MODEL 4100A(R)

0.01 to 1MHz
PUSHBUTTON OSCILLATOR
Serial No. _________

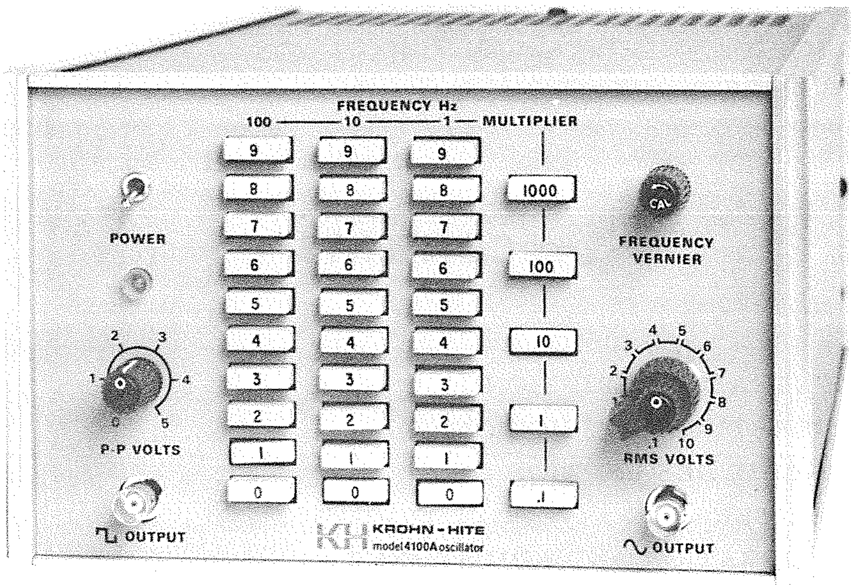
OPERATING AND MAINTENANCE MANUAL

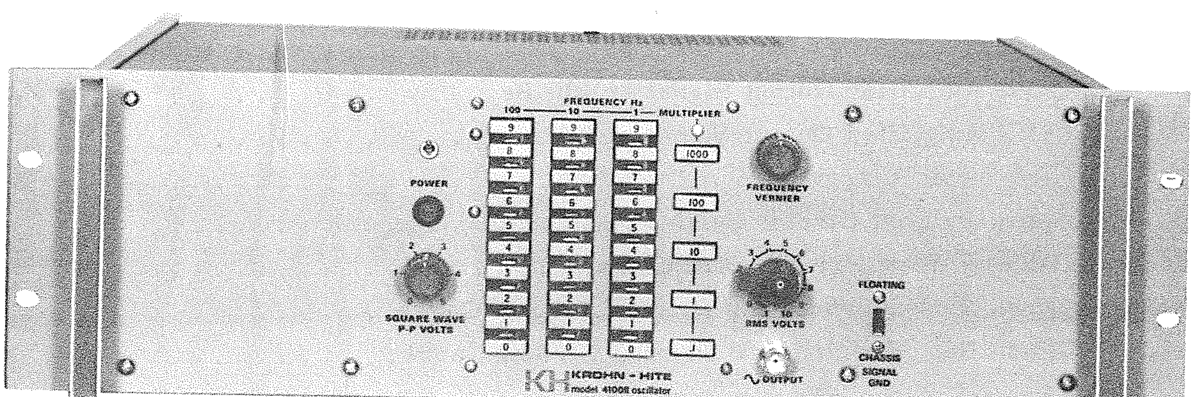
KROHN-HITE CORPORATION
255 Bodwell Street, Avon, MA 02322
Tel: (508)580-1660; Fax: (508)583-8989; TWX: 710-345-0831

Printed in USA 4/5/90

CONTENTS

ILLUSTRATIONS





Model 4100AR

Figure 1. Models 4100A and 4100AR Oscillator

SECTION 1

GENERAL DESCRIPTION

1.1 INTRODUCTION

This manual provides operation and maintenance instructions, with detailed specifications, schematic diagram and parts list, for the Model 4100A Push Button Oscillator, illustrated in Figure 1. When the suffix "R" is added to the model number the Oscillator is provided with a front panel suitable for standard rack mounting, and is identical to the bench model in operation and performance.

Reference to Operating Instructions, Section 2, is recommended before this Oscillator is put into operation. In the event the Oscillator is not functioning or fails to meet performance specifications, reference should be made to Maintenance, Section 4. However, before doing any troubleshooting it should be determined if the normal adjustments mentioned in the Calibration and Adjustment procedure, Section 5, will correct the trouble.

1.2 DESCRIPTION

The Model 4100A is a general purpose test Oscillator that provides sine and square waves simultaneously from 0.01 Hz to 1 MHz. It operates from an ac source of 115 or 230 volts, 50-400 Hz.

Sine wave output is variable from 0 to 10 volts rms open circuit or 5 volts rms across 50 ohms. Maximum power output is 1/2 watt with less than 0.02% harmonic distortion. The independent square wave output is variable from 0 to 5 volts peak to-peak and its risetime is less than 20 nanoseconds.

1.3 TECHNICAL SUMMARY

Frequency Range

0.01 Hz to 1 MHz continuously variable.

MULTIPLIER	FREQUENCY (Hz)	VERNIER RANGE (Hz)
0.1	0.01 - 99.9	0.1
1	100 - 999	1
10	1,000 - 9,990	10
100	10,000 - 99,900	100
1000	100,000 - 999,000	1000

Frequency Control

Three pushbutton decades for frequency digits, one five position pushbutton switch for multiplier. Frequency vernier is used to cover the range from 0.01 Hz to 0.1 Hz and the interval between digits of the third pushbutton decade.

Frequency Calibration Accuracy

±0.5% from 10 Hz to 100 kHz, rising to ±2% at 0.1 Hz and 1 MHz, with vernier in off position.

Frequency Stability

Vs. Time: In any period of 1 hour or less, within ±0.01% from 10Hz to 99.9kHz and ±0.1% from 0.1 Hz to 1 MHz. In any period of 10 hours or less, within ±0.05% from 10 Hz to 99.9 kHz and ±0.3% from 0.1 Hz to 1 MHz.

Vs. Line: For a 10% change in line voltage, within ±0.002% from 10 Hz to 99.9 kHz, rising to ±0.01% at 0.1 Hz and 1 MHz.

Vs. Load: No load to full load, within ±0.01% from 1 Hz to 10 kHz rising to ±0.06% at 0.1 Hz and ±0.6% at 1 MHz.

Vs. Temperature: Within ±0.02% per degree C from 10 Hz to 99.9 kHz and ±0.1% per degree C from 0.1 Hz to 1 MHz.

External Synchronization

A 1.5 volt peak to peak external signal will lock Oscillator over a range of approximately ±0.5%. See Section 2.3.

Sine Wave Output

Power: 1/2 watt.

Voltage: 10 volts rms open circuit, 5 volts across 50 ohms.

Current: 100 milliamperes rms.

Impedance: Constant 50 ohms ±2%.

DC Component: Nominal zero volts. At maximum output, drift is less than 2 millivolt per degree C, less than 1 millivolt for a 10% line voltage change, and within ±5 millivolts in any period of 10 hours or less. Drift reduced in proportion to output signal.

Distortion: Less than 0.02% from 10 Hz to 50 kHz, rising to 0.1% at 1.0 Hz and 99.9 kHz and to 1% at 0.1 Hz and 1.0 MHz.

Amplitude Stability

Vs. Time: In any period of one hour or less, within ±0.01% from 10 Hz to 20 kHz, rising to ±0.05% at 1 MHz. In any period of 10 hours or less, within ±0.02% from 10 Hz to 20 kHz, rising to ±0.1% at 1 MHz.

Vs. Line: For a 10% change in line voltage, within ±0.01% from 10 Hz to 1 MHz.

Vs. Temperature: Within ±0.01% per degree C from 10 Hz to 20 kHz, rising to ±0.1% per degree C at 1 MHz.

Hum and Noise: Less than 0.01% of output.

Cycle to Cycle Amplitude Stability: Less than 0.02%.

Frequency Response: Within ±0.05 db from 10 Hz to 10 kHz, rising to ±0.3 db at 0.1 Hz and 1 MHz.

Amplitude Control: Eleven position switch providing ten 1 volt increments from zero to 9 inclusive. In the first position (0 - 0.1) the concentric infinite resolution vernier provides continuous control from near zero (approximately 2 millivolts) to a nominal 100 millivolts. In the next ten positions this vernier covers a nominal 1 volt range. At no load with vernier control at maximum CCW position, calibration is within ±2% ±2 millivolts of indicated attenuator setting for frequencies up to 20 kHz, rising to ±5% ±20 millivolts at 1 MHz.

Tuning Transients: Typical deviation after switching, over most of the range, less than ±0.5 db recovering within 10 milliseconds or a few cycles, whichever is greater.

Square Wave Output

Voltage: Continuously adjustable from nominal zero to 5 volts peak to peak open circuit, 2.5 volts across 50 ohms.

Current: 100 milliamperes peak to peak.

Impedance: Constant 50 ohms.

DC Component: Nominal zero volts.

Waveform Details: Rise and fall time, less than 20 nanoseconds; symmetrical within ±2%; flat top with no droop and less than 5% overshoot at maximum amplitude, with 50 ohm cable feeding matched (50 ohm) load.

Floating (ungrounded) Operation

A switch is provided to disconnect the signal ground from chassis ground. In this mode performance is slightly reduced above 10 kHz.

Terminals: BNC connectors on both front panel and rear of chassis for sine wave output. BNC connector on front panel only of Bench Model 4100A and rear at chassis only for Rack Model 4100AR for square wave output.

Power Requirements

105-125 or 210-250 volts, single phase, 50-400 Hz, 55 watts.

Ambient Temperature Range

0°C to 50°C.

Dimensions and Weights

Bench Model 4100, 8 1/2" wide, 5 1/4" high, 14 1/2" deep, 16 lbs/8kg net, 22 lbs/10kg shipping. Rack-mounting Model 4100R, 19" wide, 5 1/4" high, 14 1/2" deep, 20 lbs/9kg net, 26 lbs/12kg shipping.

SECTION 2

OPERATING INSTRUCTIONS

2.1 GENERAL

On receipt of the Oscillator, carefully examine it for any damage that may have occurred in transit. If signs of damage are observed, file a claim with the transporting agency immediately, and notify your Krohn-Hite representative or Krohn-Hite Corporation directly. Do not attempt to use the Oscillator if extensive damage has occurred and do not ship it back until the carrier has inspected it. It may be opened for inspection without nullifying the warranty.

Rack-mounting models (designated by a suffix "R" after the model number) mount with four machine screws in the standard 19" rack space. No special brackets or attachments are needed.

2.2 OPERATION

To operate the Oscillator, proceed as follows:

a. Make appropriate power connections as described in Section 2.4.

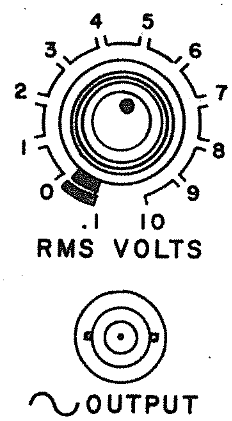
b. Make appropriate connections to the front panel or rear chassis OUTPUT connectors of the Oscillator.

c. Select the desired frequency with the three banks of ten pushbutton switches to establish up to three significant figures of the operating frequency. Select the desired frequency range by engaging one of the five MULTIPLIER pushbuttons. CAUTION! The Oscillator will not function unless one button in each of the three FREQUENCY switches and MULTIPLIER switch is depressed. For specified performance the first bank of push button switches should not be set to zero, unless frequencies below 10 Hz are required. For example, 150 Hz should not be obtained by engaging the 0, 1, 5 buttons (left to right) and the X10 MULTIPLIER. For rated performance and maximum frequency accuracy, 150 Hz should be obtained by setting 1, 5, 0, and the X1 MULTIPLIER. If the first bank of push button switches is set to zero above 10 Hz, the Oscillator will not function within its rated specifications, and the sine wave output may drop below its normal amplitude. This effect may be more pronounced on the higher frequency bands.

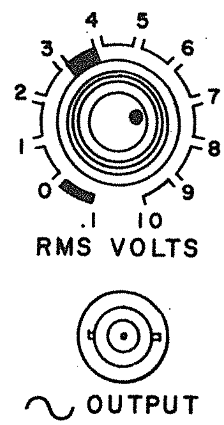
d. The three banks of ten push button switches and associated multiplier reads directly in Hz when the FREQUENCY VERNIER control is in the maximum counter clock-wise position or calibrate position. This control varies the frequency continuously by an amount equal to the increment between adjacent buttons of the third switch bank. The FREQUENCY VERNIER is also used to obtain any frequency between 0.01 and 0.1 Hz by setting all three banks of push buttons to zero and the MULTIPLIER to the X0.1 position.

e. Adjust sine wave output amplitude by means of the dual RMS VOLTS controls which consist of an eleven position switch and concentric vernier potentiometer.

