Precise Low Resistance Measurements using the B2961A and 34420A

Technical Overview

B2961A/B2962A 6.5 Digit Low Noise Power Source

Introduction

Resistance measurement is one of the most commonly performed tests to characterize electrical device properties. However, very small resistance measurements require a very precise, low-level current source to prevent device self-heating or device damage during testing.

There are many factors that need to be considered when making precise low resistance measurements:

- The 4-wire (Kelvin) measurement technique must be used to remove lead and contact resistance.
- A current source and a voltage meter with both low noise and high accuracy are required.
- Test currents must be large enough to generate sufficient voltage drop across the test resistance such that it is measurable within the test equipment's resolution limits.
- Self-heating effects caused by power dissipation need to be mini mized.
- Special measurement technique must be used to eliminate offset currents (zeroing) and to reduce the thermal electromotive force (EMF) by alternating the current direction.
- The current source and the voltage meter must be synchronized to avoid measurement error caused by source settling time.

Determining the appropriate test current is not trivial because while a larger test current gives you better measurement resolution, it also increases power dissipation and self-heating effects. This technical overview describes how to find the optimal test current for precise low resistance measurement using the Agilent B2961A 6.5 Digit Low Noise Power Source in conjunction with the Agilent 34420A 7 ½ Digit Nano Volt / Micro Ohm Meter.

Agilent B2961A/62A Low Noise Power Source

The B2961A/B2962A, a member of the Agilent B2900A Series of precision instruments, is an advanced power supply/source. It can source either voltage or current with 6.5 digits of resolution while also monitoring both voltage and current, which is essential for a variety of measurement applications (please see Figure 1).

The B2961A/B2962A possesses an intuitive graphical user interface (GUI), and it can also be controlled using free PC-based application software from Agilent. This makes it easy to begin making productive measurements immediately.

The B2961A/B2962A is a bipolar source that supports 4-quadrant operation, so the voltage and current polarities can be either positive or negative. It can source currents from 10 fA to 3 A (DC) or 10.5 A (pulsed), and voltages from 100 nV to 210 V (please see Figure 2).
In addition to the basic sourcing capabilities described above, the B2961A/B2962A also has advanced features that permit more complex testing and evaluation. These include arbitrary waveform generation, programmable output resistance function and a time domain voltage/current waveform viewer. Therefore, the B2961A/B2962A satisfies all of the requirements for precise low resistance measurement when used in combination with the Agilent 34420A.

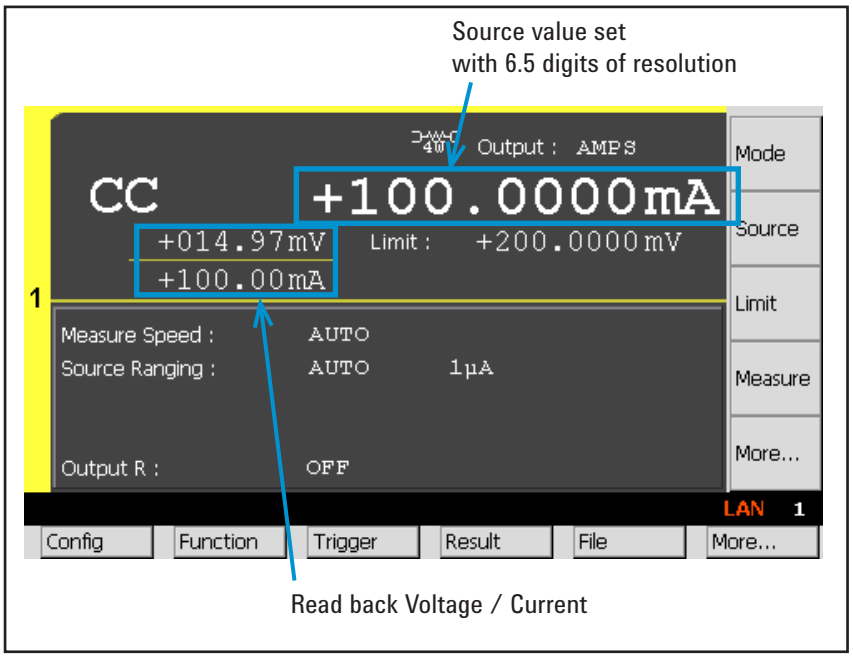

Figure 1. The B2961A/B2962A can source either voltage or current with 6.5 digits of resolution

