TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 68, Issue IV, November, 2025

RELIABILITY OF DIRECT CURRENT MOTOR DRIVER BOARD UNDER RANDOM VIBRATIONS AND HIGH TEMPERATURE

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Abstract: *This paper investigates the combined effects of mechanical vibrations and high temperatures on an electric component of an electric vehicle. This study investigates the reliability and ergonomics of a printed circuit board (PCB) component subjected to random vibrations and high temperatures. The component, an important element in the electric vehicle, is designed to operate in harsh environments characterized by mechanical stress, thermal fluctuations, and random vibrations. The study highlights the importance of considering the interplay between mechanical, thermal, and vibrational stressors in the design and testing of PCB components for electric vehicles.*

Key words: *Vibrations, printed circuit board (PCB), ergonomics, temperatures, mechanical stress.*

1. INTRODUCTION

The reliability of components and systems is a crucial aspect in the development of control and automation systems, particularly in the automotive, aerospace, and space industries. Over the past years, the demand for control and automation systems has increased due to the growing need to improve efficiency and safety in various fields.

Among the key components of control and automation systems, DC motor driver boards are widely used in numerous applications, ranging from vehicle command and control systems to industrial automation systems. These boards are responsible for controlling and regulating the electric current that powers DC motors, ensuring the correct functioning of systems, and, simultaneously, are designed to provide a high level of comfort and efficiency in their use by applying user ergonomics principles, which aim to minimize stress and risks associated with using these systems, thereby enabling users to operate the system in maximum safety and efficiency conditions..

Despite their importance, DC motor driver boards are subject to harsh environmental conditions, such as mechanical shocks, random vibrations, and high temperatures. These conditions can cause defects and interruptions in the board's functioning, which can have severe consequences on the safety and efficiency of operations.

A range of critical safety applications are activated through electronic control systems, including lane departure warning systems, collision avoidance systems, vehicle stability control systems, advanced driver assistance systems, and adaptive cruise control systems. [1]

Previous works have shown that electronic components subjected to simultaneous vibrations and temperature stress degrade faster compared to electronic components subjected to a single type of stress. [2], [3].

Wu et al [4] examined the vibration transmissibility and random vibration response of a printed circuit board (PCB) of a medical device using a calibrated finite element model.

Pitarresi et al. [5-7] considered the modeling techniques of circuit cards subjected to vibration loading. They investigated the response of surface mount lead/solder and predicted its fatigue life due to random excitation.

Previously, the progression of damage and the remaining useful life prognosis were

Received: 10.09.25; **Similarities**: 20.10.25: **Reviewed**: 10.09./ 10.09.25: **Accepted**:19.11.25.

performed using resistance spectroscopy measurements [8-10].

The electronic components situated within the engine compartment of a vehicle are prone to the cumulative effects of mechanical vibrations and high-temperature operations. Research has demonstrated that the maximum operating temperature of an electronic component in a vehicle can attain 200°C, concomitantly with a vibration level of up to 10g [11].

2. TEST VEHICLE

In this paper, the L9110S 4-Channel DC Motor Driver Board is subjected to a combination of random vibrations and high temperatures testing. The L9110S module is used for controlling the speed and direction of two DC motors, being compatible with a power supply voltage range of 2.5V to 12V. In automotive development laboratories, engineers can use motor driver boards to control auxiliary systems or testing components. For example, during the development of an electric vehicle prototype, the board can be used to control various actuators or auxiliary devices, such as ventilation systems, fluid pumps, or electric windows. The test vehicle design is presented in Fig. 1.

The tests were conducted in accordance with international standards, IEC 60068-2-14 and IEC 60068-2-64.

IEC 60068 is a collection of methods for environmental testing of electronic equipment and products to assess their ability to perform under environmental conditions including extreme cold and dry heat. IEC 60068 offers appropriate severities and prescribes various environmental conditions for measurements and tests. [12].