The switch provides ten 1 volt increments from zero to 9 inclusive. In the first switch position (0-0.1) this concentric infinite resolution vernier provides continuous output from near zero (approximately 2 millivolts) to a nominal 100 millivolts. In the next ten switch positions this vernier covers a nominal 1 volt range. A graphical representation of the required positions of both the switch and concentric vernier is shown below to obtain a sine wave out of approximately 50 millivolts and 3.7 volts rms respectively.



Position of Controls for 50
Millivolts Out



Position of Controls for 3.7
Volts Out

f. For normal Oscillator operation the FLOATING CHASSIS GROUND switch, located on the rear of the chassis, should be in the CHASSIS position. If the Oscillator is used in a system where ground loops make ungrounded or floating operation essential, this switch should be in the FLOATING position. In this position the Oscillator signal ground should be tied to a suitable remote system ground to prevent degradation of Oscillator performance, principally hum level and high frequency calibration.

2.3 EXTERNAL SYNCHRONIZATION

An EXTERNAL SYNC connector on the rear of the chassis is provided to synchronize the frequency of the Oscillator to an external signal. Connect the external signal to the EXTERNAL SYNC input connector at the rear of the chassis and tune the Oscillator to the frequency of the external signal. With an external sine or square wave synchronizing signal of 1.5 volts peak to peak, the Oscillator output will be locked in frequency to the external signal over a locking range of approximately ±1/2% of the Oscillator frequency setting. The Oscillator amplitude will change slightly and the distortion will rise to approximately 0.02% with an external sine wave synchronizing signal and to 0.1% for a square wave external signal. When the Oscillator frequency is the same as the external signal frequency, the Oscillator output will lead the external synchronizing signal by approximately 70 degrees. A±1/2% variation in the Oscillator frequency will vary their relative phase by approximately ±80 degrees.
Locking range and distortion increase linearly with the external synchronizing signal amplitude. With a 6 volt peak to peak sine wave external synchronizing signal,

the maximum recommended, the locking range will increase to ±2% and the distortion will be approximately 0.05%. With a square wave external synchronizing signal, the same locking range of ±2% will be obtained but the distortion will rise to approximately 0.4%.

2.4 LINE VOLTAGE AND FUSES

The Oscillator is normally wired for operation from an a-c power source of 105-125 volts 50 to 400 Hz, and uses a 1/2 ampere slow-blow fuse that is mounted on the rear of the chassis. It may be modified to operate from an a-c power source of 210 - 250 volts by removing the two jumpers between terminals 1 and 3, and terminals 2 and 4 of the power transformer, and connecting a jumper across terminals 2 and 3. A 1/4 ampere slow-blow fuse should be used for 210-250 volt operation. An identifying tag attached to the line cord will indicate when the Oscillator is wired for 230 volt line operation.

Access to the Oscillator is accomplished easily by removing the top and bottom covers. It is first necessary to remove the two screws centered on each side at the rear of the chassis and then pulling out the two side covers. After removing the top and bottom cover screws, the top and bottom covers may then be pulled out.

SECTION 3

CIRCUIT DESCRIPTION

3.1 INTRODUCTION

The Model 4100A, shown in the Simplified Schematic Diagram Figure 2, is an RC Oscillator whose frequency is determined by a regenerative Main Amplifier in conjunction with a frequency determining network consisting of R_1C_1 and R_2C_2. Amplitude constancy is attained by a unique dual AVC system.

One AVC circuit has low gain but fast response to provide rapid recovery from transients. It samples the peak of the positive and negative excursion of the Oscillator output, comparing it to two stable zener references VR131 and VR132, and develops a square wave error signal across a storage capacitor. This square wave,

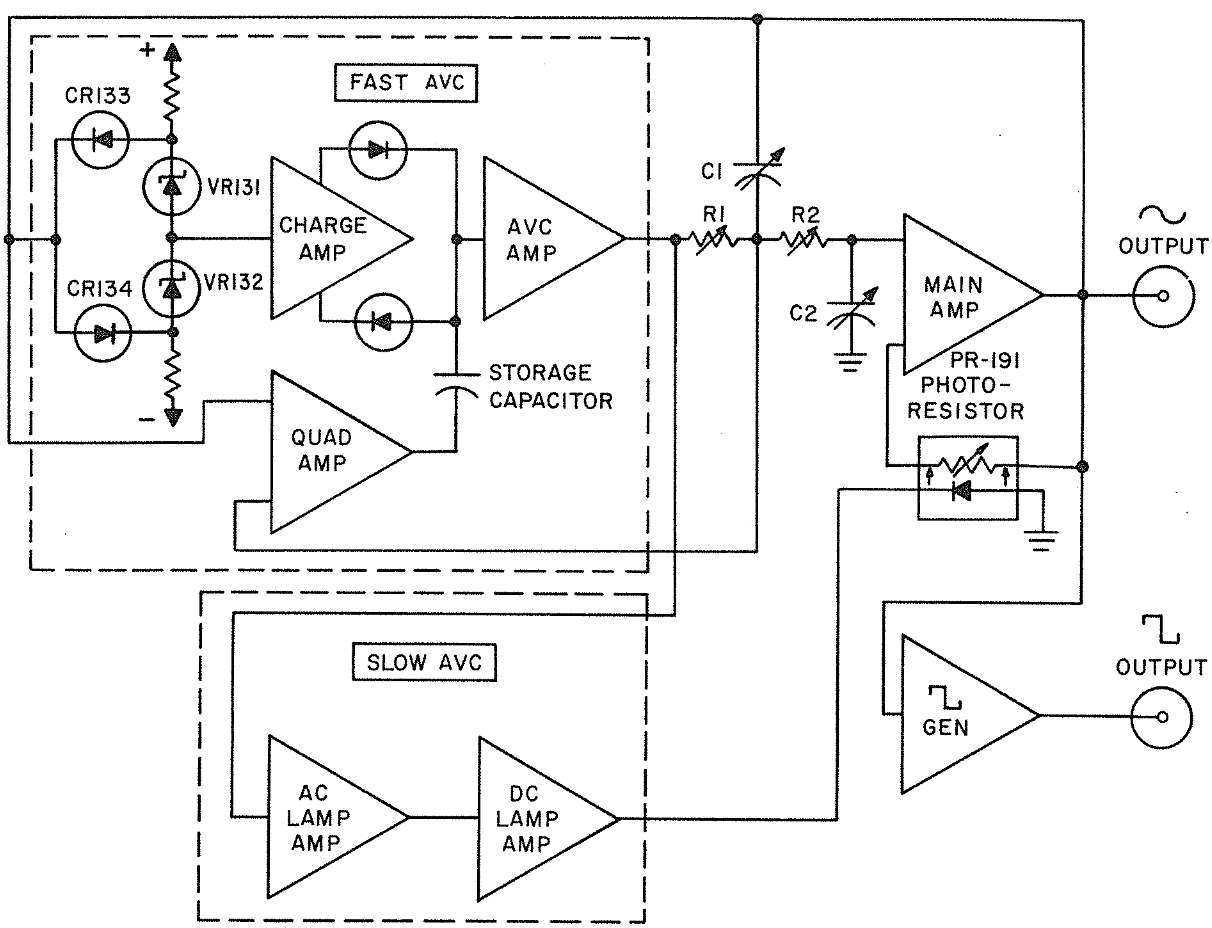


Figure 2. Simplified Schematic Diagram

which is in quadrature with the Oscillator sine wave output, after further amplification by the AVC Amplifier is fed back via the frequency determining network to the Main Amplifier.

The other AVC circuit has slow response but high gain to maintain long term amplitude stability. It uses a photoresistor, PR191, to control the gain of the Main Amplifier. A light-emitting diode in the photoresistor is controlled by the LED Amplifiers. The input to the AC LED Amplifier comes from the AVC Amplifier output. The DC LED Amplifier converts the output of the AC LED Amplifier to a DC voltage that illuminates the LED in the photoresistor. Since these high gain amplifiers precede the LED, the Oscillator output is insensitive to external shock and vibration.

In the following discussion reference to both the Simplified Schematic Diagram, Figure 2, and the Schematic Diagram Figure 8 at the end of this manual is recommended.

3.2 FREQUENCY DETERMINING CIRCUITS

The tuning controls for this Oscillator include a five station push button switch that selects a pair of frequency determining capacitors C_1 and C_2, to establish each decade of frequency. Capacitor C_1 is ten times the value of Capacitor C_2. Equal frequency determining resistors, R_1 and R_2, establish the frequency within decades, and are selected by the three banks of ten push button switches to establish up to three significant figures of frequency. A frequency vernier adjustment using a dual potentiometer essentially shunts both resistor networks to vary frequency between the smallest digit increments to provide continuous frequency coverage. This vernier is also the sole frequency control for the lowest decade of the frequency range from 0.01 to 0.1 Hz.

3.3 MAIN AMPLIFIER

The sine wave output of the Oscillator is generated by the Main Amplifier. It consists of an input FET (field effect transistor) follower, two stages of amplification, and a complimentary push-pull output stage. The FET follower Q191, isolates the high impedance frequency determining network, and drives the second stage differential amplifier Q194 and Q195. Q192 and Q193 function as a high value resistor approximating a constant-current source. The differential output from the second stage drives the third stage which is a complementary differential amplifier using an NPN transistor Q196 in series with a PNP transistor Q197. A single-ended output from the collector of Q197 drives the output stage, Q198 and Q199.

3.4 AVC

To maintain the high degree of amplitude constancy the Oscillator uses a dual AVC system. One AVC circuit has low gain but fast response to provide fast recovery from transients, and the other AVC circuit has slow response but high gain to maintain long-term amplitude stability.

In the fast AVC circuit the positive and negative peaks of the sine wave output are compared with two stable zener references VR131 and VR132 in the Charge Amplifier. Two diodes CR133 and CR134, are backed biased by these two zeners producing a positive and negative pulse when they conduct at the peaks of the sine wave. The attenuated sine wave output that drives these diodes is derived from the emitter follower Q132. Transistor Q131, used as a diode, and diodes CR131, CR132, CR135 and CR136 provide temperature compensation.

A two stage degenerative amplifier, consisting of transistors Q133 and Q135 amplifies these positive and negative pulses to an amplitude of approximately 3.5 volts peak, and provides the necessary current capacity to charge the storage capacitor whose value is varied by the band multiplier switch. The positive and negative pulses from the Charge Amplifier develop a quadrature square wave error signal across the storage capacitor through the switching diodes Q136 and Q137 which are back-biased by zener VR134. Transistor Q138, used as a zener, is for level pulling.

To maintain amplitude constancy when the sine wave output falls below its normal value, the Quadrature Amplifier adds a constant amplitude offset square wave to the storage capacitor which is out of phase with the square wave that the Charge Amplifier develops across the storage capacitor. Under normal conditions these signals cancel each other with a resulting zero error voltage. This permits the fast AVC circuit to generate a corrective error voltage when the sine wave output drops below its normal amplitude.

The Quadrature Amplifier develops a square wave whose amplitude is constant, independent of the normal fluctuations in the sine wave output due to tuning transients or other similar disturbances. This quadrature square wave is developed by adding a signal from the junction of the frequency determining network resistors to the Oscillator sine wave output. The addition of these two signals is accomplished by the differential amplifier Q243 and Q244. Before adding the signal from the network, it is first buffered by a two stage unity gain amplifier which consists of FET Q241 and transistors Q242 and Q246. The output from the collector of Q242 is fed to the first base of the differential amplifier Q243, and a portion of the Oscillator sine wave output is applied to the second base of the differential amplifier Q244. The square wave output at the collector of Q243 is shaped by limiting diodes CR241 and CR242 so that its output appearing at the emitter follower Q245 is a clean constant amplitude square wave.

The error voltage developed at the storage capacitor is amplified by the AVC Amplifier which is a three stage degenerative amplifier consisting of a FET input stage Q161, amplifier Q162 for the second stage, and a Darlington output stage, consisting of Q164 and Q165. A corrective error voltage from the AVC Amplifier is fed back through the frequency determining network components to close the loop. This completes the operation of the low gain fast AVC circuit.

