ELECTRICAL SAFETY ANALYZER

180

User's Guide

BIO-TEK®

180 Electrical Safety Analyzer

User's Guide

Bio-Tek® Instruments, Inc.
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Notices

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Fluke Biomedical
6920 Seaway Blvd.
Everett, WA 98203
Sales & Customer Service:
775-883-3400 • 800-648-7952

Service and Repair
Please call for RMA number before shipping
1420 75th Street SW
Everett, WA 98203
888-99FLUKE (888-993-5853) • 425-446-5560

http://www.flukebiomedical.com • sales@flukebiomedical.com

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Document Revision Record

Rev.	Date	Change
A	3/98	Release to production
B	4/99	Revised Dual Connector functional description.
		Clarified use of black and red cables throughout.
		Added ISO warning to Point-to Point Leakage Measurement section.
C	8/00	Added Warning due to dual lead leakage in Preface.
D	10/01	Added Current Consumption information to Instrument Specifications (page 13).
		Added Note to Step 4 of Front Panel Description regarding proper operation of three-position switch (page 16).
		Revised "open neutral" neon lamp configuration on Power Outlet Connections chart, and added Note advising review of power outlets that do not indicate "correct wiring" (page 18).

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Safety Considerations

General

This instrument and related documentation must be reviewed for familiarization with safety markings and instructions before operation.

Safety Symbols

WARNING! The *"WARNING!"* sign denotes a hazard. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in personal injury. Do not proceed beyond a *"WARNING!"* sign until the indicated conditions are fully understood and met.

CAUTION: The *"CAUTION:"* sign denotes a hazard. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the instrument. Do not proceed beyond a *"CAUTION:"* sign until the indicated conditions are fully understood and met.

The symbol to the left is the operator's manual symbol. When you see this symbol on the instrument, refer to the operator's manual.

Warnings and Cautions

WARNING! Disconnect all patient connections before connecting the device to be tested to the analyzer.

Continued connection may jeopardize patient safety by possible application of measurement currents.

WARNING! Isolation test utilizes 120 or 240 vac applied to patient leads or to external connections that are accessible to the tester. Maintain care when making connections.

Although the voltage is current limited by 120 kΩ resistor per AAMI test procedure and is safe for healthy intact skin contact, it can be felt and can result in a startle reaction.

CAUTION: Be sure that the device under test power requirements are within the capabilities of the safety analyzer, labeled as 15 amps at 120 volts and 10 amps at 240 volts.

The analyzer requires adapter cables to match the appropriate connector for line voltages other than 120V.

CAUTION: The 180 is not designed for continuous measurements. Do not leave the device under test connected and drawing high load current for extended periods.

To maintain its small hand held size, the analyzer was not designed to provide its high current capability continuously and may overheat.

CAUTION: Be sure to pause in the off (middle) position when switching polarity from normal to reverse

Inductive loads of the device under test may create high voltage transients when trying to reverse the direction of current flow instantaneously.

WARNING! Dual lead leakage must be performed with a Red Test Lead (Bio-Tek part numbers 48385 or 48387) in the jack labeled "Dual". The use of a black test lead in the "Dual" jack may result in a blown internal fuse **and false readings of 000 to 002 µA**, requiring the unit to be returned for servicing

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Introduction to the Bio-Tek 180

The Bio-Tek 180 Electrical Safety Analyzer is a highly versatile and portable instrument. It is used for the basic electrical safety evaluation of electrical systems, medical devices and physiological instrumentation. Its compact handheld size makes it an ideal addition to a service technician or engineer's toolbox for that "after service test" as well as serving as a bench top instrument for the laboratory. It does not sacrifice functions or accuracy, and its low cost permits putting one on each bench.

The analyzer is simple to use. A single master function switch, directly labeled with the test to be performed, leads the user through a complete measurement procedure. A single range meter for each measurement avoids potential erroneous readings.

The analyzer utilizes simple, yet sophisticated, electronics for true RMS measurement of current and voltage. Input impedance uses the AAMI ES1-1993 test load to compensate for high frequency components in the measurement. Resistance measurements are made with a four-wire Kelvin bridge to eliminate errors due to cable length and connector resistance.

Unique to the *180* is its capability to make a broad range of point-to-point measurements. These include leakage current and/or voltage gradients and resistance between two points. Also, the analyzer provides the voltage and measuring provision for the independent measurement of the isolation current of a device. Thus the analyzer provides the additional versatility for evaluation of electrical systems, system installation, separate components, isolation of probes, transducers, and conventional leakage current measurements.

