THE ESSENTIAL GUIDE TO DIGITAL VIDEO capture

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The purpose of this paper is to help you specify a digital vision system by providing an introduction to digital frame grabbers. We'll start by considering when a digital solution is appropriate. Following that, we'll present a discussion on key characteristics of digital frame grabbers and the decisions and tradeoffs you need to make in selecting the best solution.

1. Digital or Analog?

Advantages of a Digital Solution:

Digital is the preferred solution for applications that require higher resolution images, deeper gray scale, faster frame rates and better signal quality than can be found with a standard analog camera.

Resolution

The resolution of most analog cameras is effectively limited by their historical link to television standards and the corresponding analog signal used to transmit the image to the receiver. On the one hand, this compatibility has allowed machine vision designers to take advantage of the tremendous variety of equipment and technology available and the enormous economy of scale from the television industry. On the other hand, it has often limited their solutions to less than 13 MHz data rates and hence to deliver images on the order of 720 x 485 pixels.

While non-standard analog cameras are available that produce higher resolution images, costs increase once the decision has been made to move away from the familiar territory of standard video, whether the camera is analog or digital. And as we will see in the discussion that follows, digital cameras bring so many additional advantages that non-standard analog cameras tend to offer only short-term solutions.

Since digital cameras are not limited by compatibility with television standards, camera resolutions can soar to the limits of technology. Digital area scan cameras with 2K x 2K pixels are commonplace and digital line scan cameras are readily available with resolutions greater than 4K pixels.

Gray Scale

While enhanced spatial resolution can often allow you to simplify your image analysis by capturing finer object details, higher spatial resolution may not be the answer if changes in brightness across the object of interest are subtle. Improving the imaging system's ability to discern finer changes in brightness — to deliver more bits of gray scale — can allow image analysis software to pick out details that would otherwise be overlooked, even when additional spatial information is available. This is an area where digital cameras really excel and where analog cameras quickly falter.

The very nature of the analog transmission medium, the ubiquitous RS170A used in virtually every analog camera, means that images delivered from the camera to image capture hardware rarely if ever possess even 8 bits of valid information once digitized. Frequently 6 bits or less of valid data are actually delivered into your computer's system memory. Noise induced by nearby electrical equipment and signal reflections from the cables are just two sources of noise that is added to the image data before it is digitized by the frame grabber. This noise once digitized is difficult to remove and can make the image-processing task much more difficult.

Electrically induced noise is still present in the signals delivered to the frame grabber from a digital camera; so what is the difference? First, as you would suspect from the name, digital cameras digitize — i.e., convert the analog images to digital information in the camera within a quiet, shielded electrical environment, before the influences of the outside world have a chance to affect the sensitive analog information. This means that for the first time it is possible for a camera to send images with not just 8 bits of valid information but with 10 bits, 12 bits or more.

Second, most digital cameras use differential signaling schemes to transmit the images across the wires from the camera to the frame grabber. The international signaling standards RS422 or EIA-644 are commonly used. In both of these schemes, each data bit is transmitted on two wires that have been twisted along their length. The signal that is sent on each wire has the opposite polarity from the other. At the receiver the value of the binary data is defined as the difference in the voltage between the two wires. Differences below a predefined level are interpreted as a "0" and above another level are a "1". By twisting the two wires along their length both wires are always in close proximity and "see" essentially the same noise. Since the receiver only acts on the difference, this common-mode noise is easily removed. All this means that digital cameras deliver very fine gray scale detail to the frame grabber and hence into system memory. These better images can mean better results for you.

Frame Rates

As mentioned above, RS170 or any of the other international television standards are limited to 25 to 30 frames per second. If you need to continuously capture information faster, there are two alternatives: a non-standard analog camera or a digital camera.

From the discussion above you see that if you are going to spend the extra money for a non-standard analog camera, why not take the extra step and go digital. With a wide variety of digital cameras available spanning frame rates from less than 20 Hz to more than 1000 Hz, plus the better image integrity available from a digital camera, digital becomes the logical choice.

Some Disadvantages of a Digital Solution:

While signal quality, speed and image flexibility all play into the decision to incorporate digital cameras and frame grabbers into new designs, these advantages do not come without some drawbacks.

