Instruction Manual

Model 72C

Capacitance Meter

583

BOONTON

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SECTION I

GENERAL INFORMATION

1-1. SAFETY NOTICE
The Model 72C is furnished with a three-conductor power cable and three-prong plug so that, when the plug is inserted in a properly polarized a.c. power receptacle, the instrument is grounded. The instrument depends upon such connection to ground for equipment and operator safety.

***** WARNING *****

> To avoid the possibility of electrical shock, before anything is connected to this instrument, and before you use this instrument, make certain that its power cable is plugged into a mating a.c. receptacle that has a grounded ("earthed") contact.

Never defeat the instrument's protective grounding. For example: Do not use an extension power cable if it is not equipped with a ground conductor; do not plug the instrument into an a.c. receptacle that does not provide a high-quality earth ground. If only a two-terminal a.c. power receptacle is available, use a three-prong-to-two-prong adapter and connect the ground wire of the adapter to the power-receptacle ground. Do not use such an adapter if the ground wire cannot be grounded.

1-2. DESCRIPTION
The Model 72C Capacitance Meter provides instant, direct reading, three-terminal and differential capacitance measurements from 0.01 to 3000 pF. This coverage is divided into eight ranges, selected either by the front-panel switch or remotely, arranged in a 1 - 3 - 10 sequence. The solid-state design and crystal-controlled signal source contribute to the high stability and excellent reliability of the instrument.

The 100 kHz test signal is held to a level of 15 mV, r.m.s., allowing the measurement of capacitance of semiconductor devices. The provision for application of d.c. bias to either or both sides of the specimen makes it possible to measure these devices under operating conditions. The bias voltages can be applied either to the rear-panel terminals provided, or to the appropriate pins on the edge connector.

The 72C employs an unusual range-switching system using switching diodes and miniature reed relays; the elimination of the switch contacts from the measurement circuits assures a maximum of reliability and stability.

The instrument's phase-sensitive detector system permits the measurement of even low-Q devices (down to Q=1) without appreciably degrading the accuracy of the measurement. The 72C responds to the effective parallel capacitance of the test specimen. For a specimen with predominantly series loss and a Q-factor of less than 10, the 72C will indicate the effective parallel capacitance; i.e.:

$$C_p = C_s Q^2/(1 + Q^2)$$

Two plug-in connection adapters are supplied with the 72C. One adapter, fitted with two sets of coaxial connectors, 72-4B, is intended for use with coaxial cables and remotely located test fixtures for both three-terminal and differential mesurements. The second adapter, 72-5C, with three terminal posts, is used for wire-lead components; differential measurements are not possible with this adapter.

A linear d.c. output is available at rear-panel terminals as well as at the appropriate pins on the edge connector. This feature extends the range of applications beyond ordinary laboratory measurements to include production testing as well as a variety of control functions. Flexibility is further enhanced by the provision of remote ranging terminals; the instrument is fully capable of being integrated into a controlled test system for rapid, production-line testing.

Remote ranging is controlled by grounding the MANUAL DISABLE terminal on the rear edge connector, disabling the front-panel range switch. Grounding any one of the eight range-line terminals will then select that range.

Connection to the rear-panel edge connector should be made with an Amphenol Type 225-22221-101 plug.

1-3. ACCESSORIES FURNISHED

A. Test Post Adapter (BNC), 72-4B: for remote connections to TEST and DIFF terminals.

B. Test Post Adapter (Clips), 72-5C: grip-posts for local connection of axial-lead components.

1-4. OPTIONS AND ACCESSORIES AVAILABLE

A. Option -05: 200 μs d.c. output response time (standard unit responds in 1 ms). R.M.S. noise level 10 mV (100 kHz bandwidth).

B. Accessory 950032: Single rack-mounting kit (mounts left or right).

C. Accessory 950030: Dual rack-mounting kit.

D. Accessory 953108: Capacitance Standard, 0.1 pF.

E. Accessory 953109: Capacitance Standard, 0.3 pF.

F. Accessory 953110: Capacitance Standard, 1.0 pF.

G. Accessory 953111: Capacitance Standard, 3.0 pF.

H. Accessory 953112: Capacitance Standard, 10.0 pF.

I. Accessory 953113: Capacitance Standard, 30.0 pF.

J. Accessory 953114: Capacitance Standard, 100.0 pF.

K. Accessory 953115: Capacitance Standard, 300.0 pF.

L. Accessory 953116: Capacitance Standard, 1000.0 pF.

M. Accessory 953117: Capacitance Standard, 3000.0 pF.

N. Accessory 953119: Capacitance Decade Standard, 100 kHz: 1 - 3000 pF, in a 1-2-3 sequence

1-5. ENVIRONMENTAL DATA, OPERATING AND STORAGE

Temperature: Operating, +10°C to +40°C
Storage, -55°C to +75°C

1-6. SPECIFICATIONS

CAPACITANCE RANGE	0.01 to 3000 pF
FULL-SCALE RANGES	1, 3, 10, 30, 100, 300, 1000, 3000 pF

ACCURACY	
1 - 1000 pF, f.s.	0.5% of reading ±0.5% f.s. (Q > 5)* ±1.0% of reading ±0.5% f.s. (Q = 1 to 5)* *Add 0.005 pF on the 1 pF f.s. range.
3000 pF, f.s.	±1.0% of reading ±0.5% f.s. (Q > 5) ±2.0% of reading ±0.5% f.s. (Q = 1 to 5)
RESOLUTION	0.5% of f.s. on all ranges
METER	4-1/2" taut-band. Two linear scales: 0 to 10 (0.1 per division), and 0 to 30 (0.5 per div.).
D.C. OUTPUT	1 V, f.s., adjustable ±2% at 1, 10, 100, 1000 pF 3 V, f.s., adjustable ±2% at 3, 30, 300, 3000 pF
Linearity	±0.1% of reading ±0.01% f.s. 3000 pF range: ±0.25% of reading ±0.01% f.s.
Response Time	1 ms (see option -05, above)
Source Resistance	1 kΩ
EXTERNAL BIAS	HI TO GND: ±200 V, maximum LO TO GND: ±400 V, maximum LO to HI: ±600 V, max. (floating supply only)
TEST SIGNAL	100 kHz, crystal-controlled, 15 mV r.m.s.
TEMPERATURE INFLUENCE	

	Temperature Range	Max. Influence
Reference:	21°C to 25°C	0
Normal:	18°C to 30°C	0.2% of reading
Extreme:	10°C to 40°C	0.5% of reading

POWER REQUIREMENTS	100, 120, 220 or 240 V a.c., 50 to 400 Hz, 7 W
DIMENSIONS	132 mm high × 211 wide × 305 deep (5.2 in. × 8.3 × 12)
WEIGHT	3.15 kg (7 lbs.), approximately

SECTION II

INSTALLATION & OPERATION

2-1. INSTALLATION
Each instrument has been inspected and tested at the factory for full compliance with all specifications before packing. Notify the carrier and the factory immediately should any indication of shipping damage be apparent upon unpacking. It is recommended that the special packing materials be saved for use in the event that the instrument must be reshipped.

2-2. OPERATING CONTROLS, INDICATORS AND CONNECTORS
All controls, indicators and connectors used during operation of the 72C are described in Table 2-1, below.

Table 2-1. Operating Controls, Indicators and Connectors

ITEM	FUNCTION
FULL SCALE pF switch	Selects full-scale range of instrument.
PWR switch	Turns line power on and off. LED is lit when power is "on".
ZERO control	Used to balance out capacitance across TEST terminals contributed by exposed terminations of connecting cables, test fixtures, etc.
METER	Indicates capacitance with two linear scales, reading 0 to 10 with 0.1 per division, and 0 to 30 with 0.5 per division.
ANALOG OUTPUT terminals	Provide a d.c. voltage proportional to the meter reading, adjustable >2%.
BIAS terminals	External d.c. bias may be applied to the HI and LO Test Terminals via these posts.
LINE VOLTAGE switch	Permits selection of appropriate a.c. line voltage.
Fuse holder	Contains replaceable line fuse.
P102	A 22-pin edge connector for remote ranging and output connections. See Figure 4-4.
Test adapter	These banana plugs are used for storing the unused connection adapter: 72-4B or 72-5C.
	This safety-requirement symbol has been adopted by the International Electrotechnical Commission, Document 66 (Central Office) 3, ¶5.3, which directs that an instrument be so labeled, if, for the correct use of the instrument, it is necessary to refer to the Instruction Manual. In this case it is recommended that reference be made to the Instruction Manual when connecting the instrument to the proper power source.

2-3. OPERATING INSTRUCTIONS

A. See that the rear-panel voltage selector switch is set correctly for the line voltage used. Check also that the proper line fuse is installed: a 0.10 A fuse for 100 or 120 V; a 0.06 fuse for 220 or 240 V. If necessary, adjust the mechanical-zero screw of the meter. Plug the instrument into a power outlet and allow it to warm up for a few minutes.

B. Plug the appropriate test connection adapter into the front-panel receptacle. If remote or other coaxially connected components are to be measured, connect all cables and test fixtures to the TESY jacks of the connection adapter. The test adapter is held in place by a captive screw located in the center of the adapter.

C. Switch the instrument to its lowest range (1 pF, f.s.). Set the meter reading to zero, using the ZERO control.

> NOTE: The ZERO control uses a dual-ratio vernier to drive a differential air capacitor having a full 360° of rotation. The ZERO control turns easily for about 270°, at which point the ratio shifts from 36:1 to 6:1 and the required torque increases abruptly.

The ZERO adjustment has sufficient range to compensate for approximately 5 pF of shunt capacitance across the TEST terminals. If this range is insufficient, a small capacitor (value determined experimentally), can be connected across the DIFF terminals to effect a zero setting within the range of the ZERO control.

D. The instrument is now ready for use. Once the zero setting has been made on the lowest range, it will hold on all other ranges.

2-4. REMOTE MEASUREMENTS

A. Cable Shunt Capacitance. When more than a few inches of coaxial cable is used to connect the instrument to a remote fixture, attention must be given to the shunt capacitance of the cable. To maintain the specified accuracy, the values shown in Table 2-2 should not be exceeded.

Table 2-2. Maximum Cable Shunt Capacitance

a. HI post to ground:

RANGE	MAX. C
1 pF & 3 pF	200 pF
10 to 3000 pF	500 pF

b. LO post to ground: 500 pF, maximum, on all ranges

B. Transmission-Line Effect. At a test frequency of 100 kHz, the transmission-line effect on the remote measurement of capacitance is negligible for cable lengths up to about 20 feet. The limiting factor is the cable capacitance, which loads the low and the high test terminals of the 72C. For this reason is is preferable to use coaxial cable of Z_o = 93 Ω (13 pF per foot), or even 72 Ω cable (20 pF per foot), rather than 50 Ω cable (30 pF per foot). The measurement of 3000 pF of capacitance through two ten-foot lengths of 93 Ω cable will result in an error of approximately +0.8%; the error for 1000 pF is only +0.09%.

For exacting requirements, a reasonable correction may be made for short lengths of cable (10 to 20 feet), based upon the effect of the series inductance of both lengths of cable.

> The measured capacitance, C_m, of a specimen will differ from the true capacitance, C_t; the error will be seen as an apparent increase in

capacitance in accordance with the following expression:

$$C_m = \frac{C_t}{1 - \omega^2 LC_t} = \frac{C_t}{1 - (X_L/X_{C_t})}$$

Or, if the true capacitance is required:

$$C_t = \frac{C_m}{1 + \omega^2 LC_m} = \frac{C_m}{1 + (X_L/X_{C_m})}$$

Where L = the combined series inductance of BOTH lengths of the connecting cables and the inductance of the sample (generally small with respect to the cables' inductance).

Unless the coaxial connectors of both cables are mounted on common plates at both ends, the outer shields of the cables should be connected by low-inductance straps at both ends.

2-5. DIFFERENTIAL TERMINALS

Measurement of the relative differential capacitance between two specimen capacitors can be made by connecting one capacitor to the DIFF terminals, and the other to the TEST terminals. (The capacitance that is connected to the DIFF terminals may be as large as the full-scale value of the selected range, without introducing serious error.) The display will indicate the difference in capacitance between the two; by switching down to the next lower range (but no lower), the resolution will be improved.

Although the 72C is not calibrated for absolute differential measurements, the relative differential can be of value. For example: in determining the change of capacitance of a specimen during heat cycling, the absolute difference between the specimen and a capacitor held at a fixed temperature is not as important as the percentage change between them.

In addition to permitting differential measurements, the DIFF terminals serve another purpose: excess fixture capacitance across the TEST terminals (i.e.: capacitance beyond the normal range of the ZERO control), can be balanced out by the addition of a capacitor to the DIFF terminals (§2-3C).

2-6. D.C. BIAS

D.c. bias voltages may be applied to either or both sides of the specimen via the rear-panel bias terminals or via the proper pins on the rear edge connector. The applied voltages should not exceed ±200 volts from the HI terminal to ground, or ±400 volts from the LO terminal to ground. When bias is applied to one side only, it is recommended that the other bias terminal be connected to ground.

The sum of the two voltages (600 V, d.c.) may be applied between the HI and the LO terminals. In this connection the bias supply should not be grounded (An internal voltage divider, of resistance values of 240 kΩ from HI to ground and 510 kΩ from LO to ground, establishes the ground point.) The bias lines are internally protected by 30 mA fuses.

2-7. APPLICATIONS

The Model 72C can be used to measure the small-signal capacitance and the forward-gain parameters of bipolar and unipolar transistors at 100 kHz. Capacitance and transconductance are measured with a test signal of 15 mV; beta is measured with a base signal current of approximately 100 nA.

