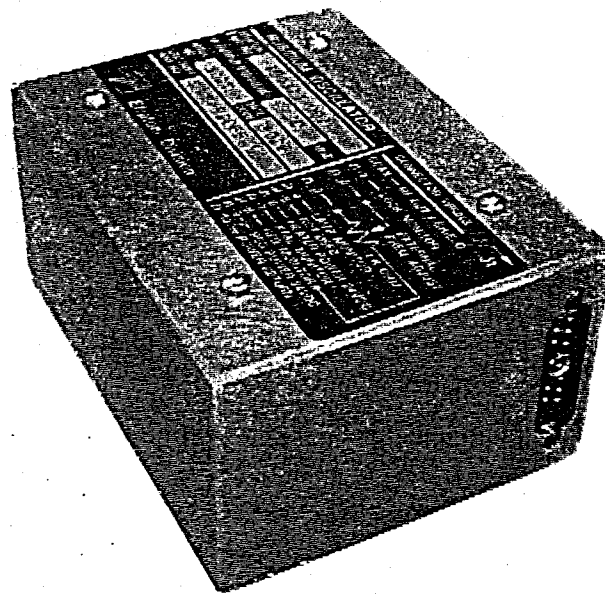


**EFRATOM**

**Time & Frequency Products, Inc.**

**DESCRIPTION AND  
OPERATION MANUAL**



**SUBMINIATURE RUBIDIUM OSCILLATOR  
MODEL FRS**

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## CHAPTER 1

### INTRODUCTION AND SPECIFICATIONS

#### 1-1. INTRODUCTION.

The Efratom Model FRS Rubidium Standard is a sub-miniature, atomic resonance-controlled oscillator that provides an extremely stable signal of 2.048 MHz TTL, 5 MHz, or 10 MHz (TTL or sinusoidal). The FRS-C is designed for instruments and equipment requiring an extremely stable and precise frequency operating in commercial/industrial environmental conditions. The FRS-N is designed primarily for use in high-performance communication and navigation systems with more stringent environmental conditions.

#### 1-2. SCOPE.

This manual contains information regarding the operation and field maintenance of the FRS. Chapters 1 and 2 contain general information concerning the unit. It is recommended that these chapters be read prior to attempting operation of the unit. Chapter 3 presents a general theory of operation for a technician or engineer who requires a better understanding of the unit's operation. Outline and assembly drawings, parts lists and schematic diagrams are contained in the Appendix.

#### 1-3. CONNECTIONS.

All necessary connections for input and output signals are externally accessible. Output signal, power, frequency adjustment, and built-in-test (BIT) functions are provided by a Cannon connector that mates with Cannon P/N DAM11W1S and DM 53740-5000.

#### 1-4. ELECTRICAL PROTECTION.

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

#### 1-5. AVAILABLE OPTIONS.

Optional output frequencies include the following: 5 MHz at 1.5 Vrms into a 50 ohm load, 2.048, 5 or 10 MHz TTL.

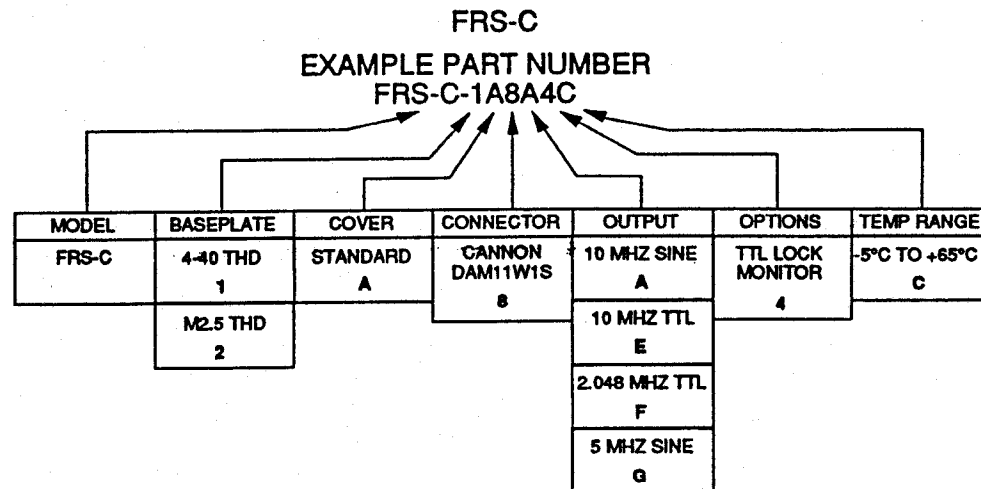
#### 1-6. SPECIFICATIONS.

The FRS 1-day stability ( $1E-10$ ) assumes an ambient temperature of  $25 (\pm 3)^{\circ}C$  and a warm-up time of forty-eight hours minimum, preceded by a maximum off time of seventy-two hours; or a warm-up time of three days with an off time of one month. After seven days of continuous operation, the one day stability is  $4E-11$ . Table 1-1 lists the specifications for the FRS Model C. Table 1-2 lists the specifications for the FRS Model N.

TABLE 1-1. SPECIFICATIONS, FRS-C

## ELECTRICAL

Output:



|   |   |
|---|---|
| Amplitude (Sine):                               | 0.5 V <sub>rms</sub> +30/-10% into 50 ohm resistive load  |
| Amplitude (TTL):                                | Low: 0 to +0.8V, High: +3.5 to +5.5V, into 50 Ohm resistive load.                                   |
| Accuracy Setting at Shipment:                   | ±5E-11 (25°C) (Accuracy after 1 year): 1E-9/Year  |
| Input Voltage Range:                            | 22 to 30 Vdc  |
| Power-steady State:                             | 12 W @ 24 Vdc at 25°C Base Plate  |
| At turn on:                                     | 2.0 A peak  |
| Input Voltage Sensitivity:                      | 5E-11 (for ±10% Vdc)  |
| Warm-up Characteristics:                        |   |
| Time to lock:                                   | ≤ 4 minutes   |
| Minutes/Freq @ 25°C:                            | 6 minutes/1E-9  |
| Long Term Drift:                                | ≤ 5E-11/Mo*, ±5E-10/Yr  |
| 1-Day Stability:                                | 1E-10/day**   |
| Short-Term Stability: (5 & 10 MHz outputs only) |   |
| 1.0 Second (Allan Var.)                         | 1E-10   |
| 10 Sec. (Allan Var.)                            | 3.16E-11  |
| 100 Sec. (Allan Var.)                           | 1E-11   |
| Phase Noise (SSB 1 Hz BW):                      | -70dBc/√Hz at 1Hz, -110dB c/√Hz at 100Hz,<br>-130 dBc/√Hz at 1 KHz                                  |
| Harmonic/Non-Harmonic Distortion:               | 10 MHz = -40 dBc (sine)/ -70 dBc;<br>5 MHz = -40 dBc/-60 dB   |
| Frequency Trim Range:                           | ±1E-9 minimum   |
| Frequency Retrace:                              | 5E-11   |
| Setting Resolution:                             | 1E-11   |
| Magnetic Field Sensitivity:                     | ≤ 4E-13/A m <sup>-1</sup> (worst case)  |
| Electrical Protection:                          | Internal diode protects against reverse polarity connection. Rf output/BIT short-circuit protected. |

## ENVIRONMENTAL

|                                |  |
|--------------------------------|--|
| Operating Temperature:         | ≤ 3E-10 from -5°C to +55°C Amb. (65°C Max baseplate) |
| Storage Temperature (non-ops): | -55°C to +85°C                                       |
| Humidity:                      | ≤ 95 % RH  |
| Altitude, Vibration, Shock:    | MIL-T-28800 Type III, Class 5                        |

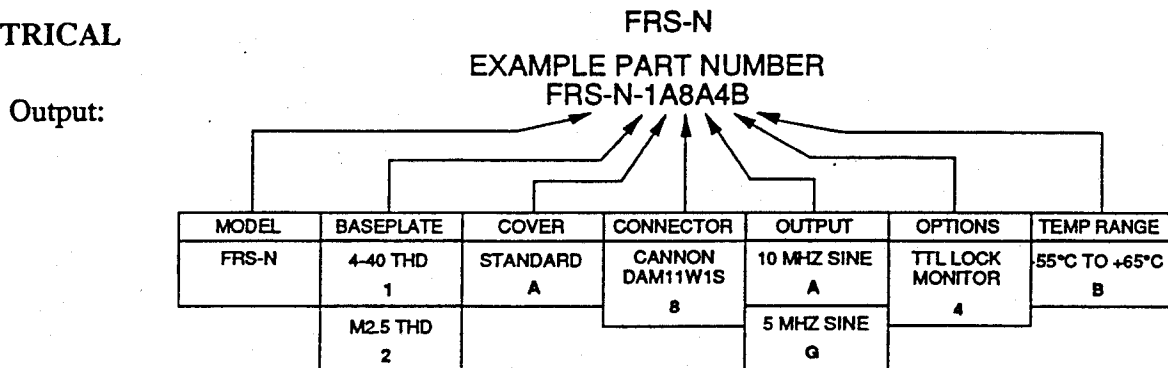
**PHYSICAL**

|                      |                                       |
|----------------------|---------------------------------------|
| Size (inches h/w/d): | 2.0 x 3.0 x 4.0 (5.1 x 7.6 x 10.2 cm) |
| Weight:              | 1.2 lbs (0.55 kg)                     |
| Connectors:          | Mate with Cannon Series DAM11W1S      |
| Baseplate Threads:   | (STD) 4-40 (M2.5 option)              |
| Warranty:            | 12 months                             |

\* After 1 month of continuous operation

\*\* Refer to Section 1-6.

**TABLE 1-2 SPECIFICATIONS, FRS-N**

**ELECTRICAL**

|   |  |
|---|--|
| Amplitude (Sine):                               | 0.5 Vrms +30/-10% into 50 ohm resistive load                                     |
| Amplitude (TTL):                                | Low: 0 to +0.8V, High: +3.5 to +5.5V, into 50 Ohm resistive load.                |
| Accuracy Setting at Shipment:                   | ±5E-11 (25°C) (Accuracy after 1 year): 1E-9/Year                                 |
| Input Voltage Range:                            | 24 Vdc nominal (22-29.5 Vdc) (RTCA DO-160B, CAT A for voltage levels and spikes) |
| Power-steady State:                             | 12 W @ 24 Vdc at 25°C Base Plate   |
| At turn on:                                     | 2.0 A peak   |
| Steady state:                                   | 21 W @ 24 Vdc (circulated air, Base Plate ~45°C)                                 |
| Input Voltage Sensitivity:                      | 5E-11 (for ±10% Vdc)   |
| Warm-up Characteristics:                        |  |
| Time to lock @ 25°C:                            | 4 minutes  |
| @ -55°C   | 8 minutes  |
| Minutes/Freq @ 25°C:                            | 6 minutes/1E-9   |
| Long Term Drift:                                | ≤ 5E-11/Mo*, ±5E-10/Yr   |
| 1-Day Stability:                                | 1E-10/day**  |
| Short-Term Stability: (5 & 10 MHz outputs only) |  |
| 1.0 Second (Allan Var.)                         | 5E-11  |
| 10 Sec. (Allan Var.)                            | 1.58E-11   |
| 100 Sec. (Allan Var.)                           | 5E-12  |
| Phase Noise (SSB 1 Hz BW):                      | -70dBc/√Hz at 1Hz, -110dBc/√Hz at 100Hz,<br>-130 dBc/√Hz at 1 KHz                |
| Harmonic/Non-Harmonic Distortion:               | 10 MHz = -40 dBc/ -65 dBc;<br>5 MHz = -40 dBc/-60 dB                             |
| Frequency Trim Range:                           | ±1E-9 minimum  |

Frequency Retrace: 5E-11  
 Setting Resolution: 1E-11  
 Magnetic Field Sensitivity:  $\leq 4E-13/A \text{ m}^{-1}$  (worst case), (3E-11/gauss), CAT. A  
 Electrical Protection: Internal diode/fuse protects against reverse polarity connection. Rf output/BIT short-circuit protected

### ENVIRONMENTAL CONDITIONS (per RTCA DO-160B)

Temperature / Altitude: CAT. E1  
     Operating Temperature: -5°C ambient to +65°C baseplate (5E-10)  
                                   25°C + 25°C ambient ( $\pm 1E-10$ )  
     Storage Temperature: -55°C to +85°C  
     Altitude:  $\leq 70,000 \text{ ft. (21,300 m)}$   
     Magnetic Field:  $\leq 4E-13/AM^{-1}$  (3E-11/0.1 millitesla)

Temperature Variations: CAT. B, (5°C per minute minimum)  
 Humidity: CAT. A, (95 RH)  
 Shock Operational: 6 g, 11 ms  
 Crash Safety: 12 g, 11 ms  
 Vibration (sinewave): Curves M, N, O  
                                   1.5 g to 500 Hz  
                                   1.0 g to 1000 Hz

Explosion: CAT. E  
 Waterproofness: CAT. X  
 Fluids Susceptibility: CAT. X  
 Sand and Dust: CAT. X  
 Fungus: CAT. X  
 Salt Spray: CAT. X  
 Magnetic Effect: CAT. A  
 Power Input: CAT. A for steady state voltage levels and voltage spikes  
                   CAT. B for ripple susceptibility  
 Voltage Spike: CAT. A  
 Audio Frequency Conducted: CAT. B  
 Susceptibility - Power Input:  
     Induced Signal Susceptibility<sup>1</sup> CAT. A  
     Radio Frequency Susceptibility<sup>1</sup> CAT. A  
     Emission of Radio Frequency<sup>1</sup> CAT. A

### PHYSICAL CHARACTERISTICS

Size (inches, h / w / l): 2.0 x 3.0 x 4.0 (5.1 x 7.6 x 10.2 cm)  
 Weight: lbs/inches cubed: 1.2 / 24  
           kg/cm cubed: 0.55 / 395  
 Connectors : Mate with Cannon Series DAM11W1S  
 Baseplate Threads: (STD) 4-40 (M2.5 option)  
 Warranty: 12 months

\* After 1 month of continuous operation

\*\* Refer to Section 1-6.

## CHAPTER 2

### INSTALLATION AND OPERATION

**2.1 INTRODUCTION.** This chapter of the manual contains information regarding the installation and operation of the Efratom Model FRS. It is recommended that this chapter be read carefully prior to attempting operation of the unit.

**2.2 SHIPPING AND RECEIVING INFORMATION.** The Model FRS is packaged and shipped in a foam-packed container. The unit is 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 Corp., Efratom Division, 3 Parker, Irvine, CA. 92718. Telephone 714/770-5000; Telex 685-635; FAX 714/770-2463. 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 should be mounted with the thermal baseplate in contact with a flat metal surface (.005 inches rms or better). Mounting screws (4-40) 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.

The heat transfer characteristics of the mounting surface must be adequate to limit the rise of the unit's baseplate to  $< +65^{\circ}\text{C}$ . The allowable environmental temperature ( $T_a$ ), for this mounting is:

$$\begin{aligned} T_a &= 65^{\circ}\text{C} - V_s I_s R_k \\ \text{Where: } V_s &= \text{Supply Voltage in volts} \\ I_s &= \text{Supply Current in amperes} \\ R_k &= \text{Thermal Resistance between unit and ambient, }^{\circ}\text{C/watt).} \end{aligned}$$

**2.4 POWER REQUIREMENTS.** The Model FRS requires an external power source capable of providing between +22 and +30 Vdc, with a minimum of 2.5 ampere output. The positive input voltages for the unit is to pins 9 (electronics) and 6 (heater) with the negative return voltage on pin 10 of the connector.

In order to obtain the cleanest output signal close to the carrier, the maximum ac ripple on the supply voltage must be less than 1 mV peak-to-peak. If non-harmonics at the supply ripple frequency (50, 60, or 400 Hz) are not a consideration, 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, ( $+65^{\circ}\text{C}$  as measured at the unit's baseplate).

2-6. SIGNAL INPUTS AND OUTPUTS. Figure 2-1, illustrates the Model FRS Cannon connector J1, and presents a functional description of the pin connections.

| PIN       | DESCRIPTION  |
|-----------|--|
| Coax..... | RF Out/Shield  |
| 1.....    | Lock Monitor   |
| 2.....    | External Frequency Adjust (wiper of potentiometer)*                        |
| 3.....    | External Frequency Adjust (ground for potentiometer)                       |
| 4.....    | Lamp Monitor*  |
| 5.....    | Not Used   |
| 6.....    | Heater Power +24 Vdc   |
| 7.....    | Crystal Monitor (crystal control voltage)*                                 |
| 8....     | External Frequency Adjust (regulator monitor - positive for potentiometer) |
| 9.....    | Regulated Input Voltage (+24 Vdc)  |
| 10.....   | Power Return   |

\*Refer to Appendix B

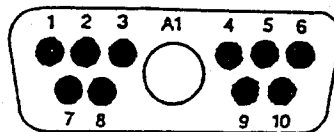


FIGURE 2-1. Cannon connector J1 Pin Arrangement

2-7. NORMAL OPERATION. When 24 Vdc is applied to pins 9 and 6(+) and 10(-), the unit will immediately begin generating a 10 MHz signal from the crystal oscillator. Within approximately 4 to 6 minutes after application of input power, the unit will "lock". The crystal is now stabilized by the atomic resonant frequency.

2-8. FUNCTIONAL OPERATION TEST EQUIPMENT. The 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. No. | ITEM                           | MINIMUM USE CHARACTERISTICS   | TEST EQUIP.           |
|-----------|--------------------------------|---|-----------------------|
| 2.1       | DC Power Supply                | Output Voltage: +22 to +30 Vdc  | Hewlett-Packard 6433B |
| 2.2       | DMM (Digital Multimeter)       | Voltage Range: 0 to 30 Vdc<br>Accuracy $\pm 1.25\%$ - Resistance Range: 0 to 150 ohm.           | Fluke 8020A or 8000A  |
| 2.3       | Freq. & Time Interval Analyzer | Ref. Freq. 10 MHz<br>Resolution: 1E-10  | Hewlett-Packard 5371A |
| 2.4       | Optional External Freq. Ref.   | Output Frequency: 10 MHz<br>Accuracy: $\pm 5E-12$<br>Stability: Parts in $10^{12}$ , or as req. | Cesium standard       |



**2.10 SHORT TERM STABILITY TEST (ALLAN VARIANCE)****NOTE**

If steps 2-9 through 2-9d have been completed, and the Allan Variance indications (as displayed on the HP-5371A) are of the required averaging times, the test results as indicated are valid. If 2-9 was not performed, continue with 2-10.

- a) With the equipment connected as shown in Figure 2-2, and the required stabilization time allowed, (refer to NOTE following 2-9b), begin the test.
- b) Allow sufficient time for the test set to display the data for the averaging times required, and verify that the UUT Allan Variance is within the tolerance listed in Table 1-1, SPECIFICATIONS.
- c) If no other tests are necessary, disconnect the test set-up.

## NOTE

Throughout the test procedures in this manual the FRS will be referred to as the UUT (Unit Under Test). In addition, connections described or illustrated pertain to the Cannon connector.

## 2.9 OPERATIONAL FREQUENCY ACCURACY TEST.

- a) Connect the equipment as shown in Figure 2-2.

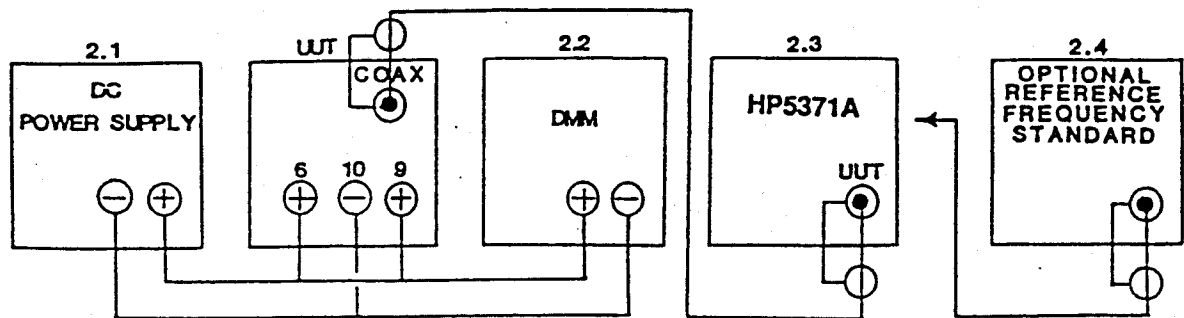


Figure 2-2. Operational Frequency Accuracy Test Setup.

- b) Adjust the DC power supply controls to obtain a  $24 \pm 1.4$  Vdc indication on the DMM. Allow sufficient time for equipment to stabilize.

## NOTE

The UUT requires 4 minutes (@ 25°C) to stabilize for the following frequency accuracy:  $\pm 1E-9$  (after 1 yr operation) of the final frequency (calibrated frequency), or the frequency before turn off, (providing turn off was within 24 hours). If the unit has been calibrated recently, the maximum frequency offset after 1 hour operation would be  $\pm 2E-11$  warmup accuracy,  $\pm 2E-11$  retrace. This assumes the last calibration was at the same ambient temperature.

- c) Begin the test (refer to Frequency & Time Analyzer or HP5371A manuals).
- d) Allow sufficient time for the test set 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 2-9b.

## CHAPTER 3

## THEORY OF OPERATION

**3.1 INTRODUCTION.** This chapter of the manual contains a general theory of operation and circuit analysis of the Model FRS Rubidium Standard. Schematic diagrams are included in the Appendix to help clarify the text.

**3.2 GENERAL THEORY.** The FRS generates a stable 10 MHz output frequency from a 20 MHz Voltage Controlled Crystal Oscillator (VCXO), whose frequency is locked to the atomic-standard "resonance frequency" of the rubidium atom (rubidium reference frequency). Figures 3-1 and 3-2 show how the standard works.

A microwave signal that is derived from the VCXO tuneable oscillator is applied to rubidium vapor contained within a heated glass cell. Light from a rubidium lamp is passed through the cell and illuminates a photo detector causing current to flow in the detector. As the applied microwave signal approaches the frequency that corresponds to the ultra-stable rubidium atomic resonance frequency, the rubidium light entering the glass cell is absorbed by the rubidium vapor to an increased extent causing a decrease in the photo detector current. This "darkening" effect is used to generate an error signal which permits continuous regulation of the quartz crystal oscillator output frequency, thereby locking it to the atomic-standard frequency.

**RUBIDIUM REFERENCE FREQUENCY.** The atomic-standard frequency ( $f_{Rb}$ ) used for reference is provided by the 6.834 GHz ground-state hyperfine transition of  $^{87}Rb$  (rubidium) atoms. The VCXO is locked to this frequency by means of a microwave signal ( $f_c$ ), generated from the 20 MHz VCXO output, having a frequency in the vicinity of  $f_{Rb}$ . The frequency synthesis and multiplication scheme is designed so that the VCXO frequency is exactly 20 MHz when the microwave frequency ( $f_c$ ) is equal to the rubidium reference frequency,  $f_{Rb}$ . The microwave signal excites vapor phase  $^{87}Rb$  atoms that are contained in the heated glass cell within the microwave cavity (resonator) (see Figure 3-2).

