

MIDAS2.0

LENS CALCULATOR

User Guide

Version 1.03

xcitex
Exciting
Technologies

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Users Guide: MiDAS Lens Calculator

Overview

The MiDAS Lens Calculator is both a stand-alone application and a component of MiDAS2.0. The Lens Calculator is designed to help the novice videographer select the appropriate optics for a measurement and to configure the test conditions. It is designed using conventional photographic equations and rules for photography, as applied to video usage. The user can select which camera they wish to use, and, since the format of video cameras very often changes depending on frame rate, it recalculates the information for each frame rate.

The Lens Calculator provides a collection of information on selecting depth of field, field angle, format size, hyperfocal distance, and other parameters. It also helps you determine how much blur your image will have when capturing high-speed events.

Theory and Formulas

The common video lens follows conventional optical imaging theory. The image on the video sensor inside the camera is taken to be the apparent reproduction of an object formed by an optical system. The object, in most cases, is an illuminated combination of finite elements. The "field" is the area that the object occupies, and, in virtually all video systems, the size of the field is defined by the physical dimensions of the sensor projected into "object space". The sensor is therefore the "field stop" of the optical system.

The size of the field is typically termed the "field of view", and can be described as either a physical size (e.g. a "field width") or an angular subtense (e.g. the "field angle"). Both descriptions are common in optical theory calculations.

Although the lens creates a reproduction of the object onto the sensor, it also creates a field of view based on the sensor size and the focal length of the lens. Shorter focal length lenses result in larger fields of view (commonly referred to as wide angle optics), while longer focal length lenses result in smaller fields of view (commonly referred to as telephoto optics). Commonly, the ratio of the field width to the sensor size is the optical "magnification", or optionally the "magnifying power". For example, if the field width is 10 meters and the sensor size is 10 mm, the magnification is $10 * 1000 / 10 = 1000:1$. Another common definition is the "overall system magnification" -- the ratio of the field of view to the final projection size on a monitor or display device. For example, if the field width is 10 meters and the display size is 300 mm, the overall system magnification is only $10 * 1000 / 300 = 33:1$. One can envision that the object is presented on the display at $1/33^{\text{rd}}$ its original size.

Conventional macro photographic scientists tend to consider positive magnification as objects larger than the sensor, whereas micro photographic scientists -- those that work with optical systems designed for microscopic analysis -- have the opposite definition. The engineers designing the MiDAS Lens Calculator follow the photographic convention; all the formulas in the MiDAS lens calculator are designed for magnification to be greater than unity when the object is larger than the sensor size. Therefore, a 50 mm lens produces a 10x magnification. The confusion may occur with some markings on microscopic lenses, where the magnification is stamped 0.5x to define an object that is twice as large as the sensor. In the MiDAS lens calculator, a 0.5x magnification describes an object that is $1/2$ the size of the sensor.

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The concept of "minimum resolution" is also important. In video systems, the minimum resolution in sensor space is (in the absence of special signal processing algorithms) defined as 1 pixel width. Perceived image sharpness is therefore a quantity based on the minimum resolution and other factors such as the zoom magnification on the monitor, the position of the viewer relative to the display and optical properties of the lens.

The "depth of field" is a quantification of perceived image sharpness using formulas honed over years of empirical data and intermixed theory. The near-focus point and far-focus point bracket the physical distances from the lens that a standard viewer using standard viewing practices will perceive an object to be sharp. The MiDAS Lens Calculator follows the theory outlined in [Applied Photographic Optics](#) (1999) by Sidney Ray, modified for conventions used herein. The "circle of confusion diameters are between 0.015 (1/2" video format" and 0.040 (1.25" format), for those accustomed to making their own calculations.

Finally, the use of photographic attachments is common with videographers. Close-up lenses (also called Diopter lenses), tube extenders, and tele-converters are common ways of "cheating" when setting up the test conditions. The engineers at Xcitech always advise users to use the proper lens at the proper settings, but acknowledge the prevalent use of photographic attachments. Therefore, the MiDAS Lens Calculator lets users calculate what impact such attachments will have on an optical system. The formulas in the calculator are again taken from conventional optical engineering textbooks, though modified to encapsulate both macro and micro photography. Specialty lenses such as macro, anamorphic and soft focus lenses will not follow the conventions exactly.

