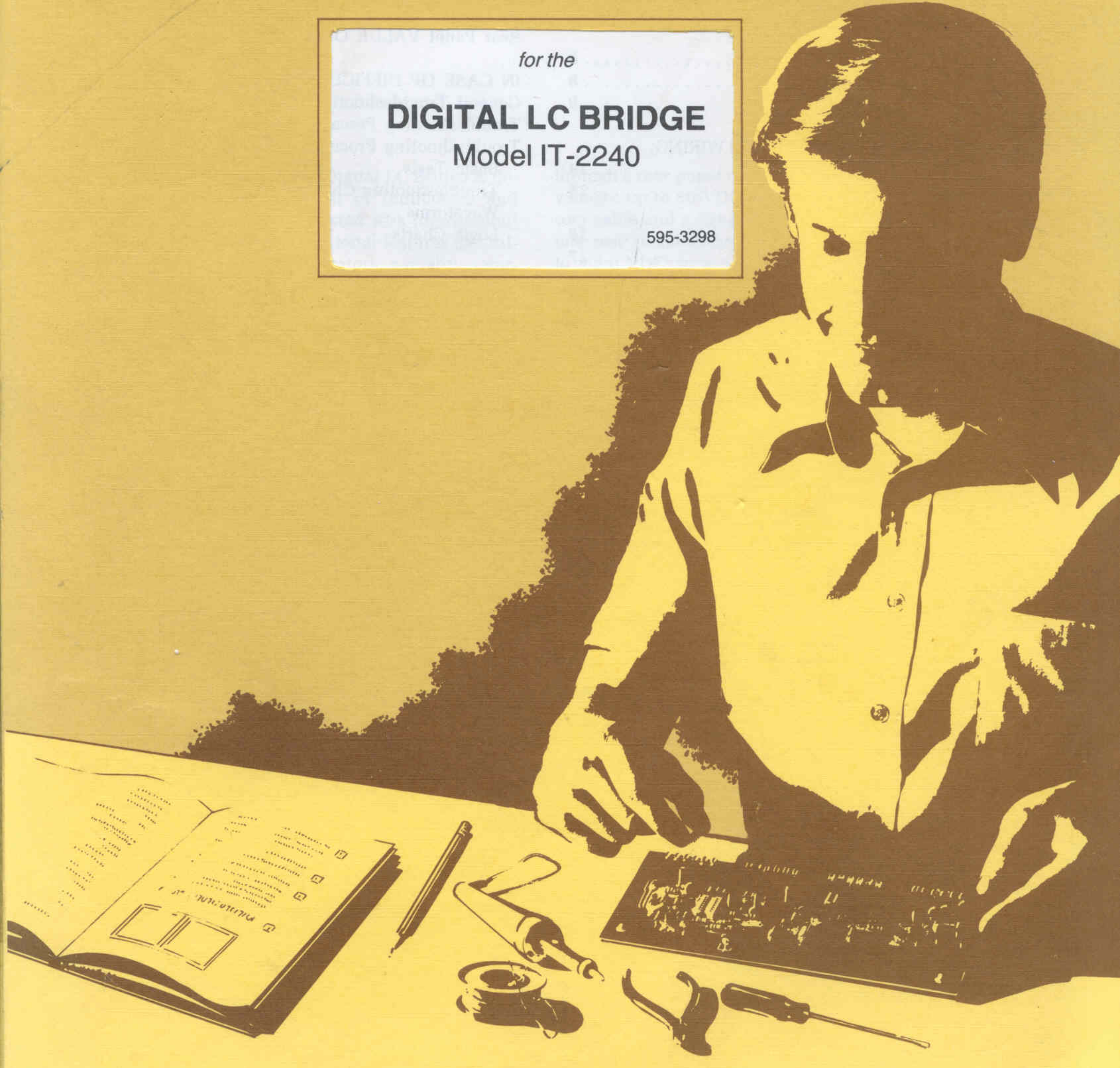
HEATHKIT® MANUAL

for the

DIGITAL LC BRIDGE

Model IT-2240

595-3298



HEATH COMPANY • BENTON HARBOR, MICHIGAN

HEATH COMPANY PHONE DIRECTORY

The following telephone numbers are direct lines to the departments listed:

Kit orders and delivery information	(616) 982-3411
Credit	(616) 982-3561
Replacement Parts	(616) 982-3571

Technical Assistance Phone Numbers

8:00 A.M. to 12 P.M. and 1:00 P.M. to 4:30 P.M., EST, Weekdays Only

R/C, Audio, and Electronic Organs	(616) 982-3310
Amateur Radio	(616) 982-3296
Test Equipment, Weather Instruments and Home Clocks	(616) 982-3315
Television	(616) 982-3307
Aircraft, Marine, Security, Scanners, Automotive, Appliances and General Products	(616) 982-3496
Computers — Hardware	(616) 982-3309
Computers — Software: Operating Systems, Languages, Utilities	(616) 982-3860
Computers — Software: Application Programs	(616) 982-3884
Heath Craft Wood Works	(616) 982-3423

YOUR HEATHKIT 90-DAY LIMITED WARRANTY

Consumer Protection Plan for Heathkit Consumer Products

Welcome to the Heath family. We believe you will enjoy assembling your kit and will be pleased with its performance. Please read this Consumer Protection Plan carefully. It is a "LIMITED WARRANTY" as defined in the U.S. Consumer Product Warranty and Federal Trade Commission Improvement Act. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

Heath's Responsibility

PARTS — Replacements for factory defective parts will be supplied free for 90 days from date of purchase. Replacement parts are warranted for the remaining portion of the original warranty period. You can obtain warranty parts direct from Heath Company by writing or telephoning us at (616) 982-3571. And we will pay shipping charges to get those parts to you . . . anywhere in the world.

SERVICE LABOR — For a period of 90 days from the date of purchase, any malfunction caused by defective parts or error in design will be corrected at no charge to you. You must deliver the unit at your expense to the Heath factory, any Heathkit Electronic Center (units of Veritechnology Electronics Corporation), or any of our authorized overseas distributors.

TECHNICAL CONSULTATION — You will receive free consultation on any problem you might encounter in the assembly or use of your Heathkit product. Just drop us a line or give us a call. Sorry, we cannot accept collect calls.

NOT COVERED — The correction of assembly errors, adjustments, calibration, and damage due to misuse, abuse, or negligence are not covered by the warranty. Use of corrosive solder and/or the unauthorized modification of the product or of any furnished componen, will void this warranty in its entirety. This warranty does not include reimbursement for inconvenience, loss of use, customer assembly, set-up time, or unauthorized service.

This warranty covers only Heath products and is not extended to other equipment or components that a customer uses in conjunction with our products.

SUCH REPAIR AND REPLACEMENT SHALL BE THE SOLE REMEDY OF THE CUSTOMER AND THERE SHALL BE NO LIABILITY ON THE PART OF HEATH FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES, INCLUDING BUT NOT LIMITED TO ANY LOSS OF BUSINESS OR PROFITS, WHETHER OR NOT FORSEEABLE.

Some states do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

Owner's Responsibility

EFFECTIVE WARRANTY DATE — Warranty begins on the date of first consumer purchase. You must supply a copy of your proof of purchase when you request warranty service or parts.

ASSEMBLY — Before seeking warranty service, you should complete the assembly by carefully following the manual instructions. Heathkit service agencies cannot complete assembly and adjustments that are customer's responsibility.

ACCESSORY EQUIPMENT — Performance malfunctions involving other non-Heath accessory equipment, (antennas, audio components, computer peripherals and software, etc.) are not covered by this warranty and are the owner's responsibility.

SHIPPING UNITS — Follow the packing instructions published in the assembly manuals. Damage due to inadequate packing cannot be repaired under warranty.

If you are not satisfied with our service (warranty or otherwise) or our products, write directly to our Director of Customer Service, Heath Company, Benton Harbor MI 49022. He will make certain your problems receive immediate, personal attention.

Heathkit® Manual

for the

DIGITAL LC BRIDGE
Model IT-2240

595-3298

WARNING: TO PREVENT FIRE OR ELECTRICAL SHOCK HAZARD, DO NOT EXPOSE THIS DIGITAL LC BRIDGE TO RAIN OR MOISTURE.

HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

Copyright © 1985
Heath Company
All Rights Reserved
Printed in the United States of America

TABLE OF CONTENTS

INTRODUCTION

The Heathkit Model IT-2240 Digital LC Bridge is designed for easy measurement of inductance and capacitance, and their associated loss (dissipation) factor. Its accuracy and operational features can fulfill the requirements of a laboratory, a quality assurance department, or an experimenter. The clearly labeled front panel lets even untrained users make error-free measurements.

You can measure inductance (L) from less than 1 μH to 2000 H and capacitance (C) from less than 1 pF to 2000 μF, over an eight-decade range, with .1 μH or .1 pF resolution on the lowest range. Test frequencies are 1000 Hz for values to 2 H or 2 μF, and 120 Hz for higher values. You can measure the dissipation factor for the component under test from .000 to 1.999 on each range. Basic measurement accuracy, with laboratory standards calibration, is ±.5% for L and C ranges, and ±3% for dissipation.

Measurements are made using high-accuracy, four-terminal (Kelvin) connections at the front panel input contacts. This type of connection lets you test components with a wide range of lead diameters and spacing, while virtually eliminating these variable effects. An Accessory cable (supplied) lets you test large or remote components. A front panel Lead Null control allows you to minimize stray capacitance on the lower C ranges. Low-level, sine wave signals are used for testing; with frequencies, voltage/current levels, and impedance modeling automatically selected to provide maximum accuracy for each range.

Capacitors and voltage-variable diodes (varicaps) can be biased from an external 0 to 10 VDC source through a rear panel connection. You can apply bias voltages up to 50 VDC by using the supplied Accessory cable and a simple decoupling circuit. A separate rear panel output provides a value output (0 to +2.0 VDC) to external fixtures for batch testing, or an X-Y plotter to chart a capacitance-versus-voltage curve.

Front panel inputs are overvoltage protected to withstand inadvertent connection of charged capacitors (50 VDC maximum) or power sources (±20 VDC for 5 seconds). Rear panel connections are resistance-protected against momentary overvoltages.

Other features include a 3-1/2 digit, high-brightness LED display with automatic decimal point placement; dual-slope A/D conversion in a single MOS/LSI* integrated circuit; high reliability integrated circuit technology; calibration with supplied or laboratory standards; application information for maximum versatility; and low-profile, compact styling.

The IT-2240 Digital LC Bridge combines accuracy, reliability, and ease of operation. It will be a useful addition to your workshop, laboratory, or inspection facility.

NOTE: After assembling your Digital LC Bridge, you will make resistance and voltage measurements. You must use an analog ohmmeter (VOM or VTVM) with a 1.5 V test voltage, and a center-scale number greater than 5 but less than 50. The DC voltmeter may be an analog or digital type having a 10 MΩ or higher input resistance.

*MOS/LSI: Metal Oxide Semiconductor/Large Scale Integration.

UNPACKING INSTRUCTIONS

DO NOT UNPACK ANY PART OF YOUR LC BRIDGE UNTIL YOU ARE INSTRUCTED TO DO SO.

The main shipping carton for your Digital LC Bridge is divided into two sections, or packs, as shown on the "Pack Index Sheet." Each of these packs may be made up of loose parts, small boxes, or bags.

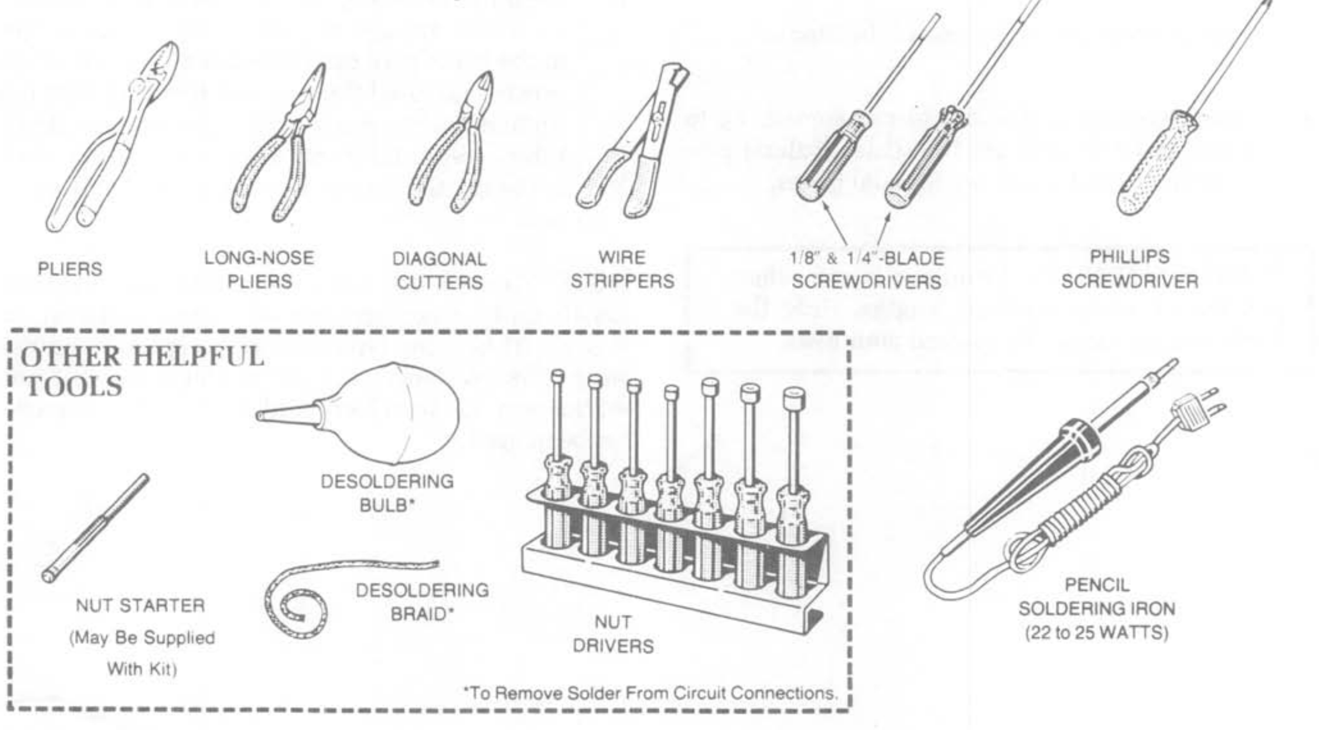
"Pack 1" contains all parts you need for the display circuit board, plus all the wire and solder you will use in the assembly of the entire kit. The remaining parts are the "Final Pack," which contains the items you will use during the assembly of the main circuit board and chassis. Do not remove any parts from the Final Pack until this Manual specifically instructs you to do so.

An instruction at the beginning of each parts list tells you which pack to open. Save all packing materials until you locate all of the parts.

ASSEMBLY NOTES

TOOLS

You will need these tools to assemble your kit.



ASSEMBLY

1. Follow the instructions carefully. Read the entire step before you perform each operation.

2. Refer to the separate "Illustration Booklet" for the Pictorials and Details. Keep the "Illustration Booklet" with the Assembly Manual. The illustrations in it are arranged in the proper sequence, as called for in the steps.

3. Pictorials show the overall operation for a group of assembly steps; Details generally illustrate a single step. When you are directed to refer to a certain Pictorial "for the following steps," continue using that Pictorial until you are referred to another Pictorial for another group of steps.

4. Position all parts as shown in the Pictorials.

5. Solder instructions are generally given only at the end of a series of similar steps. You may solder more often if you desire.

6. Each circuit part in an electronic kit has its own component number (R2, C4, etc.). Use these numbers when you want to identify the same part in the various sections of the Manual. These numbers, which are especially useful if a part has to be replaced, appear:

   — In the Parts List,

   — At the beginning of each step where a component is installed,

   — In some illustrations,

   — In Troubleshooting Charts,

   — In the Schematic,

   — In the sections at the rear of the Manual.

7. When you are instructed to cut something to a particular length, use the scales (rulers) provided at the bottom of the Manual pages.

SAFETY WARNING: Avoid eye injury when you cut off excessive lead lengths. Hold the leads so they cannot fly toward your eyes.

SOLDERING

Soldering is one of the most important operations you will perform while assembling your kit. A good solder connection will form an electrical connection between two parts, such as a component lead and a circuit board foil. A bad solder connection could prevent an otherwise well-assembled kit from operating properly.

It is easy to make a good solder connection if you follow a few simple rules:

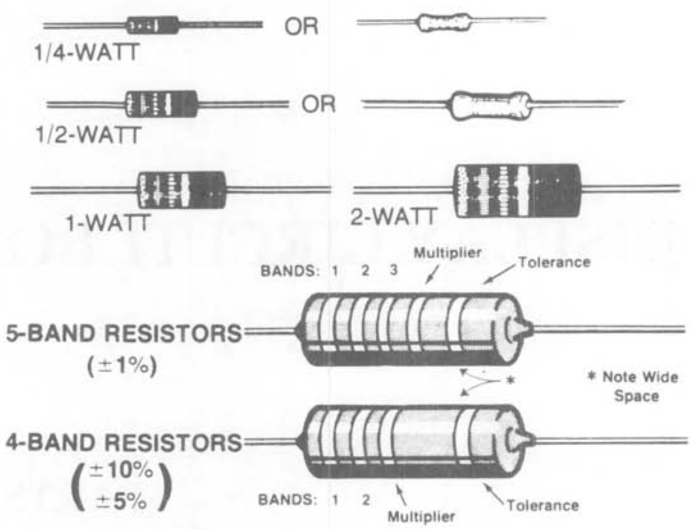
1. Use the right type of soldering iron. A 22 to 25-watt pencil soldering iron with a 1/8" or 3/16" chisel or pyramid tip works best.

2. Keep the soldering iron tip clean. Wipe it often on a wet sponge or cloth; then apply solder to the tip to give the entire tip a wet look. This process is called tinning, and it will protect the tip and enable you to make good connections. When solder tends to "ball" or does not stick to the tip, the tip needs to be cleaned and retinned.

NOTE: Always use rosin core, radio-type solder (60:40 tin-lead content) for all of the soldering in this kit. This is the type we have supplied with the parts. The Warranty will be void and we will not service any kit in which acid core solder or paste has been used.

PARTS

Resistors are identified in Parts Lists and steps by their resistance value in Ω (ohms), kΩ (kilohms), or MΩ (megohms). They are usually identified by a color code of four or five color bands, where each color represents a number. These colors (except for the last band, which indicates a resistor's "tolerance") will be given in the steps in their proper order. Therefore, the following color code is given for information only. NOTE: Occasionally, a "precision" or "power" resistor may have the value stamped on it.



Band 1 1st Digit	
Color	Digit
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

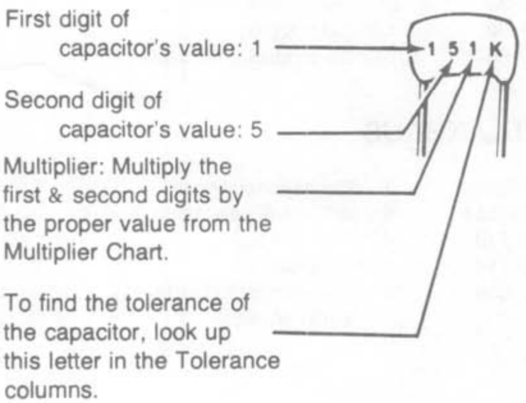
Band 2 2nd Digit	
Color	Digit
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Band 3 (if used) 3rd Digit	
Color	Digit
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Multiplier	
Color	Multiplier
Black	1
Brown	10
Red	100
Orange	1,000
Yellow	10,000
Green	100,000
Blue	1,000,000
Silver	0.01
Gold	0.1

Resistance Tolerance	
Color	Tolerance
Silver	± 10%
Gold	± 5%
Red	± 2%
Brown	± 1%
Green	± .5%
Blue	± .25%
Violet	± .1%
Gray	± .05%

Capacitors will be called out by their capacitance value in μF (microfarads) or pF (picofarads) and type: ceramic, Mylar*, electrolytic, etc. Some capacitors may have their value printed in the following manner:



EXAMPLES:

151K = 15 × 10 = 150 pF
759 = 75 ×0.1 = 7.5 pF

NOTE: The letter "R" may be used at times to signify a decimal point: as in: 2R2 = 2.2 (pF or μF).

MULTIPLIER		TOLERANCE OF CAPACITOR		
FOR THE NUMBER:	MULTIPLY BY:	10 pF OR LESS	LETTER	OVER 10 pF
0	1	±0.1 pF	B	
1	10	±0.25 pF	C	
2	100	±0.5 pF	D	
3	1000	±1.0 pF	F	±1%
4	10,000	±2.0 pF	G	±2%
5	100,000		H	±3%
			J	±5%
8	0.01		K	±10%
9	0.1		M	±20%

*DuPont Registered Trademark.

DISPLAY CIRCUIT BOARD

PARTS LIST

Remove the parts from Pack 1 and check each part against the following list and the "Parts Pictorial" (Illustration Booklet, Page 1). The key numbers correspond to the numbers on the "Parts Pictorial." Return any part that is packed in an individual envelope, with the part number on it, back into its envelope until that part is called for in a step. Do not throw away any packing material until you have accounted for all the parts.

To order a replacement part, always include the PART NUMBER. Use the Parts Order Form furnished with this kit. If a Parts Order Form is not available, refer to "Replacement Parts" inside the rear cover of this Manual. For prices, refer to the separate "Heath Parts Price List."

RESISTORS

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
A1	6-1103-12	1	110 kΩ, 1% (brn-brn-blk-org)	R302
A1	6-474-12	3	470 kΩ (yel-viol-yel)	R301, R303, R304
A2	10-1227	1	20 kΩ control	R1

CAPACITORS

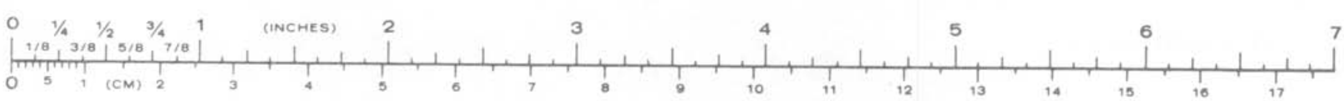
KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
B1	20-148	1	100 pF mica	C302
B2	21-761	1	.01 μF (103) glass ceramic	C308
B3	25-927	2	22 μF electrolytic	C307, C309
B4	27-193	3	.047 μF (473K) Mylar	C301, C303, C305
B4	27-228	2	.1 μF (104K) Mylar	C304, C306

WIRE-CABLE-SLEEVING

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
	340-8	6"	Small bare wire	
	340-9	6"	Large bare wire	
	343-12	48"	Shielded cable	
	344-33	18"	Black wire	
	346-35	2"	Heat-shrink sleeving	
	346-60	1-1/2"	Clear tubing	
	347-66	10-1/2"	25-conductor flat cable	

MISCELLANEOUS

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
	85-2971-1	1	Display circuit board	
C1	250-1514	8	#2 × 1/8" self-tapping screw	
C2	260-710	4	Input contact	J1, J2
C3	260-714	4	Stiffener	
C4	411-853	4	7-segment LED (light-emitting diode)	V301, V302 V303, V304



KEY No.	HEATH Part No.	QTY.	DESCRIPTION
Miscellaneous (Cont'd)			
C5	432-134	3	Socket pin (1 extra)
C6	434-253	1	40-pin IC socket
C7	434-298	4	14-pin IC socket
C8	490-185	1	Desoldering braid
			Solder
		1	Magnifier

KEY No.	HEATH Part No.	QTY.	DESCRIPTION
PRINTED MATERIALS			
D1	390-1255	1	Fuse label*
D2		1	Blue and white label*
	597-260	1	Parts Order Form*
		1	Assembly Manual (See title page for part number.)

*These parts may be packed inside the Manual.

STEP-BY-STEP ASSEMBLY

Refer to Pictorial 1-1 (Illustration Booklet, Page 2) for the following steps.

In the following steps, you will be given detailed instructions on how to install and solder the first part on the display circuit board. Read and perform each step carefully. Then use the same procedure whenever you install parts on a circuit board.

As you perform each step, check it off in the space provided. You may also wish to place a check mark near each component on the Pictorial as you install it.

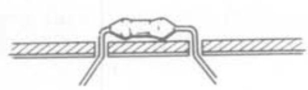
( ) Position the display circuit board as shown with the printed side up. Note that this circuit board has foil on both sides. Do NOT solder on the printed (component) side unless you are instructed to do so. The side of the circuit board **opposite the printed side** will be referred to as the foil side.

NOTE: When you install a component that has its value printed on it, position the value marking up, so it can be easily read. Diodes should be mounted with their type or part number up, if possible.

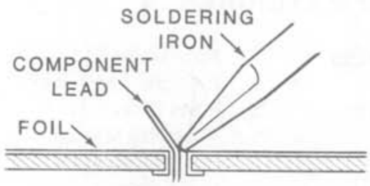
( ) Locate a 110 kΩ, 1% (brn-brn-blk-org) resistor. Hold the resistor with long-nose pliers and bend the leads straight down to fit the hole spacing on the circuit board.

( ) R302: Push the resistor leads through the holes at the indicated location near the top of the circuit board. You can install the resistor with the color bands either way.

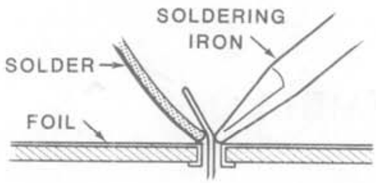
( ) Press the resistor down against the top of the circuit board. Then bend the leads outward slightly to hold it in place.



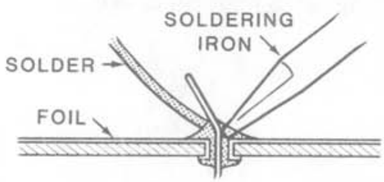
( ) Turn the circuit board over and solder the leads to the foil as follows:



1. Hold the soldering iron tip against both the lead and the circuit board foil. Heat **both** for two or three seconds.



2. Then apply solder to the other side of the connection. IMPORTANT: Let the heated lead and the circuit board foil melt the solder.

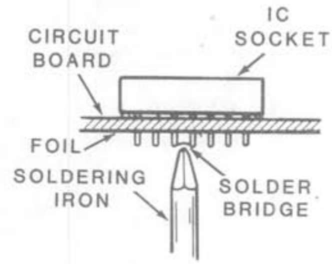


3. As the solder begins to melt, allow it to flow around the lead. Then remove the solder and the iron and let the connection cool.

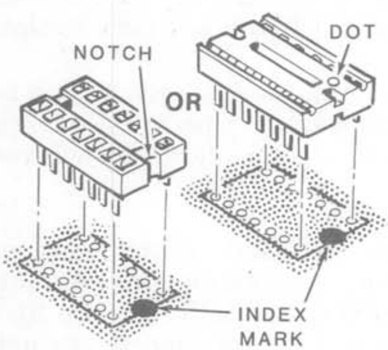
( ) Cut off the excess lead lengths close to the connection. WARNING: Hold the leads as you clip them so the ends will not fly toward your eyes.

