Instruction Manual

Model 72AD

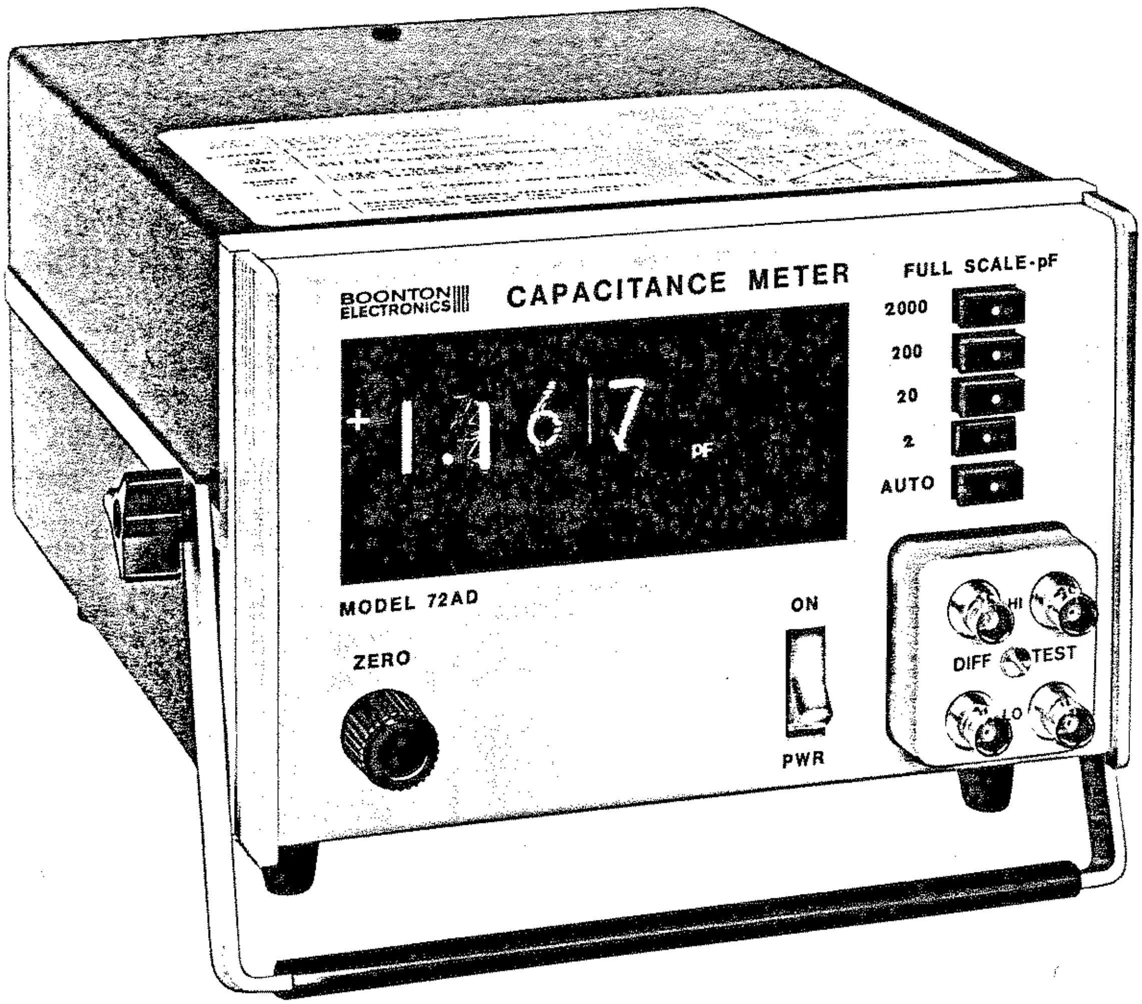
Digital Capacitance Meter

72AD
c-1172

BOONTON ELECTRONICS CORPORATION

TEL: 201-887-5110
TWX: 710-986-8241

ROUTE 287 AT SMITH ROAD
PARSIPPANY, N.J. 07054 USA



Model 72AD Digital Capacitance Meter

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

1.1 GENERAL

The Model 72AD Capacitance Meter provides instant, direct-reading, three-terminal and differential capacitance measurements from 0.05 pF to 2000 pF. This capacitance coverage is divided into four ranges, selected by panel push-buttons or remotely. These are arranged in a 2, 20, 200 and 2000 pF full-scale sequence. (1) The digital display provides 3 digits plus one readout, decimal point, and + or - indications. The solid-state design and the low-level crystal-controlled signal source contribute to the high stability and excellent reliability of the instrument.

The measurement of semiconductors is facilitated by the 15 mV rms level of the 1 MHz test signal, and by the provision for applying up to 600 volts of dc bias to the test specimen. Bias voltage, of either polarity, may be applied to either or both sides of the specimen.

The Model 72AD 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 phase-sensitive detection system permits the measurement of even low-Q devices (down to Q = 1) without sensibly degrading the accuracy of the measurement.

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

(1) For serial numbers below 280, ranges are 1, 10, 100 and 1000 pF, with 100% overrange provided.

Both linear dc and binary coded decimal outputs are available at rear-panel terminals and at the appropriate pins on the rear edge connector. These two features extend the range of applications beyond ordinary laboratory measurements to include production testing and integration into a controlled test system, using logic-level programming.

Remote ranging is controlled by grounding the EXT PROG terminal on the rear edge connector, disabling the front-panel range switches. Grounding any one of the four range-line terminals will then select that range.

Connection to the edge connector should be made with an Amphenol Type 225-22221-101 plug, or equivalent.

CHAPTER II

SPECIFICATIONS

Capacitance Range:	0.05 to 2000 pF
Full Scale Ranges:	2, 20, 200, 2000 pF
Accuracy:	0.25% rdg + 0.2% fs (Q> 5)* 2000 pF range: 0.4% rdg + 0.2% fs 0.5% rdg + 0.2% fs (Q = 1 to 5)* 2000 pF range: 2% rdg + 0.2% fs *Add 0.005 pF on lowest range
Resolution:	0.001 pF
Display:	Nixie type, 3 - 1/2 digits, display period 250 ms; encode period 10 ms
Data Outputs:	1, 2, 4, 8 BCD, digit parallel; logic level change indicates range and encode complete
DC Output:	2 volt fs ± 0.5% all ranges; source resistance 1000 Ω Linearity 0.1% rdg + 0.005% fs 2000 pF range: 0.25% rdg + 0.01% fs
Test Signal:	1 MHz, crystal-controlled, 15 mV rms; DIFF/TEST terminal balance 0.2%
External Bias:	HI to GND ± 200 V max. LO to GND ± 400 V max. LO to HI ± 600 V max (floating supply)
Programming:	Logic 0 (< +0.3 V) referred to ground selects each range and function;* one line for each range * except encode hold which is logic 1 (>+3.0 V)
Temperature Influence:	

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

Options:	Autoranging (72AD-01). Automatically upranges at 1999, downranges at 180. Ranging time is 100 ms per range.
Accessories Furnished:	Two connection adapters: a) BNC for remote connections to TEST and DIFF terminals. b) Grip-posts for local connection of axial-lead components.
Accessories Available:	External trigger adapter (72-6A). Provides an expanded triggering signal capability for integration into test systems. Triggering can be actuated by logic transition from "1" to "0", from "0" to "1", or by switch closure to ground. Single rack-mounting kit (mounts left or right) 92-1A. Dual rack-mounting kit 92-1B.
Power Requirements:	115 or 230 volts ac, ±10%, 50 to 400 Hz, 7 watts.
Dimensions:	5.2" high, 8.3" wide, 12" deep (132 x 211 x 305 mm)
Weight:	7.2 lbs. (3.27 kg)

CHAPTER III

OPERATION

3.1 INSTALLATION

Each instrument has been inspected and tested at the factory for full compliance with all specifications before packing. Should any indication of shipping damage be apparent upon unpacking, be sure to notify the carrier and the factory immediately. It is recommended that the special packing materials be saved for use in the event that the instrument must be re-shipped in the future.

3.1.1 Operating Controls and Indicators

ITEM	FUNCTION
FULL SCALE pF	These push-button switches select the full-scale range of the instrument (2, 20, 200 and 2000 pF). The AUTO switch at the bottom of the row activates the autoranging circuits (if that option has been chosen) and disengages the range switches.
PWR Switch	This rocker-type switch controls the primary ac power to the instrument. The translucent plastic rocker also serves as the pilot lamp.
ZERO Control	This control operates a differential capacitor used to balance out capacitance appearing across the TEST terminals contributed by the exposed termination of connecting cables, test fixtures, etc.

Indicator	Digital Nixie-type display, three digits plus one, decimal point, and polarity.

(The following items are on the rear panel)

BIAS Terminals	External dc bias may be applied to the HI and LO TEST terminals via these posts. The maximum values are ±200 volts from HI terminal to ground, and ±400 volts from the LO terminal to ground. The sum of these two voltages (600 V) may be applied between the HI and the LO posts, but the bias supply should be floating (no connection to ground) for this application.
Slide Switch	This switches the power transformer primary to 115 or 230 volts, in accordance with the available line voltage.
Fuse Holder	Contains the main line fuse: 0.2 ampere for 115 volts, and 0.1 ampere for 230 volts.
ANALOG Terminals	A dc voltage proportional to the capacitance reading is available at these terminals. This voltage is 2.0 volts ±0.5% for full-scale range on each range. Source resistance is 1000 ohms, linearity 0.1% rdg ± 0.005% fs.
P102	22-pin edge connector for remote ranging and readout connections.
Test Adapter	These banana plugs are used for storing the unused test connection adapter.

This safety requirement symbol has been adopted by the International Electrotechnical Commission, Document 66 (Central Office) 3, paragraph 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.

3.2 OPERATION

3.2.1 See that the rear-panel voltage selector slide switch is in the proper position for the line voltage used, and that the correct fuse for this voltage is in the fuse holder. Plug the power cord into a receptacle, turn the instrument on, and allow it to warm up for a few minutes.

3.2.2 Plug the desired test connection adapter into the front-panel receptacle. If it is planned to test components remotely via coaxial cables or with a test fixture, all of these items should be connected to the adapter jacks at this time.

3.2.3 Push the 2pF range button switch and set the indicator reading to zero, using the ZERO control.

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

3.2.4 When more than a few inches of coaxial cable are used to connect the instrument to a remote test fixture, some attention must be given to the loading capacitance of the cable. To maintain the specified accuracy, the values shown in the following table should not be exceeded:

Maximum Cable Loading Capacitance

A. HI post to ground:

RANGE	MAX. C
2 pF	100 pF
20 pF	250
200 pF	500
2000 pF	500

B. LO post to ground:

500 pF max. on all ranges

3.2.5 The instrument is now ready for use. The zero setting should hold on all ranges once it has been made on the 2pF range. If the Autoranging option instrument is used, the zero adjustment should be made with the instrument in the autorange mode.

3.2.6 The ZERO adjustment has sufficient range to compensate for approximately 3 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 zero setting within the range of the ZERO control.

3.2.7 Remote Measurement

The remote measurement of capacitance via coaxial cables introduces a measurement error owing to the transmission line effect on the test voltage transmitted from the LO terminal, and on the received current at the HI terminal.

The combined effect is such that the ratio of measured capacitance to actual capacitance is,

$$Cm/C = \frac{1 + j\omega Cr}{\left[\cos\beta\ell - \omega C Z_o (\sin\beta\ell)\right]^2 \left[1 + j\,\frac{\omega Cr\,(\cos\beta\ell) + (\sin\beta\ell) r / Z_o}{\cos\beta\ell - \omega C Z_o\,(\sin\beta\ell)}\right]}$$

where $\beta\ell$ = the electrical length of each line, in degrees

Z_o = the characteristic impedance of the line, in ohms (Note: At 1 MHz, Z_o for RG-58/U is approximately 57.5 ohms)

and r = the equivalent resistance of the Capacitance Meter from HI terminal to ground.

Range	r
2 pF	140 ohms
20 pF	7 ohms
200 pF and above	1 ohm

For the 72AD Capacitance Meter, the error is positive and its magnitude is shown in Figure 1 as a function of the measured capacitance, C_m, and cable length, ℓ.

The error is not shown for the lower two ranges for 12 foot lengths of cable, as the capacitive loading of the HI test terminal is excessive for lengths of RG-58/U greater than about 3.5 feet, and lengths of about 8 feet for the 20 pF range.

When calculating $\beta \ell$, which is the electrical length in degrees of each of the two cables, it is necessary to know the velocity of propagation of the cable at 1 MHz. Samples of RG-58/U which were tested indicate a relative velocity of 63.5%. The impedance of the same cable measured 57.5 ohms at 1 MHz.

It is imperative that the shields of both ends of the coaxial cable be tied together with a low resistance, low inductance strap for the correction curves and equation to be valid.

3.2.7.1 For short lengths of cable, a reasonable correction may be made 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, and the error will be seen as an apparent increase in capacitance in accordance with the following expression:

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

Or, if the true capacitance is required:

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

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

As an approximation, the inductance of RG-58/U cable (with shields strapped at both ends) is about 0.091 uH/ ft.

