C/OM/200-1B

Efratom Division

OPERATION AND MAINTENANCE MANUAL

MODEL

FRK (H OR L) LN

LOW NOISE RUBIDIUM FREQUENCY STANDARD

LIMITED WARRANTY

"The seller warrants that each article of goods sold by it will at the time of shipment be free from defects in materials furnished and workmanship performed by the seller. This warranty and seller's liability are limited either to granting credit or repairing or replacing, at seller's option, with reasonable promptness after return to seller of any article which is disclosed to seller's satisfaction to be defective, and only if said article is returned to the seller promptly after discovery of such defect and in no event later than ***12 months*** (or such other time period as may be specified in writing as a warranty period for a particular article) from the date of delivery thereof. Normal transportation charges in connection with an article returned shall be at the seller's expense, but only if the seller is responsible under the terms of this warranty. This warranty does not extend to any article which has been subject to misuse, neglect or accident, nor does it extend to any article which has been repaired or altered by other than the seller. **THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES EXPRESSED OR IMPLIED, INCLUDING ANY WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE. THE RIGHTS AND REMEDIES PROVIDED HEREIN ARE EXCLUSIVE AND IN LIEU OF ANY OTHER RIGHTS OR REMEDIES. IN NO EVENT SHALL SELLER BE LIABLE FOR CONSEQUENTIAL DAMAGES".**

Ball Corporation, Efratom Division, will be happy to answer any application or usage questions which will enhance your use of this unit. Please address your requests or correspondence to: **Ball Corporation., Efratom Division,** 3 Parker, Irvine, California 92718-1605, Attention: Sales Department, or call (714) 770-5000, Fax: (714) 770-2463.

European customers may contact: **Ball Efratom Elektronik GmbH,** Fichtenstrasse 25, 8011 Hofolding, West Germany, Telephone: 49-81-049040, Fax: 49-81-049918.

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SECTION I

INTRODUCTION AND SPECIFICATION

1.1 INTRODUCTION.

The Efratom Model FRK-(H or L)LN Rubidium Frequency Standard (RFS) is a compact, atomic resonance-controlled oscillator which provides an extremely pure and stable sinusoidal signal of 5 or 10 MHz, at 1 Vrms into a 50 ohm load (refer to Section 1.5 for other available options). The unit is designed for use in high-performance communication systems, frequency standard equipment, advanced navigation equipment, and all other equipment and systems which require extremelyprecise frequencies/time intervals. With the proper input power provided and suitable cooling provisions, the FRK-( )LN can be operated as a free-standing frequency standard for laboratory and testing purposes.

NOTE

Throughout this manual the models FRK-HLN & FRK-LLN will be referred to as model FRK-( )LN, indicating that the text or diagram references both models. If only one model is to be referenced, the full model designation will be printed out.

1.2 MANUAL CONTENT.

This manual contains information regarding the operation and field maintenance of the Model FRK -( ) LN, 5 MHz Rubidium Frequency Standard (RFS), with a Final Assembly No. 703-200-8. A Model FRK-( ) LN with a Final Assembly No. other than 703-200-8 is a modified unit producing a 10 MHz output, or has some other feature not standard to model 703-200-8. If a modified unit differs operationally from the standard unit an addendum will be included with this manual describing the differences. Note the information in the addendum prior to reading the manual to determine what special specification or operation aspects may exist. If an addendum has not been included for a modified unit, it can be assumed that the modification does not affect the unit's operation.

Sections I and II contain general information concerning the unit. It is recommended that these sections be read completely prior to attempting operation. Section III provides the general theory of operation for the technician or engineer who requires a more thorough understanding of the unit's operation. Section IV provides the required information for performing field maintenance on the unit. An Outline Drawing, Schematic Diagrams, Assembly Drawings and Parts Lists are provided in the Appendix.

1.3 CONNECTORS.

All necessary connectors for inputs, output and monitor signals are easily accessible from the outer cover of the unit. The unit is manufactured using either a Winchester connector, P/N SRE-20PJ, which mates with SRE-20SJ and a SMA-type coaxial connector. For other connector configurations, refer to unit label for pin out information. (Other optional connectors are available; contact the Efratom sales department).

1.4 ELECTRICAL PROTECTION.

The unit is protected against reverse polarity input power by both an internal fuse and diode. The output and monitor signals are short-circuit protected.

1.5 AVAILABLE OPTIONS

(a) External (remote) Frequency Adjustment Option.

(b) Additional Magnetic Shielding.

(c) Low Operating Temperature Option:

FRK-HLN ≤ 4E-10 from -55°C to +65°C
FRK-LLN ≤ 6E-10 from -55°C to +65°C

1.6 SPECIFICATIONS.

Pertinent performance specifications for the Models FRK-LLN and FRK-HLN are listed in Table 1.1.

Table 1.1. Specifications

CHARACTERISTICS	MODEL FRK-L (LN)	MODEL FRK-H (LN)
Output	5 or 10 MHz sine wave 1.0 Vrms into 50 ohms, floating ground (not floating with filter connector).	
Accuracy	Factory set to 5.0 MHz ±5E-11 at shipment.	
Signal to Noise (SSB 1 Hz BW)	125 dB at 10 Hz and 155 dB at 100 Hz from carrier. (5 MHz) 120 dB at 10 Hz and 147 dB at 100 Hz from carrier. (10 MHz)	
Input Power	13W at 24 Vdc, 25°C ambient; 22 to 32 Vdc; peak during warm-up, 1.8A.	
Warm-up Characteristics	≤ 10 minutes to reach 2E-10 at 25°C ambient.	
Retrace	±2E-11	
Long-term Stability	<4E-11/month	<1E-11/month
Short-Term Stability	3E-11 τ = 1 sec 1E-11 τ = 10 sec 3E-12 τ = 100 sec	1E-11 τ = 1 sec 4E-12 τ = 1 0sec 1E-12 τ = 100 sec
Trim Range	≥ 2E-9	
Voltage Variation	< 1E-11/10% change (within input power limit noted above)	
*Operating Temperature	< 3E-10 from -25°C to +65°C	<1E-10 from -25°C to +65°C
Storage Temperature	-55°C to +75°C	
Magnetic Field	< 4E-13/AM^{-1} (3E-11/0.1 millitesla)	
Altitude	< 1E-13/mbar (sea level to 21,000m)	
Humidity	95% MIL-T-5422F	
Shock	MIL-STD-810C, Method 516.2, Procedure 1	
Vibration	MIL-STD-810C, Method 514.2, Procedure 1	
Size	100mm x 99 mm x 112 mm (3.9 in. x 3.9 in. by 4.4 in.)	
Weight	1.3 Kg (2.9 lbs); 1.55 Kg (3.5 lbs.), with optional heat sink	

*Highest operating temperature as measured at the baseplate. The highest ambient temperature the unit may be operated in is dependent on the heat transfer between the unit's baseplate and the ambient.

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SECTION II

INSTALLATION AND OPERATION

2.1 INTRODUCTION.

This section of the manual contains information regarding the installation and operation of the Efratom FRK-( )LN. It is recommended that this section be read carefully prior to attempting operation of the unit.

2.2 SHIPPING AND RECEIVING INFORMATION.

The Model FRK-( )LN is packaged and shipped in a foam-packed container. The unit was inspected mechanically and electrically prior to shipment. Upon receipt of the unit, a thorough inspection should be made to ensure that no damage has occurred during shipping. If any damage is discovered, contact Ball Corporation, Efratom Division, 3 Parker, Irvine, CA. 92718-1605. Telephone (714) 770-5000; Telex 685-635. European customers should contact Ball Efratom Elektronik GmbH, Fichtenstrasse 25, 8011 Hofolding, West Germany, Telephone 08104/90 40. If reshipment of the unit is necessary, the original container and packing should be used. If the original container is not available, a suitable container with foam-packing is recommended.

2.3 MOUNTING.

The unit's baseplate has been drilled and tapped to accommodate installation. The unit should be mounted with the aluminum thermal baseplate in contact with a flat metal surface. Mounting screws must not be allowed to penetrate the baseplate more than 0.2 inches (5mm). It is recommended that the mounting surface be designed to permit free access to the unit's frequency adjust potentiometer. Refer to outline drawing 703-203-1 in the appendix for mounting dimensions.

The heat transfer characteristics of the mounting surface must be adequate to limit the rise of the unit's baseplate to < +65ºC. The maximum allowable environmental temperature (Ta), for this mounting is:

$$Ta = 65^{\circ}C - (V_s \times I_s \times R_k)$$

Where: V_s = Supply Voltage in volts

I_s = Supply Current in amperes

R_k = Thermal Resistance between unit and ambient, (ºC/watt).

NOTE

An add-on heat sink is an available option from Efratom; order Model 70223, Air Cooled Heat Sink.

2.4 POWER REQUIREMENTS.

The Model FRK-( )LN requires an external power source capable of providing between +22 and +32 Vdc, with a minimum of 1.8 ampere output. The positive input voltage for the unit is to pin L with the negative return voltage on pin P of the connector.

In order to obtain the cleanest output signal close to the carrier, the maxmum ac ripple on the supply voltage must be less than 1 mV peak-to-peak. If it is acceptable for the output frequency to contain spurious multiples of the powerline frequency (50, 60, or 400 Hz), the ripple can be higher, but in no case should the supply voltage AC +/- peak exceed the upper or lower input power limit of the unit.

2.5 INSTALLATION CONSIDERATIONS.

Some consideration must be given to the operating location of the unit regardless of its application. To minimize frequency offsets and/or non-harmonic distortion, the unit should not be installed near equipment generating strong magnetic fields such as generators, transformers, etc.

CAUTION

CARE MUST BE TAKEN TO ENSURE THAT THE MAXIMUM OPERATING TEMPERATURE IS NOT EXCEEDED, (+65°C AS MEASURED AT THE UNIT'S BASEPLATE). IN ADDITION, THE UNIT'S OUTER COVER IS A SPECIALLY DESIGNED MAGNETIC SHIELD; DAMAGE TO THE OUTER COVER COULD CHANGE ITS SHIELDING CHARACTERISTICS.

2.6 FREQUENCY AND MONITORING SIGNAL OUTPUTS.

Figure 2.1 illustrates the standard Model FRK-( )LN coaxial connector J1 with Winchester connector J2, and presents a brief functional description of the pin connections. Figure 2.2 presents the same information for the optional 8-pin, wirewrap or press-fit connector with coaxial connector.

J1 5 or 10 MHz OUTPUT
J2 A. Optional remote frequency adjust
C. Optional remote frequency adjust
D. Rb LAMP VOLTAGE SIGNAL
F. XTAL CONT VOLTAGE SIGNAL
H. RESONANCE LOCK SIGNAL
L. +22 TO +32 VDC INPUT
P. GROUND (connected to enclosure)

(Viewed rotated 180° so pin callouts are readable)

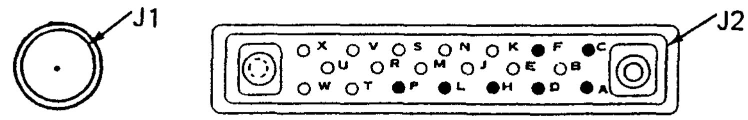


FIGURE 2.1. Winchester Connector and Pin Arrangement

AS210 WIRING

COAX 1. 5 or 10 MHz OUTPUT
NC 2. 5 or 10 MHz GROUND (isolated from enclosure)
BLACK 3. GROUND (connected to enclosure)
WHT/YEL 4. +22 TO +32 VDC INPUT
GREEN 5. RESONANCE LOCK SIGNAL
NC 6. XTAL CONT VOLTAGE SIGNAL
NC 7. Rb LAMP VOLTAGE SIGNAL
YELLOW 8. Optional remote frequency adjust
RED 9. Optional remote frequency adjust

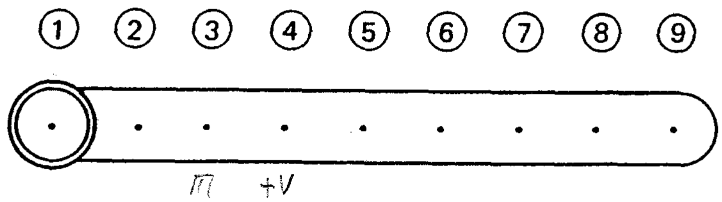


FIGURE 2.2. Optional 8-Pin, Connector with Coaxial Connector and Pin Arrangement

NOTE

Although Figure 2.1 illustrates the output signal (10 MHz) from the coaxial connector J1, the unit can be wired to provide the output signal to the Winchester connector, thus eliminating the need for the coaxial connector. For that configuration the output signal is to pin W, and the shield to pin T.

2.7 NORMAL OPERATION.

When the unit's output is terminated with a 50 ohm resistive load, and 28 Vdc is applied to J2 pins L (+) and P (-), the unit will immediately begin producing a 10 MHz signal from the crystal oscillator. Within approximately 10 minutes after application of input power, the unit will "lock". At that time the crystal is stabilized by the atomic resonant frequency.

2.8 FUNCTIONAL OPERATION TEST EQUIPMENT.

The test equipment required to functionally test the unit is listed in Table 2.1. Test equipment other than those items listed may be used provided that the performance equals or exceeds the MINIMUM USE CHARACTERISTICS as stated in Table 2.1.

TABLE 2.1. Functional Operation Test Equipment

PARA #	ITEM	MINIMUM USE CHARACTERISTICS	TEST EQUIPMENT
2.1	DC Power Supply	Output Voltage: 22 to 30Vdc Output Current: 2.0 Amps Min.	Hewlett-Packard 6433B or 6296A
2.2	DMM (Digital Multimeter)	Voltage Range : 0 to 30 Vdc Accuracy: ± 1.25% Resistance Range: 0 to 150 ohm.	Fluke 8020A or 8000A
2.3	Freq. & Time Interval Analyzer	Internal Ref. Freq: 10 MHz Accuracy: ± 1E-12 Stability: parts in 10^{12}	Hewlett-Packard 5371A Frequency & Time Interval Analyzer and HP5371A Software Kit

NOTE

Throughout the test procedures in this manual the Model FRK-( )LN will be referred to as the Unit Under Test, (UUT). All connections described or illustrated pertain to the standard Winchester connector; if the UUT has a different connector arrangement, make the described connections to the appropriate pins as described in 2.6 or the pin diagram accompaning the UUT.

2.9 OPERATIONAL FREQUENCY ACCURACY TEST.

2.9.1 Connect the equipment as shown in Figure 2.3.

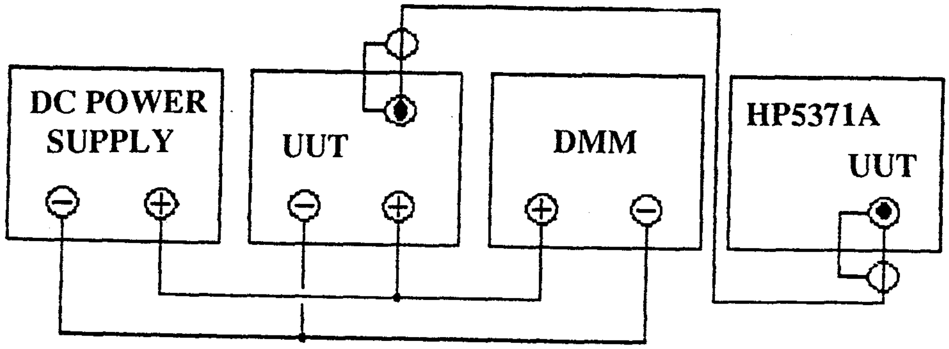


Figure 2.3. Operational Frequency Accuracy Test Setup.

2.9.2 Adjust the DC power supply controls to obtain a 28 ± 1.4 Vdc indication on the DMM.

2.9.3 Allow sufficient time for equipment to stabilize.

NOTE

The UUT requires 10 minutes stabilization to obtain the following frequency accuracy: ± 2E-10 of the final frequency (calibrated frequency), or the frequency before turn off, (if turn off was within 24 hours and at the same environmental temperature). If the UUT was in storage, the worse case error = ± 2E-10 warm-up + ± last calibration accuracy or ± 5E-10 factory setting at shipment, whichever is applicable + *aging specification.

The UUT requires 1 hour stabilization time to obtain the following accuracy: ± 2E-11 of final frequency or frequency at turn off (if turn off was within 24 hours and at the same environmental temperature). If UUT was in storage, the worse case error = ± 2E-11 warm-up +/- last calibration accuracy or ± 5E-11 factory setting at shipment, whichever is applicable + *aging specification.

* Aging Specification: FRK-HLN $\leq 1X10^{-11}$ /month
FRK-LLN $\leq 4X10^{-11}$ /month

2.9.4 Follow the instructions in the HP5371A Frequency and Time Interval Analyzer Operation Manual to begin the test.

2.9.5 Allow sufficient time for the HP5371A to indicate the UUT OFFSET for the data you require. Verify that the UUT frequency offset is within the tolerance stated in the NOTE following Step 2.9.3.

NOTE

If the UUT is not within the stated tolerance limits, perform the Frequency Adjustment procedure, paragraph 4.6.5.1 through 4.6.5.2.

2.10 SHORT-TERM STABILITY TEST (ALLAN VARIANCE)

NOTE

If you have just completed 2.9 through 2.9.5, and the Allan Variance indications (as displayed by the HP5371A) are of the required averaging times, the test results as indicated are valid. If 2.9 was not performed continue with 2.10.1

2.10.1 With the equipment connected as shown in Figure 2.3, and the required stabilization time allowed, (refer to NOTE following 2.9.3), begin the test.

2.10.2 Allow sufficient time for the HP5371A to display the required data for the averaging times, and verify that UUT Allan Variance is within tolerances listed in Table 1.1 SPECIFICATIONS.

SECTION III

THEORY OF OPERATION

3.1 INTRODUCTION.

This section of the manual contains a general theory of operation and circuit analysis of the Model FRK-( )LN Rubidium Frequency Standard. A block diagram, (Figure 3.2) has been included to help clarify the text. Schematic diagrams are included in the Appendix.

3.2 GENERAL THEORY OF OPERATION.

The unit's highly frequency-stable 5 or 10 MHz output signal is obtained from a 5 or 10 MHz Voltage Controlled Crystal Oscillator (VCXO), whose frequency is referenced and locked to the atomic ''Resonance Frequency'' of Rubidium (f_{Rb}).

3.2.1 ATOMIC REFERENCE FREQUENCY.

The atomic reference frequency is provided by the 6.834 GHz ground-state hyperfine transition of the Rb^{87} (rubidium). The VCXO is locked to the f_{Rb} at approximately 6.834 GHz, by synthesizing a microwave signal, from the 10 MHz VCXO output, having a frequency in the vicinity of f_{Rb}. The microwave signal is used to excite the rubidium atoms that are contained within a microwave cavity (resonance cell). The frequency synthesis scheme is designed so that the VCXO frequency is exactly 10 MHz when the microwave frequency is equal to f_{Rb}. The frequency of the signal applied to the microwave cavity can be maintained equal to f by generating an error signal to servo the VCXO through its control voltage.

3.2.2 RUBIDIUM LAMP.

Light from a rubidium lamp is generated by an rf excited plasma discharge. The light passes through the resonance cell, where it interacts with the rubidium atoms contained therein. Some of the light is incident upon a silicon photo detector photocell within the resonance cell. When the applied microwave frequency is equal to the f_{Rb}, the rubidium atoms resonate within the microwave field in the cavity; this causes the light reaching the photo detector to decrease. This behavior is illustrated by the left, uppermost curve in Figure 3.1.

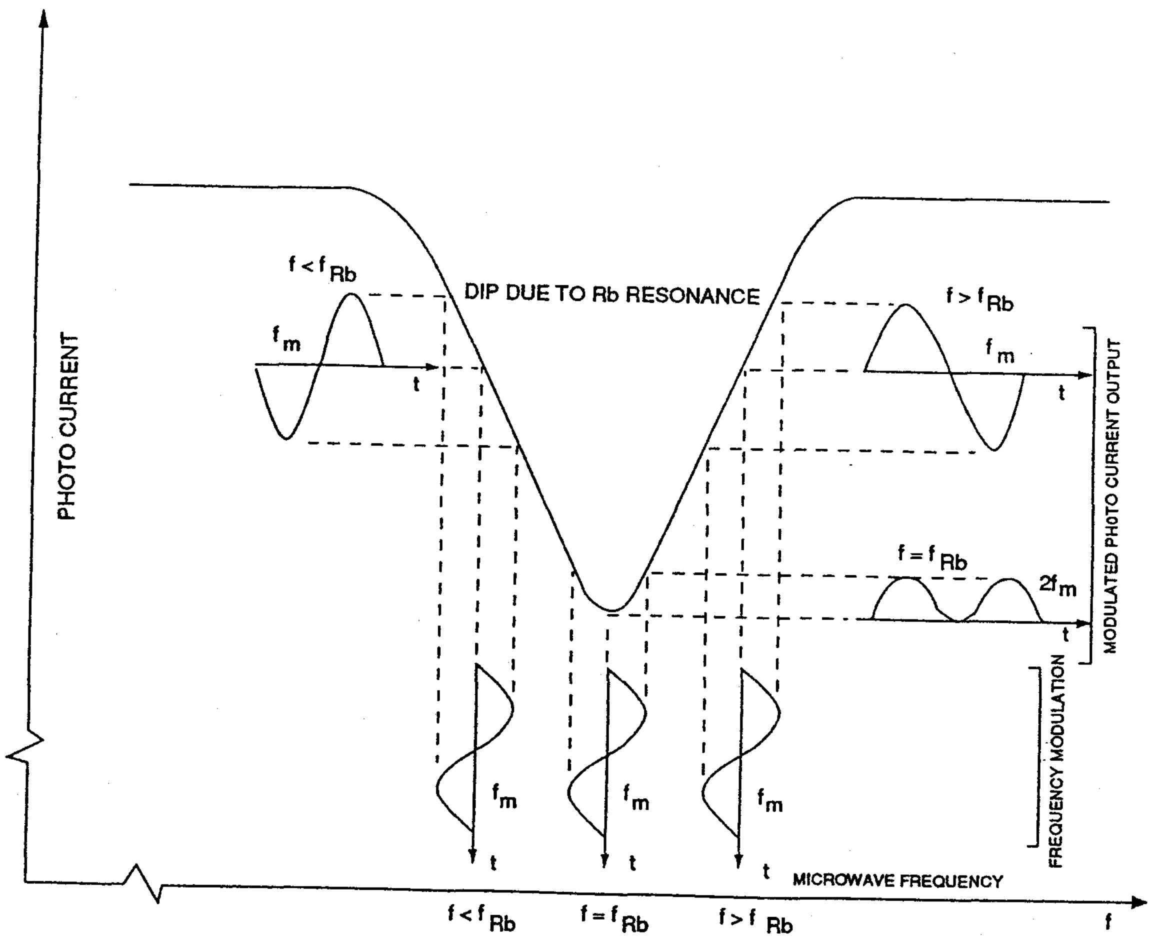


Figure 3.1. Derivation of Modulation Signal

3.2.3 OPTICAL PUMPING. The rubidium oscillator is a passive device, meaning that the atoms themselves do not produce a self-sustaining oscillation. Nevertheless, the atoms can be viewed in their simplest form as a high-Q, (Q ~10^7) series-resonant tank curcuit that is resonant at the hyperfine frequency (~6.8 GHz for rubidium atoms). The voltage source driving the tank is the microwave input coming from the Modulator/Synthesizer, and the LCR components are the rubidium atoms contained in the optical package. The atomic resonance is detected by optical means and involves a process known as Optical Pumping, by which atoms are raised to a higher state through the absorption of light energy.

The two lower levels, A and B, are the ground state hyperfine levels. Statistically speaking, the rubidium atoms will be equally divided between these two levels. If the atoms are irradiated with microwave energy at the hyperfine frequency, then those atoms in level A will make a transition to level B and vice- versa, without changing the overall distribution between the two levels (statistically). [The hyperfine frequency (f_{Rb}) is related to the hyperfine energy level separation E (joules) = h • f_{Rb} (Hz) where h = Plank's Constant = 6.6226 x 10^{-34} joule/Hz]. A third and higher energy state exists which is referred to as level C.

Level C is an optically excited state of the atom which is normally vacant; (for rubidium, this C level state can be excited by infrared light energy at the proper wavelength). Transitions to level C are known as "optical transitions" and can occur from either of the two hyperfine energy levels A or B. If only the spectral wavelength corresponding to one of the hyperfine levels is introduced, only the atoms at that hyperfine level will make the transition to level C. This condition can be generated by filtering out the spectral wavelength corresponding to one of the hyperfine levels.

If the light energy injected into the resonance cell corresponds to the wavelength required for level A to C transitions, the rubidium atoms at the A level will absorb some of the light. The absorption of light raises those atoms to the C level energy state. After a short time the atoms which were raised to the C level will emit a photon of the same wavelength that caused the energy level to increase; they then return to the ground state hyperfine level, redistributing themselves (statistically) equally between level A and B. The atoms which return to level A will again absorb the light and be raised to level C, where they will remain for the short time before emitting the photon and again redistributing themselves between the two hyperfine energy levels A and B. By this means, Optical Pumping can be used to produce a population difference between the two hyperfine levels, whereby all of the atoms are pumped into one hyperfine level (for the preceeding situation, level B). Once this condition exists, there are no atoms left in level A to be excited to level C and the light is not the proper wavelength to excite the atoms in level B to level C, therefore the light is unattenuated after passing through the resonance cell.

As discussed earlier, if a microwave field corresponding to the hyperfine frequency were applied, the atoms at level B would make a transition to level A and be available for excitation to level C by the light beam. Since each excitation of an atom in level A is accomplished by the absorption of a light photon, the net effect of applying the microwave field is to cause attenuation of the light beam. Figure 3.3 pictorially illustrates the Optical Pumping process.

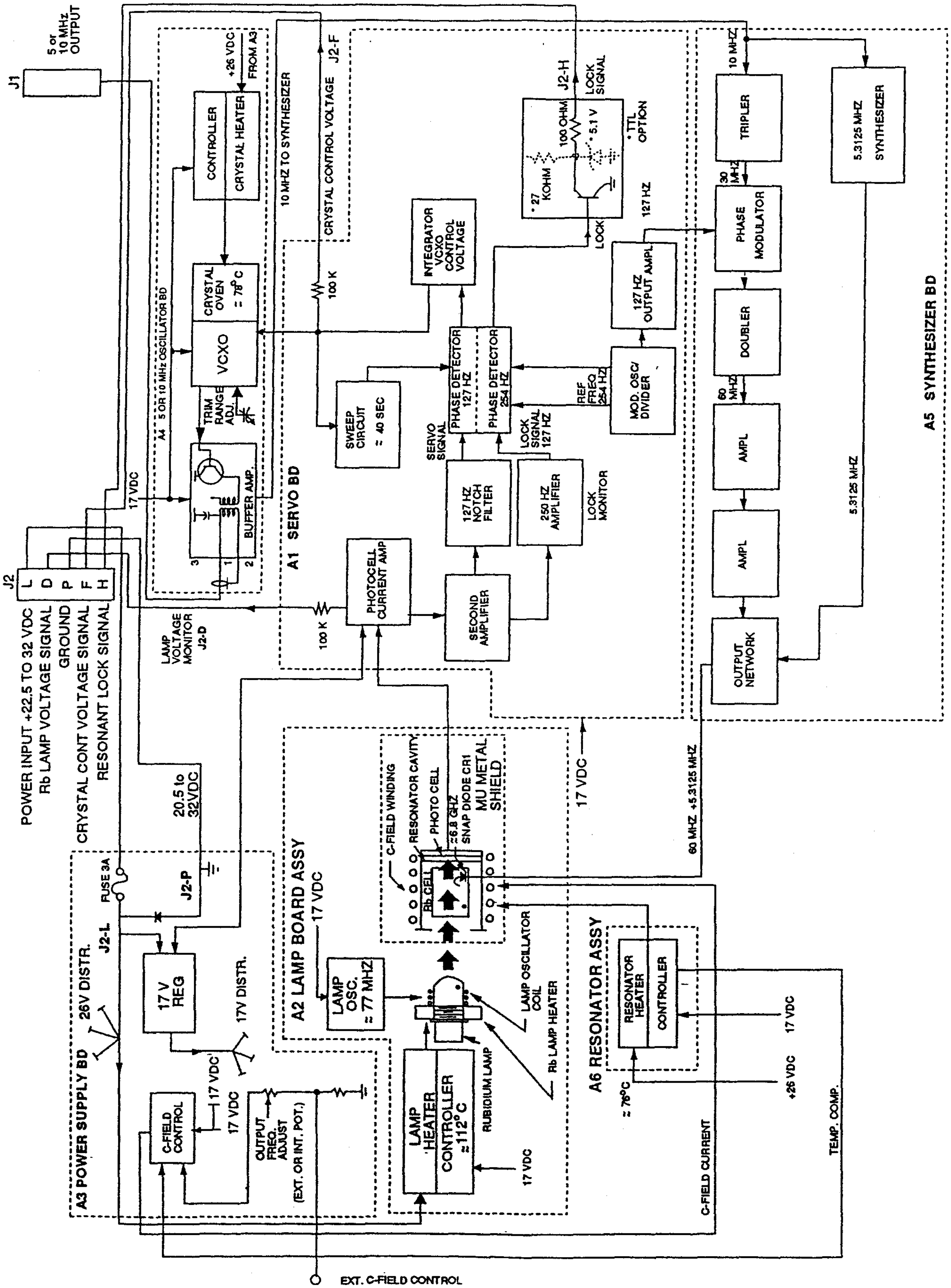


Figure 3.2. FRK Block Diagram

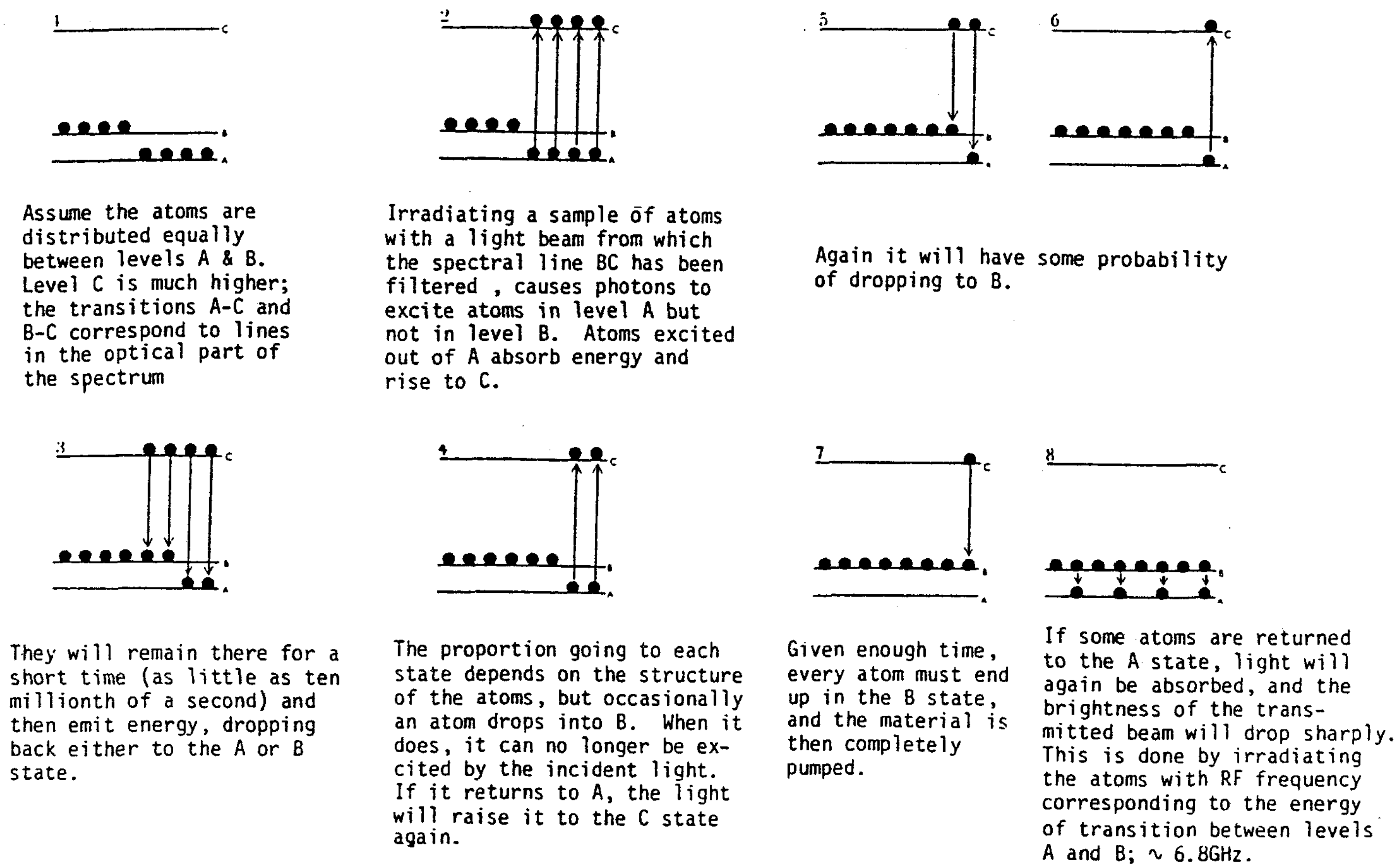


Figure 3.3. Optical Pumping Process Illustrated

If the overall energy level were to remain constant, there would be no way to generate an error signal for VCXO frequency correction. By frequency modulating the microwave signal, the light from the rubidium lamp appears to vary in intensity at the same modulation rate. This variation in the light intensity is effective at < 0.1% of the overall intensity of the light. The photocell, within the cavity, detects the variation in light intensity; the Servo Board uses this signal to indicate atomic lock and to generate the correction signal for the VCXO if the VCXO should drift off frequency.