The principle of operation of the 72C is basically that of a transmission test set. That is, the test capacitance is interposed between a low-level signal generator of fixed, known, amplitude and phase, and a calibrated phase-sensitive detector. Likewise, the forward-gain parameters of transistors can be measured, provided that the phase of the output current is proper, or is suitably altered. The necessary external circuitry and components are described in the following text. The parameters that can be measured include the following:

A. Capacitance (Three Terminal). See Figures 2-1 and 2-2.
NOTE: When measuring the capacitance of transistors, it is imperative to remember that a signal applied to the input of the test device will appear amplified in some form at the output (and usually with a phase reversal). Capacitance measurements must be made with the output of the device connected to the low test terminal (generator), and the device's input connected to the high test terminal (detector).

1. C_{rss}: Reverse transfer capacitance between drain and gate, source guarded. Device under test is fully biased. $V_{GS} = 0$.

2. C_{eb}: Emitter-to-base capacitance, collector guarded; emitter is reverse biased. $V_{CE} = 0$ (open circuit for d.c.).

3. C_{ce}: Collector-to-emitter capacitance, base guarded; collector is reverse biased. $V_{BE} = 0$ (open circuit for d.c.).

4. C_{re}: Collector-to-base capacitance, emitter guarded. Device under test is fully biased.

5. C_{cb}: Collector-to-base capacitance, emitter guarded; collector is reverse biased. $I_E = 0$ (open circuit for d.c.).

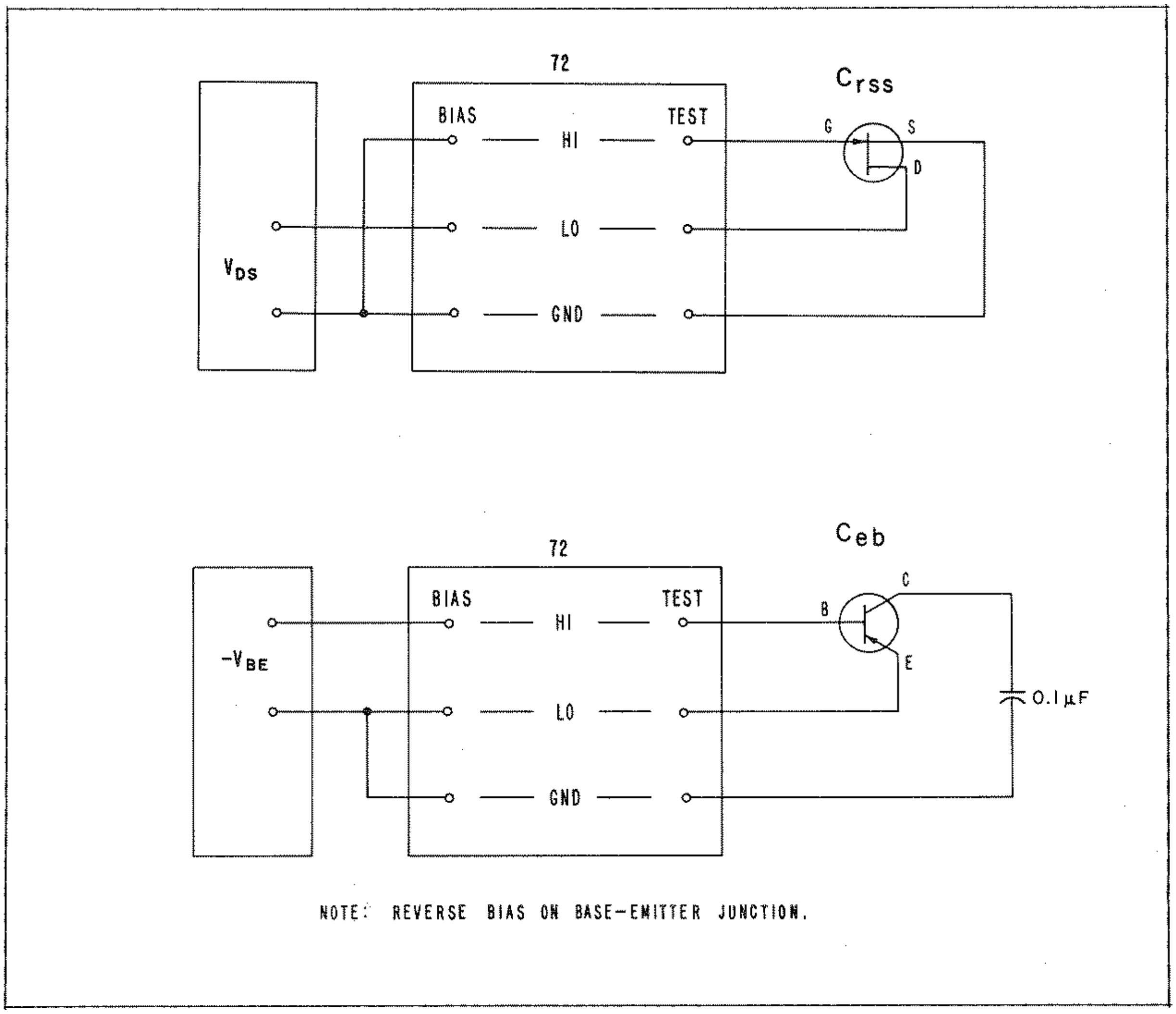

Figure 2-1. Transistor Capacitance Measurements: C_{rss} and C_{eb}

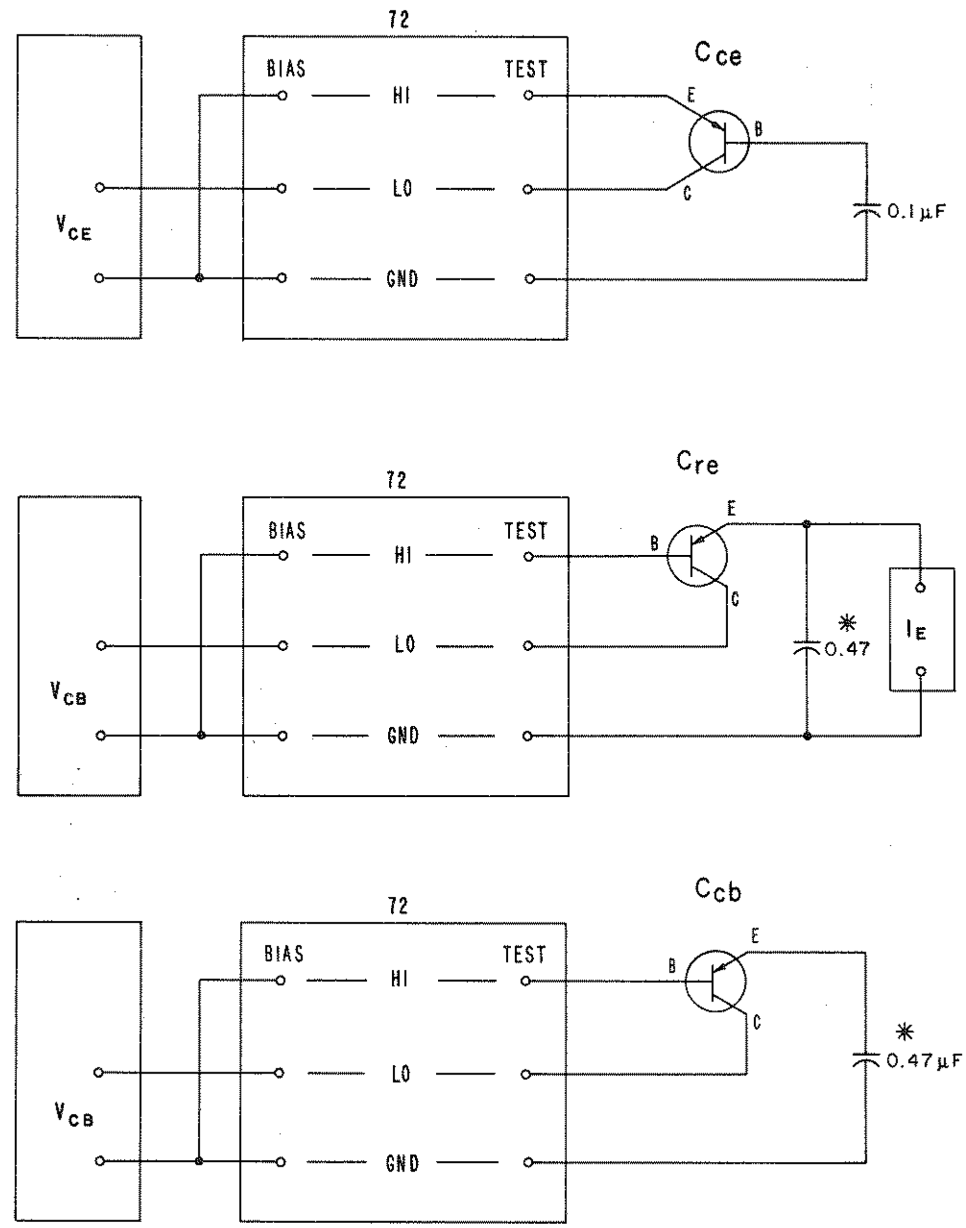

Figure 2-2. Transistor Capacitance Measurements: C_{ce}, C_{re} and C_{cb}

B. Capacitance (Two Terminal). See Figure 2-3.

1. C_{oss}: Output capacitance between drain and source, gate a.c. connected to the source. Device under test is fully biased. $V_{GS} = 0$.

2. C_{iss}: Input capacitance between gate and source with drain a.c. connected to the source. Device under test is fully biased. $V_{GS} = 0$.

3. C_{ob}: Collector-to-base capacitance. Emitter is open-circuited for both a.c. and d.c. Collector is reverse biased.

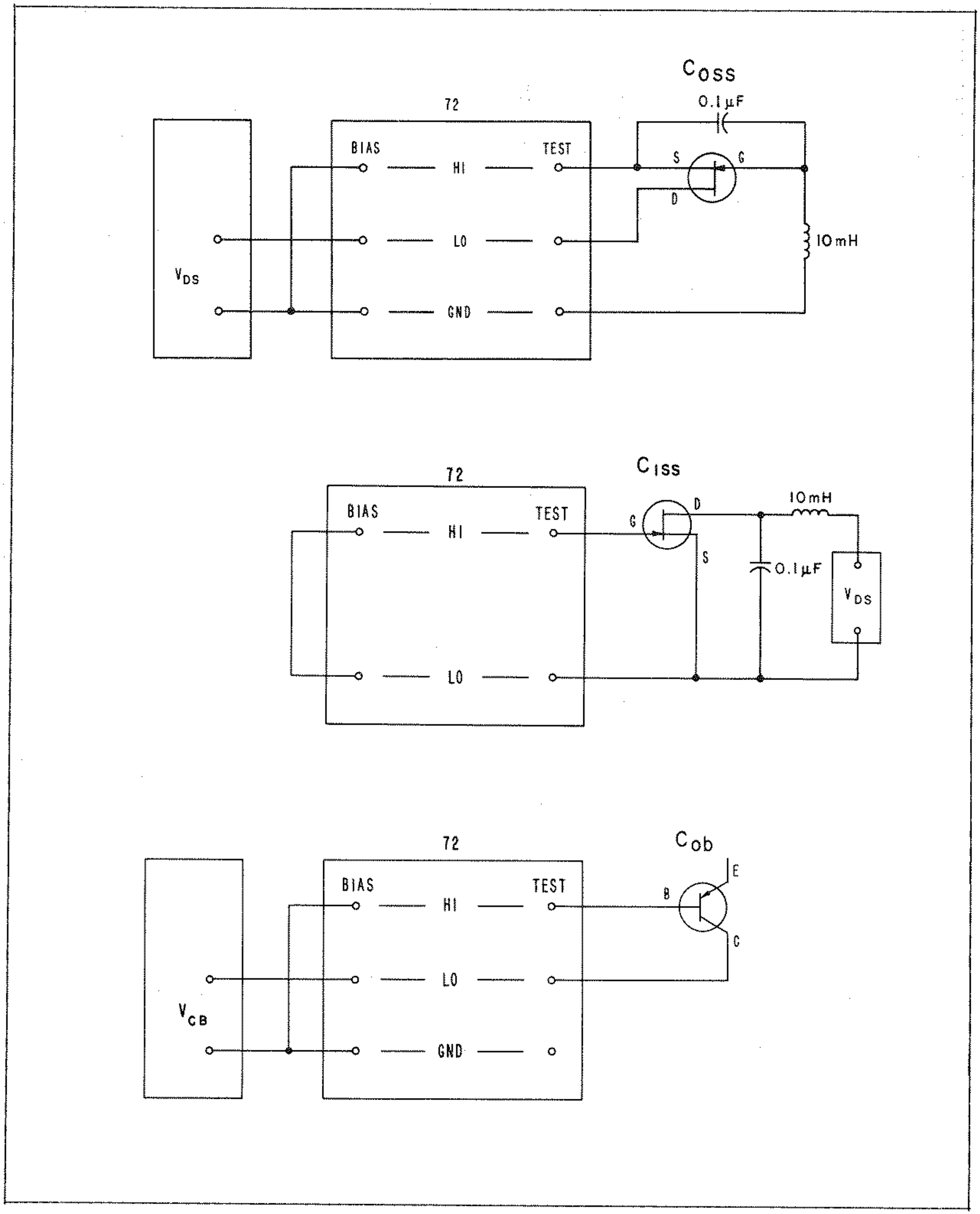

Figure 2-3. Transistor Capacitance Measurements: C_{oss}, C_{iss} and C_{ob}

C. <u>Beta</u> (h_{fe}). See Figure 2-4.
A sensibly constant base current, i_b, of 94 nA can be generated with the aid of a 10 pF capacitor connected between the 72C's LO DIFF terminal and the base of the transistor under test. The collector current, which equals βi_b, is fed to the HI TEST terminal, and the instrument responds as though a capacitance of $\beta \times 10$ pF were connected to its terminals. Beta (h_{fe}) is

equal to one-tenth of the indicated capacitance in picofarads.