**RUBIDIUM LAMP.** Light from the rubidium lamp is generated by an rf-excited plasma discharge. Rubidium in the lamp is heated to a vapor state (approximately 106°C) and subjected to a high-energy rf field. This rf field causes a plasma discharge which produces rubidium light of the proper wavelength. The light passes through rubidium vapor contained in the resonance cell, where some of the light is attenuated. The remaining light is incident upon a silicon photo detector (photocell) within the resonator cavity. When the applied microwave frequency ( $f_c$ ) is equal to the hyperfine frequency,  $f_{Rb}$ , the rubidium atoms resonate with the microwave field in the cavity, causing the light reaching the photo detector to decrease. This decrease in light intensity is made possible by the simultaneous interaction of rubidium light and microwave energy, a process called "Optical Pumping". (This behavior is illustrated by the V-shaped curve in Figure 3-3.)

The darkening effect described above is used to generate the error signal that is processed by the servo (control) circuits to correct the VCXO frequency, maintaining a "locked" condition when the applied microwave frequency ( $f_c$ ) is equal to the hyperfine frequency  $f_{Rb}$ . Figure 3-1 is a block diagram of this process.

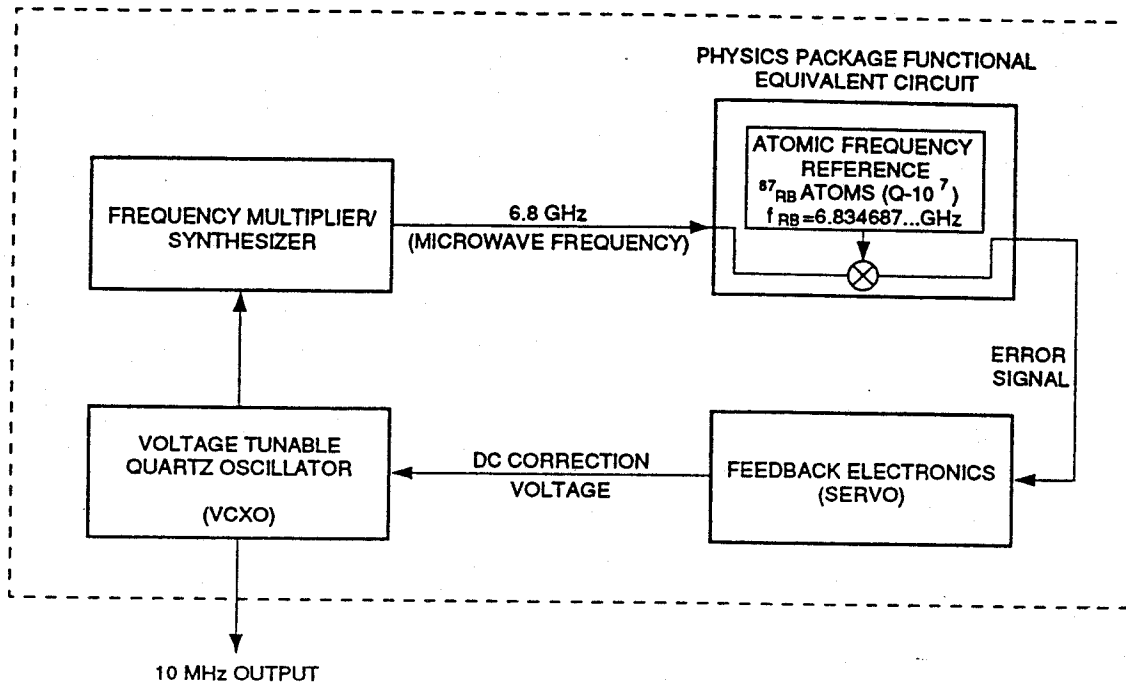
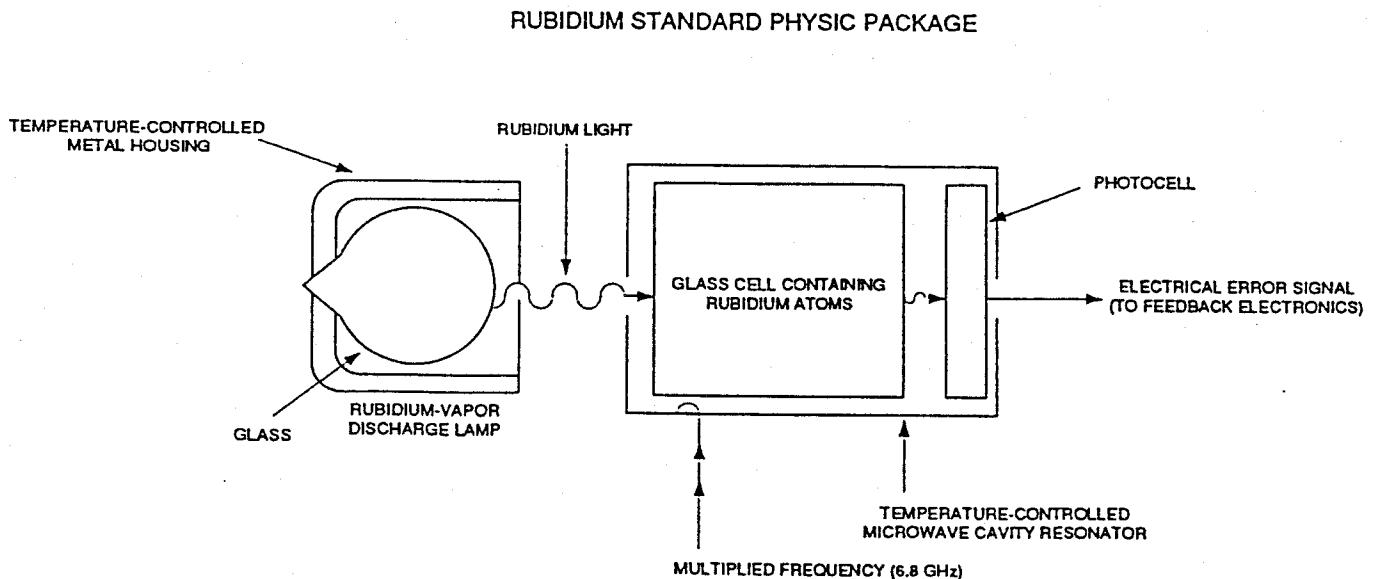


Figure 3-1. Simplified Block Diagram of Rubidium Atomic Standard



WHEN THE MULTIPLIED FREQUENCY EQUALS THE RUBIDIUM ATOM FREQUENCY, THE ERROR SIGNAL IS ZERO. WHEN THE TWO FREQUENCIES ARE DIFFERENT, AN ERROR SIGNAL IS GENERATED THAT IS USED TO "STEER" THE VCXO FREQUENCY TO THE CORRECT VALUE.

Figure 3-2. Simplified Block Diagram of Physics Package

**OPTICAL PUMPING.** The rubidium oscillator is a passive device in that the atoms themselves do not produce a self-sustaining microwave oscillation. The atomic resonance is detected passively by optical means and involves a process by which atoms are raised to a higher energy state through the absorption of light energy.

To understand how the optical darkening effect occurs, it is necessary to understand the atomic physics phenomenon called "Optical Pumping".

According to Planck's theory, when radiation is absorbed or emitted by an atom, the energy is absorbed or emitted in whole packets, or quanta, called photons. Atoms therefore exist only at specific energy levels.

For rubidium the lowest two energy levels are called the ground-state hyperfine levels and are denoted by A and B in Figure 3-4. The rubidium atoms will ordinarily be equally divided between these two levels (Figure 3-4-I). If the atoms are irradiated with microwave energy at the hyperfine frequency, then the atoms at level A will make a transition to level B and vice-versa, without changing the overall distribution between the two levels (Figure 3-4-II). This transition takes place at the hyperfine frequency of rubidium, ( $f_{Rb}$ ). The hyperfine frequency is related to the hyperfine energy level separation by a fundamental equation of physics:

$$E_{Rb} \text{ (joules)} = h f_{Rb},$$

where  $h$  = Plank's Constant =  $6.626 \text{ E-34}$  joules/Hz.

A third and much higher energy state, level C, also exists which is normally vacant. Level C is excited by infrared light energy of the proper wavelength from the rubidium lamp (Figure 3-4-III). Transitions to level C are known as "optical transitions" and can occur from either of the two hyperfine energy levels A or B. After a short time ( $\sim 25$  nsec), the atoms which were raised to the C level will emit a photon of approximately the same wavelength as the original photon. They then return to the ground state hyperfine level, redistributing themselves approximately equally between levels A and B (Figure 3-4-IV).

If the spectral wavelength corresponding to only one of the hyperfine levels is introduced, level A for example, only the atoms at that hyperfine level will make the transition to level C (Figure 3-4-V). This condition is generated by filtering out the spectral wavelength corresponding to the other hyperfine level, B. In rubidium oscillators manufactured by EFRATOM, an isotope of rubidium  $^{85}\text{Rb}$ , mixed with the  $^{87}\text{Rb}$  in the resonance cell, performs the filtering function.

As the filtered light energy passes through the resonance cell, level A to C transitions occur so that the rubidium atoms excited to the C level emit photons and return to the ground state redistributing themselves equally between levels A and B (Figure 3-4-VI). The atoms which return to level A will again absorb light and be raised to level C, where they will remain for a short time before emitting a photon and again redistributing themselves between the two levels A and B. As this process continues, eventually there will be no atoms left at level A to be excited to level C (Figure 3-4-VII). The atoms will stay at level B because the filtered

light is not the proper wavelength to excite them to level C. By this process all of the atoms are pumped to hyperfine level B, producing a population difference between the two hyperfine levels, A and B.

Once all the atoms are pumped to level B, and in the absence of the correct microwave energy, light is no longer absorbed and passes unattenuated through the resonance cell.

When a microwave field with frequency corresponding to the hyperfine frequency is applied, the atoms at level B make the transition to level A and vice-versa. However, due to optical pumping, when the atoms from level B make the transition to level A they are also available for excitation to level C by the light beam. Since each excitation of an atom at level A is accompanied by the absorption of a light photon, the net effect of applying the microwave field at the hyperfine frequency is to cause continued attenuation of the light beam. (It should be mentioned that when Rb atoms absorb photons and subsequently make  $C \rightarrow A$  or  $C \rightarrow B$  transitions, the re-emitted photons are emitted with equal probability in all directions so that most of these photons never reach the photo detector. Thus, a photon originally removed from the light beam is replaced by a photon that, in most cases, is not detected.) Figure 3-4 illustrates the Optical Pumping process.

**ELECTRONIC ANALOGUE.** The operating behavior of the physics package can be viewed in its simplest form as a high-Q series-resonant tank circuit that is resonant at the hyperfine frequency (6.8 GHz). (See Figure 3-5.) The voltage source driving the tank is the microwave frequency ( $f_c$ ) derived from the 20 MHz VCXO, and the LCR components are the rubidium atoms contained in the optical package. Figure 3-5 includes the effects of modulation, which are described below.

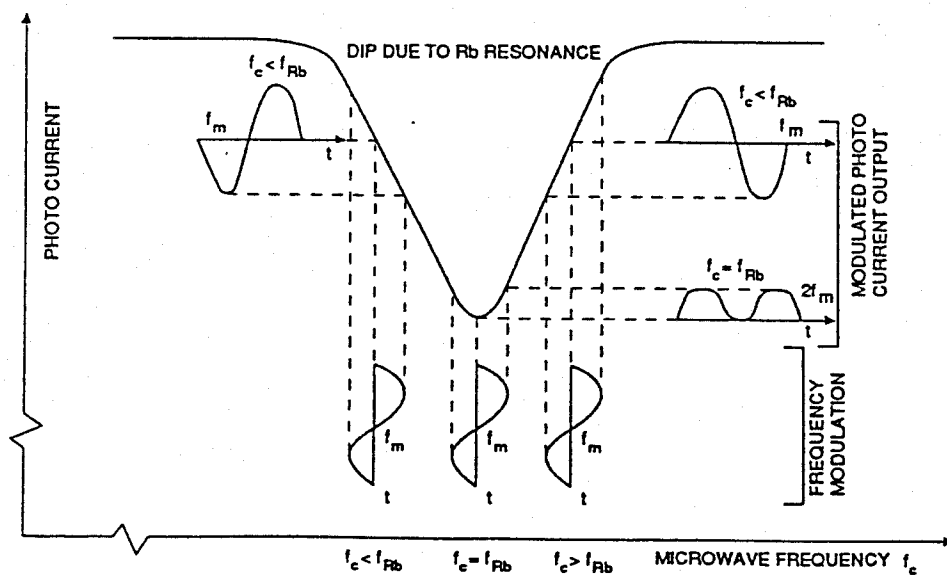
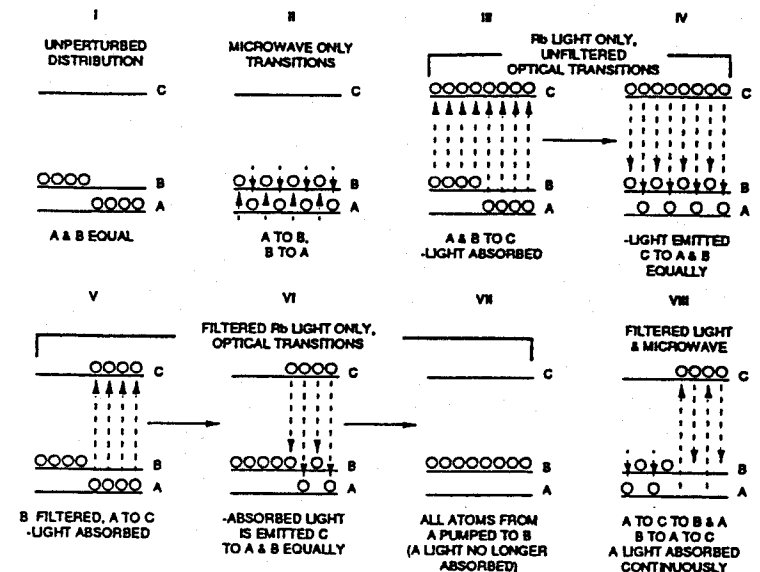


Figure 3-3. Derivation of Modulation Signal

**FREQUENCY MODULATION.** Because of the small changes in detected light intensity ( $\leq 0.1\%$ ) that are associated with locking the VCXO to the rubidium reference frequency, an ac detection scheme is used. The advantage of an ac detection scheme compared to a dc



NOTE:  
 ACTUAL OPERATION IS SHOWN IN FRAME VIII AND IS A STEADY-STATE PROCESS, STARTING FROM FRAME VII, WHEREBY THE PHENOMENA IN FRAMES V AND VI OCCUR SIMULTANEOUSLY AND CONTINUOUSLY:

- 1) B TO A (MICROWAVE TRANSITION)
- 2) A TO C (OPTICAL TRANSITION)
- 3) C TO B (REDISTRIBUTION)

} OPTICAL PUMPING

- 4) DETECTION OF MICROWAVE TRANSITION BY CONTINUOUS LIGHT ABSORPTION DURING OPTICAL PUMPING

Figure 3-4. Optical Pumping Process.

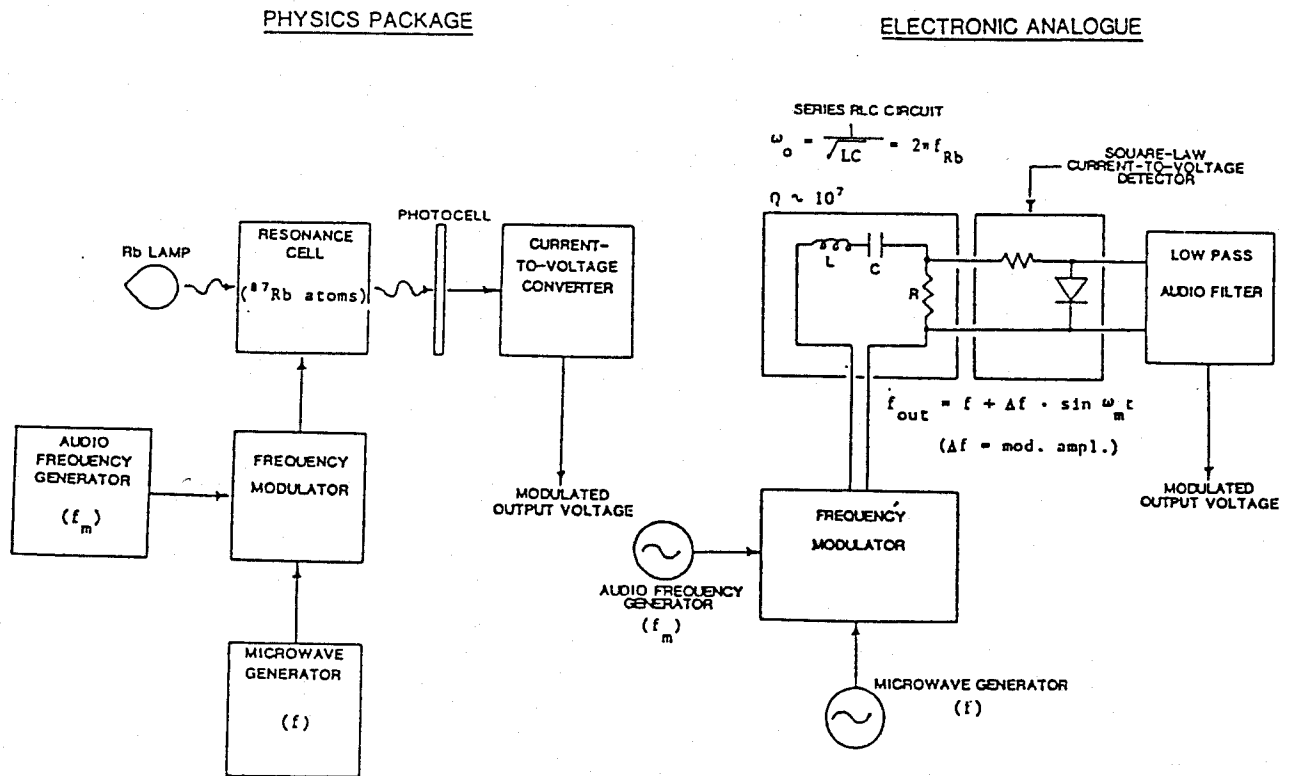


Figure 3-5. Electrical Analogue of Physics Package.

detection scheme is that small signal changes are not obscured by dc drifts. In order to generate the ac error signal for VCXO frequency correction, the microwave signal is frequency modulated. As the modulated microwave frequency approaches the hyperfine frequency, the light from the rubidium lamp varies in intensity at the modulation rate. The variation in the light intensity is very small, only about 0.1% of the overall intensity of the light. The photocell within the cavity detects the small variation in light intensity and a preamp circuit on the resonator board amplifies the signal and sends it to the servo circuits.

**RESONANT SIGNAL.** By modulating the microwave signal injected into the resonator at 127 Hz, the light striking the photocell, and therefore the output current, varies at 127 Hz as the microwave frequency approaches the hyperfine frequency (Figure 3-2). The servo circuits use this signal to generate a continuous correction signal for the VCXO.

When the microwave frequency ( $f_c$ ) in the resonator is exactly equal to the hyperfine frequency ( $f_{Rb}$ ), the 127 Hz modulation varies the microwave signal around the center of the absorption curve, resulting in a modulation of the photocell current at twice the modulation frequency, or 254 Hz (Figure 3-3). 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 microwave signal,  $f_c$ , which is synthesized from the 20 MHz VCXO, drifts off the hyperfine frequency,  $f_{Rb}$ , the photocell output reverts to the fundamental 127 Hz rate. The phase of the 127 Hz indicates if  $f_c$  is above or below  $f_{Rb}$  and this phase information is used to move the VCXO frequency in the proper direction until  $f_c$  again equals  $f_{Rb}$ .

**3.3 DETAILED CIRCUIT DESCRIPTIONS.** Figure 3-6 (and the interconnect/wiring diagram in Appendix A) illustrate the interconnections of the flex board, physics package and the associated circuitry and circuit board assemblies that comprise the rubidium frequency standard.

The two main assemblies of the FRS are the PHYSICS PACKAGE assembly and the FLEX BOARD assembly. The Flex Board interconnects four printed circuit boards (PCBs): the SERVO BOARD, the CRYSTAL OSCILLATOR BOARD, the MULTIPLIER BOARD and the POWER SUPPLY BOARD (refer to the interconnect wiring diagram in the Appendix).

**3.3.1 THE PHYSICS PACKAGE.** The function of the Physics Package is to provide the standard frequency reference and the error signal. The error signal is processed by the servo board to stabilize the frequency of the crystal oscillator.

The Physics Package has two main sub-assemblies: the LAMP ASSEMBLY and the RESONATOR ASSEMBLY. The entire physics package is enclosed in a mu-metal container to shield the resonant cell from magnetic fields.

**THE LAMP ASSEMBLY (A2 & A7).** The function of the Lamp Assembly is to generate rubidium light that contains the desired spectral lines of Rb necessary for the process of interrogating the atomic standard frequency. The lamp circuits ignite the Rb lamp and thermostatically control the lamp housing temperature at approximately 106° C (223° F), which is required to maintain the proper Rb vapor pressure in the lamp envelope.



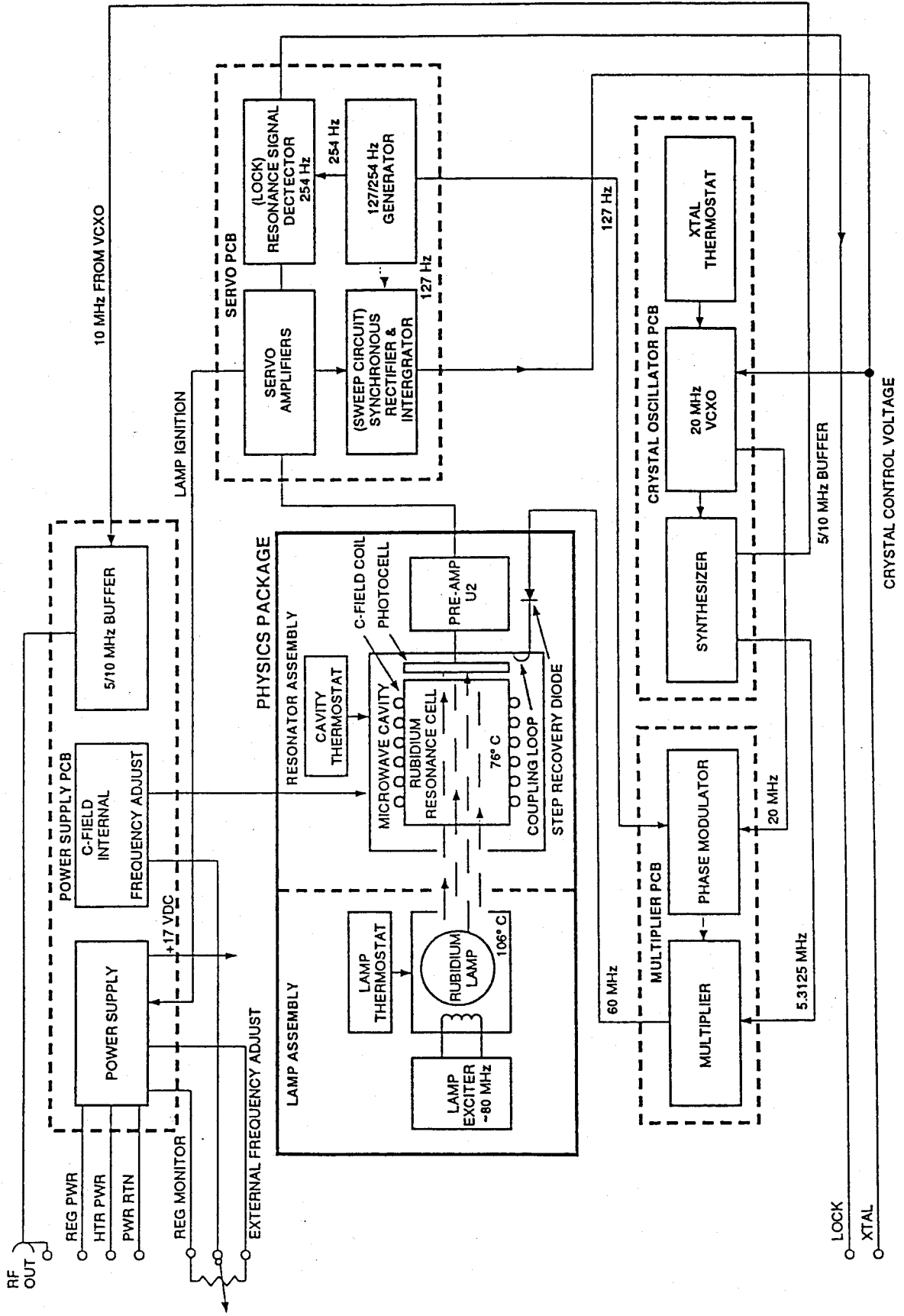


Figure 3-6. Detailed Block Diagram, FRS.

a. The Rb lamp oscillator circuit on the A2 and A7 boards is an adjustable 70 to 100 MHz modified Colpitts oscillator and rf transistor Q3 is the active element. CR1 provides temperature compensation for the ac biasing of Q3. R10 and R11 set the oscillator bias and R12 provides dc bias stabilization. C11 is adjusted to tune the circuit to the desired output frequency, while C7, C8 and C9 are rf bias caps. L5 is a frequency determining element. The remaining passive elements provide rf filtering for the power input.

