1.1 INTRODUCTION

The Rubidium Frequency Standard generates 4 coherent frequencies of 10 MHz, 5 MHz, 1 MHz and 0.1 MHz, with extremely good short and long term stability and high spectral purity. Each frequency is available from BNC connectors mounted on the front panel and on the back panel. In order to enable remote distribution of the various frequencies without interference, all the output circuits are short-circuit protected, mutually buffered and have a floating ground.

In operation, the built-in battery is automatically charged and assures continuous operation in case of external power failure or during transportation.

A meter on the front panel indicates operational functions. A shift lock helipot allows a frequency trim of $\pm 1 \times 10^{-9}$. For external frequency fine tuning a receptacle is located on the back panel. Connected to the EFRATOM receiver/controller Model EFR, the FRT can be set and controlled with the pilot frequency of a standard frequency transmitter (e.g. DCF 77, HGB, WWV).

A lamp (LED type) on the front panel indicates when the power is "on". A second one shows atomic resonance locked operation. For remote monitoring purposes, locked operations can also be obtained from a receptacle on the back panel.

SPECIFICATIONS FOR RUBIDIUM FREQUENCY STANDARD

MODEL F R T

Output Frequencies	10 MHz, 5 MHz, 1 MHz, 0.1 MHz Each frequency has two independent outputs, short circuit protected, with floating ground. Sinusoidal signal 1V rms into 50 Ω. Decoupling of common output frequencies approximately 40 dB.
Signal to Noise	> 120 dB in 1 Hz band at more than 200 Hz > 150 dB at more than 1000 Hz from nominal frequency
Long Term Stability	$< 3 \times 10^{-11}$ / month
Short Term Stability	$< 2 \times 10^{-11}$ (τ = 1 sec.) $< 5 \times 10^{-12}$ (τ = 10 sec.) $< 1 \times 10^{-12}$ (τ = 100 sec.)
Environmental Effects	
Voltage	$< 1 \times 10^{-11}$ / 10% Vdc
Temperature	$\leq 2 \times 10^{-10}$ from $-10^{\circ}C$ to $+50^{\circ}C$
Magnetic Field	$< 1 \times 10^{-12}$/ Am^{-1}
Altitude	$< 5 \times 10^{-13}$/ mbar (from 0 to 12000 m)
Frequency Trim Range	$\pm 1 \times 10^{-9}$ (adjustable with 10 turn pot.)
Warm-up Characteristic	$< 2 \times 10^{-10}$ in 10 minutes (at $25^{\circ}C$ ambient)
Power Supply	115/220V (+10%, -15%) 47-63 Hz, approx. 50 W 22-32 V dc, approx. 30 W
Stand-by Battery	Two hours reserve following primary power interruption. Automatic recharge. Back panel connector for external battery.
Back Panel Connectors	For external monitoring and frequency control
Function Monitor	Rb-Lamp, DC supply, control voltage, charging current
Indicator Lamps	Power, Operation
Mechanical Size	With 19" rack mounting - occupying no more than 1/2 standard width available and 3 standard units of height (235 x 150 x 400 mm, portable case)
Weight	27 lbs (12 kg), including battery
Warranty	1 year, lamp and cell 5 years

1.3 FUNCTIONAL DESCRIPTION

The FRT, as shown in block diagram (Fig.5), contains the miniaturized atomic frequency standard, model FRK (see FRK block diagram and schematics attached). In operation the lamp exciter circuitry generates an r.f. field, causing the Rb-atoms in the spectral lamp to ionize and to emit light. The generated light passes through the resonance cell and illuminates a silicon photo detector whose current corresponds to the light intensity.

Applying a discrete frequency (f= 6,834..... MHz) to the cavity causes atomic transitions of the Rb-atoms within the cell and the absorption of the light passing through it (optical pumping).

The exact resonance frequency causes maximum absorption of the light and is adjustable within a very small range, by the magnetic field. The effect of frequency dependent light attenuation can be used by applying a modulation method with sense information, in order to provide logic signals for controlling the crystal oscillator frequency. Conceptually this modulation can be considered to cause a relatively slow (127 Hz) variation of the frequency applied to the Rb resonance cell. As illustrated in Fig.6, the resulting photo detector current contains a 127 Hz component of opposite phase, when the frequency of the applied signal is higher than the Rb resonance frequency. 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. When the frequency of the applied signal is exactly the same as that of the Rb87 resonance, the basic modulation frequency component of the photo detector current is zero, while the second harmonic content is maximum. The second harmonic is amplified, rectified and used to drive a transistor gate to the conductive state, indicating positive lock to the Rb resonance (voltage monitoring is available at terminal Pin 5, Fig. 8).

The 10 MHz output signal of the FRK schematically shown in Fig.7, drives a pulse shaper resulting in a TTL compatible signal, which is applied to various gates and dividers accomplishing the 4 frequencies of 10 MHz, 5 MHz, 1 MHz and 0.1 MHz. Each frequency is amplified by two separate amplifiers and is available through BNC connectors at the front and back panel.

A 10 turn trim helipot on the front panel allows for fine adjustment of the frequencies.

In addition, receptacle BU 2 (Fig2) on the back panel can be used for external control purposes e.g. connected to an external frequency receiver/controller allowing automatic frequency adjustment to a signal from a VLF standard frequency transmitter (DCF 77, HGB, WWV). Locked atomic resonance operation is indicated by the lamp "operation" on the front panel. For remote monitoring the same information can be obtained at receptacle BU 3 on the back panel.

1.4 STANDARD ACCESSORIES

1 Power cable

1 Mating connector for BU 1

1 Mating connector for BU ~~2~~ 3

2 Fuses – 0.63 A

1 Fuse – 3 A

RECOMMENDED ACCESSORIES

Spare fuses

Spare Rb lamp and special tool (EEK 02)

Instrument case EEK 30

19" rack mounting hardware (EEK 31)

2. OPERATION

2.1 INSTALLATION

The FRT is available

1. in a case for lab use or portable for use in the field (part no. EEK 30)
2. installed into a 19" rack.

Since the FRT only occupies one half of the width of the 19" rack, a mounting bar is available (Part No. EEK 31). It is then simply inserted and attached by a holding screw (Fig.1, Item 16).

2.2 OPERATIONAL VOLTAGE

For a power supply 115/220 Vac ± 10%, 47 to 63 Hz or 22 to 32 Vdc can be used. The power input receptacles are on the back panel (Fig.2). A power cable and a mating dc-connector is standard equipment. The negative lead (grounded to the chassis) is connected to Pin 2, the positive lead to pin 3 of BU 1 (Fig.9). The maximum ripple is not to exceed 1 Vpp. When using a dc power supply below 27V, it is recommended that the built-in battery be disconnected by the switch on the back panel to avoid discharging (Fig.2, Item 11). During warm-up or battery-charging the power input is approximately 85 VA declining to 40 VA during operation. During external dc operation the initial current input is 2.2A declining to 1A.

In case of external power failure the built-in battery automatically takes over without interruption. Fully charged, the capacity will last for at least 2 hours (depending on the ambient temperature and the age of the batteries). Re-charging the batteries will take approx. 8 hours.

2.3 POWER "ON"

Provisions are made to use an external power supply or the built-in batteries. When using a dc power supply below 27 V, the battery circuit should be disconnected (see Fig.2, Item 11 for switch).

External ac and dc sources within the specified range can be fed simultaniously. The dc voltage obtained by the ac source is de-coupled from the dc source by means of diodes. The source showing the higher dc voltage automatically is selected for operation. Lamp 4 "power" (Fig.1) indicates the presence of ac as well as dc. Lamp 5 "operation" (Fig.1) indicates after approx. 10 minutes warm-up time the proper operation of the unit. A short flickering of Lamp 5 during warm-up period may occur but this is of no significance.

2.4 POWER "OFF"

If the FRT is not in operation, switch (Fig.2, Item 11) should be in the "disconnected" position, to avoid discharging of the batteries. The batteries should be recharged approx. every 6 months.