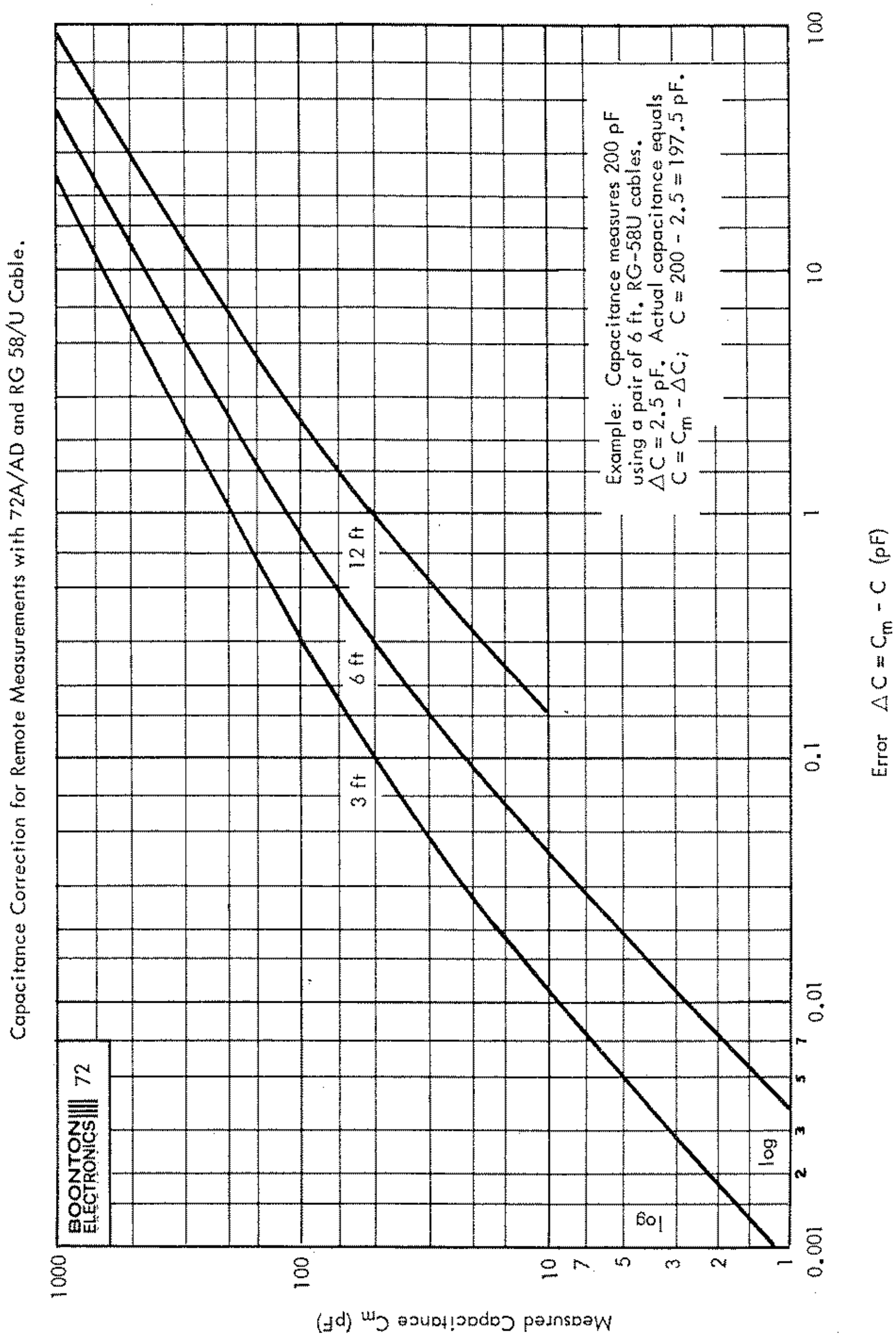


Figure 1. Capacitance Correction

3.2.8 Differential Measurements

Measurement of the capacitance differential between two specimen capacitors can be made by connecting the smaller sample to the DIFF terminals, and the larger to the TEST terminals. The display will indicate the capacitance difference between the two; by switching down to the next lower range the resolution will be improved. The capacitor connected to the DIFF terminals may be as large as the full-scale value of the selected range without introducing serious error.

Note: Differential measurements cannot be made with the instrument in the Autorange mode.

Excess fixture capacitance across the TEST terminals beyond the normal range of the ZERO control may be balanced out by the addition of a capacitor to the DIFF terminals. (See Par. 3.2.6) Values up to the full-scale value for the range in use may be used in this application without introducing additional error.

While capacitance may be measured using the DIFF rather than the TEST terminals (the display will then show the negative polarity sign), this is not recommended. The measurement accuracy in this application will be good only up to a quarter of full-scale value; using the TEST terminals, on the other hand, yields the specified accuracy up to 100% of full-scale value.

3.2.9 DC Bias

DC Bias voltage may be applied to either or both sides of the specimen via the rear-panel bias terminals, or 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, the other bias terminal must be connected to ground.

The sum of the two voltages (600 volts dc) may be applied between the HI and the LO terminals. In this connection, however, the 200-volt maximum limit of the HI side to ground may be exceeded; it is therefore strongly recommended that the bias supplied not be grounded. (An internal voltage divider establishes the ground point.)* The bias lines are internally protected by 30 mA fuses.

*Internal voltage divider resistance values are 240 kΩ from HI to ground and 510 kΩ from LO to ground.

3.2.10 External Triggering

When the 72AD must be controlled externally, as when it forms part of an existing test system, it may be found that the specific pulse characteristics required for triggering (see drawing, Chapter VII) are not available. The expanded triggering capability provided by the optional Model 72-6A Encode-Trigger Converter will allow proper triggering by any of the following signals:

1. A logic transition from "1" to "0"
2. A logic transition from "0" to "1"
3. A switch closure to ground

The input signal characteristics required by the 72-6A are:

a. For edge-triggered inputs (1 and 2, above):

Logic 1 > 2.4 V

Logic 0 < 0.8 V

Sink current < 0.8 mA

(Transitions must be monotonic to assure single triggers)

b. Switch closure input (3, above)

Open circuit voltage = 5 V
Sink current ≤ 1.0 mA
Bounce delay = 10 ms (Internal bounce delay may be increased by an external capacitor or decreased by an external resistor)

CHAPTER IV

APPLICATIONS

4.1 TRANSISTOR PARAMETERS

The Model 72AD is capable of measuring the small-signal capacitance and forward gain parameters of both bipolar and unipolar transistors at 1 MHz. Capacitance and transconductance are measured with a test signal level of 15 millivolts; beta is measured with a base signal current of approximately 100 nanoamperes.

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

4.1.1 Capacitance (Three-terminal)

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 (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 input of the device connected to the high test terminal (detector).

C_{iss} Input capacitance between gate and source with guarded drain. Device under test is fully biased. $V_{GS} = 0$.

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

C_{eb} Emitter-to-base capacitance. Collector guarded. Emitter reverse biased. $V_{CE} = 0$ (o.c. for dc).

C_{ce} Collector-to-emitter capacitance. Base guarded. Collector reverse biased. $V_{BE} = 0$ (o.c. for dc).

C_{re} Collector-to-base capacitance. Emitter guarded. Device under test is fully biased.

C_{cb} Collector-to-base capacitance. Emitter guarded. Collector reverse biased. $I_E = 0$ (o.c. for dc).

4.1.2 Capacitance (Two-terminal)

C_{ob} Collector-to-base capacitance. Emitter is open-circuited for both ac and dc. Collector is reverse biased.

NOTE: External connections for the above measurements are shown in Figure 2.

4.1.3 Beta (h_{fe})

A sensibly constant base current, i_b, of 94 nanoamperes can be generated with the aid of a 1.0 pF capacitor connected between the low differential (LO DIFF) terminal of the 72AD Capacitance Meter and the base of the transistor under test. The collector current, which equals βi_b, is fed to the high test terminal (HI TEST) and the instrument responds as though a capacitance of β times 1 pF were connected to its terminals. The value of indicated capacitance in picofarads is equal to beta (h_{fe}). 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, owing to the quadrature relation between the reactance of the current source and the input resistance.

The low differential terminal is used for the current source to offset the 180-degree phase reversal of current in the transistor.

The variable series capacitor in the base circuit (see Figure 3) must be adjusted for a value of 1.0 pF. This is simply accomplished by connecting a small jumper (unity-gain transistor) between the base and collector socket terminals, which permits the direct measurement of this capacitance. If the LO DIFF terminal is used, the reading should be adjusted for -1.0 pF, or the LO TEST terminal may be temporarily used for a reading of +1.0 pF.

Should the transistor socket and its associated circuitry have excessive capacitance from the base terminal to ground, it can be absorbed with a simple parallel-resonant circuit, using a high L/C ratio for maximum impedance. (Figure 3)

4.1.4 Forward Transconductance (g_{fs})

The 72 Series Capacitance Meters are calibrated for an input current of $+je_g \omega C\angle\theta$, 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 is small. Unfortunately, the phase of the drain current lacks the required +90 degrees.

A network is needed which presents a low impedance to the drain, and which provides the necessary phase shift of +90 degrees. The circuit shown in Figure 4, Page 21, 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,

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

The actual drain current is,

$$i_d = e_g g_{fs}$$

The voltage induced in the secondary of the transformer is,

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

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

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

where

$R \gg \omega L_s$ 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 easily measured by measuring the primary inductance with the secondary open-circuited, then short-circuited.

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

If the resistor R is selected for a full-scale reading of 2000 μmhos on the 200 pF range, the instrument will read:

C Range	g_{fs} Range
200 pF	2000 μmhos
2000 pF	20,000 μmhos

A typical toroidal transformer might have the following circuit values:

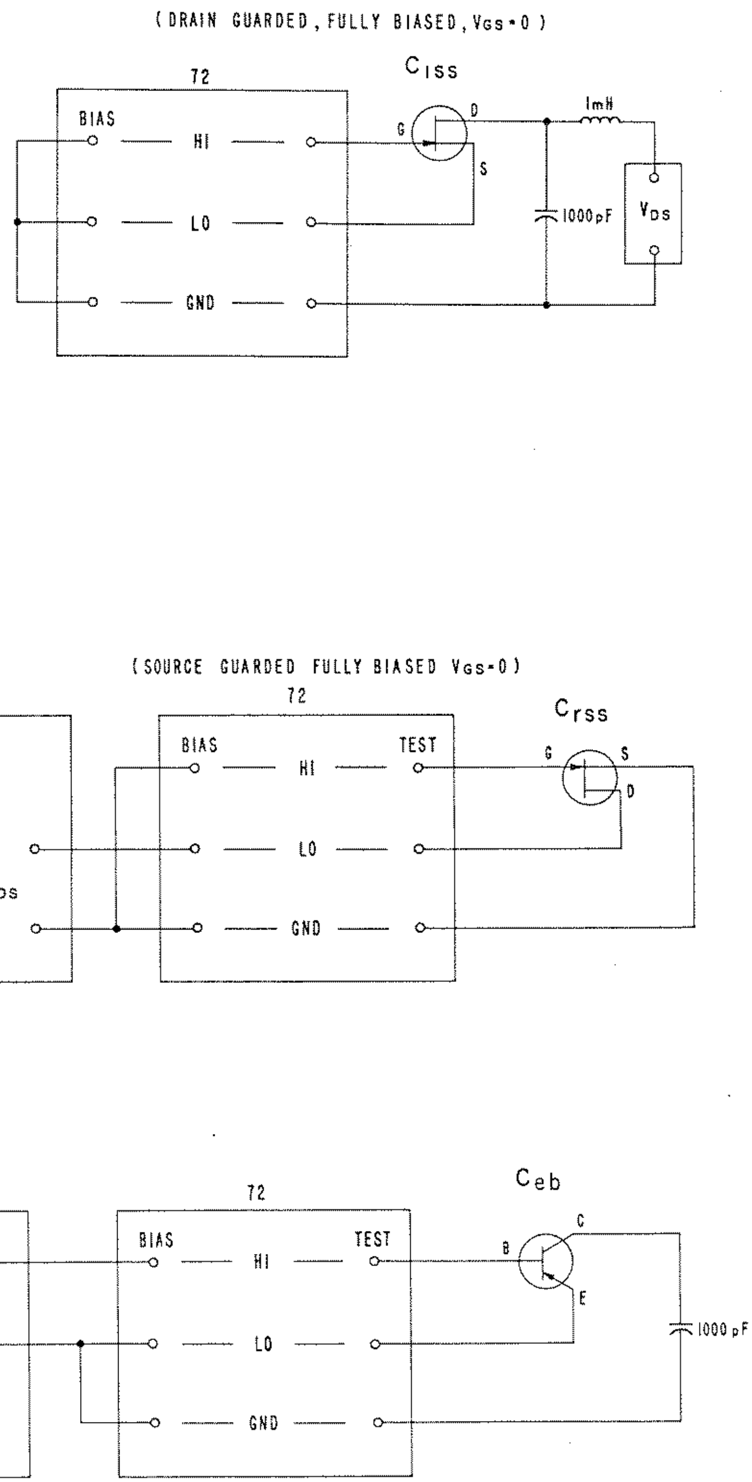
$$L_p = 250\ \mu H$$
$$L_s = 5\ \mu H$$
$$k = 0.935$$

from which,

$$M = 33\ \mu H$$

The series primary capacitance for resonance must equal 100 pF (approximately), and for a full-scale range of 2000 μmhos on the 200 pF range, the calibrating resistor should equal:

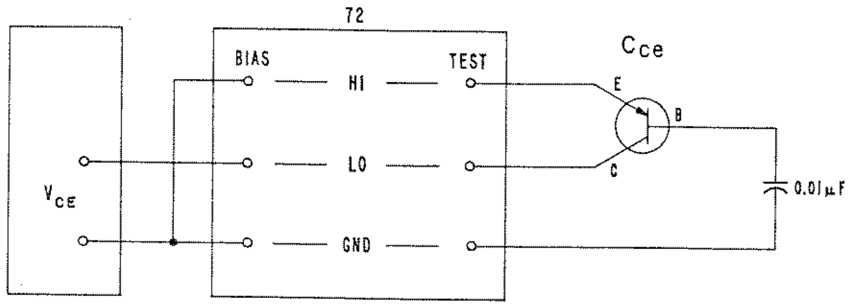
$$R = (2000)(33)/200 = 330\ \Omega$$



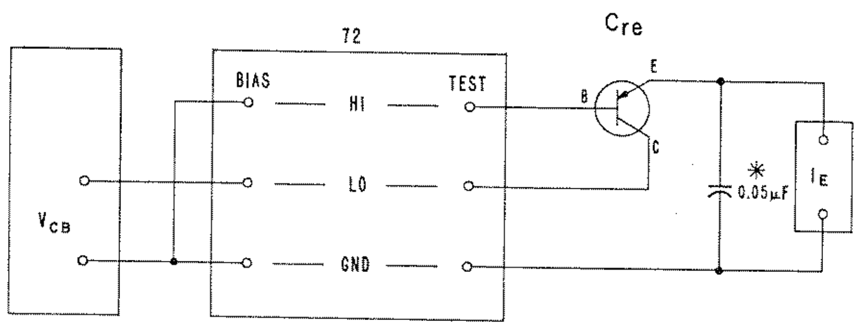
NOTE: REVERSE BIAS ON BASE EMITTER JUNCTION.