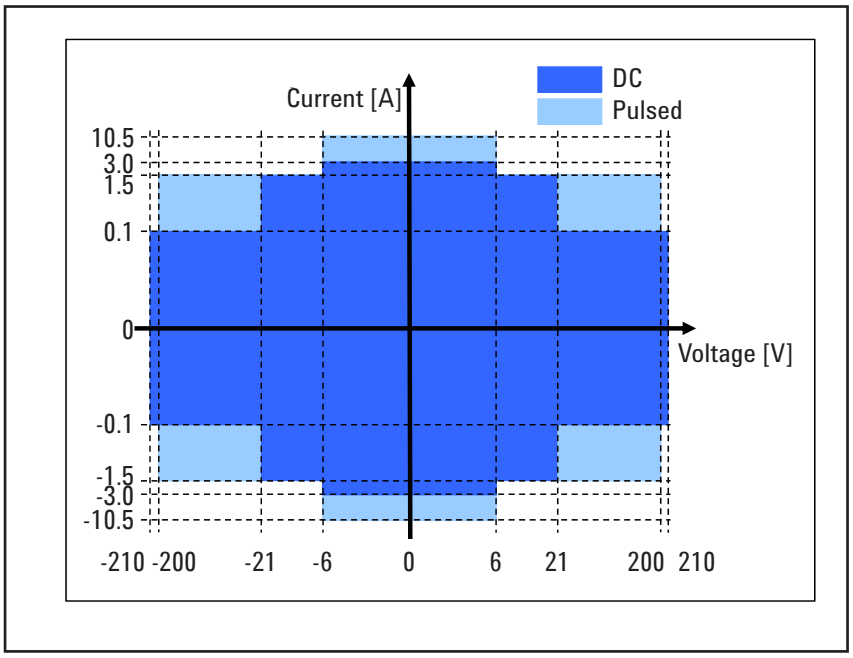

Figure 2. Broad bipolar and current ranges (4-quadrant operation)

