NI Vision

NI PCI-1405 User Manual

Single-Channel Color Image Acquisition Device

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All Class A products display a simple warning statement of one paragraph in length regarding interference and undesired operation. The FCC rules have restrictions regarding the locations where FCC Class A products can be operated.

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Federal Communications Commission

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Canadian Department of Communications

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The following conventions are used in this manual:

»	The » symbol leads you through nested menu items and dialog box options to a final action. The sequence **File»Page Setup»Options** directs you to pull down the **File** menu, select the **Page Setup** item, and select **Options** from the last dialog box.
	This icon denotes a note, which alerts you to important information.
	This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash. When this symbol is marked on a product, refer to *Getting Started with the NI PCI-1405,* for information about precautions to take.
bold	Bold text denotes items that you must select or click in the software, such as menu items and dialog box options. Bold text also denotes parameter names.
italic	Italic text denotes variables, emphasis, a cross-reference, or an introduction to a key concept. Italic text also denotes text that is a placeholder for a word or value that you must supply.
`monospace`	Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames, and extensions.
NI 1405	NI 1405 refers to the NI PCI-1405 image acquisition device.

Contents

1

Introduction

This chapter describes the NI PCI-1405 (NI 1405) and the software programming choices.

About the NI 1405

The NI 1405 is a PCI monochrome and color image acquisition device that supports a diverse range of analog cameras from many camera companies. The NI 1405 acquires images in real time and can store these images in onboard frame memory or transfer these images directly to system memory.

The NI 1405 is easy to configure, which allows you to begin acquiring images quickly. The NI 1405 ships with NI Vision Acquisition Software, which includes NI-IMAQ, the National Instruments driver software you can use to directly control the NI 1405 and other National Instruments image acquisition hardware products. Using NI-IMAQ, you can quickly and easily start your applications without having to program the device at the register level.

The NI 1405 features a precision color analog video decoder ideal for industrial and scientific environments. The NI 1405 supports both NTSC and PAL color standards as well as the RS-170 and CCIR monochrome standards. The NI 1405 also provides one external input/output (I/O) line that you can use as a trigger or digital I/O line. If you require more advanced triggering or digital I/O lines, you can use the NI 1405 and NI-IMAQ with the National Instruments data acquisition (DAQ) product line.

Software Overview

Programming the NI 1405 requires the NI-IMAQ driver software for controlling the hardware. National Instruments also offers the following application software packages for analyzing and processing your acquired images:

- **Vision Builder for Automated Inspection (AI)**—Allows you to configure solutions for common inspection tasks.
- **Vision Development Module**—Provides customized control over hardware and algorithms.

The following sections provide an overview of the driver software and application software. For detailed information about individual software packages, refer to the documentation specific to the package.

NI-IMAQ Driver Software

The NI 1405 ships with NI Vision Acquisition Software, which includes the NI-IMAQ driver software. NI-IMAQ has an extensive library of functions—such as routines for video configuration, continuous and single-shot image acquisition, memory buffer allocation, trigger control, and device configuration—you can call from your application development environment (ADE). NI-IMAQ handles many of the complex issues between the computer and the image acquisition device, such as programming interrupts and camera control.

NI-IMAQ performs all functions required for acquiring and saving images but does not perform image analysis. For image analysis functionality, refer to the *National Instruments Application Software* section of this chapter.

NI-IMAQ is also the interface path between the NI 1405 and LabVIEW, LabWindows™/CVI™, or a text-based programming environment. The NI-IMAQ software kit includes a series of image acquisition libraries for LabVIEW, LabWindows/CVI, and Measurement Studio, which contains libraries for Microsoft Visual Basic.

NI-IMAQ features both high-level and low-level functions. Examples of high-level functions include the sequences to acquire images in multi-buffer, single-shot, or continuous mode. An example of a low-level function is configuring an image sequence, which requires advanced understanding of the image acquisition device and image acquisition.

National Instruments Application Software

This section describes the National Instruments application software packages you can use to analyze and process the images you acquire with the NI 1405.

Vision Builder for Automated Inspection

NI Vision Builder for Automated Inspection (AI) is configurable machine vision software that you can use to prototype, benchmark, and deploy applications for use in LabVIEW, LabWindows/CVI, and Measurement Studio. Vision Builder AI does not require programming, but it is scalable to powerful programming environments.