( ) Check each connection. Compare it to the illustrations in Detail 1-1A. After you have checked the solder connections, proceed with the assembly on the following pages. Use the same soldering technique for each connection.

As you install IC sockets, be very careful that you do not bridge solder between socket pins. Solder that is bridged between two pins that are on the same foil is all right. If a solder bridge should occur, hold the circuit board bottom side down as shown. Then hold your soldering iron tip between the two points where solder is bridged. The solder will flow down the iron. You can also use desoldering braid (supplied).



NOTE: Before you install an IC socket, make sure the pins are straight. If there is any kind of identification mark (notch, dot, arrowhead, etc.) at or near one end of the socket, place this marked end toward the index mark on the circuit board (this index mark should still be visible after you install the socket). Then start the pins into the circuit board holes and solder them. The sockets used in a step may have fewer or a greater number of pins than shown in the detail.



Install four 14-pin IC sockets at:

( ) V304

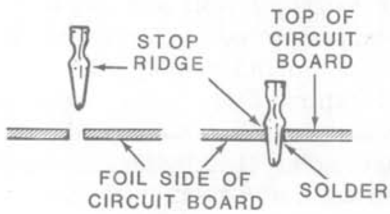
( ) V303

( ) V302

( ) V301

( ) 40-pin IC socket at U301.

NOTE: When you install socket pins, push each pin as far as possible into the hole. Then solder them to the foil.



( ) Install two socket pins at: "LAMP TEST."

NOTE: In general, solder instructions are given only at the end of a series of similar steps; you may solder more often if you wish.

Install each of the following components at the proper location on the circuit board, as indicated by its component number (C308, R303, etc.).

( ) C308: .01 µF (103). Install this capacitor as you would a resistor.

( ) R303: 470 kΩ (yel-vio-yel).

( ) R301: 470 kΩ (yel-vio-yel). Be sure you install this resistor in the proper holes.

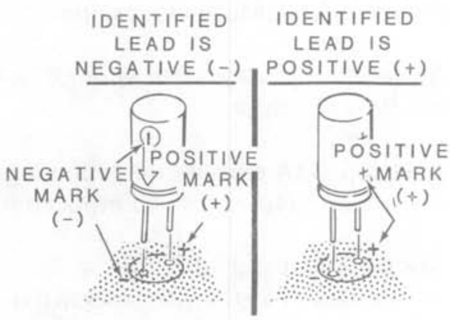
( ) R304: 470 kΩ (yel-vio-yel).

( ) Solder the leads to the foil and cut off the excess lead lengths.

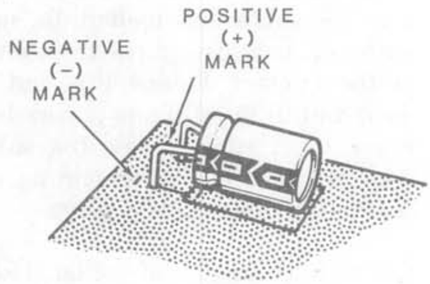
Refer to Pictorial 1-2 for the following steps.

( ) C302: 100 pF mica. Solder the leads to the foil; then cut off the excess lead lengths. NOTE: Set the cutoff leads aside for use in a later step.

When you install an electrolytic capacitor, always match the positive (+) mark on the capacitor with the positive (+) mark on the circuit board, OR, match the negative (−) mark on the capacitor with the negative (−) mark on the circuit board.



( ) C309: 22 µF electrolytic. Install this capacitor flat against the circuit board as shown.



( ) C304: .1 µF (104K) Mylar.

( ) C303: .047 µF (473K) Mylar.

( ) C301: .047 µF (473K) Mylar.

( ) C306: .1 µF (104K) Mylar.

( ) C305: .047 µF (473K) Mylar.

( ) C307: 22 µF electrolytic. Install this capacitor flat against the circuit board.

( ) Solder the leads to the foil and cut off the excess lead lengths.

Refer to Pictorial 1-3 for the following steps.

NOTE: In the following steps, use enough heat to ensure an even flow of solder.

( ) Refer to Detail 1-3A and use the following procedure to attach a stiffener to an input contact.

1. Melt a small dot of solder at each end of one side of a stiffener as shown in Part A.

2. Place the stiffener, solder dots down, into the input contact as shown in Part B. Position the stiffener against the short edge of the contact. While holding the stiffener in place with a screwdriver or other tool, heat one end until you are sure the solder has melted. Be sure the stiffener remains against the short edge of the contact. Reheat this end as required until the stiffener is parallel with the contact edge. Allow the solder to cool. Then heat the remaining end to seat the stiffener fully in place.

3. Cut two 2" lengths of solder. Use only these lengths in the following two steps.

4. Using one length of solder, melt several dots of solder into the gap between the short edge of the stiffener and the contact as shown in Part C. Use as much of the solder as possible. Then, using the screwdriver to hold the stiffener in position, melt the solder dots. Use a wiping motion to evenly distribute the solder in the gap as shown in Part D. Allow the solder to cool before proceeding to the next step.

5. Refer to Part D and use the same procedure to melt the remaining length of solder into dots along the rear edge of the stiffener. Then melt the solder along the stiffener edge, using a wiping motion. Do not allow too much solder to flow from the edge of the stiffener into the indicated corner of the contact.

( ) ( ) ( ) In the same manner, install stiffeners into the remaining three input contacts.

( ) Refer to Detail 1-3B and use two #2 × 1/8" self-tapping screws to loosely mount a contact assembly to the display circuit board at the top location of J1. Center the contact in the screened outline and center the screws in the contact holes; then tighten the screws. NOTE: Be careful not to overtighten the screws.

( ) Similarly, mount a contact assembly at the top location of J2.

( ) Install a contact assembly at the bottom of J1 facing the contact mounted at the top. Position the contact flush with and parallel to the top contact, then tighten the mounting screws.

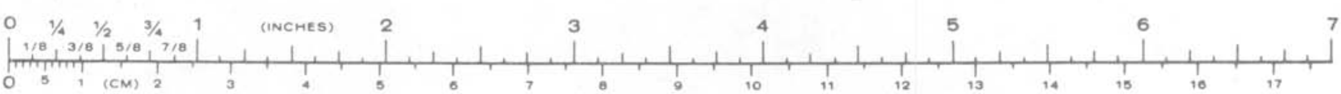
( ) Similarly, install the remaining contact assembly at the bottom location of J2.

NOTE: Read through the **next three** steps before you solder the screws to the contacts in the next step.

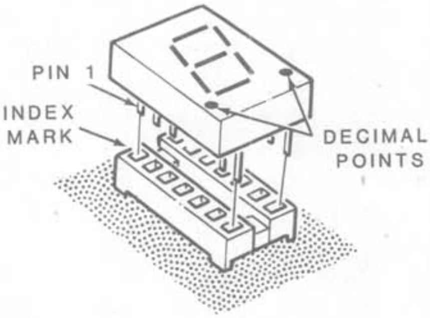
( ) Solder one side of the head of each mounting screw to its respective contact. Then solder the screw threads to the foil side of the circuit board.

( ) Examine J1 and J2. If a gap exists between contacts, carefully bend the bottom contact up or top contact down until there is no gap. When they are properly adjusted, the seam of each set of contacts should be vertically centered over the center line of the circuit board screen outline.

( ) Use the capacitor leads you set aside previously to test the input contacts for tension. If it is too easy to insert the leads, bend the contacts together to increase tension. If it is very difficult to insert the leads, carefully spread the contacts to relieve some of the tension. Properly spaced contacts allow you to insert the leads at either end of the contact without bending the leads and yet still firmly grip the inserted lead.



To install a display LED, position it so the two decimal points on one side are away from the index mark on the circuit board. Make sure the pins are straight. Then match up the pins with the holes in the socket and install the LED. Be careful that none of the pins bend as you insert them.



Install four 7-segment LEDs (light-emitting diodes) at the following locations.

( ) V304

( ) V303

( ) V302

( ) V301

Refer to Pictorial 1-4 for the following steps.

( ) R1: 20 kΩ control. Refer to Detail 1-4A and install the control on the foil side of the board with the lugs toward the top of the circuit board. Solder the mounting tabs to the component side of the board.

( ) Cut four 1-1/4" lengths of large bare wire. Then use the template shown in the inset drawing of Detail 1-4A to form each wire.

( ) Melt a small amount of solder on the indicated foil pads on the foil side of the circuit board.

( ) Holding the longer end of a formed wire with pliers, place the short end against the solder on a foil pad. Heat the wire until the solder melts; then remove the soldering iron. Hold the wire in place until the solder cools. Be sure the wire remains square with the circuit board.

( ) ( ) ( ) In the same manner, solder a wire to each of the remaining three foil pads. Keep the wires parallel to each other and square with the circuit board.

CIRCUIT BOARD CHECKOUT

Carefully inspect the foil side of the circuit board for the following most-commonly-made errors.

NOTE: There are some unused holes in the circuit board.

( ) Unsoldered connections.

( ) Poor solder connections.

( ) Solder bridges between foil patterns.

( ) Protruding leads which could touch together.

Refer to the illustrations where parts are installed as you make the following visual checks.

( ) Electrolytic capacitors for the correct position of the positive (+) or negative (−) marked leads.

( ) LEDs for proper installation.

( ) Input contacts for proper positioning.

U301 will be installed later.

Set the circuit board aside temporarily.

MAIN CIRCUIT BOARD, BOARD WIRING, AND CHASSIS ASSEMBLY

PARTS LIST

Open the Final Pack and check each part against the following list. The key numbers correspond to the numbers on the Parts Pictorial. **Do not remove any parts that are supplied on the tape strips until they are called for in an assembly step.** If a part is packed in an individual envelope with a part number on it, identify the part; then place it back into the envelope until a step calls for it. Do not throw away any packing materials until you have accounted for all the parts.

To order a replacement part, always include the PART NUMBER. Use the Parts Order Form furnished with this kit. If a Parts Order Form is not available, refer to "Replacement Parts" inside the rear cover of this Manual. For prices, refer to the separate "Heath Parts Price List."

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
RESISTORS				
NOTE: The following resistors are rated at 1/2-watt and have a tolerance of .25% unless otherwise listed.				
A1	6-689-1	2	6.8 Ω, 1-watt, 5% (blu-gry-gld)	R122, R123
A2	2-383	1	10 Ω (10R0 or 1009C)	R174
A2	2-384	1	90 Ω (90R0 or 9009C)	R175
A2	2-385	1	1000 Ω (1k or 1001C)	R173
A2	2-375	1	10 kΩ (1002C)	R172
A2	2-386	1	100 kΩ (1003C)	R171
CAPACITORS				
Mica				
B1	20-103	1	150 pF	CTEST
B1	20-158	1	500 pF	C123
Ceramic				
B2	21-140	2	1000 pF (.001)	C104, C118
B2	21-147	1	47 pF	C109
B2	21-149	1	2.7 pF	C108
Electrolytic				
B3	25-893	3	1000 μF	C132, C134, C138
B4	25-910	1	3300 μF	C136
B3	25-925	15	4.7 μF	C111, C121, C122, C129, C131, C133, C137, C141, C142, C145, C146, C155, C156, C167, C168
B3	25-927	7	22 μF	C101, C115, C116, C126, C127, C128, C135

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.

Other Capacitors

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
B5	27-228	1	.1 µF Mylar (104K)	C105
B6	29-73	4	.012 µF polypropylene (123G)	C102, C103, C114, C125
B6	29-74	2	.1 µF polypropylene (104G)	C113, C124

CONTROLS-SWITCHES-RELAYS

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
C1	10-1137	2	2000 Ω (2k) control	R144, R152
C1	10-1138	3	10 kΩ control	R137, R226, R232
C1	10-1185	4	200 kΩ control	R154, R202, R203, R243
C2	63-1421	1	Rotary switch	SW1
C3	64-945	1	4-section pushbutton switch	SW101-SW104
C4	69-86	2	Relay	RY101, RY102

METAL AND PLASTIC PARTS

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
D1	90-1339-1	1	Cabinet	
D2	200-1476-1	1	Chassis	
D3	203-2232	1	Front panel	
D4	204-2082	2	Bracket	
D5	210-86	1	Bezel	
D6	215-94	5	Heat sink	

HARDWARE

Hardware packets are marked to show the size of the hardware they contain (HDW #4, HDW #6, etc.). You may have to open more than one packet to locate all of the hardware.

#4 Hardware

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
E1	250-1412	15	4-40 × 3/8" screw	
E2	252-15	9	4-40 nut	
E3	254-9	15	#4 lockwasher	

#6 Hardware

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
E4	250-1282	1	6-32 × 1/8" set screw	
E5	250-1280	12	6-32 × 3/8" screw	
E6	250-1420	4	6-32 × 3/8" flat head screw	
E7	250-1150	1	6-32 × 1/2" screw	
E8	250-1305	1	#6 × 5/8" self-tapping screw	
E9	252-3	5	#6 nut	
E10	252-23	1	#6 thumb nut	
E11	253-60	2	#6 flat washer	
E12	254-1	4	#6 lockwasher	
E13	259-1	2	#6 solder lug	

#8 Hardware

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
E14	250-1436	2	8-32 × 3/8" screw	
E15	252-4	2	8-32 nut	
E16	254-2	2	#8 lockwasher	

Other Hardware

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
E17	252-7	1	Control nut	
E18	253-10	1	Control flat washer	
E19	254-4	2	Control lockwasher	
E20	260-16	4	Alligator clip	
E21	260-65	4	Fuse clip	

TRANSISTORS-INTEGRATED CIRCUITS

NOTE: Transistors and integrated circuits may be marked for identification in any of the following four ways:

1. Part number.
2. Type number (on integrated circuits, this refers only to the numbers printed in **bold** type; the letters may be different or missing).
3. Part number and type number.
4. Part number with a type number other than the one listed.

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
F1	417-235	2	2N4121 transistor	Q102, Q103
F1	417-998	1	PN4393 transistor	Q101
F2	442-21	2	MC**1458** IC	U112, U118
F3	442-54	1	UA**7805** IC	U124
F2	442-75	1	LM**311** IC	U113
F3	442-667	1	MC**78M15** IC	U122
F2	442-679	1	TL**061** IC	U101
F3	442-683	1	**79M05** IC	U125
F2	442-707	5	LF**353** (TL072) IC	U105, U106, U111, U115, U117
F4	442-724	1	**7107** IC	U301
F5	442-770	3	DG**211** IC	U102, U109, U116
F5	442-774	1	**4052** IC	U108
F3	442-775	1	**79M15** IC	U123
F6	442-776	2	**77000** IC	U104, U107
F5	442-777	2	CA**3280** IC	U103, U114
F5	444-329	1	"D" ROM IC	U119
F5	444-330	1	"L/C" ROM IC	U121

PINS-SOCKETS-CONNECTORS

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
G1	432-134	13	Socket pin	
G2	432-866	6	Spring connector (2 extra)	
G3	432-1129	2	4-pin plug	P101, P102
G4	432-1151	1	4-hole socket shell	S101/102
G5	434-230	9	8-pin IC socket	
G6	434-299	8	16-pin IC socket	

MISCELLANEOUS

KEY No.	HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
H1	54-1036	1	Power transformer	T1
H2	73-34	2	Red alligator clip insulator	
H2	73-159	2	Black alligator clip insulator	
H3	75-754	1	Strain relief	
H4	75-817	1	Insulating paper	
	85-2536	1	Printed circuit card connector	
	85-2970-1	1	Main circuit board	
	89-54	1	Line cord	
	100-1853	1	Calibration Package, consisting of the following components. DO NOT remove them from the envelope until you are instructed to do so.	
		1	*820 Ω resistor*	
		1	*1000 μF electrolytic capacitor*	
		1	*150 μF electrolytic capacitor*	
		1	*15 μF electrolytic capacitor*	
		1	*.15 μF capacitor*	
		2	*Alligator clips*	
H5	261-~~32~~ 34	4	Foot	
H6	352-13	1	Silicone grease	
H7	354-5	5	Cable tie	
H8	421-31	1	3/16-ampere slow-blow fuse	F102
H8	421-37	1	1-ampere fuse	F101
H9	431-13	1	4-lug terminal strip	TS1
H10	462-1100	1	Knob	
H11	490-5	1	Nut starter	
H12	490-14	1	.062 allen wrench	
H13	490-111	1	IC lifter	

TAPED COMPONENTS

The remaining parts are supplied on taped strips. It is not necessary to check them against the following list.

RESISTORS

NOTE: The following resistors are 1/4-watt, 5% tolerance unless otherwise noted.

HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
6-330-12	1	33 Ω (org-org-blk)	R139
6-151-12	3	150 Ω (brn-grn-brn)	R165, R234, R241
6-391-12	9	390 Ω (org-wht-brn)	R116, R135, R136, R183, R184, R185, R207, R208, R216
6-1301-12	7	1300 Ω, 1% (brn-org-blk-brn)	R134, R141, R142, R143, R192, R205, R245
6-222-12	7	2200 Ω (red-red-red)	R101, R121, R166, R176, R178, R209, R242
6-4991-12	2	4990 Ω, 1% (yel-wht-wht-brn)	R164, R238
6-562-12	4	5600 Ω(grn-blu-red)	R179, R181, R183, R213
6-822-12	7	8200 Ω (gry-red-red)	R112, R113, R115, R118, R167, R214, R217
6-1002-12	9	10 kΩ, 1% (brn-blk-blk-red)	R158, R159, R161, R162, R193, R227, R235, R236, R237
6-1152-12	6	11.5 kΩ, 1% (brn-brn-grn-red)	R105, R146, R194, R218, R219, R239
6-1472-12	6	14.7 kΩ, 1% (brn-yel-viol-red	R104, R107, R108, R145, R191, R223

HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
6-1742-12	1	17.4 kΩ, 1% (brn-viol-yel-red	R151
6-1822-12	5	18.2 kΩ, 1% (brn-gry-red-red)	R103, R131, R132, R133, R138
6-303-12	3	30 kΩ (org-blk-org)	R177, R224, R228
6-5622-12	8	56.2 kΩ, 1% (grn-blu-red-red)	R157, R163, R196, R197, R198, R199, R222, R231
6-683-12	4	68 kΩ (blu-gry-org)	R114, R195, R215, R221
6-8662-12	2	86.6 kΩ, 1% (gry-blu-blu-red)	R148, R225
6-1103-12	8	110 kΩ, 1% (brn-brn-blk-org)	R106, R109, R126, R127, R128, R129, R147, R201
6-124-12	7	120 kΩ (brn-red-yel)	R102, R111, R117, R119, R124, R125, R233
6-2003-12	2	200 kΩ, 1% (red-blk-blk-org)	R155, R229
6-5113-12	1	511 kΩ, 1% (grn-brn-brn-org)	R156
6-9313-12	1	931 kΩ, 1% (wht-org-brn-org)	R153
6-105-12	5	1 MΩ (brn-blk-grn)	R204, R206, R244, R246, RTEST

AXIAL-LEAD CERAMIC CAPACITORS

HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
21-761	21	.01 uF (103)	C106, C107, C117, C143, C144, C147, C148, C151, C152, C153, C154, C157, C158, C161, C162, C163, C164, C165, C166, C169, C171

DIODES

HEATH Part No.	QTY.	DESCRIPTION	CIRCUIT Comp. No.
56-26	1	1N191 (brn-wht-brn)	D117
56-56	9	1N4149	D101, D107, D108, D111, D112, D113, D114, D115, D116
56-612	1	1N5229B	D102
56-677	2	1N5350B	D103, D104
57-65	11	1N4002	D105, D106, D118, D119, D121, D122, D123, D124, D125, D126, D127

STEP-BY-STEP ASSEMBLY

MAIN CIRCUIT BOARD

Refer to Pictorial 2-1 as you read the following notes and perform the following steps.

NOTES:

1. Many circuit board drawings, such as the one shown in Pictorial 2-1, are divided into two or more sections. These sections show you which area of the circuit board you are working in for a specific series of steps.

2. Cut the "Taped Component Chart" from the last page in the Illustration Booklet. Make sure you read the instructions at the top of the chart before you use it. Note that it is divided into numbered sections which correspond to the numbered sections on the circuit board pictorial. The components are listed in the order of assembly.

3. In each series of steps, corresponding to a circuit board section, you will install parts in a top-to-bottom, left-to- right sequence. Occasionally, you may be directed to install a particular part in an area out of sequence.

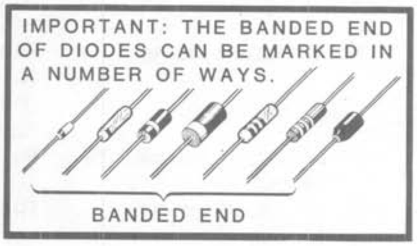
In order to make the assembly easier, you may wish to cut the parts from a section of the Taped Components Chart and, as you do this, prebend the leads and lay the parts on your work area in the exact order of assembly. Then you can hold the circuit board while you install the parts in sequence without interruption.

Start at the top of Section 1 and install the following components. The sequence of the steps matches the location of the components on the circuit board.

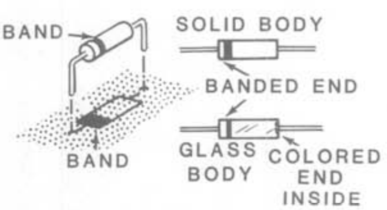
Section 1

NOTES: 1. When you install a diode, always match the band on the diode with the band mark on the circuit board. THE CIRCUIT WILL NOT WORK IF A DIODE IS INSTALLED BACKWARDS.

2. Diodes may be supplied in any of the following shapes. Always position the banded end as shown on the circuit board.



3. If your diode has a solid body, the band is clearly defined. If your diode has a glass body, do not mistake the colored end inside the diode for the banded end. Look for a band (or bands) painted on the outside of the glass.



CAUTION:ALWAYS POSITION THE BANDED END OF A DIODE AS SHOWN ON THE CIRCUIT BOARD.

(✓) D117: 1N191 (brn-wht-brn) (#56-26).

( ) R246: 1 MΩ (brn-blk-grn).

( ) R103: 18.2 kΩ, 1% (brn-gry-red-red).

( ) R101: 2200 Ω (red-red-red).

( ) D101: 1N4149 (#56-56).

( ) R104: 14.7 kΩ, 1% (brn-yel-viol-red).

( ) R105: 11.5 kΩ, 1% (brn-brn-grn-red).

( ) D102: 1N5229B (#56-612).

( ) R102: 120 kΩ (brn-red-yel).

( ) R106: 110 kΩ, 1% (brn-brn-blk-org).

( ) R114: 68 kΩ (blu-gry-org).

( ) R109: 110 kΩ, 1% (brn-brn-blk-org).

( ) R112: 8200 Ω (gry-red-red).

( ) R107: 14.7 kΩ, 1% (brn-yel-viol-red).

( ) R108: 14.7 kΩ, 1% (brn-yel-viol-red).

( ) R111: 120 kΩ (brn-red-yel).

( ) C144: .01 μF (103) glass creamic.

( ) C143: .01 μF (103) glass ceramic.

( ) R116: 390 Ω (org-wht-brn).

( ) R113: 8200 Ω (gry-red-red).

( ) R115: 8200 Ω (gry-red-red).

( ) R117: 120 kΩ (brn-red-yel).

( ) C106: .01 μF (103) glass ceramic.

( ) R118: 8200 Ω (gry-red-red).

( ) R119: 120 kΩ (brn-red-yel).

( ) C107: .01 μF (103) glass ceramic.

( ) R121: 2200 Ω (red-red-red).

( ) Solder the leads to the foil and cut off the excess lead lengths.

Section 2

( ) R178: 2200 Ω (red-red-red).

( ) R177: 30 kΩ (org-blk-org).

( ) C152: .01 μF (103) glass ceramic.

( ) C151: .01 μF (103) glass ceramic.

( ) R156: 511 kΩ, 1% (grn-brn-brn-org).

( ) R218: 11.5 kΩ, 1% (brn-brn-grn-red).

( ) R157: 56.2 kΩ, 1% (grn-blu-red-red).

( ) R158: 10 kΩ, 1% (brn-blk-blk-red).

( ) D108: 1N4149 (#56-56).

( ) R164: 4990 Ω, 1% (yel-wht-wht-brn).

( ) R161: 10 kΩ, 1% (brn-blk-blk-red).

( ) D107: 1N4149 (#56-56).

( ) R155: 200 kΩ, 1% (red-blk-blk-org).

( ) R159: 10 kΩ, 1% (brn-blk-blk-red).

( ) R151: 17.4 kΩ, 1% (brn-viol-yel-red).

( ) R153: 931 kΩ, 1% (wht-org-brn-org).

( ) C154: .01 μF (103) glass ceramic.

( ) C153: .01 μF (103) glass ceramic.

( ) R162: 10 kΩ, 1% (brn-blk-blk-red).

( ) R167: 8200 Ω (gry-red-red).

( ) D111: 1N4149 (#56-56).

( ) R166: 2200 Ω (red-red-red).

( ) R163: 56.2 kΩ, 1% (grn-blu-red-red).

( ) R146: 11.5 kΩ, 1% (brn-brn-grn-red).

( ) R165: 150 Ω (brn-grn-brn).

( ) R145: 14.7 kΩ, 1% (brn-yel-viol-red).

( ) R143: 1300 Ω, 1% (brn-org-blk-brn).

( ) R142: 1300 Ω, 1% (brn-org-blk-brn).

( ) R141: 1300 Ω, 1% (brn-org-blk-brn).

( ) R148: 86.6 kΩ, 1% (gry-blu-blu-red).

( ) R128: 110 kΩ, 1% (brn-brn-blk-org).

( ) R129: 110 kΩ, 1% (brn-brn-blk-org).

( ) C148: .01 μF (103) glass ceramic.

( ) C147: .01 μF (103) glass ceramic.

( ) D115: 1N4149 (#56-56).

( ) R147: 110 kΩ, 1% (brn-brn-blk-org).

( ) R126: 110 kΩ, 1% (brn-brn-blk-org).

( ) D104: 1N5350B (#56-677).

( ) D103: 1N5350B (#56-677).

( ) D106: 1N4002 (#57-65).

( ) D105: 1N4002 (#57-65).

( ) R124: 120 kΩ (brn-red-yel).

( ) R127: 110 kΩ, 1% (brn-brn-blk-org).

( ) R125: 120 kΩ (brn-red-yel).

( ) Solder the leads to the foil and cut off the excess lead lengths.

Section 3

( ) R209: 2200 Ω (red-red-red).

( ) R138: 18.2 kΩ, 1% (brn-gry-red-red).

( ) R207: 390 Ω (org-wht-brn).

( ) R208: 390 Ω (org-wht-brn).

( ) R214: 8200 Ω (gry-red-red).

( ) R215: 68 kΩ (blu-gry-org).

( ) R205: 1300 Ω, 1% (brn-org-blk-brn).

( ) R204: 1 MΩ (brn-blk-grn).

( ) R213: 5600 Ω (grn-blu-red).

( ) D112: 1N4149 (#56-56).

( ) R199: 56.2 kΩ, 1% (grn-blu-red-red).

( ) C162: .01 μF (103) glass ceramic.