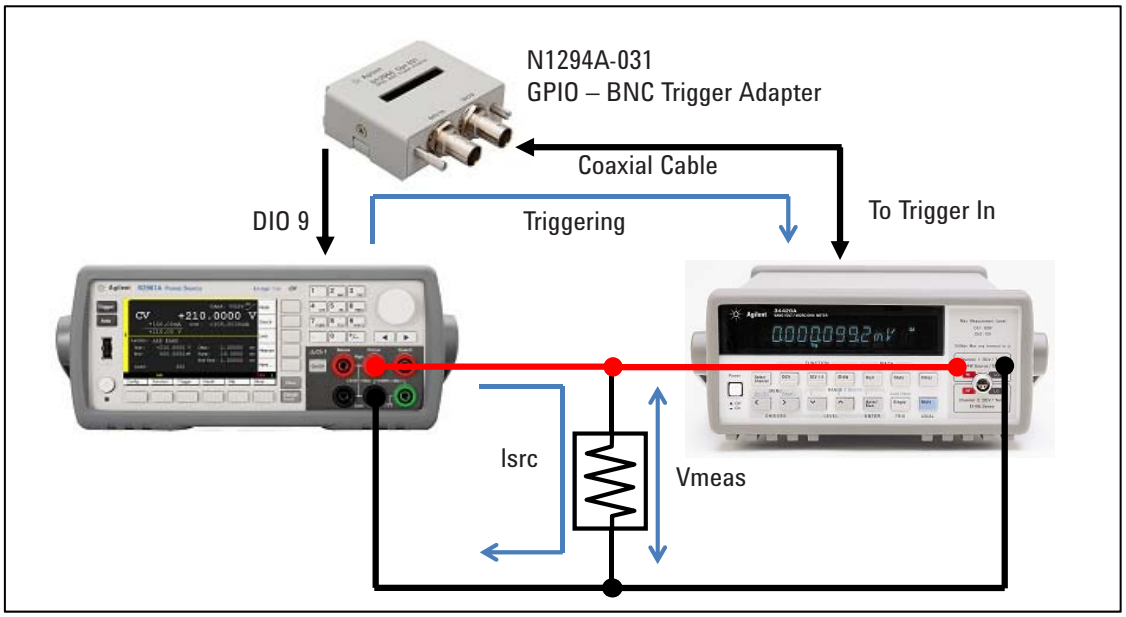

Figure 3. Diagram of the B2961A and 34420A low resistance measurement solution

Measurement System Diagram

The combination of the B2961A and 34420A provides superior performance for low resistance measurement. In the resistance measurement scheme shown in Figure 3, the 34420A performs the voltage measurement while the B2961A sources a precise current. In this setup the B2961A acts as the master and makes measurements at programmed intervals while simultaneously sending trigger signals to the 34420A to perform voltage measurements.

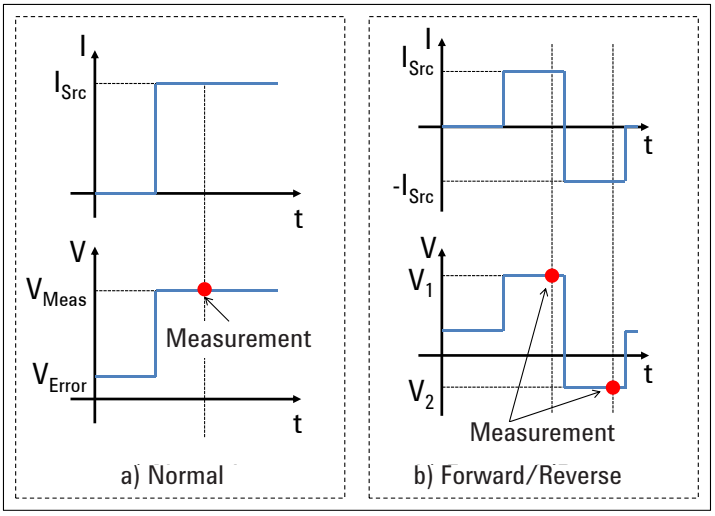

Figure 4. Technique to eliminate the measurement error caused by electro motive force

The 34420A can measure resistance without other instrumentation. Its minimum resistance range is 1 Ω and its maximum output current is 10 mA. However, the B2961A can force currents of up to 3 A, making it possible to perform measurements with resolution 300 times higher as compared with the case of the standalone 34420A. In addition, using the B2961A's list sweep mode it is possible to generate alternating polarity test currents to suppress the effects of thermal electromotive force (EMF). This is important when measuring small resistances since errors due to offset voltages and EMF can significantly affect measurement accuracy (please see Figure 4a). The following equation shows the impact of these errors on a resistance measurement made by forcing current and measuring voltage:

$$R_{Meas} = \frac{V_{Meas}}{I_{Src}} = \frac{V_{DUT}}{I_{Src}} + \frac{V_{Error}}{I_{Src}} = R_{DUT} + R_{Error}$$

This error can be eliminated by applying both forward and reverse currents (I_{Src} and $-I_{Src}$) and averaging the two voltage measurement results (please see Figure 4b). The following equation shows how to use these two measurement results to calculate the true value of the resistance:

$$R_{Meas} = \frac{V_1 - V_2}{2 \times I_{Src}} = R_{DUT}$$

Measurement Example

A measurement example is shown using a 10 mΩ metal foil resister, which exhibits a very small EMF. The measurement results are shown in Figures 5, 6 and 7.

The 34420A can measure the resistance using its internal 10 mA current source (with offset compensation) without using the B2961A (please see Figure 5). As Figure 5 shows, the data fluctuations due to electrical noise can be seen in the measurement results using a 10 power line cycle (PLC) aperture time (in other words, integration time). Although it is reduced by increasing the aperture time to 100 PLC, this makes the measurement time unacceptably long (about 8 s/point with auto compensation enabled).

