KEITHLEY

Application Note Series

Number 805

Configuring a Discrete Resistor Verification Test System

Introduction

Single point pass/fail testing of discrete resistors in their final packaged state is important for ensuring compliance with a manufacturer's specifications and identifying bad and marginally bad resistors prior to shipment. Two tests are commonly performed on resistors: the Resistor Voltage Coefficient Test and the Resistor Tolerance Band Test. These tests must be reliable to assure product quality, but must also be conducted rapidly to maintain high production throughput. In many discrete resistor production tests, separate instruments such as power supplies and DMMs are used.

When manufacturing millions of resistors a day, measurement system throughput is critical. As the number of computer-controlled instruments involved rises, the slower the overall process becomes. When a mathematical calculation must be performed, such as computing the voltage coefficient, this can slow system throughput still further as a result of the computer time needed and any pending control that must take place.

This application note presents a detailed description of how to assemble, configure and operate a discrete resistor production test system built around the Model 2400 Digital SourceMeter® Instrument, which can source and measure both current and voltage. This approach offers simpler system configuration and higher test throughput. A system configured with a separate DMM and sources takes up substantially more rack space than a system built with all these functions in one unit. In addition to higher equipment costs, three separate instruments also means there are three sets of commands to learn, complicating system programming and maintenance. Using multiple instruments and sources also makes trigger timing more complex and increases triggering uncertainty. Coordinating the operation of separate instruments also extends the measurement cycle by increasing the amount of bus traffic required, decreasing throughput.

The voltage coefficient and tolerance band tests are reviewed, general algorithms for system configuration and IEEE operation are presented, and typical sources of error are discussed. In addition, system equipment requirements are listed and a sample program is available. This application note assumes the system will be a continuous-feed operation, in which the test fixture holds only one resistor at a time. However, the techniques outlined can easily be adapted to a multi-device "batch" operation with the inclusion of a switching system for high-speed production applications.

Test Descriptions

Resistor Voltage Coefficient Test

High-megohm resistors (>$10^7\Omega$) often exhibit a change in resistance with applied voltage. This change in resistance can be characterized as the voltage coefficient. To calculate the voltage coefficient in %/V, two resistance readings at two different voltage values are required:

$$\text{Voltage Coefficient (\%/V)} = \frac{100\% \, (R_2 - R_1)}{R_1 \, (V_2 - V_1)}$$

where: R_1 = resistance calculated with first applied voltage (V_1).

R_2 = resistance calculated with second applied voltage (V_2).

Resistor Tolerance Band Test

In production testing, resistors are qualified based on their tolerances. Each resistor will be measured, then, depending on the measured value, will be placed in a bin based upon a defined tolerance, such as ±1%, ±5%, or ±10%. Setting up a tolerance band test is best shown by example.

Example Application of Tolerance Band Testing

Up to five limit values (one compliance, two high, and two low values) can be programmed into the Model 2400 Digital SourceMeter Instrument. The limit values will determine the Pass/Fail and High/Low status of subsequent measurements. An example of programmed limit values is shown in ***Figure 1***.

Tolerance:	<5%	5%	1%	5%	>5%
Bit Pattern:	010	011	000	011	010

Resistance: 0.95MΩ 0.99MΩ 1.01MΩ 1.05MΩ

Figure 1. Tolerance Band Configuration.

In this example, 1MΩ resistors are sorted by tolerances of 1%, 5%, and greater than 5%. Values less than 0.95MΩ and greater than 1.05MΩ are outside the 5% tolerance range, so these devices fail the test. The Model 2400 has four digital output lines that can be used to set up bit patterns to produce TTL level signals for controlling external equipment, such as a binning machine or handler. Only three of the digital outputs are used in this example. Note the bit patterns corresponding to each tolerance band.

From the tolerance band configuration, the following limit test is produced:

Limit	Value	Pattern	Action
R < LO Lim 2	R<.95M	010	Dig Out #2 = HI Others LO
LO Lim 2 < R < LO Lim 3	0.95M < R < 0.99M	011	Dig Out #1 and #2 = HI Others LO
LO Lim 3 < R < HI Lim 3	0.99M < R < 1.01M	000	All Outputs LO
HI Lim 3 < R < HI Lim 2	1.01M < R < 1.05M	011	Dig Out #1 and #2 = HI Others LO
R > HI Lim 2	R > 1.05M	010	Dig Out #2 = HI Others LO
Lim 1	2400 in Compliance	001	Dig Out #1 = HI Others LO

Note that Lim 1 checks the compliance state of the Model 2400 SourceMeter Instrument. This test uses the programmed compliance as the test limit. In this example, if an open circuit is detected (indicating there's no resistor in the test socket), the Model 2400 will go into compliance and Digital Output #1 will go HI.