Key Features

- Handheld instrument
- Test power line integrity
- Line voltage
- Instrument current
- Grounding resistance via 4-wire method
- Ground leakage current
- Enclosure (chassis) leakage current
- Patient (lead to ground) leakage current
- Patient (lead to lead) auxiliary current
- Patient isolation (sink) current
- Voltage gradients
- Device-to-device resistance
- Device-to-device leakage current
- Probe and transducer isolation current
- True RMS measurement
- AAMI test load

Instrument Specifications

Line Voltage	
Range	90 - 240 VAC 50/60 Hz
Accuracy	± 3% of reading, ± 1 LSD
Load Current	
Range	0 - 19.99 Amps
Accuracy	± 5% of reading, ± 1 LSD
Ground Resistance	
Range	0 - 19.99 Ohms
Accuracy	± 1% of reading, ± 1 LSD
Current source	10 mA DC
Type	4 wire bridge
Leakage Current	
Range	0 - 1, 999 µA
Accuracy:	
DC and 25 Hz to 1 kHz	± 1 % of reading, ± 1 LSD
1.0 kHz to 100 kHz	± 2.5 % of reading, ± 1 LSD
100 kHz to 1 MHz	± 5 % of reading, ± 1 LSD
Type measurement	True RMS
Impedance	1000 Ω, AAMI ESI 1993
Isolation Test	
Voltage	110% Line voltage ± 5%
Current	limited by 120 kΩ resistor
Current Capacity	
Line 90 to 140 volts	20 amps; max. on time 5 min. 15 Amps; max. on time 30 min.
Line over 140 volts	10 Amps
Current Consumption	
ESA 180	0.1 Amps @ 120 Volts – 60 Hz
Environmental	
Operating Temperature	15-40°C
Storage Temperature	-20-65°C
Relative Humidity	90 % max.
Mains voltage range	90 to 240 Volts

Standard Accessories

DESCRIPTION (QUANTITY)	PART #
USER'S GUIDE	1801000
8-FOOT BLACK CABLE – with large clamp	48386

Optional Accessories

DESCRIPTION	PART #
16-FOOT BLACK CABLE – with large clamp	48384
8-FOOT RED CABLE – with large clamp	48385
16-FOOT RED CABLE – with large clamp	48387
SOFT CARRYING CASE	97148
220V ADAPTER KIT	1800001

Front Panel Description

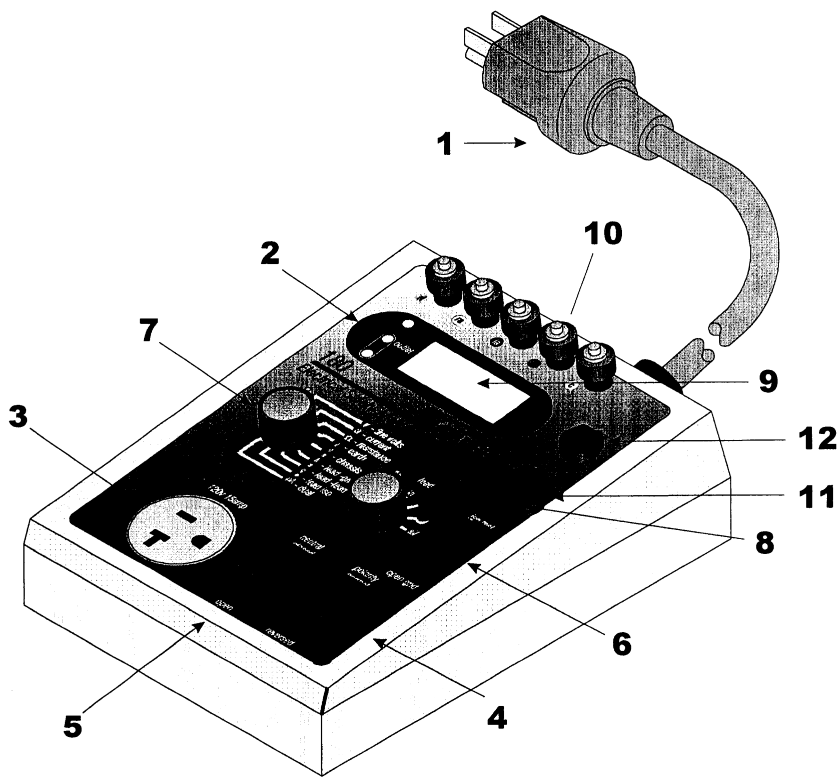

Figure 1: Bio-Tek 180 Electrical Safety Analyzer

1. POWER CORD supplies power to the Electrical Safety Analyzer and to the device under test (DUT). The measurement circuits are energized when the power cord is plugged into an outlet. There is no on/off switch.