2.5 FREQUENCY OUTPUTS

The four frequencies 10 MHz, 5 MHz, 1 MHz and 0.1 MHz are available on the front panel as well as on the back panel. The output circuits are short circuit protected and supply 1 V rms into 50 Ω. They are mutually decoupled at 40 db. All output circuits have floating ground as shown schematically in Fig.7. The maximum voltage allowed between output and chassis is 40 V rms. This circuit design avoids hum loops and is suitable for remote distribution of all 8 frequencies while the polarity of the power supply used in the connecting systems is not critical, due to the floating ground.

2.6 MONITOR

The FRK is provided with a meter on the front panel together with rotary switch (Fig.1, Item 2) to allow monitoring of the following functions:

"Light Voltage"	Indicator of meter must be within the black range for correct operation of the Rubidium lamp.
"Control Voltage"	Crystal oscillator voltage: Indicator must be within 5 - 65 divisions.
"Battery Voltage" D.C.Supply	Indicator of meter must be within black range. Below the black range indicates insufficient battery voltage.
Charging current	Indicator in positive range = charging of batteries Indicator in negative range = discharging of batteries

When the FRK is in atomic resonance locked operation a relay is energized, activating Lamp 5 at the front panel as well as output plug BU 3 at the back panel. BU 3 can be used if remote monitoring is required.

2.7 FREQUENCY ADJUSTMENT

For frequency adjustments within a range of 2×10^{-9} a helipot on the front panel together with a shift lock and a counting device have been provided (Fig.1, Item 3). The resolution is approx. 1×10^{-12}. Turning the helipot clockwise (higher reading of counting device) increases the frequency, and vice versa. In addition, frequency adjustments can be made externally through receptacle BU 2 (Fig.2 and Fig. 8) on the back panel, by connecting to a receiver/controller (e.g. EFRATOM Model EFR) which permits the FRT frequency to be automatically adjusted to a VLF standard frequency from a transmitter.

3 MAINTENANCE AND REPAIR

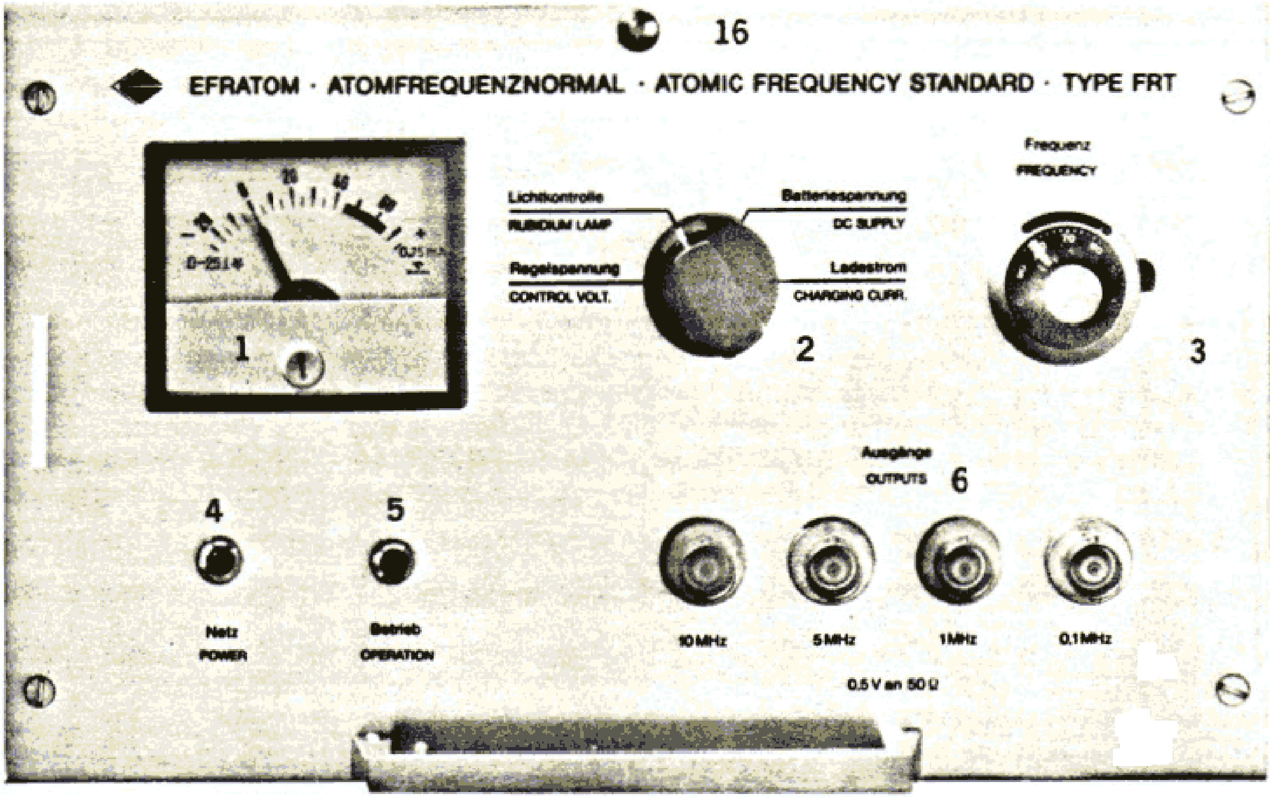
3.1 RUBIDIUM LAMP EXCHANGE

In the unlikely case that it is necessary to replace the rubidium lamp, the exchange can be made without deenergizing the unit. The Rb-lamp is accessable after removing the large slotted screw (Fig.2, Item 15) 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 Part Number EEK 02.

3.2 COMPENSATION OF CRYSTAL AGING

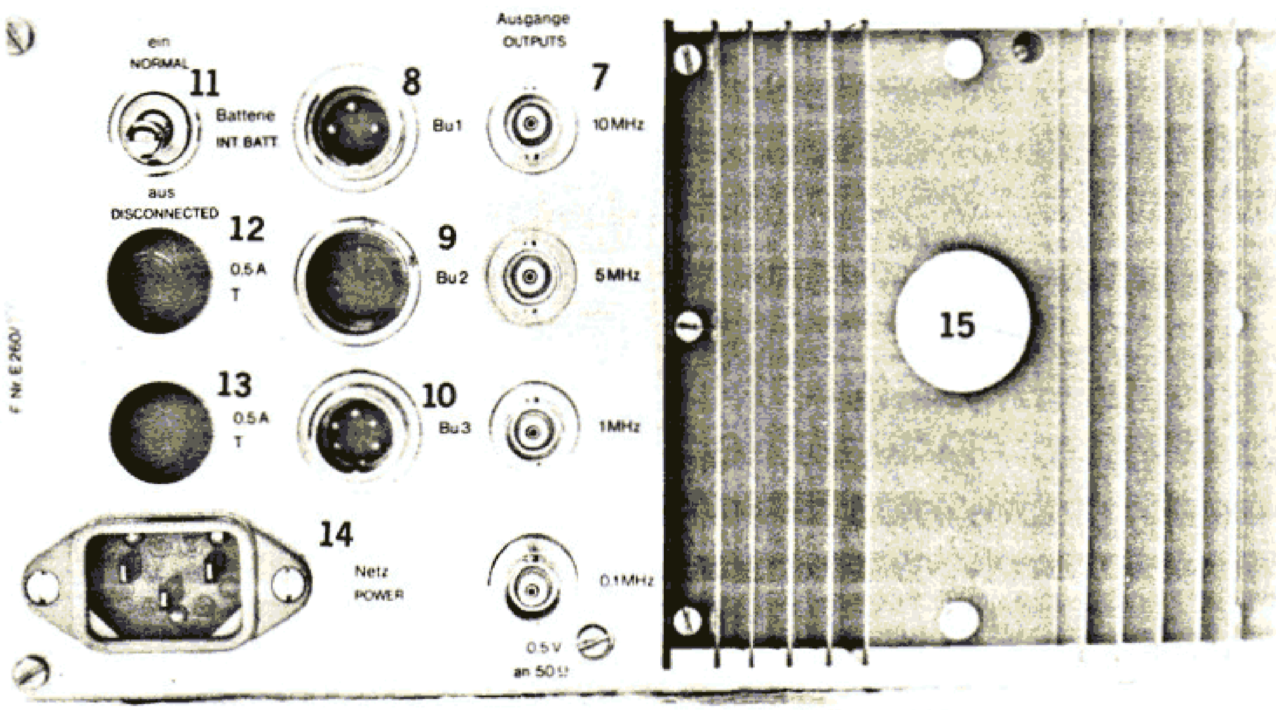
The inevitable aging of the crystal oscillator results in a deviation of the control voltage, see Paragraph 2.6. If the crystal oscillator voltage approaches the end of the control range between 5 and 65 scale divisions on the meter, a correction of the crystal oscillator base frequency must be made. Without deenergizing the FRT, the instrument case must be removed or the unit has to be taken out of the rack to reach screw (Fig.3, Item 17), making the oscillator trimmer accessable. Clockwise turning of the trimmer causes an increase of the control voltage. The adjustment should be set to 20 divisions after the FRT has operated for at least one hour.

