USER'S GUIDE

MODEL 60

IMPEDANCE MAGNITUDE METER

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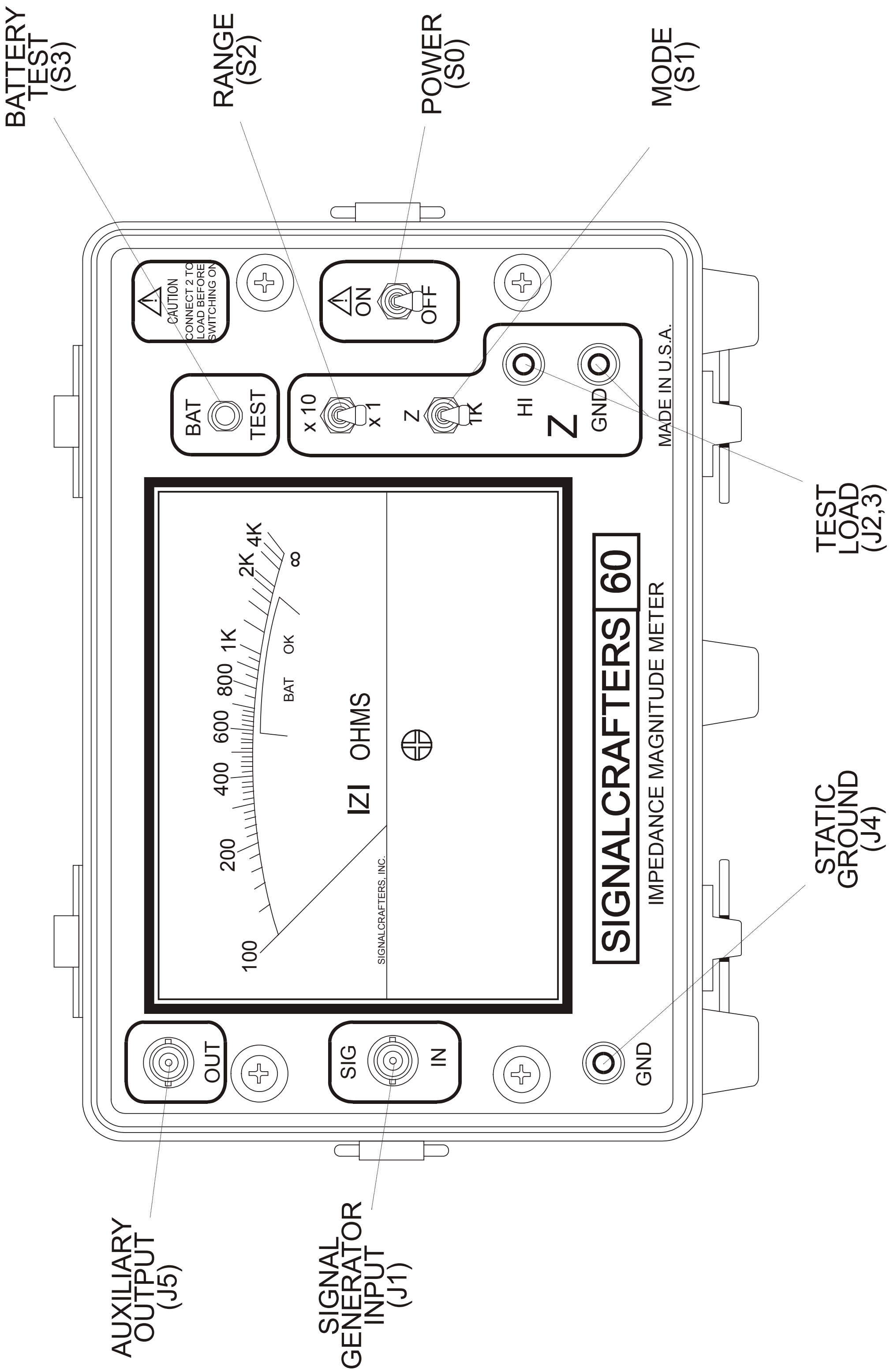


Model 60 Impedance Magnitude Meter
Figure 1

1. DESCRIPTION OF THE MODEL 60 IMPEDANCE MAGNITUDE METER

1.1 Overview

The Model 60 is an ac ohmmeter that will display the magnitude of the impedance (|Z|) of a Test Load, connected to the “Z” terminals, at any frequency from 30 kHz to 500 kHz. It has two ranges: 100 ohms to 4 k ohms (“x 1” range) and 1000 ohms to 40 k ohms (“x 10” range). An external signal generator must be connected to the “SIGIN” connector to provide the desired frequency of ac to the Test Load. The meter display of impedance is obtained by detecting the current through the Test Load while it is being driven by the signal generator source. The Model 60 circuitry calculates the indicated impedance as the ratio of voltage to current.

The Model 60 was designed with three goals in mind. First, it must be a mechanically and electrically rugged field instrument requiring only one accessory – the signal generator. Second, it must measure impedances in an electrically noisy environment such as a power line switch yard. Third, it must allow determination of test load resonant frequencies with good accuracy, i.e. within ± 1% or better.

The basic impedance-indicating accuracy of the instrument, at 20 degrees C and over most of the meter scale, is ± 10% when driven by a signal source of 1% distortion or less. At the top end of the scale above 1.2k, where scale divisions are crowded together, reading accuracy falls to ± 20%. These specifications apply if the test load is resistive, reactive, or resonant. When a resonant load is measured the maximum impedance will be shown within ± 0.2% of its true resonant frequency.

