VARIAN

R-20 Rubidium Frequency Standard

No. 210

Quantum Electronics Division

TECHNICAL INFORMATION

VARIAN associates
PALO ALTO, CALIFORNIA

CIRCA: 1966

INSTRUCTION MANUAL

INSTALLATION, OPERATION, AND SERVICE

RUBIDIUM FREQUENCY STANDARD

MODEL R-20

#210

Vector Voltmeter comparing 5 Mc/s

1 pt in 10^{11} $\equiv$ 1.08 degrees/min phase rotation.

VARIAN ASSOCIATES
Quantum Electronics Division

Publication No. Printed in USA

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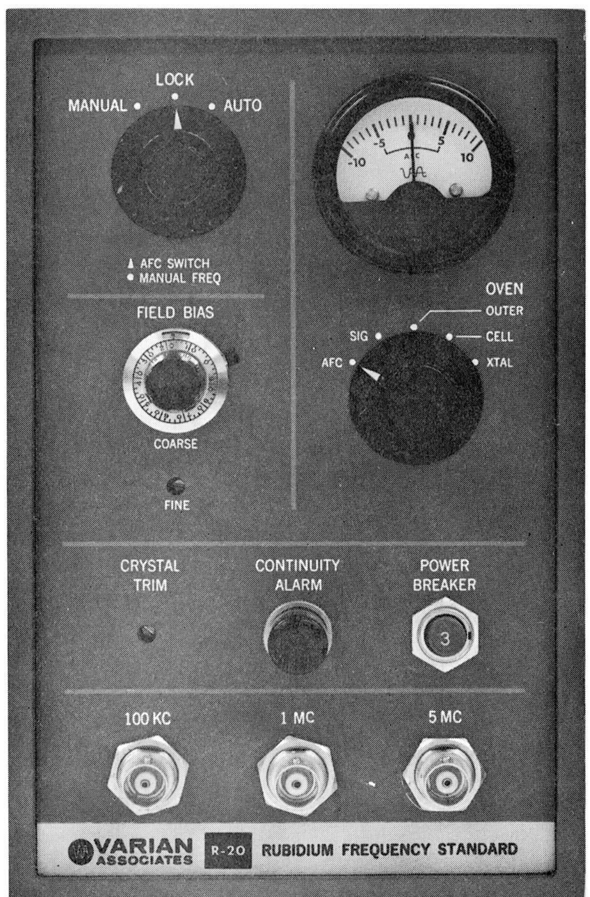

Figure 1-2. Model R-20 Rubidium Frequency Standard, Vertical

Section I
GENERAL INFORMATION

1.1 INTRODUCTION

The Varian Model R-20 Rubidium Vapor Frequency Standard produces frequency outputs at 5 Mc/s, 1 Mc/s, and 100 kc/s with a high order of stability.

1.2 GENERAL DESCRIPTION

The Model R-20 utilizes the principles of optical pumping and transmission monitoring to stabilize a 5-Mc/s crystal oscillator against a natural atomic resonance, the field-independent hyperfine transition of Rubidium 87.

Figures 1-1 and 1-2 show the R-20 Rubidium Vapor Frequency Standard. Front panel controls and metering are provided for locking the oscillator to the atomic transition and for monitoring the operation of the instrument.

The instrument is designed for continuous operation.

1.3 OPTIONAL EQUIPMENT

An optional Time Scale Changer is available that allows broad time base changes. The Time Scale Changer range encompasses Atomic Time and anticipated changes in Universal Time. Additional optional equipment and accessories may become available in the future.

1.4 GENERAL SPECIFICATIONS

Table 1-1 lists the general specifications of the R-20.

Table 1-1. Specifications

Output Frequencies	5 Mc/s, 1 Mc/s and 100 kc/s, simultaneously at front and rear panel. Other frequencies available on special order
Output Level	1v rms min into 50 ohms

Table 1-1. Specifications (Continued)

Frequency Stability	Statistical Variations (standard deviation)* 1-second intervals: 1×10^{-11} or better 100-second intervals: 5×10^{-12} or better 1×10^{-12} per day over any 1 year period**
Environmental Stability	Less than $\pm 1 \times 10^{-10}$ over the operating range of 0° to 50° C Less than $\pm 5 \times 10^{-12}$ for any orientation in the earth's magnetic field Humidity: 0 to 95%
Radio Frequency Interference	Meets MIL-I-26600, Class III
Initial Frequency Setting	$\pm 5 \times 10^{-11}$ relative to customer-specified time scale
Frequency Adjustment Range	Standard: Total range 100×10^{-10} (calibration curve is supplied) Time Scale Changer: (available on order) permits changes of $\pm 1000 \times 10^{-10}$ in increments of approximately 52×10^{-10}
Warmup Time	Specified stability is reached within one hour (at room temperature)
Alarm Indicator	Front panel continuity alarm lights whenever output frequency is off the hyperfine transition frequency. Light stays on until manual reset
Input Requirements	28v dc nominal (24-31v dc), less than 2 v rms ripple; 1.2 amp nominal at 25° C; 2.5 amp warmup
Front Panel Metering	Second harmonic level, oscillator control voltage, oven current monitored by front panel meter
Packaging	Dimensions: 7-5/8 x 4-7/8 front panel by 19-9/16 inch depth. Vertical or horizontal mounting. Weight: 20 pounds. Can be mounted in 5-7/32" high rack adapter with R-28 Power Supply

*As measured at 5-Mc/s output using the period count technique or equivalent.
**5×10^{-11} rms available on special order.

1.5 WARRANTY STATEMENT

Varian warrants each R-20 Rubidium Frequency Standard to be free of defects in materials and workmanship for a one-year period beginning with the date of receipt by the purchaser from Varian or by said purchaser's designated agent for delivery, but not to exceed fifteen months from the shipping date. This warranty shall include the replacement of any defective parts and the adjustment and servicing of the instrument by Varian. Varian's warranty liability shall run only to the actual original purchaser from Varian.

Before any R-20 is returned for warranty repair or adjustment, Varian's approval must be obtained. Varian may at its sole option, repair the R-20 in the customer's laboratory or at its service center in Palo Alto, California or in Zurich, Switzerland. Written authorization for the return and instructions as to how and where these items should be shipped will be provided. If any R-20 is to be returned to Varian, it should be sent prepaid via the means of transportation indicated in the written authorization. Varian reserves the right to reject any warranty claim, or any R-20 that has been shipped by a non-acceptable means of transportation.

When R-20 Frequency Standards are returned for repair and adjustment, it is essential that they be properly packed for shipment. The sender or its shipping agency shall assume responsibility for damage resulting from improper packing or handling, and for loss in transit.

When R-20 Frequency Standards are returned, it is necessary that the purchaser provide Varian with data on operation and any other pertinent information which will enable Varian to service and adjust the instrument.

If an instrument has become defective through misuse or abnormal operating conditions, the purchaser will be responsible for all charges incurred for repair and adjustment. In such event, an estimate of the repair charges will be submitted and proper authorization will be required before repairs are made. Varian shall have the sole responsibility for determining the cause of failure or improper operation. If it is found that an R-20 has been returned without cause, the purchaser will be notified and the R-20 will be returned at his expense.

This warranty is expressly in lieu of all other obligations or liabilities on the part of Varian unless it is otherwise agreed in writing. Under no circumstances will Varian be liable for consequential or resulting loss or damage, whether or not due to causes covered by this warranty.

Section II
INSTALLATION

2.1 UNPACKING

To provide maximum protection during shipment, the R-20 is packaged in a special protective container. To unpack the unit, take off nylon restraining tape and lift the unit out of container.

2.1.1 Receipt of Damaged Equipment

Examine the unit carefully. If there is any evidence of shipping damage, stop unpacking as soon as the damage is discovered, notify the carrier, and arrange to have the shipment inspected by a carrier agent or authorized representative. Do not delay. Inform the carrier of intent to file claim, then notify the Varian Field Engineering Department immediately. Address all correspondence to:

Varian Associates
Quantum Electronics Division
Field Engineering Department
611 Hansen Way
Palo Alto, California

Telephone: (415)326-4000
Cable: VARINT
TWX: (415)492-9253
(415)492-9254
TELEX: ~~0 33826~~ 348476
348424

Address foreign correspondence to:

Varian AG
Baarerstrasse 77
Zug, Switzerland

Telephone: 042/4 45 55
TELEX: ~~54 3 54~~ 78841.

2.2 INSTALLING THE EQUIPMENT

For bench top or portable use, no installation is required. For rack mounted use, install the accessory Frequency Standard Mounting Assembly (which houses both the R-20 and the R-28 Power Supply) in a standard 19 inch relay type rack. Insert the R-20 into the Mounting Assembly and secure with the screws provided.

Do not attempt cable connections for power input until front panel controls have been properly set. The procedure for power input connections is given in Section IV.

Section III
THEORY OF OPERATION

3.1 GENERAL THEORY

3.1.1 Introduction

The R-20 Rubidium Frequency Standard contains eight circuit cards and four assemblies: the lamp exciter assembly, the crystal oscillator assembly, the optical assembly, and the main chassis. The circuitry of this unit breaks down into three basic electronic subsystems (Figure 3-1):

(a) the optical package and the electronic servo circuit, which produce a dc error voltage for control of the 5-Mc/s crystal oscillator frequency;

(b) the crystal oscillator, which produces 5 Mc/s and the electronic frequency-synthesizing network, which produces the exciting frequencies that are applied to the optical package;

(c) the electronic frequency-division networks, which produce the working outputs of 1 Mc/s and 100 kc/s.

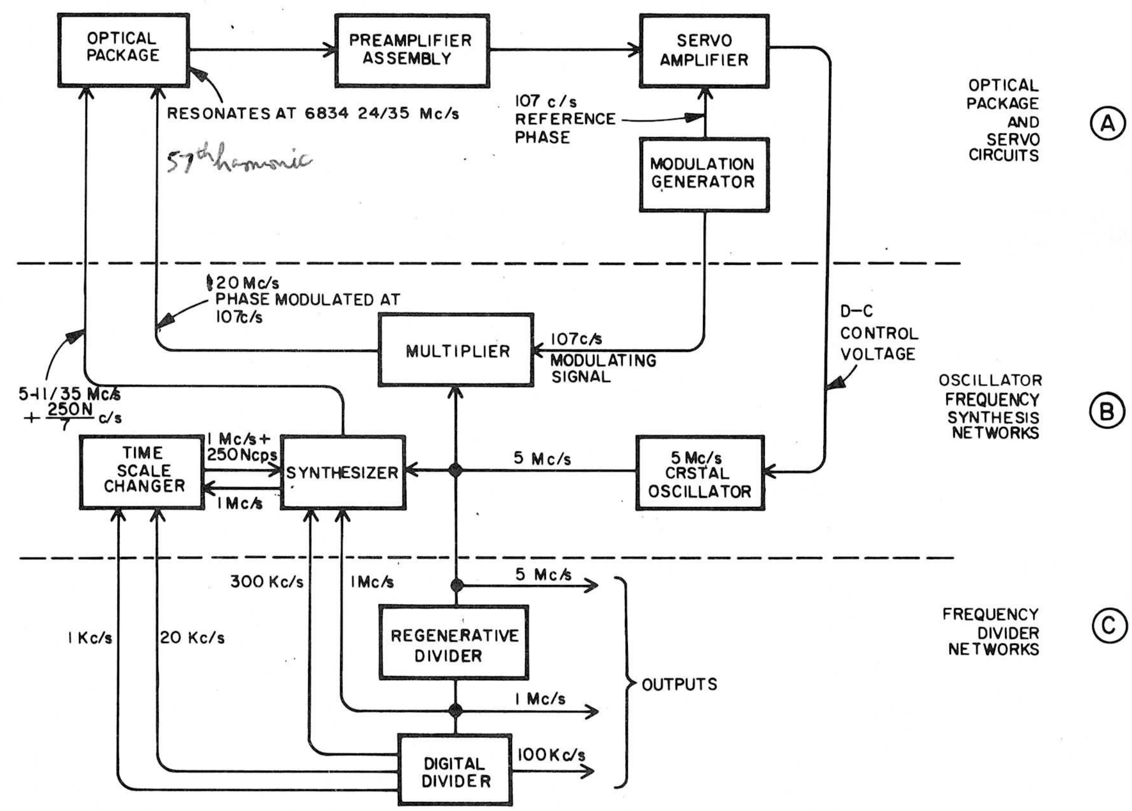

Figure 3-1. R-20 Subsystem Breakdown

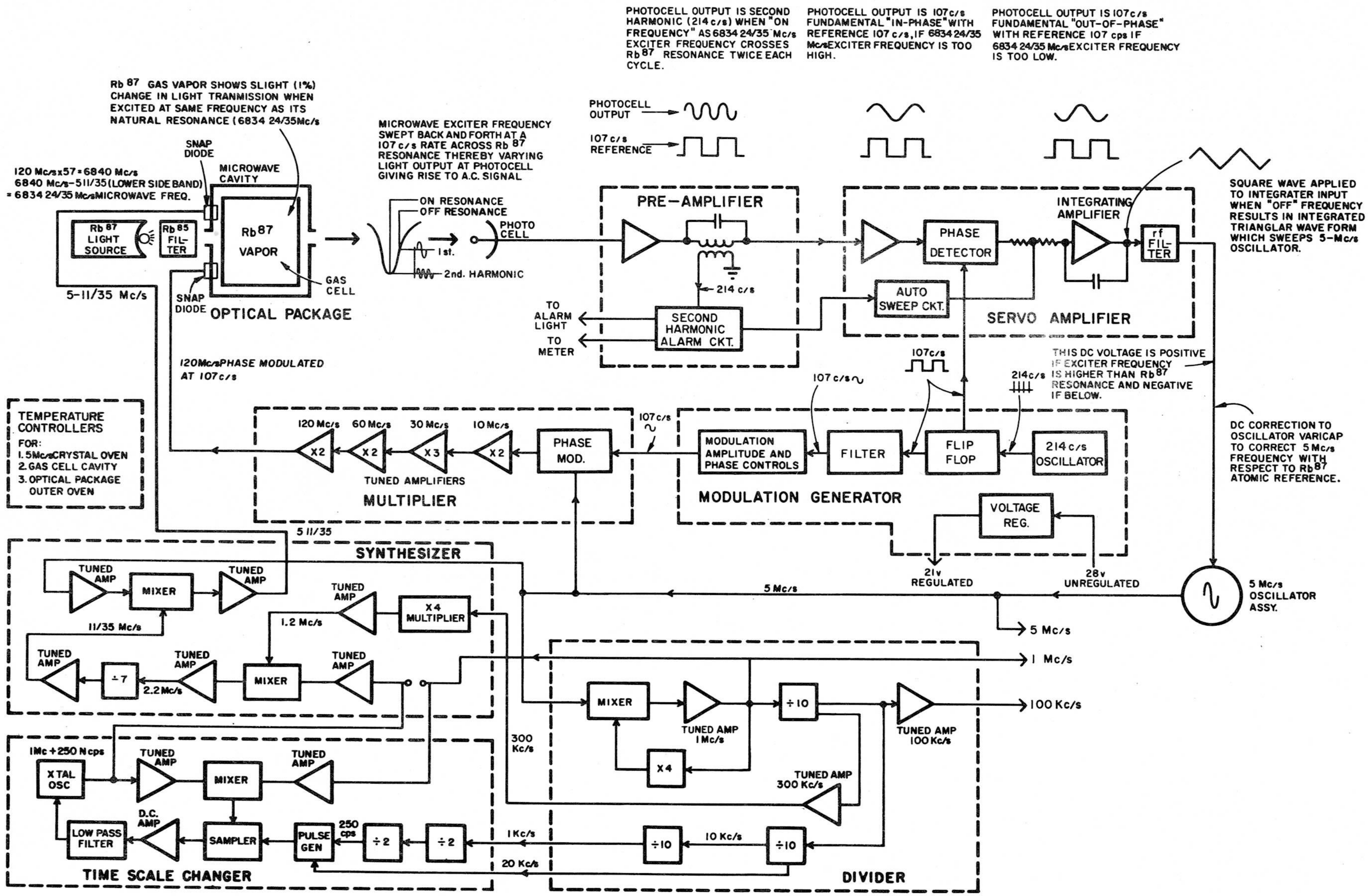

Figure 3-2. R-20 Functional Block Diagram

Figure 3-2 is a functional block diagram of the R-20. The 5-Mc/s quartz crystal oscillator shown at the lower right of this figure provides a 5-Mc/s output frequency and a 5-Mc/s base frequency for 1-Mc/s and 100-kc/s outputs as well as 120-Mc/s and 5-11/35-Mc/s inputs to the optical package. Long term stability is achieved by stabilizing the 5-Mc/s oscillator with the natural atomic resonant frequency of Rb^{87}.

3.1.2 Optical Package

In the optical package, shown in Figure 3-3, two input signals are mixed: 120 Mc/s phase modulated at 107 c/s, and 5-11/35 Mc/s. This mixture produces a lower side band of 6,834-24/35 Mc/s, which stimulates atomic transitions in the Rb^{87} gas cell.

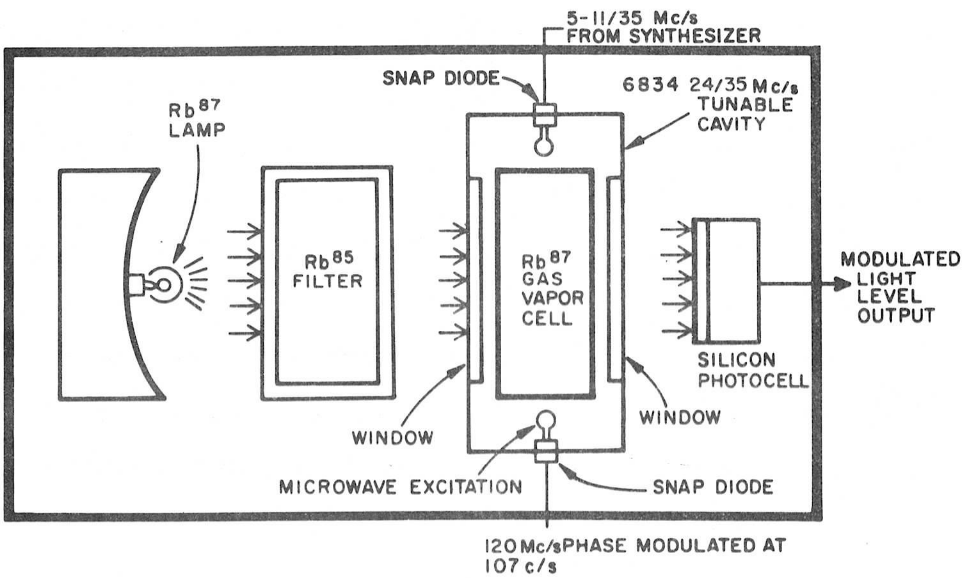

Figure 3-3. Optical Package

The Rb^{87} light from the lamp assembly passes through the Rb^{85} filter cell, then through the Rb^{87} gas vapor cell, and finally impinges on the silicon photocell. When the vapor in the gas cell is excited at the same frequency as its natural resonance, the photocell output drops very slightly, indicating a change of opacity in the Rb^{87} gas vapor (Figure 3-4).

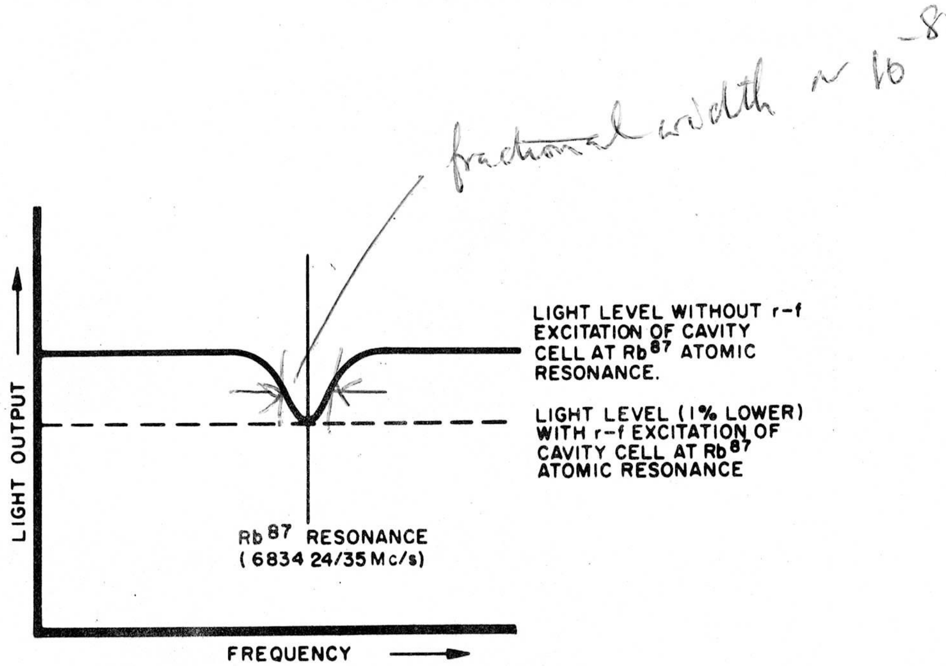

Figure 3-4. Change in Light Level with Frequency

The 107-c/s phase modulation of the 120-Mc/s signal results in a variation in light level as the 107-c/s modulation sweeps the microwave excitation in the gas-cell cavity back and forth across the resonant dip. The silicon photocell in the optical package sees this variation as an ac signal with both 214-c/s and 107-c/s components as shown in Figure 3-5. Only the 107-c/s component is used for control purposes. When the microwave excitation frequency is above the center frequency, the 107-c/s output is 180 degrees out-of-phase with respect to the 107-c/s output when the excitation frequency is below the center frequency. This produces a phase-dependent signal that is used to stabilize the 5-Mc/s oscillator.

3.1.3 Preamplifier

The preamplifier increases the photocell signal and passes it through a resonant filter, separating the 214-c/s second harmonic from the 107-c/s fundamental. In a second section of the preamplifier, the 214-c/s component of the photocell output is amplified and displayed on the front panel meter as second harmonic output (SIG). This measures the overall performance of the optical system. When the 214-c/s level drops below a preset value, the CONTINUITY ALARM light on the front panel turns on, indicating that the R-20 is unlocked

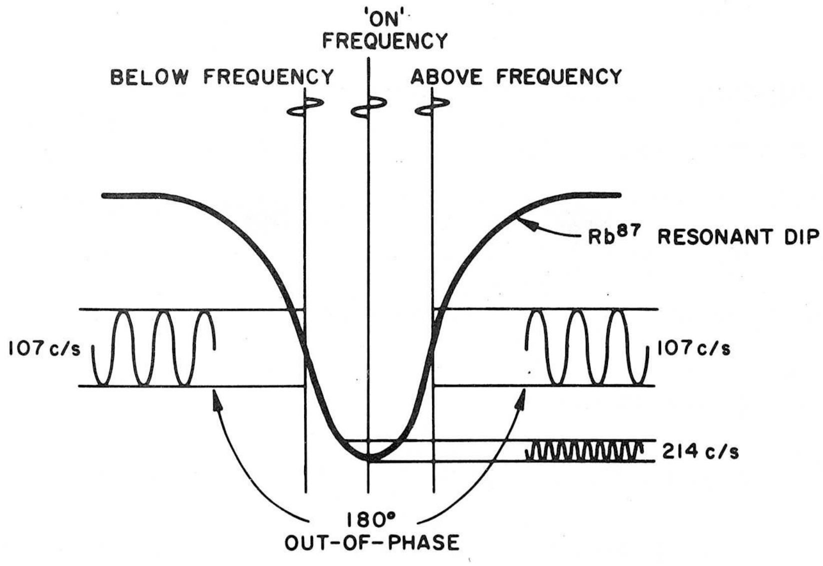

Figure 3-5. Photocell Output

and may be off frequency. In addition, the absence of a signal in the 214-c/s amplifier creates a "turn-on" signal for an automatic sweep circuit in the servo amplifier which switches the R-20 to a search mode to re-establish a "lock-on" condition.

3.1.4 Servo Amplifier

The servo amplifier amplifies and detects the phase of the 107-c/s signal. The resulting dc signal is integrated and used to control the frequency of the 5-Mc/s oscillator. A separate feature of the servo amplifier is the automatic sweep circuit which generates a triangular-shaped sweep voltage when the R-20 is "off frequency". This triangular wave form sweeps the 5-Mc/s oscillator back and forth to re-establish lock-on. When the lock-on condition is re-established, the automatic sweep signal from the preamplifier turns off the automatic sweep circuit; however the CONTINUITY ALARM light remains on to indicate that a frequency discontinuity has occurred.

3.1.5 Modulation Generator

The modulation generator produces the 107-c/s reference phase for the phase detector in the servo amplifier. It also furnishes a modulation signal for the multiplier. The 107-c/s reference phase is a square wave for switching efficiency in the phase detector circuit. The 107-c/s square wave is converted to a sinusoidal waveform in a tuned resonant circuit to phase modulate the multiplier. Modulation amplitude and phase controls are provided to facilitate adjustment of modulation amplitude and phase.

3.1.6 Frequency Derivation

The R-20 supplies three outputs which are derived as follows:

(a) 5 Mc/s, obtained from the 5-Mc/s oscillator through a buffer amplifier.

(b) 1 Mc/s, derived by coherent division of the 5-Mc/s signal.

(c) 100 kc/s, derived by coherent division of the 1-Mc/s signal.

3.1.7 Temperature Control

In order to achieve good stability of the crystal oscillator circuit, temperature control of the 5-Mc/s crystal is provided. A thermistor in the 5-Mc/s oscillator assembly oven is one arm of a bridge which feeds a correction signal to an amplifier and controls the heating element of the 5-Mc/s oscillator oven. This temperature control maintains a temperature of approximately 75 degrees C.*

Two other temperature-regulator circuits control the gas cell oven and the outer oven of the optical package in the same manner. The outer-oven temperature is maintained at approximately 60 degrees C and the gas-cell oven at 80 degrees C.

3.2 FREQUENCY DIVISION TECHNIQUES

3.2.1 Regenerative Division

In the R-20, regenerative frequency division is used to derive some of the required special frequencies. To achieve basically the same long-term stability

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*Individually set to the exact crystal frequency versus temperature turnover point.

of the 1-Mc/s output as the 5-Mc/s output, regenerative divider circuits divide 5-Mc/s into 1-Mc/s. By this means, a coherent relationship between these working outputs is obtained.

The principle of regenerative division is feedback of a multiple of the output frequency that is mixed with the input signal to produce the output frequency. Figure 3-6 gives an example of regenerative division. The 5-Mc/s input mixes with the 4-Mc/s feedback signal, producing both sum and difference frequencies in the mixer output. The sum frequency of 9 Mc/s is discriminated against and only the 1-Mc/s difference frequency is amplified by the tuned 1-Mc/s amplifier.

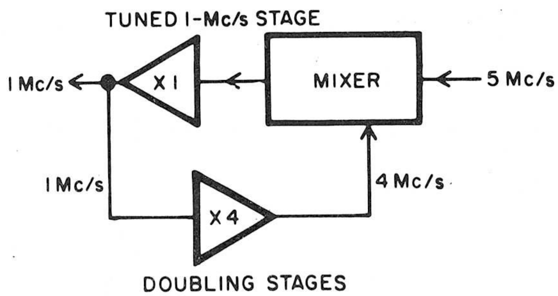


Figure 3-6. Regenerative Division

3.2.2 Binary Division

Binary division in its simplest form consist of a flip-flop circuit, the output of which changes polarity with each positive going input signal. Thus, for every complete input cycle, the output changes polarity once. With two input cycles, the output changes polarity twice, thereby completing one output cycle. The result is an output frequency that is half the input frequency.

3.2.3 Decade Division

Decade division, or divide by 10, is accomplished by using four flip-flop circuits in series. This would normally produce an output frequency that is 1/16 of the input frequency. To provide an output frequency that is 1/10 of the input frequency, a signal is fed back from the output of the last flip-flop to reset all four flip-flops to zero after ten counts.

3.3 PRINCIPLES OF OPTICAL PUMPING

The following gives an elementary explanation of the physical principles used in the optical system of the Varian Rubidium Frequency Standard.

In the energy-level diagram of Rubidium 87 shown in Figure 3-7, the two lower horizontal lines represent the two ground states in which Rubidium 87 atoms normally occur in nature. These two states exist because of the magnetic interaction of the valence electron and the nucleus of the atom. If the magnetic vectors of the valence electron and the nucleus are in the same direction more energy is contained in the atom and it is said to be in the upper ground state. If these magnetic vectors oppose each other, the atom is in the lower ground state. In equilibrium, about half the atoms occupy each state and individual atoms occasionally make transitions from one state to the other in response to thermal disturbances.

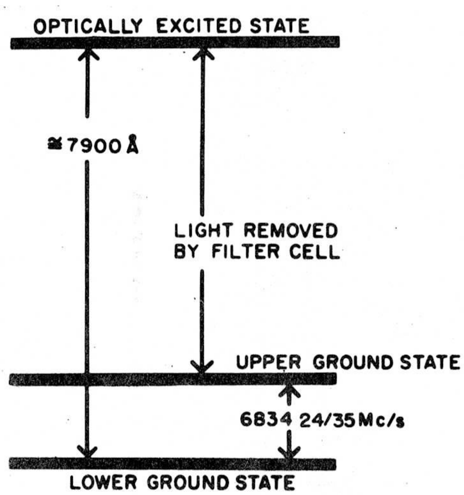


Figure 3-7. Rb^{87} Energy Level Diagram

By quantum theory the difference in energy between these states corresponds to a frequency. This frequency is approximately 6,834-24/35 Mc/s for Rb^{87}. To make use of this atomic transition as a frequency reference, it is necessary to find a means of unbalancing the population of atoms in the two ground states. This is accomplished by the process of optical pumping. A Rubidium 87 lamp excited by an rf discharge is used to produce the two wavelengths of light that correspond to the difference between each of the two ground states and the optically excited state. When this light pumps the atoms in the reference cell to the optically excited state, the valence electron is driven to an orbit of higher energy. These atoms quickly fall back at random into the two ground states. By passing the light from the Rubidium 87 lamp through a filter cell filled with Rubidium 85, it is possible to absorb selectively light having the wavelength that pumps from the upper ground state to the optically excited state. (This selective absorption in the filter cell results from the fact that the Rubidium 85 atom has a nucleus of different magnetic moment, which shifts its optical properties with respect to Rubidium 87.) Effectively, the absorption curve is detuned so the cell is transparent to light that pumps from the lower ground state but opague to light that pumps from the upper ground state. The effect of this filtered light on the reference cell is to pump atoms from the lower ground state only to the optically excited state. These atoms fall back at random. Those that fall to the upper ground state remain there, while those that fall to the lower ground state are repumped until all of them are transferred to the upper ground state. If this reference cell is now irradiated with microwave energy having a frequency of 6,834-24/35 Mc/s, transistions back to the lower ground state will be induced by the action of the microwave energy on the atoms. The atoms that undergo the microwave transition will again be pumped by the filtered light source. In the process of being pumped, they absorb light. This absorption of light gives a means of detecting the fact that the microwave transition has occurred.

The photodetector which monitors the light transmitted through the reference cell is shown in Figure 3-3, the diagram of the optical system. Frequency-modulated microwave energy is introduced to the microwave cavity containing the reference cell, and the output of the photodetector is amplified and compared with the FM modulation wave in a phase detector. A maximum absorption of light occurs when the microwave frequency exactly matches the rubidium resonance frequency. The modulated component of the photocell current is used in a high-quality frequency-lock system to correct the frequency of a crystal oscillator, as described in Section 3.1.

In addition to Rubidium 87 vapor, the reference cell contains a mixture of inert gases. This buffer gas reduces the rate at which rubidium atoms collide with the glass walls. Collisions between rubidium atoms and the glass walls cause atomic transitions, which would destroy the necessary unbalance between the ground states; collisions between rubidium atoms and the inert gas atoms are essentially elastic and do not cause such transitions. The buffer gas pressure has an influence on the microwave transition frequency of the Rubidium 87 atoms. The reference cells are deliberately filled with an amount of buffer gas that tunes the rubidium resonance to an easily synthesized frequency. Variations in buffer gas pressure are used to tune individual cells to different time scales.

