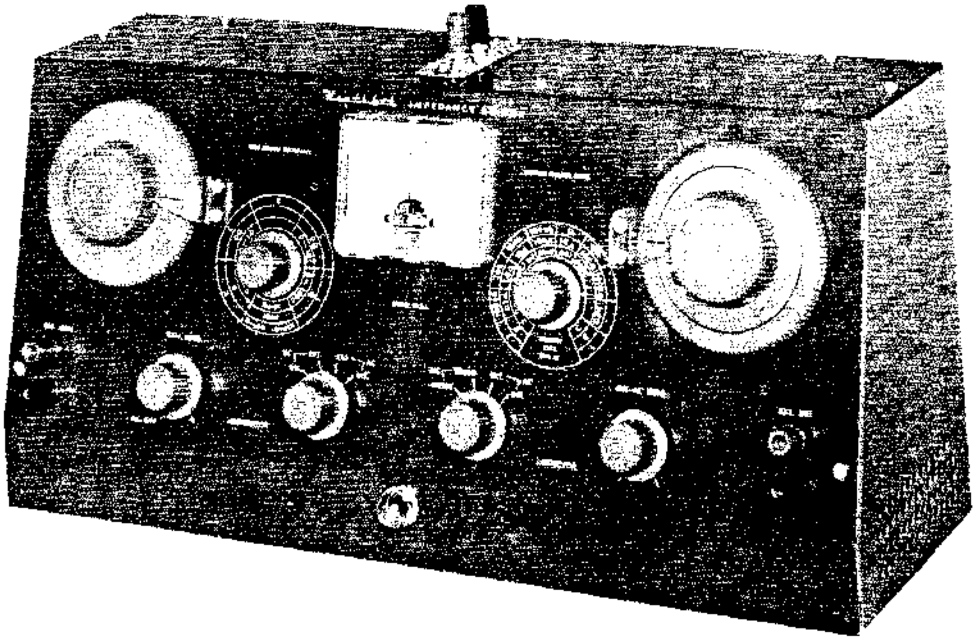
ASSEMBLY AND OPERATION OF THE HEATHKIT IMPEDANCE BRIDGE

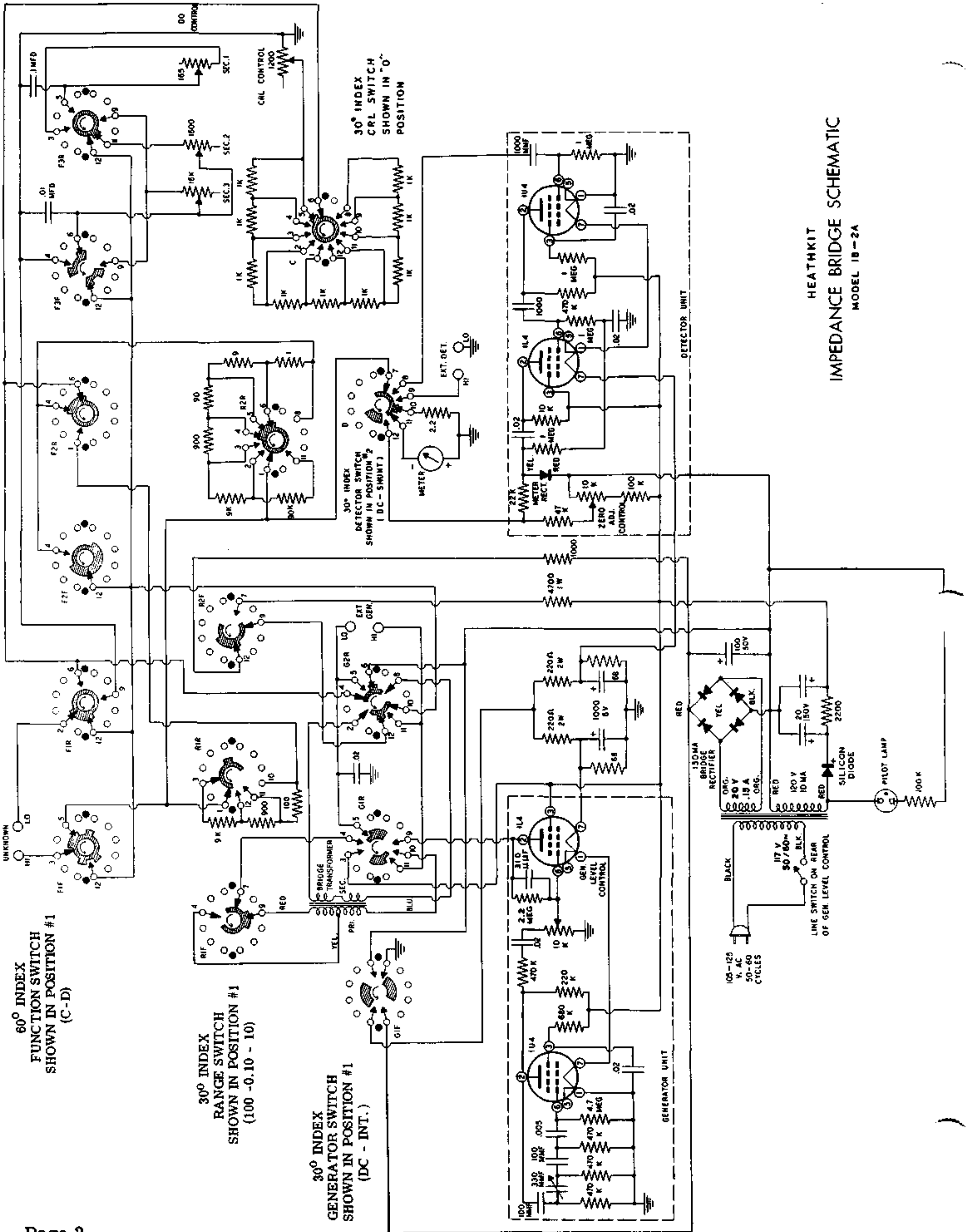
MODEL IB-2A



SPECIFICATIONS

Circuit.	4-arm impedance bridge.
DC Measurements.	Built-in power supply operating directly from 110 V AC. Panel binding posts provide for use of external supply.
Meter.	100-0-100 microampere meter.
AC Measurements.	Built-in 1000 cycle vacuum tube oscillator. Terminals on panel provide for connecting an external generator for measurement at other frequencies.
Detector.	Vacuum tube detector and rectifier make use of built-in meter. Panel binding posts provide for connection to external detector.
Resistance.	0.1 Ω to 10 megohm.
Capacitance.	100 μμfd to 100 μfd.
Inductance.	0.1 mh to 100 h.
Dissipation Factor (D).	0.002 to 1.
Storage Factor (Q).	0.1 to 1000.
Accuracy.	1/2 of 1% decade resistors used. 1/2 of 1% silver mica condensers used. Accuracy is limited more by interpretation of scales and workmanship of assembly. The following is normal: Resistance ±3% Capacitance ±3% Inductance ±10% Dissipation Factor ($D = \omega CR$) ±20% Storage Factor ($Q = \omega L/R$) ±20% Accuracy will fall off at extreme outer limits.
Power Requirements.	105-125 volts, 50/60 cycles, 10 watt.
Tube Complement.	2 - 1U4 and 2 - 1L4.
Power Supply.	Power Transformer, silicon diode, and bridge rectifier.
Cabinet Size.	8" high x 17" wide x 6" deep.
Shipping Weight.	15 lbs.

