VARIAN ASSOCIATES
INSTRUMENT DIVISION
TECHNICAL SUPPORT
MAGNETICS GROUP

# EM-390 TRAINING NOTES

## SECTION 16.0
## AUTOSHIM

### 16.1 FUNCTION

**This circuit applies 0.5 Hz modulation to the Y-Axis Shim coils in order to ascertain the degree of homogeneity efficiency in the Y-Axis. The resultant modulated output of the sample resonance in the Lock Channel is phase-detected to determine homogeneity error. Any error signal is integrated and applied as a homogeneity correcting DC level to the Y-Axis shim coils.**

### 16.2 THEORY OF OPERATION

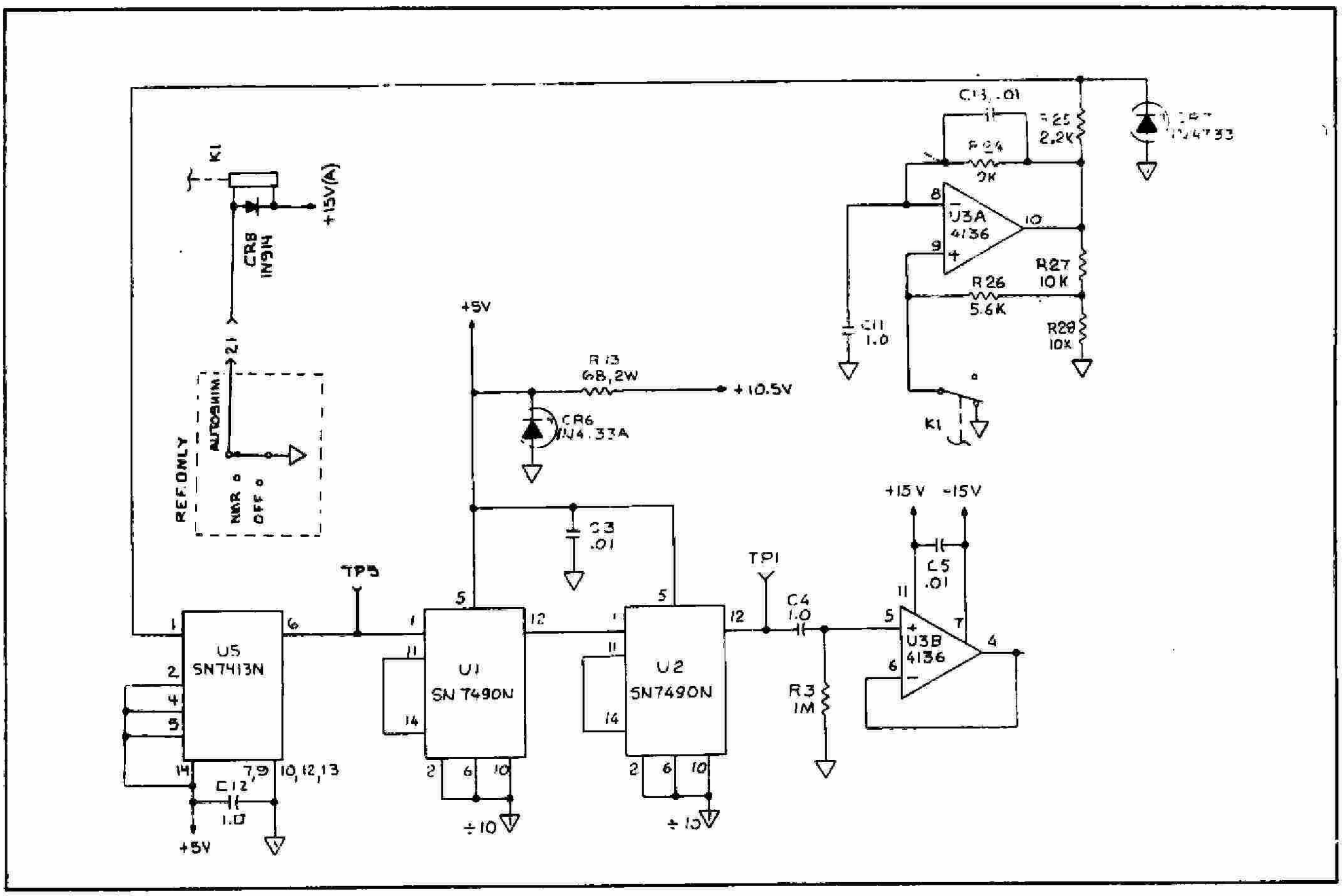


FIGURE 16-1. 0.5 Hz MODULATION

The origin of the 0.5 Hz modulation for the Y-Axis shim coils is a 50 Hz RC oscillator U3A. The AUTOSHIM position of the LOCK MODE switch energizes relay K1 which removes the ground from the non-inverting input to U3A. This allows the circuit to oscillate at the frequency of 50 Hz determined by the selection of the RC components in the stage.

The output is applied across CR7, a 5.1 volt zener diode. This will limit the output level to 5.7 volts peak-to-peak from -0.6 volts forward bias point of CR7 to +5.1 volts reverse bias point.

This semi-square wave signal is applied to U5, a Schmitt trigger squaring circuit. The output of U5 is a TTL 0 to 4 volt peak balanced square-wave at TP5.

This output is applied to U1 which has a divide-by-five circuit between pins 1 and 11 and a divide-by-two circuit between pins 14 and 12. This circuit is configured as a divide-by-10 to produce a 5 Hz TTL Logic signal to U2.

The 5 Hz is applied to U2 which is configured the same as U1 producing a divide-by-ten output or 0.5 Hz at TP1. This is applied to comparator U3B which serves as an isolation-squaring modulation output stage.

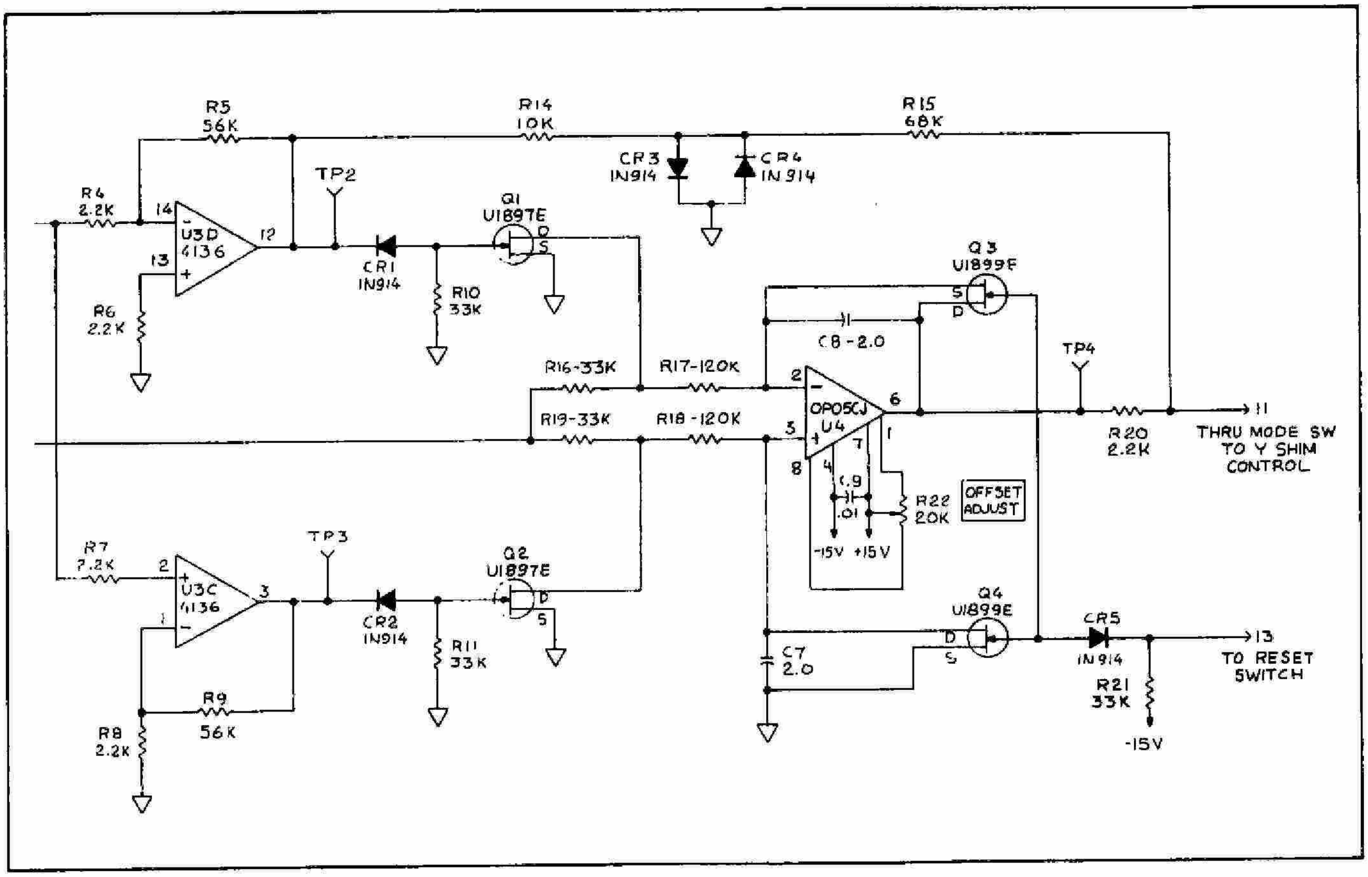


FIGURE 16-2. PHASE DETECTOR/INTEGRATOR

The 0.5 Hz from the comparator is applied to U3D inverting input and to U3C non-inverting input. The outputs at TP2 and TP3 are complementary or 180° out of phase. The signal present at TP2 is applied across parallel limiting diodes CR3 and CR4 to limit the squarewave at that point to 1.2 volts peak-to-peak (-0.6 to +0.6 volts). The signal is then applied to the Y-Axis Shim Control input as a modulation signal on the Y-Axis shim coils. The squarewaves from U3C and U3D are limited by series diodes CR2 and CR1 and applied to the switching FETs in the phase detector, Q1 and Q2.

The signal from the Lock Channel is applied through R16 and R19 to the drains of the two phase detector switch FETs. This signal is either in-phase or exactly 180° out of phase with the reference depending on the direction of error in the homogeneity setting.

When the gate of the phase-detector switch is positive, the signal on the drain to U4 input is ground. When the gate of the phase-detector switch is negative, the signal on the drain to U4 is the same as input from the Lock Channel.

Assume the signal is exactly in phase with the reference modulation. During the positive portion of the input then the switch Q1 is conducting and ground is applied to the inverting input of U4. Due to the switching signal phase inversion in U3C, Q2 is cut off applying the positive input to the non-inverting input of U4 which will produce a positive in the output (TP4). During the negative half-cycle of the input, Q1 is cut off applying a negative signal to the inverting input of U4 producing a positive in the output at TP4. Q2 of course is conducting applying 0 to U4 non-inverting input. For the in-phase condition, the signal input is detected and integrated as a positive output signal.

It should be self-evident that an out-of-phase (180°) relation between the reference modulation and the signal will produce a negative level on the output.

Capacitor C7 in the non-inverting input and capacitor C8 across the operational amplifier perform the analog integration. These are reset by the LOCK MODE switch in the STAND-BY and NMR LOCK positions by applying ground to FETs Q3 and Q4. Ground causes these FETs to conduct fully placing about 100 ohms impedance in the capacitor discharge path rapidly discharging them to zero charge storage. When the LOCK MODE switch is placed in AUTOSHIM, the ground from pin 13 is removed and the gates of Q3 and Q4 go to -15 volts for complete shut-off enabling the integrating capacitors to change their charge.

The integrated DC output is applied to the Y-Axis Shim Control input to automatically vary the homogeneity.

## 16.3 TESTS AND ADJUSTMENTS

1. Lock the signal on an NMR line and turn on the AUTOSHIM.

   a. Monitor TP5 with an oscilloscope and observe a 40-60 (16 to 25 millisecond) Hz, 3 to 4 volts p-p, square wave signal.

   b. Monitor TP1 with an oscilloscope and observe a 0.4 to 0.6 Hz (1.6 to 2.5 second), 3 to 4 volt peak-to-peak, square wave signal.

   c. Monitor TP2 and observe the same signal as TP1 (180° phase relationship) at 12 to 14 volts peak-to-peak.

   d. Monitor TP3 and observe the same signal as TP1 (0° phase relationship) at 12 to 14 volts peak-to-peak.

2. Ground the junction of R12 and R23.

   a. Monitor TP4 with a DVM capable of 1 millivolt resolution.

   b. Adjust R22 on the Autoshim card for a drift rate of less than ±15 millivolts/minute.

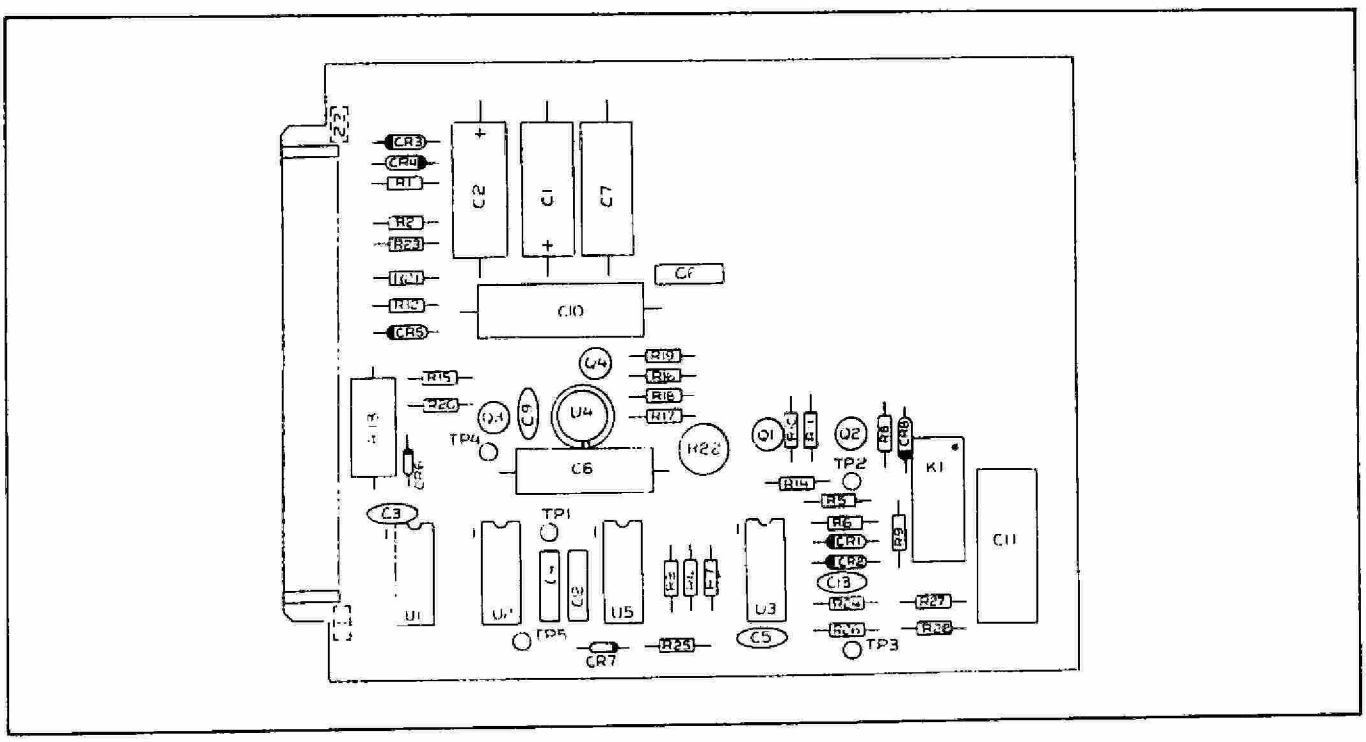


FIGURE 16-3. AUTOSHIM COMPONENT LAYOUT

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SECTION 17.0

Y-AXIS SERVO

## 17.1 FUNCTION

The Y-Axis Servo portion of the Recorder Amplifier PCB receives the output signal from the Observe Channel and translates this into mechanical pen movement to display the signal amplitude on the recorder.

## 17.2 THEORY OF OPERATION

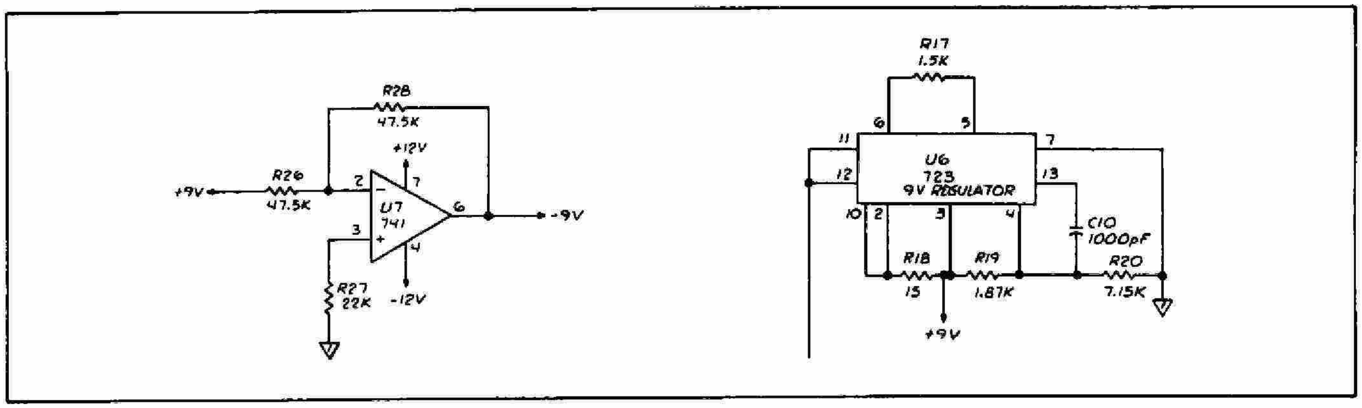


FIGURE 17-1. ±9 VOLT SUPPLY

The +24 volt unregulated Recorder Supply voltage is applied at pins 11 and 12 of U6, integrated circuit voltage regulator. The resistance ratios in this circuit cause the regulator to regulate at +9 volts DC. R18 is the current limiter sense and decreases the output when 40 milliamperes of current is drawn in the +9 volt load circuits.

The +9 volt output is applied to U7 which is a conventional inverting operational amplifier whose gain is -1. With +9 volts input, the output is -9 volts DC.

The output of the Observe Channel is applied to U1, differential amplifier. The DC level of the output of U1 is controlled by the recorder panel control BASE LINE ADJUST which applies a DC offset level to the inverting input of U1.

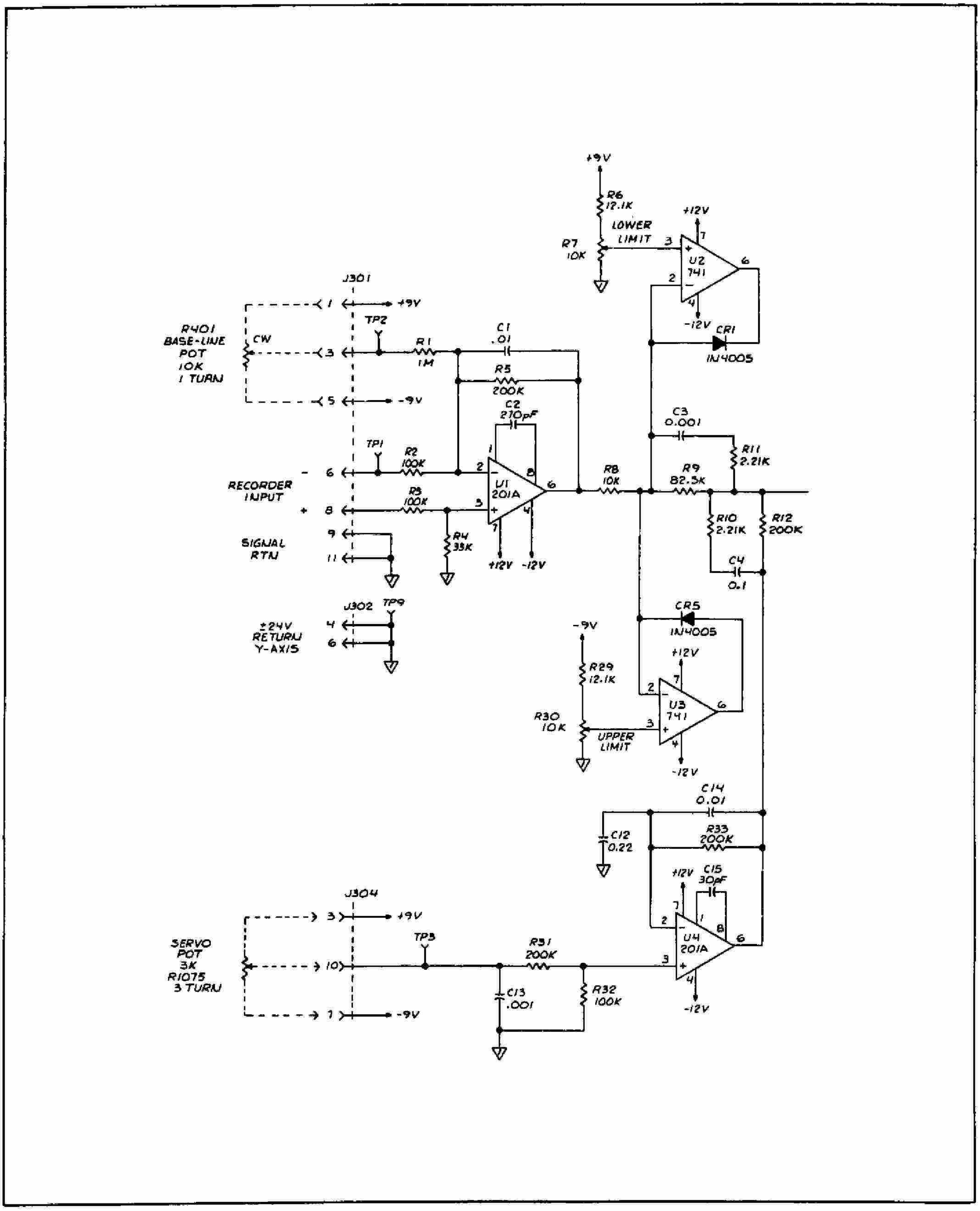


FIGURE 17-2. INPUT CIRCUITS

The amplified input is applied to the summing junction of operational amplifier U5 (not shown in Figure 17-2, See 17-3). The maximum levels of U1 output are controlled by Upper and Lower Limit clamp circuits U2 and U3. When the output of U1 exceeds the voltage in the polarity of the reference applied to the non-inverting inputs of U2 and U3, the signal is clamped at that point and will go no higher. This is to prevent the pen from being driven into the mechanical stops.

A null-anticipatory input from the Y-Axis Servo Potentiometer "bucks out" the input signal through U1. This is simply a potentiometer gauged to the Y-Axis drive motor that produces a voltage of opposite polarity to the output of U1. This voltage is buffered by U4 (gain = 1) and applied to the summing junction of U5.