The LO DIFF terminal is used for the current source in order to offset the 180° phase reversal of current in the transistor.

The measurement of beta should be made under full bias conditions. In this arrangement, the base current is independent (very nearly) of the input resistance of the transistor because of the quadrature relation between the reactance of the current source and the input resistance

The variable series capacitor in the base circuit (see Figure 2-4) must be adjusted for a value of 10 pF. This is easily accomplished by connecting a small jumper between the socket's base and collector terminals (a "unity-gain transistor"), permitting the direct measurement of this capacitance.

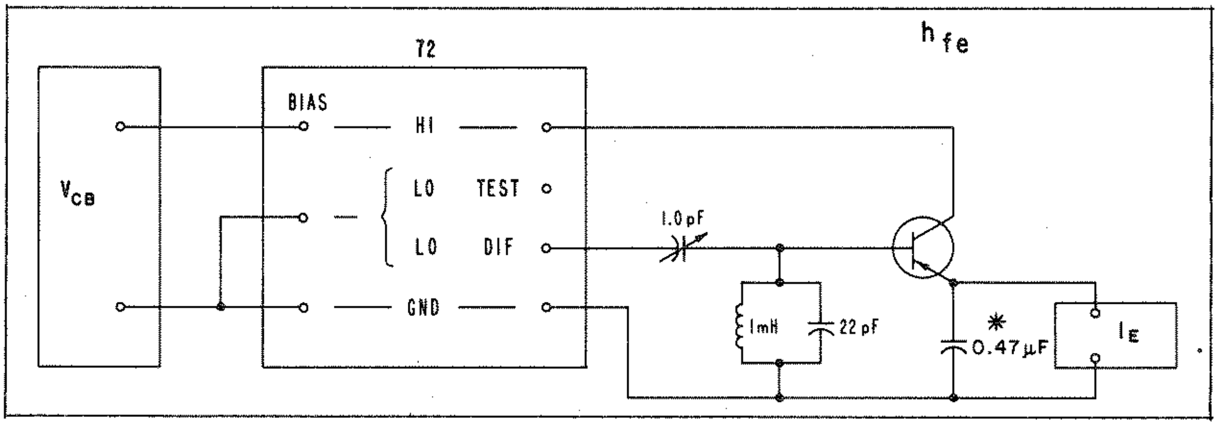

Figure 2-4. Transistor Beta Measurement

If the LO DIFF terminal is used, the reading should be adjusted for -10 pF, using the d.c. recorder output; or the LO TEST terminal may be temporarily used for a reading of +10 pF on the meter.

If the transistor socket (and its circuitry) has excessive capacitance from the base terminal to ground, it can be absorbed with a simple parallel-resonant circuit, using a high L/C ratio to obtain maximum impedance.

D. Forward Transconductance (g_{fs}). See Figure 2-5.
The 72C is calibrated for an input current of $+je_g\omega C$, where C is the full-scale value of capacitance for any given range. Connecting the gate of a unipolar transistor to the LO TEST terminal will, by definition, generate a drain current of $e_g g_{fs}$, provided that the external drain-circuit impedance

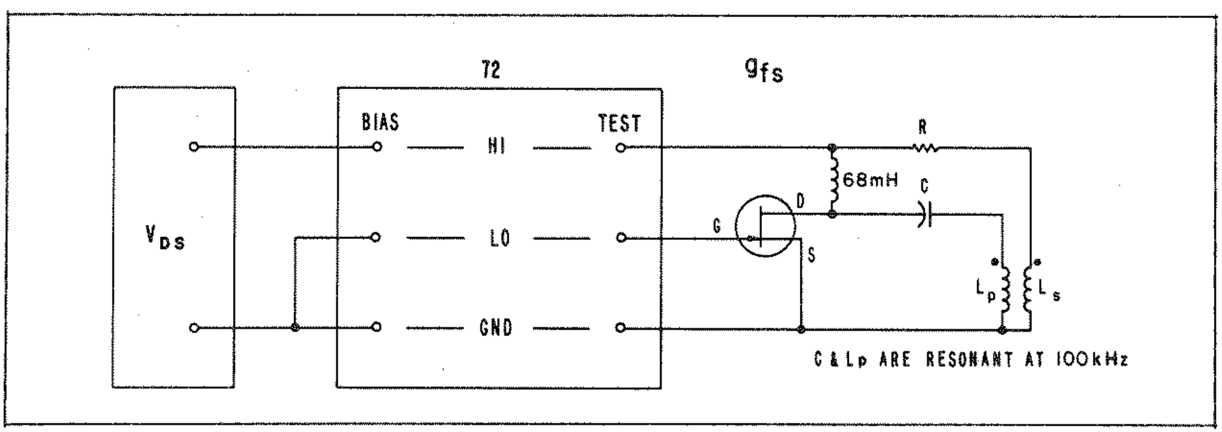

Figure 2-5. Transistor Transconductance Measurement

is small. Unfortunately, the phase of the drain current lacks the required +90 degrees.

A network is needed that presents a low impedance to the drain, and that provides the necessary phase shift of +90 degrees. The circuit shown in Figure 2-5 satisfies these conditions. The resistor, R, is the calibrating resistor for the full-scale value of g_{fs}. Its value is readily derived. The instrument is calibrated for a high-terminal current of:

$$i_c = e_g \omega C \underline{/90°}$$

The actual drain current is:

$$i_d = e_g g_{fs}$$

The voltage induced in the secondary of the transformer is:

$$e' = j i_d \omega M \underline{/90°} \text{ (polarity arranged for +M)}$$

To achieve a full-scale indication for a given value of g_{fs} the resistor, R, must have the value:

$$R = e'/i_c = \frac{e_g g_{fs} \omega M \underline{/90°}}{e_g \omega C \underline{/90°}} = g_{fs}\ M/C$$

where $R >> \omega L_s$ for the current to have the correct phase; M is the mutual inductance of the transformer and equals

$$M = k\sqrt{L_p L_s}$$

The coefficient of coupling, k, may be determined easily by measuring the primary inductance with the secondary open-circuited, then short circuited:

$$k = \sqrt{1 - (L_{sc}/L_{oc})}$$

If the resistor is selected for a full-scale reading of 1000 µS on the 100 pF range, the instrument will read:

C Range	g_{fs} Range
100 pF	1000 µS
300 pF	3000 µS
1000 pF	10,000 µS
3000 pF	30,000 µS

A typical toroidal transformer might have the following circuit values:

$$L_p = 2500\ \mu H$$
$$L_s = 50\ \mu H$$
$$k = 0.935$$

from which,

$$M = 330\ \mu H$$

The series primary capacitance for resonance must equal 1000 pF (approx.), and for a full-scale range of 1000 µS on the 100 pF range, the calibrating resistor should equal:

$$R = (1000)(330/100) = 3300\ \Omega$$

SECTION III

THEORY OF OPERATION

3-1. GENERAL NOTE

Refer to Figure 3-1, a simplified schematic diagram of the Model 72C, in connection with this explanation of the instrument's operation.

3-2. BRIDGE CIRCUITS

The output of the 100 kHz crystal-controlled oscillator appears across the secondary of the transformer, the center tap of which is at r.f. ground. One end of this secondary winding goes to the LO TEST terminal; the other end goes to the LO DIFF terminal. The HI terminals are connected together and lead to the measuring section. A differential capacitor (the ZERO control), has its stators connected across the transformer secondary winding, and its rotor connected to the common HI post connection.

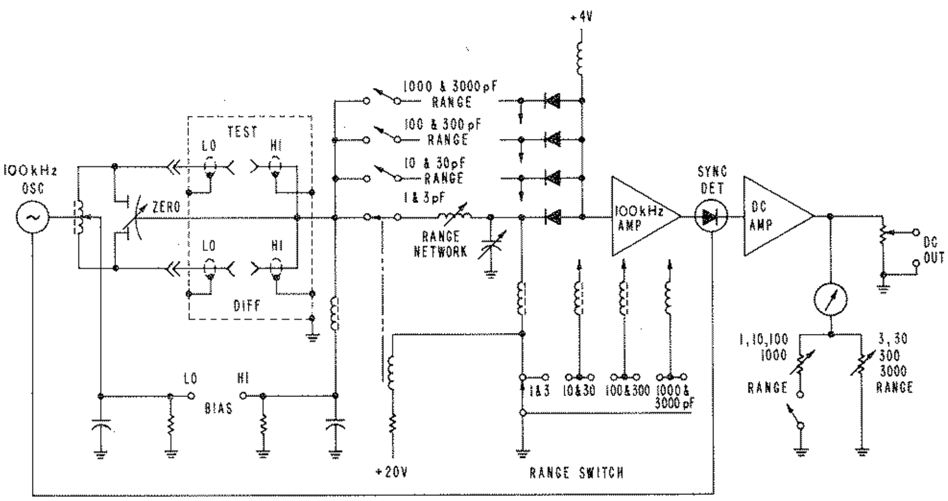

Figure 3-1. Simplified Schematic Diagram

With the instrument operating, and with both TEST and DIFF terminals open, the only signal appearing at the output of this section would be the result of the residual capacitances of the terminals and any fixtures connected to them. Adjustment of the differential capacitor (ZERO) balances out this signal, within the limits specified in §2-3C, resulting in zero output from the measuring section.

When a specimen capacitor is connected between the LO and HI TEST terminal a current directly proportional to its susceptance flows through the low-impedance series-resonant LC circuit to ground. (The appropriate resonant circuit is selected by the range-switching circuits.) The resultant voltage appearing across the capacitive part of the LC circuit is applied, through a tuned amplifier, to the synchronous detector.

The synchronous detector, gated by the crystal oscillator, converts the 100 kHz signal to d.c. and applies it to the d.c. amplifier section. The d.c. amplifier's output drives the panel meter; it also drives a voltage divider that supplies an adjustable analog output (both at the rear terminals and at the rear connector, P102), for external indication or control purposes.

3-3. RANGING CIRCUITS

Range switching in the 72C is accomplished by a combination of the panel range switch, switching diodes, and miniature reed relays. The panel switch handles only control voltages; no signal currents pass through it. This design eliminates a frequent source of errors, and improves reliability.

The switching diodes are biased "off" by the 2.4 V differential between the +6.6 V on the cathodes and the +4.2 V on the anodes. When contacts of the range switch are closed, the cathode of the appropriate diode is grounded for d.c. through an r.f. choke and a 10 kΩ resistor. As it then has a net positive bias on its anode, the diode is switched to the conducting state and thereby connects one end of its associated range network to the input of the 100 kHz amplifier. At the same time, the range switch energizes the associated reed relay through a logic circuit that then connects the other end of the range network to the output of the measuring section.

SECTION IV

MAINTENANCE

4-1. GENERAL NOTES
A. The values and tolerances shown in this section are not specifications; they are provided only as guides to maintenance and calibration.

B. For all calibration checks, the 72C requires a warm-up of one hour, minimum.

4-2. INTRODUCTION
The Model 72C is designed to operate within stated specifications over a long period. However, to achieve the maximum performance, it is desirable to check and adjust the instrument periodically. Basically, two adjustments are recommended:

A. A zero-balance check and adjustment every 500 hours of operation (three months of normal use).

B. A calibration check every 1000 hours of operation (six months of normal use).

In addition to these two periodic checks, complete adjustment procedures are described in §4-8 to §4-13. It is felt, however, that because of the complete calibration procedures performed at the BEC factory, **these adjustments are not needed when the instrument is used in normal laboratory or factory environments.** It is recommended they be performed only in case of accidental misadjustment, component failure and replacement, or when the instrument has been subjected to severe environmental stresses such as shock or vibration.

Complete schematics, a parts list, and component-location drawings are at the end of this manual and should be referred to for servicing.

4-3. TEST EQUIPMENT REQUIRED
Test equipment required for maintenance and adjustment of the 72C is listed in Table 4-1. Other models of test equipment that meet or exceed critical specifications may be used instead.

4-4. ZERO ADJUSTMENT
If, after the zero has been adjusted on the lowest range with the front-panel ZERO control, there is disagreement between the higher-range zeros, the following zero adjustment should be performed. No standards or test equipment are needed to perform this check and adjustment.

A. To check the zeros with no capacitance on the TEST terminal, set the 72C to its lowest range and adjust the front-panel ZERO control for zero indication. Now select all higher ranges and observe and record the meter indications on these ranges. The indications should not differ from zero by more than ±0.5% f.s. If a zero indication does exceed these limits, proceed as follows:

B. Turn the instrument "off" and check the meter pointer with the 72C in its normal operating position. Adjust the meter zero (black screw below the dial) to indicate exactly zero.

C. Turn the 72C "on", connect the BNC adapter to the instrument, but use no capacitor, and adjust the front ZERO control on the 1 pF range until the 72C indicates zero.

D. Select the 1000 pF range and adjust R133 (at the rear of the 72C) until the instrument indicates zero on the 1000 pF range.

E. Set the instrument to the 1 pF range and adjust the front ZERO again. Now check all other ranges, which should be within the ±0.5% f.s. limits.

If desired, the 1000 pF range zero (R133) may be reset slightly to make the maximum positive zero deviation equal to the maximum negative deviation. This procedure will minimize the zero error when the instrument is used on different ranges without front ZERO adjustment.

Table 4-1. Required Test Equipment for Maintenance and Adjustment

EQUIPMENT	CRITICAL SPECIFICATIONS	SUGGESTED MODEL
Digital D.C. Voltmeter	100 mV to 20 V. Minimum input resistance 1 MΩ	Data Precision 1350
R.F. Millivolt-meter	1 mV to 1 V, 100 kHz minimum bandwidth	Boonton Electronics 92B with r.f. probe
High-Q/Low-Q Standard	100 pF ±0.25%, Q > 500 and Q ≈ 3, at 100 kHz	(See Figure 4-3)
Capacitance Standards, 100 kHz	3000 pF ±0.1% 1000 pF ±0.1% 300 pF ±0.1% 100 pF ±0.1% 10 pF ±0.1% 1 pF ±0.1%	BEC Model 953117 BEC Model 953116 BEC Model 953115 BEC Model 953114 BEC Model 953112 BEC Model 953110
Loading Capacitor	200 pF ±5%, mica 500 pF ±5%, mica	

4-5. CALIBRATION CHECK

A. Allow a minimum of one hour warm-up. For the checks in the following paragraph, **adjust the zero with the front ZERO control at every range** prior to making measurements. Perform the Zero Adjustment (§4-4), if necessary.