In the high gain slow AVC circuit the output of the AVC Amplifier is further amplified by the AC LED Amplifier which has a gain of approximately 50. It is a two stage degenerative amplifier consisting of Q311 and output stage Q313 and Q314. The Quadrature Amplifier output is also applied to the input of the AC LED Amplifier. It maintains the LED in the photoresistor in the middle of its dynamic range.

The output of the AC LED Amplifier, which is normally a 13 volt peak to peak square wave, is converted to a dc voltage in the DC LED Amplifier which provides the power to illuminate the LED in the photoresistor PR191. This DC LED Amplifier consists of a switching transistor, Q331, that functions as a half-wave rectifier, and a two stage amplifier with differential input stage Q332 and Q333, and output stage Q334. The output of the AC LED Amplifier is half-wave rectified by the transistor Q331 whose emitter is switched by the Quadrature Amplifier. This half-wave rectified signal is applied to the base of the differential amplifier Q332. To generate a full wave rectified signal, one half of the AC LED Amplifier output is also added to the half-wave rectified signal. The full-wave rectified signal is first filtered and then amplified. The output of the DC LED Amplifier, appearing at the collector of Q334, is normally about -3 volts dc and it illuminates the LED in the photoresistor. If an amplitude disturbance occurs, this dc voltage will vary and change the resistance element in the photoresistor. Since this resistor is part of the feedback network of the Main Amplifier, it will vary the gain of the amplifier to correct this disturbance and restore the Oscillator to its normal amplitude.

3.5 SQUARE WAVE

The square wave generator consists of a Schmitt trigger circuit Q281 and Q282 which is triggered by the sine wave output. A transistor switch Q283 which is driven off and on by the Schmitt trigger provides the square wave output. A 50 ohm constant impedance output is obtained by connecting the output of the switching transistor Q283 to the center arm of the square wave amplitude control potentiometer. The square wave output is 180 degrees out of phase with sine wave output.

3.6 POWER SUPPLY

The Power Supply furnishes two regulated voltages of + 22 and -22 volts. It consists of two full-wave rectifiers CR101 and CR104 and filter capacitors C101 and C106 to provide the unregulated dc voltages. Both supplies are of the typical series type. The + 22 volt supply is the master supply using zener VR101 as a reference and amplifiers Q102 and Q103 to drive the series regulator Q101. Short circuit protection is provided by the series resistor R105 which cuts off Q102 via diode CR102. The -22 volt supply is slaved to the + 22 volt supply. A divider network consisting of R126 and R127 sets the proper voltage level for the amplifiers Q105 and Q106, which drives the series regulator Q104. Short circuit protection is provided by R117 and diode CR105. To insure starting, a zener VR102 provides a negative voltage for the regulating amplifiers in the absence of the -22 volt supply. Diode CR107 is normally conducting but permits VR102 to function when required.

SECTION 4

MAINTENANCE

4.1 INTRODUCTION

If the Oscillator is not functioning properly and requires service, the following procedure may facilitate locating the source of trouble. The general layout of major components of the Oscillator is shown in Figure 3. The Oscillator consists basically of an unregulated power supply chassis in the rear, which can swing up to facilitate maintenance, a large printed circuit card, PC418, and five small printed circuit cards associated with the frequency controls. The most frequently used check points have been provided with test points. They are identified as shown in Figure 3.

Access to the Oscillator is accomplished easily by removing the top and bottom covers. It is first necessary to remove the two screws centered on each side at the rear of the chassis and then pulling out the two side covers. After removing the top and bottom cover screws, the top and bottom covers may then be pulled out.

Many troubles may easily be found by visual inspection. When a malfunction is detected, first check the line voltage and line fuse and then make a quick check for broken wires, burnt or loose components, or similar conditions which could cause trouble. When a malfunction is encountered, before beginning troubleshooting it should be determined if the normal adjustments mentioned in Calibration and Adjustment procedure, Section 5, will correct the trouble. Any troubleshooting of the Oscillator will be greatly simplified if there is an understanding of the operation of the circuit. Before any detailed troubleshooting is attempted, reference should be made to Circuit Description, Section 3. When a problem is encountered, it should first be determined if the malfunction is present under all conditions, or is only present under certain conditions such as certain frequency selector switch positions or on certain frequency multiplier bands. If the problem seems to be of general nature, the troubleshooting procedure outlined here should be followed. If the trouble is only present under specific conditions, however, the procedure must be adapted to fit the circumstances. Caution! Because there is a 10 ohm resistor connected between signal ground and chassis when the Floating/Chassis grounding switch is in the Chassis position, the Chassis should not be used as a test point for signal ground in making measurements. The shell of the sine wave output BNC connector is a convenient signal ground test point.

4.2 PRELIMINARY CHECKS

The Oscillator should be set up as follows:

1. Frequency selector switches at 1, 0, 0
2. Frequency Multiplier switch at X100
3. Sine wave output amplitude control at maximum cw
4. Floating/Chassis grounding switch (in rear of chassis) in Chassis position

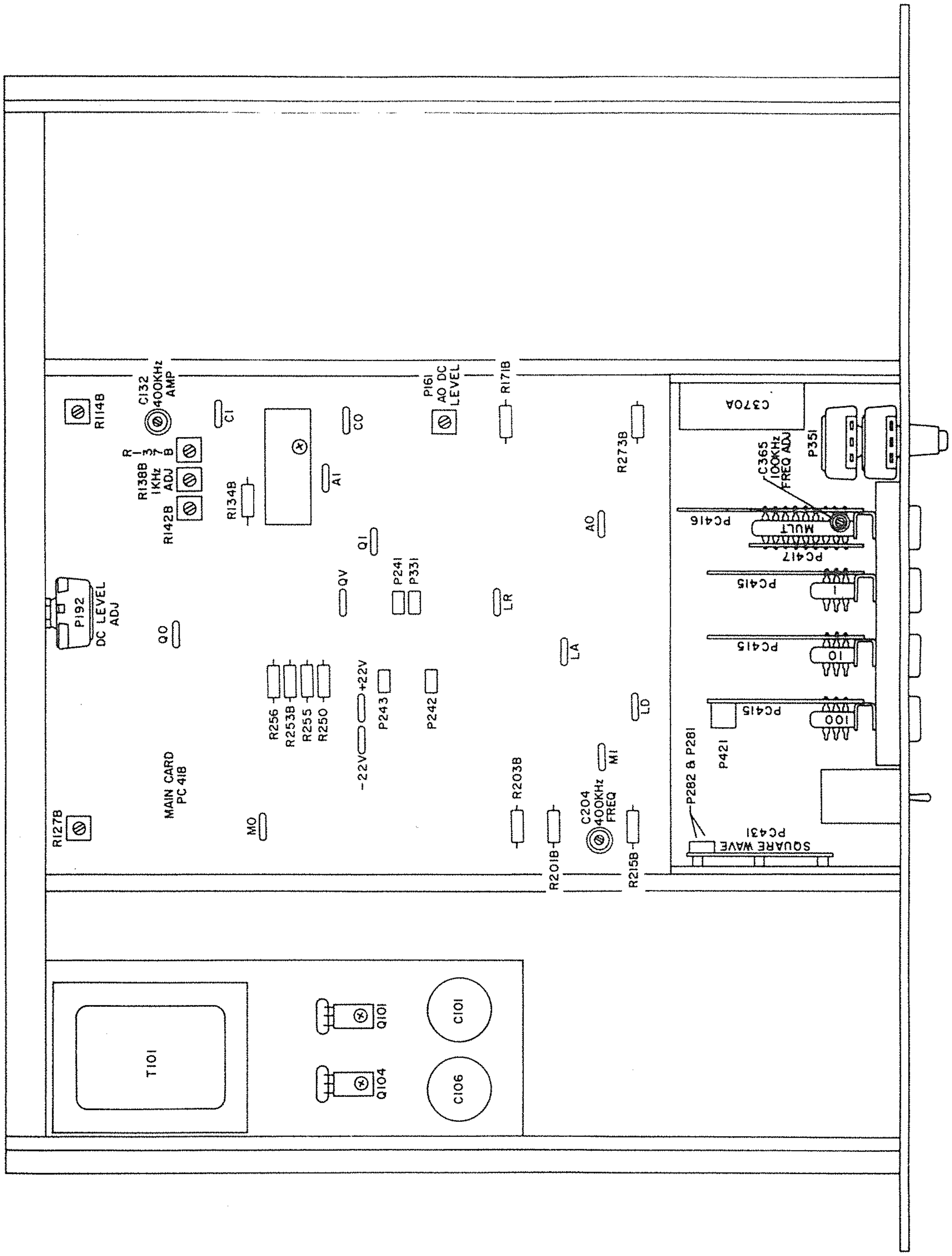


Figure 3. Exposed Top View of Oscillator

If the sine wave output appears to be correct, but the Square Wave is not, refer to Section 4. 9 . First check the two dc Power Supply voltages at the + 22 vdc and the -22 vdc test points which are on the large card as shown in Figure 3. If these levels are off by more than ±1 volt, refer to Section 4. 4.

If these supplies are correct, check the Main and AVC Amplifier output dc levels with respect to signal ground at test points (MO) and (AO) respectively, positioned on the large card as shown in Figure 3. To prevent spurious oscillations from disturbing these measurements short circuit the input of the Main Amplifier by connecting the test point (MI) on the large card to signal ground (shell of BNC connector). These dc levels should both be within less than ±0. 1 volt. If necessary adjust these levels. The screwdriver control P192 for adjusting the output dc level of the Main Amplifier is at the rear of the chassis. The screwdriver control P161 for adjusting the output dc level of the AVC Amplifier is mounted on the large card as shown in Figure 3. If the correct levels can not be obtained, the trouble is probably in either the MAIN or AVC Amplifiers respectively, and reference should be made to Section 4. 5 or Section 4. 6 whichever is applicable.

Remove the short circuit from the test point (MI) and connect test point (QI) to signal ground. Recheck the output dc level of the Main Amplifier. This level should remain at 0 ±0. 1 volt, when (QI) is shorted to ground. If it does not, the input transistor of the Main Amplifier Q191 may be defective or there is a malfunction in the frequency determining network.

Remove the short circuit from test point (QI) to signal ground and recheck the (AO) dc level. This level should again remain at 0 ±0. 1 volt, when this short circuit is removed. If it does not, the Quadrature Amplifier is probably defective and reference to Section 4. 6. 1. 3 is recommended. If the Main and AVC output dc levels are correct, a signal tracing analysis should be used to find the source of trouble.

4.3 SIGNAL TRACING

Connect an external signal source and network to the test point (MI) in the Oscillator as shown below in Figure 4. The signal ground of the external signal source should be connected to the shell of the sine wave output BNC connector. This source should be capable of providing a 10 volt rms sine wave into 1000 ohm load at 10 kHz. Adjust the external source to approximately 8 volts rms at 10 kHz, and set the Oscillator to 10 kHz (1-0-0, x 100). Check the Oscillator sine wave output voltage. This should be a sine wave with an amplitude of approximately 10 volts rms. If this signal is incorrect, the trouble is probably in the MAIN Amplifier and reference to Section 4. 5 is recommended. If the signal is correct, check the AVC Amplifier output signal at the test point (AO). Adjust the external source until the Oscillator

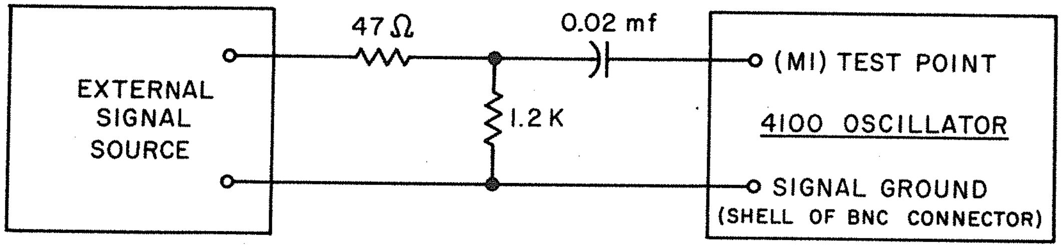


Figure 4. Circuit for External Signal Application

sine wave output is at 9 volts rms. The (AO) signal should be a square wave leading the Oscillator sine wave output by approximately 90°. As the external source is increased, this square wave should go through a null with approximately 9 volts external input and reverse phase as the external input signal is increased. If the AVC Amplifier is functioning as described, the entire Fast AVC circuit, consisting of the Charge Amplifier, Quadrature Amplifier and AVC Amplifier, is functioning properly. If the AVC Amplifier is not functioning as described above, reference to Section 4.6 is recommended.