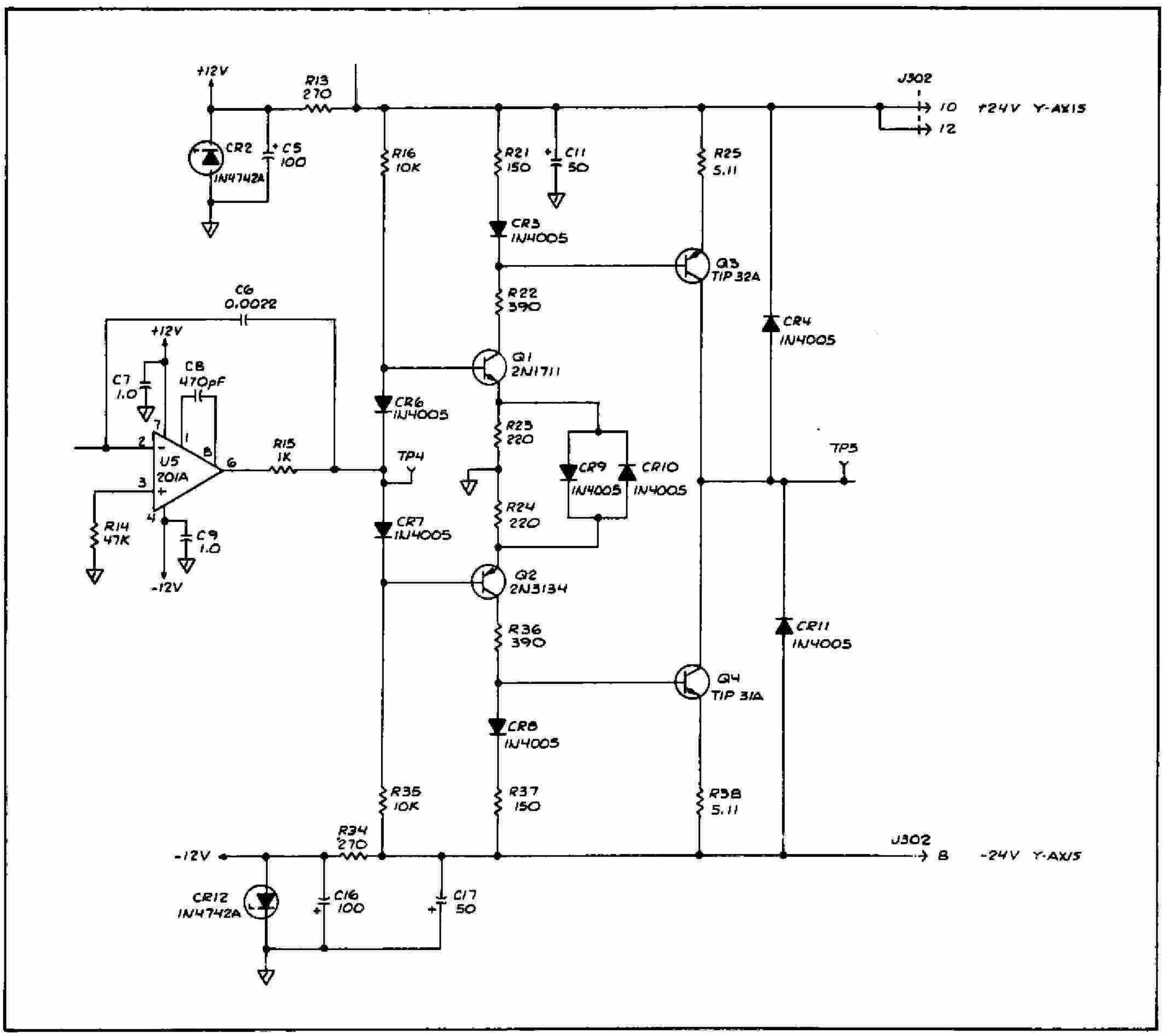


FIGURE 17-3. Y-AXIS AMPLIFIER

The combined signals in the summing junction of U5 are amplified and applied to the output power amplifiers. The inverted signal from U5 drives Q1 and Q3 on the positive DC levels and Q1 and Q4 on the negative DC levels. The forward biased diodes CR6 and CR7 not only compensate for the base-emitter biasing of Q1 and Q3 for small signals but also compensate automatically for temperature since their junction characteristics are similar to the base-emitter junction of Q1 and Q3.

The + and -12 volt sources for the operational amplifiers are derived from zener diodes CR2 and CR12.

The signal at TP5 to drive the motor is simply the DC amplified combined signal at the summing junction of U5.

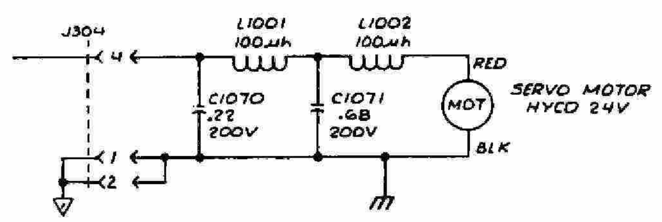


FIGURE 17-4. Y-AXIS SERVO MOTOR

The amplified DC output at TP5 of Figure 17-3 is applied to the DC Servo Motor shown in Figure 17-4. As the motor drives, the pen carriage moves in the Y-Axis, and the servo potentiometer previously described is rotated to deliver the null-anticipatory signal back to the input.

## 17.3 Y-AXIS TESTS

1. Turn the recorder ON.

   a. Check the voltage at J301-1 which should be +9 volts ± 0.5 volt.

   b. Check the voltage at J301-5 which should be -9 volts ± 0.7 volt.

   c. Check the voltage at pin 7 of U3 which should be +12 volts ± 0.6 volt.

   d. Check the voltage at pin 4 of U3 which should be -12 volts ± 0.6 volt.

2. Ensure the servo amplifier is free of spurious oscillations. A typical rise and fall time is 300 to 400 milliseconds and no overshoot at 100 percent full-scale amplitude.

3. The input sensitivity shall be 1.5 volts ± 0.1V peak-to-peak for full scale deflection. Measure this value between J301-8 and J301-9.

4. The recorder frequency response is about 2 Hz at -3 dB point at 50 percent full scale deflection.

5. The Y-Axis deadband is about 1 mm.

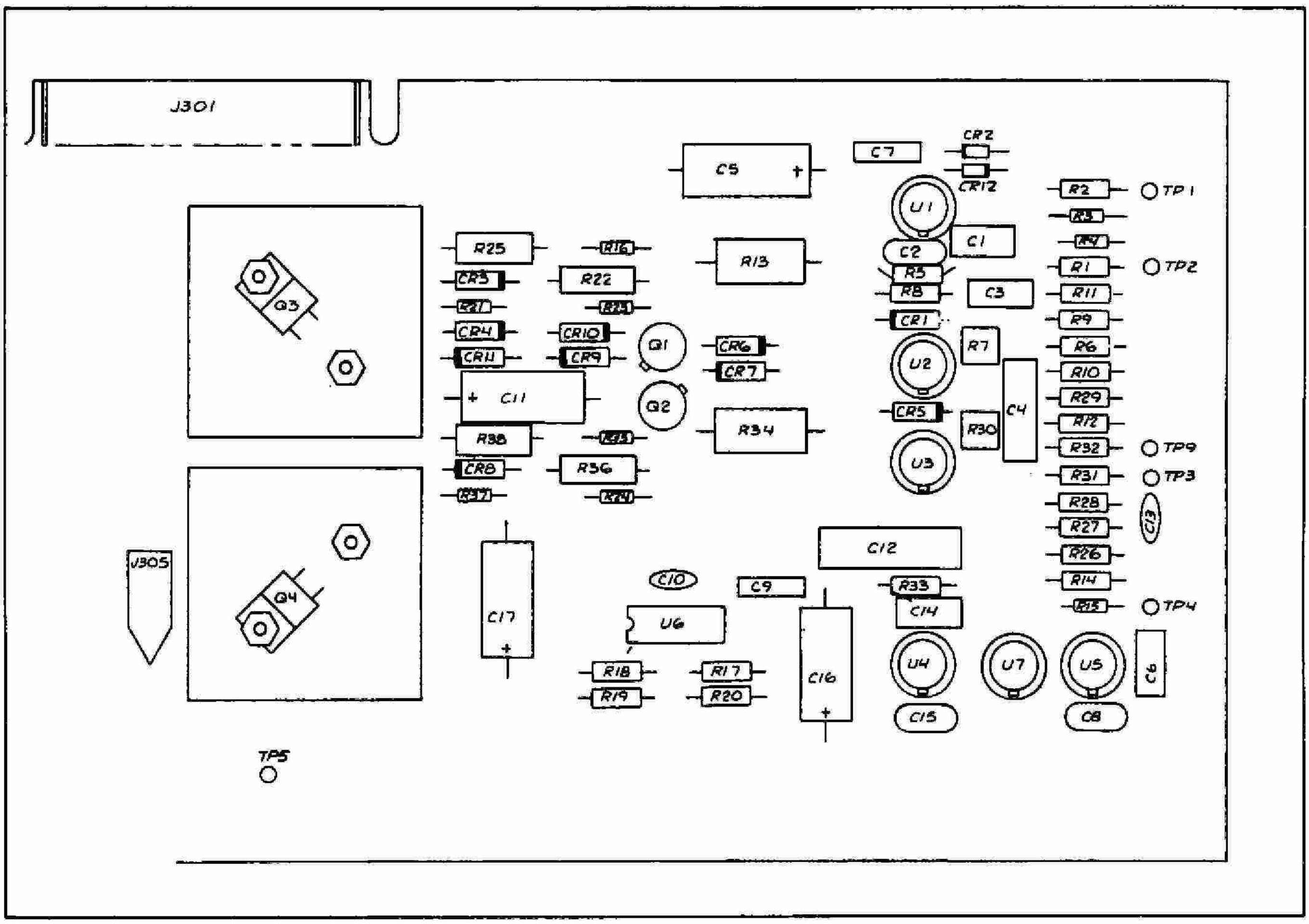


FIGURE 17-5. Y-AXIS PART LAYOUT

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# SECTION 18.0
# X-AXIS SERVO LOGIC

## 18.1 FUNCTION

The X-Axis Logic circuits determine both the rate and direction of recorder motion as directed by front panel switch positions. The circuit translates these commands to the desired movement in the X-Axis.

## 18.2 CIRCUIT THEORY

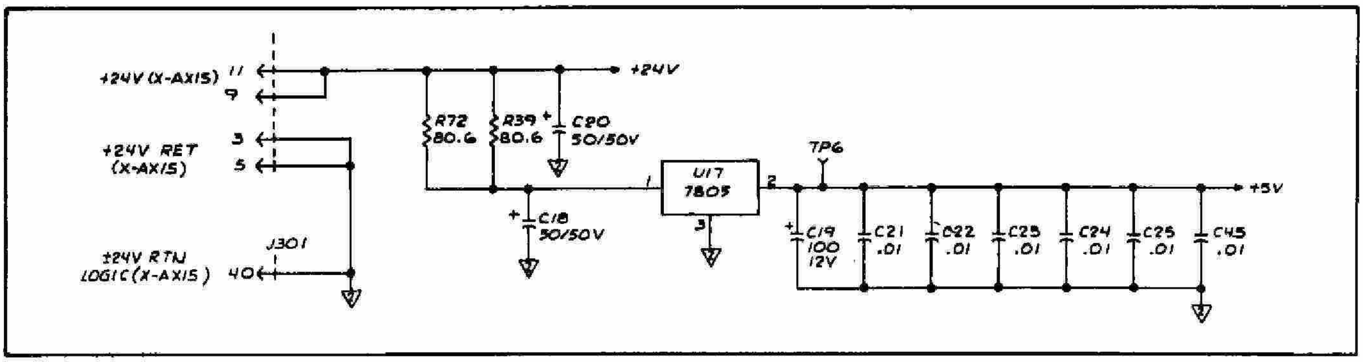


FIGURE 18-1. +5 VOLT SUPPLY

The +24 volt Unregulated Record Supply is applied after filtering to an integrated circuit voltage regulator, U17. The output is filtered by several capacitors which are located throughout the load circuits.

An RC oscillator U18 develops the driving frequency for the X-Axis Logic circuits. The IC voltage supply is derived from the + and -24 volt Unregulated Recorder Supplies with two 15 volt zener diodes, CR20 and CR21. Since the RC components in the IC U18 circuit determine the frequency of operation; varying the value of R60, one of these components, varies the frequency for exactly 206 Hz in the output.

The output of U18 drives a squaring-buffer amplifier Q10. The diode CR22 limits the negative excursion of the signal and the base-emitter junction of Q10 limits the positive excursion which produces a square wave in the output of Q10 at TP8 of 206 Hz at a nominal 4 volt amplitude.

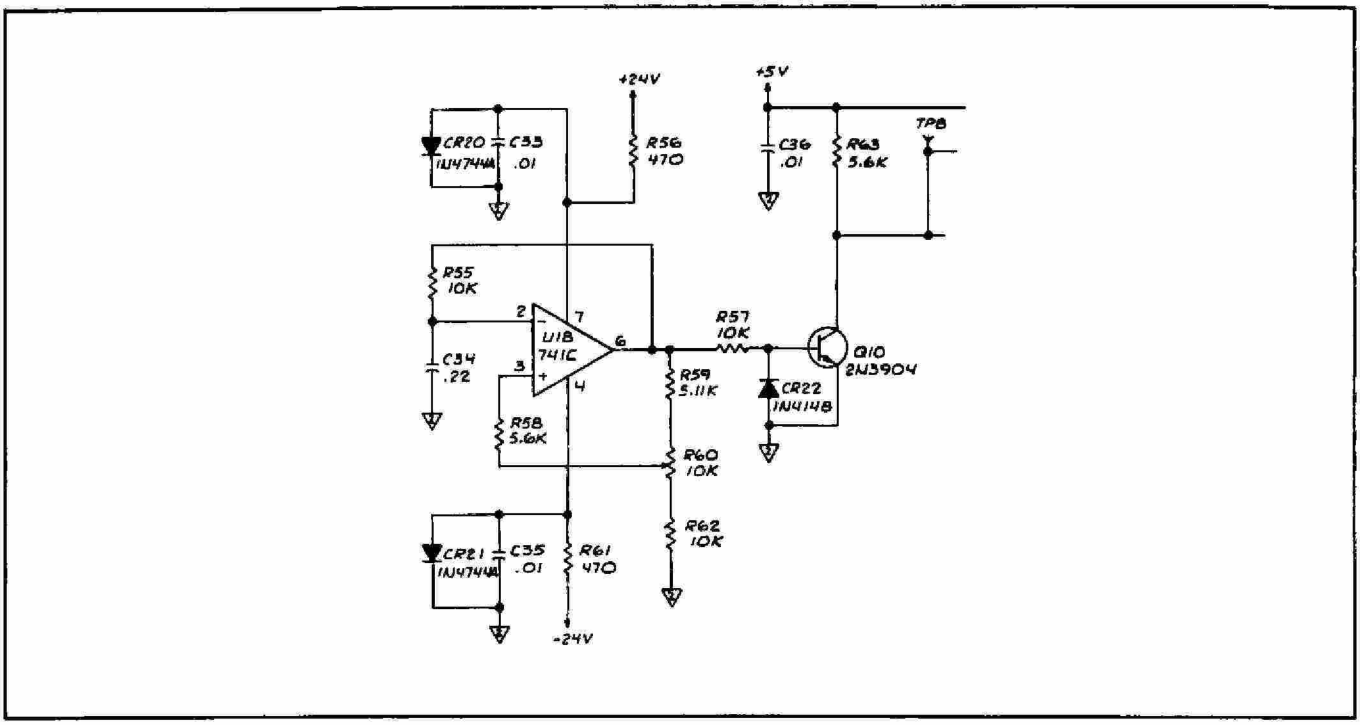


FIGURE 18-2. 206 Hz OSCILLATOR

A. SWEEP TIME DIVIDER

1. ÷2 0.5 MINUTE SCAN 103 Hz

The 206 Hz measured at TP8 is applied directly to NAND gate U22-11 at pin 12. The SWEEP TIME SELECT switch on the front panel applies ground to one of six input select lines. For 0.5 minute scan, this select line at J302-39 goes low when selected to U24-2 inverter. Notice that with no input, all the input lines are pulled up to +5 volts and only one may go to ground by switch selection. The inverted low in U24-2 is applied as a high to pin 13 of U22-11.

The output of U22-11 then is 206 Hz TTL waveform to U21-12, a bi-stable multivibrator or flip-flop which is configured as a divide-by-2. This is simply a J-K flip-flop with both J and K tied back to +5 volts.

The output at TP7 then is a divided-by-2 signal or 103 Hz drive frequency.

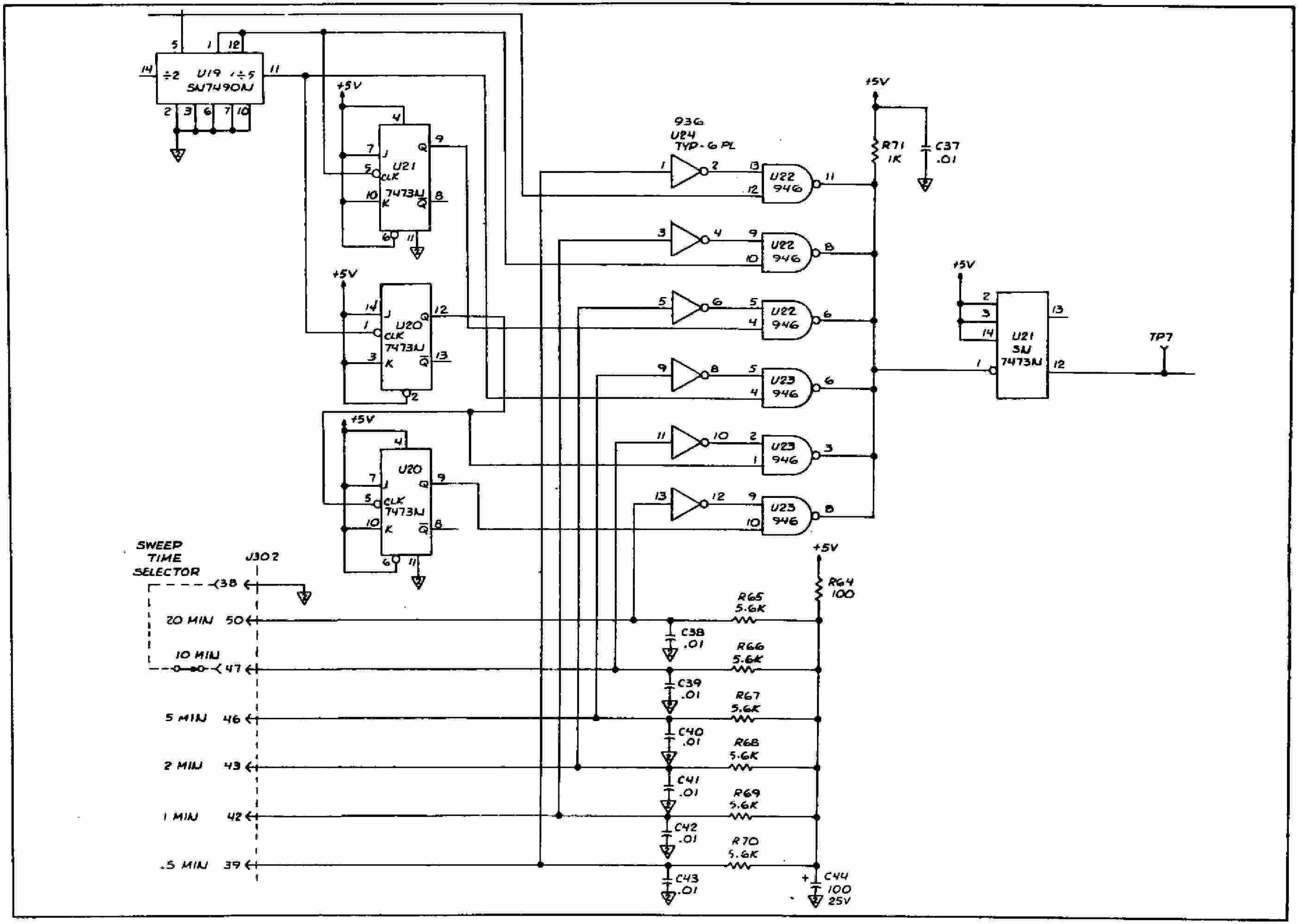


FIGURE 18-3. SWEEP TIME DIVIDER

2. ÷4 1 MINUTE SCAN 51.5 Hz

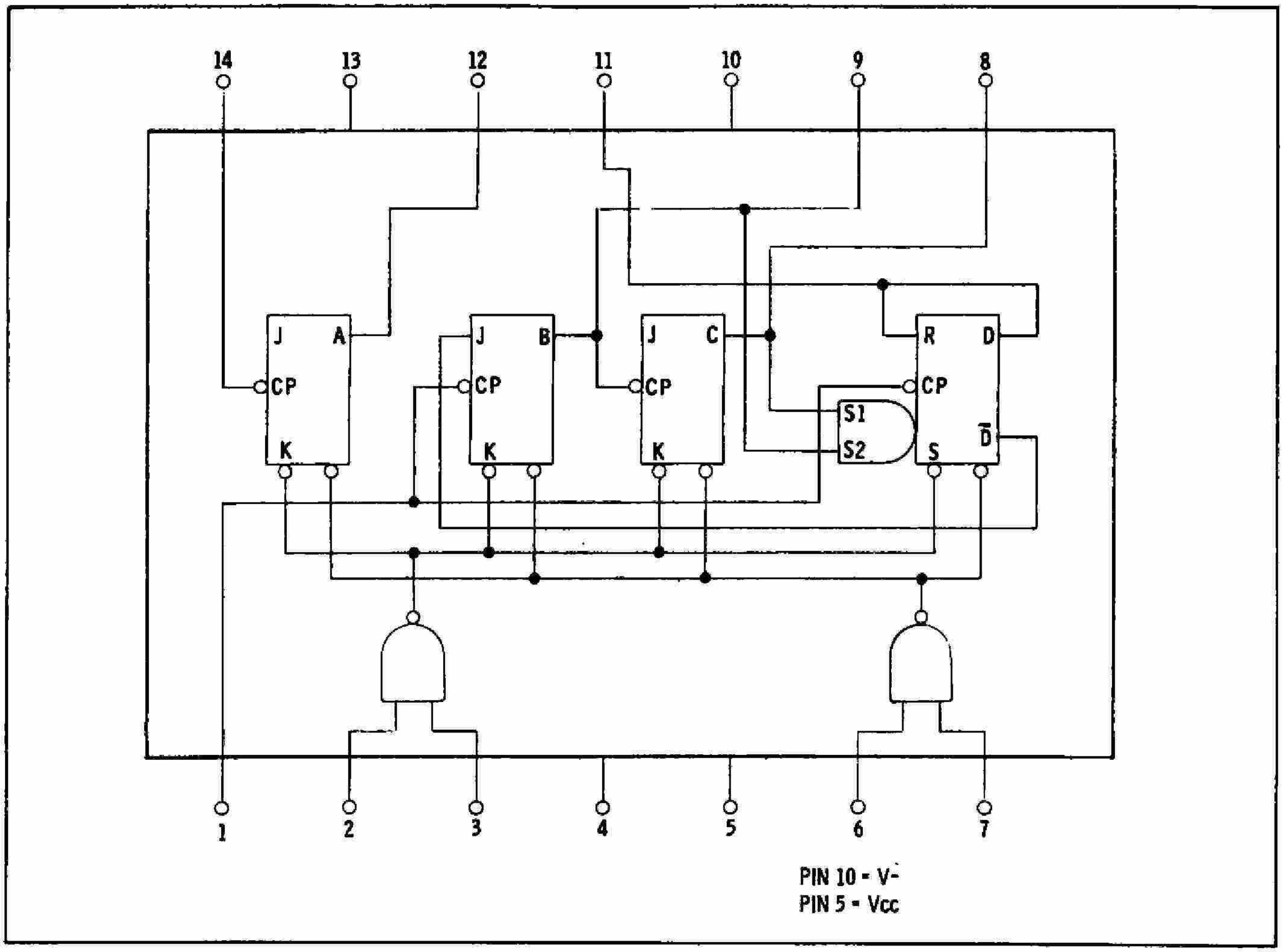


FIGURE 18-4. IC TYPE 7490 DIAGRAM

The 206 Hz of TP8 is applied to pin 14 of U19 decade divider. The circuit is so configured that there is a divide-by-two between pins 14 and 12 of the logic chip. The output of pin 12 then is 103 Hz to U22-8 pin 10. When 1 minute scan time is selected, the low on pin J302-42 is inverted to a high in U24-4 to pin 9 of U22-8 allowing the 103 Hz to pass to U21-12, the divide-by-2.