11/26/65


HEATHKIT
IMPEDANCE BRIDGE SCHEMATIC
MODEL IB-2A
60° INDEX
FUNCTION SWITCH
SHOWN IN POSITION #1
(C-D)
30° INDEX
RANGE SWITCH
SHOWN IN POSITION #1
(100 -0.10 - 10)
30° INDEX
GENERATOR SWITCH
SHOWN IN POSITION #1
(DC - INT.)
30° INDEX
DETECTOR SWITCH
SHOWN IN POSITION #2
(DC - SHUNT)
30° INDEX
CRL SWITCH
SHOWN IN "0"
POSITION
CRL CONTROL
DQ CONTROL
DETECTOR UNIT
GENERATOR UNIT
UNKNOWN
EXT. DET.
EXT. GEN.
BRIDGE TRANSFORMER
METER
ZERO ADJ. CONTROL
GEN LEVEL CONTROL
150MA BRIDGE RECTIFIER
SILICON DIODE
PILOT LAMP
117 V 50/60~
LINE SWITCH ON REAR OF GEN. LEVEL CONTROL
105-125 V. AC 50-60 CYCLES

GENERAL DESCRIPTION

The Heathkit model IB-2A Impedance Bridge is a self-contained, direct reading precision laboratory instrument designed for rapid and accurate measurement of resistance, capacitance, inductance, dissipation factors of condensers, and storage factors of inductors.

The Heathkit Impedance Bridge is a self-powered four-arm bridge of standard design for use in laboratories, service shops and schools. By use of switches, a number of basic bridge circuits are obtained.

Resistance is measured with an internal well filtered power supply operating directly from 105-120 volts AC, 50/60 cycles. This supply uses a transformer, silicon diode, and bridge rectifier.

A 100-0-100 microampere meter is used for determining balance. A 2.2 Ω resistor is shunted across the meter for protection. This may be cut out for final balance.

A built-in vacuum tube adjustable phase shift generator supplies 1000 cycles for alternating voltage measurements. A trimmer condenser provides for setting the frequency of the oscillator by means of a laboratory standard if desired. Binding posts are available for connecting to an external generator for measurements at frequencies other than 1 kc. Battery type tubes are used so that a warming up period is not required and also to eliminate change in operating characteristics due to thermal effect.

The built-in vacuum tube detector unit and meter rectifier make possible the use of the meter for AC measurements thus making unnecessary the usual headset or other device for such measurements. Provision is made for using an external detector when desirable.

THEORY

A bridge is an arrangement of impedances used for measuring various electrical properties. When used for direct current measurement of resistance, the bridge generally takes the form of the Wheatstone bridge with four resistance arms. This is the standard method for the accurate measurement of resistance.

For the measurement of circuit constants at audio frequencies, the alternating-current bridge is the most widely used device. Measurements of inductance and capacitance are made conveniently and accurately by this method. The type of AC bridge circuit used is determined by the measurement to be made. These circuits are all adaptations of the fundamental Wheatstone bridge circuit.

A characteristic of a coil or condenser which is of importance and which can be measured conveniently on an AC bridge, is the ratio of resistance to reactance. This ratio is defined as the dissipation factor D, and its reciprocal is called the storage factor Q. The defining equations are as follows:

$$D = \frac{1}{Q} = \frac{R}{X} \qquad Q = \frac{1}{D} = \frac{X}{R}$$

where R and X are the series resistance and reactance of the inductance or capacitance being measured.

Dissipation factor is directly proportional to the energy dissipated per cycle and storage factor is directly proportional to the energy stored per cycle. Dissipation factor is more commonly used for condensers because it varies with the loss, while storage factor is more commonly used for inductors since it indicates the voltage step-up in a tuned circuit.

In its basic form the bridge consists of four impedance arms A, B, C, D. The ratio of A and B is adjustable so that the variable arm D serves as a standard for measuring many values at C. The four impedances are connected in series-parallel to a source of potential E between the junctions of A and C. When the voltage drop across arm A is equal to the voltage drop across arm C, no current will flow through the detector and the bridge is in balance. This condition of balance may be indicated by the formula:

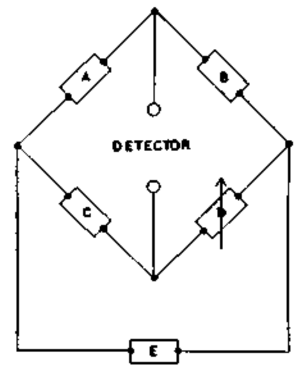


Figure 1

$$\frac{A}{C} = \frac{B}{D}$$

Two conditions are necessary for balance. Both the magnitudes of the impedances and the phase angles must be equal.

By the proper use of resistances, condensers, inductors or resistor-condenser combinations in series or parallel, the bridge may be used for measuring resistance, capacity, inductance, dissipation factor (D) and storage factor (Q).

In this bridge, selection of the various bridge combinations is made by setting the function switch to the proper position. The ratio arms of the bridge are controlled by the range switch. Balance is obtained by adjustment of the DQ and CRL dials.

RESISTANCE MEASUREMENTS

After over a century of use the Wheatstone bridge is still considered to be the fundamental circuit for the measurement of DC resistance. A Wheatstone bridge of four resistance arms, the fourth being the unknown, is used for resistance measurements. The basic equation of balance for the Wheatstone bridge is:

$$R_X = \frac{R_D R_A}{R_B}$$

R_D is read on the CRL control and the ratio R_A/R_B is read on the range dial. Thus the value of the unknown resistance is the product of the readings of the two dials.

