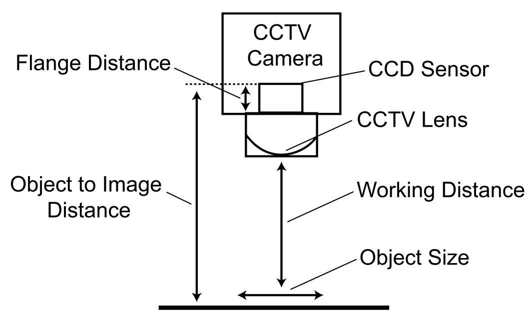
How to Determine the Focal Length Required

To choose the proper lens for an application consider the following:

- Field of View (FOV) - The size of the area to be imaged.
- Working Distance (WD) - Distance from the camera lens to the object or area under surveillance.
- CCD - The size of the camera's image sensor device.

Be consistent. If you are measuring the width of your object, use the horizontal CCD specifications, etc. If you are working in inches, do your calculations in inches and convert to millimeters at the end.

Distance Diagram



Understanding Focal Length

Video lenses are classified into three categories according to focal length: standard, wide angle and telephoto. Focal length is the distance between the camera sensor and the center of the lens. The greater the focal length, the larger the image will appear. Therefore, the greater the focal length, the more the lens becomes telephoto in application.

- **Standard Lens** - size of the object being viewed is unchanged.
- **Wide Angle Lens** - provides a wider field of view and therefore a smaller image of the object being viewed
- **Telephoto Lens** - produces a larger image of a distant object. The longer the focal length, the larger the object will appear.

$$FL = \frac{CCD \times WD}{FOV}$$

Example: You have a 1/3" C-mount CCD camera (4.8 mm horizontal). There is a 12" (305 mm) distance between the object and the front of the lens. The field of view, or object size, is 2.5" (64 mm). The conversion factor is 1" = 25.4 mm (round up).

Calculation in mm:
FL = 4.8 mm x 305 mm / 64 mm
FL = 1464 mm / 64 mm
FL = 23 mm Lens Required

Calculation in inches:
FL = 0.19" x 12" / 2.5"
FL = 2.28" / 2.5"
FL = 0.912" x 25.4 mm/inch
FL = 23 mm Lens Required

Understanding F/#

The f/number is an indication of the brightness of the lens. It is the measurement of the ratio between the focal length and the diameter of the entrance pupil (where the light enters the lens). It determines the amount of light reaching the camera sensor. The smaller the value, the larger the opening and the brighter the image produced by the lens.

Image Size

A lens produces images in the form of a circle, called the image circle. In a video camera, the imaging element has a rectangular sensor area (the image size) that detects the image produced within the image circle. The ratio of the length of the horizontal to vertical sides of a video image is called the aspect ratio, which is normally 4:3 (H:V) for a standard video camera.

Image Size Chart

Image Sensor	Image Circle	Horizontal	Vertical
1/3"	Ø6.0 mm	4.8 mm	3.6 mm
1/2"	Ø8.0 mm	6.4 mm	4.8 mm
2/3"	Ø11.0 mm	8.8 mm	6.6 mm
1"	Ø16.0 mm	12.8 mm	9.6 mm
4/3"	Ø22.5 mm	17.3 mm	13.0 mm
35mm	Ø43.0 mm	36.0 mm	24.0 mm

Image Sensor Size (units in mm)

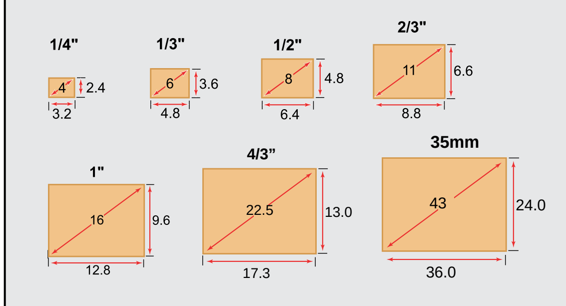
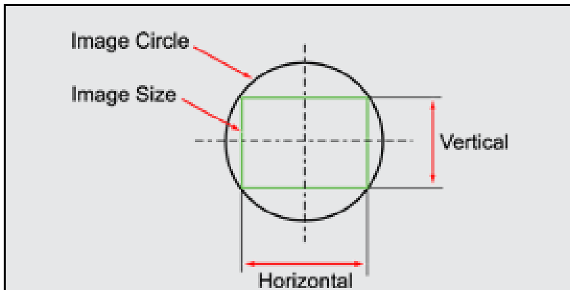


Image Size

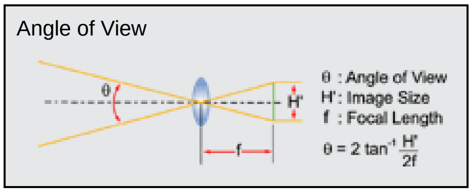


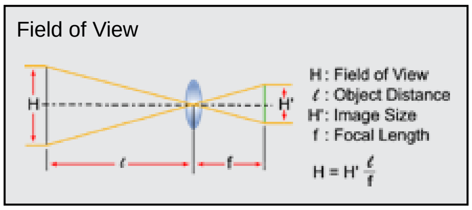
Minimum Object Distance

Minimum object distance (M.O.D.) indicates how close the lens can be placed to the object for shooting. It is measured from the vertex of the front glass of the lens.