The total division then is 4 and the output at TP7 is 51.5 Hz drive frequency.

3. ÷8 2 MINUTE SCAN 25.75 Hz

The 206 Hz oscillator frequency at TP8 is applied again to U19 pin 14. This is divided-by-2 at the pin 12 output and is now applied to U21-9, a J-K flip-flop with J and K tied back to Vcc for a divide-by-2 function. The divided-by-four frequency is then applied to U22-6 pin 4.

When 2 minute scan is selected, the low on J302-43 is inverted to a high in U24-6 to pin 5 of U22-6, enabling the 51.5 Hz to pass. This is applied to U21-12, the output stage and a divide-by-two circuit.

The total division then is 8 and the output at TP7 is 25.75 Hz drive frequency.

4. ÷20 5 MINUTE SCAN 10.3 Hz

The 206 Hz oscillator signal at TP8 is applied to decade divider U19. The signal frequency is divided-by-two between pins 14 and 12 and then divided-by-five between pins 1 and 11. The output of pin 11 of U19 is applied to U23-6 pin 4. The low when 5 minute scan is selected at J302-46 is applied through inverter U24-8 as a high to U23-6 pin 5. The divided-by-ten or 20.6 Hz is then passed to U21-12 for a final divide-by-two operation.

The output of U21-12 is a 10.3 Hz signal drive-drequency with a total division of 20.

5. ÷40 10 MINUTE SCAN 5.15 Hz

The 206 Hz oscillator signal at TP8 is applied to decade divider U19 where it is first divided-by-two between pins 14 and 12 and then divided-by-five between pins 1 and 11. The output of U19 is applied to U20-12 for a further divide-by-two before being applied to U23-3 pin 1. The low at J302-47 when 10 minute scan is selected is inverted to a high in U24-10 to U23-3 pin 2. The 10.3 Hz output of U23-3 is applied to U21-12 and is divided-by-two again.

The total division then is 40 and the output drive frequency at TP7 is 5.15 Hz.

6. ÷80 20 MINUTE SCAN 2.575 Hz

The 206 Hz oscillator output at TP8 is applied to U19 decade divider. There the signal frequency is divided-by-2 between pins 14 and 12 and then divided-by-5 between pins 1 and 11. The divided-by-10 output of U19 is applied to U20-12 where it is further divided-by-two for a divided-by-20 input to U20-9, another divide-by-2. The output of U20-9 to U23-8 pin 10 is a divide-by-40 signal. The low at J302-50 when 20 minute scan is selected is inverted to a high in U24-12 enabling U23-8 to pass the 5.15 Hz signal to U21-12 divide-by-two circuits.

The total division then is 80 and the drive frequency at TP7 is 2.575 Hz.

## B. DIRECTION AND PEN CONTROL

**U16-8 is a NAND gate with the drive frequency from TP7 applied to pin 9 on its input. This gate will pass the drive frequency if and only if the input on pin 10 of U16-8 is high. The direction control circuits determine this input logic level.**

### 1. STATIC STATE—NO SCAN SELECTED, STOP DEPRESSED

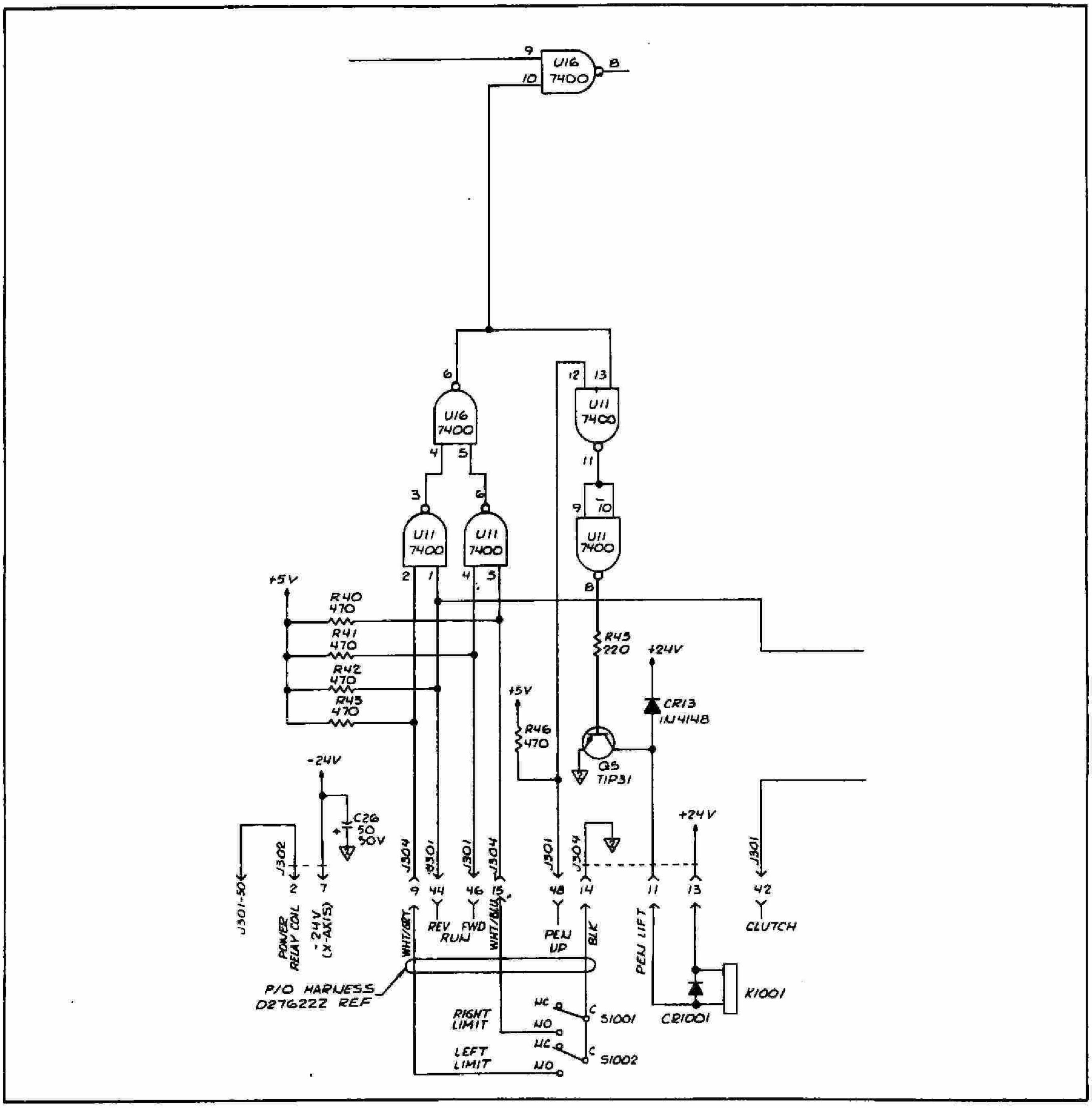


FIGURE 18-5. DIRECTION CONTROL

With neither FORWARD nor REVERSE SCAN selected, (STOP depressed), the inputs at J301 pins 44 and 46 are both low. These lows are applied to U11-3 pin 1 and U11-6 pin 4. Regardless of the logic state of the other inputs, the outputs of U11-3 and U11-6 are forced to be high. The highs from U11-3 and U11-6 are applied to pins 4 and 5 of U16-6 forcing its output to go low.

The low from U16-6 to U16-8 blocks the drive frequency preventing it from passing to the rest of the circuits ensuring the motor is stopped. The low is also applied to U11-11 producing a high in its output. Note that this is the same condition that the PEN UP switch position would produce with a low to U11-11 pin 12 through J301-48. The high from U11-11 is inverted to a low in U11-8 cutting off Q5. With Q5 cut off, K1001 is not energized and the pen is up.

With neither FORWARD nor REVERSE selected, the STOP button is depressed placing ground at J301-42 energizing the clutch relay to disengage the drive motor from the recorder. In this mode the recorder may be manually moved to any desired position.

2. FORWARD SCAN SELECTED

When FORWARD SCAN is selected, the low from J301-46 is removed from U11-6 pin 4. In the absence of RIGHT LIMIT contact, pin 15 of J304 is also open (logic high in TTL Logic) applying a logic high to U11-6 pin 5. The output of U11-6 goes low to U16-6. The output of U16-6 then goes high enabling U16-8 to pass the drive frequency to the 4-Phase generator. The high from U16-6 is also applied to U11-11 input pin 13. In the absence of a PEN UP command at pin J301-48, pin 12 of U11-11 is also high causing the output of U11-11 to go low. This is inverted in U11-8 to a high which turns on Q5 which energizes K1001 bringing the pen <u>down</u> on the paper to the "write" position. Since STOP is no longer selected, the ground at J301-42 is removed and the clutch relay de-energizes engaging the motor and mechanical drive of the recorder and the recorder carriage moves to the right.

This motion continues until the RIGHT LIMIT switch is contacted which applies a low (ground) through J304-15 to U11-6 pin 5. The output of U11-6 goes high, U16-6 output goes low, the drive frequency through U16-8 is blocked, and the pen relay is de-energized and the pen comes up off the paper. Notice that the clutch is still engaged (relay de-energized) and the carriage <u>must not be</u> moved by hand. The recorder will remain in this position until either REVERSE DIRECTION is selected or STOP is depressed and the recorder is moved manually.

3. REVERSE SCAN SELECTED

When REVERSE SCAN is selected, the low from J301-44 is removed from pin 1 of U11-3. In the absence of LEFT LIMIT contact, pin 9 of J304 is open (logic high) applying a logic high to U11-3 pin 2. The output of U11-3 then goes low to U16-6 whose output then goes high. This enables the drive frequency to pass, brings the pen down on the paper, and de-energizes the clutch to engage the motor and the carriage. The recorder moves left until the LEFT LIMIT is contacted and then stops.

C. FOUR PHASE MOTOR DRIVE

In Figure 18-6, the four phase generator circuits are shown. These circuits will translate the single train of series input pulses to four parallel outputs each differing from the others by integral multiples of 90°. These outputs will be applied to switching transistors which will either turn on current in a motor winding or cut it off depending on the transistor input level. Each full phase rotation (four input pulses) causes the motor to make eight steps and one complete mechanical rotation of 360°. We will discuss the operation starting from an assumed steady state (no input) and determine the phase rotation sequence for each mode of operation.

1. T=0, STATIC STATE—NO SCAN SELECTED, STOP DEPRESSED

With no scan selected, the input to these circuits is a high from U16-8 to U12-9 and to U16-3. See Figure 18-7 waveforms and locate this input under t=0. At the same time assume that the flip-flops U12-9 and U12-12 are both reset (Q=0, Q-bar=1) with the outputs as shown in Figure 18-7.

The high from U16-8 does nothing to change the states of these flip-flops as they remain in their current state until a negative going wavefront appears at the clock input.

The high from U16-8 is inverted to a low in U16-3 and every gate to which this output is applied will have a high in its output. That is, the outputs of U10-6, U10-8, U9-8, and U9-12.

The low from U12-9 (Q) is applied to and produces a high from U10-12, U10-8 (repeat), U15-3, and U9-12 (repeat).

The low from U12-12 (Q) is applied to and produces a low from U10-12, U9-8, U9-6, and U9-12.

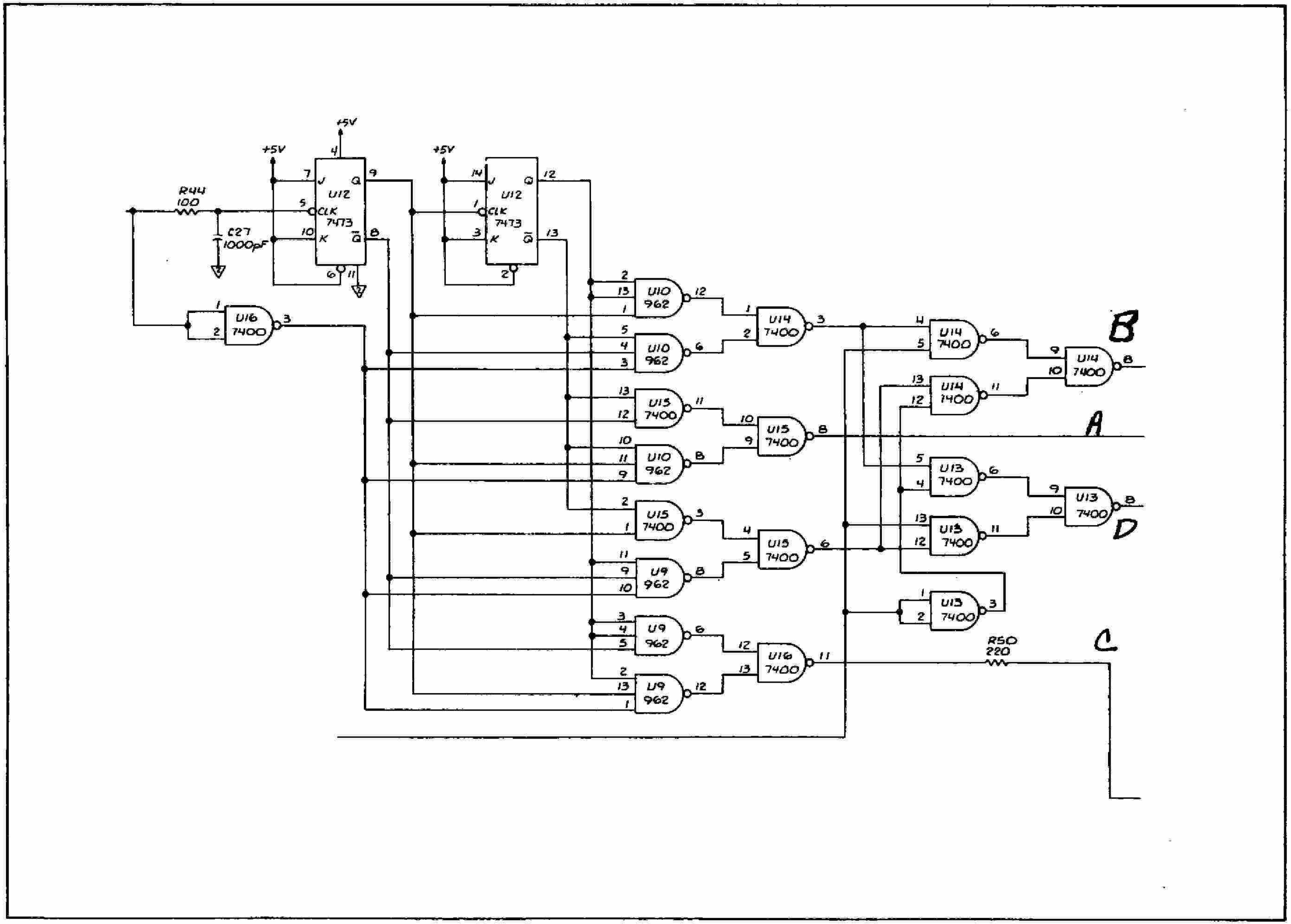


FIGURE 18-6. FOUR PHASE GENERATOR

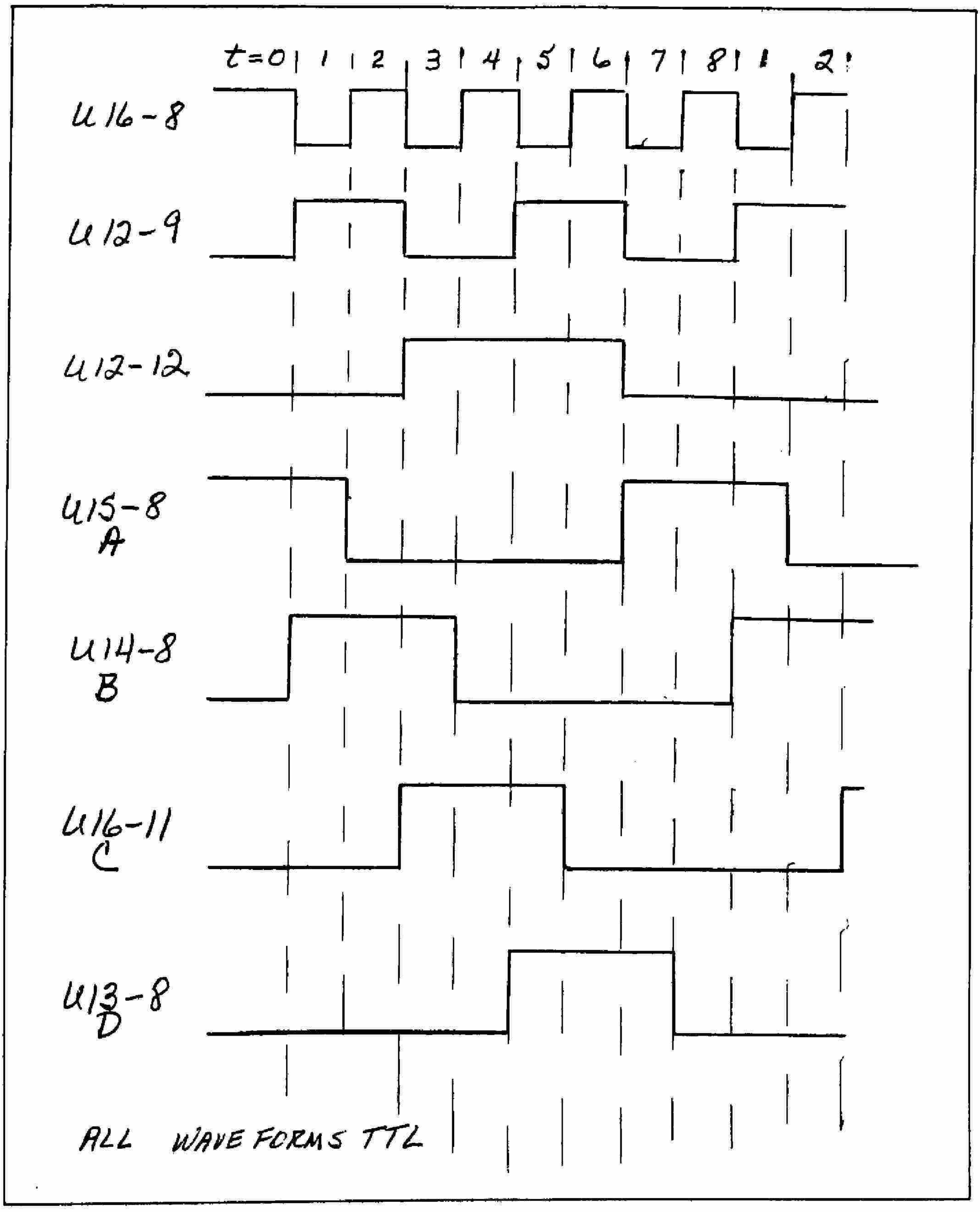


**FIGURE 18-7. FORWARD SCAN WAVEFORMS**

The only NAND gate in the first section that has a low output is U15-11 whose inputs are both high from U12-8 (Q-bar) and U12-13 (Q-bar). This low is applied to U15-8 producing a high output on "Phase A".

The highs from U10-12 and U10-6 produce a low in U14-3. This low produces highs from U14-6 and U13-6. The highs from U15-3 and U9-8 produce a low from U15-6. This low produces highs from U13-11 and U14-11.

The highs from U14-6 and U14-11 produce a low from U14-8 which is the "Phase B".

The highs from U13-6 and U13-11 produce a low from U13-8 which is the "Phase D".

The highs from U9-6 and U9-12 produce a low from U16-11 which is the "Phase C".

In the arbitrarily assumed state we have "Phase A" high and all other outputs low. In order to produce this state we did not have to place the FORWARD or REVERSE switches into their "on" position. The state will remain until we select a scan and at that time we approach T1, the first negative going clock of the input drive frequency.

2. T=1, FORWARD SCAN

The waveform from U16-8 has gone low toggling U12-9 to the "set" state with a high on Q and a low on Q-bar. The FORWARD switch is depressed so a low is applied from the REVERSE switch to U13-3, U13-11, and U14-6 producing a high from each of these NAND gates.

The low from Q-bar U12-8 produces a high from U10-6, U15-11, U9-8, and U9-6.

The low from Q U12-12 produces a high from U10-12, U9-8, U9-6, and U9-12.

This leaves two gates in the first group which could have low outputs.

U10-8 has a high from the inverted drive frequency input through U16-3, a high from Q U12-9, and a high from Q-bar U12-13 producing a low in its output.

U15-3 has a high from Q U12-9 and a high from Q-bar U12-13 producing a low in its output.

The low from U10-8 produces a high from U15-8 which is the "Phase A" output.

The two highs from U10-12 and U10-6 produce a low from U14-3. This low in turn produces highs from U14-6 and U13-6.

The low from U15-3 produces a high from U15-6 which is applied to U14-11 and U13-11 but U13-11 output is already high due to the low from REVERSE switch input. This low from REVERSE is inverted to high in U13-3 and applied to U14-11 as a high. U14-11 output then goes low (both inputs high) to U14-8 producing a high on "Phase B" output.

The two highs from U9-6 and U9-12 produce a low from U16-11 as the "Phase C" output.

Recall that the low from U14-3 was applied to U13-6 and the low from REVERSE is applied to U13-11. The highs produced by these two gates produce a low in U13-8 and is the "Phase D" output.

3. T=2, FORWARD SCAN

When the input pulse again goes positive at t=2, the flip-flops remain U12-9 set and U12-12 reset as before. The output of U16-3 now goes low which produces highs from the following gates: U10-6, U10-8, U9-8, and U9-12.

The low from Q-bar U12-8 produces highs from U10-6, U15-11, U9-8, and U9-6.

The low from Q U12-12 produces highs from U10-12, U9-8, U9-6, and U9-12.

The only low is from U15-3 which has Q of U12-9 and Q-bar of U12-13, both highs, in its input.

The highs from U15-11 and U10-8 produce a low in the output as "Phase A".

The low from U15-3 produces a high from U15-6 to U14-11 pin 13. The inverted low from REVERSE through U13-3 is high on pin 12 of U14-11 during its output low (both inputs high). This low produces a high from U14-8 which is "Phase B".

The highs from U9-6 and U9-12 produce a low in the output of U16-11 which is "Phase C".

The low from REVERSE is applied to U13-1 producing a high to U13-8 pin 10. The highs from U10-12 and U10-6 produce a low from U14-3 which is applied to U13-6 pin 5. The outputs of U13-8 and U13-6 are both high which produces a low from U13-8 as "Phase D".

4. T=3, FORWARD SCAN

U12-9 is now "reset" and U12-12 is "set".

The low from Q of U12-9 is applied to and produces highs from U10-12, U10-8, U15-3, and U9-12.

The low from Q-bar of U12-13 produces highs from U10-6, U15-11, U10-8, and U15-3.

The output of U9-8 is low since all its inputs are high producing a high from U15-6. This high is applied to U14-11 with the high from U13-3, the inverted REVERSE input. The resulting low from U14-11 drives U14-8 high which is the "Phase B" output.

The highs from U15-11 and U10-8 produce a low from U15-8 which is the "Phase A" output.

The low from U9-6 produces a high from U16-11 which is the "Phase C" output.

The highs from U10-12 and U10-6 produce a low from U14-3 to U13-6 which is high in its output. The low from REVERSE produces a high from U13-11. These two highs produce a low from U13-8 which is "Phase D".

5. T=4, FORWARD SCAN

U12-12 is still "set" and U12-9 is reset. The inverted clock from U16-3 is now low.

The low from U16-3 produces highs from U10-6, U10-8, U9-8, and U9-12.

The low from Q of U12-9 produces highs from U10-12, U10-8, U15-3, and U9-12.

