Document No. 375
March 27, 1961

HANDBOOK FOR

MODEL 784

DIGITAL OHMMETER

NON-LINEAR SYSTEMS, INC.
DEL MAR, CALIF.
October, 1961

Document No. 375
March 27, 1961

SECTION A - DESCRIPTION AND SPECIFICATIONS

The NLS Model 784 Digital Ohmmeter provides fast, accurate resistance measurements from less than 1 ohm up to 10 megohms. The measurements are instantly displayed in a row 1" high illuminated numerals complete with the decimal point. The instrument automatically selects the most sensitive range under all conditions. The packaging permits use as a bench or rack mounted instrument.

Specifications:

Ranges, Kilohms: .9999/9.999/99.99/999.9/9999. (0.1 ohms to 10 megohms)

Range Changing and Decimal Point Location: Automatic

Accuracy: ± (0.05% of reading + 1 digit) up to 5 megohms; ±0.1% of reading above 5 megohms

Average Balancing Time: 3.5 seconds, maximum.

Voltage across Test Resistor at Balance: 0 volts at 0 resistance increasing to 9.45 volts at top of each range

Bridge Excitation Supply: Internal, Zener diode type

Dimensions: $5\frac{1}{4}$" high, $15\frac{1}{4}$" deep, can be mounted in standard 19" wide rack

Primary Power: 115 volts, 60 cps, single phase. When specified, export instruments will operate on 110 or 220 volts, 50 cycles or 60 cycles

SECTION B - INSTALLATION

Primary Power Source: The instrument is designed to operate from a 115 ± 10 volt, single-phase, 60 cps alternating-current line. Allow approximately one minute warm-up time. Short-circuit protection is provided by an externally accessible, one amp, type 3AG, Slo-Blo Littelfuse. Some electromagnetic type voltage regualtors produce enough third harmonic distortion to produce improper instrument operation ("hunting" or poor resolution). Also, large power line transients or strong electrical fields can upset the instrument.

Input Terminals: Connect the shielded test leads supplied with your meter to the resistance to be measured according to the following:

Red Clip (input connector Pin #1) - "high" side of resistance to be measured

Black Clip (input connector Pin #2) - "low" side of resistance to be measured

Note: Input connector Pin #3 is shield ground, and is connected to Pin #2 and instrument chassis ground internally

Shielding: Proper shielding is very important. Only shielded test leads should be used. In areas where large amounts of electrical noise are present, it may be helpful to use twisted shielded leads. In many cases, particularly on the higher resistance ranges, it will be necessary to provide some shielding for the resistor being measured. For this purpose, NLS provides a resistor shield box with each digital ohmmeter. Where the NLS shield box cannot be used, a "U" shaped section of sheet metal may be used as a substitute and connected to the test lead shield. Excessive electrical pick-up is evidenced by either a continously changing readout or loss of resolution. Sometimes reversing the 115V power plug in the outlet receptacle will be helpful.

Grounding: The instrument chassis should be grounded. The grounding furnished by your electrical system conduit is generally adequate. Therefore, the three-prong power plug whose third prong, or ground prong, is connected to the instrument chassis, generally takes care of grounding. If you do not have a three prong wall receptacle, use a three-to-two prong adapter socket and connect its ground pigtail to electrical conduit ground. If the electrical conduit ground proves to be unsatisfactory, the instrument chassis should be connected to a better ground and preferably to a good earth ground. Inadequate grounding and/or inadequate shielding, will cause the instrument display to continually "hunt" or "oscillate", or it may cause loss of resolution (see "OTHER ADJUSTMENTS","Amplifier Gain" and the "Notice" that follows it in Section D).

Front Panel Controls: The power switch positions are OFF, STANDBY and ON. To extend the instrument's trouble-free life, use the STANDBY position when you are not actually making a measurement. At STANDBY, tube filaments are kept energized, but the thyratrons and stepping switches are turned off.

