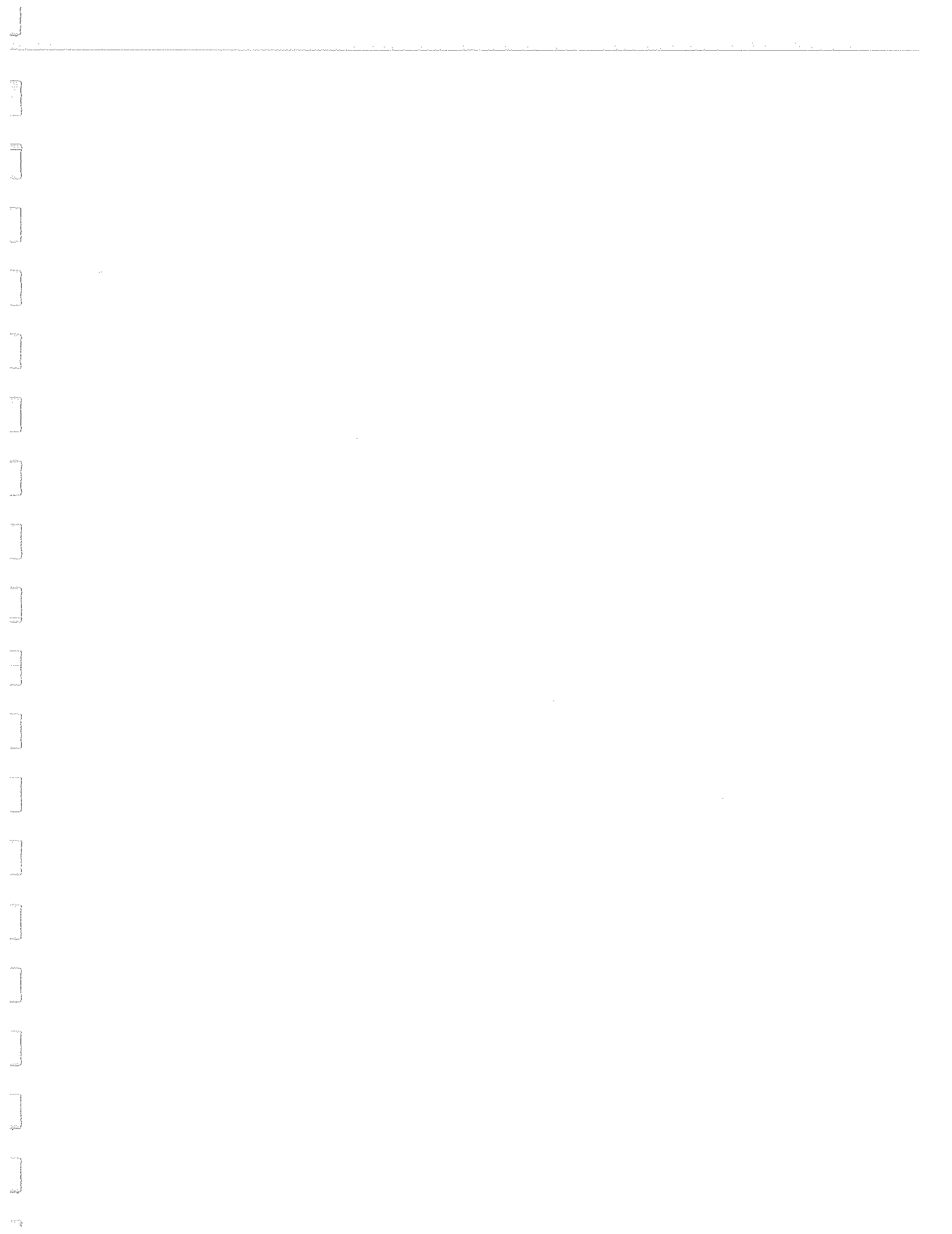
6.1 INTRODUCTION

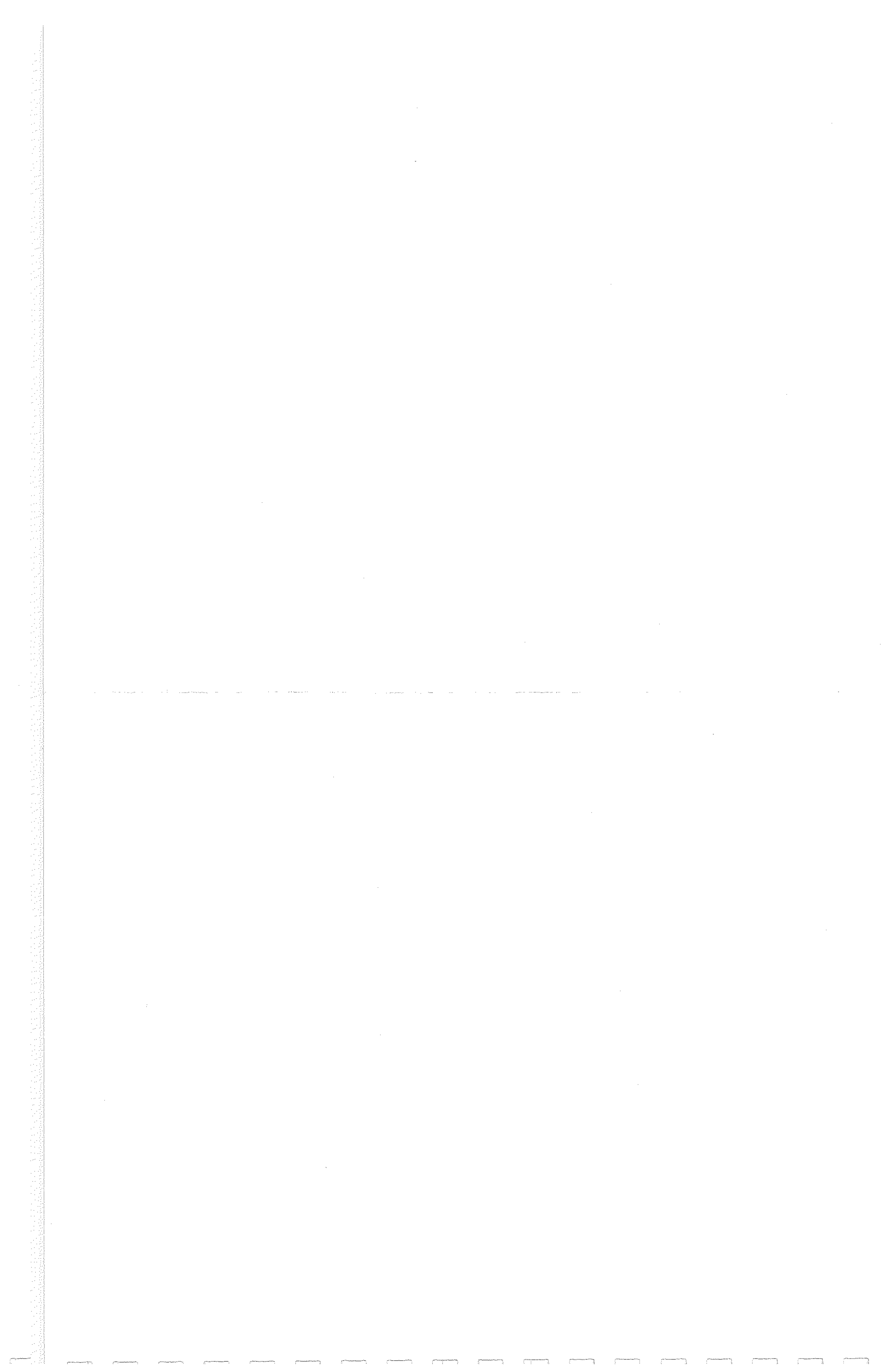
This calibration procedure should be performed by qualified personnel only. It is strongly recommended that extra precautions be taken when working with exposed circuitry, and that only insulated probes and tools be used. IT IS EXTREMELY IMPORTANT TO SHUT THE POWER SWITCH OFF AND DISCONNECT THE LINE CORD FROM THE POWER SOURCE BEFORE REPAIRING OR REPLACING COMPONENTS.

WARNING

MAINTENANCE

SECTION 6





PARTS LISTS, SCHEMATICS AND BOARD LAYOUTS

SECTION 7

Any engineering modifications will be found on a Modification Sheet inside the rear cover of this manual.

The part numbers listed are either the actual parts used or direct replacement.

7.2 ORDERING UNLISTED PARTS

When ordering parts from Krohn-Hite that are not listed, include the instrument model number (Model 4500), instrument serial number, a description and location of the part.

