LabVIEW Machine Vision

and Image Processing
Online Course

NATIONAL INSTRUMENTS™

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Austin, Texas 78759
ni.com/training

What You Need To Get Started

LabVIEW Machine Vision Online Exercises PDF

Pass the browser test at http://onlinecourses.ni.com/browsertest.htm to use the National Instruments remote computers for your exercises

\<or\>

Install LabVIEW 8 on your computer and download the exercise and solution VIs to complete the exercises on your own computer

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Lesson 1
Introduction to NI Vision

TOPICS

Image acquisition (IMAQ) products

Vision software products

Camera configuration using MAX

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NI Image Acquisition (IMAQ) Hardware

- IMAQ devices feature:
  - Connectivity with parallel digital, analog and Camera Link devices
  - Advanced triggering and I/O capabilities
  - Up to 128 MB of onboard memory
  - Compatibility with motion control and data acquisition systems using the National Instruments RTSI bus
  - Preprocessing, which allows pixel and line scaling and region-of-interest acquisition
  - Real-time acquisition

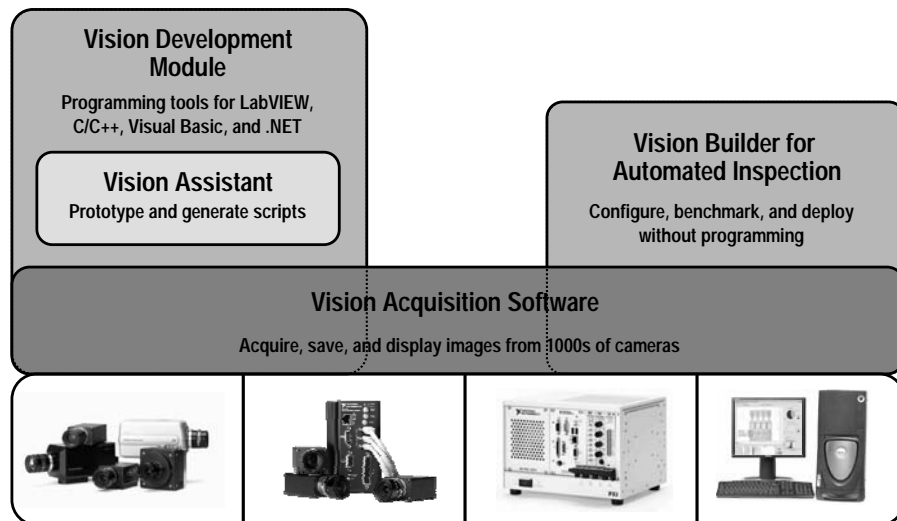**NATIONAL INSTRUMENTS** | **ni.com/training**

National Instruments' line of IMAQ devices features image acquisition boards that connect to parallel digital, analog, and Camera Link cameras. These devices include advanced triggering and digital I/O features that you can use to trigger an acquisition from an outside signal.

IMAQ devices feature up to 128 MB of onboard memory, which allows you to acquire images at extremely high rates while sustaining high-speed throughput and greater overall system performance.

Most IMAQ devices work with motion control and data acquisition hardware using the National Instruments real-time system integration bus (RTSI). On National Instruments PCI boards, you can use a ribbon cable to connect RTSI connectors on adjacent boards to send triggering and timing information from one board to another.

Real-Time Acquisition is available with LV RT on a PXI chassis or with LV RT and Vision Builder for AI on a CVS (1450 Series).

The NI Vision Product Family

Vision Development Module
Programming tools for LabVIEW, C/C++, Visual Basic, and .NET

Vision Assistant
Prototype and generate scripts

Vision Builder for Automated Inspection
Configure, benchmark, and deploy without programming

Vision Acquisition Software
Acquire, save, and display images from 1000s of cameras

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NI Vision is the image processing toolkit, or library, that adds high-level machine vision and image processing to your programming environment. NI Vision includes routines for LabVIEW, LabWindows™/CVI™, Measurement Studio, and MS Visual Studio.

NI Vision Assistant is a tool for prototyping and testing image processing applications. Create custom algorithms with the Vision Assistant scripting feature, which records every step of your processing algorithm. It also can produce a working LabVIEW VI based on the script created or generate a builder file that contains the calls needed to execute the script in C or Visual Basic. **Vision Asisstant is included as part of Vision Development Module**.

NI Vision Builder for Automated Inspection (**Vision Builder AI**) is a stand-alone prototyping and testing program, much like Vision Assistant. However, you can run your final inspection application from within Vision Builder AI. Vision Builder AI **requires no programming experience**, which enables you to develop projects in a shorter amount of time. The software includes functions for setting up complex pass/fail decisions, controlling digital I/O devices, and communicating with serial devices such as PLCs.

The NI Vision Product Family

Vision Development Module
Programming tools for LabVIEW,
C/C++, Visual Basic, and .NET

- **Vision Development Module** features:
  - Hundreds of image processing functions including pattern and geometric matching, OCR, barcode readers, object classification, and particle analysis
  - Tools to enhance images, check for presence, locate features, identify objects, and gauge parts
  - Fast application prototyping and code generation with Vision Assistant

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NI Vision Development Module includes an extensive set of MMX-optimized functions for the following machine vision tasks:

- Grayscale, color, and binary image display
- Image processing—including statistics, filtering, and geometric transforms
- Pattern matching and geometric matching
- Particle analysis
- Gauging
- Measurement
- Object Classification
- Optical character recognition

Use NI Vision Development Module to accelerate the development of industrial machine vision and scientific imaging applications.

The NI Vision Product Family

- **Vision Assistant** gives you the ability to:
  - Create complex custom algorithms
  - Generate a LabVIEW VI or C/VB program from your image processing script
  - Prototype vision systems and experiment with different image processing functions
  - Maintain your original image in the reference window while storing several images for processing in the image browser

Vision Assistant
Prototype and generate scripts

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Vision Assistant uses the NI Vision library but can be used independently of other development environments. In addition to being a tool for prototyping vision systems, you can use Vision Assistant to learn how different image processing functions perform. The Vision Assistant interface makes prototyping your application easy and efficient because of features such as a reference window that displays your original image, a script window that stores your image processing steps, and a processing window that reflects changes to your images as you apply new parameters.

The NI Vision Product Family

- **Vision Acquisition Software** hardware drivers:
  - Are compatible with LabVIEW, C/C++, Visual Basic, and .NET
  - Acquire, save, and display images from thousands of different cameras
  - Work with any NI frame grabber and IIDC-compliant FireWire camera
  - Are included with the Vision Development Module and Vision Builder AI
  - Are included with all NI Vision frame grabbers and IEEE 1394

Vision Acquisition Software

Acquire, save, and display images from 1000s of cameras

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The NI Vision Product Family

Vision Builder for Automated Inspection

Configure, benchmark, and deploy without programming

- **Vision Builder for Automated Inspection** lets you:
  - Acquire and process images with any NI frame grabber, more than 100 IEEE 1394 cameras, or the NI Compact Vision System
  - Build, benchmark, and deploy complete machine vision applications without programming
  - Configure more than 100 powerful machine vision tools including geometric matching, OCR, and particle analysis
  - Communicate triggering and inspection results directly to industrial devices over digital I/O, serial and Ethernet protocols

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NI Vision Builder for Automated Inspection is configurable machine vision software that you can use to prototype, benchmark, and deploy applications. NI Vision Builder for Automated Inspection does not require programming, yet is scalable to powerful programming environments such as LabVIEW. A built-in deployment interface is included so you can quickly deploy your inspection, guidance, and identification applications. The software also includes abilities to set up complex pass/fail decisions, control digital I/O devices, and communicate with serial devices such as PLCs.