The Lack of Standards

Television standards developed in both the U.S. and internationally have created a plug-and-play market for analog cameras and frame grabbers where components from many manufacturers will operate together; however, the lack of digital standards has often made mating digital cameras and frame grabbers a frustrating task. Digital cameras come with a variety of pixel resolutions and gray scales, multiple data channels and data formats, and unique cabling requirements. This makes getting a digital solution up and running a much more daunting task. If one camera and frame grabber do operate together, then it may well be the case that changing cameras or grabbers will yield a system that does not work without custom assistance from either the camera or grabber manufacturer.

Cost and Cabling

The tremendously high volume of television equipment produced each year has also meant that analog cameras are relatively inexpensive. Not so for the much lower volume digital cameras in use today which command significantly higher prices (but deliver higher performance).

And while analog cameras frequently connect to the grabber with a single thin coax cable that can span long distances (but with the corresponding noise added along the way), digital cameras often have heavy, cumbersome cables with 50 or more wires that can span at the most a few meters. In addition, each digital camera has its own unique cable requirements, adding to the complexity of the solution.

2. Types of Digital Cameras

Area Scan (or Matrix)

Area scan cameras use a two-dimensional sensor array to produce a two-dimensional image (a frame) and output the entire frame one line at a time. Some common resolutions for these cameras are 1024 x 1024, 1300 x 1030, and 2048 x 2048. Applications include high-end industrial machine vision inspection, microscopy and cell biology, and capturing license plates at electronic tollbooths.

Line Scan

Line scan cameras use a one-dimensional sensor array to scan line-by-line, and are typically used for applications where the motion of the object passing the camera provides the other dimension to build up a two-dimensional image. Because they are often used to inspect fast-moving objects on high speed production lines (such as in web inspection), they can have quite high data rates. They typically have higher resolutions than area scan cameras — 2048, 4096, 8192 are common — and find applications in semiconductor inspection and fluid flow analysis, for example.

TDI

TDI (time delay and integration) line scan cameras use a two-dimensional array, but produce a one-dimensional image. The second dimension of the array is used to increase the exposure (integration) time. This makes TDI cameras particularly useful in line scan applications where the exposure time would otherwise be too short, such as when the object being imaged is moving very rapidly, or in low light scanning situations when conventional line scan is not responsive enough.

3. Do you need a Frame Grabber with a Digital Camera?

Before we get into the actual choice of a frame grabber, let's talk about why you even need one if the image comes from the camera already digitized. The main reason boils down to the huge amount of data that a digital camera outputs. While analog cameras produce data at a rate equivalent to about 12 million pixels per second, digital cameras typically output at hundreds of millions of pixels per second (e.g., a four-channel*, 8-bit digital camera can output data at a rate of 160 MB/second). That's a lot of data, even for the digital inputs on modern personal computers.

Today's personal computers typically come with a variety of digital ports, including:

- Parallel printer
- RS-232 serial
- Universal serial bus (USB)
- Firewire

However, none of these has the bandwidth to handle the output of digital cameras. A USB port, for example, is limited to about two megabytes per second. In fact, the USB cameras commonly used for videoconferencing applications have built-in image compression and are still able to output images of only 320 x 200 pixels. Firewire, as yet not commonly available on motherboards, can handle about 13 megabytes per second — only just enough for a 640 x 480, 8-bit image at 30 frames/second.

Even though the analog-to-digital conversion now happens at the camera, a digital frame grabber is still a requirement in machine vision systems. A digital frame grabber is needed to accept the camera's high data rate output and to transfer the data at high speed across the PCI bus to system memory.

In addition, camera manufacturers are building multi-channel cameras to increase the data output rate by sending several pixels in parallel, and different camera manufacturers use different strategies for ordering the pixel data. The data from multi-channel cameras is often transmitted in a form that requires the frame grabber to reorder the pixel data to reconstruct the original image. Finally, a frame grabber also provides control mechanisms to operate the camera and other machine vision components in the system, such as lighting. We'll discuss several of these issues in more detail in the following sections.

*To keep frame rates high many digital cameras deliver image data via multiple, synchronized digital outputs called channels — see definition in the Glossary.

