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APPLICATION OF INFRARED THERMOGRAPHY TO NON-CONTACT TESTING OF AD/DC POWER SUPPLY

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Abstract. *Testing of AC/DC power supplies using the thermography was carried out in order to assess their assembly and operation correctness before launching them on the market. The investigation was carried out for 17 AC/DC power supplies which passed the standard tests (measurements of their basic parameters and characteristics). The investigation consisted of two steps. In the first step the dispersion of temperature on power supply boards was measured after 20 minutes operating in nominal conditions. Three regions were defined as potentially revealing a failure. In the second step the acceptable temperature increments on the boards of tested power supplies were evaluated. It was proposed to assess properties of power supplies on the basis of temperature increments on their boards, registered by an infrared camera either for 12 minutes or up to 20 minutes*.

Key words: *thermography, testing, power supply*

1. Introduction

Diagnostics of electronic systems is an actual problem of their manufacturing. Particularly significant are such testing and fault identification methods that enable diagnostics without interfering with a tested system or tested components. The examples of such solutions (non-destructive testing) are: quality (reliability) evaluation on the basis of inherent noise [1-7], Resonant Ultrasound Spectroscopy technique [8] or infrared thermography inspections [9-16].

The thermographic technology offers very advantageous conditions for assessing properties of single components, parts of systems, as well as whole systems and also for detection of faults and defects on electronics boards [9-16]. Using an infrared camera allows for the non-contact inspection of a tested object within the infrared radiation range. Emission of the infrared radiation can be recorded without any interference with a diagnosed single component, whole system or its part.

All components of the power supply mounted on the board are sources of radiation. Each of these components has its own specified emissivity coefficient, which depends on

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its structure. It was assumed that the properly constructed components have similar coefficients of emissivity and that they will affect the temperature dispersion across the board only in a specific small range. A defective component or a defective assembly of the component will case anomalous temperatures.

The mounted components are mainly SMDs.

In the paper, applying the infrared thermography for the quality diagnosis of an AC/DC power supply for a fire station (U = 18 V, I = 3 A) is proposed. The diagnosis consists in the identification of a faulted component or part of a faulted system. In the paper an AC/DC power supply is abbreviated to 'a power supply'.

2. Thermography Inspection of AC/DC Power Supply

A procedure of the power supply inspection, applying the well-known thermographic technique is proposed, in order to determine the quality of every manufactured power supply (the correctness of assembly and operation), before launching it on the market.

The thermographic method enables a non-contact measurement of the inspected surface temperature, in this case - the surface of a power supply board. We assume that an incorrect assembly or an improper operation of a tested power supply will be indicated by an increase of its temperature. At the beginning of the thermographic investigations, in the first step, the typical temperature dispersion for a few high quality power supply boards was evaluated.

The analysis of measurement results of the temperature dispersion (thermograms) enables recognizing regions with highest local temperatures of a power supply board. These regions have to be inspected if the thermograms reveal some improprieties. In this case, an investigated power supply may be not classified as operating properly. As a result, the research will determine thermographic test duration.

In the second step, the temperature increment measurement technique is used during the power supply operation, i.e. comparing temperature increments at the test starting moment $t = t_0$ and in successive moments $t = t_i$, where $i = 1, 2, \ldots, N$, and N is the number of observations (measurements) with an infrared camera till the end of testing, i.e. to $t = t_N$.

It was assumed that at the moment $t = t_0$ the temperature increment on the power supply board is constant, i.e. $T_{max0} - T_{min0} = \Delta T_0 = 0$. It was also assumed that T_{maxi} and T_{mini} are, respectively, the maximum and minimum temperature values appearing on the board at the moments t_i, where $i = 0, 1, 2, \ldots, N$. After starting the inspection procedure, the temperature on the board starts changing and at successive moments $t = t_i$ temperature increments occur on the board; they are defined as: $T_{maxi} - T_{mini} = \Delta T_i$, where $i = 1, 2, \ldots, N$. The temperature increment values can be easy determined from the thermograms and enable comparisons of region properties during testing independently of their individual emission coefficients. The aim of investigation was to determine the time moment, t_i, after turn on the power supply in terms of the effectiveness of detective of improper operating power supply.

The thermograms during investigations were carried out with a VIGO System S.A.'s VigoCam v50 infrared camera equipped with a 35 mm lens, and the tested power supply boards were situated at the distance of 0.97 m. The dimensions of the observed surfaces of tested boards were: 73.5 mm x 105 mm. The relevant parameters of the infrared camera are summarized in Table 1 [17].