3.2.4 RESONANT SIGNAL/LOCK SIGNAL LOGIC.

When light from the Rubidium lamp strikes the photocell contained within the resonator, the photocell generates a current proportional to the intensity of the light. By modulating the rf signal injected into resonator, (at 127 Hz), the light striking the photocell will vary at the modulation rate, (127 Hz), and the photocell output current will vary at the same modulation rate, (127 Hz).

When the rf being injected into the resonator is exactly equal to f_{Rb}, the 127 Hz modulation varies the light signal around the null point of the photocell current. (minimum light = minimum photocell current.) When the light signal varies around the photo current null point, the photocell output varies at twice the fundamental frequency, or 254 Hz. It is this 254 Hz signal which is used to generate the lock indicator signal. The lock indicator signal is the primary indicator that the unit is operating normally. If the rf signal, (which is synthesized from the 10 MHz VCXO), drifts off frequency (rf <> f_{Rb}), the photocell output reverts to the fundamental 127 Hz rate. The phase of the 127 Hz indicates if the rf is $< f_{Rb}$ or $> f_{Rb}$ and this phase information is used to servo the VCXO in the proper direction so that rf = f_{Rb}. This principle is illustrated in the lower three sine waves labeled MODULATION (127Hz), in Figure 3.1.

3.3 RESONATOR (Schematic Drawing No.703-221)

The function of the Resonator is to provide the correct signal to the Servo board in order to control the frequency of the crystal oscillator.

3.3.1 STEP RECOVERY DIODE.

The 60 MHz and 5.3125 MHz signals from the Synthesizer board are applied to a Step Recovery Diode, CR1. When CR1 conducts, it produces the harmonics of the 60 MHz and 5.3125 MHz signals (mixed). The fundamental frequency and the harmonic frequencies are input to the resonant cell via a resonant loop. The resonant cell and loop are tuned to select the 114th harmonic which corresponds to the resonant frequency of rubidium. The ''Response of the Atoms'' is detected by the photocell CR2 which supplies the correcting signal to the servo board.

3.3.2 RESONATOR COIL.

The resonator coil provides a magnetic field around the resonator cavity. This magnetic field is called the ''C-Field''. The strength of the C-Field is controlled by the voltage divider network on the power supply board comprised of R19 through R22. The adjustment of the C-Field is used for fine tuning of the FRK's output frequency.

3.3.3 RESONATOR CAVITY.

The resonator cavity temperature is elevated and maintained between 75°C and 78°C depending upon actual requirements of the particular FRK.

3.3.4 RESONATOR THERMOSTAT.

The operation of the resonator thermostat is typical of the heater control circuitry used in the unit. The resonator thermostat circuit consists of Q1 and U1 along with associated circuitry mounted on board 6, part of the resonator assembly, in conjuction with the resonator heater transistors, Q2 and Q3 and resonator thermistor mounted on the resonator assembly, and select resistor R15 mounted on the power supply board.

U1 is an op amp with a resistive bridge network on its inputs. The elements of the bridge network are R1, R5, and the thermistor. In one leg of the bridge is the thermistor sensing the temperature of the resonator; in the other leg of the bridge is select resistor R15.

For a given resistance value of R15, the Op Amp will drive the resonator heaters until the desired temperature is achieved. When the desired temperature is achieved, the bridge network will obtain a balanced condition. With the bridge in balanced condition, the op amp begins to regulate the power to the heater transistors, effectively maintaining the resonator at the proper temperature. In order to control the temperature overshoot, a portion of the output from U1, pin 1 is fed back to the input, this slows down the rate of change sensed at the input by the changing resistance of the thermistor. Transistor Q1 functions as a current limiter for the heater circuit. Q1 senses the current through the heater by detecting the voltage drop across R13. If the heater current becomes too high, Q1 begins to conduct which causes the bias to the heater to decrease. R11 limits the heater current when higher input voltage are present so that the maximum heater power is approximately constant.

3.4 SIMPLIFIED BLOCK DIAGRAM.

As illustrated by the simplified block diagram Figure 3.2, the Model FRK contains a servo board assembly, the lamp board assembly, a power supply assembly, a crystal oscillator assembly, the synthesizer board assembly, and the physics package (resonator assembly, Rb lamp, etc.).

3.5 SERVO BOARD, ASSEMBLY A1. (Schematic Drawing No. 100120).

The primary function of the servo circuit is to provide the crystal control voltage at E8 for the 10 MHz VCXO. The control voltage is derived by comparing the phase of the 127 Hz modulation signal with the phase of the photocell signal at E1 and E5. The secondary function is to provide the monitoring signal for the Rb lamp operation at E4, the atomic resonant lock circuit at E7 and the VCXO monitor control voltage at E9.

3.5.1 127 AND 254 Hz REFERENCE SIGNALS.

CMOS oscillator/divider U3 on the servo board, provides the 127 and 254 Hz reference signals and the 127Hz modulation signal for the rf introduced into the resonator. The oscillator frequency of 8.128 KHz is determined by C17, R19 and Select-in-test resistor R20. The divider portion of U3 divides the oscillator frequency into the required 127 and 254 Hz signals. The 127Hz reference signal is routed from U3, pin 4 to pin 11 of synchronous demodulator U4; and to the input of U6, pin 2 through the RC network R37-C24. The RC network R37-C24 plus the feedback network R38-C25 and the output RC filters (R39, C26, R40 on the servo board, and C2 and C12 on the synthesizer board) serve to waveshape the 127 Hz signal into the sinewave which is coupled to the synthesizer to modulate the rf.

The 254 Hz reference signal is routed from U3, pin 5 to pin 9 of synchronous demodulator U4. It is the 254 Hz reference signal and the 127 Hz reference signal which control the timing of the synchronous switch U4.

3.5.2 PHOTOCELL OUTPUT SIGNAL.

The photocell output, (DC bias together with 254 Hz when the unit is in the normal locked mode of operation, or 127 Hz while the unit is obtaining a lock), is routed to E1 and E5 on the servo board A1. E1 and E5 tie to the input of dual stage amplifier Ul at pins 5 and 6 respectively. The output of the first stage of amplification is capacitively coupled to the input of the second stage of amplification U1, pin 8 and routed to E4. E4 provides the Rb Lamp Monitor signal to the front panel connector.

The output of the second stage of amplification is capacitively coupled to the input of the lock-monitor circuit, pin 12 of U6; to the input of the 127 Hz Filter, pin 3 of U2. U2, pins 5, 6, and 7 set the conditions for the power supply to switch from +22 Vdc to +17 Vdc after the Rb Lamp obtains ''correct mode ignition''. When the unit is operating in its normal, locked condition the output of pin 1 of the 127 Hz filter is a 254 Hz sinewave. This output is coupled to pin 12 of the synchronous demodulator U4.

3.5.3 SYNCHRONOUS DEMODULATOR, U4.

U4 is a triple two-channel CMOS analog switch which functions as a synchronous demodulator. The 127 and 254Hz reference signal at pins 11 and 9 respectively, control the synchronous switching of two of the switches, while the third switch is controlled by the level of signal at U4, pin 10, from the lock monitor circuit, U6. In addition to the reference signals at U4, pins 9 and 11, the filter output at U4 pin 12, and the output of the lock monitor amplified at U4 pin 5, the synchronous demodulator also has a 6.8 volt reference level applied to pins 5 and 13 from the dividing/regulating network on the +17Vdc line at E2, E3.

3.5.4 INTEGRATOR U5.

U5 functions as an integrator. It's output voltage changes at a rate determined by the differential input voltage. For example, an input differential of -200 mV causes an output voltage change of +200 mV/sec. The change will continue until the differential input is nullified, (crystal returns to center frequency), or until the Op amp reaches it's maximum output voltage. The output of the integrator U5 is the crystal control voltage used to control the frequency of the VCXO via varactor A4-CR3. Part of the integrator output is also routed to the sweep control circuit at U6, pin 5.

3.5.5 SWEEP CONTROL CIRCUIT, U6.

U6 pins 5, 6, and 7 function as a comparator which controls the up/down sweep. When the unit is not locked to the atomic resonance, the output of U6 at pin 7 is fed back to the input of U5 via the synchronous demodulator U4, pin 2. This feed back signal causes the integrator U5 output to sweep the entire voltage range about once every forty seconds; this sweeps the VCXO frequency until atomic resonance lock is achieved.

3.5.6 LOCK MONITOR CIRCUITS.

As stated in 3.4.2, a portion of the photocell signal is applied to an input of the Lock Monitor circuit at U6, pin 12. U6 pins 12, 13 and 14, with associated circuitry, form a second harmonic amplifier to provide a 254 Hz signal at pin 3 of the Synchronous demodulator U4. The 254 Hz at pin 3 is chopped at the 6.8 volt reference level from U4, pin 13, at the 254 Hz rate, controlled by the 254 Hz reference signal at U4, pin 9. The resultant signal at U4 pin 4 is coupled to U6, pin 9. With the unit locked to f_{Rb} the signal at U6, pin 9 will cause the output at U6 pin 8 to increase. This increase provides the positive signal at U4 pin 10 which removes the sweep control signal from the Integrator U5; and also biases Q1 into a conduct mode which provides the Lock Monitor signal at the front panel connector.

3.6 LAMP BOARD A2. (Schematic Drawing No. 703-209)

The lamp board contains the lamp exciter circuits and lamp-housing heater circuits. The function of the lamp board is to ignite and maintain ignition of the Rb lamp, and to provide the required heating necessary to maintain the lamp housing at approximately 115°C.

3.6.1 The Rb lamp excitation circuit consists of an adjustable 79 MHz oscillator. Transistor Q2 is the active element, and the tank circuit L4, C11 maintain optimum lamp ignition.

3.6.2 The Rb lamp is mounted in a temperature-controlled housing. Q3 is mounted on the housing and acts as the heating element. Thermistor RT1 is the temperature sensor and forms part of the feedback network for the thermal control circuit U1 and Q1. Refer to paragraph 3.3.4 RESONATOR THERMOSTAT for a more complete analysis of the Heater Controller operation.

3.7 POWER SUPPLY A3 (Schematic Drawing No. 703-254).

The internal power supply provides the unregulated, filtered voltages for the Rb lamp heaters, Oscillator heater and Resonator heaters; in addition to providing the filtered and regulated voltage for the units operation. The input voltage line is fuse and diode protected against reverse polarity inputs.

The Power Supply board accepts the +22 to +32 Vdc input voltage at E2, and provides +22 Vdc, until the Rb lamp ignites, at which time the power supply is switched to +17 Vdc. The switching occurs when U2-B, on the Servo board, senses that the Rb lamp is ignited, in the correct mode, by the positive increase at pin 5. The output of U2-B is routed to the power supply board at E29. The positive voltage increase provides reverse bias for CR6, effectively removing R24 from the circuit and setting the condition for the power supply output to be lowered to the +17 Vdc required for the internal circuits of the unit.

3.7.1 +17 Vdc REGULATED POWER SUPPLY. The +17 Vdc power supply consists of Q1 and U1 along with the components in their respective circuitry mounted on the Power Supply board and pass transistor Q1 mounted on the baseplate.

The +22 to +32 Vdc input is routed across the 3 amp fuse F1 to the voltage divider circuit consisting of R5, R7. The input voltage is dropped to approximately 3 Vdc which is coupled through CR3 to U1 pin 2. Before power is applied, U1 pins 2, 3, and 6 were at ground potential. With 3 volts at U1, pin 2 and U1, pin 3 still at ground potential, the resultant offset causes U1, pin 6 to go low, turning on the power transistor Q1. The +17 volt line is fed back through CR4 and R9 to the reference zener diode, CR5. CR5 develops approximately 6.3Vdc at U1, pin 2. In addition, the 17 volt line is fed back to the voltage divider consisting of R6, R8 and R10 to apply a voltage to U1, pin 3. The voltage divider determines the voltage ratio of the 17 volt line to the voltage reference diode CR5, thus setting the voltage level of the 17 volt line.

Transistor Q1 on the power supply board functions as a current limiter by sensing the voltage drop across R14. If the current through the pass transistor becomes excessive, Q1 begins to conduct decreasing the emitter-base bias on the pass transistor, thus limiting the current flow.

3.8 OSCILLATOR BD, A4 (Schematic Drawing No.703-103).

The purpose of the Oscillator board is to provide a stable 5 or 10 MHz signal (depending on configuration) to the output connector, and a 10 MHz signal to the synthesizer board. The Oscillator board consists of the 5 MHz or 10 MHz Voltage Controlled Crystal Oscillator (VCXO), the crystal oven and thermal control circuitry, and a buffer amplifier.

3.8.1 VCXO HEATER. The 5 or 10 MHz VCXO crystals are mounted in a temperature controlled oven. The oven is heated by the heater transistor Q9. The crystal heater controller operation is basically the same as discussed in 3.3.4, with RT1 acting as the temperature sensor, balancing out R37 and Select Resistor R42. Transistor Q8 is a current limiter which senses the current through the heater by detecting the voltage drop across R49.

3.8.2 5 MHz or 10 MHz VCXO. The oscillator consists of the 5 or 10 MHz SC-Cut crystal Y1, and transistors Q1 and Q2 with associated circuitry. Q2 is the actual oscillator circuit, with Q1 setting the gain of the oscillator by controlling the bias at the base of Q2. The frequency of oscillation is determined by the capacitive tuning network consisting of C5, C6, C7 and varactor CR1. The 5 MHz signal from the VCXO is the driving signal for the Field Effect Transistor (FET) Q3. FET Q3 provides the feedback for the oscillator circuit and is used as a low-noise linear amplifier to drive the output buffer (Q4,5).

3.8.3 Buffers

3.8.3.1 5 MHz LN Oscillator (5 MHz buffer and 10 MHz doubler). The 5 MHz LN Oscillator drives the Cascade Buffer made up of Q4 and Q5. Its output is transformer coupled (through T1) to the output connector (J1). Phase complimentary signals of equal amplitude are picked off the collector and emitter of Q5 and fed to the frequency doubler (Q6, Q7). This stage feeds 10 MHz to the Synthesizer PCB.

3.8.3.2 10 MHz LN Oscillator. The 10 MHz LN Oscillator drives the Cascade Buffer, which is made up of Q4 and Q5. Its output is transformer coupled (through T1) to the output connector (J1). The signal at the emitter of Q5 drives the internal buffer Q7, which in turn feeds 10 MHz to the

Synthesizer PCB.

3.8.4 VCXO Control Voltage (electronic tuning)

3.8.4.1 10 MHz LN Oscillator

The control voltage from the Servo PCB is routed to the Oscillator PCB terminal E9. From here the voltage is fed to CR1 via the resistor network made up of R50, 51, and 52. CR2 is a reversed bias varicap, capable of electronically tuning the frequency of the crystal (Y1). The trim range of the crystal is designed to compensate for crystal aging over a period of several years, as well as temperature compensation of the Oscillator over its entire temperature range.

C7 and C8 match the Crystal Tuning Sensitivity to the varicap (CR1). C6 mechanically tunes the crystal center frequency and can be used to compensate for crystal aging during maintenance.

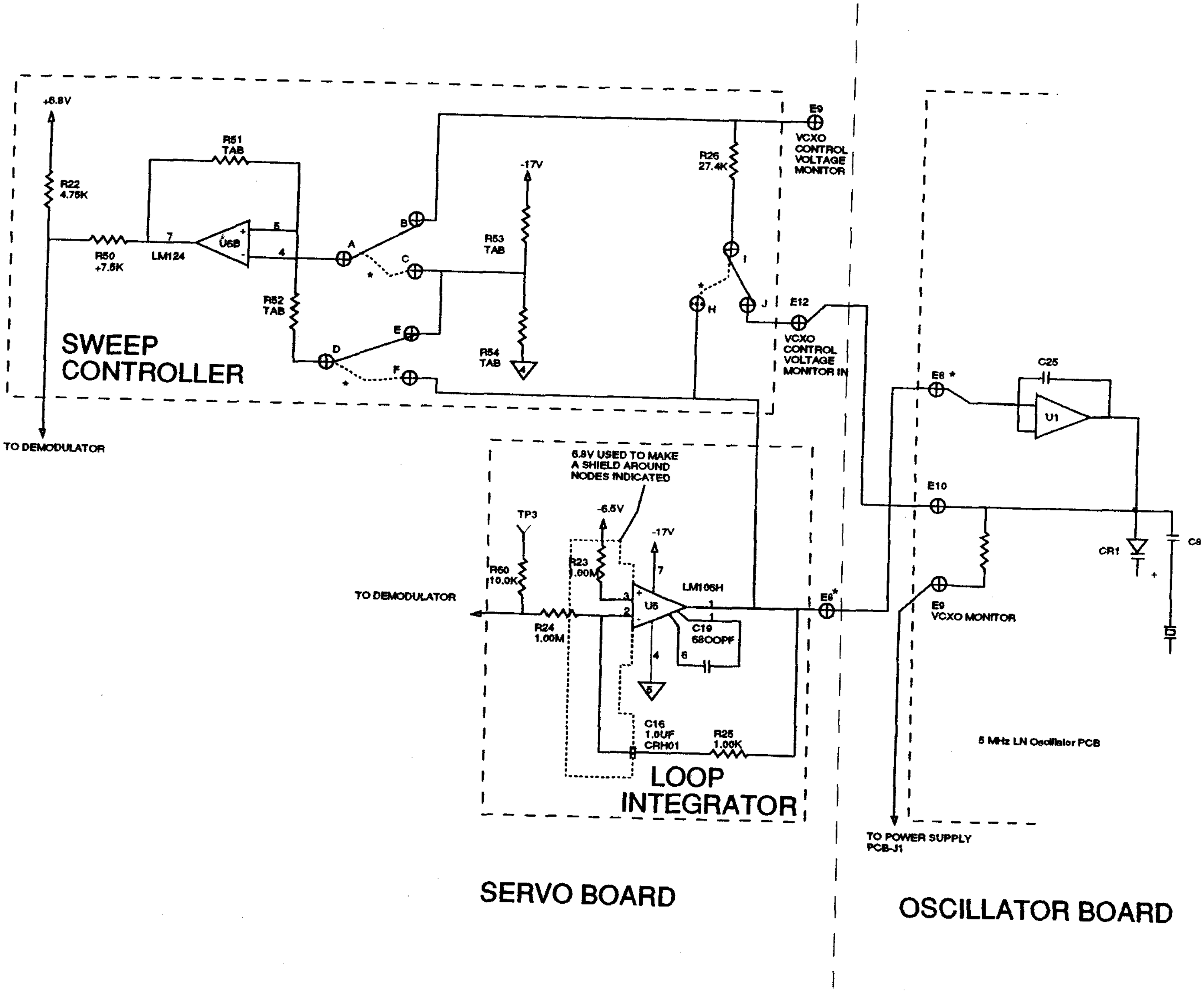
3.8.4.2 5 MHz LN Oscillator

The circuit functions very similar to the 10 MHz unit, the major difference is that an integrator stage (U1) has been added, resulting in a slower loop time constant. This feature takes full advantage of the crystal's outstanding reduced phase noise close to the carrier frequency. The interconnection of the Servo PCB, as well asthe Servo modification, and the 5 MHz LN Oscillator are shown in Figure 3-4.

3.9 SYNTHESIZER A5. (Schematic Drawing No. 703-218).

The 10 MHz signal from the crystal oscillator is applied to the input of a frequency tripler consisting of Q3, Q4 and associated circuitry. The 30 MHz signal is capacitively coupled through C13 to transformer T1. The 127 Hz from the Servo assembly is injected into the rf signal via varactor CR6. The interaction of CR6 with the tuned tank circuit on the primary of T1 serves to phase modulate the rf at a 127 Hz rate. The secondary of T1 is center tapped to provide a split phase signal that drives the bases of Q5 and Q6. The result is a 60 MHz signal that is amplified by Q7, Q8 which are class A inverting amplifiers.

A portion of the 10 MHz signal from the crystal oscillator is applied to the base of Q2. Q2 converts the sinewave to a TTL compatible trigger signal. Power for the TTL circuits is provided by the voltage regulator VR1. VR1 is a 3 pin, +5V regulating IC. The 10 MHz TTL signal is divided down in U2 and U3, and recombined in U1. The final TTL signal from U1 is a 5.3125 MHz signal. This 5.3125 MHz signal is mixed with the 60 MHz output of Q8, and routed to the Step Recovery diode in the Resonator circuit.



* SERVO JUMPERS
... 10 MHz FRK

** E8=VCXO CONTROL VOLTAGE
(ENTER 2X AT TERMINALS)

Figure 3-4. Interconnection of Servo PCB, Servo modification, and 5 MHz LN Oscillator

SECTION IV

MAINTENANCE, TROUBLESHOOTING, AND REPAIR

4.1 INTRODUCTION

This portion of the manual provides procedures for performing maintenance on the FRK-( )LN (5 & 10 MHz).

NOTE

If the unit should require service within the warranty period, contact Ball Corporation, Efratom Division for repairs. Refer to warranty page (i) for addresses and phone numbers of the repair center closest to you.

4.2 TEST EQUIPMENT

The required test equipment to ensure normal operation is listed in Table 4.1. Test equipment other than those items listed may be used, providing that the substitute equipment meets or exceeds the "Minimum Use Specifications" as listed in Table 4.1. If the required test equipment or its equivalent is not available, it is recommended that the unit be sent back to the Efratom factory whenever service is required.

Table 4-1: Required Test Equipment - Performance Tests & Trouble-shooting (TS)

INSTRUMENT	REQUIRED CHARACTERISTICS	USE	MODEL (or equivalent)
DC Power Supply	Output Voltage: 0 to 30 Vdc. Output Voltage: 2.0 Amps Min.	Perf. Test	Hewlett-Packard 6433B or 6296A
Oscilloscope	10 MHz	Perf. Test	Tektronix 465
DMM (Digital multimeter)	Voltage Range: 0 to 30 Vdc Accuracy: ±1.25% Iv, Resistance Range: 0 to 150 Ohms	Perf. Test/TS	Fluke 8000A or 8020A
RF Voltmeter	10 MHz, true rms	Perf. Test/TS	Racal Dana 9300B
Freq. and Time Interval Analyzer	Internal Ref. Frequency: 10 MHz, ±1E-12, Stability: parts in 10^{12}	Perf. Test	Hewlett-Packard 5371A or 5372A (App. Note 358-12)
Phase Comparator	Analog voltage output	Perf. Test	Hewlett-Packard K34-59991A
Precision Potentiometer	500K	Perf. Test	
Resistive Load	Feed-thru type, 50 ohms	Perf. Test	Hewlett-Packard 10100C
Timer	Capable of indicating 1 to 15 mins.	Perf. Test/TS	Any timepiece
Ref. Freq. Standard	Output: 10 MHz, ±2E-12 Accuracy	Perf. Test	Must be traceable to NIST (1)
Linear Recorder	0-10 Vdc Full Scale, 1-10 cm/hr	Perf. Test	Tracor 888
Temp. probe	Capable of measuring -50°C to 150°C	Perf. Test	Fluke 80T-150
Frequency Counter	5 MHz . 125 MHz	Perf. Test/TS	Fluke 1910A
Decade Resistance	0 > 9.999999 Mohm	Perf. Test/TS	I.E.T. Model RS200
Mixer/IF Amp.	Low noise, wideband limiting amplifier	Perf. Test	HP K79-59992A

(1) Efratom Modular Frequency System with interface to a GPS receiver recommended.

4.3 PERFORMANCE VERIFICATION TESTS

4.3.1 Output Level Test

(1) Connect the UUT as shown in Figure 4-1.

(2) Apply dc power and allow the UUT to stabilize (> 10 minutes).

(3) Measure output level with a rf voltmeter, using a 50 ohm resistive termination. Record the voltage level of output.

(4) Observed voltage level must be 1 Vrms. ±10%.

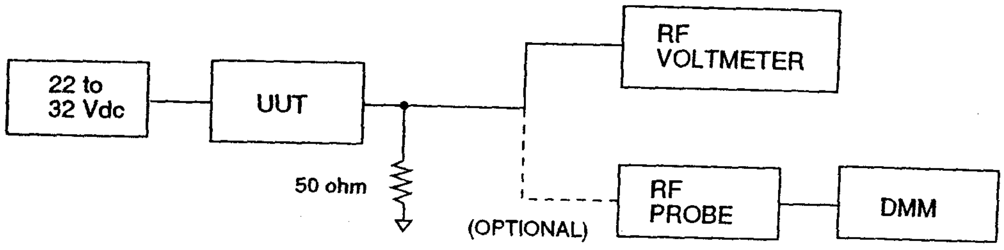


Figure 4-1. Output Level Test Configuration

4.3.2 Frequency Offset Test

(1) Connect the Unit (UUT) and the test equipment as illustrated in Figure 4-2. (As an alternative, the HP5371A may be used to measure frequency offset. Contact a HP field engineer for details.)

(2) Adjust chart recorder pen position to center scale for 0 volts input.

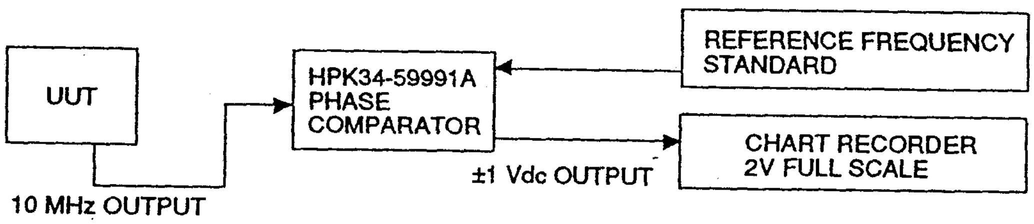


Figure 4-2. Frequency Offset Test & Long-term Stability Test Configuration

(3) Ensure that the equipment has had sufficient time to warm-up. (The UUT requires 1 hour to stabilize.)

NOTE
The maximum temperature fluctuation must not exceed 2° C.

(4) Monitor phase comparator output voltage on the chart recorder for 15 minutes. Calculate the the fractional frequency offset ($\Delta f/f$) from the phase comparator output voltage change over time ($\Delta V/\Delta t$) according to the equation:

$$\text{Fractional Frequency Offset} = \frac{\Delta V}{\Delta t} \cdot \frac{1}{10\ \text{MHz} \cdot V_{p-p}}$$

Where: $\Delta V/\Delta t$ = Slope of phase comparator output in volts/sec over a 15 min. interval (t in sec.).
V_{p-p} = Output voltage swing of phase comparator for 360° phase shift.

For the HP K34-59991A, the fractional frequency offset = $\frac{\Delta V}{\Delta t}$ X 5E-8 sec/volt.

(5) Verify that the fractional frequency offset is within the required limit.

4.3.3 Frequency Retrace Test

(1) Connect the UUT as shown in Figure 4-2.

(2) Apply dc input power to the UUT.

(3) Allow at least 1 hour for the UUT to stabilize. Measure and record the output frequency offset per Section 4.3.2, Step 4.

(4) Disconnect input power to the UUT for 24 ± 2 hours.

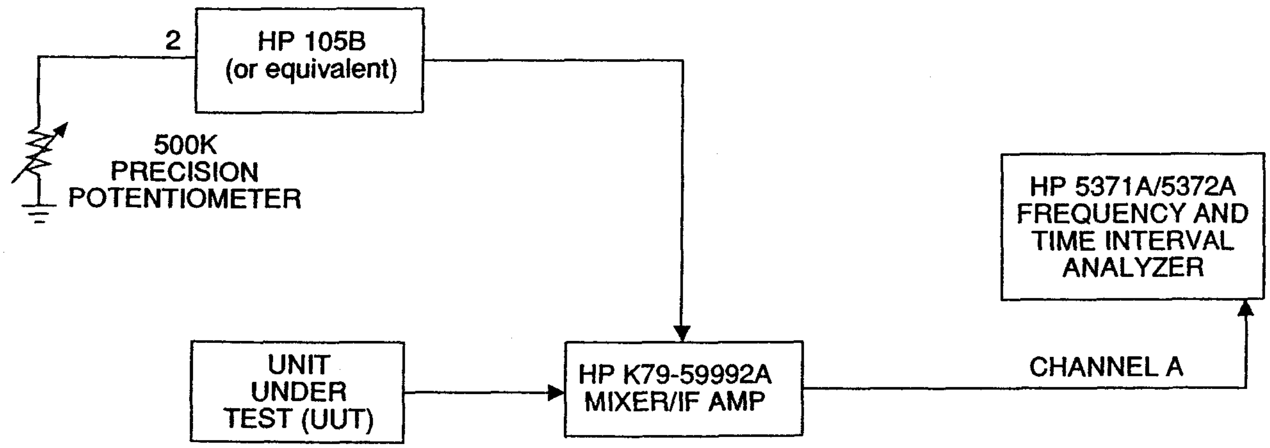
(5) Apply dc input power to the UUT.

(6) After one hour of operation, measure and record the output frequency offset per Section 4.3.2, Step 4.

(7) Determine the absolute value of the difference between the offsets marked in Step 3 and Step 6. The difference must be ±2E-11.

4.3.4 Short-term Stability (Root Allan Variance) Test

(1) Connect the UUT as shown in Figure 4-3.



NOTE:
The 1 sec. Allan Variance of the Adjustable Frequency Standard must be much better than the 1 sec. Allan Variance of the UUT.

Figure 4-3. Short Term Stability and Signal Output Tests.

(2) Apply dc input power. Allow UUT to stabilize (about 1 hour).

(3) Refer to the HP 5371A/5372A manual and Application Note 358-12, for specific details regarding measurement of Root Allan Variance using the HP5371A/5372A. If necessary, contact local HP field engineer for assistance. Tune HP 105B to produce 10 Hz IF frequency. Measure the root Allan Variance (A.V.) at 1.0 second using 100 data samples. The measured A.V. must be $\leq 3 \times 1E\text{-}11$ (for FRK-H. Since the dominant source of frequency instability at 1 sec. through 100 sec. is white FM noise, root Allan Variance at 10 sec. and 100 sec. can be calculated using the expressions:

$$A.V._{(t = 10\,sec.)} = A.V._{(t = 1\,sec.)} / \sqrt{10}$$

$$(A.V._{(t = 100\,sec.)} = A.V._{(t = 1\,sec.)} / \sqrt{100})$$

The calculated A.V. for 10 sec. must be ≤ 1E-11 (4E-12 for FRK-H). The calculated A.V. for 100 sec must be ≤ 3E-12 (1E-12 for FRK-H).