Note: Though Vision Builder for AI can build LabVIEW code much like Vision Assistant, the code generated is difficult to modify. If a customer is interested in building a LabVIEW application, they should use Vision Assistant.

Measurement and Automation Explorer

One-stop configuration of all your NI hardware

- Set camera attributes
- Configure frame grabber features
- Test your acquisition
- Access remote devices on your network

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Lesson 2
Preparing Your Imaging Environment

TOPICS

How to choose a camera

Lighting considerations

How to choose an image acquisition device

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In order to properly prepare your imaging environment for your specific application, you must first examine your inspection task to determine your machine vision requirements. During system setup, you decide the type of lighting and lens you need, and you determine some of the basic specifications of your imaging tasks.

Setting up your imaging environment is a critical first step to any imaging application. If you set up the system properly, you can focus your development energy on the application rather than problems caused by the environment, and you can save precious time during execution.

How to Choose a Camera

Deciding factors in camera choice:
- Physical dimensions of your imaging system
  – Maximize detail of features and size of projected image
- Scan type
  – Line/Area
- Format and standard of data
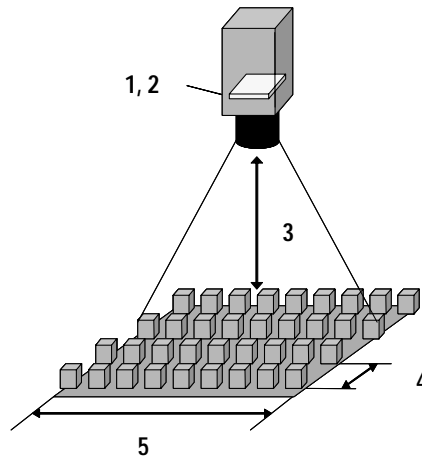 – Analog/Digital, standard or nonstandard, needed bandwidth
- Budget

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The following slides provide more information about each of these topics:

- Imaging System Parameters
  – Sensor Resolution
  – Focal Length
  – Sensor Size
- Scan Type
- Format and Standard
  – Analog formats
    - Standard interlaced formats
    - Progressive scan
  – Digital formats
    - Digital standards
    - Taps
- Section Summary

Imaging System Parameters

1. **Sensor resolution**: Number of columns and rows of pixels in camera sensor
2. **Sensor size:** Physical area of sensor array
3. **Working distance**: The distance from the front of the lens to the object under inspection
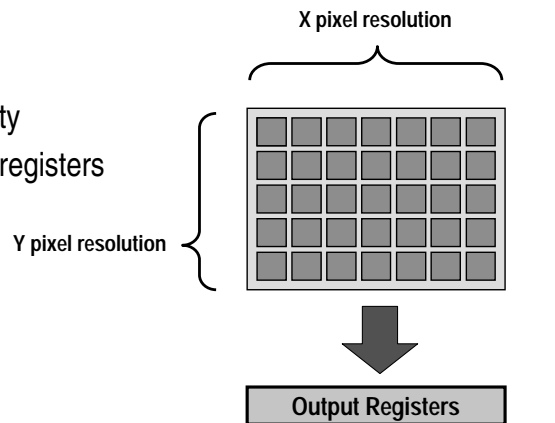4. **Feature Resolution:** Smallest feature size on object that can be distinguished.
5. **Field of view**: Area under inspection that the camera can acquire

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Sensor resolution is the number of columns and rows of CCD pixels in the camera sensor.

Sensor size is the physical area of the sensor array.

The **working distance** is the distance from the front of the lens to the object under inspection.

Feature Resolution indicates the amount of object detail that the imaging system can reproduce.

The **field of view** is the area under inspection that the camera can acquire. The horizontal and vertical dimensions of the inspection area determine the FOV.

Sensor Resolution

Camera sensors contain an array of pixels.

- Sense incident light intensity
- Output video data through registers

X pixel resolution

Y pixel resolution

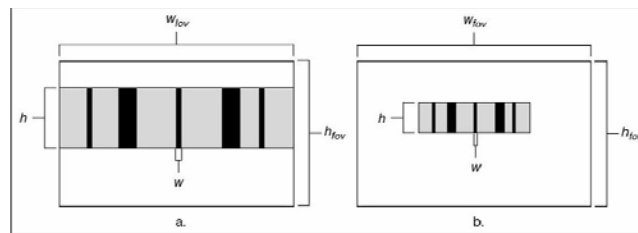Output Registers

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Acquiring images involves exposing a sensor to light and then measuring the amount of light intensity across a two dimensional field. You can transmit this measurement data serially or in parallel through output register to your NI-IMAQ software, where it is digitized.

Determining Necessary Sensor Resolution

To be properly recognized by inspection algorithms, the smallest feature in the image must be represented by at least **two pixels**.

minimum sensor resolution = (FOV / feature resolution) x 2

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You can determine the required sensor resolution of your imaging system by measuring (in real-world units) the size of the smallest feature you need to detect in the image.

To compute sensor resolution, you must first find the *field of view*, which is defined by the horizontal and vertical dimensions of the inspection area.

Use the same units for *FOV* and *size of smallest feature*. **Choose the largest FOV value (horizontal or vertical).**

Common Sensors

Cameras are manufactured with a limited number of standard sensors

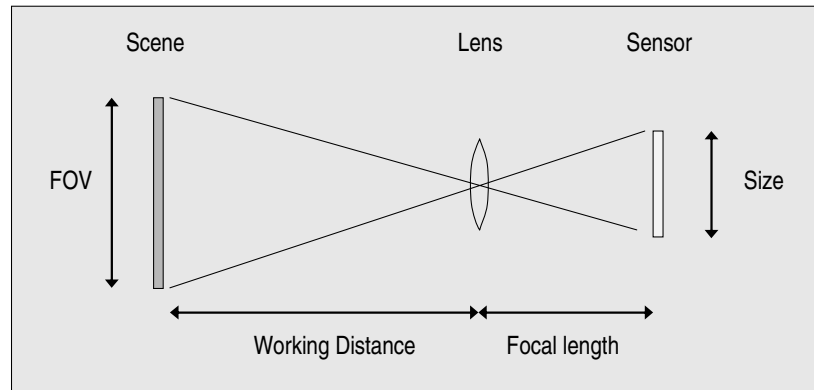| Number of CCD Pixels	FOV	Sensor Resolution
640 x 480	60 mm	0.185 mm
768 x 572	60 mm	0.156 mm
1281 x 1072	60 mm	0.093 mm
2048 x 2048	60 mm	0.058 mm
4000 x 2624	60 mm	0.030 mm

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If your required sensor resolution does not correspond to a standard sensor resolution, choose a camera whose sensor resolution is larger than you require or use multiple cameras. Be aware of camera prices as sensor sizes increase.

