

TempVIEW – A Low-Cost Thermal Imaging System Using LabVIEW and IMAQ Vision

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The Challenge: Accurately measuring and interpreting the absolute temperature distributions of thermochromic liquid crystal (TLC) thermographs using proven technology.

The Solution: Developing a cost-effective, PC-based flexible thermal imaging system using National Instruments IMAQ Vision software with LabVIEW, the LabVIEW Picture Control Toolkit, and Application Builder.

Introduction

Over the past 30 years, thermochromic liquid crystal (TLC)-based thermography systems have provided engineers with a relatively inexpensive technique for investigating thermal phenomena in the electronics, automotive, and aerospace industries, as well as in academia. But they used systems built in-house for custom applications – neither designed nor intended for commercial use.

Enter TempVIEW

Image Therm Engineering (Waltham, MA), a National Instruments Alliance Program member, took the proven TLC technology they helped to develop at the Stanford University Mechanical Engineering Department and combined it with LabVIEW and IMAQ Vision software to build TempVIEW, a flexible and powerful temperature measurement tool for a wide range of commercial and laboratory applications.

We developed TempVIEW using LabVIEW and IMAQ Vision software because they provide the ideal combination of powerful image processing, RS-232 communications, and GUI design/implementation tools in a platform-independent integrated development environment. With the software modularity of the LabVIEW data-flow programming approach and the powerful image processing tools of IMAQ Vision,

we quickly developed thermography and imaging tools used both in TempVIEW and in custom-built TLC-based imaging systems for clients.

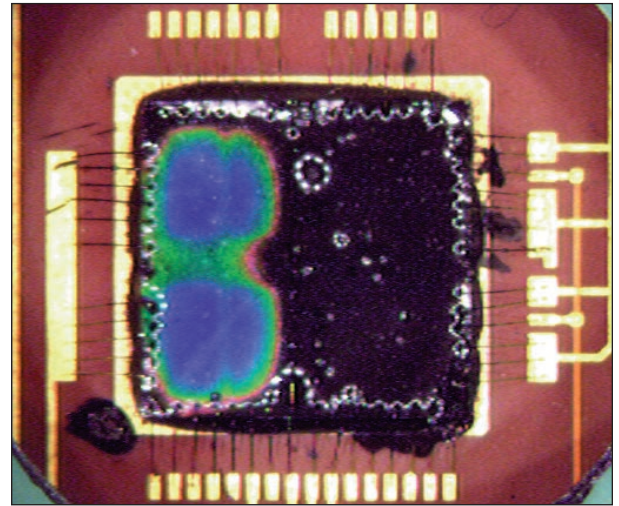
TempVIEW is a turnkey system operating on desktop Windows PCs (486 or Pentium), with a Mac OS version available on request. TempVIEW includes a plug-in color image acquisition board, color CCD camera with appropriate optics, TLC color-temperature calibration module, TLC materials, and white light source. With the LabVIEW graphical user interface, users can simplify setup, acquisition, processing, and analysis of thermographs.

Using TLC Color Response for Temperature Measurement

At the heart of TempVIEW are thermochromic liquid crystals (TLCs). Fundamentally, a liquid crystal is a thermodynamic phase, between the pure solid and pure liquid phases of matter, that exists in some organic compounds under certain conditions. At temperatures below

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the “event temperature,” a TLC is a transparent solid. At its event temperature, the TLC material will reflect visible light of a unique wavelength (color). As the temperature rises through the TLC bandwidth, the reflected color of the TLC will change. Beyond its “clearing point temperature,” the material is a transparent liquid. This selective reflection occurs in most

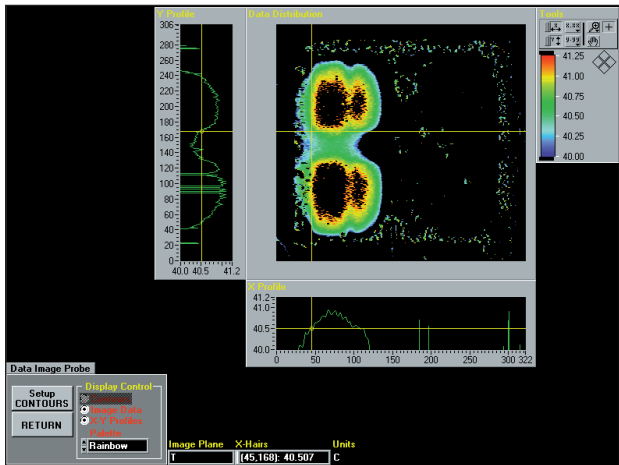


TLC Thermograph of an Operating Electronic Device Taken with TempVIEW. Die size (central colored area) is 10 mm square. Blue colors represent hotter regions (~41 °C); red colors are cooler (~39 °C); and green colors are in between.