The frequency of the microwave transition in rubidium atoms is also affected by a magnetic field. The variation of frequency with magnetic field is quite small and is proportional to the square of the applied magnetic field. This effect is used for fine tuning of individual frequency standards. A triple shield of high permeability material is used to isolate the standard from changes in environmental magnetic field.

There are other transition frequencies in Rubidium 87 similar to the transition described above, but which are directly proportional to the magnetic field. The influence of a magnetic field is very large in these cases. If the magnetic field is reduced to near zero, these magnetically dependent transitions converge on the transition that is normally used. This can happen only if the field bias control is turned down near zero and the mechanical tuning of the crystal oscillator is maladjusted. This off-frequency condition will not occur if the field bias control is never operated below 10 on the dial. If the standard is locked to a magnetically dependent line and the field bias control is turned up, the AFC meter will quickly swing to the limit of its range and the standard will unlock from the magnetic line, search out the correct line, and then lock on to it. This phenomena causes no difficulty in the normal operation of the standard since the control range of the crystal oscillator is not sufficient to reach any of the magnetically dependent transitions.

3.4 THEORY OF INDIVIDUAL CIRCUITS

3.4.1 5-Mc/s Oscillator

The 5-Mc/s oscillator circuit card, illustrated in Figure 3-8, is housed in the 5-Mc/s shielded oven assembly together with the 5-Mc/s amplifier circuit card. The oscillator circuit card uses a 5-Mc/s quartz crystal in a circuit designed to give good short-term stability. The crystal is AT cut and operates at 5-Mc/s on the fundamental mode. The crystal and oscillator components are temperature controlled at the frequency turn-over point of the crystal.

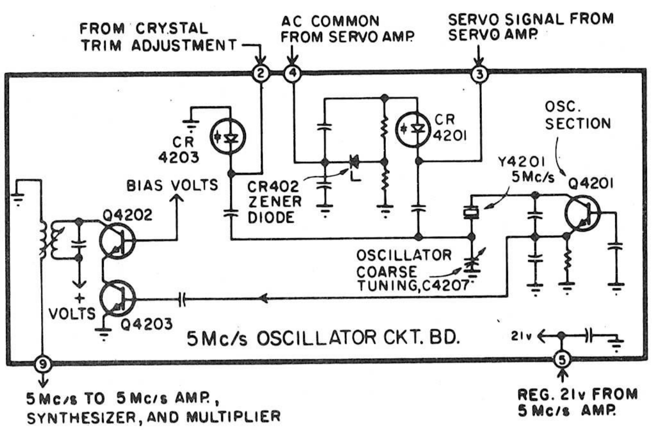


Figure 3-8. 5-Mc/s Oscillator Functional Diagram

A COARSE TUNING control C4207 at the rear of the R-20 provides an oscillator tuning adjustment of approximately 10 c/s for initial tune-up. Automatic frequency control is accomplished by application of a dc control voltage from the servo circuit to a varicap (voltage variable capacitor) in the oscillator circuit. A CRYSTAL TRIM adjustment on the front panel connects to a second varicap to center the range of the phase detector.

The 5-Mc/s frequency is produced in the oscillator stage Q4201. This circuit is a Clapp-type oscillator with capacitor division of feedback between C4204 and C4205 to the emitter of Q4201. The base of Q4201 is shunted to ground by C4202.

Resonance at 5 Mc/s is achieved by the equivalent inductive reactance of Y4201 in combination with the net capacitive reactance in series with the crystal. These capacitances are:

(a) COARSE TUNING capacitance C4207;

(b) varicap CR4201, which changes capacitance in response to servo circuit correction signal;

(c) varicap CR4203, which changes capacitance in response to adjustment of the CRYSTAL TRIM control;

(d) fixed capacitances.

Correct operating bias for varicap CR4203 comes from the CRYSTAL TRIM circuit on the front panel. Correct operating bias for varicap CR4201 is established by the voltage-regulating Zener diode CR4202 and servo control signal.

Output of the oscillator stage couples through C4217 to the buffer amplifier series-connected stage of Q4202 and Q4203. The 5-Mc/s output is coupled through T4201 to provide a low-impedance drive at card-terminations 8 and 9. Transformer T4201 is tuned for maximum output under load, approximately 1.1 volts p-p. The output at card-termination 9 couples to both the multiplier and synthesizer circuit cards and also to the buffer amplifier circuit card in the 5-Mc/s assembly.

3.4.1.1 5-Mc/s Amplifier (dual amplifiers)

The 5-Mc/s amplifier card has two buffer amplifiers, as shown in Figure 3-9. One provides an isolated low-impedance output for the divider. The other provides an isolated low-impedance output for the front and rear panel 5-Mc/s output jacks. Both amplifiers are fed by the buffer amplifier in the oscillator. The amplifier at the left side of Figure 3-9 consists of Q4301, Q4302 and Q4303. The 5-Mc/s signal couples through C4302 to the emitter-follower stage Q4301 which feeds the buffer amplifier series-connected stage of Q4303 and Q4302.

The 5-Mc/s output couples through T4301 to provide a low-impedance drive at card-termination 2. Transformer T4301 is tuned for maximum output under load, approximately 3 volts p-p.

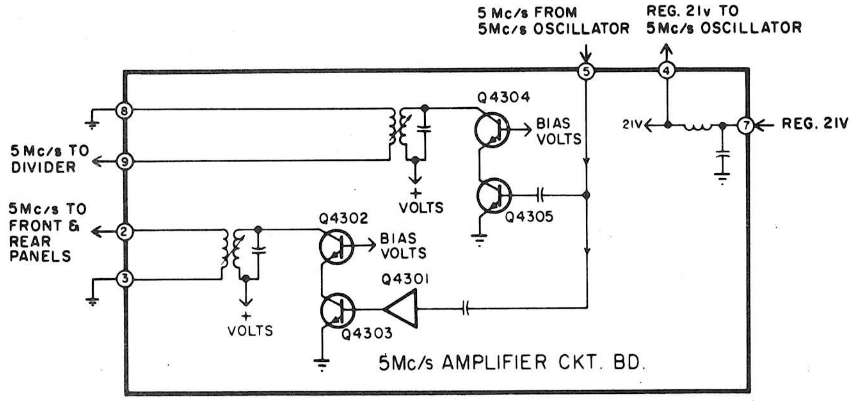


Figure 3-9. 5-Mc/s Amplifier Functional Diagram

The amplifier at the right side of Figure 3-9 consists of Q4304 and Q4305. The 5-Mc/s signal couples through C4310 to the buffer amplifier series-connected stage of Q4304 and Q4305. The 5-Mc/s output couples through T4302 to provide a low-impedance drive at card-termination 9. Transformer T4302 is tuned for maximum output under load, approximately 1.7 volts p-p.

3.4.2 1-Mc/s and 100-Kc/s Divider

The 1-Mc/s and 100-Kc/s Divider circuit card shown in Figure 3-10 divides the 5-Mc/s output down to 1 Mc/s and then to 100 Kc/s. Both signals are then fed to front and rear panel jacks. In addition, this circuit supplies 1-Mc/s and 300-Kc/s signals to the synthesizer circuit card and 20-Kc/s and 1-Kc/s signals to the time scale changer circuit card.

Regenerative division is used to accomplish the frequency division from 5 Mc/s to 1 Mc/s and decade digital division is used to accomplish the frequency division from 1 Mc/s to 300 Kc/s, 100 Kc/s, 20 Kc/s and 1 Kc/s. For reference on this subject see paragraph 3.2.

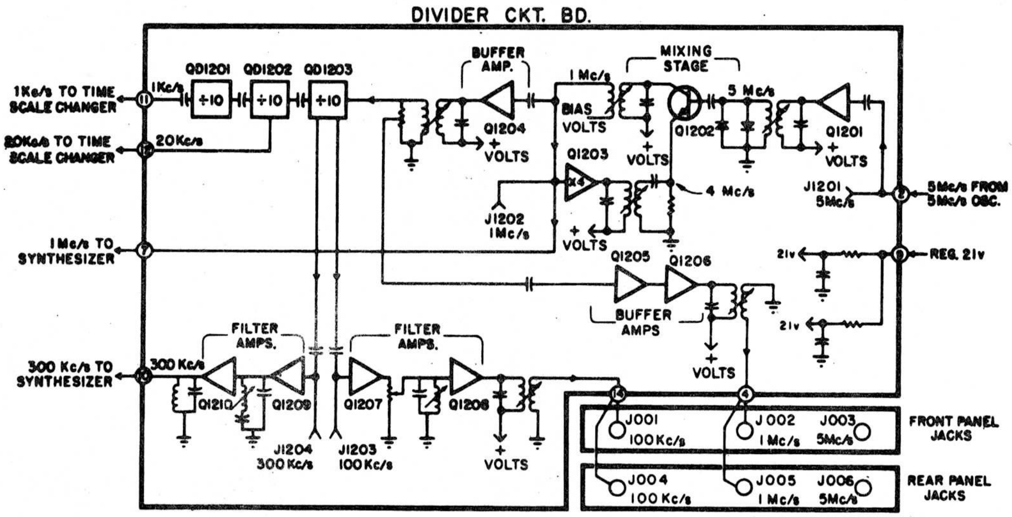


Figure 3-10. Divider Functional Diagram

The 5-Mc/s input is divided down by the first divider circuit to produce 1 Mc/s. This 1-Mc/s signal is fed to the synthesizer circuit card and to a buffer amplifier that feeds the front and rear panel 1-Mc/s output jacks. In addition, the 1-Mc/s signal connects to the first decade divider circuit to produce both 100 Kc/s and 300 Kc/s. The 100 Kc/s and 300 Kc/s outputs connect to buffer amplifiers and from there, the 100 Kc/s feeds the front and rear panel 100 Kc/s output jacks and the 300 Kc/s feeds the synthesizer circuit card.

The 5-Mc/s signal from the oscillator assembly connects to card-termination 2; this signal can be observed at testpoint J1201. The 5-Mc/s signal couples to the 5-Mc/s tuned-amplifier stage Q1201. Diodes CR1201 and CR1202, which square the waveform for switching purposes, connect to the output winding of the resonant tank. The amplified 5-Mc/s signal is then applied to the mixing stage of the first divider, Q1202. Here, 5 Mc/s is mixed with 4 Mc/s, developed by regenerative division, and results in a difference output of 1 Mc/s. The resonant tank connected to the collector of Q1202 is tuned for 1 Mc/s, thereby accepting the difference output and rejecting the sum output. The 1-Mc/s signal is then multiplied by the 4-Mc/s tuned-amplifier stage Q1203, resulting in a 4-Mc/s signal at the emitter of Q1202.

The 1-Mc/s signal is fed to decade divider stage QD1203 which produces a 100-Kc/s signal and a 200-Kc/s signal (among others). Both of these signals are assymetric and thereby are rich in harmonics and other related signals. The 100-Kc/s output of divider QD1203 is power amplified by stage Q1208 after passing through emitter follower Q1207. The 100-Kc/s signal is then supplied to the front and rear panel 100-Kc/s jacks. One of the related outputs of the 200-Kc/s signal (namely 300 Kc/s) is power amplified by tuned stage Q1210 after passing through emitter follower Q1209. The 300-Kc/s signal is then supplied to the synthesizer circuit card.

Another output of decade divider stage QD1203 is fed to decade divider stage QD1202 which produces a 20-Kc/s signal in a manner similar to the first decade divider. The 20-Kc/s output is supplied to the time scale changer circuit card. Another output of decade divider stage QD1202 is fed to the third decade divider stage QD1201 which produces a 1-Kc/s signal that is supplied to the time scale changer circuit card.

3.4.3 Synthesizer

The synthesizer circuit card shown in Figure 3-11 uses the 5-Mc/s signal from the oscillator assembly and the 1-Mc/s and 300-Kc/s signals from the divider circuit card to synthesize a 5-11/35 Mc/s signal that is fed to the optical package. The first step in this process is the multiplication of the 300-Kc/s signal to produce 1.2 Mc/s. The 1.2-Mc/s signal is then mixed with an amplified 1-Mc/s signal to produce 2.2 Mc/s. The 2.2-Mc/s signal is divided by 7 in a series of binary dividers to produce 11/35 Mc/s. This signal is then added to 5 Mc/s, resulting in the 5-11/35 Mc/s output. The basic technique of frequency division used in this circuit is discussed in greater detail in paragraph 2.2.

The 300-Kc/s signal connects through card termination 7 to tuned multiplier Q1303 with the collector circuit tuned to 1.2 Mc/s. The 1.2-Mc/s signal is then applied through tuned amplifier Q1304 to the mixing stage, consisting of CR1301 through CR1304, where it is mixed with the 1-Mc/s signal which connects through card termination 2 and tuned amplifiers Q1301 and Q1302. After mixing, the resultant 2.2-Mc/s signal is amplified by tuned amplifier Q1305 and then divided to 11/35 Mc/s in the divide by 7 stage consisting of QD1301, QD1302 and QD1303.

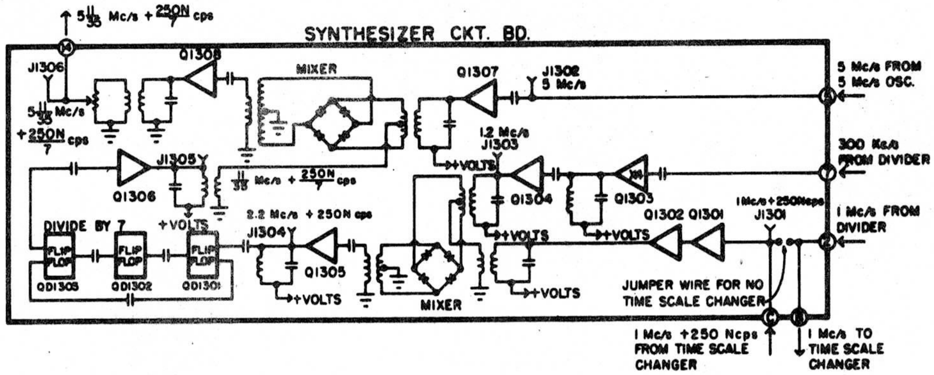


Figure 3-11. Synthesizer Functional Diagram

The three flip-flops of the divide-by-7 stage are connected in series. A reset signal fed back from the third flip-flop, QD1303, to the first flip-flop, QD1301, produces an output signal that is 1/7 the frequency of the input signal instead of the more normal 1/8. The resultant 11/35-Mc/s signal is applied through tuned amplifier Q1306 to the mixing stage, consisting of CR1305 through CR1308, where it is mixed with the 5-Mc/s signal connected through card termination 5 and tuned amplifier Q1307. After mixing, the resultant 5-11/35 Mc/s signal couples through the tuned amplifier Q1308 and the balancing adjustment R1335 to card termination 14.

3.4.4 Time Scale Changer

The time scale changer circuit card shown in Figure 3-12 produces a frequency shift in increments of ±250 cps of the 1-Mc/s signal used by the synthesizer circuit card, thereby shifting the excitation frequency of the optical package, and thus, changing the time scale. A crystal oscillator is used to provide the frequency shift. Its frequency is compared with and phase locked to the 1-Mc/s signal from the divider circuit card.

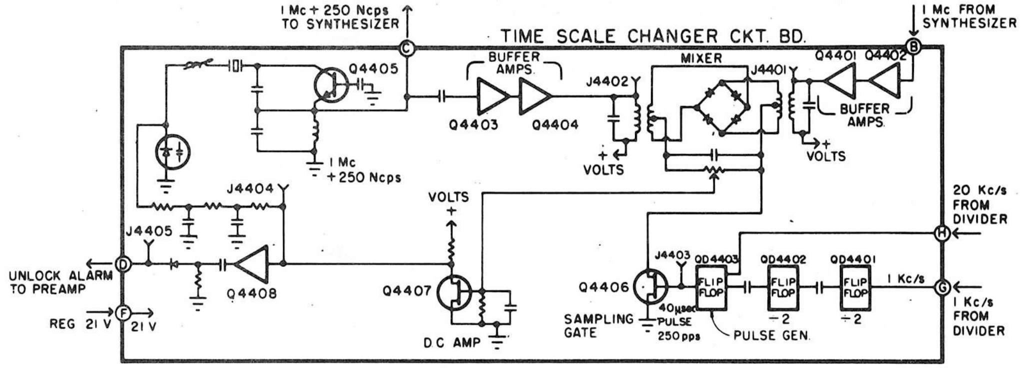


Figure 3-12. Time Scale Changer Functional Diagram

A 1-Mc/s + 250N cps signal (where N is an integer between ±20) is generated by crystal oscillator stage Q4405. The 1-Mc/s + 250N cps signal is applied through tuned amplifiers Q4403 and Q4404 to the balanced mixing stage CR4401. The 1-Mc/s signal from the Divider circuit card connects through card termination B and tuned amplifiers Q4401 and Q4402 to the balanced mixing stage. The output from the mixer is a sine wave at 250N cps which is fed to sampling gate Q4406.

The 1-Kc/s signal from the divider circuit card connects through card termination G to the binary countdown chain QD4401, QD4402, and QD4403. The first two binary elements divide the 1-Kc/s signal to 250 cps, and the third binary element is used as a pulse generator. The 250-cps signal from QD4402 sets the pulse generator negative, and the 20-Kc/s signal from the divider card, which connects through card termination H, returns the pulse generator to the positive state after 40 μsec.

The 250N-cps signal from the mixer is sampled for 40 μsec by Q4406, and the sampled voltage is held by C4424 to provide an input to dc amplifier Q4407. The output of the amplifier is used to control the frequency of the crystal oscillator to maintain phase lock by applying a dc voltage to varactor diode CR4402.

If the phase locked loop becomes unlocked, an ac voltage will appear on the varactor control line. This signal is coupled through Q4408 to CR4403, where it is rectified to produce an unlock alarm signal. The unlock alarm couples to the preamp through card termination D.

It should be noted that when the time scale changer is incorporated, the 1-Mc/s signal described in paragraph 2.4.3 is actually the 1-Mc/s + 250N cps signal produced by the time scale changer circuit card.

3.4.5 Multiplier

The multiplier circuit card shown in Figure 3-13 multiplies 5 Mc/s to 120 Mc/s in the following sequence:

INPUT	MULTIPLICATION	OUTPUT	STAGE
5 Mc/s	X2	10 Mc/s	Q902 doubler
10 Mc/s	X3	30 Mc/s	Q903 tripler
30 Mc/s	X2	60 Mc/s	Q904 doubler
60 Mc/s	X2	120 Mc/s	Q905 doubler

At the input, the 5-Mc/s signal is phase-modulated by the 107-c/s sinusoidal signal from the modulation-generator circuit. The 120-Mc/s output signal (phase modulated at 107 c/s) is fed to the snap diode in the optical package.

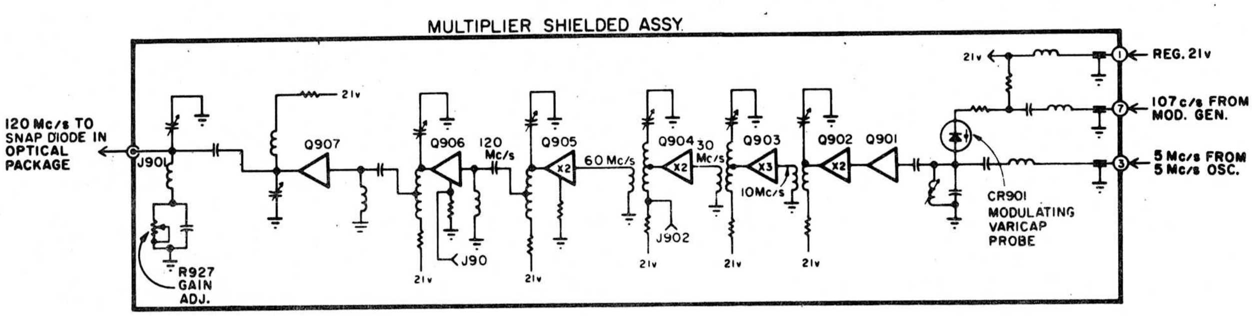


Figure 3-13. Multiplier Functional Diagram

The 5-Mc/s input signal couples to CR901, the phase-modulating varicap diode. This diode is varied in capacitance by the 107-c/s signal that comes from the modulation-generator circuit card. The result is a phase-modulated signal at the input of the impedance-matching stage Q901. This stage doubles the 5-Mc/s signal to 10 Mc/s. Stage Q903 triples this to 30 Mc/s; Q904 doubles the result to 60 Mc/s; and Q905 doubles this to 120 Mc/s. Stages Q906 and Q907 are buffer amplifiers.

3.4.6 Modulation Generator and Voltage Regulator

The modulation generator and voltage regulator circuit board has four basic functions:

(a) generating the square-wave 107 c/s frequency that switches the phase-detector stage in the servo amplifier;

(b) sinusoidally shaping the 107-c/s square wave to provide the multiplier modulation signal;

(c) triangularly shaping the 107-c/s square wave to provide horizontal sweep for an oscilloscope when observing the phase-detector output;

(d) regulating the nominal 28 volts dc input power to the R-20 unit to maintain a constant 21-volt output. In addition, the voltage regulator section supplies regulated 9 volts dc which acts as a source voltage for the field bias circuit.

The 107-c/s square wave is generated in the flip-flop section of the modulation generator, shown in Figure 3-14. The switching trigger that operates the flip-flop section comes from the unijunction oscillator, which is adjusted for 214 c/s. The flip-flop section divides by two for a 107-c/s output. The square-wave signal also passes through a tuned transformer stage, which shapes the the square wave into a sinusoidal shape so that it can be used to modulate the 5-Mc/s signal in the multiplier assembly. Controls are provided for amplitude and phase adjustment of the 107-c/s modulation signal.

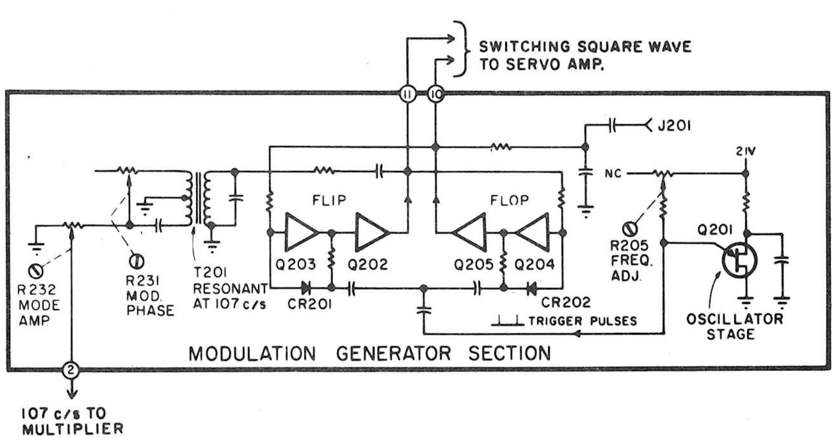


Figure 3-14. Modulation Generator Functional Diagram

Input power of 28 volts connects to the voltage regulator section, shown in Figure 3-15, and is regulated to maintain a constant 21-volt supply. A separate dc field-bias output, which energizes the magnetic-field winding in the optical package, comes from a zener diode in the voltage regulator.

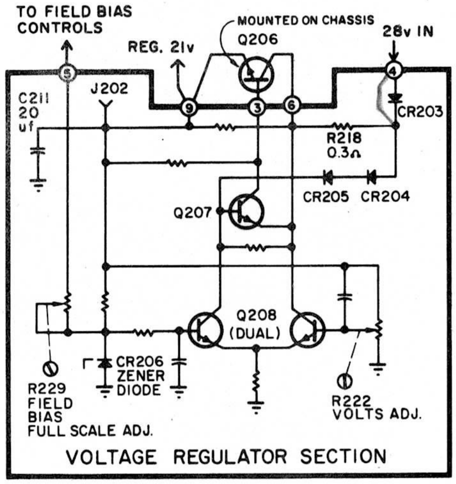


Figure 3-15. Voltage Regulator Functional Diagram

The unijunction oscillator stage Q201 creates output pulses. The RC time constant controlling the oscillator frequency consists of C203, R203, R204, and R205. Capacitor C203 discharges to ground through R205 and R203 and the emitter-to-base 1 junction of Q201 during the time the pulse is created (R203 is selected to set pulse width). When Q201 junction restores as the emitter-to-base 1 current drops, C203 begins to charge through R204 towards 21 volts. (R204 is selected to set pulse rate.) When the emitter-to-base 1 voltage of Q201 reaches the breakdown point, Q201 junction discharges the RC circuit of C203, R205 and R203 to create the output pulse.

The oscillator pulses are coupled through C202 to the flip-flop stage of Q202, Q203, Q204, and Q205. Two transistors would suffice to provide a square wave, but Q202 and Q205 are added in the separate feedback loops to provide greater power gain to square the signal. Diodes CR201 and CR202 are steering diodes that feed the trigger pulse to the conducting transistor to cut it off.

The output of the flip-flop connects through card terminations 10 and 11 to the phase-detector circuit in the servo amplifier circuit card. The signal at card termination 10 also connects through an integrating circuit which provides a triangular waveform at J201. In addition, the signal at card termination 11 couples through C212 to the modulation-amplitude and modulation-phase circuit of T201. This transformer is resonated at 107 c/s by C213 and C214 to shape the signal to a sinusoidal pattern. Output of T201 couples through the RC time constant of R231 and C215 to adjust phase over a span of approximately 90 degrees. The phase-adjusted output connects through the amplitude adjustment R232 to card termination 2.

Externally-applied 28 volts dc connects through card termination 4 to diode CR203 to energize the voltage regulator section. The chassis-mounted pass transistor Q206 provides the voltage drop, maintaining a constant 21-volt output at card termination 9 and test point J202; additional filtering of the regulated output is furnished by C211.

The regulated 21-volt output connects to one side of differential-amplifier Q208. At this point, R222 provides voltage adjustment. A reference voltage derived from CR206, a 9-volt Zener diode, holds the other side of the differential amplifier at a constant voltage. The differential amplifier output connects to base and emitter of Q207 where the two out-of-phase signals are added in phase and amplified to control pass transistor Q206.

Diode CR203, connecting to card termination 4, provides reverse voltage protection. Overcurrent protection is provided by the 0.3 ohm-resistor R218, and diodes CR204 and CR205.

Another regulated-voltage output is derived from CR206. This is the field-bias output connecting to card termination 5, adjusted by series resistance R229 so that the full-scale frequency adjustment of the FIELD BIAS coarse control is 1 part in $10^8 \pm 10^{-10}$.

3.4.7 Lamp Exciter Assembly

The lamp exciter assembly shown in Figure 3-16 is a transistorized Colpitts oscillator which furnishes the 100-Mc/s (approximately) excitation frequency for the Rb^{87} lamp in the optical package. Bias for oscillator amplifier Q031 is established by Zener diode CR031. Stabistor diode CR032 temperature compensates CR031. Two adjustments are provided: C035 adjusts frequency, and R032 adjusts gain to optimize light output.

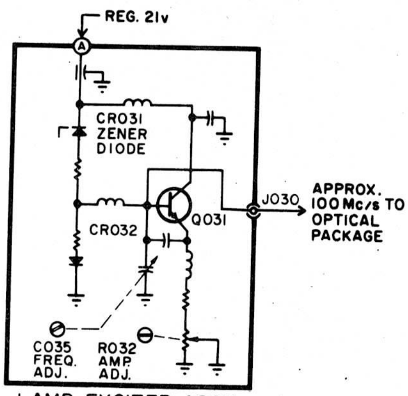


Figure 3-16. Lamp Exciter Functional Diagram

3.4.8 Optical Assembly

The optical assembly is housed in a shielded box at the rear of the unit. Three concentric magnetic shields enclose the microwave cavity in this assembly. Removing the lids gives access to the microwave cavity. Basically the optical package consists of five parts:

(a) Rb^{87} lamp assembly with parabola reflector;

(b) Rb^{85} filter cell that filters out undesired Rb^{85} light;

(c) microwave cavity assembly that houses the Rb^{87} gas cell and the snap diodes that excite the microwave cavity;

(d) silicon photocell that detects variations in the Rb^{87} light transmission;

(e) concentric shield assembly.

A separate oscillator assembly energizes the Rb^{87} lamp which is mounted at one end of the optical package. The Rb^{85} filter cell has windows at each end to permit Rb^{87} light to pass through. The Rb^{85} gas in this cell absorbs Rb^{85} light transmitted by the Rb^{87} lamp.

The microwave cavity housing the Rb^{87} gas cell is tuned to 6834-24/35 Mc/s by a mechanical tuning adjustment that varies the cavity volume. The Rb^{87} gas is excited by both the Rb^{87} light and the rf excitation that come from the two varactor diodes.

The silicon photocell at the end of the optical package detects the light level from the Rb^{87} gas cell. The light level varies with the modulation applied in the 120-Mc/s excitation frequency. The photocell output connects to the preamplifier circuit card input.

To reduce the effects of spurious magnet fields, a triple concentric permaloy shield is used. In addition to providing magnetic shielding, the inner shield serves as the outer oven.

3.4.9 Preamplifier

The preamplifier circuit card shown in Figure 3-17 amplifies the signal from the photocell in the optical package. In addition, it performs the following functions:

(a) filters the 214-c/s component from the servo signal;

(b) operates an SCR switch to turn on the front-panel CONTINUITY ALARM light when the 214-c/s signal drops below a preset level;

(c) operates the front panel meter to show 2nd-harmonic signal level;

(d) operates the automatic sweep circuit in the servo amplifier circuit card to turn it on when the 214-c/s signal drops below a preset value.

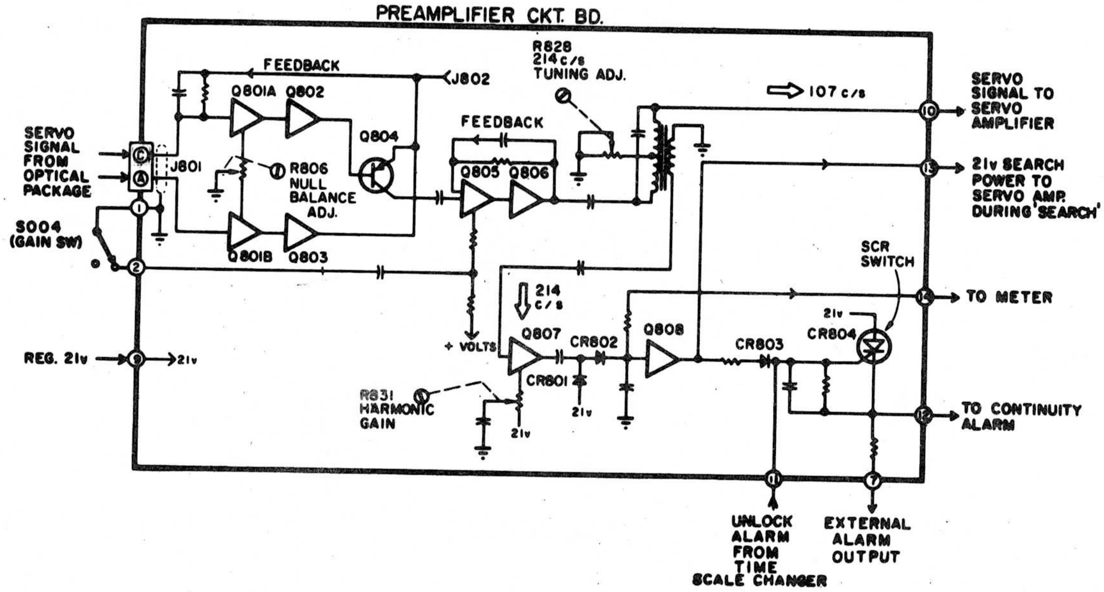


Figure 3-17. Preamplifier Functional Diagram

The photocell signal connects to the bases of differential amplifiers Q801A and Q801B. Amplifiers Q802 and Q803 deliver signals which are added in phase by the single-ended stage Q804. Control R807 is a dc null adjustment. The chassis AMPLIFIER GAIN control S004 connects through a capacitor to the emitter circuit of the next amplifier Q805, which feeds tuned transformer T801. This transformer circuit comprises a notch filter tuned to 214 c/s and is adjusted by R828. The 107-c/s signal connects through the transformer primary to card termination 10. The 214-c/s component inductively couples through T801 to the 214-c/s amplifier stage Q807, which has a second-harmonic amplitude adjustment in the emitter circuit (R831). Output from Q807 is rectified to a dc level and connected to Q808 and also to the front panel meter. The output of Q808 connects to the automatic sweep circuit in the servo amplifier circuit card and also to SCR switch CR804, which connects to the front panel CONTINUITY ALARM light. The automatic sweep circuit in the servo amplifier circuit card and the CONTINUITY ALARM light are activated when the 214-c/s component drops below a preset level. Diode CR804 is reset by the front panel CONTINUITY ALARM pushbutton; this action connects CR804 cathode and anode to turn off the SCR by reducing the junction current.

