Factors to Consider When Purchasing a High-Speed Video Camera

By Photron USA, Inc.

You have determined that your company or educational institution has a requirement for one or more high-speed video cameras. You have looked on the internet and found a number of companies who claim to be among the world's premier providers of high-speed cameras. So how do you decide which company to buy from? And how do you decide which model of camera to buy?

There are many factors that are important to consider when you purchase a high-speed camera. These factors are discussed below.

Frame rate

The first and most obvious consideration in the purchase of a high-speed camera is frame rate. How many video frames per second are required to capture sufficient video detail to allow you to analyze your high-speed event? At the low end of the market, high-speed cameras can capture images at around 1000fps. At the high end they can run at frame rates in excess of 20,000fps at 1-megapixel resolution.

Most high-speed cameras provide the ability to run at increasingly higher frame rates as the pixel resolution is reduced. You should be aware, however, that the increased frame rate is never completely proportional to the reduction in resolution and typically comes with restrictions regarding the specific numbers of horizontal and/or vertical pixels that can be selected with the reduced resolution.

There is a very wide range of performance levels and a wide range of costs for high-speed cameras. You will want to make sure that you match your application requirement with the appropriate camera so that you do not spend too much money for frame rate performance that you do not need. At the same time, you will want to spend enough money to ensure that the camera you purchase provides sufficient performance for your application.

Resolution

Another consideration in the purchase of a high-speed camera is pixel resolution. High-speed cameras are available in a variety of resolutions. Most often, the resolutions are between 1-megapixel and 4-megapixel. Higher resolutions are important when the field of view of the camera is large, or when a very small spatial resolution is required because there are a lot of fine details in the high-speed event that need to be studied.

It is important to understand that the higher the resolution of the camera, the lower the maximum frame rate will be. With a 4-megapixel camera you have 4x more pixels to process than with a 1-megapixel camera. Therefore, you will not be able to achieve the same frame rates with a higher resolution camera as with a lower resolution camera.

It is also important to understand that, in general, the higher resolution cameras are less sensitive than lower resolution cameras because their sensors have smaller pixels.

Bit Depth

Bit depth is an important consideration as it impacts image quality and the ability to apply image processing to the images to enhance their usability. Most high-speed cameras capture image data that is either 8-bit, 10-bit or 12-bit.

The higher the bit depth, the greater the amount of information that is captured by the camera. For instance, with an 8-bit image, each pixel within the image is assigned a value from 0 to 255. This means that the camera can differentiate up to 256 different grey levels – from black to pure white – within the field of view. Each pixel in a 12-bit image, on the other hand, is assigned a value from 0 to 4095, allowing the camera to differentiate up to 4096 different levels.

Images with larger bit depths contain more information, allowing the viewer to see greater details within the images. They also provide flexibility for image processing functions that can be used to enhance poorly illuminated areas, allowing those areas to be brightened for easier analysis.

There is a downside to images with greater bit depths that you should be aware of. 12-bit images are larger than 8-bit or 10-bit images, and therefore require more memory within the camera. Therefore, they will shorten the camera's record time. They also take longer to offload from the camera memory to the PC.

Light Sensitivity

In certain applications light sensitivity is the single most critical consideration when it comes to purchasing a high-speed camera because it affects so many things. Light sensitivity impacts your ability to use a short exposure time so that you can effectively eliminate motion blur when capturing a very high-speed event. Light sensitivity impacts the quality of your video because without sufficient light sensitivity your images will be dark and hard to analyze. Light sensitivity impacts your ability to focus, especially when using telescope or microscope lenses. Such lenses typically have high F-numbers and if you need to set the aperture completely open to get sufficient light onto the camera sensor, then your depth of field will be extremely narrow. A narrow depth of field makes it difficult or impossible to focus on anything but a thin plane within the camera's field of view.