As shown in the Simplified Schematic Figure 2, if the Main Amplifier and Fast AVC circuits are operating properly, the remaining circuitry in question consists of the AC and DC Amplifiers in the Slow AVC circuit. With the external source connected as before, check the DC LED Amplifier output at the test point (LD). It should be approximately zero volts dc when the Oscillator sine wave output is at 9 volts rms and increase to approximately -10 volts dc as the external signal is increased. If the DC Amplifier does not function in this manner, refer to Section 4.6.2.

4.4 POWER SUPPLY

The Power Supply consists of two separate regulated supplies of +22 and -22 volts dc. The +22 is used as a reference supply for the -22, and this fact should be kept in mind when doing any work on the supply, as a malfunction in the +22 will be reflected in the -22. If the supplies do not seem to be working properly, the +22 should be checked first. The two supplies have current limiting circuits which will shut down the supply if excessive current is being drawn from it. For this reason an apparent malfunction in the supply could be caused by an overload in one of the other circuits (e.g.) a collector to emitter short in one of the output transistors of the Main Amplifier will overload the power supply.

Nominal voltages for various points in the supplies are given in the Schematic, Figure 9. If a malfunction occurs, the error signal thus developed should be traced through the circuit to find the faulty component. Let us suppose, for example, that the +22 was lower than normal. This would produce an error signal which would make both the base and emitter of Q103 more negative than normal. Because the base moves less than the emitter the total result is a lowering of the collector from its normal value. The base of Q102 should then be more negative than normal and the collector more positive. This will raise the base of series regulator transistor Q101 and finally should correct the output level. Had there been a bad component somewhere in the circuit, this correcting action would have been blocked. The faulty component would then have been found at the point in the circuit where this action was blocked. The same basic method of troubleshooting described above may also be used in the other supply when a malfunction occurs.

If it becomes necessary to replace the reference zener Z101, the voltage of the +22 supply will probably have to be readjusted. This may be done by adjusting potentiometer R114B, located on the large card, PC418, as shown in Figure 3. R114B should be adjuted so the plus 22 supply is within +22, ±1 volt. If the -22 supply exceeds -22 ±1 volt, adjust potentiometer R127B, also located on the large card, PC418.

4.5 MAIN AMPLIFIER

When it appears that the problem has been isolated to the Main Amplifier, connect the test point (MI) to signal ground (shell of the BNC connector) and check the output dc level of the Main Amplifier at test point (MO) on the large card. This voltage can be set to zero when the Main Amplifier is functioning properly by adjusting the output dc level potentiometer P192 at the rear of the chassis. If this level cannot be set to zero ±0.1 volt, the Main Amplifier is probably defective, and the dc error signal thus developed should be traced through the circuit. For example, if the output level is plus, the feedback should raise the base of Q195 from its normal value of zero. This will then cause its collector to become more negative than normal. The base of Q196 and the collector of Q197 will also go more negative than their normal values. This should then lower the bases of Q198 and Q199 and correct the output level. If a faulty component is present in the circuit, it will prevent this corrective action from taking place. The faulty component will be found at the point in the circuit where the correcting action is blocked. The correct voltages for key points in the Main Amplifier are shown in the Schematic Figure 8. Most problems in the Main Amplifier will show up in a level check and the trouble-shooting method described above may be used to find the problem. If all the levels seem to be right and the unit seems to be working but will not put out the maximum rated output voltage or take power, Q198 and Q199 should be checked.

If it becomes necessary to replace the FET (field effect transistor), Q191, the Main Amplifier output dc level may have to be trimmed. With the same initial set up as given at the beginning of this section, check the output dc level of the Main Amplifier at test point (MO). If this level is other than zero and the rear chassis sine wave output dc level control, P192 will not correct it, change the fixed trim resistor R201B in parallel with R201A (do not disturb R201A). R201A is located on the large card. This adjustment should be made with P192 centered for optimum range of adjustment.

4.6 AVC CIRCUITS

When there appears to be trouble in the AVC circuits, the Oscillator should remain set up for a 10 kHz external input signal as shown in Figure 4. The short circuits from the test points should be removed and the signal from the external source should be varied in amplitude so that the Oscillator sine wave output varies from 9 to 11 volts rms. While making this variation the AVC Amplifier output signal at test point (AO) should be observed. When the Oscillator sine wave output is at 9 volts rms, the (AO) signal should be a square wave of at least 0.3 volts peak to peak amplitude leading the Oscillator sine wave output by approximately 90°. When the output is at 11 volts rms, the (AO) signal should be a square wave with an amplitude of at least 0.3 volts peak to peak, lagging the Oscillator sine wave output by approximately 90°. As the output is varied through 10 volts, the (AO) signal should go through a null. If this action takes place, the entire Fast AVC circuit is probably functioning properly. Proceed to check the Slow AVC circuit by referring to Section 4.6.2. If the (AO) signal is not normal, refer to Section 4.6.1.

When it is necessary to replace the FET (field effect transistor), Q161, the AVC Amplifier output dc level may have to be retrimmed. Short circuit test point (MI) to chassis, and check the AVC Amplifier output dc level at test point (AO). Adjust the (AO) dc level control P161, positioned on the large card as shown in Figure 3, until (AO) is at zero ±0.1 volt. If P161 will not zero the (AO) dc level, change the fixed trim resistor R171B in parallel with R171A (do not disturb R171A). This adjustment should be made with P161 centered for optimum range of adjustment.

4.6.1 Fast AVC Circuit

If the AVC Amplifier output signal (AO) is not correct, connect the external signal as shown in Figure 4 and check the input to the AVC Amplifier at test point (AI). This signal normally should be an approximate square wave varying through a null as the Oscillator sine wave output is varied from 9 to 11 volts rms. The (AI) signal should look like the normal (AO) signal, but inverted because the AVC Amplifier has a gain of minus one.

A normal (AI) signal but an incorrect (AO) signal indicates that the AVC Amplifier is probably not functioning and reference to Section 4.6.1.1 is recommended. If the (AI) signal is incorrect either the Charge Amplifier or the Quadrature Amplifier may be defective. Observe the output of the Charge Amplifier at test point (CO) as the Oscillator sine wave output is varied from 9 to 11 volts rms by the external signal and compare it with the correct waveforms as shown in Figure 5. If the Charge Amplifier output is incorrect, refer to Section 4.6.1.2. If the Charge Amplifier output is normal, check the output of the Quadrature Amplifier at test point (QO). It should be a square wave with an amplitude of 2-3 volts peak-to-peak, lagging the Oscillator sine wave output by approximately 90°. If this signal is incorrect, refer to Section 4.6.1.3.

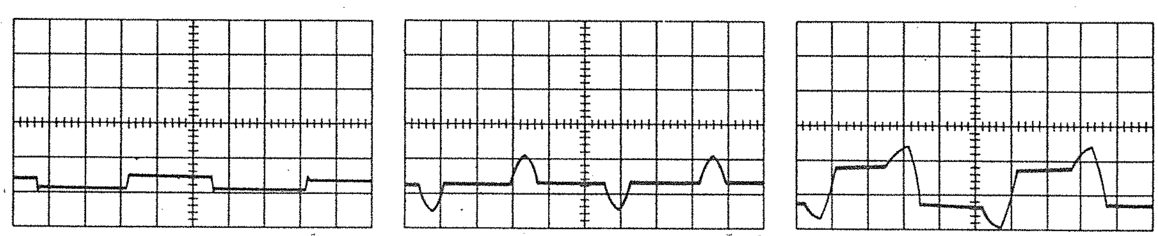
When both the (CO) and (QO) signals are correct but the (AI) signal is not, the most likely source of trouble is Z134, Q136, Q137 or Q138.

4.6.1.1 AVC Amplifier

When the output of the AVC Amplifier (AO) is not right but the input (AI) is normal and goes through a null as the Oscillator output varies from 9 to 11 volts rms, the trouble probably lies in the AVC Amplifier. To prevent any unwanted signals from disturbing the following dc measurements, short circuit (AI) to chassis ground. Nominal voltages for various points in the AVC Amplifier are shown on the Schematic Figure 9. First check the gate and source quiescent dc voltages of the FET Q161, to determine if they are normal. If the (AO) dc level is not zero ±0.1 volt and the AVC Amplifier output dc level control potentiometer, P161, will not correct it, the error voltage thus developed should be traced through the feedback loop. If, for example, the (AO) output is plus, this should drive the base of Q162, which is normally zero, more positive. This would make the collector of Q162 more negative than normal and drive the bases of Q164 and Q165 more negative to correct the (AO) output level. The faulty component will be found where the above corrective action is blocked.

4.6.1.2 Charge Amplifier

When it appears that the Charge Amplifier is not functioning properly, check the waveform of the Charge Amplifier output at test point (CO). Vary the Oscillator sine wave output from 9 volts rms to 10 volts rms and then to 11 volts rms (by varying the external source signal). The proper waveform of the (CO) signal for the three conditions are shown in Figure 5. The normal (CO) signal is shown in Figure 5b.



a. 9 volts b. 10 volts c. 11 volts

Figure 5. Charge Amplifier Output Signal (CO) with Oscillator Sine Wave Output Amplitude at 9, 10, and 11 volts rms. Vertical sensitivity 6 volts/div.

If the (CO) signals are not correct, check the emitter follower output at test point (CI) which is also the input to the Charge Amplifier. This should be a sine wave of 7 volts rms when the Oscillator sine wave output is 10 volts rms. If the (CI) signal is incorrect, the network which attenuates the Oscillator sine wave output or the transistors Q131 and Q132 are defective.

If the (CI) signal is correct but the (CO) signal is not, the problem is most likely the zener reference diodes, VR131 and VR132, or the amplifier which consists of Q133 and Q135. To determine which of these is defective, observe the waveform at the junction of VR131 and VR132. If the amplifier is functioning properly, this waveform should be similiar to the (CO) signal except that its amplitude will be reduced by the gain of the amplifier which is approximately 150. An incorrect signal at this point indicates a defective component. If VR131 or VR132 is replaced, it may be necessary to readjust potentiometer R137B, to make the positive and negative (CO) pulses, as shown in Figure 5, of equal amplitude.

4.6.1.3 Quadrature Amplifier

When it appears that the Quadrature Amplifier is not functioning, check its output at test point (QO). It should be a square wave of 2 to 3 volts peak to peak amplitude lagging the Oscillator sine wave output by approximately 90°. If this signal is not correct, check the signal at the test point (QV), which should be a sine wave leading the Oscillator sine wave output by approximately 20° with an amplitude of approximately 9 volts rms. It is important for this test that the external signal source and the Oscillator be set to the same frequency as outlined in Section 4.2. If the signal at (QO) is not correct, check Q243 and Q244 and associated components. Incorrect phase may indicate a problem in the tuning network (see Section 4.7). If the signal at (QV) is correct but (QO) is not, check Q243, Q244 and Q245 and associated components.

When it is necessary to replace the FET (field effect transistor), Q241, the dc level at test point (QV) should be checked. Short circuit test point (QI) to chassis and measure the dc level at test point (QV). It should be 0.3 ±0.1 volt. If necessary, adjust P241 to obtain a voltage of 0.3 volt dc at test point (QV).

4.6.2 Slow AVC

When it appears that the Slow AVC is defective, either the AC or DC LED Amplifiers are most likely not functioning properly. Measure the dc voltage on the output of the DC LED Amplifier at test point (LD) as the Oscillator sine wave output signal is varied from 9 to 11 volts rms by varying the external source. The dc voltage should vary from approximately zero to about -10 volts dc. If this action takes place, the Slow AVC circuit is probably functioning correctly.

If the (LD) voltage is incorrect, but the (AO) signal was found to be correct, check the output of the AC LED Amplifier at test point (LA). With (AO) set for a null, the (LA) signal should be an approximate square wave with an amplitude of approximately 8 volts peak to peak, leading the Oscillator sine wave output by approximately 90° and with a dc component of zero ±1 volt dc. The square wave amplitude should increase to over 25 volts peak to peak when the Oscillator output is 11 volts rms and decrease through a null to a signal lagging the Oscillator output by approximately 90° with an amplitude of over 4 volts peak to peak when the Oscillator output is reduced to 9 volts rms. If the (LA) signal is correct, but the (LD) dc voltage does not vary correctly, the DC LED Amplifier is probably defective. Check the signal on test point (LR). This should be the negative half-wave rectified portion of the (LA) signal but inverted with 6 volts peak to peak amplitude when the Oscillator sine wave output is at 10 volts rms, because Q331 is a rectifier with minus unity gain which is being switched off and on by the Quadrature Amplifier. If the (LR) signal is incorrect, check Q331 and associated components. If the (LA) and (LR) signals are correct, but the (LD) dc voltage does not vary correctly, check the transistors Q332, Q333 and Q334. If the (LA) signal is incorrect, the AC LED Amplifier is not functioning and the most likely source of trouble is the transistors Q311, Q312, Q313 and Q314.