The lamp oscillator ignites and maintains an electrode-less plasma gas discharge in the rubidium lamp that is mounted in the oscillator's tank circuit, C11 and L6. L6 is a step-up auto-transformer that provides a high voltage for rapid lamp ignition at turn-on.

b. The Rb lamp is mounted in a temperature-controlled housing. Q1 is mounted on the housing and acts as the heating element. Thermistor RT1 is the temperature sensor embedded in the housing and with R1 forms one side of a bridge circuit. R2 and R3 form the other side. U1 is the amplifier that senses the bridge balance and controls the heater Q1 accordingly. Q2 senses the voltdrop across R9 and limits Q1 current flow by reducing base current. R1 selects the desired operating temperature. See section d. RESONATOR HEATER CIRCUIT below for a more detailed analysis of heater controller operation.

**THE RESONATOR ASSEMBLY (A6).** The Resonator assembly consists of the Resonator board and the Resonator cavity. The cavity is constructed of mu-metal and contains the resonant cell and C-field coil. A heater ring surrounds the cavity and provides its mounting. The lid assembly on the cavity contains the photocell, step recovery diode, and a feed-through capacitor. Cavity temperature of about 74° C is maintained by the resonator heater control circuit. (See Figure 3-4).

a. **THE PHOTOCCELL PREAMP.** The resonant signal is detected by the photocell CR2 which provides a variable current signal to the preamplifier U2 on the Resonator board. The signal is routed through the "flex" board to the Servo circuits that use this signal to correct the VCXO. This "lamp volts" signal also controls the power supply voltage.

b. **STEP RECOVERY DIODE (CR1 - refer to Multiplier [A5] schematic)** . The step recovery diode is a varactor (voltage variable capacitance) diode designed for frequency multiplication. When the diode is forward-biased and is switched to reverse bias, most of the stored charge is released as a high pulse of reverse current, producing a steep waveform rich in harmonics.

A 60 MHz signal from the multiplier and a 5.3125 MHz signal from the VCXO are mixed on the multiplier board and then are applied to CR1 within the cavity. When CR1 conducts, it produces the harmonics of the 60 MHz and 5.3125 MHz mixed signals. The resonator cavity and loop are tuned to select the 114th harmonic which corresponds to the resonant frequency of the rubidium.

c. **RESONATOR COIL (A6).** The resonator "mag field" coil is wound on the rubidium cell and provides a magnetic field (the C-field) within the resonator cavity. This magnetic field functions as a fine tuning mechanism by changing the hyperfine transition frequency through what is called the "Zeeman effect"; the splitting of a spectrum line of light into several symmetrical components, which occurs when the source of light is placed in a static magnetic field. The "C-field" strength is determined by the current through the coil. The current is summed from the following sources:

**FIXED:** R13 on the Power Supply board (A3) supplies current directly to the coil.

**MANUALLY-CONTROLLED:** R14 on the Power Supply board supplies an adjustable voltage which is fed to U1 and R20 on the Resonator board. External (remote) frequency adjustment is possible by applying a 0 to 5 Vdc voltage source to P1, pin 2. (See the Power Supply schematic in the Appendix).

**COMPENSATION:** The Resonator heater (A6 assembly) current varies inversely with the ambient temperature. This condition is used to provide compensation for frequency shifts that occur due to ambient temperature changes. The voltdrop across R19 in the resonator heater circuit is used to detect the changes and is processed thru U1 and R27, or thru R12, into a temperature variable current. This current adjusts the magnetic field to compensate for the ambient temperature changes. The current is passed thru Power Supply board select-in-test resistor A3 R12 for accessibility to change the current magnitude as necessary. Positive compensation is achieved through U1 and R27 and negative compensation is achieved through R12.

d. **RESONATOR HEATER CIRCUIT (A6).** The operation of the resonator heater and its control circuits is typical of the other heater circuits in the unit. The heating elements are Q1 and Q2 which are mounted on the heater ring that surrounds the resonator cavity. The temperature sensing element, thermistor A6 R21, is embedded in the heater ring. Its resistance drops from about 10K Ohms at room temperature to less than 1K Ohm at 74°C. The remaining circuitry is mounted on the Resonator and Power Supply circuit boards.

U1 is an Op Amp with a resistive bridge network on its inputs. On one side of the bridge are fixed resistors R2 and R3. On the other side of the bridge are the thermistor R21, resistor R22 and select-in-test resistor A3 R15 on the Power Supply board, which adjusts the temperature of the Resonator.

When power is turned on the bridge is unbalanced causing the Op Amp U1 output to turn Q2 on full. This causes the voltage at the collector of Q2 to drop, turning Q1 on full. Q3 functions as a current limiter for the heater circuit. The current thru Q1 and Q2 passes thru R19 causing a voltdrop. When the voltdrop exceeds the Q3 base to junction voltage, Q3 turns on. Some of the current from the Op Amp is now diverted thru the Q3 collector to ground instead of thru the base of Q2, thus limiting the Q1 and Q2 current flow.

By selecting the resistance value of A3 R15, the Op Amp will drive the resonator heaters until the desired temperature is attained. At this point, the voltage at the R21 and R22 junction will equal the voltage at the R2 and R3 junction and the bridge will be balanced.

With the bridge balanced, the circuit regulates the power to the heater transistors, thereby maintaining the resonator at the temperature selected by A3 R15. In order to control temperature overshoot, a portion of U1, pin 1 output is fed back to the input. This slows down the rate of change sensed at the input during rapid transitions by reducing the U1 pin 2-3 difference. U1 pin 6 senses the current through the heater by detecting the voltage drop across R19 for temperature compensation as outlined in c. above. The R7, R8 divider limits the heater current when higher input voltages are present to keep the maximum heater power relatively constant.

3.3.2 SERVO BOARD ASSEMBLY (A1). The primary function of the servo circuits is to process the error signal received from the resonator preamp at J1 pin 3 to provide the crystal control voltage for the 20 MHz VCXO at J1 pin 4. The control voltage is derived by comparing the phase of the 127 Hz modulation signal with the phase of the photocell signal at J1 pin 3. The secondary function is to provide the atomic resonance lock signal at J1 pin 8.

a) 127 AND 254 Hz REFERENCE SIGNALS. The CMOS oscillator/divider U4 on the servo board provides the 127 and 254 Hz reference signals. The oscillator frequency of 8.128 KHz is determined by C22, R13 and select-in-test resistor R12. The divider portion of U4 divides the oscillator frequency into the required 127 and 254 Hz signals. The 127 Hz reference signal is routed from U4 pin 4 to pin 9 of synchronous demodulator U3; and to the input of U2, pin 2 through the RC network R36, C38. The RC network R36, C38 in addition to the feedback network R37, C37 and the output RC filters (R41, R42, and C41 on the servo board; R8, C7, and C8 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 U4 pin 5 to pin 10 of synchronous demodulator U3. The 254 and 127 Hz reference signals control the timing of analog switches in the synchronous demodulator.

b. MODULATION ERROR SIGNAL. The modulation error signal received at the photocell is preamplified on the resonator board (see Figures 3-2 and 3-7) and received at the servo (A1) input J1, pin 3. The signal is then routed through three capacitively coupled amplifier stages (U1 in pin 13, out pin 14; U1 in pin 9, out pin 8). The resultant signal is then routed to U3, pin 3 and also U1, pin 6 where it is further amplified and output from pin 7 to U3, pin 2.

c. SYNCHRONOUS DEMODULATION. The amplified modulation signal received at U3, pin 3 is subsequently demodulated at a 127 Hz rate. See Figure 3-3,  $f_m$ . The resulting demodulated output (U3, pin 4) can be observed at TP1 on the flex board. See Figure 3-7. The TP1 output signal is the result of synchronous demodulation and contains both phase and amplitude information, indicating whether above, below or "on" the rubidium frequency. The further amplified signal received at U3, pin 2 is demodulated at a 254 Hz rate. See Figure 3-2,  $2f_m$ . The resulting output (U3, pin 15) is a positive 1/2 cycle of the 254 Hz,  $2f_m$ .

signal received when "on frequency" during normal operation. This "lock" signal is used as input to the second harmonic lock circuit.

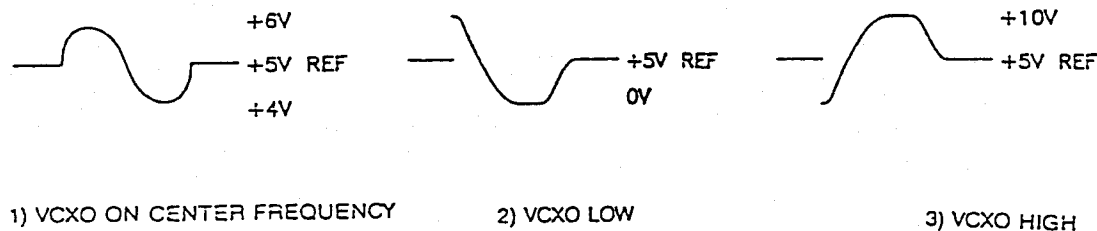


FIGURE 3-7. TP1 Phase and Amplitude Indications.

d. INTEGRATOR U5. U5 Functions as an integrator whose output voltage fluctuates at a rate proportional to the input voltage. As an example, an input differential of 1000 mV causes an output voltage change of 500 mV per second. The changes will continue until the differential input is nullified by bringing the crystal back to center frequency, or until the Op Amp reaches its maximum or minimum output voltage. The output of integrator U5 is the crystal control voltage used to control the frequency of the VCXO via a varactor diode (crystal oscillator CR1). A portion of the integrator output is also routed to the sweep control circuit at U1, pin 3.

e. SWEEP CONTROL CIRCUIT. U1, pins 1, 2, and 3 is a high hysteresis switch and controls the sweep range. Its output is either low (about 0.5 Vdc) or high (about 10.5 Vdc). When no "lock" signal is present (+10 Vdc on U3, pin 11), the output of U1, pin 1 is routed to the integrator input (U3 pin 14) via U3, pin 13. Diode CR2 clamps the U1 output to the 5 Vdc reference voltage resulting in a slow down sweep of the crystal control voltage of about 250 mV per second. When the output of U1 goes low, the differential voltage on the integrator is about 5 Vdc, resulting in an up sweep of about 2.5 V/sec. The hysteresis of U1 pins 1, 2 and 3 is set by R23, R24 and the reference voltage on pin 2. The switch changes state when the voltage on pin 3 goes higher or lower than the reference voltage on pin 2. The upper threshold is set at about 12 Vdc crystal control voltage, the lower at about 1 Vdc.

When the crystal volts signal reaches approximately 12 volts, U1, pin 1 is driven high (+10.5 V). This voltage however, is limited by the R25, CR2 clamping circuit to approximately 5.5 volts. The integrator will sense about 500 mV differential and sweep down at about 250 mV/sec. When it reaches below the 1 volt low switch level of U1, the U1 output switches low and the crystal control voltage will sweep up at about 2.5 V/sec completing the cycle. Sweeping continues until "Lock" occurs. (U3, pin 11 becomes low).

f. LOCK CIRCUITS. The lock circuit uses the positive 1/2 cycle (254 Hz) lock loop signal by integrating it through R29, C32 to a DC level. If the second harmonic is of significant amplitude (approximately 200 mv peak-to-peak), U6, pin 7 will drive low.

This low signal discharges C30 thru R28 to produce a low at  $\bar{U}3$ , pin 11. "Lock" then disables the sweep circuit by disconnecting U3, pins 13 and 14 and connecting U3 pins 12 and 14.

This switching places the integrator under fundamental loop control.

A long range (1 Hz) capture circuit functions in much the same way as the lock circuit. When the integrator is in a down sweep, the first detection of atomic resonance will be a very high positive 1/2 cycle VCXO signal. This TP1 signal is integrated by R27, C31 to a DC level. If the fundamental is of sufficient amplitude (approximately 200 mV peak-to-peak), U6, pin 1 will drive low and the lock will function as explained in the preceding paragraph.

The lock amplifier (output U2, pin 7) is designed to allow jumpers for selection of "high" or "low" lock output signals at J1 pin 8. This signal is then routed thru the buffer stage of the power supply to the external connector.

**3.3.3 CRYSTAL OSCILLATOR (A4) (VCXO).** The main elements of the VCXO are the crystal Y1, the oscillator IC U1 and the varactor diode CR1. The board also contains a thermostat circuit and a frequency divider/synthesizer. The 20 MHz AT Cut 3rd overtone crystal is temperature controlled by the thermostat circuit. Q3 functions as the heater element, RT1 as the temperature sensor, Q4 as the gain element. Q2 limits the maximum heater current during turn on.

The 20 MHz signal from the oscillator IC U1 is buffered by Q1 and converted from a TTL compatible signal to a sine wave. This signal drives the multiplier.

The complimentary 20 MHz signal from U1 (HC 320) is fed to the divider IC U2. A 5 or 10 MHz signal from U2 (HCT 393) is selected and fed to the output buffer located at the power supply PCB. The standard configuration of the oscillator PCB is for a 10 MHz output. In this case, no jumpers (JP1, 2 and 3) are needed.

For the 10 MHz sine output signal, L4 and C17 suppress sub-harmonics generated by the divider IC.

The 5 MHz and 312.5 KHz signals from the divider are added by an "exclusive OR" gate, U3 (HC 86), to provide the 5.3125 MHz synthesis signal for the multiplier output. To provide maximum isolation between the oscillator and the synthesizer IC's, two separate 5 volt regulators VR1 and VR2 are used.

**3.3.4 MULTIPLIER (A5).** The multiplier utilizes the 20 MHz sinewave signal from the VCXO to generate a 60 MHz signal for the resonator. The 5.3125 MHz signal is summed into the final stage. These summed signals are routed to a step recovery diode in the resonator where they are in turn mixed and multiplied to the 6.834 MHz signal ( $f_c$ ). A tripler consisting of Q1 and Q2 multiplies the 20 MHz signal to a 60 MHz signal. Q1 wave shapes the 20 MHz sinewave into a specific positive pulse. These pulses are amplified by Q2 to ring the tuned (60 MHz) collector tank. The DC voltage at the Q2 emitter provides DC bias for Q1 and maintains constant amplitude.

A second stage (CR1, T1 and associated circuitry) forms a modulator for the 127 Hz modulation signal from the servo. This sinewave signal is routed to CR1 (a varicap diode). This diode capacitance varies at the fundamental 127 Hz rate and forms a tuned tank with the primary of T1. The tank reactance then phase modulates the 60 MHz which is then coupled to the driver stages. The 60 MHz drivers consist of two (Q4 and Q5) capacitively coupled amplifier stages, tuned to 60 MHz. The output stage tank (Q5), is a step-down impedance matching transformer tuned to 60 MHz.

The 5.3125 MHz signal synthesized from the crystal board is received through R28 and C21 into the L6, C22 tank which is tuned to 5.3125 MHz. The resulting sinewave signal is then coupled through C23 and L7 and summed into the 60 MHz output of the multiplier.

**MULTIPLIER AGC.** The step recovery diode produces a dc bias voltage through rectification of the rf across its terminals in the process of generating harmonics. This dc bias voltage is adjusted by R30, which helps to tune the diode circuit to produce the optimum resonance in the resonator cavity. The step recovery voltage across R30 is monitored by U1 and compared to the reference voltage set by R25, R27 and the pot R24 for automatic gain control (AGC) of the Q4 stage. The output of U1 changes the bias of Q4 to keep the step recovery voltage constant. The initial setting of the multiplier is done with the AGC inoperative by installing jumper TP1 to TP2 and by turning R24 fully counter clockwise.

**3.3.5 POWER SUPPLY.** An 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 unit operation. The power supply board also houses the RF output buffer and the lock indicator buffer. The input voltage line is fuse and diode protected against reverse polarity inputs.

a. **+17 VDC REGULATED POWER SUPPLY.** The +17 Vdc power supply consists of Q1, Q2 and U1 along with the components in their respective circuitry mounted on the power supply board. Pass transistor Q1 is heat sunked to the baseplate. Refer to drawing No. 814-144 for a pictorial view of pass transistor Q1.

b. **POWER SUPPLY OPERATION.** After power is initially applied, Q1 receives sufficient voltage from Q2 (FET) to go to forward bias. Its output then rises toward the input supply and supplies power to U1. CR5 is reversed biased as the +17V line increases, until it achieves zener operation. The +17 V forces U1, pin 7 high and is applied to Q2 which increases voltage to Q1. As +17V is approached, CR5 regulates to a 6.4V reference and R5, R6 divider senses any input error for regulation. R6 sets the regulated voltage.

c. **LAMP SWITCHING CIRCUIT.** The power supply board accepts the +22 to +32 Vdc input voltage at P1 pin 9, and provides +22 Vdc until the Rb lamp lights, at which time the power supply is switched to +17 Vdc. The switching occurs when U1, pin 3 receives a lamp voltage (P1 pin 9) exceeding the 6.4 V reference on pin 2. The output of U1, pin 1 is high if lamp ignition is normal. The positive voltage reverse biases CR5, and this effectively removes R7 from the circuit. This sets the condition for the power supply output to be lowered to the +17 Vdc required for the internal circuits of the unit by the R5, R6 voltage

divider. Improper lamp ignition grounds CR4 which in turn places R7 parallel to R6. R7 now selects +22V as the regulator output.

d. **RF OUTPUT BUFFER.** The Q3 circuit is an RF output buffer designed to accept 5 or 10 MHz TTL inputs. Tabulated values are selected for sine output or TTL square wave output. The RF output signal is referenced to chassis ground.

e. **LOCK SIGNAL BUFFER.** The Q4 circuit buffers the lock signal from the servo board lock amplifier output at A1, U2, pin 7 and provides a TTL output high or low to the external connector P1, pin 1. The output is high or low when the unit is locked depending on the jumper selection at the servo board A1, U2, inputs 6 and 7.

f. **C-FIELD TUNING.** The power supply PCB contains select resistor R13 that sets the C-Field bias current. This current is fixed and should only be changed if the physics package is replaced, or if after years of operation it is necessary to recenter the C-Field tuning range.

The ten-turn potentiometer, R14, allows fine tuning of the output frequency over a range of  $\pm 1E-9$ . The output frequency can also be controlled by means of an external 1Kohm potentiometer. The power supply schematic shows the connection of this external potentiometer to main connector pins 2, 3, and 8. This potentiometer overrides the internal pot R14. The trim range of the external potentiometer is similar to the internal trim range; resolution depends on the potentiometer used.



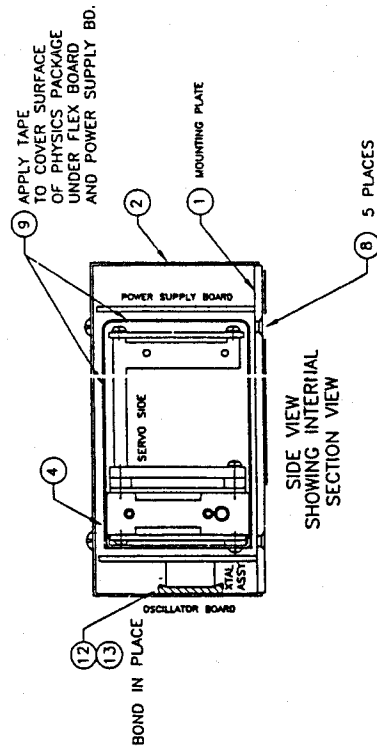
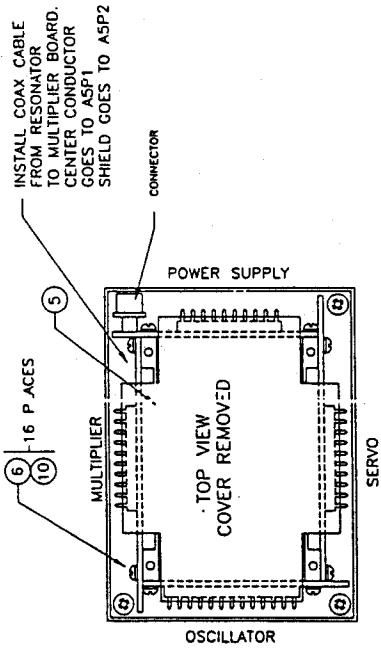
# APPENDIX A

FRS ASSEMBLY DRAWINGS, SCHEMATICS, & PARTS LISTS

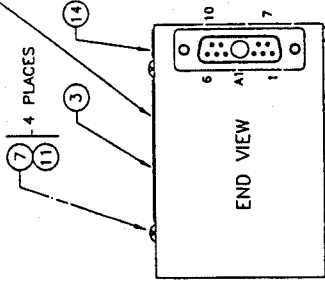
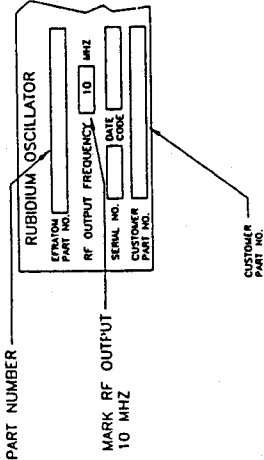
## APPENDIX

## LIST OF FRS DRAWINGS

| DWG NO.     | ASSY. | DESCRIPTION                             | PAGE NO.  |
|-------------|-------|---|-----------|
| 100318      |       | FINAL ASSEMBLY                          | A-2       |
|             |       | PARTS LIST, FINAL ASSEMBLY              | A-3       |
| 100308      |       | OUTLINE/MOUNTING DRAWING                | A-4       |
| 100339      | A8    | ASSEMBLY, FLEX BOARD                    | A-5       |
|             |       | PARTS LIST, FLEX BOARD ASSEMBLY         | A-6       |
| 814-133     |       | INTERCONNECT WIRING DIAGRAM             | A-7       |
| 814-112     | A2/A7 | ASSEMBLIES, LAMP/SUPPORT BOARDS         | A-8       |
| 814-114     |       | SCHEMATIC, LAMP BOARD                   | A-9       |
| PL814-113   |       | PARTS LIST, LAMP BOARD ASSEMBLY         | A-10      |
| PL814-112   |       | PARTS LIST, SUPPORT BOARD ASSEMBLY      | A-11      |
| 814-122     | A6    | ASSEMBLY, RESONATOR BOARD               | A-12      |
| 814-123     |       | SCHEMATIC, RESONATOR BOARD              | A-13      |
| PL814-122   |       | PARTS LIST, RESONATOR BOARD ASSEMBLY    | A-14      |
| 814-144-3   | A3    | ASSEMBLY, POWER SUPPLY BOARD            | A-15      |
| 814-142     |       | SCHEMATIC, POWER SUPPLY BOARD           | A-16      |
| PL814-144-3 |       | PARTS LIST, POWER SUPPLY BOARD ASSEMBLY | A-17,-18  |
| 814-145-2   | A1    | ASSEMBLY, SERVO BOARD                   | A-19      |
| 814-140     |       | SCHEMATIC, SERVO BOARD                  | A-20      |
| PL814-145-2 |       | PARTS LIST, SERVO BOARD ASSEMBLY        | A-21, -22 |
| 814-192     | A4    | ASSEMBLY, OSCILLATOR BOARD              | A-23      |
| 814-201     |       | SCHEMATIC, OSCILLATOR BOARD             | A-24      |
| PL814-192   |       | PARTS LIST, OSCILLATOR BOARD ASSEMBLY   | A-25      |
| 814-167     | A5    | ASSEMBLY, MULTIPLIER BOARD              | A-26      |
| 814-168     |       | SCHEMATIC, MULTIPLIER BOARD             | A-27      |
| PL814-167   |       | PARTS LIST, MULTIPLIER BOARD ASSEMBLY   | A-28, -29 |



MARK PART NUMBER



| PRODUCTION ASSEMBLY NO. | MODEL PART NO. | BASEPLATE ITEM-1 | SIZE REF | FLEX BOARD ASSEMBLY ITEM-5 | FREQUENCY RF OUTPUT |
|-------------------------|----------------|------------------|----------|----------------------------|---------------------|
| 100318-001              | FRS-1A8A       | 814-104-2        | 4-40     | 100339-001                 | 10MHZ SINE          |
| 100318-002              | FRS-2A8A       | 814-104-2        | 42.5     | 100339-001                 | 10MHZ SINE          |
| 100318-003              | FRS-1A8C       | 814-104-1        | 4-40     | 100339-002                 | 10MHZ TTL           |
| 100318-004              | FRS-2A8C       | 814-104-2        | 42.5     | 100339-002                 | 10MHZ TTL           |
| 100318-005              | FRS-1A8F       | 814-104-2        | 42.5     | 100339-003                 | 2.049MHZ TTL        |
| 100318-006              | FRS-2A8F       | 814-104-2        | 42.5     | 100339-003                 | 2.049MHZ TTL        |
| 100318-007              | FRS-1A8G       | 814-104-1        | 4-40     | 100339-004                 | 5MHZ SINE           |
| 100318-008              | FRS-2A8G       | 814-104-2        | 42.5     | 100339-004                 | 5MHZ SINE           |

USE TEST PROCEDURE NO. ATP14-100 WHEN TESTING FOR AVAILABILITY.

