Optical Calculations for Close-Up Applications

When viewing an object measuring 20mm per side from a working distance (WD) of 100mm with a 1/2" format camera (6.4 x 4.8mm, 1.5 mega pixels)

First, calculate the magnification, M, by the following formula.

$$M = B/A$$

$$M = 4.8/20 = -0.24x$$

(The horizontal screen dimension is automatically decided when the vertical dimension is decided. Therefore, the vertical screen dimension is used here).
Obtain a rough idea of the focal length required for your application with the object distance and magnification between the object size and image size by using the following formula:

$$f = -M \cdot O$$

$$f = -((-0.24)\times 100) = 24mm$$

According to the calculation a 24mm lens is required. Then, select one of the closest PENTAX lenses to 24mm: B2514D, B2518, C2514-M. Since the camera is 1.5 mega pixel, substitute the true focal length of C2514-M into the following formula to calculate the overall distance L, by adding up the figures indicated in the attached table.

$$L = -f/M + f + f + \Delta H - f \cdot M$$

$$L = -(25.00/(-0.24)) + 25.00 + 25.00 + (-10.51) - (25.00\times(-0.24))$$

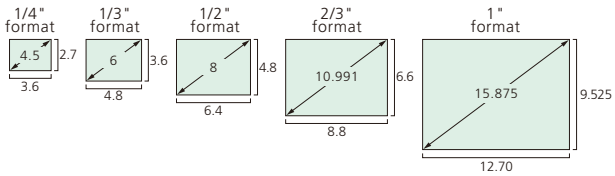
$$L = 104.17 + 25.00 + 25.00 - 10.51 + 6.00 = 149.66$$

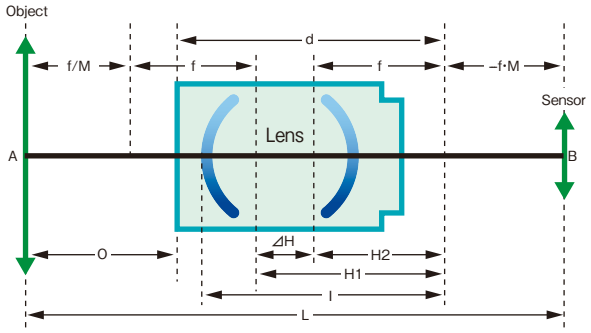
Finally, you can get an exact objective distance, O by the following formula(f·M is the length of the extension tube.)

$$O = L - d + f \cdot M$$

$$O = 149.66 - 49.53 + (25.00\times(-0.24)) = 94.13$$

Therefore, when viewing an object measuring 20mm per side on a 1/2" format camera, use the C2514-M and extension tube of 6mm in length with a WD of 94.13 (about 94mm). Use a lens with a longer f (focal length) if you want a longer WD, or a lens with a shorter focal length if you want a shorter WD.





A	Object Size(Vertical or Horizontal)
B	Imager Format Size(Vertical or Horizontal)
M	Magnification(B/A)
f	Focal Length
⊿H	Distance between 1st and 2nd Principal Point
H1	1st Principal Position
H2	2nd Principal Position
d	Distance between the front end of lens barrel and the focal point
I	Distance between the 1st lens element and the focal point
f·M	Length of the extension tube
O	Object Distance (Distance between the front end of lens barrel and the object)

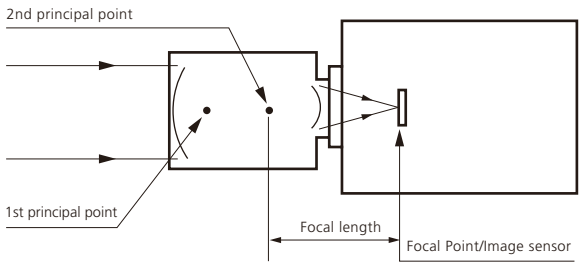
*Note: The (+) sign denotes the Object → Imager direction.