SECTION C - CALIBRATION

1. Check amplifier gain and readjust it if necessary (see instructions below under "Amplifier Gain").

2. Check the instrument's basic linearity:
   a) Short input leads. Readout should be .0000K (adjust 17 Ohm potentiometer for zero).

   b) Check, and if necessary, readjust scale factor of the instrument's lowest range, using the procedure in Step 3 below.

   c) After observing the shielding and grounding instructions in Section B, INSTALLATION, connect the instrument to a precision potentiometer, such as a Dekabox DB-265 (Electro Measurements, Inc.) or equivalent. Slowly introduce ohmic readings to see if the instrument skips any readings, or if the instrument holds to a particular reading for too large a turn of the potentiometer as compared to the other readings. If error is evident, then the range resistors should be checked for accuracy.

3. Check and, if necessary, readjust the scale factor of each range:

   a) Connect to the digital ohmmeter a precision resistance standard whose value is slightly less that the full-scale reading on the range being adjusted. For example, use a resistance standard between 900. and 999.9 ohms for the lowest range, 9000. and 9999. ohms for the next range, etc.

Scale factor adjustment accuracy is improved by using as high a value resistance as possible while keeping within the specified limits.

b) Observe the shielding and grounding directions in Section B, INSTALLATION.

c) Change the digital ohmmeter's reading by momentarily placing your fingers across the input terminals. If the digital ohmmeter reading does not agree with the known value of the resistance standard, adjust the scale factor adjustment potentiometers ("range trimmers").

There are five range trimmers mounted side by side on the range stepping switch sequentially numbered R1 through R5 from the outside edge toward the stepping switch. Range trimmer R1 adjusts scale factor for the lowest range. Next is R2 (for 9.999K range), then R3 (for 99.99K range), then R4 (for 999.9 range), and finally R5 (for 9999K range).

To reach the range trimmers, remove the instrument's outer case. Be careful to avoid hitting the stepping switch contacts or wipers.

After changing the setting of any range trimmer, replace the instrument outer case. Check the effect of the change by momentarily upset the reading, and the instrument's new reading should be within tolerance.

SECTION D - OTHER ADJUSTMENTS

Amplifier Gain: This has been properly adjusted at the factory but may require readjustment to compensate for amplifier component changes with time, or after component replacement. The gain control (R18) is a single-turn potentiometer installed on the back of the amplifier printed circuit board. If the amplifier gain is too low, the instrument's resolution will be decreased (will not "count" up and down in steps of 1 digit, but in steps of 2 or more digits). If the amplifier gain is too high, the right-hand digit on the readout will oscillate. After readjusting the gain control the instrument's case should be replaced (to keep AC pick-up out of the instrument) before re-checking. Use this procedure to check amplifier gain: (The gain control may normally be left in the full clockwise position.)

a) Slowly decrease the variable resistor resistance.

b) If amplifier gain is proper, the readings should decrease by no more than one digit at a time in the right-hand window; e.g., starting at a reading of .1016 kilohms, the display should change as follows: .1015, .1014, .1013, .1012, .1011, etc.

c) If the display does not change by 1 digit (for example, it might jump from .1016 to .1013 or to .1009), move the gain control clockwise to increase the amplifier gain. The gain control is R-18, a single-turn potentiometer installed at the rear of the amplifier printed circuit board.

Hum Control: This has been properly adjusted at the factory and should require no further attention. In some cases, however, adjustment will aid in reducing the effects of electrical noise. The hum control is a single-turn potentiometer (R-3) on the amplifier printed circuit board and is closer to the front panel than is the amplifier gain control. In adjusting, or to observe the output of the error amplifier for any reason, connect an oscilloscope between amplifier ground and either plate (Pin 1 or 6) of the last 12AX7 voltage amplifier. (Pins 1 and 6 are available as test points through two turret lug terminals exposed beside the last 12AX7 tube). Although a perfectly square waveform is not possible to achieve, the hum control should be adjusted to obtain as square a waveform as possible. Avoid having electrical noise enter through the oscilloscope leads, or when the instrument's outer case is removed. Set with an input of more than 2 megohms.