B. Connect, one at a time, the 1, 10, 100, 300, 1000 and 3000 pF standards and check the errors on the corresponding ranges. These errors should not exceed 0.5% on any range. Record the indications.

C. Before making further adjustments, analyze the results. If all ranges have errors in the same direction and approximately by the same percentage, a simple test-level adjustment will correct the calibration. However, when ranges need adjustment in different directions (i.e., some have positive, some have negative errors), or by different amounts, they will have to be calibrated separately.

4-6. CALIBRATION ADJUSTMENT

A. Test-Level Adjustment. When all ranges have drifted by approximately the same amount, a single test-level adjustment may correct the calibration. For this adjustment, warm up the 72C, remove the top cover, select the 100 pF range, zero the range, and connect a 100 pF ±0.1% standard to the TEST terminals. If the indication is not within 0.5% of the standard, adjust the ten-turn trimmer R202 on the amplifier plug-in board to obtain the correct reading within 0.1%. By this adjustment, indications on all ranges will be corrected by the same percentage. The test level is also changed by this adjustment, but this change usually is insignificant. The zeros of the ranges will not be affected.

The same result may be achieved by adjusting R142 on the 100 pF range (thus correcting all "1" ranges by the same percentage), and R146 on the 300 pF range (which corrects all "3" ranges by the same percentage).

B. Range Adjustments. For individual range adjustments, the instrument's bottom cover has to be removed in order to allow access to calibration adjustments C111, C117, and C121 on the lower left side of the instrument. To shield the instrument during these adjustments, the 72C should be set on a plain aluminum sheet; alternatively, use a test cover provided with the appropriate access holes.

1. The adjustments should always start with R202 (§4-6A) on the 100 pF range because this adjustment affects all other ranges.

2. For the 1000 pF range, connect the 1000 pF ±0.1% standard to the TEST terminal and, using a 1/16" insulated screwdriver, adjust C121 for a reading within 0.1%.

3. For the 10 pF range, use a 10 pF standard and adjust C117.

4. For the 1 pF range, use a 1 pF standard and adjust C111.

5. For all "3" ranges, select the 300 pF range, use a 300 pF standard and adjust R146 (located at the rear of the instrument).

4-7. NOTE: PERIODIC CALIBRATION
The procedures of §4-4 and 4-5 cover the recommended periodic calibration of the 72C. The adjustments in the following section are **not** recommended to be performed periodically.

4-8. MAINTENANCE AND REPAIR ADJUSTMENTS
The following adjustments are factory adjustments that are not affected by aging or drift of the components, and are therefore expected to remain set during the life of the instrument. Furthermore, their influence on the 72C's accuracy is somewhat less than the influence of direct calibration adjustments. Therefore it is **not** recommended that the adjustments described below be made during periodic calibration routine. They have to be adjusted only in circumstances described in §4-2B, or when certain characteristics they affect are known to be out of specification. The characteristic that each adjustment affects, and the method of adjustment, are described below.

4-9. POWER-SUPPLY ADJUSTMENTS R115 AND R118
Trimmer R115 should be adjusted to make the positive supply +15.0 V, within ±0.25 V. Use R118 to adjust the negative supply to -15 V ±0.25 V.

4-10. L102, L103, AND L104 LOADING ADJUSTMENT
The 72C is designed for three-terminal measurement; that is, it measures only the capacitive component between HI and LO terminals and ignores the "loading capacitance" from the HI terminal, or from the LO terminal, to ground. If fixtures or cables with high loading capacitances are used to connect the test capacitance to the 72C, and an error is introduced that is more than that specified due to capacitive loading, the loading adjustments L102, L103, and L104 have to be adjusted.

NOTE: When loading errors are intolerable (owing to inordinately large values of loading capacitance at either or both test terminals), the loading capacitance can be negated by means of a parallel inductor connected between the center conductor and ground at the offended terminal(s). The combination of loading capacitance and shunt inductance should resonate at 100 kHz. Capacitance can be added in order to avoid non-standard inductance values.

A. Loading-Error Test. To test for loading error, special loading capacitors of 200 pF and 500 pF should be constructed according to Figure 4-1.

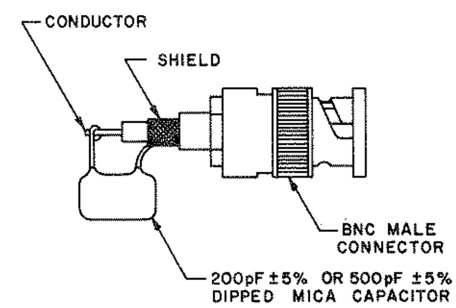

Figure 4-1. Special Loading Capacitor

To connect the loading capacitor and the test capacitor, use a BNC adapter with two BNC "Tees", as shown in Figure 4-2.

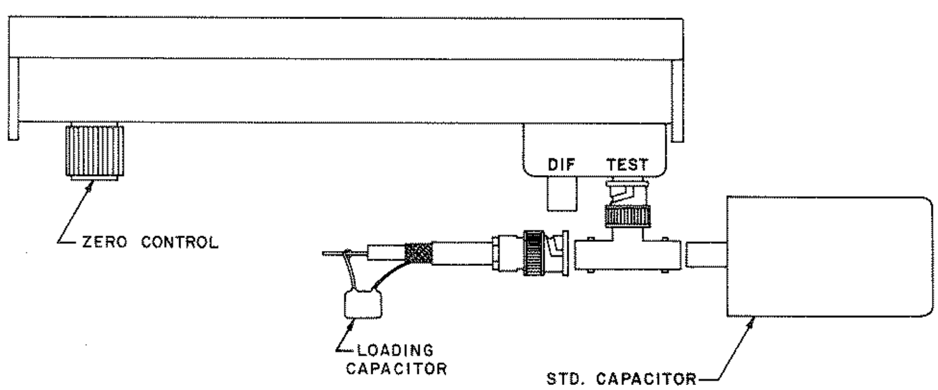

Figure 4-2. Loading Capacitor Test

For the loading test, select the desired range, connect the BNC Tee adapter as shown above, and zero the instrument with the front ZERO control.

Connect the standard capacitor to the right side of the Tee and record the instrument indication. Now disconnect the standard capacitor and connect the loading capacitor to the left side of the Tee on the HI terminal. Zero the instrument again, connect the standard capacitor to the right side of the Tee and measure the standard capacitor again. The difference between indications should be within the following limits:

HI TERMINAL LOADING	RANGE	MAXIMUM DIFFERENCE
200 pF	1, 2, or 3 pF	0.5%
500 pF	10 pF and higher	0.25%

Should the HI terminal loading cause larger errors than those listed above, adjust the loading coils as follows.

B. L102, L103, and L104 Loading-Coil Adjustments. Select the proper range, proper standard, and proper loading capacitor. Only "1" ranges have to be checked, because the next higher "3" range uses the same input circuitry. Zero the 72C and measure the standard capacitor; record the result. Now remove the standard capacitor and connect the loading capacitor to the HI terminal. Zero the instrument again, then re-connect and re-measure the the standard capacitor. If the measured value does not agree with the previous measurement, adjust:

LOADING ADJUSTMENT	RANGE
L102	1, 3 pF
L103	10, 30 pF
L104	100, 300 pF

The 1000 pF range and the 3000 pF range are adjusted with the 100 pF range adjustment.

The loading-coil adjustment may affect the calibration of the ranges to which it applies. Therefore, the calibration has to be checked (§4-5), and if required, adjusted (§4-6).

LO terminal loading should not change during the life of the instrument and should not have to be checked.

4-11. HIGH-Q/LOW-Q ADJUSTMENT C223, C228, AND T201

The 72C measures only the capacitive component, and ignores the resistive component, of the current between the HI and LO terminals. In order to accomplish this, the reference voltage to the phase detector should be in correct phase relationship to the signal voltage through the amplifier. Correct phase relationship is established by checking the instrument with high-Q and low-Q capacitors as follows.

A. High-Q/Low-Q Test. Set the 72C to the 100 pF range, zero, and connect the High-Q/Low-Q standard to the instrument. (The schematic diagram of a High-Q/Low-Q standard that is suitable for use at 100 kHz is shown in Figure 4-3.) Measure the capacitance in both the HI and LO Q position of the standard and compare the results. If they differ by more than 0.5%, the high-low Q adjustments need readjusting.

B. High-Low Q Adjustment. Set the 72C to its 100 pF range and zero with the front ZERO control. Connect the r.f. voltmeter to test point TP3 and measure the r.f. voltage, which is typically 10 - 30 mV. Adjust the phase-detector balance with C233 for a minimum indication on the r.f. voltmeter.

Now connect the High-Q/Low-Q capacitance standard to the TEST terminal and make a measurement in the HI-Q position. Record the result. Make the same measurement in the standard's LO-Q position and adjust C228 until the HI and the LO Q measurements agree within 0.25%. If the range of C228 is not sufficient to bring the indications into agreement, the core of transformer

T201 may be adjusted for the same purpose. In either case, take note that high-low Q adjustment may necessitate recalibration of the 100 pF range, as described in §4-6A.

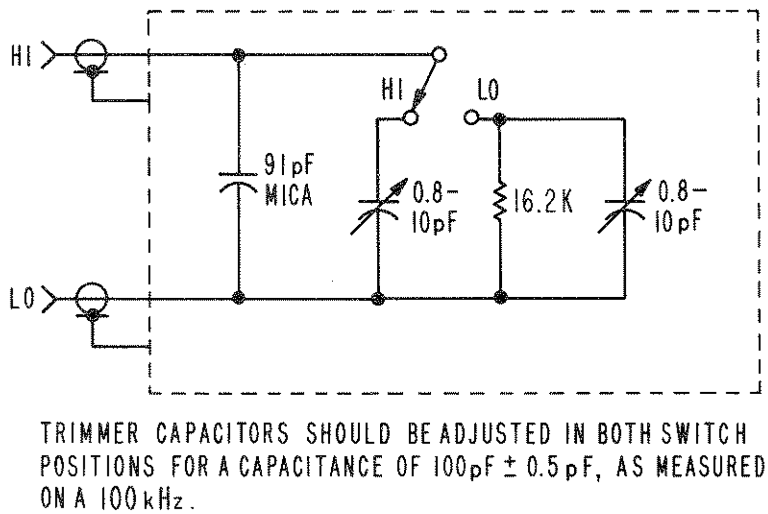

Figure 4-3. High-Q/Low-Q Standard

4-12. T401, C202 TUNING

The input transformer, T401, should be tuned to the 100 kHz crystal for proper operation of the oscillator. This may be accomplished by adjusting either the trimmer C202 or the transformer core. The core adjustment should be used only when the range of C202 is not sufficient for proper adjustment.

To adjust the trimmer C202, remove the 72C's top cover and connect the d.c. voltmeter (10 V range), to TP1 on the amplifier plug-in board. Now adjust C202 for a maximum voltage, typically +4 to +6 V, d.c.

If the maximum cannot be reached by adjusting C202, the core of transformer T401 can be adjusted. This adjustment is available at the bottom of T401 by removing the bottom cover of the 72C. Set C202 to the midpoint of its range, and vary T401's core adjustment to achieve a maximum d.c. voltage as measured at TP1.

Following either of the above adjustments, the 72C should be calibrated as described in §4-6A.

4-13. 100 kHz AMPLIFIER TUNING (L201 ADJUSTMENT)

For accurate adjustment of L201, the 100 kHz amplifier should be operated without overall feedback by unsoldering the link between the two solder terminals next to the L201 coil. Now the amplifier gain is increased by about 30 dB and the frequency response is sharply peaked at 100 kHz.

To adjust L201, set the 72C to the 100 pF range, connect the r.f. voltmeter to TP3, and adjust the ZERO control until the voltmeter indicates 0.2 to 0.5 V. Adjust the core of L201 (from the rear of the amplifier board) with a 1/16" insulated screwdriver, to peak the voltmeter indication. Resolder the link removed above. Perform the test-level adjustment (§4-6A).

4-14. TROUBLESHOOTING: GENERAL
Should the 72C fail or malfunction, a two-step approach to troubleshooting and repair is recommended: identify the defective section; and troubleshoot and repair the section.

The instruments listed in Table 4-1 will serve also for troubleshooting. The only point for attention is TP2--the input to the 100 kHz amplifier. Under normal operating conditions the signal level at this point is 150 µV at 100 kHz for a full-scale indication on every "1" range. This signal is too low to be measured accurately with the recommended instrumentation. Therefore, introduce a 10-times overload (100 pF test capacitor on the 10 pF range) to bring this level to a measurable range, for testing ranging circuitry.

4-15. IDENTIFICATION OF DEFECTIVE SECTION
To identify the defective section, use the troubleshooting block diagram (Figure 6-1), and the simplified troubleshooting schematic diagram (Figure 6-2). These diagrams should be sufficient to guide you through a logical troubleshooting sequence.

4-16. TROUBLESHOOTING DEFECTIVE SECTIONS
Figure 6-2 should be used to find the pertinent signal- and d.c.-voltage levels. This information, together with specific tests recommended in the following paragraphs, should enable an experienced troubleshooter to locate and repair defective components.

A. Power Supply. Normal output levels are as follows:

+15 V supply, (at the positive terminal of C128), +15 V ±0.25 V;
-15 V supply, (at the negative terminal of C129), -15 V ±0.25 V.