Vision Builder AI allows you to easily configure and benchmark a sequence of visual inspection steps, as well as deploy the visual inspection system for automated inspection. With Vision Builder AI, you can perform powerful visual inspection tasks and make decisions based on the results of individual tasks. With Vision Builder AI, you can migrate the configured inspection to LabVIEW, extending the capabilities of your applications if necessary.

Vision Development Module

The Vision Development Module is an image acquisition, processing, and analysis library of more than 270 functions for common machine vision tasks, such as:

- Pattern matching
- Particle analysis
- Gauging
- Taking measurements
- Grayscale, color, and binary image display

You can use the Vision Development Module functions individually or in combination. With the Vision Development Module, you can acquire, display, and store images, as well as perform image analysis and processing. Using the Vision Development Module, imaging novices and experts can program the most basic or complicated image applications without knowledge of particular algorithm implementations.

NI Vision Assistant is included with the Vision Development Module. Vision Assistant is an interactive prototyping tool for machine vision and scientific imaging developers. With Vision Assistant, you can prototype vision applications quickly and test how various vision image processing functions work.

Vision Assistant generates a Builder file, which is a text description containing a recipe of the machine vision and image processing functions. This Builder file provides a guide you can use for developing applications in any ADE, such as LabWindows/CVI or Visual Basic, using the Vision Assistant machine vision and image processing libraries. Using the LabVIEW VI creation wizard, Vision Assistant can create LabVIEW VI block diagrams that perform the prototype you created in Vision Assistant. You can then use LabVIEW to add functionality to the generated VI.

Integration with DAQ and Motion Control

Platforms that support NI-IMAQ also support NI-DAQ and a variety of National Instruments DAQ devices. This allows for integration between image acquisition devices and DAQ devices.

Use National Instruments high-performance stepper and servo motion control products with pattern matching software in inspection and guidance applications, such as locating alignment markers on semiconductor wafers, guiding robotic arms, inspecting the quality of manufactured parts, and locating cells.

2

Hardware Overview

This chapter presents an overview of the hardware functions on the NI 1405 and explains the operation of each functional unit making up the NI 1405.

Functional Overview

The NI 1405 features a high-speed data path optimized for the acquisition and formatting of video data from analog monochrome and color cameras.

The block diagram in Figure 2-1 illustrates the key functional components of the NI 1405.

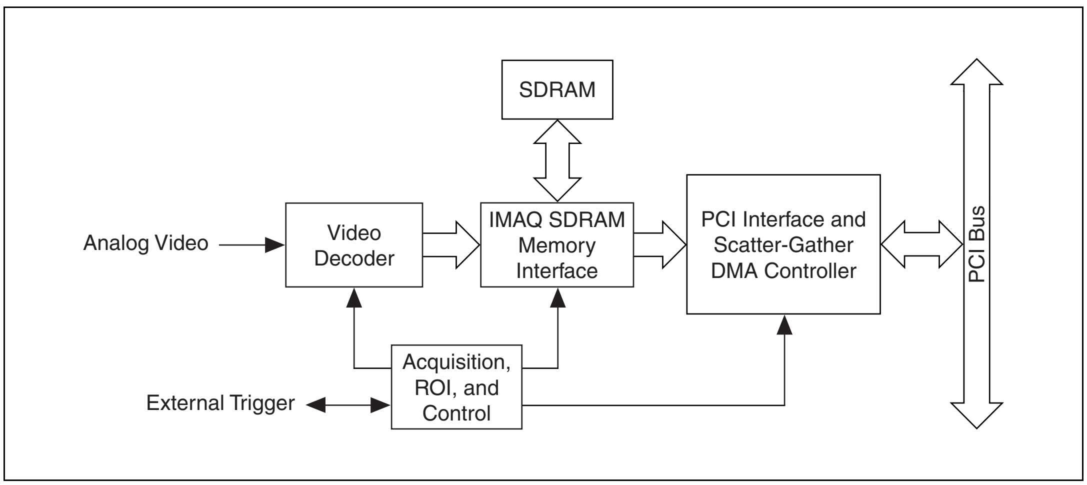

Figure 2-1. NI 1405 Block Diagram

Video Acquisition

The NI 1405 can acquire analog color video in a variety of modes and then store the images in the onboard SDRAM memory or transfer the images directly to PCI system memory.

Video Decoder

The NI 1405 supports NTSC and PAL video standards in composite format. The onboard video decoder converts the incoming video signal to red, green, and blue (RGB) data.