Environmental temperature can have an additional effect on the accuracy. At 0°C and at 40°C there can be an additional error of up to ± 20%, depending on the meter reading, over the 100 to 1k portion of the meter scale (see 4. SPECIFICATIONS for details). This applies to either the X1 or the X10 range. While the instrument is usable under even greater temperature extremes than these, the errors become quite large, particularly at scale indications above 1k.

While temperature extremes affect the accuracy of the indicated impedance magnitude, there is no appreciable effect on the frequency response. Thus the instrument can be used to correctly determine the resonant frequency of such loads over a very wide range of environmental temperatures.

The device is battery powered with two ordinary 9 V batteries. Battery life is approximately 48 hours assuming operation for four hours per day.

Operation is quite simple. Other than the Power and Battery Test switches, only the Range switch and the Mode switch require adjustment. With the Model 60 Power switch in the “OFF” position, the Test Load is connected to the “Z” terminals and an appropriate signal generator connected to “SIG IN”. With the Mode switch in the “1K” position, the Power switch is turned “ON” and the signal generator level adjusted for 10 volts RMS into the Model 60. The Mode switch is then moved to the “Z” position and the Test Lead impedance magnitude, for the frequency of the signal generator, will be displayed on the meter. The Range switch can be set, as appropriate. The frequency of the signal generator may be adjusted to observe the frequency dependency of the Test Load’s impedance.

1.2 Panel Switches, Connectors, and Meter

Please refer to figure 1 (p. iii) for the following descriptions.

ON or OFF Power Switch

When the Power switch is in the "OFF" position the internal battery power is disconnected from the circuitry and the "Z" terminals (J2, 3) are shorted together. The Battery Test switch is inoperative. It is strongly recommended that the Power switch always be in the "OFF" position until reliable connections to the Test Load are completed and returned to the "OFF" position before the Test Load is disconnected. This will reduce the likelihood of damage tot he Model 60 by high electrostatic potentials present in many environments.

When the power switch is in the "ON" position, internal battery power is connected to the circuitry and the short is removed from "Z" terminals. The instrument is now in its active state. The Battery Test switch is operative. The Meter may, or may not, show a deflection depending on other switch positions, the Test Load, and the Signal Generator State. Since there is no "warm up" beyond a few seconds, there is no merit in leaving the instrument in the "ON" state for prolonged periods between measurements.

Closing the instrument Lid will mechanically throw the Power switch to "OFF" position.

Z or 1K Mode Switch

When the switch is in the "1K" position, the measuring circuit is disconnected from the "Z" terminals (J2, 3) and connected to an internal standard resistor of 1000 ohms. The "1K" position is used to adjust the external signal generator level for 10 volts as well as disconnecting the internal circuitry from the "Z" terminals. When in this position and the signal generator level at 10 volts, the meter will indicate "1k" on the "x 1" range or "100" on the "x 10" range.

When the switch is in the "Z" position the measuring circuit is connected to the "Z" terminals (J2, 3). The Meter deflection will now indicate the magnitude of the impedance of the Test Load connected to the "Z" terminals.

- CAUTION -

When the Mode switch is in the "Z" position and the Power switch in the "ON" position, the instrument is quite vulnerable to damage from high potentials

ALWAYS THROW THE POWER SWITCH TO THE "OFF" POSITION BEFORE DISCONNECTING THE TEST LOAD FROM THE "Z" TERMINALS AND MAKE SURE THAT THE POWER SWITCH IS IN THE "OFF" POSITION UNTIL A NEW TEST LOAD IS RELIABLY CONNECTED TO THE "Z" TERMINALS.

x 10 - x 1 Range Switch

When the switch is in the "x 1" position the Meter is read directly from its "100 ohm to "4K" ohm indication. Each small division represents 20 ohm steps between "100" and "700" ohms and 50 ohms between "700" and "1K" ohms. The large scale divisions represent 100 ohm steps between "100" ohms and "1K" ohms, 200 ohms between "1K" and "2K" ohms, and 1000 ohms between "2K" ohms, and "4K" ohms.

When the switch is in the "x 10" position, the Meter indication is multiplied by 10 and indicates a Test Load impedance of 1000 to 40,000 ohms. The meter scale divisions defined in the x 1 description are also multiplied by 10.

The Auxilliary DC Output is 0 to +2.0 volts dc, for either range, in direct proportion to the Meter needle angular deflection.

BAT TEST Battery Test Switch

This is a momentary contact push button switch. Normally the Meter is connected to the impedance measuring circuitry.

When the switch is pushed the Meter is connected to the battery test circuitry. The lower scale on the Meter (”BAT OK”) indicates the relative terminal voltage of the two series-connected internal batteries. The high end of the “BAT OK” scale represents a total battery voltage of 18; the low end represents 11. The instrument will operate satisfactorily anywhere within this range of battery voltage.

The switch does not operate when the Power switch is “OFF”.