On the other hand, the data fluctuations using a 10 mA current supplied by the B2961A using a 10 PLC aperture time is less than that observed using the 34420A's internal 10 mA current source due to the B2961A's low noise current sourcing ability (please see Figure 6).

Moreover, if the current from the B2961A is increased to 100 mA then very stable measurements can be achieved with a 10 PLC aperture time. This enables the measurement time to be kept to less than 1 s/point (please see Figure 7).

As this example has shown, the combination of the B2961A and 34420A enables you to get better resistance measurement results while minimizing measurement time.

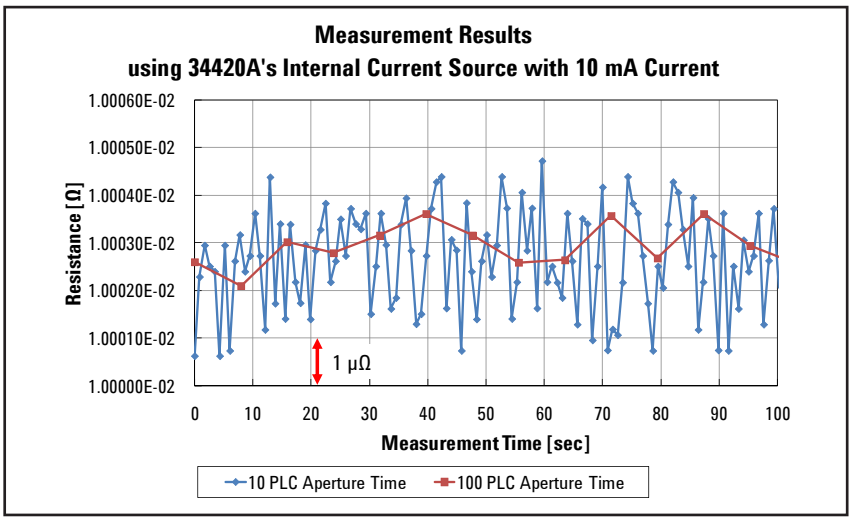

Figure 5. Measurement results using the 34420A´s internal current source

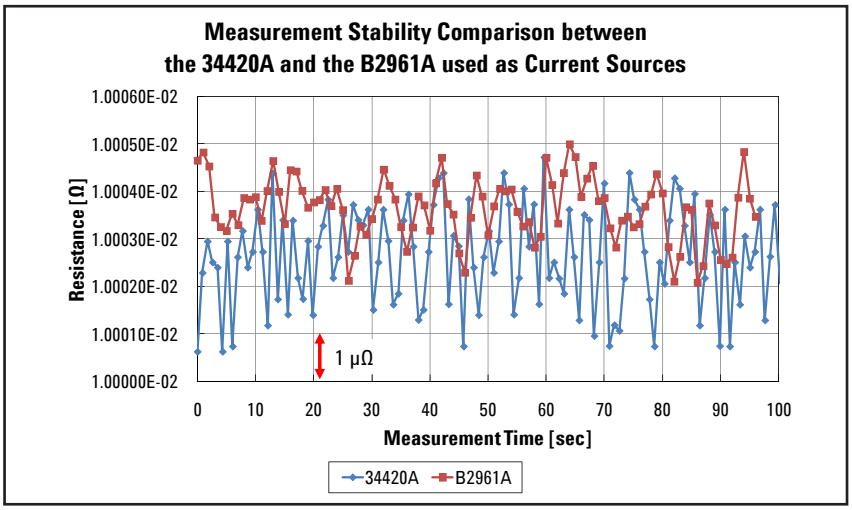

Figure 6. Measurement stability comparison between the 34420A and the B2961A used as current sources