The video decoder allows you to control numerous parameters to optimize an acquisition. You can independently adjust parameters, such as analog input range, brightness, contrast, saturation, or frequency range, which is controlled by different filters. Refer to the *Measurement & Automation Explorer Help for NI-IMAQ*, which is installed with NI-IMAQ, for a complete description of the NI 1405 video parameters.

The video decoder also strips out all necessary clock and synchronization signals included in the video signal and controls the acquisition conditions automatically. High-quality circuitry can generate the synchronization signals from poor timing signals. This allows you to acquire from, for example, a video cassette recorder (VCR).

SDRAM

The NI 1405 has 16 MB of onboard high-speed synchronous dynamic RAM (SDRAM). The NI 1405 can use the onboard RAM as a first-in first-out (FIFO) buffer, transferring the image data as it is acquired or acquiring the image data into SDRAM and holding it for later transfer to main memory.

Trigger Control and Mapping Circuitry

The trigger control monitors and drives the external trigger line. You can configure this line to start an acquisition on a rising or falling edge and drive the line asserted or unasserted, similar to a digital I/O line. You can also map many of the NI 1405 status signals to this trigger line and program the trigger line in polarity and direction.

Acquisition and ROI Circuitry

The acquisition and region-of-interest (ROI) circuitry monitors the incoming video signals and routes the active pixels to the SDRAM memory. The NI 1405 can perform an ROI acquisition on all video lines and frames. In an ROI acquisition, you select an area within the acquisition window to transfer to the PCI bus.

Scatter-Gather DMA Controllers

The NI 1405 uses three independent onboard direct memory access (DMA) controllers. The DMA controllers transfer data between the onboard SDRAM memory buffers and the PCI bus. Each of these controllers supports scatter-gather DMA, which allows the DMA controller to reconfigure on-the-fly. Thus, the NI 1405 can perform continuous image transfers directly to either contiguous or fragmented memory buffers.

Bus Master PCI Interface

The NI 1405 implements the PCI interface with a National Instruments custom application-specific integrated circuit (ASIC), the PCI MITE. The PCI interface can transfer data at a maximum rate of 132 Mbytes/s in bus master mode. The NI 1405 can generate 8-, 16-, and 32-bit memory read and write cycles, both single and multiple. The interface logic ensures that the NI 1405 can meet PCI loading, driving, and timing requirements.

Start Conditions

The NI 1405 can start acquisitions in a variety of conditions:

- **Software control**—The NI 1405 supports software control of acquisition start. You can configure the NI 1405 to capture a fixed number of fields or frames. Use this configuration for capturing a single frame or a sequence of frames.
- **Trigger control**—You can start an acquisition by enabling the external trigger line. This input can start a video acquisition on a rising or falling edge.
- **Frame/field selection**—With an interlaced camera and the NI 1405 in frame mode, you can program the NI 1405 to start an acquisition on any odd or even field.

Acquisition Window Control

You can configure numerous parameters on the NI 1405 to control the video acquisition window. A brief description of each parameter follows:

- **Acquisition window**—The NI 1405 allows you to specify a particular region of active pixels and active lines within the incoming video data. The active pixel region selects the starting pixel and number of pixels to be acquired relative to the assertion edge of the horizontal (or line) enable signal from the camera. The active line region selects the starting line and number of lines to be acquired relative to the assertion edge of the vertical (or frame) enable signal.
- **Region of interest**—The NI 1405 uses a second level of active pixel and active line regions for selecting a region of interest. When you disable the region-of-interest circuitry, the device stores the entire acquisition window into onboard or system memory. However, when you enable the region-of-interest circuitry, the device acquires only a selected subset of the image frame.

3

Signal Connections

This chapter describes cable connections for the NI 1405.

Connectors

The NI 1405 uses two BNC connectors on the front panel to connect to video data input and the external trigger signal. Figure 3-1 shows the position of the connectors.