A 3 amp fuse is soldered onto the terminals between the 2 stand-by batteries (Fig.4, Item 18). When replacing the fuse, one must be certain that the soldering iron is not grounded to the FRT chassis to avoid a short. While soldering, a heat sink must be applied to the terminals of the batteries.



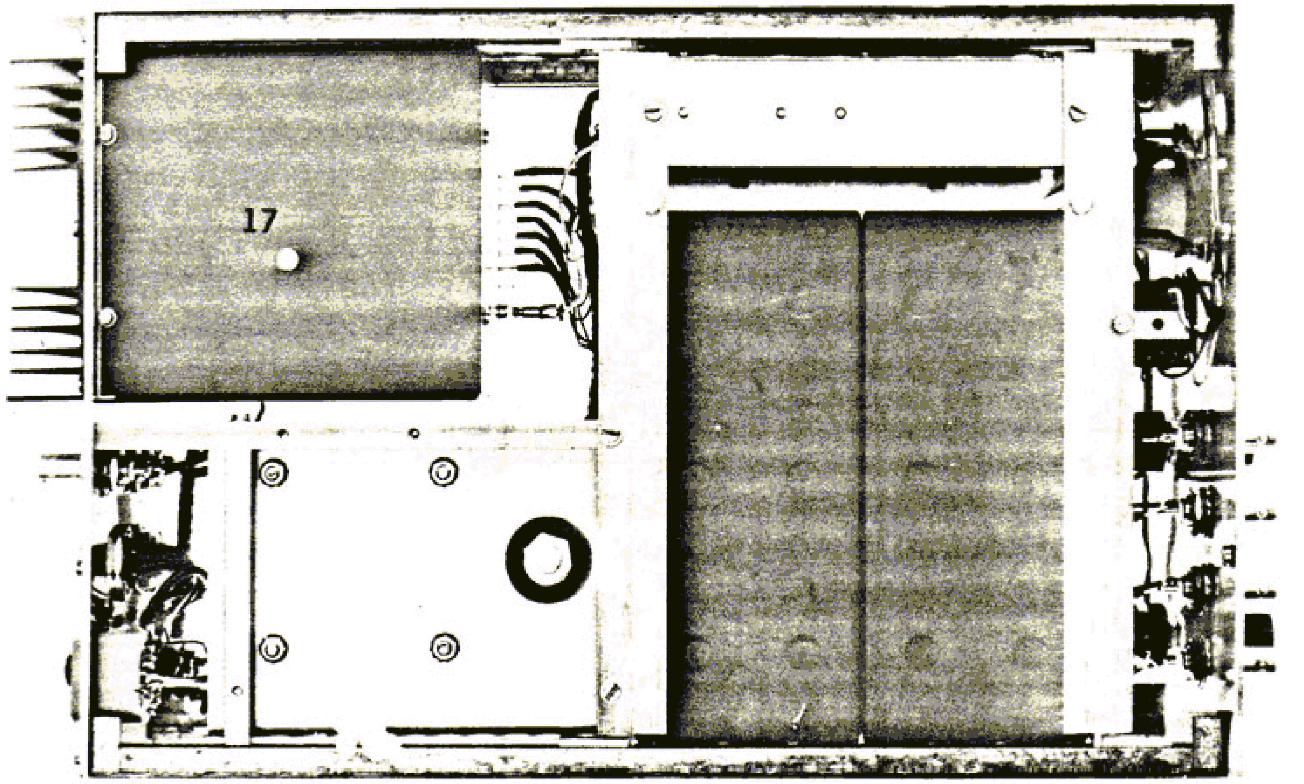
1 Meter
2 Rotary Switch
3 Frequency Fine Adjustment
4 Lamp "Power"
5 Lamp "Operation"
6 Frequency Outputs
16 Holding Screw

Fig. 1 FRONT PANEL



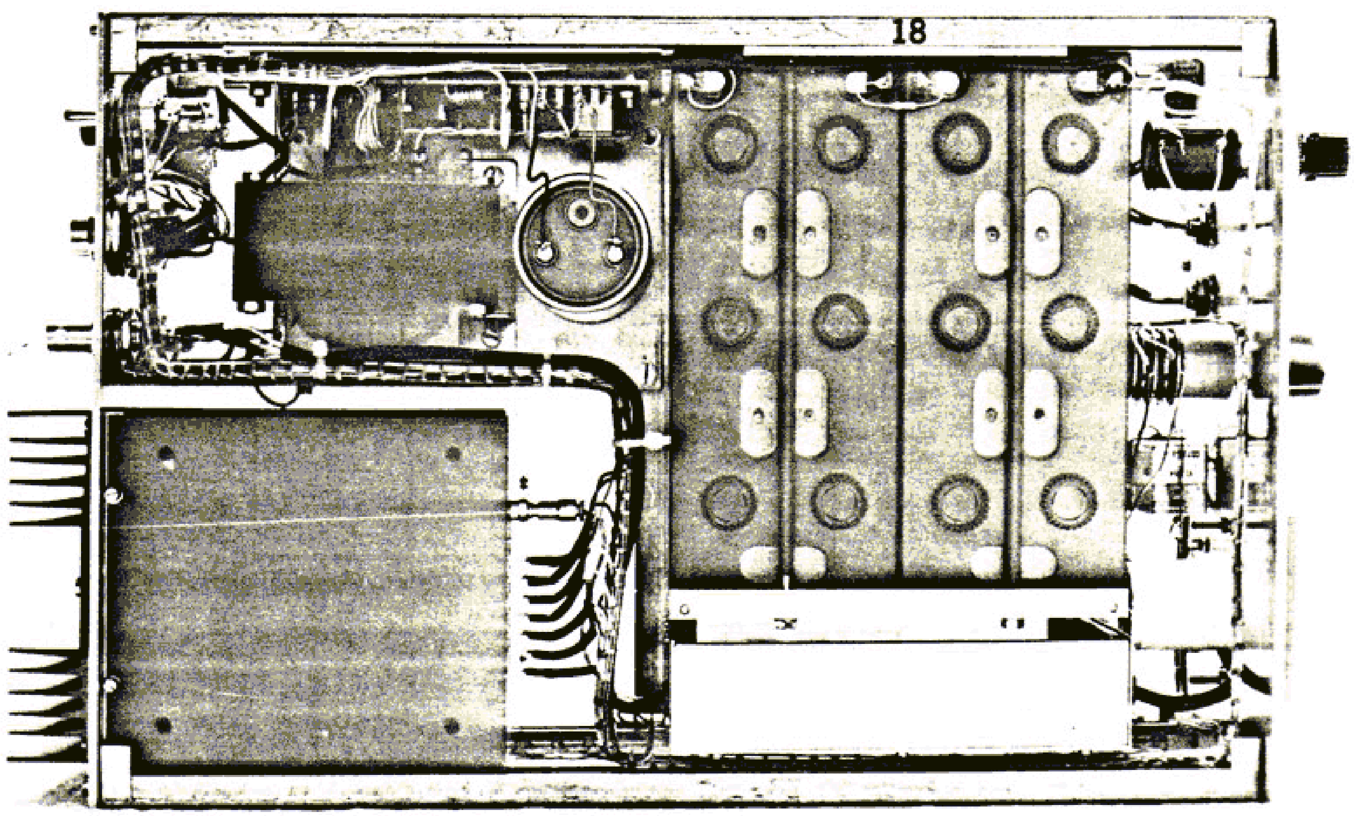
7 Frequency Outputs
8 Receptacle DC Power Supply
9 Receptacle Receiver/Controller
10 Receptacle Remote Monitoring
11 Battery Switch
12 Fuse Receiver
13 Fuse Power Supply
14 Power Input
15 Closing Screw Rb-Lamp

