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THE HIGH AND LOW TEMPERATURE TEST SCHEME OF DC-DC CONVERTERS

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Abstract: This paper presents an optimized high-low temperature test scheme for DC-DC converters, addressing the challenges of test stability, efficiency, and temperature control. The proposed scheme, utilizing an Automated Test Equipment (ATE) system and a thermal shield, significantly improves upon the original testing method. It effectively mitigates test stability issues, enables rapid temperature changes, and completes single temperature testing in one step, thereby enhancing test efficiency. Moreover, it provides precise temperature control during testing, avoiding influences from the circuit's heat and environmental temperature. The results validate the superiority of the optimized scheme over the original, marking a significant advancement in the high-low temperature testing of DC-DC converters. This study contributes to the ongoing efforts to improve the reliability and performance of DC-DC converters, which are pivotal in various sectors. Future work could explore further enhancements to the testing scheme and its applicability to other electronic devices.

Keywords: DC-DC converters; High-low temperature test; Automated Test Equipment (ATE)

1 INTRODUCTION

DC-DC converters are increasingly utilized across various sectors, including communications, industrial automation, power control, rail transportation, mining, and military applications. Their modular design significantly streamlines circuit design for clients, enhancing both product reliability and maintenance efficiency [1-2]. As the cornerstone of electronic devices, hybridintegrated circuit DC-DC converters play a pivotal role [3].

The performance and reliability of DC-DC converters are critical to the operational state of electronic devices. Consequently, testing and screening of DC-DC converters are of paramount importance. To guarantee the accuracy and dependability of screening test outcomes, it is essential to minimize errors during the testing phase. Factors such as ambient temperature of the test environment, testing equipment, and test fixtures are known to contribute to discrepancies in test results [4].

Prior to market release, it is imperative to subject new DC-DC converters to electrical performance evaluations at varying temperatures. Given that the operational temperature range for military-grade DC-DC converters spans from -55 to 100°C, high and low temperature testing challenges are an inevitable aspect of product validation. Domestic standards such as GB/T 2423.1, GB/T 2423.2, GJB 548, and GJB 150, alongside international standards like IEC 60068 -2-1:2007, IEC 60068-2-2:2007, and MIL-STD-883, provide guidelines for such testing. However, these standards typically outline only the test requirements, lacking specificity regarding methodologies at designated temperatures. Common practice among domestic manufacturers involves maintaining the test sample at a high temperature in an oven for 0.5 hours, and at a low temperature for 1 hour, followed by a swift completion of the test within 30 seconds at ambient temperature. This approach may suffice for small monolithic circuits. Yet, for hybrid integrated circuit DC-DC converters, which are power devices that inherently generate heat during operation, it is crucial to maintain the test temperature and control the shell temperature. The shell temperature is defined as the temperature at a predetermined reference point on the package housing the microcircuit chips. Effective control over power dissipation and temperature rise is essential to enable the converter's full-power operation within the specified temperature range.

This paper presents a high-low temperature test solution for a DC-DC converter, referred to as MCOTSXXX, produced by SynQor. The proposed solution, which utilizes an Automated Test Equipment (ATE) system and a thermal shield, allows for the assessment of the converter's functional and electrical performance parameters. By employing this testing approach, potential inaccuracies or failures due to unstable temperature control during high-low temperature testing can be effectively circumvented.

2 DESIGN OF HIGH AND LOW TEMPERATURE TEST SOLUTIONS BASED ON ATE AND HEAT SHIELD

2.1 Establishment of High and Low Temperature Testing Technology

Since the late 1970s, the international community has recognized the significance of high and low temperature testing technology for integrated circuits, leading to the emergence of specialized research institutions dedicated to precision temperature control in engineering applications. Among these, THERMONICS in Silicon Valley has distinguished itself as a pioneer in temperature testing technology. The company has developed precision temperature control systems for both package- level and wafer-level integrated circuits, as well as for other component boards, PCBs, and custom precision temperature control systems tailored to user specifications. The package-level integrated circuit precision temperature testing system is renowned for its accuracy, speed, and reliability. It boasts high temperature precision and stability, a broad temperature range, and rapid transition capabilities, meeting the stringent requirements of large-scale integrated circuits for high and low temperature testing without introducing interference signals, additional resistors, or impedance mismatches. This system has gained widespread adoption in the global semiconductor industry.