IEC 60068 2-14. This part of IEC 60068 provides a test to determine the ability of components, equipment or other articles to withstand rapid changes of ambient temperature. The exposure time adequate to accomplish this will depend upon the nature of the specimen [13].

IEC 60068 2-64. This part of IEC 60068 demonstrates the adequacy of specimens to resist dynamic loads without unacceptable degradation of their functional and/or structural integrity when subjected to the specified random vibration test requirements [14].

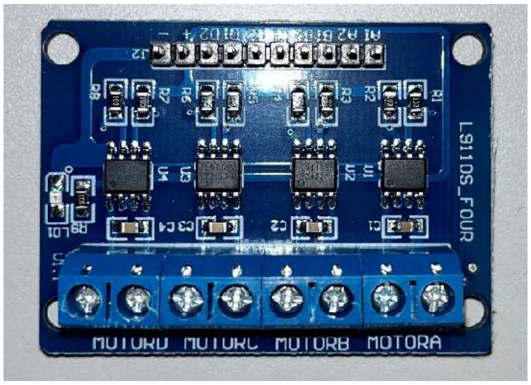


Fig. 1. test Vehicle used in this study.

Table 1

Test Board

Characteristics	
Dimension [mm]	49.8 x 36.9
weight [g]	12.4

Fig. 2. Electrodynamic vibration test system [15].

Fig. 3. Climatic chamber [16].

3. TEST EQUIPMENT AND SETUP

For this test, an electrodynamic shaker and a climatic chamber were used simultaneously, designed specifically to support a combined vibration and temperature test. The equipment used for the random vibration test is an RMS Shaker model SW8500. It is specially designed to test products from the automotive and aerospace industries. With a power of up to 45 kN and water cooling, this shaker provides high performance and reliability in vibration tests.

The equipment used for the temperature test is a climatic chamber with a volume of 1200L. It is a specialized testing equipment for controlled climatic conditions. The climatic chamber is specifically designed to be attached to the shaker, allowing a product to be tested for both vibrations and temperature at the same time.

This equipment can maintain temperatures between -70°C and 180°C and humidity between 0% and 100%. The climatic chamber is presented in Fig. 3.

The test stand consists of a shaker, an amplifier, a controller, and a PC, which, together, enables the measurement and analysis of the vibrations produced by the shaker to determine its properties and behavior.

Accelerometers are used to measure the vibrations produced by the shaker and to determine its properties and behavior. The test stand is equipped with a vibration control and regulation system, which allows the adjustment of the vibration frequency and amplitude to obtain precise and repeatable results. The accelerometers are connected to the PC to collect and analyze vibration data and display the results.

Although the vibration and temperature tests are performed simultaneously, they have separate data acquisition systems. The climatic chamber is controlled by a PC that simulates the climatic profile through software and collects data at the end of the test. Fig. 6 presents the test stand for vibration and temperature testing.

For this test, the shaker is oriented in a vertical position, and the fixing position of the module will be sandwich type.

The "sandwich" mounting method is an efficient and secure way to fix a PCB on a shaker during a vibration test. This method ensures a stable and secure fixation of the PCB, resulting in good vibration assimilation at all points of the PCB, so that the test objectives can be achieved.

Fig. 7 presents the test setup, as can be seen, a control accelerometer is mounted on the fixture, and an additional measurement accelerometer is mounted on the test board. By comparing the acceleration signals measured by the two accelerometers, the vibration transmissibility from the fixture to the test piece can be determined. This helps to identify any potential amplifications or attenuations of vibrations at the PCB level.