By determining the sensor resolution you need, you narrow down the number of camera options that meet your application needs.

Another important factor that affects your camera choice is the physical size of the sensor, known as the sensor size. The sensor's diagonal length specifies the size of the sensor's active area. The number of pixels in your sensor should be greater than or equal to the pixel resolution.

Lenses are manufactured with a limited number of standard focal lengths. Common lens focal lengths include 6 mm, 8 mm, 12.5 mm, 25 mm, and 50 mm. Once you choose a lens whose focal length is closest to the focal length required by your imaging system, you need to adjust the working distance to get the object under inspection in focus.

Lenses with short focal lengths (less than 12 mm) produce images with a significant amount of distortion. If your application is sensitive to image distortion, try to increase the working distance and use a lens with a higher focal length. If you cannot change the working distance, you are somewhat limited in choosing a lens.

As you set up your system you will need to fine tune the various parameters of the focal length equation until you achieve the right combination of components that match your inspection needs and meet your cost requirements.

Exercise: Camera Attributes

GOAL

Determine the focal length and camera resolution for a barcode application

Scenario

You are developing a system to verify that the correct barcode is placed on each newly assembled product. The length of the bar code is 62 mm. The smallest bar has a width of 0.2 mm.

- Due to mechanical constraints in the system, the lens can be no closer than 124 mm from the barcode.

- The sensor size on your camera is 10 mm.

1. Determine the optimal size of the lens (in mm) you would purchase for this application.

   Focal Length = _____

2. Your camera features a resolution of 640 x 480 pixels. Given that the smallest bar has a width of 0.2 mm, determine if the resolution of this camera is acceptable for reading this barcode.
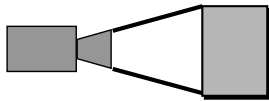
   Resolution needed for barcode: _____

   Acceptable? _____

Scan Type

Area Scan

Scans an area of pixels and acquires the entire rectangular image at once.

Line Scan

Scans one line of pixels at a time, and image is pieced together afterward.

Advantages:
– Less processing needed
– Inexpensive

Advantages:
– Faster acquisition
– Accommodate moving objects

Disadvantage:
– Slower acquisition

Disadvantages:
– Processing required to build image
– Expensive
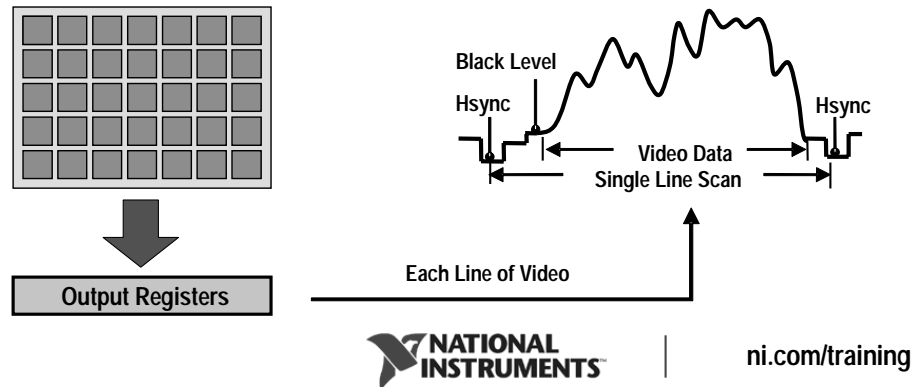
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Cameras use different methods of acquiring the pixels of an image. Two popular methods are area scan and line scan. An area scan camera acquires an area of pixels at a time. A line scan camera scans only one line of pixels at a time, providing faster acquisition. However, you must fit the lines together with software to create a whole image. Line scan cameras are useful in web inspection applications during which the object under inspection moves along a conveyor or stage in a production system. Line scan cameras also are useful in high-resolution applications because you can arbitrarily lengthen the image by fitting a specified number of lines together.
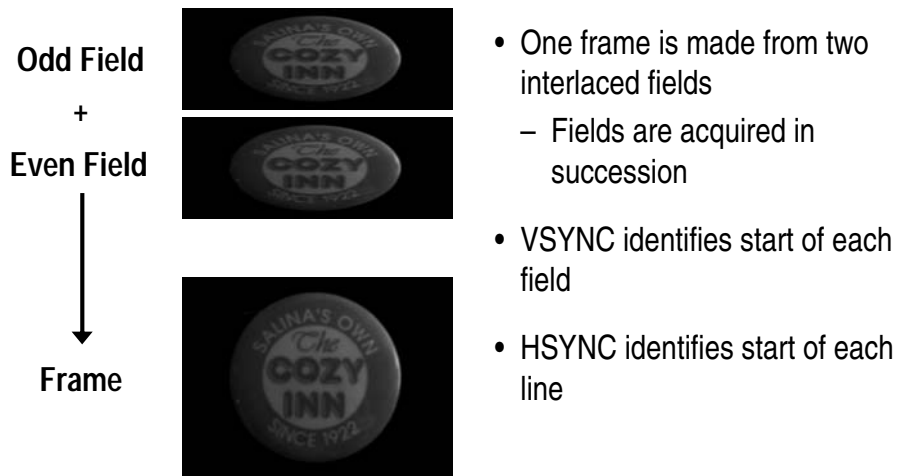
Camera Formats: Analog

- Output video signals as variable voltage level
- Established technology
- Most common type of camera

Black Level

Hsync

Hsync

Video Data

Single Line Scan

Output Registers

Each Line of Video

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Analog cameras output video signals in an analog format. The horizontal sync (HSYNC) pulse identifies the beginning of a line; several lines make up a field. An additional pulse, the vertical sync (VSYNC) identifies the beginning of a field.

Notice the black level identified in the figure. This is a reference voltage used for measuring pixel intensities. Low voltages typically indicate darker pixels, while higher voltages identify light pixels.

Analog Cameras: Interlaced Video

Odd Field
+
Even Field

↓

Frame

- One frame is made from two interlaced fields
  - Fields are acquired in succession
- VSYNC identifies start of each field
- HSYNC identifies start of each line

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For most low-end cameras, the odd and even fields are interlaced to increase the perceived image update rate, a technique that has been used by the television industry for several years. Two fields are combined to make up a frame.

In MAX, the VSYNC and HSYNC timing information relative to the pixel data is automatically set by selecting the appropriate camera configuration file. For example, you might select RS-170 or CCIR for a monochrome camera and NTSC or PAL for a color camera. Consult your camera documentation for more information on timing.

Analog Cameras: Standard Formats

Standard	Location	Frames per second	Color	Image size
RS-170	USA, Japan	30	No	640 x 480
NTSC	USA, Japan	30	Yes	640 x 480
CCIR	Europe	25	No	768 x 576
PAL	Europe	25	Yes	768 x 576

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This table is included for your reference. If you use an analog camera, it will most likely adhere to one of these four standards.

Note: These are all interlaced.