The low from Q-bar of U12-13 produces highs from U10-6, U15-11, U10-8, and U15-3.

This leaves only U9-6 to be low and it is since all inputs are high. This low produces a high from U16-11 which is the "Phase C".

The two highs from U15-11 and U10-8 produce a low from U15-8 which is the "Phase A".

The two highs from U15-3 and U9-8 produce a low from U15-6 to U14-11 (high output) and U13-11, also high output. The low from REVERSE produces a high from U14-6. This high with the high from U14-11 produces a low from U14-8 which is the "Phase B".

The highs from U10-12 and U10-6 produce a low from U14-3 to U13-6. The resulting high from U13-6 with the high from U13-11 produces a low from U13-8 which is "Phase D".

6. T=5, FORWARD SCAN

Both U12-9 and U12-12 are now "set".

The low from Q-bar U12-8 produces a high from U10-6, U15-11, U9-8, and U9-6.

The low from Q-bar U12-13 produces a high from U10-6, U15-11, U10-8, and U15-3.

All the gates in the first group are high except U10-12 and U9-12. A quick check shows all inputs to these two gates are high and the outputs of U10-12 and U9-12 are indeed low.

The highs from U15-11 and U10-8 produce a low from U15-8 which is the "Phase A" output.

The low from REVERSE produces a high from U14-6. The two highs from U15-3 and U9-8 produce a low from U15-6 to U14-11 whose output goes high. The highs from U14-6 and U14-11 force the output of U14-8 low which is the "Phase B" output.

The low from U9-12 forces U16-11 high which is the "Phase C" output.

The low on REVERSE causes U13-11 to go high. The low on U10-12 causes U14-3 to go high to U13-6. The inverted REVERSE is applied to pin 4 of U13-6 making both inputs high so the output goes low to U13-8. The output of U13-8 then is high to "Phase D" output.

7. T=6, FORWARD SCAN

Both U12-9 and U12-12 are set and the inverted clock from U16-3 is now low.

The low from U16-3 produces highs from U10-6, U10-8, U9-8, and U9-12.

The low from Q-bar of U12-8 produces highs from U10-6, U10-8, U9-8, and U9-6.

The low from Q-bar of U12-13 produces highs from U10-6, U15-11, U10-8, and U15-3.

The only gate not high is U10-12 which has all highs in the input so its output is low.

The two highs from U15-11 and U10-8 produce a low from U15-8 which is the "Phase A".

The two highs from U9-8 and U15-3 produce a low from U15-6 to U13-11 and U14-11. The low from REVERSE is applied to U14-6 making its output high. The highs from U14-6 and U14-11 produce a low from U14-8 to "Phase B".

The two highs from U9-6 and U9-12 produce a low from U16-11 which is the "Phase C" output.

The low from U10-12 forces U14-3 high to U13-6 pin 5. Pin 4 of U13-6 has a high which is the inverted REVERSE input. The output of U13-6 is low making U13-8 high for "Phase D".

8. T=7, FORWARD SCAN

Both U12-9 and U12-12 are now "reset" and the output of U16-3 is high.

The low from Q U12-9 produces highs from U10-12, U10-8, U15-3, and U9-12.

The low from Q U12-12 produces highs from U10-12, U9-8, U9-6, and U9-12.

U15-11 output is low since both Q-bar inputs are high forcing U15-8, "Phase A" output, to go high.

Both U15-3 and U9-8 outputs are high producing a low from U15-6 to U13-11 and U14-11. The output of U14-11 is low on its input. These highs then force U14-8 low which is then "Phase B" output.

Both U9-6 and U9-12 are high so U16-11 output must be low to "Phase C" output.

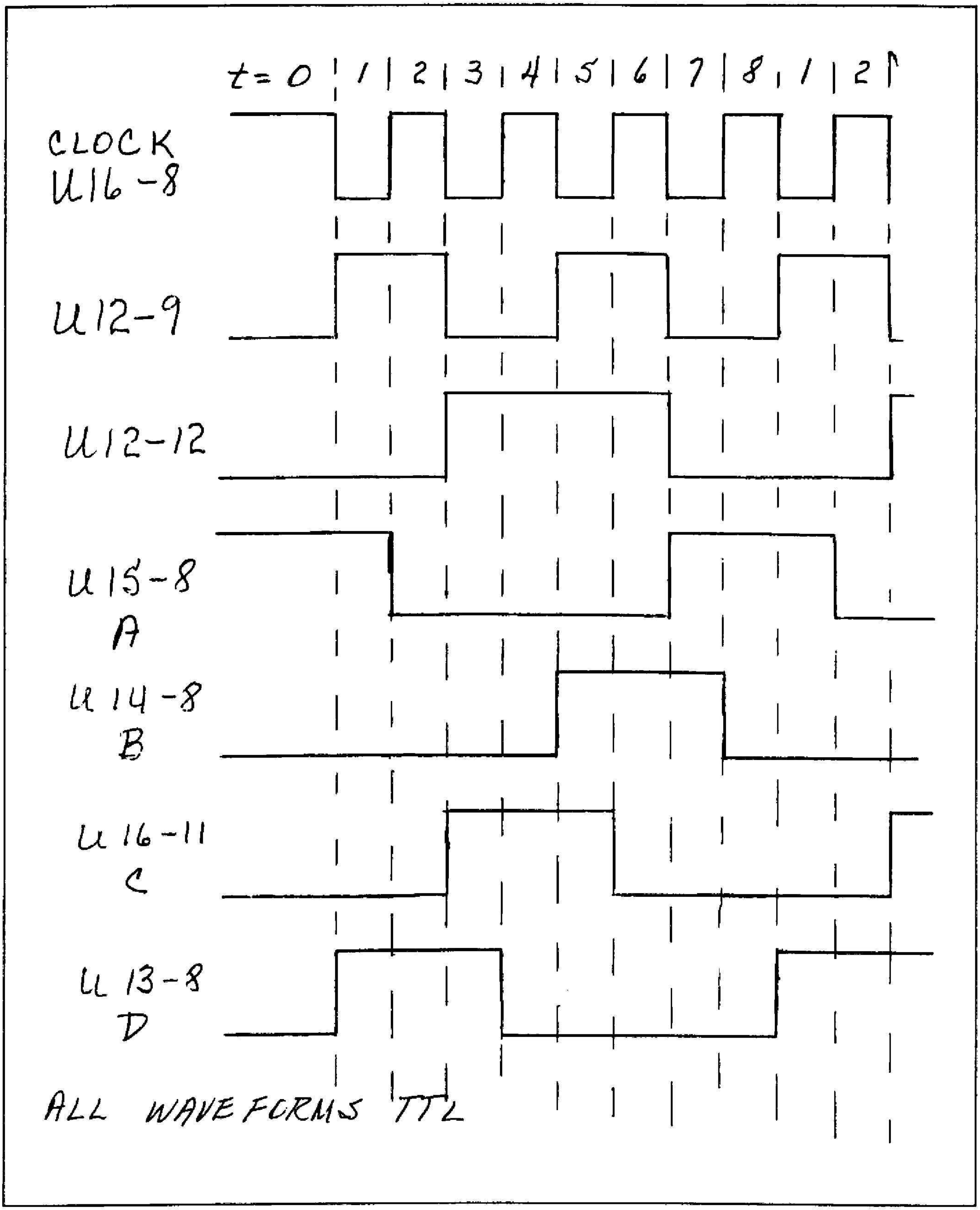


**FIGURE 18-8. REVERSE SCAN WAVEFORMS**

The low from U10-6 produces a high from U14-3 to U13-6 input. The other input of U13-6 is high from the inverted REVERSE signal from U13-3. The output of U13-6 is low forcing U13-8 output to be high to "Phase D" output.

9. T=8, FORWARD SCAN

Both U12-9 and U12-12 are "reset" and the output of U16-3 is low. This output is the same as t=0 Static State regardless of direction. Look at t=0 REVERSE scan, paragraph 10, to see that this is true. Recall that "Phase A" output only was high in the t=0 state as shown in Figure 18-8.

10. T=0, REVERSE SCAN

Both U12-9 and U12-12 are "reset" and the output of U16-3 is low.

The low from U16-3 causes highs to be produced from U10-6, U10-8, U9-8, and U9-12.

The low from Q of U12-9 produces highs from U10-12, U10-8, U15-3, and U9-12.

The low from Q of U12-12 produces highs from U10-12, U9-8, U9-6, and U9-12.

This leaves only U15-11 with highs on its input for a low to U15-8 producing a high on "Phase A".

The REVERSE switch is now open and the input to U13-3 is a high. This is inverted to a low and applied from U13-3 to U13-6 and U14-11. U14-11 output then is high. The highs in U10-12 and U10-6 produce a low from U14-3 to U14-6. U14-6 output then is also high. The highs from U14-11 and U14-6 produce a low in "Phase B" output, U14-8.

The highs from U9-6 and U9-12 produce a low in U16-11 which is the "Phase C" output.

The highs from U15-3 and U9-8 produce a low from U15-6 to U13-11 whose output is high. The low from U14-3 is also applied to U13-6 whose output also goes high. The two highs produce a low in U13-8 which is "Phase D" output.

11. T=1, REVERSE SCAN

U12-9 is "set" and U12-12 is still "reset" with the output of U16-3 now high.

The low from Q-bar U12-8 produces highs from U10-6, U15-11, U9-8, and U9-6.

The low from Q of U12-12 produces highs from U10-12, U9-8, U9-6, and U9-12.

This leaves U10-8 and U15-3 with all highs on their inputs and both outputs go low.

The low from U10-8 causes U15-8 to go high and this is the "Phase A" output.

Both U10-12 and U10-6 outputs are high which forces U14-3 output low to U14-6 and U13-6. The inverted REVERSE signal is low to U14-11 which causes its output to go high. The highs from U14-6 and U14-11 produce a low in U14-8 which is the "Phase B" output.

The highs from U9-6 and U9-12 produce a low in U16-11 which is the "Phase C" output.

The low from U15-3 causes U15-6 to go high. This is applied to U13-11 with the high from REVERSE and U13-11 output goes low causing U13-8 output to go high as "Phase D" output.

12. T=2, REVERSE SCAN

Flip-flop U12-9 is still "set" and U12-12 is "reset" with U16-3 output now low.

The low from U16-3 causes U10-6, U10-8, U9-8, and U9-12 outputs to go high.

The low from Q-bar U12-8 causes U10-6, U15-11, U9-8, and U9-6 outputs to go high.

The low from U12-12 Q output causes U10-12, U9-8, U9-6, and U9-12 outputs to go high.

The only device that is low is U15-3 in the input gates which has both inputs high.

U15-11 and U10-8 outputs are high and produce a low from U15-8 which is "Phase A" output.

Both U10-12 and U10-6 outputs are high producing a low from U14-3 to U14-6 whose output is high. The inverted REVERSE input from U13-3 is low to U14-11 causing its output to go high. The highs from U14-11 and U14-6 produce a low from U14-8 which is the "Phase B" output.

The highs from U9-6 and U9-12 produce a low in U16-11 which is the "Phase C" output.

The low from U15-3 produces a high from U15-6 to pin 12 of U13-11. Pin 13 of U13-11 is also high from REVERSE and U13-11 output goes low driving U13-8 "Phase D" output high.

13. T=3, REVERSE SCAN

U12-9 is now "reset" and U12-12 is "set".

The low from Q of U12-9 produces highs from U10-12, U10-8, U15-3, and U9-12.

The low from Q-bar of U12-13 produces highs from U10-6, U15-11, U10-8, and U10-3.

The gates with low outputs then are U9-8 and U9-6.

Both U10-8 and U15-11 outputs are high so U15-8 output, "Phase A", is low.

Both U10-12 and U10-6 outputs are high so U14-3 output is low causing U14-6 output to go high. The inverted REVERSE signal is a low from U13-3 and is applied to U14-11 causing its output to go high. Since both inputs to U14-8 are high, the output "Phase B" is low.

The low from U9-6 forces U16-11,"Phase C" output, to go high.

The low from U9-8 is inverted in U15-6 to a high to U13-11. The other input of U13-11 is also high from the REVERSE switch causing U13-11 to go low driving U13-8, "Phase D" output, high.

14. T=4, REVERSE SCAN

U12-9 is "reset" and U12-12 is set with the output of U16-3 low.

The low from U16-3 produces highs from U10-6, U10-8, U9-8, and U9-12.

The low from Q of U12-9 produces highs from U10-12, U10-8, U15-3, and U9-12.

The low from Q-bar of U12-13 produces highs from U10-6, U15-11, U10-8, and U15-3.

The highs from U15-11 and U10-8 produce a low from U15-8, "Phase A" output.

The two highs from U10-12 and U10-6 cause U14-3 output to go low to U14-6 which goes high. U14-11 has the low from U13-3 which is the inverted REVERSE signal. Both U14-6 and U14-11 outputs are high forcing U14-8, "Phase B", output to go low.

The low from U9-6 causes U16-11, "Phase C", output to go high.

Both U15-3 and U9-8 outputs are high forcing U15-6 to go low to U13-11 whose output goes high. U13-6 output is also high from the low from U13-3. These two highs cause U13-8 to go low, "Phase D" output.

15. T=5, REVERSE SCAN

Both U12-9 and U12-12 are "set".

The low from Q-bar U12-8 produces highs from U10-6, U15-11, U9-8, and U9-6.

The low from Q-bar U12-13 produces highs from U10-6, U15-11, U10-8, and U15-3.

The gates in this group which have low outputs are U9-12 and U10-12.

The highs from U15-11 and U10-8 produce a low from U15-8, "Phase A" output.

The low from U10-12 produces a high from U14-3 to U14-6 pin 4. Pin 5 of U14-6 has the high from the REVERSE applied causing U14-6 output to go low. This drives U14-8, "Phase B" output, high.

The low from U9-12 produces a high "Phase C" output from U16-11.

Both U15-3 and U9-8 outputs are high. This produces a low from U15-6 which causes the output of U13-11 to go high. U13-6 output is also high from the inverted REVERSE from U13-3. These two highs produce a low from U13-8, "Phase D" output.

16. T=6, REVERSE SCAN

Both U12-9 and U12-12 are "set" with a low from U16-3.

The low from U16-3 causes the outputs of U10-6, U10-8, U9-8, and U9-12 to go high.

The low from Q-bar of U12-8 produces highs from U10-6, U15-11, U9-8, and U9-6.

The low from Q-bar of U12-13 produces highs from U10-6, U15-11, U10-8, and U15-3.

The output of U10-12 is low since both inputs are high.

The highs from U15-11 and U10-8 produce a low from U15-8 output, "Phase A".

The low from U10-12 is inverted in U14-3 to a high to pin 4 of U14-6. Pin 5 of U14-6 has the high REVERSE input so the output of U14-6 goes low producing a high from U14-8, "Phase B" output.

The highs from U9-6 and U9-12 produce a low from U16-11, "Phase C" output.

U15-3 and U9-8 are both high. This produces a low from U15-6 during U13-11 high. U13-6 is also high since its input pin 4 is low from the inverted REVERSE input. The highs from U13-6 and U13-11 drive U13-8 low, "Phase D" output.

17. T=7, REVERSE SCAN

Both U12-9 and U12-12 are "reset".

The low from U12-9 Q output produces highs from U10-12, U10-8, U15-3, and U9-12.

The low from U12-12 Q output produces highs from U10-12, U9-8, U9-6, and U9-12.

The outputs of U10-6 and U15-11 are low since all inputs are high on each.

The low from U15-11 produces a high from U15-8 which is the "Phase A" output.

The low from U10-6 produces a high from U14-3 to pin 4 of U14-6. Pin 5 of U14-6 is high from the REVERSE input. The output of U14-6 is low causing U14-8 to go high which is the "Phase B" output.

Both U9-6 and U9-12 are high causing a low from U16-11 which is the "Phase C" output.

The two highs from U9-8 and U15-3 cause U15-6 to go low. This produces a high from U13-11 to U13-8. U13-6 output is also high since pin 4 of the input is low with the inverted REVERSE level. These two highs drive U13-8 output low which is the "Phase D" output.

18. T=8, REVERSE SCAN

The state t=8 is the same as t=0, paragraph 10. The waveforms now repeat in sequence and it is now obvious that when the direction of required recorder movement is changed, the phase of outputs B and D are reversed.

## D. OUTPUT AMPLIFIERS

The four phases generated in the preceding circuits are applied as TTL waveforms to the output switches Q6, Q7, Q8, and Q9. With a positive level on the input, the transistor involved conducts through a winding of the motor. No more than two nor less than one switch conducts for any conceivable input combination. With current flowing in the windings a resultant field is produced and the rotor will align itself with this field. The rotor then steps 45° with each half-cycle of the drive frequency from U16-8. Four cycles or 8 steps are required to rotate the rotor 360°.

The motor output to the carriage and sweep potentiometer is geared down such that 6180 steps are required for full scale recorder travel.

A clutch assembly is also part of the stepper motor. With the winding energized in STOP mode, the carriage and the motor are disengaged. Selecting a scan de-energizes the clutch relay and the motor and carriage are engaged.

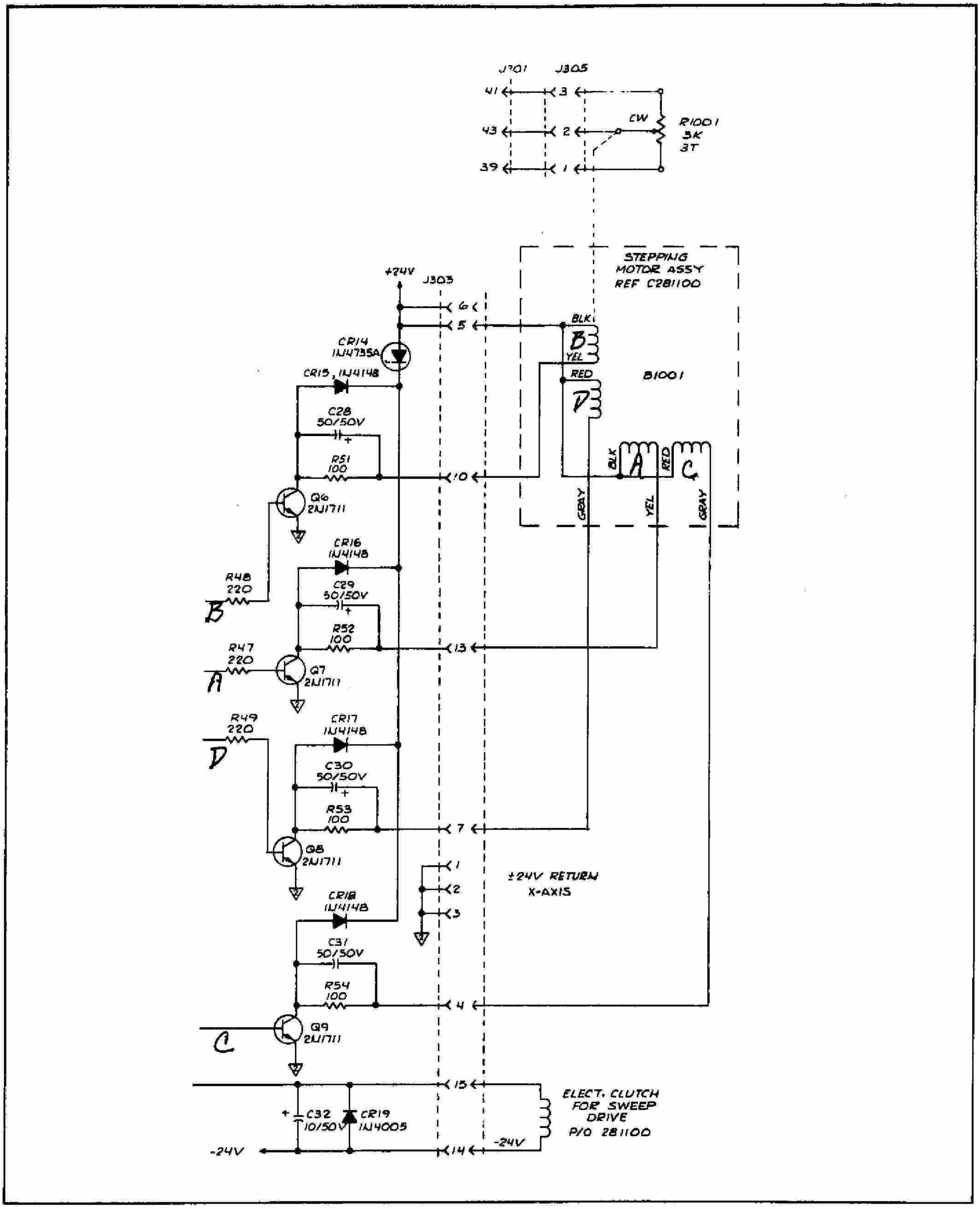


**FIGURE 18-9. OUTPUT CIRCUITS**

## 18.3 TESTS AND CALIBRATIONS

### 1. VOLTAGE TESTS

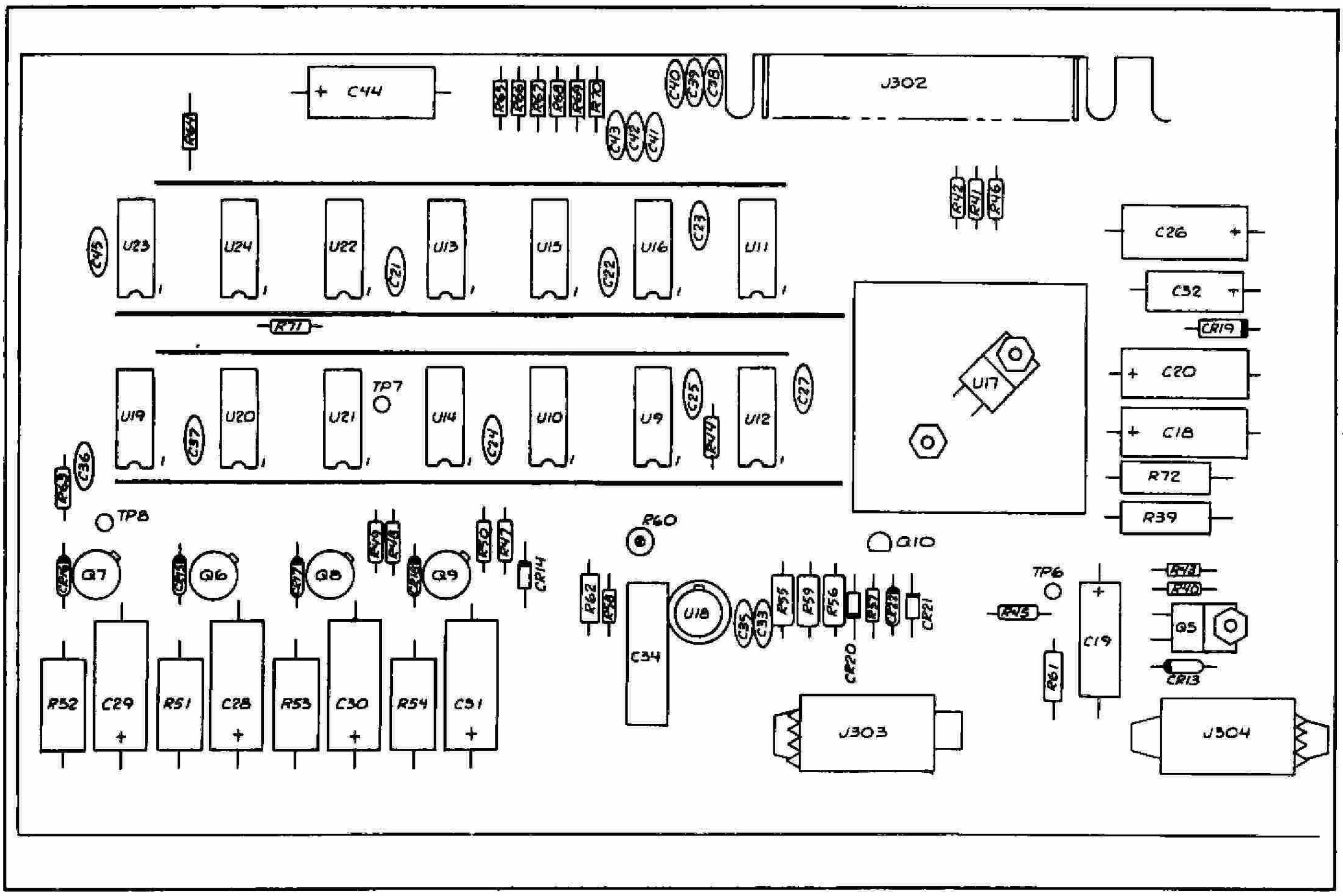


FIGURE 18-10. PART LAYOUT

a. Check the voltage at TP6 which should be +5 volts ± 0.3 volt.

b. Check the voltage at pin 7 of U18 which should be +15 volts ± 0.8 volt.

c. Check the voltage at pin 4 of U18 which should be -15 volts ± 0.8 volt.

