



## Testing for safe and efficient branch circuits

Written by Chad Reynolds, Product Manager,  
IDEAL Test and Measurement Division

### 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.<sup>1</sup>

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.<sup>2</sup>

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

<sup>1</sup> Fact Sheet on Fire in the US and Canada, National Fire Protection Agency (NFPA) 1997

<sup>2</sup> 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<sup>3</sup>

To offer protection against these conditions, the 2002 edition of the National Electrical Code (NEC), requires the installation of Arc Fault Circuit Interrupters (AFCI) in bedroom circuits in new residential circuits.<sup>4</sup> 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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<sup>3</sup> IEC Fact Sheet, Arc-Fault Circuit Protection, Illinois Electric Council, Fact Sheet #28

<sup>4</sup> 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.

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

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.<sup>5</sup> 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<sup>6</sup>. 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.

<sup>5</sup> NEC code Articles {210-19(a) FPN No. 4} {215-2(d) FPN No. 2

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

## Troubleshooting a Circuit

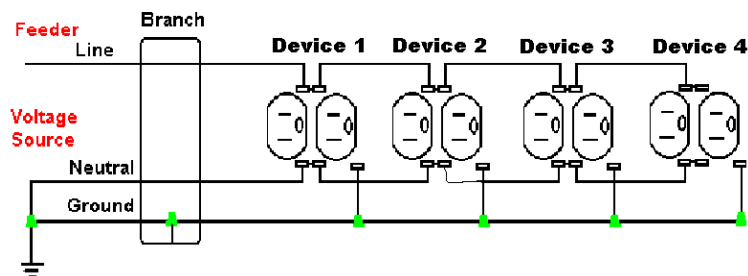
Troubleshooting to identify the cause of the high impedance within the electrical system is actually quite simple. First measure the voltage drop at the furthest receptacle from the panel on the branch circuit under test. If the voltage drop is high, than further investigation is necessary.

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 lose 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.

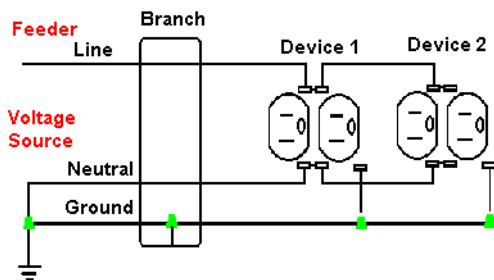
## High Impedance Ground

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, then 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 pigtailng 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 pigtailng 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<sup>7</sup> 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),<sup>8</sup> 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*



<sup>7</sup> NEC code Article {250-148}

<sup>8</sup> 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<sup>9</sup> 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 from 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<sup>10</sup>.

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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<sup>9</sup> NEC code Article {250-146(a) through (d)}

<sup>10</sup> 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.<sup>11</sup> 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 require 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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<sup>11</sup> 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.<sup>12</sup>

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."<sup>13</sup>

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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<sup>12</sup> NEC code Article {210-8 (a)}

<sup>13</sup> 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 that 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.



## SureTest® Circuit Analyzer Instruction Manual

### Introduction

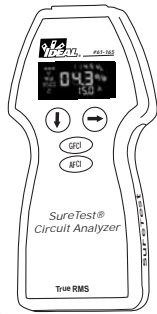
Utilizing patented technology, the SureTest® circuit analyzers "look behind walls" to identify wiring problems that can lead to personal shock hazards, electrical fires, or equipment performance issues. Personal shock hazards stem from poor grounding, false grounds, and/or no ground fault protection. Electrical fires are primarily caused from arc faults and high resistance points that lead to glowing connections in the circuit wiring. And, equipment performance issues arise due to insufficient voltage available under load, poor ground impedance, and high ground-to-neutral voltage. In fact, it's estimated that 80% of power quality performance issues are related to the faulty wiring issues stated above.