Z HI and GND Test Load Terminals

The Test Load is connected to this pair of terminals, J2 and J3, by any form of convenient insulated test leads. The terminals accept banana plugs or bare wires (#12 or smaller) in the cross hole under the binding posts. Do not use shielded, twisted pair, or parallel paired wire since any of these will introduce excessive shunt capacity. Rather, use a pair of separate leads of necessary length and kept well spaced apart. If the Test Load is truly floating with respect to earth ground, then it does not matter which terminal is connected to either end of the load. If, however, one end of the Test Load is connected to earth ground, or it is at low impedance to ground, then that end should be connected to the “GND” (J3) terminal. The “GND” terminal is internally connected to the case of the Model 60. The ungrounded or high impedance-to-ground end of the load should be connected to the “HI” (J2) terminal.

The terminals are short-circuited together when the Power switch is in the “OFF” position.

A 0.25-ampere pigtail fuse connects the “HI” (J2) terminal to the measuring circuits, internally. A 90-volt gas-tube surge protector is behind the fuse and effectively across the measuring circuit input.

CAUTION: NEVER CONNECT THE “Z” TERMINALS TO AN ACTIVE SOURCE OF VOLTAGE OR CURRENT.

To do so will cause serious damage to the instrument.

GND Static Ground

This terminal, J4, is directly connected internally to the Model 60 case. It is a similar banana jack binding post as used for the “Z” terminals.

This terminal should be connected to earth ground for safety and to minimize spurious responses in electrically noisy environments. This is particularly important if the Test Load is floating with respect to earth ground. However, if the “GND” end of the Test Load is truly connected to ground, use of the Static ground is redundant. Such a redundant ground will usually be a wise safety precaution but, under some circumstances, can introduce a spurious response.

SIG IN Signal Generator Input

The required external signal generator is connected to this BNC connector, J1. The input impedance is equal to the test load impedance plus 200Ω on the X1 range or 2000Ω on the x10 range. The signal generator level should be set to 10 VRMS, as indicated by the signal generators output level meter, while the Mode switch is in the “1K” position. The useable frequency range is from 30 kHz to 500 kHz.

OUT Auxiliary Output

A remote external meter, oscilloscope, or recorder may be connected to this BNC connector, J5. The output is single-sided at a level of 0 to +2.0 volts dc behind 1900 ohms for either the "x1" or "x10" range. The output level is in direct proportion to the angular deflection of the Meter needle. Output current is 0 to 1 mA into a 100 ohm load.

|Z| OHMS Meter

The 4 ½ inch meter is fluid damped, ruggedized and of the taut-band suspension type. It is shock-mounted to the panel with sponge rubber pads.

The main upper scale is read directly when the Range switch is in the "x1" position but must be multiplied by 10 when the Range switch is in the "x10" position. A lower "BAT OK" scale indicates the range of satisfactory internal battery voltage when the "BAT TEST" push button is pressed and the Power switch is "ON". Please note that the meter needle "zero" adjustment can NOT be made from the front of the instrument. It has been set at the factory.

2. USING THE MODEL 60

2.1 The Proper Hookup

The usual manner in which the Model 60 is connected to the Test Load and accessory instruments is shown in Figure 2. A signal generator must be connected to the "SIG IN" BNC connector, J1, to provide the proper frequency of ac driving current to the Test Load. The "OUT" connector, J5, provides a dc signal of 0 to +2.0 volts to an optional remote indicator, oscilloscope or recorder. Under most circumstances, the "GND" Static ground terminal, J4, should be connected to a good, low impedance earth ground.

