LM96- 1/2" Lens Kit

1.1 Introduction

Choosing the right lens is a critical aspect of designing an imaging system. Typically the trade off between image quality and cost drives the lens selection process. To facilitate this critical selection process, National offers the **LM96- 1/2" Lens Kit** which includes a number of fixed focus lenses from different lens suppliers with varying price and specifications. The **LM96- 1/2" Lens Kit** is fully compatible with National's SXGA range CMOS Imaging Evaluation Tools. Every lens in the kit is housed in a standard M12 lens barrel that can conveniently be screwed onto the supplied mount and attached to any **LM96XXHeadBoard** as shown in figure 1-1

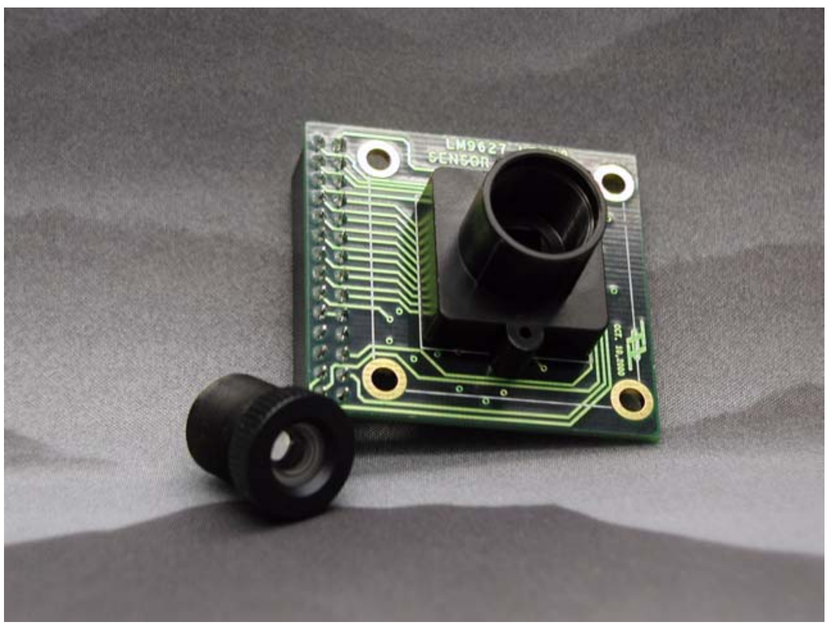


Figure 1-1 Lens And Camera HeadBoard with M12 Mount

The lenses provided with the **LM96- 1/2" Lens Kit** represent a variety of fixed focus lenses to highlight the compromise that has to be made between cost and quality. The lenses are made of different lens materials and include a different number of optical elements. Once a suitable lens system is selected out of the **LM96- 1/2" Lens Kit**, (for example a four element glass lens) modifications to the lens design, if required, can be made to accommodate specific application requirements.

This **LM96- 1/2" Lens Kit** datasheet describes the important lens specifications and their impact on image quality followed by the specifications of each lens provided in the **LM96- 1/2" Lens Kit**.

1.2 Explanation of Lens Specifications

The following sections explain the relevance of each lens specification and gives guidelines for choosing a suitable lens for a given application.

1.2.1 Lens Construction

Materials used for lenses can be broadly classified into glass and plastic. The selection of glass or plastic as a lens material involves weighing the advantages and disadvantages of both.

Glass is generally the material of choice for high end optics. There is a large selection of glass available with different indices of refraction and dispersion properties. This choice of materials makes the design of a superior optical element more achievable. Glass lenses are harder and more durable than their plastic counterparts. They are also less sensitive to temperature and humidity.

Manufacturing techniques employed for the fabrication of glass lenses, however, make them expensive compared to plastic lenses. Glass lenses are manufactured by a grinding and polishing process, which is more expensive and hard to duplicate in mass manufacturing. This process also makes it difficult and expensive to fabricate a lens with any other shape than spherical or planar.

The choice of materials for plastic lenses is limited to a few dozen. Optical designers must use the limited number of indices of refraction available to make the best lens for an application. Plastic optics are also intolerant to high temperatures and should not be used if operating or storage temperature are to exceed 70~90^{o}C, as this will cause optical deformation of the lens.

On the other hand, plastic lenses offer some advantages over glass lenses. The main process for fabrication of plastic optics is injection molding, which is less expensive and extremely reproducible in mass manufacturing. It is also possible to create lenses in more sophisticated shapes at a low cost, providing better optical performance in many applications. The lightweight, shatter resistance properties of plastic make it ideal in certain settings.

