Lenses
Selection and setup

In the following we offer some general advice on how to select and setup C and CS mount lenses. Please find detailed information in the white paper Basic optics.

Please note:

- It is the responsibility of an on-site engineer to select and apply lenses in the context of real applications.
- All calculation methods are based on the "thin lens" (an ideal lens). The differences to commercial lenses are negligible in practice. Wide-angle lenses, however, may vary considerably from the ideal.

Content

THE IMAGINGSOURCE
TECHNOLOGY BASED ON STANDARDS

EUROPEAN HEADQUARTERS
The Imaging Source Europe GmbH
Sommerstrasse 36,
D-28215 Bremen,
Germany

US HEADQUARTERS
The Imaging Source, LLC
7257 Pineville-Matthews Road,
Charlotte, NC 28226

www.theimagingsource.com/en

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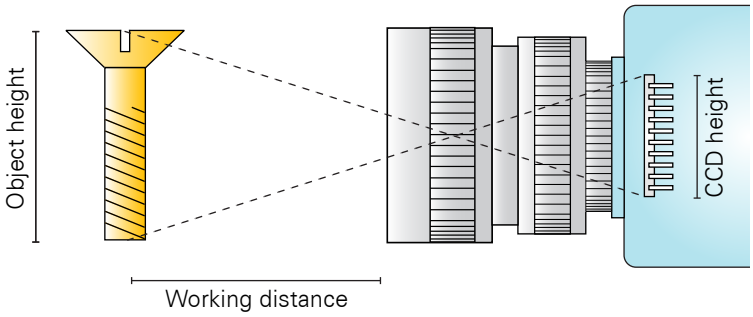
All weights and dimensions are approximate.

Step 1: Calculating the focal length

The focal length is a lens' pivotal parameter. To represent an object completely on the CCD chip, we calculate the focal length for the object height and width. The smaller value is our lenses focal length.

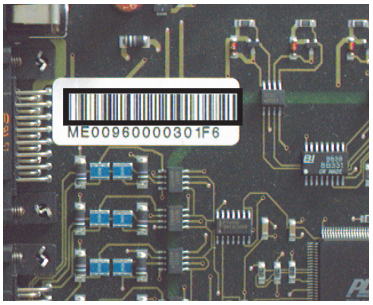
$$\text{Focal length of the width} = \frac{\text{Working distance} * \text{CCD width}}{\text{Object width} + \text{CCD width}}$$

$$\text{Focal lenght of the height} = \frac{\text{Working distance} * \text{CCD heig}}{\text{Object height} + \text{CCD heigh}}$$



CCD format	CCD height [mm]	CCD width [mm]
1/4"	2,4	3,2
1/3"	3,6	4,8
1/2"	4,8	6,4
2/3"	6,6	8,8
1"	9,6	12,8

Examples from various application areas



Barcode recognition:

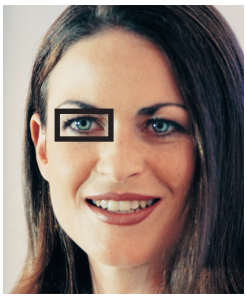
- Object width = 30 mm
- Working distance = 300 mm
- CCD format = 1/4" (CCD width = 3.2 mm)

$$\textit{Focal length of the width} = \frac{300 * 3.2}{30 + 3.2} = 28.9\text{mm}$$

Fruit sorting:

- Object height = 200 mm
- Working distance = 1000 mm
- CCD format = 1/3" (CCD height = 3.6 mm)

$$\textit{Focal length of the height} = \frac{1000 * 3.6}{200 + 3.6} = 17.7\text{mm}$$



Eye inspection:

- Object width = 50 mm
- Working distance = 350 mm
- CCD format = 1/2" (CCD width = 6.4 mm)

$$\textit{Focal length of the width} = \frac{350 * 6.4}{50 + 6.4} = 39.7\text{mm}$$

Number plate recognition:

- Object width = 600 mm
- Working distance = 10000 mm
- CCD format = 1/4" (CCD width = 3.2 mm)

$$\textit{Focal length of the width} = \frac{10000 * 3.2}{600 + 3.2} = 53\text{mm}$$

Step 2: Selecting a lens

To adjust the focal lengths for the above examples, zoom lenses would be necessary. These lenses, however, have considerable disadvantages (weight, size, price, etc.). Therefore, usually fixed focus lenses are used.

To take advantage of quality offered by The Imaging Source cameras, we recommend the use of Pentax and Computar MegaPixel series lenses (see table on the right).