7.1 ORDERING INFORMATION

When ordering parts from Krohn-Hite, specify the instrument model number (Model 4500), instrument serial number, schematic reference designation (ie; R, G, CR etc..) and the manufacturer's part number (see the list below for the manufacturer's abbreviation and FSCM number).

Address all inquiries to your local Krohn-Hite Sales Representative or directly to Krohn-Hite.

MFR NAME	FSCM	MFR NAME	FSCM
AV David Engineering, Laconia, NH	30161	IIT Components-Capacitors, Santa Ana, CA	01121
AB Allen Bradley Co., Milwaukee, WI	01121	KGN Kahgan Electronics Corp., Hempstead, NY	57582
AD Analog Devices Inc., Norwood, MA	24355	KH Krohn-Hite Corp., Avon, MA	88865
ALC Alco Electronic Products Inc.,		KLN Kelvin Industries, Fajardo, PR	91836
AMP Ampheno! North America,		KNG Kings Electronics, Tuckahoe, NY	18235
Div. of Augat Inc., North Andover, MA	95146	KRL Electronics Inc., Manchester, NH	75915
Div. of Buker-Ramo, Oak Brook, IL	29587	LRI Littlefuse Inc., Des Plaines, IL	90201
AMZ American Zetler, Irvine, CA,	50273	MAL Mallory Capacitor Co., Indianapolis, IN	26483
APD American Power Devices, Andover, MA	17545	MOT Motorola Inc.,	
AS Atlantic Semiconductor, Northridge, CA	06540	MT M-Tron Industries Mfg. Inc., Van Nuys, CA	31649
ATM Amatom Electronics Hardware,		NS National Semiconductor Corp.,	27014
Windser Locks, CT		Semiconductor Div., Santa Clara, CA	
AVX Aerovox Inc., New Bedford, MA	00656	PFP Precision Resistive Products Inc.,	
BKM Beckman Helipot Div., Fullerton, CA	73138	Medipolys, IA	
BUS Busman,		QC Quality Components Inc., St. Mary's, PA	71707
Div. of McGraw-Edison Co., St. Louis, MO	71400	RCA RCA Solid State Div., Somerville, NJ	14655
CA Circuit Assembly, Costa Mesa, CA,		RCL RCL Electronics, Div. of AMF, Electro-	27167
CDI Compensated Devices Inc., Melrose, MA		Components Group, Pompano Beach, FL	
CGM Corning Glass Works, Wilmington, NC	09353	RI Resistors Inc., Chicago, IL	83827
CK C&K Components Inc., Newton, MA		SCH IIT Shadow Inc., Eden Prairie, MN	
CLX Claretz Corp., Mt. Vernon, NY	26364	SIG Signetics, Sunnyvale, CA	
CPC Components Corp., Denville, NJ	79727	SIX Siliconix Inc., Sunnyvale, CA	100010
CM CW Industries, Warminster, PA	99800	SP Sprague Electric Co., N. Adams, MA	56289
DE Dale Electronics Inc., Columbus, NE	91637	STL Stackpole Components Co., Kallegh, NC	
DV Delevan Corp., East Aurora, NY	72619	STT Steetner-Trush Inc., Cazanova, NY	52763
DL Dialight Corp., Brooklyn, NY	50558	SUP Superior Electric Company, Bristol, CT,	
ECI Electronic Concepts Inc., Eatontown, NJ	07263	SWC Switchcraft Inc., Chicago, IL	82389
FCD Fairchild, Semiconductor Group,		TD Teledyne Semiconductor, Mountain View, CA	15818
Mountain View, CA		TI Texas Instruments, Dallas, TX	01295
FXC Ferroncube Corp., Div. of N.A. Phillips,	02114	TMY Thermalloy, Dallas, TX	13103
Saugerties, NY		TOR Torin Corp., Torrington, CT	60399
GI General Instrument Corp.,	11711	TRW TRW Capacitors, Ogalala, NE	84411
Semiconductor Div., Hicksville, NY	02289	YSA Yuasa Battery, Santa Fe, CA	
HG HI-G Co., Windsor Locks, CT			
HP Hewlett-Packard component supplied by			
Schwaber, Bedford, MA			

Manufacturer's Abbreviation and FSCM Number.