Test System Configuration

Figure 2 is a block diagram of a Model 2400-based resistor production test system for continuous-feed resistor verification.

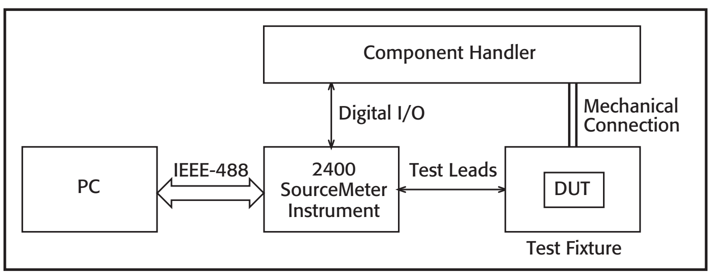

Figure 2. 2400-Based Resistor Production Test System..

Note that the resistor is placed in a test fixture with connections to the Model 2400. When triggered, the Model 2400 outputs a signal and measures the resistor. These measurements are then compared to pre-specified limits programmed into the instrument and pass/fail determinations are made. The digital I/O port on the Model 2400 sends signals to a component handler to allow fast binning of the resistors. The Model 2400 can interface directly with a component handler, freeing the PC during handling operations and allowing test data to be downloaded and stored while a new resistor is being positioned in the test fixture.

The following algorithm describes the steps involved in the operation of the test system. It assumes a continuous-feed operation involving only one resistor in the test fixture at a time.

1. Operator indicates to PC that a reel of resistors is in place and ready for test.
2. PC initiates Model 2400 operation.
3. Model 2400 waits for Start Of Test trigger from handler.
4. When the first resistor is in position, the handler sends a Start Of Test trigger signal to the Model 2400, indicating resistor is ready for testing.
5. The Model 2400 runs resistor verification procedure tests in the order stored in source memory, makes pass/fail determinations and saves data for each test: Tolerance Band and Voltage Coefficient.
6. The Model 2400 sends overall pass/fail status and End Of Test signal to handler and sends test data to PC (operations occur in parallel).
7. Repeat Steps 3–6 for remainder of resistors on reel or in tube.
8. The Model 2400 returns to idle state. New reel of resistors is installed in handler.
9. Operator indicates to PC that new reel is in place.
10. Repeat Steps 1–9 as required.

IEEE Bus Operation

Here are some general steps to follow when writing a program to set up and execute the tolerance band and voltage coefficient tests. When these tests are performed, each test point is configured and stored in a Source Memory Location. The source memory allows storing up to 100 complete test set-ups that can be initiated over the IEEE bus with a single command. The Model 2400 can step through these locations without computer intervention, which saves IEEE bus time and increases system throughput.

1. Initialize GPIB and the Model 2400.
2. Set the Model 2400 parameters that will be common to both tests (e.g., integration time, data format, etc.)
3. Define the Resistor Tolerance Band Test.
   a. Command the Model 2400 to source current: set source range, value and delay.
   b. Command the Model 2400 to measure resistance: set measure range and compliance.
   c. Set limit values and digital output bit patterns for each pass/fail outcome.
   d. Save Resistor Tolerance Band Test configuration in Source Memory Location #1.
4. Define Resistor Voltage Coefficient Test.
   a. Command the Model 2400 to source voltage # 1: set source range, value and delay.
   b. Command the Model 2400 to measure resistance # 1: set measure range and compliance.
   c. Feed value of Resistance Measurement #1 into resistor voltage coefficient equation (CALC1:MATH:NAME 'VOLTCOEF').
   d. Save Voltage Coefficient Test Set-Up for Point #1 in Source Memory Location #2.
   e. Repeat Steps a through c for Resistance Measurement #2.

f. Feed value of Resistance Measurement #2 into resistor voltage coefficient equation (CALC1:MATH:NAME 'VOLTCOEF'). This function calculates the voltage coefficient using the data from Measurements #1 and #2.
g. Save Voltage Coefficient Test Set-Up for Point #2 in Source Memory Location #3.
h. Set Pass/Fail limit values for the calculated voltage coefficient value.