Product code	Format	Focal length [mm]
H0514-MP	1/2"	5
M0814-MP	2/3"	8
H1214-M(KP)	1/2"	12
C1614-M(KP)	2/3"	16
C2514-M(KP)	2/3"	25
C3516-M(KP)	2/3"	35
C5028-M(KP)	2/3"	50

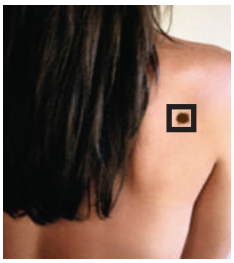
To represent the object completely on the CCD chip we select a lens whose focal length is lower than the calculated one. That means for our above examples:

- Barcode recognition: C2514-M(KP)
- Fruit sorting: C1614-M(KP)
- Eye inspection: C3516-M(KP)
- Number plate recognition: C5028-M(KP)

Please note: The lenses format has to be larger than or equal to the CCD chip's format (cf. Typical mistakes).

Step 3: How to deal with very small working distances

Especially in the case of small objects, the working distance may be smaller than the selected lenses minimal working distance (MOD). In this case, we decrease the minimal working distance by putting extension rings between the lens and the camera. We will see details at Step 4 (Setup). The following example depicts the selection of an extension ring:



Inspection of a birthmark:

- Object width = 5 mm
- Working distance = 30 mm
- CCD format = 1/4" (CCD width = 3.2 mm)

In this case the focal length is 14.7 mm and thus we select the H1214-M(KP). Its minimal object distance (MOD) is 0.25 m and thus exceeds considerably the required working distance of 3 cm. The table below indicates the use of a 5 mm extension ring.

Product code	Format	Focal length [mm]	MOD [m]
H0514-MP	1/2"	5	0,1
M0814-MP	2/3"	8	0,1
H1214-M(KP)	1/2"	12	0,25
C1614-M(KP)	2/3"	16	0,25
C2514-M(KP)	2/3"	25	0,25
C3516-M(KP)	2/3"	35	0,35
C5028-M(KP)	2/3"	50	0,90

	Focal length:	12 mm	16 mm	25 mm	50 mm	75 mm
Ring/tube	0.5	12 .. 31 cm	22 .. 54 cm	41 .. 129 cm		
	1.0	8 .. 15 cm	17 .. 28 cm	32 .. 66 cm		
	1.5	6 .. 10 cm	14 .. 20 cm	27 .. 45 cm	75 .. 175 cm	
	5.0	2 .. 3 cm	7 .. 8 cm	14 .. 16 cm	43 .. 59 cm	69 .. 125 cm
	10.0			9 .. 10 cm	29 .. 34 cm	50 .. 69 cm
	15.0				23 .. 25 cm	41 .. 50 cm
	20.0					35 .. 41 cm
	25.0					30 .. 35 cm

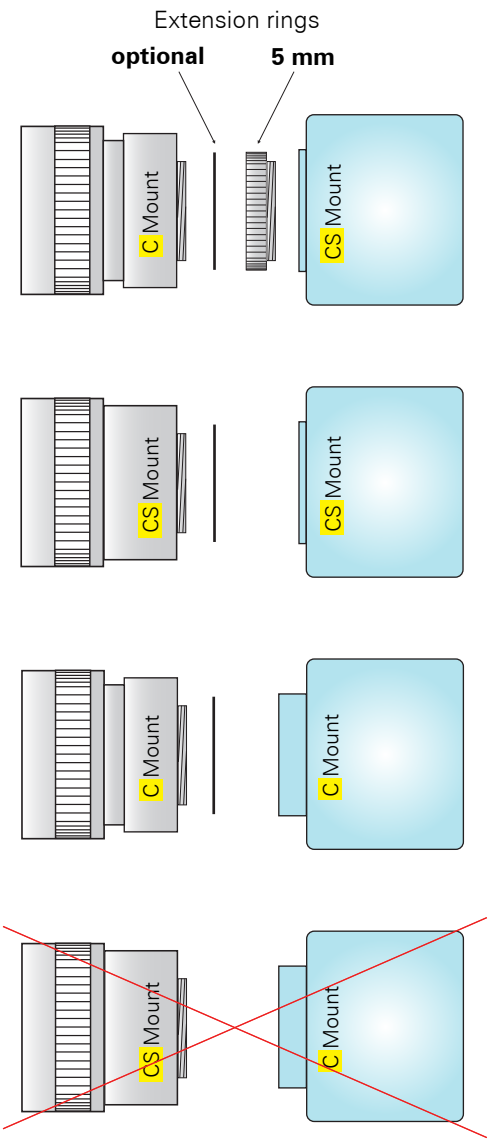
Step 4: Setup

In the field of digital image processing, we have a standardized lens mount with two variants: C mount and CS mount. This leads to four combinations (see image on the right), one of which does not work: CS mount lenses can not be used with C mount cameras.

If you, on the other hand, would like to attach a C mount lens to a CS mount camera previously simply screw a 5 mm extension ring into the camera.

