Testing for safe and efficient branch circuits

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Branch Circuit Testing

Branch circuit wiring and testing practices are primarily code driven with little thought as to why such stringent requirements are necessary. But these practices are necessary to ensure safe and efficient branch circuits. Hidden problems within a branch circuit can result in fire, electrocutions and equipment failure.

Fires

Based on the National Fire Protection Association (NFPA) and the US Consumer Product Safety Commission data, there was an estimated 406,000 residential structural fires in 1997, resulting in an estimated 3,390 civilian deaths and 17,775 injuries. Approximately 9% of the structural fires and 7% of the deaths were determined to be the result of the electrical distribution system. Residential fires were by far the biggest problem, accounting for 97% of all structural fires and 87% of deaths.[1]

The most common cause of residential electrical fires is problems within the branch circuit wiring. These problems resulted in 14,600 fires, 420 injuries and 110 deaths in 1997.[2]

Electrical Distribution	Fires	Injuries	Deaths
Installed Wiring	14,600	420	110
Cord, Plug	6,300	320	90
Switch, Outlet	4,900	160	10
Lamp, light Fix.	9,900	350	30
Other	4,600	10	10
Total	40,300	1360	250

[1] *Fact Sheet on Fire in the US and Canada, National Fire Protection Agency (NFPA) 1997*
[2] *1997 Residential Fire Loss, Consumer Product Safety Commission, 1997*

Arc Fault Circuit Interrupters

There are two main causes of fires to installed wiring within the electrical distribution system. The first is arcing within the circuit. An arc fault is characterized by an erratic flow of electricity. Because normal breakers were designed to protect against short circuits, arc faults occurring in damaged cable can continue undetected. These leads to hazardous situations such as high temperatures that could ignite nearby combustible materials[3]

To offer protection against these conditions, the 2002 edition of he National Electrical Code (NEC), requires the installation of Arc Fault Circuit Interrupters (AFCI) in bedroom circuits in new residential circuits.[4] Currently, the only devices that meet the new NEEC guidelines are Arc Fault breakers. These breakers, which are manufactured by a number of companies, have a special circuit within the breaker to detect arc fault conditions on the branch circuit.

These devices should be tested upon installation to ensure that the breaker will adequately protect the circuit. An independent arc fault tester simulates an arc fault condition on the line to determine if the breaker will protect the circuit.

High resistance connections

The second major cause of residential fires is a high resistance point in the circuit, such as a loose connection, poor splice or defective electrical device. Current flowing through these high resistance points causes heat to build up behind the wall. This can create a smoldering fire if there are combustible materials nearby, and no way to dissipate the heat.

Loose wire connections create a high resistance point within the electrical system, which can lead to a breakdown in insulation or even a fire.

Identifying potential problems

Most fixed wiring and receptacle hazards are hidden from inspection. A visual inspection in the rough-in stage of residential construction may identify obvious problems, such as a staple cutting through the conductors, but they may not identify a loose wiring connection or a bad splice.

Normal instrument testing of a static circuit reveals little about the quality of wiring or the integrity of the circuit. However, testing under load and calculating the voltage drop can identify 90% of these hidden defects.

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[3] IEC Fact Sheet, Arc-Fault Circuit Protection, Illinois Electric Council, Fact Sheet #28
[4] NEC code Articles {210.12 (A)}

Voltage Drop

Voltage drop is a measure of how much a circuit's voltage fluctuates (or drops) once a load is applied. Voltage drop can be calculated by comparing a voltage measurement with no load on the circuit to a voltage measurement under full load.

The voltage drop calculation will be most accurate when no-load conditions are compared to full load conditions. When using a digital multimeter to calculate voltage drop, remove all loads from the circuit to take the no-load measurement. For the full load measurement, use a space heater or some other appliance that will draw close to 15 amps.

$$\% \text{ Voltage Drop} = (V_{(no\text{-}load)} - V_{(load)}) / V_{(no\text{-}load)}$$

Voltage Drop can also be measured with a SureTest® Circuit Analyzer. It uses a patented technology to place a full load onto the circuit without tripping a breaker or causing any interruption to equipment on the line. The SureTest compares the voltage measurement at full load, with a measurement at no load and calculates the voltage drop.

Voltage drop at a full load can be easily taken by simply plugging the SureTest into a receptacle.

How Much Voltage Drop is Acceptable?

The National Electrical Code (NEC) recommends that the combined voltage drop of the electrical system (branch circuit and feeders) not exceed 5% for optimum efficiency.[5] It is important to note that this is a recommendation and that local inspectors, or other governing bodies, may use their own judgment on an acceptable level of voltage drop for the electrical system.

For example, the Philadelphia Housing Development Corporation (PHDC) requires contractors to calculate the voltage drop prior to installing blown insulation in existing homes[6]. If the voltage drop is 10 % or higher contractor must replace/repair the circuit prior to proceeding with the insulation.

Prior to instituting this requirement, half a dozen smoldering fires resulted from the blown insulation installations. In the 2,500 homes insulated during a two-year period after this electrical integrity test was instituted, there were no fires reported. At least 15 other municipalities have followed the PHDC's lead in requiring the load test as part of their winterization programs.