2. OUTLET INDICATORS verify the polarity and wiring of the outlet to which the Analyzer is connected. Only correctly wired outlets should be used. Not applicable to isolated power systems.

3. **TEST RECEPTACLE** supplies power to the device under test (DUT). This outlet is powered if the outlet switch is set to normal or reversed, and **NEUTRAL** is **CLOSED**.

4. **OUTLET SWITCH** with center **OFF** position permits testing with both the **NORMAL** (FORWARD) and **REVERSED** polarity of the line. *It is recommended that the switch be paused in the center **OFF** position before changing polarity.*

   Note: Failure to pause the three-position switch in the OFF position may cause switch damage or blow the internal pico fuse.

5. **NEUTRAL SWITCH** permits making leakage current measurements under the **OPEN** neutral condition as required by UL and IEC.

6. **LIFT GROUND/ISO TEST** switch is a dual-function switch. The **LIFT GND** position will open ground to the device for leakage current measurements. The **ISO TEST** position will energize the selected patient lead at 110 percent line voltage, current limited, to measure the isolation current when the main function switch is in the **LEAD ISOLATION** position. With the function switch in the **DUAL** position, the isolation test voltage is supplied to the **DUAL** connector for measuring the isolation current of a probe or transducer.

7. **FUNCTION SWITCH** provides direct, one-step selection of the measurement to be made. These are line volts, instrument current, grounding resistance, ground (internal) and chassis (external) leakage currents, and the patient leakage currents. These include lead to ground (source), lead to lead (auxiliary) and isolation (sink) current. A dual position is provided to measure leakage current between two points or isolation current of probes and transducers independent of their instruments.

8. LEAD SWITCH directs the selected patient lead measurement to the desired lead. When testing a 10-lead device, a second pass will be required for the C leads.

9. METER is a large, ½ inch, high-contrast LCD, 3½-digit display of the measured parameter. This will read up to 1999 with decimal points added where required.

10. UNIVERSAL PATIENT LEAD TERMINALS provide means for connection of the patient leads for leakage current measurement.

11. CHASSIS CONNECTOR provides means for inputting the CHASSIS CABLE with its clip for connection to the DUT's chassis or enclosure. The chassis ground resistance is measured with the FUNCTION switch in the RESISTANCE position, and the chassis leakage current is measured in the CHASSIS position.

12. DUAL CONNECTOR is used to make point-to-point measurements. For leakage and voltage measurements, the **black cable** is attached to the CHASSIS connector, and the **red cable** to the DUAL CONNECTOR. For point-to-point resistance measurements, the **black cables** are attached to the DUAL and CHASSIS connectors.

Using the Analyzer

Preparing for Use

WARNING! To assure total safety to the patient, disconnect all patient connections to the device to be tested before starting.

As it is best to start from the same position each time, place the analyzer's switches in the following initial positions:

FUNCTION switch	**LINE VOLTS**
LEAD switch	**RL**
NEUTRAL switch	**CLOSED**
OUTLET switch	**OFF** [center]

Plug the *180* into a properly rated outlet. The analyzer is equipped with a hospital-grade power plug. Grounding reliability can only be achieved when the analyzer is connected to an equivalent power receptacle marked "Hospital Grade." Grounding is important for personnel safety and to make some of the tests offered by the analyzer. **Do not circumvent for any reason.**

Verifying the Power Outlet Connections

Note: Not applicable to isolated power systems.
Three neon lamps provide indication of the polarity and condition of the outlet being used, as determined by the following chart.

REV	○	●	○	○	●	●
	●	●	●	○	○	○
OK	●	○	○	○	●	●
	correct wiring	reverse polarity	open ground	open hot	open neutral	hot/ground reversed

Note: Power outlets that do not indicate "correct wiring" should be reviewed and corrected by a qualified electrician.

If the line checks OK, plug the device to be tested into the analyzer's line receptacle. If the line is found faulty, correct the problem before proceeding.