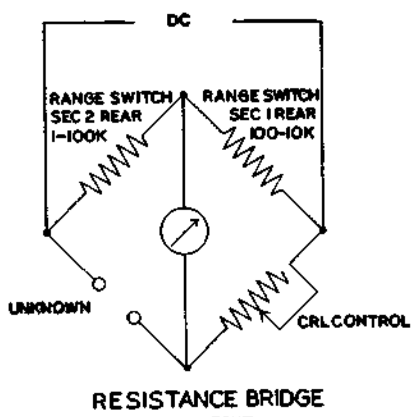


Figure 2

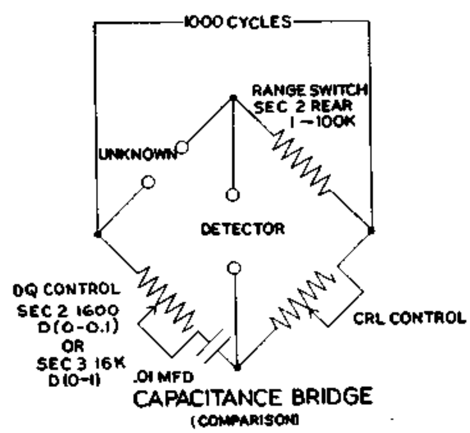


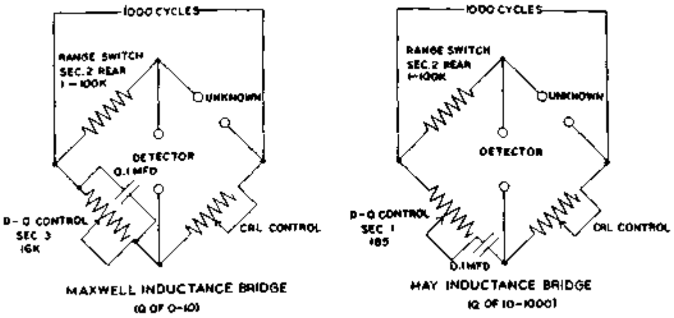
Figure 3

CAPACITY MEASUREMENTS

A Capacitance-Comparison bridge is used for the measurement of capacity. This circuit utilizes a standard condenser in series with a variable resistance. Dissipation factor is also measured with this circuit.

INDUCTANCE MEASUREMENTS

Figure 4



The Maxwell bridge is used for measuring inductances when the storage factor is below 10. In this bridge, inductance is measured in terms of capacitance. A condenser has some advantages as a standard as it gives practically no external field and is more compact.

For measuring inductances with storage factors between 10 and 1000, the Hay bridge is used. This is a modification of the Maxwell bridge. In the Hay bridge, the condenser is in series with the resistance, while in the Maxwell bridge, the condenser is in parallel with the resistance.

NOTES ON ASSEMBLY AND WIRING

The quality of parts and design of the Heathkit model IB-2A Impedance Bridge place it in the laboratory equipment class. When constructed in accordance with the instructions in this manual it will give many years of satisfactory service. We therefore urge you to take the necessary time to assemble and wire the kit carefully.

This manual is supplied to assist you in every way to complete the instrument with the least possible chance for error. We suggest you take a few minutes now and read the entire manual through before any work is started. This will enable you to proceed with the work much faster when construction is started. The large fold-in pictorials are handy to attach to the wall above your work space. Their use will greatly simplify the completion of the kit. These diagrams are repeated in smaller form within the manual. We suggest you retain the manual in your files for future reference, both in the use of the instrument and for its maintenance.

UNPACK THE KIT CAREFULLY AND CHECK EACH PART AGAINST THE PARTS LIST. In so doing, you will become acquainted with each part. Refer to the charts and other information shown on the inside covers of the manual to help you identify any parts about which there may be a question. If some shortage is found in checking the parts, please notify us promptly.

ROSIN CORE SOLDER HAS BEEN SUPPLIED WITH THIS KIT. THIS TYPE OF SOLDER MUST BE USED FOR ALL SOLDERING IN THIS KIT. ALL GUARANTEES ARE VOIDED AND WE WILL NOT REPAIR OR SERVICE EQUIPMENT IN WHICH ACID CORE SOLDER OR PASTE FLUXES HAVE BEEN USED. IF ADDITIONAL SOLDER IS NEEDED, BE SURE TO PURCHASE ROSIN CORE (60:40 or 50:50 TIN-LEAD CONTENT) RADIO TYPE SOLDER.

Resistors and controls generally have a tolerance rating of ±20% unless otherwise stated in the parts list. Therefore, a 100 KΩ resistor may test anywhere from 80 KΩ to 120 KΩ. (The letter K is commonly used to designate a multiplier of 1000.) Tolerances on condensers are generally even greater. Limits of +100% and -20% are common for electrolytic condensers. The parts furnished with your Heathkit have been specified so as to not adversely affect the operation of the finished instrument.

The oscillator circuit is designed to operate somewhere between 800 and 1200 cps. The actual frequency will depend on the components. A trimmer condenser is provided so that the frequency may be set at approximately 1 kc by use of an audio generator. The most convenient method is to use an oscilloscope. Set the audio generator at 1 kc and connect it to one set of plates of the oscilloscope. Connect the terminals on top of the bridge to the other set of plates of the oscilloscope. Set the GENERATOR switch at AC INTERNAL, the DETECTOR switch at AC INTERNAL, the GENERATOR LEVEL control clockwise, the FUNCTION switch at L-DQ and the RANGE switch a 1h. Adjust the trimmer until a circle or ellipse appears on the oscilloscope. The bridge generator frequency is then equal to the frequency of the audio generator.

If an oscilloscope is not available, headphones may be used. The output of the audio generator and the bridge oscillator may be fed into the earphones and the trimmer adjusted until zero beat is heard. The frequency of the bridge oscillator will then equal the frequency of the audio oscillator. The bridge may still be used even if an audio oscillator is not available. Tighten the trimmer condenser by turning the screw clockwise. Then turn the screw 1/2 turn counter-clockwise. This will set the oscillator at approximately 1 kc. Later adjustment may be made when additional equipment is available.

The CRL control is set as follows. Check the zero setting of the galvanometer. Set the FUNCTION switch to R. Set the GENERATOR switch to DC INTERNAL and the DETECTOR switch to DC SHUNT. Set the RANGE switch to 100 Ω on the R scale. Set the ring of the CRL control to 5. Connect the 550 Ω precision resistor supplied for calibration across the terminals on the top of the bridge. Rotate the knob of the CRL control until the galvanometer does not move when the DETECTOR switch is moved to DC METER position. The switch is spring loaded in this position so it will return to DC SHUNT position when released. Now loosen the CRL control knob and rotate it until it reads .5 on the stationary pointer. The CRL dial now will read 5.5. Tighten the CRL control knob and again check to see that the meter does not move when the DETECTOR switch is moved to DC METER position. Repeat the adjustment until the meter does not move. The CRL control is now set and ready for use.