3.4.10 Servo Amplifier

The servo amplifier circuit card shown in Figure 3-18 amplifies, phase-detects, and integrates the 107-c/s output of the preamplifier. The amplified and phase-detected signal is fed to an integrating amplifier to provide a slow response rate, and the output of the integrating amplifier feeds through a roll-off network to further modify the high-frequency response. The servo amplifier output feeds the varicap in the 5-Mc/s oscillator circuit, providing frequency corrections to maintain a stable 5-Mc/s oscillator output.

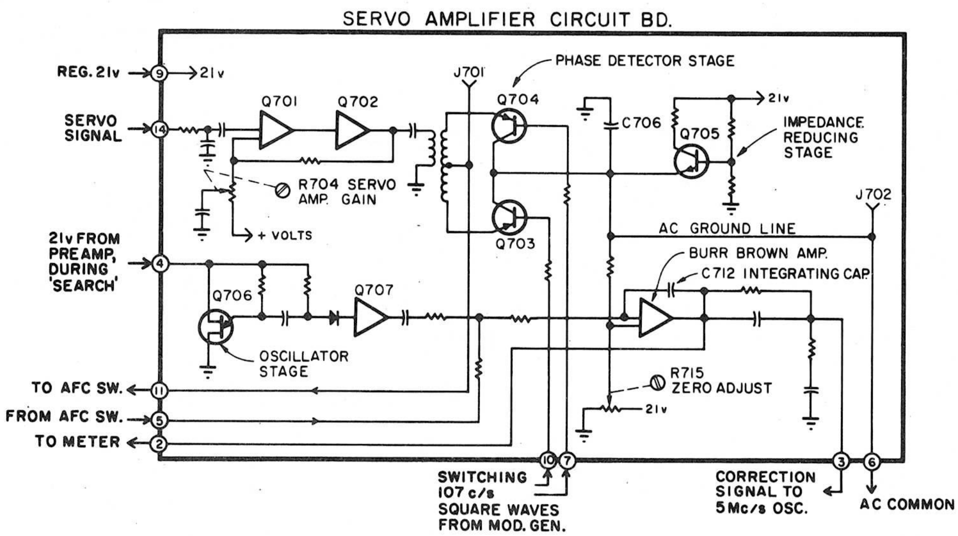


Figure 3-18. Servo Amplifier Functional Diagram

The sweep-oscillator section of the servo amplifier circuit card employs a unijunction oscillator to create a square wave which feeds the integrating-amplifier input. This square wave is then integrated to produce a triangular waveform that sweeps the 5-Mc/s oscillator, automatically establishing a lock-on condition.

The unijunction oscillator is turned on by the 21-volt switching signal generated in the preamplifier when the front panel AFC switch is at AUTO, as shown in Figure 3-19. This switching signal turns on the unijunction oscillator in the absence of a 214-c/s signal. The resulting triangular waveform in the servo amplifier output then sweeps the 5-Mc/s oscillator to re-establish a lock-on condition. When the R-20 approaches a locked-on condition, the phase-detector signal overrides the sweep signal generated by the unijunction oscillator and nullifies its effect. When the signal is centered and 214-c/s appears in the preamplifier, the 21-volt switching signal is turned off and the unijunction oscillator ceases to function.

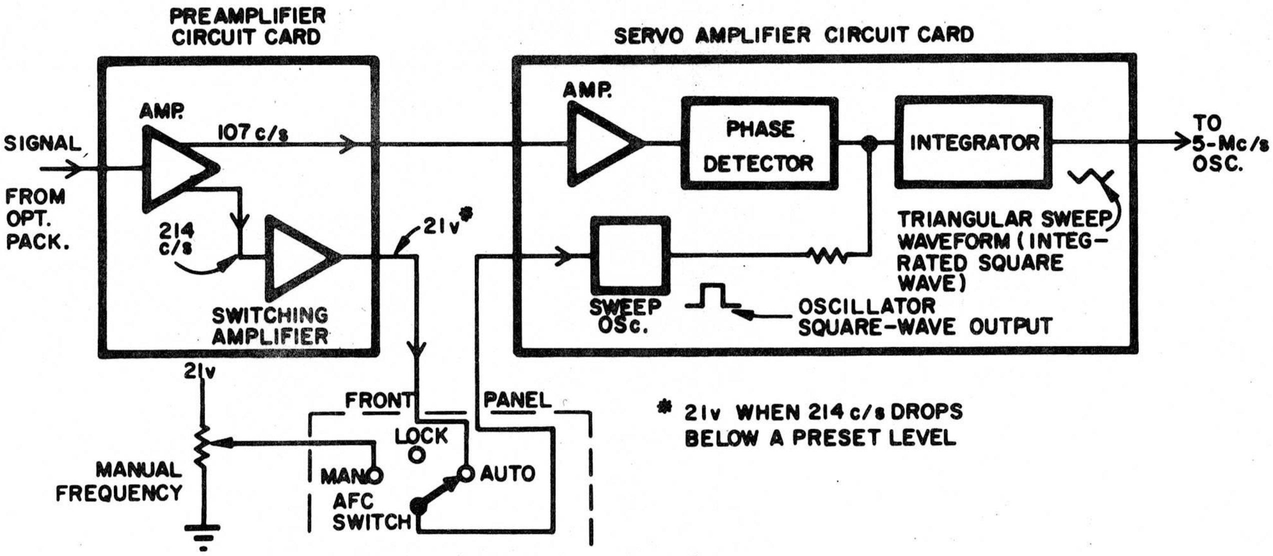


Figure 3-19. Switching of Automatic Sweep

The preamplifier output connects to the first amplifying stage, Q701; R704 is a gain adjustment in the emitter circuit of Q701. Amplifiers Q701 and Q702 are set up with dc feedback for low distortion and temperature compensation. Transformer T701 feeds the amplified servo signal to the phase-detector stage of Q703 and Q704. Reference phase from the modulation generator circuit card drives Q703 and Q704 bases. The phase-detected output at card termination 11 connects through the AFC switch on the front panel to the integrator input through card termination 5. The Burr-Brown integrating amplifier then integrates the phase-detected servo signal, with capacitive feedback furnished by C712. Integrator balance is effected by R715, which connects between 21 volts dc and ground. The servo signal connects through the roll-off network to card termination 3.

Unijunction oscillator stage Q706 oscillates at about 2 c/s when energized by 21 volts dc. The 2-c/s oscillation is then amplified by Q707 and fed to the integrator input through a large value of resistance. This large resistance effectively reduces the 2-c/s square wave at the junction of R724 and R725 to zero volts when the low-impedance servo signal is present at card termination 5. When the R-20 unit is "off" frequency, the effective impedance at R724 and R725 junction increases and the 2-c/s square wave sweep signal then appears at the integrator input.

3.4.11 Thermostat Circuit Cards

The thermostatic controlled temperature-regulating system used in the R-20 unit consists of the following circuit areas:

(a) thermostat circuit card, with an oscillator circuit and temperature-regulating amplifier that works with the thermistor and heater in the optical package inner oven;

(b) dual-thermostat circuit card with two temperature-regulating amplifiers: one for the heater and thermistor in the optical package outer oven, and one for the thermistor and heater in the 5-Mc/s oscillator oven;

(c) thermistor and heater elements in the three temperature-regulated ovens.

Temperature monitoring is achieved by comparing the thermistor resistance with a fixed-reference resistance, adjusted for the desired temperature. These two resistances are connected in a bridge circuit, with the bridge output connecting to the temperature-regulating amplifier, as shown in Figure 3-20.

The ac signals applied to the two legs of the bridge are 180 degrees out-of-phase. When the bridge output is zero volts, no correcting signal is applied to the amplifier. When the oven temperature changes slightly, it causes a change in the thermistor resistance. An ac voltage then appears at the amplifier input with a phase difference that will make the required correction. This correcting signal is amplified and then phase detected to produce a dc voltage that controls a pulsing circuit. The resultant dc pulses are applied to the heater element; pulse width determines the "on-time".

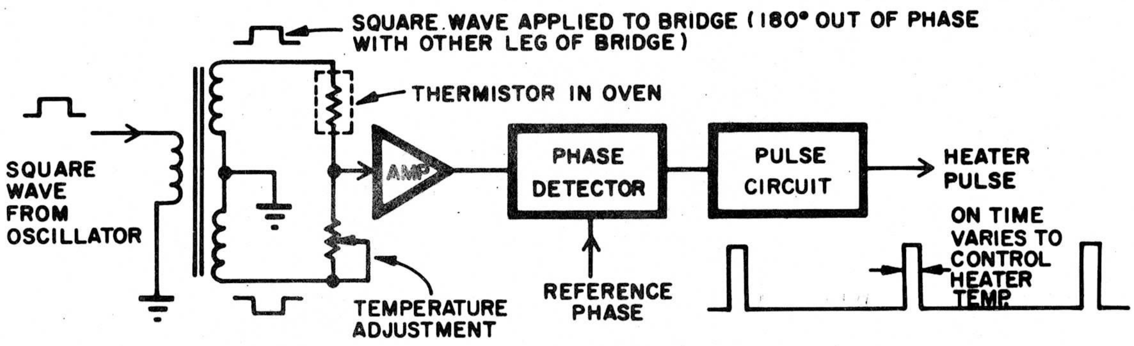


Figure 3-20. Temperature-Regulating Bridge Circuit

The duty cycle is adjusted for the proper "on-time" when no correcting signal is applied. The percentage of "on-time" is arranged so that there is a large reserve of power for quick warm-up when power is first applied.

3.4.11.1 Thermostat Circuit Card (Oscillator-Amplifier)

The thermostat circuit card shown in Figure 3-21 contains the 2-kc/s oscillator used to energize the temperature-regulating system and the temperature-regulating amplifier that work with the gas cell oven.

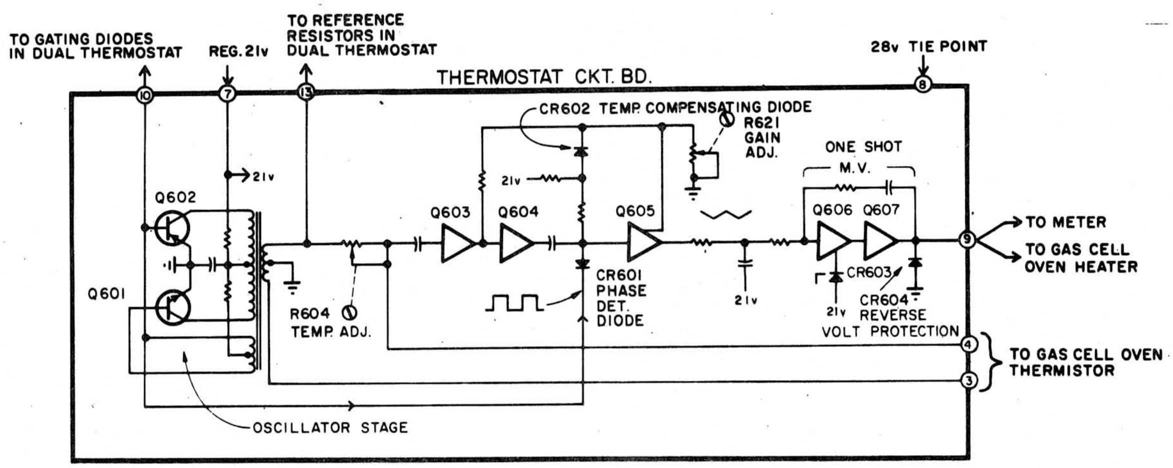


Figure 3-21. Thermostat (Oscillator-Amplifier) Functional Diagram

The oscillator stage of Q601 and Q602 is a transformer-coupled square-wave oscillator. In this circuit card, the oscillator output is fed through R604, the temperature adjustment, to amplifier Q603. Also connecting to Q603 input is the thermistor connection at card termination 4. The difference signal resulting from the two ac inputs is amplified by Q603 and Q604. At this point, the signal is phase-detected by the gating of CR601, which connects between the difference signal and a reference signal, as shown in Figure 3-22.

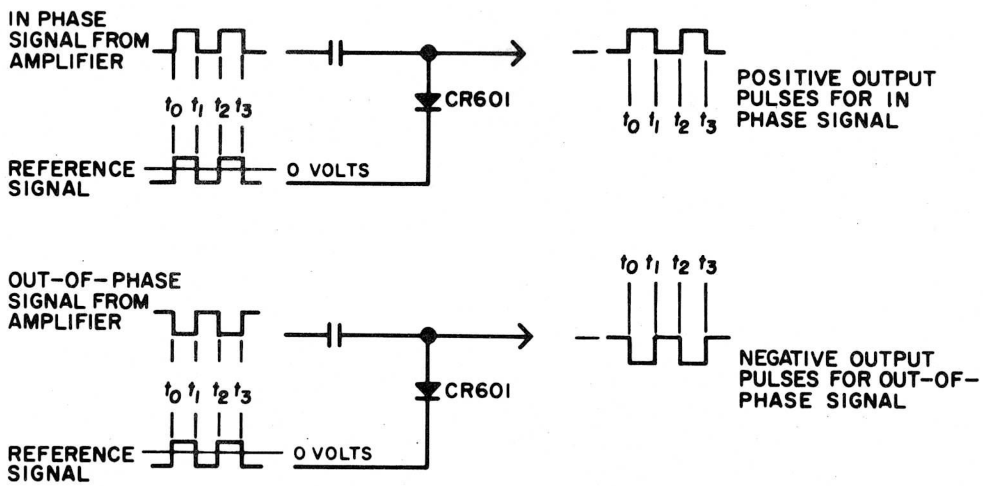


Figure 3-22. CR601 Gating Action

Amplifier Q605 amplifies the phase-detected square wave. Feedback from Q605 to Q604 is adjusted by R621 to set amplifier gain, and CR602 provides temperature compensation in the feedback loop. Between Q605 and Q606, an RC filter integrates the square wave; the resulting triangular waveform triggers the one-shot multivibrator of stages Q606 and Q607. The average dc level of the trigger pulse sets the turn-off time of the one-shot multivibrator to control the duty cycle. In this way, power applied to the heater element in the oven is closely controlled to regulate temperature.

Zener diode CR603 provides a steady dc level for the collector of Q606; diode CR604 acts only to provide reverse voltage protection for stage Q607.

3.4.11.2 Thermostat Dual Circuit Card

The thermostat dual circuit card shown in Figure 3-23 contains two amplifiers, one that controls the optical package outer oven, and one that controls the 5-Mc/s oscillator oven. Operation of these two amplifiers is identical with the temperature-regulating amplifier described in the previous section.

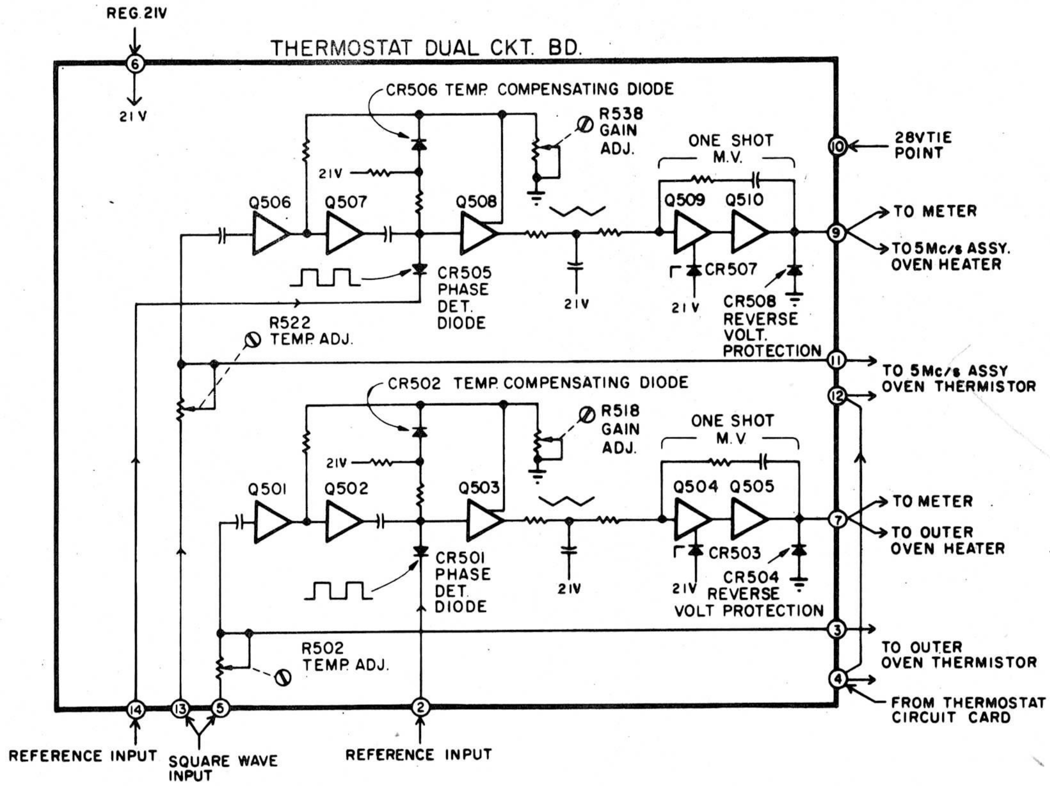


Figure 3-23. Thermostat (Dual Amplifiers) Functional Diagram

Section IV

OPERATION

4.1 GENERAL

This chapter provides instructions for initial and continued operation of the R-20. Read this chapter carefully and completely before applying power to the unit. Personnel working with the R-20 must be familiar with all operating controls and special precautions described below.

4.2 OPERATING CONTROLS

Tables 3-1 and 3-2 list all controls and indicators required for operating the R-20.

Table 4-1. Front Panel Operating Controls

Name	Position	Function
AFC Switch	MANUAL	a. Disconnects power to search oscillator. b. Opens servo loop. c. Connects an adjustable dc voltage to integrator input for manual frequency adjustment.
	LOCK	a. Disconnects power to search oscillator. b. Closes servo loop. c. Disconnects dc voltage from integrator.
	AUTO	a. Connects power to search oscillator for automatic seach when off frequency. b. Closes servo loop. c. Disconnects dc voltage from integrator.

Table 4-1. Front Panel Operating Controls (Continued)

Name	Position	Function
MANUAL FREQ Control		Applies a dc voltage to the servo amplifier integrator input (with the AFC switch switch at MANUAL) to provide manual adjustment of the 5-Mc/s oscillator frequency. Some delay in the response of the servo amplifier output occurs due to the relatively long time constant of the integrator circuit. This control provides a full-scale frequency change of approximately 1 part in 10^7.
FIELD BIAS COARSE Control		The FIELD BIAS controls adjust the magnetic field surrounding the resonant cell. The coarse control provides a total full-scale frequency change of 1 part in 10^8.
FIELD BIAS FINE Control		The fine control provides a total full-scale frequency change of 1 part in 10^{10}.
CRYSTAL TRIM Control		Screwdriver adjustment controls a dc voltage to a varicap diode in the oscillator circuit to change frequency output. This control corrects for long-term aging effects of the crystal in the oscillator assembly.
Meter Switch	AFC	Meter reads the output of the integrating amplifier.
	SIG	Meter reads the second-harmonic signal level from the preamplifier.
	OUTER OVEN	Meter reads the dc voltage across the heater element in the outer oven.
	CELL OVEN	Meter reads the dc voltage across the heater element in the cell oven.
	XTAL OVEN	Meter reads the dc voltage across the heater element in the 5-Mc/s oscillator assembly.

Table 4-1. Front Panel Operating Controls (Continued)

Name	Position	Function
CONTINUITY ALARM Light and Switch		Light turns on when the second harmonic drops below a preset level and will remain on until manually reset. Light also turns on when the time scale changer (if used) oscillator is off frequency. Push button switch resets alarm circuit.
POWER BREAKER Control		A 3-amp circuit breaker in series with the input 28-volt power supply providing protection for both the R-20 unit and the external voltage supply. (To discourage unauthorized interruption of power the POWER BREAKER is not an on-off switch.)
100 KC Connector		BNC connector for 100-Kc/s output.
1 MC Connector		BNC connector 1-Mc/s output.
5 MC Connector		BNC connector 5-Mc/s output.

Table 4-2. Rear Panel Operating Controls

Name	Function
Coarse Tuning Control	If CRYSTAL TRIM control reaches the end of its adjustment, this control adjusts oscillator frequency sufficiently to center the range of CRYSTAL TRIM control. Refer to Section 5. if crystal ages out of tuning range of coarse tuning control
Power Input and External Alarm Connector	Provides input facilities for dc power and connections for external alarms and external field bias
100 KC Connector	BNC connector for 100-Kc/s output.

Table 4-2. Rear Panel Operating Controls (Continued)

Name	Function
1 MC Connector	BNC connector for 1-Mc/s output.
5 MC Connector	BNC connector for 5-Mc/s output.

4.2.1 AFC Switch

The operator must understand the function of the AFC switch before working with the equipment. Figure 4-1 presents a functional diagram of the switch. Never switch the AFC switch into MANUAL unless necessary for manual frequency change. Switching into MANUAL takes the unit out of lock and can cause discontinuity of frequency stability.

Normal operation of the R-20 instrument will have the AFC switch at AUTO and the meter switch at SIG. The other two positions of the AFC switch, MANUAL and LOCK, are used only for troubleshooting.

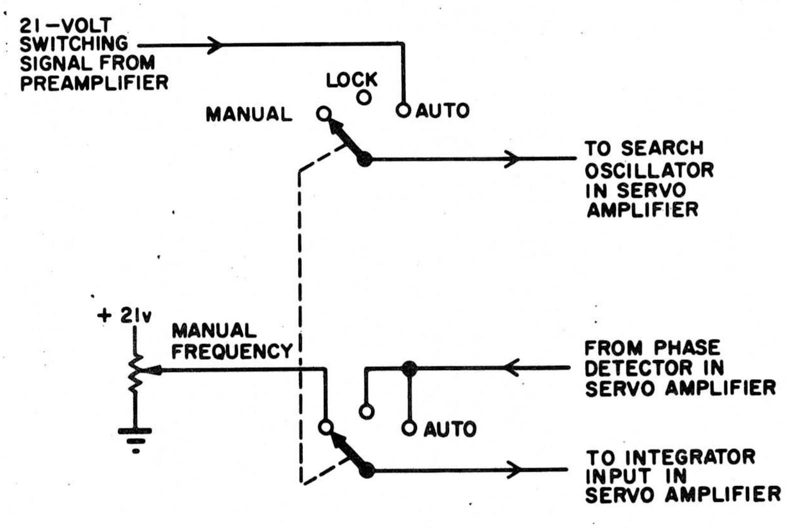


Figure 4-1. AFC Switch

4.2.2 Frequency Controls

All personnel working with the equipment should know that the front panel FIELD BIAS controls and CRYSTAL TRIM control and the rear panel coarse tuning control change the absolute frequency of the R-20. These controls must not be disturbed unless required for frequency adjustment.

4.2.3 Meter Switch

The SIG position of the meter switch monitors the 214-c/s 2nd-harmonic level which indicates the servo loop is locked to the center of the atomic resonance line. The AFC position monitors the dc voltage that controls the 5-Mc/s oscillator frequency and is used in the adjustment of the CRYSTAL TRIM potentiometer. The OVEN positions of the meter switch monitor current (interpreted in terms of voltage) in the three temperature-regulated ovens.

4.2.4 External Alarm

Provision is made for an external alarm connection at pin B of the rear-panel plug (Figure 4-2). 21 volts dc (20 ma max) appears at pin B when the 2nd-harmonic level drops below a preset value. This voltage can be connected to an external alarm (1000 ohms min) to provide a remote aural or visual indication of frequency discontinuity.

4.3 INITIAL OPERATION

This section gives instructions for applying power to the R-20 and establishing initial operating routine.

4.3.1 Operational Log

Make initial entry in Operational Log supplied with this manual. This log helps predict possible malfunctions and provides a time schedule for making periodic adjustments of the crystal oscillator to correct for aging.

4.3.2 Initial Control Settings

Prior to making power connections set front panel controls as follows:

(a) Set AFC switch to AUTO.

(b) Set meter switch to SIG.

(c) Check that FIELD BIAS setting corresponds to the setting indicated for the frequency offset shown on Figure 4-3, FIELD BIAS versus Frequency Graph. If setting is off, adjust according to Figure 4-3.

4.3.3 Power Connections

Connect 28 ±4 vdc to the power input connector at the rear of the R-20. Use Figure 4-2 for pin indications. Normally 28 vdc is supplied by the companion Power Supply Model R-28, which is an optional accessory power supply designed especially to power the R-20. An interconnecting power cable is supplied with the R-20 to interconnect the two units. (See R-28 manual for detailed instructions on Power Supply operation.)

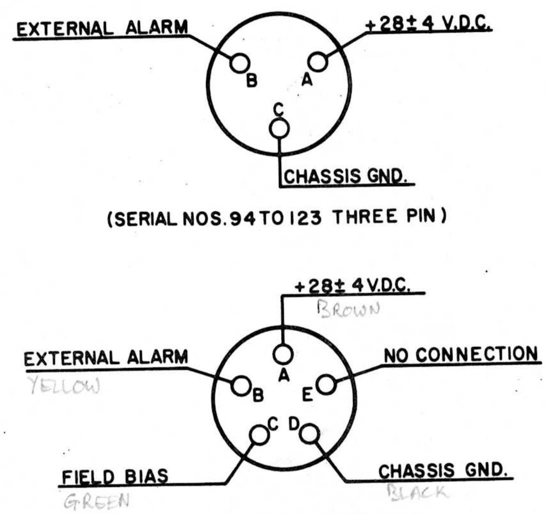


Figure 4-2. Rear Panel Power Connections

If another power supply is used, be careful that input voltage polarity is correct. There is a reverse polarity protective diode in the R-20 regulator, but prolonged exposure to reverse polarity can damage the polarized capacitors in the input power filter circuit.

The CONTINUITY ALARM light on the front panel lights as soon as power is applied. The R-20 unit does not have an ON-OFF switch and proceeds to warm up as soon as 28 volts is applied. Warm-up time is approximately 20 minutes normally. However, during initial turn-on the warm-up time is considerably longer. Do not attempt to troubleshoot until the unit has been on several hours.

4.3.4 Frequency Lock-On

With the AFC switch at AUTO and the meter switch at SIG, a lock-on condition will be indicated when the meter signal level suddenly rises. The fact that the R-20 unit is locked on can be verified by pushing the CONTINUITY ALARM pushbutton. If the lamp goes out, the R-20 is locked to its atomic resonance and correct operation has begun. If after this time a frequency discontinuity occurs (such as a momentary interruption of the 28-volt supply), the CONTINUITY ALARM light will come on and will stay on even though the unit automatically resumes a locked condition. This feature is provided to give a positive indication of any discontinuity of lock-on operation.

4.3.5 Output Connections

Once frequency output has been stabilized, the 5-Mc/s, 1-Mc/s and 100-kc/s outputs will deliver at least 1 volt rms into 50 ohms. The outputs at the front and rear panel BNC jacks which are in parallel can be connected or disconnected at any time without causing a frequency change.

4.4 CHANGING THE ABSOLUTE FREQUENCY OF THE R-20

The absolute frequency of the R-20 can be changed by altering the magnetic field surrounding the gas cell or changing the crystal on the time scale changer.

4.4.1 Change with FIELD BIAS Control

The FIELD BIAS controls on the front panel vary the magnetic field surrounding the gas cell, shifting the Rb^{87} atomic resonance. The COARSE control provides a total frequency deviation of 1 part in 10^8 and the FINE adjustment provides a total frequency deviation of 1 part in 10^{10}. Each R-20 is calibrated prior to shipment, with calibration results plotted on Figure 4-3 and Table 4-3. Adjust FIELD BIAS controls for new frequencies according to these graphs.

FINE: Increase freq. clockwise

4.4.2 Changing Time Scale Changer Crystal

When the optional time scale changer is included, the atomic resonance can be shifted by changing the crystal on the time scale changer circuit card. This provides a total frequency deviation of ±1045 parts in 10^{10} from atomic time or any other selected time base in increments of 52.254 parts in 10^{10}. The basic frequency of the R-20 is determined by the gas cell, which is normally set so that the output frequencies of the standard can be set to the A1 time scale with a 1 Mc/s crystal in the time scale changer. In this case the calibration curve (Figure 4-3) is drawn with this 1 Mc/s crystal inserted. The frequency of the crystal in the time scale changer is changed in steps of 250 cps from 1 Mc/s, the output frequencies of the R-20 being decreased by 52.254×10^{-10} for each 250 cps decrease in crystal frequency. Table 4-4 lists the crystals available for different frequency increments. When a new crystal is installed the magnetic field bias must be adjusted to set the new frequency exactly. Table 4-4 gives the necessary adjustments for each frequency; these adjustments can be translated into FIELD BIAS control settings using the calibration curve in Figure 4-3. For example, starting with a 1-Mc/s crystal installed in the time scale changer, we want to decrease the R-20 frequency by 300×10^{-10} from the initial setting at A1 time. Using the tables, insert a 998,500 cps crystal in the time scale changer to reduce frequency by 313.527 x 10^{-10} and adjust frequency to proper value with FIELD BIAS controls according to calibration curve.

In some cases, due to manufacturing tolerances in the resonance cell, the crystal supplied will not correlate with the customers specified frequency as shown in Table 4-4. In these cases the table can be made to apply by offsetting columns 1, 2 and 3 with respect to columns 4, 5 and 6 so that the supplied crystal correlates with the customers specified frequency. The crystal frequency is shown in calibration table (Table 4-3). Notice that when reducing the frequency the FIELD BIAS control must be turned clockwise enough to raise the frequency the difference between actual and intended frequency offset shown in column 6 of Table 4-4. Always check before obtaining a new crystal that the range left on the FIELD BIAS control will accommodate the necessary change.

Table 4-3. Calibration Chart

Serial No. 210 Gas Cell No. 129 Date July 8, 1967

POTENTIOMETER SETTING (TURNS)	$\frac{\Delta f}{f}$ X 10^{-10} REFERENCED to A1
0	-74.8
.5	-72.5
1.0	-67.4
1.5	-61.9
2.0	-55.8
2.5	-50.2
3.0	-44.7
3.5	-39.5
4.0	-34.6
4.5	-29.9
5.0	-25.5
5.5	-21.4
6.0	-17.0
6.5	-12.7
7.0	-08.5
7.5	-04.5
8.0	+00.4
8.5	+05.4
9.0	+10.6
9.5	+17.3
10.0	+24.9

With N A Mc T.I.C. crystal, set field bias dial to 796 for frequency offset of 000.0 of X 10^{-10} referenced to A1.