### Product Features

- True RMS
- Measures voltage drop under 12, 15 and 20-amp loads
- Measures voltage: Line, Ground-to-Neutral, Peak, Frequency
- Measures Hot, Neutral and Ground conductor impedances
- Identifies proper wiring in 3-wire receptacles
- Identifies false (bootleg) grounds
- Tests GFCIs for proper operation
- Tests AFCIs for proper operation (61-165)
- Checks for Shared Neutrals that lead to AFCI nuisance tripping (61-165)
- Verifies dedicated circuits (with 61-176 adapter)
- Includes 1-ft. extension cord and carrying case

### General Operation

The SureTest® Circuit Analyzer takes only seconds to test each outlet and circuit under a full load. This test tool checks for various wiring conditions including: correct wiring, polarity reversal and no ground per UL-1436. A simple 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 in accordance with UL-1436 and disrupts the electrical supply if a functional GFCI is present.



#61-164  
#61-165

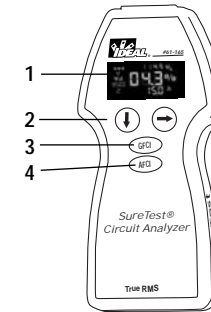
The SureTest® w/AFCI, #61-165, also tests arc fault circuit interrupter (AFCI) devices to ensure that AFCI breakers protecting the circuit have been installed correctly. This test disrupts the electrical supply if a functional AFCI is present. This tool also checks for a shared neutral condition that leads to AFCI nuisance tripping.

To maintain stated accuracies during repeated use, allow 20 seconds between insertions to adequately dissipate any heat buildup during the load testing.

**! WARNING:** Do not use on outputs from UPS systems, light dimmers or square wave generating equipment as damage to the analyzer will occur.

### SureTest Circuit Analyzer

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



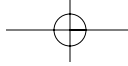
### Menu Navigation

The microprocessor's top priorities are to take live measurements and then analyze the data. Hence, the microchip occasionally will not recognize the keypad buttons being rapidly depressed, while it's executing these routines. To avoid this issue, hold down the keypad button each time until the menu changes.

The measurements taken by the SureTest are broken into five main menus positioned down the left side of the display: Wiring Configuration (•••), Voltage (V), Voltage Drop (V<sub>D</sub>), Amperage (A), and Impedance (Z). To navigate to each of the main menus, use the down arrow button (↓).

The Wiring Configuration (•••) screen indicates correct wiring, reverse polarity, hot/ground reversal and no ground conditions by sequencing the three balls. The label on the back of the product explains the wiring sequence indications.

The Voltage (V) menu displays the True RMS line voltage in real-time. This main menu has a sub-menu positioned horizontally at the bottom of the screen that displays the line voltage (RMS HN), ground-to-neutral voltage (RMS GN), Peak voltage (Peak), and Frequency (Hz). To navigate through the submenu, use the side arrow button (→).



The Voltage Drop (**V<sub>D</sub>**) screen dual displays percent voltage drop with a 15 amp load along with the resultant loaded voltage (**V<sub>L</sub>**). This main menu has a submenu, which also displays the percent voltage drop and loaded voltage with 20 amp and 12 amp loads. To navigate through the submenu, use the side arrow button (→).

The Amperage (**A**) menu displays the Estimated Load on Line (**ELL**) in real-time and holds the maximum amperage in the upper right of the display. The main menu has a submenu positioned horizontally which displays (**ASCC1**), Available Short-Circuit Current from H-N and (**ASCC2**) Available Short Circuit Current H-N-G. To navigate through the submenu, use the side arrow button. (→)

The Impedance (**Z**) main menu displays the impedance in ohms (**Ω**) of the hot conductor. This main menu has a sub-menu positioned horizontally at the bottom of the screen that also displays the neutral (**N**) and ground (**G**) conductor impedances. To navigate through the submenu, use the side arrow button (→). Note that testing the ground impedance will trip a GFCI protected circuit.