In terms of optical complexity, lens systems can contain a single optical element (lowest cost, poorer image quality) or multiple optical elements (higher cost, better image quality). Also the lens systems may be purely plastic (lower cost) or purely glass (higher cost) or even hybrid (where some of the optical elements are plastic to reduce cost).

The **LM96- 1/2" Lens Kit** provides 2 glass lenses with different numbers of optical elements:

- Lens 1: four element low profile glass lens
- Lens 2: five element glass lens

1.2.2 Lens Size

The image formed by a lens is round and its range is known as the "image circle. Lens sizes are categorized by the approximate image circle they form. This is called a "lens format". Typical lens formats for CMOS sensors include 1/4", 1/3", 1/2", and 2/3". The lens' image circle size is rounded to the nearest format size. Each sensor manufacturer supplies a slightly different array size and pixel size. To utilize a lens with a given lens format, the image array size needs to be at least as small. With digital photography the image array size is the active region of the sensor. Since the image sensor is rectangular the diagonal size of it's active region of the image must fall in the lens' image circle. (see figure 1-2)

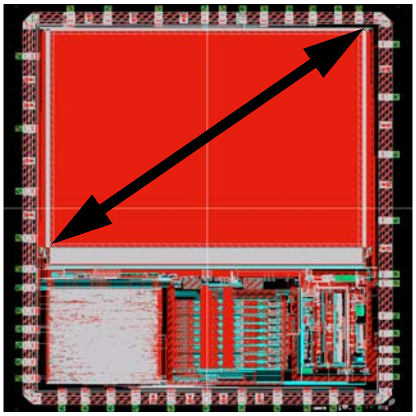


Figure 1-2 Diagonal Size Of The Sensors Active Region

Figure 1-3 The table below lists different lens formats in inches and the corresponding sensor diagonal size.These formats were adopted from vacuum tubes nomenclature and have been maintained for both CCD and CMOS.

Lens Format	Sensor's Diagonal Size
1 inch	16 mm
2/3 inch	11 mm
1/2 inch	8 mm
1/3 inch	6 mm
1/4 inch	5 mm
1/5 inch	3.5 mm
1/7 inch	2.5 mm

Figure 1-4 The following table lists National Semiconductor's Line of SXGA CMOS image sensors and the diagonal size of the active region.

Sensor	Class	Array Format(pixels)	Pixel Size (μm)	Diagonal(mm)
LM9638	SXGA, Monochrome	1280 x 1024	6.0	10 mm
LM9648	SXGA, Color	1280 x 1024	6.0	10 mm

1.2.3 Effective Focal Length

The effective focal length is determined by the lens designer. The shorter the focal length, the wider the field of view. Focal lengths shorter than the diagonal of the sensor are termed wide angle lenses, while focal lengths longer than the sensor diagonal are termed telephoto lenses, as in 35mm photography. Lenses with focal lengths approximately the same size as the sensor diagonal are termed standard lenses.

1.2.4 F Number

The f number of an optical system is defined as the ratio of the effective focal length to the diameter of the entrance pupil for an object at infinity.

From an applications standpoint, a smaller the f-number allows more light to be collected by the image sensor and thus requires a lower exposure time. Therefore a lens with a small f-number is called a “fast” lens.

1.2.5 Angle of View or Field of View:

The maximum cone or fan of rays passed by an aperture and measured at a given vertex is called the field of view. In other words, the field of view is the span of objects that can be seen through the lens.

1.2.6 Transmittance & IR Filter

Transmittance represents the amount of light that is transmitted through a lens system. The transmittance of a lens system is a function of the wavelength of the incident light. Most lenses transmit both the visible and the infrared part of the spectrum.

Color of images may be difficult to reconstruct due to the sensitivity of image sensors to infrared (IR) light. It is therefore important to filter out all IR wavelengths. IR blocking filters can either be a coating on an existing glass element of a lens or a separate plane glass filter added to a lens with all plastic elements. The wavelength at which the IR is blocked should be considered together with the transmittance curve of the IR filter.

Pigmentation can be added to plastic lenses to modify transmission characteristics. This is not advisable, however, unless there is a critical application need as adding pigmentation reduces the peak transmission of visible radiation. Typically, plastic lenses add an additional glass filter for blocking IR in the lens system.

For the lenses in the **LM96- 1/2" Lens Kit,** the transmission curves are provided on pages 9 -10.