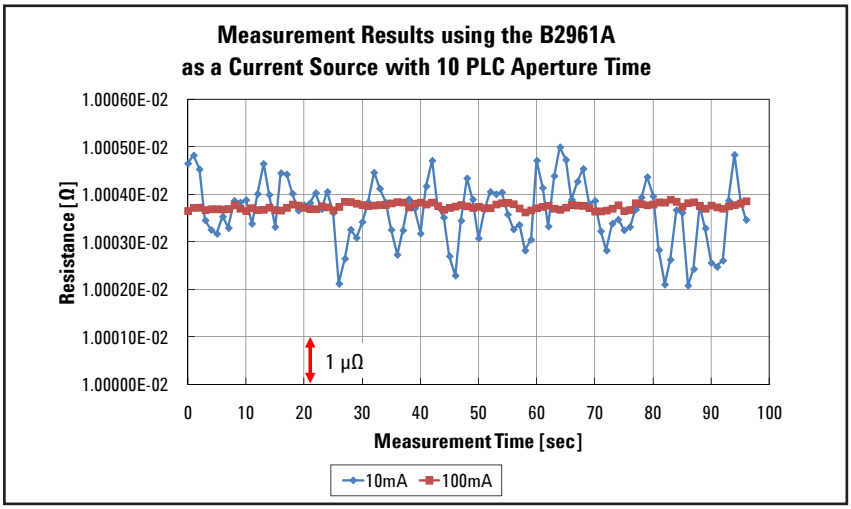

Figure 7. Measurement results using the B2961A as a current source

Methodology to determine the optimal test current

As discussed earlier, determining the appropriate test current is not trivial because while a larger test current provides better resolution, it also increases device self-heating.
The following example describes the procedure to determine the optimal current to achieve stable measurement results.

First, sampling measurements are made using the B2961A under the following conditions:

Aperture time: 10 PLC
Measurement Interval: 1 s
Test current: 10 mA, 100 mA, 500 mA, 1 A and 3 A

Measurement results are shown in Figure 8.

The minimum power dissipation is 1 mW with a test current of 10 mA, and the maximum power dissipation is 90 mW with a 3 A test current. As Figure 8 shows, the 10 mA test current result exhibits large fluctuations that prevent accurate characterization, while the other test current values display low enough noise levels to permit device evaluation. However, the test currents of 1 A and 3 A create enough device selfheating to cause the measurement curves to shift over time. After some thought, it appears that a test current of about 500 mA is appropriate for this measurement and that it strikes a good balance between measurement resolution and heat effects caused by power dissipation.

As this example shows, the most efficient way to determine the appropriate test current is to start with a small test current and gradually increase it until the noise level is acceptable and yet small enough to minimize heating effects caused by power dissipation. In this example, a 500 mA test current was determined to be the best value to balance measurement resolution requirements with power dissipation induced heating effects.

Sample Measurement Program

A sample program to make resistance measurements with the B2961A and the 34420A is available for download from the Agilent Web site (please see Figure 9). It works with C#, National Instruments LabVIEW and Microsoft Excel with VISA -COM. In addition to supporting basic resistance measurements, the program also supports the technique described in this technical overview that eliminates measurement errors.

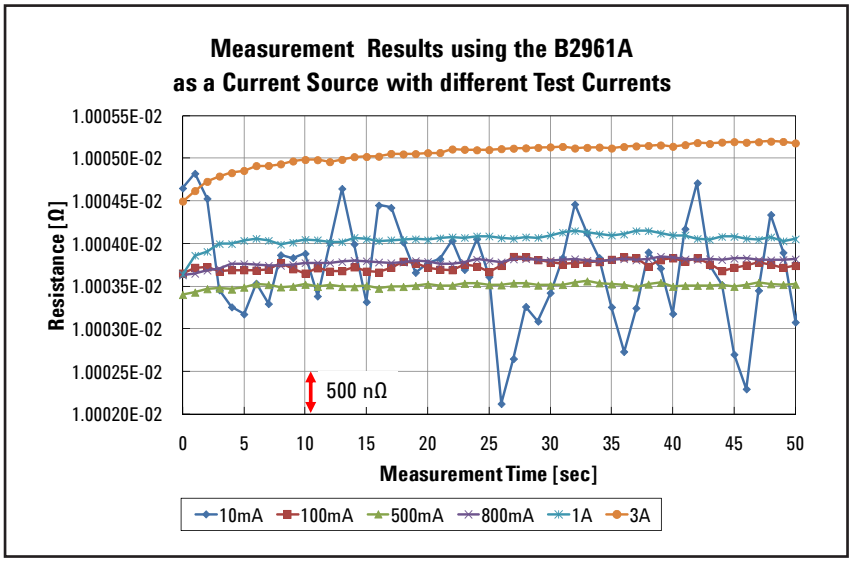

Figure 8. Measurement results using the B2961A as a current source with different test currents