4. What is Required to Capture Images from a Digital Camera?

A typical digital image capture installation consists of a digital camera, a digital frame grabber, a cable to connect the two, application software to view and store images, and software development tools.

There are several components that are necessary to build a digital image capture system:

- **A digital camera** with the appropriate scanning method, resolution, number of bits per pixel, and number of data channels to produce the image you need.
- **A camera lens**. This is usually an option from the camera manufacturer, although most cameras use standard lens mounts that are compatible with lenses from many sources.
- **A camera power supply.** This can be supplied by the frame grabber, or for complex power requirements you may need to purchase a power supply from the camera manufacturer.
- **A digital frame grabber** that supports all the features in the camera required for your application will allow you to control the environment, and transfer images at the required rate to the host computer.
- **A camera data/control cable** to connect the camera to the frame grabber. This cable is specific to both the camera and the frame grabber.
- **A computer with a free PCI bus connector.** The computer should also be specified so that the PCI chipset chosen is capable of sustaining the required data transfer rates across the bus for a given PCI bus utilization, and as a result will deliver the image when you need it.
- **An optional control cable** for the frame grabber if you need to trigger the image capture from an

external event, or provide control signals or power to external equipment.

5. Selecting a Digital Frame Grabber

Characteristics of Digital Frame Grabbers

The basic job of a frame grabber is to deliver the image you want, when you want it, to system memory. To do that across the wide range of applications where frame grabbers are used, frame grabbers must be designed to be very flexible. Below, we'll consider several characteristics of frame grabbers that are important for adapting them to your specific needs, including:

- Video input format and data rates
- Data throughput
- Control I/O
- Camera interface
- Software support
- Technical support

Video Input Format and Data Rates

Frame grabbers need to be able to handle a wide variety of digital camera data formats and data rates. This includes the different types of scanning and number of data channels discussed earlier, plus different signal types, number of bits per pixel, and pixel orientation.

Signal Types. Most cameras today use either RS422 or EIA-644 (also known as LVDS "Low Voltage Differential Signaling") for their output signals. EIA-644 operates at lower voltage differences than RS422, thus reducing the amount of noise at higher data transmission rates. RS422 can operate at 40 MB/second for cable lengths up to three meters, while EIA-644 can operate in excess of 100 MB/second. For both RS422 and EIA-644, transmission speed drops as cable length increases. A frame grabber that supports both signal types on the same board will support a wider range of cameras, including the newest models, which tend to favor LVDS communication. This way you retain flexibility in your design, especially at the early stages when you may want to experiment with a variety of camera types for your application.

Frame Rates. The maximum data rate indicates how rapidly the frame grabber can accept image data from the camera. The data rate is typically expressed in MHz, which is equivalent to millions of pixels per second per data channel. For example, an 8-bit camera with a data rate of 10 MHz can output 10 million pixels per second per channel. For a camera with a 1000 x 1000 pixel sensor, that would mean 10 frames per second. As the resolution of the image sensor and the bits/pixel and the frame rate increase, larger and larger amounts of image data must be transferred to the frame grabber. To keep frame rates high, many digital cameras deliver image data via multiple, synchronized digital outputs, called channels. Each channel is used to transfer only a portion of the image information. If that same 10 MHz camera that we mentioned above were equipped with two channels, the data output would effectively double to 20 million pixels per second (20 frames per second). In order for a digital frame grabber to be able to receive more than one pixel at a time, it must have a digital input wide enough to handle the number of simultaneous bits that the camera is transmitting. For the two-channel camera example mentioned, the camera transmits two 8-bit pixels on each clock. Accordingly, a digital grabber with at least a 16-bit input port would be required. An 8-bit, four-channel camera would need a 32-bit digital grabber. So make sure that the frame grabber you select matches up with the number of output channels in the camera (single-, dual- or four-channel cameras are common), and is compatible with the frame rate of the camera you want to use.

Pixel Order (Pixel Swizzeling). With multi-channel cameras, the order in which the pixel data is transmitted varies — in sometimes surprising ways. While the pixels might be output by starting at the upper left corner of the image and proceeding left to right and top to bottom, that's only one of many possibilities. In fact, the variations you'll encounter include almost every possible configuration. **Figure 1** illustrates a number of different pixel ordering arrangements used by various cameras. (The numbers in the grids refer to the data channel the pixel will be assigned to for output.)