4.3.5 Long-term Stability Test

Long-term stability refers to slow changes in the average frequency, with time due to secular changes in UUT physics and or electrical circuitry. Long-term stability is usually expressed as fractional frequency offset ($\Delta f/f$), for a given period of time. The daily fractional frequency offsets can be plotted to show the long-term stability.

NOTE

The long-term stability test should be performed only after the UUT has been operating continuously a minimum of 48 hours. The frequency of the UUT should be measured and recorded each day to establish the drift rate.

(1) Connect the equipment as shown in Figure 4-2.

(2) Per Section 4.3.2, Step 4, compute and record the fractional frequency offset every 24 hours over a period of 15 days.

NOTE

It is recommended to plot the daily offset graphically and use this plot to estimate long-term aging (drift rate).

(3) After completion of 1 month of aging, compute the drift rate of the UUT over the 1 month period.

(4) If the drift rate over 1 month is ≤ 4E-11 (1E-11 for FRK-H), the UUT has passed.

(5) If the drift rate is ≥ 4E-11 (1E-11 for FRK-H) , the UUT has failed and must be retested (repeat step 2).

(6) Depending on the off-time since the last operation, the environmental exposure, and the repairs performed, the unit may need to repeat this test a second time before meeting the original manufacturer's specifications.

4.4 FIELD MAINTENANCE, TROUBLESHOOTING, AND REPAIR

4.4.1 FIELD MAINTENANCE

Field maintenance consists of compensating for crystal aging and frequency adjustment. These are routine adjustments that may be made periodically to compensate for aging effects.

4.4.1.1 Crystal Aging Compensation

NOTE

The effects of crystal aging can be seen on a voltmeter. Attach a voltmeter probe to the crystal volts output monitor line of the FRK. A meter indication of <+4 Vdc or >+12 Vdc, indicates an adjustment of the crystal oscillator base frequency is required.

(1) Ensure that the UUT has been operating continuously for at least 1 hour.

(2) Locate the crystal trim adjustment on the FRK.

(3) Unscrew the Philips head screw plug that acts as the adjustment access cover. The trimmer capacitor adjustment screw will now be visible.

NOTE

For the **5 MHz LN** unit COUNTERCLOCKWISE rotation of the adjustment will INCREASE the control voltage, while CLOCKWISE rotation will DECREASE the control voltage.
For the **10 MHz LN** unit CLOCKWISE rotation of the adjustment will INCREASE the control voltage, while COUNTERCLOCKWISE rotation will DECREASE the control voltage.

(4) Using a non-metallic alignment tool, SLOWLY adjust the trimmer capacitor as necessary to obtain a +8 Vdc indication on a meter.

4.4.1.2 Frequency Adjustment

(1) Monitor the fractional frequency offset per section 4.3.2.

(2) Adjust POT (R21) on power supply board (accessed through baseplate) to obtain a fractional frequency offset that is within the required limits.

4.4.2 TROUBLESHOOTING AND REPAIR

Troubleshooting and repair consists of testing and repair of the FRK. This section contains information on fault identification and removal, repair, replacement, and calibration of the assemblies of the FRK.

NOTE:

THESE PROCEDURES ARE NOT ROUTINE ADJUSTMENTS AND PERFORMING THEM SHOULD BE CONSIDERED ONLY IN THE EVENT OF UNIT FAILURE.

a. Troubleshooting Flowcharts

A series of flow charts is provided to aid in the isolation of faults. Flowcharts are presented in logical fault isolation order and must be performed in the proper sequence given. The troubleshooting/repair procedures for the various subassemblies of the FRK are presented after each flowchart and are designed to permit the repair technician to identify the fault and replace and/or repair the subassembly.

b. FRK Disassembly

CAUTION

All FRK disassembly operations must be performed with power removed from the unit. Disassemble assemblies only as needed to make repairs.

(1) Detach the cover from the FRK assembly by removing ~~two~~ six 2mm screws on the connector face of the unit, then remove four 2mm screws that hold the bottom of the cover to the baseplate (see Figure 4-4). Once all six retaining screws are removed, hold the baseplate while gently pulling on the cover (it may be necessary to move the cover slightly from side to side as the FRK internal assembly is removed from the case).

(2) Remove any of the outside PCB assemblies by removing the M2x6 screws that fasten the boards to the FRK frame at each corner (the servo and synthesizer boards have additional screws that must also be unfastened).

(3) Once the mounting screws are removed, label all wires and coax (shielded wire) connections, and then remove each one (a soldering iron is required).

(4) Disassemble the baseplate of the FRK by removing the lamp inspection cover and all other screws on the outside face of the baseplate. This frees the baseplate from the frame.

NOTE

The Q1 Pass Transistor will still be connected. Pulling the baseplate away from the frame rapidly may unintentionally break the wire connection of the transistor.

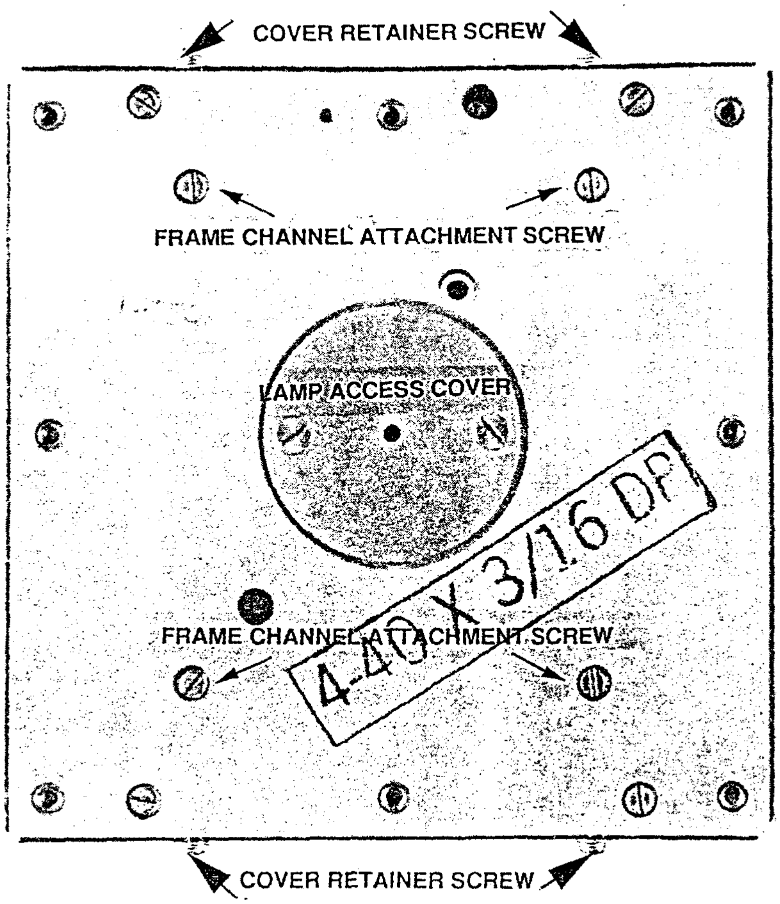


Figure 4-4. FRK Baseplate

(5) The lamp board assembly and the metal container that is the exterior of the resonator assembly are located inside the frame channel. These two assemblies are accessed by removing four M2x6 screws from the four nut blocks that are located inside the frame channel. The resonator board is located inside the mu-metal canister of the resonator assembly. Figure 4-5 is a wiring diagram that illustrates how the FRK boards and the physics package are connected together.

(6) Before the lamp assembly can be removed from the baseplate end of the FRK unit, all wires must be disconnected from each end of C1 and C2. These feedthrough capacitors (which are frame mounted) must be removed completely from the frame. Once this has been accomplished, removal of the two M2x6 screws at the opposite corners of the lamp PCB allows it to be lifted away from the interior frame channel.

(7) Remove the resonator assembly from the connector end of the unit by unsoldering the 10 wires that connect the resonator to the other board assemblies of the unit. Disconnect the wires from the locations shown in Table 4-2.

Table 4-2. Resonator Disconnect Points

Servo Bd.	Power Supply Bd.	Synthesizer Bd.
A1E1	A3E21	A5E6
A1E5	A3E22	A5E7
	A3E23	
	A3E24	
	A3E25	
	A3E26	
	A3E27	
	A3E28	

(8) Remove the M2x6 screws at each corner of the resonator assembly PCB, allowing the entire resonator assembly to be removed from the interior frame channel.

(9) The inner shield lid of the resonator can is assembled to the can with a tight mechanical fit. The lid is removed by gently tapping around the circumferance of the lid's exposed lip.

(10) Separate the resonator assembly's PCB from the inner shield can by removing the three M2 nuts spaced around the light entry hole in the PCB.

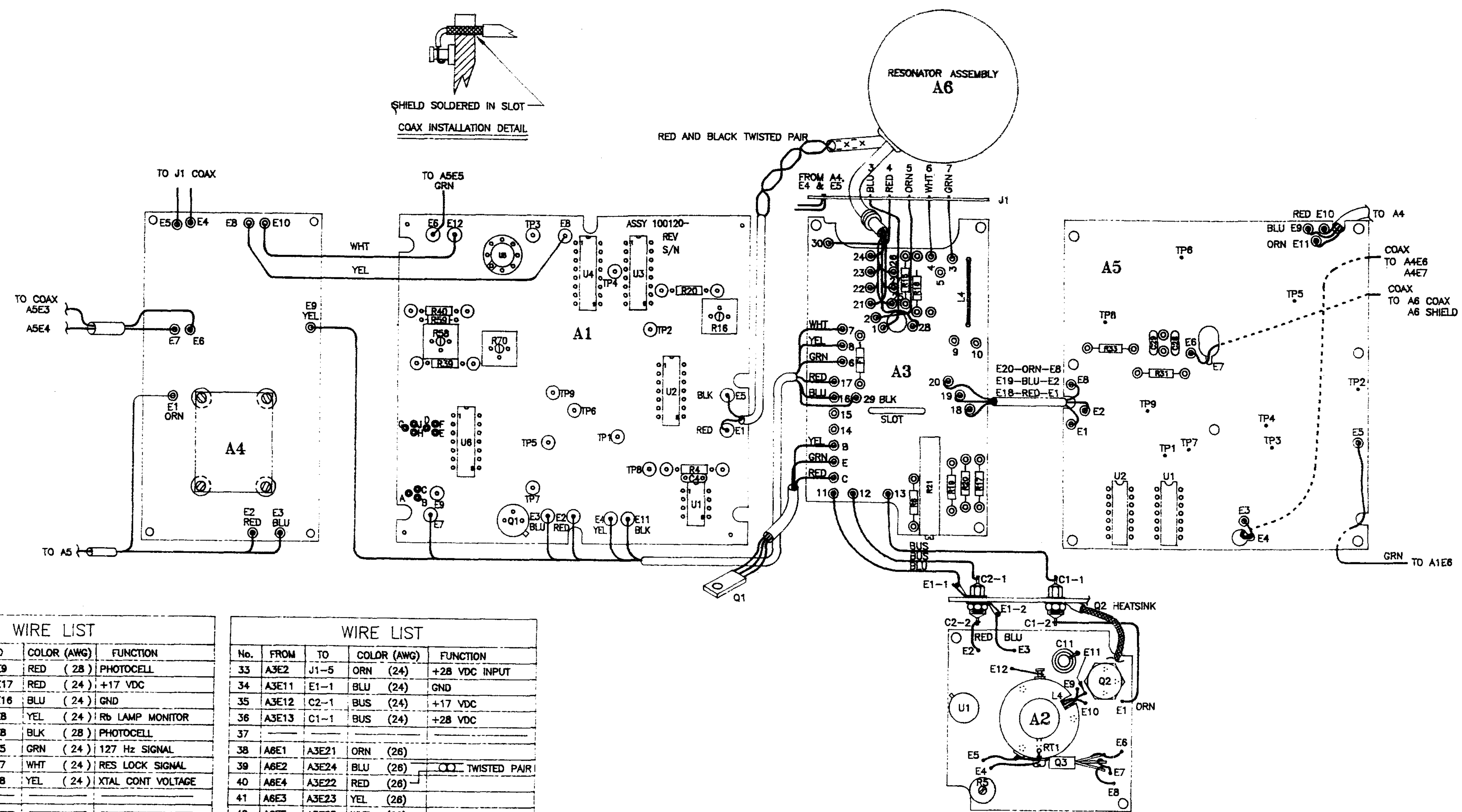
(11) Having completed these steps, the resonator housing, with the heater control PCB attached, can be removed from the inner shield can for service.

The FRK can now be visually inspected for burned components or broken connections. Placed on a test bench and powered up, signal traces can also be obtained from the test points on the various board assemblies (refer to Section 4.4.2.5, Detailed FRK Circuit Descriptions).

NOTE

Disassembly of the FRK should be performed only to to the level necessary to identify a fault (or faults). Excessive disassembly may introduce other problems into the unit, making it impossible to repair.

After repairs have been completed, and the FRK reassembled, refer to Section 4.3 for Performance Verification Tests that must be performed before the FRK is returned to service. Refer to Section 4.4.2.6 is alignment is required for any of the repaired or replaced assemblies.



WIRE LIST				
No.	FROM	TO	COLOR (AWG)	FUNCTION
1	A1E1	A6E9	RED (28)	PHOTOCELL
2	A1E2	A3E17	RED (24)	+17 VDC
3	A1E3	A3E16	BLU (24)	GND
4	A1E4	A3E8	YEL (24)	Rb LAMP MONITOR
5	A1E5	A6E8	BLK (28)	PHOTOCELL
6	A1E6	A5E5	GRN (24)	127 Hz SIGNAL
7	A1E7	A3E7	WHT (24)	RES LOCK SIGNAL
8	A1E8	A4E8	YEL (24)	XTAL CONT VOLTAGE
9	—	—	—	—
10	—	—	—	—
11	A1E11	A3E29	BLK (24)	
12	A1E12	A4E10	WHT (24)	
13	A2E1	C1-2	ORN (24)	+28 VDC
14	A2E2	C2-2	RED (24)	+17 VDC
15	A2E3	E1-2	BLU (24)	GND
16	—	—	—	—
17	A4E1	A5E11	ORN (24)	+28VDC (VIA A3E20)
18	A4E2	A5E10	RED (24)	+17 VDC (VIA A3E18)
19	A4E3	A5E9	BLU (24)	GND (VIA A3E19)
20	A4E4	J1-1	COAX	5MHz OUTPUT
21	A4E5	J1-1	SHIELD	
22	—	—	—	—
23	A4E6	A5E3	COAX	5MHz
24	A4E7	A5E4	SHIELD	
25	A4E9	A3E6	GRN (24)	
26	A5E1	A3E18	RED (24)	+17 VDC
27	A5E2	A3E19	BLU (24)	GND
28	A5E6	A6	COAX	RESONATOR
29	A5E7	A6	SHIELD	
30	A5E8	A3E20	ORN (24)	+28 VDC
31	—	—	—	—
32	A3E1	J1-3	BLU (24)	GND INPUT

WIRE LIST				
No.	FROM	TO	COLOR (AWG)	FUNCTION
33	A3E2	J1-5	ORN (24)	+28 VDC INPUT
34	A3E11	E1-1	BLU (24)	GND
35	A3E12	C2-1	BUS (24)	+17 VDC
36	A3E13	C1-1	BUS (24)	+28 VDC
37	—	—	—	—
38	A6E1	A3E21	ORN (26)	
39	A6E2	A3E24	BLU (26)	TWISTED PAIR
40	A6E4	A3E22	RED (26)	
41	A6E3	A3E23	YEL (26)	
42	A6E5	A3E25	WHT (28)	
43	A6E6	A3E26	BLK (26)	
44	A6E7	A3E28	GRN (26)	
45	A6E10	A3E27	BRN (28)	
46	—	—	—	—
47	—	—	—	—
48	—	—	—	—
49	—	—	—	—
50	A3E4	J1-6	WHT (24)	RES LOCK SIGNAL
51	A3E3	J1-7	GRN (24)	XTAL OSC MONITOR
52	A3E30	J1-4	RED (24)	HTR POWER INPUT

Figure 4-5. 5 MHz FRK-( )LN Wiring Diagram

c. FRK Assembly Repair

If troubleshooting has indicated that the FRK assembly has failed and the assembly must be repaired instead of being replaced, the following sections provide repair guidelines.

SN6WRMAP3 SOLDER, per QQ-S-571, and a 35 to 40 watt soldering iron should be used to accomplish the soldering that might need to be done on the FRK.

> **CAUTION**
> Excessive heat can cause the etched circuit wiring to separate from the board material.

If it becomes necessary to solder in the general area of any of the high frequency contacts in the unit (terminal points), clean the contacts immediately upon completion of the soldering.

The adjustments, repair, or alignments required by the fault isolation flowcharts should be followed by the retesting of the procedure that led to the fault isolation to ensure the unit is functioning as required.

d. Overall FRK Troubleshooting (Fault Isolation Flowchart)

Figure 4-6 is the overall troubleshooting flowchart that should be followed to locate a fault in the FRK unit. For additional information, refer to the assembly drawings and schematics presented in Appendix B, and to the text in the following sections that describes the operation of the major FRK boards and circuits.

(1) Rubidium Lamp Replacement

Although this is seldom a cause for failure in the FRK (refer to 4.4.2.5 (2) for symptoms), the Rubidium lamp is replaceable. The Rubidium lamp is accessed by removing the two screws holding the Lamp Cover Plate to the baseplate (refer to Figure 4-8). A slotted access plate is beneath the cover plate. Once the access plate has been removed, the base of the lamp housing is visible.

> **CAUTION**
> The lamp housing is at the electrical potential of the unit (28 Vdc) and a short will occur if an attempt to remove the lamp is made with power applied to the unit. The lamp housing is extremely hot, as well. Extreme care must be exercised when removing the lamp to avoid burns.

Once all power to the unit is off, carefully unscrew the rubidium lamp and lift it from the housing (use a pair of needle nose pliers for this task). Make sure the replacement lamp is clean and that its surface is free of any oils or grease and screw the bulb into the housing. Once the bulb is firmly seated in the housing, replace the access plate and the Lamp Cover Plate, and replace the two screws previously removed.

Apply power to the FRK and, after allowing sufficient warm-up time, run a performance test to ensure that the unit is fully functional.

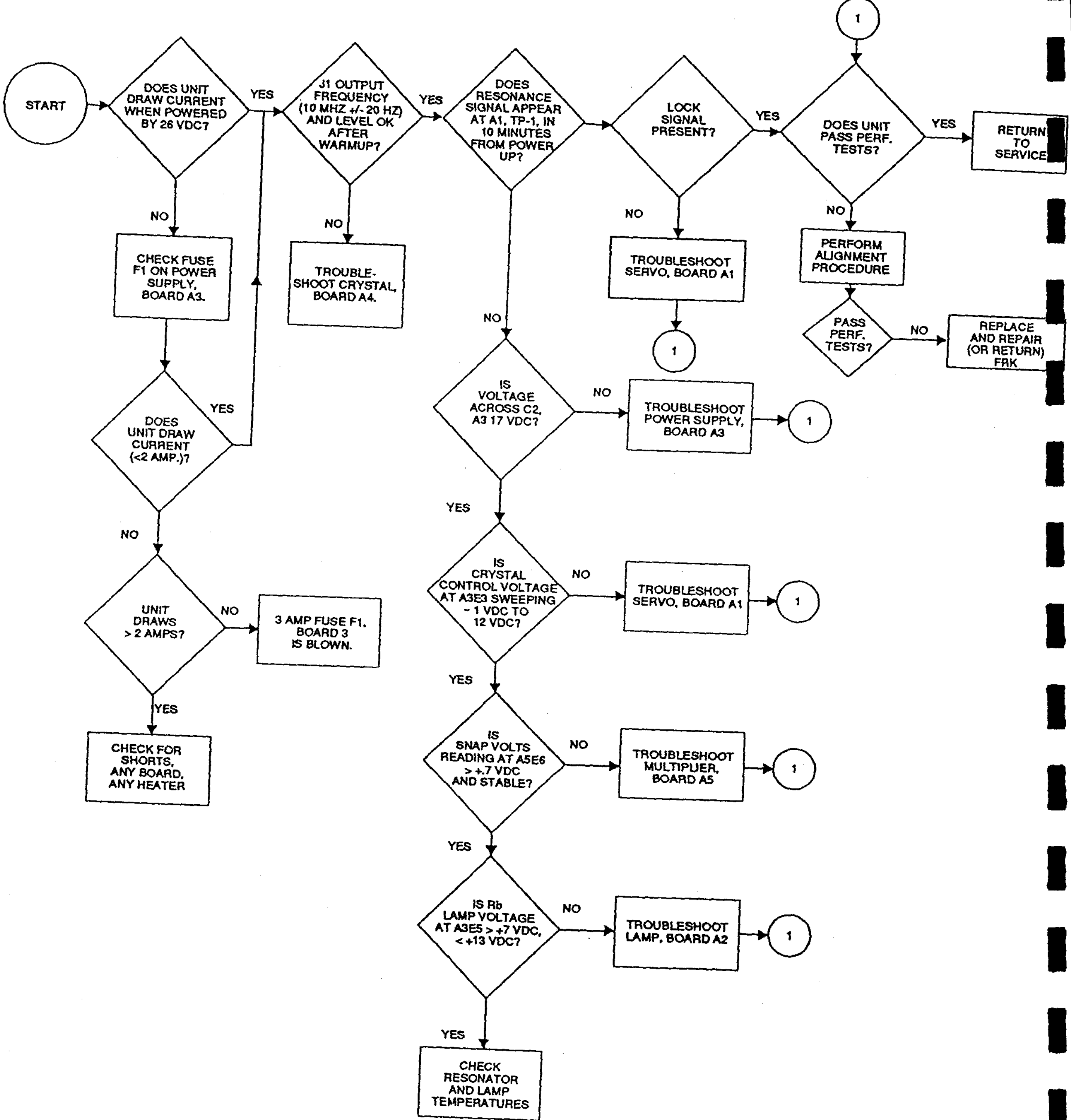


Figure 4-6. FRK Troubleshooting Overview

4.4.2.1 Detailed FRK Circuit Descriptions

a. Resonator Assembly (schematic 703-221)

The function of the resonator assembly is to compare the multiplied and synthesized output frequency of the crystal oscillator to the ground-state hyperfine transition frequency of ^{87}Rb. It provides a 127 Hz error signal to the servo board to lock the crystal frequency to the atomic transition.

(1.) Microwave Cavity - The microwave (resonator) cavity is constructed of silver plated copper and housed in a mu metal shield. It contains the rubidium resonance cell. The photocell is mounted in the bottom of the cavity and placed behind the Rb glass cell, directly in the light path of the Rb spectral lamp. The step recovery diode with coupling loop and the condenser assembly are located at the open end of the cavity. Cavity temperature is maintained by the resonator thermostat circuit. The C-field coil is wound on the outside of the copper microwave cavity.

(2.) Step Recovery Diode - The 60 MHz and 5.3125 MHz from the multiplier are summed at the output of the multiplier/synthesizer board and then applied to the step recovery diode. This diode, CR1, produces electromagnetic radiation having frequencies given by the expression (60 n + 5.3125 m) MHz, where n = a positive integer and m = an integer. The diode is part of a tuned coupling loop, tuned to the 114th harmonic of 60 MHz (n = 114); the coupling loop is inside a microwave cavity that is tuned to the same frequency. The bandwidth of the microwave cavity assembly is wide in comparison with the bandwidth of the atomic transition (< 1 kHz), so that the atoms function as a narrow-band filter for the microwave signal. The diode can be replaced by gaining access to the light entry end of the resonator assembly PCB. An access hole in the PCB provides clearance to remove first the diode retaining screw and then the diode itself (refer to Figure 4-7).

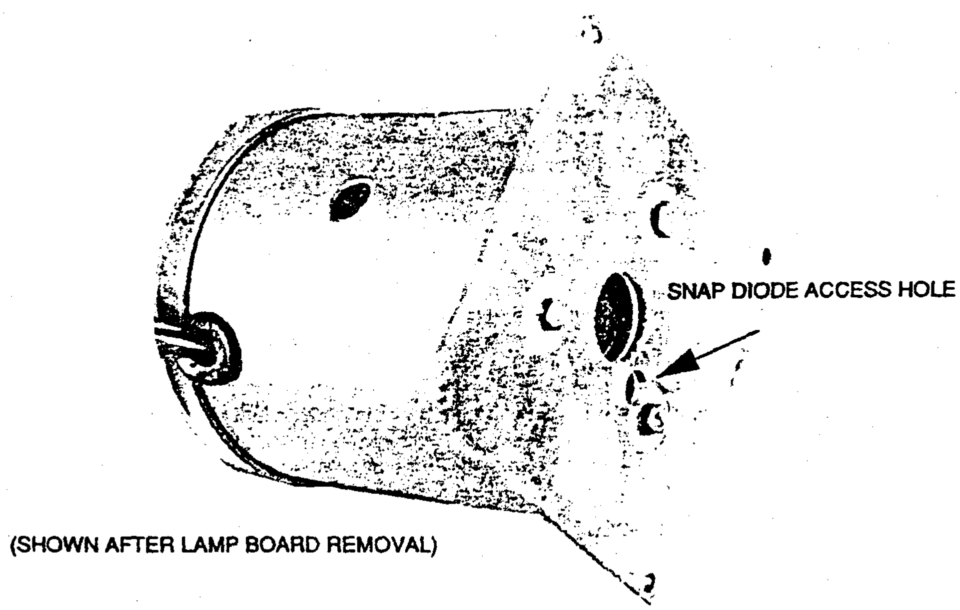


Figure 4-7. Snap Diode Access Hole on Resonator Assembly

(3.) Photocell - The photocell current is proportional to the total light incident on the photocell CR2. Minimum current results when a microwave field corresponding to the Rb hyperfine frequency is applied simultaneously with pumping light. Photocell problems are unlikely (always check the lamp assembly and power supply first), but manifest themselves as instable lamp monitor dc voltages, or as sporadic noise on the servo board's TP1 resonance signal. The photocell is replaced as part of the complete resonator assembly.

(4.) C-Field Coil - The C-field coil is wound on the microwave cavity and provides a dc magnetic field (the C-field) within the resonator cavity. Variation of this magnetic field allows fine tuning of the 10 MHz output frequency by shifting the Rb frequency hyperfine transition by the second order Zeeman effect. The "C-field" strength is determined by current from three sources:

R17 on the power supply board supplies a fixed current to the coil.

R21, the 24 turn potentiometer, on the power supply PCB, provides a variable current for frequency adjustment.

The temperature compensation circuit formed by Q2, Q3, R13 and R16 provides a current that varies with temperature. The power to heat the microwave cavity increases approximately 40 mW for every degree centigrade decrease of the ambient temperature. This results in a current change through resonator heater transistors Q2 and Q3, and through R13 on the resonator thermostat assembly. The voltage across R13 is routed to R16 on the power supply board and back to the C-field coil. Decreases in ambient air temperature causes the voltage across R13 to rise, providing more C-field current, and raising the output frequency.

The most common C-field problem is an open winding. An ohmeter is used to check for this situation by removing power to the FRK and measuring from A3E27 to A3E19. A good C-field coil will give a reading of approximately 30 ohms.

(5.) Resonator Thermostat (part of resonator board assembly, refer to schematic 703-221) - the resonator thermostat consists of U1, Q1, and associated circuitry on the resonator PCB, and Q2, Q3, and RT1 mounted on the resonator cavity housing. U1 is the temperature control element, Q1 is a current limiting element, and Q2 and Q3 are the heat source.

U1 and the resistive bridge network on its inputs form the temperature control section. E1 receives +12 Vdc from the power supply board to power this section. R5 and R7 form a fixed voltage divider that references U1, pin 3. Thermistor RT1 and the series combination of R1 and the temperature select resistor form a voltage divider on the other op-amp input, U1, pin 2. The feedback network of R8 and C4 serves to control U1's output response when the inputs reach equilibrium.

During the high power dissipation period of the warm-up cycle, the current through Q2 and Q3 must be limited to a safe level of ~1 amp. This is done by sensing the current draw of Q2 and Q3 at R13. An increase in heater current causes an increase in voltage at the base of Q1. As Q1 turns on, it shunts a portion of Q2's base drive current to ground, allowing only the preset maximum current to flow. R11 and R12 form a voltage divider network that provides for the preset maximum current to be automatically shifted up or down, depending on the heater supply voltage. This is done to maintain a reasonably constant power dissipation during warm-up over the range of input voltage to the FRK.

As the thermostat circuit reaches equilibrium, the voltage output of U1 drops to a level that operates Q2 in a vernier control mode. The current through Q2 and Q3 folds back to a nominal 100 mA. The current foldback reduces the voltage drop across R13 to the point where Q1 does not conduct and effectively drops out of the circuit.

The resonator assembly is protected from a runaway heater control problem by thermal fuse F1, mounted on the resonator cavity housing.

b. Lamp, Assembly A2, (Schematic 703-209)

The lamp assembly consists of the lamp oscillator circuit, the lamp housing assembly, the lamp thermostat circuit, and the rubidium lamp. The function of the lamp assembly is to ignite and maintain the electrodeless plasma gas discharge of the rubidium lamp, and to maintain the temperature of the lamp housing at approximately 115°C.

The most common fault condition involving the lamp assembly is the generation of spurious noise on the unit output. This condition can be detected at TP1 of the servo board, where the lamp noise will cause severe disturbances to the resonance signal. If the disturbances are too severe, the unit may fail to lock. The spurious noise problem is very difficult to isolate due to the electro-mechanical aspects of the circuit and is typically remedied by replacing the entire lamp assembly. Occasionally, noise from the lamp can be eliminated by changing the oscillator frequency to a lower frequency, or by changing the rubidium lamp. The two most likely lamp failure modes are the loss of vacuum due to glass failure and Rb depletion. Glass failure will prevent lamp ignition (make sure the lamp oscillator circuit is not the cause of failure before lamp removal), whereas Rb depletion results in a whitish tint to the lamp light (another cause of this symptom is an improper lamp thermostat temperature). In case of Rb depletion and/or lamp thermostat failure, the FRK will not develop a resonance signal (refer to section 4.4.2.6, subsection h, Resonance Search).

NOTE

The loss of Rb cannot be detected by the decay of lamp voltage.

Lamp replacement is covered is Section 4.4.1.7 (1), FRK Lamp Replacement.

(1.) Lamp Oscillator - The lamp oscillator circuit is a modified Colpitts design consisting of Q2 as the active element, tank circuit L4 and C11 as the power transfer and primary resonant network, L3 as a secondary frequency control element, and associated bias circuitry.

Mechanical capacitor C11 provides for current/frequency adjustment of the oscillator and is accessible from outside the unit. Figure 4-8 illustrates the location of the adjustment port.