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[5] *NEC code Articles {210-19(a) FPN No. 4} {215-2(d) FPN No. 2*

[6] Kinney, Larry "Assessing the Integrity of Electrical Wiring" *Home Energy* Sept/Oct 1995: 5,6

Troubleshooting a Circuit

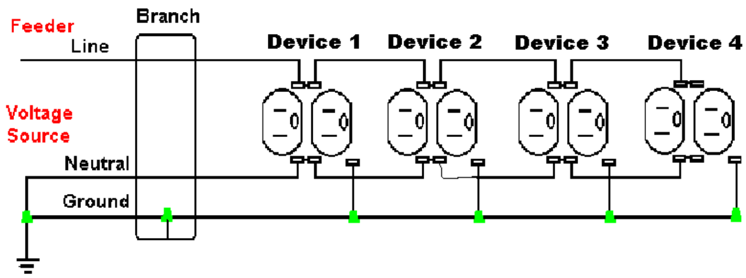
Troubleshooting to identify the cause of the high impedance within the electrical system is actually quite simple. First measure the voltage drop at the furthest receptacle from the panel on the branch circuit under test. If the voltage drop is high, than further investigation is necessary.

Testing the remaining receptacles in sequence, from next furthest from the panel to the closest to the panel, will identify the problem.

If the voltage drop reading changes significantly from one receptacle to the next, then the problem is a high impedance point at or between the two receptacles. It is usually located at a termination point, such as a bad splice or loose wire connection, but it might also be a bad receptacle.

If the reading steadily decreases as you get closer to the panel, with no significant decreases between receptacles, then the wire may be undersized for the length of run, or for the load on the line. Check at the panel to see if the wire is sized per code, and measure the current on the branch circuit.

The reading may not decrease at all from the last receptacle to the first. This would indicate that the problem could be at the first splice, or at the panel itself. Most poor panel connections show up as hot spots on the panel. These can be checked quickly with an infrared temperature meter.



By testing receptacle in sequence from furthest from the panel to closest with a load test, hidden defects can be identified and corrected

Testing the integrity of the branch circuit under load can have a dramatic effect on the ability to positively identify hidden defects within the branch circuit.

Electrical shock

An estimated 58 people loose their life each week as a result of electric shock. These deaths are a result of consumer products, large appliances and installed home wiring. In an electrical system, the grounding system is the primary protection against electrical shock hazards. It provides a low resistance pathway to ground to protect against electrical faults.

There are several conditions that can occur within the grounding system that would lessen the protection against electrical shock. Three of the most common are high impedance grounds, false grounds, and a poor earth grounding system.

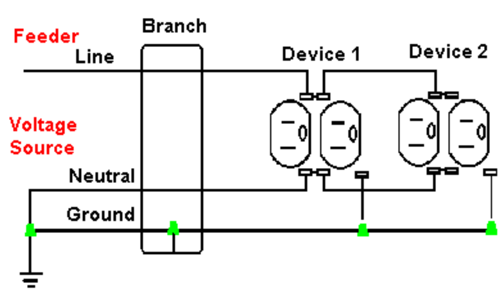
High Impedance Ground

A good electrical ground is more than following NEC requirements, it must also be a low impedance system. The ground path is the fault path for stray current. If electricity follows the path of least resistance, than the ground circuit must have a lower resistance than an individual to protect them. The rule of thumb for protecting people is to maintain a ground impedance of less than one Ohm.

Maintaining a good quality ground starts with wiring the circuit correctly. The NEC requires that the removal of any device cannot interrupt the ground path. Receptacle manufacturers have responded by supplying receptacles with only a single grounding connection. This would prohibit electricians from wiring the device in series with the grounding circuit.

Pigtail Connections

A common method of ensuring that the ground remains intact is through the use of a pigtail connection. To make a pigtail connection, take both ground wires and join them with a 6-inch wire of the same color that has been stripped on either end. Hold all three tightly and bind them together with a wire connector. Be sure to use the right size connector for the size and number of wires.



The grounding circuit must not rely on any device to maintain the circuit. The NEC requires that the removal of any device cannot interrupt the ground path

Special connectors are available to make this job easier, such as the Greenie® Grounding Connector from IDEAL. With the Greenie, a bare copper wire is inserted through a hole at the top of the connector. All the wires are then bound together, by twisting the Greenie until tight.

Special connectors, like the Greenie, make pigtailing easy, saving time and ensuring code compliance

Pre-made pigtails are becoming more popular because of the time-savings involved. The Term-a-Nut® Pigtail Connector combines a twist-on wire connector with a pre-crimped pigtail. The ultra-flexible, six-inch lead provides hassle-free positioning in a junction box, and the grounding pigtails come with a pre-crimped fork connection for quick and easy installation of the device.

By combining a twist-on connector with a pre-crimped pigtail, the Term-a-Nut Pigtail facilitates pigtailing of hot, neutral and ground conductors, reducing labor by two-thirds

Bonding the Junction Box to the Grounding Conductor

In many wiring applications, more than one equipment-grounding conductor enters a junction box. According to section 250-148[7] of the NEC, where more than one equipment-grounding conductor enters a box, all such conductors shall be spliced or joined within the box or to the box.