Analog Cameras: Progressive Scan (Nonstandard)

- Non-interlaced; no separate fields
- All lines in a frame are exposed at same time
- Eliminates any "ghosting" resulting from object motion
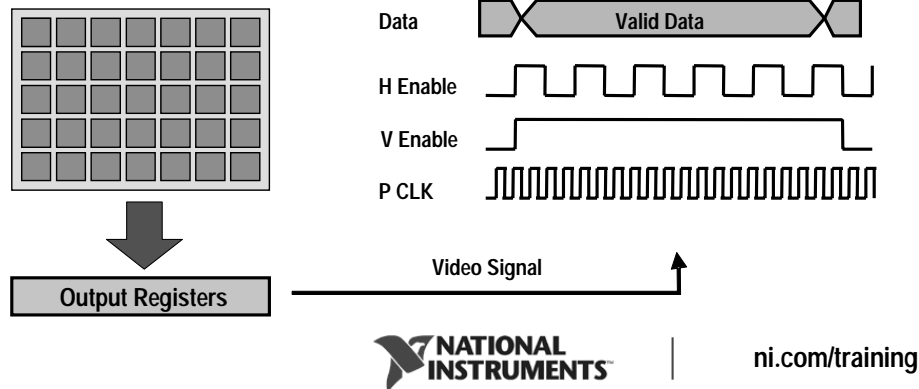
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Progressive scan cameras are typically used in applications where the object or the background is in motion. Instead of acquiring the image one field at a time and then interlacing them for display, the CCD array in progressive scan cameras acquires the entire scene at once. If you use a standard analog camera in a motion application, there is a slight delay between the acquisition of each of the two fields in a frame. This slight delay causes blurring in the acquired image. Progressive scan cameras eliminate this problem by acquiring the entire frame at once, without interlacing. If you have motion in a scene and you only have a standard analog camera with interlaced video, you can use the National Instruments configuration software to scan only one field of each frame, which will eliminate blurring in the acquired image.

Camera Formats: Digital

- Digitizer housed inside the camera
- High image quality and pixel depth
- Large image sizes and high frame rates

Data — Valid Data
H Enable
V Enable
P CLK
Output Registers — Video Signal

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Digital cameras use three types of signals – data lines, a pixel clock, and enable lines.

- Data lines – Parallel wires that carry digital signals corresponding to pixel values
    - Digital cameras typically represent pixels with 8, 10, 12, or 14 bits
    - Color digital cameras can represent pixels with up to 24 bits
    - Depending on your camera, you may have as many as 24 data lines representing each pixel
- Pixel clock – A high-frequency pulse train that determines when the data lines contain valid data.
    - On the active edge of the pixel clock, digital lines have a constant value that is input to your IMAQ device
    - The pixel clock frequency determines the rate that pixels are acquired
- Enable lines – Indicate when data lines contain valid data
    - The HSYNC signal, also known as the Line Valid signal, is active while a row of pixels is acquired. The HSYNC goes inactive at the end of that row
    - The VSYNC signal, or Frame Valid signal, is active during the acquisition of an entire frame.

Digital line scan cameras consist of a single row of CCD elements and only require a HYSNC timing signal. Digital area scan cameras need both HSYNC and VSYNC signals.

Digital Cameras: Standard and Nonstandard

Interface	⊕ Advantages	⚠ Disadvantages
Parallel	High speed Easy to configure	Complex cabling No interface standards
IEEE 1394 (FireWire)	Simple cabling Low cost	Slower data transfer rate
CAMERA Link®	High speed Uniform cables Standard interface	10m cable length limit

The parallel interface standard is well-established that provides a wide range of acquisition speeds, image sizes, and pixel depths. Parallel cameras often require you to customize cables and connectors to suit your image acquisition device.
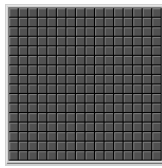
The IEEE 1394 standard offers simple daisy chain cabling with a uniform interface, but lacks some data throughput capabilities as well as trigger synchronization capabilities. You can trigger the camera, not the board.

The Camera Link standard was developed by a consortium of companies, including National Instruments, representing the framegrabber and camera industries. This standard is designed to offer speed and trigger functionality with the ease of standardized cables and interfaces.
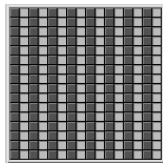
Digital Cameras: Taps

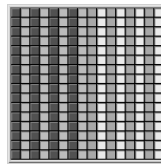**A tap, or channel, is a group of data lines that carry one pixel**

- Single-tap cameras latch only one pixel during the active edge of the pixel clock
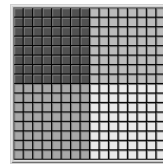- Multi-tap cameras can access multiple pixels during one active edge

| 1 tap | 2 taps interlaced vertically | 4 taps split and interlaced vertically | 4 taps in quadrants |

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Increasing the speed of a digital camera's pixel clock or acquiring more than one pixel at a time greatly improves acquisition speed.

Note: Taps only apply to CL and Parallel cameras. The 1394 bus transfers data in packets, so the idea of taps does not apply to those cameras.

Camera Formats: Summary

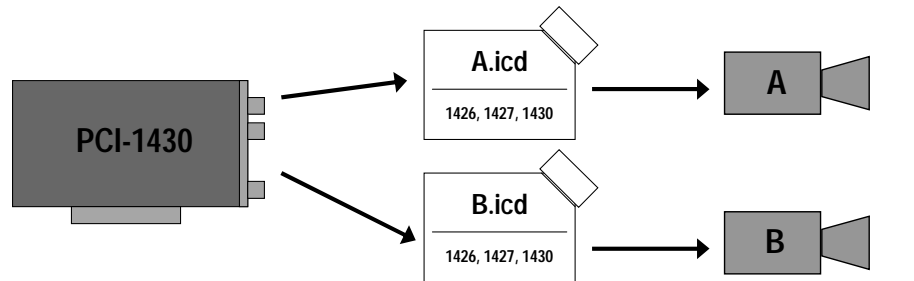| ⌇⌇ **Analog**		⊓⊔⊓ **Digital**	
⊕ Advantages		⊕ Advantages	
	– Established technology		– High speed, high pixel depth, and large image sizes
	– Simple cabling		– Programmable controls
	– Low cost		– Less image noise
⚠ Disadvantages		⚠ Disadvantages	
	– Little market variation		– Expensive
	– Potentially poor image quality		– May require custom cables
			– May require **camera files** for custom configuration

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When choosing between digital and analog cameras, keep in mind that digital cameras tend to be more expensive than analog cameras, but they allow faster frame rates, higher bit and spatial resolution, and higher signal-to-noise ratios.

Analog cameras are based on older, proven technology and are therefore more common and less expensive. A low-cost, monochrome analog camera is an appropriate choice for most beginner vision applications.

Camera Files (.icd)

- Define camera specifications such as speed, image size, pixel depth, number of taps, and modes
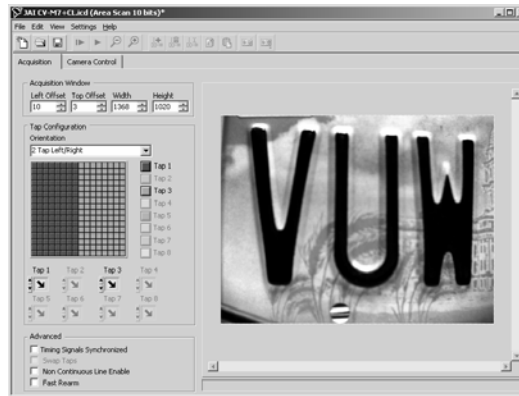- Tell your IMAQ device how to interact with your cameras

Because digital cameras vary in specifications such as speed, image size, pixel depth, number of taps, and modes, NI-IMAQ requires a camera file specific to your camera to define all of these values in order to use that camera with your image acquisition device. Camera files are custom designed to provide efficient and effective interaction between your camera and your image acquisition device. You can find a list of camera files that have been tested and approved by National Instruments online at the Camera Advisor (ni.com/cameras).