Table 4-4. Available Time Scale Change Crystals

Column 1	2	3	4	5	6
Increment	Crystal Part No.	Crystal Frequency cps	Fractional Freq. Offset $\frac{\Delta f}{f} \times 10^{-10}$		
			Intended	Actual	Difference
+20	980218-01	1005,000	1,000	1045.089	-45.089
+19	980218-02	1004,750	950	992.835	-42.835
+18	980218-03	1004,500	900	940.580	-40.580
+17	980218-04	1004,250	850	888.326	-38.326
+16	980218-05	1004,000	800	836.071	-36.071
+15	980218-06	1003,750	750	783.817	-33.817
+14	980218-07	1003,500	700	731.562	-31.562
+13	980218-08	1003,250	650	679.308	-29.308
+12	980218-09	1003,000	600	627.054	-27.054
+11	980218-10	1002,750	550	574.799	-24.799
+10	980218-11	1002,500	500	522.545	-22.545
+ 9	980218-12	1002,250	450	470.290	-20.290
+ 8	980218-13	1002,000	400	418.036	-18.036
+ 7	980218-14	1001,750	350	365.781	-15.781
+ 6	980218-15	1001,500	300	313.527	-13.527
+ 5	980218-16	1001,250	250	261.272	-11.272
+ 4	980218-17	1001,000	200	209.018	- 9.018
+ 3	980218-18	1000,750	150	156.763	- 6.763
+ 2	980218-19	1000,500	100	104.509	- 4.509

Table 4-4. Available Time Scale Change Crystals (Continued)

Column 1	2	3	4	5	6
Increment	Crystal Part No.	Crystal Frequency cps	Fractional Freq. Offset $\frac{\Delta f}{f} \times 10^{-10}$		
			Intended	Actual	Difference
+ 1	980219-20	1000,250	50	52.254	- 2.254
0	980218-21	1000,000	00	00.000	00
- 1	980218-22	999,750	- 50	- 52.254	2.254
- 2	980218-23	999,500	-100	-104.409	4.509
- 3	980218-24	999,250	-150	-156.763	6.763
- 4	980218-25	999,000	-200	-209.018	9.018
- 5	980218-26	999,750	-250	-261.272	11.272
- 6	980218-27	998,500	-300	-313.527	13.527
- 7	980218-28	998,250	-350	-365.781	15.781
- 8	980218-29	998,000	-400	-418.036	18.036
- 9	980218-30	997,750	-450	-470.290	20.290
-10	980218-31	997,500	-500	-522.545	22.545
-11	980218-32	997,250	-550	-574.799	24.799
-12	980218-33	997,000	-600	-627.054	27.054
-13	980218-34	996,750	-650	-670.308	29.308
-14	980218-35	996,500	-700	-731.562	31.562
-15	980218-36	996,250	-750	-783.817	33.817
-16	980218-37	996,000	-800	-836.071	36.071
-17	980218-38	995,750	-850	-888.326	38.326
-18	980218-39	995,500	-900	-940.580	40.580

Table 4-4. Available Time Scale Change Crystals (Continued)

Column 1	2	3	4	5	6
Increment	Crystal Part No.	Crystal Frequency cps	Fractional Freq. Offset $\frac{\Delta f}{f}$ x 10^{-10}		
			Intended	Actual	Difference
-19	980218-40	995,250	- 950	- 992.835	42.835
-20	980218-41	995,000	-1000	-1045.089	45.089

Difference: Column 6 is equal to the amount that the field bias dial must be turned.

Section V

ADJUSTMENTS

5.1 GENERAL

This section lists and describes the adjustments used for tuning and maintaining the R-20. These controls are located inside the instrument cover to discourage unauthorized personnel from using them. Be very certain that adjustments are necessary; many of them are very difficult without proper test equipment and detailed procedures.

5.2 LAMP EXCITER ASSEMBLY

5.2.1 Frequency Adjustment C035

This capacitor sets the frequency of the lamp exciter circuit.

5.2.2 Amplitude Adjustment R032

This potentiometer sets gain of the lamp exciter.

5.3 MICROWAVE CAVITY ADJUSTMENTS

Microwave cavity adjustments should never be attempted by the customer.

5.4 PREAMPLIFIER ADJUSTMENTS

5.4.1 Gain Switch S004

This chassis-mounted switch is a 10-to-1 attenuator to lower preamplifier gain during tuneup adjustment to avoid saturation.

5.4.2 Null Adjustment R807

This potentiometer zeros the dc voltage across the silicon photocell.

5.4.3 Tuning Adjustment R828

This potentiometer is part of the RCL circuit of the resonating transformer T801. It is adjusted for maximum rejection of the 214-c/s component from the 107-c/s signal.

5.4.4 2nd Harmonic Level Adjustment R831

This potentiometer adjusts the 2nd-harmonic gain and is set for a specific reading (8) on the front panel meter.

5.5 SERVO AMPLIFIER ADJUSTMENT

5.5.1 Servo Amplifier Gain R704

This potentiometer adjusts the forward loop gain of the servo system and should be adjusted about 10% less than saturation.

5.5.2 Zero Balance R715

This potentiometer adjusts the dc input to the integrator for zero drift of the integrator output with no signal applied. It is adjusted by removing the pre-amplifier card and adjusting for zero drift on the meter.

5.6 5-MC/S ASSEMBLY ADJUSTMENTS

5.6.1 Transformer T4201

Tunes Q4202, 5-Mc/s amplifier stage on the 5-Mc/s oscillator circuit card.

5.6.2 Transformer T4301

Tunes Q4302, 5-Mc/s amplifier stage on the 5-Mc/s amplifier circuit card.

5.6.3 Transformer T4302

Tunes Q4304, 5-Mc/s amplifier stage on the 5-Mc/s amplifier circuit card.

5.7 MODULATION GENERATOR AND VOLTAGE REGULATOR ADJUSTMENTS

5.7.1 Oscillator Frequency R205

This potentiometer adjusts the time constant of an RC network to set the frequency of the 214-c/s Unijunction oscillator which triggers the 107-c/s flip-flop stage.

5.7.2 107-c/s Phase R231

This potentiometer adjusts the phase of the sinusoidal signal applied to the varicap in the multiplier. It is adjusted by observing the phase-detector output using the reference output of the modulation generator for a horizontal oscilloscope drive and adjusting for a zero phase condition (no splitting on the line).

5.7.3 107-c/s Amplitude R232

This potentiometer adjusts the amplitude of the 107-c/s sinusoidal signal applied to the varicap in the multiplier. It is adjusted for a 4 to 1 ratio of fundamental to second harmonic.

5.7.4 21-Volt Adjust R222

This potentiometer sets the voltage of the voltage regulator circuit.

5.7.5 Field Bias Adjustment

This potentiometer sets the range of the front panel FIELD BIAS adjustments so that the FIELD BIAS coarse control provides 1 part in 10^8 ±1 part in 10^{10} frequency adjustment.

5.8 MULTIPLIER ADJUSTMENTS

Table 5-1 lists the multiplier assembly adjustments.

Table 5-1. Multiplier Adjustments

Gain Adjustment R927	Sets multiplier output amplitude
Adjustable Inductor L901*	Tunes Q901 input to 5 Mc/s
Tuning Capacitor C912*	Tunes Q902 output to 10 Mc/s
Tuning Capacitor C918*	Tunes Q903 output to 30 Mc/s
Tuning Capacitor C922*	Tunes Q904 output to 60 Mc/s
Tuning Capacitor C928*	Tunes Q905 output to 120 Mc/s
Tuning Capacitor C934*	Tunes Q906 output to 120 Mc/s
Tuning Capacitor C940*	Tunes Q907 output to 120 Mc/s
Tuning Capacitor C941	Tunes output of multiplier to match multiplier load

*Not recommended for customer adjustment.

5.9 1-MC/S AND 100-KC/S DIVIDER ADJUSTMENTS*

Table 5-2 lists the adjustments for the 1-Mc/s and 100-Kc/s divider assembly.

Table 5-2. Divider Adjustments

Tuning Transformer T1201	Tunes Q1201, 5-Mc/s amplifier
Tuning Transformer T1202	Tunes Q1202, (÷5) stage to 1 Mc/s
Tuning Transformer T1203	Tunes Q1203, (X4) stage to 4 Mc/s
Tuning Transformer T1204	Tunes Q1206, 1-Mc/s amplifier
Tuning Transformer T1205	Tunes Q1204, 1-Mc/s amplifier
Tuning Transformer T1208	Tunes Q1208, 100-Kc/s amplifier
Tuning Inductor L1201	Tunes Q1208 band-pass filter to 100 Kc/s
Tuning Inductor L1203	Tunes Q1210, 300-Kc/s amplifier
Gain Adjustment R1219	Sets 1-Mc/s output

5.10 SYNTHESIZER ADJUSTMENTS*

Table 5-3 lists the adjustments for the synthesizer assembly.

Table 5-3. Synthesizer Adjustments

Tuning Transformer T1301	Tunes Q1302, 1-Mc/s amplifier
Tuning Transformer T1302	Tunes Q1304, 1.2-Mc/s amplifier
Tuning Transformer T1303	Tunes 2.2-Mc/s mixer output
Tuning Transformer T1304	Tunes Q1306, 11/35-Mc/s amplifier
Tuning Transformer T1305	Tunes Q1307, 5-Mc/s amplifier
Tuning Transformer T1306	Tunes 5-11/35-Mc/s mixer output
Tuning Transformer T1307	Tunes Q1308, 5-11/35-Mc/s amplifier
Tuning Inductor L1301	Tunes Q1303, (X4) multiplier
Tuning Inductor L1302	Tunes Q1305, 2.2-Mc/s amplifier
Gain Adjustment R1335	Sets 5-11/35-Mc/s amplitude

*Not recommended for customer adjustment.

5.11 TIME SCALE CHANGER ADJUSTMENTS*

Table 5-4 lists the adjustments for the time scale changer assembly.

Table 5-4. Time Scale Changer Adjustments

Tuning Transformer T4401	Tunes Q4401, 1-Mc/s amplifier
Tuning Transformer T4402	Tunes Q4403, 1-Mc/s + 250N c/s amplifier
Tuning Inductor L4401	Tunes Q4405 oscillator output to 1-Mc/s + 250N c/s
Tuning Inductor L4402	Adjusts frequency of Q4405 oscillator to 1-Mc/s + 250N c/s
Gain Adjustment R4407	Adjusts gain of phase-locked loop
Bias Level R4430	Sets Q4407 bias

5.12 THERMOSTAT ADJUSTMENTS

5.12.1 Temperature Adjustment R604*

This potentiometer sets the temperature of the gas-cell oven.

5.12.2 Gain Adjustment R621

This potentiometer sets the gain of the thermostat amplifier. This control is set just below the point of oscillation in the same manner as a typical servo system.

5.13 DUAL THERMOSTAT ADJUSTMENTS

5.13.1 Temperature Adjustment R502*

This potentiometer sets the temperature of the outer oven.

5.13.2 Gain Adjustment R518

This potentiometer sets the gain of the thermostat amplifier.

*Not recommended for customer adjustment.

5.13.3 Temperature Adjustment R522*

This potentiometer sets the temperature of the oscillator oven.

5.13.4 Gain Adjustment R538

This potentiometer sets the gain of the thermostat amplifier.

*Not recommended for customer adjustment.

Section VI
MAINTENANCE

6.1 INTRODUCTION

This section contains information required to perform corrective maintenance in the R-20. The section includes periodic maintenance procedures, a list of test equipment, disassembly instructions, and trouble isolation data. Maintenance on the R-20 should only be attempted by skilled technicians who are acquainted with the equipment. Maintenance personnel should use the information in Chapters 3 and 4 and the diagrams in Chapter 7 for support.

Trouble isolation is presented in two steps. The first step localizes the inoperative circuit card or assembly. The second isolater the faulty component. All assemblies can be repaired except the optical package, which should be returned to the factory for repair or replacement.

6.2 PERIODIC MAINTENANCE

Trimming the crystal oscillator circuit to reduce the servo control voltage is the only periodic maintenance required on the R-20. The frequency of this adjustment is dependent on the aging rate of the quartz crystal oscillator. Since oscillator frequency correction to the hyperfine transition frequency is limited by the gain of the servo loop, it is important to keep this servo correction voltage small; it should never be allowed to exceed half scale on the AFC meter.

Adjust oscillator as follows:

(a) Set meter switch to AFC.

NOTE

Turn controls slowly. Rapid movement could cause servo to unlock, nullifying sense of controls.

(b) Adjust CRYSTAL TRIM control until meter reads zero (center scale). If range of CRYSTAL TRIM control is not sufficient to achieve this, adjust coarse tuning control on rear panel until center point is reached.

(c) If coarse tuning has been required, adjust CRYSTAL TRIM control to the center of its range. In case crystal aging has pulled crystal frequency outside range of coarse tuning control, see paragraph 6.

6.3 TEST EQUIPMENT

Table 6-1 lists the test equipment required to perform maintenance on the R-20.

Table 6-1. Test Equipment

Instrument	Specification
Electronic Counter	5-Mc/s
Oscilloscope	5-Mc/s Y-channel response 5-Mc/s X-channel response
Electronic Voltmeter	Response to 120 Mc/s
Multimeter	20 K ohms/volt
Thermocouple Bridge	25 deg C to 90 deg C

6.4 DISASSEMBLY AND ACCESS INSTRUCTIONS

Figure 6-1 shows the R-20 with cover removed, and Figure 6-2 gives assembly locations.

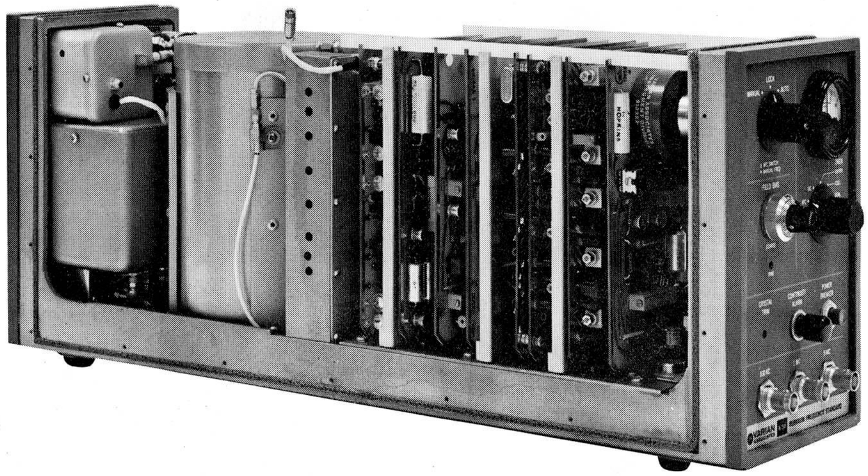


Figure 6-1. R-20 with Cover Removed

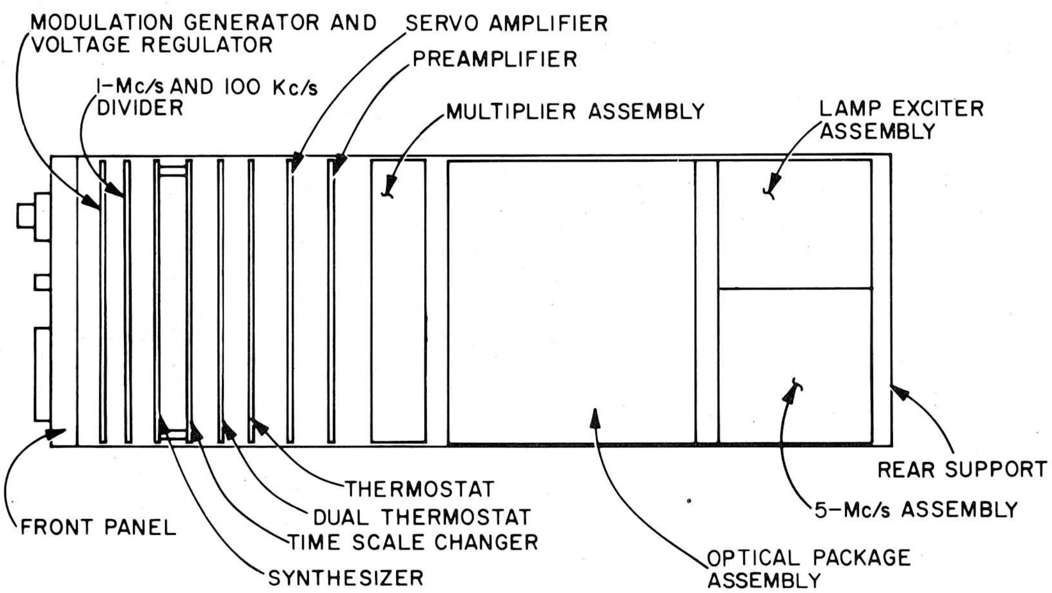


Figure 6-2. R-20 Circuit Boards and Assemblies

6.4.1 Removing Circuit Board

To remove circuit boards, remove cover, snap the spacer bars out of place, and pull the desired card straight up.

6.4.2 Removing Multiplier Assembly

Remove multiplier as follows:

(a) Remove cover.

(b) Disconnect cable that hooks to preamplifier circuit card in front of multiplier assembly.

(c) Disconnect cable that hooks to connector on top of multiplier assembly.

(d) Remove the 4 multiplier retaining screws from bottom of unit.

(e) Pull multiplier up, as shown in Figure 6-3.

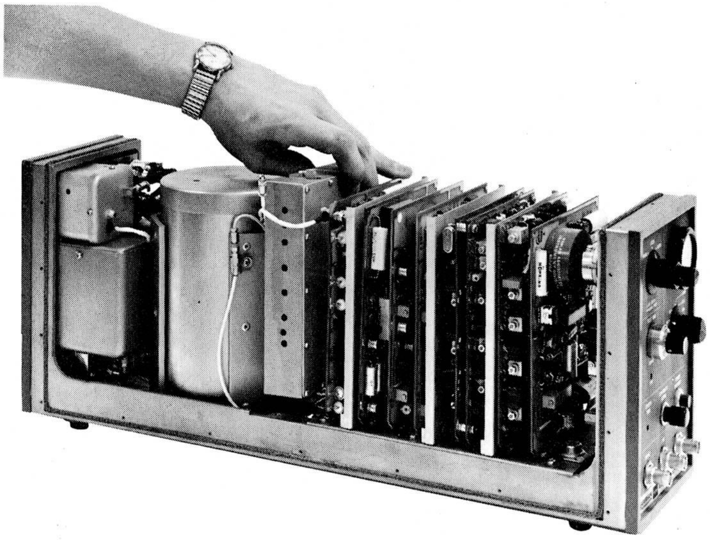


Figure 6-3. Removing Multiplier Assembly

6.4.3 Lamp Access

To observe the Rb^{87} lamp, remove the outer cover, Mu-metal shield covers, and insulation on the optical package. Do not attempt maintenance on the interior of the optical package. Figure 6-4 shows the covers, the last of which must be held while observing lamp.

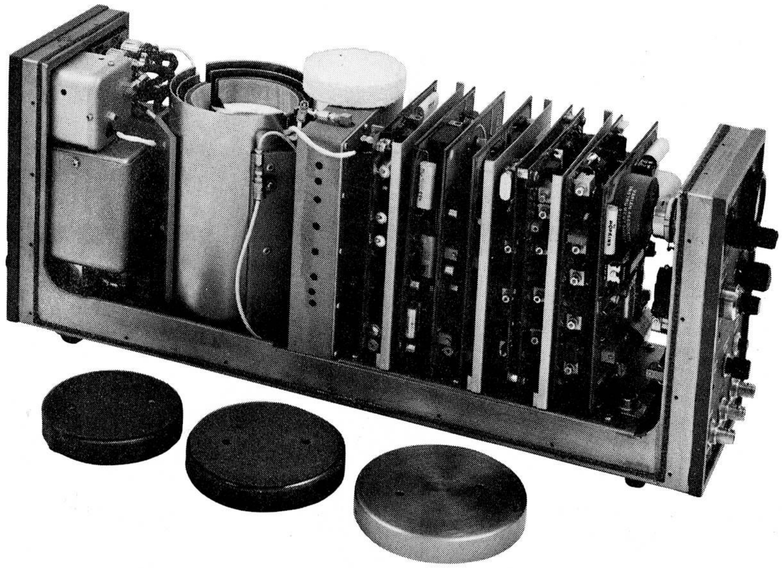


Figure 6-4. Observing Rb^{87} Lamp

6.4.4 Removing the 5-Mc/s Oscillator

Remove the 5-Mc/s oscillator as follows:

(a) Remove cover.

(b) Disconnect all cables going to the optical package.

(c) Remove four screws on bottom of chassis retaining optical package and lift out optical package (Figure 6-5).

(d) Disconnect output coaxial cable and power plug.

(e) Unscrew 5-Mc/s oscillator assembly from rear apron and lift out.

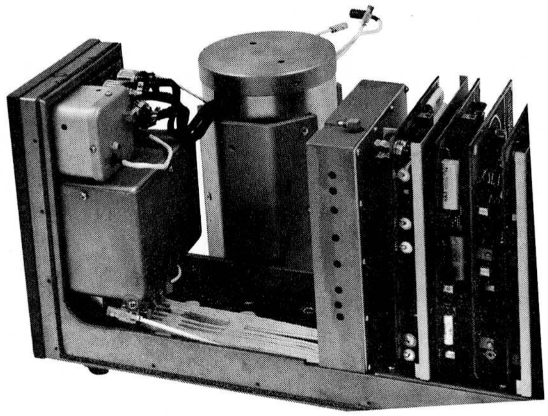


Figure. 6-5. Removing Optical Package

6.4.5 Removing Lamp Exciter

Remove lamp exciter as follows:

(a) Remove cover.

(b) Disconnect output coaxial cable and power plug.

(c) Unscrew lamp exciter from rear apron and lift out.

6.5 GENERAL TROUBLESHOOTING

This section gives procedures for isolating a malfunction to a particular assembly. Malfunctions can generally be related to one of the following areas:

(a) a non-operative servo loop with no control of the 5-Mc/s oscillator;

(b) instability and frequency deviation in the 5-Mc/s, 1-Mc/s or 100 Kc/s outputs.

(c) low amplitude in the 5-Mc/s, 1-Mc/s or 100 Kc/s outputs;

(d) failure of R-20 to automatically lock or CONTINUITY ALARM light fails to light when unit goes 'off lock'.

The procedures given below describe performance conditions that various assemblies should exhibit.

6.5.1 Non-Operative Servo Loop

The servo loop, shown in Figure 6-6, consists of the optical package, preamplifier, servo amplifier, and rf sections. The servo loop should first be checked for optical package output (section 6.5.1.1). Since the optical package must be repaired at Varian, assume it is functioning properly until all other circuits in servo loop have been checked.

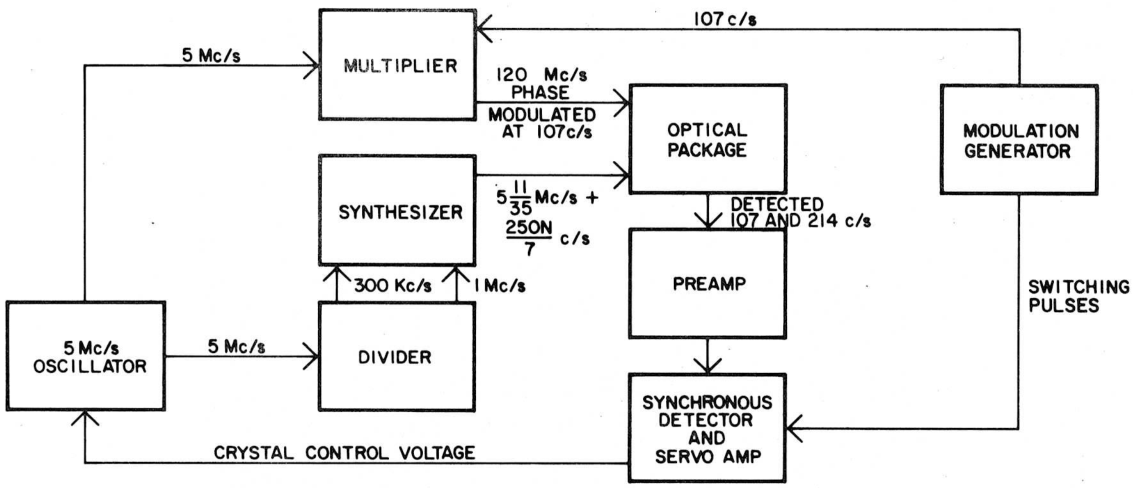


Figure 6-6. Servo Loop

6.5.1.1 Optical Package Output

Check the resonance signal output of the optical package with the procedure given below. If this resonance signal is absent, check preamplifier circuit card and phase detector section of the servo amplifier circuit card, as described in section 6.5.1.2. If optical package is not producing a signal but preamplifier and amplifier sections appear in order, check optical package inputs using section 6.5.1.3.

Check the resonance signal output of the Rb^{87} cell as follows:

(a) Place AFC switch at MANUAL.

(b) Connect an oscilloscope Y-input to servo amplifier phase detector output J701.

(c) Connect the oscilloscope X-input to modulation generator and voltage regulator jack J201 and set oscilloscope controls for an XY input.

(d) Rotate the MANUAL FREQ knob for a maximum vertical deflection. Note that a maximum signal is seen for two positions of the MANUAL FREQ knob. One is a positive-going signal and the other is a negative-going signal. As the MANUAL FREQ knob is rotated from one position to the other, the oscilloscope signal should pass through a null. A typical oscilloscope display is shown in Figure 6-7.

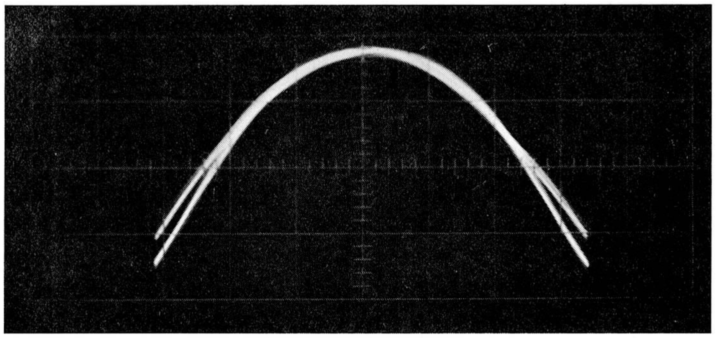


Figure 6-7. Resonance Signal

(e) If oscilloscope display shows no servo amplifier phase detector output, check the preamplifier for 650 mv p-p output at preamplifier card termination 10 as the MANUAL FREQ knob is rotated through resonance. If this signal is present, check servo amplifier card according to section 6.6.2.

6.5.1.2 Preamplifier and Servo Amplifier Check

Use the following test to check that preamplifier and servo amplifier circuits are working properly.

(a) Set up the test network shown in Figure 6-8.

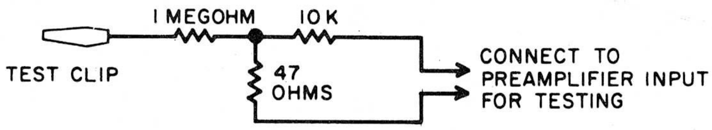


Figure 6-8. Test Circuit

(b) Connect a multimeter across C712 on the servo amplifier circuit card to monitor the dc output of this circuit card.

(c) Connect the test circuit of Figure 6-8 to the preamplifier circuit card input. (Do not disconnect the preamplifier input from the optical package.)

(d) Remove the 100-Kc/s and 1-Mc/s divider circuit card.

(e) Place the AFC switch at LOCK.

(f) Place the front panel meter switch at AFC.

(g) Place the modulation generator and voltage regulator circuit card on a card extender.

(h) Connect the test circuit test clip first to card-termination 10 and then to card-termination 11. The front panel meter should reverse polarity and the test multimeter should read a saturated output of approximately 12 vdc both ways.

(i) Switch the front panel meter switch to SIG.

(j) Connect the test circuit test clip to J201 of the modulation generator and voltage regulator circuit card. The front panel meter should show approximately 7.5 and the multimeter should read approximately 10 vdc.

(k) Switch the chassis-mounted gain switch S004 to the 10-to-1 attenuate position (toggle pointing away from chassis). The meter reading should drop to approximately 4 vdc and the front panel meter should show approximately zero.

(l) Check phase detector output by placing AFC switch at LOCK and checking for continuity between card terminations 5 and 11 of the servo amplifier circuit card. Repeat with AFC switch at AUTO.

6.5.1.3 Optical Package Inputs

The several inputs to the optical package are shown in Figure 6-9. Check these inputs as follows:

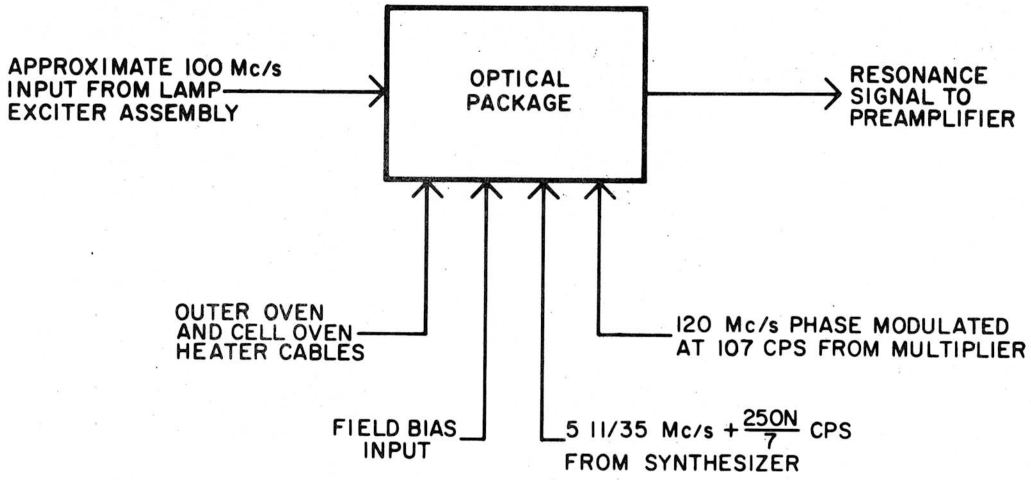


Figure 6-9. Optical Inputs

(a) Check lamp exciter assembly by uncovering optical package (section 6.4.3) and observing lamp. Lamp should emit a purplish glow. If lamp does not glow, either the lamp exciter is not functioning or the Rb^{87} lamp is defective. Check the lamp exciter output by removing lamp exciter cover and measuring voltage at micon solder connection inside the exciter assembly. A minimum of 5 volts rms should be present. If not, check exciter assembly using Section 6.6.8. If exciter output is normal, contact Varian for replacement of Rb^{87} lamp.

(b) Use the front panel meter to check temperature control inputs to the optical package. If the R-20 has been kept at a constant ambient temperature, any large deviation of one meter reading with respect to another indicates an irregularity in the temperature control circuitry. (If the ambient temperature of the operating environment changes the front panel oven meter readings will change indicating a change in current to the heater elements.) Make further tests as indicated by the meter readings and the list below:

XTAL	Section 6.6.7, Dual Thermostat Circuit
CELL	Section 6.6.6, Thermostat Circuit
OUTER	Section 6.6.7, Dual Thermostat Circuit

(c) The absence of field-bias voltage to the optical package will cause a frequency shift but will not affect the operation of the servo loop. Check pin C of J007 for a maximum of 500 mv. If no dc signal is present, check voltage regulator section of modulation generator and voltage regulator board.

(d) Check the 120-Mc/s output of the multiplier assembly for approximately 1v rms with an rf VTVM at J901.

(e) Check the 5-11/35-Mc/s output of the synthesizer circuit card for approximately 100 mv rms with an rf VTVM at J405.

(f) Check for an approximate 70-mV sinusoidal output from the modulation generator and voltage regulator circuit board at card-termination 2.

If the inputs to the optical package are satisfactory, but no resonance signal output is observed, a malfunction exists in the optical package. CONSULT VARIAN ASSOCIATES QUANTUM ELECTRONICS DIVISION SERVICE DEPARTMENT, PALO ALTO, CALIFORNIA, FOR INFORMATION.

6.5.2 Instability and Frequency Deviation in 5-Mc/s, 1-Mc/s or 100 Kc/s outputs.

Use the following procedures to check the 5-Mc/s, 1-Mc/s, and 100 Kc/s outputs. Table 6-2 lists some probable causes of frequency instability and the appropriate tests. Since there should be coherence between the three outputs of the R-20, instability in the 1-Mc/s or 100-Kc/s outputs that is not present in the 5-Mc/s output should be considered a malfunction in the 1-Mc/s and 100-Kc/s divider circuit card.

Table 6-2. Instability Tests

CAUSE	TEST
Low Servo Amplifier gain	See sections 6.5.1.1 and 6.5.1.2.
Defective Optical Package	See section 6.5.1.
Improper temperature in the gas-cell oven, the 5-Mc/s oscillator oven, or the outer oven. (Or thermal instability in any of the three ovens.)	See section 6.5.1.3, step (b).
Low 120-Mc/s excitation to the snap diode in the gas-cell cavity resulting from a malfunction in the multiplier (or too high 120-Mc/s excitation resulting from a misadjustment of the multiplier diode bias adjustment).	See section 6.5.1.1. When making this test, peak the oscilloscope signal for maximum amplitude with the MANUAL FREQ knob.
Misadjustment of the lamp exciter assembly	See section 6.6.8.
Other than a zero dc bias condition of the silicon photocell resulting from a malfunction in the input circuit of the preamplifier.	See section 6.6.1.
A malfunction in the 1-Mc/s divider circuit resulting in a lack of coherence in the 1-Mc/s output that is used in the synthesizing process.	See section 6.5.2.2.
A malfunction in the synthesizer resulting in a lack of coherence in the 5-11/35 Mc/s output.	See section 6.5.2.3.
Unstable 5-Mc/s Oscillator.	See Section 6.5.1.