**GFCI Test Button**

Depressing this button displays the GFCI main menu. Two tests can be performed in this menu: **GFCI** and **EPD**. The GFCI tests Ground Fault Circuit Interrupting devices by faulting 6-9mA from hot-to-ground per UL-1436. The **EPD** tests those breakers, which have an **Equipment Protective Device** feature that trips the breaker if a ground fault of greater than 30mA is detected. Pressing the side arrow button (→) navigates between these two tests. Once the desired test is highlighted, depress the GFCI test button on the keypad to activate the test.



**AFCI Test Button**

Depressing this button displays the AFCI main menu. Two tests can be performed in this menu: **AFCI** and **NEUT**. The AFCI tests **Arc Fault Circuit Interrupting** devices by creating a 106-141 amp short-duration arc between the hot and neutral conductors per UL1436. The **NEUT** tests for a Shared **Neutral** or falsely grounded neutral conductor, which causes AFCI breakers to nuisance trip with normal loads. This test applies 300mA between hot and neutral to ensure that the AFCI breaker does not trip.



**Testing Procedure**

**Wiring Verification**

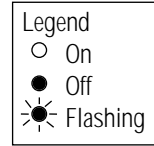
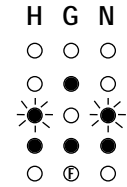
Immediately after being inserted into a receptacle, the SureTest displays the IDEAL logo while it performs a battery of tests. The first test result displayed is the wiring condition. The SureTest checks for the following conditions and indicates the test result on the display.



**Wiring Condition**

**Display Indication**

- Correct Wiring
- No Ground
- Polarity Reversal
- Open/Hot Neutral
- False Ground



If the wiring condition is other than normal, the SureTest is limited on its measurements that can be performed. If a no ground condition exists, only the line voltage and voltage drop measurements are available. In a hot/ground reversal, open neutral or open hot condition, the unit will not have any power so the display will be blank.

**Notes:**

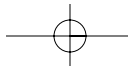
- 1) Will not detect two hot wires in a circuit.
- 2) Will not detect a combination of defects.
- 3) Will not detect reversal of grounded and grounding conductors.

**False Ground Indication**

The SureTest indicates when a false ground condition exists from an improper bond via a bootleg (ground jumper wire at the outlet device) or inadvertent contact of the ground wire to the neutral connection. Note that if the SureTest is within 15-20 feet of the main panel, the unit will indicate a false ground condition on a properly wired circuit due to its close proximity to the proper ground-neutral bond in the main panel.

**Voltage Measurements**

The line voltage measurement should be 120VAC +/-10% fluctuation at 60 Hz. The peak voltage should be 1.414 times the rms line voltage reading for a clean sine waveform. Ground-to-neutral voltage should be less than 2 VAC. In a single-phase circuit, a higher ground-neutral voltage indicates excessive current leakage between the neutral and ground conductors. In a 3-phase circuit with a shared neutral, a high ground-neutral voltage could indicate an unbalanced load between the three phases or harmonic distortion on the shared neutral. Excessive ground-neutral voltage may result in inconsistent or intermittent equipment performance.



### Troubleshooting Tips for Voltage Issues

Measurement	Expected Result	Problem	Possible Causes	Possible Solutions
Line Voltage 120VAC 220VAC	108-132VAC 198-242VAC	High/low	Too much load on the load on circuit.	Redistribute loads on the circuit.
			High resistance connection within the circuit or at the panel.	Locate high resistance connection/device and repair/replace.
			Supply voltage too high/low.	Consult power company.
Neutral-Ground Voltage	<2VAC Voltage	High G-N >2VAC	Current leaking from neutral to ground.	Identify source of leakage: multiple bonding points, equipment or devices.
			Unbalanced 3-phase system.	Check load balance and redistribute load.
			Triplen harmonics returning on neutral in 3-phase system.	Oversize neutral to impedance. Reduce harmonic effect via filter or other methods.
Peak Voltage 120VAC 220VAC	153-185VAC 280-342VAC	High/low peak voltage	Supply voltage too high/low.	Consult power company.
			High Peak Loads on line caused by electronic equipment on line.	Evaluate number of electronic devices on circuit and redistribute if necessary.
Frequency	60HZ	High/low frequency	Supply frequency too high/low.	Consult power company.