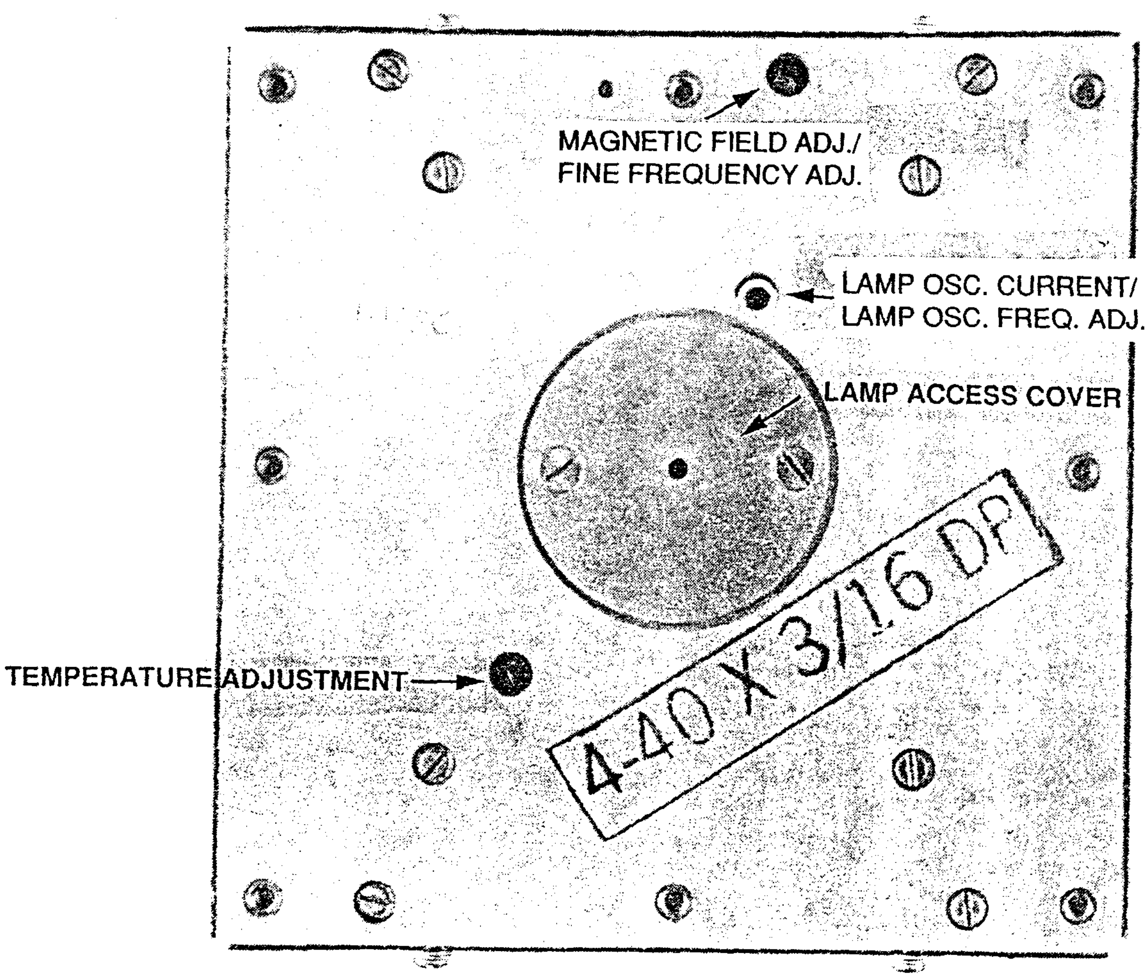


Figure 4-8. Lamp Adjustment Ports

Adjusting C11 tunes the oscillator's frequency over a range of approximately 70 MHz to 90 MHz. Within this range of adjustment there are specific optimum frequencies that should be used (refer to Section 4.4.1.7.2, Lamp Oscillator Tuning, part b, FRK Alignment Procedures). The operational frequency that is chosen is determined by finding the highest frequency setting that produces optimum ignition characteristics and noise free operation. In normal stabilized operation, the oscillator current draw from the regulated supply (E2) is a nominal 120 mA.

(2.) Lamp Thermostat - the lamp thermostat consists of U1, Q1, R5 and associated circuitry on the PCB, and Q3 and RT1 mounted on the lamp housing. U1 is the temperature control element, RT1 is part of the resistive bridge network at U1's inputs, Q1 is a current limiting element, and Q3 is the heat source element.

Op-Amp U1 is controlled by a balanced bridge circuit on its inputs. R3 and R6 form a fixed voltage divider that biases U1, pin 3. Thermistor RT1 and the series combination of R4 and R5 form the dynamic leg of the bridge. RT1 senses the temperature on the lamp housing and potentiometer R5 selects the stabilized temperature. The R5 potentiometer is accessible from outside the unit. Figure 4-14 illustrates the location of the adjustment port.

The operation of current limiter Q1 and heater transistor Q3 is essentially the same as the resonator thermostat circuit, which is discussed in detail in Section 4.4.2.5, part e.

c. Servo Board, Assembly A1 (schematic 10017)

The primary function of the servo circuit is to amplify and demodulate the photocell output to generate the crystal control voltage at E8 for the 10 MHz VCXO. The control voltage is derived by comparing the phase of the 127 Hz modulation signal with the phase of the photocell signal at E1 and E5. Secondary functions are to provide the monitoring signal for the Rb lamp operation at E4, the atomic resonant lock circuit at E7 and the VCXO control voltage monitor at E9.

(1.) Preamplifier - The photocell output, (dc bias together with the 254 Hz error signal when the unit is in the normal locked mode of operation, or 127 Hz error signal while the unit is obtaining a lock), is routed to E1 and E5 on the servo board A1. E1 and E5 tie to the input of dual stage amplifier U1 at pins 5 and 6 respectively. The output of the first stage of amplification is capacitively coupled to the input of the second stage of amplification (U1, pin 8) and directly coupled to E4 and U2-B, pin 5. E4 provides the Rb Lamp Monitor signal to the front panel connector.

U2-B senses the voltage at E4 and determines if the Rb lamp has ignited and if it is in "Correct Mode Ignition". Proper lamp ignition (<3 minutes after turn-on) will cause U2-B output, E11, to switch from <1 Vdc to >15 Vdc. The E11 voltage is fed to the power supply (Board 3, E29), where it switches the regulated unit power from 22 Vdc to 17 Vdc.

The output of the second amplifier (U1, Pin 13) is connected to Test Point (TP) 1, the primary oscilloscope monitoring point of the FRK. U1, pin 13, is also capacitively coupled to U2-A, the 127 Hz active bandpass filter, and to U6, the 254 Hz active bandpass filter.

(2.) Reference Signal Generation - 127 and 254 Hz Reference Signals - CMOS oscillator/divider U3 on the servo board, provides the 127 and 254 Hz reference signals and the 127 Hz signal which modulates the rf injected into the resonator. The primary oscillator frequency of 8.128 Khz is determined by C17, R19 and select-in-test resistor R20. The divider portion of U3 divides the primary oscillator frequency into the required 127 and 254 Hz signals. The 127 Hz reference signal is routed from U3, pin 4 to pin 11 of synchronous demodulator U4 and to pin 2, of U6, through the RC network R37/C24. The RC network R37/C24, the feedback network R38/C25, and the output RC filters (R39, C26, R40 on the servo board, and C2, R3, and C12 on the synthesizer board) serve to waveshape the 127 Hz signal into the sinewave that is coupled to the synthesizer to modulate the rf. R40 of the output RC filter is also used to adjust the modulation level to the multiplier and the phase of the correction signal at TP3.

The 254 Hz reference signal is routed from U3, pin 5 to pin 9 of synchronous demodulator U4. The 254 Hz reference signal is correlated with the photocell output to detect unit lock.

The dc voltage of approximately 6.8 Vdc generated by CR2 is also a reference signal. This DC level is used to bias the ac signals that are processed by U4 and U5, and to bias op-amps U6 and U5.

(3.) 127 Hz Signal Processing - As explained in the "pre-amplifier" section, the 127 Hz signal processing starts at the photocell inputs E1 and E5. U1-A and U1-B provide two stages of high gain amplification. The output of U1-B, pin 13, feeds both active bandpass filters, U2-A, the 127 Hz, and U6, the 254 Hz.

NOTE

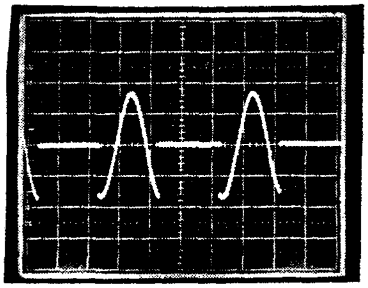
For troubleshooting purposes it is usually best to control the rubidium loop manually. Connect a potentiometer of 10 Kohms, or more, across C22 on the servo board. Disconnect the wire soldered to E8 and connect this wire to the wiper of the potentiometer. This technique provides for manual control of the VCXO's output frequency and critical servo functions.

The servo correction signal is amplitude modulated onto a 127 Hz subcarrier that passes through the 127 Hz filter, U2-A. When the system is locked, this signal (TP-2) appears as a 254 Hz sine wave, with a noticeable 127 Hz component. From TP2, the signal is routed to the synchronous demodulator U4, pin 12.

U4 is a triple two-channel CMOS analog switch that functions as a synchronous amplitude demodulator. The 127 and 254 Hz reference signals at pins 11 and 9 respectively, control the synchronous switching of two of the switches. A third switch is controlled by the level of the signal at U4, pin 10, from the lock detector circuit, U6, pin 8. U4, pins 5 and 13, receive the 6.8 Vdc reference level from CR2. When the unit sweeps near atomic lock, U4, pin 10 receives a "high" signal (>12 Vdc) that switches the output of the 127 Hz filter U2-A to the output of the demodulator, U4, pin 15, for dynamic tracking. The demodulator output is monitored at TP3 and appears as shown in Figure 4-15.

The signal from U4, pin 15 is direct coupled to U5, pin 2. U5 functions as the servo loop integrator. Its output voltage changes at a rate determined by the differential input voltage. For example, an input differential of -200 mV causes an output voltage change of +200 mV/sec. The change will continue until the differential input is nullified, (the crystal returns to center frequency), or until the Op amp reaches its maximum output voltage.

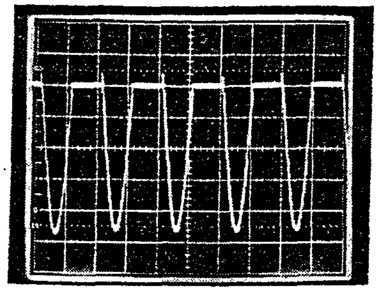
The output of the integrator, E8, is the crystal-control voltage that steers the frequency of the VCXO by means of a varactor diode in the oscillator tuning circuit. A portion of the integrator output is routed to the sweep control circuit at U6, pin 5.



TP-3 Normal Signal 1 volt/div., 50 ms./div.

Figure 4-9. Demodulator Output (Servo Board)

(4.) Lock Circuit - A portion of the photocell signal is applied to an input of the Lock Monitor circuit at U6, pin 12. U6-D, with its associated circuitry, forms a 254 Hz active bandpass filter that connects to pin 3 of the synchronous demodulator U4. The output signal at U4, pin 4 is coupled to U6, pin 9, and is monitored at TP6 (refer to Figure 4-10). With the unit locked, the negative offset at U6, pin 9 will cause the output at U6, pin 8 to go high. This provides the positive signal at U4, pin 10 that removes the sweep signal from the integrator, U5. It also biases Q1 into a conduct mode that provides the Lock Monitor signal at the front panel connector (pin H for the Winchestor connector, pin 5 for the 8-pin connector with coax). When the unit is locked, the Lock Monitor line as a resistance of 150 ohms to ground. Otherwise the Lock Monitor is an open circuit.



Normal Signal 1 volt/div., 1 volt/div, 2 ms./div

Figure 4-10. Signal Waveform at TP6

(5.) Sweep Circuit - To allow the FRK to compensate for several years of crystal aging, in addition to frequency offsets of the crystal caused by environmental changes (e.g., temperature changes), the trim range of the oscillator is very wide compared to the width of the atomic resonance. To aid servo acquisition, the crystal frequency is swept over the entire trim range until atomic resonance can be detected.

This is accomplished by switching the integrator input (U5, pin 2) to U6, pin 7 via U4 (the unit is unlocked when U6, pin 14 is low). U6-B functions as a high hysteresis voltage comparator. The trigger points are controlled by R51 and R52 and the voltage reference. The lower trigger point is approximately 1.5 Vdc, the higher trigger point is approximately 16 Vdc. If the output of U5 is equal to or lower than the lower trigger point, the output of U6 becomes 0 Vdc, resulting in about a -.7 Vdc differential to the integrator. With R24 = 1 M and C18 = 1 µF its output will rise .7 V/s until the upper trigger point of 16 Vdc is reached. At this point, the output of U6 will go high, resulting in about a +.7 Vdc differential at the integrator input. This will decrease U5's output by .7 V/s. The result is a sweep time of about 40 s. Due to the fast sweep, atomic resonance can be detected for only 100 ms at a time during each sweep cycle. Reliable transition from sweep to locked operation is facilitated by CR3.

d. Power Supply, board assembly A3 (schematic 703-254) - the internal power supply provides the unregulated, filtered voltages for the Rb lamp heaters, the crystal heater, and the resonator heaters, in addition to providing the filtered and regulated voltage to the unit's electronics. The input voltage line is fuse and diode protected against reverse polarity inputs.

The power supply board accepts the +22 to +32 Vdc input voltage at E2, and provides regulated +22 Vdc at E12, E17, and E18, until the Rb lamp ignites, at which time the power supply is switched to +17 Vdc. The switching occurs when U2-B, on the servo board, senses that the Rb lamp is ignited, in the correct mode, by the positive increase at U2-B, pin 5. The output of U2-B is routed to the power supply board at E29. The positive voltage increase provides reverse bias for CR6, effectively removing R24 from the circuit and setting the condition for the power supply output to be lowered to the +17 Vdc required for the internal circuits of the unit.

(1.) Regulated Power Supply - The +17 Vdc power supply consists of Q1 and U1 along with the components in their respective circuitry mounted on the power supply board and pass transitor Q1, which is mounted on the baseplate of the FRK.

The +22 to +32 Vdc input is routed across the 3 amp fuse (F1) to the voltage divider circuit that consists of R5 and R7. The input voltage is dropped to approximately 3 Vdc, which is coupled through CR3 to U1, pin 2. Before power is applied, U1, pins 2, 3 and 6, were at ground potential. With 3 volts at U1, pin 2, and U1, pin 3 still at ground potential, the resultant offset causes U1, pin 6 to go low, turning on the power transistor Q1. The +17 volt line is fed back through CR4 and R9 to the reference zener diode, CR5. CR5 develops approximately 6.3 Vdc at U1, pin 2. In addition, the 17 volt line is fed back to the voltage divider consisting of R6, R8 and R10 to apply a voltage to U1, pin 3. The voltage divider determines the voltage ratio of the 17 volt line to the voltage reference diode CR5, thus setting the voltage level of the 17 volt line.

Transistor Q1 on the power supply board functions as a current limiter by sensing the voltage drop across R14. If the current through the pass transistor becomes excessive, Q1 begins to conduct, decreasing the emitter-base bias on the pass transisitor, thus limiting the current flow.

e. Crystal Oscillator (VCXO) Assembly (schematic 703-103-5) - the purpose of the 5 or 10 MHz oscillator is to provide a clean and stable output frequency to the output connector, and a 10 MHz signal to the synthesizer. To optimize the reduction of phase noise the crystal is selected to match the output frequency. The oscillator board contains the Voltage Controlled Crystal Oscillator (VCXO), the crystal oven andthermal control, and a buffer amplifier. The output signals are transformer coupled to the output connector J1 and to the synthesizer circuit. In the case of the 5 MHz Ln Oscillator a doubler circuit is used to generate the 10 MHz signal to the Synthesizer.

(1.) Crystal Oscillator - the oscillator incorporates an AT Cut 3rd-overtone crystal, with an operating temperature of about 80°C. The crystal is mounted in the crystal housing assembly, which is heater controlled to the operating temperature of the crystal. The frequency adjustment is via L2, C6, 7 and 8. L2 is used for coarse adjustment and C7/8 for fine adjustment of the sweep range and center frequency. Roughly a 1E-6 adjustment is expected for a crystal control voltage range of 1.0 to 14 volts. These voltages correspond to the sweep mode of the crystal control voltage, which is approximately 1.0 to 14 volts.

The gain stage of the oscillator is formed by Q2, with C4 and L1 selected to provide a resonant frequency of about 70 - 80% of the nominal crystal frequency. The output buffer stage has Q3 as a source follower to buffer the crystal network from the loading of the following buffer stages.

The AGC stage utilizes Q1 to form an AGC circuit, which controls the output voltage of the oscillator at the source of Q3 to approximately 1.2 Vpp. C5 is used to adjust the AGC voltage at the collector of Q1 to 0.5 Vdc for nominal conditions. This provides the capability of decreasing or increasing the oscillator loop gain by adjusting the bias condition of Q1.

(2.) Crystal Buffer Section - the output buffer amplifier section consists of Q5 and Q4.

Q6 is a FET device used as a high input impedance decoupling stage between the oscillator circuit and the output drivers. The 10 MHz signal at the gate of Q6 is a nominal 1.4 v.p.p.

The cascade arrangement guarantees maximum decoupling between input and output. T1 is tuned to 5 or 10 MHz by C16, 17 and matches the output impedance of Q4 to the nominal 50 ohm load on J1.

The 10 MHz signal for the Synthesizer is generated by either the frequency doubler Q6, 7 (driven by complimentary signals of Q5), or by the buffer formed by Q7, depending on the configuration. T2 is tuned to 10 MHz via C22.

(3.) Crystal Thermostat - the crystal oven thermostat circuit consists of U2, Q8, and associated circuitry on the P.C.B, and Q9 and RT1 mounted on the oven assembly. U2 is the temperature control element, Q8 is a current limiting element, and Q9 is the heat source.

U2 and the resistive bridge network on its inputs form the temperature control section. Thermistor RT1, mounted on the crystal oven, is the sensing element in the input network, R40 and R43 set the reference voltage. R42 functions as the temperature select component. During warmup, the oven heater transistor Q1 would be destroyed by runaway current if not for Q8, which serves as a current limiter. In the current limit mode, Q8 senses the voltage across R49 to determine Q1's emitter current. As the R49 voltage approaches ~.4 Vdc, Q5 starts conducting, reducing the voltage at Q9's base to the level required to throttle Q9's current to a nominal 400 mA. The power delivered to the oven in the warm-up mode is kept constant over the range of supply voltages by the R46, R48 network. The higher the supply voltage, the less maximum current is allowed in Q9.

f. Synthesizer - Board Assembly A5 (schematic 703-285-1)

The synthesizer assembly contains a frequency multiplier circuit and a frequency synthesis section. Q3 through Q8 make up the multiplier section and Q2, U1, and U2 perform the synthesis.

(1.) Multiplier - the 10 MHz signal from the crystal oscillator is applied to the input of a frequency tripler consisting of Q3, Q4, and associated circuitry. C9 and L3 are tuned to 30 MHz. R12 limits the Q of the tank to about 30. The 30 MHz signal is capacitively coupled through C13 to transformer T1. At this point, the 127 Hz modulation signal, biased at a nominal 6.5 Vdc, comes into E5 and modulates the rf signal via varactor CR6. The interaction of CR6 with the tuned tank circuit on the primary of T1 serves to phase modulate the rf at a 127 Hz rate. The secondary of T1 is center tapped to provide a split phase signal that drives the doubler circuit of Q5 and Q6. The result is a 60 MHz signal that is amplified by Q7 and Q8. C17/L5, C21/L8, and C27/L10 are tuned to 60 MHz. Q7 and Q8 are Class A inverting amplifiers. The 60 MHz signal at E6 drives the snap diode in the physics package through a coax cable. C29 matches the coax-cable to the driver stage. R31 and R34 provide the bias voltage for the snap diode.

Refer to Figure 4-11 for waveform and amplitude illustrations for the multiplier circuit's test points (T.P. 2, 3, 4, 5, 6, 8).

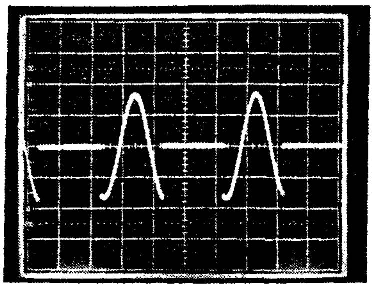
The adjustable parameters of the multiplier circuit include L3, T1, L5, L8, L11, C29, and R34. Adjustments of these component values should not be necessary except if other components are replaced during repairs. In this event, see section 4.4.2.6, subsection f., which covers the alignment procedures for the synthesizer, board A5.

(2.) Synthesizer Circuitry - the 10 MHz input signal from the crystal oscillator is applied to the base of Q2. Q2 converts the sine wave input to a TTL compatible trigger signal. This signal is coupled into U2-A, Pin 1. U2-A functions as a divide by "2" block, with a 5 MHz TTL signal coming out on pin 3. One branch of the 5 MHz signal goes to U2-B, pin 13. U2 functions as a divide by "16" block, producing a 312.5 KHz TTL signal output from pin 8 and passing to U1. U1-C is an "exclusive OR" gate which mixes the 5 MHz and 312.5 KHz input signals to produce an output at pin 8 that contains the upper and lower mixing products, 4.6875 MHz and 5.3125 MHz. The signals are then routed across tuned tank L11/C30. This tank is tuned at 5.3175 MHz and selects this frequency from the two that are injected. The capacitive coupling of C26 and the filtering action of L11/C30 converts the TTL signal at TP7 into a sine wave signal referenced to ground at TP-9. Finally, the signal leaves TP-9 and is summed with the 60 MHz at E6, from which both frequencies are routed to the step recovery diode.

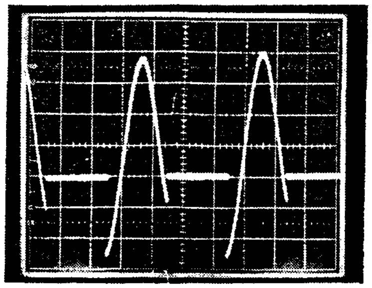
Refer to Figure 4-11 for waveform and amplitude illustrations for TP1, TP7, and TP9 of the synthesizer circuit.

NOTE: all signals monitored with X10 oscilloscope probe.

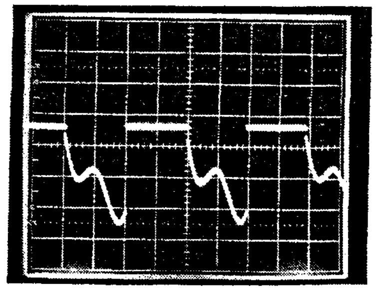
SERVO BOARD



TP-3: normal correction signal
500 mV/div., 2 ms/div

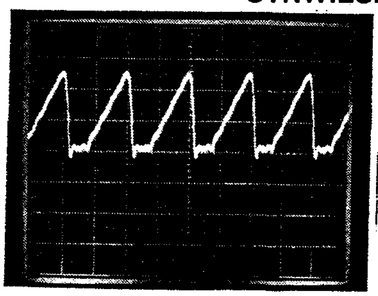


TP-3: 20 Mohm resistor
from C18 to Ground
500 mV/div, 2 ms/div

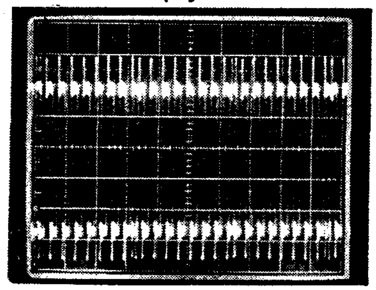


TP-3: 20 Mohm resistor
from C18 to +17 Vdc
500 mV/div., 2 ms/div.

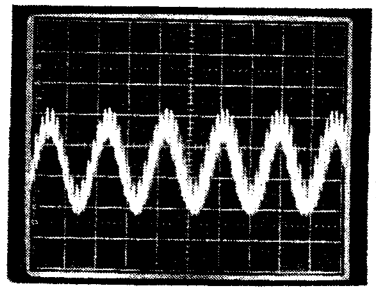
SYNTHESIZER BOARD (Synthesizer Section)



TP-1 dc coupled, 0 Vdc
at center scale, 1 V/div.,
50 ns/div.

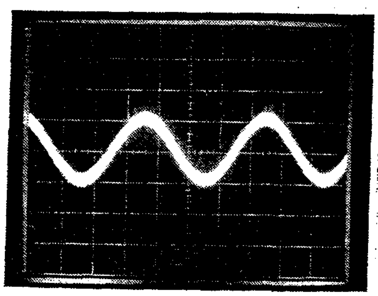


TP-7 dc coupled, 3.0 Vdc
at center scale, 1V/div.,
500 ns/div.

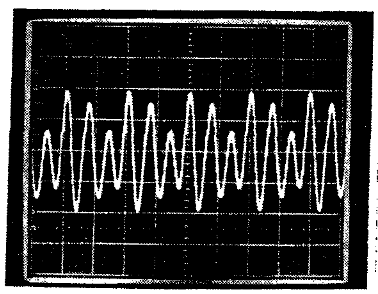


TP-9 normal signal
500 mv/div., 100 ns/div.

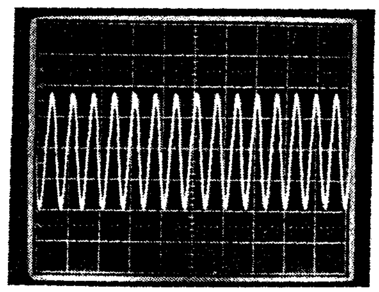
SYNTHESIZER BOARD (Multiplier Section)



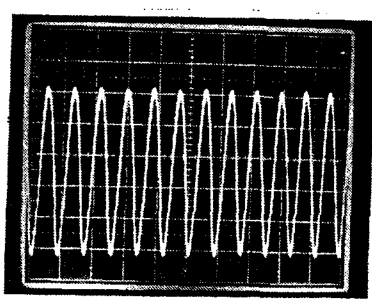
TP-2 Normal signal, 6.5 Vdc center
scale, 50 mV/div., 2 ms/div.,
20 MHz B.W. limit,



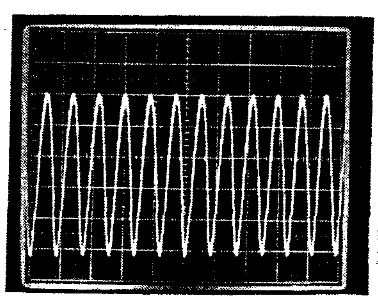
TP-3 normal signal
1 V./div., 50 ns/div.



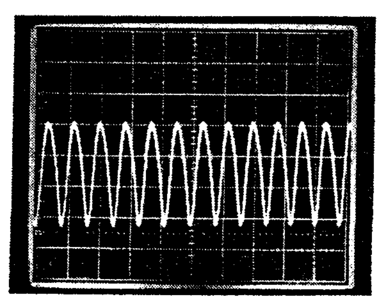
TP-4 normal signal
500 mV./div., 50 ms/div.



TP-5 normal signal
500 mV/div., 20 ns./div.



TP-6 normal signal
1V/div., 20 ns/div.



TP-8 normal signal
5V/div., 20 ns/div.

Figure 4-11. Waveform and Amplitude Traces for Servo and Synthesizer Boards.

4.4.2.2 FRK Alignment Procedures

NOTE
It is not necessary to perform all alignment procedures each time the FRK is repaired. Perform only those alignments that pertain to the board, or assembly, that has been repaired or replaced.

a. Regulated Voltage Supply:

(1) Before power is applied to the FRK, connect a voltmeter across C2 of the Power Supply, Assembly A3. Observe the meter while applying power. At the instant of turn-on the voltmeter should read ~ 23 Vdc. Within 3 minutes the lamp should ignite, switching the regulated voltage to a lower level. If the unit has been warmed up previously to this test, the lamp will ignite instantly upon applying power and no voltage transition will be seen. The regulator output voltage at C2 should be 17.3 Vdc ± .3 V. after lamp ignition.

+17.34v

(2) If the measured voltage falls outside the range of 17.3 Vdc ± .3V, an adjustment will be necessary. Locate R6 on the power supply board, assembly A3. Increasing the value of R6 will increase the regulator output voltage.

b. Lamp Temperature Setting:

(1) Apply power to the FRK and allow at least 15 minutes for temperature stabilization.

(2) Remove the lamp access cover from the base plate.

(3) Measure the temperature of the lamp housing by placing a temperature probe next to the rubidium lamp. Allow time for the temperature probe readings to stabilize. Turn off the power to the unit momentarily and record the probe reading. Remove the probe and reapply power. The temperature measured should be a nominal 113°C ± 2°C. If the recorded temperature is out of specification, an adjustment is necessary. Locate the temperature access hole in the baseplate and adjust A2R5. Repeat the temperature measurement and adjustment step until the proper lamp housing temperature is obtained.

c. Lamp Oscillator Tuning

(1) Tuning the lamp oscillator requires that the regulated voltage supply to the lamp board (C2-1) be interrupted and a 0 to 500 milliamp meter be installed in series.

(2) Locate the frequency access hole in the baseplate and insert an isolated tip driver until mechanical capacitor C11 is engaged.

(3) The oscillator frequency can be monitored using a scope probe as an antenna. By holding the probe in close proximity to the rubidium lamp the probe signal can drive a frequency counter directly or after amplification from an oscilloscope buffer amplifier.

(4) Apply power to the unit and allow at least 15 minutes for stabilization. Adjusting C11 will change the oscillator current and frequency.

(a) Set the lamp oscillator current to the low side of 125 to 145 mA, to a point that gives an oscillator frequency of 91.5, 87.0, 84.5, 79.0, 78.5, 77.5, 76.5, 71.0 or 69.5 MHz. After setting the frequency, remove power to the unit for 5 minutes. Then re-apply power and verify normal ignition and operation.

(b) If parasitic oscillations (i.e. spurs) appear at A1TP1 (see 4.4.1.7.1 (2)), set the lamp oscillator frequency as far away from the parasitic point as practical.

d. Resonator Temperature Setting:

(1) Apply power to the FRK and allow at least 15 minutes for temperature stabilization.

(2) Locate the resonator temperature probe hole in the power supply board, assembly A3 (see Figure 4-19). Remove any foam or other material that prevents clear vision of the glass resonator cell through the probe hole. Install the temperature probe and read the temperature. The resonator temperature should be +74°C ± 3°C.

(3) If the temperature reading does not conform to the specified range, an adjustment is necessary. Locate R15 on the power supply board, assembly A3. Decreasing the value of R15 will increase the temperature of the resonator. Allow 5 minutes of stabilization time between temperature readings and adjustment steps.

e. Crystal Oscillator, Board Assembly 4

CRYSTAL OVEN TEMPERATURE SETTINGS

(1) Apply power to the FRK and allow at least 15 minutes for temperature stabilization.

(2) Locate the crystal oven assembly on the crystal oscillator board, assembly A4. There is a label on the top of each oven assembly and a slotted crystal inspection window. The label and the crystal are marked with a turning point temperature in °C. The oven temperature, as monitored with a temperature probe, should be set at or slightly above the temperature marked on the crystal to optimize unit temperature coefficient. In the event no temperature reference can be found on the crystal, set the oven within +75°C and +82°C.

(3) If the reading obtained with the temperature probe does not correspond with the parameters described in Section 2., an adjustment is required.

(4) Locate R42 on the crystal oscillator board, assembly A4. Increasing the value of R8 will lower the oven temperature. Allow 5 minutes of temperature stabilization after changing the setting of R8/ R42 before monitoring the result.

TRANSFORMER TUNING

I think they mean T1

(1) Connect an oscilloscope probe to J1 (rf connector). Slowly turn the slug for T3 until the 10 MHz signal at J1 reaches a minimum.

(2) Connect an oscilloscope probe at E6. Adjust T2 for a maximum signal.

TRIM RANGE SETTINGS

Before correcting the trim range, the crystal oven needs to be set to the correct temperature (see above). Allow >1 hour of warm-up at the correct crystal temperature setting before correcting the trim range. Disconnect the yellow wire that is terminated at E9 and fold it back out of the way.

NOTE

Do not allow the bare end of the wire to touch the chassis or other circuitry.

(1) Adjust C6 in 3 or 4 turns from flush. Install a 27pF capacitor in C8. Tack in a select inductor into L2. (Start with a 25 windings inductor.)

(2) Check for unit oscillation by measuring AGC voltage at the collector of Q1. (.3V to .7V).

(3) Run the output of the board (from E4 and E5) into a frequency counter. (Function: frequency; resolution: .1 Hz - house standard, or 10 MHz unit run into back.)

Run a jumper from E8 to ground. (This will establish the low end of the frequency range.)

Run the same jumper from E8 to a 20 volts line. (This will establish the high end of the frequency range.)

Satisfactory tuning requires a range greater than or equal to 2.5 Hz for a 5 MHz unit, 5 Hz for a 10 MHz unit.

