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Contents

Volume 100
Issue 1
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ISSN 1726-5479

Editorial

International Frequency Sensor Association (IFSA) Celebrates the 10th Anniversary I
Sergey Y. Yurish

Research Articles

A Log Amplifier Based Linearization Scheme for Thermocouples
Nikhil Mondal, A. Abudhahir, Sourav Kanti Jana,Sugata Munshi and D. P. Bhattacharya 1

Uncertainty Analysis of Thermocouple Circuits
B. Vasuki, M. Umapathy, S. K. Velumani 11

Calibration System for Thermocouple Testing
Dragan R. Milivojevic, Visa Tasic, Marijana Pavlov, Zoran Andjelkovic 16

Embedded Processor Based Automatic Temperature Control of VLSI Chips
Narasimha Murthy Yayavaram, Saritha Chappidi, Sukanya Velamakuri 27

Field of Temperature Measurement by Virtual Instrumentation
Libor Hargaš, Dušan Koniar, Miroslav Hrianka, Jozef Čuntala 45

Analyzing Electroencephalogram Signal Using EEG Lab
Mukesh Bhardwaj and Avtar. K. Nadir 51

New Aspects in Respiratory Epithelium Diagnostics Using Virtual Instrumentation
Dušan Koniar, Libor Hargaš, Miroslav Hrianka, Peter Bánovčin 58

A PC-based Technique to Measure the Thermal Conductivity of Solid Materials
Alety Sridevireddy, K. Raghavendra Rao. 65

A New Wide Frequency Band Capacitance Transducer with Application to Measuring Metal Fill Time
Wael Deabes, Mohamed Abdelrahman, and Periasamy K. Rajan 72

A Novel Hall Effect Sensor Using Elaborate Offset Cancellation Method
Vlassis N. Petoussis, Panos D. Dimitropoulos and George Stamoulis 85

A Review of Material Properties Estimation Using Eddy Current Testing and Capacitor Imaging
Mohd. Amri Yunus, S. C. Mukhopadhyay and G. Sen Gupta 92

Surface Plasmon Resonance Based Fiber Optic Sensor with Symmetric and Asymmetric Metallic Coatings: a Comparative Study
Smita Singh, Rajneesh K. Verma and B. D. Gupta 116

Increasing of Excursion Range of Absolute Optical Sensors Intended for Positioners
Igor Friedland, Ioseph Gurwich, Amit Brandes.. 125

Field-Effect-Transistor Behavior of a Multiwall Carbon Nano Fiber Directly Grown on Nickel Electrodes
L. W. Chang, P. S. Wu, J. T. Lue and Z. P. Chen.. 137

Classification of Fiber-Optic Pressure Sensors with Amplitude Modulation of Optical Signal
Vladyslav Kondratov, Vitalii Redko.. 146

New e-Book

Laboratories of Instrumentation for Measurement
Maria Teresa Restivo, Fernando Gomes de Almeida, Maria de Fátima Chouzal, Joaquim Gabriel Mendes, António Mendes Lopes.. 161

Authors are encouraged to submit article in MS Word (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com
Please visit journal's webpage with preparation instructions: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm

Sensors & Transducers Journal, Vol. 100, Issue 1, January 2009, pp. 45-50

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Field of Temperature Measurement by Virtual Instrumentation

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Abstract: This paper introduces about temperature determination for given dot of picture through image analysis. Heat transfer is the transition of thermal energy from a heated item to a cooler item. Main method of measurement of temperature in image is Pattern Matching, color scale detection and model detection. We can measure temperature dependency at time for selected point of thermo vision images. This measurement gives idea about the heat transfer at time dependences. *Copyright © 2009 IFSA.*

Keywords: Thermal analysis, Pattern matching, LabVIEW

1. Heat Transfer Physical Problems

Heat transfers in a subject are defined as the movement of energy due to a difference in temperature. When an object or fluid is at a different temperature than its surroundings or another object, transfer of thermal energy, also known as heat transfer, or heat exchange, occurs in such a way that the body and the surroundings reach thermal equilibrium [1]. It is known the following three physical mechanisms, all of which the heat transfer executes:

1.1. Conduction

Heat conduction takes place through different mechanisms in different media. Theoretically it takes place in a gas, in a fluid and in metals. A typical property for heat conduction is that the heat flux is proportional to the temperature gradient.