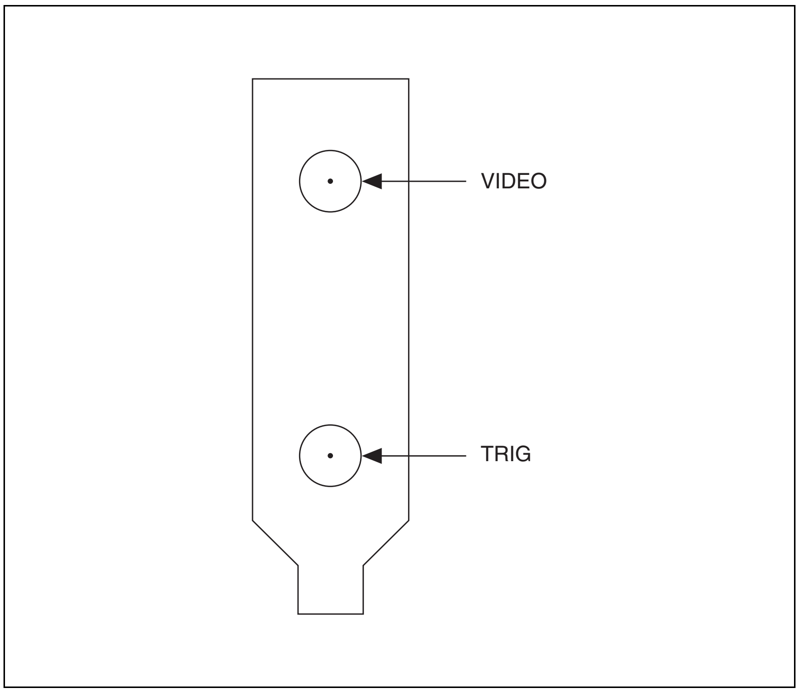

Figure 3-1. NI 1405 Connectors

Signal Descriptions

Table 3-1 describes the signal connections on the NI 1405 connectors.

Table 3-1. I/O Connector Signals

Signal Name	Description
VIDEO	**Composite Video**—This signal allows you to make a referenced single-ended (RSE) connection to the video channel.
TRIG	**External trigger**—You can use this TTL I/O line to start an acquisition or to control external events. You can program the triggers to be rising- or falling-edge sensitive. You can also program the triggers to be programmatically asserted or unasserted, similar to the function of a digital I/O line, or to drive internal status signals by using the onboard events.

A

Introduction to Color

Color is the wavelength of the light we receive in our eye when we look at an object. In theory, the color spectrum is infinite. Humans, however, can see only a small portion of this spectrum—the portion that goes from the red edge of infrared light, which is the longest wavelength, to the blue edge of ultraviolet light, which is the shortest wavelength. This continuous spectrum is called the visible spectrum, as shown in Figure A-1.

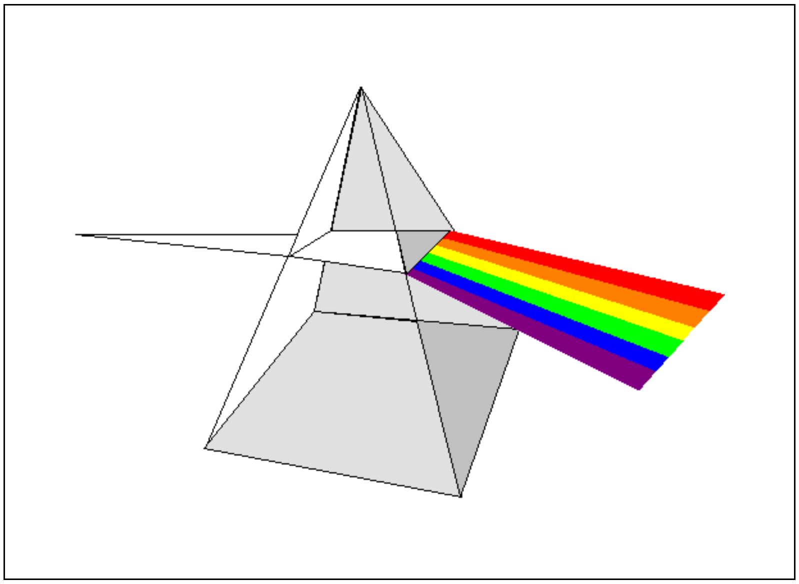

Figure A-1. White Light and the Visible Spectrum

White light is a combination of all colors at once. The spectrum of white light is continuous and goes from ultraviolet to infrared in a smooth transition. You can represent a good approximation of white light by selecting a few reference colors and weighting them appropriately.
The most common way to represent white light is to use three reference components, such as red, green, and blue (R, G, and B primaries). You can simulate most colors of the visible spectrum using these primaries. For example, video projectors use red, green, and blue light generators, and an RGB camera uses red, green, and blue sensors.