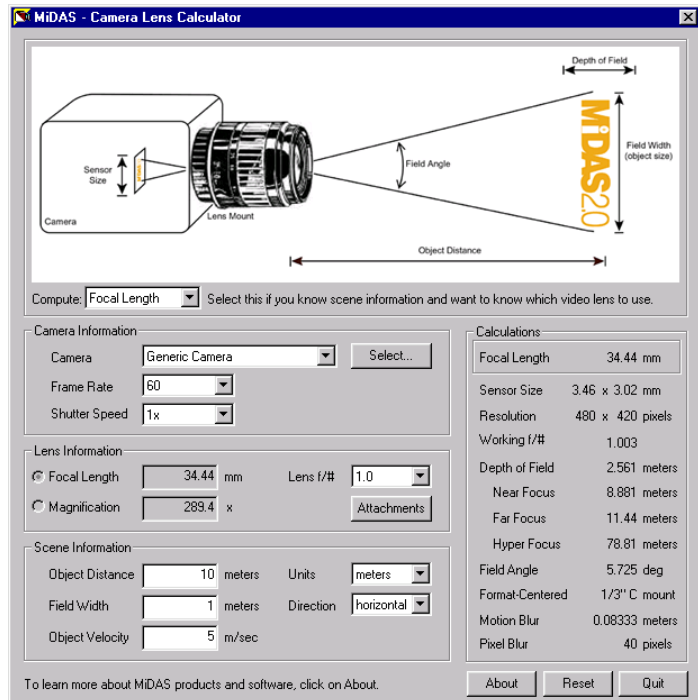
It is important to recognize that the formulas used in the optics calculator are generalized for common video applications -- specialty cases will require special modifications to these formulas.

Using the Lens Calculator

There are four modes of primary operation for the Lens Calculator. These modes are selected via the drop down box directly underneath the top graphic. The four choices to compute for are:

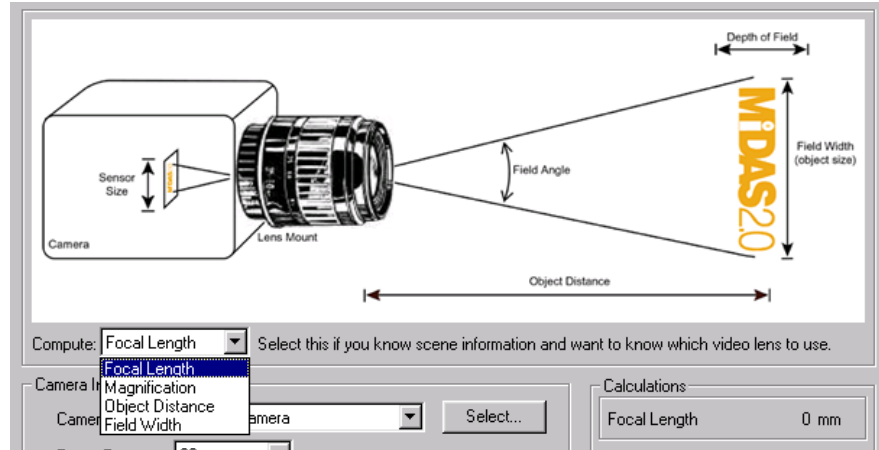
1. Focal Length
2. Magnification
3. Object Distance
4. Field Width

You may also compute information regarding the motion blur and pixel blur. These parameters are explained later in this User Guide.

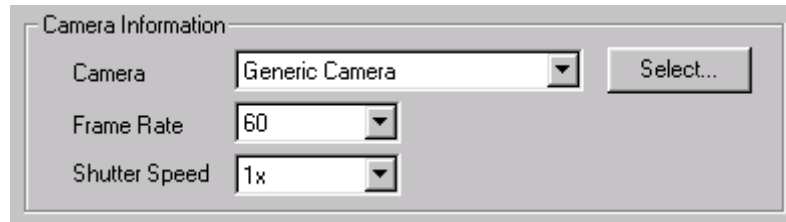


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Depending on which of these options you select, various entry fields will become active or disabled. (white or gray). You are only allowed to change the active (white areas). A quick note to the right of the computation drag-down menu explains what each is used option is used for.



After selecting the particular quantity to solve for, you must next set the camera information. If you have a specific camera in mind, click on the **SELECT...** button and locate the information file for that camera. . When you click on the **SELECT...** button, a standard **OPEN** dialog window will appear. Inside of this dialog, you can select multiple camera files and they will all be loaded and placed inside of the drop-down Camera selection control for your use.