1.2. Convection

Heat convection takes place through the net displacement of a fluid, which transports the heat content in a fluid through the fluid's own velocity. The term convection is also used for the heat dissipation from a solid surface to a fluid, where the heat transfer coefficient and the temperature difference across a fictive film describe the flux.

1.3. Radiation

Heat transfer by radiation takes place through the transport of photons, which solid surfaces can absorb or reflect. There is surface-to-surface radiation, which accounts for shadowing and diffuse reflections between radiating surfaces. There is also surface-to-ambient radiation where the ambient surroundings are treated as a black body with known temperature.

1.4. Heat Equation

The fundamental law describing all heat transfer is the first law of thermodynamics. This is the basic principle of conservation of energy. However, internal energy is a rather inconvenient quantity to measure.

Therefore, the basic law is usually rewritten in terms of temperature, T:

$$\rho C_p\left(\frac{\partial T}{\partial t}+(\mathbf{u}.\nabla)T\right)=-(\nabla.\mathbf{q})+\tau : \mathbf{S}-\frac{T}{\rho}\frac{\partial \rho}{\partial t}\bigg|_p\left(\frac{\partial p}{\partial t}+(\mathbf{u}.\nabla)p\right)+Q$$

where:
ρ - density (kg/m^3),
C_p - specific heat capacity at constant pressure (J/(kg·K)),
T - absolute temperature (K),
u - velocity vector (m/s),
q - heat flux by conduction (W/m^2),
p - pressure (Pa),
τ - viscous stress tensor (Pa),
S - strain rate tensor (1/s):

$$\mathbf{S}=\frac{1}{2}\left(\nabla\mathbf{u}+(\nabla\mathbf{u})^T\right)$$

Q - contains heat sources other than viscous heating (W/m^3).

The fundamental law uses Fourier's law of conduction:

$$q_i=-k\frac{\partial T}{\partial x_i},$$

which states that the conductive heat flux, q, is proportional to the temperature gradient;
k - thermal conductivity (W/(m·K)).

In a solid, the thermal conductivity can be different in different directions. Then k becomes a tensor. For 3D:

$$k = \begin{bmatrix} k_{xx} & k_{xy} & k_{xz} \\ k_{yx} & k_{yy} & k_{yz} \\ k_{zx} & k_{zy} & k_{zz} \end{bmatrix}.$$

The heat equation accepts two basic types of boundary conditions:

- specified temperature;
- specified heat flux.

The former conditions are of Dirichlet types and prescribe the temperature at a boundary:
$T = T_0$,

T_0 -boundary Temperature, or specifies the inward heat flux: $n.q = q_0$, where
q is the total heat flux vector (W/m^2);
n is the normal vector of the boundary;
q_0 is the inward heat flux (W/m^2), normal to the boundary.

2. Pattern Matching

Pattern matching quickly locates regions of a grayscale image that match a known reference pattern, also referred to as a model or template. When using pattern matching, we must create a template that represents the object for which we are searching. Application then searches for instances of the template in each acquired image, calculating a score for each match. This score relates how closely the template resembles the located matches [2].

Pattern matching finds template matches regardless of lighting variation, blur, noise, and geometric transformations such as shifting, rotation, or scaling of the template. These algorithms are some of the most important functions in machine vision because of their use in varying applications.

Pattern matching provides application with the number of instances and the locations of template matches within an inspection image. For example, we can search an image containing a printed circuit board (PCB) for one or more fiducially marks. The machine vision application uses the fiducially marks to align the board for chip placement from a chip mounting device. Searching for and finding image features is the key processing task that determines the success of many gauging applications.

