Keysight Technologies
Temperature Characteristic Evaluations of RF Components and Materials using the E4991A Impedance/Material Analyzer

Application Note
Introduction

In the research and development of electronic components and materials, product development cycle time has been reduced in order to meet the demand from end users. In accordance with this trend, more emphasis is being placed on improving the efficiency of temperature characteristic evaluation, which plays a major role in ensuring end-product reliability and performance.

This application note introduces an efficient and highly reliable measurement system (shown in Figure 1) for evaluating temperature characteristics of components and materials using a combination of the E4991A-007, Temperature Characteristics Test Kit, with an ESPEC1 bench-top temperature chamber (SU-261).

Table 1. Keysight Technologies E4991A specification summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating frequency:</td>
<td>1 MHz to 3 GHz (1 mHz resolution)</td>
</tr>
<tr>
<td>Converted parameters:</td>
<td></td>
</tr>
<tr>
<td>Material parameters:</td>
<td></td>
</tr>
<tr>
<td>Basic impedance accuracy:</td>
<td>±0.8%</td>
</tr>
<tr>
<td>Impedance range:</td>
<td>0.13 Ω to 20 kΩ</td>
</tr>
<tr>
<td>DC bias:</td>
<td>0 V to ±40 V (1 mV resolution), 100 μA to 50 mA, -100 μA to -50 mA (10 μA resolution)</td>
</tr>
</tbody>
</table>

1. ESPEC is a Keysight Channel Partner
2. Material measurement firmware (Option E4991A–002) is required.
3. 10% accuracy range
4. DC bias source (Option E4991A–001) is required.
Overview

The temperature characteristic test kit, Option E4991A-007, is a new solution for temperature characteristic measurements of components and materials. The E4991A-007 is one option of the E4991A RF impedance/material analyzer that provides a complete measurement solution for a wide range of applications, from evaluating electronic materials used in RF components to evaluating various impedance parameters of components.

New capabilities for evaluating RF components

Temperature drift compensation function

With a powerful temperature drift compensation function, the E4991A-007 provides highly accurate temperature characteristic analysis capability within a wide temperature range from –55 °C to +150 °C. Figure 2 shows the typical 10% measurement accuracy range of the E4991A-007 compared to the 4291B RF impedance/material analyzer. The 4291B requires both high and low impedance test heads for obtaining a wide impedance measurement range, while the E4991A-007 covers a wider impedance measurement range with a single test head.

![](image)

Figure 2. Typical 10% measurement accuracy comparison of E4991A-007 and 4291B Impedance/material analyzers.
The temperature drift compensation function is a new technique available in the E4991A. Using this function, open and short compensation can be performed at eight pre-defined temperature points so that temperature drift error can be drastically reduced (see Figure 3).

![Figure 3. Effect of the temperature drift compensation function](image)

**Easy system integration using the E4991A-007 with ESPEC temperature chamber**

![Figure 4. The configuration of automated temperature characteristic test system](image)
The E4991A-007 includes the following features to simplify configuration of a temperature characteristic test system (Figure 4).

1. **Standard 1-m extension cable:**
   The extension cable makes it possible to extend the impedance test head to the temperature chamber for system flexibility.

2. **Heat-resistant cable with 7-mm test port:**
   The heat-resistant cable can be used within the range from –55 °C to +150 °C, while maintaining high accuracy. This extension cable has a 7-mm test port that supports various test fixtures for component and material measurements.

3. **VBA sample program for easy system integration:**
   A VBA sample program is compatible with the ESPEC SU-261 bench-top temperature chamber and controls the chamber over the USB/GPIB interface. This program also includes an intuitive graphical user interface (GUI), which provides the measurement parameter setup and temperature profile setup with easy operation as shown in Figure 5. In addition, this program can be easily modified to fit other company’s temperature chambers.

![Figure 5. VBA sample program](image)
Overview of the ESPEC Temperature Chamber

Compact Design for Laboratory Use

The ESPEC temperature chamber, model SU-261, provides a wide temperature range from –60 °C to +150 °C and covers the entire temperature range of the E4991A-007 (Figure 6). The SU-261 is designed to integrate easily with the E4991A-007. This is specifically advantageous for the research and development of electronic components and materials requiring evaluation in a wide temperature range.

Figure 6. The ESPEC bench-top temperature chamber (SU-261)
Chamber features

- Compact size:
  The compact design is beneficial for laboratories with a lack of space. The freezer uses a rotary compressor, reducing size and weight even further.

- GPIB interface:
  GPIB is used for connecting to the E4991A or to an external controller, allowing remote control of the chamber functions.

- Measuring port:
  As shown in Figure 7, a measuring port is available for installing the high temperature test head of the E4991A-007, eliminating the need to create additional measurement access holes.