( ) C161: .01 μF (103) glass ceramic.

( ) C117: .01 μF (103) glass ceramic.

( ) R223: 14.7 kΩ, 1% (brn-yel-viol-red).

( ) R217: 8200 Ω (gry-red-red).

( ) R216: 390 Ω (org-wht-brn). Be sure you install this resistor in the proper holes.

( ) D116: 1N4149 (#56-56).

( ) Solder the leads to the foil and cut off the excess lead lengths.

Section 4

( ) R206: 1 MΩ (brn-blk-grn).

( ) R201: 110 kΩ, 1% (brn-brn-blk-org).

( ) C158: .01 μF (103) glass ceramic.

( ) R197: 56.2 kΩ, 1% (grn-blu-red-red).

( ) R198: 56.2 kΩ, 1% (grn-blu-red-red).

( ) R227: 10 kΩ, 1% (brn-blk-blk-red).

( ) R222: 56.2 kΩ, 1% (grn-blu-red-red).

( ) R196: 56.2 kΩ, 1% (grn-blu-red-red).

( ) R191: 14.7 kΩ, 1% (brn-yel-viol-red).

( ) R194: 11.5 kΩ, 1% (brn-brn-grn-red).

( ) R228: 30 kΩ (org-blk-org).

( ) R224: 30 kΩ (org-blk-org).

( ) C164: .01 µF (103) glass ceramic.

( ) C163: .01 µF (103) glass ceramic.

( ) C166: .01 µF (103) glass ceramic.

( ) C165: .01 µF (103) glass ceramic.

( ) R225: 86.6 kΩ, 1% (gry-blu-blu-red).

( ) C171: .01 µF (103) glass ceramic.

( ) R133: 18.2 kΩ, 1% (brn-gry-red-red).

( ) R131: 18.2 kΩ, 1% (brn-gry-red-red).

( ) R134: 1300 Ω, 1% (brn-org-blk-brn).

( ) R132: 18.2 kΩ, 1% (brn-gry-red-red).

( ) R139: 33 Ω (org-org-blk).

( ) R136: 390 Ω (org-wht-brn).

( ) Solder the leads to the foil and cut off the excess lead lengths.

Section 5

( ) R221: 68 kΩ (blu-gry-org).

( ) R195: 68 kΩ (blu-gry-org).

( ) C157: .01 µF (103) glass ceramic.

( ) R193: 10 kΩ, 1% (brn-blk-blk-red).

( ) R219: 11.5 kΩ, 1% (brn-brn-grn-red).

( ) R192: 1300 Ω, 1% (brn-org-blk-brn).

( ) R234: 150 Ω (brn-grn-brn).

( ) R231: 56.2 kΩ, 1% (grn-blu-red-red).

( ) R229: 200 kΩ, 1% (red-blk-blk-org).

( ) R236: 10 kΩ, 1% (brn-blk-blk-red).

( ) R235: 10 kΩ, 1% (brn-blk-blk-red).

( ) D114: 1N4149 (#56-56).

( ) D113: 1N4149 (#56-56).

( ) R237: 10 kΩ, 1% (brn-blk-blk-red).

( ) R238: 4990 Ω, 1% (yel-wht-wht-brn).

( ) R239: 11.5 kΩ, 1% (brn-brn-grn-red).

( ) R245: 1300 Ω, 1% (brn-org-blk-brn).

( ) R241: 150 Ω (brn-grn-brn).

( ) R242: 2200 Ω (red-red-red).

( ) R233: 120 kΩ (brn-red-yel).

( ) R244: 1 MΩ (brn-blk-grn).

( ) R176: 2200 Ω (red-red-red).

( ) C169: .01 µF (103) glass ceramic.

( ) R179: 5600 Ω (grn-blu-red).

( ) R181: 5600 Ω (grn-blu-red).

( ) R182: 5600 Ω (grn-blu-red).

( ) D123: 1N4002 (#57-65).

( ) R135: 390 Ω (org-wht-brn).

( ) Solder the leads to the foil and cut off the excess lead lengths.

Section 6

( ) D118: 1N4002 (#57-65).

( ) D119: 1N4002 (#57-65).

( ) D121: 1N4002 (#57-65).

( ) D122: 1N4002 (#57-65).

( ) D124: 1N4002 (#57-65).

( ) D125: 1N4002 (#57-65).

( ) D126: 1N4002 (#57-65).

( ) D127: 1N4002 (#57-65).

( ) R185: 390 Ω (org-wht-brn).

( ) R184: 390 Ω (org-wht-brn).

( ) R183: 390 Ω (org-wht-brn).

( ) Solder the leads to the foil and cut off the excess lead lengths.

( ) RTEST: 1 MΩ (brn-blk-grn). Cut this resistor from the strip and set it aside until it is called for in the "Tests and Adjustments" section.

Refer to Pictorial 2-2 for the following steps. Solder each part to the foil as you install it.

Section 1

Install five socket pins at the following locations:

( ) TPAC

( ) TPDC

( ) TP1

( ) TP2

( ) TP3

( ) 8-pin IC socket at U101.

( ) 16-pin IC socket at U109.

( ) 16-pin IC socket at U102.

( ) 8-pin IC socket at U111.

( ) 16-pin IC socket at U103.

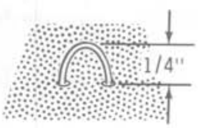
Install three 8-pin IC sockets at:

( ) U112

( ) U105

( ) U106

( ) W103: 1" small bare wire. NOTE: Cut the proper length of **small** bare wire from the length of wire you received in Pack 1. Then install it as shown, solder the leads to the foil, and cut off the excess lead lengths.



( ) W102: 1" small bare wire.

( ) W101: 1" small bare wire.

Section 2

Install three socket pins at:

( ) TP6

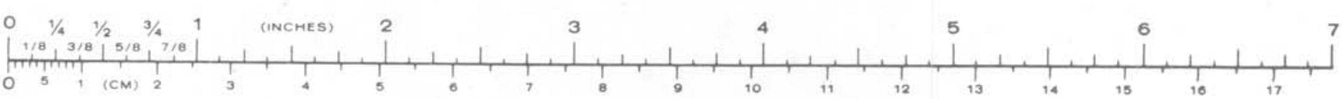
( ) TP4

( ) TP5

( ) 8-pin IC socket at U113.

( ) W104: 1" small bare wire.

( ) 16-pin IC socket at U114.



Install three 8-pin IC sockets at:

( ) U115

( ) U117

( ) U118

Install three 16-pin IC sockets at:

( ) U116

( ) U108

( ) U121

Section 3

Install five socket pins at:

( ) TP7

( ) TP8

( ) TP9

( ) TP10

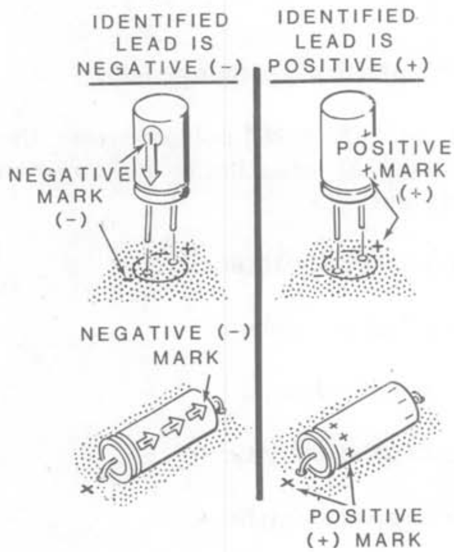
( ) TP11

( ) 16-pin IC socket at U119.

Refer to Pictorial 2-3 for the following steps.

Section 1

When you install an electrolytic capacitor, always match the positive (+) mark on the capacitor with the positive (+) mark on the circuit board, OR, match the negative (−) mark on the capacitor with the negative (−) mark on the circuit board.



( ) C129: 4.7 µF electrolytic.

( ) C142: 4.7 µF electrolytic.

( ) C141: 4.7 µF electrolytic.

( ) C102: .012 µF (123G) polypropylene.

( ) C101: 22 µF electrolytic.

( ) C103: .012 µF (123G) polypropylene.

( ) C146: 4.7 µF electrolytic.

( ) C104: 1000 pF (.001) ceramic.

( ) C105: .1 µF (104K) Mylar.

( ) C145: 4.7 µF electrolytic.

( ) Solder the leads to the foil and cut off the excess lead lengths.

Section 2

( ) C113: .1 μF (104G) polypropylene.

( ) C114: .012 μF (123G) polypropylene. Be sure you install this capacitor in the proper circuit board holes.

( ) C118: 1000 pF (.001) ceramic.

( ) C156: 4.7 μF electrolytic.

( ) C123: 500 pF mica.

( ) C115: 22 μF electrolytic.

( ) C116: 22 μF electrolytic.

( ) C167: 4.7 μF electrolytic.

( ) C109: 47 pF ceramic.

( ) C111: 4.7 μF electrolytic.

( ) C168: 4.7 μF electrolytic.

( ) C108: 2.7 pF ceramic.

( ) Solder the leads to the foil and cut off the excess lead lengths.

Section 3

( ) C155: 4.7 μF electrolytic.

( ) C122: 4.7 μF electrolytic.

( ) C121: 4.7 μF electrolytic.

( ) C125: .012 μF (123G) polypropylene. Be sure you install this capacitor in the proper circuit board holes.

( ) C126: 22 μF electrolytic.

( ) C124: .1 μF (104G) polypropylene. Be sure you install this capacitor in the proper circuit board holes.

( ) C127: 22 μF electrolytic.

( ) C128: 22 μF electrolytic.

( ) Solder the leads to the foil and cut off the excess lead lengths.

Section 4

( ) C131: 4.7 μF electrolytic.

( ) C133: 4.7 μF electrolytic.

( ) C135: 22 μF electrolytic.

( ) C137: 4.7 μF electrolytic.

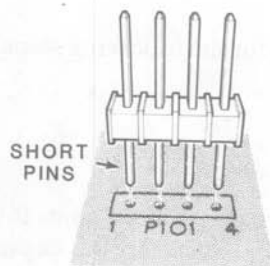
( ) Solder the leads to the foil and cut off the excess lead lengths.

C132, C134, C136, and C138 will be installed later.

Refer to Pictorial 2-4 for the following steps.

Section 1

To install a plug, insert the short end of the pins into the circuit board holes and solder them to the foil.

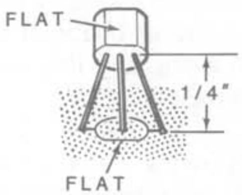


Install two 4-pin plugs at:

( ) P101

( ) P102

When you install a transistor, position the flat on the transistor over the flat of the outline on the circuit board. Then insert the leads into the circuit board holes and solder them to the foil. Cut off any excess lead lengths.



( ) Q101: PN4393 (#417-998).

( ) Q102: 2N4121 (#417-235).

When you install a control, insert the leads and position the control against the circuit board. Then solder the leads to the foil and cut off any excess lead lengths.

( ) R144: 2000 Ω (2k) control.

When you install a relay, align the pins with the circuit board holes and insert them into the board. Solder the pins to the foil and cut off the excess lead lengths.

( ) RY101: Relay.

( ) R122: 6.8 Ω, 1-watt (blu-gry-gld).

( ) R123: 6.8 Ω, 1-watt (blu-gry-gld).

( ) Solder the leads to the foil and cut off the excess lead lengths.

Section 2

( ) R154: 200 KΩ control.

( ) R152: 2000 Ω (2k) control.

( ) R137: 10 kΩ control.

( ) Q103: 2N4121 (#417-235).

( ) R175: 90 Ω, 1/2-watt (90R0 or 9009C).

( ) R172: 10 kΩ, 1/2-watt (1002C).

( ) R171: 100 kΩ, 1/2-watt (1003C).

( ) R226: 10 kΩ control.

( ) R173: 1000 Ω, 1/2-watt (1K or 1001C).

( ) RY102: Relay.

( ) R174: 10 Ω, 1/2-watt (10R0 or 1009C).

( ) Solder the leads to the foil and cut off the excess lead lengths.

Section 3

( ) R203: 200 kΩ control.

( ) R202: 200 kΩ control.

( ) R243: 200 kΩ control.

( ) R232: 10 kΩ control.

Refer to Pictorial 2-5 for the following steps.

NOTE: When a step calls for hardware, only the screw size is given. For instance, if "6-32 × 3/8" hardware" is called for, it means you should use a 6-32 × 3/8" screw, one or more #6 lockwashers, and a 6-32 nut at the indicated mounting hole. The Detail referred to in the step will show the proper number and placement of each hardware item. Use the plastic nut starter furnished with the kit to pick up #4 and #6 nuts and start them onto screws.

( ) Position a **78M15** IC (#442-667) as shown in Part A of Detail 2-5A and bend the leads 90°, 3/4" from the center of the mounting hole.

WARNING: The silicone grease you will use in the following steps helps transfer heat from the IC to the heat sink. The grease is not caustic, but make sure you do not get it into your eyes, ears, nose, mouth, or onto clothing. Always wash your hands after you use the grease. Keep this and all chemicals out of the reach of children.

( ) Make a small cut in the silicone grease pod. Then apply a thin coating of grease to the metal side of the IC.

( ) U122: Refer to Part B of the Detail and insert the leads of the IC into holes I, G, and O. While holding the IC above the circuit board, slide a heat sink under the IC and line up the holes of the IC, heat sink, and circuit board. Secure the IC with 4-40 × 3/8" hardware. Center the heat sink in the circuit board outline and tighten the hardware.

( ) Solder the IC leads to the foil and cut off the excess lead lengths.

Similarly, install ICs and heat sinks at the following locations. Use 4-40 × 3/8" hardware and silicone grease on each IC.

( ) U123: **79M15** IC (#442-775).

( ) U124: **7805** IC (#442-54).

( ) U104: **77000** IC (#442-776).

( ) U107: **77000** IC (#442-776).

( ) F101: Refer to inset drawing #1 and insert fuse clips at F101. Be sure to position the shoulder of each clip toward the outside as shown. Then insert a 1-ampere fuse into the clips to hold them in position, and solder the clips to the foil.

( ) F102: In the same manner, install fuse clips at F102, using a 3/16-ampere fuse. Then remove the fuse.

( ) Refer to inset drawing #2, Part A and prepare the length of clear tubing.

( ) Refer to Part B of the inset and slide the prepared tubing over a 3/16-ampere fuse. Then push the fuse into the clips at F102.

( ) Refer to Detail 2-5B and cut off lugs 1, 2, and 3 of section SW104 of the 4-section switch.

( ) SW101-SW104: 4-section pushbutton switch. Insert the lugs into the circuit board holes. Solder lug 1 of SW101 and lug 6 of SW104. Then check the switch assembly to be sure it is flat against the circuit board. If necessary, reheat the lugs to reposition the switch, then solder the remaining lugs.

NOTE: In the following steps, be sure to match the positive or negative marks on the capacitors with the corresponding marks on the circuit board.

( ) C136: 3300 μF electrolytic.

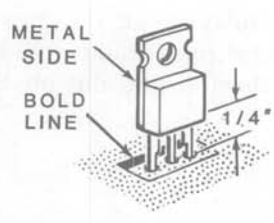
( ) C132: 1000 μF electrolytic.

( ) C134: 1000 μF electrolytic.

( ) C138: 1000 μF electrolytic.

( ) Solder the leads to the foil and cut off the excess lead lengths.

( ) U125: Install a **79M05** IC (#442-683) vertically at U125. Position the metal side of the IC over the bold line of the outline as shown. Then solder the leads to the foil.



( ) Refer to inset drawing #3 and mount the long side of a bracket at CA. Use a 4-40 × 3/8" hardware.

( ) Similarly, mount another bracket at CB.

( ) CTest: Set the remaining 150 pf mica capacitor aside. It will be used in "Tests and Adjustments".

NOTE: All remaining ICs will be installed later.

CIRCUIT BOARD CHECKOUT

Carefully inspect the foil side of the circuit board for the following most-commonly-made errors. (Note that there are some unused holes in the circuit board.)

( ) Unsoldered connections.

( ) Poor solder connections.

( ) Solder bridges between foil patterns.

( ) Protruding leads which could touch together or touch the chassis when the circuit board is installed later.

Refer to the illustrations where parts are installed as you make the following visual checks.

( ) Transistors for the proper **type** and **installation**.

( ) Electrolytic capacitors for the correct **position** of the positive (+) or negative (−) marked leads. NOTE: All electrolytic capacitors will have their negative (−) lead to the right of the capacitor except C136.

( ) Diodes for the correct **type** and correct **position** of the banded ends. NOTE: All diodes will have their banded end to the right.

( ) Soldered in ICs for the proper **type** and **installation**.

BOARD WIRING

Refer to Pictorial 3-1 for the following steps.

( ) Cut the length of 25-conductor flat cable to 10".

In the following steps you will separate the 10" flat cable into groups, making four cables and two individual wires. To do this, separate the wires at one end approximately 1/4" using a pair of cutters as shown in the inset drawing. Let the sharp edges of the cutter seat in the groove between the wires, and then cut them apart. Then pull the group of wires from the cable.

Position the cable so the outer black wire is toward the top as shown. Then pull the following groups from the cable and cut them to the dimensions given. NOTE: You can use the pictorial as a template.

( ) One 12-wire cable (black through brown).

( ) One 3-wire cable, cut to 4" (red through yellow).

( ) One wire, cut to 6-1/2" (green).

( ) One 4-wire cable, cut to 5-1/4" (blue through white).

( ) One 4-wire cable, cut to 4-3/4" (black through orange).

( ) One wire uncut (yellow).

Refer to Pictorial 3-2 for the following steps.

NOTE: To prepare wires, as in the following steps, cut the wires to the lengths indicated and remove 1/4" of insulation from each wire end. Tightly twist each bare wire end and add a small amount of solder to hold the fine strands together.

Prepare each of these cables and the two wires, in the following steps, as shown in the Pictorial. Separate and shorten the wires as shown. NOTE: You can use the pictorial as a template.

( ) 12-wire cable. Fold the 12-wire cable as shown after you have prepared all the wires.

( ) 3-wire cable.

( ) 6-1/2" green wire.

( ) 5-1/4" 4-wire cable.

( ) 4-3/4" 4-wire cable.

( ) 10" yellow wire.

Set the 4-3/4" 4-wire cable, and the green and yellow wires aside until they are called for later.

Refer to Pictorial 3-3 for the following steps.

Connect the previously prepared cables to the main circuit board in the following steps. Solder them to the foil side and cut off the excess wire lengths.

3-WIRE CABLE, End A:

( ) Red to hole AU.

( ) Orange to hole AV.

( ) Yellow to hole AW.

End B will be connected later.

4-WIRE CABLE, End A:

( ) Blue to hole BK.

( ) Violet to hole BL.

( ) Gray to hole BM.

( ) White to hole BN.

End B will be connected later.

12-WIRE CABLE, End A:

( ) Black to hole AX.

( ) Brown to hole AY.

( ) Red to hole AZ.

( ) Orange to hole BA.

( ) Yellow to hole BB.

( ) Green to hole BC.

( ) Blue to hole BD.

( ) Violet to hole BE.

( ) Gray to hole BF.

( ) White to hole BG.

( ) Black to hole BH.

( ) Brown to hole BJ.

Position the cable as shown. End B will be connected later.

( ) Cut two 9" lengths of black wire. Remove 1/4" of insulation from each end of each wire.

( ) Twist the two black wires together to within 1-1/2" of each end.

( ) At one end of the twisted pair, connect either wire to hole AK.

( ) Connect the other wire to hole AL.

( ) Cut two 3/4" pieces of heat-shrink sleeving.

NOTE: In the following steps, (NS) means not to solder because other wires will be connected later. "S-" with a number, such as (S-2), means to solder the connection. The number following the "S-" tells how many wires are in the connection.

( ) Refer to Detail 3-3A and slide a piece of sleeving over the free end of each black wire. Then connect the wires to SW104 as follows.

NOTE: Refer to the inset drawing on the Pictorial whenever a step directs you to "make a mechanically secure connection."

( ) Either lead to lug 1 (S-1). Make a mechanically secure connection.

( ) The other lead to lug 2 (S-1). Make a mechanically secure connection.

( ) Slide the sleeving over each switch lug. Then use the heat of a match or other source to shrink the sleeving over the lugs and wires.

( ) Cut off SW104 lug 3 as close to the switch body as possible.

( ) Position the black wires about 1-1/2" above the circuit board as shown in the Pictorial.

Refer to Detail 3-3B for the following three steps.

( ) Position the display circuit board over the main circuit board. Line up the bare wires coming from the foil side of the display board with holes BP, BR, BS, and BT. Then slide the wires into the holes.

( ) Mount the display circuit board to brackets CA and CB on the main circuit board. Use 4-40 × 3/8" hardware.

( ) Solder the wires at BP, BR, BS, and BT on the main circuit board and cut off the excess lead lengths. Resolder the wires on the display board, if necessary.

Connect the free end of the 3-wire cable to control R1 as follows:

( ) Red to lug 3 (S-1).

( ) Orange to lug 2 (S-1).

( ) Yellow to lug 1 (S-1).

Connect the free end of the 12-wire cable to the display circuit board as follows. Push the wires into the indicated holes and solder them to the **component** side of the circuit board. Then cut off the excess wire lengths. NOTE: Holes CE through CL are not marked on the circuit board. Holes CA, CB, and CC are located between the LED display sockets and J1 and J2.

( ) Brown to hole CA.

( ) Black to hole CB.

( ) White to hole CC.

( ) Gray to hole CM.

( ) Violet to hole CL.

( ) Blue to hole CK.

( ) Green to hole CJ.

( ) Yellow to hole CH.

( ) Orange to hole CG.

( ) Red to hole CF.

( ) Brown to hole CE.

( ) Black to hole CD.

Set the circuit boards aside.

CHASSIS ASSEMBLY

Refer to Pictorial 4-1 for the following steps.

( ) Refer to inset drawing #1 and peel the backing from a rubber foot. Then mount the foot as shown on the bottom of the chassis. Do not cover any holes.

( ) Similarly, mount rubber feet in the remaining three corners of the chassis.

( ) Position the chassis as shown.

( ) Use a screwdriver or other tool to scrape off any paint around chassis holes DC, DF, DG, DH, and DJ (indicated with arrows).

( ) TS1: Refer to Detail 4-1A and install a 4-lug terminal strip at TS1 on the outside of the rear panel. Use 6-32 × 3/8" hardware and position the solder lugs toward the bottom of the chassis.

( ) Install a 6-32 × 1/2" screw with two #6 lockwashers at DC. Then install two #6 flat washers and a thumb nut on the screw as shown in the Pictorial.

( ) Refer to Detail 4-1B and mount a #6 solder lug at DH. Use a 6-32 × 3/8" screw and a 6-32 nut. Position the lug as shown.

( ) Similarly, mount another #6 solder lug at DJ.

( ) Refer to Detail 4-1C and scrape the varnish from each side of both mounting flanges of the power transformer.

( ) T1: Mount the power transformer at DF and DG with 8-32 × 3/8" hardware. Position the transformer leads as shown and form each group toward the side of the chassis.

( ) Refer to inset drawing #2 and install cable ties around the six transformer secondary leads in the two locations shown. Cut off the excess cable tie length.

Locate the 4-wire cable (blk-brn-red-org) you set aside earlier.

( ) Refer to Detail 4-1D, Part A, and crimp and solder a spring connector on the end of each wire at end A of the cable.

( ) S101/102: Position a 4-pin socket shell so the slots are up as shown in Part B of the Detail. Then position the spring connector on the black wire so the locking tab is up, and push it into hole 1 of the socket shell until it locks into place.

Similarly, push the remaining spring connectors into the socket shell as follows:

( ) Brown wire into hole 2.

( ) Red wire into hole 3.

( ) Orange wire into hole 4.

Connect the wires at end B of the cable to the 4-lug terminal strip as follows.

( ) Black to lug 1 (S-1).

( ) Brown to lug 2 (S-1).

( ) Red to lug 3 (S-1).

( ) Orange to lug 4 (S-1).

( ) Refer to Part A of Detail 4-1E and carefully remove the outer insulation from the end of the line cord as shown.

( ) Twist the strands of each wire together and melt a small amount of solder on the ends to keep the strands together. Then trim the prepared ends to 1/4".

( ) Refer to Part B of the Detail and insert the prepared end of the line cord through chassis hole DD. Position the strain relief as shown; then insert the prepared line cord end through the shoulder on the strain relief and back through the side hole.

( ) Refer to Detail 4-1E, Part C, and route the prepared end of the line cord back through the upper hole in the strain relief and pull the cord tight. Then push the shoulder of the strain relief into chassis hole DD. Secure the strain relief with a #6 × 5/8" self-starting screw at hole DE.

( ) Connect the green line cord wire to lug DH (S-1). Make a mechanically secure connection.

( ) Connect one end of the previously prepared 6-1/2" green wire to solder lug DJ (S-1). Make a mechanically secure connection.

( ) Install a cable tie around the line cord, the green wire from lug DJ, and the two black transformer wires. Position the ends of all the wires even; then extend the small green wire 1/2" in front of the others, and tighten the cable tie. Be sure the tie is at the edge of the line cord insulation as shown. Cut off the excess cable tie length.

( ) Write "3/16A, 3AG, Slow Blow" in the blank on the fuse label.

( ) Peel the backing from the fuse label and install the label as shown.

Refer to Pictorial 4-2 for the following steps.

( ) Install the front panel and bezel on the chassis as shown. Use 6-32 × 3/8" flat head screws.

( ) SW1: Install the rotary switch (#63-1421) at SW1 on the front panel. Use two control lockwashers, a control flat washer, and a control nut. Position the switch with the solder lugs as shown.

( ) Cut two 1" pieces of small bare wire.

Refer to inset drawing #1 for the following two steps. NOTE: Spacing between the switch lugs may be different then shown.

( ) Connect a 1" small bare wire from switch SW1 lug 1 (S-1) to lug 2 (NS).

( ) Connect a 1" small bare wire from switch SW1 lug 5 (NS) to lug 6 (S-1).

( ) Turn the shaft of SW1 fully counterclockwise.

( ) Refer to inset drawing #2 and start a 6-32 × 1/8" setscrew into the knob.

( ) Install the knob on the shaft of SW1. Align the pointer with the 200 pF range position and tighten the setscrew.

Refer to Pictorial 4-3 for the following steps.

( ) Position the circuit board assembly as shown.

Connect the wires of the line cord and transformer primary group as follows. Solder each lead to the foil and cut off any excess lead length.

( ) Green to hole AA.

( ) Either black transformer lead to hole AB.

( ) The other black transformer lead to hole AH.

( ) Line cord white lead to hole AD.

( ) Line cord black lead to hole AE.

NOTE: No wires will be connected to holes AC, AF, AG, or AJ.

Connect the secondary wires coming from transformer T1 to the main circuit board as follows. Solder each lead to the foil and cut off any excess lead length.

( ) Green/yellow to hole AM.

( ) Either green to hole AN.

( ) The other green to hole AP.

( ) Red/yellow to hole AR.

( ) Either red to hole AS.

( ) The other red to hole AT.