Let's look at one example in some detail, the example labeled two-channel, half lines, reverse, and let's assume that the grid represents a 1024 x 1024 pixel array. In this example, two pixels are output on the first pixel clock, pixel 0 from the top left corner of the image and pixel 1023 from the top right corner of the image. On each successive clock, the next pixel output is taken from one step closer to the centerline of the image. After the entire first line of pixels is output, the camera shifts to the second line, where it starts again with pixel 0 and pixel 1023 and works toward the center.

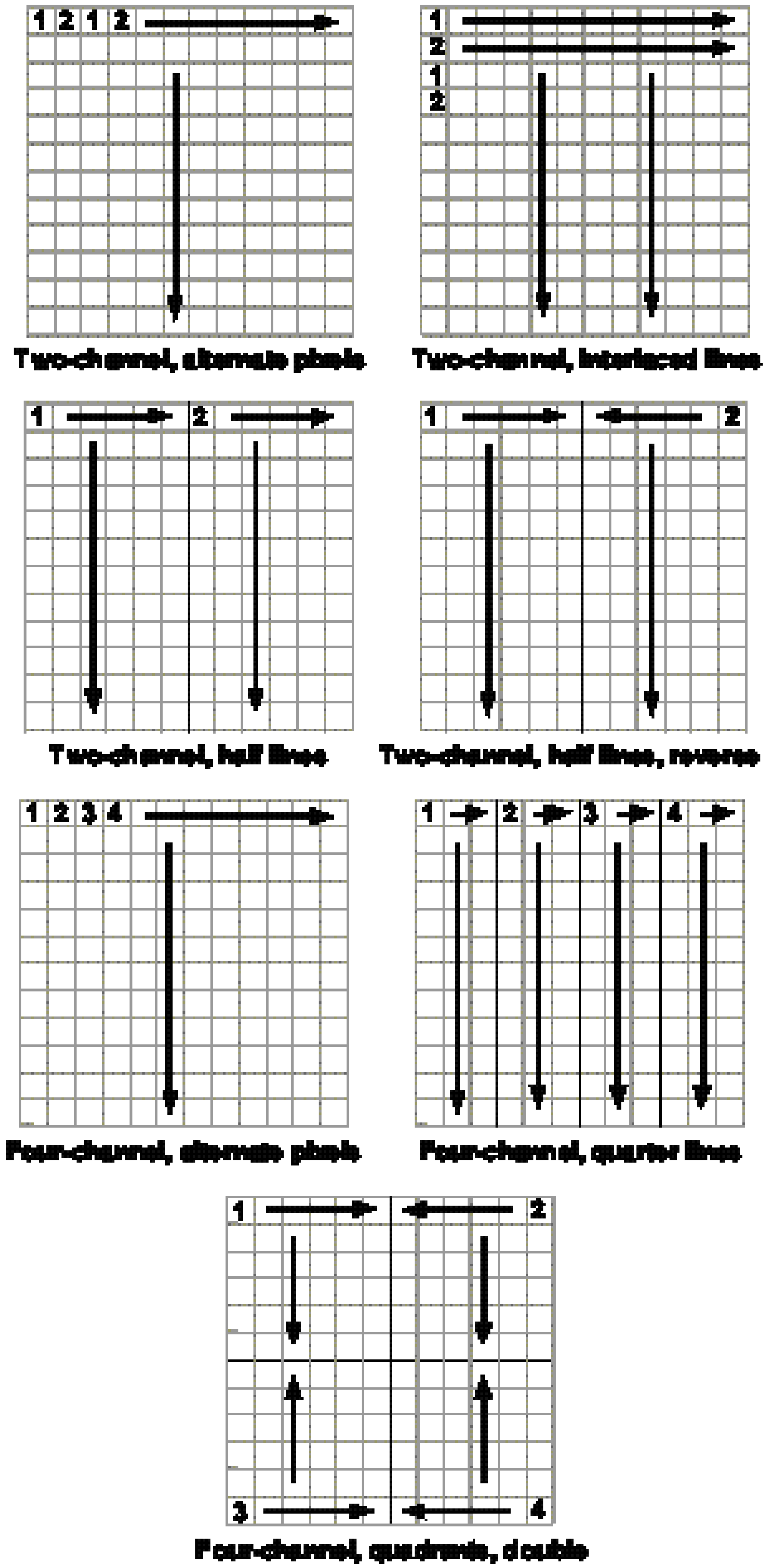

Figure 1. Common Pixel Ordering Arrangements

If this information were simply transferred to system memory as-is, the end-user application would not have a coherent image but would instead need to de-scramble the image in software — a time-consuming task.