SCHEM	REF.	DESCRIPTION	MFR	PART NUMBER	NUMBER	SCHEM	REF.	DESCRIPTION	MFR	PART NUMBER	NUMBER
C100	0.01uF	20%	SP	5GASS10	412310	C100	DIODE, RECTIFIER	AS	1N4002	244002	
C101	800uF	10%	MAL	TCG801U040L1LP	471780	C101	DIODE, RECTIFIER	AS	1N4002	244002	
C102	800uF	10%	MAL	TCG801U040L1LP	471780	C102	DIODE, RECTIFIER	AS	1N4002	244002	
C103	6.8uF	20%	ITT	TAP46.8M35	471568	C103	DIODE, RECTIFIER	AS	1N4002	244002	
C104	6.8uF	20%	ITT	TAP46.8M35	471568	C104	DIODE, RECTIFIER	AS	1N4002	244002	
C110	0.47uF	20%	ITT	SR301E474MAA	413447	C110	DIODE, LOW LEAKAGE	FCD	FD300	280300	
C111	3.2uF	1%	KH	441532	441532	C111	DIODE, LOW LEAKAGE	FCD	FD300	280300	
C112	3.2uF	1%	KH	441532	441532	C112	DIODE, LOW LEAKAGE	FCD	FD300	280300	
C113	0.32uF	1%	KH	441432	441432	C113	DIODE, SWITCHING	APD	1N4149	234149	
C114	0.32uF	1%	KH	441332	441332	C114	DIODE, SWITCHING	APD	1N4149	234149	
C115	3200pF	1%	KGN	DM19C322F	421232	C115	DIODE, HOT CARRIER	HP	1N6263	286263	
C116	220pF	10%	KGN	DM15C221K	423122	C116	DIODE, HOT CARRIER	HP	1N6263	286263	
C117	22pF	10%	KGN	DM15C220K	423022	C117	DIODE, SWITCHING	APD	1N4149	234149	
C118	10-60pF	TRIMMER	KH	482010	482010	C118	DIODE, SWITCHING	APD	1N4149	234149	
C119	3.2uF	1%	KH	441532	441532	C119	DIODE, SWITCHING	APD	1N4149	234149	
C120	0.32uF	1%	KH	441432	441432	C120	DIODE, SWITCHING	APD	1N4149	234149	
C121	0.32uF	1%	KH	441332	441332	C121	DIODE, SWITCHING	APD	1N4149	234149	
C122	3200pF	1%	KGN	DM19C322F	421232	C122	DIODE, SWITCHING	APD	1N4149	234149	
C123	TRIM					C123	DIODE, SWITCHING	APD	1N4149	234149	
C124	330pF	5%	KGN	DM15C331J	423133	C124	DIODE, SWITCHING	APD	1N4149	234149	
C125	TRIM					C125	DIODE, SWITCHING	APD	1N4149	234149	
C126	0.1uF	20%	LNX	SR21E104MAA	413410	C126	FUSE, SLOW BLOW,	BUS	MFG1/16A	021001	
C133	6.8uF	20%	ITT	TAP46.8M35	471568	C133	FUSE, SLOW BLOW,	BUS	MFG1/16A	021001	
C134	6.8uF	20%	ITT	TAP46.8M35	471568	C134	FUSE, SLOW BLOW,	BUS	MFG1/16A	021001	
C135	2pF	10%	KH	411002	411002	C135	RECEPTACLE,	SWC	EAC301	029030	
C142	0.1uF	20%	LNX	SR21E104MAA	413410	C142	RECEPTACLE,	SWC	EAC301	029030	
C143	0.1uF	20%	LNX	SR21E104MAA	413410	C143	RECEPTACLE,	SWC	EAC301	029030	
C144	0.1uF	20%	LNX	SR21E104MAA	413410	C144	RECEPTACLE,	SWC	EAC301	029030	
C152	10pF	10%	KH	411010	411010	C152	AC POWER,	AMP	31010	370402	
C153	51pF	10%	KGN	DM15C510K	422051	C153	AC POWER,	AMP	31010	370402	
C157	0.1uF	20%	LNX	SR21E104MAA	413410	C157	CONNECTOR, BNC	AMP	31010	370402	
C158	0.1uF	20%	LNX	SR21E104MAA	413410	C158	CONNECTOR, BNC	AMP	31010	370402	
C160	470pF	10%	KGN	DM15C471K	423147	C160	CONNECTOR, BNC	AMP	31010	370402	
C161	6.8uF	20%	ITT	TAP46.8M35	471568	C161	CONNECTOR, BNC	AMP	31010	370402	