If greater accuracy of the DQ control calibration is desired (more than that obtainable by simply zero-setting the knob), proceed in the following manner:

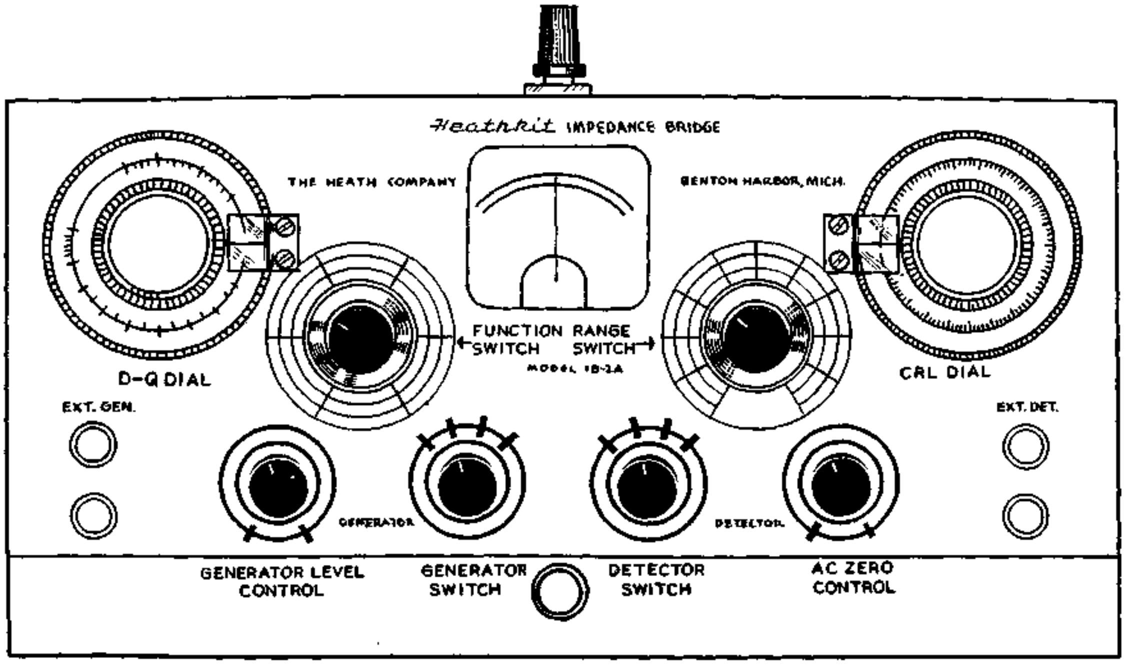
1. Set up the controls as outlined for the CRL calibration. Remove the 550 Ω precision resistor from the terminals on top of the bridge.

2. Disconnect the end of the wire connecting lug 2 of the rear section of the DQ control to lug 6 on the rear deck of function switch FS at the switch.

3. Temporarily connect a jumper wire (clip-leads will suffice, if available) between lug 1 of the rear section of the DQ control and lug 1 of terminal strip TS on top of the bridge. Connect another lead between lug 2 of the same rear section and lug 2 of the binding post strip (the red post). Turn on the power. Set the CRL controls to read 160 Ω and adjust the DQ control to bring the meter to zero (this will occur near the 0.1 mark on the DQ knob). Verify this adjustment by turning the DETECTOR switch to DC METER. No pointer movement is noticeable at exact zero. The adjustment is critical, so use care.

   When the bridge has been balanced, note the position of the 0.1 mark on the DQ dial with respect to the pointer. Correct the knob setting to read exactly 0.1 and rebalance the bridge to check. A double check may be made by turning the RANGE switch to 1000 Ω. The bridge should balance at 1.0 on the DQ dial.

   When calibration is complete, remove the jumpers and reconnect the proper leads to the control and the switch FS.



FRONT PANEL SHOWING CONTROLS

Figure 17

DC Resistance Measurements

1. Plug in the cord and turn on the switch mounted on the GENERATOR LEVEL control.
2. Check the zero setting of the galvanometer.
3. Connect the unknown resistance to the terminals on top of the bridge.
4. Set the FUNCTION switch to R.
5. Set the GENERATOR switch to DC INTERNAL.
6. Set the DETECTOR switch to DC SHUNT.
7. Set the CRL DIAL to zero.

For greater indicating accuracy of DC resistance measurements, external batteries may be used as follows:

Provided the CRL dial is not turned below 1, the following external battery voltages in series with additional resistance may be used:

On multipliers	not more than	in series with
0.1 Ω, 1.0 Ω, 10 Ω, 100 Ω	67 1/2 V	not less than 1500 ohms.
1 KΩ	135 V	not less than 4000 ohms.
10 KΩ, 100 KΩ, 1 Megohm ...	202 1/2 V	not less than 6500 ohms.

8. Set the RANGE switch (CRL multiplier dial) to the setting that results in minimum deflection of the galvanometer. Choose the setting that gives a reading to the left of the zero mark.
9. Turn the rim of the CRL control for approximate balance, then continue with the center knob for further balance.
10. For final balance, turn the DETECTOR switch to DC METER.
11. Multiply CRL reading by multiplier setting of the RANGE switch to find the resistance. For resistance measurements below 1 Ω, it is recommended that an external galvanometer of greater sensitivity be used.

    Low resistance measurements are subject to errors due to the internal resistance of the bridge and resistances of the contacts and leads. The internal resistance of the bridge can be measured by shorting the unknown terminals with a piece of heavy wire and balancing the bridge in the usual manner. It will probably be of the order of .02 Ω. The lead resistance can be partially eliminated by connecting the resistance directly to the binding post. Cleaning the leads will also help to minimize errors in lead resistance. When measuring low resistances, the internal resistance of the bridge should be subtracted from the measured value of resistance to give the corrected value.

Inductance Measurements at 1000 Cycles

1. Connect the unknown inductor to the terminals on top of the bridge.
2. Set the GENERATOR switch to AC INTERNAL.
3. Set the DETECTOR switch to AC INTERNAL.
4. Set the FUNCTION switch to L-DQ. Set the DQ dial at 50%.
5. Set the AC ZERO control so that the meter reads 100 microamperes counterclockwise. The GENERATOR LEVEL control should be in counterclockwise while this is done.
6. Set the GENERATOR LEVEL control so that the meter will move about half scale.
7. Set the RANGE switch so that the meter will read maximum counterclockwise.
8. Alternately adjust the CRL and DQ dials until the meter reads maximum counterclockwise. Move the GENERATOR LEVEL control clockwise as balance is approached so that at final balance it will be in maximum clockwise position. If the DQ setting tends to go above 10, set the FUNCTION switch to L-Q and again balance as above.
9. Multiply the CRL reading by the multiplier setting of the RANGE switch to find L. Q is read directly from the DQ or Q scale.