NOTES-UNLESS OTHERWISE SPECIFIED

FRS

BALL, EFRATOM DIVISION      CONTRACT No.      CAGE CODE 55761      100318-001      REVISION LTR. B  
 TITLE: PARTS LIST, FINAL ASSEMBLY, FRS      REVISION DATE 91-5-15

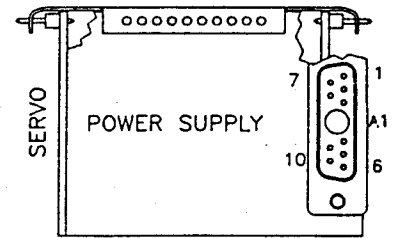
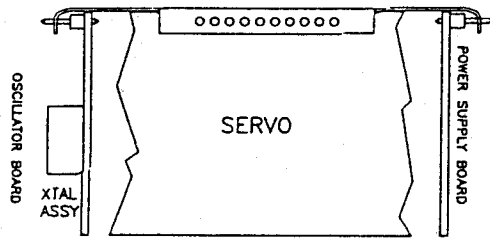
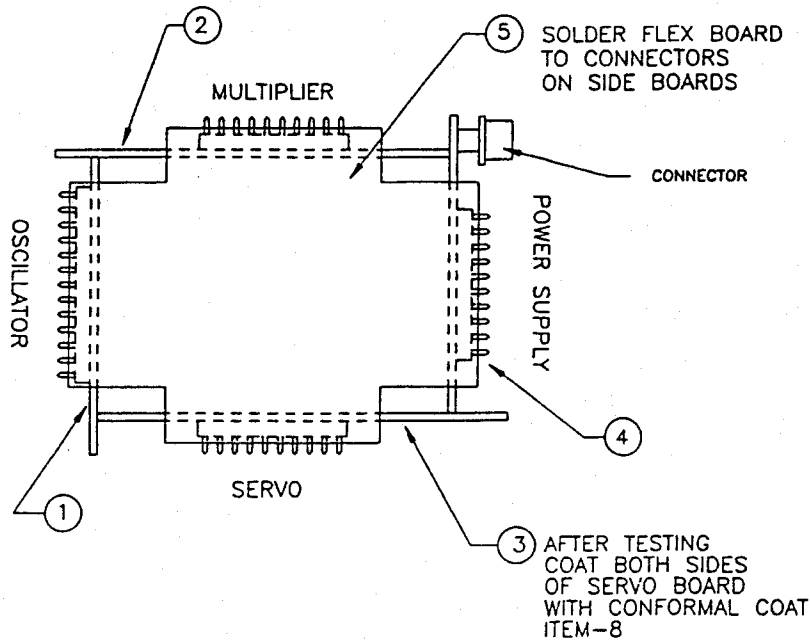
SHEET 2

| FIND No. | QTY REQ | PART OR IDENTIFYING No. | SPEC. OR MANUFACTURER | NOMENCLATURE OR DESCRIPTION | REFERENCE DESIGNATOR | UNIS No. |
|----------|---------|-------------------------|-----------------------|-----------------------------|----------------------|----------|
| 1        | 1       | SEE TAB ON SHT 2        |                       | BASEPLATE 4-40 THREAD       |                      |          |
| 2        | 1       | 814-105                 |                       | COVER                       |                      |          |
| 3        | 1       | 100141-001              |                       | LABEL, NAMEPLATE            |                      |          |
| 4        | 1       | 814-110                 |                       | PHYSICS PACKAGE ASSEMBLY    |                      |          |
| 5        | 1       | SEE TAB ON SHT 2        |                       | FLEX BOARD ASSEMBLY         |                      |          |
| 6        | 16      | MS51957-2               |                       | SCREW, PAN HD 2-56x3/16     |                      | 2821424  |
| 7        | 4       | MS51957-13              |                       | SCREW, PAN HD 4-40x1/4      |                      | 2821417  |
| 8        | 5       | MS24693C2               |                       | SCREW, FLAT HD 4-40x1/4     |                      | 2821353  |
| 9        | A/R     | 70423-3                 |                       | TAPE, MYLAR (1" WIDE)       |                      |          |
| 10       | 16      | MS35338-134             |                       | WASHER, LOCK NO. 2          |                      | 2821390  |
| 11       | 4       | MS35338-135             |                       | WASHER, LOCK NO. 4          |                      | 2821391  |
| 12       | 1       | 814-127-1               |                       | INSULATOR, MYLAR            |                      |          |
| 13       |         |                         |                       | NOT USED                    |                      |          |
| 14       | 1       | 713-040                 |                       | WARRANTY LABEL              |                      |          |

PARTS LIST, FINAL ASSEMBLY

A-3





TABULATION FOR PARTS SELECTION

| FLEX BOARD ASSY NO. | FREQUENCY RF OUTPUT | OSCILLATOR ITEM-1 | MULTIPLIER ITEM-2 | SERVO BD. ITEM-3 | POWER SUPPLY ITEM-4 |
|---------------------|---------------------|-------------------|-------------------|------------------|---------------------|
| 100339-001          | 10MHZ SINE          | 814-192-1         | 814-167-1         | 814-145-2        | 814-144-2           |
| 100339-002          | 10MHZ TTL           | 814-192-2         | 814-167-1         | 814-145-2        | 814-144-3           |
| 100339-003          | 2.048MHZ TTL        | 814-192-3         | 814-167-1         | 814-145-2        | 814-144-3           |
| 100339-004          | 5MHZ SINE           | 814-192-4         | 814-167-1         | 814-145-2        | 814-144-4           |
| 100339-005          | 13MHZ TTL           | 101243-001        | 814-167-2         | 814-145-2        | 814-144-3           |

ASSEMBLY, FLEX BOARD (100339/REV B)

BALL, EFRATOM DIVISION      CONTRACT No.      CAGE CODE 55761      100339-00X      REVISION LTR. B.  
 TITLE: PARTS LIST, FLEX BOARD ASSY, RUBIDIUM FREQ.      REVISION DATE 5-15-91

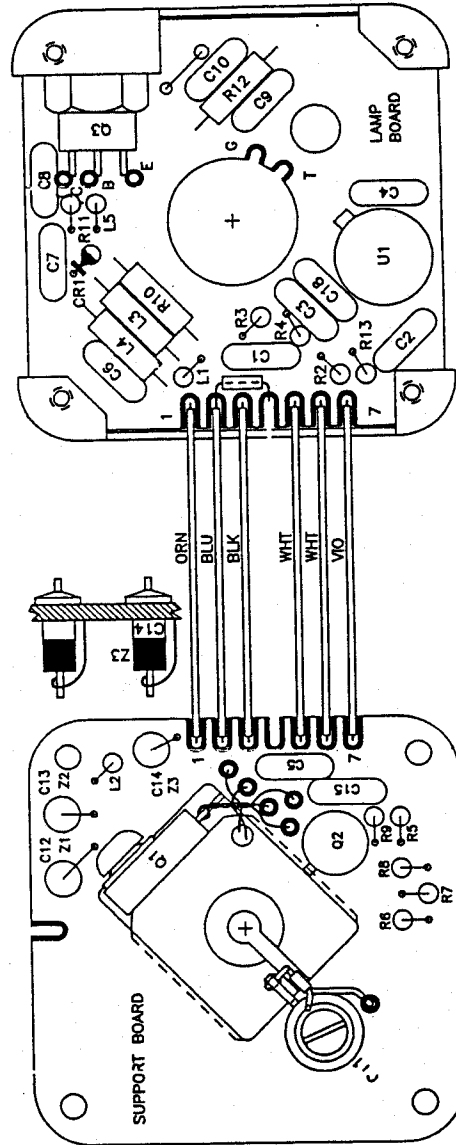
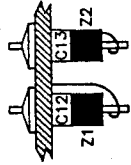
SHEET      2

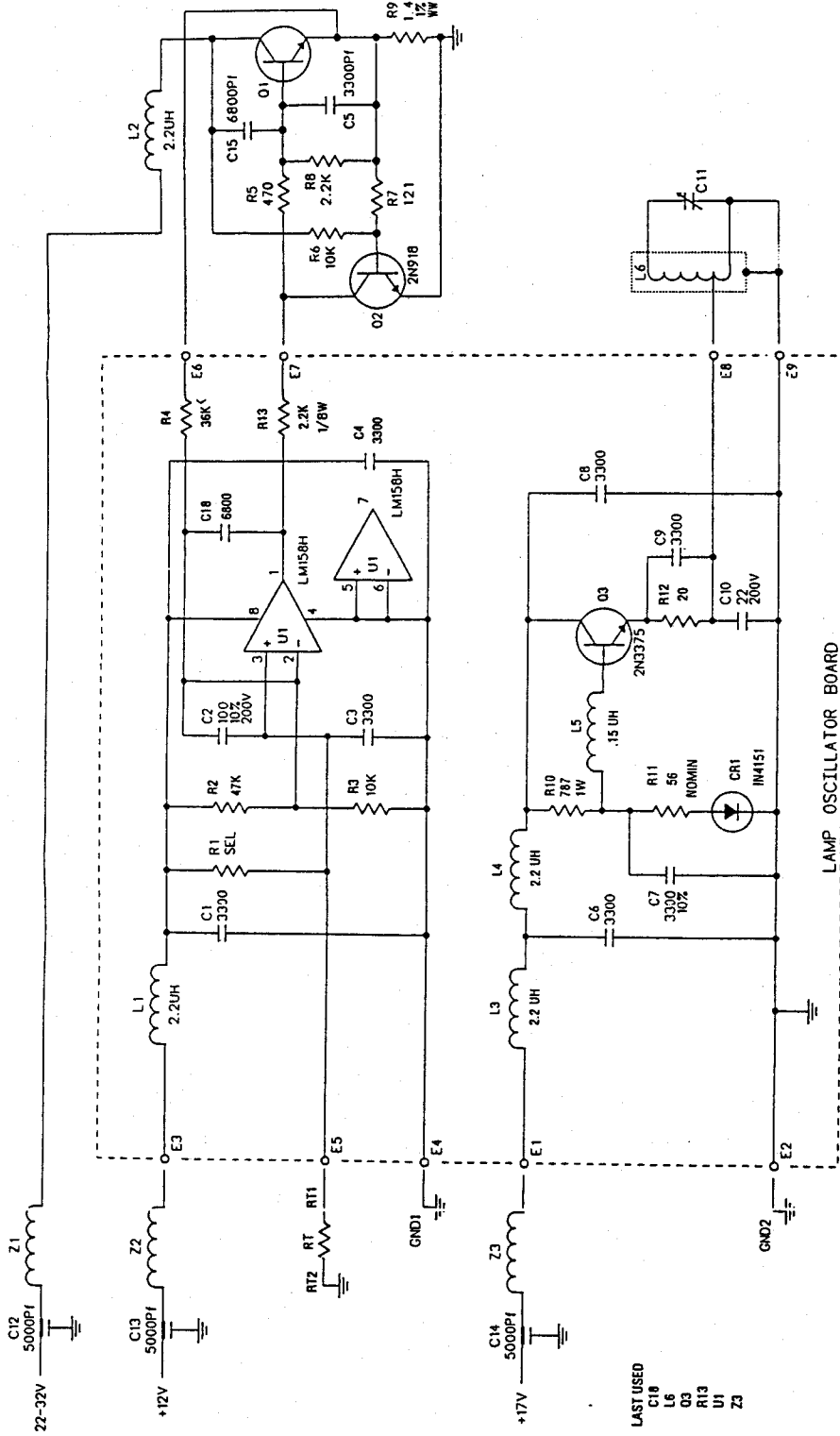
| FIND No. | QTY REQ | PART OR IDENTIFYING No. | SPEC. OR MANUFACTURER | NOMENCLATURE OR DESCRIPTION     | REFERENCE DESIGNATOR | UNIS No. |
|----------|---------|-------------------------|-----------------------|---------------------------------|----------------------|----------|
| 1        | 1       | SEE TAB ON SHT 2        |                       | OSCILLATOR/SYNTHESIZER ASSEMBLY |                      |          |
| 2        | 1       | SEE TAB ON SHT 2        |                       | MULTIPLIER ASSEMBLY             |                      |          |
| 3        | 1       | SEE TAB ON SHT 2        |                       | SERVO BOARD ASSEMBLY            |                      |          |
| 4        | 1       | SEE TAB ON SHT 2        |                       | POWER SUPPLY ASSEMBLY           |                      |          |
| 5        | 1       | 814-134-2               |                       | FLEX BOARD(KAPTON)              |                      |          |
| 6        |         |                         |                       | NOT USED                        |                      |          |
| 7        |         | A/R SN63WRMAP3          |                       | SOLDER                          |                      |          |
| 8        |         |                         |                       | NOT USED                        |                      |          |

PARTS LIST, FLEX BOARD ASSEMBLY









- LAST USED  
 C10  
 L6  
 Q3  
 R13  
 U1  
 Z3

2. RESISTANCE VALUES ARE OHMS, +/-1%, 1/10W.  
 1. CAPACITANCE VALUES ARE PICOFARADS, +/-5%, 50V.  
 NOTES: UNLESS OTHERWISE SPECIFIED.

**HERE C11 & PAGE H23  
 NO HOT LOCK**

BALL, EFRATOM DIVISION      CONTRACT No.      CAGE CODE 55761      814-113      REVISION LTR. L  
 TITLE: PARTS LIST, LAMP BOARD ASSY      REVISION DATE 91-5-13

SHEET 2

| FIND No. | QTY REQ | PART OR IDENTIFYING No. | SPEC. OR MANUFACTURER | NOMENCLATURE OR DESCRIPTION             | REFERENCE  |          |
|----------|---------|-------------------------|-----------------------|---|------------|----------|
|          |         |                         |                       |   | DESIGNATOR | UNIS No. |
| 1        | 1       | 814-115                 |                       | P.W.B.                                  |            | 814-115  |
| 2        | 1       | MK1 2.21K               | *2                    | RESISTOR, MF, 2.21K OHM, 1/8 W          | R13        | 4703035  |
| 3        | 1       | MK1 10K                 | *2                    | RESISTOR, MF, 10K OHM, 1/8 W            | R3         | 4703029  |
| 4        | 1       | MK1 36K                 | *2                    | RESISTOR, MF, 36K OHM, 1/8 W            | R4         | 4703314  |
| 5        | 1       | MK2 56.2                | *3,4                  | RESISTOR, MF, 56 OHM, 1/4W NOM          | R11        | 4701286  |
| 6        |         |                         |                       | NOT USED                                |            |          |
| 7        | 1       | RWR8157870FR            |                       | RESISTOR 1 W WIREWOUND 787 OHM          | R10        | 4702028  |
| 8        | 1       | RWR80520R0FR            |                       | RESISTOR 2 W WIREWOUND 20 OHM           | R12        | 4701967  |
| 9        | 1       | EDPT 22 PF NPO          |                       | CAPACITOR, CERAMIC 22 PF NPO            | C10        | 1500742  |
| 10       | 1       | CKR05BX101KSV           |                       | CAPACITOR, CERAMIC 100 PF               | C2         | 1500685  |
| 11       | 7       | C322C332K1G5CA          | KEMET                 | CAPACITOR, CERAMIC 3300 pf NPO          | C1,3,4,6-9 | 1500580  |
| 12       | 1       | MS75083-3               | *4                    | INDUCTOR 0.15UH                         | L5         | 1801443  |
| 13       | 3       | MS75084-4               |                       | INDUCTOR 2.2UH                          | L1,3,4     | 1801448  |
| 14       | 1       | 1N4151                  |                       | DIODE                                   | CR1        | 4800084  |
| 15       | 1       | LM158H                  |                       | INTEGRATED CIRCUIT                      | U1         | 3130993  |
| 16       |         |                         |                       | NOT USED                                |            |          |
| 17       | 1       | MK1 47.5K               | *2                    | RESISTOR, MF, 47K OHM, 1/8 W            | R2         | 4703014  |
| 18       | 1       | CKR05BX682KSV           |                       | CAPACITOR 6800PF                        | C18        | 1500695  |
| 19       | 1       | 705-142                 | *4                    | TRANSISTOR 2N3375                       | Q3         | 705-142  |
| 20       | 1       | 814-117-1               |                       | LAMP SPACER                             |            |          |
| 21       | 2       | MS51957-4               |                       | SCREW, 2-56x5/16 CRES PAN HD            |            | 2821434  |
| 22       | A/R     | 70411                   |                       | THERMAL JOINT COMPOUND                  |            | 70411    |
| 23       | A/R     | MIL-W-16878 TYPE E      |                       | WIRE, 24 AWG STRANDED                   |            |          |
| 0        |         |                         | NOTES:                | *1. ALL STANDUP COMPONENTS TO HAVE      |            |          |
| 0        |         |                         |                       | 0.02 MIN. CLEARANCE ABOVE THE P.C.B.    |            |          |
| 0        |         |                         |                       | *2. MAY USE RCR05GXXXJR                 |            |          |
| 0        |         |                         |                       | *3. MAY USE RCR07GXXXJR                 |            |          |
| 0        |         |                         |                       | *4. TO USE ALTERNATE TSTR (2N3375)      |            |          |
| 0        |         |                         |                       | MADE BY THOMPSON (LOGO"ST") MUST USE    |            |          |
| 0        |         |                         |                       | RESISTOR R11(75 OHM), MK2) AND INDUCTOR |            |          |
| 0        |         |                         |                       | L5(0.12UH, MS75083-2). SEE TAB ON LAMP  |            |          |
| 0        |         |                         |                       | ASSY AND SCHEMATIC LAMP CIRCUIT.        |            |          |

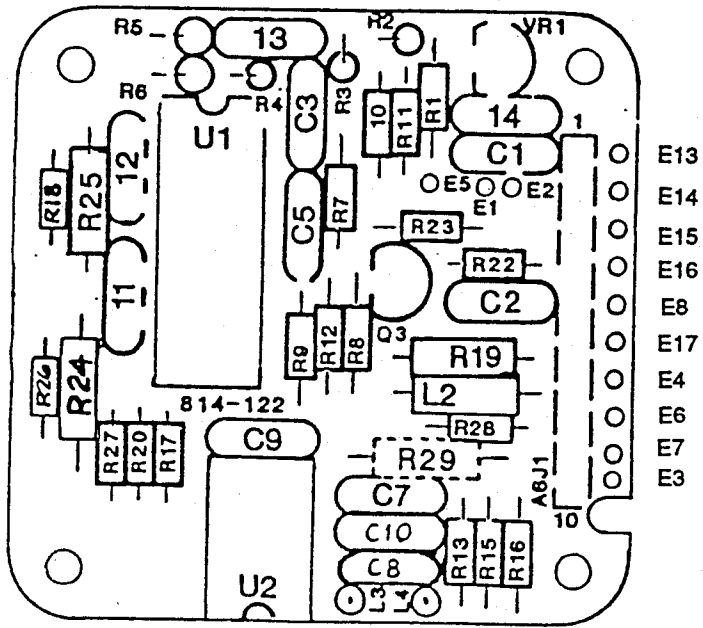
PARTS LIST, LAMP BOARD A2 ASSEMBLY (PL814-113/REV L)

BALL, EFRATOM DIVISION      CONTRACT No.      CAGE CODE 55761      814-112      REVISION LTR. V  
 TITLE: PARTS LIST, LAMP ASSEMBLY      REVISION DATE 91-5-13