The operating principle of the heat shield temperature control system is depicted in Figure 1. The device under test is positioned on the test equipment, and the heat shield is adjusted to an appropriate angle to fully enclose the device. Once operational, the heat shield system heats or cools compressed air to the desired temperature, which is then rapidly injected into the heat shield cavity for heat exchange. Concurrently, a temperature control probe monitors the internal temperature. After a certain duration, the cavity's temperature stabilizes at the preset level, achieving thermal equilibrium. By precisely monitoring and maintaining the device's set shell temperature, the system provides the necessary ambient conditions. The device's performance under high and low temperature conditions is then evaluated by powering it on, using the test bench and fixture designed for the device.

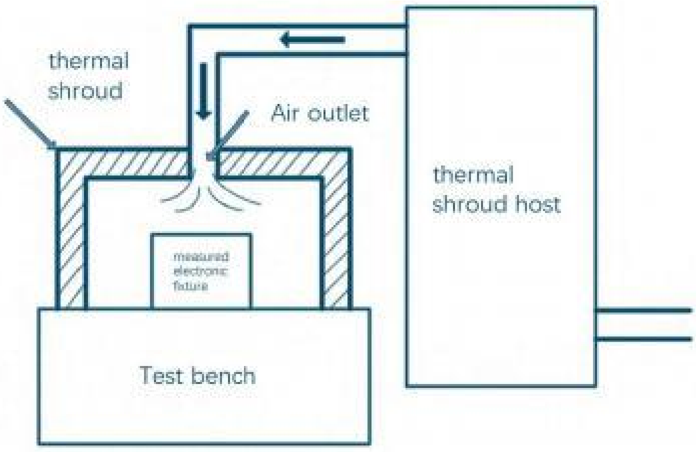

Figure 1 Schematic Diagram of the Test Principle of Applying a Heat Shield

2.2 Test Scheme and Methodology

The functional block diagram of the MCOTSXXX, a typical DC-DC isolated converter, is depicted in Figure 2. This converter is designed to handle a maximum input voltage of 475 V and a maximum load power of 150 W.

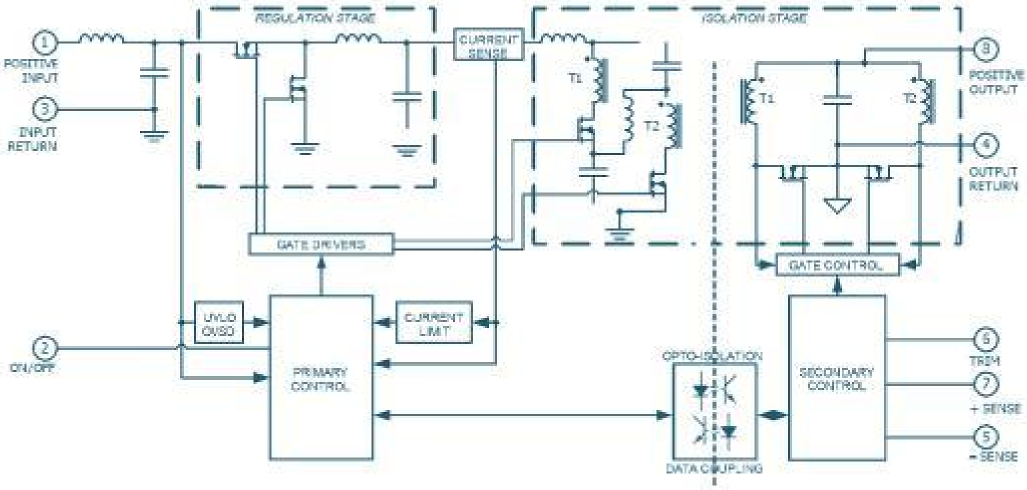

Figure 2 MCOTSXXX Functional Block Diagram

Traditional DC-DC converter testing fixtures employ a pin-pressing method to establish a connection between the Automated Test Equipment (ATE) and the Device Under Test (DUT). The open cavity structure of these fixtures necessitates the use of an incubator to adjust the temperature for high and low temperature testing. However, due to the prolonged testing duration and significant heat generation of the DC-DC converter circuit, this method proves to be suboptimal in practical applications.