Table 1 Relevant parameters of VigoCAM v50 camera [17]

Parameter	Value/Function description
Detector type	Non-cooled bolometric matrix (FPA)
Spectrum range	8÷14 μm
Thermal resolution	≤ 0.065°C (for temperature 30°C)

To determine the properties of power supplies (AC/DC power supplies for a fire station: U = 18 V, I = 3 A) the infrared thermography was used after a preliminary standard test of the power supplies was performed. The tested power supplies are assumed to be operating properly during the standard tests (measurements of basic parameters and characteristics of the power supplies).

3. Results of Investigation

The investigation was carried out for 17 power supplies which passed successfully the standard tests consisting of measurements of their basic parameters and characteristics.

The investigations consist of:

in the first step:

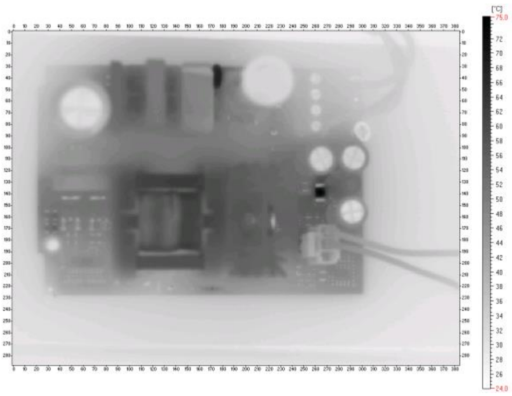
- the thermography inspection of the tested power supplies (the dispersion of temperature) after operating in nominal conditions after 20 minutes,
- determining the regions with the maximum temperature values,
- evaluating the regions with the maximum local temperature values,

in the second step:

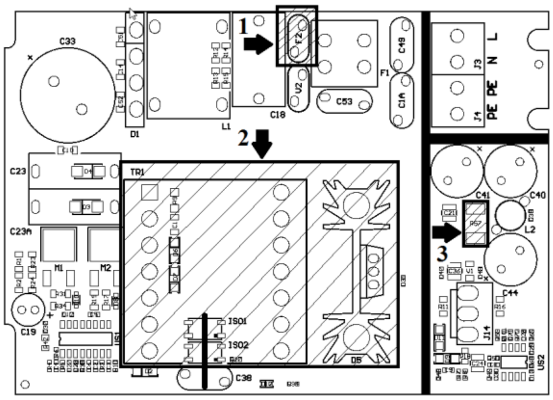
- the thermography inspection of the tested power supplies during operating (the temperature increment measurement),
- the elaboration of rules for the classification of power supplies for the sake of their quality.

For investigated power supply the standard test duration (measurements of basic parameters and characteristics) is equal to 20 minutes; it is typical for examination of these power supplies. The temperature dispersion on the tested power supply board was checked after their 20, 40 and 180 minutes operation in normal conditions. Thermograms revealed that the temperature dispersion on the board after 20 minutes is stable.

In Fig. 1a the thermogram of the power supply No. 3, taken after 20 minutes operating in nominal conditions is presented, the maximum temperature is equal to 75°C. Three regions with the highest local temperatures were recognized and they are marked on the power supply board, as presented in Fig. 1b. One can expect that components operating in these regions will be the reason of a possible failure (this is most likely). Of course, the increase of the temperature of the board may also result from a failure of any component located in other regions of the board.



a)



b)

Fig. 1 The inspected power supply No. 3:
a) thermogram taken after 20 minutes operating in nominal conditions,
b) power supply board with the highest temperature regions marked:
1 –thermistor, 2 –main transformer, 3 –resistor.

For the evaluation of the local maximum temperature values in the selected regions, the temperatures were measured during 20 minutes of operating of power supplies, after their earlier 20 minutes operation (stable state). The maximum temperatures for the investigated power supply were as follows: region 1 – 62,5^{o}C, region 2 – 56^{o}C, region 3 – 65^{o}C, and the dispersion of these local maximum temperatures were estimated as 5^{o}C for regions 1 and 3, and about 7^{o}C for region 2. The thermal data of thermistors, transformers and resistors applied in this type of power supplies are collected in Table 2.

The maximum temperatures of components taken from the technical data are higher than the measured ones in the investigated power supplies. It was found that the local maximum temperatures for every one of high quality power supplies can be similar.