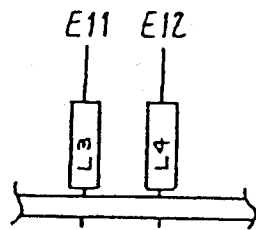
SHEET 2

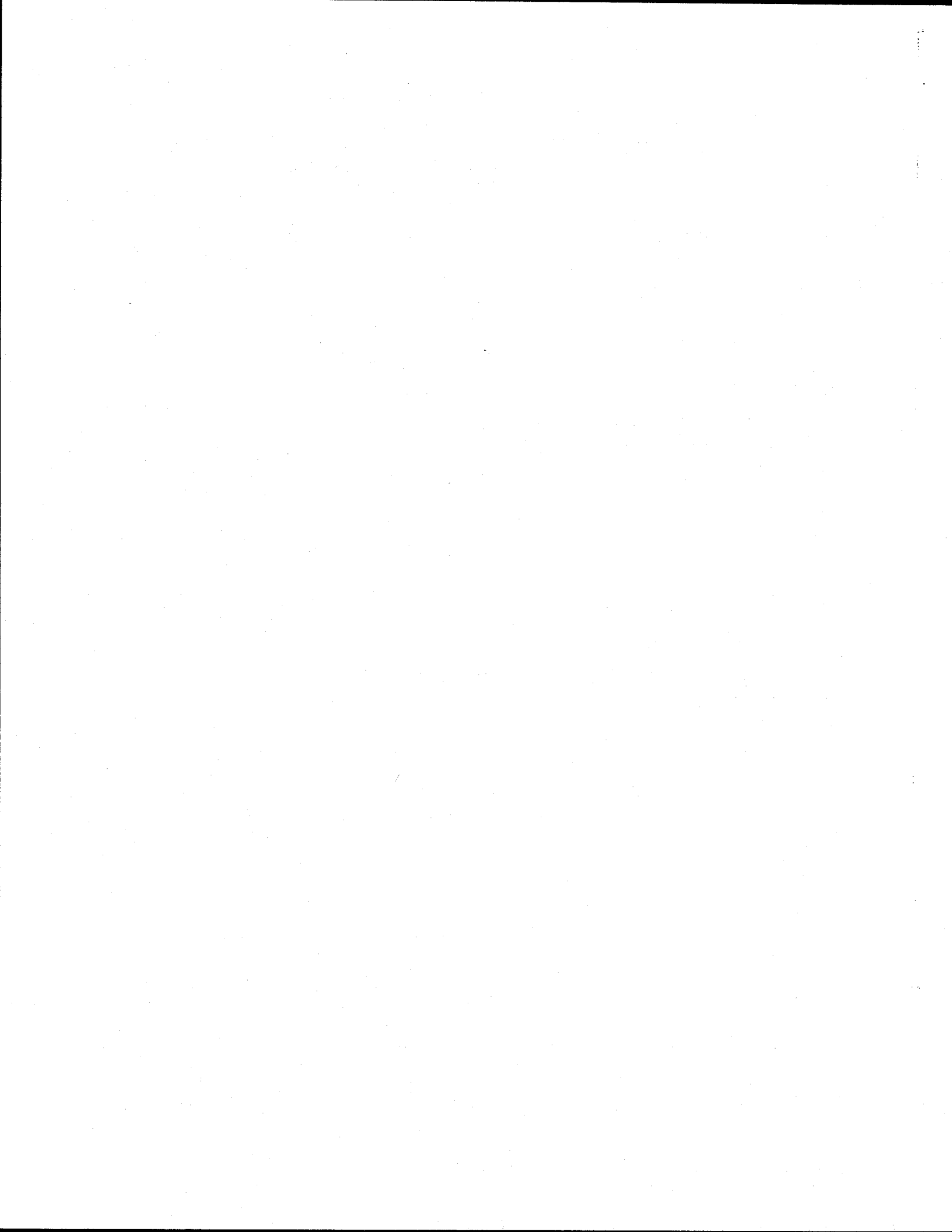
| FIND No. | QTY | PART OR IDENTIFYING No. | SPEC. OR MANUFACTURER | NOMENCLATURE OR DESCRIPTION                          | REFERENCE DESIGNATOR | UNIS No. |
|----------|-----|-------------------------|-----------------------|--|----------------------|----------|
| 1        | 1   | 814-116                 |                       | LAMP SUPPORT BOARD                                   |                      |          |
| 2        | 1   | 814-117-2               |                       | LAMP SPACER  |                      |          |
| 3        | 6   | MS51957-3               |                       | SCREW, 2-56x1/4 CRES PN HD                           |                      | 2821428  |
| 4        | A/R | LOCKTITE #222           |                       | COMPOUND, THREAD LOCKING                             |                      |          |
| 5        | A/R | MIL-W-16878E            |                       | WIRE, 28 AWG STRANDED                                |                      |          |
| 6        | A/R | SN63WRMAP3              |                       | SOLDER   |                      |          |
| 7        | A/R | 704-215-1               |                       | WIRE, 26AWG, 99.9% SILVER, SPRING TEMPER L6(9 TURNS) |                      |          |
| 8        | 1   | 100299-001              |                       | LAMP HOUSING ASSEMBLY                                |                      |          |
| 9        | A/R | 70424-12                |                       | ADHESIVE RTV, BLACK                                  |                      |          |
| 10       | A/R | 70424-7                 |                       | ADHESIVE RTV 108                                     |                      |          |
| 11       | 1   | 100297-001              |                       | COIL FORM  |                      |          |
| 12       | 3   | 1126-1115-502AD         | CDI                   | CAPACITOR, FEED THRU                                 | C12-14               | 1500032  |
| 13       | 1   | 8053                    |                       | CAPACITOR, VARIABLE 1.5-14PF                         | C11                  |          |
| 14       | 1   | B57232-A1103-M          |                       | *1 THERMISTOR (M85)                                  | RT                   | 5301106  |
| 15       | A/R | AMS-3655                |                       | TUBING, TEFLON 30 AWG                                | LEADS OF RT          |          |
| 16       |     |                         |                       | NOT USED   |                      |          |
| 17       | 1   | 814-113                 |                       | LAMP BOARD ASSEMBLY                                  |                      |          |
| 18       | 1   | 814-120-2               |                       | LAMP, FILLED   |                      |          |
| 19       | A/R | AMS-3655                |                       | TUBING TEFLON 26 AWG                                 |                      |          |
| 20       |     |                         |                       | NOT USED   |                      |          |
| 21       | 1   | MJE802                  |                       | TRANSISTOR   | Q1                   | 4801151  |
| 22       |     |                         |                       | NOT USED   |                      |          |
| 23       |     |                         |                       | NOT USED   |                      |          |
| 24       | 1   | B52200F006              |                       | WASHER #4 BELLEVILLE                                 |                      | 2820531  |
| 25       | 1   | MS51957-14              |                       | SCREW, PAN HD 4-40x5/16                              |                      | 2821418  |
| 26       |     |                         |                       | NOT USED   |                      |          |
| 27       |     |                         |                       | NOT USED   |                      |          |
| 28       |     |                         |                       | NOT USED   |                      |          |
| 29       | A/R | 70411                   |                       | THERMAL JOINT COMPOUND                               |                      |          |
| 30       | 1   | 814-158                 |                       | PLUG-LAMP COIL                                       |                      |          |
| 31       | 3   | 2643000101              |                       | FERRITE BEAD   | Z1-3                 | 1850160  |
| 32       | 1   | MS75084-4               |                       | INDUCTOR 2.2UH                                       | L2                   | 1801448  |
| 33       | 1   | 2N918                   |                       | TRANSISTOR   | Q2                   | 4800210  |
| 34       | 1   | C322C332K1G5CA          | KEMET                 | CAPACITOR 3300PF NPO                                 | C5                   | 1500580  |
| 35       | 1   | CKR05BX682KS            |                       | CAPACITOR 6800 PF                                    | C15                  | 1500695  |
| 36       | 1   | MK1 121                 | *2                    | RESISTOR, MF, 121 OHM, 1/8 W                         | R7                   | 4703010  |
| 37       | 1   | MK1 475                 | *2                    | RESISTOR, MF, 475 OHM, 1/8 W                         | R5                   | 4703358  |
| 38       | 1   | MK1 10K                 | *2                    | RESISTOR, MF, 10K OHM, 1/8 W                         | R6                   | 4703029  |
| 39       | 1   | RWR81S1R40FR            |                       | RESISTOR 1.40 ohm WW                                 | R9                   | 4702014  |
| 40       | 1   | 43-77-1                 | THERMALLOY            | INSULATOR (THERMALFILM)                              | XQ1                  | 1002594  |
| 41       | 1   | MK1 2.21K               | *2                    | RESISTOR, MF, 2.21K OHM, 1/8 W                       | R8                   | 4703035  |
| 42       |     |                         |                       | NOT USED   |                      |          |
| 43       | 1   | 250-169                 |                       | MICA WINDOW  |                      |          |
| 0        |     |                         | NOTE:                 | *1 MAY USE THERMOMETRICS BR55KB103-L                 |                      |          |
| 0        |     |                         |                       | 1.8 LONG   |                      |          |
| 0        |     |                         |                       | *2. MAY USE RCR05GXXXJR                              |                      |          |

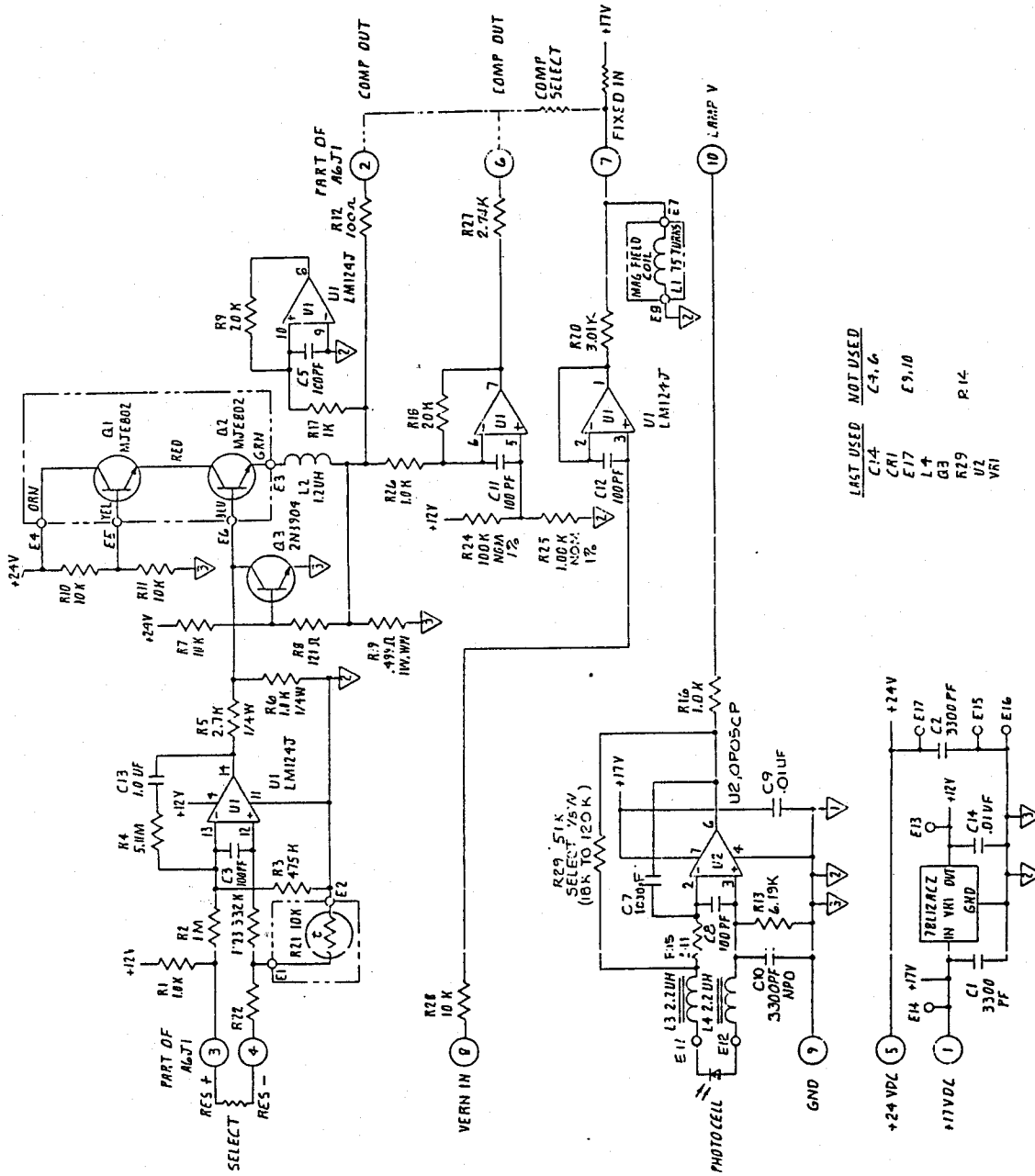
PARTS LIST, SUPPORT BOARD A3 ASSEMBLY (PL814-112/REV V)



R29 IS MOUNTED  
ON SOLDER SIDE  
DURING TEST



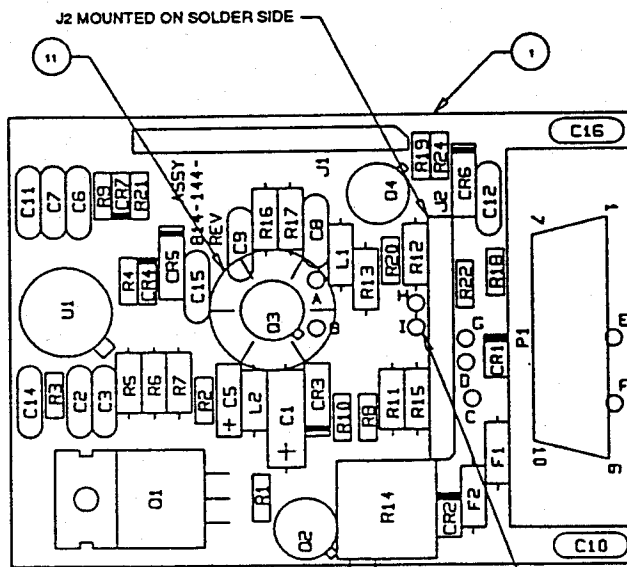








| TABULATION CHART               |                    |  |
|--------------------------------|--------------------|--|
| COMPONENT VALUES FOR RF OUTPUT |                    | COMPONENT VALUES FOR TTL OUTPUT        |
| ASSEMBLY                       | ASSEMBLY           | ASSEMBLY                               |
| 814-144-2                      | 814-144-4          | 814-144-3                              |
| 10 MHz SINE                    | 5 MHz SINE         | 10 MHz TTL                             |
| L1- 9.5UH                      | L1- 18UH           | L1- OMIT                               |
| L2- 16UH                       | L2- 47UH           | L2- REPLACE WITH R23 130 OHM 1W, RYF81 |
| R16- 910 OHM NOM               | R16- 910 OHM NOM   | R16- 100 OHM NOM                       |
| R17- 1.0K NOM                  | R17- 1.0K NOM      | R17- 270 OHM NOM 1/4W                  |
| R18- 1.0K                      | R18- 1.0K          | R18- OMIT                              |
| C8- 47PF NOM                   | C8- 82PF NOM       | C8- JUMPER                             |
| C9- 6800PF NOM                 | C9- 6800PF NOM     | C9- 0.47UF NOM                         |
| C16- 0.1UF                     | C16- 0.1UF         | C16- JUMPER                            |
| C17- 240PF NOM NPO             | C17- 240PF NOM NPO | C17- OMIT                              |
|                                |                    | INSTALL JUMPER A-B                     |
|                                |                    | INSTALL HEATBANK (ITEM 11) ON C9       |



NOTES: UNLESS OTHERWISE SPECIFIED.

1. WORKMANSHIP SHALL BE PER MIL-STD-883C REQUIREMENT 9. (NO CERTIFICATIONS REQUIRED)
2. ALL SOLDERING, WIRING AND COMPONENT MOUNTING SHALL MEET THE REQUIREMENTS OF IPC-S-815 CLASS III.
3. LEADS SHOULD BE PARTIALLY CLINCHED OR SWAGED FOR PART RETENTION PRIOR TO SOLDERING. (FOR REF. ONLY SEE MLP-44428 TYPE B OR TYPE III).
4. AFTER SOLDERING, CLEAN ASSEMBLY TO REMOVE ALL FLUX RESIDUE.
5. IDENTIFY WITH ASSY DASH No. AND PARTS LIST REV. LETTER.
6. LEAD PROJECTION BELOW BOARD SURFACE SHALL BE .020 MIN .060 MAX.
7. FOR SCHEMATIC DIAGRAM SEE DRAWING NUMBER 814-142

INSTALL LEAD OF R12 IN PAD H FOR + COMPENSATION  
INSTALL LEAD OF R12 IN PAD I FOR - COMPENSATION

| -4              | SEE SEPARATE PARTS LIST PL814-144-4 |                         |                               |                             |          |            |                     |
|-----------------|-------------------------------------|-------------------------|-------------------------------|-----------------------------|----------|------------|---------------------|
| -3              | SEE SEPARATE PARTS LIST PL814-144-3 |                         |                               |                             |          |            |                     |
| -2              | SEE SEPARATE PARTS LIST PL814-144-2 |                         |                               |                             |          |            |                     |
| -1              | NOT USED                            |                         |                               |                             |          |            |                     |
| ASSEMBLY NUMBER | CAGE CODE                           | PART OR IDENTIFYING No. | SPECIFICATION OR MANUFACTURER | NOMENCLATURE OR DESCRIPTION | MCI CODE | DESIGNATOR | REFERENCE UNITS No. |
| PARTS LIST      |                                     |                         |                               |                             |          |            |                     |

ASSEMBLY A3, POWER SUPPLY BOARD (814-144/REV P)

BALL, EFRATOM DIVISION

CONTRACT No.

CAGE CODE 55761

814-122

REVISION LTR. T

REVISION DATE 91-4-3

TITLE: PARTS LIST, RESONATOR BOARD ASSEMBLY

SHEET

2

| FIND No. | QTY REQ | PART OR IDENTIFYING No. | SPEC. OR MANUFACTURER | NOMENCLATURE OR DESCRIPTION   | REFERENCE DESIGNATOR | UNIS No. |
|----------|---------|-------------------------|-----------------------|-------------------------------|----------------------|----------|
| 1        | 1       | 814-124                 |                       | P.C.B.                        |                      |          |
| 2        | 1       | BBL-110-G-F             | SAMTEC                | CONNECTOR                     | A6J1                 | 2100542  |
| 3        | A/R     | SN63WRMAP3              |                       | SOLDER                        |                      |          |
| 4        |         |                         |                       | NOT USED                      |                      |          |
| 5        | 2       | MS75804-4               |                       | INDUCTOR 2.2 uH               | L3,4                 | 1801448  |
| 6        | 1       | RWR81SR499FR            |                       | RESISTOR 1W, WW .499 ohm      | R19                  | 4702034  |
| 7        | 1       | MS75084-1               |                       | INDUCTOR 1.2 uH               | L2                   | 1801444  |
| 8        | 1       | RCR07G102JR             |                       | RESISTOR 1/4 W CARBON 1.0K    | R6                   | 4701686  |
| 9        | 1       | RCR05GXXXJR             | SELECT IN TEST        | RESISTOR 1/8 W CARBON, SIT    | R29                  |          |
| 10       | 1       | RCR07G272JR             |                       | RESISTOR 1/4 W CARBON 2.7K    | R5                   | 4701715  |
| 11       | 1       | MK2 100K                |                       | RESISTOR, METAL FILM 100K     | R24                  | 4701170  |
| 12       | 1       | MK2 1.00K               |                       | RESISTOR, METAL FILM 1.00K    | R25                  | 4701153  |
| 13       | 1       | 2N3904                  |                       | TRANSISTOR NPN                | Q3                   | 4800197  |
| 14       | 1       | CK06BX105KSV            |                       | CAPACITOR, CERAMIC 1.0UF      | C13                  | 1500697  |
| 15       | 5       | C320C101K2G5CA          |                       | CAPACITOR, CERAMIC 100PF NPO  | C3,5,8,11,12         | 1500565  |
| 16       | 2       | RCR05G101JR             |                       | RESISTOR 100 ohm 1/8 W CARBON | R12,15               | 4701599  |
| 17       | 3       | C322C332K1G5CA          | KEMET                 | CAPACITOR, CERAMIC 3300pF NPO | C1,2,10              | 1500580  |
| 18       | 3       | CKR05BX103KSV           |                       | CAPACITOR CERAMIC .01 uF      | C7,9,14              | 1500687  |
| 19       | 1       | RCR05G334JR             |                       | RESISTOR 1/8 W CARBON 330K    | R23                  | 4701642  |
| 20       | 4       | RCR05G102JR             |                       | RESISTOR 1/8 W CARBON 1.0K    | R17,26,1,22          | 4701600  |
| 21       | 1       | RCR05G272JR             |                       | RESISTOR 1/8 W CARBON 2.7K    | R27                  | 4701634  |
| 22       | 1       | RCR05G622JR             |                       | RESISTOR 1/8 W CARBON 6.2K    | R13                  | 4701661  |
| 23       | 4       | RCR05G103JR             |                       | RESISTOR 1/8 W CARBON 10K     | R10,11,7,28          | 4701601  |
| 24       | 2       | RCR05G203JR             |                       | RESISTOR 1/8 W CARBON 20K     | R9,18                | 4701623  |
| 25       | 1       | RCR05G474JR             |                       | RESISTOR 1/8 W CARBON 470K    | R3                   | 4701652  |
| 26       | 1       | RCR05G105JR             |                       | RESISTOR 1/8 W CARBON 1.0M    | R2                   | 4701604  |
| 27       | 1       | RCR05G515JR             |                       | RESISTOR 1/8 W CARBON 5.1M    | R4                   | 4701655  |
| 28       | 1       | RCR05G121JR             |                       | RESISTOR 1/8 CARBON 120 ohm   | R8                   | 4701526  |
| 29       | 1       | LM124J                  |                       | INTEGRATED CIRCUIT            | U1                   | 3130985  |
| 30       | 1       | OP05CP                  | PMI ONLY              | INTEGRATED CIRCUIT            | U2                   | 3130018  |
| 31       | 1       | 78L12ACZ                |                       | VOLTAGE REGULATOR             | VR1                  | 4002225  |
| 32       | 1       | RCR05G302JR             |                       | RESISTOR 3.0 K                | R20                  | 4701637  |

PARTS LIST, RESONATOR (A6) BOARD ASSEMBLY (PL814-122/REV T)

**POWER CHART**

| UNIT | RES | RES | RES | RES |
|------|-----|-----|-----|-----|
| U1   | U2  | U3  | U4  | U5  |

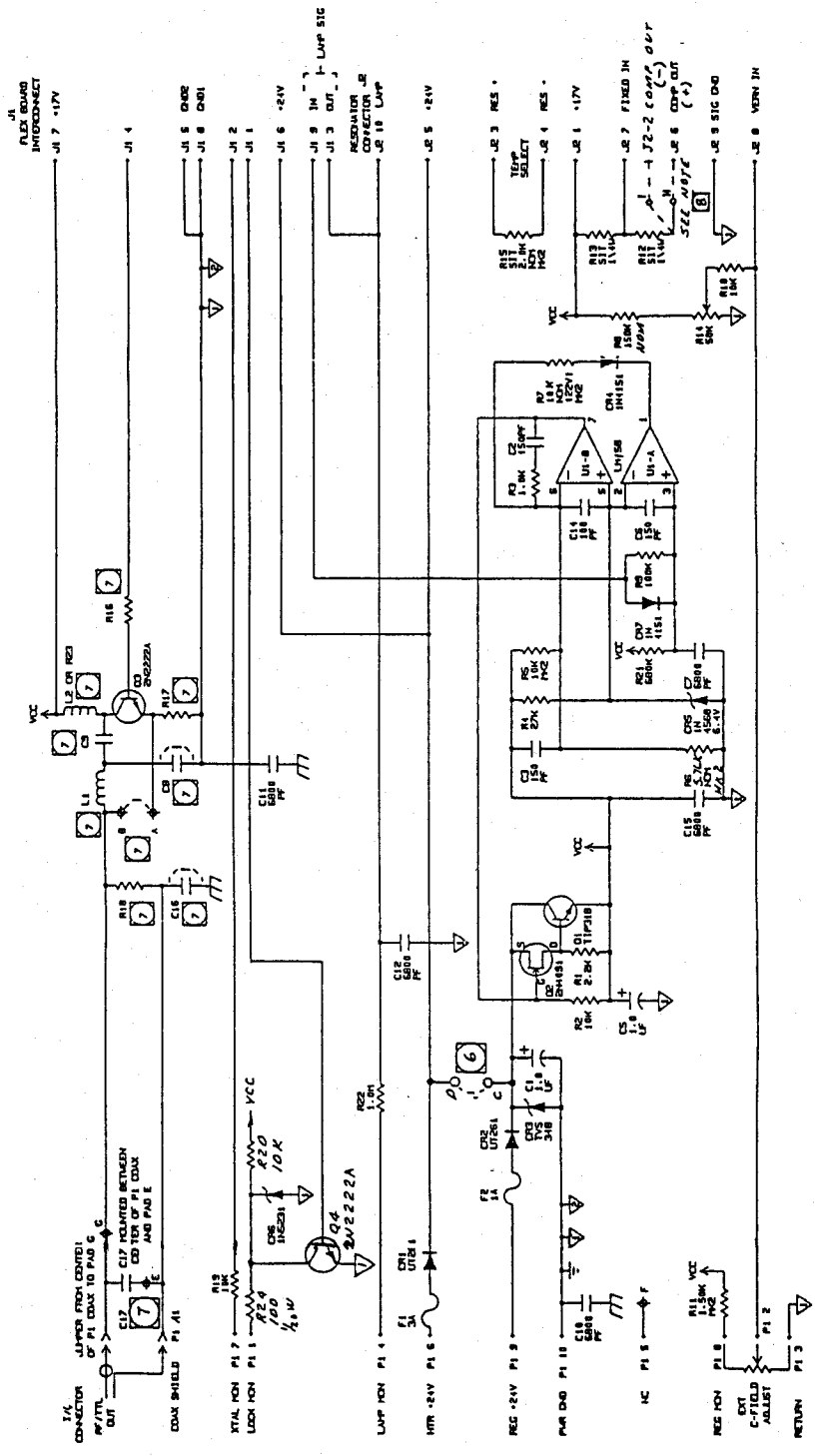
- NOTES:** UNLESS OTHERWISE SPECIFIED
- RESISTORS ARE 1/4W P.C.E. VALUES ARE IN OHMS.
  - CAPACITORS ARE 50V UNLESS OTHERWISE SPECIFIED. VALUES ARE IN UF.
  - USE MFR'S OR INDUCTOR FOR SMT CAPACITORS.
  - USE SMT OR THROUGH HOLE FOR SMT CAPACITORS.