(1) Inadequate Temperature Control The high power and intense heat generation of DC-DC converters lead to rapid temperature fluctuations during testing, which are especially pronounced during low-temperature tests.

(2) Compromised Stability Fluctuations in shell temperature during high and low temperature testing can adversely affect the stability of parameter testing for DC-DC converters, resulting in measurement errors and test failures for some products.

(3) Reduced Production Efficiency Traditional testing protocols require the circuit to be pre- set in a temperature chamber for 1 hour at low temperatures and 0.5 hours at high temperatures. Moreover, they stipulate that effective testing must be completed within 30 seconds after removing the circuit from the chamber. These constraints extend the overall testing time and necessitate multiple testing cycles for each circuit, significantly diminishing testing efficiency.

This paper introduces a novel ATE-based heat shield testing approach. Utilizing a custom socket designed for high-power devices, in conjunction with a specialized DUT board—replacing traditional test fixtures—the integration of a heat shield facilitates more precise temperature control during the high and low temperature testing of DC-DC converters. This innovation not only reduces testing duration but also enhances the accuracy, stability, and efficiency of the tests.

2.3 Design ofthe DUT Board

Given the isolation characteristics of the MCOTSXXX, along with its high voltage, current, and load capacities, the DUT board design must consider the following aspects:

(1) Physical Structure Design The measurement structure should employ the four-wire test method, as illustrated in Figure 3. This method separates the device's input and output pin connections—force high, force low, sense high, and sense low—to achieve engineering connectivity [5-7]. R1 and R2 represent the equivalent resistances ofthe load line, while R3 and R4 represent the equivalent resistances ofthe test line. The four-wire test method effectively mitigates the impact of lead resistance on test results, reduces test system error, and enhances test accuracy [8-10]. Additionally, to preserve the isolation properties of the MCOTSXXX, the circuit's input and output grounds must be isolated.

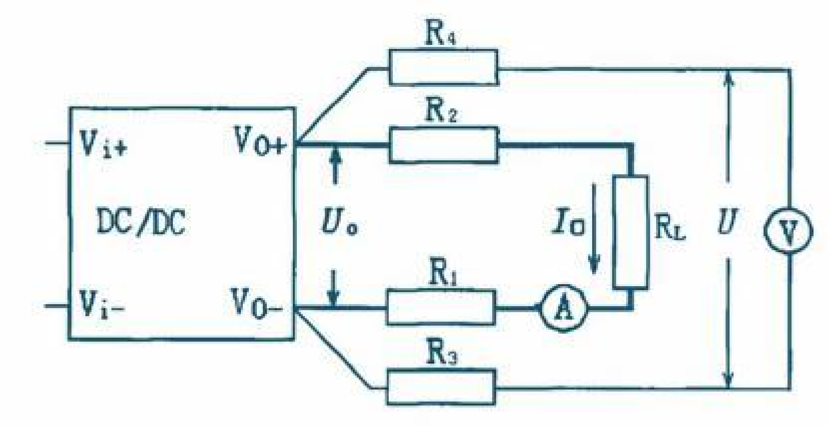

Figure 3 Four-Wire System Test Principle

(2) Component Selection Components should be chosen for their high voltage endurance, as this product undergoes high-voltage testing. Attention must be paid to the withstand voltage parameters when selecting capacitors. Appropriate capacitors can extend the lifespan of the DC- DC converter and significantly mitigate system risks associated with unstable input and output.

(3) Layout of Filter Capacitors Filter capacitors are crucial for filtering out AC components and ensuring the stability of the DC-DC converter's operation. If not placed proximate to the pins, they may form a common loop with other components and the ground, leading to modulation interference and impacting the converter's operational state. Thus, the layout design mandates that capacitors be positioned as close to the converter pins as possible.