(4) C8 sets the range. (Increasing C8 increases the frequency sweep range. It also decreases the board oscillation frequency).

L2 sets the center frequency. (Increasing L2 windings decreases the board oscillation frequency.)

The frequency must be set so that the center of the frequency range is 5.000000 MHz, or 10.000000 MHz.

(5) Peak transformer T1 so that the output from E6 is greater than 2.5V peak-to-peak.

(6) Peak transformer T2 and select resistor R19 (100 ohms) so that the output from E4 into a 50 ohm load is about equal to 3.0 volts peak-to-peak.

The final step is to reconnect the yellow wire to terminal E9.

f. Synthesizer Board Alignment, Assembly A5

TRANSFORMER TUNING

(1) Connect a dc voltmeter to E6 through a 10 Kohm isolation resistor. Apply power to the FRK. Adjust potentiometer R34 for the maximum dc voltage. Tune inductors L3, T1, L5 and L8 in sequence for the maximum dc voltage at E6.

(2) Attach an oscilloscope probe to TP9. Tune L11 for a maximum signal of 5.312 MHz.

OUTPUT COAX MATCHING

(1) If the synthesizer has been replaced, transfer the C29 value from the old board.

(2) If the Resonator assembly has been replaced, select C29.

(3) Connect a dc voltmeter to E6 through a 10 Kohm isolation resistor. Apply power to the FRK. Adjust potentiometer R34 for the maximum dc voltage.

(4) Select C29 for the maximum dc voltage at E6.

RESISTANCE TUNING

Refer to the Synthesizer board alignment procedure under "Resonance Search."

g. Servo Board Alignment, Assembly A1

LAMP VOLTS SETTING

(1) Monitor E4 with a dc voltmeter. Apply power to the FRK and allow at least 15 minutes for temperature stabilization.

(2) Locate R4 on the servo board. Adjust R4 for a nominal 11 Vdc ±2 at E4.

127 HZ REFERENCE ADJUSTMENT

(1) Monitor TP4 with a X10 oscilloscope probe. The probe will drive a frequency counter directly, or an oscilloscope with a buffered output to the counter.
(2) Locate R20 and adjust for a frequency counter reading of 127 Hz ± 1 Hz.

MODULATION AMPLITUDE

(1) Monitor E6 with an oscilloscope.

(2) Adjust R58 for a signal amplitude of 400 mV ± 50 mV peak to peak.

h. Resonance Search

BANDPASS FILTERS (This procedure is recommended only for replacement boards)

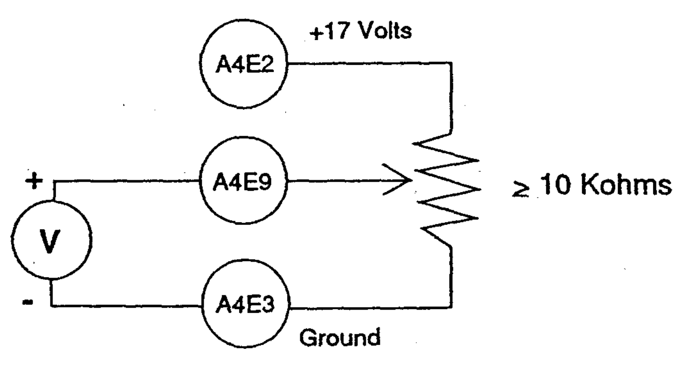
(1) Disconnect power to the unit.

(2) Locate R16 and R70 potentiometers on the servo board, assembly A1.

(3) Adjust both potentiometers to a point approximately midway in their adjustment range. Lock should be obtained. If lock does not occur, move on to Bandpass Filter Tuning section and adjust the filters.

CRYSTAL CONTROL VOLTAGE (10 MHz Unit)

(1) Disconnect the yellow wire terminated at A1E8 on the servo board assembly. Connect this yellow wire to a potentiometer as shown below:



(2) Monitor the 10 MHz output of the unit with a frequency counter.

(3) Apply power to the unit and allow at least 15 minutes for thermal stabilization.

(4) Monitor A1TP1 on the servo board with an oscilloscope.

(5) Adjust the output frequency with the test potentiometer to 1 Hz above or below 10 MHz.

(6) Monitor the dc voltage at A5E6 through a 10 Kohm isolation resistor using a voltmeter.

(7) Adjust potentiometer R34 on the synthesizer board, assembly A5, for maximum voltage, then decrease the voltage slowly, watching the oscilloscope for an ac waveform of 127 Hz.

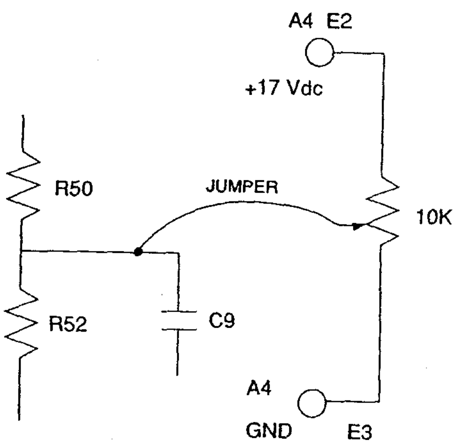
(8) At the first sign of a signal at A1TP1, adjust the output frequency for a maximum 127 Hz signal. Adjust R34 for the maximum signal amplitude.

(9) Disconnect power to the FRK. Remove the test potentiometer and reconnect the yellow wire to A1E8. Apply power to the FRK. Atomic lock should be acquired automatically, resulting in a 254 Hz signal at A1TP1.

CRYSTAL CONTROL VOLTAGE (5 MHz Unit)

(1) Disconnect the yellow wire terminated at A1E8 on the servo board assembly.

(2) Connect a 10 k potentiometer as follows:



(3) Monitor the 5 MHz output of the unit with a frequency counter.

(4) Apply power to the unit and allow at least 15 minutes for thermal stabilization.

(5) Monitor A1TP1 on the servo board with an oscilloscope.

(6) Adjust the output frequency with the test potentiometer to .5 Hz above or below 5 MHz.

(7) Monitor the dc voltage at A5E6 through a 10 Kohm isolation resistor using a voltmeter.

(8) Adjust potentiometer R34 on the synthesizer board, assembly A5, for maximum voltage, then decrease the voltage slowly, watching the oscilloscope for an ac waveform of 127 Hz.

(9) At the first sign of a signal at A1TP1, adjust the output frequency for a maximum 127 Hz signal. Adjust R34 for the maximum signal amplitude.

(10) Disconnect power to the FRK. Remove the test potentiometer and reconnect the yellow wire to A1E8. Apply power to the FRK. Atomic lock should be acquired automatically, resulting in a 254 Hz signal at A1TP1.

i. Bandpass Filter Tuning: Servo Board, Assembly A1

127 HZ ACTIVE BANDPASS FILTER (U2-A) ADJUSTMENT (SERVO LOOP)

(1) Verify that the FRK is stabilized and locked.

(2) Monitor A1TP3 with an oscilloscope.

(3) Connect a 20 megohm resistance jumper between U5, pin 2 and E2.

(4) Adjust potentiometer R16 to obtain a waveform as shown in Figure 4-12.

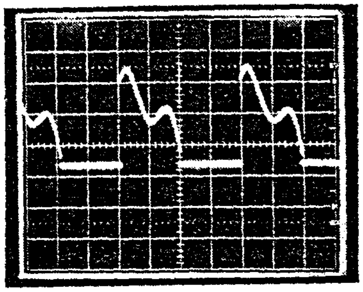


Figure 4-12. Waveform, Servo Board (TP-3)

254 HZ ACTIVE BANDPASS FILTER (U6) ADJUSTMENT (LOCK MONITOR)

(1) Monitor A1TP6 with an oscilloscope.

(2) Verify that the unit is stabilized and locked.

(3) Adjust potentiometer R70 to obtain the most symmetrical negative cycle waveform possible (see Figure 4-13).

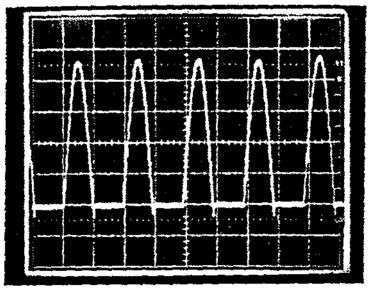


Figure 4-13. Waveform, Servo Board (TP-6)

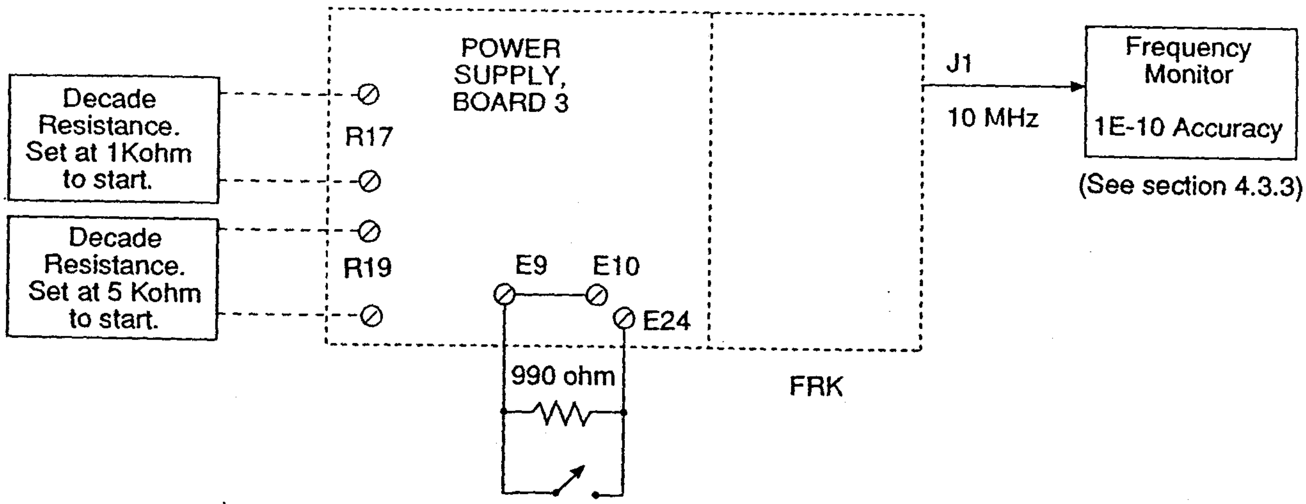
j. C-Field Adjustments: Power Supply Board, Assembly A3

(1) Set the magnetic field trim range and centering. R17 and R19 are the selected components. R17 functions as the primary frequency centering control. R19 works in conjunction with potentiometer R21 to provide a means of manually adjusting the 10 MHz output frequency. R17 and R19 are slightly interactive during their adjustments, therefore the use of two decade boxes for this alignment is suggested (refer to schematic 703-254).

(2) Start the adjustment by setting R17 to ~ 1.2 Kohm and R19 to ~ 120 Kohm. Lower values of R17 shift the frequency higher, while lower values of R19 allow R21 to adjust over a wider range.

(3) Select R17 and R19 so that R21 can adjust the output frequency >1E-9 above and below 10 MHz (or 5 MHz, if this is a 5 MHz FRK).

(4) Connect the unit in the test configuration as shown below.



(5) Apply power to the FRK and allow at least 1 hour stabilization time.

4.4.2.3 FRK Temperature Testing Procedure

FRK Temperature Testing Procedure - this test requires the UUT be placed in an environmental testing chamber. Connect the test equipment as shown in Figure 4-14.

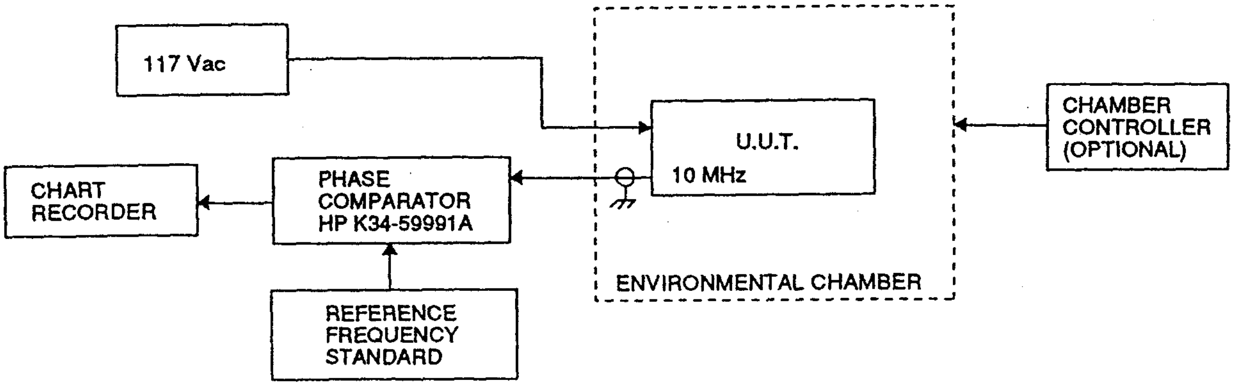


Figure 4-14. Environmental Test Chamber Set-up

(1) Adjust the chamber controls so that the air temperature is maintained at +30° C ambient

(2) Apply ac input power to the UUT. Allow sufficient warm-up time to allow the unit's output frequency to stabilize (> 60 min.). If the UUT was operated continuously for greater than 60 minutes prior to this test, no additonal operation time is required.

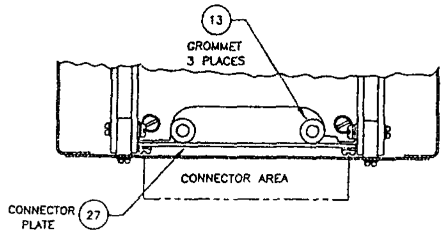
(3) Start frequency recording. This monitoring should continue throughout the test. The frequency resolution of the chart recorder must be $\Delta f/f = 1 \times 10E\text{-}11$/division.

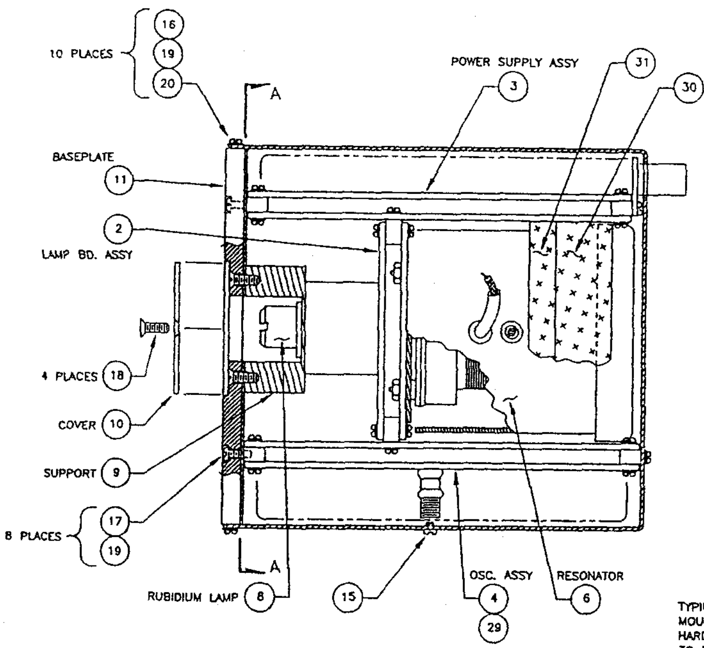
(4) The temperature chamber can be controlled manually or automatically. Set the temperature cycles for the chamber as shown in the "Required" column. Use the left column to document the actual test run conditions so they can be used for future reference.

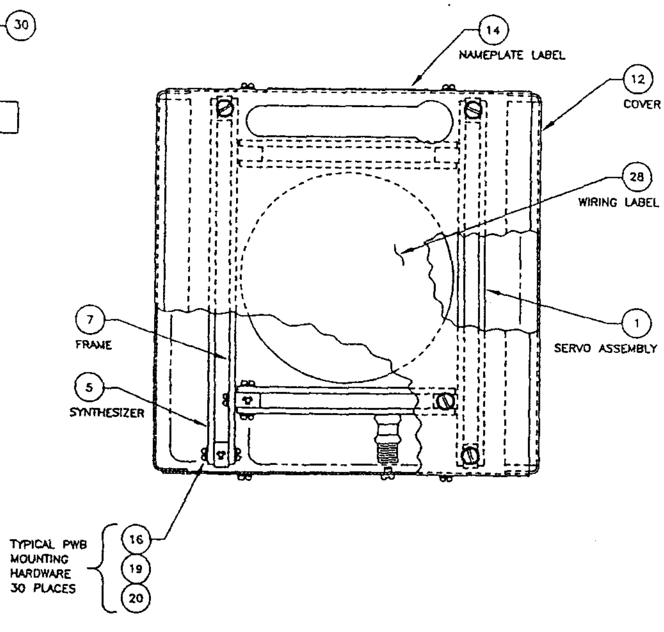
	Required
A. Ambient _______ ° C	(+30 ± 2° C)
Cycle Time ________ hrs	(≥ 1.5 hr.)
B. Low Temperature _____ ° C	(+15 ± 2° C)
Cycle Time ________ hrs	(≥ 1.5 hr.)
C. High Temperature ______ ° C	(+65 ± 2° C)
Cycle Time ________ hrs	(≥ 1.5 hr.)

APPENDIX

LIST OF DRAWINGS







FINAL ASSEMBLY, FRK (203-200-001)

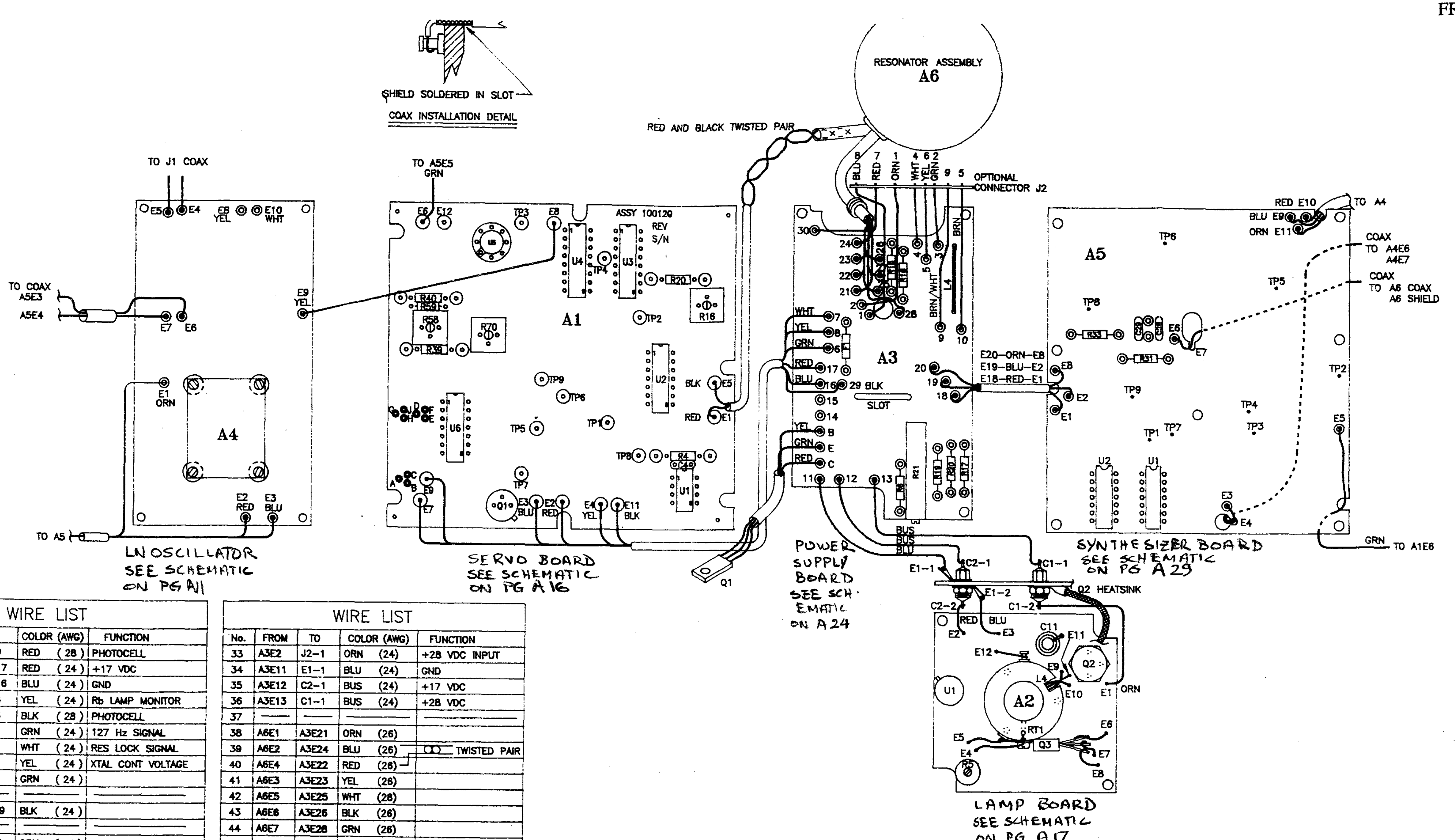
BALL, EFRATOM DIVISION CONTRACT No. CAGE CODE 55761 PL 703-200-1 REVISION LTR.
REVISION DATE 91-04-25

TITLE: PARTS LIST, FRK

SHEET 2

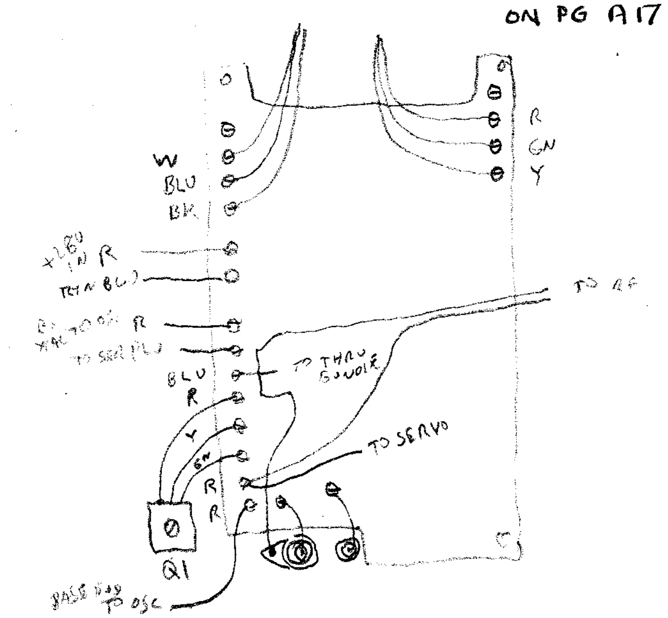
FIND No.	QTY REQ	PART OR IDENTIFYING No.	SPEC. OR MANUFACTURER	NOMENCLATURE OR DESCRIPTION	REFERENCE DESIGNATOR	UNIS No.
1	1	100120-001		SERVO BOARD	A1	
2	1	703-208-1		LAMP BOARD ASSEMBLY	A2	
3	1	703-253-1		POWER SUPPLY ASSEMBLY	A3	
4	1	703-214-1		OSCILLATOR ASSEMBLY	A4	
5	1	703-283-1		SYNTHESIZER ASSEMBLY	A5	
6	1	703-223-1		RESONATOR ASSEMBLY	A6	
7	1	703-226-1		FRAME ASSEMBLY		
8	1	250-165-1		RUBIDIUM LAMP ASSEMBLY		
9	1	703-239		LAMP SUPPORT		
10	1	703-242		COVER PLATE		
11	1	703-245-3		BASEPLATE ASSEMBLY (4-40)		
12	1	250-091		MU-METAL COVER		
13	3	MS35489-4		GROMMET		2801398
14	1	705-150		NAMEPLATE, LABEL		
15	1	MS51957-39		SCREW, PAN HD, 8-32 x 1 /8		2821433
16	38	85ST-M2x4		SCREW, M2 x 4		70425-1
17	8	85ST-M2x6		SCREW, M2 x 6		70425-3
18	4	963ST-M2.5x10		SCREW, FLAT HD M2.5 x 10		2820500
19	54	6798ST-IN2.2		WASHER, LOCK 2.mm (I.T.)		
20	46	MW-400		WASHER, FLAT 2mm		2821475
21				NOT USED		
22	A/R	704-232-1		ADHESIVE SEALANT (PURPLE)		
23	A/R	SN63WRMAP3		SOLDER		2102572
24	A/R	M17/93-RG178		CABLE, COAX		6001032
25	A/R	70422-1		TUBING, SHRINK		
26	A/R	MIL-W-16878, TYPE E		WIRE, 22 AWG INSULATED, TEFLON		
27	1	703-246-1		CONNECTOR PLATE ASSEMBLY (PIN & COAX)		
28	1	703-238-5		LABEL, CONNECTOR WIRING		
29	1	703-248		INSULATOR, OSCILLATOR BOARD		
30	A/R	70424-3		FOAM POLYURETHANE (ECCOFOAM FPH)		
31	1	100298-001		INSULATOR FOAM		

PARTS LIST, FRK FINAL ASSEMBLY (PL 703-200-1)

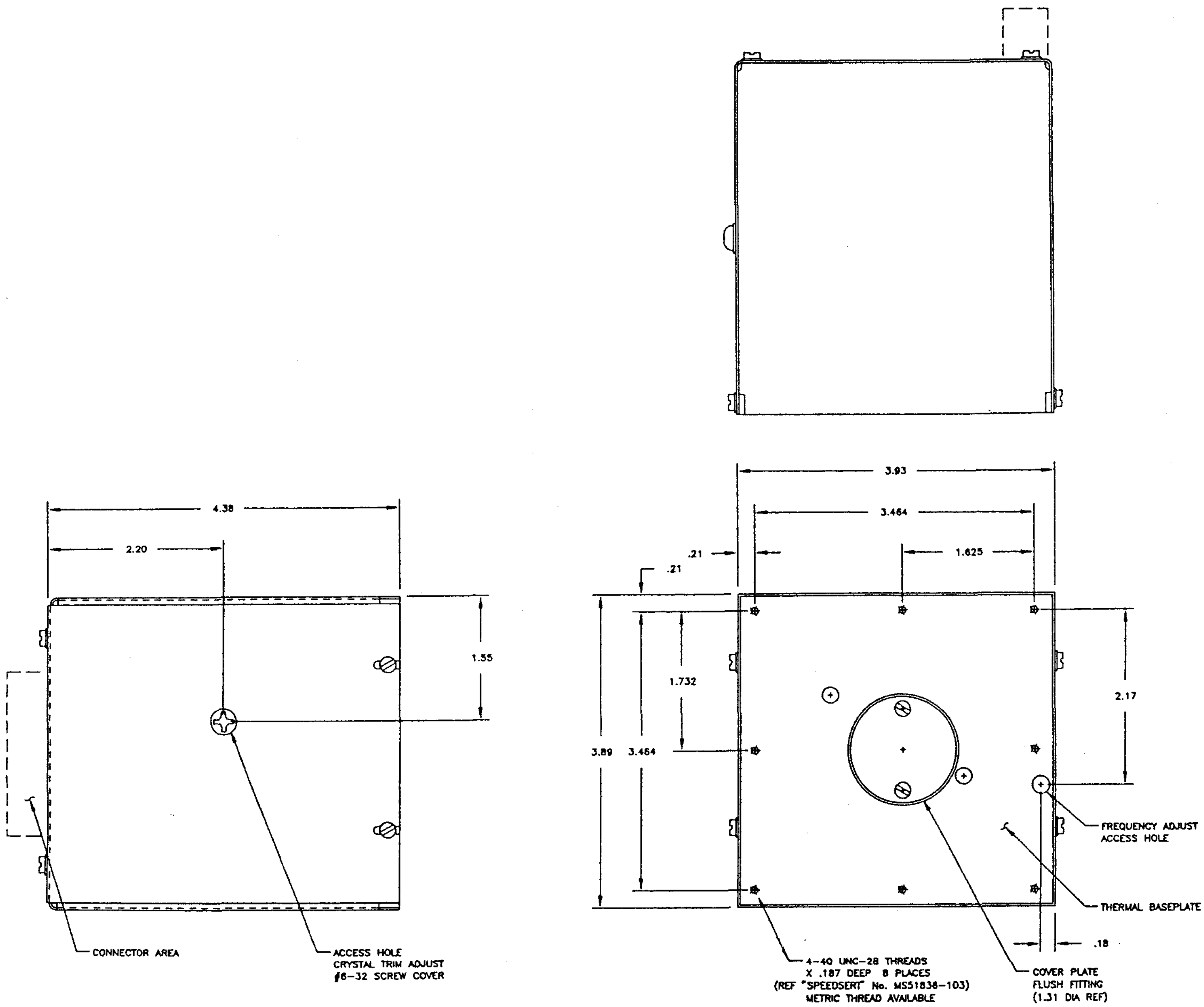


WIRE LIST				
No.	FROM	TO	COLOR (AWG)	FUNCTION
1	A1E1	A6E9	RED (28)	PHOTOCELL
2	A1E2	A3E17	RED (24)	+17 VDC
3	A1E3	A3E16	BLU (24)	GND
4	A1E4	A3E8	YEL (24)	Rb LAMP MONITOR
5	A1E5	A6E8	BLK (28)	PHOTOCELL
6	A1E6	A5E5	GRN (24)	127 Hz SIGNAL
7	A1E7	A3E7	WHT (24)	RES LOCK SIGNAL
8	A1E8	A4E9	YEL (24)	XTAL CONT VOLTAGE
9	A1E9	A3E6	GRN (24)	
10	—	—	—	—
11	A1E11	A3E29	BLK (24)	
12	—	—	—	—
13	A2E1	C1–2	ORN (24)	+28 VDC
14	A2E2	C2–2	RED (24)	+17 VDC
15	A2E3	E1–2	BLU (24)	GND
16	—	—	—	—
17	A4E1	A5E11	ORN (24)	+28VDC (VIA A3E20)
18	A4E2	A5E10	RED (24)	+17 VDC (VIA A3E18)
19	A4E3	A5E9	BLU (24)	GND (VIA A3E19)
20	A4E4	J1–1	COAX	10MHz OUTPUT
21	A4E5	J1–1	SHIELD	
22	—	—	—	—
23	A4E6	A5E3	COAX	10MHz
24	A4E7	A5E4	SHIELD	
25	—	—	—	—
26	A5E1	A3E18	RED (24)	+17 VDC
27	A5E2	A3E19	BLU (24)	GND
28	A5E6	A6	COAX	RESONATOR
29	A5E7	A6	SHIELD	
30	A5E8	A3E20	ORN (24)	+28 VDC
31	—	—	—	—
32	A3E1	J2–8	BLU (24)	GND INPUT