5. Set Trigger Model.
6. Initiate Testing.
7. Store Data.

Typical Sources of Error

Depending on the magnitude of the resistors, special measurement techniques must be used to avoid measurement errors. For low resistance (<100Ω) measurements, lead resistance and thermal EMFs may cause problems. When measuring high resistances (>10MΩ), leakage currents and electrostatic interference may cause erroneous readings.

Lead Resistance

A common source of error when measuring small resistances (<100Ω) is the series resistance from the test leads running from the Model 2400 to the resistor. This series resistance is added into the measurement when making a 2-wire connection (see ***Figure 3***). The effects of lead resistance are particularly detrimental when long connecting cables and high currents are used, because the voltage drop across the lead resistance becomes significant compared to the measured voltage.

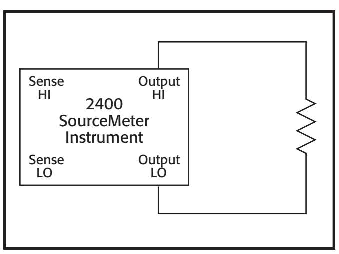

Figure 3. Two-Wire Technique

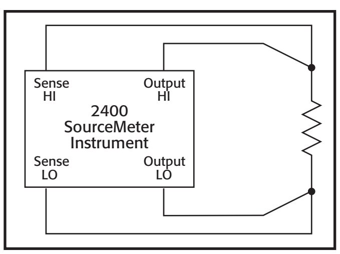

Figure 4. Four-Wire Technique

To eliminate this problem, use the four-wire remote sensing method rather than the 2-wire technique. With the 4-wire method (***Figure 4***), a current is forced through the resistor using one pair of leads and the voltage across the resistor is measured through a second set of leads. As a result, only the voltage drop across the resistor is measured.

Thermal EMFs

Thermal electromotive forces (EMFs) or voltages are created when dissimilar metals in a circuit are at different temperatures. To eliminate the effects of these unwanted voltages, use the offset-compensated ohms measurement method. In general, this method measures resistance at a specified source level, then subtracts a resistance measurement made with the source set to zero. With the source current set to zero, only the voltage due to thermal EMFs will be measured.

Offset-compensated ohms can be calculated automatically from the Model 2400's front panel or over the bus. To configure this function from the front panel, use the **FCTN** key. To configure this function over the bus, use the CALC1 subsystem.

Leakage Current

Stray leakage in cables and fixtures can be a source of error in measurements involving high resistances, such as testing high megohm resistors. To minimize this problem, use high resistance materials to construct test fixtures.

The Model 2400's built-in cable guard offers another way to reduce leakage currents. The guard is a low impedance point in the circuit, which is nearly the same potential as the high impedance point to be guarded. This is best illustrated by example (***Figure 5***).

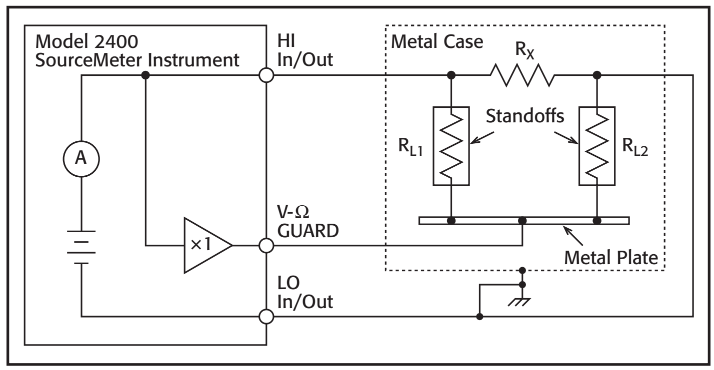

Figure 5. Model 2400's Built-In Guard.

In this example, the resistor to be measured (R_X) is mounted on two insulated stand-offs (R_L). Guarding is used in this circuit to ensure that all the current flows through R_X, not through the standoffs. This circuit is guarded by connecting the V-Ω Guard terminal of the Model 2400 to the metal plate. This will put the bottom of insulator R_{L1} at almost the same potential as the top. Since both ends of the insulator are at nearly the same potential, no significant current can flow through it. Therefore, all the current will flow through the resistor as desired. The LO In/Out terminal must be connected to the metal shield to avoid noise due to common mode and other interferences.

WARNING: Guard is at the same potential as output HI. Thus, if hazardous voltages are present at output HI, they are also present at the Guard terminal.

In general, cable guard should be used when sourcing or measuring low currents (<1μA).

