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IPC-TM-650 TEST METHODS MANUAL

1 Scope The Power Density Rating (PDR) for Embedded Resistors test method covers procedures for the demonstration of the ability to operate the embedded device safely, without a permanent change in the electrical characteristic of the device. The procedure consists of monitoring a resistance change from its nominal value as a function of the dissipated power. During the test, the applied voltage or current stimulus is held until the device temperature is stable, the steady resistance reading is reached, and the dissipated power is measured. This process is repeated with higher dissipated power until the measured resistance change exceeds the specification limits. The results are presented in terms of the dissipated power density rating (PDR) factor for the embedded resistive device.

This document describes testing procedure for power density rating of embedded resistive devices, which operate in complex electrical and thermal environments, and for which existing procedures are not adequate or inapplicable.

2 Applicable Documents

IPC-4811 Specification for Embedded Passive Device Resistor Materials for Rigid and Multilayer Printed Boards

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1.3 Ambient Conditions

3 Terminology When current passes through a resistor, electrical energy is dissipated by the resistor in the form of heat. A resistor can be used at any combination of voltage and current as long as its dissipating power (P) does not exceed the maximum power rating ($P_{\max}$) indicating how much power the resistor can convert into heat and absorb or/and transfer away without any damage to itself or to the surrounding circuitry.

3.1 Electrical Resistance, R

$$R = V / I \quad (1)$$

R is a ratio of voltage V over current I , (Ohm's law), the unit of measure is ohm [Ω].

3.2 Dissipated Power, P

Direct current (DC):

$$P = VI; \quad P = V^2 / R; \quad P = I^2 R \quad (2)$$

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Number 2.5.34	
Subject Power Density Rating for Embedded Resistors	
Date 07/12	Revision
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Alternating current (AC):

$$P = V^* I^* \cos(\varphi) \quad (3)$$

V^* and I^* are voltage and current amplitudes, and φ is the phase angle between V^* and I^* .

3.3 Power Density Rating The power density rating (PDR) is defined as the total dissipated power normalized by the effective surface area (heat flux cross sectional area).

$$PDR = P_{\max} / S \quad (4)$$

where, S is the area of the embedded resistor or device defined as one-side of the heat flux area.

3.4 Power Density Rating Comments

- The power that can be dissipated by a resistor is limited by the size of the resistor and the maximum operational temperature of the resistive material.
- The power ratings depend on thermal management of the heat generated from the resistor.
- The use of heat sinks can lower the device's operating temperature and consequently increase the power rating.
- Higher glass transition temperature laminate materials in which the resistive device is embedded can allow higher operating temperatures.

4 Test Specimen This method recommends testing the embedded resistors in configurations that reflect the actual functional application (Figure 1).

The recommended geometrical attributes of the embedded resistors are specified in the IPC-4811.

4.1 Sampling The sampling procedure for the tested specimen should be defined in the specification for that device. The sampling procedure should provide sufficient data to estimate the average quality and the variability of the lot being examined.

4.2 Conditioning The test results can be influenced by temperature, moisture content and other electrically active residuals originating from the processing conditions such as



IPC-TM-650		
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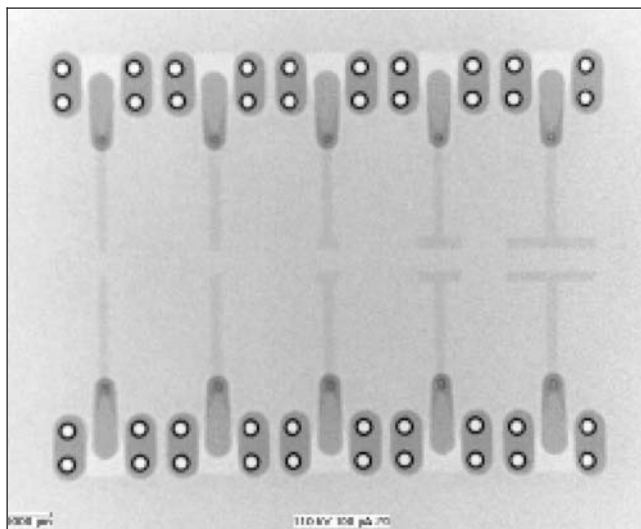


Figure 1 An X-Ray Image of Thin Film Resistors Embedded Inside a Printed Circuit Board

plating, circuit developing baths and soldering re-flows. Materials so affected should be brought to equilibrium with appropriate atmosphere and temperature control before testing. Description of the conditioning should be included in the testing report.