4.7 TUNING NETWORK

Problems on certain multiplier bands or on certain positions of the frequency selector push button switches will usually be caused by something in the tuning network. If the trouble appears only at a particular setting of the frequency selector push-button switches, the problem is most likely one of the frequency determining resistors associated with that setting. The Schematic Diagram, Figure 8, shows which resistors come into play for each setting of the frequency selector push-button switches. After determining which switch position is bad, reference to this figure should point out the faulty resistor. All of the frequency determining resistors R366 to R419 are mounted on the three printed circuit cards PC415 (X100), PC415 (X10) and PC415 (X1) that are attached to the push button switches. The resistors are located on these cards as shown on Figure 11.

If one of the frequency determining band capacitors C364 to C370 is defective or out of tolerance, the Oscillator will not function properly or the frequency calibration will be in excess of its rated tolerance in <u>two</u> adjacent bands. This condition prevails because each tuning capacitor is used on two bands. For example, on band 4 (X100 multiplier), the frequency determining capacitors are C366A (1790pf) and C367A (19602pf). On band 3 (X10 multiplier) C367A is used again in addition to C368A (.1976mf). Therefore, if C367A or trimmer capacitor C367B, which is in parallel with C367A, is out of tolerance, the frequency accuracy will be out of calibration on both bands 3 and 4. The tuning capacitors are mounted on the printed circuit card PC 416 that is attached to the multiplier push button switch. The position of these capacitors on this card is shown on Figure 11. When the frequency is out of calibration by a small amount, it is recommended that the trim capacitors C366B to C370B, whichever is applicable, be changed rather than the fixed capacitors C366A to C370A.

4.8 SINE WAVE OUTPUT ATTENUATOR

The Schematic Diagram, Figure 8, also shows the concentric decade sine wave output attenuator used on the Oscillator. If trouble is encountered with the attenuator, it should first be determined which position of the switch is bad. After determining this, reference to the appropriate resistor in the attenuator table, shown in Figure 9, should point out the faulty component.

4.9 SQUARE WAVE

The Square Wave circuit depends on the Oscillator sine wave output for its operation. If the Square Wave does not seem to be working, check to see if the Oscillator is operating properly before attempting to troubleshoot the Square Wave. The Oscillator should be set up as follows before beginning troubleshooting of the Square Wave.

a. Oscillator frequency at 1 kHz.

b. Square Wave amplitude control at maximum cw.

If no Square Wave appears at the output, check the waveform at the test point (SO), which is the output of the Schmitt trigger. The signal here should be a square wave of approximately 3.9 volts peak-to-peak amplitude. If the (SO) signal is incorrect, the trouble is probably in Q281 or Q282, or their associated components. If the correct signal is present at (SO) but not at the Square Wave output BNC connector, check the Square Wave output transistors Q283 and Q284 and associated components.

SECTION 5

CALIBRATION AND ADJUSTMENT

5.1 INTRODUCTION

The following procedure is provided for the purposes of facilitating the calibration and adjustments of the Oscillator in the field, and adherence to this procedure should restore the Oscillator to its original specifications. If any difficulties are encountered, please refer to Maintenance, Section 4. If any questions arise which are not covered by this procedure, please consult our Factory Service Department. The location of all major components, modular sub-assemblies, test points, screwdriver controls and adjustments are shown in Figure 3.

Access to the Oscillator is accomplished easily by removing the top and bottom covers. It is first necessary to remove the two screws centered on each side at the rear of the chassis and then pulling out the two side covers. After removing the top and bottom cover screws, the top and bottom covers may then be pulled out.

5.2 TEST EQUIPMENT REQUIRED

The following test equipment is required to perform these tests:

a. Oscilloscope - having direct coupled horizontal and vertical amplifier with at least 10 mv/cm sensitivity and band width of 50 MHz - Tektronix Type 545 or equivalent.

b. Differential Comparator Plug-In Unit - Tektronix Type W or equivalent.

c. Wide Band Plug-In Unit - Tektronix Type 1A1 or equivalent.

d. Precision Frequency and Period Counter - capable of measuring frequency from 100 Hz to 1 MHz and period from 1000 seconds to 1.0 millisecond. Counter, Hewlett Packard 5245L.

e. Voltmeter-reading to 50 volts DC. Multimeter, Hewlett Packard 3490A.

f. Precision AC Differential Voltmeter - capable of measuring voltage from 10 mv to 10 volts RMS from 30 Hz to 50 kHz with ±0.1% accuracy. Fluke Model 931P or equivalent.

g. Variable auto-transformer to adjust the line voltage from 105 to 125 volts. VARIAC, General Radio W5MT3A.

h. Distortion Analyzer - capable of measuring distortion below 0.01% from 1 Hz to 100 kHz. Distortion Analyzer, Krohn-Hite 6800.

i. Spectrum or Wave Analyzer - capable of measuring harmonics below 1% from 100 kHz to 1 MHz. Spectrum Analyzer, Hewlett Packard 3585A.

5.3 POWER SUPPLY

With the Oscillator operating at 115 volts line, and frequency at 100 Hz (1-0-0, X1) check the + 22 and -22 volt regulated supplies with respect to signal ground (shell of BNC connector). The Floating/Chassis grounding switch located on the rear of the chassis should be in the Chassis position. All test points locations are shown in Figure 3.

	Test Point	Voltage and Tolerance
a.	+ 22 volt test point on large card PC418	+ 22 ±1 vdc

If necessary, adjust potentiometer R114B to obtain +22 volts dc.

	Test Point	Voltage and Tolerance
b.	-22 volt test point on large card PC418	-22 ±1 vdc

If necessary, adjust potentiometer R127B to obtain -22 volts dc.

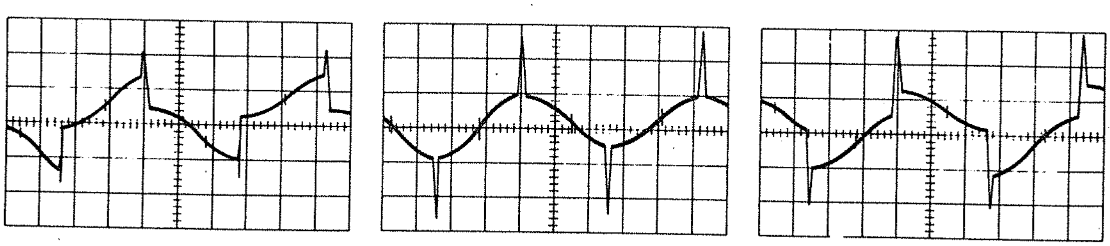
5.4 DC LEVEL ADJUSTMENTS

Adjust all dc level controls to zero ±10 mv, in the following order:

	Test Point	Control
a.	(AO) test point on large card PC418	P161 located on large card PC418
b.	(MO) test point on large card PC418	P192 located on rear of chassis

5.5 AVC AMPLIFIER ADJUSTMENT

To obtain low distortion it is necessary that the AVC Amplifier be adjusted properly. Set the Oscillator frequency to 100 Hz (1-0-0, X1). Connect a high sensitivity oscilloscope (at least 10mv/cm) to the AVC Amplifier output at test point (AO), located on the large card PC418, as shown in Figure 3. The square wave component in the (AO) signal should be less than 10 mv peak to peak. If it is not, adjust P331 (located on the large card) for minimum (AO) signal. Figure 6b shows the (AO) signal, which is a sine wave with spikes at peak amplitude, when P331 is adjusted correctly. Note the absence of a square wave signal. In Figure 6a P331 is off one way and in Figure 6c, P331 is off the other way; and both have a 20

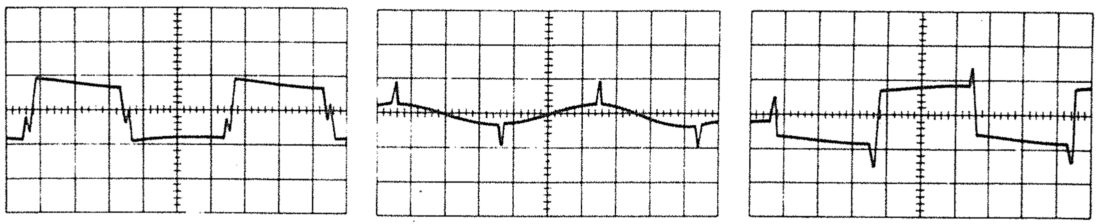


a. Low Ohms   b. Correct Ohms   c. High Ohms

Figure 6. AVC Amplifier Output Signal (AO) at 100Hz.
Vertical Sensitivity - 20mv/div.

mv peak to peak square wave superimposed on the sine wave signal.

Change the Oscillator frequency to 1Hz (0-9-0, X0.1). The square wave components in the (AO) signal should be less than 100 mv peak to peak. If it is excessive, adjust P421 for minimum (AO) signal. P421 is located on the printed circuit card PC416, which is attached to the Hundreds Decade push button switch assembly. The location of components on this card is shown in Figure 8. Figure 7b shows the (AO) signal when P421 is trimmed correctly. In Figures 7a and 7c, P421 is trimmed incorrectly.



a. Low b. Correct c. High

Figure 7. AVC Amplifier Output Signal (AO) at 9 Hz.
Vertical Sensitivity - 50 mv/div.

Set the multiplier switch to the X10 position. Measure the output dc level of the AVC Amplifier at test point (AO). It should be 0±10 millivolts. If it is not, adjust potentiometer R142B, for minimum dc level. R142B is located on the large card PC418, as shown in Figure 3.

5.6 DISTORTION

(Note: It is essential that the procedure outlined in Section 5.5 be performed before making any distortion measurements).

A low distortion analyzer (such as the Krohn-Hite Model 6800) may be used to check total harmonic distortion between 1 Hz and 100 kHz. The distortion readings should fall within the tolerances listed below:

Oscillator Frequency	Tolerance
1 Hz-10 Hz	0.1%
10 Hz-50 kHz	0.02%
50 kHz-99.9 kHz	0.1%

For frequencies above 100 kHz, the use of a wave or spectrum analyzer (such as the HP 3585A) is recommended. Total harmonic distortion should be less than 1% from 100 kHz to 1 MHz.

5.7 FREQUENCY CALIBRATION

Set the Oscillator frequency to 10 Hz (1-0-0, X0.1) with the frequency vernier in the CAL position (maximum ccw). Check the frequency calibration using a frequency counter. If the frequency is out of calibration by more than ±0.5%, refer to Maintenance Section 4.7. Repeat the above procedure at 100 Hz (1-0-0, X1), 1 kHz (1-0-0, X10), and 10 kHz (1-0-0, X100). If the frequency is out of calibration by more than ±0.5%, refer to Maintenance Section 4.7.

Set the Oscillator frequency to 100 kHz (1-0-0, X1000) with the frequency vernier in the CAL POSITION (maximum ccw). Check the frequency calibration using a frequency counter. For optimum calibration accuracy the Oscillator should be permitted to warm up for not less than 30 minutes and all the covers should be in position. Slide the covers back to obtain access to the adjustments and then return them before taking a frequency measurement. If the frequency is out of calibration by more than 0.5%, adjust trimmer capacitor C365, located on the printed circuit card, PC416 which is attached to the multiplier push button switch. The location of the components on this card is shown in Figure 3. Check the frequency calibration at 400 kHz. If calibration is off more than ±1%, adjust trimmer capacitor C204 located on the large card, PC418, as shown in Figure 3. Check the frequency at 999 kHz. If calibration is off more than ±1%, adjust <u>fixed</u> trim resistor R215B in parallel with R215A (do not disturb R215A). R215B is located on the large card, PC418, as shown in Figure 3.

5.8 ATTENUATOR CALIBRATION

The output attenuator of the Oscillator uses a single decade switch attenuator plus concentric vernier. Set the Oscillator frequency to 1000 Hz (1-0-0, X10). Using an ac voltmeter with better than 0.25% accuracy, check the calibration of the attenuator with the vernier off (maximum ccw) and the switched decade attenuator in the 9-10 position (maximum CW). It should be within ±2% of 9 volts rms. If necessary adjust potentiometer R138B, located on the large card PC418, as shown in Figure 3.

5.9 FREQUENCY RESPONSE

Using a suitable voltmeter, such as the Fluke Model 931P, compare the output voltage versus frequency from 10 Hz to 10 kHz; it should be within ±0.5%. The absolute voltage accuracy is not important because only changes in voltage are observed.

