# EFRATOM
CALIFORNIA, INC.

INSTALLATION AND OPERATION
MANUAL

RUBIDIUM FREQUENCY STANDARD MODEL **FRK**

TABLE I

# TABLE OF CONTENTS

Section

TABLE II

TERMINAL CONNECTIONS

FRK

1. 10 MHz Output (1 V rms, 50 ohms)
2. 10 MHz Ground (isolated from enclosure – see Figure 3)
3. Negative, power supply ground (connected to enclosure)
4. +28 V dc power supply (23-32 V dc)
5. OPN – Monitor – atomic resonance controlled operation
6. VCXO – Monitor – crystal oscillator control voltage
7. RBL – Monitor – voltage, optical package
8. }
9. } Optional remote frequency adjust

## TABLE III

## SPECIFICATION RUBIDIUM FREQUENCY STANDARD MODEL FRK

| | |
|---|---|
| Output | 10 MHz sine wave 1 V rms, $R_o$ = 50 ohms. |
| Signal to Noise | >120 dB in 1 Hz band at more than 200 Hz from nominal frequency |
| Supply Voltage | 28 V dc (23 V to 32 V dc) |
| Power Consumption | 13 W at 25°C ambient |
| Warm-up Characteristic | 10 minutes to reach $2 \times 10^{-10}$ (from ambient of 25°C, I max = 1.7 A) |
| Long Term Stability | $<1 \times 10^{-10}$ / month (typ. $3 \times 10^{-11}$ / month) |
| Short Term Stability | $<5 \times 10^{-11}$ for $\tau$ = 1 sec. (typ. $2 \times 10^{-11}$) |
| Trim Range | $2 \times 10^{-9}$ (25 turn pot) |
| Environmental | |
| Voltage | $<1 \times 10^{-10}$ from 23 V to 32 V dc |
| Temperature | $<1 \times 10^{-9}$ from -25°C to +65°C (typ. $5 \times 10^{-10}$) |
| Magnetic Field | $<1 \times 10^{-12}$ / $Am^{-1}$ |
| Altitude | $<5 \times 10^{-13}$ / mbar |
| Temperature Range* | -25°C to +65°C |
| Storage Temperature | -30°C to +70°C |
| Size | 3.9 x 3.9 x 4.4 inches (100 x 99 x 112 mm) |
| Weight | 2.2 lbs (1 kg) |
| Electrical Protection | An internal diode and fuse protects against reversed polarity connection. |
| Electrical Connections | Coaxial output receptacle OSM 211; jack/terminal mates with OSM 501-3 flexible plug/cable or equivalent. Power input, monitor signals, and optional external frequency trim. Contacts are eight push-on connector pins 0.052" diameter, spaced 0.197" O.C. |
| Monitor Signals | Atomic resonance controlled operation, crystal oscillator and optical package monitor voltage. |
| Cooling | Base plate contact with heat transfer surface 65°C or lower. Optional Heat Sink, Model EEK-10, may be used for cooling by ambient air in applications having no suitable heat transfer surface. |
| Warranty | 1 year; lamp and resonance cell 3 years. |

*The highest possible environmental temperature depends on the thermal impedance of the unit with respect to its environment. The values specified refer to measurements made at the base plate of the unit.

RUBIDIUM ATOMIC FREQUENCY STANDARD

MODEL FRK

OPERATING INSTRUCTIONS

# I GENERAL INFORMATION

## 1.1 DESCRIPTION

The Model FRK Rubidium Frequency Standard is a sub-compact atomic resonance controlled oscillator which provides an extremely pure and stable sinusoidal signal at a frequency of 10 MHz. It is designed for use in high performance communications systems, frequency standard equipment, advanced navigation equipment and all other systems and equipment applications which require extremely precise frequencies and time intervals.

## 1.2 SPECIFICATIONS

Specifications for the FRK unit are given in Table III.

## 1.3 ACCESSORIES

Accessories available for use with the FRK include the Model EEK-10 Air Cooled Heat Sink for applications in which a suitable heat transfer surface is not available. Also available is a mating connector for the 10 MHz output, type OSM 501-3.

## 1.4 OPTIONS

The Model FRK may be ordered with alternate internal resistor configuration which permits optional external frequency adjustment.

# II INSTALLATION

## 2.1 INITIAL INSTALLATION

Prior to shipment, this unit is required to pass rigid mechanical and electrical inspection procedures, and is guaranteed to be free from defects. As soon as the unit is unpacked, it should be inspected for damage which may have occurred in transit. Save packing materials until this inspection is completed.

## 2.2 MOUNTING

The Model FRK is shipped ready for installation in equipment or, with suitable cooling provisions and power supply connections, it may be operated as a free-standing frequency standard.

The unit may be mounted with the aluminum thermal base plate in contact with a flat metal surface using eight metric screws (M 2.6). The mounting screws should not be allowed to penetrate the base plate more than 0.200 inches (5 mm). The heat transfer characteristic of the mounting surface must be adequate to limit the temperature rise of the FRK base plate to 65°C. The allowable environmental temperature, $T_a$, for this mounting method is

$$T_a = 65°C - V_s \, I_s \, R_K \; .$$

where

$V_s$ is supply voltage (volts)

$I_s$ is supply current (amps)

$R_K$ is the thermal resistance of the cooling surface (°C/watt)

It is recommended that the mounting surface be designed to permit free access to the frequency trim potentiometer and the spectral lamp service port (large slotted screw – see Figure 8.)

An alternate method of mounting is by using four 8/32 screws in the enclosure (Figure 5). In this case the EEK-10 heat sink must be attached securely to the thermal base plate.

## 2.3 POWER SUPPLY CONNECTIONS

The FRK requires power supply voltage between 23 and 32 V dc. The negative connection must be made to terminal pin (3) and the positive connection must be made to terminal pin (4). (Table II and Figure 7.)

CAUTION: Reverse polarity protection for semi-conductor components is provided by a diode and fuse. Replacement of the fuse is an internal repair operation. (See Section 5.4)

In order to realize the best signal to noise ratio performance of 120 dB, the maximum ac ripple on the output of the power supply must be less than one millivolt peak to peak, particularly at 120 Hz. When the best signal to noise ratio is not important, the ripple can be higher but in no case should the supply voltage exceed the upper limit of the FRK. It is, therefore, possible to design the power supply for low ripple performance at a lower current than the warm-up value of about 1.7 A and permit a voltage with a higher ac component during warm-up (approx. 10 minutes).

## 2.4 FREQUENCY OUTPUT CONNECTIONS

The 10 MHz sinusoidal output is 1 V rms with a source impedance of 50 ohms. The output is short circuit protected. The coaxial output receptacle is OSM 211 which mates with coaxial cable plug OSM 501-3. The output is illustrated in Figure 3.

## 2.5 MONITOR SIGNAL CONNECTIONS

The terminal pins 5, 6, and 7 (Figure 7 or Table II) are provided to monitor the operation of the FRK.

The resonance signal derived from the atomic transition switches a transistor gate which is connected to terminal pin 5. This switch, illustrated in Figure 4, can be used to control a relay or a lamp. When the correct resonance signal for control of the crystal oscillator is present, the gate is closed. Maximum switching capacity is 70 V, 50 mA. When switching inductive loads, a diode must be used.

The control voltage of the quartz crystal oscillator is available at terminal pin 6. This signal, with no load, varies between 0.6 V and 17 V and the source resistance is 27 K. The circuit is short circuit protected.

Terminal pin 7 provides an indication of proper operation of the rubidium lamp. For nominal operation the signal is 6 to 12 V. An inoperative lamp is indicated by a signal of approximately 3 V. The internal resistance of this circuit is approximately 6 K.

# III OPERATING INSTRUCTIONS

## 3.1 WARM-UP

After the application of power, the Model FRK requires a short warm-up period. The closure of the transistor gate, .terminal pin 5 (Section 2.5) will occur within 10 minutes, indicating control of the quartz crystal oscillator by the atomic resonance. During warm-up the crystal oscillator monitor voltage, terminal pin 7 (Section 2.5) will vary slowly between the limits due to the automatic search for the rubidium atomic resonance.

## 3.2 CHECK-OUT

After a short warm-up period the monitor signals should be checked at terminal pins 5, 6 and 7 to determine that the frequency is locked to the rubidium resonance, the quartz crystal oscillator control voltage is within the normal range. (Section 2.5).

## 3.3 FREQUENCY ADJUSTMENT

The frequency of the FRK may be adjusted over a range of approximately $2 \times 10^{-9}$ by means of 25 turn potentiometer accessible through an access hole in the base plate of the unit (Figure 6). An option which may be requested from the factory provides for remote frequency adjustment using an external potentiometer connected to terminal pins 8 and 9.

Prior to shipment the frequency of the FRK is set within $\pm 5 \times 10^{-11}$ of 10 MHz.

# IV PRINCIPLE OF OPERATION

## 4.1 SYSTEM ORGANIZATION

The basic organization of the FRK rubidium resonance controlled oscillator is illustrated conceptually in the FRK Block Diagram.

The frequency of the voltage controlled crystal oscillator (VXCO) is multiplied and synthesized to match the frequency of the rubidium resonance (approximately 6834.68 MHz).

The resulting signal is applied to the rubidium optical resonator cell within which atomic transitions are induced when the frequencies of the signal and the Rb 87 atomic resonance are precisely equal. Optical radiation from a rubidium lamp also passes through the resonance cell and illuminates a silicon photo detector. Atomic transitions due to resonance increase the absorption of the rubidium light within the cell with a corresponding change in the photo detector current. This effect is used to generate a control signal which continuously and automatically regulates the voltage controlled crystal oscillator frequency such that it corresponds to the Rb 87 atomic resonance.

In order to provide logic signals with sense information as required for the control system, a modulation method is used. Conceptually this modulation may be considered to cause a relatively slow (127 Hz) variation of the frequency applied to the rubidium resonance cell. As illustrated in Figure 2, the resulting photo detector current contains a 127 Hz component of opposite phase when the frequency of the applied signal is higher. These ac signals of opposite phase are converted to dc signals of opposite polarity for control purposes in the phase detector which utilizes the modulation oscillator signal as a reference.

## 4.2 LOCK SIGNAL LOGIC

When the frequency of the applied signal is exactly the same as that of the Rb 87 resonance, the fundamental modulation frequency component of the photo detector current is zero and the second harmonic content is maximum as illustrated in Figure 2. This second harmonic component is amplified, rectified and used to drive a transistor gate to the conducting state. This gate is available at terminal pin 5 (Section 2.5) indicating positive lock to the rubidium resonance.

## 4.3 BLOCK DIAGRAM

FRK Block Diagram illustrates circuit interactions. It shows a magnetic field within the rubidium optical resonator necessary to accomplish the atomic resonance conditions which permit the fine adjustment of frequency (Section 3.3).