**⚠ WARNING:** Do not exceed the unit's maximum voltage rating of 250VAC.

### Voltage Drop (V<sub>D</sub>) Measurements

The SureTest measures the line voltage, applies a load on the circuit, measures the loaded voltage, then calculates the voltage drop. Results are displayed for 12A, 15A, and 20A loads. The National Electrical Code recommends 5% as the maximum voltage drop for branch circuits for reasonable efficiency (NEC article 210-19. FPN 4). And, the voltage under load (V<sub>L</sub>) should not drop below 108VAC for reliable equipment operation.

A good branch circuit should start out with less than 5% voltage drop at the furthest receptacle from the panel at the end of the cable run. Then, each receptacle tested in sequence towards the panel should show a steady decrease in voltage drop. If the voltage drop is above 5% and does not noticeably decrease as you get closer to the first device on the circuit, then the problem is between the first device and the panel. Visually check the terminations at the first device, the wiring between the device and the panel, and the circuit breaker

connections. High resistance points can usually be identified as hot spots using an infrared thermometer or by measuring the voltage across the breaker. If the voltage drop exceeds 5% but noticeably decreases as you nearer the panel, the circuit may have undersized wire, too long of a cable run, or too much current on the circuit. Check the wire to ensure that it is sized per code and measure the current on the branch circuit. If a voltage drop reading changes significantly from one receptacle to the next, then the problem is a high impedance point at or between 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.

### Troubleshooting Tips for Voltage Drop

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

### Estimated Load on Line (ELL) Measurement

The SureTest now estimates the load on a branch circuit to provide an indication of how much capacity in the circuit remains or to quickly check if the circuit is dedicated. This function is a rough estimate (no stated accuracy), as accurately measuring circuit current has to be done with a clamp meter at the electrical panel. The proprietary way in which these calculations are made allows the user to plug the unit into an outlet and quickly determine the current load on that branch circuit.

Both the distance of the SureTest from the load and branch circuit impedance will affect accuracy. Best accuracy is obtained by positioning the SureTest in the same outlet as the largest load on line; otherwise, try to position the SureTest between the load(s) and the electrical panel. The maximum amperage reported by the tester is 15A.

### ASCC Measurement

The SureTest calculates the Available Short-Circuit Current (ASCC) that the branch circuit can deliver through the breaker during a bolted fault (dead-short) condition.

The ASCC is calculated by dividing the line voltage by the circuit's line impedance (hot + neutral). Depressing the side arrow (→) displays the worst-case scenario where all three conductors (hot, neutral, ground) are shorted together -- the neutral and ground provide a lower impedance via a parallel return path. Note that this second test will trip a GFCI. See the following equations for clarification.

$ASCC_1 = \text{Line Voltage } (V_{HN}) / (\text{Hot } \Omega + \text{Neu } \Omega)$

$ASCC_2 = \text{Line Voltage } (V_{HN}) / (\text{Hot } \Omega + 1/(1/\text{Neu } \Omega + 1/\text{Grd } \Omega))$

**Impedance (Z) Measurements**

If the voltage drop measurement exceeds 5%, analyze the hot and neutral impedances. If one is significantly higher than the other, the problem is with the conductor with the much higher impedance. Then, check all connections on that conductor back to the panel. If both impedances appear high, the source can be undersized wire for the length of run, a bad device, or poor connections at the pigtails, devices, or panel.

The ground impedance measured should be less than 1 ohm as a rule of thumb to ensure that fault current has a sufficient path back to the panel. IEEE states the ground impedance should be less than 0.25 ohms to ensure the ground conductor can safely return any fault current which could damage equipment on the circuit. Surge suppression systems require a good ground to adequately protect equipment from transient overvoltages. Note that a small amount of current is applied to the ground conductor to accurately measure its impedance. By the inherent nature of this test, a GFCI protected circuit will trip unless the device is temporarily removed from the circuit.