SECTION E - THEORY OF OPERATION

Non-Linear Systems' digital ohmmeters employ the Wheatstone bridge circuits with the decade rheostats and ratio arms automatically operated by stepping switches. If the bridge is unbalanced, the error amplifier voltage output (square wave) becomes sufficient to cause the thyratrons to pulse the stepping switches (thereby switching resistors in the bridge) until balance is restored. Additional decks on the stepping switches are connected to the digital readout and provide contact closures to illuminate the proper numerals.

Document No. 375
March 27, 1961

The amplifier is fed by a chopper which alternately samples the potential difference between opposite arms of the bridge. If the bridge unbalance is such that the resistance value of the decade rheostat is too low, then "UP" pulses are issued by the error amplifier. If the decade rheostat resistance is too high, then "DOWN" pulses are issued. If sufficient bridge unbalance is present, either the "UP" or "DOWN" pulse thyratrons in the error amplifier are fired. These thyratrons drive the stepping switches. If a decade rheostat is driven by "UP" pulses to a "9", then the "UP" pulses transfer to the next decade to the left and drive it toward "9". If a decade rheostat is driven to a "0" by down pulses, then the down pulses transfer to the next decade to the left. When all decades reach 9, the "UP" pulses are routed to the range change unit and change it to a higher range. If the instrument has a zero in the left-hand window, and the instrument is not operating in its lowest range, then pulses drive the range unit stepping switch to change the instrument to a lower range. Since the stepping switches are unidirectional in their movement, both "UP" and "DOWN" pulses are almost always required to achieve a balanced bridge. The logical sequence in which the "UP" and "DOWN" pulses are routed through the stepping switches results in fast, unambiguous attainment of proper balance.

SECTION F - MAINTENANCE

The only periodic maintenance required is to lubricate the stepping switches. Complete lubircation instructions are given in the NLS Model 484 Digital Voltmeter Instruction Manual, which accompanies this document.

SECTION G - TROUBLESHOOTING

1. Unstable Readout

   a) Electrical noise pick-up in test leads or test resistor.
   b) Microphonic electron tube in amplifier.
   c) Amplifier gain too high.
   d) Noisy bridge excitation supply (Zener diode type supply).
   e) Inadequate instrument grounding.
   f) Excessive voltage transients or third harmonics in power line (See Section B).
   g) "Noisy" chopper in amplifier.
   h) "Noisy" or open-circuited bridge-circuit resistor.
   i) Poor connection somewhere. Perform continuity check. Check also continuity of "pulse" circuitry through stepping switch coils and contacts and wiring associated with stepping switch coils.
   j) Unstable thyratrons.
   k) Insufficient stepping switch wiper tension. Tension has been properly set at factory and should require no further attention unless wipers become damaged.

2. Decreased Resolution

   a) Bridge excitation voltage too low (below 15 volts) or too noisy.
   b) See 1 (a), 1 (e) and 1 (f), above.
   c) Amplifier gain too low. 5751 WEAK OR INPUT LEADS TOO LONG

3. Readout Display Will not Change

   a) Bridge excitation supply voltage (18 volts) not reaching the bridge circuits.

Document No. 375
March 27, 1961

b) Line voltage too low.
c) Faulty amplifier.
d) Open circuit in logic circuits or stepping switch coils or contacts.

Note: Readout may fail to either increase or decrease, or both. If it fails in only one direction, check ciruitry and components associated with the UP pulse or DOWN pulse line whichever the case may be.