A feed-back control affecting the magnetic field is provided in order to reduce the effects of small variations in Rb 87 cell temperature upon frequency. This feature contributes to rapid frequency stabilization during warm-up as well as improved stability characteristics throughout a wide range of environmental temperature variation.

# V MAINTENANCE

The Model FRK is essentially maintenance free and the only routine check that should be anticipated involves the aging of the quartz crystal which may cause its base frequency to approach the limit of control. While degradation of the rubidium lamp is very unlikely, simple provisions have been included for replacement if necessary.

## 5.1 REMOVAL OF ENCLOSURE

The enclosure of the FRK may be removed by loosening the four screws which enter the aluminum base plate and by removing two screws in the end opposite the base plate (terminal end). The enclosure is a magnetic shield which should be handled carefully.

## 5.2 COMPENSATION OF CRYSTAL AGING

If the quartz crystal oscillator voltage approaches the end of the control range (1 to 16 V, Section 2.5) a correction of the crystal oscillator base frequency must be made. This is accomplished by adjusting the oscillator trimmer (Figure 8). Clockwise adjustment of the trimmer causes an increase in the control voltage. The adjustment should be made after the unit has operated for at least one hour and the control voltage should be 5 V.

## 5.3 RUBIDIUM LAMP EXCHANGE

In the unlikely case that it is necessary to replace the rubidium spectral lamp, the exchange can be made without turning the unit off. The lamp is accessible (Figure 6) after removing the large slotted screw in the heat sink. A special tool is provided with the replacement lamp in order to make the exchange. The replacement lamp is specified as PN EEK-02.

## 5.4 FUSE REPLACEMENT

The FRK is protected against reversed polarity power connection by a fuse. Replacement of the fuse requires removal of the enclosure. Location is illustrated in Figure 9.

Replacement fuses are specified as Pico Fuse 275003.

The replacement of a fuse should only be undertaken if adequate facilities and skills are available. Damage caused in the process will invalidate the warranty.

For assistance and advice in making this or any other repair or adjustment, please feel free to contact:

EFRATOM CALIFORNIA INC.
3303 Harbor Blvd., Suite E1
Costa Mesa, CA. 92626
Tel. (714) 556-1620 TWX 685-635

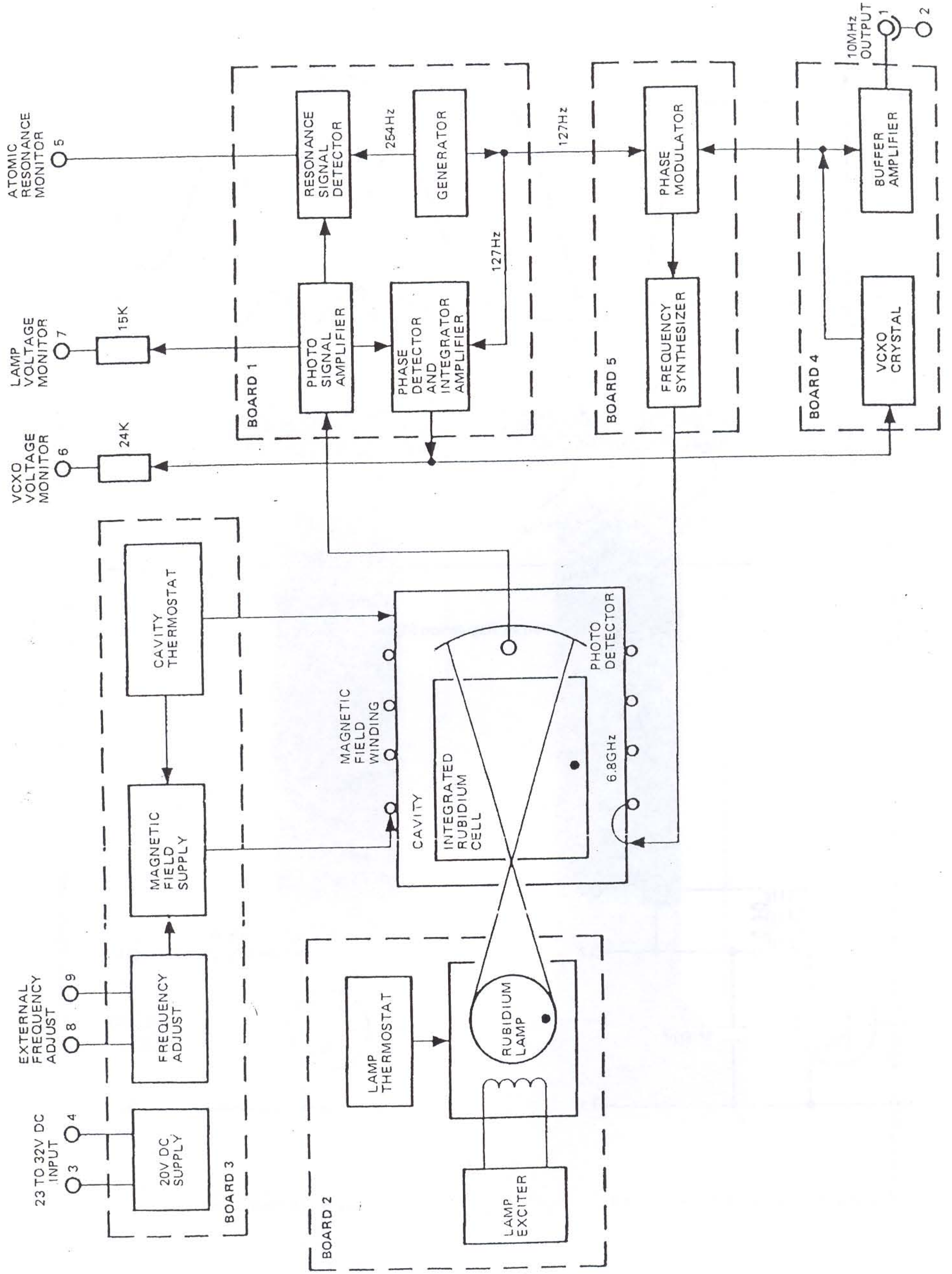



Figure 1. Efratom Model FRK Block Diagram

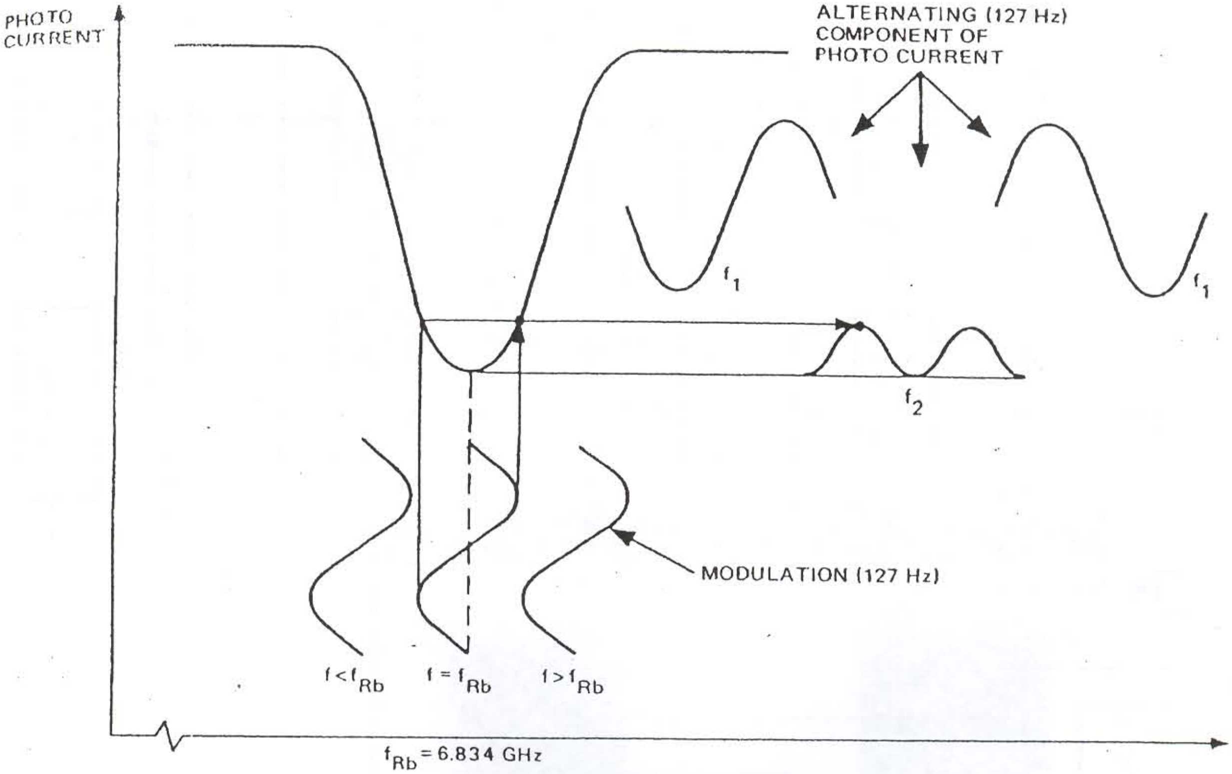



Figure 2. Derivation of Regulation Signal

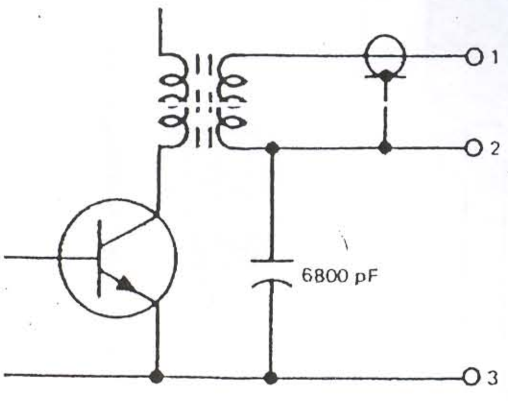



Figure 3. Output Amplifier (Schematic)