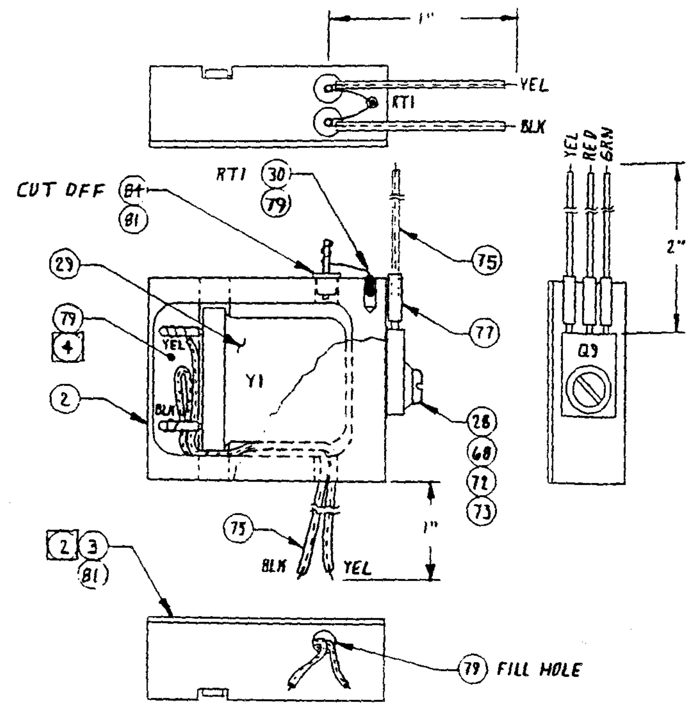
WIRE LIST				
No.	FROM	TO	COLOR (AWG)	FUNCTION
33	A3E2	J2–1	ORN (24)	+28 VDC INPUT
34	A3E11	E1–1	BLU (24)	GND
35	A3E12	C2–1	BUS (24)	+17 VDC
36	A3E13	C1–1	BUS (24)	+28 VDC
37	—	—	—	—
38	A6E1	A3E21	ORN (26)	
39	A6E2	A3E24	BLU (26)	TWISTED PAIR
40	A6E4	A3E22	RED (26)	
41	A6E3	A3E23	YEL (26)	
42	A6E5	A3E25	WHT (28)	
43	A6E6	A3E26	BLK (26)	
44	A6E7	A3E28	GRN (26)	
45	A6E10	A3E27	BRN (28)	
46	—	—	—	—
47	A3E9	J2–9	BRN/WHT (24)	REMOTE FREQ ADJ
48	A3E10	J2–5	BRN (24)	+17 V OUT
49	A3E5	J2–6	YEL (24)	Rb LAMP MONITOR
50	A3E4	J2–4	WHT (24)	RES LOCK SIGNAL
51	A3E3	J2–2	GRN (24)	XTAL OSC MONITOR
52	A3E30	J2–7	RED (24)	HTR POWER

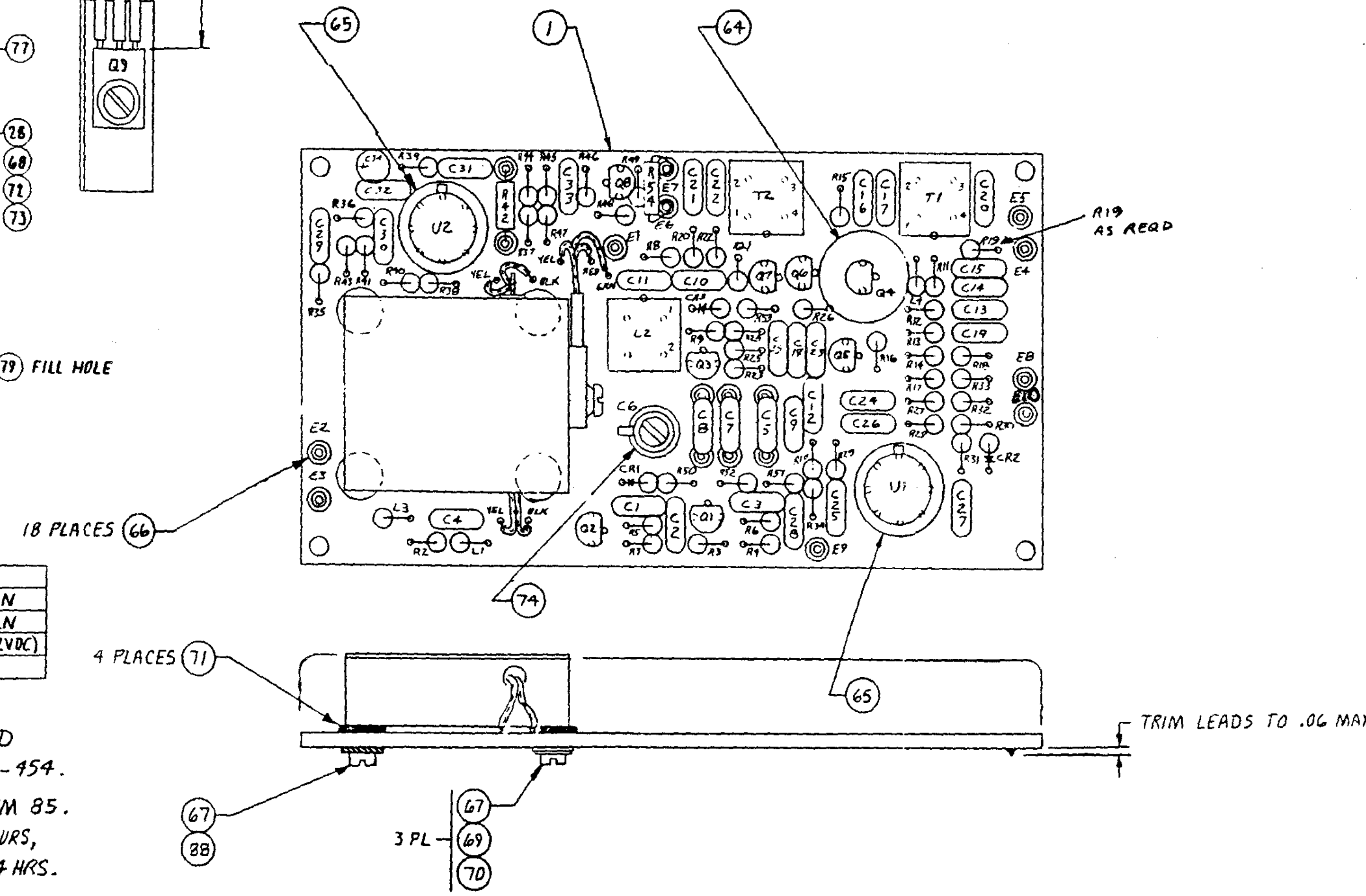


WIRING DIAGRAM, (10 MHz Unit)



OUTLINE DRAWING, FRK (703-203-1)





TABULATION					
PART NO.	R44	R45	R46	R49	USED ON
703-102-1	6.81K	1.00K	10K	1.10Ω	FRK-HLN
703-102-2	3.09K	2.00K	4.3K	.806Ω	FRK-HLN (12VDC)
703-102-3	SEE SEPARATE DWG				MNT

NOTES–UNLESS OTHERWISE SPECIFIED

1. SOLDER PER REQT 5 OF MIL-STD-454.
2. BOND LID TO HOUSING USING ITEM 85. CURE AT +60°C TO +70°C FOR 2 HOURS, OR CURE AT ROOM TEMP FOR 24 HRS.
3. MARK PART NO. ON ASSEMBLY.
4. APPLY APPROX 1/2" BEAD RTV ITEM-79 TO HOUSING. THEN PRESS CRYSTAL DOWN INTO PLACE. TACK WIRES ALSO WITH RTV.

BALL, EFRATOM DIVISION   CONTRACT No.   CAGE CODE 55761   PL 703-102-1   REVISION LTR.
REVISION DATE 91-04-25

TITLE: PARTS LIST, LN OSCILLATOR

SHEET 2

FIND No.	QTY REQ	PART OR IDENTIFYING No.	SPEC. OR MANUFACTURER	NOMENCLATURE OR DESCRIPTION	REFERENCE DESIGNATOR	UNIS No.
1	1	703-104		PRINTED WIRING BOARD		
2	1	70583-2		HOUSING, CRYSTAL		
3	1	70584		COVER, CRYSTAL		
4	1	EDPT 12 PF NPO		CAPACITOR 12 PF NPO	C18	1500738
5	1	EDPT 27 PF NPO		CAPACITOR 27 PF NPO	C11	1500763
6	1	EDPT 33 PF NPO		CAPACITOR 33 PF NPO	C16	1500747
7	1	EDPT 68 PF NPO		CAPACITOR 68 PF NPO	C22	1500758
8	3	EDPT 100PF NPO		CAPACITOR 100PF NPO	C26,30,32	1500764
9	1	EDPT 270PF NPO		CAPACITOR 270PF NPO	C17	1500776
10	1	EDPT SELECT NPO		CAPACITOR 10 PF NOMINAL	C7	
11	1	EDPT SELECT NPO		CAPACITOR 27 PF NOMINAL	C8	
12	1	C320C122J2GSCA		CAPACITOR 1200 PF +/-5% COG	C4	
13	1	C320C SELECT		CAPACITOR 600PF NOMINAL	C5	
14	3	CKR05BX104KSV		CAPACITOR 0.1 UF	C3,10,27	1500688
15	1	CKR06BX474KSV		CAPACITOR 0.47UF	C31	1500700
16	16	CKR05BX682KS		CAPACITOR 6800PF +/-10%	C1,2,9,12-15,19-21,23,28,24,29,33,35	1500695
17	1	CKR06BX105KSV		CAPACITOR 1 UF	C25	
18	1	ETPW 2C 10/6.3		CAPACITOR 10UF, TANTALUM	C34	
19	1	PC26T140		CAPACITOR, VARIABLE, 1-14PF	C6	1501499
20	1	MV1646		DIODE, VARACTOR	CR1	
21	1	1N5235B		DIODE, ZENER	CR2	
22	1	1N4151		DIODE	CR3	
23	1	MS75084-4		INDUCTOR 2.2UH	L1	
24	2	MS75085-10		INDUCTOR 180UH	L3,L4	
25	1	70277-SELECT		INDUCTOR 10-25UH	L2	
26	7	2N3904		TRANSISTOR	Q1,2,4-8	
27	1	JANTX2N4857		TRANSISTOR	Q3	
28	1	MJE802		TRANSISTOR	Q9	
29	1	704-286		CRYSTAL 5MHZ	Y1	
30	1	B43KB273K		THERMISTOR 27K+/-10% @25'C	RT1	
31	1	70277-1		TRANSFORMER 13:3	T2	
32	1	MK2 33.2 OHM		RESISTOR 33.2 OHM	R15	4701245
33	2	MK2 56.2 OHM		RESISTOR 56.2 OHM	R18,22	4701286

BALL, EFRATOM DIVISION   CONTRACT No.   CAGE CODE 55761   PL 703-102-1   REVISION LTR.
REVISION DATE 91-04-25

TITLE: PARTS LIST, LN OSCILLATOR

SHEET 3

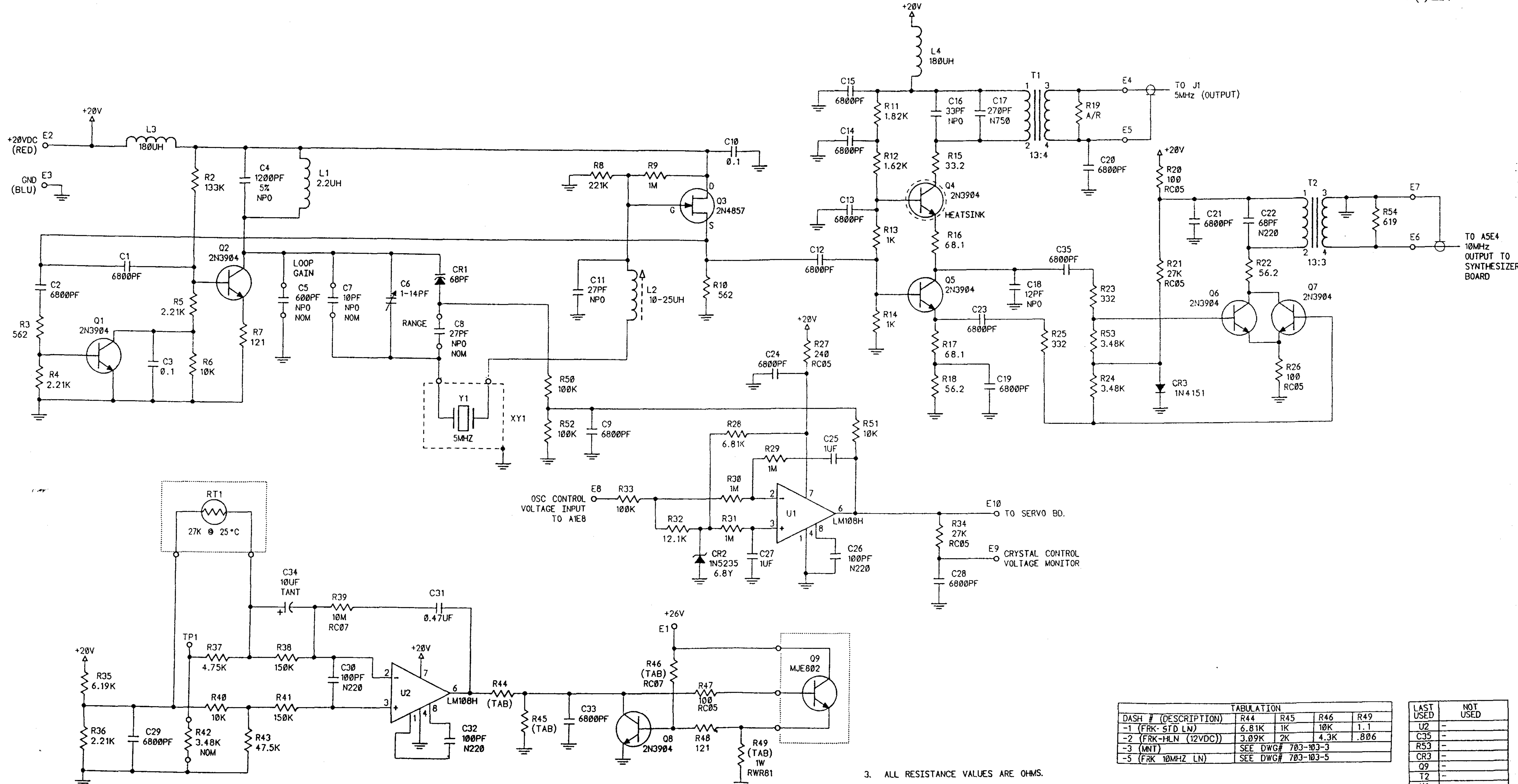
FIND No.	QTY REQ	PART OR IDENTIFYING No.	SPEC. OR MANUFACTURER	NOMENCLATURE OR DESCRIPTION	REFERENCE DESIGNATOR	UNIS No.
34	2	MK2 68.1 OHM		RESISTOR 68.1 OHM	R16,17	4701296
35	2	MK2 121 OHM		RESISTOR 121 OHM	R7,48	4701178
36	2	MK2 332 OHM		RESISTOR 332 OHM	R23,25	4701248
37	2	MK2 562 OHM		RESISTOR 562 OHM	R3,10	4701287
38	3	MK2 1.00K		RESISTOR 1.00K	R45,13,14	4701153
39	1	MK2 619 OHM		RESISTOR 619 OHM	R54	4701292
40						
41	1	MK2 1.62K		RESISTOR 1.62K	R12	4701163
42	1	MK2 1.82K		RESISTOR 1.82K	R11	4701166
43	3	MK2 2.21K		RESISTOR 2.21K	R4,5,36	4701196
44	2	MK2 3.48K		RESISTOR 3.48K	R24,53	4701235
45	1	MK2 4.75K		RESISTOR 4.75K	R37	4701260
46	1	MK2 6.19K		RESISTOR 6.19K	R35	4701288
47	2	MK2 6.81K		RESISTOR 6.81K	R28,44	4701290
48	3	MK2 10.0K		RESISTOR 10.0K	R6,40,51	4701167
49	1	MK2 12.1K		RESISTOR 12.1K	R32	
50	1	MK2 47.5K		RESISTOR 47.5K	R43	4701267
51	3	MK2 100K		RESISTOR 100K	R33,50,52	4701170
52	1	MK2 133K		RESISTOR 133K	R2	4701180
53	2	MK2 150K		RESISTOR 150K	R38,41	4701185
54	1	MK2 221K		RESISTOR 221K	R8	4701212
55	4	MK2 1MEG		RESISTOR 1MEG	R9,29,30,31	
56	1	MK2 SELECT		RESISTOR (3.48K SELECT NOMINAL)	R42	
57	1	RCR05G241JS		RESISTOR 240 OHM 1/8W	R27	
58	3	RCR05G101JS		RESISTOR 100 OHM 1/8W	R20,26,47	
59	2	RCR05G273JS		RESISTOR 27 OHM 1/8W	R21,34	
60	1	RCR05G103JS		RESISTOR 10K	R46	
61	1	RCR05G106JS		RESISTOR 10 MEG 1/4W	R39	
62	1	RWR81S1R10FR		RESISTOR 1.10 OHM 1W	R49	
63	2	UA108HMQB		INTEGRATED CIRCUIT	U1,U2	
64	1	TXC20B		HEAT SINK	XQ	
65	2	7717-107N		TRANSISTOR PAD (8-PIN)	XU1,XU2	
66	18	70416-2		SOLDER TERMINAL		
67	4	70425-3		SCREW, M2x6		

BALL, EFRATOM DIVISION CONTRACT No. CAGE CODE 55761 PL 703-102-1 REVISION LTR.
REVISION DATE 91-04-25

TITLE: PARTS LIST, LN OSCILLATOR

SHEET 4

FIND No.	QTY REQ	PART OR IDENTIFYING No.	SPEC. OR MANUFACTURER	NOMENCLATURE OR DESCRIPTION	REFERENCE DESIGNATOR	UNIS No.
68	1	70425-15		SCREW, M3x6		
69	4	70414-18		WASHER, SPRING M2		
70	4	70414-4		WASHER, FLAT M2		
71	4	2191		WASHER, FIBER		
72	1	B52200F006		WASHER, BELLEVILLE		
73	1	61B586		WASHER, MICA	XQ9	
74	1	5622-1-007		WASHER, MYLAR	UNDER C6	
75	A/R	MIL-W-16878 TYPE E		WIRE, 28AWG, TEFLON (YEL,BLK,RED,GRN)		
76				NOT USED		
77	A/R	70422-1		SHRINK FIT SLEEVING 3/32		
78				NOT USED		
79	A/R	3145 RTV		SILICONE RUBBER, GRAY		
80				NOT USED		
81	A/R	LOCKTITE 00241		ADHESIVE, THERMAL "OUTPUT"		
82	A/R	MIL-I-46058 TYPE UR		CONFORMAL COAT, POLYURETHANE		
83	A/R	SN63WRMAP3		SOLDER		
84	2	70276		TERMINAL, HERMETIC		
85				NOT USED		
86				NOT USED		
87	1	70277-11		TRANSFORMER 13:4	T1	
88	1	6798ST-A2		WASHER, EXTERNAL TOOTH M2		



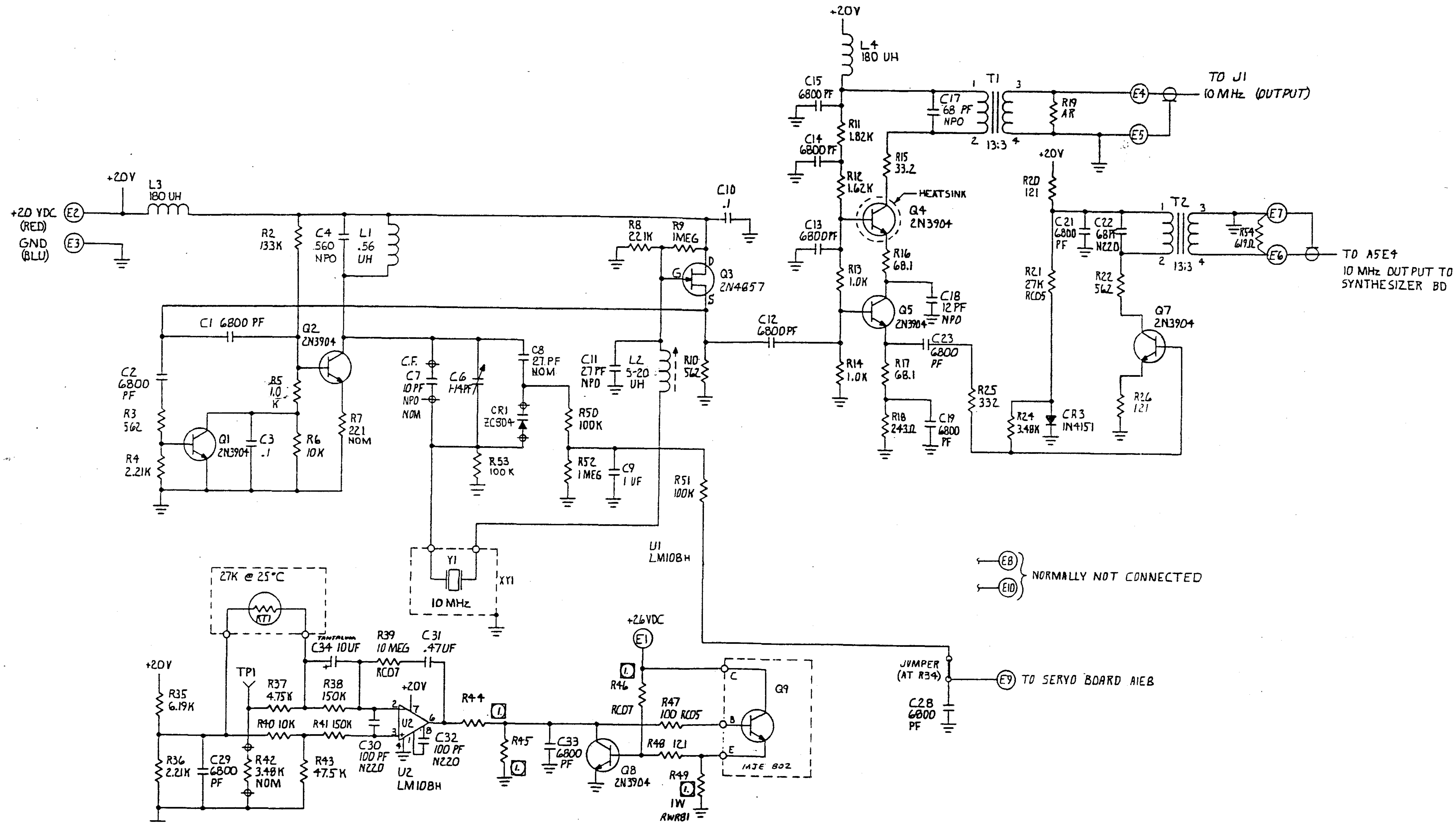
TABULATION				
DASH # (DESCRIPTION)	R44	R45	R46	R49
-1 (FRK-STD LN)	6.81K	1K	10K	1.1
-2 (FRK-HLN (12VDC))	3.09K	2K	4.3K	.806
-3 (MNT)	SEE DWG# 703-103-3			
-5 (FRK 10MHZ LN)	SEE DWG# 703-103-5			

LAST USED	NOT USED
U2	-
C35	-
R53	-
CR3	-
Q9	-
T2	-
Y1	-
L4	-
RT1	-
E10	-

3. ALL RESISTANCE VALUES ARE OHMS.
2. ALL CAPACITANCE VALUES ARE MICROFARADS.
1. FOR ASSEMBLY SEE DWG# 703-102.
NOTES: UNLESS OTHERWISE SPECIFIED.

Mine is 10MHz - NEXT PAGE →

SCHEMATIC, 5 MHz LN OSCILLATOR (703-103-TAB)

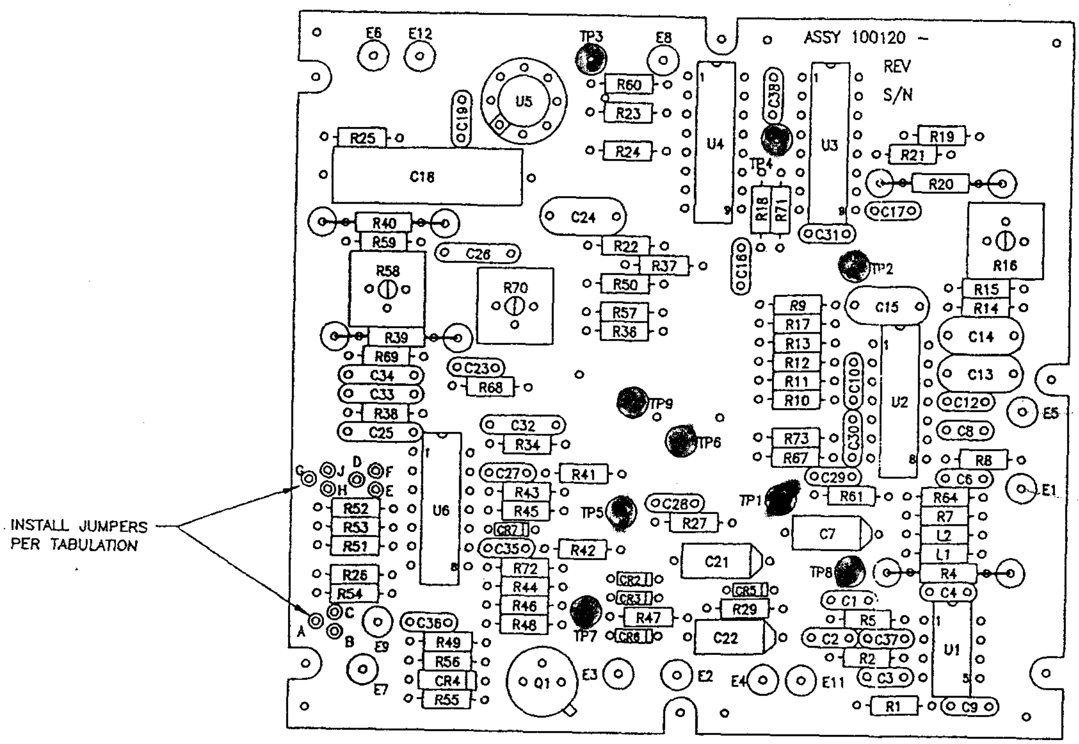


NOTES- UNLESS OTHERWISE SPECIFIED

1. SEE TABULATION BLOCK FOR COMPONENT VALUE.
2. FOR ASSEMBLY DRAWING SEE NO. 703-102-5
3. USE WITH NORMAL (NON-LN) SERVO BOARD.

BOARD A4

SCHEMATIC, 10 MHz LN OSCILLATOR (703-103)



LEGEND

ARTWORK 100119
REV A

NOTES: UNLESS OTHERWISE SPECIFIED.

1. PART ATTACHMENT, WIRING, SOLDERING, CLEANING AND WORKMANSHIP SHALL BE IN ACCORDANCE WITH IPC-S-815 CLASS 111.
2. CONFORMAL COAT BOTH SIDES OF BOARD IN ACCORDANCE WITH MIL-STD-275 USING MATERIAL CONFORMING TO MIL-I-46058. MASK TEST POINTS, TERMINALS, MOUNTING SURFACES AND COMPONENT ADJUSTMENT SCREWS PRIOR TO APPLICATION.
3. IDENTIFY ASSEMBLY WITH ASSEMBLY NUMBER, REVISION LETTER, AND SERIAL NUMBER PER MIL-STD-130.
4. FOR SCHEMATIC SEE DRAWING NUMBER 100117.
5. ALL COMPONENTS SHOWN ON DRAWING MAY NOT BE USED ON ALL ASSEMBLIES SEE TABULATION AND PARTS LIST FOR EACH ASSEMBLY.

TABULATION CHART

ASSEMBLY No.	DESCRIPTION	INSTALL JUMPERS
100120–000	BASIC ASSEMBLY	NONE
100120–001	STANDARD VERSION	A–C, D–F, G–H
100120–002	TTL VERSION	A–C, D–F, G–H
100120–003	LOW NOISE 5 MHz VERSION	A–B, D–E, G–J
100120–004	LOW NOISE TTL VERSION	A–B, D–E, G–J
100120–005	SPECIAL FOR GLOBAL	A–C, D–F, G–H
100120–006	LOW NOISE 10 MHz VERSION	A–B, D–E, G–J

ASSEMBLY, SERVO BOARD (100120)

BALL, EFRATOM DIVISION CONTRACT No. CAGE CODE 55761 DRAWING No. 100120-1 REVISION LTR.

REVISION DATE 91-04-25

PARTS LIST, SERVO BD FILENAME:100120 .DBF SHEET 2

FIND No.	QTY REQ PER ASSY No. 100120-XXX -001	-002	-003	-004	-005	-006	-007	-008	-009	-010	CAGE CODE	PART OR IDENTIFYING No.	SPEC. OR MANUFACTURER	NOMENCLATURE OR DESCRIPTION		HCI CODE	REFERENCE DESIGNATOR	UNIS No.
1	1	1	1	1	1	1						100118-001	EFRATOM	P.C.B. FABRICATION SERVO BOARD				
2	2	2	2	2	2	2						EDPT100PFNPO	STETTNER	CAP, NPO	100PF		C17,37	1500764
3	1	1	1	1	1	1						CKR05BX102KS	MIL-C-39014	CAP, CER, 200V, 10%,	1000PF		C8	1500704
4	5	5	5	5	5	5						CKR05BX682KS	MIL-C-39014	CAP, CER, 100V, 10%	6800PF		C1-3,19,31	1500965
5	9	9	9	9	9	9						CKR05BX104KS	MIL-C-39014	CAP, CER, 50V, 10%,	0.1UF		C9,10,12,16,23,27,29,35,38	1500688
6	2	2	2	2	2	2						CKR06BX105KS	MIL-C-39014	CAP, CER, 50V, 10%,	1.0UF		C6,28	1500697
7	3	3	3	3	3	3						T322D106M035AS	KEMET	CAP, TANT, 35V, 20%	10UF		C7,21,22	1502105
8	1	1	1	1	1	1						22NA103K	S&EI	CAP, POLY, 50V, 10%,	.01UF		C25	1500142
9	4	4	4	4	4	4						22NA473J	S&EI	CAP, POLY, 50V, 5%,	.047UF		C26,C32-34	1500148
10	4	4	4	4	4	4						22NA104J	S&EI	CAP, POLY, 50V, 5%,	0.1UF		C13-15,24	1500144
11	1	1	1	1	1	1						M83421/01-1252S	MIL-C-83421	CAP, MF CRH01,30V,10%	1.0UF		C18	1501109
12	3	3	3	3	3	3						1N4151		DIODE,			CR3,CR6,CR7	4800084
13	1	1	1	1	1	1						1N5235B		DIODE, 6.8V ZENER			CR2	4800092
14	1	1	1	1	1	1						1N5245		DIODE, 15V ZENER			CR5	4800094
15														NOT USED				
16	2	2	2	2	2	2						MS75084-4	MIL-C-15305	INDUCTOR	2.2UH		L1,L2	1801448
17	1	1	1	1	1	1						OP27BZ		I.C., OPAMP			U1	3132958
18														NOT USED				
19	1	1	1	1	1	1						CD4060BF		I.C.,			U3	3130670
20	1	1	1	1	1	1						CD4053BF		I.C.,			U4	3130688
21	1	1	1	1	1	1						LM108H/883B		I.C., OPAMP			U5	
22	2	2	2	2	2	2						LM124J		I.C., OPAMP			U2,U6	3130984
23	1	1	1	1	1	1						7717-4N		SPACER, TO-5 (3 LEAD)			Q1	70418-1
24	1	1	1	1	1	1						7717-107N		SPACER, TO-5 (8 LEAD)			U5	2102217
25	A/R	A/R	A/R	A/R	A/R	A/R						SN63WRMAP3		SOLDER				2102572
26	20	20	20	20	20	20						70416-2		TERMINAL			TP1-TP9, E1-E9,E11,12	
27														NOT USED				
28	1	1	1	1	1	1						MK2 100		RES, MF, 1/4W, 1%,	100		R55	4701170
29	1	1	1	1	1	1						MK2 464		RES, MF, 1/4W, 1%,	464		R29	4701260
30	4	4	4	4	4	4						MK2 1.00K		RES, MF, 1/4W, 1%,	1.00K		R7,25,42,46	4701153
31	1	1	1	1	1	1						MK2 2.21K		RES, MF, 1/4W, 1%,	2.21K		R27	4701196
32	1	1	1	1	1	1						MK2 3.48K		RES, MF, 1/4W, 1%,	3.48K		R2	4701235
33	1	1	1	1	1	1						MK2 3.57K		RES, MF, 1/4W, 1%, NOM	3.57K		R68	4701236

PARTS LIST, SERVO BOARD (PL 100120) PAGE 1 OF 3

BALL, EFRATOM DIVISION   CONTRACT No.   CAGE CODE 55761   DRAWING No. 100120-1   REVISION LTR.