The perception of a color depends on many factors, such as the following:

- *Hue*, which is the perceived dominant color. Hue depends directly on the wavelength of a color.
- *Saturation*, which is dependent on the amount of white light present in a color. Pastels typically have a low saturation while very rich colors have a high saturation. For example, pink typically has a red hue but has a low saturation.
- *Luminance*, which is the brightness information in the video picture. The luminance signal amplitude varies in proportion to the brightness of the video signal and corresponds exactly to the monochrome picture.
- *Intensity*, which is the brightness of a color and is usually expressed as light or dark. For example, orange and brown may have the same hue and saturation; however, orange has a greater intensity than brown.

Image Representations

Color images can be represented in several different formats. These formats can contain all color information from the image or they can consist of only one aspect of the color information, such as hue or luminance. The following image representations can be produced using the NI 1405.

RGB

The most common image representation is 32-bit RGB format. In this representation, the three 8-bit color planes—red, green, and blue—are packed into an array of 32-bit integers. This representation is useful for displaying the image on a monitor. The 32-bit integer is organized as follows:

0	RED	GREEN	BLUE

where the high-order byte is not used and the low-order byte is blue.

Color Planes

The red, green, or blue planes can be returned individually. Each plane is extracted from the RGB image and represented as an array of 8-bit integers.

Hue, Saturation, Luminance, and Intensity Planes

The NI 1405 can return an 8-bit Luminance (L) plane, but not Hue (H) or Saturation (S) planes. You can use the NI Vision Development Module or Vision Builder AI to convert the RGB data from the NI 1405 to HSL or Hue, Saturation, and Intensity (HSI) planes.

Luminance, intensity, hue, and saturation are defined using the red, green, and blue values in the following formulas:

$$\text{Luminance} = 0.299 \times \text{Red} + 0.587 \times \text{Green} + 0.114 \times \text{Blue}$$

$$\text{Intensity} = (\text{Red} + \text{Green} + \text{Blue}) / 3$$

$$\text{Hue} = \text{ATN2 (Y, X)}$$

where

$$Y = (\text{Green} - \text{Blue}) / \sqrt{2} \text{ and}$$

$$X = (2 \times \text{Red} - \text{Green} - \text{Blue}) / \sqrt{6}$$

$$\text{Saturation} = 255 \times \left(1 - \frac{3 \times Min(R, G, B)}{R + G + B}\right)$$

32-Bit HSL and HSI

You can also pack the three 8-bit HSL planes or the three HSI planes in one array of 32-bit integers, which is equivalent to the 32-bit RGB representation.

B

Technical Support and Professional Services

Visit the following sections of the National Instruments Web site at `ni.com` for technical support and professional services:

- **Support**—Online technical support resources at `ni.com/support` include the following:
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Glossary

A

acquisition window	The image size specific to a video standard or camera resolution.
active line region	The region of lines actively being stored. Defined by a line start (relative to the vertical synchronization signal) and a line count.
active pixel region	The region of pixels actively being stored. Defined by a pixel start (relative to the horizontal synchronization signal) and a pixel count.
address	Value that identifies a specific location (or series of locations) in memory.
area	A rectangular portion of an acquisition window or frame that is controlled and defined by software.

B

brightness	A constant that is added to the red, green, and blue components of a color pixel during the color decoding process.
buffer	Temporary storage for acquired data.
bus	A group of conductors that interconnect individual circuitry in a computer, such as the PCI bus; typically the expansion vehicle to which I/O or other devices are connected.

C

CCIR	Comite Consultatif International des Radiocommunications. A committee that developed standards for video signals. Also used to describe signals, boards, and cameras that adhere to the CCIR standards.
color space	The mathematical representation for a color. For example, color can be described in terms of red, green, and blue; hue, saturation, and luma; or hue, saturation, and intensity.

composite video	A type of color video transmission where synchronization, luma, and chroma information are transmitted on one analog signal.
contrast	A constant multiplication factor applied to the luma and chroma components of a color pixel in the color decoding process.

D

DAQ	Data acquisition. (1) Collecting and measuring electrical signals from sensors, transducers, and test probes or fixtures and inputting them to a computer for processing. (2) Collecting and measuring the same kinds of electrical signals with A/D or DIO boards plugged into a computer and possibly generating control signals with D/A and/or DIO boards in the same computer.
DMA	Direct memory access. A method by which data can be transferred to and from computer memory from and to a device or memory on the bus while the processor does something else; DMA is the fastest method of transferring data to/from computer memory.
driver	Software that controls a specific hardware device, such as an image acquisition device.
dynamic range	The ratio of the largest signal level a circuit can handle to the smallest signal level it can handle (usually taken to be the noise level), normally expressed in decibels.

E

external trigger	A voltage pulse from an external source that triggers an event, such as A/D conversion.