( ) Refer to inset drawing #1 and cut the insulating paper as shown.

( ) Peel the backing from the insulating paper. Position it onto the foil side of the circuit board and press it into place.

( ) Position the main circuit board in the chassis as shown.

( ) Temporarily mount the main circuit to the chassis at DL and DM. Use two 4-40 × 3/8" screws. Tighten the screws only finger tight.

Connect the free ends of the 4-wire cable to switch SW1 as follows:

( ) White wire to lug 5 (S-2).

( ) Gray wire to lug 4 (S-1).

( ) Violet wire to lug 3 (S-1).

( ) Blue wire to lug 2 (S-2).

( ) Push 4-pin socket shell S101/102 onto P101 at the rear of the main circuit board so the black wire is at pin 1 of P101.

( ) Carefully peel the backing from the blue and white label. Then press the label onto the rear panel in the area shown in inset drawing #2. Be sure to refer to the numbers on the label in any correspondence you may have with the Heath Company about your Digital LC Bridge.

( ) Locate the calibration package (#100-1853) and remove the two alligator clips and the 820 Ω (gry-red-brn) resistor.

( ) Refer to Detail 4-3A and install an alligator clip onto one lead of the resistor. Use as little heat as necessary to make the connection.

( ) Similarly, install the other alligator clip onto the remaining lead of the resistor.

( ) Return the resistor assembly to the calibration package until called for in a step.

This completes the major assembly of your Heathkit Digital LC Bridge. Carefully inspect the chassis wiring for solder bridges, poor solder connections, and proper lead placement. Then proceed to "Tests and Adjustments."

TESTS AND ADJUSTMENTS

This section of the Manual is divided into two parts, "Resistance Checks," and "Operational Tests." In the first part, "Resistance Checks," you will use an ohmmeter to verify wiring and component installation. In the second part, "Operational Tests," you will use a DC voltmeter to make voltage measurements as you install designated integrated circuits on the circuit boards.

You will need an ohmmeter that provides a 1.5-volt DC test voltage; most analog volt-ohmmeters (VOM or VTVM) have this test voltage. In addition, the meter should have a center-scale number greater than 5 but less than 50.

You will also need a DC voltmeter for the operational tests. It should have an input impedance of 10 MΩ or greater so it will not load down the circuit being tested and cause a false reading. We suggest that you use an analog meter. If you use a digital voltmeter, the readings for some measurements may be jittery. Do not use a meter that has its common lead connected to earth ground.

IMPORTANT: Do not proceed with the following tests unless you have the recommended test instruments.

RESISTANCE CHECKS

CAUTION: Do not connect the line cord to an AC outlet until you are instructed to do so in a step.

NOTE: In the following tests, if you do not obtain the proper results, do not proceed further until you have found and corrected the problem. Refer to the "Resistance Checks Problem Chart" on Page 34.

Set the front panel controls as follows:

( ) POWER switch to the out (OFF) position.

( ) Push either the L or C switch part-way in until both switches spring to the out position.

( ) Set the RANGE switch to the 200 pF position.

( ) Be sure the "+15", "-15", "+5", and "-5" solder pads on the foil side of the main circuit board are **not** soldered together.

Refer to Pictorial 5-1 for the test point locations.

NOTE: Most ohmmeters have a positive test voltage polarity ("+" input lead), while some others have a negative test voltage polarity. You will determine the polarity of your ohmmeter test voltage in the next four steps.

( ) Connect the ohmmeter common test lead to the TP DC socket pin.

( ) Set the ohmmeter range to X10 or X100.

( ) Touch the ohmmeter input lead to the TP AC socket pin and note the resistance reading.

( ) Reverse the ohmmeter leads and again note the resistance reading.

If the first reading was lower than the second, your ohmmeter has a positive test voltage polarity. This identifies the ohmmeter input lead as the "+" lead. If the second reading was lower than the first, your ohmmeter has a negative test voltage polarity, identifying the ohmmeter common lead as the "+" lead. Be sure to keep this in mind when you are directed to use the ohmmeter "+" or "−" lead in the following tests.

CAUTION: In the following steps, use only the X10 or X100 ranges of your ohmmeter. Other meter ranges may cause excessive currents or may produce erroneously low readings.

Allow time for any capacitors in the circuit to charge before you take a final reading.

( ) Connect either ohmmeter lead to the line cord round pin. Touch the other ohmmeter lead to the rear panel GND stud. The ohmmeter should read approximately 0 ohms.

( ) Touch the ohmmeter lead to each line cord flat pin. The ohmmeter should read an open circuit (infinity) at each pin with the POWER switch in or out.

( ) Connect either ohmmeter lead to one line cord flat pin. Touch the other ohmmeter lead to the other line cord flat pin. The ohmmeter should read an open circuit (infinity) with the POWER switch out, and between 20 and 40 ohms with the POWER switch in. Reset the POWER switch to the out (OFF) position.

( ) Connect the ohmmeter "-" lead to TP1.

Touch the ohmmeter "+" lead to each of the points in Chart A and check for the readings indicated. NOTE: The symbol ">" in this chart means greater than; ≈ means approximately.

CHART A

TEST POINT		READING
( )	GND stud	≈0 Ω
( )	U104, pin 4	>2000 Ω
( )	U104, tab	>3000 Ω
( )	U107, pin 4	>1500 Ω
( )	U107, tab	>80 Ω
( )	I of U122	>9000 Ω
( )	TP7	>6000 Ω
( )	TP8	>100 Ω
( )	I of U123	>40 Ω
( )	I of U124	>10 kΩ
( )	TP9	>2000 Ω
( )	I of U125 (tab)	>40 Ω
( )	TP10	>100 kΩ
( )	TP11	>75 Ω

Reverse the ohmmeter leads, touch the "-" lead to the same test points, and check for the readings in Chart B.

CHART B

TEST POINT		READING
( )	GND stud	≈0 Ω
( )	U104, pin 4	>2000 Ω
( )	U104, tab	>5000 Ω
( )	U107, pin 4	>1500 Ω
( )	U107, tab	>20 kΩ
( )	I of U122	>35 Ω
( )	TP7	>300 Ω
( )	TP8	>6000 Ω
( )	I of U123	>30 kΩ
( )	TP9	>75 Ω
( )	I of U124	>35 Ω
( )	I of U125 (tab)	>40 kΩ
( )	TP10	>2000 Ω
( )	TP11	>5000 Ω

( ) Disconnect the ohmmeter leads.

Proceed to "Operational Tests."

RESISTANCE CHECKS PROBLEM CHART

Check the circuit areas listed in the following chart for the cause of an improper resistance reading. Also inspect the foil areas connected or adjacent to the listed component(s) for solder bridges between foils. The most common errors in circuit board construction are poor solder connections and solder bridges to adjacent foils. As you check the foils on a circuit board, it may be helpful to refer to the "Circuit Board X-Ray Views," (Illustration Booklet, Page 27 and 28).

If you still are unable to locate the cause of a problem, refer to the "In Case of Difficulty" section of this manual.

PROBLEM	POSSIBLE CAUSE OF LOW READING
Improper reading at line cord.	1. Wiring at AB to AL on main circuit board, at SW104, or at solder lug DH. 2. T1. 3. F102. 4. SW104.
Improper reading at GND stud.	1. Wiring at AA on main circuit board or at solder lug DJ.
Improper reading at U104, pin 4.	1. Short in +15 volt circuitry. 2. U104.
Improper reading at U104, tab.	1. Short in −15 volt circuitry. 2. U104.
Improper reading at U107, pin 4.	1. Short in +5 volt circuitry. 2. U107. 3. Wiring at AZ on main circuit board and CE on display circuit board. 4. SW101, SW102.
Improper reading at U107, tab.	1. Short in −5 volt circuitry. 2. U107. 3. Wiring at AY on main circuit board and CF on display circuit board.
Improper reading at I of U122.	1. C132. 2. D118, D119. 3. U122.
Improper reading at TP7.	1. C131. 2. U122. 3. "+15" solder pads not open.
Improper reading at TP8.	1. C133. 2. U123. 3. "-15" solder pads not open.
Improper reading at I of U123.	1. C134. 2. D121, D122. 3. U123.
Improper reading at TP9.	1. C135. 2. U124. 3. "+5" solder pads not open.
Improper reading at I of U124.	1. C136. 2. D124, D125. 3. U124.
Improper reading at I of U125.	1. C138. 2. D126, D127. 3. U125.
Improper reading at TP10.	1. V301 to V304. 2. D123. 3. Wiring at AX on main circuit board, and CD on display circuit board.
Improper reading at TP11.	1. C137. 2. U125. 3. "-5" solder pads not open.

OPERATIONAL TESTS

This part of the "Tests and Adjustments" contains a series of tests that will check out your Digital LC Bridge to make sure it is operating correctly. You will also install the ICs, each at the proper time, as you go through these tests and verify all of the circuits. Be sure you follow the IC installation instructions carefully.

Refer to Pictorial 5-2 for the locations of controls and test points.

PRESETTING THE CONTROLS

( ) Preset the controls on the main circuit board as follows:

20 CAL – Fully CCW
200 CAL – Fully CCW
LO D ZERO – Center of rotation
HI D ZERO – Center of rotation
D CAL – Center of rotation
VALUE CAL – Fully CCW
2000 CAL – Fully CCW
VALUE ZERO – Center of rotation
BUFFER ZERO – Center of rotation

( ) Unplug S101/102 from P101 at the rear of the main circuit board, and push the wires against the rear panel to keep them out of the way.

( ) Preset the LEAD NULL control on the front panel fully CW.

( ) Set the RANGE switch to the 200 pF position.

( ) Push the "C" switch in.

HOW TO MAKE THE TESTS

Use the following sequence for each test in the Charts.

1. Read the "Instruction or Test" information in each step carefully. It will tell you what to measure, or what the procedure is, and what the results should be.

2. Before you follow any instruction where an IC is to be installed or a solder connection is to be made, **turn off the LC Bridge power** (POWER switch out). Then, after you have performed the operation, turn the LC Bridge power back on and proceed.

Be sure you obtain the correct test results in each step before you proceed. If you do not obtain the proper results, turn off the power to the Digital LC Bridge and refer to the "Area of Possible Problem" column.

The "Area of Possible Problem" column tells you where to look for the difficulty. When a particular part is mentioned, check that part and the other components connected to it to see that they are installed and/or wired correctly. Refer to the "Circuit Board X-Ray Views" or to the schematic to help you locate these other components. More specifically:

- Check diodes for the correct position of the banded end, and electrolytic capacitors for the correct position of the "+" or "−" marked leads.

- When an IC is listed, be sure the correct IC is installed at that location, and make sure pin 1 is in the correct position. Note that all ICs on the main circuit board have pin 1 located in the same position.

- Carefully check the ICs and make sure no pins have accidentally bent underneath the IC. Make sure all pins are in their socket holes.

- Carefully inspect the foils near the circuit areas listed in the chart for solder bridges. Compare the foil areas with the "Circuit Board X-Ray Views."

- If you are still unable to locate the problem, refer to the "In Case of Difficulty" section of the Manual for further assistance.

CAUTION: When you make voltage measurements, be sure to touch your voltmeter probe only to the indicated test point. Should your probe slip and short to an adjacent pin, connection, or wire, severe damage to the LC Bridge could result.

WARNING: Hazardous voltages are present in several areas of the LC Bridge when the line cord is connected to an AC power source. See Pictorial 5-2. Be especially careful to avoid these areas when you are making voltage measurements.

( ) Connect the line cord to a 120 VAC outlet.

( ) Connect the common lead of a DC voltmeter to TP1.

NOTES: 1. All voltage readings are ±10% unless otherwise stated. Calibration standard values displayed during these tests may not be accurate.

2. When a waveform is referred to in a step, see "Waveforms" on Page 68. Use these waveforms, along with DC voltages and visual checks, to verify proper circuit operation when you are not sure you obtained the correct results in a step.

( ) Push the POWER switch in and proceed to step #1.

Refer to Pictorial 5-2 for the location of the test points.

INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
1. Measure: ( ) +15 volts at TP7. ( ) −15 volts at TP8.	1. C131, C132; or C133, C134. 2. D118, D119, D121, or D122. 3. U122 or U123. 4. Wiring at AB to AL, at AR to AT, or at SW104 on the main circuit board. 5. F102. 6. T1. 7. SW104.
2. Measure: ( ) +5 volts at TP9. ( ) −5 volts at TP11.	1. C135, C136; or C137, C138. 2. D124, D125, D126, or D127. 3. U124 or U125. 4. Wiring at AM to AP on main circuit board.
3. ( ) Turn the LC Bridge off, unplug the line cord, and remove the two circuit board mounting screws. Turn the board over and solder the +15, −15, +5, and −5 solder pads together. Remount the circuit board, connect the line cord and the common meter lead, and turn the LC Bridge on.	
4. Measure: ( ) +15 VDC at TP7 and U104 pin 4. ( ) −15 VDC at TP8 and U104 tab.	1. Short or open in +15 or −15 power supply circuits. 2. C141 to C166. 3. R177. 4. U104, U122, U123.
5. Measure: ( ) +5 VDC at TP9 and U107 pin 4. ( ) −5 VDC at TP11 and U107 tab. ( ) +4.7 VDC at TP10 and V304 pin 14. (foil side of the display board).	1. Short or open in +5 or −5 power supply circuits. 2. C167 to C171, C307, C309. 3. R178. 4. U107, U124, U125. 5. D123. 6. Wiring at AX, AY, or AZ on main circuit board; at CD, CE, or CF on display circuit board. 7. SW101, SW102.

NOTE: Some of the integrated circuits used in the LC Bridge are CMOS (complementary metal oxide semiconductor) devices. They are rugged and reliable parts once they are installed, but they may be damaged by static electricity as you install them. The remaining ICs are not subject to the same kind of damage. However, you should treat all ICs as though they were of the CMOS type to avoid any confusion between them, thereby providing the proper protection in every instance. Use the procedure, described in Detail 5-2A, without interruption, to install an IC.

INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
6. ( ) Unplug the line cord and unmount the circuit board. Install a 7107 IC (#442-724) at U301 on the display circuit board. Remount the board and reconnect the line cord. Be sure the C switch is still pushed in, and turn the Bridge on.	
7. ( ) Short the LAMP and TEST socket pins on the display circuit board together. The display should show "1888." Unshort the pins; display should read "000." Short together SW101 pins 1 and 2. Rotate LO D Zero CW. The display should increase from "000" to approximately "028". Recenter the control.	1. R133, R134, R137 to R139, R176, R241, R242, R301 to R304. 2. C301 to C306, C308 3. V301 to V304 4. Wiring at AX to BF on the main circuit board, or CD to CM on the display board. 5. U301. See waveforms 27 to 30.
8. ( ) Turn off the power and install the "D" ROM IC (#444-329) at U119.	

INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
9. ( ) Use the DC voltmeter to verify the high (H) and low (L) voltage conditions shown in the following "truth table" for U119. The letter H corresponds to a voltage greater than 2.4 VDC, and the letter L corresponds to a voltage less 0.5 VDC. Voltages may vary during switching. Disregard any display readings.	1. U119. See Logic Charts I, and II on Pages 71 and 72. 2. R179 to R182. 3. Wiring at BK to BN on main circuit board, or at SW1. 4. SW1.

RANGE	U119 pin 1	2	3	4	5	6	7
200 pF	H	H	L	H	H	L	H
2 nF	L	H	H	H	H	L	H
20 nF	H	L	H	H	H	L	H
200 nF	H	H	L	H	H	L	H
2 μF	L	H	H	H	H	L	H
20 μF	H	L	H	L	H	L	L
200 μF	H	H	L	H	L	L	L
2000 μF	H	H	H	H	L	H	L

INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
10. ( ) Turn off the power and install the "L/C" ROM IC (#444-330) at U121.	
11. ( ) Verify the following "truth table as you did above in step 9.	1. U121. See Logic Charts I, III on Pages 71 and 73. 2. D115, D116. 3. RY101, RY102.

RANGE	U121 pin 1	2	3	4	5	6	7
200 pF	L	L	L	H	H	H	H
2 nF	H	L	L	H	H	H	H
20 nF	L	H	L	H	H	H	H
200 nF	H	H	L	L	H	L	H
2 μF	L	L	H	H	L	L	L
20 μF	L	L	H	H	L	L	L
200 μF	L	L	H	H	L	L	L
2000 μF	L	L	H	H	L	L	L

INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
12. ( ) Verify the following displays.	1. V302 to V304. 2. R183 to R185. 3. Wiring at BG to BJ on main circuit board, or CA to CC on display circuit board. 4. U119.

RANGE	DISPLAY
200 pf	"00.0"
2 nF	".000"
20 nF	"0.00"
200 nF	"00.0"
2 μF	".000"
20 μF	"0.00"
200 μF	"00.0"
2000 μF	" 000"

INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
13. Turn off the power and install the following ICs. ( ) U101: TL061 IC (#442-679). ( ) U102: DG211 IC (#442-770). ( ) U103: CA3280 IC (#442-777). ( ) Set the L/C Bridge RANGE switch to 200 pF. ( ) Connect one end of the yellow wire set aside earlier to TP AC. ( ) Connect the DC voltmeter common lead to TP1 and the other lead to TP DC.	

In the following steps you will test for AC voltages. The free end of the yellow wire will be connected to the indicated test point. The test voltage is then measured at TP DC. Be careful to touch only the test point with the wire.

INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
14. ( ) Touch the yellow wire to TP2. Measure +3.6 (±.8) VDC.	1. U101 circuitry. See waveform 1. (Refer to "Waveforms" on Page 68). 2. R246. 3. C129. 4. Q101. 5. D101, D102, D117. 6. U101, U102.
15. ( ) Touch the yellow wire to TP3. Measure +.9 (±.3) VDC.	1. U103B circuitry. See waveform 2. 2. U104 circuitry. See waveforms 3, 4. 3. R147, R162, R165 to R167. 4. Q102. 5. D103, D104. 6. SW102, pins 8, 9 circuitry. 7. U103, U104.
16. Turn off the power and install the following ICs. ( ) U105: LF353 (TL072) IC (#442-707). ( ) U106: LF353 (TL072) IC (#442-707). ( ) U111: LF353 (TL072) IC (#442-707). ( ) U112: MC1458 IC (#442-21).	
17. ( ) Check U105 pin 7 for −10 VDC.	1. R141 to R146, R163. 2. U105.
18. ( ) Touch the yellow wire to TP4. Measure +1.0 (±.2) VDC.	1. U106A circuitry. See waveforms 5,6, and 7. 2. F101. 3. R123, R147. 4. Open at J1 and/or J2. 5. Wiring at BP to BT on main circuit board, or jumpers to display circuit board. 6. U106.

STEP INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
19. ( ) Touch the yellow wire to U111 pin 7. Measure +2.7 VDC.	1. U111A and U111B circuitry. See waveforms 5, 6, and 7. 2. U112A and U112B circuitry. See waveforms 16 and 17. 3. R207, R218. 4. D107, D108, D111. 5. Q102. 6. SW102. 7. U103, U111, U112.
20. ( ) Touch the yellow wire to U105 pin 1. Measure +.8 VDC.	1. U105A circuitry. See waveforms 8 and 9. 2. Wiring at AW on main circuit board, or at control R1. 3. U105.
21. Turn the power off and install the following ICs: ( ) U108: 4052 IC (#442-774). ( ) U116: DG211 IC (#442-770). ( ) U117: LF353 (TL072) IC (#442-707). ( ) Insert the 150 pF mica capacitor (CTEST) between J1 and J2.	
22. ( ) Touch the yellow wire to TP5. Measure +.07 (±.03) VDC.	1. U107 circuitry. See waveforms 10 and 11. 2. U108 circuitry. See waveforms 12 and 13. 3. U116B and U116C circuitry. 4. U106B circuitry. 5. RY102. 6. R1, R171. 7. C108, C109. 8. D105, D106. 9. Wiring at AU on main circuit board, or R1. 10. SW102. 11. U106, U107, U108, U116.
23. ( ) Touch the yellow wire to TP6. Measure +1.8 (±.3) VDC.	1. U117A and U117B circuitry. See waveforms 21, 23, and 24. 2. U116A circuitry. 3. R224, R228, R232 to R234. 4. SW102. 5. U116, U117.
24. ( ) Turn off the power and install an MC1458 IC (#442-21) at U118.	
25. ( ) The display shows "150.0" (± 20.0). Set the RANGE switch to 2 nF position. The display should show ".150" (±.030). Set the RANGE to the 20 nF position. The display should show "0.15" (±.15).	1. U118 circuitry. See waveforms 25 and 26. 2. U301 circuitry. 3. R1, R131 to R134, R172, R173, R176, R243 to R245. 4. C108, C109, CTEST 5. Wiring at AU to AW on main circuit board, R1. 6. SW102.
26. Turn off the power and install the following ICs: ( ) U109: DG211 IC (#442-770). ( ) U113: LM311 IC (#442-75). ( ) U114: CA3280 IC (#442-777). ( ) U115: LF353 (TL072) IC (#442-707). ( ) Set the RANGE switch to 200 pF.	

INSTRUCTION OR TEST	AREA OF POSSIBLE PROBLEM
27. ( ) Measure +2.5 VDC at U113 pin 7.	1. U113 circuitry. See waveform 18. 2. U109.
28. ( ) Push and hold the "D" switch in. The Display should show ".010" (±.010). NOTE: It may take up to one minute for reading to stabilize. ( ) Remove the 150 pF (CTEST) capacitor. Solder a 1 MΩ (brn-blk-grn) resistor, RTEST, in parallel with CTEST. Then install the assembly at J1/J2. Hold the "D" switch in and adjust D CAL to display "1.060" (±.010). It may be necessary to cut W104 open. ( ) Remove the test assembly.	1. If the "C" value varies more than 5% different from step 25. A. U109 circuitry. See waveform 19. B. U114 circuitry. See waveforms 20 and 22. C. U115 circuitry. D. D112. E. Q103. 2. U114B circuitry. 3. U115B circuitry. 4. RTEST.
29. Locate the Calibration Pack, #100-1853. In the following five steps, you will use parts from this package. Be sure to insert the "+" lead of capacitors into the "+" marked jack (J1) or the "−" lead into the "−" marked jack (J2). Use long-nose pliers to help insert the leads into the jacks.	
30. ( ) Set the RANGE switch to 200 nF and insert the 150 nF (.15 μF) capacitor. The display should show approximately "150.0". Remove the capacitor and set it aside.	1. U108 circuitry. 2. U116C circuitry. 3. R174, R175.
31. ( ) Set the RANGE switch to 20 μF and insert the 15 μF capacitor. The display should show approximately "15.00". Remove the capacitor and set it aside.	1. U102 circuitry. 2. U109B, D circuitry. 3. U116B, D circuitry. 4. RY101, RY102. 5. R122, R123, R174.
32. ( ) Set the RANGE switch to 200 μF and insert the 150 μF capacitor. The display should show approximately "150.0". Remove the capacitor and set it aside.	1. U109A circuitry.
33. ( ) Set the RANGE switch to 2000 μF and insert the 1000 μF capacitor. The display should show approximately "1000". Remove the capacitor and set it aside.	1. U116A circuitry. 2. R122, R123. 3. RY101, RY102. 4. U104, U107, U116.
34. ( ) Set the RANGE switch to 200 nF and insert the 150 nF (.15 μF) capacitor. Push the "L" switch. The display should show approximately "170.0". Remove the capacitor and set it aside.	1. SW102 circuitry.

( ) Push the POWER switch off (out) and unplug the line cord.

( ) Disconnect the yellow wire and the voltmeter leads.

( ) Remove the two 4-40 × 3/8" screws that hold the main circuit board in place at DL and DM. Then place #4 lockwashers over the screws and loosely reinstall them. Tighten the screws only finger tight.

( ) Loosely install two 4-40 × 3/8" screws and #4 lockwashers at DQ and DR to secure the display circuit board.

( ) Loosely install two 4-40 × 3/8" screws and #4 lockwashers at DN and DP on the main circuit board. Now tighten all six mounting screws.

( ) Connect S101/102 to P101 (NORM) on the main circuit board.

( ) Return all calibration parts to the Calibration Pack.

This completes the "Tests and Adjustments." Proceed to "Calibration."

CALIBRATION

There are two different methods you can use to calibrate your Digital LC Bridge. You can use the resistor and four capacitors in the calibration package (#100-1853) supplied with your kit; or you can use laboratory standard capacitors and a precision dissipation resistor of exact, known values. Refer to the "Specifications" if you want to compare the accuracies of these two methods.

- If you intend to use the calibration package, proceed directly to "Adjustments" on Page 45. NOTE: If your LC Bridge has not been calibrated in the last six months, complete the instructions in "Supplied Reference Maintenance" on Page 47 to "reform" the capacitors before you start these adjustments. Note also that there should be a 24-hour rest period after the "reforming" before you use the capacitors.

- If you intend to use the laboratory (high precision) method, refer to "Laboratory Standards Preparation" below. You will need four capacitors and a resistor with certified (or measured) values within 0.1%.

LABORATORY STANDARDS PREPARATION

To calibrate your Digital LC Bridge with laboratory standard components, either use capacitors that have a certified value at the required frequency, or capacitors that have been measured on a high-precision instrument to provide "transfer" accuracy. This instrument must provide a sinusoidal test voltage at a frequency of 1000 Hz or 120 Hz as indicated below. For a dissipation standard, use a resistor with a certified value, or measure a resistor on a high-precision ohmmeter to determine its value within 0.1%.

The laboratory standard components you will need are listed below.

150 nF standard—Use any value between 100 nF (.10 μF) and 190 nF (.19 μF) known within 0.1% at 1000 Hz. It must have a dissipation of 0.2% (.002) or less.

15 μF standard—Use any value between 10 μF and 19 μF known within 0.1% at 120 Hz. It must have a dissipation of 10% (.10) or less.

150 μF standard—Use any value between 100 μF and 190 μF known within 0.1% at 120 Hz. It must have a dissipation of 10% (.10) or less.

1000 μF standard—Use any value between 1000 μF and 1900 μF known within 0.1% at 120 Hz. It must have a dissipation of 10% (.10) or less.

Dissipation standard—This calibration value results from the parallel connection of a resistor (R) and the 150 nF standard capacitor (C). The approximate value for R is determined from:

$R = 120/C$ Where R is in kΩ, and C is in nF (.001 μF).

For a 100 nF capacitor, approximately 1200 Ω is required; and for a 190 nF capacitor, approximately 630 Ω is required. Once you have determined the general value, measure the resistor's exact value within 0.1%. Also measure the Digital LC Bridge test frequency on the 200 nF range to within 0.1%. You can then calculate a dissipation standard number (approximately 1.200) from:

$D = 1000/(6.283 \times f \times R \times C)$ Where f is in kHz, R in kΩ, and C is in nF.

ADJUSTMENTS

NOTE: If you are using the calibration package, you must calibrate the Digital LC Bridge at the ambient temperature indicated on the envelope. Calibration at a temperature other than this may result in an adjustment error as high as 1% per degree Fahrenheit, or you might even be unable to adjust the Bridge to the required value. If you are using laboratory standards, calibrate the Bridge at the rated temperature (marked on the standard), or the temperature at which you measured the standards.