6.5.2.1 5-Mc/s Frequency Test

If a frequency standard is available for a comparison measurement, the stability and the absolute frequency of the 5-Mc/s frequency can be checked at either the front or rear panel connectors. The reference frequency and the 5-Mc/s frequency from the R-20 instrument can be compared visually by a Lissajous pattern on an oscilloscope with a frequency response of at least 5-Mc/s in both X and Y channels. Amplitude of the 5-Mc/s output should be at least 1 volt rms into 50 ohms.

If another standard is not available and the stability or absolute frequency is questionable, a comparison to VLF can be made, or a crude frequency check can be made with a frequency counter. Keep in mind the accuracy limitation of both methods. If the frequency appears to be inaccurate by as much as 10^{-8} the crystal oscillator is unlocked from the hyperfine transition and must be locked up, as indicated by resonance signal, before further frequency checks can be made. If the frequency appears to be inaccurate by as much as 10^{-8} it is possible that the field bias control has been adjusted from its initial setting, as specified on the data sheet and calibration curve given in Figure 4-3, or that there is a malfunction in the field bias circuit. Check the field bias voltage at the power connector at rear of R-20 (J11 pin C) with a high impedance dc voltmeter. The difference, if any, between the bias voltage observed and that recorded on the final calibration sheet could account for an average frequency deviation of 3×10^{-11} per millivolt. Such deviation indicates component failure in the field bias circuit, or a component value change. After repairing circuit (in case of component failure) reset field bias to voltage indicated on the final calibration sheet.

If the frequency is measured and differs from the initial frequency by as much as 10^{-10} and the field bias is properly set, it is possible that the shields surrounding the gas cell are allowing extraneous magnetic fields to affect the dc field established by the field coil. Also, although care is exercised not to allow any of the components inside the shield to contain magnetic material, severe shock, high magnetic fields, or both, could cause a component within the shield to become permanently magnetized, thus disturbing the dc field bias. If there is reason to suspect the integrity of the magnetic field existing in the gas cell, the field can be measured and compared with the initial field by measuring the spacing of the Zeeman lines. The Zeeman transitions are field dependent (700 Kc/s per gauss) and therefore provide a convenient means of accurately measuring the field existing in the gas cell.

6.5.2.1.1 Magnet Field Check

Use the following procedure to check the spacing between the Zeeman transitions.

(a) Set FIELD BIAS COARSE control to point specified on data sheet or Figure 4-3. Adjust crystal trim control so that meter reads 0 in AFC position.

(b) Disconnect synthesizer input to optical package. Connect a stable 5 to 6 Mc/s oscillator at the synthesizer input to the optical package and tune to 5-11/35 (5.314285) Mc/s with approximately 1 v rms level. A Micon adapter No. 9065 is convenient for making the oscillator connection.

(c) Carefully tune the frequency until lock is obtained and meter reads 0 in AFC position. Adjust oscillator voltage level for maximum resonance signal. Measure the variable oscillator output with electronic counter and record. (The frequency measured at this point will depend on the value of the time scale changer crystal.)

(d) Adjust R232 for maximum modulation amplitude. Connect oscilloscope to phase detector output as in section 6.5.1.1, only leave AFC switch in LOCK position.

(e) Carefully scan up spectrum until Zeeman line is found. It may be very weak. Use oscilloscope display and Figure 6-10 to locate line and assure that the line found in the second one (it is the strongest of the three). If Zeeman line cannot be found, the optical package should be degaussed according to section 6.5.2.1.2.

(f) Zero the AFC meter (it may be noisy) and measure the synthesized frequency. The difference between the two frequencies is the Zeeman spacing and is an accurate measure of the field in the gas cell. The frequency difference measured should agree with that recorded on the data sheet or Figure 4-3 to an accuracy of ±2 Kc/s. If not the optical package should be degaussed.

6.5.2.1.2 Degaussing the Optical Package

The optical package is degaussed by subjecting it to a 60-c/s field sustained at high current for a short period of time. One procedure is as follows:

(a) Place an autotransformer (Variac) between ac power input and a high current such as a metal etching tool (Glensner Marwedel Model No. 11-048) or an ac arc welder.

(b) Using the leads from the current source make a five turn coil around the optical package.

(c) Adjust transformer to 0, turn on supply, and adjust transformer rapidly to maximum. Then reduce input slowly, taking about 30 seconds to return to zero. Do not apply current for more than 30 seconds; otherwise permanent damage to the winding can result.

If a high current ac source is not available, use the following procedure:

(a) Disconnect J007 and J008.

(b) Connect a variable autotransformer (Variac) to a 110 vac line. Connect a 25 ohm 10 watt resistor and a 3 amp full scale ac ammeter in series with the Variac and pin C of J007. Connect the other Variac lead to pin F of J007.

(c) Start from 0 current and increase rapidly until ammeter reads 1.5 amp. Then reduce current evenly to zero in about 30 seconds.

6.5.2.2 1-Mc/s and 100-Kc/s Frequency Check

Check the 1-Mc/s and 100-Kc/s outputs by a Lissajou pattern on an oscilloscope. Use the 5-Mc/s output as a reference signal. Any error of frequency in the 1-Mc/s or 100-Kc/s outputs is due to a malfunction in the 1-Mc/s and 100-Kc/s divider circuit card.

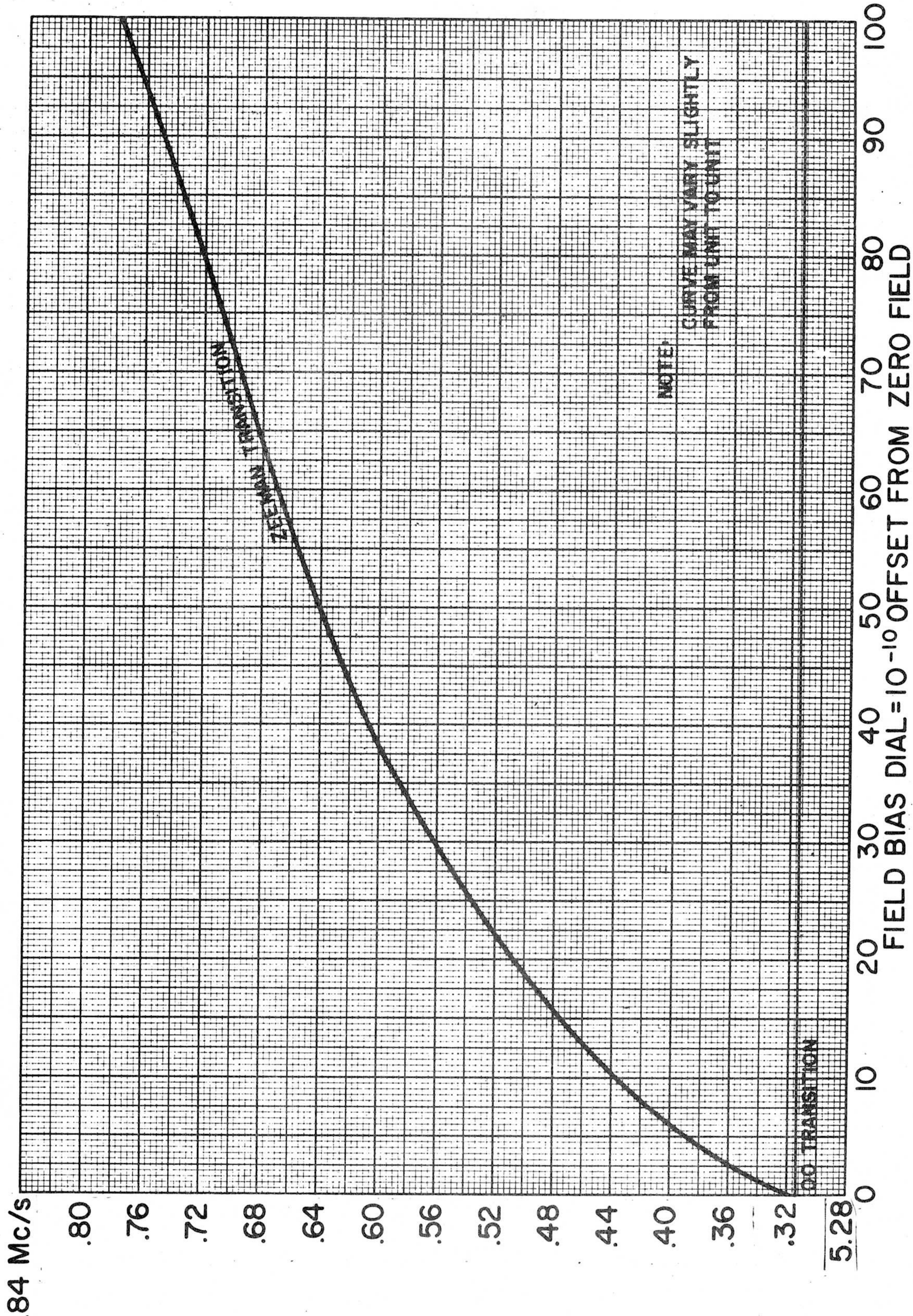


Figure 6-10. Zeeman Line Frequency Versus Field Bias

Amplitude of both the 1-Mc/s and 100-Kc/s outputs should be approximately 1 v rms into 50 ohms.

6.5.2.3 5-11/35 Mc/s Frequency Check

(a) Check for synthesizer output of approximately 100 mv using a VTVM at J1306.

(b) Connect oscilloscope Y-channel to J1306.

(c) Connect oscilloscope X-channel to 1-Mc/s output at front or rear panel jack.

(d) Adjust oscilloscope X and Y gain to observe the Lissajous pattern which for a correct 5-11/35 Mc/s output should resemble the pattern shown in Figure 6-11.

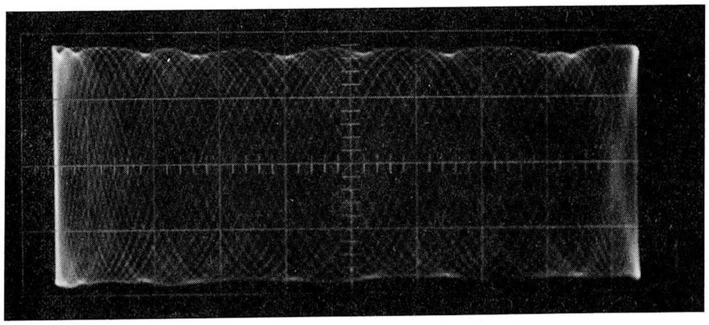


Figure 6-11. 1-Mc/s and 5-11/35 Mc/s Lissajous Pattern

6.5.2.4 Time Scale Changer Check

Check time scale changer as follows.

(a) Check for 40 μsec negative sampling pulse of 2.7 volt amplitude and 4 msec repetition rate at J4403.

(b) Check that dc varactor tuning voltage at J4404 is between 3.5 and 10.5 volts.

(c) Connect a 50 pf capacitor in series with multimeter and J4404. Check that ac ripple voltage is less than 0.11 volt rms. An ac signal of 2.1 volt rms indicates an unlock condition.

(d) Check that signals at J4401 and J4402 are at least 0.5 volt rms.

(e) Connect electronic counter to J4402. Check that frequency agrees with frequency stamped on crystal can.

6.5.2.5 120-Mc/s Frequency Check

To check 120-Mc/s multiplier output, connect electronic counter to J901 and measure frequency. Then check amplitude. The output amplitude of the multiplier varies considerably from unit to unit. However, less than 100 mv output indicates a malfunction in the multiplier assembly.

6.5.3 Low Amplitude in the 5-Mc/s, 1-Mc/s or 100-Kc/s Outputs.

If 5-Mc/s output amplitude is significantly lower than 1 v rms, check 5-Mc/s oscillator assembly using section 6.6.9. If 1-Mc/s or 100-Kc/s outputs fall below this level, check the divider assembly using section 6.6.5.

6.5.4 R-20 Fails to Lock Automatically or CONTINUITY ALARM Fails to Function

The R-20 should resume a lock condition after a discontinuity in operation if the AFC switch is at AUTO. With the AFC switch in this position, the 21-volt switching signal from the 214-c/s section of the preamplifier connects to the automatic sweep circuit in the servo amplifier. The automatic sweep circuit generates a sweep signal which can be checked as a dc voltage change at the integrator input, with 21 volts applied at card termination 4. If this section of the servo amplifier is functioning properly, then the automatic sweep circuit is not functioning, because the 214-c/s amplifying section of the preamplifier is not generating a 21-volt signal when the 214-c/s component drops below a preset value (or the 21-volt signal is not getting through the AFC swtich). In this case, see section 6.6.1.

If the CONTINUITY ALARM lamp is on and there is a time scale changer installed, the trouble could be in the dc amplifier, crystal oscillator or divider circuits of the time scale changer or in the low frequency divider circuits of the 1-Mc/s and 100-Kc/s divider. In this case, see sections 6.6.8 and 6.6.5.

If the continuity alarm is caused by an unlock condition in the time scale changer, no automatic sweep will be generated in the AUTO position of the AFC switch.

The CONTINUITY ALARM lamp can be checked at any time by pressing the pushbutton (which connects 21 volts to the lamp). If the lamp is good, but does not light, then the trouble is located in the 214-c/s amplifying section of the preamplifier. With the meter switch at SIG, the second-harmonic level can be observed. A normal signal indication shows that the first section of the 214-c/s amplifier is functioning, indicating that the malfunction lies in the dc amplifying section of the 214-c/s amplifier.

6.6 INDIVIDUAL CIRCUIT TESTS

The following sections provide information for performing tests on all circuits of the R-20 that are field repairable. Each section includes a list of inputs and outputs, measurement conditions, a table of relevant voltages, and an illustration showing test points and waveforms. This information should be used in conjunction with related circuit descriptions given in section II and the circuit diagrams provided in section VIII.

When checking dc voltages in the following tests, note that specific voltages in transistor circuits vary from unit to unit. This is due to differences in transistor beta and tolerances in circuit components. The most consistent voltage in transistor circuits is the base-to-emitter voltage. Silicon transistors exhibit a consistent base-to-emitter voltage of approximately 600 mv and germanium transistors show a base-to-emitter voltage of approximately 150 mv. This characteristic of transistors can be utilized in locating defective transistors.

6.6.1 Preamplifier Circuit

The preamplifier has the following inputs:

(a) photocell input at J801;

(b) 21-volt regulated input at card termination 9;

(c) S004, chassis-mounted gain switch connection through card termination 2.

The preamplifier has the following outputs:

(a) 107-c/s signal output at card termination 10;

(b) 21-volt switching signal output at card termination 13;

(c) CONTINUITY ALARM light output at card termination 12;

(d) rectified 214-c/s output to front panel meter at card termination 14;

(e) external alarm signal output through card termination 7.

Table 6-3 lists the dc voltages at the preamplifier test points. To perform dc voltage checks, put card on card extender and connect a 1 μf capacitor across the input terminals at J801 to prevent the preamplifier from oscillating with the input disconnected. (The connection from the photocell must be removed to use the extender card.) Those voltages noted with asterisks are taken with a VTVM because of the high impedance at these test points. For other voltages, use a 20K ohm/volt multimeter. See Figure 6-12 for test points.

Table 6-3. Preamplifier Test Voltages

Test Point	Voltage VDC	Test Point	Voltage VDC
Q801A Base*	+2.68	Q804 Base	+14.7
Q801A Emitter*	+2.16	Q804 Emitter	+14.8
Q801A Collector*	+6.3	Q804 Collector	+5.7
Q801B Base*	+2.68	Q805 Base	+15.0
Q801B Emitter*	+2.16	Q805 Emitter	+15.1
Q801B Collector*	+6.3	Q805 Collector	+10.6
Q802 Base*	+6.3	Q806 Base	+10.6
Q802 Emitter*	+6.0	Q806 Emitter	+10.8
Q802 Collector*	+14.8	Q806 Collector	+5.4
Q803 Base*	+6.3	Q807 Base	+17.1
Q803 Emitter*	+6.0	Q807 Emitter	+17.4
Q803 Collector	+14.8	Q807 Collector	+8.2
CR804 voltages vary with 214-c/s level.		Q808 voltages vary with 214-c/s level.	

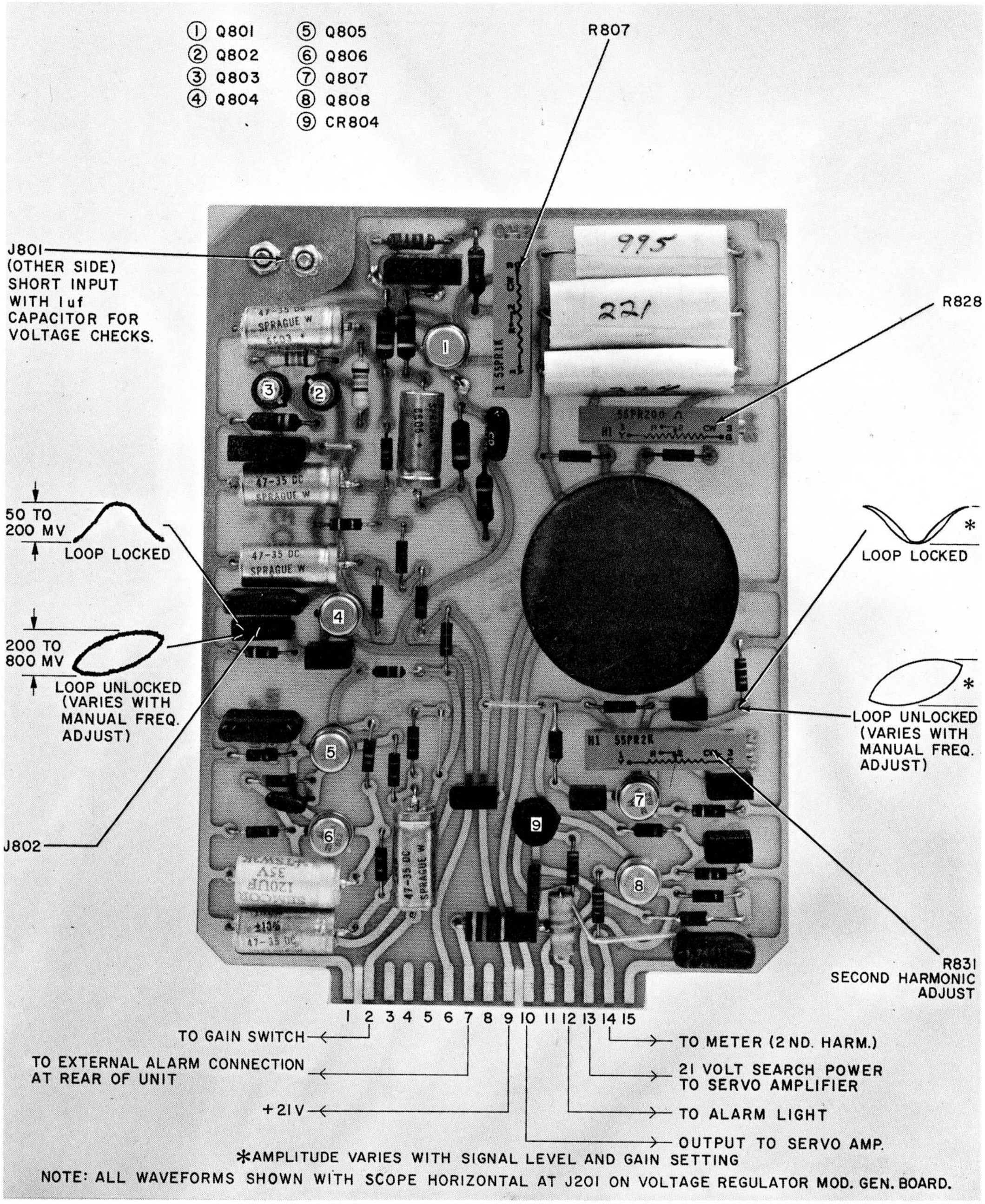


Figure 6-12. Preamplifier Circuit Board

6.6.2 Servo Amplifier Circuit

Inputs to the servo amplifier are:

(a) 21-volt regulated input at card termination 9;

(b) servo signal at card termination 14;

(c) 21-volt switching signal at card termination 4;

(d) switching square waves at card terminations 7 and 10.

Outputs of the servo amplifier are:

(a) correction signal for the 5-Mc/s oscillator assembly through card termination 3;

(b) ac common at card termination 6 which is biased at 11 volts.

Table 6-4 lists the dc voltages at various test points. To make tests, place servo amplifier card on a card extender and use a 20K ohm/volt multimeter.

To observe Q706 and Q707 voltage changes during AFC sweep, remove divider circuit card so that the servo system will not be locked with the AFC switch at auto or lock. Figure 6-13 shows the servo amplifier.

The wave forms illustrated are obtained by placing the AFC switch at MANUAL and rotating the MANUAL FREQ knob very slowly. The waveforms will appear on both sides of the center resonance. The output of the phase detector will invert passing through resonance.

6.6.3 Modulation Generator and Voltage Regulator Circuit

Input to the modulation generator and voltage regulator circuit card is:

(a) unregulated 28 volts from the input plug.

Outputs of the modulation generator and voltage regulator circuit card are:

(a) reference phase that connects to the phase detector in the servo amplifier from card terminations 10 and 11;

Table 6-4. Servo Amplifier Test Voltages

Test Point	Voltage VDC	Test Point	Voltage VDC
Q701 Base Q701 Emitter Q701 Collector	+8.1 +8.7 +3.7	Q706 Emitter	rises from approx. 7.5 vdc to 11 vdc during AFC sweep
Q702 Base Q702 Emitter Q702 Collector	+3.7 +3.1 +8.3	Q706 Base 2	21 vdc during AFC sweep
Q703 (no dc voltages applied to Q704) Q704 (no dc voltages applied to Q704)		Q707 Base	rises from zero to approx. 650 mv during AFC sweep
Q705 Base Q705 Emitter Q705 Collector	+11.1 +10.6 +17.8	Q707 Collector	rises from zero to approx. 17.5 vdc during AFC sweep

(b) triangular wave at J201 used for oscilloscope horizontal sweep when observing the phase-detector output;

(c) sinewave 107-c/s output at card termination 2 which is used to phase modulate the multiplier;

(d) regulated 21-volt output at card termination 9 from the voltage regulator section;

(e) the zener-regulated field bias output to the front panel FIELD BIAS controls through card termination 5;

(f) connections to the chassis-mounted pass transistor Q206 through card termination 3 (base connection), card termination 6 (collector connection), and card termination 9 (emitter).

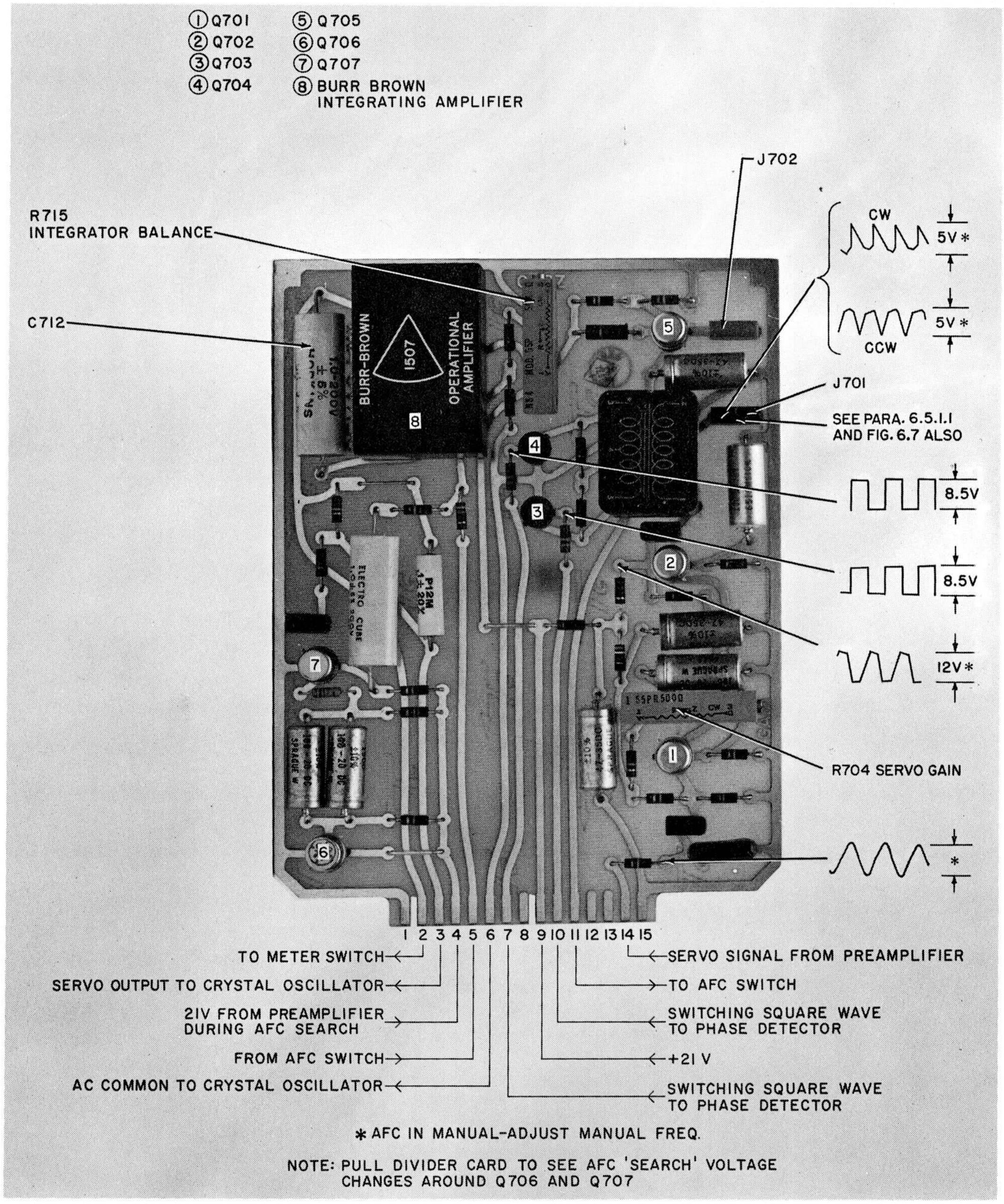


Figure 6-13. Servo Amplifier Circuit Board

To check the modulation generator section, first check for the triangular waveforms at J201. Then check for square waves at card terminations 10 and 11. Finally check for the trigger spikes at C202.

To check the voltage regulator, measure dc voltages around Q207 and Q208. Bear in mind that these voltages vary somewhat depending on the unregulated input voltage applied.

Table 6-5 lists dc voltages at various test points. To test circuit, place card on a card extender and measure voltages with a 20K ohm/volt multimeter. Figure 6-14 shows the circuit.

Table 6-5. Modulation Generator and Voltage Regulator Test Voltages

Test Point	Voltage VDC	Test Point	Voltage VDC
Q201 Emitter	+8.2	Q205 Base	+9.4
Q201 Base 1	zero	Q205 Emitter	+9.9
Q201 Base 2	+18.3	Q205 Collector	+18.8
Q202 Base	+9.7	Q206 Base	+21.6
Q202 Emitter	+10.1	Q206 Emitter	+21.0
Q202 Collector	+18.8	Q206 Collector	Input minus 1
Q203 Base	+0.080	Q207 Base	+26.2
Q203 Emitter	zero	Q207 Emitter	Input minus 1
Q203 Collector	+9.7	Q207 Collector	+21.6
Q204 Base	+0.10	Q208 Bases	+9.2
Q204 Emitter	zero	Q208 Emitters	+8.7
Q204 Collector	+9.6	Q208 Collector 1	+26.2
		Q208 Collector 2	Input minus 1

6.6.4 Synthesizer Circuit

Inputs to the synthesizer circuit are:

(a) regulated 21 volts at card termination 9;

(b) 5-Mc/s from the 5-Mc/s oscillator assembly at card termination 5;

(c) 1-Mc/s from the 1-Mc/s and 100-Kc/s divider at card termination 2;

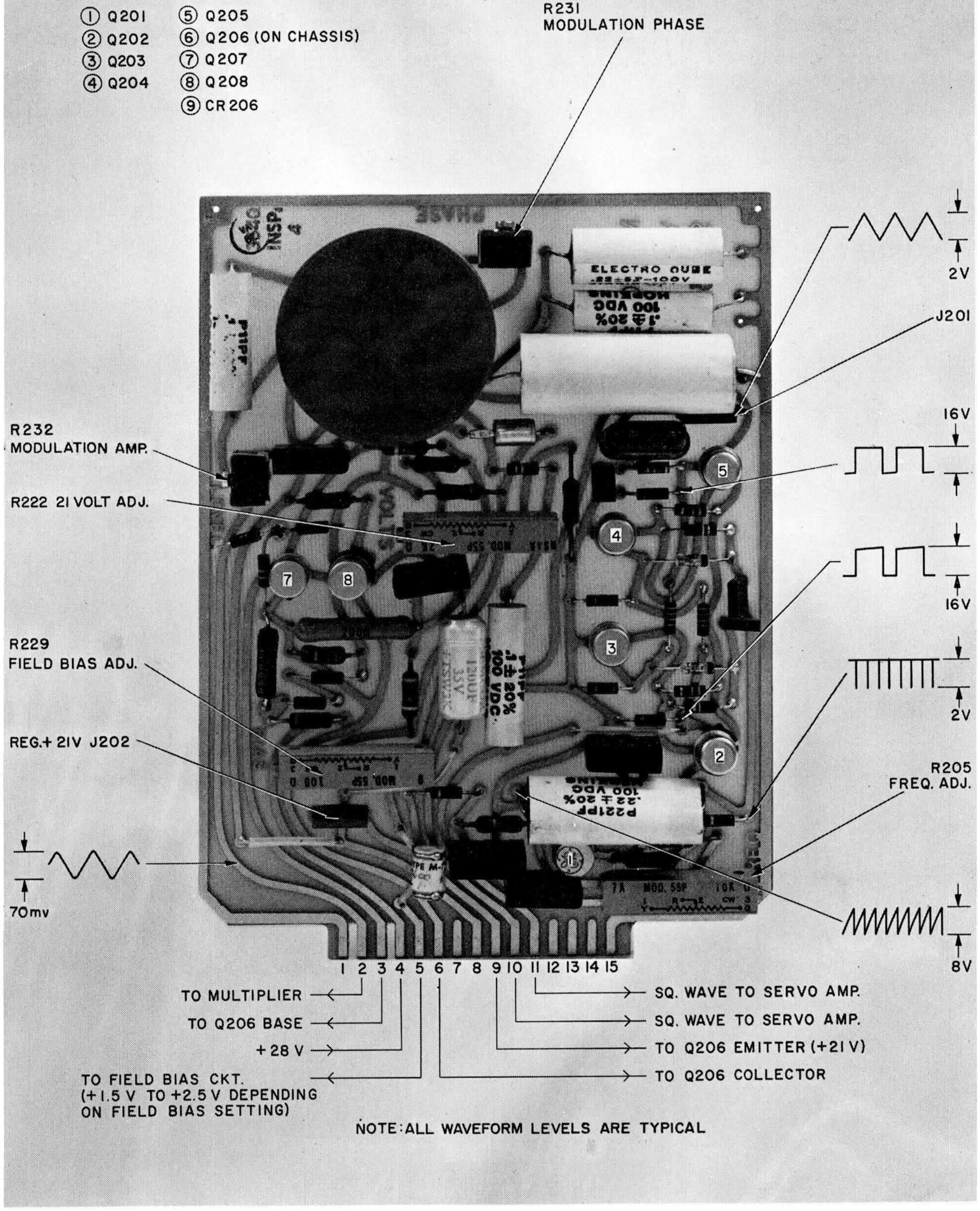


Figure 6-14. Modulation Generator and Voltage Regulator Circuit Board

(d) 300-Kc/s from the 1-Mc/s and 100-Kc/s divider at card termination 7.

Output of the synthesizer circuit is:

(a) 5-11/35-Mc/s to the optical package at card termination 14.

Table 6-6 lists dc voltages at various test points. To test circuit, place card on a card extender and use a 20K ohm/volt multimeter. Figure 6-15 shows the synthesizer circuit.