Measuring the Line Voltage

From the recommended start position, with the FUNCTION switch in the LINE VOLTS position, the meter will display the line voltage with a resolution of one volt. With the POLARITY switch in the NORMAL position and the DUT turned on, the meter display will continue to read line voltage but under the load of the device being tested. Depending on the device's operating current and the electrical supply wiring, the voltage differential may be significant. The value under load should be checked against the device's ratings, to ensure that the actual value remains within prescribed limits. An excessive drop also suggests that a dedicated line of increased capacity should be run to the instrument.

Measuring the Device's Current

Switch the FUNCTION switch to CURRENT. The meter will display the device's current to 19.99 Amperes. The POLARITY switch should be in NORMAL, NEUTRAL CLOSED, and the device should be turned on and placed in its maximum load condition to obtain the proper reading. Logging this data may help in spotting problems early by noting changes in values.

Measuring the Chassis Grounding Resistance

This test is only applicable to devices utilizing three-wire (grounded) power cords. Connect the **black cable** to the CHASSIS connector on the front panel of the analyzer. Clamp the clip of the cable to the DUT's exposed chassis or the enclosure if conductive. Care should be taken to ensure that bare metal is reached and that both jaws of the clip are in contact with the chassis. Metal labels or incidental conductive hardware should not be used for this test.

If a non-conducting enclosure is used, and no chassis is readily accessible, a safety ground terminal can be used.

Once connection is made, rotate the FUNCTION switch to RESISTANCE and read its value directly in ohms to 19.99 ohms. This test is best made with the POLARITY switch in the OFF (center) position.

Measuring Leakage Currents

Measuring Ground Leakage Currents

The earth leakage current is the current that flows normally in the ground wire of the device and thus only applicable to devices utilizing three-wire (grounded) power cords. See section entitled "Theory of Operation" for additional discussion on earth leakage current. The connection is made internally in the *180*, so no external connectors are required for this test.

The current is measured by switching the FUNCTION switch to GROUND. The leakage current will be displayed to 1999 µA (microAmperes). Measurement should be made under all combinations of the POLARITY switch, NORMAL and REVERSE, NEUTRAL switch, CLOSED and OPEN and the device power turned ON and OFF. ***Be sure to pause in the off (middle) position when switching from normal to reverse.*** Power to the outlet will be OFF with NEUTRAL open.

Measuring Chassis (Enclosure) Leakage Currents

The chassis [enclosure] leakage current is the current that flows between the conductive chassis or enclosure and earth (ground) measured through a 1,000 ohm impedance.

Connect the **black cable** to the CHASSIS connector on the front of the Analyzer. Clamp the clip on the cable in turn to accessible conductive sections of the chassis and the enclosure. Metal labels or incidental conductive hardware are not applicable for this test.

If a non-conducting enclosure is used, present standards require connection to the enclosure via a 200 cm^2 conductive foil in intimate contact with the enclosure. This can be accomplished with a 14 X 14 cm (5.5 X 5.5 in) piece of aluminum foil taped to the surface and the cable clipped to the foil.

To make the measurement, place the FUNCTION switch in the chassis position and read the display in microAmperes. The reading should be made under all combinations of the POLARITY switch, NORMAL and REVERSE, NEUTRAL switch, CLOSED and OPEN, GROUND CLOSED and LIFTED and the device power turned ON and OFF. ***Be sure to pause in the off (middle) position when switching from normal to reverse.*** Power to the outlet will be OFF with NEUTRAL open.

Measuring Lead-to-Ground (Patient Source) Currents

Patient lead to ground leakage current is the current that would flow through individual patient leads and all patient leads connected together if the patient was to come into contact with earth ground.

Connect the patient leads to the corresponding snaps on the top of the Analyzer. If the device has 10 leads, connect the limb leads and C1 (V1) initially and repeat with C2 (V2) through C6 (V6). Lead nomenclature for this test is not important.

Select LEAD TO GROUND with the FUNCTION switch and read leakage current in microAmperes for any combination of the patient lead selected by the LEAD switch. The reading should be made under all combinations of the POLARITY switch, NORMAL and REVERSE, NEUTRAL switch, CLOSED and OPEN, GROUND CLOSED and LIFTED and the device power turned ON and OFF. Rotate the LEAD switch to each lead to test individually and then tc ALL for testing with all leads connected together.