( ) If necessary, remove the 8 cabinet screws and slide the cabinet off (toward the rear panel).

( ) Plug the line cord into an AC outlet and turn the Digital LC Bridge on.

( ) Push the "C" switch in.

NOTE: Allow the Digital LC Bridge to warm up at least one hour before you proceed with the calibration.

PRESETTING THE CONTROLS

Perform these steps if you are not familiar with the locations of the various controls, or if you have recently repaired the Digital LC Bridge. If it has been recently factory serviced, calibration was done at that time and would not normally be required now.

If you just completed the assembly of your Digital LC Bridge, you will have already preset these controls; proceed to the "Fine Adjustments."

This section will:

A. Familiarize you with the locations and names used to identify the calibration controls and jumpers.

B. Minimize the possibility of erroneous high or low readings which may occur during the calibration, due to randomly set controls.

C. Improve the effectiveness of voltage and resistance measurements during troubleshooting if a problem should arise during calibration.

Refer to Pictorial 5-2 for the following steps.

Set the switches, controls, and jumpers as follows:

20 CAL	Fully Counterclockwise
200 CAL	Fully Counterclockwise
LO D ZERO	Center of rotation
HI D ZERO	Center of rotation
D CAL	Center of rotation
VALUE CAL	Fully Counterclockwise
2000 CAL	Fully Counterclockwise
VALUE ZERO	Center of rotation
BUFFER ZERO	Center of rotation
W101 to W104	Closed

Set the front panel LEAD NULL control fully clockwise.

Proceed to the "Fine Adjustments."

FINE ADJUSTMENTS

NOTES:

1. Handling the body of the calibration capacitors during the following steps may heat them and cause a temporary value change. Therefore, handle them only by their leads and for only the shortest possible time. You may also use needlenose pliers to minimize heating.

2. If you will be using the components from the calibration package, be sure to save the envelope for future use.

3. If you fail to obtain the desired results in any of the following steps, refer to the "In Case of Difficulty" section. Locate and correct any problem before proceeding to the next step.

4. When a standard component is called for, use the appropriate value from the calibration package, or the appropriate component from your laboratory standards.

Refer to Pictorial 5-2 for the following steps.

1. Set the RANGE switch to 200 nF. Set the BUFFER ZERO control fully clockwise. Then adjust the VALUE ZERO control for a display of "00.0".

2. Set the BUFFER ZERO control fully counterclockwise. Some value; for example, "02.0" should be displayed. **Slowly** adjust the BUFFER ZERO control clockwise until the display just changes from "00.1" to "00.0". Then rotate the control clockwise an additional 30° (one "hour" of a clock).

3. Install the 150 nF (.15μF) standard capacitor.

4. Set the RANGE switch to 20 μF. Adjust the VALUE ZERO control to show the capacitor value rounded to 2 digits; for example, "153.6" would become "0.15".

5. Set the RANGE switch to 200 nF. Set the VALUE CAL control fully counterclockwise and observe the display. If the value displayed is higher than that of the 150 nF standard, cut jumper W101. If the display still reads higher, or if W101 has already been cut, cut jumper W102. If the display is still higher, cut W103. The proper number of jumpers has been cut when the display is at least 20 counts (ignoring the decimal point) below the "150 nF standard" value. Then adjust the VALUE CAL control until the display reads the 150 nF standard value.

6. Repeat steps 4 and 5 until no further adjustment is required.

7. Set the RANGE switch to 20 μF. Then install the "15 μF standard" capacitor. Be sure to observe the polarity markings on the capacitor. Adjust the 20 CAL control to display the 15 μF standard value.

8. Set the RANGE switch to 200 μF and install the 150 μF standard capacitor, observing polarity. Adjust the 200 CAL control to display the 150 μF standard value.

9. Set the RANGE switch to 2000 μF and install the 1000 μF standard capacitor, observing polarity. Adjust the 2000 CAL control to display the 1000 μF standard value.

10. Reinstall the 150 nF standard capacitor.

NOTE: The HI D ZERO and LO D ZERO controls in the following steps have a zero position (the display shows ".000") where numbers displayed clockwise from the zero are considered positive (+) and numbers displayed counterclockwise from the zero are considered negative (−). All settings must be set clockwise from the zero to be positive values.

11. Set the RANGE switch to 200 nF. Set the HI D ZERO control fully clockwise. Push the D switch in and hold it while adjusting the HI D ZERO control counterclockwise to display a positive ".002". Do not adjust past the zero point. Set the RANGE switch to 2 µF, hold the D switch in, and adjust the LO D ZERO control first fully clockwise, and then counterclockwise, to display a positive ".002".

12. Set the RANGE switch to 200 nF. Hold the D switch in and note this display reading. While still holding the D switch in, set the RANGE switch to 2 µF and readjust the LO D ZERO control to the same display reading. Do not adjust it through the zero point.

13. Set the RANGE switch to 200 nF. Connect the dissipation standard resistor in parallel with the 150 nF standard capacitor.

14. Hold the D switch in and adjust the D CAL control to display the dissipation standard value within ±.002. If you are unable to adjust up to the required display, cut jumper W104. If you are unable to adjust down to the required display, close jumper W104 (if open).

15. Disconnect the dissipation standard resistor and repeat steps 12 to 14 until no further adjustment is required.

16. Disconnect the 150 nF standard capacitor. Set the RANGE switch to 200 pF. Adjust the front panel LEAD NULL control to display the lowest number, typically less than "00.5".

( ) Return the calibration references to the calibration package. Store these components as described in "Supplied References Maintenance." If you used calibrated laboratory standards, store them as you would the supplied references.

NOTE: The inductance (L) ranges of the Digital LC Bridge have been calibrated as a result of the capacitance (C) calibration.

( ) Turn the Digital LC Bridge power off and disconnect the line cord from the AC outlet.

This completes the calibration of your Digital LC Bridge. Be sure to read "Maintaining Your Bridge's Accuracy" on Page 48 before proceeding to "Final Assembly."

SUPPLIED REFERENCE MAINTANENCE

GENERAL

The calibration components you received with your Digital LC Bridge should provide several years of stability and precision if you store and handle them as follows, and reform them regularly.

1. Do not allow these calibration components to be exposed to temperatures outside the range of 60 to 90oF (15 to 32°C). Prolonged storage at high or low temperatures will irreversibly alter their values.

2. Do not mechanically stress the leads of these components. Use needlenose pliers to insert the leads into the LC Bridge input contacts. This will not only minimize heating of parts, but also will minimize stress on the leads.

3. At least annually, but not more than twice a year, perform the following "Capacitor Reforming" steps. For the 15 µF, 150 µF, and 1000 µF electrolytic capacitors, and to a lesser degree for the 150 nF (.15 µF) film capacitor, the application of a forming voltage reduces the tendency of the electro-chemical structure in these parts to degrade and/or drift.

CAPACITOR REFORMING

NOTE: This procedure should not be required within the first six months of the purchase date.

( ) Connect the line cord to an AC outlet and turn the Digital LC Bridge power on.

( ) Move S101/102 from P101 (NORM) to P102 (CAL) at the rear of the main circuit board.

Refer to the CAL row markings for terminal strip TS1 on the rear panel for the following capacitor connection steps.

( ) Loosen the "−" and "+15" screws on rear panel terminal strip TS1, and then carefully secure the leads of the 150 nF (.15 μF) capacitor under the screw heads. Position the lead with the band or color dot to the "−" screw. This connects a 15 VDC source to the capacitor through a current-limiting resistor. Allow the capacitor to "form" for approximately one hour. Then remove it and set it aside.

CAUTION: Be sure to observe the polarity markings on the electrolytic capacitors in the following steps, so they are not reverse-voltaged. Also be sure to attach them to the correct terminals or they may be over-voltaged. If either condition occurs, the value of the capacitor may be irreversibly altered.

( ) Loosen the "−" and "+5" screws then secure the ends of the leads of the 15 μF capacitor under the screw heads. This connects the capacitor to a 5 VDC source through a current-limiting resistor. Allow the capacitor to "form" for approximately one hour. Then remove it and set it aside.

( ) Similarly connect the leads of the 150 μF capacitor to the "−" and "+5" terminals. Leave the capacitor connected for approximately one hour. Then set it aside.

( ) Similarly connect the leads of the 1000 μF capacitor to the "−" and "+5" terminals. Leave the capacitor connected for approximately one hour. Then set it aside.

No conditioning of the reference resistor is necessary.

( ) Remove S101/102 from P102 and reconnect it to P101.

( ) Tighten the terminal strip screws.

( ) Allow a 24 hour minimum rest period before you use the capacitors for calibration. Mark the date the capacitors were conditioned on the calibration package envelope as a reminder.

MAINTAINING YOUR BRIDGE'S ACCURACY

1. Because the initial aging of its components may cause small calibration shifts in your Digital LC Bridge, it may take some time for a newly-assembled Bridge to fully stabilize.

2. Even Digital LC Bridges that have stabilized over a period of time may still have small calibration shifts when they are exposed to high or low temperature extremes for the first time. If you are likely to use your Digital LC Bridge over a wide temperature range, you should expose it for a period of time to both the high and low temperatures, and then recalibrate it.

3. All precision instruments require regular recalibration to ensure maximum accuracy, even after time and temperature stabilization. The period between calibrations may vary from a few weeks for newly-assembled instruments to several months for those that have fully stabilized. You should also consider recalibration prior to critical use.

4. When you are in doubt about the accuracy of your Digital LC Bridge, verify it **only** against a precision standard. Other forms of verification may be significantly in error.

FINAL ASSEMBLY

CABINET INSTALLATION

Refer to Pictorial 6-1 for the following steps.

( ) Be sure connector S101/102 is pushed onto P101 (NORM) at the rear of the main circuit board.

( ) Slide the Digital LC Bridge into the cabinet as shown. Secure the cabinet to the rear panel with four 6-32 × 3/8" screws.

( ) Secure the cabinet to the chassis bottom with four 6-32 × 3/8" screws.

ACCESSORY CABLE CONSTRUCTION

Refer to Pictorial 6-2 for the following steps.

( ) Refer to Detail 6-2A and prepare four 12" lengths of shielded cable.

( ) Refer to Detail 6-2B and slide a black alligator clip insulator over end A of two of the shielded cables.

( ) Similarly, slide red alligator clip insulators over end A of the remaining two shielded cables.

( ) Refer to Detail 6-2C and install an alligator clip on end A of each of the four shielded cables.

( ) After the solder has cooled, push each of the four alligator clip insulators down over the respective alligator clips as shown in the Pictorial.

Refer to Detail 6-2D for the following steps.

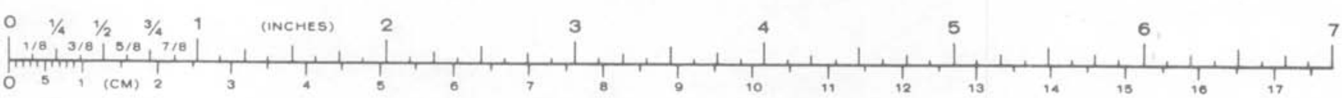
NOTES: 1. In some of the following steps, you may find the shield wires of cables too large to insert in the circuit board holes. If this occurs, trim the shield wires thinner with diagonal cutters so the shield will fit in the hole.

2. Solder each lead as you connect it and cut off any excess lead lengths.

( ) Position the printed circuit card connector as it is shown in the Detail.

( ) Connect the center lead at end B of one shielded cable with a black insulator to the indicated hold (near the − sign) on the printed circuit card connector.

( ) Connect the shield wires of the shielded cable to the indicated hole.



( ) Connect the center lead at end B of one red insulator shielded cable to the indicated hole (near the + sign) on the printed circuit card connector.

( ) Connect the shield wires of the shielded cable to the indicated hole.

( ) Turn the printed circuit card connector over as shown in Detail 6-2E.

Refer to Detail 6-2E and connect end B of the remaining red insulator shielded cable to the printed circuit card connector as follows. Solder each lead and cut off any excess lead length.

( ) Center lead to the indicated hole (near the + sign).

( ) Shield wires to the indicated hole.

Again, refer to detail 6-2E and connect end B of the remaining black insulator shielded cable to the printed circuit card connector as follows. Solder each lead and cut off any excess lead length.

( ) Center lead to the indicated hole (near the − sign).

( ) Shield wires to the indicated hole.

( ) Refer to the inset drawing on Pictorial 6-2 and use a cable tie to secure the two cables with black insulators to the printed circuit card connector at the location shown.

( ) Use another cable tie to secure the two shielded cables with red insulators at the other location on the printed circuit card connector.

This completes the "Final Assembly." Proceed to "Operation."

OPERATION

> WARNING: To prevent fire or electrical shock hazard, do not expose your Digital LC Bridge to rain or moisture.

This portion of the Manual is divided into several parts. The first section, "General," tells you about the control functions, the display, safety precautions, and other operating information of a general nature. The next part, "Measurements," gives you complete and detailed operating instructions. The remaining three sections; "Measurement Considerations," "Accessory Cable/Test Fixture Use," and "Rear Panel VALUE OUT Usage"; present guidelines and techniques you can use to get the best possible accuracy and the most effective use of your LC Bridge.

Be sure to read all of this information carefully before you use your Digital LC Bridge.

GENERAL

CONTROL FUNCTIONS

Refer to Pictorials 7-1 and 7-2.

DISPLAY — Displays the capacitance, inductance, or dissipation factor value from 000 to 1999 with automatic decimal point placement, as required.

RANGE switch — Selects the desired measurement range for capacitance (C) or inductance (L) functions.

C switch — Selects the capacitance (C) measurement function.

L switch – Selects the inductance (L) measurement function.

D switch — Selects the dissipation (D), or loss, measurement function.

"+", "−" slots — Input connectors for the capacitor or inductor being measured. These are 4-terminal "Kelvin-type" connections.

LEAD NULL — Provides a nulling adjustment on the 200 pF range and allows you to minimize stray capacitance when you use the Accessory cable or a test fixture.

VALUE OUT — Provides a DC voltage (0 to +2V through 2200 Ω) proportional to the "L" or "C" being measured. The "-" terminal is tied to ground.

BIAS IN — Provides a means to apply a DC bias voltage (0 to +10 V) to capacitors. Input resistance is 8200 Ω; output polarity is as shown on the front panel. The "-" terminal is tied to ground. Inoperative in the "L" function.

GND terminal — Provides a direct ground connection for use with the Accessory cable or a test fixture.

SAFETY MARKING

The front and rear panels of the Digital LC Bridge are labeled with the following standard operator symbol:

⚠

This advises the operator to refer to this Manual for operating information.

SAFETY PRECAUTIONS

Occasionally, you may use your Digital LC Bridge while you check, maintain, or repair electronic equipment which contains DANGEROUSLY HIGH VOLTAGES. Because of this potential danger, you should always observe the following safety procedures:

1. Always handle test probes by the insulated portion only. Be careful not to touch any exposed metal parts.

2. When you are measuring high voltages, turn off the power to the equipment being tested before you connect test leads. If this is not possible, be very careful to avoid accidental contact with any object that could provide a ground return path (circuit completion).

3. Insulate yourself from ground whenever possible by standing on a properly insulated floor covering.

4. Whenever possible, use only one hand when you make measurements with the equipment power turned on. Keep the free hand in your pocket or behind your back to prevent accidental shock.

DISPLAY UNITS/POLARITY

The measurement display is a direct readout of the component value. The units are indicated by the position of the RANGE switch and the decimal point is automatically positioned. All readings are positive.

OVERRANGE INDICATION

Whenever the value of the component being measured exceeds 1999 counts in the selected range, the display will show a 1 in the left-most position and the appropriate decimal point will be lit. All other digits are blanked. The same display occurs whenever the input contacts ("+", "−") are shorted during a capacitance measurement, or open during an inductance measurement.

± 1 COUNT

It is normal for the right-hand digit of the display to alternate one number above and below a reading on successive readings, and one or two numbers under certain conditions. Measurement displays of low value capacitors or high value inductors may be more unstable in the presence of stray line-frequency radiation.

WARM-UP

For maximum stability and accuracy, you may wish to leave the Digital LC Bridge on continuously during the day. To insure best accuracy, allow a 30-minute warm-up period. However, you can make measurements immediately upon turn-on. A slight readjustment of the LEAD NULL may be necessary for measurements on the 200 pF range.

INPUT OVERLOAD PROTECTION

CAUTION: Before you measure any capacitors with the Digital LC Bridge, discharge them through a resistor. The "+", "−" input circuitry is protected against input overloads as long as the overload is within the limitations indicated in the "Specifications" section of this Manual.

The BIAS IN terminal will withstand a continuous ± 20 VDC overload. The VALUE OUT terminal will withstand a continuous short to ground or a continuous ± 20 VDC overload.

FUSE REPLACEMENT

The Digital LC Bridge is protected by two fuses. One is in series with the AC line voltage. Replace this fuse only with the same rated value as shown on the fuse label located on the inside rear panel. The second fuse is in series with the "+" input connector to protect against charged capacitors or a direct power input. To prevent hazardous situations or damage to the Digital LC Bridge, this fuse should only be replaced with a 1 Ampere, 250V, 3AG, standard fuse.

MEASUREMENTS — BASIC OPERATION

The normal measurement procedure is as follows:

- **Warm-up** — Connect the Digital LC Bridge line cord to a 120 VAC outlet, push the POWER switch ON (in), and allow a 30-minute warm-up period.

- **Component Leads**

  SIZE: See if you can properly insert the component leads into the front panel "+" and "−" input connectors. These connectors will accommodate lead diameters to .062″ (AWG #14, 1.6 mm), with lead spacing from .2″ (5.1 mm) to 2.5″ (63.5 mm). Use the Accessory Cable or another testing fixture for component leads that fall outside these ranges. Refer to "Accessory Cable/Test Fixture Use" on Page 57.

  CONDITION: Leads should be clean of waxes, fluxes, and oils. An accumulation of these substances can cause intermittent contact on small leaded components.

- **Select the Function** — Select the appropriate measurement function, "L" or "C".

  If you do not know the type of component, select the "C" function. This limits the maximum test voltage amplitude. An inductor will normally overrange on most ranges, or give greatly different values on adjacent ranges, indicating an abnormal condition. A resistor will display a low value with a low "D" on all but the lowest range, where it will suddenly have a high dissipation. Certain types of high- value, wire-wound resistors or RF chokes may exhibit some capacitance, but will not produce the same values on different ranges. A resistance reading will usually determine if the component is actually a resistor or inductor.

- **Select the Range** — Select an appropriate range.

  If you do not know the value, start with the highest range; and then reduce it until a reading between 200 and 2000 is displayed.

- **Capacitor Bias** — Determine if you need a DC bias from available component specifications. A bias voltage is normally required for varicap diodes and some types of tantalum capacitors. If the required bias is 10 volts or less, apply it to the rear panel BIAS IN terminals. The bias voltage supply must have low output ripple, good regulation, and be capable of supplying the bias voltage across an 8200 Ω load. If this bias is critical, you can measure it directly at the front panel "+" and "−" input connectors. Bias voltages of 10 to 50 VDC must be applied using the Accessory Cable. Bias voltages above 50 VDC CAN NOT be used.

- **LEAD NULL Adjustment** — To measure low value capacitors, set the RANGE switch to 200 pF and adjust the LEAD NULL control for a minimum reading, usually "00.1" or "00.2". Since the stray capacitance value is decade-reduced, it becomes insignificant on higher ranges. Other uses for this control are discussed in "Accessory Cable/Test Fixture Use" (Page 57).

- **Connect the Component** — Insert the leads of the component to be measured. Use needlenose pliers to help insert small or overly large component leads. No shock hazard exists at the low test voltages used.

  NOTE: To ensure proper contact, do not insert more than one lead at a time into the input connector. To prevent erroneous readings, components must be isolated from (earth) ground.

- **Read the Value** — Observe the display. If the reading is above 2000 or below 200, select the next (higher or lower) range for greater accuracy and resolution.

  NOTE: Some inductors are sensitive to currents and will likely indicate a lower value on a lower (high current) range. If a great difference between readings exists, the higher range value is most likely to be correct.

- **Determine the Units** — Determine the unit of measurement from the front panel RANGE switch legend (i.e., pF, nF, μF, etc.).

- **Read the Dissipation Factor** — Determine the dissipation factor by pushing and holding the "D" switch until the display stabilizes. Refer to vendor specifications or compare readings with similar parts to determine if the reading is acceptable. Generally, the "D" reading for good capacitors will be .150 or less; good inductors will read .500 or less. See "Measurement Considerations."

- **Accuracy Determination** — You can determine the uncertainty (accuracy) of the value displayed by inserting your readings into the following formula:

  ± {(.5% of C) + [(1.5% of C) × (D reading)] + .5pF + 1 count}.

  OR

  ± {(.5% of L) + [(1.5% of L) × (D reading)] + .5 μH + 2 counts}.

  For example, a "C" reading of 150.2 nF with a .100 "D" reading provides an uncertainty of:

  = ± [(.005 × 150.2) + (.015 × 150.2 × .100) + .5 pF + .1]

  = ± [.75 + .23 + .0005 (insignificant) + .1]

  = ± 1.08 nF

  The above calculations show that all of the measured characteristics (stray capacitance, etc.) except the value of the capacitor itself are relatively insignificant.

- **Discharging Capacitors** — Discharge any bias-charged capacitors after measurement, but DO NOT use a short circuit or you may damage the capacitor.

  Capacitors biased using the rear terminal strip will discharge through the Bridge. Capacitors with externally applied bias must be discharged directly. Disconnect the capacitor from the Bridge WITHOUT TOUCHING its leads or terminals. Then, carefully discharge it through a low-value, high wattage resistance, such as a 100 Ohm, 10 watt, wire-wound resistor. (This resistor may become very warm.)

MEASUREMENT CONSIDERATIONS

Capacitors and inductors are more difficult to measure than resistors because you have to use an AC test frequency to measure them. And since inductors and capacitors are usually not pure reactance, you also have to use either a series or parallel combination of resistance (R) and reactance (X) to represent their electrical characteristics.

One of the most troublesome measurement difficulties occurs because the value of most inductors and some capacitors can change as the AC test frequency or test level changes. As a result, parts manufacturers usually specify the test conditions when they establish component values. This was considered when the test frequencies and voltage/current levels were chosen for this LC Bridge; thus, they are representative of the manufacturer's normal testing conditions and frequencies (120 Hz and 1000 Hz). A series-equivalent circuit is used to measure inductance (L), and a parallel-equivalent circuit is used to measure capacitance (C).

Measurement differences are strongly influenced by the D value (loss factor) of a component; and they can show up as a function of frequency variations or level variations. The readings you obtain for a part on the 2 μF or 2 H range (1000 Hz test frequency), for example, may be different from what you get on the 20 μF or 20 H range (120 Hz test frequency) for high loss (high D value) components. If a component has a high dissipation (D) factor, be suspicious about the indicated value (L or C), especially if the D function is overranged.

Although both capacitors and (especially) inductors may be sensitive to test levels, inductors with ferrite or iron cores are especially sensitive. Refer to the "Specifications" (Page 74) for the test levels used. This may influence the range you chose for measurements.

Pictorial 7-3 shows the mathematical relationships for the different elements in inductors and capacitors. When the series resistance is low or the parallel resistance is high, the measured value of the component will be nearly equal to its actual value. This is equivalent to a low D value (low loss). When the series resistance is high or the parallel resistance is low, there will be a significant difference between the measured value and the actual value.

INDUCTANCE MEASUREMENTS

- The Digital LC bridge measures the total reactance connected to its inputs. Both the unknown inductor and any lead length contribute to this, as leads have both inductive and resistive properties.

  For greater accuracy on low L measurements, minimize the load impedance. Short, closely spaced, twisted leads reduce pickup of stray line frequency or RF radiation. Use of the Accessory Cable adds only slight L and R properties because of the 4-terminal input connection. See "Accessory Cable/Test Fixture Usage" in this section.

- A series-equivalent circuit is the usual representation for inductive reactance. However, there are times when a parallel-equivalent circuit is a better model. At low frequencies, the major aspect of loss is the resistance in the wire and the series circuit is the best choice. If the inductor has an iron or ferrite core, the significant loss at high frequencies may be the core loss (resulting from eddy currents or hysteresis). Here, the parallel circuit is the best choice. The mathematical models of Pictorial 7-3 can help you translate between these models.

- When you are making high inductance measurements, keep stray capacitance and AC pickup to a minimum. Keep your hands as far away from the inductor as possible. Keep test leads short and direct. Enclosing the inductor in a large, grounded metal enclosure to minimize stray capacitance may be helpful for inductances greater than 20 H.

CAPACITANCE MEASUREMENTS

- You can measure electrolytic capacitors greater than 2000 µF as follows:

  A. Measure any capacitor between 1000 µF and 2000 µF. Record this value (C_{ref}.).

  B. Connect the unknown capacitor in series with the measured capacitor. Record this value (C_s).

  C. Compute the unknown capacitor value (C_x) from the equation:

  $$C_x = \frac{(C_{ref}) \times (C_s)}{(C_{ref}) - (C_s)}$$

  Using this method, you can measure capacitors up to 10,000 µF within 2% resolution, and up to 100,000 µF within 10%.

- The Digital LC Bridge measures parallel capacitance only. The relationship between parallel and series C is:

  $$C_s = (1 + D^2) \times C_p$$

  Pictorial 7-4 shows the relationship between C_s and C_p. To use the graph, first measure the C_p and D values of the capacitor. Locate the D value along the horizontal axis. Then move up the graph to the curve, and over to the vertical (multiplier) axis. Multiply the C_p value by the multiplier to obtain the C_s value.

- There will be no significant difference in readings for electrolytic capacitors measured at 120 Hz versus a 100 Hz test frequency (representing power line frequencies).

DISSIPATION (D) FACTOR MEASUREMENTS

- For convenience or comparison, you may want to identify the "Q" (quality factor) of an inductor. This is the reciprocal of the D factor ($Q = 1/D$). However, for very low D values the ±1 count resolution may make the Q value only approximate.

- The Digital LC Bridge measures D to 1.999. For capacitors, this is generally adequate. Some inductors, however, can have a D exceeding 2.000. To measure the D of such coils:

  A. Measure a coil of about 10 times the inductance of the coil with the high D. Record its inductance (L_{ref}) and loss (D_{ref}).

  B. Connect the high D coil in series with the previously measured coil. Record the series inductance (L_s) and loss (D_s).

  C. Compute the unknown inductance (L_x) and loss (D_x) from the following equation:

  $$L_x = L_s - L_{ref}$$

  $$D_x = \frac{(D_s \times L_s) - (D_{ref} \times L_{ref})}{(L_s - L_{ref})}$$

  Should a larger coil not be available, you can use separate measurements of the inductance and resistance used to compute the loss from:

  $D = R/(2 \times pi \times f \times L_x)$ Where f is the measurement frequency.

- When you are using a mathematical model to calculate equivalent series resistance (ESR) for a capacitor, an unrealistically low figure may result since ESR specifications also include the resistance of wire leads and internal foil as well as dielectric loss (which is frequency dependent).