Optical Data Unit:「mm」※「%」

Model	Focal Length (f)	1st Principal Positon (H1)	2st Principal Positon (H2)	Distance between H1 and H2 (⊿H)	Optical Path Length (I)	Total Length (d)	Entrance Pupil Position	Diameter of Entrance Pupil	Exit Pupil Position	Diameter of Exit Pupil Position	Distortion ※	Vignetting ※	Back Focus Length (in air)	Mechanical Focus (Adjustable focusing range by rotating focus ring)	Remarks
5 Mega-Pixel Lens															
C814-5M	8.2	-49.9	-8.2	41.7	77.7	66.2	-57.1	6.0	-64.2	47.0	-4.9	71.5	11.5	0.6	W.D.=250mm,y=5.5
C1614-5M	16.0	-29.6	-16.0	13.6	58.6	47.4	-40.9	11.2	-54.3	37.9	-0.5	60.1	11.5	2.3	W.D.=250mm,y=5.5
C2514-5M	25.0	-9.8	-25.0	-15.2	47.6	35.3	-22.4	17.4	-50.2	35.0	-1.0	65.2	12.3	5.5	W.D.=250mm,y=5.5
C5028A-M02	51.4	-80.0	-61.7	18.4	109.7	76.7	-77.2	18.1	-59.0	17.2	0	98.1	33.0	2.9	M=-0.2
C5028A-M035	51.1	-88.1	-69.0	19.0	116.9	76.2	-85.7	18.0	-66.7	17.2	0	98.3	40.7	3.9	M=-0.35
Mega-Pixel Lens															
H614-MQ	6.0	-35.2	-6.0	29.2	42.0	47.2	-39.5	–	-21.8	–	-4.3	54.6	12.4	–	W.D.=280mm,y=4.0
H1214-M	12.4	-17.8	-12.4	5.4	41.0	46.0	-25.8	9.1	-34.5	25.3	-0.7	59.0	11.5	1.5	W.D.=250mm,y=4.0
C1614-M	16.0	-18.0	-16.0	2.0	46.6	50.7	-30.2	11.3	-68.0	47.9	-2.0	43.9	14.6	1.5	W.D.=250mm,y=5.5
C2514-M	25.0	-14.5	-25.0	-10.5	39.5	49.5	-19.6	17.6	-31.4	22.1	-1.2	48.0	11.5	3.5	W.D.=250mm,y=5.5
C3516-M	34.0	-10.9	-34.0	-23.0	47.1	52.9	-11.3	20.8	-34.3	21.0	-0.9	61.5	11.9	3.5	W.D.=250mm,y=5.5
C5028-M	50.0	-47.4	-50.0	-2.6	46.5	51.5	-3.2	18.2	-26.5	9.7	-0.1	79.4	21.0	3.5	W.D.=250mm,y=5.5
C7528-M	72.8	-57.4	-72.8	-15.4	72.8	77.2	16.1	25.9	-36.2	12.9	0	96.5	30.9	10.5	W.D.=250mm,y=5.5
Manual Iris Lens (1/2" format)															
H416	4.3	-42.0	-4.3	37.7	59.3	61.0	-45.9	2.8	-47.1	29.9	-35.8	43.0	10.4	–	
H612A	6.2	-38.9	-6.2	32.7	58.1	63.5	-44.5	5.5	-70.3	62.3	-5.8	42.0	14.3	0.3	
H1212B	12.2	-26.7	-12.2	14.5	47.6	53.0	-38.5	10.7	-322.6	282.8	-4.3	45.9	13.9	1.1	
Manual Iris Lens (2/3" format)															
C418DX	4.9	-36.9	-4.9	32.0	51.4	53.0	-41.2	2.7	-46.2	25.5	-29.7	25.9	9.8	–	
C815B	8.5	-31.2	-8.5	22.6	53.6	57.5	-39.1	5.9	-120.1	82.7	-4.2	29.2	10.9	0.6	
C1614A	16.2	-20.1	-16.2	3.9	41.0	50.5	-30.3	12.6	-44.4	34.5	-1.9	57.0	13.2	1.1	
Manual Iris Lens (1" format)															
B1214D-2	12.7	-34.3	-12.7	21.7	63.5	67.5	-42.2	8.7	-33.9	23.4	-1.7	20.0	14.4	0.7	
B1218A	12.4	-24.6	-12.4	12.2	39.5	57.8	-31.8	6.9	-29.9	16.6	-3.8	28.8	10.4	0.6	
B2514D	25.1	-25.6	-25.1	0.5	51.4	54.8	-30.3	18.2	-30.8	22.4	-2.8	37.1	15.0	2.6	
B2518	25.0	-22.1	-25.0	-2.9	31.1	57.5	-12.0	14.6	-17.8	10.4	1.4	31.7	14.9	1.2	
B5014A	49.9	-47.3	-49.9	-2.6	57.4	65.5	-8.1	37.5	-28.0	21.0	0.8	59.3	18.1	2.8	
Line Scan Lens															
YF5028A-02	51.4	-80.0	-61.7	18.4	109.7	76.7	-77.2	18.1	-59.0	17.2	-0.1	66.0	33.0	2.9	M=-0.2, Diagonal y=22.5
YF5028A-035	51.1	-88.1	-69.0	19.0	116.9	76.2	-85.7	13.0	-66.7	17.2	0	67.8	40.7	3.9	M=-0.35,Diagonal y=22.5
YF/YK5028 ※※	52.0	-54.8	-52.0	2.8	71.1	103.3	-57.1	18.6	-54.5	19.4	0.2	41.4	37.0	19.7	M=-0.2, Diagonal y=22.5
YF/YK3528 ※※	36.3	-61.8	-36.3	25.5	89.9	103.3	-72.3	13.2	-51.0	18.6	0.1	34.0	33.2	20.1	M=-0.2, Diagonal y=22.5
UV Lens															
B2528-UV	25.0	-24.9	-25.0	0.2	34.9	42.9	-25.9	–	-26.1	–	-4.1	87.7	12.8	4.1	266nm, y = 8.0
B7838-UV	77.5	-77.6	-77.5	0.1	96.8	126.8	-78.8	–	-78.8	–	-0.2	98.4	71.3	23.1	250nm, y = 8.0