Inductance measurements at other frequencies may be made by using an external generator. Set the GENERATOR switch to EXTERNAL GENERATOR and measure as outlined for 1000 cycles.

Capacitance Measurements at 1000 cycles

1. Connect the unknown capacitance to the terminals on top of the bridge.
2. Set the GENERATOR switch to AC INTERNAL.
3. Set the DETECTOR switch to AC INTERNAL.
4. Set the FUNCTION switch to C-DQ. Set the DQ dial to zero.
5. Set the AC ZERO control so that the meter reads 100 microamperes counterclockwise. The GENERATOR LEVEL control should be in counterclockwise position while this is done.
6. Set the GENERATOR LEVEL control so the meter will read about half scale.
7. Set the RANGE switch so that the meter will read maximum counterclockwise.
8. Adjust the CRL and DQ dials until the meter reads maximum counterclockwise. The GENERATOR LEVEL control should be moved clockwise as balance is approached so that at final balance it is in maximum clockwise position. If the DQ setting tends to go below one, set the FUNCTION switch to CD and again balance as above.
9. Multiply the CRL reading by the multiplier setting on the RANGE switch to find C. Read D directly on the DQ dial.

Capacitance measurements at frequencies other than 1000 cycles may be made by using an external generator and following the method outlined above.

The CRL reading is independent of frequency. Dissipation factor and storage factor both depend upon frequency, however, so a correction factor must be applied to the D-Q readings. For 1 kc, the D and Q readings are direct. For frequencies other than 1 kc, the dissipation factor D is obtained by multiplying the observed value of D by the frequency in kilocycles. Storage factor Q at any frequency is the observed value on the DQ dial multiplied by the frequency in kilocycles or the observed value on the Q dial divided by the frequency in kilocycles.

IN CASE OF DIFFICULTY

1. Check the wiring by following each wire on the pictorial and in the instrument, inspecting the soldered connections on each end and then checking off that wire on the pictorial with a colored pencil. This will reveal mistakes and omissions in wiring, which is the most frequent cause of difficulties. Often having a friend check the wiring will reveal a mistake consistently overlooked.
2. Check the position of the switches on the panel and be sure they are in the proper position.
3. Check the tubes.
4. Check the voltages between tube socket terminals and chassis. The readings should come reasonably close to the values tabulated below, if a vacuum tube voltmeter with 11 megohm input resistance is used. Other type meters may give considerably lower readings. If a voltage reading fails to check with the tabulation, investigate the portion of the circuit involved by checking the resistors and condensers.

VOLTAGE CHART

SOCKET	TUBE	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7
GENERATOR F	1U4	0	50-55	45-50	NC	0	.3-.35*	1.4-1.45
H	1L4	1.4-1.45	95-105	100-110	NC	1.4-1.45	NS	2.4-2.6
DETECTOR N	1U4	0	40-45	35-40	NC	0	.3-.35*	1.4-1.45
S	1L4	1.4-1.45	70-75	100-110	NC	1.4-1.45	22-23*	2.4-2.6

* - Negative with respect to chassis.
NC - No connection.
NS - Not significant.
All measurements made with GENERATOR LEVEL control set at maximum, GENERATOR switch at AC INTERNAL, DETECTOR switch at AC INTERNAL, FUNCTION and RANGE switches in maximum clockwise position.
Unless otherwise indicated, all voltages are positive and measured to chassis.
Line voltage - 115 volts, 60 cycles.