ACCESSORY CABLE/TEST FIXTURE USE

Do not use the front panel connectors to measure components with very large diameter leads (over 1/16"); use the Accessory Cable. You can also use this Cable to:

— Measure physically large components that are secured to a chassis and/or are not removeable.

— "Batch" measure components on tape carrier strips which are not to be removed.

— Measure low value capacitors or high value inductors where a shielded enclosure is used to reduce pick-up from stray line-frequency or RF radiation.

— Connect to calibration standards.

Pictorial 7-5 illustrates a circuit you can use for the Accessory Cable, or other test fixture cabling. The length of the wiring does not introduce significant measurement error because of the 4-terminal input connectors. You can omit the ground lead or use twisted pair wiring for each power/sense circuit if you are measuring capacitors greater than .01 μF or inductors less than 20 H. The Accessory Cable is directly useable on the lower C ranges without a ground wire (adjustment of the LEAD NULL control is required). However, the greatest reduction of stray capacitance is provided if you connect the shield wire foil area of the Accessory circuit card to the rear panel GND stud with a separate clip lead.

NOTE: The null value that you get when you use the Accessory Cable on lower C ranges may not be as low as the null you get when not using the Accessory. You will also have to change the LEAD NULL adjustment if you move the wiring when you are measuring small value capacitors with the Accessory. Use tape to hold the leads in place. The null value should be subtracted from the display readings. To null, short the red leads together and the black leads together; then adjust the LEAD NULL control for the lowest display reading.

The Accessory Cables can be connected to a special purpose test fixture for repetitive measurements. The fixture connection points may be of the 4-terminal (Kelvin) type to eliminate contact resistance effects. However, bringing all four leads to the fixture and making only one connection at each component lead is usually accurate except for large C or small L values. Grounding of the fixture is required for large L or small C values.

NOTE: DO NOT ground either component lead. A floating test circuit is used and grounding either component lead will cause inaccurate readings. Be aware that the case of some components is internally connnected to one lead.

Pictorial 7-5 also shows connections to capacitors when bias voltages of 10 VDC or less are applied. The DC source is connected to the rear panel BIAS IN terminals. If the capacitor is also to be measured without bias applied, the DC source can be removed via a switch, or set to 0 VDC. Note that simply turning the DC source off may not remove bias voltage resulting from charged capacitors in the source.

Pictorial 7-6 illustrates the external bias circuit for applying up to 50 VDC to capacitors. A 220 ohm resistor and 2000 μF capacitor are required for decoupling. The bias source may be grounded at the negative (−) lead. Minimal output current is required, but the supply should have low ripple and good regulation. The resistor/capacitor circuit breaks the DC path between the Digital LC Bridge output and the capacitor under test, allowing the AC test voltage to be superimposed on the DC bias. DO NOT set the bias voltage above 50 VDC. This circuitry also blocks any DC bias from the Digital LC Bridge applied at the BIAS IN terminals. Allow enough time for the capacitors (the 2000 μF and capacitor under test) to charge through the 220 ohm resistor; about 5 seconds. The display may be unstable until charging is completed.

WARNING: Voltages above 30 VDC are considered dangerous. Be sure to discharge the capacitor in the test circuit and the capacitor under test as described in the "Basic Operation" section.

REAR PANEL VALUE OUT USAGE

The VALUE OUT terminal provides a 0 to 2.0 VDC (±5%) level, through 2200 ohms, which is proportional to the value of the L or C under test. No output for the D function is available. This feature provides several possible uses:

- You can obtain direct X-Y plotting of capacitance versus voltage when you are using the BIAS IN terminals or an external DC bias source. This allows you to measure the characteristics of voltage variable capacitor diodes (varicaps). The full-scale deflection of the X channel should be adjusted for the maximum bias applied to the BIAS IN terminals. The Y channel input should then be adjusted to some appropriate full-scale value for the component under test. See Pictorial 7-7.

- You can obtain a high-low indication by using a differential voltmeter, as shown in Pictorial 7-8. The meter would be zeroed with a standard value installed, and variations from the standard would be displayed as "+" or "−" readings. If the meter scaling is adjustable, a direct readout of the deviation from the standard in capacitance, inductance, or percentage can then be provided.

- A similar technique to that of a high-low indication, shown in Pictorial 7-9, incorporates a differential camparator used to control a relay. The relay can then turn on an alarm or control a "bin selection" device for sorting.

In any of the above applications, allow time for settling of the display before you evaluate the results.

IN CASE OF DIFFICULTY

NOTE: It is important that you read the following "General Troubleshooting Information" and "Troubleshooting Precautions" sections before you attempt to service your Digital LC Bridge.

This section of the Manual is divided into three parts. The first, "General Troubleshooting Information," describes what to do about the difficulties that may occur right after your Digital LC Bridge is assembled.

The second area, "Troubleshooting Precautions," points out the care you should take when servicing your Digital LC Bridge to prevent damage to components.

The last area, "Troubleshooting Procedures," provides specific methods to locate problems that occur. It also lists one or more conditions or components ("Possible Causes") that could cause each difficulty.

GENERAL TROUBLESHOOTING INFORMATION

WARNING: Be sure to push the POWER switch OFF (out) and disconnect the line cord before removing the cover of your Digital LC Bridge.

1. Recheck the wiring. Trace each lead in colored pencil on the Pictorial as you check it. It is frequently helpful to have a friend check your work. Someone who is not familiar with the unit may notice something you have consistently overlooked.

2. About 90% of the kits returned for repair do not function properly because of poor soldering. Therefore, you can correct many troubles by carefully inspecting the connections to make sure they are soldered as described in the "Soldering" section of the Manual. Reheat any doubtful connections.

3. Closely examine each circuit board foil to see that no solder bridges exist between adjacent foils. If you are not sure whether or not a solder bridge exists, compare the circuit board foil with the "X-Ray Views" in the Illustration Booklet, Page 27. Remove any solder bridges by holding the circuit board above the soldering iron, foil side down, and then placing a **clean** soldering iron tip between the two bridged points until the excess solder flows **down** onto the tip of the iron. You can also place desoldering braid over the bridge; then heat the braid with the soldering iron until the excess solder flows into the braid. Also examine the component side of the circuit boards for any solder that may have built up there.

4. Make sure each transistor is in its proper location (correct part number and/or type). Make sure each transistor lead is in the proper hole and has a good solder connection to the foil. NOTE: All transistors have their flat side facing the same direction.

5. Check each integrated circuit (IC) for proper installation and location (correct type installed). Make sure the dot or marked (pin 1) end of each IC is over the index mark on the circuit board. Be sure each lead of the IC is inserted into the socket and not bent out or under. NOTE: All ICs in sockets on the main circuit board have the pin 1 end positioned in the same direction.

6. Check the displays for proper installation. Make sure the decimal point end of each is at the bottom of the display board. Be sure each lead is inserted into its socket and not bent out or under. NOTE: All displays have the pin 1 end positioned in the same direction.

7. Check each capacitor value. Make sure a capacitor of the correct value is installed at each capacitor location. Check electrolytic capacitors to make sure the positive (+) or negative (−) marked lead is in the appropriately marked hole on the circuit board. NOTE: All electrolytic capacitors on the main circuit board (except C136) have the polarity marks positioned in the same direction.

8. Check each resistor value carefully. It would be easy, for example, to install a 33 Ω (org-org-blk) resistor where a 30 kΩ (org-blk-org) resistor is called for. This is especially true for resistors with four or five color bands, since each band can be quite narrow. A resistor that is discolored, or cracked, or shows any signs of bulging would indicate it has been damaged and should be replaced. Since a damaged resistor is often an indication of some other difficulty (such as faulty wiring), you should try to locate the cause of the damage before replacing the part.

9. Make sure the banded end of each diode is positioned correctly. NOTE: All diodes on the main circuit board have the banded end positioned in the same direction.

10. Check for bits of solder, wire, or other foreign matter which may be lodged in the circuit board wiring.

11. Check all component leads connected to the circuit board. Make sure leads do not extend through the board and touch other connections or parts.

NOTE: In the extreme case where you are unable to resolve a problem, refer to the "Customer Service" information located inside the rear cover of this Manual. Your Warranty is located inside the front cover.

TROUBLESHOOTING PRECAUTIONS

Observe the following precautions when you are troubleshooting your Digital LC Bridge.

1. Make sure you do not short any adjacent terminals or foils when you are making tests or voltage measurements. If a probe or test lead should slip and short two adjacent connections together, for example, it is very likely to damage one or more of the transistors, ICs, or diodes.

2. Be especially careful when you test any circuit that contains an IC or transistor. Although these components have an almost unlimited life when used properly, they are much more vulnerable to damage from excess voltage and current than many other parts.

   CAUTION: Be especially careful when you are removing or installing any CMOS integrated circuit. It would be a good idea to treat all ICs as if they were of this type. This will eliminate any confusion or question. Refer to the special handling procedures for CMOS ICs in Detail 5-2A (Illustration Booklet, Page 18).

3. DO NOT remove any components while the Digital LC Bridge is turned on. Push the POWER switch to OFF (out) before removing ICs or unsoldering any component.

4. When you make repairs to the Digital LC Bridge, be sure you eliminate the cause as well as the effect of the trouble. If, for example, you should find a damaged resistor, be sure you find out what caused the damage. If the cause is not eliminated, the replacement resistor may also be damaged when you put the Digital LC Bridge back into operation.

5. In several areas of the circuit boards, the foil patterns are very narrow. When you unsolder a part to check or replace it, avoid excessive heat. A suction-type desoldering tool makes part removal easier. You may also be aided by using the desoldering braid supplied with your kit. Consult the instructions for use on the package.

6. Do not flex the transformer, line cord, or RANGE switch wires excessively or they may break at the circuit board. When you service the Digital LC Bridge circuit boards, unplug S101/102 from P101 at the rear of the main circuit board, remove the six circuit board mounting screws. The circuit board assembly can then be pivoted (toward the right) and rested upside down on your work bench with all foil-side connections easily accessible.

COMPONENT REPLACEMENT

To replace faulty resistors or capacitors, first clip them from their leads. Then heat the solder on the foil side and allow each lead to fall out of its hole. Use a suction-type desoldering tool or desoldering braid to remove any excess solder in the holes. Preshape the leads of the replacement part and insert them into the holes in the circuit board. Solder the leads of the new part to the foil and cut off the excess lead lengths.

You can remove transistors in the same manner as resistors and capacitors. Make sure you install the replacement transistor with its leads in the proper holes. Then solder the leads quickly to avoid heat damage. Cut off the excess lead lengths.

FOIL REPAIR

To repair a break in a circuit board foil, bridge solder across the break. Bridge large gaps in the foil with a length of bare wire. Lay the wire across the gap and solder each end to the foil. Carefully trim off any excess bare wire.

TROUBLESHOOTING PROCEDURES

This part of the "In Case of Difficulty" section is divided into four parts; "Basic Tests," "Troubleshooting Chart," "Waveforms," and "Logic Charts."

The "Basic Tests" will help you to identify a general problem area in the Digital LC Bridge. To do this, you will be directed to use some of the steps in the "Tests and Adjustments" section. These checks will provide you with a systematic, circuit-by-circuit check of the Bridge's operation. They are also effective after a unit has been in service for some time.

You will need a high input-impedance voltmeter (10 MΩ or higher) to complete the "Basic Tests." Voltage readings may vary ±10% (unless otherwise indicated) from those shown in the charts.

The "Troubleshooting Charts" identify problems (and possible causes) of a specific nature in each of the measurement functions of the Digital LC Bridge. If you have a specific problem area identified, you should read through the chart until you find the "Possible Cause" associated with the problem.

The "Waveforms" and "Logic Charts" sections provide support information for detailed troubleshooting.

In any of these areas, keep the following in mind:

1. In any area where circuit operation appears to be improper, but is not clearly so, you may find it helpful to review the "Circuit Description" on Page 77.

2. Refer to the "Circuit Board X-Ray Views" and the Schematic to locate the various components or circuit areas listed in the "Possible Cause" column of the charts.

3. Refer to the "Semiconductor Identification Charts" on Page 89 to identify diode, transistor, and IC basings. A cross-reference of Heath part numbers and manufacturer's type designations is also included. In several cases, where performance parameters of the part are critical or unique, only the Heath part number is shown.

4. Some circuit areas use ICs or LEDs of the same type. An IC or LED thought to be faulty can often be interchanged with one known to be good.

Basic Tests

In these procedures, you will be directed to the "Operational Tests" (Page 36) steps in the "Tests and Adjustments" section of the Manual. You may also be given a testing setup prior to performing the step. If you do not obtain the indicated results in a step, consult the "Area of Possible Problem" column for that step, which identifies components or circuit areas which may be at fault.

Follow this sequence for each test:

1. Carefully and completely read through the "Instruction or Test" information in each step to be sure you are familiar with what is required and what is expected to result from the test.

2. In any instruction where you have to make a solder connection, push the POWER switch to OFF (out) and unplug the line cord before you perform the instruction.

NOTES:

1. Ignore steps that instruct you to install an IC where one is already installed. However, use the information provided to verify that the proper IC is installed, and that the pin 1 end is positioned correctly.

2. The "Tests and Adjustments" section is primarily intended to be used to check unloaded IC outputs and control signals in a newly-assembled Digital LC Bridge. But you can also use tests at these points to troubleshoot a unit that has been in service for a period of time. However, these signals now have loads connected to them which may affect the results you obtain in a test. If you do not obtain the proper results at an IC output, for example, it may be due to a failure in that circuit, or in another area associated with that circuit. If you are in doubt, consult the Schematic to see if other ICs can be removed from the output of the IC being tested to eliminate these as possible causes of a problem.

Refer to Pictorial 5-2 (Illustration Booklet, Page 18) for the location of test points.

( ) Unplug S101/102 from P101 and push the cable out of the way, toward the rear panel.

( ) Remove the six 4-40 × 3/8" screws and #4 lockwashers that secure the circuit boards to the chassis.

( ) Unsolder and clear the "+15", "−15", "+5", and "−5" solder pads on the foil side of the main circuit board.

( ) Temporarily remount the circuit boards with two 4-40 × 3/8" screws at DL and DM.

( ) Connect the voltmeter common lead to TP1.

( ) Push the "C" switch in.

( ) Set the RANGE switch to 200 pF.

( ) Push the POWER switch ON (in).

POWER SUPPLY AND A/D CIRCUITRY

Perform the steps in the following numbered boxes, starting on Page 37:

( ) Step 1.

( ) Step 2.

( ) Step 3.

( ) Step 4.

( ) Step 5.

( ) Step 6.

( ) Step 7.

CONTROL CIRCUITRY

Perform the steps in the following numbered boxes, starting on Page 38:

( ) Step 8.

( ) Step 9.

( ) Step 10.

( ) Step 11.

( ) Step 12.

EXCITATION CIRCUITRY

Perform the steps in the following numbered boxes, beginning on Page 40:

( ) Step 13.

( ) Step 14.

( ) Step 15.

( ) Step 16.

( ) Step 17.

( ) Step 18.

( ) Step 19.

( ) Step 20.

SENSING CIRCUITRY

( ) Remove U114.

Perform the steps in the following numbered boxes, starting on Page 41:

( ) Step 21.

( ) Step 22.

( ) Step 23.

( ) Step 24.

( ) Step 25.

( ) Reinstall U114.

This completes the "Basic Tests." If, after having identified and corrected any problem you encountered, you obtain the proper results in these tests, the basic measurement circuitry is operating properly. However, if you obtained the proper results but still have some difficulty in any of the functions of the Digital LC Bridge, you may do the following:

A. Refer to the "Troubleshooting Chart" to determine if any of the problems listed describe the problem you are encountering.

B. Repeat the "Basic Tests." You may want to have someone else observe the tests with you in the event you may have overlooked something.

C. Contact the Heath factory, or a Heath/Zenith Computers and Electronics center for further assistance, or for servicing your Digital LC Bridge.

Troubleshooting Charts

The following charts list the "Conditions" and the "Possible Causes" of a number of malfunctions in the operation of the Digital LC Bridge. If a particular part or area is mentioned (J1, U104, etc.) as a possible cause, check these parts to see that they are correctly wired or installed. Also check to see that the proper part was installed in that location. It is also possible for a part to be faulty.

NOTES:

1. Make sure you have completed the "Basic Tests" section before you proceed with the following charts.

2. Improper measurement conditions may be identified in some cases as a "Possible Cause" of a problem. It may be helpful in these cases to refer to the "Measurements" section (Page 53), which provides techniques to minimize the effects of the test environment on the accuracy or stability of measurements.

PROBLEM	POSSIBLE CAUSE
Unit is inoperative (reads zero or overrange) on all ranges.	1. F101 open. 2. Poor or open contact at J1, J2. Clean or adjust as required. 3. Component under test is defective (open or shorted) or not an inductor or capacitor. 4. Short or open at R121-R123, D103-D106 circuitry. 5. Open in jumper wiring to display circuit board or at SW101. 6. Failed ±15 or ±5 V supplies. 7. U101 oscillator inoperative. 8. U118 circuitry. 9. U108, U116, U121, RY102 circuitry. 10. R171 to R175.
Unit cannot be calibrated using 150 nF standard on 200 nF range.	1. Incorrect number of jumpers (W101-W103) open or closed. 2. Incorrect adjustment of R232 or R243. 3. SW1, U119, U102 test frequency selection (1000 Hz). 4. U113, U109C, U115A, U114A loss correction circuitry. 5. Standard inaccurate or outside required temperature range. 6. R155, R174, R175.
Unit cannot be calibrated using 15 μF standard on 20 μF range.	1. Incorrect adjustment of R144. 2. U109D circuitry. 3. R154 circuitry, or R175. 4. U108, U116 circuitry. 5. Standard inaccurate or outside required temperature range.
Unit cannot be calibrated using 150 μF standard on 200 μF range.	1. U109A circuitry. 2. R152 circuitry. 3. U116, RY101, RY102 circuitry. 4. Standard inaccurate or outside required temperature range.
Unit cannot be calibrated using 1000 μF standard on 2000 μF range.	1. Incorrect adjustment of R152. 2. U116A circuitry. 3. R226 circuitry. 4. Poor connection at J1, J2. 5. U104, U107 6. Standard inaccurate or outside required temperature range.

PROBLEM	POSSIBLE CAUSE
Unit is inaccurate, when compared to laboratory standards, at 22°C on:	
20 nF to 2000 μF range.	1. Incorrect adjustment of R144, R232, R243, R152, R154, or R226. 2. Laboratory standard is outside required temperature range. 3. "D" of standard is high, increasing measurement error. 4. Excessive line-voltage or RF radiation is present.
200 pF or 2 nF range.	1. Incorrect LEAD NULL adjustment. 2. Excessive wire lengths or stray capacitance in "standard" enclosure, or enclosure not grounded. 3. Open wiring at AA on main circuit board. 4. U105A circuitry. 5. D105, D106, U106B, U107 circuitry. 6. U117 circuitry "noisy".
2 mH to 20 H range.	1. "Standard" altered by test level or frequency. 2. Excessive wire lengths in "standard" circuitry. 3. "D" of standard high, increasing measurement error. 4. Excessive line-voltage or RF radiation present.
200 μH range	1. Excessive wire lengths in "standard" circuitry. 2. Poor contact at J1, J2. 3. U104, U107.
200 H, 2000 H ranges. NOTE: You can get an approximate (±2%) verification by measuring 20 nF (.02 μF) on the 200 H range or 2 nF (.002 μF on the 2000 H range and calculating the equivalent inductance from: $L\,eq = I/\omega^2 \times C)$ Where $\omega = 2 \times \pi \times f$ (test) and f(test) is measured within .1 Hz.	1. "Standard" altered by test level or frequency. 2. Excessive line-voltage or RF radiation is present. 3. Excessive stray capacitance in "standard" enclosure, or enclosure not grounded.

Heathkit®

PROBLEM	POSSIBLE CAUSE
"D" Reading zero or overrange on all ranges.	1. Q103, U114, U115 circuitry. 2. SW101, R137 circuitry.
"D" function cannot be calibrated using "dissipation standard" resistor with "150 nF standard".	1. Improper adjustment sequence of R203, R137. See "Calibration". 2. W104 incorrectly opened or closed. 3. "Dissipation standard" inaccurate or outside required temperature range. 4. U114B, U115B circuitry. 5. U114.
"D" function is inaccurate (when compared to laboratory standard) at 22° C.	1. Incorrect adjustment of R137, R202, R203. 2. Value of standard less than 200 counts on range used. 3. Dissipation standard altered by test level or frequency. 4. Q103. 5. U114, U115, U301.
BIAS IN function does not operate correctly; applied bias does not appear at component under test.	1. Component polarity is reversed. 2. S101/102 improperly installed. 3. Open in S101/102 wiring. 4. SW102, R118, C106 circuitry. 5. D103, D104. 6. U104.
VALUE OUT function inoperative or output voltage too low.	1. Output is loaded by measurement circuitry. 2. S101/102 incorrectly installed or wired. 3. Open in S101/102 wiring. 4. R176.

Waveforms

The waveforms discussed in this section and shown on Page 26 of the Illustration Booklet are for Digital LC Bridge circuits that are operating properly. Each waveform is identified by a number. These identification numbers are used in the following chart, on the schematic, and as a reference in some "Area of Possible Problem" boxes in the "Tests and Adjustments" section.

To check for the presence of the following waveforms, you will need a DC-coupled oscilloscope with a vertical calibration at 2 V/div, and with a time base (horizontal) calibration of 20 μs/div, .5 ms/div, and 100 ms/div. You must use a high impedance (10 MΩ suggested), low-capacitance probe with the oscilloscope.

Set the Digital LC Bridge as follows:

( ) Push the POWER switch ON (in).

( ) Push the C switch in.

( ) Set the RANGE switch to 200 nF.

( ) Install the 150 nF standard capacitor.

( ) Clip the dissipation standard resistor across the capacitor.

( ) Connect the oscilloscope ground lead to TP1.

At each waveform step, perform each of the following steps:

1. Adjust the oscilloscope for the designated voltage and time settings for the waveform to be observed. Adjust the vertical position ("zero") level to some convenient point. NOTE: The dot on the left edge of each waveform indicates the DC "zero" level to which it is referenced.

2. Connect or touch the oscilloscope probe to the indicated test point.

3. Adjust the triggering controls of the oscilloscope to obtain a clear presentation.

4. If you obtain the proper waveform (Illustration Booklet, Page 26), proceed to the next step. If you do not, make sure the test connections are correct. Then refer to the information provided in the "Comments" column to determine what circuit areas should be inspected.

NOTE: Waveforms 1 through 15 and 20 through 24 are pure AC sine wave signals with no appreciable DC component and are similar to the waveform shown in Waveform 1. The peak-to-peak value of these signals is given in the chart.

WAVE-FORM	OSCILLOSCOPE VERT (/div)	HORIZ (/div)	TEST POINT	SINE-WAVE PK-PK	COMMENT
1	2V	.5 ms	TP2	9.4	Confirms oscillator operation. Waveform has an 8.3 ms period for 120 Hz on 20 μF and higher ranges.
2	---	---	U103-12	2.2	Confirms operation of test level regulator. Unregulated circuit signal is approximately the same when you remove U112.
3	---	---	U104-13	2.2	Confirms operation of U104 and overvoltage protection circuit.
4	---	---	TP3	2.2	
5	---	---	Hole BR	2.2	Confirms input and general operation of U106A, U107, U108 circuitry. Signal is at fixed levels vs range for c; varies for L.
6	---	---	Hole BS	<.05	
7	---	---	TP4	2.2	
8	---	---	Hole AW	1.6	Confirms U105A circuitry. Signal at AW is inverted from TP3. Signal at AV varies with LEAD NULL control setting.
9	---	---	Hole AV	.2	
10	---	---	Hole BT	<.05	Confirms operation of U106B, U107, U108 circuitry. Signal is at fixed levels vs range for L; varies for C.
11	---	---	TP5	.35	
12	---	---	U108-3	.35	
13	---	---	U106-7	.35	
14	---	---	U111-1	5.8	Confirms U111 scaling circuitry.
15	---	---	U111-7	5.8	Signal has fixed levels vs range.
16	2 V	.5 ms	U112-1	---	Confirms U112A (rectifier) circuitry operation.
17	2 V	.5 ms	Band end D108	---	
18	2 V	.5 ms	U113-7	---	Confirms U113 (comparator) circuitry operation.
19	2 V	.5 ms	U109-11	---	Confirms U115A, U114A, Q103 loss correction circuitry operation. Signal varies in proportion to "D" of part under test.
20	---	---	U114-15, –16	2.9	Confirms input signal to U114A.

(continued)

WAVE-FORM	OSCILLOSCOPE VERT (/div)	HORIZ (/div)	TEST POINT	SINE-WAVE PK-PK	COMMENT
21	---	---	U116-2	.35	Confirms inputs/outputs of U117A summing amplifier circuitry.
22	---	---	U114-13	.80	
23	---	---	U117-1	4.3	
24	---	---	TP6	4.3	Confirms U117B buffer circuitry. Signal should vary only with value.
25	2 V	.5 ms	U118-1	---	Confirms U118A rectifier circuit.
26	2 V	.5 ms	unbanded end D114	---	
27	2 V	20 μs	U301-38	---	Confirms U301 oscillator circuit.
28	2 V	100 ms	U301-34	---	Confirms "reference" portion of A/D operation. Display may vary from probe loading.
29	2 V	100 ms	U301-28	---	Confirms "buffer" portion of A/D operation. Duration of "step" levels varies with input.
30	2 V	100 ms	U301-27	---	Confirms "integrator" portion of A/D operation. Peak varies with input.

Logic Charts

The RANGE switch (SW1) has combinations of closures which are determined by the range selected. In addition, the D and L function switches (SW101 and SW102) provide individual control signals which are applied to the U119 and U121 inputs. U119 and U121 are read-only memory (ROM) ICs which have many possible output voltage combinations determined by their inputs.

The Logic Charts in this section identify the switch closures and ROM outputs used in the Digital LC Bridge circuitry. These are an aid in detailed troubleshooting. The charts indicate the voltage levels corresponding to logic high (H) and low (L) signals for these components when referenced to ground.

In tracing circuit operation, be careful to consider how these logic signals are used as inputs or control signals to associated circuits.

LOGIC CHART I RANGE SWITCH

Logic Low (L): Less than +.2 VDC.
Logic High (H): Greater than +4.0 VDC.

Comments: R179 to R182 act as "pull-up" resistors to maintain a logic high for the switch outputs. Logic low signals are provided by the switch contacts grounding the input line.

NOTE: For clarity, only low (L) logic levels are shown. All others are high (H).

	U119, U121 Inputs		
RANGE	Pin 12 X4	Pin 11 X2	Pin 10 X1
200 pF	L	L	L
2 nF	L	L	
20 nF	L		L
200 nF	L		
2 μF		L	L
20 μF		L	
200 μF			L
2000 μF			

LOGIC CHART II "D" ROM (U119)

Logic Low (L): Less that +.3 VDC.
Logic High (H): Greater than +3.5 VDC.