Pattern matching techniques include normalized cross-correlation, pyramidal matching, scale- and rotation-invariant matching, and image understanding. Normalized cross-correlation is the most common method for finding a template in an image. This is shown in Fig. 1. Because the underlying mechanism for correlation is based on a series of multiplication operations, the correlation process is time consuming. To increase the speed of the matching process, reduce the size of the image and restrict the region of the image in which the matching occurs. [3], [4].

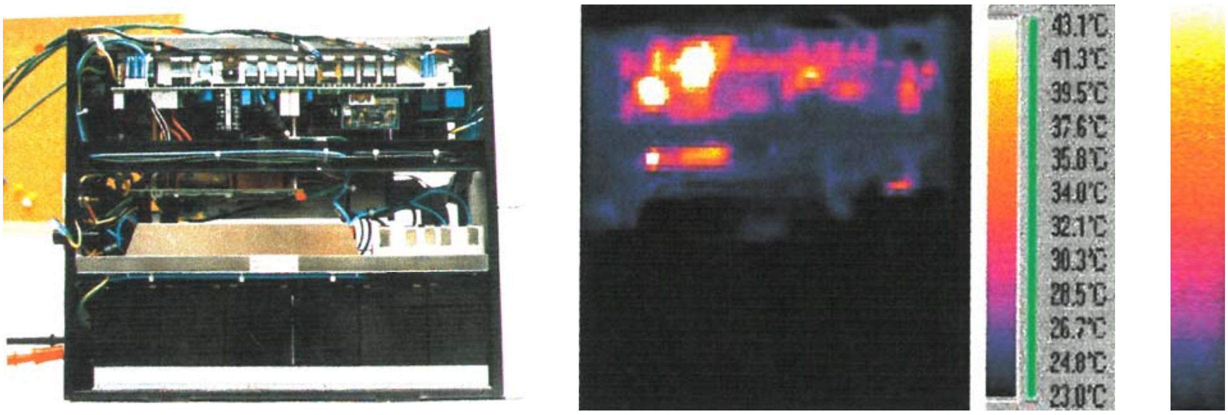
Consider a subimage $w(x, y)$ of size $K \times L$ within an image $f(x, y)$ of size $M \times N$, where $K \le M$ and $L \le N$. The correlation between $w(x, y)$ and $f(x, y)$ at a point (i, j) is given by

$$C(i, j) = \sum_{x=0}^{L-1} \sum_{y=0}^{K-1} w(x, y)\, f(x+i, y+j),$$

where $i = 0,1,\ldots M-1$, $j = 0,1\ldots N-1$, and the summation is taken over the region in the image where *w* and *f* overlap.

3. Sampling of Measured Thermal Data

This measurement serves for temperature determination for given dot of picture through image analysis for back-up power supply (Fig. 1). Measurement is realized based on knowledge of color scale from image. In principle we were trying to measure the temperature from chosen dots of picture that has been scanned by thermo – vision camera. Because the time – sequence of pictures exists, then we were able to determine the change of temperature in given dot in time – dependency.



a) b) c)

Fig. 1. Example of analyzed device (back-up power supply (a), thermal image (b) and template (c).

Principle of measurement outgoes from next considerations. Picture consists from pixels (Picture dots), whereby every dot is related with certain value of color, that is expressed by numerical information. Because every colored picture consists from color areas (mostly RGB model occurs), it is necessary to distribute this information into three fields. By distributing numerical information we are able to reach values of picture's dot. Also information about dot's placement (axes) that are serving for interpretation of temperature is able to be obtained in this way. The front panel of application is in Fig. 2.

For temperature assignment to picture dot (Fig. 3), it is necessary to find-out placement of colored scale and adequate temperature scale. Placement of colored scale is being found – out based on comparison of object's shapes method (pattern matching). Range of temperature corresponding to given scale is entered manually.