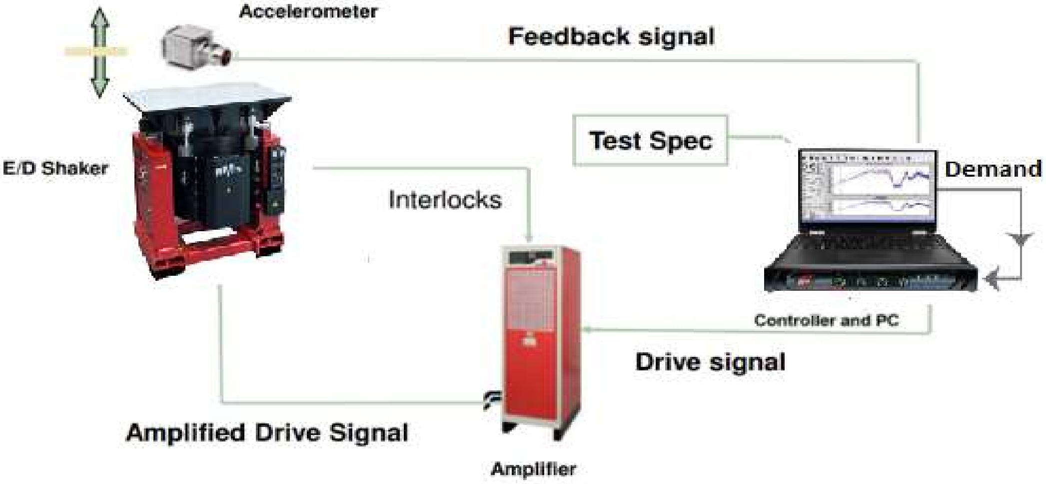


Fig. 4. Control loop for vibration test.

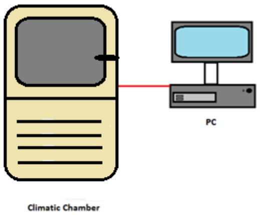


Fig. 5. Control loop for temperature test.

Fig. 6. Test equipment (Climatic chamber+Shaker).

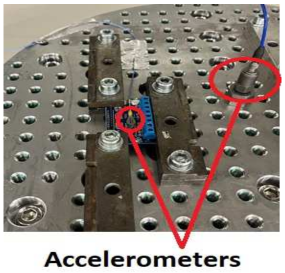


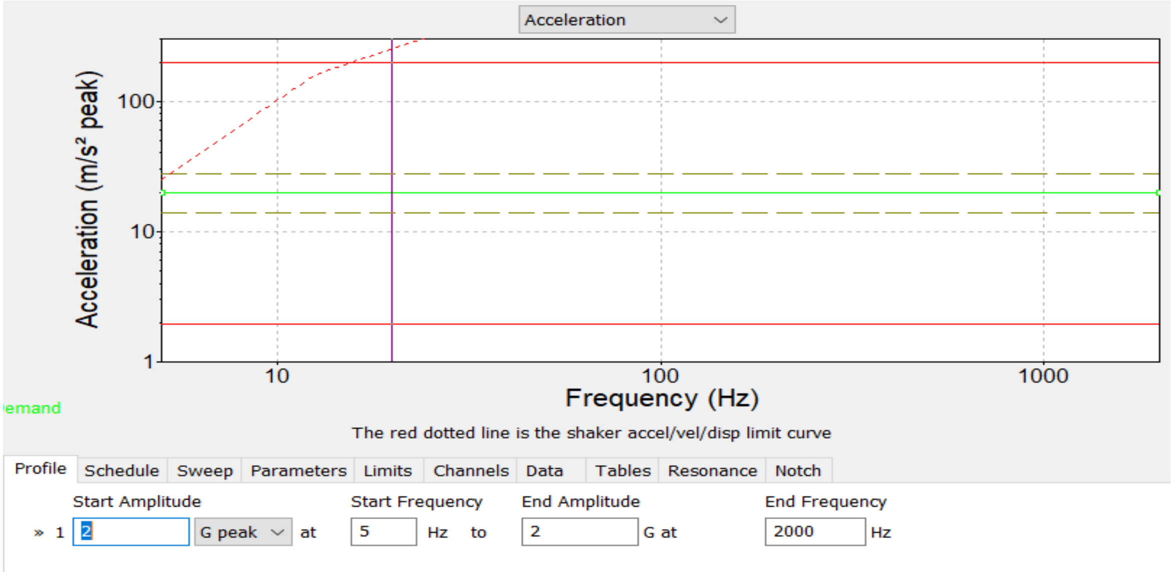
Fig. 7. Test setup, including control accelerometer