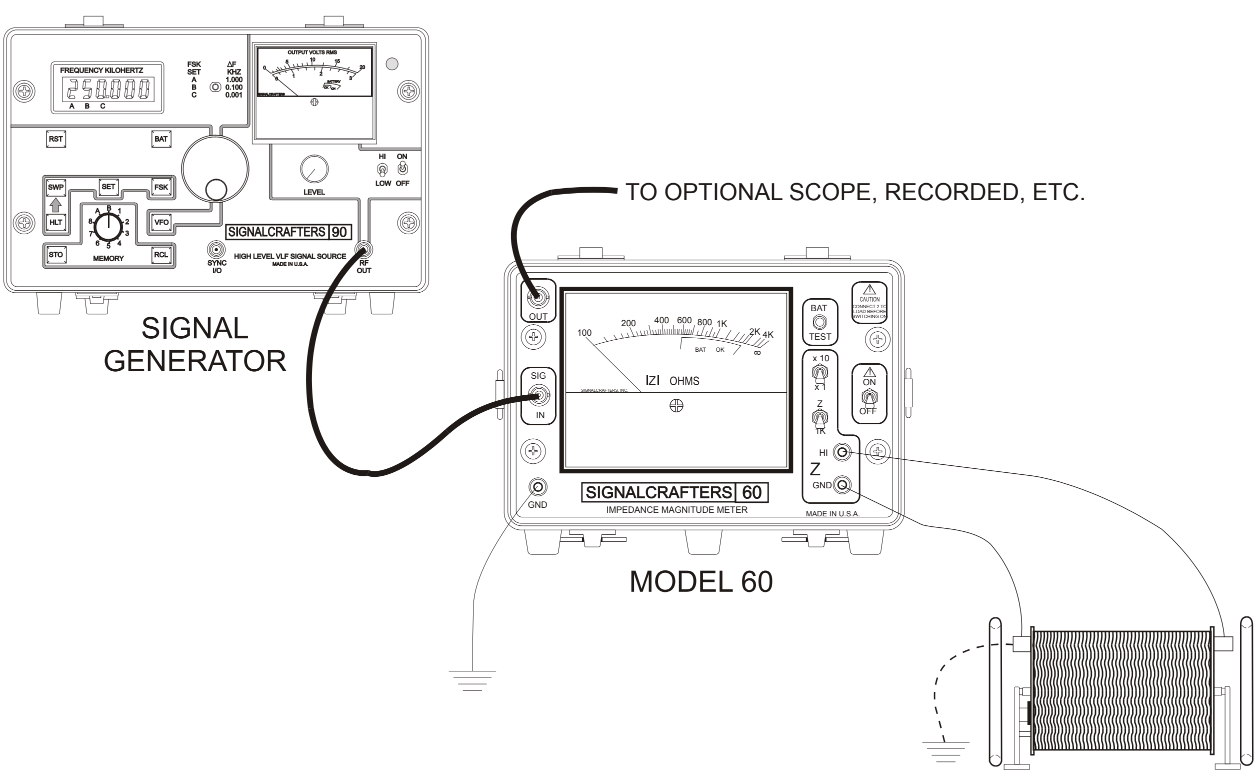


Figure 2

Connecting the Test Load

CAUTION

BEFORE CONNECTING THE TEST LOAD TO THE “Z” TERMINALS MAKE SURE THE MODEL 60 POWER SWITCH IS IN THE “OFF” POSITION. ALSO, SWITCH TO THE “OFF” POSITION BEFORE DISCONNECTING THE TEST LOAD FROM THE “Z” TERMINALS.

The Test Load of unknown impedance is connected to the “Z” terminals, J2 and J3, with a pair of individual, single conductor test leads of the shortest convenient length (see Test Leads, below). If the Test Load is floating with respect to earth ground, then either terminal of the load can be connected to either Z terminal of the Model 60. However, if one terminal of the Test Load is grounded, or at a low impedance to ground, then that terminal must be connected tot he “GND” Z terminal, J3. The undergrounded or high impedance-to-ground terminal of the load is connected to the “HI” Z terminal, J2. Once these connections are firmly and reliably made then the Model 60 ON-OFF switch may be thrown to the “ON” position and the measuring procedure carried out.

Test Leads

Connecting the Model 60 to the Test Load will add some artifact capacitance in parallel with the Test Load’s capacitance. Part of this added capacitance, C_{ZM}, is the 60-70 pF internal capacitance of the Model 60, itself. A second part of the capacitance, added by the measuring process, is introduced by the test leads. This second, lead-induced added capacitance, C_{CTL}, can be readily estimated by using the following equation:

$$C_{CTL} = \frac{3.677}{\log_{10}(s/d)}$$

where: C_{CTL} = test lead shunt capacitance per foot, pF

s/d = ratio of average test lead spacing to lead wire diameter

In Table 1, the lead-induced added capacitances, C_{CTL}, are shown for several test lead lengths and separations assuming that the test lead lengths and separations assuming that the test leads are #18 wire (0.040 inches in diameter).

Table 1. Test lead-induced shunt capacitance, C_{CTL}

Each test lead length, feet	Average separation of the test leads, inches				
	3"	6"	12"	24"	48"
1	2 pF	2 pF	2 pF	1 pF	1 pF
5	10 pF	8 pF	7 pF	7 pF	6 pF
10	20 pF	17 pF	15 pF	13 pF	12 pF
20	39 pF	34 pF	30 pF	26 pF	24 pF
40	78 pF	68 pF	59 pF	53 pF	48 pF

Inductance of the test leads will be negligible.

Auxiliary Output to Optional Indicator or Recorder

A 0 to + 2.0 volt signal appears at the "OUT" BNC connector, J5, for a 0 to full scale Meter deflection, either range. This signal is behind 1900 ohms and therefore will supply virtually the full dc level to a high input impedance device (100,000 ohms or greater) or 0 to 1.0 milliampere into a 100 ohm input impedance device. The output signal is directly proportional to the angular deflection of the Meter needle.

2.2 Measuring the Impedance Magnitude

When connections have been completed as described in Section 2.1 above, the measurement of the Test Load's impedance can proceed. Once the Test Load has been reliably connected to the Z terminals the Power switch can be thrown to the "ON" position. With the Mode switch in the "1K" position, adjust the signal generator to an output level of 10 V_{RMS}, as indicated on the signal generators output level meter, and to the desired frequency. Next turn the Mode switch to the "Z" position and read the Test Loads impedance magnitude from the meter indication. With the Range switch in the "x10" position, the meter indication must be multiplied by 10. If the Test Loads impedance is less than 4000 ohms then throw the Range switch to "x1" and read the impedance directly from the meter scale.

No damage will occur to the meter from low Test Load impedances that force the needle against the left hand scale limit.

The signal generator may be changed to a new frequency to determine the frequency-dependency of the Test Loads impedance.

Capacitance Artifact

The Model 60's internal capacitance, C_{ZM}, (60-70 pF) plus that of the connecting leads, C_{CTL}, will be added to the shunt capacitance of the Test Load. This added capacitance will lower the apparent frequency for a given measured impedance by an amount depending on the ratio of the added "artifact" capacitance, C_M, and the Test Loads own shunt capacitance, C_O. If the Test Load consists of a parallel-connected inductance-capacitance pair, the correct resonant peak frequency, fo, can be found with the following equation:

$$fo = f_M \times (1 + C_M / C_O)^{1/2}$$

where: fo = correct resonant frequency of the measured impedance

f_M = signal generator frequency for the measured impedance

C_M = artifact capacitance — $C_{ZM} + C_{CTL}$, in pF

C_O = shunt capacitance of the Test Load, in pF.