NI Camera File Generator

Free utility for creating your own digital camera files

Provides control over:
- Tap configuration
- Pulse generation
- Triggering
- Acquisition size and offset
- Serial Communication

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If you do not find a camera file for your camera at the Camera Advisor, you can create a custom camera file using the NI Camera File Generator. The NI Camera File Generator is a menu-driven, configuration environment for generating new camera files to equip cameras for which National Instruments does not have files, or for adding features to existing NI camera files. The NI Camera File Generator is a free software tool available from the Camera Advisor Web site.

Selecting a Camera

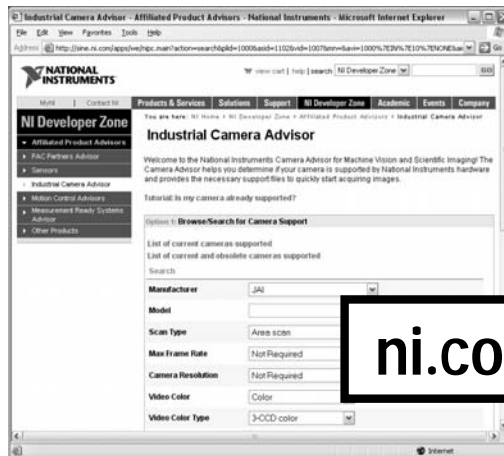Selecting a camera is an important step in preparing your imaging environment. You should use the parameters of your application to decide whether you need an analog or digital imaging system.

National Instruments offers **Camera Advisor** (www.ni.com/cameras), a one-stop Web resource for selecting an imaging camera featuring features and specifications for more than 100 cameras.

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Camera Advisor

- Helps you select the right camera
- Contains full camera specifications

ni.com/cameras

Camera Advisor is a one-stop Web resource that engineers and scientists can use when selecting an imaging camera. Using this virtual catalog of cameras, you can view features and specifications for more than 100 cameras. Camera Advisor also explains how various cameras work with National Instruments hardware and software.

By visiting this section of `ni.com`, you can compare different models and makes of cameras, such as line scan, area scan, progressive scan, and digital and analog cameras. You can also use Camera Advisor to compare the technical details and specifications of various cameras. You will also find a complete list of cameras that have been tested and are fully compatible with National Instruments products.

Lighting: A Critical Consideration

- Lighting is one of the most important aspects in setting up your imaging environment.

  - Separates the feature you want to inspect from the background of the image
  - Makes your image processing easier and faster
  - Reduces glare, shadows, and effects caused by changes in weather or time of day

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If objects in your image are covered by shadows or glare, it becomes much more difficult to examine the images effectively. Some objects reflect large amounts of light due to the nature of their external coating or their curvature. Poor lighting setups in the imaging environment can create shadows that fall across the image.

When possible, position your lighting setup and your imaged object such that glare and shadows are reduced or eliminated. If this is not possible, you may need to use special lighting filters or lenses, which are available from a variety of vendors.

Ring Lighting

Light encircles the camera lens

➕ Advantage: Even illumination without shadows along lens axis
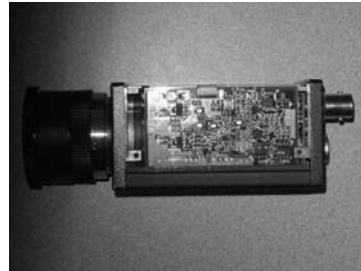
⚠️ Disadvantage: Can produce a circular glare

Ring lighting creates intense shadow-free light in the axis of the camera. It is often combined with polarizers which filter glares caused by illuminating shiny objects.

Strobe Lighting

Light pulses as frame is acquired.

➕ Advantage: Reduces motion blur

⚠️ Disadvantages: May have to apply artificial gain to avoid dark images

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Strobe lights turn on and off very rapidly in order to illuminate objects at very specific points in time. When an object is in motion in front of the camera, it sometimes helps to illuminate the object only briefly with a strobe light in order to reduce blur in the image. Since the object is illuminated only briefly, it is sometimes necessary to apply a gain to the image so that the pixels do not appear too dark in the image. This gain can be applied within the cameral, onboard your IMAQ device, or programmatically within the software.

Backlighting

Object placed between camera and light source.

➕ Advantage: creates a sharp contrast that makes finding edges and measuring distances easy

⚠️ Disadvantage: curved objects can diffract light.

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Use backlighting when you can solve your application by looking only at the shape of an object. This figure shows an image of a stamped metal part that was acquired using a backlight.

Many other factors, such as your camera choice, contribute to your decision about appropriate lighting for your application. You may wan to choose lighting sources and filters whose wavelengths match the sensitivity of the CCD sensor in your camera and the color of the object under inspection.

Diffused Lighting

- Some objects reflect light due to their surface texture or curvature
- You can use diffused lighting to eliminate glare

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In this example, the first barcode image was acquired using highly directional light, which increased the sensitivity of specular highlights, or glints, causing a glare that makes the image difficult to analyze. The second barcode was acquired using diffused lighting to reduce glare.

Optics Resources

- National Instruments recommends the following partner companies for your lighting and lens needs:

  - Graftek Imaging   www.graftek.com
  - Edmund Industrial
    Optics   www.edmundoptics.com
  - Fostec   www.fostec.com
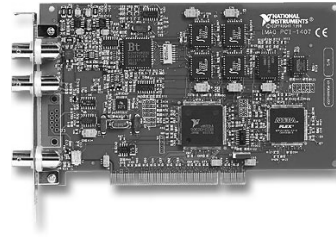 - Stocker & Yale   www.stkr.com

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Visit `ni.com` for information on some of NI's partners who specialize in lighting equipment for the vision industry.

Analog IMAQ Hardware

- Support for color and monochrome cameras
  - Up to four monochrome channels

- Standard and nonstandard formats
  - All worldwide standards (RS-170, CCIR, NTSC, PAL)
  - S-video and progressive scan connections

- Plug into PCI and PXI form factors

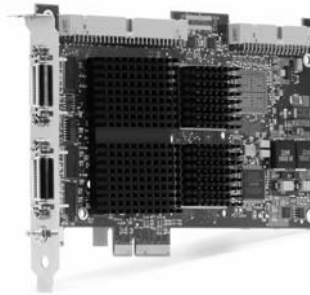*NATIONAL INSTRUMENTS* | **ni.com/training**

The IMAQ PCI/PXI-1409 image acquisition board offers easy-to-use driver and camera configuration software for up to four standard and nonstandard cameras. You can use the 1409 to acquire data from nonstandard cameras featuring variable pixel clocks from 2 MHz to 40 MHz. You can configure monochrome acquisition from RS-170, CCIR, NTSC, PAL, and RGB, and progressive scan cameras. You can configure color image acquisition from NTSC, PAL, and RGB cameras using the StillColor™ feature.