F

field	For an interlaced video signal, a field is half the number of horizontal lines needed to represent a frame of video. The first field of a frame contains all the odd-numbered lines, the second field contains all of the even-numbered lines.
FIFO	First-in first-out memory buffer. The first data stored is the first data sent to the acceptor; FIFOs are used on devices to temporarily store incoming data until that data can be retrieved.
frame	A complete image. In interlaced formats, a frame is composed of two fields.

H

HSI	Color encoding scheme using Hue, Saturation, and Intensity information, where each pixel in the image is encoded using 8 bits for hue, 8 bits for saturation, and 8 bits for intensity.
HSL	Color encoding scheme using Hue, Saturation, and Luma information where each pixel in the image is encoded using 32 bits: 8 bits for hue, 8 bits for saturation, 8 bits for luma, and 8 unused bits.
hue	Represents the dominant color of a pixel. The hue function is a continuous function that covers all the possible colors generated using the R, G, and B primaries. *See also* RGB.

I

I/O	Input/output. The transfer of data to/from a computer system involving communications channels, operator interface devices, and/or data acquisition and control interfaces.
instrument driver	A set of high-level software functions, such as NI-IMAQ, that control specific plug-in computer boards. Instrument drivers are available in several forms, ranging from a function callable from a programming language to a virtual instrument (VI) in LabVIEW.
intensity	The sum of the red, green, and blue primaries divided by three: (red + green + blue)/3.

interlaced	A video frame composed of two interleaved fields. The number of lines in a field are half the number of lines in an interlaced frame.
interrupt	A computer signal indicating that the CPU should suspend its current task to service a designated activity.

L

luma	The brightness information in the video picture. The luma signal amplitude varies in proportion to the brightness of the video signal and corresponds exactly to the monochrome picture.

M

MTBF	Mean time between failure.

N

NI-IMAQ	Driver software for National Instruments hardware.
NTSC	National Television Standards Committee. The committee that developed the color video standard used primarily in North America, which uses 525 lines per frame. *See also* PAL.
NVRAM	Nonvolatile RAM. RAM that is not erased when a device loses power or is turned off.

P

PAL	Phase Alternation Line. One of the European video color standards; uses 625 lines per frame. *See also* NTSC.
PCI	Peripheral Component Interconnect. A high-performance expansion bus architecture originally developed by Intel to replace ISA and EISA. PCI offers a theoretical maximum transfer rate of 132 Mbytes/s.
pixel	Picture element. The smallest division that makes up the video scan line; for display on a computer monitor, a pixel's optimum dimension is square (aspect ratio of 1:1, or the width equal to the height).

pixel count	The total number of pixels between two horizontal synchronization signals. The pixel count determines the frequency of the pixel clock.

R

real time	A property of an event or system in which data is processed as it is acquired instead of being accumulated and processed at a later time.
resolution	The smallest signal increment that can be detected by a measurement system. Resolution can be expressed in bits, in proportions, or in percent of full scale. For example, a system has 12-bit resolution, one part in 4,096 resolution, and 0.0244 percent of full scale.
RGB	Color encoding scheme using red, green, and blue (RGB) color information where each pixel in the color image is encoded using 32 bits: 8 bits for red, 8 bits for green, 8 bits for blue, and 8 bits for the alpha value (unused).
ROI	Region of interest. A hardware-programmable rectangular portion of the acquisition window.
RS-170	The U.S. standard used for black-and-white television.
RSE	Referenced single-ended. All measurements are made with respect to a common reference measurement system or a ground. Also called a grounded measurement system.

S

saturation	The amount of color pigment present. The lower the saturation, the more white is present in the color. Pink is a red with low saturation.
scatter-gather DMA	A type of DMA that allows the DMA controller to reconfigure on-the-fly.
SDRAM	Synchronous dynamic RAM.

T

transfer rate	The rate, measured in bytes/s, at which data is moved from source to destination after software initialization and set up operations. The maximum rate at which the hardware can operate.
trigger	Any event that causes or starts some form of data capture.

trigger control and mapping circuitry	Circuitry that routes, monitors, and drives the external trigger line. You can configure this line to start or stop acquisition on a rising or falling edge.
TTL	Transistor-transistor logic.

V

VI	Virtual Instrument. (1) A combination of hardware and/or software elements, typically used with a PC, that has the functionality of a classic stand-alone instrument (2) A LabVIEW software module (VI), which consists of a front panel user interface and a block diagram program.

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