Selecting a Lens for your Camera

Technical Application Note TAN2010002

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1.1 Subject

Technical Application Note (TAN2010002): Selecting a Lens for Your Camera

1.2 Applicable Product(s)

- **All Imaging Cameras**

1.3 Application Note Description

This application note explains the following important factors to consider when selecting a lens for your imaging camera:

- Lens mount
- Lens focal length
- Sensor size
- Sensor spatial resolution

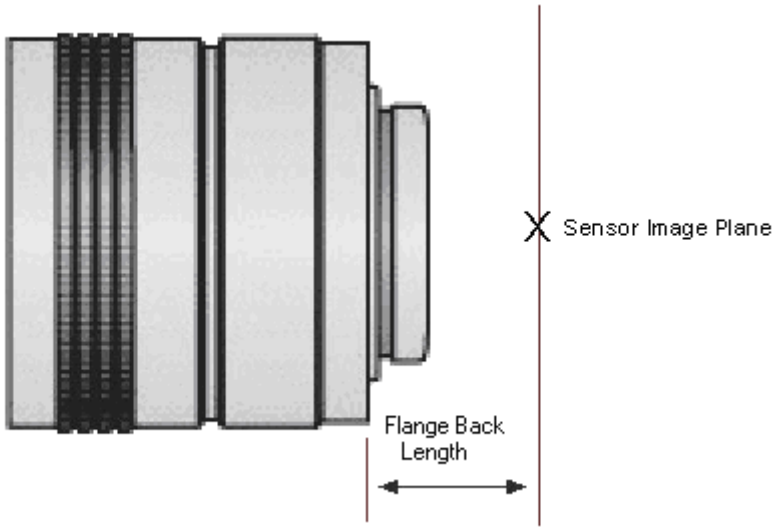
1.3.1 Camera Lens Mount

You must select a lens that is compatible with the lens mount of the camera. Most Point Grey imaging cameras are equipped with either a C- or CS-mount. Point Grey also provides 5 mm C-to-CS mount spacers, M12 lens mounts and CS-to-M12 adapters.

1.3.1.1 Flange Back Distance on C- and CS-mount cameras

C- and CS-mount lenses are both threaded lens mounts found on most industrial CCD cameras and lenses. The difference between C and CS-mount equipment is the distance between the flange of the lens (the part of the case that butts up against the camera) and the focal plane of the lens (where the CCD sensor must be positioned). This is known as the flange back distance.

Diagram of typical C or CS-mount lens



The C-mount lens specification for flange back distance is 17.52 mm, and on CS-mount lenses it is 12.52 mm. However, on Point Grey cameras, these physical distances are offset due to the presence of both a 1 mm infrared cutoff (IRC) filter and a 0.5 mm sensor package window. These two pieces of glass fit between the lens and the sensor image plane. The IRC filter is installed by Point Grey on color cameras. In monochrome cameras, it is a transparent piece of glass. The sensor package window is installed by the sensor manufacturer. Both components cause refraction, which requires some offset in flange back distance to correct. Consult your camera's Technical Reference manual for the exact flange back distance measurement.

If you have a CS-mount camera and a C-mount lens, you can add a 5mm spacer to obtain the correct focus. If, however, you have a C-mount camera and a CS-mount lens, correct focus cannot be achieved.

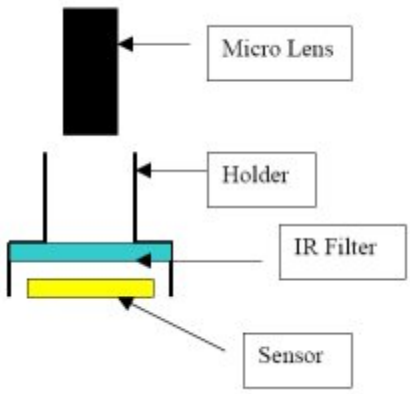
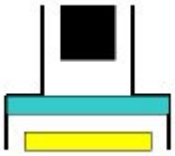
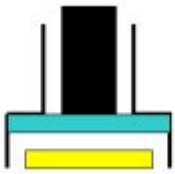
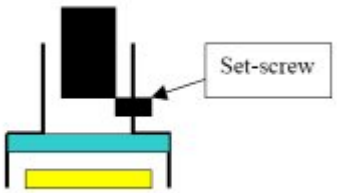
1.3.1.2 Compatibility with M12 Microlenses

M12 (sometimes referred to as S-mount) optics are often a popular alternative to C- or CS-mount optics due to their smaller size and lower cost. Point Grey offers a variety of M12-based products, including lens mounts (plastic or metal), lenses, a CS-to-M12 adapter, and some cameras with M12 lens mount pre-installed.

Point Grey's cast metal M12 lens holder is made of zinc alloy and is designed to fit larger format sensors such as the Sony ICX445 CCD and the Sony IMX035 CMOS. Additional features include a set screw for adjusting back focal distance, dowel pins for precise alignment of the lens holder to the camera circuit board, and an IRC filter.