When the output voltage cannot be set within the specified limit, check for an external "short" by checking the temperature of the series regulators (IC101, 102, and 103). High temperatures indicate external shorts; a cool regulator indicates trouble in the power supply--or normal operation.

B. 100 kHz Oscillator. Normal operating levels are

at LO terminal: 100 kHz, 15 mV ±2 mV
at TP1: +4 to +6 V, d.c.
at J101, pin X: 1.5 V, r.m.s., 100 kHz

Check C202 or T401 tuning (§4-12). When grossly out of tune, the oscillator will not oscillate.

C. Ranging Circuitry. Ranges are selected by reed relays K101 to K103 and switching diodes CR109 to CR112. If a particular range is activated, that range's reed relay is closed and its associated switching diode is forward biased. Normal voltage levels are as follows:

	Pin 3 or pin 5 of IC106 or IC107	Pin D of J101
Range Activated	0 V	4.2 V
Range Not Activated	+20 V	4.2 V

If the voltage on pin 3 or pin 5 of IC106 or IC107 is pulled down when the proper range is selected, but the range is not activated properly, look for trouble in the reed relays, diodes CR109-CR112, and associated circuitry.

If pin 3 or 5 voltage is not pulled down by range selection, the trouble is in the range switch, ranging lines, or in IC106 and/or IC107.

The "3" ranges are selected by decreasing indicator M101 current by opening K104 contact.

D. 100 kHz Amplifier. The amplifier is a tuned feedback amplifier with a closed-loop gain of approximately 70 dB. The open-loop gains by stages are

First Stage (Q203 and Q204): 54 dB
Second Stage (Q205): 23 dB
Third Stage (Q207): 23 dB

An output level of 0.5 V at TP3 is produced by an input level of 150 μV at pin D of J201; the input level is too low to measure accurately with normal instrumentation.

To troubleshoot the amplifier, check d.c. operating voltages and signal levels as shown in Figure 6-2. Replace defective components, if necessary. If this does not restore normal gain, check L201's tuning (§4-13).

The condition in which the 72C operates normally in one or more ranges (but not in all ranges), indicates that the trouble is in the ranging circuitry. The amplifier should not be serviced in that case.

E. Phase-Sensitive Detector. The phase-sensitive detector circuitry consists of bridge circuit CR205-CR208, and overload detector Q208 and Q209. Normal operating levels at full scale (100 pF on the 100 pF range) are:

100 kHz Amplifier Output TP3: 500 mV, 100 kHz
Detector Output at TP2: +0.5 V, d.c.
Phase-Reference Drive at C228: 10 V, 100 kHz

When the 72C is zeroed, the phase-detector output at TP2 should be 0 mV.

Normal overload sensor voltage on pin S, J101, is -15 V when indication is on-range (100 kHz amplifier output at TP3 of 1.5 V, 100 kHz). With an overload condition (TP3 voltage above 1.8 V), the pin-S voltage should change to +12 V.

F. Phase-Reference Channel. The phase-reference channel consists of the reference amplifier Q206, and a voltage-divider and phase-shifting network. Normal operating levels are

Input (Q206 base): 1.0 V, 100 kHz
Ouput at T201 secondary: 4 V, 100 kHz

T201 is tuned for maximum output at 100 kHz, and finally adjusted for correct phase (§4-11).

G. Output Amplifier. Operational amplifier A101 drives the meter circuit and the analog output. Normal operating levels (with 100 pF on the 100 pF range), are

Input at pin 3: +0.5 V
Ouput at pin 6: +4.0 V

An overload signal causes the amplifier to clamp to a maximum positive output; the overload signal is then applied to pin 8, whose normal voltage (up to 1.5 V at pin 3) is 0, and whose overload voltage (above 1.8 V at pin 3) is up to +12 V.

The input and output voltage of the 72C's output amplifier will be zero if there is zero input to the 72C and the instrument is properly zeroed.

4-17. EXTERNAL PIN ASSIGNMENTS

Rear-panel connector P102 makes available +15 V and +5 V for use with BEC options; it also provides an analog output for a recorder. In addition, pins are available for the following purposes: (1) for the connection of external voltage supplies to bias the HI and/or LO terminal; (2) for remote ranging. See Figure 4-4 and Table 4-2 for pin locations and descriptions.

Table 4-2. External Pin Assignments

TERMINAL	FUNCTION	REMARKS
A	+15 V	Power for BEC-supplied options only
B	+5 V	" " " " " "
1	±HI terminal bias	±200 V, d.c., maximum
2	±LO terminal bias	±400 V, d.c., maximum
3	Ground	
4	+ Analog output	+1 V, f.s., 1-10-100-1000 range +3 V, f.s., 3-30-300-3000 range Z ≈ 1 kΩ
5	Ground	
7	Manual disable	Connect to ground to disable front-panel programming
9	3000 pF range	Pins 9-16 are external range-programming inputs. Logic 0, or connection to common, selects corresponding range. These lines may be used as outputs to indicate current operating range: the range line corresponding to the operating range will be at logic 0 (logic 0 < +0.5 V).
10	1000 pF range	
11	300 pF range	
12	100 pF range	
13	30 pF range	
14	10 pF range	
15	3 pF range	
16	1 pF range	

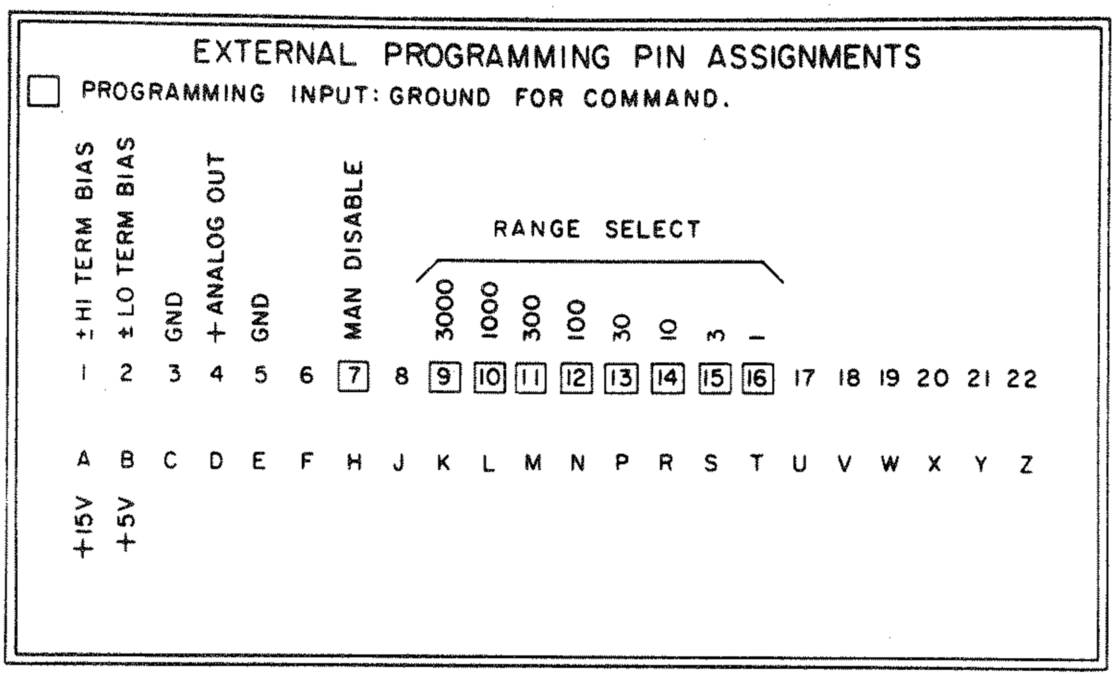

Figure 4-4. External Connections

SECTION V

LIST OF REPLACEABLE PARTS

5-1. INTRODUCTION

The List of Replaceable Parts begins with major assemblies, including PC boards complete with all their parts, followed by miscellaneous parts, and components not mounted on PC boards. Then all the components of the individual assemblies (including PC boards) are listed.

To simplify ordering, please note the following:

A. When ordering a component or an assembly, the BEC Part Number is all that we need. However, part numbers can suffer changes during transmission and it is safer to include also a brief description. Examples:

1) BEC Part #200050: Mica Capacitor, 470 pF, 1%, 500V.

2) BEC Part #102409: Oscillator PC Board Assembly.

B. The number printed on a PC board is NOT an assembly number; it is the number for the bare board, alone. To order a complete assembly--the board with all its components installed--order it by the BEC Part Number given in the Assembly section of this table.

C. Unless otherwise identified, the number on a schematic diagram or on a parts-location diagram is NOT an assembly number; it is the number for just the diagram itself.

Table 5-1. Manufacturers' Federal Supply Code Numbers

NUMBER	NAME	NUMBER	NAME
00213	Nytronics	27735	F-Dyne Electronics
00241	Fenwal Electronics	32897	Erie
01121	Allen Bradley	32997	Bourns, Inc., Trimpot Div.
01295	Texas Instruments	33883	RMC
02660	Amphenol	34430	Monsanto
04222	AVX	54426	Buss Fuses
04713	Motorola Semiconductor	56289	Sprague Electric
04901	Boonton Electronics	57582	Kahgan Electronics
06776	Robinson Nugent	71450	CTS Corp.
07263	Fairchild Semiconductor	73138	Beckman Instr., Helipot Div.
14655	Cornell-Dubilier	74970	E.F. Johnson
16482	Belden	78526	Stanwyck
17117	Electronic Molding	81840	Ledex, Inc.
19701	Mepco Electronics	83330	H.H. Smith
20307	Arco (Micronics)	91637	Dale Electronics
27014	National Semiconductor	96804	J.W. Miller
27264	Molex, Inc.	98291	Sealectro Corp.

LIST OF REPLACEABLE PARTS

Item	Description	Mfr.	Mfr's Part #	BEC Part #
			ASSEMBLIES	
	Front Sub-Panel Assembly	BEC		072038
	Rear Panel Assembly	BEC		072039
	Master P.C. Board Assembly	BEC		072040
	Oscillator-Amplifier Board Assembly	BEC		072041
	Oscillator Transformer Assembly	BEC		072042
	Rotary-Switch Assembly	BEC		062013
	Variable Inductor Assembly	BEC		072043
	Amplifier Output-Transformer Assembly	BEC		072044
	Phase-Sensitive Detector Assembly	BEC		072045
FRONT SUB-PANEL ASSEMBLY, PART NUMBER 072038				
C402	Cap Cer 0.01 µF 20% 1000V	56289	C023A102J103M (5GA-S10)	224228
C403	Cap Cer 0.01 µF 20% 1000V	56289	C023A102J103M (5GA-S10)	224228
F401	Fuse 0.1 A Slo Blow (220/240V)	54426	MDL	545519
F401	Fuse 0.2 A (120V)	54426	MDL 0.2	545508
F402	Fuse 1/32 A 250V AGC	54426	AGC	545525
F403	Fuse 1/32 A 250V AGC	54426	AGC	545525
J401	Conn Pin Female	27264	Reel #02-06-1231	479320
J406	Conn Pin Female	27264	Reel #02-06-1231	479320
J407	Conn Pin Female	27264	Reel #02-06-1231	479320
J408	Conn Pin Female	27264	Reel #02-06-1231	479320
J409	Conn Pin Female	27264	Reel #02-06-1231	479320
J410	Conn Pin Female	27264	Reel #02-06-1231	479320
J427	Conn Pin Female	27264	Reel #02-06-1231	479320
J428	Conn Pin Female	27264	Reel #02-06-1231	479320
J429	Conn Pin Female	27264	Reel #02-06-1231	479320
J430	Conn Pin Female	27264	Reel #02-06-1231	479320
J431	Conn Pin Female	27264	Reel #02-06-1231	479320
J432	Conn Pin Female	27264	Reel #02-06-1231	479320
P401	Conn Line Cord	16482	17252	477281
R401	Res Comp 510k ohm 5%	01121	EB	344568
R402	Res Comp 240k ohm 5%	01121	EB	344537
S402	Switch	81840	Series 210	466230
T402	XFMR Power	04901	BEC	446071
REAR PANEL ASSEMBLY, PART NUMBER 072039				
C404	Cap Var 1.8-8.7 pF	74970	160-0305-001	275138
CR401	Diode LED Red Diffused	34430	MV5025	536000
J411	Conn Pin Female	27264	Reel #02-06-1231	479320
J412	Conn Pin Female	27264	Reel #02-06-1231	479320
J413	Conn Pin Female	27264	Reel #02-06-1231	479320
J414	Conn Pin Female	27264	Reel #02-06-1231	479320
J415	Conn Pin Female	27264	Reel #02-06-1231	479320
J416	Conn Pin Female	27264	Reel #02-06-1231	479320
J417	Conn Pin Female	27264	Reel #02-06-1231	479320
J418	Conn Pin Female	27264	Reel #02-06-1231	479320
J424	Conn Pin Female	27264	Reel #02-06-1231	479320
J425	Conn Pin Female	27264	Reel #02-06-1231	479320
J426	Conn Pin Female	27264	Reel #02-06-1231	479320
M101	Meter Analog & Scale M/F 554247, 554248	04901	BEC	554249
P402	Banana Plug with Stud 6/32 x 3/4	83330	416	477178
S401	Rocker Switch (white) ON/OFF		RSW-04-22-SD-BB-S-W1-BK	465203
T401	Oscillator Transformer Assy for 72C			072042
MASTER P.C. BOARD ASSEMBLY, PART NUMBER 072040				
A101	IC LM301AN Op Amp	27014	LM301AN	535012
C101	Cap PC 0.1 µF 10% 630V	19701	C280CG/A100K	234091
C102	Cap PC 0.15 µF 10% 630V	19701	C280MCG/A150K	234147
C103	Cap Mica 43 pF 5% 300V	20307	DM5-EC430J	205014
C104	Cap Mica 100 pF 5% 500V	20307	DM15F101-J	200001
C105	Cap Mica 910 pF 1% 100V	20307	RDM15FA911F03	200075
C106	Cap Mica 0.01 µF 1% 300V	20307	RDM30FD103F03	203017