TLCs both on heating and cooling, with minimal hysteresis.

The reflected color distribution for most TLC materials varies continuously from the longer wavelengths (red) at the event temperature to shorter wavelengths (blue) at the clearing point temperature. Because a TLC material also transmits a significant amount of the incident light with virtually no modification, we view TLCs against a nonreflecting (black) background to prevent this unimportant light from adversely affecting the interpretation of the selectively reflected light. We capture the color-temperature response with a color camera and use a color-versus-temperature calibration curve to create a very effective TLC-based thermography system.

The fact that color is a subjective entity and can be difficult to quantify posed some particularly acute problems in building efficient TLC-based thermography systems. Because studies have proved that the human eye decomposes color into a combination of the red, green, and blue (RGB) primary colors, many machine vision systems have implemented this natural tristimulus decomposition of color. Though simple and straightforward, this implementation is not efficient for



The TempVIEW Dynamic Image Probe Interface Showing Linked X-Y Data Profiles

TLC-based thermography because it requires three values (RGB) to interpret the temperature at each point in a TLC thermograph.

To address this issue, TempVIEW uses a very efficient, scalar-based (single value) color descriptor that is a further decomposition of RGB, designed specifically for TLC thermography. This implementation is very computationally and memory efficient (requires one-third the memory); it has the added feature of being a single-valued, monotonically increasing function of temperature. With this implementation, we radically improve the image processing and temperature interpretation performance of the system.

Making Measurements with TempVIEW

Before using TempVIEW to make temperature measurements, the following steps must be taken:

1. Select the TLC material and calibrate its color-temperature.
2. Apply the TLC to the device under test (DUT).
3. Activate the DUT (i.e. power up the

- device, turn on flow, etc.).
4. Illuminate the DUT and focus the camera on it.

TLC Color-Temperature Calibration Module

TempVIEW includes our patented RS-232-coupled calibration device for fully automatic or manual color-temperature calibration of virtually any TLC material. This device records the color response of the TLC as it is subjected to successively higher temperatures on a solid-state, PID-controlled test surface. LabVIEW also simplified the development of this module significantly.

Image Acquisition/Storage/Processing/Analysis

TempVIEW has built-in on-the-fly image acquisition, averaging, and storage to assist users with system setup and for acquiring TLC thermographs. TempVIEW also includes features such as scaling and calibration of acquired images, a region-of-interest (ROI) specification (using built-in IMAQ Vision tools), and image retrieval from disk for postprocessing.

LabVIEW and IMAQ Vision radically simplified our development and substantially decreased our time-to-market for this product. We were able to add functionality difficult to implement in other environments.

With the TempVIEW processing tools, you can extract a color or temperature-image plane with ROI control, create and

apply masks (aids to determine valid regions of the image), perform thresholding, and apply spatial filters interactively. Values are automatically converted to temperature as specified ($^{\circ}\text{C}$, $^{\circ}\text{F}$, $^{\circ}\text{K}$) using the TLC color-temperature calibration data. Other extraction planes include red, green, blue, saturation, and intensity, along with other, user-defined quantities.

The TempVIEW thermograph analysis tools include dynamic data probing with point value, and linked X-Y data profile display. We used the LabVIEW Picture Control Toolkit and IMAQ Vision to design and implement a module so users can interactively calibrate the physical-to-screen coordinate system for any image being analyzed, giving them a simple, direct mechanism for making spatial measurements of the thermal phenomena present in their thermographs.

Conclusions

TempVIEW has received much interest in the electronics and gas turbine industries, as well as academic laboratories because it offers excellent performance (0.5°C temperature accuracy, $1\ \mu\text{m}$ spatial resolution) at a substantially lower cost than competing technologies, such as infrared.

LabVIEW and IMAQ Vision radically simplified our development and substantially decreased our time-to-market for this product. We were able to add functionality difficult to implement in other environments. The portability of LabVIEW code simplifies maintenance and configurability for both PC and Macintosh platforms.

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