C163	6.8uF	20%	ITT	TAP46.8M35	471568	C163	CONNECTOR, BNC	AMP	31010	370402	
C170	3-9pF	TRIMMER	KH	482003	482003	C170	CONNECTOR, BNC	AMP	31010	370402	
C171	TRIM					C171	CONNECTOR, BNC	AMP	31010	370402	
C173	0.1uF	20%	LNX	SR21E104MAA	413410	C173	CONNECTOR, BNC	AMP	31010	370402	
C174	0.1uF	20%	LNX	SR21E104MAA	413410	C174	CONNECTOR, BNC	AMP	31010	370402	
C176	2pF	TRIMMER	KH	411002	411002	C176	CONNECTOR, BNC	AMP	31010	370402	
C178	3-9pF	TRIMMER	KH	482003	482003	C178	CONNECTOR, BNC	AMP	31010	370402	
C182	510pF	10%	KGN	DM15C511K	423151	C182	CONNECTOR, BNC	AMP	31010	370402	
C192	0.22uF	20%	ITT	SR305E224MAA	413422	C192	CONNECTOR, BNC	AMP	31010	370402	
C193	1uF	10%	KH	441511	441511	C193	CONNECTOR, BNC	AMP	31010	370402	
C194	1uF	10%	KH	441511	441511	C194	CONNECTOR, BNC	AMP	31010	370402	
C195	1uF	10%	KH	441511	441511	C195	CONNECTOR, BNC	AMP	31010	370402	
C198	0.01uF	20%	SP	5GASS10	412310	C198	CONNECTOR, BNC	AMP	31010	370402	
C211	6.8uF	20%	ITT	TAP46.8M35	471568	C211	CONNECTOR, BNC	AMP	31010	370402	
C212	0.1uF	20%	LNX	SR21E104MAA	413410	C212	CONNECTOR, BNC	AMP	31010	370402	
C232	0.1uF	20%	LNX	SR21E104MAA	413410	C232	CONNECTOR, BNC	AMP	31010	370402	
C233	0.1uF	20%	LNX	SR21E104MAA	413410	C233	CONNECTOR, BNC	AMP	31010	370402	
C237	0.1uF	20%	LNX	SR21E104MAA	413410	C237	CONNECTOR, BNC	AMP	31010	370402	
C247	0.1uF	20%	LNX	SR21E104MAA	413410	C247	CONNECTOR, BNC	AMP	31010	370402	
C250	2pF	10%	KH	411002	411002	C250	CONNECTOR, BNC	AMP	31010	370402	
C251	0.1uF	20%	LNX	SR21E104MAA	413410	C251	CONNECTOR, BNC	AMP	31010	370402	
C252	3.9pF	10%	KH	411939	411939	C252	CONNECTOR, BNC	AMP	31010	370402	
C253	6.8uF	20%	ITT	TAP46.8M35	471568	C253	CONNECTOR, BNC	AMP	31010	370402	
C255	0.01uF	20%	SP	5GASS10	412310	C255	CONNECTOR, BNC	AMP	31010	370402	
C256	6.8uF	20%	ITT	TAP46.8M35	471568	C256	CONNECTOR, BNC	AMP	31010	370402	
C271	0.1uF	20%	LNX	SR21E104MAA	413410	C271	CONNECTOR, BNC	AMP	31010	370402	
C272	0.1uF	20%	LNX	SR21E104MAA	413410	C272	CONNECTOR, BNC	AMP	31010	370402	
C273	0.1uF	20%	LNX	SR21E104MAA	413410	C273	CONNECTOR, BNC	AMP	31010	370402	
C277	0.1uF	20%	LNX	SR21E104MAA	413410	C277	CONNECTOR, BNC	AMP	31010	370402	
C278	0.1uF	20%	LNX	SR21E104MAA	413410	C278	CONNECTOR, BNC	AMP	31010	370402	
C282	0.47uF	20%	ITT	SR301E474MAA	413447	C282	CONNECTOR, BNC	AMP	31010	370402	
C283	1uF	10%	KH	441511	441511	C283	CONNECTOR, BNC	AMP	31010	370402	
C284	1uF	10%	KH	441511	441511	C284	CONNECTOR, BNC	AMP	31010	370402	
C285	1uF	10%	KH	441511	441511	C285	CONNECTOR, BNC	AMP	31010	370402	
C293	1uF	10%	KH	441511	441511	C293	CONNECTOR, BNC	AMP	31010	370402	