The only exception is for isolated receptacles, covered in section 250-146 (d),[8] where isolated receptacles are required for the reduction of electrical noise (electromagnetic interference).

For metal junction boxes, the grounding conductors from each device also needs to be connected to the box with a listed grounding device, or a grounding screw, that is not used for any other purpose.

The Term-a-Nut grounding products come in a variety of configurations for fast and efficient grounding to Article 250 of the National Electrical Code

[7] *NEC code Article {250-148}*
[8] *NEC code Article {250-146(d)}*

Bonding the Receptacle Grounding Terminal to the Junction Box

A device may have to be bonded to the junction box with a jumper. According to section 250-146[9] of the NEC, an equipment bonding jumper shall be used to connect the grounding terminal of a grounding-type receptacle to a grounded box unless grounded as in (a) through (d).

(a) A surface mounted box, where the device yoke and the box have direct metal-to-metal contact. This connection can be used to ground the device. This provision does not apply to cover-mounted receptacles unless the box and cover combination have been listed as providing an acceptable ground continuity between the box and receptacle.
(b) Contact devices or yokes designed and listed for providing the grounding connection between the device and the junction box. These shall be permitted in conjunction with the supporting screws to establish the grounding circuit between the device yoke and flush-type boxes.
(d) Floor boxes designed for and listed as providing satisfactory ground continuity between the box and the device. Isolated receptacles that is required for the reduction of electrical noise (electromagnetic interference) on the grounding circuit. In these applications, the grounding terminal is purposely insulated form the receptacle mounting to reduce the electrical noise coming from other loads on the branch circuit.

The receptacle grounding terminal is connected to an insulated equipment grounding conductor run with the circuit conductors. This grounding conductor is permitted to pass through one or more sub-panels without connection to the panel board grounding terminal as permitted in Section 384-20[10].

Note that the use of an isolated equipment grounding conductor does not relieve the requirement for grounding the raceway system and junction box.

False Grounds

The neutral conductor can only be bonded to the ground conductor at the main neutral buss, where a large copper conductor carries all the return and faulted current back to the earth. Sometimes through error or ignorance, the neutral and ground are connected upstream from the service entrance. This is called a false, or bootleg ground. If the neutral and ground are connected anywhere else in the building, all grounded metal becomes part of the neutral conductor, constantly energized and creating various voltage potentials on electronic equipment.

When using common receptacle testers, this condition shows up as normally wired. Only the SureTest® Circuit Analyzer can correctly identify a false ground condition within 15 feet of the receptacle under test.

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[9] *NEC code Article {250-146(a) through (d)}*
[10] *NEC code Article {384-20}*

Earth Ground

The pathway to ground extends beyond the main panel to the earth ground system. The earth ground could be a single ground rod, multiple ground rods, a mat or a grid system. Section 250-56 addresses the system by stating that if the ground electrode is not less than 25 ohms a second electrode should be added at least 6 feet from the first.[11] The grounding system can be tested with a three-pole earth resistance tester, or a ground resistance clamp meter.

A ground resistance clamp meter enables electricians to measure the resistance of the ground electrode in a fraction of the time required using the traditional three-point fall of potential test.

Large ground systems, such as those found in substations and power stations,may requires a large grounding grid to obtain a sufficiently low value of ground resistance. In these applications, the soil resistivity can play a large role in determining the requirements of the grounding grid. Inaccurate resistivity tests can lead to unnecessary costs in the design of the system. To ensure a low impedance grounding system, include the ground electrode, or earth ground as part of your standard testing procedures in your facility.

By using a four-pole ground resistance meter, the soil resistivity can be tested to determine what the grounding requirements are. Inaccurate resistivity tests can lead to unnecessary costs in the design of the system.

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[11] *NEC code Article {384-20}*

Ground Fault Circuit Interrupters

Electrical code requires the installation of ground fault circuit interrupters (GFCIs) in residential dwellings to protect against shock. Receptacles in bathrooms, garages, outdoors, crawl spaces, unfinished basements, kitchens and near wet bar sinks require protection.[12]

A GFCI is a receptacle with a built in circuit to detect leakage current to ground on the load side of the device. When the GFCI detects leakage current to ground, it will interrupt power to the load side of the device, preventing a hazardous ground fault condition.

These devices should be tested regularly, because they rely on mechanical connections that will degrade over time. According to a recent study performed by the Leviton Institute on average 15% of GFCIs were inoperative when tested. "Voltage surges from lightning, utility switching and other sources all take their toll on the devices, which is why Underwriters Laboratories (UL) requires that GFCIs be tested monthly."[13]

Using proper grounding techniques, testing and maintaining a good electrical ground and installing protection devices are the best ways to protect people and equipment from electrical shock.

Equipment Failure

When sensitive electronic equipment fails, the initial reaction is to throw our hands up and blame it on poor power quality. This makes the problem seem unmanageable and out of our control. Most of these problems are actually under our control, because 80% of all power quality problems are found in the electrical distribution and grounding system.

In addition to preventing the possibility of fire, a good low impedance electrical system will protect electronic equipment. A high resistance connection, like a loose wire, will cause the voltage to fluctuate, or drop, when a large load is applied. If the voltage drops low enough, it can cause electronic equipment to lock up, reset or shut down completely.