![Figure 7. A measuring port of the ESPEC SU-261](image)

<table>
<thead>
<tr>
<th>Table 2. ESPEC Chamber SU-261 specification summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature Control</strong></td>
</tr>
<tr>
<td><strong>Refrigeration System</strong></td>
</tr>
<tr>
<td><strong>Temperature Range</strong></td>
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<tr>
<td><strong>Temperature Control Stability</strong></td>
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<tr>
<td><strong>Temperature Uniformity</strong></td>
</tr>
<tr>
<td><strong>Temperature Heat-up Time</strong></td>
</tr>
<tr>
<td><strong>Temperature Cool-down Time</strong></td>
</tr>
<tr>
<td><strong>Lowest Attainable Temperature</strong></td>
</tr>
<tr>
<td><strong>Capacity (L)</strong></td>
</tr>
<tr>
<td><strong>Inside Dimensions (W x H x D mm)</strong></td>
</tr>
<tr>
<td><strong>Outside Dimensions (W x H x D mm)</strong></td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
</tr>
</tbody>
</table>
System configuration

To configure a system using the ESPEC temperature chamber, Option E4991A-007 is required.

As shown in Figure 8, this option contains the extension cable, heat-resistant cable, VBA sample program, test fixture station, and test-head stand. Also, the open and short standards are furnished for temperature drift compensation.

Figure 8. Option E4991A-007, Temperature Characteristic Test Kit

1. Please note that the Keysight 82357A USB/GPIB Interface is required to control the chamber from the E4991A. The USB/GPIB interface is not included in the Option E4991A-007.
Measurement procedures

The following is a general procedure for evaluating temperature characteristics using the E4991A-007 with the ESPEC temperature chamber:

1. Configure a test system:
   Configure an automated temperature characteristic measurement system as shown in Figure 4.

2. Load the application program:
   Using the VBA function of the E4991A, load the sample program that is provided with the E4991A-007. This sample program controls settings, measurements, and analysis interactively via the intuitive GUI.

3. Setup the E4991A and temperature chamber:
   The program is first used to setup the E4991A and temperature chamber. For the E4991A, the parameters for measurement and sweep must be defined in advance. For the temperature chamber, the VBA sample program can set each temperature parameter, such as the start/stop temperature, measurement points, waiting time, and number of repeating cycles.

4. Perform the temperature drift compensation:
   To ensure highly accurate measurements, we recommend using the temperature compensation function. In this case, open and short compensation must be performed at the 7-mm test port with standards included. This compensation is carried out at the pre-defined temperature points. Once you extract the compensation data, it can be used repeatedly in different measurement conditions. If a more accurate measurement result is required to perform open and short compensation at actual measurement points are recommended.

5. Connect the test fixture:
   Before connecting a test fixture, Open/Short/Load (if necessary, low loss capacitor calibration is performed) calibration should be performed at the tip of the 7-mm test port of the heat-resistant cable at normal temperatures. In addition, the compensation (which is corresponded to test fixtures) needs to be performed.

   For temperature characteristic measurements of axial/radial leaded devices and SMD, the 16194A high temperature component test fixture can be used with the E4991A-007. Also, for dielectric and magnetic materials, the 16453A dielectric material test fixture and the 16454A magnetic material test fixture are available.
6. Connect the DUT:
Connect the DUT to the test fixture positioned in the temperature chamber.

7. Measure a device:
When the measurement has started, the program automatically controls the temperature chamber and the E4991A (based on the settings made in Step 3). After finishing the measurement, temperature characteristics data is saved in the E4991A in a CSV file format and can be edited by using external application software.

8. Validate measurement results:
Figure 9 shows actual temperature characteristic evaluation results of a 1 nH inductor at 100 °C. This chart shows impedance and frequency characteristic measurement results of the E4991A and 4291B. From this result, the effectiveness of the temperature drift compensation can be confirmed.

Figure 9. Measurement results of a 1 nH inductor (E4991A vs. 4291B)
Summary

In this application note, we discussed how to create an automated temperature characteristic measurement system using the E4991A RF Impedance/Material Analyzer with the ESPEC temperature chamber SU-261. As described, both Keysight and ESPEC can provide all necessary equipment and accessories for your system integration. Also, the new temperature drift compensation function can drastically improve temperature measurement accuracy, especially in a high frequency range. We hope this application note makes it easier and faster for you to create your test system.

Keysight Trade Up Program

Migrate from the Keysight 4191A, 4291A, and 4291B RF impedance/material analyzers and take advantage of the new E4991A's performance and save with Keysight Trade Up!

The Keysight Trade Up program assists current 4191A, 4291A, and 4291B RF impedance/material analyzer owners upgrade to more advanced measurement solutions that will increase test efficiency, reduce test costs, and help get their products to market quickly. Current Keysight 4191A, 4291A, and 4291B owners can trade-in their older instruments and receive credit towards the purchase of a new E4991A impedance/material analyzer.

E4991A-007 RF Impedance/material analyzer

- Highly accurate impedance measurement up to 3 GHz
- RF I-V method achieves wide impedance measurement range
- Temperature characteristic measurements for electronic components (Option E4991A-007)
  - Measurement accuracy is improved by temperature drift compensation function
  - Temperature range is covered from –55 °C to +150 °C
- Temperature characteristic measurements for dielectric and magnetic materials (Option E4991A-002/-007)
  - Various test fixtures are available for material measurements (16453A/16454A)
- Support the ESPEC temperature chamber (SU-261)
- Automated temperature characteristic measurement system can be easily established by using the VBA program (Option E4991A-007)

Note: Credit amounts will vary. Keysight Trade Up is not available in all countries. Additional trade-in terms and conditions may apply. Please contact your local Keysight Technologies representative for a current list of eligible countries and more details.

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