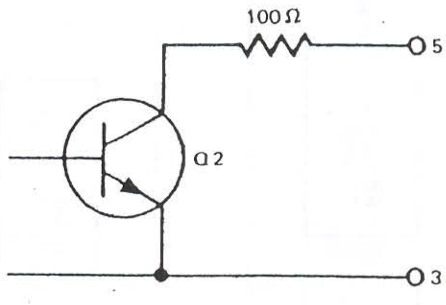



Figure 4. Monitor Signal Circuit

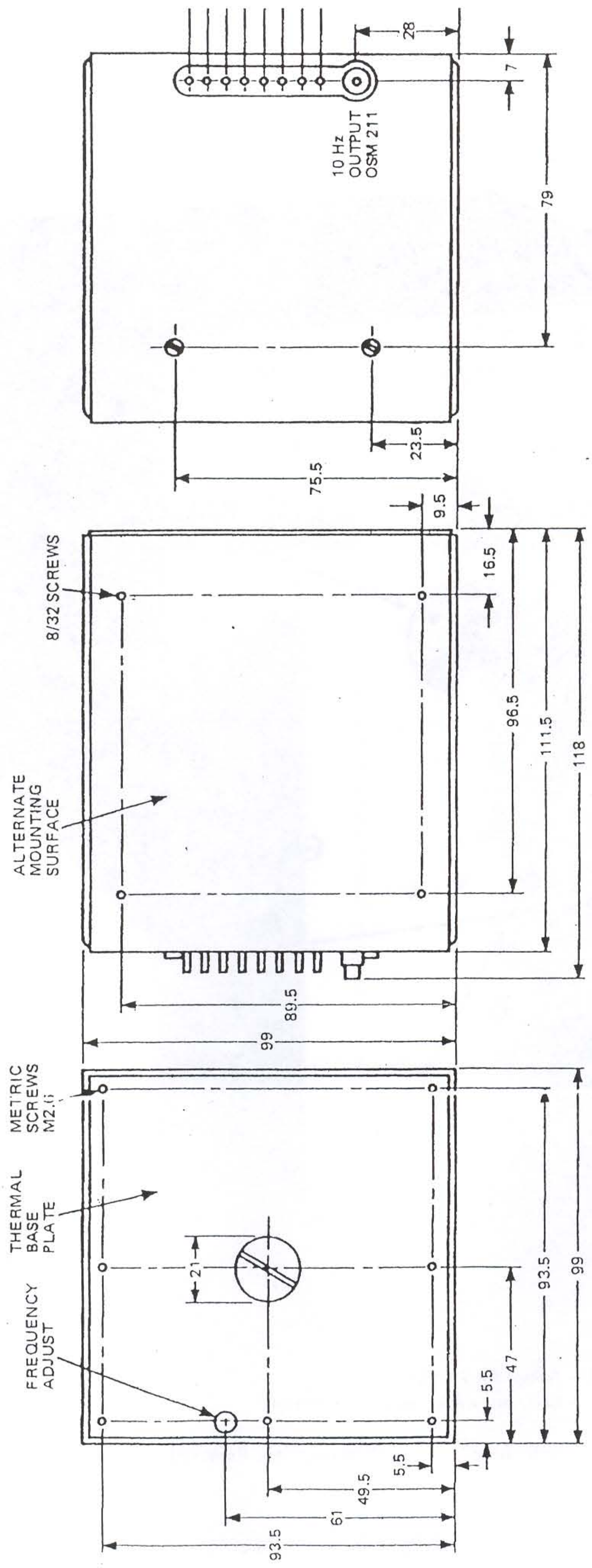
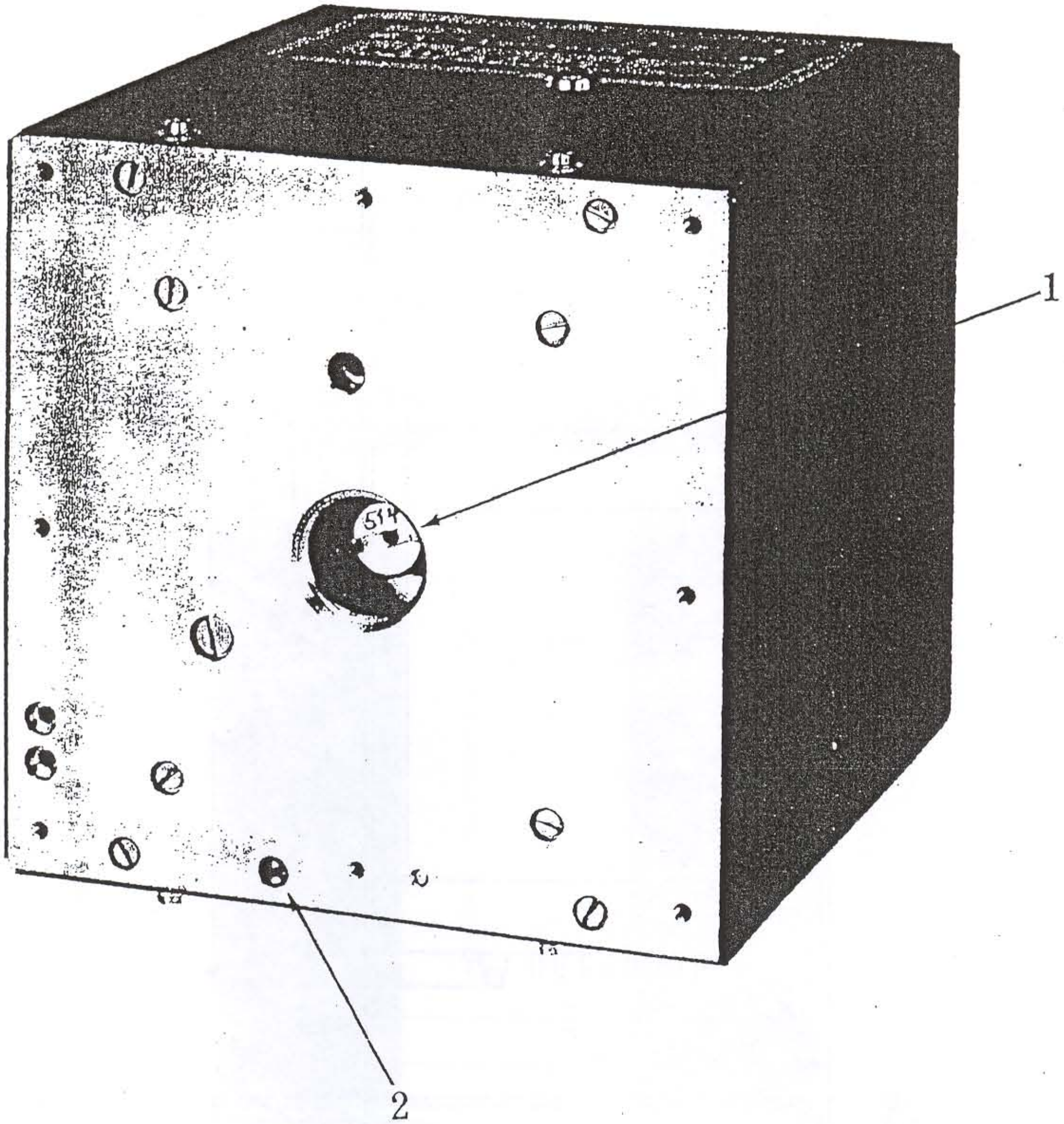



Figure 5. Principal Measurements
(Dimensions in Millimeters)