Troubleshooting Tips - Impedances

Measurement	Expected Result	Problem	Possible Causes	Possible Solutions
Hot and Neutral Impedance	<0.0048Ω/foot of 14 AWG wire	High conductor impedance	Too much load on branch circuit.	Redistribute the load on the circuit.
	<0.003Ω/ foot of 12 AWG wire		Undersized wire for length of run.	Check code requirements and rewire if necessary.
	<0.001Ω/ foot or 10 AWG wire		High resistance connection within the circuit or at the panel.	Locate high resistance connection/device and repair/replace.
Ground Impedance	< 1 Ω to protect people	High ground impedance	Undersized wire for length of run.	Check code requirements and re-wire if necessary.
	<0.25Ω to protect equipment		High resistance connection within the circuit or at the panel.	Locate high resistance connection/device and repair/replace.

**GFCI Testing**

To test the GFCI device, the SureTest® creates an imbalance between the hot and neutral conductors by leaking a small amount of current from hot to ground using a fixed value resistor. The test current applied by the SureTest® should not be less than 6mA or greater than 9mA per UL-1436. A functional GFCI should sense the imbalance and disconnect the power. The SureTest displays the actual test current in milliamps and trip time in milliseconds.

To conduct a GFCI test, press the GFCI button to enter the GFCI main menu. The GFCI symbol in the display should be highlighted as the default test. If EPD is lit, then use the side arrow (→) to highlight the GFCI symbol. Then, press the GFCI button to activate the test. The actual current being leaked to ground is displayed. The TEST icon and hourglass symbol appear on the display to let the user know that the GFCI test is being performed. The GFCI device should trip within the UL established guideline causing the display to blank out with the loss of power. When the GFCI device is reset, the unit displays the actual trip time that the GFCI took to respond to the current imbalance and open the circuit. Pressing the down arrow button (↓) returns it to the wiring verification mode. If the GFCI fails to trip, the SureTest terminates the test after 6.5 seconds. Further inspection should determine whether the GFCI circuitry is faulty, the GFCI is installed incorrectly, or if the circuit is protected by a GFCI device.

UL Guideline for trip time:  $T = \left(\frac{20}{I}\right) 1.43$  Where: T = seconds (s)  
I = milliamps (mA)

**Notes:**

- 1) In order to test a GFCI 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 source, such as to a metal, water or gas pipe.
- 2) All appliances or equipment on the ground circuit being tested should be unplugged to help avoid erroneous readings.

In addition to performing a GFCI test for evaluating personal protection from shock hazards, the SureTest can also conduct testing to ensure equipment protection from ground faults exceeding 30mA. The method of operation is the same as the GFCI test noted in the first paragraph above but uses a different resistor to create a 30mA leakage current from hot-to-ground. To conduct an EPD test on an Equipment Protective Device, press the GFCI button to enter the GFCI main menu. The GFCI symbol in the display should be highlighted as the default test. Press the side arrow (→) button to highlight the EPD symbol. Then, press the GFCI button to activate the test. The actual current being leaked to ground is displayed. The TEST icon and hourglass symbol appear on the display to let the user know that the EPD test is being performed. The EPD should trip causing the display to blank out with the

loss of power. When the EPD is reset and power is restored, the unit displays the actual trip time that the EPD took to respond to the current imbalance and open the circuit. Pressing the down arrow button (↓) returns it to the wiring verification mode. If the EPD fails to trip, the SureTest terminates the test after 6.5 seconds. Further inspection should determine whether the EPD circuitry is faulty, the EPD is installed incorrectly, or if the circuit is protected by an EPD.

**Troubleshooting Tips**

Measurement	Expected Result	Problem	Possible Causes	Possible Solutions
GFCI Test	GFCI trips within trip time	GFCI doesn't trip within proper trip time.	GFCI maybe installed improperly.	Check wiring for proper installation in accordance with manufacturer's instructions and NEC.
		GFCI doesn't trip.	GFCI may be defective.	Check wiring and ground. Replace GFCI if necessary.