To alleviate this problem, many digital frame grabbers incorporate pixel swizzeling circuitry to dynamically rearrange the pixels into scan line order so that the application can immediately begin the image-processing task. Again, there is no standard way of emptying the data from a multi-channel digital camera, so look for your frame grabber to be able to handle multiple swizzeling modes — the more the better — so that you can convert data from any camera of your choice into scan line ordered images in system memory.

Data Throughput

With high resolution images, high frame rates, and multiple channels, digital cameras can push a lot of data at the frame grabber. Consider an 8-bit/pixel camera with 1024 x 1024 resolution, running at 25 frames per second — that's over 25 MB/second of data. Add multiple channels, a few more bits per pixel, and higher frame rates, and you can challenge the data bandwidth of the fastest PCs. Below, we'll consider two issues that affect data throughput: using data buffers onboard the frame grabber and allocating memory for storing the images.

Data Buffering. The peripheral component interconnect (PCI) bus is standard in newer PCs. PCI supports multiple bus masters, meaning that a device, such as a frame grabber, can take control of the PCI bus and move data directly between itself and the computer's main memory without having to go through the main processor. A bus master can burst data across a well-designed PCI bus at 132 Mbytes/second. However, sustained rates can be considerably lower due to contention for the bus from multiple bus master devices and the choice of PCI chipset in the computer. Getting an estimate of the sustained bus transfer rate is a more meaningful figure to monitor.

It's relatively easy for digital applications to exceed the sustained rate of the PCI bus. A common way for a frame grabber to sustain data transfers, without losing data while another device has control of the bus, is to use an onboard data buffer. The higher the input data rate from the camera relative to the output data rate to the PCI bus, the more data the frame grabber needs to buffer. The maximum transfer rate that a frame grabber can sustain depends on the efficiency of its buffering scheme and on the efficiency of the PCI bus.

In some high performance applications, the data rate from the camera can even exceed the 132-MB/second burst rate of the PCI bus (for example, a sophisticated 8-bit, four-channel camera can output data to the frame grabber at 160MB/second — exceeding the theoretical maximum for the PCI bus!). If that input rate is sustained long enough, any fixed-size buffer on the frame grabber will eventually be overrun.

As a general rule then, look for your frame grabber to have onboard memory to buffer image data when the PCI bus gets jammed. While more is always better, the tradeoff for unlimited buffering is cost. A frame grabber with 2 MB onboard memory is usually sufficient for standard digital applications.

In addition, carefully choose your host computer so that the PCI chipset used gives you the best chance of high sustained transfer rates.

Memory Allocation. Frame grabber applications need a large amount of memory in the PC to store images. In Windows 95/98/NT systems, the easiest way to manage this memory is for the frame grabber to use a kernel-level driver to capture a contiguous block of memory, which is done when the operating system is started. This method of allocating memory has a significant disadvantage: when the application is finished using the memory, the only way to release the memory for use by other applications is to restart the operating system without the memory allocation request.

The alternative to requesting memory at boot time is to request it when the application starts running. By requesting the memory at run-time, the application can free the memory when it is no longer needed. However, large, contiguous blocks of memory might not be available at run-time because the memory tends to get fragmented as applications open and close.

The solution to both of these problems is a technology called scatter/gather. A frame grabber that supports scatter/gather uses small blocks of memory as if the memory were one large, contiguous block. The frame grabber does this by building a table of addresses of the small blocks and then stepping through the table to fill the blocks with the completed image. The result is that the image appears to the application as one large block, and the memory can still be released when no longer needed. Choosing a frame grabber that supports scatter/gather means more effective use of memory; you might be able to use less memory in the computer, saving on overall system cost.

Camera Interface

A complete interface for a camera includes a camera configuration file and a cable.