1 – Access for Rb Lamp
2 – Frequency Adjustment Access Hole

Figure 6. Base Plate End With Heat Sink Removed

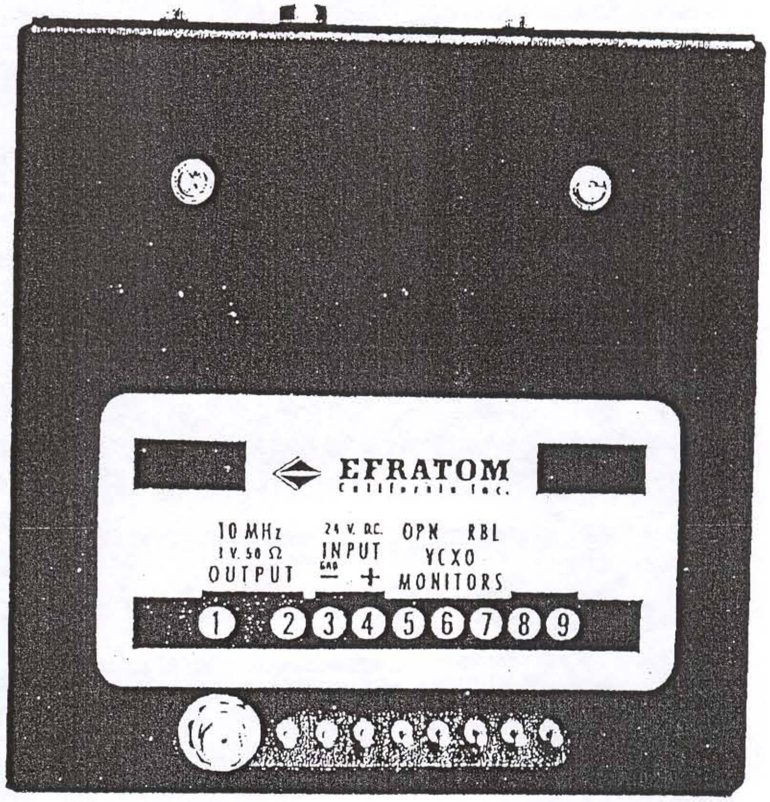
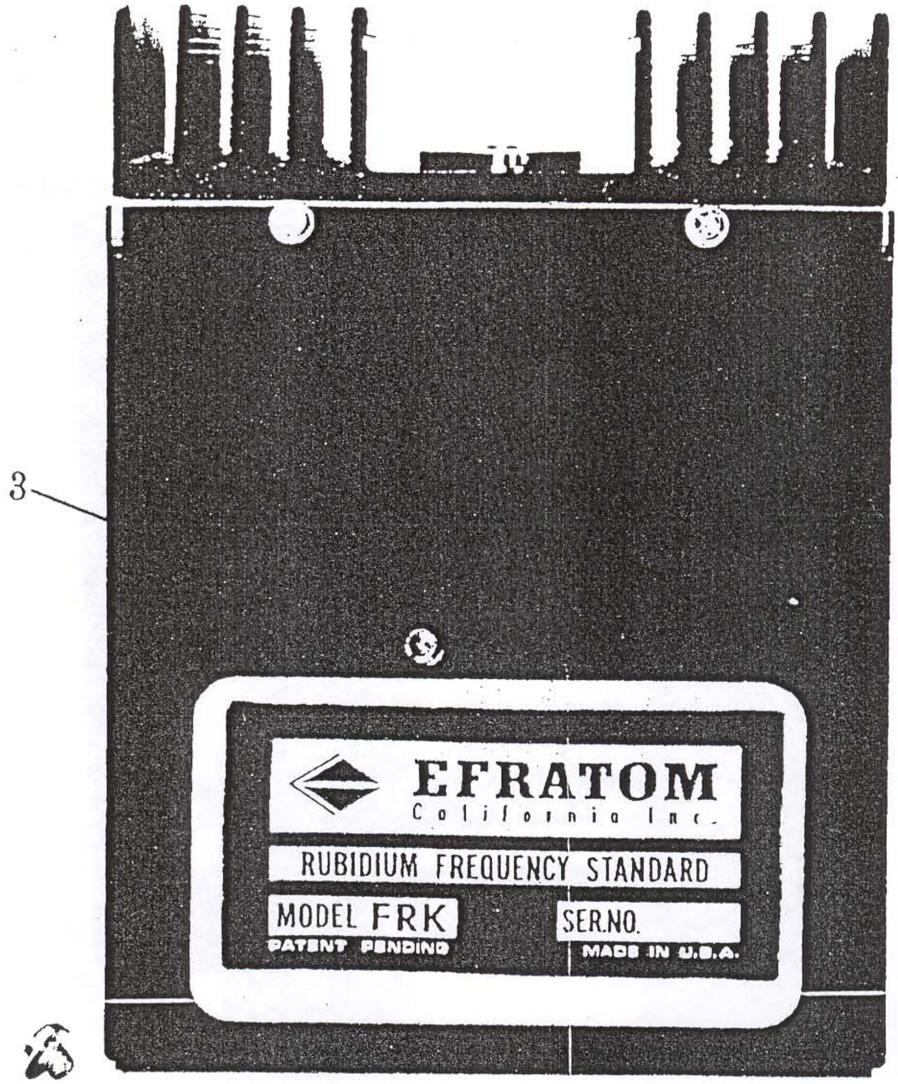
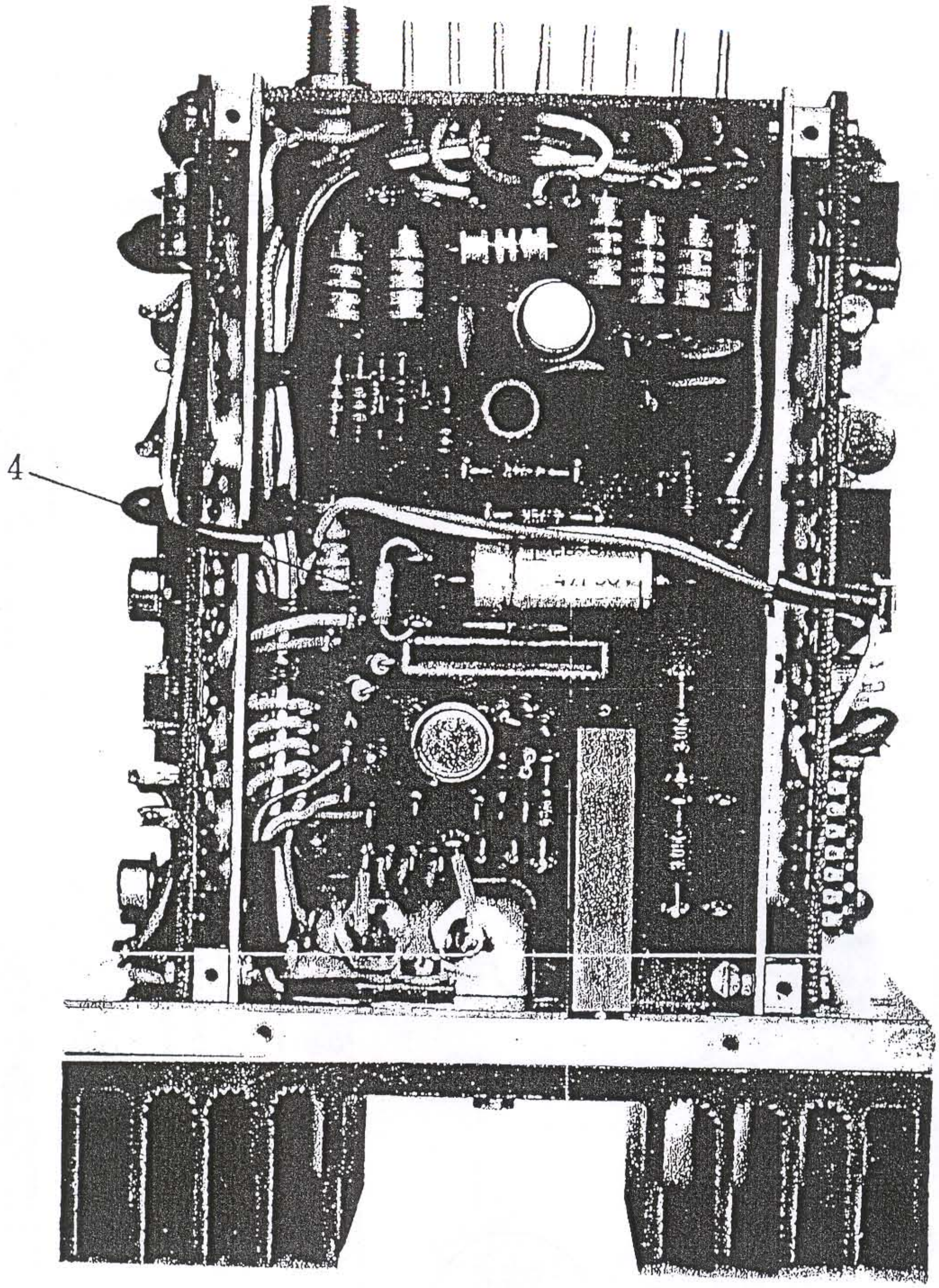



Figure 7. Terminal End




3 – Access Port

Figure 8. Quartz Oscillator Trimmer

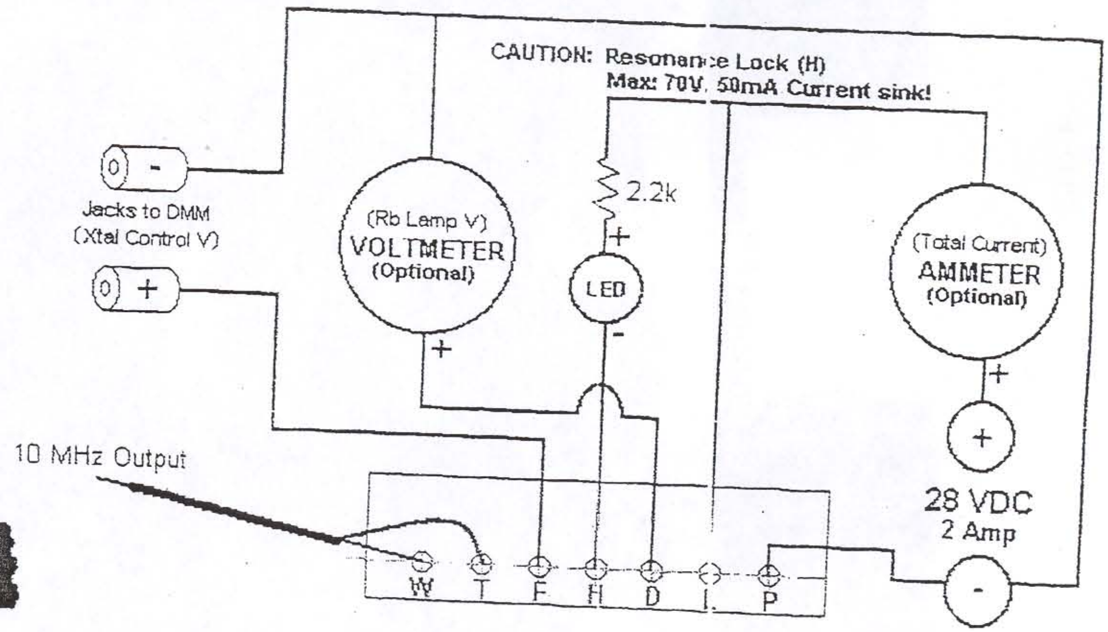



4 — Fuse

Figure 9. Voltage Regulator

FRK Test Fixture
Wiring Diagram

Pin Out for your FRK Rubidium Oscillator
J1-P- Ground
J1-L- +22 to +32 VDC Input
J1-W- 10 MHz Output
J1-T- Shield
J1-F- Xtal Control Voltage Signal
J1-H- Resonance Lock Signal
J1-D- Rb Lamp Voltage Signal