PARTS LIST, SERVO BD   FILENAME:100120 .DBF   REVISION DATE 91-04-25

SHEET 3

FIND No.	QTY REQ PER ASSY No. 100120-XXX -001	-002	-003	-004	-005	-006	-007	-008	-009	-010	CAGE CODE	PART OR IDENTIFYING No.	SPEC. OR MANUFACTURER	NOMENCLATURE OR DESCRIPTION		HCI CODE	REFERENCE DESIGNATOR	UNIS No.
34	1	1	1	1	1	1						MK2 4.75K		RES, MF, 1/4W, 1%,	4.75K		R22	4701260
35	1	1	1	1	1	1						MK2 5.76K		RES, MF, 1/4W, 1%	5.76K		R9	4701280
36														NOT USED				
37	2	2	2	2	2	2						MK2 9.09K	STETTNER	RES, MF, 1/4W, 1%,	9.09K		R15,69	4701317
38	4	4	4	4	4	4						MK2 10.0K	STETTNER	RES, MF, 1/4W, 1%,	10.0K		R4,17,60,61	4701167
39	1	1	1	1	1	1						MK2 22.1K	STETTNER	RES, MF, 1/4W, 1%,	22.1K		R43	4701210
40	3	3	3	3	3	3						MK2 27.4K	STETTNER	RES, MF, 1/4W, 1%,	27.4K		R1,26,73	4701220
41														NOT USED				
42														NOT USED				
43	2	2	2	2	2	2						MK2 47.5K	STETTNER	RES, MF, 1/4W, 1%,	47.5K		R50,57	4701267
44	1	1	1	1	1	1						MK2 56.2K	STETTNER	RES, MF, 1/4W, 1%,	56.2K		R13	4701285
45	6	6	6	6	6	6						MK2 82.5K	STETTNER	RES, MF, 1/4W, 1%,	82.5K		R10,11,34,39,59,67	4701311
46	4	4	4	4	4	4						MK2 100K	STETTNER	RES, MF, 1/4W, 1%,	100K		R18,36,64,71	4701171
47	1	1	1	1	1	1						MK2 332K	STETTNER	RES, MF, 1/4W, 1%,	332K		R37	4701247
48	1	1	1	1	1	1						MK2 309K	STETTNER	RES, MF, 1/4W, 1%,	309K		R19	4701241
49	2	2	2	2	2	2						MK2 475K	STETTNER	RES, MF, 1/4W, 1%,	475K		R41,72	4701270
50	1	1	1	1	1	1						MK2 SELECT	STETTNER	RES, MF, 1/4W, 1%	SELECT		R20	
51	6	6	6	6	6	6						MK2 1.00M	STETTNER	RES, MF, 1/4W, 1%,	1.00M		R8,23,24,38,44,45	4701153
52	1	1	1	1	1	1						RCR07G915JS	MIL-R-39008	RES, FC, 1/4W, 5%,	9.1M		R47	4701744
53	2	2	2	2	2	2						3386P-1-502	BOURNS	RES, VARIABLE	5.0K		R16,70	4750257
54														NOT USED				
55	1	1	1	1	1	1						3386P-1-503	BOURNS	RES, VARIABLE,	50K		R58	4750258
56	1	1	1	1	1	1						RCR07G205JS	MIL-R-39008	RES, FC, 1/4W, 5%	2.0M		R21	4701572
57	1	1	1	1	1	1						CKR05BX332KR	MIL-C-39014	CAP, CER, 100V, 10%,	3300PF		C4	1500705
58	1	1	1	1	1	1						MK2 511	STETTNER	RES, MF, 1/4W, 1%,	511		R5	4701282
59	1	1	1	1	1	1						CCR05CG202JR	MIL-C-20	CAP, NPO, 50V, 5%	2000PF		C30	1500622
60	A/R	A/R	A/R	A/R	A/R	A/R						QQW343S26S1T	QQ-W-343	WIRE, UNINSULATED 26AWG			JUMPERS A-C, D-F, G-H	
61	1	1	1	1	1	1						MK2 22.1K	STETTNER	RES, MF, 1/4W, 1%,	22.1K		R12	4701210
62	1	1	1	1	1	1						MK2 3.48K	STETTNER	RES, MF, 1/4W, 1%,	3.48K		R14	4701235
63	1	1	1	1	1	1						MK2 100K	STETTNER	RES, MF, 1/4W, 1%,	100K		R51	4701171
64	1	1	1	1	1	1						MK2 82.5K	STETTNER	RES, MF, 1/4W, 1%,	82.5K		R52	4701311
65	1	1	1	1	1	1						MK2 39.2K	STETTNER	RES, MF, 1/4W, 1%,	39.2K		R53	4701250
66	1	1	1	1	1	1						MK2 33.2K	STETTNER	RES, MF, 1/4W, 1%,	33.2K		R54	4701245

PARTS LIST, SERVO BOARD (PL 100120) PAGE 2 OF 3

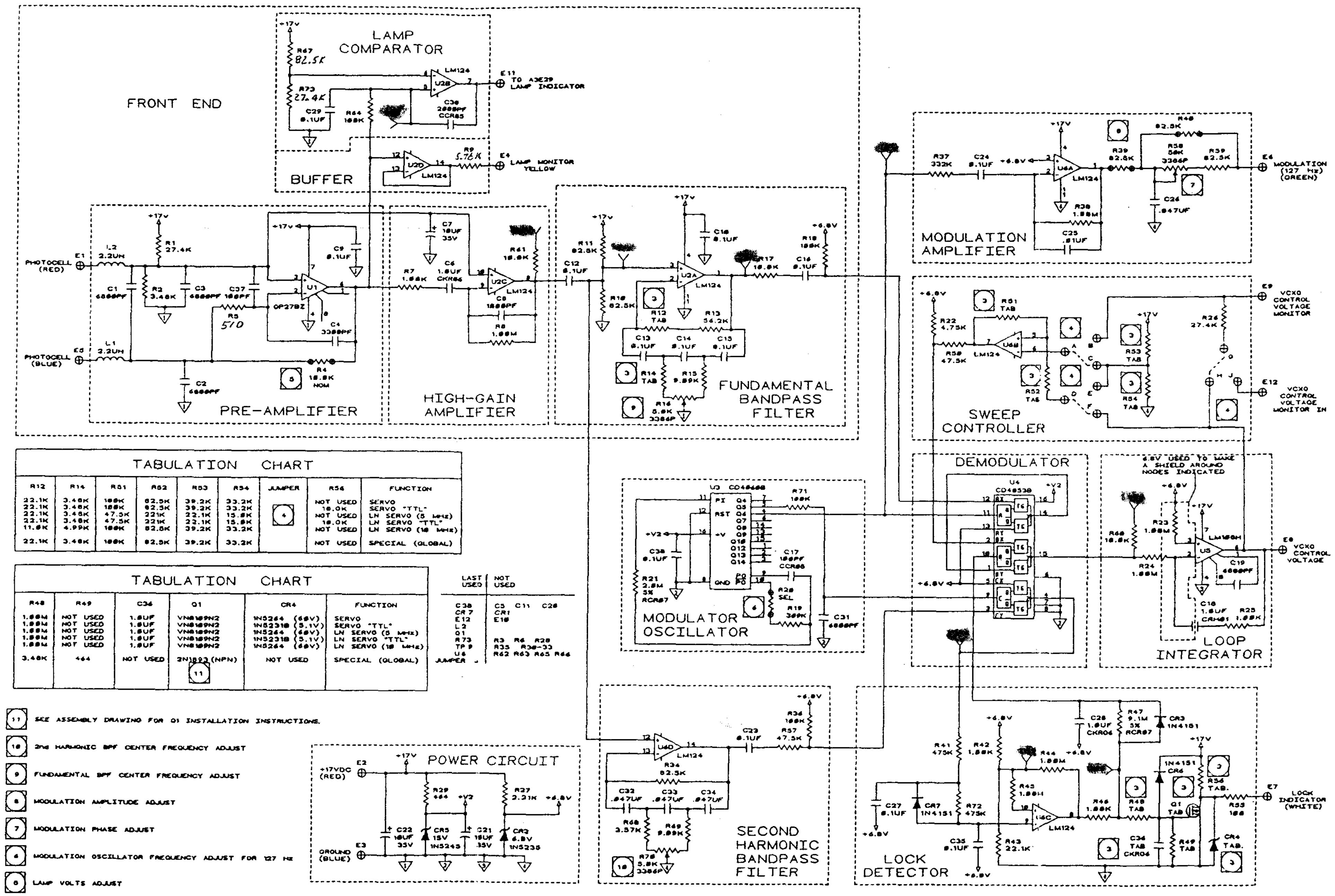
BALL, EFRATOM DIVISION CONTRACT No. CAGE CODE 55761 DRAWING No. 100120-1 REVISION LTR.

REVISION DATE 91-04-25

PARTS LIST, SERVO BD FILENAME:100120 .DBF SHEET 4

FIND No.	-001	-002	-003	-004	-005	-006	-007	-008	-009	-010	CAGE CODE	PART OR IDENTIFYING No.	SPEC. OR MANUFACTURER	NOMENCLATURE OR DESCRIPTION	HCI CODE	REFERENCE DESIGNATOR	UNIS No.
67	0	1	0	1	0	0						MK2 10.0K	STETTNER	RES, MF, 1/4W, 1%, 10.0K		R56	4701167
68	1	1	1	1	1	1						MK2 1.00M	STETTNER	RES, MF, 1/4W, 1%, 1.00M		R48	4701153
69	0	0	0	0	1	0						MK2 464	STETTNER	RES, MF, 1/4W, 1%, 464		R49	4701260
70	1	1	1	1	0	1						CKR06BX105KS	MIL-C-39014	CAP, CER, 50V, 10%, 1.0UF		C36	1500697
71	1	1	1	1	1	1						VN0109N2	SUPER-TEX	TRANSISTOR, MOS FET		Q1	
72	1	1	1	1	0	1						1N5264B		DIODE, 60V ZENER		CR4	4800096

PARTS LIST, SERVO BOARD (PL 100120) PAGE 3 OF 3



TABULATION CHART

R12	R14	R51	R52	R53	R54	JUMPER	R56	FUNCTION
22.1K	3.48K	100K	82.5K	39.2K	33.2K	4	NOT USED	SERVO
22.1K	3.48K	100K	82.5K	39.2K	33.2K		10.0K	SERVO "TTL"
22.1K	3.48K	47.5K	221K	22.1K	15.0K		NOT USED	LN SERVO (5 MHz)
22.1K	3.48K	47.5K	221K	22.1K	15.0K		10.0K	LN SERVO "TTL"
11.0K	4.99K	100K	82.5K	39.2K	33.2K		NOT USED	LN SERVO (10 MHz)
22.1K	3.48K	100K	82.5K	39.2K	33.2K		NOT USED	SPECIAL (GLOBAL)

TABULATION CHART

R48	R49	C34	Q1	CR4	FUNCTION
1.00M	NOT USED	1.0UF	VN0109N2	1N5264 (60V)	SERVO
1.00M	NOT USED	1.0UF	VN0109N2	1N5231B (5.1V)	SERVO "TTL"
1.00M	NOT USED	1.0UF	VN0109N2	1N5264 (60V)	LN SERVO (5 MHz)
1.00M	NOT USED	1.0UF	VN0109N2	1N5231B (5.1V)	LN SERVO "TTL"
1.00M	NOT USED	1.0UF	VN0109N2	1N5264 (60V)	LN SERVO (10 MHz)
3.48K	464	NOT USED	2N1893 (NPN) 11	NOT USED	SPECIAL (GLOBAL)

LAST USED	NOT USED
C38	C5 C11 C20
CR7	CR1
E12	E10
L2	
Q1	
R73	R3 R6 R28
TP9	R35 R30-33
U6	R62 R63 R65 R66
JUMPER J	

11 SEE ASSEMBLY DRAWING FOR Q1 INSTALLATION INSTRUCTIONS.

10 2nd HARMONIC BPF CENTER FREQUENCY ADJUST

9 FUNDAMENTAL BPF CENTER FREQUENCY ADJUST

8 MODULATION AMPLITUDE ADJUST

7 MODULATION PHASE ADJUST

6 MODULATION OSCILLATOR FREQUENCY ADJUST FOR 127 Hz

5 LAMP VOLTS ADJUST

4 INSTALL JUMPERS A-C, D-F, G-H.
FOR LOW NOISE UNITS ONLY: INSTALL JUMPERS A-B, D-E, G-J.

3 SEE TABULATION CHART FOR COMPONENT VALUES.

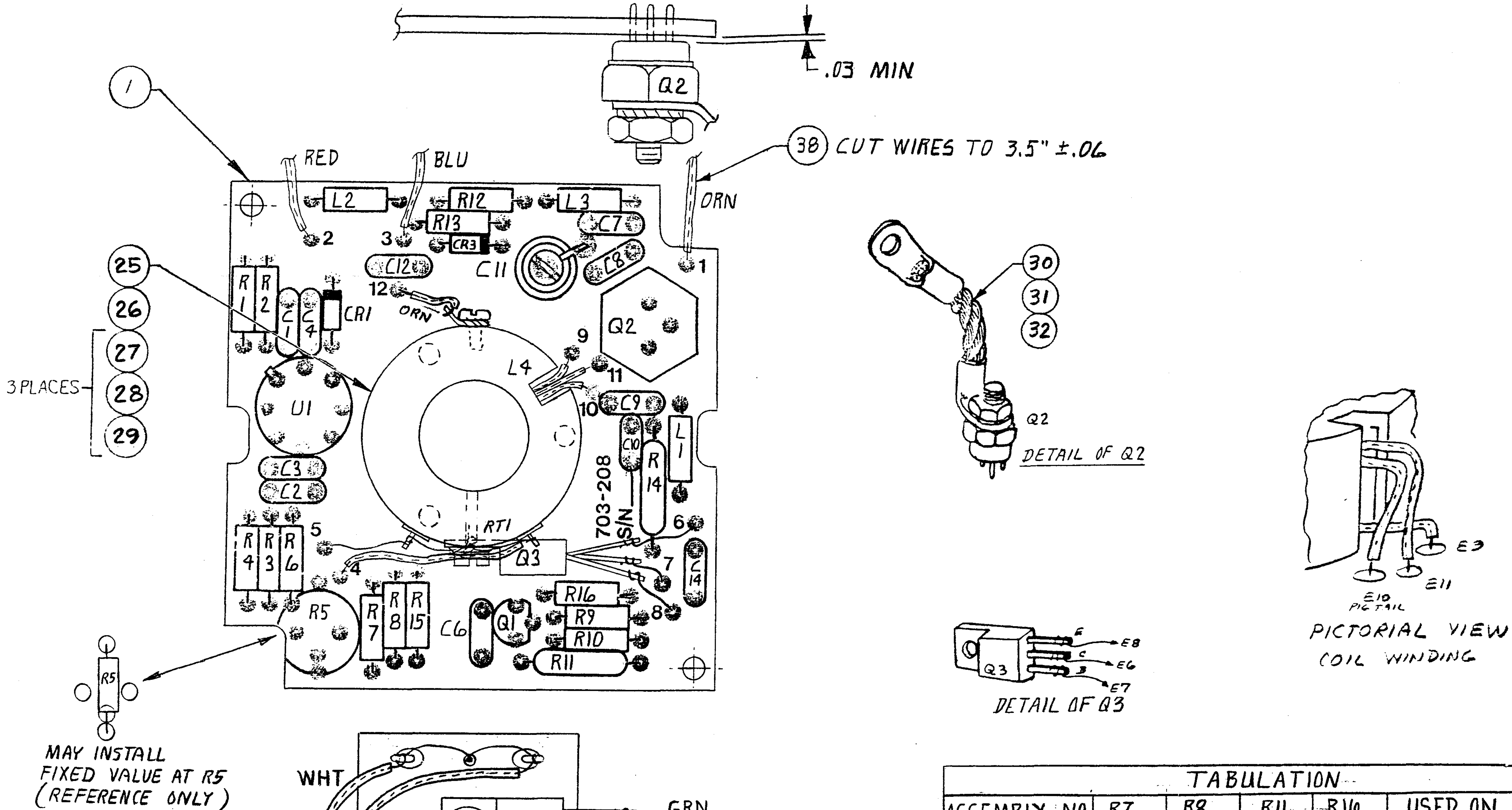
2. CAPACITORS ARE 50V MIN. OF CERAMIC. (CKR05BX----K5)

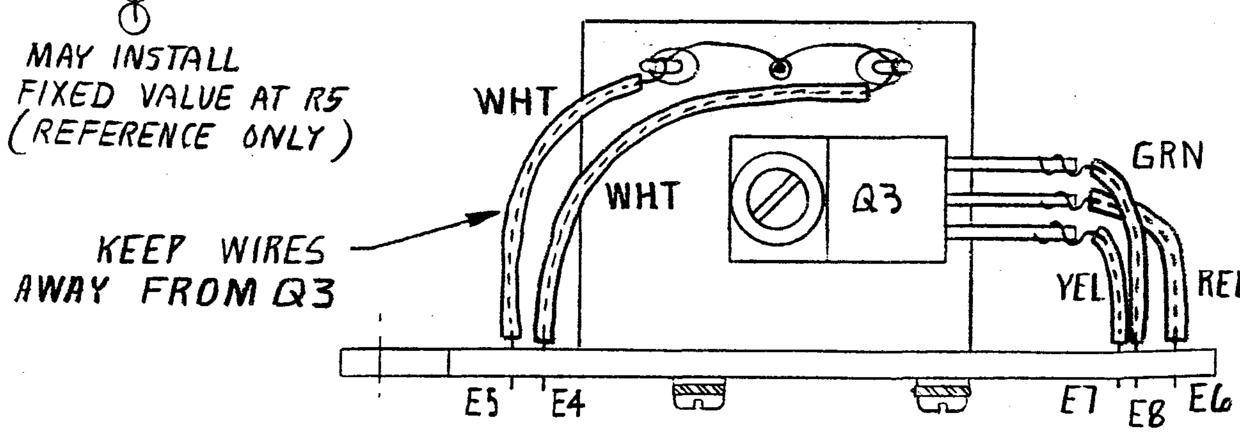
1. RESISTORS ARE 1/4W, 1% FIXED FILM (MK2 ----)

NOTES: UNLESS OTHERWISE SPECIFIED.

BOARD A1

SCHEMATIC, SERVO BOARD (100117)





TABULATION					
ASSEMBLY NO	R7	R8	R11	R16	USED ON
703-208-1	8.25K	332Ω	1.00Ω	39.2K	FRK-H
703-208-2	12.1K	681Ω	.619Ω	4.32K	FRK-HLN(12VDC)

BALL, EFRATOM DIVISION CONTRACT No. CAGE CODE 55761 PL 703-208-1 REVISION LTR. U
REVISION DATE 6-6-90

TITLE: PARTS LIST LAMP BOARD ASSY FRK

SHEET 2

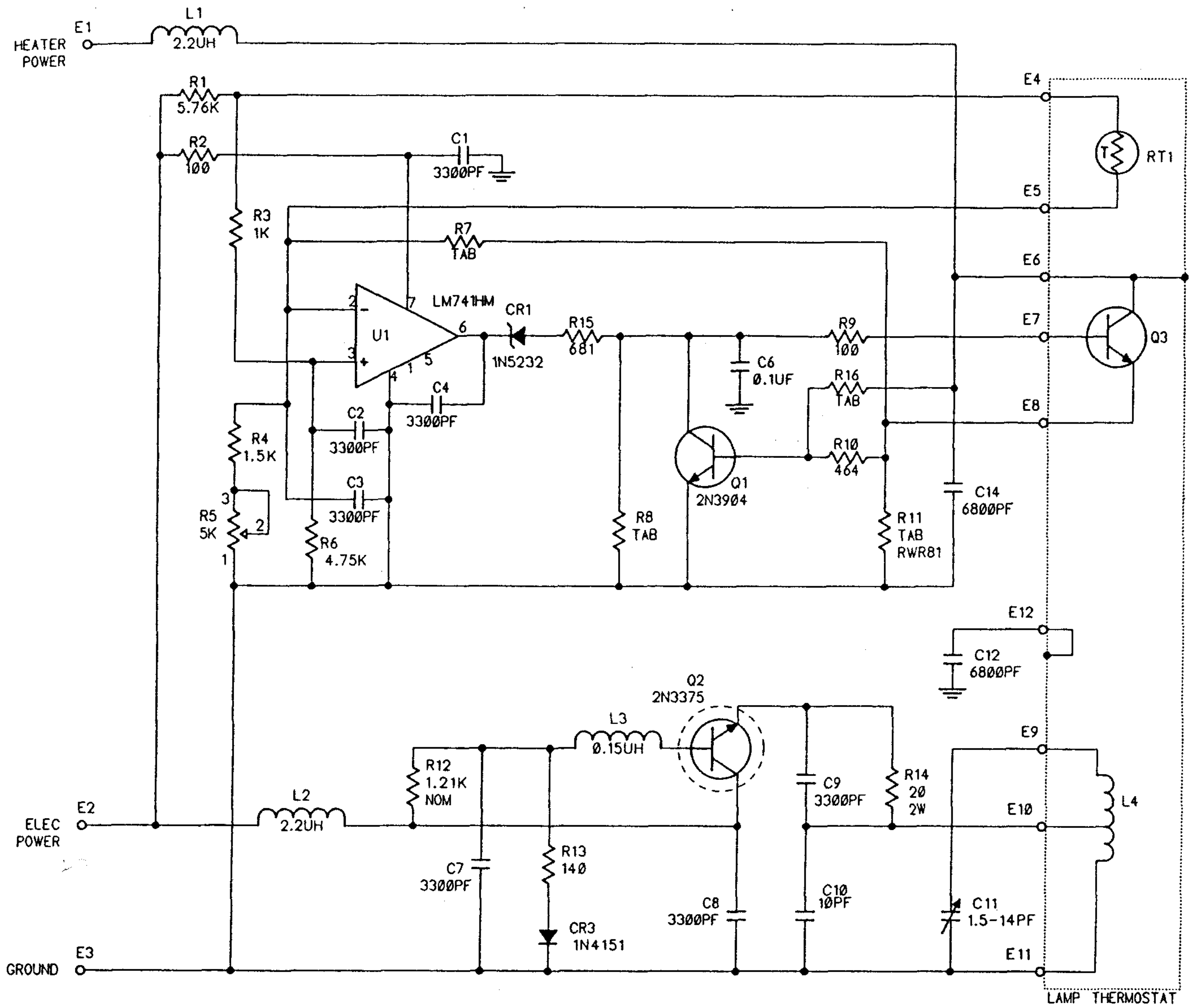
FIND No.	QTY REQ	PART OR IDENTIFYING No.	SPEC. OR MANUFACTURER	NOMENCLATURE OR DESCRIPTION	REFERENCE DESIGNATOR	UNIS No.
1	1	703-210-1		PRINTED WIRING BOARD		
2	1	EDPT 10PF NPO	S-T	CAPACITOR 10PF	C10	1500734
3	7	C322C332K1G5CA	KEMET	CAPACITOR 3300PF	C1-4,7-9	1500579
4	1	PC32T140	JOHNSON	CAPACITOR, VARIABLE 1.5-14PF	C11	1501515
5	1	1N5232B	MOT	DIODE, ZENER	CR1	4800091
6	1	1N4151	F	DIODE, SWITCHING	CR3	4800084
7	1	MS75083-3	DELEVAN	INDUCTOR 0.15UH	L3	1801443
8	2	MS75084-4	DELEVAN	INDUCTOR 2.2UH	L1,L2	1801448
9	1	2N3904	MOTOROLA	TRANSISTOR	Q1	4800197
10	1	2N3375	MOTOROLA	TRANSISTOR	Q2	4800194
11	1	LM741HMQB	F	INTEGRATED CIRCUIT	U1	3131016
12	2	MK2 100 OHM	S-T	RESISTOR 100 OHM	R2,9	4701171
13	1	MK2 681 OHM	S-T	RESISTOR 681 OHM	R15	4701297
14	1	MK2 1K	S-T	RESISTOR 1K	R3	4701153
15	1	MK2 1.5K	S-T	RESISTOR 1.5K	R4	4701161
16	1	MK2 4.75K	S-T	RESISTOR 4.75K	R6	4701267
17	1	MK2 5.76K	S-T	RESISTOR 5.76K	R1	4701280
18	1	MK2 8.25K	S-T	RESISTOR 8.25K	R7	4701309
19	1	MK2 39.2K	S-T	RESISTOR 39.2K 1/4W	R16	4701250
20	1	RWR80520R0FR		RESISTOR 20 OHM 2W	R14	4701967
21	1	RWR81S1R00FR		RESISTOR 1.00 OHM 1W	R11	4702010
22	1	3339P-1-502	BOURNS	RESISTOR VARIABLE 5K	R5	4750249
23	1	MK2 332 OHM	S-T	RESISTOR 332 OHM	R8	4701248
24	2	CKR05BX682KSV	KEMET	CAPACITOR 6800PF	C12,14	1500695
25	1	70331-1		THERMOSTAT ASSEMBLY		
26	1	250-169		MICA WINDOW		
27	3	70425-3		SCREW, M2 x 6		
28	3	70414-4		WASHER, FLAT, M2		
29	3	6798ST-1N2.2		WASHER, LOCK, M2		
30	1	70334		HEATSINK CABLE		
31	1	MS35650-304		NUT, HEX, 10-32		2821407
32	1	MS35333-73		WASHER, IT LOCK, No. 10		2821386
33	1	MK2 140 OHM	S-T	RESISTOR 140 OHM 1/4W	R13	4701181
34	1	CKR05BX104KSV		CAPACITOR 0.1UF	C6	1500688

BALL, EFRATOM DIVISION CONTRACT No. CAGE CODE 55761 PL 703-208-1 REVISION LTR. U
REVISION DATE 6-6-90

TITLE: PARTS LIST LAMP BOARD ASSY FRK

SHEET 3

FIND No.	QTY REQ	PART OR IDENTIFYING No.	SPEC. OR MANUFACTURER	NOMENCLATURE OR DESCRIPTION	REFERENCE DESIGNATOR	UNIS No.
35	1	7717-107N		TRANSISTOR PAD (8 PIN)	XU1	2102217
36	1	MK2 464 OHM	S-T	RESISTOR 464 OHM 1/4W	R10	4701266
37	1	MK2 1.21K NOM	S-T	RESISTOR 1.21K NOMINAL	R12	4701158
38	A/R	MIL-W-16878, E.T.		WIRE, 24AWG, TEFLON, RED-BLU-ORN		



2. RESISTANCE VALUES ARE OHMS.

1. FOR ASSEMBLY SEE DWG# 703-208.

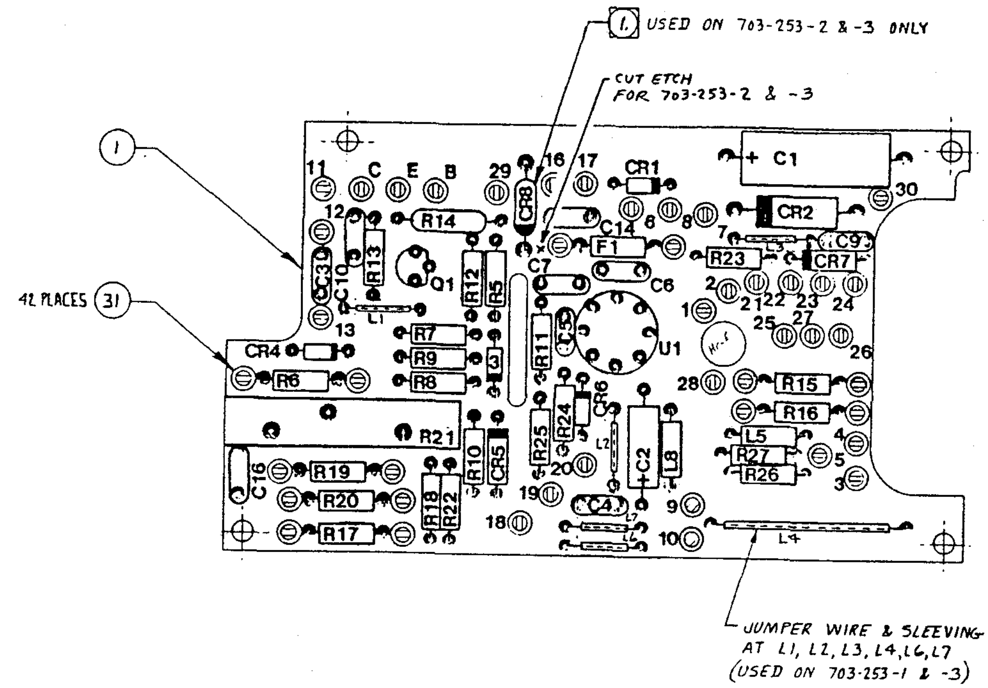
NOTES: UNLESS OTHERWISE SPECIFIED.