Item	Description	Mfr.	Mfr's Part No.	BEC Part No.
MASTER P.C. BOARD ASSEMBLY, PART NUMBER 072040 (CONTINUED)				
C107	Cap Mica 15 pF 5% 300V	20307	DM5-CC150J	205035
C108	Cap EL 1000 µF 35V	57582	KSMM-1000-35	283350
C109	Cap EL 1000 µF 35V	57582	KSMM-1000-35	283350
C110	Cap Mica 200 pF 5% 100V	20307	DM5-FA201J	205024
C111	Cap Var Cer 5.1-50 pF (Green)	56289	GKR50000	281006
C112	Cap Mica 62 pF 5% 300V	20307	DM5-EC620J	205015
C113	Cap Mica 100 pF 1% 500V	20307	DM-15-101-F	200045
C114	Cap Mica 910 pF 1% 100V	20307	RDM15FA911F03	200075
C115	Cap Cer 0.001 µF 500V	33883	Z5U	224114
C116	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C117	Cap Var Cer 5.1-50 pF (Green)	56289	GKR50000	281006
C118	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C119	Cap Cer 0.001 µF 500V	33883	Z5U	224114
C120	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C121	Cap Var Cer 5.1-50 pF (Green)	56289	GKR50000	281006
C122	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C123	Cap Cer 0.001 µF 500V	33883	Z5U	224114
C124	Cap Cer 0.001 µF 500V	33883	Z5U	224114
C125	Cap Cer 0.001 µF 500V	33883	Z5U	224114
C127	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C128	Cap EL 100 µF 25V	56289	TE-1211 (30D107G025DD2)	283105
C129	Cap EL 100 µF 25V	56289	TE-1211 (30D107G025DD2)	283105
C130	Cap Mica 30 pF 5% 500V	20307	DM-10-300-J	200073
C131	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C132	Cap PE 0.22 µF 10% 100V	19701	719B1C224PK101SA	234168
C135	Cap Cer 1.0 µF 20% 50V	04222	SR305E105MAA	224264
C136	Cap Cer 1.0 µF 20% 50V	04222	SR305E105MAA	224264
C137	Cap Mica 33 pF 5% 300V	20307	DM5-EC330J	205010
C138	Cap Mica 33 pF 5% 300V	20307	DM5-EC330J	205010
C139	Cap Mica 33 pF 5% 300V	20307	DM5-EC330J	205010
C140	Cap Mica 33 pF 5% 300V	20307	DM5-EC330J	205010
C141	Cap Mica 33 pF 5% 300V	20307	DM5-EC330J	205010
CR101	Diode Sig 1N914	01295	1N914	530058
CR102	Diode Sig 1N914	01295	1N914	530058
CR103	Diode Sig 1N914	01295	1N914	530058
CR104	Diode Bridge KPB-02	20307	KBP-02	532013
CR105	Diode Bridge KPB-02	20307	KBP-02	532013
CR107	Diode Sig 1N914	01295	1N914	530058
CR108	Diode Sig 1N914	01295	1N914	530058
CR109	Diode Sig 1N914	01295	1N914	530058
CR110	Diode Sig 1N914	01295	1N914	530058
CR111	Diode Sig 1N914	01295	1N914	530058
CR112	Diode Sig 1N914	01295	1N914	530058
CR113	Diode ZEN 1N5230B	04713	1N5230B	530103
CR114	Diode Sig 1N914	01295	1N914	530058
CR115	Diode Sig 1N914	01295	1N914	530058
IC101	IC 7805UC Regulator	07263	µA7805UC	535011
IC102	IC 7805UC Regulator	07263	µA7805UC	535011
IC104	IC LM723CN Regulator	27014	LM723CN	535037
IC105	IC LM723CN Regulator	27014	LM723CN	535037
IC106	IC SN75451AP	01295	SN75451AP	534006
IC107	IC SN75451AP	01295	SN75451AP	534006
IC108	IC SN75451AP	01295	SN75451AP	534006
IC110	IC SN74LS12N	01295	SN74LS12N	534330
J101	Conn 22 Pin	02660	143-022-07	479231
K101	Relay Coil M/F 802151	04901	BEC	470502
K102	Relay Coil M/F 802151	04901	BEC	470502
K103	Relay Coil M/F 802151	04901	BEC	470502
K104	Relay Coil M/F 802151	04901	BEC	470502
L101	Inductor 56 mH 10%	96804	9250-566	400428
L102	Inductor 15-40 mH	96804	9062	400423
L103	Inductor 0.65-1.3 mH	96804	9058	400424
L104	Inductor 120-280 µH	96804	9056	400230
L105	Inductor 1.5 mH	78526	DINK 1500	400136
L106	Inductor 68 mH 10%	96804	9250-686	400419
L107	Inductor 68 mH 10%	96804	9250-686	400419
L108	Inductor 68 mH 10%	96804	9250-686	400419
L109	Inductor 68 mH 10%	96804	9250-686	400419
L110	Inductor 68 mH 10%	96804	9250-686	400419
L111	Inductor 10 mH 10%	96804	9250-106	400422

Item	Description	Mfr.	Mfr's Part No.	BEC Part No.
MASTER P.C. BOARD ASSEMBLY, PART NUMBER 072040 (CONTINUED)				
P101	Conn Pin (male)	98291	229-1086-000-550	477240
P105	Conn Pin (male)	98291	229-1086-000-550	477240
P106	Conn Pin (male)	98291	229-1086-000-550	477240
P107	Conn Pin (male)	98291	229-1086-000-550	477240
P108	Conn Pin (male)	98291	229-1086-000-550	477240
P109	Conn Pin (male)	98291	229-1086-000-550	477240
P110	Conn Pin (male)	98291	229-1086-000-550	477240
P111	Conn Pin (male)	98291	229-1086-000-550	477240
P112	Conn Pin (male)	98291	229-1086-000-550	477240
P113	Conn Pin (male)	98291	229-1086-000-550	477240
P114	Conn Pin (male)	98291	229-1086-000-550	477240
P115	Conn Pin (male)	98291	229-1086-000-550	477240
P116	Conn Pin (male)	98291	229-1086-000-550	477240
P117	Conn Pin (male)	98291	229-1086-000-550	477240
P123	Conn Pin (male)	98291	229-1086-000-550	477240
P124	Conn Pin (male)	98291	229-1086-000-550	477240
P125	Conn Pin (male)	98291	229-1086-000-550	477240
P126	Conn Pin (male)	98291	229-1086-000-550	477240
P127	Conn Pin (male)	98291	229-1086-000-550	477240
P128	Conn Pin (male)	98291	229-1086-000-550	477240
P129	Conn Pin (male)	98291	229-1086-000-550	477240
P130	Conn Pin (male)	98291	229-1086-000-550	477240
P131	Conn Pin (male)	98291	229-1086-000-550	477240
R103	Res Comp 1.3k ohm 5%	01121	EB	344311
R104	Res Comp 100k ohm 5%	01121	EB	344500
R105	Res Comp 100k ohm 5%	01121	EB	344500
R106	Res Comp 5.1k ohm 5%	01121	EB	344368
R107	Res Comp 1.0k ohm 5%	01121	CB	343300
R108	Res Comp 1.0k ohm 5%	01121	CB	343300
R109	Res Comp 2k ohm 5%	01121	EB	344329
R110	Res Comp 10k ohm 5%	01121	EB	344400
R111	Res Comp 10k ohm 5%	01121	EB	344400
R112	Res Comp 10k ohm 5%	01121	EB	344400
R113	Res Comp 10k ohm 5%	01121	EB	344400
R114	Res MF 3.32k ohm 1%	19701	5043 (RN55D)	341350
R115	Res Var 1k ohm 10% 0.5W	73138	72P	311316
R116	Res MF 3.01k ohm 1%	19701	5043 (RN55D)	341346
R117	Res MF 3.32k ohm 1%	19701	5043 (RN55D)	341350
R118	Res Var 1k ohm 10% 0.5W	73138	72P	311316
R119	Res MF 3.01k ohm 1%	19701	5043 (RN55D)	341346
R120	Res Comp 1.2k ohm 5%	01121	EB	344308
R121	Res Comp 3.9k ohm 5%	01121	CB	343357
R122	Res Comp 3.9k ohm 5%	01121	CB	343357
R123	Res Comp 3.9k ohm 5%	01121	CB	343357
R124	Res Comp 5.1k ohm 5%	01121	CB	343368
R125	Res Comp 5.1k ohm 5%	01121	CB	343368
R126	Res Comp 5.1k ohm 5%	01121	CB	343368
R127	Res Comp 5.1k ohm 5%	01121	CB	343368
R128	Res Comp 5.1k ohm 5%	01121	CB	343368
R129	Res Comp 5.1k ohm 5%	01121	CB	343368
R130	Res Comp 5.1k ohm 5%	01121	CB	343368
R131	Res Comp 5.1k ohm 5%	01121	CB	343368
R132	Res MF 10.0k ohm 1%	19701	5043 (RN55D)	341400
R133	Res Var 20k ohm 10% 1W	91637	Model 784	311266
R134	Res Comp 4.7M ohm 5%	01121	EB	344665
R135	Res Comp 10M ohm 5%	01121	CB	343700
R137	Res Comp 10k ohm 5%	01121	EB	344400
R138	Res MF 63.4k ohm 1%	19701	5043 (RN55D)	341477
R139	Res MF 10.0k ohm 1%	19701	5043 (RN55D)	341400
R140	Res MF 3.65k ohm 1%	19701	5043 (RN55D)	341354
R141	Res MF 26.1k ohm 1%	19701	5043 (RN55D)	341440
R142	Res Var 5k ohm 10% 1W	91637	Model 784	311268
R143	Res Comp 1.3k ohm 5%	01121	EB	344311
R144	Res Var 200 ohm 10% 1W	91637	Model 784	311269
R145	Res MF 54.9k ohm 1%	19701	5043 (RN55D)	341471
R146	Res Var 5k ohm 10% 1W	91637	Model 784	311268
R147	Res MF 1.21k ohm 1%	19701	5043 (RN55D)	341308
R148	Res Comp 4.7k ohm 5%	01121	EB	344365
R149	Res Comp 1.8k ohm 5%	01121	CB	343325
R150	Res Comp 1.8k ohm 5%	01121	CB	343325

Item	Description	Mfr.	Mfr's Part No.	BEC Part No.
MASTER P.C. BOARD ASSEMBLY, PART NUMBER 072040 (CONTINUED)				
R151	Res Comp 1.3k ohm 5%	01121	EB	344311
XA101	Socket IC 8 Pin	06776	ICN-083-S3-G	473041
XIC104	Socket IC 14 Pin	06776	ICN-143-S3-G	473019
XIC105	Socket IC 14 Pin	06776	ICN-143-S3-G	473019
XIC106	Socket IC 8 Pin	06776	ICN-083-S3-G	473041
XIC107	Socket IC 8 Pin	06776	ICN-083-S3-G	473041
XIC108	Socket IC 8 Pin	06776	ICN-083-S3-G	473041
XIC110	Socket IC 14 Pin	06776	ICN-143-S3-G	473019
OSCILLATOR-AMPLIFIER BOARD ASSEMBLY, PART NUMBER 072041				
A201	IC LM301AN Op Amp	27014	LM301AN	535012
C201	Cap Cer 0.01 µF 100V	32897	805-000X5V0103Z	224119
C202	Cap Var Cer 5.1-50 pF (Green)	56289	GKR50000	281006
C204	Cap Cer 0.001 µF 500V	33883	Z5U	224114
C205	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C206	Cap Cer 0.001 µF 500V	33883	Z5U	224114
C207	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C209	Cap Mica 250 pF 5% 500V	20307	DM15251J	200036
C210	Cap Mica 30 pF 5% 500V	20307	DM-10-300-J	200073
C211	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C212	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C213	Cap Mica 100 pF 5% 500V	20307	DM15F101-J	200001
C214	Cap Mica 1500 pF 1% 500V	14655	CD19FD152F-03	200531
C215	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C216	Cap Cer 0.001 µF 500V	33883	Z5U	224114
C217	Cap PE 0.22 µF 10% 100V	19701	719B1C224PK101SA	234168
C220	Cap Cer 0.001 µF 500V	33883	Z5U	224114
C221	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C222	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C223	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C224	Cap PE 0.47 µF 10% 100V	19701	719B1GE474PK101SB	234169
C224	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C225	Cap PE 0.22 µF 10% 100V	19701	719B1C224PK101SA	234168
C226	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C227	Cap PE 0.22 µF 10% 100V	19701	719B1C224PK101SA	234168
C228	Cap Var Cer 5.1-50 pF (Green)	56289	GKR50000	281006
C229	Cap Mylar 0.1 µF 10% 100V	19701	C280MAH/A100K (only)	234080
C230	Cap Mica 8200 pF 1% 100V	14655	CD19FA822F-03	200532
C231	Cap Mica 8200 pF 1% 100V	14655	CD19FA822F-03	200532
C232	Cap Mica 39 pF 5% 500V	20307	DM15E390J	200025
C233	Cap Var Cer 5.1-50 pF (Green)	56289	GKR50000	281006
C234	Cap PE 0.022 µF 20% 250V	19701	C280AE/P22K	234079
C235	Cap PE 0.022 µF 20% 250V	19701	C280AE/P22K	234079
C236	Cap Cer 0.001 µF 500V	33883	Z5U	224114
C237	Cap PE 0.022 µF 20% 250V	19701	C280AE/P22K	234079
C238	Cap PE 0.022 µF 20% 250V	19701	C280AE/P22K	234079
C239	Cap Cer 0.01 µF 100V	32897	805-000X5V0103Z	224119
CR201	Diode Sig 1N914	01295	1N914	530058
CR202	Diode 1N5240B	04713	1N5240B	530077
CR203	Diode Sig 1N914	01295	1N914	530058
CR204	Diode Sig 1N914	01295	1N914	530058
CR205	Diode S/F 530058 (4)	04901	BEC	530131
CR206	Diode S/F 530058 (4)	04901	BEC	530131
CR207	Diode S/F 530058 (4)	04901	BEC	530131
CR208	Diode S/F 530058 (4)	04901	BEC	530131
CR209	Diode Sig 1N914	01295	1N914	530058
CR210	Diode Sig 1N914	01295	1N914	530058
CR211	Diode Sig 1N914	01295	1N914	530058
CR212	Diode Sig 1N914	01295	1N914	530058
L201	Inductor Variable Assy for 72C			072043
L202	Inductor 2.2 mH	00213	WEE-2200	400141
L203	Inductor 2.2 mH	00213	WEE-2200	400141
Q201	Xistor FET 2N5949 N-Channel	04713	2N5949	528019
Q202	Xistor FET 2N5949 N-Channel	04713	2N5949	528019
Q203	Xistor S/F 528143	04901	BEC	528145
Q204	Xistor NPN 2N5088	04713	2N5088	528047
Q205	Xistor 40673 S/F 528054 Blue	04901	BEC	528119
Q206	Xistor NPN 2N2219	04713	2N2219	528014
Q207	Xistor 40673 S/F 528054 Blue	04901	BEC	528119