Comments: The function input at pin 13 (from SW101) is coupled through R136 to +5 VDC for D and to ground for L or C. The Chart shows only the values for C function; the L function is identical.

NOTE: For clarity, only low (L) levels are shown. All others are high (H). An "X" indicates either a high or low is acceptable (don't care). Only "legal" input codes (16 of a possible 32) are shown in the upper part of the chart.

U119

INPUTS		OUTPUTS							
Pin 13 A4	Pins 12, 11, 10 A3 A2 A1	Pin 9 Q8	Pin 7 Q7	Pin 6 Q6	Pin 5 Q5	Pin 4 Q4	Pin 3 Q3	Pin 2 Q2	Pin 1 Q1
D	RANGE	N.C.	1kHz	R8	$\overline{\text{R7,R8}}$	$\overline{\text{R6}}$	DP2	DP3	DP4
L	200 pF			L			L		
L	2 nF			L					L
L	20 nF			L				L	
L	200 nF			L			L		
L	2 µF			L					L
L	20 µF		L	L		L		L	
L	200 µF		L	L	L		L		
L	2000 µF		L		L				
	200 pF			L					L
	2 nF			L					L
	20 nF			L					L
	200 nF			L					L
	2 µF			L					L
	20 µF		L	L		L			L
	200 µF		L	L	L				L
	2000 µF		L		L				L
For A5 = H (Illegal input)									
X	X X L	L	L	L	L	L	L	L	L
X	X X H								

LOGIC CHART III "L/C" ROM (U121)

Logic Low (L): Less than +.4 VDC.
Logic High (H): Greater than +3.5 VDC.

Comments: RY101 and RY102 act as "pull-ups" at pins 6 and 7. The function input at pin 13 (from SW102) is coupled through R135 to +5 VDC for L and to ground for C.

NOTE: For clarity, only low (L) levels are shown. All others are high (H). An "X" indicates either a H or L is acceptable (don't care). Only "legal" input codes (16 of a possible 32) are shown in the upper part of the chart.

U121

INPUTS		OUTPUTS							
Pin 13 A4	Pins 12, 11, 10 A3 A2 A1	Pin 9 Q8	Pin 7 Q7	Pin 6 Q6	Pin 5 Q5	Pin 4 Q4	Pin 3 Q3	Pin 2 Q2	Pin 1 Q1
L/C	RANGE	N.C.	RY102	RY101	$\overline{RE}$	$\overline{RD}$	RC	RB	RA
L	200 pF						L	L	L
L	2 nF						L	L	
L	20 nF						L		L
L	200 nF			L		L	L		
L	2 µF		L	L	L			L	L
L	20 µF		L	L	L			L	L
L	200 µF		L	L	L			L	L
L	2000 µF		L	L	L			L	L
	200 µH		L	L	L			L	L
	2 mH			L		L	L		
	20 mH						L		L
	200 mH						L	L	
	2 H						L	L	L
	20 H						L	L	L
	200 H						L	L	L
	2000 H						L	L	L
For A5 = H (Illegal input)									
X	X X L								
X	X X H	L	L	L	L	L	L	L	L

SPECIFICATIONS

Accuracy specifications apply at 22°C (72°F) after a 10 minute warm-up.

L (INDUCTANCE)

Ranges	200 μH to 2000 H; 8 decades.
Accuracy (±4 counts)*	±[.5% (L) + [1.5% (L) x D + .5 μH] for readings from 10 to 2000 counts when the Bridge is calibrated using laboratory standards.
Excitation	1000 Hz sinusoidal: 80 mA on 200 μH range decading to 8 μA on 2 H range. 120 Hz sinusoidal: 6 μA on 20 H range; .6 μA on 200 H, 2000 H ranges.
Impedance Model	Series R, L equivalent.

C (CAPACITANCE)

Ranges	200 pF to 2000 μF; 8 decades.
Accuracy (±2 counts)*	±[.5% (C) + 1.5% (C) x D + .5 pF] for readings from 10 to 2000 counts when the Bridge is calibrated using laboratory standards.

*When the Bridge is calibrated using the Heath-supplied calibration package, add .5% to 1000 Hz ranges and 2% to 120 Hz ranges. Heath-supplied standards must be within ±.5°C (±1°F) of calibration temperature during use, and stored within 15° to 32°C (60° to 90°F) to maintain maximum accuracy.

Excitation	1000 Hz sinusoidal: .8 VAC on 200 pF to 2 μF ranges. 120 Hz sinusoidal: .66 VAC on 20 μF range; .066 VAC on 200 μF, 2000 μF ranges.
Impedance Model	Parallel R, C equivalent.
DC Bias	±.01 VDC. 0 to 10 VDC may be applied via rear terminals. Up to 50 VDC may be applied using external circuitry.

D (DISSIPATION)

Range	000 to 1.999, limited to D × μF = 1000 on 2000 μF range.
Accuracy (±20 counts)*	±3% for value displays greater than 200 counts.

GENERAL

Measurement Connection	Front panel slotted inputs accommodate leads up to 1/16″ in diameter and 2-1/2″, apart and provide 4-terminal (Kelvin) measurement. Accessory assembly (provided) allows 4-terminal measurement of large or remote parts.
Excitation Frequency Accuracy	±3%.
Overvoltage Protection	Input protected against ±20 VDC/VAC (5 seconds maximum), or capacitor up to 2000 μF charged to 50 VDC. Higher overvoltage will cause an internal 1- ampere fuse to open.
Display	3-1/2 digit (1999 maximum count), .43″ high-brightness LED.
Sampling Rate	2-1/2 per second.
Value Out	0 to +2.0 VDC (±5%), proportional to L, C value, provided at rear panel terminals.
Temperature Coefficient	±(.1 × Accuracy)/°C for L, C. ±(.05 × Accuracy)/°C for D.

Operating Temperature	10 to 40°C (50 to 104°F).
Storage Temperature	0 to 50°C (32 to 122°F).
Power Requirements	120 VAC, 60 Hz, 15 watts maximum.
Dimensions (overall)	3-3/4"H × 10"W × 12-1/2"D. (9.5 cm × 25.4 cm × 31.8 cm).
Weight	6.5 lbs (2.9 kg).

The Heath Company reserves the right to discontinue products and to change specifications at any time without incurring any obligation to incorporate new features in products previously sold.

CIRCUIT DESCRIPTION

Refer to Pictorial 8-1, the Functional Block Diagram, and the Schematic as you read the "Circuit Description" section. The component numbers are arranged in the following groups to help you locate specific parts on the Schematic and circuit boards.

1-99	Parts mounted on the chassis or accessed through the front panel.
100-299	Parts located on the main circuit board.
300-399	Parts located on the display circuit board.

THEORY OF OPERATION

Pure capacitance (C) and inductance (L) are considered easy to measure. But in real components, they combine with resistance (R) and other types of losses to form impedance (Z). Therefore, to measure C or L, the reactive (X) portions must be separated from the resistive portions of impedance.

The Digital LC Bridge uses the phase relationship properties of reactance and resistance to measure C and L. When an AC signal is applied to an impedance, the resistive response remains in phase with the signal source, while reactance responses fall at a ±90 degree phase angle, depending on the type of reactance. The Functional Block Diagram illustrates how this property is used to measure capacitance.

The excitation circuit generates an AC signal (E_x) at one of two frequencies which is applied to the unknown capacitor. The voltage sensing circuit then detects the voltage drop across the capacitor (EH to EL). The difference voltage (E sense) is coupled to the regulation circuit as a reference feedback signal.

The regulation circuit detects changes in the feedback signal, and then applies a corrective voltage to the excitation circuit to maintain a constant test voltage level. For a constant voltage, the current through a capacitor is proportional to the capacitance. The capacitor current (I_x) is applied to the current sense circuit which holds the EL terminal near 0 volts and generates an AC voltage (I sense) that reflects the total impedance of the capacitor. This signal is then applied to the measurement circuit.

The measurement circuit generates an impedance feedback signal and applies it to the loss correction/sensing circuit. For this signal to be representative only of reactance, it must be at a 90 degree phase shift (quadrature) from the test signal. The resistive portion of the signal (in phase) must be subtracted from the impedance signal to meet this requirement.

In the loss correction/sensing circuit a square wave from the regulation circuit gates the impedance signal on and off. (A switched quadrature signal will have an average DC voltage of 0 volts.) Any DC present in the switched impedance signal is used to control the gain of an inverting amplifier with an input that is in phase with the regulation circuit signal. The output of this amplifier is the loss correction signal, applied as a second input to the measurement circuit. The interaction of these circuits causes the output of the Measurement circuit to be at quadrature, representing only the (capacitive) reactance portion of the impedance signal. This output signal is then scaled and converted to a DC voltage (Value output), and applied to the analog-to-digital (A/D) Convertor.

The A/D circuit provides a digital display proportional to the ratio of its "In" and "Reference" inputs (In/Ref). For C (and L) measurements, the "Reference" is a constant DC voltage; thus, the display is proportional to only the "In" voltage, which represents the C or L value.

When the measurement circuit produces a DC voltage for C or L measurements, it also produces conditions for loss measurement. The loss correction/sensing circuit gain control voltage is also applied to a second amplifier with a fixed DC input. Since the gain required in the first amplifier is proportional to the loss present in the impedance signal, the second amplifier's output is also proportional to the loss. Dissipation factor (D) in a parallel combination of C and R (the circuit model used) is the ratio of loss current to capacitor current. For D measurements, the D output is applied to the A/D In, and a scaled amount of the Value output voltage is applied to the A/D Reference input. The display then reflects the loss current/capacitance current ratio.

For inductance measurements, the circuit regulates the current through the component, connecting the I sense voltage to the regulation circuit. The constant AC current generates an E sense voltage proportional to the inductive impedance. This signal is then applied to the measurement circuit, which operates with the loss correction/sensing circuit to subtract the in-phase portion of the impedance signal, resulting in a quadrature signal proportional to the inductance. The resulting voltage is then scaled and converted to a DC voltage for measurement by the A/D circuit.

D for a series L-R circuit (the circuit model used here) is the ratio of loss voltage to inductance voltage. When D is measured, the D output, proportional to the series loss, is applied to the A/D circuit input and a scaled amount of the Value output is applied to the A/D converter Reference input. The ratio of these voltages provides a direct D display.

The wide range of L and C values measured requires several gain levels in the current sense circuit. The Range switch circuit provides inputs to the sensing control circuit to select one of five resistances for component current sensing.

The Range switch circuit also provides inputs to the Range-DP control circuit, which selects one of three gain levels in the regulation circuit, one gain change in the measurement circuit, and one of two test frequencies in the excitation circuit. The Range-DP circuit also switches the proper decimal point for the selected range (none for the 2000 μF/H range).

The power supply circuit converts the 120 VAC line voltage into ±5 and ±15 VDC to operate the Digital LC Bridge circuits. The test components are used for "Tests and Adjustments" only.

In addition to providing the AC test signal, the excitation circuit can provide up to +10 VDC of bias for capacitors when a DC source is connected to the rear panel Bias In terminals. The Value output voltage is available for external usage at the Value Out terminal.

DETAILED CIRCUIT DESCRIPTION

120 Hz, 1 kHz OSCILLATOR

U101, Q101, and U102A, B, and D form a low-distortion, constant amplitude, sine wave oscillator at either of two frequencies. The amplitude and frequency are controlled by independent positive and negative feedback paths. Negative feedback, which controls the output level, passes from U101 pin 6 through R104 to pin 2 of U101. Positive feedback, which determines the operating frequency, is coupled from pin 6, through C103 and R109, and across R106 and C102 to pin 3.

At power on, C101 is discharged, biasing Q101 on. This places R103 in parallel with R105 to reduce the negative feedback level and start the oscillator. The positive peak of any signal appearing at U101 pin 6 reverse biases D101, but the negative peak of any signal will forward bias D101 and D102 when it exceeds about 4.7-volts. The voltage on C101 then increases until it reaches about −1 VDC, which starts to turn Q101 off. The resistance of Q101 then adds to R103 to increase the negative feedback and limit the oscillator output. This feedback interaction results in a constant amplitude from U101, which is coupled to U103B.

U102 consists of FET switches which turn on at a logic low. For 120 Hz operation, U102B is turned on by a low at the 1 kHz signal. The voltage at R111 is then high, turning off U102A,D. The R103/R109 and R102/R106 circuits provide "Lead" and "Lag" phase shifting so that maximum feedback occurs at 120 Hz. For 1 kHz operation, U102B is turned off by a high from the 1 kHz signal. The voltage at R111 is then low. This turns U102A and D on, reducing the overall resistance in the positive feedback circuit and increasing the oscillator operating frequency. R101 limits the charging current for C101, while R102 sets the capacitor's discharge rate. These stabilize oscillator operation. U102C is not used in the circuit. It is connected at pins 9 and 11 for manufacturing tests only.

EXCITATION VOLTAGE CONTROL

The output from U101 is coupled by R112 to U103B. For purposes of clarity, a simplified diagram of U103B is shown in Pictorial 8-2. The ID current sources are essentially matched, producing a common-mode (equal) negative bias on R112 and R113. The R_D value is quite small, making the inputs appear shorted together. Any variation in input current through R112, R_D, and R113 produces a voltage change across R_D which, through internal circuitry, controls the IOUT current source. A gain-controlling current (I_{GM}) combines with I_D to make the I_{OUT} current proportional to $I_{RD} \times I_{GM}$.

A control voltage from the regulation circuit is connected through R162 to Q102, which translates this voltage (Vcontrol/R162) into I_{GM} for U103B. The output current of U103B, proportional to I_{GM} times I_{RD}, then develops a voltage across R115 which is fed to power amplifier U104. The output voltage of U103B is thus controlled (programmed) over a wide range by I_{GM}. C104 filters any high frequency noise from the output signal.

U103A is not used. It is grounded, through R116, only for manufacturing tests.

POWER AMPLIFIER

U104 is a power amplifier with unity voltage gain. It provides the higher currents needed to measure high value capacitors and low value inductors. The AC voltage from U103B, coupled through C105 to R117 and R118 at the input of U104 is thus buffered and, appears at the output (pin 3) of U104 and is coupled to the component being tested.

DC bias voltage, necessary for some capacitors, is connected from the rear panel Bias In to R118 and through R117 to the input of U104. This provides a DC offset voltage, which is routed through the protection circuit to the test connectors. Since U104 has no voltage gain, the bias voltage at R118 appears unchanged at pin 3 and charges the capacitor under test.

OVERVOLTAGE PROTECTION

Under normal conditions, only the AC test voltage appears at test jacks J1 and J2. If a charged capacitor or voltage source is connected to the test connectors, protection is needed for the measurement circuitry.

Normally, the voltages at J1 and J2 are below the thresholds of D103/D104, D105, and D106. When a charged capacitor is connected at J1 and J2, depending on polarity, either D105 or D106 begins conducting, limiting voltage at U107 to ±.7 VDC. This voltage also applies forward bias through F101 to D103 and D104 until the threshold of approximately ±13 volts is reached. When D103/D104 conducts, the low impedance of this circuit, through R123, allows the capacitor to discharge through R122 and RY101 and/or R121.

If a very large charged capacitor, or voltage above 20 VDC appears at J1 and J2, it will cause excess current flow through F101, opening the fuse and removing the overvoltage from U104. C111 prevents DC voltages (below its 50 volt rating) from reaching U106A.

VOLTAGE SENSE DIFFERENTIAL AMPLIFIER

Voltage measurements across a component being tested are made in a floating, or differential, manner. U106A measures the voltage of the component by subtracting any AC voltage appearing at J_{LS}, the low sense contact, from that at J_{HS}, the high sense contact.

Assume voltage appears only at J1 (JHS). The AC voltage at JHS is coupled through C111 and R126 to pin 2. With pin 3 appearing to be grounded, negative feedback current is provided through R129 to prevent any signal from appearing at pin 2. With R126 equal to R129, this results in an inverted output signal equal to the input voltage.

Assuming voltage now appears only at J2 (JLS), any AC voltage appearing at pin 3 of U106A is halved by voltage divider R127 and R128. The R126/R129 feedback circuit establishes the circuit gain at 2, for any pin 3 voltage, producing an output voltage equal to that at J2 (JLS) but not inverted. The circuit operates independently for JHS and/or JLS voltages, so the combined voltage at the output of U106A is then equal to the voltage difference between J1 and J2, or the voltage across the component. This output voltage becomes E sense for measurements.

R124 and R125 are normally shorted when J1 and J2 make proper contact with the leads of the component being tested. Should a poor contact be made, the resistors act to couple some of the test voltage to U106A, preventing circuit overrange. However, there will be a large error and may be some instability in the display reading.

CURRENT SENSING (SINK)

While it performs only a limited function, the current sensing circuitry is the central circuit for the Digital LC Bridge.

Any component test current flows from U104, through the component, and to the junction of several decade-related resistors. U108 (and other circuits) selects the proper resistor for the function (L or C) and range selected, and connects it to the output of U107. U107 uses its gain to keep the voltage at pins 1 and 2 equal. Therefore, U107 provides current through the selected precision resistor equal to that through the unknown component. This current (sink) action holds the J2 end of the component near 0 volts.

The input voltage to U106B is an accurate, decade-related representation of the current through the resistor. The input impedance of U106B is very high to limit circuit loading. To provide maximum accuracy when the low value resistors are selected, the switching must be as resistance-free as possible. The extra switching in this circuitry ensures low switching resistance. U108 provides dual switching contacts for R171, R172, R173, or the R174/R175 combination, for ranges to the 200 nF range. U116C provides additional switching contacts on this range because the switch resistance (X3, Y3) of U108 is high compared to the combined value of R174/R175. U116B and RY102 select R174 only, and provide connections for this resistor, used on the 2 μF to 2000 μF ranges. All switches in U108 are off on these ranges. The output of U106B becomes the I sense voltage for measurements.

LEAD NULL OFFSET

For most capacitance ranges, stray capacitance and the value of C108 are negligible. On the 200 pF and 2 nF ranges, however, these become significant, although constant. Therefore, they could be subtracted from the displayed value. The Lead Null circuit provides the means to remove most of this offset.

U105B couples an AC signal to R1 which is an inverted, proportional sample of the test voltage. R1 then couples some of this signal through C109 to the current sense circuit. Stray capacitance and C108 also couple small amounts of the test signal to the same current sense point. Properly adjusted, R1 sets an equal but opposite-phased current to cancel (null) the effects of stray capacitance current. Without the value of C108, stray values would be so small as to keep R1 near one end of its range. C108 moves the null adjustment point more within the linear area of the control range.

REFERENCE FEEDBACK GAIN AMPLIFIER

For inductance measurements, a voltage proportional to the test current is connected to the junction of R151, R153, and R155. Capacitance measurements feed the test voltage to this point. Three test levels are used, in combination with the current sensing resistors (R171-R175) and one other scaling change, to provide the eight test ranges.

The output of U111A remains at a constant 1.7 VAC for each range. For the first five ranges (200 pF-2 μF), both switch sections of U109 remain open, while the sensing resistors switch from 100 kΩ to 10 Ω. The 1 kHz test signal remains at .8 VAC for these ranges, and R155 and R156 set the gain of the U111A circuit.

For the next range (20 μF), the test voltage must change to .66 VAC at 120 Hz. U109D closes, placing R153 and R154 in parallel with R155 to increase the gain of U111A. R154 calibrates the range. For the last two ranges (200-2000 μF), the test voltage must change to .066 VAC. U109A closes, while U109D opens, placing R151 and R152 in parallel with R155 to further increase the gain of U111A. R152 provides calibration for both of these ranges.

For inductance measurements, the test current is regulated, but calibration remains the same. The inductance ranges use the same test voltages and frequencies, which produce test currents of from 80 mA to .066 μA. The sensing resistors are used in reverse order for inductance ranges, starting with R174 (10 Ω) for the lowest to R171 for the three highest. Switches U109A and D operate in the same manner as for capacitance measurements.

The output of U111A is fed to two circuits. The first circuit produces a phase-shifted output used to drive the "quadrature" switch. The second circuit is the loss correction circuit, which uses a portion of the sensed test signal, to cancel the in-phase (resistance) portion of the measured signal.

PHASE SHIFT BUFFER

Operation of the loss correction circuit is based on the relationship of voltage and current in a purely reactive component. Reactive voltage and current are in "quadrature" (have a 90° phase angle). The quadrature switch circuit produces a DC output corresponding to the phase relationship between its input signal and its switching signal. To help center its operating range, a slight phase shift offset in the U111B circuit advances the switching signal phase and is later matched in other circuits which cancel this effect by advancing the measured signal phase the same amount.

For all 1000 Hz test frequency ranges, U109B remains open. C114 and R157 then provide an approximate 15 degree phase shift. The high input impedance of U111B prevents loading of the signal from U111A, and its unity gain produces the same output as U111A. For the 120 Hz ranges, U109B closes, switching C113 in parallel with C114, to produce the same 15 degree shift for the 120 Hz ranges.

EXCITATION VOLTAGE REFERENCE

The output of the regulation circuit is a DC voltage to Q102, which controls the gain of U103. This voltage results from the error between a DC voltage proportional to the feedback signal and a fixed reference to which it is compared.

The DC reference voltage is provided by U105B, connected as an inverter with pin 5 grounded. Input current is produced by the +15 VDC supply across R141-R145. The output at pin 7 is a negative voltage which provides feedback current through R146 to hold the inverting input (pin 6) at 0 volts. R144 calibrates the output, while jumpers W101-W103 change the input current in fixed steps, providing a wide circuit adjustment range. The output voltage is adjusted to approximately −10 VDC.

FULL-WAVE RECTIFIER, ERROR INTEGRATOR

The AC signal from U111B is rectified by U112A and its output is applied to the input of integrator U112B. This is accomplished through two paths.

The positive portion of U111B's output drives the output of U112A negative. Pin 6 of U112B is maintained at 0 volts by feedback action; thus D108 is reverse biased, disconnecting U112A from the circuit. Feedback through D107 prevents U112A's output from being driven to its negative limit. With D108 reverse biased and U112A pin 2 at 0 volts, no useable output from U112A is developed through R161 or R164. Thus, for a positive U111B output, the only current is through R159 to U112B.

For the negative portion of the output from U111B, the output of U112A goes positive. This forward biases D108, drives the junction of R161/R164, and produces feedback to pin 2 through R161. The equal values of R161 and R158 produce an output from U112A that is equal, but inverted, to the U111B output. This positive voltage drives the U112B input, through R164, while the negative signal from U111B drives the same input through R159 at half the R164 current, making the net input current positive. In fact, the positive current through R159 for positive portions of U111B output, and the positive net current for the negative portion of the U111B output, are equal. These are summed at the input of U112B, and are proportional to the AC output of U111B.

Without negative current from U105B through R163, the positive currents mentioned above are averaged (integrated) by charging C115. However, since no DC feedback exists between U112B pins 6 and 7, a constantly increasing negative U112B output results as a response to any positive input as an attempt to maintain equal voltages at pins 5 and 6. This negative increase tends to reverse bias Q102 to lower the gain of U103. This reduces the test voltage/current level, which reduces the feedback signal through U111 and results in reducing the U112A DC output. Due to the high gain levels, this feedback could reduce the test level to zero since any positive input to U112B would be counteracted.

Without positive current at the U112B input, negative current from U105B would force the U112B output positive in the manner described above, thus increasing test levels and feedback. From the combined efforts of these two inputs, the feedback signal and the test voltage/current levels are maintained at a precise level, set by the current through R163.

Although no direct DC feedback exists in the U112B circuit, there is high AC feedback through C116. R165 and R166 provide discharge paths for the C115 and C116 voltages to speed the circuit response. D111 limits temporary negative output voltages, since this would completely reverse bias Q102. R167 provides an approximate bias, with R165 and R166, to Q102 in the "Tests and Adjustments," before U112 is installed.

VALUE, LOSS SUMMING AMPLIFIER

Two signals are combined at the input of U117A. The first is the sensed current or voltage (I sense or E sense) containing the reactive and loss voltage components. The second is an inverted signal adjusted to cancel the loss portion of the sensed signal. A gain change is also provided on the highest L and C range.

The sensed signal is applied through R225-R227 to the input of U117A. On all except the highest range, U116A remains closed, bypassing R225 and R226. The input current through R227 is then matched by feedback current through R229. The loss correction signal at R228 also contributes current which adds or subtracts to the R229 current in proportion to the output of voltage control amplifier U114A.

On the highest range, sensitivity to the sensed signal is decreased by U116A being opened (turned off). This adds R225 and R226 in series with the sensed signal input path, with R226 calibrating the highest range. The U117A output signal is then fed to the phase shift circuit of U117B.

PHASE SHIFT BUFFER

The phase shift of the quadrature switching signal at U111B is matched by a phase shift, at U117B, of the sensed signal. The output from U117A is applied to C124, C125, U116D, R231, and R234. This circuit shifts the signal phase about 15 degrees at 120 Hz and 1 kHz to match the shift from U111B. R232 and R233 provide a means to cancel any internal DC offset in U117B, ensuring that the output at pin 7 will be at a 0 VDC level. The output from U117B is applied to the U118A and B measurement circuit, and as feedback through U109C to the loss correction circuit.

COMPARATOR, QUADRATURE SWITCH

The signal from U111B must be converted to an "on-off" square wave to drive the quadrature switch used to sample the loss feedback signal from U117B.

U113 is a high-gain, high-speed device which switches quickly in response to a small voltage difference between its inputs. The inverting (−) input is grounded through R208, setting the switching threshold at 0 volts. When the signal at R207 goes positive, the output quickly switches from low to high, being pulled to +5 VDC by R213. This positive change is also AC- coupled as a hysteresis-type feedback through R209/C118 to speed the switching action. When the input passes back through 0 volts, circuit action reverses with R209/C118 again speeding the transition.

U113 drives switch U109C, at a 50% duty cycle, which applies the loss sensing signal to the input of U115A. The switch output is held at 0 volts by R214 when U109C is open.

INTEGRATOR

This circuit controls U114A and B, through Q103, in response to any DC content in the loss feedback signal.

The switched loss feedback signal from U109C is applied to U115A through R215. This signal is integrated by C121 in the same manner as described in the error integrator circuit of U112B. Any DC in the signal causes a continuously increasing DC output at U115A, pin 1; for example, a negative DC input causes an increasingly positive DC output, and vice versa. The output voltage drives current-to-voltage translator Q103, which operates similarly to Q102, to controls the gain of U114A and B. AC feedback and improved circuit response are provided by R216, R217, and C122. D112 limits any temporary negative voltage condition.

LOSS VOLTAGE CONTROL

Loss correction is centered at U114A. The input from U111A to U114A is inverted, but in phase with the test voltage/current, while the amplifier gain corresponds responds to the loss of the tested component. As previously described, the U114A output is summed through R228 to U117A to cancel out any in-phase (loss) portion of the measured signal.

The inverting (−) input of U114A is referenced to ground through R219, making the circuit a noninverting amplifier. The input signal produces an input current through R218, an internal resistance (R_D), and R219 in the same manner as in the circuit of U103B. C123 provides a small phase adjustment for the 1000 Hz ranges, while gain is controlled by Q103.