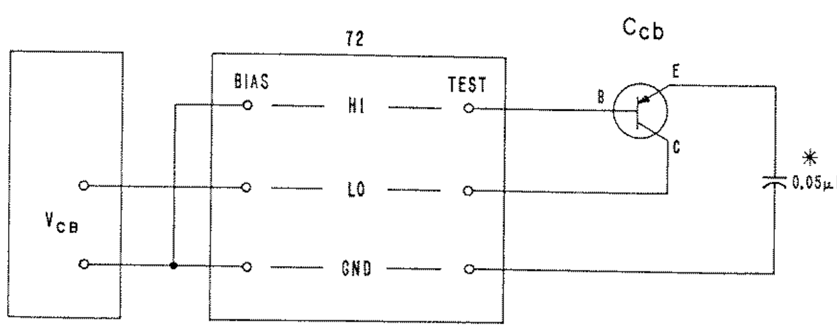
Figure 2. Transistor Capacitance Measurements.

72AD
a-472



(EMITTER GUARDED, FULLY BIASED)





* A better by-pass obtains with a 2.5μH inductor in series with a 0.01 μF capacitor.

Figure 2. (Cont'd.)

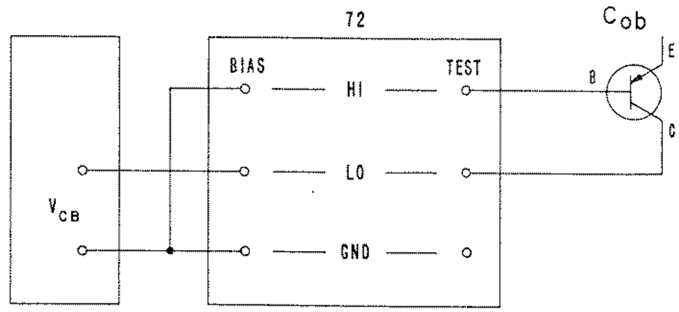


Figure 2. (Cont'd.)

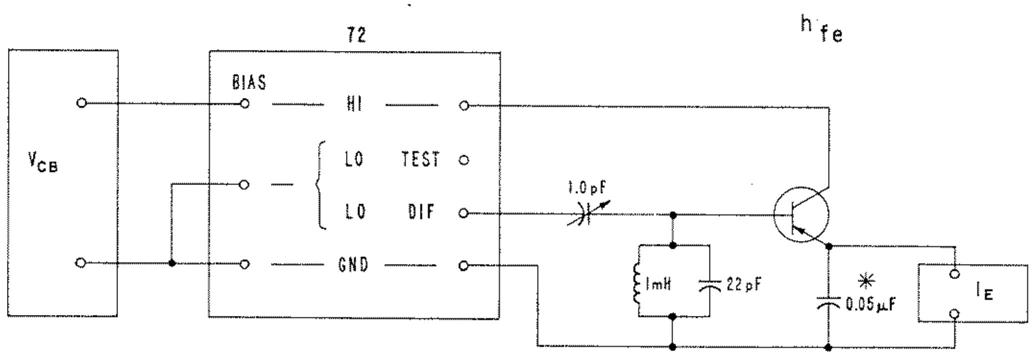


Figure 3. Transistor Beta Measurement

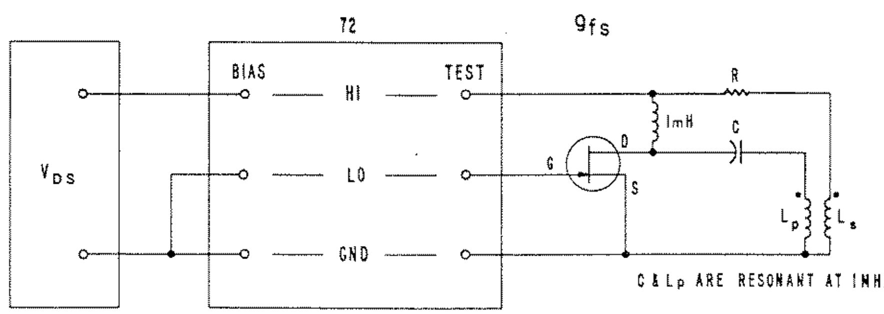


Figure 4. Transistor Transconductance Measurement

CHAPTER V

THEORY OF OPERATION

(Refer to the Simplified Schematic, Figure 5, in connection with this explanation.)

5.1 BRIDGE CIRCUITS

The output of the 1 MHz crystal-controlled oscillator appears across the secondary of the input transformer whose center-tap is at RF ground. One end of this winding goes to the LO TEST terminal, and the other end to the LO DIFF terminal. The HI terminals are connected together and lead to the output connection of the measuring section. A differential capacitor (ZERO) has its stators connected across the transformer secondary winding, and its rotor to the common HI post connection.

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 control) balances out this signal, within the limits specified in Section 3.2.6, resulting in zero output from the bridge section.

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

The synchronous detector, gated by the crystal oscillator, converts the 1 MHz signal to dc and applies it to the dc amplifier section. The output of the dc amplifier is available at the ANALOG terminals, supplying a dc analog output voltage for external indication or control purposes. The dc is also applied to the digital section. Here, the signal is processed to extract range information, decimal point position, over- and under-range information, and polarity indication.

The processed signal is applied to the dual-slope analog-to-digital converter, where the analog information is converted to digital form and applied to the digital display unit. The information displayed is also made available in BCD form at the rear edge-connector, for external system applications.

5.2 RANGING CIRCUITS

Range switching in the 72AD is accomplished by a combination of panel switches, switching diodes, and miniature reed relays. The panel switches handle only control voltages; no signal currents pass through their contacts, which eliminates a frequent source of errors and improves reliability.

With all panel range switches open, the switching diodes are biased off by the 2.4 volt differential between the +6.6 volts on their cathodes and the +4.2 volts on their anodes. When a range switch is closed, the cathode of the appropriate diode is grounded for dc through an rf choke and 10 k 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 1 MHz amplifier. At the same time, the range switch energizes the associated reed relay which connects the other end of the range network to the output of the measuring section.

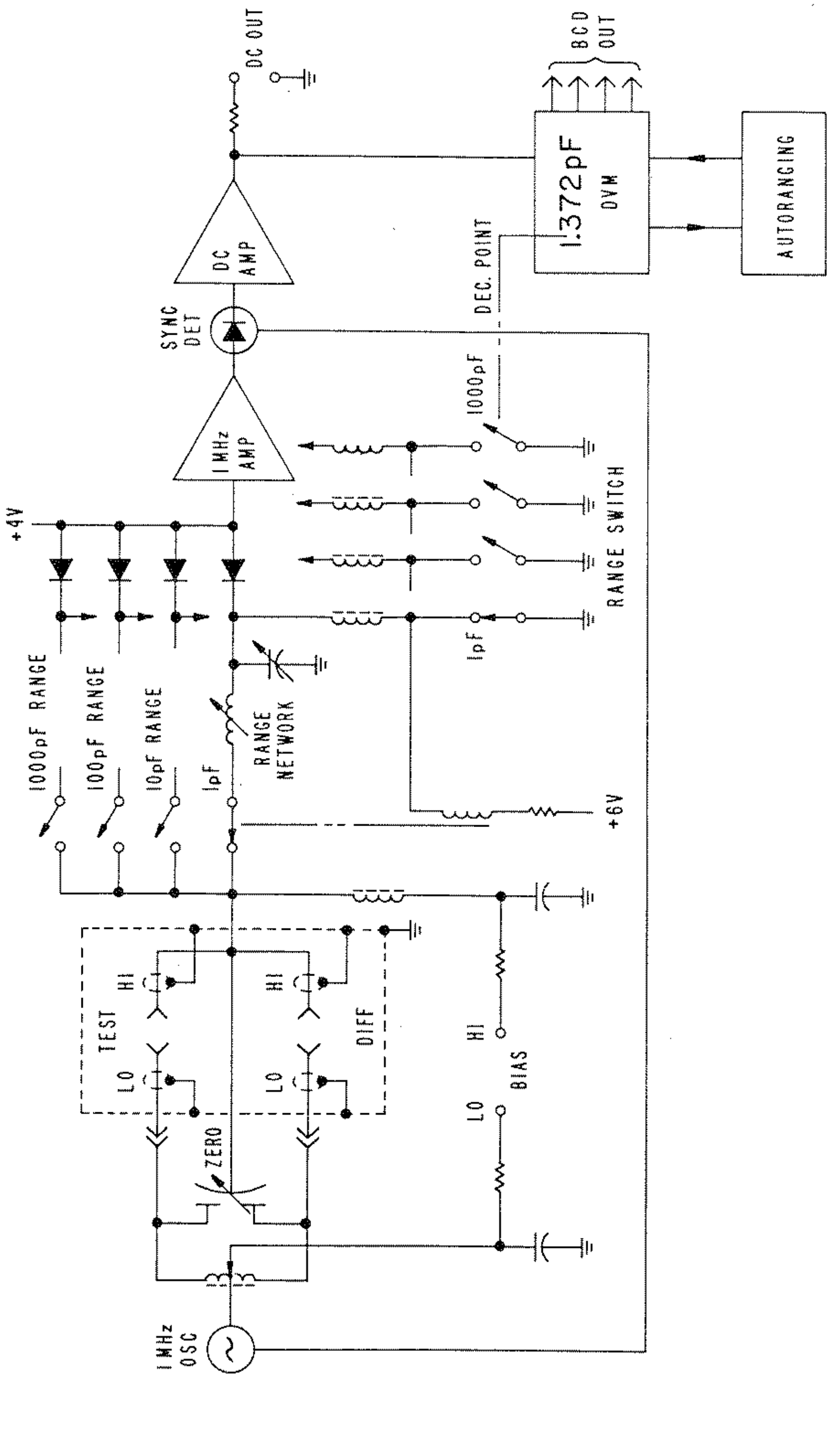


Figure 5. Simplified Schematic

CHAPTER VI

MAINTENANCE

6.1 PERIODIC CALIBRATION

The Model 72AD is designed to provide trouble-free operation over long periods of time. However, as with any measuring instrument, it is advisable to follow a program of periodic calibration against known standards. Should there be any indication of operational malfunction, of course, such a calibration check will also be an aid in pinpointing the trouble before detailed troubleshooting is attempted.

6.1.1 Equipment Required for Calibration

a. Digital or differential dc voltmeter, ± 0.005% accuracy.

b. DC Voltmeter, such as a standard VOM.

c. RF Millivoltmeter, such as a Boonton Electronics Model 92 Series.

d. 100 pF ± 0.25% standard capacitor, switchable from high Q to a Q of 3. (BEC Model 71-1A or equivalent)

e. 1000 pF ± 0.1% standard capacitor. (BEC CS-1000)

f. 100 pF ± 0.1% standard capacitor. (BEC CS-100)

g. 10 pF ± 0.1% standard capacitor. (BEC CS-10)

h. 1 pF ± 0.1% standard capacitor. (BEC CS-1)

6.2 CALIBRATION PROCEDURE

Remove the screw on the top rear of the instrument cover and take off the cover. Turn the instrument on, allow it to warm up for a half-hour, then follow the steps outlined in the following pages.

NOTE: Refer to Figure 6 for identification of the controls mentioned in the following procedure.

6.2.1 Oscillator Tuning

Switch the instrument to the 2000 pF range, and connect the dc voltmeter to test point TP 1. Adjust C204 for a maximum reading on the voltmeter, which will normally be in the range of +5 to +14 volts.