Fig. 2 BACK PANEL



17 Closing Screw

Fig. 3 BOTTOM VIEW



18 Fuse

Fig. 4 TOP VIEW

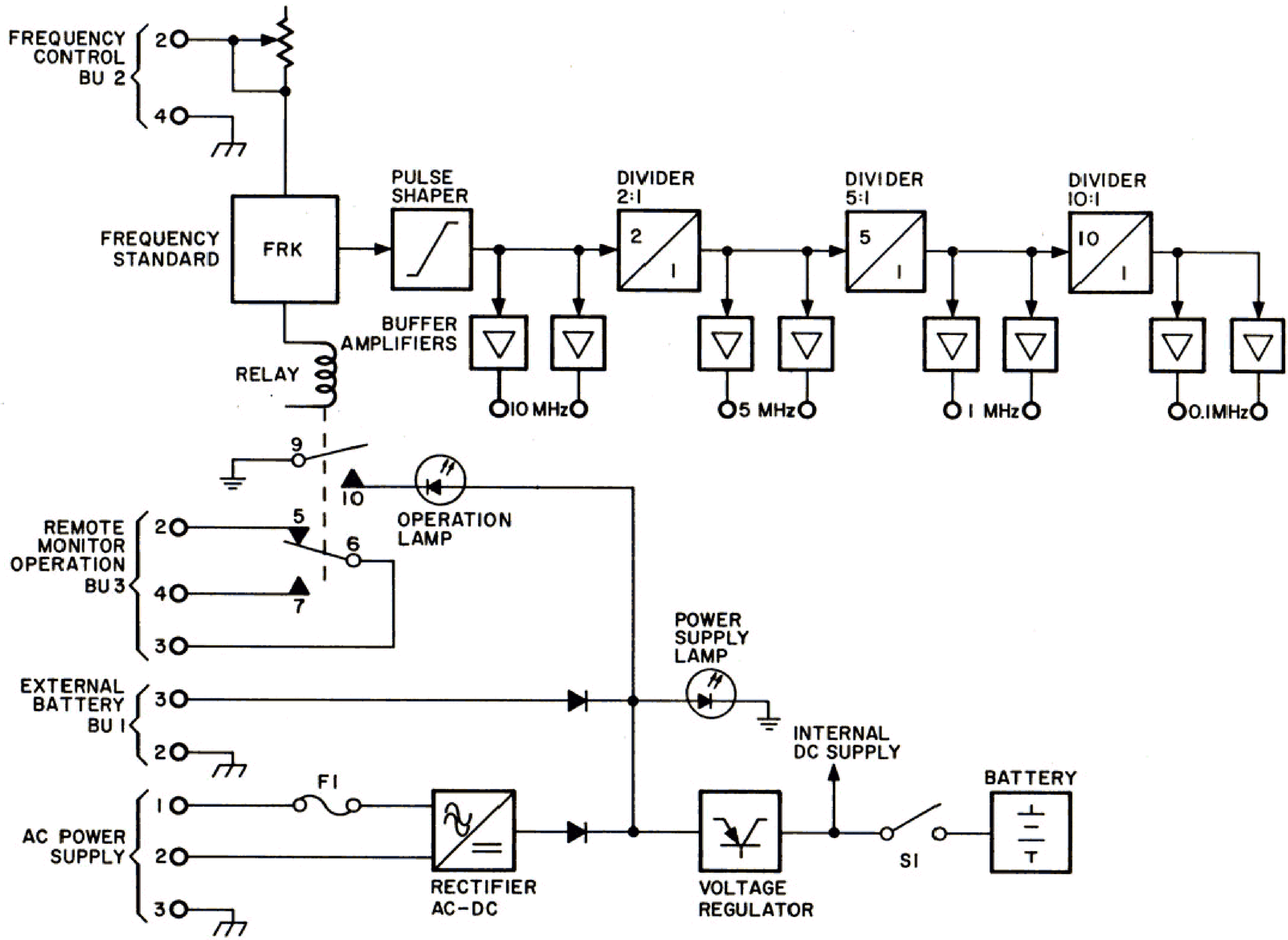


Fig. 5 – EFRATOM MODEL FRT BLOCKDIAGRAM

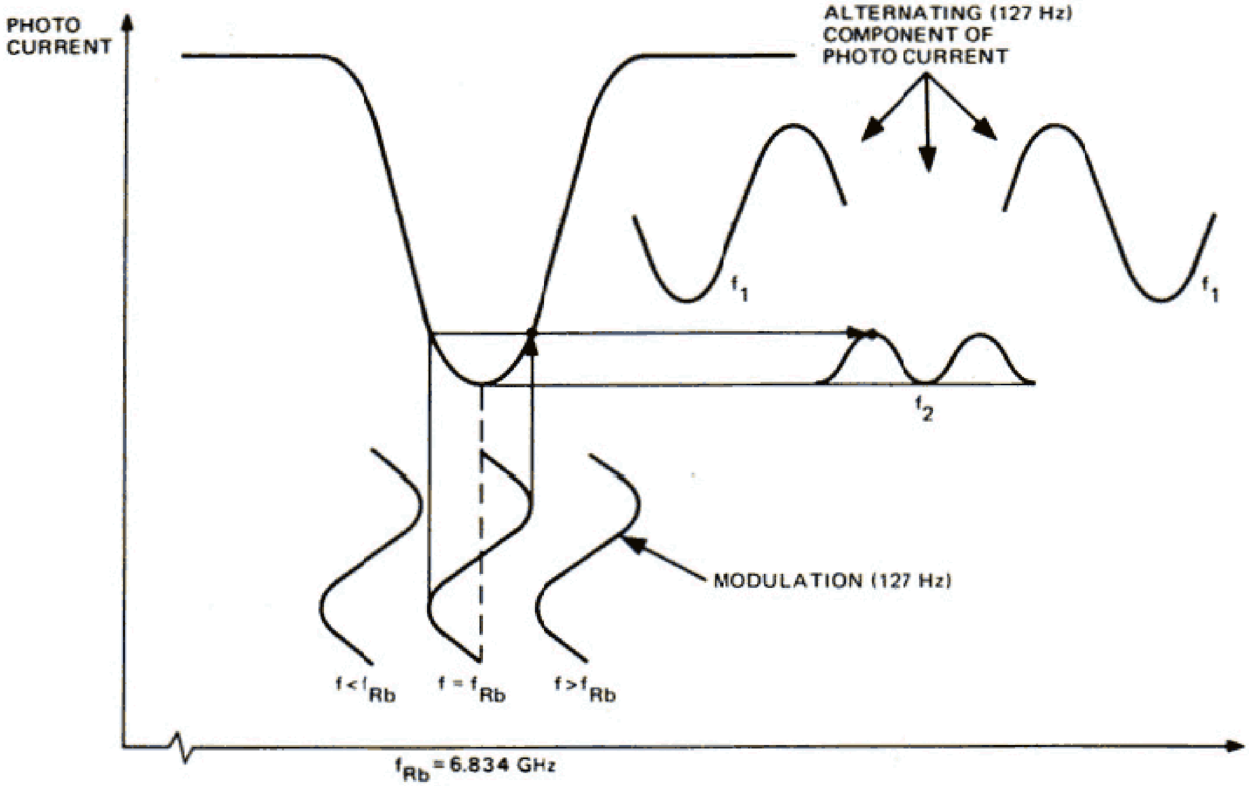


Figure 6. Derivation of Regulation Signal

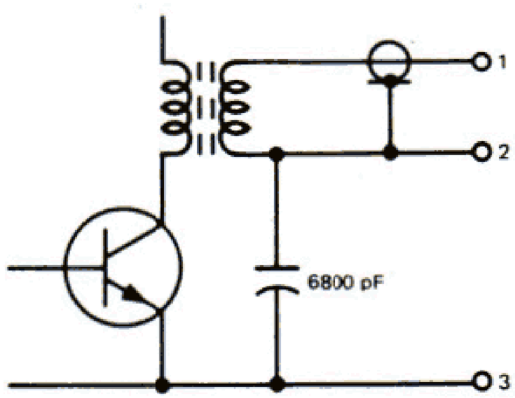


Figure 7. Output Amplifier (Schematic)