Fig. 8. Test setup, device under test

4. EXPERIMENTAL MODAL ANALYSIS

Before the start of the test, a sine-sweep profile will be used to determine the dynamic behavior of the product. This test is performed before each random vibration test, with the role of detecting the frequencies at which the components or the tested structure enter resonance, indicating that it should be performed both before and after the test to see if the product has changed its mechanical properties.

For the sine-sweep test, a vibration profile with an amplitude of 2G and a range of 5-2000 Hz will be considered (Fig. 9). After the sine sweep test was completed, resonance points were detected. Higher peaks indicate the frequency-location of the higher mode-shapes and natural frequencies (Fig. 10).



The red dotted line is the shaker accel/vel/disp limit curve

	Start Amplitude			Start Frequency			End Amplitude		End Frequency	
» 1	2	G peak	at	5	Hz	to	2	G at	2000	Hz

Fig. 9. Sine-sweep profile.

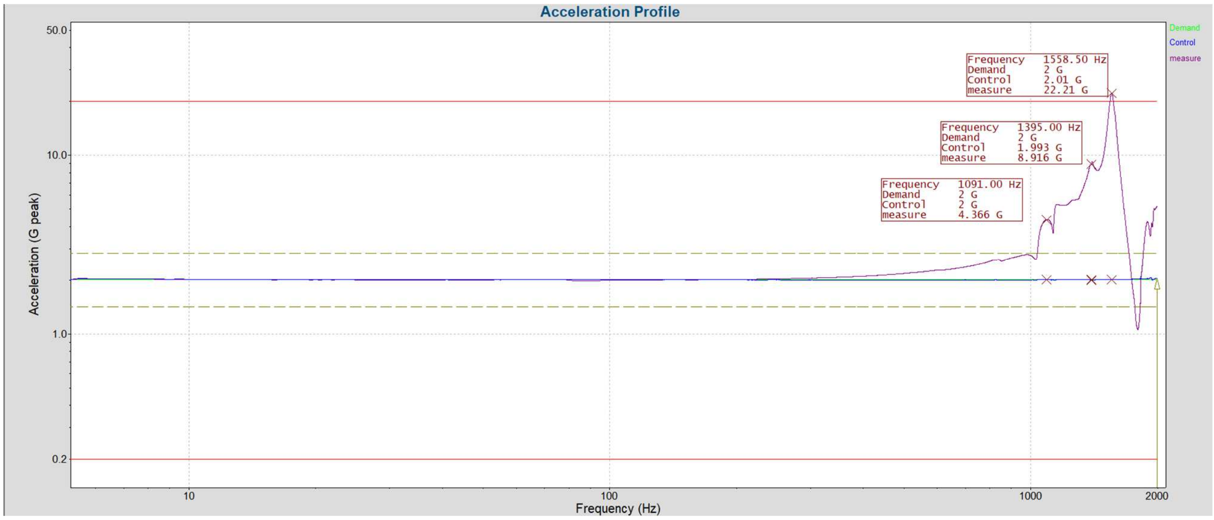
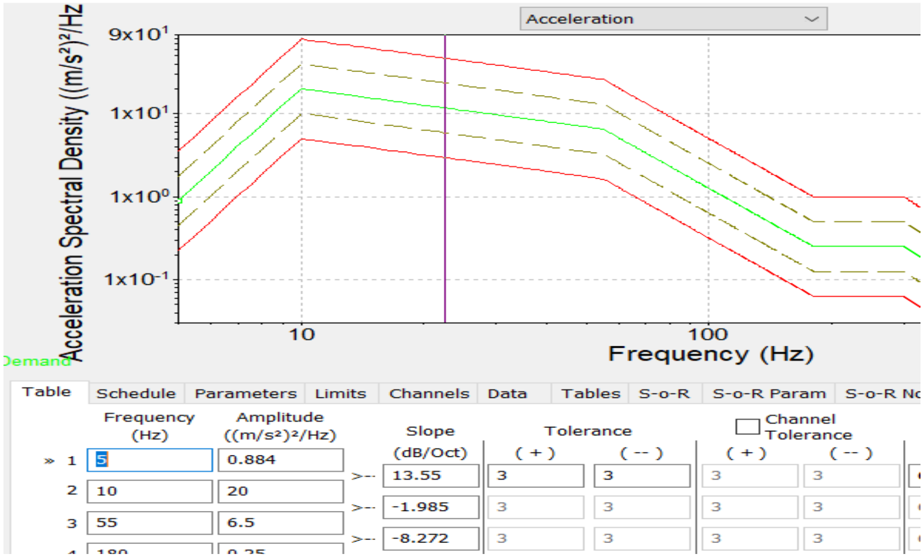
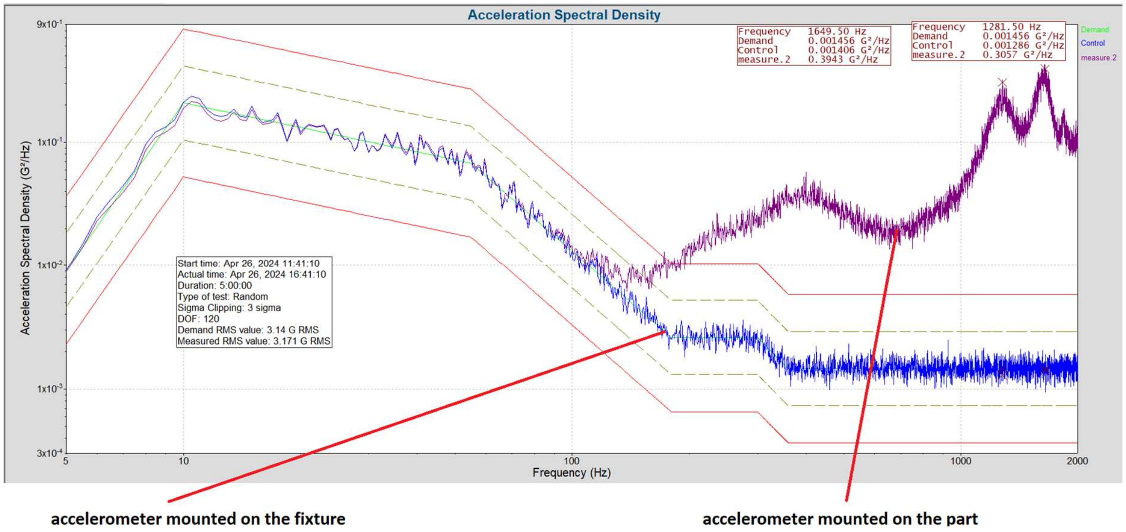


Fig. 10. Sine-sweep before random test results.



	Frequency (Hz)	Amplitude ((m/s²)²/Hz)	Slope (dB/Oct)	Tolerance (+)	Tolerance (--)	☐ Channel Tolerance (+)	Channel Tolerance (--)
» 1	5	0.884					
			13.55	3	3	3	3
2	10	20					
			-1.985	3	3	3	3
3	55	6.5					
			-8.272	3	3	3	3

Fig. 11. Random profile.



Start time: Apr 26, 2024 11:41:10
Actual time: Apr 26, 2024 16:41:10
Duration: 5:00:00
Type of test: Random
Sigma Clipping: 3 sigma
DOF: 120
Demand RMS value: 3.14 G RMS
Measured RMS value: 3.171 G RMS

accelerometer mounted on the fixture

accelerometer mounted on the part

Fig. 12. Random test results.