6.2.2 Test Level

With the instrument still on the 2000 pF range, connect the RF Millivoltmeter between the LO terminal on the front panel and ground. Adjust R209 for a reading of 15 mV ± 2 mV.

6.2.3 Low Q Adjustment

Switch the 72AD to the 200 pF range. Connect the 100 pF ± 0.25% standard capacitor (Model 71-1A) to the TEST terminals and record the capacitance reading. Switch the standard to the low Q position (Q = 3) and again read the capacitance value. If the two values obtained are not the same, adjust C229 until they coincide.

6.2.4 Front-Panel Zero

Switch instrument to the 2 pF range. Connect dc voltmeter to the ANALOG terminals on the rear panel. With nothing connected to the TEST terminals, adjust the front panel ZERO control for a zero indication on the voltmeter. See that the readout on the digital display is within 0.000 ± 2 digits.

6.2.5 2000 pF Range Zero

After setting the front panel ZERO control on the 2 pF range, switch the instrument to the 2000 pF range. With the TEST terminals open, touch up R129 (accessible through opening in the rear panel) for a reading of zero on the dc voltmeter. This adjustment should be sufficient provided that the phase detector balance adjustment (R246) has not been disturbed. Should this not be the case, then R129 and R246 must be adjusted as follows:

Turn the instrument over and remove the bottom cover. Locate R126 on the Master Board. Referring to the schematic (830523, Sheet 1 of 2), connect the TOP terminal of R126 to ground with a short clip lead. Then, adjust R129 for a reading of zero on the dc voltmeter. Remove the grounding lead, replace the bottom cover, and adjust R246 for zero dc output on the voltmeter.

6.2.6 Amplifier Gain Adjustment

Switch the 72AD to the 200 pF range, connect the 100 pF ± 0.1% standard capacitor (CS-100) to the TEST terminals, and the digital dc voltmeter to the Analog terminals. Adjust R126 for a voltmeter reading of +1 V ± 0.1%

6.2.7 DVM Zero Adjustment

Switch the 72AD to the 200 pF range. With nothing connected to the TEST terminals, adjust R1016 for a 000 indication on the digital display.

NOTE: Adjustments on the DVM are accessible through a cutout on the left-hand side of the case.

6.2.8 DVM Gain Adjustment

Switch the 72AD to the 200 pF range, and connect the 100 pF ± 0.1% standard capacitor (CS-100) to the TEST terminals. Adjust R1027 for a digital indication of 100.0 ± 1 digit.

6.2.9 2000 pF range

With the 72AD on the 2000 pF range, connect the 1000 pF ± 0.1% standard capacitor (CS-1000) to the TEST terminals. Adjust C116 for a reading of 1000 ± 1 digit.

6.2.10 20 pF Range

Switch the 72AD to the 20 pF range and connect the 10 pF ± 0.1% standard capacitor (CS-10) to the TEST terminals. Adjust C113 for a reading of 10.00 ± 1 digit.

6.2.11 2 pF Range

Switch the 72AD to the 2 pF range and connect the 1 pF ± 0.1% standard capacitor (CS-1) to the TEST terminals. Adjust C106 for an indication of 1.000 ± 2 digits.

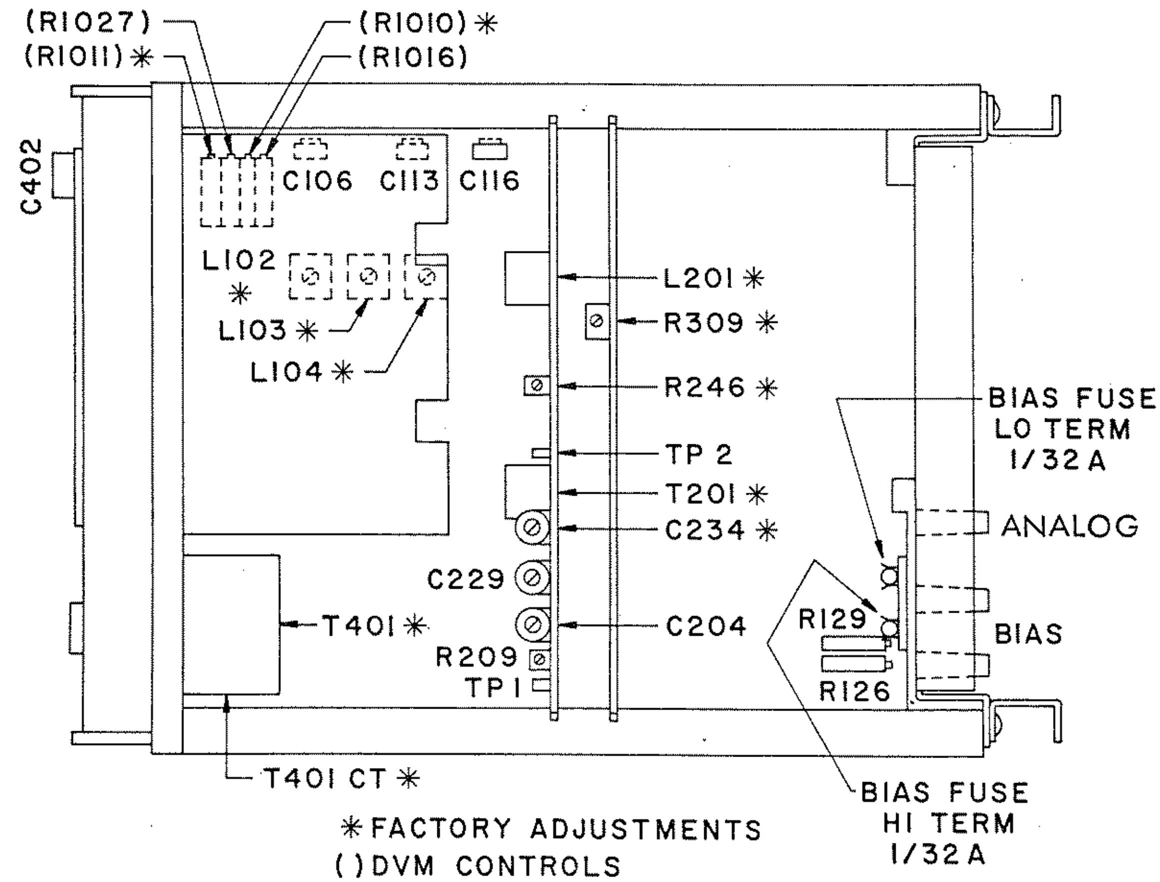


Figure 6. Calibration Adjustments

CHAPTER VII

INTERFACE INFORMATION

7.1 PROGRAMMING INPUTS

Pin No.	Function	Comment	Active Level*	Unit Loads**
C	External Program	Disables Panel Switches	Low	1
4	Autorange Enable	1 of 5 program lines may be selected. Multiple selection will cause incorrect readings.	Low	2.5
5	2 pF (range select)		Low	1.5
7	20 pF (range select)		Low	1.5
9	200 pF (range select)		Low	1.5
11	2000 pF (range select)		Low	1.5
K	Encode Hold	Logic 1 holds reading	High	n/a
19	Encode Trigger	Starts encode cycle	Low pulse	6.5

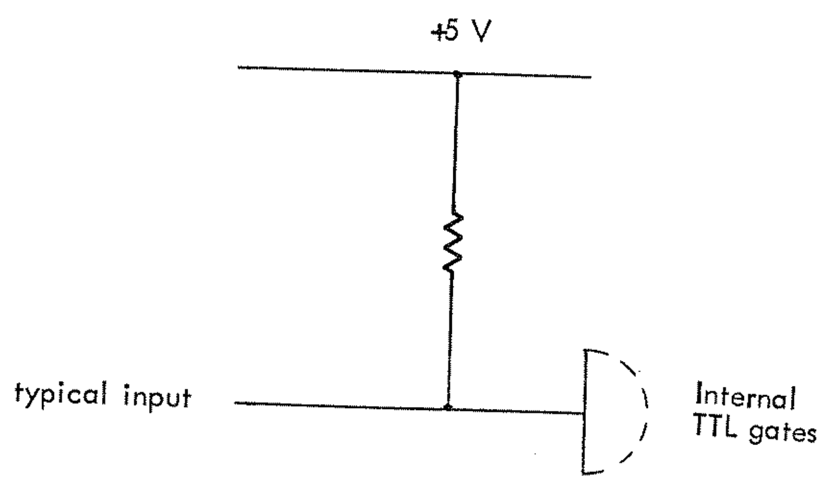
* Low level $\leq$ 0.3 V

High level $\geq$ 3.0 V

**Unit load = 1.6 mA

Input Characteristics

Each input (except for "encode hold") is TTL compatible. Internal pull-up resistors allow the use of open collector drivers if desired.



7.2 DATA OUTPUTS

Pin No.	Function	Comment	
L M N P R S T U V W X Y Z	1 (MSD) 8 4 2 BCD 1 encoded 8 data 4 2 1 8 4 2 (LSD) 1	Parallel BCD data corresponding to numeric display on front panel	These data lines are affected by "hold" and "trigger" inputs
J	Polarity	Logic 1 = negative reading	
5 7 9 11	2 pF 20 pF 200 pF 2000 pF (range output)	These range lines may be used as outputs during manual or autorange operation. Selected range is at Logic 0, others at Logic 1.	
16 17	overrange underrange	Logic 0 = overrange (> 100% fs) Logic 0 = underrange (< 9% fs)	
18	encode complete	Logic 0 = encode cycle in progress	

Output Characteristics

All data outputs are DTL/TTL compatible, and will drive one standard TTL load.

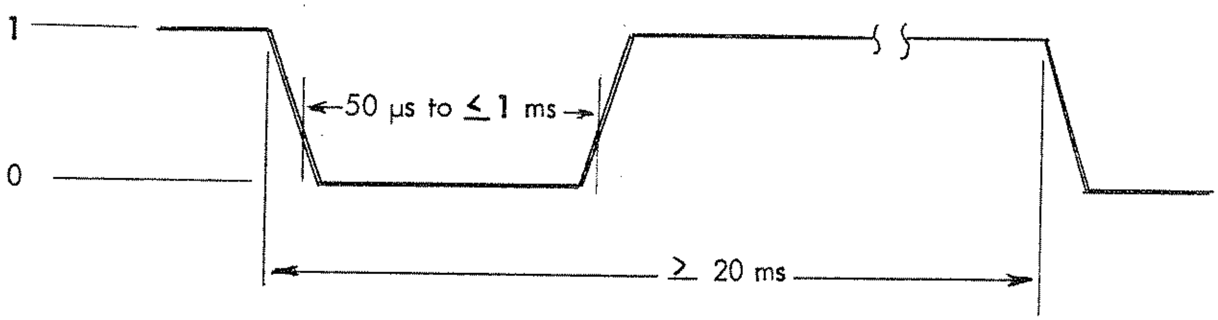
$V_o \geq +3$ V (source current $\leq$ 100 μA) at Logic 1

$V_o \leq +0.5$ V (sink current $\leq$ 1.6 mA) at Logic 0

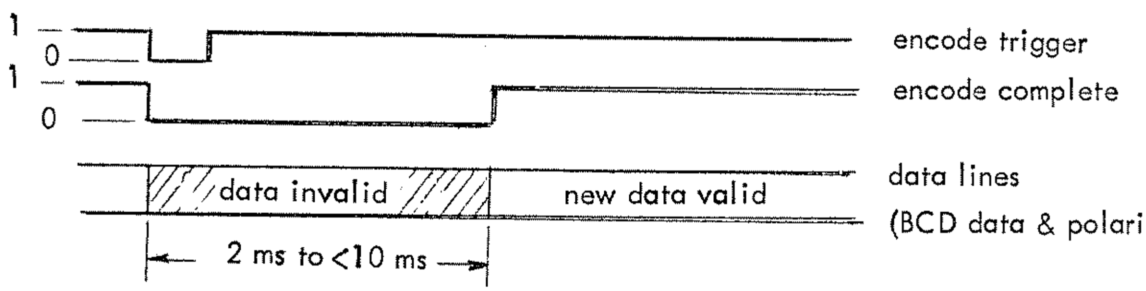
7.3 WAVEFORMS AND TIMING

7.3.1 External Triggering

Apply Logic 1 to hold input. The following signal, applied to encode trigger input, will start an encode cycle:



7.3.2 Data Output Timing



7.3.3 Response to Input and Range Changes

a. Response to capacitance step changes:

Analog output settles within 1 ms. An encode cycle initiated ≥ 250 ms following the step will be accurate to within one count of the final reading.

b. Response to capacitance range changes:

A range-to-range settling time of 10 ms should be allowed for using the analog output.

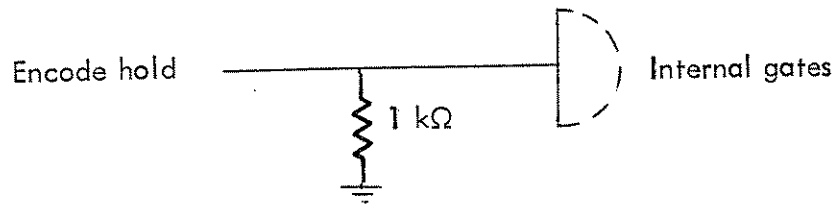
For digital data, the range-settling time should be added to the encode trigger delay of 250 ms to yield an accurate conversion

c. Autorange response time (manual mode)

Final Range	Response Time (max)
2 pF	500 ms
20 pF	600 ms
200 pF	700 ms
2000 pF	800 ms

7.3.4 "Encode Hold" Input

The encode hold input is active in the high state. An internal pull-down resistor provides a quiescent low state.