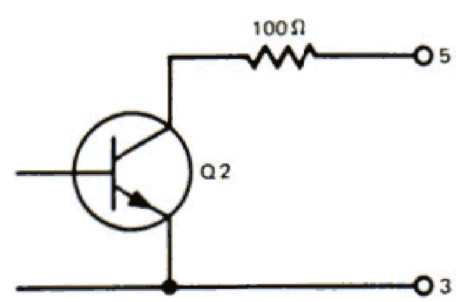
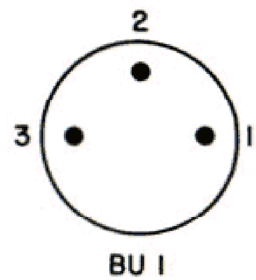


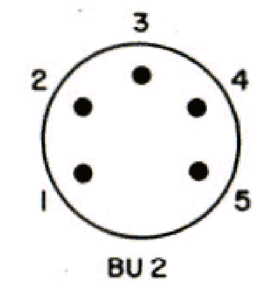
Figure 8. Monitor Signal Circuit



EXTERNAL BATTERY

2 NEGATIVE TERMINAL

3 POSITIVE TERMINAL



FREQUENCY CONTROL

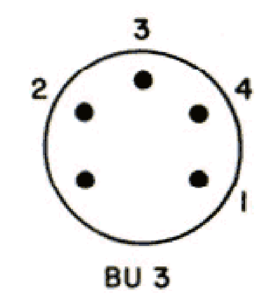
2 POSITIVE TERMINAL

4 NEGATIVE TERMINAL

DC SUPPLY TO RECEIVER

3 NEGATIVE TERMINAL

5 POSITIVE TERMINAL



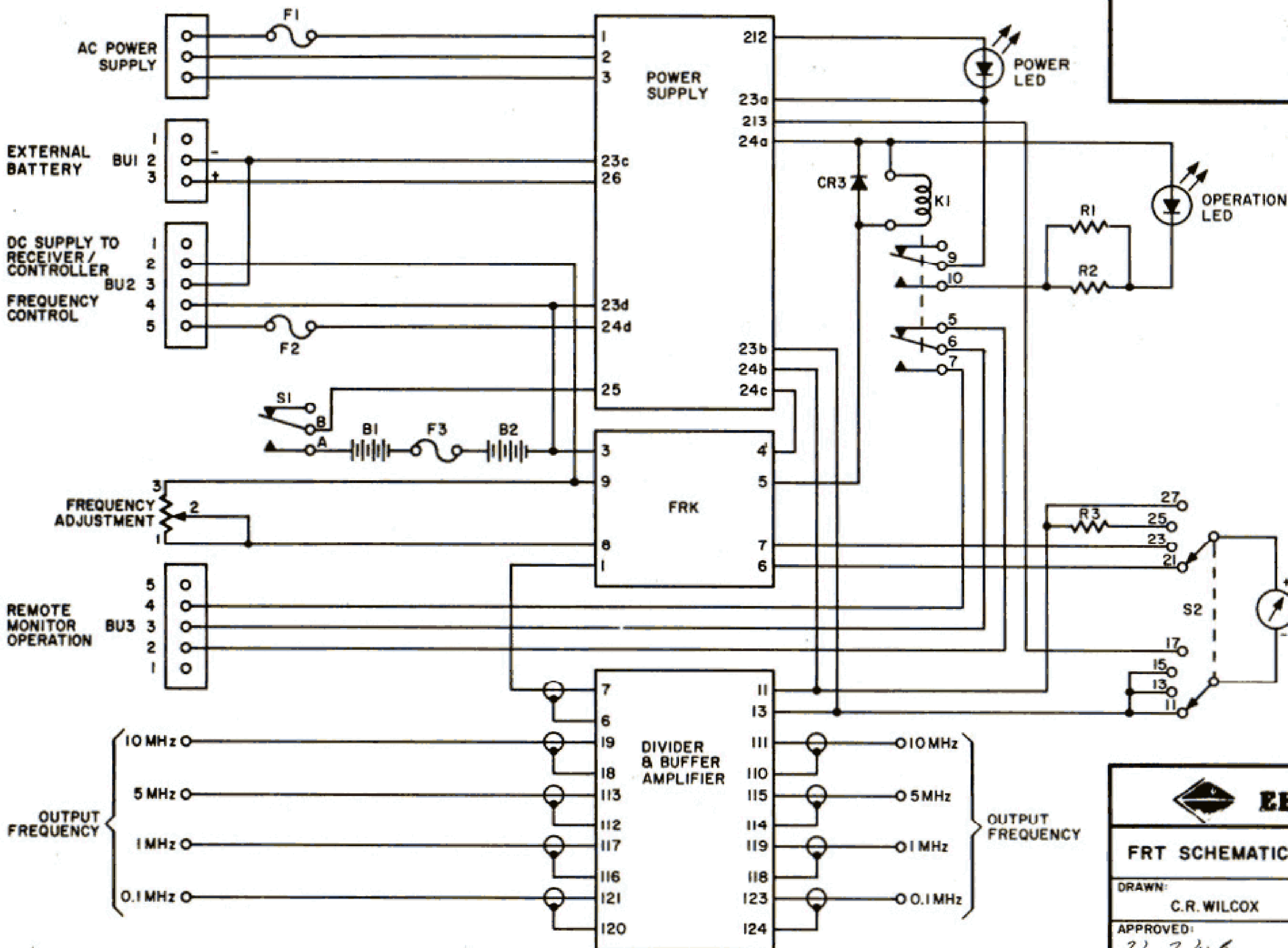