2. Check the signal at TP8 with an oscilloscope and frequency counter.

a. The frequency is set by R60 to 206 Hz ± 2 Hz.

b. The square-wave amplitude is 3 to 4 volts peak-to-peak.

3. Check the signal at TP7 with an oscilloscope and frequency counter.

   a. The amplitude is 3 to 4 volts peak-to-peak.

   b. The frequency vs SWEEP TIME should be:

| SWEEP TIME MINUTES | TP7 FREQUENCY HERTZ |
|---|---|
| 0.5 | 103 |
| 1 | 51.5 |
| 2 | 25.75 |
| 5 | 10.3 |
| 10 | 5.15 |
| 20 | 2.575 |

4. Select 0.5 MINUTES SWEEP TIME and set the FORWARD RUN Switch. Observe the output signals as shown in Figure 18-7.

5. Select 0.5 MINUTES SWEEP TIME and set the REVERSE SCAN Switch. Observe the output signals as shown in Figure 18-8.

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EM-390 TRAINING NOTES

SECTION 19.0
ACCESSORY PANEL

## 19.1 FUNCTION

The accessory panel is used to interface between the EM-390 spectrometer and either the oscilloscope or the ORTEC 547 Time Averaging Computer (TAC). Both can be connected to the EM-390 simultaneously but the oscilloscope Y-Axis input must be changed when switching between the system and the TAC.

## 19.2 THEORY OF OPERATION

### 1. OSCILLOSCOPE RAMP CIRCUIT

The ramp output of the X-Axis oscilloscope sweep is applied to pin 3 of the Ramp Sweep Amplifier in the Accessory section. The input is applied across a voltage divider to -15 volts consisting of R1, R3, and potentiometer R8. R8 is adjusted to place the zero crossing of the ramp at zero in the output. This is accomplished by varying the voltage level of the signal applied to the inverting input of U1A.

The gain of U1A is set by R9 for proper amplitude of the ramp to the Field Controller. The gain is adjusted for correct spectral chemical shift display on the oscilloscope. The output is to P1011-13 on the interconnect PCB.

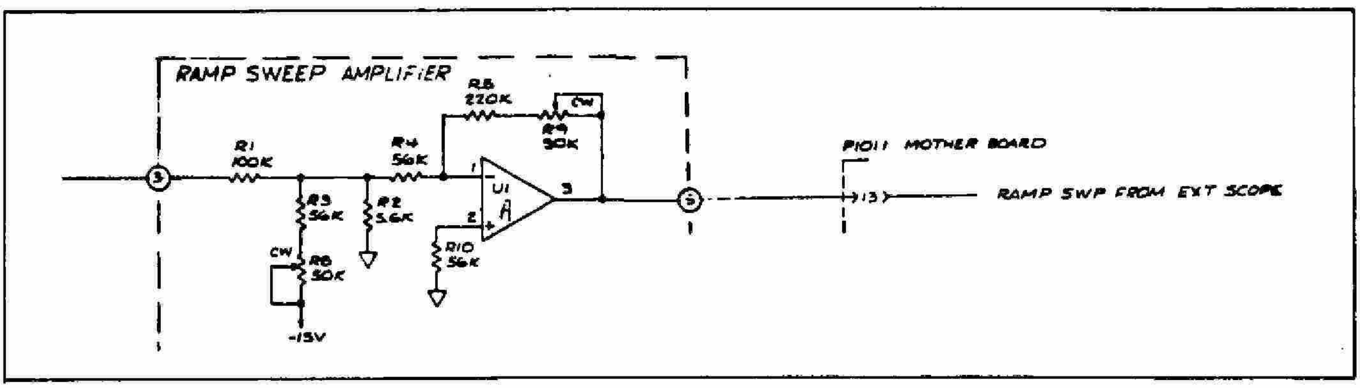


FIGURE 19-2. OSCILLOSCOPE RAMP

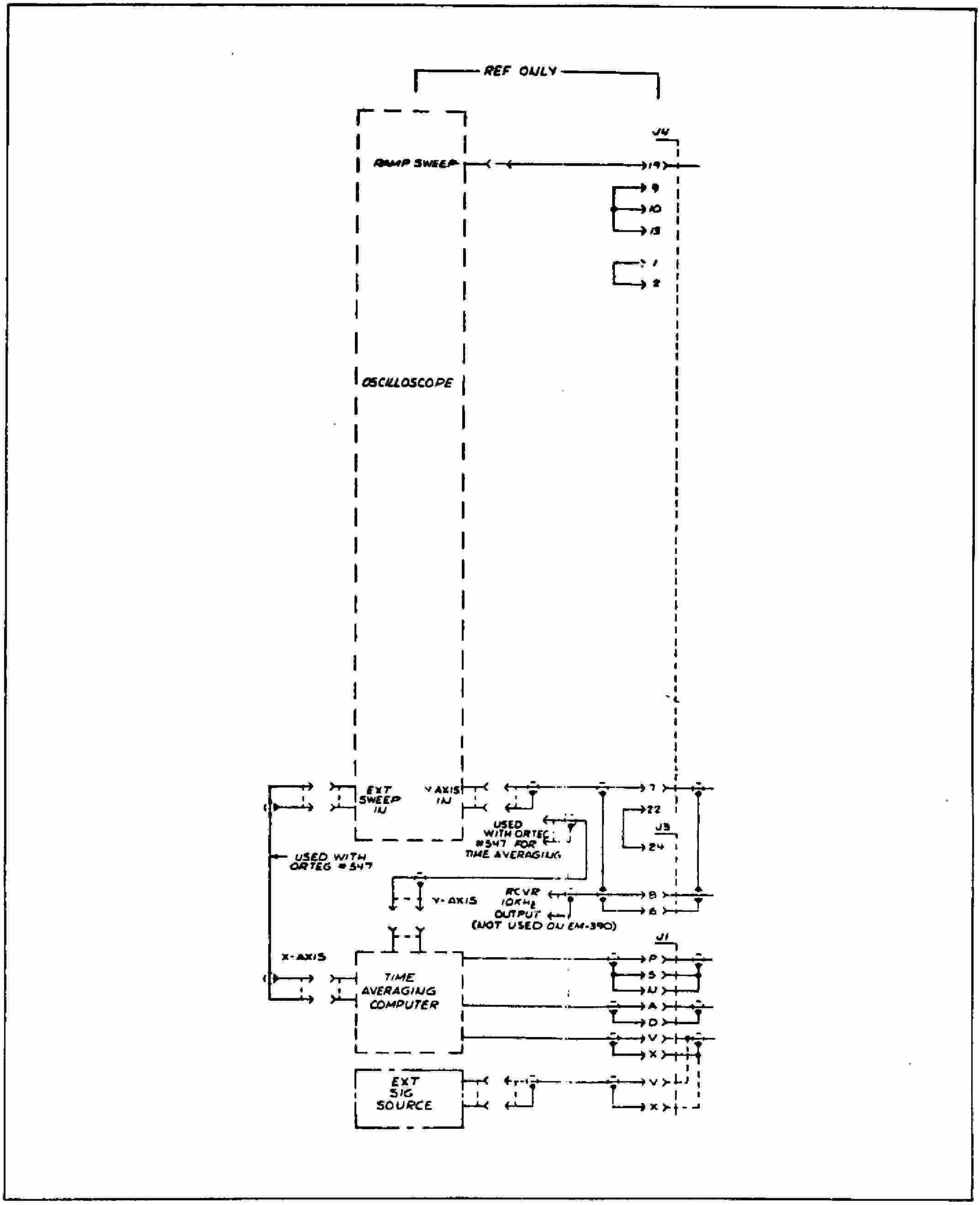


FIGURE 19-1. ACCESSORY INTERCONNECT

2. TIME AVERAGING COMPUTER RAMP

The X-Axis Sweep ramp from the Time Averaging Computer is applied through pin 6 of the card to two different circuits.

The input to the first circuit is through R12 and across K1 contacts to U1D, a buffer inverting operational amplifier with a gain of -½.

The output of U1D is applied to inverting unity gain amplifier U1C inverting input. The output of U1C is applied through pin 7 to P1011-15 of the interconnect PCB.

The other circuit of this PCB is from the input ramp through R26 charging C5. The value of the charge on C5 is coupled through C2 to the inverting input of U1B. As C5 charges positively the output of U1B goes negative. The output of U1B is applied to U2, a monostable multivibrator configured to free run as long as pin 4 is positive.

The output of U1B is positive only during the fly-back (negative-going) portion of the sawtooth. During this time the monostable multivibrator U1 produces multiple outputs to Q1. R22 potentiometer determines the DC average of the output by controlling the "on" time of the multivibrator which determines the duration of the positive going output pulse.

While U2 is free-running, transistor Q1 conducts through K1 winding opening up the ramp input to U1D during the ramp flyback time.

Were the flyback not eliminated, for the few seconds of the flyback the EM-390 NMR lock would be lost due to the rapid field change. The fly-back elimination enables the system to remain in lock during TAC operation.

## 19.3 PERFORMANCE SPECIFICATION

The EM-390 system must hold lock when operating with the ORTEC 547 TAC under the following conditions.

| | |
|---|---|
| SWEEP WIDTH TAC | 900 Hz (10 PPM) and lower |
| INPUT MODE TAC | NMR-RECUR |
| SWEEP TIME TAC | 25 Seconds |
| SWEEP WIDTH EM-390 | 10 PPM |
| LOCK LEVEL | MIDSCALE or higher |
| LOCK MODE | AUTOSHIM |
| END OF SWEEP | +10 PPM |
| LOCK SAMPLE | 1% TMS |

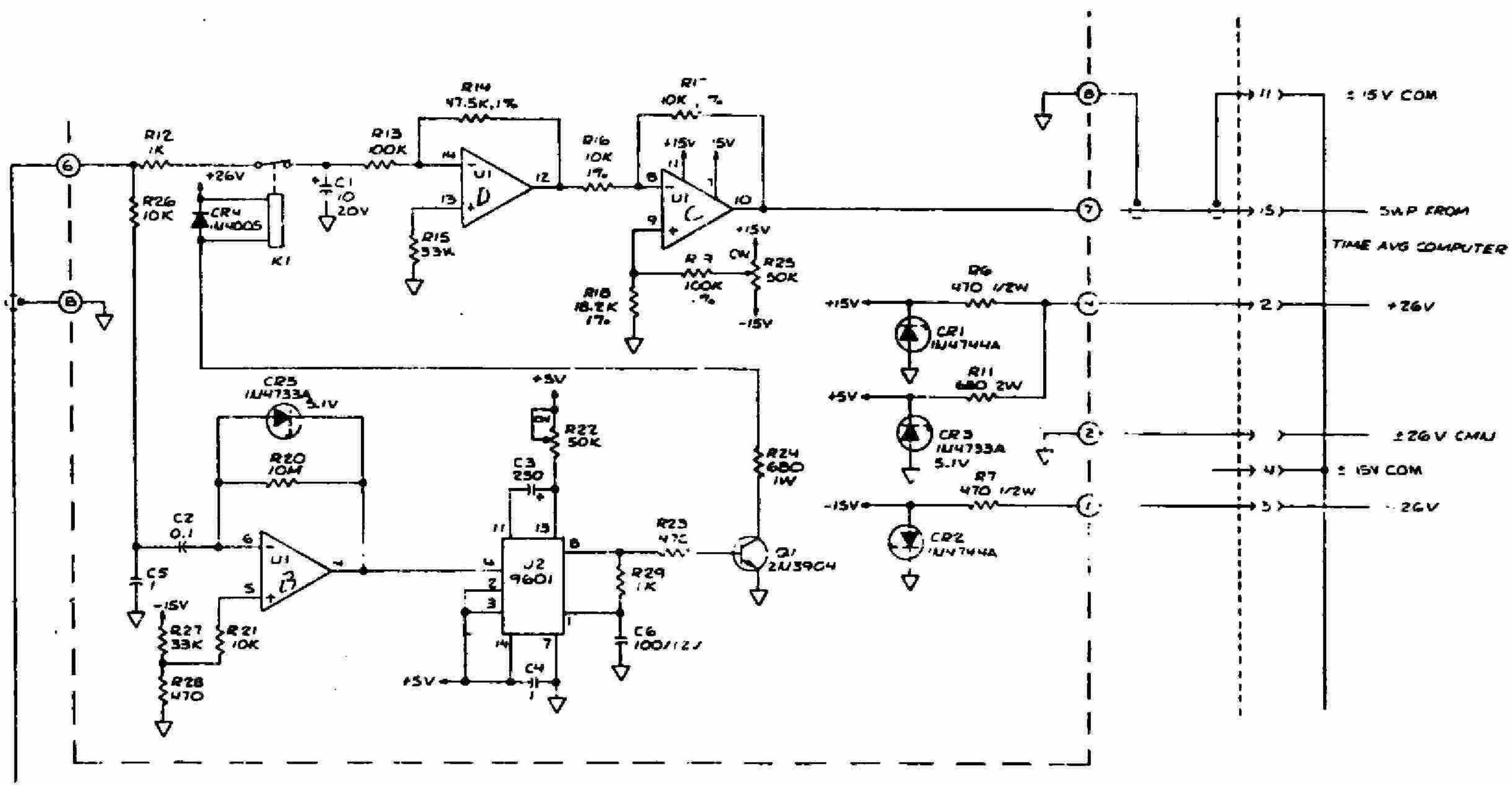


**FIGURE 19-3. TAC SWEEP AMPLIFIER**

## 19.4 OSCILLOSCOPE TESTS

1. Insert the REFERENCE sample (TMS and CHCl3 943346-07) in the probe and depress OSCILLOSCOPE push button on MODE switch.

2. Set SWEEP WIDTH to 10 PPM.

3. Use STANDBY (unlocked) position of LOCK MODE Switch.

4. Adjust the Oscilloscope for minimum X GAIN and use the X POSITION to center the trace on the oscilloscope. Set X GAIN for 10 centimeters of width on the oscilloscope.

5. Set the oscilloscope SWEEP TIME for about 4 seconds per scan.

6. Increase OBSERVE RF POWER to around 0.3 mG.

7. Turn LOCK POWER OFF.

8. Adjust END OF SWEEP until two resonance peaks are seen on the oscilloscope. SPECTRUM AMPLITUDE should be adjusted for a convenient display and RF POWER should be adjusted below saturation.

9. Determine the position of the TMS and chloroform peaks on the oscilloscope and adjust R9 on the accessory panel until these peaks are 7.3 centimeters apart as observed on the 10 centimeter grid of the oscilloscope. R9 is toward the center of the spectrometer.

10. Momentarily go to NORMAL operation and set the END OF SWEEP control to zero. Use the COARSE and FINE OFFSET controls to place TMS at chart zero on the recorder. Go back to OSCILLOSCOPE Mode.

11. Adjust R8 until the TMS peak on the oscilloscope is directly at the right hand grid mark while the END OF SWEEP control is at zero.

12. Rotate the SWEEP WIDTH control and check that the TMS response remains with 1 centimeter on the oscilloscope as the control is varied from 1 through 10 PPM.

## 19.5 ORTEC-547 TESTS AND ADJUSTMENTS

1. Connect the ORTEC 547 to the EM-390.

2. Connect a DC Voltmeter to the output of U3 (R14) on the FIELD CONTROL card.

3. Turn on the TAC and set the controls to stop the sweep.

4. Depress the TAC button on the spectrometer control switch.

5. Adjust R25 on the Accessory panel for 0±0.01 volt as read on the voltmeter. Ensure the recorder arm is still on chart zero.

6. Lock the EM-390 system to an NMR resonance and adjust for a midscale reading on the LOCK meter.

7. Set the TAC for a 25 second SWEEP TIME and a 900 Hz SWEEP WIDTH.

8. Set the AUTO-STOP-SCANS control to OFF and the INPUT MODE to NMR RECUR.

9. Depress the RUN control button on the TAC.

10. Observe the voltage at the output of U3 on a slow scan DC oscilloscope. It must follow the ramp voltage and on retrace it should exhibit an exponential decay with a time constant around 1 second (90% change in 2.3 seconds). The step at the end of the decaying signal must not be greater than 10% of the peak amplitude.

11. Adjust R22 to minimize this step.

12. Observe the LOCK meter. The lock will exhibit a disturbance on the return of the ramp signal but NMR lock must be maintained for any setting of the Sweep Width on the TAC.

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# EM-390 TRAINING NOTES

## SECTION 20.0
## SPIN DECOUPLER ACCESSORY

### 20.1 FUNCTION

This unit generates a sinusoidal signal having a frequency from 20 KHz to 30 KHz in one of the following modes:

1. DECOUPLE
2. SPIN TICKLE
3. INDOR

Regardless of mode, the frequency is swept with the system recorder X-AXIS movement. It may be set using a thumbwheel switch calibrated in PPM OFFSET with a variable FINE FREQUENCY potentiometer.

The output signal of this unit is applied to the EM-390 console to the Field Modulator Amplifier and out to the modulation coils.

### 20.2 CIRCUIT THEORY

The + and -24 volts Unregulated System Supply is applied to an integrated circuit voltage regulator with outputs of +15 and -15 volts. The plus 15 volts is set exactly by the adjustment R20. The minus 15 volts depends for its exact value on the value of the +15 volt regulation. The outputs are used only in the Spin Decoupler.

U1 is the precision -10 volt regulator and is illustrated in Figure 20-2. The -15 volt supply is applied to the base and collector of Q1. The input to Q1 from U1 causes -10 volts DC to be present on the emitter of Q1. The -10 volts is applied to zener diode CR2 which produces a -8.8 volt reference. This is divided by voltage divider R4 and R5 to produce -2.19 volts at the non-inverting input of U1. The -10 volts regulated is applied to a voltage divider network of R6, R7, and potentiometer R18 to apply between -1.84 volts to -2.38 volts on the input of U1 depending upon the setting of R18. This potentiometer is set to provide exactly -10 volts from the emitter of Q1. A level-shift zener diode (6.8V) CR1 places the output of U2 into the operating range of Q1.

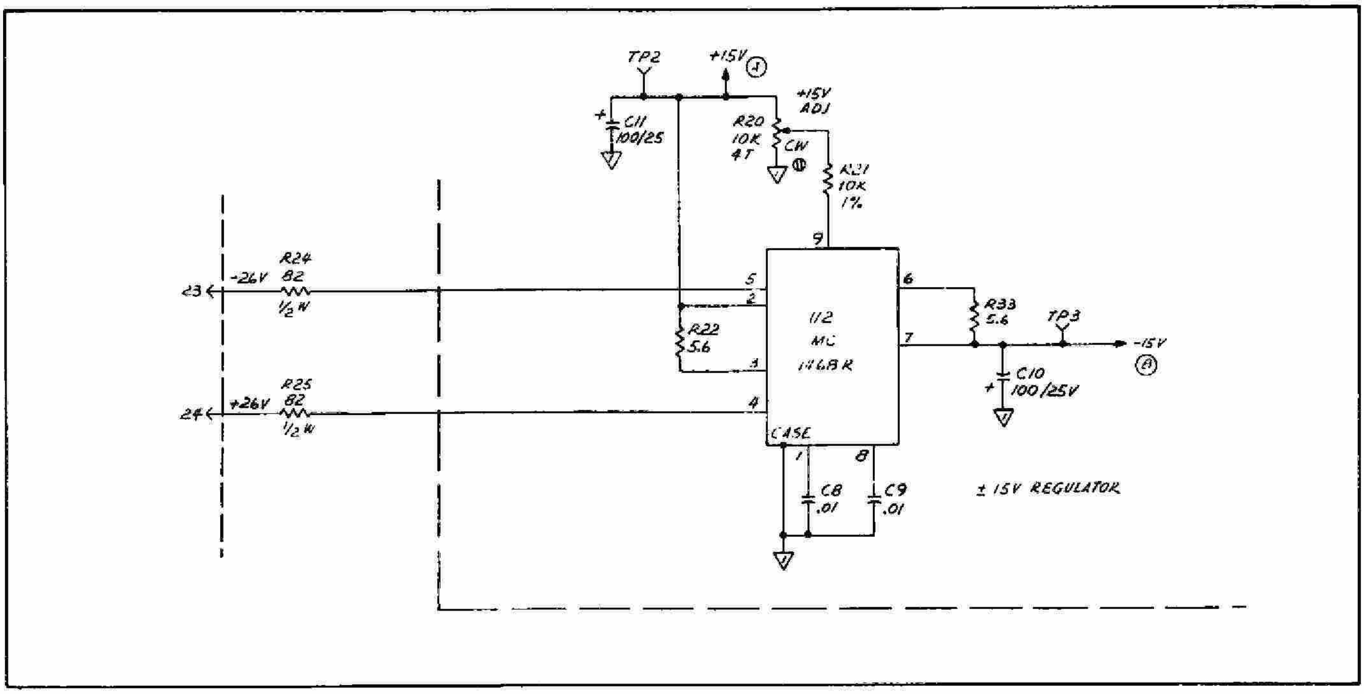



FIGURE 20-1. ±15 VOLT REGULATOR

The -10 volts regulated supply is applied to the thumbwheel OFFSET switch. This switch and associated resistance networks select a portion of the -10 volts input and applies it to the non-inverting input of buffer operational amplifier U15. The output of U15 is applied through R97 OFFSET PPM Calibration to the inverting input of U3, a summing junction.

The -10 volts regulated is also applied to the FINE FREQUENCY 10-turn potentiometer on the Spin Decoupler front panel. The output of this control is applied to the summing junction of U3.

The -10 volt regulated is also applied to the contacts of relay K3 to one of two screwdriver adjustments. With K3 de-energized as shown, the proton or NORMAL offset adjustment R38 and resistor R99 attenuates the signal to the summing junction of U3. In OTHER NUCLEI mode, relay K3 energizes placing potentiometer R100 and R75 in the circuit. These controls are set for 25 KHz from the Spin Decoupler with all other inputs zero.

The VCO Tracking input from the Field Control PCB is applied to the contacts of K1 to one of two Tracking adjustments. R16 and potentiometer R17 set the level for NORMAL or proton operation. R14 and potentiometer R15 set the level for OTHER NUCLEI operation.