Measuring Lead-to-Lead (Auxiliary) Currents

The lead-to-lead current flows from any patient lead to any other patient lead and to all other leads connected together. Under normal conditions, the current is primarily input bias current, measurement current or lead off sensing current. The worst-case condition will be measured from the individual lead to all others connected together. This is the measurement made by the *180.*

Measurement is made with the patient leads connected to the snaps on top of the analyzer and the FUNCTION switch placed in the LEAD TO LEAD position. Selection by the LEAD switch will test the individual leads. Note that the ALL position has no meaning in this test.

If the device under test utilizes a 10-lead patient input, test each C (V) lead in turn individually.

Measuring Lead Isolation (Patient Sink) Currents

WARNING! **High voltage, 110 percent of line volts, with respect to earth ground is accessible at the patient connections (snaps) during part of this test. Take care when handling the patient leads.**

The patient lead isolation current would flow in individual leads or all leads connected together if line volts were to come into contact with the patient.

Measurement is made with the patient leads attached to the snaps on top of the analyzer, the FUNCTION switch placed in LEAD ISOLATION position, and the individual lead to be tested selected by the LEAD switch. To apply the high voltage to the lead safely, press the LIFT GROUND/ISO TEST switch to ISO TEST. The voltage is only applied when pressed. While ISO TEST is energized, read isolation current in microAmperes. The test should be performed in all combinations of the POLARITY switch, NEUTRAL switch and with the device under test ON and OFF.

Point-to-Point Measurements

Measuring Leakage and Isolation Currents

The *180* prvides the capability of making **leakage current** and **isolation current measurements** between selected points, otherwise known as a dual lead measurement. For leakage current measurements, connect the **black cable** to the CHASSIS connector and the **red cable** to the DUAL connector. With the FUNCTION switch in the DUAL position, clip the two cables to the two points for which the leakage current is to be measured. The meter will display the leakage current between the two points to 1999 µA. The number displayed is also the voltage gradient in millivolts between the two points based on a volt meter with an input impedance of 1000 Ω.

To measure the electrical isolation of a probe or transducer, electrical connection must be made to each side of the isolation barrier by **red** and **black cables** as described above. Set the function switch to DUAL and toggle the LIFT GROUND/ISO TEST switch to ISO. This will apply isolated line voltage between the two sides and the meter will display the isolation current that flows. The actual method for making connection to either side of the isolation barrier will vary with the device to be tested, thus, full details cannot be provided here.

WARNING! ⚠ **High voltage, 110 percent of line volts, will be accessible between the red and black cables when the lift ground/iso test switch is in the ISO position. Take care when handling the cables.**

Measuring Resistance

In addition, the *180* can make **resistance measurements** between selected points. If electrical devices are involved, it is desirable that they be turned off. Connect two **black cables** to the CHASSIS and DUAL connectors, and clip onto the two points to be measured Set the FUNCTION switch to RESISTANCE, and the display will read the resistance between the two points. To compensate for possible DC components in the leakage current flowing between the two points, reverse the two clips and average the readings. **Note:** It is necessary to remove any device connected to the device receptacle in the analyzer to make this measurement.

Theory of Operation

This section reviews the parameters measured by the *180* electrical analyzers, how they occur, and typical values found.

Figure 2 is a block diagram of a typical line-operated instrument with patient connections. All measured parameters are labeled for discussion. Understanding the mechanism that creates these parameters should be helpful in investigating and resolving problems that may arise, thus ensuring a safer environment. It should be recognized that these voltages and currents are a natural phenomenon, and their presence within reasonable limits does not constitute a hazard. A significant change from previous measurements or from the device specification should be carefully reviewed with suspicion.

LINE VOLTAGE [VL] is the mains power supplied by the electrical distribution system of the hospital. It is shown as a three-wire system of HOT, NEUTRAL and GROUND with NEUTRAL, like GROUND, returned to true earth at their entry into the building. The voltage measured will depend upon :

- The power utility company's output and distribution to the hospital
- The distribution system within the hospital, primarily a function of age where older systems have marginal capacity for the electrical needs of today's equipment
- The load on the line being measured; not only that of the device under test, but of other devices on the same line.

The *180* measurement is made between the HOT and NEUTRAL wires via transformer coupling to isolate the measuring circuits from the line. As recommended, measurement of the line voltage with the device under test **OFF** and then **ON** will indicate whether the line is adequate for the device. A large drop may suggest that a dedicated line of higher amperage should be run in for the device.