REMOTE MONITOR OPERATION

2 NORMALLY OPEN

3 COMMON

4 NORMALLY CLOSED

Fig. 9 — CONNECTORS

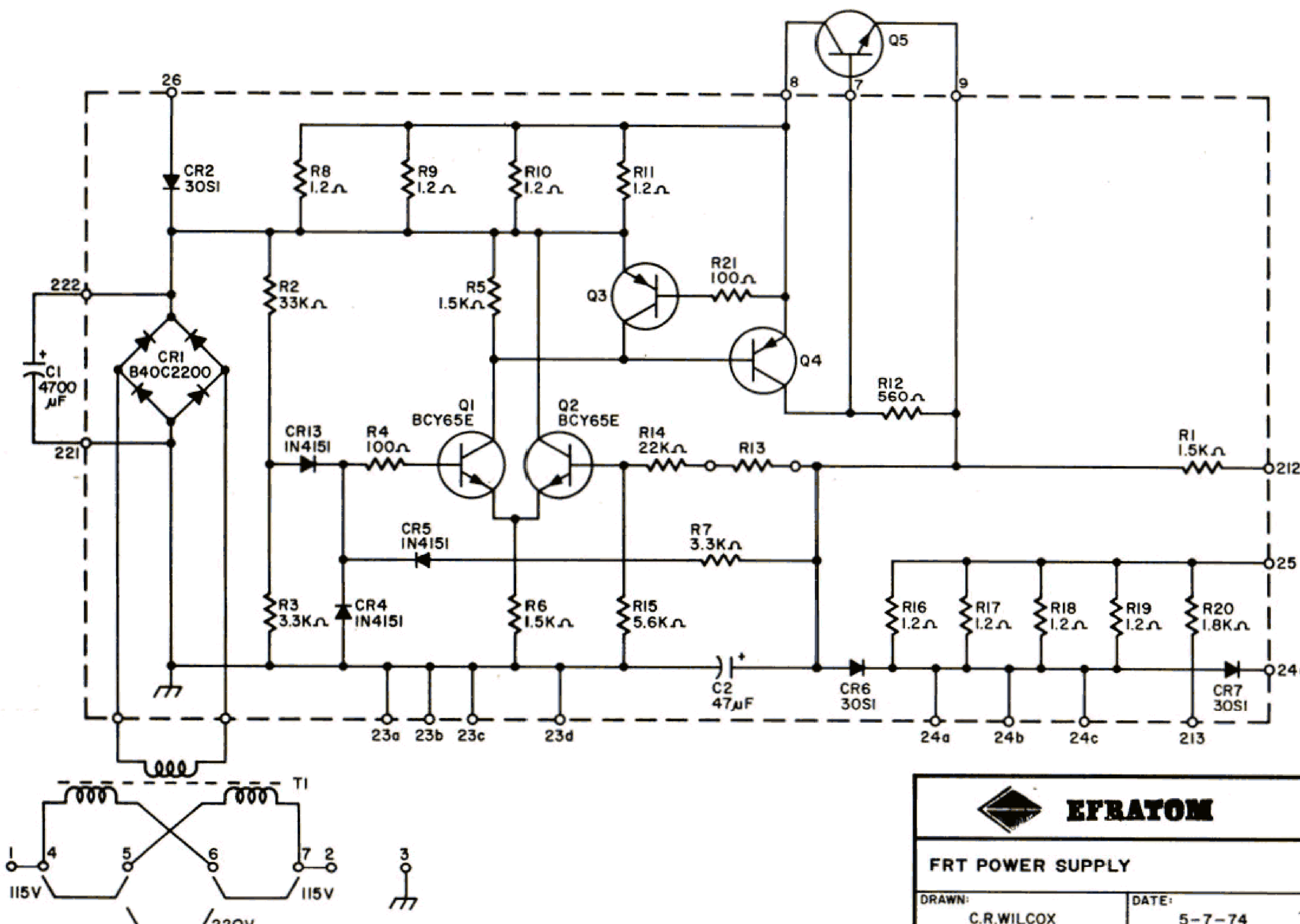


REVISIONS:

EFRATOM

FRT SCHEMATIC

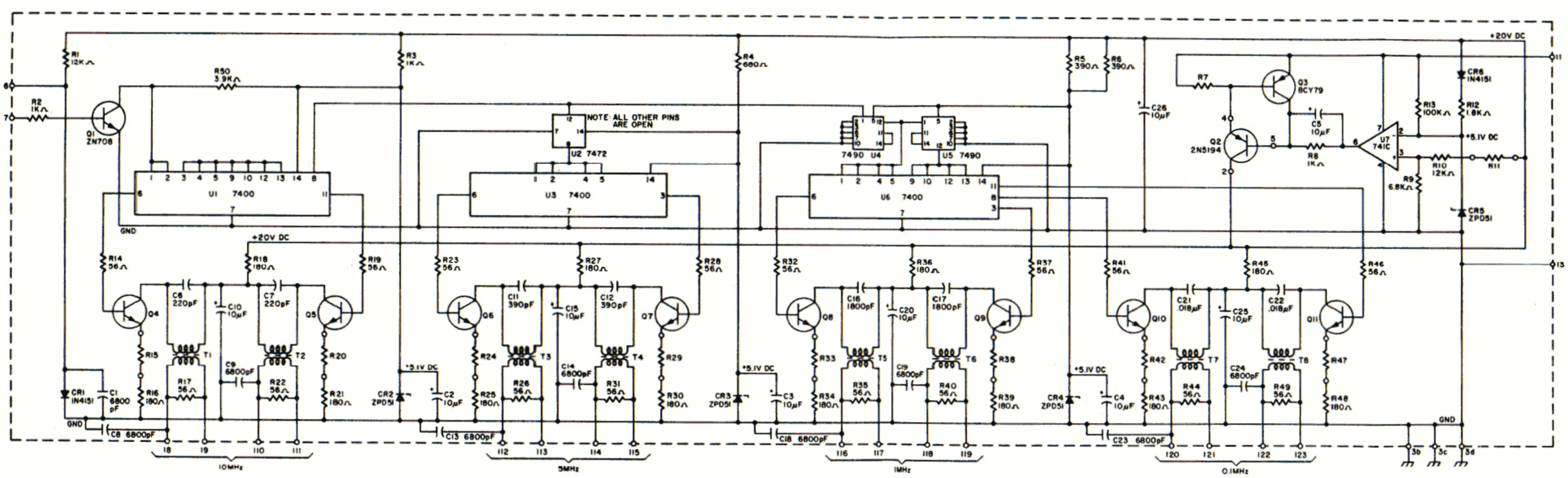
DRAWN: C.R. WILCOX	DATE: 5-5-74
APPROVED: V. Wiedemann	DATE: 6-17-74
REVISED:	DRAWING NO.:



EFRATOM

FRT POWER SUPPLY

DRAWN: C.R.WILCOX	DATE: 5-7-74
APPROVED: [signature]	DATE: 6-17-74
REVISED:	DRAWING NO.:

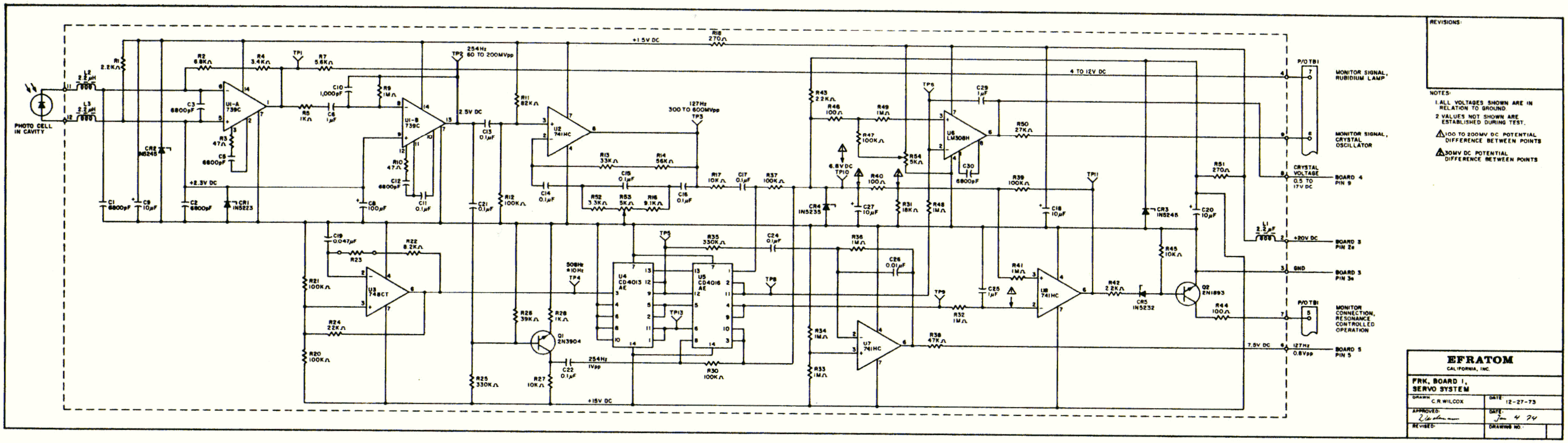


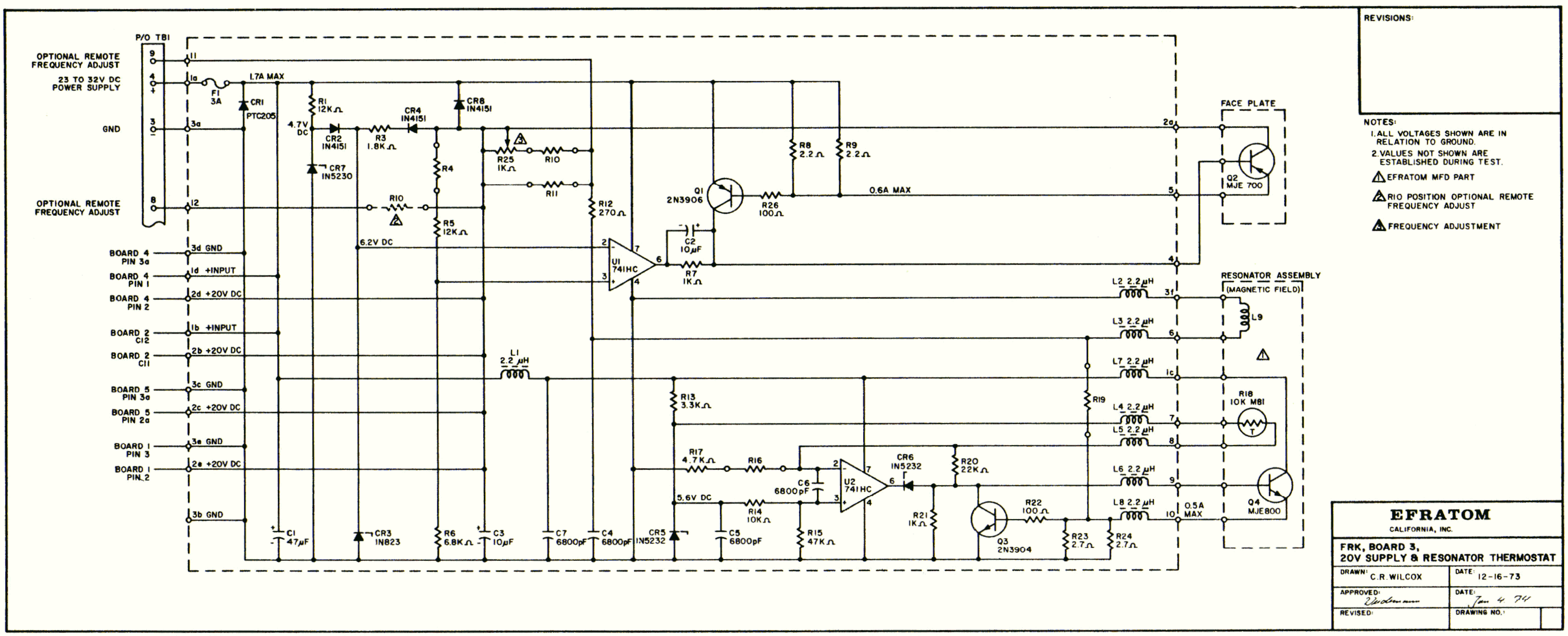
REVISIONS

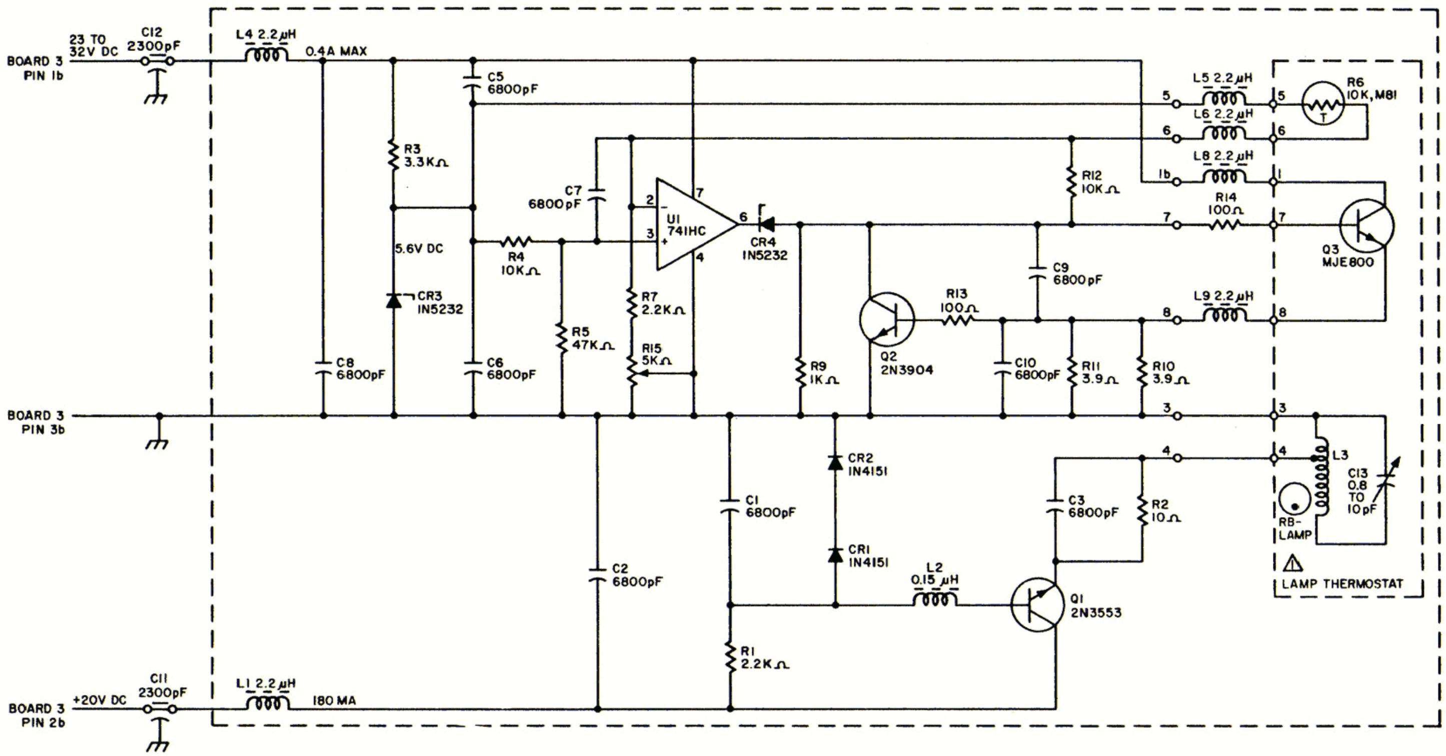
EFRATOM

FRT DIVIDER & BUFFER AMPLIFIER

DRAWN C.R.WILCOX	DATE 5-9-74
APPROVED	DATE 6-17-74
REVISED	DRAWING NO.