The 1407 Series boards offer low-cost, single-channel monochrome accuracy. You can configure the 1407 for standard RS-170 and CCIR analog monochrome cameras. Unlike other low-cost machine vision image acquisition boards, the 1407 Series offers advanced features such as partial image acquisition, onboard decimation, lookup table processing, programmable gain, and triggering.

You can configure your 1411 Series board for color image acquisition from standard NTSC, PAL, and S-Video cameras. You can also acquire from monochrome RS-170 and CCIR cameras. Unlike other color machine vision boards, the 1411 offers fast color conversion to hue, saturation, and luminance (HSL) image data. This is especially useful for high-speed color matching and inspection applications, even in varying illumination conditions.

Digital IMAQ Hardware

- Support for 32-bit color and 16-bit monochrome cameras
  - Multiple taps
  - Multiple cameras
  - Pixel clock up to 85 MHz

- Standard and nonstandard interfaces
  - IEEE-1394, CameraLink, parallel digital

- Plug into PCI, PXI, PCIe form factors

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With a digital camera and a digital IMAQ board, you can acquire images at thousands of frames/s with greater grayscale resolution and more spatial resolution. National Instruments 1424 Series boards for PCI and PXI/CompactPCI are some of the fastest digital image acquisition boards available, with a 50 MHz pixel clock and 32-bit wide digital input (four 8-bit pixels). Using up to 128 MB of onboard memory, the 1424 can acquire data at a top rate of 200 MB/s. The 1422 Series boards feature a 16-bit input and a 40 MHz pixel clock for lower cost digital image acquisition applications.

National Instruments offers IMAQ hardware for the low-voltage differential signaling (LVDS) standard. LVDS extends the performance of the commonly-used digital camera RS-422 differential data bus, which limits frequency to the 20 MHz range. However, LVDS cameras can clock data out at 50 MHz using the IMAQ PCI-1424 LVDS board. You can also use the LVDS of the IMAQ board to transmit data as far as 100 ft. LVDS also reduces noise significantly.

The IMAQ PCI-1428 is the newest digital image acquisition board from National Instruments. The PCI-1428 offers high-resolution digital imaging with simple cabling for Camera Link cameras. Camera Link is a new industrial, high speed serial data and cabling standard developed by NI and other companies for easy connectivity between the PC and camera. Camera Link offers future data rate capabilities up to 2.3 gigabits per second.

Compact Vision System

- Embedded high-performance processor for increased inspection speed
- 3 FireWire camera inputs
- Integrate with other devices through Ethernet, serial, and digital I/O
- Configure with NI Vision Builder
  for Automated Inspection, or program
  with NI LabVIEW and
  Vision Development Module

The new National Instruments CVS-1454 Compact Vision System extends the power of LabVIEW Real-Time to a new rugged machine vision package that withstands the harsh environments common in robotics, automated test, and industrial inspection systems. The NI CVS-1454 offers unprecedented I/O capabilities and network connectivity for distributed machine vision applications. It uses FireWire® (IEEE 1394) technology, compatible with more than 40 cameras with a wide range of functionality, performance, and price. In addition, you can connect up to three cameras to one CVS-1454 to significantly lower the price of your deployed system. You can also integrate the NI CVS-1454 with the industrial measurement and control capabilities of NI Compact FieldPoint. To program the CVS-1454, you have the choice of configuring your machine vision application quickly with Vision Builder for Automated Inspection, or programming your application with LabVIEW and the Vision Development Module.

Lesson 3
Acquiring and Displaying Images

TOPICS

NI-IMAQ utility functions
Single and multiple buffer acquisitions
Displaying images
Triggering features of NI-IMAQ

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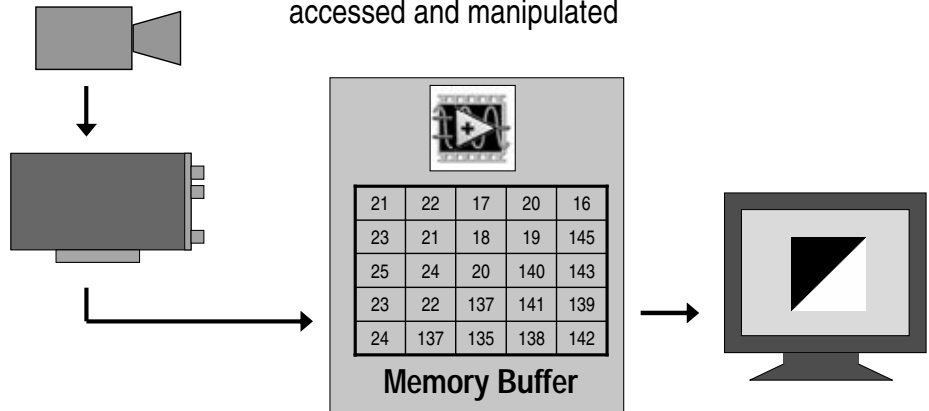
Images in Memory

Images are not displayed directly when acquired.

- Stored in a memory buffer so they can be accessed and manipulated

21	22	17	20	16
23	21	18	19	145
25	24	20	140	143
23	22	137	141	139
24	137	135	138	142

Memory Buffer

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Vision Acquisition Software

- **NI-IMAQ for IEEE 1394 Cameras** driver
- **NI-IMAQ** driver for NI frame grabber devices
- **NI-IMAQ I/O** personality for reconfigurable devices (FPGA)

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NI-IMAQ is a complete and robust API for image acquisition. Whether you are using LabVIEW, Measurement Studio, Visual Basic, or Visual C++, NI-IMAQ gives you high-level control of National Instruments image acquisition devices. NI-IMAQ performs all of the computer- and board-specific tasks, allowing straightforward image acquisition without register-level programming. NI-IMAQ is compatible with NI-DAQ and all other National Instruments driver software for easily integrating an imaging application into any National Instruments solution. NI-IMAQ is included with your hardware at no charge.

NI-IMAQ features an extensive library of functions that you can call from your application programming environment. These functions include routines for video configuration, image acquisition (continuous and single-shot), memory buffer allocation, trigger control, and board configuration. NI-IMAQ performs all functionality required to acquire and save images. For image analysis functionality, refer to the IMAQ Vision software analysis libraries, which are discussed later in this course.

NI-IMAQ resolves many of the complex issues between the computer and IMAQ hardware internally, such as programming interrupts and DMA controllers. NI-IMAQ also provides the interface path between LabVIEW, Measurement Studio, or other programming environments and the hardware product.