High state loading $\leq$ 5 mA

Low state loading $\leq$ 1.6 mA

Note that the driving device must source at least 3 mA at the 3 V high state threshold to drive the 1 kΩ pulldown resistor.

7.4 OTHER CONNECTIONS

Terminal	Function	Remarks
A	LO terminal bias	± 400 V max. to ground (200 V max. in Serial Nos. 155 and below)
B	Common	
D	Common	
E	No connection	
F	"	
H	"	
1	HI terminal bias	± 200 V max. to ground.
2	DC analog output	+ 2 V fs, Z ≅ 1 kΩ
3	Common	
6	Internal connection	Do not connect to these points.
8	"	"
10	"	"
12	"	"
13	No connection	
14	"	
15	"	
20	- 15 vdc	Power for BEC-supplied options or accessories only.
21	+ 15 vdc	
22	+ 5 vdc	

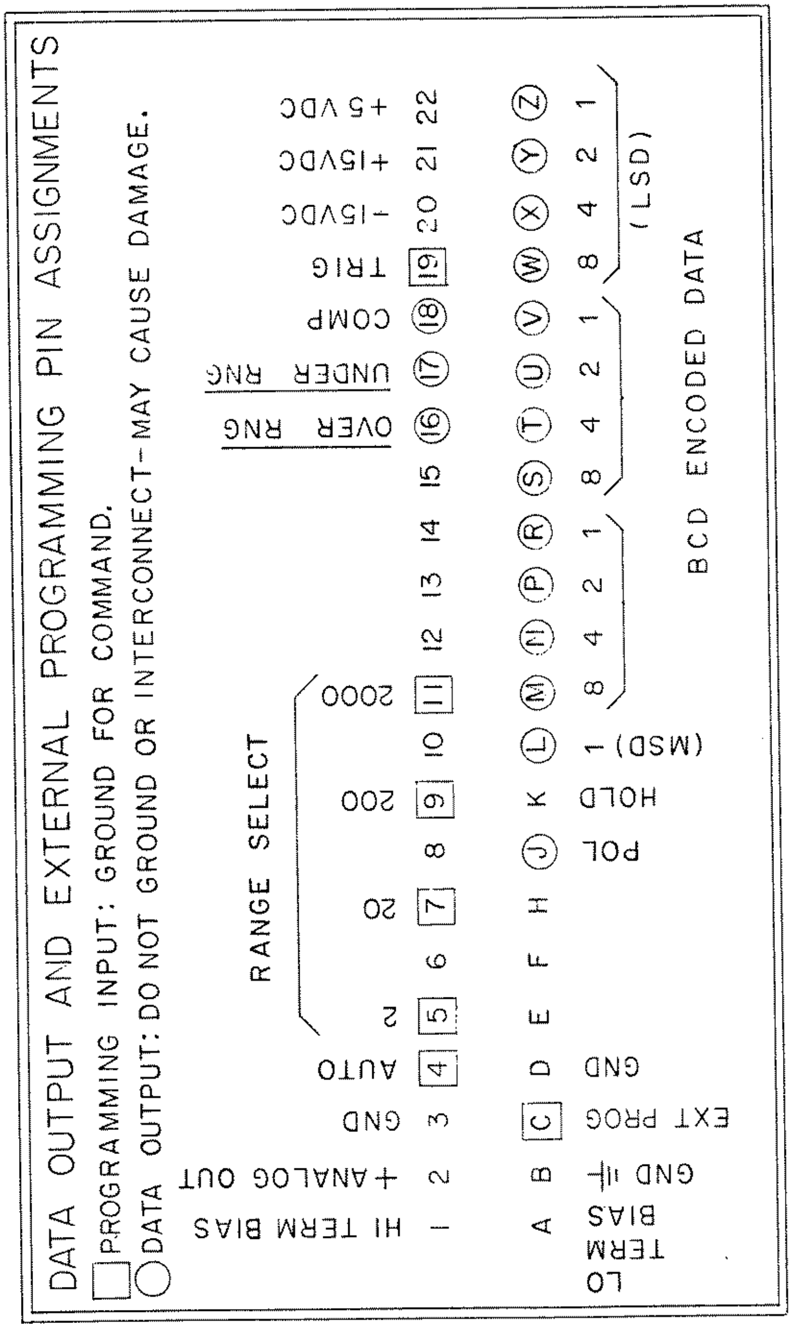
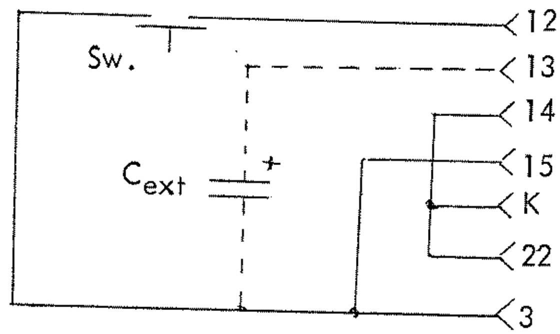


Figure 7. Rear Terminal Connections.

72-6A ENCODE-TRIGGER CONVERTER

External Trigger Connections

1. To trigger on switch closure:

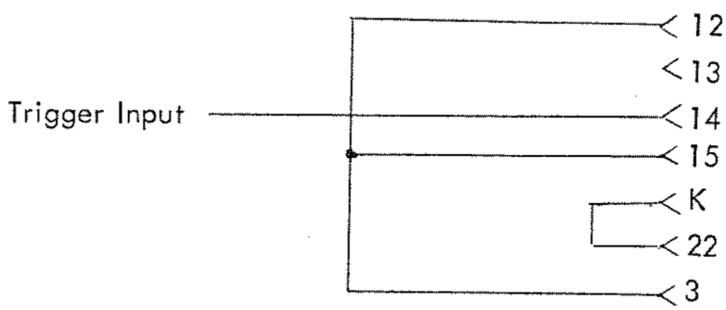


Additional switch bounce delay may be obtained with C_{ext}.

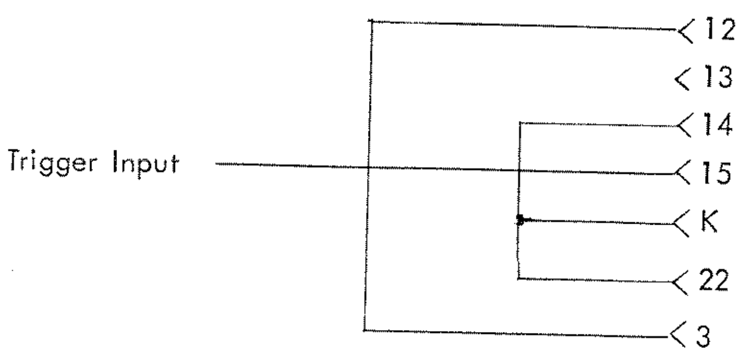
$$C_{ext} = \frac{\text{delay (ms)}}{100} \quad (\mu F)$$

A snap-action switch is suggested for manual operation.

2. To trigger on positive logic transition (0 to 1):



3. To trigger on negative logic transition (1 to 0):



72AD
a-1172

Figure 8

TABLE OF REPLACEABLE PARTS

MODEL 72AD

CAPACITORS

Reference		Description	BEC Part Number
C101	Capacitor, fixed	470 nF 10% 630 V	234107
C102	" "	100 nF 630 V	234091
C103	" "	82 pF ± 5%	200074
C104	" "	910 pF ± 1%	200075
C105	" "	10 nF ± 1%	203017
C106	Capacitor, variable	2 - 20 pF Blue	281005
C107	Capacitor, fixed	68 pF ± 5%	200031
C108	" "	82 pF ± 5%	200074
C109	" "	680 pF ± 1%	200015
C110	" "	1 nF 500 V	224114
C111	" "	"	"
C112	" "	100 nF 250 V	234080
C113	Capacitor, variable	5 - 50 pF Green	281006
C114	Capacitor, fixed	100 nF 250 V	234080
C115	" "	"	"
C116	Capacitor, variable	5 - 50 pF Green	281006
C117	Capacitor, fixed	100 nF 250 V	234080
C118	" "	1 nF 500 V	224114
C119	" "	100 nF 250 V	234080
C120	" "	22 nF 250 V	234079
C121	" "	30 pF ± 5%	200073
C122	" "	250 μF 40 V	283207
C123	" "	"	"
C124	" "	22 nF 250 V	234079
C125	" "	100 μF 25 V	283105
C126	" "	"	"
C127	" "	100 pF 500 V	200001
C128	" "	5 pF (factory selected)	200043
C201	Capacitor, fixed	100 nF 250 V	234080
C202	" "	1 nF 500 V	224114
C203	" "	"	"
C204	Capacitor, variable	15 - 60 pF	281008
C205	Capacitor, fixed	100 nF 250 V	234080
C206	" "	"	"
C207	" "	"	"
C208	" "	1 nF 500 V	224114
C209	" "	100 nF 250 V	234080
C210	" "	27 pF ± 5%	200076
C211	" "	1 nF 500 V	224114
C212	" "	250 pF ± 5%	200036
C213	" "	100 nF 250 V	234080

Reference		Description	BEC Part No.
C214	Capacitor, fixed	30 pF ± 5%	200073
C215	" "	10 nF 100 V	224119
C216	" "	160 pF ± 5%	200048
C217	" "	100 nF 250 V	234080
C218	" "	39 pF ± 5%	200025
C219	" "	100 nF 250 V	234080
C220	" "	1 nF 500 V	224114
C221	" "	37 pF ± 5% 500 V	220119
C222	" "	100 nF 250 V	234080
C223	" "	"	"
C224	" "	"	"
C225	" "	"	"
C226	" "	1 nF 500 V	224114
C227	" "	100 nF 250 V	234080
C228	" "	"	"
C229	Capacitor, variable	5 - 18 pF	281007
C230	Capacitor, fixed	10 nF 100 V	224119
C231	" "	680 pF ± 1%	200015
C232	" "	"	"
C233	" "	39 pF ± 5%	200025
C234	Capacitor, variable	15 - 60 pF	281008
C235	Capacitor, fixed	22 nF 250 V	234079
C236	" "	"	"
C237	" "	"	"
C238	" "	"	"
C301	Capacitor, fixed	50 μF 25 V	283159
C303	" "	15 nF 200 V	234063
C401	Capacitor, fixed	680 pF ± 1%	200015
C402	Capacitor, variable	1.8 - 8.7 pF	275138
C403	Capacitor, fixed	10 nF 600 V	234077
C404	" "	"	"
C405	" "	100 nF 250 V	234080
		RESISTORS	
R101	Resistor, fixed	5.1 kΩ 5% 1/2W	301104
R102	" "	"	"
R103	" "	1.3 kΩ 5% 1/2W	301090
R104	" "	100 kΩ 5% 1/2W	301135
R105	" "	11 kΩ 5% 1/2W	301112

72AD
a-472

Reference		Description	BEC Part No.
R106	Resistor, fixed	10 kΩ 5% 1/2W	301111
R107	" "	"	"
R108	" "	"	"
R109	" "	"	"
R110	" "	100 kΩ 5% 1/2W	301135
R111	" "	5.1 kΩ 5% 1/2W	301104
R112	" "	2 kΩ 5% 1/2W	301094
R113	" "	3 kΩ 5% 1/2W	301098
R114	" "	1 kΩ 5% 1/2W	301087
R115	" "	3.9 kΩ 5% 1/4W	300096
R116	" "	"	"
R117	" "	5.1 kΩ 5% 1/4W	300099
R118	" "	"	"
R119	" "	"	"
R120	" "	"	"
R121		Not Used	
R122	" "	5.1 kΩ 5% 1/4W	300099
R123	" "	"	"
R124	" "	"	"
R125	" "	"	"
R126	Resistor, variable	1 kΩ 20% 1W	311256
R127	Resistor, fixed	10 kΩ 1% 3/8W	326376
R128	" "	100 Ω 5% 1/2W	301063
R129	Resistor, variable	20 kΩ 10% 1W	311266
R130	Resistor, fixed	4.7 MΩ 5% 1/2W	301175
R131	" "	10 MΩ 5% 1/2W	301183
R132	" "	63.4 kΩ 1% 3/8W	340455
R133	" "	10 kΩ 1% 3/8W	326376
R134	" "	2 kΩ 5% 1/2W	301094
R135	" "	24 kΩ 5% 1/2W	301120
R136	" "	"	"
R137	" "	2 kΩ 5% 1/2W	301094
R138		Not Used	
R139	" "	8.2Ω 5% 1/2W	301505
R140	" "	"	"
R141		Not Used	
R142		Not Used	
R143	" "	4.7 Ω 5% 1/2W	301508
R144	" "	3.65 kΩ 1% 3/8W	340307
R145	" "	100 Ω 5% 1/4W	300058
R146		Not Used	
R147		Not Used	
R148	Resistor, fixed	1.37 kΩ 1% 3/8W	340257
R149	" "	"	"
R150	" "	100 Ω 5% 1/4W	300058
R151	" "	3.3 kΩ 5% 1/2W	301099