Grounding is another concern for electronic equipment. While ground impedance of one Ohm or less may protect people from electric shock, it may not be adequate protection for electronic equipment. IEEE recommends a ground impedance to be less than 0.25 Ohms for proper protection.

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[12] *NEC code Article {210-8 (a)}*

[13] *Study Identifies potential GFCI weaknesses*, Electrical Marketing, August 18, 2000

Isolated Grounds and Dedicated Circuits

It is often easier to isolate sensitive electronic equipment than to re-wire an entire circuit. This can be done by running an isolated ground for the equipment in question, or by running a new dedicated circuit.

An isolated ground protects the equipment from other equipment on the same grounding circuit. Electronic equipment can create noise, which can interfere with the operation of other equipment on the circuit. It is important to note than an isolated ground will not protect equipment from harmonic distortion running through a shared neutral.

In some cases, running a dedicated circuit is necessary to completely isolate a piece of equipment in order to ensure protection.

Branch Circuit Testing

The hidden dangers associated with branch circuit wiring are very serious, but fortunately the precautions are straightforward. We can protect ourselves and equipment by using certified devices and testing equipment from reputable manufacturers and implement policies on branch circuit testing. These policies should include verifying proper wiring, testing devices, checking the integrity of the branch circuit, and measuring the integrity of the grounding system.

Check all devices immediately after installation to verify proper wiring and test devices. Receptacles should be checked to avoid common wiring errors, such as reversed polarity or an open neutral. Checking the voltage level with a voltage tester quickly verifies that the receptacle has been correctly wired for either 120 or 220VAC. Checking continuity across a switch verifies that it working correctly. A variety of testers are available on the market to test these devices quickly and accurately.

Test electrical circuits under load to test the integrity of the branch circuit. The voltage drop test can identify high resistance connections, which can lead to fires, breakdown in insulation, and poor efficiency of the electrical system, which can contribute to erratic equipment operation.

Test the integrity of the grounding system, which includes not only the grounding conductors, but also the ground rod or grid system. A low impedance on both of these systems is essential to protect against electrical shock.

In summary branch circuit testing is an important part of wiring any circuit. It verifies that devices have been wired up correctly and allows you to protect yourself against the hidden defects in an electrical system.

IDEAL®

#61-154
#61-155

SureTest® Circuit Analyzer and SureTest® w/AFCI Instructions

Introduction

The SureTest® family of circuit analyzers were designed to troubleshoot branch circuits quickly, easily and accurately. They have a patented technology that allows them to test branch circuits under a full load condition to identify hidden problems behind the wall that will not be found with traditional testing methods.

Product Features

- True RMS
- Measures voltage drop under 12, 15 and 20-amp load
- Line voltage
- Peak voltage
- Frequency
- Ground impedance
- Hot and neutral conductor impedances
- Ground-neutral voltage
- Identifies proper wiring in 3-wire receptacles
- Identifies false (bootleg) grounds
- Verifies dedicated circuits (with 61-176 adapter)
- Tests GFCIs for proper operation
- Tests AFCI's for proper operation (61-155)
- Includes carrying case
- Includes 1-ft. extension cord

General Operation

The SureTest® Circuit Analyzer, #61-154 and SureTest® Circuit Analzer, #61-155 take only seconds to test each outlet and circuit under a full load. They check for various wiring conditions, including: correct wiring, polarity reversal, hot/ground reversal and no ground. A simple programming menu gives access to measurements of line voltage, voltage drop under a full load condition, ground-neutral voltage and line impedances. The ground fault circuit interrupter (GFCI) test is performed separately and will disrupt the electrical supply if a functional GFCI is present

The SureTest® w/AFCI, #61-155, will also test arc fault circuit interrupter (AFCI) test to ensure that AFCI breakers protecting the circuit have been installed correctly and are operating properly. This test is performed separately in accordance with UL1436, and will disrupt the electrical supply if a functional AFCI is present.

For proper troubleshooting of a branch circuit, insert the SureTest into the furthest receptacle from the panel. Any discrepancies from a normal reading during a measurement indicate that a problem has been detected in the circuit. Allow at least 20 seconds between insertions. Repeatedly inserting the SueTest into a receptacle will cause the unit to heat up which may affect the accuracies.

> **WARNING:** Do not use on outputs from UPS systems, light dimmers or square wave generating equipment.

General Specifications

Case construction:	ABS UL 94 V/0/5VA rated
Operating Range:	108 to 132 Volts
Display:	97x32 Pixel Graphics Display with backlight
Dimensions:	6.5” x 3” x 1”
Weight:	9.4oz

Environmental Specifications

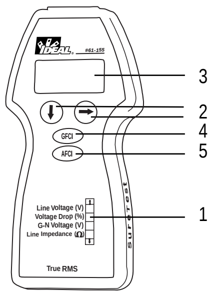
Operating Temp.:	0° C to 50° C
Storage Temp.:	0° C to 50° C
Humidity:	<80% RH
Altitude:	2000m (6667 ft.)
Safety:	Designed to IEC 1010-1 UL3111
Input Rating:	150VAC Category III
Overvoltage Category:	Cat III: Distribution level mains, fixed installations Cat II: Local level mains, appliances, portable equipment Cat I: Signal level, special equipment or parts of equipment, telecommunications, electronics
Pollution Degree 2:	Do not operate in environments where conductive pollutants may be present