With the sine wave output attenuator set in the 9-10 volt position and the concentric vernier amplitude control off (maximum ccw), check the sine wave output at 400 kHz (4-0-0, X1000). It should be within ±3% of 9 volts rms. If necessary adjust trimmer capacitor C132, located as shown in Figure 3.

5.10 AMPLITUDE STABILITY

The long term amplitude stability may be monitored by using a suitable ac voltmeter such as the Fluke Model 931P or equivalent. Connect the output of the Oscillator prior to the output attenuator to the input of the 931P. Set the Oscillator frequency to 1 KHz. Adjust the input voltage controls on the 931P for a null at maximum sensitivity. When using the Fluke Model 931P in the maximum sensitivity (0.1%) position, changes in ac voltages of 0.002% can be observed.

5.11 HUM AND NOISE (Cycle to Cycle Stability)

This specification can be checked by using a Tektronix scope with a type W differential comparator type plug-in unit or equivalent. Using 1 millivolt per centimeter sensitivity, check the cycle to cycle peak amplitude variations with the Oscillator output at 7 volts rms. The peak variation due to hum or noise should be less than 2 mv (2 cm). The hum and noise should be observed on the peak of the waveform.

5.12 HUM MODULATION

Using the same method as above in step 5.11, check the line frequency modulation or beat at approximately 62 Hz and 124 Hz. The maximum peak excursion should be less than 1 mv (1 cm).

5.13 OUTPUT IMPEDANCE

Connect the 50 ohm output to an ac voltmeter. Adjust the output attenuator for a reading of 10 volts. Load the output with 50 ohms. The output voltage should drop to 5 volts. This check can be performed at various attenuator settings. In each case the output voltage should drop 6 db when shunted with the matched load.

5.14 EXTERNAL SYNCHRONIZATION

Connect a 1 kHz signal of 1/2 volt rms amplitude to the SYNC input connector located on the rear of the chassis. Set the Oscillator to approximately 1 kHz (1-0-0, X10). Connect the output of the Oscillator to the vertical amplifier of the scope and connect the external Oscillator to the horizontal amplifier of the scope. Set the scope up for display of a circular Lissajous pattern. The Oscillator should lock to the external signal over a range of approximately ±0.5%.

5.15 SQUARE WAVE ADJUSTMENTS

5.15.1 Symmetry

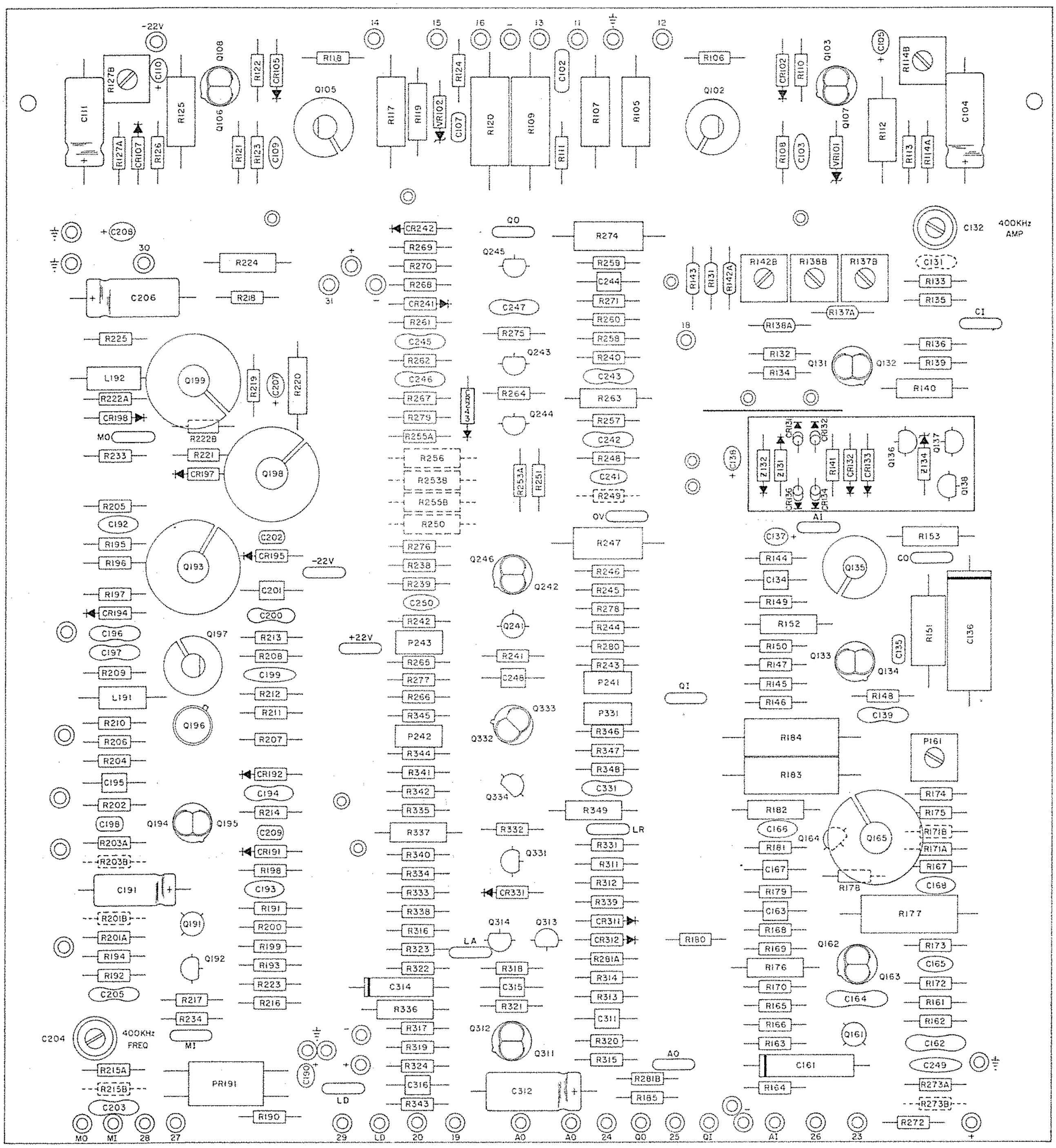
Using a wide-band oscilloscope (frequency range at least 50 MHz) connect the scope lead with a 50 ohm termination at the scope input to the Square Wave output of the Oscillator. Set the Oscillator frequency to 1 kHz (1-0-0, X10). Set the square wave amplitude control full CW. While observing the square wave symmetry, adjust Potentiometer P281, located on the square wave card, as shown in Figure 3, for a 1% symmetrical waveform.

5.15.2 DC Level

Adjust Potentiometer P282, located on the square wave card, for zero dc level on the Square Wave output. This can be observed on the scope or by using a dc voltmeter connected to the square wave output terminal.

5.15.3 Rise and Fall Time

Using a 50 MHz or greater bandwidth oscilloscope, with the sweep time calibrated for 20 nanoseconds per centimeter, measure the rise and fall time of the Square Wave at 1 MHz (9-9-9, X1000). The rise time is considered to be the horizontal displacement between the 10% and 90% points. The tolerance is less than 20 nanoseconds.



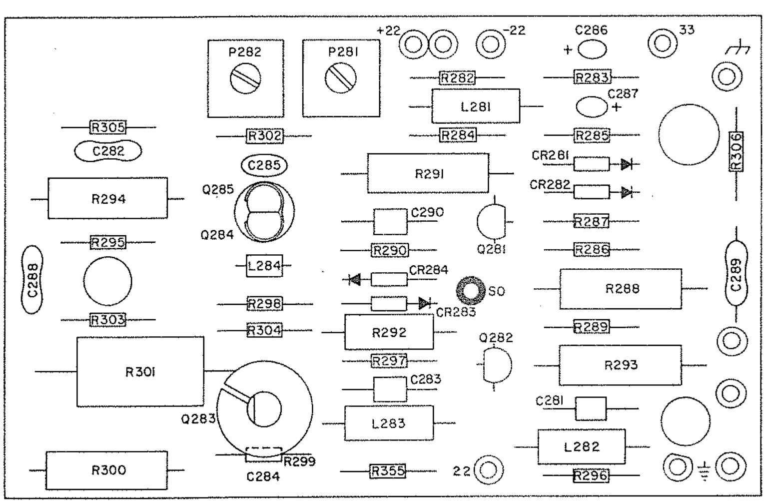
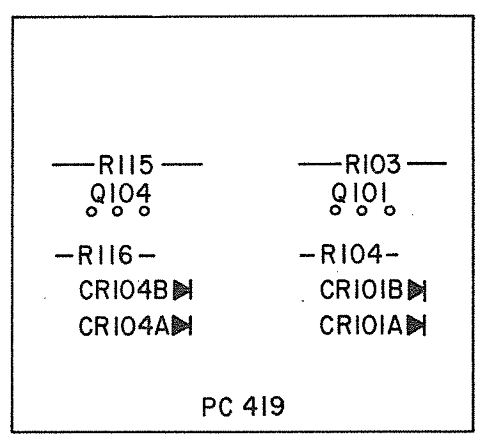


FIGURE 10. SQUARE WAVE PRINTED CIRCUIT CARD (PC431)



RESISTORS

Symbol	Description			Mfr.	Mfr. Part No.
R101	10	10%	1/4W	AB	CB1011
R102	100K	10%	1/4W	AB	CB1041
R103	330	10%	1W	AB	GB3311
R104	470	10%	1/4W	AB	CB4711
R105	4.7	10%	2W	AB	HB47G1
R106	330	10%	1/4W	AB	CB3311
R107	3.3K	10%	1W	AB	GB3321
R108	1K	10%	1/4W	AB	CB1021
R109	1K	10%	2W	AB	HB1021
R110	1.5K	10%	1/4W	AB	CB1521
R111	22	10%	1/4W	AB	CB2201
R112	1.8K	10%	1W	AB	GB1821
R113	5.6K	10%	1/4W	AB	CB5621
R114A	680	10%	1/4W	AB	CB6811
R114B	1K	POT		BKM	72PM
R115	330	10%	1W	AB	GB3311
R116	470	10%	1/4W	AB	CB4711
R117	4.7	10%	2W	AB	HB47G1
R118	220	10%	1/4W	AB	CB2211
R119	1K	10%	1/2W	AB	EB1021
R120	470	10%	2W	AB	HB1021
R121	10K	10%	1/4W	AB	CB1031
R122	1.5K	10%	1/4W	AB	CB1521
R123	15K	10%	1/4W	AB	CB1531
R124	22	10%	1/4W	AB	CB2201
R125	1K	10%	1W	AB	GB1021
R126	3.9K	5%	1/4W	AB	CB3925
R127A	3K	5%	1/4W	AB	CB3025
R127B	1K	POT		BKM	72PM
R131	374	1%	1/8W	KID	M3-3740-T100F
R132	220	10%	1/4W	AB	CB2211
R133	1K	10%	1/4W	AB	CB1021
R134A	680	10%	1/4W	AB	CB6811
R134B	TRIM			AB	TYPE CB
R135	13K	5%	1/4W	AB	CB1335
R136	1K	10%	1/4W	AB	CB1021
R137A	11K	1%	1/8W	KID	M3-1102-T100F
R137B	5K	POT		BKM	72PM
R138A	750	1%	1/8W	KID	M3-7500-T100F
R138B	1K	POT		BKM	72PM
R139	330	10%	1/4W	AB	CB3311
R140	2.7K	10%	1/2W	AB	EB2721
R141	3.92K	1%	1/8W	KID	M3-3921-T100F
R142A	562	1%	1/8W	KID	M3-5620-T100F
R142B	500	POT		BKM	72PM
R143	1.1K	1%	1/8W	KID	M3-1101-T100F
R144	2.21K	1%	1/8W	KID	M3-2211-T100F
R145	1K	10%	1/4W	AB	CB1021
R146	680	10%	1/4W	AB	CB6811
R147	220	10%	1/4W	AB	CB2211
R148	3.9K	10%	1/4W	AB	CB3921
R149	330	10%	1/4W	AB	CB3311
R150	5.6K	10%	1/4W	AB	CB5621
R151	1.8K	10%	1W	AB	GB1821
R152	120	10%	1/2W	AB	EB1211
R153	2.2K	10%	1/2W	AB	EB2221
R161	1K	10%	1/4W	AB	CB1021
R162	1K	10%	1/4W	AB	CB1021
R163	100	10%	1/4W	AB	CB1011
R164	1M	10%	1/4W	AB	CB1051
R165	6.8K	10%	1/4W	AB	CB6821
R166	68K	10%	1/4W	AB	CB6831
R167	1M	10%	1/4W	AB	CB1051
R168	22K	10%	1/4W	AB	CB2231
R169	330	10%	1/4W	AB	CB3311
R170	10	10%	1/4W	AB	CB1011
R171A	470K	10%	1/4W	AB	CB4741
R171B	TRIM			AB	TYPE CB
R172	4.7K	10%	1/4W	AB	CB4721
R173	1.8K	10%	1/4W	AB	CB1821
R174	330	10%	1/4W	AB	CB3311
R175	18K	10%	1/4W	AB	CB1831
R176	1.8K	10%	1/2W	AB	EB1821
R177	150	5%	3W	KH	TYPE KM-300-150
R178	330	10%	1/4W	AB	CB3311
R179	3.9K	10%	1/4W	AB	CB3921
R180	6.8K	10%	1/4W	AB	CB6821
R181	15K	10%	1/4W	AB	CB1531
R182	1	10%	1/2W	AB	EB10G1
R183	560	5%	2W	AB	HB5611
R184	560	5%	2W	AB	HB5611
R185	1K	10%	1/4W	AB	CB1021
R190	1K	10%	1/4W	AB	CB1021
R191	5.1K	5%	1/4W	AB	CB5125
R192	1K	10%	1/4W	AB	CB1021
R193	330	10%	1/4W	AB	CB3311
R194	330	10%	1/4W	AB	CB3311
R195	9.1K	5%	1/4W	AB	CB9125
R196	1K	10%	1/4W	AB	CB1021
R197	1K	10%	1/4W	AB	CB1021
R198	1.5K	10%	1/4W	AB	CB1521
R199	100	10%	1/4W	AB	CB1011
R200	22K	10%	1/4W	AB	CB2231
R201A	6.8K	10%	1/4W	AB	CB6821
R201B	TRIM			AB	TYPE CB
R202	220	10%	1/4W	AB	CB2211
R203A	8.2K	10%	1/4W	AB	CB8221
R203B	TRIM			AB	TYPE CB