Angle of View and Field of View

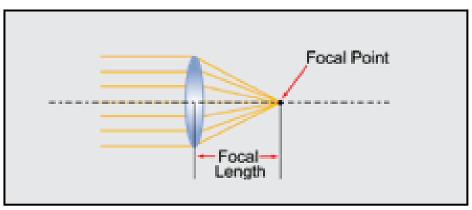
The angle of view is the shooting range that can be viewed by the lens given a specified image size. Normally the angle of view is measured assuming a lens is focused at infinity. The angle of view can be calculated if the focal length and image size are known. If the distance of the object is finite, the angle is not used. Instead, the dimension of the range that can actually be shot, or the field of view, is used.





Focal Length

Distance between the principle point in the optical system and the focal point. For a single thin lens, the focal length is equal to the distance between the center of the lens and the focal point.

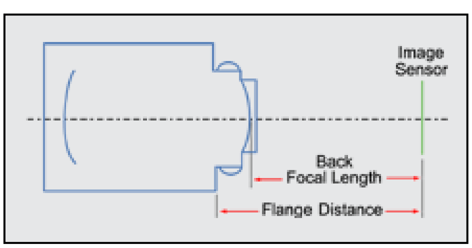


Back Focal Length

Distance between vertex of the rear element lens and image sensor.

Flange Distance

Distance between mechanical mount surface and image sensor (in air).
C-Mount=17.526 mm / .690"
CS-Mount=12.526 mm / .493"



Relationship Between Angle of View and Image Sensor Size

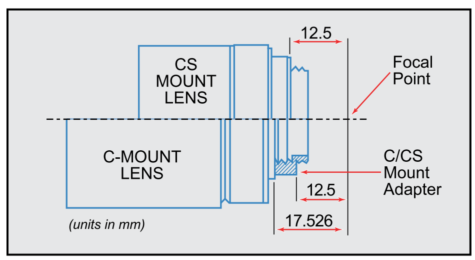
Cameras with different image sensor chip sizes (such as 1/3", 1/2", 2/3", 1" and 4/3"), using the same focal length lens, will each yield a different field of view.
Lenses designed for a larger image sensor device will work on a new, smaller size camera. However, if a lens designed for a smaller format image sensor device (i.e. 1/3") is placed on a larger one (i.e. 2/3"), the image on the monitor will have dark corners. Image sensor sizes are in a ratio of 1:0.69:0.5:0.38:0.25. This means that a 1/2" format is 50% of a 1" format, a 1/2" format is 75% of a 2/3" format and a 1/3" format is 75% of a 1/2" format.

Camera to Monitor Magnification

Camera Format	Monitor Size (diagonal)					
	9"	14"	15"	18"	20"	27"
1/3"	38.1X	59.2X	63.5X	76.2X	84.6X	114.1X
1/2"	28.6X	44.5X	47.6X	57.2X	63.5X	85.7X
2/3"	20.8X	32.3X	34.6X	41.6X	46.2X	62.3X
1"	14.3X	22.2X	23.8X	28.6X	31.8X	42.9X
4/3"	10.6X	16.4X	17.6X	21.1X	23.5X	31.7X

C-Mount and CS-Mount Lens Compatibility

When using a C-mount lens for a CS-mount camera, a C/CS-mount adapter (5mm thick) is required.



General Lens Formulas

Magnification
m = Image Size/Object Size

Object to Image Distance
OI =[FL x (1+m)^2]/m
OI =m(FL) + (FL+VOA+BF) + FL/m
VOA =Vertex to Vertex Lens Length

Object to Lens Distance
OL =FL + FL(m)

Lens to Image Distance
LI =FL + FL/m

(~ distance to the nodal points:
FL + FL(m) to the front vertex.)

F/# =1/(2NA)
F/# =FL / Entrance Pupil Diameter
NA =1/2 F/#
NA =sin θ/2

Effective F/#
Eff. F/# = F/# (m+1)

Clear Aperture (Minimum)
Aperture = FL/(F/#)

Depth of Focus
DoF = 0.00002/NA^2 (in inches)
DoF= 0.0005/NA^2 (in mm)

Conversion Factors
1 inch =25.4 millimeters
1 meter =39.37 inches
1 degree =Π/180 radians
1 degree =0.0174533 radians
1 micron (μ) =0.001 millimeter
1 micron (μ) =1,000 nanometers
1 micron (μ) =10,000 angstroms