1.2.7 MTF

The Modulation Transfer Function (MTF) is a merit function characterizing an optical system in terms of image contrast at various spatial frequencies. Specifically, MTF quantifies the ability of an optical system to transfer the contrast of an object to the image formed by the system. An MTF curve is a plot of the modulation vs. spatial frequency. Since the definition of MTF is very generic it can be either applied to selected components of the imaging system or to the entire system.

1.3 Image Quality:

Image quality is a subjective impression. Judging image quality is a perceptual ability as well as a somewhat learned skill. Many formulas exist for predicting image quality. Each is appropriate under a particular set of viewing conditions. These expressions are typically obtained from data in which multiple observers view many images with a known amount of degradation. The observers rank the images from worst to best and then an equation is derived that relates the ranking scale to the amount of degradation.

Early metrics were created for film based cameras. Image quality was related to the camera lens and film modulation transfer functions. With the advent of televisions, image quality centered on the perception of raster lines and the minimum SNR required for a good imager. Here, it was assumed that the studio camera provided a perfect image and only the receiver affected the image quality.

The system MTF is the major component of the imaging system analysis. It describes how sinusodal patterns propagate through the imaging system. Images with higher MTF and less noise are generally judged as having better image quality.

An evaluation of all components used in processing the optical information of the incident light is required to determine and tune the overall image quality on the system level. For example, there is no advantage to using a high quality sensor and/or digital image processor if the chosen lens is limiting the image quality.

1.3.1 Lens Specifications:

Relative Illumination:

Every lens generates a circular image on the image sensor, which deteriorates in brightness toward its edge. Relative Illumination is the illumination of the sensor at the edges of the image circle expressed as a percentage of the illumination of the sensor on the optical axis.

Resolution:

Another important metric to determine image quality is resolution. Resolution is defined as the smallest resolvable spatial frequency. Various resolution test charts are available to measure resolution. These charts are test targets containing groups of black lines separated by white spaces, or converging wedged lines and spaces. Resolution is expressed as line pairs per millimeter resolved in the image.

Aberrations:

Aberrations are departures from the ideal lens. These image errors are usually measured by the amount by which the rays miss the image point of a perfect lens. The two main types of aberrations are Chromatic Aberration and Monochromatic Aberration. As a general guideline, a lens system with multiple elements will correct aberrations better than a single element lens system.

Chromatic Aberration:

Image imperfection caused by light of different wavelengths following different paths through an optical system. This happens because the index of refraction varies with wavelength. Chromatic Aberration should be considered for color imaging applications.

Monochromatic Aberration:

Monochromatic Aberrations occur for all wavelengths of light. The five primary aberrations, also called the Seidel aberrations, are Spherical Aberration, Coma, Astigmatism, Field Curvature, and Distortion.

Spherical Aberration:

Image error caused by spherical lenses. Light rays which strike the lens far from the optical axis focus at points in front or behind the focal point. This occurs because an ideal lens is hyperbolic, not spherical. A sphere's curvature departs greater from a hyperbola the farther you move from the optical axis. Spherical aberration pertains only to object points that are on the optical axis.

Coma:

Image error associated with off-axis object points. Coma stems from the fact that the effective focal lengths will differ for rays traversing off-axis regions of the lens. A point source affected by coma will appear as a cone. Coma is dependent on the shape of the lens.

Astigmatism:

Image error caused by focal length differences in the tangential and sagittal planes. Astigmatism will cause horizontal and vertical lines not to be in focus together. Astigmatism pertains only to off-axis object points.

Field Curvature:

Image error arising from the incorrect approximation of the image surface as a plane. Every optical system has associated with it a basic field curvature, called the Petzval curvature. Field curvature results in the edges of the images not to be in focus with the center of the image.

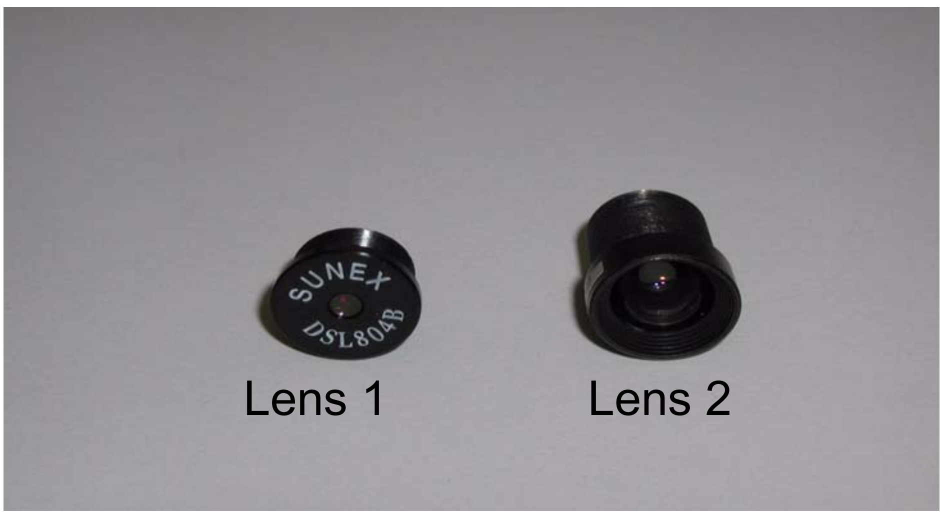
Distortion:

Image error whose origin lies in the fact that the magnification may be a function of the off-axis image distance. When the magnification on the optical axis is less the off-axis magnification, pincushion distortion results. When magnification is greater on-axis than off-axis, barrel distortion results.

1.4 Lenses In The LM96- 1/2" Lens Kit

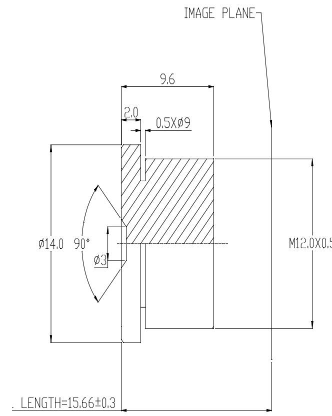
Two fixed focus lenses are provided in the **LM96- 1/2" Lens Kit** to allow the user to evaluate image quality vs. cost trade offs in the imaging system.

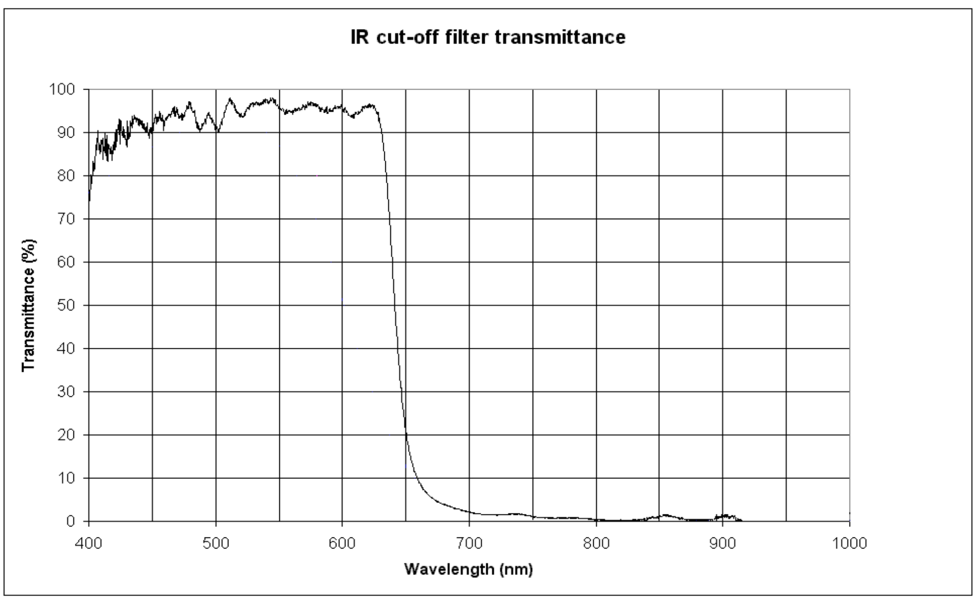
Kit Lens Number	Description
Lens 1	Four Element, Low Profile Glass Lens
Lens 2	Five Element Glass Lens



1.4.1 Lens 1 Four Element, Low Profile Glass Lens

Image Circle	9.8 mm diameter
Construction	Four Glass Elements
Effective Focal Length	9.5 mm
Diagonal Field Of View	54.6°
F/#	F/3.2
MTF	80% at 25 cy/mm on axis 70% at 25 cy/mm 27deg from axis
Relative Illumination	62%
35mm Equivalent	40.7mm
Thread Size	M12
IR Filter	coating, 650nm cutoff
Min. Object Distance	1.5 m





Lens 2 Five Element Glass Lens

Image Circle	10.3 mm diameter
Construction	Five element glass
Effective Focal Length	10 mm
Angle Of View	54.5^{o}
F/#	F/2.8
MTF	TBD
Relative Illumination	68%
35 mm Equivalent	40.8
Thread Size	M12
IR Filter	630nm cutoff
Min. Object Distance	1.2 m