Symbol	Description			Mfr.	Mfr. Part No.
R204	330K	10%	1/4W	AB	CB3341
R205	180	5%	1/4W	AB	CB1815
R206	820	10%	1/4W	AB	CB8211
R207	390	10%	1/4W	AB	CB3911
R208	100	10%	1/4W	AB	CB1011
R209	220	10%	1/4W	AB	CB2211
R210	220	10%	1/4W	AB	CB2211
R211	390	10%	1/4W	AB	CB3911
R212	100	10%	1/4W	AB	CB1011
R213	100	10%	1/4W	AB	CB1011
R214	3K	5%	1/4W	AB	CB4325
R215A	1.3K	5%	1/4W	AB	CB1021
R215B	TRIM			AB	TYPE CB
R216	1.2K	10%	1/4W	AB	CB1221
R217	240	5%	1/4W	AB	CB4311
R218	1.5K	10%	1/4W	AB	CB1521
R219	1.2K	10%	1/4W	AB	CB1521
R220	2.2	10%	1/2W	AB	EB22G1
R221	10	10%	1/4W	AB	CB1001
R222A	10	10%	1/4W	AB	CB1001
R222B	2.7	10%	1/4W	AB	CB27G1
R223	22K	10%	1/4W	AB	CB2231
R224	2.2	10%	1/2W	AB	EB22G1
R225	82	10%	1/4W	AB	CB8201
R226	422	1%	1/8W	KID	M3-4220-T100F
R227	4.7	10%	1/4W	AB	CB47G1
R228	500	0.5%	1/4W	KID	M4-5000-T100D
R229	250	0.5%	1/4W	KID	M4-2500-T100D
R230	250	0.5%	1/4W	KID	M4-2500-T100D
R231	125	0.5%	1/4W	KID	M4-1250-T100D
R233	100	10%	1/4W	AB	CB1011
R234	100	10%	1/4W	AB	CB1011
R235	100	10%	1/4W	AB	CB1011
R236	100	10%	1/4W	AB	CB1011
R237	47	5%	1/4W	AB	CB4705
R238	4.7K	10%	1/4W	AB	CB4721
R239	120	10%	1/4W	AB	CB1211
R240	1K	10%	1/4W	AB	CB1011
R241	2.2K	10%	1/4W	AB	CB2221
R242	6.8K	10%	1/4W	AB	CB6821
R243	100	10%	1/4W	AB	CB1011
R244	22K	10%	1/4W	AB	CB2231
R245	330	10%	1/4W	AB	CB3311
R246	1K	10%	1/4W	AB	CB1021
R247	1.8K	10%	1W	AB	GB1821
R248	390	10%	1/4W	AB	CB3911
R249	TRIM			AB	TYPE CB
R250	TRIM			AB	TYPE CB
R251	12K	10%	1/4W	AB	CB1231
R253A	15K	10%	1/4W	AB	CB1531
R253B	TRIM				TYPE CB
R255A	33K	10%	1/4W	AB	CB3331
R255B	TRIM			AB	TYPE CB
R256	TRIM			AB	TYPE CB
R257	470	10%	1/4W	AB	CB4711
R258	3.3K	10%	1/4W	AB	CB3321
R259	68K	10%	1/4W	AB	CB6831
R260	27K	10%	1/4W	AB	CB2731
R261	120K	10%	1/4W	AB	CB1241
R262	2.7K	1%	1/4W	AB	CB2721
R263	1.5K	10%	1/2W	AB	EB1521
R264	100	10%	1/4W	AB	CB1011
R265	5.6K	10%	1/4W	AB	CB5621
R266	8.2K	10%	1/4W	AB	CB8221
R267	1.5K	10%	1/4W	AB	CB1521
R268	6.8K	1%	1/4W	AB	CB6821
R269	5.6K	1%	1/4W	AB	CB5621
R270	820	1%	1/4W	AB	CB8211
R271	10K	1%	1/4W	AB	CB1035
R272	3.3K	10%	1/4W	AB	CB3321
R273A	680	10%	1/4W	AB	CB6811
R273B	TRIM			AB	TYPE CB
R274	820	10%	1W	AB	GB8211
R275	330	10%	1/4W	AB	CB3311
R276	22K	10%	1/4W	AB	CB2231
R277	100K	5%	1/4W	AB	CB1045
R278	16K	5%	1/4W	AB	CB1635
R279	470	10%	1/4W	AB	CB4711
R280	820	10%	1/4W	AB	CB8211
R281A	1K	10%	1/4W	AB	CB1021
R281B	39	10%	1/4W	AB	CB3901
R282	10	10%	1/4W	AB	CB1001
R283	470	10%	1/4W	AB	CB4711
R284	15K	10%	1/4W	AB	CB1531
R285	8.2K	10%	1/4W	AB	CB8221
R286	22K	10%	1/4W	AB	CB2231
R287	2.2K	10%	1/4W	AB	CB2221
R288	1K	10%	1W	AB	GB1021
R289	100	10%	1/4W	AB	CB1011
R290	270	10%	1/4W	AB	CB2711
R291	470	10%	1W	AB	GB4711
R292	1.5K	10%	1/2W	AB	EB1521
R293	1K	10%	1W	AB	GB1021
R294	340	1%	3W	KH	TYPE KM-300-340
R295	150	10%	1/4W	AB	CB1511
R296	120	10%	1/4W	AB	CB1211
R297	220	10%	1/4W	AB	CB2211
R298	100	10%	1/4W	AB	CB1011
R299	15	10%	1/4W	AB	CB1501

RESISTORS (CONT.)

Symbol	Description			Mfr.	Mfr. Part No.
R300	340	1%	3W	KH	TYPE KM-300-340
R301	220	10%	2W	AB	HB2211
R302	39	10%	1/4W	AB	CB3901
R303	270	10%	1/4W	AB	CB2711
R304	1.8K	10%	1/4W	AB	CB1821
R305	220	10%	1/4W	AB	CB2211
R306	56	10%	1/4W	AB	CB5601
R311	22K	5%	1/4W	AB	CB2235
R312	2.7K	10%	1/4W	AB	CB2721
R313	15K	10%	1/4W	AB	CB1531
R314	6.8K	10%	1/4W	AB	CB6821
R315	1.8K	10%	1/4W	AB	CB1821
R316	15K	10%	1/4W	AB	CB1531
R317	4.7K	10%	1/4W	AB	CB4721
R318	1.8K	10%	1/4W	AB	CB1821
R319	8.2K	10%	1/4W	AB	CB8221
R320	1.6K	5%	1/4W	AB	CB1625
R321	1.8K	10%	1/4W	AB	CB1821
R322	100	10%	1/4W	AB	CB1011
R323	330	10%	1/4W	AB	CB3311
R324	68K	5%	1/4W	AB	CB6835
R331	1K	10%	1/4W	AB	CB1021
R332	5.6K	10%	1/4W	AB	CB5621
R333	39K	5%	1/4W	AB	CB3935
R334	4.7K	10%	1/4W	AB	CB4721
R335	4.3K	5%	1/4W	AB	CB4325
R336	1.8K	10%	1/2W	AB	EB1821
R337	2.2K	10%	1/2W	AB	EB2221
R338	39K	10%	1/4W	AB	CB3931
R339	82	10%	1/4W	AB	CB8201
R340	3K	5%	1/4W	AB	CB3025
R341	47K	10%	1/4W	AB	CB4731
R342	1M	10%	1/4W	AB	CB1051
R343	220	10%	1/4W	AB	CB2211
R344	82K	10%	1/4W	AB	CB8231
R345	47K	10%	1/4W	AB	CB4731
R346	100K	10%	1/4W	AB	CB1041
R347	4.7K	10%	1/4W	AB	CB4721
R348	180K	10%	1/4W	AB	CB1841
R349	330	10%	1/2W	AB	EB3311
R351	150K	10%	1/4W	AB	CB1541
R352A	2.8K	1%			
R352B	330K	10%	1/4W	AB	CB3341
R353	562				
R354	270K	10%	1/4W	AB	CB2741
R355	2.7	10%	1/4W	AB	CB27G1
R356	TRIM			AB	TYPE CB
R357	10K	10%	1/4W	AB	CB1031
R358	10	10%	1/4W	AB	CB1001
R359	220	10%	1/4W	AB	CB2211
R360	100	10%	1/4W	AB	CB1011
R361A	10K	10%	1/4W	AB	CB1031
R361B	2.2K	10%	1/4W	AB	CB2221
R362	4.7K	10%	1/4W	AB	CB4721
R363	1K	5%	1/4W	AB	CB1025
R364	22M	10%	1/4W	AB	CB2261
R365	27	10%	1/4W	AB	CB2701
R366	558.5	.1%	1/4W	PRP	GP1/4-558.5-T100B
R367	558.5	.1%	1/4W	PRP	GP1/4-558.5-T100B
R368	628.3	.1%	1/4W	PRP	GP1/4-628.3-T100B
R369	628.3	.1%	1/4W	PRP	GP1/4-628.3-T100B
R370	718.2	.1%	1/4W	PRP	GP1/4-718.2-T100B
R371	718.2	.1%	1/4W	PRP	GP1/4-718.2-T100B
R372	837.9	.1%	1/4W	PRP	GP1/4-837.9-T100B
R373	837.9	.1%	1/4W	PRP	GP1/4-837.9-T100B
R374	1005.5	.1%	1/4W	PRP	GP1/4-1005.5-T100B
R375	1005.5	.1%	1/4W	PRP	GP1/4-1005.5-T100B
R376	1257.0	.1%	1/4W	PRP	GP1/4-1257-T100B
R377	1257.0	.1%	1/4W	PRP	GP1/4-1257-T100B
R378	1676.0	.1%	1/4W	PRP	GP1/4-1676-T100B
R379	1676.0	.1%	1/4W	PRP	GP1/4-1676-T100B
R380	2514.0	.1%	1/4W	PRP	GP1/4-2514-T100B
R381	2514.0	.1%	1/4W	PRP	GP1/4-2514-T100B
R382	5036.0	.1%	1/4W	PRP	GP1/4-5036-T100B
R383	5036.0	.1%	1/4W	PRP	GP1/4-5036-T100B
R384	5592	.1%	1/4W	PRP	GP1/4-5592-T100B
R385	5592	.1%	1/4W	PRP	GP1/4-5592-T100B
R386	6291	.1%	1/4W	PRP	GP1/4-6291-T100B
R387	6291	.1%	1/4W	PRP	GP1/4-6291-T100B
R388	7190	.1%	1/4W	PRP	GP1/4-7190-T100B
R389	7190	.1%	1/4W	PRP	GP1/4-7190-T100B
R390	8388	.1%	1/4W	PRP	GP1/4-8388-T100B
R391	8388	.1%	1/4W	PRP	GP1/4-8388-T100B
R392	10.066K	.1%	1/4W	PRP	GP1/4-10.066K-T100B
R393	10.066K	.1%	1/4W	PRP	GP1/4-10.066K-T100B
R394	12.582K	.1%	1/4W	PRP	GP1/4-12.582K-T100B
R395	12.582K	.1%	1/4W	PRP	GP1/4-12.582K-T100B
R396	16.776K	.1%	1/4W	PRP	GP1/4-16.776K-T100B
R397	16.776K	.1%	1/4W	PRP	GP1/4-16.776K-T100B
R398	25.165K	.1%	1/4W	PRP	GP1/4-25.165K-T100B
R399	25.165K	.1%	1/4W	PRP	GP1/4-25.165K-T100B
R400	50.329K	.1%	1/4W	PRP	GP1/4-50.329K-T100B
R401	50.329K	.1%	1/4W	PRP	GP1/4-50.329K-T100B
R402	55.92K	.1%	1/4W	PRP	GP1/4-55.92K-T100B
R403	55.92K	.1%	1/4W	PRP	GP1/4-55.92K-T100B
R404	62.91K	.1%	1/4W	PRP	GP1/4-62.91K-T100B
R405	62.91K	.1%	1/4W	PRP	GP1/4-62.91K-T100B
R406	71.9K	.1%	1/4W	PRP	GP1/4-71.9K-T100B
R407	71.9K	.1%	1/4W	PRP	GP1/4-71.9K-T100B
R408	83.88K	.1%	1/4W	PRP	GP1/4-83.88K-T100B
R409	83.88K	.1%	1/4W	PRP	GP1/4-83.88K-T100B
R410	100.66K	.1%	1/4W	PRP	GP1/4-100.66K-T100B
R411	100.66K	.1%	1/4W	PRP	GP1/4-100.66K-T100B
R412	125.8K	.1%	1/4W	PRP	GP1/4-125.8K-T100B
R413	125.8K	.1%	1/4W	PRP	GP1/4-125.8K-T100B
R414	168.3K	.1%	1/4W	PRP	GP1/4-168.3K-T100B
R415	168.3K	.1%	1/4W	PRP	GP1/4-168.3K-T100B
R416	252.9K	.1%	1/4W	PRP	GP1/4-252.9K-T100B
R417	252.9K	.1%	1/4W	PRP	GP1/4-252.9K-T100B
R418	508.3K	.1%	1/2W	PRP	GP1/2-508.3K-T100B
R419	508.3K	.1%	1/2W	PRP	GP1/2-508.3K-T100B
R420	390	10%	1/4W	AB	CB3911
R421	3.3M	10%	1/4W	AB	CB3351
R422	1M	10%	1/4W	AB	CB1051
R423	220K	5%	1/4W	AB	CB2245
R424	22K	10%	1/4W	AB	CB2231
R425	8.2K	10%	1/4W	AB	CB8221
R427	22K	5%	1/4W	AB	CB2235
R428	1.6K	5%	1/4W	AB	CB1625
R429	1.6K	5%	1/4W	AB	CB1625
R430	22K	5%	1/4W	AB	CB2235
R431	100K	10%	1/4W	AB	CB1041
R432	18K	10%	1/4W	AB	CB1831
R433	220	10%	1/4W	AB	CB2211