Before beginning of analysis, we are defining object which creates the color scale. Then at the process of plotting the temperature is assigned to individual dots based on mentioned scale. Principle of analysis is that after discover of placement of color scale, the selected area of picture is transformed into numerical field. That means that numerical intervals are being created, which corresponds to certain temperature range. Individual elements of field are consequently compared with numerical values of chosen dots. When the match is found between numerical value and interval that is obtained from field representing color scale, then temperature value is added to dot.

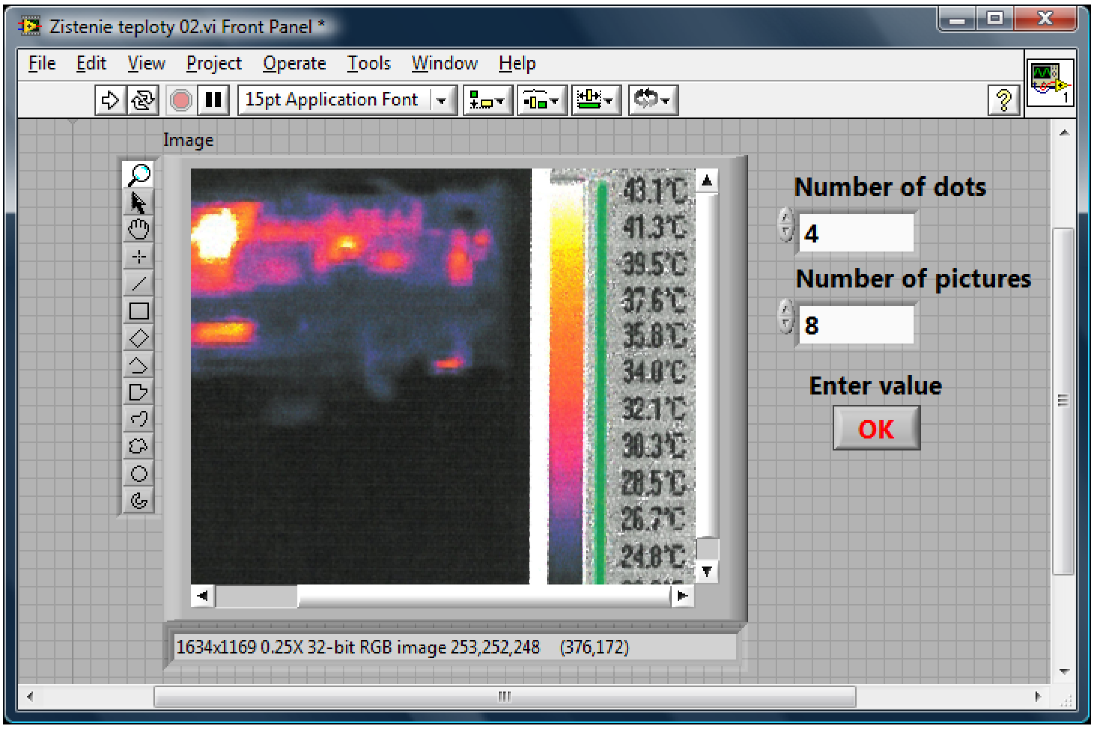


Fig. 2. Thermal analyzing application front panel.