4. Some Readout Numerals Dark

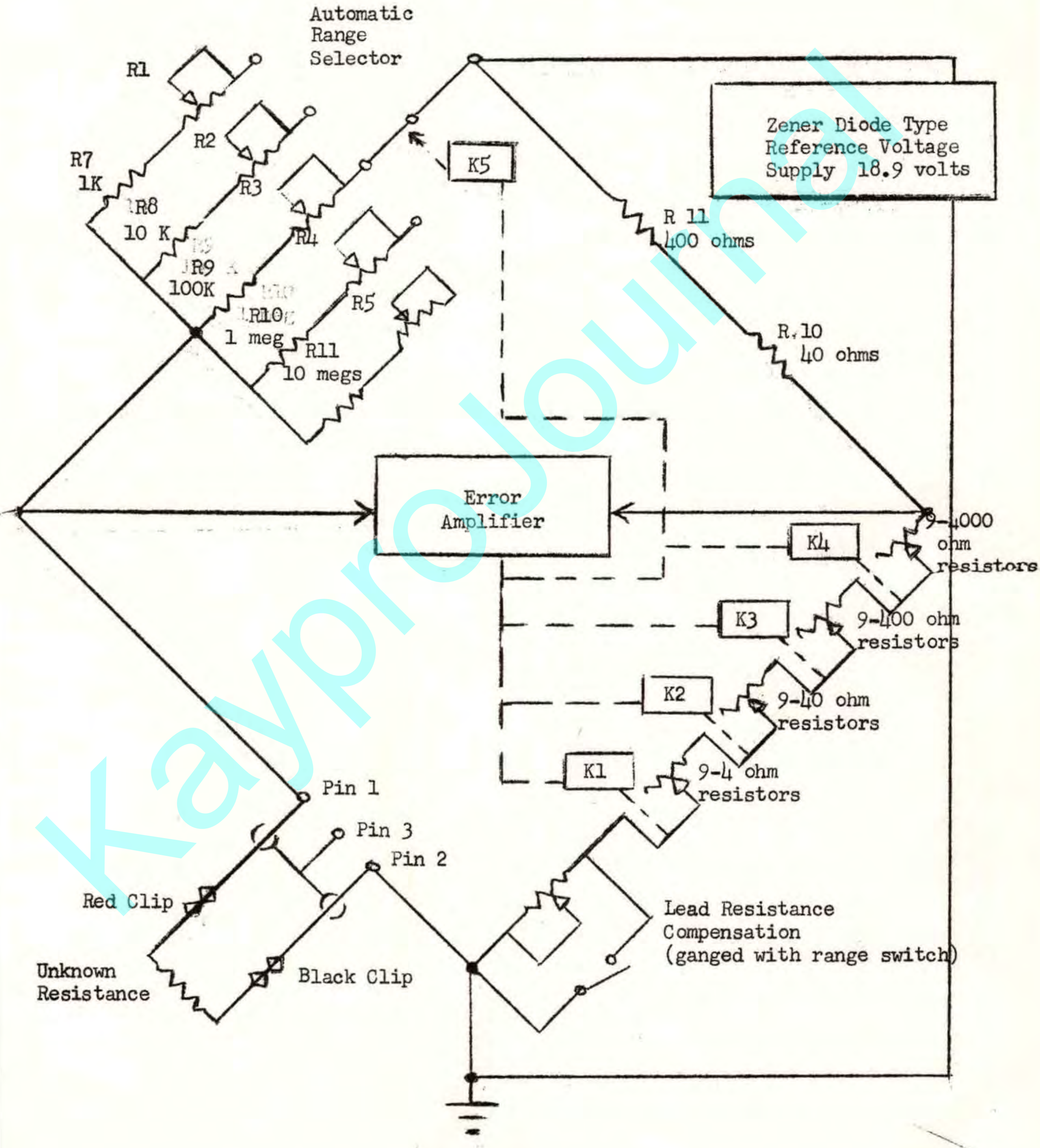
a) Lamp bulb failure.
b) Faulty readout lamp center contact.
c) Broken wire.