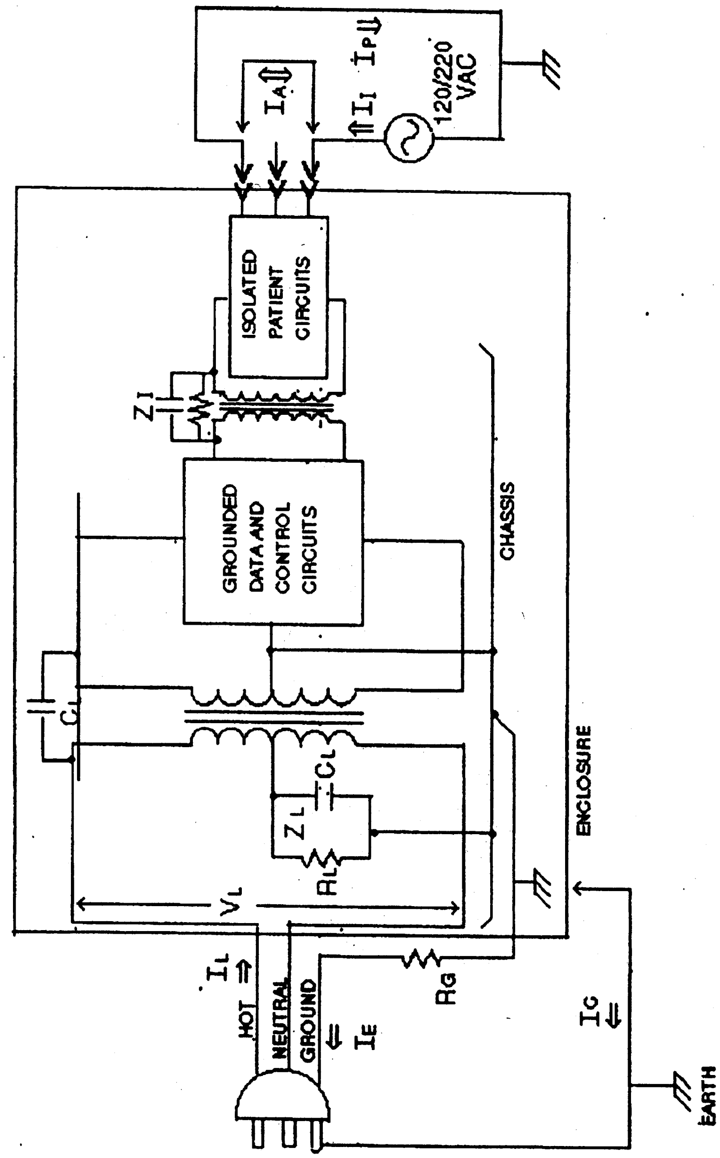

Figure 2: Bio-Tek 180 Electrical Safety Analyzer

INSTRUMENT CURRENT [I_L] is the current used by the device under test. When turned on, the device should be operated in its various modes to determine the worst condition to track. Verify that the device under test current is within the current rating of the *180* being used.

Measurement is made in the HOT wire via transformer coupling to ensure that the total current is measured, as it is possible that the NEUTRAL and GROUND wire could share the return path.

GROUND WIRE RESISTANCE [RG] (grounding resistance) is the resistance from the device's conductive "grounded" chassis to the grounding terminal on the receptacle in which it is plugged. The resistance is largely composed of the GROUND wire in the power cable and is directly proportional to its length. See ***Table 1*** for typical values for a 10-foot cable. The resistance measurement also includes the junction resistance in connecting the wire at both ends, and the bulk resistance of the chassis from the grounding point to the point of measurement.

Table 1. Ground Resistance of 10-Foot Power Cable
(will vary slightly with wire stranding)

WIRE SIZE AWG	RESISTANCE MILLIOHMS
18	64
16	41
14	25

Underwriters Laboratory (UL) limits the ground resistance to 100 milliohms (0.1 ohms) for new products, and National Fire Protection Association (NFPA) to 150 milliohms, or 500 milliohms for devices in the field. Maintaining a low resistance is important to protect against the chassis becoming "hot" as a result of an internal fault causing current to flow to the chassis. The resulting voltage drop across the ground wire will raise the potential of the chassis with respect to the local ground and thus create a potential hazard.