TABULATION

ASSEMBLY	R7	R8	R11	R16	USED ON
703-208-1	8.25K	332	1	39.2K	FRK-H
703-208-2	12.1K	681	0.619	4.32K	FRK-HLN(12VDC)

LAST USED	NOT USED
U1	-
C14	C5,13
R16	R15
CR3	CR2
Q3	-
E12	-
RT1	-
L4	-

SCHEMATIC, LAMP BOARD (703-209)



NOTES-UNLESS OTHERWISE SPECIFIED

1. SEE SCHEMATIC NO. 703-254.

TABULATION		
PART NO.	DESCRIPTION	
703-253-1	CR8 NOT USED, INSTALL JUMPER L1,L2,L3,L4 L6,L7	STANDARD P.S.
703-253-2	INSTALL CR8 & CUT ETCH BETWEEN CR8-C AND FUSE F1	USED WITH FILTER CONN & SEPARATE HEATER PWR
703-253-3	INSTALL CR8 & CUT ETCH BETWEEN CR8-C & FUSE F1. DO NOT INSTALL L1,L2,L3,L4,L6,L7 INSTALL JUMPER AT L1,L2,L3,L4,L6,L7	USED WITH SEPARATE HEATER POWER

ASSEMBLY, POWER SUPPLY BOARD (703-253-TAB)

BALL, EFRATOM DIVISION   CONTRACT No.   CAGE CODE 55761   PL 703-253-1   REVISION LTR.
REVISION DATE 91-04-25

TITLE: PARTS LIST, POWER SUPPLY (A3)

SHEET 2

FIND No.	QTY REQ	PART OR IDENTIFYING No.	SPEC. OR MANUFACTURER	NOMENCLATURE OR DESCRIPTION	REFERENCE DESIGNATOR	UNIS No.
1	1	703-255		PRINTED WIRING BOARD		
2	1	EDPT 3x4 3.3PF NPO		CAPACITOR 3.3PF	C5	1500777
3	1	EDPT 5x6 47PF NPO		CAPACITOR 47PF	C7	1500752
4	5	CKR05BX682K	AVX	CAPACITOR 6800PF	C3,4,6,9,10	1500695
5	2	CKR95BX104KS		CAPACITOR 0.1UF	C14,16	1500688
6	1	T322D106M035AS	KEMET	CAPACITOR 10UF	C2	1502105
7	1	600D176G060KD4	SPRAGUE	CAPACITOR 17UF 60V	C1	1500420
8	1	1.5KE43A	G.S.	DIODE	CR2	4800019
9	1	1N4578		DIODE	CR5	4800086
10	4	1N4151		DIODE	CR1,3,4,6	4800084
11	1	1N5242		DIODE	CR7	4800093
12	1	251003	LITTLE FUSE	FUSE 3 AMP	F1	
13	1	MK2 100 OHM		RESISTOR 100 OHM	R13	4701171
14	1	MK2 392 OHM		RESISTOR 392 OHM	R23	4701253
15	1	MK2 2.21K		RESISTOR 2.21K	R7(NOMINAL)	4701196
16	1	MK2 3.83K		RESISTOR 3.83K	R25	4701237
17	1	MK2 4.75K		RESISTOR 4.75K	R22	4701260
18	1	MK2 6.81K		RESISTOR 6.81K	R10	4701291
19	3	MK2 10K		RESISTOR 10K	R12,24,8	4701167
20	1	MK2 12.1K		RESISTOR 12.1K	R5	4701175
21	1	MK2 5.62K		RESISTOR 5.62K	R9	4701279
22	1	MK2 200K		RESISTOR 200K	R11	4701205
23	6	MK2 XXX		RESISTOR SELECT	R15-17,19,20	
24	1	RW80U1R10F	D	RESISTOR 1.1 OHM 2W WIREWOUND	R14	
25	1	3059Y-1-503		POTENTIOMETER 50K	R21	4750227
26	1	2N3906		TRANSISTOR	Q1	4800198
27	1	MS75084-1		INDUCTOR 1.2UH	L8	1801444
28	1	LM748H		INTEGRATED CIRCUIT	U1	
29				NOT USED		
30	1	7717-107N		PAD - 8 PIN SOLDER	XU1	2102217
31	42	70416-3		SOLDER TERMINAL		
32				NOT USED		
33	1	MK2 1K		RESISTOR 1K	R26	4701153
34	1	MK2 1K		RESISTOR 1K	R27	4701153

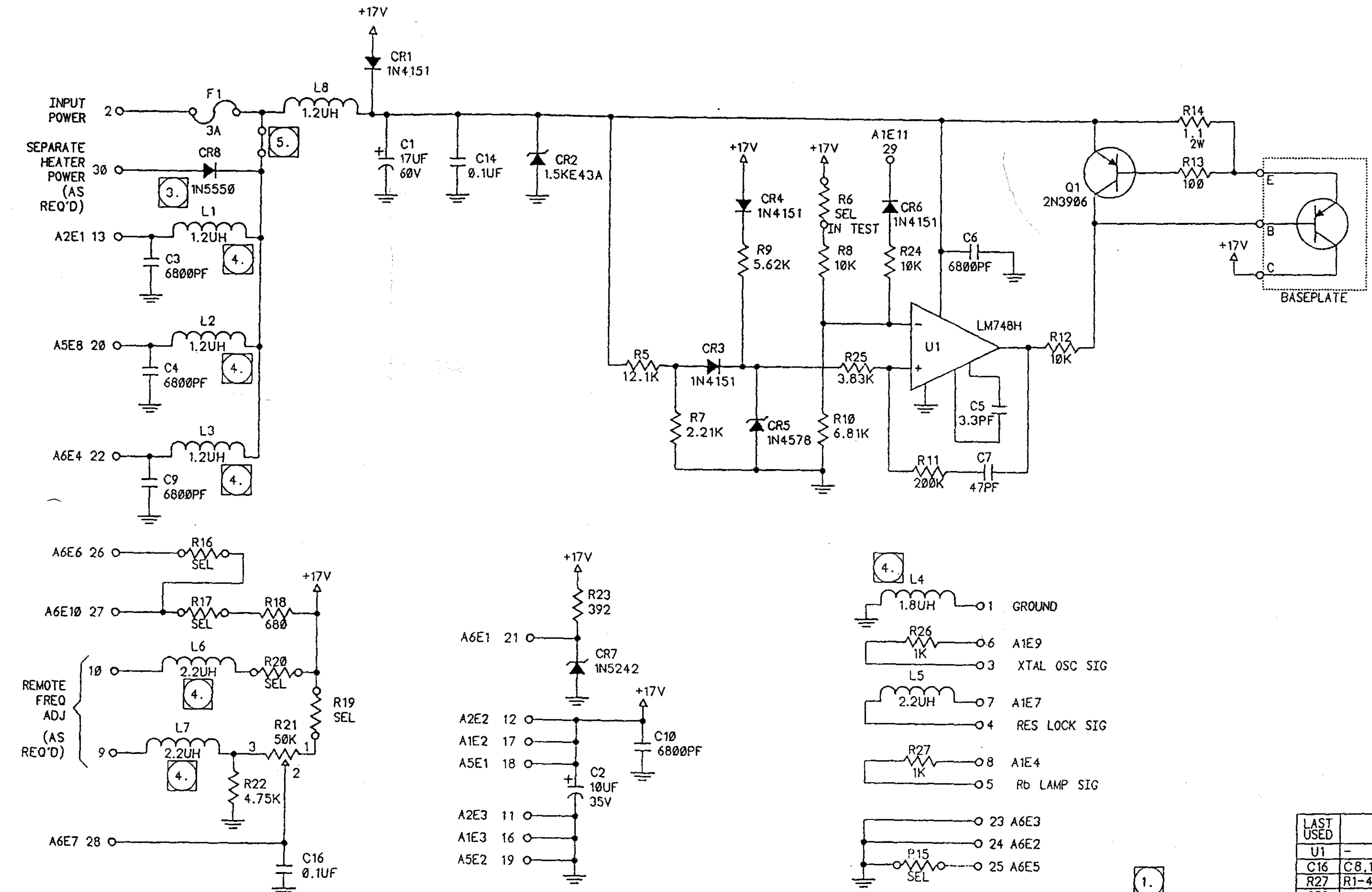
PARTS LIST, POWER SUPPLY BOARD (PL 703-253-1) PAGE 1 OF 2

BALL, EFRATOM DIVISION CONTRACT No. CAGE CODE 55761 PL 703-253-1 REVISION LTR.
REVISION DATE 91-04-25

TITLE: PARTS LIST, POWER SUPPLY (A3)

SHEET 3

FIND No.	QTY REQ	PART OR IDENTIFYING No.	SPEC. OR MANUFACTURER	NOMENCLATURE OR DESCRIPTION	REFERENCE DESIGNATOR	UNIS No.
35	1	MS75084-4	DALE	INDUCTOR 2.2UH	L5	1801448
36	1	MK2 681 OHM		RESISTOR 681 OHM	R18	4701297



ASSEMBLY TABULATION	
703-253-1	STANDARD
703-253-2	W/ FILTER CONNECTOR
703-253-3	SEPARATE HEATER POWER

LAST USED	NOT USED
U1	-
C16	C8,11-13,15
R27	R1-4
CR8	-
Q1	-
L8	-
F1	-

5. REMOVE JUMPER FOR SEPARATE HEATER POWER.

4. L1,L2,L3,L4,L6,L7 INSTALLED WITH FILTER CONNECTOR. JUMPERS INSTALLED WITHOUT FILTER CONNECTOR.

3. INSTALL CR8 WITH SEPARATE HEATER POWER ONLY.

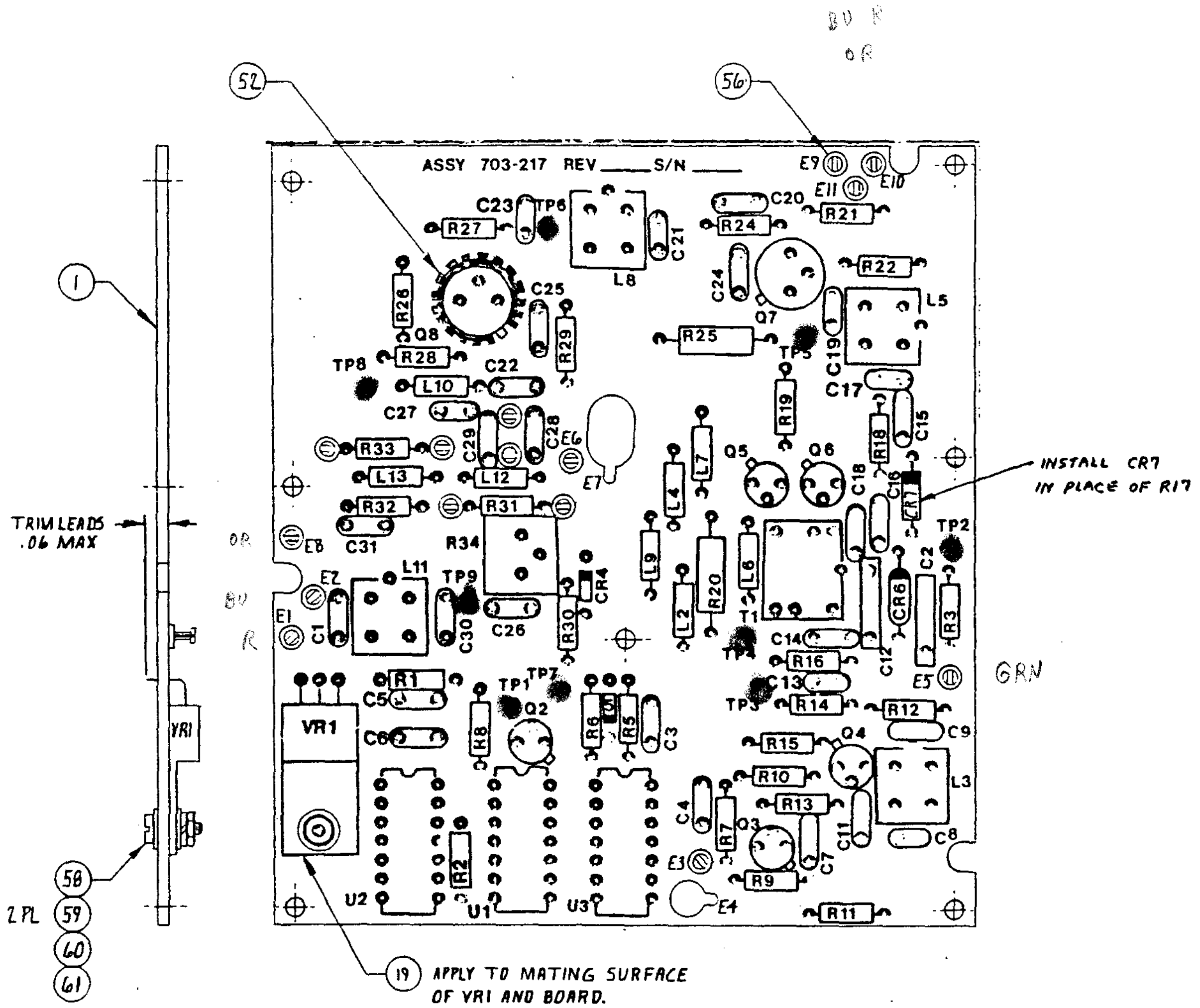
2. RESISTANCE VALUES ARE OHMS.

1. FOR ASSEMBLY SEE DWG# (TABULATION).

NOTES: UNLESS OTHERWISE SPECIFIED.

BOARD A3

SCHEMATIC, POWER SUPPLY BOARD (703-254)



NOTES: UNLESS OTHERWISE SPECIFIED.
1. FOR SCHEMATIC DIAGRAM SEE DWG NO. 703-218-1,-2.

TABULATION	
703-218-1	STD. AS SHOWN
703-218-2	LN. R7 IS 5K

ASSEMBLY, SYNTHESIZER BOARD (703-217)

BALL, EFRATOM DIV CONTRACT NO. CAGE CODE 55761 703217-1 REVISION DATE 91-04-29

TITLE: PARTS LIST SYNTHESIZER ASSEMBLY BOARD 5 (A5)

FIND NO.	QTY	PART OR IDENTIFYING NO.	SPEC. OR MANUFACTURER	NONMENLCATURE OR DESCRIPTION	REFERENCE DESIGNATOR
1	1	703-219	E	Printed Wiring Board	
2	1	EDPT 3.9 PF NPO	S-T	Capacitor 3.9 PF	C13
3		NOT USED			
4	1	EDPT 15PF NPO	S-T	Capacitor 15PF	C21
5	2	EDPT 22PF NPO	S-T	Capacitor 22PF	C19,C27
6	1	EDPT 33PF NPO	S-T	Capacitor 33PF	C23
7	1	EDPT 39PF NPO	S-T	Capacitor 39PF	C17
8	1	EDPT 47PF NPO	S-T	Capacitor 47PF	C18
9	1	EDPT 68PF NPO	S-T	Capacitor 68PF	C9
10	1	EDPT 82PF NPO	S-T	Capacitor 82PF	C29
11	2	EDPT 100PF NPO	S-T	Capacitor 100PF	C14, C28
12	1	C052C272K2G5CA	KEMET	Capacitor 2700PF +/- 10%	C30
13	14	CKR05BX682KS	AVX	Capacitor 6800PF +/- 10%	C1,3,4,7,8,11,15,16, 20,22,24,25,26,31
14	2	22NA473J	S&E1	Capacitor .047UF +/- 5% 50V	C2,12
15	2	CKR05BX104KS	KEMET	Capacitor .1UF	C5,C6
16	3	IN4151	F	Diode	CR4,5,7
17	1	MV1638	KNOX	Diode, Varactor	CR6
18	2	IM-2 .15UH	Dale	Inductor .15UH	L6,10
19	AR	TYPE 120		Thermal Joint Compound	
20	5	1025-38	Delevan	Inductor 5.6UH	L4,7,9,12,13
21	1	1025-50	Delevan	Inductor 18UH	L2
22	2	70277-4	E	Inductor, Variable (GRN,Yel)	L3,11
23	2	70277-3	E	Inductor, Variable (RED,Yel)	L5,8
24	1	7805CT	Natn'l	Voltage Reg.	VR1
25	3	2N2369A	F	Transistor	Q2-4
26	2	2N3553	M	Transistor	Q7,8
27	1	MK2 47.5 Ohms	S-T	Resistor 47.5 Ohms +/- 1% 1/4W	R1
28	4	MK2 56.2 Ohms	S-T	Resistor 56.2 Ohms +/- 1% 1/4W	R19,20,24,28

BALL, EFRATOM DIV CONTRACT NO. · CAGE CODE 55761 703217-1 REVISION DATE 91-04-29

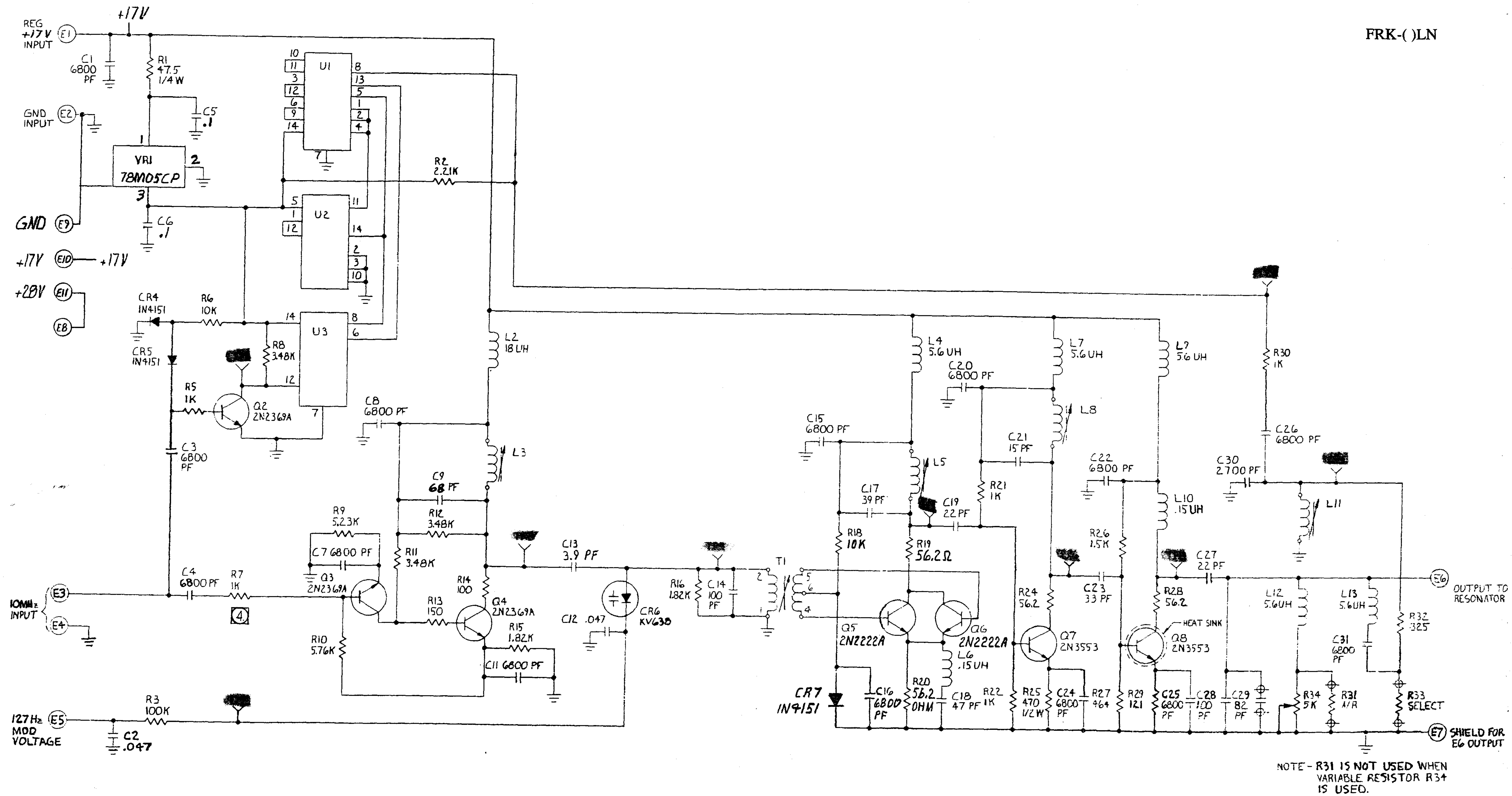
TITLE: PARTS LIST SYNTHESIZER ASSEMBLY BOARD 5 (A5)

FIND NO.	QTY	PART OR IDENTIFYING NO.	SPEC. OR MANUFACTURER	NONMENLCATURE OR DESCRIPTION	REFERENCE DESIGNATOR
29	1	MK2 100 Ohms	S-T	Resistor 100 Ohms +/- 1% 1/4W	R14
30	1	MK2 121 Ohms	S-T	Resistor 121 Ohms +/- 1% 1/4W	R29
31	1	MK2 150 Ohms	S-T	Resistor 150 Ohms +/- 1% 1/4W	R13
32	1	MK2 464 Ohms	S-T	Resistor 464 Ohms +/- 1% 1/4W	R27
33	1	MK2 825 Ohms	S-T	Resistor 825 Ohms +/- 1% 1/4W	R32
34	5	MK2 1K Ohms	S-T	Resistor 1K Ohm +/- 1% 1/4W	R5,7,21,22,30
35	1	MK2 1.5K Ohms	S-T	Resistor 1.5K Ohms +/- 1% 1/4W	R26
36	2	MK2 1.82K Ohms	S-T	Resistor 1.82K Ohms +/-1% 1/4W	R15,16
37	1	MK2 2.21K Ohms	S-T	Resistor 2.21 K Ohms +/-1% 1/4W	R2
38	3	MK2 3.48K Ohms	S-T	Resistor 3.48K Ohms +/-1% 1/4W	R8,11,12
39	1	MK2 5.23K Ohms	S-T	Resistor 5.23K Ohms +/-1% 1/4W	R9
40	1	MK2 5.76K Ohms	S-T	Resistor 5.76K Ohms +/-1% 1/4W	R10
41		NOT USED			
42	2	MK2 10K Ohms	S-T	Resistor 10K Ohms +/- 1% 1/4W	R6,18
43	1	MK2 100K Ohms	S-T	Resistor 100K Ohms +/- 1% 1/4W	R3
44	2	MK2 Select A/R	S-T	Resistor Select +/- 1% 1/4W	R31,33
45	1	RCR20G471JS	MIL	Resitor 470 Ohms +/- 5% 1/2W	R25
46	2	2N2222A		Transistor	Q5,6
47	1	3339P-1-502	Bourns	Resistor Variable 5K Ohms	R34
48	1	70278-1	E	Transformer	T1
49	1	SN54LS00J	T.I.	Integrated Circuit	U1
50	1	SN54LS93J	T.I.	Integrated Circuit	U2
51	1	SN5472J	T.I.	Integrated Circuit	U3
52	1	200-.250-.318	HSP	Heatsink	XQ8
53		NOT USED			
54	3	7717-4N	T.	TSTR PAD (TO-5)	
55	5	7717-93N	T.	TSTR PAD (TO-18 Spreader)	
56	15	90416-3	K.	Solder Terminal	

BALL, EFRATOM DIV	CONTRACT NO.	CAGE CODE 55761	703217-1	REVISION DATE 91-04-29

TITLE: PARTS LIST SYNTHESIZER ASSEMBLY BOARD 5 (A5)

FIND NO.	QTY	PART OR IDENTIFYING NO.	SPEC. OR MANUFACTURER	NONMENLCATURE OR DESCRIPTION	REFERENCE DESIGNATOR
57	AR	SN63WRMAP3	MIL	Solder	
58	1	85ST-MX8		Screw, Metric M3X8	
59	2	125ST-3		Washer, Flat M3	
60	1	127ST-3		Washer, Split Lock M3	
61	1	934ST-M3		Nut, Metric M3	

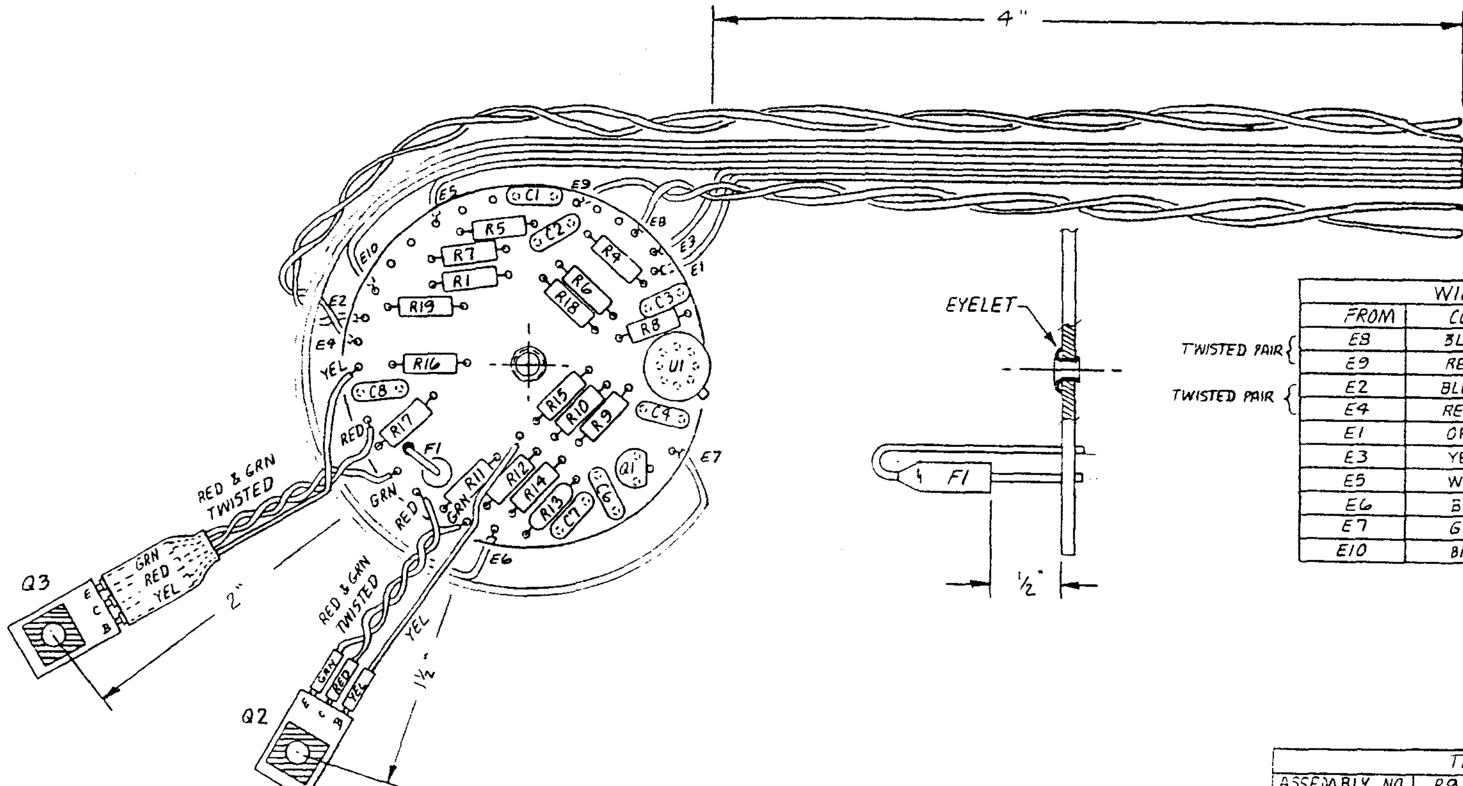


NOTES: UNLESS OTHERWISE SPECIFIED
1. RESISTANCE VALUES ARE IN OHMS.
2. CAPACITANCE VALUES ARE IN MICROFARADS.
3. FOR ASSEMBLY SEE DWG 703-217.
4. SEE TABULATION.

4

TABULATION	
703-218-1	STD, AS SHOWN
703-218-2	LN, R7 IS 5K

BOARD A5
SCHEMATIC, SYNTHESIZER BOARD (PL 703-218)



WIRE LIST				
	FROM	COLOR	AWG	DESTINATION
TWISTED PAIR	E8	BLK	28	A1E5
	E9	RED	28	A1E1
TWISTED PAIR	E2	BLU	26	A3E24
	E4	RED	26	A3E22
	E1	ORN	26	A3E21
	E3	YEL	26	A3E23
	E5	WHT	28	A3E25
	E6	BLK	26	A3E26
	E7	GRN	26	A3E28
	E10	BRN	28	A3E27

TABULATION					
ASSEMBLY NO.	R9	R10	R11	R13	USED ON
703-220-1	3.2K	1.0K	10K	.619Ω	FRK-H
703-220-2	SEE SEPARATE DWG				FRK-H(GPS)
703-220-3	2.32K	845Ω	4.75K	.402Ω	FRK-HLN(12VDC)

NOTES – UNLESS OTHERWISE SPECIFIED

1. FOR SCHEMATIC SEE DRAWING NO. 703-221.
2. FOR PRINTED WIRING BOARD SEE DRAWING NO. 703-222.

ASSEMBLY, RESONATOR HEATER (703-220-TAB)

BALL, EFRATOM DIVISION CONTRACT No. CAGE CODE 55761 PL 703-220-1 REVISION LTR.
REVISION DATE 91-04-25

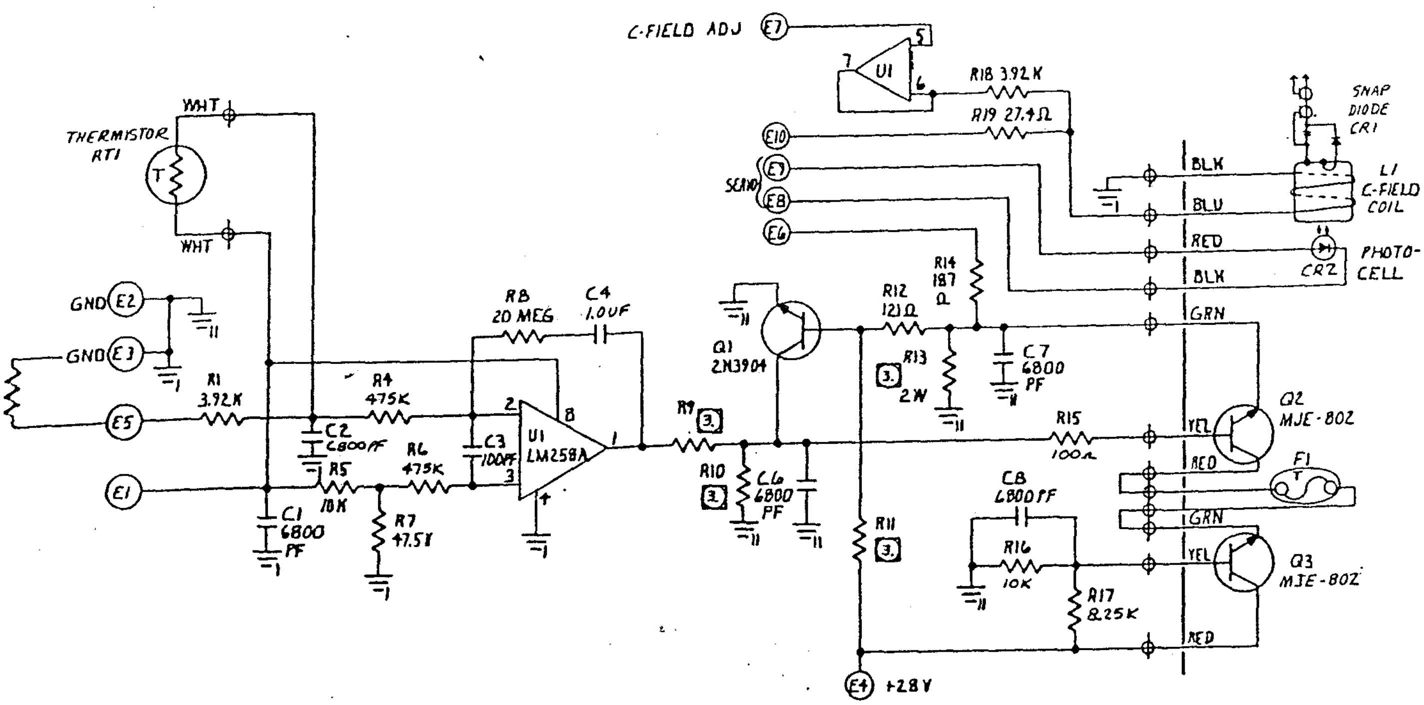
TITLE: PARTS LIST, RESONATOR HEATER (A6)

SHEET 2

FIND No.	QTY REQ	PART OR IDENTIFYING No.	SPEC. OR MANUFACTURER	NOMENCLATURE OR DESCRIPTION	REFERENCE DESIGNATOR	UNIS No.
1	1	703-222		P.W.B.		
2	1	EDPT 100PF NPO		CAPACITOR 100PF	C3	1500764
3	5	CKR05BX682KS		CAPACITOR 6800PF	C1,2,6,7,8	1500965
4	1	CKR06BX105KS		CAPACITOR 1UF	C4	1500697
5	1	2N3904		TRANSISTOR	Q1	4800197
6	1	MK2 27.4 OHM		RESISTOR 27.4 OHM	R19	4701220
7	1	MK2 100 OHM		RESISTOR 100 OHM	R15	4701171
8	1	MK2 121 OHM		RESISTOR 121 OHM	R12	4701178
9	1	MK2 187 OHM		RESISTOR 187 OHM	R14	4701191
10	1	MK2 1K		RESISTOR 1K	R10	4701153
11	2	MK2 3.92K		RESISTOR 3.92K	R1,18	4701238
12				NOT USED		
13	1	MK2 3.24K		RESISTOR 3.24K	R9	4701229
14	1	MK2 8.25K		RESISTOR 8.25K	R17	4701309
15	3	MK2 10K		RESISTOR 10K	R5,16,11	4701167
16	1	MK2 47.5K		RESISTOR 47.5K	R7	4701267
17	2	MK2 475K		RESISTOR 475K	R4,6	4701270
18	1	RCR07G206JS		RESISTOR 20 MEG 1/4W	R8	4701704
19	1	RWR80SR619FR		RESISTOR 0.619 OHM 2W	R13	
20	1	LM258A		INTEGRATED CIRCUIT	U1	3130995
21	1	D139-002	3M	THERMAL CUT-OFF, MTP	F1	4300712
22	1	A2196GS5-3	STIMPSON	EYELET		2820504
23	2	MJE-802		TRANSISTOR	Q2,3	
24	A/R	RTV-108		SILICONE RUBBER, RTV		70424-7
25	A/R	SN63WRMAP3		SOLDER		2102572
26	A/R	MIL-W-16878 TYPE E		WIRE, STRANDED, TEFLON INS		

PARTS LIST, RESONATOR HEATER (PL 703-220-1)

TABULATION					
ASSEMBLY NO.	R9	R10	R11	R13	USED ON
703-220-1	3.2K	1.0K	10K	.619Ω	FRK-H
703-220-3	2.32K	845Ω	4.75K	.402Ω	FRK-HIN(12VDC)



SCHEMATIC, RESONATOR HEATER BOARD