Table 6-6. Synthesizer Test Voltages

Test Point	Voltage VDC	Test Point	Voltage VDC
Q1301 Base	+4.7	QD1301 pin 1	+9.0
Q1301 Emitter	+4.1	QD1301 pin 2	+10.5
Q1301	+15	QD1301 pin 3	+10.0
		QD1301 pin 4	+11.5
Q1302 Base	+4.1	QD1301 pin 5	+10.0
Q1302 Emitter	+3.4	QD1301 pin 6	+13.0
Q1302 Collector	+15	QD1301 pin 7	+11.5
Q1303 Base	+5.0	QD1301 pin 8	+9.0
Q1303 Emitter	+4.5	QD1301 pin 9	+10.5
Q1303 Collector	+8.1	QD1301 pin 10	0
Q1304 Base	+3.5	QD1302 pin 1	+4.3
Q1304 Emitter	+2.9	QD1302 pin 2	+6.5
Q1304 Collector	+12	QD1302 pin 3	+4.3
		QD1302 pin 4	+7.5
Q1305 Base	+5.7	QD1302 pin 5	+6.5
Q1305 Emitter	+5.2	QD1302 pin 6	+9.0
Q1305 Collector	+12.5	QD1302 pin 7	+7.5
Q1306 Base	+5.4	QD1302 pin 8	+4.3
Q1306 Emitter	+4.8	QD1302 pin 9	+6.1
Q1306 Collector	+18	QD1302 pin 10	0
Q1307 Base	+5.3	QD1303 pin 1	0
Q1307 Emitter	+5.0	QD1303 pin 2	+2.1
Q1307 Collector	+18	QD1303 pin 3	0
		QD1303 pin 4	+3.1
Q1308 Base	+5.2	QD1303 pin 5	+2.1
Q1308 Emitter	+4.7	QD1303 pin 6	+4.3
Q1308 Collector	+8.5		

Table 6-6. Synthesizer Test Voltages (Continued)

Test Point	Voltage VDC	Test Point	Voltage VDC
QD1303 pin 7 QD1303 pin 8	+3.1 0	QD1303 pin 9 QD1303 pin 10	+1.6 0

6.6.5 1-Mc/s and 100-Kc/s Divider Circuit

Input to the 1-Mc/s and 100-Kc/s divider circuit is:

(a) 5-Mc/s from 5-Mc/s oscillator assembly at card termination 2.

Outputs of the 1-Mc/s and 100-Kc/s divider circuit are:

(a) 1-Mc/s to synthesizer at card termination 7;

(b) 300-Kc/s to synthesizer at card termination 10;

(c) 20-Kc/s to synthesizer at card termination 12;

(d) 1-Kc/s to synthesizer at card termination 11;

(e) 1-Mc/s to front and rear output jacks at card termination 4;

(f) 100-Kc/s to front and rear output jacks at card termination 14.

Table 6-7 lists dc voltages at various test points. To test circuit, place card on a card extender, short the 5-Mc/s input at J1201 to ground, and use a 20K ohm/volt multimeter. Figure 6-16 shows the circuit card.

6.6.6 Thermostat Circuit

Inputs to the thermostat circuit card are:

(a) unregulated 28 volts at card termination 8;

(b) regulated 21 volts at card termination 7;

(c) the return line from the thermistor in the gas-cell oven at card termination 4.

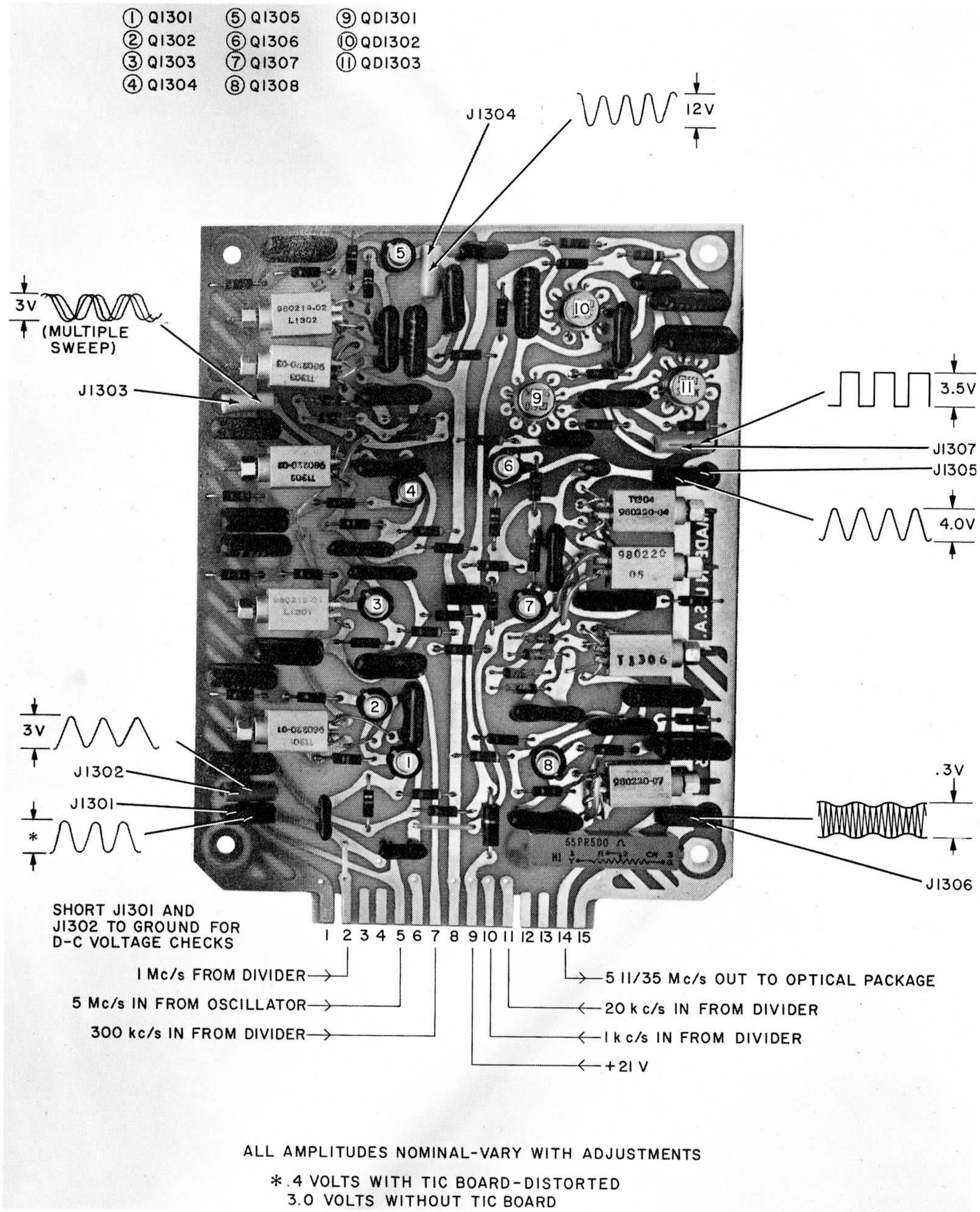


Figure 6-15. Synthesizer Circuit Board

Table 6-7. 1-Mc/s and 100-Kc/s Divider Test Voltages

Test Point	Voltage VDC	Test Point	Voltage VDC
Q1201 Base	+1.75	Q1210 Base	+9.6
Q1201 Emitter	+2.2	Q1210 Emitter	+9.0
Q1201 Collector	+6.9	Q1210 Collector	+19.5
Q1202 Base	+4.5	QD1201 pin 1	+8.9
Q1202 Emitter	+4.4	QD1201 pin 2	+8.9
Q1202 Collector	+11.5	QD1201 pin 3	+8.6
Q1203 Base	+3.1	QD1201 pin 4	+7.7
Q1203 Emitter	+3.8	QD1201 pin 5	+7.7
Q1203 Collector	+12.5	QD1201 pin 6	+8.3
Q1204 Base	+1.8	QD1201 pin 7	+11.5
Q1204 Emitter	+10.7	QD1201 pin 8	+9.2
Q1204 Collector	+13.0	QD1202 pin 1	+5.1
Q1205 Base	+11.4	QD1202 pin 2	+5.1
Q1205 Emitter	+10.7	QD1202 pin 3	+4.8
Q1205 Collector	+17.5	QD1202 pin 4	+3.9
Q1206 Base	+10.7	QD1202 pin 5	+3.9
Q1206 Emitter	+10.0	QD1202 pin 6	+4.5
Q1206 Collector	+17.5	QD1202 pin 7	+7.7
Q1207 Base	+9.7	QD1202 pin 8	+5.5
Q1207 Emitter	+9.0		
Q1207 Collector	+19.5	QD1203 pin 1	+1.1
Q1208 Base	+5.0	QD1203 pin 2	+1.1
Q1208 Emitter	+4.4	QD1203 pin 3	+.85
Q1208 Collector	+16.5	QD1203 pin 4	0
Q1209 Base	+9.4	QD1203 pin 5	+.65
Q1209 Emitter	+8.8	QD1203 pin 6	+.65
Q1209 Collector	+19.5	QD1203 pin 7	+3.9
		QD1203 pin 8	+1.5

Outputs of the thermostat circuit card are:

(a) the 28-volt heater pulse at card termination 9;

(b) the square-wave output to the gas-cell oven thermistor at card termination 3;

(c) the reference square-wave output to the gating diodes in the dual thermostat circuit card at card termination 10;

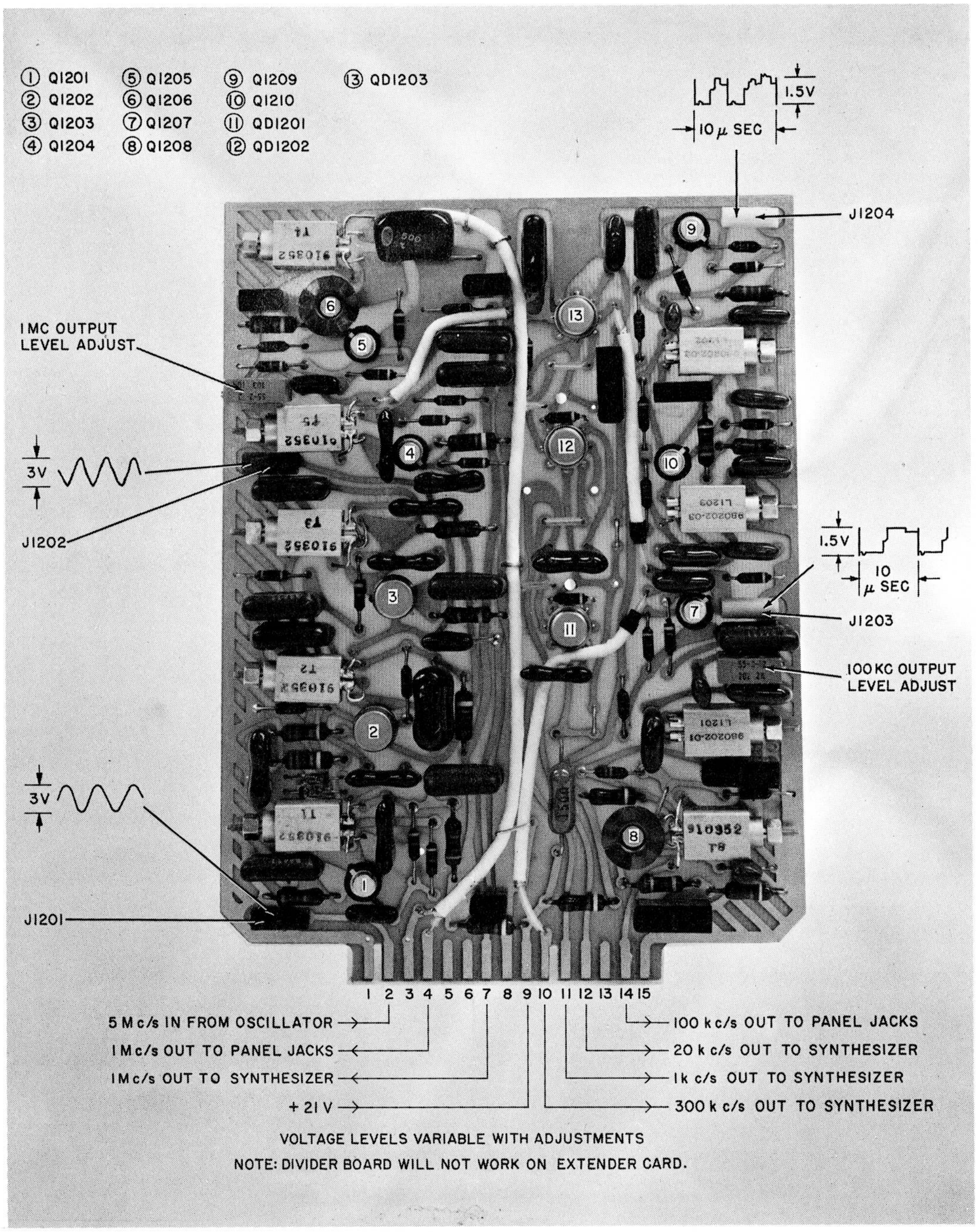


Figure 6-16. 1-Mc/s and 100-Kc/s Divider Circuit Board

(d) the square-wave output to the reference resistors in the dual thermostat circuit card at card termination 13.

Table 6-8 lists dc voltages at various test points. To test circuit, place card on a card extender and use a 20K ohm/volt multimeter. Figure 6-17 shows the circuit card.

NOTE

Since the output of Q605 is integrated by C610, the dc voltage at the base of Q606 will vary according to heater current.

Table 6-8. Thermostat Test Voltages

Test Point	Voltage VDC	Test Point	Voltage VDC
Q601 Base	+0.450	Q605 Base	-0.175
Q601 Emitter	0	Q605 Emitter	+0.350
Q601 Collector	+19.0	Q605 Collector	+10.3
Q602 Base	+0.450	Q606 Base	+11.0
Q602 Emitter	0	Q606 Emitter	+10.8
Q602 Collector	+19.0	Q606 Collector	+0.600
Q603 Base	+6.0		
Q603 Emitter	+6.3	Q607 Base	+0.170
Q603 Collector	+5.7	Q607 Emitter	0
Q604 Base	+5.7	Q607 Collector	varies with pulse width
Q604 Emitter	+5.2		
Q604 Collector	+10.3		

6.6.7 Dual Thermostat Circuit

Inputs to the dual thermostat circuit are:

(a) the square-wave inputs to the reference resistor side of the thermistor bridge circuit in each amplifier at card terminations 5 and 13;

(b) the reference square-wave input to the gating diodes in each amplifier section at card terminations 2 and 14;

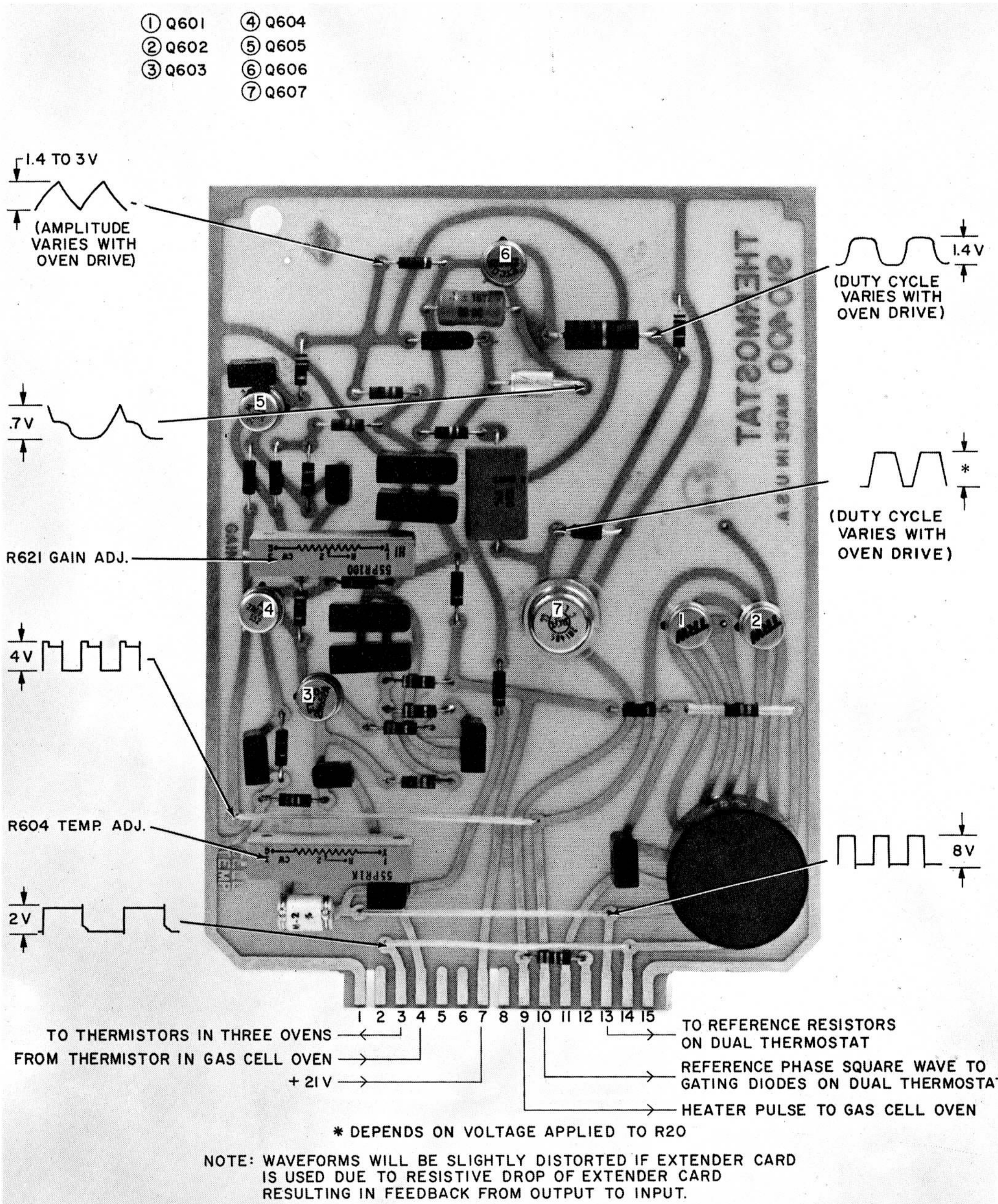


Figure 6-17. Thermostat Circuit Board

(c) the return lines from the oven thermistors to each amplifier section at card terminations 3 and 11;

(d) regulated 21 volts at card termination 6;

(e) unregulated 28 volts at card termination 10 which serves as a 28-volt tiepoint.

Output of the dual thermostat circuit is:

(a) 28-volt heater pulses to the outer oven at card termination 7 and to the 5-Mc/s assembly oven at card termination 9.

Table 6-9 lists dc voltages at various test points. To test circuit, place card on a card extender and use a 20K ohm/volt multimeter. Figure 6-18 shows the circuit.

NOTE

Since the outputs of Q503 and Q508 are integrated by C509 and C519, respectively, the dc voltage at the bases of Q504 and Q509 will vary according to heater current.

6.6.8 Time Scale Changer Circuit

Inputs to the time scale changer are:

(a) regulated 21 volts from synthesizer at card termination F;

(b) 1-Mc/s from synthesizer at card termination B;

(c) 1-Kc/s from synthesizer at card termination G;

(d) 20-Kc/s from synthesizer at card termination H.

Output of the time scale changer is:

(a) 1-Mc/s + 250N c/s to synthesizer at card termination C.

Table 6-9. Dual Thermostat Test Voltages

Test Point	Voltage VDC	Test Point	Voltage VDC
Q501 Base	+6.0	Q506 Base	+6.0
Q501 Emitter	+6.3	Q506 Emitter	+6.3
Q501 Collector	+5.2	Q506 Collector	+5.2
Q502 Base	+5.2	Q507 Base	+5.2
Q502 Emitter	+4.7	Q507 Emitter	+4.7
Q502 Collector	+10.3	Q507 Collector	+10.3
Q503 Base	-0.175	Q508 Base	-0.175
Q503 Emitter	+0.350	Q508 Emitter	+0.350
Q503 Collector	+10.3	Q508 Collector	+10.3
Q504 Base	+11.0	Q509 Base	+11.0
Q504 Emitter	+10.8	Q509 Emitter	+10.8
Q504 Collector	+2.0	Q509 Collector	+2.0
Q505 Base	+0.400	Q510 Base	+0.400
Q505 Emitter	0	Q510 Emitter	0
Q505 Collector	varies with pulse width	Q510 Collector	varies with pulse width

Table 6-10 lists dc voltages at various test points. To test circuit, use a 20K ohm/volt multimeter. Figure 6-19 shows the circuit board.

6.6.9 Lamp Exciter and Rubidium Lamp

The lamp exciter should not be adjusted or disturbed unless the Rubidium 87 bulb is replaced. If the bulb is replaced, allow it to "burn in" for several days. If it produces as much signal as the old bulb did before it failed, and if it strikes reliably after turn-on, no readjustment is necessary. If the bulb will not strike when power is applied, turn GAIN control R032 located on the side of the exciter (Figure 6-20) clockwise until it strikes. FREQUENCY control C035 located on the top of the exciter (Figure 6-20) may also require tuning in counterclockwise direction to make the bulb strike.

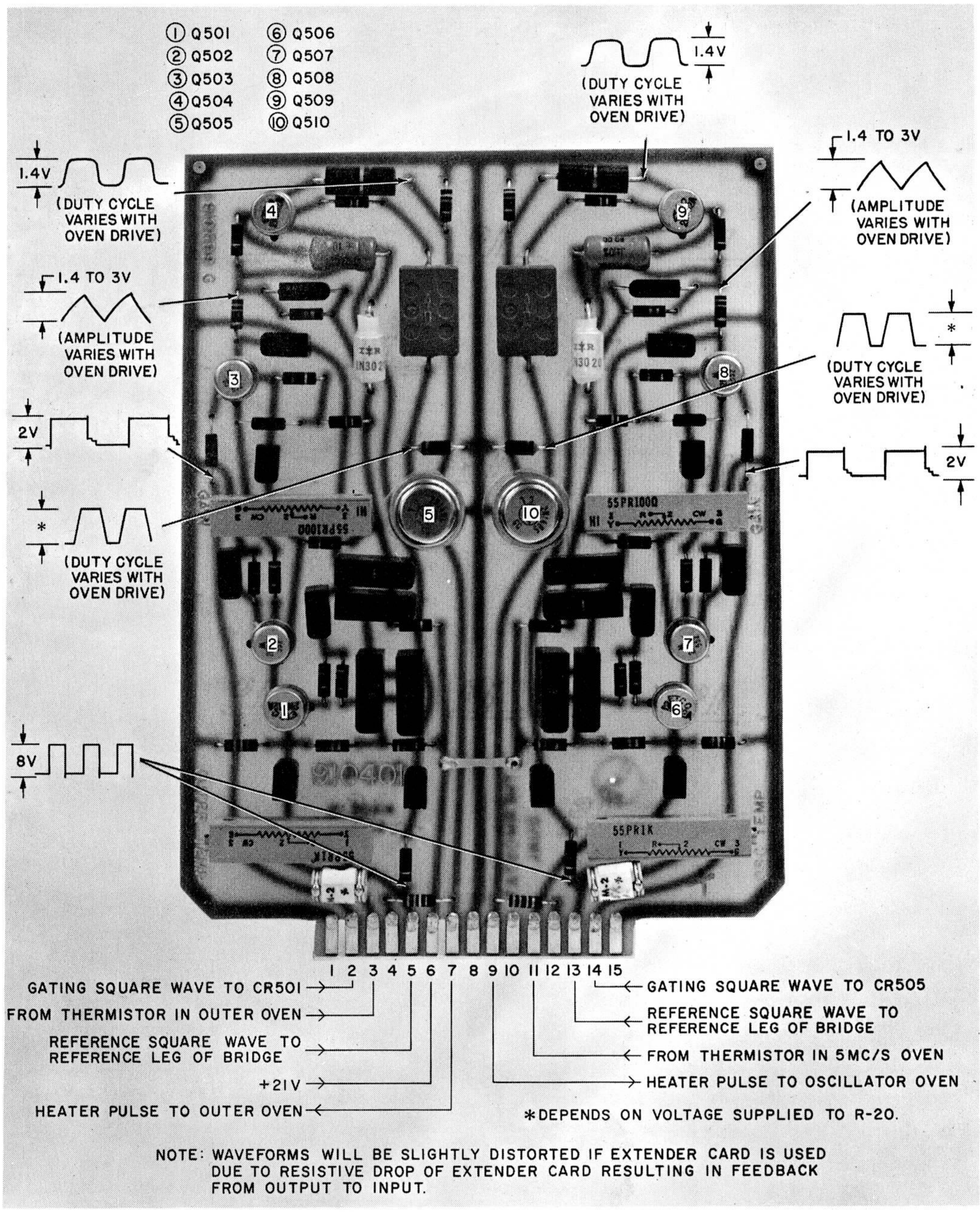


Figure 6-18. Dual Thermostat Circuit Board

Table 6-10. Time Scale Changer Test Voltages

Test Point	Voltage VDC	
Q4401 Base	+10.0	
Q4401 Emitter	+9.4	
Q4401 Collector	+20.0	
Q4402 Base	+4.8	
Q4402 Emitter	+4.1	
Q4402 Collector	+9.4	
Q4403 Base	+10.0	
Q4403 Emitter	+9.3	
Q4403 Collector	+20.0	
Q4404 Base	+4.8	
Q4404 Emitter	+4.2	
Q4404 Collector	+9.3	
Q4405 Base	+6.0	
Q4405 Emitter	+5.4	
Q4405 Collector	+14.7	
Q4406 Gate	+3.2	
Q4406 Source	0	
Q4406 Drain	0	
Q4407 Gate	+0.31	
Q4407 Source	0	
Q4407 Drain	+7.0	
Q4408 Base	+6.8	
Q4408 Emitter	+6.1	
Q4408 Collector	+21.0	
	Alarm OFF	Alarm ON
Q4409 Gate	+22.0	+19.5
Q4409 Source	0	+19.0
Q4409 Drain	+20.0	+20.0

Test Point	Voltage VDC
QD4401 pin 1	+8.1
QD4401 pin 2	+10.0
QD4401 pin 3	+8.1
QD4401 pin 4	+9.6
QD4401 pin 5	+10.3
QD4401 pin 6	+12.5
QD4401 pin 7	+9.6
QD4401 pin 8	+8.1
QD4401 pin 9	+10.0
QD4401 pin 10	0
QD4402 pin 1	+4.0
QD4402 pin 2	+5.7
QD4402 pin 3	+4.0
QD4402 pin 4	+5.2
QD4402 pin 5	+5.6
QD4402 pin 6	+8.1
QD4402 pin 7	+5.2
QD4402 pin 8	+4.0
QD4402 pin 9	+5.7
QD4402 pin 10	0
QD4403 pin 1	0
QD4403 pin 2	+4.16
QD4403 pin 3	0
QD4403 pin 4	+2.3
QD4403 pin 5	+1.9
QD4403 pin 6	+4.0
QD4403 pin 7	+0.5
QD4403 pin 8	+1.1
QD4403 pin 9	+3.2
QD4403 pin 10	0

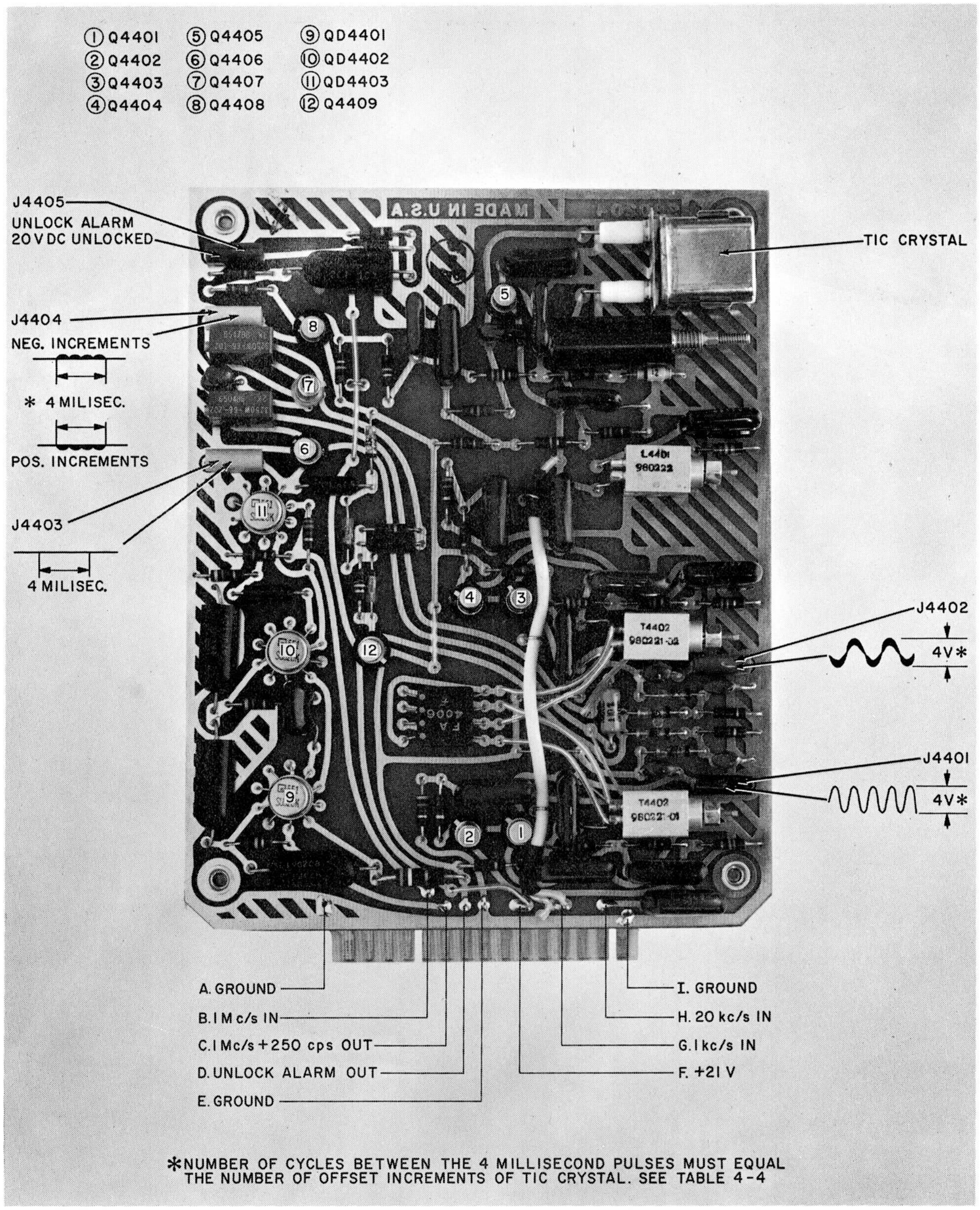


Figure 6-19. Time Scale Changer Circuit Board

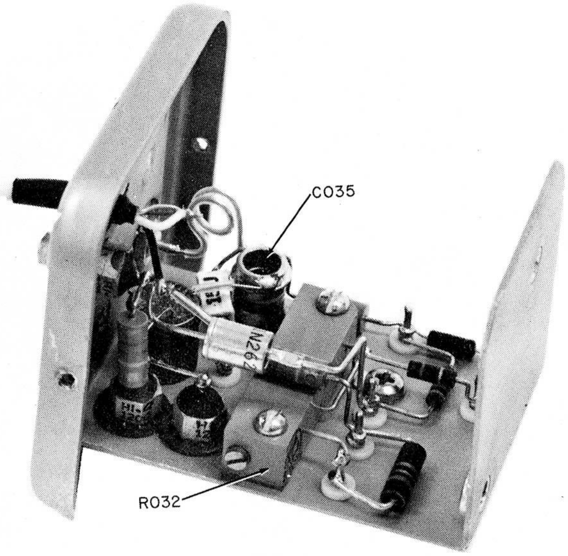


Figure 6-20. Lamp Exciter Assembly

NOTE

Maladjusting R032 or C035 can render instrument inoperative.

Once the bulb is lit and is operating in the correct mode, adjust R032 until the dc exciter current is approximately 0.18A or 180mA. Then tune C035 and R032 to get maximum resonance signal; check to make sure that the lamp will strike after it has been turned off for a few minutes. The signal amplitude may have to be compromised to achieve reliable start-up. The correct operating mode will produce an intense purple light as distinguished from a pale purple when the lamp is not operating correctly.