Reference		Description	BEC Part No.
R201	Resistor, fixed	47 kΩ 5% 1/2W	301127
R202	" "	100 kΩ 5% 1/2W	301035
R203	" "	160 kΩ 5% 1/2W	301140
R204	" "	1 kΩ 5% 1/2W	301087
R205	" "	1.5 kΩ 5% 1/2W	301091
R206	" "	270 Ω 5% 1/2W	301073
R207	" "	10 Ω 1% 1/4W	315039
R208	" "	1/21 kΩ 1% 1/4W	315089
R209	Resistor, variable	1 kΩ 10% 0.75W	311226
R210	Resistor, fixed	8.25 kΩ 1% 3/8W	326309
R211	" "	2 kΩ 5% 1/2W	301094
R212	" "	562 Ω 1% 1/2W	306209
R213	" "	100 kΩ 5% 1/2W	301135
R214	" "	33.2 kΩ 1% 3/8W	340421
R215	" "	100 kΩ 1% 3/8W	326501
R216	" "	47 kΩ 5% 1/2W	301127
R217	" "	100 kΩ 5% 1/2W	301135
R218	" "	560 kΩ 5% 1/2W	301153
R219	" "	33 Ω 5% 1/2W	301051
R220	" "	150 kΩ 5% 1/2W	301139
R221	" "	1 kΩ 5% 1/2W	301087
R222	" "	270 Ω 5% 1/2W	301073
R223	" "	100 kΩ 5% 1/2W	301135
R224	" "	2.7 kΩ 5% 1/2W	301097
R225	" "	820 Ω 5% 1/2W	301085
R226	" "	6.2 kΩ 5% 1/2W	301106
R227	" "	3.9 kΩ 5% 1/2W	301101
R228	" "	47 kΩ 5% 1/2W	301127
R229	" "	100 kΩ 5% 1/2W	301135
R230	" "	560 kΩ 5% 1/2W	301153
R231	" "	47 Ω 5% 1/2W	301055
R232	" "	56 Ω 5% 1/2W	301157
R233	" "	1 kΩ 5% 1/2W	301087
R234	" "	"	"
R235	" "	270 Ω 5% 1/2W	301073
R236	" "	39 kΩ 5% 1/2W	301125
R237	" "	12 kΩ 5% 1/2W	301113
R238	" "	68 Ω 5% 1/2W	301059
R239	" "	270 Ω 5% 1/2W	301073
R240	" "	2.67 kΩ 1% 3/8W	340291
R241	" "	49.9 Ω 1% 3/8W	340084
R242	" "	2.7 kΩ 5% 1/2W	301097
R243	" "	5.23 kΩ 1% 1/4W	325396
R244	" "	"	"
R245	" "	"	"
R246	Resistor, variable	500 Ω 10% 1/2W	311281
R247	Resistor, fixed	5.23 kΩ 1% 1/4W	325396

Reference		Description		BEC Part No.
R301	Resistor, fixed	47 kΩ 5% 1/2W		301127
R302		Not Used		
R303		Not Used		
R304	" "	10 kΩ 5% 1/2W		301111
R305		Not Used		
R306		Not Used		
R307	" "	47 kΩ 5% 1/2W		301127
R308	" "	1 MΩ 5% 1/2W		301159
R309		Not Used		
R310	" "	140 kΩ 1% 3/8 W		340491
R311	" "	100 kΩ 5% 1/2W		301135
R401	Resistor, fixed	510 kΩ 5% 1/2W		301152
R402	" "	240 kΩ 5% 1/2W		301144

SEMICONDUCTORS

A101	Op. Amplifier	LM301A		535002
A201	"	"		"
CR101	Diode	L. Pwr. Silicon	1N914	530058
CR102 to CR110	"	"	"	"
CR111	"	1.5 A 200 V	KBP02	532013
CR112		Not Used		
CR113	Diode, Zener	16 V 5% 500 nW	1N5246B	530090
CR114	" "	"	"	"
CR115	" "	"	"	"
CR116	" "		1N5234B	530093
CR201	Diode	L. Pwr. Silicon	1N914	530058
CR202	"	"	"	"
CR203	"	"	1N5240B	530077
CR204	"	"	1N914	530058
CR205	"	"	"	"
CR206	"	"	"	"
CR207	"	"	1N5227B	530095
CR208	"	"	1N914	530058
CR209	"	"	"	"
CR210	"	"	5082-2800	530122
CR301	Diode	L. Pwr. Silicon	1N914	530058
CR302		Not Used		

72AD
a-472

Reference		Description		BEC Part No.
CR303		Not Used		
CR304	Diode	L. Pwr. Silicon	1N914	530058
CR305 -CR308		Not Used		
CR309	Diode	L. Pwr. Silicon	1N914	530058
CR310	"	"	"	"
CR311	"	"	"	"
Q101	FET	Junction, Silicon	2N5459	528019
Q102	"	"	"	"
Q103	Transistor	PNP, Silicon	2N3905	528025
Q104	FET	Junction, Silicon	2N5459	528019
Q105	"	"	"	"
Q106	Transistor	NPN, Silicon	2N4921	528034
Q107	"	PNP, Silicon	2N4918	528033
Q201	Transistor	Dual Gate FET	40673	528054
Q202	"	FET, Silicon	TIS58	528038
Q203	"	Junction, Silicon	2N5459	528019
Q204	"	FET, Dual Gate	40673	528054
Q205	"	"	"	"
Q206	"	NPN, Silicon	2N2219	528014
Q207	"	"	2N3903	528024
Q301		Not Used		
Q302	Transistor	NPN, Silicon	MPS6512	528059
Q303	"	"	"	"
IC101		Integrated Circuit	SN75451P	534006
IC102		"	"	"
IC301		Integrated Circuit	SN74L00N	534002
IC302		"	"	"
IC303		Not Used		
IC304		Integrated Circuit	SN74L00N	534002

INDUCTORS

Reference		Description	BEC Part No.
L101	Choke, RF	2.2 mH	400141
L102	Coil, RF	120 - 280 μH	400230
L103	"	14 - 28 μH	400231
L104	"	1.5 - 3 μH	400232
L105	Choke, RF	4.7 mH	400113
L106	"	2.2 mH	400141
L107 to L111	"	"	"
L201		Variable Inductor Unit	400233
L202	Choke, RF	2.2 mH	400141
L203	"	"	"
L204	"	"	"

GENERAL

F401	Fuse	0.2 A Slo Blo (115 V)	545508
F401	"	0.1 A Slo Blo (230 V)	545519
F402	"	1/32 A 250 V AGC	545525
F403	"	"	"
K101		Reed Relay	471000
K102		"	"
K103		"	"
S401		Switch, On/Off	465165
S402		Switch, Push-button	465164
S403		Switch, 115/230 V	465134
T402		Transformer, Power	446056
Y201		Crystal, 1 MHz	547020

SUPPLEMENTAL TABLE OF REPLACEABLE PARTS

MODEL 72AD-01

(Autoranging Option)

Reference		Description		BEC Part No.
C302	Capacitor, fixed	100 nF 200V		230116
C304	" "	1 nF		234018
R302	Resistor, fixed	10 kΩ 5% 1/2W		301111
R303	" "	4.7 kΩ 5% 1/2W		301103
R305	" "	750 Ω 5% 1/2W		301084
R306	" "	51 Ω 5% 1/2W		301056
R308	" "	1 MΩ 5% 1/2W		301159
R309	Resistor, variable	50 kΩ 20% 1/2W		311282
R310		Not used		
R312	Resistor, fixed	47 kΩ 5% 1/2W		301127
R313	" "	"		"
R314	" "	10 kΩ 5% 1/2W		301111
R315	" "	47 kΩ 5% 1/2W		301127
R316	" "	10 kΩ 5% 1/2W		301111
R317	" "	"		"
R318	" "	"		"
R319	" "	47 kΩ 5% 1/2W		301127
R320	" "	"		"
R321	" "	"		"
R322	" "	"		"
R323	" "	"		"
R324	" "	"		"
R325	" "	100 kΩ 5% 1/2W		301135
R326	" "	"		"
R327	" "	10 kΩ 5% 1/2W		301111
R328	" "	"		"
IC301		Integrated Circuit	SN74L00N	534002
IC302		"	"	"
IC303		"	SN151810N	534004
IC304		"	SN74L00N	534002
IC305		"	N8471A	534005
IC306		"	"	"
IC307		"	SN74L74N	534003

72AD
a-472

Reference		Description		BEC Part No.
CR302	Diode	L. Pwr. Silicon	1N914	530058
CR303	"	"	5240B	530077
CR305	"	"	"	"
CR306	"	"	"	"
CR307	"	"	"	"
CR308	"	"	"	"
CR312 through CR329	"	"	"	"
Q301	Transistor		MPS 6512	528059
Q304	"		2N4871	528051
Q305	"		MPS 6512	528059
Q306	"		"	"
Q307	"		"	"
Q308	"		"	"

TABLE OF REPLACEABLE PARTS

DIGITAL VOLTMETER

NOTE: As the Digital Voltmeter section of the 72AD (Schematic 830525, Sh. 1 & 2) is a purchased assembly, Boonton Electronics part numbers have not been assigned to its components.

Reference		Description	Mfrs. Part Number
C1001	Capacitor, fixed	2 µF 50 V	TRW X463UW
C1002	" "	470 nF 50 V	TRW X463UW
C1003	" "	22 pF	Centralab DD220
C1004	" "	1 nF	Centralab DD102
C1005	" "	25 nF	Centralab CK253
C1006	" "	10 nF 100 V	Elmenco 1DP-103
C1007	" "	1 nF	Centralab DD102
C1008	" "	"	"
C1009	" "	22 pF	Centralab DD220
C1010	" "	680 pF	Centralab DD 681
C1011	" "	25 nF	Centralab CK253
C1012	" "	20 nF	Sprague TG-S20
C1013	" "	680 nF 35 V	Sprague 196D
C1014	" "	1000 µF 10V	Amp. C437D1000AR
C1015	" "	500 pF	Centralab DD501
C1016	" "	25 µF 20 V	Mallory MTA D20
C1017	" "	200 pF	Centralab DD201
C1018			
C1019	" "	2 nF	Centralab DD202
C1020	" "	"	"
C1021	" "	1 nF	Centralab DD102
C1022	" "	2 nF	Centralab DD202
C1023	" "	4.7 µF 20 V	Sprague 196D475X0020SE3
C1024	" "	2,2 nF 100 V	Elmenco GDP-1-222
R1001	Resistor, fixed	90.9 kΩ 1%	RN60E
R1002	" "	10 kΩ 1%	RN60E
R1003	" "	1 kΩ 10%	RC07
R1004	" "	1 kΩ 1%	RN60E
R1005	" "	40.7 kΩ 1%	RN60E
R1006	" "	357 kΩ 1%	RN60E
R1007	" "	5 MΩ 1%	RN 65D
R1008	" "	1.5 kΩ 10%	RC07
R1009	" "	470 Ω 10%	RC07
R1010	Resistor, variable	100 kΩ	Spectrol 41-2-104
R1011	" "	200 Ω	Spectrol 41-2-1-201
R1012	Resistor, fixed	49.9 kΩ 1%	RN60E
R1013	" "	5.6 kΩ 10%	RC07