Accuracy

Line Voltage:	108.0 - 132.0VAC	1.0%	+/- 1 digit
Peak Voltage	151.0 - 185.0VAC	1.0%	+/- 1 digit
Frequency:	45.0 - 85.0Hz	1.0%	+/- 1 digit
Voltage Drop:	0.1% - 20.0%	1.0%	+/- 1 digit
Ground-Neutral Voltage:	0.0 - 24.0 VAC	1.0%	+/- 1 digit
Impedances:	0.01 - 9.99Ω	1.0%	+/- 1 digit
GFCI Trip Time :	1mS - 7000mS	1.0%	+/- 1 digit

SureTest® Circuit Analyzer

1. Menu Structure
2. Menu Buttons
3. Display
4. GFCI Test Button
5. AFCI Test Button



Menu Structure

The measurements taken by the SureTest model ST-2D are organized into a simple menu. The first measurement in each menu selection is listed on the face of the unit. To the right of each menu is the unit of measure for the tests performed within that menu. The grid, and up and down arrows are representative of how the display will indicate the units position within the menu. The grid has four regions (one for each menu selection). When the unit is in the line voltage menu, the first section of the grid will be shaded in on the display to indicate that the unit is in the first menu selection. When the unit is in the Voltage Drop menu, the second section of the grid of the grid will be shaded in on the display to indicate that the unit is in the second menu selection. This follows for the Ground-Neutral Voltage and Line Impedance menus as well.

Additional tests are located in the sub-menu for each of these menu selections. An up arrow indicates that the unit is in the main menu, and a down arrow indicates that the unit is in a sub-menu. This will be displayed just under the menu grid on the unit's display. Using the menu grid and menu level indication will help the user step through the menu as indicated by the menu structure listed on the face of the unit.

Menu Buttons

The SureTest model ST-2D uses two buttons to navigate through the measurement menu. The down arrow button (↓) moves the unit forward to the next menu selection. If the SureTest is on the last menu selection (Line Impedance), pressing the down arrow button returns the unit to the first menu selection (Line Voltage).

The side arrow button (→) moves the unit through all the measurements within the menu selection. If the SureTest is in the last measurement of the menu selection, pressing the side arrow button returns the unit to the first measurement.

The quick reference guide at the end of this manual lists all of the available measurements in the SureTest menu.

Display

The graphical LCD on the SureTest ST-2D indicates the value of the measurement function, the test being performed and the position within the menu structure.

1. Test results
2. Measurement Icon
3. Menu Structure Icon

Measurement Icon

The measurement icon is located on the right-hand side of the display. The icon consists of the measurement symbol and text to describe which test is being measured. For example, the following icon indicates that the numerical value displayed is the True RMS line voltage.

Menu Structure Icon

The menu structure icon is to the right of the measurement icon. It consists of a grid and either an up or down arrow. The grid on the display has four regions that correspond to each of the menu selections as listed on the face of the unit. The appropriate region is shaded in to indicate which test is being performed. If the unit is performing any test within the Line Voltage menu or sub-menu, the first region is shaded. The arrow underneath the grid indicates whether the unit is in the main menu or sub-menu. An up-arrow (↑) indicates that the unit is in the main menu, and a down arrow (↓) indicates that the unit is in a sub-menu. If the unit is performing a test within the Line Voltage sub-menu, the first region of the grid will be shaded with a down arrow underneath the grid.

GFCI Test Button

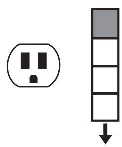
This button activates the GFCI test. This test can be activated from any point within the SureTest menu.

AFCI Test Button

This button activates the AFCI test. This test can be activated from any point within the SureTest menu.

Wiring Verification

Immediately after being inserted into a receptacle, the SureTest checks for proper wiring. While it is performing this test, the IDEAL logo will be displayed on the LCD. The SureTest 61-154 checks for the following conditions and indicates the test result on the display next to the receptacle test icon.



Wiring Condition	Display Indication
Normal	Wiring OK
No Ground	Error No Ground
Polarity Reversal	Error Rev Polarity
Hot/Ground Reversal	No Display
Open Hot/Open Neutral	No Display

If the wiring is OK, enter the SureTest measurement menu by pressing the down arrow button (↓). If no ground condition exists, the user may enter the measurements menu, but only the line voltage and voltage drop measurements are available. In a polarity reversal condition, the SureTest will not be able to take any measurements, so the unit will not be able to access the measurement menu under these conditions. In a hot/ground reversal, open hot or open neutral condition, the unit will not have power for any measurements, so the unit will not display any information.

WARNING:

An indication of "NoGround" in the wiring verification test indicates a safety hazard is present. Defective grounds must be repaired prior to the GFCI test.

WARNING:

If the SureTest® unit does not power up when plugged, contact a licensed electrician to diagnose the problem.

False Ground Indication

The neutral conductor can only be bonded to the ground conductor at the main neutral buss, where a large copper conductor carries all the return and faulted current back to the earth. Sometimes through error or ignorance, the neutral and ground are connected upstream from the service entrance. This condition is referred to as a false or bootleg ground. Common receptacle testers will test this condition as a normal wiring condition.