It is critical to understand that there is a huge variation in light sensitivity among the high-speed cameras that are out in the market. Light sensitivity is typically presented as an ISO value. The higher the ISO value, the more sensitive a camera should be. However, when you look at a marketing datasheet or brochure for a given camera, you need to take the information regarding light sensitivity with a degree of skepticism. There are standards – such as ISO 12232 Ssat – that define how to measure light sensitivity, but many high-speed camera vendors do not adhere to the standards when they measure the ISO values of their cameras. Other vendors publish ISO values for their cameras but do not specify exactly which ISO standard (ISO 12232 Ssat, for example) the values conform to. Without such information the ISO values are meaningless.

You should be aware that there are many ways to make a camera appear to be more sensitive than it actually is. Two common approaches are to increase gamma and/or increase gain. Such practices will result in a lower level of image quality, but this might not be immediately obvious in a quick product demonstration by a clever sales guy.

The bottom line regarding light sensitivity is that you should always have an on-site evaluation prior to the purchase of any high-speed camera to make sure that it provides the image quality and light sensitivity required for your application. If you are considering cameras from different vendors, then a side by side test of those cameras is essential.

Minimum Exposure Time

A camera's minimum exposure time is often a critical factor in choosing a high-speed camera. Some very fast high-speed events require extremely short exposure times – sometimes even less than 1 microsecond – to stop the motion of those high-speed events. A camera's ability to achieve a sub-microsecond exposure is dependent on two things. First, the camera's sensor must be capable of performing such a short exposure. Second, the camera's sensor must be sensitive enough that when it does utilize a sub-microsecond exposure it can capture enough photons of light during the exposure to be able to generate video that is of sufficient quality for analysis. A short

exposure does no good if the end result is a sequence of images that are so dark that you cannot see what happened within the high-speed event.

Internal Memory

The amount of internal memory is an important issue for consideration when purchasing a high-speed camera, as a high-end, high-speed camera can generate a huge amount of data in a very short time. For instance, a high-end camera can generate 128GB of 12-bit image data in just under 4.5 seconds when run at 20,000fps at 1-megapixel resolution. Because no streaming mechanism exists to allow this amount of data to be transferred to a PC or external storage device in real time, high-speed cameras have internal memory to which the image data is initially captured. After the recording is completed, the image data can then be offloaded to a more permanent location.

To determine how much internal memory is required by a camera to capture a given high-speed event, you need to know the frame rate (i.e. fps) that the camera will be running at, the resolution that the camera will record at, the duration of time that the event will last and the bit depth of the images that are generated. When you know this information, you can determine the amount of internal memory that is required for the event. Below are equations that can be used to calculate memory requirements.

Equations:

(H) resolution x (V) resolution x frame rate x seconds x 1.5 (if 12-bit sensor) = memory (in bytes)

(H) resolution x (V) resolution x frame rate x seconds x 1.25 (if 10-bit sensor) = memory (in bytes)

(H) resolution x (V) resolution x frame rate x seconds x 1.0 (if 8-bit sensor) = memory (in bytes)

Example for 12-bit images:

1024 pixels x 1024 pixels x 20,000fps x 2.0 seconds x 1.5 = 62,914,560,000 bytes = 62.91 gigabytes

Data Offload Speed

After you have captured video of a high-speed event, you will need to transfer it from the internal memory on the camera to a more permanent location for storage and analysis. It is important that there is a fast and convenient mechanism to facilitate this.

Most camera suppliers have chosen to implement Gigabit Ethernet to enable the transfer of image data from the high-speed camera, as nearly all PCs are already configured with this type of interface. You should be aware that not all Gigabit Ethernet implementations are the same. For instance, Gigabit Ethernet using TCP/IP protocol tends to be inefficient for downloading large video sequences because there is a lot of overhead involved with that protocol. Gigabit Ethernet using UDP protocol, on the other hand, is quite efficient and can result in image data transfer speeds of up to 5GB per minute. Not all camera manufacturers implement UDP protocol. Further, some camera manufacturers provide two Gigabit Ethernet connectors (instead of one) so that data transfer speeds can be doubled.