Image Acquisition Functions

- Acquisition management
  - Configure sessions and memory allocation

- Single buffer acquisition
  - Acquire images to one memory buffer

- Multiple buffer acquisition
  - Acquire images to multiple memory buffers

- Trigger
  - Synchronize acquisition with real-world events

- Display
  - Customize image display and user interface

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NI-IMAQ and IMAQ Vision use five categories of functions to acquire and display images:

- Acquisition Management functions—Allocate and free memory used for storing images; begin and end image acquisition sessions
- Single buffer acquisition functions—Acquire images into a single buffer using the snap and grab functions
- Multiple buffer acquisition functions—Acquire continuous images into multiple buffers using the ring and sequence functions
- Display controls—Display images for processing
- Trigger functions—Link a vision function to an event external to the computer, such as receiving a pulse to indicate the position of an item on an assembly line

Acquisition Management Functions

Interface Management	Memory Management

IMAQ Init
» Opens a session with the camera or device

IMAQ Close
» Ends a session

IMAQ Create
» Creates an image buffer in memory

IMAQ Dispose
» Removes an image from memory

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IMAQ Init loads camera configuration information and configures the IMAQ device. Interface Name (default img0) refers to the device name from MAX. IMAQ Init generates an IMAQ Session that will be used to reference any future NI-IMAQ driver calls.
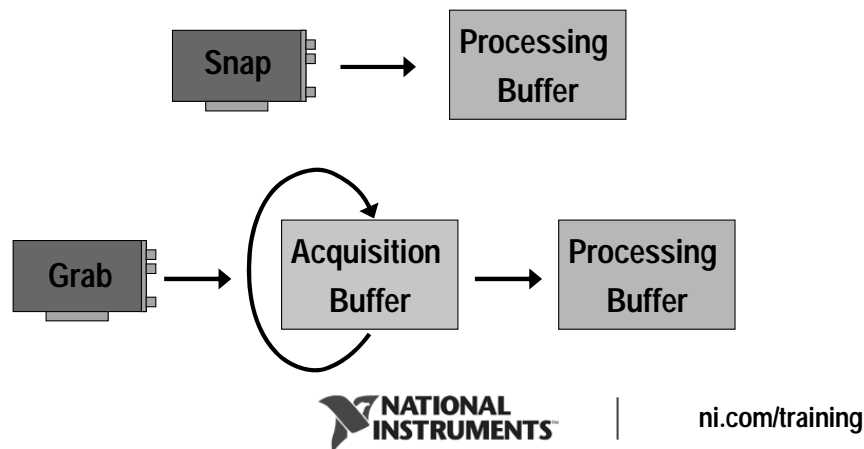
IMAQ Close directs the board to stop acquiring images, release any allocated resources back to the system, and close the specified IMAQ Session. Restarting LabVIEW produces the same results as IMAQ Close.

IMAQ Create creates an image buffer that you input into any of the acquisition functions of your IMAQ device.

IMAQ Dispose disposes an image and frees the memory allocated for the image. Call IMAQ Dispose only when the image is no longer required for the remainder of the processing.

Single Buffer Acquisition – Snap and Grab

- A snap is a one-shot acquisition
- A grab is continuous

- Both use a single buffer
  - Grab overwrites the same buffer

Snap → Processing Buffer

Grab → Acquisition Buffer → Processing Buffer

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Snaps and Grabs are the most basic types of acquisitions. You used these functions in the MAX configuration exercise earlier in the course. A snap is simply a snapshot, in which you acquire a single image from the camera. A grab is more like a video, in which you acquire every image that comes from the camera. The images in a grab are displayed successively, producing a full-motion video, consisting of around 25 to 30 frames per second.

Single Buffer Acquisition Functions

Snap	Grab

IMAQ Snap
» Acquires an image from the device and writes it to a buffer

IMAQ Grab Setup
» Prepares device to continuously acquire images

IMAQ Grab Acquire
» Retrieves an image from device and writes it to a buffer
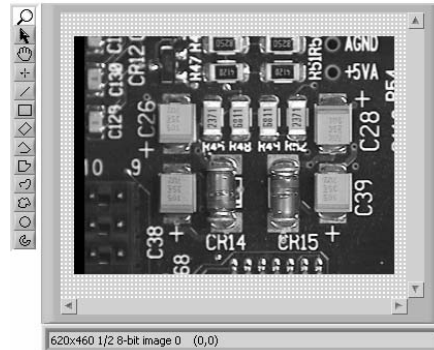
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These are high-level functions that configure your IMAQ device for you. If you choose to control more of the low-level features of your board, take a look at the "LL Snap" and "LL Grab" examples in the Example Finder.

Image Display

Most common method of viewing
images

- Display is not necessary for
acquiring images

- Displayed image is not necessarily
the acquired image
  - Color palette may change or be
limited
  - Viewed image may not represent
all data acquired

620x460 1/2 8-bit image 0   (0,0)

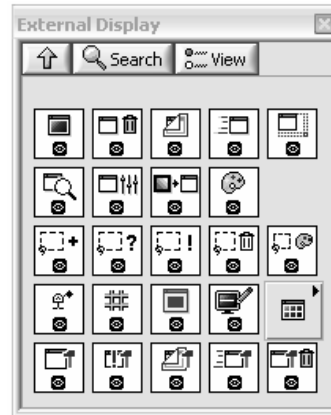**NATIONAL INSTRUMENTS** | **ni.com/training**

One of the first things you will want to do when you acquire an image is display it on your monitor. With LabVIEW 7.0 the **Image Display** control was introduced, allowing users to embed the image on the front panel. This is the easiest method and the one you will use during this course.

Remember that when you display images, the display may differ from the actual image stored in memory. For instance, if your monitor only displays 16 or 256 colors, but you want to display an 8-bit monochrome image, the image may appear distorted depending on how many colors are being used by other programs. In addition, if you acquire a 10-, 12-, 14-, or 16-bit image, you will only be able to display an 8-bit representation of that image. (This is limited by the operating system and video output hardware.)

The display of your images is not necessary for required for acquisition and processing. If your application does not require a human operator, you may want to eliminate all displays from the application's source code.

WindDraw VIs

- Alternate display method based on floating (dialog) windows

- Separate palette and functions

- Provide up to 16 different display windows that are not connected to main program window
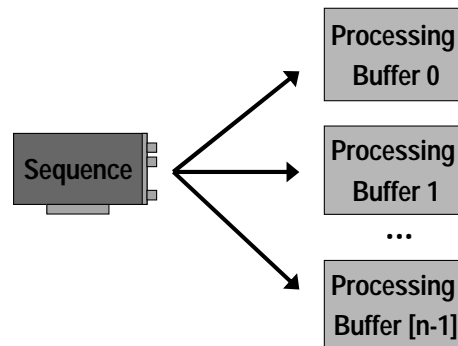

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IMAQ WindDraw opens or refreshes a display window. Use3 this VI to open up to 16 display windows and give each window certain properties, such as a window title.

Images in LabVIEW

The Image type is a *pointer* to a memory location (buffer) that holds image data. It does not follow usual dataflow. Data can change without notice. Functions read data from this location without consideration for what that data is.

Multiple Buffer Acquisition - Sequence

- A sequence is a one-shot acquisition of multiple frames into multiple buffers.