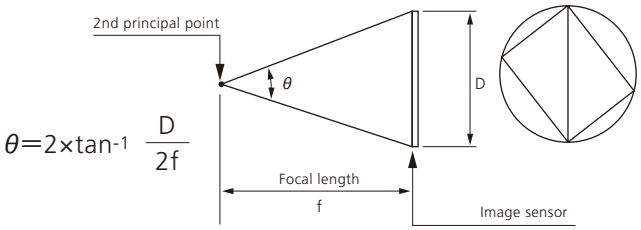
※※ These models adopt a floating mechanism and are not covered by the calculation above. Please contact us for details.

Focal length



Rays from infinitely distant objects are condensed internally in the lens at a common point on the optical axis. The point at which the image sensor of the CCD camera is positioned is called the focal point. By virtue of design, lenses have 2 principal points, 1st principle point and a 2nd principle point. The distance between the 2nd principle point and the focal point (image sensor) determines to focal length of the lens.

Angle of View



$$\theta = 2 \times \tan^{-1} \frac{D}{2f}$$

The angle formed by the two lines from the 2nd principle point and the edges of the sensor is called the angle of view. Therefore, the focal length of the lens is fixed regardless of the image format size of the CCTV camera. Conversely, the angle of view varies in accordance with the image size. The focal lengths in the catalogue are nominal and the angles of view calculated by the formula referring to the focal lengths are approximate.

F Number

$$\text{F number} = \frac{f}{A}$$

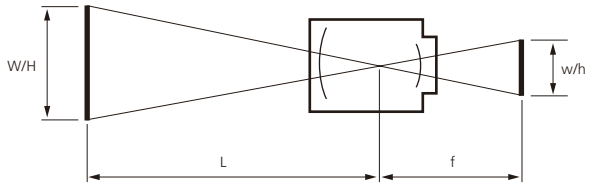
f = focal length
A = effective aperture (diameter of entrance pupil)

The F number is the index for the amount of light that passes through a lens. The smaller the number, the greater the amount of light. The F number is a ratio between the focal length and the effective aperture as follows.

Field of View

The field of view varies along with the focal length of the lens as follows.

* See page 18 for the calculation method for close-up applications.