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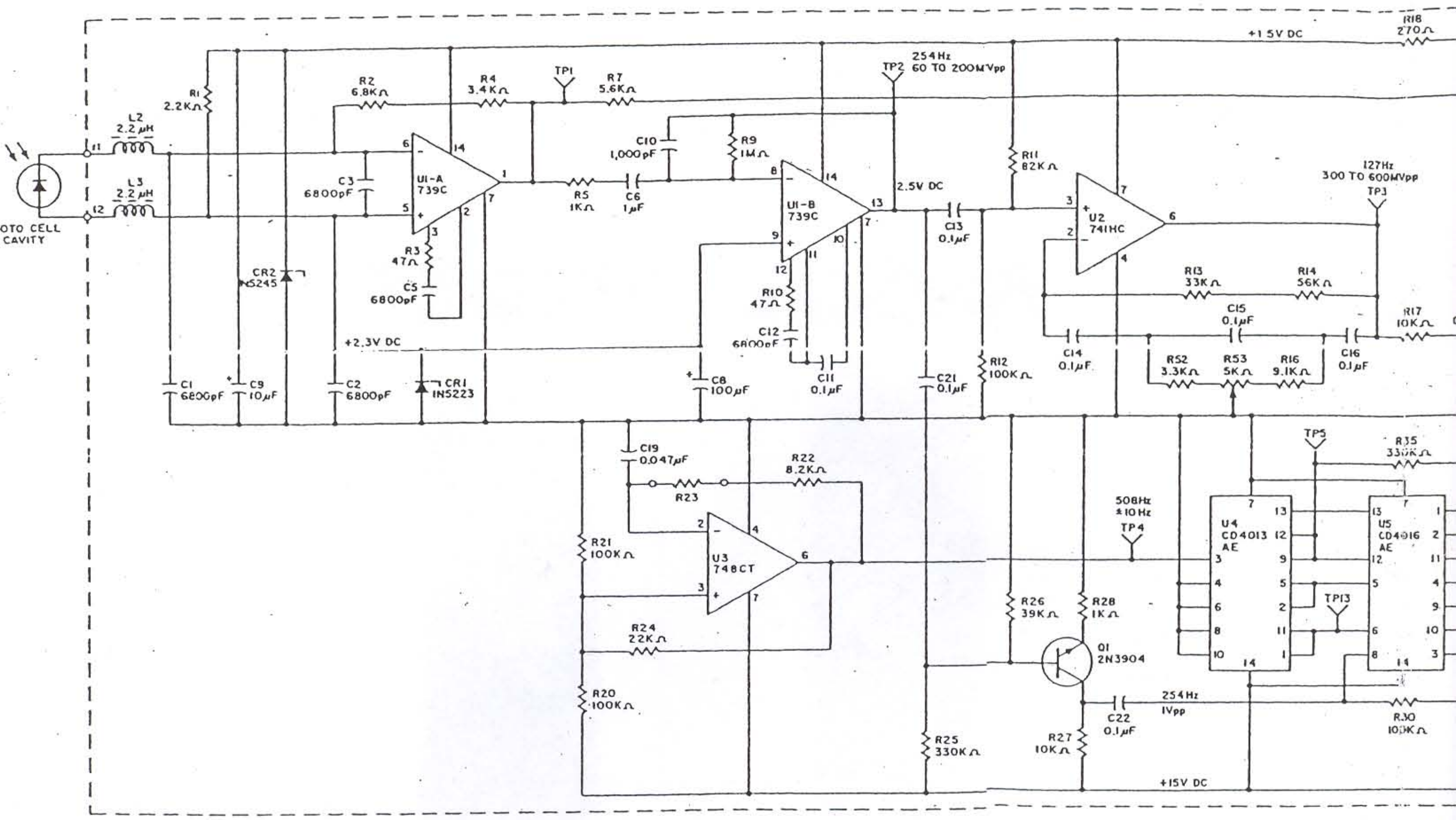
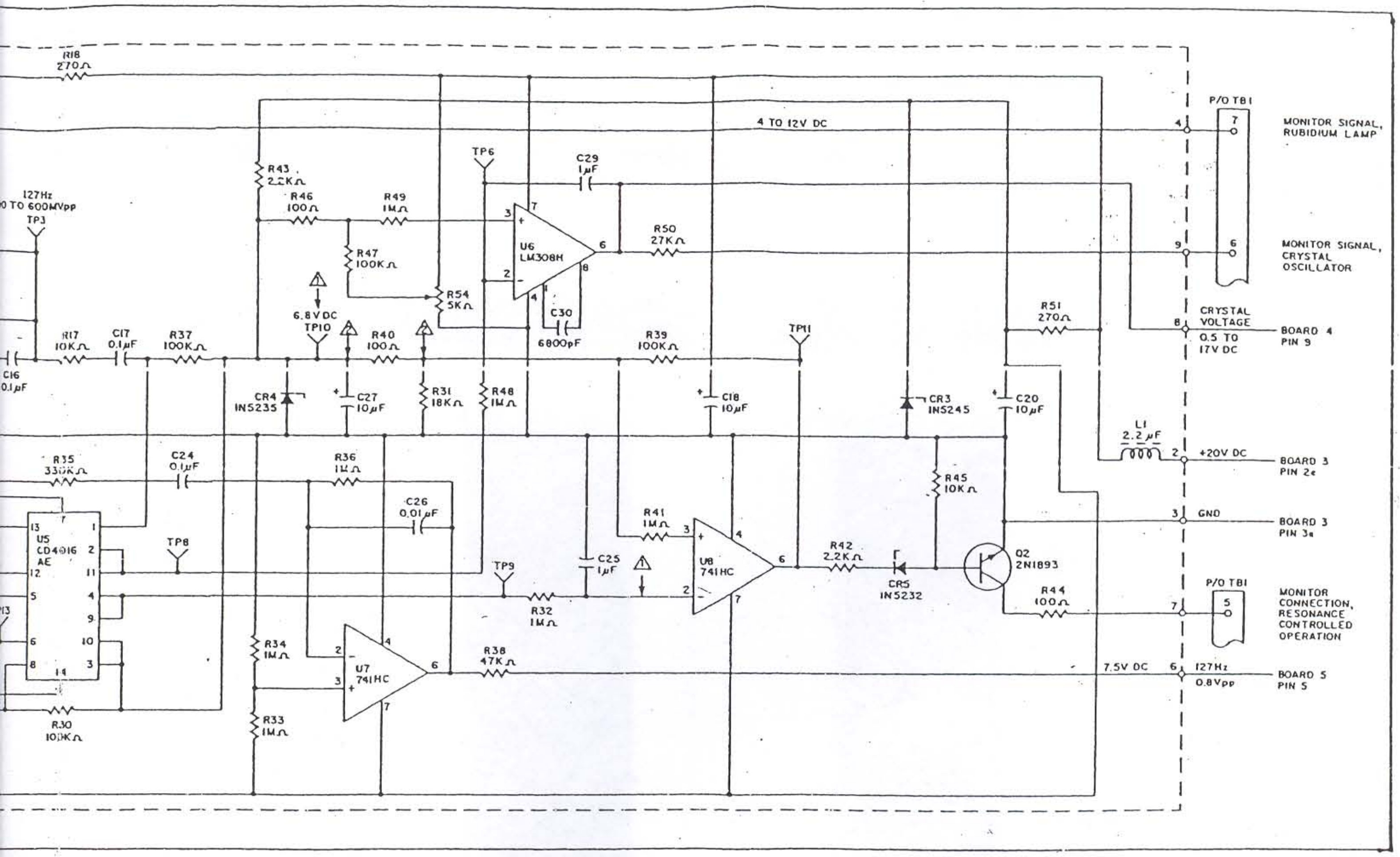


PHOTO CELL IN CAVITY
L2 2.2µH
L3 2.2µH
R1 2.2KΩ
R2 6.8KΩ
R4 3.4KΩ
TP1
R7 5.6KΩ
TP2 254Hz 60 TO 200MVpp
+15V DC
R18 270Ω
C3 6800pF
U1-A 739C
R3 47Ω
C5 6800pF
CR2 5245
C10 1,000pF
R9 1MΩ
R5 1KΩ
C6 1µF
U1-B 739C
R10 47Ω
C12 6800pF
C11 0.1µF
2.5V DC
C13 0.1µF
R11 82KΩ
U2 741HC
127Hz 300 TO 600MVpp
TP3
R13 33KΩ
R14 56KΩ
C15 0.1µF
R17 10KΩ
C14 0.1µF
C16 0.1µF
R52 3.3KΩ
R53 5KΩ
R16 9.1KΩ
+2.3V DC
C1 6800pF
C9 10µF
C2 6800pF
CR1 1N5223
C8 100µF
C21 0.1µF
R12 100KΩ
TP5
R35 330KΩ
C19 0.047µF
R22 8.2KΩ
R23
U3 748CT
R21 100KΩ
R24 22KΩ
R20 100KΩ
508Hz ±10Hz
TP4
U4 CD4013 AE
U5 CD4016 AE
TP13
R26 39KΩ
R28 1KΩ
Q1 2N3904
254Hz 1Vpp
C22 0.1µF
R27 10KΩ
R25 330KΩ
R30 100KΩ
+15V DC




REVISIONS:

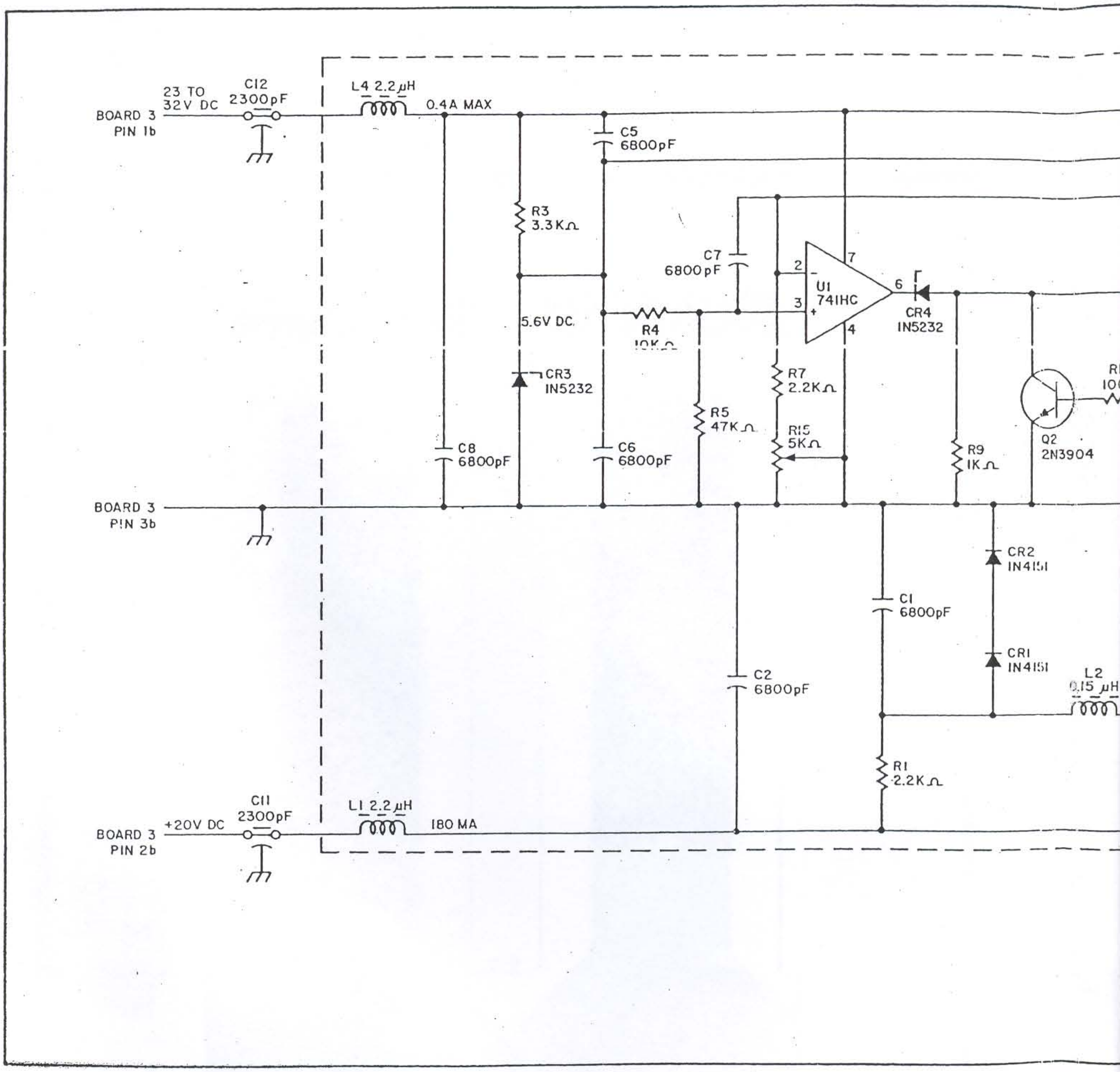
NOTES:

1. ALL VOLTAGES SHOWN ARE IN RELATION TO GROUND.
2. VALUES NOT SHOWN ARE ESTABLISHED DURING TEST.

⚠1 100 TO 200MV DC POTENTIAL DIFFERENCE BETWEEN POINTS

⚠2 30MV DC POTENTIAL DIFFERENCE BETWEEN POINTS

| | |
|---|---|
| **EFRATOM** CALIFORNIA, INC. | |
| FRK, BOARD 1, SERVO SYSTEM | |
| DRAWN: C.R.WILCOX | DATE: 12-27-73 |
| APPROVED: *(signature)* | DATE: Jan. 4 74 |
| REVISED: | DRAWING NO.: |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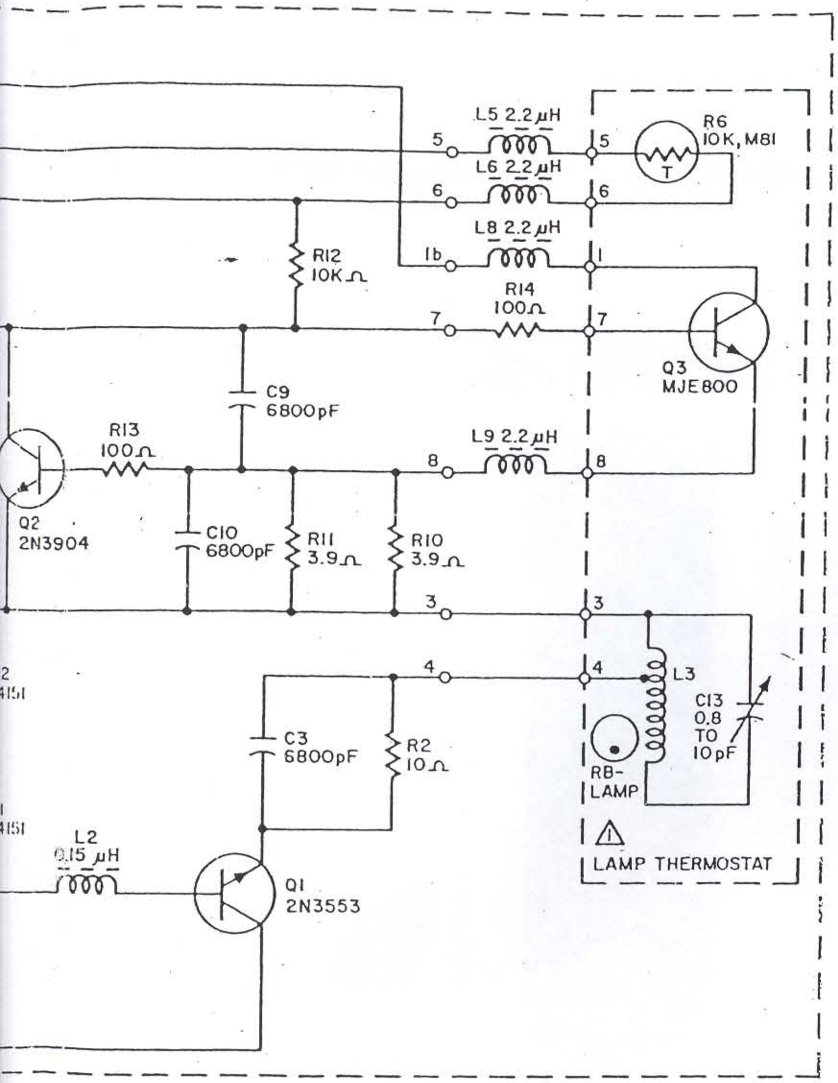
PIN 1b
23 TO
32V DC
C12
2300pF
L4 2.2 µH
0.4A MAX
C5
6800pF
R3
3.3KΩ
C7
6800pF
2
3
7
6
4
U1
741HC
CR4
1N5232
5.6V DC.
R4
10KΩ
CR3
1N5232
R7
2.2KΩ
R5
47KΩ
R15
5KΩ
R9
1KΩ
Q2
2N3904
C8
6800pF
C6
6800pF
BOARD 3
PIN 3b
CR2
1N4151
C1
6800pF
CR1
1N4151
L2
0.15 µH
C2
6800pF
R1
2.2KΩ
BOARD 3
PIN 2b
+20V DC
C11
2300pF
L1 2.2 µH
180 MA

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NOTES:

1. ALL VOLTAGE SHOWN ARE IN RELATION TO GROUND.
2. VALUES NOT SHOWN ARE ESTABLISHED DURING TEST.

⚠ EFRATOM MFD PART

| EFRATOM CALIFORNIA, INC. | |
| --- | --- |
| FRK, BOARD 2, LAMP UNIT | |
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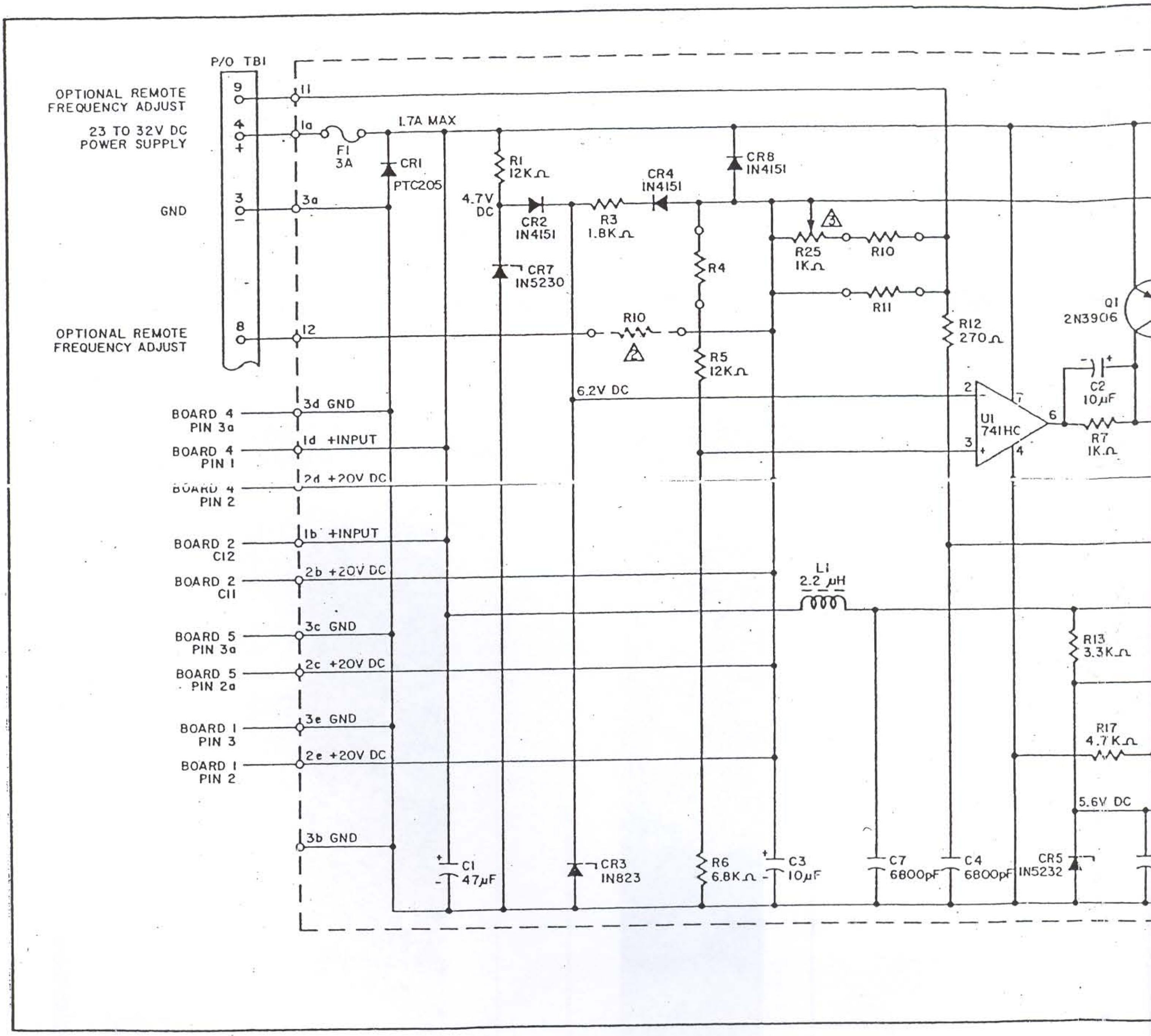
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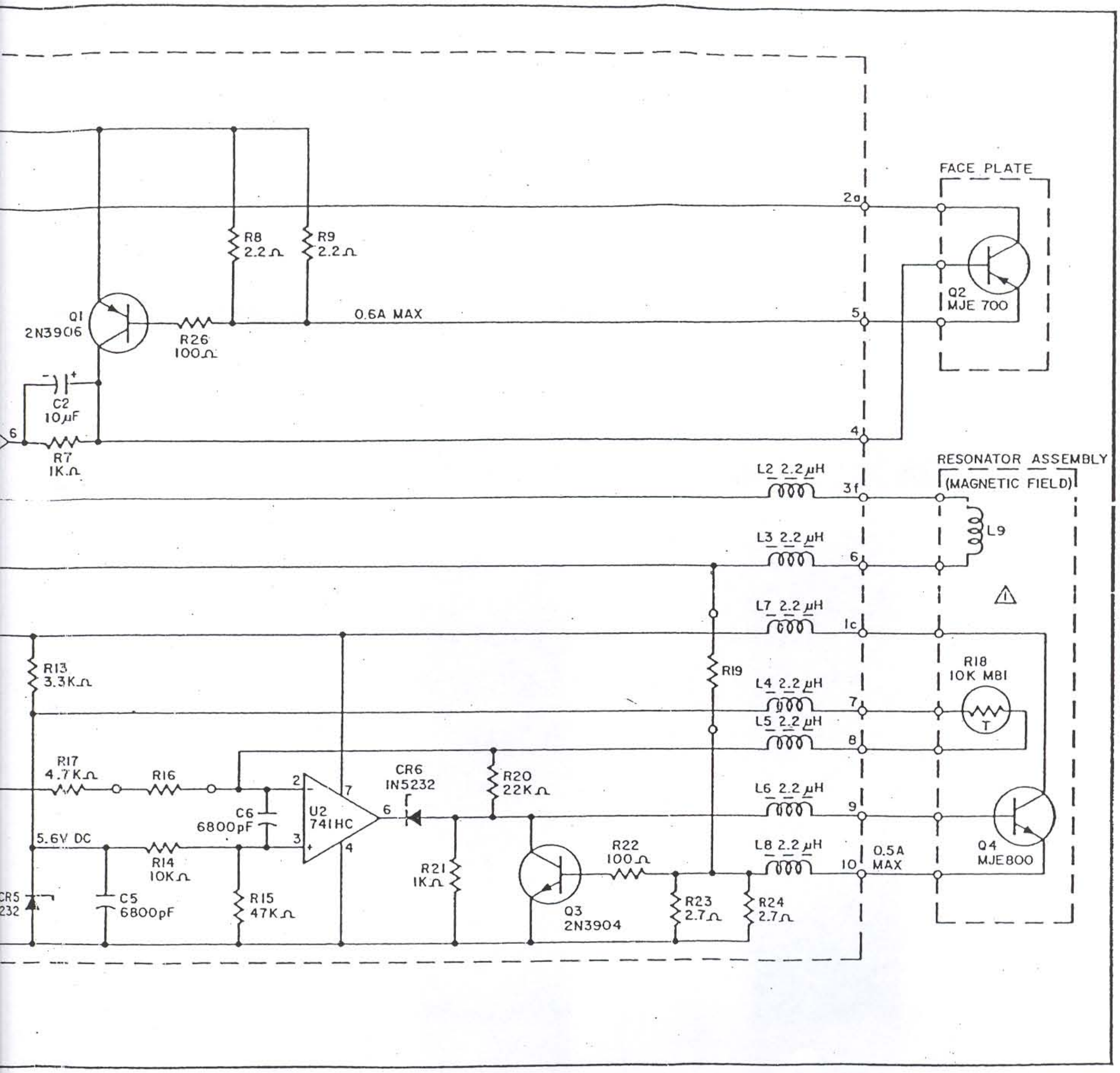
OPTIONAL REMOTE FREQUENCY ADJUST
23 TO 32V DC POWER SUPPLY
GND
OPTIONAL REMOTE FREQUENCY ADJUST
1.7A MAX
F1 3A
CR1 PTC205
R1 12KΩ
4.7V DC
CR2 IN4151
R3 1.8KΩ
CR4 IN4151
CR8 IN4151
CR7 IN5230
R4
R10
R5 12KΩ
R25 1KΩ
R11
R12 270Ω
Q1 2N3906
C2 10µF
U1 741HC
R7 1KΩ
6.2V DC
3d GND
1d +INPUT
2d +20V DC
1b +INPUT
2b +20V DC
3c GND
2c +20V DC
3e GND
2e +20V DC
3b GND
BOARD 4 PIN 3a
BOARD 4 PIN 1
BOARD 4 PIN 2
BOARD 2 C12
BOARD 2 C11
BOARD 5 PIN 3a
BOARD 5 PIN 2a
BOARD 1 PIN 3
BOARD 1 PIN 2
L1 2.2 µH
R13 3.3KΩ
R17 4.7KΩ
5.6V DC
C1 47µF
CR3 IN823
R6 6.8KΩ
C3 10µF
C7 6800pF
C4 6800pF
CR5 IN5232