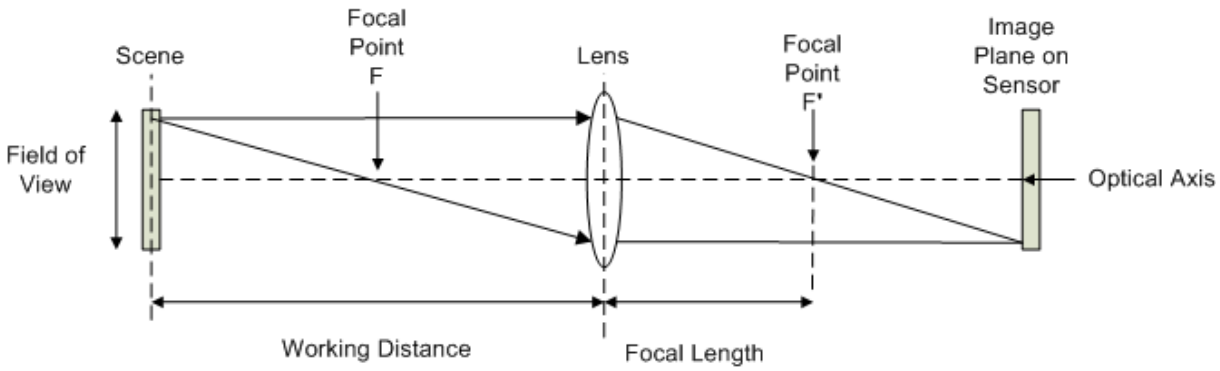
Point Grey also has available a CS-to-M12 lens adapter, which is useful for attaching M12 lenses to a camera equipped with a CS-mount lens holder.

There may be some compatibility issues with particular wide angle (short focal length) M12 lenses. Compatibility issues are primarily a result of back focal length differences, as explained below.

The distance required for the lens to be in focus is greater than the length of the lens holder, requiring the lens to be unattached from the holder in order for it to be focused.	
The distance required for the lens to be in focus is less than the length of the lens holder. The image will still be unfocused even with the lens screwed all the way into the lens holder.	
The microlens may encounter the IR filter before being able to come into focus.	
The microlens may be in focus, but is too short to be fixed in place by the lens set screw.	

1.3.2 Lens Focal Length

Another important consideration when selecting a lens is its focal length. This is the distance from the optical center of the lens to the focal point. The focal point is the position on the optical axis where all incoming rays that are parallel to the optical axis will intersect. With the correct focal length, focus is achieved when all rays originating from the same point on the scene refract so that they intersect at exactly the same point on the image plane. This concept is illustrated in the diagram below. Note that with a symmetric lens, focal points F and F' are equidistant from the lens. A ray that passes through F refracts so that it is parallel to the optical axis before it hits the image plane.



A lens with a focal length approximately equal to the diagonal size of the sensor format reproduces a perspective that generally appears normal to the human eye. Lenses with shorter than normal focal lengths, also called 'wide angle' lenses, can capture a larger field of view. Lenses with longer than normal focal lengths, or 'telephoto' lenses, capture a smaller field of view. Therefore, when considering focal length, you must, in turn, consider the sensor size, the field of view you want to capture, and approximately how far from your subject the lens will be located, also known as the 'working distance.'

There are different ways to calculate a desired focal length. Many lens manufacturers provide lens selection calculators on their websites that produce a recommended focal length. One simple way is to use the following equation:

$$focal\_length = \frac{(sensor\_size \times working\_dist.)}{field\_of\_view}$$

For example, consider a 1/2" sensor (12.7 mm), a working distance of 100 mm, and a field of view of 100 mm:

$$focal\_length = \frac{(12.7 \times 100)}{100}$$

The result is a focal length of 12.7 mm. Once you choose a focal length that best meets your requirements, you may need to adjust your working distance to achieve focus. Also, keep in mind that lenses with shorter focal lengths often exhibit more pronounced distortion. The actual amount of distortion will depend on the specific lens being used.

1.3.3 Sensor Size

When purchasing a lens, make sure it is compatible with the optical size of the image sensor (for example, 1/3", 2/3", and so on) used in your camera. The lens must be able to project an image that covers the whole sensor. A lens made for a larger format sensor, such as 2/3", can usually be used with a smaller format sensor, such as 1/3". However, the apparent focal length will seem larger by the same factor as the sensor is smaller. The effect is comparable to applying a centered region of interest on a larger sensor. A lens made for a smaller sensor, such as 1/3", cannot be used with a larger sensor, such as 1/2", because the lens will most likely not project a large enough image to cover the whole sensor.

The following table shows the approximate width (W), height (H), and diagonal (D) of the active area for different sized sensors, and the crop factors associated with using a certain lens on a smaller sensor. For example, a 6 mm 1/3" lens on a 1/4" sensor results in a crop factor of 1.33. This means

the angle of view and field of view of this combination would be comparable to using a ~8 mm (6 x 1.33) lens made for a 1/4" sensor.