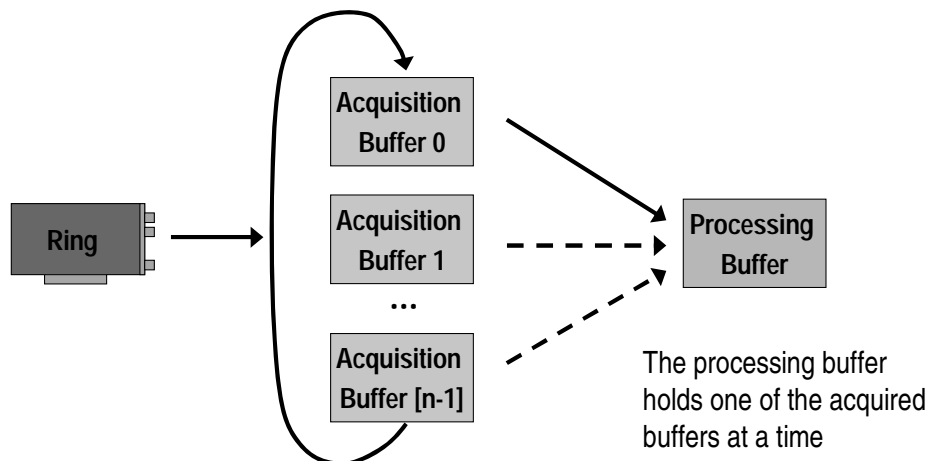|	
	Processing Buffer 0
Sequence	**Processing Buffer 1**
	...
	Processing Buffer [n-1]

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Sequences and Rings are cousins to the other two types of acquisitions that you've studied, Snaps and Grabs.

A sequence of images is a one-shot acquisition that fills up multiple buffers with images a single time. You can use NI-IMAQ functionality to specify a certain number of frames to skip between each acquisition buffer. For example, if your camera acquires 30 frames per second, use a sequence to acquire 30 images with no frames skipped and an acquisition time of one second, or to acquire 30 images with one frame skipped after each buffer with acquisition time of two seconds.

Multiple Buffer Acquisition - Ring

- A ring is a continuous acquisition into multiple buffers.

Ring

Acquisition Buffer 0

Acquisition Buffer 1

...

Acquisition Buffer [n-1]

Processing Buffer

The processing buffer holds one of the acquired buffers at a time

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A ring is similar to a sequence in that it uses multiple buffers, but a ring acquires images continuously. Each buffer is filled one at a time until all buffers contain an image. When all buffers are full, NI-IMAQ writes over the existing images one at a time, beginning with the first buffer. When you get ready to process or display an image from one of these buffers, you simply extract it from the ring, while the ring continues in the background.

Note: A ring is typically better than a grab for obtaining images for Vision analysis. A ring function will extract one buffer while another buffer is being updated.

Multiple Buffer Acquisition Functions

Sequence	Ring
IMAQ Sequence » Acquires a number of images from the device and writes them to memory buffers	**IMAQ Configure List** » Allocates a memory to a list of acquisition buffers **IMAQ Configure Buffer** » Adds a buffer to the list **IMAQ Extract Buffer** » Extracts a buffer from the acquisition list into the processing buffer

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The **IMAQ Sequence** VI fills up multiple buffers with a series of images.

After initializing a session with the image acquisition device, the **IMAQ Configure List** VI is used to set parameters for the list of acquisition buffers used in the session. Each buffer is allocated in memory and assigned to the list with the IMAQ Configure Buffer VI.

IMAQ Configure Buffer allocates one buffer at a time, so it must be used in a loop. Each buffer is given a unique name based on the loop index.

During the acquisition, the **IMAQ Extract Buffer** VI is used to access a specific buffer in the list. The VI extracts an acquisition buffer into a processing buffer (which is automatically allocated by the driver) so the user can manipulate and view it.

Using Triggers

- May need to coordinate an image acquisition with motion control, data acquisition, or real-world events.
  - Can **drive** or **receive** trigger signals
    - RTSI bus for NI device synchronization
    - External lines for real-world coordination

- Examples:
  - Start image acquisition with external trigger received as the unit under test passes in front of the camera.
  - Send trigger to DAQ card to acquire data as each frame is read from camera.

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All triggers, whether they are driven or received, have programmable polarity. In the following sections, a trigger is said to have a value of logical '0' if it is unasserted (if it is low for a high-true trigger signal and high for a low-true trigger signal), and a logical '1' if the trigger is asserted.

Driving Trigger Lines

Internal signals that can drive triggers:
- Acquisition Done
- Acquisition in Progress
- Pixel Clock (PCLK)
- Unasserted (logical "0")
- Asserted (logical "1")
- Horizontal Synchronization Signal (HSYNC)
- Vertical Synchronization Signal (VSYNC)
- Frame Start
- Frame Done
- Scaled Encoder

Trigger

IMAQ Trigger Drive

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Signal Name	Signal Description
Acquisition Done	This signal will pulse to a logical '1' once the last piece of data from an image acquisition is captured by the IMAQ board.
Acquisition in Progress	This signal will remain a logical '1' from the time a capture command is sent to the IMAQ board until the last byte of data is captured.
Pixel Clock	The clock signal used to latch incoming data from the A/D converter
Unasserted	Logical '0'
Asserted	Logical '1'
HSYNC	Horizontal synchronization signal that is produced at the beginning of each line by the camera
VSYNC	Vertical synchronization signal that is produced at the beginning of each line by the camera
Frame Start	High when a frame is being captured
Frame Done	Asserted at the end of each frame that is captured

Receiving Trigger Signals

- Read trigger signals on any external or RTSI line

- Configure a triggered acquisition with any of the following actions:
  - Trigger start of acquisition
  - Trigger start of each buffer list
  - Trigger each buffer
  - Trigger each line (linescan)
  - Trigger end of acquisition

Trigger

IMAQ Trigger Read

IMAQ Configure Trigger

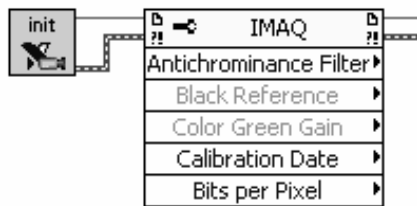**NATIONAL INSTRUMENTS** | ni.com/training

Assert External Trigger 0

Call IMAQ Init to get an interface number to the board. Call IMAQ Trigger Drive VI to drive External Trigger 2 Asserted. The **Get/Set** input must be set to TRUE to set the value of the trigger.

Check Value of External Trigger Line 0

Call IMAQ Init to get an interface number to the board. IMAQ Trigger Read VI is used to sense the current value of External Trigger 2. The value of the trigger is returned in **Trigger status**.

IMAQ Property Node

- Used to set and get properties of acquisition, IMAQ device, acquired image, and connected encoders

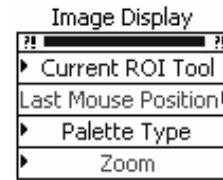- Properties are carried through **IMAQ Session** wire.

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The IMAQ Property Node and theIMAQ 1394 Property Node get and/or set image acquisition properties. The nodes are expandable. Evaluation starts from the top and proceeds downward until an error or the final evaluation occurs.

Image Display Property Node

- Set and get properties of Image Display control on front panel and currently displayed image
  - Tools available to user
  - Region currently selected
  - Palette used for display
  - Read or set Zoom level
  - many, many more…

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End of Self-Study Section

Thank you for completing the self-paced portion of the
LabVIEW Machine Vision Online Course.
You will learn more about Vision software in the live, online portion
of the course.

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