The U114A internal circuitry responds to the input and gain control currents to produce an output current to R228 and R224. R224 increases the output load current to improve internal circuit linearity at low current levels. Without R224, the output current would only pass through R228, and the circuit sensitivity may not be high enough for very low loss levels. Since current flows equally through both resistors, all levels of operation are effectively doubled to extend the measurement range. This scaling does not affect the circuit operation since the circuit as a whole is a closed feedback loop. R221 serves to program the R_D resistance.

The previous descriptions have shown how the excitation, regulation, and loss correction circuits work together to provide an AC voltage proportional to the L or C value. The remaining descriptions will explain the conversion of this voltage to a digital display.

FULL-WAVE RECTIFIER, INTEGRATOR/ SCALING

The output of U117B is coupled through by C126 to U118A and B. Except for D113 and D114 being reversed to produce a negative output from U118A, this circuit rectifies the AC voltage at its input exactly as U112A does. Its output is applied to integrator U118B.

The integrating circuit of U118B is slightly different from previous integrating circuits. It has a DC feedback to force its output to a DC voltage proportional to the AC-related input currents. The output is a positive, 0 to +2.0 VDC signal for each L or C range. R243 to R245 provide zeroing of any offset voltage in U118B. The output voltage of U118B is also provided, through current limiting resistor R176, as a DC voltage for external measurement or comparison.

DISSIPATION VOLTAGE SCALING

The loss correction circuit relies on gain control of U114A by current from Q103, which is proportional to the loss of the part being tested. An equal current from Q103 is applied to U114B to provide a DC voltage also proportional to loss.

Voltage from the +15 VDC supply is divided by R191 and R192 to provide a constant input current for U114B (through R193). Therefore, only the gain control current from Q103 controls the output. This circuit operates as an inverter with its output current, a product of IGM × IRD, equally divided between R197 and R198. This division increases the internal operating currents to reduce potential errors at low loss and value levels. Current through R197 provides the input for U115B, while R195 programs the R_D for this circuit.

Current through R197 causes a feedback current through R199, R201, and R202 to provide an output at U115B proportional to the loss. Gain is calibrated by R202, and W104 provides a coarse calibration step to extend the adjustment range of R202. C117 produces high AC feedback to reduce circuit noise, while R203 to R205 provide a zero adjustment. R206 furnishes a linearity correction for high loss and high value readings. The output of U115B is a positive 0 to +2.0 VDC level representing the loss of the component being tested.

Note that the input circuits of U114A and B are impedance-matched, the output currents of both are halved, and the I_D and gain control currents are matched. These similarities slave the operation of U114B to that of U114A so the DC output of U114B remains proportional to component loss.

VALUE, DISSIPATION MEASUREMENT SCALING NETWORK

The A/D display results from a 0 to +2.0 VDC measurement input with a +1.0 VDC (or 0 to +1.0 VDC) reference input. These are scaled and/or selected by switch SW101.

Input to the A/D converter is provided directly from U118B, through SW101 pins 8 and 9, for all L and C measurements. The +1.0 VDC reference input for these functions is provided by voltage divider R133/ R134 through pins 5 and 6 of SW101.

The A/D input for the D function is provided from U115B through SW101 pins 7 and 8. To limit the full scale A/D reference input to +1.0 VDC, the output of U118B is halved by a voltage divider and this scaled voltage is fed to the A/D circuit through pins 4 and 5 of SW101. A slight offset adjustment to the A/D IN LO input is also provided by R137-R139. This is used for zeroing this function (as a special adjustment) when low dissipation is measured at low L or C values. This adjustment is enabled only for D measurements.

A/D (Analog-to-Digital) CONVERTER

All functions provide a DC voltage which is applied through switches to the input of the A/D converter. The converter uses a dual-slope ramp technique to convert the ratio of two DC voltages to a digital display. A single integrated circuit, U301, incorporates counting, decoding, and display-driving circuitry, in addition to the digital conversion circuits. The following paragraphs describe how this circuit operates.

The entire A/D conversion timing sequence is driven by the oscillator shown in simplified form in Pictorial 8-3. R302 and C302 determine the oscillator frequency, approximately 40 kHz. The oscillator signal is internally divided to provide a 10 kHz clock used by the digital and timing circuits within the A/D converter. This provides 2-1/2 conversions per second (400 ms period), which gives quick response to measurement trends and this exact sampling internal suppresses line-voltage frequency (50 and 60 Hz) noise. The display segments are checked during testing when the LAMP TEST pins are shorted together. This shorts the supply voltage to the oscillator, causing it to stop, and lights "1888" on the display.

The 10 kHz clock provides the timing intervals shown in Pictorial 8-4 to the switching circuit shown in Pictorial 8-5. There are three sequential time intervals in each measurement cycle: integration of the input signal (INT), application of a reference voltage (REF), and an offset self-correction interval (auto-zero, or A/Z). These are explained separately below.

INT (Integration)

At the beginning of this interval (internal clock counters at 0000), the INT switch closes. The REF and A/Z switches are open.

The A/D input voltage, filtered by R303 and C303, is applied to U301 at pin 31 (IN HI). Pin 30 (IN LO) is (essentially) connected to ground. Any voltage present at pin 31 is coupled through a high input-impedance, unity-gain buffer to R304.

Assume that C306 has 0 volts of charge, and that C305 is shorted. DC voltage at the output of the buffer causes current flow through resistor R304. The gain of the integrator causes an equal current of opposite polarity to flow into C306 to hold the negative (−) input equal to its positive (+) input (circuit ground). C306 develops a charge voltage that is opposite in polarity to the input voltage and of a peak magnitude (at the end of the INT interval) that is proportional to the input voltage. The actual value of R304 or C306, however, is not critical to measurement accuracy, as is explained later.

The INT interval is a constant 1000 clock pulses (0.1 second) for each measurement cycle. This 0.1 second interval was chosed to improve measurement stability in the presence of radiated (or input-coupled) AC signals at the line voltage frequencies of 50 and/or 60 Hz. The 0.1 second period contains an exactly even number of cycles at these frequencies (five for 50 and six for 60 Hz) and, since the voltage is equal at the same (even) points on a sine wave, the display stability is not greatly affected by the presence of AC on the DC. At the end of the INT interval, the comparator output is either high or low, depending upon the polarity of the integrator output voltage (even for very low A/D input voltages). The state of the comparator output at the end of the INT interval controls the polarity of the reference voltage described next.

REF (Reference)

During this interval, the REF switch (see Pictorial 8-5) is closed and the INT and A/Z switches are open. The reference circuit shown is internal to U301 and should not be confused with other reference circuitry.

The reference voltage within U301, applied during the REF interval, is constant during each measurement cycle and may be either positive or negative, depending on the polarity of the A/D input.

The polarity of the reference voltage is determined by the comparator output (logic level) at the end of the preceding INT interval and is opposite in polarity to the input voltage. Similar to the previous INT operation, this causes the integrator output to down ramp from its peak back to a zero level. When the zero level is reached, the comparator output changes state, signaling that the REF interval is complete.

The difference between the INT and REF intervals is that, during the INT interval, the slope of the integrator output (to the peak value) is proportional to the input voltage. During the REF interval, the slope is proportional to the (constant) REF voltage.

Note that the only change during this interval is the buffer input voltage (A/D input during INT; reference voltage during REF). For this reason, the measurement results (display) depend only on the A/D input and the reference voltages. The actual value of R304 or C306 is unimportant since the same parts are used for both the up-ramp and down-ramp.

Since the slope of the integrator output during the REF interval is constant, the time when the integrator output is returned to the zero level is proportional to the peak voltage reached at the end of the INT interval, which is proportional to the input voltage.

Counting circuits in the integrated circuit accumulate clock pulses during the REF interval until the comparator output changes state (reaches zero level). For a low input level, the zero level is reached quickly and only a few counts are accumulated. For full-scale inputs, however, up to 2000 counts may be accumulated. These situations are illustrated in Pictorial 8-4. You should note that, for ease of understanding, the integrator and buffer waveforms in Pictorial 8-4 correspond to a negative A/D input voltage. These are normally inverted in the Digital LC Bridge since the A/D circuit is measuring only positive voltages.

This circuit operation, as described earlier, depends only on the A/D input and reference voltages. The following equation shows this mathametically:

$$\text{Counts Displayed} = \frac{(\text{IN HI} - \text{IN LO})}{(\text{REF HI} - \text{REF LO})} \times 1000$$

where IN HI – IN LO = A/D input = V_{IN} and
REF HI – REF LO = reference voltage = V_{REF}

For the L and C functions, VIN is the 0 to +2.0 VDC, U118B ("V") output, and VREF is a fixed +1.0 VDC. For the D function, VIN is the 0 to +2.0 VDC, U115B ("D") output, and VREF is 0 to +1.0 VDC (one-half of the U118B output).

The following equations further simplify these relationships:

$$\text{Counts Displayed} = \text{"V"} \times 1000 \text{ for L and C}$$

$$\text{Counts Displayed} = \frac{\text{"D"}}{\text{"V"}} \times 2000 \text{ for D.}$$

If 2000 counts are accumulated and the integrator output has not been returned to the zero level, the comparator output does not change state. This is used to indicate an overrange.

The number of counts accumulated is internally stored, while other storage circuits register the polarity (or if an overrange occurred). The count and overrange data are then decoded to drive the LED display. The duration of the REF interval is variable from 0 counts (0 seconds) to 2000 counts (0.2 seconds). The auto-zero function begins immediately upon completion of the REF interval, and is described next.

A/Z (Auto-Zero)

Without correction circuitry, the operation of the A/D circuit would be highly sensitive to some variable conditions such as semiconductor error voltages, temperature, etc. U301 automatically performs a self-correction on each measurement cycle, which almost completely eliminates the effects of these variables.

During the A/Z interval, the A/Z switches shown in Pictorial 8-5 are closed and the INT and REF switches are open. The switch that closes to ground at the buffer input causes its output (one end of C305) to be equal to any offset voltage error in the buffer. The switch that closes across the comparator (and integrator) causes the other end of C305 to be at a voltage equal to the total offset voltages of these circuits (and any current-induced error voltages). The end-to-end voltage on C305 at the end of the A/Z interval is, therefore, equal to the sum of all of these errors, and offsets the operation of the circuit by this amount during the next INT and REF intervals. Since the integrator and A/Z switches are very high resistance semiconductor circuits, there is no discharge path that would affect this voltage during the INT and REF intervals. Any input to C305 is not reduced at its output and, therefore, C305 appears as a short circuit during these times. This auto-zeroing action makes U301 appear to have perfect circuitry for each measurement cycle.

The A/Z interval begins at the end of the combined INT and REF intervals (1000 to 3000 clock cycles) and ends when the internal clock counter circuits increment from 3999 to 0000. A new INT interval then begins and the measurement cycle repeats.

The only component parameters that have an effect on the circuit's measurement performance are the long-term stability of the reference voltage (after calibration) and the leakage resistance of C305 and C306 (which is very large). The R141, R191, and R133 connections are all tied to the +15 VDC supply, and these each establish or regulate the "V", "D", and fixed reference voltages. The A/D's ratio-measuring circuitry automatically cancels out any variation in this voltage. These elements combine to provide a stable and accurate measurement circuit.

A/D DISPLAY and SUPPLY VOLTAGE CIRCUIT

As you can see on the Schematic, numeric LED displays V301 to V304 are powered from the +4 volt supply. Each display segment connected to U301 is returned (via pin 21) to the power supply ground through current-regulating drivers (FET's) inside U301. This display drive technique minimizes variations in brightness from +4 volt supply variations.

Decimal numbers from 000 to 999 are shown on V301 to V303 as lighted combinations of the seven segments, and a separate 1 is lighted in V304 for displays from 1000 to 1999.

Decimal point segments in V302 to V304 are lighted by a logic low level to R185, R184, and R183, respectively. The decimal point drive circuitry is described later.

U301 measurement circuits are powered from the +5 volt supply (V DD at pin 1), which is filtered by C309, and from the −5 volt supply (pin 26), filtered by C307. The internal digital supply voltage (V DD to TEST) is filtered by C308.

RANGE SWITCH

Switch SW1 provides BCD (binary-coded-decimal) logic signals to U119 and U121 as a ground (logic 0) from switch contacts 1 (or 2), 3, and 4, in binary combinations. Ungrounded contacts are held at +5 volts by pull-up resistors R179, R181, and R182. The X1, X2, and X4 inputs to U119 and U121, therefore, change from logic "000" (decimal 0) on the 200 pF/µH range to logic "111" (decimal 7) on the 2000 µF/H range.

RANGE CONTROL

Integrated circuit U119 is a read-only memory (ROM) IC which provides a set of specific output logic levels for each set of input levels. The input levels from Range switch SW1 connect to pins 10, 11, and 12 for X1, X2, and X4, respectively, while a fourth input from SW101 (D) connects to pin 13. The outputs (pins 1 to 7) control various range-related circuits in response to these inputs.

The outputs at pins 1, 2, and 3 light the display decimal points at V304, V303, and V302, respectively, by placing a logic low at DP4, DP3, and DP2 for the L and C functions. For the D function, only the decimal point at V304 (DP4) is lighted.

The outputs at pins 4, 5, and 6 control FET switches U109D, U109A, and U116A, respectively. The output at pin 7 controls the test frequency selection at U102B and the phase shift capacitor selection at U109B and U116D. These outputs are the same for the L, C, or D function.

SENSE CONTROL

Another ROM, U121, also provides specific output levels for each set of input levels from SW1. Inputs from SW1 are the same as for U119, with the fourth input, at pin 13, coming from L switch SW102. The output levels from pins 1 to 7 control various current-sensing and sensitivity-related circuitry.

Outputs from pins 1, 2, and 3 control the internal switching in U108 using the RA, RB, and RC inputs. The pairs of FET switches closed in U108 correspond to the binary code shown on the schematic (near U108). These switches select current sensing resistors (R171 to R175) as shown. When RC is high, all switches in U108 are opened and disabled.

The outputs at pins 4 and 5 of U121C control U116C and U116D, respectively. These switches operate in conjunction with U108 or RY102 to select the lower-value sensing resistors.

The output at pin 6 powers RY101. This relay switches R122 across R121 when higher test currents are required from U104. D115 protects the output of U121 from the reverse voltage developed by the coil of RY101 when the relay de-energizes.

The output at pin 7 powers RY102, which acts with U116C to select the 10 Ω current-sensing resistor (R174). D116 protects the U121 output.

POWER SUPPLY INPUT

Power from a 120 VAC source is connected to the Digital LC Bridge through fuse F102 and Power switch SW104 to transformer T1. The secondary windings of T1 provide the lower AC voltages, which are rectified, filtered, and regulated to power the various circuits.

±15 VOLT SUPPLIES

Positive half-cycles at the Red secondary leads of T1 are rectified by D118 and D119 to charge C132 to approximately +22 VDC. This voltage is then series-regulated by U122 to provide a +15 VDC output at C131. This type of regulator is internally short-circuit protected. The "+15" solder pad on the foil side of the main circuit board provides a means to disconnect the load circuitry from the regulator output. The +15 volt supply is then further filtered in other circuits by C141, C143, etc.

Negative half-cycles are rectified by D121 and D122 to charge C134 to −22 VDC, which is regulated by U123 to −15 VDC. The output of U123 is then filtered by C133, and the "-15" solder pad allows disconnection of the load circuitry. The −15 VDC supply is further filtered in other circuits by C142, C144, etc.

±5 VOLT and +4 VOLT SUPPLIES

Positive half-cycles at the Green secondary leads of T1 are rectified by D124 and D125 to charge C136 to approximately +11 VDC. This voltage is then series-regulated by U124 to provide +5 volts at C135. The "+5" solder pad allows disconnection of the load circuitry from the regulator. Further filtering is provided in other circuits by C167, C169, and C171.

Similarly, D126 and D127 rectify the negative half-cycles to charge C138 to −11 VDC for input to U125. The regulated −5 VDC output is then filtered by C137, and the "−5" solder pad allows the regulator to be disconnected from the load circuitry. C168 provides further filtering in other circuits.

The +4 volt supply (actually about 4.3 VDC) is provided by the voltage drop across D123 from the +5 volt supply. This reduced voltage lowers the power dissipation in U301.

MISCELLANEOUS CIRCUITS

In the "Tests and Adjustments" section, you tested several AC voltage points by measuring DC voltage. This DC voltage is produced by connecting TP AC to the test point. D117 then rectifies the voltage, charging C129 to a positive DC level. R246 provides a discharge path and TP DC provides a measuring point.

The RTEST and CTEST components are used in the "Tests and Adjustments" section to provide a simple test of the "C" and "D" circuit operation on the 200 pF range.

SEMICONDUCTOR IDENTIFICATION CHARTS

DIODES

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	KEY NUMBER
D117	56-26	1N191	A1
D101, D107-D116	56-56	1N4149	
D102	56-612	1N5229B	
D103, D104	56-677	1N5350B	
D105, D106, D118-D127	57-65	1N4002	

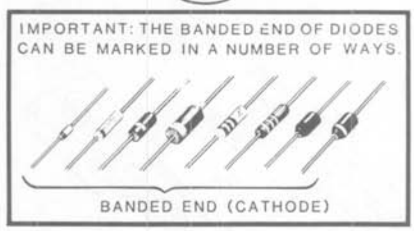
DISPLAYS

V301-V304	411-853	HP7651	B1

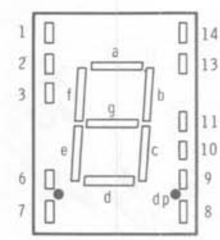
TRANSISTORS

Q102, Q103	417-235	2N4121	C1
Q101	417-998	PN4393	C2

A1



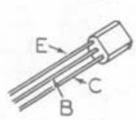
B1



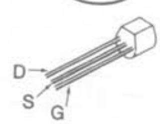
PIN CONNECTION

1. CATHODE a
2. CATHODE f
3. ANODE
4. NO PIN
5. NO PIN
6. NO CONN.
7. CATHODE e
8. CATHODE d
9. CATHODE dp
10. CATHODE c
11. CATHODE g
12. NO PIN
13. CATHODE b
14. ANODE

C1



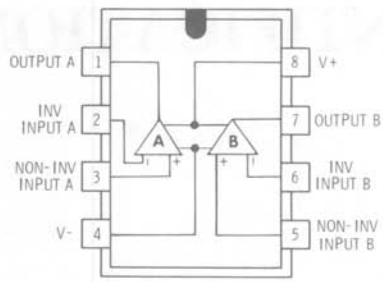
C2



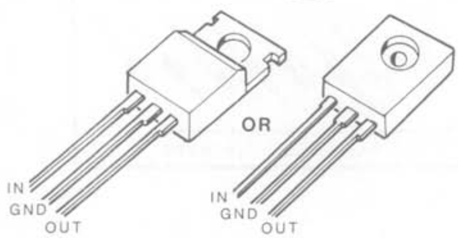
INTEGRATED CIRCUITS

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	KEY NUMBER
U112, U118	442-21	MC1458N	D1
U124	442-54	7805	D2
U113	442-75	LM311N	D3
U122	442-667	78M15	D2
U101	442-679	TL061CP	D4
U125	442-683	79M05	D5
U105, U106, U111, U115, U117	442-707	LF353N/ TL072	D1
U301	442-724	ICL7107CPL	D6
U102, U109, U116	442-770	DG211C	D7
U108	442-774	4052B	D8
U123	442-775	79M15	D5

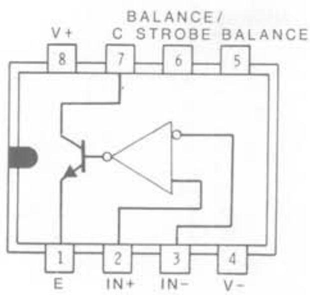
D1



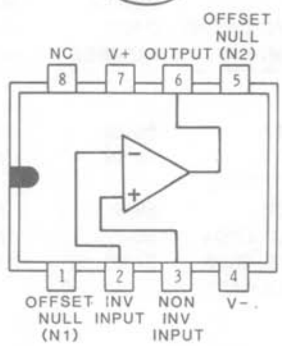
D2



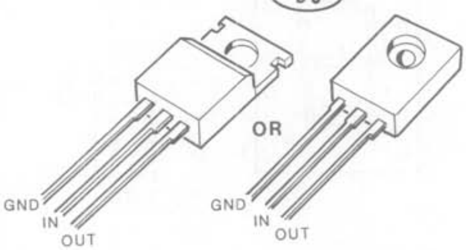
D3



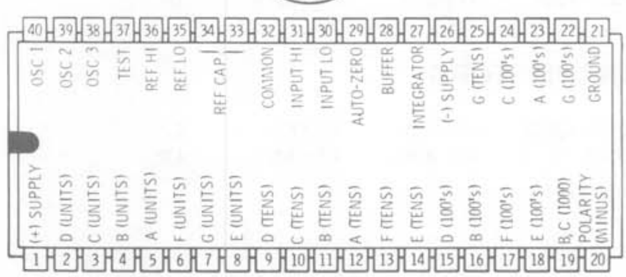
D4



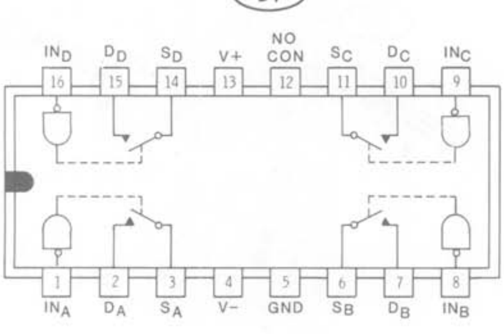
D5



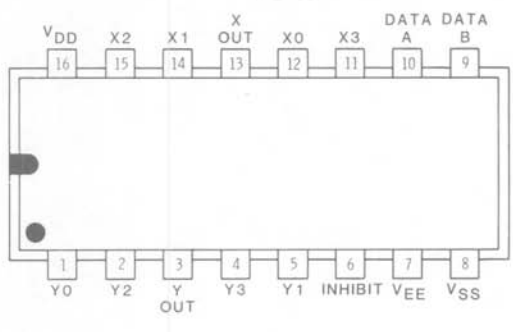
D6



D7



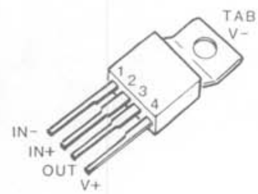
D8



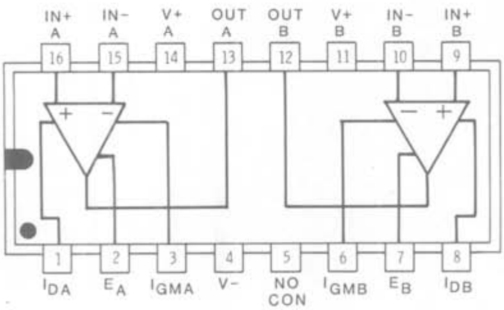
Heathkit®

COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	KEY NUMBER
U104, U107	442-776	µA77000U1C OR µA759U1C	D9
U103, U114	442-777	CA3280E	D10
U119	444-329	Available only from Heath Co.	D11
U121	444-330	Available only from Heath Co.	D11

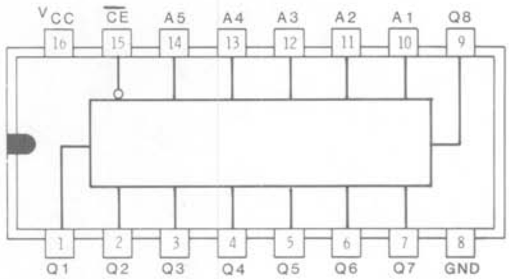
D9



D10



D11



CUSTOMER SERVICE

REPLACEMENT PARTS

Please provide complete information when you request replacements from either the factory or Heath Electronic Centers. Be certain to include the **HEATH** part number exactly as it appears in the parts list.

ORDERING FROM THE FACTORY

Print all of the information requested on the parts order form furnished with this product and mail it to Heath. For telephone orders (parts only) dial 616 982-3571. If you are unable to locate an order form, write us a letter or card including:

- Heath part number.
- Model number.
- Date of purchase.
- Location purchased or invoice number.
- Nature of the defect.
- Your payment or authorization for COD shipment of parts not covered by warranty.

Mail letters to: Heath Company
Benton Harbor
MI 49022
Attn: Parts Replacement

Retain original parts until you receive replacements. Parts that should be returned to the factory will be listed on your packing slip.

OBTAINING REPLACEMENTS FROM HEATH ELECTRONIC CENTERS

For your convenience, "over the counter" replacement parts are available from the Heath Electronic Centers listed in your catalog. Be sure to bring in the original part and purchase invoice when you request a warranty replacement from a Heath Electronic Center.

TECHNICAL CONSULTATION

Need help with your kit? — Self-Service? — Construction? — Operation? — Call or write for assistance. you'll find our Technical Consultants eager to help with just about any technical problem except "customizing" for unique applications.

The effectiveness of our consultation service depends on the information you furnish. Be sure to tell us:

- The Model number and Series number from the blue and white label.
- The date of purchase.
- An exact description of the difficulty.
- Everything you have done in attempting to correct the problem.

Also include switch positions, connections to other units, operating procedures, voltage readings, and any other information you think might be helpful.

Please do not send parts for testing, unless this is specifically requested by our Consultants.

Hints: Telephone traffic is lightest at midweek — please be sure your Manual and notes are on hand when you call.

Heathkit Electronic Center facilities are also available for telephone or "walk-in" personal assistance.

REPAIR SERVICE

Service facilities are available, if they are needed, to repair your completed kit. (Kits that have been modified, soldered with paste flux or acid core solder, cannot be accepted for repair.)

If it is convenient, personally deliver your kit to a Heathkit Electronic Center. For warranty parts replacement, supply a copy of the invoice or sales slip.

If you prefer to ship your kit to the factory, attach a letter containing the following information directly to the unit:

- Your name and address.
- Date of purchase and invoice number.
- Copies of all correspondence relevant to the service of the kit.
- A brief description of the difficulty.
- Authorization to return your kit COD for the service and shipping charges. (This will reduce the possibility of delay.)

Check the equipment to see that all screws and parts are secured. (Do not include any wooden cabinets or color television picture tubes, as these are easily damaged in shipment. Do not include the kit Manual.) Place the equipment in a strong carton with at least THREE INCHES of *resilient* packing material (shredded paper, excelsior, etc.) on all sides. Use additional packing material where there are protrusions (control sticks, large knobs, etc.). If the unit weighs over 15 lbs., place this carton in another one with 3/4" of packing material between the two.

Seal the carton with reinforced gummed tape, tie it with a strong cord, and mark it "Fragile" on at least two sides. Remember, the carrier will not accept liability for shipping damage if the unit is insufficiently packed. Ship by prepaid express, United Parcel Service, or insured Parcel Post to:

Heath Company
Service Department
Benton Harbor, Michigan 49022

HEATH ZENITH

HEATH COMPANY • BENTON HARBOR, MICHIGAN

THE WORLD'S FINEST ELECTRONIC EQUIPMENT IN KIT FORM

LITHO IN U.S.A.