Camera Configuration Files. A camera configuration file is required to configure the digital frame grabber for a particular camera. This file provides the frame grabber with all the information it needs to work with a given camera. Each file is unique for each camera, and multiple files may be required to access many different operating modes of a camera. You can expect frame grabber vendors to provide prewritten configuration files for popular-selling cameras. However, this is only part of the solution. If the set of features your application requires doesn’t exactly match any of the available configuration files, or if you need to modify the configuration, or even change cameras, you’ll need an easy way to create your own camera definition files. That’s where a Camera Configuration Application comes in very handy.

Camera Configuration Applications give you ultimate flexibility for your design needs. These applications should let you create, modify, and test configuration files. The application should require no knowledge of the frame grabber's internal architecture, and it should allow interactive experimentation with camera parameters, including a video window that reacts in real time to configuration changes. The application should let you configure a broad range of parameters, including data format, data framing, exposure control, camera modes, image acquisition modes, strobe polarities and duration, synthesized clock output frequency, HD/VD frequency, polarity and pulse widths, and default values for all control outputs. It is also important that this application is also straightforward and easy-to-use, so that you can get up and running quickly without having to spend an inordinate amount of time figuring out how to get your camera configured.

New camera models with enhanced feature sets are continually being delivered by camera manufacturers. You can guard against frame grabber obsolescence by selecting a board that can grow with your system: making sure you have both the ability to handle multiple input signals and formats, and a Camera Configuration Application to write the appropriate configuration files, gives you control and flexibility.

Cables. Cabling issues with digital frame grabbers are enough to make anyone wish for the good old days of analog. Analog video systems might not have had the data rates and image resolution of digital, but at least you could buy a cable off the shelf to connect your camera and frame grabber.

Unfortunately, there are no standards in the digital world for cables either. With one-, two-, and four-channel designs; 8, 10, 12, or 14 bits/channel; and RS422 or EIA-644 signals; getting cables can be a real problem. Having cables made in low volumes can be very expensive, so frame grabber manufacturers typically have off-the-shelf cables for only the most popular-selling cameras. For lower volume cameras, look for vendors to supply cables with connectors on one end for the frame grabber and open wires on the other end, so that all you have to do is solder on the appropriate camera connectors.

Control I/O

Input/output (I/O) control plays an important role in many machine vision applications. For example:

- It is often necessary to coordinate the timing of an image capture to an industrial process.
- Some applications use resettable cameras, with the computer generating the camera reset pulse.
- In other applications, the electrical pulse that is sent to the camera to expose a new image can also be sent to the frame grabber to cause an image capture.
- Some cameras can use a computer-generated pulse width to set their exposure time.

If your frame grabber can handle these signals itself, you won't need to buy a separate digital I/O card, saving overall system cost.

Strobes and Triggers. A minimal digital I/O capability for a frame grabber might be a single output, often called a strobe, and a single digital input, sometimes called the trigger. Other frame grabbers offer eight or more general-purpose digital I/O lines to control other industrial devices.

Pixel Clock. Most digital cameras provide their own pixel clock to the frame grabber. For standard frame and pixel rates, using the camera-generated clock works fine. However, some applications require custom frame and pixel rates; in these situations, the frame grabber must create the pixel clock for the camera. A pixel clock source on the frame grabber provides more flexibility for the system designer.

Sync Signals. In the continuous stream of pixel data output by the camera, the frame grabber must be able to determine where one image row ends and a new row begins. Similarly, the frame grabber must know when the last row of an image frame has been sent and the next frame is about to start. Typically, digital cameras provide this information through horizontal and vertical synchronization signals called Line Data Valid (LDV) and Frame Data Valid (FDV), or something similar. Theoretically, a frame grabber should be able to count pixels and, knowing the image resolution, be able to determine the start of a new line or frame. In practice, it isn't that simple, and digital frame grabbers need to be able to use the camera's synchronization signals.