6.6.10 5-Mc/s Oscillator

Adjustments and repair on this assembly require extreme care and a thorough understanding of the equipment. Normally the Varian service department should make any needed adjustments or repair.

Trouble in the 5-Mc/s oscillator could be either low or distorted output (below 1 v rms) or off frequency so far that the coarse tuning adjustment will not return the oscillator to 5-Mc/s. If the 5-Mc/s output is low or distorted the trouble is likely on one of the circuit cards located in the oscillator. Since the output appearing at P014 comes only from the oscillator card, trouble on P014 but not on P011, P012, or P013 isolates which card is at fault.

6.6.11 Multiplier

Adjustment of the multiplier should be attempted only after all other circuits appear to be functioning normally and the oscillator is set to 5-Mc/s ±5 parts in 10^8. With an oscilloscope, observe the resonance signal at the output of the synchronous detector (J701 on servo board). Carefully tune C941 (Figure 6-21) of multiplier until optimum power is being delivered to the snap diode on the optical package, as indicated by maximum resonance signal. If no signal is found return C941 to its original position and try C940 (Figure 6-21). Progress on down to C928. If no signal is found the multiplier can be returned to near original condition by tuning for maximum rf output into 50 ohm load. If a ;onance signal is located maximize it by means of C928, C934, C940 and C941.

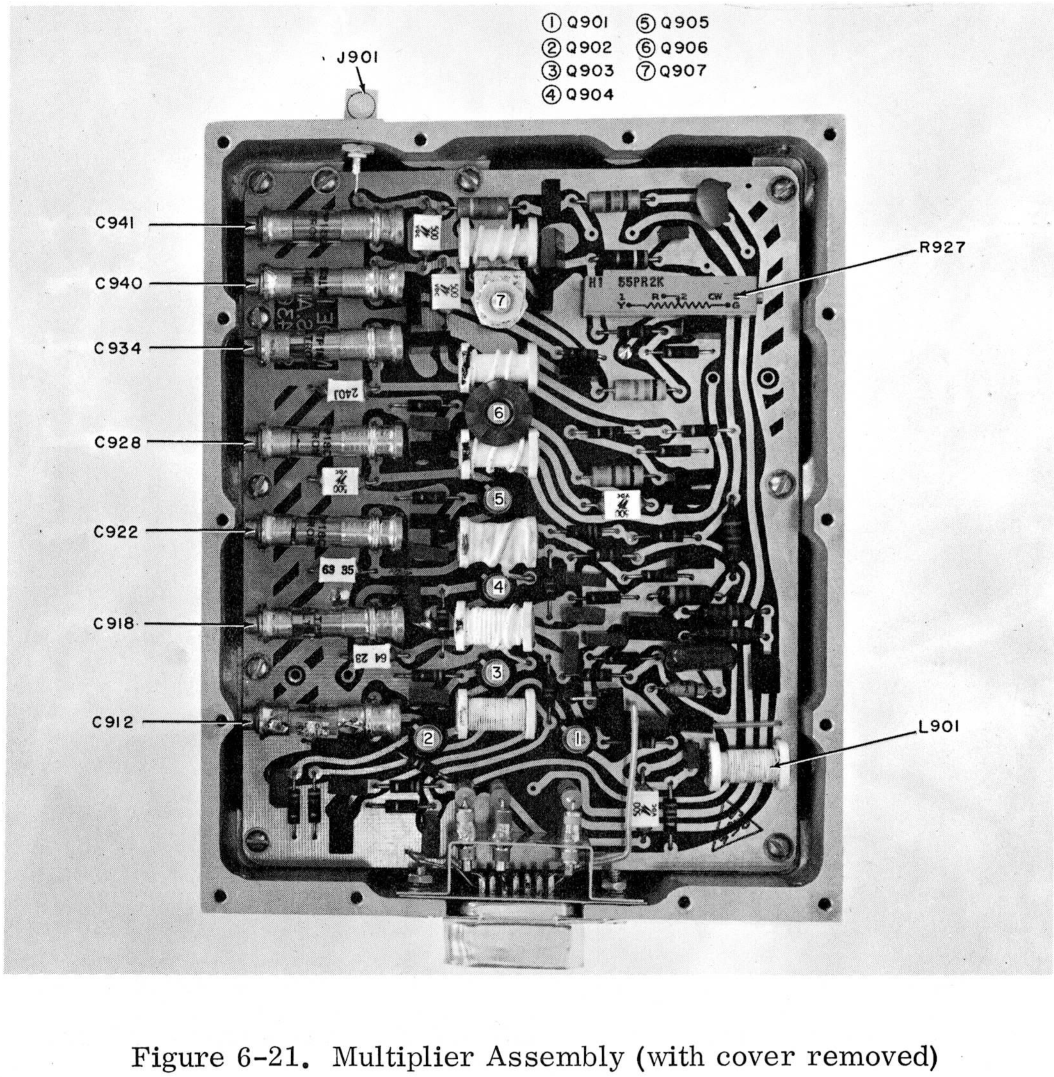


Figure 6-21. Multiplier Assembly (with cover removed)

Whenever the multiplier is returned it is necessary to check that the phase of the resonance signal is synchronized with that of the reference in the synchronous detector. If adjustment of phase is required proceed as described in section V.

Section VII

REPLACEMENT PARTS

7.1 GENERAL

This section lists various replacement parts that can be ordered from Varian for instrument repair purposes.

7.2 Table 7-1 lists replacement plug-in assemblies for the R-20.

Table 7-1. Plug-In Assemblies

Schematic Reference	Part Description	Mfg Code	Manufacturer's Designation	Varian Number
	Lamp Exciter Assy			910427
	Crystal Oscillator Assy			910428
	Optical Package Assy			910330
	Modulator Generator and Voltage Regulator Assy			910356
	1-Mc/s and 100-Kc/s Divider Assy			
	(without Time Scale)			910509-01
	(used with Time Scale)			910509-02
	Synthesizer Assy			
	(without Time Scale)			910516-01
	(with Time Scale)			910516-02
	Thermostat, Dual Assy			910401

Table 7-1. Plug-In Assemblies (Continued)

Schematic Reference	Part Description	Mfg Code	Manufacturer's Designation	Varian Number
	Thermostat Assy			910400
	Servo Amplifier Assy			910351
	Preamplifier Assy			910384
	Multiplier Assy			910436

7.3 Table 7-2 lists replacement chassis electronic parts for the R-20.

Table 7-2. Chassis Electronic Parts

Schematic Reference	Part Description	Mfg Code	Manufacturer's Designation	Varian Number
C001	Capacitor, 0.047 pf, 50 v	037	601PE473-0.5W4	41-709290
C002, 3	Capacitor, 150 uf, 50 v	03	BR-150-50	41-508799
J001, 2, 3, 4, 5, 6	Connector	190	MICON 9141	58-039900
J007	Connector, Receptacle	023	126-198	51-409107
P007	Connector, Plug	023	126-195	51-309607
J008	Connector, Receptacle	023	126-218	51-409105
P008	Connector, Plug	023	126-217	51-309605
J009	Connector, Receptacle	023	126-221	51-409109
P009	Connector, Plug	023	126-220	51-309609
J010	Connector, Receptacle	023	126-214	51-309804
P010	Connector, Plug	023	126-215	51-409904
P011, 012, 013, 014	Connector	190	MICON 1026	58-019881

Table 7-2. Chassis Electronic Parts (Continued)

Schematic Reference	Part Description	Mfg Code	Manufacturer's Designation	Varian Number
J200, 300, 400, 500, 600, 700, 800	Connector, Receptacle	166	2VH15/1AB3	51-403318
J900	Connector, Receptacle	023	57-20140	51-408714
FL001	Filter, rf			998069
M001	Meter, 100-0-100 Microamp	189	150C200X1	76-131955
R001	Resistor, 330K, 1/4W, 5%	011	TYPE CB	32-301633
R002	Resistor, 180K, 1/4W, 5%	011	TYPE CB	32-301618
R004, 005	Resistor, 100K, 1/4W, 5%	011	TYPE CB	32-301610
R006, 012	Resistor, 20 Ohm, 1/4W, 1%	060	TYPE M2	31-242200
R007A and B	Resistor, Var, 10 Ohm	084	6334B2096-1-100	37-570001
R009	Resistor, Var, 500 Ohm, 2W, 3%	049	7216-R500L5	37-999967
R010	Resistor, 220 Ohm, 1/4W, 1%	060	TYPE M3	31-243220
R011	Resistor, 160 Ohm, 1/4W, 1%	060	TYPE M3	31-243160
R013	Resistor, Var, 100K, 1.5W, 10%	049	MODEL 55P 100K	36-884610
R014	Resistor, 220K, 1/4W, 5%	011	TYPE CB	32-301622
L001	Reactor, Toroid	119	EK-010A	43-111997
CB001	Switch, Circuit Breaker	005	D6755-1-3	71-639914

Table 7-2. Chassis Electronic Parts (Continued)

Schematic Reference	Part Description	Mfg Code	Manufacturer's Designation	Varian Number
S001	Switch, Rotary	004	PA-2003	71-710993
S002	Switch Assy			998060
S003	Switch, Momentary Contact	048	SW953-6	71-299989
S004	Switch, Toggle	169	TS-3	71-129977
Q206	Transistor	193	2N1485	62-901485

7.4 Table 7-3 lists replacement chassis mechanical parts for the R-20.

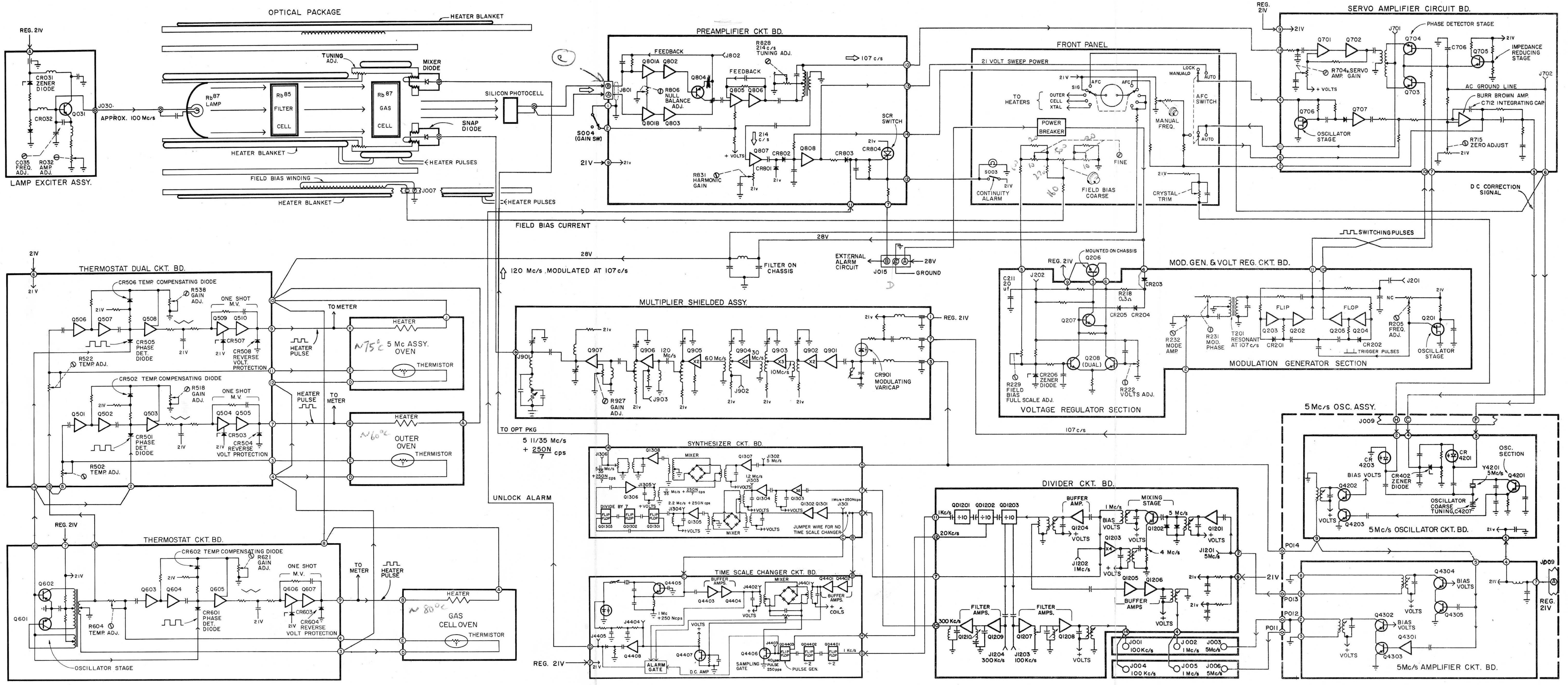
Table 7-3. Chassis Mechanical Parts

Schematic Reference	Part Description	Mfg Code	Manufacturer's Designation	Varian Number
	Chassis Cover			910407
	Knob, Round (1/8" Shaft)	016	50-1-1G	23-519946
	Knob, Dial Skirted	016	70-3-2G	23-529818
	Knob, Dial Skirted (1/4" shaft thru)	016	70-3CB-2G	23-529813
	Dial, Vernier	049	2607	23-569861
	Spacer Holder, P.C.B.			910467
	Foot, Rubber	192	9115	23-621910
	Front Panel Escutcheon (Vertical)			910409-01
	Front Panel Escutcheon (Horizontal)			910409-02

7.5 Table 7-4 lists the code number and manufacturer's name for replacement parts given in Tables 7-1, 7-2, and 7-3.

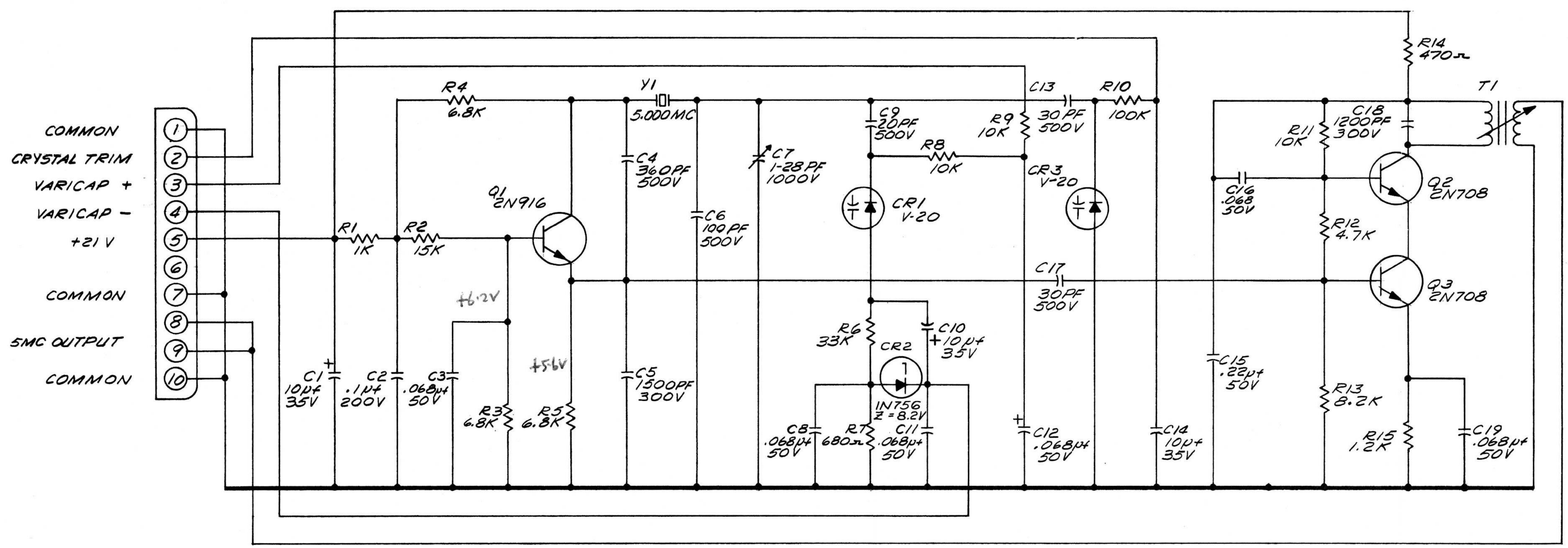
Table 7-4. Manufacturer Code List

Code No.	Manufacturer
003	Cornell Dubilier Electric Co.
004	Centralab Division of Globe Union
005	Texas Instruments, Inc.
011	Allen-Bradley Co.
016	Raytheon Manufacturing Co.
023	Amphenol-Borg Electronics Corp.
037	Good-All Electric Mfg Co.
049	Helipot Corp.
060	K. F. Development Co.
072	Bendix Aviation Corp.
084	Bourns Laboratories, Inc.
119	Triad Transformer Corp.
166	Viking Industries
189	International Instruments Co.
190	Micon Electronics Co.
191	Philadelphia Briefcase Co.
192	Rubbercraft Co.
193	R.C.A.



OPTICAL PACKAGE
HEATER BLANKET
LAMP EXCITER ASSY.
PREAMPLIFIER CKT. BD.
FRONT PANEL
SERVO AMPLIFIER CIRCUIT BD.
FIELD BIAS CURRENT
THERMOSTAT DUAL CKT. BD.
MULTIPLIER SHIELDED ASSY.
MOD. GEN. & VOLT REG. CKT. BD.
MODULATION GENERATOR SECTION
VOLTAGE REGULATOR SECTION
5 Mc/s OSC. ASSY.
5Mc/s OSCILLATOR CKT. BD.
SYNTHESIZER CKT. BD.
DIVIDER CKT. BD.
THERMOSTAT CKT. BD.
TIME SCALE CHANGER CKT. BD.
5Mc/s AMPLIFIER CKT. BD.
GAS CELL OVEN
OUTER OVEN
5 Mc ASSY. OVEN
UNLOCK ALARM
120 Mc/s MODULATED AT 107 c/s
EXTERNAL ALARM CIRCUIT
FILTER ON CHASSIS

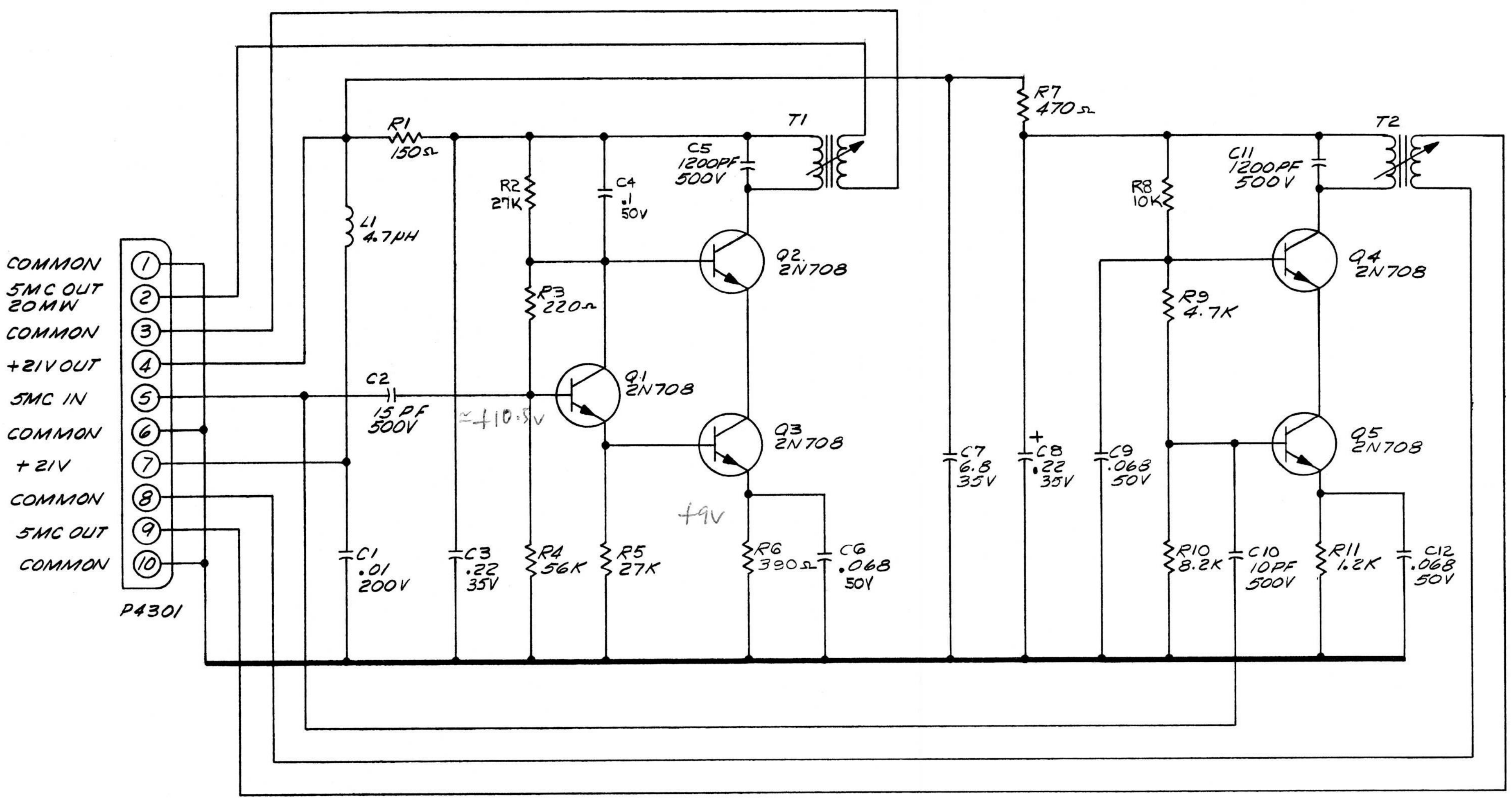
R-20



NOTES:
1. UNLESS OTHERWISE INDICATED, ALL RESISTORS ARE ½ W, 5 %

SCHEMATIC
5MC OSCILLATOR
910361E

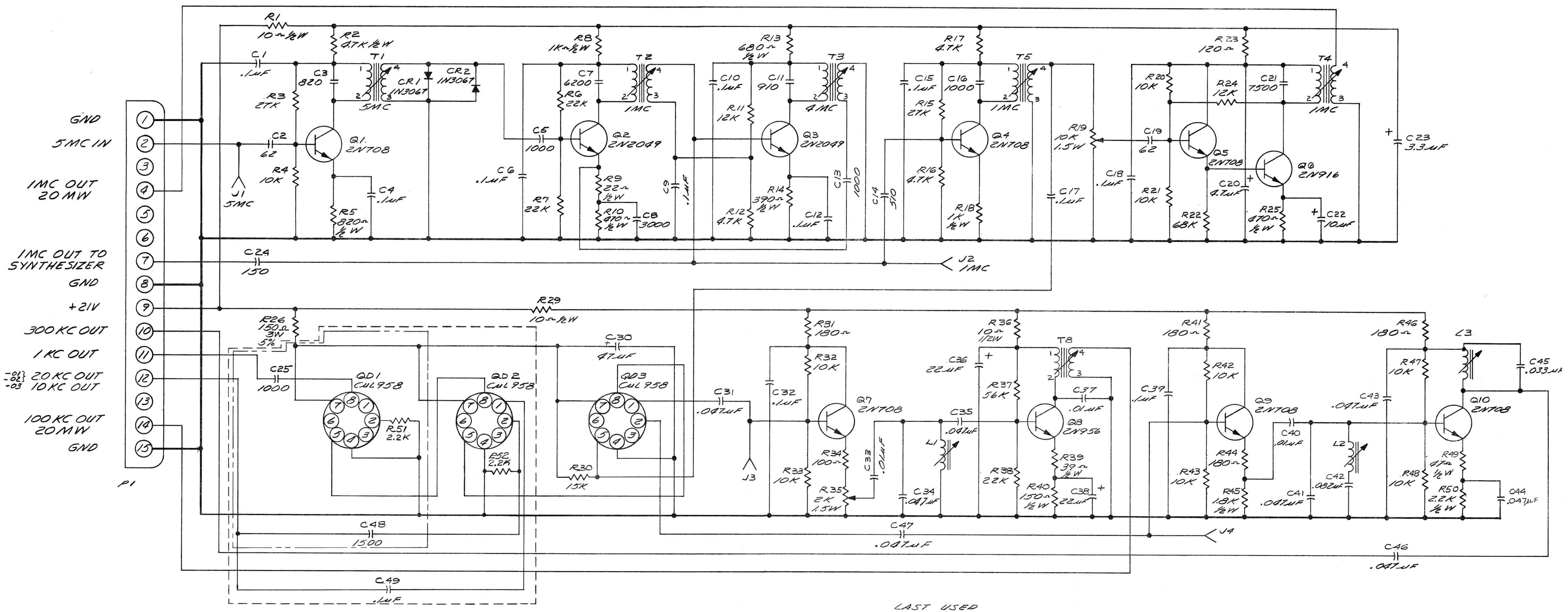
R-20



2. UNLESS OTHERWISE NOTE ALL CAP. ARE IN μf

1. UNLESS OTHERWISE NOTED ALL RESISTORS ARE IN OHMS, 1/4 W, 5%

SCHEMATIC
5MC AMPLIFIER
910440 E



5. P/N 910509-03: ELIMINATE COMPONENTS WITH AREA ENCLOSED BY ----- LINE. R26 BECOMES 250Ω 5 WATTS, 5%.

4. -01 VERSION: ELIMINATE COMPONENTS WITHIN AREA INCLOSED BY DASHED LINE. R26 BECOMES 500Ω 5 WATT 5%.

3. -02 VERSION: AS SHOWN WITH C49 OMITTED

2. ALL CAPACITORS ARE IN µµF UNLESS OTHERWISE NOTED

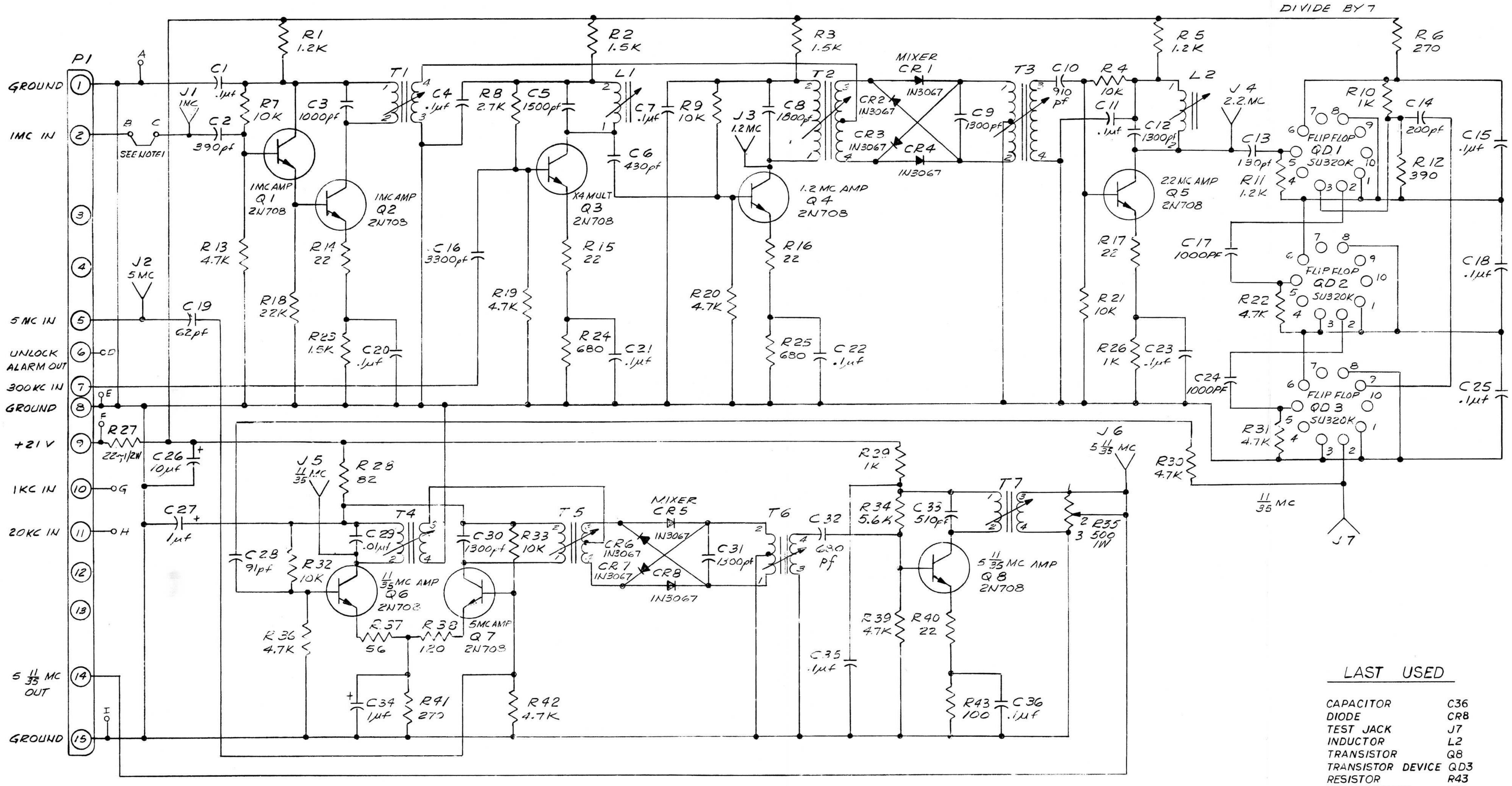
1. UNLESS OTHER WISE NOTED ALL FIXED RESISTORS ARE 1/4 WATT, CORNING TYPE C. ALL 1/4 WATT RESISTORS ARE 5%. ALL 1/2 WATT RESISTORS ARE 2%.

LAST USED

CAPACITOR	C49
DIODE	CR2
INDUCTOR	L3
RESISTOR	R52
TEST JACK	J4
TRANSFORMER	T8
TRANSISTOR	Q10
TRANSISTOR DEVICE	QD3

SCHEMATIC - 1MC & 100KC
DECADE DIVIDER
910503L

R-2D



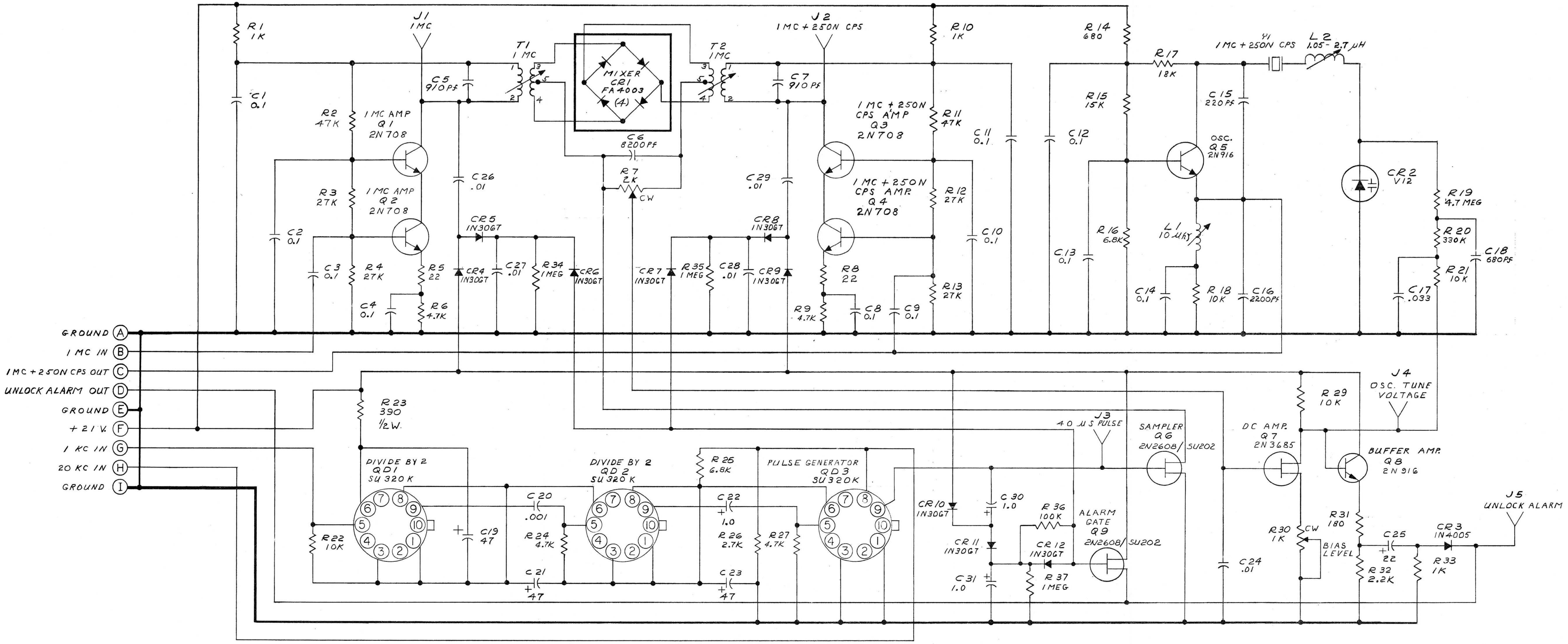
LAST USED

CAPACITOR	C36
DIODE	CR8
TEST JACK	J7
INDUCTOR	L2
TRANSISTOR	Q8
TRANSISTOR DEVICE	QD3
RESISTOR	R43
TRANSFORMER	T7

NOTES:

1. FOR -01 VERSION, JUMPER WIRE CONNECTED BETWEEN B&C.
   FOR -02 VERSION, "A" THROUGH "I" CONNECTED TO "A" THROUGH "I" ON TIME SCALE CHANGER (910519)
2. UNLESS OTHERWISE NOTED ALL RESISTORS ARE IN OHMS, 1/4W, 5%.
3. UNLESS OTHERWISE NOTED ALL CAPACITORS ARE IN MICROFARADS.