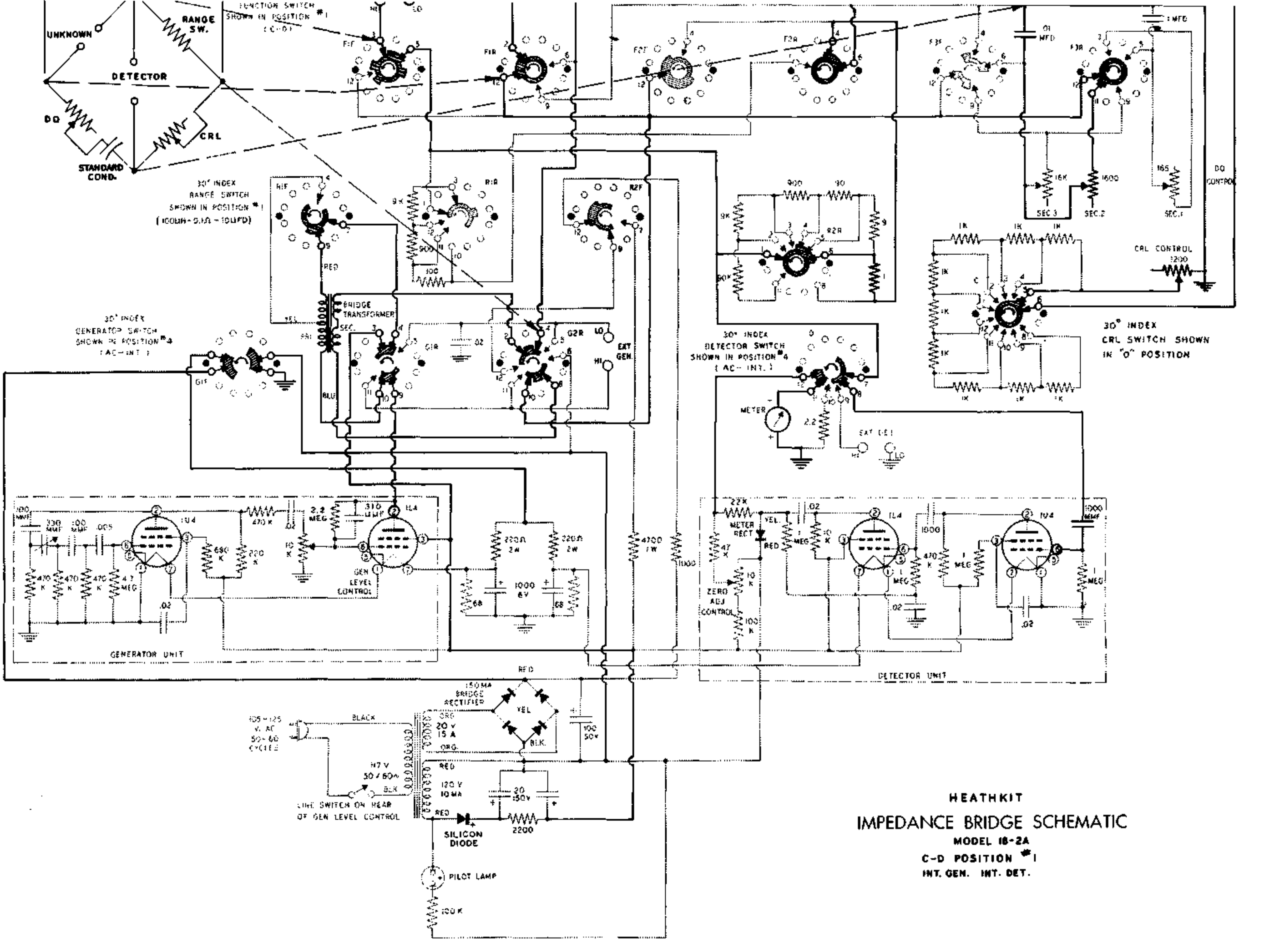
BIBLIOGRAPHY

Hague, B., "Alternating-Current Bridge Methods," Sir Isaac Pitman and Sons, Ltd., London

Terman, F. E., "Radio Engineers' Handbook," section 13, McGraw-Hill Book Co., New York

Stout, M. B., "Basic Electrical Measurements," ch. 9, 13, Prentice-Hall, Inc., New York

Harris, F. K., "Electrical Measurements," ch. 7, 15, John Wiley and Sons, New York