As an alternative to downloading images over a standard network, some cameras have the ability to download images to removable nonvolatile memory such as SD cards and CFast cards, or to integrated SSD drives. Such download methods can be very useful, but when you calculate the overall transfer time required to get your image data from the internal camera memory to a PC, you will need to consider both the time required to transfer images from the camera to the nonvolatile memory and the time required to transfer images from the nonvolatile memory to the PC.

Color vs Monochrome

When you purchase a high-speed camera, you will have to decide between a color and a monochrome camera. Oftentimes when a camera purchase is being considered, the marketing guys want a color camera because color video is more impressive in general to the viewer. People see in color, so they prefer to watch color videos rather than monochrome videos.

However, it is important to understand that because of the way high-speed sensors are made, a monochrome camera will be two to three times more sensitive than the equivalent color camera. Unless color changes within a high-speed event are critical (and sometimes they are) to the analysis of the event, the monochrome camera is typically a better choice.

Camera Size

High-speed cameras come in all shapes, sizes and weights. The physical size of a high-speed camera is an important consideration if your application provides only a limited space in which to fit the camera. In such a case a small camera is desirable.

It is important to understand, though, that there are some important trade-offs involved in purchasing a smaller size camera. Small cameras are often less sensitive than larger cameras due to the implementation of small sensors with small pixels. In general, they also have lower frame rate performance and less memory because they contain less internal space for the electronics that impact these performance parameters.

Some manufacturers have employed a tethered head methodology to camera design where a significant amount of the electronics that are usually located within the camera itself are instead contained within a “central processor” that can support multiple camera heads, each connected to the processor via a cable. This tactic allows the camera heads to be extremely small and lightweight. A side benefit of this design technique is that the memory components (where images are stored during a recording) are located in the processor and are safely retained even if a camera head is destroyed during a high-speed event.

Product Warranty

The duration of the camera warranty is an important consideration when purchasing a high-speed camera because it illustrates how confident the camera supplier is in the reliability of a camera. If a camera company provides a 2-year warranty (over the more typical 1-year warranty) then that company is expressing a high degree of confidence that the camera will perform reliably for years to come.

Support

Finally, vendor support should always be an important consideration when purchasing a high-speed camera.

1. Is your camera sales guy willing to travel to your location and provide you with an in-depth product demonstration or does he simply send you a demo camera and leave it up to you to figure out how to use it?
2. Is your sales guy knowledgeable regarding the camera products he represents?
3. Is your sales guy knowledgeable regarding the usage of high-speed cameras in your specific application?
4. Is on-site operator training included after you purchase a camera?
5. Do you have direct access to application engineers who can answer questions for you regarding operational issues or give you advice on how to set up the camera to perform in an optimal manner for your application?
6. Do you have easy, ongoing access to camera software updates?

If the answer is “no” to any of these questions, then you might want to consider working with a different camera supplier. Remember – if you are dissatisfied with the pre-sales support you get from a camera supplier, then you will definitely be unhappy with the support that you get after you purchase the camera and the sales guy has received his commission.

Summary

Frame rate, resolution and light sensitivity are typically the most important factors to think about when purchasing high-speed cameras, but as discussed above there are a number of other things that you need to think about as well.

We hope that you consider Photron when you perform your research regarding high-speed cameras. Photron has a broad portfolio of high-speed cameras that have been designed to accommodate many different applications. Here are a few of the advantages that we provide:

- Megapixel resolution to 21,000fps
- Reduced resolution frame rates to 2.1Mfps
- Resolution to 4 megapixels
- Unparalleled light sensitivity with custom designed CMOS sensors
- Minimum exposure time to 159 nanoseconds
- Up to 128GB of internal memory
- Fast image transfer to a PC or SSD
- Extremely rugged camera design
- Standard 2-year product warranty
- Experienced and dedicated sales and support