5 Apparatus The method requires a power source meter and electrical resistance meter, such as Keithley¹ Source Meter or equivalent, for sourcing the applied DC power and measuring the resulting current resistance. The resolution of resistance measurements should be in the range of about 0.1 Ω or better.

5.1 Power requirements The power capacity of the power sourcing instrumentation should be sufficient to maintain the test power until it reaches the value defined in the test failure/acceptance criteria where the specimen-maximum power will be dissipated. The voltage level should be stable to within $\pm 0.1\%$ of the set value during the testing time. An output current of 1 μA to 1 A is usually sufficient for most testing conditions. The power dissipated during the test may vary depending on the specimen resistance thermal characteristics, and the failure mechanism.

5.2 Circuit controls The apparatus should be equipped with a circuit breaking device with adjustable current/voltage

sensors, and be capable of disconnecting the power source in the case of overloading conditions. The current/voltage-sensing circuit should measure the specimen power and allow for adjustment consistent with the specimen characteristics. The sensing device should respond at the power level that is indicative of the test conditions reaching the failure criteria.

5.3 Power level controls The power level should be adjustable with the possibility of setting discrete power level values in at least 20 steps. It is recommended that the initial power P_0 is set at 1/10 of the nominal operational power of the device. A computerized experimental set-up is recommended to carry out the test.

In the case of sourcing voltage, the initial voltage, $V_0 = \sqrt{0.1 * P_{nom} * R_0}$. For example, if the initial value of $R_0 = 50 \Omega$ and $P_{nom} = 0.1 \text{ W}$ then the initial voltage V_0 corresponding to 0.1 of P_{nom} (i.e., $P_0 = 0.010 \text{ W}$), is $\sqrt{0.1 * 0.1 \text{ W} * 50 \Omega} \approx 0.7 \text{ V}$. The voltage level V_n should be increased in steps of $V_s \leq V_0$, each step having duration of about 60 s. The specimen current I_n should be monitored and recorded at every power step (see 5.3.1).

In the case of sourcing current, the initial current, $I_0 = \sqrt{0.1 * P_{nom} / R_0}$. For example, if the initial value of $R_0 = 50 \Omega$ and $P_{nom} = 0.1 \text{ W}$, then the initial voltage V_0 corresponding to 0.1 of P_{nom} (i.e., $P_0 = 0.010 \text{ W}$), is $\sqrt{0.1 * 0.1 \text{ W} / 50 \Omega} \approx 0.014 \text{ A}$. The current level I_n should be increased in steps of $I_s \leq I_0$, each step having a duration of about 60 s. The specimen voltage V_n should be monitored and recorded at every power step (see 5.3.2).

5.3.1 Linear Voltage Steps Increasing voltage in constant voltage steps will result in a quadratic increase of power. At the n_{th} voltage step the power P_n is given by (5):

$$P_n = (V_0 + nV_s)^2 / R_n \quad (5)$$

Example: $R_n = R_0 = 50 \Omega$, $V_0 = 0.7 \text{ V}$, $V_s = 0.3 \text{ V}$. At $n = 11$ step $V_{11} = 4 \text{ V}$ and the corresponding applied power $P_{11} = (0.7 \text{ V} + 11 * 0.3 \text{ V})^2 / 50 \Omega = 0.32 \text{ W}$.

5.3.2 Linear Current Steps Increasing current from I_0 by adding a constant current step, I_s , will result in a quadratic increase of applied power. At the n_{th} current step the power P_n is given by (6):

$$P_n = (I_0 + nI_s)^2 * R_n \quad (6)$$

1. Certain commercial equipment and materials are identified in this document in order to specify adequately the experimental procedure. In no case does such identification imply recommendations nor does it imply that the material or equipment identified is necessarily the best available for this purpose.