C294	1uF	10%	KH	441511	441511	C294	CONNECTOR, BNC	AMP	31010	370402	
C298	0.01uF	20%	SP	5GASS10	412310	C298	CONNECTOR, BNC	AMP	31010	370402	
C319	1uF	10%	KH	441511	441511	C319	CONNECTOR, BNC	AMP	31010	370402	
C320	0.32uF	1%	KH	441432	441432	C320	CONNECTOR, BNC	AMP	31010	370402	
C323	0.1uF	20%	LNX	SR21E104MAA	413410	C323	CONNECTOR, BNC	AMP	31010	370402	
C324	0.1uF	20%	LNX	SR21E104MAA	413410	C324	CONNECTOR, BNC	AMP	31010	370402	
C330	3.9pF	10%	KH	411939	411939	C330	CONNECTOR, BNC	AMP	31010	370402	
C331	0.1uF	20%	LNX	SR21E104MAA	413410	C331	CONNECTOR, BNC	AMP	31010	370402	
C332	0.1uF	20%	LNX	SR21E104MAA	413410	C332	CONNECTOR, BNC	AMP	31010	370402	
C333	0.1uF	20%	LNX	SR21E104MAA	413410	C333	CONNECTOR, BNC	AMP	31010	370402	
C337	0.1uF	20%	LNX	SR21E104MAA	413410	C337	CONNECTOR, BNC	AMP	31010	370402	
C347	0.1uF	20%	LNX	SR21E104MAA	413410	C347	CONNECTOR, BNC	AMP	31010	370402	
C351	0.1uF	20%	LNX	SR21E104MAA	413410	C351	CONNECTOR, BNC	AMP	31010	370402	
C352	0.1uF	20%	LNX	SR21E104MAA	413410	C352	CONNECTOR, BNC	AMP	31010	370402	
C353	0.1uF	20%	LNX	SR21E104MAA	413410	C353	CONNECTOR, BNC	AMP	31010	370402	
C354	0.1uF	20%	LNX	SR21E104MAA	413410	C354	CONNECTOR, BNC	AMP	31010	370402	
C355	2pF	10%	KH	411002	411002	C355	CONNECTOR, BNC	AMP	31010	370402	
C370	3-9pF	TRIMMER	KH	482003	482003	C370	CONNECTOR, BNC	AMP	31010	370402	
C371	TRIM					C371	CONNECTOR, BNC	AMP	31010	370402	
C373	0.1uF	20%	LNX	SR21E104MAA	413410	C373	CONNECTOR, BNC	AMP	31010	370402	
C374	0.1uF	20%	LNX	SR21E104MAA	413410	C374	CONNECTOR, BNC	AMP	31010	370402	
C376	2pF	TRIMMER	KH	411002	411002	C376	CONNECTOR, BNC	AMP	31010	370402	
C378	3-9pF	TRIMMER	KH	482003	482003	C378	CONNECTOR, BNC	AMP	31010	370402	
C382	510pF	10%	KGN	DM15C511K	423151	C382	CONNECTOR, BNC	AMP	31010	370402	
C392	0.22uF	20%	ITT	SR305E224MAA	413422	C392	CONNECTOR, BNC	AMP	31010	370402	
C393	1uF	10%	KH	441511	441511	C393	CONNECTOR, BNC	AMP	31010	370402	
C394	1uF	10%	KH	441511	441511	C394	CONNECTOR, BNC	AMP	31010	370402	
C398	0.01uF	20%	SP	5GASS10	412310	C398	CONNECTOR, BNC	AMP	31010	370402	
C419	1uF	10%	KH	441511	441511	C419	CONNECTOR, BNC	AMP	31010	370402	
C421	6.8uF	20%	ITT	TAP46.8M35	471568	C421	CONNECTOR, BNC	AMP	31010	370402	
C422	0.47uF	20%	ITT	SR301E474MAA	413447	C422	CONNECTOR, BNC	AMP	31010	370402	
C423	1uF	10%	KH	441511	441511	C423	CONNECTOR, BNC	AMP	31010	370402	
C424	1uF	10%	KH	441511	441511	C424	CONNECTOR, BNC	AMP	31010	370402	
C425	1uF	10%	KH	441511	441511	C425	CONNECTOR, BNC	AMP	31010	370402	
C426	0.1uF	20%	LNX	SR21E104MAA	413410	C426	CONNECTOR, BNC	AMP	31010	370402	
C427	0.1uF	20%	LNX	SR21E104MAA	413410						