Note: Access to all readout lamps is easily achieved:

1. Turn off the main power.
2. Remove the plastic readout hood (push it upwards).
3. Push the metal "ears" (on the side of the readout assembly) outwards.
4. Swing the readout out of the instrument.

The lamps are G.E. Aviation Instrument Lamp No. 328, V4, 200 Ma. In some special readouts other lamps are used: No. 330, 14V, 80 Ma and No. 327, 28V, 40 Ma.

Document No. 375
March 27, 1961



Model 784 Digital Ohmmeter Simplified Circuit Diagram

Document No. 375

SECTION E **Theory of Operation**

NLS digital ohmmeters employ the Wheatstone bridge circuit with the decade rheostats and ratio arms automatically operated by stepping switches. If the bridge is unbalanced, the error amplifier voltage output (square wave) becomes sufficient to cause the thyratrons to pulse the stepping switches (thereby switching resistors in the bridge) until balance is restored. Additional decks on the stepping switches are connected to the digital readout and provide contact closures to illuminate the proper numerals.

The amplifier is fed by a chopper which alternately samples the potential difference between opposite arms of the bridge. If the bridge unbalance is such that the reststance value of the decade rheostat is too low, then UP pulses are issued by the error amplifier. If the decade rheostat resistance is too high, then DOWN pulses are issued. If sufficient bridge unbalance is present, either the UP or DOWN pulse thyratrons in the error amplifier are fired. These thyratrons drive the stepping switches. If a decade rheostat is driven by UP pulses to a 9, then the UP pulses transfer to the next decade to the left and drive it toward 9. If a decade rheostat is driven to a 0 by down pulses, then the down pulses transfer to the next decade to the left. When all decades reach 9, the UP pulses are routed to the range change unit and change it to a higher range. If the instrument has a zero in the left-hand window, and the instrument is not operating in its lowest range, then pulses drive the range unit stepping switch to change the instrument to a lower range. Since the stepping switches are unidirectional, both UP and DOWN pulses are almost always required to achieve a balanced bridge. The logical sequence in which the UP and DOWN pulses are routed through the stepping switches results in fast and unambiguous attainment of proper balance.

SECTION F **Maintenance**

The only periodic maintenance required is to lubricate the stepping switches. Most points can be reached with an artist's sable rigger brush, number 4. There should not be enough lubrication on the brush to form a drop. The following points are to be lubricated with clock oil:

Wiper assembly bearing
Wiper inner sides where brush springs ride
Each pair of wiper contacts

The following points are lubricated with light mineral oil:

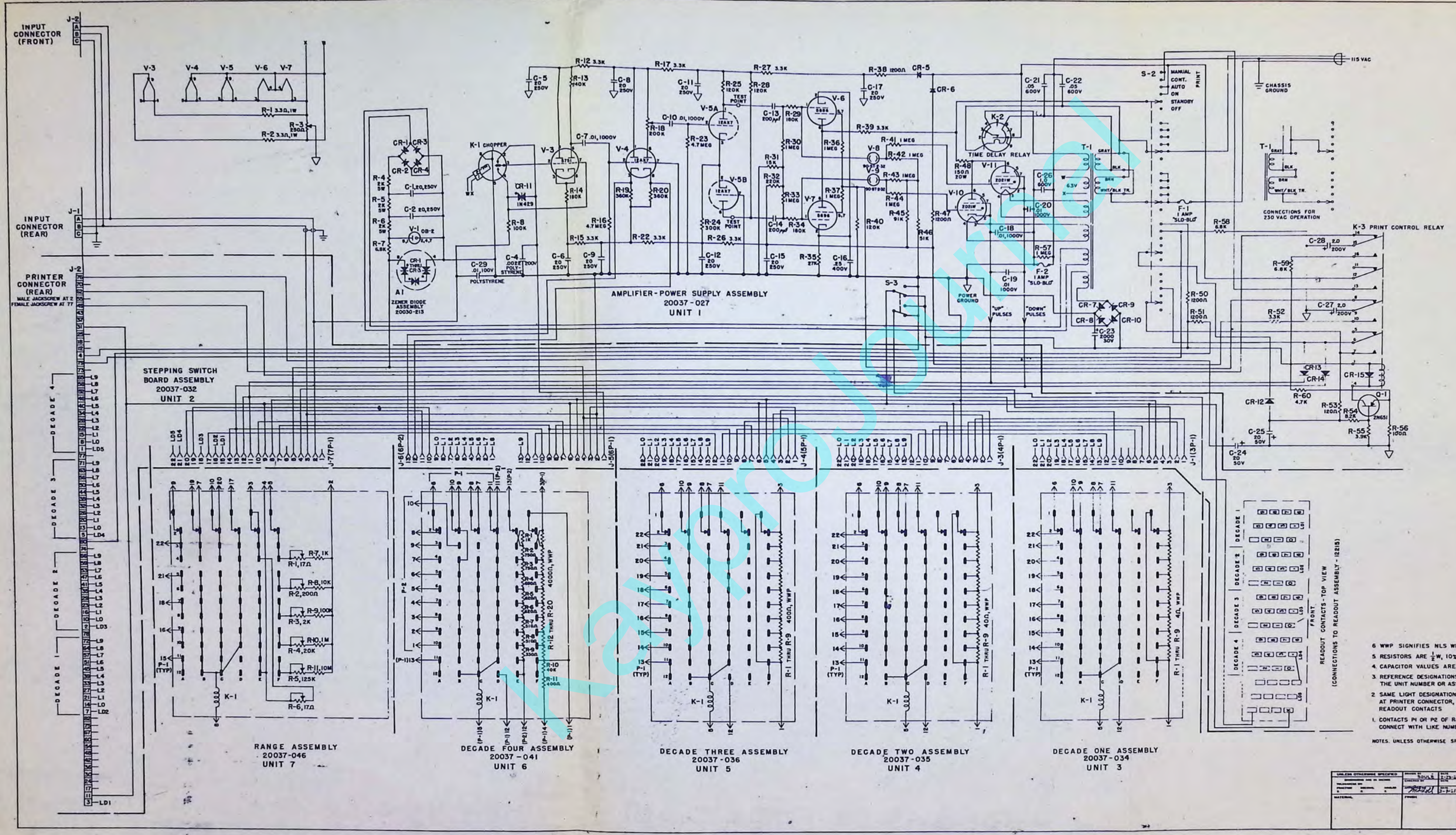
Armature bearing
Pawl bearing
Pawl spring hooks

The ratchet teeth are lubricated with a 50-50 (by volume) mixture of powdered mica and clock oil. This mixture is applied in two dips to the teeth while the switch rotates.

Lubrication is do be done at 25,000 revolutions or at 6 months, whichever is first. The second lubrication is at 75,000 revolutions or six months. At every additional 200,000 revolutions (or 9 months) lubrication is required. If the instrument has not been used for 3 months, it should be lubricated.

After many hours of operation, a black deposit will form near the lubrication points. If this deposit becomes excessive, it may simply be wiped off.

REVISIONS				
1	ALL	C-25 WAS 10 MFD, C-13 WAS [illegible] 200V; R-53 WAS 470Ω, [illegible] 15K; R-55 WAS 2.7K; C-24 WAS 10 MFD; R-56 WAS 150Ω; REVISED LD CONNECTIONS TO [illegible] REMOVED C-40	3-22-61 MTS	3-23-61
2	ALL	ADDED JACKSCREW LOCATIONS [illegible] R-7 WAS 5K	[illegible] MTS	[illegible]
3	ALL	REMOVED CONNECTION TO PIN [illegible]; R-18 WAS 100K [illegible]	3-30-61 MTS	3-31-61
4	ALL	INTERCHANGED CONNECTIONS TO PINS 4 & 8 OF 1K-2 TO AGREE WITH PRINTED CIRCUITRY	4-11-61 MTS	4-12-61