Item	Description	Mfr.	Mfr's Part No.	BEC Part No.
OSCILLATOR-AMPLIFIER BOARD ASSEMBLY, PART NUMBER 072041 (CONTINUED)				
Q208	Xistor PNP 2N3905	04713	2N3905	528025
Q209	Xistor MOS 3N161	01295	3N161	528132
R201	Res MF 6.19k ohm 1%	19701	5043 (RN55D)	341376
R202	Res Var 2k ohm 10% 1W	91637	784	311264
R203	Res MF 3.32k ohm 1%	19701	5043 (RN55D)	341350
R204	Res MF 4.32k ohm 1%	19701	5043 (RN55D)	341361
R205	Res MF 33.2k ohm 1%	19701	5043 (RN55D)	341450
R206	Res Comp 100k ohm 5%	01121	EB	344500
R207	Res MF 100k ohm 1%	19701	5043 (RN55D)	341500
R208	Res Comp 1.2k ohm 5%	01121	EB	344308
R209	Res Comp 6.8k ohm 5%	01121	EB	344380
R210	Res Comp 560k ohm 5%	01121	EB	344572
R211	Res Comp 33 ohm 5%	01121	EB	344150
R212	Res Comp 1k ohm 5%	01121	EB	344300
R213	Res MF 10 ohm 1%	09701	5043 (RN55D)	341100
R214	Res Comp 150k ohm 5%	01121	EB	344517
R215	Res Comp 100k ohm 5%	01121	EB	344500
R216	Res Comp 2.7k ohm 5%	01121	EB	344341
R217	Res Comp 1k ohm 5%	01121	EB	344300
R218	Res MF 590 ohm 1%	19701	5043 (RN55D)	341274
R219	Res Comp 2.4k ohm 5%	01121	EB	344337
R220	Res Comp 2.2k ohm 5%	01121	EB	344333
R221	Res Comp 120k ohm 5%	01121	EB	344508
R222	Res Comp 47k ohm 5%	01121	EB	344465
R223	Res Comp 2.2M ohm 5%	01121	EB	344633
R224	Res Comp 510 ohm 5%	01121	EB	344268
R226	Res Comp 270 ohm 5%	01121	EB	344241
R227	Res Comp 47 ohm 5%	01121	EB	344165
R228	Res Comp 56 ohm 5%	01121	EB	344172
R229	Res Comp 47k ohm 5%	01121	EB	344465
R230	Res Comp 24k ohm 5%	01121	EB	344437
R231	Res Comp 1.5k ohm 5%	01121	EB	344317
R232	Res Comp 100 ohm 5%	01121	EB	344200
R233	Res Comp 1.2k ohm 5%	01121	EB	344308
R234	Res MF 2.67k ohm 1%	19701	5043 (RN55D)	341341
R235	REs MF 49.9 ohm 1%	09701	5043 (RN55D)	341167
R236	Res Comp 2k ohm 5%	01121	EB	344329
R237	Res Comp 2.7k ohm 5%	01121	EB	344341
R238	Res MF 5.23k ohm 1%	19701	5043 (RN60D)	325396
R239	Res MF 5.23k ohm 1%	19701	5043 (RN60D)	325396
R240	Res Comp 10M ohm 5%	01121	EB	344700
R241	Res MF 5.23k ohm 1%	19701	5043 (RN60D)	325396
R242	Res Var 100 ohm 10% 1W	32997	3005P-1-101	311338
R243	Res MF 5.23k ohm 1%	19701	5043 (RN60D)	325396
R244	Res Comp 10k ohm 5%	01121	CB	343400
R245	Res Comp 47k ohm 5%	01121	EB	344465
R246	Res Comp 100 ohm 5%	01121	CB	343200
R247	Res Comp 2.4k ohm 5%	01121	EB	344337
RT201	Thermistor 50 ohm 10%	00241	CB15L1	325011
T201	Phase Sens Det XFMR Assy for 72C			072045
T202	Amplifier Output XFMR Assy for 72C			072044
XA201	Socket IC 8 Pin	06776	ICN-083-S3-G	473041
XQ205	Socket Xistor 4 Pin	17117	7004-265-5	473051
XQ207	Socket Xistor 4 Pin	17117	7004-265-5	473051
Y201	Crystal 100k Hz Parallel Resonant	71450	HC-13/U w/holder	547016
OSCILLATOR TRANSFORMER ASSEMBLY, PART NUMBER 072042				
C401	Cap MPC 0.01 µF 2% 50V	27735	MPC-53-.01-50-2	234142
P402c	Banana Plug with Stud 6/32 x 3/4	83330	416	477178
P402d	Banana Plug with Stud 6/32 x 3/4	83330	416	477178

SECTION VI
SCHEMATIC DIAGRAMS

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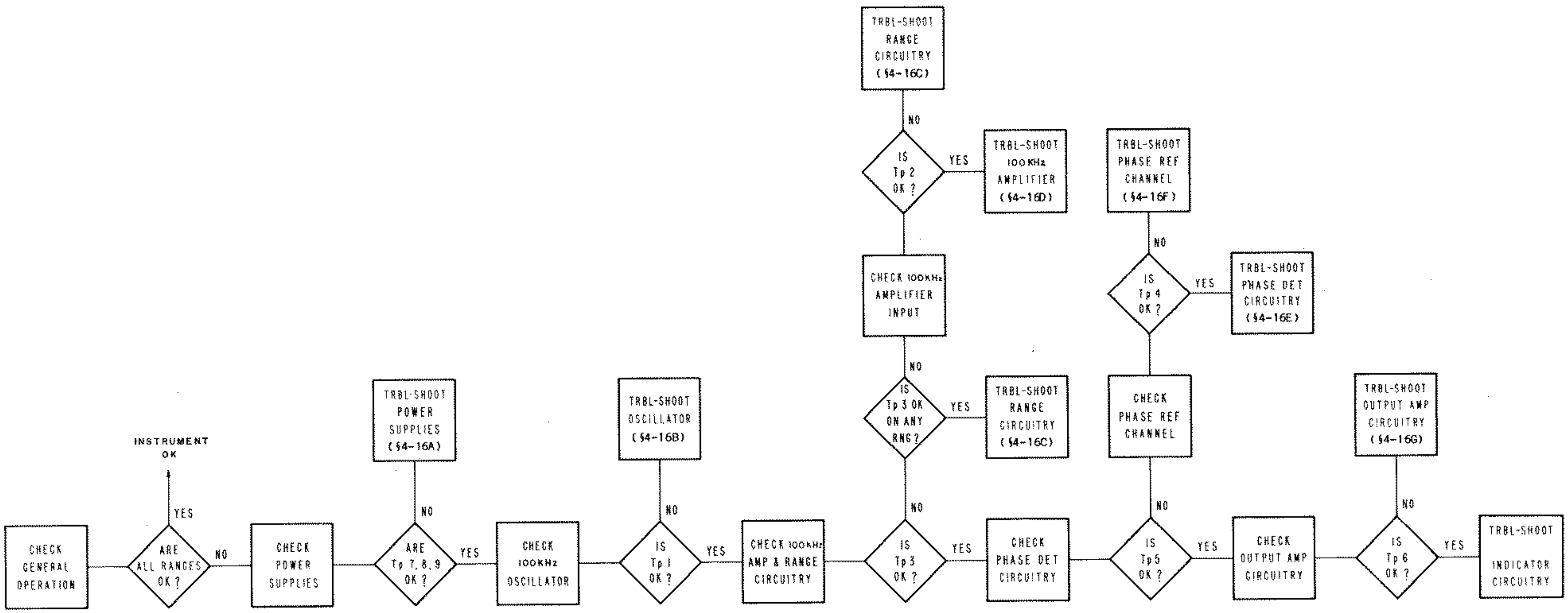
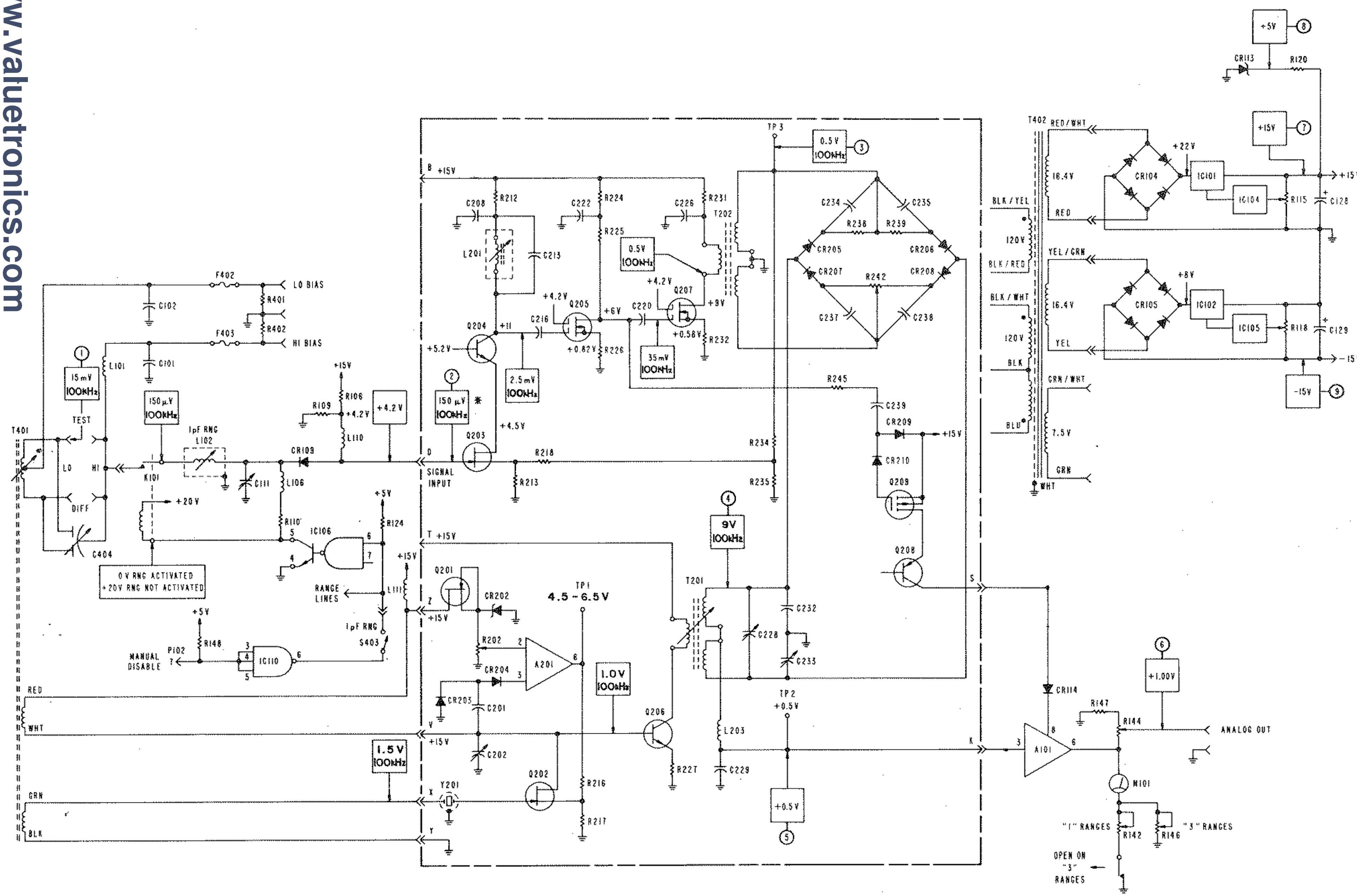
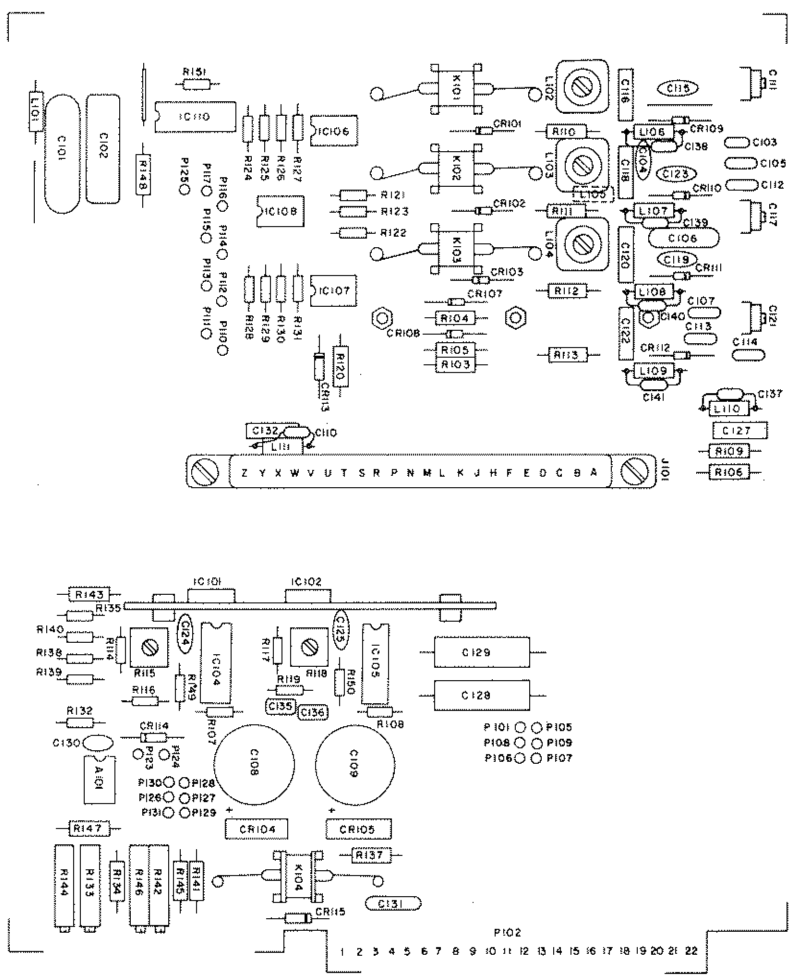


Figure 6-1.
Troubleshooting Block Diagram
(D830716A)



SIGNAL VOLTAGES SHOWN WITH:
1 pF TEST ON 1,3 RANGE.
10 pF TEST ON 10,30 RANGE.
100 pF TEST ON 100,300 RANGE.
1000 pF TEST ON 1000,3000 RANGE.
* TEST POINT 2 TEST 100pF ON 10 RANGE.