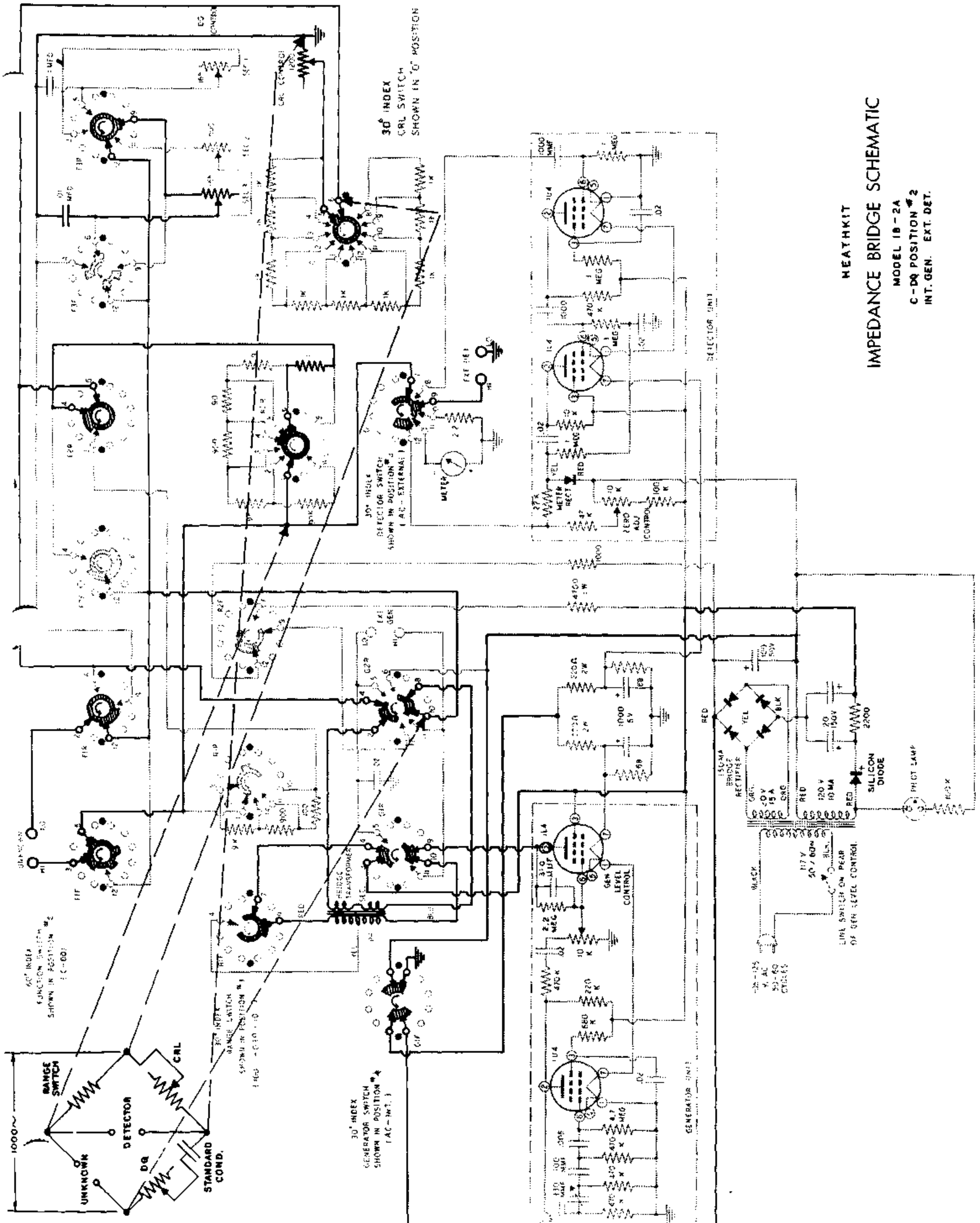
HEATHKIT

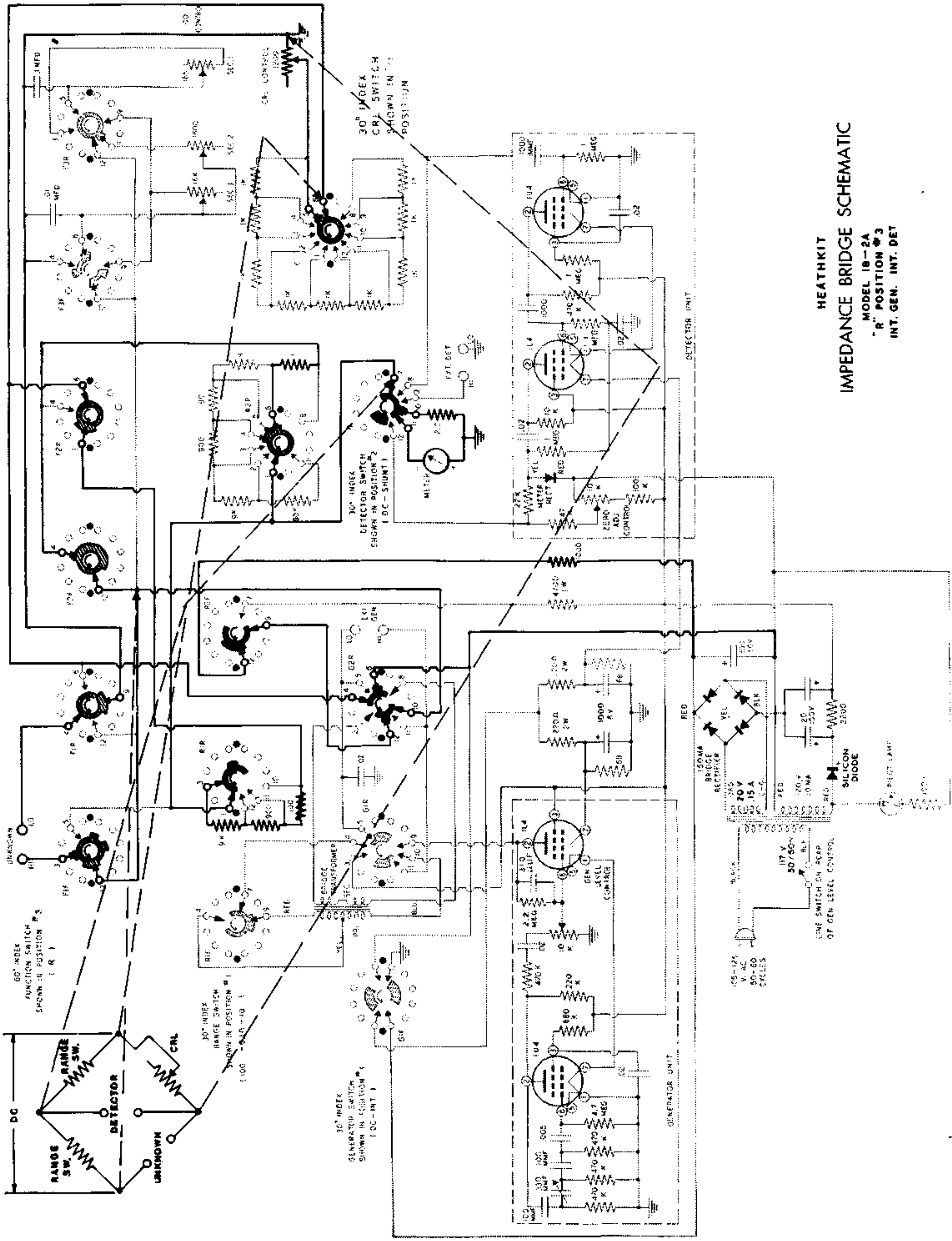
IMPEDANCE BRIDGE SCHEMATIC

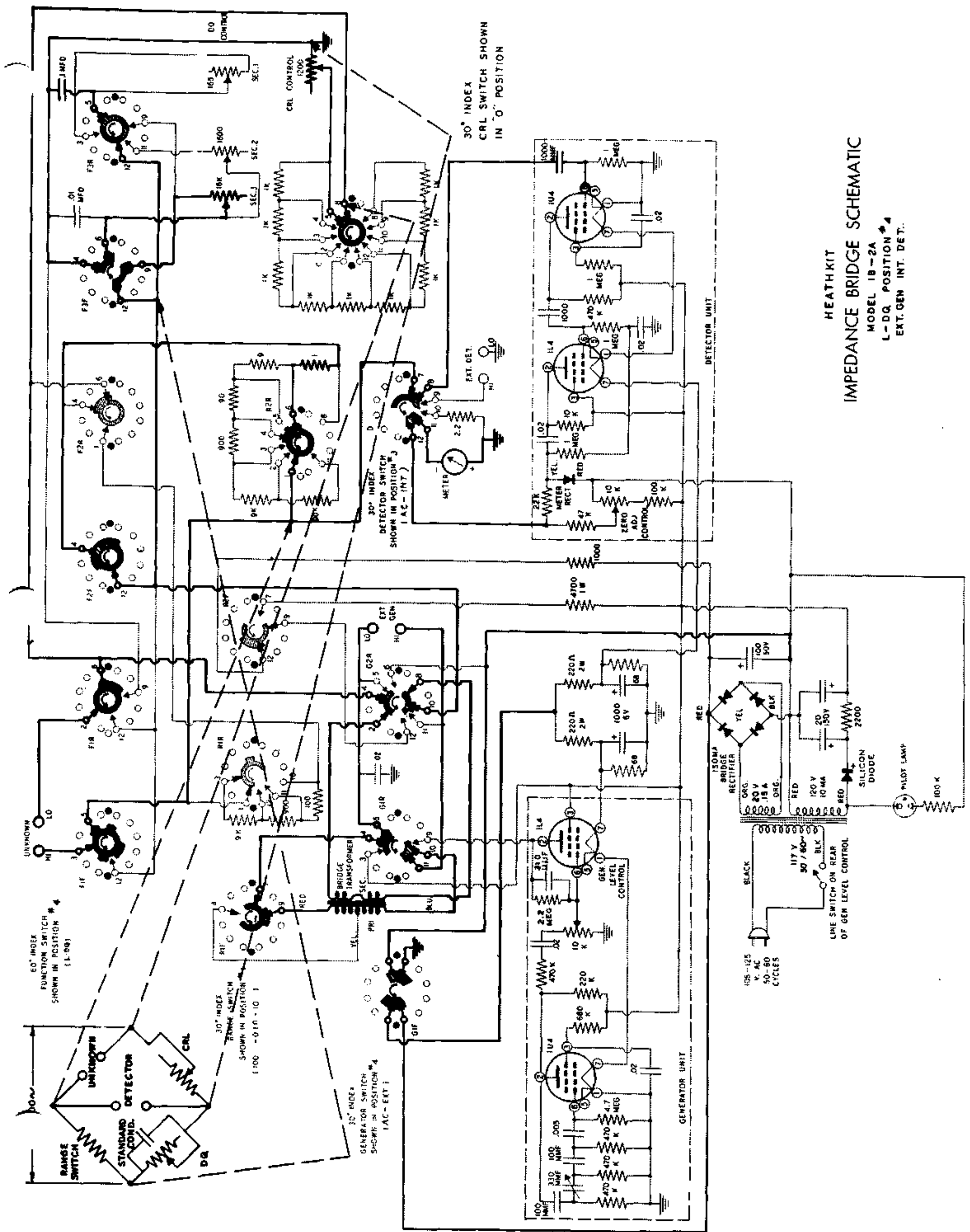
MODEL IB-2A

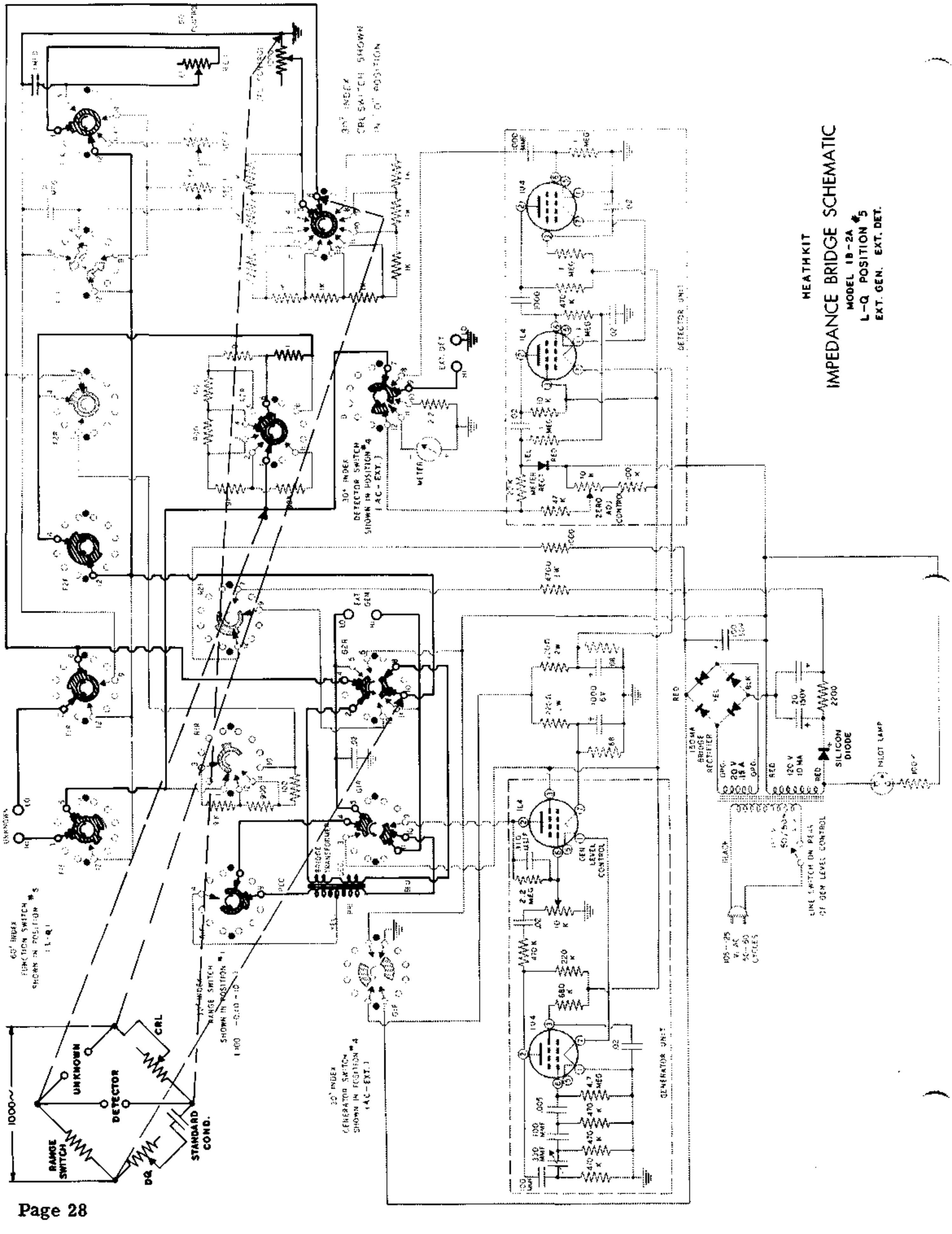
C-D POSITION #1

INT. GEN. INT. DET.


HEATHKIT
IMPEDANCE BRIDGE SCHEMATIC
MODEL IB-2A
C-DQ POSITION #2
INT. GEN. EXT. DET.
30° INDEX
CRL SWITCH
SHOWN IN "0" POSITION
30° INDEX
DETECTOR SWITCH #3
SHOWN IN POSITION #1
(AC-EXTERNAL)
60° INDEX
FUNCTION SWITCH #2
SHOWN IN POSITION
(C-DQ)
30° INDEX
RANGE SWITCH
SHOWN IN POSITION #1
30° INDEX
GENERATOR SWITCH #4
SHOWN IN POSITION #1
(AC-INT.)
DETECTOR UNIT
GENERATOR UNIT
GEN LEVEL CONTROL
ZERO ADJ CONTROL
METER
METER RECT
BRIDGE TRANSFORMER
EXT DET
EXT GEN
UNKNOWN
STANDARD COND.
DETECTOR
RANGE SWITCH
CRL
DQ
1000~
SILICON DIODE
PILOT LAMP
150MA BRIDGE RECTIFIER
120 V 10 MA
117 V 50/60N
LINE SWITCH ON REAR OF GEN LEVEL CONTROL
BLACK
RED
YEL
BLK
1U4
1L4


HEATHKIT
IMPEDANCE BRIDGE SCHEMATIC