The SureTest model ST-2D will analyze the neutral and ground conductors to identify a potential false ground condition. If the unit is within 15 feet of a connection between neutral and ground, the SureTest will indicate a potential false ground condition.

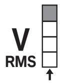
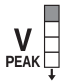
A false ground may also be indicated if the receptacle is within 15 feet of the neutral-ground bonding point at the main panel. After the false ground condition has been checked out, press the down arrow button (↓) to enter the measurement menu.

SureTest Measurements

Use the down arrow (↓) and side arrow (→) buttons to navigate through the measurement menu as outlined in the menu buttons section of this manual. There are four measurement menu options; line voltage, voltage drop, ground-neutral voltage and line impedance.

Line Voltage Measurements

There are three tests within the line voltage menu.

Measurement	Icon
Line Voltage	
Peak Voltage	
Frequency	

The line voltage measurement is the first measurement within this menu selection. Pressing the side arrow button (→) moves the unit from measurement to measurement within the line voltage menu. Pressing the down arrow button (↓) moves the unit to the next menu selection – Voltage Drop.

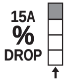
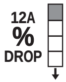
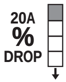
Troubleshooting Tips

The line voltage tests are conducted without a load. If these results are not met, it could be a problem with the circuit, or a load on the circuit. To determine what may be causing the problem, turn off the loads on the circuit and re-check. If the test results do not change, than the problem may be within the circuit. If the test results return to normal, than the problem is being caused by one or more of the loads on the circuit.

Measurement	Expected Result	Problem	Possible Causes	Possible Solutions
Line Voltage	108-132V	High/low line voltage	- Too much load on branch circuit - High resistance connection within the circuit or at the panel - Supply voltage too high/low	- Redistribute the load on the circuit - Locate high resistance connection/device and repair/replace - Consult power company
Peak Voltage	153-185V	High/low peak voltage	- Supply voltage too high/low - Distorted wave form caused by electronic equipment on the line	- Consult power company - Evaluate # electronic devices on circuit and redistribute if necessary
Frequency	60Hz	High/low frequency	- Supply frequency too high/low	- Consult power company

Voltage Drop Measurements

There are three tests within the voltage drop menu.

Measurement	Icon
Voltage Drop at 15-Amp load	
Voltage Drop at 12-Amp load	
Voltage Drop at 20-Amp load	

The National Electrical Code recommends 5% as the maximum voltage drop for branch circuits for reasonable efficiency (NEC article 210-19. FPN 4). High voltage drop could be an indication of a high resistance connection within the circuit, undersized wire for the load or length of run, or a defective device on the branch circuit.

All of the voltage drop measurements are taken under an actual 12-Amp load and extrapolated for 15 amp and 20 amp measurements. This allows the user to test a 15-Amp rated circuit at full capacity or 80% capacity, and test a 20-Amp rated circuit under a full capacity. Voltage drop under a 15 amp load is the first measurement within this menu selection. Pressing the side arrow button (→) moves the unit from measurement to measurement within the line voltage menu. Pressing the down arrow button (↓) moves the unit to the next menu selection – Ground-Neutral Voltage.

Troubleshooting Tips

Measurement	Expected Result	Problem	Possible Causes	Possible Solutions
Voltage Drop	<5%	High voltage drop	- Too much load on the branch circuit - Undersized wire for length of run - High resistance connection within the circuit or at the panel	- Redistribute the load on the circuit - Check code requirements and re-wire if necessary - Locate high resistance connection/device and repair/replace

Ground-Neutral Voltage Measurement

There is only one test within the Ground-Neutral Voltage menu. In a single-phase circuit, high ground-neutral voltage indicates excessive leakage between the neutral and ground conductors. In a 3-phase circuit with a shared neutral, a high ground-neutral voltage could also indicate unbalanced load between the three phases, or harmonic distortion on the shared neutral. A reading of less than 2 Volts usually indicates a usable outlet. An excessive ground-neutral voltage may result in inconsistent or intermittent equipment performance. Pressing the down arrow button (↓) moves the unit to the next menu selection – Line Impedance.

Troubleshooting Tips

Measurement	Expected Result	Problem	Possible Causes	Possible Solutions
Ground-Neutral Voltage	<2V	High G-N voltage	- Current leaking from neutral to ground - Unbalanced 3-phase system - Harmonic content returning on neutral in 3-phase system	- Identify source of leakage (multiple I bonding points) - Check load balance and re-distribute load - Oversize neutral or de-rate transformer to dissipate heat

Line Impedance Measurements

There are three tests within the line impedance menu.

Measurement	Icon
Hot conductor impedance	
Neutral conductor impedance	
Ground impedance	

The hot conductor impedance measurement is the first measurement within this menu selection. Pressing the side arrow button (→) moves the unit from measurement to measurement within the line impedance menu. Pressing the down arrow button (↓) returns the unit to the first menu selection – Line Voltage.