Table 2 lists examples of changes in the resonant peak frequency assuming the following: the inductor is 265 microhenries, the connecting test leads are 10 feet long, and the leads are spaced apart by an average of 24 inches (C_M = 13 + 70 or 83 pF).

Table 2. Capacitance artifact (23 pF) frequency error, parallel resonance

Apparent frequency, f_M kHz	Test Load capacitance, C_0 pF	Correct frequency, f_0 kHz	Frequency error
49.985	38270	50.000	15 Hz
99.880	9588	100.000	120 Hz
199.045	2390	200.000	955 Hz
296.800	1061	300.000	3200 Hz
392.510	597	400.000	7489 Hz
485.595	382	500.000	14405 Hz

At frequencies well away from resonant peaks or for non-resonant Test Loads the correct frequency, fo, can be found from the signal generator frequency, f_M, when the Test Loads shunt capacitance, C_O, is known from:

$$fo = f_M \times (1 + C_M / C_O)$$

where: fo = correct frequency for the measured impedance

f_M = signal generator frequency for the measured impedance

C_M = artifact capacitance — $C_{ZM} + C_{CTL}$, if pF

C_O = shunt capacitance of the Test Load, in pF.

Table 3 lists examples of frequency errors introduced by the artifact capacitance in parallel resonant Test Loads but away from resonant peaks, or in non-resonant Test Loads. As above, it is again assumed that the connecting leads are 10 feet long and spaced an average of 24 inches apart (C_M = 23 pF).

Table 3. Capacitance artifact (23 pF) frequency error, non-resonant Test Load

Test Load capacitance C_0 pF	Signal generator frequency, f_M, is low by
40,000	0.05%
10,000	0.2%
2,000	1.2%
1,000	2.3%
500	4.6%
200	11.5%
100	23.0%

3. MAINTAINING THE MODEL 60

3.1 Batteries

Two 9 volt NEDA 1604 batteries, such as Eveready No. 216 "transistor" batteries, are used to power the Model 60. They are series connected. The average current drain is 7 milliamperes when the Power switch is "ON"; no drain occurs when switched "OFF". A typical battery life is about 48 hours assuming a 4 hour on /20 hour off cycle. The battery state can be determined by pressing the Battery Test switch when the Power switch is "ON" and observing the Meter reading on the lower "BAT OK" scale. Under the normal load presented by the instrument, the top (right hand) end of the "BAT OK" scale indicates a total battery voltage of 18 volts while the bottom (left hand) end indicates 11 volts and the end of useful battery life. The instrument will not operate properly when the Meter reading is below the bottom of the "BAT OK" scale.

Longer battery life can be obtained by using NEDA 1604A alkaline batteries such as Eveready No. 522. Such batteries will give about twice the operating hours as the ordinary zinc-carbon units suggested above. While there may be circumstances where longer life is necessary, alkaline batteries tend to cost about three times that of the more ordinary zinc-carbon variety.

To replace the batteries the front panel must be removed from the case. To do this, remove the four black Phillips head screws from the front panel and lift the panel, with its attached circuit board / battery bracket, from the case. The batteries are retained in clips on the inner – or meter side – of the bracket. Unsnap the worn out batteries and replace with fresh batteries. It does not matter which battery connector goes to which battery. However, be sure to polarize the connectors on each battery appropriately. To check that the batteries have been correctly installed, switch the Power to "ON" and press the Battery Test switch. If the new batteries are fresh and the installation is proper, the Meter will read toward the top (right hand end) of the "BAT OK" scale. The front panel may then be reinstalled in the case. Be careful to see that no wires or cables are pinched between the panel and the case brackets.

3.2 Z-Terminal Fuse

A 0.25 ampere pigtail (Little fuse Pico II) fuse protects the internal circuitry from accidental potentials applied to the Z terminals. Blowing this fuse should occur only rarely. A symptom of this fuse being open is normal operation when the Mode switch is in the "1K" position but no meter movement off the "∞" position when in the "Z" position regardless of any impedance connected to the Z terminals. This fuse is soldered between turret posts on the circuit board inside the instrument. To replace the fuse the front panel must be removed form the case.

Remove the front panel as described in Section 3.1, above. The fuse can be seen on the circuit board near the wire connected to the "HI" Z terminal. To remove the defective fuse, heat the turret terminals with a small soldering iron and pull the pigtail fuse lead out with a small soldering iron pliers. Replace the blown fuse with a new one by pushing the pigtail leads down into the turret terminals while heating with the soldering iron. Possibly a very small amount of rosin-core solder (do NOT use acid-core solder) will help make the new solder joint secure. Test to see that the fuse replacement has restored normal operation by connecting a known impedance, such as a resistor between 100 and 40,000 ohms, to the Z terminals. Turn the Power "Z" mode. The meter should indicate the correct magnitude of the impedance you just connected to the Z terminals. If this test was successful the panel may be reinstalled in the case.