If a camera file does not exist for your particular camera, you can create your own using the format given in the section titled “Creating Your Own Camera File”. If you do not have a specific camera in mind, you can use the built-in “Generic Camera” which has general values.

After you have selected your camera, select the Frame Rate and Shutter Speed using the drop down boxes. The Frame Rate will affect the resolution, which in turn affects the sensor size used in computations. The Frame Rate will also affect the motion blur calculations. The Shutter Speed affects only the motion blur calculations.

There are three basic parameters to any lens that are controlled by the video engineer -- focal length, aperture and focus point. Most over-the-counter optics are designed for maximum performance with the focus ring set to infinity. The $f\#$ is, to the first order, the ratio of the focal length to internal aperture of the lens.

Now we are ready to enter specific information about your measurement. Each of the four different compute modes will require different inputs. The following table lists the combinations of inputs required for each of the modes

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Compute Mode	Required Inputs
Focal Length	Object Distance –AND– Field Width.
Magnification	Field Width
Object Distance	Focal Length –AND– Field Width
Field Width	Magnification -OR– Focal Length –AND– Object Distance

As each mode is selected, the appropriate input regions will become active in the Lens Information and the Scene Information regions. You can only input the Focal Length (in mm) or the Magnification; you cannot input both, since they depend directly on one another. Therefore in the case of compute mode set to Field Width, you can use the selection buttons to the left of Focal Length and Magnification to select which one you would like to input.

The screenshot shows a software interface with two main sections: "Lens Information" and "Scene Information".

Lens Information: Contains two radio buttons. The "Focal Length" radio button is selected. Next to it is a text input field containing "0" followed by "mm". To the right is a "Lens f/#" dropdown menu showing "1.0". Below the radio buttons is a "Magnification" radio button with an input field containing "0" followed by "x". To the right of the magnification input is an "Attachments" button.

Scene Information: Contains three input fields. The first is "Object Distance" with an input field containing "0" followed by "meters". To its right is a "Units" dropdown menu showing "meters". The second is "Field Width" with an input field containing "0" followed by "meters". To its right is a "Direction" dropdown menu showing "horizontal". The third is "Object Velocity" with an input field containing "0" followed by "m/sec".

Select the appropriate Lens f/# using the drop-down box. The **ATTACHMENTS** button is described in the subsequent section titled "Lens Attachments".

In the Scene Information region, in addition to the Object Distance and Field Width, you can also select the preferred units for input and display, the direction of motion, and the Object Velocity. Selection of the units is self-explanatory. All values in the input boxes will be scaled appropriately to reflect the newly selected units, with the exception of Focal Length, which is always given in mm. The direction of motion is given with respect to the axes of the camera sensor.

A selection of **HORIZONTAL** implies that the object of interest will be oriented/moving along the horizontal axis of the camera. This selection is used to control the sensor size since the horizontal and vertical resolution for cameras are often different. The final input is the Object Velocity. This quantity is used for the motion blur calculations and is described in the next section titled "Motion and Pixel Blur".

After all the relevant parameters have been entered, the calculations region on the right is updated automatically with the corresponding results. The item selected in the first "Compute" drop-down control is displayed in the first line. In the following lines, additional supplemental calculation results are presented.

Calculations	
Focal Length	34.44 mm
Sensor Size	3.46 x 3.02 mm
Resolution	480 x 420 pixels
Working f/#	1.003
Depth of Field	2.561 meters
Near Focus	8.881 meters
Far Focus	11.44 meters
Hyper Focus	78.81 meters
Field Angle	5.725 deg
Format-Centered	1/3" C mount
Motion Blur	0.08333 meters
Pixel Blur	40 pixels

The MiDAS Lens Calculator calculates the following results:

Focal length	the distance from the rear principle plane to the focal point. A focal length equal to the diagonal of a sensor is generally considered to be "standard" -- providing a perspective (viewpoint) consistent with the human eye. Focal lengths larger than the diagonal of the sensor are generally considered to be "telephoto", providing narrow perspective. Focal lengths smaller than the diagonal of the sensor are generally considered to be "wide angle" or "retrofocus". To compare formats (e.g. video to 35 mm photography), compare the standard focal length ratio. Focal lengths are always expressed in mm.										
Magnification	the ratio of sensor size to field width. Magnifications less than unity have larger field widths. Magnifications are unitless.										
Field width	the physical dimension, in chosen units, of the object field. If HORIZONTAL is chosen, the field width describes the long dimension of the field. If VERTICAL is chosen, the field width is the other dimension.										
Object Distance	the physical dimension, in chosen units, that will yield the sharpest image for a lens of specific focal length and field width. The object distance is theoretically computed from the front principle plane of the lens, not necessarily from the physical front of the lens, though this approximation is usually sufficient. The object distance is not dependent on the focus setting of the lens, though most lens designers will set the infinity (best) focus of the lens to be at the correct object distance.										
Sensor resolution	the number of horizontal and vertical pixels in use.										
Sensor size	the size of the sensor in use for a chosen frame rate, calculated by multiplying the center-to-center pixel size by the number of pixels.										
Format	<p>The convention attached to the diagonal dimension of the sensor active area and the corresponding lens mount. The numerical component is based on the diagonal size of the sensor, as follows:</p> <table border="0"> <tr> <td>1/3"</td> <td>6 mm</td> </tr> <tr> <td>1/2"</td> <td>8 mm</td> </tr> <tr> <td>2/3"</td> <td>11 mm</td> </tr> <tr> <td>1"</td> <td>16 mm</td> </tr> </table> <p>The alphabetic component is a convention based on the register of flange focal distance and the mount type that produces no noticeable vignetting, as follows:</p> <table border="0"> <tr> <td>C</td> <td>standard c-thread video mount</td> </tr> </table>	1/3"	6 mm	1/2"	8 mm	2/3"	11 mm	1"	16 mm	C	standard c-thread video mount
1/3"	6 mm										
1/2"	8 mm										
2/3"	11 mm										
1"	16 mm										
C	standard c-thread video mount										

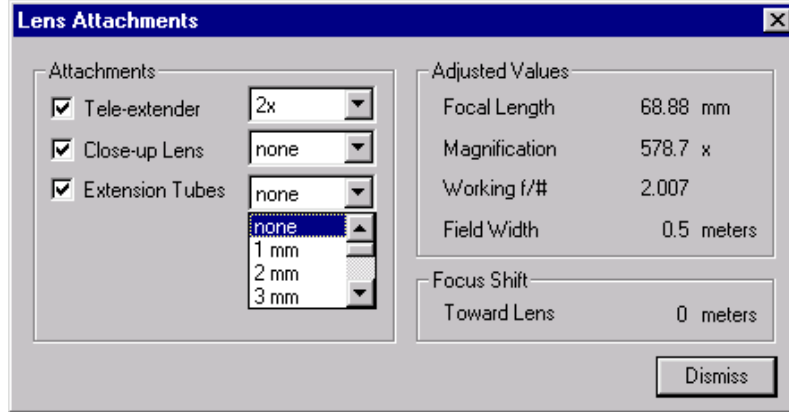
	<p>B 46 mm flange, also commonly known as F, AI, E, AI-S and D mount</p> <p>Note that some cameras allow users to select the active area within a sensor. The MiDAS Lens Calculator shows the format for an active area centered on the sensor. If the area is not centered, the user must re-calculate the format required.</p>
Working f#	The actual cone of light created by the lens aperture and the sensor plane. The <i>f#</i> stamped on the lens describes the cone of light (as a ratio) when the lens is used at its infinite object distance. The working, or actual <i>f#</i> , describes the ratio as the lens is actually used. The Working <i>f#</i> may be larger (less light) depending on the actual position of the object.
Depth of field	The overall distance between near focus and far focus that an image will be perceptibly sharp to the average user.
Near focus	The distance from the lens to the closest point in object space that will be perceptibly sharp when the lens is focused at the optimum object distance.
Far focus	The distance from the lens to the farthest point in object space that will be perceptibly sharp when the lens is focused at the optimum object distance. A far focus of "infinity" indicates that all points farther than the optimum object distance will be perceptibly sharp.
Hyper focus	Also called the "hyperfocal distance". The distance from the lens to a point in object space whereby all objects from 1/2 the hyperfocal distance to infinity will be perceptibly sharp. An approximation for macro-photography that is not appropriate for close-up photography or photomicrography.
Field Angle	The full angle subtended by the field width to the lens, based on the object distance.
Motion Blur	The amount of blur that will be evident in the image, in units of measure in object space.
Pixel Blur	The number of pixels that will show blur of the motion. (See below)

Motion and Pixel Blur

Motion blur and pixel blur calculations are made using the various camera, lens, and scene information. The motion blur quantity depends only upon the Object Velocity, Frame Rate, and Shutter Speed. The result is given in terms of distance the object has traveled during the exposure time. The pixel blur depends on the same values as the motion blur, and in addition, also depends on the sensor size in pixels, the direction of motion (horizontal/vertical), and the Magnification. The pixel blur is given as the number of pixels that the object has "blurred" through during the exposure time.