RE

NO
1.
2




| REVISIONS: |
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NOTES:

1. ALL VOLTAGES SHOWN ARE IN RELATION TO GROUND.
2. VALUES NOT SHOWN ARE ESTABLISHED DURING TEST.

⚠1 EFRATOM MFD PART

⚠2 R10 POSITION OPTIONAL REMOTE FREQUENCY ADJUST

⚠3 FREQUENCY ADJUSTMENT

| EFRATOM<br>CALIFORNIA, INC. | |
|---|---|
| FRK, BOARD 3,<br>20V SUPPLY & RESONATOR THERMOSTAT | |
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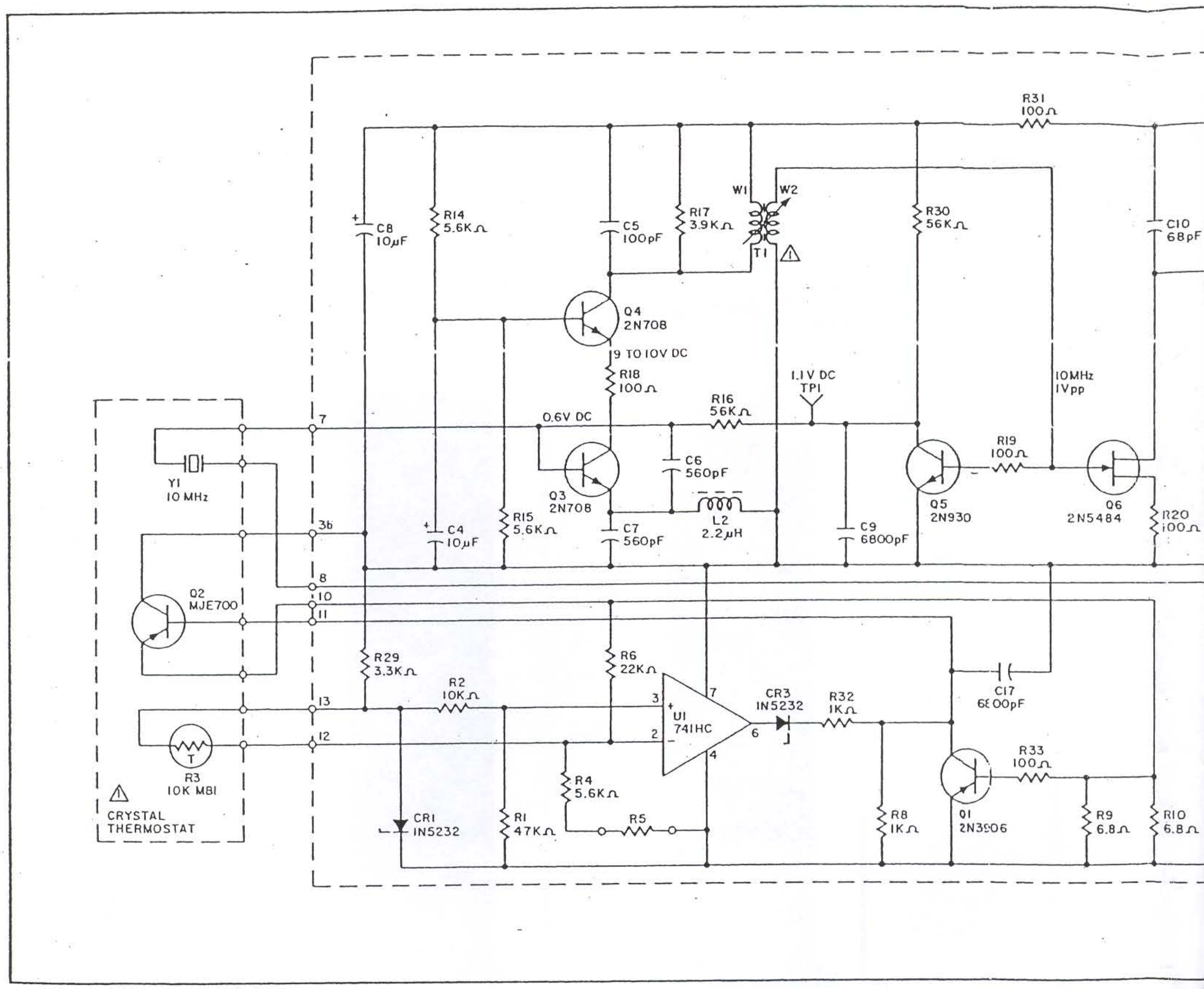
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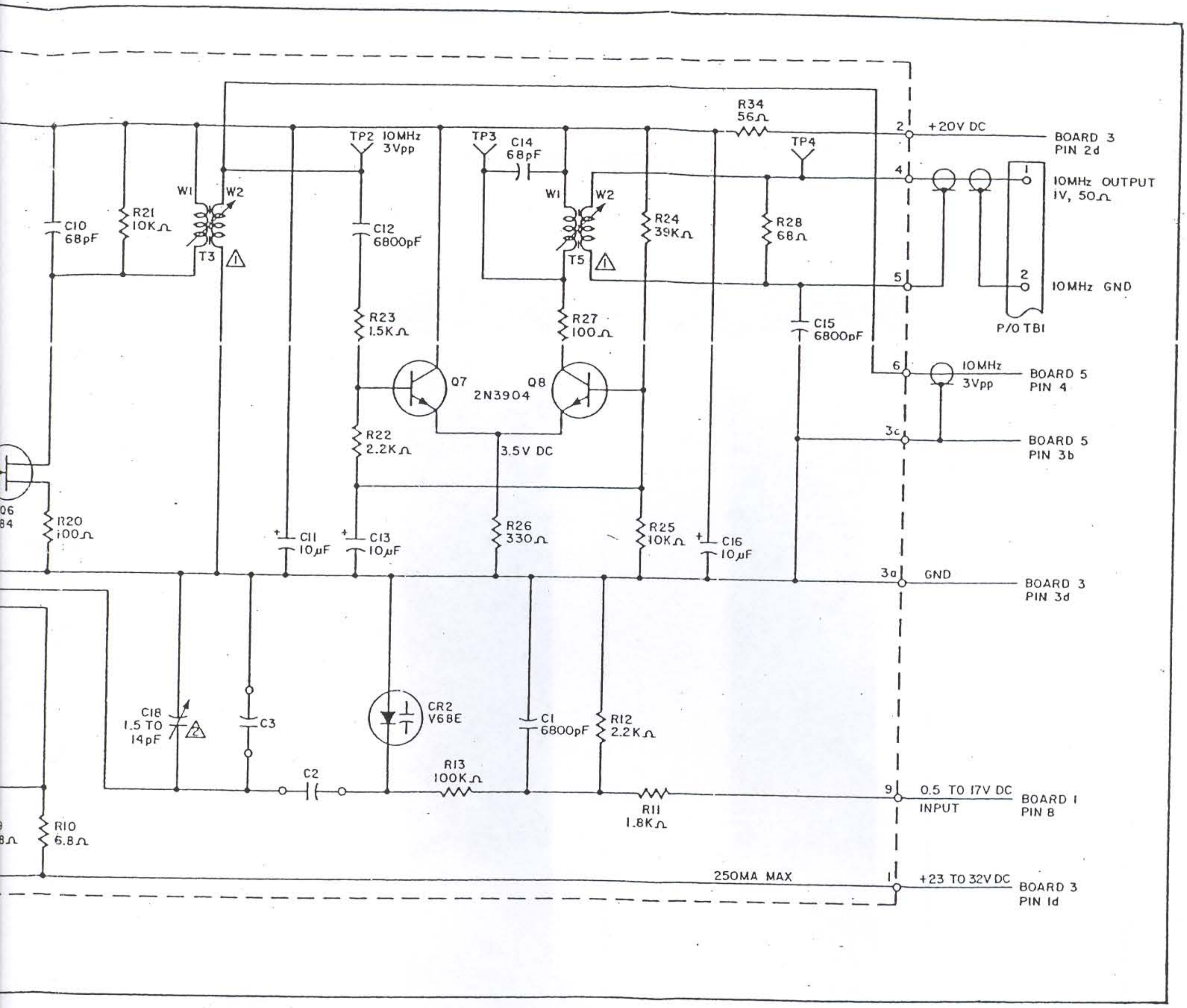
100Ω
W1
W2
T1
C8
10μF
R14
5.6KΩ
C5
100pF
R17
3.9KΩ
R30
56KΩ
C10
68pF
Q4
2N708
9 TO 10V DC
R18
100Ω
1.1V DC
TP1
10MHz
1Vpp
R16
56KΩ
0.6V DC
7
Y1
10 MHz
C6
560pF
R19
100Ω
Q3
2N708
L2
2.2μH
Q5
2N930
Q6
2N5484
R20
100Ω
3b
C4
10μF
R15
5.6KΩ
C7
560pF
C9
6800pF
8
10
11
Q2
MJE700
R29
3.3KΩ
R6
22KΩ
C17
6800pF
13
12
R2
10KΩ
U1
741HC
CR3
1N5232
R32
1KΩ
R3
10K MBI
R4
5.6KΩ
R33
100Ω
CRYSTAL
THERMOSTAT
CR1
1N5232
R1
47KΩ
R5
R8
1KΩ
Q1
2N3906
R9
6.8Ω
R10
6.8Ω