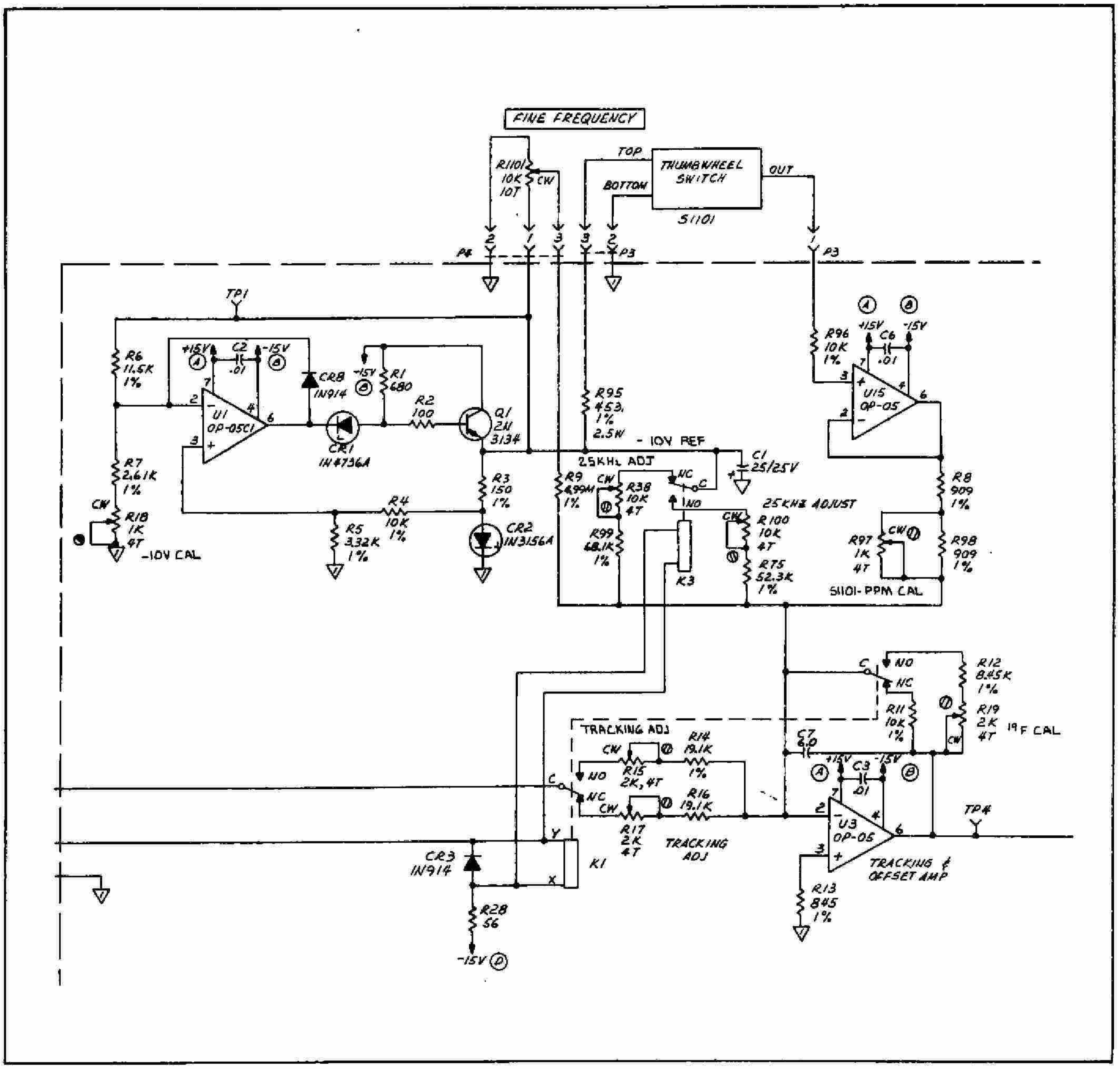



FIGURE 20-2. VCO CONTROL SIGNAL

The combined input to U3 is amplified and inverted to a positive level at TP4. This signal is the VCO control voltage to be applied to the 40 to 60 KHz VCO U1105. The gain of U3 is also controlled by relay K1. In the NORMAL or proton mode, the gain is fixed by R11. In OTHER NUCLEI mode the gain is adjusted by potentiometer R19 in series with R12. These and the other adjustments discussed enable nuclei change without internal adjustment of the decoupler.

The VCO Control signal is applied to a VCO in the inner portion of the temperature controlled oven. The circuits discussed previously are in the outer section of this oven and the circuits yet to be discussed lie outside the oven. The temperature sensing thermistor RT1101 is part of a bridge circuit on the input to U4. The bridge consists of R30, RT1101, R31, and R34. Any imbalance in the bridge is amplified by U4 and applied to the pass-gate driver Q2 which in turn drives the pass-gate Q3. The current through the passgate is the heater current.

The heater current is such to maintain balance in the input bridge with the set point 45°C ± 3°C with regulation to 0.1°C. The heater is in series with the thermal switch S1 which is a fuseable link type which opens at 70°C. If the switch should open, it must be replaced to restore operation.

The output of the VCO is 40 KHz to 60 KHz pulses to a divide-by-two IC U6. This IC outputs a balanced square wave of 20 KHz to 30 KHz to U10A and to U7, the integrated circuit phase locked loop IC.

Vcc for the PLL IC U7 is from the -15 volts zener regulated to -8.2 volts by zener diode CR7.

The output of the PLL IC U7 is 25 KHz when the IC is not locked to the VCO. This output when unlocked is adjusted by R45 to exactly 25 KHz and applied to Q4 for squaring and buffering before being applied to U10B NAND gate. The signals at the gates U10A and U10B are squared and applied through U10D and U10C to the inputs of the mixer M1. These frequencies are 20 to 30 KHz at pin 8 of M1 and 25 KHz at pin 1 of M1. If the system is not locked, these frequencies are <u>not</u> equal.

The difference frequency from the mixer is filtered by an RC filter on the output of the mixer and applied to U11-10. This IC and RC network C58, C39, C40, C37, R63, R62, and R65 comprise a bandpass filter with a low limit of about 200 Hz. The output of U11-10 is applied to a voltage divider network CR12 and CR11 with the signal across R70 and C43 (TP9) driving a voltage comparator U11-12. The non-inverting input of U11-12 has a bias of -1.6 volts. The comparator has a hysteresis of about 0.3 volt. When the input then is -1.9 volts to the inverting input, the output goes to +12 volts. In this state, U11-12 output cuts off Q6 (LED is off in the unlocked state) and turns on Q5 which enables a search ramp generator. When the voltage on the inverting input of U11 goes more positive than -1.6 volts, the output of U11-12 goes negative turning on Q6 (LED turns on in the locked state) and turning off Q5 which will disable the search ramp.

The LED on the front panel which lights in the locked mode has -15 volts at P3-5. Q6 must conduct to place path to ground at P3-4 to light the LED. Therefore, a negative output of U11-12 is required in the locked mode. When this occurs, Q5 is cut off and Relay K2 de-energizes (as shown) opening up the search ramp to the Phase Locked Loop IC U7. This occurs when the PLL output and the VCO output are within the pull-in range of 200 Hz set by the bandpass filter U11-10.

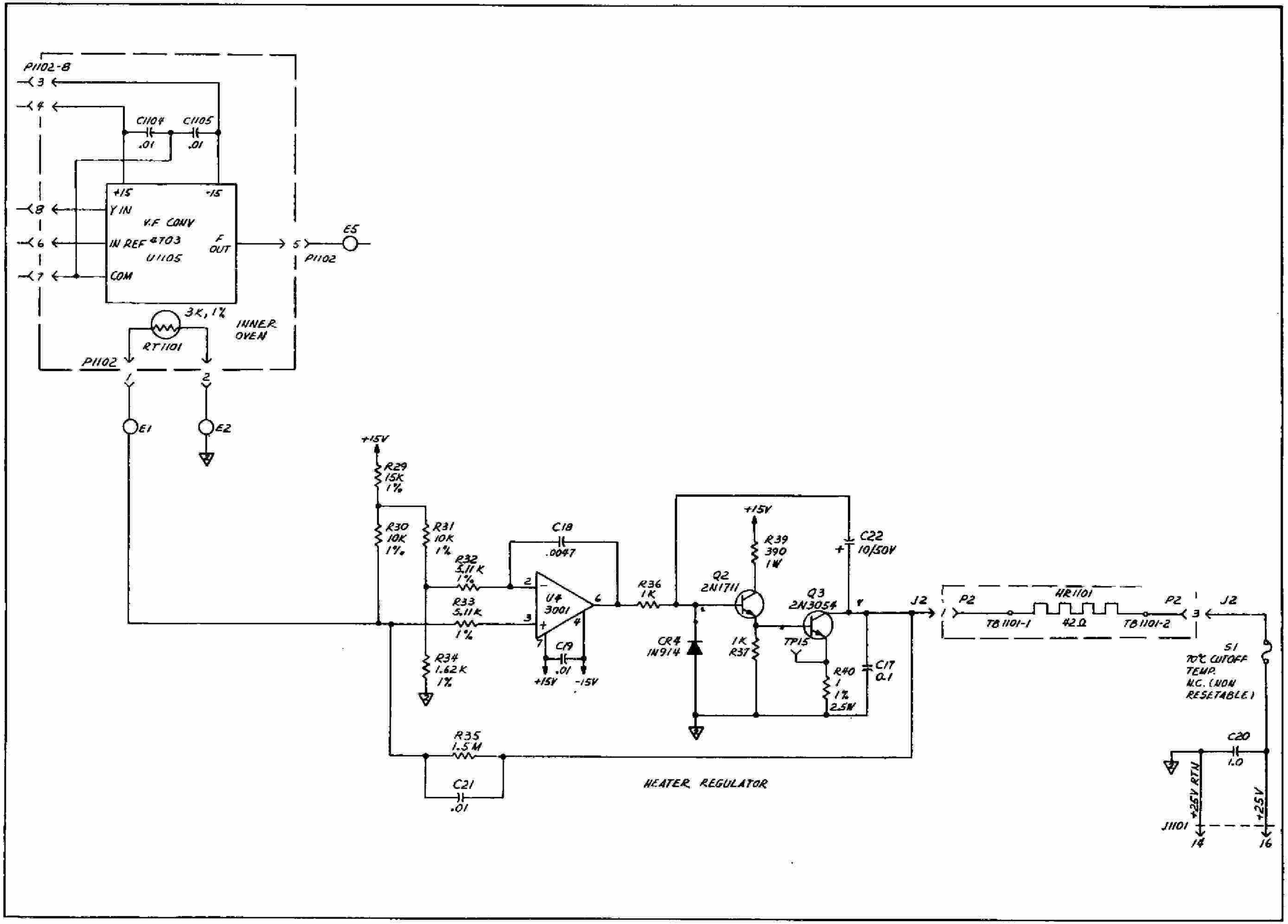



FIGURE 20-3. VCO AND TEMPERATURE CONTROL

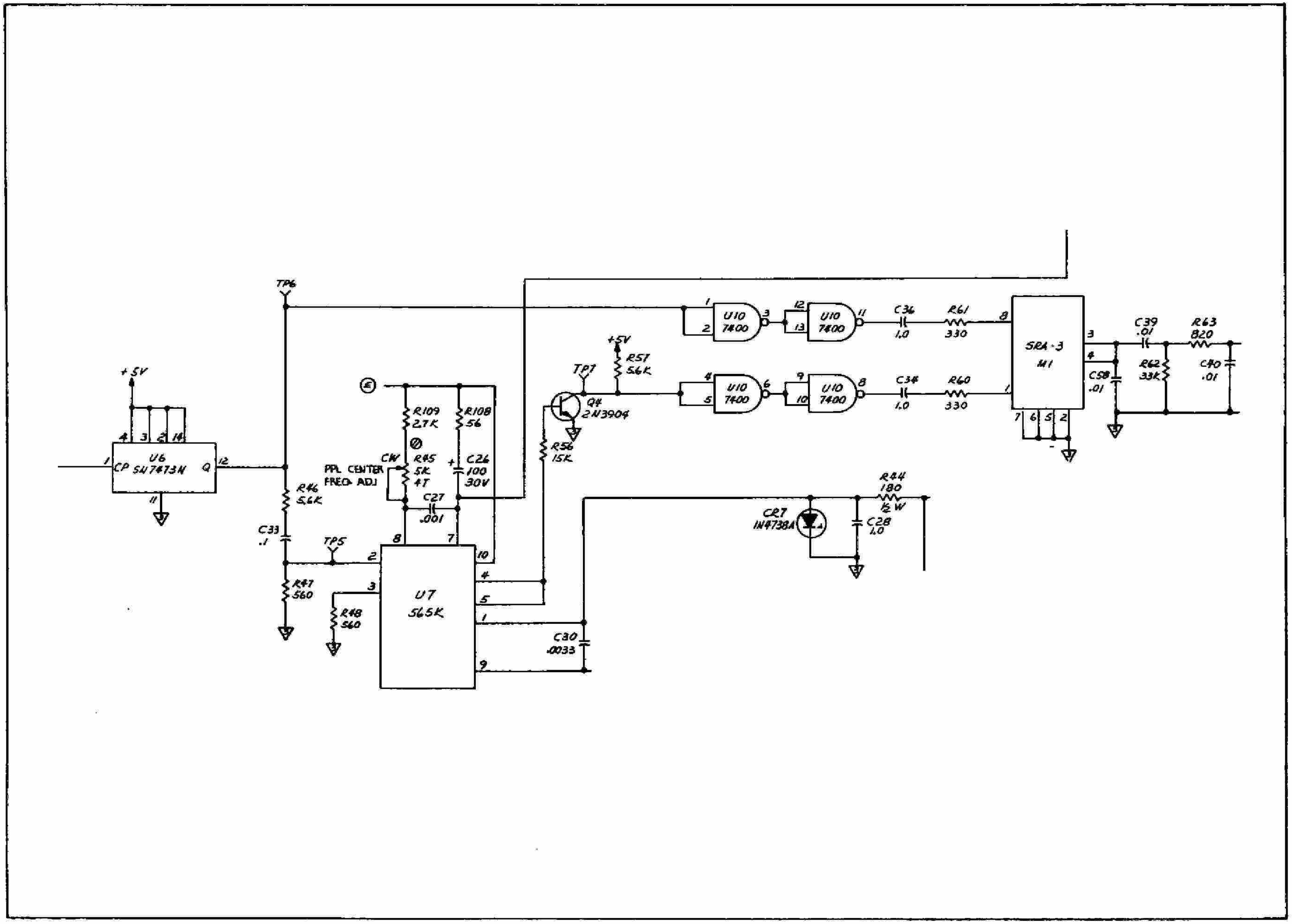



FIGURE 20-4. PHASE LOCKED LOOP CIRCUITS

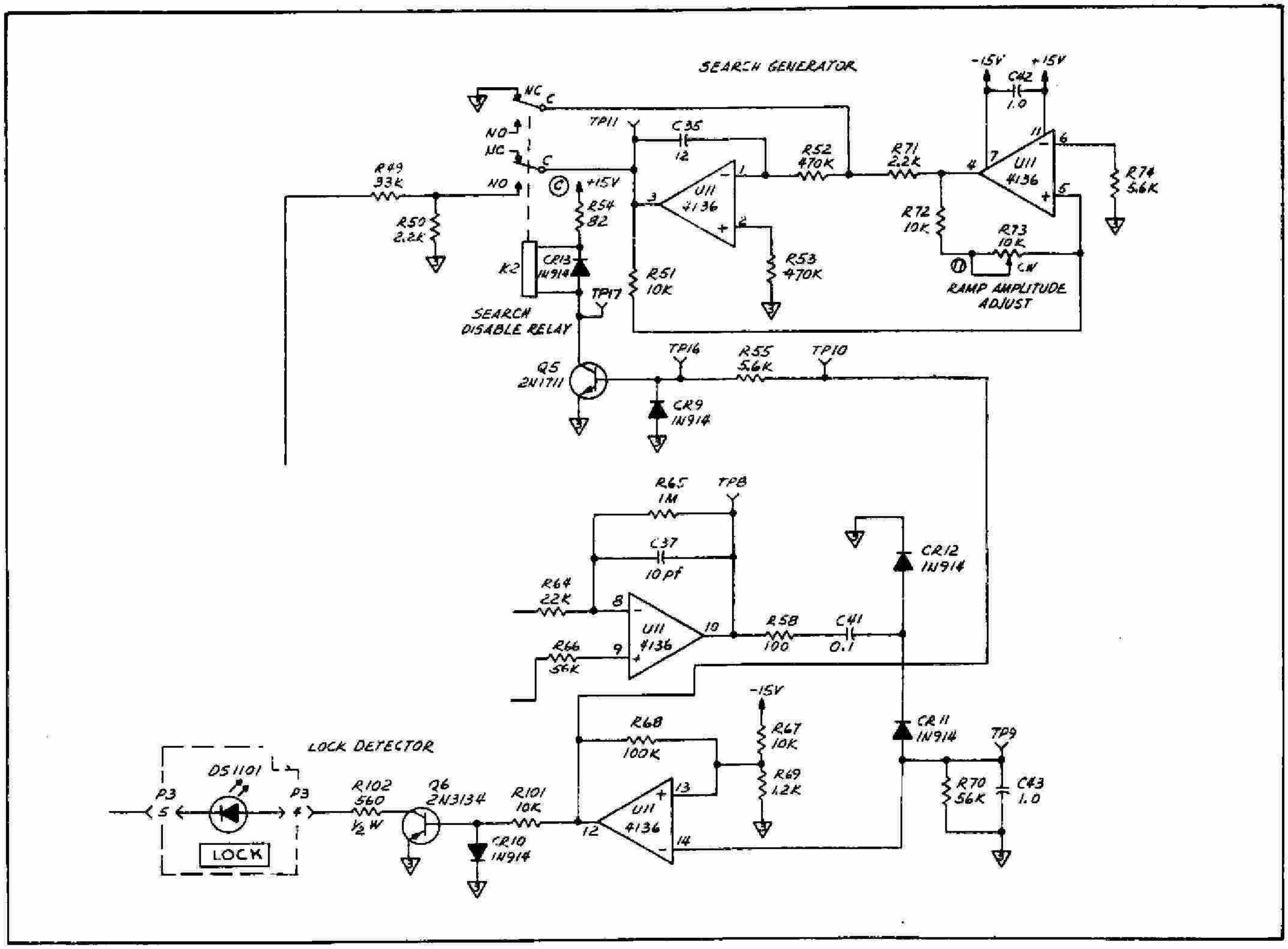



FIGURE 20-5. SEARCH RAMP CONTROL

When lock has not been achieved, the output of U11-12 is positive turning on Q5 which energizes K2. This relay enables the triangle-wave generator U11-4 and U11-3 to produce a search ramp which sweeps the PLL U7 through an output range of 18 KHz to 32 KHz. When the output of the PLL is swept within 200 Hz of the 20 KHz to 30 KHz of the VCO, the output of U11-12 goes negative turning off Q5 which de-energizes K2 removing the search ramp from the PLL U7.

The output of the PLL U7 to U12 is a triangular waveform. U12 buffers this signal and applies it to a triangle-to-sine wave converter which is U13 and the associated circuit components. R107 and C47 are adjusted for minimum distortion of the sine-wave output to UP13.

C48 and R85 make up a high pass filter so that the signal at TP13 has a +6 dB per octave slope. This is used to compensate for the frequency dependent modulation index of the coils in the probe. This means that the amplitude of the signal at 30 KHz is about 1.5 times the amplitude at 20 KHz.

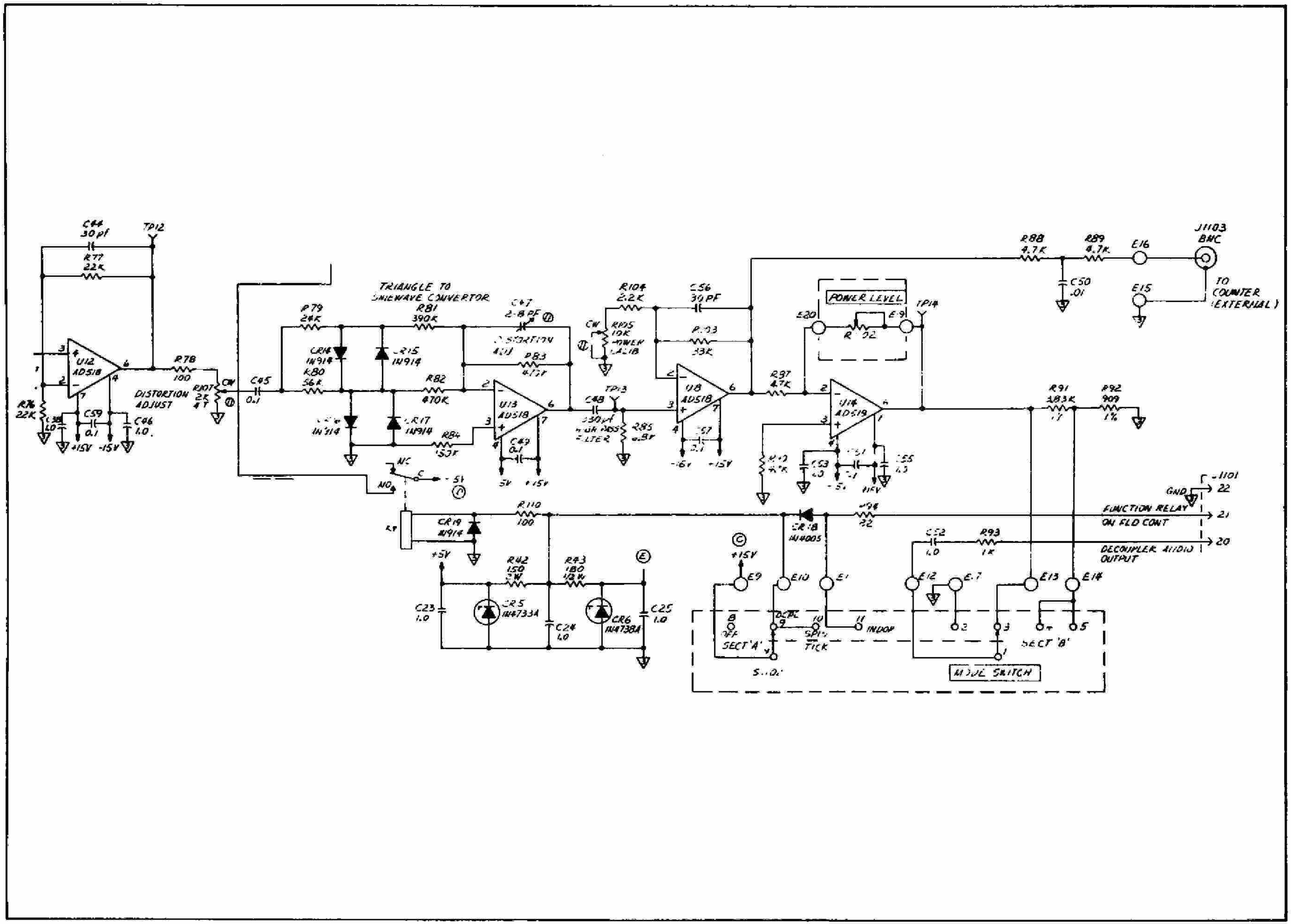



**FIGURE 20-6. OUTPUT SECTION**

The signal is applied to U8 non-inverting input. U8 is a buffer amplifier whose gain is controlled by potentiometer R105. This control sets the maximum level of the output.

U14 is a variable gain output amplifier with gain control accomplished by the POWER LEVEL front panel control. This control will vary the gain from 0 to 2X.

When the DECOUPLER MODE switch is OFF the supply voltages for U6, U10, and the PLL U7 are turned off so that no 20 to 30 KHz signal is present within the decoupler.

In the DECOUPLE mode, the 20 KHz to 30 KHz signal is fed through C52, R93, and J1101-20 to the Field Modulator circuit board in the console.

In the SPIN TICKLING mode the modulation signal amplitude is reduced by a factor of 10.

In the INDOR mode the low level is maintained and, in addition, a relay control line J1101-21 is energized which activates the INDOR circuit in the Field Control circuit board in the console.

## 20.3 TESTS AND ADJUSTMENTS

1. POWER SUPPLY ADJUSTMENTS

   a. Turn the Spin Decoupler OFF.

   b. Open the Spin Decoupler and remove the oven cover.

   c. Unplug connector P2.

   d. Turn the Spin Decoupler to DECOUPLE.

   e. Set the 10 Turn potentiometer R1101 FINE FREQUENCY Control to midrange which is five turns from either stop.

   f. Set the thumbwheel switch S1101 COARSE FREQUENCY to +000.0 PPM.

   g. Set the voltage at TP2 to +15 volts ± 0.1V with R20.

   h. The voltage at TP3 should be −15 volts ± 0.2V.

   i. Set the voltage at TP1 to −10 volts ± 0.1V with R18.