SEMICONDUCTORS & MISC.

Symbol	Description	Mfr.	Mfr. Part No.
CR101A	DIODE, RECTIFIER	GI	1N4002
CR101B	DIODE, RECTIFIER	GI	1N4002
CR102	DIODE, SWITCHING	APD	1N4149
CR104A	DIODE, RECTIFIER	GI	1N4002
CR104B	DIODE, RECTIFIER	GI	1N4002
CR105	DIODE, SWITCHING	APD	1N4149
CR107	DIODE, SWITCHING	APD	1N4149
CR131	DIODE, SWITCHING	APD	1N4149
CR132	DIODE, SWITCHING	APD	1N4149
CR133	DIODE, SWITCHING	APD	1N4149
CR134	DIODE, SWITCHING	APD	1N4149
CR136	DIODE, SWITCHING	APD	1N4149
CR137	DIODE, SWITCHING	APD	1N4149
CR191	DIODE, SWITCHING	APD	1N4149
CR192	DIODE, DUAL	MOT	MZ2361
CR194	DIODE, SWITCHING	APD	1N4149
CR195	DIODE, DUAL	MOT	MZ2361
CR197	DIODE, SWITCHING	APD	1N4149
CR198	DIODE, SWITCHING	APD	1N4149
CR241	DIODE, SWITCHING	APD	1N6263
CR242	DIODE, SWITCHING	APD	1N4149
CR243	DIODE, SWITCHING	APD	1N4149
CR281	DIODE, SWITCHING	APD	1N4149
CR282	DIODE, SWITCHING	APD	1N4149
CR283	DIODE, SWITCHING	APD	1N4149
CR284	DIODE, SWITCHING	APD	1N4149
CR311	DIODE, SWITCHING	APD	1N4149
CR312	DIODE, SWITCHING	APD	1N4149
CR331	DIODE, SWITCHING	APD	1N4149
CR351	DIODE, SWITCHING	APD	1N4149
CR352	DIODE, SWITCHING	APD	1N4149
Q101	SERIES REGULATOR	MOT	TIP31A
Q102	TRANSISTOR, PNP	MOT	MPS6518
Q103	TRANSISTOR, NPN	TI	TIS97
Q104	SERIES REGULATOR	MOT	TIP31A
Q105	TRANSISTOR, PNP	MOT	MPS6518
Q106	TRANSISTOR, NPN	TI	TIS97
Q107	TRANSISTOR, NPN	MOT	2N5225
Q108	TRANSISTOR, NPN	MOT	2N5225
Q131	TRANSISTOR, NPN	MOT	2N5225
Q132	TRANSISTOR, NPN	MOT	MPS6566
Q133	TRANSISTOR, PNP	MOT	MPS6518
Q134	TRANSISTOR, NPN	MOT	2N5225

SEMICONDUCTORS & MISC. (CONT.)

Symbol	Description	Mfr.	Mfr. Part No.
Q135	TRANSISTOR, PNP	MOT	2N2907
Q136	TRANSISTOR, PNP	MOT	MPS3640
Q137	TRANSISTOR, PNP	MOT	MPS3640
Q138	TRANSISTOR, PNP	MOT	MPS3640
Q161	N-CHANNEL FET	AME	2N4302
Q162	TRANSISTOR, NPN	MOT	MPS6515
Q163	TRANSISTOR, NPN	MOT	2N5225
Q164	TRANSISTOR, NPN	MOT	MPS6515
Q165	TRANSISTOR, NPN	RCA	2N5189
Q191	N-CHANNEL FET	AME	2N4302
Q192	TRANSISTOR, PNP	MOT	MPS6518
Q193	TRANSISTOR, NPN	MOT	2N2219A
Q194	TRANSISTOR, NPN	MOT	MPS6566
Q195	TRANSISTOR, NPN	MOT	MPS6566
Q196	TRANSISTOR, NPN	MOT	2N5189
Q197	TRANSISTOR, PNP	MOT	MPS6518
Q198	TRANSISTOR, NPN	MOT	2N2219A
Q199	TRANSISTOR, PNP	MOT	2N2905A
Q241	N-CHANNEL FET	AME	2N4302
Q242	TRANSISTOR, PNP	MOT	MPS6518
Q243	TRANSISTOR, NPN	MOT	MPS6566
Q244	TRANSISTOR, NPN	MOT	MPS6566
Q245	TRANSISTOR, NPN	MOT	2N4265
Q246	TRANSISTOR, PNP	MOT	MPS6518
Q281	TRANSISTOR, PNP	MOT	MPS3640
Q282	TRANSISTOR, PNP	MOT	MPS3640
Q283	TRANSISTOR, NPN	MOT	MPS3646
Q284	TRANSISTOR, NPN	MOT	MPS3646
Q285	TRANSISTOR, PNP	MOT	MPS3640
Q311	TRANSISTOR, NPN	MOT	TIS97
Q312	TRANSISTOR, NPN	MOT	2N5225
Q313	TRANSISTOR, NPN	MOT	MPS6515
Q314	TRANSISTOR, PNP	MOT	MPS6518
Q331	TRANSISTOR, NPN	MOT	MPS3646
Q332	TRANSISTOR, PNP	MOT	2N5087
Q333	TRANSISTOR, PNP	MOT	MPS6518
Q334	TRANSISTOR, NPN	TI	TIS92
VR101	DIODE, ZENER, 18V	APD	1N967B
VR102	DIODE, ZENER, 18V	APD	1N967B

Symbol	Description	Mfr.	Mfr. Part No.
VR131	DIODE, ZENER, 9V	APD	1N937B
VR132	DIODE, ZENER, 9V	APD	1N937B
VR134	DIODE, ZENER, 6.8V	APD	1N957B
DS101	LAMP, INDICATOR, POWER	ELD	EG03-CCB-N110
F101	FUSE, SLOW BLOW, 115VAC	BUS	MDL-.5A
	FUSE, SLOW BLOW, 230VAC	BUS	MDL-.25A
L191	15uHy	DLV	1537-40
L192	1uHy	DLV	1537-12
L193	1uHy	DLV	1537-12
L281	3.3uHy	DLV	1537-24
L282	3.3uHy	DLV	1537-24
L283	3.3uHy	DLV	1537-24
L284	BEAD, FERRITE	STK	57-0181
L351	1uHy	DLV	1537-12
P161	25K POT	BKM	72PM
P192	10K 30% 3/4W	CTS	307089
P241	5K POT	BKM	72XW
P242	5K POT	BKM	72XW
P243	5K POT	BKM	72XW
P281	5K POT	BKM	72PM
P282	100 POT	BKM	72PM
P331	200K POT	BKM	72XW
P351	DUAL, 50K 10% 2W	AB	JJ94296
P352	60 10% 2W	AB	JAIN056P600UA
P241	200 POT	BKM	72XW
PR191	RESISTOR, PHOTO	CL	CLM8000
S101	SWITCH, TOGGLE, POWER	CK	U11
S102	SWITCH, SLIDE, GROUND	CW	GF123
S103	SWITCH, PUSHBUTTON, MULTIPLIER	KH	5XF-10
S104	SWITCH, PUSHBUTTON,DECADE	KH	10XF-20
S105	SWITCH, PUSHBUTTON,DECADE	KH	10XF-20
S106	SWITCH, PUSHBUTTON,DECADE	KH	10XF-20
S191	SWITCH, ROTARY, ATTENUATOR	KH	B2269
T101	TRANSFORMER, POWER	KH	B2541

MANUFACTURERS' CODE

AB	(01121)	Allen Bradley Co.	Milwaukee, WI
AME	(15815)	Amelco, Inc.	Mountain View, CA
APD	(50273)	American Power Devices	Andover, MA
AVX	(00656)	Aerovox Corp.	New Bedford, MA
BKM	(73138)	Beckman Heliopot Div.	Fullerton, CA
BUS	(71400)	Bussman Mfg.	St. Louis, MO
CD	(88419)	Cornell-Dubilier, Inc.	Newark, NJ
CK	(09353)	C+K Components	Watertown, MA
CTS	(71450)	CTS Corporation	Elkhart, IN
CW	(79727)	C-W Industries	Warminster, PA
DLV	(99800)	Delevan Electronics	E. Aurora, NY
ELD	(03797)	Eldema Corp.	Compton, CA
GI	(11711)	General Instrument Corp.	Hicksville, NY
KGN	( )	Kahgan Electronics	Hempstead, NY
KH	(88865)	Krohn-Hite Corp.	Avon, MA
KID	(12126)	Kidco, Inc.	Medford, NJ
MAL	(37942)	Mallory Capacitor Co.	Indianapolis, IN
MOT	(04713)	Motorola Semiconductor	Phoenix, AZ
PRP	( )	Precision Resistive Products	Mediapolis, IA
QC	( )	Quality Components, Inc.	St. Mary's, PA
RCA	(02735)	Radio Corp. of America	Somerville, NJ
SP	(56289)	Sprague Electric Co.	N. Adams, MA
STK	(78488)	Stackpole Carbon	St. Mary's, PA
STT	( )	Stettner-Trush	Cazenovia, NY
TI	(01295)	Texas Instruments, Inc.	Dallas, TX
TRW	(84411)	TRW Capacitor Div.	Ogallala, NE