20037 SHT 2

4

6 WWP SIGNIFIES NLS WIRE WOUND PRECISION RESISTOR

5 RESISTORS ARE $\frac{1}{2}$W, 10% TOL.

4 CAPACITOR VALUES ARE IN MICROFARADS

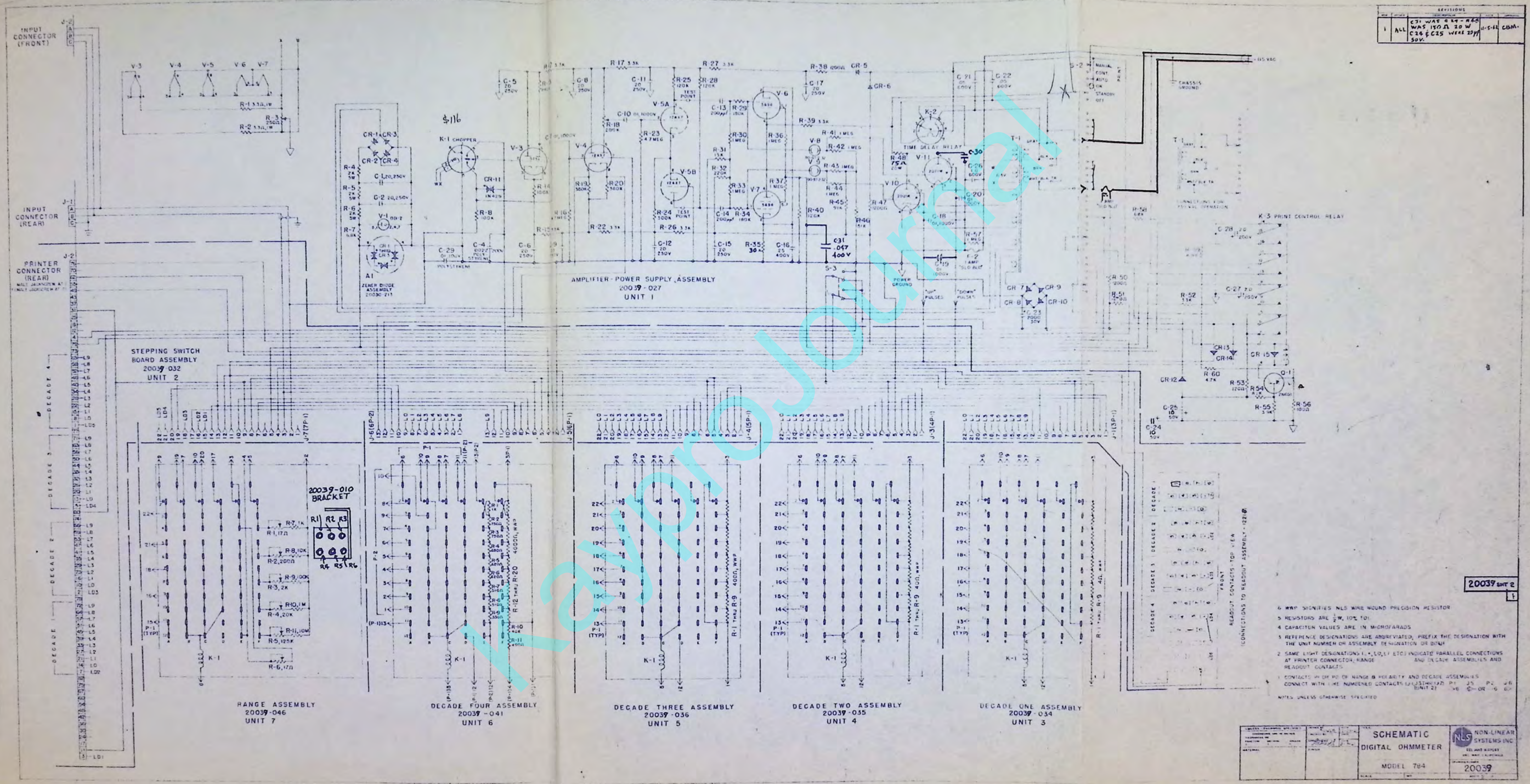
3 REFERENCE DESIGNATIONS ARE ABBREVIATED; -PREFIX THE DESIGNATION WITH THE UNIT NUMBER OR ASSEMBLY DESIGNATION OR BOTH