**COMPONENT VALUES FOR 11V OUTPUT**

| COMPONENT | VALUE | ASSEMBLY | ASSEMBLY |
|-----------|-------|----------|----------|
| U1        | 11V   | 11V      | 11V      |
| U2        | 11V   | 11V      | 11V      |
| U3        | 11V   | 11V      | 11V      |
| U4        | 11V   | 11V      | 11V      |
| U5        | 11V   | 11V      | 11V      |

**TEMP COMPENSATION FOR CONNECTION**

|                                  |              |
|----------------------------------|--------------|
| TEMP COMPENSATION FOR CONNECTION | NO PAD       |
| TEMP COMPENSATION FOR CONNECTION | 22.2 TO 22.2 |
| TEMP COMPENSATION FOR CONNECTION | 22.2 TO 22.2 |
| TEMP COMPENSATION FOR CONNECTION | 22.2 TO 22.2 |



BALL, EFRATOM DIVISION CONTRACT NO. CAGE CODE 55761 PL 814-144-3 REVISION LTR. K  
 TITLE: PARTS LIST, POWER SUPPLY ASSY REVISION DATE 91-4-3

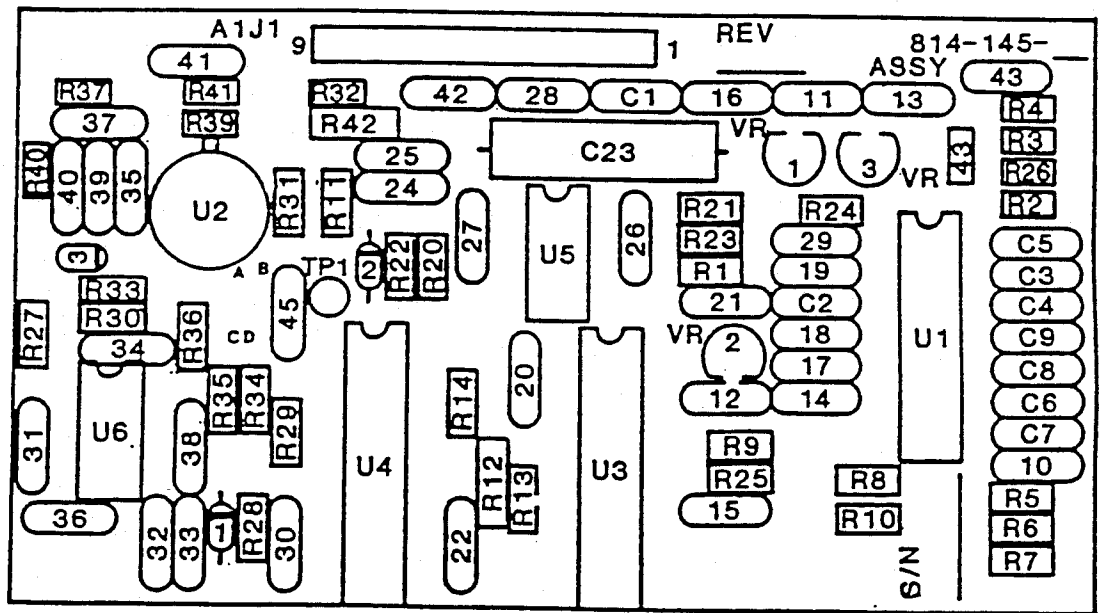
SHEET 2

| FIND NO. | QTY | PART OR IDENTIFYING NO. | SPEC. OR MANUFACTURER | NOMENCLATURE OR DESCRIPTION  | REFERENCE DESIGNATOR | UNIS NO. |
|----------|-----|-------------------------|-----------------------|------------------------------|----------------------|----------|
| 1        | 1   | 814-143                 | EFRATOM               | PRINTED WIRING BOARD         |                      |          |
| 2        | 1   | 814-148                 | EFRATOM               | HEAT SINK                    |                      |          |
| 3        | 2   | 4750-5                  | RAF                   | SCREW, JACK SOCKET           |                      |          |
| 4        | 1   | M551957-14              |                       | SCREW, PAN HD, 4-40x5/16 LG  |                      | 2821418  |
| 5        | 1   | 5607-45                 | SEASTROM              | WASHER, SHOULDER             |                      | 2820391  |
| 6        | 3   | MS35338-135             |                       | WASHER, LOCK #4              |                      | 2821391  |
| 7        | 1   | NAS620C4L               |                       | WASHER, FLAT #4              |                      | 2821482  |
| 8        | 1   | KFS2-440                | PEM                   | NUT, CAPTIVE                 |                      | 2820954  |
| 9        | 2   | NAS671C4                |                       | NUT, HEX, #4                 |                      | 2821486  |
| 11       | 1   | TXC20B                  | IERC                  | HEATSINK                     | XQ3                  | 2602125  |
| 12       | 1   | J223-07FR-54            | AAVID                 | INSULATOR                    | XQ1                  | 3100241  |
| 13       | 3   | 7717-133N               | THERMALLOY            | INSULATOR TO-18              | XQ2, XQ3, XQ4        | 2102218  |
| 14       | A/R | 704-232                 | LOCTITE               | COMPOUND, THREAD LOCKING     |                      |          |
| 15       | A/R | M16878                  | MIL-W-16878           | WIRE, 28 AWG STRANDED TYPE E |                      |          |
| 17       | A/R | SN63WRMAP3              | QQ-W-371              | SOLDER                       |                      |          |
| 20       | 1   | CKR05BX101KS            | MIL-C-39014           | CAPACITOR, CERAMIC 100 PF    | C14                  | 1500685  |
| 21       | 3   | CKR05BX151KS            | MIL-C-39014           | CAPACITOR, CERAMIC 150 PF    | C2,3,6               | 1500689  |
| 23       | 5   | CKR05BX682KS            | MIL-C-39014           | CAPACITOR, CERAMIC 6800 PF   | C7,10-12,15          | 1500695  |
| 24       | 6   | CKR05BX682KS            | MIL-C-39014           | CAPACITOR, CERAMIC 6800 PF   | C9,7,10-12,15        | 1500695  |
| 26       | 1   | C320C474M5USCA          | KEMET                 | CAPACITOR, CERAMIC 0.47 UF   | C9                   | 1503032  |
| 27       | 1   | 173D105X9050V           | SPRAGUE               | CAPACITOR, TANTALUM 1.0 UF   | C5                   | 1500072  |
| 28       | 1   | CSR13G105K *2           | MIL-C-39003           | CAPACITOR, TANTALUM 1.0 UF   | C1                   | 1500708  |
| 29       | 2   | 1N4151                  |                       | DIODE                        | CR4, CR7             | 4800084  |
| 30       | 1   | 1N4568                  |                       | DIODE                        | CR5                  | 4800085  |
| 31       | 1   | 1N5231B                 |                       | DIODE, ZENER                 | CR6                  | 4800090  |
| 32       | 1   | TVS348 *5               |                       | DIODE                        | CR3                  | 4802259  |
| 33       | 2   | UT261 *3                |                       | DIODE                        | CR1, CR2             | 4802136  |
| 34       | 1   | 251001                  | LITTELFUSE            | FUSE 1A                      | F2                   | 4300180  |
| 35       | 1   | 251003                  | LITTELFUSE            | FUSE 3A                      | F1                   | 4302506  |
| 36       | 1   | CA-S09-20T-40-125       | CA CORP               | CONNECTOR                    | J1                   | 2102502  |
| 37       | 1   | SS-110-G-2              | SAMTEC                | CONNECTOR                    | J2                   | 2102090  |

BALL, EFRATOM DIVISION      CONTRACT NO.      CAGE CODE 55761      PL 814-144-3      REVISION LTR. K  
 TITLE: PARTS LIST, POWER SUPPLY ASSY      REVISION DATE 91-4-3

SHEET 3

| FIND NO. | QTY | PART OR IDENTIFYING NO. | SPEC. OR MANUFACTURER | NOMENCLATURE OR DESCRIPTION              | REFERENCE DESIGNATOR | UNIS NO. |
|----------|-----|-------------------------|-----------------------|--|----------------------|----------|
| 42       | 1   | CBD11W1M3S000-867.0     | POSITRONIC            | CONNECTOR (WITH PINS)                    | P1                   | 2102722  |
| 43       | 1   | FDS4201D                | *7 POSITRONIC         | CONTACT, COAX                            | PLA1                 | 2103287  |
| 44       | 2   | 2N2222A                 |                       | TRANSISTOR                               | Q3,4                 | 4800188  |
| 45       | 1   | 2N4091                  |                       | TRANSISTOR                               | Q2                   | 4800199  |
| 46       | 1   | TIP31B                  |                       | TRANSISTOR                               | Q1                   | 4802114  |
| 47       | 1   | MK1 100 OHM             | *4                    | RESISTOR MF 1/8W 100 OHM NOM             | R16                  | 4703031  |
| 48       | 1   | RNC50H1000FR            | MIL-R-55182           | RESISTOR MF 1/20W 100 OHM                | R24                  | 4703027  |
| 49       | 1   | RWR81S1300FR            | *6 MIL-R-39007        | RESISTOR WW 1W 130 OHM                   | R23 (L2 LOC)         | 4701969  |
| 50       | 1   | MK2 274 OHM             |                       | RESISTOR MF 1/4W 274 OHM NOM             | R17                  | 4701223  |
| 55       | 1   | MK2 1.5K                |                       | RESISTOR MF 1/4W 1.5K                    | R11                  | 4701161  |
| 56       | 1   | MK2 2K                  |                       | RESISTOR MF 1/4W 2K NOM SEL              | R15                  | 4701193  |
| 57       | 1   | MK1 2.2K                | *4                    | RESISTOR MF 1/8W 2.2K                    | R1                   | 4701628  |
| 58       | 1   | MK2 5.76K               |                       | RESISTOR MF 1/4W 5.76K NOM               | R6                   | 4701280  |
| 59       | 4   | MK1 10K                 | *4                    | RESISTOR MF 1/8W 10K                     | R2,10,19,20          | 4701601  |
| 60       | 2   | MK2 10K                 |                       | RESISTOR MF 1/4W 10K NOM                 | R7,5                 | 4701167  |
| 61       | 1   | MK1 27 K                | *4                    | RESISTOR MF 1/8W 27K                     | R4                   | 4701635  |
| 62       | 1   | J299P-1-503             | BOURNS                | RESISTOR, VARIABLE 50K                   | R14                  | 4750245  |
| 63       | 1   | MK1 100K                | *4                    | RESISTOR MF 1/8W 100K                    | R9                   | 4701602  |
| 64       | 1   | MK1 150K                | *4                    | RESISTOR MF 1/8W 150K NOM                | R8                   | 4701615  |
| 65       | 1   | RCR05G684JR             | MIL-R-39008           | RESISTOR FC 1/8W 680K                    | R21                  | 4701664  |
| 66       | 1   | RCR05G105JR             | MIL-R-39008           | RESISTOR FC 1/8W 1MEG OHM                | R22                  | 4701604  |
| 67       | 2   | MK2 SIT                 |                       | RESISTOR MF 1/4W NOM (OPEN)              | R12,13               |          |
| 68       | 1   | LM158H                  |                       | I.C. OP AMP                              | U1                   | 3130993  |
| 69       | 1   | MK1 1K                  | *4                    | RESISTOR MF 1/8W 1K                      | R3                   | 4703171  |
|          |     | NOTES:                  |                       |  |                      |          |
|          |     | REF                     | *2                    | MAY USE M39003/01-2596                   |                      |          |
|          |     | REF                     | *3                    | MAY USE SEMTECH JSM2                     |                      |          |
|          |     | REF                     | *4                    | MAY USE RCR05GXXXJS                      |                      |          |
|          |     | REF                     | *5                    | USE P6KE56A-GEN'L INST OR MOT            |                      |          |
|          |     | REF                     | *6                    | 814-144-3 HAS NOTE L2 LOCATION           |                      |          |
|          |     | REF                     | *7                    | MAY USE DM121073-201,CANNON,CONTACT COAX |                      |          |



(A1) ASSEMBLY, SERVO BOARD (814-145/REV G)

BALL, EFRATOM DIVISION      CONTRACT No.      CAGE CODE 55761      814-145-2      REVISION LTR. U  
 REVISION DATE 91-4-3

TITLE: PARTS LIST, SERVO BOARD ASSEMBLY

SHEET      2

| FIND No. | QTY REQ | PART OR IDENTIFYING No. | SPEC. OR MANUFACTURER | NOMENCLATURE OR DESCRIPTION                     | REFERENCE   |          |
|----------|---------|-------------------------|-----------------------|---|-------------|----------|
|          |         |                         |                       |   | DESIGNATOR  | UNIS No. |
| 1        | 1       | 814-141                 |                       | P.C.B.  |             | 814-141  |
| 2        | 1       | CA-S09-20T-40-125       | CIRCUIT ASSY          | CONNECTOR                                       |             | 2102502  |
| 3        | 1       | 70416-2                 |                       | TERMINAL  | TP1         | 70416-2  |
| 4        |         |                         |                       | NOT USED  |             |          |
| 5        | 1       | MK2 5.11K               |                       | RESISTOR 1/4W M.F. 5.11K NOM                    | R42         | 4701276  |
| 6        | 1       | MK2 442K                |                       | RESISTOR 1/4W M.F. 442K                         | R12         | 4702688  |
| 7        | 1       | RNC55H7322FR            |                       | RESISTOR 73.2K +/-1%                            | R23         | 4702357  |
| 8        | 1       | MK2 68.1K               |                       | RESISTOR 1/4 W M.F. 68.1K                       | R24         | 4701295  |
| 9        |         |                         |                       | NOT USED  |             |          |
| 10       | 1       | RCR05G102JR             |                       | RESISTOR 1/8W CARBON 1.0K                       | R21         | 4701600  |
| 11       | 1       | RCR05G512JR             |                       | RESISTOR 1/8W CARBON 5.1K                       | R1          | 4701653  |
| 12       | 3       | MK1 10K                 |                       | RESISTOR 1/8W 10K M.F.                          | R11,30,32   | 4701601  |
| 13       | 1       | RCR05G333JR             |                       | RESISTOR 1/8W CARBON 33K                        | R4          | 4701641  |
| 14       |         |                         |                       | NOT USED  |             |          |
| 15       | 1       | RCR05G224JR             |                       | RESISTOR 1/8W CARBON 220K                       | R41         | 4701629  |
| 16       |         |                         |                       | NOT USED  |             |          |
| 17       | 6       | RCR05G104JR             |                       | RESISTOR 1/8W CARBON 100K<br>R7,9,10,14,25,27   |             | 4701602  |
| 18       |         |                         |                       | NOT USED  |             |          |
| 19       | 3       | RCR05G334JR             |                       | RESISTOR 1/8W CARBON 330K                       | R36,34,29   | 4701642  |
| 20       | 2       | RCR05G205JR             |                       | RESISTOR 1/8W CARBON 2.0M NOM                   | R20,22      | 4701625  |
| 21       | 4       | RCR05G105JR             |                       | RESISTOR 1/8W CARBON 1.0M                       | R13,28,37,8 | 4701604  |
| 22       | 4       | RCR05G205JR             |                       | RESISTOR 1/8W CARBON 2.0M                       | R2,3,39,40  | 4701625  |
| 23       | 3       | RCR05G475JR             |                       | RESISTOR 1/8W CARBON 4.7M                       | R5,6,35     | 4701605  |
| 24       | 2       | RCR05G106JR             |                       | RESISTOR 1/8W CARBON 10M                        | R31,33      | 4701605  |
| 25       | 1       | RNC50H2003FR            |                       | RESISTOR 200K +/-1%                             | R43         | 4701784  |
| 26       | 1       | RNC50H3482FR            |                       | RESISTOR 34.8K +/-1%                            | R26         | 4701801  |
| 27       |         |                         |                       | NOT USED  |             |          |
| 28       |         |                         |                       | NOT USED  |             |          |
| 29       |         |                         |                       | NOT USED  |             |          |
| 30       | 7       | CKR05BX101KSV           |                       | CAPACITOR, CERAMIC 100pf<br>C3,8,14,19,24,33,39 |             | 1500685  |
| 31       | 1       | CKR05BX331KSV           |                       | CAPACITOR, CERAMIC 330pf                        | C7          | 1500691  |
| 32       | 1       | CKR05BX561KSV           |                       | CAPACITOR, CERAMIC 560pf                        | C5          | 1500694  |

BALL, EFRATOM DIVISION      CONTRACT No.      CAGE CODE 55761      814-145-2      REVISION LTR. U  
 TITLE: PARTS LIST, SERVO BOARD ASSEMBLY      REVISION DATE 91-4-3

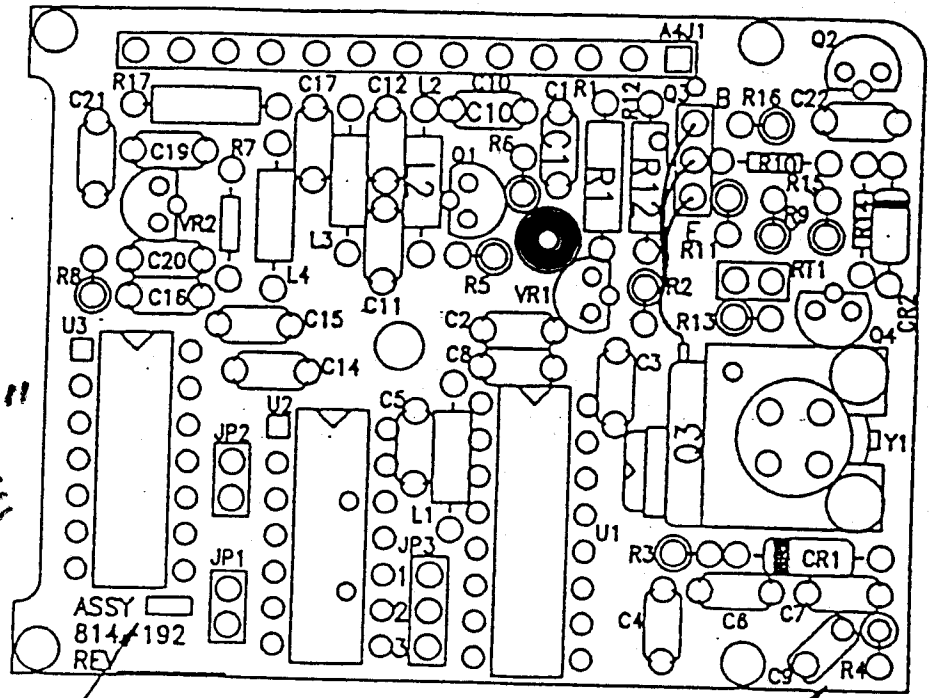
SHEET      3

| FIND No. | QTY REQ | PART OR IDENTIFYING No. | SPEC. OR MANUFACTURER | NOMENCLATURE OR DESCRIPTION   | REFERENCE DESIGNATOR | UNIS No. |
|----------|---------|-------------------------|-----------------------|---|----------------------|----------|
| 33       | 11      | CKR05BX682KSV           |                       | CAPACITOR, CERAMIC 6800pf<br>C1,16,18,21,27-30,36,42,43                     |                      | 1500695  |
| 34       | 1       | CKR05BX103KSV           |                       | CAPACITOR, CERAMIC .01uf  | C37                  | 1500687  |
| 35       | 1       | CKR05BX473KSV           |                       | CAPACITOR, CERAMIC .047uf   | C41                  | 1500693  |
| 36       | 20      | CKR05BX104KSV           |                       | CAPACITOR, CERAMIC 0.1uf<br>C2,4,6,9-13,15,17,20,25,26,31,32,34,35,45,38,40 |                      | 1500688  |
| 37       | 1       | C320C101K2G5CA          |                       | CAPACITOR, CERAMIC 100pf NPO  | C22                  | 1500565  |
| 38       | 1       | MKC18601.0/63           |                       | CAPACITOR, CERAMIC 1.0uf  | C23                  | 1501323  |
| 39       |         |                         |                       | NOT USED  |                      |          |
| 40       |         |                         |                       | NOT USED  |                      |          |
| 41       |         |                         |                       | NOT USED  |                      |          |
| 42       | 1       | 1N4151                  |                       | DIODE   | CR2                  | 4800084  |
| 43       |         |                         |                       | NOT USED  |                      |          |
| 44       |         |                         |                       | NOT USED  |                      |          |
| 45       | 1       | LM340LAZ5.0             |                       | VOLTAGE REGULATOR 5V  | VR3                  | 4001007  |
| 46       | 2       | 78L12ACZ                |                       | VOLTAGE REGULATOR 12V   | VR1,2                | 4001022  |
| 47       | 1       | LM158H                  |                       | INTEGRATED CIRCUIT  | U2                   | 3130993  |
| 48       | 1       | LM108J-8                |                       | INTEGRATED CIRCUIT  | U5                   | 3130982  |
| 49       | 1       | LM124J                  |                       | INTEGRATED CIRCUIT  | U1                   | 3130985  |
| 50       | 1       | LM393J                  |                       | INTEGRATED CIRCUIT  | U6                   | 3131012  |
| 51       | 1       | CD4053BF                |                       | INTEGRATED CIRCUIT  | U3                   | 3130668  |
| 52       | 1       | CD4060BF                |                       | INTEGRATED CIRCUIT  | U4                   | 3130670  |
| 0        |         |                         |                       |   |                      |          |
| 0        |         |                         |                       |   |                      |          |
| 0        |         |                         |                       |   |                      |          |

NOTE: 1. MK-1 RESISTORS MAY BE USED IN PLACE OF RCRO5GXXXJS  
 2. CR1 & CR3 ARE NOT USED



C11 ADJ.  
SCH. P. A9  
ABOVE "VR1"  
THIS PAGE



3.