The inspection period equal to 20 minutes of power supply operating has been chosen for the second step.

Table 2 Thermal data of power supply components

Component	Temperature [°C]		Remarks
	Minimum	Maximum	
Thermistor	-55	+200	Made to order
Transformer	-40	+125	
Resistor	-55	+155	

The second step of examining 17 power supplies was concerned on the temperature increment measurements. The thermograms of power supply boards were taken by an infrared camera during 20 minutes of operating, after turning on a power supply. The number of measurement points was equal to N = 10; the measurements were taken every 2 minutes. The results of the temperature increment measurements on the tested boards surface are presented in Fig. 2.

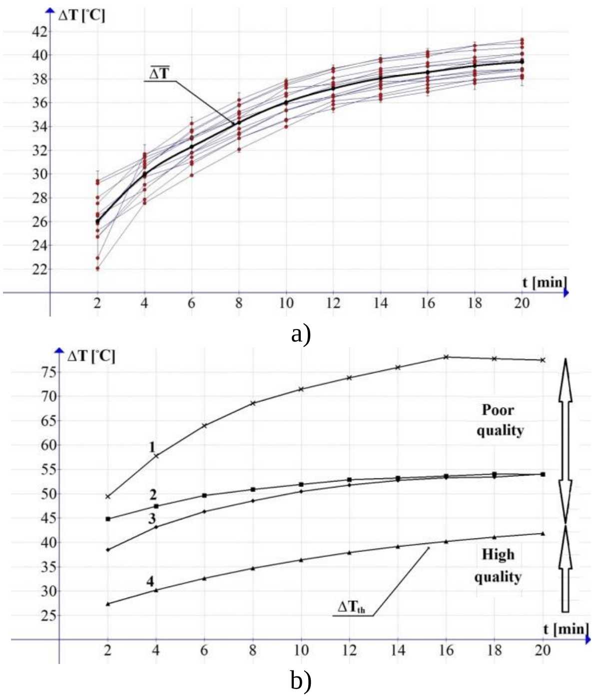


Fig. 2 The temperature increments ΔT for:

a) 14 power supplies with similar temperature conditions, $\overline{\Delta T}$ – the mean heating characteristic,

b) the power supply No. 16 – curve 1, No. 17 – curve 2, No. 8 – curve 3, ΔT_{th} – the threshold heating characteristic – curve 4.

In Fig. 2a results of the temperature increments for 14 power supplies are presented. It is easy to recognize that the values of temperature increments for all measurement points are similar. The mean value of these measurement results is presented in Fig. 2a. Formally, it is *the mean heating characteristic* $\overline{\Delta T}$ of the investigated power supplies. The standard uncertainty u of $\overline{\Delta T}$ values at measurement points (Fig. 2a) is greater for the starting point i = 1 (i.e. for t_1 = 2 min), and smaller for final points i = 8, 9, 10 (i.e. for t_8 = 16 min, t_9 = 18 min, t_{10} = 20 min), and is equal to $u_1 = \pm 4{,}6^{o}$C, $u_8 = \pm 2{,}5^{o}$C $u_9 = \pm 2{,}4^{o}$C, and $u_{10} = \pm 2{,}3^{o}$C, respectively.

The *mean heating characteristic* $\overline{\Delta T}$ was approximated on the basis of measurement results by the relation:

$$\overline{\Delta T} = 22 + 22\,[1 - \exp(-\frac{t}{12})] \tag{3.1}$$

This relation was estimated for time t ≥ 2 min.

To the relation (3.1) at every measurement point the calculated standard uncertainty u_i (i = 1, 2, …, 10) was added. This characteristic was approximated by the below relation, called the threshold heating characteristic ΔT_{th}:

$$\Delta T_{th} = 24 + 22\,[1 - \exp(-\frac{t}{12})] \tag{3.2}$$

The relation (3.2), as ΔT_{th} is presented in Fig. 2b, as curve 4. The value of ΔT_{th} evaluated for t = 12 minutes or 20 minutes, enables evaluation the quality of investigated power supply according to the following classification rules:

$\Delta T \leq 38^{o}$C - a high quality power supply
 ΔT evaluated for t = 12 min
$\Delta T > 38^{o}$C - a poor quality power supply
or (3.3)
$\Delta T \leq 42^{o}$C - a high quality power supply
 ΔT evaluated for t = 20 min
$\Delta T > 42^{o}$C - a poor quality power supply

where:
38^{o}C, and 42^{o}C are the threshold heating values of temperature increments for the above test durations, respectively, see Fig. 2b, and
ΔT is the value of temperature increment evaluated for the investigated power supply after its operation for 12, and 20 minutes, respectively.