2 SAME LIGHT DESIGNATIONS (L+, LO, L1 ETC) INDICATE PARALLEL CONNECTIONS AT PRINTER CONNECTOR, RANGE AND DECADE ASSEMBLIES AND READOUT CONTACTS

1. CONTACTS P1 OR P2 OF RANGE & POLARITY AND DECADE ASSEMBLIES CONNECT WITH LIKE NUMBERED CONTACTS (J-1, J-3 THRU J-7). P-1 (UNIT 2) →6 J-5 6⟶ OR P-2 →6 J-6 6⟶

NOTES. UNLESS OTHERWISE SPECIFIED

UNLESS OTHERWISE SPECIFIED	DRAWN BY SOULE 2-23-61	TITLE SCHEMATIC DIGITAL OHMMETER	NON-LINEAR SYSTEMS INC. DEL MAR AIRPORT DEL MAR, CALIFORNIA
MATERIAL	FINISH	MODEL 784	20037
		SCALE / WT.	SHEET 2



INPUT CONNECTOR (FRONT)
INPUT CONNECTOR (REAR)
PRINTER CONNECTOR (REAR)
K-1 CHOPPER
A1 ZENER DIODE ASSEMBLY
AMPLIFIER-POWER SUPPLY ASSEMBLY
20039-027
UNIT 1
TIME DELAY RELAY
K-3 PRINT CONTROL RELAY
CHASSIS GROUND
115 VAC
STEPPING SWITCH BOARD ASSEMBLY
20039-032
UNIT 2
20039-010 BRACKET
RANGE ASSEMBLY
20039-046
UNIT 7
DECADE FOUR ASSEMBLY
20039-041
UNIT 6
DECADE THREE ASSEMBLY
20039-036
UNIT 5
DECADE TWO ASSEMBLY
20039-035
UNIT 4
DECADE ONE ASSEMBLY
20039-034
UNIT 3
READOUT CONTACTS-TOP VIEW
(CONNECTIONS TO READOUT ASSEMBLY -122)
C31 WAS .02 - R48 WAS 150Ω 20 W C24 & C25 WERE 20μf 50V.
20039 SHT 2
6 WWP SIGNIFIES NLS WIRE WOUND PRECISION RESISTOR
5 RESISTORS ARE ½W, 10% TOL
4 CAPACITOR VALUES ARE IN MICROFARADS
3 REFERENCE DESIGNATIONS ARE ABBREVIATED, PREFIX THE DESIGNATION WITH THE UNIT NUMBER OR ASSEMBLY DESIGNATION OR BOTH
2 SAME LIGHT DESIGNATIONS (L-, LO, L1 ETC) INDICATE PARALLEL CONNECTIONS AT PRINTER CONNECTOR, RANGE AND DECADE ASSEMBLIES AND READOUT CONTACTS
1 CONTACTS P1 OR P2 OF RANGE & POLARITY AND DECADE ASSEMBLIES CONNECT WITH LIKE NUMBERED CONTACTS OF J3 THRU J7
NOTES UNLESS OTHERWISE SPECIFIED
SCHEMATIC
DIGITAL OHMMETER
MODEL 784
NON-LINEAR SYSTEMS INC.
20039