MODEL IB-2A
"R" POSITION #3
INT. GEN. INT. DET


HEATHKIT
IMPEDANCE BRIDGE SCHEMATIC
MODEL IB-2A
L-DQ POSITION #4
EXT. GEN INT. DET.
30° INDEX
CRL SWITCH SHOWN
IN "0" POSITION
DQ CONTROL
CRL CONTROL 1200
DETECTOR UNIT
GENERATOR UNIT
30° INDEX DETECTOR SWITCH SHOWN IN POSITION #3 (AC-INT)
60° INDEX FUNCTION SWITCH SHOWN IN POSITION #4 (L-DQ)
30° INDEX RANGE SWITCH SHOWN IN POSITION (100-010-10)
30° INDEX GENERATOR SWITCH SHOWN IN POSITION #4 (AC-EXT)
EXT. DET.
EXT GEN
UNKNOWN
METER
METER RECT
ZERO ADJ CONTROL
BRIDGE TRANSFORMER
GEN LEVEL CONTROL
150MA BRIDGE RECTIFIER
SILICON DIODE
PILOT LAMP
117 V 50/60~
LINE SWITCH ON REAR OF GEN LEVEL CONTROL
105-125 V. AC 50-60 CYCLES
RANGE SWITCH
STANDARD COND.
DETECTOR
CRL
DQ


HEATHKIT
IMPEDANCE BRIDGE SCHEMATIC
MODEL IB-2A
L-Q POSITION #5
EXT. GEN. EXT. DET.
UNKNOWN
DETECTOR
CRL
RANGE SWITCH
DQ
STANDARD COND.
1000~
SILICON DIODE
PILOT LAMP
BRIDGE TRANSFORMER
METER
DETECTOR UNIT
GENERATOR UNIT