Electrostatic Interference

High resistance measurements may be affected by electrostatic interferences, which occur when an electrically charged object is brought near an uncharged object. To reduce the effects of electrostatic fields, a shield can be built to enclose the circuit being measured. As shown in ***Figure 5***, a metal shield, connected to ground, surrounds the resistor being tested. This also acts as a safety shield because the metal plate is at guard potential.

Example Program

Keithley has developed an example program that performs the Voltage Coefficient and the Tolerance Band Tests on ten 1MΩ resistors. In this program, the Voltage Coefficient Test is run first, using test voltages of 100V and 200V. The compliance current is set for 10mA, and the upper and lower limits are set for ±0.1%/V. The tolerance band test is performed at a test current of 10mA, with tolerance bands of ±1% and ±5%. The limit structure and bit patterns for the tolerance band test are the same as in the previous example.

At the end of the test, an output report is produced that gives the resistor number, the voltage coefficient, and the actual measured resistance.

To obtain a copy of the Example Program as a digital file, access Keithley's World Wide Web site at www.keithley.com.

Note: The test program may require some modifications, depending on the type of handler used and its specific timing requirements.

Equipment List

The following equipment is required to assemble the continuous-feed resistor verification system and to run the example program:

1. Keithley Model 2400 Digital SourceMeter Instrument
2. PC with KPCI-488A Interface Card
3. Resistor handler and test fixture
4. Keithley Model 7007 IEEE-488 Interface Cable
5. Custom DB-9 digital I/O handler interface cable (to interface the Model 2400 to the handler)
6. Test leads to connect the Model 2400 to the test fixture.

Alternative Solutions

It would be possible to configure an alternative solution for discrete resistor production testing by using separate sources and measurement instruments to replace the functions provided by the Model 2400. For example, if higher levels of accuracy are needed, the Model 2001 and Model 2002 DMMs both combine extensive measurement capabilities with the digital I/O capabilities required to interface with a component handler. Separate voltage and current sources could be used to supply the necessary test signals.

For measuring low currents from high-valued resistors, test engineers may need to add an electrometer to the test configuration. Conversely, a low-noise DMM or micro-ohmmeter may be needed to perform tolerance band testing of very low-valued resistors.

KEITHLEY

A GREATER MEASURE OF CONFIDENCE

KEITHLEY INSTRUMENTS, INC. ■ 28775 AURORA RD. ■ CLEVELAND, OH 44139-1891 ■ 440-248-0400 ■ Fax: 440-248-6168 ■ 1-888-KEITHLEY ■ www.keithley.com

BELGIUM
Sint-Pieters-Leeuw
Ph: 02-3630040
Fax: 02-3630064
info@keithley.nl
www.keithley.nl

CHINA
Beijing
Ph: 86-10-8447-5556
Fax: 86-10-8225-5018
china@keithley.com
www.keithley.com.cn

FRANCE
Saint-Aubin
Ph: 01-64532020
Fax: 01-60117726
info@keithley.fr
www.keithley.fr

GERMANY
Germering
Ph: 089-84930740
Fax: 089-84930734
info@keithley.de
www.keithley.de

INDIA
Bangalore
Ph: 080-26771071, -72, -73
Fax: 080-26771076
support_india@keithley.com
www.keithley.com

ITALY
Peschiera Borromeo (Mi)
Ph: 02-5538421
Fax: 02-55384228
info@keithley.it
www.keithley.it

JAPAN
Tokyo
Ph: 81-3-5733-7555
Fax: 81-3-5733-7556
info.jp@keithley.com
www.keithley.jp

KOREA
Seoul
Ph: 82-2-574-7778
Fax: 82-2-574-7838
keithley@keithley.co.kr
www.keithley.co.kr

MALAYSIA
Penang
Ph: 60-4-643-9679
Fax: 60-4-643-3794
koh_william@keithley.com
www.keithley.com

NETHERLANDS
Gorinchem
Ph: 0183-635333
Fax: 0183-630821
info@keithley.nl
www.keithley.nl

SINGAPORE
Singapore
Ph: 65-6747-9077
Fax: 65-6747-2991
koh_william@keithley.com
www.keithley.com

SWITZERLAND
Zürich
Ph: 044-8219444
Fax: 044-8203081
info@keithley.ch
www.keithley.ch

TAIWAN
Hsinchu
Ph: 886-3-572-9077
Fax: 886-3-572-9031
info_tw@keithley.com
www.keithley.com.tw

UNITED KINGDOM
Theale
Ph: 0118-9297500
Fax: 0118-9297519
info@keithley.co.uk
www.keithley.co.uk

Printed in the U.S.A. No. 1803 05.18.10