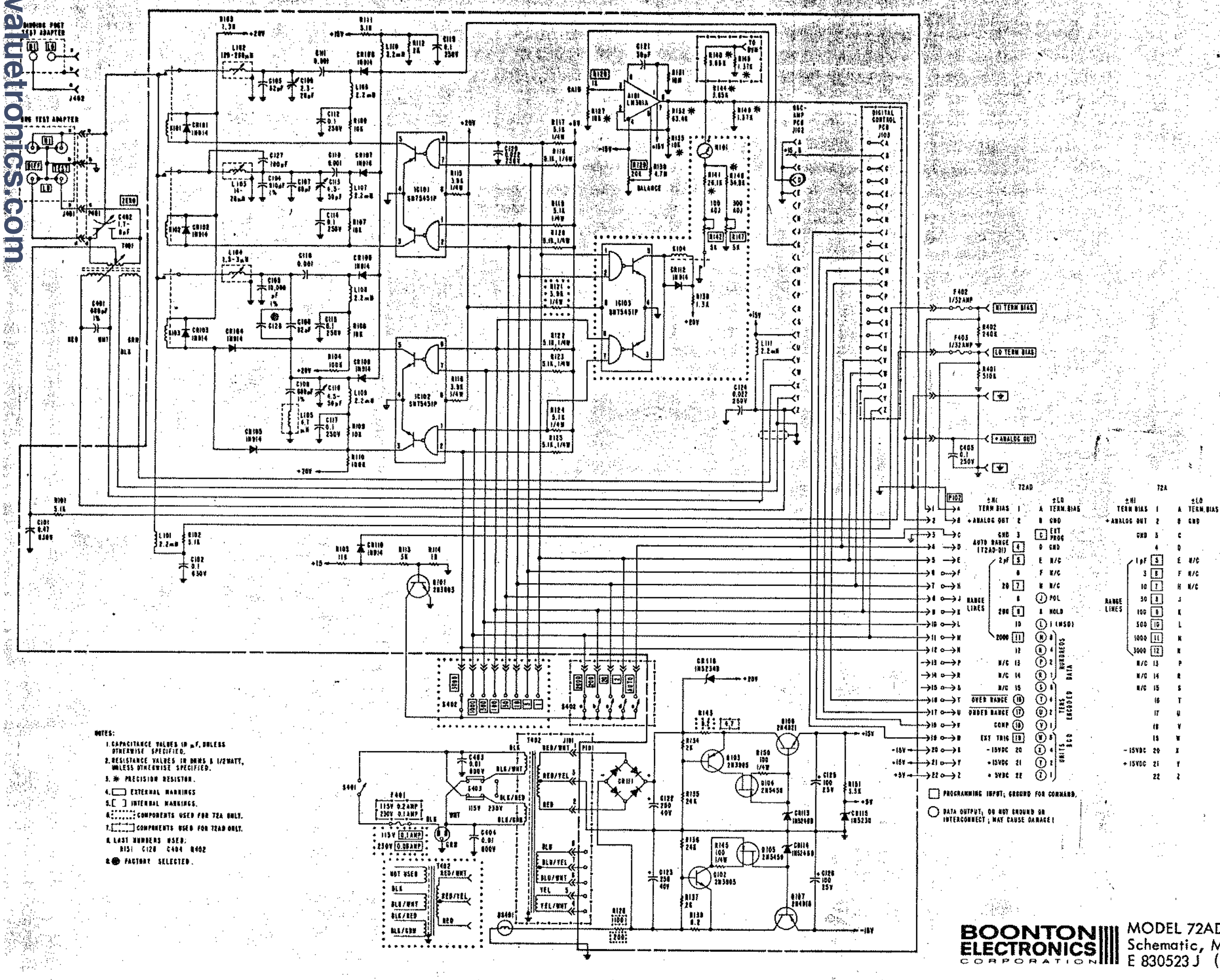
Reference		Description	Mfrs. Part No.
R1014	Resistor, fixed	1 kΩ 10%	RC07
R1015	" "	1.91 MΩ 1%	RN65D
R1016	Resistor, variable	10 kΩ	Spectrol 41-2-1-103
R1017	Resistor, fixed	45.3 kΩ 1%	RN60E
R1018	" "	25.5 kΩ 1%	RN60E
R1019	" "	33 kΩ 10%	RC07
R1020	" "	1.5 kΩ 10%	RC07
R1021	" "	47 Ω 10%	RC07
R1022	" "	1 kΩ 10%	RC07
R1023	" "	100 kΩ 10%	RC07
R1024	" "	806Ω 1%	RN60D
R1025	" "	100 kΩ 1%	RN60D
R1026	" "	200 Ω 1%	RN60D
R1027	Resistor, variable	200 Ω	Spectrol 41-2-1-201
R1028	Resistor, fixed	825 Ω 1%	RN60E
R1029	" "	4.99 kΩ 1%	RN60E
R1030	" "	49.9 kΩ 1%	RN60E
R1031	" "	470 Ω 10%	RC07
R1032	" "	49.9 kΩ 1%	RN60E
R1033	" "	"	"
R1034	" "	"	"
R1035	" "	4.99 kΩ 1%	RN60E
R1036	" "	560 Ω 10%	RC07
R1037	" "	825 Ω 1%	RN60E
R1038	" "	5.6 kΩ 10%	RC07
R1039	" "	1 kΩ 10%	RC07
R1040	" "	390 kΩ 10%	RC07
R1041	" "	10 kΩ 10%	RC07
R1042	" "	22 kΩ 10%	RC07
R1043	" "	2.2 kΩ 10%	RC07
R1044	" "	10 kΩ 10%	RC07
R1045	" "	1 kΩ 10%	RC07
R1046	" "	270Ω 10%	RC07
R1047	" "	5.6 kΩ 10%	RC07
R1048	" "	22 Ω 10%	RC07
R1049	" "	18 kΩ 10% 1/2W	RC20
R1050	" "	68 kΩ 10% 1W	RC32
R1051	" "	560 Ω 10%	RC07
R1052	" "	3.3 kΩ 10%	RC07
R1053	" "	3.16 kΩ 1%	RN60D
R1054	" "	2.2 kΩ 10%	RC07
R1055	" "	10 kΩ 10%	RC07
R1056	" "	1.5 kΩ 10%	RC07
R1057	" "	4.75 kΩ 1%	RN60D
R1058	" "	5.36 kΩ 1%	RN60D
R1059	" "	2 Ω 10% 1/2W	RC20
R1060	" "	1.5 kΩ 10%	RC07
R1061	" "	7.15 kΩ 1%	RN60D
R1062	" "	5.6 kΩ 10%	RC07
R1063	" "	2.7 kΩ 10%	RC07
R1064	" "	1 kΩ 10%	RC07

72AD
a-472

Reference		Description	Mfrs. Part No.
R1065	Resistor, fixed	220 Ω 10%	RC07
R1066	" "	5.6 kΩ 10%	RC07
R1067	" "	1 kΩ 10%	RC07
R1068	" "	56 kΩ 10% 1/2W	RC20
R1069	" "	4.7 kΩ 10%	RC07
R1070	" "	10 kΩ 10%	RC07
R1071	" "	"	"
R1072	" "	1 MΩ 10%	RC07
R1073	" "	"	"
R1074	" "	"	"
R1075	" "	10 kΩ 10%	RC07
R1076	" "	750 Ω 10%	RC07
R1077	" "	"	"
R1078	" "	"	"
R1079	" "	"	"
R1080	" "	2.2 kΩ 10%	RC07
R1081	" "	"	"
R1082	" "	4.7 kΩ 10%	RC07
R1083	" "	750 Ω 10%	RC07
R1084	" "	4.7 kΩ 10%	RC07
R1085	" "	39 kΩ 10% 1/2W	RC20
R1086	" "	5.6 kΩ 10%	RC07
R1087	" "	39 kΩ 10% 1/2W	RC20
R1088	" "	5.6 kΩ 10%	RC07
R1089	" "	10 kΩ 10%	RC07
R1090	" "	"	"
R1091	" "	"	"
R1092	" "	5.6 kΩ 10%	RC07
to			
R1097	" "	"	"
R1098	" "	10 kΩ 10%	RC07
R1099	" "	"	"
R1100	" "	"	"
R1101	" "	56 kΩ 10% 1/2W	RC07
to			
R1106	" "	"	"
R1107	" "	33 kΩ 10%	RC07
R1108	" "	33 kΩ 10%	RC07
R1109	" "	"	"
R1110	" "	39 kΩ 10%	RC07
R1111	" "	"	"
R1112	" "	"	"
R1113	" "	"	"
R1114	" "	"	"
R1115	" "	"	"
R1116	" "	10 kΩ 10%	"

Reference	Description	Mfgs. Part No.
CR1001	Diode, Zener	Motorola 1N5229
CR1002	" "	" 1N825
CR1003	" "	" "
CR1004	Diode	Sylvania 1N457
CR1005	"	" "
CR1006	"	" "
CR1007	"	IRC 1N4004
CR1008	"	Sylvania 1N457
CR1009	"	IRC 1N4001
RC1010	"	" "
CR1011	Diode, Zener	Motorola 1N5233B
CR1012	Diode	Sylvania 1N457
CR1013	"	" "
CR1014	"	Sylvania 1N283
CR1015	"	" "
CR1016	"	" 1N457
to		
CR1019	"	" "
CR1020	"	1N914
IC1001	Dual Op. Amp	Motorola MC1437L
IC1002	Diff. Comparator	" MC1710P
IC1003	Voltage Regulator	Fairchild µa723C
IC1004	Quad, 2 Input Gate	Motorola MC846
IC1005	" "	" "
IC1006	Hex Inverter	" MC836P
IC1007	Tri 3 Input Gate	" MC862P
IC1008	Quad, 2 Input Gate	Motorola MC846
IC1009	Decade Counter	T.I. SN7490N
IC1010	" "	" "
IC1011	" "	" "
IC1012	Decoder/Driver	T.I. SN7441N
IC1013	" "	" "
IC1014	" "	" "
IC1015	Quad, 2 Input Gate	Motorola MC846
IC1016	" "	" "
Q1001	Transistor	Motorola 2N3643
Q1002	"	Fairchild 2N3644
Q1003	"	" 2N3568
Q1004	"	Motorola 2N2646
Q1005	"	" 2N5457
Q1006	"	Fairchild 2N3644
Q1007	"	" "
Q1008	"	Motorola 2N3643

Reference	Description	Mfgs. Part No.
Q1009	Transistor	Industro TRS2504
Q1010	"	" "
Q1011	"	Motorola 2N4037
Q1012	"	RCA 40250
Q1013	"	Fairchild 2N3644
Q1014	"	Motorola 2N4410
to		
Q1025	"	" "
Q1026	"	2N3903

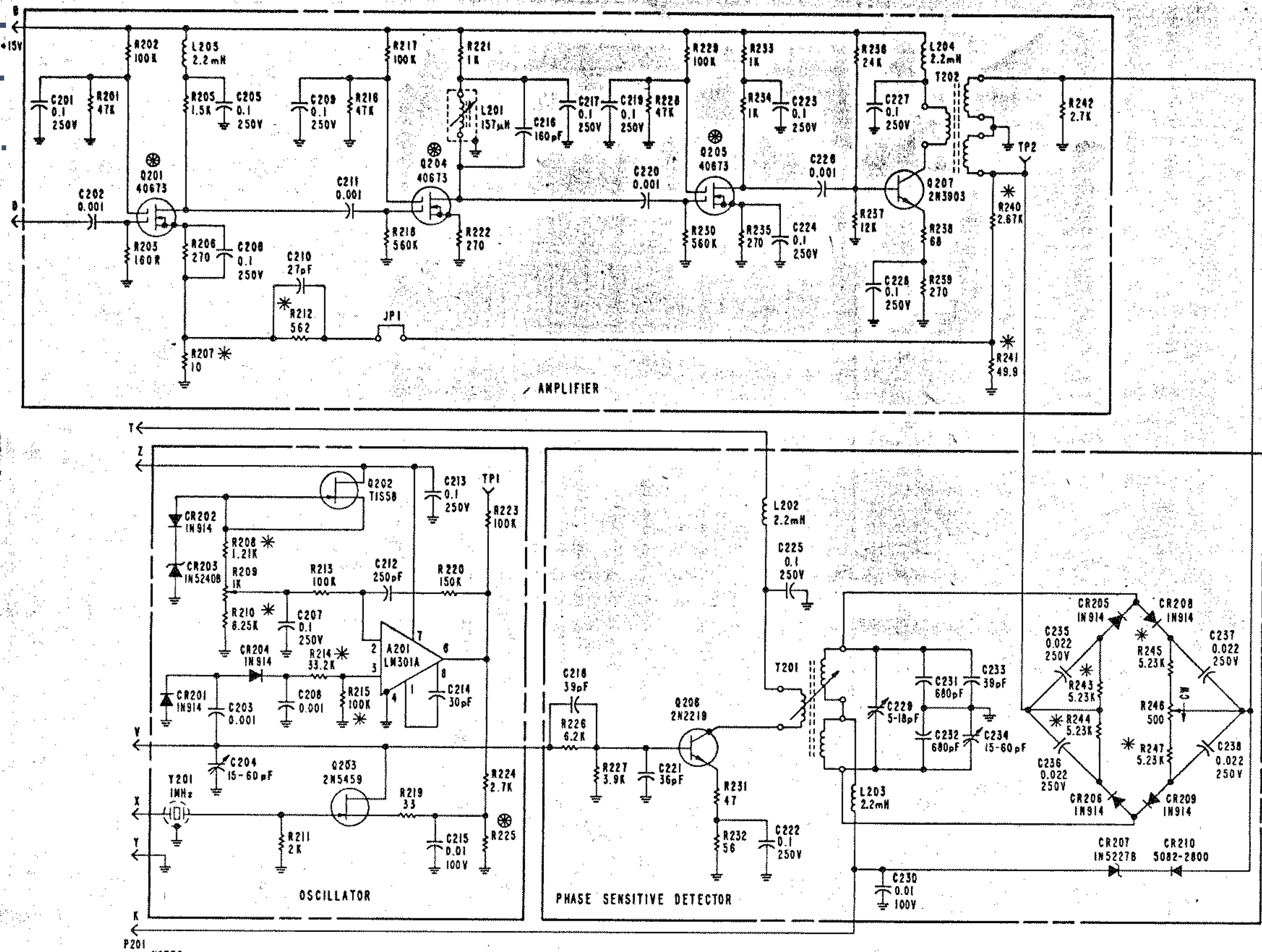


NOTES:
1. CAPACITANCE VALUES IN μF, UNLESS OTHERWISE SPECIFIED.
2. RESISTANCE VALUES IN OHMS & 1/2WATT, UNLESS OTHERWISE SPECIFIED.
3. ✱ PRECISION RESISTOR.
4. ▭ EXTERNAL MARKINGS.
5. [ ] INTERNAL MARKINGS.
6. ⋯ COMPONENTS USED FOR 72A ONLY.
7. ⋯ COMPONENTS USED FOR 72AD ONLY.
8. LAST NUMBERS USED: R151 C128 C404 R402
9. ● FACTORY SELECTED.

□ PROGRAMMING INPUT; GROUND FOR COMMAND.
○ DATA OUTPUT; DO NOT GROUND OR INTERCONNECT; MAY CAUSE DAMAGE!