Lens Attachments

After you have solved for a base scenario as described above, you can also examine the effects of standard lens attachments on the computed results. Click on **ATTACHMENTS** in the Lens Information region and the following dialog will appear.



Using this dialog, you can select various settings for Tele-extenders, Close-up Lens Attachments, and Extension Tubes. The adjusted values are computed on the right.

The adjusted values from the lens attachments are dependent upon the solution from the base scenario in the main MiDAS Lens Calculator window. In order for the attachment results to be computed, the base scenario must first be solved. If, in the main MiDAS Lens Calculator window, the calculations still show '0' for some of the results, it is likely that you have not input sufficient information for the base scenario to be solved. Input additional information into the entry boxes in the main window until valid solutions appear in the Calculations area. Once the base scenario is solved, the adjusted values as a result of the lens attachments will also update.

The following are information used in the attachments screen:

Close-up lenses	Supplemental lenses normally screwed onto the front of a photographic lens for close up work. Also called Diopter lenses and typically sold in +1, +2 and +4 diopter sets. These lenses have the effect of changing the focal length without changing the effective aperture of the lens, and cause some degradation of image quality (astigmatism and field curvature).
Tele-extenders	Also known as a tele-extender, range extender, matched multiplier or Barlow lens. These screw mount optics go between the prime lens and the video camera. Since they are pupil matched, they allow the close focus of the prime lens to be retained, but with twice the effective focal length and 1/2 the aperture. The effect is the conversion of a standard lens into a telephoto macro lens. Some slight image degradation is visible.
Extension tubes	These screw in tubes extend the distance from the video camera body to the lens. The result is use of the lens at image space conjugates not intended by the lens designers, causing a reduction of the object distance -- a close-up effect. Use of these tubes significantly impairs the

performance of the prime lens and is not recommended.

The following are calculated in the attachments window:

Focal length	the distance from the rear principle plane to the focal point. Focal lengths are always expressed in mm.
Magnification	the ratio of field width to sensor size. Magnifications greater than unity have larger field widths.
Field width	the physical dimension, in chosen units, of the object field. If HORIZONTAL is chosen, the field width describes the long dimension of the field. If VERTICAL is chosen, the field width is the other dimension.
Focus Shift	The distance that the user must move the object towards the lens to be at the optimal focal position for that lens. The focal shift is not dependent on the focus point of the lens -- it is strictly a change in object distance.

Creating your Own Camera File

The camera files (*.cam) are text files, which contain basic information about camera frame rate and resolution capabilities. Below is a copy of a sample camera file.

```
#  
# name of the camera  
#  
My 500fps Camera  
  
#  
# pixel size: horiz, vertical (in 1e-6 meters)  
#  
7.4, 7.4  
  
#  
# capabilities: fps, horizres, vertical res  
#  
60, 480, 420  
125, 480, 420  
250, 480, 420  
500, 320, 280
```

Empty lines and lines beginning with a '#' are ignored by MiDAS. They are used only to help organize the data file. The first non-empty, non-commented line in the file is used as the name of the camera. This string is displayed in the camera selection drop down box within MiDAS Lens Calculator.

The next non-empty, non-commented line should have the horizontal and vertical pixel size of the sensor. These values should be supplied in units of μm (1e-6 meters).

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Each of the subsequent lines should contain the various frame rate and corresponding horizontal and vertical resolution capabilities of the camera. For instance, the first line in the above file states that the camera can capture at 60 fps at a resolution of 480 pixels horizontal and 420 pixels vertical (lines).

There is no need for any –end—characters.

Use a general text editor like WordPad or NotePad to create the camera files. For example, the following camera file named “another.cam” was created in WordPad, a generic Windows text editing software application included with each Windows installation. “