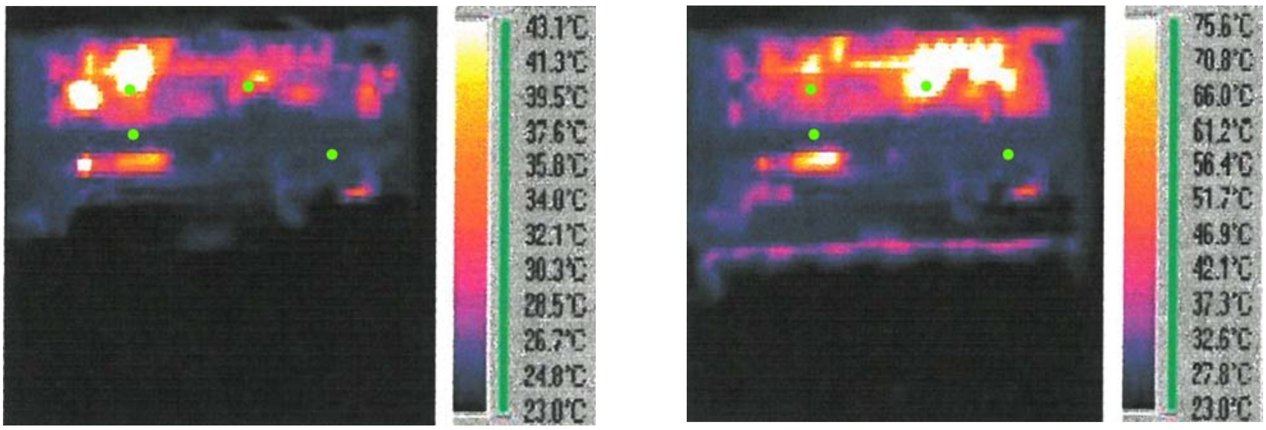


Fig. 3. Selected points (green dots) for temperature measurement.

This process is applied for all dots that are chosen. Because at selection of place for temperature measurement we also discovered values of axes of measured dots, we can apply this process automatically for different pictures from time sequence of measurement. So this process helps us to determine the temperature distribution in given dot in dependency of measurement time. The time dependency of temperature for selected dots is in Fig. 4.

4. Conclusions

Heat transfer for power supply is very important parameter. If the temperature of device is very high, it could be dangerous. The devices on semiconductor base may be destroyed with this process. Measurement of temperature fields can be helpful in the process of circuits design. We can simulate heat transfer in some software (e.g. COMSOL), but the verification of simulation must be done. In this paper is describing the verification using thermal camera and image analysis of thermal image. We can determine the time dependency of temperature by this method. We can also determine whether the cooler is necessary. The placement of cooler can be designed for these circuits.

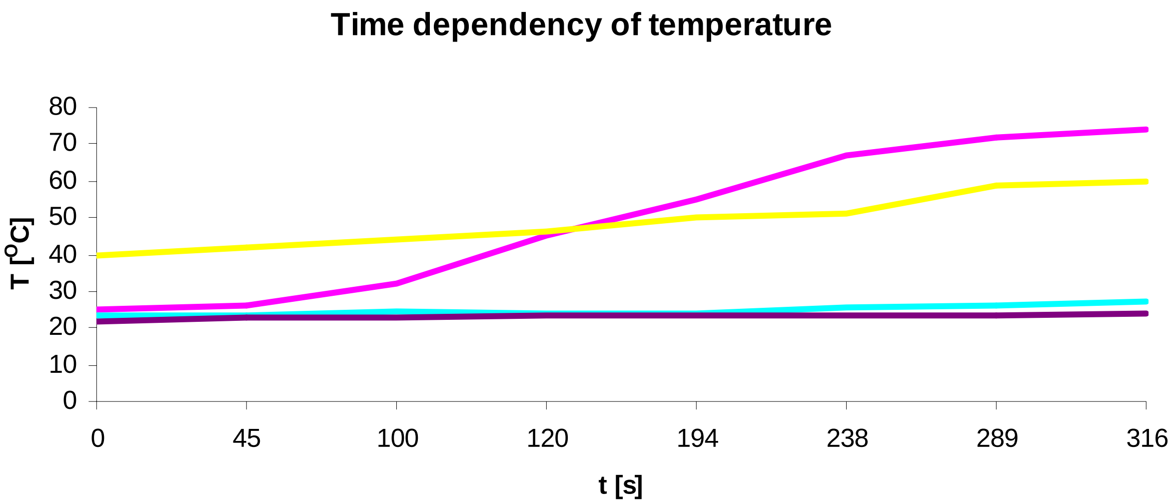


Fig. 4. The time dependency of temperature for selected dots.

Acknowledgements

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

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