Because of the low values of resistance being measured, the *180* utilizes a four-wire Kelvin bridge to make the measurement. This avoids the introduction of errors due to contact resistance of the cable connectors and to the length of the test cable. Resistance is measured between the clip on the black chassis cable and the grounding pin receptacle of the *180*.

GROUND LEAKAGE CURRENT $[I_E]$ (internal chassis current) is the current that flows in the GROUND wire of the power cable to return the chassis leakage current to true earth ground. This current does not constitute a hazard as long as the ground wire remains intact and the current does not become excessive. This could occur by a major fault, resulting in the ground wire sharing the load current with the neutral wire or supplying the total return. In addition to the rise of the chassis potential with respect to the local ground reference, the local ground reference can rise with respect to true earth as established by the cold water pipes. It should be pointed out that this current becomes the chassis leakage current for conductive enclosure when tested under open ground condition as discussed below.

Leakage current is due to the proximity of the hot wire or line potential components to the chassis represented by ZL, a combination of capacitance, CL, and resistance, RL, components. Particular sources of this current are as follows:

- **Power transformers and motors with large winding masses in close proximity to large conductive masses which are physically mounted to the chassis.** Such leakage can be both capacitive, across a dielectric, and resistive through conductive flux residue or poor insulation.

- **Line filters installed to protect against conductive EMI, particular in newer computerized devices.** These components include real capacitance from both the hot and neutral wires to ground. Typical leakage currents are in the 100 to 500 µA range although special low leakage units, down to 50 µA, are available, specifically targeted for the medical device industry.
- **Switching power supplies with significant electronics directly connected to the power line, and complicated by the introduction of the higher switching frequencies used in the supply.**
- **Power cable with the parallel run of the hot wire in intimate contact with the ground wire.** Leakage current is dependent upon wire gauge, insulation dielectric, and length. Typical values for a ten foot cable can range from 10 to 15 µA. A special low leakage cable is available with comparative leakage of 3 to 4 µA.

The measurement is made using the 1000-ohm AAMI load placed directly in series with the ground wire. Open neutral will usually represent the worst case.

CHASSIS [ENCLOSURE] LEAKAGE CURRENT [IC], also referred to as dual leakage current, flows between the accessible conductive chassis or enclosure and earth ground. As stated above, under the condition of an open ground, this current is the same as the earth current. With ground intact, the current should be very low, reflecting the milliohm impedance of the ground wire paralleling the 1000-ohm AAMI load.

Differentiation between the earth and chassis currents is made due to the wide use of insulated enclosures today. Therefore, there is no accessibility to a conductive chassis. Under these conditions the earth current represents total leakage current, while the chassis current, measured with a 14X14 cm piece of foil placed in intimate contact with the enclosure, provides indication of potential hazard due to contact.

Capacitance between the chassis and the foil will determine the current measured, which usually will be low.

The *180* measures chassis leakage from the exposed metal part on the DUT, through the black cable and the AAMI load, back to the ground. Measurement should be made under all conditions, particularly with ground lifted and open neutral, which usually represents the worst case.

LEAD TO GROUND [I_P] (patient source) current is the current that flows between an individual patient lead and ground. It represents the condition of a patient with leads attached touching ground such as an electric bed. If the patient connections are not isolated, then this current will reflect the earth current when teste under the open ground condition, as this is its only path back to true earth.

For devices incorporating isolated patient connections, this curren is reduced by the patient isolating impedance ZI, a combination of resistive and capacitive leakage. Although originally required only for devices incorporating intra-cardiac electrodes or conductive pathways directly to the heart, it has found its way int standards for all devices having any patient-applied parts.

Measurement is made to the lead selected by the lead selector switch, with the other side of the AAMI load connected to system ground. Current measured should be the same for all leads, including the **ALL** position, as the current represents the isolation impedance to the patient circuit.

LEAD TO LEAD [I_A] (auxiliary current) is the current that flows fror one lead to another lead and includes the following:

- Bias current of the input amplifier
- Reverse leakage current of input protection diodes
- Lead-off sensing current
- Impedance measurement current such as for respiration

The currents can be DC or AC or a combination of both, and thus needs to be measured utilizing true RMS technique. This avoids the wave form introducing errors in converting to an RMS value, since each wave form (DC, AC sine or square) has its own conversion factor. The measurements are made with a true RMS converter to provide the common base necessary for accurate readout with a variety of common wave forms.
Measurement is made with a completely floating circuit to avoid extraneous leakage currents to ground introducing errors. Measurement is made from the selected lead to all other leads connected together thus reducing the permutations required to cover all possibilities. The single lead carrying the most current will generally be the reference lead, RL, as this acts as the return for the other leads. Therefore, the leads can be taken in groups of four with the common reference lead, RL, and then summed.