**AFCI Testing (#61-165 only)**

The SureTest® w/AFCI applies 8-12 current pulses in less than a half second across hot-to-neutral with each pulse no longer than 8.3ms in duration, and having an amplitude of 106-141 amps in accordance with UL1436. A functional AFCI breaker should recognize these current pulses as a dangerous arc and disconnect the power to the circuit. To restore power, reset the breaker at the panel.

To properly test the AFCI, execute the following steps:

- 1) Consult the AFCI manufacturer's installation instructions to determine that the AFCI is installed in accordance with the manufacturer's specifications.
- 2) Plug in the SureTest and check for correct wiring of receptacle and all remotely connected receptacles on the branch circuit. Then, go to the panel and operate the test button on the AFCI installed in the circuit. The AFCI must trip. If it does not, do not use the circuit - consult an electrician. If the AFCI does trip, reset the AFCI.
- 3) Return to the tester and press the AFCI button on the tester to enter the AFCI main menu. The AFCI symbol in the display should be highlighted as the default test. If NEUT is lit, then use the side arrow (→) to highlight the AFCI symbol. Then, press the AFCI button to activate the test. The TEST icon and lightning bolt symbol light brightly on the display to let the user know that the AFCI test is being performed. The AFCI device should trip causing the display to blank out with the loss of power. If the AFCI fails to trip, the SureTest® will not lose power and the display shows a dimly lit

lightning bolt. This non-trip condition would suggest:

- a) A wiring problem with a totally operable AFCI, or
- b) Proper wiring with a faulty AFCI.

Consult with an electrician to check the condition of the wiring and AFCI.

- 4) CAUTION: AFCIs recognize characteristics unique to arcing, and AFCI testers produce characteristics that mimic some forms of arcing. Because of this, the tester may give a false indication that the AFCI is not functioning properly. If this occurs, recheck the operation of the AFCI using the test and reset buttons. The AFCI's test button function should demonstrate proper operation.

Note: The AFCI circuitry is protected by a thermal sensor to assure long life. If a thermometer icon appears in the display during repeated AFCI testing, the sensor delays further testing until the circuitry cools. At that point, the testing will automatically continue.

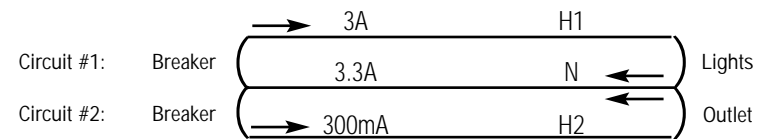
**Shared Neutral Test (#61-165 only)**

AFCI breakers are prone to nuisance tripping when wired with a shared neutral or when the neutral conductor is accidentally grounded before the panel. The AFCI tripping occurs because it senses an imbalance between the current going out on the hot and the current returning on the neutral. A shared neutral between two hot conductors creates this imbalance. See the illustration below to see how this imbalance can occur.

The SureTest can test for these conditions by applying a small load of 300mA between hot and neutral to simulate a normal load and ensure that the AFCI breaker does not trip. To conduct a shared neutral test, press the AFCI button to enter the AFCI main menu. Press the side arrow (→) to highlight the NEUT symbol. Then, press the AFCI button to activate the test. The TEST icon will light brightly while the test is being conducted. The AFCI breaker should not trip. If the breaker does trip, a shared neutral is the probable cause.

Illustration:

SureTest Shared Neutral Test w/300mA load



### Troubleshooting Tips

Measurement	Expected Result	Problem	Possible Causes	Possible Solutions
AFCI Test	AFCI trips	AFCI does not trip.	AFCI installed incorrectly.	Check wiring and re-wire device according to manufacturer's instructions.
			AFCI defective.	Replace AFCI.
			High source of line impedance or resistance.	Check for high voltage drop.
Shared Neutral Test	AFCI does not trip	AFCI does trip.	Shared neutral exists.	Re-wire circuit per AFCI manufacturer's Instructions.