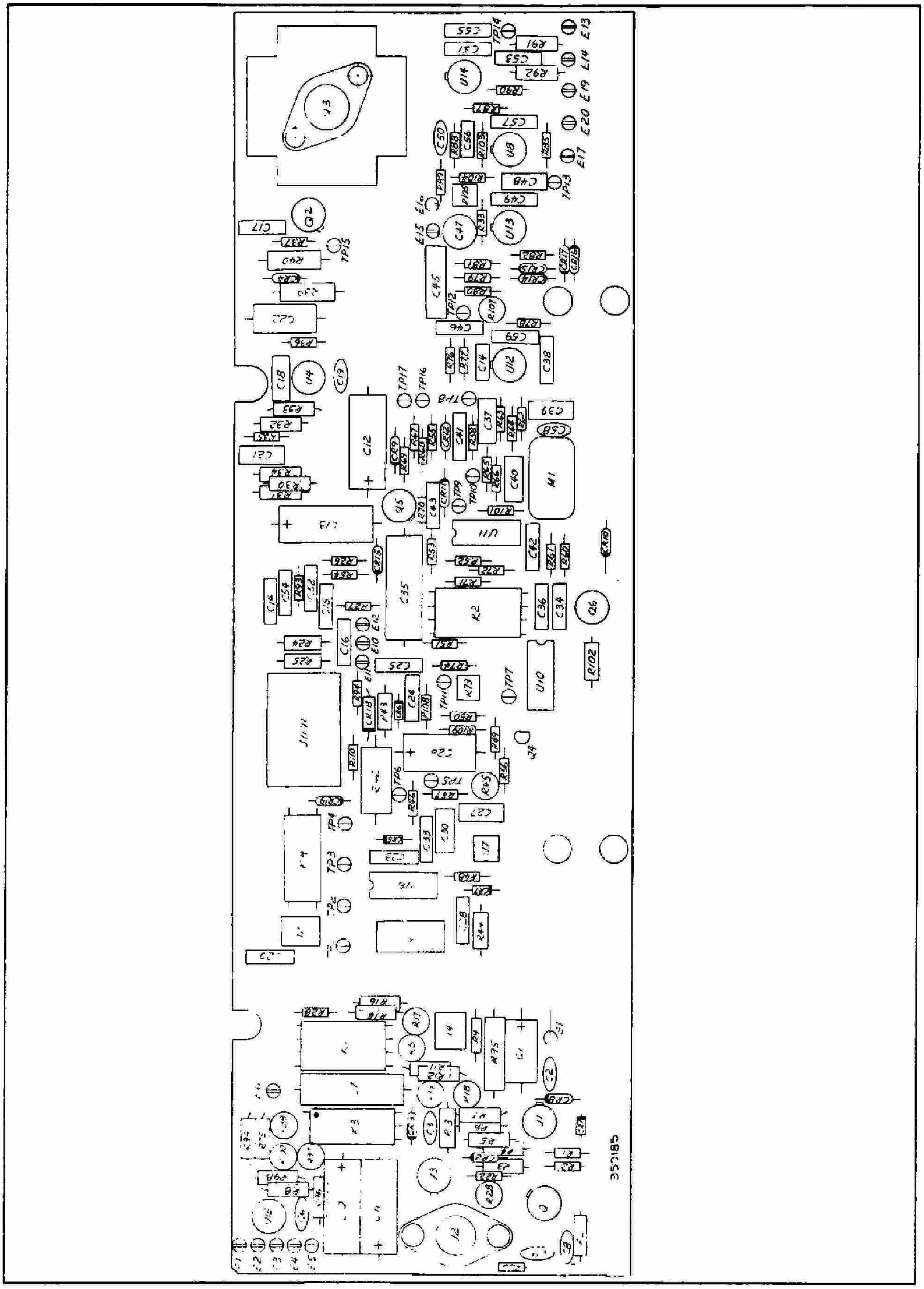


FIGURE 20-7. PART LOCATION

2. OVEN CONTROL SECTION

a. Turn the Spin Decoupler OFF.

b. Reconnect connector P2.

c. Put the cover back in place but do not bolt it on. Ensure the cover tightly fits with no mounting hardware.

d. Turn the Spin Decoupler to DECOUPLE. Allow 20 minutes warm-up time before proceeding.

e. Monitor the voltage at TP15 which should be 0.1 to 0.3 volt DC. If the voltage is outside this range the system has not yet warmed up sufficiently or the circuit is not regulating.

f. The case temperature of U5 in the inner oven should be +48°C to 53°C using a heat sensor (thermometer or thermocouple) attached to U5 case and the oven cover closed.

g. Momentarily short CR4 to ground and observe the transient response of TP15 signal which should be well damped.

h. Check the voltage across CR5 which should be +5 volts ± 0.25 volt. Turn the Spin Decoupler OFF and the voltage across CR5 must go to zero. Turn the Spin Decoupler back to DECOUPLE.

i. Check the voltage across CR6 which should be +8 ± 0.4 volt DC.

j. Check the voltage across CR7 which should be -8 ± 0.4 volt DC. Turn the Spin Decoupler switch to OFF and the voltage across CR7 must go to zero. Turn the Spin Decoupler back to DECOUPLE.

3. FIXED OFFSET AND PPM CALIBRATION

a. Measure the voltage at pin 7 of J1101 with the EM-390 in the NORMAL mode.

1) END OF SWEEP must be at zero.

2) Recorder arm must be at chart zero. This position may be varied to place the voltage at pin 7 of J1101 at 0 ± 0.5 millivolts.

b. Recheck the voltage at TP2 and readjust R20 to obtain 15±0.1 volts if necessary.

c. Recheck the voltage at TP1 and readjust R18 to obtain -10 volts ± 0.1 volt if necessary.

d. The thumbwheel switch S1101 should be set at +000.0 PPM.

e. Connect a high resolution frequency counter to TP6 and record the frequency.

f. Set thumbwheel switch S1101 to +10.0 PPM.

g. The frequency at TP6 should change by +900 Hz ± 3 Hz.

h. Adjust R97 to meet the above criterion. When adjusting R97 note that the +000.0 PPM frequency also changes so there must be several adjustments in order to make the correct calibration.

i. The frequency at TP6 must also be in the 20 KHz to 30 KHz range. If not, adjust R38 to move the frequency into this range.

j. Set S1101 to -000.0 PPM and note the frequency at TP6.

k. Set S1101 to -10.0 PPM and the frequency at TP6 should shift by -900 Hz ± 3 Hz.

l. Set the thumbwheel switch S1101 to +000.0 PPM and adjust R38 to obtain a frequency of 25.000 KHz ± 1 Hz at TP6.

m. Adjust END OF SWEEP on EM-390 to produce -360±1 millivolt at pin 7 of J1101.

n. Adjust R17 to obtain a frequency change at TP6 of +900 Hz ± 10 Hz.

o. Adjust END OF SWEEP on EM-390 to produce 0±0.1 millivolt at pin 7 of J1101.

p. Select $^{19}$F OTHER NUCLEI Operation.

q. For the following adjustments quickly lift the oven cover, make the adjustments, and then restore the oven cover.

r. Measure and record the frequency at TP6.

s. Set the thumbwheel switch to +10.0 PPM and adjust R19 until the frequency difference is 846±3 Hz.

t. Again several adjustments are required between S1101 at +000.0 and S1101 at +10 PPM before the correct calibration is obtained.

u. Set the thumbwheel switch to +000.0 and adjust R100 for a frequency of 25.000 KHz ± 5 Hz at TP6.

v. Adjust END OF SWEEP control on the EM-390 for a -360±1 millivolt level at pin 7 of J1101.

w. Adjust R15 to obtain a frequency change at TP6 of +846±10 Hz.

x. Restore the reading of 0±0.1 millivolt at pin 7 of J1101 with the END OF SWEEP control on the EM-390.

y. Restore the EM-390 to NORMAL ($^1$H) operation.

z. Set R1101 FINE FREQUENCY fully clockwise and record the frequency at TP6.

aa. Set R1101 FINE FREQUENCY fully counterclockwise and record the frequency at TP6.

ab. This CCW frequency should be +100±10 Hz higher than the CW frequency.

ac. Set R1101 back to its midrange.

4. PHASE LOCKED LOOP AND SEARCH RAMP ADJUSTMENTS

a. Connect a jumper from TP5 to ground.

b. Connect a jumper from TP16 to ground.

c. Set S1101 thumbwheel switch to +60 PPM.

d. Connect a high resolution counter to TP7 which should have a 0 to +4 volt square wave present.

e. Adjust R45 to obtain a frequency of 24.5 KHz ± 250 Hz.

f. Remove the ground from TP16 and apply it to TP17.

g. Observe the frequency at TP7 which is now swept using a 0.01 second count interval for easier frequency reading.

h. Adjust R73 such that the minimum frequency point is 18 KHz to 19 KHz and the maximum frequency point is 31 KHz to 32 KHz.

i. Check the triangle waveform at TP11 which should be less than ±10 volts with a ramp speed of 2.4 volts per second ± .8 volts per second.

j. Connect an oscilloscope to TP9 and observe the detector voltage while sweeping. Check proper operation in Figure 2. Observe the frequency of TP7 simultaneously.

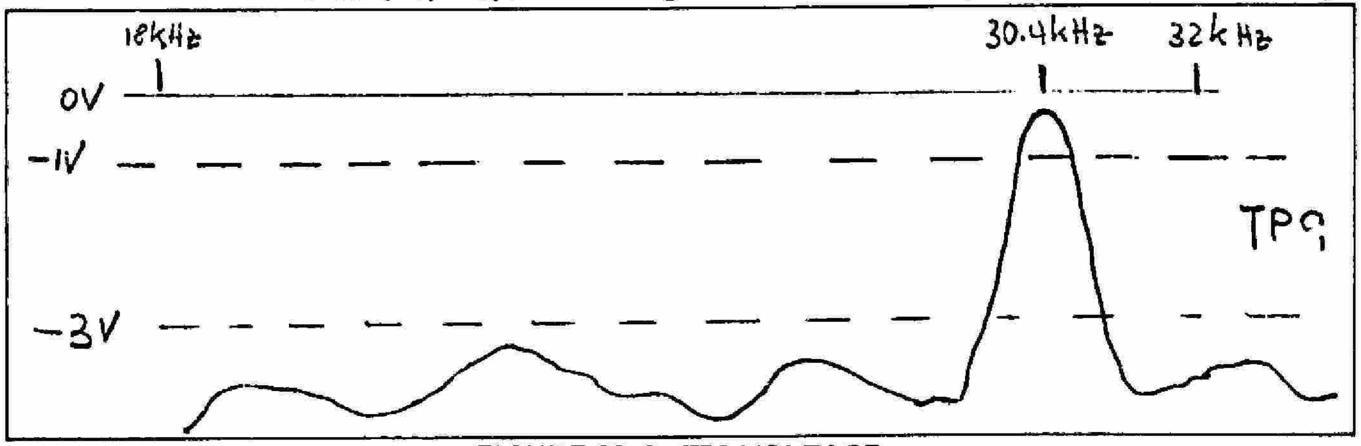



FIGURE 20-8. TP9 VOLTAGE

k. The DC voltage at TP9 should be more positive than -1 volt when the PLL U7 output frequency at TP7 is within 200 Hz of the frequency of TP6.

l. The DC voltage at TP9 should be more negative than -3 volts when the PLL U7 output frequency at TP7 is outside 200 Hz of the frequency at TP6.

m. Connect the oscilloscope to TP10 and observe the following signal in Figure 3 while watching the frequency counter on TP7.

n. Check for a clean +12 to -12 volt transition and a clean -12 to +12 volt transition at TP10. There should be no chopping of this waveform.

o. Set the thumbwheel switch to -60.0 PPM and observe the same signals as indicated in Figure 2 and Figure 3. The zero beat transition occurs now at 19.6 KHz. Observe frequency at TP7.

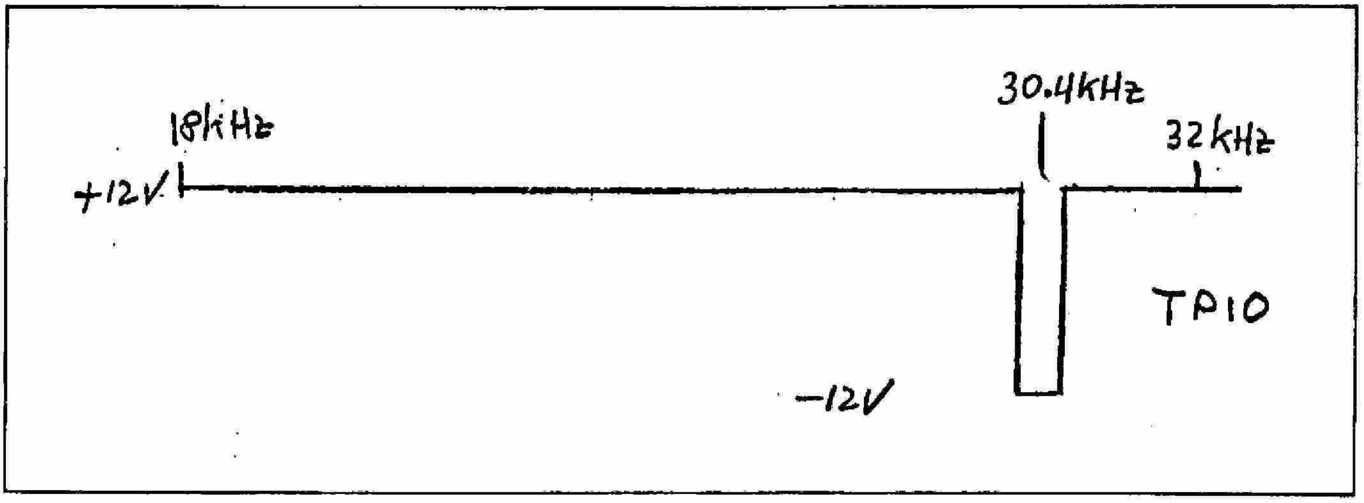



FIGURE 20-9. TP10 WAVEFORMS

p. Set the thumbwheel to +000.0 PPM and observe the same signal as indicated in Figure 2 and Figure 3 while monitoring the frequency at TP7. The zero beat transition is now at 25 KHz.

q. Remove the grounds from TP5 and TP17.

r. The PLL U7 should lock within 10 seconds, the LED should turn ON, the relay K2 should be de-energized, and the voltage at TP10 should be a steady -10 volt minimum.

s. Set the thumbwheel switch S1101 to +10 PPM and check that no voltage transition occurs at TP10 and PLL U7 remains locked (PLL Tracking speed test).

t. Set the thumbwheel switch S1101 to +000.0 PPM.

u. Momentarily short TP5 to ground. Lock should be attained within 10 seconds after removal of the short at TP5.

v. Move the thumbwheel switch S1101 to +60 PPM.

w. Momentarily short TP5 to ground. Lock should be attained within 10 seconds after the short on TP5 is removed.

x. Move the thumbwheel switch S1101 to -60 PPM.

y. Momentarily short TP5 to ground. Lock should be attained within 10 seconds after the removal of the short at TP5.

5. TRIANGLE TO SINE WAVE CONVERTER AND AUDIO OUTPUT ADJUSTMENTS

a. Set the thumbwheel switch to +000.0.

b. After lock-up observe the signal at TP12 which should be a 4 to 6 volt peak-to-peak clean triangular waveform.

c. Connect a low capacity oscilloscope probe to TP13 and adjust R107 and C47 for the best possible sine wave signal as indicated in Figure 4.

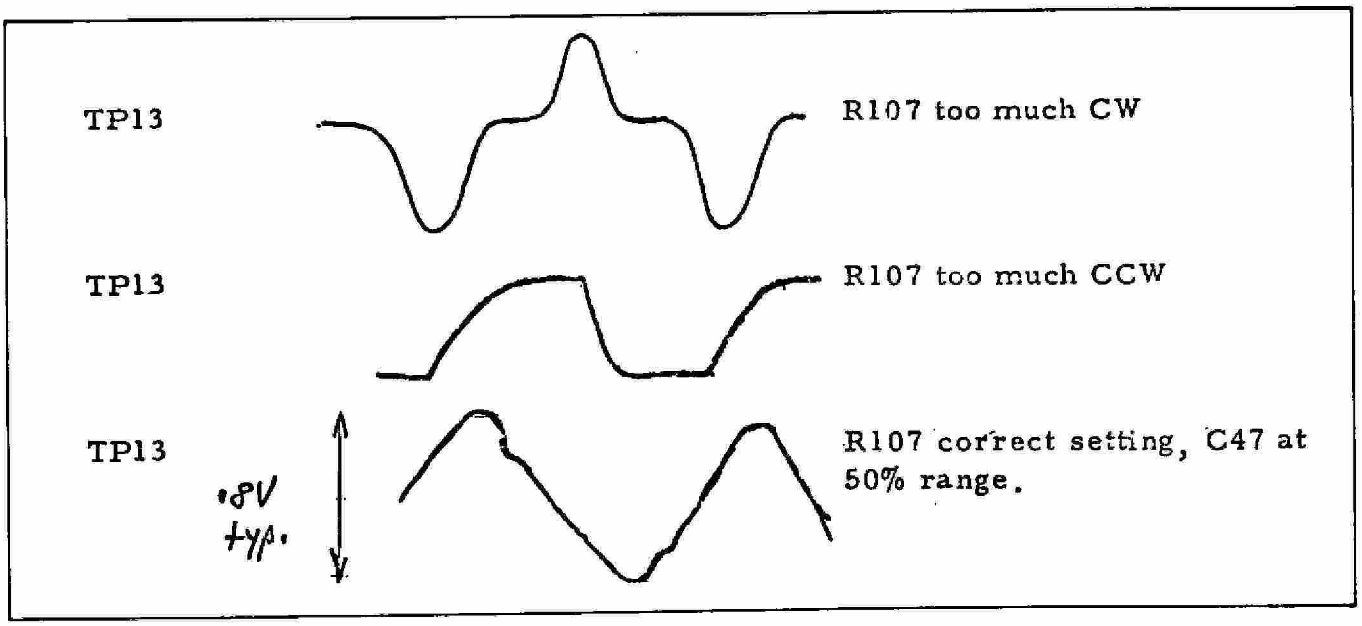



FIGURE 20-10. TP13 WAVEFORM

d. The voltage at TP13 should be at least 0.5 volt peak-to-peak and not more than 1.2 volts peak-to-peak. This voltage varies with R107 and C47 settings – typically 0.8 volt peak-to-peak.

e. Connect the oscilloscope to TP14 and set R1102 SPIN DECOUPLER POWER fully clockwise.

f. Adjust R105 to obtain a 12 volt peak-to-peak ± 0.6 volt signal.

g. Set the thumbwheel switch to -56.0 PPM.

h. Measure and record the signal amplitude at TP14.

i. Set the thumbwheel switch to +56.0 PPM.

j. Measure and record the signal amplitude at TP14.

k. The ratio of the second reading to the first reading should be at least 1.25 and not more than 1.5. Also, the distortion of the sine wave signal should not change appreciably.

l. Change the value of the capacitor C47 to meet the above specification. After each capacitor change, set the thumbwheel switch at +000.0 and readjust R105 as in step g.

m. This step (m.) is a compromise between low distortion and the required frequency dependent signal amplitude slope.

n. Connect the oscilloscope to pin 20 of J1101 and record the signal amplitude.

o. Set the mode switch to the SPIN TICKLE position.

p. The amplitude of pin 20 of J1101 should be reduced by a factor of 5.2±.26.

q. Check the DC voltage at pin 21 of J1101 which should be 0 volts.

r. Set the mode switch to the INDOR position.

s. The same reduced signal amplitude should be present at pin 20 of J1101.

t. Check the voltage at pin 21 of J1101 which should be +15 VDC.

u. Permanently mount the oven cover and reassemble the spin decoupler.

VARIAN ASSOCIATES
INSTRUMENT DIVISION
TECHNICAL SUPPORT
MAGNETICS GROUP

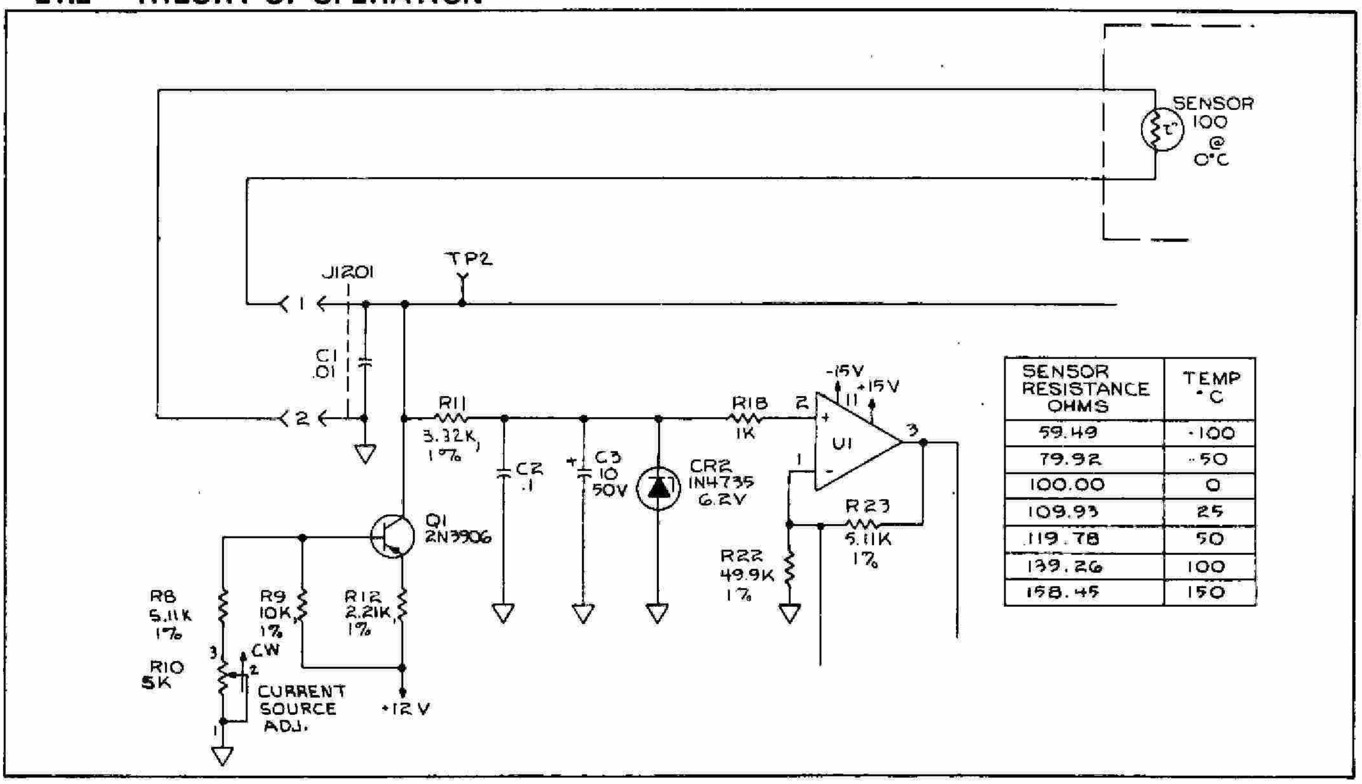
# EM-390 TRAINING NOTES

## SECTION 21.0
## VARIABLE TEMPERATURE CONTROL

### 21.1 FUNCTION

This unit is used to control the temperature of the NMR sample. Cooling is provided by a Joule-Thompson cryostat assembly 950167 in the probe. This cryostat also contains a platinum sensor and a heater. High pressure gas (800 to 1400 psi) is forced through a small opening and cooling occurs from the expansion of the gas. The gas flows past the heater and then the sensor compares the gas temperature with the desired temperature that the operator has dialed in with the thumbwheel TEMPERATURE SET switch on the controller. A proportional control is maintained through the heater to keep the sample at the desired temperature.