Software Support

When it comes to time-to-market, the support available from the frame grabber vendor for application development might be the most important aspect of the entire decision. You'll want to consider several points in application development support:

- Support for high-level programming languages (C/C++, Pascal, Fortran) and operating systems (DOS, Windows 3.x, Windows 95/98, Windows NT)
- Support for prototyping or rapid application development (Visual Basic, Delphi)
- Support for third-party libraries for image processing or other specialized applications
- Source code examples
- Documentation

The key here is to make sure the frame grabber comes with everything you need to successfully develop your system. Make sure libraries are available for the programming languages and operating systems you plan to use. In some cases, you can mix languages; for example, calling Windows DLL routines developed in C from an application program written in Visual Basic.

Third-Party Libraries. If your application involves image processing or other specialized calculations, you might be able to take advantage of software supplied by a third party. If so, it's good to know that the vendors supplying the frame grabber software and the third-party software have worked together to make sure their products are compatible. Major commercial image processing packages include Optimas, XCaliper, Image Pro, Vision Blox and Halcon.

Source Code Examples. No matter which language, operating system, or third-party software you'll be using, you'll find it much easier to start your development with some good source code examples. Modifying and patching together vendor-supplied routines is the quickest and surest way to get your software development started. Vendor-supplied examples are written to use the frame grabber or other library in the most efficient and effective way, and the routines come already tested and debugged.

Documentation. Good documentation is also indispensable. The documentation should be complete, but concise. It should be well organized, so you can quickly locate the information you need, when you need it. The documentation should include both information about the hardware features and detailed reference information for the software library functions and other supplied software.

Technical Support Can Make the Difference

Vendor support is absolutely crucial to your success. No matter how many wonderful features and specifications the frame grabber has on paper, if you can't get it to work in your system, and do so on schedule, it's not the right choice. When you get stuck, think you've encountered a bug, or just need some advice, it's nice to know that help is just a phone call away. Can you quickly get in touch with someone really knowledgeable about the frame grabber and software? Can you speak directly with the design engineer? And, what if you're working late or on a weekend to meet a deadline— do they have a bulletin board or World Wide Web site you can check for recent software updates, application notes, lists of frequently-asked questions, and other materials that might help you solve problems?

Summary

Building a digital machine video system is certainly more complicated than building analog systems, but the improved resolution and speed of digital systems often make the additional work worthwhile, if not a necessity. While lack of standards in the digital world means that you can't expect the same level of off-the-shelf support, you should expect frame grabber vendors to make life a little easier by providing you with a good, easy-to-use Camera Configuration Application, open-ended cables, robust software development support, and expert technical support. So do your homework, determine your system requirements, look for a digital frame grabber with all the features necessary to support your camera, allow for flexibility in this ever-changing digital world, and find the right vendors to act as development partners to help you succeed as you make the move to digital.

Glossary of Terms

API

Application Programming Interface. Libraries of functions that let a programmer control the frame grabber from a high-level programming language without having to know details of the internal design of the frame grabber.

Area Scan Camera

A camera that exposes a rectangular array of sensors to create a two-dimensional image.

Bits/Pixel

For a monochrome camera, this describes the maximum number of resolvable gray levels. Eight bits per pixel (256 gray levels) is quite common, with 10, 12 and 16 bits/pixel available in some models.

Burst PCI Rate versus Sustained PCI Rate

A bus master can burst data across a well-designed PCI bus at 132 MB/second. Other users of the bus can request and gain access to the bus, lowering the sustained performance. The ability of a frame grabber to sustain data transfers without losing data is related to the ability of the grabber to buffer data while another user has control of the bus. The higher the input data rate from the camera, the more the grabber needs to buffer. The maximum transfer rate that a grabber can sustain is related to how efficient the buffering scheme on the board is and how efficient the PCI interface is.

Camera Configuration File

A file that gives the frame grabber all of the information it needs to work with a particular camera, such as the data format, data framing, exposure control, camera modes, image acquisition modes, strobe polarities and duration, synthesized clock output frequency, HD/VD frequency, polarity and pulse widths, and default values for all control outputs. Each file is unique for each camera.

Channels (or Taps)

As the resolution of the image sensor and the bits/pixel and the frame rate increase, larger and larger amounts of image data must be transferred to the frame grabber. To keep frame rates high, many digital cameras deliver image data via multiple, synchronized digital outputs, called channels or taps. Each channel is used to transfer only a portion of the image information. For example, the Dalsa CA-D4 is a 1024 x 1024, 8-bit/pixel camera that can operate as either a one- or two-channel camera. With a single channel it can deliver 25 million pixels/second, at 21 frames/second. But by switching to two-channel mode, each channel transmitting 25 million pixels/second, the frame rate increases to 40 frames/second.