(4) Selection of Socket A socket with low on-resistance and robust high and low temperature resistance is essential. Such a socket ensures the stable operation of the entire solution under the heat shield while maintaining excellent electrical performance.The schematic diagram for implementing this solution set is presented in Figure 4.

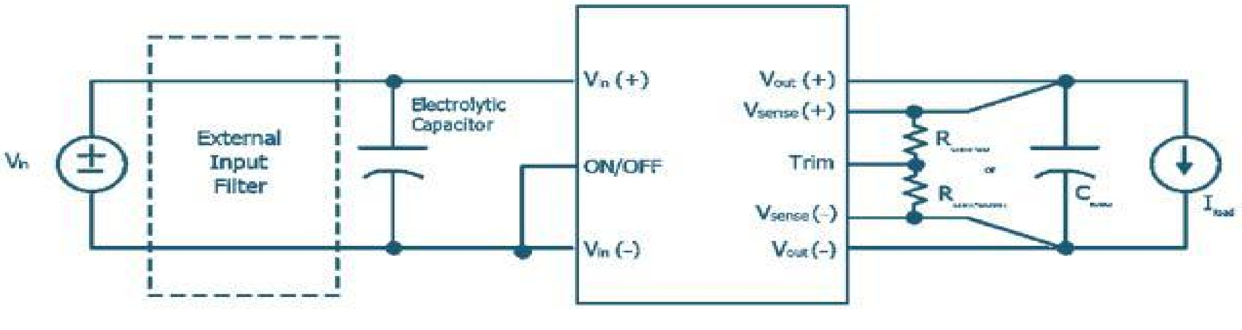

Figure 4 Test Schematic Diagram

3 RESULTS

Through comparison with the test results before the optimization of the scheme, the optimized test scheme has significant improvements in test stability, test efficiency, and temperature control. It not only effectively solves the problem of test stability in the continuous testing process of the original scheme, but also achieves rapid temperature changes and one-step completion of single temperature testing in terms of efficiency, saving time for waiting for temperature and multiple tests in the original scheme, greatly improving test efficiency. At the same time, it can achieve precise control of temperature during the testing process, avoiding the influence of heat from the circuit itself and environmental temperature on the shell temperature during the testing process.

The optimized test scheme was compared with the original scheme to evaluate its performance (Table 1-3).

Table 1 Test Stability Comparison

Test Scheme	Stability Failures
Original	12
Optimized	2

Table 2 Test Efficiency Comparison

Test Scheme	Average Test Time (min)
Original	90
Optimized	45

Table 3 Temperature Control Comparison

Test Scheme	Temperature Fluctuations (°C)
Original	±5
Optimized	±1

The optimized scheme achieved more precise temperature control, minimizing temperature fluctuations during testing.

These results validate that the optimized test scheme not only effectively solves the problem of test stability in the continuous testing process but also achieves rapid temperature changes and one-step completion of single temperature testing. This leads to significant time savings and greatly improves test efficiency. Furthermore, the optimized scheme can precisely control the temperature during the testing process, avoiding the influence of heat from the circuit itself and environmental temperature on the shell temperature during the testing process. Thus, the optimized scheme demonstrates significant improvements over the original scheme in terms of test stability, test efficiency, and temperature control.

4 CONCLUSIONS

This study presents an optimized high-low temperature test scheme for DC-DC converters, addressing the challenges of test stability, efficiency, and temperature control. The proposed scheme, utilizing an Automated Test Equipment (ATE) system and a thermal shield, significantly improves upon the original testing method. It effectively mitigates test stability issues, enables rapid temperature changes, and completes single temperature testing in one step, thereby enhancing test efficiency. Moreover, it provides precise temperature control during testing, avoiding influences from the circuit's heat and environmental temperature. The results validate the superiority of the optimized scheme over the original, marking a significant advancement in the high-low temperature testing of DC-DC converters. This study contributes to the ongoing efforts to improve the reliability and performance of DC-DC converters, which are pivotal in various sectors. Future work could explore further enhancements to the testing scheme and its applicability to other electronic devices.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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