Table 2

Resonance Peaks Before Vibration Testing and Temperature.

Frequency (Hz)	Peak (G)
1091	4.36
1395	8.91
1558	22.21

After completing the sine-sweep test, profiles were created for the random vibration test and the temperature test (Table 2). For the random vibration and temperature tests, values were used that are typical for testing electronic products in the automotive industry. These tests aim to accelerate the aging of products to determine their lifespan and identify potential manufacturing defects before they enter the production process.

For the temperature test, a temperature profile was performed, starting from the ambient temperature of 25°C and increasing to 85°C at a rate of 1°C per minute. The product was exposed to a maximum temperature of four hours, followed by a decrease in temperature to 25°C at a rate of 1°C per minute. The total temperature test lasted 6 hours. The vibration test was conducted for a duration of 5 hours, long enough to reveal possible defects that could reduce the product's reliability.

For the vibration test, the following values were used, as described in Table 3, which fall within the range of 5-2000 Hz. After entering these values into the software of the shaker, a vibration profile will be generated (Fig. 11).

Following the test, the equipment used generated measurements based on the information provided by the measurement equipment. The graph is presented in Fig. 12.

Table 3

Frequency

Frequency (Hz)	PSD $(m/s^2)^2$/H
5	0.884
10	20
55	6.5
180	0.25
300	0.25
360	0.14
1000	0.14
2000	0.14
RMS acceleration	30.8 m/s^2

Table 4

Peaks measured random tests.

Frequency (Hz)	ASD (G^2/Hz)
1281.5	0.3057
1649.5	0.3943

Based on the results, it can be observed that the vibration values felt at the level of the tested piece are higher than those at the level of the fixture on which the piece is mounted. The accelerometer mounted on the product measures higher vibrations than the accelerometer mounted on the fixture on which the product is held due to the differences in how they are mounted and the resonance effects they produce in the testing system (Table 4).

These vibrations are influenced by the product's characteristics, such as mass, stiffness, and resonance frequencies, as well as how it is attached to the fixture. Fig. 13 presents the result of the temperature test, which shows a temperature graph with no unwanted deviations, the test ran according to the requirements.

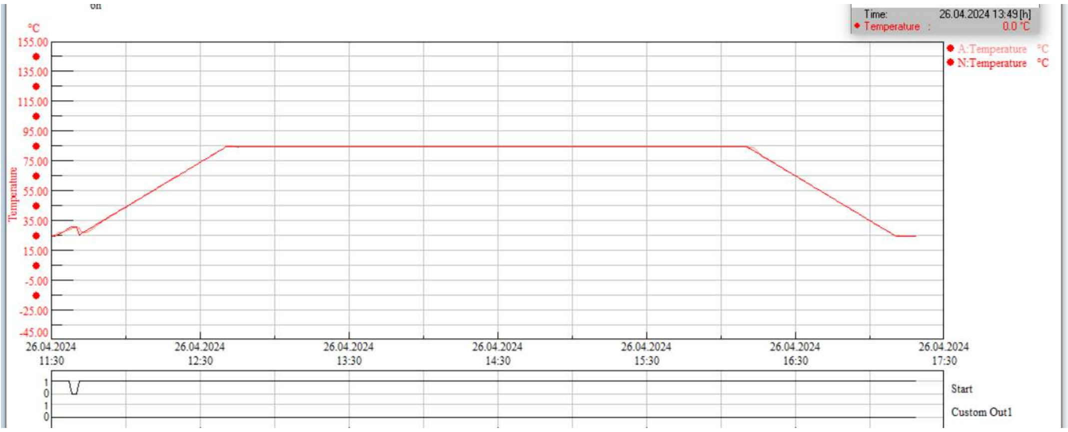


Fig. 13. Temperature test results.