Dimensions in mm				*Crop factor using a lens made for…*					
Sensor	*W*	*H*	*D*	*1/4"*	*1/3"*	*1/2"*	*1/1.8"*	*2/3"*	*1"*
1/4"	3.6	2.7	4.5	1	1.33	1.78	2.00	2.44	3.56
1/3"	4.8	3.6	6		1	1.33	1.50	1.83	2.67
1/2"	6.4	4.8	8			1	1.13	1.38	2.00
1/1.8"	7.1	5.4	9				1	1.22	1.78
2/3"	8.8	6.6	11					1	1.45
1"	12.8	9.6	16						1

1.3.4 Sensor Spatial Resolution and Megapixel Lenses

Another important factor when selecting a lens is the number of pixels relative to the total sensor area. This measurement is usually inversely proportional to the pixel (unit cell) size–the higher the number of pixels, the smaller the individual pixels and the closer together they are. In turn, the smaller the pixel spacing on a sensor, the better its ability to record (sample) small detail. This ability is referred to as spatial frequency or spatial resolution. High density sensors require 'megapixel' lenses built with higher quality optical components that can project images at a resolution equal to or higher than that of the sensor.

Sensor spatial resolution is measured in line-pairs per millimeter (lpm), which denotes the smallest size of repeated pairs of black/white bars a sensor can resolve. A 1/3" 1.3 MP sensor, such as the Sony ICX445 with a pixel size of just 3.75 micrometers, can resolve ~133 lpm (1/3.75 µm /2). Megapixel lenses can project images at greater detail to make use of the higher pixel density of small format megapixel sensors like the Sony ICX445 (1/3" 1.3MP) or Sony ICX655 (2/3" 5MP).

The resolution of a lens is measured using the Modulation Transfer Function (MTF), which measures the amplitude (contrast) of a projected image of a black/white line-pair pattern as a function of its spatial frequency in lpm. The higher the spatial frequency of such a pattern, the more likely the projected image will blur into a uniform gray. The frequency at which blurring begins to be noticeable should be equal to or higher than the sensor's spatial resolution. Therefore, it is advisable to use a megapixel lens with a megapixel sensor. Using a regular lens on a megapixel sensor may result in blurred images, since the lens may not provide a high enough resolution for the sensor. Although it is acceptable to use a megapixel lens with a non-megapixel sensor, it may be impractical from a cost-benefit perspective.

The following table shows a sample of sensors used in Point Grey cameras and whether a megapixel lens should be used with them.

Sensor	*Size*	*Width (pixels)*	*Height (pixels)x*	*Pixel size (square µm)*	*lpm*	*megapixel lens required?*
ICX618	1/4"	648	488	5.6	89	no
ICX424	1/3"	648	488	7.4	68	no
ICX414	1/2"	648	488	9.9	51	no
ICX204	1/3"	1032	776	4.65	108	recommended
ICX445	1/3"	1288	964	3.75	133	yes
ICX267	1/2"	1392	1032	4.65	108	recommended
ICX274	1/1.8"	1624	1224	4.4	114	yes
ICX655	2/3"	2448	2048	3.45	145	yes
ICX625	2/3”	2448	2048	3.45	145	Yes

1.4 Other Resources

Description	Link
List of lens manufacturers	Knowledge Base Article 131
Lens holders, adapters and spacers offered by Point Grey	Point Grey Product Accessories Site
List of sensors used in Point Grey cameras	Knowledge Base Article 23
Additional information about lens resolution and MTF	http://www.cambridgeincolour.com/tutorials/lens-quality-mtf-resolution.htm
Additional information about image sensor sizes	http://www.dpreview.com/news/0210/02100402sensorsizes.asp

1.5 Additional Downloads and Support

Access more Technical Application Notes on the web at www.ptgrey.com/support/downloads.

Point Grey Research Inc. endeavors to provide the highest level of technical support possible to our customers. Most support resources can be accessed through the Product Support section of our website: www.ptgrey.com/support.

Creating a Customer Login Account

The first step in accessing our technical support resources is to obtain a Customer Login Account. This requires a valid name, e-mail address, and camera serial number. To apply for a Customer Login Account go to www.ptgrey.com/support/downloads/.

Knowledge Base

Our on-line knowledge base at www.ptgrey.com/support/kb/ contains answers to some of the most common support questions. It is constantly updated, expanded, and refined to ensure that our customers have access to the latest information.

Product Downloads

Customers with a Customer Login Account can access the latest software and firmware for their cameras from our downloads site at www.ptgrey.com/support/downloads. We encourage our customers to keep their software and firmware up-to-date by downloading and installing the latest versions.

Contacting Technical Support

Before contacting Technical Support, have you:

1. *Read the product documentation and user manual?*
2. *Searched the Knowledge Base?*
3. *Downloaded and installed the latest version of software and/or firmware?*

If you have done all the above and still can't find an answer to your question, contact our Technical Support team at www.ptgrey.com/support/contact/.