Troubleshooting Tips

Measurement	Expected Result	Problem	Possible Causes	Possible Solutions
Hot conductor impedance	<0.48Ω/ foot of 14 gauge wire <0.03Ω/ foot of 12 gauge wire <0.01Ω/ foot of 10 gauge wire	High conductor impedance	- Too much load on branch circuit - Undersized wire for length of run - High resistance connection within the circuit or at the panel	- Redistribute the load on the circuit - Check code requirements and re-wire if necessary - Locate high resistance connection/device and repair/replace
Neutral conductor impedance	<0.48Ω/ foot of 14 gauge wire <0.03Ω/ foot of 12 gauge wire <0.01Ω/ foot of 10 gauge wire	High conductor impedance	- Too much load on branch circuit - Undersized wire for length of run - High resistance connection within the circuit or at the panel	- Redistribute the load on the circuit - Check code requirements and re-wire if necessary - Locate high resistance connection/device and repair/replace
Ground impedance	<1Ω to protect personnel <0.25Ω to protect equipment	High ground impedance	- Too much load on branch circuit - Undersized wire for length of run - High resistance connection within the circuit or at the panel	- Redistribute the load on the circuit - Check code requirements and re-wire if necessary - Locate high resistance connection/device and repair/replace

GFCI Testing

The SureTest® applies 6mA though a fixed resistor to trip the GFCI. A functional GFCI will disconnect the power. The reset button for the GFCI may be at the receptacle or at the panel.

> **Note:** The SureTest will not allow the GFCI test if a no ground condition exists. Repair the ground circuit before testing.

To activate the GFCI test, press the GFCI button (GFCI) from anywhere within the measurement menu. The actual current being bled from hot to neutral will be displayed. (6mA is the nominal current sent through the fixed resistor. The actual current will vary depending on the line voltage per UL1436.) Test in progress will than appear on the display to let the user know that the GFCI test is being performed. The unit will bleed the current until the GFCI trips, or up to 6 seconds.
If the GFCI device is functioning properly, it will disconnect power, and the display on the unit will go out. When the circuit is reset and power is restored, the unit will display the actual time that the GFCI took to trip the circuit. Pressing the down arrow button (↓) resets the unit and returns it to the wiring verification mode.

If the GFCI fails to trip, the SureTest will show invalid on the display, indicating that the GFCI may be installed incorrectly, or the GFCI may be defective.

> **Note:** In order to test GFCIs in a 2-wire system (no ground), the #61-175 ground continuity adapter must be used. Connect the alligator clip on the adapter to a ground, such as a metal water or gas pipe.

Troubleshooting Tips

Measurement	Expected Result	Problem	Possible Causes	Possible Solutions
GFCI Test	GFCI trips with trip time <200mS	GFCI does not trip (invalid test), or trip time >200mS	- GFCI may be installed incorrectly - GFCI may be defective	- Check wiring and re-wire device according to manufacturer's instructions - Repair/replace GFCI

AFCI Testing (#61-155 only)

The SureTest® w/AFCI applies a high current pulse onto the line within 8 consecutive half-cycles in accordance with UL1436. A functional AFCI breaker will disconnect the power to the circuit. To restore power, reset the breaker at the panel.

> **Note:** The SureTest will not allow the AFCI test if a wiring problem exists. Repair the circuit before testing.

To activate the AFCI test, press and hold the AFCI button from anywhere within the measurement menu. The unit will countdown from 3 and display a lighting bolt to let the user know that the test is being performed. if the user releases the AFCI test button before the lighting bolt appears, the test will be aborted.

If the circuit is protected by an AFCI breaker it will disconnect power, and the display on the unit will go out.

If the AFCI fails to trip, the SureTest® will show invalid on the display, indicating that the AFCI may be installed incorrectly, the AFCI may be defective, or the line impedance was too high to allow sufficient current to pass through the circuit for a proper test. Use the SureTest® to identify and locate the cause of the high resistance and repair the circuit.

Troubleshooting Tips

Measurement	Expected Result	Problem	Possible Causes	Possible Solutions
AFCI Test	AFCI trips	AFCI does not trip (invalid test)	- AFCI may be installed incorrectly - AFCI may be defective - High line impedance (>Ω) does not allow enough current to flow through circuit to run AFCI test	- Check wiring and re-wire device according to manufacturer's instructions - Repair/replce GFCI - Locate high resistance/device and repair/replace

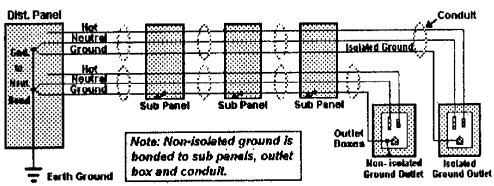
Optional Accessories

#61-175 Ground Continuity Adapter
This adapter allows the operator to verify that a cabinet or equipment chassis has been properly bonded to the system ground. Plugging the SureTest into the ground continuity adapter will isolate the SureTest from the electrical ground. If the equipment is properly grounded, then connecting the alligator clip from the ground continuity adapter to the cabinet or equipment chassis should provide a pathway to ground, and consequently a normal wiring condition on the SureTest.

After the ground continuity adapter has been connected, the SureTest can be used to measure the ground impedance of the cabinet or equipment chassis. See the section on Line Impedance Measurements for test instructions.