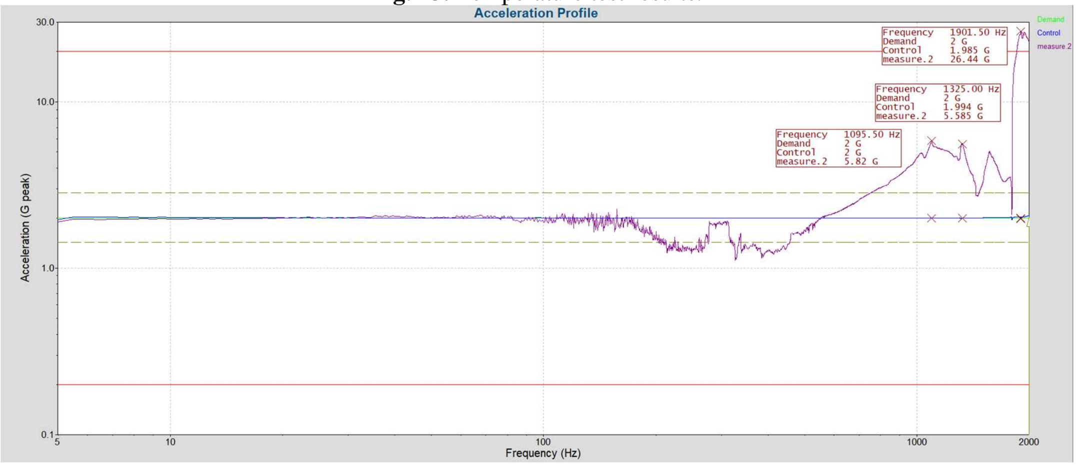


Fig. 14. Sine-sweep after random test results.

Table 5

Resonance Peaks After Vibration Testing and Temperature.

Frequency (Hz)	Peak (G)
1095.50	5.82
1325	5.58
1901	26.44

After completing the random vibration and temperature tests, another sine sweep test will be performed to see if the behavior of the tested piece changes. The profile and input parameters are the same as those used in the initial sine sweep test (Table 5). After the test was completed, these resonance points were detected.

5. CONCLUSIONS

Within the scope of this work, the reliability of the L9110S 4-Channel DC Motor Driver Board product was studied, with the behavior of the product under random vibration and high temperature solicitations being examined.

The purpose of the test was to discover any potential defects caused by the solicitations that occur in the product's life cycle.

In the case of reduced product reliability, the failure of the product would damage the user's integrity and ergonomics due to changes in the product's operation and handling of systems controlled by the product, which could generate risks and excessive demands on the human body.

Upon completing the test, the product does not show visible signs of mechanical defects.

The reliability test demonstrated that the product is capable of resisting random vibration and high temperature solicitations with minimal changes in resonance frequencies.

These results suggest that the product has high reliability and can be used in applications involving vibrations and high temperatures. Additionally, the product is designed to ensure high ergonomics, which is important for its users.

6. ACKNOWLEDGEMENTS

The research presented in this paper was supported by Vitesco Technologies Company.

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Fiabilitatea plăcii de control a motorului de curent continuu în condiții de vibrații aleatorii și temperaturi ridicate

Această lucrare investighează efectele combinate ale vibrațiilor mecanice și ale temperaturilor ridicate asupra unei componente electrice a unui vehicul electric. Acest studiu investighează fiabilitatea și ergonomia unei componente de placă de circuit imprimat (PCB) supuse la vibrații aleatorii și temperaturi ridicate. Componenta, un element important în vehiculul electric, este concepută pentru a funcționa în medii dure caracterizate de solicitări mecanice, fluctuații termice și vibrații aleatorii. Studiul subliniază importanța luării în considerare a interacțiunii dintre factorii de stres mecanici, termici și vibraționali în proiectarea și testarea componentelor PCB pentru vehicule electrice.

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