BOONTON ELECTRONICS CORPORATION

MODEL 72AD
Schematic, Master Board
E 830523 J (1 of 2)

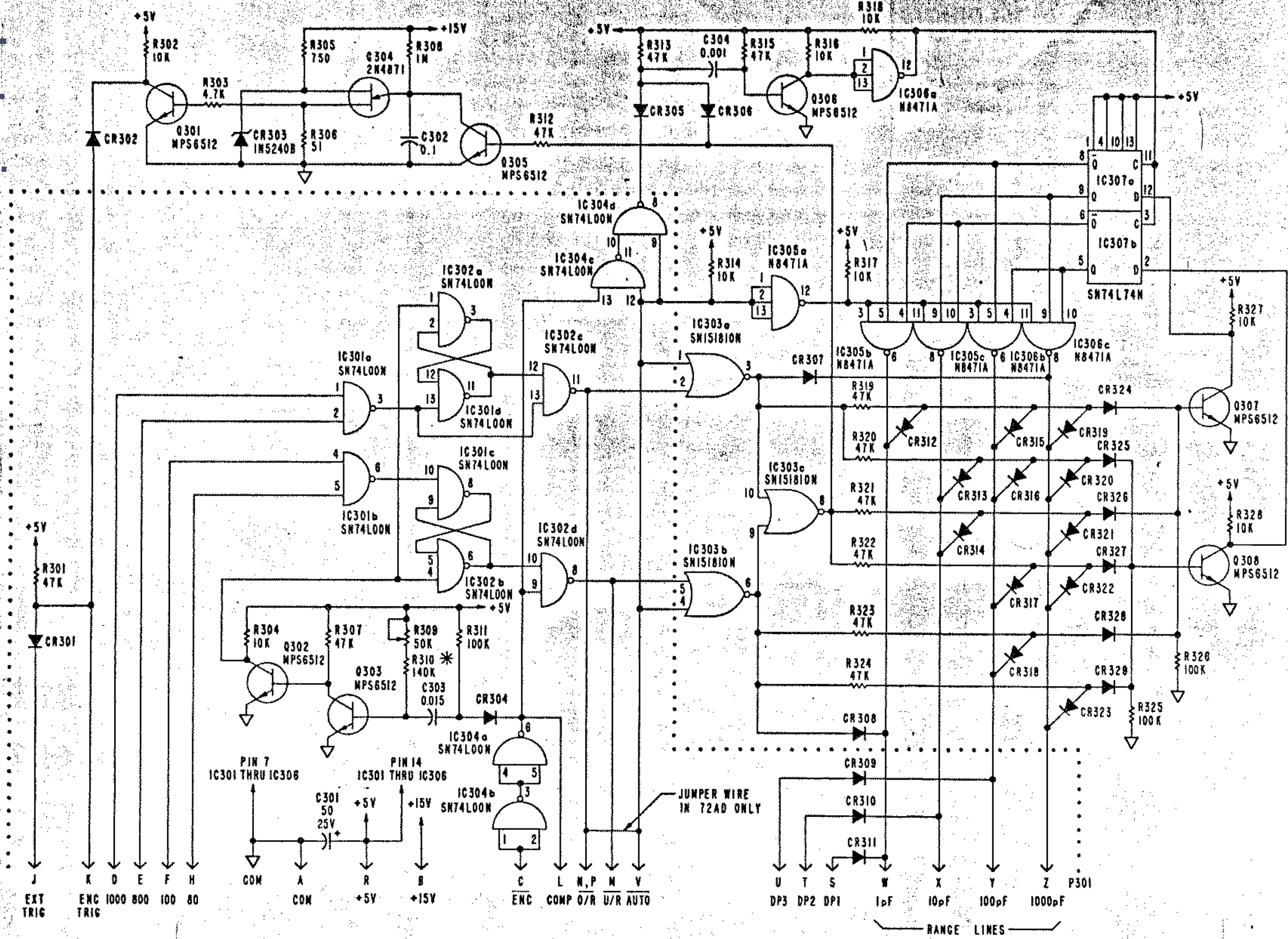


NOTES:

1. CAPACITANCE VALUES IN μF, UNLESS OTHERWISE SPECIFIED.
2. RESISTANCE VALUES IN OHMS AND 1/2 WATT, UNLESS OTHERWISE SPECIFIED.
3. ⊛ FACTORY SELECTED VALUE.
4. ✳ PRECISION RESISTOR.
5. LAST NUMBER USED: R247 C238 Q207 L205
6. NUMBERS NOT USED: R204

BOONTON ELECTRONICS CORPORATION

MODEL 72AD
Schematic, Oscillator/Amplifier
D 830523 E (Sh. 2 of 2)

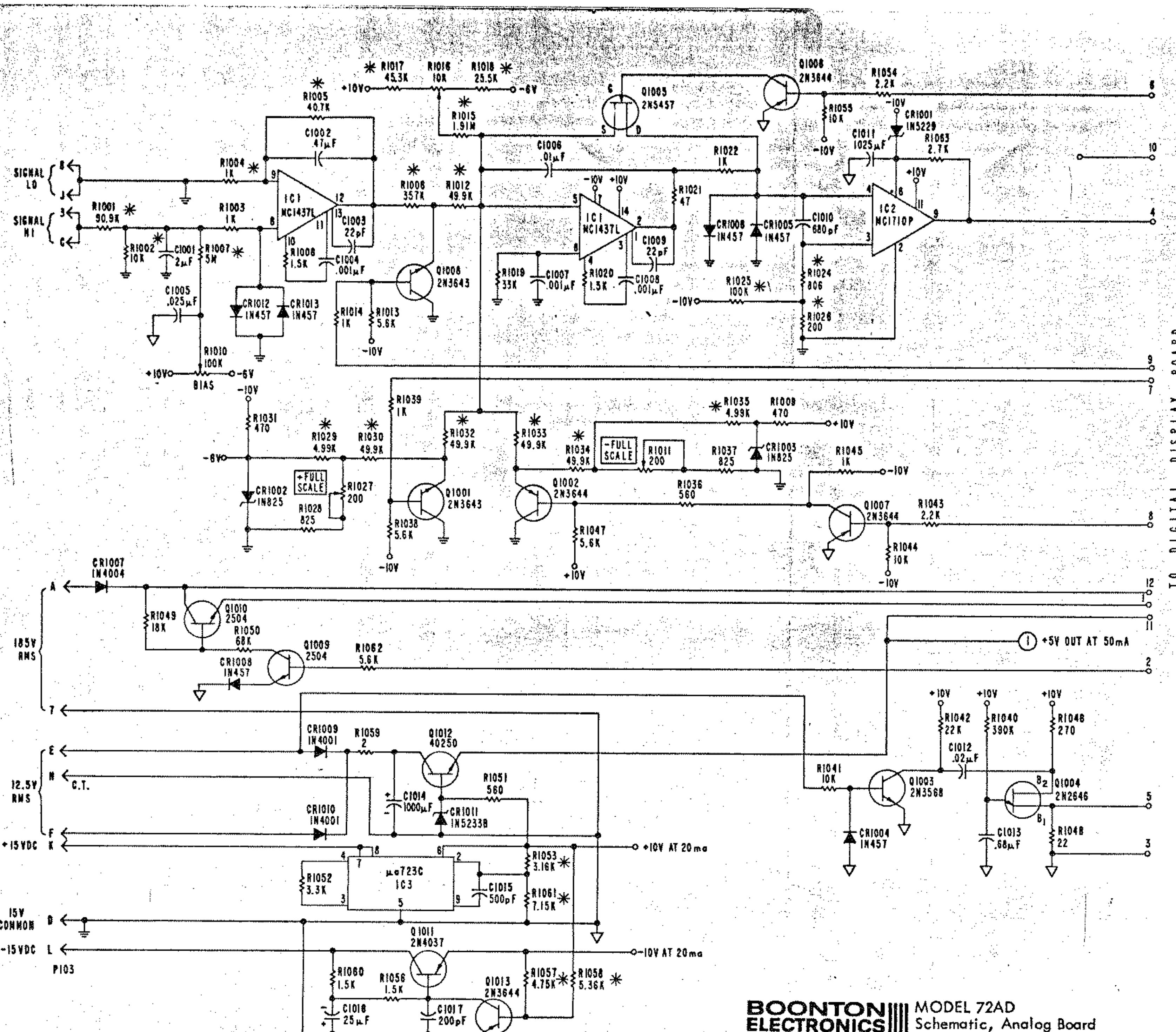


NOTES:

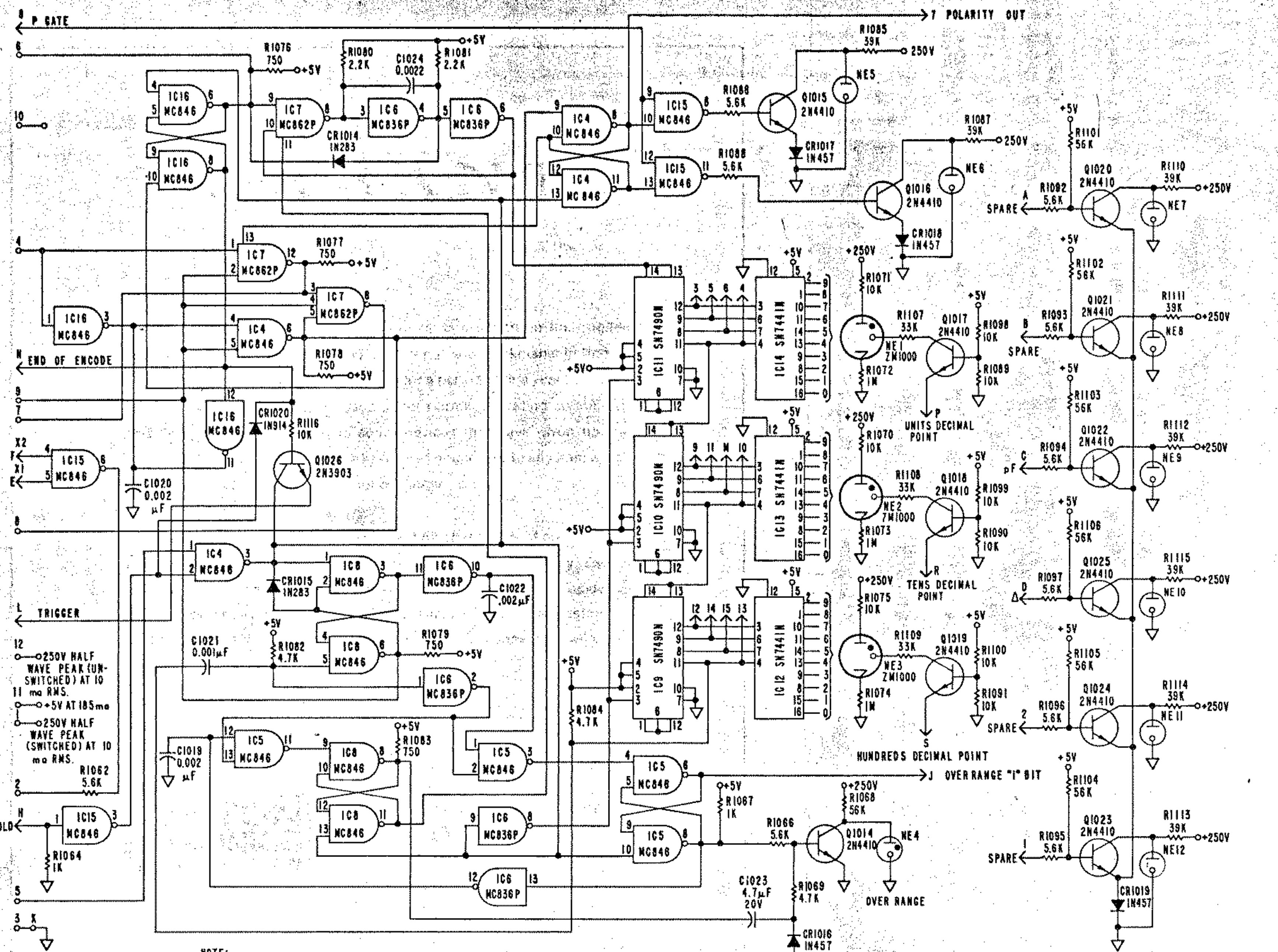
1. CAPACITANCE VALUES IN µF AND 200V, UNLESS OTHERWISE SPECIFIED.
2. RESISTANCE VALUES IN OHMS AND 1/2 WATT, UNLESS OTHERWISE SPECIFIED.
3. ALL DIODES TO BE TYPE IN914, UNLESS OTHERWISE SPECIFIED.
4. ALL COMPONENTS OUTSIDE OF DOTTED LINE ARE FOR AUTORANGE 72AD-01.
5. ✳ PRECISION RESISTOR.
6. ▽ COMMON.
7.
8. LAST NUMBER USED: R328 C304 CR329

BOONTON ELECTRONICS CORPORATION

MODEL 72AD
Schematic, Digital Control Board
D 830524 D



BOONTON ELECTRONICS CORPORATION
MODEL 72AD
Schematic, Analog Board
D 830525A (Sh. 1 of 2)



NOTE:

o— TO ANALOG BOARD.

← EDGE CONNECTOR P104.

NUMBERS NOT USED:
C1025

BOONTON ELECTRONICS CORPORATION

MODEL 72AD
Schematic, Digital Display Board
D 830525C (Sh. 2 of 2)