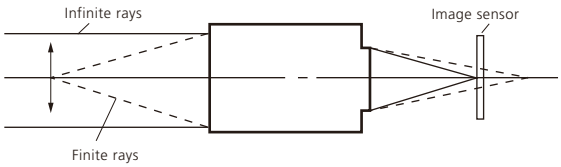
$$\frac{w}{W} = \frac{h}{H} = \frac{f}{L}$$

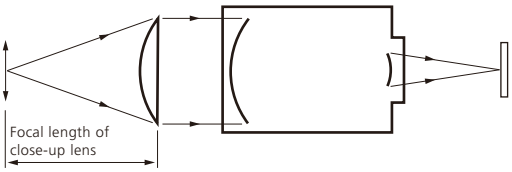
W: width of object
H : height of object
w : width of image sensor
1" format=12.7mm, 2/3" format=8.8mm,
1/2" format=6.4mm, 1/3" format=4.8mm
h : height of image sensor
1" format=9.525mm, 2/3" format=6.6mm,
1/2" format=4.8mm, 1/3" format=3.6mm
f : focal length
L : object distance

Example: To show the full image of a 2.64m high object positioned 10m away from the camera on a monitor with a 2/3 format camera

$$\frac{h}{H} = \frac{f}{L} \longrightarrow \frac{6.6}{2{,}640} = \frac{f}{10{,}000} \longrightarrow f = 25\text{mm}$$

Close-Up Application





There are two methods for imaging closer than the minimum object distance of a lens.

1) Extension Tube (Macro Ring)

When the rays originate from a finite object distance, the rays are condensed at a point further than the focal point, while the rays from infinite distance are condensed at the actual focal point. The focus adjustment moves the lens barrel toward the object to shift the focusing point at the image sensor. However, the amount of focusing adjustment is mechanically limited as set by the minimum object distance. Extension Tube (Macro Ring) is inserted in between the lens and the camera to shift

* Do not use a extension tube with a zoom lens.

2) Close-Up Lens

The close-up lens has a positive meniscus lens as a supplementary lens. Generally, 3 types of close-up lenses are available, close-up lens No. 1, 2 and 3 have focal lengths of 1,000mm (1000mm/1), 500mm (1,000mm/2), and 333mm (1,000mm/3), respectively. When an object is placed at the focal point of the close-up lens, the rays from the object are converted by the close-up lens to be parallel rays against the optical axis as seen on the right.

Depth of Field

When an object is focused, it is typically observed that the area in front and behind the object is also in focus. The range in focus is called depth of field. When the background is extended to infinity, the object distance (focusing distance) is called the hyper focal distance. Depth of field is calculated by the following formula.

$$H = \frac{f^2}{C \times F}$$

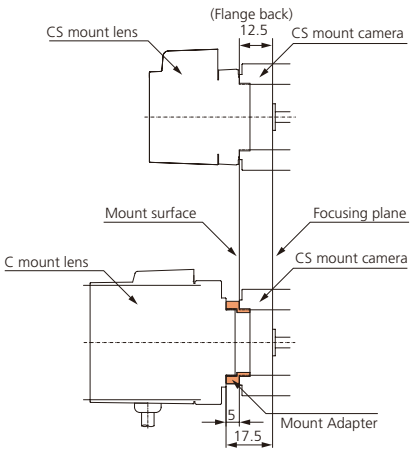
$$T1 = \frac{B(H+f)}{H + B}$$

$$T2 = \frac{B(H-f)}{H - B}$$

F = F No.
H = hyper focal distance
f = focal length
B = object distance (measured from image sensor)
T1 = near limit
T2 = far limit
C = circle of least confusion
1" format= 0.04mm, 2/3" format= 0.03mm,
1/2" format=0.02mm, 1/3" format=0.015mm, 1/4" format=0.011mm

Depth of field increases when:
*Focal length is shorter
*F-number is larger
*Object distance is longer

CS and C Mount



The CS mount has been adopted because it is difficult to manufacture a compact, high-performance, and low-cost mount if the optical design requires a back focus longer than the focal length of the lens. The flange back of a CS mount is about 5mm shorter than that of a C mount, so please use CS mount lens only with a CS mount camera. Install a 5mm Mount adapter between the camera and lens when using a C mount lens with a CS mount camera.