Figure 6-2.
Troubleshooting Schematic Diagram
(E830715B)



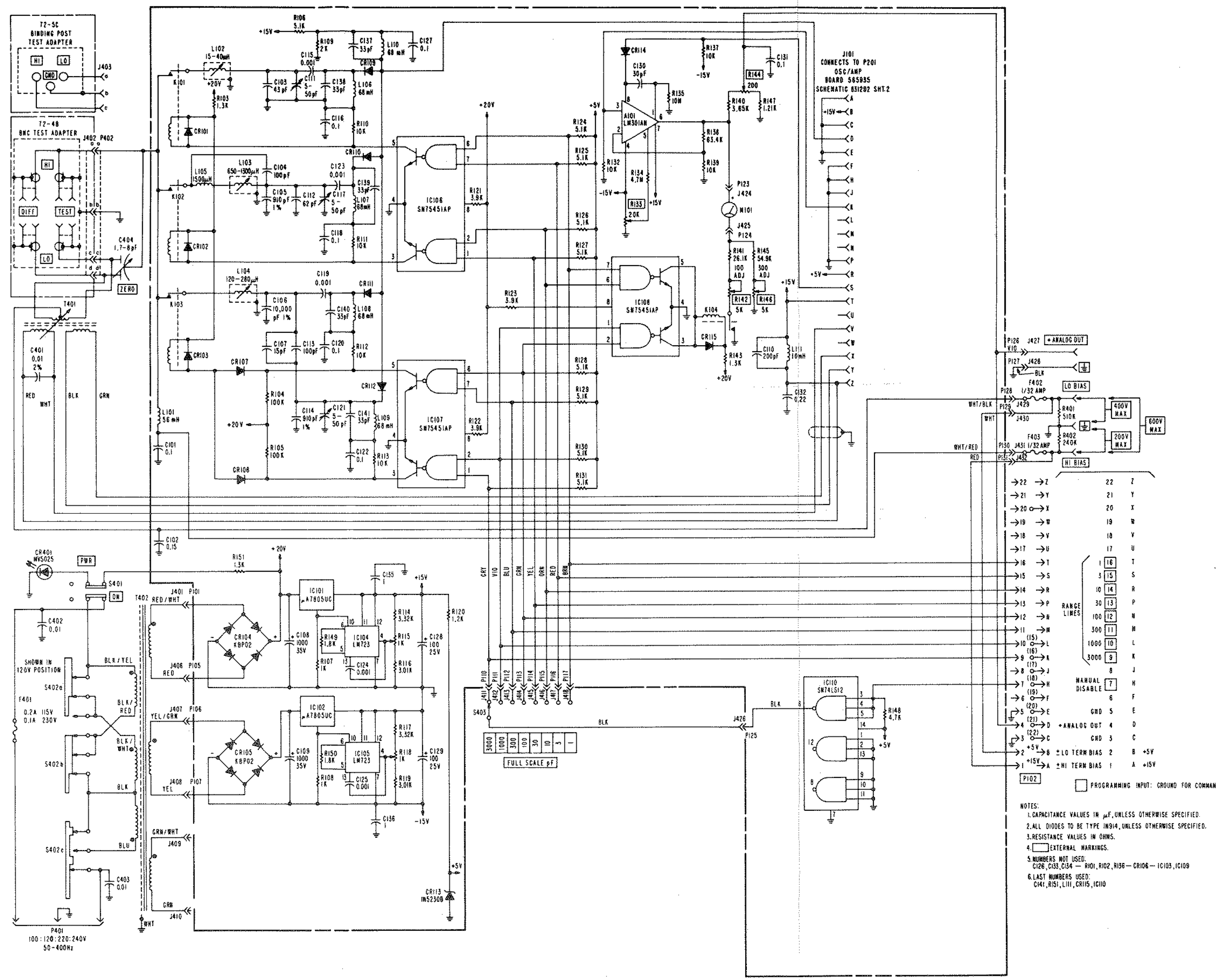
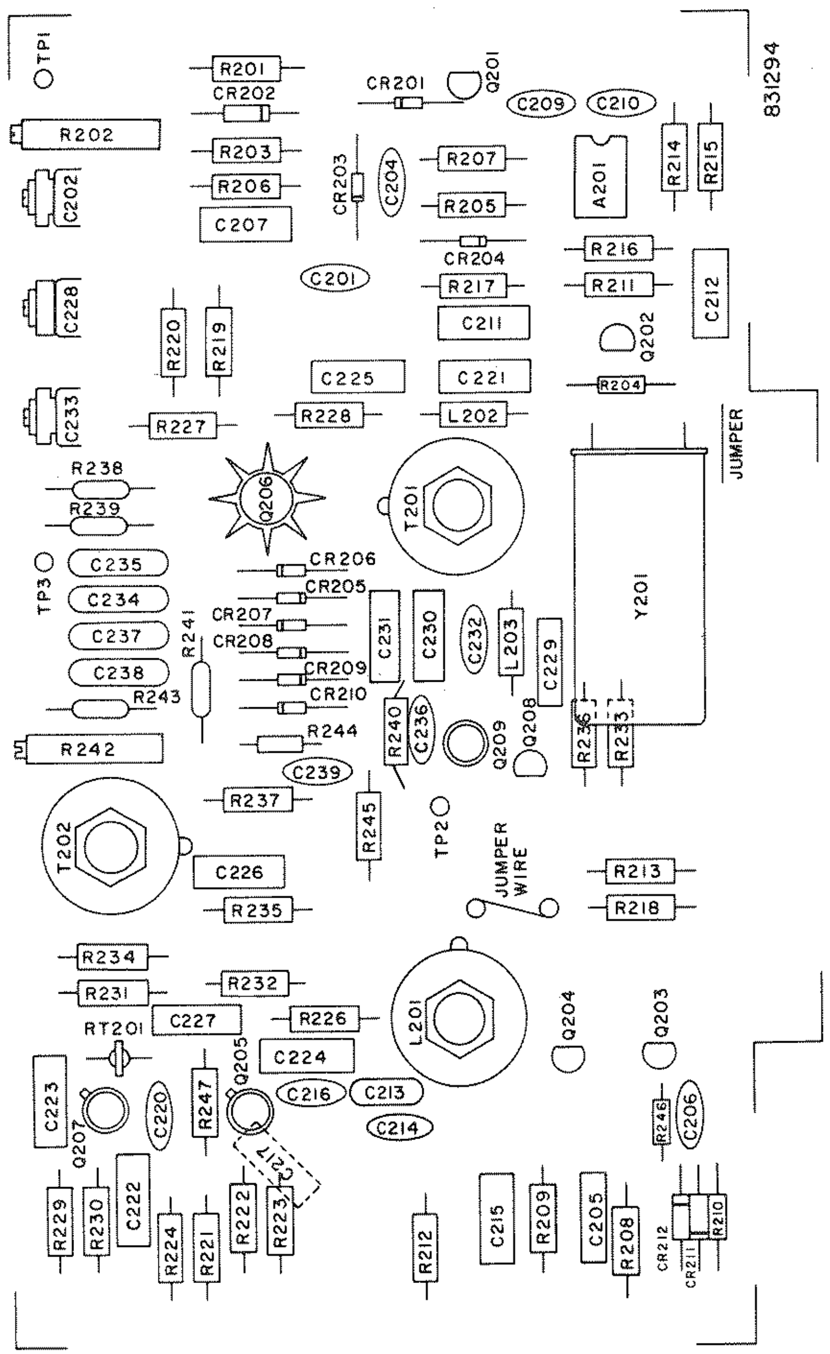
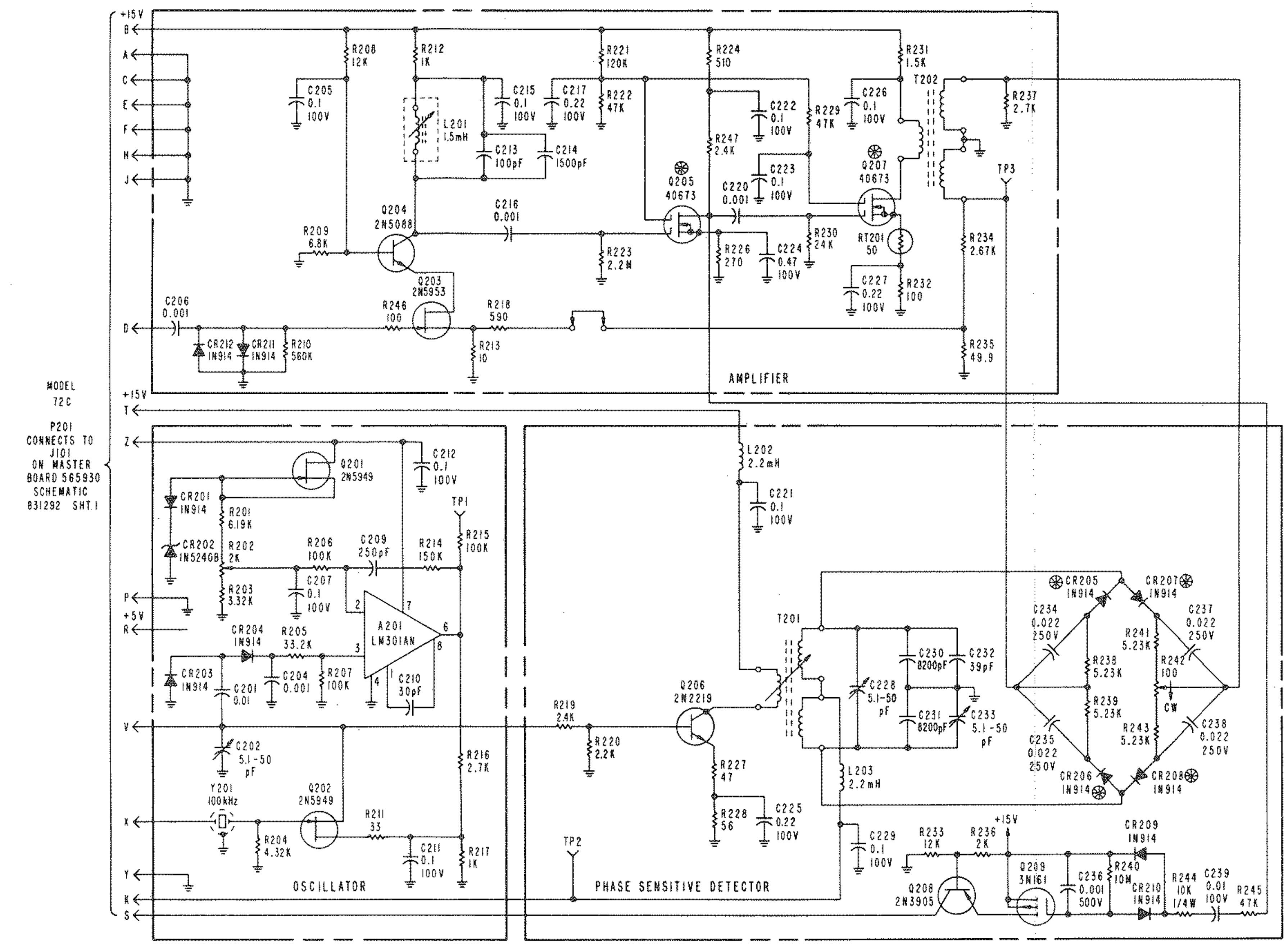


Figure 6-3.
Master P.C. Board, Schematic Diagram
(E831292A, Sheet 1 of 2)





NOTES:
1. CAPACITANCE VALUES IN μF, UNLESS OTHERWISE SPECIFIED.
2. RESISTANCE VALUES IN OHMS.
3. ✲ SELECTED VALUE.
4. LAST NUMBERS USED: C239 R247 Q209 CR212
5. NUMBERS NOT USED: C203 C208 C218 C219 R225

Figure 6-4.
Oscillator-Amplifier, Schematic Diagram
(D831292A, Sheet 2 of 2)
6-9/6-10