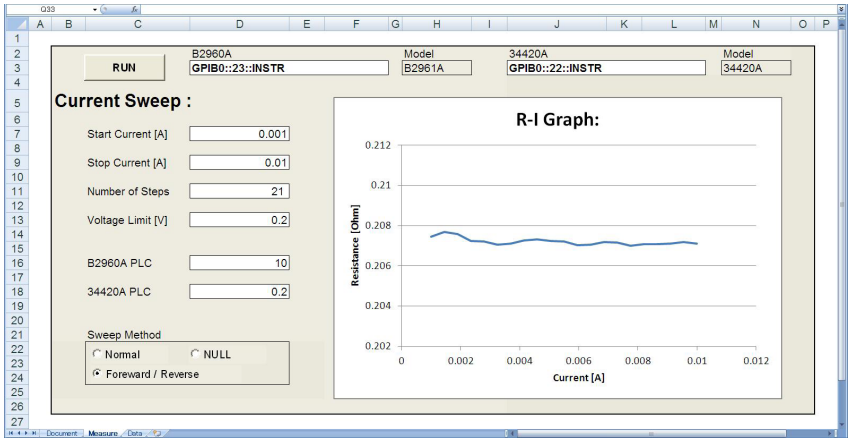

Figure 9. Sample measurement program to make resistance measurements with the B2961A and the 34420A

www.agilent.com
www.agilent.com/find/precisionSOURCE

myAgilent

www.agilent.com/find/myagilent
A personalized view into the information most relevant to you.

www.axiestandard.org

AdvancedTCA® Extensions for Instrumentation and Test (AXIe) is an open standard that extends the AdvancedTCA for general purpose and semiconductor test. Agilent is a founding member of the AXIe consortium.

www.lxistandard.org

LAN eXtensions for Instruments puts the power of Ethernet and the Web inside your test systems. Agilent is a founding member of the LXI consortium.

www.pxisa.org

PCI eXtensions for Instrumentation (PXI) modular instrumentation delivers a rugged, PC-based high-performance measurement and automation system.

Three-Year Warranty

www.agilent.com/find/ThreeYearWarranty
Beyond product specification, changing the ownership experience. Agilent is the only test and measurement company that offers three-year warranty on all instruments, worldwide.

Agilent Assurance Plans

www.agilent.com/find/AssurancePlans
Five years of protection and no budgetary surprises to ensure your instruments are operating to specifications and you can continually rely on accurate measurements.

www.agilent.com/quality

Agilent Electronic Measurement Group
DEKRA Certified ISO 9001:2008
Quality Management System

Agilent B2900A Series Precision Instruments

The B2900A series lines up products for both precision source and precision measurement.

www.agilent.com/find/b2900a

For more information on Agilent Technologies' products, applications or services, please contact your local Agilent office. The complete list is available at:
www.agilent.com/find/contactus

Americas	
Canada	(877) 894 4414
Brazil	(11) 4197 3600
Mexico	01800 5064 800
United States	(800) 829 4444
Asia Pacific	
Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 112 929
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Other AP Countries	(65) 375 8100
Europe & Middle East	
Belgium	32 (0) 2 404 93 40
Denmark	45 45 80 12 15
Finland	358 (0) 10 855 2100
France	0825 010 700*
	*0.125 €/minute
Germany	49 (0) 7031 464 6333
Ireland	1890 924 204
Israel	972-3-9288-504/544
Italy	39 02 92 60 8484
Netherlands	31 (0) 20 547 2111
Spain	34 (91) 631 3300
Sweden	0200-88 22 55
United Kingdom	44 (0) 118 927 6201

For other unlisted countries:
www.agilent.com/find/contactus
(BP-09-27-13)

Product specifications and descriptions in this document subject to change without notice.

Published in USA, February 12, 2014
5991-1854EN

Agilent Technologies