If Step 3 (How to deal with very small working distances) should have turned out to require an additional extension ring, simply put it between the camera and the lens (like a grommet).

Please note: The Imaging Source exclusively manu–factures CS mount cameras. Each of the cameras is shipped with a 5 mm extension ring.



Product code	Mount	Format	Focal length [mm]	MOD [m]
H0514-MP	C	1/2"	5	0,1
M0814-MP	C	2/3"	8	0,1
H1214-M(KP)	C	1/2"	12	0.25
C1614-M(KP)	C	2/3"	16	0.25
C2514-M(KP)	C	2/3"	25	0.25
C3516-M(KP)	C	2/3"	35	0.35
C5028-M(KP)	C	2/3"	50	0.90

Special case: Wide-angle lenses

Very large objects and/or small working distances often force us to use lenses with very small focal lengths. The following example depicts the selection of such wide-angle lenses:

Waste sorting:

- Object width = 700 mm
- Working distance = 500 mm
- CCD format = 1/4" (CCD width = 3.2 mm)

In this case the focal length is 2.3 mm and thus one of the lowest commercially available. Therefore, we use the Computar T 2314 FICS-3 (see table below).

Computar wide-angle lenses are used for applications which require the lowest focal lengths.

Please note: These lenses are only available as CS mount versions and therefore can not be used with C mount cameras (see Step 4: Setup).

Product code	Mount	Format	Focal length [mm]	MOD [m]
T 2314 FICS-3	CS	1/3"	2.3	0.2
T 0412 FICS-3	CS	1/3"	4	0.2

Please note: The optical quality of wide-angle lenses falls short of the quality of "normal" lenses. This may be a crucial point in the context of visualization purposes and/or customer presentations since a bad image quality often rubs off on the complete system.

Typical mistakes

The bewildering variety of optical components, as well as "historical legacy issues" originating from the world of picture tubes, lead to different mistakes when selecting these components. In the following you will find the three most basic misunderstandings:

Incorrect: The lens format and the camera format have to be identical.

Correct: The lens format should preferably be larger than the CCD format since optical flaws appear at the rim of the lens.

Incorrect: If the lens format is larger than the CCD format it has to have a larger/smaller focal length.

Correct: The focal length exclusively depends on the CCD format, the working distance and the object size (please see Step 1: Calculating the focal length).

Incorrect: Extension rings increase/decrease the depth of field.

Correct: Extension rings decrease the minimal working distance (please see Step 3: How to deal with very small working distances).

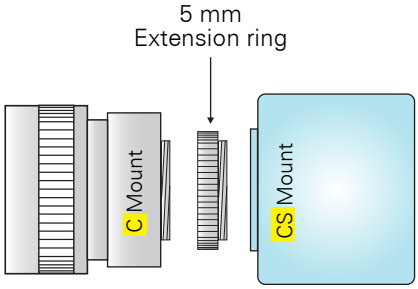
Fixing blurred images

There are two basic reasons for blurred images:

- The lens quality is lower than the quality of modern CCD chips. The Pentax M Series recommended in this white paper (please see Step 2: Selecting a lens) has been especially designed to work with modern CCD chips. Wide-angle lenses, however, have weaknesses due to their construction (please see Special case: Wide-angle lenses).
- The lens setup is incorrectly arranged. This usually leads to extremely blurred images. In such cases please proceed as follows:

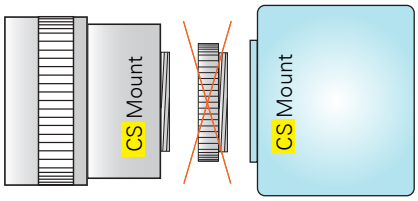
C Mount lens / CS Mount camera:

Please check whether a 5 mm extension ring has been screwed between the camera and the lens. The Imaging Source exclusively manufactures CS mount cameras. Each of the cameras is shipped with a 5 mm extension ring.



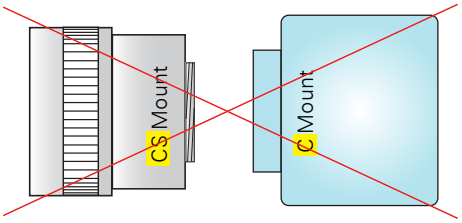
CS Mount lens / CS Mount camera:

If you have accidentally screwed a 5 mm extension ring between the camera and the lens, you will only be able to focus on close objects.



CS Mount lens / C Mount camera:

This configuration only allows to focus on very close objects. If this is not your aim, then you have to use a CS mount camera. The Imaging Source exclusively manufactures CS mount cameras.



"Sticking" extension rings:

If you previously have used the camera or the lens with a thin extension ring, it often "sticks" to either of them. In such cases you are not able to focus to infinity for no apparent reason.