### 21.2 THEORY OF OPERATION




| SENSOR RESISTANCE OHMS | TEMP °C |
|---|---|
| 59.49 | -100 |
| 79.92 | -50 |
| 100.00 | 0 |
| 109.93 | 25 |
| 119.78 | 50 |
| 139.26 | 100 |
| 158.45 | 150 |

FIGURE 21-1. SENSOR INPUT

Q1 is a constant current source with an output of 3 ma through the sensor. This value is set by the adjustment of potentiometer R10. Since the collector impedance (essentially the sensor resistance) is small (less than 10%) of the emitter resistance, the collector voltage depends only on the value of the sensor. This voltage at room temperature is about +330 millivolts.

This voltage is applied through R11 to a filter circuit of R11, C2, and C3. A protective zener diode prevents accidental overload of U1A should the sensor be inadvertantly removed with power on. U1A buffers and amplifies the voltage developed across the sensor and applies it to a differential comparator U1B.

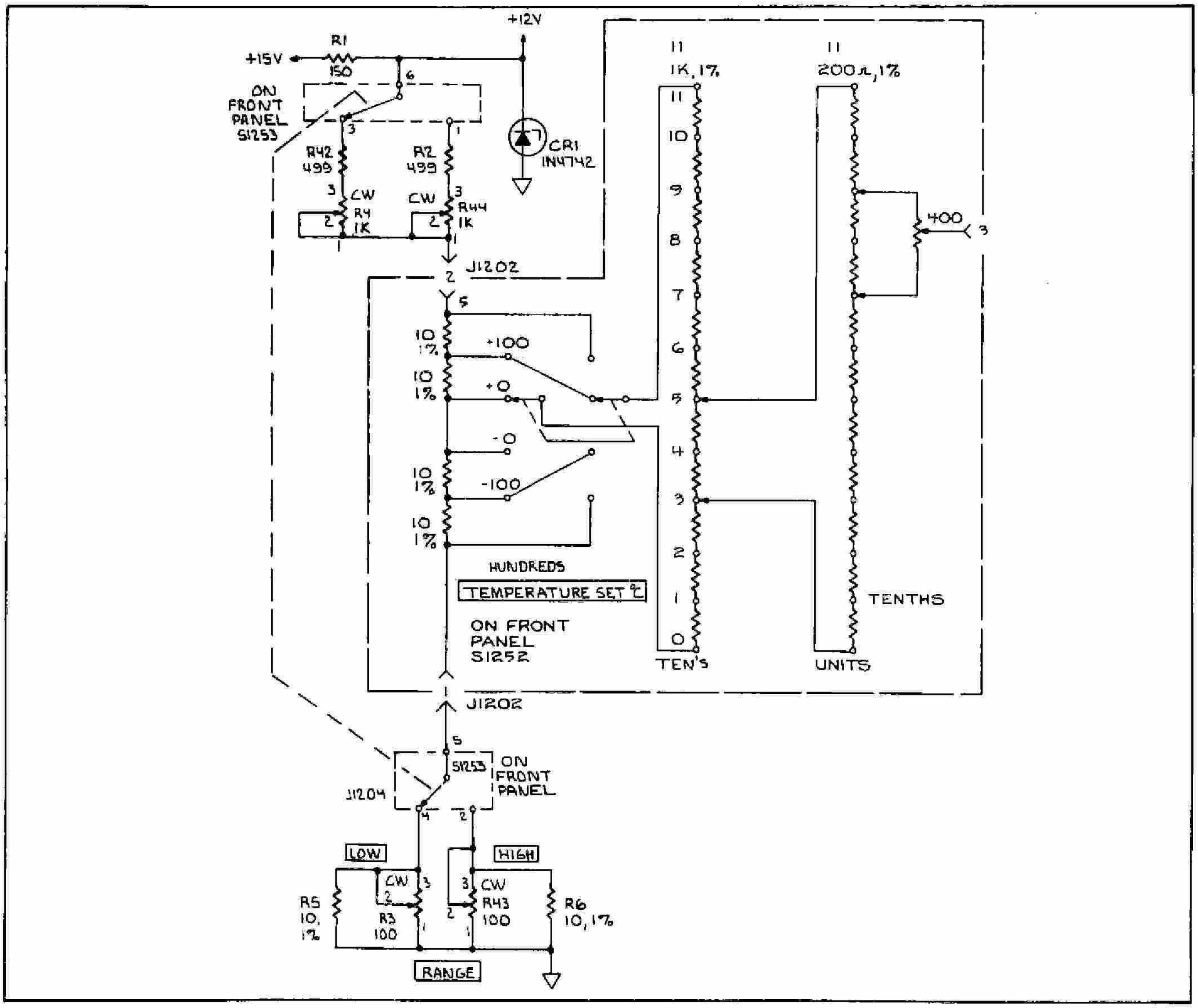



FIGURE 21-2. TEMPERATURE SET

As shown in Figure 21-2 the thumbwheel TEMPERATURE SET switch is part of a voltage divider network that precisely divides the zener regulated positive voltage into small increments for temperature control. This voltage is used to "buck-out" the voltage generated across the sensor by the constant current source. Calibration is accomplished by adjusting the LOW OFFSET R3 and LOW SPAN R4 on the LOW RANGE and HIGH OFFSET R43 and HIGH SPAN R44 on the HIGH RANGE. These controls determine the amount of voltage across the thumbwheel switch.

The voltage at pin 6 inverting input of U1B is the positive voltage from the sensor. The voltage at pin 5 non-inverting input of U1B is the positive voltage from the thumbwheel TEMPERATURE SET voltage divider. When the temperature is high, the voltage from U1B is negative. This negative voltage is limited by CR3 to -0.6 volt into U1D. This voltage is amplified by U1D driving transistor amplifier Q2 to cut off the output current to the heater. If the temperature is low, the output of U1B is positive. This positive voltage is limited by CR4 to +0.6 volt into U1D. The output of U1D goes positive turning Q2 on full which drives Q3 placing full current through the heater. When the temperature of the sample is nearly correct the output of U1B is near zero. This puts the output of U1D near zero and the conduction of Q2 and Q3 is regulated by this output to maintain the correct temperature.

When the sensor temperature reaches or exceeds 200°C, the voltage from the sensor to U1C is sufficient to drive its output positive. This point is set by adjustment R29 in the inverting input of U1C. When the output of U1C goes positive Q4 turns on placing ground on Q2 base cutting off Q2 and Q3 removing current from the heater.

Recall the three states of the U1B output. They are high (+12V) for temperature low, 0 volts for temperature correct, and low (-12V) for temperature high.

Assume temperature is high. The heater is cut-off and TEMPERATURE DECREASING lamp should light. The negative from U1B applied to U2B causes its output to go positive turning on LED CR1251 DECREASING lamp. The + from U2B is inverted in U2A to a negative from U2A which will back-bias LED CR1252 INCREASING lamp cutting it off.

When the temperature is proper the U1B output is about zero. The outputs of U2B and U2A then are almost zero which will forward bias both LEDs CR1251 and CR1252 and both light.

When the temperature is low, the U1B output is positive. U2B output is then negative and CR1251 is back-biased and does not light. U2A output is positive and CR1252 LED (INCREASING) is lighted.

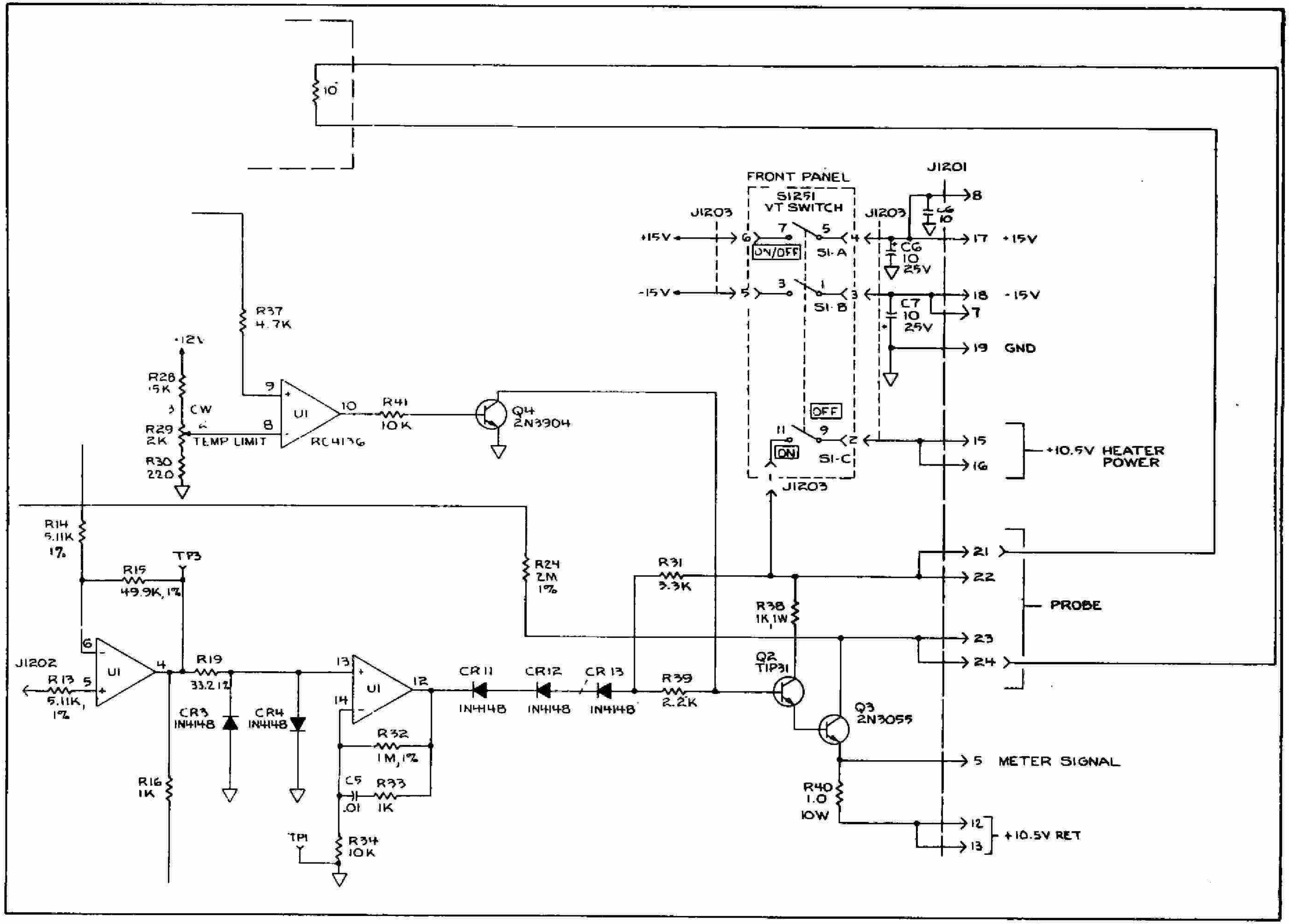



FIGURE 21-3. TEMPERATURE CONTROL

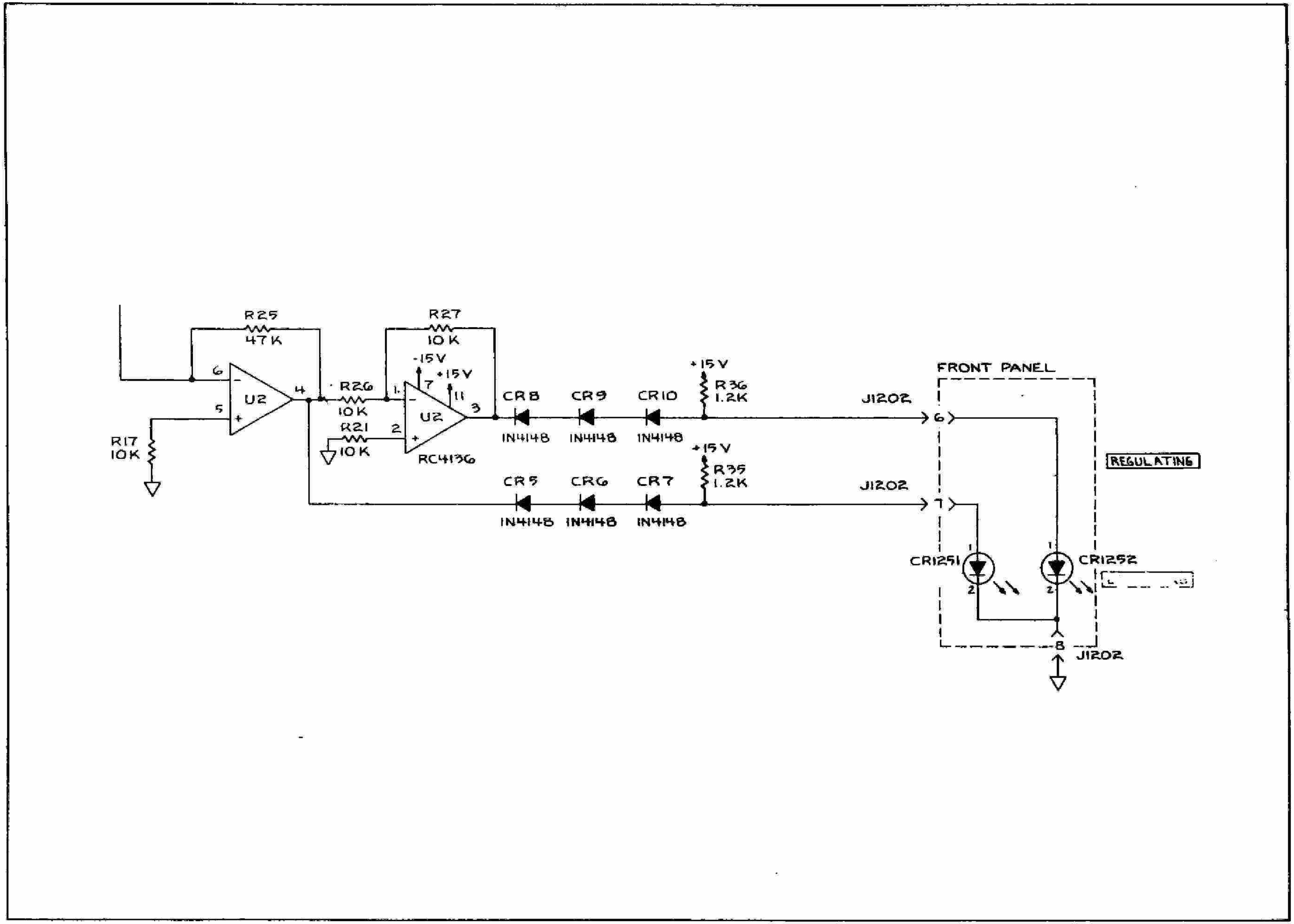



FIGURE 21-4. INDICATING LEDs

## 21.3 TEMPERATURE CALIBRATION

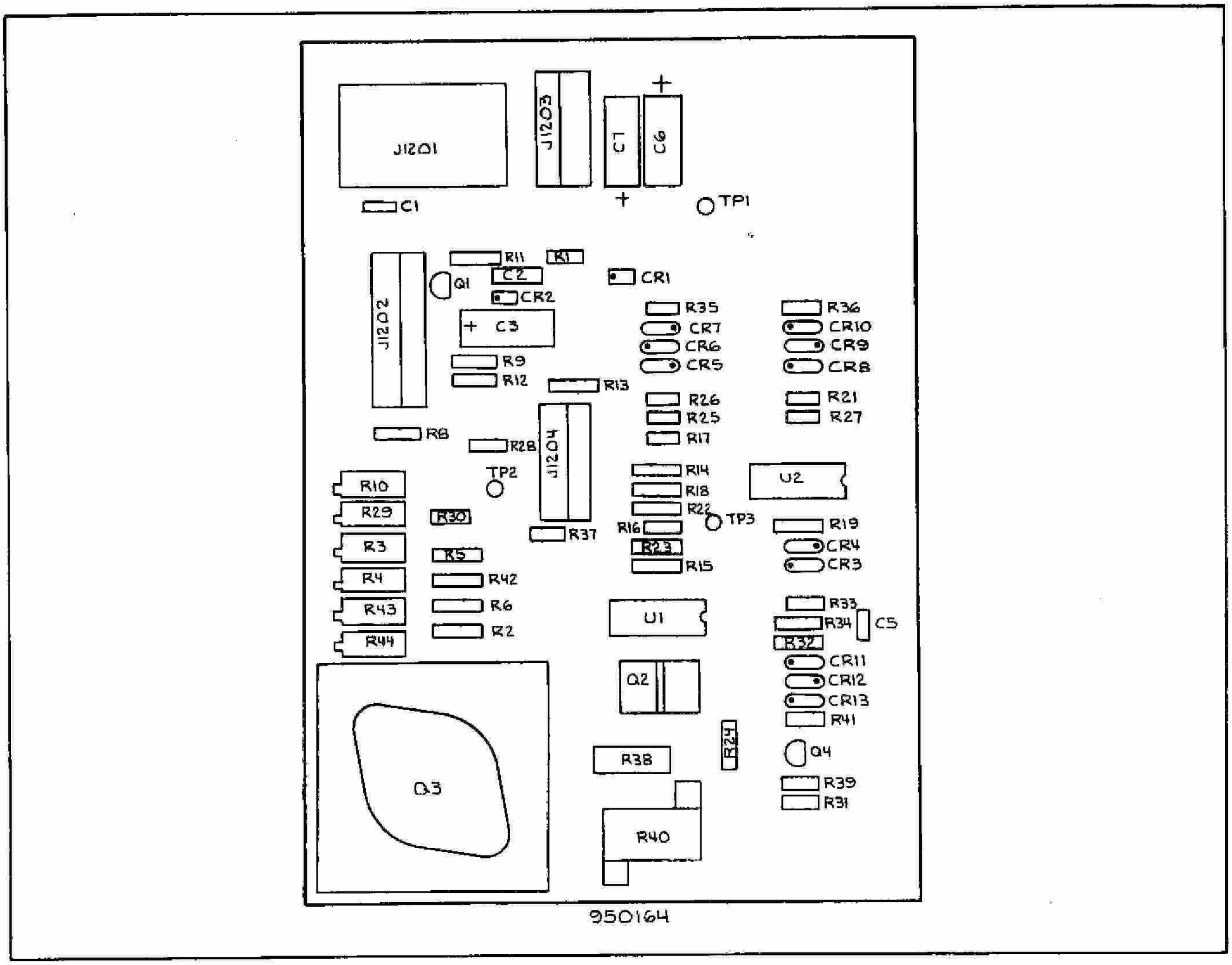



FIGURE 21-5. PARTS LAYOUT

1. CURRENT ADJUST

a. The current adjust control does not normally need adjustment.

b. If it has been physically mis-adjusted remove the leads from pins 1 and 2 of J1201 to the sensor in the probe.

c. Connect a 100 ohm 1 percent resistor across pins 1 and 2 ot J1201 to simulate the sensor.

d. Adjust R10 for an indication of 0.300 volts across the 100 ohm resistor.

e. If the High Temperature Limit is to be set, remove the 100 ohm resistor and do not reconnect the probe leads.

2. HIGH TEMPERATURE LIMIT SET

a. The high temperature limit set does not normally need adjustment. A mis-adjustment here poses a severe peril to the probe due to heat and over temperature stress.

b. Dial 199.9°C on the VT controller.

c. Insert a 177 ohm 1 percent resistor across pins 1 and 2 of J1201 with the probe leads disconnected. This resistance simulates the 200°C point for the sensor.

d. Adjust R29 for heater current shut-off by observing the VT CURRENT position of the LEVEL Meter on the front panel of the console.

e. Remove the 177 ohm resistor.

f. Restore the normal connections to pins 1 and 2 of J1201.

3. HIGH TEMPERATURE CALIBRATIONS

WARNING

Ethylene glycol boils at 197°C. Sealed samples will explode at 190°C due to increased vapor pressure.

CAUTION

Do not adjust R10 (current source) or R29 (high temperature limit) during calibration. If either control should be accidentally misadjusted, go back to paragraphs 1. and 2. of these instructions before proceeding.

a. Insert the ethylene glycol sample (943346-05) in the probe.

b. Install the pressure cap and adjust the thumbscrew until the sample will spin.

c. Set the gas pressure input to 800 psi. This must be carefully done as variations in gas pressure adversely affect calibration.

d. Set the controller for +120°C.

e. Wait 10 to 15 minutes for the system to reach equilibrium.

f. Adjust R44 for exactly 603±1.8 Hz spacing between the peaks.

g. Wait after each adjustment 10 to 15 minutes for system equilibration.

h. Set the controller to +60°C.

i. Wait 10 to 15 minutes for the system to reach equilibrium.

j. Adjust R43 for 114.3±1.8 Hz spacing between the peaks.

k. Wait after each adjustment 10 to 15 minutes for system equilibration.

l. R43 and R44 are highly interactive and must be adjusted several times before their proper ratios are obtained. Continue to adjust at +120°C and +60°C until no improvement can be made.

4. LOW TEMPERATURE CALIBRATION

a. Insert the methanol sample in the probe (943346-33).

b. Install the pressure cap and adjust the thumbscrew until the sample starts to spin.

c. Set the gas pressure to 1400 psi.

d. Set the controller for -35°C.

> **WARNING**
>
> Methanol freezes at -90°C. Do not go lower than this temperature unless another form of calibration such as a thermometer or thermocouple is used.

e. Lock the system to TMS in the AUTOSHIM mode.

f. Wait 10 to 15 minutes for the system to reach equilibrium.

g. Adjust R4 for 186.6±1.6 Hz spacing between the methanol peaks.

h. Allow 10 to 15 minutes after each adjustment for system stabilization.

i. Set the controller to -65°C.

j. Wait 10 to 15 minutes for the system to reach equilibrium.

k. Adjust R3 for 209.5±1.6 Hz spacing between the peaks.

l. Wait after each adjustment 10 to 15 minutes for system equilibration.

m. R3 and R4 are highly interactive and must be adjusted several times before their proper ratios are obtained.

> NOTE
>
> If the low temperature point is not easily reached, then there is either a pressure drop in the system or the temperature is below the dew point (adsorber malfunction) and the adsorber must be dried.

5. CORRECTIVE MAINTENANCE

a. Monitor the flow rate from the exhaust hose barb with the system at magnet temperature (+34°C).

b. If the flow rate decreases when the temperature is moved to a -65°C or so it is an indication that ice is forming in the air path restricting flow.

c. Another indication of ice formation is that the spinner may cease to operate normally.

d. If the VT CURRENT meter as monitored from a stable condition at a temperature below 0°C starts to decrease and go to zero it is an indication that the Joule-Thompson orifice is icing up.

e. If any of these indications are observed proceed as follows:

1) Remove the adsorber from the system.

2) The outlet should be capped or connected to a source of dry helium gas if available.

3) Connect the inlet to a vacuum pump.

4) Heat the adsorber in an oven at a temperature of 350° F (177°C) for 24 hours while maintaining a vacuum. If an oven is not available, obtain 24 inches of Briskeat, 115V, 48W heating tape and wrap the adsorber with it connected to a 115 volt power source.

5) Periodically purge the adsorber with helium (if available) for a few minutes during the bakeout.

6) After bakeout, allow the adsorber to return to room temperature while maintaining vacuum.

7) Allow the adsorber to cool completely before opening the fittings or removing vacuum.

f. If difficulty is still encountered in low temperature operation, there is a pressure or flow loss somewhere in the system that must be found by visual inspection using a soap solution.