SCHEM	REF.	DESCRIPTION	MFR	PART NUMBER	NUMBER	SCHEM	REF.	DESCRIPTION	MFR	PART NUMBER	NUMBER
R138	20K	1% 1/4W	KH	850319A	850319A	R232	5K	POT 1/2W	BKM	72PMS5K	658250
R139	10K	1% 1/4W	KH	850315	850315	R233	12.4K	1% 1/4W	KH	850312	850312
R140	10K	POT	KH	850315	850315	R234	10K	5% 1/4W	AB	CB2025	927310
R141	4K	0.1% 1/4W	KH	822239	822239	R235	2K	5% 1/4W	AB	CB2025	927310
R142	69.5K	0.1% 1/4W	KH	822369	822369	R236	6.65K	1% 1/4W	KH	850266	850266
R143	4.7K	5% 1/4W	AB	CB4725	927247	R237	1% 1/4W	1% 1/4W	KH	850271	850271
R144	100K	POT 1/2W	BKM	72PMS100K	658410	R245	2K	POT	KH	B935	620221
R145	121K	1% 1/4W	KH	850412	850412	R247	10K	1% 1/4W	KH	850310	850310
R146	330	5% 1/4W	AB	CB3315	927133	R248	100K	POT 1/2W	BKM	72PMS100K	658410
R147	649K	1% 1/4W	KH	850464	850464	R249	6.8M	5% 1/4W	AB	CB8555	927568
R150	47K	5% 1/4W	AB	CB4735	927347	R250	24K	5% 1/4W	AB	CB2435	927324
R151	100K	5% 1/4W	AB	CB1045	927410	R251	220	10% 1/4W	AB	CB2211	928122
R152	100K	5% 1/4W	AB	CB1045	927410	R252	10K	1% 1/4W	KH	850310	850310
R153	100K	5% 1/4W	AB	CB1045	927410	R253	47	10% 1/4W	AB	CB4701	928047
R154	139K	0.1% 1/4W	KH	822413	822413	R254	2K	5% 1/4W	AB	CB2025	927220
R155	7.5M	5% 1/4W	AB	CB7555	927751	R255	62	5% 1/4W	AB	CB2025	927062
R156	100K	POT 1/2W	BKM	72PMS100K	658410	R256	10	10% 1/4W	AB	CB1001	928010
R157	24K	5% 1/4W	AB	CB2435	927224	R257	49.9	1% 1/4W	KH	850049	850049
R158	5.6K	5% 1/4W	AB	CB5625	927256	R260	453	1% 1/4W	KH	850049	850049
R159	220	10% 1/4W	AB	CB2211	928122	R261	61.9	1% 1/4W	KH	850061	850061
R160	47	10% 1/4W	AB	CB4701	928047	R262	495	1% 1/4W	KH	825149	825149
R161	27	10% 1/4W	AB	CB2701	928027	R263	61.1	1% 1/4W	KH	850060	850060
R162	2K	5% 1/4W	AB	CB2025	927220	R264	495	1% 1/4W	KH	825149	825149
R163	62	5% 1/4W	AB	CB6205	927220	R265	54.9	1% 1/4W	KH	850054	850054
R164	600	1% 1/4W	KH	825160	825160	R266	550	1% 1/4W	KH	850155	850155
R165	1.3M	1% 1/4W	KH	850513	850513	R267	50K	POT	KH	631350	631350
R166	30K	5% 1/4W	AB	CB3035	927330	R267	50K	POT	KH	631350	631350
R167	2K	5% 1/4W	AB	CB2025	927220	R267	50K	POT	KH	631350	631350
R171	2K	5% 1/4W	AB	CB2025	927220	R267	50K	POT	KH	631350	631350
R172	1K	5% 1/4W	AD	CB1025	927210	R267	50K	POT	KH	631350	631350
R173	1K	5% 1/4W	AB	CB1025	927210	R267	50K	POT	KH	631350	631350
R174	220	10% 1/4W	AB	CB2211	928122	S100	SWITCH, PUSHBUTTON		KH	B3386	343033
R175	51K	5% 1/4W	AB	CB5135	927351	S101	SWITCH, SLIDE		KH	SW42280PC	346615
R176	10K	1% 1/4W	KH	850310	850310	S102	SWITCH, SLIDE		CK	GR123	345054
R177	37.4K	1% 1/4W	KH	850337	850337	S110	SWITCH, PUSHBUTTON		KH	B4124	344313
R178	10K	1% 1/4W	KH	850310	850310	S120	SWITCH, PUSHBUTTON		KH	B4124	344313
R179	619	1% 1/4W	BKM	72PMS5K	658250	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R180	5K	POT 1/2W	BKM	72PMS5K	658250	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R181	20K	1% 1/4W	KH	850319A	850319A	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R182	510	5% 1/4W	AB	CB5115	927151	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R183	1M	5% 1/4W	AB	CB1055	927510	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R184	10M	10% 1/4W	AB	CB1061	928610	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R185	10K	1% 1/4W	AB	CB1055	927510	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R186	10K	1% 1/4W	KH	850310	850310	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R187	10K	1% 1/4W	KH	850310	850310	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R188	10K	1% 1/4W	KH	850310	850310	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R189	10K	1% 1/4W	KH	850310	850310	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R190	10K	1% 1/4W	KH	850310	850310	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R191	10K	1% 1/4W	KH	850310	850310	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R192	1M	5% 1/4W	AB	CB1055	927510	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R193	10M	10% 1/4W	AB	CB1061	928610	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R194	10K	1% 1/4W	AB	CB1055	927510	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R195	10K	1% 