If the temperature increment at t_6 = 12 minutes is higher than 38^{o}C, it means that the investigated power supply has to be additionally examined, especially its components from three defined regions. In such a case we propose to perform a quality procedure by the infrared thermography inspection, which takes only 12 minutes of operation of the investigated power supply.

A different value of ΔT_{th} can be also applied in the classification rules (3.3), but for a suitable time of power supply operating, for example ΔT_{th} equal to 41^{o}C at t = 16 minutes.

It was surprising that for 3 power supplies (No. 8, No. 16 and No.17) the results of temperature increment measurements totally differed from those obtained for the rest 14 power supplies. All power supplies are assumed to be operating properly during the standard tests. The results of temperature increment measurements for power supplies No. 16, No. 17 and No. 8 are presented in Fig. 2b, as curves 1, 2, 3, respectively. Especially surprising is the result of the temperature increment measurements for the power supply No. 16. After 20 minutes of operating the temperature increment was equal to 77^{o}C.

For the power supplies No. 8, No. 16 and No. 17, very detailed measurements of their parameters, and characteristics were carried out, supplemented by the mechanical inspection of transformers. It was found that the problem lied in the construction of transformers (the transformer core being unglued – No. 8 and No. 17, and an asymmetrical winding on the transformer core – No. 16).

As can be seen (Fig. 2b, curves 1, 2, 3), the temperature increment levels for the power supplies No. 16, No. 17 and No. 8, from the beginning of measurements are significantly higher than the threshold heating characteristic ΔT_{th} (Fig. 2b, curve 4). If the classification rules (3.3) are applied, these power supplies will be classified as poor quality power supplies.

Below, the other case of failure has been described. The thermistor failure was triggered off (catastrophic failure, short circuit) after 8 minutes of power supply operation. The results of the temperature increments measurements of this power supply are presented in Fig. 3.

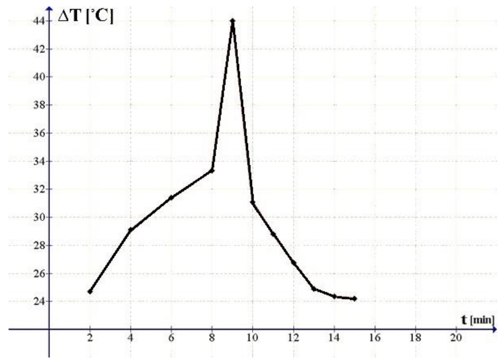


Fig. 3 Temperature increments ΔT for power supply for which the fail of thermistor was triggered off after 8 minutes of power supply operating.

The temperature increment rapidly increased at t_4 = 8 minutes, and then it rapidly decreased and this incident brought the total failure of the investigated power supply. Changing ΔT as a function of time from the measurement starting point t = 2 minutes to the point t = 8 minutes, after turning on the investigated power supply, is compatible with the characteristics of the heating power supplies (Fig. 2a). The experiment showed that the thermistor damage results in a temporary increase of the temperature of the investigated power supply board. The presumption is that such damage may occur at any time during the power supply operation. Therefore, it is difficult to detect such damage during the first minutes of its operation (but, of course, it is also possible). In this case the temperature increment ΔT, measured on the power supply board in time t = 12 minutes is smaller than the threshold value ΔT_{th} of heating characteristics. This is an indication that some component of the power supply was destroyed.

3. Conclusion

The investigations carried out for AC/DC power supplies revealed a necessity of evaluating their quality.

To sum up, checking the quality of power supplies within the period from 12 minutes to 20 minutes consists in determining whether the temperature increment ΔT on the board is the correct one or if it exceeds the threshold value. If ΔT is greater than the threshold value, detailed tests must be carried out in order to find what has been damaged.

If the temperature increments are in order of 24^{o}C after 12 minutes of power supply operating, it means that the classification rules (3.3) are not satisfied. In this case some catastrophic failure of components can be expected.

The described procedure is used for AC/DC power supplies testing before launching them on the market.

The proposed scenario of the thermographic investigation can be applied for other systems. All steps of the investigation should be realized.

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