SCHEMATIC
5 11/35 SYNTHESIZER
910514 D



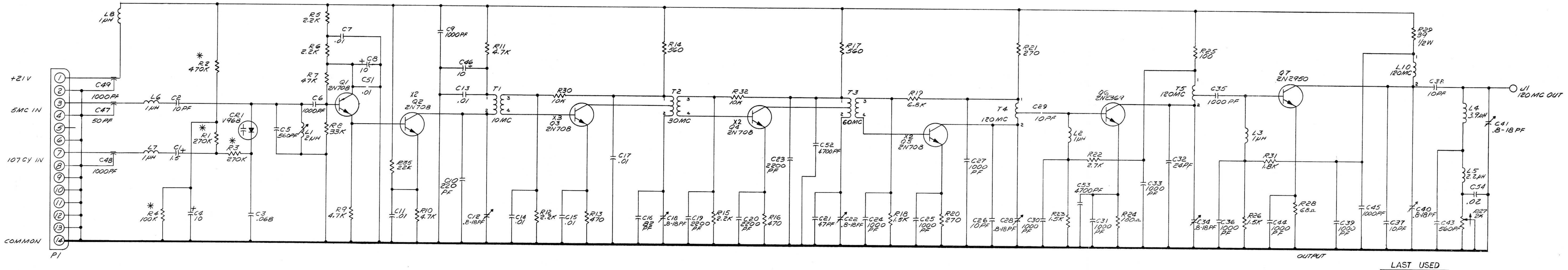
LAST USED

C 31
R 37
CR 12
L 2
Q 9
QD 3
CU 1
R 28 DELETED

3. UNLESS OTHERWISE NOTED ALL CAPACITANCE IS IN UF
2. UNLESS OTHERWISE NOTED ALL RESISTANCE IS IN OHMS
1. UNLESS OTHERWISE NOTED ALL RESISTORS ARE 1/4 WATT

SCHEMATIC - TIME SCALE CHANGER

910519 D

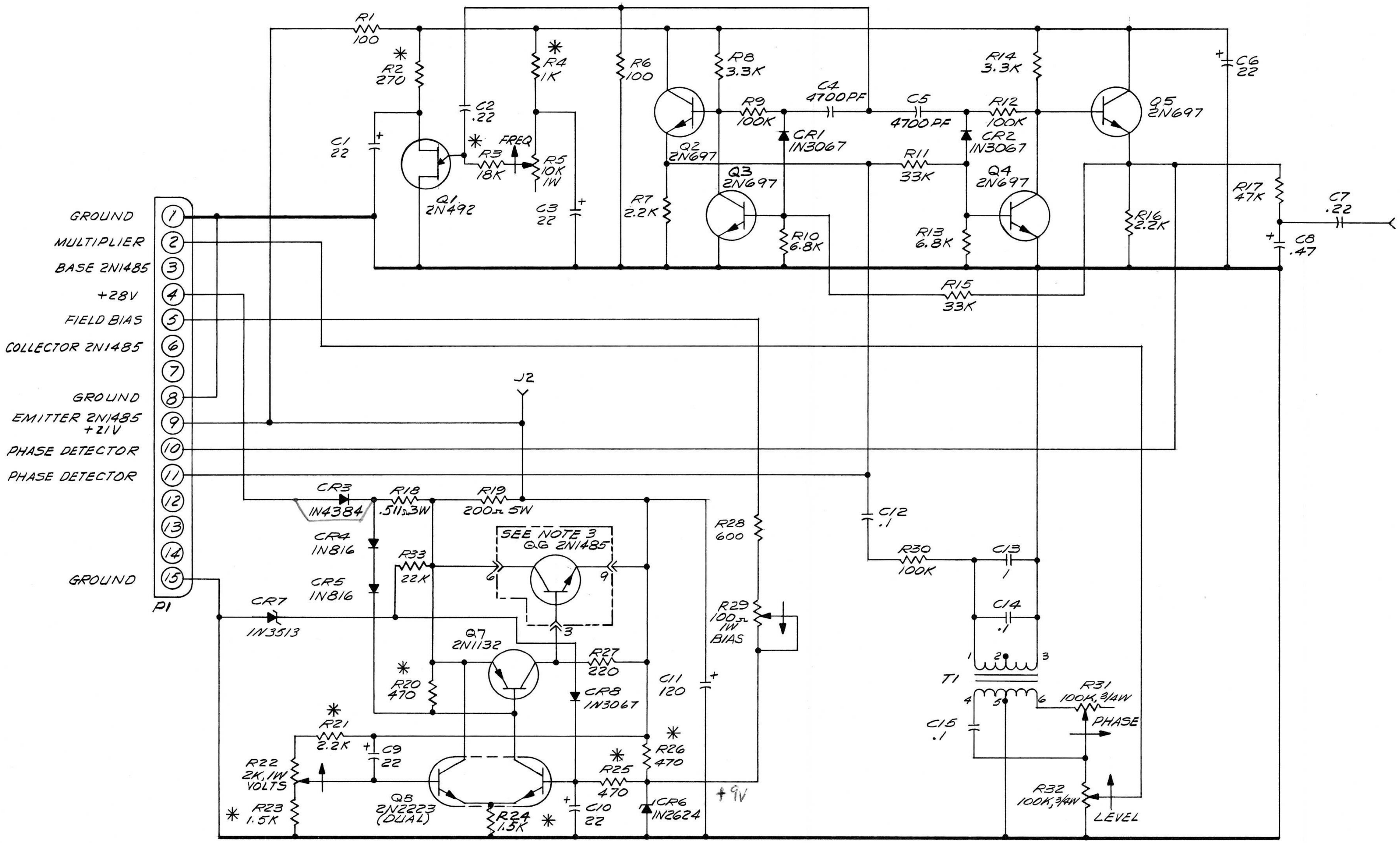


LAST USED

CAPACITOR	C54
DIODE	CR1
CONNECTOR	J1
INDUCTOR	L10
CONNECTOR	P1
TRANSISTOR	Q7
RESISTOR	R35
TRANSFORMER	T5

3. * INDICATES CORNING GLASS RESISTORS TYPE C5 (1/2W)
2 UNLESS OTHERWISE NOTED ALL CAP. ARE IN μf
1 UNLESS OTHERWISE NOTED ALL RESISTORS ARE IN OHMS, 1/4 W, 5%

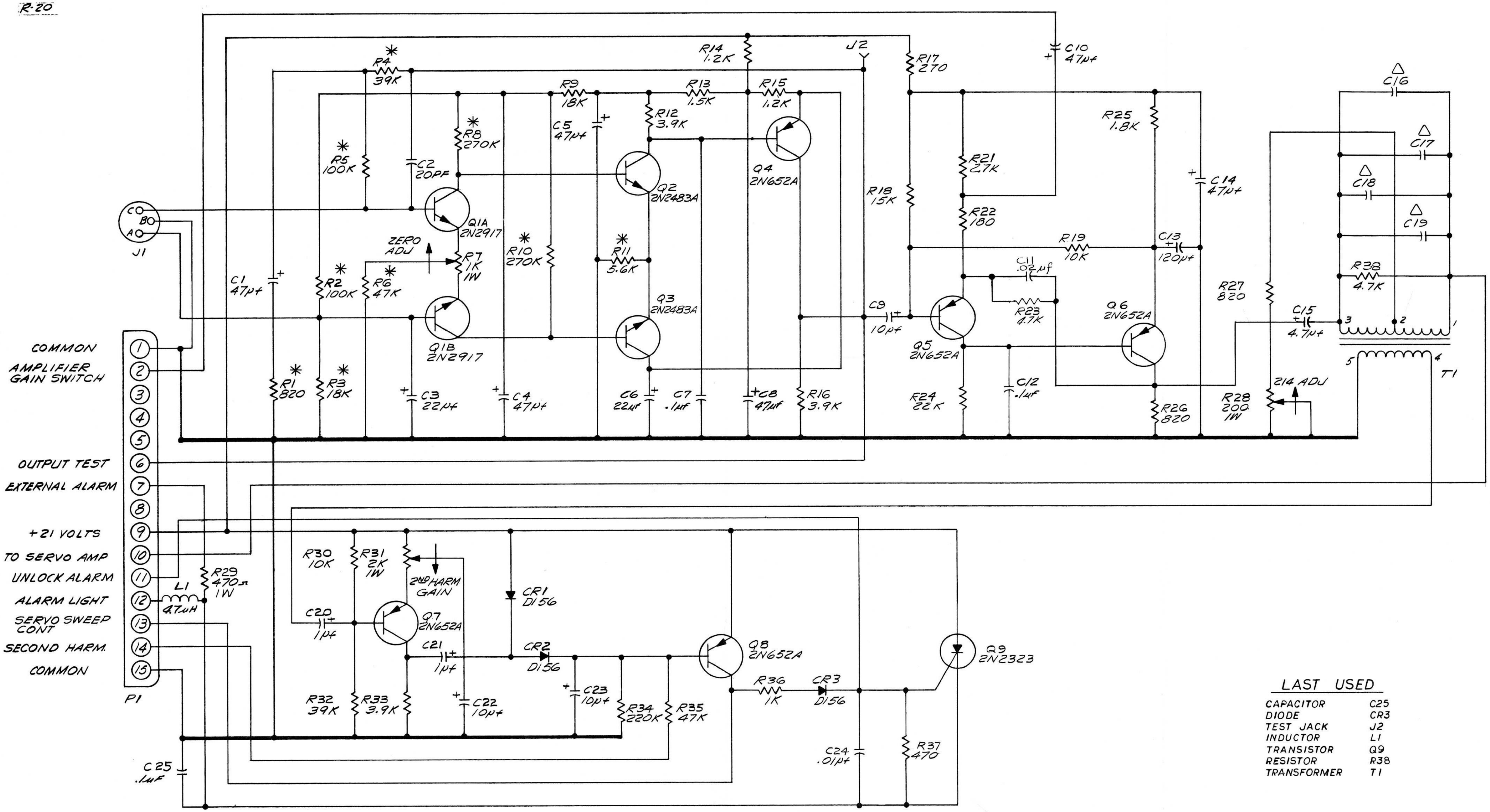
SCHEMATIC,
MULTIPLIER
R 910322 F



LAST	USED
CAPACITOR	C15
DIODES	CR15
TEST JACK	J2
TRANSISTOR	Q8
RESISTOR	R33
TRANSFORMER	T1

4. * INDICATES CORNING GLASS RESISTORS TYPE C5 (1/2W)
3. Q6 IS LOCATED ON CHASSIS AND IS SHOWN HERE FOR REF. ONLY. PIN NUMBERS SHOWN REFER TO P1
2. UNLESS OTHERWISE NOTED ALL CAP. ARE µf
1. UNLESS OTHERWISE NOTED ALL RESISTORS ARE IN OHMS, 1/4 W, 5%

SCHEMATIC, MODULATION GENERATOR & VOLTAGE REGULATOR
910357 G



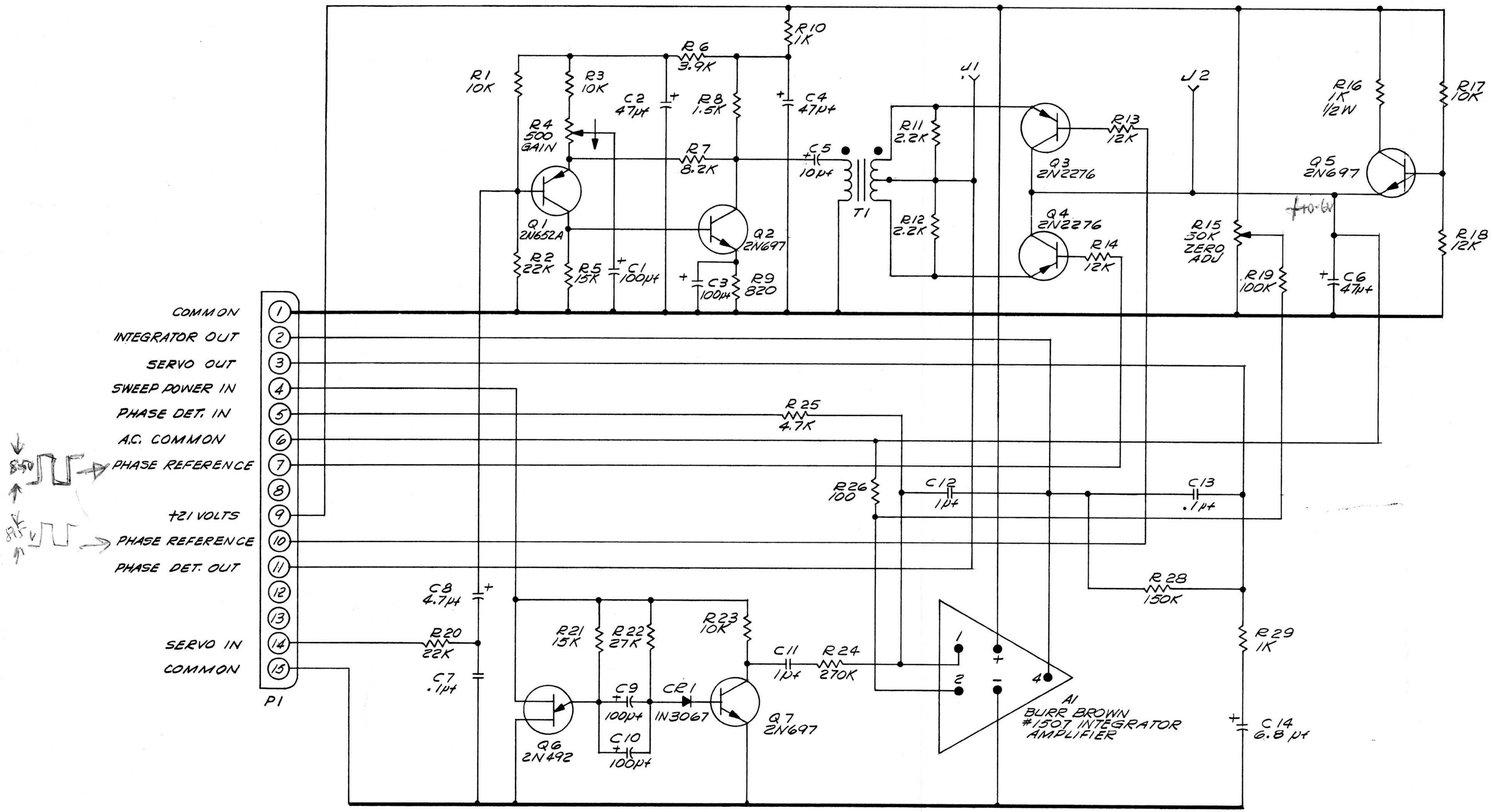
LAST USED

CAPACITOR	C25
DIODE	CR3
TEST JACK	J2
INDUCTOR	L1
TRANSISTOR	Q9
RESISTOR	R38
TRANSFORMER	T1

3. ✱ INDICATES THESE RESISTORS ARE CORNING GLASS TYPE C-20 (½W)
2. △ INDICATES THESE CAPACITORS ARE SELECTED
1. UNLESS OTHERWISE NOTED ALL RESISTORS ARE IN OHMS, ¼W, 5%

SCHEMATIC
PRE-AMPLIFIER
910381 H

R-20



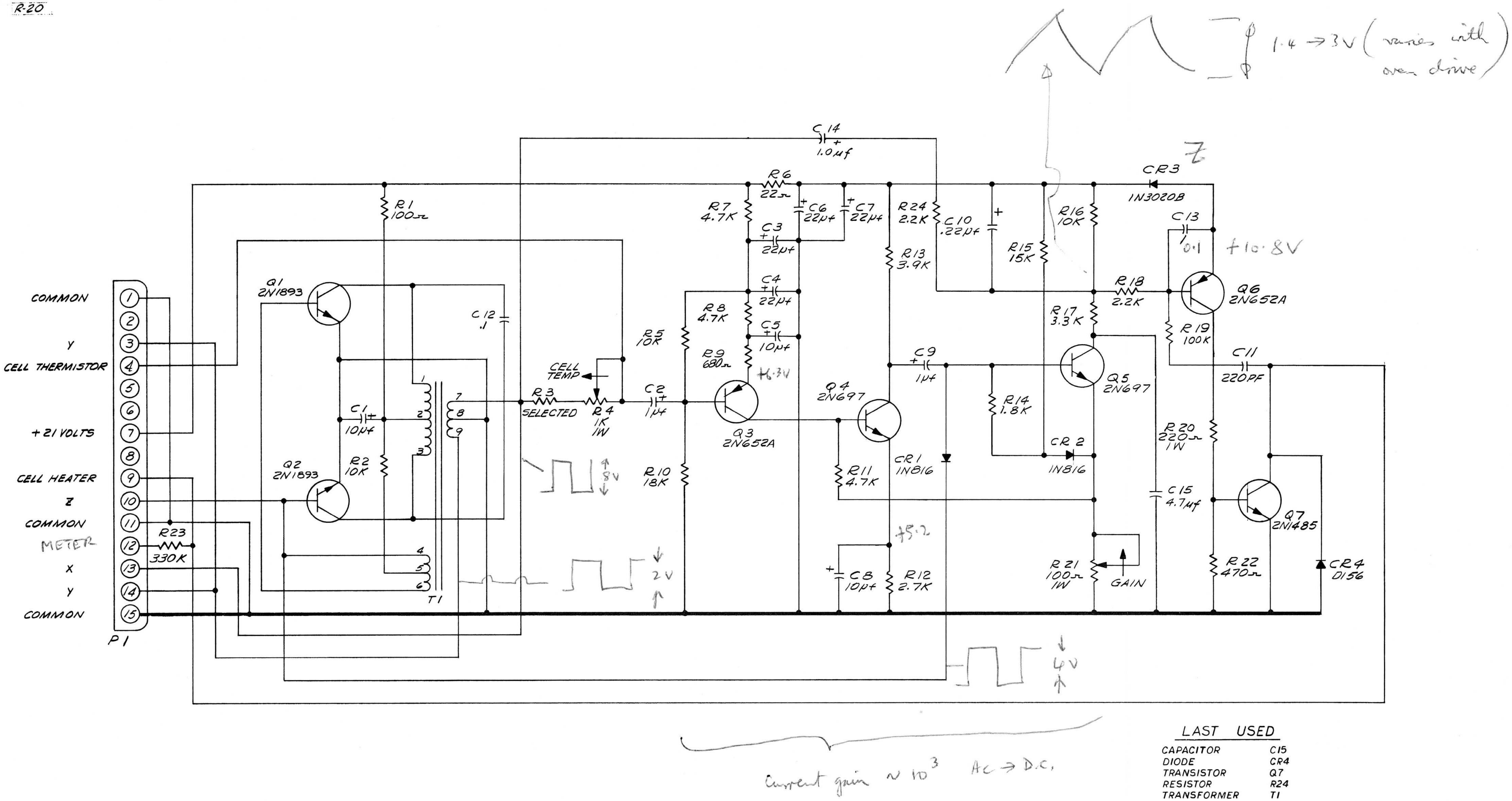
LAST USED

AMPLIFIER	A1
CAPACITOR	C14
DIODE	CR1
CONNECTOR	J2
TRANSISTOR	Q7
RESISTOR	R29
TRANSFORMER	T1

1. UNLESS OTHERWISE NOTED ALL RESISTORS ARE IN OHMS, $\frac{1}{4}$W, 5%

SCHEMATIC
SERVO AMPLIFIER
910335 C

R-20



LAST USED

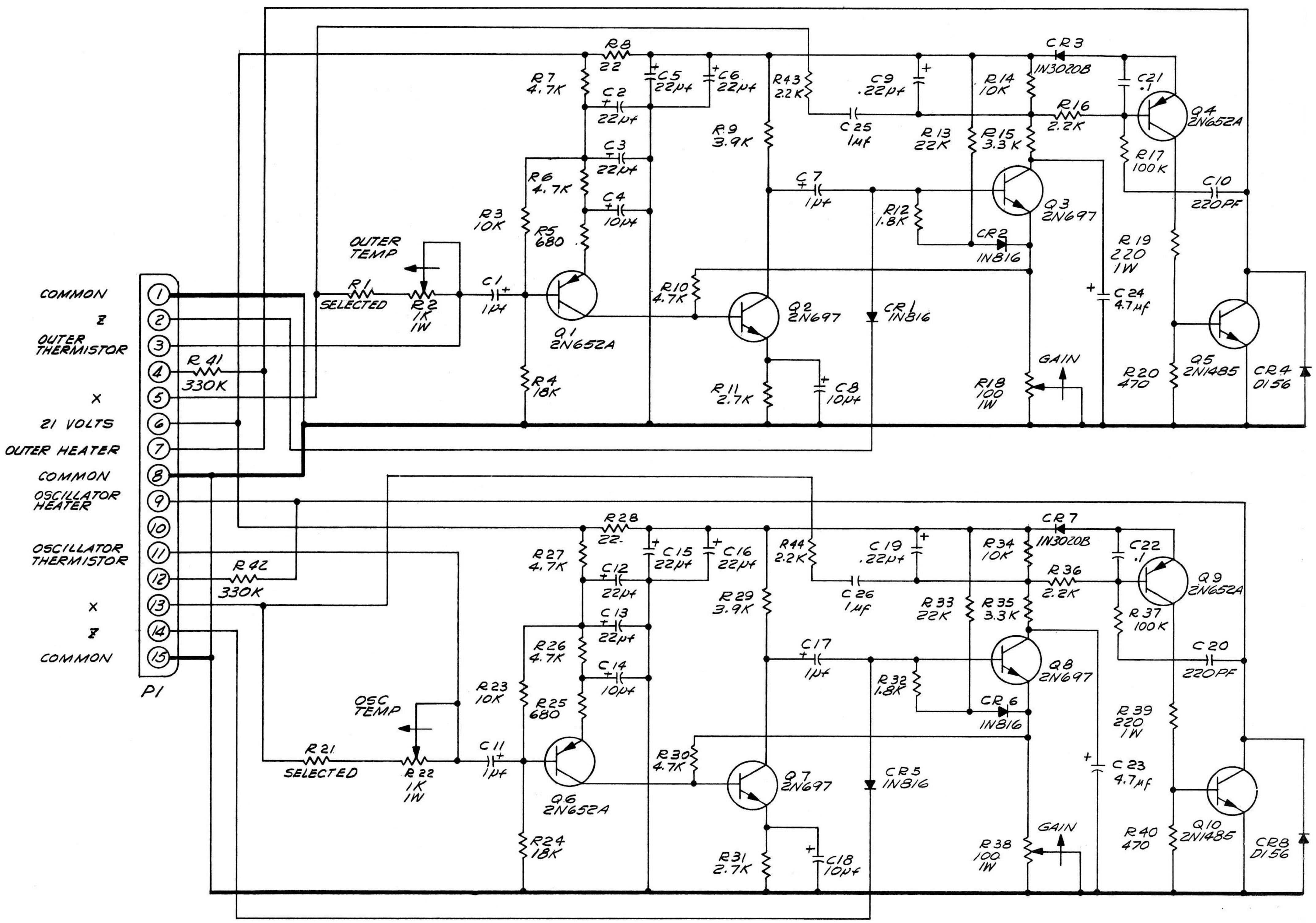
CAPACITOR	C15
DIODE	CR4
TRANSISTOR	Q7
RESISTOR	R24
TRANSFORMER	T1

2. UNLESS OTHERWISE NOTED ALL CAP. ARE IN μf

1. UNLESS OTHERWISE NOTED ALL RESISTORS ARE IN OHMS, $\frac{1}{4}$ W, 5%

SCHEMATIC
THERMOSTAT
910396 G

R-20



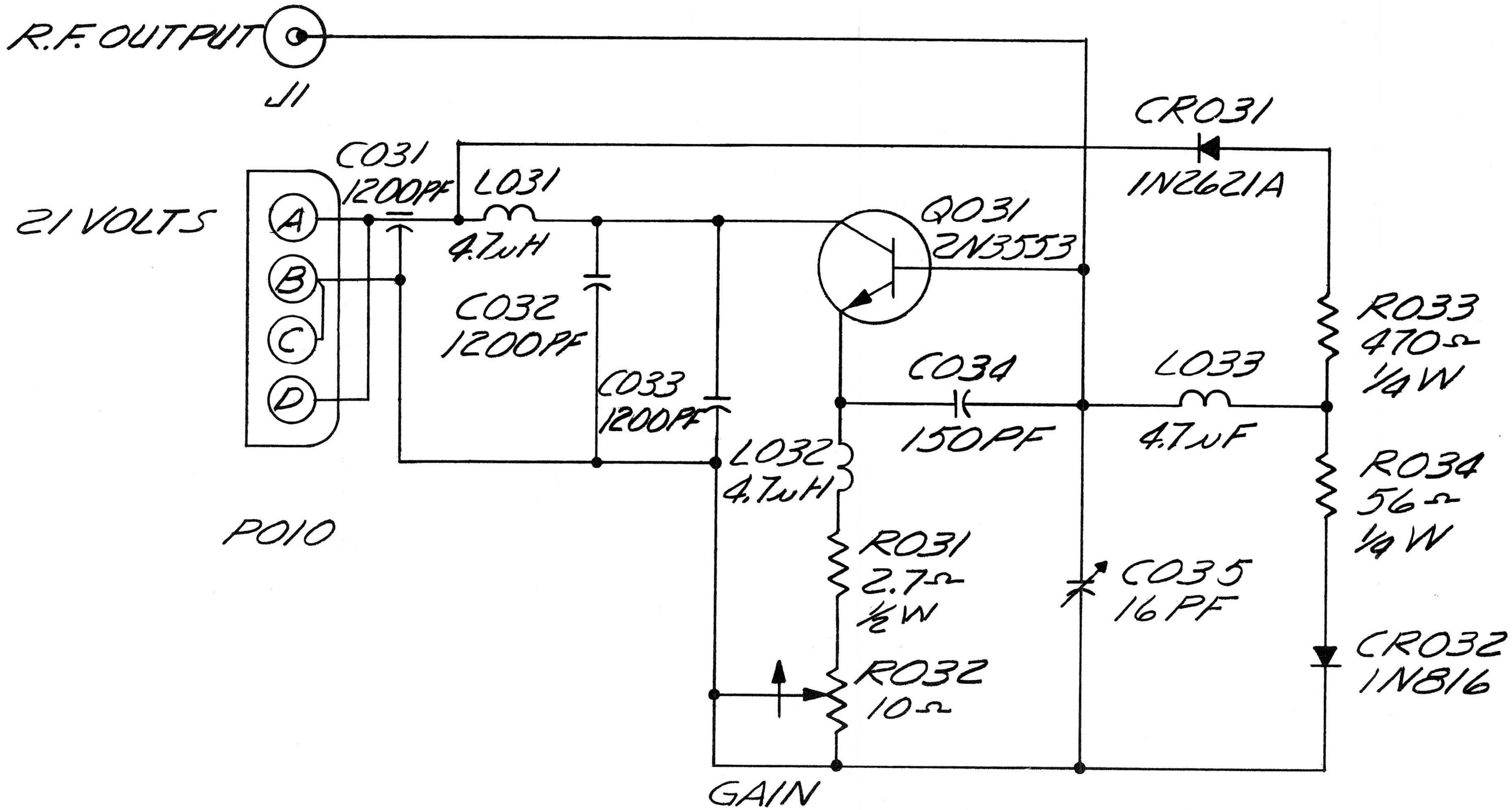
LAST USED

CAPACITOR	C26
DIODES	CR8
TRANSISTOR	Q10
RESISTOR	R44

1. UNLESS OTHERWISE NOTED ALL RESISTORS ARE IN OHMS, $\frac{1}{4}$ W, 5%

SCHEMATIC
THERMOSTAT DUAL
910397 E

R-20



C.Chandler 1-29-65

1. ALL CAPACITORS ARE 500 VOLTS

Q.E.D.

C

SCHEMATIC,
LAMP EXCITER
910473 B

CHANGED FROM	REVISED & REDRAWN	REVISED PER EO
NUM		
EO	7031	992
DFT		
CHK		
DATE	8/	
REV	H	J

DRAWN: CORNWELL, W — DATE: 8/15/66
CHECKED — DATE
APPROVED — DATE: 8/15/66
UNLESS OTHERWISE SPECIFIED: FRAC ± / DEC ± / ANG ± / FIN ✓
DIVISION: Q.E.D. — SCALE: / — CODE: C — CLASS

WIRING DIAGRAM R20

VARIAN associates, PALO ALTO 2, CALIFORNIA

SIZE — DRAWING NO: 910468 — REV: J

110P 20.

varian/quantum electronics division

quality control test procedure

MODEL / PART NUMBER		EFFECTIVE DATE	Page
R-20 TEST DATA			1 of 1

APPLICABILITY SCHEMATIC NUMBER	DESCRIPTION	ORIGINATOR	CHECKED
Rev.	R-20 SERIAL NUMBER 210	D. Parton	

1. Regulator voltage 21 VDC.
2. Maximum fundamental signal at J802 on preamp. 580 mV
3. Second harmonic signal at lock at J802 on preamp. 140 mV
4. Output signal levels: 5MHZ 1.25 VRMS
   1MHZ 1.0 VRMS
   100KHS 1.0 VRMS
5. Environmental test results:

TEMP.	Δf FROM AMBIENT	2nd HARMONIC
0 °C	+1.2 $\times 10^{-11}$	95
25 °C	Reference	90
50 °C	-3.0 $\times 10^{-11}$	40

6. Short term stability (1 second average):
   5MHZ .75 $\times 10^{-11}$
   1MHZ 1.1 $\times 10^{-11}$
   100KHZ 1.35 $\times 10^{-11}$
7. Average frequency change 1.0 $\times 10^{-11}$ in 15 days.
8. Zeeman frequency 420.18 KHZ at field bias dial setting of 796 .
9. With N A MHZ TIC crystal set field bias dial to 796 for frequency offset of 000.0 $\times 10^{-11}$ referenced to A-1.
10. At above field bias dial setting, the repeatability of frequency is .4 $\times 10^{-11}$.
11. From cold start at above field bias dial setting:

	TIME	FREQ.
	1 hour	299.72 $\times 10^{-10}$
	2 hours	299.76 $\times 10^{-10}$
FINAL	3 hour	299.99 $\times 10^{-10}$

12. Panel meter readings @ 24° ± 5°C after 3 hour warmup:

AFC 20 SIG 70 OUTER 22 CELL 28 XTAL 30

OPERATIONAL LOG
MODEL R-20 FREQUENCY STANDARD
Serial No. 210

DATE	FIELD BIAS SETTING	METER READINGS					NOTES
		AFC	SIG	OUTER	CELL	XTAL	
27/3/68	796	20	40	10	25	20	TURN ON
28/6/68							Battery replaced
16/1/69	794	-30	80	20	30	30	
5/3/69	794	+8	65	25	30	30	
22/4/70		0	60	28	30	33	
20/5/70	7.86						