3.3 Cleaning

The front panel may require periodic cleaning to maintain appearance and readability. When cleaning is required, first remove loose debris with a soft cloth or brush. More stubborn soil and stains may then be removed with a soft cloth dampened with a mild water and soap or detergent solution. When doing this, do not allow solution to flow through the panel holes into the terminals, connectors, switches, or interior of the instrument. Always work with only a slightly dampened cloth. Avoid the use of harsh or abrasive cleaners or any form of organic solvents.

Be particularly careful not to scratch the meters plastic window. The painted aluminum case may also be cleaned with a mild water and soap or detergent solution. If a water solution fails to remove such substances as grease or tar, then naptha, kerosene, or mineral spirits may be used. Do not use lacquer or epoxy thinner or nail polish remover as they will damage the paint.

3.4 Repairs

The Model 60 should be returned to the factory for repairs beyond the replacement of batteries and the Z terminal fuse. Please telephone the factory (973 781-0880) for a Return Authorization Number and return the instrument, shipping prepaid. Be sure to include a short description of the trouble.

4. SPECIFICATIONS

IMPEDANCE MAGNITUDE:

x1 Range	100 to 4000 ohms
x10 Range	1000 to 40,000 ohms
Connector	Banana jack binding post pair

FREQUENCY RANGE: 30 kHz to 500 kHz

ACCURACY AT 20°C:

Meter reading of: 100 to 1.2 k ± 10%
1.2 k to 4 k ± 20%
(applies to both x1 and x10 range)

TEMPERATURE ERRORS[1]:

	0° C		20° C		40° C	
|Z|[2] OHMS	READS OHMS	% ERROR	READS OHMS	% ERROR	READS OHMS	% ERROR
100	88	-12	100	0	95	-5
200	200	0	200	0	200	0
400	400	0	400	0	450	+12
700	720	+3	700	0	750	+7
1K	1.2K	+20	1K	0	980	-2
2K	3.0K	+50	2K	0	1.9K	-5

TEST LOAD DRIVE VOLTAGE:

10 VRMS
(current limited by generator source impedance)

Z-METER SOURCE RESISTANCE:

x1 Range 200 ohms
x10 Range 2000 ohms
(In series with Test Load)

DISPLAY:

Meter 4 ½ inch taut band, ruggedized, fluid damped, shock mounted.
Scales 100 to 4K ohms, infinity
BAT OK

SIGNAL INPUT:

Level 10 VRMS
Input Impedance That of Test Load plus 200 ohms on the x1 Range;
2000 ohms on the x10 range
Connector BNC

OUTPUT:

O to +2.0 volts, dc, behind 1.9 k ohms.
(0 to 1.0 mA into 100 ohm recorder)
Connector BNC

Z TERMINALS SURGE PROTECTION:

90 volt gas-tube surge protector behind 0.25 ampere fuse

POWER SUPPLY:

2 NEDA 1604 9 volt batteries
(Eveready Type 216)
7 mA current drain. Normal life 48 hrs at 4 hrs/day.

SIZE:

23 cm x 15 cm x 21.5 cm high (9in x 6 in x 8 ½ in high)

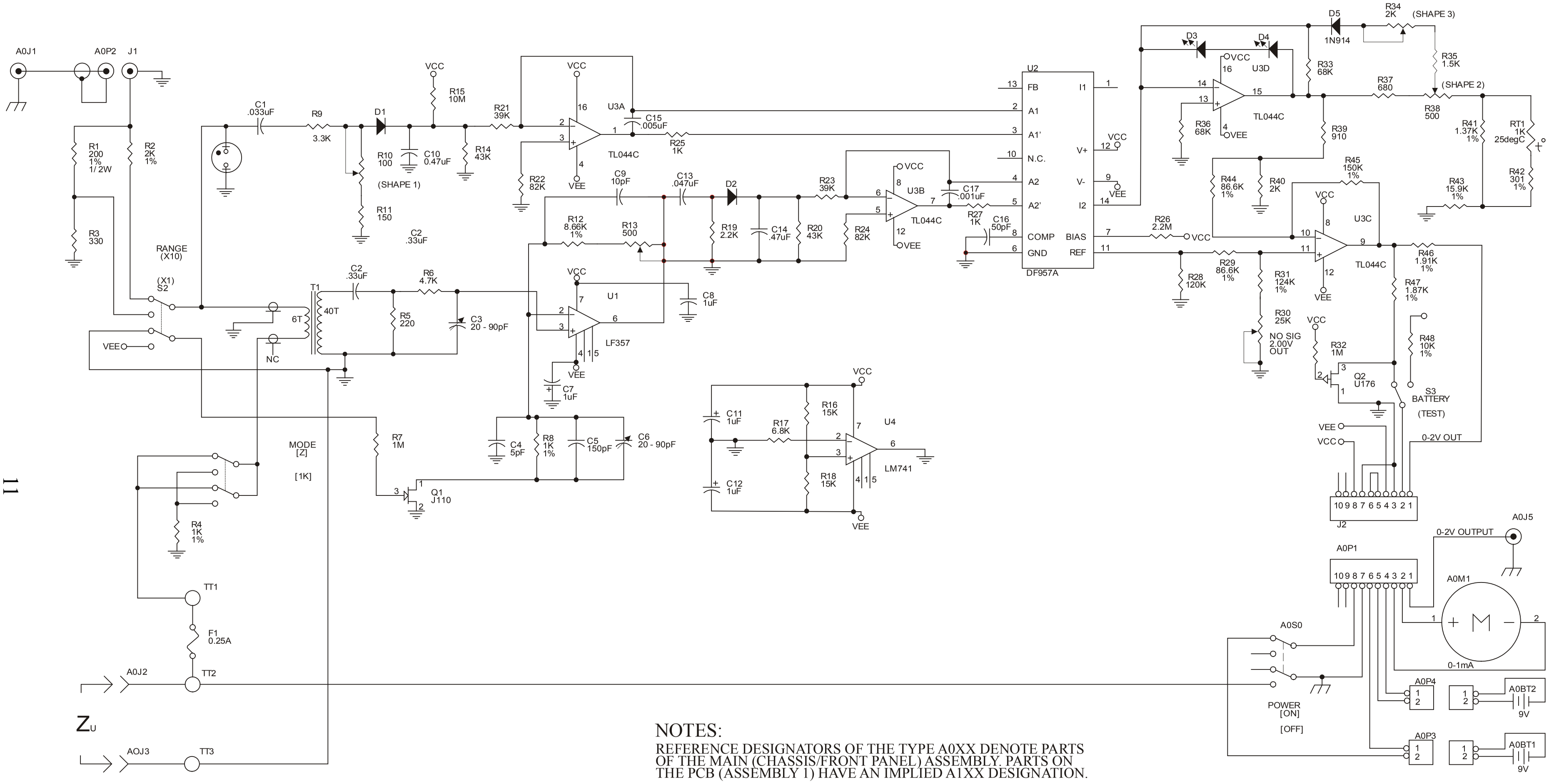
WEIGHT:

2.3 kg (5 lb) (less connecting cables)

SIGNAL SOURCE REQUIREMENTS:

Frequency 30 kHz to 500 kHz
Voltage level 10 VRMS
Level meter Output voltage
Output Z 50 ohms or less

5. SCHEMATIC DIAGRAM



NOTES:
REFERENCE DESIGNATORS OF THE TYPE A0XX DENOTE PARTS OF THE MAIN (CHASSIS/FRONT PANEL) ASSEMBLY. PARTS ON THE PCB (ASSEMBLY 1) HAVE AN IMPLIED A1XX DESIGNATION.

THE TL044 QUAD AMP CAN BE REPLACED BY TWO TI022 DUAL AMP PACKAGES - - PLEASE NOTE THAT WHEN DOING SO PIN ONE OF THE SECOND PAIR INSERTS INTO SOCKET PIN 9.

IC POWER CONNECTIONS:

I.C.	TYPE	V+ PIN(S)	V- PIN(S)
U1	LF357	7	4
U2	DF957A	12	9
U3	TL044C	8, 16	4, 12
U4	MC741C	7	4
REF.	TL022C.	8.	4.

Model 60 Impedance Magnitude Meter
Schematic Diagram
Figure 3

REFERENCE DESIGNATION	PART NUMBER	DESCRIPTION
R1	10D3126	Resistor, MF, 200 ohm 1%, 0.5 W
R2	10A2722	Resistor, MF, 2.0K ohm 1%, 0.25 W
R3	10B1609	Resistor, CF, 330 ohm 5%, 0.25 W
R4	10F2693	Resistor, MF, 1.0K ohm 1%, 0.25 W
R5	10B1605	Resistor, CF, 220 ohm 5%, 0.25 W
R6	10E1637	Resistor, CF, 4.7 K ohm 5%, 0.25 W
R7	10C1693	Resistor, CF, 1 Megohm 5%, 0.25 W
R8	10F2693	Resistor, MF, 1.0K ohm 1%, 0.25 W
R9	10E1633	Resistor, CF, 3.3K ohm 5%, 0.25 W
R10	12B0018	Trim Pot, 100 ohm Cermet, Top Adj, 3/8" Sq
R11	10B1601	Resistor, CF, 150 ohm 5%, 0.25 W
R12	10E2783	Resistor, MF, 8.66K ohm 1%, 0.25 W
R13	12G0020	Trim Pot, 500 ohm Cermet, Top Adj, 3/8" Sq
R14	10B1660	Resistor, CF, 43K ohm 5%, 0.25 W
R15	10G1717	Resistor, CF, 10 Megohm 5%, 0.25 W
R16	10F1649	Resistor, CF, 15K ohm 5%, 0.25 W
R17	10F1641	Resistor, CF, 6.8K ohm 5%, 0.25 W
R18	10F1649	Resistor, CF,15K ohm 5%, 0.25 W
R19	10D1629	Resistor, CF, 2.2K ohm 5%, 0.25 W
R20	10B1660	Resistor, CF, 43K ohm 5%, 0.25 W
R21	10C1659	Resistor, CF, 39K ohm 5%, 0.25 W
R22	10D1667	Resistor, CF, 82K ohm 5%, 0.25 W
R23	10C1659	Resistor, CF, 39K ohm 5%, 0.25 W
R24	10D1667	Resistor, CF, 82K ohm 5%, 0.25 W
R25	10D1621	Resistor, CF, 1K ohm 5%, 0.25 W
R26	10F1701	Resistor, CF, 2.2 Megohm 5%, 0.25 W
R27	10D1621	Resistor, CF, 1K ohm 5%, 0.25 W
R28	10E1671	Resistor, CF, 120K ohm 5%, 0.25 W
R29	10K2879	Resistor, MF, 86.6K ohm 1%, 0.25 W