LOCATE C9 & R4 AS SHOWN.

5.

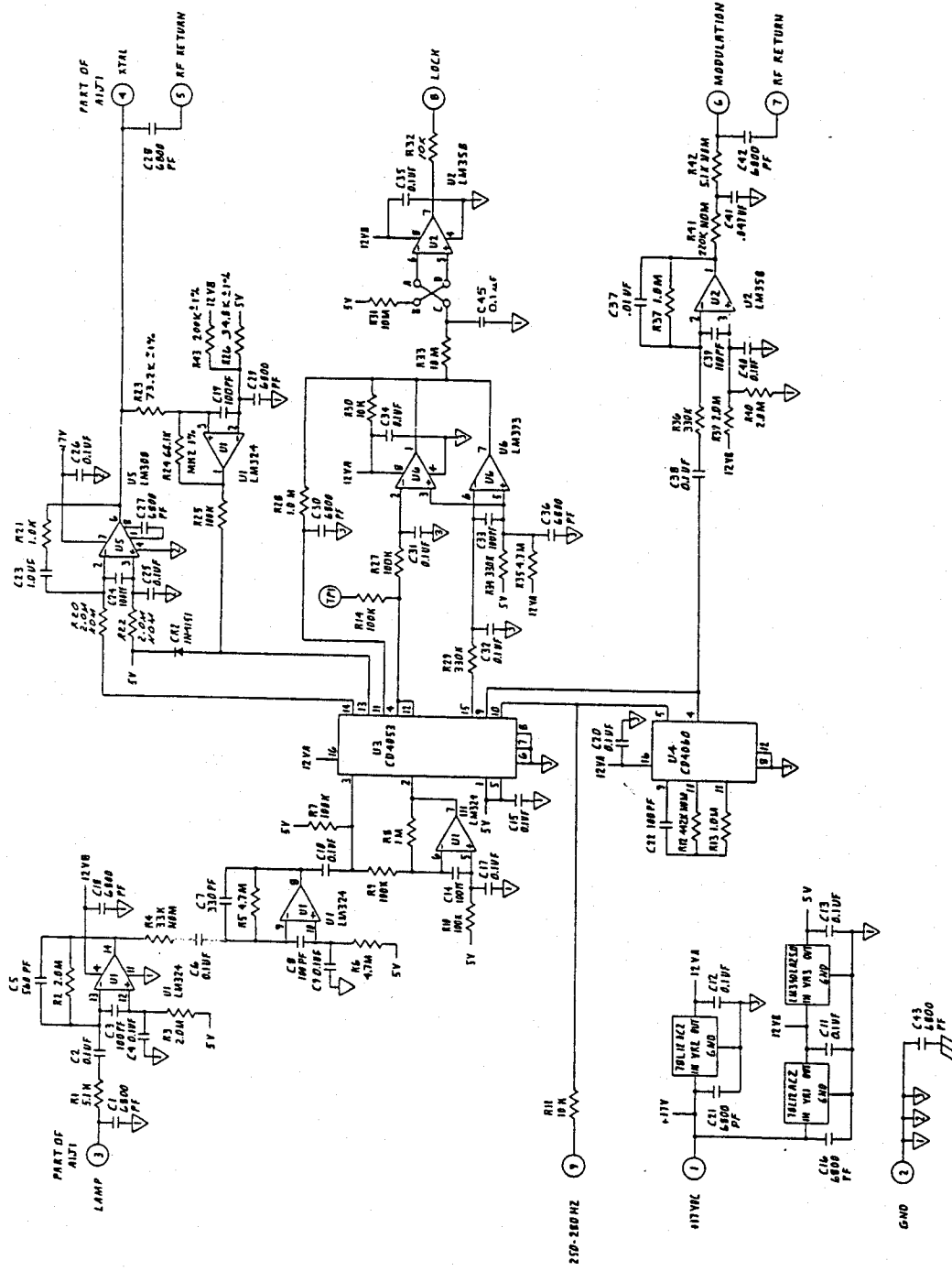
| PRODUCTION ASSY NO | RF OUTPUT     | TABULATION BOARD MODIFICATION                    |                          |
|--------------------|---------------|--|--------------------------|
|                    |               |  |                          |
| 814-192-1          | 10 MHz SINE   | AS SHOWN, NO JUMPERS                             |                          |
| 814-192-2          | 10 MHz TTL    | REPLACE R7 WITH JUMPER, DO NOT INSTALL L4 OR C17 |                          |
| 814-192-3          | 2.048 MHz TTL | CUT AT U2-11 JUMPER U2-9 TO R7                   | JP3-1 TO JP3-3           |
|                    |               | CUT AT U2-10 JUMPER U2-9 TO U3-9                 | JP1                      |
|                    |               | CUT AT U2-4 JUMPER U2-3 TO U3-10                 | JP2                      |
| 814-192-4          | 5 MHz SINE    | CUT AT U2-11 JUMPER U2-10 TO R7                  | JP3-1 TO JP3-2           |
|                    |               | REPLACE R7 WITH JUMPER,                          | DO NOT INSTALL L4 OR C17 |

- 5. SLEEVE STAND-UP RESISTORS R3, R4, R9, R13 USING CLEAR HEATSHRINK TUBING (ITEM 43). R4 MUST BE FACE AWAY FROM C4 DURING SOLDERING.
- 4. BOND INSULATOR FOAM (ITEM 41) TO CRYSTAL ASSY (ITEM 2) USING RTV ADHESIVE (ITEM 42) AS SHOWN.
- 3. IDENTIFY WITH ASSEMBLY DASH NUMBER AND REVISION LETTER.

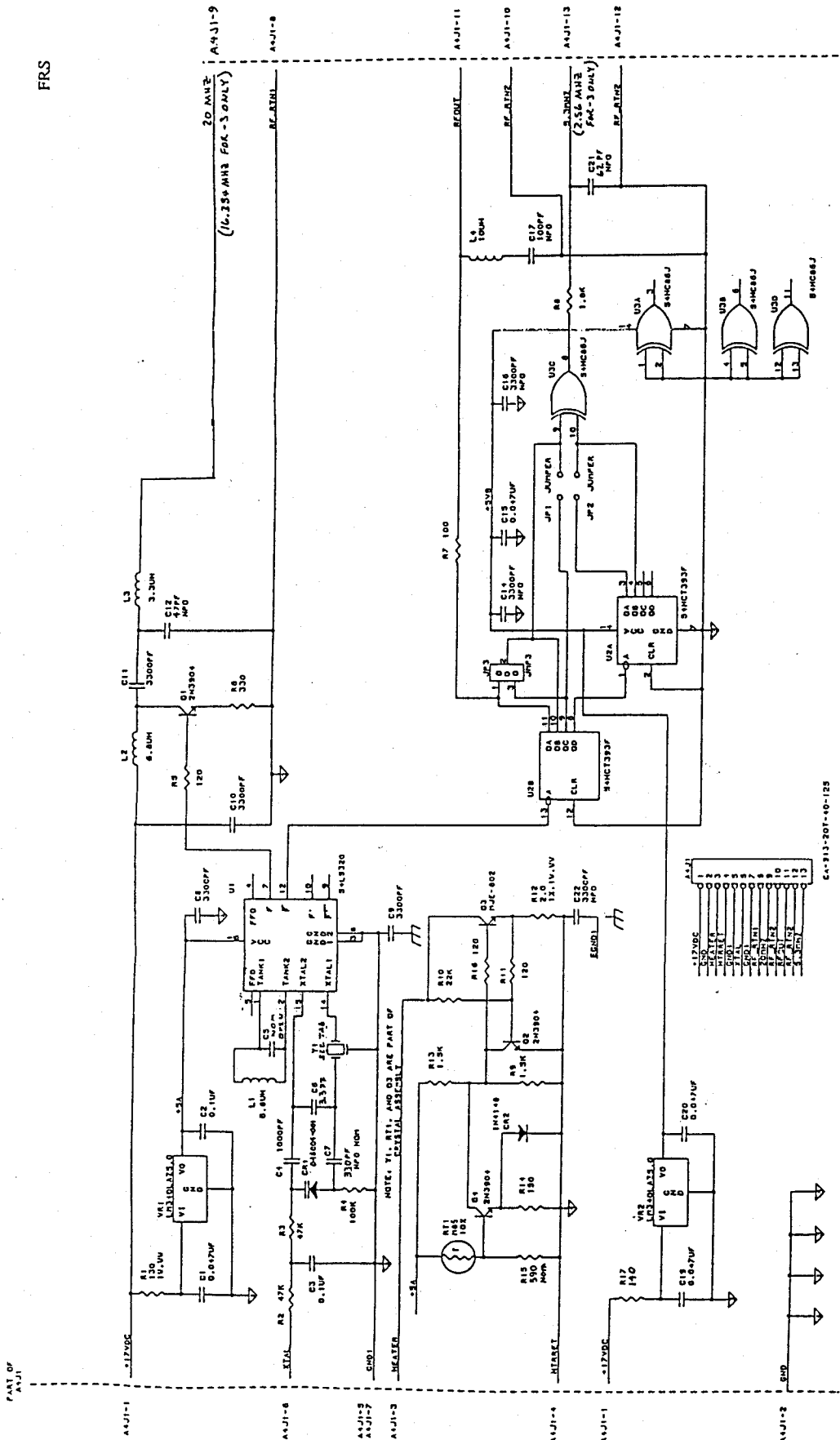
- 2. FOR SCHEMATIC SEE 814-201.
- 1. PART ATTACHMENT, WIRING, SOLDERING, CLEANING AND WORKMANSHIP SHALL BE IN ACCORDANCE WITH IPC-S-815 CLASS III.

NOTES: UNLESS OTHERWISE SPECIFIED.

ASSEMBLY A4, OSCILLATOR BOARD (814-192/REV T)



SCHEMATIC, SERVO BOARD (814-140/REV K)  
A20



| ASSEMBLY  | OUTPUT      | DESCRIPTION  |
|-----------|-------------|--|
| 814-192-1 | 10 MHz 81MC | AS SHOWN, NO JUMPERS   |
| 814-192-4 | 8 MHz 81MC  | CUT AT US-10. JUMPER FROM US-10 TO A7. DO NOT INSTALL L4 OR C17.   |
| 814-192-3 | 2.0 MHz TTL | CUT AT US-11. JUMPER FROM US-8 TO A7. CUT AT US-11. JUMPER FROM US-3 TO US-10. REPLACE R3 WITH JUMPER. DO NOT INSTALL L4.        |
| 814-192-2 | 10 MHz TTL  | CUT AT US-11. JUMPER FROM US-8 TO A7. CUT AT US-11. JUMPER FROM US-3 TO US-10. REPLACE R3 WITH JUMPER. DO NOT INSTALL L4 OR C17. |

GALL, EFRATCH DIVISION

CONTRACT No.

CAGE CODE 55761

ASSEMBLY No. 814-192

REVISION LTR. -  
REVISION DATE 9-10-90

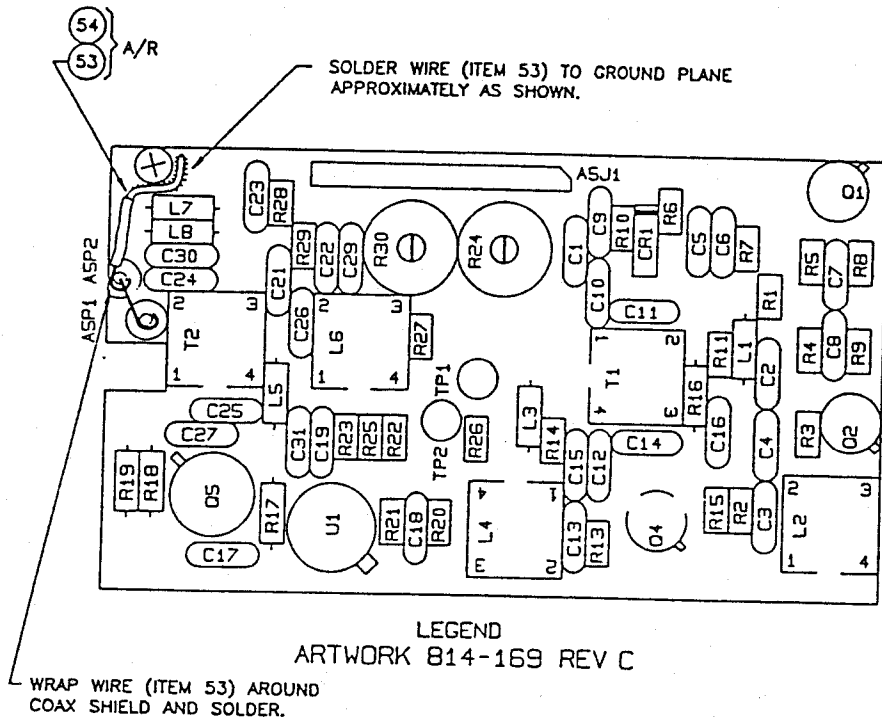
TITLE: PARTS LIST, PRINTED WIRING ASSY CRYSTAL OSCILLATOR

SHEET 1.002

| FIND No. | QTY REQ |     |     |     |    |    |    |    |    |     | CAGE CODE         | PART OR IDENTIFYING No. | SPEC. OR MANUFACTURER            | NOMENCLATURE OR DESCRIPTION | ECI CODE       | REFERENCE DESIGNATOR | UNITS No. |
|----------|---------|-----|-----|-----|----|----|----|----|----|-----|-------------------|-------------------------|----------------------------------|-----------------------------|----------------|----------------------|-----------|
|          | -1      | -2  | -3  | -4  | -5 | -6 | -7 | -8 | -9 | -10 |                   |                         |                                  |                             |                |                      |           |
| 1        | 1       | 1   | 1   | 1   |    |    |    |    |    |     | 814-202           | EFRATCH                 | PRINTED WIRING BOARD             |                             |                |                      |           |
| 2        | 1       | 1   | 1   | 1   |    |    |    |    |    |     | 814-207           | EFRATCH                 | CRYSTAL ASSEMBLY                 |                             |                |                      |           |
| 3        | 1       | 1   | 1   | 1   |    |    |    |    |    |     | CA-513-207-40-125 |                         | CONNECTOR                        |                             | Y1             |                      |           |
| 4        | 1       | 1   | 1   | 1   |    |    |    |    |    |     | *1 MK1 150        |                         | RESISTOR, 150 OHM, 1/8W          |                             | J1             |                      | 2102503   |
| 5        | 2       | 2   | 2   | 2   |    |    |    |    |    |     | *1 MK1 599        |                         | RESISTOR, 590 OHM, 1/8W, NOMINAL |                             | R14            |                      | 4702868   |
| 6        | 1       | 1   | 1   | 1   |    |    |    |    |    |     | *1 MK1 1.5K       |                         | RESISTOR, 1.5K OHM, 1/8W         |                             | R15            |                      | 4702938   |
| 7        | 1       | 0   | 0   | 0   |    |    |    |    |    |     | *1 MK1 100        |                         | RESISTOR, 100 OHM, 1/8W          |                             | R9,13          |                      | 4702867   |
| 8        | 3       | 3   | 3   | 3   |    |    |    |    |    |     | *1 MK1 120        |                         | RESISTOR, 120 OHM, 1/8W          |                             | R7             |                      | 4703051   |
| 9        | 1       | 1   | 1   | 1   |    |    |    |    |    |     | *1 MK1 330        |                         | RESISTOR, 330 OHM, 1/8W          |                             | R5,11,16       |                      | 4701526   |
| 10       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | *1 MK1 1.8K       |                         | RESISTOR, 1.8K OHM, 1/8W         |                             | R6             |                      | 4701639   |
| 11       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | *1 MK1 22K        |                         | RESISTOR, 22K OHM, 1/8W          |                             | R3             |                      | 4701617   |
| 12       | 2       | 2   | 2   | 2   |    |    |    |    |    |     | *1 MK1 47K        |                         | RESISTOR, 47K OHM, 1/8W          |                             | R10            |                      | 4702268   |
| 13       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | *1 MK1 100K       |                         | RESISTOR, 100K OHM, 1/8W         |                             | R2,3           |                      | 4701651   |
| 14       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | FR8B1S2800FR      |                         | RESISTOR, 2.00 OHM, 1W, W        |                             | R4             |                      | 4701651   |
| 15       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | FR8B1S1300FR      |                         | RESISTOR, 130 OHM, 1W, W         |                             | R12            |                      | 4702814   |
| 16       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | MK2 140           |                         | RESISTOR, 140 OHM                |                             | R1             |                      | 4701969   |
| 17       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | EDPT 27PF NFO     |                         | CAPACITOR, 27PF, NFO             |                             | C12            |                      | 4701181   |
| 18       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | EDPT 68PF NFO     |                         | CAPACITOR, 68PF, NFO             |                             | C12            |                      | 1500743   |
| 19       | 1       | 0   | 1   | 0   |    |    |    |    |    |     | EDPT 100PF NFO    |                         | CAPACITOR, 100PF, NFO            |                             | C21            |                      | 1500758   |
| 20       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | C315C151K1G5CA    |                         | CAPACITOR, 150PF, NFO, NOMINAL   |                             | C17            |                      | 1500764   |
| 21       | 7       | 7   | 7   | 7   |    |    |    |    |    |     | C122C332K1G5CA    |                         | CAPACITOR, 3300PF, NFO           |                             | C7             |                      | 1503024   |
| 22       | 2       | 2   | 2   | 2   |    |    |    |    |    |     | EDPT NFO          |                         | CAPACITOR, SELECT, NOMINAL, OPEN |                             | C8-11,14,16,22 |                      | 1500580   |
| 23       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | CKR058X102KSV     |                         | CAPACITOR, 1000PF                |                             | C5,6           |                      |           |
| 24       | 4       | 4   | 4   | 4   |    |    |    |    |    |     | CKR058X473KSV     |                         | CAPACITOR, 0.047UF               |                             | C4             |                      | 1500704   |
| 25       | 2       | 2   | 2   | 2   |    |    |    |    |    |     | CKR058X104KSV     |                         | CAPACITOR, 0.1UF                 |                             | C1,15,19,20    |                      | 1500693   |
| 26       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | MS75084-6         |                         | CAPACITOR, 3.3UF                 |                             | C2,3           |                      | 1500688   |
| 27       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | MS75084-9         |                         | INDUCTOR, 3.3UH                  |                             | L3             |                      | 1502933   |
| 28       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | MS75084-10        |                         | INDUCTOR, 5.6UH                  |                             | L1             |                      | 1801449   |
| 29       | 1       | 0   | 1   | 0   |    |    |    |    |    |     | MS75084-12        |                         | INDUCTOR, 6.5UH                  |                             | L2             |                      | 1801445   |
| 30       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | 704-288           |                         | INDUCTOR, 10UH                   |                             | L4             |                      | 1801446   |
| 31       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | 184143            |                         | DIGGE, HYPER ABRUPT              |                             | C21            |                      | 4800197   |
| 32       | 3       | 3   | 3   | 3   |    |    |    |    |    |     | 2H3904            |                         | DIGGE                            |                             | C22            |                      | 4001007   |
| 33       | 2       | 2   | 2   | 2   |    |    |    |    |    |     | LM340LA25.0       |                         | TRANSISTOR                       |                             | Q1,2,4         |                      | 3132071   |
| 34       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | 54LS320J          | TI                      | VOLTAGE REGULATOR, 5V            |                             | V2,2           |                      | 3131127   |
| 35       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | 54HCT393F         | ECA                     | IC, 54HCT393                     |                             | U1             |                      | 2621428   |
| 36       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | 54HC36J           | TI                      | IC, 54HC36J                      |                             | U2             |                      |           |
| 37       | 2       | 2   | 2   | 2   |    |    |    |    |    |     | MS51957-3         |                         | IC, 54HC86J                      |                             | U3             |                      |           |
| 38       | AR      | AR  | AR  | AR  |    |    |    |    |    |     | 271               | LOCKTITE                | SCREEN, PAN RD, 2-56 X 1/4 LG    |                             |                |                      |           |
| 39       | AR      | AR  | AR  | AR  |    |    |    |    |    |     | 70424-19          | LOCKTITE                | ADHESIVE                         |                             |                |                      |           |
| 40       | 0       | 1   | 1   | 1   |    |    |    |    |    |     | JO.3000.125T24    | LOCKTITE                | ADHESIVE, TAK-PAX                |                             |                |                      |           |
| 41       | 1       | 1   | 1   | 1   |    |    |    |    |    |     | 614-164           | SQUIRES ELEC.           | JUMPER WIRE, PRESLEEVED          |                             | (E7)           |                      |           |
| 42       | A/R     | A/R | A/R | A/R |    |    |    |    |    |     | 70424-7           |                         | INSULATOR FOAM                   |                             |                |                      |           |
| 43       | A/R     | A/R | A/R | A/R |    |    |    |    |    |     | 70422-3           |                         | ADHESIVE, ETV 108                |                             |                |                      |           |
|          |         |     |     |     |    |    |    |    |    |     |                   |                         | SLEEVING, HEATSHRINK, CLEAR      |                             |                |                      |           |
|          |         |     |     |     |    |    |    |    |    |     |                   |                         | MAY USE RCROSSXXXS               |                             |                |                      |           |

NOTES: UNLESS OTHERWISE SPECIFIED.