### Optional Accessories

#### #61-183 Alligator Clip Adapter

This adapter allows the SureTest to analyze non-outlet based circuits for branch circuit safety and performance. Simply plug the alligator clip adapter into the IEC connection on the front of the SureTest. Then, properly connect the hot (black), neutral (white) and ground (green) alligator clips onto the circuit. Correct test results are dependent on making good connections with the alligator clips onto the circuit.

 **WARNING:** The SureTest is designed for 120/240VAC circuits only. Do not exceed the rating of the SureTest with this adapter.

This adapter also allows the operator to use the SureTest (#61-165 only) to verify AFCI protection on non-outlet based circuits in bedrooms, such as on circuits used for lighting, ceiling fans, and smoke detectors.

#### #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 isolates 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 back to the panel. See the section on Line Impedance Measurements for test instructions for ground impedance.

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 record the ohms value. (See the section on Line Impedance Testing for details on obtaining the ground impedance value). 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 record the ohms value.

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

#### Maintenance

Clean case with a damp cloth and mild detergent. Do not use abrasives or solvents.

#### Service and Replacement Parts:

This unit has no user-serviceable parts. To inquiry about service information, call Technical Support at 877 201-9005 or visit our website at [www.testersandmeters.com](http://www.testersandmeters.com).

Repair address is:

IDEAL INDUSTRIES, INC.  
 Attention: Repair Dept.  
 1000 Park Ave.  
 Sycamore, IL 60178

**General Specifications**

Characteristics

Display  
 Display update for Volt  
 Over-range Indication on all functions  
 Operating Environment,  
 Relative Humidity  
 Storage Environment:  
 Case Construction:  
 Altitude:  
 Dimensions:  
 Weight:  
 Safety:

Description

128 x 64 OLED with backlight  
 Less than 2.5 times Second.  
 Display "OL"  
 32°F to 122°F (0°C to 50°C) at <80%RH  
 32°F to 122°F (0°C to 50°C) at <80% RH  
 ABS UL 94V/0/5VA rated  
 6561.7 ft (2000m)  
 6.4" (L) x 3" (W) x 1.4" (D)  
 162mm (L) x 76mm (W) x 36mm (D)  
 9.4 oz (267g)  
 UL61010B-1, Cat III-300V  
 UL-1436 for AFCI, GFCI & Outlet



Accessories:

Includes 1' plug adapter, carrying case, instruction manual. Optional alligator clip adapter available.

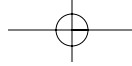
Double Insulation

Instrument has been evaluated and complies with insulation category III (overvoltage category III). Pollution degree 2 in accordance with IEC-644. Indoor use.

**Measurement Specifications:**

All specifications are at 23°C ± 5°C at less than 80% relative humidity.  
 Accuracy is state as ± ([% of range] + [counts]).  
 AC converter is true rms sensing.

Measurement	Ranges	Resolution	Accuracy
Line Voltage	85.0 - 250.0 VAC	0.1V	1.0% ± .2V
Peak Line Voltage	121.0 - 354.0 VAC	0.1V	1.0% ± .2V
Frequency	45.0 - 65.0 Hz	0.1Hz	1.0% ± .2Hz
% Voltage Drop	0.1% - 99.9%	0.1%	2.5% ± .2%
Voltage Loaded	10.0 - 250.0 VAC	0.1V	2.5% ± .2V
Neutral-Ground V	0.0 - 10.0 VAC	0.1V	2.5% ± .2V
Impedance - Hot Neutral, & Ground	0.00 Ω - 3.00 Ω > 3 Ω	0.01Ω	2.5% ± .02Ω Unspecified.
GFCI Trip Time	1mS to 6.500S counter.	1 mS	1.0% ± 2mS
GFCI Trip Current	6.0 - 9.0 mA	0.1 mA	1.0% ± .2mA
EPD Trip Current	30.0 - 37.0 mA	0.1 mA	1.0% ± .2mA



### Limited Warranty

This meter is warranted to the original purchaser against defects in material or workmanship for two years from the date of purchase. 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.