This adapter can also be used to test GFCI receptacles on 2-wire circuits. Connect the alligator clip on the adapter to a ground, such as a metal water or gas pipe prior to testing the GFCI.

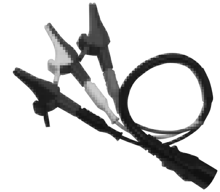
#61-176 Isolated Ground Adapter
This adapter allows the operator to verify that a receptacle is completely isolated from the system ground that is bonded to other devices on the branch circuit.



Test the ground impedance of the receptacle and make a note of the results (See the section on Line Impedance Testing for details). Remove the SureTest and plug it into the isolated ground adapter. Attach the alligator clip to the center receptacle screw or metal junction box, and re-insert the SureTest into the receptacle and make a note of the result.

The isolated ground adapter creates a parallel pathway to ground, which results in a lower reading on a receptacle with an isolated ground. If the two readings are the same, than the receptacle does not have an isolated ground. If the reading taken with the isolated ground adapter is lower, than the receptacle has an isolated ground.

#61-183 Lighting Circuit Adapter
This adapter allows the operator to use the SureTest on residential lighting circuits to verify that bedroom lighting circuits are protected by the AFCI (61-155 only), and identify and locate high resistance points within the circuits.



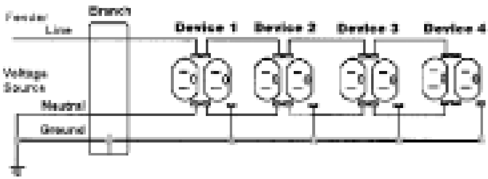
Simply plug the lighting circuit adapter into the IEC connection on the top of the SureTest, and connect the hot (red), neutral (white) and ground (green) alligator clips onto the circuit. Correct test results are dependant on making good connections with the alligator clips onto the circuit.

Note: The SureTest is designed for 120V circuits only. Do not exceed the rating of the SureTest with this adapter.

Locating High Resistance Connections

Troubleshooting to identify the cause of the high impedance within the electrical system is actually quite simple. First measure the voltage drop at the furthest receptacle from the panel on the branch circuit under test. If the voltage drop is high, than further investigation is necessary.
Testing the remaining receptacles in sequence, from next furthest from the panel to the closest to the panel, will identify the problem.

If the voltage drop reading changes significantly from one receptacle to the next, then the problem is a high impedance point at or between the two receptacles. It is usually located at a termination point, such as a bad splice or loose wire connection, but it might also be a bad receptacle.



If the reading steadily decreases as you get closer to the panel, with no significant decreases between receptacles, then the wire may be undersized for the length of run, or for the load on the line. Check at the panel to see if the wire is sized per code, and measure the current on the branch circuit.
The reading may not decrease at all from the last receptacle to the first. This would indicate that the problem could be at the first splice, or at the panel itself. Most poor panel connections show up as hot spots on the panel. These can be checked quickly with an infrared temperature meter.

Quick Reference Guide Measurement Menu

Line Voltage Menu

Line Voltage Measurement	Press → for next test	**Peak Voltage Measurement**	Press→ for next test	**Frequency Measurement**	Press→ for first test
Press↓ to advance to Voltage Drop Menu					

Voltage Drop Menu

Voltage Drop Measurement @ 15-Amp	Press → for next test	**Voltage Drop Measurement @ 12-Amp**	Press → for next test	**Voltage Drop Measurement @ 20-Amp**	Press → for first test
Press ↓ to advance to Ground-Neutral Voltage Menu					

Ground-Neutral Voltage Menu

Ground-Neutral Voltage Measurement					
Press ↓ to advance to Line Impedance Menu					

Line Impedance Menu

Hot Conductor Impedance Measurement	Press → for next test	**Neutral Conductor Impedance Measurement**	Press → for next test	**Ground Impedance Measurement**	Press → for first test
Press ↓ to advance to Line Voltage menu					

⧈ Service of Double-Insulated Appliances

In a double-insulated controller, two systems of insulation are provided instead of grounding. No equipment grounding means is provided in the cordset of a double-insulated product, nor should a means for equipment grounding be added to the controller. Servicing a double-insulated controller requires extreme care and knowledge of the system, and should be done only by qualified service personnel. Replacement parts for a double-insulated controller must be identical to the parts they replace.

Lifetime Limited Warranty

This meter is warranted to the original purchaser against defects in material or workmanship for the lifetime of the meter. During this warranty period, IDEAL INDUSTRIES, INC. will, at its option, replace or repair the defective unit, subject to verification of the defect or malfunction. This warranty does not apply to defects resulting from abuse, neglect, accident, unauthorized repair, alteration, or unreasonable use of the instrument.

Any implied warranties arising out of the sale of an IDEAL product, including but not limited to implied warranties of merchantability and fitness for a particular purpose, are limited to the above. The manufacturer shall not be liable for loss of use of the instrument or other incidental or consequential damages, expenses, or economic loss, or for any claim or claims for such damage, expenses or economic loss.

State laws vary, so the above limitations or exclusions may not apply to you. This warranty gives you specific legal rights, and you may also have other rights, which vary from state to state.

Warranty limited solely to repair or replacement; no warranty of merchantability, fitness for a particular purpose or consequential damages.

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