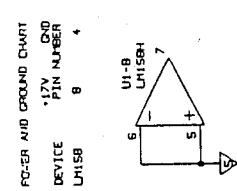
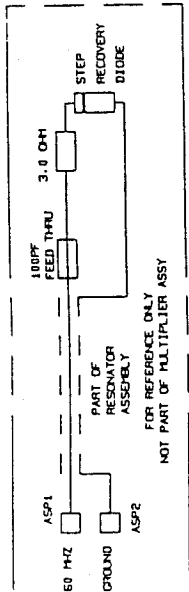
1. WORKMANSHIP SHALL BE PER MIL-STD-454K REQUIREMENT 9. (NO CERTIFICATIONS REQUIRED)
2. ALL SOLDERING, WIRING AND COMPONENT MOUNTING SHALL MEET THE REQUIREMENTS OF IPC-S-815 CLASS III.
3. LEADS SHOULD BE PARTIALLY CLINCHED OR SWAGED FOR PART RETENTION PRIOR TO SOLDERING. (FOR REF. ONLY SEE MIL-P-46843B TYPE II OR TYPE III).
4. AFTER SOLDERING, CLEAN ASSEMBLY TO REMOVE ALL FLUX RESIDUE.
5. IDENTIFY ASSEMBLY WITH ASSEMBLY NUMBER (AND DASH NO. IF REQ'D), REVISION LETTER AND SERIAL NUMBER.
6. LEAD PROJECTION BELOW BOARD SURFACE SHALL BE .020 MIN .060 MAX.
7. FOR SCHEMATIC DIAGRAM SEE DRAWING NUMBER 814-168
8. INSTALL ITEM 52 (TERMINALS) 3 PLACES (TP1, TP2, ASP1) FUNNEL SWAGE CIRCUIT SIDE PRIOR TO SOLDERING.
9. VIEW SHOWN IS FOR PCB 814-169 REV C ONLY



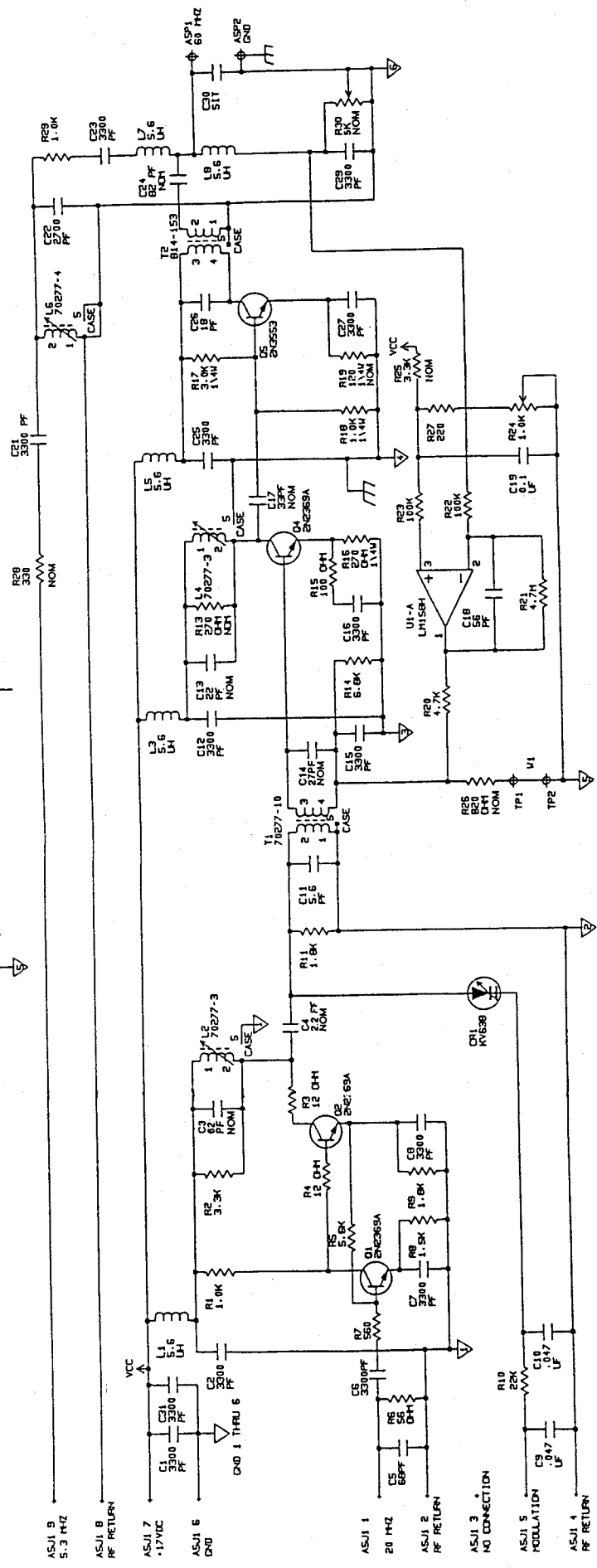
| TABULATION |            |
|------------|------------|
| FRS        | PARTS LIST |
| 10MHz TTL  | 814-167-1  |
| 13MHz TTL  | 814-167-2  |

ASSEMBLY A5, MULTIPLIER BOARD (814-167/REV E)

- NOTES :** UNLESS OTHERWISE SPECIFIED.
1. RESISTORS ARE 1/8 WATT. 5% COMPOSITION. VALUES ARE IN OHMS.
  2. CAPACITORS ARE CERAMIC. VALUES ARE IN MICRO FARADS.
  3. FOR ASSEMBLY DRAWING SEE DRAWING 814-167



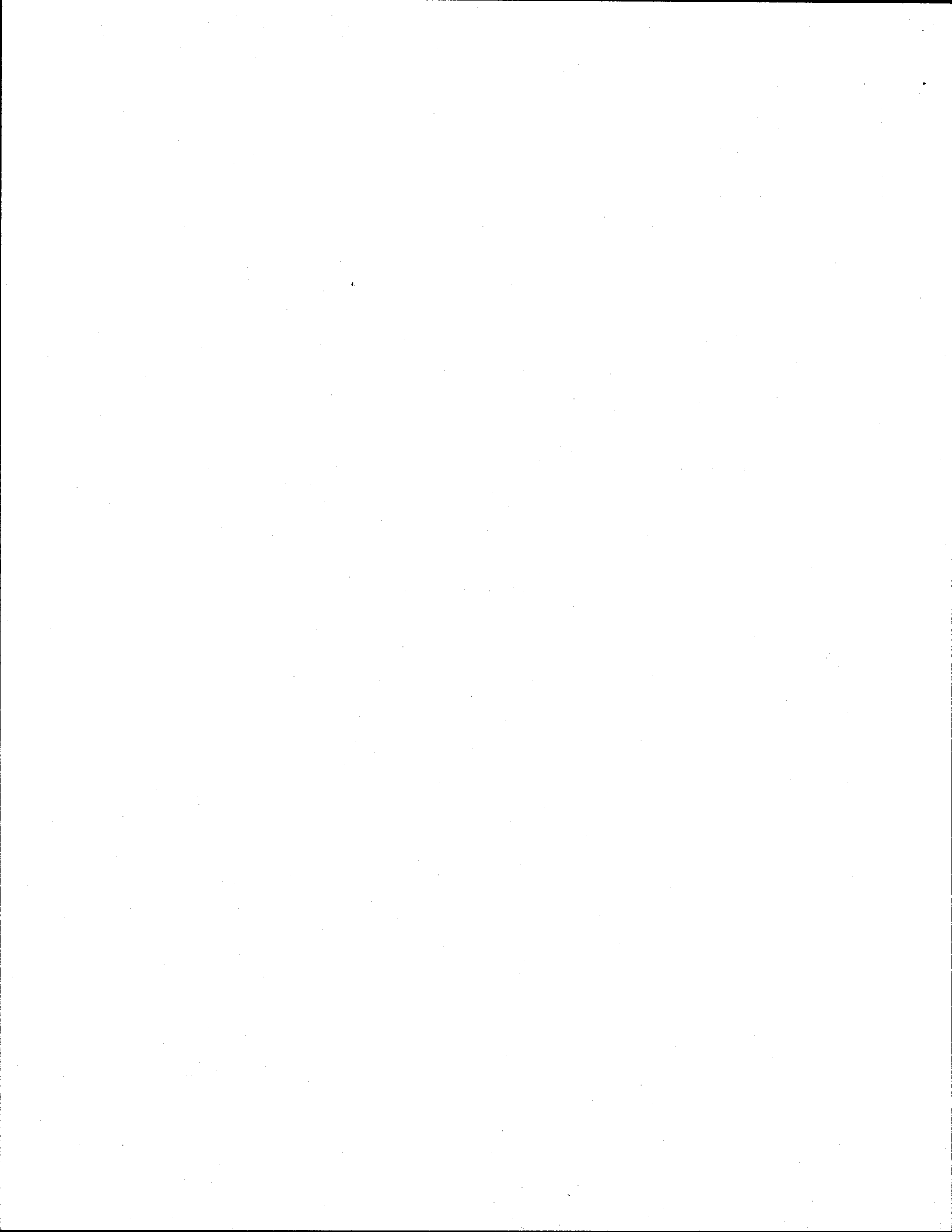
| LAST USED | NOT USED |
|-----------|----------|
| C31       | C20, C28 |
| L8        | O3       |
| O5        | R12      |
| R30       |          |
| T2        |          |
| U1        |          |
| U1        |          |
| CR1       |          |



TABULATION

|                    | C3        | C11    | C13       | C14       | C17       | C22       | R28        |
|--------------------|-----------|--------|-----------|-----------|-----------|-----------|------------|
| 5 & 10MHZ SINE TTL | 62 PF NDM | 5.6 PF | 22 PF NDM | 27 PF NDM | 33 PF NDM | 18 PF NDM | 330 NDM    |
| 13MHZ TTL          | 47 PF NDM | OPEN   | 12 PF NDM | 22 PF NDM | 27 PF NDM | 22 PF NDM | 820 PF NDM |
|                    |           |        |           |           |           |           | 1 K NDM    |

SCHEMATIC, MULTIPLIER BOARD (814-168/REV F)  
A27



BALL, EFRATOM DIVISION      CONTRACT No.      CAGE CODE 55761      814-167-2      REVISION LTR. -  
 TITLE: PARTS LIST, 13MHZ MULTIPLIER BD ASSEMBLY      REVISION DATE 91-05-21

SHEET 2

| FIND No. | QTY REQ | PART OR IDENTIFYING No. | SPEC. OR MANUFACTURER | NOMENCLATURE OR DESCRIPTION                    | REFERENCE DESIGNATOR | UNIS No. |
|----------|---------|-------------------------|-----------------------|--|----------------------|----------|
| 1        | 1       | 814-169                 | EFRATOM               | P.W.B. FABRICATION                             |                      |          |
| 2        | A/R     | SN6JWRMAP3              | QQ-S-571              | SOLDER   |                      |          |
| 3        | 1       | CA-S09-20T-40-125       | CIRCUIT ASSY          | CONNECTOR, 9 PIN                               | A5J1                 | 2102502  |
| 4        | 1       | EDPT 2.2 PF NPO         | STETTNER              | CAPACITOR, CER 2.2PF NOM                       | C4                   | 1503020  |
| 5        |         |                         |                       | NOT USED                                       |                      |          |
| 6        | 2       | EDPT 22 PF NPO          | STETTNER              | CAPACITOR, CER 22 PF NOM                       | C14,C26              | 1500742  |
| 7        |         |                         |                       | NOT USED                                       |                      |          |
| 8        | 1       | EDPT 12 PF NPO          | STETTNER              | CAPACITOR, CER 12 PF NOM                       | C13                  | 1500738  |
| 9        | 1       | EDPT 27 PF NPO          | STETTNER              | CAPACITOR, CER 27 PF NOM                       | C17                  | 1500743  |
| 10       |         |                         |                       | NOT USED                                       |                      |          |
| 11       | 1       | EDPT 56 PF NPO          | STETTNER              | CAPACITOR, CER 56 PF                           | C18                  | 1500753  |
| 12       | 1       | EDPT 68 PF NPO          | STETTNER              | CAPACITOR, CER 68 PF                           | C5                   | 1500758  |
| 13       | 1       | EDPT 82 PF NPO          | STETTNER              | CAPACITOR, CER 82 PF NOM                       | C24                  | 1500760  |
| 14       | 1       | EDPT 820 PF Y5P         |                       | CAPACITOR, CER 820 PF NOM                      | C22                  | 1500796  |
| 15       | 14      | C322C332K1G5CA          |                       | CAPACITOR, CER 3300 PF                         |                      | 1500580  |
|          |         |                         |                       | C1, 2, 6-8, 12, 15, 16, 21, 23, 25, 27, 29, 31 |                      |          |
| 16       | 2       | CKR05BX473KS            | MIL-C-11015           | CAPACITOR, CER .047uF                          | C9, 10               | 1500693  |
| 17       | 1       | CKR05BX104KS            | MIL-C-11015           | CAPACITOR, CER 0.1uF                           | C19                  | 1500688  |
| 18       | 1       | EDPT (SELECT)           | STETTNER              | CAPACITOR, CER SELECT                          | C30                  |          |
| 19       | 1       | KV638                   |                       | DIODE, VARACTOR                                | CR1                  | 4800966  |
| 20       | 5       | MS75084-9               |                       | INDUCTOR, 5.6UH                                | L1, L3, L5, L7-8     | 1801449  |
| 21       | 2       | 70277-3                 | EFRATOM               | INDUCTOR, VARIABLE                             | L2, L4               |          |
| 22       | 1       | 70277-4                 | EFRATOM               | INDUCTOR, VARIABLE                             | L6                   |          |
| 23       | 3       | 2N2369A                 |                       | TRANSISTOR, NPN                                | Q1, Q2, Q4           | 4800190  |
| 24       | 1       | 2N3553                  |                       | TRANSISTOR, NPN                                | Q5                   | 4800195  |
| 25       | 2       | RCR05G120JR             |                       | RESISTOR, 1/8W 5% 12 OHM                       | R3, R4               | 4701525  |
| 26       | 1       | RCR05G560JR             |                       | RESISTOR, 1/8W 5% 56 OHM                       | R6                   | 4701656  |
| 27       | 1       | RCR05G101JR             |                       | RESISTOR, 1/8W 5% 100 OHM                      | R15                  | 4701599  |
| 28       | 1       | RCR05G271JR             |                       | RESISTOR, 1/8W 5% 270 OHM NOM                  | R13                  | 4701632  |
| 29       | 1       | RCR05G221JR             |                       | RESISTOR, 1/8W 5% 220 OHM                      | R27                  | 4701627  |
| 30       |         |                         |                       | NOT USED                                       |                      |          |
| 31       | 1       | RCR05G561JR             |                       | RESISTOR, 1/8W 5% 560 OHM                      | R7                   | 4702263  |
| 32       | 3       | RCR05G102JR             |                       | RESISTOR, 1/8W 5% 1.0K                         | R1, R28, R29         | 4701600  |
| 33       | 1       | RCR05G152JR             |                       | RESISTOR, 1/8W 5% 1.5K                         | R8                   | 4701527  |



BALL, EFRATOM DIVISION      CONTRACT No.      CAGE CODE 55761      814-167-2      REVISION LTR. -  
 TITLE: PARTS LIST, 13MHZ MULTIPLIER BD ASSEMBLY      REVISION DATE 91-05-21

SHEET 3

| FIND No. | QTY REQ | PART OR IDENTIFYING No. | SPEC. OR MANUFACTURER | NOMENCLATURE OR DESCRIPTION   | REFERENCE     |          |
|----------|---------|-------------------------|-----------------------|-------------------------------|---------------|----------|
|          |         |                         |                       |                               | DESIGNATOR    | UNIS No. |
| 34       | 2       | RCR05G182JR             |                       | RESISTOR, 1/8W 5% 1.8K        | R9,R11        | 4701617  |
| 35       | 2       | RCR05G332JR             |                       | RESISTOR, 1/8W 5% 3.3K        | R2, (R25 NOM) | 4701640  |
| 36       | 1       | RCR05G472JR             |                       | RESISTOR, 1/8W 5% 4.7K        | R20           | 4702265  |
| 37       | 1       | RCR05G562JR             |                       | RESISTOR, 1/8W 5% 5.6K        | R5            | 4701657  |
| 38       | 1       | RCR05G682JR             |                       | RESISTOR, 1/8W 5% 6.8K        | R14           | 4702604  |
| 39       | 2       | RCR05G104JR             |                       | RESISTOR, 1/8W 5% 100K        | R22,R23       | 4701602  |
| 40       | 1       | RCR05G223JR             |                       | RESISTOR, 1/8W 5% 22K         | R10           | 4702268  |
| 41       | 1       | RCR05G475JR             |                       | RESISTOR, 1/8W 5% 4.7M        | R21           | 4701550  |
| 42       | 1       | RCR07G121JR             |                       | RESISTOR, 1/4W 5% 120 OHM NOM | R19           | 4701691  |
| 43       | 1       | RCR07G271JR             |                       | RESISTOR, 1/4W 5% 270 OHM     | R16           | 4701714  |
| 44       | 1       | RCR07G102JR             |                       | RESISTOR, 1/4W 5% 1.0K        | R18           | 4701686  |
| 45       | 1       | RCR07G302JR             |                       | RESISTOR, 1/4W 5% 3.0K        | R17           | 4701716  |
| 46       | 1       | RCR05G821JR             |                       | RESISTOR, 1/8W 5% 820 OHM     | R26           | 4702264  |
| 47       | 1       | 3386P-1-102             | BOURNS                | RESISTOR, VAR 1.0K            | R24           | 4750253  |
| 48       | 1       | 70277-10                | EFRATOM               | TRANSFORMER                   | T1            |          |
| 49       | 1       | 814-153                 | EFRATOM               | TRANSFORMER                   | T2            |          |
| 50       | 1       | LM158H                  | NATIONAL              | I.C. OP-AMP                   | U1            | 3130993  |
| 51       | 1       | CCR05CG470JR            |                       | CAPACITOR CER 47 PF NOM       | C3            | 1502522  |
| 52       | 3       | M55155/30-09            | MIL-T-55155           | TERMINAL                      | TP1,TP2,A5P1  | 2101101  |
| 53       | A/R     | QQ-W-343S24SIT          | QQ-W-343              | WIRE, 24AWG, BUSS             |               |          |
| 54       | A/R     | 24GATWTFL               |                       | SLEEVING, 24AWG, AMS-3655     |               |          |
| 55       |         |                         |                       | NOT USED                      |               |          |
| 56       | 1       | 3339P-1-502             |                       | RESISTOR, VAR, 5K NOM         | R30           | 4750249  |
| 57       | 3       | 7717-46N                |                       | PAD, TRANSISTOR               | XQ1,2,4       | 2102342  |
| 58       | 1       | 5203-11                 |                       | PAD, TRANSISTOR               | XQ5           | 3100370  |
| 0        |         |                         |                       |                               |               |          |
| 0        |         |                         |                       |                               |               |          |

\*NOTE: 1.USE MK1 RES IF RCR05GXXXJR UNAVAIL.  
 2.USE MK2 RES IF RCR07GXXXJS UNAVAIL.

**APPENDIX B**

**FRS MONITORS AND ADJUSTMENTS AT CONNECTOR J1**

**Lamp Voltage Monitor,  
Crystal Control Voltage Monitor,  
and External Frequency Adjustments**

### Lamp Voltage Monitor

When the FRS unit is assembled its lamp voltage is set at the factory to ~14 volts. Over the first year of operation this voltage level will decay by 2 to 3 volts. After the first year of operation this decay becomes much less. The decay can go as low as 6 volts before the operation of the unit is affected.

Lamp voltage levels also vary depending on the state of the unit. When a FRS is first powered up the lamp voltage is between 1.5 to 3 volts. Once the rubidium lamp ignites, lamp voltage rises to between 14 to 9 volts in a working unit, depending on its operating duration. This voltage change is used to switch the FRS internal regulated power supply from 22 to 17 Vdc. The lamp requires 22 volts to ignite, but after ignition only 17 volts is required to maintain operation.

Functionally, the lamp monitor circuit measures the lamp voltage through a 1 megOhm resistor (that protects the lamp circuit). The reading will change depending on the input impedance of the voltage measuring device. The higher the input impedance, the more accurate the measurement will be. The resistor and the input impedance form a voltage divider that reduces the measured voltage.

#### NOTE:

The lamp voltage monitor is for factory use and reference only, and is not intended as customer use. If there is a special requirement that makes it necessary to monitor the lamp voltage level in the field, the customer should contact Efratom's Marketing or Customer Service groups so that Efratom's technical staff can evaluate these needs and make recommendations.

## **Crystal Voltage Monitor**

The crystal voltage controls the crystal oscillator output frequency through the error signal, slaving the oscillator output to the atomic frequency. As the unit warms up the crystal voltage sweeps the oscillator frequency to detect the atomic frequency signal. The voltage range of these sweeps is between 1.5 and 12 volts dc. Upon detecting the atomic frequency the unit locks and the monitor circuit automatically controls the crystal voltage at the level necessary to lock the output signal to the atomic frequency. Generally, this is any voltage from 2 to 10 volts (but typically 4 to 8 volts), depending on conditions.

The lock monitor is normally used by Efratom as an indication that the output frequency is locked to the atomic frequency. In this use, the lock monitor signal supercedes both the lamp voltage and crystal voltage as a failure indication.

### **NOTE:**

The crystal voltage monitor is for factory use and reference only, and is not intended as customer use. If there is a special requirement that makes it necessary to monitor the crystal voltage level in the field, the customer should contact Efratom's Marketing or Customer Service groups so that Efratom's technical staff can evaluate these needs and make recommendations.

## External Frequency Adjustment

The external frequency adjustment feature allows the user to change the output frequency of the FRS over a range of  $\pm 1$  to  $\pm 1.5 \times 10E-9$  using a customer supplied 1000 Ohm potentiometer, or placing 0 to +5 volts across the external connector pins (from a customer supplied source). When a potentiometer is used, pins 2 (wiper), 3 and 8 (ends) are connected. For 0 to +5 volts, pins 2(+) and 3 (gnd) are used.

When either of these two methods are used, they will override the setting of the internal frequency adjustment.

The following figures show simple schematics of the external frequency adjustment connections.

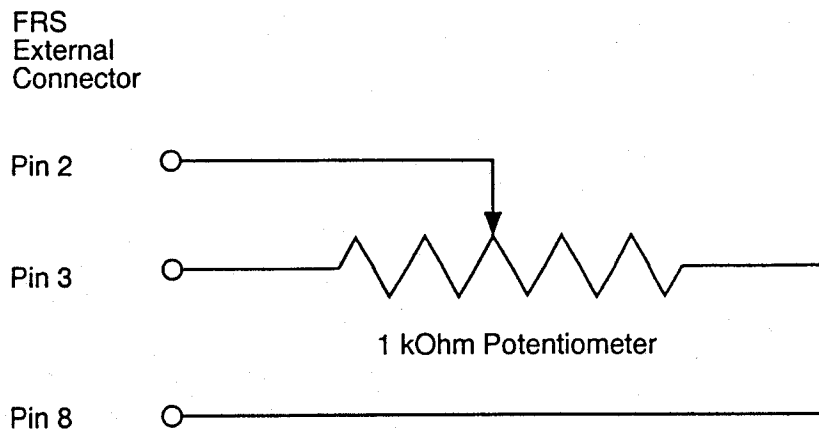


Figure B1. Potentiometer Connections

### 0 to +5 Volt Connections

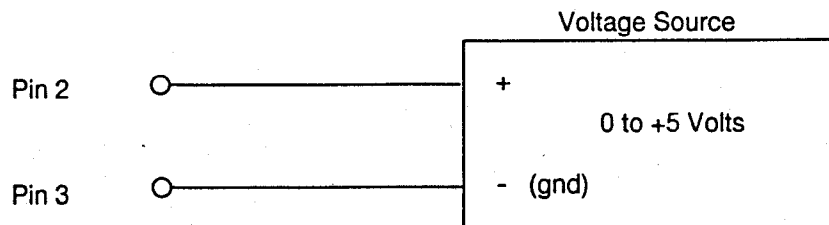


Figure B2. 0 to +5 Volt Connections

## LIMITED WARRANTY

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"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 to either 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 AND 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."

Efratom Time & Frequency Products, Inc. will be happy to answer any application or usage questions which will enhance your use of the unit. Please address your requests or correspondence to: EFRATOM Time & Frequency Products, Inc., 3 Parker, Irvine, California 92718-1696, Attention: Sales Department, or call (714) 770-5000, Fax: (714) 770-2463.

European customers may contact: Efratom Elektronik GmbH, Fichtenstr 25, 85649 Hofolding, Germany, Telephone: 08104-66240; Telex 529701; Fax: 08104-6622428.