LEAD ISOLATION [I_I] (patient sink) current is the current that would flow into the device under test if the patient were to come into contact with full line voltage. This could occur with an electric bed which has become ungrounded and has a short to the frame. While measurement is made in each individual lead, a common value will be found for all leads as well as for the **ALL** position, as this is the measurement for the isolation of the patient circuit. To assure proper reading, the test should be run with ground intact.

For this test, the *180* provides a specially shielded line voltage secondary on its power transformer that minimizes internal leakage currents from the measuring circuit. This avoids the necessity of measuring the current and subtracting it from all readings. The current is limited with a 120 kΩ resistor for user protection. For additional safety, the current is only applied to the patient leads when the **TEST** switch is pressed to **ISO**.

DUAL MEASUREMENT capability is provided to extend the use of the *180* to that of:

- **Ohmmeter** capable of making resistance measurements in the milliohm range for chassis bonding measurements.
- **Low impedance (1,000 Ω) voltmeter** as specified by the NFPA with a range to 1,999 mV.
- **1,000 Ω microAmmeter** to measure the leakage current between two devices or between the DUT and a local ground reference. Range is to 1,999 µA.
- **Isolation tester** for ultrasound probes and other transducers independently from the device in which it is used.

RESISTANCE MEASUREMENTS between two points are made to verify the integrity of permanently installed equipment whose ground cannot be broken to measure the chassis leakage current. These are usually high-power devices which can have high leakage currents and depend on the bonding of all chassis to a common point for safety.

The resistance between two points is measured in the RESISTANCE mode of the FUNCTION switch, utilizing two **black cables** for input leads through the CHASSIS and DUAL connectors. Care needs to be exercised to ensure that ground connections do not provide parallel measurement circuits causing erroneous results. This is accomplished by not connecting any device to the *180* instrument receptacle.

Measurement is made with 10 mA DC current and is highly resistant to AC currents flowing between the measurement points as a result of chassis leakage current from either or both devices. However, such leakage current may have a DC component from rectification within the instrument. This DC current adds and subtracts from the measurement current resulting in some error. This can be corrected by reversing the connections and averaging the two readings.

LEAKAGE CURRENT AND VOLTAGE GRADIENT between two points is also measured for permanently installed equipment as additional verification of the integrity of the installation. These measurements are equivalent, as the relationship between volts and current across 1,000 Ω is one mV per μA.

Measurement is made from the **DUAL** position of the **FUNCTION** switch with one black cable in the **CHASSIS** connector and a red cable in the **DUAL** connector as meter inputs.

The measurement circuit is isolated from ground and, to be maintained, must avoid having a device plugged into the Analyzer's receptacle. These should be removed during any dual measurements.

Connection of the two cables to the surface of choice will result in direct display of the leakage current or gradient. Measurement is made to 1999 μA or 1999 mV, respectively.

ISOLATION TESTING of probes and transducers making internal contact to a patient is provided to ensure the reliability of the isolation barrier. These devices incorporate electrical circuits which can introduce or sink hazardous currents to the patient if s/he comes into contact with line potential, or becomes grounded as previously described. Additional difficulty is generated with these devices, as they generally require sterilization before use. Thus, testing before sterilization is recommended.

Maintenance and Calibration

Your *180* needs little maintenance or special care; however, it is a calibrated measuring instrument and should be treated as such. Avoid dropping the instrument or other mechanical abuse that could cause a shift in the calibrated settings.

CLEANING the analyzer should be done occasionally with a damp cloth and a mild detergent. Care should be taken to avoid the entrance of liquids.

CABLES should similarly be wiped down with the same care, and inspected for damage and deterioration of the insulation. The cable entrance to their connectors should be checked for integrity of the cable clamp and strain relief.

CALIBRATION of the *180* is best done at the factory on a yearly schedule, as we are equipped with the appropriate tools and reference instruments traceable to the National Institute of Standards and Technology (NIST).

Service and Repair
1420 75th Street SW
Everett, WA 98203
888-99FLUKE (888-993-5853) • 425-446-5560
http://www.flukebiomedical.com • sales@flukebiomedical.com

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