For a digital frame grabber to be able to receive more than one pixel at a time, it must first have a digital input wide enough to handle the number of simultaneous data bits the camera is transmitting. In two-channel mode, the Dalsa CA-D4 transmits two 8-bit pixels on each clock. A digital grabber with at least a 16-bit input port would be required.

EIA-644

An electrical specification for the transmission of digital data. EIA-644 and RS422 are “balanced” data transmission standards that require two wires per signal. The state of the signal at the receiver is determined by the potential difference between the two wires and not by the difference between the signal on a single wire and ground. Since each wire in the pair is subjected to roughly the same transmission environment, electrical noise adds equally to both wires. This “common mode” noise is subtracted at the receiver. This makes both of these standards particularly useful in noisy environments. EIA-644 operates at lower voltage differences than RS422, providing higher transmission bandwidths. EIA-644 transmitters and receivers also introduce less line-to-line skew, meaning that signal integrity is better preserved even when the transmitter is RS422 and the receiver is EIA-644. EIA-644 is also commonly known as LVDS (Low Voltage Differential Signaling), sometimes as RS644.

Frame Rate

The number of complete images the camera can output to the frame grabber per unit time.

Line Scan Camera

A camera that exposes a one-dimensional array of sensors. The second dimension of the image is created by the relative motion between the object being imaged and the camera.

LUTs (Input Look-up Tables)

Look-up Tables are useful for several pixel operations that free the processor from mundane pixel mapping. Typical uses include

- applying a gamma correction
- mapping the input pixel values to another set of values
- performing a threshold operation to produce a binary image

LVDS

Low Voltage Differential Signaling. Also known as EIA-644 (or sometimes also called RS644). An electrical standard for the transmission of digital data. LVDS signals require twisted-pair cabling. See definition under EIA-644.

Onboard Data Buffer

Memory on the frame grabber board used to temporarily store image data received from the camera before transferring that data to the main memory on the personal computer. Data buffers help prevent data loss when the image data is received faster than it can be transferred to computer memory.

PCI Bus

The peripheral component interconnect (PCI) bus is used on newer personal computers. PCI supports multiple bus master devices with a burst transfer rate of 132 Mbytes/second. Sustained transfer rates can be significantly less due to the particular motherboard implementation and the number of other devices contending for access to the bus.

Pixel Clock Source

Although most digital cameras provide their own pixel clocks, the frame grabber must create the pixel clock for the camera in situations where a custom frame and pixel rate are required.

Pixel Order/ Pixel Swizzeling

The order in which pixels in the image are output by the camera. On multi-channel cameras, a variety of pixel ordering schemes are used, which results in the image being output in an incoherent format. A frame grabber must be able to reorder the received data to re-create the image, so digital frame grabbers incorporate pixel swizzling circuitry to dynamically rearrange the pixels into scan line order and as a result the application can immediately begin the image processing task.

Resolution

The ability of a camera to resolve details in a scene is dependent on the type of lens employed and the relation of the camera to the scene. Therefore, manufacturers often describe the resolution of a camera by stating the number of horizontal and vertical picture elements contained in the image sensor. For example, the Pulnix TM1300 area scan camera has 1300 picture elements in each of 1300 rows.

RS422

An electrical standard for the transmission of digital data. See definition for EIA-644.

Scatter/Gather

A frame grabber that supports scatter/gather can use many small blocks of memory as if they were a single large contiguous block. It does this by building a table of addresses of the small blocks and stepping through the table to fill the blocks with the completed image, so that it appears to the application as one large block. Without scatter/gather technology, a frame grabber must use a kernel-level device driver to reserve memory at bootup, with the disadvantage that the memory can’t be freed without rebooting the system.

Taps

Multiple digital outputs on a camera used to simultaneously transfer two or more pixels to increase the data transfer rate of the camera. Also called channels — see definition under Channel.

TDI Line Scan Camera

A line scan camera that uses a two-dimensional sensor array as a multi-stage integrator to increase the exposure time.

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