REVISIONS:

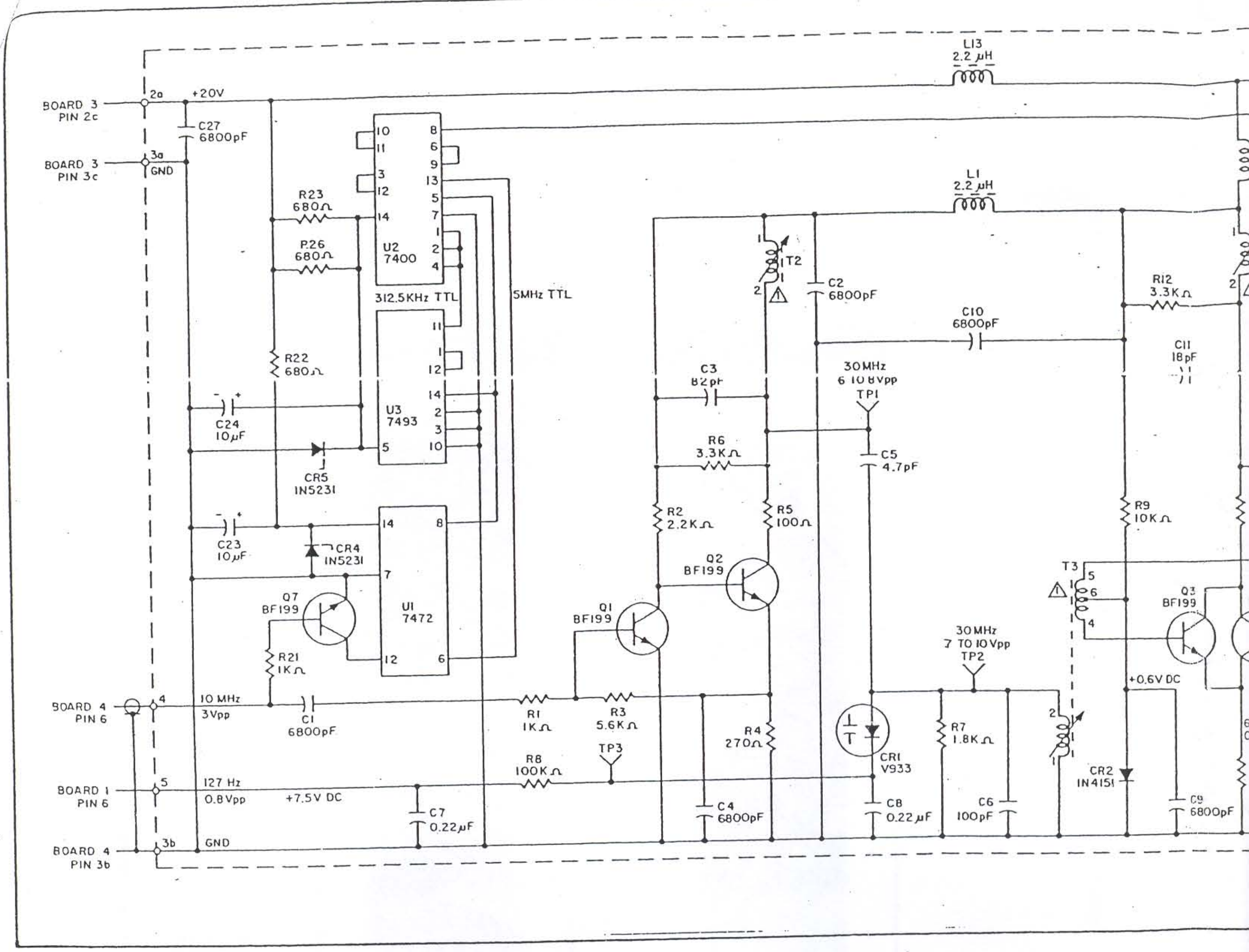
NOTES:

1. ALL VOLTAGES SHOWN ARE IN RELATION TO GROUND.
2. VALUES NOT SHOWN ARE ESTABLISHED DURING TEST.

⚠1 EFRATOM MFD PART

⚠2 CRYSTAL FREQUENCY ADJUSTMENT

| EFRATOM CALIFORNIA, INC. | |
|---|---|
| FRK, BOARD 4, CRYSTAL OSCILLATOR | |
| DRAWN: C.R.WILCOX | DATE: 12-21-73 |
| APPROVED: *Weidmann* | DATE: *Jan 4. 73* |
| REVISED: | DRAWING NO.: |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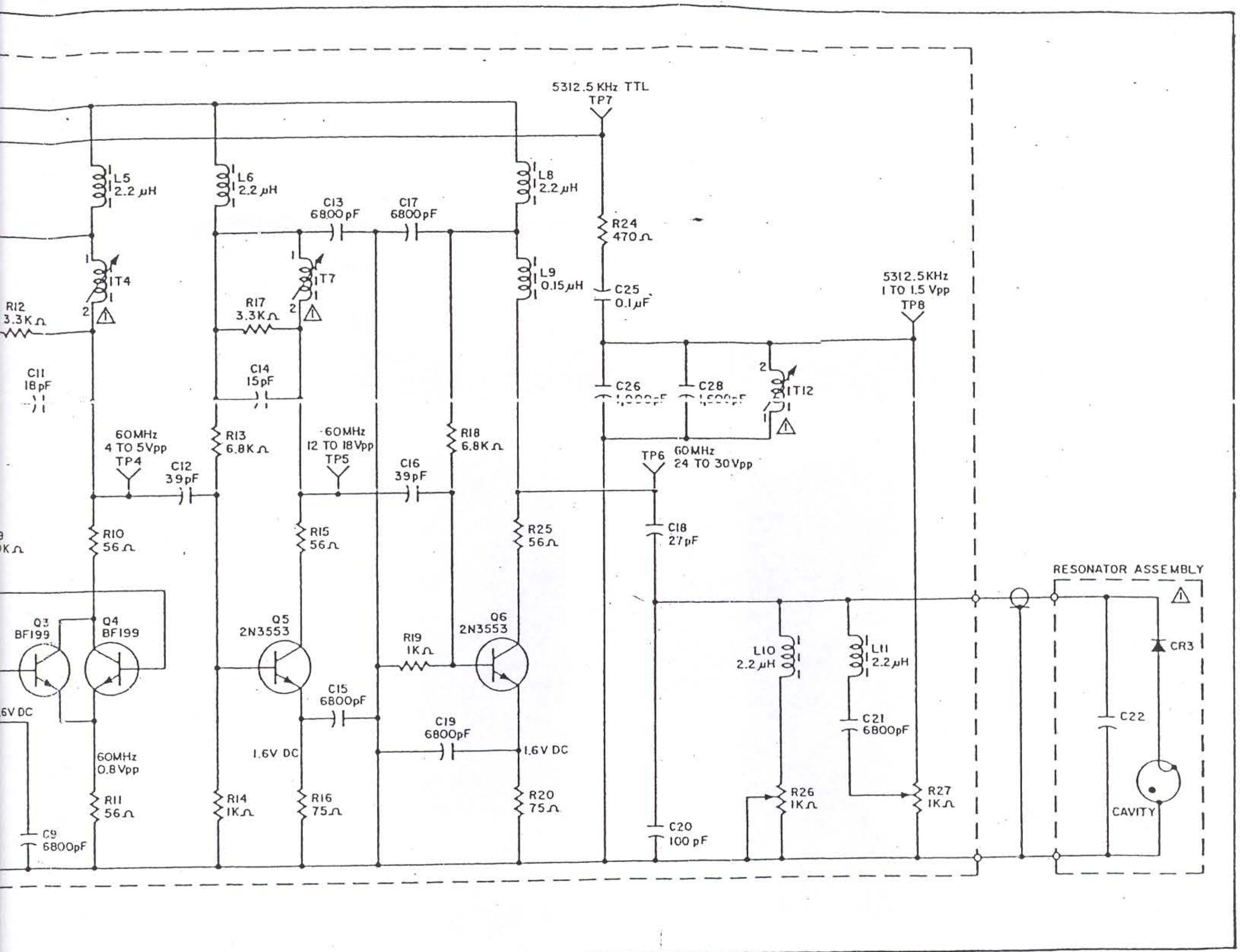
BOARD 3 PIN 3c
BOARD 4 PIN 6
BOARD 1 PIN 6
BOARD 4 PIN 3b
2a
3a
GND
4
5
3b
+20V
C27 6800pF
R23 680Ω
R26 680Ω
R22 680Ω
U2 7400
312.5KHz TTL
5MHz TTL
U3 7493
C24 10µF
CR5 1N5231
C23 10µF
CR4 1N5231
Q7 BF199
U1 7472
R21 1KΩ
10 MHz 3Vpp
C1 6800pF
127 Hz 0.8Vpp
+7.5V DC
C7 0.22µF
L13 2.2 µH
L1 2.2 µH
T2
C2 6800pF
C10 6800pF
C3 82pF
R6 3.3KΩ
R2 2.2KΩ
R5 100Ω
Q2 BF199
Q1 BF199
R1 1KΩ
R3 5.6KΩ
R4 270Ω
R8 100KΩ
TP3
C4 6800pF
30MHz 6 TO 8Vpp
TP1
C5 4.7pF
30MHz 7 TO 10Vpp
TP2
CR1 V933
R7 1.8KΩ
C8 0.22µF
C6 100pF
R12 3.3KΩ
C11 18pF
R9 10KΩ
T3
Q3 BF199
+0.6V DC
CR2 1N4151
C9 6800pF




REVISIONS:

NOTES:

1. ALL VOLTAGES SHOWN ARE IN RELATION TO GROUND.
2. VALUES NOT SHOWN ARE ESTABLISHED DURING TEST.

⚠ EFRATOM MFD PART

| | |
|---|---|
| **EFRATOM** CALIFORNIA, INC. | |
| FRK, BOARD 5, SYNTHESIZER | |
| DRAWN: C.R.WILCOX | DATE: 12-19-73 |
| APPROVED: Dieckmann | DATE: Jan 4. 73 |
| REVISED: | DRAWING NO.: |