1/4W	KH	850310	850310	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R196	10K	1% 1/4W	KH	850310	850310	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R197	TRIM					S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R198	10K	5% 1/4W	AB	CB1035	927310	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R199	158	1% 1/4W	KH	850115	850115	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R200	1.33K	1% 1/4W	KH	850213	850213	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R201	TRIM					S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R202	4.42K	1% 1/4W	KH	850244	850244	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R203	500	POT 1/2W	BKM	72PMS500	658150	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R204	1.43K	1% 1/4W	KH	850214	850214	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R205	33K	10% 1/4W	AB	CB3331	928333	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R206	2K	5% 1/4W	AB	CB2025	927220	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R207	5.1M	5% 1/4W	AB	CB5155	927551	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R208	10K	5% 1/4W	AB	CB1035	927310	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R209	4.7K	5% 1/4W	AB	CB4725	927247	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R210	510K	5% 1/4W	AB	CB5145	927451	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R211	2K	5% 1/4W	AB	CB2025	927220	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R212	5.1M	5% 1/4W	AB	CB5155	927551	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R213	10K	5% 1/4W	AB	CB1035	927310	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R214	4.7K	5% 1/4W	AB	CB4725	927247	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R215	510K	5% 1/4W	AB	CB5145	927451	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R216	100K	5% 1/4W	AB	CB1045	927410	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R217	100K	5% 1/4W	AB	CB1045	927410	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R218	100K	5% 1/4W	AB	CB1045	927410	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R219	100K	5% 1/4W	AB	CB1045	927410	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R220	510K	5% 1/4W	AB	CB5145	927451	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R221	510K	5% 1/4W	AB	CB5145	927451	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R222	100K	5% 1/4W	AB	CB1045	927410	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R223	100K	5% 1/4W	AB	CB1045	927410	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R224	100K	5% 1/4W	AB	CB1045	927410	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R225	100K	5% 1/4W	AB	CB1045	927410	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R226	1K	POT 1/2W	BKM	72PMS1K	658210	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R227	9.53K	1% 1/4W	KH	850295	850295	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R228	100K	5% 1/4W	AB	CB1045	927410	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R229	100K	5% 1/4W	AB	CB1045	927410	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R230	1K	POT 1/2W	BKM	72PMS1K	658210	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R231	9.53K	1% 1/4W	KH	850295	850295	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R232	5K	POT 1/2W	BKM	72PMS5K	658250	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R233	12.4K	1% 1/4W	KH	850312	850312	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R234	10K	5% 1/4W	AB	CB2025	927220	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R235	2K	5% 1/4W	AB	CB2025	927220	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R236	6.65K	1% 1/4W	KH	850266	850266	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R237	1% 1/4W	1% 1/4W	KH	850271	850271	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R238	2K	POT	KH	B935	620221	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R239	10K	1% 1/4W	KH	850310	850310	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R240	10K	1% 1/4W	KH	850310	850310	S260	SWITCH, PUSHBUTTON		KH	B4124	344313
R241</											