REFERENCE DESIGNATION	PART NUMBER	DESCRIPTION
R30	12E0025	Trim Pot, 25K ohm Cermet, Top Adj, 3/8" Sq
R31	10B2895	Resistor, MF, 124K ohm 1% 0.25 W
R32	10C1693	Resistor, CF, 1 Megohm 5%, 0.25 W
R33	10K1665	Resistor, CF, 68K ohm, 5%, 0.25 W
R34	12C0022	Trim Pot, 2K ohm Cermet, Top Adj, 3/8" Sq
R35	10D1625	Resistor, CF, 1.5K ohm 5%, 0.25 W
R36	10K1665	Resistor, CF, 68K ohm 5%, 0.25 W
R37	10C1617	Resistor, CF, 680 ohm 5%, 0.25 W
R38	12G0020	Trim Pot, 500 ohm Cermet, Top Adj, 3/8"
R39	10F1620	Resistor, CF, 910 ohm 5%, 0.25 W
R40	10F1628	Resistor, CF, 2K ohm 5%, 0.25 W
R41	10G2706	Resistor, MF, 1.37K ohm 1%, 0.25 W
R42	10F2932	Resistor, MF, 301K ohm 1%, 0.25 W
R43	10F3023	Resistor, MF, 16.9 ohm 1%, 0.25 W
R44	10K2879	Resistor, MF, 86.6K ohm 1%, 0.25 W
R45	10E2903	Resistor, MF, 150K ohm 1%, 0.25 W
R46	10E2720	Resistor, MF, 1.91K ohm 1%, 0.25 W
R47	10F2719	Resistor, MF, 1.87K ohm 1%, 0.25 W
R48	10A2789	Resistor, MF, 10K ohm 1%, 0.25 W
RT1	14G0001	Thermister, 1000 ohm
C1	16R0336	Capacitor, Metal Film, 0.033 µF, 5% 100 V
C2	16V0337	Capacitor, Metal Film, 0.33 µF, 5%, 100 V
C3	18F0002	Capacitor, Trimmer, 20-90 pF 100V, Vert Adj
C4	16A0019	Capacitor, Disc Ceramic, 5 pF 20%, 50 V
C5	16E0157	Capacitor, Mica, 150 pF 5%, CM04/DM10
C6	18F0002	Capacitor, Trimmer, 20-90 pF 100V, Vert Adj
C7	16G0275	Capacitor, Tantalum, 1.0 µF 20%, 35 V
C8	16G0275	Capacitor, Tantalum, 1.0 µF 20%, 35V
C9	16A0151	Capacitor, Mica, 10 pF, 500 V DM-10
C10	16G0335	Capacitor, Metal Film, 0.47 µF 5%, 100 V

REFERENCE DESIGNATION	PART NUMBER	DESCRIPTION
C11	16G0275	Capacitor, Tantalum, 1.0 µF 20%, 35 V
C12	16G0275	Capacitor, Tantalum, 1.0 µF 20%, 35 V
C13	16E0332	Capacitor, Metal Film, 0.47 µF 5%, 100 V
C14	16G0335	Capacitor, Metal Film, .047 µF 5%, 35 V
C15	16B0040	Capacitor, Disc Ceramic, .005 µF, 100 V
C16	16A0011	Capacitor, Disc Ceramic, 51 pF 10%, 50V
C17	16E0038	Capacitor, Disc Ceramic, .001 µF, 100 V
D1	30E0007	Diode, 1N34A Ge Point Contact
D2	30E0007	Diode, 1N34A Ge Point Contact
D3, D4	40K0002	LED, T 1 ¾ Red
D5	30A0005	Diode, 1N914 Silicon
Q1	30K0379	Transistor, J110 J FET, N Channel
Q2	30E0381	Transistor, J176 J FET, P Channel
U1	32C0065	IC, LF357N Single OP. AMP
U2	34D0012	CUSTOM IC, DF-957A Power Meter Chip
U3	32D0052	IC, TL044CN Quad OP.AMP.
U4	32F0055	IC, 741C Single OP. AMP.
S1, S2	44D0004	Switch, Toggle, DPDT PCB Mount
S3	44D0102	Switch, Push Button, SPDT Momentary
S4	44F0003	Switch, Toggle, DPDT w/long flat handle
PCB	50G0024	Custom, PC Board, Model 60
UX1, UX4	52B0310	Socket, IC, 8-Dip, 0.3" Spacing
UX2	52K0311	Socket, IC 14-Dip, 0.3" Spacing
UX3	52F0312	Socket, IC, 16-Dip, 0.3" Spacing
J1 / 1	52K0395	Connector, PCB Miniature Spring Socket
J1 / 2	52F0396	Connector, PCB Vertical Braid Shield Recpt
J2	52C0368	Connector, PCB 10 Pin M.025 D., .100 CTR Gold
AOP2	52B0398	Connector, Cable Braid Plug-in Termination
TT-1, TT-2	52C0547	Terminal, PCB Turret, for 1/16" Board
F1	54G0045	Fuse

REFERENCE DESIGNATION	PART NUMBER	DESCRIPTION
T1	85G0108	CUSTOM VA TRANSFORMER FOR MOD 60
BT1, BT2	60K0101	BATTERY, 9V, 1604 NEDA
	86E0063	
	86B0073	
	74E0124	
	74F0217	
	78B0024	