NOTES:
1. ALL VOLTAGES SHOWN ARE IN RELATION TO GROUND.
2. VALUES NOT SHOWN ARE ESTABLISHED DURING TEST.
100 TO 200MV DC POTENTIAL DIFFERENCE BETWEEN POINTS
30MV DC POTENTIAL DIFFERENCE BETWEEN POINTS
EFRATOM
CALIFORNIA, INC.
FRK, BOARD 1, SERVO SYSTEM
DRAWN: C.R.WILCOX
DATE: 12-27-73
MONITOR SIGNAL, RUBIDIUM LAMP
MONITOR SIGNAL, CRYSTAL OSCILLATOR
PHOTO CELL IN CAVITY


NOTES:
1. ALL VOLTAGES SHOWN ARE IN RELATION TO GROUND.
2. VALUES NOT SHOWN ARE ESTABLISHED DURING TEST.
EFRATOM MFD PART
R10 POSITION OPTIONAL REMOTE FREQUENCY ADJUST
FREQUENCY ADJUSTMENT
EFRATOM
CALIFORNIA, INC.
FRK, BOARD 3, 20V SUPPLY & RESONATOR THERMOSTAT
DRAWN: C.R.WILCOX
DATE: 12-16-73
FACE PLATE
RESONATOR ASSEMBLY (MAGNETIC FIELD)
OPTIONAL REMOTE FREQUENCY ADJUST
23 TO 32V DC POWER SUPPLY



REVISIONS:

NOTES:

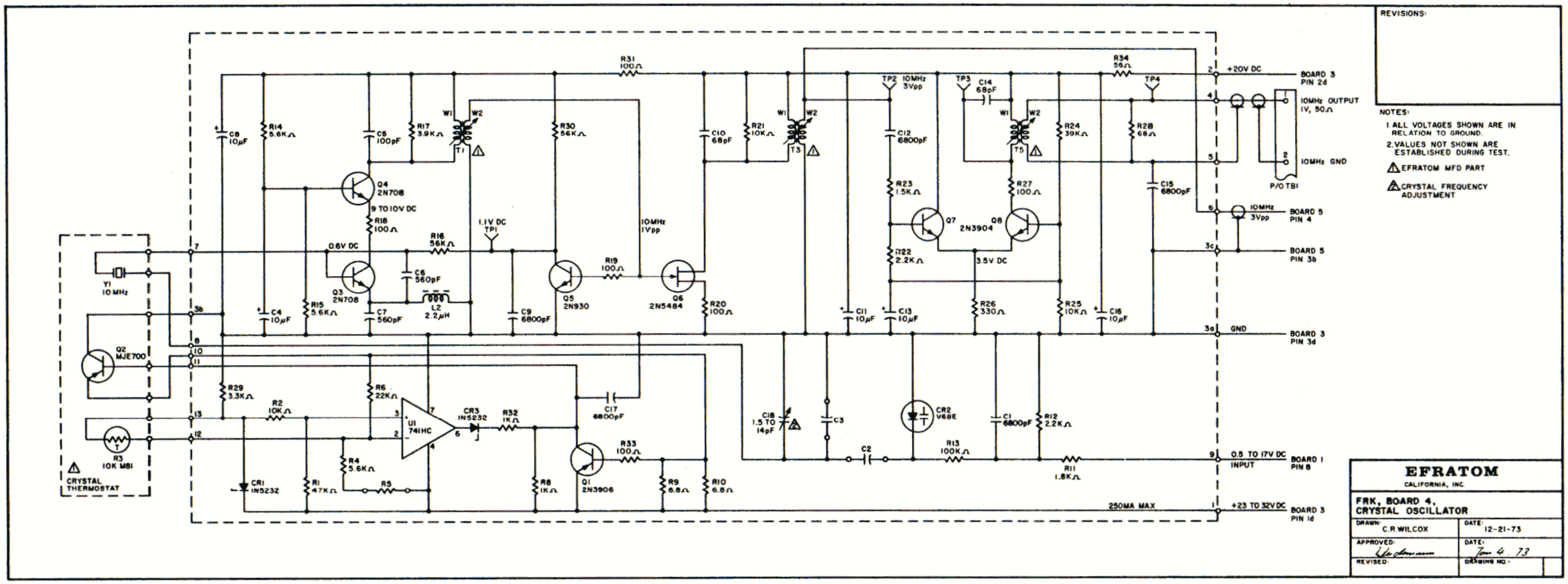
1. ALL VOLTAGE SHOWN ARE IN RELATION TO GROUND.
2. VALUES NOT SHOWN ARE ESTABLISHED DURING TEST.

△ EFRATOM MFD PART

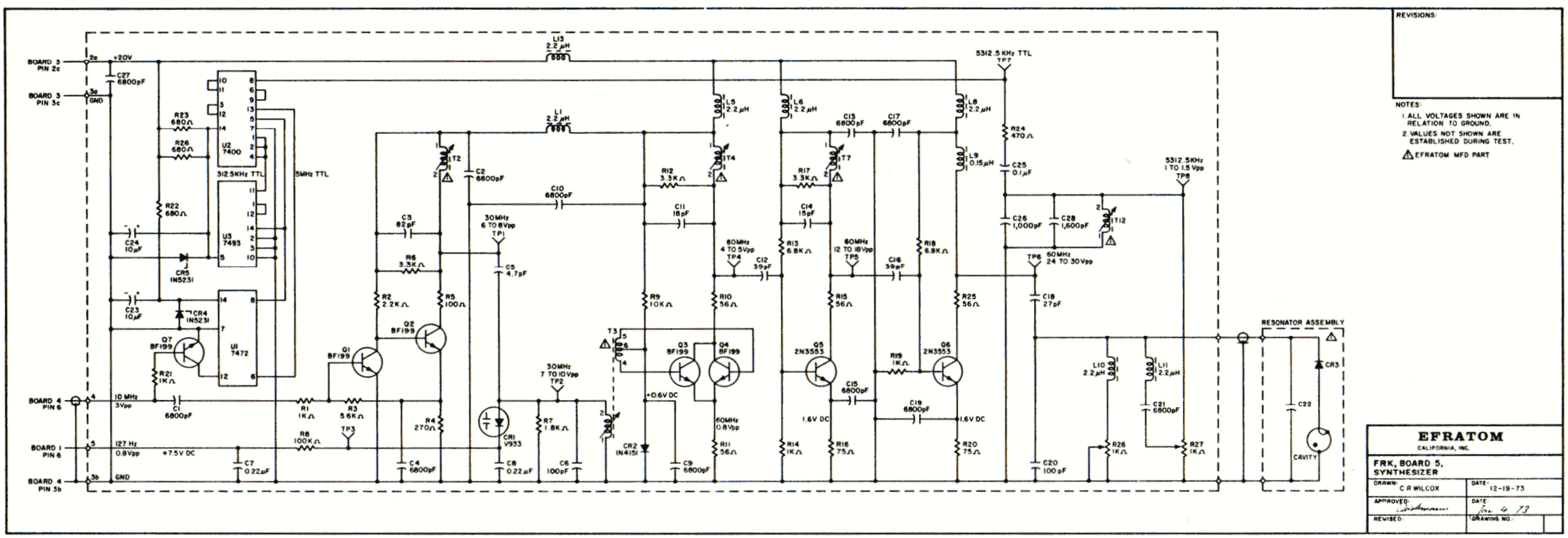
EFRATOM
CALIFORNIA, INC.

FRK, BOARD 2, LAMP UNIT

DRAWN: C.R.WILCOX	DATE: 12-15-73
APPROVED: Vuidleman	DATE: Jan 4 74
REVISED:	DRAWING NO.:



REVISIONS:
NOTES:
1. ALL VOLTAGES SHOWN ARE IN RELATION TO GROUND.
2. VALUES NOT SHOWN ARE ESTABLISHED DURING TEST.
EFRATOM MFD PART
CRYSTAL FREQUENCY ADJUSTMENT
EFRATOM
CALIFORNIA, INC.
FRK, BOARD 4, CRYSTAL OSCILLATOR
DRAWN: C.R.WILCOX
DATE: 12-21-73
APPROVED:
DATE: Jan 4 73
REVISED:
DRAWING NO.:
+20V DC
BOARD 3 PIN 2d
10MHz OUTPUT 1V, 50Ω
10MHz GND
P/O TB1
10MHz 3Vpp
BOARD 5 PIN 4
BOARD 5 PIN 3b
GND
BOARD 3 PIN 3d
0.5 TO 17V DC INPUT
BOARD 1 PIN 8
+23 TO 32V DC
BOARD 3 PIN 1d
250MA MAX
CRYSTAL THERMOSTAT



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:
DATE: Jan 4 73
REVISED:
DRAWING NO.:
BOARD 3 PIN 2c
BOARD 3 PIN 3c
BOARD 4 PIN 6
BOARD 1 PIN 6
BOARD 4 PIN 3b
RESONATOR ASSEMBLY
CAVITY
5312.5KHz TTL
5312.5KHz 1 TO 1.5 Vpp
312.5KHz TTL
5MHz TTL